FM 5-35

WAR DEPARTMENT

ENGINEER FIELD MANUAL

REFERENCE DATA

February 15, 1941

FM 5-35

ENGINEER FIELD MANUAL

REFERENCE DATA

Prepared under direction of the
Chief of Engineers

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

For sale by the Superintendent of Documents, Washington, D. C.
Price 75 cents

WAR DEPARTMENT,
WASHINGTON, *February 15, 1941.*

FM 5-35, Engineer Field Manual, Reference Data, is published for the information and guidance of all concerned.

[A. G. 062.11 (10-2-40).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

DISTRIBUTION:

R 2, 5, 17 (10), 36, 7 (5);
IR 4 (5); Bn 2-11, 17 (5);
C 2, 5, 17 (10), 3, 6, 7, 9, 10, 11 (5).

TABLE OF CONTENTS

ENGINEER FIELD MANUAL

REFERENCE DATA

CHAPTER 1

ENGINEER TROOPS AND OPERATIONS

SECTION I

GENERAL

■ 1. PURPOSE AND SCOPE.—*a.* The Engineer Field Manuals are designed to furnish technical information, describe the organization of engineer units, and outline typical procedures that may be followed in the conduct of the more common operations undertaken by engineers in the theater of operations. Local conditions in the field will always affect the application of these procedures, tables, and formulas; they should be taken as suggestions and guides to be used with judgment and modified to conform to the situation rather than as regulations to be rigidly followed.

b. The purpose of this manual is to present the fundamentals from the Engineer Field Manuals, FM 5-5 to FM 5-30, inclusive, in such condensed form as to be available in a single text when needed for ready reference in the field. Information and instructional matter not needed by experienced engineers or details available elsewhere required for deliberate construction have been omitted. Other data required for field construction have been added.

■ 2. BASIC CONCEPTIONS.—*a.* The purpose of the engineer arm is to assist in the accomplishment of the mission of the force as a whole. The amount and character of engineer work necessary to render this assistance will depend upon the nature of the terrain, the climate, the resources and development of the theater of operations, and the character of enemy activity.

b. The mission of engineers is to increase the combat effectiveness of all other arms through the execution of work to—

(1) Facilitate movement of our troops.

(2) Impede movement of the enemy.

(3) Provide for shelter and comfort of our troops.

■ 3. DUTIES IN THEATER OF OPERATIONS.

a. Remove or pass obstacles.

b. Provide stream crossings.

c. Repair and construct roads.

d. Repair, extend, and operate railways and inland waterways.

e. Construct wharves and other facilities for water transportation.

f. Construct and maintain landing fields.

g. Execute demolitions and create obstacles.

h. Give technical assistance and furnish tools, supplies, and materials for construction of protective works and camouflage.

i. Construct works requiring special equipment and training.

j. Fight as riflemen in emergency. (See fig. 26.)

k. Make and distribute maps.

l. Construct shelters.

m. Construct supply and evacuation establishments.

n. Provide water supply.

o. Provide and operate general utilities.

■ 4. CHARACTER OF CONSTRUCTION.—All work of engineers in war should be simple in conception, design, and execution. No construction should be better than is necessary to meet bare requirements. It should be accomplished with the greatest possible economy of material and force in the minimum of time, and plans therefor should be flexible to permit of last minute changes or alterations. For most structures, factors of safety can be extremely low and standards of durability limited. Standardization is desirable and will facilitate work in rear areas; however, in the theater of operations it will generally be necessary to make a maximum use of expedients. Officers and men alike must be trained in locating materials by engineer reconnaissance, and in employing maximum ingenuity, resourcefulness, and common sense in their use.

SECTION II

ENGINEER UNITS

■ 5. KINDS OF UNITS.—*a. General engineer troops.*

(1) With infantry divisions.

(*a*) Combat battalion (assigned to triangular division).

(*b*) Combat regiment (assigned to square division).

(2) With armored units—combat battalion (armored).

(3) With cavalry units—squadron (assigned to cavalry division).

(4) Nondivisional units.

(*a*) Combat regiment (corps) (assigned to corps).

(*b*) General service regiment (assigned to army and higher units).

(*c*) Engineer regiment (aviation) (assigned to GHQ Air Force).

(*d*) Separate battalion (assigned to army and higher units).

b. Special engineer troops.

(1) Camouflage units.

(*a*) Army camouflage battalion.

(*b*) GHQ camouflage battalion.

(2) Ponton units.

(*a*) Light ponton company.

(*b*) Heavy ponton battalion.

(3) Railway units.

(*a*) Railway operating battalion.

(*b*) Railway shop battalion.

(4) Mapping units.

(*a*) Corps topographic company.

(*b*) Army topographic battalion.

(*c*) GHQ topographic battalion.

(5) Supply units.

(*a*) Water supply battalion.

(*b*) Dump truck company.

(*c*) Depot company.

(*d*) Shop company, mobile.

c. Engineer headquarters.—These are indicated in the following table for the assignment of engineer units to a type GHQ force of three armies.

TABLE I.—*Assignment of engineer units to a type GHQ force of three armies*

Strength		Designation of engineer unit	Number[1] normally assigned to various tactical units					
Officers	Enlisted men		Division	Corps	Army	GHQ reserve	Air force	Total in GHQ force
----	----	Combat battalion (triangular division)	[2] 1	----	----	----	----	9
----	----	Engineer squadron	[3] 1	----	----	----	----	----
----	----	Engineer battalion (armored division)	[4] 1	----	----	----	----	----
----	----	Combat regiment (square division)	[5] 1	----	----	----	----	18
----	----	Combat regiment (corps)	----	2	----	----	----	18
----	----	General service regiment	----	----	3	10	----	19
----	----	Separate battalion	----	----	6	30	----	48
----	----	Camouflage battalion (army)	----	----	1	----	----	3
----	----	Camouflage battalion (GHQ)	----	----	----	1	----	1
----	----	Heavy ponton battalion	----	----	2	8	----	14
----	----	Topographic battalion (army)	----	----	1	----	----	3
----	----	Topographic battalion (GHQ)	----	----	----	1	----	1
----	----	Water supply battalion	----	----	1	3	----	6
----	----	Depot company	----	----	1	9	----	12
----	----	Dump truck company	----	----	2	18	----	24
----	----	Light ponton company	----	----	4	12	----	24
----	----	Topographic company (corps)	----	1	----	----	----	9
----	----	Shop company, mobile	----	----	1	3	----	6
----	----	Engineer headquarters (GHQ)	----	----	----	1	----	1
----	----	Engineer headquarters (communications zone)	----	----	----	1	----	1
----	----	Engineer headquarters (communications zone section)	----	----	----	3	----	3
----	----	Engineer headquarters (army)	----	----	1	----	----	3
----	----	Engineer headquarters (corps)	----	1	----	----	----	9
----	----	Engineer headquarters (railway)	----	----	----	1	----	1
----	----	Engineer headquarters (railway grand division)	----	----	----	5	----	5
----	----	Railway operating battalion	----	----	----	15	----	15
----	----	Railway shop battalion	----	----	----	2	----	2
----	----	Engineer headquarters (aviation)	----	----	----	----	1	1
----	----	Engineer regiment (aviation)	----	----	----	----	2	2

[1] Does not include engineer units in subordinate tactical units.
[2] Per infantry division (triangular).
[3] Per cavalry division.
[4] Per armored division.
[5] Per infantry division (square).

NOTE.—This distribution is merely illustrative and is based on the normal needs of a type GHQ Force consisting of a GHQ Air Force and 3 type armies with 3 type corps each consisting of 1 triangular and 2 square infantry divisions.

■ **6. ENGINEERS WITH INFANTRY DIVISIONS.**—*a. Combat battalion.*—As the engineer component of the triangular infantry division, this unit performs the normal general engineer work

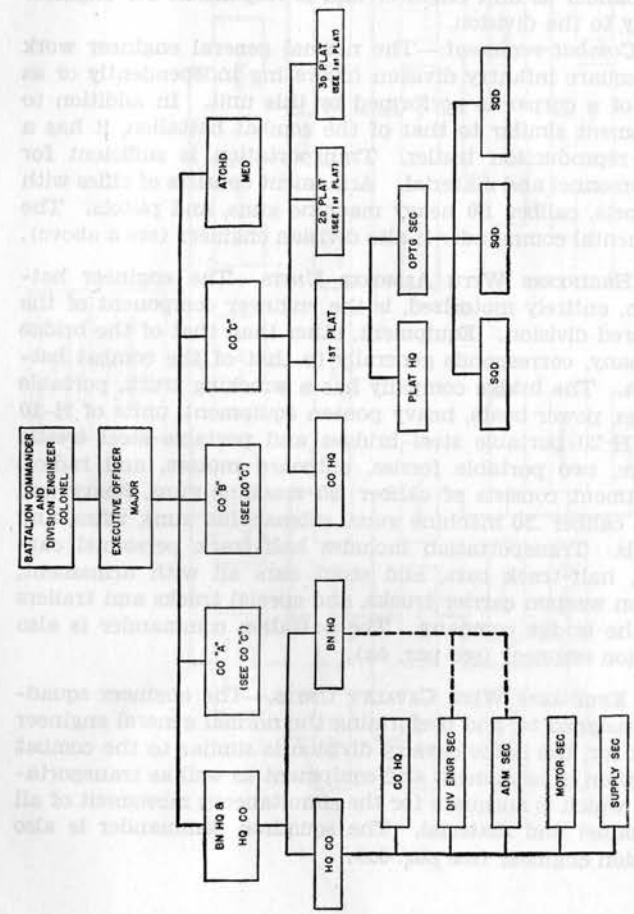


FIGURE 1.—Engineer combat battalion (triangular division).

for the division when the division is operating as part of a corps. The combat battalion will often be reinforced to meet the needs of an independent division. Transportation is sufficient for all personnel and material; armament consists of rifles, bayonets, caliber .30 heavy machine guns, and pistols. The battalion commander is also on the staff of the division commander as unit engineer and is responsible for engineer supply to the division.

b. Combat regiment.—The normal general engineer work of a square infantry division (operating independently or as part of a corps) is performed by this unit. In addition to equipment similar to that of the combat battalion, it has a map reproduction trailer. Transportation is sufficient for all personnel and material. Armament consists of rifles with bayonets, caliber .30 heavy machine guns, and pistols. The regimental commander is also division engineer (see *a* above).

■ 7. ENGINEERS WITH ARMORED UNITS.—The engineer battalion, entirely motorized, is the engineer component of the armored division. Equipment, other than that of the bridge company, corresponds generally to that of the combat battalion. The bridge company has a wrecking truck, portable cranes, power boats, heavy ponton equipment, units of H-10 and H-20 portable steel bridges and portable steel trestle bridge, two portable ferries, outboard motors, and radios. Armament consists of caliber .50 machine guns, heavy and light caliber .30 machine guns, submachine guns, rifles, and pistols. Transportation includes half-track personnel carriers, half-track cars, and scout cars all with armament, ½-ton weapon carrier trucks, and special trucks and trailers for the bridge company. The battalion commander is also division engineer (see par. 6*a*).

■ 8. ENGINEERS WITH CAVALRY UNITS.—The engineer squadron assigned to, and performing the normal general engineer work for, the horse cavalry division is similar to the combat battalion in armament and equipment as well as transportation, which is adequate for the simultaneous movement of all personnel and material. The squadron commander is also division engineer (see par. 6*a*).

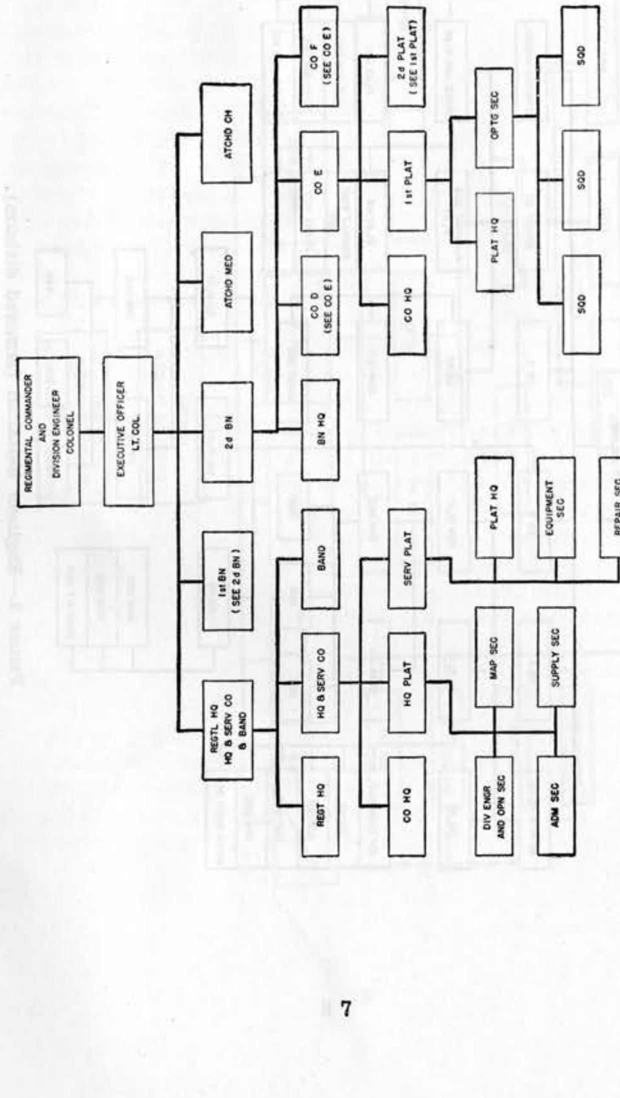


FIGURE 2.—Engineer regiment, combat (square division).

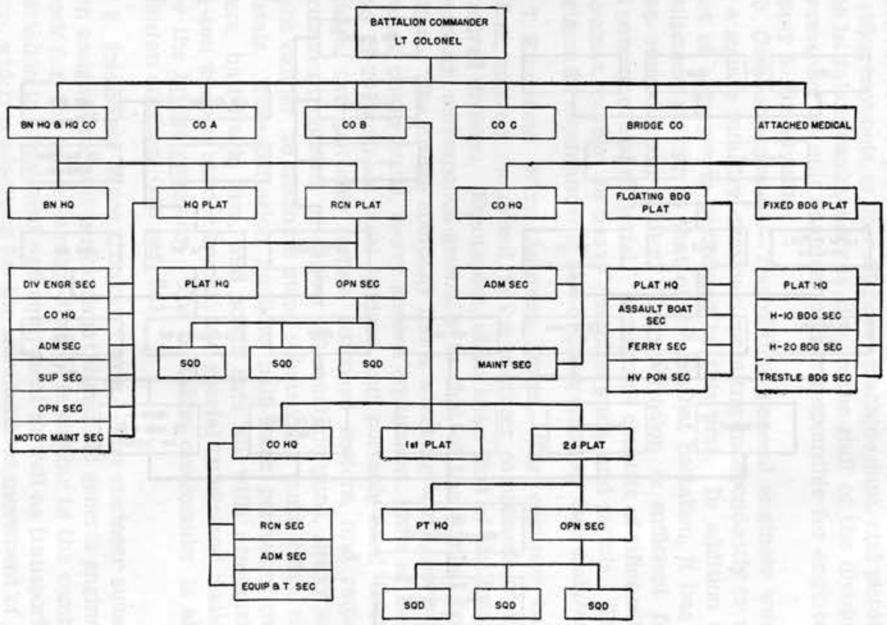


FIGURE 3.—Engineer battalion (armored division).

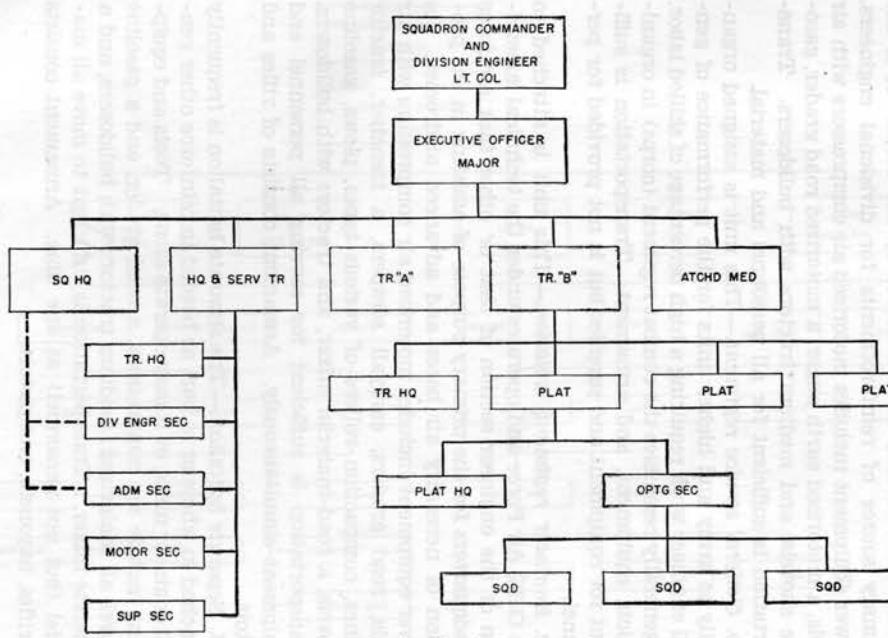


FIGURE 4.—Engineer squadron.

■ 9. NONDIVISIONAL GENERAL ENGINEER UNITS.—*a. Combat regiment (corps).*—Two such regiments are assigned to each type army corps for the performance of general engineer work in forward parts of the corps service area and such division service areas as may be taken over by the corps. It is the primary source of reinforcements for divisional engineers. Power equipment includes motorized air compressors with air tools, a motorized earth auger, a motorized road grader, gasoline shovels, and medium tractors with bulldozers. Transportation is sufficient for all personnel and material.

b. General service regiment.—This unit is assigned organically to army and higher units for the performance of general engineer work requiring a high percentage of skilled labor. It generally resembles the combat regiment (corps) in organization, equipment, and armament. Transportation is sufficient for equipment and supplies but is not provided for personnel.

c. Engineer regiment, aviation.—This unit is attached to the GHQ Air Force and operates under the technical supervision of the engineer section of that or other task air force headquarters for the primary purpose of assisting in the provision of necessary air bases and advanced airdromes. Its power equipment includes motorized air compressors with air tools, road graders, carryall scrapers, a trencher, tractor cranes, compaction rollers of various types, plows, gasoline shovels, a road-material mixer, and tractors with bulldozers. Transportation is sufficient for moving all personnel and equipment simultaneously. Armament consists of rifles and pistols.

d. Separate battalion.—The separate battalion is frequently attached in whole or in part as needed to reinforce other general engineer units, or it may operate alone. Tools and equipment include air compressors, a road grader, and a gasoline shovel, all motorized; medium tractors with bulldozers, and a concrete mixer. Transportation is sufficient to move all matériel (but not personnel) at one time. Armament consists of rifles, bayonets, and pistols.

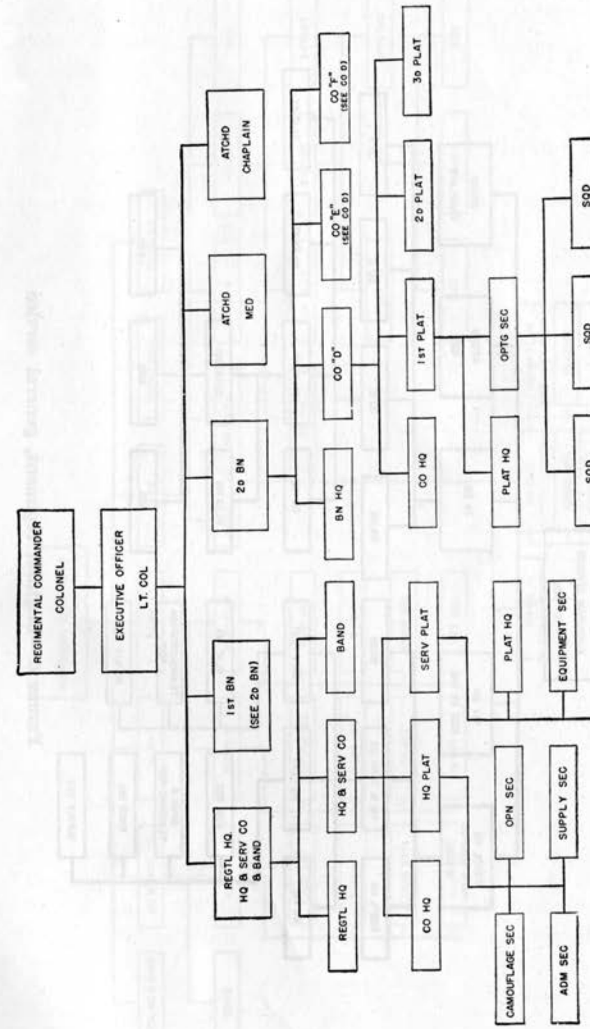


FIGURE 5.—Engineer regiment, combat (corps).

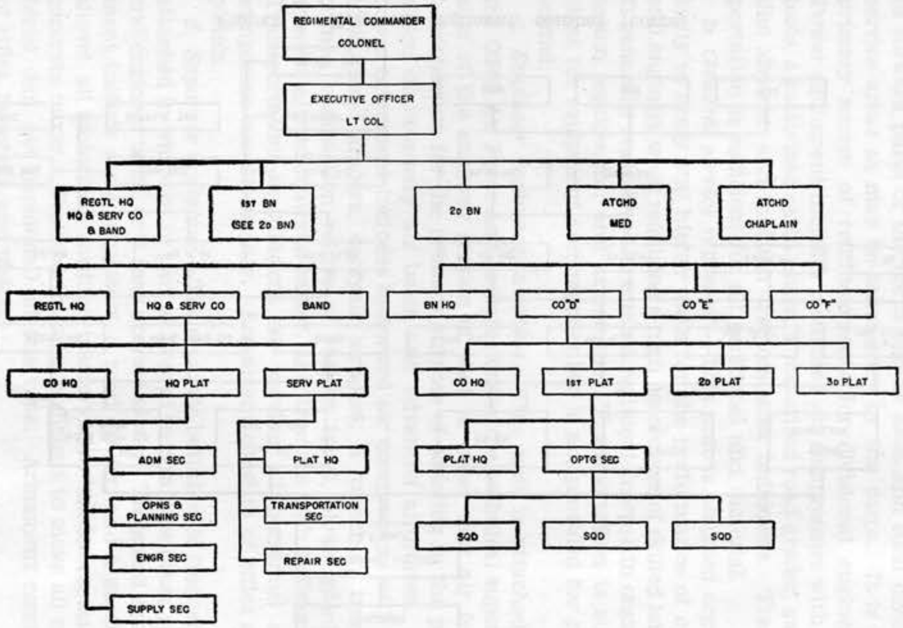


FIGURE 6.—Engineer regiment, general service

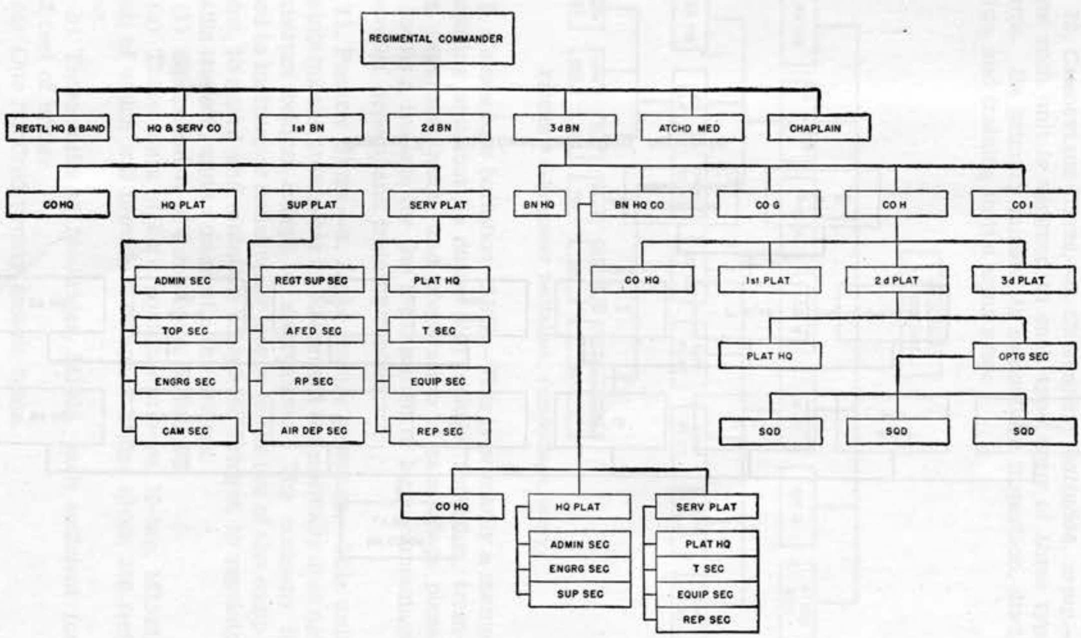


FIGURE 7.—Engineer regiment, aviation.

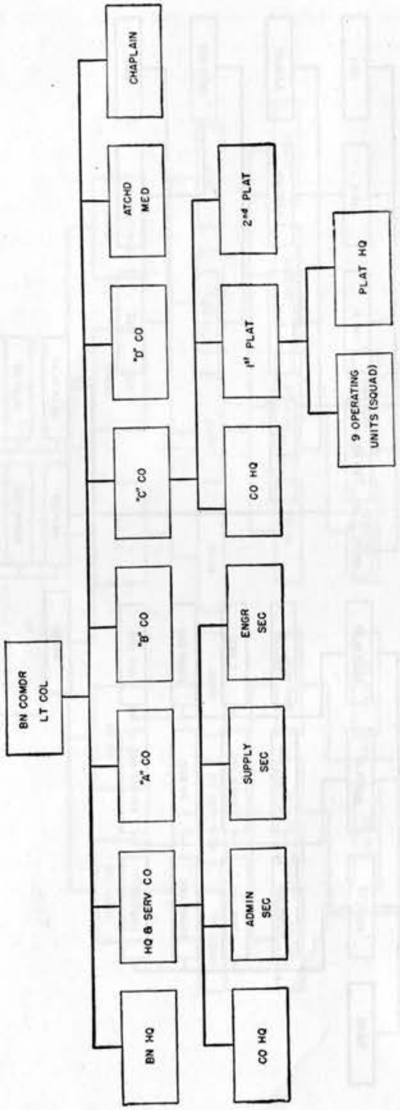


FIGURE 8.—Engineer battalion, separate.

■ 10. CAMOUFLAGE UNITS.—*a. Camouflage battalion, army.*—One such unit is assigned to each type army of three type corps. Its primary mission is camouflage inspection, discipline, and training in the army area.

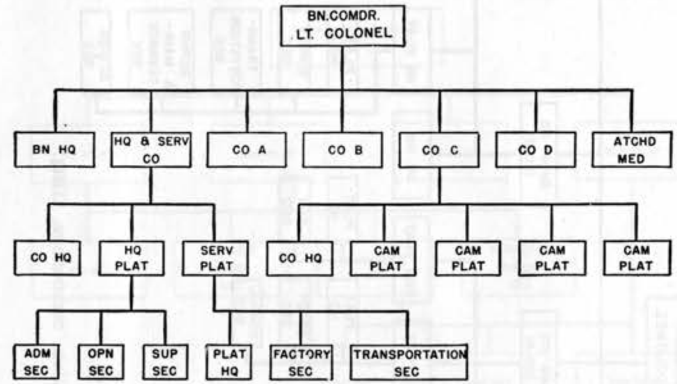


FIGURE 9.—Engineer battalion, camouflage, army.

b. Camouflage battalion, GHQ.—This is primarily a manufacturing unit, but its duties also include inspection, training, experimentation, and preparation of camouflage plans. It forms a nucleus for the organization of large camouflage factories, depots, and training centers.

■ 11. PONTON UNITS.—*a. Light ponton company.*—This unit maintains and transports its equipment but normally does not construct bridges except in emergencies. The company is used to instruct or assist other troops in the use of the equipment, to guard and maintain completed bridges, to regulate traffic thereon, and to dismantle the bridges.

(1) Equipment is of three types, as follows:

(*a*) Three units of light ponton equipage, 10-ton, M1938, each of which will provide a complete bridge about 250 feet long.

(*b*) Three units of footbridge, M1935, each sufficient for 432 feet of bridge.

(*c*) One hundred twenty assault boats.

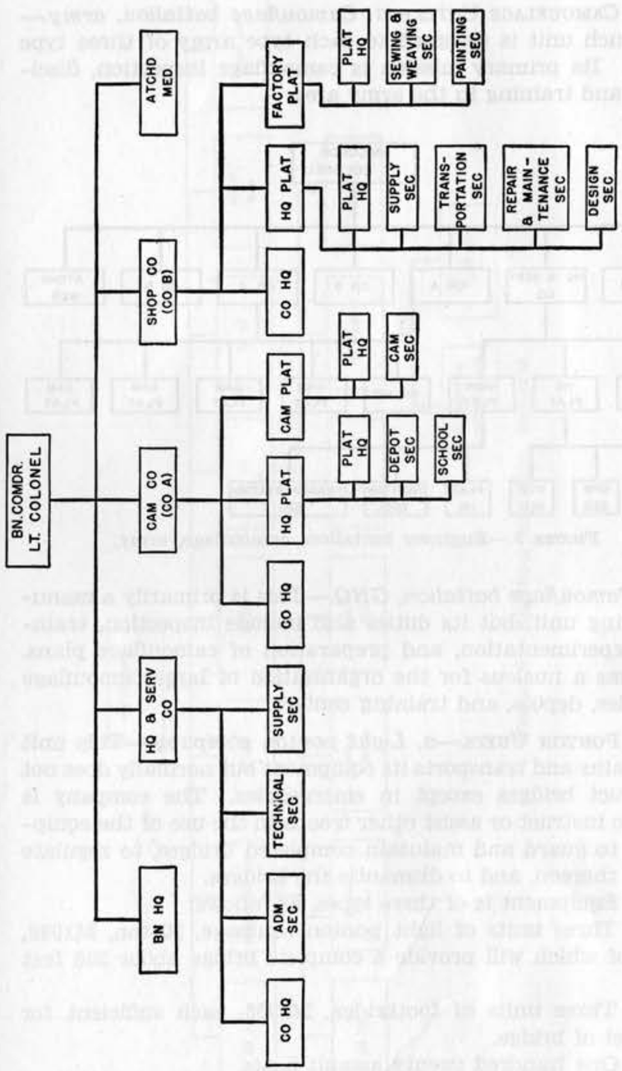


FIGURE 10.—Engineer battalion, camouflage, GHQ.

(2) The company has sufficient transportation for all personnel and equipment except that prime movers for the 99 trailers on which the ponton equipage is transported must be furnished from other sources by higher command.

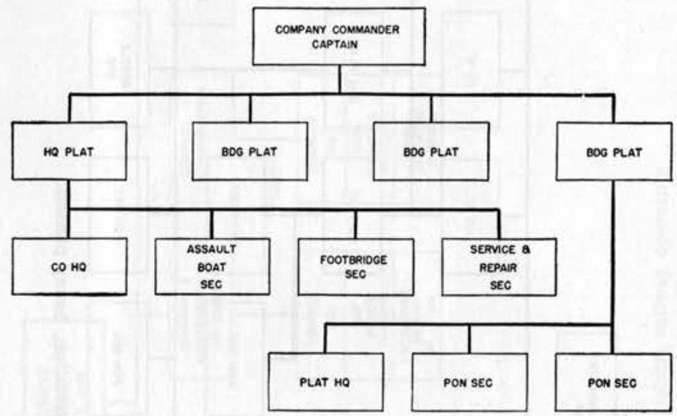


FIGURE 11.—Engineer company, light ponton.

b. Heavy ponton battalion.—This unit maintains and transports the heavy ponton equipage, 25-ton, M1940. The battalion is not organized primarily for construction of ponton bridges, which is normally the function of general engineer troops. However, under some circumstances the battalion may construct the bridge. Like the light ponton company, it is often used to instruct and assist other troops, to guard and maintain completed bridges, to regulate their traffic, and to dismantle them. Bridging equipment carried on semi-trailers drawn by 4 by 4 trucks consists of four complete units, each of which will afford 250 feet of bridge.

■ 12. RAILWAY UNITS.—*a. Railway operating battalion.*—The mission of this unit is to operate the trains and yards of a railway division; to maintain the track and structures of the division; and to make running repairs to equipment. A railway operating battalion may also be assigned to the operation and maintenance of a large railway terminal or regulating station.

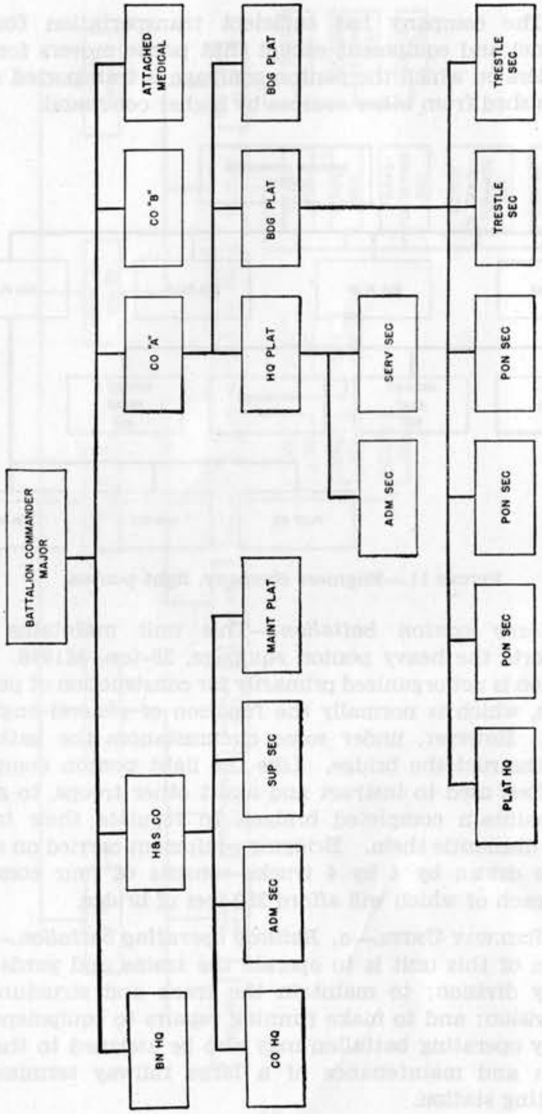


FIGURE 12.—Engineer battalion, heavy ponton.

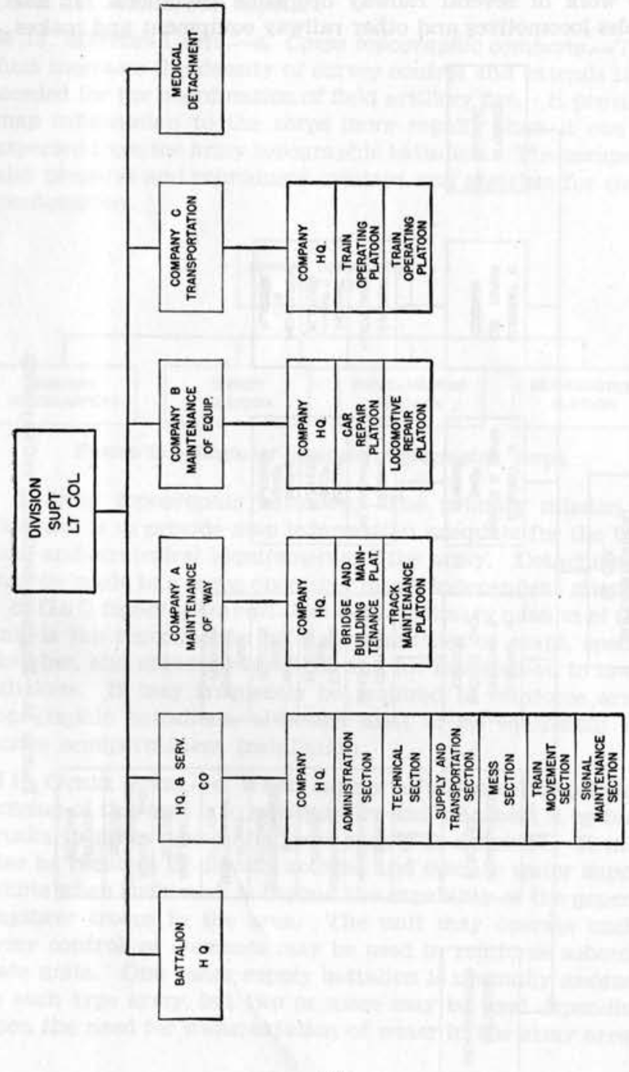


FIGURE 13.—Engineer battalion, railway operating

b. Railway shop battalion.—This unit handles the heavy shop work of several railway operating battalions. It assembles locomotives and other railway equipment and makes

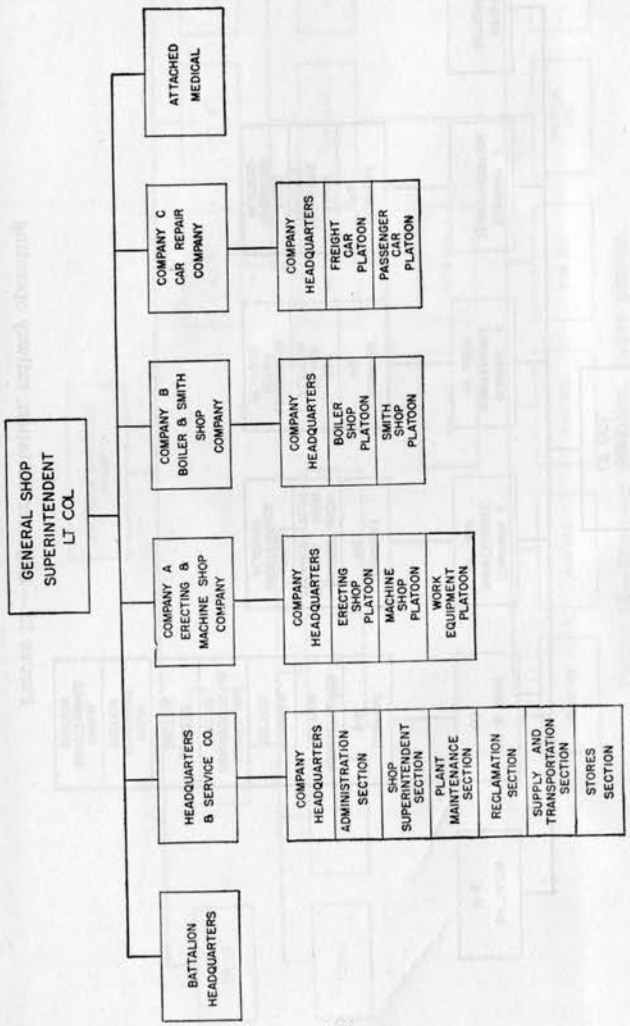


FIGURE 14.—Engineer battalion, railway shop.

all major repairs thereto. It also manufactures replacement parts not available in depots.

■ 13. MAPPING UNITS.—*a. Corps topographic company.*—This unit increases the density of survey control and extends it as needed for the coordination of field artillery fire. It provides map information to the corps more rapidly than it can be expected from the army topographic battalion. The company also prepares and reproduces overlays and sketches for corps headquarters.

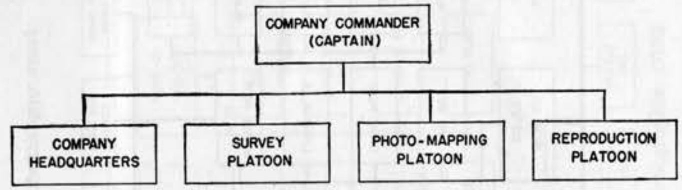


FIGURE 15.—Engineer company, topographic, corps.

b. Army topographic battalion.—The primary mission of this unit is to provide map information adequate for the tactical and strategical requirements of the army. Detachments may be made to a corps operating on an independent mission.

c. GHQ topographic battalion.—The primary mission of this unit is the reproduction in large quantities of maps, special sketches, and drawings for GHQ and for distribution to lower echelons. It may frequently be required to reinforce army topographic battalions, although most of its equipment requires semipermanent installation.

■ 14. OTHER UNITS.—*a. Water supply battalion.*—The primary mission of this unit is to purify water and transport it by tank trucks to areas where the local supply is deficient. It may also be required to develop sources and operate water supply points when such work is beyond the capability of the general engineer troops in the area. The unit may operate under army control, or elements may be used to reinforce subordinate units. One water supply battalion is normally assigned to each type army, but two or more may be used depending upon the need for transportation of water in the army area.

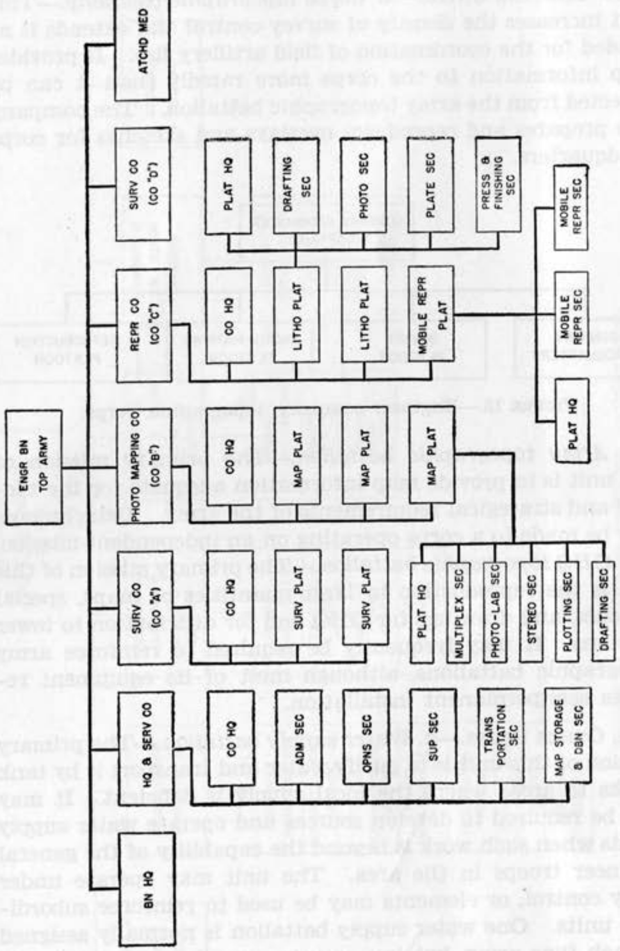


FIGURE 16.—Engineer battalion, topographic, army.

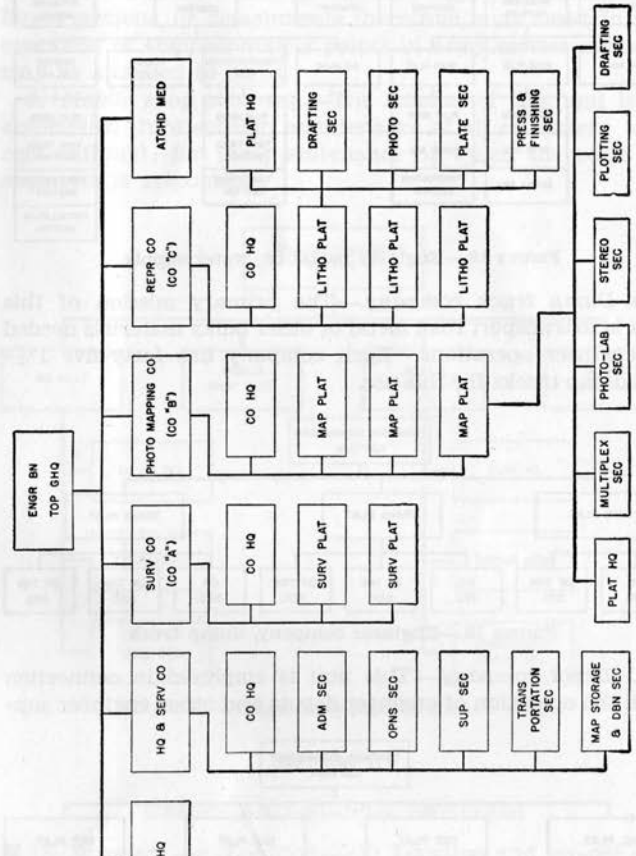


FIGURE 17.—Engineer battalion, topographic, GHQ.

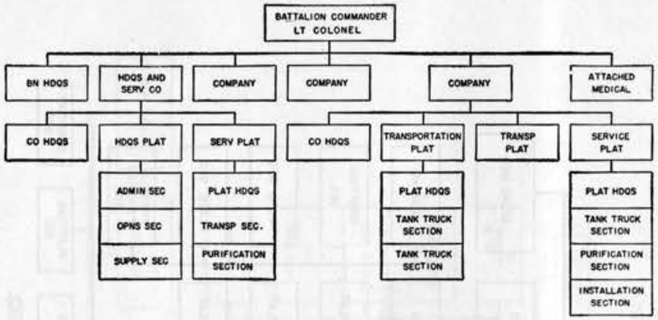


FIGURE 18.—Engineer battalion, water supply.

b. Dump truck company.—The primary mission of this unit is to transport road metal or other bulky materials needed in engineer operations. Each company has forty-five 1½-ton dump trucks for this use.

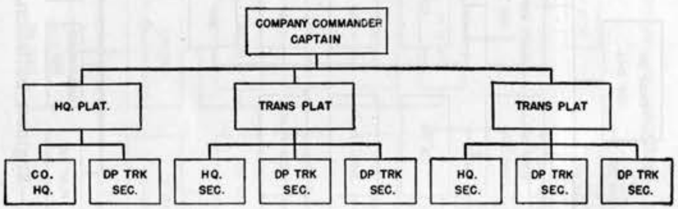


FIGURE 19.—Engineer company, dump truck.

c. Depot company.—This unit is employed in connection with the operation of engineer depots and other engineer sup-

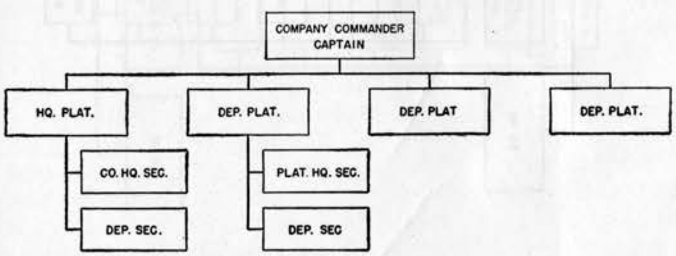


FIGURE 20.—Engineer company, depot.

ply points. It may form a nucleus for a large special engineer depot or the engineer section of a general depot, or it may operate alone a smaller engineer supply establishment. Depot sections, or detachments therefrom, may assist in the operation of engineer supply points in army service areas or may be attached to corps.

d. Mobile shop company.—The mission of this unit is to accomplish third echelon maintenance of all equipment (except railway), for the maintenance of which the corps of engineers is responsible.

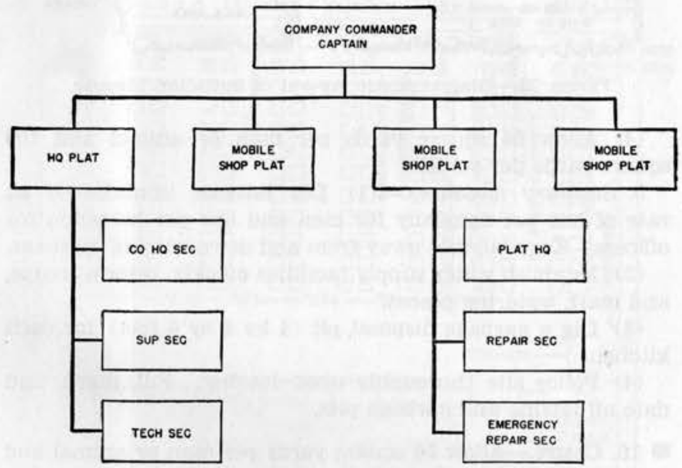


FIGURE 21.—Engineer company, mobile shop.

SECTION III

CAMPS AND SUPPLY SYSTEMS

■ 15. BIVOUACS.—*a. Location.*—(1) Location and lay-out depend upon the tactical situation.

(2) Locate near the route which is being used, and parallel thereto when possible.

(3) Make maximum use of natural cover and avoid regular patterns.

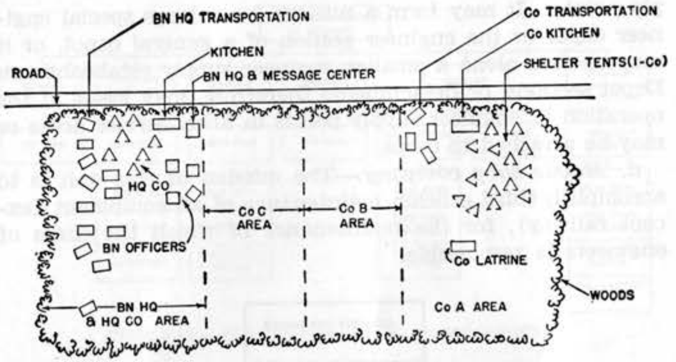


FIGURE 22.—Diagrammatic lay-out of battalion bivouac.

(4) Allow 50 square yards per man or animal and 100 square yards per vehicle.

b. Sanitary measures.—(1) Dig latrines immediately at rate of one per company for men and one per battalion for officers. Keep latrines away from and down wind of kitchens.

(2) Establish water supply facilities quickly, inform troops, and mark watering places.

(3) Dig a garbage disposal pit (4 by 4 by 4 feet) for each kitchen.

(4) Police site thoroughly upon leaving. Fill, mark, and date all latrine and garbage pits.

■ 16. CAMPS.—Allow 50 square yards per man or animal and 100 square yards per vehicle.

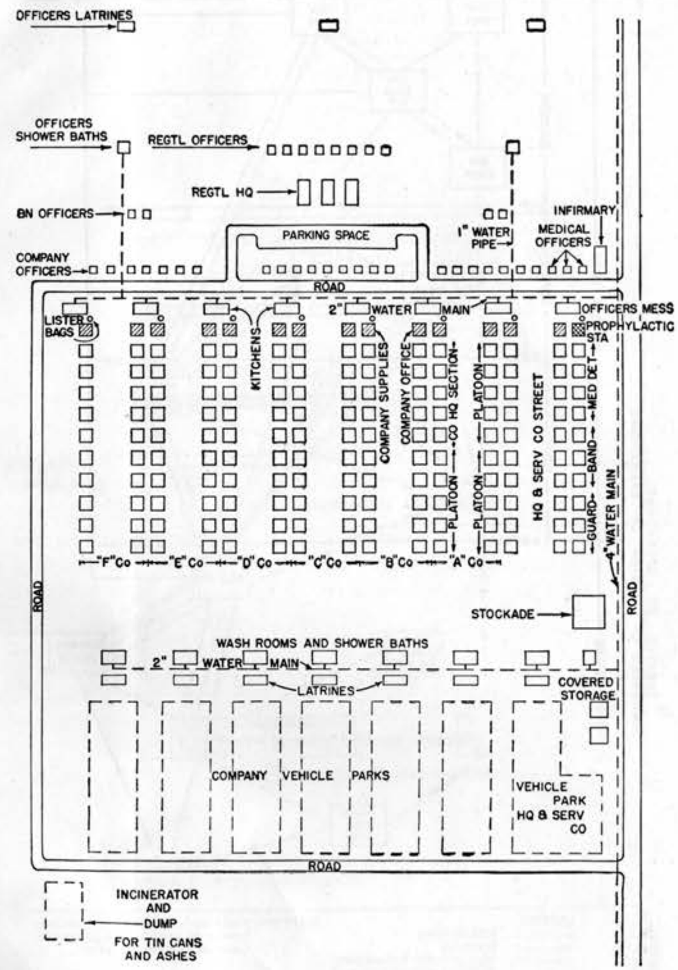


FIGURE 23.—Diagrammatic lay-out of regimental camp.

■ 17. SUPPLY.

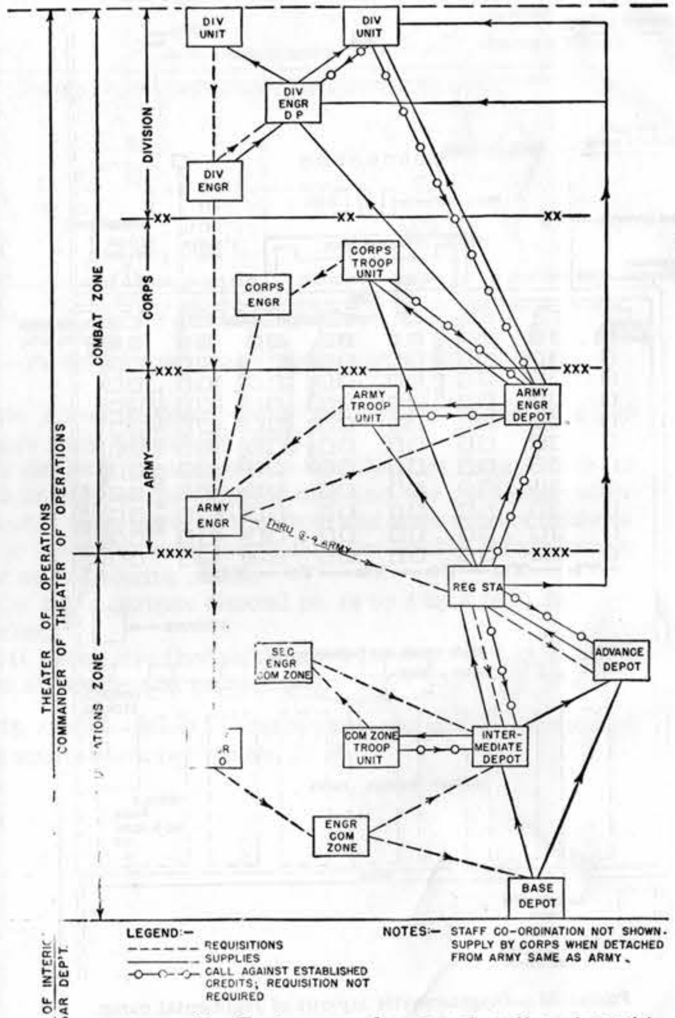


FIGURE 24.—Engineer supply; normal routing of requisitions and forwarding of engineer supplies in theater of operations.

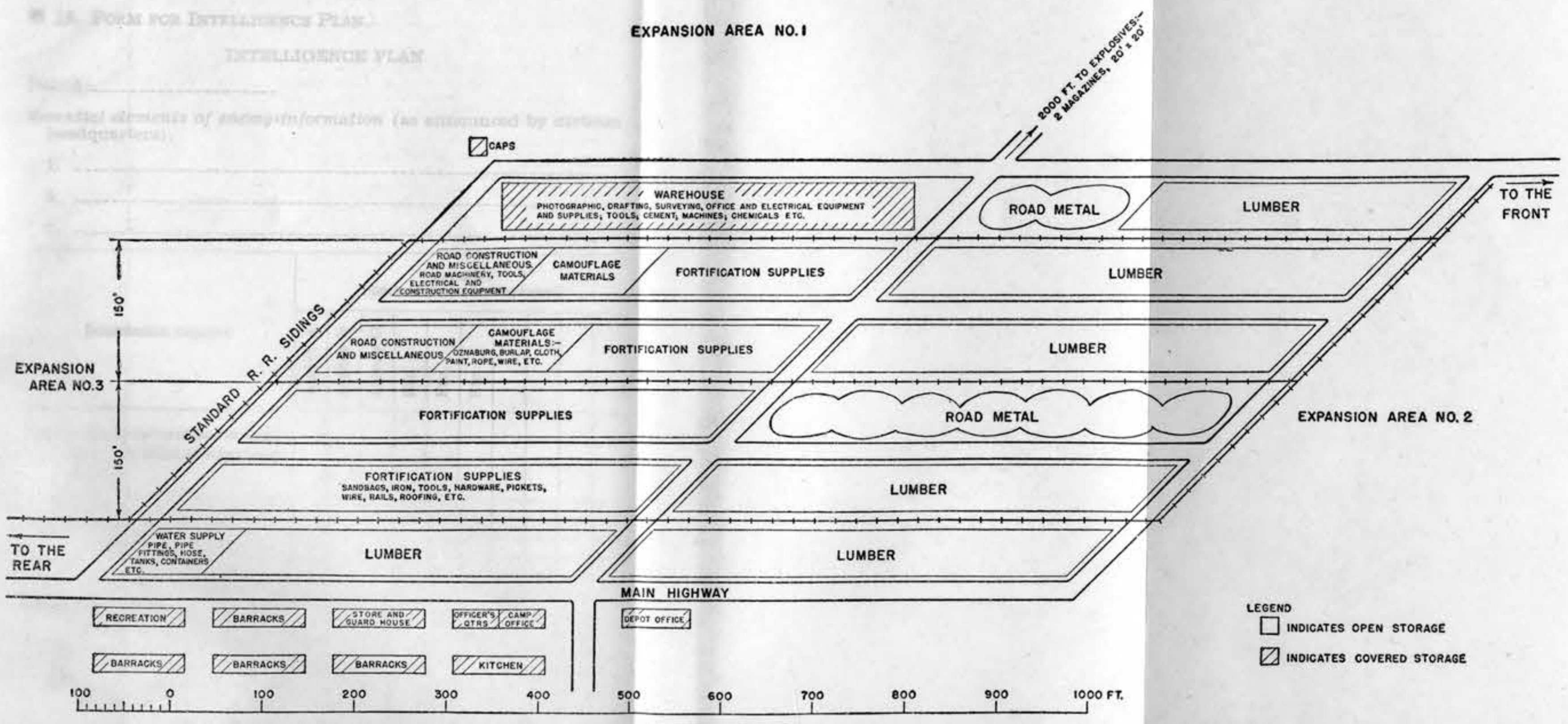


FIGURE 25.—Typical army engineer depot in combat zone, showing communications, lay-out of stocks, and expansion areas (based on estimated 15-day stockage for army of 3 corps of 3 square divisions each); minimum operating force, 1 depot company.

282736°—41 (Face p. 28)

SECTION IV

FORMS AND ORDERS

■ 18. FORM FOR INTELLIGENCE PLAN.

INTELLIGENCE PLAN

Period:____________________

Essential elements of enemy information (as announced by division headquarters).

1. ______________________________
2. ______________________________
3. ______________________________

Information required	Agencies (check those to be employed)									
	Agency A	Agency B	Agency C	Etc.	Etc.	Etc.				
Information to be furnished immediately to division or other headquarters:										
(1)________										
(2)________										
(3)________										
Etc.________										
________										
________										
Information for primary use of engineers:										
(1)________										
(2)________										
(3)________										
Etc.________										
________										
________										

■ 19. FORM FOR RECONNAISSANCE INSTRUCTIONS.—In the following form, check numbered items on which information is desired, and use the blank right hand column for additional instructions, listed *a, b, c,* etc.

RECONNAISSANCE INSTRUCTIONS

No. ------ ---------------------------- (Organization)

To ---------------------------- ---------------------------- (Place)

Effective ----------------19---- ---------------------------- (Date and hour)

Maps:

Reconnoiter and report information as indicated below by items checked (#). Report also any other information of technical importance incidentally secured.	SPECIAL INSTRUCTIONS Areas and roads to be reconnoitered in connection with missions ordered. Hour and destination of reports.
1. GENERAL FEATURES (complete report with particular attention to other items checked). 2. ADVERSE ENGINEER SITUATION IN CONNECTION WITH ATTACHED UNIT (column delayed, insufficient engineers attached, insufficient supplies, etc.). 3. AVENUES OF APPROACH. 4. BRIDGES. 5. CAMP SITES (suitable for a battalion or larger unit. Give details on availability of wood, water, cover). 6. COVER (suitable for reserve position for battalion or large unit. Generally suitable for camouflage of activities). 7. DEFENSIVE POSITIONS. 8. DEMOLITIONS BY ENEMY (details, labor, materials, and time necessary to repair). 9. ERRORS IN EXISTING MAPS. 10. FIELDS OF FIRE. 11. MATERIALS AND PLANT. 12. OBSERVATION. 13. OBSTACLES TO OUR MOVEMENT (natural and artificial). 14. OBSTACLES TO ENEMY MOVEMENT (suitable points). 15. RAILROADS. 16. ROADS. 17. STREAMS (width, depth, fords, ferries, navigability, condition of banks and approaches). 18. UTILITIES (garages, machine shops, electric plants, water-supply plants, gas systems). 19. WATERWAYS.	

BY ORDER OF

---------------------------- (Signature)

---------------------------- (Grade and organization)

■ 20. **FORMS FOR RECONNAISSANCE REPORTS.**—*a. General reconnaissance.*

ENGINEER RECONNAISSANCE REPORT

General features

Date-------------------- Party--------------------

1. Route followed--
2. Roads traveled:

From—	To—	Type	Width	Condition

3. Obstacles encountered on roads (list in order met and describe briefly. Indicate materials available locally for passing each) ------
4. Streams crossed:

Name	Width	Capacity of bridge	Width of bridge

5. Telephone lines.

From—	To—	Number of wires	Condition

6. Towns.

Name	Approximate population	W [1]	E [1]	G [1]

7. Road materials.

Located at—	Kind and quantity

[1] Indicate serviceability of water, electric, and gas systems.

8. Camp sites at which fuel and water are available.

9. Feasible points on roads or railroads for creating obstacles.

Location	Type of obstacle	Estimate of explosive required

10. Additional information [2]

(Signature)

(Grade)

b. Construction materials and equipment.

ENGINEER RECONNAISSANCE REPORT

Construction materials and equipment

Date__________ Party__________
Map reference__________
1. Area covered by reconnaissance__________
2. Standing timber:
General location if plentiful__________
Specific location if scarce__________
Range of sizes__________
Accessibility from roads__________
3. Lumber yards.

Location	Quantities	Cutting machinery

[2] Indicate good defensive positions, location of enemy lines, navigability of streams, fords, ferries, railroad sites, condition of railroads, and rolling stock, etc.

4. Hardware stores.

Location	General description of stock

5. Gravel pits.

Location	Machinery at pit	Daily capacity

6. Quarries.

Location	Crushing machinery	Daily capacity

7. Brickyards (location) __________
8. Road machinery.

	Location	Number
Plows		
Scrapers		
Rollers		
Concrete mixers		
Miscellaneous		

9. Pile drivers (location) --
10. Barbed wire.

Location	Approximate quantity
--	----------

11. Additional material or equipment ----------------------------
12. Remarks --

(Signature)

(Grade)

c. Roads, bridges, water supply, etc.—See sections I, II, and V, chapter 2.

■ 21. Engineer Situation Report. — The following example may be used as a guide in reporting an engineer situation. Appropriate entries should be made under applicable headings or different headings substituted.

(Organization)

(Place)

(Date and hour)

No. ———
Maps:

1. ENEMY INFORMATION (including prepared obstacles).
2. OTHER OBSTACLES.
3. WEATHER.
4. ROADS AND RAILROADS.
5. STREAM CROSSINGS.
6. COVER.
7. CAMOUFLAGE.
8. ENGINEER SUPPLIES.
9. WATER SUPPLY.
10. UTILITIES.

(Signature)

(Grade)

■ 22. Illustrative Orders.—The following orders are samples of orders issued by various types of engineer units. They are intended to illustrate form and subject matter only and must not be taken as tactical models. Coordinates of places are indicated by parentheses ( ) after the name. For general instructions concerning combat orders, see FM 101–5 (SOFM).

Illustrative order No. 1

FIELD ORDER FOR A COMBAT REGIMENT ENGAGED ON ENGINEER DUTIES

———

5th Engrs
RJ 599–D, near WHITEHALL, PA ( )
16 June 19—, 11:00 PM

FO 23

Maps: Topographical Map, Gettysburg-Antietam, 1:21, 120; New Oxford, Abbotstown, Hanover, Bonneville, Taneytown, and Kingsdale sheets.

1\. *a.* The enemy on our front occupies a position along the general line IRISHTOWN ( )—NEW OXFORD ( ). Our attack of this date forced his withdrawal for a distance of about 2 miles on the left of our division front.

b. Our division, in conjunction with the rest of the First Army, resumes the attack at 4:00 AM, 17 June; 9th Brig on the left, 10th Brig on the right. For details of operations, etc., see Annex No 1.

2\. This regiment will assist the attack by maintaining the routes of communication and assisting the forward movement of the artillery.

3\. *a.* The 1st Bn (less Co C) will repair and maintain roads and bridges in rear of the 9th Brig.

b. Co C is attached to the 5th FA Brig, effective at 4:00 AM, 17 June. The CO, Co C, will report to the CG, 5th FA Brig, prior to midnight 16–17 June, for instructions.

c. The 2d Bn will maintain roads in the 10th Brig zone of action, and will complete the trestle bridge across SOUTH BRANCH CONEWAGO CREEK near RJ 500–A ( ).

d. (1) Hq and Serv Co with the band attached, will continue to operate from its present location. The CO, Hq and Serv Co, will provide for an adequate supply of road materials north of SOUTH BRANCH CONEWAGO CREEK.

(2) The Div Engr Sec and Lighting Plant will continue to operate with the Fwd Ech DHQ.

(3) The gravel pit and water supply point will remain in operation in present location.

x. (1) Priority of road maintenance will be given to the division main supply road and to those roads shown on overlay No 2, "Road Circulation Plan."

4\. *a.* Supply.

(1) Class I railhead: LITTLESTOWN ( ).—Railhead distribution at 10:00 PM.

(2) Ammunition railhead: LITTLESTOWN.

(3) Engineer.

Army depot: TANEYTOWN ( ).
Div. DP: RJ 599–D ( ).

b. Aid Sta: RJ 599–D. Evacuation through Coll Stat at CR 633 ( ).

c. For other administrative details see Adm O No. 8.

5\. Command posts and axes signal communication.

5th Div: SMALL ( )—GEO LAWRENCE ( ).
5th Engrs: RJ 599–D—IRISHTOWN ( ).
Hq and Serv Co: RJ 599–D.
1st Bn: RJ 559–G ( ).
2d Bn: REBERT ( ).
5th FA Brig: VALLEY SCHOOL ( ).

G
Colonel

Annex: No. 1, G–3 Information.
Distribution: A, and 5th FA Brig.

Illustrative order No. 2

FIELD ORDER FOR A COMBAT REGIMENT IN COMBAT AS RIFLEMEN

3d Engrs
WHITE FARM, PA (   )
3 Aug 19 —, 1:30 PM

FO 17

Maps: Topograpical Map, Gettysburg-Antietam, 1:21,120; Hunterstown—Arendtsville sheets.

1. *a.* The enemy still occupies the observation station on hill 339 (   ) on the right boundary of the zone of action of the 5th (left) Brig.
   b. Our division continues the attack extending the zone of action of the 5th Brig to the left to include hill 242 (   ). 1st Bn, 4th Inf is on the right of the 5th Brig. 2d Bn, 30th Inf is on the left of the 6th Brig. 1st Bn, 10th FA from positions near SMITH S H (   ) supports operations in the area including hill 339.
2. This regiment (less 1st Plat, Co E) will seize and hold the observation station on hill 339.
   Formation: column of battalions. LD and boundaries (see Opn overlay).
3. *a.* The 1st Bn will clear WHITE FARM and will attack at 2:00 PM in the direction RJ 225 (   )—hill 339 (see Opn overlay).
   b. The 2d Bn (less 1st Plat, Co E) will await orders in regimental reserve in vicinity of RJ 225.
   c. The 1st Plat, Co E, with three Hq and Serv Co trucks attached, will continue maintenance of the division main supply road extending its operations to include COOKTOWN and RJ 243 (   ).
   d. The Rr Ech will await orders at WHITE FARM.
4. *a.* Am dump, RJ 225. S-4 will obtain extra ammunition by truck from LAWTON (   ).
   b. All vehicles will be held mobile and under cover in assembly positions near WHITE FARM.
   c. Aid Sta: Initial location, SW of RJ 225.
   d. Other details, no change.

5. Command posts and axes signal communication.
   3d Engrs: WHITE FARM—RJ 225—RJ 282 (   )—hill 339.
   Rr Ech: WHITE FARM.
   1st Bn: RJ 282.
   2d Bn: RJ 225.
   1st Plat, Co E: HOLT (   ).
   1st Bn, 10th FA: SMITH S H.
   4th Inf: LAND CR (   ).
   30th Inf: MERRITT S H (   ).

A
Colonel

Annex: Opn overlay.
Distribution: A, and to CO's 4th Inf, 30th Inf, and 1st Bn, 10th FA.

Illustrative order No. 3

ENGINEER PARAGRAPH IN A DIVISION ATTACK ORDER

x x x x

3. *f.* The 1st Engrs. (less Dets) will be prepared to assemble at CR 725 (   ) on 2 hours' notice for use in division reserve.

x x x x

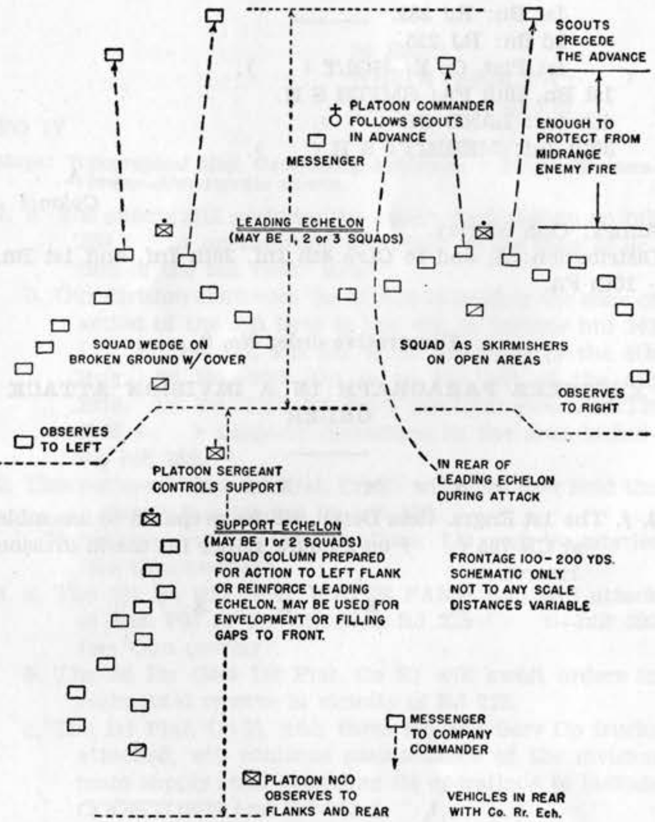


FIGURE 26.—Disposition of an engineer (3-squad) platoon in an attack as riflemen.

