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WAR DEPARTMENT

ENGINEER FIELD MANUAL

Volume II
MILITARY ENGINEERING
(*TENTATIVE*)

PART TWO
DEFENSIVE MEASURES

ENGINEER FIELD MANUAL

VOLUME II

MILITARY ENGINEERING

(*Tentative*)

PART TWO

DEFENSIVE MEASURES

PREPARED UNDER THE DIRECTION OF THE CHIEF OF ENGINEERS

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BY ORDER OF THE SECRETARY OF WAR:

DOUGLAS MACARTHUR,
General,
Chief of Staff.

OFFICIAL:

C. H. BRIDGES,
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FOREWORD

Engineer Field Manual, Volume II, Military Engineering, is a compendium of technical information and suggestions as to the conduct of the most common operations undertaken by engineer troops in the theater of operations. The user of this manual should recognize that local conditions in the field will always profoundly affect the application of the principles and formulas given herein. The manual contains suggestions and guides to judgment rather than regulations to be rigidly adhered to.

The manual will be published in three parts as follows:

Part One, Communications:

Chapter 1. Roads.
2. Bridges.
3. Military Railways.
4. Surveys and maps. (This chapter will be published when it becomes necessary to revise TM 2180–30 and 2180–37.)

Part Two, Defensive Measures:

Chapter 1. Camouflage.
2. Field Fortifications.
3. Explosives and Demolitions.

Part Three, Construction and Utilities:

Chapter 1. General Construction.
2. Water Supply.
3. Light and Power.

ENGINEER FIELD MANUAL

VOLUME II, MILITARY ENGINEERING

(TENTATIVE)

PART TWO

DEFENSIVE MEASURES

(The matter contained herein supersedes TR 195–20, December 20, 1927 (including Changes No. 1, January 2, 1931), TR 195–25, December 1, 1927, TR 195–30, May 15, 1926 (including Changes No. 1, January 2, 1929), and TR 195–40, June 15, 1926)

Volume II supersedes the Engineer Field Manual, edition of 1918 (Professional Papers of the Corps of Engineers, U. S. Army, No. 29)

CHAPTER 1

CAMOUFLAGE

SECTION I

GENERAL PRINCIPLES

1. Definition.—*Camouflage* is work done for the purpose of deceiving the enemy as to the existence, nature, or location of material, troops, or military works. The importance of camouflage depends in general upon the activity and effectiveness of the enemy's air service, although it is important to camouflage against ground observation.

2. Basic principle.—The basic principle of camouflage is deception. Deception is accomplished by suppressing all signs of abnormal activity near the object or deceiving the enemy as to the purpose of such activity; by making the object indistinguishable from its surroundings; by making the object appear to be something else; or by complete concealment.

3. Hostile observation.—Hostile observation may be of two kinds, direct and indirect. *Direct observation* is by direct vision, aided or unaided by field glasses or telescopes. It is obtained from observation posts or aircraft. *Indirect observation*, which is by far the most dangerous, is from the study of aerial photographs.

4. Patterns.—The pattern formed on aerial photographs by the features of the terrain influences to a large degree the measures taken toward deception or concealment. Patterns may be large and simple or intricate and confused. Detection by aerial photography is more difficult when an object is located in terrain showing a complex photographic pattern. Patterns are made by form, shadow, texture, and color.

a. Form.—Form is the most important element. Regular forms quickly attract the eye, while irregular forms of human origin are lost in the irregular forms of the natural features.

b. Shadow.—Shadow is what discloses form, and from the shadow the experienced aerial photograph reader can visualize the object casting it.

c. Texture.—Texture in camouflage is a quality opposed to smoothness or polish and is illustrated by a rug of long nap. The nap is composed of innumerable fine hairs, each one when erect casting a shadow. When the rug is trod upon, the hairs are pressed down and texture is lost. When brushed, the hairs become erect and texture is regained. Substance with much surface texture absorbs light and photographs dark; if location in texture and surface reflects light, it photographs light. Grass or other vegetation possesses this property in a marked degree. The longer it is the darker it appears in the photographs, but when pressed down by the foot the amount of shadow is lessened, and it consequently appears lighter. Hence the obviousness from the air of a slight track or path in grass which is quite inconspicuous from the ground.

d. Color.—Color is the least important of the four elements that contribute to form patterns in the photograph, as it can be translated only into tones of black and white. Colors which may appear to the eye to match the locality do not match in photographs unless the texture of the material approximates the texture of the locality. Painted canvas or burlap of the same color as grass photographs much lighter on account of reflection due to lack of texture.

5. Relative importance of camouflage requirements.—Field experience has shown that the relative importance of camouflage requirements is about as follows:

a. Proper choice of position—40 per cent.

b. Camouflage discipline (careful observance of camouflage regulations)—25 per cent.

c. Proper erection of camouflage material—20 per cent.

d. Camouflage material used—15 per cent.

6. Types of camouflage.—The types of camouflage include—

a. Concealment, as by the use of screening to prevent direct observation of our activities.

b. Variegated painting to deceive the observer as to the true pattern of what he sees.

c. Fish nets hung with garlands of burlap or other material to cover batteries and other objects to make a blurred and inconspicuous record on an aerial photograph.

d. Road screens of natural or artificial material.

e. Dummies which, though visible to the enemy, confuse and deceive him.

Section II

RECONNAISSANCE

7. Use of aerial photographs.—The most important means of reconnoitering for camouflage information are aerial photographs. If possible, a complete series of photographs should be used showing the terrain before occupation by our forces, and from time to time thereafter, in order that the camouflage measures adopted by us may conform to the requirements of the locality and in order that errors in camouflage technique may be discovered early.

8. Use of maps.—By the use of accurately contoured maps it is possible to determine what points in the terrain occupied by our forces are directly visible from the enemy position. This is of assistance in determining where road screening is worth while.

9. Local material.—Camouflage reconnaissance should determine the location of local materials which can be used for camouflage purposes. These include principally brush and poles and local commercial stocks of iron wire, lumber, chicken wire, burlap, and paint.

10. Seasonal changes.—The entire position occupied by our forces must be reconnoitered from time to time to determine the effect of seasonal changes of vegetation upon camouflage in the area. This reconnaissance is made partly by personal visit and partly by the study of aerial photographs.

11. Reconnaissance and choice of positions.—The most important factor in the camouflage of a position is intelligent reconnaissance. Whether or not the terrain has been photographed by the enemy has an important bearing upon the choice of position. If it has not been photographed, the position can be hidden in many ways, so long as the method is maintained. If the terrain has been photographed, the position is best hidden by offering the least disturbance to the surroundings. The points to be sought embrace—

a. Ease of access without making incriminatory tracks either during installation, in supplying food and ammunition, or in relieving personnel.

b. Natural concealment or ease of concealment by camouflage.

c. Defilading both from direct observation posts and balloons or by flash in the case of artillery.

d. Suitable locations for auxiliaries to the main position such as camps, kitchens, and latrines, easily camouflaged and easily accessible yet not so close as to cause discovery of the main position.

Section III

CONSTRUCTION

12. Camouflage materials.—*a. Natural.*—The best materials for camouflage are natural ones, as they possess the textures of the locality. The objection to them is that they must be constantly renewed, whereupon the feet of the men replenishing the camouflage tread down the area around the point to be hidden until the position looks like a black bull's-eye in the center of a white target.

(1) Natural materials include grass, weeds, foliage, branches, vegetation of all kinds, sod, etc. They may be self-supporting or erected on frames or wire. Natural materials must be renewed at short intervals, otherwise withering and fading will cause detection of the position.

(2) Another class of natural camouflage material is débris natural to the locality, such as is found in shell-torn villages

and battlefields. This débris may be so distributed over and around positions that in the confused pattern of light and shadow it will be impossible to distinguish anything suspicious.

b. Artificial.—Artificial camouflage materials for cover of various kinds are furnished by the camouflage sections. The most important of these are wire netting and fish net, both garnished with burlap, grass, or other material in colors suited to the terrain where they will be used.

(1) There are two methods of garnishing wire or fish nets with burlap:

(*a*) The better method is to knot burlap strips into the wire or fish net. Strips 5 feet long and 1 inch wide are woven and knotted at each end into the wire or net. The proportion of bare space in a covering of this type is about 30 per cent. (See fig. 1.) The strips are thinned out gradually at the edges. The strips give the approximate texture to the cover when correctly colored to the surroundings. The thickly woven central portion serves to conceal what may be under it and the thinned edges cast a faint, indeterminate shadow which, merging into the inequalities of the terrain, renders it unnoticeable in aerial photographs. Since the thinned edges allow objects under them to show, the cover must be much larger than the object over which it is placed.

(*b*) The other method is to slash a lightweight burlap by cutting slits from 6 to 15 inches long in various directions and then stretching the burlap on wire netting or fish net so that about 75 per cent of the wire is covered with burlap and the rest is bare. The burlap is tied to the wire at 1-foot intervals with strong twine. The texture of this covering causes it to photograph lighter than the knotted burlap net.

(2) Wire netting 6 feet wide is cut into standard lengths of 30 feet. Burlap strips are woven into this wire, which is then rolled up ready to transport. Inasmuch as covers of various dimensions are built up from these, the thinned portion is furnished in separate rolls which are used for the edges of the cover when erected. Every accomplished requisition for wire netting should contain about 15 per cent of thinned strips which should be distinctively marked. Particular care should be taken, when slashed burlap is used on these strips, to see that the burlap overlaps from 6 to 12 inches on one side and one end, otherwise the sheets of burlap will shrink away from

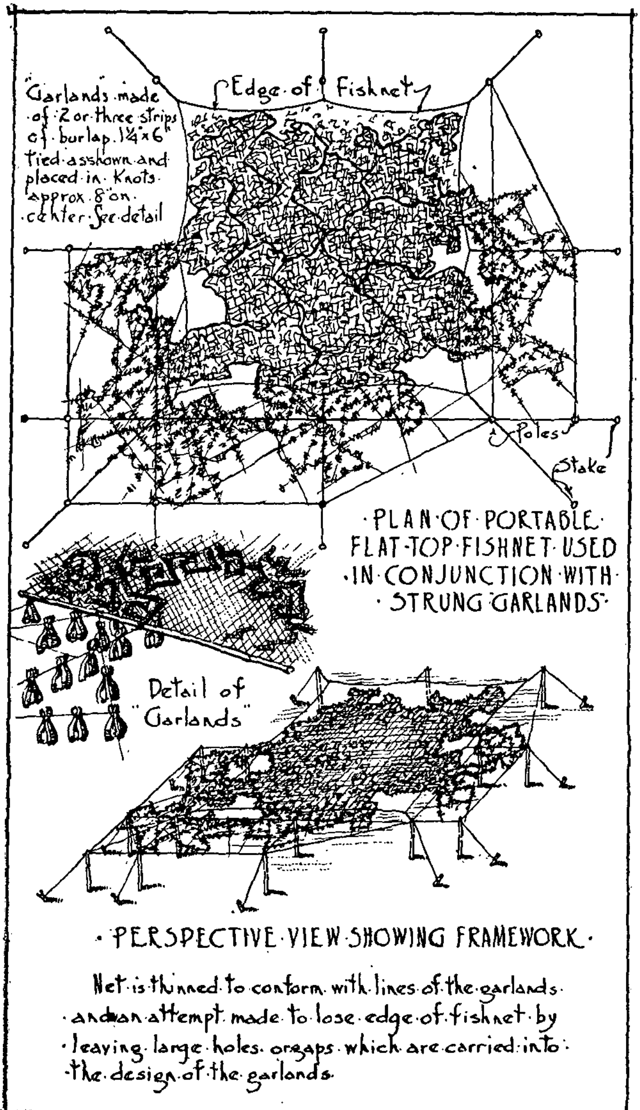

FIGURE 1.—Framework and cover

the edges of the strips or wire and each individual strip will be outlined on an aerial photograph by a black border.

(3) The sizes of fish nets recommended for future use are 32 by 40 feet for 6-inch guns or larger, 32 by 32 feet for 3-inch guns, and 10 by 10 feet or 16 by 16 feet for machine guns.

(4) Fish nets, because of their portability, are used principally for mobile artillery, which carries them as a part of its equipment. Wire netting is used for batteries or guns in more or less stabilized positions, for observation posts, dugout and mine entrances, and sometimes for concealment of concentrations of troops. It is supported on wire frames stretched on posts and strongly guyed. It has the advantage of being rigid enough to bridge considerable gaps between supports without sagging, of being more permanent, and, in case of fire, of not dropping the whole fabric on men and matériel underneath; but it is more bulky than fish nets and less easily moved. For spoil covers, and when material is laid directly on the surface desired to be rendered inconspicuous, painted burlap may be used. Its efficiency is very limited, however, as such a practice, though covering up obvious differences in color or value, shows both form and shadow.

(5) Garlands are made of two or three strips of burlap 1¼ by 6 inches, tied together about 1½ inches from one end. These knots are then secured to a light wire framework so that they are approximately 8 inches apart. They are useful for screens for thickening overhead cover, at entrances to shelters, etc. (See fig. 1.)

(6) Colors of fish net and wire netting camouflage must be standardized, because material must be used over a wide front and during changing seasons. As a rule, mottled patterns are best for general use. Solid-color patterns are objectionable. Some experiments will be needed to find colors and patterns adapted to use in America. In general, the standard colors will be the six used in France: No. 1, a light yellow; No. 2, dark green; No. 3, yellow ocher; No. 4, brown earth color; No. 5, reddish brown; and No. 6, dark reddish brown.

13. Standard method of erecting wire frame for wire netting or net covers.—*a.* There are many problems which demand flat-top covers, usually of wire netting, but sometimes of net, of various dimensions and irregular size. Often no material for the support can be had except wire from the engineer dumps.

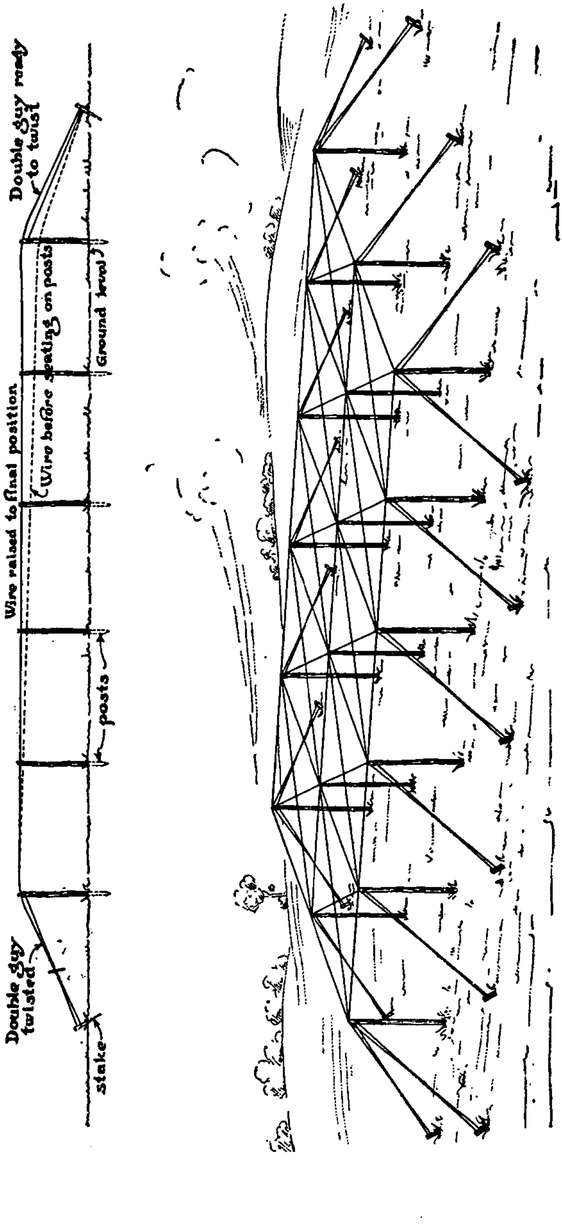

FIGURE 2.—Flat-top wire frame

b. (1) The following method of erection is easy and expeditious even for men without experience. It lends itself to any size or shape, and may be used to support either a finished cover or plain wire netting as a base for natural materials. (See fig. 2.)

(*a*) Posts should be made about 3 inches in diameter, cut square at the top, and sharpened at the bottom. They are placed preferably about 12 feet apart in each direction though conditions often necessitate a greater distance.

(*b*) The outside rows of posts should be driven in the ground just far enough to stand alone, and strong guy stakes should be driven about 12 feet from them.

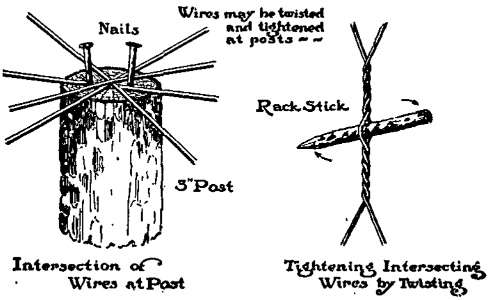

FIGURE 3.—Detail of flat-top wire frame

(*c*) Two nails should be driven in the head of each post, about 1 inch apart. (See fig. 3.)

(*d*) The end of the wire, No. 8 or 9, should be wound fast around the head of the first post, then taken with a turn around the guy stake and back over the top of the post between the nails, forming a double guy.

(*e*) The wire should then be stretched along the line of the posts by several men, being supported by a nail about 1 foot below the top of the last post of the row, then given a turn around the guy stake and brought back and made fast to the top of the post. Cut the wire from the coil at this point. (See fig. 2.)

(*f*) The wire should then be pushed up over the tops of all the posts in the row and seated between the nails, thus stretching it tight.

(*g*) Proceed similarly with each parallel line of posts, then in the same manner run wires at right angles to the first series, forming squares.

(*h*) Run diagonal wires across each line of posts, placing the wire between the nails.

(*i*) Tighten all guy wires by twisting with a rack stick or large nail. Tighten the diagonal wires in the same manner at all crossings. This will tighten the whole frame.

(*j*) Drive the nails home, to avoid catching the cover when spread. If poles are of even height and flat topped, the nails may be dispensed with, though they assist greatly in quick work.

(2) This method is quick and gives a rigid and lasting frame. After erection any of the interior posts may be shifted in position to accommodate battery needs without affecting the stiffness of the frame. By placing additional posts on the edges and wiring them in accordance with the previously mentioned principles, any irregular shape may be made. If only hard, steel wire is obtainable, it is easily annealed by heating it until red hot in a fire and allowing it to cool gradually. It is impossible to do good light work with hard wire.

14. Erection of natural materials.—*a.* In the use of natural materials, which are always the best when properly and intelligently handled, care must be taken to place the materials in their natural positions, otherwise they will reflect light differently and show in aerial photographs. For instance, cut grass thrown over a path lies flat and photographs nearly as light as the path itself. A thatched cover of branches, particularly evergreens, reflects light to such an extent as to photograph nearly white. Branches thrown on upside down, as is generally the practice with untrained men, photograph almost white. The underside of a leaf is a very different color from the upper side. Also branches should not be thrown on camouflage material with the stem out. Trees do not grow that way.

b. In making a cover of natural material two methods are successful:

(1) On a standard wire frame erect a flat top of two layers of wire netting separated about 4 inches by brush placed between the layers. This will serve to stick the covering material in, the two layers holding the branches or cuttings upright. They will invariably fall flat if only one layer of netting is used.

(2) Stretch wires overhead at different heights and in several directions. Fasten them to trees or posts and suspend small trees, branches, or shrubs by their tips from these wires. A natural appearance is then presented to the eye or lens.

c. In case paint or solutions preserving the natural color of the foliage are not used the materials must be renewed at night upon the earliest indication of deterioration.

d. When a position placed in thick woods in leaf is presumably to be occupied after leaves fall, a cover of brown burlap may be stretched over the position. As the leaves fall, thinning the natural cover, they will be caught on the burlap, and when the trees are bare the cover will present the leaf-covered appearance of the ground.

e. Where some thinning out of trees in a wood for a position or path is necessary, it is often sufficient to bend saplings and small trees over the thinned space, fastening them with wires.

15. Road screening.—*a.* Road screening is erected to prevent balloon or terrestrial observers from seeing traffic pass along visible roads. Its purposes are to prevent the enemy intelligence observers from counting the road traffic, and so estimating what troop movements are taking place in our areas, and to keep the enemy from observing and shelling vehicles moving over an exposed road. The first purpose is at times most important.

b. Most roads may be sufficiently screened by a lateral screen, 6 to 12 feet high. This must be guyed solidly to the ground with good stakes to keep the wind and shells from knocking it down. It should be 20 to 50 yards from the road to allow free room for guy wires. When the road is on a high embankment, the screen must be close to the edge of the road. Gaps must be left at intervals in the screening for lateral communication. In a salient, lateral screening may be necessary on both sides of a road to prevent enemy observation. Figures 4, 5, and 6 give details of lateral screenings.

c. When a road is nearly perpendicular to the front, it may be economical to echelon the screening, as shown in Figure 4. The angle of these wings of screening, their length, and distance apart can be easily estimated by drawing a diagram showing the road and the enemy's line of sight. Care must be taken to have plenty of overlap between successive screens.

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d. A road perpendicular to and sloping downward toward the front must often be cross screened. It may require lateral screening also. Figure 7 gives details of cross screening.

e. Road screening can be made either from natural materials available in the vicinity, such as brush and cuttings, or from artificial camouflage materials, such as plain burlap or wire netting garnished with camouflage material or burlap strips.

(1) Brush either cut on the site and woven with smooth wire into a screen, or fabricated in rolls at some favorable point and hauled to the site for erection, makes a very durable road screen for lateral and echelon screening. Figure 6 gives details of fabricating screen from brush.

(2) Wire netting garnished with camouflage material in the same manner as described in paragraph 12 can be used. A more satisfactory method of garnishing is by means of burlap strips of alternate light and dark color as shown in Figure 5. The alternating color is used to secure greater opacity. Plain material is probably as effective. When wire netting is used for overhead cross screening, a 3-foot width is used. The burlap strips are made 2 inches wide and 12 feet long. These strips are woven once across the netting and back again, leaving two 3-foot ends hanging below. These dangle down and allow high loads to pass through but obstruct the view to a 6-foot depth.

(3) Plain burlap is suitable for either lateral or cross screening. It should be used for overhead cross screening if available on account of its light weight. It should be slashed, as shown in Figure 7, to cut down wind resistance. Plenty of holes are necessary to let the wind blow through, and these should be small and close together, rather than large and unduly separated. Otherwise even strong screens will blow over.

f. Overhead road screening is generally only necessary for short stretches, and then perhaps only 6 to 12 separate screens need be erected. This requires poles 20 to 25 feet long, usually made by splicing 2 short ones. The amount of road screening necessary to hide all visible important roads from enemy observers varies widely with the terrain. The opacity necessary for road screening varies with the distance from the enemy observer. A good rule is that three-fourths of the surface of the screening should be opaque.

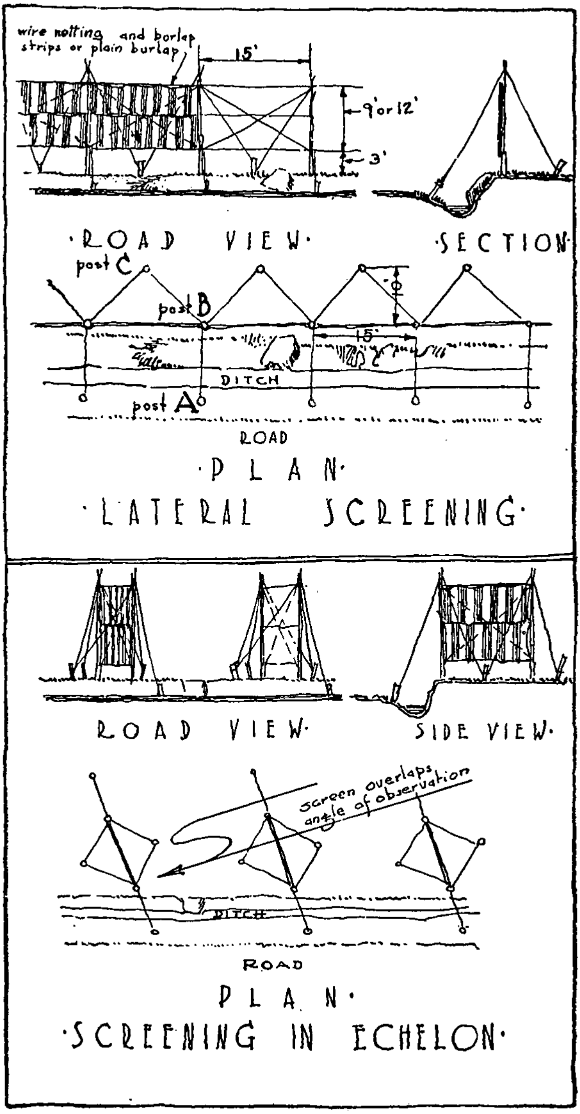

wire netting and burlap strips or plain burlap
15'
9' or 12'
3'
ROAD VIEW
SECTION
post C
post B
15'
DITCH
post A
ROAD
PLAN
LATERAL SCREENING
ROAD VIEW
SIDE VIEW
screen overlaps angle of observation
DITCH
ROAD
PLAN
SCREENING IN ECHELON

FIGURE 4

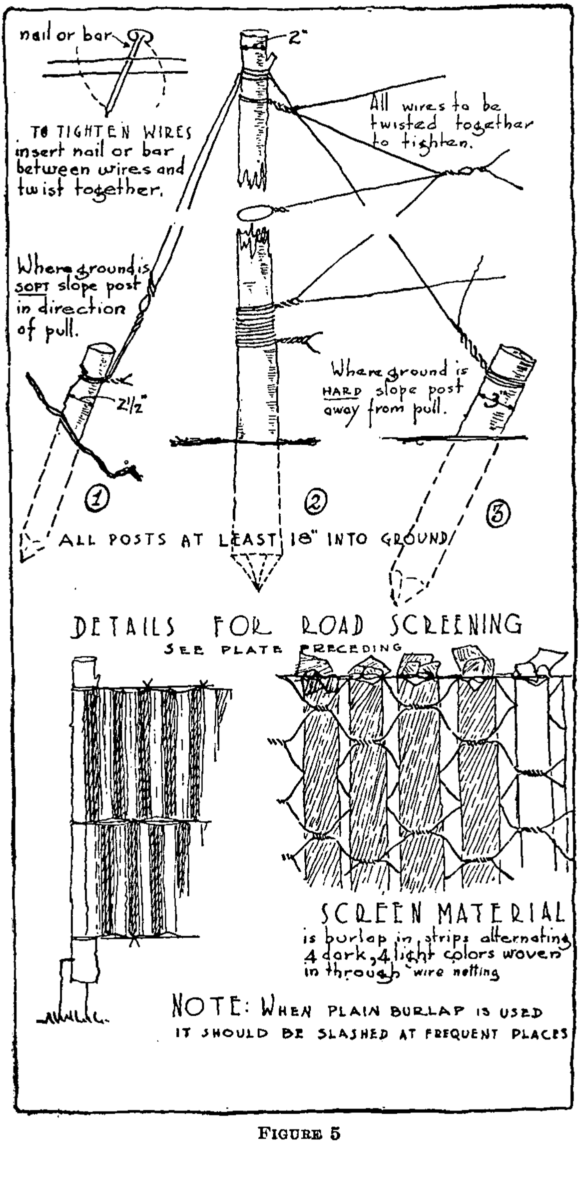

nail or bar
2"
All wires to be twisted together to tighten.
TO TIGHTEN WIRES insert nail or bar between wires and twist together.
Where ground is SOFT slope post in direction of pull.
2½"
Where ground is HARD slope post away from pull.
3"
1
2
3
ALL POSTS AT LEAST 18" INTO GROUND
DETAILS FOR ROAD SCREENING
SEE PLATE PRECEDING
SCREEN MATERIAL
is burlap in strips alternating 4 dark, 4 light colors woven in through wire netting
NOTE: WHEN PLAIN BURLAP IS USED IT SHOULD BE SLASHED AT FREQUENT PLACES

FIGURE 5

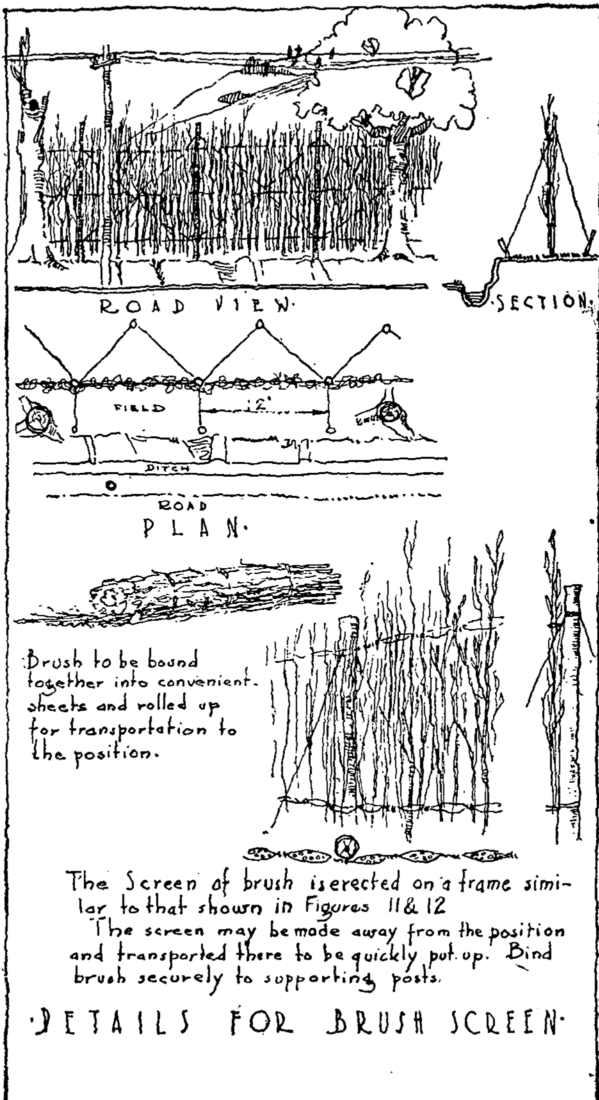

ROAD VIEW
SECTION
FIELD
12'
DITCH
ROAD
PLAN
Brush to be bound together into convenient sheets and rolled up for transportation to the position.
The Screen of brush is erected on a frame similar to that shown in Figures 11 & 12
The screen may be made away from the position and transported there to be quickly put up. Bind brush securely to supporting posts.
DETAILS FOR BRUSH SCREEN

FIGURE 6

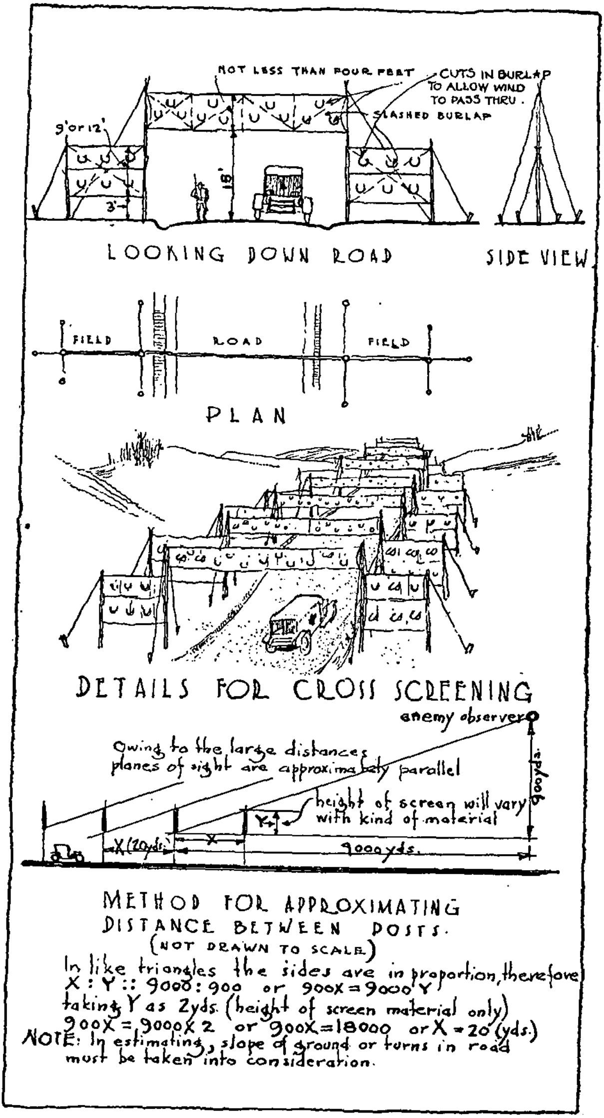

NOT LESS THAN FOUR FEET
CUTS IN BURLAP TO ALLOW WIND TO PASS THRU.
SLASHED BURLAP
9' or 12'
18'
3'
LOOKING DOWN ROAD
SIDE VIEW
FIELD
ROAD
FIELD
PLAN
DETAILS FOR CROSS SCREENING
enemy observer
Owing to the large distances planes of sight are approximately parallel
height of screen will vary with kind of material
900 yds.
Y
X (20yds.)
X
9000 yds.
METHOD FOR APPROXIMATING DISTANCE BETWEEN POSTS.
(NOT DRAWN TO SCALE)
In like triangles the sides are in proportion, therefore
X : Y :: 9000 : 900 or 900X = 9000 Y
taking Y as 2yds. (height of screen material only)
900X = 9000 X 2 or 900X = 18000 or X = 20 (yds.)
NOTE: In estimating, slope of ground or turns in road must be taken into consideration.

FIGURE 7

16. Snow camouflage.—*a.* It is virtually impossible to camouflage in snow. Time expended in such work is almost wholly wasted. Available labor is much more profitably expended in digging under such circumstances. However, if an attempt at camouflage is insisted upon, it is well to keep the following in mind: Trails track with mud and snow. They melt out early and leave a black line. Snow falls through camouflage material and the holes show dark. It soon melts off the warm roofs of dugouts.

b. The remedies are as follows:

(1) When snow first falls, keep activity at a minimum. Often snow soon melts in places and it is only on the first clear morning that an unbroken white sheet exists. Then enemy aircraft is unusually active, like hunters after a snowstorm.

(2) Cover trails, dugout roofs, etc., with fresh snow. Renew this covering as often as needed. Cover parts of camouflage with something to hold snow and then scatter snow on this sheet. The entire surface need not be covered, but the form should be broken up with the snow.

(3) If any white cloth is available, use this in patches to cover the camouflage. Cloth in the quantities necessary is so difficult to obtain that it would probably only be furnished for areas where snow lies unbroken on the ground for long periods.

17. Observation posts.—*a.* Observation posts are of two classes:

(1) For close observation in the trench system or trenches themselves.

(2) For distant observation, such as observation posts for intelligence, for artillery adjustment, or for both.

b. Any observation post which shows artificial construction is apt to be useless. It will almost certainly be noted and, when most needed, will be destroyed by the enemy. Hence, effective camouflage is especially important for observation posts. Observation posts should preferably be located in one of two ways:

(1) Underground where natural folds or slopes allow chambers and loopholes to be made from within, leaving the terrain undisturbed, access being provided through a shaft or tunnel.

(2) Concealed in some existing structure or object.

c. Trench observation posts are useful only when occupied trench lines are within a few hundred yards of each other. A standard type of camouflaged provision for such posts consists of a wire frame with a cement coating, simulating the material of the parapet. (See fig. 8.) These camouflaged observation posts have loopholes covered with painted wire gauze, and are placed at the end of a short sap from the trench, the observation post forming the overhead cover. They are not armored and depend on their likeness to the parapet for protection. Posts for close observation located out from trenches are often spotted by the trails or saps leading to them. These latter can generally be hidden or they can be given a false objective.

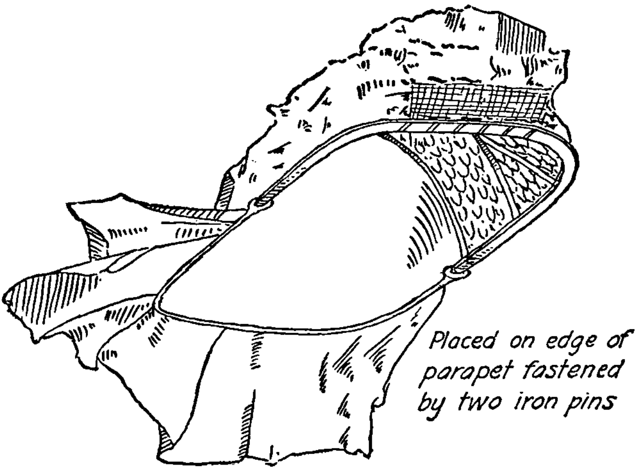
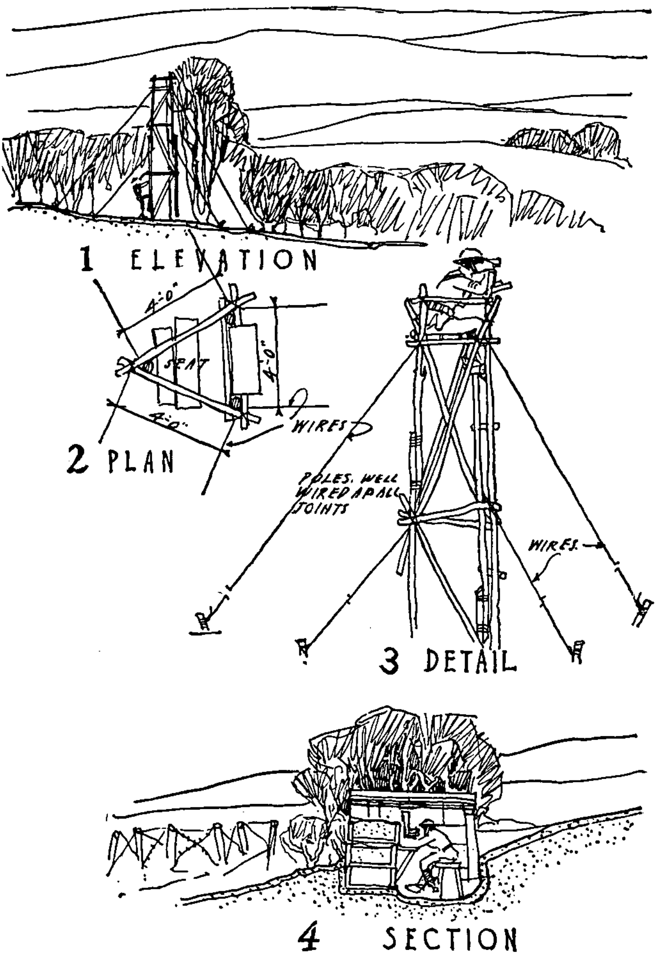


FIGURE 8.—Camouflaged cover for observation post

d. Observation posts for artillery and intelligence should have the greatest command possible and may be at considerable distances back of the lines, equipped with high-power telescopes. They can often be successfully concealed in old buildings, cellars, trees, etc. A well-concealed observation post in a tall tree, in woods subject to gas attacks, is very valuable, for the observer may remain above the gas long after the woods must be evacuated by those on the ground. Loopholes for artillery and intelligence observation posts must be of considerable size to accommodate instruments and two or three observers. It is essential that the exterior of the loopholes should be irregular in shape and the observation post must be so constructed



OBSERVATION POSTS

UPPER ONE LOCATED IN WOODS · LOWER ONE IN HEDGE.

FIGURE 9

that the light from behind may not show through. It is often necessary to provide a curtain to close the loophole when not in use.

18. Cave shelters.—*a*. Dugouts built in deliberately planned defense lines can be successfully hidden under a cover of camouflage, providing the position fits into woods, clumps of trees or brush, or into broken-up terrain. If the dugouts must be built in open fields, the camouflage will show up, especially after exposure for some time, but it is worth while anyway to conceal the working party and the exact nature and state of the work. It might be practicable, at times, to use false work to deceive the enemy as to the connection between these dugouts and the trench system when the trenches are put in later.

b. The exact location of dugouts may be concealed by covering the entrance niche so that it does not show. The disturbance of earth should be minimized and the spoil covered by sod, brush, or artificial material, which is placed directly on the spoil and should have a contour very nearly that of the original surface, or the entire surface in that area should be so irregularly broken up by scattering the parapet or digging up the soil, that the dugout roof will be lost in the confusion.

19. Communications.—*a*. Telephone and telegraph air lines may be rendered less conspicuous by painting tops of poles dark green or black, by sodding spoil at the base of poles, and by cutting the grass close up to the poles when mowing a field. Telephone lines in trenches are difficult to conceal. The trench is almost certain to show unless great care is taken in concealing it. Trenches should be dug under cover of hedgerows, trees, etc., when possible. When placed in the open, the trenches must be concealed by covering with camouflage material.

b. Roads, railroads, and paths can not be hidden except for short lengths, but they can be controlled so that their true objective is not discovered. Narrow-gauge tracks along the edge of a road do not show except where the road makes a right-angle turn. There the railroad curve will show if not covered. The spur of a railroad, road, or path branching off from the main road to a military position is generally very important evidence of the exact whereabouts of the position, and so the location of this turnout should be selected and hidden carefully so as to escape detection. For instance, a spur run into a wood should, if possible, take off where the main line is obscured in the woods, or a narrow-gauge spur from a main line to a battery or dump on a road should have its turnout curve hidden under camouflage and then should follow up the road to the battery.

c. To avoid tracks—

(1) Use existing roads and paths wherever possible.

(2) Build new roads and paths under cover, using natural cover as much as possible. Do not cover a trail with straight lines of material. The lines will show. Cover it with irregular patches, not necessarily contiguous and preferably not of the same material. For instance, mix brush patches with artificial material.

(3) Carry new roads and paths past the position to another road, a house, or a dummy position. Make sure that the road is used past the true position.

(4) When new paths can not be avoided make them follow existing lines, such as fences, hedges, ditches, edges of plowed fields, or the like. Keep the paths narrow and avoid cutting corners.

(5) Confine traffic to one route. Keep this route narrow and confine traffic to the route by the liberal use of trip wires.

20. Command posts.—*a.* Command posts are important targets and should be hidden. Arrangements should be made to cover the vehicles at headquarters with a screen, and a screen should conceal vehicles stopping at the message center. This must be done cleverly, otherwise the enemy will soon learn that a large horizontal screen is a sign indicating a headquarters.

b. The location of smaller command posts is apt to be disclosed by the telephone lines converging on them. These lines, whether overhead or in a trench, show, because they are straight and because they cut across natural lines. The 100 to 300 yard lengths of telephone wires converging on a command post should be hidden. The telephone trench should follow along existing ground lines or the uncovered wires should be laid in an existing ditch or on the bare ground, and the formation of paths along the wires should be prohibited.

21. Artillery.—*a.* Artillery batteries may be camouflaged by an overhead covering of camouflage material erected as described in paragraph 13. Seventy-five-mm. guns and 155-mm. howitzers require 6½ feet headroom from gun pit to camouflage material. Heavy and medium field artillery require 7½ to 9 feet headroom. The higher camouflage material stands, the more shadow it causes and the greater its visibility. Nets only 2 or 3 feet above the ground cast very trifling shadows; hence it is desirable to dig down 3 or 4 feet for light field artillery and 5 to 6 feet for heavy and medium field artillery. This, of course, has the additional advantage of providing protection against shell bursts. Pathways in and around the battery should be wired off to keep men from cutting corners and thereby spreading the paths.

b. An embrasure must be provided in the camouflage material large enough to permit the guns to fire through required angles of fire without hitting the inflammable camouflage material. There are three main types of embrasures, the split type which is most common, the rolling embrasure, and the counterweighted embrasure. (See figs. 10, 11, and 12.)

c. Blast marks show on aerial photographs as white blurs in front of each gun. These can be hidden by covering them with branches held in place by driving a few 12 or 18 inch stakes at intervals in the blast marks. This camouflage may have to be renewed frequently. It should be distributed so as not to cover exactly the blast mark but so as to break up the pattern.

d. Heavy artillery requires better camouflage than lighter artillery because it remains in one position longer and requires a more elaborate firing position. A concentration of heavy artillery can be hidden only partially; firing positions are usually very large and very obvious. A railroad spur position can be concealed for two or three weeks in case it is very important that the initial installation and firing be secret.

22. **Dumps.**—*a.* In general, dumps are so large and the activity around them so intense that their concealment is rarely practicable. The building of new dumps or the refilling of old ones reveals plans of attack. A good camouflage measure for large dumps in rear areas is to scatter buildings irregularly or to place the buildings in and around woods and clumps of bushes so as to make poor night bombing targets. A dump should not be near any landmarks easily visible at night, such as a large white building or a distinctive body of water. If

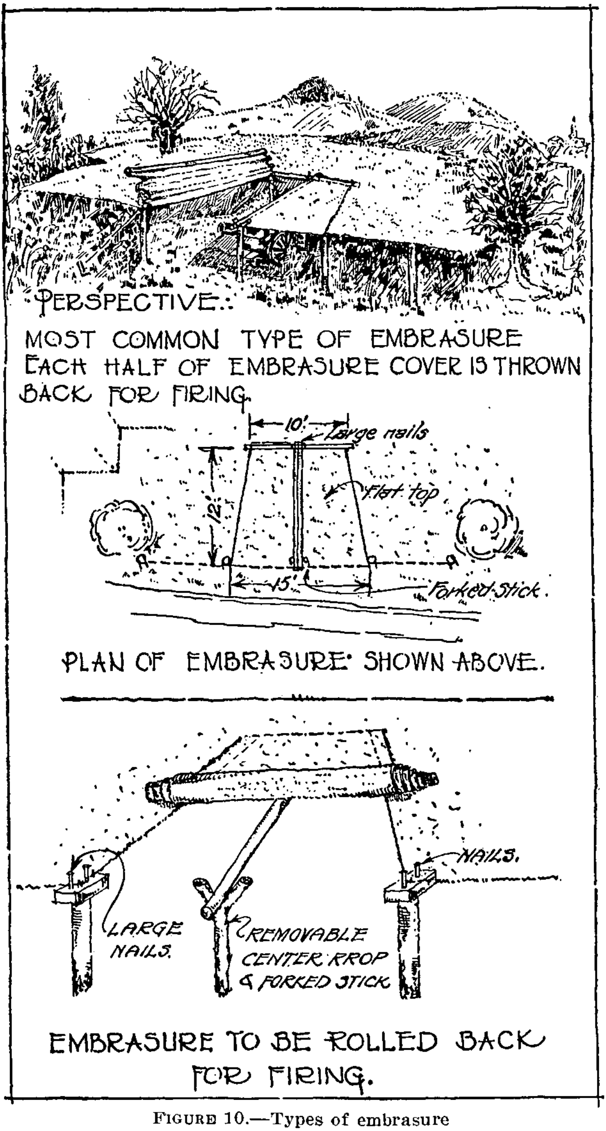


FIGURE 10.—Types of embrasure

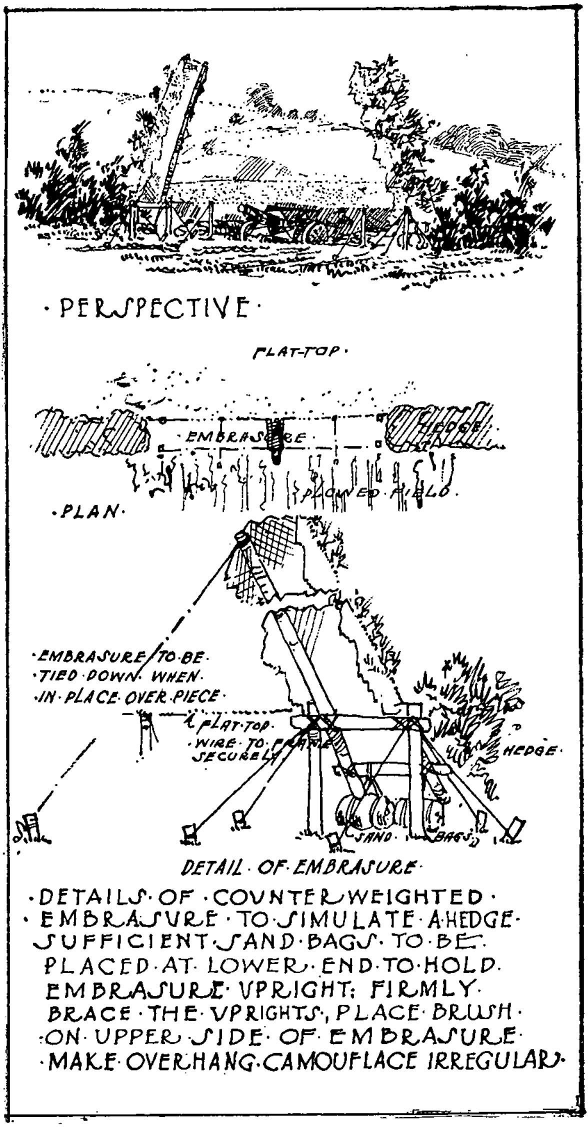


FIGURE 11.—Counterweighted embrasure

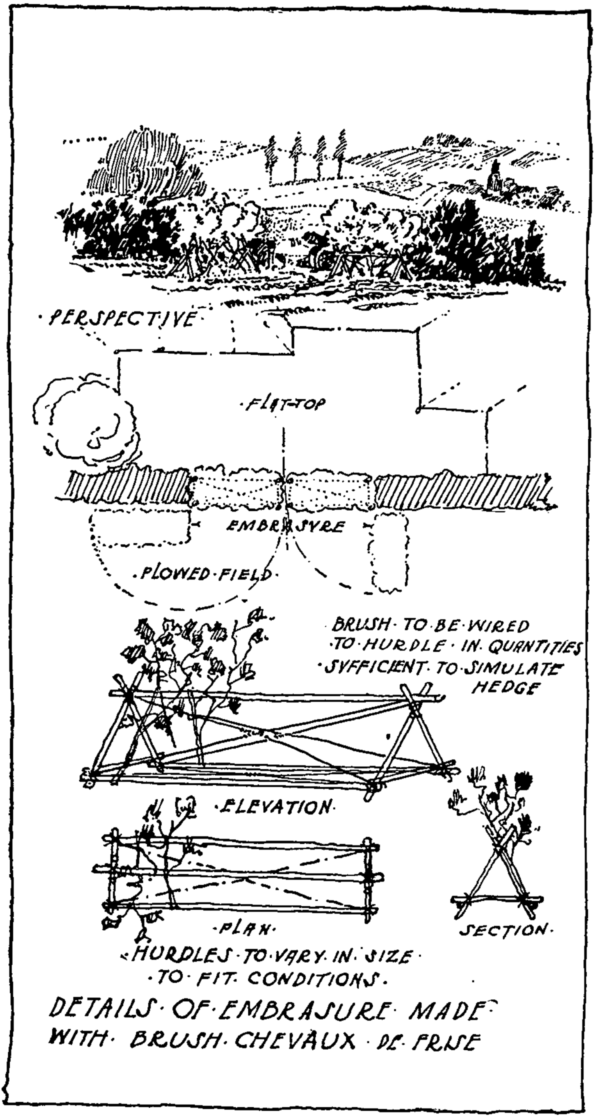


FIGURE 12.—Embrasure details

bombing activity becomes intense and effective, large dumps must be broken up and scattered. This dispersion, of course, complicates the system of supply.

b. More effective measures must be adopted for the smaller forward dumps subject to shell fire. These are as follows (see fig. 13):

(1) Locate dumps, as far as requirements of service and the labor of construction will permit, in places favorable for concealment in woods, in scattered brush or trees, in a quarry, or, for engineer and ration dumps, in a village. Avoid important crossroads, a lone building or group of buildings, or the immediate vicinity of a battery.

(2) Lay out the dump so that the material is scattered and fits in with the natural features of the terrain as far as possible. Small artillery dumps may be well concealed and perfectly accessible by placing the ammunition boxes irregularly at the bottoms of hedgerows.

(3) Cover piles of material with sufficient screening to prevent the enemy from seeing the quantity of stores on hand.

(4) Restrict traffic to a few routes so that tracks will not indicate the nature of the place. If possible, provide return routes for wagons and trucks so that their turning will not mark up the area.

23. Camps.—*a.* Camps must be located all over the forward areas, especially during an advance. Shelter tents can usually be hidden with a reasonable expenditure of effort by placing them irregularly among bushes and trees and by covering them over with brush and grass. Out in the open they may be grouped irregularly under a single cover of artificial camouflage material or of brush supported on wire.

b. The concealment of troops is much simpler in woods and villages than in the open, and such locations should be utilized to the fullest extent. In woods, if not very thick, use overhead cover of proper color or cover tents with branches or brush, and avoid all regularity in placing tents or shelters. In villages, utilize to the utmost capacity existing buildings, walls, basements, etc. A shelter in a tumble-down or roofless enclosure may be disguised by leaning broken timbers against the wall above the shelter to represent fallen rafters, and scattering dirt, brick dust, or débris over the shelter. In yards, shelters should be scattered and placed near fences, hedges, or

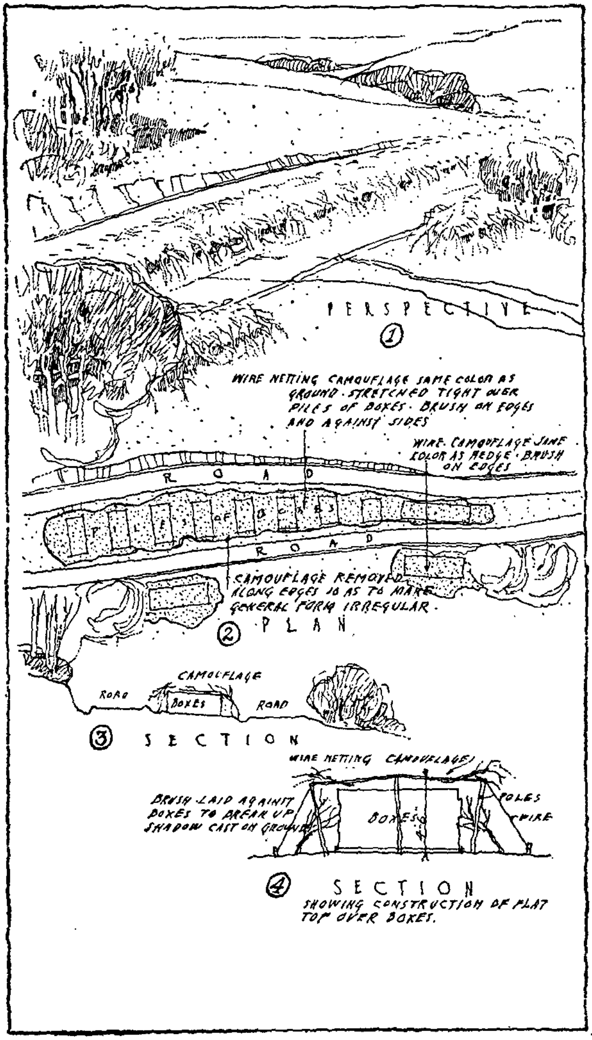


FIGURE 13.—Ammunition dump located between two roads on hillside

trees. Disguise them with paint blotches, mud, or tar, and throw brush or grass on them. Especially cover up the ends and entrances.

c. To conceal a bivouac in the open, cover the area with camouflage material on a standard wire cover. Grass or hay may be used, as the bivouac is temporary. About 5 square yards of cover per man is sufficient. The wiring is to be erected as described in paragraph 13. The wires may serve as support for tent ridges. In covering any large area, care must be taken to come exactly to the existing edge of a field. Half covered fields, or those where edges of cover do not exactly coincide with existing boundaries, are very evident in photographs. When a cover occupies exactly the same area as the field underneath it, even if the color is not exactly the same, it appears in photographs as though some normal agricultural development had taken place.

d. Large tents can be treated in exactly the same way as shelter tents. The irregular grouping of the tents to fit in with existing concealment is the most essential feature. (See fig. 14 ③ and ④.)

24. Buildings in general.—*a.* Buildings, on account of their height, always cast strong shadows and, as they have rectangular forms, are easily picked out on aerial photographs. It is almost impossible to conceal a building, except a very small one, so that it will not show in a photograph. Therefore the siting of buildings is of the greatest importance, and no building layout in forward zones should ever be drawn up without considering carefully all camouflage measures.

b. Eighty per cent of the value of the camouflage of buildings lies in their correct location.

(1) Woods should be used for locations of buildings to the utmost possible extent.

(2) If scattered clumps of trees or bushes exist, tie the buildings into them; avoid the open as far as possible. Never arrange buildings in rows nor space them regularly.

(3) If one building in a regular layout be detected, the whole group can easily be destroyed by bombing.

c. A flat-roofed building is less visible than a peak-roofed one, because, with the sun on one side, the hard straight line in the latter between the side in light and that in shadow is very conspicuous.

