EXTRACTS FROM

TRAINING REGULATIONS

195—30

EXPLOSIVES AND DEMOLITIONS

NATIONAL GUARD AND RESERVE OFFICERS SCHOOL

ENGINEER BRANCH

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Section III

HANDLING AND CARE OF EXPLOSIVES

18. General.—It must always be remembered that explosives are never safe unless handled with utmost care. Carelessness and rough handling are likely to cause explosions and accidents. Never let "*familiarity breed contempt.*"

19. 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.

20. 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 magazine.

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.

21. 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.

22. 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.

23. 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.

24. 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 quantities are to be thawed the special type of double boiler shown in Figure 2 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.

25. **General precautions with regard to explosives.**—*a.* Don't forget the nature of explosives and remember that they can be handled with comparative safety only by exercising proper care.

b. Don't connect lead wires to blasting machine until ready to fire charge, and don't leave lead wires attached to machine after charge is fired.

c. Don't hold blasting caps in hand while crimping. Place the cap on the fuze and hold the fuze.

d. Don't smoke while handling explosives, and don't handle explosives near an open light.

e. Don't 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. Don't handle or store explosives in or near a dwelling place.

g. Don't leave explosives in a wet or damp place. Keep them in a suitable dry place under lock and key. Don't let irresponsible persons have the key.

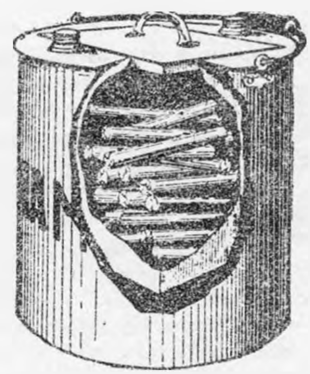


FIG. 2.—Du Pont thawing kettle, showing two compartments and dynamite.

h. Don't explode a charge to spring a bore hole and then immediately reload, as the bore hole will still be hot.

i. Don't tamp with iron or steel bars or tools. Use only a blunt wooden tamping stick.

j. Don't explode a charge until everyone is out of danger.

k. When using safety fuze don't 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. Don't use frozen or chilled dynamite.

m. Don't thaw dynamite except as recommended in this text.

n. Don't put dynamite on shelves directly over steam or hot-water pipes.

o. Don't prime a charge or connect charges for electric firing during the immediate approach or progress of a thunderstorm.

p. Don't carry detonating caps in your pocket.

q. Don't tap or otherwise investigate detonating caps.

r. Don't take caps from the box by means of a wire, a nail, or a similar instrument.

s. Don't pull on the wires of an electric cap.

t. Don't crimp a cap with the teeth or with a knife. Use the cap crimper.

u. **Don't store or transport caps with high explosives.**

v. **Don't cut the safety fuze short to save time.**

w. **Don't operate the blasting machine half-heartedly.**

x. **Don't leave detonators exposed to the direct rays of the sun.**

y. **Don't open a case of explosives in a magazine.**

z. **Don't have matches around explosives.**

aa. **Don't force a primed cartridge into a drill hole. Have hole of ample size for cartridge.**

ab. **Don't handle safety fuze carelessly in cold weather. When cold it is stiff and cracks easily.**

ac. **Don't use a weak detonator. Use the prescribed detonator or a more powerful one.**

SECTION V

PREPARATION OF CHARGES

41. **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.

42. **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 primer.

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.

43. **Priming TNT blocks.**—Remove the cork from the TNT block and 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 TNT block.

44. **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. 22.) 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 42.

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.

FIG. 22.—Punch hole with handle of cap crimper

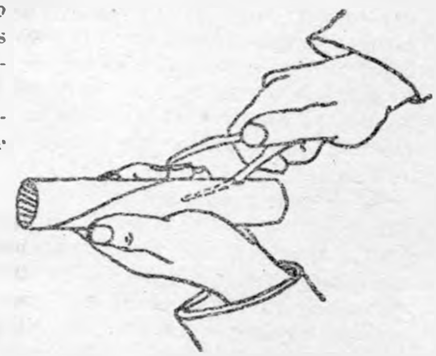


FIG. 23.—Punch a hole in side of cartridge with handle

45. **Priming in the side of cartridges.**—*a.* Punch a hole in the cartridge about 1½ inches from one end. Point the hole in 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 23. Slip the cap with fuze attached into the hole. Tie a piece of cord firmly around the fuze and then around the cartridge. (Fig. 24.)

b. This method of priming places the cap advantageously for tamping.

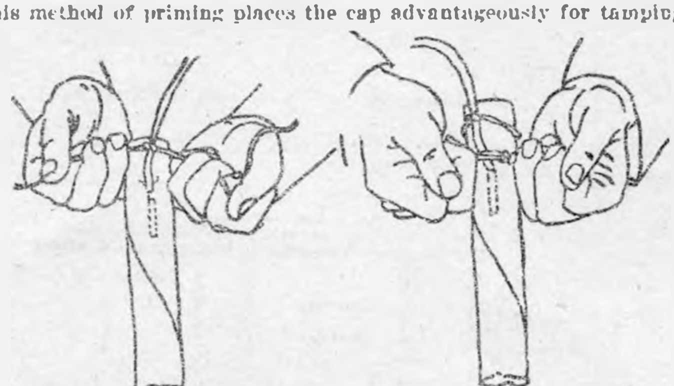


FIG. 24.—Tie cord around fuze and cartridge

46. Priming with electric tetryl caps.—*a*. To prime a TNT 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. 25A.) Loop these ends around the cartridge. (Fig. 25B.) Punch another hole in the top a little to 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. 25C.)

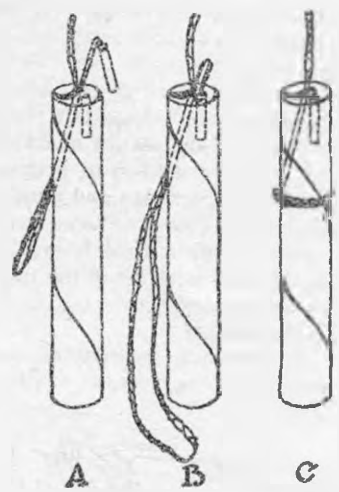


FIG. 25.—Priming with electric cap

47. Priming detonating cord.—*a*. Detonating cord is used as a detonating agent for TNT. 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 TNT 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 26.

FIG. 26.—Detonating cord primed with tetryl cap and union

(2) By tying two tetryl caps together, as shown in Figure 27.

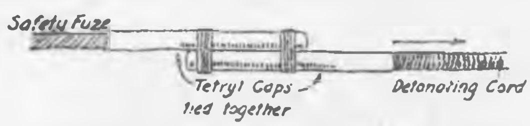


FIG. 27.—Detonating cord primed with two tetryl caps

(3) By attaching a primer consisting of a tetryl cap and block of TNT to the cord, as shown in Figure 28.

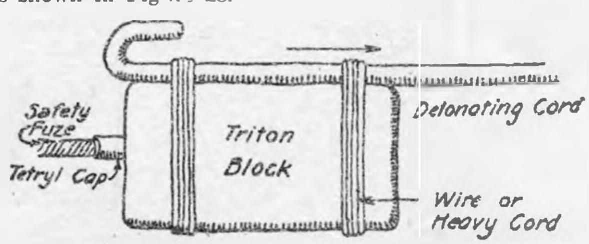


FIG. 28.—Detonating cord primed with one triton block

(4) By using a tetryl cap and TNT block in which an end of the detonating cord has been inserted, as shown in Figure 29.

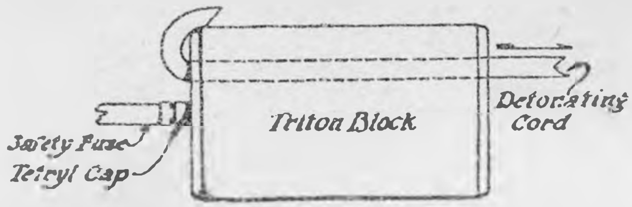


FIG. 29.—Detonating cord primed with one triton block

48. Simultaneous detonation.—Simultaneous detonation or the detonation of several charges at th 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.

49. 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. 30.) Make this twist tightly to keep the electrical resistance in the joint at a minimum.

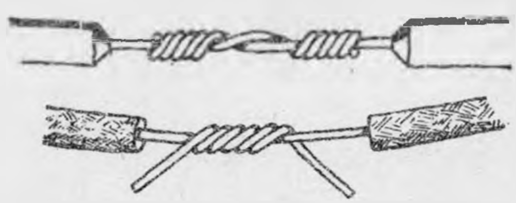


FIG. 30.—Correct method of splicing connecting and detonating wires

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. 31.)

FIG. 31.—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 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.

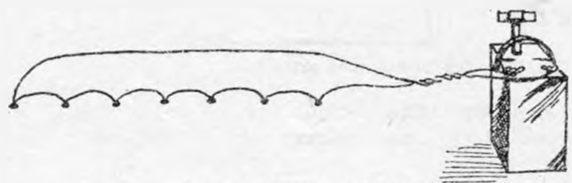


FIG. 32.—Series connection

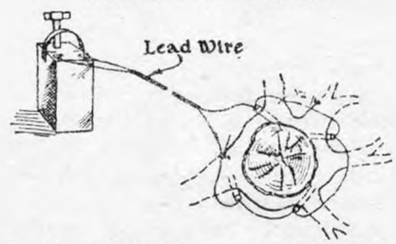


FIG. 33.—A stump blast connected in series

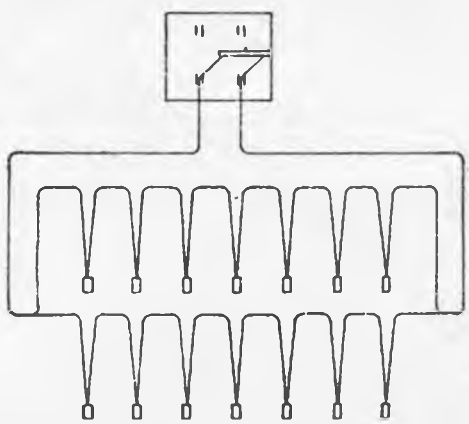


FIG. 34.—Two separate series connected in parallel

50. 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 30 to 33 give examples of such connections.

b. Parallel circuits may be used when power or lighting circuits form the source for the detonating current. Figure 34 shows such a connection. The blasting machine is not designed for, and should not be used with, parallel circuits.

51. 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.

52. Locating a break.—Make sure that the ends of the lead wire are separated and not touching anything. (See fig. 35.) 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

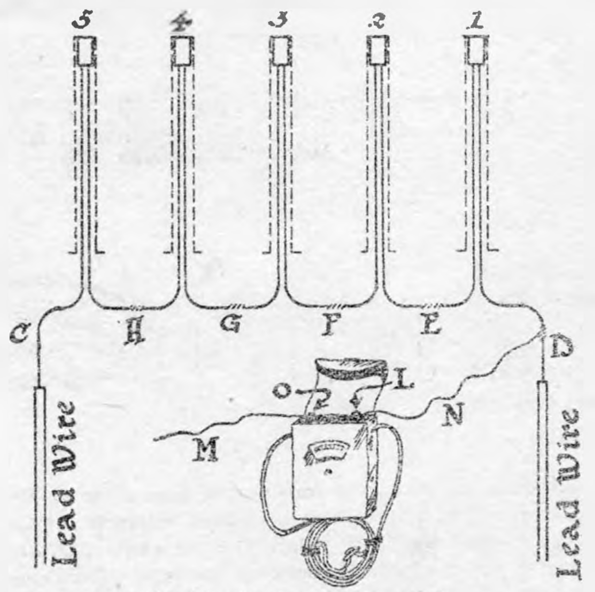


FIG. 35.—Testing blasting circuit

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. 60.)