Illustrative order No. 4

FIELD ORDER FOR A GENERAL SERVICE REGIMENT WITH A CORPS

———

350th Engrs
FAIRFAX, VA ( )
5 Oct 19—, 1:00 PM

FO 38

Map: USGS, 1:125,000; Mt. Vernon quadrangle.

1. *a.* The enemy opposes our army on the general line WOODBRIDGE ( )—MANASSAS ( ).
   b. Our army continues its preparations for the attack. The II Corps prepares to attack in the general direction HOLMES ( )—MARTINDALE ( ). For details see FO No 36, 350th Engrs. Effective 5:00 AM 6 Oct the corps rear boundary is advanced to HILL ( )—SEATON ( )—RJ 258 ( ) (all incl) and the divisional rear boundary is advanced to the BARR ( )—HOLMES ( )—SMITHSON ( ) road (all excl).
   c. Army engineer troops take over engineer operations in rear of HILL—SEATON—RJ 258 (all excl) by 1:00 PM 6 Oct. The 351st Engrs (Gen Serv), First Army take over the area work from the 350th Engrs. The P RR (HOYT ( )—ALMER ( )—WILTON ( )) is taken over by the army for operation at 8:00 PM today. For disposition of engineer troops in II Corps, effective 5:00 AM 6 Oct see Annex No. 1, Engineer situation map.
2. This regiment, with 413th Engrs (Sep Bn) attached, effective 5:00 AM 6 Oct, will execute general engineer work in that portion of the corps zone of action west of HOLMES—HOLT—WILTON—SEATON (all incl) and will extend the P RR from ALMER JUNCTION to HOLMES.
3. *a.* The 1st Bn (less Co A), with Co D, 413th Engrs attached, will repair the P RR from ------ to ------.
   b. The 2d Bn (less Cos E and F), with Co C, 413th Engrs attached, will continue general engineer work in its present area.

c. The 413th Engrs (less Cos C and D), with Co A, 1st Bn, 350th Engrs attached, will continue maintenance of the corps main supply road WHITE (   )—HOLT—HOLMES and will extend their operations to include HOLMES.

d. Co E will take over general engineer operations in that portion of the corps zone of action to be vacated by the 3d Div.

e. Co F will take over general engineer operations in that portion of the corps zone of action to be vacated by the 2d Div.

f. Hq and Serv Co will operate from ALMER. Detachments and equipment with units of regiment will remain unchanged.

g. The band will remain attached to the supply section of Hq and Serv Co.

x. (1) Reconnaissance of new areas will be initiated at once.

(2) Troop movements will be effected after 7:00 PM tonight.

(3) For schedule of engineer work and priorities and distribution of regimental and special equipment see Annex No. 2, Engineer work.

4. *a.* Supply.

(1) Class I railhead: ALMER JUNCTION (   ). S-4 will draw for the regiment and attached troops at 10:00 PM.

(2) Engineer.

Army depot: ALEXANDRIA (   ).

Regimental supply point: ALMER.

b. Evacuation.

(1) Aid Sta.

350th Engrs: ALMER.

413th Engrs: HOLT.

(2) Casualties by truck or ambulance to ALMER.

c. For other administrative details see Annex No. 3, Extracts Adm O No 25, II Corps.

5. Command posts.

a. Engineers.

350th Engrs: ALMER after 9:00 PM.

1st Bn: ALMER JUNCTION.

2d Bn: WHITE.

413th Engrs: HOLT after 5:00 AM 6 Oct.

Co E, 350th Engrs: RJ 350 (   ) after 5:00 AM 6 Oct.

Co F, 350th Engrs: CR 400 (   ) after 5:00 AM 6 Oct.

b. For command posts of other engineer units and corps and divisional troops see Annex No. 4, Command posts.

L

Colonel

Annexes:

No. 1, Engineer situation map.

No. 2, Engineer work.

No. 3, Extracts Adm O No 25, II Corps.

No. 4, Command posts.

Distribution: A.

Illustrative order No. 5

FIELD ORDER FOR A WATER SUPPLY BATTALION

76th Engrs (W Sup)
VIVA, TEX ( )
FO 9 25 May 19 —, 4:00 PM

Maps: USGS 1:125,000; Alton, Millis, and Waverly quadrangles.

1. *a.* No important changes in the enemy situation.
b. Our army continues its preparation for the attack.
c. The water supply in the LEWIS FLATS area (ALLIS ( )—BOND ( )—COLBY ( )—DEVON ( ) (all incl)) must be supplemented by water transported in motor vehicles. Four tank cars are to be spotted at OLGA ( ) siding at 8:00 PM and 8:00 AM daily, commencing 26 May. Purification sections of Serv Plat, Hq and Serv Co, are attached to corps as follows: to I Corps two sections and to II Corps two sections. Engineer troops are in charge of general engineer work in the LEWIS FLATS area as follows: north of LEWIS ( )—WATSON ( ) road (excl), III Corps; south of LEWIS—WATSON road (incl) and west of AUSTIN CREEK ( ) and MILL GULCH ( ), 21st Engrs (Gen Serv) First Army; south of LEWIS—WATSON road (incl) and east of AUSTIN CREEK and MILL GULCH, 60th Engrs (Sep Bn) First Army.
2. This battalion (less dets) will transport water in the LEWIS FLATS area and will assist in the establishment and maintenance of water DP's.
3. *a.* Co A, with one purification sec Hq and Serv Co attached, will report to the CG III Corps for operation in that portion of the LEWIS FLATS area within the corps zone of action. Clearing VIVA ( ) by 7:00 PM, it will march via ELLSWORTH ( )—COLBY road to LESLIE ( ) where it will pass to the control of the III Corps. It will revert to battalion control when the corps rear boundary is advanced to exclude the general line COLBY—DEVON.
b. Co B will operate from OLGA and transport water to water DP's in the area ALLIS—BOND—JONES FARM ( )—BOWIE ( ) (all incl).

c. Co C will operate from OLGA and transport water to water DP's in the area LEWIS—WATSON road (incl)—JONES FARM—BOWIE (both excl).
d. Hq and Hq and Serv Co (less dets) will operate from OLGA. Storage facilities will be established at OLGA.
e. Water analysis dets will report to CO's of Cos B, and C.
x. (1) The battalion (less Co A and dets) will clear VIVA by 8:00 PM and will march via RJ 248 ( ) to OLGA. Order of march: Hq, Co B, Co C, Hq and Serv Co, Med Det.
(2) Reconnaissance of area will be initiated at once and detailed plans of operation submitted by 7:00 AM 26 May.
4. *a.* Supply.
(1) Class I.
Rhd: OLGA after 4:00 AM 26 May.
Bn (less Co A and Dets): OLGA 10:00 AM.
Co A: through III Corps.
(2) Engineer.
Army depot: LAWRENCE ( ).
Army shop: LAWRENCE.
Bn Sup Pt: OLGA after 5:00 AM 26 May.
b. Aid Sta: OLGA after 5:00 AM 26 May.
Evacuation via Coll Sta: OLGA after 4:00 AM 26 May.
Medical mobile laboratories: WESTON ( )—HOGAN ( ).
Army medical laboratory: WHEATON ( ).
Other administrative details: No change.
5. Command posts.
Bn: OLGA after 5:00 AM 26 May.
Co B: Same.
Co C: Same.
Co A: through Engr Hq III Corps at HORTON ( ).
Army Engr Hq: WHEATON.
Army Med Hq: WHEATON.
21st Engrs: HOLLY ( ).
60th Engrs: WILBUR ( ).

W
Major

Distribution: A, and 21st and 60th Engrs.

Illustrative order No. 6

ENGINEER PARAGRAPHS IN A DIVISION ADMINISTRATIVE ORDER

________- 1st Div
Adm C 12 MILTON, MD ( )
2 Aug 19—, 4:00 PM

Maps: Topographical Map, Gettysburg-Antietam, 1:21,120; Emmitsburg, Taneytown and Kinsdale sheets.

1. SUPPLY.

a. ________________

b. Class I:

Rhd: GALT ( ) effective 8:00 PM 4 June.

1st Engs: 9:00 PM.

c. ________________

d. Water.

(1) DP's: LEWIS FARM ( ), AKRON ( ), RJ 694 ( ).

(2) All water for drinking will be chlorinated.

e. Engineer.

(1) Rhd: PINEY CREEK ( ).

(2) DP commencing 3 June: CR 626 ( ).

f. ________________

2. EVACUATION.

a. ________________

b. ________________

c. ________________

d. Captured material.

(1) ________________

(2) ________________

(3) Engineer materials will be taken over by 1st Engrs and utilized for divisional work.

3. TRAFFIC.

a. Circulation.

(1) See Annex No. 3—Circulation Map, effective 6:00 AM 4 June.

(2) Control.

(*a*) Traffic control posts will be maintained at GALT, CR 469 ( ), TANEYTOWN ( ), WHITE MILL ( ) and DASHERS MILL ( ), and at such temporary detours as may be established.

(*b*) Traffic priority: Ammunition vehicles, engineer vehicles, ration vehicles.

b. Construction and maintenance of routes.

(1) Division main supply road: WESTMINSTER ( )—TANEYTOWN — BRIDGEPORT ( ) — two-track.

(2) GALT—CR 538 ( )—TANEYTOWN road will be will be maintained for motor traffic—two-track.

(3) RJ 438 ( ) to RJ 490 ( ) road (south of TANEYTOWN) will be maintained for motor traffic—one-track.

(4) All crossings over PINEY CREEK will be maintained.

(5) Signs will be posted indicating direction of traffic as shown on circulation map.

4. TRAINS.

a. ________________

b. ________________

c. ________________

d. 1st Engrs: RJ 626 ( ) released.

5. PERSONNEL.

a. ________________

b. ________________

6. MISCELLANEOUS.

a. ________________

b. ________________

c. For employment of engineer troops see Annex No 7, Engineer plan.

d. ________________

BY COMMAND OF MAJOR GENERAL A:

X
Chief of Staff

OFFICIAL:
Y
A C of S, G-4

Annexes:

No 3, Circulation map.

No 7, Engineer plan.

Illustrative order No. 7

ENGINEER ANNEX TO A DIVISION ADMINISTRATIVE ORDER

ANNEX NO 7 TO ADMINISTRATIVE ORDERS NO 18

1st DIVISION

ENGINEER PLAN

1st Div
MILTON, MD ( )
2 Aug 19—, 4:00 PM

Maps: Gettysburg-Antietam, 1:21,120, Taneytown and Kingsdale sheets.

1. ROADS AND BRIDGES.
   a. Priority will be given the following work:
   Maintenance of ALTON TURNPIKE ( ) as two-track divisional main supply road.
   Maintenance of HOLT ( )—CR 590 ( )—SEATON ( ) road as two-track road for corps loads.
   Repair and maintenance of CR 590—RJ 600 ( ) road as one-track motor road for divisional loads.
   Maintenance of roads in immediate vicinity of railhead and engineer distributing point.
   b. Other roads indicated on circulation map will be maintained for light motor transport only.
   c. Road and traffic signs will be supplied for road system and all temporary detours.
   d. All bridges over MARSH CREEK ( ) will be maintained.
   e. Traffic control on temporary detours will be under the engineers until it can be taken over by the military police.
2. WATER SUPPLY.
   a. Following water supply points for drinking water will be operated by the engineers commencing 5:00 AM 3 Aug.
   AKRON ( ): two 2,000-gallon tanks operated by divisional pumping set.

SMITH FARM ( ), LEWIS S H ( ), and RJ 430 ( ): each a 3,000-gallon canvas tank.
   b. Distribution of water will be controlled by the division engineer.
   c. All water sources will be marked with signs in accordance with GO 8.
3. ENGINEER SUPPLY.
   a. Supply points.
   Army depot: SMITHTOWN ( ).
   Division distributing point: RJ 438 ( ).
   b. Local and captured engineer material will be taken over for divisional use.
   c. Intrenching tools for divisional troops will be delivered to regiments upon request of commanders.
   d. Dumps of engineer material in division area will be taken over by the corps as the advance progresses.
   e. No changes in methods of issue.
4. MISCELLANEOUS.
   a. 5 KW set will accompany the Fwd Ech of Div Hq. The local plant at EIBERT ( ) will be operated for the Rr Ech of Div Hq.
   b. Map section will operate from RJ 438 after 9:00 PM 2 Aug.
5. ENGINEER TROOPS.
   a. 1st Bn 1st Engrs (less Co A) with command post at CR 500 ( ) will be in charge of general engineer work in the area north of line: CR 590 ( )—WOOD ( ) (both excl.).
   b. 2d Bn 1st Engrs, with Co A attached, with command post at CR 480 ( ) on ALTON TURNPIKE will be in charge of general engineer work in the area south of line: CR 590—WOOD (both incl.).
   c. Div Engr Sec accompanies the Fwd Ech of Div Hq.
   d. Command post, 1st Engrs: RJ 438.

BY COMMAND OF MAJOR GENERAL A:

X
Chief of Staff

OFFICIAL:
Y
A C of S, G–4

Distribution: Same as Adm O No 18.

CHAPTER 2

COMMUNICATIONS, CONSTRUCTION, AND UTILITIES

SECTION I

ROADS

■ 23. TRAFFIC CAPACITY.—The maximum capacity of a single road lane is obtained when vehicles move about 33 miles per hour. However, for all practical purposes the capacity remains constant for speeds from 25 to 45 miles per hour. At these speeds the normal capacity of a single traffic lane carrying military vehicles only is about 750 vehicles per hour. At bottlenecks this may be increased by cutting the distance between vehicles to about one-third of that for open highway driving. This ultimate capacity, with speeds of 25 to 35 miles per hour, is about 2,000 vehicles per hour. At night the ultimate capacity at 15 miles per hour is about 1,200 vehicles per hour.

■ 24. MINIMUM DESIGN REQUIREMENTS.—*a. Width.*—9 feet per lane; 10 feet desirable (4 feet for trails used by foot troops and horse cavalry).

b. Carrying capacity.—9,000-pound wheel load on pneumatic tires.

c. Grades.—Not more than 10 percent for motor traffic.

d. Curves.—Radii greater than 150 feet (otherwise additional width should be provided).

e. Overhead clearance.—11 feet; 14 feet desirable.

■ 25. TRAFFIC SIGNS.—These are needed to mark the location of, or direction to, military installations, crossroads, geographical points, etc. Letters should be of the following sizes:

a. For roads traveled only by foot troops.—4 inches high.

b. For main roads.—4 inches high (sign should be not less than 17 by 17 inches, and at least 4 feet above the road crown).

■ 26. FORM FOR ROAD RECONNAISSANCE.

REPORT OF ROAD RECONNAISSANCE

1. Road reported upon ______________________
(Name or designation of road and points ______________________ between which inspection was made)
2. Date of reconnaissance ______________________
3. Character of road ______________________
(Concrete, macadam, gravel, earth, etc.)
4. Thickness of pavement ______________________
(Indicate if estimated)
5. Usable width ______________________
(Also indicate whether one, two, or more tracks)
6. Limiting grades ______________________
7. Bridges and culverts.

Location	Dimensions	Capacity	Conditions

8. Priority and nature of needed repairs or improvements.

Location	Work needed	Estimated man-hours	Materials required

9. Materials available locally.

Kinds of materials	Location	Quantity

____
(Name, grade, organization)

■ 27. CONSTRUCTION OF MILITARY ROADS.—*a. General.*—The basic necessity of all road construction is to provide adequate drainage ("Get water off and rock on"). Base courses should be well graded and compacted. Top course should be capable of resisting the abrasive action of traffic for which the road is designed. In general, civil standards are too high for military roads.

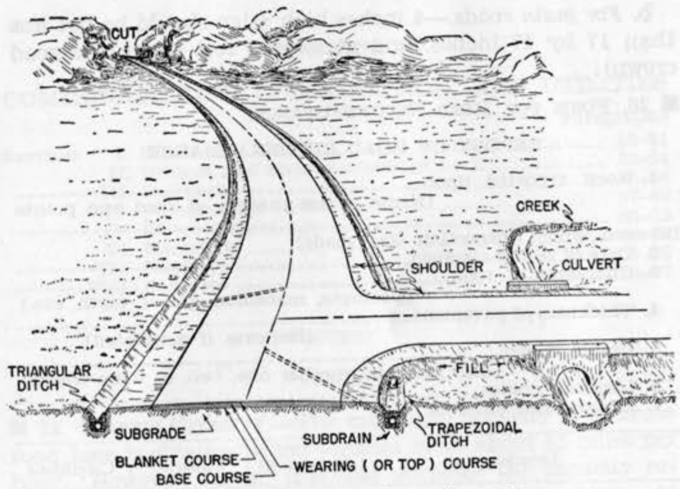


FIGURE 27.—Nomenclature of roads.

b. Steps in construction.—Construction of a road involves—

(1) Clearing trees, brush, and vegetation from the right-of-way.

(2) Grubbing stumps and roots from the foundation. (Stumps cut off at ground level may be left if fill will be over 1 foot high.)

(3) Grading, shaping, and compacting the subcourses.

(4) Laying and shaping the upper and top courses.

■ 28. ORGANIZATION OF MAINTENANCE PARTIES.—In general, the two methods of organizing engineer units for most efficient maintenance of roads are as follows:

a. Patrol.—A certain designated section of road is assigned to a small designated unit, this unit working as a whole or in shifts depending on the situation. For continuous maintenance, under normal conditions, a combat or general service platoon should be assigned about 5 to 10 miles of road with trucks to move men readily and less under adverse conditions.

b. Gang.—A large unit goes over the road at infrequent intervals making all necessary repairs. This method of organization should be used in military operations only in cases of high type roads subject to slight or infrequent damage.

■ 29. DETERMINATION OF CROSS-SECTIONAL AREA OF CULVERTS.—Having determined the drainage area in acres, the following nomograph will give the necessary area of cross section of culvert to supply proper drainage:

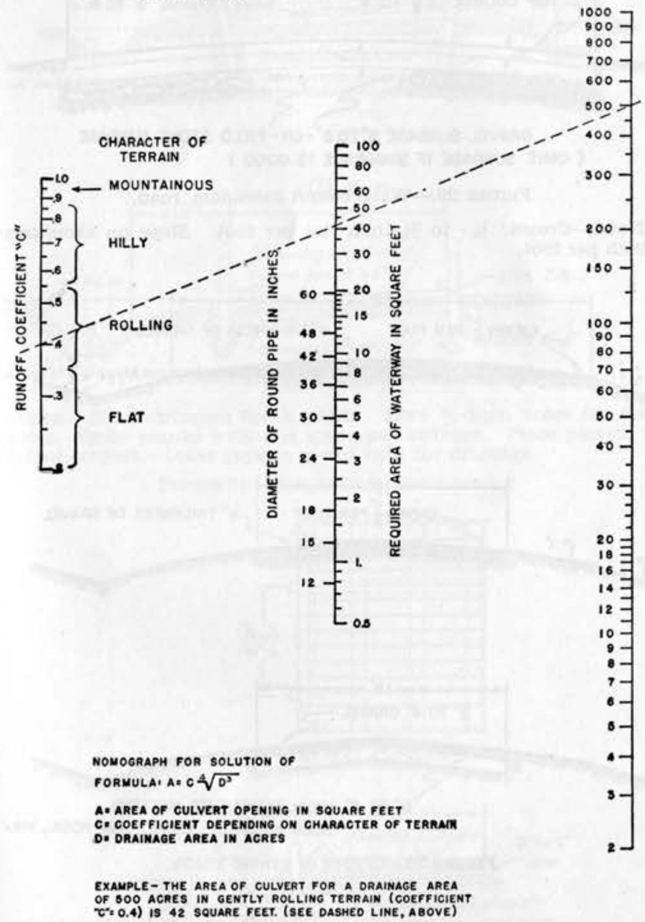


FIGURE 28.—Nomograph based on Talbot's formula.

NOTE.—Culverts should have slope at bottom to carry off flows and extend well beyond side slopes of road unless slopes are well revetted.

■ 30. Typical Cross Sections of Roads.

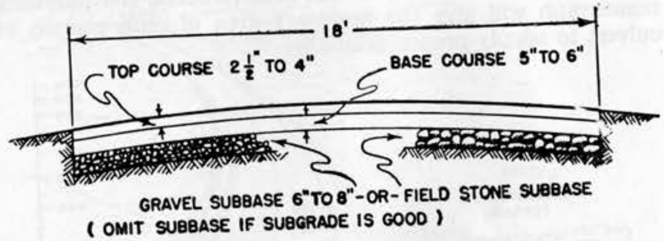


Figure 29.—Waterbound macadam road.

Note.—*Crown:* ¼- to ⅜-inch rise per foot. *Slope on shoulders:* 1 inch per foot.

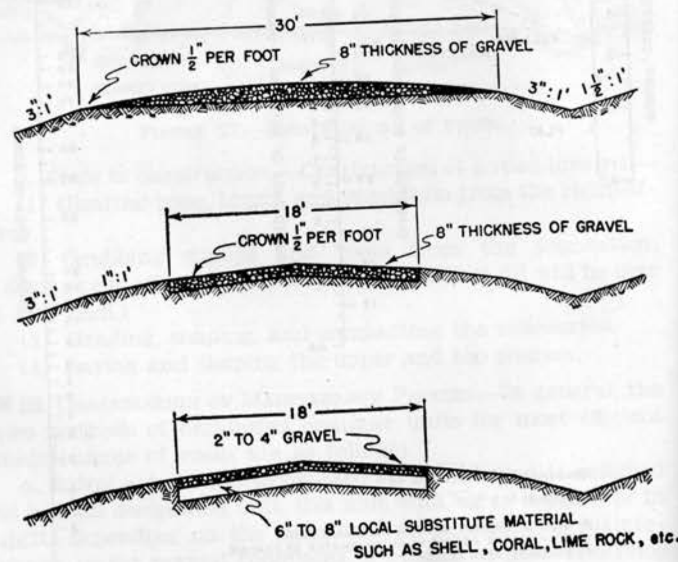
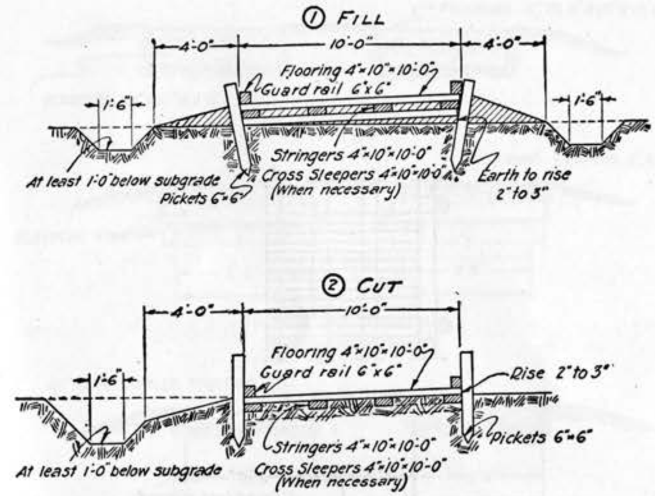


Figure 30.—Types of gravel roads.



Note.—Have stringers break joints. Bore ⅜-inch holes for floor spikes. Spike planks with one spike per stringer. Place pickets at 15-foot centers. Leave gaps in guard rails for drainage.

Figure 31.—Single-lane plank road.

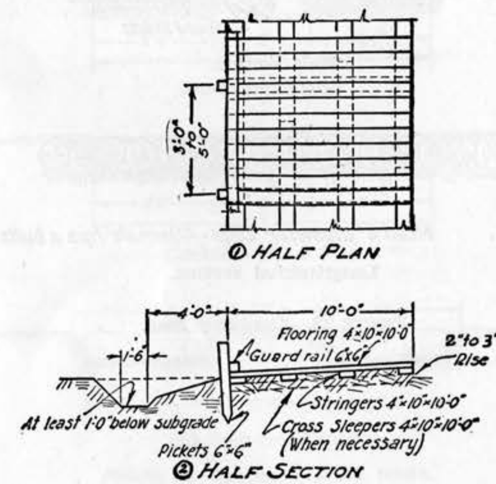
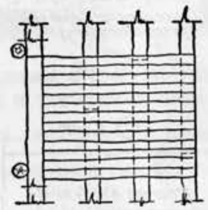
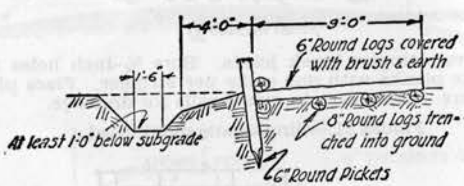


Figure 32.—Two-lane plank road (see note, fig. 31).



Half plan.

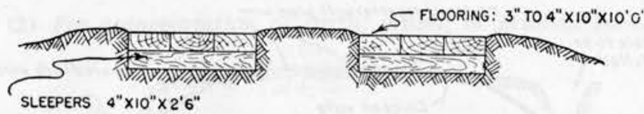


Half section.

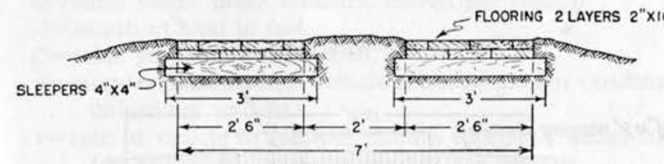
Mean 6" diameter Logs - Alternate tips & butts

Longitudinal section.

FIGURE 33.—Corduroy road.

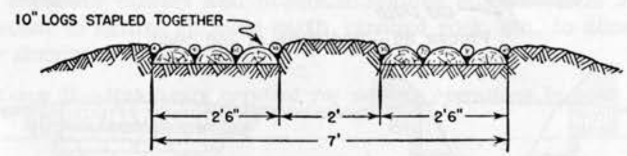


Standard lumber.

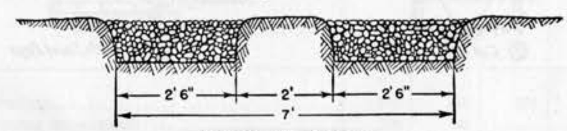


Improvised materials.

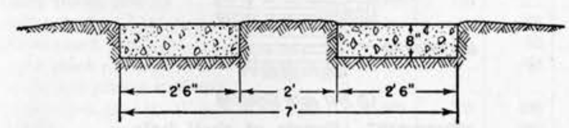
Plank-tread road.



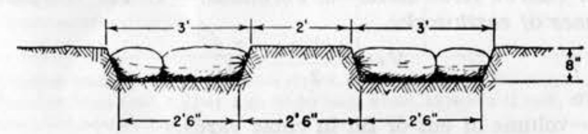
Corduroy-tread road.



Metal-tread road.



Concrete-tread road.



Sandbag-tread road.

FIGURE 34.—Types of tread roads.

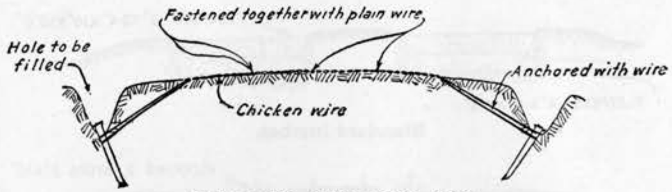


FIGURE 35.—Wire-mesh road.

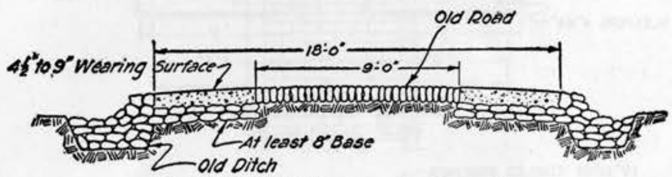


FIGURE 36.—Widening of old road.

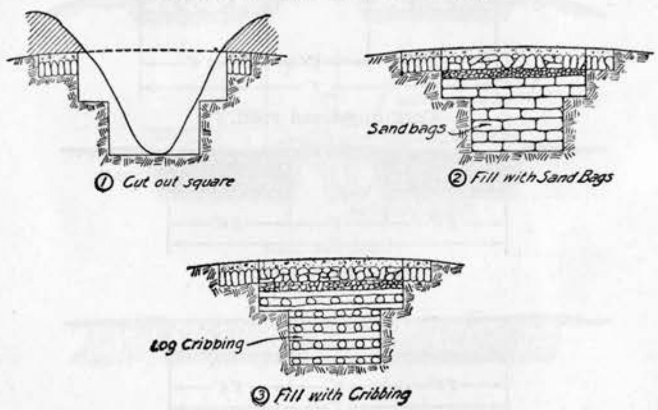


FIGURE 37.—Repair of shell hole.

■ 31. **USEFUL ROAD DATA.**—*a. Formulas.*—(1) *For computing volumes of earthwork.*

$$V=\frac{(A_1+A_2)}{2}\times\frac{L}{27}$$

where

V =volume of cut or fill in cubic yards.
A_1=area of cross section at one end in square feet.
A_2=area of cross section at other end in square feet.
L =distance between end sections in feet.

(2) *For transportation of earth, gravel, or crushed rock.*

$$Q=\frac{60}{d+\frac{2l}{r}}\times C$$

where

Q=cubic yards, place measure, moved per hour.
l=length of haul in feet.
C=cubic yards moved per load.
d=minutes during which vehicle is not in motion (loading, unloading, waiting).
r=rate of vehicle in feet per minute (normally about 200 for animal-drawn vehicles; 700 for trucks).

b. Tables.—Add 8 percent to figures in work-capacity tables to allow for officers and noncommissioned officers. Add 20 percent to figures on loose earth, crushed rock, etc., to allow for shrinkage when rolled.

TABLE II.—*Man-hours required for various operations in road construction*

Operation	Man-hours required for 100 linear yards			
	(1)	(2)	(3)	(4)
(1) Grading	290	135	135	85
(2) Placing large stones	200	90	-------	-------
(3) Spreading small stones	70	30	-------	-------
(4) Placing stones, (2)+(3)	270	120	-------	-------
(5) Placing plank			65	-------
(6) Spiking plank			30	-------
(7) Laying plank road, (5)+(6)			95	-------
(8) Cutting and placing corduroy				80
(9) Construction, (1)+(4), (1)+(7) or (1)+(8)	560	255	230	165
(10) Ditching	260	260	260	260
(11) Construction, (9)+(10)	820	515	490	425
(12) Unloading material	85	40	60	-------
(13) Construction, (11)+(12)	905	555	550	-------

[1] Macadam road, 9 feet wide, 12 inches of rock, ditches 4.5 square feet cross section.
[2] Macadam tread road, 2.5 feet wide under each wheel, 12 inches of rock, ditches 4.5 square feet cross section.
[3] Plank road, 9 feet wide, ditches 4.5 square feet cross section.
[4] Corduroy road, 9 feet wide, ditches 4.5 square feet cross section.

TABLE III.—*Loosening, excavating, and loading earth*

Material	Cubic yards per man per hour						
	Loosening earth		Excavation with pick and shovel to depth indicated (feet)				Loading trucks or wagons—man with shovel in loose soil
	Man with pick	Man with 2-horse plow	0 to 3	0 to 5	0 to 8	0 to 10	
Sand			2.1	1.8	1.5	1.5	1.8
Sandy loam	6.0	60	2.0	1.7	1.4	1.3	2.4
Gravel, loose			1.5	1.4	1.2	1.1	1.7
Common loam	4.0	40	1.3	1.2	1.0	1.0	2.0
Light clay	1.9	27	.9	.8	.7	.7	1.7
Dry clay	1.4	20	.6	.6	.5	.5	1.7
Wet clay	1.2	17	.5	.5	.5	.4	1.2
Hardpan	1.4	20	.4	.4	.4	.4	1.7

TABLE IV.—*Man-hours required for clearing and grubbing*

Width (feet)	Man-hours per 100 linear yards		
	Light clearing	Medium clearing [1]	Heavy clearing
30	10–40	40–105	105–630
40	14–55	55–140	140–840
50	18–70	70–175	175–1,050

[1] In the eastern part of the United States the average for this class of work is about 350 man-hours per acre.

TABLE V.—*Capacities of various items of road-construction equipment*

Item	Capacity
Power shovels:	
3/8-yard bucket	24 cubic yards per hour assuming medium soil, good operator, adequate depth of cut, no lost time.
1/2-yard bucket	30 cubic yards per hour assuming medium soil good operator, adequate depth of cut, no lost time.
3/4-yard bucket	40 cubic yards per hour assuming medium soil, good operator, adequate depth of cut, no lost time.
Steam roller	6½ cubic yards of loose rock compacted in 1 hour. 25 square yards new macadam road rolled in 1 hour.
Elevating grader:	
Small	50 cubic yards place measure loaded per hour.
48-inch belt	250 cubic yards place measure loaded per hour.
Blade grader, 7½-ton self-propelled.	440 square yards gravel road surface scarified and reshaped per hour. 50 cubic yards loose rock or loose earth spread per hour.

TABLE VI.—*Capacity of scrapers*

	Slip	Fresno	Rotary Fresno	2-wheel	4-wheel
Size, cubic yards	1/4–1/2	1/2–1	1/2–2½	1/3–10	1–12
Economical hauls, feet	Under 100	300	600	300–3,000	500–6,000

TABLE VII.—*Cubic yards per hour (compact measure) moved by 60-hp. bulldozer*

Length of haul (feet)	Rate of grade in percent up hill			Level	Rate of grade in percent, down hill			
	15	10	5	0	5	10	15	20
50	32.6	49.0	65.3	81.6	114.0	146.0	179.0	212.0
100	20.1	30.1	40.2	50.2	70.3	90.4	110.5	130.6
150	14.0	21.2	28.3	35.3	49.3	63.5	77.5	91.8
200	10.9	16.1	21.6	26.9	37.7	48.5	59.1	69.9
250	8.5	12.9	17.1	21.5	30.0	38.6	47.3	55.8
300	7.2	10.6	14.2	17.8	24.9	31.9	39.1	46.1
350	6.0	9.0	12.0	15.0	21.0	26.9	33.0	38.9
400	5.2	7.7	10.2	12.9	18.1	23.1	28.4	33.5
450	4.5	6.7	8.9	11.2	15.7	20.1	24.7	29.0
500	3.9	5.8	7.8	9.8	13.8	17.6	21.7	25.5
550	3.5	5.2	6.9	8.7	12.2	15.6	19.2	22.5
600	3.2	4.6	6.1	7.8	10.9	13.9	17.1	20.1

NOTE.—For other sizes of bulldozer apply a suitable factor, e. g., 0.75 for a 45 hp. or 1.60 for a 95 hp. tractor. (The heavy line drawn across each column indicates the economical limit of haul.)

TABLE VIII.—*Man-hours required for spreading by hand*

Material	Cubic yards per man-hour
Earth dumped on road	2½
Loose rock:	
Dumped on road	2½
Dumped alongside road	1¼
Loose screenings dumped on road	1

TABLE IX.—*Man-hours required for effecting emergency passage of mine craters*

Method of repair	Man-hours required
With shovels alone	4 × volume in cubic yards.
With shovels and wheelbarrows	2 × volume in cubic yards.
With shovels and wagons where distance is not over 200 yards and number of wagons is one-fourth number of men.	2 × volume in cubic yards.
With shovels and scrapers	1 × volume in cubic yards.
With standard bridge trestle and bents (trained workmen).	15 × diameter in yards.
With timbers (trees in vicinity, trained workmen)	60 × diameter in yards.
Detour of corduroy (corduroy available in vicinity)	18 × diameter in yards.
Detour of planks	9 × diameter in yards.

NOTE.—The volume of a conical mine crater is:

$$V=\frac{\pi D^2 d}{12}$$

Where
V=volume of crater in cubic yards.
π=3.1416 (or 22/7 approx.).
D=distance across top of crater in yards.
d=depth of crater in yards.

TABLE X.—*Cubic yards of gravel or crushed rock, loose, required per 100 linear yards of road*

Width of road (feet)	Depth spread (inches)						
	3	3½	4	4½	5	6	8
9	25.0	29.2	33.3	37.5	41.7	50.0	66.7
10	27.8	32.4	37.0	41.7	46.3	55.5	74.1
18	50.0	58.4	66.7	75.0	83.3	100.0	133.3
20	55.5	64.8	74.1	83.3	92.6	111.1	148.2

NOTE.—Screenings are required at the rate of ¼ cubic yard for each cubic yard of loose material comprising the wearing surface. Crushed rock usually weighs between 2,300 and 2,800 pounds per cubic yard. Granite weighs 2,800 pounds per cubic yard and limestone 2,500 pounds per cubic yard. For a water-bound macadam road 10 gallons of water may be required per square yard of surface. Crushed stone decreases 20 percent in volume when it is rolled.

TABLE XI.—*Materials required per 100 linear yards of plank-tread road for motor transportation*

Material	Requirements per 100 linear yards	
	Number of pieces	Weight (tons)
Flooring, 4 inches x 10 inches x 10 feet	180	10
Sleepers, 4 inches x 10 inches x 30 inches	120	1.7
Spikes, 6-inch	540	0.12

NOTE.—Leave ½ inch between edges of floor plank. Boat spikes, 6 inches by ½ inch, are driven staggered, one for each plank in each sleeper, in ⅜-inch round holes. In emergency, nail with 60d wire nails.

TABLE XII.—*Materials required for single-lane plank road for motor transportation*

Material	Requirements per 100 linear yards	
	Number of pieces	Weight (tons)
(1) Pickets, 6 inches x 6 inches x 4 feet	40	0.8
(2) Guardrail, 6 inches x 6 inches x 10 feet	55	2.8
(3) Flooring, 4 inches x 10 inches x 10 feet	351	19.5
(4) Stringers, 4 inches x 10 inches x 10 feet	120	6.7
(5) Sleepers, 4 inches x 10 inches x 10 feet	75	4.2
(6) Guardrail spikes, 8-inch	220	---------
(7) Floor spikes, 6-inch	1,404	.3

NOTE.—For an 18-foot road all quantities are doubled except items (1), (2), and (6), which remain as above. Average weight of lumber is 40 pounds per cubic foot. Sleepers are used only when necessary.

TABLE XIII.—*Materials required for single-lane corduroy road without stringers or guardrails*

Material	Requirements per 100 linear yards	
	Number of pieces	Weight (tons)
Logs, 6 inches mean diameter, 10 feet long	600	28

NOTE.—Any available material may be used. Calculations are based on white oak at 48 pounds per cubic foot. Timber will generally be cut alongside road and transported by hand or snaking.

TABLE XIV.—*Materials required for single-lane corduroy road with stringers and guardrails*

Material	Requirements per 100 linear yards	
	Number of pieces	Weight (tons)
(1) Stringers, 6 inches mean diameter, 10 feet long	120	10
(2) Flooring, 6 inches mean diameter, 10 feet long	600	28
(3) Guardrails, 6 inches mean diameter, 10 feet long	55	2.6
(4) Pickets, 6 inches greatest diameter, 4 feet long	40	.6
(5) Guardrail spikes, 10-inch	220	---------
(6) Floor spikes, 10-inch	2,400	.9

NOTE.—Any available material may be used. Calculations are based on white oak at 48 pounds per cubic foot. Timber will generally be cut alongside road and transported by hand or snaking. For an 18-foot road, items (1), (2), and (6) are doubled; items (3), (4), and (5) remain as above. Spikes are ½-inch.

TABLE XV.—*Man-days and materials required per mile for maintenance of double-lane macadam road, conditions average*

Conditions	Traffic	Men per day	Material (tons)	3-ton truck-loads
Dry weather	Ordinary	6	2	1
Rainy weather	do	12	3	1
Cold, freezing, and thawing	do	16	16	6
Spring thaw	do	80	80	27
Rainy weather	Continuous	120	[1] 24	8
Rainy weather	Continuous (under shell fire).	240	[1] 40	14

[1] Under such conditions road material would be piled alongside of road whenever possible.

TABLE XVI.—*Volumes of cuts and fills in cubic yards per 100 linear feet of length*

Average depth of cut or height of fill (feet)	Side slope 1 on 1—width of base of cut or crown of fill (feet)								Add for each additional 2 feet of width	Add where slope is 1½ on 1	Add where slope is 2 on 1
	14	16	18	20	22	24	26	28			
1	56	63	70	78	85	92	100	107	7	2	4
2	119	133	148	163	178	192	208	222	15	7	15
3	189	211	233	256	278	300	323	344	22	16	33
4	267	296	326	356	385	415	444	474	30	30	59
5	352	389	426	463	500	537	574	611	37	46	93
6	444	489	533	578	622	667	710	756	45	67	133
7	544	596	648	700	752	803	855	907	52	91	181
8	652	711	770	830	889	948	1,010	1,067	59	118	237
9	767	833	900	967	1,033	1,100	1,167	1,233	67	150	300
10	889	936	1,037	1,111	1,185	1,259	1,333	1,407	74	185	370
11	1,019	1,100	1,181	1,263	1,344	1,426	1,507	1,589	82	224	448
12	1,156	1,244	1,333	1,422	1,511	1,600	1,688	1,778	89	267	534
13	1,300	1,396	1,493	1,589	1,685	1,781	1,888	1,974	96	313	626
14	1,452	1,556	1,659	1,763	1,867	1,970	2,074	2,178	104	363	725
15	1,611	1,722	1,833	1,944	2,055	2,166	2,268	2,389	111	426	852
16	1,778	1,896	2,015	2,133	2,251	2,370	2,488	2,607	119	474	948
17	1,952	2,078	2,204	2,330	2,456	2,581	2,707	2,833	126	534	1,068
18	2,133	2,267	2,400	2,533	2,666	2,800	2,933	3,067	133	598	1,196
19	2,322	2,463	2,604	2,744	2,885	3,025	3,168	3,307	141	667	1,334
20	2,519	2,667	2,815	2,963	3,111	3,259	3,408	3,556	148	740	1,480
21	2,722	2,878	3,033	3,189	3,344	3,500	3,657	3,811	156	815	1,630
22	2,933	3,096	3,259	3,422	3,585	3,748	3,913	4,074	163	894	1,788

NOTE.—For fills under 2 feet allow 20 percent for shrinkage; over 2 feet allow 15 percent.

TABLE XVII.—*Gyratory rock crushers*

Size No.	Dimensions, receiving spider openings (inches)		Capacity in tons per hour varying with character of rock		Horsepower for crusher, elevator, and screen	Approximate weight of crusher (pounds)
	Each about	Both about	Tons	To pass diameter ring (inches)		
2	8 x 22	8 x 44	5- 10	2¼	12- 15	10,000
3	8½ x 24	8½ x 48	10- 20	2½	20- 25	15,000
4	9 x 27	9 x 54	15- 30	2½	25- 30	23,500
5	12 x 35½	12 x 71	25- 50	2½	30- 50	32,000
6	12½ x 37	12½ x 74	45- 90	3	40- 60	44,000
7½	14 x 44	14 x 88	90-150	3½	75-125	67,500
8	19 x 60	19 x 120	130-225	4	100-150	100,000
10	25½ x 72	25½ x 144	400-600	5	175-250	180,000

TABLE XVIII.—*Jaw rock crushers*

Jaw opening (inches)	Weight on skids (pounds)	Horsepower required	Capacity (cubic yards per hour) [1] for indicated ring size product (inches)			
			¾	1	1½	2½
10 x 16	4,700,	18-25	3½	6	8	11
9 x 20	9,800	25-35	7	10	18	30
12 x 20	9,900	26-35	6	9	16	28
15 x 20	10,200	25-35	----	9	16	27
4 x 40	8,500	35-50	14	20	32	----
9 x 40	14,000	40-55	11	16	38	52
18 x 38	29,000	60-90	----	----	27	52
21 x 38	30,000	60-90	----	----	----	50

[1] Average capacities shown may vary 25 percent according to character of material

Table XIX A.—*Bituminous road materials*

Material	Source	Form	Grade designation—temperature °F. applied	Remarks
Cutback asphalts (RC and MC).	Product of refining crude petroleum oils containing asphalts.	Liquids—asphalt residues fluxed with more volatile petroleum distillates.	*Rapid curing* RC-0 50-120 -1 50-120 -2 100-175 -3 150-200 -4 175-250 -5 175-250	Naphtha (highly volatile), evaporating quickly, leaving asphalt cement binder, permits early use of surface.
			Medium curing MC-0 50-120 -1 80-125 -2 150-200 -3 175-250 -4 175-250 -5 200-275	Kerosene (less volatile) does not evaporate so quickly and cures more slowly than RC types.
Asphaltic road oils (SC)	Product of refining crude petroleum oils containing asphalt.	Liquids—low volatile oils left or blended with asphalt residues near end of refining process.	*Slow curing* SC-0 50-120 -1 50-120 -2 120-180 -3 175-250 -4 200-275 -5 200-275 -6 250-300	Penetration 200.
Asphaltic cements (AC) or paving asphalts.	Product of refining crude petroleum oils containing asphalts.	Semiliquids or solids	AC-1 250-350 -2 250-350 -3 250-350 Also graded by penetrations.	Penetrations 30 to 100 used for crack and joint fillers.
Powdered asphalt (PA)	Product of refining crude petroleum oils containing asphalt.	Hard and solid asphalts ground to powder.		Used with SC oils to produce extra tough road surfaces.
Asphalt emulsions (AE)	Asphalt cements in water with an emulsifying agent.	Liquids	*Rapid, medium, and slow setting* RS-1 60-120	Freezing destroys emulsion. Penetration and surface treatments.
			MS-1 60-120 -2 60-120 -3 60-120	Road and plant mixes with coarse aggregate.
			SS-1 50-120 -2 50-120	Road and plant mixes with fine aggregate.
Road tar (RT) priming oils.	All road tars are products of coking bituminous coal.	Liquids	RT-1 60-125 -2 60-125 -3 80-150	Waterproofs surfaces preparatory to placing other bituminous surfaces.
Cold tars (TC)	All road tars are products of coking bituminous coal.	Liquids	RT-4 80-150 -5 80-150 -6 80-150 -7 150-225	Road mixes and patching.

TABLE XIX A.—*Bituminous road materials*—Continued

Material	Source	Form	Grade designation—temperature °F. applied	Remarks
Hot tars (TH)	All road tars are products of coking bituminous coal.	Nonliquids	RT-8 150–225	Patching and seal-coats.
			-9 150–225	
			-10 175–250	Plant mix and seal-coats.
			-11 175–250	
			-12 175–250	Penetration macadam.
Cutback tars (RTCB)	Tars combined with volatile distillates from coal or watergas tar.	Liquids	RTCB-5 60–120	Patching mixtures.
			-6 60–120	
Rock asphalt	Natural combinations of asphalt with sand or stone.	Solids		Mined and used locally where found.

TABLE XIX B—*Typical users of asphaltic materials*

Purpose or use	Grade or designation: Rapid curing	Medium curing	Slow curing	Paving asphalts with penetration [1] of—
Dust palliative		MC-0, -1, -2	SC-0, -1, -2	
Prime coats:				
Tightly bonded surfaces		MC-0	SC-1	
Loosely bonded fine grained surfaces		MC-1	SC-2	
Loosely bonded coarse grained surfaces		MC-2	SC-3	
Seal and carpet coats:				
With or without light sand cover	RC-0			
Coarse sand cover	RC-1	MC-2, -3		
Clean ¼-inch aggregate cover	RC-2			
Clean ½-inch aggregate cover	RC-3			150–200
Clean ⅝-inch aggregate cover	RC-4			150–200
Clean ¾-inch aggregate cover	RC-5	MC-4, -5		150–200
Graded gravel aggregate cover		MC-2, -3	SC-3	
Gravel mulch		MC-2	SC-2	
Road mix:				
Open graded aggregate:				
Sand	RC-1, -2	MC-3		
Maximum diameter 1 inch, high percentage passing 10 mesh		MC-3, -4		
Macadam aggregate	RC-2, -3			
Dense graded aggregate:				
High percentage passing 200 mesh		MC-2	SC-2	
Maximum diameter 1 inch, high percentage passing 200 mesh		MC-2, -3	SC-2, -3	

[1] Penetrations of 100, 120, 150, and 200 show increasing softness or fluidity. Penetrations of 85, 70, 60, 50, 40, etc., show increasing hardness or solidity. Road oil SC-6 (with high viscosity) and the softest paving asphalts both have penetrations of about 200.

TABLE XIX B.—*Typical uses of asphaltic materials.*—Continued

Purpose or use	Grade or designation			
	Rapid curing	Medium curing	Slow curing	Paving asphalts with penetration of—
Cold patch:				
Open graded aggregate	RC-2	MC-3	SC-3	
Dense graded aggregate		MC-2	SC-2	
Cold laid plant mix:				
Open graded aggregate:				
Sand	RC-2, -3			
Maximum diameter 1 inch, high percentage passing 10 mesh	RC-3		SC-3	
Macadam aggregate	RC-4, -5			
Dense graded aggregate:				
High percentage passing 200 mesh		MC-3, -4	SC-3, -4	
Maximum diameter 1 inch, median percentage passing 200 mesh		MC-4	SC-4	
Aggregate precoating followed with asphalt		MC-0	SC-1	
Hot laid plant mix	RC-4, -5	MC-4, -5	SC-5, -6	150-200
Penetration macadam:				
Cold weather	RC-5		SC-6	
Hot weather				100-200
Asphaltic concrete				40-150

SECTION II

BRIDGES AND STREAM CROSSINGS

32. GENERAL DATA.

TABLE XX.—*Commercial sizes of timber in inches*

2 x 4	2 x 6	2 x 8	2 x 10	2 x 12	2 x 14	2 x 16
		3 x 8	3 x 10	3 x 12	3 x 14	3 x 16
4 x 4	4 x 6	4 x 8	4 x 10	4 x 12	4 x 14	4 x 16
	6 x 6	6 x 8	6 x 10	6 x 12	6 x 14	6 x 16
		8 x 8	8 x 10	8 x 12	8 x 14	8 x 16
			10 x 10	10 x 12	10 x 14	10 x 16
				12 x 12	12 x 14	12 x 16
					14 x 14	14 x 16
						16 x 16

NOTE.—Ordinary lengths are 12 to 20 feet. Bills of material show number of pieces, cross section, length, kind, grade, and surfacing, as 4—6″ x 12″ x 16′ yellow pine (YP), No. 1, rough (Rgh). Dimensions before surfacing are given.

TABLE XXI.—*Design and reconnaissance data*

	Design of new bridge	Examination of existing structures
Safety factors:[1]		
Wood	3.0	4.0.
Steel	1.75	2.2.
Impact allowable:		
Wood	None except 25 percent for abutments.	25 percent.
Steel[2]	$I=\frac{25}{(L+125)}$	$I=\frac{25}{(L+125)}$ (May use 25 per cent for small bridges.)
Stringer efficiency (same for both wood and steel, except in large and important bridges).[3]	90 percent (even number of stringers well distributed). 80 percent (odd number of stringers well distributed).	80 percent (if reasonably well distributed, otherwise less, based on any one stringer carrying more than its proportional share).
Dead load	Compute (first assuming a dead load and checking back on it).	Generally assumed from data in Field Manual (or computed if time permits).

[1] In designing large and important bridges, which may be used over protracted periods, it will be better to employ the factors of normal civil practice (4.0 for wood and 2.2 for steel). [2] L is span in feet. [3] See paragraph 38.

TABLE XXII.—*Typical and critical bridge loads*

	Description	Gross weight (lbs.)	Axle loads (pounds): Front[1]	Axle loads (pounds): Intermediate[2]	Axle loads (pounds): Rear[3]	Distance in inches between—: (1) and (2)	Distance in inches between—: (2) and (3)	Distance in inches between—: (1) and (3)
Bridges built for H-10 (division) loads will carry any of these if vehicles are not overloaded.	Men in single file	140 per foot						
	Pack train in single file	250 per foot						
	Horse cavalry in single file	185 per foot						
	Escort wagon, 4-mule	5,000	1,800		3,200			72
	Car, motor, heavy	5,700	1,400		4,300			132
	Truck, 1½-ton	9,000	2,200		6,800			145
	Truck, 2½-ton, searchlight	15,450	4,050	5,700	5,700	150	46	196
	Truck, 3-ton, cargo	14,000	3,600	5,200	5,200	132	46	178
	Truck, 4-ton, cargo (towing) 155-mm howitzer	16,500	6,100	5,200	5,200	142	52	194
		10,000			10,000			[1] 216
	Tractor, medium, M1 (towing), 155-mm howitzer	16,000						[2] 75
		10,000	1,000		9,000			[1] 156
	Combat car, M2	19,000						[2] 116
	Balloon winch, type C-2	21,000	9,500		11,500			163
	Shovel, engineer	20,000	11,200		8,800			126
	Truck, water purification	21,150	6,750		14,400			227
	Road grader, engineer	15,700	6,000		9,700			216
	Tractor, carrier, engineer	17,000	4,500		12,500			168
	Tractor, carrier, semitrailer	18,900	3,700	7,900	7,300	144	156	300
Same for H-15 (corps and army) loads	Truck, 7½-ton, 114 inches from and towing	34,400	8,000	13,200	13,200	204	52	256
	155-mm gun, M1	30,000	10,000	10,000	10,000	209	46	255
	Truck (AA), 120 inches from and towing	25,500	8,500	13,500	13,500	168	48	216
	3-inch AA gun, M2A2	17,000	8,500		8,500			160
	Tractor, heavy, M1	30,000						[2] 82
	Tank, light[3], M2A4	23,000						[2] 98
	Truck, field servicing, E-2 (AC)	34,000	7,800	13,100	13,100	169	52	221
	Truck, wrecking, F-2 (AC)	32,000	7,700	12,150	12,150	169	52	221
	Truck, crane, engineer	33,400	10,900		22,500			181

[1] Distance in inches between axle of towed load and last axle of prime mover.

[2] Length of normal ground contact of crawler tread.

[3] Can be carried on H-10 timber trestle bridge with spans less than 20 feet. Medium tank requires bridges built for H-20 loads.

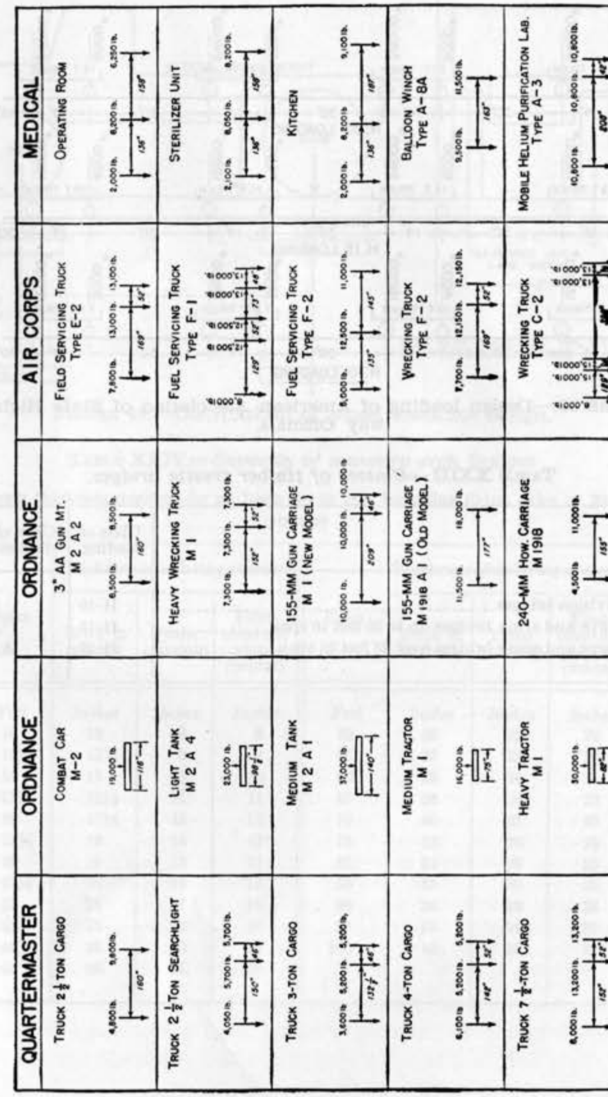


FIGURE 38.—Typical wheel and axle loads.

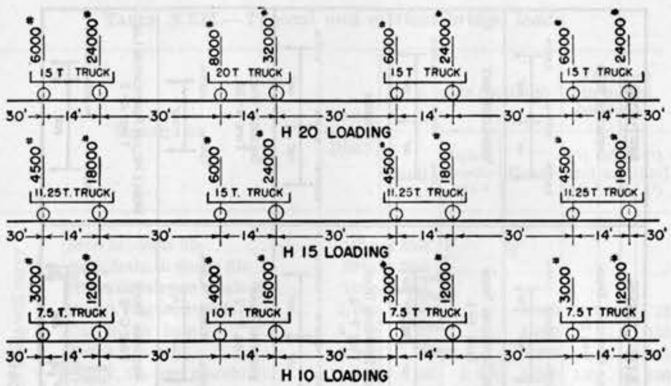


FIGURE 39.—Design loading of American Association of State Highway Officials.

TABLE XXIII.—*Classes of timber trestle bridges.*

	Class of loading	Class of bridge
For division bridges	H-10	B
For corps and army bridges up to 25 feet in span	H-15	A
For corps and army bridges over 25 feet in span	H-20	AA

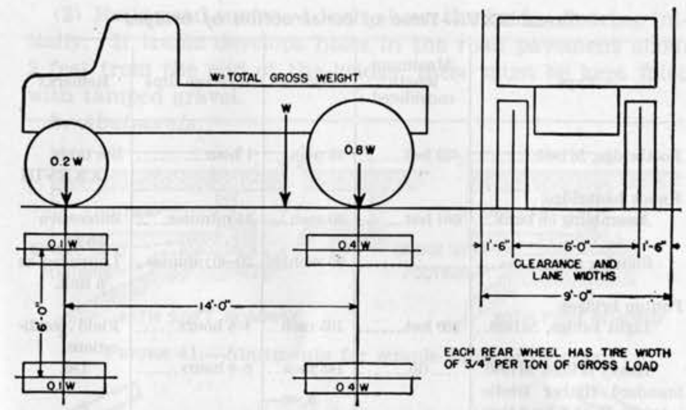


FIGURE 40.—Distribution of wheel loads for design.

TABLE XXIV.—*Capacity of masonry arch bridges*

[Crown thickness required for all loads up to and including 10-ton axles or 20-ton tanks]

Span	Thickness of arch ring at crown			Span	Thickness of arch ring at crown		
	Brick in cement	Plain concrete	First-class cut stone (ashlar)		Brick in cement	Plain concrete	First-class cut stone (ashlar)
Feet	*Inches*	*Inches*	*Inches*	*Feet*	*Inches*	*Inches*	*Inches*
10	12	8	8	50	26	22	20
12½	13½	9	9	55	27	23	20½
15	15	10	10	60	28	24	21
17½	16½	11	11	65	29	26	22
20	17½	13	12	70	30	27	23
22½	18	14	13	75	32	28	24
25	19	15	14	80	34	29	25
27½	20	16	15	85	35	30	26
30	21	17	16	90	36	32	28
35	22	18	17	95	38	34	29
40	23	20	18	100	40	36	30
45	25	21	19				

TABLE XXV.—*Time of construction of bridges*

Type	Maximum length considered	Personnel	Average time	Remarks
Footbridge, M1935	432 feet	43 men	1 hour	See table XXXVIII
Kapok footbridge:				
Assembling on bank	264 feet	30 men	35 minutes	Successive bays.
Shoving across		90 men	20–40 minutes	Launched as a unit.
Ponton bridges:				
Light bridge, M1938	250 feet	103 men	4–6 hours	Field conditions.
Heavy bridge, M1940	do	145 men	6–8 hours	Do.
Standard timber trestle bridge H-15 6 by 8 inch posts with wood stringers	8 bays, 120 feet.	40 men [1]	12 hours [2].	
Or steel stringers	200 feet			
Portable steel bridge:				
H-10	72 feet	42 men	1–2 hours	One hour less if crane is used.
H-20	125 feet	60 men	4–6 hours	
Spar bridge	40 feet	40 men	3 hours.	
Spar trestle bridge	do	do	5 hours.	
Pile bridge	7 bays, 105 feet, 20-foot piles	100 men	6 days.	
Crib bridge	7 bays, 105 feet.	200 men	4 days.	
Railroad bridge	do	Variable, 40–200.	2 months to 4 days.	

[1] A stiff bottom and standard bridge members are assumed. If members have to be assembled out of smaller material, it may be necessary to add men for extra work or to increase time allowance. Work on abutments (but not approaches) considered.

[2] Including time for assembling standard trestles.

NOTE.—Material is assumed unloaded on the spot, with average conditions. Extra time or men must be provided, where necessary, for work on approaches, cutting of banks, and unloading.

■ 33. APPROACHES, ABUTMENTS, AND FOUNDATIONS.—*a. Bridge approaches.*—(1) Provide straight road for at least 50 yards at each end of the bridge with a slight upgrade toward the bridge becoming level at abutments.

(2) Build road surface 1 inch above the bridge flooring initially. If traffic develops holes in the road pavement about 2 feet from the end of the bridge, these must be kept filled with tamped gravel.

b. Abutments.

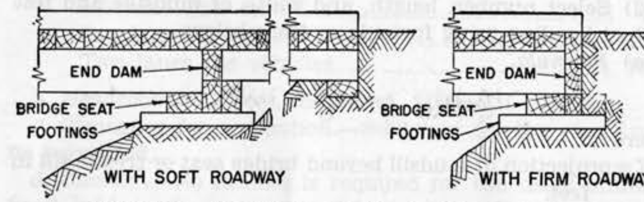


FIGURE 41.—Abutments for simple stringer bridges.

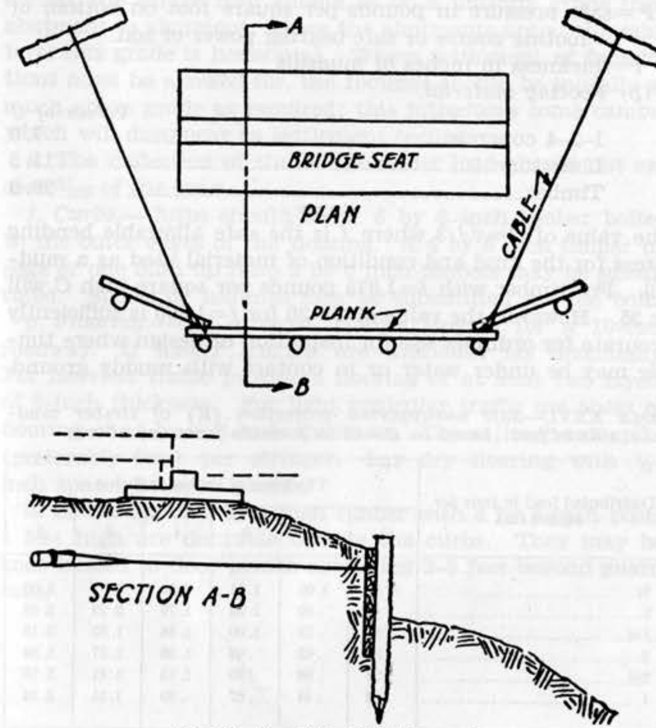


FIGURE 42.—Pile retaining wall.

c. Design of foundations and footings.—(1) Compute the required area of bearing on the ground (see table CXLI) to carry total load. If mudsills are required, assume abutment sill provides no bearing and mudsills provide full area.

(2) Select number, length, and width of mudsills and test against bending using formula or table below.

(*a*) *Formula.*

$$t=K\frac{\sqrt{P}}{C}$$

where

K=projection of mudsill beyond bridge seat or trestle sill in feet.

C=constant, depending on material of mudsill.

P=safe pressure in pounds per square foot on bottom of footing course or safe bearing power of soil.

t=thickness in inches of mudsills.

(*b*) *Footing material.*

	Values of C
1-2-4 concrete	7.0
Limestone	11.5
Timber	20.0

The value of $C=\sqrt{f/3}$ where f is the safe allowable bending stress for the kind and condition of material used as a mudsill. For timber with f=1,875 pounds per square inch C will be 25. However, the value of C=20 for f=1,200 is sufficiently accurate for ordinary use for inspection or design where timber may be under water or in contact with muddy ground.

TABLE XXVI.—*Safe unsupported projection (K) of timber mudsills in feet (based on C=20 in formula from (a) above)*

Distributed load in tons per square foot	Thickness of timber in inches					
	1	2	3	4	5	6
¾	0.51	1.03	1.54	2.06	2.57	3.09
1	.44	.89	1.34	1.79	2.23	2.68
1½	.36	.73	1.09	1.46	1.82	2.18
2	.31	.63	.94	1.26	1.57	1.89
2½	.28	.56	.85	1.13	1.41	1.70
4	.22	.44	.67	.89	1.11	1.34

■ 34. OTHER DESIGN CRITERIA.—*a. Minimum width of roadway.*

	Feet
Men on foot, single file	1½
Antitank gun	6
Machine gun carts	4½
One lane for vehicles	10
Two lanes for vehicles	18

b. Headroom.—11 feet, minimum, 14 feet if possible.

c. Clearance for navigation.—Sufficient for the river traffic permitted.

d. Camber.—No camber is required for the usual military fixed bridge when in use. When all settlement has occurred, the bridge floor should be on a uniform grade from abutment to abutment; where the abutments are at the same level this grade is horizontal. Where settlement of foundations must be allowed for, the footings should be initially as much above grade as required; this introduces some camber which will disappear as settlement occurs.

e. The deflection of the bridge under load should not exceed 1/200 of the span.

f. Curbs.—Curbs should be of 6 by 6 inch timber bolted to the outer edges of the flooring. A 4 by 6 inch timber on edge or one built up from 2 by 6 inch timbers may be substituted. Spikes or lashings may be substituted for the bolts.

g. Flooring.—Use at least 11-foot lengths for a 10-foot roadway. If longer lengths are available, lay diagonally. For heaviest traffic provide a flooring of at least two layers of 3-inch thickness. For light vehicular traffic use chess or flooring of at least 2-inch thickness. Use at least one spike (preferably two) per stringer. Lay dry flooring with ¼-inch spaces between planks.

h. Handrails of 2 by 4 inch timber with 4 by 4 inch posts 3 feet high are desirable outside the curbs. They may be knee-braced to floor planks extending 2-3 feet beyond guard rails.

■ 35. BENDING.—*a. Criterion for maximum bending.*

$$\text{Distance } r = W_F \times \frac{l}{W} \text{ (fig. 43)}$$

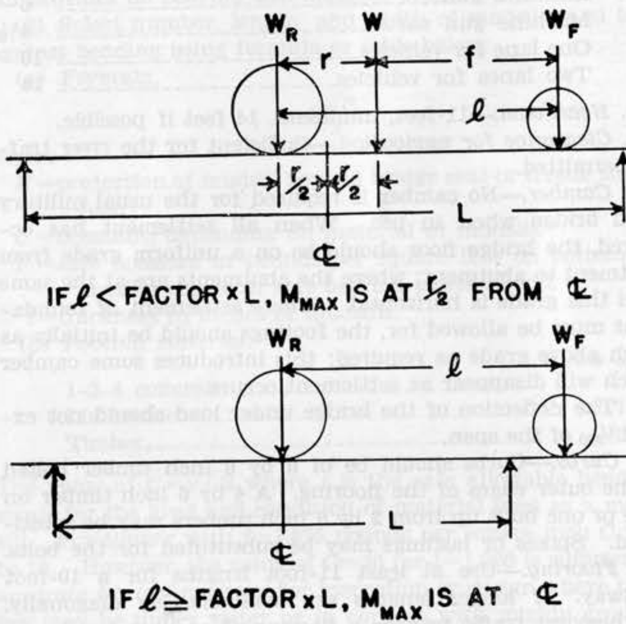


FIGURE 43.—Positions of heavier axle load (W_R) on bridge to produce maximum bending.

TABLE XXVII.—*Values of load factor (see fig. 43)*

Load proportioning	Value of factor
$W_R = W_F$	0.586
$W_R = 2W_F$	.551
$W_R = 3W_F$	.535
$W_R = 4W_F$	.527

b. Bending moment.—(1) The formulas for bending moment are—

$$M = \frac{WL}{4} \text{ (concentrated center load } W\text{)}$$

$$M = \frac{WL}{8} \text{ (total load } W \text{ uniformly distributed over span } L\text{)}$$

$$M = \frac{W(4a+b)}{8} \text{ (uniform, moving load } W \text{ partially distributed)}$$

where

M=moment in inch-pounds at center of a simple beam.

W=total load in pounds.

L=span in inches.

b=length of load in inches.

$a = \frac{L-b}{2}$, or distance in inches of each end of load from nearest end of span.

(2) Resisting moment must be equal to or greater than the total maximum external bending moment. The formulas for resisting moments are—

$$M = fS \text{ (all beams)}$$

$$M = \frac{fbd^2}{6} \text{ (rectangular timbers)}$$

$$M = \frac{fd^3}{10} \text{ (round timbers)}$$

where

M=resisting moment in inch-pounds.

f=maximum working fiber stress for material (see ch. 4).

b=breadth of rectangular timber in inches.

d=depth of rectangular timber in inches or diameter of round timber.

S=section modulus, I/y in inches cubed (in.^{3}) from handbooks.

■ 36. STRINGER STRENGTH.—*a.* Design and check strength of stringers, using the following formulas, diagrams, and tables. Impact, dead load, and stringer efficiency are not considered. I-beams listed are the lightest-weight standard. Values of f: 1,600 (rectangular timber); 1,000 (green logs); 18,000 (steel).

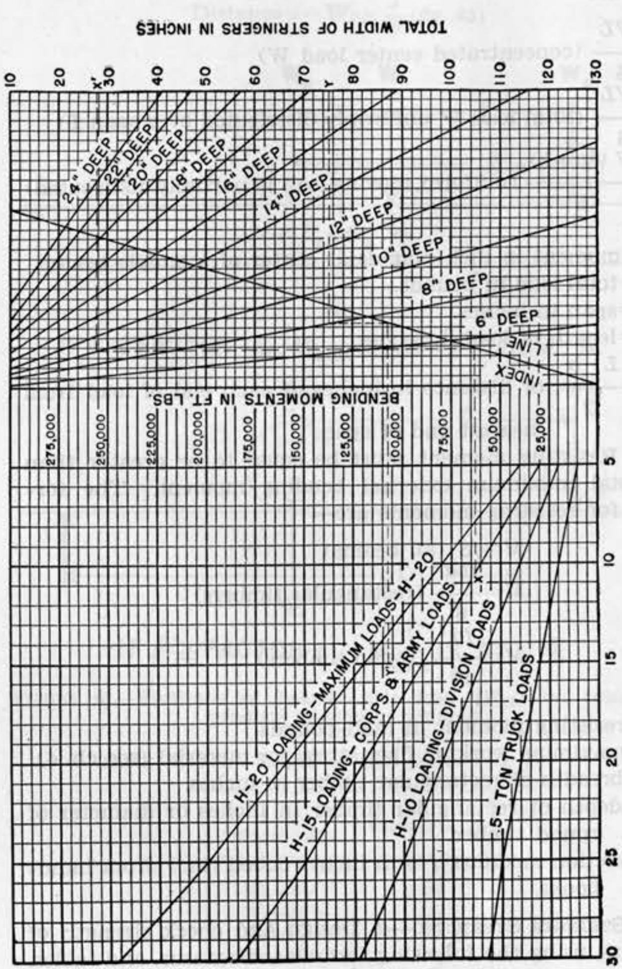


FIGURE 44.—Diagram for rectangular timber stringers.