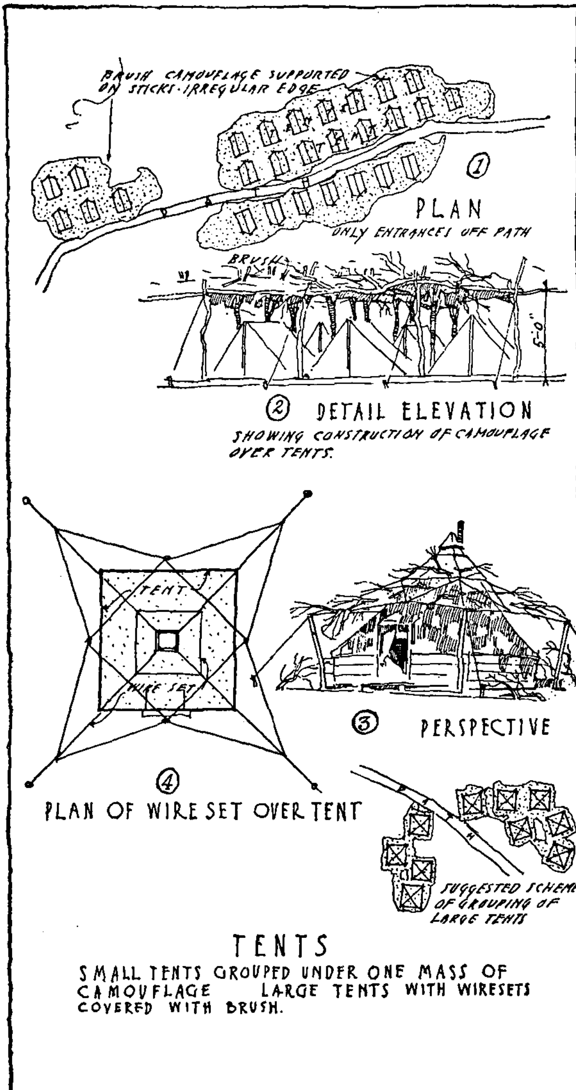

BRUSH CAMOUFLAGE SUPPORTED ON STICKS-IRREGULAR EDGE
① PLAN
ONLY ENTRANCES OFF PATH
BRUSH
5'-0"
② DETAIL ELEVATION
SHOWING CONSTRUCTION OF CAMOUFLAGE OVER TENTS.
TENT
WIRE SET
③ PERSPECTIVE
④ PLAN OF WIRE SET OVER TENT
SUGGESTED SCHEME OF GROUPING OF LARGE TENTS
TENTS
SMALL TENTS GROUPED UNDER ONE MASS OF CAMOUFLAGE LARGE TENTS WITH WIRESETS COVERED WITH BRUSH.

FIGURE 14

d. If new boards, bright tin, or corrugated iron are used for roofs, they must be painted in a flat color or daubed with tar or mud to remove the shining or conspicuous color. Old boards are better than new; rough boards are better than dressed. Tar paper is a good covering. The rougher the surface the less conspicuous the building is in the photograph.

e. After any conspicuous color in buildings is neutralized, bushes and brush should be piled irregularly on the roof. It is not necessary to cover it entirely, but by letting some brush extend beyond the roof lines the rectangular form is broken up. Increase this breaking up of form by placing bushes or brush on the ground, extending irregularly from the building. As the airplane view gives the appearance of flattening out all objects in the landscape, this method, if well carried out, will give the appearance from the air of bushes or blurs and render it almost impossible to distinguish objects clearly enough to bomb them.

25. Airdromes.—Airdromes are subjected to severe bombing. They are the favorite target of enemy bombers. The camouflage measures to be adopted consist in the irregular scattering of the hangars and barracks to fit the concealing features of the terrain and, if need be, in reducing the visibility of the individual hangars by covering them with a dull rough surface. The whole gives a target hard to locate in the first place, and hard to hit if it is located. Hangars and barracks are very often successfully hidden in woods. However, they should not be concentrated in a small wood or along an edge of a wood, because a wood is visible at night and if one is known to be fully occupied it can be bombed with effect. It is better to scatter the hangars widely; some in woods and some off alone in the open. This scattering of hangars and locating them in places favorable for concealment are facilitated by locating hangars 300 to 500 yards from the flying field and taxying the machines between the hangars and the field. Tarring roads leading to the airdrome aids materially in concealment.

26. Camouflage in open warfare.—*a.* Effective camouflage is a far more difficult problem in open warfare than in a stabilized position, inasmuch as the requisite time and labor are more available in the latter case, and because it is more difficult to conceal moving objects than stationary ones. Also, it is more important to conceal stationary objects. However, the principles of camouflage apply equally to open warfare and, while their proper application is less vital than in stabilized situations, it is nevertheless important. It is impossible to conceal from a reasonably alert enemy, especially if he possesses a good air force, that there is activity of some kind taking place in a certain area. The problem therefore is to deceive him, not as to the *presence* of our troops in this area, but as to the *nature* of our operations, the *exact location* of individual units and the *extent of our strength*, and to supplement this deception with such measures of concealment as may be applied.

b. Dummy bases, dumps, camps, railways, and other military essentials, not too well nor too slovenly camouflaged, may be advantageously employed to mislead the enemy as to our numbers, dispositions, and objectives.

TABLE I.—*Transportation of camouflage materials*

Article	Unit	Weight per unit in pounds	Number of units per load			
			Escort wagon	1-ton truck	2-ton truck	3-ton truck
Burlap	Sq. yd	1.2	1,100	1,100	1,600	1,875
Wire netting (with stripped burlap).	20 sq. yd. roll.	42	30	30	60	100
Wire netting (chicken wire) 1¼-in. mesh.	100 by 3 foot roll.	60	30	30	60	100
Fish net 32 ft. by 40 ft	Per net	140	10	10	20	30
32 ft. by 32 ft	do	115	12	12	24	35
Fish nets	Per sq. yd	1	1,200	1,200	2,400	3,600
Poles 12 to 15 ft., top diameter 2 in.	Each	115	18	18	36	54
Stakes 3 ft. long, diameter 3 in	do	8	250	250	500	750
Wire, smooth, No. 8 to No. 16	250 ft. coil	100	20	20	40	60

27. Reference data.—*a. Road camouflage.*—Bill of materials for one mile of lateral road screening, 12 feet high:

	3-ton truck loads
360 each, poles, 12 to 15 feet, top diameter 2 inches	5
750 each, stakes, 3 feet long, diameter 3 inches	3
30,000 feet smooth wire, No. 9 to No. 16	2
1,800 yards fabricated brush rolls, 12 feet wide	24
Or 7,200 yards burlap, plain, 36 inches wide	1
Or 3,600 yards wire-netting camouflage, 6 feet wide	3

½ keg staples or nails.

b. Overhead camouflage.—Bill of stakes and wire required for supports for each 1,000 square yards of camouflage covering:

17 stakes, 2½ feet long and 3 inches in diameter.

67 poles, 5 to 8 feet long, 3 to 4 inches in diameter.

1.8 rolls wire No. 8, No. 9, or No. 10, smooth.

1.2 rolls wire No. 14 or No. 16, smooth.

5 pounds nails.

CHAPTER 2

FIELD FORTIFICATIONS

SECTION I

PRINCIPLES OF FIELD FORTIFICATION

28. Organization of the ground.—*a. Definition.*—The organization of the ground is the utilization of the terrain to secure the most effective tactical disposition of the troops thereon by taking advantage of the naturally defensive features and improving them by the use of field fortifications.

b. Composition.—A defensive position consists of a system of mutually supporting defensive areas or tactical localities of varying size, each with a definite assignment of troops and mission.

c. Sectors.—The commander of a force on the defensive divides his front into sectors and assigns them to the several units for occupation, organization, and defense. The sector in the defensive corresponds to the zone of action in the offensive. While the extension of sector boundaries to the front defines the responsibilities of the several units for distant defense, the fire of units for close defense can not be restricted to lanes leading straight to the front. Each unit on the defensive must also be given the definite mission of covering the front of adjacent units by flanking fire in close defense. By application of the principle of mutual support, dead spaces are eliminated, and all parts of the terrain immediately in front of a position are covered by the fire of the defense.

d. Combat groups.—The combat group is the smallest tactical locality. All other tactical localities are made up of combat groups. It is occupied by a force varying from a squad to a platoon, disposed in groups of from four to eight men, to cover by fire a definite portion of the terrain. The fundamental principle of the defensive tactics of the combat groups is that each combat group should be able to cover by fire its own front, the fronts of the adjacent combat groups of the same echelon, and the unoccupied intervals between it and these adjacent combat groups.

e. Strong points.—A strong point is composed of several combat groups disposed laterally and in depth and commanded generally by a company commander. The garrison of a strong point is usually a company, but it may be held by a force varying from two platoons to two companies, depending on the terrain and other conditions. The combat groups of a strong point are located with a view to resistance to the front and flanks and, if necessary, to the rear. When fully organized a strong point should be capable of a protracted all-around defense.

f. Line of resistance.—The line of resistance of any defensive position is the line on which the principal defense of the position is made. It usually is the forward line of the combat echelons. After long occupation it may develop into a continuous trench or parallel. The line of resistance of the principal defense or battle position of a defensive system is called the main line of resistance and is the base or reference line which governs the location of all elements of the defensive system.

g. Support line.—Long occupation of a position generally will lead to the construction of parallels connecting the combat groups in support of the line of resistance. This line of trenches, practically continuous, and from 100 to 300 yards in rear of the line of resistance, is known as the support line of the position.

h. Centers of resistance.—A center of resistance is composed of several strong points disposed laterally and in depth and commanded by a single officer, generally a battalion commander. The garrison of a center of resistance is usually a battalion, but in exceptional cases may consist of a battalion with one or two rifle companies attached. One or more (usually two) of the rifle companies are located on the line of resistance and the remainder of the garrison is held in battalion reserve. The function of the battalion reserve is to counterattack when the integrity of the center of resistance has been seriously threatened. Should the tactical situation prevent counterattack, the reserves must stop or delay the further advance of the enemy and must accordingly be prepared for defense to the front, flanks, and rear. Therefore they organize strong points so located as to afford mutual support with reserve units of adjacent battalions and to cover the foreground by fire at least as far to the front as the supports.

i. Battalion reserve line.—The general line on which the forward elements of companies in battalion reserve are disposed is called the battalion reserve line. This line is from 400 to 900 yards in rear of the line of resistance (300 to 600 yards in rear of the support line). Some of the combat groups should be on the forward slope of commanding ground in order to cover the foreground by fire at least as far to the front as the support line and to render mutual support between adjacent strong points. Between the strong points the battalion reserve line may be located on the reverse slope, and such location may be advantageous for the formation of counterattacks.

j. Regimental reserve line.—In the defensive the regiment deploys with one or two battalions as combat or first line battalions and one or two reserve battalions. The combat battalions organize centers of resistance as described heretofore. The primary mission of the regimental reserve is to maintain the integrity of the sector of the battle position held by the regiment and its principal means is the counterattack. To meet a situation where the centers of resistance in front have been overrun by the enemy and the counterattack is not practicable, the regimental reserve organizes for stubborn resistance. The organization usually consists of a row of strong points prepared for all-around defense and located not only for mutual support between themselves and the regimental reserve units of adjacent regiments but also for the support of front centers of resistance, particularly their flanks. The general line on which the forward elements of companies in regimental reserve are disposed is called the regimental reserve line. It is usually located from 400 to 900 yards in rear of the battalion reserve line, 800 to 1,800 yards in rear of the line of resistance. Due to the necessity of covering the foreground by fire at least as far as the battalion reserve line and rendering mutual support between adjacent strong points, some of the combat groups of the strong points organized by the regimental reserve should be on the forward slope of commanding ground. In the intervals between strong points the regimental reserve line may be located on the reverse slope should the terrain be favorable. Machine guns located on the regimental reserve line should be able to place defensive fires in front of the line of resistance.

29. Battle position.—The term *battle position* is applied to the belt of ground organized as above described consisting of three approximately parallel rows of strong points as follows: A forward row of strong points embracing the main line of resistance and the support line, a second row of strong points embracing the battalion reserve line, and a third row embracing the regimental reserve line.

30. Outpost area.—The enemy situation permitting, every battle position should be covered by an outpost to the front. The area in front of the main line of resistance of the battle position occupied by the outpost is called the outpost area. When practicable the line of resistance of the outpost in position defense should be located at least 1,500 yards in front of the main line of resistance in order to prevent the enemy from emplacing machine guns within reach of the latter.

31. Reserve battle position.—In any defensive situation the commander must always consider the possibility of defeat in the selected battle position and the necessity of continuation of the defense farther to the rear. Such a position is designated as the *reserve battle position.*

32. Switch positions.—In addition to the several positions or organized areas of a defensive zone paralleling the front, additional positions are provided oblique to the front and connecting the forward position or areas with those in rear. These oblique positions, designated *switch positions* are established on the flanks of localities in the defensive system where, due to lack of natural defensive strength or for other reasons, there is a probability of an enemy penetration.

33. Defensive works.—The defensive works constructed consist of:

a. Machine-gun emplacements and fire trenches located, concealed, and constructed to develop the fire power of the defenders and to protect the occupants from the effect of hostile fire.

b. Obstacles so located as to be covered throughout by the fire of the defense (otherwise they are of no value) and to hold the attacking forces under the effective fire of automatic weapons. The bulk of the obstacles used in the organization of a battle position are artificial, and of these the wire entanglement furnishes the best obstacle for the least expenditure of time and labor.

c. Approach trenches.—Approach trenches are constructed approximately perpendicular to the front to provide covered communication between the front and rear elements of a defensive position.

d. Switch trenches running obliquely between trenches paralleling the front of a battle position and the approach trenches, particularly between the battalion and regimental reserve lines. A switch trench differs from an approach trench in that it is located primarily for combat, though it may also serve as a communication trench.

e. Observation posts.—As required.

f. Command posts.—As required.

g. Aid stations.—As required.

h. Communications.—In a defensive system, where roads and trails do not exist or are inadequate, a sufficient number must be constructed or existing ones must be improved to provide adequate means for the prompt movement of reserves, for the bringing forward of supplies and ammunition, and for the evacuation of wounded and of salvaged materials. When a stream lies within or closely in rear of the battle position, numerous crossings, supplementing those at the established roads, should be provided in order to facilitate the movement of troops across country and to provide alternative stream crossings in case those on established routes of traffic are shelled.

i. Shelters designed to protect the defenders from the concentrated fire of the enemy.

j. Dummy works may be constructed and occupied areas connected by dummy trenches in order to confuse the enemy as to the defensive dispositions.

34. Relative importance of works.—*a.* The positions or areas of a defensive system should generally be organized in the following order:

(1) The battle position;

(2) The outpost area;

(3) The reserve battle position;

(4) Switch positions;

but the order of importance may be changed by the situation, as, for example, in taking up the defensive following an offensive the organization of the battle position and that of the outpost area are practically of equal importance.

b. (1) The relative importance of the elements of organization of a battle position may be taken as follows:

(*a*) Machine-gun emplacements.

(*b*) Reasonable field of fire.

(*c*) Fire trenches on line of resistance and support line.

(*d*) Continuous obstacle in front of line of resistance.

(*e*) Obstacles protecting combat groups of front line strong points.

(*f*) Temporary command posts, observation posts and aid stations, and routes of communication.

(*g*) Completion of trenches and obstacles in front line strong points. Shelters.

(*h*) Fire trenches and obstacles on battalion and regimental reserve lines.

(*i*) Completion of trenches and obstacles in centers of resistance.

(*j*) Permanent command posts, observation posts, aid stations, and shelters.

(*k*) Completion and improvement of trenches and obstacles in the position.

(2) The foregoing list should not be taken to mean that each item of work is completed before the following item is begun. In practice, work proceeds simultaneously on several items. Those items which can usually be completed within six hours, and which may be said to fall in first group priority, include—

Machine-gun emplacements (open type).

Reasonable field of fire.

Squad trenches, simple standing type on line of resistance.

Continuous obstacle in front of line of resistance.

Shallow connecting trenches between squad trenches on lines within combat groups.

Command posts; observation posts; aid stations.

Camouflage.

SECTION II

THE EFFECTS OF PROJECTILES

35. General.—The penetration and effects of small-arm and artillery projectiles are very variable. Fortifications must be designed with large factors of safety. However, maximum probable penetrations and effects must be kept in mind, so that works may be strong enough to resist the fire that can be brought against them without an unnecessary expenditure of labor and material.

36. Penetration of rifle bullets.—*a.* The United States Army rifle, M1903, caliber .30, is a fair example of the small arm used by the various nations. It can be fired at a maximum rate of 20 shots per minute. With the present 150-grain bullet it has a flat trajectory giving a wide danger zone at all probable ranges. The maximum ordinate at 500 yards is 2 feet; at 1,000 yards, 14.5 feet; and at 2,500 yards, 271 feet. The new boat-tail bullet, weighing 172 grains, gives a flatter trajectory and a much greater range.

b. The following table gives approximate maximum penetrations in various materials of the 172-grain bullet, which are somewhat greater than the penetrations of the service 150-grain bullet:

TABLE II.—*Maximum penetration of 172-grain bullet in inches*

Material	Range		
	200 yards	600 yards	1,500 yards
Armor	0.30	0.10	0.10
Gravel or broken stone	8.00	7.00	6.00
Brick masonry [1]	4.00	4.00	4.00
Concrete, 1-2½-5 mix	1.65	1.20	1.10
Oak	20.00	20.00	12.00
Sand, dry	12.00	11.00	11.00
Earth, loam	27.00	27.00	27.00
Greasy clay	60.00	40.00	30.00

[1] Greater penetrations may occur when bricks are laid in soft mortar and bullets strike in mortar.

37. Penetration of automatic rifle and machine-gun bullets.—*a.* Caliber .30 automatic rifle and machine-gun bullets have the same penetration as rifle bullets.

b. Caliber .50 machine-gun bullets penetrate at short range up to 1 inch of special steel (tank) armor.

38. General rule for the penetration of armor by small-arm bullets.—It may be taken as a general rule that specially designed armor-piercing rifle and machine-gun bullets at their most favorable ranges can penetrate special steel (tank) armor twice their caliber in thickness, and that armor of greater thickness gives protection against them.

39. Penetration of 37-mm. projectiles.—*a*. The 37-mm. projectile fired from the service piece with a muzzle velocity of 1,300 feet per second penetrates 0.625 inch of special steel (tank) armor at 300 yards range.

b. A projected 37-mm. gun having a muzzle velocity of 2,000 feet per second has been tested and penetrates 1 inch of special steel (tank) armor at 300 yards range.

40. Effects of artillery fire.—*a*. Light artillery projectiles, 75-mm. (3-inch) to 105-mm. (4-inch), inclusive, produce inappreciable effects upon trenches and shelters, but are most effective against exposed personnel by reason of their fragmentation.

b. Medium and heavy artillery projectiles, 4.7-inch (120-mm.), to include the heaviest types, are used for the destruction of shelters, trenches, and other types of fortifications. The following table gives some conception of their relative effectiveness, but it must be borne in mind that craters vary greatly with the nature of the soil and depth to which the shell penetrates before explosion. This penetration is dependent upon both the kind and setting of the fuze and also upon the soil. The tabular dimensions must be considered as average.

TABLE III.—*Probable crater dimensions in feet in virgin soil*

Caliber	Penetration 1 to 2 lengths		Penetration 3 to 4 lengths	
	Diameter	Depth	Diameter	Depth
155-mm. (6-inch)	11.5	3.5	11.5	5.0
220-mm. (8.7-inch)	15.0	4.5	18.0	7.5
370-mm. (14.6-inch)	20.0	7.0	33.0	20.0

41. Effects of trench mortar and airplane bombs.—*a*. Trench mortar bombs have a high angle of fall and can reach defiladed objects. Due to their low velocity, they have little penetrative power. On the other hand, they carry heavier bursting charges than artillery projectiles of corresponding weight and caliber. They are consequently especially effective when used against entanglements or other obstacles, and produce serious destructive effects when they fall within trenches.

b. Airplane bombs have low velocity and little penetrative power. They carry heavy bursting charges, produce many fragments, and are frequently of large size. The present tendency is toward an increase in size and destructive power. They have in the past been used chiefly against large targets in rear of the combat units; for example, concentrations of reserves, roads, and railroads, ammunition and supply dumps, higher headquarters, cantonments, and cities.

SECTION III

UNDERGROUND WATER AND ITS RELATION TO FIELDWORKS

42. General.—The possible presence of underground water should always be considered before starting the construction of extensive fieldworks. In some localities it is so close to the surface that even the simplest trench digging can not be undertaken and all defensive works have to be parapets, breastworks, or other structures built entirely above the ground level.

43. Forms in which underground water occurs.—*a*. Underground water occurs in three forms: As a saturated zone at the surface, as ground water, and as water-bearing horizons.

(1) *Saturated surface layers.*—Saturated surface layers are found in localities where the formation underlying the subsoil is impervious. Such formations usually consist of clay or rock containing a considerable percentage of clay. If this underlying rock is entirely impermeable there will be dry ground below and cave shelters may be built by sinking through the saturated ground into the dry ground below taking care to seal the shaft through the saturated layer. Such a procedure is not recommended, however, and should be utilized only when shelters can not be located elsewhere. The surface zone of saturation is usually deepest on the flats and shallowest on the slopes and summits. Its total depth will rarely exceed 5 to 7 feet and will vary somewhat with the season. Hence shelters constructed during the summer may be dry when

constructed, only to be flooded during the winter. Flood plains of streams are usually saturated at certain seasons and should be avoided as much as possible when planning fieldworks.

(2) *Ground water.*—The upper surface of ground water in localities where it occurs is roughly parallel to the surface of the ground. The depth to the ground water surface depends chiefly on the character of the rock formation and the quantity of rainfall. In pervious or almost pervious strata the zone of saturation is usually below the depth required by military works, while impervious or only partly pervious rocks hold the water near the surface. Depth also varies according to the season. In general the depth from the ground surface to the upper level of ground water is a maximum in the spring and a minimum in the fall and may vary as much as 10 to 12 feet. It may be determined by examining wells and springs or by sinking some shafts or bore holes. No fieldworks can be maintained below the upper level of the ground water.

(3) *Water-bearing horizons.*—Water-bearing horizons are formed when a pervious or fractured stratum is contained between two impervious layers. Such a formation seriously interferes with the construction of underground works and may prohibit them if the amount of water is considerable. The base of a limestone formation resting on clay is almost invariably a locus of water.

b. Faults.—A fault is a dislocation of geological formation caused by a slipping of rock masses along a plane of fracture. If a fault traverses a water bearing bed which is under hydrostatic head the water may reach the surface or may penetrate a zone of fracture along the fault, forming a saturated zone of considerable width. The siting of trenches or cave shelters across or near faults should be avoided unless it has been established that the faults are not water bearing.

44. Investigation for ground water.—Geological maps, if available, assist in investigating for underground water. It should be understood that the data they show are general in their application and that any specific location should be investigated on the spot. The presence of underground water and the ground formation can best be determined by test pits or bore holes, and such tests should be made before any extensive fieldwork construction is undertaken. Outcroppings of underground water in the form of springs and swamps and local wells indicate the location of the ground-water level.

Section IV

STANDARD TYPES OF FIELDWORKS

45. Clearing field of fire.—*a.* Large scattered trees, if left standing, give less cover to an attacker than if cut down, and are sometimes useful as range marks. Unless they can be entirely removed or converted into dead abatis, only the lower branches should be cut off. Thick brushwood left standing may sometimes serve as an obstacle, but infantry can usually pass with ease any but the thickest growth of this kind. Therefore it is imperative to clear such growth. It is rarely possible or desirable to undertake the wholesale clearing of woods, and the work is usually restricted to clearing the undergrowth and removing the lower branches of the larger trees. Narrow lanes running obliquely in front of a line to be defended may be entirely cleared through woods and swept by machine-gun fire.

b. The following tools will be found useful in clearing woods: Double-bitted axes, brush hooks, canthooks, hatchets, machetes, mattocks, and cross-cut saws. In situations where extensive clearing is necessary those classes of the above tools not found in quantity in the equipment of combat units should be procured from the larger engineer supply establishments. Large trees may be cut down by the use of explosives, but the lack of large quantities of explosives for this purpose ordinarily makes it impracticable.

c. The following figures will be found useful in estimating the time required for a given job of clearing. The unit in each case is 100 square yards.

(1) Area is covered with brush up to 6 inches in diameter and contains about 25 trees, 6 inches to 2 feet in diameter: Chopping or sawing down trees and clearing brush, 5½ man-hours.

(2) Area is covered with undergrowth and some small trees not exceeding 12 inches in diameter: Chopping or sawing down trees and clearing brush, 2 man-hours.

(3) Area is covered only with small brush: Clearing, 1 man-hour.

46. Trench traces.—Five standard trench traces are shown in Figure 15: The traversed, wavy, octagonal, zigzag, and echelon. The one most suitable to the tactical situation and the terrain should be employed, combinations and modifications being made to meet the requirements of special conditions.

47. Standard trench profiles.—*a*. Trenches constructed in the face of the enemy and under difficult conditions necessarily vary in profile in order to meet those conditions, but standard profiles are prescribed for use except where unusual conditions require modification or do not admit of complete execution. The standard profiles shown should be used in all instruction

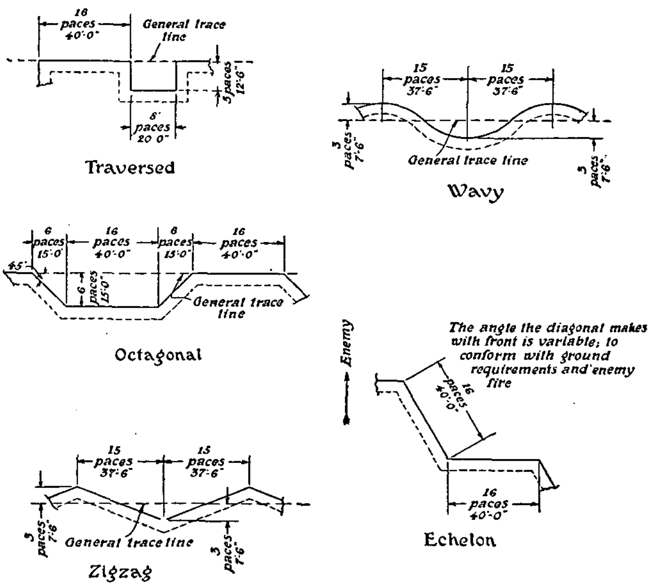


FIGURE 15.—Standard trench traces

and training. They give a comparatively wide trench. Experience teaches that the advantage of additional protection offered by a narrow trench is more than offset by the freedom of circulation provided by the wider trench and by the fact that the wider trench is not easily blocked by cave-ins. Officers and men should familiarize themselves with these profiles so as to avoid confusion and loss of time in constructing trenches under difficult conditions. Figure 16 shows the terms adopted for the various parts of a standard trench. The standard profiles are shown in Figures 17 to 23. The development of a simple standing trench into the A or B standard type is shown by Figure 20.

b. The following remarks apply to the standard profiles.

(1) *The simple standing trench* (fig. 17) is unrevetted and provides no room for circulation in rear of the firing line. It

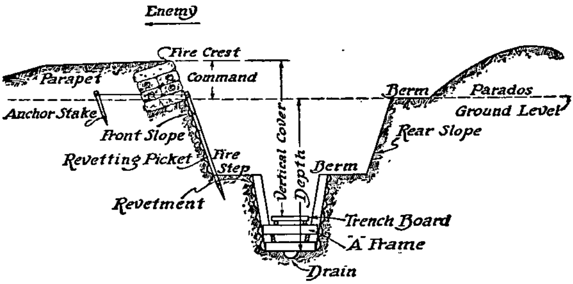


FIGURE 16.—Trench nomenclature

is the first profile sought when trenches must be constructed rapidly, but should be developed to type A in order to provide better cover and communication, as soon as time, labor, and material permit.

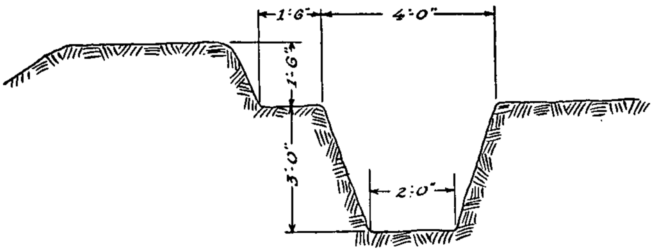


FIGURE 17.—Standard profile, simple standing trench

(2) *Type A* (figs. 18 and 21) is unrevetted (except for the parapet of the fire trench and the fire step) and therefore is the standard for hard ground, where the excavated slopes will stand without revetment. In soft ground this profile should be developed to type B as soon as time, labor, and material permit.

(3) *Type B* (figs. 19 and 22) is deeper and wider than type A, with the lower half of the trench revetted throughout with

A-frame supports and the upper half unrevetted, with wide berms on easy slopes so as to avoid blocking of the trench by cave-ins under shell fire.

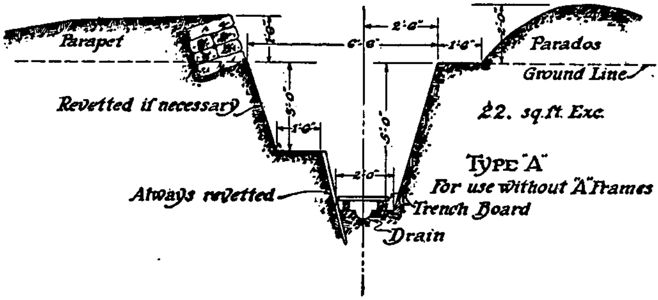


FIGURE 18.—Standard profile, fire trench, type A

c. Figure 23 shows a wide communication trench (type C) used in special cases for main thoroughfares in order to provide ample room for the increased traffic, litter bearers, etc.

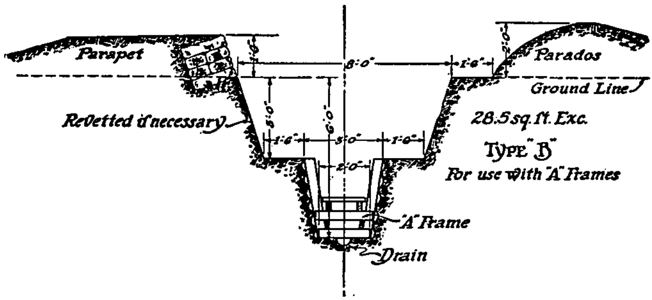


FIGURE 19.—Standard profile, fire trench, type B

d. The berms at top of A-frames (see figs. 22 and 23) may be omitted at first, if necessary to save time and labor, and the ground above sloped as shown by broken lines in the drawings. These berms, however, should be constructed as soon as opportunity affords, in order to prevent the earth above from falling into the bottom of the trench and blocking the drain.

e. The height of parapet adopted as a standard for fire trenches (1 foot 6 inches) should be varied to suit conditions of terrain requiring more command, or where ground water or hard rock is encountered, making the excavation of the trench to full depth impossible. In such a case the profile of

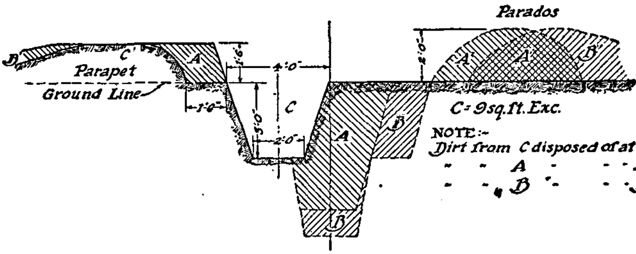


FIGURE 20.—Simple standing trench, showing development into standard fire trench, types A and B

the trench, except for the parados, will remain the same, all parts of the trench bearing the same relation to each other, although the distance of any particular part above or below ground level will vary from the distance shown on the drawings.

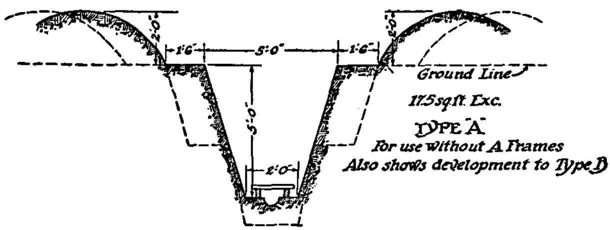


FIGURE 21.—Standard profile, communication trench, type A

f. The fundamental dimensions of standard profiles are—

(1) Height of *fire crest* above *fire step*—4 feet 6 inches.

(2) Height of *parapet*—1 foot 6 inches.

(3) Height of *parados*—2 feet.

(4) Depth of *type A trenches*—5 feet.

(5) Depth of *type B* same as A plus 1 foot for A-frames—6 feet.

(6) Bottom width of *all trenches* (except broad communication trench)—2 feet.

(7) Width of *all berms* (including fire step)—1 foot 6 inches.

(8) *Unrevetted slopes* (in excavation)—approximately 3 on 1.

(9) The *excavated profile for type A fire trench*—same as that required for type A communication trench, except for the additional excavation necessary to provide a 1½ foot fire step.

(10) The *excavated profile for type B fire trench*—same as that for type B communication trench.

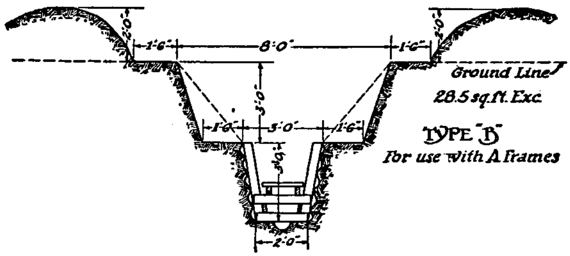


FIGURE 22.—Standard profile, communication trench, type B

(11) Ruling dimensions (top width by depth):

Fire trench	Communication trench
Type A, 6½ by 5 feet	5 by 5 feet
Type B, 8 by 6 feet	8 by 6 feet

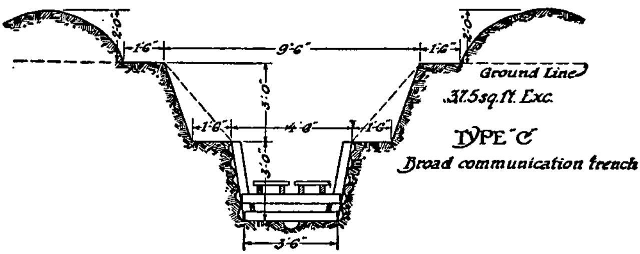


FIGURE 23.—Standard profile, communication trench, type C

48. Breastworks.—If the need for additional command, or the presence of water, rock, or very hard material, makes the construction of standard trenches impracticable, breastworks must be constructed. The profile of the breastworks should approximate the standard trench profile as nearly as possible. A parados should be constructed to protect against the back blast and fragments from shells. In some cases the entire protection above the fire step may be constructed in fill and be revetted, as shown in Figure 24. Traverses are provided as in standard trenches. Careful provision for drainage in wet soils may greatly reduce the height of the breastworks and consequently the labor required for their construction.

49. Trench intersections.—An approach trench should enter a traversed parallel at the rear of a traverse. If it continues beyond the parallel it should leave it at a point not less than 25 yards from the point of entrance. The trace of the parallel between these two points should be modified to provide easy communication. A better solution is to provide two independent crossings, in order that traffic may not be blocked if one of these crossings is destroyed.

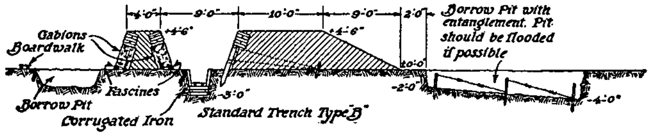


FIGURE 24.—Breastwork in wet soil

50. Length of excavation for a given general trace.—If the length of the general trace of a trench line is known the actual length of trench to be dug may be found by multiplying by the appropriate coefficient, as follows:

Type of trench trace	*Coefficient*
Traversed.	1.33
Octagonal.	1.09
Zigzag.	1.07
Echelon.	1.08

51. Estimates of time, labor, and tools.—*a.* Table IV gives figures for use in estimating time, labor, and tools required for trench construction. It is applicable to day work by inexperienced men using pioneer tools. The figures given represent the best performance that can be anticipated from large groups of soldier labor.

b. Estimates must be reduced from the totals indicated by Table IV for night work, rain or other unfavorable weather conditions, and annoyance by enemy fire, in the discretion and based upon the experience of the estimating officer. Night work is about one-half as effective as day work. Night work should be planned to take full advantage of moonlight hours, and the duration of the moon and probable cloud conditions should be carefully considered when preparing estimates.

TABLE IV.—*Day work, single relief, using pioneer tools*[1]

Soil	Number cubic feet of excavation per man in—							
	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	8 hours
Hard[2]	15	24	32	40	47	54	61	67
Medium	23	37	49	60	71	81	91	100
Soft[3]	30	50	66	80	94	108	121	133

[1] This table contemplates a rest of 10 minutes every hour after the first hour.
[2] All must be loosened with a pick. Requires 2 picks to 1 shovel.
[3] Requires little or no picking. Requires 1 pick to 2 shovels.

TABLE V.—*Hours required to complete 3½-foot and 5-foot tasks; or if not completed, percentage finished in 8 hours (day work, using pioneer tools)*

Nature of soil	Type A unrevetted								Type B revetted			
	Fire trench				Communication trench				Fire and communication trench			
	One relief		Two reliefs		One relief		Two reliefs		One relief		Two reliefs	
	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet
Very hard	90%	60%	5.5	7.25	7.0	80%	4.0	5.75	70%	50%	6.75	85%
Average	5.25	8.0	3.5	5.0	4.0	6.5	2.75	4.0	7.5	70%	4.5	6.5
Light	3.5	5.75	2.5	3.5	3.0	4.5	2.0	3.0	5.25	90%	3.5	6.0

52. Revetments.—*a.* A *revetment* is a retaining wall or facing for maintaining earth slopes at a steeper angle than their natural angle of repose.

b. Revetments may be classified as follows:

(1) The *retaining wall type*, which is self-supporting and acts on the gravity principle for retaining walls. It is largely used in connection with fills, parapets, and breastworks.

(2) The *surface* or *superficial type*, which must be supported and acts largely by protecting the revetted surface from the

disintegrating and erosive effects of weather and from abrasion due to occupation of trench. When strongly constructed it may also serve to retain loose materials and prevent settlement. It is principally used in cuts.

c. A good revetment must possess the following qualities:

(1) Simplicity of detail.

(2) Adaptability to available materials.

(3) Ease of fabrication and erection.

(4) Low fragmentation under shell fire.

(5) Ease of removal from obstructed trenches.

d. In general, revetments should be constructed only when obviously required and should not be more extensive than necessary. They require a great deal of labor and material and should, therefore, be avoided if possible. On the other hand, during long occupation of trenches and when time, labor, and materials are available, extensive revetments make the garrison more comfortable and reduce maintenance.

e. If the sides of the excavation are carefully sloped the amount of revetment required is greatly reduced. Unevenness causes rain to lodge in or erode the surface, to soak into the earth, and results in the rapid disintegration of the slope. The steeper the slopes of a trench are the greater is the need for revetment to prevent them from caving.

f. The interior slope of the parapet of fire trenches (not the entire front slope) is always revetted. In addition, only the lower 2 or 3 feet of a trench usually require revetment. For standard profiles, as illustrated by Figures 18 to 23, inclusive, this involves revetment to the level of the fire step or lower berm. Such revetment supports portions of the trench subject to the most wear, preserves drainage, is seldom injured by the enemy's fire, and preserves the profile of the bottom of the trench for clearing after a cave-in.

53. **Retaining wall types of revetment.**—*a.* As these revetments must be self-supporting, they should always take the form of a properly built retaining wall. The thickness at any level should be at least one-half the remaining height and the average thickness not less than one-third of the total height.

b. Sandbag revetment is easily and quickly constructed, does not splinter from shelling, and is especially useful for emergency work, for repairs, crowning, and revetting the interior slopes of parapets.

c. (1) The standard sandbag is 14 by 26½ inches flat, with an attached tie string 3 inches from the top of the bag. When filled three-fourths full each bag weighs from 45 to 75 pounds, depending upon the material and whether it is wet or dry, averaging approximately 65 pounds, and fills a space approximately 4¾ by 10 by 19 inches. Thus 10 linear feet of parapet revetment, as illustrated in Figures 18 and 19, require

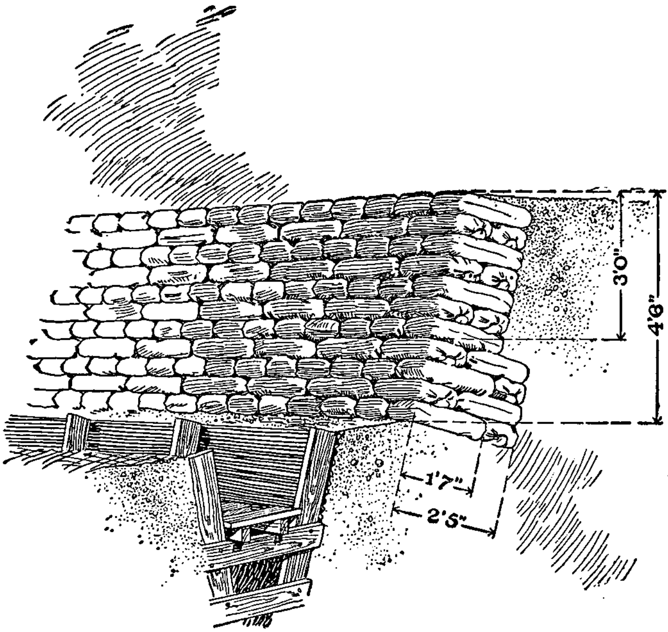


FIGURE 25.—Sandbag revetment

48 sandbags, and 10 linear feet of revetment for front slope and parapet, as illustrated by Figure 25, require 156 sandbags.

(2) Sandbags 18 by 32 inches flat have been issued in the past. When filled three-fourths full they weigh approximately 135 pounds and fill a space approximately 6 by 16½ by 25 inches. A small sandbag 12½ by 25 inches flat was extensively purchased during the World War. When filled three-fourths full it weighs approximately 45 pounds and fills a space approximately 4 by 9 by 18 inches.

d. When laying sandbags attention should be paid to the following points:

(1) Tuck bottom corners of bags in before filling.

(2) Fill bags uniformly about three-fourths full.

(3) Build revetment at slope of from 3 on 1 to 4 on 1.

(4) Lay bags with beds perpendicular to slope.

(5) Lay bottom row headers on prepared bed. Alternate intermediate rows as stretchers and headers and complete with a top row of headers.

(6) Lay bags with seams and choked ends inward.

(7) Break joints and beat bags into a rectangular shape with the back of a shovel.

(8) A sandbag revetment will last much longer if wire netting, preferably doubled, is placed over the face.

e. Sod revetment is more durable than sandbag revetment, and its use is recommended where sods can be obtained in sufficient quantity. Sods are cut 18 by 9 inches, laid grass down except the top layer, and pinned together with wooden pegs. The principles given in (3), (4), (5), (7), and (8) above for sandbag revetment apply.

f. Stones and bricks may be used for revetment in the form of retaining walls laid dry, in which case a slope of not steeper than 4 on 1, beds at right angles to the face, and broken joints are especially important. Due to the danger from flying splinters in case a stone revetment is hit by a shell, its use is not recommended where other material is available. If used in a parapet it should always be crowned with earth-filled sandbags.

54. Surface types of revetment.—*a.* This form of revetment consists of two parts—the revetting material which retains the earth and the supports which hold the revetting material in place. It is most useful in retaining the slopes of trenches, since little additional excavation is needed.

b. The revetting material may consist of expanded metal, wire netting (chicken wire), corrugated iron sheets, brushwood hurdles, burlap, canvas, poles, brush or lumber, or combinations of these materials, depending on the materials available and the nature of the soil.

c. The supports for the revetment may be—

(1) Standard A-frames for use in the bottom third of the trench, placed 3 feet center to center and supporting revetting material described above. (See figs. 26 and 27.) Methods of

placing these frames around corners in traversed trenches are shown in Figure 28.

(2) If A-frames are not available and the soil permits, the revetment may be supported by means of pickets driven into the bottom of the trench and braced, as shown in Figure 29.

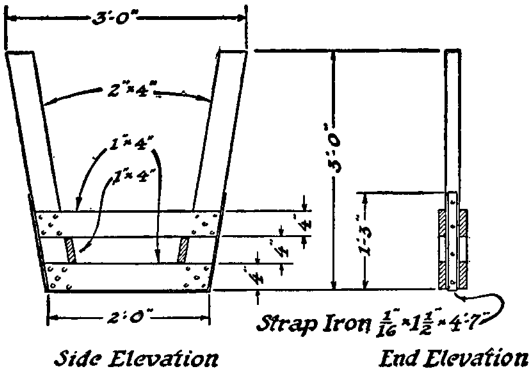


FIGURE 26.—Standard A-frame

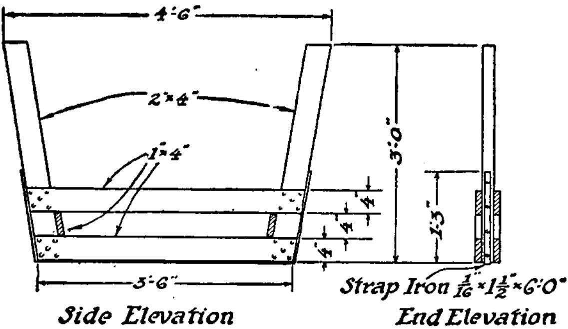


FIGURE 27.—Special A-frame for use in communication trench, type C

(3) Anchored revetting pickets are used when revetting front slopes of fire trenches (fig. 30), or in other special cases where high revetment is required. Revetting pickets should be from 2 to 3½ inches in diameter, straight, pointed at the small end, and driven into the ground from 1 to 1½ feet. Light

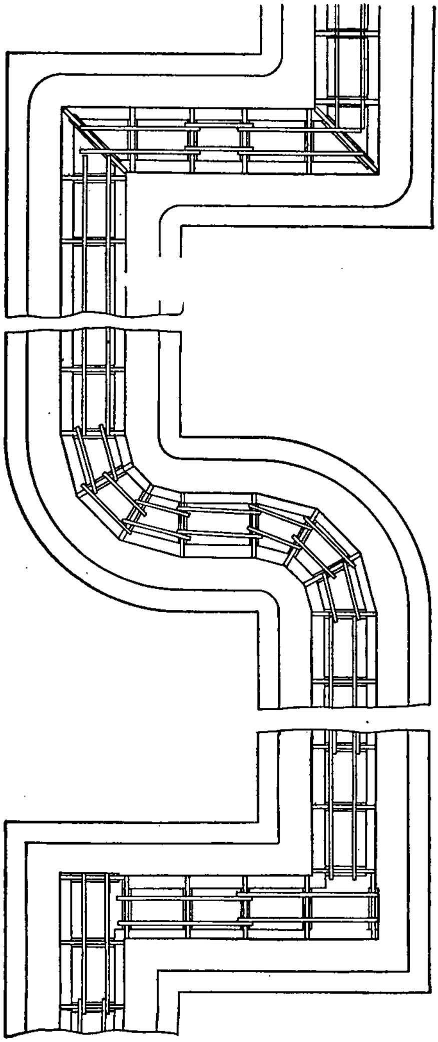


FIGURE 28.—Placing A-frames

angle-iron pickets may also be used. Lateral spacing of pickets varies with the soil and the character of the working materials. For example, burlapped chicken wire requires more

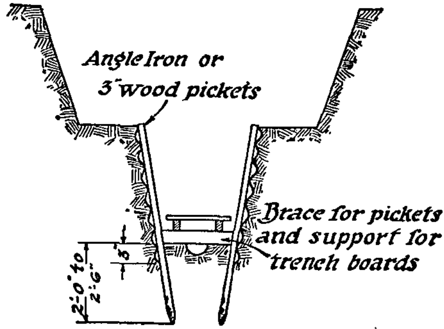


FIGURE 29.—Braced revetting pickets

closely spaced supports than sheets of corrugated iron. Similarly, sand requires more support than firm clay. Spacing may vary from 1½ to 6 feet. Anchor pickets should be driven firmly

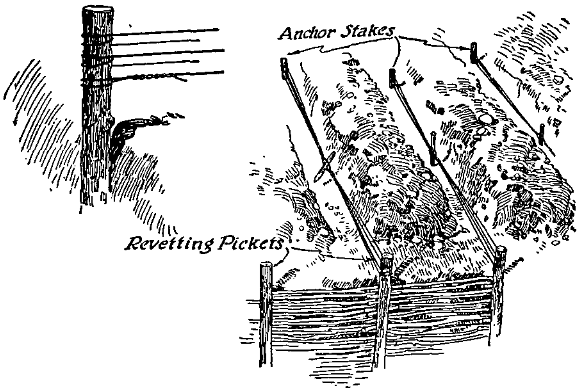


FIGURE 30.—Method of wiring and anchoring revetment

into solid ground 8 to 10 feet from the edge of the trench, staggered so as to avoid forming a plane of weakness parallel to the trench, and inclined so as to be perpendicular to the direction of pull on the anchor wire. Anchor wires, preferably

No. 14 American wire gauge, should pass at least four or five times between picket and stake. Each strand should take a round turn around the head of the anchor picket and then the strands should be twisted together with a short stick to tighten them.

(4) Struts resting against opposite walls of a trench are for use only in narrow, deep trenches in which there is little circulation, as in shell slits for protection against shell fire.

d. Expanded metal and wire netting are used most effectively either alone or in combination with burlap, canvas, or similar materials. The burlap checks evaporation and prevents disintegration and erosion, and the metal or netting supports the burlap. If burlap or similar material is not available, grass, leaves, twigs, etc., may be substituted with good results.

e. In placing expanded metal or wire netting revetment (fig. 31), the following operations are necessary:

(1) Cut vertical grooves for the anchor pickets throughout the length of the bay at the spacing decided upon.

(2) Drive the two end pickets of each bay first and anchor them back loosely.

(3) Stretch the metal or a double thickness of netting behind the two end pickets, holding it taut until these pickets are pulled into their grooves by tightening the anchor wires.

(4) Drive remaining pickets and anchor them back, thus drawing the revetting material tight against the surface to be revetted.

f. A continuous brush revetment of the superficial type may be constructed by driving pickets from 2½ to 3 inches in diameter at about 1-pace intervals along the face of the surface to be revetted and about 4 inches from it. The tops of the pickets should project above the ground. The space behind the pickets is then packed with small straight brush laid parallel to the surface and held in place by the pickets, which are drawn back firmly by means of wire and anchor pickets.

55. Brush work.—*a.* In practically all wars brush has been used extensively in the revetment and improvement of earthworks. While its value in modern warfare is not always commensurate with the labor and skill involved in its use, its flexible utility and ready availability in forested areas will still result in its extensive use in the future. At times it may be the only material available. It may be used as hurdles, gabions, fascines, continuous revetment already described, or any combination of these.

b. Almost any kind of brush, reasonably straight, tough, flexible, and free from refractory branches, dangerous thorns,

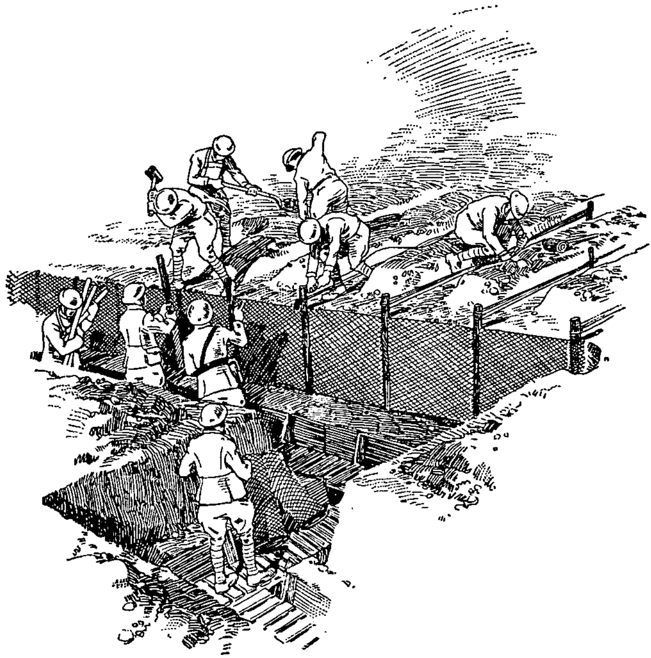


FIGURE 31.—Constructing wire-mesh revetment

or other objectionable characteristics is suitable; but willow, birch, ash, hickory, hazel, and similar woods are desirable. Split bamboo of pliable dimensions, reeds, and vines are also valuable. Brush for weaving should not be more than an inch in diameter at the butt. That to be used without weaving may be of larger size. When cut, brush should be assorted in sizes for the various uses and made up in bundles weighing

40 to 60 pounds, the butts in one direction. Poles of 2½ inches diameter at the butt or larger are not bundled but are piled together. They are used for posts, pickets, struts, binders, grillage, and similar purposes. It is frequently best to fabricate hurdles, gabions, or fascines at the point where the brush is cut, later transporting the finished brushwork to the point of use.

c. (1) A brushwood hurdle is a woven revetment unit, usually 6 feet long and of the required height. (See fig. 32.) It is constructed on sharpened pickets which are driven 18

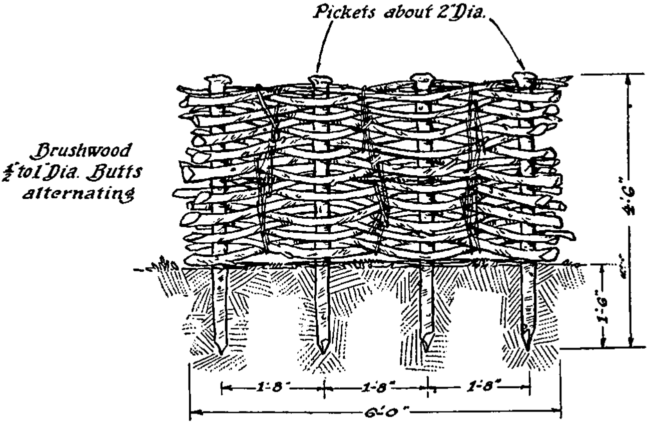


FIGURE 32.—Brush hurdle

inches into the ground. The pickets are about 2 inches in diameter and are spaced approximately 1 foot 8 inches apart—that is, four pickets to a hurdle. The two outer pickets should be about 6 inches from the ends of the hurdle except when woven with vines or other very flexible material.

(2) To construct the hurdle, drive the pickets into the ground firmly, and run two strands of plain wire, 14 or 16 A. W. G., along the pickets near the ground, taking a turn round each picket. Twist these wires together until they are quite tight, then weave the brushwood in and out of the pickets, beginning at the bottom and keeping it pressed firmly down on the wire. Each length of brushwood should pass alternately

66842°—32——5

in front and rear of the picket. If the brushwood is not long enough to reach the length of the hurdle, twist another piece to it or tie a piece to it with wire. Since it is seldom possible to bend a piece of brushwood round the end picket and take it back along the hurdle, it should be allowed to extend about 6 inches beyond the end picket in weaving and later cut off. Continue until halfway up and insert a couple of strands of wire, twisted as before. Complete the hurdle and finish in the same way with wire along the top. Then sew the hurdle in three or four places from top to bottom with plain wire using a double or saddler's stitch. Saw off the ends flush. Three men should make a hurdle in half an hour.

(3) When placing the hurdle the bank should be cut away to a proper slope as indicated by the profile sketches. The hurdle should be laid against the bank and the pickets driven into the ground 18 inches. The tops of the pickets are then anchored as has been described for other surface revetment types.

d. (1) A gabion (fig. 33) is a cylindrical basket with open ends, made of brush woven on pickets. The usual dimensions are 2 feet outside diameter and 2 feet 9 inches height of wattling. On account of the sharp curvature of the form, somewhat better brush is required for gabions than for hurdles.

(2) The gabion form, Figure 33 ①, is of wood, 21 inches in diameter, with equidistant notches around the circumference, equal in number to the number of pickets to be used, not less than 8 and not more than 14. A smaller number is used if the brush is large and stiff, and a large number if it is small and pliable. The notches should be of such depth that the pickets will project 1 inch outside the circle. The pickets should be 1¼ to 1¾ inches in diameter, 3 feet 6 inches long, and sharpened, half of them at the small end and half at the large end.

(3) To make a gabion the form is placed on the ground and the pickets are driven vertically in the notches, large and small ends down alternately. The form is then raised a foot and held by placing a lashing around outside the pickets, tightened with a rack stick (fig. 33 ②). The wattling is woven from the form up to within 1 inch of the tops of the pickets. The form is then dropped down, the gabion inverted, and the wattling completed to within 3 inches of the ends of the pickets. If the brush is small, uniform, and pliable, pairing will make a better wattling than single strands. If not for

immediate use, the gabion must be sewed as described for hurdles. Three men should make a gabion in an hour.

(4) Gabions may be made without the forms, but the work is slow and not so regular. The circle is struck in the ground and the pickets driven at the proper points. The weaving is

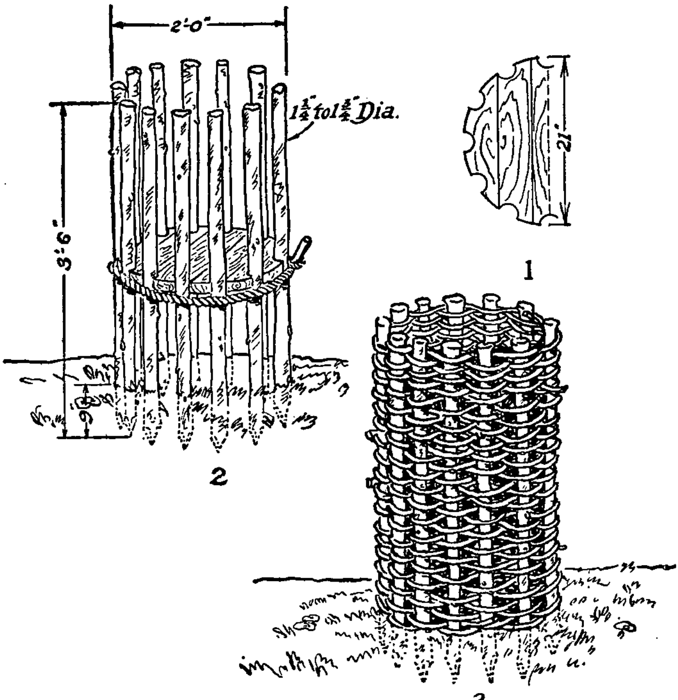


FIGURE 33.—Brush gabion

done from the ground up. The entire time of one man is required to keep the pickets in proper position.