53. 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, 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.

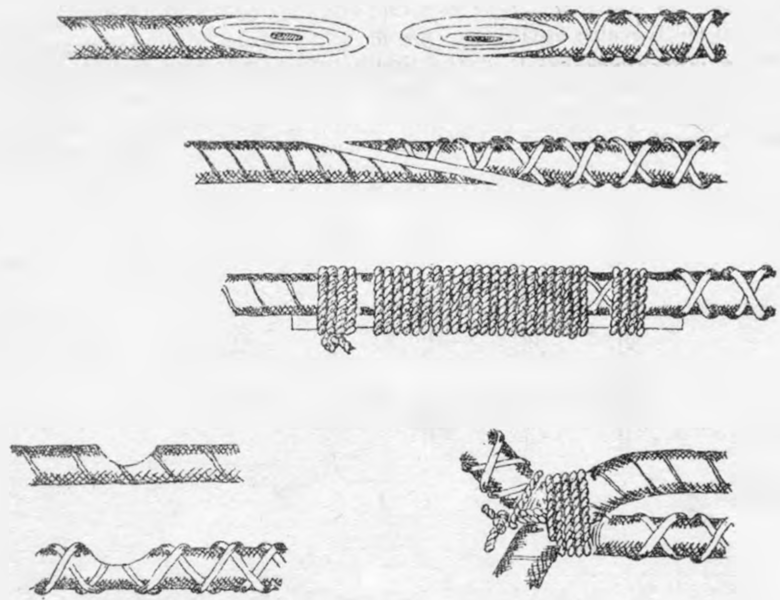


FIG. 36.—Fuze splicing

54. Splices.—*a*. To splice time or instantaneous fuze or to splice instantaneous fuze to time fuze, cut the ends to be joined obliquely. (See fig. 36.) 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 branches from a main, splice in the same way as above, cutting the fuze as shown in Figure 37.

b. To connect a branch of detonating cord to a main (see fig. 38), first drill priming hole completely through a block of TNT; 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.

FIG. 37.—Beginning of double splice

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 subparagraph *b*. First, slit the branch for a distance of about 8 inches with the cord slitter. Then place the split end of the branch as shown in Figure 39. Complete the splice as shown in Figure 40.

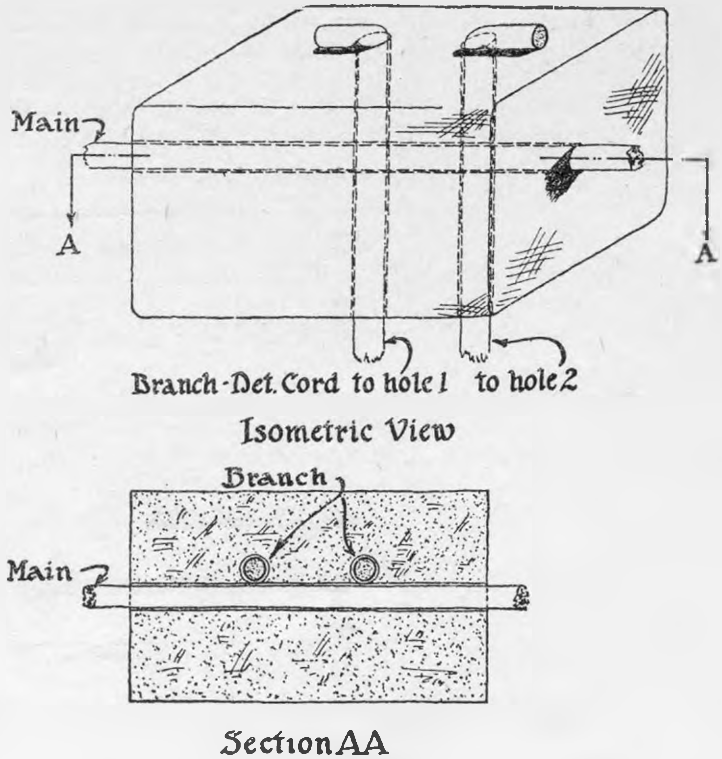


FIG. 38.—Detonating cord spliced using a block of triton

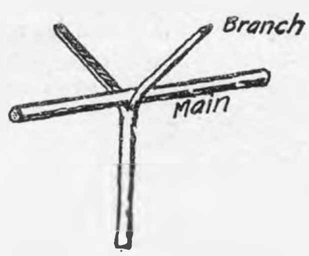


FIG. 39.—Beginning splice with cord

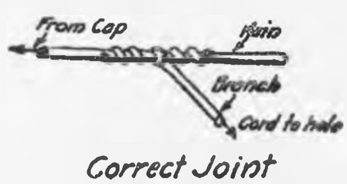


FIG. 40.—Splice with cord complete

55. 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.

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

56. **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 41 is used to make bore holes in earth. The spoil is re-

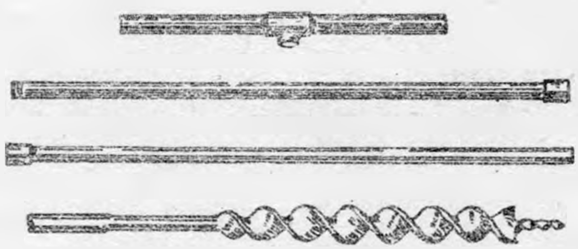


FIG. 41.—Earth auger

moved by periodically pulling up the auger and cleaning it. The drill and hammer shown in Figure 42 are used to drill holes in hard rock. The miner's spoon shown in Figure 43 is very convenient for enlarging bore holes and removing pebbles therefrom. Posthole diggers are useful for placing charges in soft earth.

FIG. 42.—Hand drill and drilling hammer

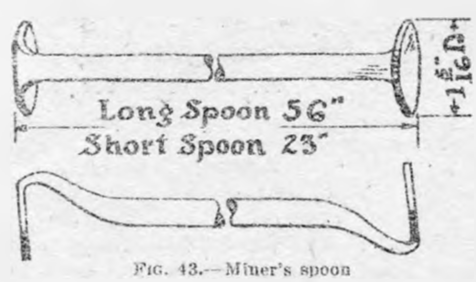


FIG. 43.—Miner's spoon

b. In drilling bore holes water is poured into the hole, making a mud of the spoil, which acts as a lubricant. This mud 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 desired size is obtained. (See fig. 44.) Ample time must be allowed between charges for the bore hole to cool.

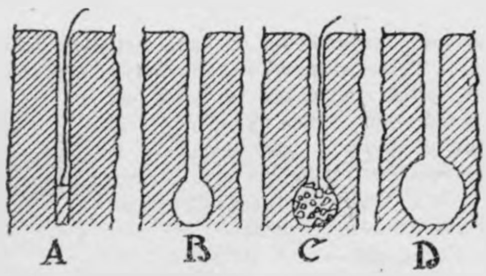


FIG. 44.—Springing a drill or bore hole

57. 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

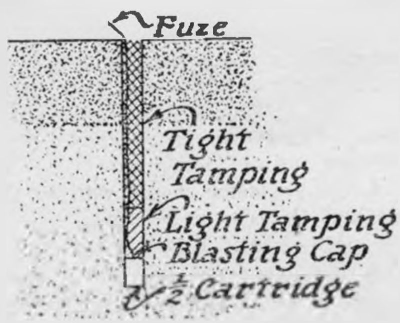


FIG. 45.—Light tamping immediately over charge to protect cap followed by heavy tamping

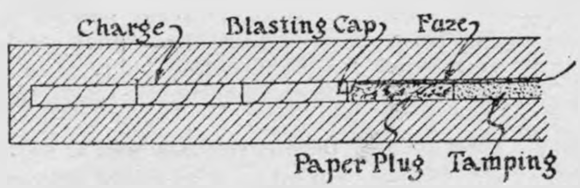


FIG. 46.—Use of wad of paper serves as a safety indicator of where to stop in case tamping must be removed because of misfire

earth lightly. Then add more earth and tamp firmly, using a wooden tamping stick. (See figs. 45 and 46.) 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 l ›cks of triton must be broken up in order to place them in small drilled holes.

58. 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. 45.)

e. Various means of tamping are shown in a number of the figures illustrating the use of explosives. (See Sec. X.) Ordinarily sandbags filled with earth can be used to best advantage.

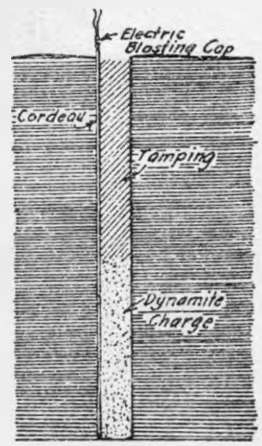


FIG. 47.—Cordeau extending to bottom of bore hole

59. 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.

60. 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.

SECTION VI

PREPARATION AND CALCULATION OF MINE CHARGES

61. 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 TR 195–35.) 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.

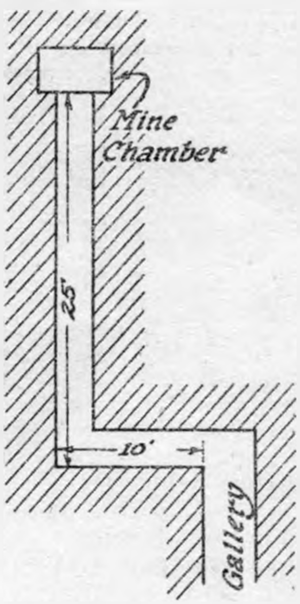


FIG. 48.—Dog leg

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:

(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. 48.)

62. **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.

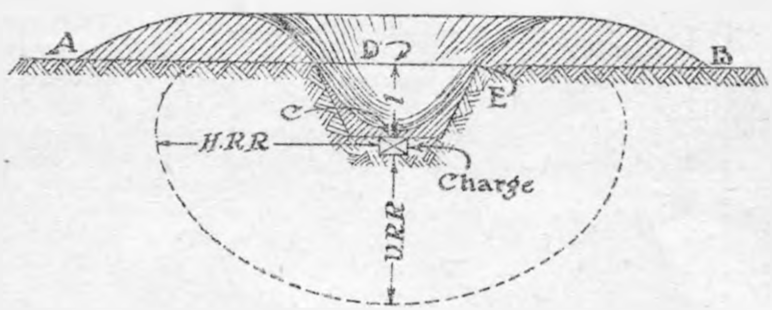


FIG. 49.—Cross section of typical crater

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 49 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 approximately 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.*

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.

63. **Determination of charges and radius of rupture of mines.**—*a.* Table II gives a means of determining the necessary charge of one-half pound blocks of TNT for a crater of the desired type. First, select the 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.

TABLE II.—*Constants for determining charges in one-half-pound blocks of triton and radii of rupture for mines*

Kind of material	Camouflet, 1-line	Under-charged, 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	Charges under 50 blocks, add 100 per cent.
Hard sand	.014	.038	.084	.252	Charges 50 to 200 blocks, add 50 per cent.
Hardpan	.016	.046	.100	.300	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.
Radius of rupture, 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 I) for charge in pounds of other explosives.

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.

64. **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.

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 explosive, if practicable. In the event of the charge, solidly packed, not entirely filling the mine chamber sand bags 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.