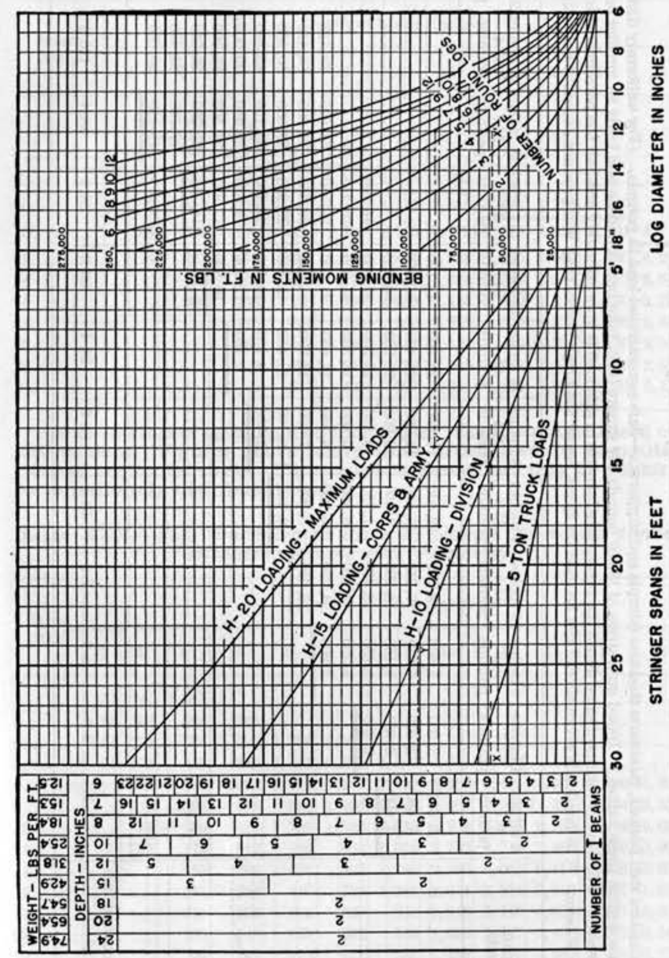


FIGURE 45.—Diagram for I-beams and round log stringers.

TABLE XXVIII.—*Safe loads for single I-beams*

American standard steel I-beams, minimum thickness (simple end supports).—Safe concentrated load in pounds. (For uniformly distributed loads use double these values.) Based on a stress of 18,000 pounds per square inch, take proportionate safe loads for smaller or greater unit stresses. For heavier beams of same depth the percentage increase in safe load is approximately one-half the percentage increase in weight of beam. The last loads given should not be used on spans below the black line as they will produce excessive deflections.

Span (feet)	3 inches 5.7 pounds	4 inches 7.7 pounds	5 inches 10.0 pounds	6 inches 12.5 pounds	7 inches 15.3 pounds	8 inches 18.4 pounds	10 inches 25.4 pounds	12 inches 31.8 pounds	15 inches 42.9 pounds	18 inches 54.7 pounds	20 inches 65.4 pounds	24 inches 79.9 pounds
5	2,000	3,600	5,800	8,700	12,400	17,050	29,300	43,150				
6	1,650	3,000	4,850	7,250	10,350	14,200	24,400	35,950				
7	1,400	2,550	4,150	6,200	8,850	12,200	20,950	30,850				
8		2,250	3,650	5,450	7,750	10,650	18,300	27,000	44,200			
9			3,250	4,850	6,900	9,500	16,300	24,000	39,250			
10			2,900	4,350	6,200	8,550	14,650	21,600	35,350	53,050	70,150	104,350
12				3,650	5,200	7,100	12,200	18,000	29,450	44,200	58,450	86,850
14					4,450	6,100	10,450	15,400	25,250	37,900	50,100	74,550
16						5,350	9,150	13,500	22,100	33,150	43,850	65,250
18							8,150	12,000	19,650	29,450	39,000	58,000
20								10,800	17,650	26,500	35,100	52,200
25									14,150	21,200	28,050	41,750
30										17,700	23,400	34,800
35										15,150	20,050	29,800
Section modulus S-In^3	1.7	3.0	4.8	7.3	10.4	14.2	24.4	36.0	58.9	88.4	116.9	173.9

TABLE XXIX.—*Concentrated safe loads in pounds for rectangular wooden beams for each inch of width*

Span (feet)	Depth of beam (inches)										
	4	6	8	10	12	14	16	18	20	22	24
2	710	1,125	1,500								
4	356	800	1,425	1,875	2,250						
6	237	533	950	1,480	2,135	2,625	3,000				
8	177	400	710	1,110	1,600	2,175	2,845	3,375	3,750	4,125	
10	143	320	570	888	1,280	1,745	2,279	2,880	3,550	4,300	4,7 0
12	118	267	475	740	1,066	1,454	1,896	2,400	2,960	3,580	4,260
14		228	406	635	914	1,245	1,626	2,055	2,580	3,072	3,655
16		200	356	556	800	1,090	1,424	1,800	2,225	2,690	3,200
18			316	494	710	968	1,264	1,600	1,975	2,390	2,848
20			284	444	640	871	1,137	1,440	1,778	2,150	2,560
22				404	581	792	1,035	1,308	1,617	1,956	2,328
24				371	533	727	948	1,200	1,481	1,794	2,132

NOTE.—Stringers on simple end supports. Computations based on net sections. Figures above heavy lines determined by computations of horizontal shear. Figures below heavy lines may be doubled for a uniformly distributed load.

TABLE XXX.—*Safe concentrated loads in pounds for round timber stringers (simple end supports)*

Span (feet)	Diameter of beam (inches)											
	2	3	4	5	6	7	8	10	12	14	16	18
2	131	441	1,048									
3	88	294	698	1,366								
4	65	221	524	1,022	1,768	2,808						
5	52	176	419	820	1,412	2,245	3,350	6,544	11,310			
6		147	349	684	1,178	1,871	2,790	5,462	9,425	14,961	22,340	31,808
8		110	262	511	884	1,404	2,092	4,088	7,069	11,225	16,754	23,856
10		89	209	410	706	1,123	1,675	3,272	5,655	8,980	13,404	19,086
12		74	175	342	589	935	1,395	2,732	4,713	7,482	11,170	15,904
14			150	292	506	802	1,198	2,340	4,065	6,415	9,574	13,632
16			131	256	442	702	1,046	2,044	3,534	5,613	8,377	11,928
18			116	228	393	625	931	1,818	3,142	4,989	7,447	10,603
20			105	205	353	562	838	1,636	2,827	4,490	6,702	9,543
22			96	186	322	511	763	1,489	2,570	4,082	6,093	8,675
24				171	295	469	698	1,365	2,356	3,742	5,585	7,952

NOTE.—Based on an allowable stress of 1,000 pounds per square inch.

b. The following formulas give the allowable loads on particular stringers. An allowance for impact of 25 percent is included.

(1) Rectangular wooden stringers:

$$W=\left(\frac{f}{22.5}\right)\frac{bd^2}{L}-\frac{4uL}{10}$$

(2) Standard I-Beams of minimum web thickness:

$$W=930\frac{Nd^2}{L}-0.4uL$$

(3) Standard I-beams of average web thickness:

$$W=1050\frac{Nd^2}{L}-0.4uL$$

For uniformly distributed loads, the total load given above may be increased to the amount given by the following formula:

$$U=W\left(\frac{2L}{2L-T}\right)$$

where

L=stringer span in feet.
N=number of I-beams.
T=length of tank or tractor track in contact with the floor, in feet.
U=total uniformly distributed safe load of length T in pounds.
W=allowable concentrated load in pounds.
b=total width of stringers of depth d in inches.
d=depth of stringer in inches.
f=allowable bending stress in pounds per square inches (usually 1,000 to 1,800; see table CXLIII).
u=uniform dead load of span in pounds per linear foot (see table XXXI).

■ 37. Dead Load.—In hasty design of short span bridges it is usually sufficient to add an extra stringer to take care of the dead load. For long spans using light stringers it may be necessary to add 25 percent of the number needed for the live load.

Table XXXI.—*Dead loads, highway bridge decks*

	Pounds per linear foot		
Type of stringer	Wood	Steel	Steel.
Type of floor	Wood	Wood	Concrete.
One-way	250-350	250-400	800 up.
Two-way	350-500	400-700	1,300 up.

Note.—*The figures on concrete are based on a slab thickness of 6 inches and weight at 150 pounds per cubic foot. The weight of timber is about 40 pounds per cubic foot.*

■ 38. Stringer Arrangement and Distribution.

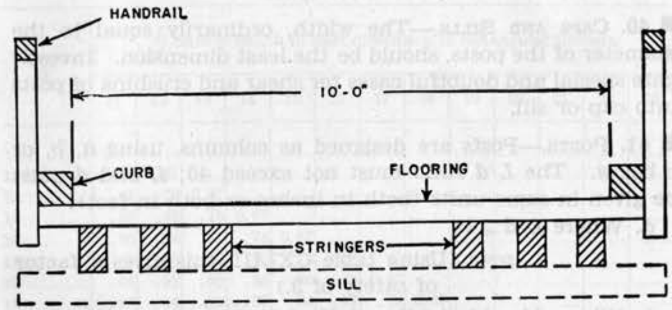


Figure 46.—Transverse cross section of typical stringer bridge.

a. For design the proportion of the wheel load on any one stringer is:

$$\frac{S'}{8}+\frac{1}{N}$$

where

N=total number of stringers.
S'=stringer spacing in feet center to center.

b. For a simple one-track stringer bridge, with an even number of stringers, it is considered that stringers can be placed to allow a stringer efficiency of 90 percent to be used in design. For reconnaissance the determination of stringer efficiency is a matter of judgment. If the flooring is satisfactory, assume a stringer efficiency of 80 percent. Tables XXXV and XXXVI provide a quick means of determining bridge capacities for various classes of stringers. For the worst conditions, figure the live load supported by stringers on the basis that the flooring acts as a simple beam between stringers.

■ 39. SHEAR.—The maximum vertical shear develops at the supports and occurs as the maximum load passes that point. In timber the maximum horizontal shear occurs when the load is at a distance from the support of three times the beam depth, or at the center when the span is six times the depth or less. Horizontal shear per unit of horizontal stringer cross section area is equal to the reaction at the support divided by the vertical stringer cross section and multiplied by 3/2. This is important only for short spans.

■ 40. CAPS AND SILLS.—The width, ordinarily equal to the diameter of the posts, should be the least dimension. Investigate special and doubtful cases for shear and crushing of posts into cap or sill.

■ 41. POSTS.—Posts are designed as columns, using *a*, *b*, or *c* below. The L/d ratio must not exceed 40; L and d must be given in same units (both in inches or both in feet).

a. Where $L/d \leqq 11$

$p=s$ (Using table CXLIII, this gives a factor of safety of 3.)

b. Where $11 < L/d < K$ and $K=0.64\sqrt{E/s}$

$$p=s\left[1-\frac{1}{3}\left(\frac{L}{Kd}\right)^4\right]$$ (Using table CXLIII, this gives a factor of safety of 2.25.)

c. Where $L/d > K$ and $K=0.64\sqrt{E/s}$

$$p=1.2\times0.274\frac{E}{(L/d)^2}$$ (This gives a factor of safety of 2.5.)

d. For round columns replace d in the above formulas by 70/79 times the diameter.

e. For reconnaissance investigations use the formula:

$$p=s\left(1-\frac{L}{60d}\right)$$

where

L=unsupported length of the column.
d=least dimension of the column.
E=modulus of elasticity.
s=unit working stress for compression parallel to the grain (table CXLIII).
$K=0.64\sqrt{E/s}$ (for select merchantable Douglas fir $K=22.5$)
p=allowable unit load.
P=total load=pA.
A=cross-sectional area.

TABLE XXXII.—*Values of the expression* $\left(1-\frac{1}{3}\left(\frac{L}{Kd}\right)^4\right)$

Values of K	$\frac{L}{d}$ ratio of length to least dimension in rectangular timbers												
	11	12	13	14	15	16	17	18	19	20	21	22	23
11	0.67												
12	.76	0.67											
13	.83	.76	0.67										
14	.87	.82	.75	0.67									
15	.90	.86	.81	.75	0.67								
16	.92	.89	.86	.80	.74	0.67							
17	.94	.92	.89	.85	.80	.74	0.67						
18	.96	.94	.91	.88	.84	.79	.73	0.67					
19	.97	.95	.93	.90	.87	.83	.78	.73	0.67				
20	.98	.96	.94	.92	.89	.86	.83	.78	.73	0.67			
21	.98	.97	.95	.93	.92	.88	.86	.82	.77	.72	0.67		
22	.98	.97	.96	.94	.93	.91	.88	.85	.81	.77	.72	0.67	
23	.99	.98	.97	.95	.94	.92	.90	.87	.84	.81	.77	.72	0.67

NOTE.—This table can also be used for timber columns not rectangular L/d being equivalent to 0.289 L/r where r is the least radius of gyration of the section.

TABLE XXXIII.—*Safe loads, square wood posts, and for various values of L/d in formula of paragraph 41e*

[Fiber stress assumed to be 1,200 in the formula. Proportionate increases or decreases should be used for higher or lower stresses]

Size (inches)	Length (feet)	$\frac{L}{d}$	Safe unit working stress *p*	Safe load *P* for post=*pA*
4 by 4	2	6	1,080	17,280
4 by 4	4	12	960	15,360
4 by 4	6	18	840	13,440
4 by 4	8	24	720	11,520
4 by 4	10	30	600	9,600
6 by 6	4	8	1,040	37,440
6 by 6	6	12	960	34,560
6 by 6	8	16	880	31,680
6 by 6	10	20	800	28,800
6 by 6	12	24	720	25,920
6 by 6	14	28	640	23,040
6 by 6	16	32	560	20,160
8 by 8	6	9	1,020	65,280
8 by 8	8	12	960	61,440
8 by 8	10	15	900	57,600
8 by 8	12	18	840	53,760
8 by 8	14	21	780	49,920
8 by 8	16	24	720	46,080
8 by 8	18	27	660	42,240
8 by 8	20	30	600	38,400
8 by 8	22	33	540	34,560
8 by 8	24	36	480	30,720

■ 42. PILES.—Construct pile bents in dimensions similar to trestle bents. When the height from the bottom is less than 8 feet no bracing is required. Place bracing above water when required. For greater stability batter piles are frequently used. If the pile rests on a hard stratum it is designed as a column. Otherwise determine the safe load by loading test piles or by the following rough formulas:

For piles driven by drop hammer: $P=\frac{2wh}{s+1.0}$

For piles driven by steam hammer: $P=\frac{2wh}{s+0.1}$

where
P=safe load in pounds.
w=weight of hammer in pounds.
h=height of fall of hammer in feet.
s=average penetration of the pile under several successive blows of the hammer, in inches.

TABLE XXXIV.—*Bearing power of piles of 1 foot mean diameter*

Character of soil	Penetration (feet)	Probable safe load (pounds)	Character of soil	Penetration (feet)	Probable safe load (pounds)
Soft mud	15	4,500	Compact sand	10	20,000
	30	10,000		12	24,000
Soft clay	10	7,000		15	28,000
Compact silt	15	10,000		20	36,000
	20	13,000		30	48,000
	30	20,000	Sand and gravel	8	20,000
Stiff clay	10	15,000		10	24,000
	15	23,000		12	28,000
	20	30,000		15	34,000
	30	45,000		20	43,000
Compact sand	8	16,000		30	60,000

NOTE.—For other pile diameters the safe load will vary in proportion to the diameter.

■ 43. TIMBER PIERS.—Make timber piers of trestle, pile, or crib construction. They are used when simple bents do not provide sufficient support, stability, and stiffness.

■ 44. BRIDGE RECONNAISSANCE FORM.

FORM FOR BRIDGE RECONNAISSANCE

Bridge ____________
Class ____________
Sheet No.____ in ____ sheets

Map reference____________________________
Date________________ Party________________
(If necessary, use back of sheets, repeat number of headings.)

Location

1. Designation of route____________________________
(road, railroad, canal, or stream)
2. Two towns on route____________________________
3. Name of nearest town; direction and distance from bridge____
____

4. Stream, canal, road, or railroad crossed by bridge----------------
5. Local name of bridge----------------
6. Remarks ----------------

Description of bridge

7. Type ----------------
8. Spans ----------------
9. Total length----------------
10. Net length ----------------
11. Total width----------------
12. Width of roadway----------------
13. Clearances.

   Above roadway---- { Horizontal---------------- / Vertical ----------------

   Under roadway ----------------
14. Floor system.
   (*a*) Flooring ----------------
   (*b*) Stringers and floor beams----------------
   (*c*) Curbs, handrails----------------
15. Number and width of sidewalks----------------
16. Piers----------------
17. Abutments ----------------
18. Wing walls ----------------
19. Paving ----------------
20. Maximum loads: Now using bridge---- Reported capacity----
21. Remarks ----------------

Description of crossing

(Make plan and profile on extra sheet showing (*a*) all bridges involved in crossings; (*b*) bridge being reported on)

22. One of---------- bridges involved in crossing----------------

----

23. Character of stream. Maximum depth { Low water---------- / High water---------- / Observed ----------
24. Velocity: Feet per second----------------
25. Floods per year---------- months----------------
26. Amount and character of debris carried at high water--------
27. Character of bed and banks of stream----------------
28. Approaches.
   (*a*) --------end. Straight length------width------height --------cut or fill.
   (*b*) --------end. Straight length------width------height --------cut or fill.
29. Remarks ----------------

----

30. Description of connecting roadway between several bridges involved in crossing----------------

----

Recommendations

31. List in order of practicability for new construction. (Pile bents, trestle, crib supports, etc.) ----------------

----
32. Remarks ----------------

----
33. Estimate of time required for construction----------------
34. Troops ----------------
35. Bill of materials (use extra sheet)----------------
36. Location of construction camp----------------
37. Remarks ----------------

■ 45. **Determination of Allowable Loads on Existing Bridges.**—*a. General.*—Newer bridges are usually designed on the basis of H-loadings (figs. 39 and 40) as follows:

Main Federal and State highways (including strategic highways)-------------------- H-15
Principal State and county roads---------- H-10

Older bridges will vary, and no assumption should be made as to design basis unless indicated on the bridge or by posted sign capacity. For new bridges with heavy concrete or other type floors giving wide load distribution, the H-loading (in tons) may be exceeded by 50 percent on one-lane bridges, and by 100 percent on multiple-lane bridges, by single vehicles at steady speeds of 5 m. p. h. For other bridges under same conditions the posted capacity should not be exceeded by more than 25 percent. Wherever excessive deflections or signs of strain appear after trial the posted loads should not be exceeded. Assume that flooring and stringers, especially in older bridges, are weaker than abutments and intermediate supports unless these are obviously damaged or rotted. In case of doubt, the following more detailed check methods should be employed.

b. Flooring.—Rule of thumb: For heavy loads, planking thickness (inches) should be at least 1½ times clear distance between stringers (feet); minimum permissible thickness is 2½ inches if worn or 2 inches if new. In doubtful cases, way planks or a second layer of flooring (spiked down) should be added. Investigate floors from below and do not assume asphalt surfacing adds any strength.

c. Stringers.—See paragraphs 36 to 39, inclusive, or tables XXXV and XXXVI.

TABLE XXXV.—*Hasty estimation of bridge capacities—steel stringers*

[Number of I-beams required for 10-ton single-axle load]

Span c. to c. (feet)	Depth and weight of standard minimum weight beams								
	6″ 12.5#	7″ 15.3#	8″ 18.4#	9″ 21#	10″ 25.4#	12″ 31.8#	15″ 42.9#	18″ 54.7#	20″ 65.4#
6	4.2	2.9	2.2	1.4	------	------	------	------	------
8	5.6	4.0	2.9	1.9	1.7	------	------	------	------
10	7.1	5.0	3.7	2.4	2.2	1.4	------	------	------
12	8.6	6.0	4.4	2.9	2.6	1.7	------	------	------
14	10.2	7.2	5.3	3.5	3.0	2.0	------	------	------
16	12.2	8.3	6.1	4.1	3.5	2.3	1.5	------	------
18	13.6	9.5	6.9	4.6	4.0	2.6	1.7	------	------
20	------	10.6	7.8	5.2	4.5	3.0	1.8	------	------
25	------	------	10.2	6.8	6.0	3.7	2.4	1.6	------
30	------	------	------	8.6	7.6	4.9	3.1	2.1	------
35	------	------	------	------	------	6.1	3.7	2.5	1.9

NOTES.—1. Explanation of use of table:

a. To find the safe concentrated load for ordinary traffic moving at standard speeds, take the ratio of number of I-beams available to tabular value and multiply by 10 tons.

b. If beams are not minimum weight and ratio of actual weight of beams to minimum weight of beams for size can be determined, increase the value found in *a* above by ½ the percentage of increase in weight over minimum weight. Otherwise assume beams are minimum and disregard actual weights.

c. For emergencies, with traffic control guards to insure reduced speeds, only one vehicle on bridge at a time, and no gear shifting on bridge, 1½ the value found above may be used.

d. To find the gross truck weight allowable, multiply the safe axle load by 1.25.

2. The above table is based on the following data:

Dead load of 4-inch plank flooring 10 feet long with two 6- by 6-inch curbs plus actual stringer weight.

Impact on basis of formula: $I=\frac{25}{(L+125)}$ (*L* equals span in feet).

Stringer efficiency of 80 percent included.

Safe tensile stress of 18,000 p. s. i. used.

TABLE XXXVI.—*Hasty estimation of bridge capacities—wooden stringers*

[Total stringer widths in inches required for 10-ton single-axle load]

Span c. to c. (feet)	Depth of stringers				
	6″	8″	10″	12″	14″
6	62	34	22	15	12
8	82	46	30	21	15
10	------	60	38	26	20
12	------	72	46	32	24
14	------	------	54	38	27
16	------	------	64	44	32
18	------	------	74	50	36
20	------	------	84	58	42

NOTES.—1. Explanation of use of table:

a. To find the safe concentrated load for ordinary traffic moving at standard speeds, take the ratio of stringer width available to tabular value and multiply by 10 tons.

b. In emergency, with traffic control guards to insure reduced speeds only one vehicle on the bridge at a time, and no gear shifting on bridge, 1½ this value can be used.

c. To find the gross truck weight allowable, multiply the single safe axle load by 1.25.

2. The above table is based on the following data:

a. Dead load of 4-inch plank flooring 10 feet long with two 6 by 6-inch curbs plus actual stringer weight.

b. Impact of 25 percent and stringer efficiency of 80 percent included.

c. Fiber stress of 1600 p.s.i. used. If actual allowable fiber stress is less, decrease allowable load on proportional basis.

d. Trestles.—For caps and sills see paragraph 40. For posts use table XXXIII and table XXXIV for piles.

e. Other parts.—If sufficient time is available, continue the investigation to the other parts of the structure.

■ 46. SUSPENSION BRIDGES.—*a. Formulas for determining stresses in cables.*

(1) For a uniform load:

$$T=\frac{S/2}{S\ \theta}=\frac{Sx\sqrt{L^2+16d^2}}{8d}$$

(2) For a concentrated load (approximate):

$$T=\tfrac{1}{2}\sqrt{S^2+\left[\frac{L}{4d}\,(S+W)\right]^2}$$

where

T=maximum cable tension (in all cables at one tower).

W=concentrated live load on bridge.

S=sum of all live and dead loads on bridge cables (including impact and all other loads).

L=span in feet between towers.

d=deflection (sag) of cable in feet at midpoint below tops of towers.

θ=angle made with the horizontal by tangent to cable at tower.

b. Formula for length of cables between towers.

$L+\frac{8d^2}{3L}$ (approximation based on a circular curve).

c. Formula for length of slings (omitting any allowance for camber).

$$y=\left(\frac{4d}{L^2}\right)x^2$$

where

y=length of sling.

x=distance from middle point of bridge to sling.

■ 47. FOOTBRIDGE EQUIPMENT, M1935.—One unit makes 432 feet of footbridge or 144 feet of wide bridge. Standard load for a 1½-ton truck is 9 bays or 108 feet of footbridge. An infantry rifle company can cross on this bridge in 3 minutes during daylight or in 10 minutes at night.

FIGURE 47.—Construction of footbridge by successive bays.

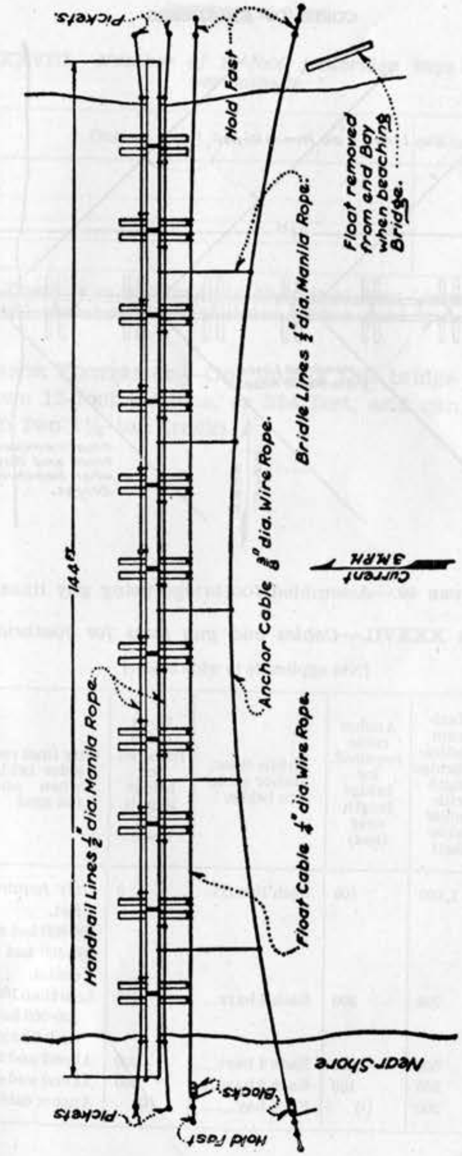


FIGURE 48.—Assembled footbridge using anchor and float cables.

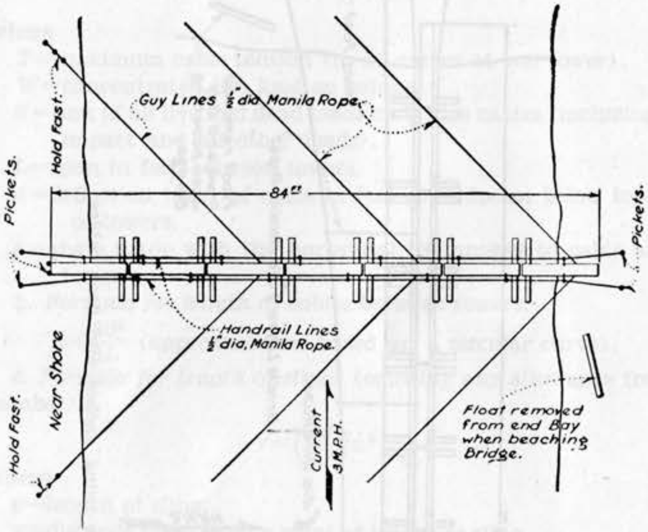


FIGURE 49.—Assembled footbridge using guy lines.

TABLE XXXVII.—*Cables and guy lines for footbridge*

[Not applicable to wide bridge]

Current in main channel of stream (m. p. h.)	Maximum practicable bridge length with anchor cable (feet)	Anchor cable required for bridge length over (feet)	Bridle lines, anchor cable to bridge	Float cable required for bridge length over (feet)	Guy lines required both sides bridge to bank when anchor cable not used
0	1,000	500	Each 10 bays	0	Only required over 100 feet. 100-300 feet at end. 300-500 feet at end and center.
1	700	300	Each 6 bays	300	Less than 100 feet at end. 100-300 feet at end and each 6 bays.
2	500	200	Each 4 bays	200	At end and each 4 bays.
3	350	100	Each 2 bays	100	At end and each 2 bays.
4	200	(1)	Each bay	(1)	Anchor cable required.

[1] Any length.

TABLE XXXVIII.—*Number of 12-foot footbridge bays constructed per minute*

Current (m. p. h.)	Day	Night
Less than 2	2	1
2 to 3	1½	¾
Over 3	1	½

NOTE.—These rates require 40 to 50 trained men (depending upon the current) under service conditions with a good site. (See table XXV.)

■ 48. KAPOK FOOTBRIDGE.—One unit of this bridge consists of twenty-two 12-foot sections, or 264 feet, and can be transported on two 1½-ton trucks.

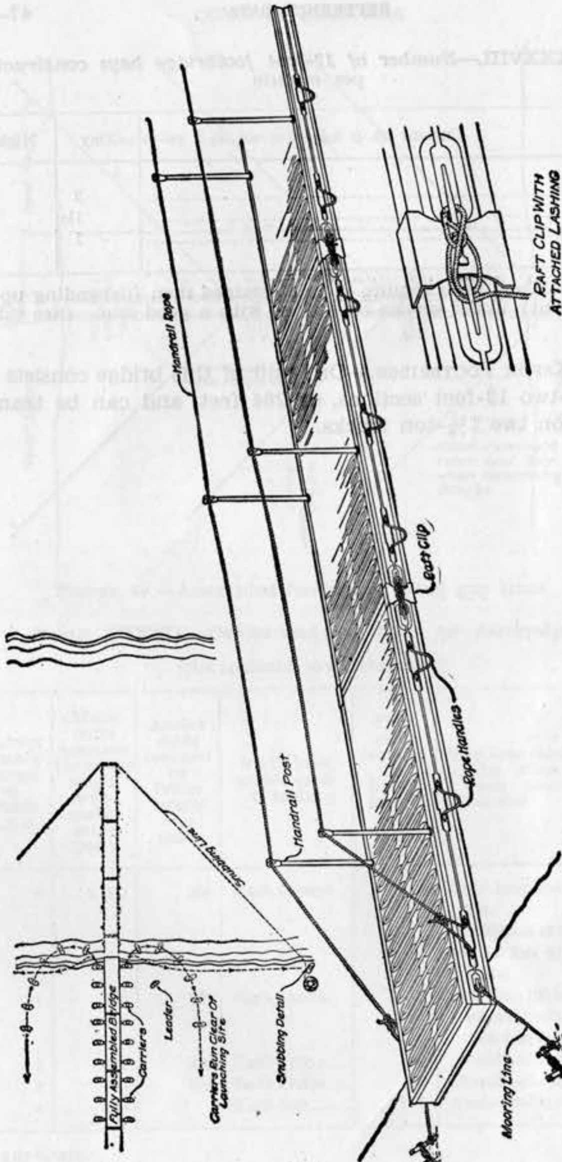


FIGURE 50.—Kapok footbridge.

■ 49. PONTON BRIDGES.

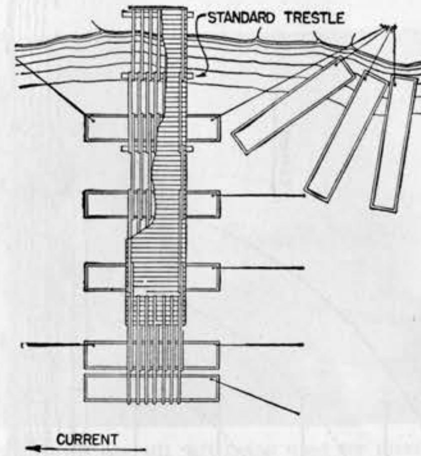


FIGURE 51.—Method of construction by successive pontons.

NOTE.—The length of cable between anchor and ponton should be at least ten times the depth of the stream.

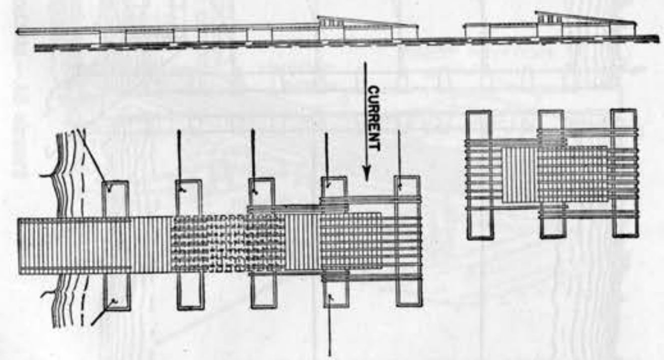


FIGURE 52.—Method of construction by parts. (First bay may be a trestle bay instead of as shown.)

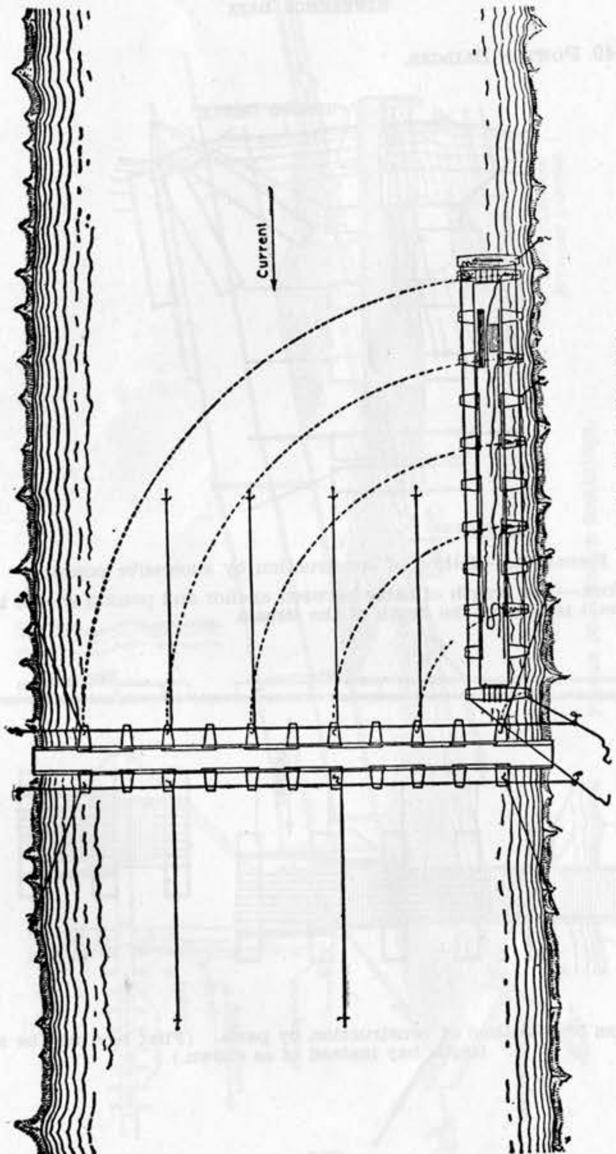


FIGURE 53.—Method of construction by conversion.

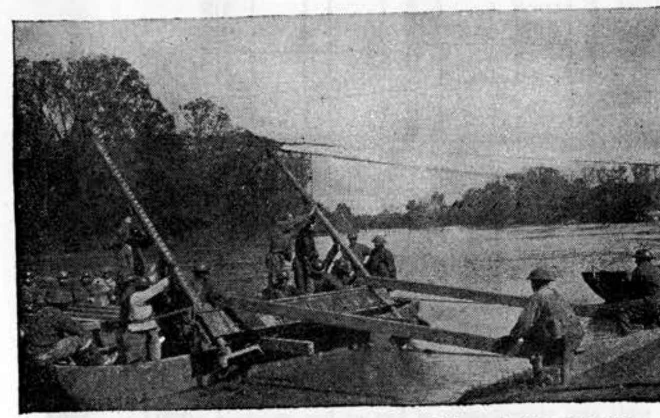


FIGURE 54.—Hinge sill raft being used for placing trestle.

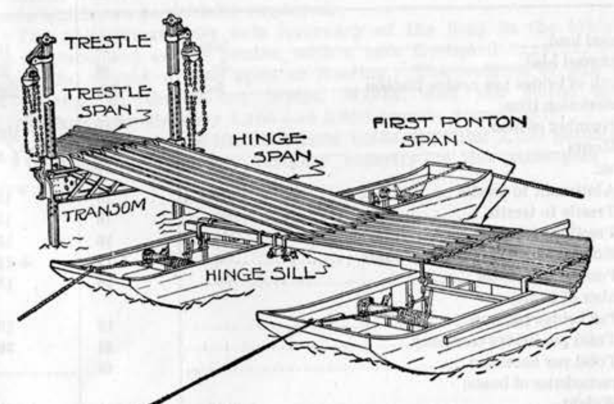


FIGURE 55.—Hinge sill raft and trestle (23-ton M1924 bridge).

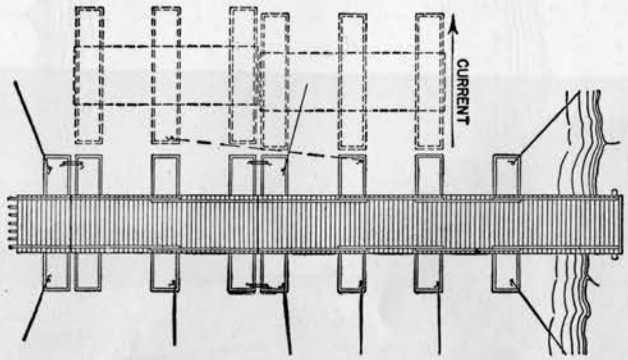


FIGURE 56.—Raft draw span in floating bridge.

TABLE XXXIX.—*Characteristics of standard ponton equipage*

	Heavy ponton battalion, M1924	Light ponton company, M1938
Normal load.....tons..	[1] 23	10
Reinforced load.....do....	46	20
Length of bridge per bridge platoon.....feet..	[2] 250	[2] 250
Construction time:		
Number of men.....	145	103
Hours.....	6-8	4-6
Spans:		
Abutment to trestle.....feet..	16	15
Trestle to trestle.....do....	16	15
Trestle to hinge.....do....	16	15
Effective length of hinge sill raft.....do....	4-12	4-12
Ponton to ponton.....do....	16	15½
Number of boats:		
Per bridge platoon.....	12	12
Total per bridge company.....	24	36
Total per battalion.....	48	....
Characteristics of boats:		
Weight.....pounds..	4,000	1,450
Length.....feet..	32	28
Width, maximum.....do....	6½	5½
Safe buoyancy (freeboard 9 inches).....pounds..	27,100	15,000
One span of flooring.....do....	4,100	2,600
Net buoyancy [3].....do....	23,100	12,400

See footnotes at end of table.

TABLE XXXIX.—*Characteristics of standard ponton equipage*.—Con.

	Heavy ponton battalion, M1924	Light ponton company, M1938
Trestles:		
Number per bridge platoon.....	4	4
Capacity, unreinforced.....tons..	25	20
Weight.....pounds..	[4] 1,690	1,050
Width of roadway (clear).....feet..	11¼	10
Number of balk under roadway per span, normal construction.....	9	8
Ferrying capacity, men per boat, exclusive of crew.....	58	[5] 25
Number men in boat crew.....	7 to 9	[5] 5 to 7

[1] Loads over 20 tons must be at intervals of over 32 feet.

[2] Four trestles are used in this bridge in normal construction. Using all basic quantities, lengths given can be built. Unless all trestles can be used, length of single bridge that can be built by several platoons of equipage end to end is considerably less than 250 feet times the number of units employed. In this case exact length of bridge that can be built must be computed using only number of spans which can be actually employed.

[3] The approximate net safe buoyancy of the boat in the bridge is the displacement of the ponton with a safe freeboard (approx. 9 in.) minus the weight of one span of flooring. The weights of one span of flooring of the 23-ton bridge, M1924, and the 10-ton bridge, M1938, are approximately 4,100 and 2,600 pounds, respectively.

[4] A duralumin trestle has also been made weighing 1,200 pounds.

[5] With outboard motor, ferrying capacity is 40 passengers with crew of 3.

TABLE XL.—*Maximum safe loads for various types of ponton bridges*

Type of bridge	Maximum gross load (pounds)	Maximum axle load (pounds)	Minimum distance between vehicles (feet)	Maximum speed (m. p. h.)	Width of roadway (clear) (feet)
7½-ton, M1926, normal [1]	15,000	12,000	32	5	10
7½-ton, M1926, reinforced [2]	30,000	24,000	32	5	10
10-ton, M1938, normal [3]	20,000	16,000	35	5	10
10-ton, M1938, reinforced [4]	40,000	32,000	35	5	10
23-ton, M1924, normal [5]	46,000	32,000	32	5	11¼
25-ton, M1940 [6]					

[1] Normal span of 16 feet between boat centers, seven 4- by 6-inch balk and 2 siderails in each ponton bay and each trestle and hinge span, and 1 layer of 2⅛-inch chess.

[2] One extra boat in each boat span. Seven balk and 2 siderails in boat spans and 12 balk and 2 siderails in abutment, trestle, and hinge spans. (This is the 15-ton bridge.)

[3] Normal span of 15½ feet between boat centers, eight 4- by 6-inch balk and 2 siderails in each ponton bay and in each trestle and hinge span, and 1 layer of 2⅛ inch chess.

[4] One extra boat in each boat span. Eight balk and 2 side rails in boat spans and 14 balk and 2 siderails in abutment, trestle, and hinge spans. (This is the 20-ton bridge.)

[5] Normal span of 16 feet between boat centers, nine 5¾₆- by 7¾-inch balk and 2 siderails in each bay, 1 layer of 2⅞-inch chess, and 1 transverse balk in the center of each span.

[6] This bridge, now under design, will replace the 23-ton bridge, M1924.

■ 50. TRESTLE BRIDGES.

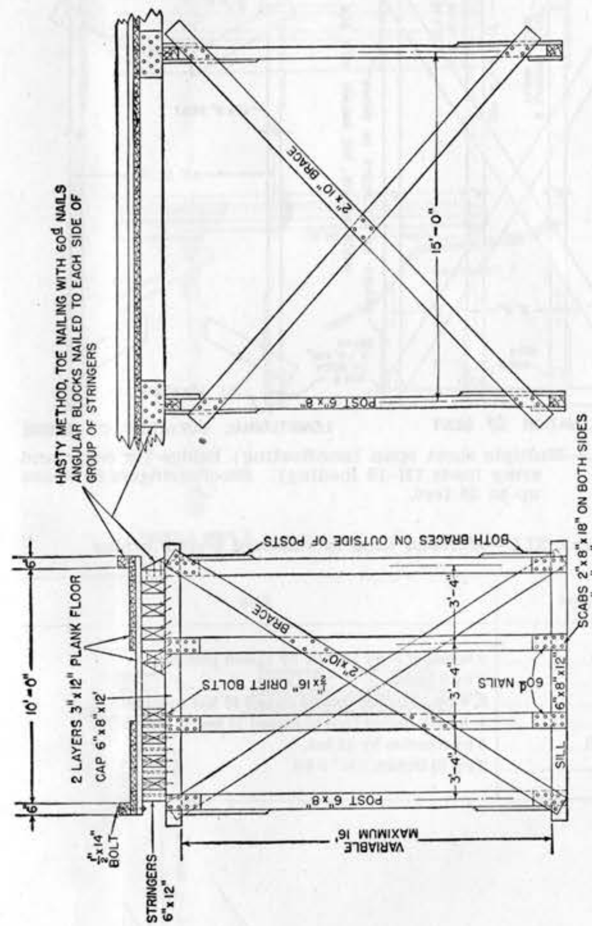


FIGURE 57.—Multiple short span (nonfloating) bridge for corps and army loads (H-15 loading). Wood stringers in spans up to 15 feet.

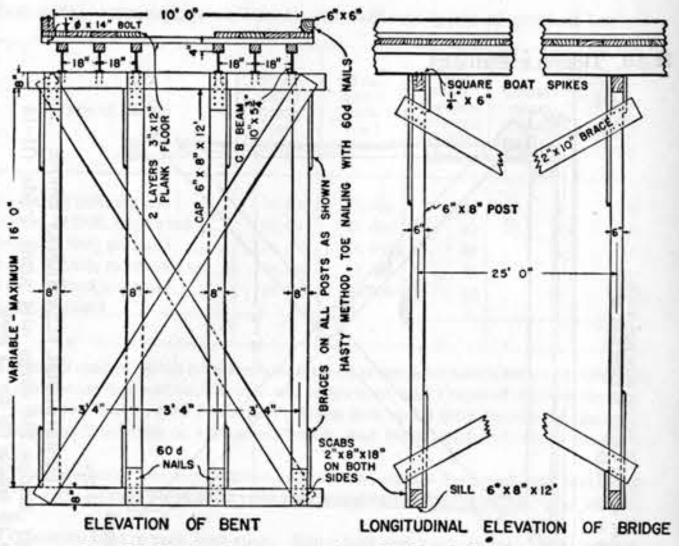


FIGURE 58.—Multiple short span (nonfloating) bridge for corps and army loads (H–15 loading). Steel stringers in spans up to 25 feet.

TABLE XLI.—*Material used in standard trestle bridge*

Material	Size
Flooring	2 layers of 3- by 12-inch by 11-foot planks.
Curbs	6 by 6 inches.
Stringers	8, 6 by 12 inches (not to exceed 16 feet in length).
Posts	4, 6 by 8 inches (not to exceed 16 feet in length).
Cap and sill	6 by 8 inches by 12 feet.
Bracing	2 by 10 inches.

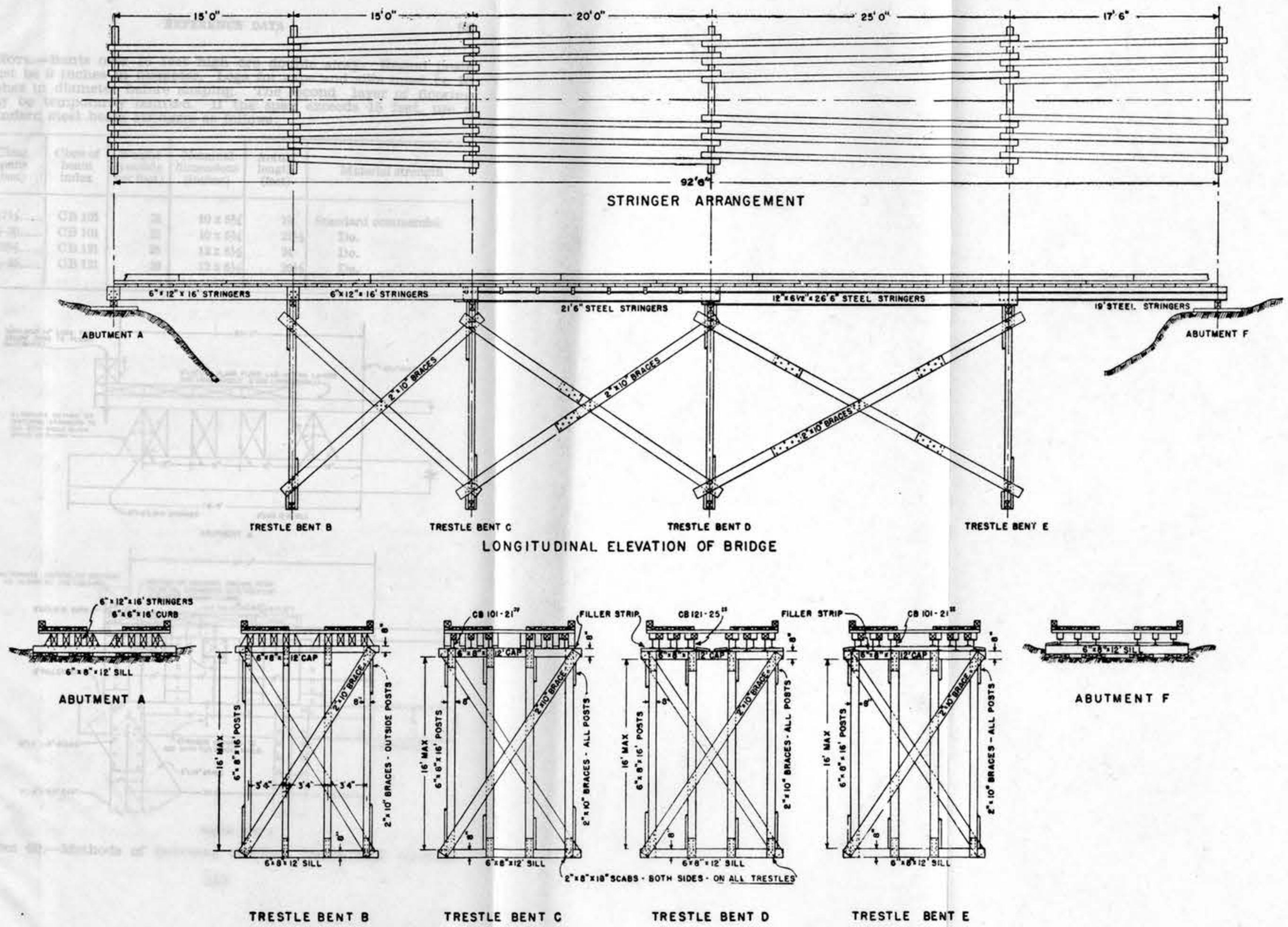


FIGURE 59.—Typical bridge, showing several types of trestles and stringers.

U. S. GOVERNMENT PRINTING OFFICE : 1941—O-282736

NOTE.—Bents over 16 feet high are double story. Round posts must be 9 inches in diameter. Logs for caps and sills must be 10 inches in diameter before shaping. The second layer of flooring may be temporarily omitted. If the span exceeds 15 feet, use 6 standard steel beam stringers as follows:

Clear spans (feet)	Class of beam index	Weight (pounds per foot)	Nominal dimensions (inches)	Actual length (feet)	Material strength
15-17½	CB 101	21	10 x 5¾	19	Standard commercial.
17½-20	CB 101	21	10 x 5¾	21½	Do.
20-22½	CB 121	25	12 x 6½	24	Do.
22½-25	CB 121	25	12 x 6½	26½	Do.

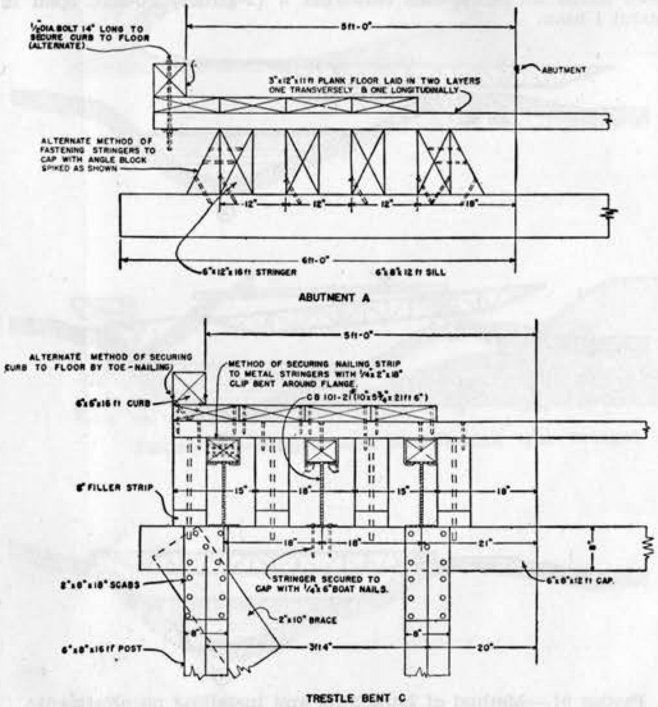


FIGURE 60.—Methods of fastening standard bridge deck material.

■ 51. **Steel Trusses.**—*a. Portable H–10 type.*

Table XLII.—*Permissible loadings of portable H–10 truss bridge for various lengths of span*

Number of girders	36 feet	48 feet	60 feet	72 feet	84 feet	96 feet	108 feet
2	H–20	H–15	-------	H–10	-------	-------	-------
3	-------	-------	H–20	H–15	-------	H–10	-------
4	-------	-------	-------	H–20	H–15	-------	H–10

Note.—The 12-foot box girder section weighs 1140 pounds. The 72-foot (2-girder) span can be carried on nine 1½-ton trucks or five 2½-ton trucks. Under ideal conditions an experienced crew of 42 men under an officer can construct a (2-girder) 60-foot span in about 1 hour.

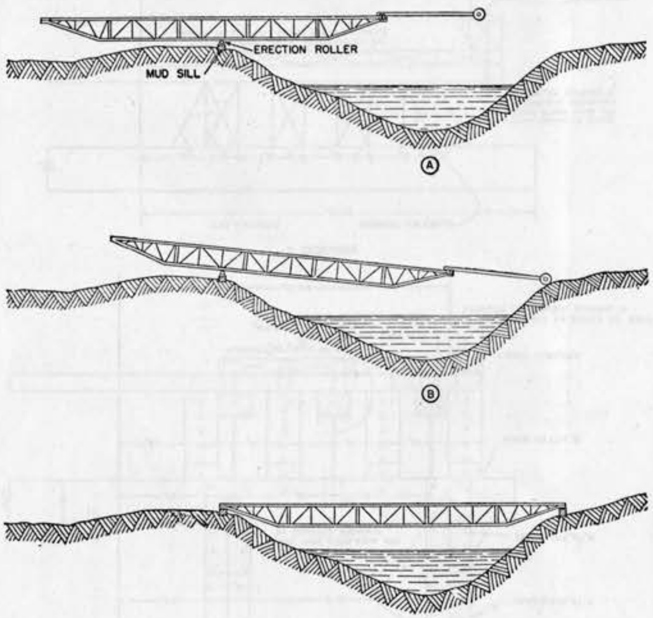


Figure 61.—Method of launching and installing on abutments.

b. Portable H–20 type.—The long span (nonfloating) bridge for corps and army loads (H–20 loading) built with two girders will carry all army loads on spans up to 125 feet. The box girder section, 2 by 6 by 12½ feet, weighs 1,730 pounds. The material for the 125-foot span weighs about 43 tons and can be carried in twenty-four 1½-ton trucks.

■ 52. **Spar Bridges; Trestle Bents.**

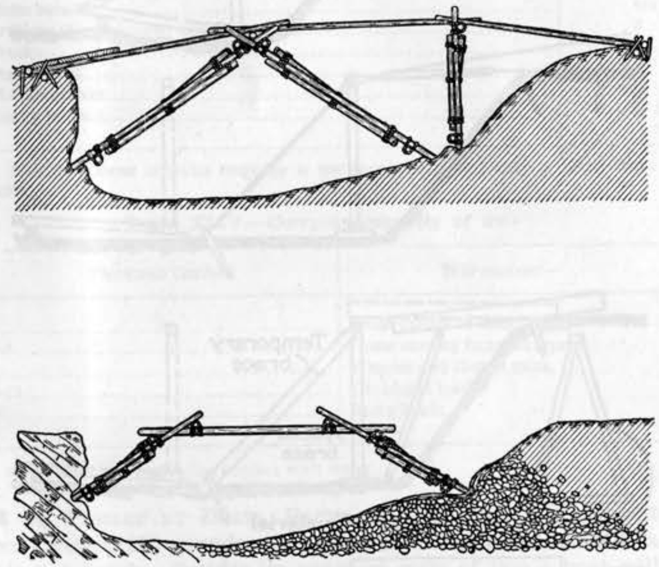


Figure 62.—Single- and double-lock spar bridges.

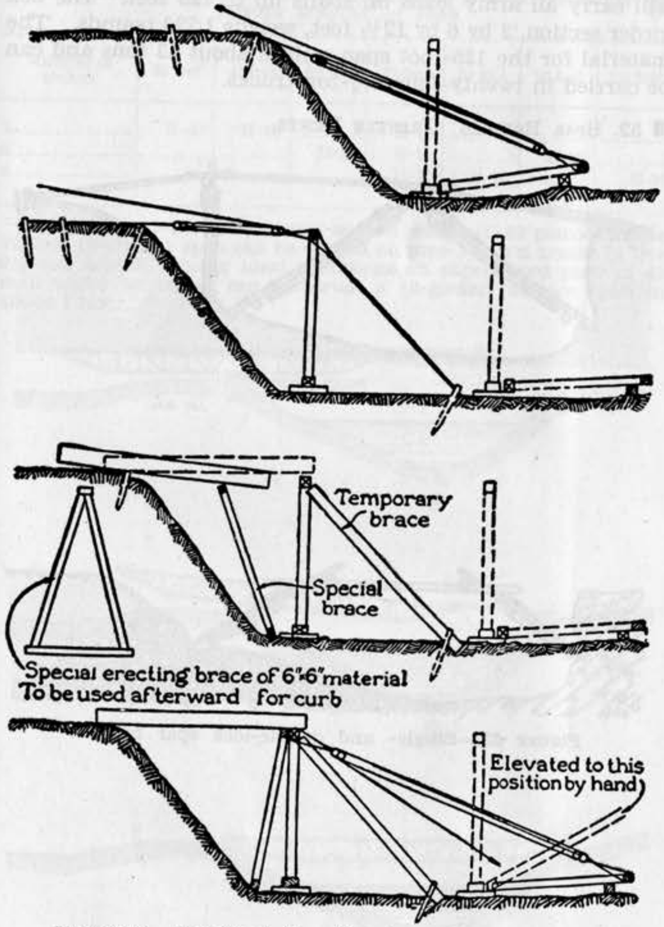


FIGURE 63.—A method of erecting framed trestle bents.

■ 53. PASSAGE BY FORDS AND ON ICE.

TABLE XLIII.—*Fordable depths*

Type of unit	Depth of water (feet)
Infantry	3½
Horse cavalry	4½
Artillery (horse-drawn) and wagons	3
Trucks	2
Light tanks	1–3
Medium tanks	2–4
Heavy tanks	4–6

NOTE.—These depths require a moderate current and a hard bottom.

TABLE XLIV.—*Carrying capacity of ice* [1]

Thickness (inches)	Will support—
3	Small groups of men.
4–5	Horse cavalry in small groups.
7	Wagons and 75-mm guns.
9–12	Divisional loads.
20	Army loads.

[1] New sound ice in floating contact with water.

■ **54. PASSAGE BY BOATS, RAFTS, AND FERRIES.**—The assault boat weighs 200 pounds. Ten boats are the normal load of a 1½-ton truck. Besides its engineer crew of two a boat will carry—

9 men.

8 men and a machine gun or 60-mm mortar with some ammunition.

7 men and one heavier item of infantry battalion equipment (81-mm mortar or communication section).

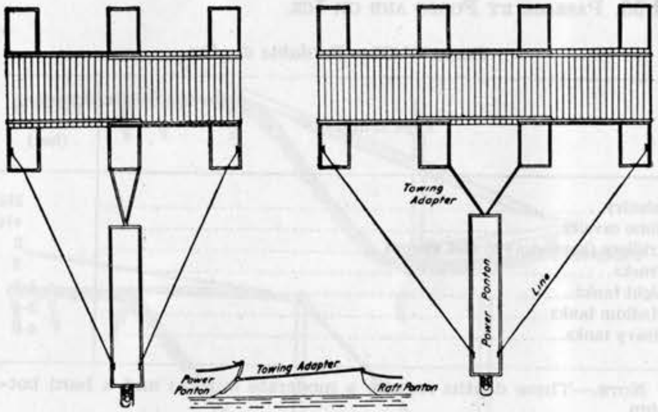


FIGURE 64.—Rafts made from ponton equipage.

A two-boat light ponton raft with two simple landing stages (see fig. 66) can be constructed in about 1 hour by 48 men after equipment is delivered. This ferry has a 10-foot by 21-foot platform that carries one gross truck load of 5 tons or a uniform load of 7 tons, making 6 or more round trips per hour. On narrow streams the ferry may be drawn across by cables fixed to both banks or by cables attached to the raft pulled from shore. When outboard motors are used on free rafts, several may operate at one site. See further details on rafts in TM 5-270.

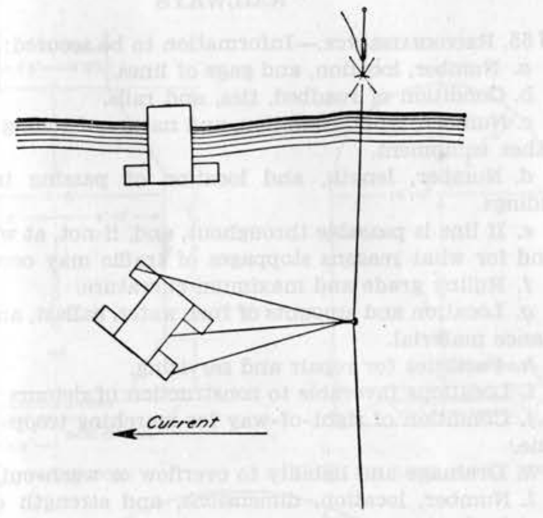


FIGURE 65.—Trail ferry with landing stage.

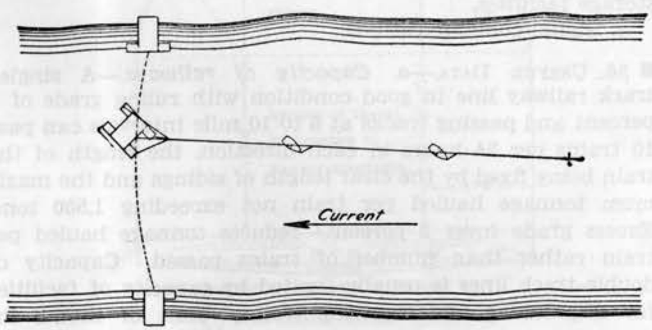


FIGURE 66.—Flying ferry.

Section III

RAILWAYS

■ 55. **Reconnaissance.**—Information to be secured:

a. Number, location, and gage of lines.

b. Condition of roadbed, ties, and rails.

c. Number, types, condition, and nature of rolling stock and other equipment.

d. Number, length, and location of passing tracks and sidings.

e. If line is passable throughout, and, if not, at what points and for what reasons stoppages of traffic may occur.

f. Ruling grade and maximum curvature.

g. Location and amounts of fuel, water, ballast, and maintenance material.

h. Facilities for repair and servicing.

i. Locations favorable to construction of detours.

j. Condition of right-of-way for marching troops along the line.

k. Drainage and liability to overflow or wash-out.

l. Number, location, dimensions, and strength of tunnels and bridges.

m. Location and capacity of platforms, ramps, loading and storage facilities.

n. Signal communications.

■ 56. **Useful Data.**—*a. Capacity of railways.*—A single-track railway line in good condition with ruling grade of 1 percent and passing tracks at 6 to 10 mile intervals can pass 10 trains per 24 hours in each direction, the length of the train being fixed by the clear length of sidings and the maximum tonnage hauled per train not exceeding 1,500 tons. Excess grade (over 2 percent) reduces tonnage hauled per train rather than number of trains passed. Capacity of double-track lines is usually limited by capacity of facilities for dispatching and receiving trains. Rule of thumb for determining the capacity of a terminal: Cars handled per 24 hours equal two-thirds of total length of track in receiving or classification yard divided by average length of car.

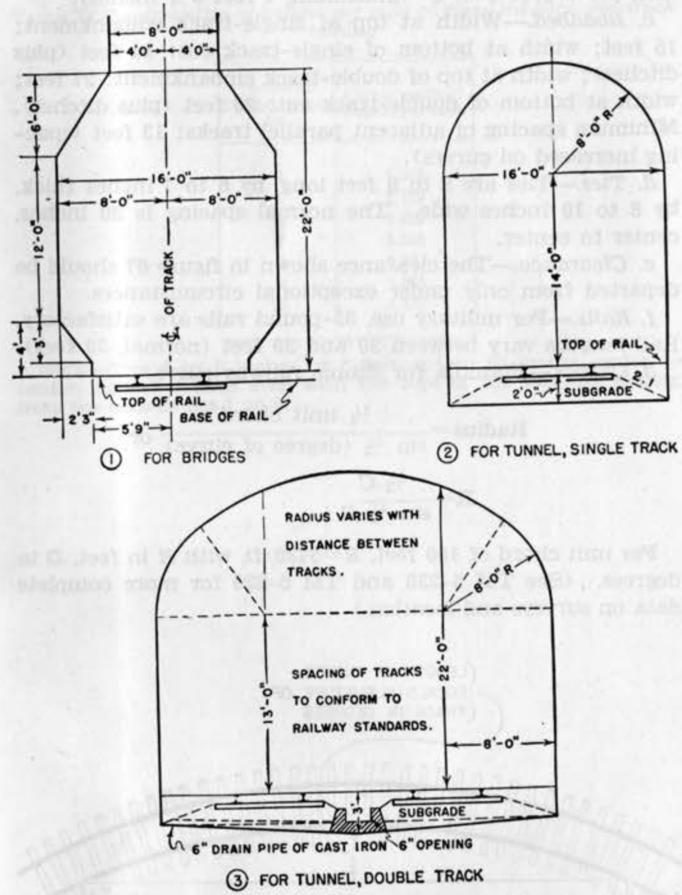


Figure 67.—Standard clearance diagrams for bridges and tunnels.

b. Gage.—Standard gage is 4 feet 8½ inches measured at point ⅝ inch below top of rail. Overgage on curves: $\frac{1}{16}$ inch per degree over 8° (maximum, 4 feet 9¼ inches).

c. Roadbed.—Width at top of single-track embankment: 15 feet; width at bottom of single-track cut: 14 feet (plus ditches); width at top of double-track embankment: 27 feet; width at bottom of double-track cut: 26 feet (plus ditches). Minimum spacing of adjacent parallel tracks: 13 feet (spacing increased on curves).

d. Ties.—Ties are 8 to 9 feet long, by 6 to 7 inches thick, by 8 to 10 inches wide. The normal spacing is 20 inches, center to center.

e. Clearance.—The clearance shown in figure 67 should be departed from only under exceptional circumstances.

f. Rails.—For military use, 85-pound rails are satisfactory. Rail lengths vary between 30 and 39 feet (normal, 33 feet).

g. Curves.—Formula for simple railway curve:

$$\text{Radius}=\frac{\frac{1}{2}\text{ unit chord}}{\sin\frac{1}{2}\text{ (degree of curve)}}\text{ or}$$

$$R=\frac{\frac{1}{2}C}{\sin\frac{1}{2}D}$$

For unit chord of 100 feet, $R=5730/D$, with R in feet, D in degrees. (See TM 5-235 and TM 5-236 for more complete data on surveys and location.)

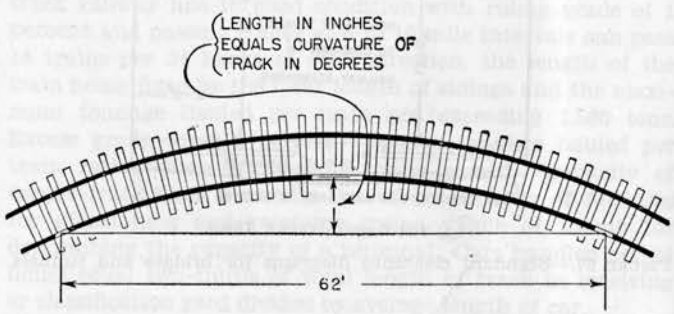


FIGURE 68.—Method of determining approximate degree of curvature.

h. Ballast.—Ballast is used only when absolutely required for support or drainage.

TABLE XLV.—*Quantity of ballast per mile of standard gage one-track railway*

Inches of ballast under tie	Cubic yards of ballast per mile
4	1,529
5	1,779
6	2,032
7	2,295
8	2,577
9	2,863
10	3,137

NOTE.—Ties 6 by 8 inches by 8 feet, spaced 20 inches center to center; ballast dressed even with the tops of the ties and sloping from the ends of ties 1 on 4.

i. Characteristics of rolling stock.

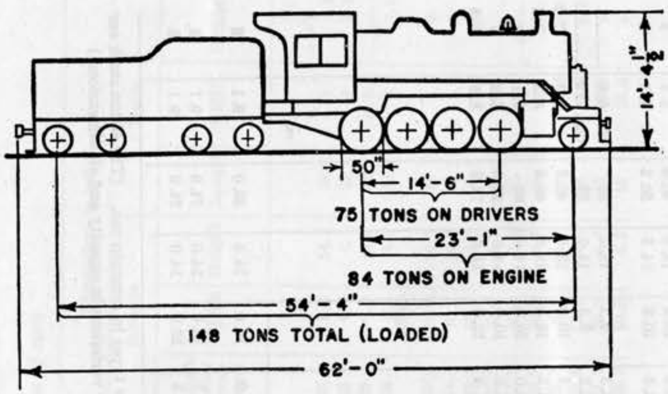
TABLE XLVI.—*Dimensions and capacities of cars*

Type of car	Capacity: Tons	Capacity: Men (8 square feet per man and equipment)	Capacity: Animals (light draft at 22 inches)	Capacity: Cubic feet	Weight empty in tons	Height from rails to top of floor	Outside: Length (center of couplings)	Outside: Width	Outside: Height	Inside: Length	Inside: Width	Inside: Height
Military:												
Box	20	24	13	-------	12	3.8	28	9.6	14.1	24.2	8	8.8
Flat and gondola	20	-------	-------	-------	10	3.8	28	9.0	7.1	24.4	8	3.3
Tank, 5-000-gallon	-------	-------	-------	-------	14	3.8	28	9.0	13.0	22.1	dia. 6.4	-------
Caboose	-------	-------	-------	-------	13	3.8	28	9.5	14.3	20.6	8	7.0
Typical commercial: [1]												
Box	30	38	20	2,750	18	3.5	39.8	10.3	14.5	36	8.5	9
	40	43	22	3,100	20	3.6	44.3	10.3	14.5	40.5	8.5	9
	50	43	22	3,100	24	3.7	44.3	10.3	14.5	40.5	8.5	9
Flat	40	-------	-------	-------	18	3.7	42.0	10.0	7.3	40.0	9	-------
	50	-------	-------	-------	20	3.7	47.0	10.0	7.3	45	9	-------
	70	-------	-------	-------	25	3.7	52.0	10.0	6.7	50	9	-------
Stock	30	-------	20	2,625	20	3.7	39.5	9.5	14.0	36	8.5	8.5
	40	-------	20	2,625	22	3.7	39.5	9.5	14.0	36	8.5	8.5
Gondola	50	-------	-------	1,570	22	3.7	44.5	10.0	8.0	40	9.9	4
	70	-------	-------	1,920	25	3.7	52.5	10.3	7.3	48	10.0	4
Automobile	40	45	22	3,100	20	3.6	44.3	10.3	14.5	40.5	8.5	9
	50	53	27	3,850	25	3.6	54.3	10.3	14.5	50.5	8.5	9
Tank:												
8,000-gallon	40	-------	-------	-------	20	3.7	38.3	9.3	13.2	33	dia. 6.6	-------
10,000-gallon	50	-------	-------	-------	24	3.7	38.3	9.3	14.0	33	dia. 7.2	-------
Refrigerator	30	([2])	-------	2,570	28	3.7	41.5	10.0	13.5	40.5	8.2	7.2
	40	([3])	-------	2,570	30	3.7	43.5	10.0	13.5	40.5	8.2	7.5
Baggage	-------	-------	-------	-------	45	3.7	70.0	10.0	14.0	60	9.1	8
Caboose	-------	-------	-------	-------	20	3.7	38.0	10.0	14.0	27.5	8.2	7
Diner	-------	-------	-------	-------	90	3.7	83.0	10.0	14.0	78.5	8.5	8.5
	Passenger capacity											
	2 per double seat		3 per 2 double seats	3 per section								
Coach	70		46	-------	60	3.7	72.0	10.0	14.0	63.0	9.1	8
Sleeper, 12 sections and drawing room	53		40	40	70	3.7	82.5	10.0	14.0	74.0	9.1	8
Sleeper, 16 sections	64		48	48	70	3.7	82.5	10.0	14.0	74.0	9.1	8

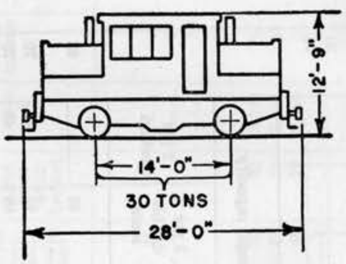
[1] There are no standard dimensions of commercial cars. The figures given are for some types in common use. (The 40-ton stock car comes in 32 lengths varying from 35 feet 7 inches to 41 feet 10 inches. All types have similar variations in capacity and all dimensions.)