(5) If brush is scarce, gabions may be made with 6 inches of wattling at each end, the middle left open. In filling, the open part may be lined with straw, grass, brush cuttings, or grain sacks, to keep the earth from running out. Also iron gabions may be constructed and carried in engineer supply establishments.

e. (1) A *fascine* (fig. 34) is a cylindrical bundle of brush closely bound. The usual length is 18 feet and the diameter 9 inches when compressed. Lengths of 9, 6, and 3 feet, when needed, are conveniently obtained by sawing a standard fascine into pieces.

(2) Fascines are made in a cradle which consists of five trestles. A trestle is made of two sticks about 6½ feet long and 3 inches in diameter, driven into the ground and lashed at the intersection as shown in Figure 34 ①.

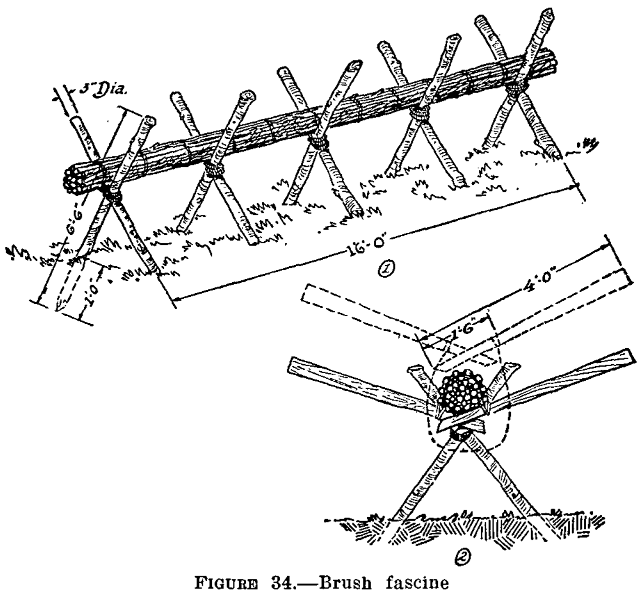


Figure 34.—Brush fascine

(3) To build a fascine, straight pieces of brush, 1 or 2 inches at the butt, are laid on the trestles, the butts projecting at the end 1 foot beyond the trestle. Leaves should be stripped and unruly branches cut off or partially cut through, so that they will lie close. The larger straighter brush should be laid on the outside, butts alternating in direction, and smaller stuff in the center. Dispose the brush so that the fascine is of uniform size, strength, and stiffness from end to end.

(4) When the cradle is nearly filled the fascine is compressed or choked by the fascine choker (fig. 34 ②), which con-

sists of two bars 4 feet long joined 18 inches from the ends by a heavy chain or wire 4 feet long. To choke, two men standing on opposite sides pass the chain under the brush and exchange bars. Then they bear down on the long ends until the fascine is properly compressed.

(5) When a large number of facines is required and brush is plentiful at one point, a portable frame as illustrated by Figure 35 may be constructed. It is used at the site of the brush, one man being assigned to each lever, and the completed fascines are transported where needed. Such a frame speeds up the compressing and binding processes.

(6) Binding is done with a double turn of wire, 12 or 14 A.W.G. The fascine should be bound in 12 places, 18 inches apart, the end binders 3 inches outside the end trestles.

(7) Improvised binders may be made from rods of live brush; hickory or hazel is the best. Place the butt under the foot and twist the rod to partially separate the fibers and make it flexible. A rod so prepared is called a withe. To use a withe, make a half turn and twist at the smaller end, pass the withe around the fascine and the large end through the eye. Draw taut and double the large end back, taking two half hitches over its own standing part.

(8) When the fascine is choked and bound, saw the ends off square 9 inches outside the end binders. After a cradle is made, as illustrated in Figure 34 ①, four men can make one fascine per hour, with wire binding. Withes require one man more. A frame, as illustrated in Figure 35, speeds up the work but requires a larger working party.

f. Hurdles make an excellent surface revetment and are used extensively for that purpose. Gabions are used principally in the construction of parapets and breastworks in wet ground (fig. 24), and to a limited extent in the repair of caved-in trenches. Fascines may be used to advantage at the back edge of the firing step; that is, at the top of the surface revetment of the lower third of a standard profile. They stand wear much better than sandbags. Fascines may also be used in connection with the footings for gabions and as a crown for gabion, hurdle, or other types of revetment. Figure 36 illustrates a gabion and fascine breastwork topped with sandbags.

56. Revetting materials carried in engineer supply establishments.—Sandbags, corrugated iron, expanded metal, metal lath, wire netting (chicken wire), pickets (including light angle-iron pickets), and binding wire are normally carried in the

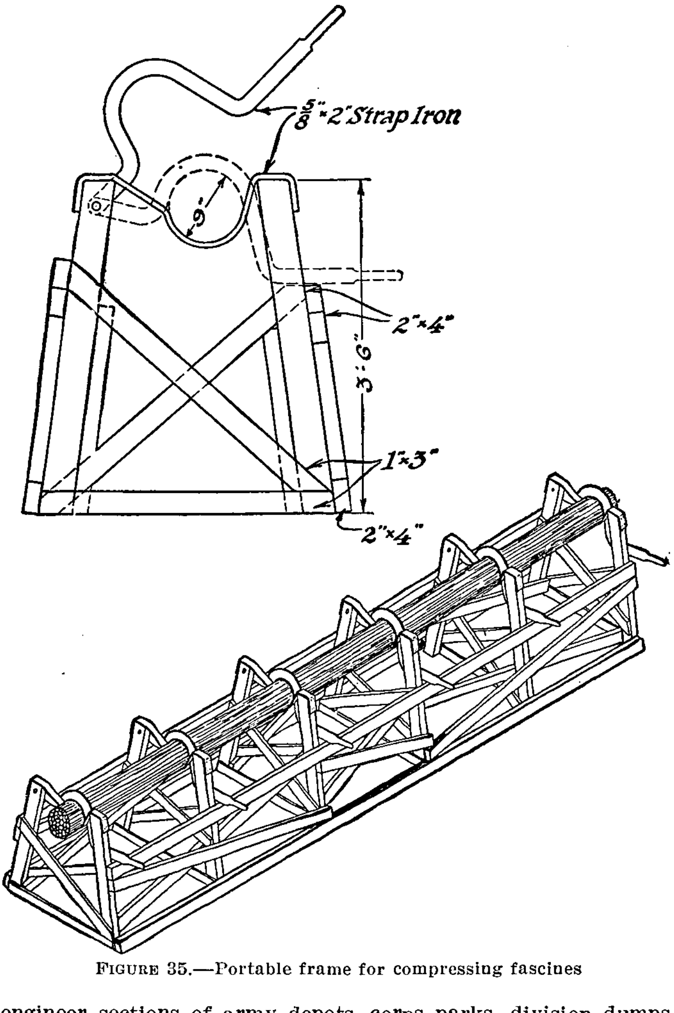


FIGURE 35.—Portable frame for compressing fascines

engineer sections of army depots, corps parks, division dumps, and division distributing points. Except for sandbags, which are standardized as noted in paragraph 53 *c* (1), they are commercial articles purchased in the open market as required.

57. Machine-gun emplacement with splinter-proof cover.—A simple type of machine-gun emplacement, with splinter-proof cover for guns and crew, accommodating a section of two guns, is shown in Figure 37. This type may be used in connection with existing trenches or in an isolated position with or without concealed approaches.

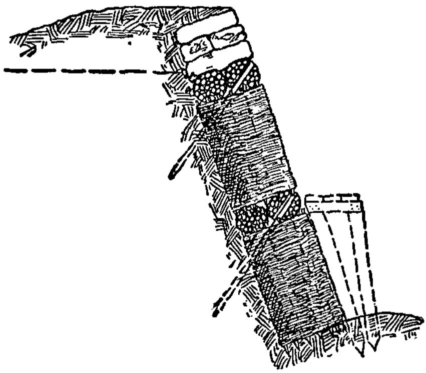


FIGURE 36.—Gabion and fascine breastwork topped with sandbags

TABLE VI.—*Machine-gun emplacement—Bill of material and work data for Figure 37*

Item	Emplacement for 2 guns
Logs, 6 inches in diameter, 8 feet long	24
Logs, 4 inches in diameter, 10 feet long	220
Poles, 2 inches in diameter, 6 feet long	40
Timbers, 6 by 8 inches, 3 feet long	4
Boards, 1 by 12 inches, 2 feet long	5
Stakes, 12 inches long	200
T bases, standard	2
Corrugated iron or roofing paper ... square feet	750
Camouflage material ... do	1,900
Sandbags	240
Wire, smooth, No. 10 ... feet	500
Brush, for revetting steps ... bundles	1
Excavation ... cubic feet	1,500
Work:	
Excavation in hours, 12 men	10
Revetting, roofing, etc., in hours, 12 men	14
Total in hours, 12 men	24
8-hour shifts, 12 men	3

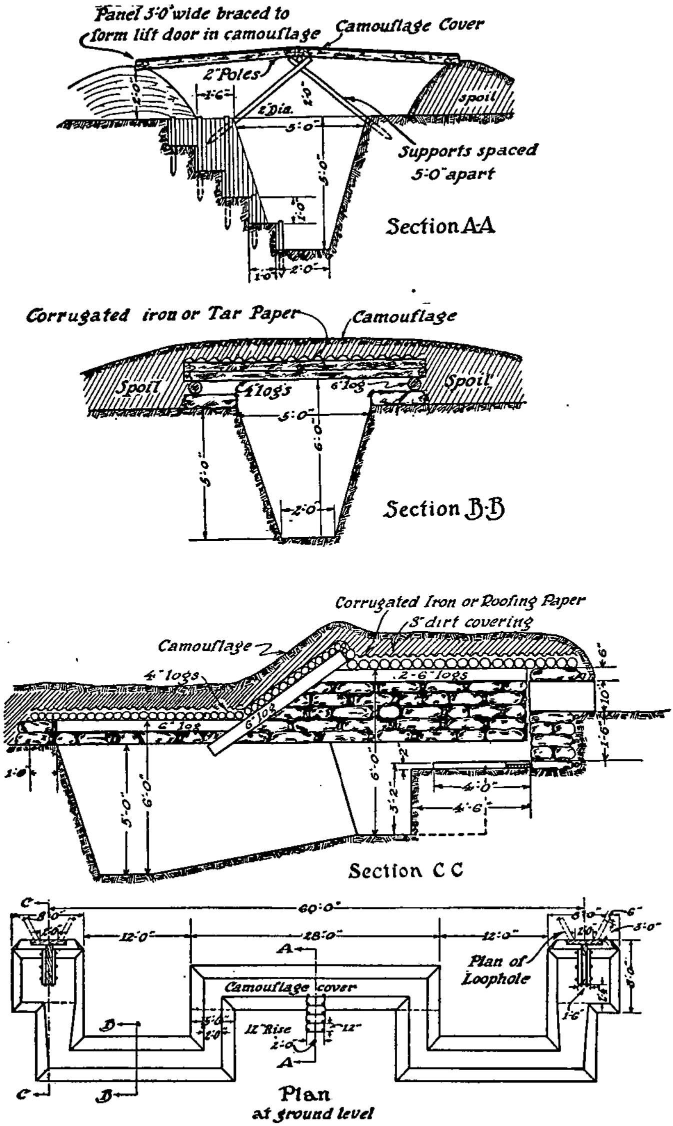


FIGURE 37.—Two-gun machine-gun emplacement with splinter-proof shelter

58. Reinforced concrete emplacement.—Figure 38 shows an emplacement providing protection against 210-mm. (8.25-inch) shells. A shelter of the same dimensions, but without loopholes, may be used for sheltering two gun crews to operate machine

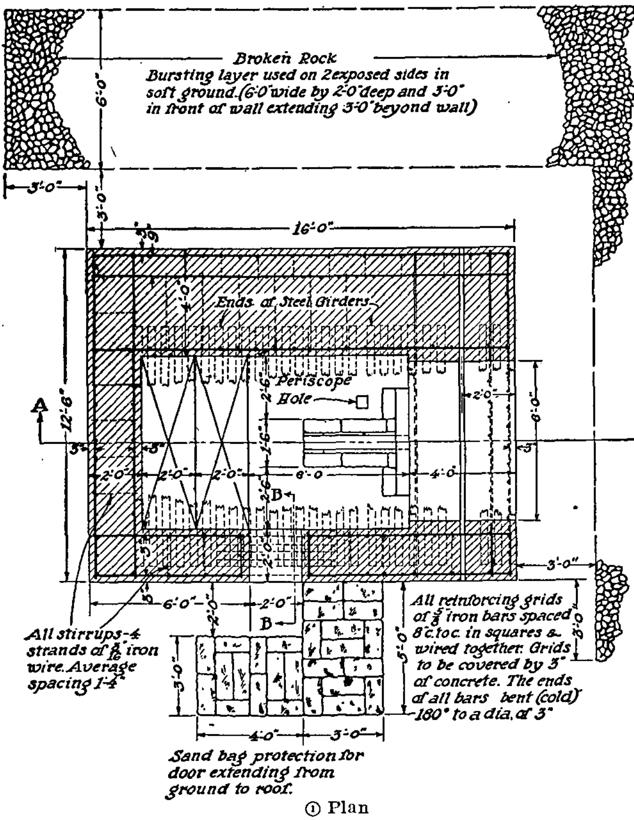
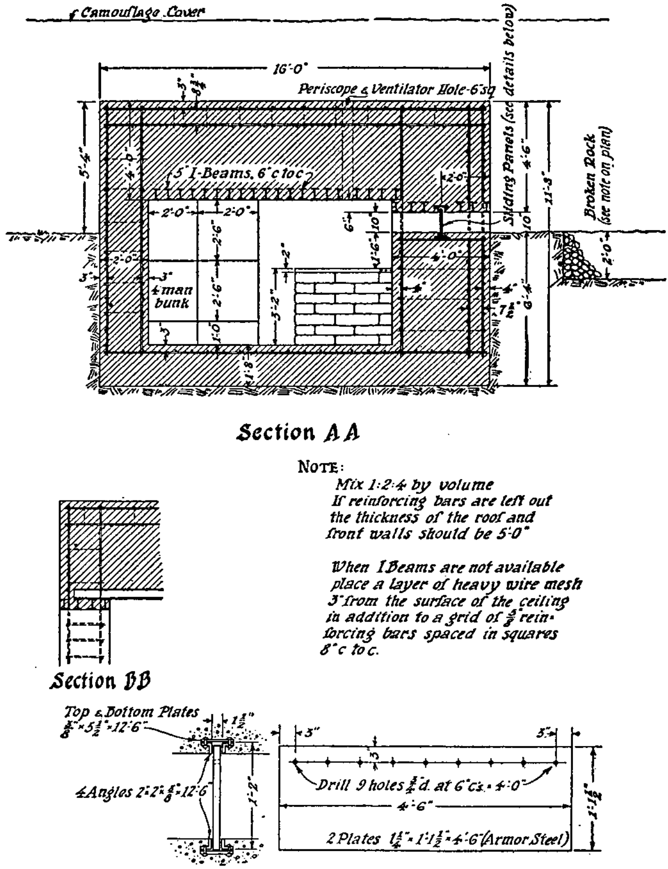


FIGURE 38.—Shellproof machine-gun emplacement

guns from near-by open emplacements. In this case it should be lowered so as to be more easily concealed, and the thickness of the floor may be reduced to 12 inches. Due to the large amount of material and more or less elaborate construction plant required, the use of concrete emplacements is restricted to positions not under direct observation of the enemy and provided with good transportation facilities, preferably near a light railway line.



② Section and details of sliding panels

FIGURE 38.—Shellproof machine-gun emplacement

A minimum period of two weeks must be allowed for the hardening of Portland cement, so that the emplacement may be considered effective, and one month for it to attain practically full strength. Newly developed quick-hardening alumina cement attains an effective strength in 24 hours. In soft ground, in order to prevent shells from penetrating and exploding under the floor, a course of broken rock, as indicated in the drawing, or concrete bursters, should be placed protecting the exposed sides. The embrasure is fitted with a pair of armor-steel panels sliding in metal grooves set in the concrete. The steel panels are sufficiently thick to withstand a direct hit by a new type 37-mm. projectile. They may be moved in the grooves by means of a pinch bar inserted in the holes, drilled in the plates, so that an aperture is left only sufficiently wide to fire through in the desired direction. By installing the steel panels it is practicable to provide an arc of fire of 60°. Bill of material and work data are given below:

TABLE VII.—*Shellproof machine-gun emplacement—Bill of material and work data for Figure 38*

Item	Weight in tons	Amount
Cement	19.5	103 barrels (3.8 cubic feet per barrel).
Sand	46.5	32 cubic yards.
Broken stone or gravel	93	64 cubic yards.
Water	29	7,000 gallons (approximate).
I beams, 5-inch	1.6	27—9 feet long. 4—5 feet long.
Iron wire for stirrups, 3/16 inch (No. 4)	.07	1,500 linear feet.
Round iron bars for reinforcing grids, 5/8 inch	3.4	6,500 linear feet.
Embrasure panels, complete, consisting of	.5	1.
2 armor steel plates 1¼ inches by 1 foot; 1½ inches by 4 feet 6 inches.		
4 angles, 2 by 2 by 3/8 inch by 12 feet 6 inches.		
2 plates, 3/8 by 5½ inches by 12 feet 6 inches.		
Sandbags		375.
T base, standard		1.
Bunk, 4-man, double-deck		1.
Camouflage screen		5,600 square feet.
Plank, 2 inches for forms	3.6	900 square feet.
Posts, 2 by 6 inches, for forms	1.1	550 lineal feet.
Broken stone for burster course	31	21 cubic yards.
Total weight (approximate)	230	
Excavation for emplacement		50 cubic yards.
Excavation for burster course		21 cubic yards.
Volume of concrete		70 cubic yards.
Work:		
Excavation, 20 men		9 hours.
Erecting forms, placing burster layer, etc., 20 men		10 hours.
Mixing and placing concrete		20 hours.
Total (material at the site, 20 men)		39 hours.
Total 8-hour shifts, 20 men		5.
Period for hardening (minimum):		
Portland cement		2 weeks.
Alumina cement		24 hours.

59. Obstacles.—*a. Principles of design and construction.*—In the design and construction of obstacles the following principles should be observed:

(1) The obstacle should afford the attacker neither cover nor concealment while holding him under the effective fire of the defense.

(2) By employing types of low visibility, by avoiding regular geometric layouts with lines terminating in angles indicative of the location of flanking machine guns, the organization of the defense, especially the machine-gun locations, is withheld from the enemy. The obstacles should present a confused, irregular, and unsystematic appearance. Such obstacles give little indication of the defensive organization and are difficult to range upon. The attacker has difficulty in determining when the obstacle has been breached or destroyed. The construction of straight lines of obstacles that indicate the location of machine guns must always be avoided.

(3) While being sufficiently dense to prevent easy penetration, an obstacle should not be so heavy as to be readily visible on an airplane photograph. A thin, broad, irregular obstacle, preferably a wire entanglement, is of low visibility, more difficult to destroy by fire, and quite as effective as the same amount of material in a denser structure. Such an obstacle will frequently escape detection from the air.

(4) Several comparatively narrow belts of obstacles, separated by intervals, are more effective than the same material in a single belt. If additional protection is required, another belt should be added rather than broaden the existing one. Belts should be of such width, however, that a single shell burst, even that of a large trench mortar bomb, can not make a passable breach through the obstacle. Belts should be from 4 to 10 yards wide and the intervals between them from 15 to 40 yards.

(5) It is not usually the wire entanglement itself which shows on an airplane photograph, but rather the increased length of grass, untrodden plowed ground, and other changes in surface texture resulting from the presence of the obstacle. Paths following the edges of obstacles and passing through the gaps in them frequently indicate their presence on airplane photographs.

(6) Wire entanglements should be constructed in accordance with standard designs.

(7) Obstacles should be of the simplest possible design so that they may be quickly, easily, and quietly erected by average troops with average training, in the dark and in the presence of the enemy.

(8) Obstacles should be strongly anchored to the ground and well supported so that they can not be easily pushed aside or otherwise removed.

(9) The first element erected should afford immediate protection, after which the construction is continued to the rear.

(10) Wire should be strung loosely, for if taut it is more readily cut by wire cutters and shell fire. Ordinary procedure results in loosely strung wire.

(11) The construction should require the minimum number of men, who should not be bunched in groups vulnerable to fire.

(12) Speed in construction is obtained by means of—

(*a*) Simple design.

(*b*) Careful organization of work and supply of material.

(*c*) A systematic procedure, having the form of a drill in which each man has simple and definite tasks.

(*d*) Selection of especially skilled men for the actual construction, the less skilled men being employed carrying materials.

(13) The obstacles should be of a type not easily destroyed by fire, either hostile or friendly. It is desirable that frontal fire should pass over the obstacle rather than through it. The obstacle should not interfere with the defender's view or fire.

(14) The gaps should be closed when not in use by means of portable obstacles. Gaps should be covered by fire, especially gaps that have been made by the enemy. Portable obstacles should be available for quickly closing gaps made by the enemy.

b. Materials.—(1) Barbed wire is encountered in various styles. The standard is the familiar 2-wire type of No. 12, A. S. & W. gage wire with four-point barbs, spaced approximately 4 inches apart. The length on a commercial reel, as shipped from the factory, is about 420 yards, and the weight of a full reel about 100 pounds, plus the weight of the reel, about 5 pounds. Reels of about one-half the foregoing size are also obtainable, and are desirable. Hand bobbins are usually made up at the rear from the large size reels, contain 25 yards of wire, and weigh from 7 to 8 pounds each. They are always used when constructing entanglements.

(2) To make bobbins, secure 1-inch round or square sticks approximately 2½ feet long. When necessary round off the ends to facilitate handling. It is desirable to drive 8-penny or 10-penny nails through the stick about 8 inches from each end. Improvise trestles similar to those used in making fascines. Pass a pick handle, piece of pipe, or other suitable article through the reel, and place in the trestle so that the

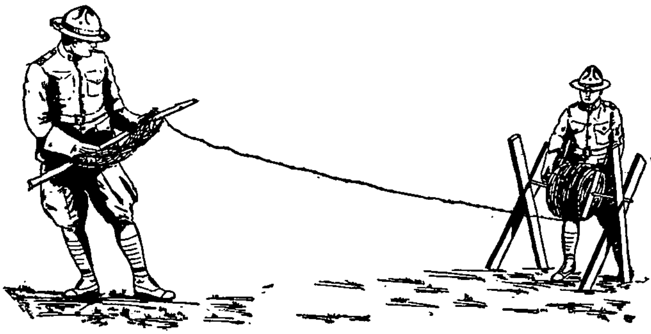


FIGURE 39.—Making bobbins

wire may be unreeled from the *bottom*. Two men work at making bobbins, one at the bobbin and one at the reel, alternating duties from time to time. The bobbin man fastens the end of the wire to one of the nails in a bobbin stick and draws the wire out over a measured distance of 25 yards. The man at the reel controls the movement of the reel by hand or by braking with a stick. The bobbin man grasps the stick at the center with both hands and keeps his hands in this position while making the bobbin. Maintaining a constant strain on the wire, he moves toward the reel at the same time winding the wire on the bobbin by overhand movements so that the wire is passed alternately over and around first one end of the stick, then the other, coming to rest on the nails, as illustrated in Figure 39. When the 25-yard length of wire has been wound the wire is cut and the free end marked with white rag or tape and secured. The result is a compact bobbin of light weight. One man can easily carry four such bobbins, two in each hand, or six on a stick on his shoulder.

(3) Wooden pickets are cut in near-by woods or are shipped from the rear. They should range in diameter from 2½ to 4 inches, and should be cut 5 feet long for the high entanglement and 2 feet 6 inches for the low type. Pickets split from a log by quartering should be avoided, as they increase materially the visibility of an entanglement.

(4) Figure 40 illustrates standard types of screw pickets, the helix permitting them to be screwed noislessly into the ground.

(5) Figure 41 illustrates standard types of angle-iron pickets.

60. Table of wire-entanglement materials.—The following table gives data relative to standard entanglement materials:

TABLE VIII.—*Wire-entanglement materials*

	Weight in pounds	Length in feet		Number easily carried by 1 man	Weight of man load
		′	″		
Wooden picket, long, 3 to 4 inches diameter	12–16	5	0	3	36–48
Wooden picket, short, 2 to 3 inches diameter	4–8	2	6	8	32–48
Screw picket, long	9	4	10	4	36
Screw picket, medium	6	2	8	6	36
Screw picket, anchor	4	1	9	8	32
Angle iron, long	10	6	0	4	40
Angle iron, short	6	3	8	6	36
Full reel wire, 420 yards (approximate)	105	1, 260		½	[1] 52. 5
Bobbin, 25 yards	7–8	75		4–6	28–48

[1] Full-sized reels are carried by two men upon their shoulders by means of a picket passed through the hole in the reel.

61. Types of entanglements.—*a.* The following obstacles may be considered standard and methods for their construction are outlined:

(1) High-wire entanglement.

(2) Double-apron fence.

(3) Low-wire entanglement.

(4) Belts of Ribard wire or concertina.

(5) Portable wire obstacles.

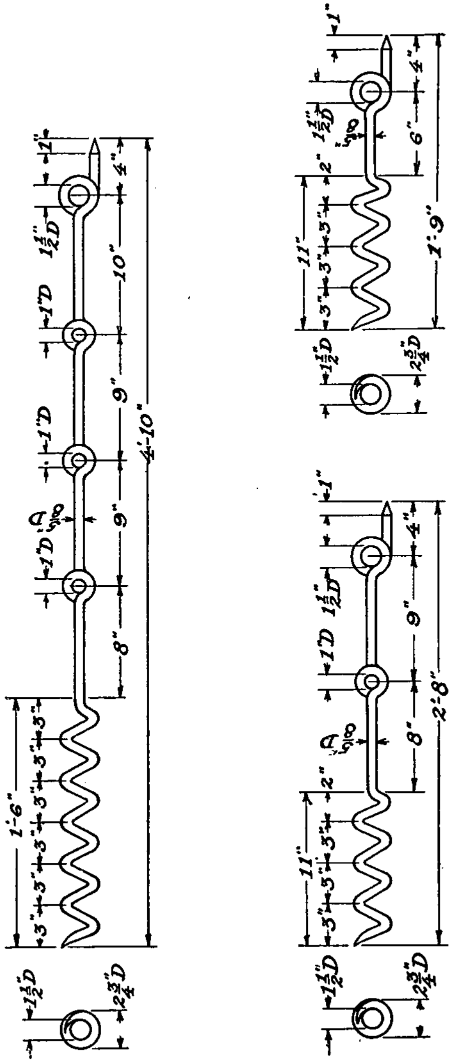


FIGURE 40.—Screw pickets

b. The following table gives data relative to the material required for 1,000 yards of single-belt entanglement:

TABLE IX.—*Material required for 1,000 yards of single-belt entanglement*

Type of entanglement	Long pickets	Medium pickets	Anchor pickets	Barbed wire, 420-yard reels	Barbed wire on reels	Steel wire No. 5	Plain wire No. 12	Plain wire No. 18	Staples made of 3/8-inch round rods
					Pounds	*Pounds*	*Pounds*	*Pounds*	
High-wire	640	-----	[1] 320	[2] 48	[3] 5,040	-----	-----	-----	-----
Double-apron	320	-----	640	38	3,990	-----	-----	-----	-----
Low wire	-----	320	640	29	3,045	-----	-----	-----	-----
Ribard (2 cylinders side by side)	302	-----	-----	54	5,670	2,367	623	20	[4] 600
Concertina (2 cylinders side by side)	302	-----	-----	75	7,875	-----	1,315	84	600
4-strand wire fence	300	-----	-----	11	1,155	-----	-----	-----	-----

[1] For front anchorage if used.
[2] Plus 3 if front anchorages are used.
[3] Plus 315 if front anchorages are used.
[4] 1,100 feet of rods.

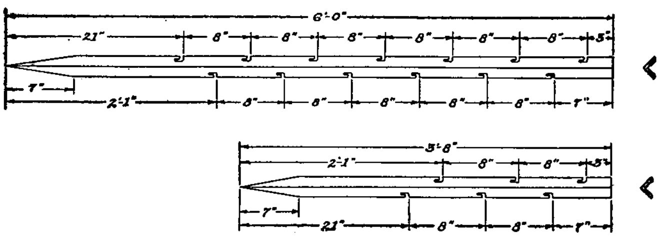
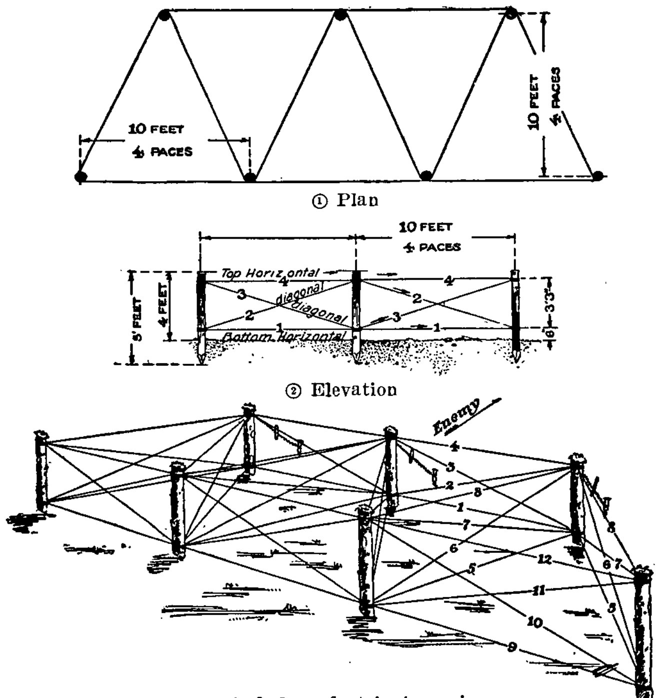


FIGURE 41.—Angle-iron pickets

62. General remarks on wire-entanglement drills.—The following remarks and precautions are applicable to all entanglement drills.

a. The line of stakes toward the enemy for high wire and the center line for double apron and low wire should be traced and marked in the manner described for trenches. The use of tracing tape is highly desirable for night work in the presence of the enemy.

b. The men are given numbers in the order in which they first proceed to work, each having definite, limited tasks. They start at intervals, so that men doing different tasks will not be bunched, exposed to fire, or interfere with each other. One row of pickets is set by pacing. The others are placed by eye, using the paced row as a guide. The elements nearest the enemy should be placed first, and work continued to the rear.



① Plan

② Elevation

③ Order of stringing wire

FIGURE 42.—High-wire entanglement

c. Pickets should be carried under the left arm and placed on the ground with the right hand so that the end of the screw or the point of the picket faces the enemy, indicating the spot at which the picket is to be erected. For carrying, all bundles of screw and iron pickets should be wrapped with a sandbag and secured in at least two places by a turn of plain wire with the ends twisted together. Enough end to this wire must always be left so that it can be untwisted by hand without pliers. Bundles of long wooden pickets should be tied together in at least two places with plain wire. Short wooden pickets are best carried in sandbags, a suitable number in each bag; two bags are tied together and slung over the shoulder. Screw pickets must be screwed in so that the eyes are parallel to the length of the

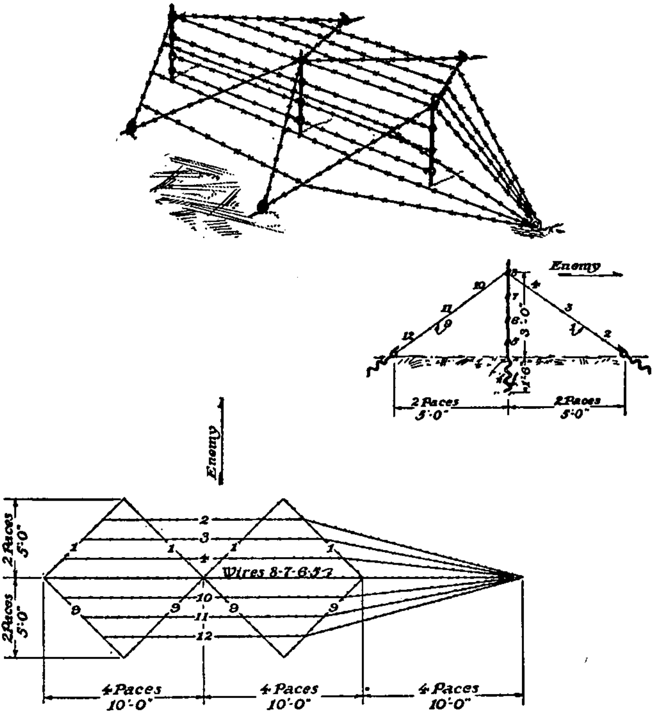


FIGURE 43.—Double-apron fence

entanglement, and the eye points in the direction from which the men are working; that is, toward the starting point. Compliance with this rule facilitates placing wires. Wooden pickets, used as holdfasts (anchors), should be driven in approximately at right angles to the stay wire to be attached to them, but screw anchorage pickets must be placed in prolongation of this stay wire.

d. In running out barbed wire two men work together; one man walks out with the bobbin, unwinding as he goes, and the other stretches the wire and fastens it to the pickets.

e. In the erection of the entanglement the following rules should be observed:

(1) Men fastening the wires must always work facing the enemy.

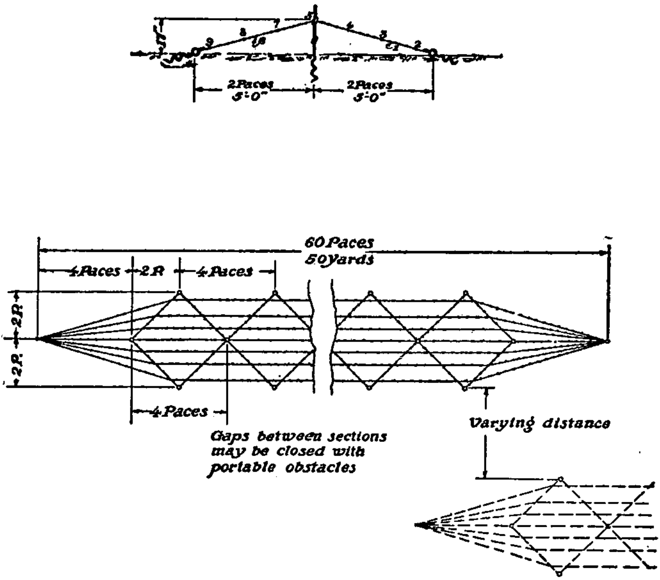


FIGURE 44.—Low-wire entanglement

(2) To fasten wire in top eye of screw picket, pull the fixed wire (the one leading toward the starting point) taut and slip the wire up into the eye, turn the running end up over the eye, thus threading the wire in the eye. Then take a turn with the running end over the standing end and around the picket below the eye. (See fig. 45.)

(3) To fasten the wire in a lower eye of a screw picket when there is already a wire in the top eye—

(*a*) Pull the standing end taut and slip the wire up into the eye. Then take a bight on the running end, pass it around the picket above the eye, and take a turn with the bight on the running end. (See fig. 45.)

(*b*) If one eye is on the opposite side of the pickets from the others, the wire must be forced down into the eye, and the bight on the running end passed around the picket under the eye.

(4) The foregoing rules (2) and (3) apply whichever way the wiremen are working, from right to left or left to right,

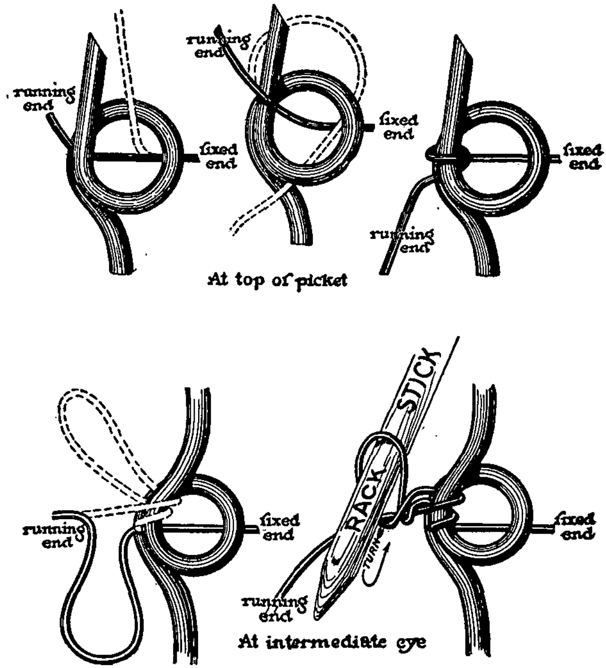


FIGURE 45.—Proper method of fastening wire to screw pickets

and if carried out, the wire will be firmly fixed in the eye and can not slip up or down the picket; also, if one bay is cut, the wire in the bays on either side remains taut and does not slip through the eyes.

(5) Wires are fastened to wooden pickets as shown in Figure 46.

(6) To fix one wire to another a short length of smooth wire may be used or the two wires may be twisted together by

means of a rack stick as shown in Figure 47. This is the better method and is known as "windlassing."

(7) Each member of a wiring party is equipped with a rack or windlass stick.

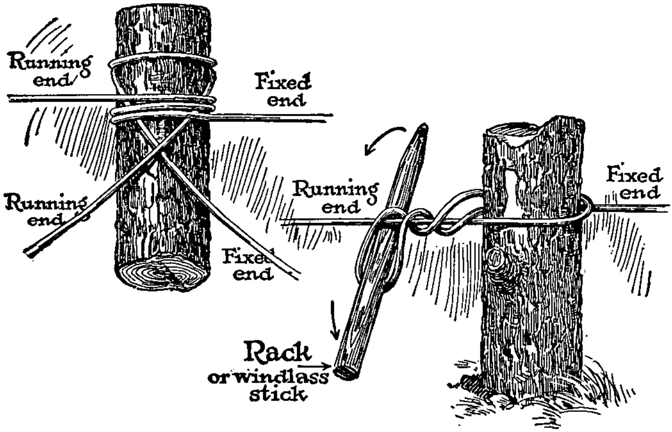


FIGURE 46.—Proper method of fastening wire to wood pickets

f. The carrying parties indicated in paragraphs 63, 64, 65, and 69 can carry at one trip all the material required for 50 yards of entanglement. If a round trip to the dump requires more time than the construction of 50 yards of the obstacle,

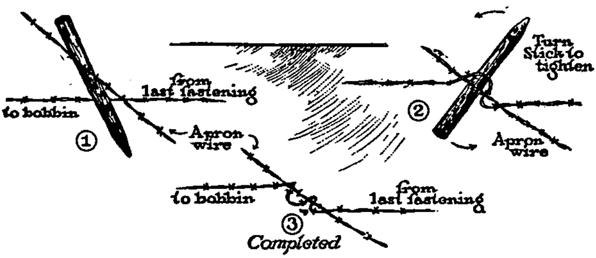


FIGURE 47.—Method of fastening two wires together by "windlassing"

the strength of the carrying party must be increased accordingly. Specially skilled crews of picked men, undisturbed, have erected wire entanglements in less than one-quarter of the time stated in Table X, paragraph 78.

63. Drill for erecting high-wire entanglement.

50 yards high-wire entanglement (two rows of stakes)

Material	Wiring party	Carrying party
8 bundles (32) long pickets. 40 25-yard bobbins barbed wire.	1 noncommissioned officer (carries pliers). 16 men (each carries a stick). 1 man, carrier.	1 noncommissioned officer. 18 men.

Nos.	First task	Second task	Third task
N. C. O.	Leads party to head of work.	Paces front panel and indicates location of pickets; supervises work.	
1 2	Each man carries out one bundle pickets.	Place pickets of front panel.	String bottom horizontal wire, zigzag panel.
3 4		Place pickets of rear panel.	String first diagonal wire, zigzag panel.
5 6		Screw in pickets of front panel.	String second diagonal wire, zigzag panel.
7 8		Screw in pickets of rear panel.	String top horizontal wire, zigzag panel.
9 10	Each man carries out four bobbins barbed wire.	String bottom horizontal wire, front panel.	String bottom horizontal wire, rear panel.
11 12		String first diagonal wire, front panel.	String first diagonal wire, rear panel.
13 14		String second diagonal wire, front panel.	String second diagonal wire, rear panel.
15 16		String top horizontal wire, front panel.	String top horizontal wire, rear panel.
17		Carry out 4 bobbins barbed wire.	

NOTE.—Nos. 1 to 4 place pickets lightly in ground. In stringing, odd numbers run out coils, even numbers fix wire to pickets.

Each additional row of high-wire entanglement

Material	Wiring party	Carrying party
4 bundles (16) long pickets. 32 25-yard bobbins.	1 noncommissioned officer. 10 men.	1 noncommissioned officer. 12 men.

NOTE.—A drill for erecting the additional row of high-wire entanglement may be readily improvised based upon the above drill for the first row.

64. Drill for erecting double-apron fence.

50 yards double-apron fence

Material	Wiring party	Carrying party
4 bundles (16) long pickets. 4 bundles (32) anchor pickets. 32 25-yard bobbins barbed wire.	1 noncommissioned officer (carries pliers). 9 men (carry rack sticks).	1 noncommissioned officer. 15 men.

<table>
<tr><th>Nos.</th><th>First task</th><th>Second task</th><th>Third task</th><th>Fourth task</th><th>Fifth task</th></tr>
<tr><td>N. C. O.</td><td colspan="5">Carries out 1 bundle long pickets. Paces off and indicates to Nos. 1, 2, and 3 location of pickets. Supervises work.</td></tr>
<tr><td>1</td><td rowspan="3">Each carries out 1 bundle long pickets.</td><td rowspan="3">Lay out and screw in pickets of the center line.</td><td>Run out front diagonal wire.</td><td>Run out bottom horizontal wire of fence.</td><td>Run out rear diagonal wire.</td></tr>
<tr><td>2</td><td>Fasten front diagonal wire on anchor pickets.</td><td rowspan="2">Fasten bottom horizontal wire of fence on pickets, Nos. 2 and 3 working on alternate pickets.</td><td>Fasten rear diagonal wire on long pickets.</td></tr>
<tr><td>3</td><td>Fasten front diagonal wire on long pickets.</td><td>Fasten rear diagonal wire on anchor pickets.</td></tr>
<tr><td>4</td><td rowspan="4">Each carries out 1 bundle anchor pickets.</td><td rowspan="2">Lay out and screw in front anchor pickets. No. 4 places pickets at head of work.</td><td>Run out trip wire, front apron.</td><td>Run out second horizontal wire of fence.</td><td>Run out top horizontal wire, rear apron.</td></tr>
<tr><td>5</td><td>Windlass trip wire to diagonal wire.</td><td>Fasten second horizontal wire of fence on pickets.</td><td>Windlass top horizontal wire to diagonal wire.</td></tr>
<tr><td>6</td><td rowspan="2">Lay out and screw in rear anchor pickets. No. 7 places picket at end of work.</td><td>Run out second horizontal wire, front apron.</td><td>Run out third horizontal wire of fence.</td><td>Run out second horizontal wire, rear apron.</td></tr>
<tr><td>7</td><td>Windlass second horizontal wire to diagonal wire.</td><td>Fasten third horizontal wire of fence on pickets.</td><td>Windlass second horizontal wire to diagonal wire.</td></tr>
<tr><td>8</td><td rowspan="2" colspan="2">Carry out 32 bobbins of barbed wire.</td><td>Run out top horizontal wire, front apron.</td><td>Run out top horizontal wire of fence.</td><td>Run out trip wire, rear apron.</td></tr>
<tr><td>9</td><td>Windlass top horizontal wire to diagonal wire.</td><td>Fasten top horizontal wire of fence on pickets.</td><td>Windlass rear trip wire to diagonal wire.</td></tr>
</table>

NOTE.—Diagonal and apron wires begun and finished on end anchor pickets. Horizontal wires on fence not carried down to end anchor pickets.

65. Drill for erecting low-wire entanglement.

50 yards low-wire entanglement

Material	Wiring party	Carrying party
3 bundles medium pickets (1 of 6, 2 of 5 each). 4 bundles (32) anchor pickets. 24 25-yard bobbins barbed wire.	1 N. C. O. (carries pliers). 6 men (carry rack sticks).	1 N. C. O. 13 men.

Nos.	First task	Second task	Third task	Fourth task	Fifth task	Sixth task
N.C.O.	Carries out 1 bundle medium pickets. Paces off and indicates to Nos. 1 and 2 location for their pickets. Lays out own pickets. Supervises work.					
1	Carries out 1 bundle medium pickets.	Carries out 1 bundle medium pickets.	Lay out and screw in center line of pickets.	String and fasten front diagonal wire.	String and windlass top horizontal wire, front apron.	String and windlass top horizontal wire, rear apron.
2	Carries out 1 bundle anchor pickets.	Carries out 1 bundle anchor pickets.				
3	Carries out 1 bundle anchor pickets.	Carries out 1 bundle anchor pickets.	Lay out and screw in outer anchor pickets.	String and windlass trip wire, front apron.	String and fasten horizontal wire, center line.	String and windlass second horizontal wire, rear apron.
4	Carries out 4 bobbins barbed wire.	Carries out 4 bobbins barbed wire.				
5	Carries out 4 bobbins barbed wire.	Carries out 4 bobbins barbed wire.	Lay out and screw in inner anchor pickets.	String and windlass second horizontal wire, front apron.	String and fasten rear diagonal wire.	String and windlass trip wire, rear apron.
6	Carries out 4 bobbins barbed wire.	Carries out 4 bobbins barbed wire.				

NOTE.—No. 3 places anchor picket at head of work. No. 5 places anchor picket at foot of work. Diagonal wire of rear apron and horizontal wire on center line of pickets are not carried down to end anchor pickets. Low-wire entanglements are slow to erect at night, owing to the difficulty of seeing the pickets.

66. Ribard wire.—*a.* The elements of Ribard wire consist of seven wire circular frames 3 feet 4 inches in diameter, spaced 3 feet 4 inches apart, and on which are stretched six longitudinal strands and three diagonal strands of barbed wire. By twisting the elements in opposite directions from each end they can be closed up for transportation. When extended each element has a length of 20 feet. Figure 48 shows a portion of an element extended. Its chief advantages are its low visibility, portable character, resistance to destruction by artillery, and rapidity of erection.

b. Figures 49 and 50 show the method of making up the Ribard coils. Circles of heavy (about No. 5) smooth steel wire, each containing a 6-pointed star of No. 12 smooth wire, are first made up as shown in Figure 49. These are then placed in a frame as shown in Figure 50 and three diagonal barbed wires are placed between the circles connecting opposite vertices of the triangles. Finally, six horizontal wires are added

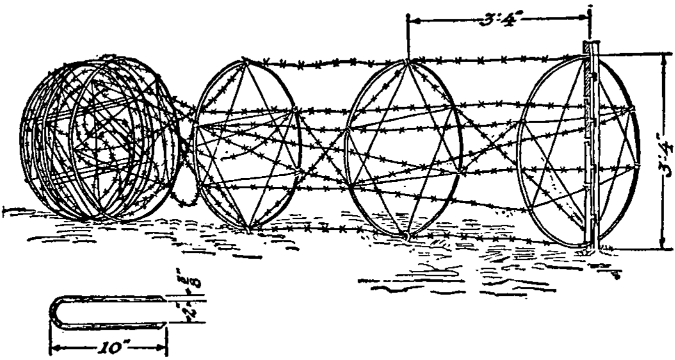


FIGURE 48.—Partially opened Ribard element showing stapling and supports

connecting the points of the stars. The elements are then removed from the frame. Two men grasp the ends. Both twist strongly to the right, approaching each other at the same time. The cylinder closes into a compact coil, which is then placed on the ground compressed with the feet, and tied with tracing tape. Usually two men work at each table making circles and three men at each frame wiring the circles together. The average time per cylinder is 20 minutes. Seventy yards barbed wire, 30 yards heavy steel wire for circles, and 40 yards light smooth wire are required. One Ribard element is a load for one man.

67. Barbed-wire concertinas.—*a*. Like the Ribard element, this type of obstacle is prepared in advance and in the field

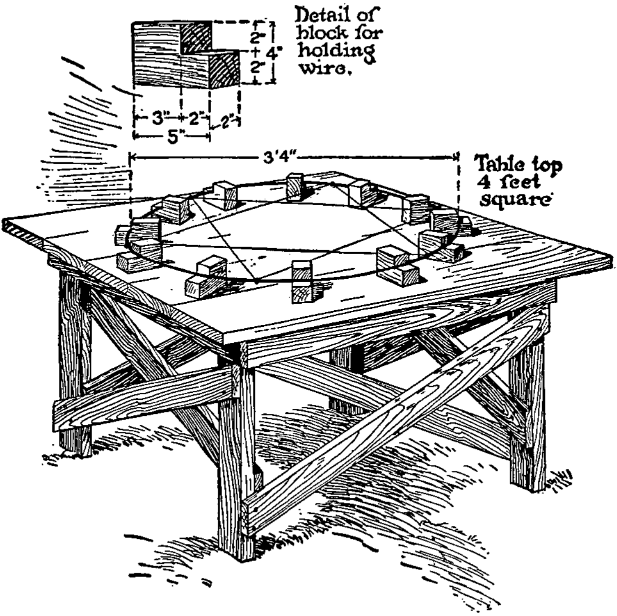


FIGURE 49.—Table for making Ribard circles

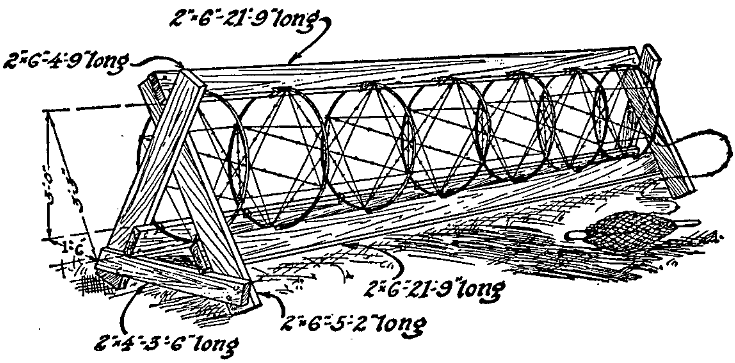
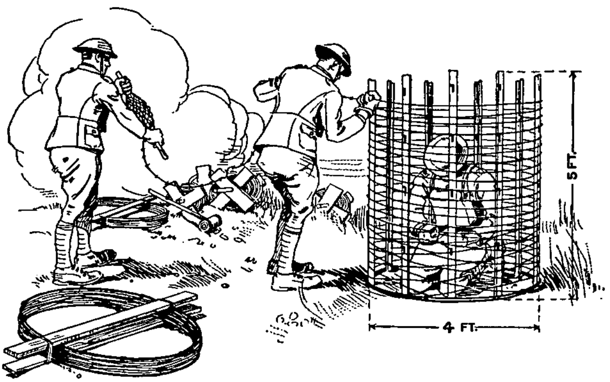


FIGURE 50.—Frame for constructing Ribard elements

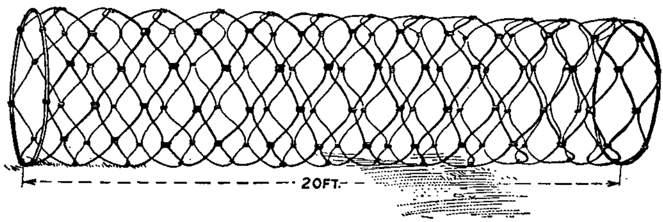
needs only to be opened out, supported on a wire strung between posts, and stapled to the ground.

b. Draw on the ground a circle 4 feet in diameter. Place nine posts—an odd number is essential—equally distant, approximately 17 inches apart around this circle and drive them, leaving a height of 5 feet above ground. Angle-iron pickets are much easier to work with than wooden ones. One 100-yard coil of barbed wire is required per concertina, with



① Element collapsed and prepared for carrying

② Method of making concertina elements with either plain or barbed wire



③ Concertina extended

FIGURE 51.—The concertina

short lengths of plain wire for fastening. The unit party is three men. No. 1 works inside the framework; Nos. 2 and 3 run out the coil, No. 2 helping No. 1 if necessary.

Average time per concertina is 20 minutes. Take two complete turns around the nine posts with No. 12 plain wire, or four turns with No. 14 wire, and bind these turns together at each interval between posts, so as to form a secure end ring for pulling the concertina out. Fasten the end of the barbed wire to the plain wire and take 24 turns with it around the posts in a spiral form, binding two consecutive turns together at every other interval, using No. 14 to No. 20 plain wire for binders. Make two turns with plain wire and make fast. It assists to have a nonagonal-shaped framework to fit inside the top of the pickets, so as to keep them properly spread out. It is easily removed when the concertina is finished.

c. The easiest method of carrying is to wire a slat to each face of the closed roll, the slats parallel to each other. The points 90° from the slat fastenings are then lightly tied with tape. The concertina can easily be carried by two men, or with reasonable ease by one man if in the open.

68. Ribard and concertina entanglements.—*a.* Ribard elements and concertinas open out to a length of about 20 feet and are formed into an entanglement by tying end to end. The elements are supported between posts spaced 20 feet apart and carrying a taut top horizontal wire, to which the elements are secured. Each coil should also be stapled, in at least three places to the ground, with a staple as shown in Figure 48. The entanglement may be thickened in depth as desired by adding successive lines. Figure 52 shows the manner in which Ribard or concertina elements are arranged to form an entanglement.

b. The entanglement has the advantages of low visibility, rapidity, and ease of construction once the elements are prepared, and difficulty of destruction by artillery owing to its strength and resiliency. Being stapled to the ground, it is difficult to pass, and in double lines with a top horizontal wire it forms an exceedingly efficient barrier.

69. Drill for erecting Ribard wire or concertina entanglement.

50 yards double-belt Ribard wire or concertina

Material	Wiring party	Carrying party
4 bundles (16) long pickets. 4 anchor pickets. 14 coils Ribard wire or concertina. 2 50-yard coils barbed wire. 30 wire staples. 24 8-inch pieces No. 18 plain wire.	1 noncommissioned officer (carries pliers). 10 men (Nos. 1 and 2 each carry 12 pieces plain wire; 9 and 10 each carry 15 staples; all carry rack sticks).	1 noncommissioned officer, 20 men.

50 yards double-belt Ribard wire or concertina—Continued

<table>
<tr><th>Nos.</th><th>First task</th><th>Second task</th><th>Third task</th><th>Fourth task</th><th>Fifth task</th></tr>
<tr><td>N. C. O.</td><td colspan="5">Carries out 4 anchor pickets. Paces off distances and locates pickets. Supervises work.</td></tr>
<tr><td>1</td><td rowspan="4">Carry out 4 long pickets each.</td><td rowspan="4">Each lays out and screws in 4 long pickets.</td><td rowspan="2">Open out and place in front line of pickets 1 Ribard element or concertina.</td><td rowspan="2" colspan="2">Wire coils together in both belts, No. 1 working on enemy side, No. 2 opposite.</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Open out and place in front line of pickets 1 Ribard element or concertina.</td><td rowspan="2">Open out and place in second line of pickets 1 Ribard element or concertina.</td><td>Run horizontal wire along top of pickets, first row.</td></tr>
<tr><td>4</td><td>Fasten wire to pickets.</td></tr>
<tr><td>5</td><td>Carries out 1 Ribard element or concertina and cuts tape.</td><td>Lays out and screws in 4 anchor pickets.</td><td rowspan="2">Open out and place in front line of pickets 2 Ribard elements or concertinas.</td><td rowspan="2">Open out and place in second line of pickets 2 Ribard elements or concertinas.</td><td>Windlass coils to wire at 3 points between each 2 pickets.</td></tr>
<tr><td>6</td><td rowspan="5">Carry out 2 Ribard elements or concertinas and cut tie tapes.</td><td rowspan="3">Carry out 1 Ribard element or concertina coil and cut tie tapes.</td><td>Run horizontal wire along top of pickets, second row.</td></tr>
<tr><td>7</td><td rowspan="2">Open out and place in front line of pickets 2 Ribard elements or concertinas.</td><td rowspan="2">Open out and place in second line of pickets 2 Ribard elements or concertinas.</td><td>Fasten wire to pickets.</td></tr>
<tr><td>8</td><td>Windlass coils to wire at 3 points between each 2 pickets.</td></tr>
<tr><td>9</td><td rowspan="2">Carry out 1 coil barbed wire.</td><td rowspan="2">Open out and place in front line of pickets 1 Ribard element or concertina.</td><td rowspan="2">Open out and place in second line of pickets 2 Ribard elements or concertinas.</td><td rowspan="2">Staple down both belts.</td></tr>
<tr><td>10</td></tr>
</table>

NOTE.—Nos. 6, 7, 8, 9, and 10 place coils in intervals between pickets in tasks Nos. 1 and 2.