SECTION VIII

CALCULATION OF DEMOLITION CHARGES

69. 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. 62.) A *breaching charge* is a charge sufficient to blast out a cone of material of which the charge is at the apex and the base has a radius equal to R. (See fig. 50.)

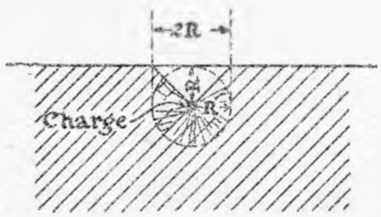


FIG. 50.—Breaching charge

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:

Material	R	K
Poor masonry	All values	.375
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	1.30
	5 to 7 feet	.83
	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 51 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 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 72, 73, and 74.

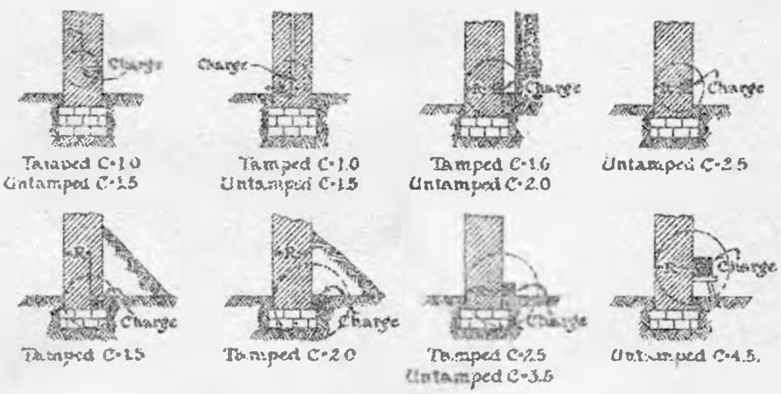


FIG. 51.—Values of C

70. Chart for solution of formula $N=R^3KC$.—*a*. Charts I, II, and III may be used to solve the formula $N=R^3KC$ for values of R from 1 to 35 feet.

b. To use these charts—

(1) Place a straight edge horizontally at the proper value of R.

(2) Where the straight edge intersects the curve labeled R^3, drop a line vertically to intersect the line labeled with the proper value of C.

(3) Project this point of intersection horizontally to intersect the line labeled with the selected value of K.

(4) Project this point vertically and read on the scale at the top of the chart the value of R^3KC. If this amount is under 100 blocks, add 25 per cent to get the proper charge. If it is over 100 blocks, add 10 per cent.

71. 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 52 shows a breaching charge to the left and a shattering charge to the right. Figure 53 shows a charge placed in a countermine to

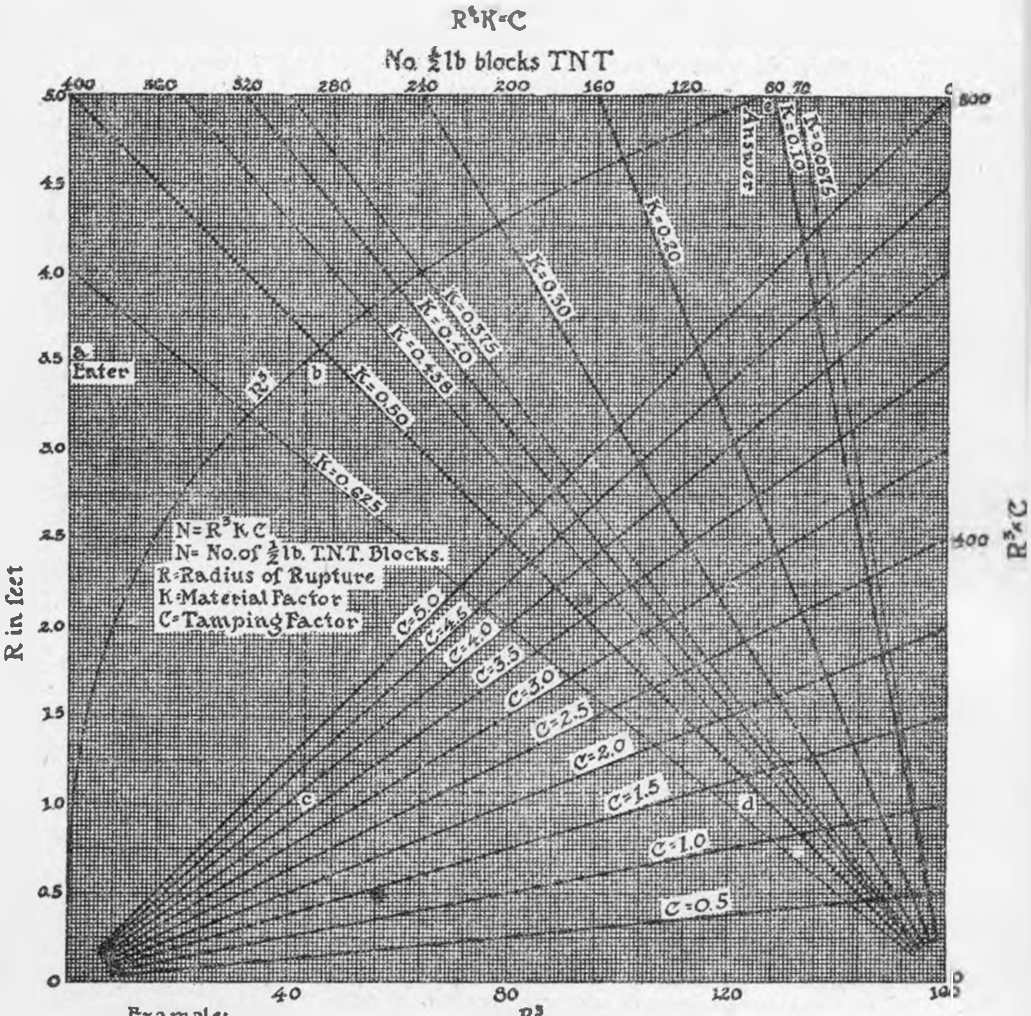
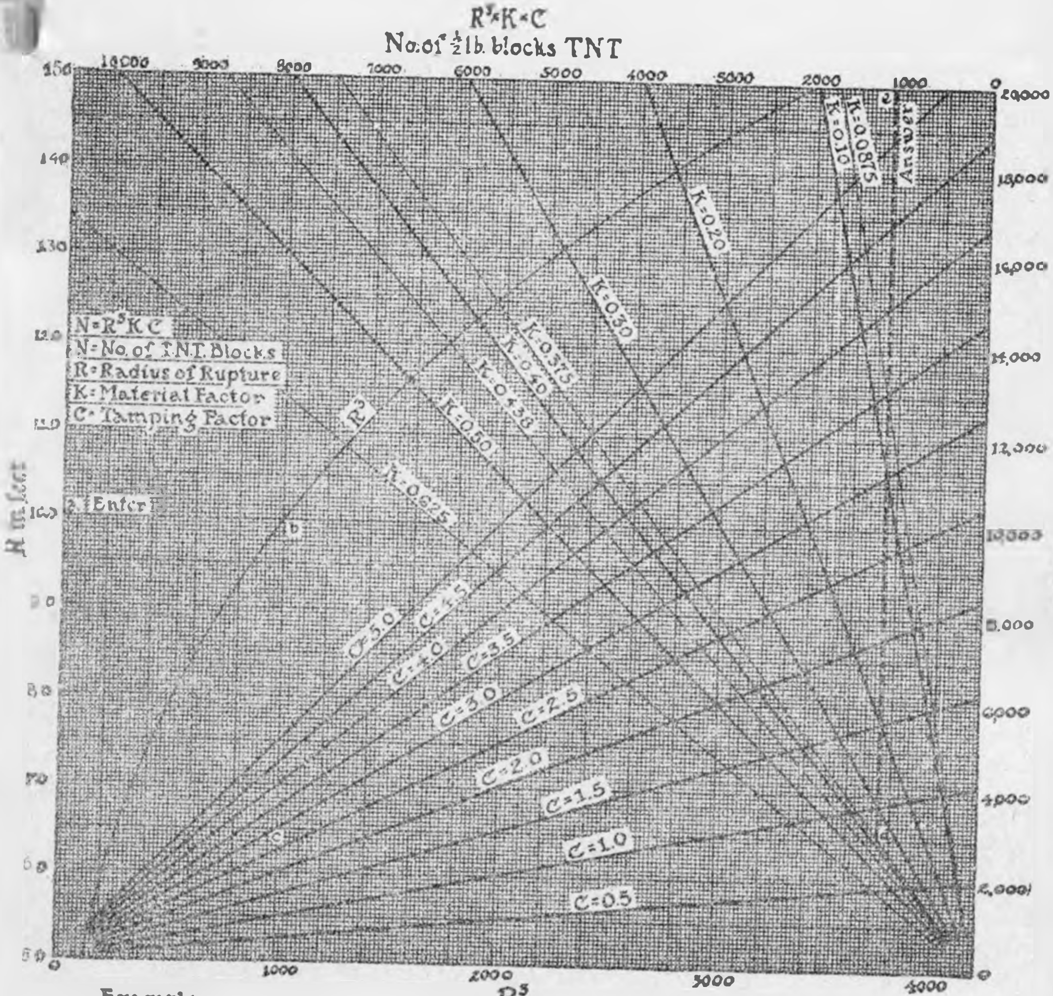


Chart I

Example:
When R=3.5'
K=0.50 (Good masonry R between 5' and 5')
C=4.0 Estimate of Conditions.
Starting at "a", reading to "b", to "c", to "d" and to "e"
Value of N at "e" = 86. Add 25%. Use 108 blocks TNT



Example:
When R=10'
K=0.575 (Good masonry-R over T)
C=3.0 Estimate of Conditions.
Starting at "a", reading to "b", to "c", to "d" and to "e".
Value of N at "e"=1125. Add 10% Use 1238 blocks TNT.