[2] Ice capacity, 4 tons.

[3] Ice capacity, 5 tons.



CONSOLIDATION 2-8-0 STEAM LOCOMOTIVE



GASOLINE-MECHANICAL LOCOMOTIVE

FIGURE 69.—Standard locomotives.

TABLE XLVII.—*Characteristics of standard locomotives*

	75-ton steam	30-ton gasoline-mechanical
Normal load	1,000-ton train	500-ton train.
Normal pay load	500 tons	250 tons.
Length of siding	1,400 feet	700 feet.
Fuel consumption per hour	4,400 pounds coal	35 gallons.
Fuel capacity	10 tons coal	150 gallons.
Water consumption per hour	3,400 gallons	
Tender capacity, water	7,000 gallons	

j. Man-hour data.

TABLE XLVIII.—*Rates of miscellaneous tasks in railway construction.*

Task	Man-hours required [1] for— Each 100 linear yards	Each job
Laying ties	16	
Laying, bolting, and spiking track	32	
Lining track	16	
Placing ballast	256	
Inserting frog		[2] 3
Constructing turn-out:		
In old line		[2] 192
In new line		[2] 96

[1] Material on job. Special equipment available. Grading previously completed.
[2] Assumes use of 12 experienced men.

SECTION IV

CONSTRUCTION IN WAR

■ 57. RECONNAISSANCE DATA.—*a. Requirements for all types of construction sites.*—(1) Sufficient size for present needs and future possible expansion, with adequate room for dispersion.

(2) Adequate water supply.

(3) On or near railroad of sufficient capacity for supply and personnel movement.

(4) Available for lease (if not already owned or leased by the Government) for period up to 5 years.

(5) Largely free from floods.

(6) Adequate drainage with porous soils.

(7) Roads good or potentially good.

(8) Climate favorable for training contemplated.

(9) No insect pests.

(10) Location strategically convenient.

(11) Material and labor locally available at reasonable prices.

b. Additional requirements for semipermanent camp sites.—(1) Accessible to adequate training area.

(2) Accessible to suitable target range area.

(3) Recreational facilities nearby.

(4) Grazing facilities for animals (applies also to remount depot sites).

TABLE XLIX.—*Space requirements for preliminary estimates*

Per—	Space (square yards)	
	Semipermanent camps	Bivouacs
Man	50	50
Animal	50	50
Vehicle	100	100

NOTE.—This includes room for roads, assembly areas, and other space requirements except for training and storage. One acre equals 4,840 square yards. Dispersion and concealment are desirable for bivouacs.

■ 58. SEMIPERMANENT CAMPS.—*a. Requirements.*—(1) Necessary facilities: barracks, messes, latrines, baths, lavatories, administration buildings, hospital, guardhouse, storehouses, post exchange, officers' mess, officers' quarters, recreation building. Tents can be used where erection of buildings is impracticable.

(2) Also necessary for horse units: stables, corrals, watering troughs.

(3) Also necessary for motor units: shops.

(4) Locate kitchens, hospitals, warehouses, stables, motor parks, and offices near roads.

(5) Locate latrines, stables, and incinerators away from kitchens and mess halls to minimize fly and odor nuisance.

(6) Provide compact lay-out but allow for future expansion.

(7) Use standard building, 20 by 100 feet, for all possible construction in semipermanent camps.

b. Type plans and data.

TABLE L.—*Bill of materials, standard building 20 by 100 feet*

BILL NO. 1. For frame

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	140	Piece	2 by 4 inches	8 feet	747	3,111	Lumber.
2	61	do	2 by 4 inches	12 feet	488	2,034	Do.
3	51	do	⅞ by 4 inches	12 feet	204	850	Do.
4	64	do	⅞ by 2 inches	12 feet	128	534	Do.
5	6	do	⅞ by 6 inches	12 feet	36	150	Do.
6	32	Pound	20d	4 inches		32	Nails.
7	11	do	10d	3 inches		11	Do.
8	7	do	6d	2 inches		7	Do.

BILL NO. 2. For wood and felt covered building (add to bill No. 1)

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	4	Piece	⅞ by 4 inches	12 feet	16	67	Lumber.
2	1,016	do	⅞ by 6 inches	8 feet	4,064	16,933	Do.
3	26	Roll	32 inches	40 feet 6 inches		1,040	2-ply prepared roofing, including nails, metal caps, and cement.
4	5	do	32 inches	162 feet		325	1-ply prepared roofing, including nails, metal caps, and cement.
5	300	Piece	¼ by 1½ inches	4 feet		150	Laths.
6	65	Pound	8d	2½ inches		65	Nails.
7	3	do	3d	1⅛ inches		3	Do.

TABLE L.—*Bill of materials, standard building 20 by 100 feet*—Con.

BILL No. 3. For corrugated steel covered building (add to bill No. 1)

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	100	Piece	2 by 4 inches	8 feet	534	2,225	Lumber.
2	26	Pound	20d	4 inches		26	Nails.
3	289	Piece	27½ inches	8 feet		3,613	2½-inch corrugated steel sheets, black, 28 gage.
4	22	Pound	7/16 inch	1½ inches		22	Nails, barbed, roofing, 10 gage.
5	11	do	3/16 inch	⅜ inch		11	Rivets.
6	11	Roll	36 inches	166 feet 8 inches		330	Building, paper.
7	18	Pound	No. 16			18	Wire, galvanized.
8	2	do	No. 14	¾ inch		2	Staples, poultry netting.
9	400	Piece	¼ by 1½ inches	4 feet		200	Laths.
10	2	Pound	3d	1⅛ inches		2	Nails 15 gage.

NOTE.—Materials included in items Nos. 6, 7, 8, 9, and 10 will be used if insulation is required.

BILL No. 4. For 24 sash

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	48	Piece	⅞ by 3 inches	12 feet	144	600	Lumber.
2	1	Roll	36 inches	100 feet		50	Transparent plastic sheet.
3	3	Pound	4d	1½ inches		3¾	Nails.

BILL No. 5. For 2 pairs of doors, type 1

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	4	Piece	⅞ by 8 inches	8 feet	22	92	Lumber.
2	23	Piece	⅞ by 6 inches	8 feet	92	383	Do.
3	2	Piece	⅞ by 3 inches	8 feet	4	17	Do.
4	1	Piece	¾ inch	3 feet		½	Wood dowel.
5	8	Each		10 inches		20	T-hinges and necessary screws.
6	1½	Pound	6-d	2 inches		1½	Nails.
7	½	Pound	4-d	1½ inches		½	Do.
8	1	Piece	⅜ inch	12 feet		1	Rope, manila.
9	2	Each	½ inch	¾ inch		1	Screw eyes, wire, #106 Sargent or equal.
10	4	Each		3 inches		1	Screw hooks and eyes.

BILL No. 6. For 50 two-man bunks

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	100	Piece	2 by 4 inches	12 feet	800	3,334	Lumber.
2	300	Piece	⅞ by 6 inches	14 feet	2,100	8,750	Do.
3	136	Piece	⅞ by 6 inches	8 feet	542	2,266	Do.
4	26	Piece	2 by 2 inches	8 feet	70	292	Do.
5	100	Piece	⅞ by 3 inches	14 feet	350	1,458	Do.
6	84	Piece	⅞ by 3 inches	8 feet	168	700	Do.
7	28	Pound	8-d	2½ inches		28	Nails.
8	20	Pound	6-d	2 inches		20	Do.
9	4	Pound	3-d	1¼ inches		4	Do.

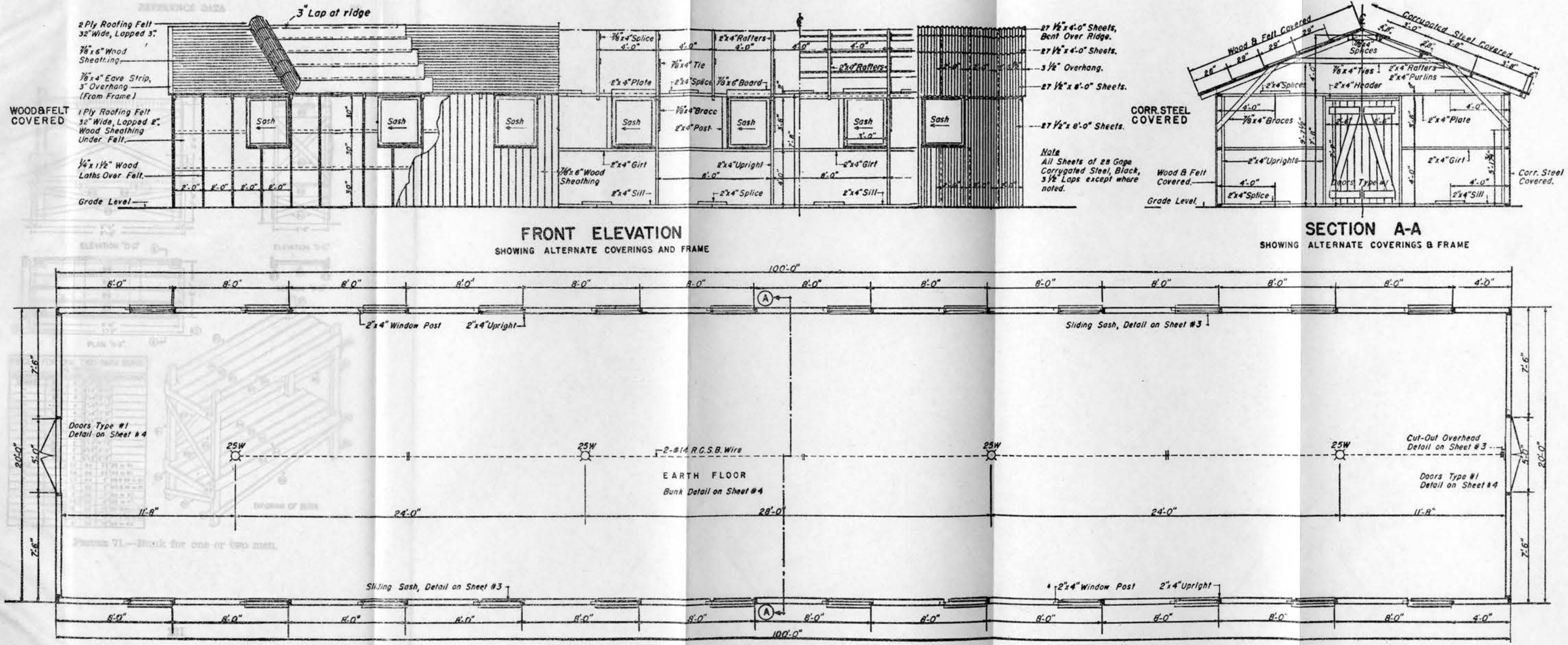
Table L.—*Bill of materials, standard building 20 by 100 feet*—Con.

Bill No. 7. Electrical

Item	Quantity	Unit	Size	Length	Feet, board measure	Weight (pounds)	Description
1	210	Feet	Number 14			5¼	Wire, R. C. S. B., solid copper.
2	1	Each	30 amperes, 125 volts.			1	Cut-out, main line, plug fuse, double pole.
3	2	do	15 amperes				Fuses, plug.
4	4	do				1¼	Socket, pull, brass, S22 (P. and S. cat. 38, base B. P.).
5	50	do	Number 12			7½	Knobs, split porcelain, with nail and leather washer.
6	2	do	⅝ by 3 inches				Tubes, porcelain.
7	4	do	25 watts				Lamps, Mazda, 115-volt.
8	10	do	1¼ inches				Screws, for cut-out and socket, No. 8, F. H. bright.
9	4	do		3 feet			Cord, linen, with chain and link tassel.

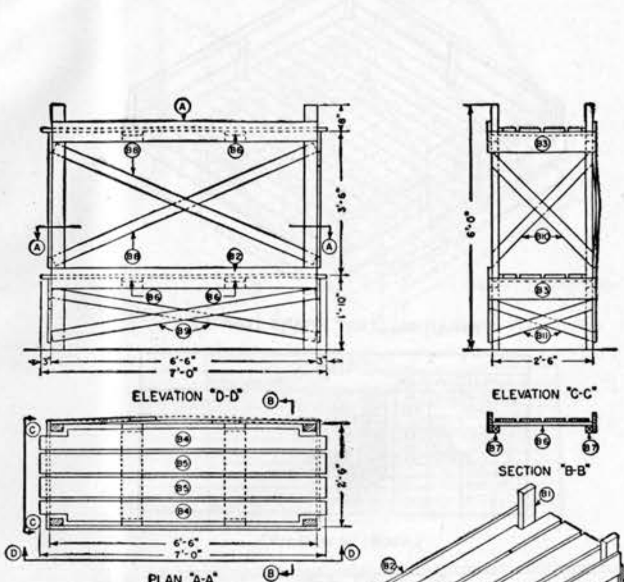
Number of pieces of wood sheathing must be adjusted when specified width is not available.

Allowance included for cutting waste only. To cover other losses add: For lumber, 3 percent (minimum, 1 piece each size); for nails, rivets, and screws, 10 percent.



U. S. GOVERNMENT PRINTING OFFICE : 1941—O-282736

FIGURE 70.—Standard building 20 by 100 feet.



PIECES FOR ONE TWO-MAN BUNK (25 REQUIRED)					
DESCRIPTION	MARKED	NO PC	SIZE	L'GTH	APPLICATION
LUMBER	B1	4	2"x4"	6'-0"	
"	B2	4	1"x6"	6'-6"	
"	B3	4	1"x6"	2'-7½"	
"	B4	4	1"x6"	7'-0"	
"	B5	4	1"x6"	7'-0"	
"	B6	4	1"x6"	2'-6"	
"	B7	8	2"x2"	6"	
"	B8	2	1"x3"	7'-0"	
"	B9	2	1"x3"	6'-7½"	
"	B10	2	1"x3"	3'-10"	
"	B11	2	1"x3"	2'-8"	
NAILS		32	8d	2½"	B2 to B1
"		24	8d	2½"	B3 to B1
"		24	6d	2"	B8 & B9 to B1
"		16	6d	2"	B10 & B8 to B1
"		8	6d	2"	B6 to B7
"		24	6d	2"	B2 to B7
"		16	3d	1½"	B4 & B5 to B6
"		16	3d	1½"	B4 & B5 to B3
"		2	3d	1½"	B8 to B8

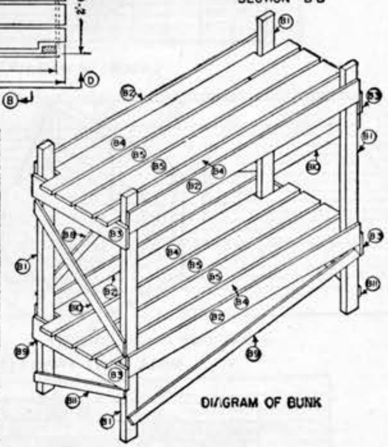
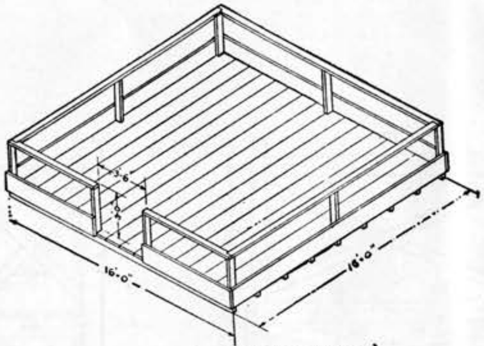


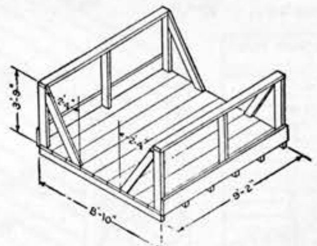
Figure 71.—Bunk for one or two men.



PYRAMIDAL TENT FRAME (LARGE)

BILL				
No Pcs	Size	L'gth	Ft BM	Items
9	2"×4"	16'-0"	96	Floor Sleepers.
	6,8 or 10		256	Floor Boards S1S & 2E. 1" Lumber
5 lbs				Nails for Floor.
4	2"×4"	16'-0"	43	Railing
3	2"×4"	10-0"	20	Posts.
4	1"×12	16'-0"	64	Skirt Boards.
3 lbs	20 d	4"		Nails for framing.
1 lb	10 d	3"		" " "

LABOR: 24 MAN HRS.

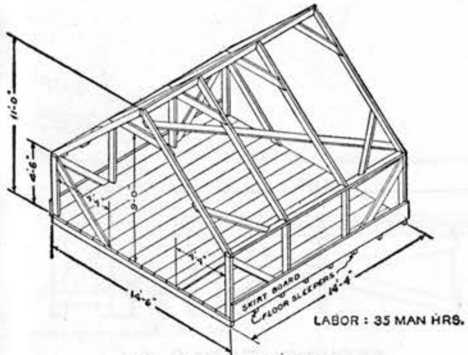


WALL TENT FRAME (SMALL)

BILL				
No Pcs.	Size	L'gth	Ft BM	Items
6	2"×4"	10'-0"	40	Floor Sleepers.
	6,8 or 10		81	Floor Boards S1S & 2E. 1" Lumber.
2 lbs	8 d	2½"		Nails for Floor.
2	2×4"	10-0"	13	Railing.
2	"	12'-0"	16	Posts.
2	"	10-0"	13	Braces
2	"	10'-0"	13	Skirt Boards.
2 lbs	20 d	4"		Nails for Framing.
1 lb.	10 d.	3"		" " "

LABOR: 10 MAN HRS.

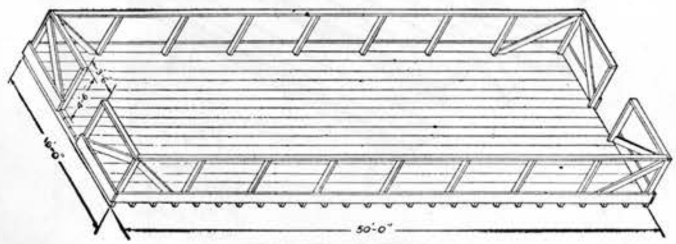
FIGURE 72.—Pyramidal and small wall tent frames.



LABOR : 35 MAN HRS.

WALL TENT FRAME (LARGE)

BILL				
No Pcs	Size	L'gth	Ft BM	Items
8	2"×4"	16'-0"	85	Floor Sleepers
	6,8 or 10		208	Floor Boards, S1S & 2E. 1" Lumber.
4 lbs	8 d	2½"		Nails for Floor
10	2×4"	10-0"	67	Roof Rafters and Ties
3	"	16'-0"	32	Ridge Board and Rafter Plates
2	"	18'-0"	24	Posts
2	1"×6"	16-0"	16	Long Braces on Rafters.
2	1"×6"	12-0"	12	Short Braces " " "
4	2"×4	14-0"	37	Braces at Posts.
2	1"×12	16-0"	32	Skirt Boards
4 lbs	20 d	4"		Nails for Framing
1 lb	10 d	3"		" " "

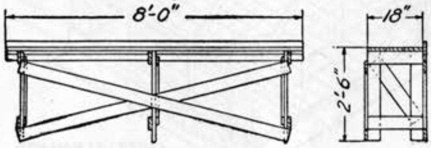


HOSPITAL WARD TENT FRAME

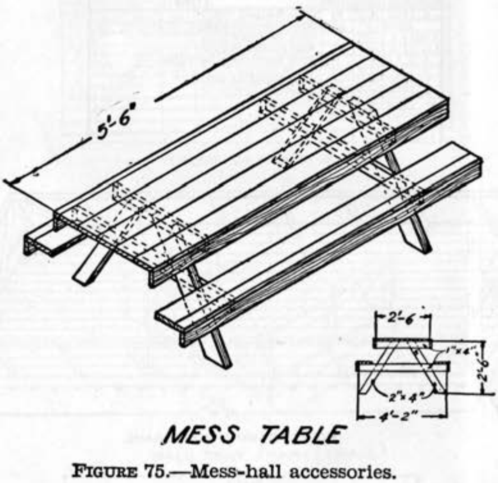
BILL				
No Pcs	Size	L'gth	Ft BM	Items
26	2"×4"	16'-0"	277	Floor Sleepers
	6,8 or 10		800	Floor Boards, S1S & 2E. 1" Lumber.
15 lbs	8 d	2½"		Nails for Floor.
10	2"×4"	14-0"	93	Railing
6	"	18'-0"	72	Posts
4	"	16'-0"	43	Braces
10	1"×12"	14-0"	140	Skirt Boards
5 lbs	20 d			Nails for Framing
4 lbs	10 d			" " "

LABOR: 64 MAN HRS.

FIGURE 73.—Large wall and hospital ward tent frames.

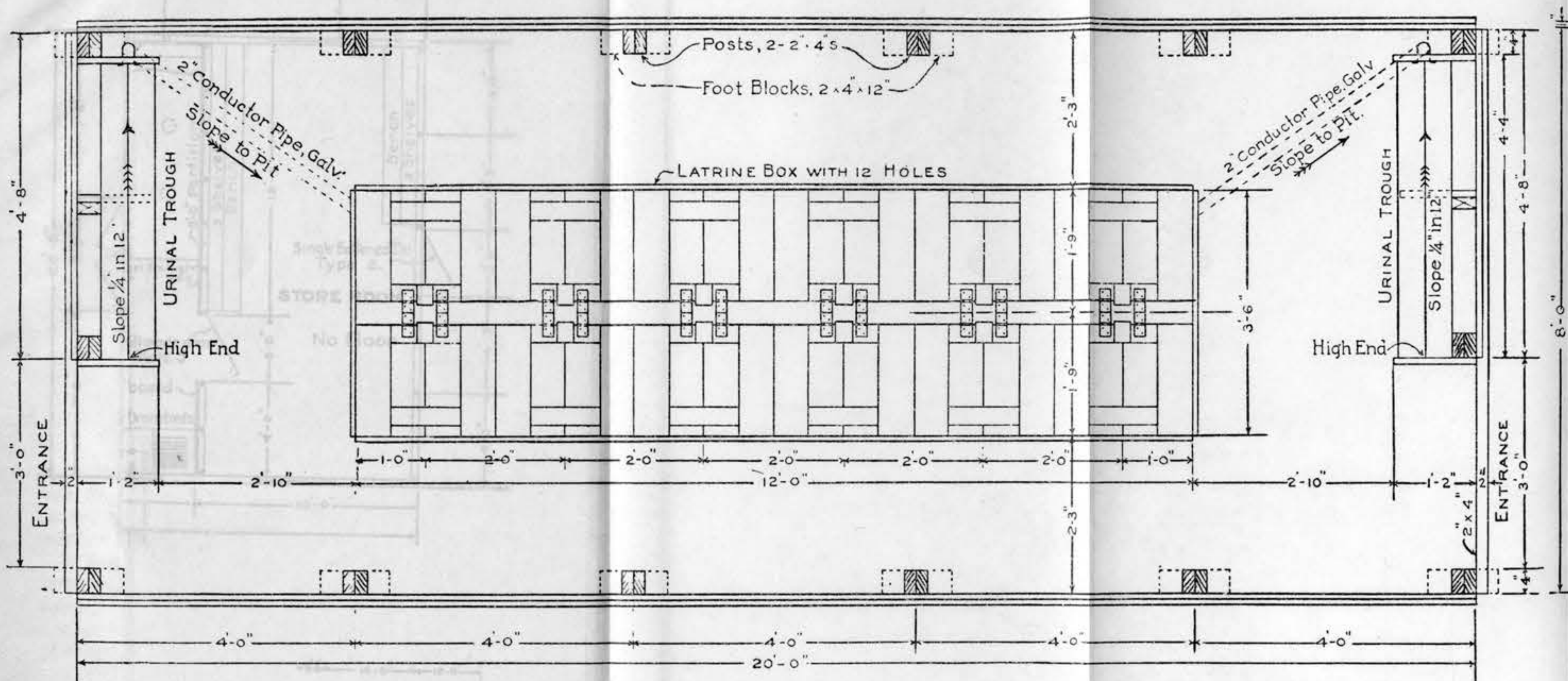


SERVING TABLE

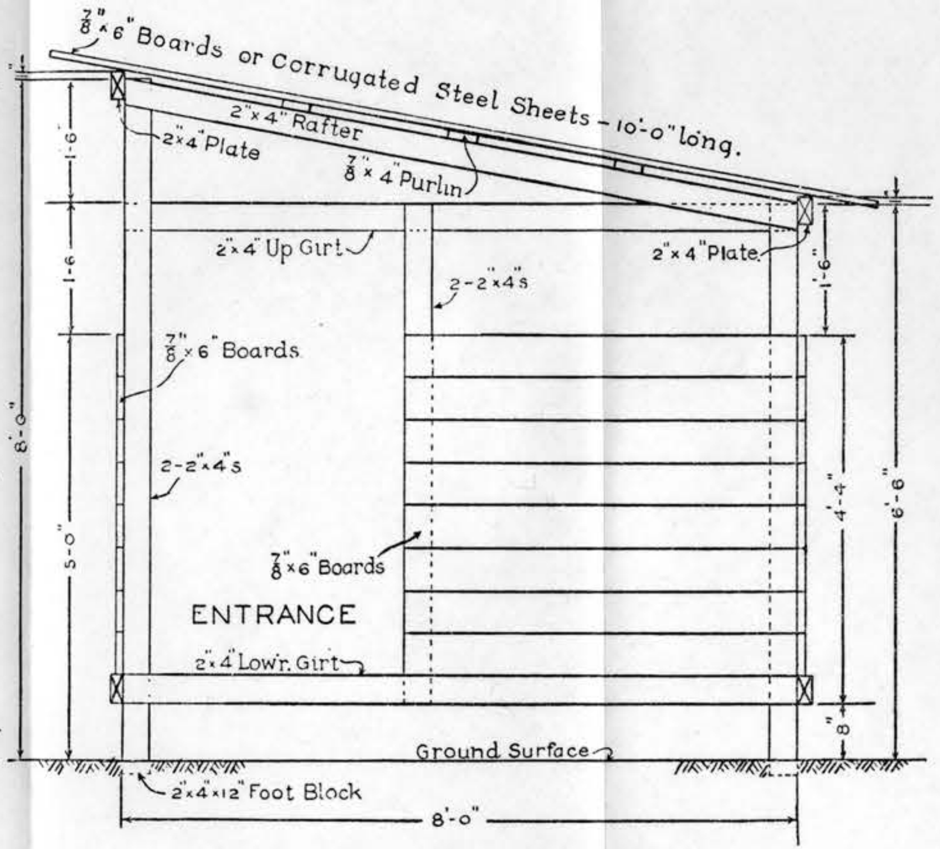


MESS TABLE

FIGURE 75.—Mess-hall accessories.



SECTIONAL PLAN



END ELEVATION

Entrances to be screened with burlap or brush screens, when necessary.

NOTE - Omit "Prepared Roofing" if Cover Strips are used

BILL FOR LATRINE SHELTER-WOOD ROOF				
No Pcs	Size	Length	Ft BM	Items
34	2"x4"	8'-0"	181	Studs U.&L. End Girts & Foot Blocks
6	2"x4"	10'-0"	40	Roof Rafters
8	2"x4"	12'-0"	64	Plates & Lower Girts on Sides
20	7/8"x6"	16'-0"	160	Sheathing on Sides
49	7/8"x6"	10'-0"	245	Sheathing on Roof & Ends
6	7/8"x4"	12'-0"	24	Purlins
40	7/8"x3"	10'-0"	100	Strips for covering Roof joints if used.
3 Rolls	32" W.			2 Ply "Prepared Roofing, Nails, Caps, Cem.
6 lbs	20 d.	4"		Nails for Framing.
8 lbs	10 d.	3"		Nails for Framing.
12 lbs	8 d.	2½"		Nails for Sheathing

LABOR on Shelter (wood roof) incl. 2 Urinal Troughs = 24 MAN HRS.

BILL FOR 12 HOLE LATRINE BOX				
No Pcs	Size	Length	Ft BM	Items.
4	2"x4"	12'-0"	32	Frame
6	7/8"x8"	8'-0"	32	Cover, Top only
4	7/8"x6"	12'-0"	24	Lids and Two End Boards.
10	7/8"x4"	10'-0"	33	End Boards, Sides & Fillers.
3	7/8"x3"	8'-0"	6	Lid Battens and Stop Blocks.
1 lb.	20 d.	4"		Nails for Framing.
½ lb	10 d.	3"		Nails for Framing.
5 lbs.	8 d.	2½		Nails for Sheathing.
1 Roll	32" W.			Tar Paper for Fly-proofing, Nails, Caps, etc.
24	2" W	3 11/16"		Hinges, Fast Joint & necessary screws.

LABOR = 22 MAN HOURS

BILL FOR TWO URINAL TROUGHS				
No Pcs	Size	Length	Ft BM	Items.
1	2"x4"	6'-0"	4	Bracket Support
1	7/8"x8"	6'-0"	4	End Boards
3	7/8"x6"	10'-0"	15	Trough and Splash Boards
1	7/8"x4"	6'-0	2	Bracket
1 Roll	32" W.	40½'		Tar Paper, Heavy, incl Nails, Cement & Caps
½ lb.	10 d.	3"		Nails
1 lb.	8 d.	2½"		Nails
2	2"			Elbows for Conductor Pipe, Galv.
2	2"	2'-6"		Conductor Pipe, Galv.
2	2"	4'-0"		Conductor Pipe, Galv.

LABOR = 3 MAN HOURS

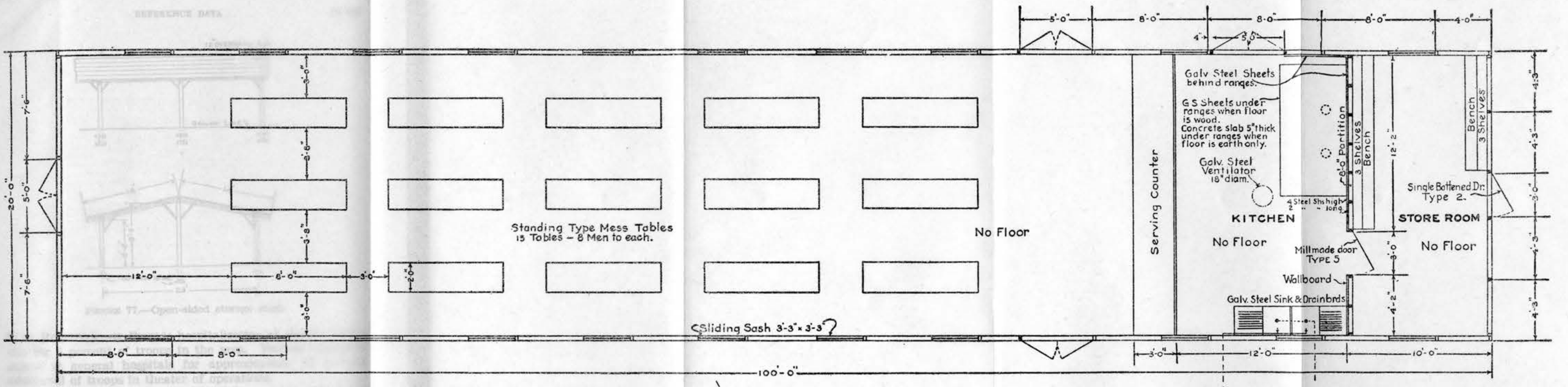
FIGURE 76.—Latrine.

BILL FOR METAL ROOF ON SHELTER IF USED				
No Pcs	Size	Length	Ft BM	Items.
	27½" W	10'-0"		Corrugated Steel Sheets, No 28 Ga.
	# 10	1½"		Nails Barbed Roofing.
½ lb.	5/32 hole			Lead Washers.

BILL FOR TEMPORARY LATRINE SHELTER				
No Pcs	Size	Length	Ft BM	Items
14	2"x4"	10'-0"	93	Studs
1	4'-0"	21'-0"		Canvas for Screening: or Burlap
1	4'-0"	30'-0"		" "

LABOR = 5 MAN HOURS

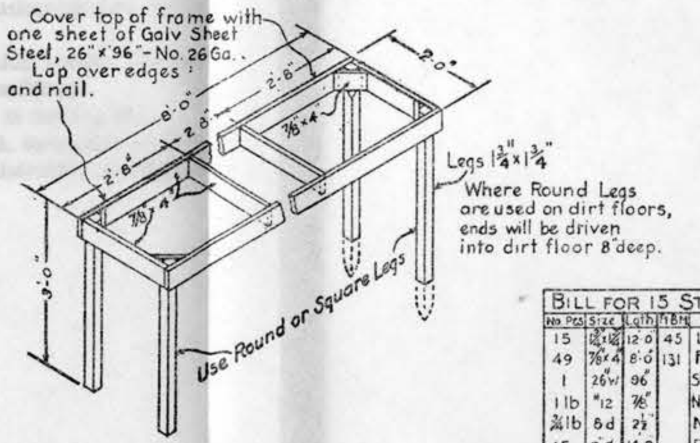
U. S. GOVERNMENT PRINTING OFFICE : 1941—O-282736



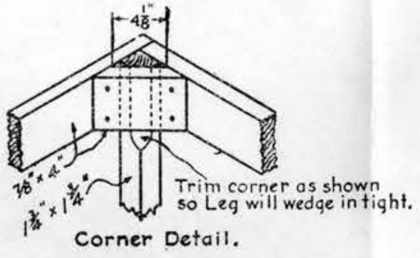
PLAN

KITCHEN AND MESS HALL

~ Capacity 120 men. ~

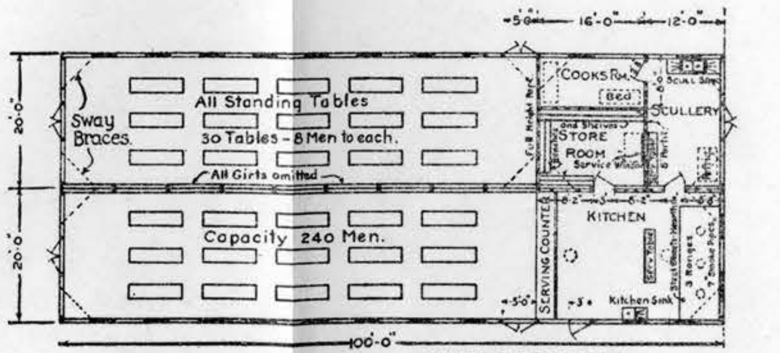


BILL FOR 15 STANDING TABLES				
No. Pcs	Size	Lgth	FBM	Items
15	1¾ x 1¾	12'-0"	45	Legs.
49	⅞ x 4	8'-0"	131	Frame & Corner Braces
1	26" w	96"		Sheet Steel, Galv. (for Top)
1 lb	#12	⅞"		Nails, Roofing, Barbed.
¾ lb	8d	2½"		Nails for Framing.
15	2" ø	14'-0"		Round Legs if used.



STANDING TABLE

Labor: 1½ Man Hrs.



PLAN OF MESS HALL
CAPACITY 240 MEN
(2–20' x 100' Buildings joined together)

FIGURE 74.—Standard building adapted for kitchen and mess.

U. S. GOVERNMENT PRINTING OFFICE : 1941—O-282736

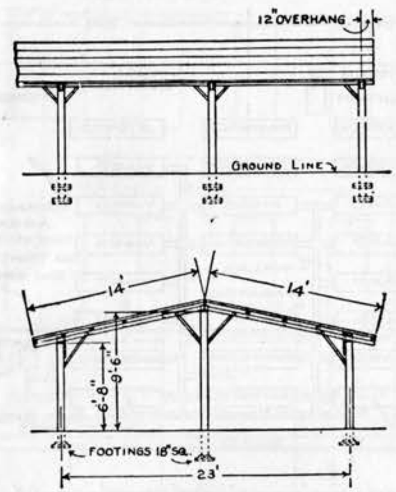


FIGURE 77.—Open-sided storage shed.

■ 59. HOSPITALS.—*a*. Provide hospitalization at station hospitals for 5 percent of troops in the area. Provide hospitalization at general hospitals for approximately 10 percent additional of troops in theater of operations.

b. Place latrines, feces destructor, and morgue well away from other buildings, where odor and fly nuisances are minimized.

c. Provide road access to wards, operation rooms, clinics, storehouses, kitchens, and administration buildings.

d. Use tents where building construction is not feasible.

e. In estimates, allow for floors in wards, operating rooms, clinics, kitchens, dining rooms, and administration buildings.

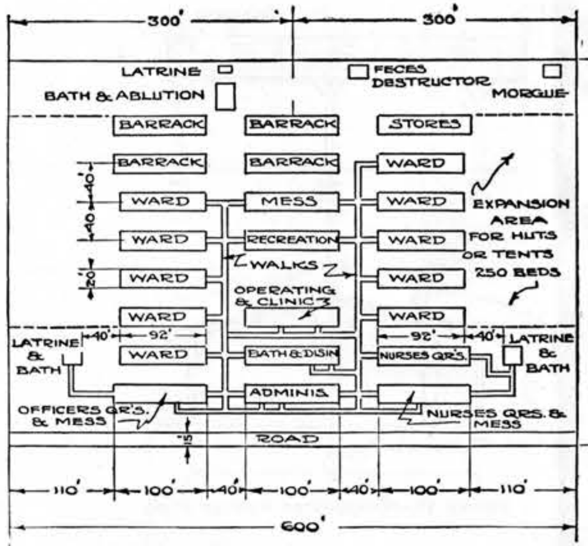


FIGURE 78.—Typical lay-out for 250-bed station hospital.

■ 60. DEPOT LAY-OUT.—*a.* Lay out warehouse area in sections with ladder track on each side connected by house tracks about 1,700 feet long.

b. Space house tracks 150 feet apart.

c. Place warehouses on one side of each house track. Provide open storage on opposite side.

d. Provide fire breaks 50 feet wide between open and covered storage areas.

e. Store as many articles as possible in the open.

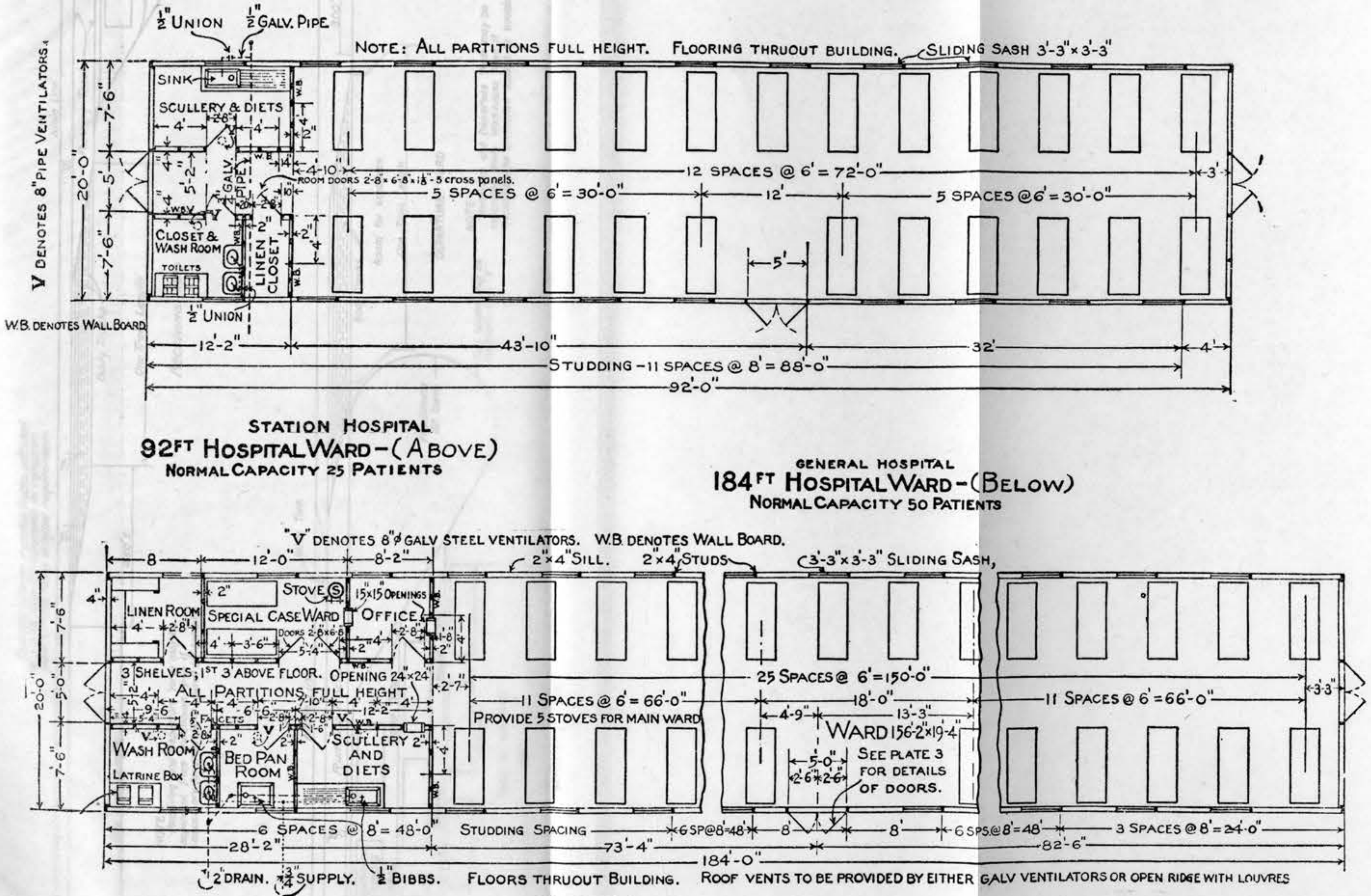


FIGURE 79.—Hospital wards.

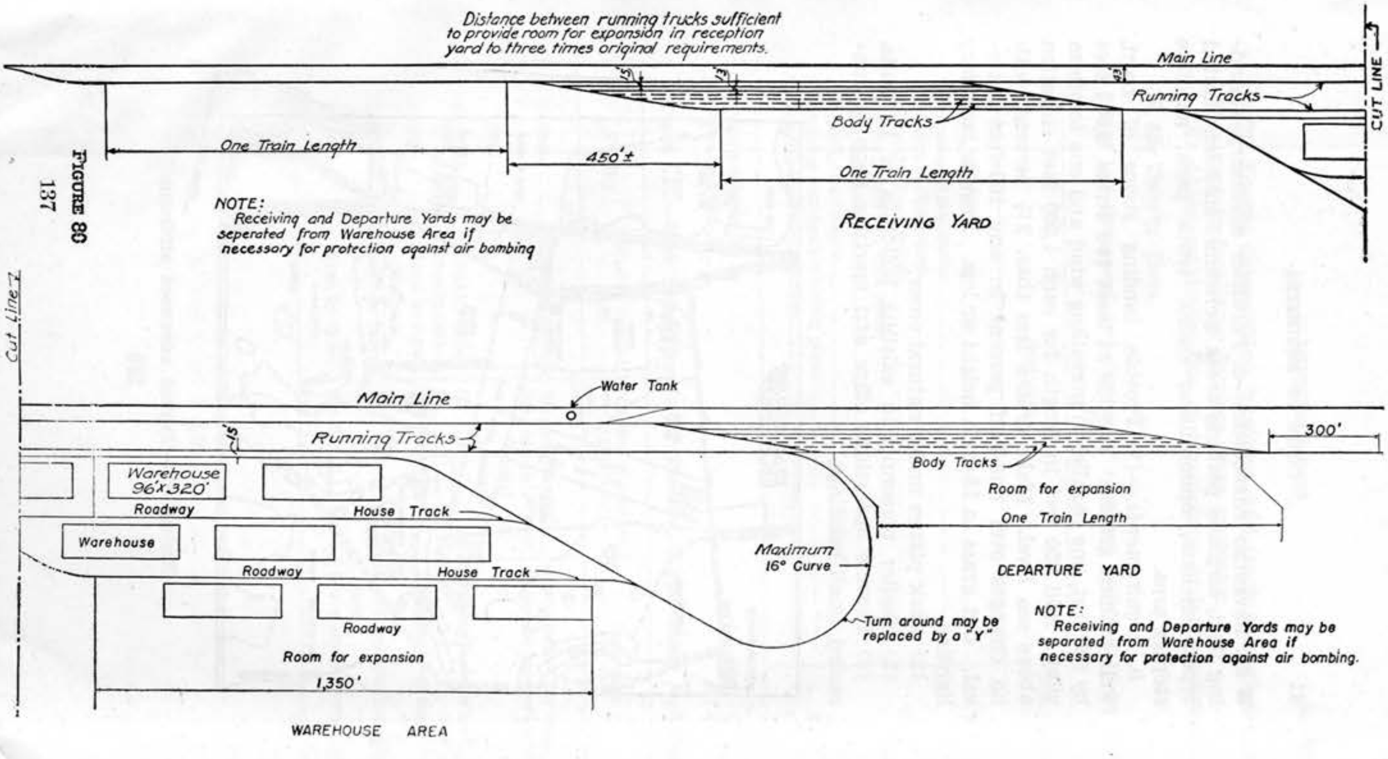

Distance between running trucks sufficient to provide room for expansion in reception yard to three times original requirements.
Main Line
CUT LINE
Running Tracks
Body Tracks
One Train Length
450'±
One Train Length
NOTE:
Receiving and Departure Yards may be seperated from Warehouse Area if necessary for protection against air bombing
RECEIVING YARD
Cut Line
Main Line
Water Tank
Running Tracks
300'
Body Tracks
Warehouse 96'x320'
Roadway
House Track
Warehouse
Room for expansion
One Train Length
Maximum 16° Curve
Roadway
House Track
DEPARTURE YARD
Turn around may be replaced by a "Y"
NOTE:
Receiving and Departure Yards may be separated from Warehouse Area if necessary for protection against air bombing.
Roadway
Room for expansion
1,350'
WAREHOUSE AREA

FIGURE 80

■ 61. ADVANCED AIRDROMES.—*a. Facilities necessary.*—Landing field, airplane parking areas, personnel shelters, limited repair shelters, ammunition dump, truck park, gasoline storage area.

b. Requirements.—(1) Provide landing strips of hard, well-drained ground. Provide at least two strips, 3,000 feet by 500 feet, one parallel to prevailing wind and one to storm wind. Add 250 feet in length for each 1,000 feet elevation above sea level. Make grades less than 2½ percent, with no changes over one-half percent in any 100-foot interval. Cut grass to 15-inch height or less. Provide boundary lighting.

(2) Park planes under natural cover.

(3) Shelter personnel in existing buildings or in tents.

(4) Provide operations office and machine shop in concealed small buildings.

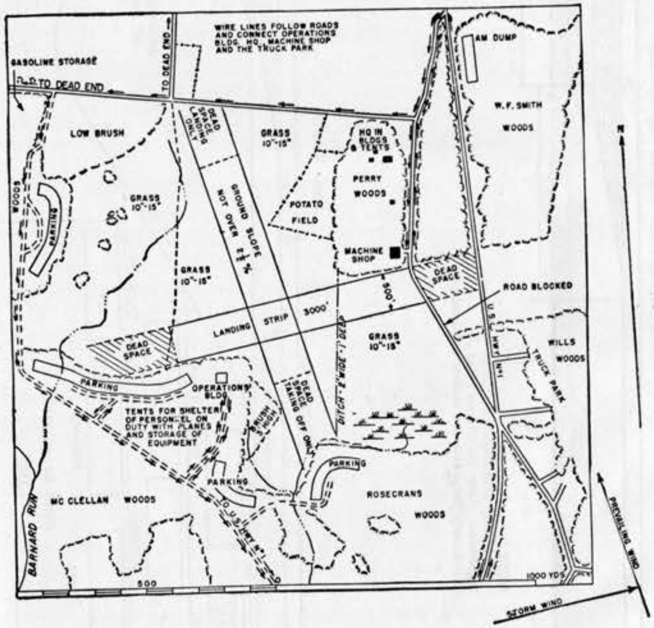


FIGURE 81.—Typical advanced airdrome.

(5) Locate ammunition, gasoline, and truck storage areas with view to localizing damage from explosion.

(6) Make maximum use of camouflage and concealment.

■ 62. USEFUL DATA.

TABLE LI.—*Personnel for erection of standard building 20 by 100 feet*

Operation	Number of men
Piers and sills	24
Assembly of side frames	36
Erection of side frames	(1)
Assembly of end frames	(2)
Placing rafters and knee braces	36
Applying sheathing	36
Applying roof boards	36
Applying composition roofing paper	36
Hanging doors and windows	24

[1] All available.
[2] 9 at each end.

TABLE LII.—*Unit requirements for theater of operations facilities*

Facility	Size of typical unit	Number of men per typical unit	Basic ratio
Barrack	20 feet by 100 feet	50 (single bunks)	40 square feet per man.
		100 (double tier bunks) (in emergency).	20 square feet per man.
Hospital	20 feet by 92 feet	25	90 square feet per man.
(all facilities)	20 feet by 184 feet	50	
Latrine	20 feet by 8 feet (12 seats).	240–480	1 seat per 20–40 men.
Bathhouse	20 feet by 24 feet	240	1 bathhouse per battalion area.
Lavatory	20 feet by 12 feet	100–200	1 lavatory per company.

TABLE LIII.—*Approximate man-hours for construction under average conditions*

Type of construction	Man-hours
Standard barracks (no floor), 20 by 100 feet	270
Type A floor	360
Type B floor	590
92-foot hospital ward:	
Type A floor	335
Type B floor	550
184-foot hospital ward:	
Type A floor	670
Type B floor	1,090
Mess hall, 20 by 100 feet (no floor)	330
Latrine, 12-seat	50
Bathhouse:	
Concrete floor	225
Wood and corrugated iron floors	200
Open-sided storage shed (216 feet long)	300
50 bunks (2-man)	200
Camp, 1,000-man unit, buildings only (all floors type A)	13,500
Station hospital, buildings only (250-bed) (all floors type A)	10,000
General hospital, buildings only (all floors type A)	28,750
Camp, triangular infantry division	165,000

SECTION V

WATER SUPPLY

■ 63. GENERAL.—*a. Methods of supply.*—In the theater of operations water is procured locally by using organizations wherever practicable. However, when local supplies are limited or unsatisfactory, engineer personnel install and operate the necessary water supply facilities.

b. Responsibility.—Under the latter conditions engineers are responsible for the quality and quantity of water supplied and for delivery to the point where it is distributed to using organizations. Medical personnel assist as may be necessary for laboratory examinations and sanitary inspections. Handling of water in organization water containers and sterilizing bags, and in the canteen of the individual soldier, is the responsibility of organization commanders, acting with the advice and assistance of attached medical personnel.

c. General water supply duties of engineers.

(1) Reconnaissance and collection of data.

(2) Development of sources.

(3) Purification.

(4) Construction and operation of establishments.

(5) Transportation to distributing points.

d. Water supply activities of unit engineers.—In addition to the general engineer water supply duties, unit engineers are responsible for the following specific activities within their areas:

(1) Recommendations as to methods of supply, quantity of water to be supplied, and conservation of water.

(2) Collection and transmission to higher echelons of data pertaining to water.

(3) Enforcement of water discipline at water supply points.

(4) Regulation of traffic at water supply points.

(5) Posting of signs to indicate safe and unsafe water.

(6) Preparation of maps and sketches to show locations of water supply points.

(7) Maintenance of records of water supply establishments in the area.

(8) Arrangements with higher engineer echelons for the delivery of water by truck, railway, or pipe line when local supplies are inadequate.

e. Basic considerations.—(1) Camouflage, defense against air and chemical attack, and wide dispersion of water supply points are provided insofar as possible.

(2) Water supply work in forward areas is taken over by engineers of rear echelons whenever time and existing conditions permit.

(3) General engineer troops normally execute all engineer water supply tasks, except those involving the transportation of water by truck or railway and the operation of purification trucks.

■ 64. WATER SUPPLY POINTS.—*a. Factors to be considered in selecting water distributing points.*—(1) Proximity to kitchens and troops to be supplied.

(2) Accessibility to water source.

(3) Safety from enemy light artillery.

282736°—41——10

(4) Concealment from enemy air and ground observation.
(5) Parking space for waiting vehicles.
(6) Situation with regard to general scheme for traffic control.
(7) Existence of a natural elevation suitable for installation of storage tanks.
(8) Hardness of ground and natural drainage.
(9) Type of containers to be filled.

b. Lay-out of water distributing points.

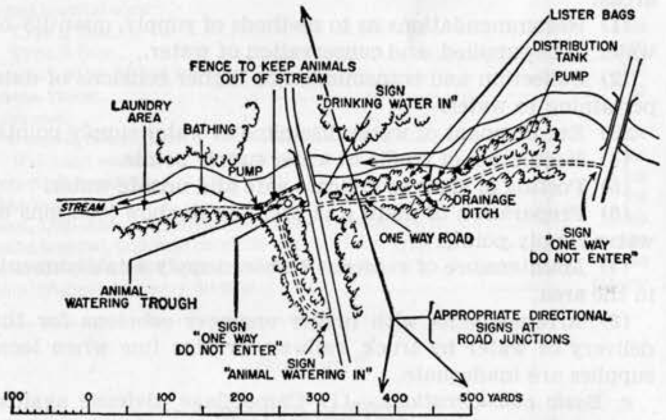


FIGURE 82.—Typical water distributing point.

TABLE LIV.—*Man-hours for installing a water distributing point*

Task	Man-hours required	Size of party (squads)	Remarks
Erect timber trestle platform for 3,000-gallon canvas tank.	16	1 or 2	Materials at the site using power tools.
Erect 3,000-gallon tank	2	1	After platform is constructed.
Set up pump and hose	1	½	
Install 260-gallon animal watering tank and hand pump.	1	½	

c. Organization of water distributing points.

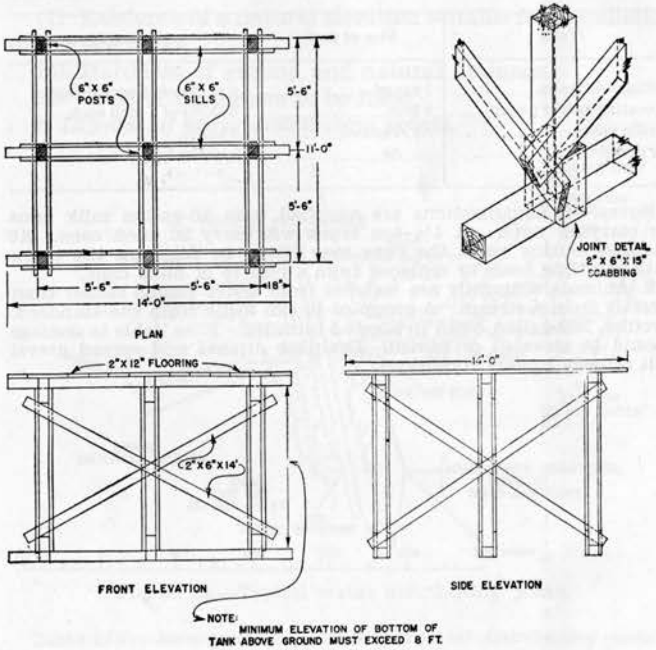
TABLE LV.—*Type organization for operating a water distributing point*

Task	Size of party	Remarks
Filling milk cans	1 squad	2 shifts of ½ squad each.
Operating power pump	2 men	2 shifts of 1 man each.
Traffic police	As required	3 shifts.
Air guards	do	Do.

NOTES.—1. Organizations are supplied with 10-gallon milk cans for carrying water. A 1½-ton truck will carry 30 such cans. At the distributing point the cans may either be filled on the truck with multiple hoses or replaced from a reserve of filled cans.

2. Animals ordinarily are watered from water basins rather than directly from a stream. A group of 10 can drink from the standard, circular, 260-gallon basin in about 5 minutes. Hose liable to damage should be elevated or buried. Drainage ditches and spread gravel will remedy muddy conditions.

■ 65. Water Tank Platform.



BILL OF MATERIAL

NO. PIECES	SIZE	LENGTH	ITEM
6	6" X 6"	14'	CAPS AND SILLS
9	6" X 6"	8'	POSTS
12	2" X 6"	14'	BRACES
14	2" X 12"	14'	FLOORING
36	2" X 6"	15"	SCABS
45 LBS.	40 D		NAILS

FIGURE 83.—Timber trestle platform for the 3,000-gallon canvas storage tank.

■ 66. Standard Pumps.

TABLE LVI.—*Standard pump characteristics*

Type	Capacity (gallons per minute)	Size of connections (inches)	Horse-power of motor	Speed of pump (revolutions per minute)
Standard portable, centrifugal [1]	[3] 55	[5] 1½	2½	2,000
Purification truck [2]	[4] 100	([6])	14	2,000

[1] The pump issued with the portable purification unit is interchangeable with the standard, portable, centrifugal pump; these data are applicable also to the portable purification unit when it is operated as a simple pump.
[2] When operated as a simple pump.
[3] Against a total head of 50 feet (including 15-foot suction lift).
[4] Against a total head of 90 feet (including a 20-foot suction lift).
[5] If bushing is removed this pump may be used with 2-inch connections.
[6] Purification truck has a 3-inch pump. Actual intake connection, however, is reduced by bushing to 2½ inches; discharge connection is reduced to 2 inches.

■ 67. Water Reconnaissance Report.

Organization____________________________________
Place____
Date____

1. Location of water source: Map_____________; map coordinates ___________; local name________________.
2. Date and hour inspected___________________________
3. Well, spring, stream, lake, pond (line out terms not applicable).
4. Rate of flow_________________ gallons per day.
5. Character of water: Clarity_____________; taste___________; odor__________.
6. Temperature of water_________°F.
7. Result of tests (if tests impossible at time of inspection, take sample of water as prescribed on back of sheet) (latest report of local Board of Health, if available).
____
____
8. Location of possible sources of pollution__________________
____
9. Possibility of chemical contamination (chemical warfare agents, poisoning, etc.)_____________________________________
____
10. Accessibility to railroad, highway, or trail_________________
____
11. Well.

a. Type (dug, driven, drilled, or bored) (for characteristics see table LIX, FM 5-35).
b. Diameter: top____________feet; bottom____________feet.
c. Depth of well____________feet.

d. Depth of water__________feet.
e. Distance from surface of ground to water surface__________ feet.
f. Type, condition, and depth of casing or lining______________
____
g. Present method of recovering water______________________
h. Protection provided against entrance of surface water (coping, watertight basin, ditching, etc.)______________________________
____
12. Spring.
a. Protection provided against entrance of surface water (coping, watertight basin, ditching, etc.)______________________________
____
b. Present method of delivering water______________________
13. Stream or pond.
a. Sketch of cross section (show width, maximum depth, and height of banks above water surface) (reference to photograph, if one is made).
b. Surface velocity__________feet per second.
c. Nature of bed_______________________________________
d. Nature of banks_____________________________________
14. Existing installations.
a. Purification facilities (sedimentation tanks, chlorinating apparatus, filter, etc.)____
b. Pumps.

Type	Size (horse-power)	Speed (revolutions per minute)	Intake connection (size and type)	Discharge connection (size and type)	Capacity (gallons per day)

c. Engines.

Type	Size (horse-power)	Speed (revolutions per minute)

d. Electrical equipment ___________________________________
____
e. Storage facilities.

Type	Elevation (feet)	Capacity (gallons)

f. Pipe-line lay-out (draw sketch showing arrangement, kind, lengths, and sizes of pipe, elevations, and heads of water).
g. Condition of existing installations_________________________
____
____
15. Proposed development.
a. Description ____
____
b. Material available___________________________________
____
c. Material required ___________________________________
____
d. Man-hours required _________________________________

____
(Signature)

____
(Grade and organization)

NOTE.—Back of sheet may be used for sketches or additional information.

The following instructions should be printed on the reverse side of the form:

INSTRUCTIONS FOR TAKING SAMPLES OF WATER

If sample is to be used for chemical examination only:

1. Use a clean glass bottle, holding from 2 quarts to a gallon, with a well-fitting stopper or a clean, unbroken cork.
2. Rinse out the bottle two or three times with the water to be sampled.
3. In sampling a well, support the bottle in a string or wire cradle, weighted at the bottom. Lower the bottle until the neck is 2 or 3 inches below the surface. It is advantageous to attach the stopper to a separate string, so the bottle can be opened below the surface of the water. In sampling a stream or pond, hold the bottle so the neck is well below the surface. Allow the bottle to fill.
4. Insert stopper or cork, stretch a clean cloth over it, and tie down the cloth below the flange of the neck.
5. Label the sample.

If the sample is to be used for bacteriological examination:

1. Use a sterilized bottle and stopper. Never use corks.
2. Avoid touching the neck of the bottle or the stopper with the fingers.
3. Before removing the stopper and after filling, the neck of the bottle, and the tap or spout from which the sample is taken, should be heated in a clean flame (alcohol torch) to just over the boiling point of water (212° F.).

Precautions: Never let the water entering the sample bottle flow over the hand. Before taking a sample from the spout of a pump or from a tap, allow water to waste for a time.

■ 68. ESTIMATING QUANTITY OF WATER AT SOURCES.—*a. Wells.*— Draw the water level down a measured distance by pumping, note time required for surface to reach its original level, and compute capacity in gallons between the two levels; or run a pumping test, using containers of known volume.

b. Springs.—Note the time required to fill a container of known capacity or measure the flow of the outlet stream.

c. Streams.—Determine the flow by $Q=av$ where Q is the quantity of flow in cubic feet per second, a the area of cross section of the stream in square feet, and v the mean velocity (3/4 of surface velocity in the main current) of the stream. A rectangular weir built of planks can be used for measuring the flow in small streams. (See table LVII.)

TABLE LVII.—*Discharge over a sharp crested rectangular weir 12 inches wide*[1]

Depth (inches)	Gallons per minute	Depth (inches)	Gallons per minute	Depth (inches)	Gallons per minute
1	36	4¾	375	8½	900
1¼	50	5	405	8¾	939
1½	66	5¼	436	9	978
1¾	84	5½	468	9¼	1,020
2	102	5¾	500	9½	1,062
2¼	122	6	533	9¾	1,104
2½	143	6¼	567	10	1,147
2¾	165	6½	601	10¼	1,190
3	188	6¾	636	10½	1,234
3¼	212	7	672	10¾	1,279
3½	237	7¼	708	11	1,323
3¾	263	7½	745	11¼	1,369
4	290	7¾	783	11½	1,414
4¼	317	8	821	11¾	1,461
4½	346	8¼	860	12	1,508

[1] Depth is measured from crest of weir to surface of water impounded by weir.

d. Artesian wells.—Measure the height of the jet from the top of the vertical well pipe and obtain flow from table LVIII. For pipe diameters not listed, Q varies approximately as the square of the diameter.

TABLE LVIII.—*Flow of artesian wells in gallons per minute*

Height of jet (inches)	Diameter of pipe (inches)			Height of jet (inches)	Diameter of pipe (inches)		
	1	2	3		1	2	3
½	3.96	15.6	35.6	15	22.0	87.8	198
1	5.60	22.4	50.4	20	25.4	102	228
2	7.99	32.0	71.9	30	30.9	123	278
4	11.3	45.3	102	40	35.8	142	323
6	13.9	55.5	125	60	43.8	175	394
8	16.0	64.0	144	108	58.9	236	531
10	17.9	71.6	161	144	68.0	272	612

■ 69. DEVELOPMENT OF SOURCES.—*a. Dams.*—A type design for a small dam (usually not over 5 feet in height) is shown in figure 84.

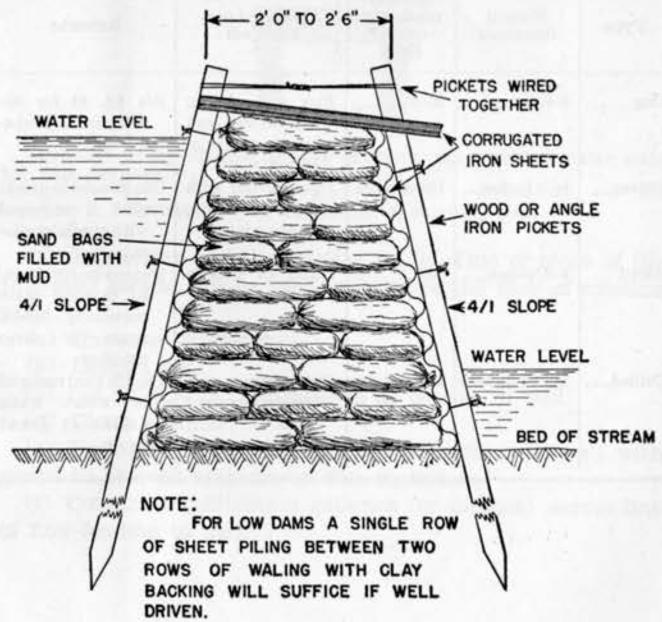


FIGURE 84.—Design for a small dam.

b. Springs.—The following steps should be taken in developing a spring:

(1) Provide a substantial collecting basin.

(2) Walls of water-tight casing should extend 1 to 2 feet above and below ground surface to exclude surface wash. V-shaped ditches constructed on the up-hill side of the spring will assist in diverting surface wash.

(3) Provide a tight cover to keep out dust, leaves, etc.

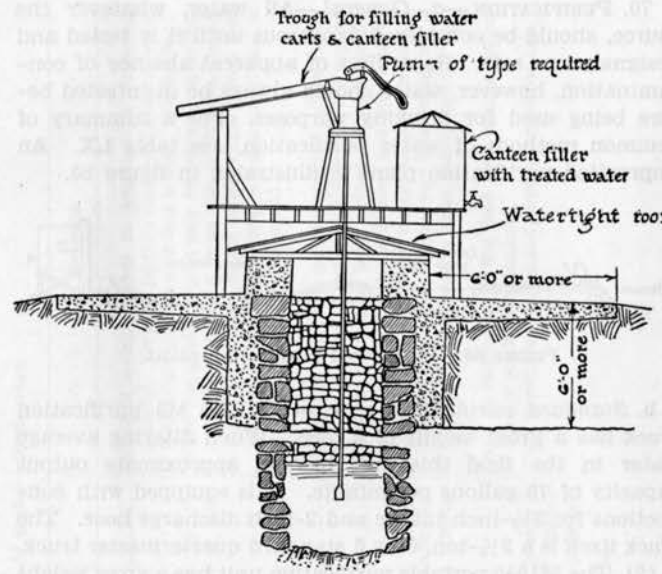
(4) Prohibit dipping of buckets or containers in spring.

(5) Supply water by pipe to storage tank or point of delivery.

c. Wells.—(1) *Types.*—Based on the method of construction, wells are classified as shown in table LIX.

TABLE LIX.—*General characteristics of wells*

Type	Normal diameters	Normal maximum depths (feet)	Method of construction	Remarks
Dug	3-6 feet	20-30	Pick and shovel; use bucket and windlass to raise material.	See fig. 85 for development of existing well.
Driven	¼-3 inches	150 or more	Pipes driven with maul, pile driver, or water jet.	Can be used in quicksand if equipped with special strainer.
Bored	4-8 inches	100	Hand or power-driven augers.	Cannot be constructed in solid earth containing rock strata or large boulders.
Drilled	1½-12 inches	300 or more	Power-driven percussion or rotary drills.	Used in hard material or where water exists at great depth.



NOTE.—If pump should require priming, use purified water only for this purpose.

FIGURE 85.—Development of existing well.

(2) *Increasing yield of existing wells.*—One or more of the following means can be used to increase the flow of existing wells:

(*a*) Increase diameter.

(*b*) Deepen well.

(*c*) Set off charge of explosives at bottom of well.

(*d*) Clean strainer.

(*e*) Pack pocket around strainer at bottom of well with gravel to prevent entrance of fine materials.

(*f*) Construct infiltration galleries (or ditches) across line of flow leading to well.

■ 70. PURIFICATION.—*a. General.*—All water, whatever the source, should be considered dangerous until it is tested and designated as safe. Regardless of apparent absence of contamination, however, water should always be disinfected before being used for drinking purposes. For a summary of common methods of water purification, see table **LX**. An improvised purification plant is illustrated in figure 86.

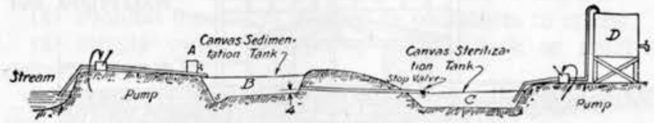


FIGURE 86.—Improvised purification plant.

b. Standard purification units.—(1) The M3 purification truck has a gross weight of 8 tons. When filtering average water in the field this unit has an approximate output capacity of 70 gallons per minute. It is equipped with connections for 2½-inch intake and 2-inch discharge hose. The truck itself is a 2½-ton, 6 by 6 standard quartermaster truck.

(2) The M1940 portable purification unit has a gross weight of 750 pounds. Its capacity for filtering average water in the field is approximately 10 gallons per minute. Both suction and discharge connections are for 1½-inch hose. The unit may be transported in any standard truck or trailer of ½-ton capacity or larger.

c. Water tests.—The purification truck has facilities for making water tests to determine turbidity, *pH* value, and residual chlorine content. The portable purification unit includes facilities for determining *pH* value and residual chlorine content.