70. The knife rest or cheval-de-frise.—The knife rest consists of a framework of wood or iron, upon which is strung barbed wire. It is sometimes called a cheval-de-frise. The

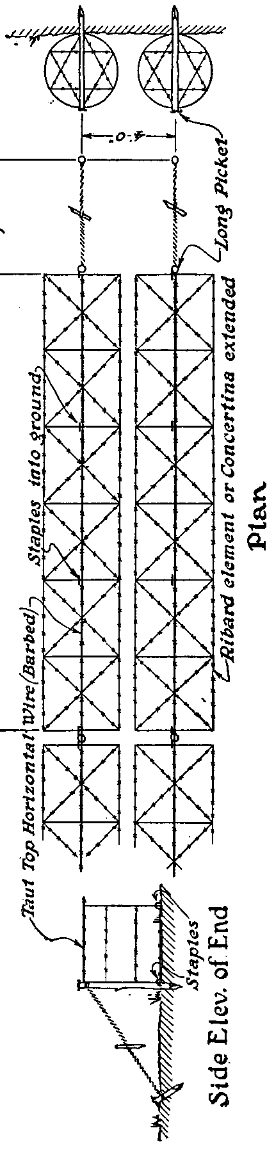
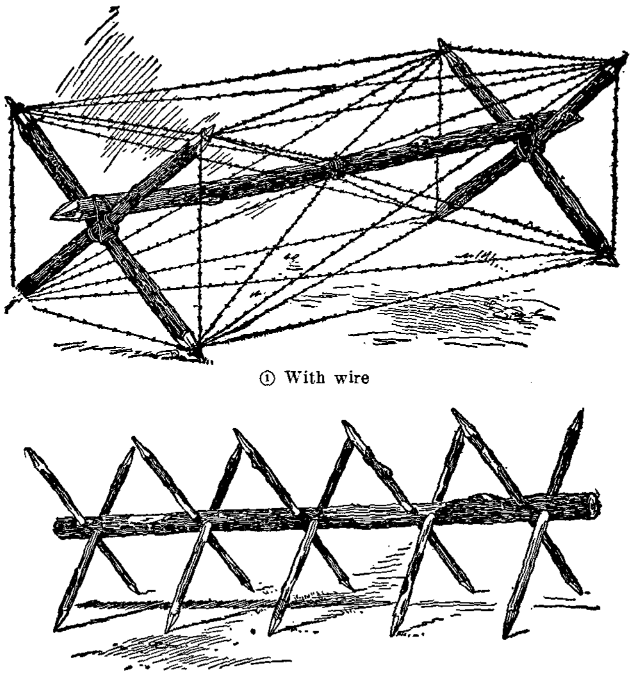


FIGURE 52.—Double-belt Ribard or concertina entanglement

framework, if the iron type, may be made collapsible and hence easier to transport, as well as being more difficult to see and stronger than the wooden type. In shape, the framework of the knife rest is of the same appearance as a common sawbuck. Figure 53 shows its construction. Chevaux-de-frise are frequently used to stop temporary gaps in entanglements,



① With wire

② Without wire

FIGURE 53.—Knife rest or cheval-de-frise

to barricade trenches leading toward the enemy, and to barricade roads and streets.

71. The gooseberry and the hedgehog.—*a.* The gooseberry, illustrated in Figure 54, consists of barbed-wire balls connected by spirals of the same material. It is used principally to block trenches. For this purpose the balls should be made with a diameter slightly greater than the width of the trench in order that, when jammed into place, they will be more difficult to remove. They may also be used to make emergency repairs to existing obstacles.

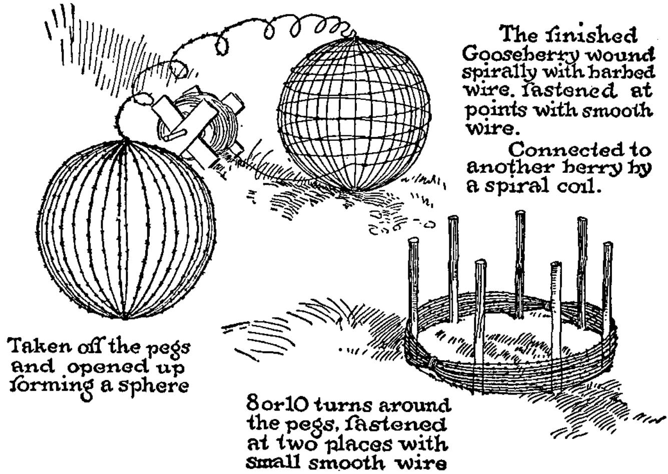


FIGURE 54.—The gooseberry

b. The hedgehog.—The nature and manner of construction of this obstacle are illustrated in Figure 55. It is used in the same way as the gooseberry.

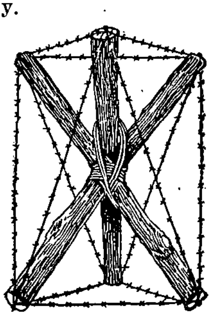


FIGURE 55.—The hedgehog

72. **Abatis.**—*a. Dead abatis.*—Dead abatis is made by felling trees toward the enemy and placing them so closely together that the branches form a barrier against an advance. The

difficulty of passage is increased by the addition of barbed wire interlaced in the branches of the trees. The wire lacing also makes the removal of the barrier more difficult. This type of barrier is highly efficient as a rapid means of blocking a road lined with trees. In the case of a road between two rows of trees the trees on both sides are so felled that their tops interlock, making the barrier as dense as possible. Trees are preferably only partially cut through when felled so that their removal may be more difficult. Dead abatis has the disadvantages of being conspicuous and also inflammable when dry. For these reasons it is often worth while to go to the greater labor of building live abatis for defenses in a wood.

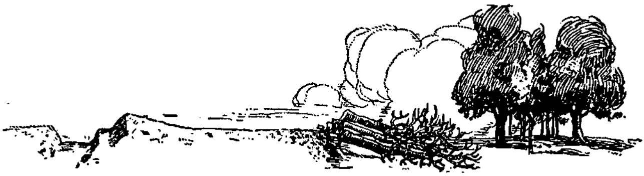
b. Live abatis.—(1) In the organization of woods, where the growth is suitable, it is possible to form a barrier by bending down, interlacing, and tying the easily bent saplings and lower branches of adjacent trees in such a way that the obstacle is invisible to both ground and air observers. (See fig. 56.) This type of barrier is usually constructed in extended depth and is practically impassable to advancing infantry, unless the circumstances are such that trench knives or axes can be used.

(2) It is sometimes the practice in connection with the use of live abatis to augment its impassability by the addition of a number of plain or barbed wires strung from sapling to sapling or tree to tree. The use of pickets in this situation should be avoided as they increase the visibility of the barrier.

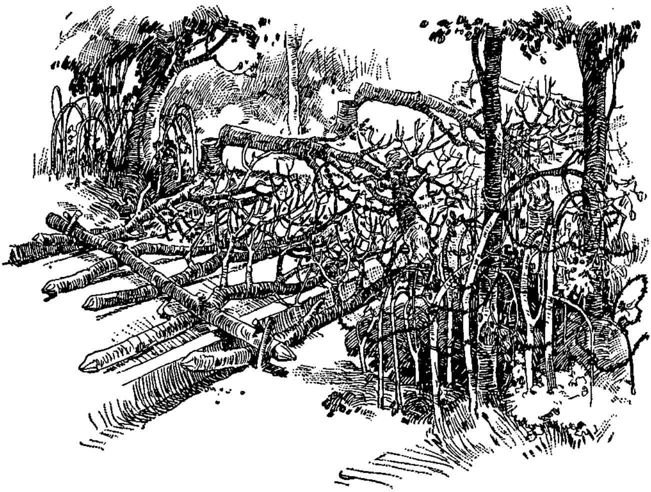
(3) In the organization of fairly dense woods abatis is not always continuous; gaps are left at points which would naturally be the avenue of approach of advancing elements. These lanes of access are directed toward lines of supplementary barriers of double-apron or high-wire entanglement, there being definite lanes cut through the woods along the enemy side of these barriers, and bounded by them and the abatis. These lanes are under fire from well-placed flanking weapons and are under good observation. The object of this type of organization is to herd the enemy into zones from which he can not easily find an exit and which are swept by the fire of automatic weapons.

(4) Lanes should not be too wide, as they then become visible from the air. It is possible in fairly dense woods to clear lanes 6 to 20 feet wide and to bring together the branches overhead, thus concealing their position.

73. Inundations.—Inundations form serious obstacles to the attacker. They also may seriously limit counterattacks. They are created by building dams at suitable points. An extensive survey is frequently a necessary preliminary step to determine the area and depth to be inundated and height and best



① Dead abatis protecting hasty trench in woods



② Dead abatis blocking road with live abatis on its flank

FIGURE 56.—Abatis

location of the dam. In a stream with a firm bottom it requires at least 4 feet of water to be a serious obstacle to infantry and 6 feet as a minimum should be sought. If the bottom is soft, or if the inundation is combined with other obstacles, a lesser depth suffices. A barbed-wire entanglement prepared in advance and inundated is a most formidable obstacle.

Inundations are very effective obstacles against tanks or any form of vehicle.

74. **Tank obstacles.**—*a*. The most effective defense against tanks is the 37-mm. gun or other infantry accompanying gun of greater caliber. The use of tank obstacles presupposes a passive defense, although such obstacles should not limit or impede counterattacks. The construction of tank obstacles involves a great deal of time, labor, and for many types a great deal of material.

b. Points at which advancing tanks are limited as to their lines of approach; for example, causeways passing extensive swamps, roads through timber heavy enough to serve as an effective tank obstacle, and the entrances to the stone villages

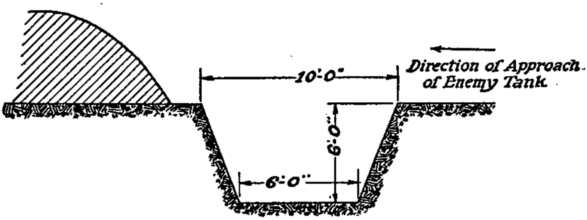


FIGURE 57.—Antitank ditch

of western Europe, are the most favorable locations for tank obstacles. Their construction is not usually warranted except in such favorable locations.

c. Trenches and entanglements are not usually effective obstacles against tanks. However, trenches filled with wire may hold up or delay the infantry accompanying the tanks and thereby break up the attack. Heavy abatis may serve as an effective obstacle; light and live abatis generally do not. Light tanks can penetrate woods when the large trees are scattered and the undergrowth is not excessively heavy.

d. Figure 57 shows the minimum excavation that can be considered an effective tank obstacle. The earth may be scattered and the ditch camouflaged to the point that it is invisible to approaching tanks. A ditch blocking a road may be supplied with a camouflaged bridge adequate for the normal traffic of the defenders but not strong enough to carry the enemy tanks.

c. Heavy obstacles consisting of concrete blocks, railroad rails imbedded in the ground or in concrete, and rubble masonry have been used. Such obstacles should be designed by the engineers when the need for their use arises, due consideration being given to the size and power of the tanks they are to withstand.

75. Antitank mines.—*a.* Antitank mines are land mines, of the controlled or contact type, buried in the ground or scattered on the surface and camouflaged, used to destroy or disable enemy tanks. The controlled mines will rarely be used. In the few situations where mines of this type are advantageous the destruction of enemy personnel and matériel in general will be the object sought for. They will infrequently be used against tanks alone. Contact mines find their greatest application in position warfare where there is ample time to bury them carefully in mine fields and to camouflage the spot where each mine is buried. In open warfare antitank mines must be scattered on the surface, concealed in the grass, or other vegetation. The ease with which they may be discovered and removed by troops detailed to accompany the tanks for that purpose makes their effectiveness in open warfare problematical.

b. Antitank mines of the contact variety will invariably be placed at intervals over an area to form a mine field. The following principles govern the location and layout of mine fields:

(1) The mine field should be used in connection with tank obstacles, natural or artificial, so that tanks in avoiding the obstacle will pass over the field. An exception to this rule occurs when mines are planted within wire entanglements to destroy any tanks that attempt to open lanes through the entanglement for the attacking infantry. Figure 58 shows the use of a mine field with an antitank obstacle on a road.

(2) The mine field, regardless of whether it is composed of mines buried in the ground or merely placed on the surface, must be carefully camouflaged. A bombardment by artillery will destroy a mine field. If the regular arrangement of mines in a field is disclosed to the enemy by spots on an aerial photograph he will destroy it by artillery fire or arrange for the removal or destruction of the mines by troops accompanying the tank attack.

(3) To prevent the removal of the mines the mined area should be covered by small-arms fire of the defenders.

(4) The mines in a field should be in at least two rows, laid checkerboard fashion. The intervals between adjacent mines in a row must be so small as to prevent a tank from passing through the row without exploding at least one mine. The distance between rows should not exceed twice the interval between mines in a row. Sometimes, in order to economize on material and labor, transverse beams or sleepers are laid across adjacent mines. The interval between mines may then be greater than the width between treads of the tank. This scheme has the disadvantage that mines will often be set off outside the area of the tank. Unless excessively large charges have been used, in which case no economy of material is

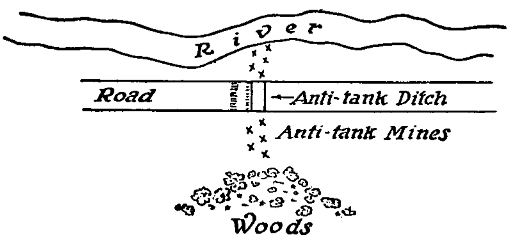


FIGURE 58.—Antitank obstacle with mines

effected, no damage is done to the tank. It has the advantage that mines may be set off under the belly of the tank over which the tank would pass unharmed if the beams were not used.

(5) To prevent the defenders from entering the mine field with vehicles, guns, or tanks by accident or through ignorance of the location of the field, the mined area must be definitely located on maps and, in addition, the area should be wired in with bands of entanglement.

c. The amount of explosive which should be used in an antitank mine depends on the size of the tanks against which the mines are to be used. A comparatively small charge exploded under any part of a tank will disable it, whereas it requires a very large charge outside the area covered by the tank to do any damage. It is more desirable to prepare a larger number of mines with smaller charges from the available supply of explosive and space them more closely, so that any explosion that occurs will be under the tank setting off the charge, than to concentrate the available explosive in comparatively few mines, widely spaced. The material that will ordinarily be used as the charge in antitank mines is our standard explosive triton as issued. However, it may often be necessary to use high-explosive shells of various calibers. The following table gives data as to the disabling effect of various charges on certain types of tank used during the World War and suggestions as to the size of charges to be used against similar tanks.

TABLE X.—*Disabling effect of various charges on certain types of tank*

Nature, size, and location of charge	Degree of disablement	
	Mark V star	Light Renault
One 3-inch high-explosive shell buried 6 inches under track.	None	Permanent.
One 3-inch Stokes mortar high-explosive shell buried 6 inches under track.	None. Very slight damage.	No test.
One 6-inch high-explosive shell buried 6 inches under track.	Permanent	Do.
One 3-inch high-explosive shell on ground under belly.	No test	Permanent.
One 6-inch high-explosive shell on ground under belly.	Permanent	Permanent. Complete destruction.
2 pounds triton buried 6 inches under track.	No test	Temporary. Considerable repair required.
15 pounds triton buried 6 inches under track.	Permanent	No test.
30 pounds triton buried 6 inches under track.	Permanent. Very extensive destruction.	Do.
15 pounds triton buried 1 foot in ground 2 feet from tank.	No test	Temporary.
25 pounds triton buried 1 foot in ground 2 feet from tank.	do	Permanent.
15 pounds triton buried 1 foot in ground 5 feet from tank.	do	None. No damage.
50 pounds triton buried 1 foot in ground 5 feet from tank.	do	Temporary.
2 pounds triton on ground under belly	do	Do.

NOTE.—The Mark V star (British) is a heavy tank weighing about 33 tons and carrying a crew of 8. The Renault is a light tank weighing 7¼ tons and carrying a crew of 2.

Minimum charges for antitank mines:

Against light tanks similar to the Renault—

One 75-mm. high-explosive artillery shell, or one 75-mm. infantry howitzer shell, or 5 pounds of triton or its equivalent in other loose explosive.

Against medium tanks (15 to 20 tons in weight)—

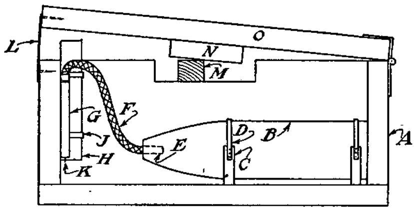
Two 75-mm. high-explosive artillery shells, or two 75-mm. infantry howitzer shells, or one 155-mm. high-explosive artillery shell, or 10 pounds of triton or its equivalent in other loose explosive.

Against heavy tanks similar to the Mark V star (British)—

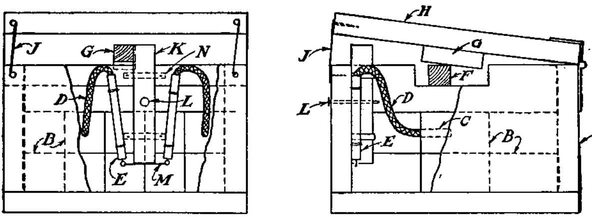
One 155-mm. high-explosive artillery shell.

15 pounds of triton or its equivalent in other loose explosive.

d. Figure 59 shows a mine for which only standard demolition equipment is required. This mine may be built to accommodate any size of charge. The wooden case may consist of a suitable ammunition packing case or other box. In case one or more shells are to form the charge a proper sized box to hold



A Box
B Explosive Shell
C Wooden Cradle
D Strap Iron Ties
E Tetryl Caps (Duplicate)
F Instantaneous Fuses (Dup.)
G Friction Fuse Lighters (Duplicate. Stapled to wall of Box)
H Wooden Plunger
J Strap Iron Guides (For plunger)
K Cross tie Wire (Bet. Fuse Lighters)
L Tie Wires
M Wooden Cross Bar (Size varied to break under various loads)
N Breaker Block
O Wooden Lid



A Box
B Explosive Charge
C Tetryl Cap
D Instantaneous Fuse
G Breaker Block
H Wooden Cover
J Tie Wires
K Wooden Plunger
E Friction Fuse Lighter (Stapled to wall of Box)
F Wooden Cross Bar (Size varied to break under various loads)
L Safety Pin (12d. nail. To be removed after mine is placed)
M Cross tie Wire (Between fuse lighters)
N Strap Iron Guides (For plunger)

FIGURE 59.—Antitank mine

the shell or shells laid on their side together with the firing mechanism shown in the illustration of the standard mine is prepared. The two tetryl caps are inserted in the well in the booster charge of the shell. Unless the booster charge is left in the shell the tetryl caps may fail to explode the cast triton in the shell.

e. The items of the standard demolition equipment used in the above described mine are susceptible to deterioration by moisture. The mine must, therefore, be carefully waterproofed. This may be accomplished by wrapping the box with two courses of tarred paper and sealing all joints in the paper with roofing tar. A more suitable means of detonating the charge in land mines is under investigation and will be available in the future.

f. Figure 60 shows the slight modifications in the mine and the arrangement for setting off the charge by a trip wire. This arrangement finds application when mines are to be used in connection with wire entanglements.

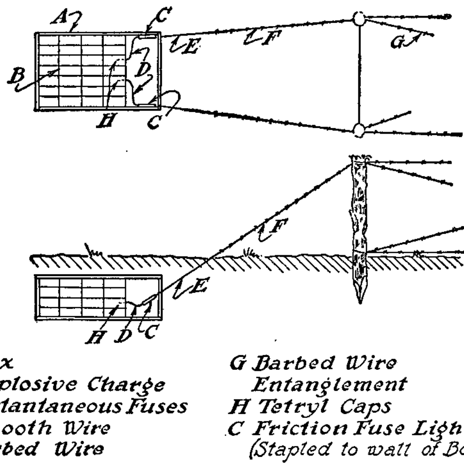


FIGURE 60.—Antitank mine with a trip wire

76. **Latrines.**—*a*. Latrines should be located in offsets from trenches, usually not more than 50 yards away from and in a place convenient of access for the men who will use them. They should not be located in dugouts, except in very large ones where special provision is made for ventilation. They should not be located near points which are likely to draw fire.

b. Accommodation both in latrine and urinal facilities should be provided for at least 2 per cent of the command. If a trench system is to be occupied a considerable time, facilities should be provided for at least 5 per cent of the command.

c. *Types*.—(1) *Bucket type*.—Any type of bucket or can, provided with a seat and cover, may be used. The buckets are placed in an excavation from which they can be easily removed, and a routine arrangement made for emptying them. This system is used only where deep latrines can not be constructed.

(2) *Deep latrines.*—The straddle type (fig. 61), and the box-seat type (fig. 62), are the usual types. Pits should be dug

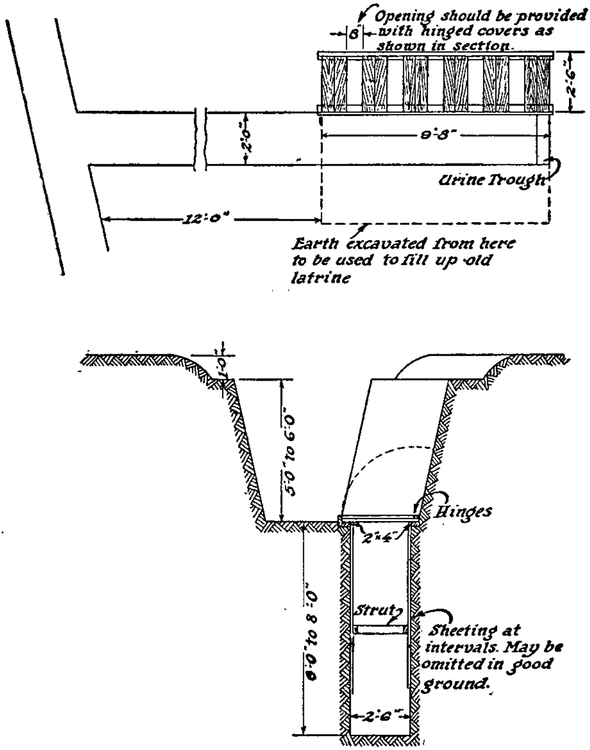


FIGURE 61.—Deep latrine, straddle type

6 to 8 feet deep and, when filled to within 2 feet of the top, should be completely filled with earth and a new latrine dug.

d. Urine troughs or tubs should be provided in every latrine; troughs may be easily made of standard corrugated-iron sheets.

77. Ladders and steps.—*a.* Ladders form the most satisfactory means of exit from trenches for the purpose of attack.

Permanent ladders 5 feet long and in sufficient numbers for patrols are ordinarily fixed to the front wall of a trench.

b. In preparation for attack a large number of loose ladders should be placed in the parallels of departure. When the attack is about to start these may be supplemented by taking

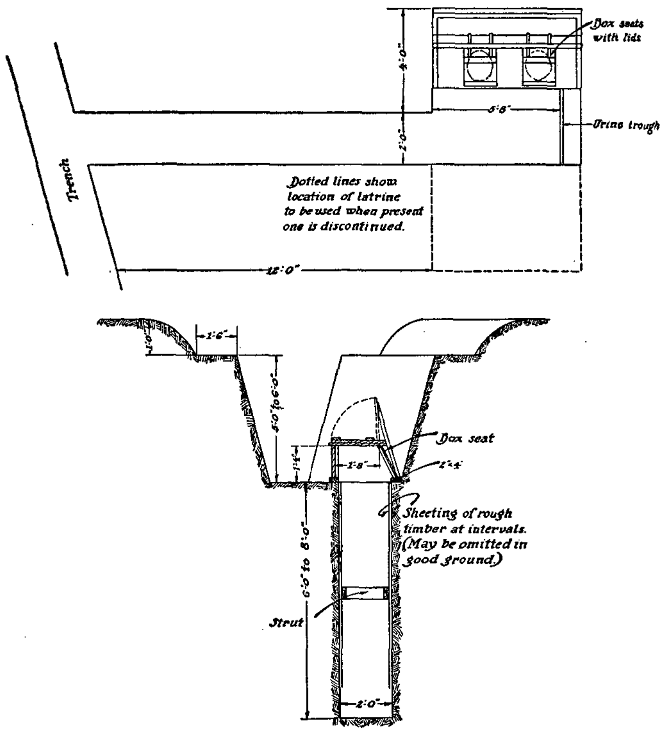


FIGURE 62.—Deep latrine, box-seat type

up trench boards and using them as ladders, after knocking off alternate crosspieces.

c. Steps.—To permit travel over the surface of the ground at night, ladders, steps, or ramps should be provided along the communication trenches throughout the position. Steps may be cut into the earth and revetted. Figures 63 and 64 show simple types of sortie ladders and steps.

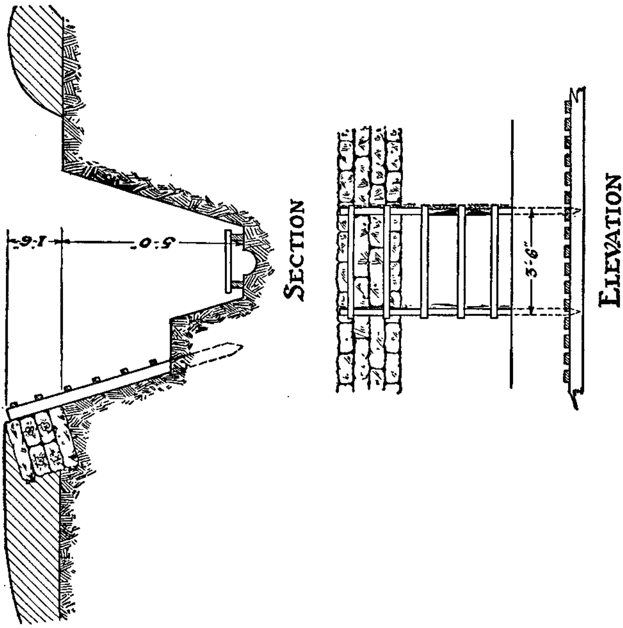


FIGURE 63.—Sortie ladder

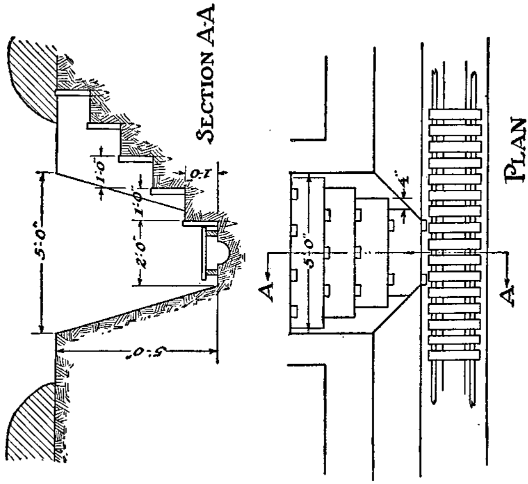


FIGURE 64.—Sortie steps

78. Estimates.—*a.* Tables XI and XII contain estimates for certain types of works in order that approximate computations may be made. It must be borne in mind that the figures in the tables are *approximations* only, based upon *average conditions, day work, and engineer tools.* The actual time and labor necessary vary greatly with such elements as training and morale of personnel, weather, soil conditions, proximity and activity of the enemy, kind and number of tools available, whether the work is done by day or night, and many other contingencies which the estimating officer must evaluate to the best of his experience and ability. For night work add 50 per cent to man-hours in tables. For infantry tools add 40 per cent to man-hours in tables. The personnel indicated in Table XII represents the maximum number of men that can ordinarily be used effectively on the given item of work.

TABLE XI.—*Time and labor estimates*

Description of work	Results	Man-hours	Reference in this manual	Remarks
Excavation cubic feet	100	8	Table IV	
Trenches, type A, unrevetted—				
Fire linear feet	5	8	Fig. 18 Table V	
Communication do	5	6.5	Fig. 21 Table V	
Revetment (front slope of trench only):				
Sandbag type linear feet	50	64	Fig. 25	
Wire-mesh type do	50	8	Fig. 31	Materials at site.
Automatic-rifle emplacement	1	4		
Machine-gun emplacement:				
Shallow type	1	4		
Standing type	1	9		
Splinter-proof type, double emplacement	1	288	Fig. 37	Do.
Reinforced concrete type	1	[1] 720	Fig. 38	Do.
Emplacement for 37-mm. gun	1	3		
Emplacement for 3-inch mortar	1	24		
Wire entanglement:				
High-wire entanglement (two rows of stakes) yards	50	9	Fig. 42 Par. 61	Do.
Double-apron fence do	50	5	Fig. 43 Par. 61	Do.
Clearing the field of fire: [2]				
Small brush square yards	100	1	Par. 45	
Undergrowth and some small trees square yards	100	2	do	
Brush and trees do	100	5½	do	

[1] Plus the time necessary for the concrete to reach its effective strength. (See par. 58.)
[2] This contemplates fairly complete clearing, including removal of débris. A light clearing or thinning out to improve the field of fire can be accomplished in less time.

TABLE XII.—*Approximate time and labor estimates for hasty works* [1]

Work	Number of men	Number of man-hours in—		
		Soft soil	Average soil	Hard soil
Company command post, hasty [1]	2–3	12	18	24
Company observation post, hasty [1]	2	6	9	12
Light 2-man shelter in trench [2]	2	6	9	12
Aid station, local, hasty [1]	2–4	12	18	24
Battalion observation post, hasty [1]	2–4	10	15	20
Battalion command post, hasty [1]	8–16	50	75	100
Battalion aid station, hasty [1]	8–16	50	75	100

[1] Plans for these works are not given, as the nature of the work must be adapted to the terrain features available. The working parties and man-hours given are the minimum required in order to provide protection comparable to that given other elements of the defense in a hasty organization of the ground.
[2] For plans see Sec. V.

b. These tables should be of value to commanders and staff officers in determining the extent to which it is possible to organize any given front in a given time with a given number of men. They are also of value as a measure of the efficiency of the troops, and especially of the junior officers who actually supervise the work. Time allowances are liberal and troops who do not come up to these standards are below average.

c. Estimates for defensive positions involve a summation based upon the total length of the various types of trenches to be dug, the number of emplacements for infantry weapons to be constructed, the drainage requirements, and trench accessories contemplated. Table XI gives time and labor figures, which should be carefully weighed in view of local conditions, for the more important units in this summation. Highly organized positions, particularly those containing many light and heavy shellproof shelters, require large quantities of materials, the procurement and transportation of which are separate problems of great magnitude. There is a most important distinction between the works that are characteristic of a hasty organization and of a deliberate organization. Hasty organization is understood to mean one that can be installed during a single day; that is, in six to eight hours, and with no materials except for wire entanglements. Deliberate organization requires much time, labor, and materials, accordingly it should not be undertaken except on the orders of higher commanders, usually the commander in chief, who alone is qualified to decide whether the situation calls for such effort and who alone can make available the great supplies of materials and other facilities.

d. The following general rules for the execution of the work after estimates have been made are applicable to all details of field fortification:

(1) Assign to each organization the construction of the works it will itself occupy and defend.

(2) Assign to each organization the work it is best equipped and trained to perform.

(3) Assign work of general interest, such as clearing the field of fire, improvement of routes, etc., to special units and attached troops.

(4) Avoid the splitting up of any unit amongst a large number of tasks, especially if they are widely distributed. Assign as few different tasks as possible and all in the same locality.

(5) Avoid the shifting of units or individuals from one task to another.

(6) Avoid the assignment of men from different organizations to the same task.

(7) Avoid the splitting of units or violation of tactical integrity. Use complete squads, complete platoons, and even complete companies as far as possible.

(8) If there be not enough men for all tasks in the allotted time, make sure that the most important tasks will be completed on time, and others as far as possible.

(9) It will never be possible to observe all of the foregoing rules precisely. Each should be given all the weight that the situation permits.

SECTION V

PROTECTED SHELTERS

79. Classification of shelters based on degree of protection.—Protected shelters are classified according to the degree of protection they afford, as follows:

a. Splinter-proof shelters protect against rifle and machine-gun fire, splinters of high-explosive shell, and grenades, but not against direct hits by 3-inch shells. They require only that an overhead cover of compact earth of about 1 foot in thickness (or its equivalent in other material) be securely supported. When these shelters are numerous and are carefully located, casualties may be greatly reduced.

b. Light shelters protect against direct hits, and in some cases against a continued bombardment by 3-inch shells.

c. Light shellproof shelters protect against continuous bombardment by all shells up to and including the 6-inch.

d. Heavy shellproof shelters protect against continuous bombardment by at least 8-inch shells. Some types may be proof against larger shells or against all types of artillery fire.

80. Classification based on method of construction.—Shelters may further be classified as to the method of construction, which depends on the character of the ground, the materials available, and the protection required. The classification is—

a. Surface shelters.—These structures, or at least the greater portion of them, are built at or above the surface of the ground. This type has a maximum of observation and facility of exit and requires a minimum of labor; on the other hand, it is relatively conspicuous, requires considerable cover material, and provides the least protection. Shelter of this type is seldom used for the protection of personnel in advanced lines, unless it can be concealed in woods, on a steep reverse slope, or among the buildings of a village, or unless the underground water level is so close to the surface that the cut-and-cover type can not be used. One exception to this rule, however, may be the reinforced concrete shelter, though this type often approaches cut-and-cover construction. Light shelters, consisting of almost any type of small improvised shed covered with a layer of earth, may be used for the protection of ammunition and stores. These shelters should be of small capacity, well dispersed, and carefully concealed.

b. Cut-and-cover shelters.—(1) This type consists of an open excavation in which the framework for the shelter is placed, after which the excavation is back-filled around and over the framework to the level of the original surface, or somewhat above. To increase the resisting power of the overhead cover, concrete, steel beams, broken stone, and other materials of high resistance to penetration are used in the roof construction. It is a type intermediate between the surface and the cave shelter.

(2) The cut-and-cover shelter, comparing it with the cave shelter, is adapted for use as dressing stations because it is easily cleaned, is well ventilated and lighted, and facilitates the ready admission and evacuation of casualties. Cut-and-

cover shelters are generally more quickly constructed but require much larger quantities of material than cave shelters. They do not resist intensive shelling as well and are more difficult to conceal than cave shelters.

(3) When surface and underground water or the hardness of underlying rock makes the construction of cave shelters impracticable, cut-and-cover shelters may be used. They are also used where need for rapidity of exit prohibits the use of cave shelters (as in important machine-gun shelters in or near the front line); in wooded areas or in buildings where concealment is easy and where ample material is available; in situations requiring immediate shelter which can be most quickly obtained by this type.

(4) A cut-and-cover shelter providing protection against 6-inch shell does not usually present great difficulties, but it is generally impracticable to attempt to get protection by cut-and-cover methods against heavier shell without constructing the shelters partially or entirely of concrete.

c. Concrete shelters.—With an adequate supply of plant, materials for the aggregate and for forms, protection may be obtained by either surface or cut-and-cover methods by the construction of concrete shelters.

d. Cave shelters.—(1) Cave shelters are constructed entirely below the surface of the ground by mining methods and have a cover of undisturbed or virgin earth. They are the least conspicuous of all types and afford the greatest protection which can be secured before the shelter is completed. They require a minimum of material. They also afford a minimum of observation, worse living conditions than other types, greater difficulty of exit, and their drainage may be difficult.

(2) Cave shelters should be constructed in preference to other types whenever material and time are available and physical and ground-water conditions permit. It is difficult if not impossible to increase the overhead protection of these shelters after completion, since the protection depends upon the depth at which the chamber is built. For this reason it is important not to underestimate the amount of protection needed when the depth is determined. On the other hand, it is equally important not to overestimate the amount of protection needed, because of the time, labor, and material involved in going to unnecessary depths.

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81. Choice of type.—The type adopted should be suitable to all the conditions of the case; each selection is a separate and distinct problem. The more important considerations are as follows:

a. The *use* for which the shelter is designed. This is usually the most important consideration and depends on the tactical situation.

b. The *terrain,* with especial reference to slope and its effect on the type of entrances and the rapidity with which overhead cover can be gained, wooded areas and buildings which provide materials and facilitate concealment, and the disposal of spoil. Reverse-slope positions are difficult for the artillery to hit and are usually easily drained.

c. The *subsurface conditions,* such as extent and character of underlying rock, position and thickness of impervious and water-bearing strata, and the amount of water to be controlled. (See Sec. III.)

d. The *facilities available,* including time, personnel, tools, material, and transportation.

82. Protection against aerial bombing.—In future wars airplanes and dirigibles will undoubtedly play an even more active part than in the past. Consequently, protected shelters may be necessary in rear areas for security against enemy aerial bombing.

83. Location.—*a.* Shelters should be near the combat or assembly positions of the troops occupying them. This rule, of the utmost importance near the front, is of relatively less importance toward the rear.

b. The facilities for cover and concealment afforded by the terrain influence the location of shelters. Steep reverse slopes, quarries, etc., can be prepared to afford excellent shelter with comparatively little labor. Every advantage should be taken of any natural shelter in the locality, tactical considerations permitting.

c. Splinter-proof and light shelters are the only types permitted in the outpost lines and main line of resistance. Cave shelters are located in rear lines, off communication trenches, switch trenches, and in strong points in the reserve line.

84. Facility of exit.—*a.* Facility of exit is secured by designing shelters of small capacity, a minimum depth below ground, and having unrestricted entrances. It is particularly important near the front.

b. Large shelters are provided with at least two entrances and preferably with a third for emergency use. This supplementary exit should emerge in a different trench from the other two, or at least at some point well concealed or camouflaged, permitting the garrison to escape and launch a counterattack on an enemy attacking the main entrance. Entrances should be spaced to avoid the danger of one shell burst blocking two of them (a minimum of 40 feet apart and separated by a traverse or angle in the trench). Large systems of cave shelters should be constructed to provide one entrance for every 25 men.

85. Concealment.—*a.* It is important that the location and number of shelters be concealed from hostile observation.

b. Surface shelters to be inconspicuous must be hidden by existing features of the terrain, as in a wood or among buildings in a village.

c. For concealment, cut-and-cover shelters must be kept low. The surface of the ground where disturbed must be restored to its previous appearance. Necessary measures should be taken to conceal the work while in progress.

d. Cave shelters are the easiest to conceal, as they do not disturb the natural surface of the ground. However, it is difficult to dispose of the spoil without attracting the attention of the enemy.

e. It is very important during construction to conceal all signs of activity. Construction materials and excavated earth must be carefully camouflaged and strict camouflage discipline demanded of the men carrying on the work.

f. Concealment is facilitated by placing the entrance to a shelter in a trench, thereby providing a protected outlet and inlet and avoiding overground trails or footpaths

86. Observation.—Shelters should, if practicable, be provided with means of observation, such as loopholes in a surface shelter or a periscope in the roof of a cave shelter. The upper end of the periscope should be camouflaged.

87. Drainage, ventilation, and gas proofing.—*a. Drainage.*—(1) In the case of surface shelters, drainage presents few difficulties.

(2) In the case of deep shelters, it sometimes becomes a complex problem which includes the following elements:

(*a*) The exclusion of surface water from the entrance.

(*b*) The exclusion of seepage from the chambers, shafts, and galleries.

(*c*) The removal of water that has collected in the chambers and galleries.

b. Ventilation.—In the hasty or splinter-proof shelter, ventilation presents no problem; but in the cave shelter, with its underground chambers, it becomes of vital importance. Ventilation is provided by the entrances and by openings through the roof, all so equipped that they can be closed to exclude gas. For further details see paragraphs 136, 137, and 138.

c. It should be possible to make all shelters, and particularly those below ground, gas tight. A shelter not in use should be sealed to exclude gas, otherwise, casualties may occur when it is again used. For details of gas proofing see paragraph 129.

88. Requirements for shelters in advanced positions.—*a.* Shelters in advanced lines should be—

(1) Well distributed, placing the troops close to their combat positions.

(2) Constructed without going to great depths in order to provide for ease of exit.

(3) Provided with a direct and easy exit (even at some sacrifice of cover).

(4) Of small capacity (from two to eight men).

(5) Of a type that can be rapidly constructed.

(6) Concealed as thoroughly as possible.

These requirements limit the type to the splinter-proof or the light shelter.

b. The construction of light shelters is usually started by infantry holding the front lines. They are located in the individual rifle pits or in the trenches resulting from organizing the position. To prevent caving, they are lined with logs or timber, depending upon material available. They should have at least 4 feet of cover. For construction details see paragraphs 116 to 135, inclusive.

89. Requirements for shelters in rear positions.—Shelters in rear positions may be larger and deeper than those at the front. The occupants have more time to emerge after the warning of the attack has been received, and can occupy their positions more deliberately. They can be given the maximum of overhead cover in order to withstand the bombardment of heavy shells, giving the troops occupying them the necessary rest and feeling of security. These shelters are built entirely below ground, if underground water conditions permit, and are carefully hidden from enemy aerial observation.

90. Thickness of overhead cover.—The thickness of overhead cover is governed by—

a. The artillery fire to be resisted.

b. The character of the covering material.

c. The arrangement of the successive layers.

d. The interior construction of the shelter.

91. Materials employed.—Materials for overhead cover fall into two main classes:

a. Virgin soil (in undisturbed condition) existing in the case of cave shelters.—This is the best form of cover if sufficient thickness can be provided. It may, however, particularly in soft ground, be reinforced by the addition of a bursting layer consisting of any of the following materials:

(1) Concrete slab bursters, which are described in paragraph 103.

(2) Broken stone or brick, layer at least 18 inches thick.

(3) Layer of I-beams, reinforced concrete beams, or rails set on edge and firmly wired together.

b. Artificial substitutes used in all forms of cut-and-cover and surface shelters.—Artificial substitutes in addition to earth are employed in the construction of cut-and-cover and surface shelters. Protection is usually secured by alternating layers of various resisting materials; but to acquire a degree of protection equal to that of the deepest cave shelters would cause the mound to project too far above the ground and would involve too great a quantity of material. Consequently cut-and-cover and surface shelters (other than those of concrete) are designed for protection against calibers less than 8 inches.

92. Thickness of cover for various shells.—*a.* The following table may be used for computing the thickness of cover required for various shells under different ground conditions. (See Sec. II.)

TABLE XIII.—*Minimum thickness in feet of overhead cover*

Nature of cover	Size of projectile								
	Rifle, machine gun, fragments	3 inches	4 inches	6 inches	8 inches	10 inches	12 inches	16 inches	18 inches
Reinforced concrete	------	1.0	2.4	3.4	5.0	6.0	------	7.0	------
Masonry, solid: Brick, stone, plain concrete	------	1.5	3.6	5.1	7.5	9.0	------	11.0	------
Logs, 8″ minimum diameter wired	------	2.0	4.8	6.8	10.0	12.0	------	------	------
Crushed stone	------	3.5	8.4	11.0	17.5	21.0	------	------	------
Tamped or packed earth	1.0	7.5	18.0	25.5	37.5	------	------	------	------
Loose earth	3.0	10.0	24.0	34.0	------	------	------	------	------
Cave shelters:									
Sandstone or granite	------	2.0	6.0	8.0	10.0	13.0	14.0	17.0	24.0
Soft limestone	------	3.0	9.0	11.0	15.0	20.0	21.0	27.0	36.0
Undisturbed earth	------	5.0	12.0	17.0	25.0	30.0	32.0	40.0	48.0

Figures to the right of and below the heavy line are for shelters that would normally be constructed by cut-and-cover methods; those to the left are normally for surface shelters. The dividing line is not fixed, as the determination of the type depends on the location, materials, and the labor and time available.

b. The figures in the table are for material of uniform character from the top of the chamber to within a foot of the surface. If a tamping layer of soft material overlies rock, the total depth from surface to chamber roof must be increased by the effective depth of the tamping layer.

c. Excavation for cut-and-cover shelters reaches practical limits at a depth of cut of about 12 feet below the surface. All shelters with a base to be placed lower than this should be constructed by mining methods (cave shelters).

93. Layers; arrangement and number.—*a.* The strength of the overhead cover depends as much on the manner in which the various layers of covering are arranged as on the character of the materials of which it is composed. The proper arrangement of layers is shown in Figure 65.

b. Component layers consist of the following:

(1) *Bursting layers* must be provided for all cut-and-cover and surface shelters to cause the force of the explosion to be expended upward, due to lack of tamping effect. They are effective against shells with instantaneous and short-delay

fuzes. The bursting layer may be made from any of the materials listed in paragraph 91*a*, should be in the form of an umbrella, and should extend well beyond the shelter on the sides and toward the enemy. It should extend to a point well beyond a line drawn tangent to the bottom edge of the shelter at an angle of 45° to the vertical. Bursting layers should be covered with not more than 9 inches of earth, which should preferably be sodded. This serves to conceal the shelter, prevents flying splinters, and reduces the distintegration of the burster layer by several hits in the same place.

(2) *Distributing layers* of logs firmly wired together, steel I-beams, rails, or concrete beams set on edge are essential to distribute the strain and to prevent the penetration of shell

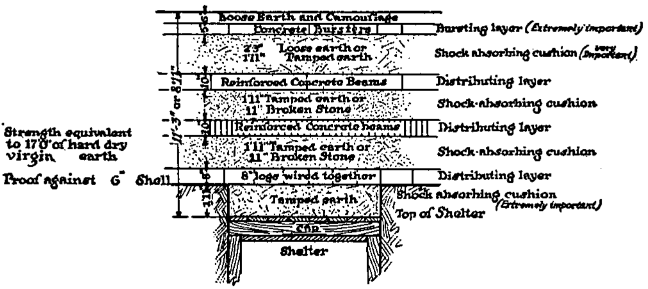


FIGURE 65.—Diagrammatic section showing name, character, and correct manner of placing successive layers of artificial cover

fragments. These layers are placed in accordance with principles illustrated by the example in *c* below. The weight of the over-head cover is carried by the lowermost distributing layer which rests on berms left in the natural soil. Thus, the weight of the cover and the shock of explosion are transmitted to these berms rather than to the interior framework.

(3) *Shock-absorbing cushions* are essential beneath the bursting layer, over the top of the inner framework, and between the distributing layers. The one beneath the bursting layer may be of loose or tamped earth, the others of tamped earth or broken stone, except the one immediately above the shelter, which should be of tamped earth. Fascines are sometimes substituted for tamped earth with satisfactory results. The omission of these shock-absorbing cushions is one of the most fre-

quent causes of the failure of cut-and-cover shelters. The top and bottom cushions are the most vital, and under no circumstances should they be omitted.

c. Proper interior support is essential to secure the full value of overhead cover. The clear span of the interior framework must not exceed 6 feet 6 inches for cut-and-cover or 8 feet for cave shelters. The figures for cover are based on the use of these spans and upon the use of standard-size timbers properly supported. If these are not used, the cover provided, if based on Table XIII, may be insufficient.

d. The shock or blow of the explosion strikes the stiff distributor course and is spread over the cushion; the latter absorbs part of it and further spreads its effect before it strikes the next distributor course, where it is again spread over a wider area, until finally, when the blow reaches the inner shell of the shelter chamber, it is so distributed and absorbed as to be sustained without rupture.

e. An example of the computation for cover to protect against 6-inch shell, using several classes of material, similar to that used in Figure 65, is given. It is assumed that the material available for cover consists of 8-inch diameter logs, standard bursters and beams, and earth, the latter to be tamped or packed. With the general number and arrangement of layers determined on, it is desired to find the thickness of earth that is to be distributed in the cover. From Table XIII the total cover for tamped earth alone is 25.5 feet. Any other material except loose earth reduces this figure by the ratio of thickness used to thickness required if the material were to be used alone. Thus reinforced concrete would be required in thickness of 3.4 feet if used alone, but as 0.415 foot only is used in one layer of concrete bursters, the layer has a value equivalent to 12.2 per cent of the total thickness for the material used alone. The following values are used in the above manner in the computation of the percentage equivalence of the whole thickness for each material used, except earth:

2 layers standard concrete beams	0.83 foot thick (or high).
1 layer standard concrete bursters	.415 foot thick
1 layer of 8-inch diameter logs	.66 foot thick

Then the per cent of total cover allocable to these materials is—

			Per cent
Concrete beams	$(0.83 \div 3.4) \times 2 =$		48.8
Concrete bursters	$0.415 \div 3.4$	=	12.2
Logs	$0.66 \div 6.8$	=	9.7
			70.7
Per cent of cover allocable to tamped earth			29.3
			100.0

25.5×29.3 per cent=7.5 feet or four layers of equal thickness at 1.88 feet each.

94. Concrete as overhead cover.—*a.* Concrete, either plain or reinforced, is a most effective shell-resisting material.

b. There are apparent drawbacks to the use of concrete in active warfare, but some may be more apparent than real. These drawbacks are—

(1) There are too many workers concentrated in a small area.

(2) Construction time is long when Portland cement is used.

(3) Cement at the front is likely to deteriorate; it is necessary and difficult to keep it dry.

(4) Due to interruptions, it is often impossible to obtain a continuous pour of concrete and a truly monolithic shelter.

c. The use of quick-hardening, or alumina, cement concrete in place of standard Portland cement reduces the construction time, because the former attains about 75 per cent of its full strength in 24 hours, against 24 days for Portland cement concrete; it also permits of work at relatively lower temperatures. The final forms (beams, slabs, etc.) may be removed, if necessary, about 30 hours after pouring alumina cement concrete.

d. Where the amount of concrete to be poured is relatively large, and other conditions, as hostile interference and observation, do not control, concrete mixing should always be done by power mixers if they can be obtained. The mixing of concrete by machinery should be made the rule, even in small batches of a few yards, to reduce the time of the operation and the number of men necessary.

e. The construction time includes the whole period of work from commencement of labor to the time when the structure becomes effective for use. The factor of transportation of materials may have a delaying effect if the amounts required are excessive. Comparing shelters of equal capacity and resistance, the necessary transportation for materials for a concrete shelter is, in most cases, considerably less than for a shelter constructed of lumber, logs, rails, concrete beams, and crushed stone.

f. Existing conditions may cause cement to deteriorate. The ability to protect cement from deterioration increases in proportion to the distance from the front line.

g. The liability to interruptions in pouring depends on the location of the shelter with regard to the front line. The shortened period of construction due to the use of machinery on a well-coordinated job lessens the importance of this drawback.

95. Standard construction materials.—*a.* During the World War standard materials were developed for use in the construction of protected shelters and were distributed by engineer agencies. Their use resulted in economy of material and labor. The construction materials described are a result of experience in the World War and are given as a guide for establishing standard materials under future similar conditions.

b. Cases will often occur where round timbers cut near the site will have to be used in lieu of dimensioned lumber. The following table gives a number of standard-size sawed timbers and the round timbers which should be used in lieu of them.

TABLE XIV.—*Equivalent timbers used as beams*

Sawed timbers, width×depth	Area (square inches)	Equivalent round timber diameter in inches	Area (square inches)
1×4	4	3	7.1
1½×6	9	4½	15.9
2×4	8	4	12.6
2×6	12	5	19.6
2×8	16	6	28.3
2×10	20	7	38.5
3×3	9	3½	9.6
3×6	18	6	28.3
3×10	30	8	50.3
3×12	36	9	63.6
4×4	16	5	19.6
5×10	50	10	78.5
6×6	36	7	38.5
8×8	64	10	78.5
8×12	96	13	132.7
8×14	112	14	154.0
8×16	128	15	177.0
12×12	144	14	154.0

NOTE.—The equivalent round timbers are also safe as columns. In making up the table, primary consideration was given to the resistance to bending. However, in every case the round timber will resist more vertical shear than the timber of rectangular cross section to which it is equivalent.

96. Dimensions governing standard shelter materials.—The following tables give the sizes of the various classes of galleries and shafts and include material lists for cases and frames for these classes.

TABLE XV.—*Dimensions of gallery and shaft cases and frames*

Size of—	Inside clear	
	Height	Width
Chamber gallery	6′ 4″	8′ 0″
Great gallery	6′ 4″	6′ 6″
Common gallery	6′ 4″	3′ 0″
Half gallery	4′ 6″	3′ 0″
Branch gallery	2′ 10″	3′ 0″
Small branch gallery	2′ 4″	2′ 0″

TABLE XVI.—*Material list, gallery and shaft cases*

Item	Great gallery	Common gallery	Half gallery	Branch gallery	Small branch gallery
Cap	1-4×10×7′2″	1-3×10×3′6″	1-3×10×3′6″	1-3×10×3′6″	1-2×10×2′4″
Sill	1-3×10×7′2″	1-3×10×3′6″	1-3×10×3′6″	1-3×10×3′6″	1-2×10×2′4″
Post	2-4×10×6′6″	2-3×10×6′6″	2-3×10×4′8″	2-3×10×3′0″	2-2×10×2′6″
Spreader	2-1×10×6′6″	2-1×10×3′0″	2-1×10×3′0″	2-1×10×3′0″	2-1×10×2′0″
Nails [1] pounds	¼ lb. 10d.	¼ lb. 10d.	¼ lb. 10d.	¼ lb. 10d.	¼ lb. 10d.
Weight do	385	220	180	150	75

[1] Nails for spreaders only.

TABLE XVII.—*Material list, gallery and shaft frames*

Item	Chamber gallery	Chamber gallery	Great gallery	Common gallery
Cap, I-beam [1]	1-3×5×9′0″			
Beam shoe	2 standard			
Cap		2-3×10×9′0″	1-6×9×7′6″	1-6×8×4′0″
Sill		1-4× 6×9′0″	1-4×6×7′6″	1-3×6×4′0″
Post	2-6×6×6′6″	2-6× 6×6′6″	2-6×6×6′6″	2-6×6×6′6″
Spreader		2-1× 6×8′0″	2-1×6×6′6″	2-1×6×3′0″
Nails [2] pounds		0.4 lb. 10d.	0.4 lb. 10d.	0.2 lb. 10d.
Weight do	250	440	375	255

[1] I-beams 3″×5″×9¾ pounds per foot. [2] Nails for spreaders only.

Item	Half gallery	Branch gallery	Small branch gallery
Cap	1-6×6×4′0″	1-4×5×3′8″	1-3×4×2′6″
Sill	1-3×6×4′0″	1-3×4×3′8″	1-3×3×2′6″
Post	2-6×6×4′8″	2-4×4×3′0″	2-3×3×2′6″
Spreader	2-1×6×3′0″	2-1×4×3′0″	2-1×3×2′0″
Nails [1] pounds	0.2 lb. 10d.	0.2 lb. 10d.	0.2 lb. 10d.
Weight do	195	80	35

[1] Nails for spreaders only.

97. Cases, gallery, and shaft.—*a.* The standard common gallery case is shown in Figure 66. It is designed as a lining, without additional lining material, for use in horizontal gal-

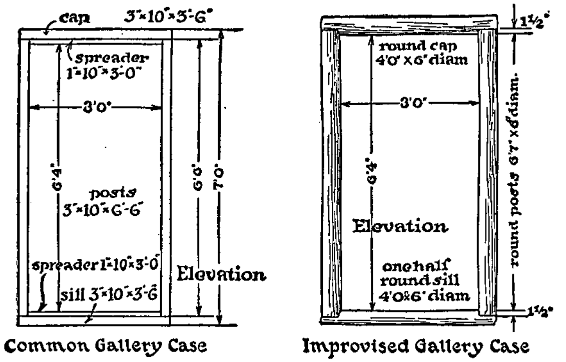


FIGURE 66.—Gallery cases

leries, inclined passages, and in shafts; the dimensions of lumber used vary with the size of gallery or shaft (Table XVI). In horizontal and inclined passages the cases are ordinarily

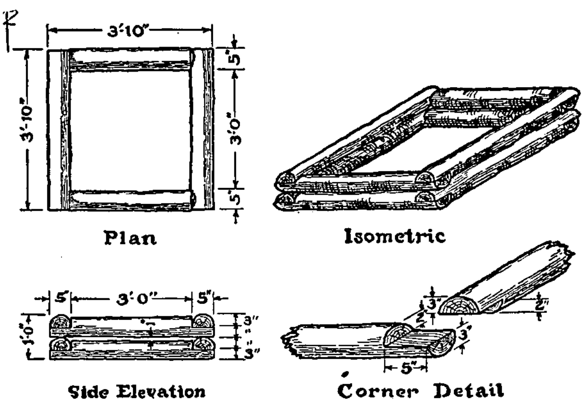


FIGURE 67.—Improvised shaft set

placed in a vertical position and in shafts they are always horizontal. When dimension lumber is not at hand, cases may be improvised from round timber as shown in the figure.

b. The great gallery case finds little use except in the application to special approaches or passages, as in first aid shelters. When used in this way the cases may be narrowed to any width desired for economy in excavation without sacrifice of space. The use of the branch gallery case provides for the constructtion of the timbered light shelter shown in Figures 78 and 79. It also fulfills the requirement for ventilation shafts in cave shelters. The half and branch gallery cases serve for machine-gun shafts, for emergency exits, or for access to observation posts.