Chart II

(Face p. 22.) No. 2

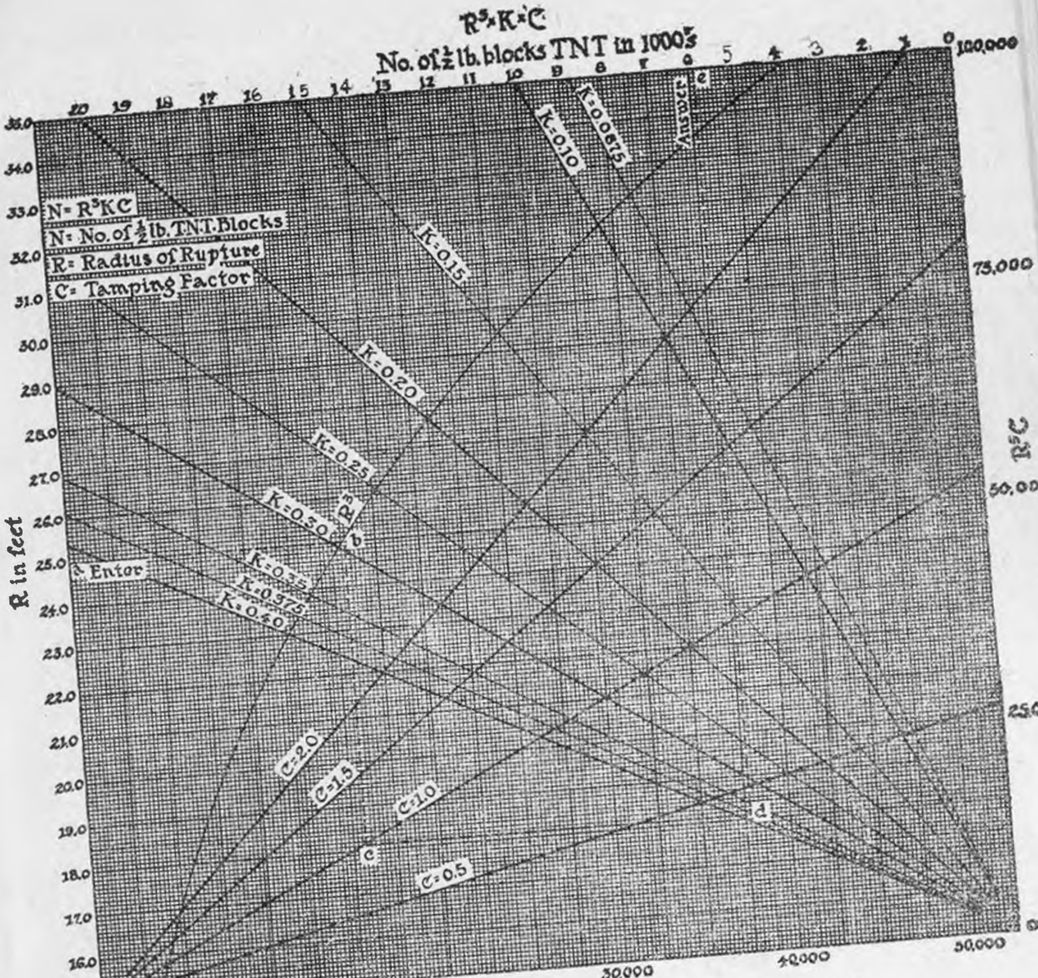


Chart III

Example:

When R=25'

K=0.375 (for Shale)

C= 1.0 (Landmine)

Starting at "a", reading to "b", to "c" to "d" and to "e".

Value of N at "e"=5900. Add 10%. Use 6490 blocks TNT destroy a hostile drift. This charge must be kept at least 2 R below the surface to avoid shattering the surface of the ground.

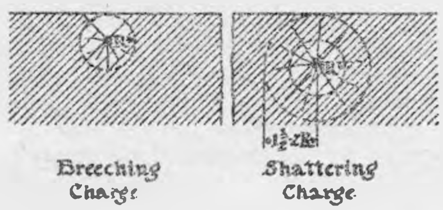


Fig. 52.—Breaching charge to left, shattering charge to right

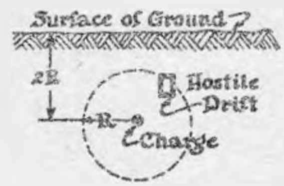


Fig. 53.—Mine charge or camouflet

72. 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:

$$N = 3.2 \, R^3KC \text{ per yard}$$

where N, R, K, and C have the same significance as in paragraph 69.

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.

delayed until a given moment and then executed at once.

b. Single charges are computed as follows (see fig. 54):

(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.

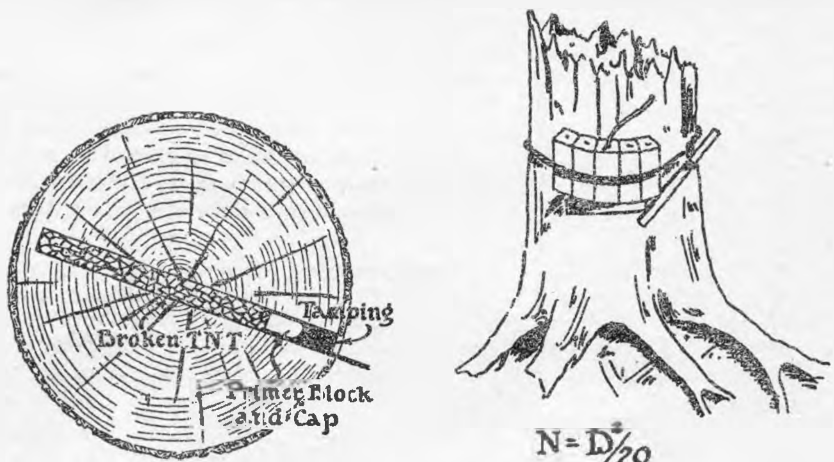
74. Steel.—*a.* Bessemer steel crystallizes, breaks, and throws its fragments away from the explosive. Open-hearth steel tears and may throw fragments in any direction. These fragments are frequently large and may be thrown with force enough to carry them from 400 to 1,000 yards or more. Extra precautions 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:

$$N = \frac{3}{4} A$$

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 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



Diameter=30''.
Charge ($N = \frac{D^2}{125}$)=7.2 blocks TNT.
Blocks are broken up to fill bore hole.

FIG. 54.—Charges for cutting timber

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.

74½. 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 69*b*, 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 69*b*, 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 mid-point will blast away a part of the concrete in compression and the structure will fall of its own weight.

75. Reduction from TNT to other explosives.—Determine the number of one-half pound blocks of TNT required, N in all formulas given, and divide this figure by 2, thus obtaining the number of pounds of TNT to be used. Divide this value by the relative strength of the explosive to be used, given in Table I, and the result will give the required number of pounds of the explosive.

SECTION IX

DEMOLITIONS

76. **Purpose and objects.**—*a.* 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.

b. The principal objects of military demolitions are—

(1) Natural or artificial objects having no intrinsic or permanent value, such as accidents of the ground or purely military structures.

(2) Natural or artificial objects having intrinsic or permanent value and adapted to useful purposes in times of peace, such as buildings, bridges, etc.

c. Demolition of objects having intrinsic or permanent value is permissible only under a strict military necessity. Such demolitions should only be undertaken in an emergency and when explicitly ordered by competent authority.

d. The subject of demolition is primarily within the province of the engineers, but it should be familiar to all line officers, as the area of operations is so extensive in modern warfare that engineers are not always available to perform the work. Consequently all combatant troops are supplied with demolition outfits and instructed in their use.

77. **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.

78. 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.

79. 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.

80. Execution of a demolition.—*a.* The execution of a demolition requires an estimate of the situation, a decision as to demolition to be employed, preparation of a bill of material, preparation and placing of charge, and firing.

b. The estimate should cover the following points:

(1) The object.

(2) The time available.

(3) The extent of demolition necessary to fulfill the mission.

(4) The possible location of the charges, accessibility, tamping required, and the safe distance for the personnel when detonation occurs.

(5) The nature of the material to be blasted.

(6) The explosive and demolition equipment available.

c. The decision should include—

(1) The location of the charges.

(2) The size of the charges.

(3) The method of detonation.

d. The bill of material should include—

(1) The amount of explosive.

(2) The quantity and type of detonators.

(3) The fuze, detonating cord, lead wire, and blasting machines required.

(4) Tools necessary to prepare the material for charging.

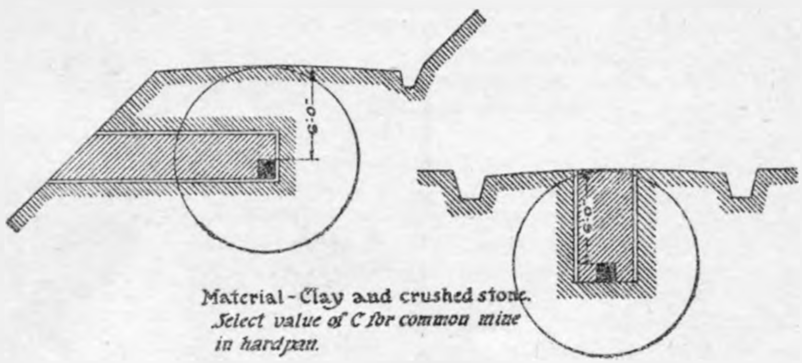
(5) Engineer and other labor needed.

81. 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 field works generally.

82. **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. 55 and par. 63.)

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. 56 and 57.)



Charge: $N = C\ l^3 + 100\%$. (See par. 63.)
$C = 0.10$. $l = 6'$.
$N = 1\ (216) = 21.6 + 100\%$.
$N = 43$ blocks TNT.
Tamp thoroughly.

FIG. 55.—Road mine

d. Charges can be determined as explained in paragraphs 63 and 69.

83. **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.

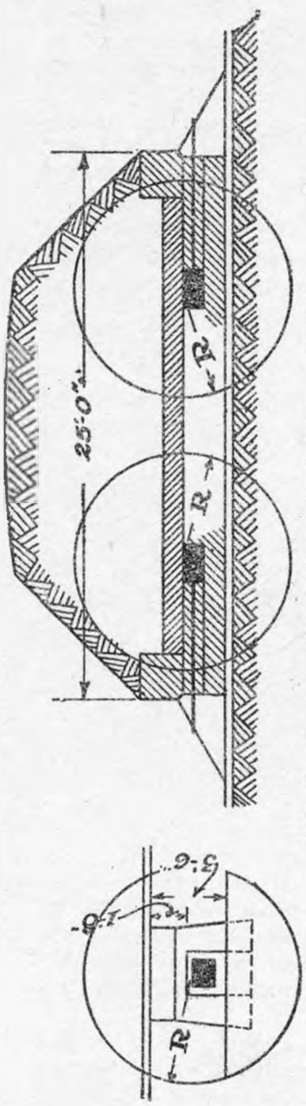
c. Charges may be computed as explained in paragraphs 63, 69, and 70.

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.

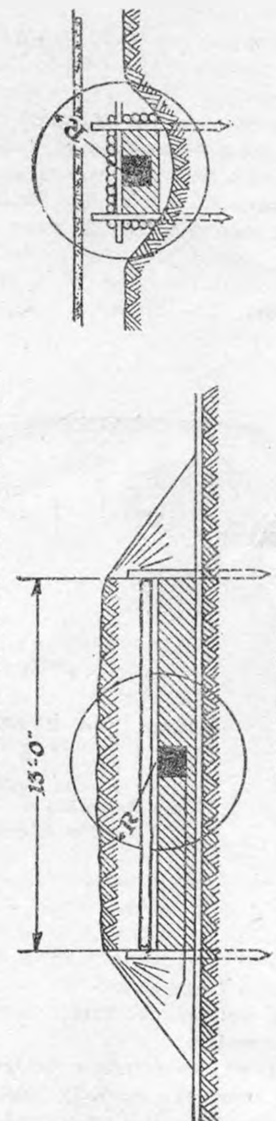
(2) Ponton bridges may be hastily disabled by cutting loose the center bays and destroying or sinking as many boats as possible.

(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.



Material.—Concrete with earth and crushed stone overburden.
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.

FIG. 56.—Destruction of concrete culvert



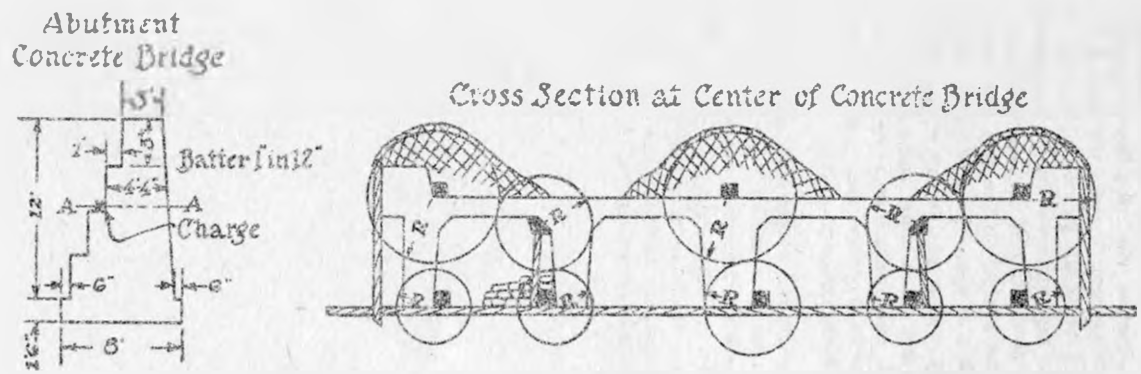
Material.—Timber and earth.
Charge: $N = R^3KC + 25\%$.
$R = 3'$; $K = 0.375$; $C = 1$.
$N = (3)^3 (0.375) (1) + 25\% = 10.13 + 2.53$
N=13 blocks TNT.
Tamp thoroughly.