TABLE LX.—*Methods of water purification*

Method	Effect on quality	Agent	Remarks
Sedimentation	Reduces turbidity and bacterial contamination.	Gravity alone	Speed of action depends on coarseness of suspended material. Very fine particles may remain in suspension indefinitely unless a coagulant is used. (See below.)
	Decreases some forms of coloring if a coagulant is used.	Gravity assisted by the action of alum or other coagulant.	When coagulant is used it may be necessary to employ an alkali to increase, or an acid to decrease, the *pH* value of the water to the range within which best coagulation will occur. Alum, which is an acid salt as well as coagulant, acts as an acid.
Filtration	Reduces turbidity and bacterial contamination and color.	Slow filter [1]	Capacity of slow filters ranges from 2 to 6 million gallons per acre per day. Mud deposited on filter bed requires frequent removal by hand methods. Existing plants may be utilized, but size of plant and time required usually make this method impracticable in the field.
		Rapid filter [1] (use coagulant in addition to filtering material).	Effective coagulation requires very sensitive control of *pH* values. (See remarks under sedimentation.)
		Gravity filter [2]	May be improvised in the field for a semipermanent camp or similar establishment.
		Pressure filter [2] (water is forced through filtering material under pressure).	Used in purification truck and portable purification unit.

[1] Carefully graded sand and gravel usually used as filtering material.
[2] A type of rapid filter.

TABLE LX.—*Methods of water purification*—Continued

Method	Effect on quality	Agent	Remarks
Disinfection	Destroys most bacteria	Pure chlorine or chlorine contained in the form of calcium hypochlorite, sodium hypochlorite, or chlorinated lime (bleaching powder).	When chlorine is employed a sufficient amount must be added to produce a residual chlorine content of 1.0 part per million. Allow 30 minutes before water is used for drinking, and before residual chlorine test is made. Hypochlorite for Lyster bags is issued in sealed glass tubes. Hypochlorite as supplied commercially usually contains from 60 to 70 percent free chlorine by weight. Chlorinated lime usually contains from 20 to 30 percent free chlorine when fresh.
		Tincture of iodine	Two and one-half teaspoonfuls of standard 7 percent tincture of iodine are used for one Lyster bag (36 gallons); 2 drops are used per quart (canteen) of water. Wait 30 minutes after mixing before drinking.
		Heat	At least 10 minutes of steady boiling is required to sterilize water.
Softening	Removes or reduces hardness.	Hydrated lime	Reduces carbonate hardness. Converts hardness due to magnesium compounds to form which can be removed by soda ash.
		Soda ash	Reduces noncarbonate hardness, except when due to magnesium compounds. (For magnesium compounds see remark under hydrated lime.)
		Zeolite minerals	All types of hardness may be removed by percolation of water through zeolite filters.
		Heat	Prolonged boiling will reduce hardness due to bicarbonates.
Activated carbon	Eliminates certain tastes and odors and reduces chemical contamination by adsorbing dissolved gases.	Activated carbon	Ordinarily applied in mixing basins prior to sedimentation or filtration, either separately or together with coagulant. Often applied in form of black alum or activated alum (alums with activated carbon added during manufacture). Also used as filtering material. Dosage of carbon ranges from 0.5 to 50 or more parts per million.
Aeration	Reduces odors and tastes due to dissolved gases; removes objectionable gases such as CO_2; adds oxygen for oxidation of ferrous iron to assist in its precipitation.	Air	Accomplished by passing water through the air as mist or small droplets. The finest spray is the most effective. Also accomplished by forcing compressed air into water, or by the introduction of air through negative pressures created when water flows through a constricted passageway. Pouring boiled water from one sterile container to another will help to eliminate the flat taste.
Distillation	Converts salt water into fresh water.	Heat[3]	Removes impurities having boiling points greater than water. Often employed to purify excessively contaminated water. Requires elaborate plant and large quantities of fuel. Other methods of evaporation and recondensation will achieve similar results.

[3] For water containing bicarbonates, or up to 400 parts per million of chlorides and sulphates, ion exchange materials such as zeokarb or deacidite (or equivalent) can be used alone or in combination for demineralization.

■ 71. **Pipe Flow Computations.**—*a. Manning formula.*—The Manning formula for flow of water under pressure in pipes is as follows:

$$v=\frac{0.590\ d^{2/3}\ s^{1/2}}{n} \qquad (1)$$

Formulas (2) and (3) are convenient forms for solving for pipe discharge and for head loss due to pipe friction.

$$Q=0.46\frac{d^{8/3}\ s^{1/2}}{n} \qquad (2)$$

$$H_l=2.87\ n^2\frac{lv^2}{d^{4/3}} \qquad (3)$$

where

v=mean velocity of water in feet per second.
d=diameter of pipe in feet.
r=mean hydraulic radius=$\frac{d}{4}$
l=length of pipe in feet.
H_l=loss of head in feet in length l.
s=mean slope of hydraulic gradient in distance=$\frac{H_l}{l}$
Q=discharge of pipe in cubic feet per second.
n=Manning coefficient of roughness, varying directly with the degree of roughness of the pipe. The value for cast iron pipe commonly falls between 0.013 and 0.015, with extreme values of 0.011 and 0.017.

b. Nomograph.—A straight line on the nomograph given in figure 87, determined by any two variables in the Manning formula, will pass through the corresponding values of the other two variables.

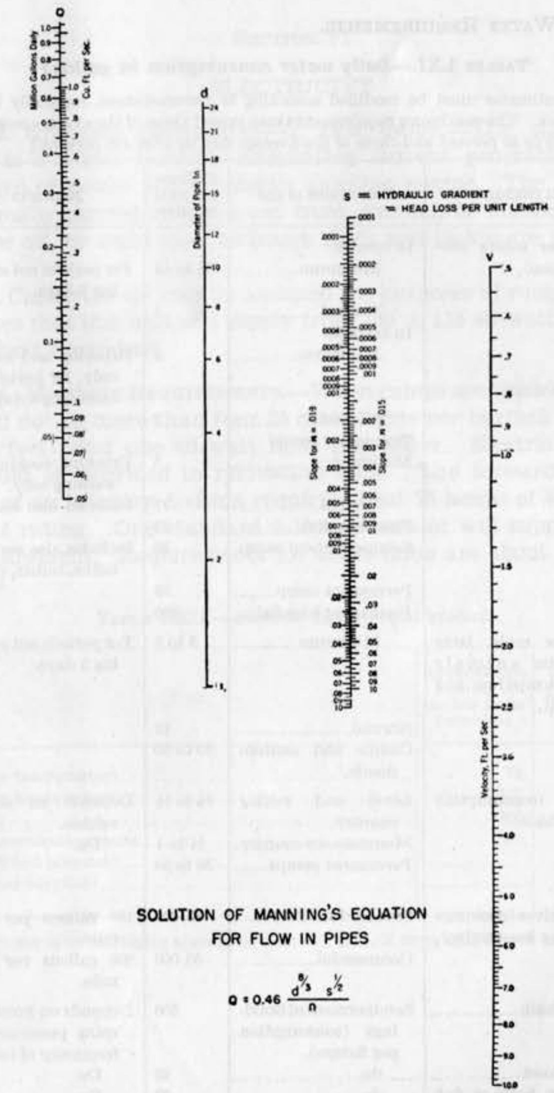


Figure 87.—Nomograph for solving Manning formula.

282736°—41——11

■ 72. WATER REQUIREMENTS.

TABLES LXI.—*Daily water consumption in gallons*

[These estimates must be modified according to circumstances, especially in hot climates. The maximum requirements may exceed those of the average month by from 15 to 40 percent and those of the average day by over 100 percent.]

Unit consumer	Conditions of use	Gallons per unit per day	Remarks
Man (per capita consumption).	In combat:		
	Minimum	⅓ to ½	For periods not exceeding 3 days.
	Normal	1	
	In bivouac:		
	Minimum	1	Drinking and cooking only, for periods not exceeding 3 days.
	Normal	2	
	Temporary camp:		
	Minimum	5	Drinking, cooking, and washing only.
	Normal	15	Includes also bathing.
	Field hospital	25	
	Semipermanent camp	30	Includes also water for baths, toilets, etc.
	Permanent camp	50	
	Permanent hospital	200	
Horse or mule, large domestic animals (consumption per animal).	Minimum	3 to 5	For periods not exceeding 3 days.
	Normal	10	
	Camps and cantonments.	30 to 50	
Motors (consumption per vehicle).	Level and rolling country.	⅛ to ½	Depends on size of vehicle.
	Mountainous country	¼ to 1	Do.
	Permanent camps	30 to 50	
Locomotives (consumption per locomotive).	Standard military	33,000	150 gallons per train mile.
	Commercial	50,000	200 gallons per train mile.
Shower bath	Semipermanent buildings (consumption per fixture).	300	Depends on number of using personnel and frequency of use.
Water closet	do	40	Do.
Lavatory, basin or sink	do	20	Do.
Urinal	do	40	Do.

SECTION VI

ELECTRICITY

■ 73. STANDARD GENERATOR.—*a. Description.*—The standard set is a 5-kva. portable alternating current generator. Its source of power is a 4-cylinder gasoline engine. The unit is normally carried on a 1½-ton truck and can be manhandled, on or off, by eight men, although skids and tackle are preferable.

b. Capacity.—It may be assumed for purposes of rough estimates that this unit will supply from 100 to 115 40-watt lamps or their equivalent.

■ 74. MILITARY REQUIREMENTS.—When camps are lighted there need not be more than four 25-watt lights per barrack (20 by 100 feet) and one 40-watt light per officer. Electric lamps should be provided in recreation halls. The forward echelon of an infantry division requires about 75 lamps of 40 to 60 watt rating. One standard 5-kva. generator will supply this requirement. Requirements for other units are about as follows:

TABLE LXII.—*Electric light requirements*

Unit	Approximate number of outlets to be furnished	Power in kilowatts required
Corps headquarters	75	4.5
Army headquarters	150	9.0
GHQ	600	36.0
Communications zone	600	36.0
10,000-bed hospital [1]		135.0
250-bed hospital [1]		4.5

[1] Power is for sterilizing apparatus, dentist's tools, X-rays, etc., as well as for light.

75. Useful Information.—*a. Power in direct current (d. c.) circuits.*—In a d. c. circuit, power in watts (W) is equal to electromotive force (e. m. f.) in volts (E) multiplied by current in amperes (I): $W=EI$.

b. Power in alternating current (a. c.) circuits.—In a. c. circuits, true power in watts (W) is equal to the product of the power factor in percentage (pf) by the e. m. f. in volts (E) by the current in amperes (I): $W=(pf)\ EI$.

c. Ohm's law for d. c. circuits.—In d. c. circuits, the e. m. f. in volts (E) is equal to the current in amperes (I) multiplied by the resistance in ohms (R): $E=IR$.

d. Units.—(1) *Kva.*—The unit used for measuring the apparent power of an a. c. generator operating on circuits subject to change in power factor is the kilovolt-ampere.

$$\text{kilovolt-ampere}=\frac{\text{volt} \times \text{ampere}}{1{,}000}$$

(2) *Kw.*—The unit used for measuring true power in an a. c. circuit is the kilowatt.

$$\text{kilowatt}=\text{kilovolt-ampere} \times \text{power factor } (pf)$$

(3) *Hp.*—The unit used for measuring mechanical work is the horsepower (hp).

$$1\ hp=746 \text{ watts}$$

(4) *Wire sizes.*—The unit used for measuring wire sizes is the mil.

$$1 \text{ mil}=.001 \text{ inch}$$

In tables, wire size is expressed in circular mils (cross-sectional area). The wire size in circular mils is the square of the diameter in mils.

76. Form for Electrical Reconnaissance Report.

ELECTRICAL RECONNAISSANCE

Reconnaissance party:

....	Area............	Date............
....	Map............	Photographs............
....		

Prime movers	Generators	Transmission lines
Type............ (Steam, internal combustion, water wheel.)	Type............ (Alternating or direct current.)	Type............ (2-wire; 3-wire Edison; 1, 2, 3 phase alternating current.)
	Number of machines............	Current...... Voltage...... (Alternating current or direct current.)
Fuel............ (Coal, oil, gas.)	Kilovolt amperes............ Kilowatts...... Volts......	Conductors............ (Size and material.)
.... (Amount on hand.)	Amperes.. Power factor..	Location............ (On poles or below ground.)
	Frequency............ Revolutions per minute...... Horsepower.. Maker..	Transformers............
.... (Feed.) Horsepower............	General condition............	Substation............ (Whether transformer or synchronous converter.)
Lubricants............ (Kind and amount on hand.)		
		Condition............
Water supply............ (Character and amount.) General condition............	*Switchboard*	*Electrical supplies*
....	Instruments............ Interconnections............ Condition............	Location............ General kind............ Inventory............

Recommendations ....
....

■ 77. WIRING.

TABLE LXIII.—*Electrical characteristics of copper wire*

Brown & Sharpe (B. & S.) gage	Cross section		Weight, resistance, and length			Safe current-carrying capacity in amperes for lengths of 100 feet or less	
	Diameter in mils	Area in circular mils	Pounds per 1,000 feet	Feet per pound	Ohms per 1,000 feet	Rubber insulation	Bare or weather-proof wire
0000	460.00	211,600	639.33	1.56	0.04906	225	325
000	409.64	167,805	507.01	1.97	.06186	175	275
00	364.80	133,079	402.09	2.49	.07831	150	225
0	324.95	105,592	319.04	3.14	.09831	125	200
1	289.30	83,694	252.88	3.95	.12404	100	150
2	257.63	66,373	200.54	4.99	.15640	90	125
3	229.42	52,634	159.03	6.29	.19723	80	100
4	204.31	41,742	126.12	7.93	.24869	70	90
5	181.94	33,102	100.01	10.00	.31361	55	80
6	162.02	26,250	79.32	12.61	.39546	50	70
*7	144.28	20,816	62.90	15.00	.49871	38	54
8	128.49	16,509	49.88	20.05	.62881	35	50
*9	114.43	13,594	39.56	25.28	.79281	28	38
10	101.89	10,381	31.37	31.38	1.0	25	30
*11	90.74	8,234	24.88	40.20	1.2607	20	27
12	80.81	6,530	19.73	50.69	1.5898	20	25
*13	71.96	5,178	15.65	63.91	2.0047	14	22
14	64.08	4,107	12.41	80.58	2.5908	15	20

NOTES.—1. Sizes marked * are not used for electrical work.
2. For aluminum wire the carrying capacity of any given size should be taken as 84 percent of the value given in above table.
3. If current exceeds the safe current-carrying capacity of the largest wire, two or more wires should be used.

TABLE LXIV.—*Bill of electrical material for one standard 20 by 100 foot barrack*

Item	Quantity	Unit	Size	Weight in pounds	Description
1	210	Feet	No. 14	5¼	Wire, R. C. S. B. solid copper.
2	1	Each	125-volt, 30-ampere.	1	Cut-out, main line, plug fuse, double pole.
3	2	Each	15-ampere		Fuses, plug.
4	4	Each		1¼	Socket, pull, brass, S22 (P&S), cat. 38, base BP.
5	50	Each	No. 12	7½	Knobs, split porcelain, with nail and leather washer.
6	2	Each	⅝ by 3 inches		Tubes, porcelain.
7	4	Each	25 watts		Lamps, Mazda, 115-volt.
8	10	Each	1½ inches		Screws, for cut-out and socket, No. 8, F. H. bright.
9	4	Each	3 feet		Cord, linen, with chain and link tassel.

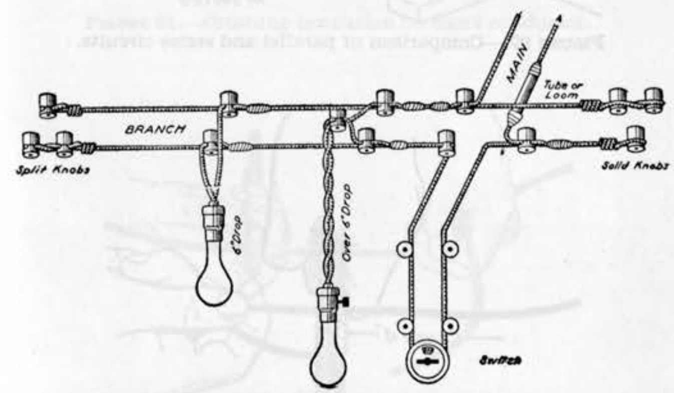


FIGURE 88.—Lighting installation using porcelain knobs.

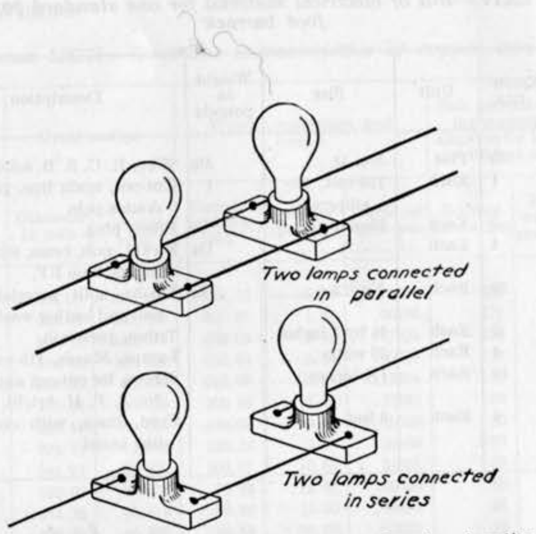


FIGURE 89.—Comparison of parallel and series circuits.

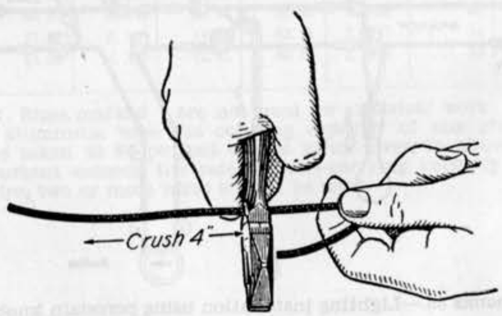


FIGURE 90.—Crushing insulation on long conductor.

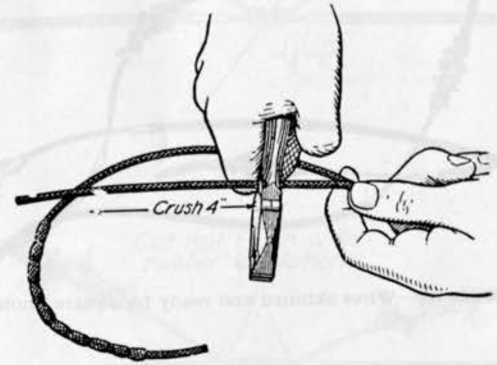


FIGURE 91.—Crushing insulation on short conductor.

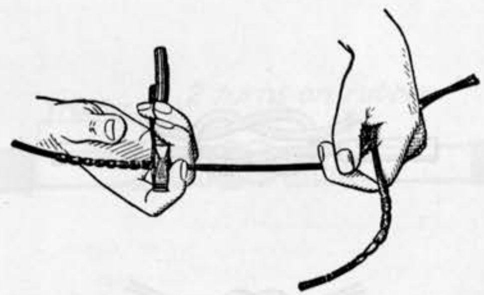


FIGURE 92.—Skinning conductor.

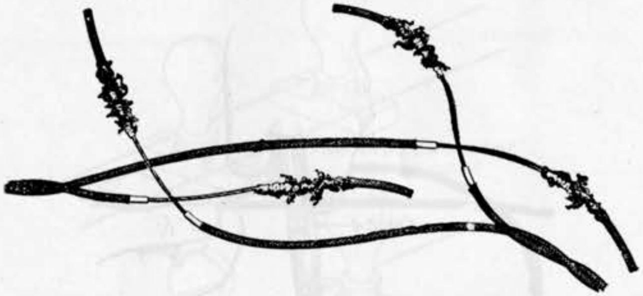


FIGURE 93.—Wires skinned and ready for square knots.

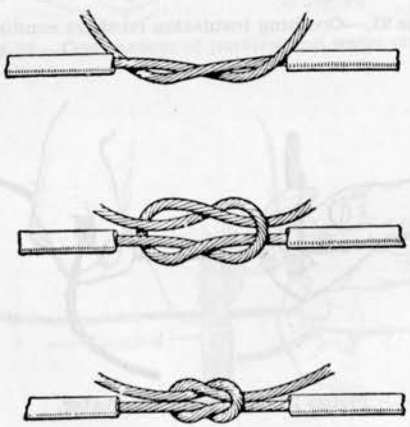


FIGURE 94.—Tying square knots.

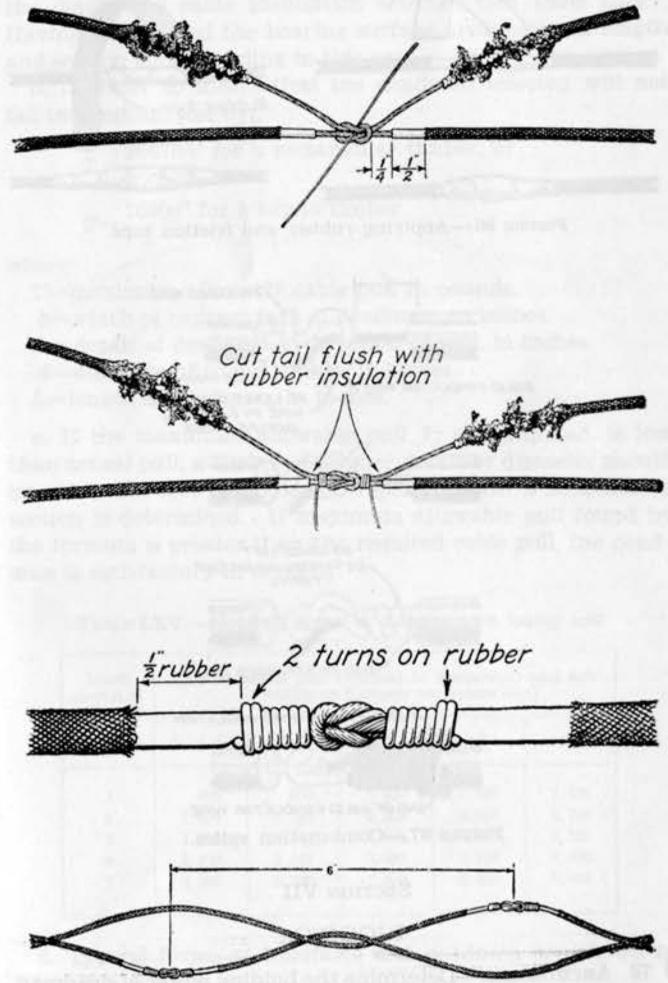


FIGURE 95.—Finishing the splice.

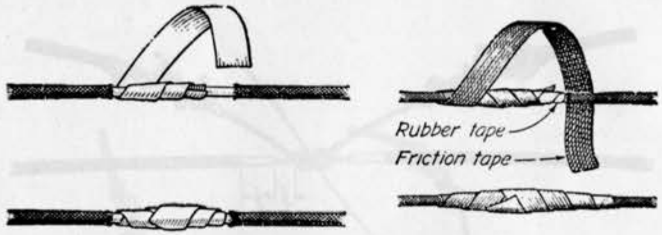


FIGURE 96.—Applying rubber and friction tape.

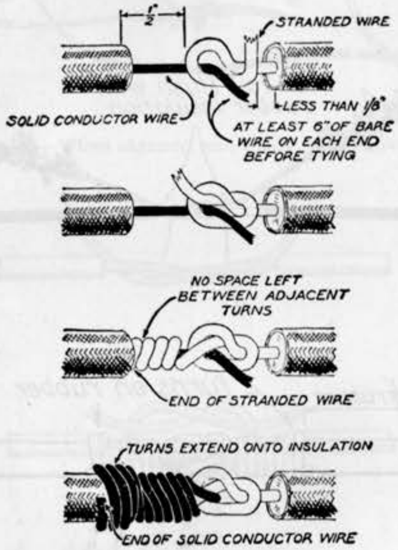


FIGURE 97.—Combination splice.

SECTION VII

RIGGING

■ 78. ANCHORAGES.—Determine the holding power of deadman as follows:

a. For a given cable pull, the number of square feet of deadman bearing surface required is determined by dividing the

total pull to be placed on the deadman by the value given for the depth and cable inclination selected (see table LXV). Having determined the bearing surface area, select a length and section corresponding to this area.

b. In order to insure that the deadman selected will not fail in bending, test by:

$$T=\frac{2667bh^2}{L} \text{ for a rectangular timber, or}$$

$$T=\frac{1600d^3}{L} \text{ for a round timber}$$

where

T=maximum allowable cable pull in pounds.
b=width of contact face of deadman, in inches.
h=depth of deadman in direction of pull, in inches.
d=diameter of round timber, in inches.
L=length of deadman, in inches.

c. If the maximum allowable pull T, as computed, is less than actual pull, a timber of greater depth or diameter should be used, and test computation repeated until a satisfactory section is determined. If maximum allowable pull found by the formula is greater than the required cable pull, the deadman is satisfactory in bending.

TABLE LXV.—*Holding power of deadman in loamy soil*

Mean depth of anchorage (feet)	Declination of pull (vertical to horizontal) and safe resistance (pounds per square foot)				
	Vertical	1/1	1/2	1/3	1/4
3	600	950	1,300	1,450	1,500
4	1,050	1,750	2,200	2,600	2,700
5	1,700	2,800	3,600	4,000	4,100
6	2,400	3,800	5,100	5,800	6,000
7	3,200	5,100	7,000	8,000	8,400

d. Typical forms of holdfasts and deadmen are shown in figure 106.

■ 79. **Slings.**—The most common sling is made by splicing two ends of a rope together. To use the sling, pass it around the article to be lifted. Pass the bight formed by one end through the bight formed by the other and then over the lifting hook. If the sling is the same size as the lifting rope, it should make a minimum angle of 30° with the horizontal. At this angle, the stress in each branch of the sling is equal to the stress in the lifting rope. If the angle is greater than 30°, the load is limited by the strength of the lifting rope; if less than 30°, by the strength of the sling.

■ 80. **Gin Pole or Standing Derrick.**—To erect a gin pole, lash the tackle to the spar or suspend it by a sling run through slot in the head of the pole. Locate the foot of the gin pole. Lay a line through the point to mark the location of the fore and back guys. Lay another line at right angles to this. Lay off on the four lines distances equal to twice the length of the spar for level ground, plus necessary allowances. Erect anchorages at these points. Make the four guys fast to the top of the spar. Lay the spar along one of the guy lines with the butt nearly in the footing. Fasten a footrope to the butt and to an anchorage on the same side of the footing as the spar. Raise the top by hauling the back guy with a running tackle. Let the fore guy out. Take up the slack on the side guys. Continue until spar is in position, keeping the slack out of all guys. For heavy poles it may be necessary to erect a light gin pole or shears first and use this to erect the heavy pole. In hard ground, dig a hole about 1 foot deep for the butt of the gin pole. In soft ground, prepare an excavation with a wood floor base to transmit the ground pressure over a larger area.

■ 81. **Knots, Lashings, and Tackle.**

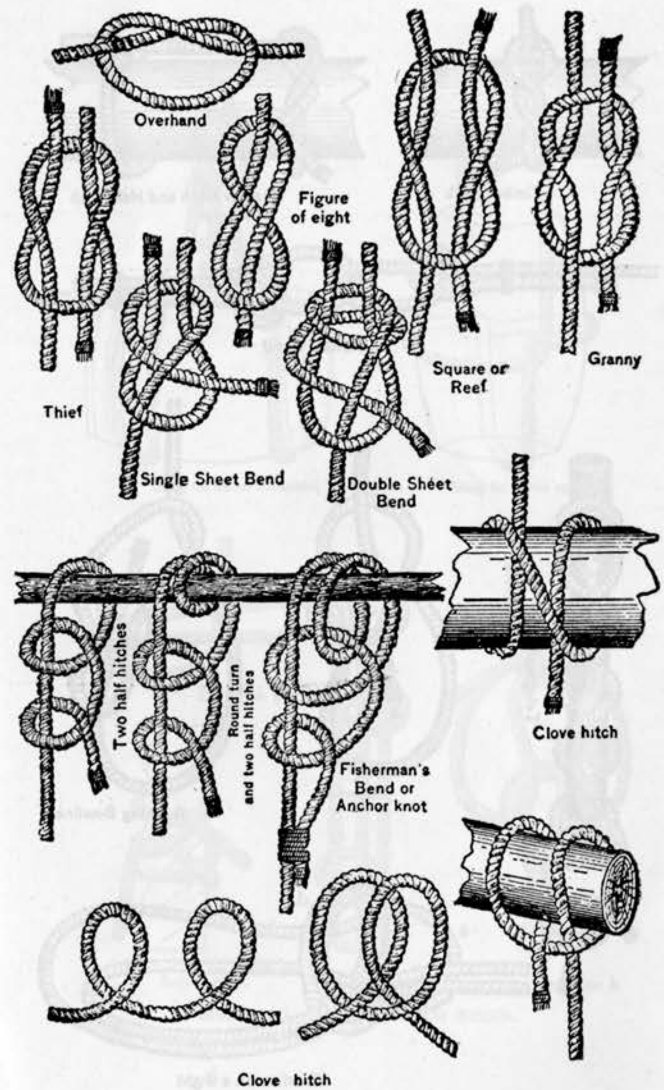


Figure 98.—Types of knots.

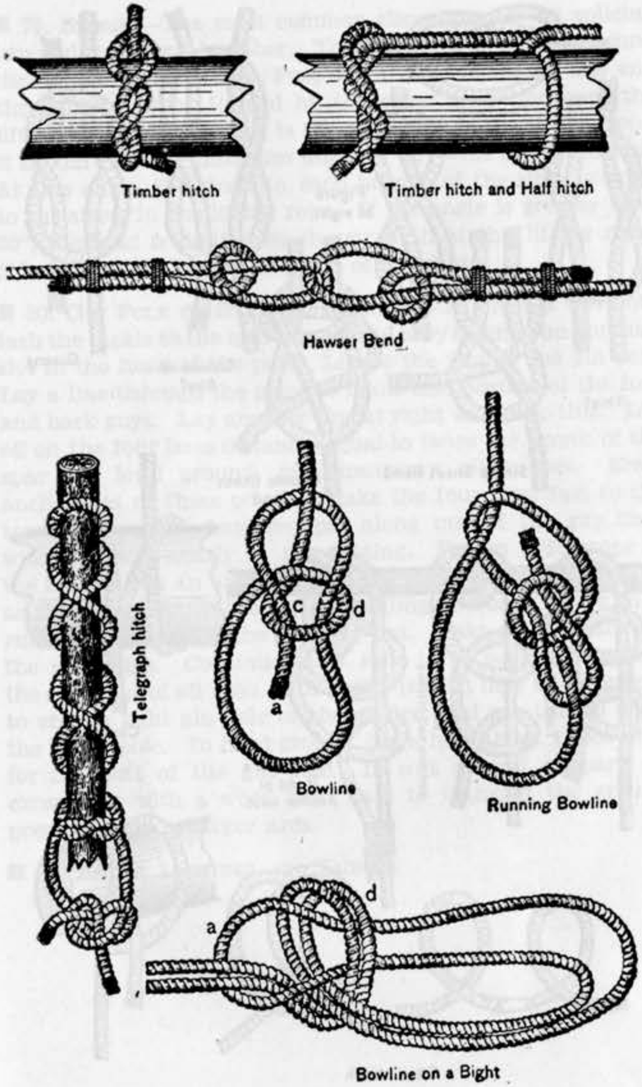


FIGURE 99.—Types of knots.

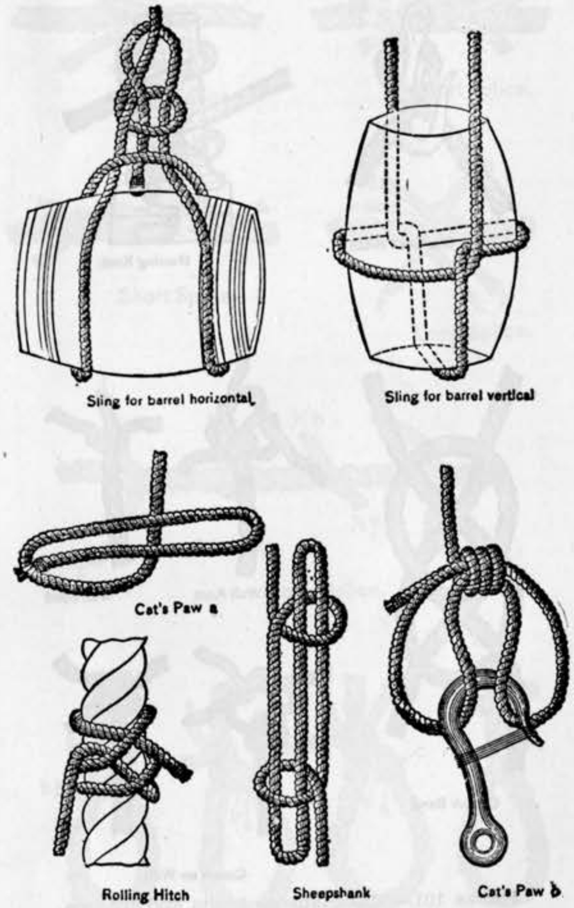


FIGURE 100.—Miscellaneous knots.

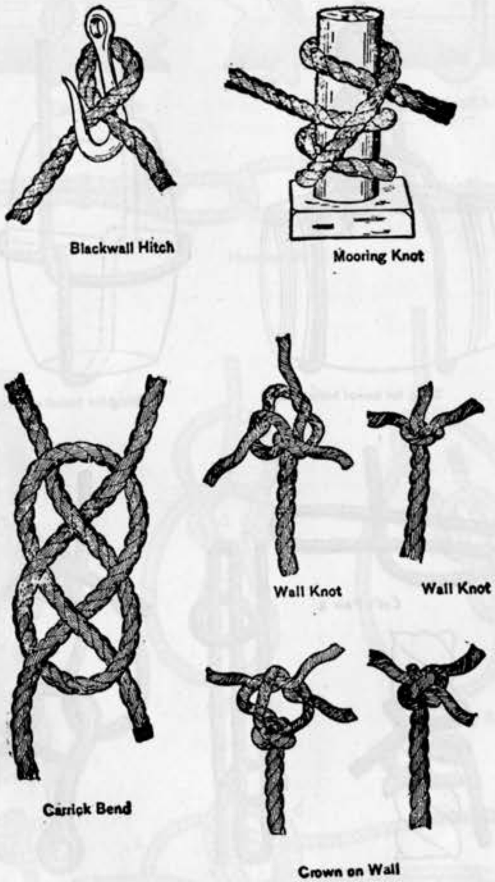


FIGURE 101.—Miscellaneous knots and hitches.

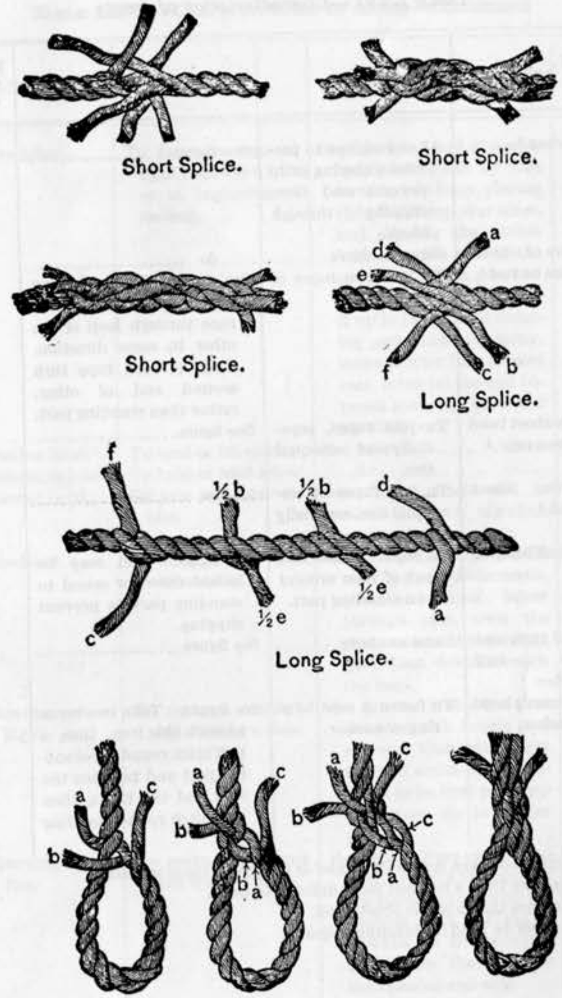


FIGURE 102.—Splices.

TABLE LXVI.—*Characteristics of knots*

Name	Use	Directions for tying	Figure reference
1. Overhand	At end of rope to prevent unlaying or to prevent end from slipping through block.	See figure	98
2. Figure of eight	Same as above	do	98
3. Square or reef [1]	To join two ropes of same size.	See figure. Pass standing and running parts of each rope through loop of the other in same direction. Ends of each rope turn around end of other, rather than standing part.	98
4. Single sheet bend or weavers'. [2]	To join ropes, especially of unequal size.	See figure	98
5. Double sheet bend. [3]	To join ropes of unequal size, especially wet ones.	do	98
6. Two half hitches [4]	To belay or make fast end of rope around own standing part.	See figure. End may be lashed down or seized to standing part to prevent slipping.	98
7. Round turn and two half hitches.	Same as above	See figure	98
8. Fisherman's bend or anchor.	To fasten a rope to a ring or anchor.	See figure. Take two turns around the iron, then a half hitch round the standing part and between the ring and the turns, then half hitch round standing part.	98

[1] Care must be taken not to tie a thief or granny as these will slip.
[2] More secure than a reef but more difficult to untie.
[3] More secure than a single sheet bend.
[4] Must never be used for hoisting a spar.

TABLE LXVI.—*Characteristics of knots*—Continued

Name	Use	Directions for tying	Figure reference
9. Clove hitch	To fasten a rope at right angles to a spar or at beginning of lashing.	See figure. If end of spar is free, hitch made by first forming two loops, placing right-hand loop over other, and slipping the double loop over the end of the spar. Otherwise, pass end of rope round spar, bring it up to the right of standing part, cross over latter, make another turn around spar, bring up the end between spar, last turn and standing part.	98
10. Timber hitch [5]	To haul or lift spars	See figure	99
11. Telegraph hitch.	To hoist or haul a spar.	do	99
12. Hawser bend	To join two large cables.	See figure. Each end is seized to own standing part.	99
13. Bowline [6]	To form a loop that will not slip.	See figure. Make loop with standing part underneath, pass end from below through loop, over the part, around the standing part, then down through the loop.	99
14. Bowline on a bight.	To make a comfortable sling for a man.	See figure. Make first part as above with double part of rope, then pull bight through sufficiently to allow it to be bent past loop and come up in proper position.	99
15. Running bowline.	To make a slip knot that will not bind.	See figure. Pass end around spar. Form a loop around the standing part with the running end. Make a bowline on the standing part below the loop—on the running-end side.	99

[5] Can be easily loosened when strain is taken off, but will not slip under load. When used for hauling spars, a half hitch is added near end of spar.
[6] Length of bight depends on purpose for which knot is required.

TABLE LXVI.—*Characteristics of knots*—Continued

Name	Use	Directions for tying	Figure reference
16. Cat's paw	To secure a rope to the mouth of a hook.	See figure. Form two equal bights; take one in each hand and roll them along the standing part till surrounded by three turns of the standing part; then bring both loops (or bights) together and pass over the hook, and mouse the hook.	100
17. Sheep shank	To shorten a rope or pass a weak spot.	See figure. Take a half hitch with the standing parts around the bights.	100
18. Rolling hitch	To haul a larger rope or cable.	See figure. Take two turns around the large rope in the direction in which it is to be hauled, and one half hitch on the other side of the hauling part.	100
19. Blackwall hitch	To attach a single rope to a hook of a block for hoisting.	See figure	101
20. Mooring knot	To make fast to a mooring or snubbing post.	See figure. Take two turns around the mooring or snubbing post, pass the free end under the standing part, take a third turn above the other, pass the free end between the two upper turns.	101
21. Carrick bend	To fasten guys to derricks.	See figure	101
22. Wall knot and crown on wall.	To finish the end of a rope to prevent unlaying.	do	101

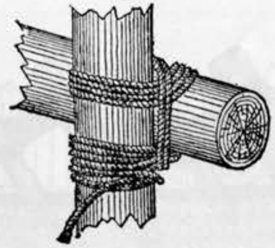


FIGURE 103.—Square lashing.

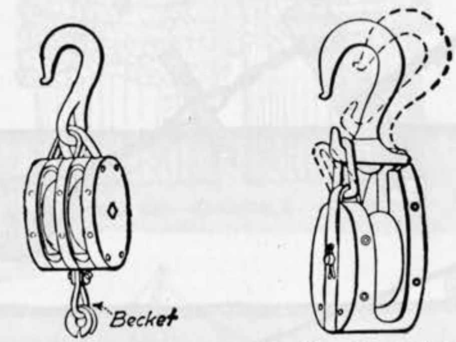


FIGURE 104.—Double wooden block and snatch block.

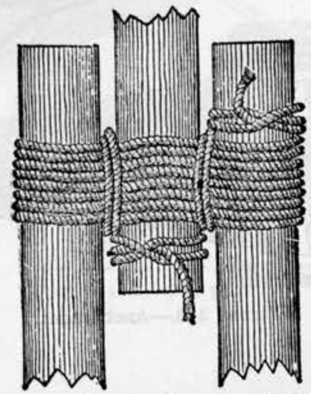


FIGURE 105.—Lashing for tripod.

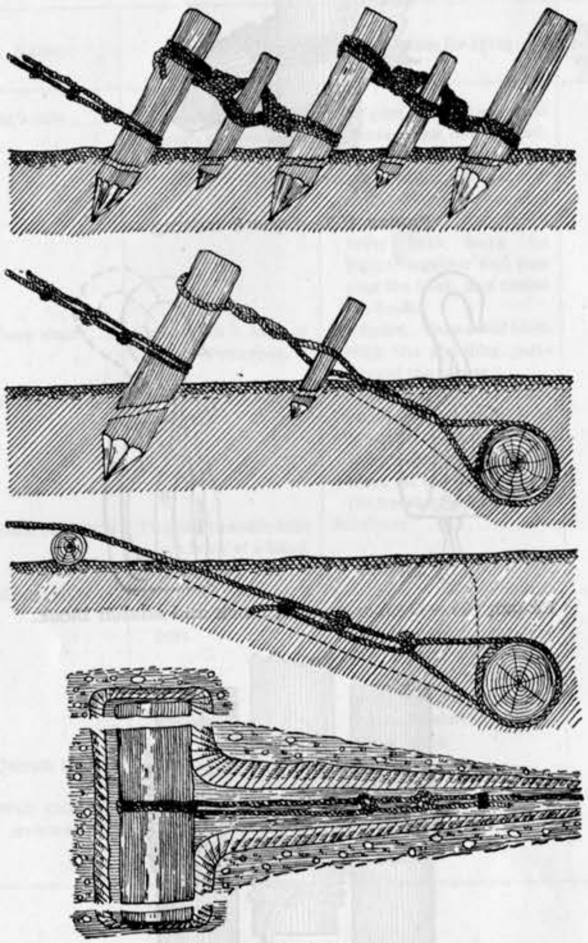


FIGURE 106.—Anchorages.

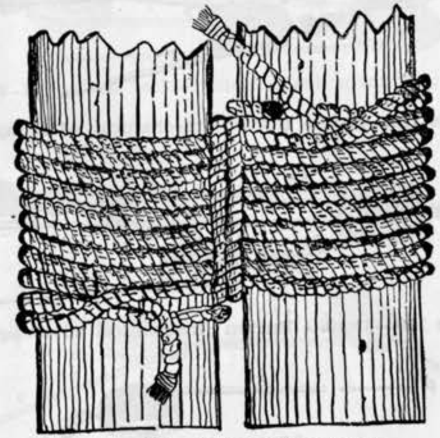


FIGURE 107.—Lashing for shears.

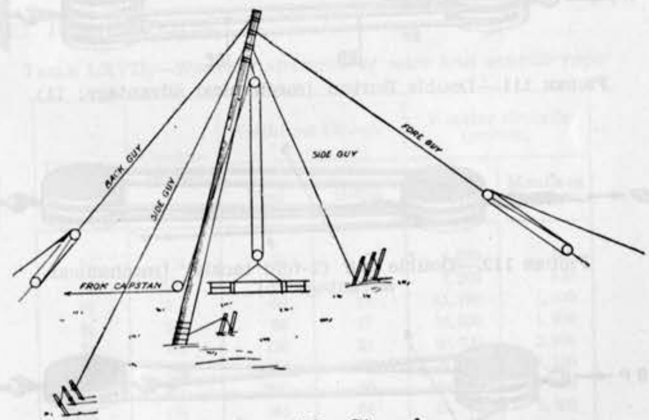


FIGURE 108.—Gin pole.

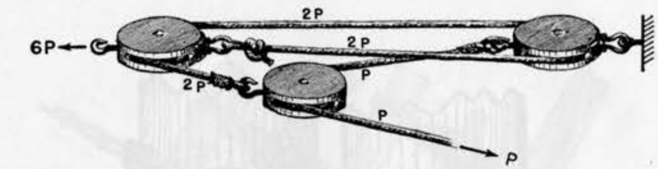


FIGURE 109.—Single Burton (mechanical advantage: 6).

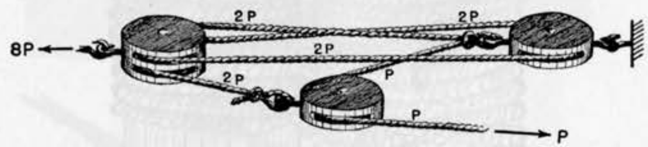


FIGURE 110.—Double Burton (mechanical advantage: 8).

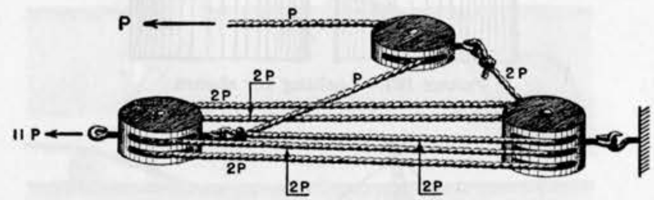


FIGURE 111.—Double Burton (mechanical advantage: 11).

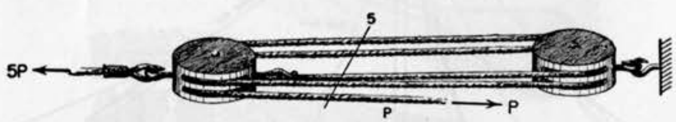


FIGURE 112.—Double luff (2-fold tackle) (mechanical advantage: 5).

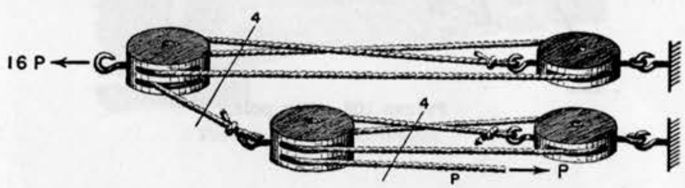


FIGURE 113.—Luff on luff (mechanical advantage: 16).

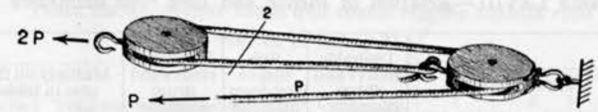


FIGURE 114.—Gun tackle (mechanical advantage: 2).

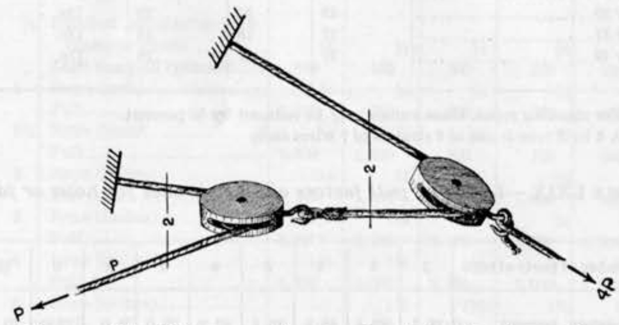


FIGURE 115.—Whip on whip (mechanical advantage: 4).

■ 82. RIGGING TABLES.

TABLE LXVII.—*Working strength of wire and manila rope*

Diameter	Circumference	Weight per 100 feet		Working strength (pounds)	
		Steel	Hemp	Steel	Manila or hemp
3/8	1 1/4	13	5	4,000	400
1/2	1 1/2	39	7	7,000	850
5/8	2	60	13	11,100	1,520
3/4	2 3/8	88	17	15,300	1,900
7/8	2 3/4	120	24	20,700	2,300
1	3 1/8	158	28	28,000	3,100
1 1/4	4	250	46	42,000	4,300
1 1/2	4 3/4	365	64	58,700	5,900
1 3/4	5 1/2	525	84	76,000	7,900
2	6 1/4	632	115	96,000	10,300
2 1/2	7 7/8	988	117	110,000	16,500
3	9 1/2	1,421	255	116,000	22,500

TABLE LXVIII.—*Relation of sheave and wire rope diameters*

Type of rope	Desirable sheave and drum diameter [1]	Safe sheave and drum diameter	Minimum sheave and drum diameter	Multiply all figures in table
6 by 7 [2]	72	42	28	×rope diameter.
6 by 19	45	30	20	Do.
6 by 37	27	18	14	Do.
8 by 19	31	21	16	Do.

[1] For standing ropes, these values may be reduced by 50 percent.
[2] A 6 by 7 rope is one of 6 strands of 7 wires each.

TABLE LXIX.—*Lead line pull factors and efficiencies for hoist or fall wire ropes*

Number of parts of rope	2	3	4	5	6	7	8	9	10
Efficiency, percent	96.1	92.4	88.9	86.5	82.2	79.0	76.0	73.0	70.3
Lead line pull factor	.52	.36	.28	.23	.20	.18	.165	.15	.14

NOTE.—The stress in the lead line equals the load multiplied by the lead line pull factor.

TABLE LXX.—*Simple block and tackle rigging manila rope* **(factor of safety 3)**

Load to be lifted (tons)	Total number of sheaves in blocks	2 (2 single blocks)	3 (1 single, 1 double)	4 (2 double blocks)	5 (1 double 1 triple	6 (2 triple blocks)
½	Smallest permissible rope diameter (inch)	½	7/16	⅜	⅜	⅜
	Lead line pull (pounds)	540	380	300	250	220
1	Rope (inch)	¾	⅝	½	½	½
	Pull	1,100	760	600	500	440
1½	Rope (inch)	⅞	¾	⅝	⅝	½
	Pull	1,600	1,100	900	750	660
2	Rope (inches)	1⅛	⅞	¾	⅝	⅝
	Pull	2,200	1,500	1,200	1,000	880
3	Rope (inches)	1 5/16	1⅛	1	⅞	¾
	Pull	3,300	2,300	1,800	1,500	1,300
4	Rope (inches)	1½	1¼	1⅛	1	1
	Pull	4,400	3,000	2,400	2,000	1,800
6	Rope (inches)	------	1½	1 5/16	1¼	1⅛
	Pull	------	4,500	3,600	3,000	2,600
8	Rope (inches)	------	------	1⅝	1½	1 5/16
	Pull	------	------	4,800	4,000	3,500

TABLE LXXI.—*Properties of chains*

Size (inches)	Safe working strength (pounds)	Approximate weight (pounds per 100 feet)
⅜	1,800– 3,000	175
7/16	2,500– 3,800	230
½	3,300– 5,000	300
⅝	5,000– 7,600	470
¾	8,000–11,000	650
⅞	10,000–15,000	880
1	12,000–20,000	1,130
1⅛	16,000–26,000	1,420
1¼	19,000–32,000	1,650

NOTE.—Chains are manufactured in such a wide variety of grades that no definite strength can be given for any one size. The above properties are limits for some standard sling and dredge chains.

SECTION VIII

CONCRETE

■ 83. MATERIALS.—*a. Shipment and storage of cement.*—Cement is usually shipped in bags of 94 pounds each (considered 1 cubic foot) or barrels equivalent to four bags each. It should be stored in a weatherproof building and at least 8 inches from walls and ground or floor to insure ventilation.

b. Fine aggregate.—That part of the aggregate passing a ⅜-inch screen is called fine aggregate. Clay and silt should not constitute more than 3 percent of the sand by weight, or together with coal particles, shale, shell, etc., not more than 5 percent by weight. (See table LXXII for a suitable gradation.)

TABLE LXXII.—*Gradation of fine aggregates*

Passing—	Percent by weight
⅜ inch (standard square mesh)	100
No. 4	95–100
No. 16	35–75
No. 50	10–25
No. 100	2–7

c. Coarse aggregate.—Coarse aggregate will not pass a ⅜-inch screen. Broken stone, gravel, slag, and cinders are commonly used. Maximum size of coarse aggregate depends on the use to be made of the concrete: for plain concrete in mass construction, 1½ to 6 inches; for reinforced work, 1 inch; for thin reinforced members, ¾ inch.

d. Water.—Water used in concrete should be clean and free from excessive amounts of oil, acid, alkali, or organic matter. Sea water is undesirable but may be used in emergency.

■ 84. PROPORTIONING CONCRETE MIXES.—The following tables can be used to select trial proportions for concrete mixtures used for various types of work:

TABLE LXXIII.—*Strength of concrete mixtures*

Water content[1] (U. S. gallons per 94-pound sack of cement)	Assumed compressive strength at 28 days (pounds per square inch)	
	(2)	(3)
8	1,750	2,750
7	2,300	3,300
6	3,000	4,000
5	3,800	4,900

[1] Surface water or moisture carried by aggregate must be included as part of mixing water.

[2] Data published at time water-cement ratio strength law was announced in 1918. These values should be used in the absence of preliminary tests and careful control.

[3] Values representative of present day cements.

TABLE LXXIV.—*Approximate quantity of surface water carried by average aggregates*

Aggregate	Water (gallons per cubic foot)
Very wet sand	¾ to 1.
Moderately wet sand	About ½.
Moist sand	About ¼.
Moist gravel or crushed rock	About ¼.

TABLE LXXV.—*Suitable slumps for concrete*

Type of structure	Slump (inches)	
	Minimum	Maximum
Massive sections, pavements and floors laid on ground	1	4
Heavy slabs, beams or walls	3	6
Thin walls and columns, ordinary slabs or beams	4	8

Table LXXVI.—*Trial mixtures for various water-cement ratios*

Slump (inches)	Trial mix dry compact volumes for maximum size of aggregate indicated	
	1 inch	2 inches and over
Water-cement ratio 5½ gallons per sack		
½ to 1	1:2:3	1:2:3½.
3 to 4	1:1¾:2½	1:1¾:3.
5 to 7	1:1½:2	1:1½:2½.
Water-cement ratio 6 gallons per sack		
½ to 1	1:2¼:3¼	1:2¼:4.
3 to 4	1:2:3	1:2:3½.
5 to 7	1:1¾:2½	1:1¾:3.
Water-cement ratio 6¾ gallons per sack		
½ to 1	1:2½:3½	1:2½:4.
3 to 4	1:2¼:3¼	1:2¼:3¾.
5 to 7	1:2:3	1:2:3½.
Water-cement ratio 7½ gallons per sack		
½ to 1	1:3:4	1:3:4¾.
3 to 4	1:2½:3¾	1:2½:4¼.
5 to 7	1:2¼:3½	1:2¼:3¾.

NOTES.—1. Water-cement ratios indicated include moisture contained in the aggregate.

2. Proportions are given by volume, aggregate dry, and compact. Thus 1: 2: 3½ indicates 1 volume of cement, 2 volumes of sand, and 3½ volumes of coarse aggregate.

3. If the aggregates are to be measured in the damp and loose condition they will occupy greater volumes than when dry and compact. Amount should be determined by test. Approximate average value for sand, 20 percent; for coarse aggregate, 6 percent.

■ 85. **Quantities of Materials.**—Use table LXXVII to estimate quantities of materials required in concrete construction.

Table LXXVIIA.—*Quantities of materials*

Mix by volume, job damp materials	Materials per cubic yard of concrete			Product of a 1-bag batch (cubic feet)
	Cement (sacks)	Sand (cubic feet)	Stone (cubic feet)	
1:1¼:2	9.6	12.0	19.1	2.82
1:1½:3	7.6	11.4	22.8	3.55
1:2:3	7.1	14.2	21.3	3.82
1:2:3.5	6.5	13.0	22.7	4.16
1:2:4	6.0	12.0	24.0	4.47
1:2.2:3	6.8	15.0	20.4	3.97
1:2.2:3.5	6.3	13.9	22.2	4.26
1:2.5:3	6.5	16.1	19.4	4.18
1:2.5:3.5	6.0	15.0	21.0	4.49
1:2.5:4	5.6	14.0	22.4	4.83
1:2.5:5	5.0	12.5	25.0	5.43
1:3:5	4.7	14.1	23.5	5.76
1:3:6	4.2	12.6	25.2	6.38
1:3¼:4	5.2	16.2	20.8	5.21
1:3¼:5	4.6	14.5	23.2	5.82
1:3¾:5	4.3	16.0	21.4	6.32
1:3¾:6	3.9	14.7	23.5	6.89
1:1½	15.5	23.3	----------	1.77
1:2	12.8	25.6	----------	2.13

Table LXXVIIB.—*Dimensions for measuring boxes*

Capacity (cubic feet)	Inside measure (inches)		
	Length	Breadth	Height
1	12	12	12
1¼	15	15	9⅝
1½	15	15	11½
1¾	15	15	13½
2	18	18	10⅝
2¼	18	18	12
2½	18	18	13⅜
2¾	18	18	14⅝
3	18	18	16

282736°—41——13

■ 86. MIXING, PLACING, AND CURING.—*a. Mixing.*—Batches of concrete mixed by hand should not exceed 1 cubic yard or be larger than can be placed in 30 minutes. Machine mixing should continue for at least 1 minute after all materials are in the mixer.

b. Placing.—The following precautions should be observed:

(1) Fill forms from several points to prevent segregation.

(2) Tamp concrete in layers 1 to 2 feet in thickness.

(3) Provide construction joints to allow for temperature changes.

(4) Pour concrete continuously whenever possible. If impossible to pour continuously, remove all laitance, dust, etc., and roughen the old surface or dowel the old and new surfaces together by keyways or steel bars.

c. Curing.—(1) Concrete, in order to gain its full strength, must be kept moist for from 2 to 10 days after placing (depending on the type of cement used). This may be accomplished by—

(*a*) Covering concrete with wet burlap, canvas, straw, or earth and wetting it down periodically.

(*b*) Laying water pipe around green concrete and allowing water to trickle through small holes in pipe.

(*c*) Building earth or plank dykes around surface and keeping it flooded with water (for flat surfaces).

(*d*) Wetting forms before placing concrete to prevent absorption of mixing water by wood.

(2) The time of set is greatly affected by the curing temperatures. As the temperature falls, the set is slowed down, and below freezing weather makes the placing of concrete extremely hazardous. The temperature of setting concrete must be maintained above freezing by—

(*a*) Heating water and aggregates and addition of lime products before mixing.

(*b*) Covering concrete in place with insulating material such as straw, earth, etc.

(*c*) Providing artificial heat by canvas enclosures heated by salamanders, live steam, or unit heaters.

■ 87. FORMS.—*a. Materials.*—White pine, spruce, and the softer southern pines are the best lumber for forms. All lumber should be dressed at least on one side and both edges. Either 1- or 2-inch boards are suitable for lagging.

(1) One-inch lagging requires—
Studding or joists: 2 by 4 to 2 by 6 inches.
Distance between supports: 18 to 24 inches.

(2) Two-inch lagging requires—
Studding or joists: 4 by 6 to 4 by 10 inches.
Distance between supports: 4 to 5 feet.

b. Cleaning.—Remove all sawdust, shavings, dirt, old concrete, etc., from forms and wet or oil them before placing concrete.

c. Removal.—Usually, forms should remain in place longer for reinforced than for plain concrete, and longer for horizontal or loaded than for vertical or unstressed members. As a guide:

Walls in mass work: 1 to 3 days.
Thin walls: in summer, 2 days; in cold weather, 5 days.
Columns: in summer, 2 days; in cold weather, 4 days.

d. Type forms.—The following figures illustrate the general principles of form construction:

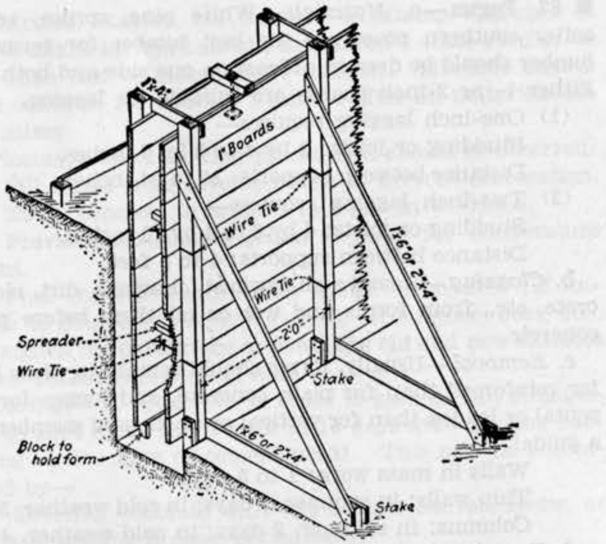


FIGURE 116.—Externally braced form.

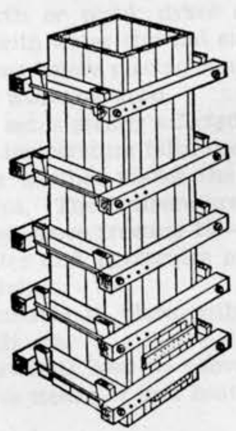


FIGURE 117.—Column form.

CHAPTER 3

DEFENSIVE MEASURES

SECTION I

FIELD FORTIFICATIONS

■ **88. DEFENSIVE AREAS.**—*a. Squad and platoon.*

TABLE LXXVIII.—*Frontages (in yards)*

Size of unit defense areas	Minimum (heavily wooded terrain)			Maximum (flat, open terrain)		
	Interval between defense areas	Frontage actually occupied	Total front defended	Interval between defense areas	Frontage actually occupied	Total front defended
1 squad (12 men)	25	30	55	100	50	150
Platoon, less 1 squad (2 squads)	50	75	125	150	100	250
Full platoon (3 squads)	100	100	200	200	200	400

b. Company.—A company can defend a front of 400 to 600 yards; front and depth actually occupied are from 200 to 400 yards and 100 to 300 yards, respectively.

c. Battalion.—A battalion can defend, in heavily wooded terrain or with limited observation and fields of fire, a front not to exceed 800 yards; in average terrain, not to exceed 1,500 yards.

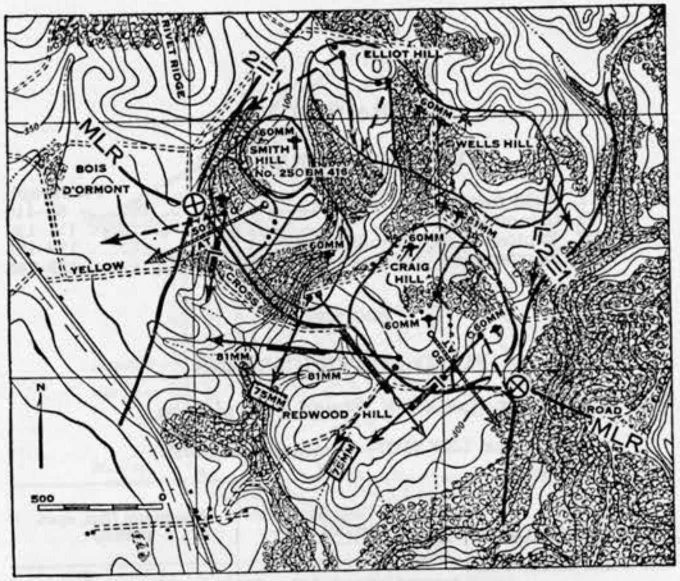


FIGURE 118.—Battalion defense area.

NOTE.—Locations and fires of all weapons of the battalion to include light machine guns of rifle companies and locations of their 60-mm mortars are shown. Primary target areas for the 81-mm mortars and normal barrages of supporting artillery are shown. Note that some of the 60-mm mortars are attached to front-line platoons and that the caliber .30 light machine guns are employed in the defense in the same manner as caliber .30 heavy machine guns.

TABLE LXXIX.—*Placing of barrages and concentrations fired by batteries of Field Artillery* (dimensions in yards)

Caliber	Type	Burst of 1 shell	Area of barrage		Area of concentration	Minimum safe distance from Infantry	
			Normal	Emergency		In open	In trenches
75-mm	Gun	5 x 30	100 x 200	100 x 300	100-300	200-500	200-400
105-mm	Howitzer	9 x 40	100 x 300	100 x 400	200-400	300-400	200-400
155-mm	Gun / Howitzer	9 x 70			200-400	600-700	300-400

■ 89. EFFECT OF PROJECTILES ON FIELD FORTIFICATION.—*a. Small arms.*

TABLE LXXX.—*Safe thickness of material to protect against non-armor-piercing bullets, caliber .30 (174 grains)*

Material	Maximum penetration (inches)	Least thickness to be provided for protection (inches)
Armor plate	0.3	0.5
Concrete (plain)	2.0	3.0
Brick masonry (well cured)	5.0	7.0
Gravel	8.0	10.0
Dry sand	12.0	14.0
Moist sand	14.5	18.0
Solid oak	20.0	24.0
Earth loam	30.0	36.0
Greasy clay	60.0	72.0

TABLE LXXXI.—*Penetration of caliber .30 and caliber .50 armor-piercing bullets*

Type	Projectile weight (grains)	Armor penetration in inches at—		Thickness of armor to provide protection (inches)
		100 yards	300 yards	
Caliber .30, M6	174	⅝		1
Caliber .50, M6	753		1	2

TABLE LXXXII.—*Penetration of special armor-piercing weapons*

Antitank (AT) gun	Projectile weight (pounds)	Muzzle velocity (feet per second)	Armor penetration in inches at—	
			600 yards, normal impact	1,000 yards 20° impact
25-mm	0.72	3,000	1.95	1.3
37-mm	1.85	2,600	2.20	1.5
47-mm	3.50	2,000	1.90	1.2

b. Artillery and aircraft.—Formula for maximum penetration of projectiles, impact normal:

$$P=\frac{0.23\,WAK}{D^2}$$

where

P=penetration of projectile in feet.
W=weight of projectile in pounds.
D=diameter of projectile in inches.
A=a constant depending on striking velocity according to table LXXXIII.

TABLE LXXXIII.—*Values of A in penetration formula*

Velocity (feet per second)	A	Velocity (feet per second)	A	Velocity (feet per second)	A
130	0.33	657	4.77	1,180	8.76
197	.72	720	5.34	1,250	9.15
262	1.21	788	5.89	1,320	9.54
328	1.76	854	6.41	1,375	9.92
394	2.36	920	6.92	1,445	10.29
460	2.97	985	7.40	1,510	10.64
525	3.58	1,050	7.87	1,575	10.98
592	4.17	1,113	8.31	1,640	11.20

K=a constant, depending upon the nature of the resistance, as follows:

0.64 for concrete masonry.
0.94 for stone.
1.63 for brickwork.
2.94 for sandy earth.
3.86 for ploughed earth.
5.87 for clay soil.

W and D must be obtained from characteristic tables of the projectile under consideration.

TABLE LXXXIV.—*Penetration of field artillery projectiles in ordinary compact soil*

Caliber	Striking velocity (feet per second)	Angle of impact (degrees)	Penetration (feet)	
			Vertical	Horizontal
75-mm	730	45	4	4
105-mm	800	45	5	5
155-mm	770	45	7	7
8-inch	790	45	9	9
240-mm	806	45	14	14

TABLE LXXXV.—*Effect of angle of impact on penetration of artillery projectiles*

Angle of impact	Behavior of projectile
Less than 7°	Ricochets.
7° to 25°	Ricochets after traveling short distance or remains in ground at slight depth.
25° to 40°	Tendency for nose of projectile to turn toward surface. Slight penetration.
Greater than 40°	Maximum penetration.

TABLE LXXXVI.—*Crater dimensions of artillery projectiles*

Caliber	Slight penetration		Medium penetration	
	Diameter (feet)	Depth (feet)	Diameter (feet)	Depth (feet)
75-mm	4	1.5	5	3
105-mm	6.5	2.5	7.5	3.75
155-mm	10	4	12	5
8-inch	11.5	4	13.5	5
240-mm	14	4	15.5	5.5

c. Aircraft bombs.

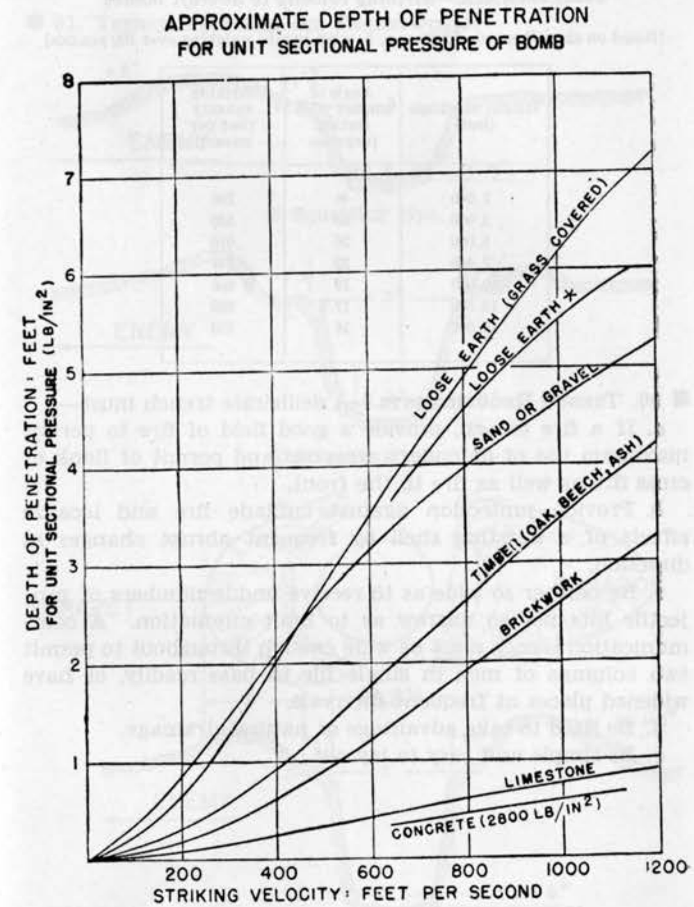
TABLE LXXXVII.—*Crater dimensions of aircraft bombs in sandy loam*

Weight of bomb (pounds)	Depth of crater (feet)	Diameter at surface (feet)	Earth displaced (cubic yards)
With instantaneous fuze:			
100	2	9	4
300	3	13	10
600	5	17	17
1,100	6	20	28
2,000	7	22	47
With delay fuze:			
100	5	20	30
300	7	27	70
600	10	37	170
1,100	13	45	320
2,000	17	50	600

TABLE LXXXVIII.—*Typical dimensions of aircraft bombs*

Weight of bomb (pounds)	Over-all length [1] (feet)	Maximum diameter (inches)	Sectional pressure [2] (pounds per square inch)
2,000 (light case)	14 (9)	24	4.4
1,100 (heavy case)	6 (4)	12	9.7
550 (medium case)	5 (4)	15	3.1
220 (medium case)	4½ (2)	10	2.8
100 (medium case)	4 (2)	9	1.6
20 (antipersonnel)	2 (1)	5	1.0

[1] Figures in parentheses in this column are lengths of charge container only.
[2] Weight divided by maximum cross-sectional area.