98. Frames, chamber, gallery, and shaft.—*a.* Standard types of frames are shown in Figure 68. They are used in horizontal or inclined passages or in shafts, to support the accompanying sheeting which forms the lining of the passage or shaft. For use in shafts all timbers of a frame should be the same size as given for frame posts. The dimensions are such as to permit a frame spacing of not over 4 feet on centers. When dimension lumber is not available, frames can be improvised from round timber as shown in the figure.

b. The chamber frame is designed for use in the rooms or chambers of cave shelters. The posts may be furnished in 6 by 6 inch dimension timber or round logs at least 6 inches in diameter at the small end. If the latter are used, they must be straight and as free from knots as possible. Caps are 3 by 5 inch steel I-beams, 9 feet long, weighing 9¾ pounds per foot. They are held on the posts by standard beam shoes fastened to the posts by spikes or lag screws. A 2-inch notch is cut in the floor to receive the bottom of the post. In soft ground, foot blocks of 3 by 10 inch plank, 18 inches long, are placed under the posts. In very soft ground, such as clay, the bottoms of the posts should be sunk from 4 to 6 inches into the floor. If steel I-beams are not available, 6 by 10 inch timber or two 3 by 10 inch planks spiked together may be used for the cap.

99. Standard sheeting.—Sheeting is used for supporting the ground between frames in chambers and galleries and in inclines and shafts where frames rather than cases are used. Two-inch sheeting is furnished for the roof and 1½-inch for the sides. It is normally made in 5-foot lengths varying from 4 to 10 inches in width. For frame spacing of 3 feet center to center, 4-foot lengths of sheeting afford economy of material and work. Boards selected from the side sheeting should be used for head boards and stair risers which are 1½ by 10 inches by 3 feet

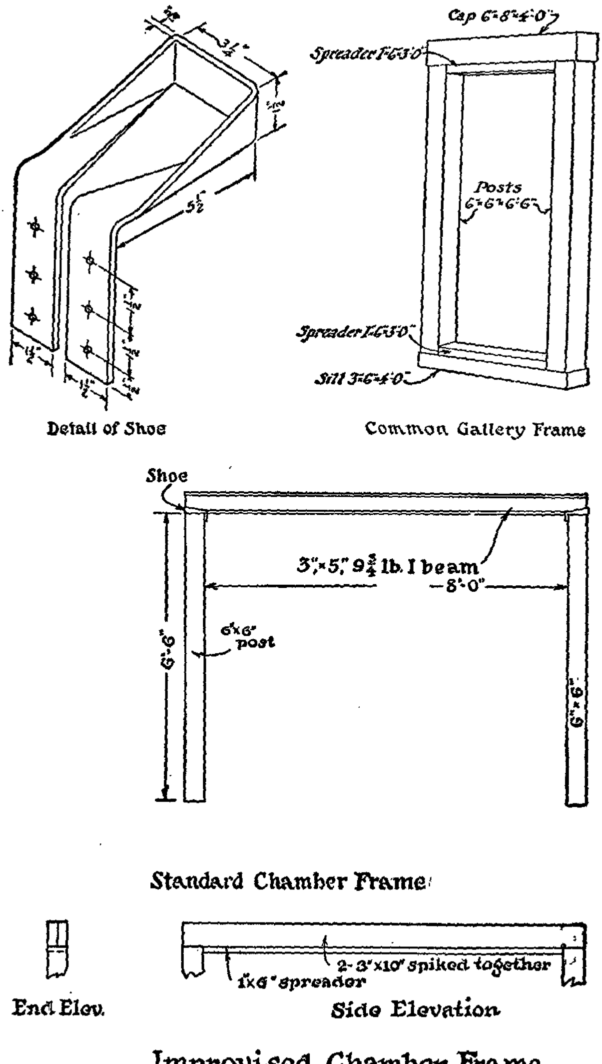


FIGURE 68.—Frames for chamber and gallery

6 inches in stepped inclines. If standard sheeting is not available and ground conditions are favorable, round poles 2½ inches in diameter at the butt and 4 to 5 feet long may be used instead.

100. Wedges.—Wedges are used for bracing timbers tightly against the walls and roofs of excavations, holding them in place until the settling of the ground has rendered displacement impossible. Wedges must be provided in large quantities and freely used. The dimensions of the wedge are shown in Figure 69.

101. Sandbags.—The standard sandbag is 14 by 26½ inches flat, with an attached tie string 3 inches from the top of the bag. When filled three-fourths full, it weighs from 45 to 75 pounds, depending upon the material and whether it is wet or dry, and fills a space approximately 4¾ by 10 by 19 inches. Other sizes of bags are frequently encountered.

102. Bunk posts.—Bunk posts are 4 by 4 inches and 2 by 4 inches, and are used for supporting the double tier of bunks in shelters. The 4 by 4's should be placed under the caps of the frames, thus providing additional support. In case standard materials are not available, round timber 4 inches in diameter at the small end may be substituted.

103. Standard concrete bursters and beams.—Standard bursters and beams are used in cave shelters to provide a burster layer over entrances and in cut-and-cover shelters to provide bursting and distributing layers. They provide an efficient means of protection only when wired securely together, and should never be used unless so secured. Loops are provided at the corners of the bursters and on top of the beams for this purpose. Details are shown in Figure 69.

104. Use of lumber.—Commercial lumber cut to proper lengths is used for props, bunks, gas curtain frames, battens for holding timbers in place during construction, and for strapping incline and shaft sets together, making bomb recesses, baffle boards, etc. Scrap lumber obtained during cutting should be used in conjunction with wedges for blocking timbers in place.

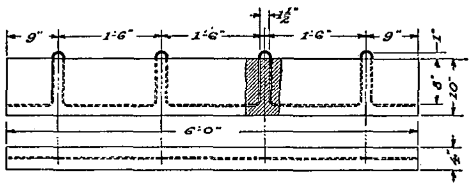
105. Corrugated steel arches.—Arches are fabricated from heavy corrugated steel. (Fig. 70.) They are classified as to name and size as—

a. Two man, for splinter-proof and light shelters.

b. Light elephant, for splinter-proof and light shelters.

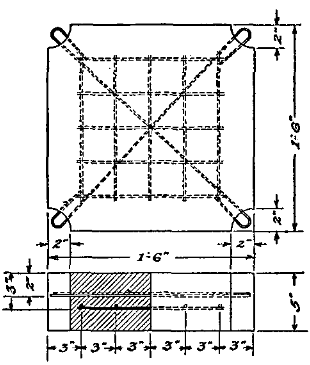
c. Elephant, for light shellproof shelter.

106. Quick-hardening cement.—*a.* For war work when a saving of days is essential, the use of quick-hardening or



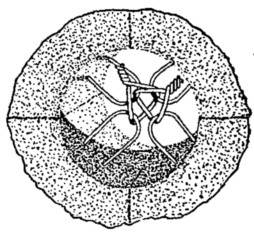
Made in lengths of 6ft. 12ft. and 15ft.
Weight 38# per ft.
For 6'-0" beam 11ft. $\frac{3}{16}$" dia. rod or #6 wire
" 12'-0" " 22 " " " " " " "
" 15'-0" " 28 " " " " " " "

Concrete Beam

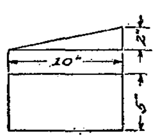


Weight 145 #
19 ft. of $\frac{3}{16}$" dia. rod or #6 wire

Concrete Burster



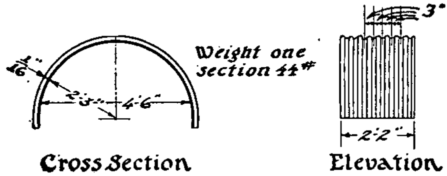
Burster Assembly



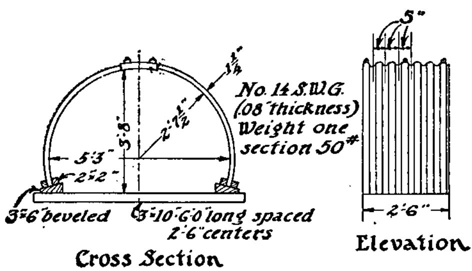
Wedge

FIGURE 69.—Standard materials

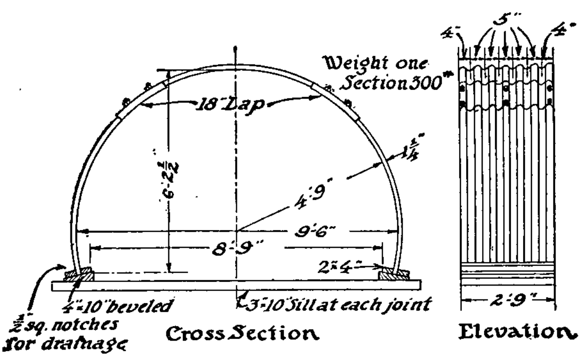
alumina cement permits the construction of fieldworks of concrete which have an effective strength in 24 hours instead of about the same number of days as is the case for Portland



Two Man



Light Elephant



Elephant

FIGURE 70.—Corrugated steel arches

cement. Concrete made with quick-hardening or alumina cement also has a much higher ultimate strength than when Portland cement is used.

b. The following table indicates the relative value of Portland and alumina cements. The data are taken from a series of tests by the United States Bureau of Public Roads, a medium mix being used.

TABLE XVIII.—*Compressive strength of 6 by 12 inch concrete cylinders, pounds per square inch*

Age	1-2-4		1-3-6	
	Lumnite	Portland	Lumnite	Portland
24 hours	4, 960	346	2, 303	----------
7 days	6, 200	1, 276	3, 465	468
28 days	6, 318	2, 867	3, 689	814

NOTE.—The figures, 1-2-4, 1-3-6, indicate proportions by volume of cement, fine aggregate (sand), and coarse aggregate (gravel or broken stone), respectively.

107. Methods of excavation.—*a.* In earth the pick and shovel are used to make the excavation, with the aid of such accessory tools as crowbars and pick mattocks. In advancing an incline or gallery, care should be taken not to open up more ground than is necessary to accommodate the timbering. Methods of rock excavation are not discussed here for the reason that shelter construction in rock is unusual.

b. Removal of the excavated material.—(1) In small headings the excavated material or "spoil" is removed from the working faces by shoveling it into bags which are carried away to the place of disposal. In fairly large headings, wheelbarrows and small tramcars may be used to convey the material away. For large jobs, an electric railway installation may be desirable. In cases where disposition must be made at a considerable distance it is generally advisable to install light tracks and to operate small cars. To avoid noise, however, when close to the enemy, cars should have roller bearings and wheels cushioned with rubber or other sound-killing material. Removal through shafts is ordinarily done by means of buckets and hand-operated windlasses or small power hoists.

(2) On all work in mines or shelters close to the enemy, it is necessary to use what are called "daylight dumps"; that is,

dumps which can be used in the daytime and yet not be observed by the enemy. These dumps are simply temporary storage places for the sandbags packed with spoil. At night men get out on top of the trenches and either dump the sandbags or spill the material from them into shell holes, old mine craters, abandoned trenches, sunken roads, behind hedges, or in any place concealed from the enemy. It is bad practice to build mounds of spoil. All material must be carefully camouflaged from airplane observation. When the spoil is of a contrasting color, it is usually necessary to camouflage it carefully with clay or other suitable material. The engineer officer in charge must carefully supervise all this work and see that the working parties do not leave spoil which should be screened from observation. A careful investigation of an area usually discloses some convenient sunken road, trench, or hedge which can be used to advantage in disposing of spoil.

108. Timbering.—*a.* To prevent caving, all shafts, inclines, galleries, and chambers are timbered. In very firm soil during construction it is sometimes practicable to drive inclines and galleries short distances ahead without lining them; but they should not be allowed to stand in such condition for any length of time. Wooden linings are of two general types—those constructed with cases and those with frames and sheeting.

b. Bracing.—When frames and sheeting are used, frames should be braced transversely and a strong system of diagonal bracing installed. They should be braced longitudinally with sprags both at the top and bottom; one brace at the top tying cap and post and one at the ground tying sill and post. The two ends should be strongly braced diagonally.

c. Bunks.—In the recess type of chamber, bunks are placed in two tiers at right angles to the length of the chamber and are spaced 2 feet on centers. In the gallery type they are placed in two tiers on each side of the chamber and parallel to its length and are 2 feet 3 inches wide. Details are shown in Figures 87 and 88. Wire netting (chicken wire), strengthened by wire stretched across the bunks, can be used to support canvas, shelter halves, or bed sacks.

109. Driving an incline with cases.—*a.* In driving an incline with cases (fig. 85) the dimensions of a common gallery case are first marked at the entrance. In ordinary soil, excavation is started at the bottom, and the sill, with its spreader attached, accurately placed. Then the posts are put in, excavating only enough to set them. A place is excavated for the cap, which is put in position and the remaining earth dug out.

b. The excavation is carried horizontally for the length of two cases when the stepped incline is commenced. The excavation for the sill of each succeeding case is lowered 10 inches, providing for the steps. Cases are put in position as described above, except that headboards and risers are nailed in position to prevent the earth from caving in between successive caps and sills.

c. Attempt should never be made to excavate ahead for several cases to be timbered later. This endangers the lives of those working, and if the face or sides begin to " run " involves an immense amount of labor and leaves a weak entrance.

d. In very loose and caving soil the cap must be put in position first and supported while the grooves for the ground sill and posts are excavated, for which purpose two "crutches" (fig. 85) are used. A crutch consists of an upright piece of timber carrying a crosspiece the length of which is equal to the width of two cases. The upright piece rests upon the ground sill of a case already placed and is raised to proper height by wedges. The part of the crosspiece which projects in advance is made 2 inches higher than the rear part to support the cap somewhat above its final level and allow the posts to be easily inserted. The rear part of the crosspiece is attached to the upright by an iron rod or short chain. When the case is set and adjusted to position, the crutches are taken down by removing the wedges and are replaced under the next cap.

e. Each case should be temporarily tied back to the previous one immediately upon being put in, at top and bottom, by means of a short length of sheeting, to be later replaced by 1 by 6 inch battens.

110. Driving a gallery with cases.—The driving of a gallery with cases is the same operation as described for driving an incline with cases, except that excavation is not stepped and the headboards and risers are omitted.

111. Driving a gallery or chamber with frames and sheeting.—*a. Galleries.*—(1) If driven from the bottom of an incline, the direction of the gallery is marked by scores on the incline cases.

(2) Two gage rods are prepared, giving the extreme height and breadth of the excavation; that is, the height of the frame

plus two thicknesses of top sheeting, and the breadth of the frame plus four thicknesses of side sheeting. The middle of each gage rod is also plainly marked. A gallery frame is set up, carefully located, and fastened in position with battens and braces. The top gallery sheeting is started on top of the cap and driven until held in place by the earth. It is given the proper upward pitch by a scantling laid across the ends of the sheeting and held down by fastening to or under the

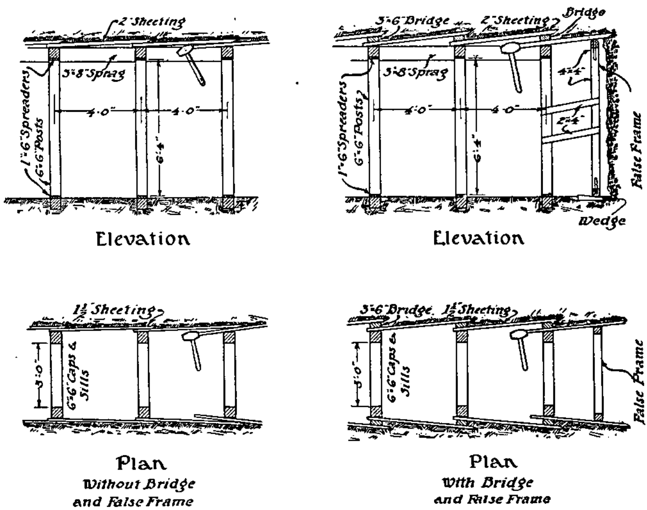


FIGURE 71.—Detail of gallery construction

gallery frame. The side sheeting is started in the same way against the outer faces of the posts and given an outward slant by bracing the outer ends slightly away from the sides of the gallery. Earth is now excavated and the sheeting advanced, keeping the front ends in solid earth to hold them steady.

(3) In this way the gallery is advanced one gallery interval, usually about 3 or 4 feet, when a second frame is placed. Its position is verified by the score marks for direction and grade. It is then secured in place by nailing battens to it and the preceding frame. Wedges are inserted between the frame and the sheeting, and the gallery is continued by the same methods. When the sheeting is advanced only by hard driving, the frames

are slightly inclined to the rear at first and are afterwards driven forward until vertical.

(4) If, while advancing the sheeting, the pressure upon it becomes so great as to spring it, a false frame must be used. (Fig. 71.) This consists of a cap, a sill, and two posts, connected by mortises and tenons. The posts have tenons, and the cap and sill mortises at each end. The cap may be rounded on top, and, for facility in setting up and removing, its mortises are longer than the width of the tenons. The latter are held in place by key wedges when the frame is in position. The false frame is usually made the same height as the common frames and wider by twice the thickness of the sheeting.

(5) In using this frame, the sill is first placed accurately in position at a half interval in advance, the posts are set up, and the cap placed upon them and wedged. The whole frame is then raised about 2 inches by driving wedges under the sill, and is secured by battens. The sheeting now rests directly upon the cap and posts and has enough inclination to clear the next frame by its own thickness, as is required. The next frame is then set up, the wedges driven under the sheeting, and the false frame removed, which is easily done, owing to its construction.

(6) In loose, caving ground, when the pressure on the sheeting is too great for driving, bridges are used (fig. 71) which consist of 3-inch blocks of width and length equal to the cap or post. A frame being in position, a bridge is placed over the cap, supported at each end by wedges the thickness of the sheeting. The bridge is used to keep the rear sheeting off the cap, thereby allowing an opening through which the forward sheeting is driven. As the sheeting is driven forward piece by piece, it is sometimes necessary to pick the material away from the point of each board. In this manner the entire shield of sheeting is advanced until in its final position. The next set is blocked into position and the same process continued. When necessary to hold up the sheeting during the final operation of placing the next set, a false set, as described, or posts and headboard may be put in place, to be removed when the next permanent set is placed. Side sheeting is driven as for roof sheeting under the above ground conditions.

(7) To drive the gallery in very loose soil, a *shield* may be used to prevent the earth in front and above from caving into

the gallery. When the excavation at top of gallery has advanced as far as it can go without causing the caving to extend beyond the top sheeting, a piece of plank a foot wide and in length equal to the width of the gallery is placed directly under the top sheeting and against the face of the excavation and is held in place by braces at its ends secured to the gallery lining. The earth is excavated until a second plank of the shield can be placed in the same way as before under the first one. This is continued until the entire face is covered. The top and side sheeting are then driven forward and the top plank of the shield is removed and replaced in advance, after which each plank is removed and replaced in succession, as previously described.

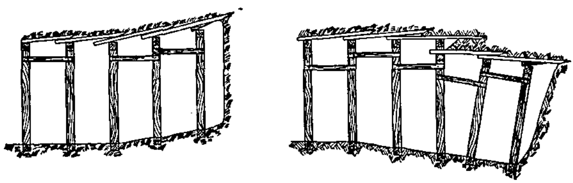


FIGURE 72.—Change of slope

(8) *Change of slope.* (Fig. 72.)

(*a*) To pass from a horizontal to an ascending gallery, it is only necessary to give the top sheeting the proper angle by holding down its back end with a piece of scantling placed across the gallery for that purpose, and to give the side sheeting the proper inclination, cutting trenches in the bottom of the gallery for the lower pieces if necessary.

(*b*) In passing from a horizontal to a descending gallery the roof may be carried forward horizontally and the floor given the desired pitch by increasing the height of the consecutive frames until enough headroom is obtained to allow the top sheeting for the descending gallery to be inserted at the proper height and in the new direction. The frame at this point is made with a cap (upon which the sheeting rests directly), and a second crosspiece below it, serving as a cap for the descending gallery. From this point forward the frames may be set perpendicular to the axis of the gallery.

(*c*) If the descending gallery is very steep and the horizontal pressure of the soil great, it may be necessary to strengthen the posts of the last two or three vertical frames by crosspieces near their upper ends.

(9) *Changing direction horizontally.*

(*a*) In changing direction horizontally with frames and sheeting (fig. 73), if the soil will stand for a distance of one frame interval, or even less, it is only necessary to place one or more frames at an angle until the necessary change is secured. The sheeting on the outside is placed by running the forward end past the frame and then inserting the rear end behind the last bay of sheeting.

(*b*) If the sides require constant support, the outer one may be continued in the old direction until the wedge left is thick enough to permit the sheeting to be driven in the new direction.

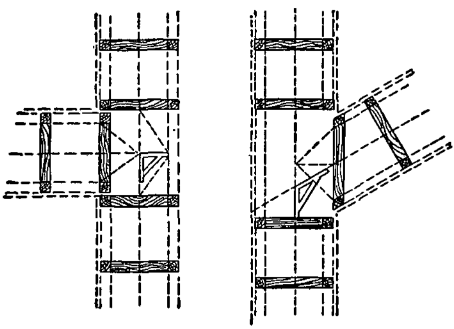


FIGURE 73.—Breaking out returns

A short bay may be put in to reduce the amount of work to be done. Frames with extra long caps and sills are required, and the last one used is given an extra post on the outside to take the sheeting in the new direction.

(*c*) For abrupt changes of direction in large galleries it is customary to drive in the original direction entirely past the turning point and then break out a gallery in the new direction. A gallery starting out from the side of another is called a *return* and is rectangular or oblique, according to the angle made by its axis with that of the original gallery, which is called the *gallery of departure.*

(*d*) That the return may be broken out, the interval between the frames of the gallery of departure at this point must be such as to admit between the posts a frame and the side sheeting of the return. (Fig. 73.) This part of the gallery of departure is called a *landing*, and its floor is made horizontal.

(*e*) If the return is oblique, its width, measured along the gallery of departure, is determined by an oblique section, and may be so great that the strength of the lining of the gallery of departure does not allow the necessary length of landing. In this case a short rectangular return is first broken out from the side of the gallery of departure and the new gallery is broken out from the side of this return. The latter method diminishes the length of the landing when the change of direction is less than 45°.

(*f*) The floor of a return is started at the level of the floor of its landing. In firm soils, which will stand for a short time without support, the first frame may be set up entirely outside the gallery of departure and may be of the same height in clear as this gallery. When the soil is bad, however, and side sheeting is required in the gallery of departure, the first frame of the return must be set up against this sheeting in the interval between the posts of the landing. This makes the clear height of the return at this frame less than that of the gallery of departure by a little more than the thickness of the sheeting. When the first frame of the return is set against the sheeting of the gallery of departure, the sheeting may be pulled or cut away to permit excavation, beginning in either case with the top plank.

(*g*) The first frame of an oblique return should be so set that the sides of the posts are parallel to the side walls of the return, thus giving a good bearing to the side sheeting.

(*h*) In very bad soil the first few frames of a return must be firmly braced by battens connecting them together and by struts across the gallery of departure to resist the backward thrust of the earth. The latter are removed when the return is sufficiently advanced.

b. *Chambers*.—(1) In carrying a wide face of ground as in chamber excavations, care must be taken to prevent falls of earth from the roof, and excavation of the whole face in one piece should not be attempted.

(2) The earth should be excavated on the sides and top, leaving a supporting bench in the center, which should not be excavated until the frame is put in place.

(3) Chambers should not be at intervals of less than 20 feet.

112. Sinking a shaft with cases.—Shafts are usually sunk with cases. A shaft case of the required size is put together and accurately placed on the site of the shaft, the dimensions of which are marked on the ground outside it. The case is then removed and the earth excavated to the depth of the case which is placed in the excavation with its top flush with the surface of the ground. Its position is carefully verified and it is secured in position by packing earth around it. The excavation is then continued for the depth of another case which is put in place as follows:

a. One end piece is placed in position, the two sides are engaged with the end and pushed back into position; a pocket-shaped excavation is made beyond the end of one of the side pieces and running back 3 or 4 inches into the side wall; the remaining end piece is inserted in this cavity far enough to allow its opposite end to slip over the side and fall into place by drawing against the side pieces. The case may be toe-nailed and fastened to the higher one by short battens.

b. The next case is placed in the same way, care being taken not to excavate two consecutive pockets in the same corner. It is well to fill up these pockets by stuffing in from below before placing the next case.

c. Upon reaching the level of the top of the gallery the pieces on the gallery side of the shaft are omitted if the ground is firm, but if it needs support these pieces are put in place and secured by cleats or braces.

113. Sinking a shaft with frames and sheeting.—*a.* In sinking a shaft with frames and sheeting (fig. 74), the size and position having been fixed, the top frame is laid down and staked in place, with scores on the end pieces accurately in the desired position. The excavation of the shaft is then begun, making it enough larger than the top frame to take the sheeting all around. Usually the first interval can be dug without driving the sheeting. It is undercut so that at the level of the second frame it will be larger in each direction than at the top by twice the thickness of the sheeting. Gage rods cut to the length and width of the excavation and plainly marked at the middle points should be provided. The inconvenience of working under the top frame may be avoided by marking the sides carefully and digging the first interval before setting the top frame.

b. When the shaft is deep enough the second frame is put in place and *nailed* together. The top and second frame are connected by nailing to them four battens of proper length (two on each side) (fig. 74), which suspend the second from the top

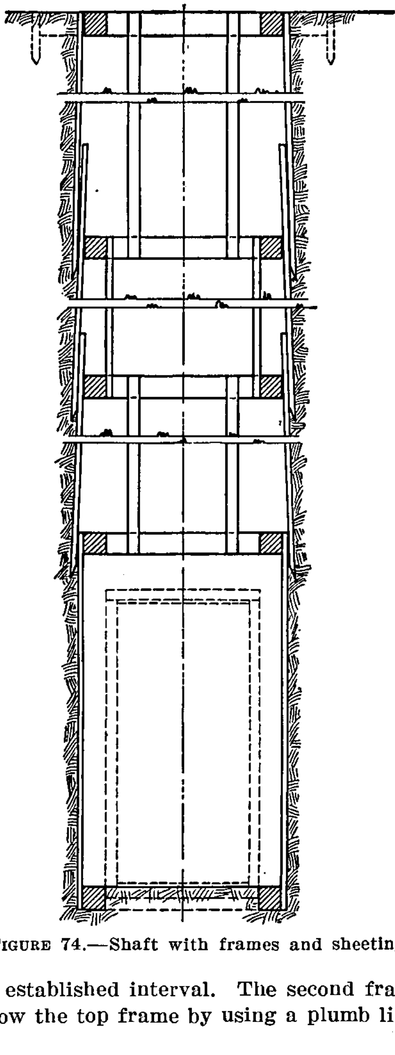


FIGURE 74.—Shaft with frames and sheeting

frame at the established interval. The second frame is placed vertically below the top frame by using a plumb line.

c. The sheeting is inserted outside the top frame, beveled end first, bevel inside, and pushed down until its top is flush with the top frame. The lower end of the sheeting is held out from the lower frame by suitable wedges, and the excavation of the second interval is commenced.

d. In ordinary soil the sides of the shaft now require support. Sheeting is therefore introduced and pushed down as the excavation proceeds, the wedges previously placed being driven down as the sheeting is inserted.

e. If the pressure of the earth becomes great enough to spring the sheeting planks inward, an auxiliary frame is introduced. This is a frame similar to the shaft frames but from 4 to 6 inches larger in outside dimensions. The sheeting rests directly against the outside of this frame, and is thus held out far enough to allow the third frame to be placed and the wedges to be inserted as before. The auxiliary frame is then removed and used in the next interval.

f. Successive frames are placed in the same manner (fig. 74) until the one directly over the gallery is reached. Care is taken to place this frame at exactly the right height, and the shaft is then continued to the required depth. A frame is placed at the bottom with its top at the level of the floor of the gallery and the sheeting is allowed to rest directly against the outside of this frame. When the soil permits it, the sheeting is omitted wholly or in part over the portion of the shaft which is to form the gallery entrance.

g. Precautions.—In sinking shafts, especial care must be taken to make the excavation no larger than is required for placing the lining, since, if a vacant space is left outside the lining, the sides of the shaft may give through its entire height and fall against the lining with a blow, crushing it in. This has often been the cause of fatal accidents in both shafts and galleries.

114. Lines and grades.—*a. Line.*—A string stretched along shallow saw cuts in the centers of caps and sills is the simplest method of maintaining straight lines in timber construction. Plumb bobs hung from nails in the center of the caps are used for lining by eye. Sills should be leveled and posts plumbed while the frame or case is being lined and blocked into place.

b. Grades.—The minimum grade which will insure drainage in galleries and chambers is about 1 foot per 100 feet (1 per cent). Uniform grades are difficult to maintain without a level and a grade board. A convenient size of grade board is made from a straight-edged piece of 1½ by 6 inch lumber from 6 feet to 12 feet long with a small cleat nailed on one end. The cleat is of such thickness that when the board is placed on a surface, with a carpenter's level on top, the desired grade will be obtained when the level bubble is centered.

115. Surface shelters.—From the standpoint of construction, surface shelters fall into the following groups:

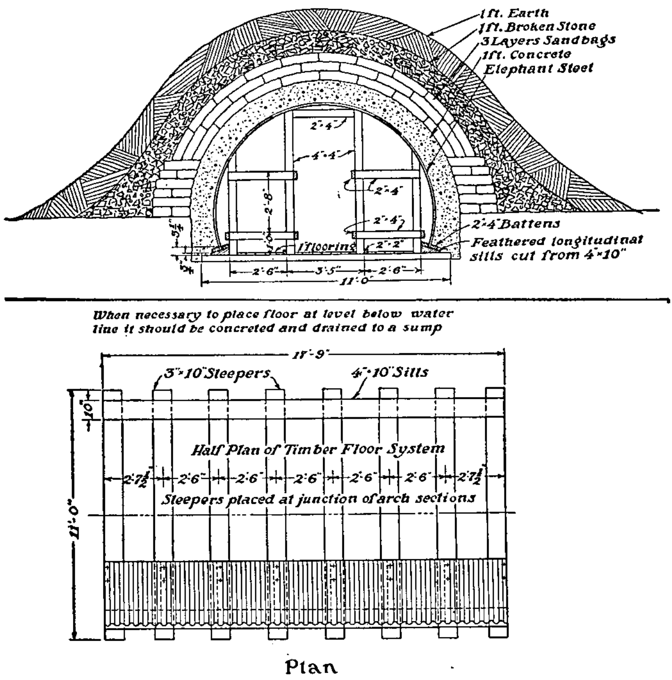


FIGURE 75.—Corrugated steel surface shelter; capacity, 12 men

a. Surface shelters concealed in woods or behind reverse slopes.

b. Shelters constructed by reinforcing buildings in a village.

c. Reinforced concrete shelters above ground.

d. Small light shelters for the protection of ammunition and stores.

116. Surface shelters concealed in woods or behind reverse slopes.—*a.* This form varies from the hasty splinter-proof type to the light shellproof type.

b. The hasty splinter-proof type is usually of an improvised nature, built out of the materials at hand; for example, a shed built with logs and corrugated iron covered with a light layer of earth. No standard form of construction can be specified.

c. A form of light shellproof type, with material list, is shown in Figure 75. It has a capacity of 12 men and protects against 3-inch shells. Standard elephant corrugated steel is used with a covering of 1 foot each of concrete, sandbags, crushed stone, and tamped earth. The ends consist of wood partitions, having doors, and are protected to the same extent by carrying the cover around the ends. The bunks are made in the standard way with some alteration for roof curvature. This type is described as an example, but if the specified materials are not available, other material can be substituted for the cover and the lining may be of timber.

TABLE XIX.—*Corrugated steel surface shelter* (*fig. 75*)

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Corrugated arch section, complete.	Elephant	Each	7	2,100
Post, bunk, one cut	4 by 4 by 13 feet	do	4	275
Do	4 by 4 by 10 feet	do	4	215
Sill, feathered from 4 by 10 inches.	4 by 10 by 6 feet	do	3	240
Sleeper	3 by 10 by 11 feet	do	8	880
Bunk frame, crosswise, 3 cuts.	2 by 4 by 12 feet	do	4	130
Bunk frame, lengthwise, to cut.	do	do	12	385
Batten	do	do	6	190
Sprag, cross, and longitudinal.	do	do	4	130
Nailing strip, post	2 by 2 by 12 feet	do	3	50
End lumber	2 by 6 by 8 feet	do	24	770
Flooring	1 inch	Square foot	150	600
Wedges	Standard	Each	20	30
Wire netting	36 inches wide, 2-inch mesh.	Linear foot	78	20
Wire, bunks	No. 12	do	320	10
Staples	⅞, No. 9	Pound	6	6
Nails	Tenpenny	do	5	5
Do	Twentypenny	do	6	6
Cement (1-2-4 concrete)	In bags	Bag	100	9,800
Crushed stone or gravel		Cubic yard	[1] 40	108,000
Sand		do	8	21,600
Sandbags	Standard	Each	1,200	600
Total				146,042

[1] Includes 15 cubic yards for concrete Remainder may be alternated by brickbats if available.

TABLE XIX.—*Corrugated steel surface shelter* (*fig. 75*)—Continued

Items	Pounds	Tons
Lumber	3, 895	1. 95
Steel	2, 100	1. 05
Cement	9, 800	4. 90
Crushed stone or gravel	108, 000	54. 00
Sand	21, 600	10. 80
Miscellaneous	647	. 32
Total	146, 042	73. 02

117. Shelters constructed by reinforcing buildings in villages.—When protected shelters are constructed inside of buildings they should generally be proof against at least 6-inch shell, because buildings form a favorite target for artillery. Eight feet of artificial cover consisting of dry walls (large slabs of rock, masonry, or concrete), timbers or poles wired together, and undisturbed building walls give this protection. Where possible, the chamber of the shelter should be placed in an excavation below the ground level of the building and the covering material supported on berms, in which case it becomes a cut-and-cover type. Figure 76 shows a room in a building used as a shelter, the cover being placed on the floor above and the floor stringers shored up. This type may be used where conditions do not permit cut-and-cover construction.

118. Reinforced concrete shelters above ground.—Shelters of this type may be used to protect personnel in relatively large numbers provided it is practicable to assemble the material necessary for construction. The design of these shelters follows accepted practice for reinforced design so far as placing reinforcements is concerned. Ordinarily they may be used in connection with emplacements for the protection of the crew on duty at the emplacement and for observation and command posts under proper conditions.

119. The splinter-proof shelter.—*a.* One of the simplest forms of splinter-proof shelter for use in mobile warfare is shown in Figure 77. This type is frequently constructed by the infantry soldier in the advanced lines, and he must be trained in performing the task. His natural tendency is to dig a niche in the forward interior slope of the trench, which is the proper location for the shelter, but the result is an unsupported recess which quickly caves under the effects of shell fire and weather conditions.

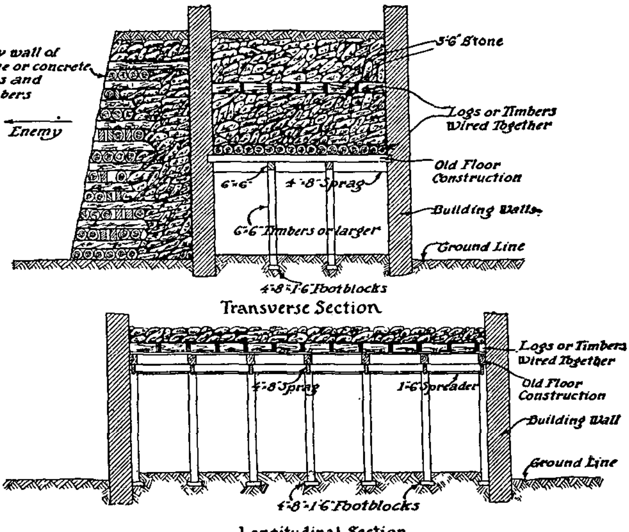


FIGURE 76.—Shelter in reinforced building

b. Construction.—An open excavation is made closely following the dimensions given in Figure 77. The ceiling of the shelter should be at ground level, or slightly below, and the logs rest on berms of virgin earth, which should be at least 18 inches

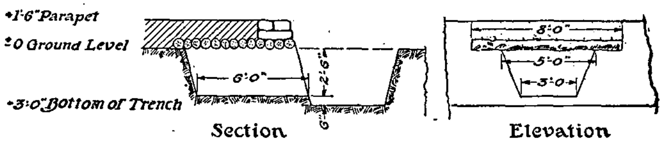


FIGURE 77.—Splinter-proof shelter

wide. Logs should be not less than 6 inches in diameter and firmly wired together. Earth is then back filled and the original appearance of the parapet restored. The shelter may be made waterproof by the use of corrugated iron or tar paper.

TABLE XX.—*Splinter-proof shelter* (*fig.* 77)

MATERIAL LIST

Item	Size	Unit	Quantity	Weight
				Pounds
Logs, roof	6-inch diameter by 8 feet	Each	13	1,000
Wire	No. 12	Linear foot	100	3
Sandbags	Standard	Each	30	15
Total weight				1,018

120. Light shelters.—*a.* Types of light shelter, proof against 3-inch shells, with material list included, are shown in Figures 78 and 79.

b. Construction.—In firm soil, these types can usually be constructed by digging into the face of the trench without cutting all the way to the surface of the ground. In loose soil, it is necessary to make an open excavation and back fill. Both types of shelter must closely fit the excavation, which is accomplished by cutting the excavation accurately to size and by ramming dirt into any space outside the frame. The floor should slope slightly toward the trench to provide drainage, and a baffle board should be placed as indicated in the figure. The burster course is placed by excavating a portion of the parapet, placing the course, and back filling so that the original appearance of the parapet is restored.

121. Light steel arch shelters.—The two lighter types of corrugated steel arch shown in Figure 70 are especially useful in consolidating captured trenches after an attack in trench warfare. Splinter-proof cover can be rapidly obtained by placing several in captured trenches so as to form a tunnel and shoveling earth on their tops and sides. At least 4 feet of cover should be provided.

122. Cut-and-cover shelters.—*a.* Cut-and-cover shelters of the light shell-proof type are grouped into three classes, according to the manner of interior construction.

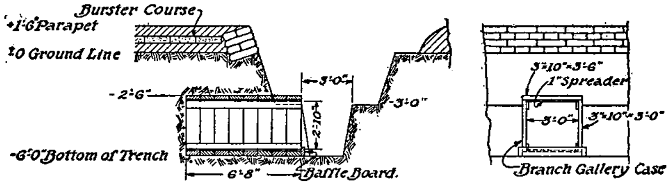
(1) *Timbered shelters* may be constructed by using standard materials sent forward from engineer supply points or of round timbers procured near the site.

(2) *Standard corrugated steel* arches are quickly and easily assembled and are recommended for the interior construction

of cut-and-cover shelters whenever they can be obtained. Corrugated steel sections when bolted together form water-tight arched support.

(3) *Concrete shelters* should be constructed with reinforcement to obtain economy of cement and aggregates. When time, labor, material, and transportation are available, they offer superior facilities from the standpoint of protection, living conditions, and adaptability.

b. Cover.—The type and thickness of cover required for a cut-and-cover shelter depend on the kind of material available and on the location and use to be made of the shelter. Protection is provided as described in paragraphs 90 to 94, inclusive, which give the thickness of cover and arrangement of the successive layers.



Section Elevation

Timber

FIGURE 78.—Light shelters

TABLE XXI.—*Light shelter (fig. 78)*

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Cases, gallery	Branch	Each	8	1,200
Batten	1 by 4 by 14 feet	do	2	35
End lumber	1½ by 6 by 14 feet	do	2	85
Wedges	Standard	do	16	25
Baffle board	2 by 10 by 4 feet	do	1	25
Nails	Twentypenny	Pound	5	5
Bursters	Standard	Each	20	2,900
Wire	No. 12	Linear foot	20	1
Sandbags	Standard	Each	30	15
Total weight				4,291

TABLE XXII.—*Light shelter* (*fig. 79*)

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Floor	3 by 10 by 6 feet	Each	6	360
End	do	do	3	180
Baffle board	2 by 10 by 6 feet	do	1	40
Floor strips	1 by 2 by 12 feet	do	1	8
Corrugated arches	Two man	do	3	132
Nails	Twentypenny	Pound	2	2
Bursters	Standard	Each	20	2, 900
Wire	No. 12	Linear foot	20	1
Sandbags	Standard	Each	30	15
Total weight				3, 638

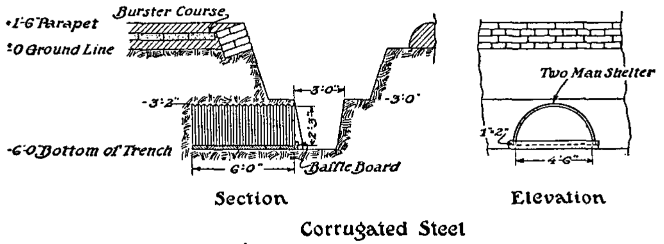
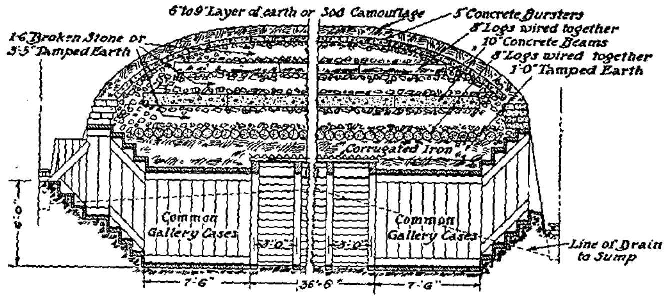


FIGURE 79.—Light shelters

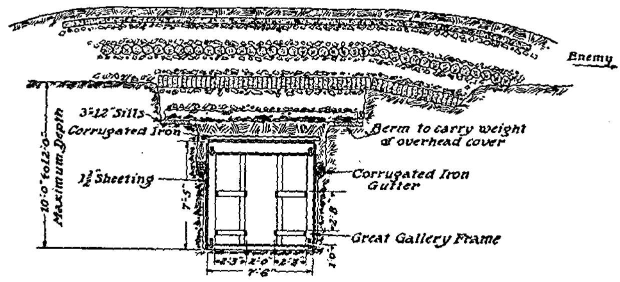
c. Excavation.—The cut to contain the shelter should be limited to a maximum depth of from 10 to 12 feet. If it is necessary to go below this depth, greater economy of labor and material is obtained by the construction of cave shelters. The sides of the cut should be excavated with as little batter as possible, leaving only sufficient clearance for placing the frames and sheeting.

d. Berms.—These must provide for carrying the entire weight of the artificial cover, which must never rest on the interior framework of the shelter.

123. Cut-and-cover timbered shelters.—*a.* A cut-and-cover shelter having an interior lining of timber is illustrated in Figure 80. The capacity of the shelter is 24 men and it protects against 6-inch shell.



Longitudinal Section



Transverse Section

FIGURE 80.—Cut-and-cover timber shelter

TABLE XXIII.—*Cut-and-cover timber shelter (fig. 80)*

MATERIAL LIST

Item	Size	Unit	Quantity[1]	Weight (pounds)
Frames, gallery	Great	Each	13 (2)	4,875
Post bunk	4 by 4 by 6 feet 6 inches	do	14 (2)	485
Sprag, top and bottom, sides.	3 by 8 by 11 feet	do	12 (2)	1,055
Sills, berm	3 by 12 by 12 feet	do	17 (2)	2,450
Baffle board	2 by 12 by 3 feet 6 inches.	do	1	30
Stair stringers	2 by 10 by 10 feet	do	1	65
Stair treads	2 by 10 by 12 feet	do	1	80
Brace, diagonal	2 by 6 by 8 feet	do	1	30
Sheeting, top	2 by 6 by 12 feet	do	50 (8)	2,400
Bunk frame, crosswise, to cut.	2 by 4 by 8 feet	do	7 (1)	145
Bunk frame, lengthwise	2 by 4 by 7 feet	do	48 (8)	895
Sprag, top, center	2 by 4 by 11 feet	do	6 (1)	175

[1] Figures in parentheses show quantities required for unit length of 6 feet.

TABLE XXIII.—*Cut-and-cover timber shelter (fig. 80)*—Continued

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Risers	1½ by 10 by 3 feet 6 inches.	Each	9	160
Headers	do	do	8	140
Sheeting, sides	1½ by 6 by 12 feet	do	100 (15)	3, 600
Sheeting, ends only	1½ by 6 by 10 feet	do	15	450
Stair risers	1 by 10 by 3 feet	do	3	30
Batten	1 by 6 by 10 feet	do	10	200
Revetting boards, to cut	do	do	4	80
Wedges	Standard	do	184 (20)	260
Cases, gallery	Common	do	27	5, 940
Flooring	1 inch	Sq. ft	90 (15)	360
Corrugated iron, galvanized.	No. 20, 8 feet by 24 inches.	Sheet	24 (4)	691
Wire netting	36 inches wide, 2-inch mesh.	Lin. ft	156 (26)	40
Wire, bunks	No. 12	do	480 (80)	12
Staples	⅞, No. 9	Pound	12 (2)	12
Nails	Fortypenny	do	12 (2)	12
Do	Twentypenny	do	20 (4)	20
Do	Tenpenny	do	10 (2)	10
Sandbags	Standard	Each	100	50
Bursters	do	do	750 (88)	108, 750
Wire, binding	No. 12	Lin. ft	3, 500 (400)	105
Beams, concrete	Standard	do	3, 400 (380)	129, 200
Logs	8-inch diameter	do	3, 000 (360)	50, 400
Crushed stone, if used		Cu. yd	300 (20)	810, 000
Total weight				1, 123, 207

WEIGHTS

Item	Pounds	Tons
Lumber	23, 905	11. 95
Concrete beams and bursters	237, 950	118. 97
Logs	50, 400	25. 20
Crushed stone	810, 000	405. 00
Miscellaneous	952	. 48
Total weight	1, 123, 207	561. 60

b. The maximum spacing of frames is 3 feet, but where timber is available the spacing should be at 2 feet centers. The maximum span should not exceed 6 feet 6 inches. Where exceptional strength is more essential than large capacity shorter spans should be used. All frames must be spragged (braced with distance pieces) both at the top and bottom at the sides and at the top in the center. The sprags must be placed to bear both on the posts and on the caps or sills as the case may be.

c. Long boards instead of standard sheeting should be used in sheeting this type. The boards should be given full bearing on the posts, and the joints should be staggered. Nails should be used where possible. With standard sheeting, overlap to the full width of the frame to get full bearing. Corrugated iron is placed on top of the chamber, and side gutters

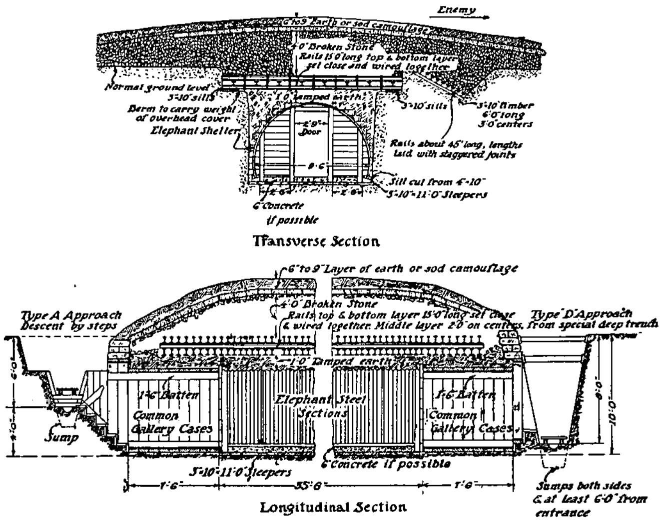


FIGURE 81.—Cut-and-cover corrugated steel shelter

are fastened to the outside as indicated in the figure. These may be of corrugated iron or of wood. They lead to sumps in the trenches as shown by the dotted line.

d. Without proper framing and bracing, the full strength of the timber is not developed and the resistance against explosions is only a fraction of that afforded by the same material properly used.

124. Cut-and-cover corrugated steel shelters.—*a*. A cut-and-cover shelter having an interior lining of corrugated steel is illustrated in Figure 81, with a material list in Table XXIV. The capacity of the shelter is 24 men, and it protects against 6-inch shell. Bunks are not shown in the drawing, but they are covered in the material list in Table XXIV. They are arranged as in the surface shelter. (Fig. 75.)

b. In construction care should be taken that the foundation is firm and that the arches are not spread at the bottom, thus causing a depression at the top of the arch which materially weakens it and forms joints through which water may seep. If a concrete floor is provided, it should be about 6 inches thick.

TABLE XXIV.—*Cut-and-cover corrugated steel shelter (fig. 81)*

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Corrugated arch section, complete.	Elephant	Each	14	4,200
Sill, feathered from 4 by 10 inches.	4 by 10 by 6 feet	do	6	480
Post, bunk, 1 cut	4 by 4 by 13 feet	do	7	485
Do	4 by 4 by 10 feet	do	7	375
Sleeper	3 by 10 by 11 feet	do	15	1,650
Sills for rails	3 by 10 by 12 feet	do	24	2,880
Baffle boards	2 by 12 by 3 feet 6 inches	do	1	30
Stair stringers	2 by 10 by 10 feet	do	1	65
Stair treads	2 by 10 by 6 feet	do	2	80
Diagonal braces	2 by 6 by 8 feet	do	1	30
End lumber	do	do	24	770
Batten	2 by 4 by 12 feet	do	12	385
Bunk frame, crosswise, 3 cuts.	do	do	7	225
Bunk frame, lengthwise to cut.	do	do	24	770
Sprag, cross and longitudinal.	do	do	8	255
Nailing strip, post	2 by 2 by 12 feet	do	6	95
Stair risers	1 by 10 by 3 feet	do	3	30
Batten	1 by 6 by 10 feet	do	7	140
Reveting boards	do	do	4	80
Cases gallery	Common	do	21	4,620
Wedges	Standard	do	124	175
Nails	Twentypenny	Pound	15	15
Do	Tenpenny	do	15	15
Staples, bunks	7/8-inch, No. 9	do	12	12
Wire netting, bunks	36 inches wide, 2-inch mesh.	Lin. ft.	156	40
Wire, bunks	No. 12	do	640	20
Wire, binding	do	do	4,000	120
Bursters	Standard	Each	750	108,750
Rails, railroad	15 feet at 75 pounds (yd.)	do	172	64,500
Rails, railroad, varied lengths.	At 75 pounds (yd.)	Lin. ft.	880	22,000
Sandbags	Standard	Each	100	50
Cement, for floor if used		Bag	36	3,528
Sand, for floor if used		Cu. yd.	3	8,100
Crushed stone, for floor if used.		do	7	18,900
Crushed stone, or gravel, fill		do	250	675,000
Total weight				918,870

TABLE XXIV.—*Cut-and-cover corrugated steel shelter* (*fig. 81*)—Continued

WEIGHTS

Item	Pounds	Tons
Lumber	13, 620	6. 81
Rails	86, 500	43. 25
Cement	3, 528	1. 76
Sand	8, 100	4. 05
Crushed stone or gravel	693, 900	346. 95
Steel arches	4, 200	2. 10
Bursters	108, 750	54. 38
Miscellaneous	272	. 14
Total weight	918, 870	459. 44

125. Cut-and-cover reinforced concrete shelter.—*a.* Most reinforced concrete shelters are of the cut-and-cover type. The use of large concrete shelters is generally limited to reserve positions in stabilized situations.

b. Figure 82 illustrates a brigade command post of reinforced concrete. It is not given as a standard but as an example of the method of reinforcement. The grillage of bars on 6-inch centers is usually of ⅜-inch rods. Reinforcement spaced at greater distance is of larger size, up to three-fourths inch. On the inside of the chamber a layer of expanded metal, or similar fabric, is placed for added protection against spalls. It is better to have a large number of rods of small diameter than a small number of large diameter. The weight of reinforcement runs about 5 pounds per cubic foot of concrete.

c. The structure may be built without any cover, but cover with a burster course should be added, if possible, to localize the action of a bursting shell. The figure shows cover with a course of bursters.

d. The approximate quantities for the command post illustrated are shown in the material list.

TABLE XXV.—*Brigade command post* (*fig. 82*)

MATERIAL LIST

Item	Unit	Quantity	Weight (tons)
Cement, 1 : 2 : 4 concrete (450 cubic yards concrete).	Bags (1 cubic foot)	2, 700	135
Sand	Cubic yard	200	270
Crushed stone	do	400	540
Reinforcing metal	Pounds	40, 000	20
Bursters	Each	1, 600	116
Lumber for forms	Foot b. m	2, 400	5
Total weight			1, 086

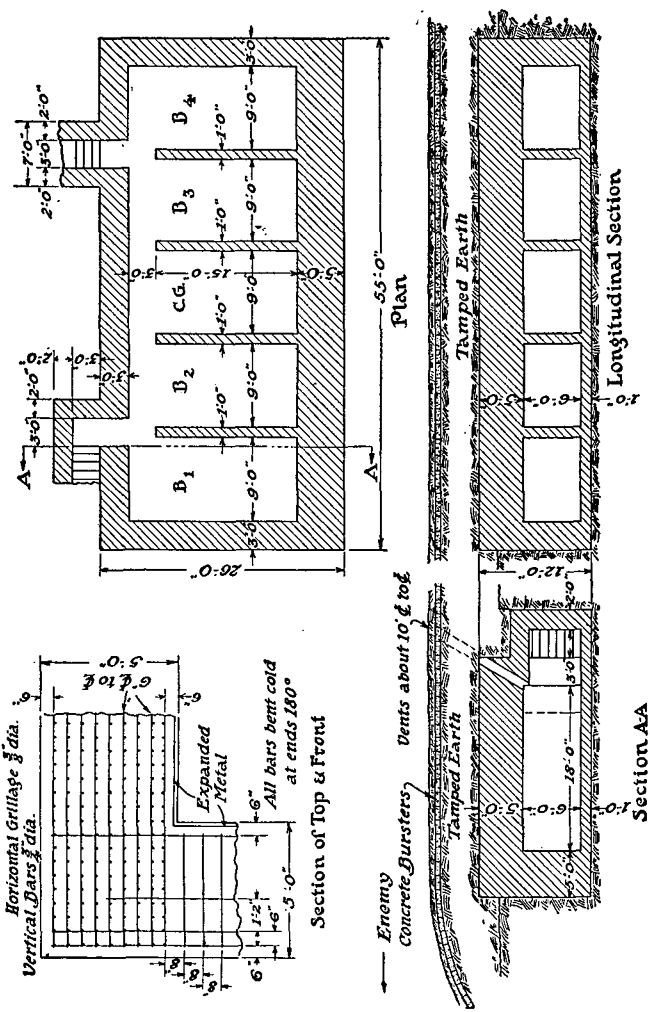


FIGURE 82.—Brigade command post

126. Cave shelters.—*a.* The standardization and simplification of cave shelter construction facilitate the use of the standard materials already described.

b. There are two standard types of cave shelters—the *recess* type and the *gallery* type. Variations may occur in shelters for special purposes, as in the case of first-aid shelters which require wider entrances and passages, and gentler slopes for handling litters.

(1) The *recess type*, 8 feet inside width, employs the chamber gallery. The passage in the shelter is at the side, thus leaving the bunk space in a recess with the bunks perpendicular to the passage. This type is recommended for use where conditions do not impose another selection. It is favored by economy in space, labor, and material per occupant; there are 70 cubic feet of excavation per linear foot and per occupant, and 113 feet board measure of lumber per man are required.

(2) The *gallery type*, 6 feet 6 inches inside width, employs the great gallery. In this type the connecting passage or entrance is central with the axis of the room, thus permitting two lines of bunks parallel with the long axis of the chamber, one on each side of the passage. There are 62 cubic feet of excavation per linear foot and 93 cubic feet per occupant, and 185 feet board measure of lumber per occupant are required. It is simpler to construct than the recess shelter, but this advantage is usually outweighed by the economy of the recess type in excavation and materials.

c. In the construction of shelters, the room or chamber proper, the connecting passages, the entrances which may be by incline or not as the conditions require, and the approach to the entrances are to be considered. Layouts for several requirements as to use of cave shelters are given in Figures 86 to 92.

d. In addition to the classification of types given above, shelters may fall in any of the following classes:

(1) Infantry cave shelters (personnel). (Figs. 86, 87, and 88.)

(2) Command posts. (Fig. 89.)

(3) Artillery cave shelters. (Figs. 90 and 91.)

(4) First-aid cave shelters. (Fig. 92.)

e. In connection with the approach or connecting galleries between chambers, the details of gallery construction with frames and sheeting with standard material are shown in Figures 71, 72, and 73.

127. Plans and layout for cave shelters.—*a. Plans.*—Before starting work location sketches showing over-all dimensions are necessary in order that the proper material may be ordered or prepared.

b. Layout.—(1) The work is simplified if the shelter is so placed that all entrances are perpendicular to the same base line. The chamber should be perpendicular to the probable direction of fire, for the reason that the probable error of artillery fire in deflection is less than the probable error in range.

(2) Lay a base line parallel to the long axis of the chamber and so mark this line that it can be easily relaid should it be destroyed.

(3) Mark the center lines of the entrances on this base line; and from each side of the mark, at a distance equal to one-half the outside width of the entrance, erect perpendicular lines to the points where the first frames are to be placed. The perpendiculars to the two ends of a frame must be of equal length so that the first frames will be set parallel to the base line. *It is very important that these first frames be accurately set.*

(4) The horizontal distance of each frame from the base line and the difference in elevation between the various frames must be determined. This work is usually done with a carpenter's level and square, and difficulty will be experienced in checking accurately.

(5) The axis of the incline must be carried in a plane perpendicular to the base line, which is usually accomplished by sighting along the sides of the incline.