FIG. 57.—Destruction of timber culvert

(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 69 and from Charts I, II, and III.

(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 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 58 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.



NOTE.—The 8 top charges tamped with mud, other charges held with sandbags or blocked in.

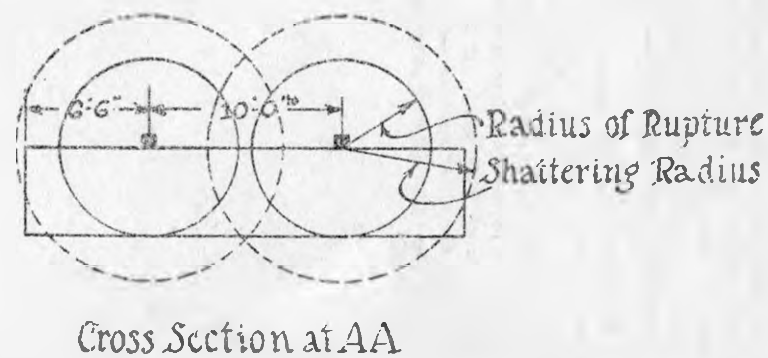


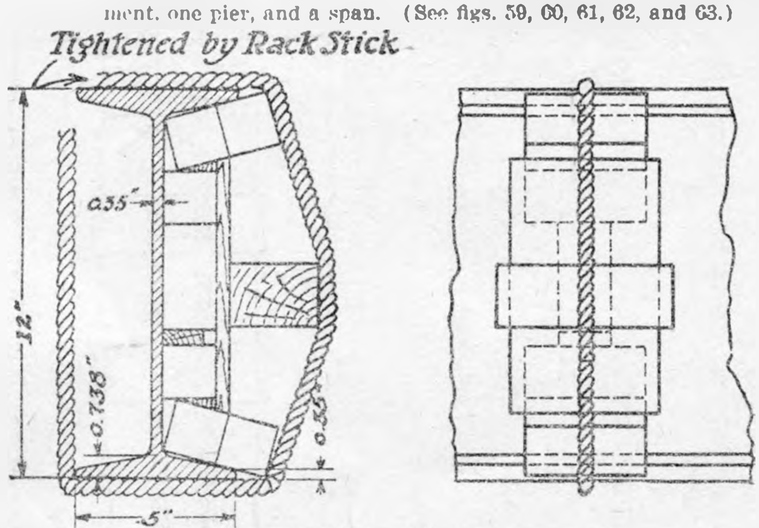
FIG. 58.—Method of placing charge on concrete bridge

(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. 59, 60, 61, 62, and 63.)



$12'' \times 0.35'' = 4.20$ sq. in.

$2(5.00 - 0.35)\left(\frac{0.35 + 0.738}{2}\right) = 5.06$ sq. in.

Total $= 9.26$ sq. in.

$\frac{3}{4} \times 9.26 = 6.94$ blocks.

Charge: 7 blocks TNT.

FIG. 59.—Destruction of steel I beam, showing calculation of charges and wedging

(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 member to be cut and held in place by boards, wire, or wedges

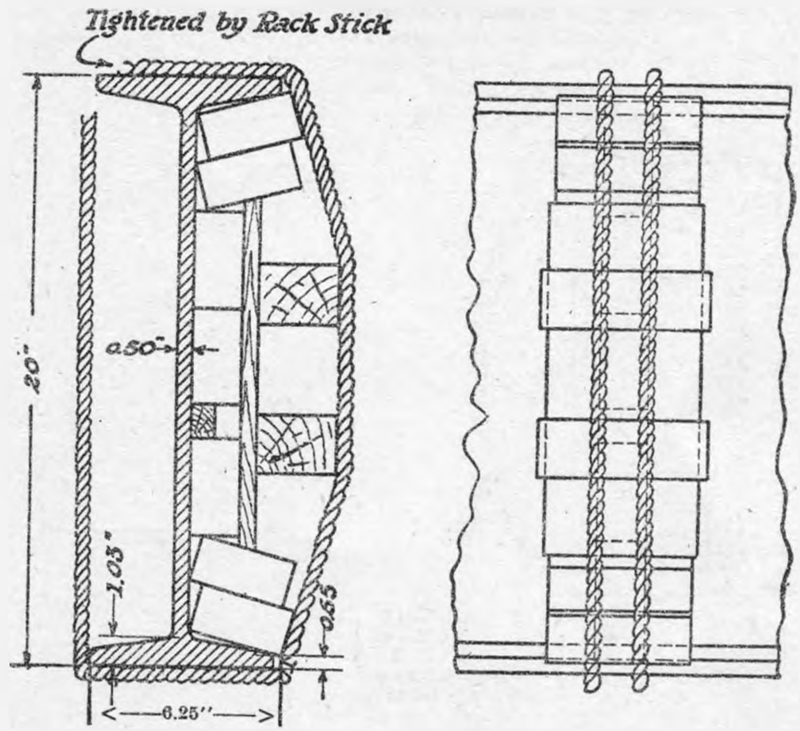
(f) In case of emergency concentrated charges of high explosive may be placed in contact with the tension members of the chords.

(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 confronted 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).



$$20'' \times 0.50'' = 10.00 \text{ sq. in.}$$

$$2(6.25-0.50)\left(\frac{0.55''+1.03''}{2}\right) = 9.08 \text{ sq. in.}$$

Total = 19.08 sq. in.

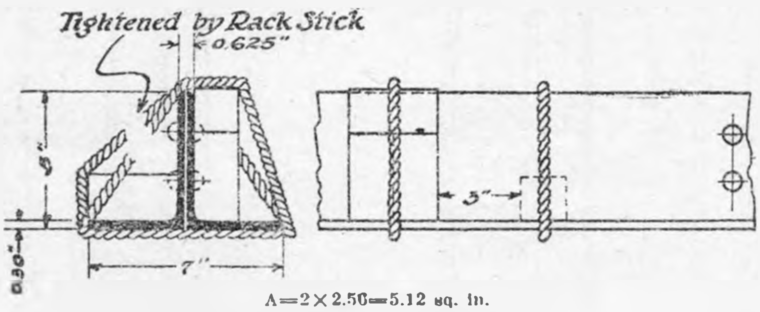
$\frac{3}{4} \times 19.08 = 14.31$ blocks.

Charge: 15 blocks TNT.

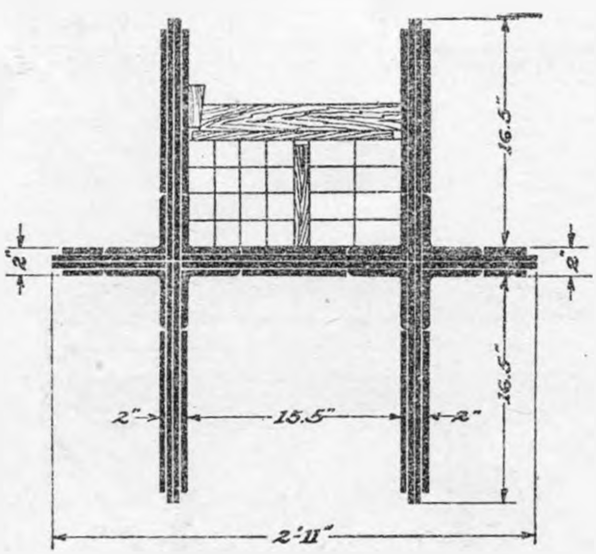
FIG. 60.—Destruction of steel I beam, showing calculation of charges and wedging

(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 to choose the former procedure because the resulting bridge would usually be stronger and more reliable.

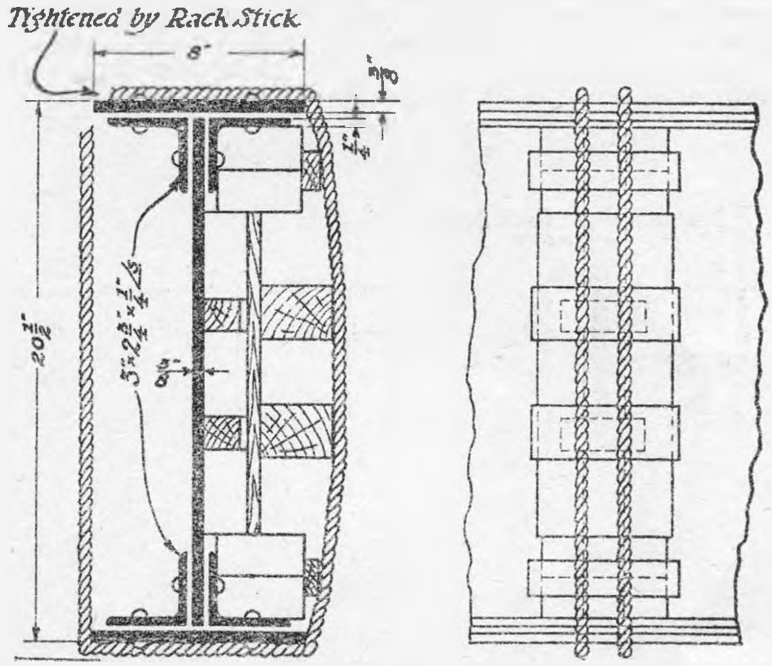


$A = 2 \times 2.56 = 5.12$ sq. in.
$N = \frac{3}{4} A = \frac{3}{4}(5.12) = 3.84$ blocks.
Charge: 4 blocks TNT.

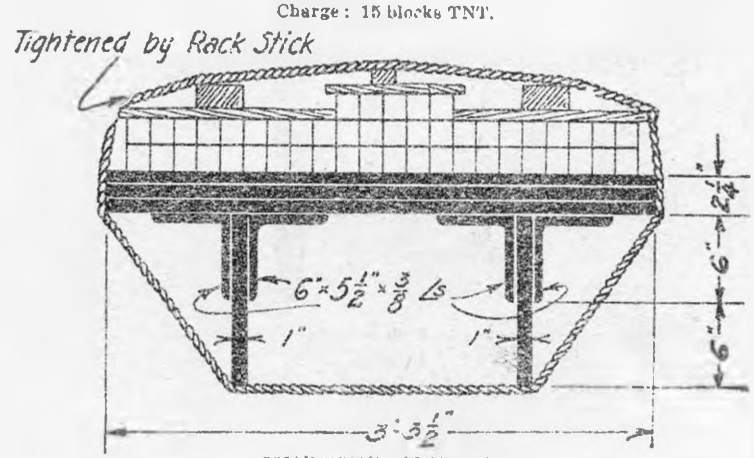


$16.5'' \times 2'' \times 4 = 132.0$ sq. in.
$35'' \times 2'' = 70.0$ sq in.
Total $= 202.0$ sq. in.
$\frac{3}{4} \times 202 = 151.5$ blocks.
Charge: 152 blocks TNT.