NOTE.—Gives approximate depth of penetration at normal angles of impact, for unit sectional pressure. To obtain total penetration multiply value for penetration taken from the figure by sectional pressure given in Table LXXXVIII.

FIGURE 119.—Penetration of aircraft bombs.

TABLE LXXXIX.—*Striking velocity of aircraft bombs*

[Based on aircraft speed of 200 m. p. h. with bombs weighing over 100 pounds]

Height of release (feet)	Angle of impact with vertical (degrees)	Striking velocity (feet per second)
1,000	46	290
3,000	33	520
5,000	26	610
7,500	22	710
10,000	19	800
12,500	17.5	880
15,000	16	950

■ 90. TRENCH REQUIREMENTS.—A deliberate trench must—

a. If a fire trench, provide a good field of fire to permit maximum use of defender's weapons and permit of flank or cross fire as well as fire to the front.

b. Provide protection against enfilade fire and localize effects of a bursting shell by frequent abrupt changes in direction.

c. Be neither so wide as to receive undue numbers of projectile hits nor so narrow as to limit circulation. A communication trench must be wide enough throughout to permit two columns of men in single file to pass readily, or have widened places at frequent intervals.

d. Be sited to take advantage of natural drainage.

e. Be simple and easy to lay out.

■ 91. TRENCH PROFILES AND BREASTWORKS.

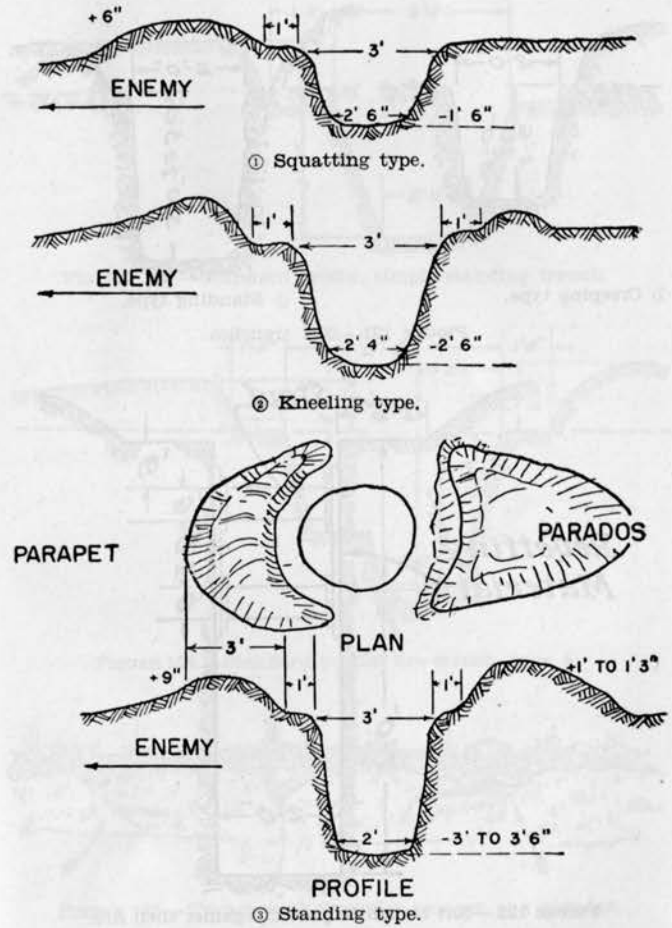
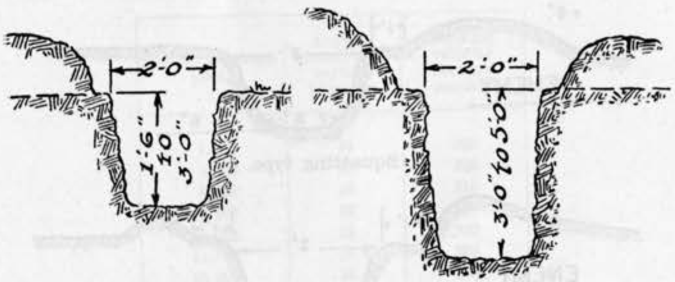


FIGURE 120.—Development of a fox hole.



① Creeping type. ② Standing type.

FIGURE 121.—Slit trenches.

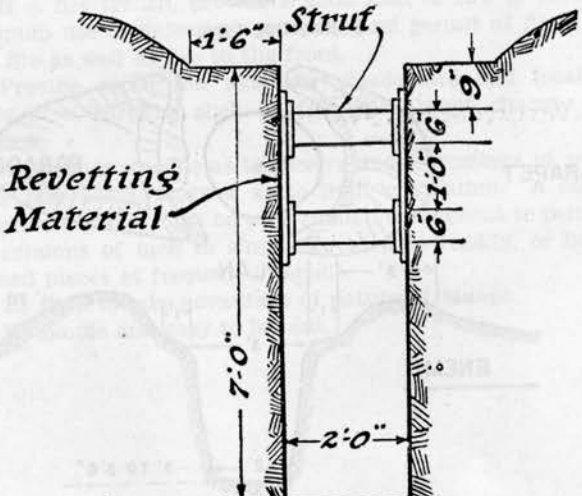


FIGURE 122.—Slit trench to protect against shell fire.

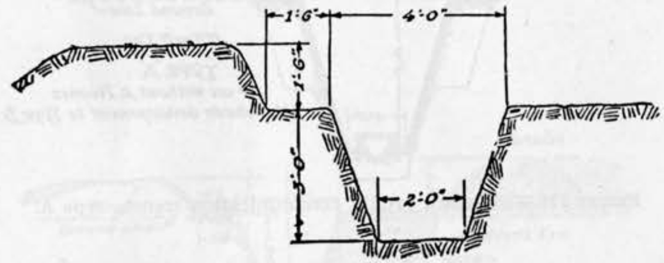


FIGURE 123.—Standard profile, simple standing trench.

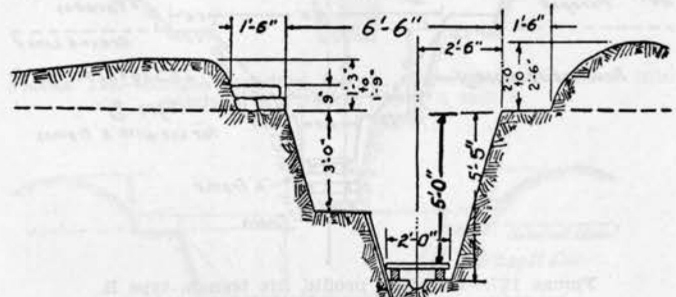


FIGURE 124.—Standard profile, fire trench, type A.

FIGURE 125.—Trench with irregular parapet and parados.

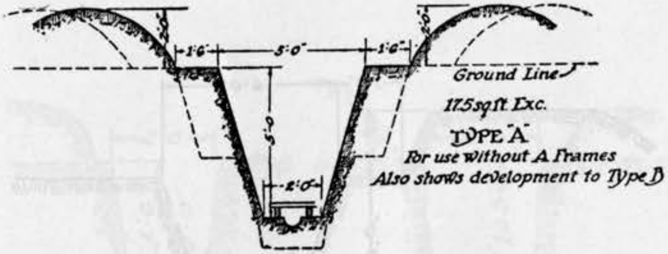


FIGURE 126.—Standard profile, communication trench, type A.

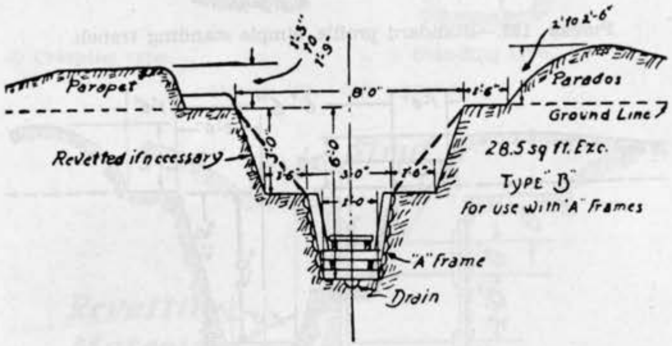


FIGURE 127.—Standard profile, fire trench, type B.

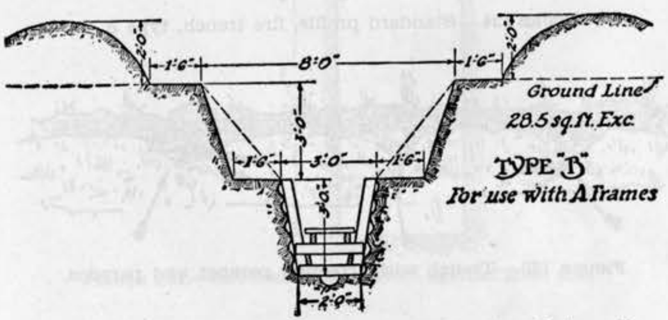


FIGURE 128.—Standard profile, communication trench, type B.

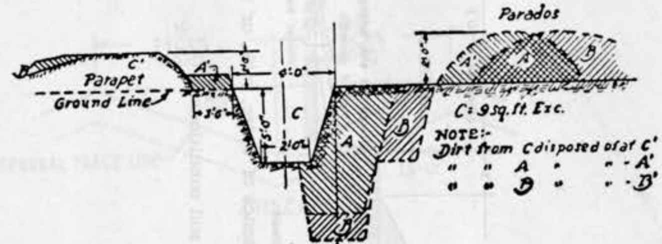


FIGURE 129.—Simple standing trench, showing development into standard fire trench, types A and B.

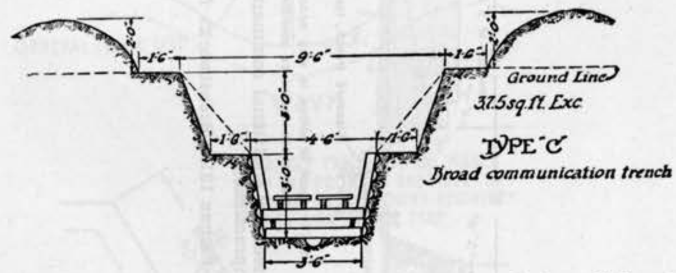
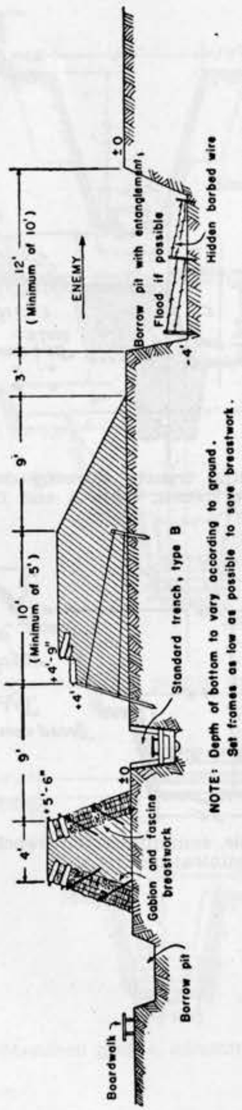


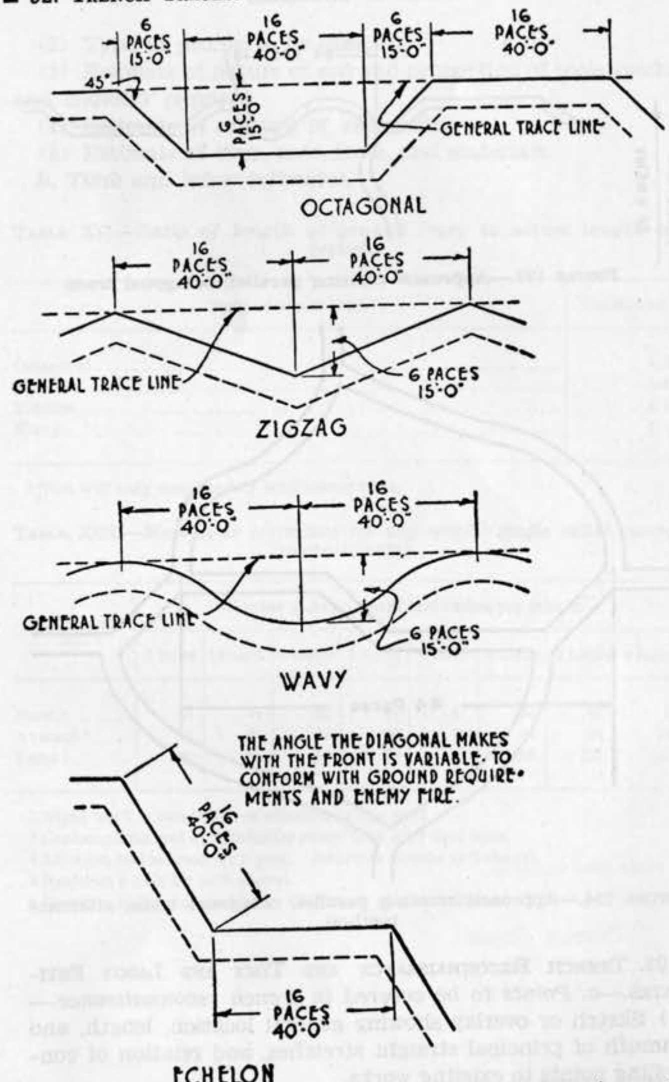
FIGURE 130.—Standard profile, communication trench, type C; broad communication trench.



NOTE.—Used if there is need for additional command or if presence of water, rock, or very hard material makes standard trench impracticable.

FIGURE 131.—Breastworks for difficult soil conditions.

■ 92. TRENCH TRACES.



NOTE.—For squads with over 8 men all 16-pace dimensions may be increased 2 paces per additional man. Make a general change in direction every 75 to 125 paces.

FIGURE 132.—Standard trench traces.

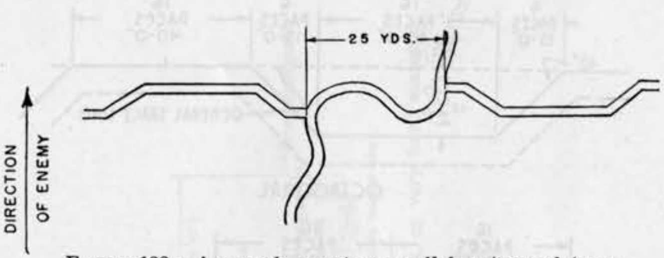


FIGURE 133.—Approach crossing parallel, octagonal trace.

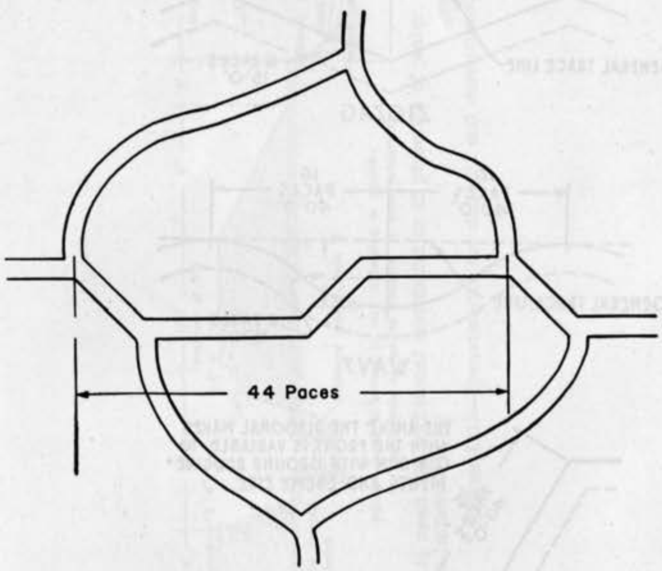


FIGURE 134.—Approach crossing parallel, octagonal trace, alternate method.

■ 93. TRENCH RECONNAISSANCE AND TIME AND LABOR ESTIMATES.—*a. Points to be covered in trench reconnaissance.*—(1) Sketch or overlay showing general location, length, and azimuth of principal straight stretches, and relation of controlling points to existing works.

(2) Type of profile to be used.

(3) Estimate of nature of soil and proportion of tools (picks and shovels) required.

(4) Estimate of amount of excavation.

(5) Estimate of time, men, tools, and materials.

b. Time and labor estimates.

TABLE XC.—*Ratio of length of general trace to actual length of trench.*

Type of trench trace	Coefficient
Octagonal	1.09
Zigzag	1.07
Echelon	[1] 1.08
Wavy	1.11

[1] This will vary considerably with actual trace.

TABLE XCI.—*Man-hour estimates for day work,*[1] *single relief, using pioneer tools*[2]

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

[1] Night work is two-thirds as effective as day work.
[2] Contemplates rest of 10 minutes every hour after first hour.
[3] All must be loosened with pick. Requires 2 picks to 1 shovel.
[4] Requires a pick for each shovel.
[5] Requires little or no picking. Requires 1 pick to 2 shovels.

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

Nature of soil	Type A unrevetted								Type B revetted			
	Fire trench				Communication trench				Fire and communication trench			
	One relief		Two reliefs		One relief		Two reliefs		One relief		Two reliefs	
	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet	3½ feet	5 feet
Hard	85%	60%	5.5	7.25	7.0	75%	4.0	5.75	65%	45%	7.00	80%
Average	5.75	90%	3.5	5.0	4.0	6.75	2.75	4.0	95%	65%	4.5	6.5
Light	3.75	6.0	7.5	3.5	2.75	4.5	2.0	3.0	6.00	85%	3.5	5.0

TABLE XCIII.—*Man-hours for clearing brush for fields of fire*

Nature of area to be cleared	Method	Man-hours required
Area 100 square yards covered with brush under 6 inches in diameter and contains 25 trees 6 inches to 2 feet in diameter (heavy clearing).	Chopping or sawing trees and clearing brush.	7
Area 100 square yards covered with undergrowth and some trees not exceeding 12 inches in diameter (medium clearing).	do	3.5
Area 100 square yards covered only with small brush (light clearing).	Clearing brush	1.5

■ 94. TRENCH DRAINAGE.

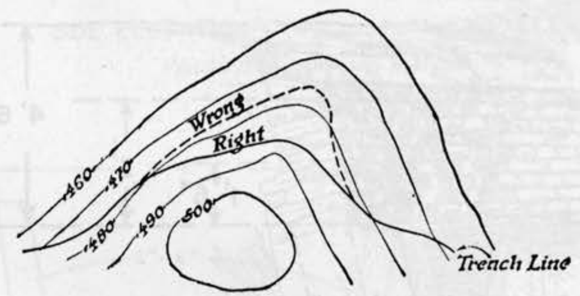


FIGURE 135.—Siting trenches to eliminate low spots.

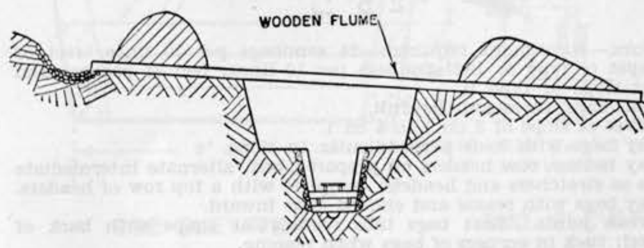


FIGURE 136.—Surface water carried over trench.

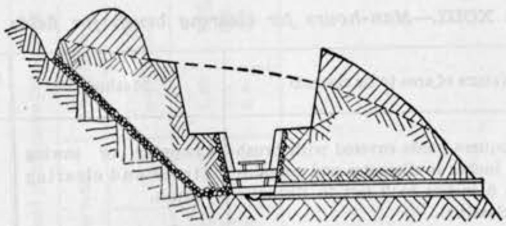
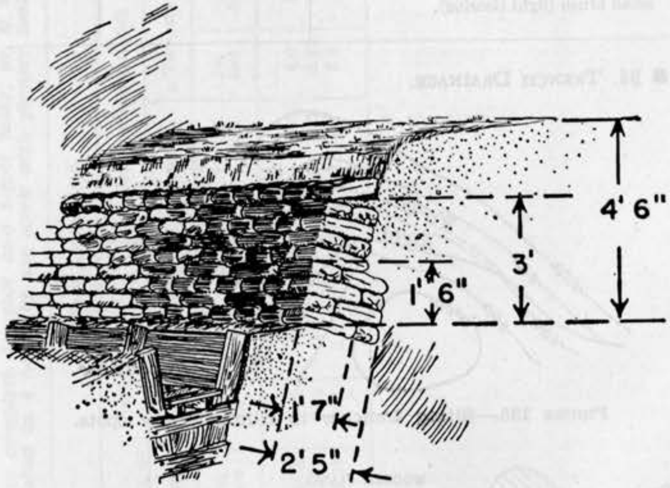


FIGURE 137.—Surface water carried under trench.

■ 95. TRENCH REVETMENT.



NOTE.—Revetment required.—24 sandbags per 10 linear feet of parapet of type A; 132 sandbags per 10 linear feet of parapet and front slope of type B.

Fill bags three-fourths full.

Revet at slope of 3 on 1 to 4 on 1.

Lay bags with beds perpendicular to slope.

Lay bottom row headers on prepared bed; alternate intermediate rows as stretchers and headers; complete with a top row of headers.

Lay bags with seams and choked ends inward.

Break joints. Beat bags into rectangular shape with back of shovel; tuck in corners of bags when placing.

Revetment will last longer if wire netting, preferably doubled, is anchored over face.

FIGURE 138.—Sandbag revetment.

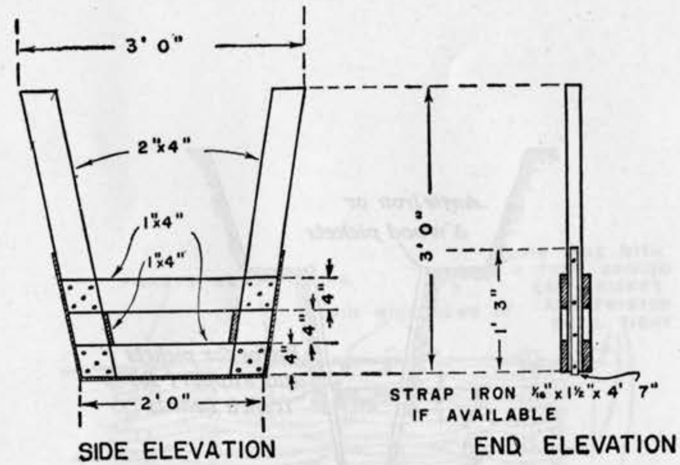


FIGURE 139.—Standard A-frame.

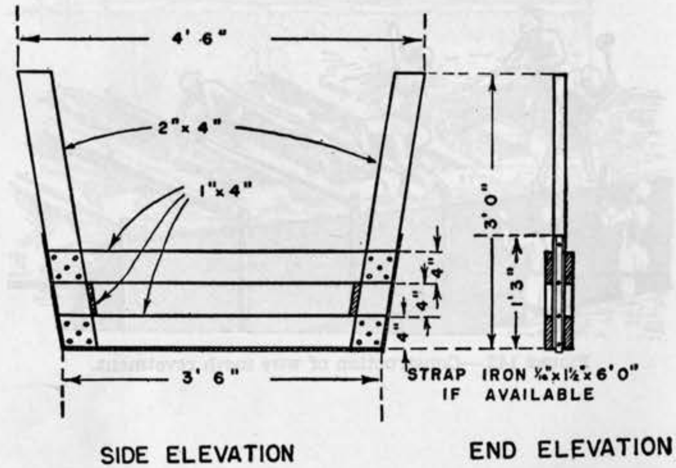


FIGURE 140.—Special A-frame for use in communication trench, type C.

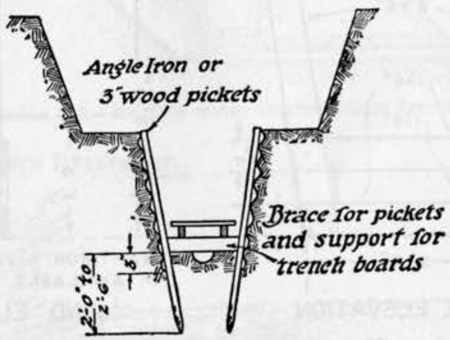


FIGURE 141.—Braced revetting pickets.

FIGURE 142.—Construction of wire mesh revetment.

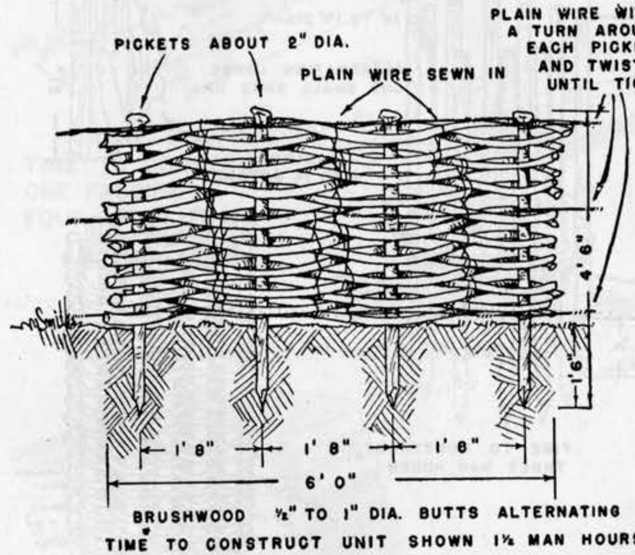


FIGURE 143.—Brush hurdle.

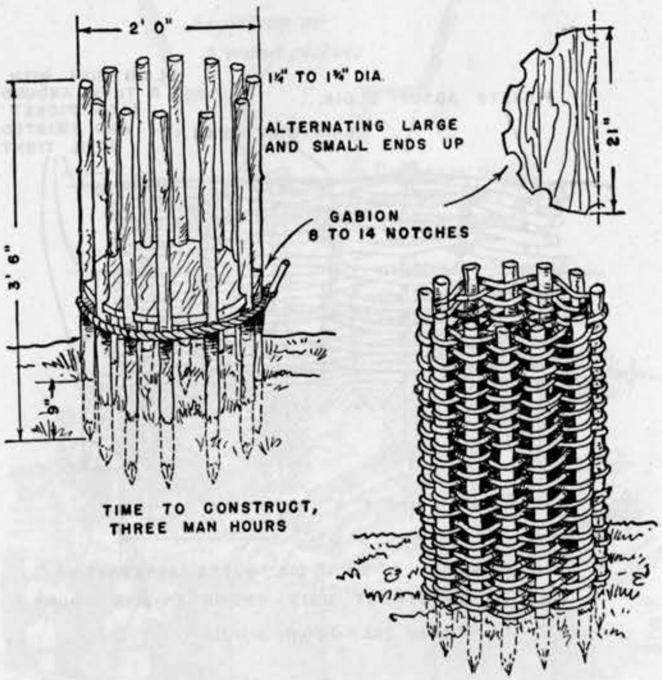


FIGURE 144.—Brush gabion.

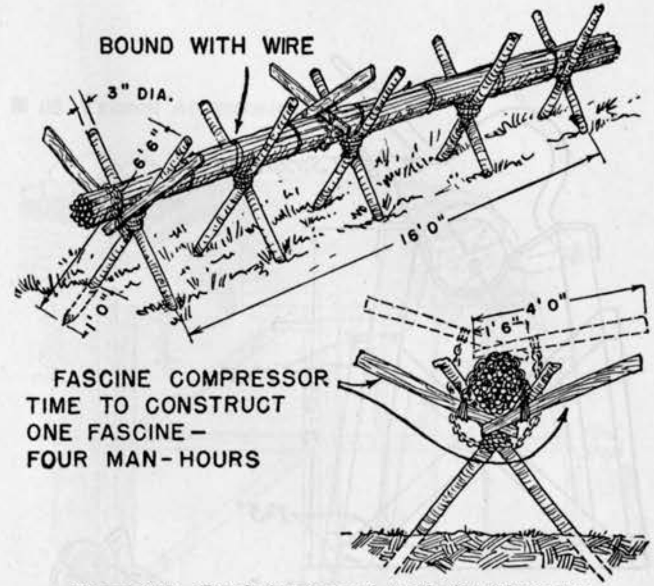


FIGURE 145.—Brush fascine and cradle for fabrication.

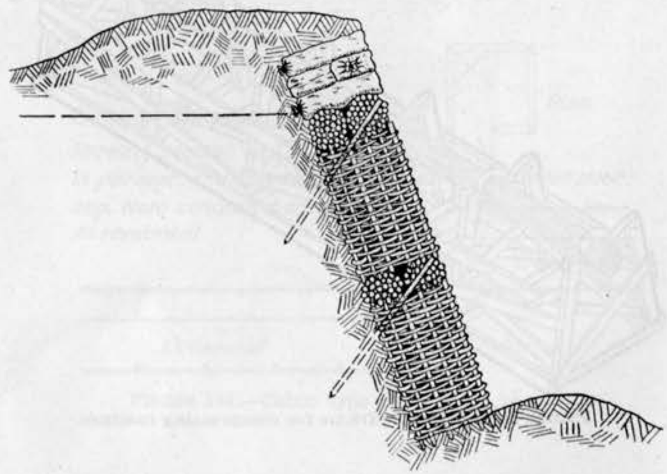


FIGURE 146.—Gabion and fascine breastwork topped with sandbags.

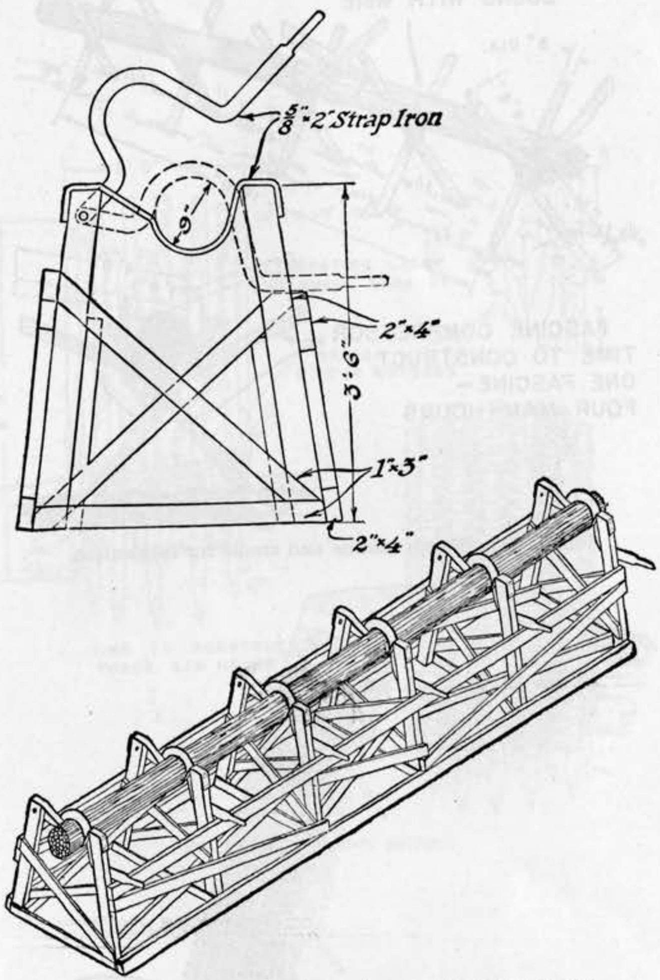


FIGURE 147.—Portable frame for compressing fascines.

■ 96. TRENCH ACCESSORIES.

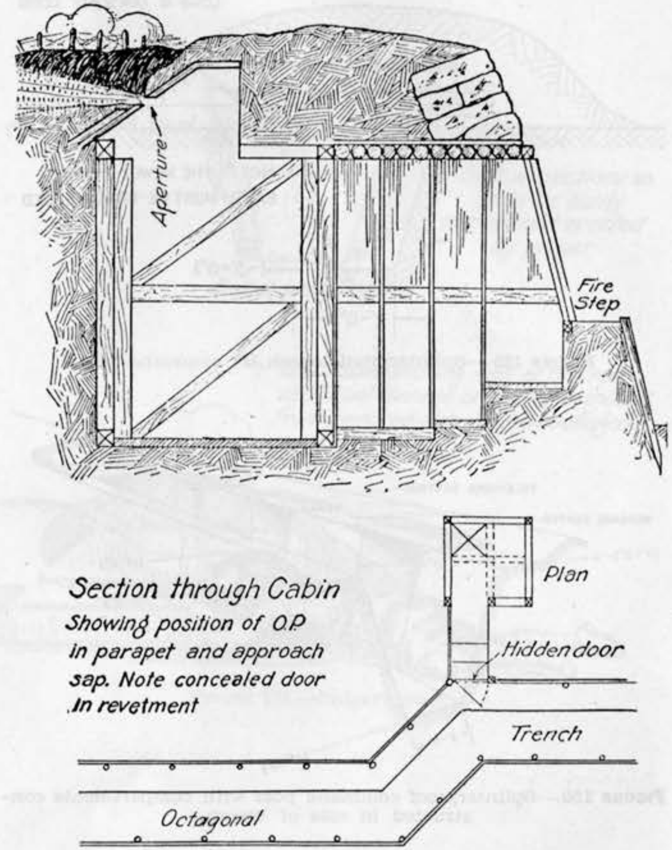


FIGURE 148.—Cabin type observation post.

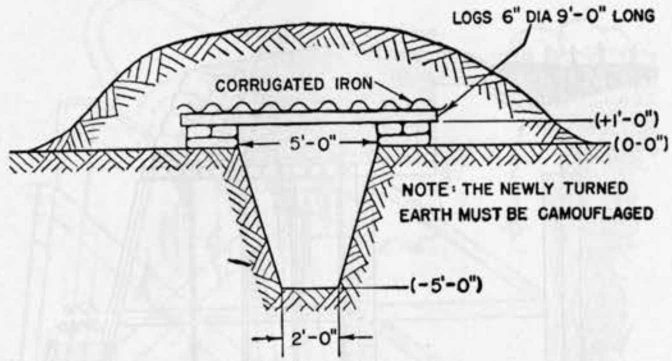


FIGURE 149.—Splinterproof trench for command post.

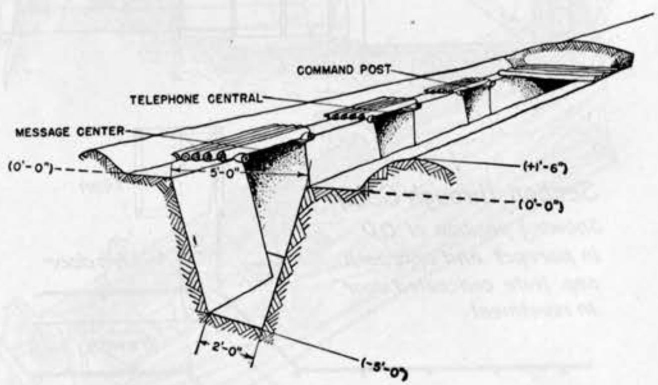


FIGURE 150.—Splinterproof command post with compartments constructed in side of trench.

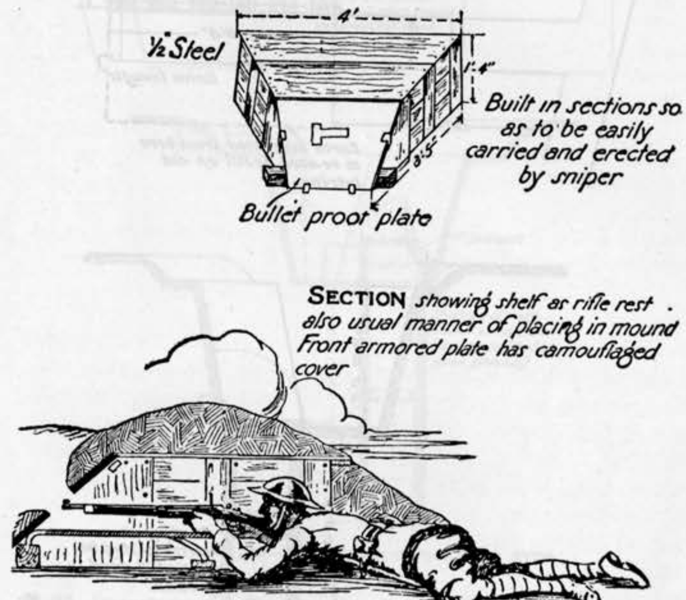
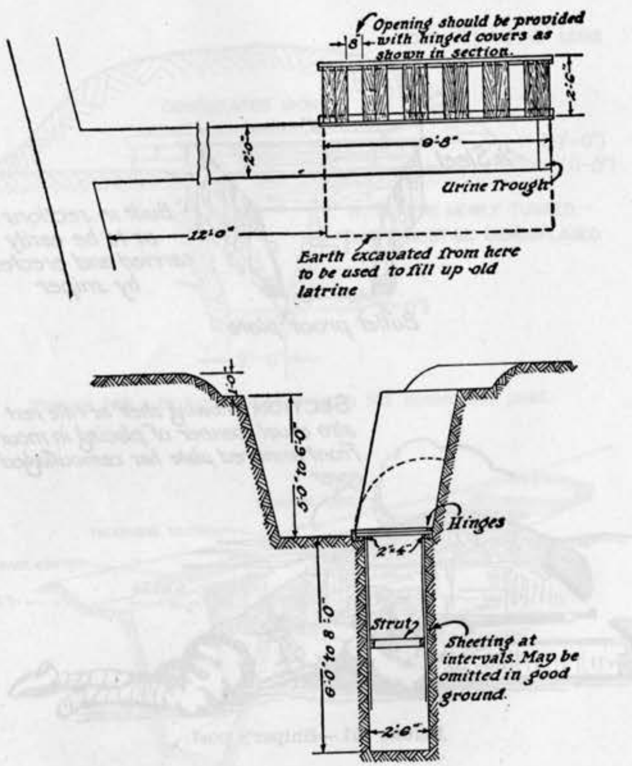


FIGURE 151.—Sniper's post.



NOTE.—Should accommodate at least 4 percent of command and 8 percent for long periods.

FIGURE 152.—Deep latrine, straddle type.

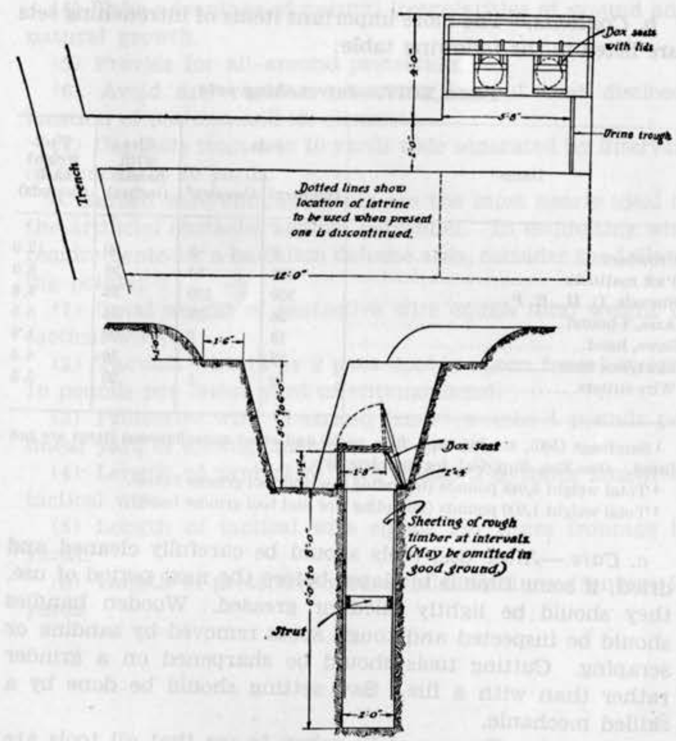


FIGURE 153.—Deep latrine, box-seat type.

■ 97. INTRENCHING TOOLS.—*a. Issue.*—Sets of intrenching tools are included in the equipment of the following units:

	Infantry sets
Engineer battalion, combat (triangular division)	3
Engineer regiment, combat (square division)	6
Engineer regiment, combat (corps)	2
	Cavalry sets
Engineer squadron	4

b. Contents.—The more important items of intrenching sets are listed in the following table:

TABLE XCIV.—*Intrenching sets*

Items [1]	Sets		Size with handle (inches)	Unit weight each (pounds)
	Infantry [2]	Cavalry [3]		
Crowbars	4	2	60	12.0
Pick mattocks	125	65	36	8.0
Shovels, D. H., R. P	250	130	39	4.6
Axes, 4-pound	26	13	36	5.5
Saws, hand	13	6	26	1.8
Saws, one man	13	7	36	4.5
Wire cutters	9	6	20	5.3

[1] Sandbags (500), tracing tape, files, nails, and other miscellaneous items are not listed. (See Eng. Sup. Cat. for complete lists.)

[2] Total weight 3,048 pounds (including saw and tool grinder boxes).

[3] Total weight 1,800 pounds (including saw and tool grinder boxes).

c. Care.—After use, tools should be carefully cleaned and dried; if some time is to elapse before the next period of use, they should be lightly oiled or greased. Wooden handles should be inspected and rough spots removed by sanding or scraping. Cutting tools should be sharpened on a grinder rather than with a file. Saw setting should be done by a skilled mechanic.

d. Storage.—Care must be taken to see that all tools are returned to proper boxes and that each box contains the number and kind of tools specified on the list attached thereto. A dry, well-ventilated place is needed for the storage of tools, as well as for sandbags, tape, and similar accessories. If bags become wet they should be dried separately before being bundled and put away. Tools are wired together in bundles of five for ease in handling.

■ 98. GENERAL PROCEDURES IN LOCATION, DESIGN, AND CONSTRUCTION OF OBSTACLES.—*a.* (1) Cover throughout by fire.

(2) Have protective obstacles under observation at all times.

(3) Deny to enemy cover of sheltering ground.

(4) Take advantage of natural irregularities of ground and natural growth.

(5) Provide for all-around protection.

(6) Avoid any regular, geometric lay-out that discloses location of position and its elements.

(7) Use belts from 4 to 10 yards wide separated by intervals of from 15 to 40 yards.

b. Barbed wire entanglements are the most nearly ideal of the artificial obstacles against personnel. In estimating wire requirements for a battalion defense area, consider the following points:

(1) Total weight of protective wire equals total weight of tactical wire.

(2) Tactical wire (4 by 2 pace double-apron fence) weighs 10 pounds per linear yard of entanglement.

(3) Protective wire (4-strand fence) weighs 4 pounds per linear yard of entanglement.

(4) Length of protective wire equals 2½ times length of tactical wire.

(5) Length of tactical wire equals 1¼ times frontage in yards.

(6) Length of protective wire equals 3⅛ times frontage in yards.

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

Type of entanglement	Pickets			Barbed wire			Plain wire (pounds)		Staples made of ⅜-inch round rods	Man-hours for 50 yards of entanglement [1]	Weight of material (pounds) (pickets and wire) per linear yard of entanglement
	Long	Medium	Anchor	420-yard reels	30-yard bobbins	On reels (pounds)	No. 10	No. 16			
High wire	640		[2] 320	[3] 46	640	[4] 4,830				[5] 9	12
Double apron:											
4 and 2 pace	320		640	37	520	3,885				[5] 5	10
6 and 3 pace	220		440	37	520	3,885				[5] 4½	8
Low wire		220	440	29	400	3,045				[5] 3½	6.25
Concertina (2 cylinders) side by side)	302			75		7,875	700	90	600	[6] 3	12
Four-strand wire fence (protective wire around combat groups)	300			11	154	1,155				[5] 2	4

[1] Specially skilled crews of picked men, undisturbed, have erected entanglements in less than ¼ of times stated in this column.
[2] For front anchorage, if used.
[3] Plus 3 if front anchorages are used.
[4] Plus 315 if front anchorages are used.
[5] Erection of entanglement only, does not include making bobbins or carrying party. Man-hours for carrying party vary depending on distance and rate of carrying.
[6] Erection of fence only; does not include making of cylinders or carrying party.

TABLE XCVI.—*Characteristics of wire-entanglement materials*

	Weight	Length		Number easily carried by one man	Weight of one-man load
	Pounds	*Ft.*	*In.*		*Pounds*
Wooden pickets:					
Long, 3- to 4- inch diameter	12-16	5	0	3	36-48
Short, 2- to 3- inch diameter	4-8	2	6	8	32-48
Screw pickets:					
Long	9	4	10	4	36
Medium	6	2	8	6	36
Anchor	4	1	9	8	32
Angle iron:					
Long	10	6	0	4	40
Short	6	3	8	6	36
Full reel wire, 420 yards	105	1,260		½	[1] 52.5
Bobbin, 30 yards	8-9	90		4-6	32-54

[1] Full-sized reels are carried by 2 men upon their shoulders by means of stake or picket passed through hole in reel.

99. Types of Standard Wire Entanglements.

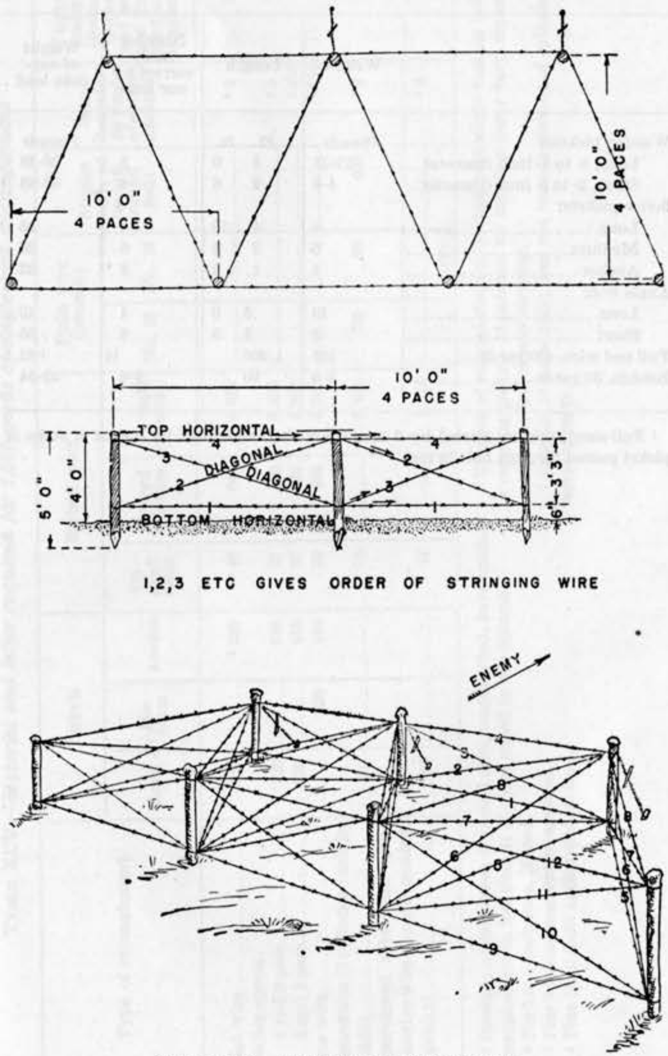


Figure 154.—High wire entanglement.

Table XCVII.—*Drill for erecting 50 yards of high wire entanglement (two rows of stakes)*

Materials	Wiring party	Carrying party
8 bundles (total of 32) long pickets. 32 30-yard bobbins barbed wire.	1 noncommissioned officer (carries pliers). 16 men (each carries a rack stick). 1 man, carrier.	1 noncommissioned officer. 18 men.

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

Note.—Numbers 1 to 4 place pickets lightly in ground. In stringing, odd numbers run out bobbins, even numbers fix wire to pickets.

TABLE XCVII.—*Drill for erecting 50 yards of high wire entanglement (two rows of stakes)*—Continued

Each additional row of high-wire entanglement

Material	Wiring party	Carrying party
4 bundles (total of 16) long pickets. 24 30-yard bobbins.	1 noncommissioned officer. 10 men.	1 noncommissioned officer. 12 men.

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

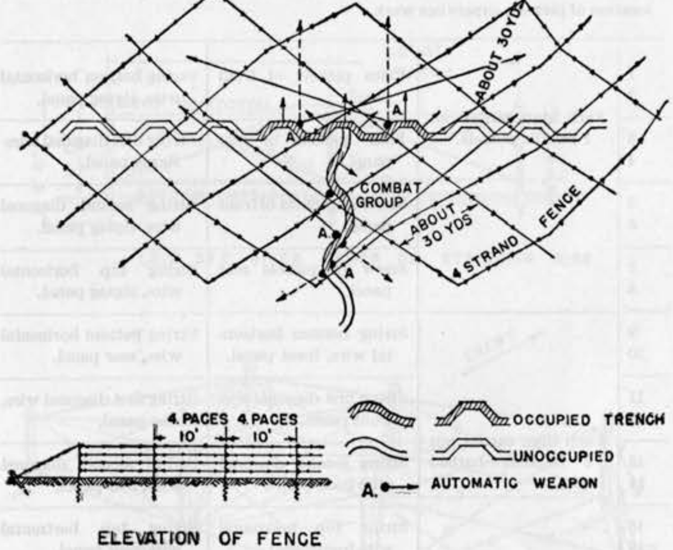


FIGURE 155.—Spider web entanglement, showing use of 4-strand fences as obstacles around combat group without disclosing occupied portion of trenches. Can be developed into single or double-apron fence.

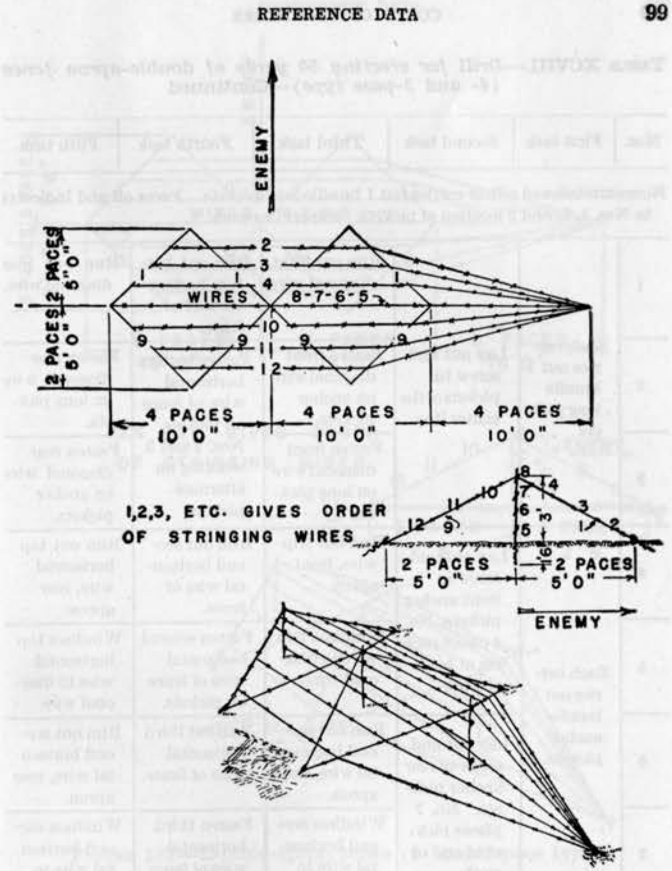


FIGURE 156.—Double-apron fence (4- and 2-pace type).

TABLE XCVIII.—*Drill for erecting 50 yards of double-apron fence (4- and 2-pace type).*

Material	Wiring party	Carrying party
4 bundles (16) long pickets. 4 bundles (32) anchor pickets. 26 30-yard bobbins barbed wire.	1 noncommissioned officer (carries pliers). 9 men (carry rack sticks).	1 noncommissioned officer. 15 men.

Table XCVIII.—*Drill for erecting 50 yards of double-apron fence (4- and 2-pace type)*—Continued

Nos.	First task	Second task	Third task	Fourth task	Fifth task
	Noncommissioned officer carries out 1 bundle long pickets. Paces off and indicates to Nos. 1, 2, and 3 location of pickets. Supervises work.				
1			Run out front diagonal wire.	Run out bottom horizontal wire of fence.	Run out rear diagonal wire.
2	Each carries out 1 bundle long pickets.	Lay out and screw in pickets of the center line.	Fasten front diagonal wire on anchor pickets.	Fasten bottom horizontal wire of fence on pickets, Nos. 2 and 3 working on alternate pickets.	Fasten rear diagonal wire on long pickets.
3			Fasten front diagonal wire on long pickets.		Fasten rear diagonal wire on anchor pickets.
4		Lay out and screw in front anchor pickets. No. 4 places pickets at head of work.	Run out trip wire, front apron.	Run out second horizontal wire of fence.	Run out top horizontal wire, rear apron.
5	Each carries out 1 bundle anchor pickets.		Windlass trip wire to diagonal wire.	Fasten second horizontal wire of fence on pickets.	Windlass top horizontal wire to diagonal wire.
6		Lay out and screw in rear anchor pickets. No. 7 places picket at end of work.	Run out second horizontal wire, front apron.	Run out third horizontal wire of fence.	Run out second horizontal wire, rear apron.
7			Windlass second horizontal wire to diagonal wire.	Fasten third horizontal wire of fence on pickets.	Windlass second horizontal wire to diagonal wire.
8	Carry out 26 bobbins of barbed wire.	(cont.)	Run out top horizontal wire, front apron.	Run out top horizontal wire of fence.	Run out trip wire, rear apron.
9			Windlass top horizontal wire to diagonal wire.	Fasten top horizontal wire of fence on pickets.	Windlass rear trip wire to diagonal wire.

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

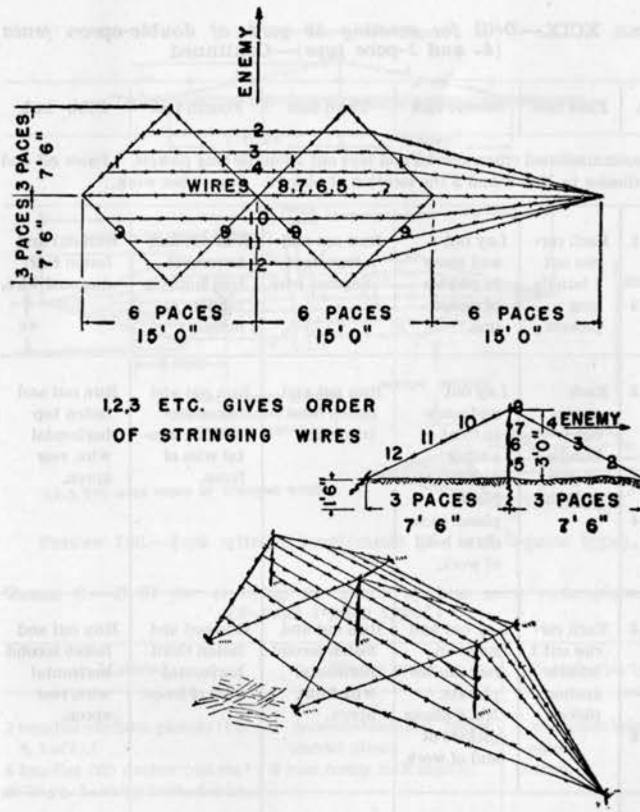


Figure 157.—Double-apron fence (6- and 3-pace type).

Table XCIX.—*Drill for erecting 50 yards of double-apron fence (6- and 3-pace type)*

Material	Wiring party	Carrying party
3 bundles (total of 11) long pickets. 4 bundles (total of 22) anchor pickets. 26 30-yd. bobbins barbed wire.	1 noncommissioned officer (carries pliers). 8 men (carry rack sticks).	1 noncommissioned officer. 15 men.

Table XCIX.—*Drill for erecting 50 yards of double-apron fence (6- and 3-pace type)*—Continued

Nos.	First task	Second task	Third task	Fourth task	Fifth task
Noncommissioned officer carries and lays out 1 bundle long pickets. Paces off and indicates to Nos. 1 and 2 the location of pickets. Supervises work.					
1 2	Each carries out 1 bundle long pickets	Lay out and screw in pickets of center line.	Run out and fasten front diagonal wire	Run out and fasten bottom horizontal wire of fence.	Run out and fasten rear diagonal wire.
3 4	Each carries out 1 bundle anchor pickets.	Lay out and screw in front anchor pickets. No. 3 places pickets at head of work.	Run out and fasten front trip wire.	Run out and fasten second horizontal wire of fence.	Run out and fasten top horizontal wire, rear apron.
5 6	Each carries out 1 bundle anchor pickets.	Lay out and screw in rear anchor pickets. No. 6 places pickets at end of work.	Run out and fasten second horizontal wire front apron.	Run out and fasten third horizontal wire of fence.	Run out and fasten second horizontal wire, rear apron.
7 8	Carry out 26 bobbins of wire.		Run out and fasten top horizontal wire, front apron.	Run out and fasten top horizontal wire of fence.	Run out and fasten trip wire, rear apron.

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

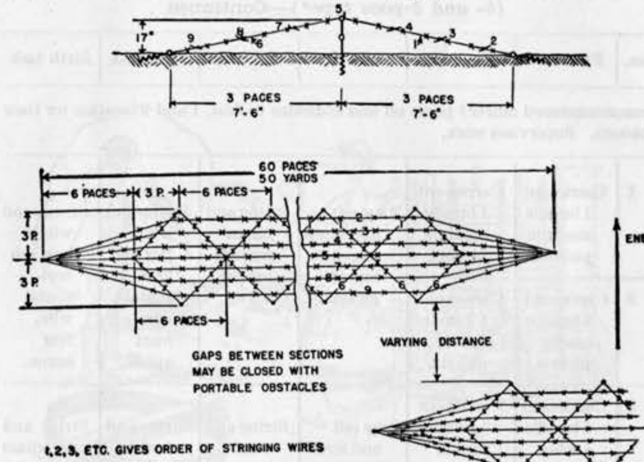


Figure 158.—Low wire entanglement (6- and 3-pace type).

Table C.—*Drill for erecting 50 yards of low wire entanglement (6- and 3-pace type*)*

Material	Wiring party	Carrying party
2 bundles medium pickets (1 of 6, 1 of 5).[1] 4 bundles (22) anchor pickets.[2] 20 30-yd. bobbins barbed wire.	1 noncommissioned officer (carries pliers). 6 men (carry rack sticks).	1 noncommissioned officer. 13 men.

* Changes in drill for low wire (4- and 2-pace type):
[1] Three bundles medium pickets (1 of 6, 2 of 5 each).
[2] Four bundles (32) anchor pickets.

TABLE C.—*Drill for erecting 50 yards of low wire entanglement (6- and 3-pace type*)*—Continued

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

*Changes in drill for low wire (4- and 2-pace type):

[1] 3 bundles medium pickets (1 of 6, 2 of 5 each).

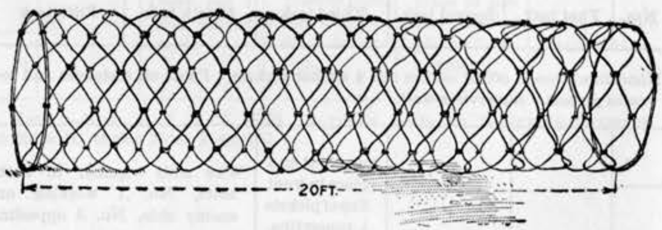
[2] 4 bundles (32) anchor pickets.

[3] Carries out 1 bundle medium pickets. Paces off and indicates to Nos. 1 and 2 location for their pickets. Lays out own pickets. Supervises work.

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

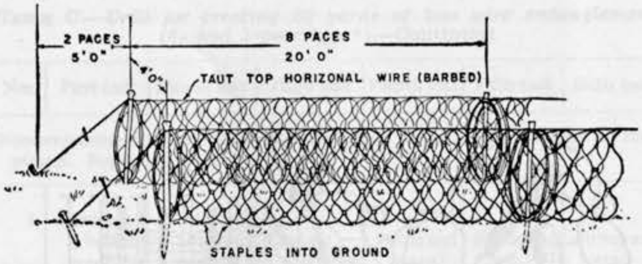
① Element collapsed and prepared for carrying.

② Method of making concertina element with either plain or barbed wire.



③ Concertina extended.

FIGURE 159.—Concertina.



CONCERTINA EXTENDED

FIGURE 160.—Double-belt concertina entanglement.

TABLE CI.—*Drill for erecting 50 yards of concertina entanglement*

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

Nos.	First task	Second task	Third task	Fourth task	Fifth task
Noncommissioned officer carries out 4 anchor pickets. Paces off distances and locates pickets. Supervises work.					
1			Open out and place in front line of pickets 1 concertina.	Wire coils together in both belts, No. 1 working on enemy side, No. 2 opposite.	
2	Carry out 4 long pickets each.	Each lays out and screws in 4 long pickets.	Open out and place in front line of pickets 1 concertina.	Open out and place in second line of pickets 1 concertina.	Run horizontal wire along top of pickets, first row.
3					
4					Fasten wire to pickets.

TABLE CI.—*Drill for erecting 50 yards of concertina entanglement*—Continued

Nos.	First task	Second task	Third task	Fourth task	Fith task
5	Carries out 1 concertina and cut tie tapes.	Lays out and screws in 4 anchor pickets.	Open out and place in front line of pickets 2 concertinas.	Open out and place in second line of pickets 2 concertinas.	Windlass coils to wire at 3 points between each 2 pickets.
6		Carry out concertina coil and cut tie tapes.			Run horizontal wire along top of pickets, second row.
7	Carry out 2 concertinas and cut tie tapes.		Open out and place in front line of pickets 2 concertinas.	Open out and place in second line of pickets 2 concertinas.	Fasten wire to pickets.
8					Windlass coils to wire at 3 points between each 2 pickets.
9		Carry out 1 coil barbed wire.	Open out and place in front line of pickets 1 concertina.	Open out and place in second line of pickets 2 concertinas.	Staple down both belts.
10					

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

■ 100. CONSTRUCTION DETAILS FOR WIRE ENTANGLEMENTS.

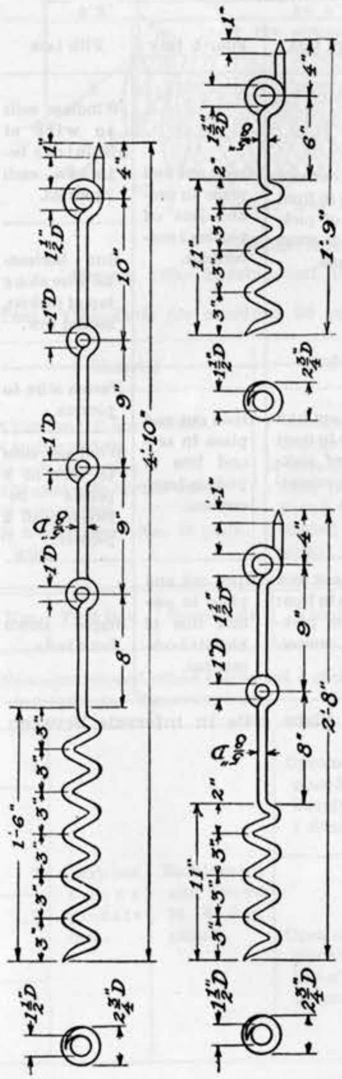


FIGURE 161.—Screw pickets.

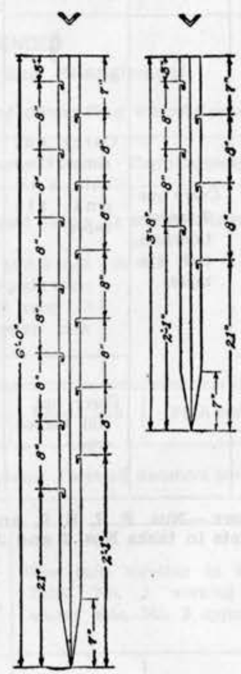
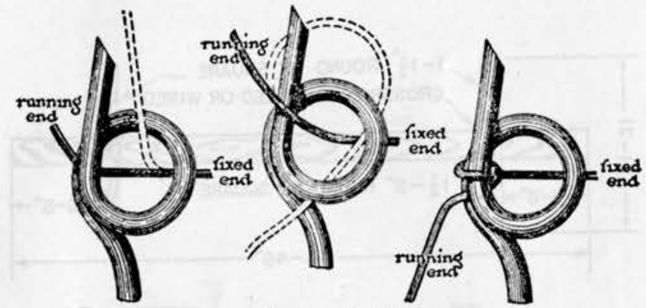
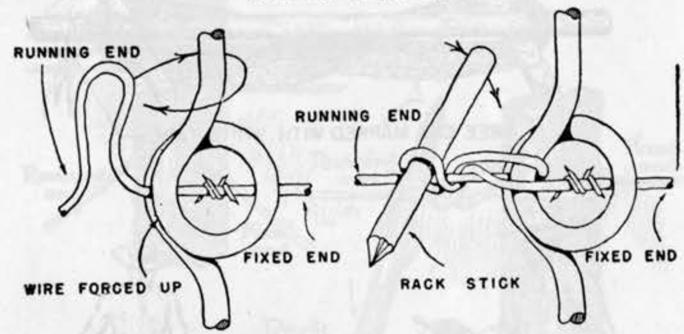


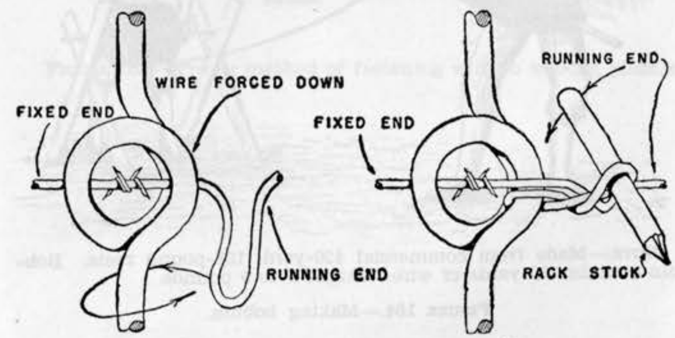
FIGURE 162. Angle-iron pickets.



① At top of picket.

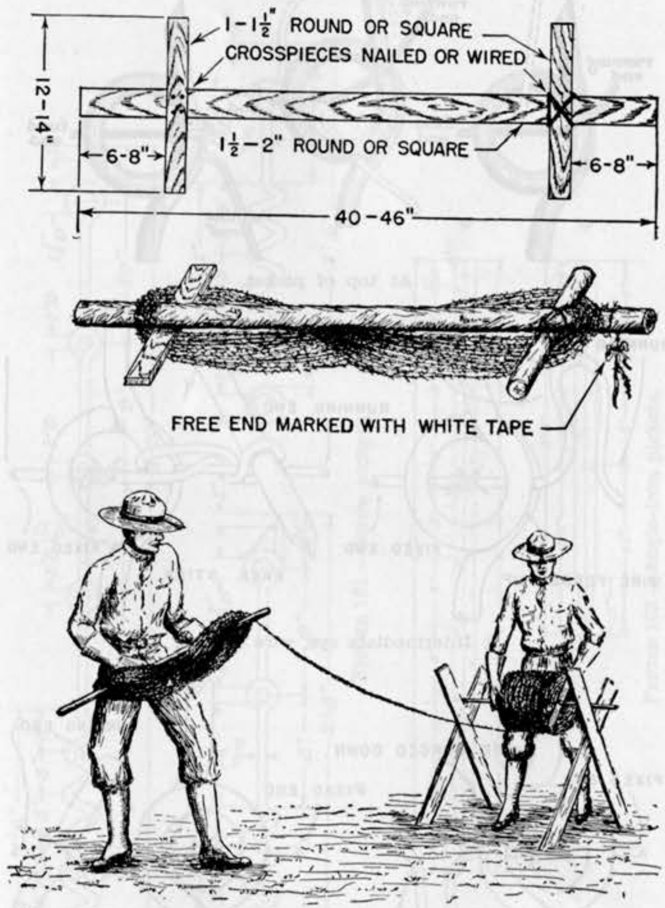


② Intermediate eye, wire on top.



③ Intermediate eye, wire underneath.

FIGURE 163.—Proper method of fastening wire to screw pickets.



NOTE.—Made from commercial 420-yard, 105-pound reels. Bobbin contains 30 yards of wire—weight 8 to 9 pounds.

FIGURE 164.—Making bobbin.

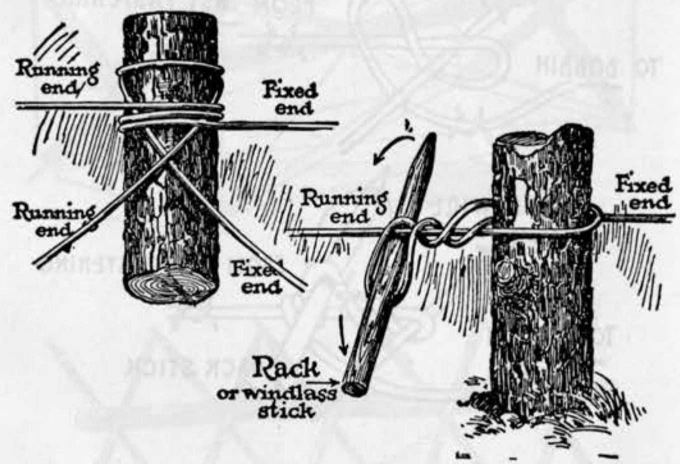


FIGURE 165.—Proper method of fastening wire to wooden pickets.