128. Entrances.—*a. Approach to entrance.*—(1) The term "approach to entrance" is given to that portion of the ground in front of the entrance which must be excavated in order to provide the necessary headroom without sacrificing overhead cover. The approach is usually necessary whether entrance is gained from a trench or a reverse slope.

(2) To simplify construction one standard type of approach to entrance has been adopted. (See figs. 83 and 85.)

(3) It is a direct descent from a standard trench by steps leading downward in the direction of the entrance. If desired, the sides of the approach may be flared. It is designed for use in a standard fire trench but with slight modification may be used in any form of special trench without fire step.

(4) *Approaches from reverse slope.*—Except in cases where entry is made in a nearly vertical bluff or the face of a quarry an approach is necessary to reach the first timbered section of an entrance on a reverse slope. It usually consists of a

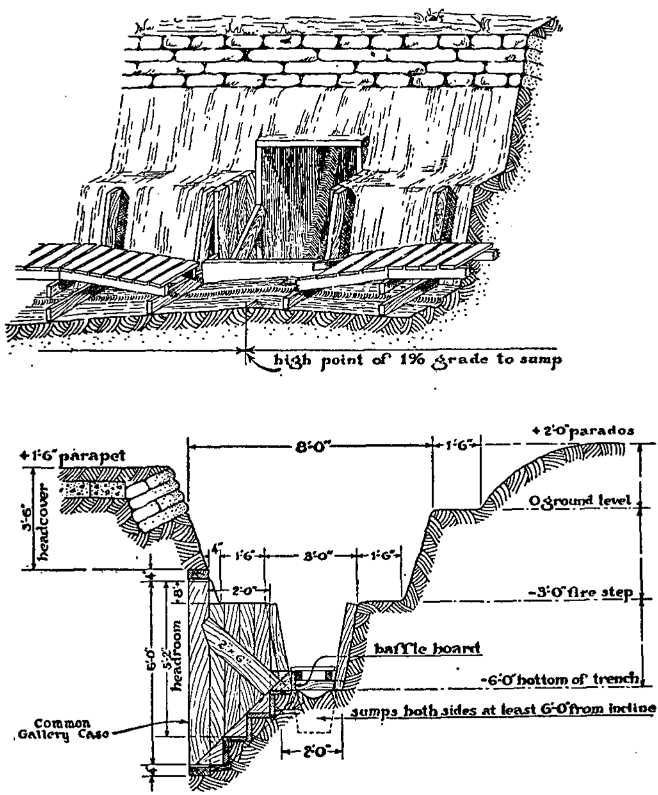


FIGURE 83.—Approach to entrance

narrow trench driven forward on a slight upgrade to facilitate drainage until sufficient headcover is secured. It will probably need revetment near the entrance, and being a conspicuous feature on an airplane photograph must be carefully camouflaged both during construction and after completion.

TABLE XXVI.—*Approach to entrance of cave shelter (fig. 83)*

MATERIAL LIST

Item	Size	Unit	Quantity	Weight (pounds)
Gallery case [1]	Common	Each	1	220
Diagonal braces, to cut	2 by 6 inches by 8 feet	do	1	32
Baffle board	2 by 12 by 3 feet 6 inches	do	1	28
Revetting boards, to cut	1 by 6 by 10 feet	do	4	80
Stair stringers, to cut	2 by 10 by 10 feet	do	1	66
Stair treads, to cut	2 by 10 by 6 feet	do	2	80
Stair risers	1 by 10 by 3 feet	do	3	30
Concrete bursters	Standard	do	42	6,090
Sandbags	do	do	30	15
Nails	Twentypenny	Pound	3	3
Wire, bursters	No. 12	Linear foot	40	2
Total weight				6,646

[1] Cut posts to 6 feet 2 inches long.

b. Protection.—(1) Entrances should be concealed from enemy observation and protected from destructive shell fire. Usually they open to the rear (out of the front slope of a trench), occasionally to a flank, but *never* to the front. They should be so far apart that more than one can not be blocked by a single shell burst, usually 50 feet and never less than 40 feet. There should be at least one traverse or an angle or bend in the trench between them, and they should be at least 5 feet from such traverse.

(2) There should be at least 3 feet initial head cover over the top of the first frame of the entrance proper; and a burster course, from 5 to 12 inches thick, composed of rock, broken stone, or concrete slabs should be placed above the entrance, not more than one foot from the surface. No attempt should be made to strengthen the head of the incline by logs, rails, I-beams, concrete arches, extra heavy timbers, or complicated bracing. The amount of protection gained in this way would be very little more than that of a single burster course, and it would be much more apt to cause a serious block in the entrance if hit, because of the difficulty of clearing away broken logs, twisted rails, etc.

c. Concealment.—The best protection for entrances to cave shelters is concealment from direct observation and from discovery by aerial photography. (See chapter 1.) To avoid direct observation, entrances should be located on reverse slopes, in old quarries, sunken roads, etc. To avoid detection by airplane photography, they should be located in trenches used for other purposes. They should cause no visible break in the parapet, nor otherwise modify the appearance of the trench. Rectangular notches in, or projections from, the firing crests of trenches are especially conspicuous and easily distinguished on airplane photographs. Locating shelters in woods protects them from both direct and airplane obervation.

d. Grenade protection.—No form of defense against grenades which would tend to obstruct the entrance to a cave shelter or delay rapid exit can be permitted. The only protection allowable is a grenade or bomb pit at the bottom of the dugout, constructed by lining a shaft in prolongation of the inclined shaft to a depth of 6 feet below the gallery level. (See fig. 86.) This is constructed after the shelter is completed and may be used also as a sump, but must be kept clear of débris. Grenade pits are constructed only in shelters in forward areas where raids are likely to occur.

e. Exclusion of rain and trench water.—(1) *Rain water* may be excluded by erecting some form of weatherproof shelter over the entrance.

(2) *Trench water* may be excluded by leaving a dam of unexcavated ground between the trench and the entrance; by using baffle boards for the same purpose; and by sumps, constructed not closer than 6 feet from the entrance. (See pars. 139, 140, and 141.)

129. Gas proofing.—*a.* Due to their low level, protected shelters are particularly subject to gas concentration, and in all cases protection must be provided by means of curtains in the entrances. During extended gas attacks, men must be enabled to work and rest inside the shelter with their gas masks off. This is most important in shelters where men are placed, pending evacuation, who are so wounded that they can not wear a gas mask, in shelters used for medical dressing stations, telephone central and signal stations, observation posts, headquarters, and other activities whose efficiency would be considerably reduced by wearing the gas mask.

b. Adjustable curtains made from blankets and supported on a light, sloping framework are the most effective means of excluding gas from shelters. They must be made at the shelter site and built to fit each shelter.

c. Gas curtains *must* be—

(1) Impervious to gas.

(2) Of the simplest possible construction.

(3) Such as to permit of rapid exit in case of a raid.

(4) Readily rolled up and put out of the way when not in use.

(5) So arranged as to drop in place instantly.

d. Curtain frames should be nailed securely to the sides and top of the entrance timbers, close timbered for this purpose. It is sometimes necessary to place curtain frames on the steps, but they should be placed in horizontal entrances or horizontal approaches to inclines whenever possible. The curtain frame for stairways (fig. 84) is similar to that used for horizontal entrances.

e. The curtain proper is made from an Army blanket, chemically treated or soaked with water to make it impervious to gas. Suitable blankets for dugout curtains are carried in stock by division gas officers and may be obtained from them on requisition. Front, rear, and side views are shown in Figure 84. The curtain is fastened to the frame at the top by a cleat. Three inches of blanket material are left projecting above the top of this cleat to be later fastened tightly to the underside of the cap. The 1 inch by 2 inch strip at the bottom of the blanket must be of perfectly straight material, and when it becomes warped it should be immediately replaced. When used in an incline, this cleat is allowed to rest on the floor of the steps and the curtain should clear the side lagging by one-half inch. Judgment should be used in cutting the blanket to the proper size in an opening. Weights made from nuts, washers, scraps of iron, bullets, etc., are fastened along the side edges of the curtain. Gas curtains should clear the side lagging by one-half inch and the floor by 1½ inches when placed in horizontal entrance approach. When not in use, the blanket is rolled up and placed on the shelf at the top of the frame.

f. The flooring or steps in front of a gas curtain should be kept clear of all mud or refuse. Curtains and blanket-covered frames should be kept moist at all times. They should be sprayed daily with water or with gas-proofing solutions which should always be kept on hand. A pail or other container, filled with fresh chloride of lime, should be kept on hand at all times in gas-proof dugouts. During gas attacks,

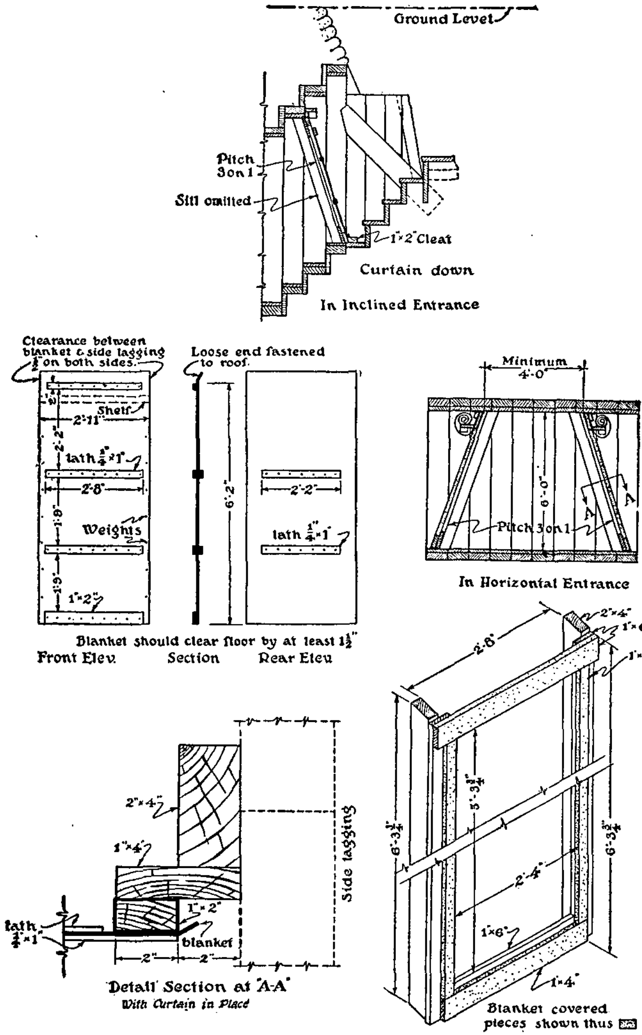


FIGURE 84.—Gas curtain details

or when men have been exposed to gassed terrain, the chloride of lime container should be opened and placed in the air lock between the curtains, for use of all personnel entering the dugout, to destroy mustard gas on the feet or hands. Mustard gas, or similar agent, carried into a dugout soon converts the dugout into a gas trap.

TABLE XXVII.—*Gas curtain for protected shelters (fig. 84)*

MATERIAL LIST

Item	Size	Unit	Quantity
Curtain:			
Blanket	6 by 7 feet	Each	1
Tacks		Package	2
Nails	Tenpenny	Pound	2
Small weights		Each	16
Laths	½ by 1 by 2 feet 8 inches	do	2
Do	1½ by 1 by 2 feet 2 inches	do	2
Bottom strip	1 by 2 by 2 feet 8 inches	do	1
Top cleat	1 by 2 by 2 feet 11 inches	do	1
Frame:			
Frame pieces, front	2 by 4 by 16 feet	do	1
Sash	1 by 4 by 16 feet	do	1
Molding	1 by 2 by 16 feet	do	1
Top and shelf	1 by 6 by 8 feet	do	1
Furring	1 by 2 by 12 feet	do	2
Nails	Tenpenny	Pound	1
Do	Twentypenny	do	2

g. Number and position of curtains.—There should be two gas curtains in every entrance, in order to make a gas trap or space between the two and permit of entry and exit during attack without allowing an appreciable amount of the gas to get into the dugout. The curtain frame should be set on a slope of 3 on 1. Whenever possible, curtain frames should slope in opposite directions with curtain on the outside. (See fig. 84.) The space between the two blankets should be as great as possible in order to secure the maximum dilution of the gas which will inevitably get in. In first-aid stations curtains are placed at least 8 feet apart or at top and bottom of the incline. In short horizontal entrances the curtains are necessarily closer to one another, but the space should be as great as possible and never less than 4 feet at the top.

h. Other openings.—Curtains may be made for windows in the same manner as for entrances, except that only one curtain need be installed. Holes made for periscopes and for ventilation purposes should have blanket-covered plugs hanging near-by to stop up the openings in case of a gas attack. Old clothes may also be used. Any openings behind entrance timbers should be filled with clay, old clothes, or sandbags. All crevices around the curtain frame in either the frame or entrance timbers should be calked with pieces of blanket. Unless this is done the curtains are useless. If a dugout is not practically gas-tight, all pretense of protection should be removed.

i. Use of the collective protector.—(1) Gas-proof dugouts protected with curtains only are tenable for a very few hours, and then only on the condition that no one leaves or enters the dugout during the time the gas concentration is around the entrance. Unless means are provided for introducing fresh air to the dugout, it becomes a gas trap instead of a protection.

(2) In order to make a gas-proof dugout tenable for a period of several hours it is necessary to build up a slight positive air pressure within the dugout; first, to prevent seepages of gas through cracks that can not be closed, and second, to prevent gas being brought in by a rush of air when personnel enter or leave the dugout.

(3) This positive pressure may be secured by means of an air filter which introduces filtered air into the dugout on the principle of the gas mask and provides a current of air passing from the inside of the dugout to the outside through the minute openings which might otherwise allow the entrance of gas from the outside.

(4) The dugout air filter, referred to above, consists of a case containing the purifying units (canister), a tube connected with the outside air, and a hand-driven air pump similar to that on a blacksmith's forge. The pump is operated by personnel in the dugout as necessary, and at least 50 per cent of the time when a concentration of gas is around the outside of the dugout.

130. Inclined entrances.—*a.* In order to standardize construction, one type of incline has been adopted, using standard gallery cases placed vertically. Details are given in Figure 85.

b. The normal size of case is the common gallery type, but in the construction of first-aid shelters a larger size should be used.

c. This type of entrance is also known as the stepped incline and has been selected on account of the ease with which the timbers may be set by unskilled labor. Standard cases are used except at the top, where the posts are sawed to a length of 6 feet 2 inches. The headroom is 5 feet 2 inches.

d. The estimate of cases required for a 45° incline for any depth equals the vertical depth in inches between landings divided by 10, plus 1. The estimate of cases for a 31° incline suitable for a first-aid shelter entrance equals twice the differ-

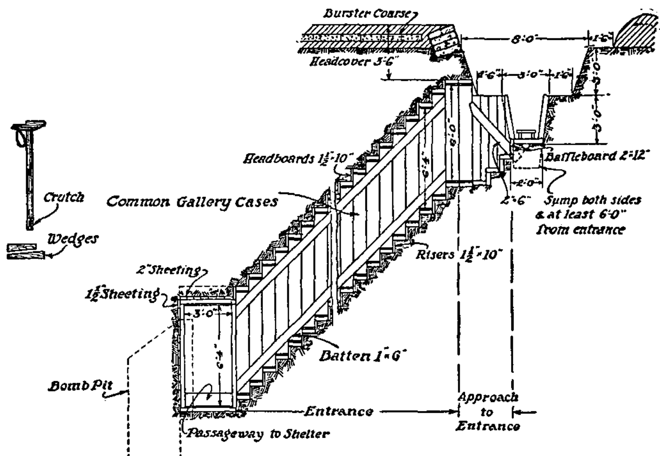


FIGURE 85.—Inclined entrance

ence in feet in elevation between landings. This slope provides for a stairway of 6-inch risers and 10-inch treads.

131. Emergency exit.—*a.* An emergency exit should be added as soon after the completion of the shelter as possible. It may consist of an incline or a vertical shaft equipped with a ladder.

b. It should emerge at some point such as a shell hole, where it is secure from observation and detection by enemy troops actually on the ground. Its purpose is to prevent the trapping of troops in the shelter and to permit launching a counterattack by the occupants.

132. Infantry cave shelters.—*a.* An example of a layout for infantry cave shelters of the recess type is shown by Figure 86 with a material list in Table XXVIII. The capacity of the shelter is 30 men in double-tier bunks. Inclines having a depth of 25 feet between landings and approaches are covered. It is desirable to extend the weight columns in the requisition, to assist the engineer supply officer in providing for transportation.

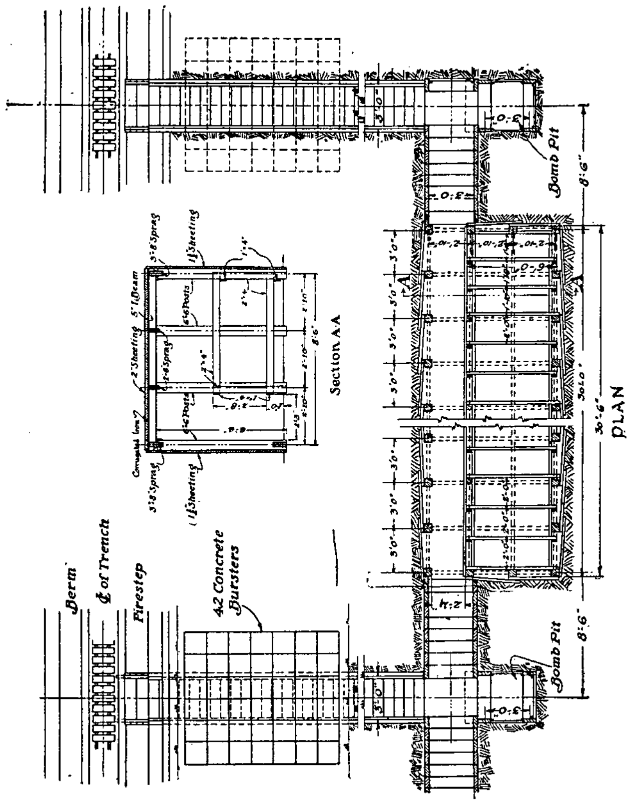


FIGURE 86.—Infantry cave shelter (recess type)

b. An example of a gallery type infantry cave shelter, with material list in Table XXIX, is shown in Figure 87. Materials for inclines and approaches are not included. The capacity of the shelter is 24 men in double-tier bunks. Estimates for any arrangement of connecting passages and entrances may be made by using the proper combinations.

c. Standard arrangements of infantry cave shelters with connecting passages, inclines, and entrances are shown in Figure 88.

TABLE XXVIII.—*Infantry cave shelter, recess type (fig. 86)*

Material list

CHAMBER

Item	Size	Unit	Quantity [1]	Weight (pounds)
Frame, I-beam	Chamber	Each	11 (2)	2,750
Posts, end frames only	6 by 6 by 6 feet 6 inches	do	4	310
Post, bunk	4 by 4 by 6 feet 6 inches	do	4 (1)	140
Sprag, top and bottom, sides.	3 by 8 by 6 feet	do	20 (4)	960
Sheeting, top, 4 inches to 10 inches wide.	2 by 6 by 5 feet	do	180 (36)	3,600
Sprag, top, center	2 by 6 by 6 feet	do	10 (2)	240
Bunk frame, lengthwise.	2 by 4 by 6 feet	do	32 (6)	515
Bunk frame, crosswise	1 by 4 by 6 feet	do	10 (2)	80
Post, bunk	2 by 4 by 3 feet 8 inches	do	20 (4)	195
Sheeting, side, 4 to 10 inches wide.	½ by 6 by 5 feet	do	280 (56)	4,200
Sheeting, ends only	1½ by 6 by 5 feet	do	56	840
Battens	1 by 6 by 12 feet	do	5 (1)	120
Bunk frame	1 by 4 by 7 feet	do	10 (2)	95
Wedges	Standard	do	110 (20)	155
Flooring, if used	1-inch	Square foot	100 (20)	400
Corrugated iron, galvanized.	9 feet by 24 inches, No. 20.	Sheets	20 (4)	640
Wire netting, bunks	72 inches wide, 2-inch mesh.	Linear foot	65 (13)	30
Wire, bunks (8 crosswise).	No. 12	do	750 (150)	25
Staples, bunks	⅞-inch, No. 9	Pound	15 (3)	15
Nails	Tenpenny	do	1.25 (.25)	2
Do	Twentypenny	do	20 (4)	20
Total weight				15,332

PASSAGES AND BOMB PITS

Item	Size	Unit	Quantity	Weight (pounds)
Gallery cases	Common	Each	28	6,160
Battens	1 by 6 by 10 feet	do	8	160
Wedges	Standard	do	112	160
Sheeting, top, bomb pit.	2 by 6 by 5 feet	do	14	280
Sheeting, side, bomb pit.	1½ by 6 by 5 feet	do	48	720
Furring strips, bomb pit.	2 by 2 by 6 feet	do	12	95
Nails	Tenpenny	Pound	8	8
Total weight				7,583

[1] Figures in parentheses show quantities required for unit length of 6 feet.

TABLE XXVIII.—*Infantry cave shelter, recess type (fig. 86)*—Continued

TWO INCLINES (25 FEET BETWEEN LANDINGS)

Item	Size	Unit	Quantity	Weight (pounds)
Cases, gallery	Common	Each	62	13,640
Battens	1 by 6 by 10 feet	do	28	560
Wedges	Standard	do	248	345
Headers and risers	1½ by 10 by 3 feet 6 inches.	do	122	2,135
Nails	Tenpenny	Pound	10	10
Total weight				16,690

TWO APPROACHES

Cases, gallery	Common	Each	2	440
Diagonal braces, to cut.	2 by 6 by 8 feet	do	2	65
Baffle board	2 by 12 by 3 feet 6 inches	do	2	55
Revetting boards	1 by 6 by 10 feet	do	8	160
Stair stringers	2 by 10 by 10 feet	do	2	130
Stair treads	2 by 10 by 6 feet	do	4	160
Stair risers	1 by 10 by 3 feet	do	6	60
Wedges	Standard	do	8	10
Concrete bursters	do	do	84	12,180
Sandbags	do	do	60	30
Nails	Twentypenny	Pound	10	10
Wire, bursters	No. 12	Linear foot	80	4
				13,304

MATERIAL LIST CONSOLIDATED

Item	Unit	Quantity[1]	Weight (pounds)
Gallery frames, I beams, chamber size	Each	11 (2)	2,750
Gallery cases, common size	do	92	20,240
6 by 6 by 6 feet 6 inches	do	4	310
4 by 4 by 6 feet 6 inches	do	4 (1)	140
3 by 8 by 6 feet	do	20 (4)	960
2 by 12 by 3 feet 6 inches	do	2	55
2 by 10 by 10 feet	do	2	130
2 by 10 by 6 feet	do	4	160
2 by 6 by 8 feet	do	2	65
2 by 6 by 6 feet	do	10 (2)	240
2 by 6 by 5 feet (or equivalent 4 to 10 inches wide).	do	194 (36)	3,880
2 by 4 by 6 feet	do	32 (6)	515
2 by 4 by 3 feet 8 inches	do	20 (4)	195
2 by 2 by 6 feet	do	12	95
1½ by 10 by 3 feet 6 inches	do	122	2,135
1½ by 6 by 5 feet (or equivalent 4 to 10 inches wide).	do	384 (56)	5,760

[1] Figures in parentheses show quantities required for unit length of 6 feet.

TABLE XXVIII.—*Infantry cave shelter, recess type (fig. 86)*—Continued

MATERIAL LIST—CONSOLIDATED—Continued

Item	Unit	Quantity [1]	Weight (pounds)
1 by 10 by 3 feet	Each	6	60
1 by 6 by 12 feet	do	5 (1)	120
1 by 6 by 10 feet	do	44	880
1 by 4 by 7 feet	do	10 (2)	95
1 by 4 by 6 feet	do	10 (2)	80
Wedges, standard	do	478 (20)	670
1-inch flooring	Square foot	100 (20)	400
Corrugated iron, galvanized, 9 feet by 24 inches, No. 20.	Sheets	20 (4)	640
Wire netting, bunks, 72 inches wide, 2-inch mesh.	Linear foot	65 (13)	30
Wire, bunks, No. 12	do	750(150)	25
Wire, binding, No. 12	do	80	4
Staples, ⅞ inch, No. 9	Pound	15 (3)	15
Nails, tenpenny	do	20(.25)	20
Nails, twentypenny	do	30 (4)	30
Concrete bursters, standard	Each	84	12,180
Sandbags, standard	do	60	30
Total weight			52,909

WEIGHTS

Item	Pounds	Tons
I-beams and shoes (chamber frames)	1,025	0.51
Lumber	38,910	19.45
Concrete bursters	12,180	6.09
Miscellaneous	794	.40
Total	52,909	26.45

TABLE XXIX.—*Infantry cave shelter, gallery type (fig. 87)*

MATERIAL LIST

Item	Size	Unit	Quantity [1]	Weight (pounds)
Frames, gallery	Great	Each	13 (2)	4,875
Post, bunk	4 by 4 by 6 feet 6 inches.	do	14 (2)	485
Sprag, top and bottom, sides	3 by 8 by 6 feet	do	24 (4)	1,150
Sheeting, top, 4 to 10 inches wide.	2 by 6 by 5 feet	do	180 (30)	3,600
Bunk frame, crosswise, to cut.	2 by 4 by 8 feet	do	7 (1)	150
Bunk frame, lengthwise	2 by 4 by 7 feet	do	48 (8)	895

[1] Figures in parentheses show quantities required for unit length of 6 feet.

TABLE XXIX.—*Infantry cave shelter, gallery type (fig. 87)*—Continued

MATERIAL LIST—Continued

Item	Size	Unit	Quantity[1]	Weight (pounds)
Sprag, top center	2 by 4 by 6 feet	Each	48 (8)	895
Sprag, top center	2 by 4 by 6 feet	do	12 (2)	190
Sheeting, side, 4 to 10 inches wide.	1½ by 6 by 5 feet	do	360 (60)	5,400
Sheeting, ends only, 4 to 10 inches wide.	do	do	30	450
Wedges	Standard	do	130 (20)	180
Flooring	1 inch	Square foot	90 (15)	360
Corrugated iron, galvanized	8 feet by 24 inches, No. 20.	Sheet	24 (4)	696
Wire netting	36 inches wide, 2-inch mesh.	Linear foot	156 (26)	40
Wire, bunk	No. 12	do	480 (80)	12
Staples	⅞ inch, No. 9	Pound	12 (2)	12
Nails	Fortypenny	do	12 (2)	12
Total				18,507

[1] Figures in parentheses show quantities required for unit length of 6 feet.

WEIGHTS

Item	Pounds	Tons
Lumber	17,735	8.86
Miscellaneous	772	.39
Total	18,507	9.25

133. Command posts.—*a.* Several plans of command posts are shown in Figure 89. The layout of command posts can not be standardized, as each situation will present a different problem in providing the floor space required with the least expenditure of labor and material. The floor space required for command posts of various units is given in paragraph 142. Material lists for a complete work may be computed as heretofore indicated.

b. Note that in the suggested designs of command posts in Figure 88 all passages are of the common gallery size and the rooms are of the chamber gallery size. In general, command posts for the larger units will consist of a combination or rather small chambers at right angles to the passage and long recessed chambers along the passage. The small chambers will normally be used for combined offices and quarters for the commissioned personnel of the staff while the long recessed chambers will contain bunks for the enlisted men. Chambers built at right angles to the passages should not extend more than 15 feet unless ventilation holes or shafts are constructed in the end of the room.

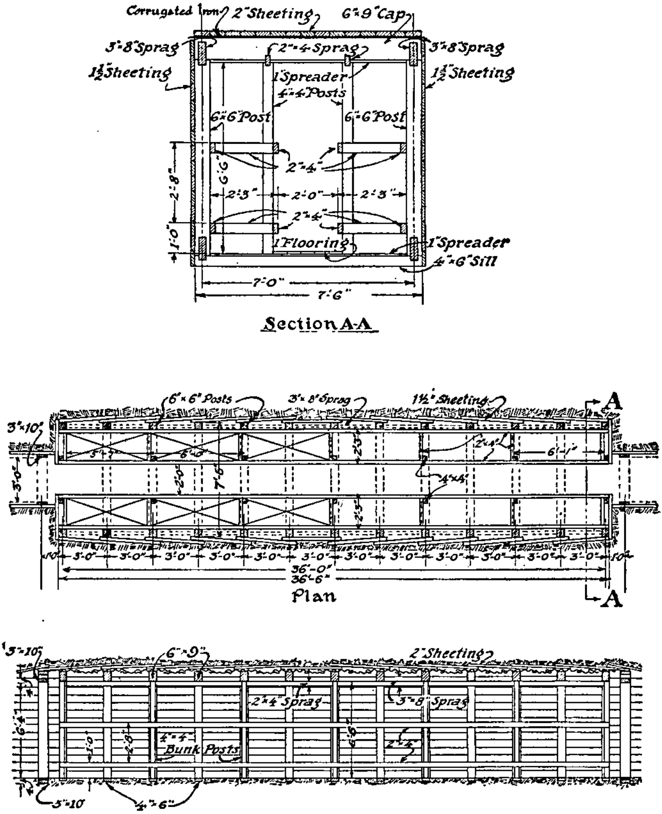


FIGURE 87.—Infantry cave shelter (gallery type), longitudinal section

c. In computing the floor space of shelters to be used for command posts, the area of passages should not be included, since all passages must be kept open and unobstructed.

134. Artillery cave shelters.—*a.* Layouts for artillery cave shelters are shown in Figures 90 and 91. Note that the standard chamber gallery and the common gallery sizes are used. Estimates for material for the arrangements shown, or for any adopted arrangement, may be made as heretofore indicated.

b. The arrangement of the four guns of a battery in line is not essential, as they may be echeloned or divided into groups.

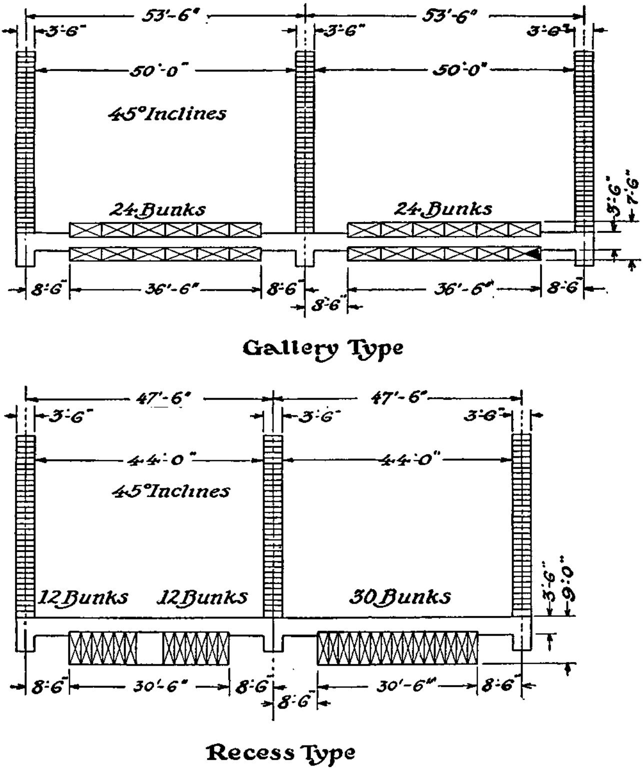


FIGURE 88.—Standard infantry cave shelters

Not more than 15 men per piece should be housed at the gun, the remainder of the unit being housed in a shelter 200 or 300 yards away. It is advisable in some cases to construct the command post away from the guns. A first-aid shelter should be located 200 or 300 yards away.

c. Where conditions prohibit the construction of cave shelters, some form of cut-and-cover shelter may be substituted. The designs shown in the figures are not intended for any particular gun or howitzer.

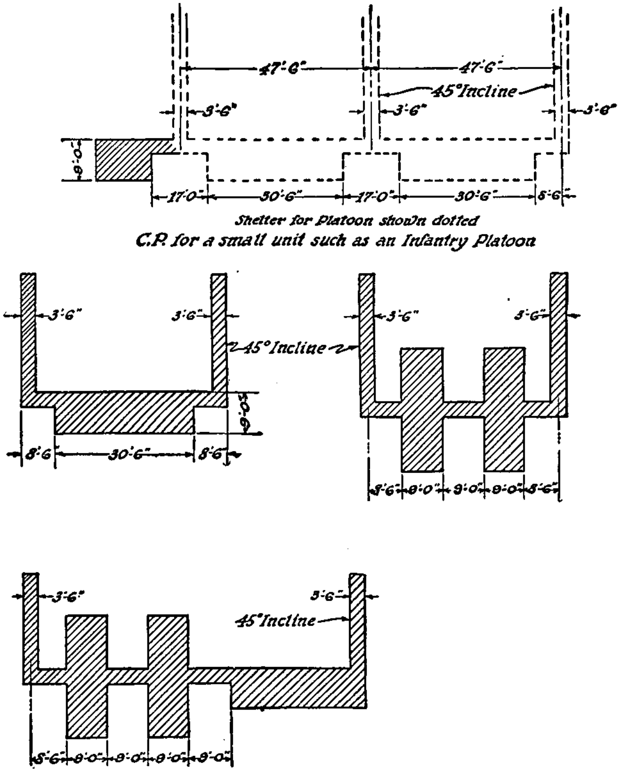


FIGURE 89.—Command posts

135. First-aid cave shelters.—*a.* Figure 92 shows a shelter adapted for first-aid use, having ease of passage for litter bearers through the passages, aisles, and inclines. Note that the rooms are made with the standard chamber gallery frames and the connecting aisles with the great gallery frames with the caps and sills shortened to a length of 5 feet 6 inches. The

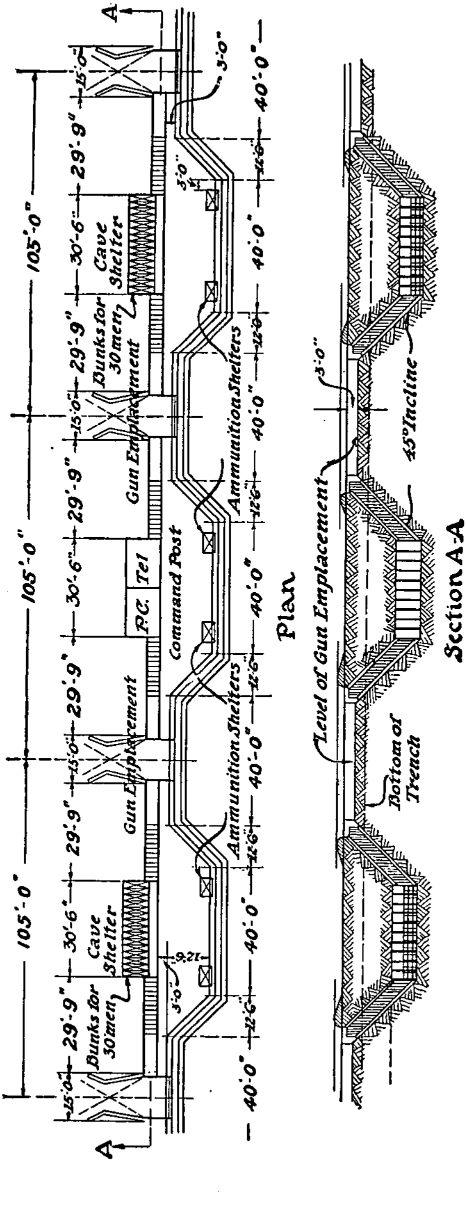


FIGURE 90.—Artillery cave shelter

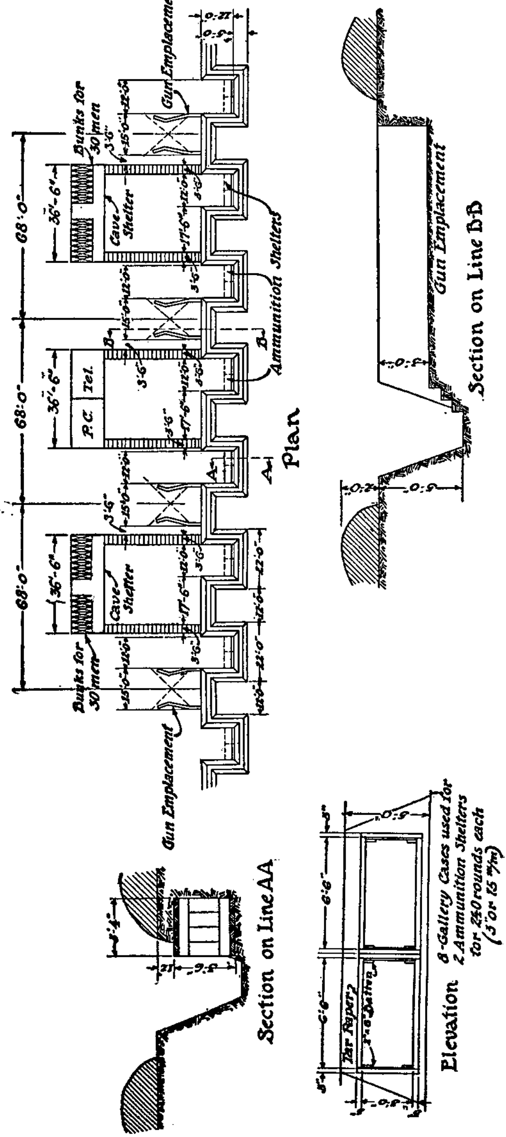


FIGURE 91.—Artillery cave shelter

estimate for material for this arrangement may be obtained as heretofore indicated.

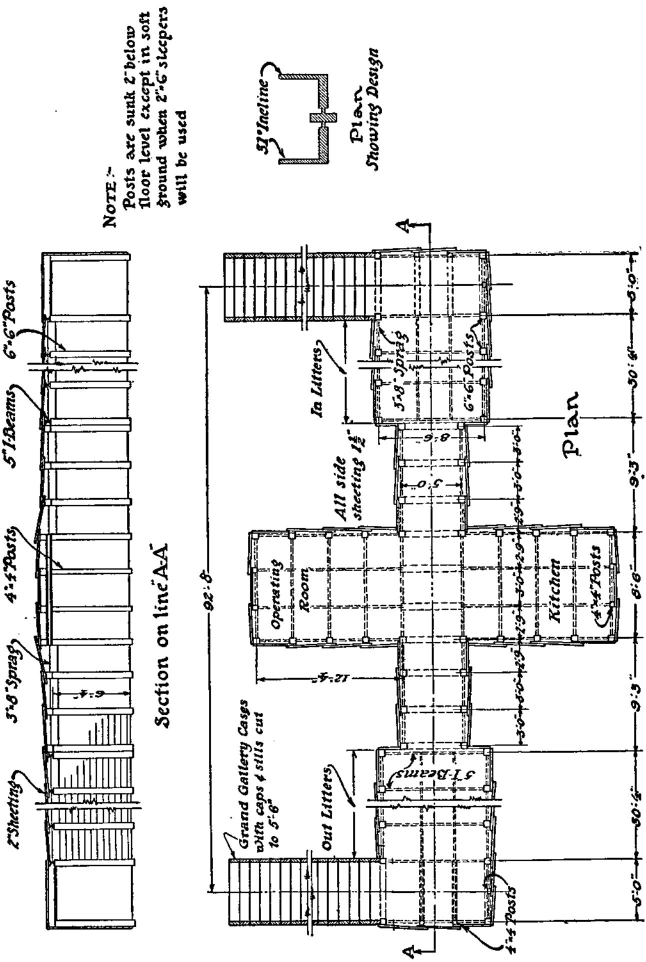


FIGURE 92.—First-aid cave shelter

b. The 45° incline is too steep for handling litters with ease; an incline of about 31° is preferable.

136. Ventilation.—Ventilation, particularly in reference to cave shelters, is very important and should be given careful consideration. It includes the following problems:

a. Providing a sufficient circulation of pure air through the incline, shafts, galleries, and chamber.

b. The exclusion of gas from all parts of the shelter. (See par. 129.)

c. Providing a supply of air when the entrances and ventilation shafts are closed during a prolonged gas attack.

137. Circulation of fresh air.—*a.* In the case of *surface* and *cut-and-cover shelters* no serious difficulties arise, and the problem may be handled usually by keeping the entrances open.

b. In the case of *cave shelters*, ventilating shafts, in addition to the entrances, are usually necessary. They are in the form of small vertical shafts, which may be bored from within after completion of the shelter. A stovepipe through one of these shafts assists the circulation of air materially. In some cases, where the ventilating shaft is not provided, a small fire near one of the entrances will create a draft and thus keep the air purified. In very large and elaborate systems of shelters a forced draft may be caused by means of fans.

c. A gallery should not be driven more than 60 feet without artificial ventilation. The only possible way of ventilating a gallery with a single opening is to force fresh air to the working breast, which may be done through a duct of wood or metal, or canvas or other hose. A pressure blower, worked by hand or power, is among the essential items of mining equipment. For excavations of moderate extent a portable forge forms a convenient ventilating device. If a gallery passes under surface cover a drill hole made through the roof and breaking the surface under protection of the cover may be used to promote ventilation. In a system of galleries having two or more outlets, air may be exhausted from one and drawn in through the other. Screens or doors may be arranged to compel the desired distribution of fresh air. Vacuum operation is never as satisfactory as a pressure system.

138. Supply of air during gas attack.—In any future use of chemical agents in war, such agents will, in all probability, be used to maintain a continuous concentration in certain areas for comparatively long periods of time. Assuming that 1 cubic yard of air is sufficient for one man for two hours, the air in an occupied shelter would become unfit for breathing within four or five hours after the gas curtains were closed. For this reason it is important to determine the best methods of supplying fresh air during such periods of gas concentration. Standard methods have not been developed.

139. Surface and rain water.—Surface and rain water must be excluded from all shelter entrances. If the drainage of the trench is sluggish, two sumps must be dug in the bottom of the trench at least 6 feet clear of the sides of the entrance, and strongly revetted. The bottom of the trench in front of the entrance must then be graded to the sumps so that the highest point comes in front of the entrance. Where the entrance takes off directly from the trench, baffle boards must be used. These should extend at least 6 inches beyond the sides of the entrance, and to a height of 10 inches above the bottom of the trench. The admission of direct rainfall into the entrances must be prevented either by the design of the entrance or by the construction of some form of light covering.

140. Seepage.—Protection against water seeping into the chambers is essential, particularly in the case of cave shelters. This is accomplished by placing corrugated iron in the roof, above the sheeting in a cut-and-cover shelter. (See fig. 80.) In cave shelters a strip of corrugated iron is placed on top of the cap of the frame. The sheeting is then driven over the top of the iron. The space between caps is filled with an additional piece of corrugated iron which is supported by the sprags. (See fig. 87.) Seepage is thus carried to the sides of the chamber, where it is collected in a gutter leading to a sump.

141. Removal of water from chambers and galleries.—Such water as gains entrance to chambers and galleries in spite of precautions must be taken care of or it will collect and flood the shelter. Galleries should always be driven on a 1 per cent, or 1 foot to 100 feet, grade and all slopes should fall toward a point or points where the water can be disposed of. If the shelter has a level entrance such as might occur in a reverse slope location, nothing is required except to regulate the slopes so that all water will run to the mouth. If the shelter is entered by an incline, a pit or sump must be formed at the bottom into which water can collect, and from which it can be raised to the surface by pumping or bailing. Using a 1 per cent slope, the floor of the gallery should be sloped laterally and a gutter formed along one side.

142. Floor space for shelters.—The following table gives data from which the amount of shelter construction may be approximated:

	Square feet
Troops, per man occupying	9 to 12
First-aid station, per litter	28
Command post, platoon	100
Command post, company	200
Command post, battalion	400
Command post, regiment	600
Command post, brigade	800
Command post, division	1,600

143. Time for shelter construction.—*a.* Table XXX gives estimates for construction time for various shelters as illustrated in this section. The estimates are based on the assumption of average firm soil, well-trained men, and the material delivered at the site. They include the time of the labor required to dispose of the excavated material and to handle the construction material. The area used is that of the room providing shelter and does not include areas in passageways or inclines. The estimates are subject to considerable uncertainty on account of the variety of conditions encountered.

b. With men untrained in this character of work the man-hours per square foot of chamber may be increased 50 per cent; after a period of experience, however, a detail should approach the above estimate. The time of construction may be shortened by increasing the size of the detail where the conditions of work make this possible.

TABLE XXX.—*Shelter-construction data, average soil, material at site*

Type	Figure No.	Description	Protects against shell	Capacity (men)	Work detail	Square feet
Surface	9	Corrugated steel.	3-inch	12	1 sergeant, 2 squads.	150
Do	12	Splinter proof.	Splinters and fragments.	2	2 men	18
Do	13	Light timber	3-inch	2	do	20
Do	13	Light steel	do	2	do	27
Do	10	Barracks	Splinters and fragments.	40	1 sergeant, 16 men.	2,000
Cut-and-cover	14	Timber	6-inch	24	1 platoon	234
Do	15	Steel	do	24	do	290
Do	16	Concrete	12-inch	50	do	825
Cave	21	Recess	do	30	1 sergeant, 16 men.	240
Do	22	Gallery	do	24	do	234

TABLE XXX.—*Shelter-construction data, average soil, material at site*—Continued

Type	Material			Construction time				Per occupant	
	Tons	Tons per occupant	Tons per square foot	Hours	Man-hours	Man-hours per square foot	Man-hours per occupant	Excavation (cubic feet)	Feet (b. m.)
Surface	73	6	0.5	20	320	2.0	27	36	80
Do	.5	.25	.03	4	8	.4	4	66	-------
Do	2	1	.1	5	10	.5	5	39	171
Do	2	1	.08	6	12	.5	6	45	74
Do	120	3	.06	32	544	.3	14	4	222
Cut-and-cover	562	24	2.4	48	2,064	8.8	86	240	250
Do	459	19	1.6	44	1,892	6.5	79	230	142
Do	1,096	[1] 22	1.3	88	3,784	4.6	75	286	[2] 48
Cave	27	.9	.1	136	2,312	9.6	77	130	328
Do	28	1.2	.1	136	2,312	9.9	96	168	448

[1] Based on a capacity of 50 men, if for shelter, or 43.8 tons per person if shelter is designed for staff use of about 25 persons.
[2] For forms.

144. Quantities of materials required.—*a.* Material lists for any layout in which the standard materials are used may be made up from the list for each type of structure included in the layout. Thus, for a cave shelter, the tables for a certain type of chamber, an entrance passage (inclined or otherwise), and an approach to entrance will ordinarily be used. (See fig. 86.) If several chambers are connected underground, the table for the proper size of gallery for the connecting passage will also be used.

b. The following allowances have been made in the tables for materials:

(1) Standard wedges per set:

Framed gallery ---------- 10

Cased gallery ---------- 4

(2) Sandbags, per square foot of revetting face ---------- 3

(3) Bursters, per entrance (7 by 6) ---------- 42

(4) Miscellaneous:

Wire netting, 36-inch, 2-inch mesh, per bunk linear foot ---------- 6.5

Staples, per bunk, pound, ⅞-inch, No. 9 ---------- .5

145. Rate of work, cave shelters.—In calculating the size of working parties and the rate of work, the following figures may be taken as average:

a. Inclines and passages:

1 man picking 1 man filling sandbags 1 man carrying for each 10 feet of entrance	1 relief. 0.6 cubic yard per hour.

b. Chamber section:

2 men picking 2 men bagging 2 helpers	1 relief. 1.2 cubic yards per hour.

Add 1 man per pickman for every 10 feet of carry.

c. Gallery section:

The same as for chamber section.

d. Surface carrying party:

1 man, 100 sandbags a distance of 200 feet in 8 hours, under ordinary trench conditions.

1 bag equals 0.5 cubic foot, about 50 pounds.

CHAPTER 3

EXPLOSIVES AND DEMOLITIONS

SECTION I

GENERAL PRINCIPLES

146. Explosives.—*a. Definitions.*—(1) *Explosive.*—Any mixture or chemical compound which, under the influence of heat or mechanical action, undergoes a sudden chemical change with the liberation of energy and the development of high gas pressure is called an explosive. The chemical change develops heat which further expands the liberated gas.

(2) *Deflagration.*—When the rate of transformation is slow, as in black powder, the explosion consists only of a quick combustion, known as *deflagration.* An example of deflagration is found in the firing of a cannon; the propellent charge continues to develop energy until the projectile leaves the muzzle.

(3) *Detonation.*—When the rate of transformation is very great it is called *detonation.* A detonation is not instantaneous but starts from a given point and travels away from that point in all directions with a high but measurable velocity. This velocity varies with the nature and density of the explosives, being about 22,960 feet per second for triton.

(4) Comparing the mechanical effects of deflagration and detonation, the former may be considered as giving a push, the latter as delivering a blow.

b. Classes.—Explosives may be classified chemically and according to their effects.

(1) Chemically, explosives may be divided into the following classes:

(*a*) Mixtures of two or more substances which react to produce the explosion. One agent must be oxidizing and another reducing. An example is black powder, a mixture of potassium nitrate, sulphur, and charcoal.

(*b*) Chemical compounds which can undergo a breaking up of the molecules and rearrangement of the atoms into other molecules with evolution of heat. Examples are nitroglycerin, nitrocellulose, and trinitrotoluene.

(*c*) Chemical compounds which decompose into their elements with explosive violence. An example is mercuric fulminate.

(2) From the standpoint of effect, explosives may be divided as follows:

(*a*) Slow explosives, often called low-order explosives, are those which merely burn (deflagration), the reaction taking place only on the surface. They are progressive, and hence give a rending and thrusting effect. They must be thoroughly tamped for successful use. They are used principally in quarries and mines.

(*b*) High explosives, often called high-order explosives, are those in which combustion is rapid and violent, occurring almost instantaneously (detonation). They develop enormous pressures suddenly and produce a shattering effect extremely effective for military demolitions. They can be used in holes and underground, and also for structural demolitions where tamping is not feasible For example, in quarry work slow explosives break out the rock in large pieces, while in tunnel work high explosives shatter the rock into small pieces. It should be understood that tamping is of value with high explosives, as well as with slow, and should be effected wherever possible in order to economize on explosive.

147. Requisites of a military explosive.—A military explosive for demolitions should be—

a. Not too sensitive to shock or friction.

b. Of a high velocity of detonation.

c. Of high power.

d. Of high density.

e. Stable in character.

f. Not too difficult of detonation.

g. Unaffected by changes of temperature and moisture.

h. Convenient in form for packing and loading.

i. Obtainable in large quantities in the United States.

148. The standard explosive.—*a.* The explosive more nearly fulfilling the foregoing requirements than any other is triton or

T. N. T. (trinitrotoluene), which is the standard for issue to the Army of the United States for demolition in forward areas. For general use in rear areas and for extensive demolition projects where the actual explosive used is immaterial other commercial explosives are issued. T. N. T. is manufactured in the form of light-yellow crystals from the successive nitration of toluene. Toluene is produced by by-product coke ovens as a by-product in the manufacture of illuminating gas and in the manufacture of kerosene from crude petroleum. The last-named source is the principal one. It melts at 176° F.

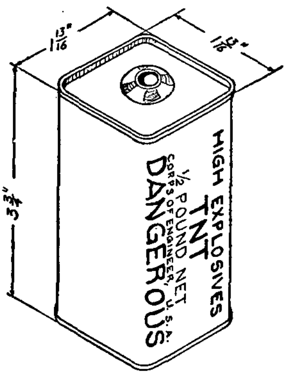


FIGURE 93.—Half-pound block, T. N. T., in cardboard container

b. Triton as issued to the service has a density of 1.46. It is issued in rectangular half-pound blocks, 1⅞ inches square by 3¼ inches long. Each block is incased in a cardboard container (see fig. 93) closed at both ends with lacquered tin. There is at one end a cylindrical hole to receive the detonating cap. The hole is temporarily closed by a paper diaphragm, which is punctured by the insertion of the detonating cap or cordeau.

c. Triton is insensitive in all forms and requires a powerful detonating agent. It will not detonate even under strong pressure or severe blows. Mercuric fulminate will not detonate untamped triton. It can be detonated by the issue tetryl caps and by detonating cord.

d. Triton burns at 266° F. In small quantities it can be burned without danger of detonation. In large quantities the

TABLE XXXI.—*Characteristics of principal military explosives*

Name	Relative strength T. N. T.= 1.00 comparison by weight	Freezing	Fumes	Detonating cap required	Uses	Remarks
Triton or T. N. T.	1.00	N. F.[1]	Poisonous (1)	No. 8 tetryl cap	General military use in forward areas.	Safe to handle.
Nitro-starch	1.00	N. F.[1]	Poisonous (4)	No. 6 to No. 8 blasting cap.	Similar to T. N. T. mentioned above, and can be substituted therefor.	Keep dry. Safe to handle.
Picric acid	1.00	N. F.[1]	Poisonous (5)	For small charge No. 7 cap; for large charge No. 8 cap.	Is adapted for same class of work and is comparable to T. N. T. Can be substituted therefor.	Keep dry; avoid contact with metals, especially lead.
Ammonal (British explosive).	1.05	N. F.[1]	Poisonous (1)	For small charge No. 7 cap; for large charge No. 8 cap.	Superior to other explosives for mine charges and any work where the heaving effect secured by a slow rate of detonation is desired.	Keep dry.
Dynamite, straight, 20% to 60%.	50%=1.00	L. F.[2]	Poisonous (4)	No. 6 to No. 8 cap	Quick shattering action. Adapted for outside work. 20% to 40%.—Adapted for stump and subsoil blasting. 40% to 60%.—Adapted for mud capping boulders and digging post holes. 50% to 60%.—Adapted for artesian wells and general engineering uses. 60%.—Adapted for quarrying, ice blasting, and log jams.	More sensitive than other types and the sensitiveness increases with the strength. It resists water very well.

See footnote at end of table.

TABLE XXXI.—*Characteristics of principal military explosives*—Continued

Name	Relative strength T. N. T.=1.00 comparison by weight	Freezing	Fumes	Detonating cap required	Uses	Remarks
Dynamite, ammonia (extra) 17% to 60%.	60%=0.90	L. F.[2]	Poisonous (1)	No. 8 cap	Not so quick and shattering. Best suited for work in soft rock; also for hard rock where a shattering action is not desired. Can be used to better advantage than straight dynamite for earth excavation.	Does not stand water as well as the straight dynamites.
Blasting gelatin	2.1	Not L. F.	Poisonous (2)	For small charge No. 8 cap; for large charge use a booster consisting of 2 sticks of dynamite each containing a No. 8 cap.	Very quick and shattering. It is adapted for some special cases of tunnel driving; shaft sinking, deep-well shooting, and submarine work.	Freezes at about 35° F. and is then sensitive to shock, otherwise very safe.
Gelatin dynamite, 25% to 90%.	60%=0.90	L. F.[2]	Poisonous (3)	No. 8	A good general-purpose explosive. Specially good for underwater work and tunnel driving where there is sufficient ventilation to dilute the fumes.	Should never be used for mud capping.

[1] N. F. indicates nonfreezing.
[2] L. F. indicates low freezing.

(1), (2), (3), (4), (5) indicate the order of poisonous fumes, the most dangerous being (1).

heat generated will invariably raise the temperature to the detonating point.

e. Triton is insoluble in water, and it is successfully used for demolition work under water.

f. The detonation of triton produces poisonous gases, but in open air these are so rapidly dissipated as to be harmless. It is not recommended for work underground.

g. Triton is used by the British under the name "trotyl," by the French under the name "tolite," and by the Germans under the name "sprengmunition 02."

149. Magazine locations.—*a.* A magazine should be located with a view to both accessibility and safety. A good location is an isolated ravine. Damp locations should be avoided as much as possible, but when it is impossible to avoid damp locations good drainage and proper ventilation should be provided.

b. When there are two or more magazines located in the same vicinity they should be separated as follows:

Pounds of explosives	Separation of magazines
Over 50	Detached.
Over 5,000	200 feet.
Over 25,000	200 feet plus 2⅔ feet for each 1,000 pounds.

150. Magazine construction.—*a.* Permanent magazines for high explosives should be bullet proof, fireproof, weatherproof, and well ventilated. For permanent construction magazines of soft brick or corrugated iron with sand-filled walls are recommended. Brick for magazine construction should be as soft as possible consistent with good quality and durability in order to avoid large fragments in case of an explosion. The thickness of sand walls to protect against service ammunition should be about 11 inches. Stone, concrete, and hard brick construction are not suitable because of their dangerous fragmentation in case of an explosion.

b. The magazines should be carefully ventilated by providing openings just above the ground line and just below the roof.

c. Heavy sheet-iron sections make the most satisfactory temporary magazines.

d. Temporary magazines may be made to accommodate moderate-sized stocks of explosives in the following manner:

(1) In a dry bluff excavate a chamber of the requisite size and timber to prevent caving.

(2) In the open, on a light wooden frame, erected on the plan of a box house, with a wedge roof, construct a magazine of light-weight corrugated iron.

(3) Erect a light wooden frame as described above and cover with a tent of proper size, or canvas.

e. When single magazines are not isolated and where magazines are constructed in groups, it is good practice to surround each magazine with a barricade to prevent fragments damaging adjacent buildings or magazines in case of an explosion, and also, in case of active military operations, to protect each magazine from bomb or shell fragments.