FIG. 51. -Destruction of built-up girders, showing calculation of charges and wedging



(20½″ − ¾″) × ⅜″ = 7.41 sq. in.
8″ × ⅜″ × 2 = 6.00 sq. in.
(3″ + 2¾″) × ¼″ × 4 = 5.75 sq. in.
Total = 19.16 sq. in.
¾ × 19.16 = 14.37 blocks.
Charge: 15 blocks TNT.



39½″ × 2¼″ = 88.88 sq. in.
12″ × 1″ × 2″ = 24.00 sq. in.
(6″ + 5½″) × ⅜″ × 4 = 17.25 sq. in.
Total = 130.13 sq. in.
¾ × 130.13 = 97.6 blocks.
Charge: 98 blocks TNT

FIG. 61—(Continued).—Destruction of built-up girders, showing calculation of charges and wedging.

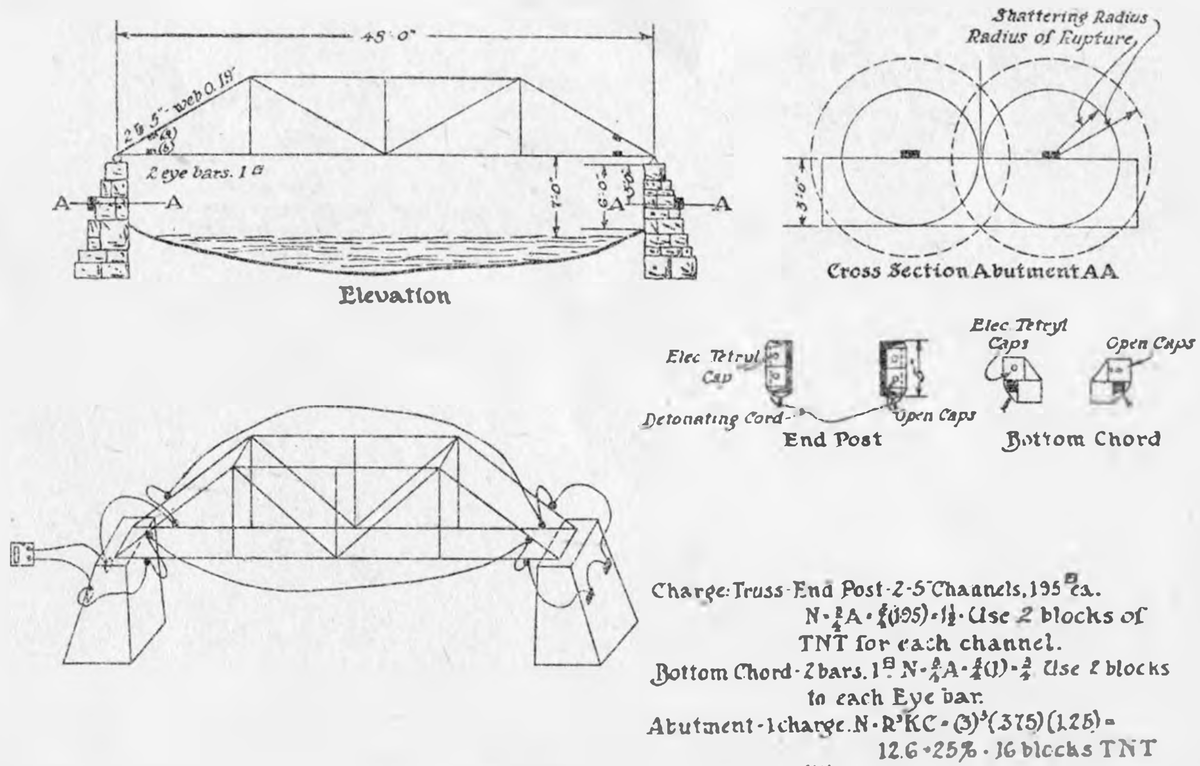
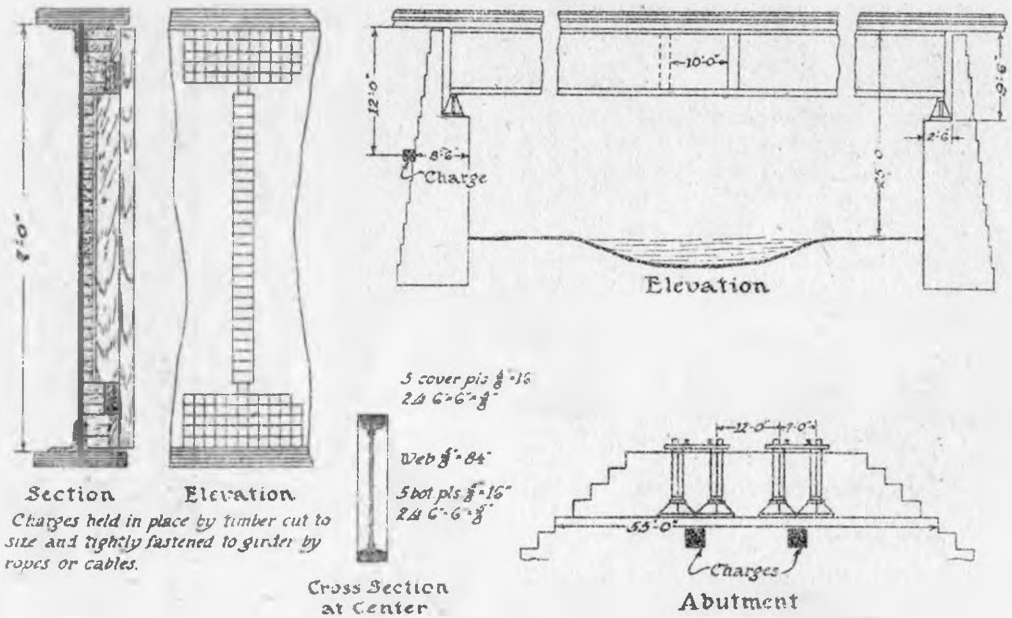


FIG. 62.—Steel truss bridge prepared for demolition



GIRDERS:

10	plates ⅝"-16"	= 100.00	sq ins
4 angles	6"-6"-⅝"	= 30.00	" "
1 web	84"-⅝"	= 52.50	" "
	total	182.50	" "

$N = \frac{3}{8} A = \frac{3}{8} \times 182.50 = 157$ blocks TNT

ABUTMENT: $N = R^3KC + 10\%$

$R = 8.5;\ K = 0.49;\ C = 1.25$

$N = (8.5)^3 (0.49)(1.25) + 10\%$

$= 376 + 10\%$

$N = 414$ blocks TNT

Two charges of 414 ea. = 828

FIG. 63 — Steel-girder railroad bridge prepared for demolition

84. 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 fishplates 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 hot. Figure 64 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.

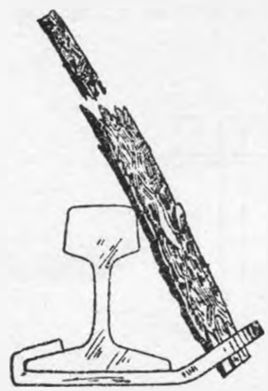


FIG. 64.—Lever for twisting railroad rails

(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.

(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.

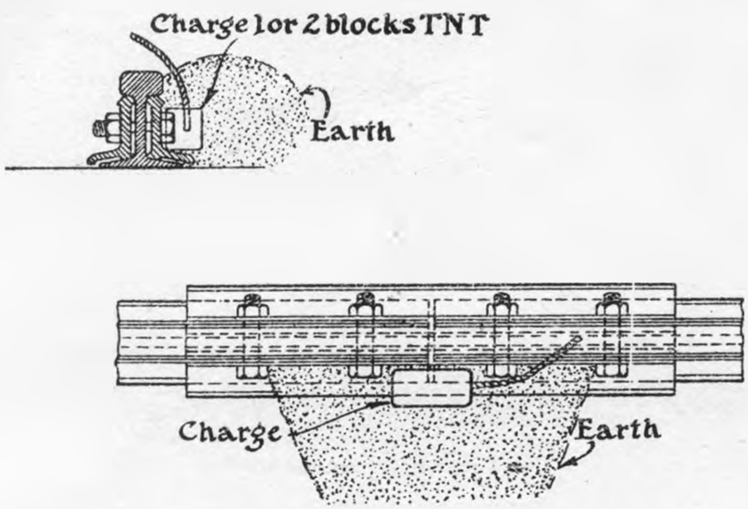
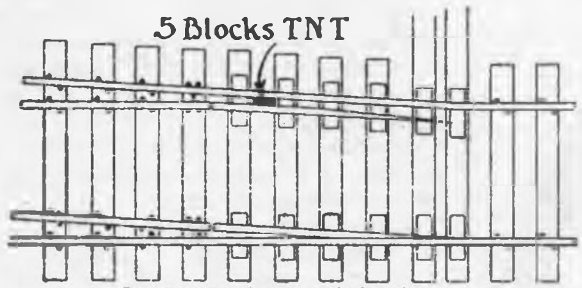


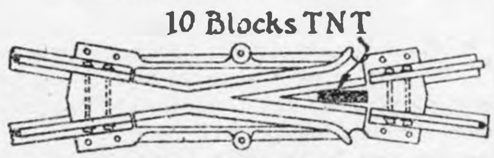
FIG. 65.—Charge for destroying railway tracks

(5) Figures 65 and 66 show methods of placing charges. One or two blocks of triton, tamped with loose earth, will break railroad rail. (See par. 74.)

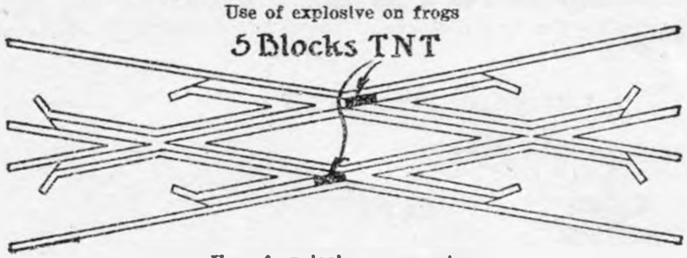
b. Blocking a tunnel effectively interrupts railroad traffic. Arrangements may be made for a head-on collision at the center of the tunnel between a car or locomotive and a moving locomotive or the tunnel may be demolished by placing explosive charges along the haunches for a distance of 50 to 60 feet 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.



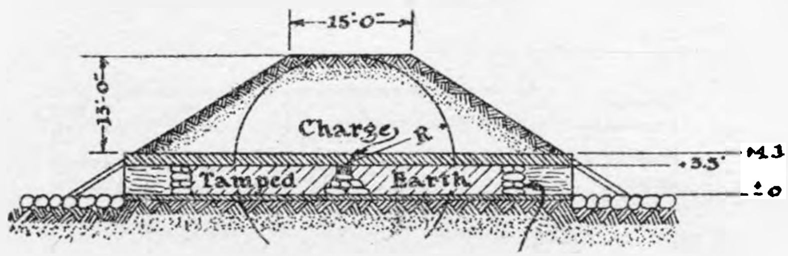
Use of explosive on switch points



Use of explosive on frogs



Use of explosive on crossings



Use of explosive on railroad fill

Sandbage or dry masonry

$N = R^3KC + 10\%$.

$R = 13.8'$, $K = .0875$, $C = 1$.

$N = (13.8)^3(.0875)(1) + 10\%$.

$N = 230 + 23 = 253$ blocks TNT.

Fig. 66.—Typical railroad demolitions

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.

85. 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.