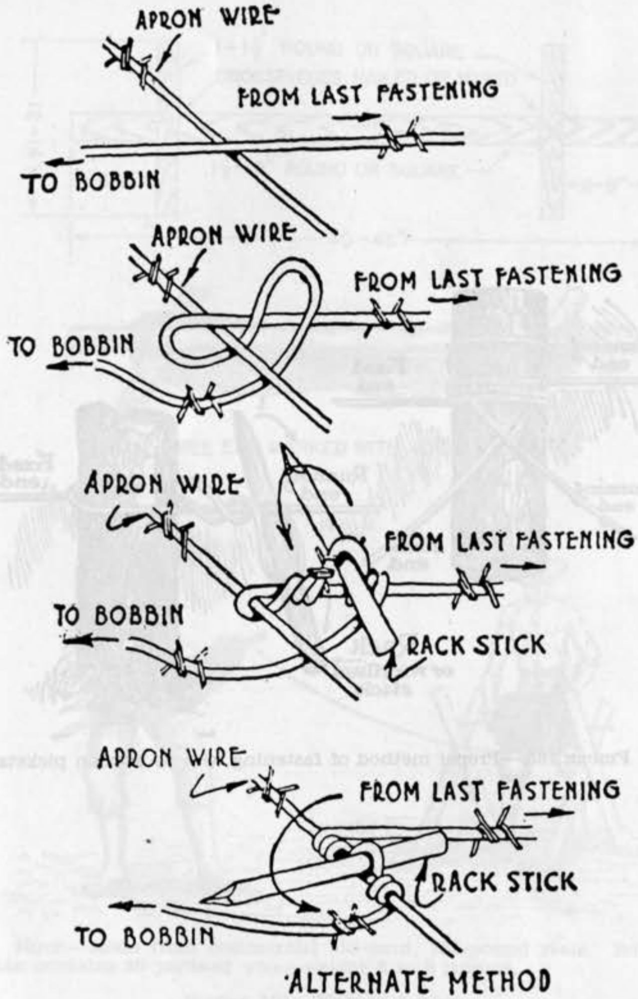


FIGURE 166.—Method of fastening two wires together by "windlassing."

■ 101. MISCELLANEOUS OBSTACLES.

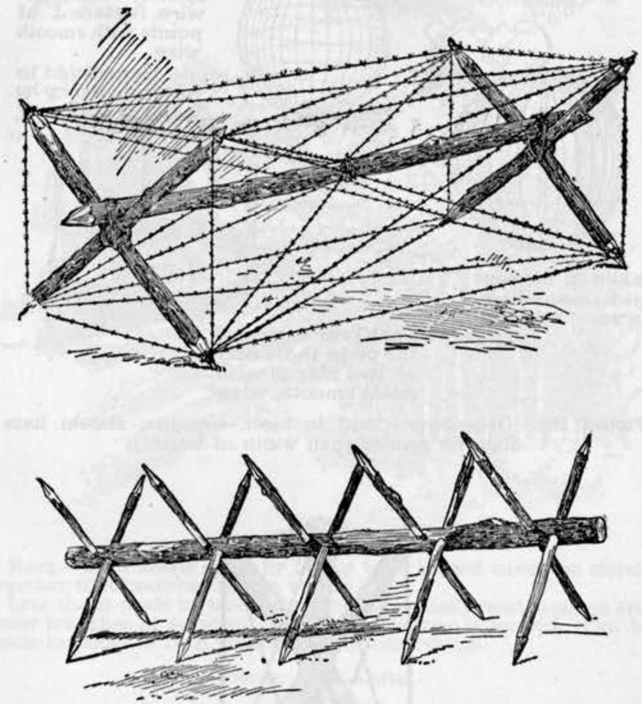


FIGURE 167.—Knife rest or cheval-de-frise.

NOTE.—Used to stop temporary gaps in entanglements, barricade trenches leading toward enemy, barricade roads, and as underwater obstacle when made of iron framework.

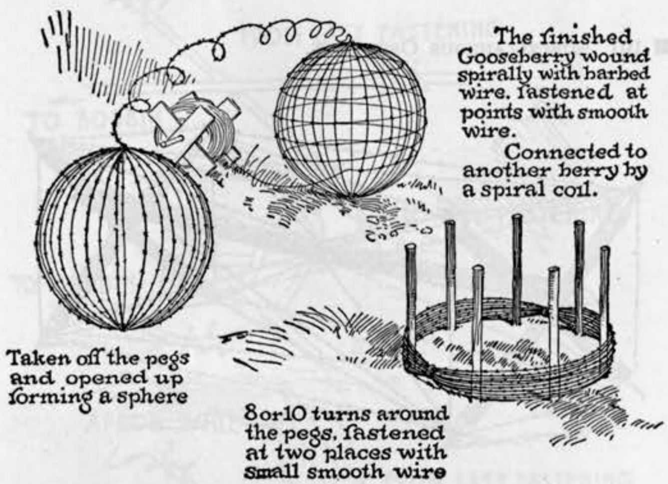
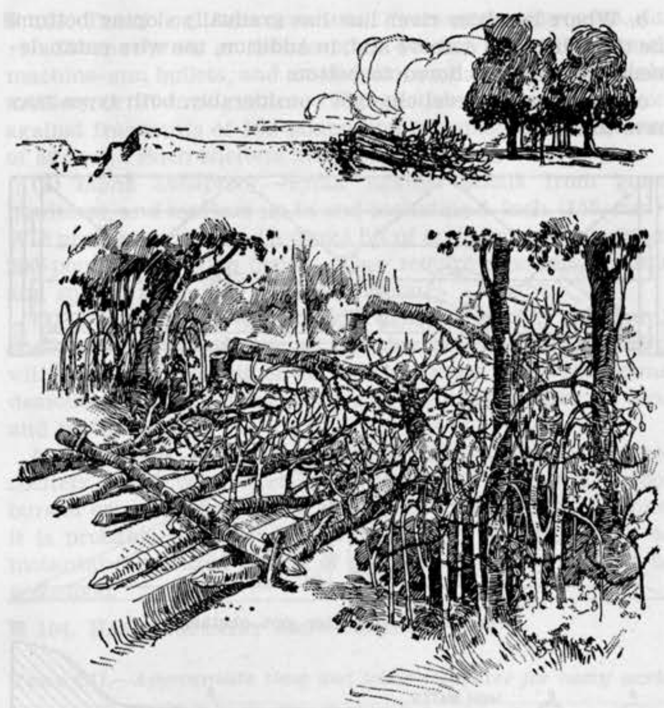


FIGURE 168.—Gooseberry (used to block trenches; should have diameter greater than width of trench).

FIGURE 169.—Hedgehog (used to block trenches).



NOTE.—Dead abatis made by felling trees toward enemy so closely together that branches form a barrier.
Live abatis made by interlacing and tying easily bent saplings and lower branches of adjacent trees so that barrier is formed. Can be made invisible to both ground and air observation.

FIGURE 170.—Abatis.

■ 102. UNDERWATER OBSTACLES.—*a*. Where beach or river line has steeply sloping bottom, use—

(1) Small, sensitive contact mines.
(2) Heavy logs anchored or tied to shore to form booms.
(3) Heavy cables or chains stretched between piling.
(4) All adjusted so as to be under water but close to surface.

b. Where beach or river line has gradually sloping bottom, use those listed in *a* above and, in addition, use wire entanglements securely anchored to bottom.

c. Where water level changes considerably, both types may have to be used.

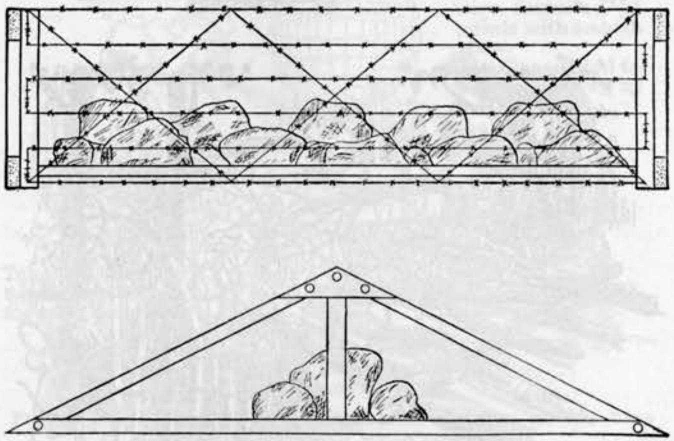
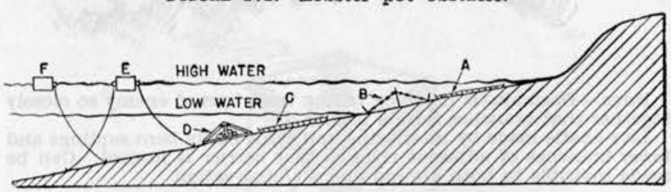


FIGURE 171.—Lobster pot obstacle.



A and B—Standard types of entanglements and obstacles constructed during low water and securely anchored. Railroad iron may be driven in sand beach where heavy surf occurs.
C and D—Lobster pots, chevaux-de-frise, concertinas, etc., constructed on shore, sunk in place, and picketted or anchored to bottom.
E and F—Small, sensitive contact mines or log booms.

FIGURE 172.—Typical underwater obstacles on a gradually sloping bottom.

■ 103. TYPES OF SHELTERS AND PROTECTION AFFORDED.—*a.* (1) *Shrapnelproof or splinterproof.*—Proof against shrapnel, machine-gun bullets, and small splinters but not against light artillery or 37-mm gunfire. Will probably afford protection against fragments of 500-pound bombs exploding at distance of 50 feet. Such shelters are easily provided.

(2) *Light shellproof.*—Proof against shells from guns, howitzers, and mortars up to and including 6-inch (155-mm). Will probably withstand a direct hit of an instantaneous fuzed 200-pound demolition bomb. They require considerable time and special materials for construction.

(3) *Heavy shellproof.*—Proof against 8-inch (200-mm) shell, against single hits of heavier shells. Will probably withstand a direct hit of an instantaneous fuzed 500-pound demolition bomb. They require great expenditures of time and materials.

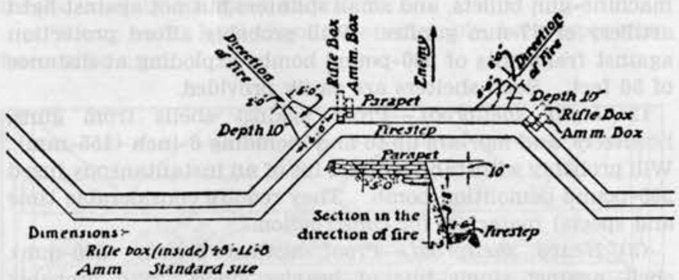
b. Protection in light shellproof and heavy shellproof shelters could be materially increased by use of a 2-foot burster course and a greater amount of cover. If this is done, it is probable that direct hits of delayed action as well as instantaneous fuzed bombs of the sizes mentioned could be withstood.

■ 104. HASTY INFANTRY EMPLACEMENTS.

TABLE CII.—*Approximate time and labor estimates for hasty works*

Work	Number of men	Number of man-hours in— Soft soil	Average soil	Hard soil
Company command post, hasty	2–3	12	18	24
Company observation post, hasty	2	7	10	12
Light 2-man shelter in trench	2	7	10	12
Aid station, local, hasty	2–4	12	18	24
Battalion observation post, hasty	2–4	10	15	20
Battalion command post, hasty	8–16	50	75	100
Battalion aid station, hasty	8–16	50	75	100

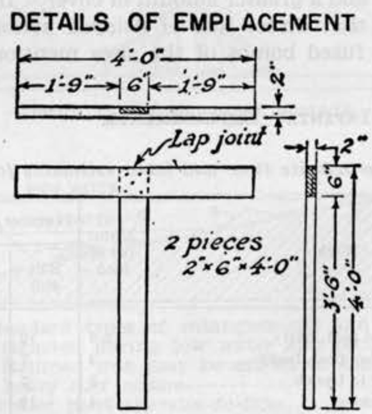
NOTE.—For plans see section VII, FM 5–15.



NOTE.—Should provide for—

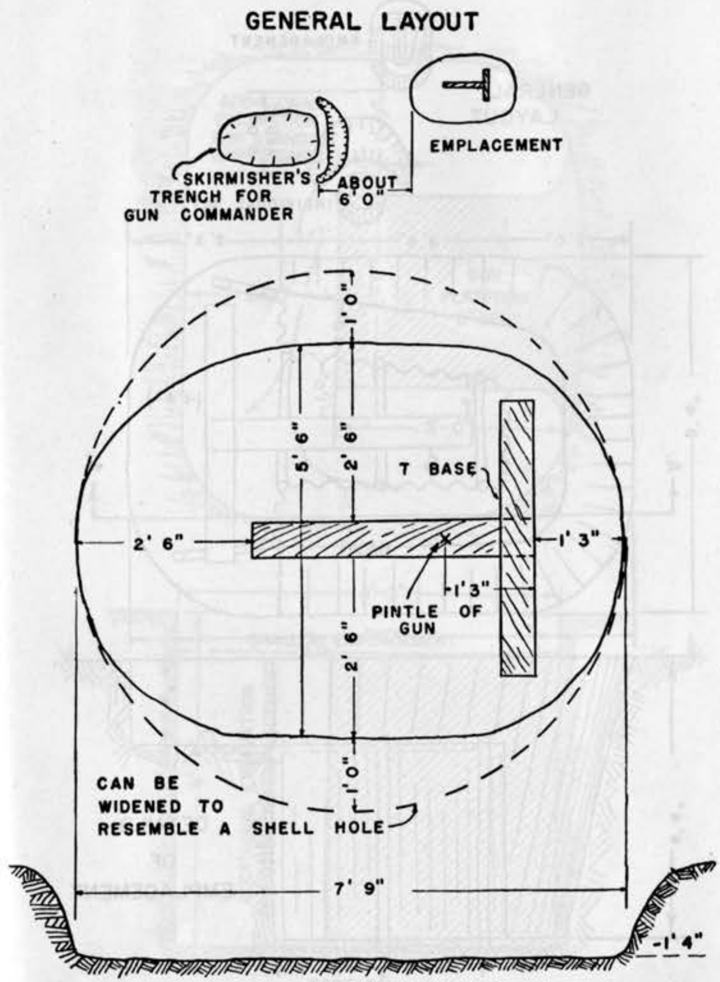
Firing recess in parapet 5 feet long and 10 to 12 inches deep.
Box for rifle, 48 by 12 by 8 inches, with gas curtain.
Box for ammunition, 20 by 20 by 12 inches, with gas curtain.

FIGURE 173.—Automatic rifle emplacement



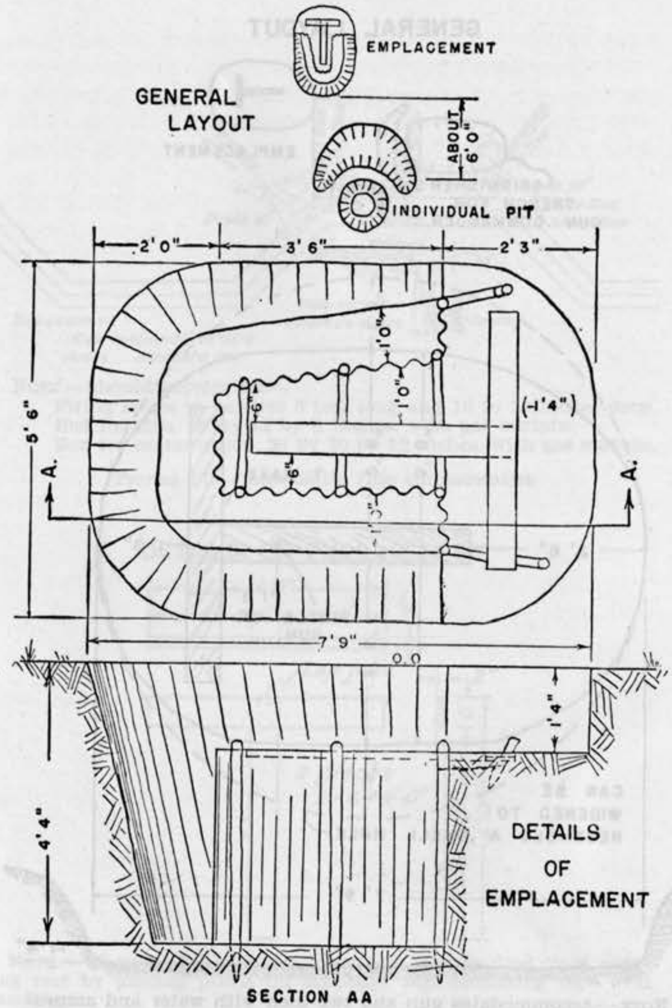
NOTE.—When no T-base is available, gun may be fired from sandbag rest by placing pintle on sandbags and anchoring legs with sandbags.

FIGURE 174.—Detail of T-base.



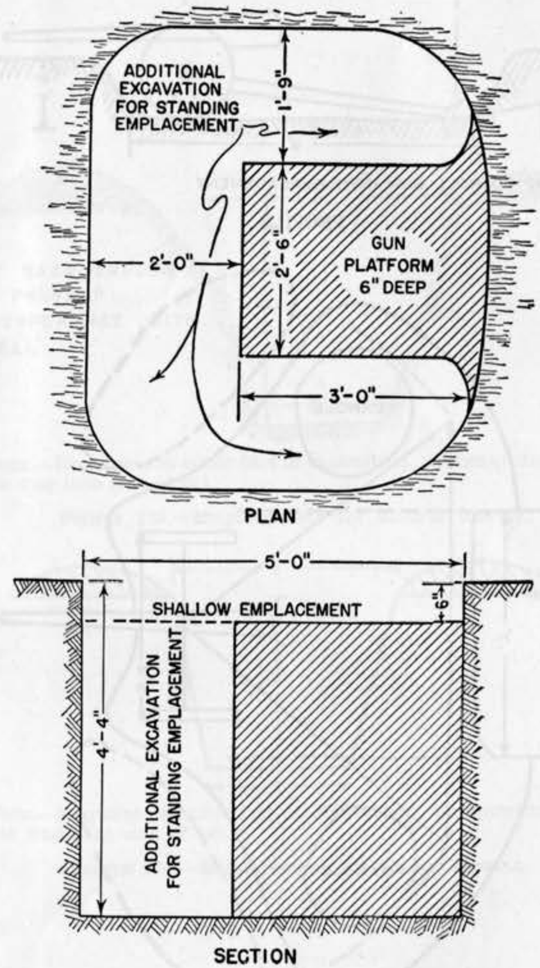
NOTE.—Accommodates gun and two men with water and ammunition boxes. Requires 60 cubic feet excavation—3 man-hours in soft soil. If for caliber .50, length should be 10 feet and will require 75 cubic feet of excavation.

FIGURE 175.—Open emplacement for heavy machine gun—shallow type (T-base may be omitted).



NOTE.—May be made from shallow type by deepening that part of pit occupied by personnel. Will require 3 man-hours for deepening and 3 man-hours for revetting in soft earth.

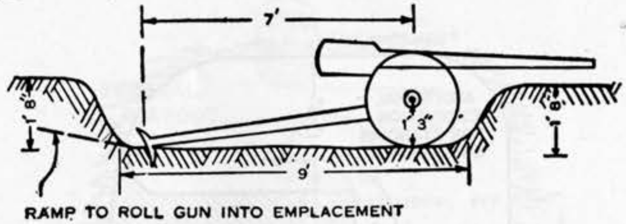
FIGURE 176.—Open emplacement for heavy machine gun—standing type.



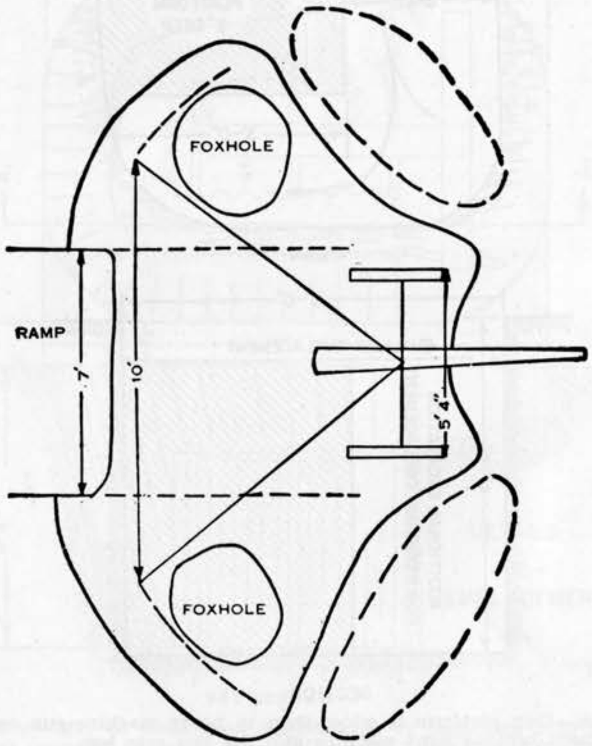
NOTE.—Gun platform is wider than in heavy machine-gun emplacement because light machine gun has two rear legs.

FIGURE 177.—Light machine-gun emplacement.

282736°—41——17



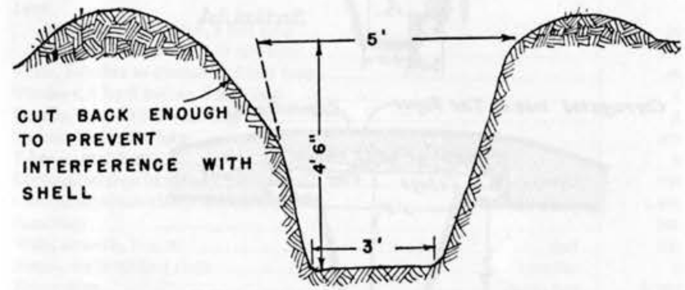
PROFILE



PLAN

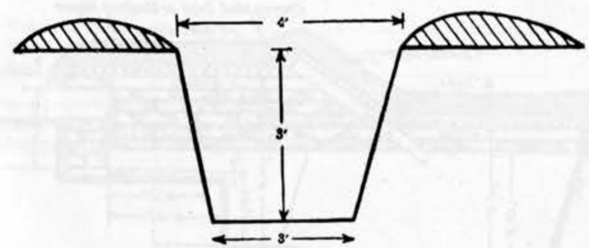
NOTE.—Requires 175 to 200 cubic feet of excavation. Should be used only in stabilized or semistabilized warfare.

FIGURE 178.—Emplacement for 37-mm antitank gun.



NOTE.—Requires 150 cubic feet of excavation. Ammunition niches to be dug into side of pit.

FIGURE 179.—Emplacement for 81-mm mortar.



NOTE.—Requires 60 cubic feet of excavation. Ammunition niches to be dug into side of pit.

FIGURE 180.—Emplacement for 60-mm mortar.

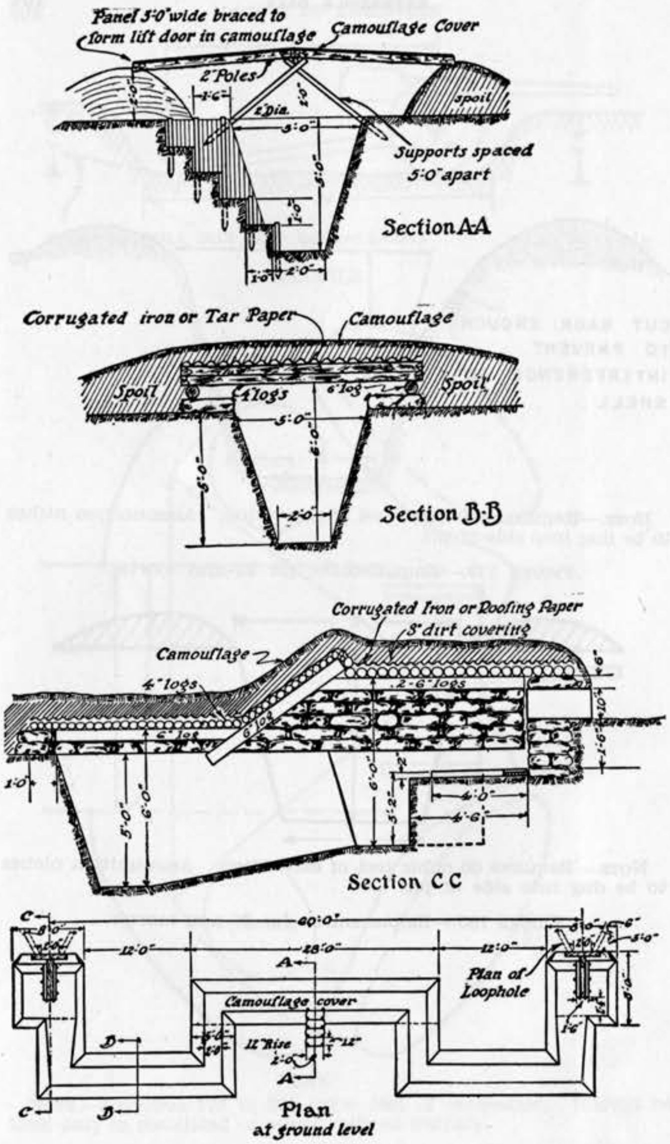


FIGURE 181.—Two-gun, heavy machine-gun emplacement with splinter-proof shelter.

TABLE CIII.—*Machine-gun emplacement—bill of material and work data for figure 181*

Item	Emplacement for 2 guns
Logs:	
6 inches in diameter, 8 feet long	24
4 inches in diameter, 10 feet long	220
Poles, 2-inches in diameter, 6 feet long	40
Timbers, 6 by 8 inches, 3 feet long	4
Boards, 1 by 12 inches, 2 feet long	5
Stakes, 12 inches long	200
T-bases, standard	2
Corrugated iron or roofing paper ... square feet	750
Camouflage material ... do	1, 900
Sandbags	240
Wire, smooth, No. 10 ... feet	500
Brush, for revetting steps ... bundles	1
Excavation ... cubic feet	1, 500
Work:	
Excavation, 12 men ... hours	10
Revetting, roofing, etc., 12 men ... do	14
Total, 12 men ... do	24
Total man-hours	288
8-hour shifts, 12 men	3

NOTE.—Can be used in connection with existing trenches or in isolated positions, and adapted for caliber .50 or light machine guns.

■ 105. Light Shellproof Emplacements.

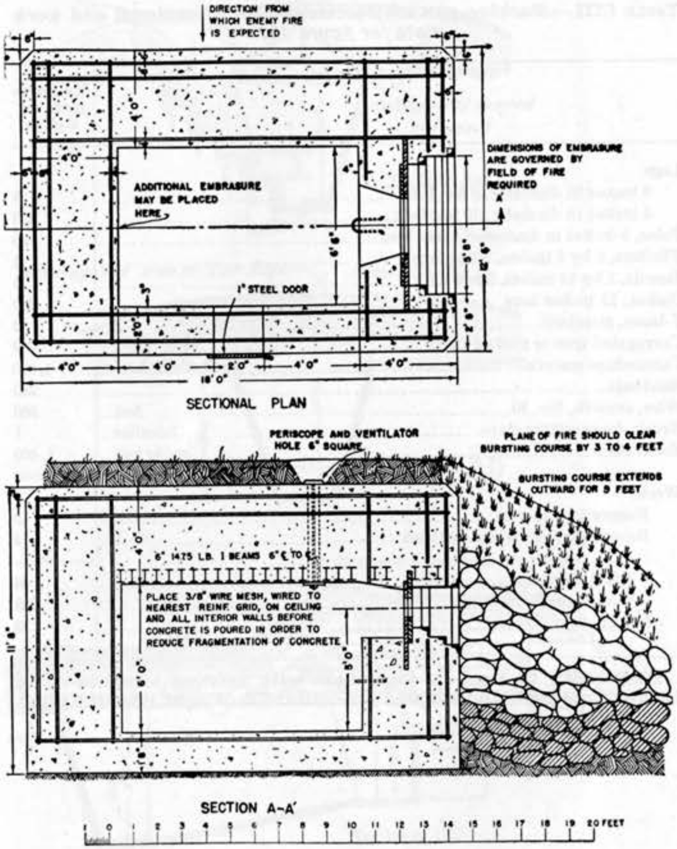


Figure 182.—Light shellproof machine-gun emplacement (sectional plan and elevation).

NOTES (fig. 182)

Mix: 1:2:3 by volume.
Water cement ratio; (6½ gallons per sack approx.). 90 by volume.

All reinforcement is ⅝-inch steel bars spaced 8 inches c. to c. in squares welded or wired together; welding preferred. Outside grids to be placed 6 inches from surface; inside grids 4 inches from surface.

Ties consist of 4 strands of $\frac{3}{16}$-inch iron wire between two surface grids with average spacing of 1 foot 4 inches in both directions and hooked or welded stirrups of ⅝-inch bars between inner front and

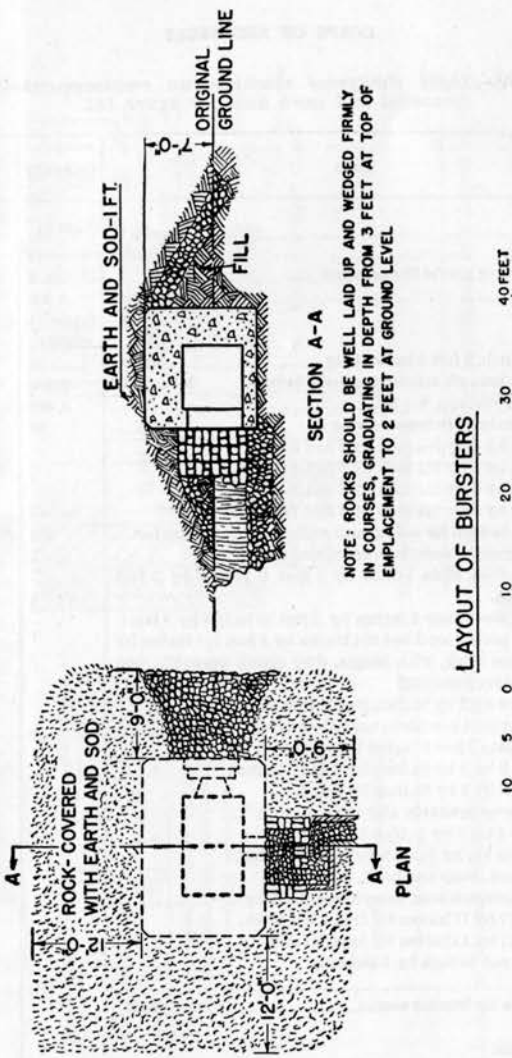


Figure 183.—Light shellproof machine-gun emplacement (lay-out of bursters).

rear surface grids with average spacing 3 feet horizontally and 8 inches vertically.

Concrete faces not protected by earth or bursting courses may be faced with ½ to 1-inch steel plates if attack by infantry weapons at close range is anticipated.

TABLE CIV.—*Light shellproof machine-gun emplacement—bill of material and work data for figure 182*

Item	Quantity	Weight (tons)
Cement ... barrels [1]	143	26.8
Sand ... cubic yards	43	53
Broken stone or gravel (for cement) ... do	64.5	88
Water ... gallons	3,800 (approximately)	16
I-beams, 6-inch, 9 feet 6 inches long ... pieces	24	1.7
Round iron bars for reinforcing grids ⅝-inch ... linear feet	6,900	3.6
Iron wire for stirrups, 3/16-inch ... do	1,600	.08
Angles for embrasure corner armor ... do	32	.25
3 each 4 by 4 by 9/16 inch by 6 feet 4 inches.		
1 each 4 by 4 by 9/16 inch by 5 feet 8 inches.		
2 each 4 by 4 by 9/16 inch by 2 feet 1½ inches.		
2 each 4 by 4 by 9/16 inch by 1 foot 7 inches.		
Wire mesh, ⅜-inch for ceiling and walls ... square feet	263	.20
Embrasure panels, complete, consisting of—	1	1.6
1 armor steel plate 1 inch by 3 feet 6 inches by 5 feet 6 inches.		
1 armor steel plate 2 inches by 2 feet 10 inches by 7 feeet.		
1 armor plate door 3 feet 2½ inches by 1 foot 2½ inches by 4 inches thick, with hinges, door clamp assembly, and port cover assembly.		
6 angles 2 by 2 by ⅜ inch by 9½ inches long.		
Steel door for port complete, consisting of—	1	.35
1 steel plate 2 feet 6 inches by 6 feet by 1 inch thick.		
2 angles 2 by 2 by ⅜ inch by 5 feet 6 inches.		
2 angles 2 by 2 by ⅜ inch by 2 feet.		
1 port cover assembly and cap.		
2 hinges 4 by 6 by ½ inch thick.		
1 lock bar 1½ by ½ inch by 1 foot 3 inches.		
Door hook, hasp and hook, hinge bolts.		
Cover for periscope hole, complete, consisting of—	1	.05
1 plate 11 by 11 inches by 1¼ inches thick.		
1 plate 11 by 11 inches by ½ inch thick.		
1 round rod ¾ inch by 3 feet long.		
Sandbags	174	---
Broken stone for burster course ... square yards	110	165
Lumber:	---	5
For forms:		
2-inch ... square feet	975	
2 by 6 inch ... linear feet	700	
2 by 4 inch ... do	330	
2 by 2 inch ... do	36	

[1] Approximately 4 cubic feet cement per barrel.

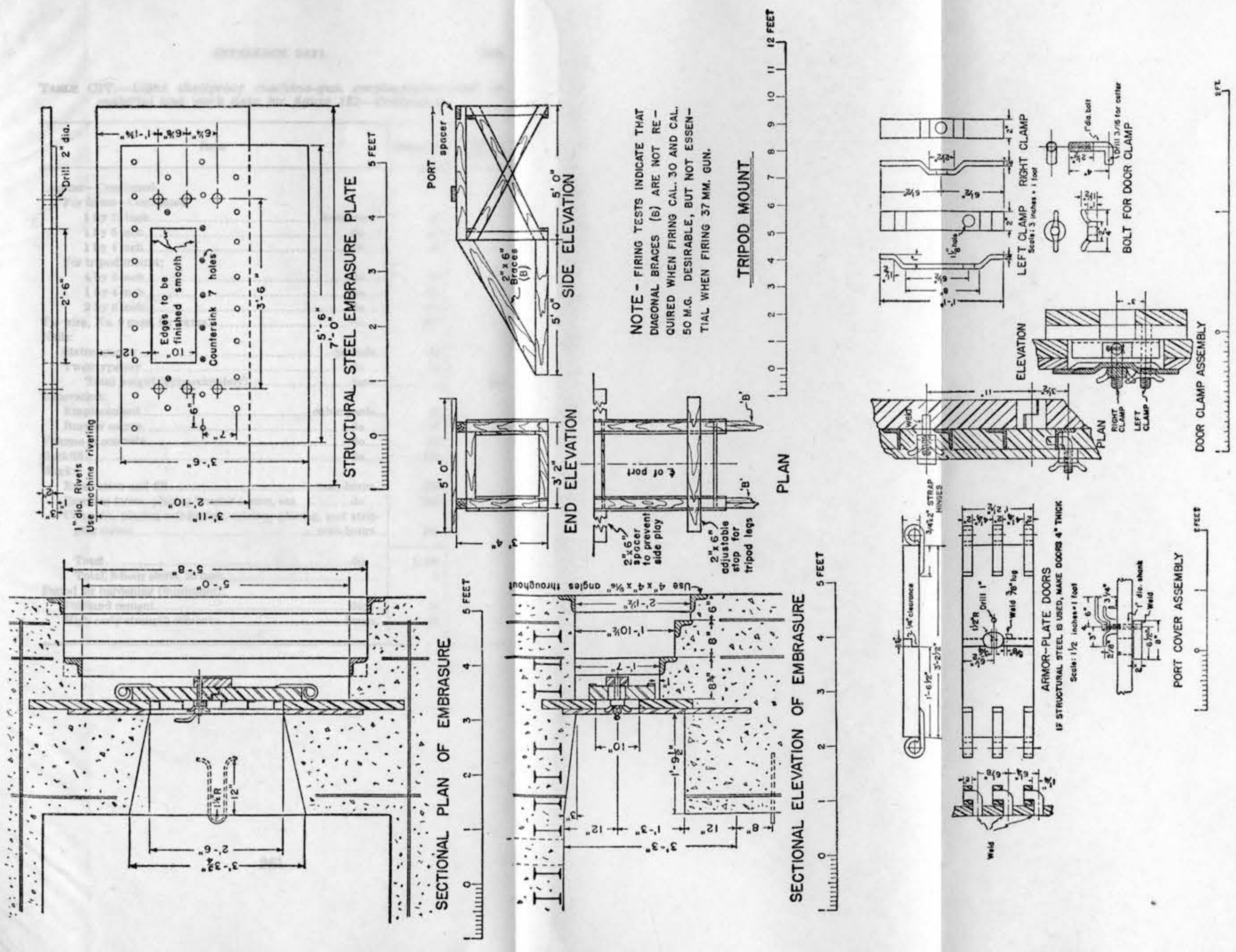


FIGURE 184.—Light shellproof machine-gun emplacement (section and details of embrasure and tripod mount).

282736°—41 (Face p. 260)

TABLE CIV.—*Light shellproof machine-gun emplacement—bill of material and work date for figure 182*—Continued

Item	Quantity	Weight (tons)
Lumber—Continued.		
For forms—Continued.		
1 by 12 inch .... linear feet..	50	
1 by 6 inch .... do....	40	
1 by 4 inch .... do....	40	
For tripod mount:		
4 by 4 inch .... do....	22	
1 by 4 inch .... do....	37	
2 by 6 inch .... do....	31	
Tie wire, No. 9 gage, for forms .... do....	800	
Nails:		
Sixteenpenny .... pounds..	60	
Twentypenny .... do....	60	
Total weight (approximately) .... tons..	....	362
Excavation:		
Emplacement .... cubic yards..	58	
Burster course .... do....	49	
Volume of concrete .... do....	82	
Backfill .... do....	120	
Work:		
Excavation and fill .... man-hours..	320	
Erecting forms, placing burster course, etc .... do....	350	
Concrete, placing reinforcing, mixing, placing, and stripping forms .... man-hours..	450	
Total .... do....	1, 120	
Total, 8-hour shifts, 20 men	7	
Period for hardening (minimum):		
Portland cement .... days..	14	
High early strength cement .... hours..	24	

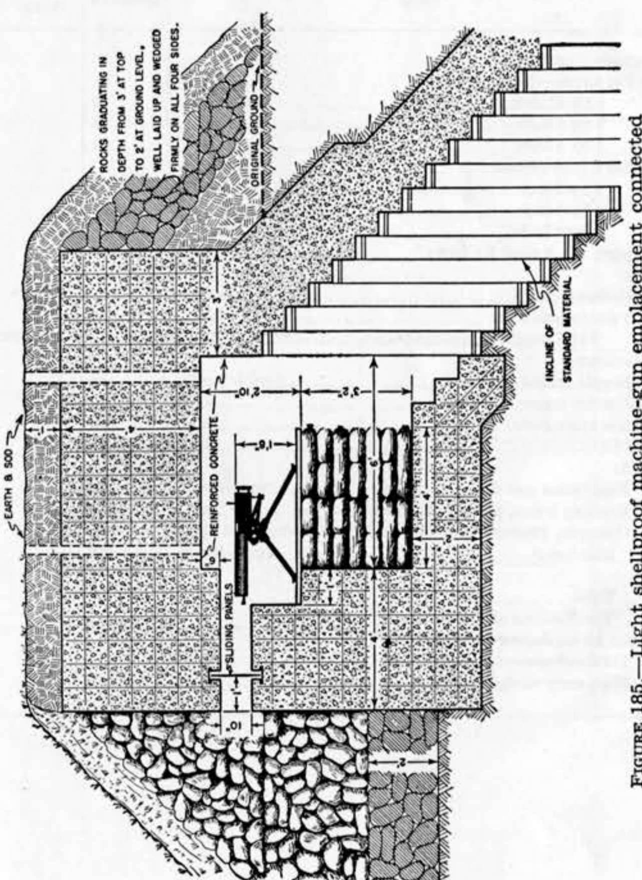


FIGURE 185.—Light shellproof machine-gun emplacement connected with underground shelter.

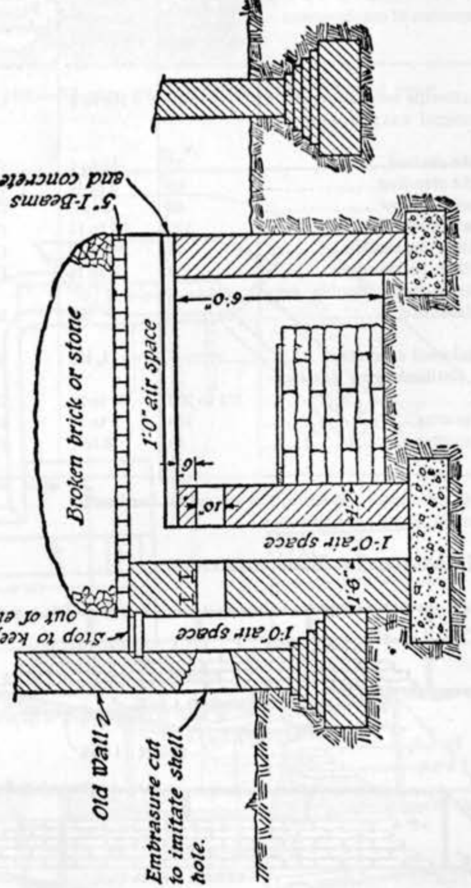


FIGURE 186.—Machine-gun emplacement in a ruined house.

■ 106. Estimates for Infantry Emplacements.

Table CV.—*Time and labor estimates for emplacements using pioneer tools*

Designation of emplacement	Excavation required (cubic feet)	Man-hours [1] (approx.)	Figure reference	Remarks
Automatic-rifle emplacement	37	1½ to 4	173	
Machine-gun emplacement, type:				
Light shallow	15	½ to 1	177	
Light standing	85	5 to 10	177	
Heavy shallow	60	3 to 7	175	
Heavy standing	120	[2] 7 to 13	176	
Caliber .50, shallow	75	3½ to 9	175	
Caliber .50, standing	150	9 to 18	176	
Splinter-proof, double emplacement		288	181	Material at site.
Reinforced concrete		1,120	182	Do.
37-mm antitank gun emplacement	175 to 200	10 to 24	178	
81-mm mortar	150	9 to 18	179	
60-mm mortar	60	3 to 7	180	

[1] First figure is for soft earth, the second for hard earth.
[2] Does not include revetments.

■ 107. Artillery Emplacements.

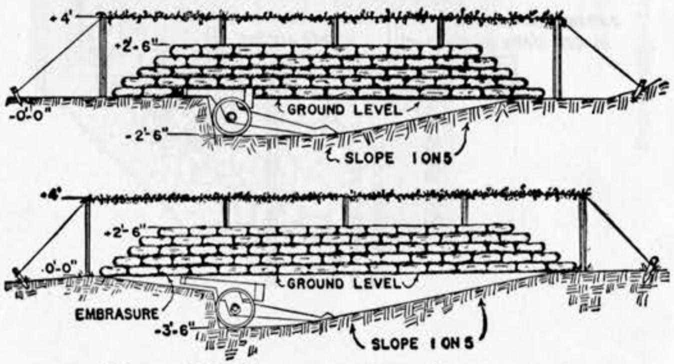


Figure 187.—75-mm gun in sunken position.

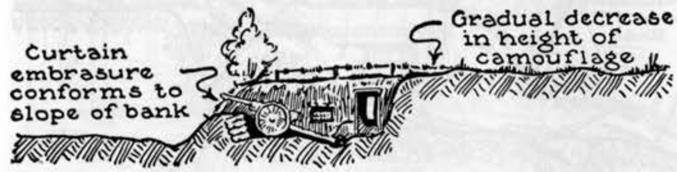


Figure 188.—75-mm gun in bank along edge of road.

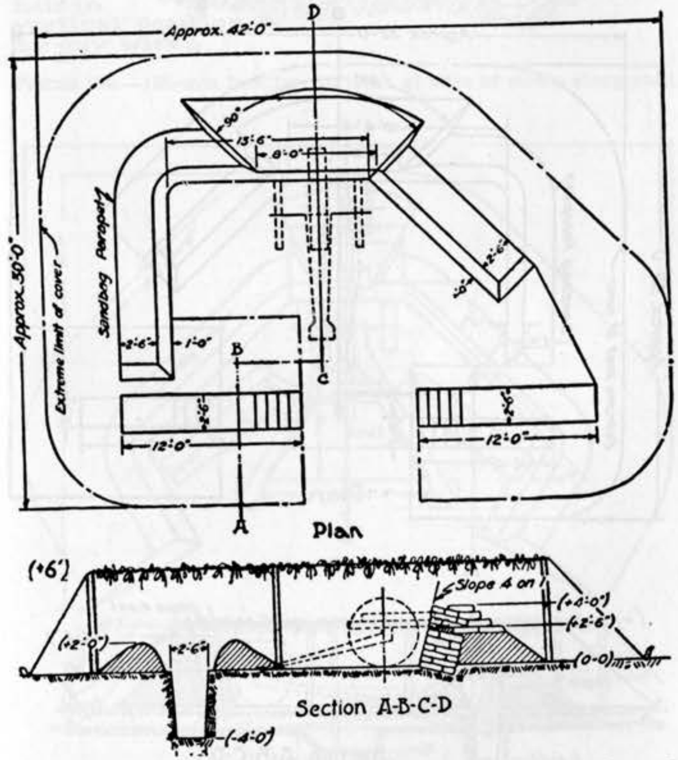


Figure 189.—Emplacement for 75-mm gun (French, high-speed rubber-tired wheels).

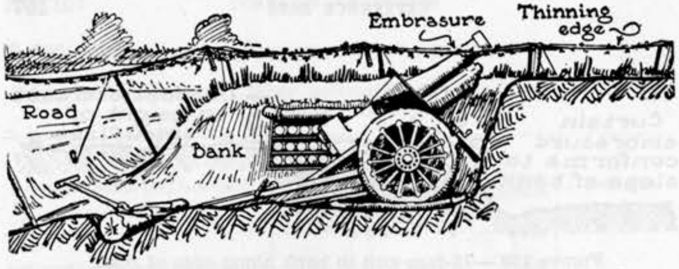


Figure 190.—155-mm howitzer in bank along edge of road.

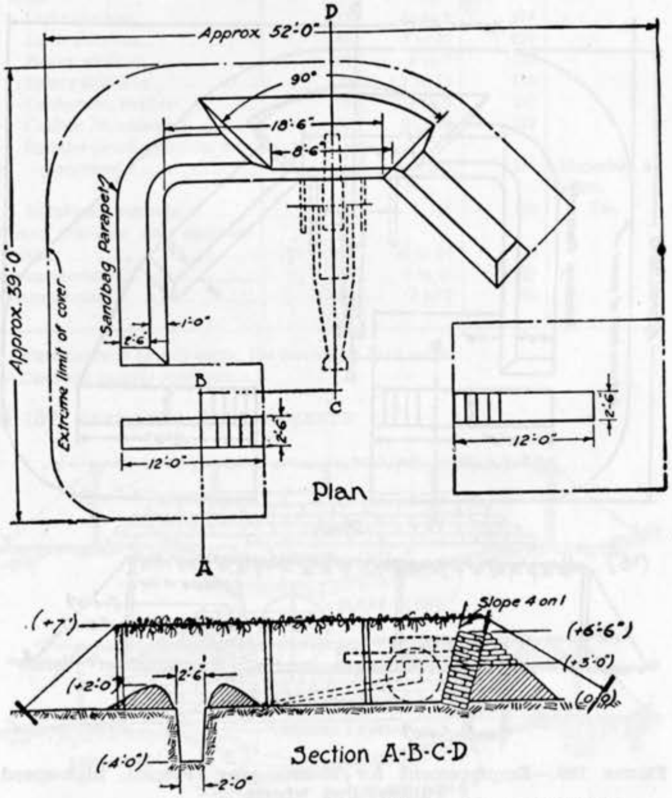


Figure 191.—Emplacement for 155-mm howitzer, M1918 (high speed).

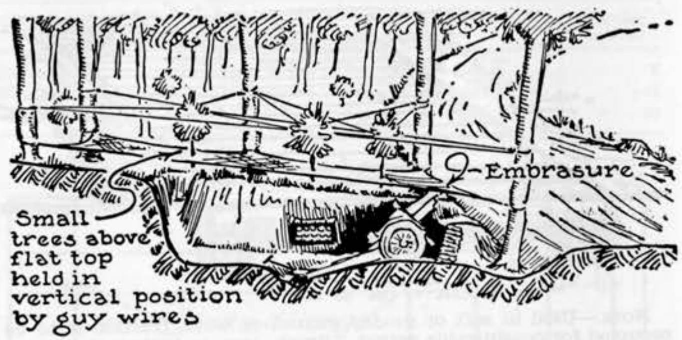


Figure 192.—155-mm howitzer in bank at edge of woods along road.

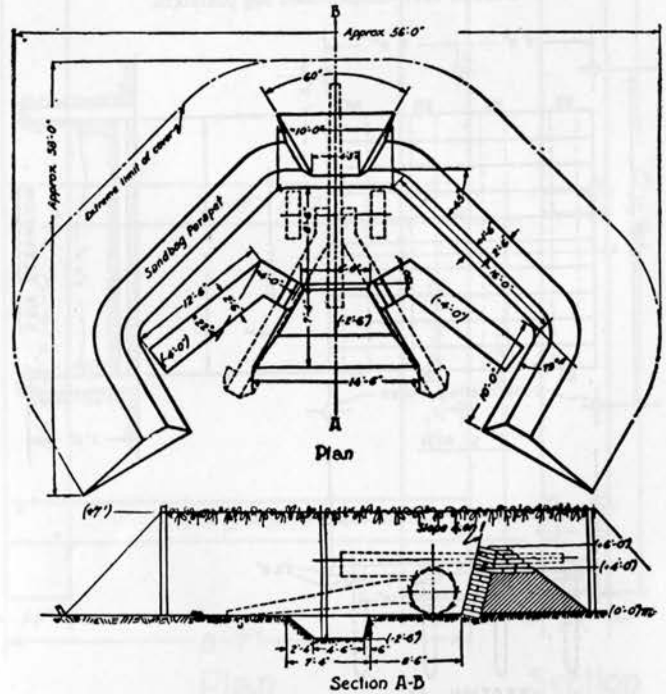
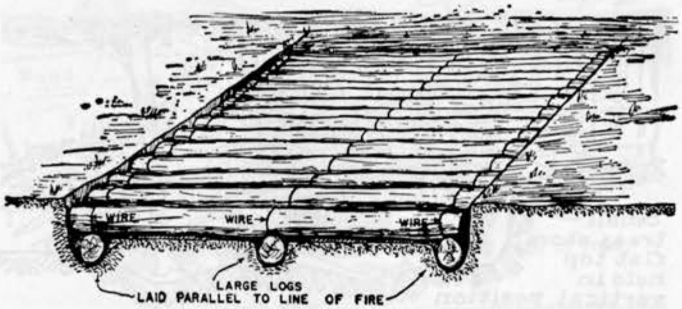


Figure 193.—Emplacement for 155-mm gun (G. P. F.).

■ 108. Gun Platforms and Trail Supports.



NOTE.—Used in soft or muddy ground or when position is to be occupied for considerable period. Brush, logs, or broken stone may also be used.

FIGURE 194.—Improvised log platform.

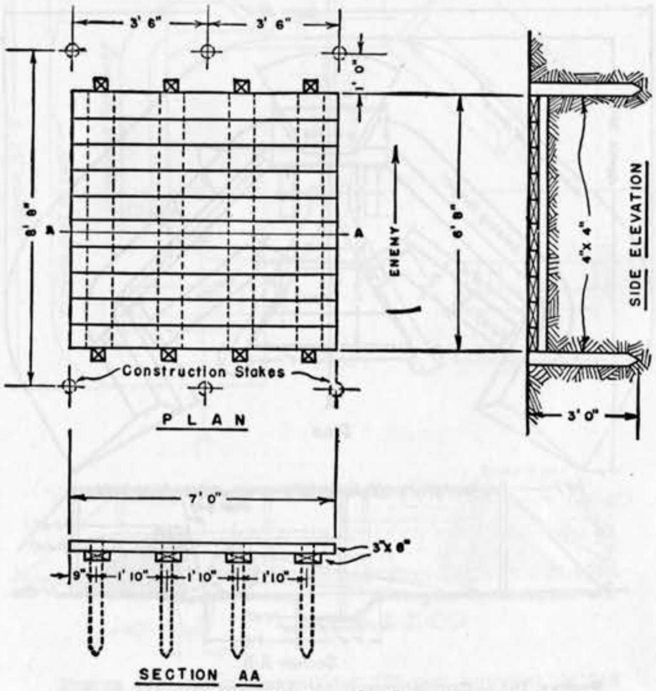


FIGURE 195.—Platform for 75-mm gun.

TABLE CVI.—*Bill of material for figure 195*

Description	Size	Number required
Posts	4 inches by 4 inches by 3 feet	8
Sills	3 inches by 8 inches by 6 feet 8 inches	54
Decking	3 inches by 8 inches by 7 feet	10

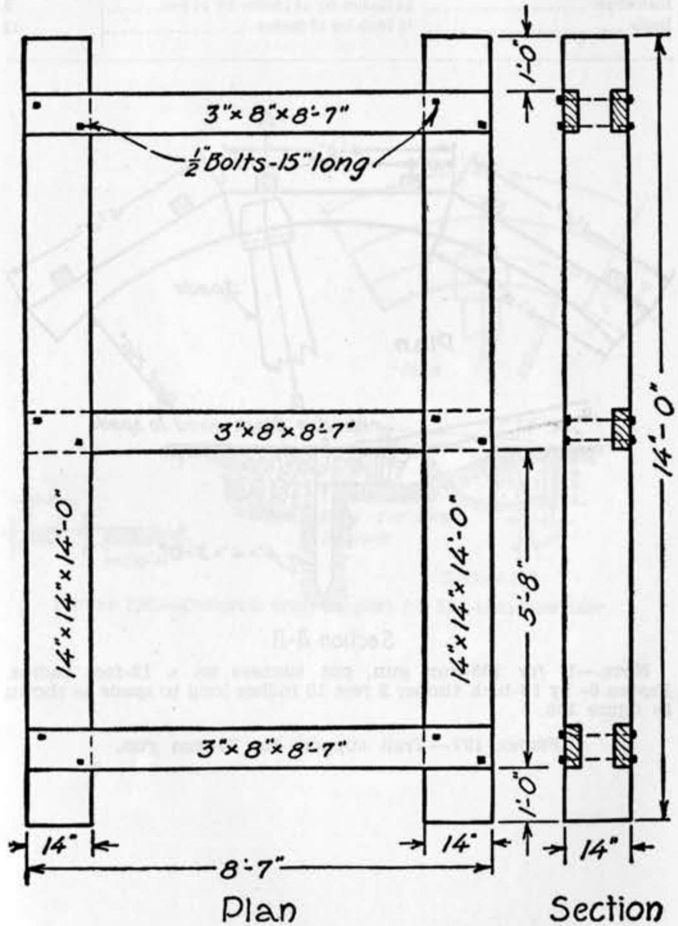
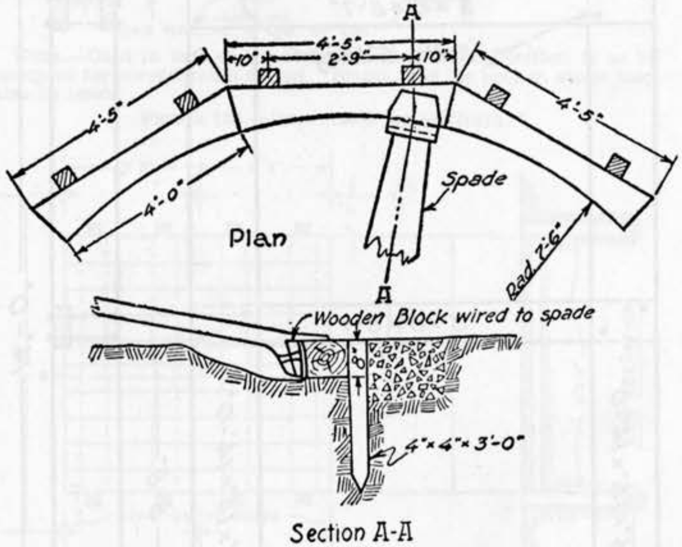


FIGURE 196.—Wheel support for 155-mm gun (G. P. F.).

TABLE CVII.—*Bill of material for figure 196*

Description	Size	Number required
Crosspieces	3 inches by 8 inches by 8 feet 7 inches	5
Runways	14 inches by 14 inches by 14 feet	2
Bolts	½ inch by 15 inches	12



NOTE.—If for 155-mm gun, cut timbers on a 12-foot radius. Fasten 8- by 16-inch timber 2 feet 10 inches long to spade as shown in figure 198.

FIGURE 197.—Trail support for 75-mm gun.

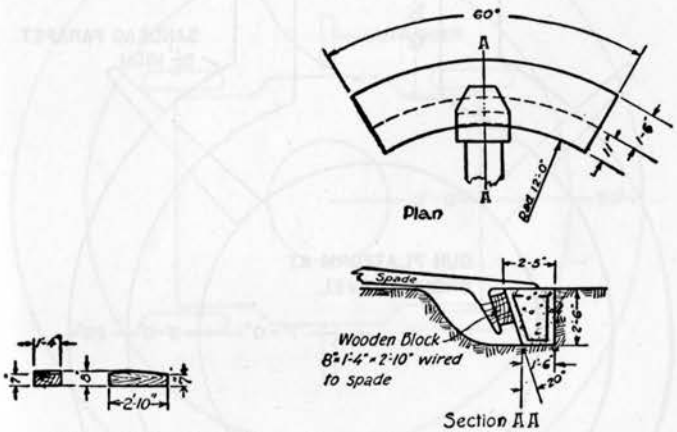


FIGURE 198.—Concrete trail support for 155-mm howitzer.

■ 109. PROTECTION FOR ANTIAIRCRAFT UNITS.—*a. 3-inch gun; 37-mm automatic cannon; searchlight; director; height finder.*

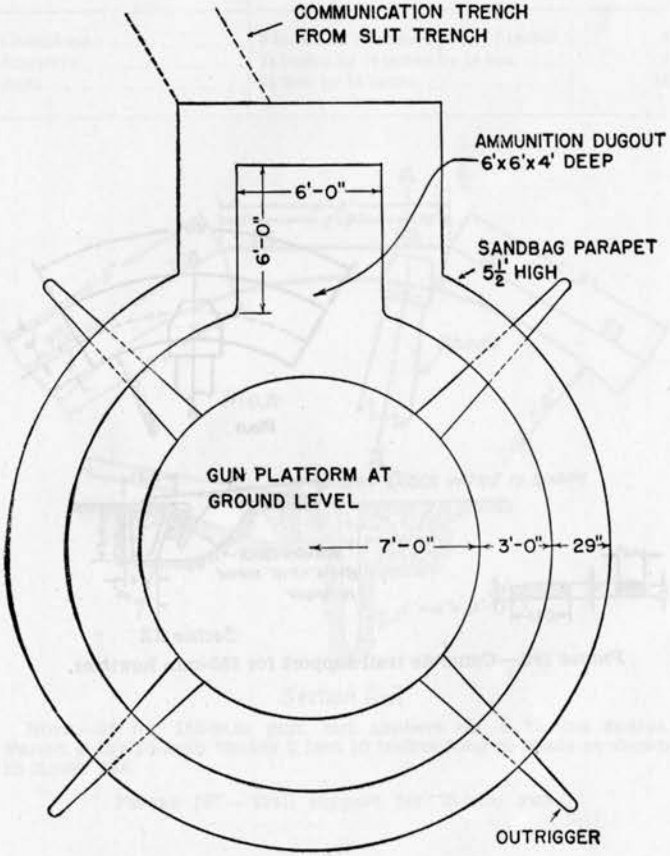
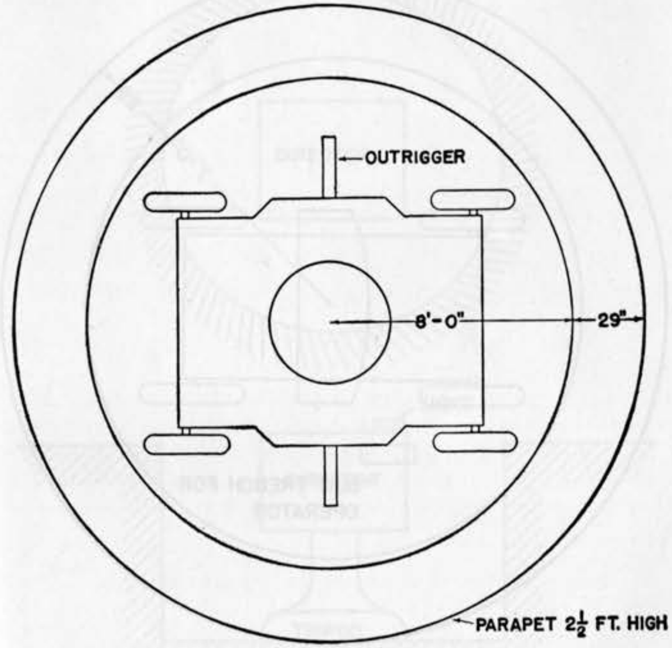


FIGURE 199.—Protection for 3-inch gun (antiaircraft).



NOTE.—Wheel supports may be provided in wet or soft soil.

FIGURE 200.—Protection for 37-mm automatic cannon (antiaircraft).

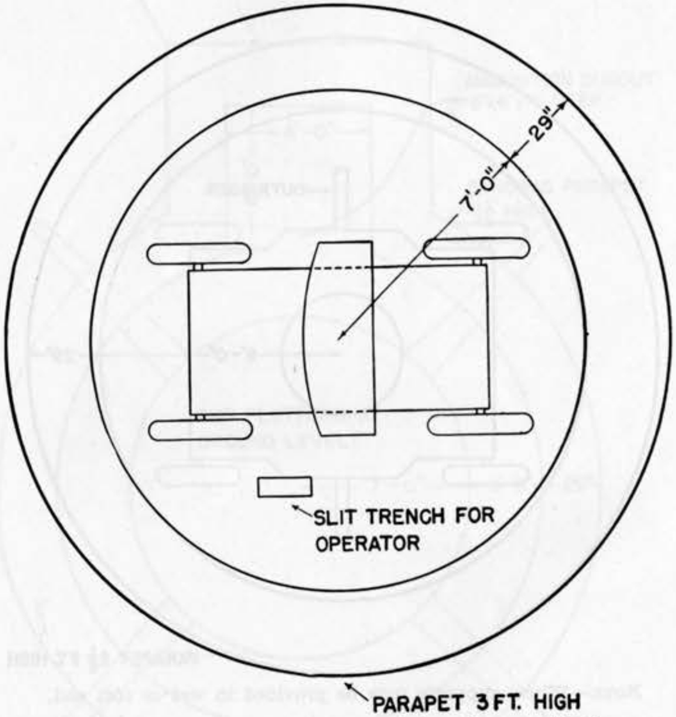


FIGURE 201.—Protection for antiaircraft searchlight.

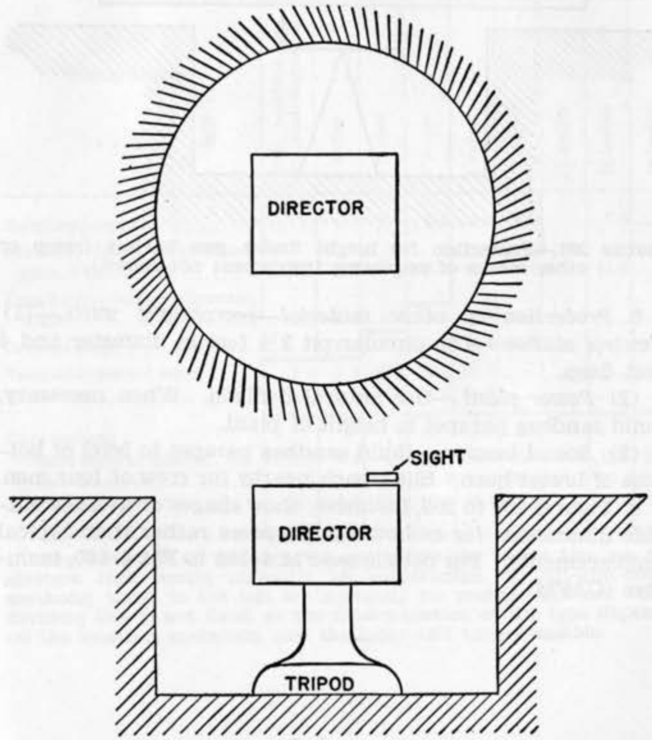


FIGURE 202.—Protection for director, gun battery (ramp or other means of emplacing instrument not shown).

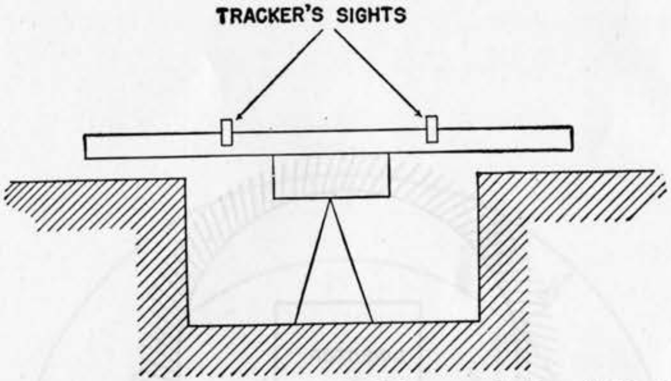


FIGURE 203.—Protection for height finder, gun battery (ramp or other means of emplacing instrument not shown).

b. Protection of other material—searchlight units.—(1) *Control station.*—Dig circular pit 2½ feet in diameter and 4 feet deep.

(2) *Power plant.*—Use natural deflade. When necessary, build sandbag parapet to height of plant.

(3) *Sound locator.*—Build sandbag parapet to level of bottom of lowest horn. Slit trench nearby for crew of four men.

c. Figures 199 to 203, inclusive, show shapes or average outside dimensions for camouflage purposes rather than typical emplacements. For details see FM 4–105 to FM 4–160, inclusive (CAFM).

■ 110. SHELTERS.

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

Nature of cover	Size of projectile								
	Rifle, machine gun fire, shell fragments	3 inches	4 inches	6 inches	8 inches	10 inches	12 inches	16 inches	18 inches
Reinforced concrete	-----	1.0	2.4	3.4	5.0	6.0	-----	7.0	-----
Masonry, solid: brick, stone, plain concrete	-----	1.5	3.6	5.1	7.5	9.0	-----	11.0	-----
Logs, 8-inch minimum diameter, wired	-----	2.0	4.8	6.8	10.0	12.0	-----	-----	-----
Crushed stone	-----	3.5	8.4	11.0	17.5	21.0	-----	-----	-----
Tamped or packed earth	1.0	7.5	18.0	25.5	37.5	-----	-----	-----	-----
Loose earth	3.0	10.0	24.0	34.0	45.0	-----	-----	-----	-----
Cave shelters:									
Sand stone or granite	-----	2.0	6.0	8.0	10.0	13.0	14.0	17.0	24.0
Soft limestone	-----	3.0	9.0	11.0	15.0	20.0	21.0	27.0	36.0
Undisturbed earth	-----	5.0	12.0	17.0	25.0	30.0	32.0	40.0	48.0

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

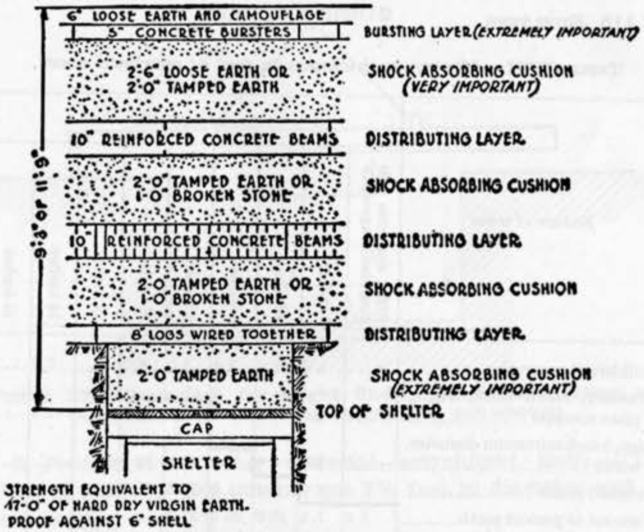


FIGURE 204.—Diagrammatic section showing name, character, and correct manner of placing successive layers of artificial overhead cover.

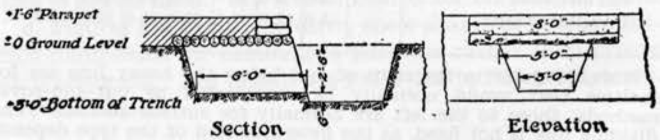


FIGURE 205.—Splinterproof shelters.

TABLE CIX.—*Bill of material for figure 205*

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

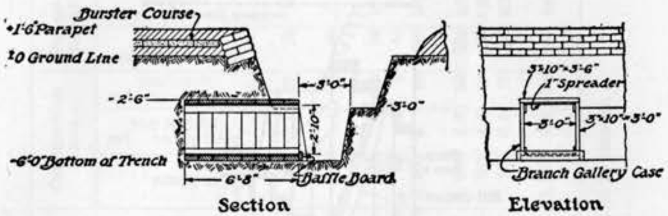


FIGURE 206.—Light shelter against 3-inch shells.

TABLE CX.—*Bill of material for figure 206*

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

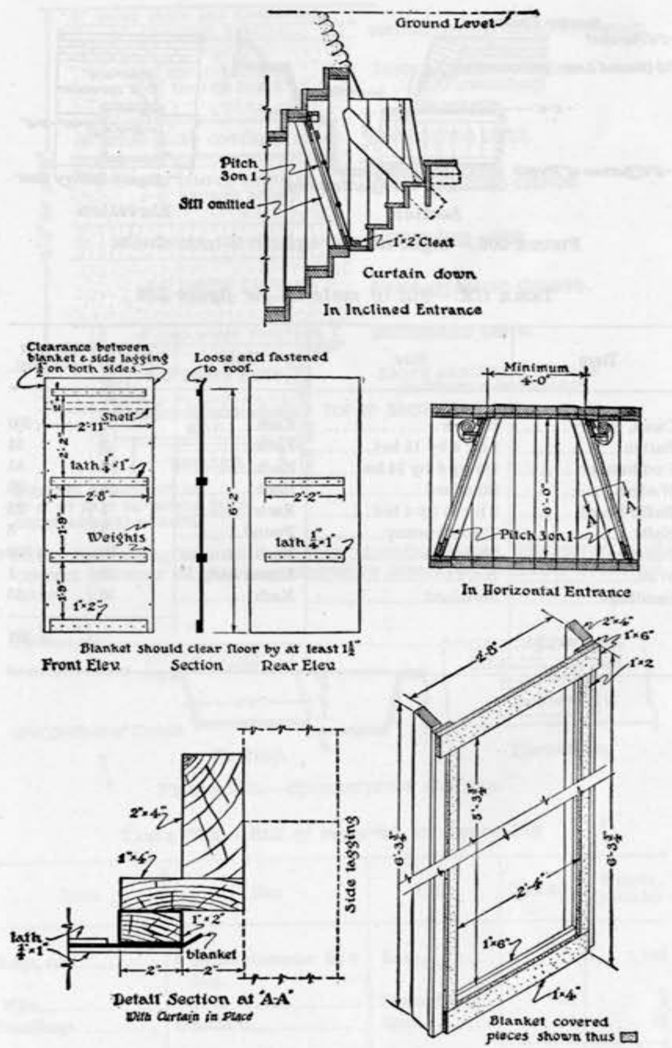


FIGURE 207.—Gas curtain details.