151. Magazine operation.—*a*. Never store caps in the same magazine with explosives.

b. Always ship old stocks first. Arrange stocks so that old stocks will be readily accessible.

c. Allow no metal tools to be introduced into the magazine.

d. Allow no matches, fire, lamps, or spark-producing devices in a magazine.

e. Store cases of dynamite and other nitroglycerin explosives right side up, so that the cartridges will lie flat and not stand on end.

f. Do not store any miscellaneous material in magazines with explosive.

g. Keep the grounds around the magazine free of brush and dry leaves. Keep a fence, preferably of barbed wire, around the magazine.

h. Never open packages of explosives within the magazine, and use wooden wedge and mallet for opening or closing packing boxes.

i. Rubber or other soft-soled shoes should be used in magazine.

j. Turn cases of dynamite every 30 days, if practicable, when dynamite is not frozen.

152. Transportation.—*a*. Rail transportation is thoroughly regulated by the Interstate Commerce Commission, and all persons shipping explosives by rail should obtain a copy of their regulations and follow them implicitly.

b. In hauling explosives by truck or wagon cover any exposed metal parts of the vehicle with boards or canvas. Cover the stock with a tarpaulin. Avoid congested streets and unnecessary stops. Travel carefully and slowly over rough roads.

c. Never haul caps with other explosives.

153. Old dynamite.—*a*. Old deteriorated dynamite often assumes a dark color and is soft and mushy. The cases are frequently discolored by dark-brown stains due to leaking of the cartridges. This kind of dynamite must be handled very carefully. It will often fail to detonate or will burn instead of detonating, giving off poisonous fumes.

b. Such dynamite should be destroyed by taking it to an open field, opening the cases carefully, removing the cartridges, slitting them, and spreading them over the ground. If the dynamite appears to be too wet to burn readily, pour a little kerosene over it. Place a small pile of paper, shavings, etc., close enough to the dynamite for the flame to burn along the paper and ignite the dynamite. After lighting the paper withdraw to a safe distance until the dynamite is completely burned.

c. Cases should be piled and burned separately. Not more than 100 pounds should be burned at one time. When more than that amount must be destroyed select a new space for each lot, as it is not safe to place dynamite on the hot ground of the preceding burning. Packing boxes that have contained dynamite are dangerous. They should never be used again, but burned, employing similar precautions to those prescribed for damaged dynamite.

154. Thawing dynamite.—*a*. Frozen dynamite can not develop its full strength in a blast. Some provision must therefore be made for thawing it before use. The fundamental rule for thawing dynamite is to thaw slowly, with the cartridges lying on their side, and not to place the dynamite over an active source of heat.

b. Where thawing must be done in large quantities a special house should be constructed. The Du Pont Co. or the Bureau of Mines will furnish specifications for such a house. When only small quantitites are to be thawed the special type of double boiler shown in Figure 94 may be used. These boilers come in two sizes, having a capacity of 30 pounds and 60 pounds, respectively.

c. To use the double boiler, first see that the explosive compartment is empty. Then heat the water to be used in a separate container. Test this water with the hand until it is as hot as can be borne, then pour it into the water jacket. Then add the dynamite stick by stick. The double boiler should now be placed in a barrel or box and surrounded with dry hay.

d. Dynamite may be kept from freezing, or if frozen thawed by placing it in a pile of stable manure. The cartridges must not come in actual contact with the manure, since they might absorb moisture.

155. General precautions with regard to explosives.—*a.* Do not forget the nature of explosives and remember that they

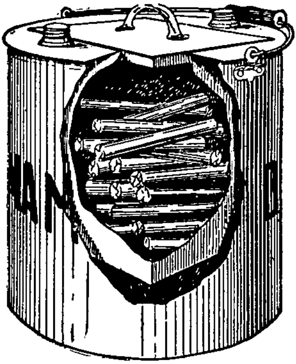


FIGURE 94.—Du Pont thawing kettle, showing two compartments and dynamite

can be handled with comparative safety only by exercising proper care.

b. Do not connect lead wires to blasting machine until ready to fire charge, and do not leave lead wires attached to machine after charge is fired.

c. Do not hold blasting caps in hand while crimping. Place the cap on the fuze and hold the fuze.

d. Do not smoke while handling explosives, and do not handle explosives near an open light.

e. Do not leave explosives in a field or any place where animals can get at them. Animals like the taste of dynamite and will eat it if they have an opportunity. It is poisonous, in addition to the danger of an explosion.

f. Do not handle or store explosives in or near a dwelling place.

g. Do not leave explosives in a wet or damp place. Keep them in a suitable dry place under lock and key. Do not let irresponsible persons have the key.

h. Do not explode a charge to spring a bore hole and then immediately reload, as the bore hole will still be hot.

i. Do not tamp with iron or steel bars or tools. Use only a blunt wooden tamping stick.

j. Do not explode a charge until everyone is out of danger.

k. When using safety fuze do not hurry in seeking a reason for the failure of a charge to explode. Wait 30 minutes and then explode the charge by another charge placed at least 2 feet from the old one.

l. Do not use frozen or chilled dynamite.

m. Do not thaw dynamite except as recommended in this text.

n. Do not put dynamite on shelves directly over steam or hot-water pipes.

o. Do not prime a charge or connect charges for electric firing during the immediate approach or progress of a thunderstorm.

p. Do not carry detonating caps in your pocket.

q. Do not tap or otherwise investigate detonating caps.

r. Do not take caps from the box by means of a wire, a nail, or a similar instrument.

s. Do not pull on the wires of an electric cap.

t. Do not crimp a cap with the teeth or with a knife. Use the cap crimper.

u. Do not store or transport caps with high explosives.

v. Do not cut the safety fuze short to save time.

w. Do not operate the blasting machine half-heartedly.

x. Do not leave detonators exposed to the direct rays of the sun.

y. Do not open a case of explosives in a magazine.

z. Do not have matches around explosives.

aa. Do not force a primed cartridge into a drill hole. Have hole of ample size for cartridge.

ab. Do not handle safety fuze carelessly in cold weather When cold it is stiff and cracks easily.

ac. Do not use a weak detonator. Use the prescribed detonator or a more powerful one.

SECTION II

DEMOLITION EQUIPMENT

156. Service demolition equipment.—*a.* The service demolition equipment consists of the following items:

Chest (container for the equipment).
- Boxes, cap, engineer.
- Boxes, tin, match.
- Caps, blasting, tetryl, electric.
- Caps, blasting, tetryl, nonelectric.
- Circuit detectors, or galvanometers.
- Cord, detonating, 20-yard spools.
- Crimpers, cap.
- Drills, cordeau.
- Exploders, magneto, 30-cap or 10-cap.
- Explosive, T. N. T., rectangular.
- Fuze, instantaneous.
- Fuze, time.
- Lighters, fuze.
- Matches, safety, boxes.
- Pliers, side-cutting, 8-inch.
- Reels, wire, firing.
- Slitters.
- Tape, friction, ¾-inch, insulating.
- Twine, hemp, 4-ounce ball.
- Unions, detonating cord.
- Wire, firing, double lead No. 14, 1,000-foot coils.

b. The small tin box provided in the equipment will hold the six boxes of safety matches carried in the chest. Its purpose is to keep these matches dry.

c. The engineer cap box is made from a solid block of hard maple and is bored to hold 50 tetryl caps, nonelectric. The purpose of the box is to protect the caps from moisture and from shock. A smaller box of the same general type, but holding only six caps, is provided for cavalry use.

157. Magneto exploders or blasting machines.—*a.* Blasting machines are used to generate the current for electric detonation. The blasting machine consists of a small portable dynamo. The current generated by the rotation of the armature passes through the windings of the field magnet, intensifying the field. The voltage arises as the armature revolves, and this continually intensifies the field.

b. One type of service machine is known commercially as the Dupont No. 3. It has a capacity of 30 electric blasting caps with copper wire leads and weighs 25 pounds. It is shown in Figure 96. This machine is operated by the downward thrust of a rack bar which rotates the magneto armature. When the rack bar reaches the end of its stroke the firing circuit is completed and the voltage is sufficient to create a detonating current through it. Another type of blasting machine issued to the service is known as the Hercules 10-cap blasting machine. (See fig. 95.) It has a capacity of 10 electric blasting caps with a possible overload of 100 per cent. It is operated by a vigorous twist of the handle. It weighs 4¾ pounds.

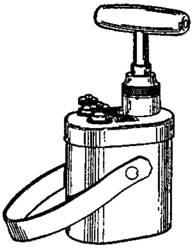


FIGURE 95.—Ten-cap exploder or blasting machine

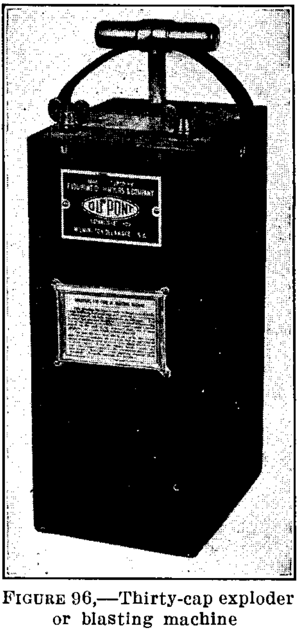


FIGURE 96,—Thirty-cap exploder or blasting machine

158. Galvanometer.—*a.* The galvanometer is an instrument used in demolition work to determine whether a blasting circuit is closed or open; that is, whether a circuit is in proper condition for the blast or, because of defective wiring or other reasons, will fail to transmit the electric current. (See par. 180.) The service galvanometer can also be used to measure the amount of resistance, thus indicating the existence of leaks or short circuits.

b. The galvanometer should be handled carefully and kept dry. It should be tested before being used by placing a short piece of copper wire lightly across its two binding posts. If

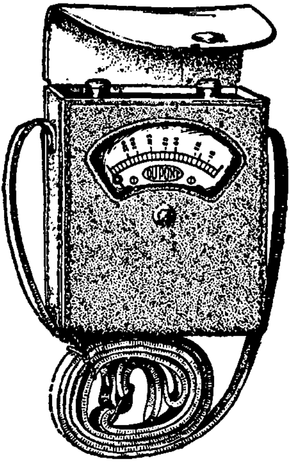


FIGURE 97.—Galvanometer

the needle does not move across the scale, the battery cell is weakened and must be replaced. To replace this cell, remove the screws in the face of the metal case, lift out the dead cell, and insert the new cell. Be careful that the + and — poles are connected to the corresponding wires.

c. To test a circuit, touch the ends of the two lead wires to the two binding posts of the galvanometer. If the circuit is perfect, the needle will move along the scale. If the needle does not move, there is a break in the circuit. If the needle moves only slightly, there is a place of high resistance, such as a bad joint. If the caps are placed in parallel, each cap must be tested individually. Each series in a parallel series circuit must also be tested individually. For location of breaks see paragraph 181.

d. It is well to test the electric circuit and individual caps from a position where the tester is safe in case the cap should be set off by the small galvanometer current. Millions of caps have been tested with this current without mishap, but it is well to remember that there is always danger in handling explosives and that utmost care must be employed at all times.

159. Safety fuze.—*a.* Safety fuze is the medium for bringing sparks to fire blasting caps or to ignite charges of blasting powder. It is made of a thin train of powder tightly compressed in, and partially waterproofed by, inner and outer wrappings. Safety fuze as issued to the service is known as time or Bickford fuze. It burns at the rate of about 32 to 40 seconds to the foot. The rate of burning for each roll should be tested before use. It may be ignited by a match or by a fuze lighter. When a match is to be used, the end of the fuze should be split and opened to insure contact between the flame and the powder train. A slight sputtering sound indicates that the fuze is lighted.

b. Safety fuze is manufactured in lengths of 50 feet and made into rolls. It is white in color and has a smooth outer surface.

c. Safety fuze should be stored in a cool, dry place. In using this fuze care should be taken to prevent it from twisting or "kinking." Two inches should be cut off the end and discarded, and the freshly cut end inserted in the cap because the powder in the end is likely to have become damp and ineffective. The end to be inserted should be cut squarely and not diagonally. It should be pushed gently against the charge in the blasting cap before the cap is crimped. If the end is slightly too large to enter the cap, do not cut away any of the outer covering, but squeeze the end between the thumb and finger until it is small enough.

160. Instantaneous fuze.—*a.* Instantaneous fuze is used to secure simultaneous or practically simultaneous detonation. It is also used to carry the fire to the cap when the firer is at considerable distance from the charge.

b. Instantaneous fuze is recognizable by the *red braid* used in its manufacture. This braid gives the instantaneous fuze a rough outer surface by which it may be distinguished in the dark. It must never be confused with safety or time fuze. It burns at the rate of 120 feet per second.

c. Instantaneous fuze should not be lighted directly.

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161. Detonating cord or cordeau.—*a.* Detonating cord, as issued to the service, is a small lead tube filled with pulverized triton. It has a velocity of detonation of about 16,000 feet per second. It is quite insensitive and can not be exploded by hammering, knocking, or burning. It is exploded by blasting caps, electric blasting caps, and tetryl caps. The extreme violence of its explosion is sufficient to detonate high explosives in contact with it.

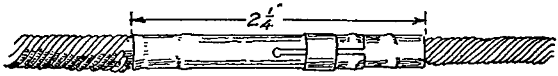


FIGURE 98.—Union for attaching blasting cap to cordeau

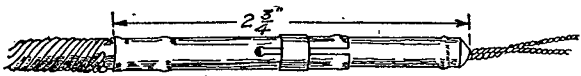


FIGURE 99.—Special union for attaching electric cap to cordeau

b. Cordeau is issued in 20-yard lengths, each length being wrapped on a spool.

c. Detonating cord is subject to deterioration and should be tested for strength before using.

162. Cordeau accessories.—*a.* Explode cordeau by means of an electric or blasting cap and safety fuze. A "union" should be used to hold the cap in place. (See figs. 98 and 99.) The union is crimped on the cordeau and the cap crimped on the

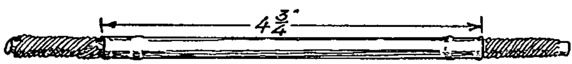


FIGURE 100.—Cordeau sleeve

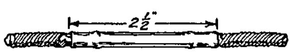


FIGURE 101.—Cordeau coupling

fuze. The cap is then inserted in the slotted end of the union and held in place by carefully sliding the tightening ring of the union. Care must be taken to exert no unnecessary pressure on the fulminate or tetryl end of the cap.

b. For splicing two lengths of cordeau together, a brass coupling or sleeve crimped to both pieces of cordeau assures a tight connection. It is quite necessary that the two lengths of cordeau should be in absolute contact inside of sleeve. (See figs. 100 and 101.)

163. The cord slitter.—*a.* The cord slitter is a special tool for ripping or slitting the end of the cordeau covering when making connections from a branch to a surface main line. (See fig. 102.)

b. To use the slitter, insert the cordeau in the slitter tube to the point where it is desired to slit the cordeau. Close the

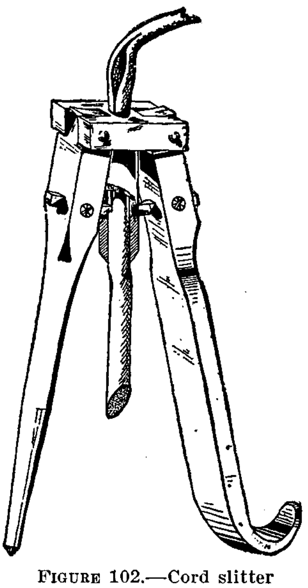


FIGURE 102.—Cord slitter

FIGURE 103.—Cap crimper

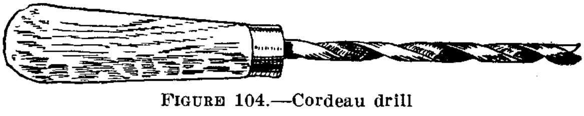


FIGURE 104.—Cordeau drill

handles of the slitter tightly and pull the slitter forward. Be careful to have the cordeau to be cut straightened out and free from twists or kinks.

164. Cordeau drill.—*a.* Figure 104 shows the cordeau drill. This drill is used to bore a hole through T. N. T. blocks so that the blocks may be strung on a length of cordeau.

b. To use the drill, remove the cork from the end of a block of T. N. T. and insert the drill. Hold the block in the left hand. Rotate the drill clockwise with the right hand, at the same time exerting a downward pressure.

165. Cap crimper.—Figure 103 shows the cap crimper issued to the service. This crimper is madé of blue steel and is 7 inches long. In addition to the crimper, it is provided with a fuze cutter. One handle is pointed and may be used with care as a punch for making holes for detonating caps when priming dynamite cartridges. This use of metal in contact with dynamite is a permissible exception to the general rule. The other handle has a screw-driver point. The crimper is so made that it can not squeeze the copper shell of the cap so tightly as to interfere with the burning of the powder train and cause misfire.

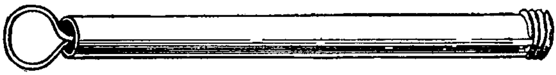


FIGURE 105.—Fuze lighter

166. Tape and twine.—*a.* Tape is included in the equipment for insulation of the lead wires at joints and for wrapping splices and joints of time and instantaneous fuze and detonating cord.

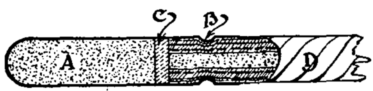
b. The twine is intended for general use, to tie joints and splices, and in some instances to tie caps to a charge.

167. Firing wire reel.—*a.* The firing wire reel is a wooden reel carrying 1,000 feet of firing wire. One end of the two leads of firing wire is made fast to one side of the box and is always available for connection to the blasting machine. The other end is free.

b. To use the reel, unwind the wire to the desired length by pulling on the free end. Connect this end to the cap wires and the other end to the blasting machine. To rewind, remove the leads from the blasting machine and cap wires, and turn the crank handle until all the wire is rewound.

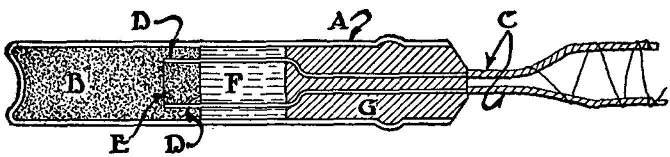
168. Fuze lighters.—*a.* The fuze lighter consists of a paper tube containing friction powder and a mechanical means of igniting the powder. The open end is placed over the time fuze and crimped to it with the cap crimper by means of the wire around the end of the tube. A ring is provided at the opposite end of the tube. This ring is fastened to a wire extending down into the powder within the tube. By giving the ring a quick pull, a sharp point on the wire is pulled through the friction powder, causing its combustion and the ignition of the fuze.

b. Although an issue article, fuze lighters have not been entirely satisfactory. Care must be taken not to pull the safety fuze away from cap or cartridge. Frequent failures to



A: *Detonating charge.*
B: *Crimp.* C: *Plug.*
D: *Safety fuze.*

FIGURE 106.—Section of blasting cap



A. Copper shell to hold filling material, " G," securely in place.
B. Detonating charge.
C. Insulated lead wires.
D. Ends of lead wires projecting into charge.
E. Platinum wire or " bridge " which is heated by the electric current.
F. Plug.
G. Filling material.

FIGURE 107.—Section of an electric blasting cap

function have occurred. In civilian practice a box of matches or miner's acetylene lamp is generally used.

169. Detonators.—*a.* In practice, detonation of explosives is initiated by the detonation of a small quantity of a more sensitive explosive.

b. A No. 6 or No. 8 blasting cap will detonate all explosives discussed in Section I except triton. The tetryl or tetryl electric cap is necessary to insure detonation of triton.

c. Commercial blasting caps are numbered consecutively from 1 to 10, according to their strength, and contain, respectively, 0.3, 0.4, 0.54, 0.65, 0.80, 1.0, 1.5, 2.0, 2.5, and 3.0 grains of an explosive mixture of 85 per cent fulminate of mercury and 15 per cent potassium chlorate. No. 6 and No. 8 caps are the most commonly used. The numbers of blasting caps of equal strength are the same in all countries. Figure 106 shows a blasting cap in cross section.

d. Electric blasting caps are special forms of detonators fired by means of an electric current. They correspond in strength to blasting caps of the same number. Figure 107 shows an electric blasting cap in cross section.

e. Tetryl blasting caps and tetryl electric caps are standard for Army use. They are similar in design to commercial detonators. The explosive used (tetryl) is detonated by a small charge of fulminate of mercury, which in turn is exploded by heat as in the commercial caps.

SECTION III

METHODS OF HANDLING EXPLOSIVES

170. Primers and priming.—*a.* High-explosive charges are usually detonated by a primer placed in the charge. A primer is a high-explosive cartridge with a detonating cap inserted. The operation of making and placing these primers is known as priming.

b. Primers should be carefully made—

(1) To insure the complete detonation of the explosive.

(2) To keep the detonator from pulling out of the explosive.

(3) To guard against moisture.

(4) To permit easy and safe loading of bore holes.

(5) To keep the safety or instantaneous fuze when used from pulling out of the blasting cap.

171. Priming with tetryl cap and safety fuze.—*a.* Cut off square and discard 2 or 3 inches of fuze. Cut off a sufficient length to reach from the charge in the bore hole to at least several inches above the top of the bore hole. This length must be sufficient to give the blaster time to withdraw to a safe distance after lighting the fuze.

b. Remove one cap from the cap box by hand. Shake the cap very gently to remove any dirt in the open end of the cap. If the end of the fuze is flattened, roll it between the thumb and finger. Slip the cap gently over the end of the fuze, so that the fuze reaches down to the explosive charge in the cap. The fuze must be cut square. An obliquely cut fuze may double over the powder core and cause a misfire. Do not twist the fuze into the cap and do not use force or violence when making the priming.

c. When the cap is placed over the fuze, fasten it securely in place with the cap crimper. Crimp the cap close to its open end; to make the crimp farther down might cause an explosion.

d. When the primer is to be used under water, protect the union between cap and fuze by a coating of soap, axle grease, wax, or commercial cap-sealing compound. Never use a substance that contains any free oil for sealing a cap.

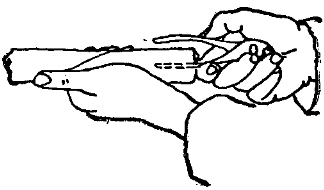


FIGURE 108.—Punch a hole with handle of cap crimper

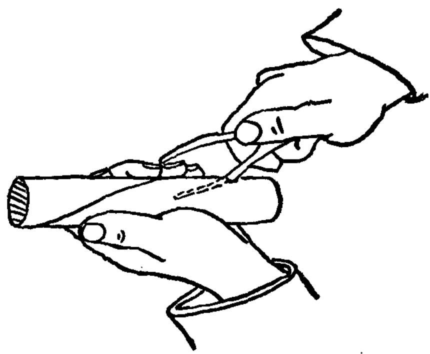


FIGURE 109.—Punch a hole in side of cartridge with handle

172. Priming T. N. T. blocks.—Insert the cap into the hole. Tie a piece of string around the fuze just above the cap, leaving enough fuze between the knot and the cap to protect the cap from any pull. Make this string fast around the T. N. T. block.

173. Priming in the end of dynamite cartridges.—*a.* With the handle of the cap crimper or a wooden awl punch a hole straight into the end of the cartridge for a sufficient depth to receive all of the copper shell of the cap. (See fig. 108.) Insert the cap with the fuze attached into the hole and fasten it there with a cord tied first around the cartridge and then around the fuze. To waterproof this primer close the hole where the fuze enters the cartridge with any of the sealing materials listed in paragraph 171.

b. Another method of priming in the end is to unfold the paper from the end of the cartridge and punch a hole directly into the center of the exposed dynamite. Close the loose part of the paper shell around the fuze and tie it tightly. This method is applicable to underwater work when the tied end is rendered water-tight with soap or similar material.

c. Priming in the end has the advantage of placing the detonator in the best possible position for detonation, but it also has the disadvantage of leaving the cap in a bad position for tamping.

174. Priming in the side of cartridges.—*a.* Punch a hole in the cartridge about 1½ inches from one end. Point the hole in

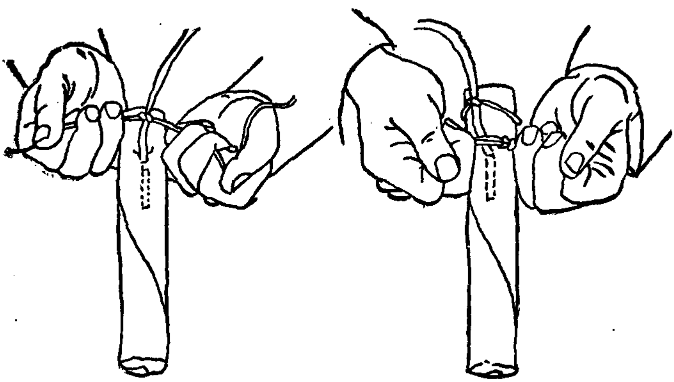


FIGURE 110.—Tie cord around fuze and cartridge

and toward the other end, so that when the cap is inserted it will be as nearly as possible parallel to the sides of the cartridge, as shown in Figure 109. Slip the cap with fuze attached into the hole. Tie a piece of cord firmly around the fuze and then around the cartridge. (Fig. 110.)

b. This method of priming places the cap advantageously for tamping.

175. Priming with electric tetryl caps.—*a.* To prime a T. N. T. block with an electric tetryl cap, insert the cap in the hole in the block. Make a loop in the fuze end of the lead wires and pass this loop around the block in such a manner as to put the pull on the free end, thus leaving the wire from the loop to the cap slack.

b. To prime a dynamite cartridge with the electric cap, punch a hole from the center of the end of the cartridge in a slanting direction so that it will come out at the side 2 or 3 inches from the end. Insert the end of the doubled-over wires of the cap. (Fig. 111 ①.) Loop these ends around the cartridge. (Fig. 111 ②.) Punch another hole in the top a little to

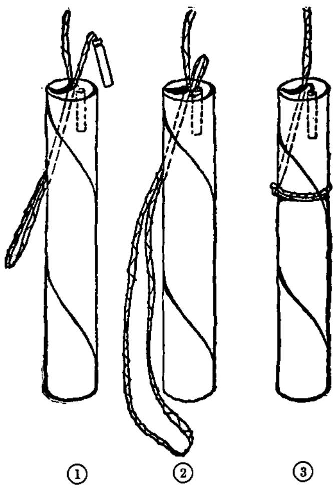


FIGURE 111.—Priming with electric cap

one side of the first and straight down. Insert the cap in this last hole as far as possible. Take up the slack on the wires. (Fig. 111 ③.)

176. Priming detonating cord.—*a.* Detonating cord is used as a detonating agent for T. N. T. However, the cord itself must be detonated. Triton blocks can be strung on detonating cord like beads and used as a necklace to cut posts, trees, etc. When it is desired to detonate T. N. T. directly from detonating cord, run the detonating cord clear through the block of triton.

b. Detonating cord may be primed—

(1) By means of a tetryl cap and union, as shown in Figure 112.

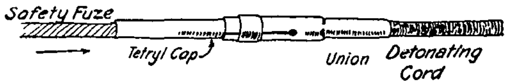


FIGURE 112.—Detonating cord primed with tetryl cap and union

(2) By tying two tetryl caps together, as shown in Figure 113.

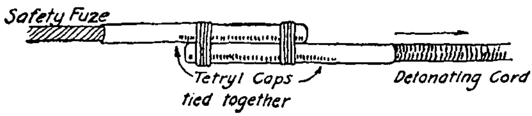


FIGURE 113.—Detonating cord primed with two tetryl caps

(3) By attaching a primer consisting of a tetryl cap and block of T. N. T. to the cord, as shown in Figure 114.

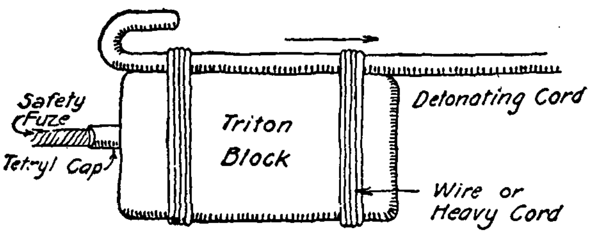


FIGURE 114.—Detonating cord primed with one triton block

(4) By using a tetryl cap and T. N. T. block in which an end of the detonating cord has been inserted, as shown in Figure 115.

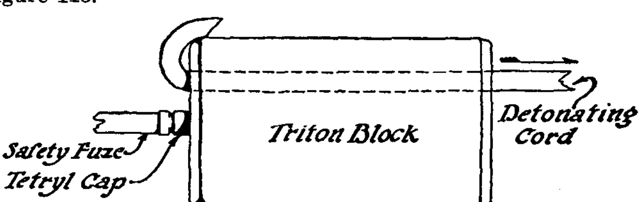


FIGURE 115.—Detonating cord primed with one triton block

177. Simultaneous detonation.—Simultaneous detonation or the detonation of several charges at the same instant may be secured by the following methods:

a. Electricity.

b. Electricity with detonating cord.

c. Time fuze with detonating cord.

d. Time fuze with induced detonation.

e. Time fuze with instantaneous fuze.

178. Wiring the electric circuit.—*a*. Electric detonation is readily divided into 3 distinct phases—wiring, testing, and firing the electric circuit. The wiring is also divided into 3 parts—connecting the detonator wires either directly or by means of connecting wires, connecting the proper detonator wires to the lead wires, and connecting the lead wires to the blasting machine.

b. Before connecting detonator wires scrape the bare ends of the wires with a knife blade; then join them with a long twist. (See fig. 116.) Make this twist tightly to keep the electrical resistance in the joint at a minimum.

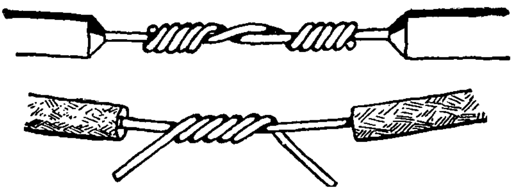


FIGURE 116.—Correct method of splicing connecting and detonating wires

c. Before fastening connecting or detonator wires to lead wires scrape the ends of both sets; then bend the end of the lead wire back sharply and take several turns of the detonator wire around the loop. (See fig. 117.)

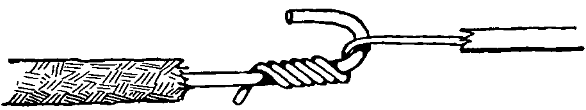


FIGURE 117.—A method of attaching connecting or detonating wire to a lead wire

d. To connect the lead wires to the blasting machine, loosen the wing nuts on the two binding posts and hook the ends around the binding posts; then tighten the wing nuts on the wires. The officer or noncommissioned officer in charge of the work should do this personally. The lead wires must not be connected to the blasting machine until he has assured himself that the circuit is complete and that no one is within the danger zone.

e. It should be the duty of a selected individual to remain constantly at the blasting machine to disconnect the lead wires

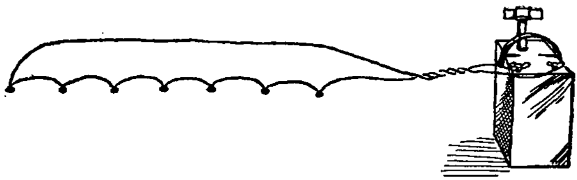


FIGURE 118.—Series connection

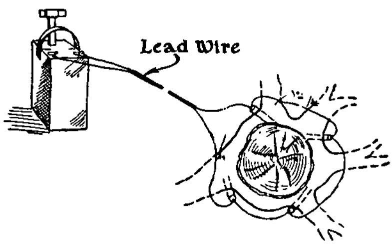


FIGURE 119.—A stump blast connected in series

from the machine immediately after each shot and keep them disconnected except when a shot is being fired.

f. Naked joints in the circuit must be protected against short circuits. To secure this protection, tape all joints that are likely to come in contact with moisture.

179. Connections.—*a.* When using a blasting machine make all connections in series. To do this, connect one wire from each charge to one wire in the next charge, and so on to the end until only the two end wires are left free. Connect these to the ends of lead wires. Figures 118 and 119 give examples of such connections.

b. Parallel circuits may be used when power or lighting circuits form the source for the detonating current. Figure 120 shows such a connection. The blasting machine is not designed for, and should not be used with, parallel circuits.

180. Testing a circuit.—To test a circuit with the galvanometer or circuit tester, touch the two lead wires to the two binding posts after all connections except those to source of power are ready for the blast. If the circuit is perfect, the needle will move along the scale. If the needle does not move, there is either a break or point of high resistance in the circuit. A slight movement of the needle may indicate a circuit which contains a point of high resistance.

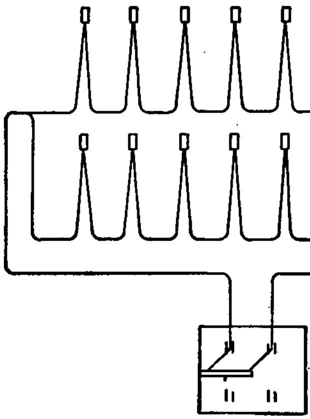


FIGURE 120.—Two separate series connected in parallel

181. Locating a break.—Make sure that the ends of the lead wire are separated and not touching anything. (See fig. 121.) Secure a piece of connecting wire, *N*, to end connection, *D*, of the circuit. The wire must be long enough to reach from joint, *C*, to joint, *D*. Hold the bare end of *N* against contact post, *L*, and connect contact post, *O*, either directly or through a second piece of lead wire, *M*, to joint, *C*. If the galvanometer now shows a circuit, the break is in the lead wires and they must be repaired. If it does not show a circuit, connect contact post, *O*, with each of the bare joints, *E*, *F*, *G*, and *H*, in succession. If, for example, in so doing, the galvanometer shows a circuit when *O* is connected with *F* but none when connected with *G* the break is between *F* and *G*. If the break is above the tamping, repair it. If it is below the tamping, handle the particular shot involved as a misfire. (See par. 189.)

182. **Computing resistance.**—*a*. The electric tetryl cap with 12-foot leads has a resistance of 1.5 ohms and requires a current of 0.4 ampere. The lead wire has a resistance of 2.541 ohms per 1,000 feet. To determine the resistance of a circuit,

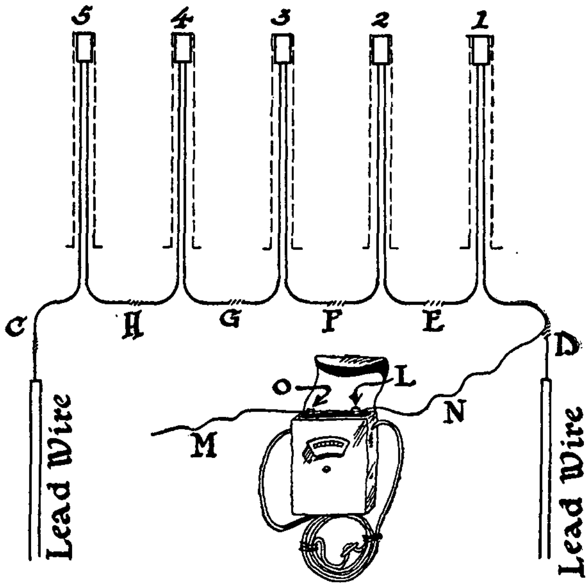


FIGURE 121.—Testing blasting circuit

multiply the number of caps in the circuit by 1.5 and add to this result the number of 1,000-foot lengths of lead wire multiplied by 2.541. Then add to this result the resistance of the blasting machine, 30 ohms.

b. The voltage of the blasting machine is 45. $E=IR$, where E=the voltage, I the current in amperes, and R the resistance in ohms. Hence $I=E/R$. Divide the voltage by the resistance, and if the circuit can be fired the resultant I must be over 0.4 ampere. Thus the total resistance in a circuit must not exceed 112.5 ohms if the blasting machine is used. In like manner the capacity of other sources of power can be computed with respect to requirements of the installed circuit.

183. Splices.—*a.* To splice time or instantaneous fuze or to splice instantaneous fuze to time fuze, cut the ends to be joined

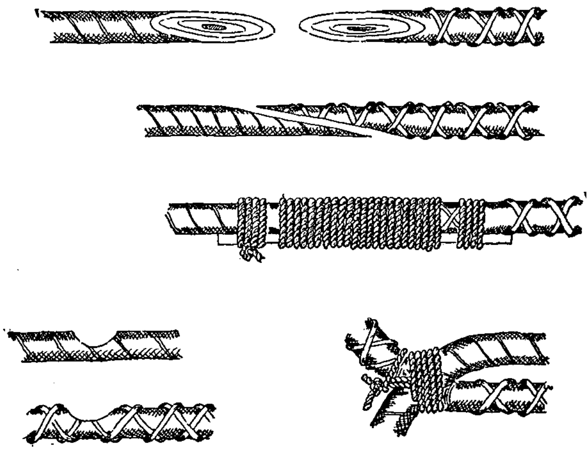


FIGURE 122.—Fuze splicing

obliquely. (See fig. 122.) Be careful that no powder falls out. Place the cut ends carefully on each other, dropping a few grains of powder between the ends. Compress the ends together and wrap the joint with friction tape. To make two

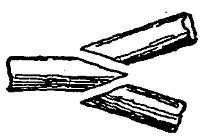


FIGURE 123.—Beginning of double splice

branches from a main, splice in the same way as above, cutting the fuze as shown in Figure 123.

b. To connect a branch of detonating cord to a main (see fig. 124), first drill priming hole completely through a block of T. N. T.; then, at right angles to first hole, drill through the block as many holes as there are branches, thread the main through the longitudinal hole, pass the branch lines through the block from side to side, and fasten by making right-angle bends at ends of cord.

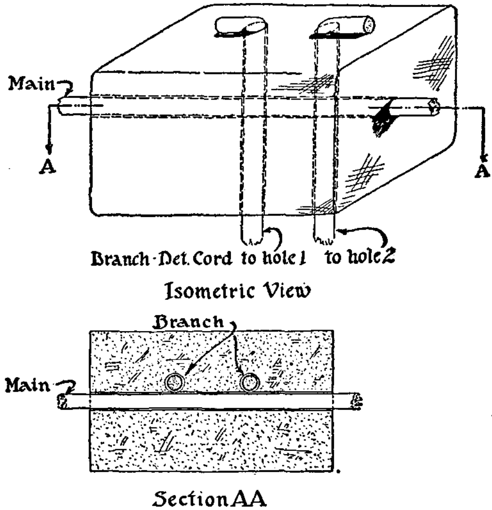


FIGURE 124.—Detonating cord spliced using a block of triton

c. To connect a branch of detonating cord to a main, the following procedure may be observed, but does not give as reliable results as that described in b above. First, slit the

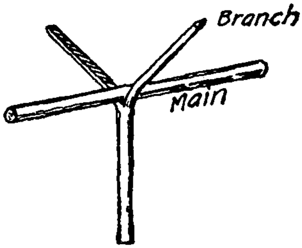


FIGURE 125.—Beginning splice with cord

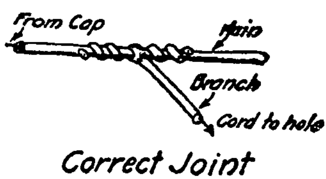


FIGURE 126.—Splice with cord complete

branch for a distance of about 8 inches with the cord slitter. Then place the split end of the branch as shown in Figure 125. Complete the splice as shown in Figure 126.

184. Induced detonation.—Induced detonation is secured by placing a blasting cap in a block of triton and detonating this by means of the mechanical shock in air from a charge detonated near by. It is of value in obtaining simultaneous detonation, and results are certain within distances as listed below. To obtain successful detonation by this method, the charge detonated sympathetically must contain a firmly seated open cap, the mouth of which points directly toward the initial charge. There must be no intervening object.

TABLE XXXII.—*Practical distances for obtaining induced detonation*

Initial charge	Distances in inches	Initial charge	Distances in inches
1 block triton	24	5 blocks triton	60
2 blocks triton	36	6 blocks triton	72
4 blocks triton	48	8 blocks triton	96

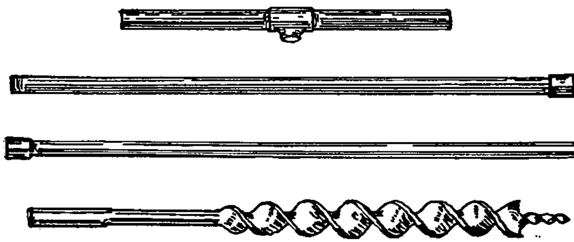


FIGURE 127.—Earth auger

185. Preparation of bore holes.—*a.* The pioneer equipment of the engineer company includes certain tools useful in explosive work. The earth auger shown in Figure 127 is used to

FIGURE 128.—Hand drill and drilling hammer

make bore holes in earth. The spoil is removed by periodically pulling up the auger and cleaning it. The drill and hammer shown in Figure 128 are used to drill holes in hard rock. The miner's spoon shown in Figure 129 is very convenient for enlarging bore holes and removing pebbles therefrom. Posthole diggers are useful for placing charges in soft earth.

b. In drilling bore holes water is poured into the hole, making a mud of the spoil, which acts as a lubricant. This mud

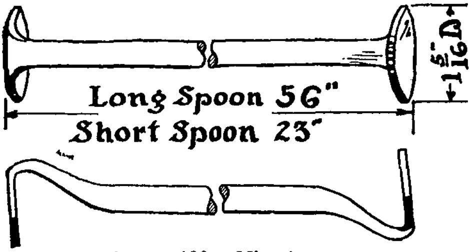


FIGURE 129.—Miner's spoon

must be removed. In shallow holes this is done with the miner's spoon.

c. After drilling a hole to the desired depth in hard material, it is sprung to form a chamber for the charge. To spring the bore hole, explode several small charges, one after the other, in the bottom of the bore hole until a chamber of the

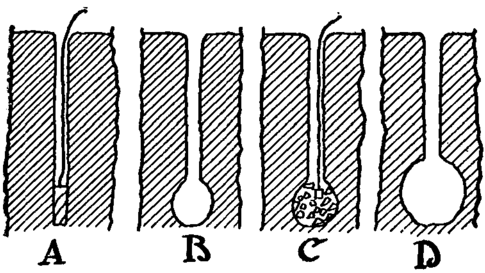


FIGURE 130.—Springing a drill or bore hole

desired size is obtained. (See fig. 130.) Ample time must be allowed between charges for the bore hole to cool.

186. Loading bore holes.—Slip the charge into the hole and press it into place with the tamping stick. Place the primer last. Begin tamping the hole with a small wad of dry paper. Then pour earth on top of this wad. Tamp this earth lightly. Then add more earth and tamp firmly, using a wooden tamping stick. (See figs. 131 and 132.) When loading with dynamite, in dry holes, always slit the cartridges (except the primer) just before placing them in the hole. This gives a more compact charge and results in greater efficiency. Rectangular blocks of triton must be broken up in order to place them in small drilled holes.

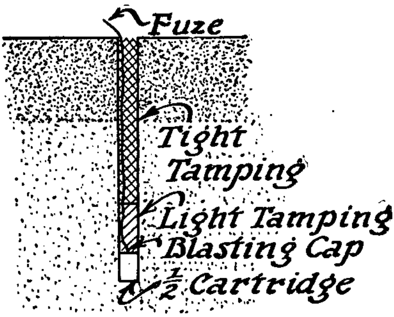


FIGURE 131.—Light tamping immediately over charge to protect cap, followed by heavy tamping

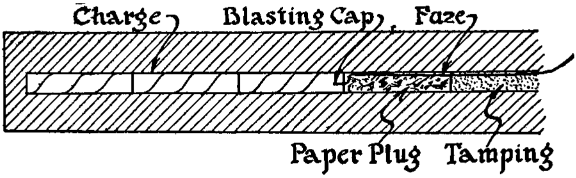


FIGURE 132.—Use of wad of paper serves as a safety indicator of where to stop in case tamping must be removed because of misfire

187. Tamping.—*a.* Tamping is the operation necessary to close a bore hole or otherwise confine a charge. The material used in tamping is called "stemming." Stemming should be free from stone and grit.

b. Water makes a fair tamping material, and in holes where the high explosive is covered with water further tamping may be omitted.

c. A wooden tamping stick should always be used. An old broom or shovel handle is ideal for small holes, while a straight sapling can be used for large and deep ones.

d. Tamping near the charge should be light and easy, increasing in power as the amount of earth between stick and charge increases. Full powered blows with a heavy stick should not be used, but preferably short, rapid blows. (See fig. 131.)

e. Various means of tamping are shown in a number of the figures illustrating the use of explosives. Ordinarily sandbags filled with earth can be used to best advantage.

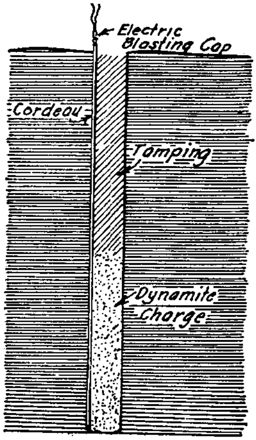


FIGURE 133.—Cordeau extending to bottom of bore hole

188. Firing.—*a.* Firing means the setting off or exploding of the blast. The actual operation of firing should always be done by the officer or noncommissioned officer in charge. He should not fire the charge until he is sure that it is properly loaded and tamped and that all persons or animals near by are protected.

b. If a blaster can not get under safe cover, he should always face the charge with his back to the sun, as this gives him a better chance to see and avoid flying missiles.

c. Near-by roads should be patrolled to see that no one approaches in the direction of the charge.

d. After a blast is fired the blaster should wait to allow falling rocks to drop and for the smoke and fumes to clear away.

e. When demolishing railroad rails, I-beams, and structural iron generally, place blasting machine, working force, and any observers under cover if possible or, if not, on the side on which the charge is placed, so metal fragments will be blown away from them.

189. Misfires.—*a.* When a misfire results the action of the blaster must be governed by conditions. When the electric caps and blasting machine are used, it is safe for the blaster to investigate immediately. This investigation should consist of a search for broken wires, faulty connections, short circuits, etc. The lead wires should be disconnected before beginning this search.

b. When caps and fuzes are used, the blaster should wait at least 30 minutes before investigating the charge and, when possible, should wait several hours in order to avoid the possibility of being injured by a "hangfire" or delayed explosion. If the charge is untamped, insert another primer and fire a second time. If it is tamped but is in soft ground, place another charge near by. Detonate this second charge, thus exploding the misfire.

c. It is always dangerous to attempt to remove the misfire, and every effort should be made to explode it by adjacent charges. When this is impossible, the tamping and charge should be removed very gently and carefully with the miner's spoon.

190. Mines and camouflets.—*a.* The destruction of an enemy's position, or a portion of it, so that an attack may be made with expectation of success is the primary object of underground warfare, which includes in addition defense against hostile mines. (See Chapter 2.) Surface works are attacked by mines and underground works by camouflets. A camouflet is a mine so charged that the destructive effect does not reach the surface. The explosion of a mine always reveals the position of the chamber by forming a crater at the surface, while experience has shown that the discharge of a camouflet is very difficult to locate. As an explosion shatters the ground within a certain radius of its center, it will destroy a part of the attacking works, as well as those of the opponent within that radius. This destruction of one's own galleries and the attendant shattering of the ground, always difficult to drive through, are serious handicaps. Mines are not exploded without careful consideration of the consequences.

b. Charges for mines and camouflets are carefully gauged to obtain the desired radius of destruction and no more. If undercharged, the destructive purpose of the explosion is not accomplished; if overcharged, it not only wastes the explosive but the consequent shattering or even cratering of the ground will unnecessarily hamper further advance. The determination of the size of the charge is based on four factors:

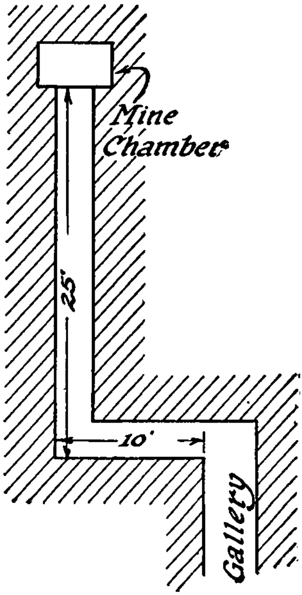


FIGURE 134.—Dog leg

(1) Kind of explosive used.

(2) Character of material in which charge is placed.

(3) Depth of mine.

(4) Results sought.

c. The charges for mines and camouflets may be placed at the end of attack galleries and tamped by a series of walls and sandbags, but preferably in specially excavated chambers. So far as possible, all mines are fired electrically. The size of the charge varies greatly, according to the work to be performed.

Probably the largest single charge used by the Allies in the World War was approximately 50 tons of ammonal.

d. An attack gallery is often given an offset consisting of two right-angled turns just before it reaches the point where a camouflet is exploded or countermining is expected. This feature is called a "dog leg," and is intended to prevent the explosion from destroying the main part of the gallery. The nearest angle of the dog leg should be at least 25 feet from the mine chamber and the offset should be from 6 to 10 feet. (See fig. 134.)

191. Effects of explosion.—*a.* It may be assumed as sufficiently exact for present purposes that charges of the same explosive develop total energies directly proportional to their weights. This energy is exerted in all directions in the compression of the surrounding medium. The maximum distance out from the center of the charge to which the explosion will destroy mine galleries is called the *radius of rupture, R. R.* The surface joining the ends of these radii is called the *surface of rupture.*

b. If the distance between the charge and the surface is less than the radius of rupture, the charge will blow out, forming a *crater.* This relief of pressure on one side shortens all radii of rupture which have a component in that direction, but does not appreciably affect those which have no such component. Hence when material is displaced the surface of rupture is ellipsoidal; when no material is displaced it is spherical.

c. The hole in the surface left by the blown-out material is called a crater. The determination of the crater which a particular charge in a particular place will produce, or what charge must be put in that place to produce the given crater, or where a given charge must be placed to produce a desired crater, are problems constantly arising in military mining.

d. Figure 135 shows a cross-section of a typical crater in earth. The position of the charge is indicated. *AB* is the surface of the ground; *CD* is the line of least resistance, commonly designated *L. L. R.*, or in the formula l; *DE* is the crater radius, and *CE* the radius of explosion. *VRR* is the vertical radius of rupture and *HRR* the horizontal radius of rupture. All the elements of the crater are reckoned with respect to the position of the charge and the opening of the original ground surface. This opening for level ground is similar in form to, and is approximainly the intersection of, the spheroid of rupture with the ground surface.

e. Craters are designated as *one-lined, two-lined,* etc., according as the diameter is once, twice, or three times the line of least resistance, *L. L. R.* A two-lined crater is also called a *common mine;* less than two-lined, *undercharged;* and more than two-lined, *overcharged.* As previously defined, a mine which does not break the surface is called a *camouflet.*

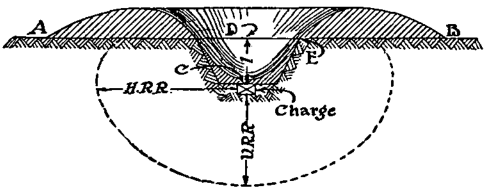


FIGURE 135.—Cross section of typical crater

f. A common mine is recommended for a road crater. Under no circumstances should a road crater be more than three-lined, for such craters have a very gentle slope and the road can readily be made passable again.

TABLE XXXIII.—*Constants for determining charges in one-half-pound blocks of triton and radii of rupture for mines*

Kind of material	Camouflet, 1-line	Undercharged, 1½-line	Common, 2-line	3-line	Remarks
Light earth	0.010	0.024	0.054	0.162	Multiply by l^3 for charge in one-half-pound blocks of triton.
Common earth	.012	.030	.066	.188	
Hard sand	.014	.038	.084	.252	Charges under 50 blocks, add 100 per cent.
Hardpan	.016	.046	.100	.300	Charges 50 to 200 blocks, add 50 per cent. Charges 200 to 500 blocks, add 25 per cent. Charges over 500 blocks, add 10 per cent.
Radius of rupture:					
Horizontal	1.0	1.4	1.7	2.5	Multiply these numbers by l for radius in feet.
Vertical	1.0	1.0	1.1	1.2	

NOTE.—Multiply above constants by $\frac{l^3}{2}$ and add percentage as indicated for charge in pounds of triton. Divide the charge in pounds of triton by the *relative strength* (see Table XXXI) for charge in pounds of other explosives.

192. Determination of charges a[redacted] radius of rupture of mines.—*a.* Table XXXIII gives a mea[redacted] of determining the necessary charge of one-half-pound blocks [redacted] T. N. T. for a crater of the desired type. First, select [redacted] desired depth in feet that the charge is to be placed. Taking this as the value of *l*, cube this value and multiply it by the proper constant given in the table. When the charge to be used is under 50 blocks, add ~~100~~ per cent. When the charge is over 50 blocks and under 200, add 50 per cent. When the charges are over 200 blocks and under 500, add 25 per cent. For charges over 500 blocks, add 10 per cent.

b. When using the above table judgment must be exercised in classifying the soil under the headlines given. Experience indicates that the table usually gives an excessive charge for the results indicated and that tabular charges can be reduced after experience has been gained as to character of the material in which the charge is placed and best manner of utilizing the explosive employed. In this connection it should be borne in mind that in military mining when explosives are plentiful an excellent maxim for the first charge is *do not spare the powder.* Every charge should be carefully observed and future economies made if practicable.

c. Determination of mine charges by diagram.—Figure 136 is a diagram for determining mine charges without the necessity for computations. To use this diagram, place a straightedge (such as the edge of a piece of paper) across the diagram so that it passes through the proper material factor, *K*, on the left vertical line and through the depth of charge, *L*, on the right vertical line. Place a pencil or pin point where the straightedge crosses the interior or index vertical line. Now, pivot the straightedge about the pin point until it passes through the type of crater, *C*, on the left vertical line. Now, read off the number of ½-pound blocks, *N*, of T. N. T. required for the charge, as shown at the point where the straightedge intersects the right-hand vertical line. These simple operations are illustrated upon the face of the diagram itself.

193. Electrical firing of mines.—*a.* In large mines two complete firing circuits should be installed, so that if one fails there will be another available. As the success of the mine depends very largely on the proper placing and tamping of the charge, the officer in immediate charge personally supervises all loading.

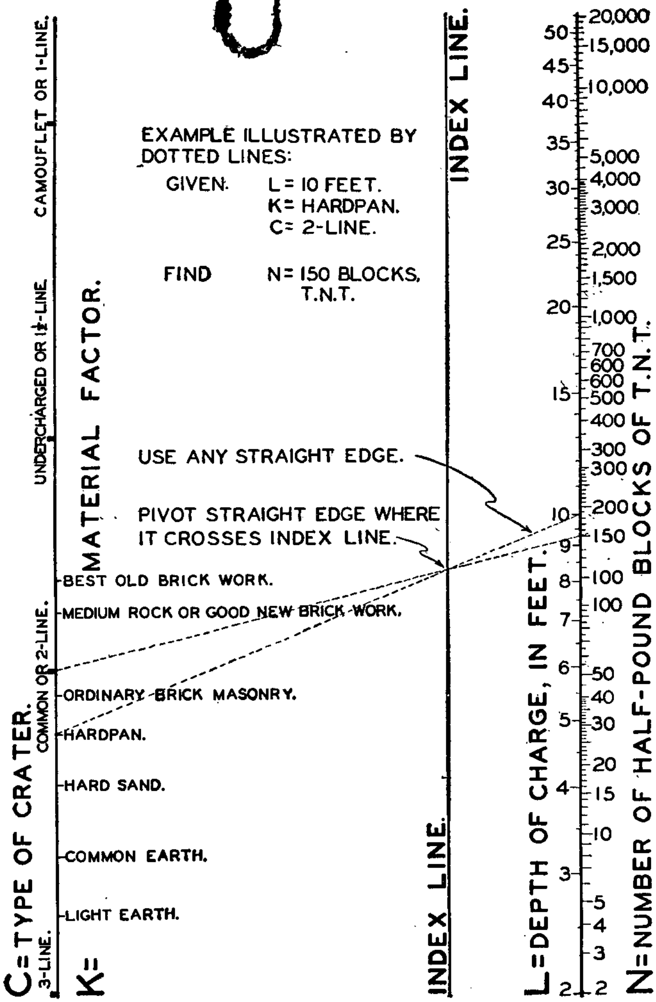


FIGURE 136.—Diagram for calculating mine charges, T. N. T. (the manner of using the diagram is illustrated by the dotted lines)

b. The bulk of the explosive for an individual mine is not taken to the mine shaft until the mine is to be charged. The material is carried into the trench by working parties and deposited at mine shafts or other places indicated by the officer in charge. Where large charges are used, special mine chambers are cut to the exact size required for the calculated cubic contents of the explosives, if practicable. In the event of the charge, solidly packed, not entirely filling the mine chamber, sandbags filled with clay or earth are used to fill it completely. The charge should be carefully packed in the chamber and primers inserted to best advantage, depending on size of charge and number of detonators used. Hand electric torches are used while at work. No candles or naked lights should be allowed in the vicinity. Lead wires are connected with the detonators and carefully hooked up out of the way, usually just under the cap sills. Plenty of slack must be allowed for these leads, so that detonators may not be jerked out of primers or charge. They are carried up to the dugout or trench from which it is planned to fire the mine.

c. The tamping should be very thorough. Sandbags filled with clay or earth are excellent stemming material. Tamping should be carried for approximately 20 to 30 feet from the charge; then leave an air space of perhaps 12 or 15 feet. Place sandbags for another 20 or 30 feet and continue with this alternate tamping and air spacing until the thickness of the tamping is not less than the horizontal radius of rupture. The tamping required will depend on the size of charge and other conditions encountered. For camouflets, if time allows, tamp to a distance of twice the calculated radius of rupture. Strengthen the tamping by pieces of timber, crossing each other diagonally, and with their ends securely jammed into the sides of the gallery. The air spaces should be approximately 20 per cent of the whole tamping. The tamping is done by a selected crew of experienced miners. Various devices are employed to keep the enemy guessing while loading the charge and tamping. In laying charges in clay the utmost quiet must prevail, and every precaution possible to insure this must be insisted on. The floors of the gallery should be covered with sandbags. Blankets can be hung at various places along the galleries to deaden noise. Miners must wear canvas shoes or work in their socks. Talking should only be allowed when necessary and then in as low tones as possible. Only the officer and necessary assistants should be allowed in the gallery at time of charging.

d. All connections must be thoroughly tested before charging, and if firing the mine is delayed, whenever it is decided to fire. The detonators, electric leads, and exploders are usually tested before being brought up to the trenches, but this is not always possible if underground fighting is in progress. The officers on duty in trenches must have an adequate supply of all electrical equipment on hand, together with testing apparatus, in order to be prepared for an emergency.

e. It is the usual practice to locate a magazine underground in some central position. A large supply of high explosive is maintained there in addition to all accessories for firing. Portable or mobile charges, generally from 40 to 50 pounds, and other high explosives are kept in these magazines or placed in various main galleries in safe places. These charges are made with primers and detonators in place and with 4 to 5 feet of safety fuze attached. In the event of breaking into enemy galleries or entrance by the enemy these mobile charges are immediately ready for use, and the fuze needs only to be lighted.

f. The most common mistake on the part of officers is to fire their mines too soon. Coolness and good judgment must be used. Mines already charged are frequently left for days or even weeks before firing. Care to prevent moisture or water reaching the charges must be taken. All detonators are very securely wired to the electric lead wires, insulated tape being then wrapped around connections, followed by liquid rubber solution liberally applied over the whole surface of tape. The electric leads are usually run out from reels, which admit of their being laid handily in the galleries. From the mouth of the shaft they are carried to the firing dugout and are hung up in a safe position until the mine is to be fired, when the leads are connected to the blasting machine. Two blasting machines are used, and both should be pushed down hard at the same moment.

g. Orders to load charges or fire mines are given by the responsible officer, and only in the event of an emergency are subordinates allowed to fire mines without orders.