86. 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.

87. 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 half way down the well and exploded.

88. 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.

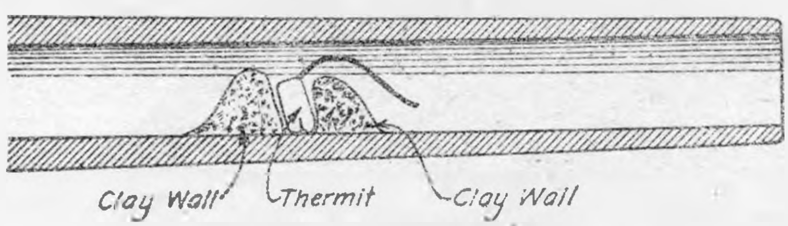


FIG. 67.—Thermit used to destroy bore of gun.

b. (1) Thermit, a mixture of powdered aluminum and hematite ($2Al + Fe_2O_3$), 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 bore or to fuze the breechblock to the gun. The operation is easy to perform, and there is no danger of explosion.

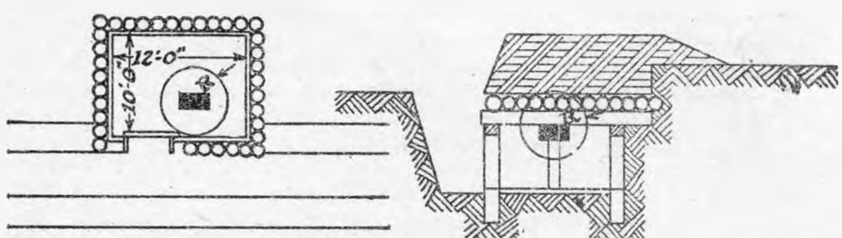
(3) If the breech gear can not be operated, the gun should be elevated at about 5° and a wall of clay built inside the bore at arm's length from the muzzle. A canvas bag containing a mixture of 20 pounds of thermit and 3 ounces of carbon dust, into which a spoonful of ignition powder, furnished by the 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. 67.) 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.

89. 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.

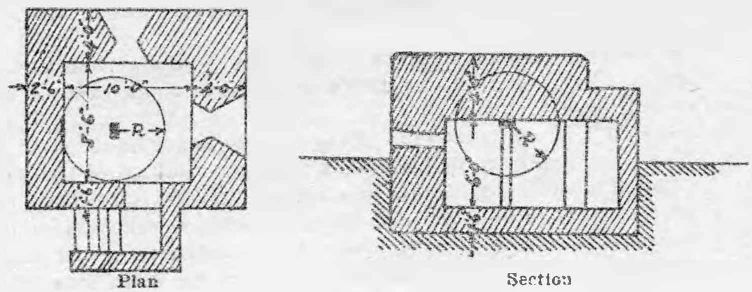
c. Shells must be handled carefully. They should be carried on improvised stretchers and jolting must be avoided.



Material.—Timber and earth.
Charge: $N = R^3KC + 25\%$.
$R = 3'$; $K = 0.375$; $C = 4.5$.
$N = (3)^3(.375)(4.5) + 25\% = 45.6 + 11.4$.
$N = 57$ blocks TNT.
Charge is supported against roof of shelter by struts.

FIG. 68.—Destruction of splinter proof

d. Projectiles weighing 200 pounds or more must be exploded singly. When 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.



Material.—Reinforced concrete.

Charge: $N = R^3KC + 10\%$; $R = 3'$; $K = 1.0$; $C = 4.5$.

$N = (3)^3(1)(4.5) + 10\% = 121.5 + 12.2.$

$N = 134$ blocks TNT.

FIG. 69.—Destruction of concrete cover

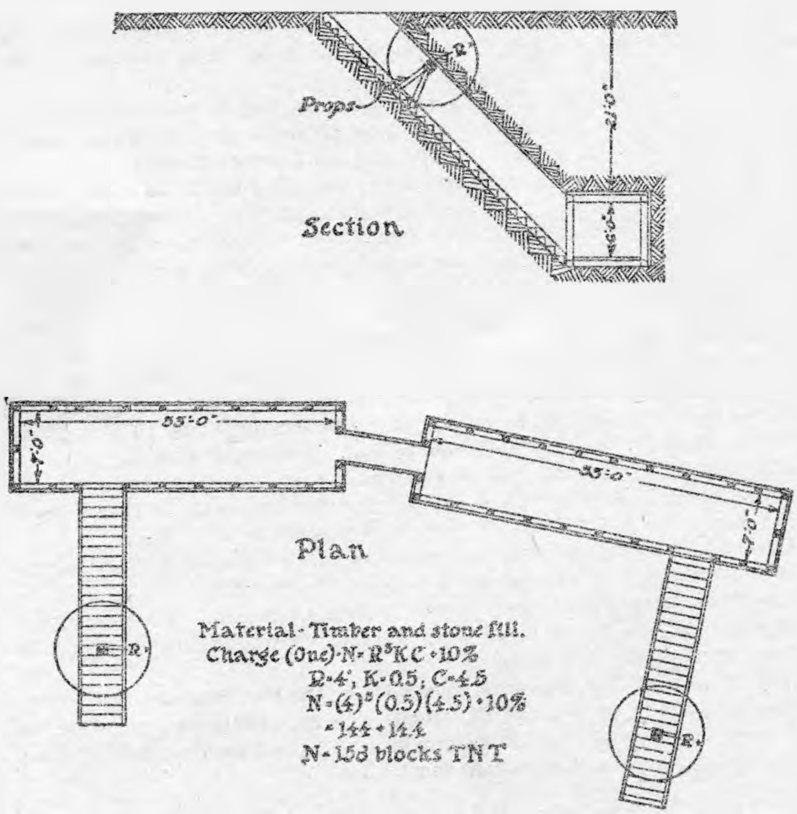


FIG. 70.—Destruction of bomb proof

c. 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.

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.

90. **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. 68, 69, and 70.)

91. **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.

92. **Bangalore torpedoes.**—*a.* A Bangalore torpedo consists of a section of pipe or other similar casing filled with a high explosive. Due to its weight, shape, and the care necessary in assembling, it is difficult to carry long distances or over broken ground, and the results from its use are not certain.

b. The torpedo is usually made up in three 10-foot sections consisting of a leading end, a center section, and a trailing end. The leading end is fitted with a rounded wooden nose to prevent it from being caught in the wire or making a scratching noise. The trailing end is fitted with a wooden plug and a greased paper sleeve through which the priming fuze is inserted. The center piece is joined to the end pieces by male and female joints. The sections are filled with TNT blocks placed end to end. Provision must be made to carry the detonation past the joints by detonating cord, or by induced detonation (see par. 55). Each section is carried forward separately and assembled near the site.

c. After assembling at the site, the torpedo should be pushed forward on the ground under the belt of wire where the breach is desired.

d. The Bangalore torpedo party should consist of 8 men. Two men carry each section and the remaining 2 men carry extra wooden noses, firing devices, etc.

e. Detonation by safety fuze is recommended as the best method. The safety fuze should be cut to burn about 15 seconds. As an additional precaution, an instantaneous fuze primer should be provided. If the time fuze fails to detonate the cap, this instantaneous fuze can be used.

SECTION X

THE USE OF EXPLOSIVES IN ENGINEERING

93. **General.**—The military engineer is confronted with many and varied construction projects. Often in these projects the use of explosives will be imperative, and still more often their use will facilitate the progress of the work. Hence brief descriptions of a few such uses are included herein. These descriptions are not intended as hard and fast methods but merely to serve as guides. As the officer becomes more and more familiar with the use of explosives, various methods will suggest themselves. Every demolition project should be studied both for improvements in the manner of using the explosive and as to its bearing on future work.

94. **Road and railroad building.**—*a*. Explosives are used in road and railroad building for the following purposes:

(1) Removing stumps and bowlders.
(2) Opening ditches.
(3) Opening vertical drains.
(4) Loosening hard ground in grading.
(5) Blasting rock in grading.

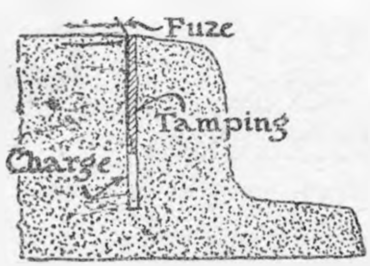


FIG. 71.—Location of vertical bore hole in road cut

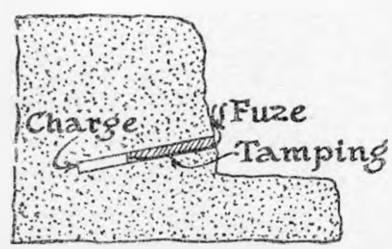


FIG. 72.—Location of horizontal or flat bore hole in road cut

(6) Blasting for surfacing and ballasting materials. Stump and bowlder blasting are described in paragraphs 99 and 100, respectively.

b. (1) Hard clay or rock in cuts may be loosened by blasting with charges loaded in horizontal or vertical holes. The selection of the direction of the holes must be governed by the nature of the ground. Where the ground has horizontal sea the vertical hole (fig. 71) is preferable; with vertical seams or where the ground is hardest at the top the flat hole (fig. 72) is preferable.

(2) With vertical holes, drill a line of holes all the way across the cut to a depth of about 1 foot below grade and spaced from three-fourths to four-fifths of their depth up to 6 feet. Above 6 feet, spacings should be from one-half to

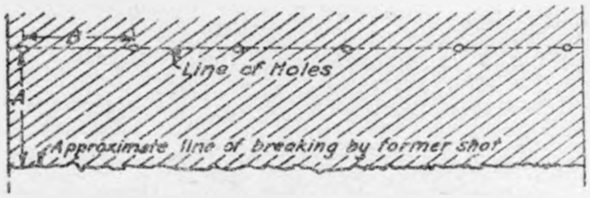


FIG. 73.—Plan of approximate loading for cut work

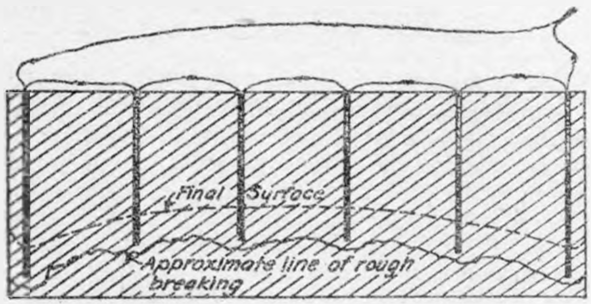


FIG. 74.—Elevation of approximate loading for cut work

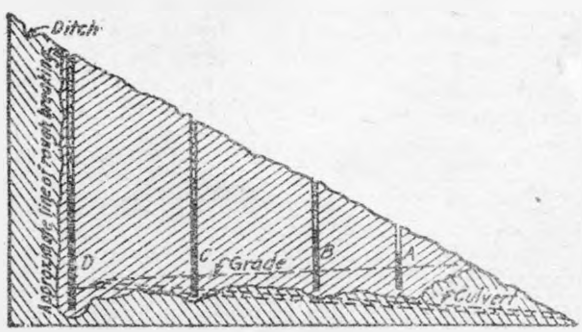


FIG. 75.—Excavated material to be hauled elsewhere

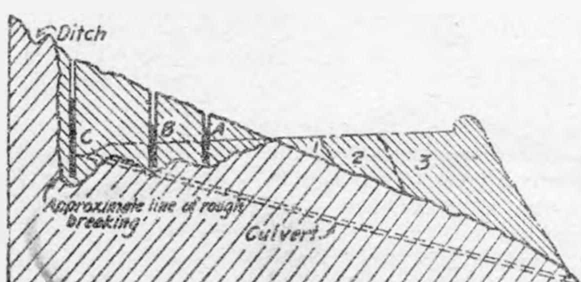


FIG. 76.—Excavated material to be used as fill

three-fourths of the depth. The burden (A in fig. 73) should be slightly greater than the spacing between holes (B).

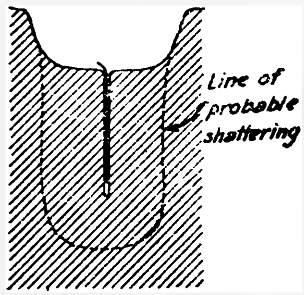


FIG. 77.—Loading to blast a shallow post hole

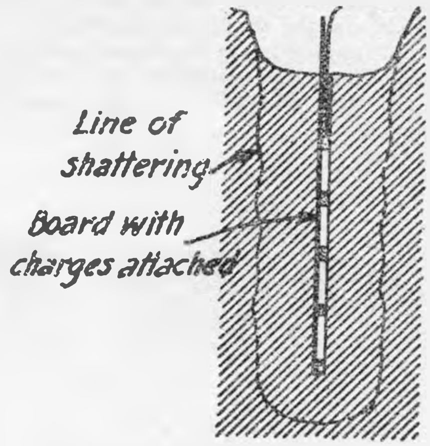


FIG. 78.—Loading a deep hole

(3) All holes should be sprung before final loading. The amount of the charge should be determined by experiment.

c. There are two methods of making sidehill cuts. In one method (fig. 75) all of the ground is excavated and the roadbed is on solid ground. In the other (fig. 76) the cut is not as wide and the spoil is used as filling.

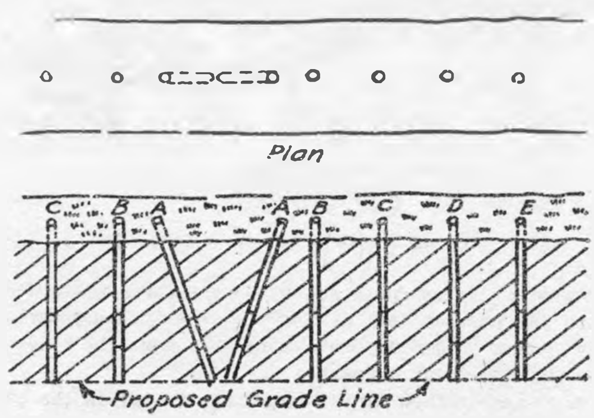


FIG. 79.—Digging a trench

d. Explosives may also be used to advantage in loosening soil for road machines or hand digging or to speed up steam-shovel excavation. They may also be used for side ditching, etc.

95. **Digging.**—Triton and dynamite are both useful for digging holes for telephone and other poles. To blast post holes in earth, first remove the surface to depth of from 6 to 8 inches or down to the hard ground and to the full diameter of the desired hole. Then prepare a bore hole and load as shown

in Figures 77 and 78. In rock the bore hole must be chambered before final firing.

96. Digging trenches with vertical walls.—Figure 79 shows a method for digging trenches with vertical walls. The holes indicated A should be fired together, and the remaining holes in the order indicated alphabetically.

97. Scrapping heavy machinery and blasting old foundations.—Explosives are often used in construction work for scrapping heavy machinery and for blasting old masonry or concrete. Methods involved are fully described in Sections VIII and IX.

FIG. 80.—Loading a tap-rooted stump with a single charge

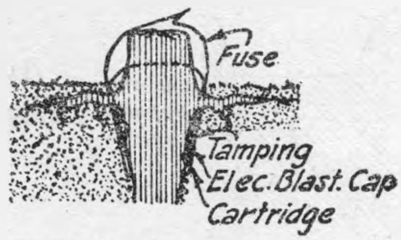


FIG. 81.—Loading a tap-rooted stump for an electric blast

98. Ice gorges.—*a.* Ice gorges choking up running streams and threatening bridges, dams, and other structures may be blasted by boring and loading bore holes or by mud capping.

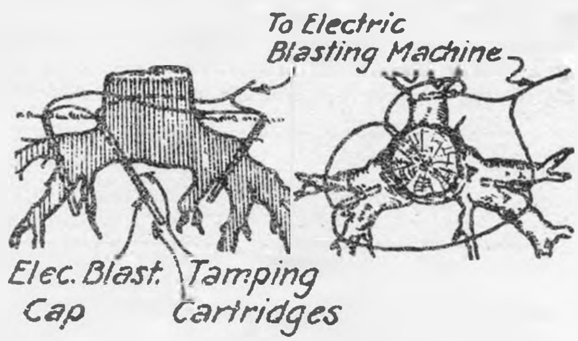


FIG. 82.—Loading lateral-rooted stumps

(1) In the first method holes should be cut through the ice at frequent intervals and the charges, tied to blocks of wood, thrust through the holes and allowed to float under the ice a little way from the holes. Such blasts raise the ice and then break it apart.

(2) In the second method large charges are loaded on the ice at frequent intervals and fired.

b. Definite amounts of explosives to be used in ice blasting can not be given but must be determined by test charges. In general, ice 3 or 4 feet thick will require charges of about 15 pounds of triton.

99. Stump blasting.—*a.* Stump blasting varies with the classes of stumps and soils involved. Some stumps have heavy tap-roots; others have only lateral, spreading roots, while still others have both. Green stumps are harder to blast than dead ones. Stumps in firm soil are more easily blasted than stumps in loose, sandy soil.

b. Figure 80 shows a method of placing charges for blasting tap-rooted stumps. Figure 81 shows another method in which the holes are bored into

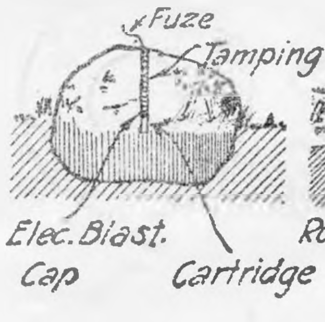


FIG. 83.—Blockhole charge for shattering a large bowlder

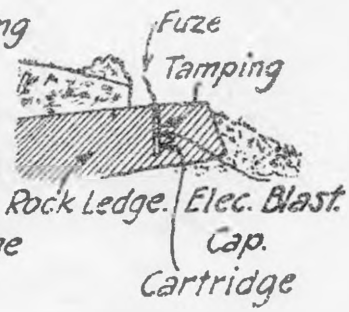


FIG. 84.—Blockhole charge for shattering rock outcrop

the earth immediately alongside of the tap-root and spaced equally around it. This method requires more explosives but less labor than the first method. Figure 82 shows a method of charging for large, lateral-rooted stumps.

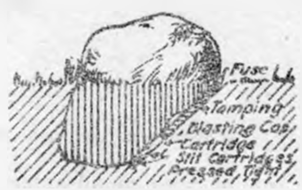


FIG. 85.—Snakehole charge for shattering or moving large bowlder

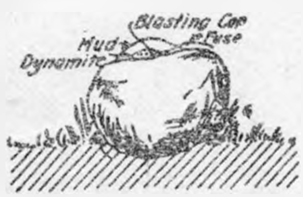


FIG. 86.—Correctly placed mudcap

100. Blasting bowlders.—Bowlders may be blasted by *blockholing, snakeholing, or mudcapping.*

c. Blockholing consists of drilling a hole into the bowlder and charging it with a small amount of high explosive. It is the best method for breaking very hard and very large bowlders. (See figs. 83 and 84.)

FIG. 87.—Loading a cut charge in a well

b. Snakeholing consists of placing a hole under and immediately against the bottom of a bowlder, charging and tamping the hole. (Fig. 85.)

c. Mudcapping is known by a variety of names: *Bulldozing*, *blistering*, *poulticing*, and *adobe shooting*. It is made possible by the shattering action of high

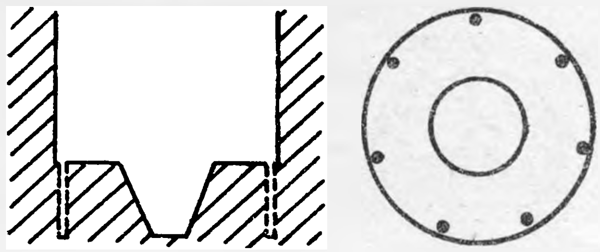


FIG. 88.—Completing the excavation

explosives. Figure 86 shows a method of mudcapping. The explosive should be placed on the bowlder at the place where the rock would be struck to break it with a hammer. When the bowlder is embedded in the ground, a snake hole should first be made to roll it out on the surface, as the confining dirt makes the bowlder much harder to break with a mudcap shot.

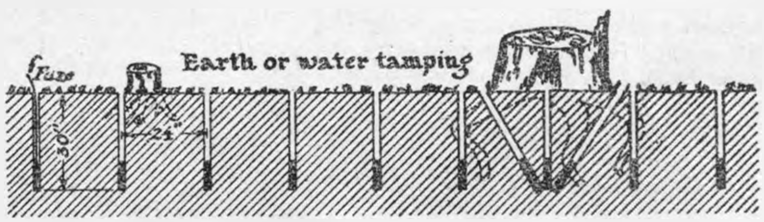


FIG. 89.—Propagated ditch blast. Charges fired by induced detonation

101. Blasting wells.—*a*. Explosives can be used to advantage in sinking wells through rock or ground which can not otherwise be dug to advantage. Figure 87 shows the first shot, and Figure 88 the excavation shot.

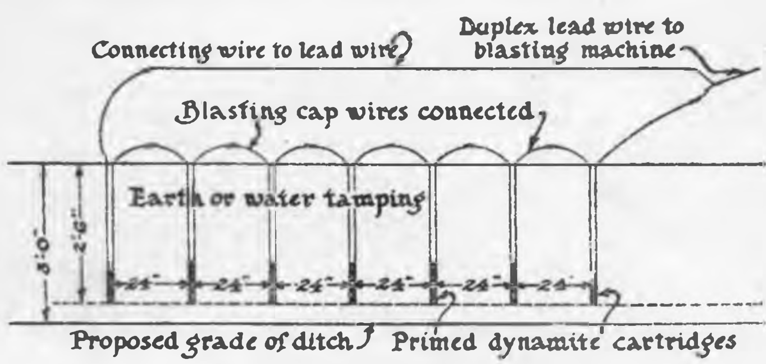


FIG. 90.—Electrically fired ditch blast

b. Often the supply of water from drilled wells can be increased by blasting. Such blasting endangers the water supply already present, however, and the advice of a geologist should first be obtained. The well is blasted by setting off a charge in the bottom.

102. Ditching and drainage.—*a.* Ditch blasting is effective in all classes of ground, from solid rock to loam, but is not effective in loose sand or gravel. There are two methods of ditch blasting, the *propagation method* and the *electric method.*

(1) In the propagation method charges are loaded and fired as shown in Figure 89. The size of hole and amount of explosive required are determined by first blasting a few test holes. When 40 per cent and 60 per cent dynamite is used caps are not required, except for the initial charge.

(2) Figure 90 shows the loading for the electrical method.

b. Figure 91 illustrates a blasted drainage hole providing vertical drainage where ditched drainage is impracticable.

FIG. 91.—Blasted drainage hole

103. Other uses.—Explosives may be used to great advantage in quarrying, tunneling, submarine blasting, etc. Such work is complicated, and the services of an experienced blaster are required in order to secure the best results.