194. Calculation of breaching charge.—*a.* The *radius of rupture* is that of a sphere within the surface of which a charge of explosive will completely shatter and displace all material.

The *radius of rupture* is designated by *R. R.*, or *R.* in formula below. (See also par. 191.) A *breaching charge* is a charge sufficient to completely rupture the object to which it is applied.

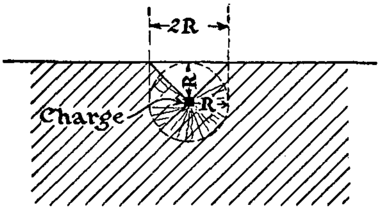


FIGURE 137.—Breaching charge

b. The following formulas give the amount of explosive required for a breaching charge:

(1) $N=R^3KC+25$ per cent for charges under 100 blocks.

(2) $N=R^3KC+10$ per cent for charges over 100 blocks.

N=Number of one-half-pound blocks of triton required.

R=Radius of rupture. Figure R as the depth to which disintegration is desired, measured from the center of surface of contact between the charge and the material to be destroyed.

K=A factor dependent upon the material blasted.

C=A factor dependent upon the location and tamping of the charge.

c. Values of K are as follows:

TABLE XXXIV.—*Values of material factor, K, for use in calculating breaching charges*

Material	R	K
Good masonry, concrete, rock	Under 3 feet	.625
	3 to 5 feet	.50
	5 to 7 feet	.438
	Over 7 feet	.375
Dense concrete, first-class masonry	Under 3 feet	.81
	3 to 5 feet	.65
	5 to 7 feet	.57
	Over 7 feet	.49
Reinforced concrete	Under 3 feet	1.25
	3 to 5 feet	1.00
	5 to 7 feet	.88
	Over 7 feet	.75

d. The value of *C* depends upon the location of the charge and the extent of the tamping. *C* equals 1.0 for charges placed in a bore hole and thoroughly tamped. For charges placed against a masonry wall but not tamped, $C=4.5$. Thorough tamping gives great economy in the use of explosives. The actual value selected for *C* will range between 1 and 4.5, and the selection of a proper value depends largely on the experience of the blaster. Figure 138 shows typical loadings with the proper values of *C* selected.

e. It must be understood that the above formulas give only approximate results. It will usually be found that the charges derived from them are adequate for the work desired. It

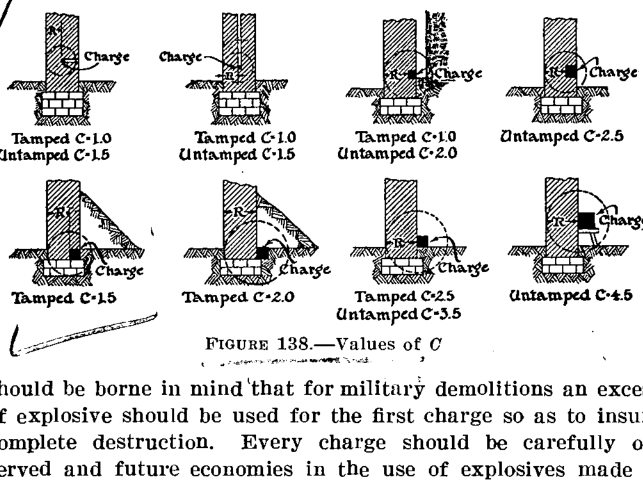


FIGURE 138.—Values of *C*

should be borne in mind that for military demolitions an excess of explosive should be used for the first charge so as to insure complete destruction. Every charge should be carefully observed and future economies in the use of explosives made if practicable. Similar remarks are applicable to the demolitions formulas given in paragraphs 197, 198, and 199.

f. Experience indicates that the most effective procedure for the demolition of reinforced concrete is to first shatter the concrete surrounding the reinforcing steel and then cut the exposed rods by a second series of charges.

195. Determination of breaching charges by diagram.—This diagram (fig. 139) is based upon the formula given in paragraph 194. To use the diagram, place a straightedge (such as the edge of a sheet of paper) through the material factor, *K*, on the left-hand vertical line and through the radius of rupture, *R*, on the right-hand vertical line. Place a pencil or pin point where the straightedge crosses the interior or

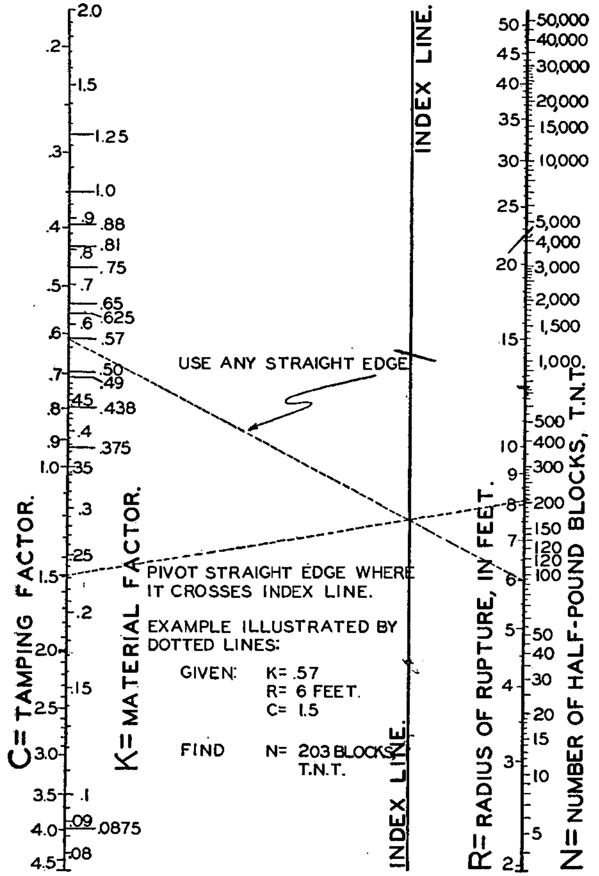


FIGURE 139.—Diagram for calculating breaching charges. T. N. T. (the manner of using the diagram is illustrated by the dotted lines)

index line. Now rotate the straightedge about the pin point until it passes through the tamping factor, *C*, on the left-hand vertical line. Now read from the right-hand vertical line the number of ½-pound blocks, N, of T. N. T. These simple operations are illustrated on the face of the diagram itself.

196. Shattering charges.—Shattering charges differ from breaching charges in that the material is only loosened and is not blasted away. Such charges are used in quarrying, as an aid to mechanical demolition, and in mining. The shattering effect extends from one and a half to two times the radius of rupture. Figure 140 shows a breaching charge to the left and a shattering charge to the right. Figure 141 shows a charge placed in a countermine to destroy a hostile drift. This charge must be kept at least 2 R below the surface to avoid shattering the surface of the ground.

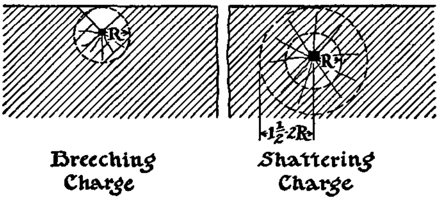


FIGURE 140.—Breaching charge to left, shattering charge to right

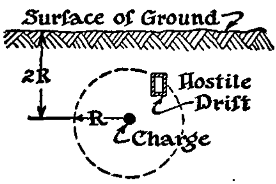


FIGURE 141.—Mine charge or camouflet

197. Distributed charges.—Distributed charges are charges placed in a continuous row or chain extending the entire length of the slab or wall to be destroyed. Such charges can be determined from the formula:

$$N=3.2\ R^2KC \text{ per yard}$$

where N, R, K, and C have the same significance as in paragraph 194.

For reinforced concrete, R should be taken as one and one-fourth times the thickness of the slab. Charges in chains or rows require about twice as much explosive as concentrated charges. Their use is the exception, and should be restricted to demolitions of thin slabs or walls. Since detonating cord is subject to deterioration which is not apparent to the eye, too much dependence should not be placed on distributed charges which ~~are to~~ be set off by detonating cord.

198. ~~Timber.—a.~~ Timber can be destroyed by ~~fire~~ and by cutting, as ~~well as by~~ explosives. Explosives are used principally when the demolition must be delayed until a given moment and then executed at once.

b. Single charges are computed as follows (see fig. 142):

(1) External charge:

$$N=\frac{D^2}{20}$$

N=~~Number~~ one-half-pound blocks of triton required.

D=Least diameter of timber in inches.

(2) Internal charges:

$$N=\frac{D^2}{125}$$

N and D have same values as in (1) above.

c. A ready rule for triton blocks is to allow 8 blocks per square foot of cross section for external charges and 1½ blocks per square foot for internal charges.

d. External charges should be placed so that adjacent blocks are in contact with each other and with the surface to be destroyed. It is advantageous to place triton blocks with their long axis perpendicular to the plane of the section to be cut. It is important to concentrate the charge and assure complete detonation. For the sizes of timber usually encountered, girdling is unimportant and can not be effected without sacrificing the considerations enumerated above.

e. The above formulas should be used for cutting piling. When practicable, an external charge should be placed below water level, as water acts as a tamping agent. The charge may be attached to a board, shoved down to the proper depth and the board then lashed in place.

199. Steel.—*a.* Bessemer steel crystallizes, breaks, and throws its fragments away from the explosive. Open-hearth steel tears and may throw fragments in any direction. These fragments are frequently large and may be thrown with force enough to carry them from 400 to 1,000 yards or more. Extra precautions must be taken to shield the firing detachment.

b. For the purpose of computing the untamped charges required to destroy I-beams, built-up girders, columns, etc., the following formula may be used:

$$N = \tfrac{3}{4}\ A$$

where N equals number of one-half-pound blocks of triton required, and A equals area in square inches of the cross section of the steel member.

c. To cut a steel member, place along one side of the desired line of rupture a charge of triton. The blocks should be in

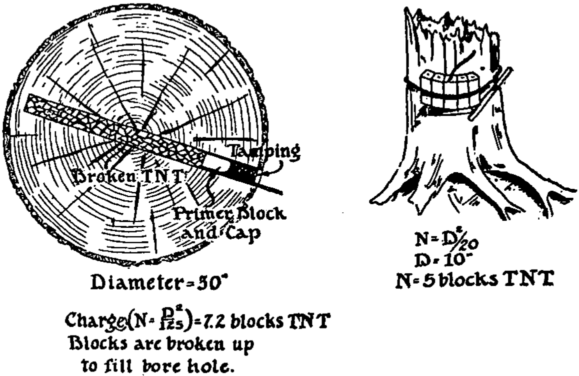


FIGURE 142.—Charges for cutting timber

contact with each other if practicable. If the form of the member is such that the charge must be distributed on opposite sides, the opposing portions should be offset so that their action will combine to produce shear. The portions of the charge, if directly opposed, will tend to neutralize each other. Built-up members present special difficulties in that they are frequently of very irregular form and that it is difficult to secure close contact between the explosive and all plates. The above formula is applicable provided the difficulties can be overcome with the charge indicated; otherwise the charge must be increased. Experience indicates that if a tamping of moist clay is employed, charges may be reduced 50 per cent provided the explosive acts upon the entire section to be cut.

d. Railroad rails can be cut by one or two blocks of triton tamped with loose earth.

e. When the destruction of a reinforced concrete structure involves a two-phase demolition in which the concrete is first shattered and removed, after which the reinforcing bars are cut, the following formula for cutting the bars should be used:

$$N=2A$$

N and A have the same significance as above. In general, each bar must be charged separately. In some cases, when the bars are small, one block, placed between two bars, may suffice to cut both.

200. Concrete, plain and reinforced.—*a.* The destruction of plain concrete structures presents no special difficulty. The members of such structures must necessarily be subjected only to compressive stresses. It is necessary only that the charges used shatter the concrete and displace some of the shattered material. The formula in paragraph 194 with appropriate values for K and C will give adequate charges.

b. Unless very large charges, much greater than found by the formula in paragraph 194, are used on reinforced concrete, the result will be to shatter the concrete and to leave the reinforcing practically undamaged. If plenty of time is available and explosives must be conserved, it may be desirable in the demolition of certain reinforced concrete structures to first shatter and remove the concrete surrounding the reinforcing steel and then cut the exposed rods by a second series of charges. However, by attacking that part of the concrete which is under compression where the bending moment is maximum and where, also, the reinforcing is least, the structure will probably fall, due to its dead load, without having the reinforcement cut by further charges. The charge should be placed so that it will shatter the concrete in compression and that the force of the explosion will act in the direction of the bending caused by the load, where such bending action is present. Thus, in the case of a simple reinforced beam or girder, supported at its ends, a charge on the top of the beam or girder at its midpoint will blast away a part of the concrete in compression and the structure will fall of its own weight.

201. Reduction from T. N. T. to other explosives.—Determine the number of one-half-pound blocks of T. N. T. required, N in all formulas given, and divide this figure by 2, thus obtaining the number of pounds of T. N. T. to be used. Divide this value by the relative strength of the explosive to be used, given in Table XXXI, and the result will give the required number of pounds of the explosive.

Section IV

THE DEMOLITION PROJECT

202. Purpose and objects.—The purpose of military demolitions is to destroy or make unserviceable any object in the theater of war, the preservation of which would be unfavorable to our own troops or favorable to the enemy. Objects protected by international agreement or the laws of war, however, are not destroyed.

203. Methods.—*a.* Demolition may be accomplished by fire, water, mechanical means, artillery fire, or by charges of explosives. The demolitions herein treated do not include those made by fire, water, and mechanical means, as they are simple and too varied to permit detailed description. Neither does it include demolitions accomplished by artillery. When it is possible to place charges of explosives judiciously, the results are more effective, more certain, and more economical than those secured by artillery fire.

b. Deliberate demolition will be employed when ample time is available to make thorough reconnaissance and careful preparations. Economy of material is of considerable importance, and partial failure may not be serious, as the work may in many cases be completed in a second series of operations.

c. Hasty demolition will be required when ample time is not available to make careful preparations. In this form economy of material is of secondary importance, as failure to accomplish the mission is unpardonable. However, in all cases, common sense and good judgment should be used, since the question of supply, if not cost, makes it important to avoid waste.

d. Structures should be attacked at their most vulnerable points, where the minimum of demolition will involve the maximum effort for repair. For example, on a railroad it is more effective to demolish a large bridge than to expend the same amount of labor in demolishing the track.

204. Points for hasty demolition.—For hasty demolition and for cutting girders, etc., the following points should be remembered:

a. The blocks of triton or other explosive used must everywhere be in contact with each other and with the object to be destroyed.

b. The charge as a whole must be firmly fixed to the object and, if possible, tamped..

c. All fuzes or lead wires and detonators must be properly arranged.

d. The largest portion of the charge should be nearest the greatest cross section.

e. Use plenty of explosive.

205. Assuring detonation.—*a.* Alternate methods of firing charges should usually be installed. Operations in the recent war have shown the danger of long leads for surface demolitions, as they are often cut by shell fire, and electrical firing should be used only when essential; e. g., for simultaneous cutting of several girders of a bridge.

b. Firing by time fuze is the best method to adopt during a retreat, as once the charge is placed a box of matches is sufficient to detonate it.

206. Objects subject to demolition.—Structures and objects subject to demolition include highways, railroads, bridges, viaducts, tunnels, railway rolling stock, water tanks, buildings, telegraph and telephone lines, artillery, ammunition and explosives, supplies, dugouts and shelters, machine-gun emplacements, command posts, observation posts, barbed-wire entanglements, and other artificial obstacles and fieldworks generally.

207. Roads.—*a.* If the object is to delay the enemy temporarily, roads may be rendered impassable by flooding when practicable; by felling trees across the road; by placing abatis or other obstacles; by placing barricades in the streets where a road passes through a village; or by disabling the important bridges.

b. Road craters form efficient obstacles if they are made at points where the maximum dislocation of traffic is produced. Where deviation of traffic is possible, road craters are worthless. Consequently, they should be made in embankments, cuts, fills, causeways over marshy ground, at crossroads, or in villages, if no side roads are left open. (See fig. 143 and par. 192.)

c. As traffic must be maintained during the period of preparation, tunneling under the road will be necessary and may require one or two days' work, but for hasty demolition it is often possible to utilize culverts or existing dugouts under the roadway. If the crater is to be in the vicinity of a village, a tunnel may be driven from a cellar or well, but if these are not available a small vertical shaft should be sunk at the roadside and a chamber driven from the bottom. The shafts and tunnels will generally require timbering. (See figs. 144 and 145.)

d. Charges can be determined as explained in paragraphs 192 and 194.

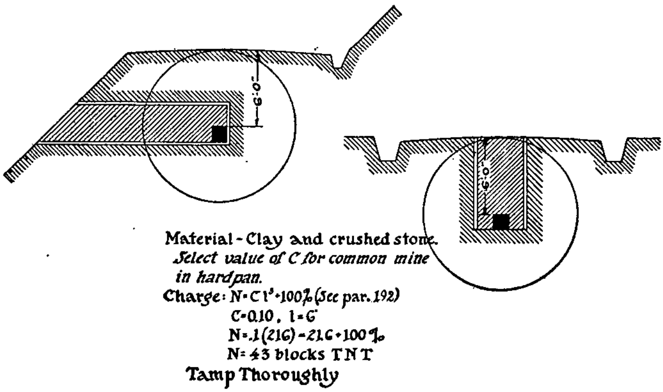


FIGURE 143.—Road mine

208. Bridges.—*a.* Bridges are natural objects for attack, as reconstruction is usually slow. As the difficulty of repairing bridges when the abutments are destroyed is much greater than when they are intact, the object of any bridge demolition, time being available, should be to destroy the approaches and abutments as well as the bridge itself. This is especially important if a detour is impossible.

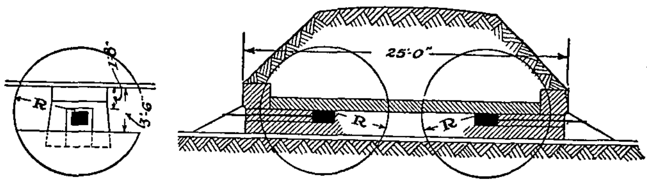
b. The best way to attack a bridge approach or abutment is to place a large charge under the roadway close behind the abutment. A tunnel may be driven if the approach is an embankment; otherwise a shaft should be sunk by the roadway and a chamber driven from it to the center of the road.

c. Charges may be computed as explained in paragraphs 192, 194, and 195.

d. Various types of bridge demolitions are as follows:

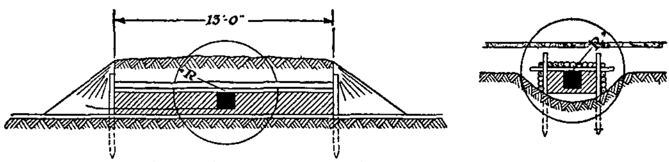
(1) Light wooden bridges may be cut down with saws or axes; sprinkled with inflammable oil and burned; pulled from the abutments with tackle or demolished with explosives.

(2) Ponton bridges may be hastily disabled by cutting loose the center bays and destroying or sinking as many boats as possible.



Material-Concrete with earth and crushed stone over-burden.
Charge $N = R^3KC + 25\%$
$R = 5'$; $K = 0.65$; $C = 1$
$N = (5)^3(0.65)(1) + 25\% = 81.3 + 20.3$
$N = 102$ blocks TNT
Tamp thoroughly.

FIGURE 144.—Destruction of concrete culvert



Material-Timber and earth.
Charge-$N = R^3KC + 25\%$
$R = 3'$; $K = 0.375$; $C = 1$
$N = (3)^3(0.375)(1) + 25\% = 10.13 + 2.53$
$N = 13$ blocks TNT
Tamp thoroughly.

FIGURE 145.—Destruction of timber culvert

(3) Suspension bridges may be destroyed by cutting the main chains or cables at the saddles over the piers, if these points are readily accessible, or at the anchorages.

(4) Masonry bridges of all kinds can be effectively destroyed only by using explosives. Except for reinforced concrete bridges, it is feasible and desirable, when time is available, to cut deep chambers into the masonry, place the charges therein,

and tamp them thoroughly. Charges in one-half pounds of triton for masonry structures can be determined by formulas given in paragraph 194 and from Figures 136 and 139.

(5) A masonry arch may be demolished by placing charges of explosive along the haunches or at the crown. If time is very limited and the roadway need not be kept open, a charge or charges placed on the roadway form an effective method of demolition. A relatively large amount of explosive will be required, particularly if there is no time for tamping. The demolition is generally as complete as when charges at the

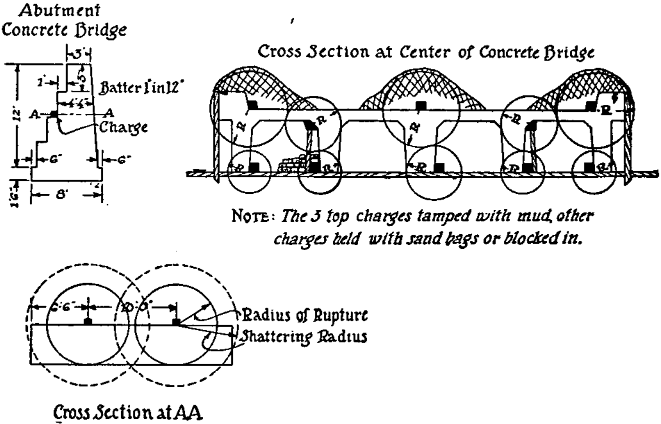


FIGURE 146.—Method of placing charge on concrete bridge

haunches are used. In the case of a reinforced concrete deck girder span the charges should be placed at the mid-point of the span, so that the dead weight will cause it to fall when the concrete is shattered. If the charges are to be placed some time prior to the actual destruction of the span and the roadway must be kept open in the meantime, they must be located underneath the span. Such placing of the charges frequently takes a great deal of time. Care must be exercised to place the various charges so that the concrete in compression is shattered. An equally effective and much more rapid method is to place the charges, tamped or untamped, as circumstances indicate, on the roadway over the beams. Figure 146 shows a girder span prepared for demolition by a combination of the two methods outlined above.

(6) The most complete demolition of a reinforced concrete arch bridge is obtained by attacking the piers. In the case of a multiple arch bridge, the destruction of an intermediate pier causes both of the adjacent arches to fall. Because of the massive section of a pier, large charges are required unless the pier is recessed to receive the charge. Sometimes piers are made hollow and filled with sand. It is only necessary in such cases to cut a hole through the shell and detonate a suitable tamped charge placed deep in the filling to completely destroy the pier.

(7) From the standpoint of economy of time and explosive and completeness of destruction, the best method to be followed in the demolition of a multiple span reinforced concrete deck girder bridge is to attack the supporting bents or piers.

(8) To destroy pile bridges or similar structures below the water line, compute the charge, bind it securely to a board, thrust the board down beside the pile until the desired depth is reached, and lash board against the pile and fire.

(9) (*a*) To destroy steel truss or girder bridges on masonry piers it will often be sufficient to demolish the piers, if they are high, as the trusses or girders in falling will be rendered worthless.

(*b*) However, it is frequently easier to cut the bridge members than it is to demolish the abutments and piers. If possible, it is preferable to cause the simultaneous destruction of at least one abutment, one pier, and a span. (See figs. 147, 148, 149, 150, 151, and 152.)

(*c*) The main trusses should be cut near the abutments, and care should be taken in placing the charges to facilitate the dropping of the span.

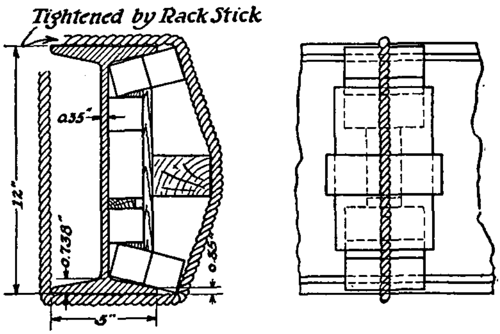
(*d*) Where a bridge has several spans, the longest one should be destroyed. If the spans are of equal length, either destroy the one where the stream is deepest and swiftest or the one nearest the enemy.

(*e*) Charges for cutting steel must be firmly placed against the members to be cut and held in place by boards, wire, or wedges.

(*f*) In case of emergency concentrated charges of high explosive may be placed in contact with the tension members of the chords.

(*g*) Where bridges have been demolished by the enemy, careful search should be made for delayed action or contact mines on either side of the abutments, as these mines are sometimes placed by the enemy with the object of causing casualties when the construction of new abutments is begun.

(10) The engineer officer will have to exercise careful judgment in determining just how much of the bridge must be demolished to cause the enemy the necessary delay. The extent of demolition necessary depends upon the nature of the construction, its height and span, the nature of the approach, and whether or not there exists an easily accessible approach in the vicinity for a temporary bridge. He will frequently be con-



$$12'' \times 0.35'' = 4.20\,\square''$$
$$2(5.00-0.35)\left(\frac{0.35+0.738}{2}\right) = 5.06\,\square''$$
$$\text{Total} = 9.26\,\square''$$
$$\tfrac{3}{4} \times 9.26\,\square'' = 6.94 \text{ blocks.}$$

Charge 7 blocks TNT

FIGURE 147.—Destruction of steel I-beam, showing calculation of charges and wedging

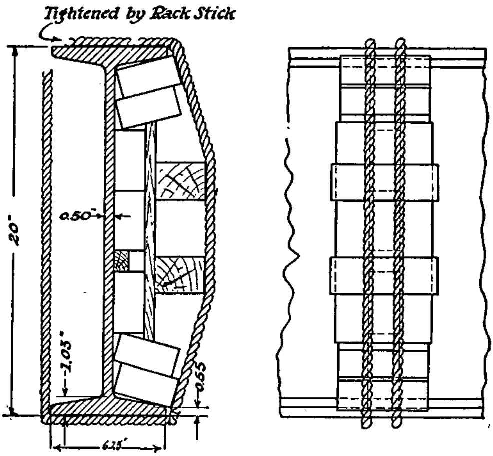
fronted with the problem of whether to destroy 2, 3, or possibly more bays. This decision will depend upon—

(*a*) The tactical situation (how long the enemy must be delayed).

(*b*) Possibilities of rapid reconstruction (whether or not the enemy may use the remaining piers if only the spans are destroyed).

(*c*) The amount of time and material which will be required to construct, in the vicinity, a temporary bridge over the obstacle.

(*d*) The possible reconstruction of the bridge for use by his own forces. As a general rule, it may be stated that demolitions should be of such extent that it would take the enemy longer to repair the damage than to construct a new temporary bridge. Destruction of greater extent than this is usually a waste of explosives. If it is carried only to the point where it would take the enemy just as long to repair the damage as to make a temporary structure, it would be to his advantage



$$20'' \times 0.50'' = 10.00\ \square''$$
$$2(5.75 - 0.50)\left(\frac{0.55'' + 1.05''}{2}\right) = 9.08\ \square''$$
$$\text{Total} = 19.08\ \square''$$
$$\tfrac{3}{4} \times 19.08\ \square'' = 14.31 \text{ blocks}$$
Charge 15 blocks TNT

FIGURE 148.—Destruction of steel I-beam, showing calculation of charges and wedging

to choose the former procedure because the resulting bridge would usually be stronger and more reliable.

209. Railroads.—*a*. (1) Railroad tracks may be temporarily disabled by distributing men along a section of the line and overturning it, preferably at an embankment or fill, or the fish-plates may be removed at one end, a heavy chain fastened to the track, and the entire track pulled up with a locomotive. The ties may then be loosened from the rails, piled, and burned. The rails may be thrown on the fire and twisted while

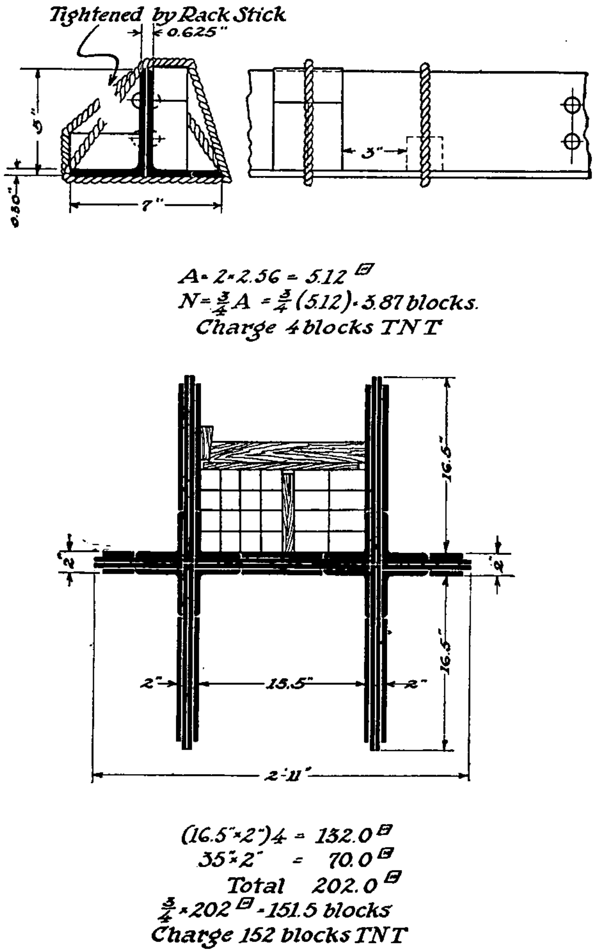
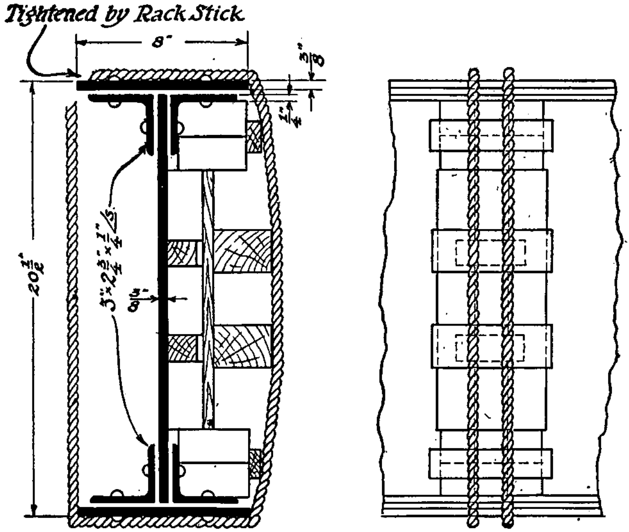


FIGURE 149.—Destruction of built-up girders, showing calculation of charges and wedging



$(20\frac{1}{2}'' - \frac{3}{4}'') \times \frac{3}{8}'' = 7.41\,\square''$

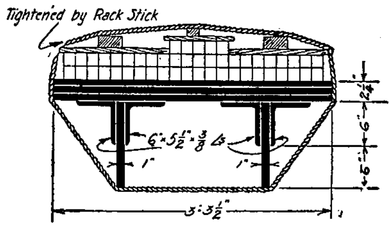
$8'' \times \frac{3}{8}'' \times 2 = 6.00\,\square''$

$(3'' + 2\frac{3}{4}'') \times \frac{1}{4}'' \times 4'' = 5.75\,\square''$

$\text{Total} = 19.16\,\square''$

$\frac{3}{4} \times 19.16\,\square'' = 14.37$ blocks

Charge 15 blocks TNT.



$39\frac{1}{2}'' \times 2\frac{1}{4}'' = 88.88\,\square''$

$12'' \times 1'' \times 2'' = 24.00\,\square''$

$(6'' + 5\frac{1}{2}'') \times \frac{3}{8}'' \times 4 = 17.25\,\square''$

$\text{Total} = 130.13\,\square''$

$\frac{3}{4} \times 130.13\,\square'' = 97.6$ blocks

Charge 98 blocks T.N.T.

FIGURE 150.—Destruction of built-up girders, showing calculation of charges and wedging

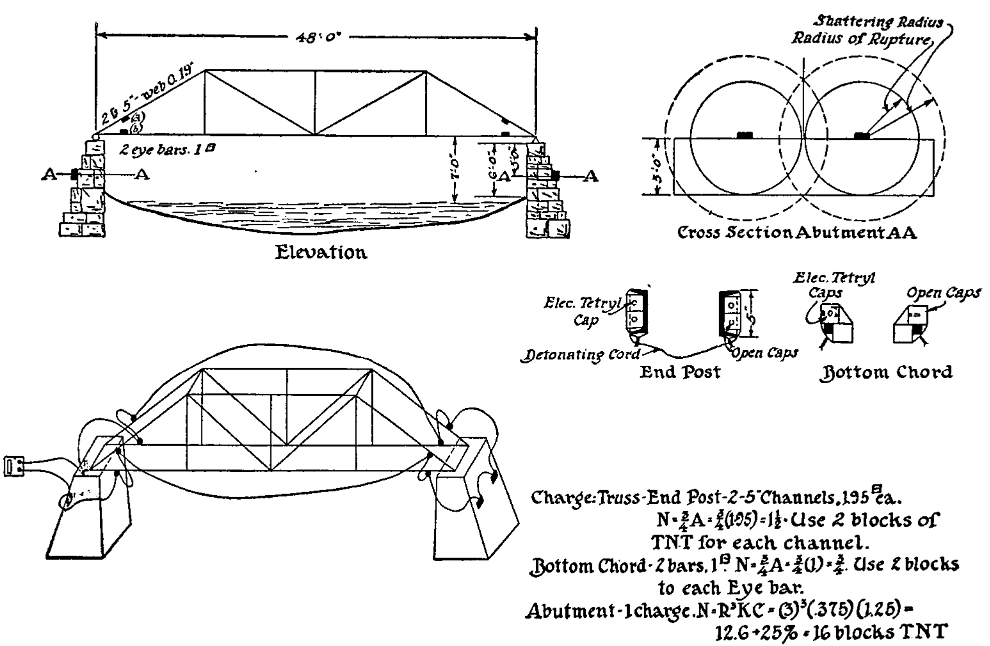


FIGURE 151.—Steel truss bridge prepared for demolition

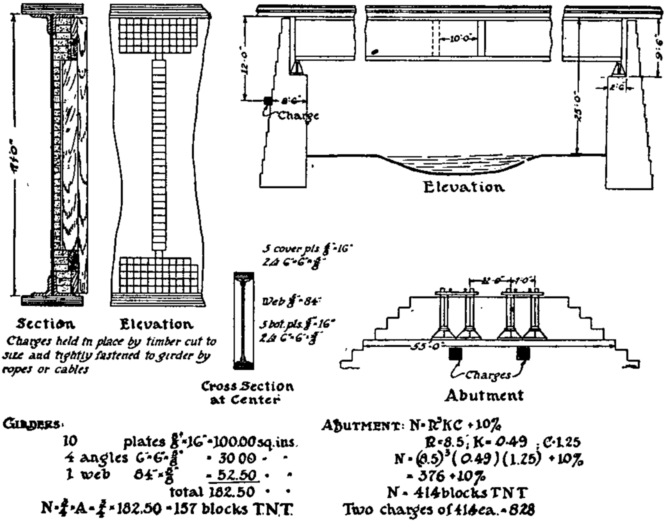


FIGURE 152.—Steel-girder railroad bridge prepared for demolition

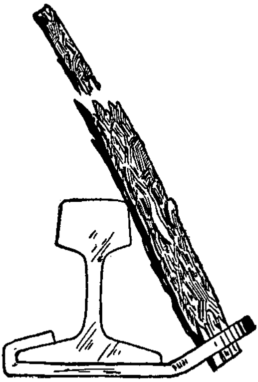


FIGURE 153.—Lever for twisting railroad rails

hot. Figure 153 illustrates a lever for twisting railroad rails. If the demolition is made on a curve, the repair of the track will be more difficult, as curved rails are harder to replace than straight ones.

(2) Trains may be wrecked or delayed by removing rails or by cutting them with high explosives and camouflaging the break.

(3) A considerable extent of track may be demolished in a short time by employing a squad of 8 men and a push car loaded with high explosives, detonators, fuze, and wire. The car is pushed by 2 men while 2 men prepare the charges, detonators, and fuzes, and hand them, together with the necessary wire, wedges, etc., to 2 men walking beside the car, who properly place, bind, and tamp them. Two men follow at a distance of 250 yards to detonate the charges.

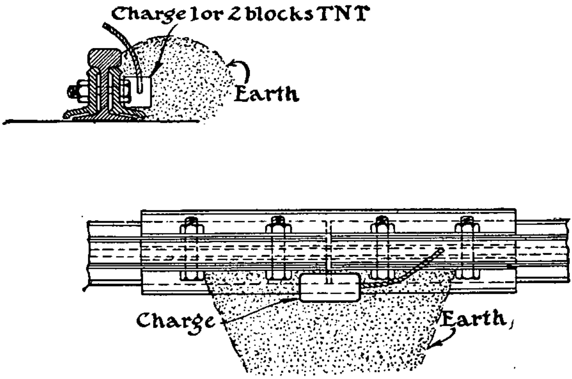
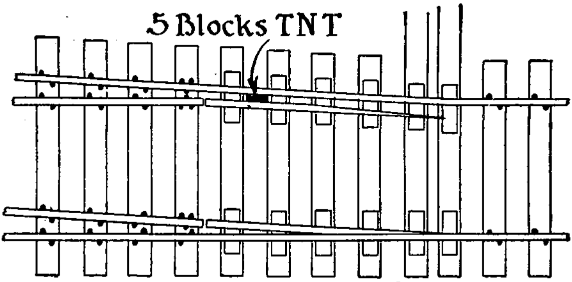


FIGURE 154.—Charge for destroying railway tracks

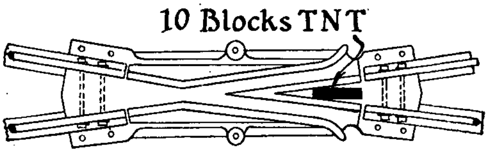
(4) If two charges are used to cut out a section of rail, they should be placed on opposite sides, at a distance of about 2 feet from each other, to gain a shearing effect.

(5) Figures 154 and 155 show methods of placing charges. One or two blocks of triton, tamped with loose earth, will break railroad rail. (See par. 199.)

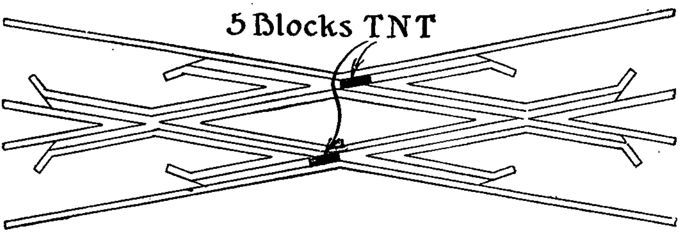
b. Blocking a tunnel effectively interrupts railroad traffic. Arrangements may be made for a head-on collision at the center of the tunnel between a car or locomotive and a moving locomotive or the tunnel may be demolished by placing explosive charges along the haunches for a distance of 50 to 60 feet from the entrance. The charges should be placed well inside the tunnel lining; they should be well tamped and spaced at intervals equal to twice the line of least resistance.



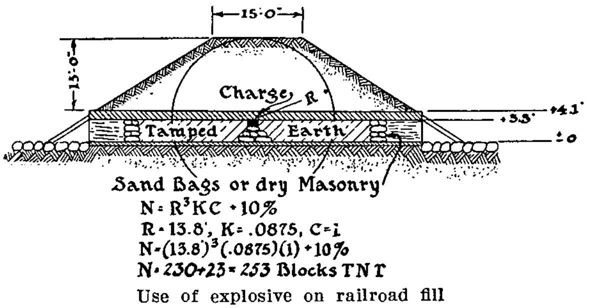
Use of explosive on switch points



Use of explosive on frogs



Use of explosive on crossings



Use of explosive on railroad fill

FIGURE 155.—Typical railroad demolitions

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c. To demolish rolling stock, the same parts on all locomotives and cars should be destroyed so that parts may not be interchanged. To accomplish the task thoroughly it is advisable to detail men to destroy definite parts.

(1) Two blocks of triton will break a reverse lever or side rod.

(2) Three blocks will break a cylinder.

(3) To break a driver, place 3 blocks of triton near the bearing spring.

(4) If the engine is cold, 3 blocks of triton may be placed in the boiler.

(5) A tender may be destroyed by exploding 3 blocks of triton in the bottom of the tank.

(6) A water tank may be ruined by placing a charge inside if it is filled with water, as the force of the explosion will cause the joints to leak. If the tank is empty, 4 blocks of triton may be placed outside at any point near the bottom so as to cut a hole, thereby rendering the tank useless.

210. Telegraph and telephone lines.—*a.* Telegraph and telephone lines may be temporarily disabled by cutting or grounding the wires. If there is a lineman in the party, a section of the wire may be cut out and replaced by wire of low conductivity but of the same gauge so as not to be detected by the eye.

b. Telegraph and telephone lines can be completely destroyed by cutting down and burning or demolishing the poles and cutting the wires.

211. Frame buildings.—Lightly constructed frame buildings can be demolished by closing the doors and windows and exploding a concentrated charge on the ground floor equal to from one-quarter pound to 1 pound of triton per cubic yard volume of the first story. A 4-room cottage may require from 14 to 28 blocks, depending upon the class of structure.

212. Wells.—A well or cistern may be destroyed by placing an explosive charge in a shaft from 6 to 12 feet from the well and at a depth of 10 to 15 feet from the surface, or if the ground is soft a bore hole may be made near the edge of the well and loaded with explosive. If neither of these methods is practicable, a concentrated charge of high explosive may be suspended halfway down the well and exploded.

213. Artillery.—*a.* (1) A gun may be temporarily disabled by opening the breech and setting a block of triton against the hinge, then partially closing the breech and exploding the charge.

(2) A 3-inch gun may be effectively destroyed by placing 5 blocks of triton inside the bore close to the muzzle. The muzzle should then be filled with clay and well tamped and the charge exploded. By this method of demolition, pieces of the gun are likely to be blown 1,000 yards away, and care must be taken not to cause casualties among the demolition parties.

b. (1) Thermit, a mixture of powdered aluminum and hematite ($2Al+Fe_2O_2$), may be used for the disabling of artillery and in many other cases where the destruction of metallic objects is required.

(2) When thermit is ignited its temperature rises to 5,000° F., and the operation is intended to form a lump of steel in the

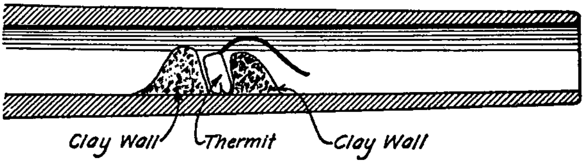

FIGURE 156.—Thermit used to destroy bore of gun

bore or to fuze the breechblock to the gun. The operation is easy to perform and there is no danger of explosion.

(3) If the breech gear can not be operated, the gun should be elevated at about 5° and a wall of clay built inside the bore at arm's length from the muzzle. A canvas bag containing a mixture of 20 pounds of thermit and 3 ounces of carbon dust, into which a spoonful of ignition powder, furnished by the manufacturer, has been inserted, is placed against this wall of clay. A second wall of clay is then built between the charge and the muzzle and against the charge. The charge is ignited by means of a fuze leading over the outer clay wall. (See fig. 156.) When the molten metal has cooled to a bright red, water should be thrown on it. The operation requires from 5 to 10 minutes, and should result in a lump of high carbon steel fuzed into the bore which can not be removed with chisels.

(4) If the breech gear is intact, the gun should be elevated, the thermit ignited in the powder chamber, and the breech closed. This will result in the breechblock and the gun being fuzed together.

214. Unexploded shells and bombs.—*a.* Unexploded shrapnel, high-explosive and gas shells, aerial and gas bombs, and grenades found on the field should be destroyed under the supervision of an engineer or ordnance officer.

b. If the projectile is in a trench or shell hole where fragments may not be projected a great distance, it should be destroyed without handling; otherwise it must be moved to a specially prepared trench which should be at least 6 feet in depth and narrow, so that fragments will be projected vertically rather than horizontally. Shells exploded on the ground surface without tamping will send fragments 1,000 yards.

c. Shells must be handled carefully. They should be carried on improvised stretchers and jolting must be avoided.

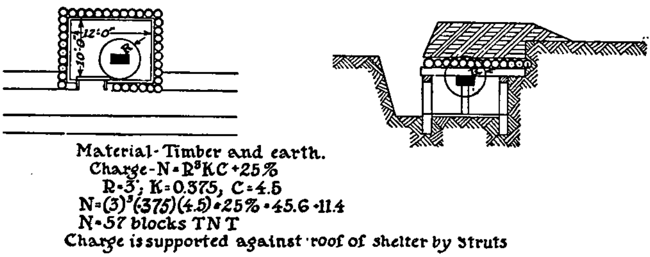

FIGURE 157.—Destruction of splinter-proof shelter

d. Projectiles weighing 200 pounds or more must be exploded singly. Where many shells are to be exploded they should be collected into lots of 200 pounds and each lot destroyed separately. The projectiles should be placed in a row and in contact so that the explosion of one will explode the entire lot. In all cases they should be covered with earth or filled sandbags. Traffic must be stopped within a radius of 500 yards, and a splinter-proof shelter at 150 yards must be available for the demolition party.

e. Gas shells and bombs should be handled the same as other projectiles except that shells of 100 pounds should be exploded singly. The gas cloud from a shell of this size will not be dangerous at 500 yards. Holes or trenches in which gas shells have been exploded must be filled, and gas masks worn during the work.

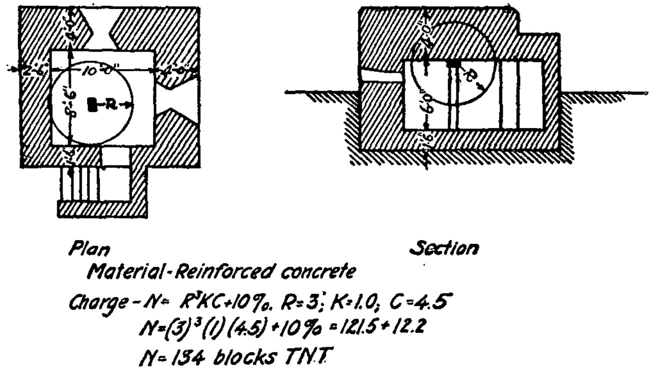

FIGURE 158.—Destruction of concrete cover

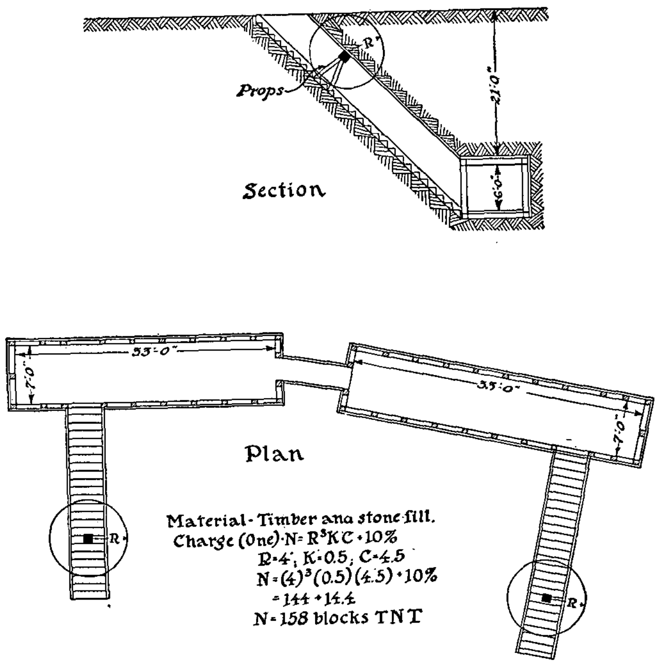

FIGURE 159.—Destruction of bomb-proof shelter

f. Boxes of enemy explosive must be opened and carefully examined, as detonators and hand grenades may be distributed through the explosives with the object of causing casualties.

215. Demolition plans.—It is the duty of the engineer officer on the staff of a commanding officer of troops to prepare plans for the demolition of the structures which should be destroyed in case of a retreat. In this connection plans should be drawn up to include the demolition of bridges, railroads, canals, defensive structures, roads, etc., which would be of assistance to the enemy. In some situations these structures should be prepared for demolition at the earliest opportunity, and at the first signs of a probable retreat charges should be placed and the necessary orders to provide for firing issued. (See figs. 157, 158, and 159.)

216. Wire entanglements.—*a.* Passages through belts of wire may be cleared by wire cutters, tanks, artillery fire, and explosives.

b. The infantry is equipped with wire cutters and will normally breach the belts of wire in their attacks. Engineers may assist in special conditions where special appliances are required.

c. A single line or chain of triton blocks placed end to end and touching, detonated at a single point, has cleared gaps 10 yards wide in double-apron wire. The chain should be placed beside and not between pickets.

217. Bangalore torpedoes.—A Bangalore torpedo consists of a section of gutter pipe or other similar casing filled with a high explosive and is used for making a breach in a barbed-wire entanglement to permit the passage of infantry. By observing the following precautions, successful results can be obtained.

a. Make them handy, not cumbersome; short, not long. (Four feet long is sufficient for one depth of double-apron wire.)

b. Put a piece of detonating cord (cordeau) the length of the torpedo through the T. N. T. to assure detonation.

c. Be generous in the amount of T. N. T., not economical. (For one depth of double-apron wire, about 20 pounds should be used in each torpedo.)

d. Have a man place the torpedo in the enemy's wire. Do not try complicated ways of pulling it by rope through pulleys.

e. Fire it by electricity, using an alternative circuit if necessary.

f. Insert safety or time fuze, but use it only as a last resort when both electric circuits have failed.

g. Place the torpedo aga[illegible]icket.

h. Place it perpendicular to th[illegible]the wire.

i. Use a ridge through the wire in preference to a hollow or a depression.

Section V

MINE WARFARE

218. General.—Military mining as discussed in this section embraces the tactical use of underground works for the attack or defense of fortified localities. The method consists in starting a vertical shaft within our own lines and driving underground galleries at various levels to the vicinity of the objective where a chamber is constructed and charged with explosives. The charge is set off at a prearranged time with the object of destroying the objective or so disorganizing the defenders that it may be taken by aboveground attackers. Appropriate objectives are those points which can not properly be engaged or destroyed by artillery fire such as areas organized with deep dugouts. Considerations which affect the chances of successful mining and which must be weighed in choosing the objectives are: The geological conditions, the personnel and the materials available, the probability of surprise, and the distance which separates the opposing lines. Favorable geological conditions are essential and water-bearing strata or hard rock are unsuitable because of the slowing up of the operations and the difficulty of concealing the work. Mining operations require a great number of men and a considerable quantity of materials. Surprise is dependent upon speed and silence. The distance separating the opposing lines should not be so great as to render the labor disproportionate to the result obtained or the difficulty of removing material, ventilating, and draining the works too great.

219. Tactics of military mining.—The elements of surprise are most important. Surprise is gained by deceiving the enemy as to the fact of mining operations which are being undertaken. Failing this, surprise as to the location and time of setting off the charge is sought. Mining operations must be fully coordinated with the operations in general, since local mining operations lead to no results commensurate with the effort required, unless they are coordinated with the general plan of operations of our forces. In mine warfare as in other operations the flanks must be gallery is very vulnerable to a flank attack ly countermine. Feints are used in misleading the enemy as to the location of our principal mine operation. A feint is accomplished by driving a gallery with a considerable amount of noise while a flanking gallery is driven as silently as possible.

220. Detection of enemy mining activity.—Enemy mining activities may be detected by surface observation and listening, by the study of airplane photographs, and by underground listening.

221. The camouflet.—The camouflet is a loaded mine so charged as to cause no effect at the surface; that is to say, no crater. It is the chief weapon of the miner for the destruction of enemy underground works.

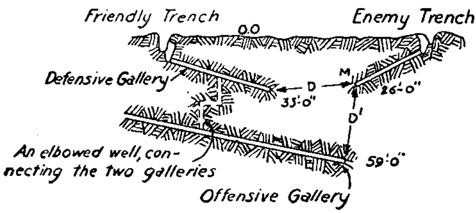

FIGURE 160.—Offensive mining

222. Offensive mining.—Figure 160 illustrates a plan of offensive mining in suitable soil. The upper or defensive gallery is started from the front line and the lower or offensive gallery is started from the rear. Both galleries are in the same vertical plane, the lower being more advanced in the direction of the enemy. In the upper gallery very little attempt is made to deaden the noise, while work in the lower gallery is carried on silently. An enemy listener easily confuses one with the other and the offensive gallery passes under him. Distances *D* and D^1 are the same. Where a sandy clay forms the top soil and a soft limestone the subsoil, this method can be adopted only with difficulty, as the conditions are then reversed. The top gallery being in clay, it would be comparatively easy to do noiseless work but extremely difficult to carry on the lower gallery in limestone without noise.

223. Defensive mining.—Precautions against enemy mining activities include an efficient lookout and listening service and countermines. Countermines may be arranged fanwise, the interval between galleries depending upon the range of listening in different soils. In clay the distance between galleries should not be greater than 60 feet, in soft rock this may be safely doubled. Listening galleries are usually put out in Y form and these galleries are of smaller size, often 3 feet by 2 feet in cross section. If desired, holes may be bored from the ends of these listening galleries and listening devices placed in them.

224. Arrangement of mining system.—The maximum offensive or defensive power is reached when the mining operations are extended throughout the whole of the ground in which mining is possible. There may be galleries at one, two, or even three levels, according to the depth of the ground that is suitable. The different parts of the system must materially support each other and the flanks must be guarded.

225. Classes of mine galleries.—*a.* The dimensions of galleries and shafts for mine warfare are determined by the use made of them, their length, and the minimum space in which men can work. The classification and dimensions are shown in Table XIV. If troops or guns are to be passed through galleries, they must be made large enough for that purpose. Great and common galleries will usually meet these requirements. Galleries used only to reach the proper point to place the explosive are made of the size which is most rapidly driven and can be sufficiently ventilated. This is usually the half gallery, in which men can work without too much restraint, through which the excavated earth can be transported by efficient methods, and in which reasonable ventilation can be maintained by simple means. Branches or small branches may be used when near the objective points. They are rapidly driven for short distances, 20 feet or so, but when longer the difficulties of digging, earth disposal, and ventilation become too great. When the soil permits the use of augers, drill holes will usually be employed for this purpose instead of small branches.

b. Shafts.—Shafts are vertical wells dug to reach the required elevation from which a gallery is to take off or for the purpose of ventilating a gallery. The size of the shaft may range from the smallest in which a man can work, 3 feet by 3 feet, to any size which may be required.

c. The place prepared for the reception of the explosive is called the mine chamber. For the computation of explosive charges see Sections III and IV of this chapter.

226. Construction.—The methods of driving galleries are the same as those used in the construction of protected shelters as described in paragraphs 109 to 113, inclusive.

227. Precautions after an explosion.—After the explosion of a charge in a main gallery, great care must be exercised in allowing men to return to work. Carbon monoxide and carbon dioxide are caused by the detonation of high explosives and the presence of the former even in the most minute quantities is sufficient to cause death in a very short time. After an explosion a gallery must on no account be worked in until it has been ventilated by bratticing or by some other method, such as continuous air pumps. Bratticing, the best method, consists of dividing a shaft or gallery into two distinct passages by means of temporary partitions so as to form two air channels, one for the exit of the foul air and the other for the intake of fresh air. Water-soaked sheets, blankets, canvas, and even piled up sandbags can be used for this purpose.

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