TABLE CXI.—*Shelter construction data, average soil, material at site*

Type	Figure No. in FM 5-15	Description	Protects against shell	Capacity (men)	Work detail	Square feet	Material			Construction time			Per occupant	
							Tons	Tons per occupant	Tons per square foot	Man-hours	Man-hours per square foot	Man-hours per occupant	Excavation (cubic feet)	Feet (board measure)
Surface	123	Corrugated steel	3-inch	12	1 sergeant, 2 squads.	150	101	8.5	0.68	330	2.0	28	36	82
Cut and cover	127	Splinter proof	Splinters and fragments.	2	2 men	18	.5	.25	.03	8	.4	4	66	----
Do	128	Light timber	3-inch	2	do	20	2	1	.1	10	.5	5	39	171
Do	129	Light steel	do	2	do	27	2	1	.08	12	.5	6	45	74
Do	130	Timber	6-inch	24	1 sergeant, 2 squads.	234	562	24	2.4	2,100	9	88	240	250
Do	131	Steel	do	24	do	290	459	19	1.6	1,900	6.5	80	230	142
Do	132	Concrete	10-inch	50	do	825	1,086	[1] 22	1.3	3,800	4.6	76	286	[2] 48
Cave	146	Recess	Depends on depth.	30	1 sergeant, 16 men.	240	27	.9	.1	2,300	9.6	77	130	328
Do	147	Gallery	do	24	do	234	28	1.2	.1	2,300	9.9	96	168	448

[1] Based on a capacity of 50 men, if for shelter, or 43.5 tons per person if shelter is designed for staff use of about 25 persons.
[2] For forms.

SECTION II

CAMOUFLAGE

■ 111. PROCEDURE.—*a.* Make camouflage effective primarily against aerial photographs.

(1) Hide form and shadow without changing texture or color.

(2) Do not make telltale tracks.

b. In choosing positions, consider mission, ease of access, natural concealment, defilade, and lay-out.

(1) Use aerial photographs to aid in selecting positions.

(2) Look first for natural concealment and cover; second, for terrain with a confused pattern; third, for most favorable existing routes.

(3) Plan lay-outs of main position and auxiliaries in detail before occupation.

c. Tie in camouflage with existing features.

d. Use natural materials wherever practicable.

(1) Place in natural positions.

(2) Keep green vegetation fresh.

e. Use fish nets for quick erection of flat-tops and drapes; chicken-wire for permanent flat-tops. Fish net is easy to handle but shrinks when wet, expands on drying, and deteriorates with extended use. Chicken wire is stronger and more durable than fish net, but is heavier, stiffer, and more bulky.

f. Match colors to surroundings.

g. Make flat-tops *flat.*

h. Thin out garnishing near edges.

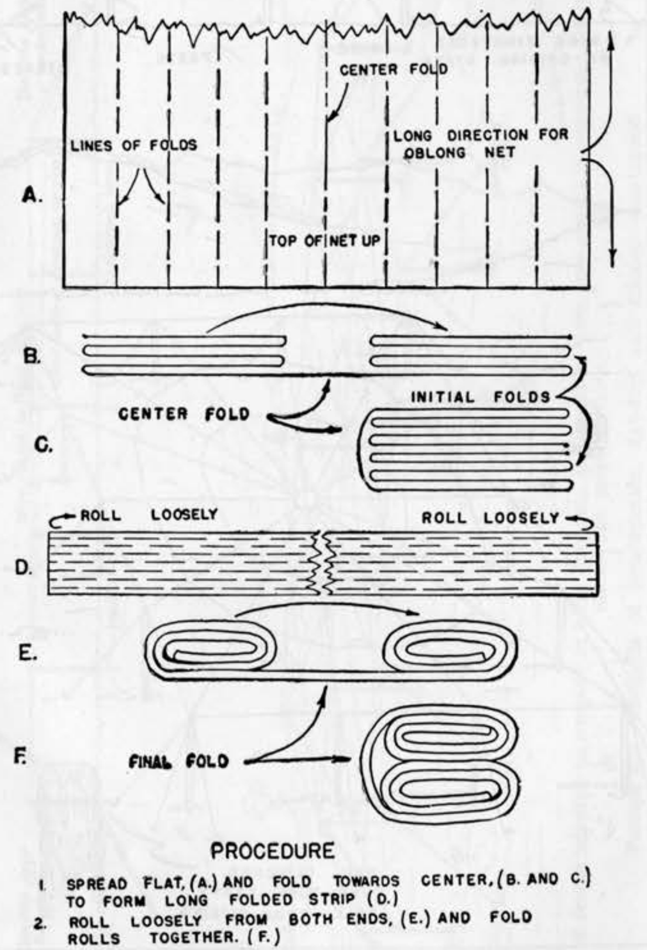
i. Exaggerate irregularities of outline.

j. Keep cover as close to the ground as practicable.

k. Enforce camouflage discipline.

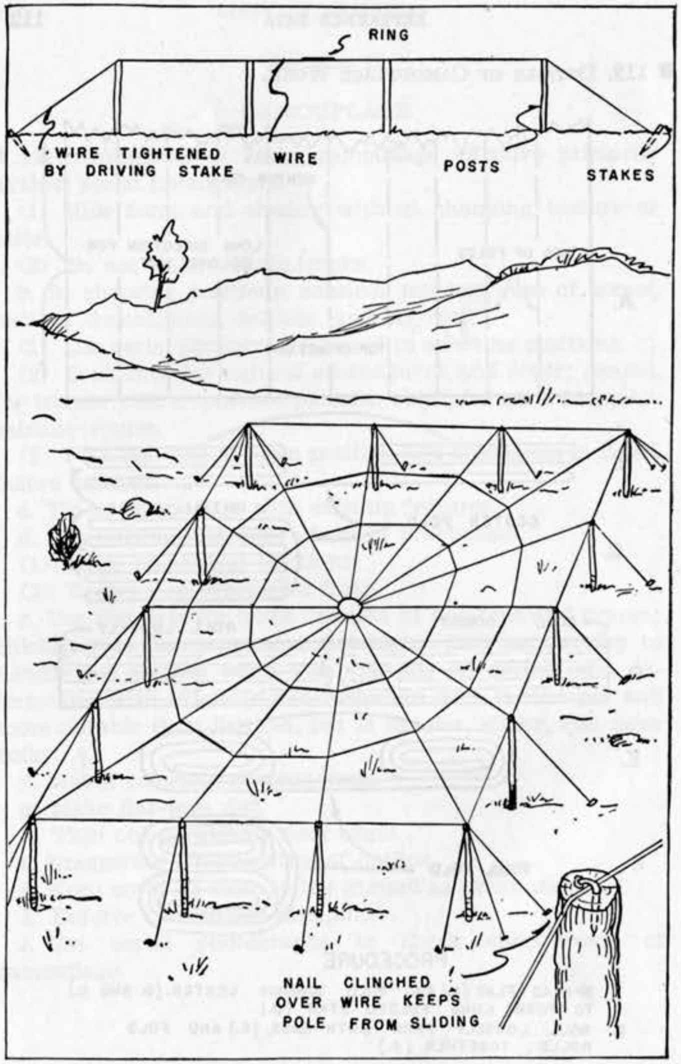
l. Use aerial photographs to check effectiveness of camouflage.

■ 112. DETAILS OF CAMOUFLAGE WORK.



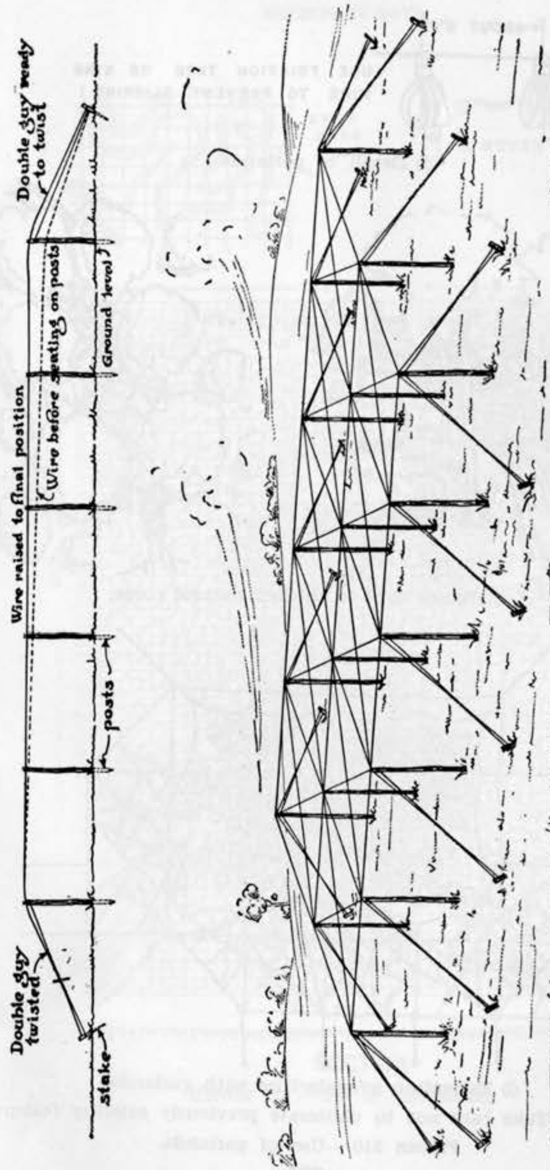
NOTE.—The folding procedure permits erecting the net from under the supporting frame with minimum disturbance to adjacent ground and vegetation.

FIGURE 208.—Method of folding fish nets.



① Type of frame used primarily to support fish nets; simple to construct but less durable than type ② on page 285.

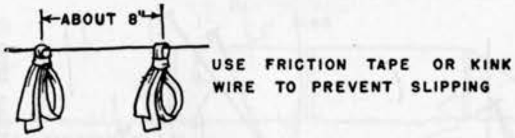
FIGURE 209.—Methods of construction, flat-top wire frames.



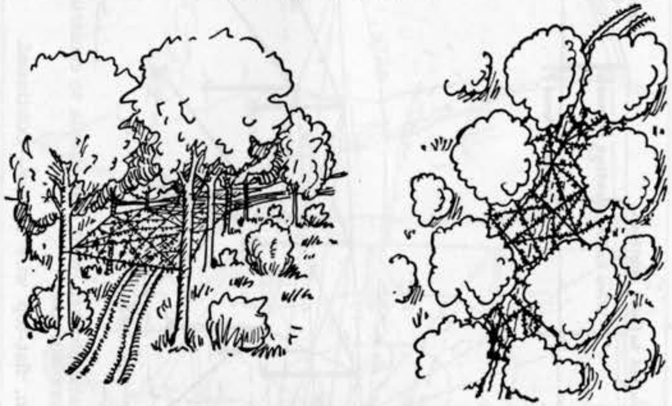
② Type of frame adapted to support of both fish nets and chicken wire; less simple to construct than type ① above but more durable.

FIGURE 209.—Methods of construction, flat-top wire frames—Continued.

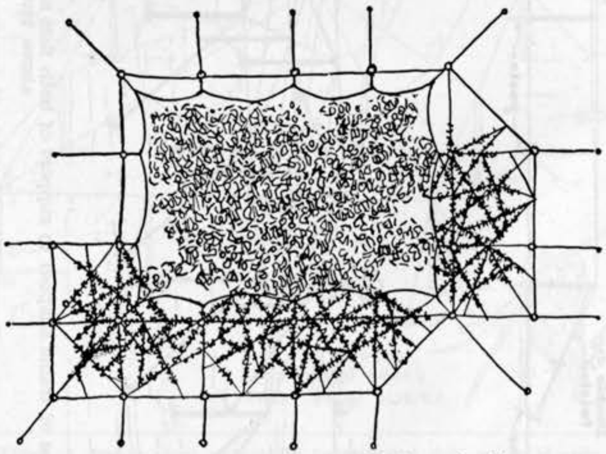
282736°—41——19



① Detail of garlands.



② Garlands used to thicken natural cover.



③ Extending irregularities with garlands.

NOTE.—Take care not to obliterate previously existing features.

FIGURE 210.—Use of garlands.

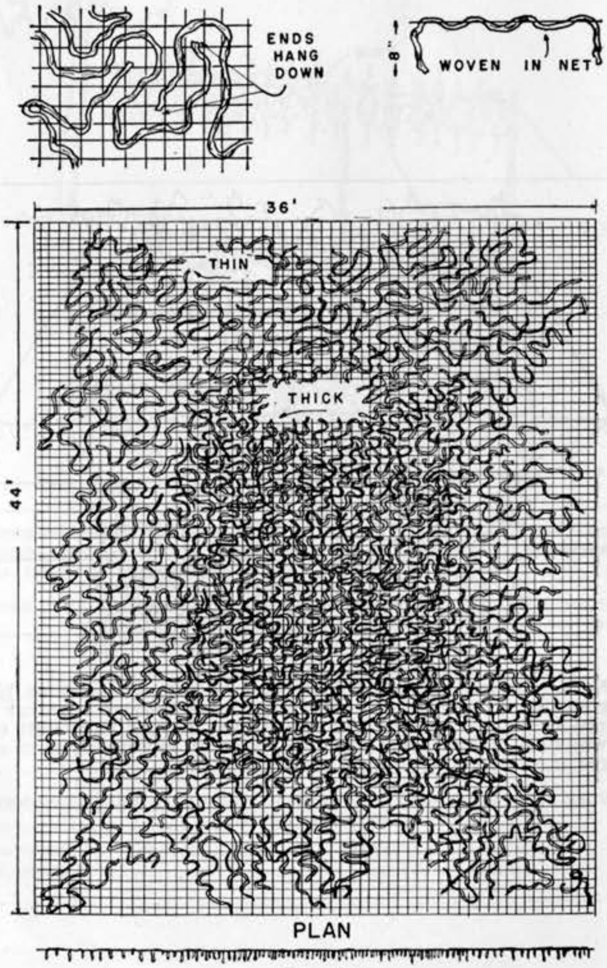
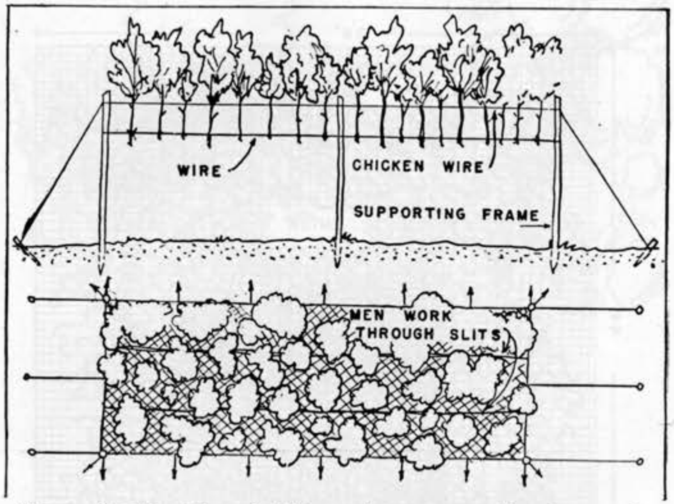
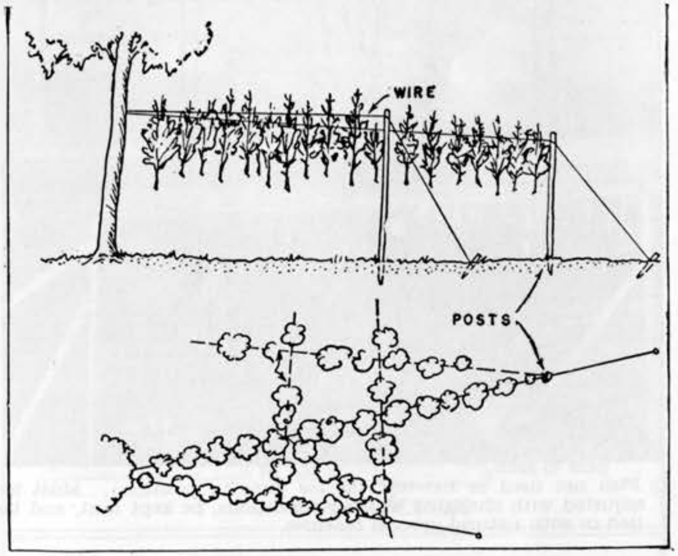


FIGURE 211.—Use of garnishing.



NOTE.—Stretch strips of chicken wire on supporting frame, placing strips side by side without overlap; work through openings between strips, placing branches and shrubs through wire, butt ends down; hold branches and shrubs upright by guy-wiring butt ends three or four ways to chicken wire.

FIGURE 212.—Preparation of overhead cover with natural materials. (See also fig. 209.)

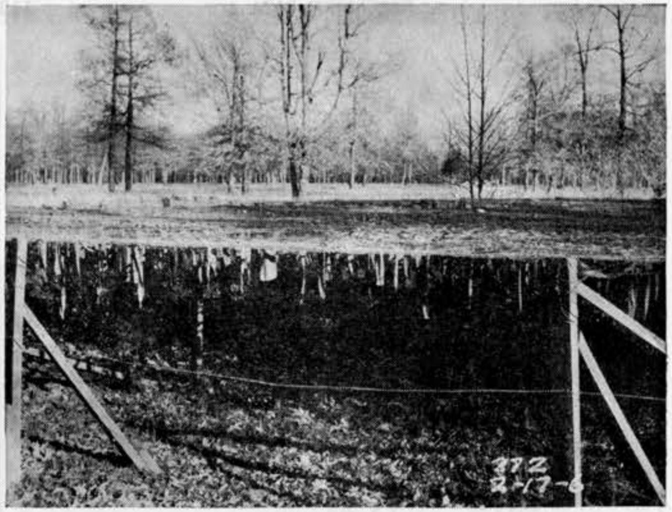


NOTE.—Stretch wires overhead at varying heights and in several different directions; from the wires, suspend branches by fastening them near the tips so they hang vertically.

FIGURE 213.—Preparation of overhead cover with natural materials (alternate method).

TABLE CXII.—*Materials required for flat-top covers*

Item	Fish nets, 36 by 44 feet	Chicken wire, 1,000 square yards
Stakes, 2½ feet by 3 inches diameter	20	40 to 100.
3-inch poles, lengths as needed	18	80 to 100.
Wire, smooth, No. 12 or larger	500 feet	6,000 feet.
Nails, assorted	½ pound	5 pounds.



① Fish net used as flat-top (as for guns in position). Must be adjusted with changing weather conditions, be kept taut, and be tied in with natural ground features.

② Fish net used as drape (as to cover trucks, tanks, etc.). Must be tied in with natural ground features.

FIGURE 214.—Uses of issue fish nets.

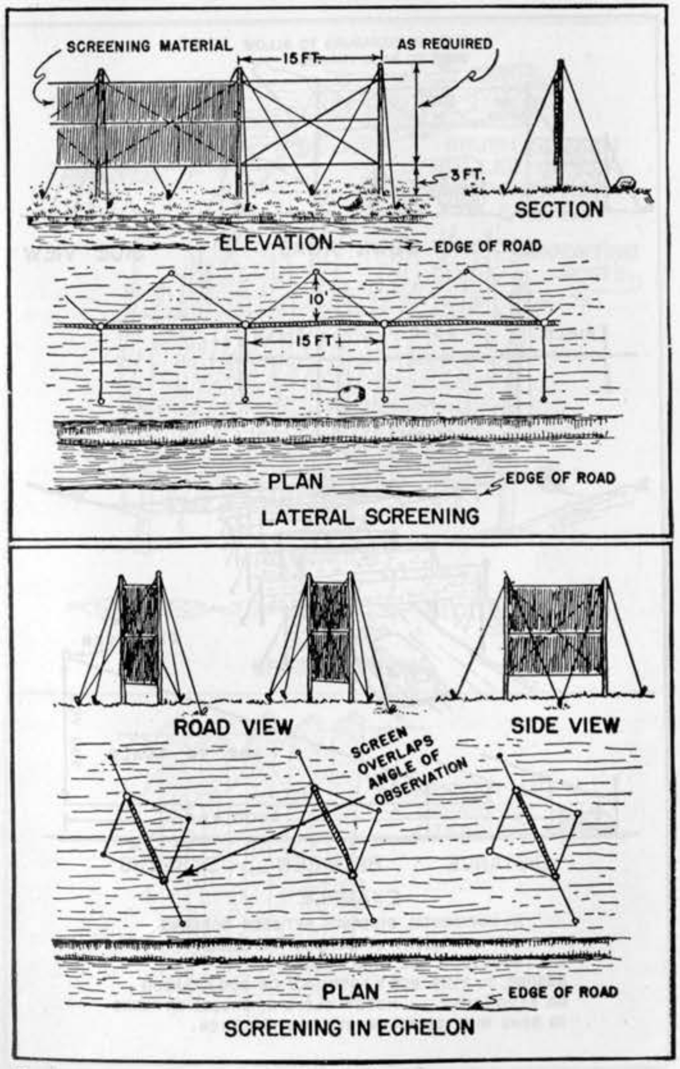


FIGURE 215.—Methods of road screening for roads parallel or oblique to front, respectively.

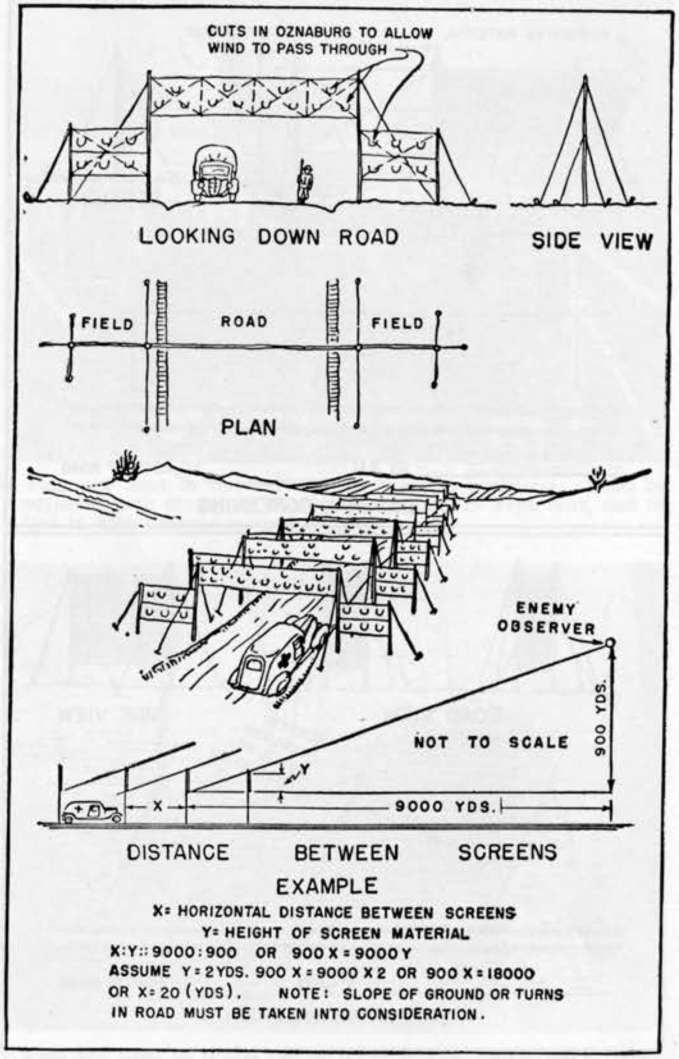


FIGURE 216.—Method of road screening for roads perpendicular to front.

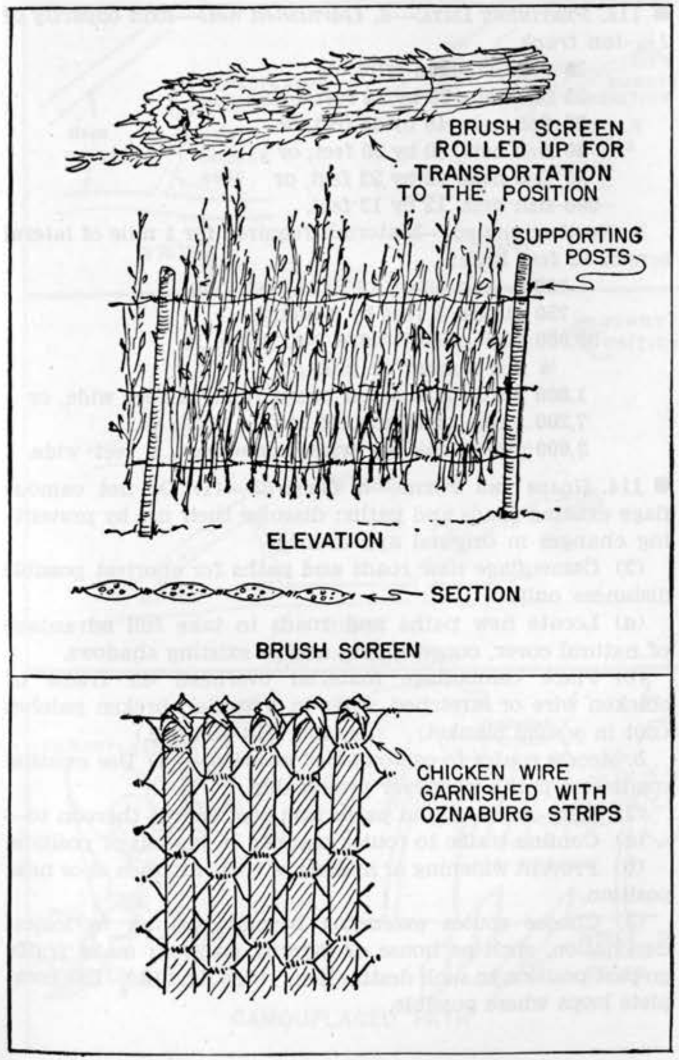


FIGURE 217.—Details of road screens.

■ 113. Pertinent Data.—*a. Garnished nets—load capacity of 1½-ton truck.*

25 rolls chicken wire, or
25 fish nets, 36 by 44 feet, or
20 fish nets, 45 by 45 feet, or
40 fish nets, 30 by 30 feet, or
80 fish nets, 22 by 22 feet, or
200 fish nets, 12 by 12 feet.

b. Road screening.—Materials required for 1 mile of lateral screen 12 feet high:

360 2-inch poles, 12 to 15 feet long.
750 stakes, 3 feet by 3 inches.
30,000 feet smooth wire, No. 9–No. 16.
½ keg staples or nails.
1,800 yards fabricated brush rolls, 12 feet wide, or
7,200 yards oznaburg, 40 inches wide, or
3,600 yards chicken wire camouflage, 6 feet wide.

■ 114. Roads and Paths.—*a. General.*—(1) Do not camouflage existing roads and paths; disguise their use by preventing changes in original appearance.

(2) Camouflage new roads and paths for shortest possible distances only.

(*a*) Locate new paths and roads to take full advantage of natural cover, concealment, and of existing shadows.

(*b*) Place camouflage material overhead on frame of chicken wire or stretched wires in irregular, broken patches (not in a solid blanket). (See figs. 213 and 218.)

b. Access routes to camouflaged position.—(1) Use existing roads and paths whenever practicable.

(2) Wire-in roads and paths and post guards thereon to—

(*a*) Confine traffic to routes planned in lay-out of position.

(*b*) Prevent widening or making of turn-arounds at or near position.

(3) Choose routes extending beyond position to logical destination, such as house or dummy position; make traffic go past position to such destination. (See fig. 218.) Use complete loops where possible.

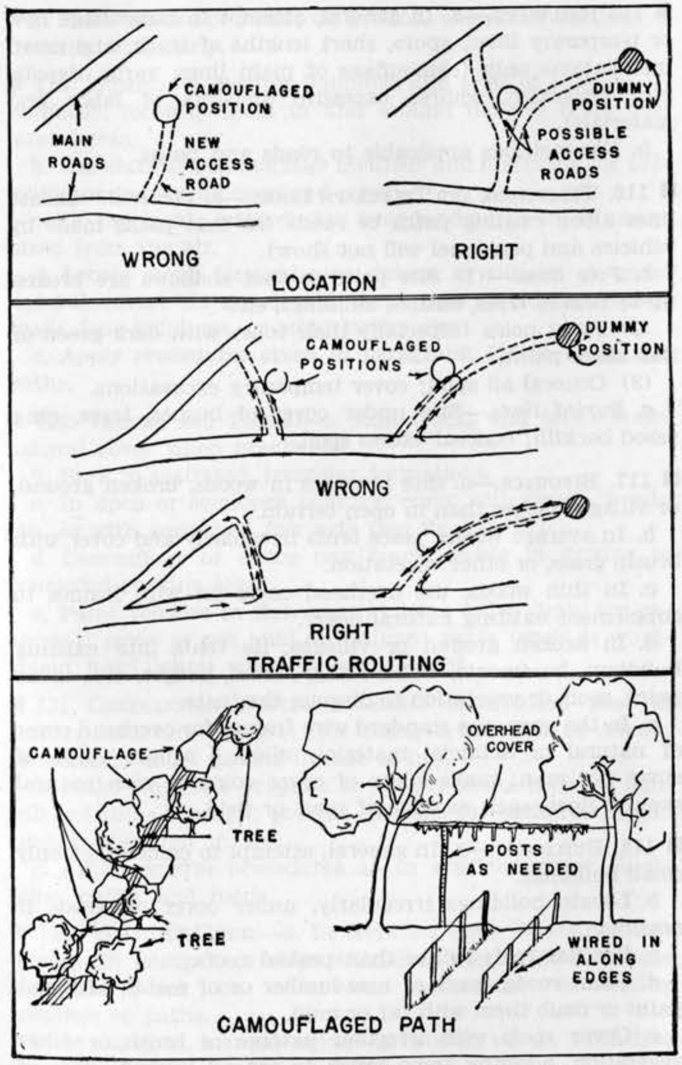


Figure 218.—Camouflage of paths and roads.

■ 115 RAILWAYS.—*a.* In general, attempt to camouflage new or temporary lines, spurs, short lengths of track, and small installations only (camouflage of main lines, yards, depots, etc., generally requires excessive amounts of labor and materials).

b. Use methods applicable to roads and paths.

■ 116. TELEPHONE AND TELEGRAPH LINES.—*a. General.*—Locate lines along existing paths or roads (so that paths made by vehicles and personnel will not show).

b. Pole lines.—(1) Site poles so that shadows are broken up by nearby trees, bushes, buildings, etc.

(2) Paint poles (especially their tops) with dark green or flat black paint.

(3) Conceal all spoil; cover temporary excavations.

c. Buried lines.—Site under cover of bushes, trees, etc.; resod backfill; conceal excess spoil.

■ 117. BIVOUACS.—*a.* Site bivouacs in woods, broken ground, or villages rather than in open terrain.

b. In average woods, place tents irregularly and cover with brush, grass, or other vegetation.

c. In thin woods, use overhead cover on wire frames to supplement existing natural cover.

d. In broken ground or villages, tie tents into existing buildings, basements, walls, ruins, fences, hedges, etc., using paint, mud, or vegetation to disguise the tents.

e. In the open, use standard wire frames for overhead cover of natural or artificial material; allow 5 square yards of cover per man; make edges of cover coincide with natural ground lines, such as edge of road or field.

■ 118. BUILDINGS.—*a.* In general, attempt to camouflage only small buildings.

b. Locate buildings irregularly, under cover of woods if possible.

c. Use flat roofs rather than peaked roofs.

d. Paint roofs, made of new lumber or of metal, with flat paint or daub them with tar or mud.

e. Cover roofs with irregular patches of brush or other vegetation, allowing some brush to extend beyond edges of roofs.

f. Place bushes or brush on ground, extending outlines of building irregularly.

■ 119. DUMPS.—*a.* Scatter buildings and piles of supplies irregularly, locating them in and around natural cover over large areas.

b. Use standard camouflage methods and materials for providing or improving overhead cover.

c. Do not locate large dumps near landmarks easily recognized from the air.

d. Locate small forward-area dumps in villages or under natural cover; do not locate them near prominent crossroads, lone buildings, or other landmarks.

e. Apply procedures given in paragraph 114 to roads and paths.

■ 120. TRUCKS AND TANKS.—*a.* Run trucks and tanks under natural cover when practicable.

b. Park in scattered, irregular formations.

c. In open or semiopen country, cover with brush, weeds, etc., or with garnished fish nets (see fig. 214 ②).

d. Camouflage or efface new tracks made in driving to concealed parking areas.

e. Paint vehicles in flat, neutral color (olive drab, for example); cover or put mud on brilliant parts (such as windshield, head lights) when exposed to light.

■ 121. OBSERVATION POSTS.—*a.* Locate observation post in existing structure or object (for example, in trench or cellar), or locate it under ground in side of hill.

b. Make loopholes irregular in shape; locate them so light will not shine through; provide curtains for background and closing when not in use.

c. Apply general procedures as to artificial cover, discipline, paths, and roads.

■ 122. MACHINE GUNS.—*a.* In trenches, cover V-shaped embrasure in parapet, or slope shoulders thereof to eliminate shadows. Cover or otherwise camouflage connecting trenches or paths.

b. In the open, take advantage of existing cover; when this is inadequate—

(1) Use artificial cover as shown in figure 219, or

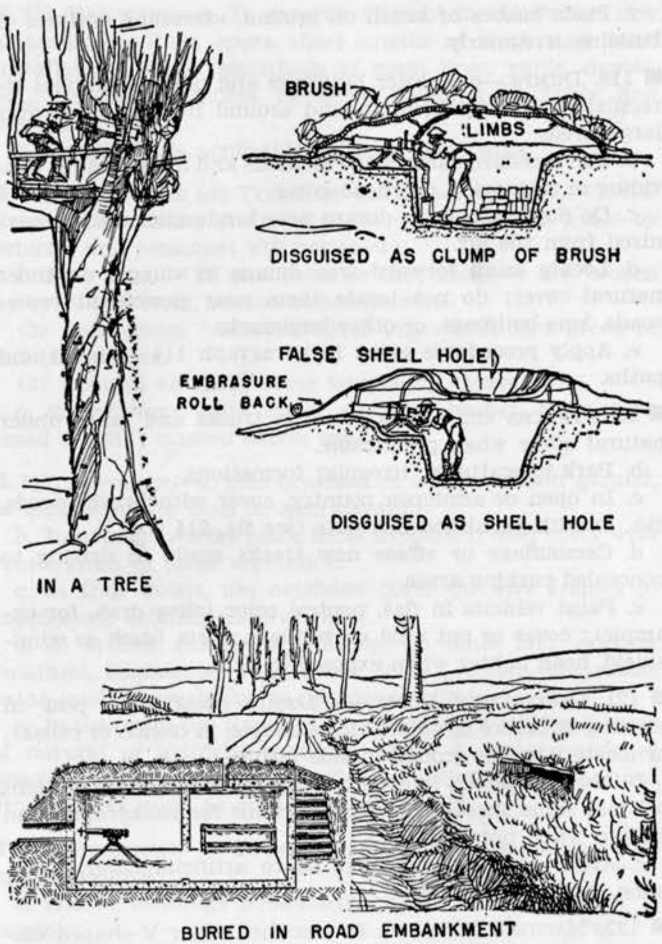


FIGURE 219.—Camouflage applied to machine-gun emplacements.

(2) Use standard 12 by 12 foot fish net as flat-top or drape. Reduce height of net by digging in the gun, and conceal elsewhere all spoil which cannot be covered by the same net.

■ 123. INFANTRY MORTARS.—When existing cover is inadequate, use standard 12- by 12-foot fish nets as flat-tops or drapes; arrange cover so that it may be rolled back to permit firing; reduce height of cover by digging in mortar; conceal spoil.

■ 124. ANTITANK GUNS (37-mm).—When existing cover is inadequate, use standard 22- by 22-foot fish net as flat-top or drape, arranged so that the gun can be moved into or out of firing position quickly.

■ 125. FIELD ARTILLERY BATTERIES.—*a.* When practicable, locate batteries under cover of woods.

(1) Avoid positions necessitating clearing for field of fire; look for natural openings.

(2) Edge of woods is usually a good position (see fig. 220).

b. In open terrain, use overhead covers on wire frames, blending them with natural features (clumps of brush and weeds, hedge lines, ditches, scattered trees, etc.).

(1) In most cases, guns must be placed under individual 36- by 44-foot fish net flat-tops, scattered irregularly to fit terrain.

(2) When terrain permits, a battery may be placed under a single, chicken wire flat-top. (See fig. 222).

(*a*) *Advantages.*—Intrabattery paths are concealed; control is facilitated.

(*b*) *Disadvantages.*—Requires more labor and materials; forms a better target if discovered by enemy.

c. When in or near villages, buildings, etc., use debris and similar material to break form and shadow of gun and pit.

d. Provide embrasures which can be opened and closed. (See fig. 221.)

e. Reduce height of covers by digging in guns.

f. Conceal blast marks in growing fields by covering with vegetation; in plowed fields, by spading. (No blast marks occur over roads or very hard ground.)

g. Keep as few men as possible at guns; keep other personnel under cover in rear.

h. Paint guns and accompanying vehicles in a flat, neutral color which blends with surrounding vegetation. Cover polished bright and glass surfaces or cover with mud film.

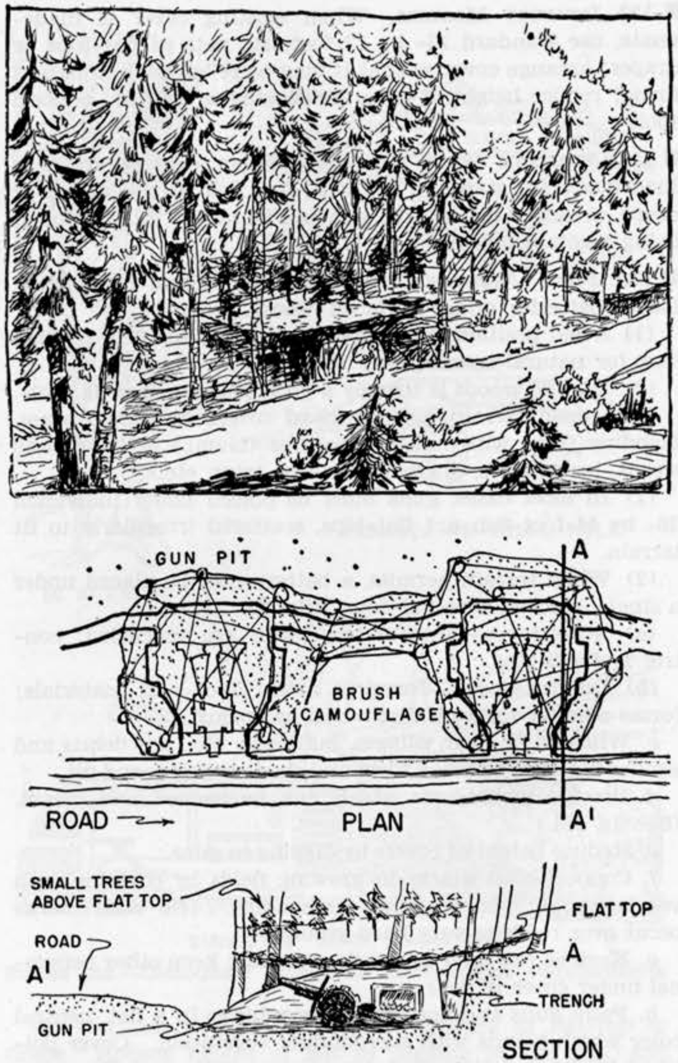


FIGURE 220.—Camouflage applied to artillery positions at edge of woods.

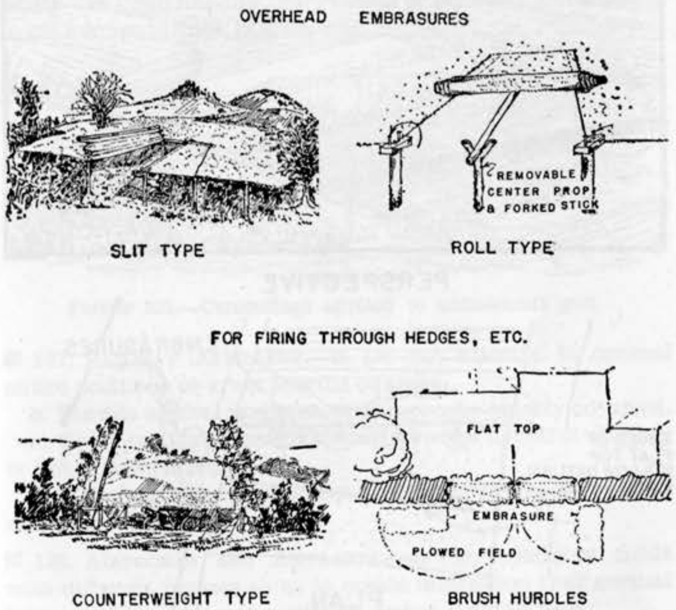


FIGURE 221.—Camouflage applied to artillery embrasures.

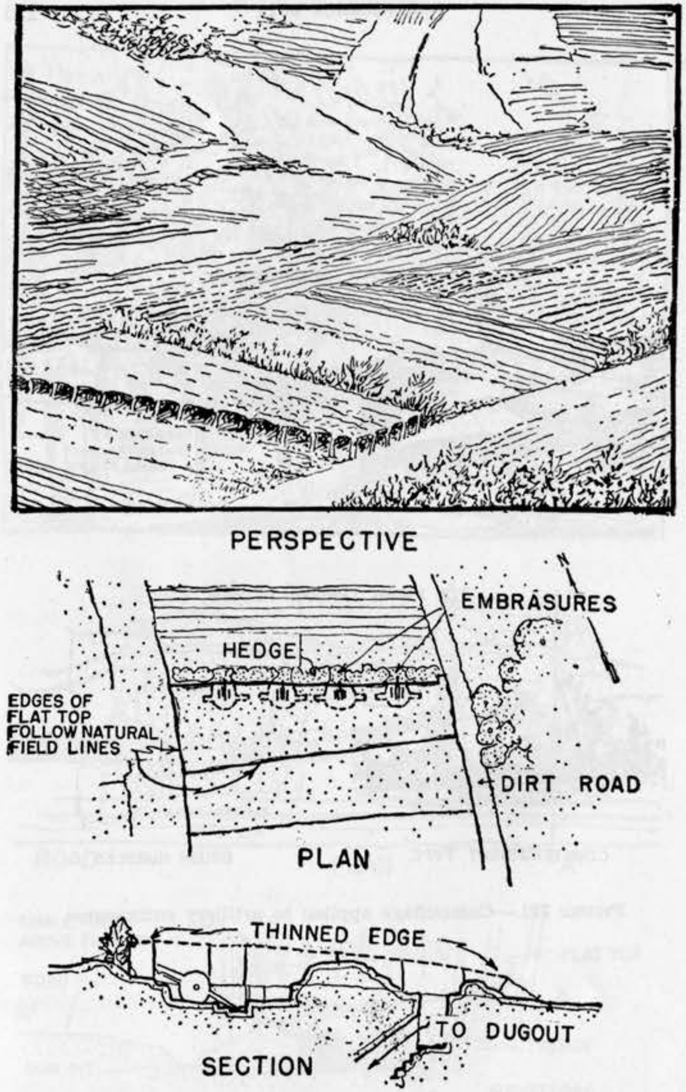


FIGURE 222.—Camouflage applied to artillery positions, battery under single cover.

■ 126. ANTIAIRCRAFT BATTERIES.—*a*. Provide for 360° traverse and for elevation from horizontal to vertical.

b. Use standard 36- by 44-foot fish nets or other standard materials to erect cover at trunnion height, allowing gun barrel to extend through; paint gun barrel so as to match cover; dig in outriggers and remove platforms. (See fig. 223.)

c. Conceal power plant in natural cover; where no cover exists, use small flat-top; bury cables or lay them along paths, in high grass, shrubs, bushes, etc.

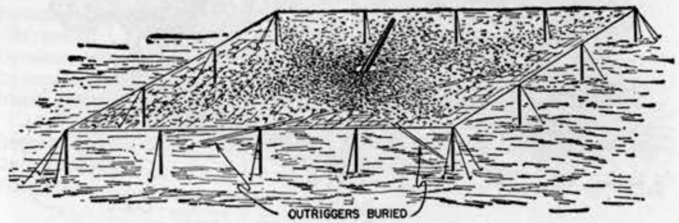


FIGURE 223.—Camouflage applied to antiaircraft gun.

■ 127. RAILWAY ARTILLERY.—*a*. Do not attempt to conceal entire positions or great lengths of track.

b. Provide several positions, which can be quickly occupied.

c. Cover each position sufficiently to make doubtful whether or not it is occupied.

d. Make artillery equipment resemble ordinary railway equipment.

■ 128. AIRDROMES AND AIRPLANES.—*a*. Plant landing fields with different grasses so as to create impression that normal lines of adjacent areas continue across landing field.

b. Space hangars irregularly, taking advantage of natural cover; improve natural cover by use of standard materials and methods.

c. Consider constructing hangars underground with concealed entrances (offers high protection, but requires great amounts of labor, time, materials; provides physical protection as well as concealment).

d. Disperse parked airplanes; run them tailfirst under cover; improve natural cover by use of standard materials and methods.

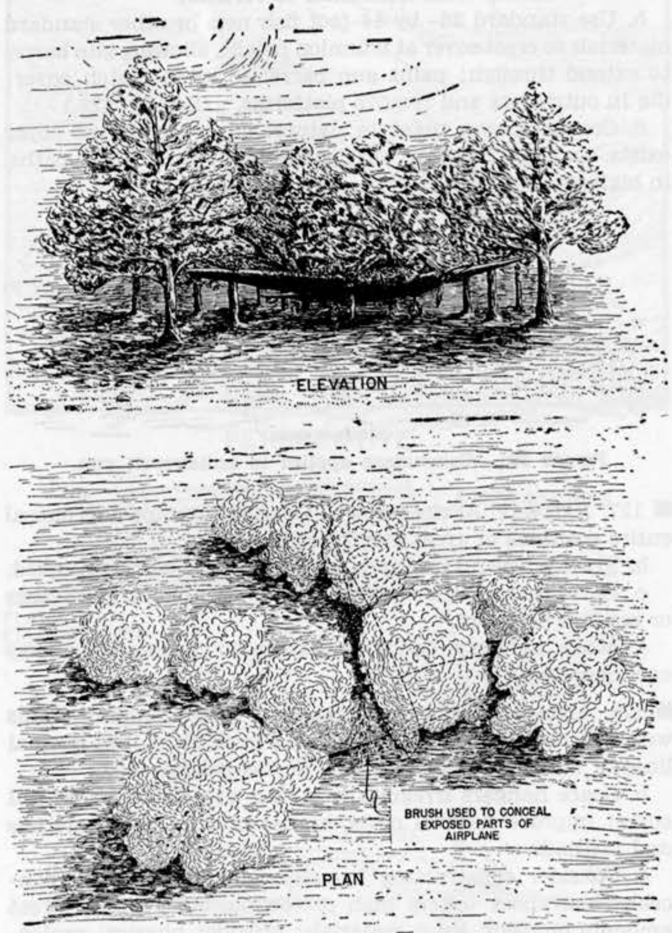


FIGURE 224.—Camouflage applied to airplane.

SECTION III.

EXPLOSIVES AND DEMOLITIONS

■ 129. CHARACTERISTICS AND PROPERTIES OF MILITARY EXPLOSIVES AND FUSES.

TABLE CXIII.—*Properties of military explosives*

Explosive	Relative strength (by weight)	Detonation by—
TNT	1.00	Issue special tetryl cap.
Nitrostarch	.90	No. 8 commercial blasting cap.
Dynamite, ammonia (extra), 60 percent.	.90	Do.
Dynamite, gelatin, 60 percent	.90	Do.
Dynamite, straight, 50 percent	1.00	No. 6 to No. 8 commercial blasting cap.
Blasting gelatin	2.10	No. 8 commercial blasting cap (large charges must be primed).
Guncotton, dry	1.20	No. 6 to No. 8 commercial blasting cap.
Guncotton, wet	1.20	Primer of guncotton, dry.
Picric acid	1.06	No. 7 commercial blasting cap (small charge).
		No. 8 commercial blasting cap (large charge).
Dynamite, ammonia nitrate	1.20	Do.
Ammonal	1.05	Do.
Gunpowder	.33	Flame.

TABLE CXIV.—*Characteristics of issue fuses*

Type	Identified by—	Rate of burning in feet per second (approx.)	Form of issue	Use	To ignite
Fuse, blasting, time.	White, smooth surface.	0.03 (32-40 seconds per foot).	50-foot rolls.	To fire nonelectric caps. To ignite instantaneous fuse. To ignite blasting powder.	Use match, fuse lighter, etc.
Fuse, blasting, instantaneous.	Red braid, rough surface.	120	do	To fire nonelectric caps.	Splice with time fuse; ignite latter.
Cord, detonating PETN.	Yellow, rough surface.	20,000	100-foot rolls.	To induce detonation in high explosives intimately adjacent.	Use issue detonating cap.

TABLE CXV.—*Maximum distances for obtaining induced detonation of cap in air (open end of cap directed at charge)*

Initial charge	Distance (inches)	Initial charge	Distance (inches)
1 block TNT	24	5 blocks TNT	60
2 blocks TNT	36	6 blocks TNT	72
4 blocks TNT	48	8 blocks TNT	96

■ 130. ELECTRIC FIRING.—*a. Electrical constants.*—(1) Cap, including 12-foot lead wires: resistance 1.5 ohms; current required 1.0 ampere.

(2) Lead wire, 500 feet of No. 18 (B. & S.) double conductor: resistance usually less than 7 ohms.

(3) Exploders: 10- and 30-cap capacity.

(4) Batteries, dry and wet, in good condition: internal resistance usually under ½ ohm per cell.

(5) Ohm's law: $E = IR$ (Voltage = current times resistance).

b. Locating and repairing break in wire circuit.—See figure 225.

(1) Secure connecting wire *N* to end connection *D*; hold wire *N* against binding post *L*; connect binding post *O* to joint *C*.

(2) If galvanometer shows satisfactory circuit, break is in lead wires.

(3) If galvanometer fails to show satisfactory circuit, connect binding post *O* successively to joints *H, G, F*, etc., until satisfactory circuit is shown.

(4) Break is between last joint showing unsatisfactory circuit and first joint showing satisfactory circuit.

(5) If break is above tamping, repair it; if below tamping, handle as misfire.

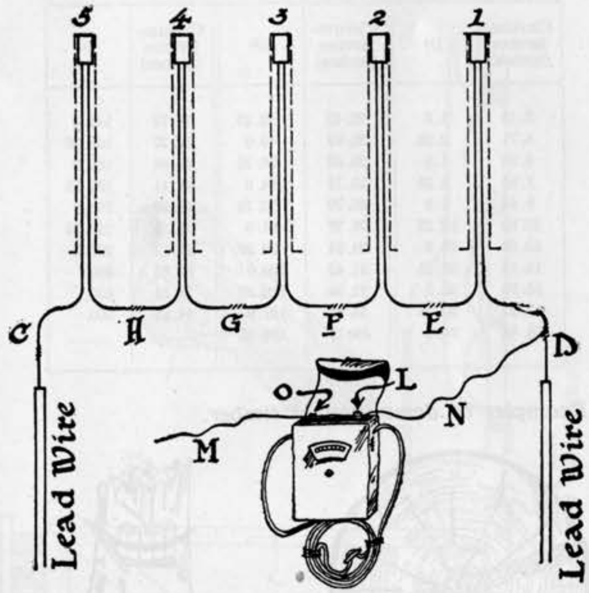


FIGURE 225.—Testing a wire circuit.

■ 131. DEMOLITION OF TIMBER.—*a. Formulas for circular cross sections.*

(1) External charge: $N = \frac{D^2}{20}$

(2) Internal charge: $N = \frac{D^2}{125}$

where

N = number ½-pound blocks TNT required.

D = diameter of cross section in inches.

b. Rules of thumb for all types of cross sections.—(1) *External charge.*—Use eight ½-pound blocks TNT per square foot of cross section.

(2) *Internal charge.*—Use one and a half ½-pound blocks TNT per square foot of cross section.

TABLE CXVI.—*Values of D^2 in timber demolition formula*

Circumference (inches)	D^2	Circumference (inches)	D^2	Circumference (inches)	D^2
3.14	1.0	20.42	42.25	37.70	144.0
4.71	2.25	21.99	49.0	39.27	156.25
6.28	4.0	23.56	56.25	40.84	169.0
7.85	6.25	25.13	64.0	42.41	182.25
9.42	9.0	26.70	72.25	43.98	196.0
10.99	12.25	28.27	81.0	45.55	210.25
12.56	16.0	29.84	90.25	47.12	225.0
14.13	20.25	31.42	100.0	62.83	400
15.70	25.0	32.99	110.25	78.54	625
17.27	30.25	34.56	121.0	94.25	900
18.85	36.0	36.13	132.25	------	------

c. Examples of demolition of timber.

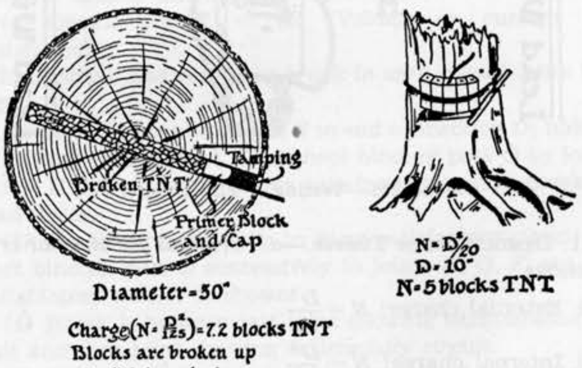


FIGURE 226.—Use of TNT in felling trees.

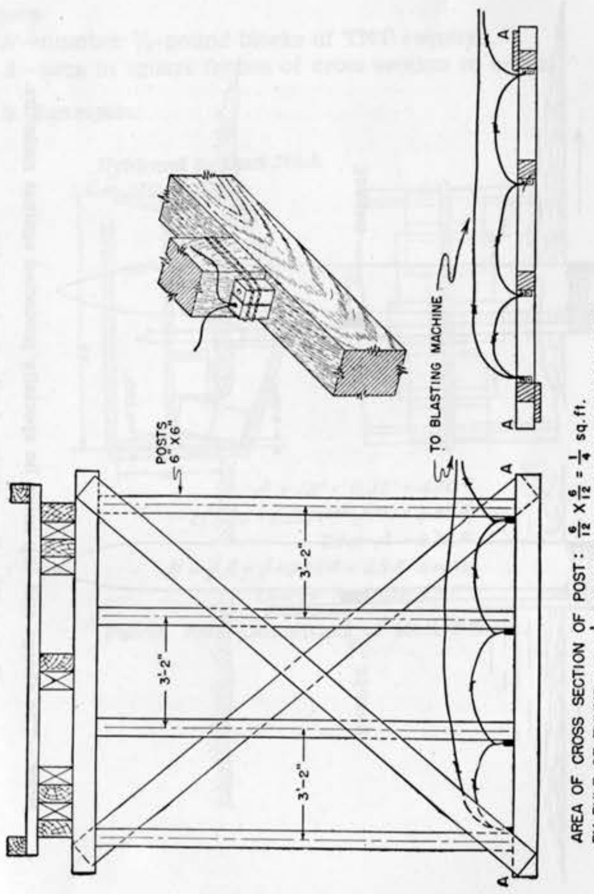
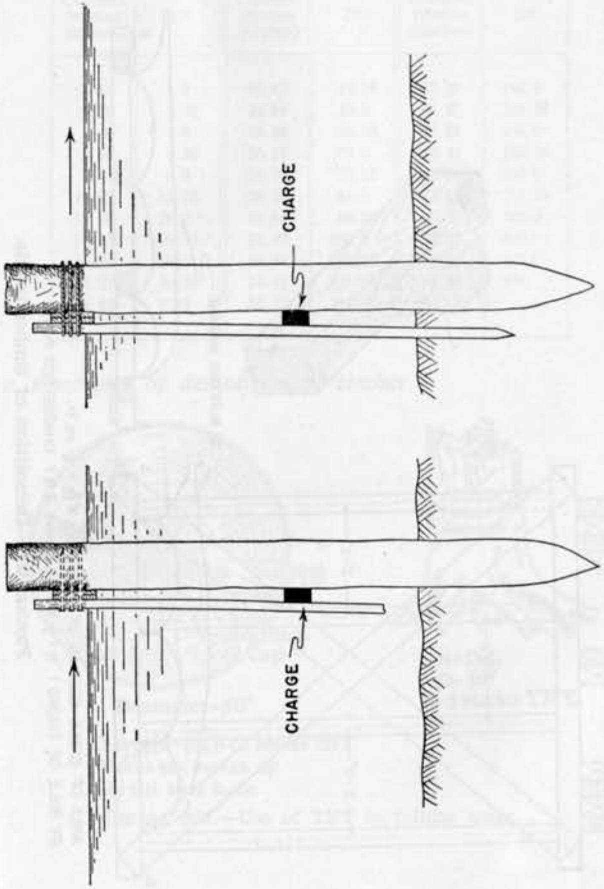


FIGURE 227.—Demolition of timber trestle.



NOTE.—The charge and cap must be specially protected against moisture.

FIGURE 228.—Demolition of piles under water.

■ 132. DEMOLITION OF STEEL MEMBERS.—*a. Formula.*

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

where

N=number ½-pound blocks of TNT required.

A=area in square inches of cross section to be cut.

b. Examples.

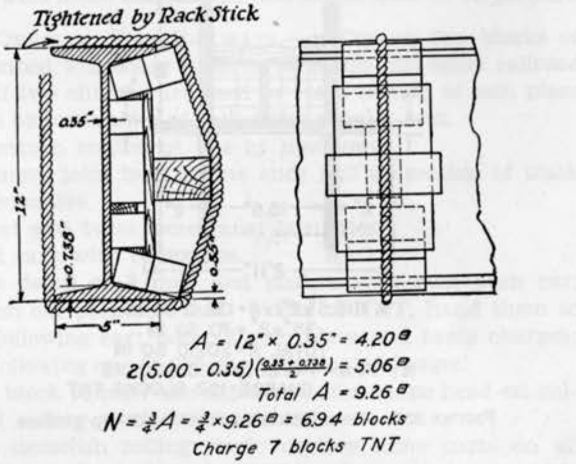


FIGURE 229.—Demolition of steel I-beam.

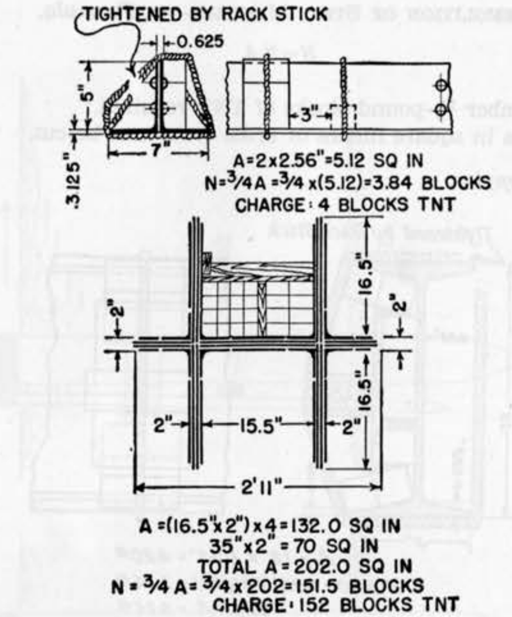


FIGURE 230.—Demolition of steel built-up girders.

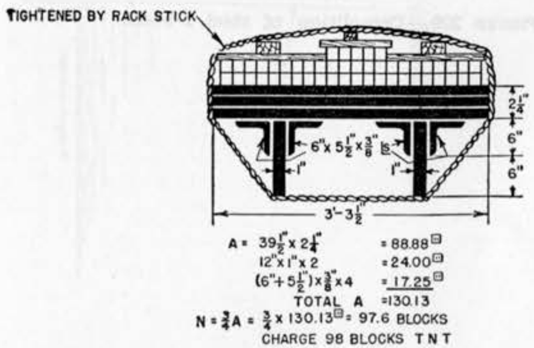


FIGURE 231.—Demolition of steel built-up girder.

c. Points to be observed.—(1) Blocks should be in contact with each other.

(2) Place largest portion of charge nearest area of greatest cross section.

(3) If form of member is such that charge must be distributed on opposite sides, opposing portions should be offset.

(4) If blocks are in intimate contact with section, and if tamped with moist clay charge may be reduced by 50 percent.

■ 133. DEMOLITION OF RAILWAYS.—*a.* One or two blocks of TNT tamped with loose earth or sandbags will break railroad rails. If two charges are used to cut a section of rail, place them on opposite sides of rail, offset about 2 feet.

b. Overturn section of line by manpower.

c. Remove joint bars at one end; pull up section of track with locomotive.

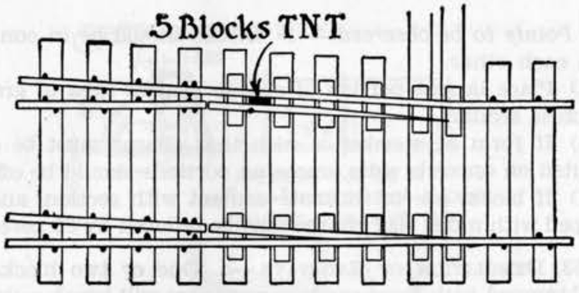
d. Heat and twist loose rails; burn ties.

e. Cut rails with explosives.

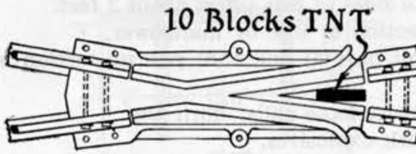
f. Use detail of 8 men and push car: 2 men push car; 2 men on car prepare (fuse) blocks of TNT, hand them to 2 men following car; latter 2 men place and tamp charges; 2 men following car at 250 yards detonate charges.

g. To block tunnel: use explosives or arrange head-on collision of rolling stock within tunnel.

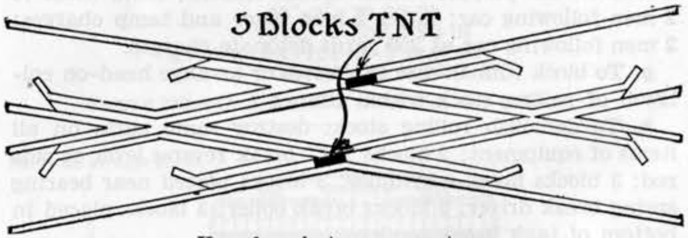
h. To demolish rolling stock: destroy same parts on all items of equipment; 2 blocks TNT break reverse lever or side rod; 3 blocks break a cylinder; 3 blocks placed near bearing spring break driver; 3 blocks break boiler; 3 blocks placed in bottom of tank break tender.



Use of explosive on switch points.



Use of explosive on frogs.



Use of explosive on crossings.

FIGURE 232.—Examples of railway demolitions.

■ 134. **DEMOLITION BY BREACHING** (rock, plain concrete, brick, masonry).—*a. Formulas.*

$N=R^3KC+25$ percent (charges under 100 blocks), or

$N=R^3KC+10$ percent (charges over 100 blocks)

where

N=number of ½-pound blocks of TNT required.

R=radius of rupture (in feet): depth to which disintegration is desired, measured from center of surface of contact between charge and material to be destroyed. (See fig. 235.)

K=a factor dependent upon material blasted. (See table CXVII.)

C=a factor dependent upon location and tamping of charge. (See fig. 233.)

TABLE CXVII.—*Values of K in breaching formulas*

	R	K
Ordinary earth	All values	0.09
Poor masonry, shale and hardpan, good timber and earth construction.	do	.38
Good masonry, concrete, rock	Under 3 feet	.63
	3–5 feet	.50
	5–7 feet	.44
	Over 7 feet	.38
Dense concrete, first-class masonry	Under 3 feet	.81
	3–5 feet	.65
	5–7 feet	.57
	Over 7 feet	.49
Reinforced concrete (Concrete only, will not cut bars.)	Under 3 feet	1.25
	3–5 feet	1.00
	5–7 feet	.88
	Over 7 feet	.75

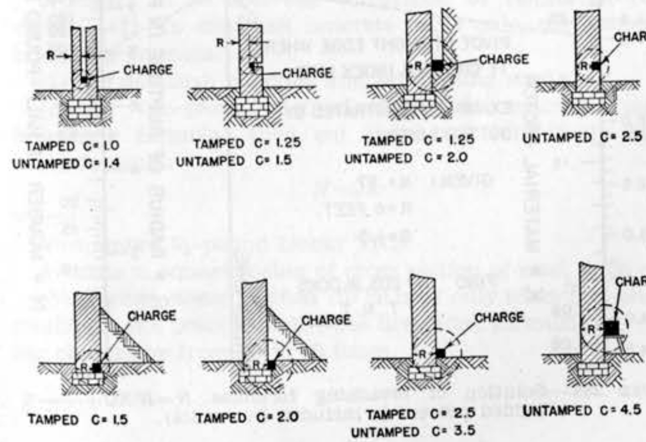


FIGURE 233.—Values of C in breaching formulas.

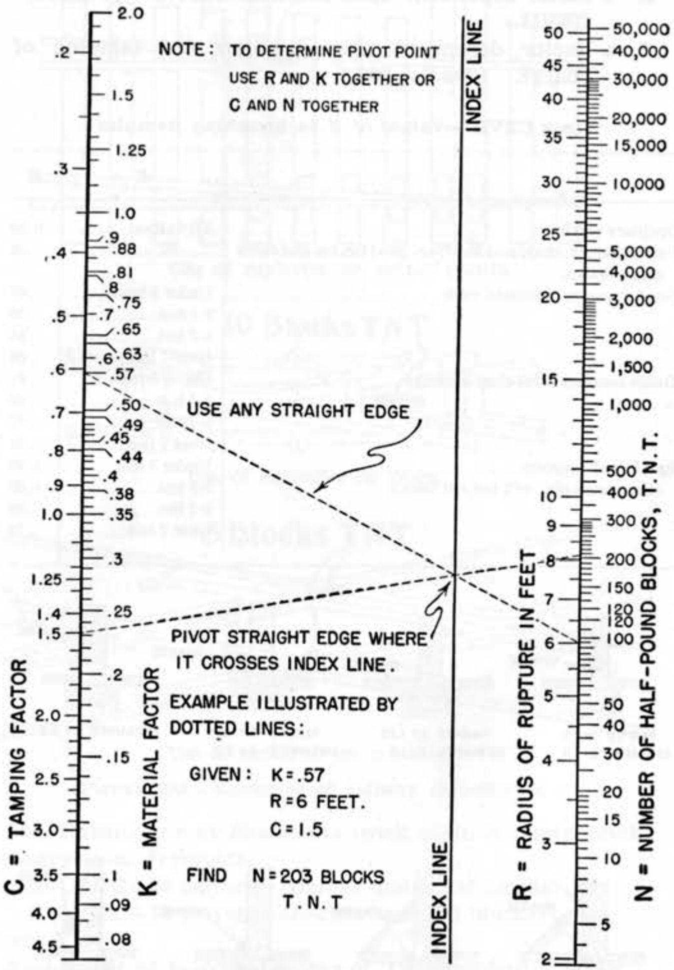


FIGURE 234.—Solution of breaching formulas: $N=R^3KC+$——% (added percent is included in results).

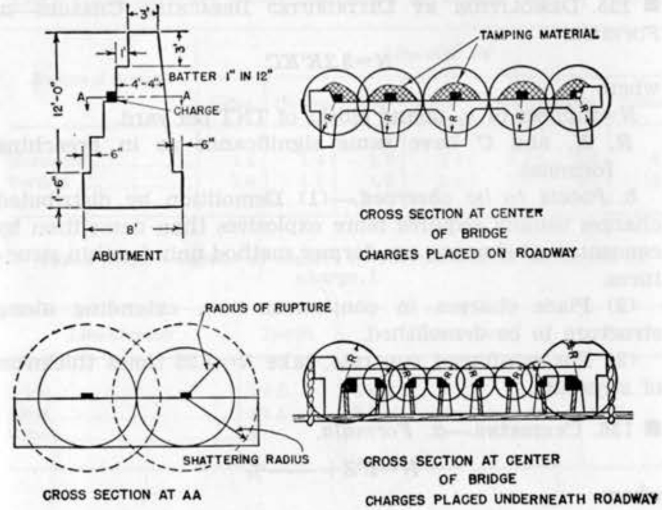


FIGURE 235.—Methods of placing charges in demolition of reinforced concrete span.

b. Points to be observed (breaching of reinforced concrete).—(1) To demolish concrete parts only, use standard breaching formula.

(2) To demolish concrete and reinforcing steel—

(*a*) *By two-phase method.*—Demolish concrete, using breaching formula; then cut individual reinforcing bars, using formula:

$$N=2A$$

where

N=number ½-pound blocks TNT.

A=area in square inches of cross section of steel to be cut.

(*b*) *By one-phase method* (to be used only when two-phase method is not practicable).—Use breaching formula, increasing charges by from 20 to 40 times.

■ 135. DEMOLITION BY DISTRIBUTED BREACHING CHARGES—*a. Formula.*

$$N=3.2R^2KC$$

where

N=number of ½-pound blocks of TNT per yard.

R, K, and C have same significance as in breaching formulas.

b. Points to be observed.—(1) Demolition by distributed charges usually requires more explosives than demolition by concentrated charges; use former method only for thin structures.

(2) Place charges in continuous row, extending along structure to be demolished.

(3) For reinforced concrete, take R=1.25 times thickness of structure.

■ 136. CRATERING.—*a. Formula.*

$$N=L^3Z+\text{——}\%$$

where

N=number of ½-pound blocks of TNT required.

L=depth to top of charge in feet.

Z=a factor depending on nature of soil (see table CXVIII) and on line of crater.

TABLE CXVIII.—*Values of Z in crater formula*

Kind of material	Camouflet 1-line	Undercharged 1½-line	Common 2-line	3-line	4-line	5-line	6-line
Light earth	0.010	0.024	0.054	0.162	0.36	0.70	1.23
Common earth	.012	.030	.066	.188	.44	.86	1.51
Hard sand	.014	.038	.084	.252	.56	1.10	1.93
Hardpan	.016	.046	.100	.300	.67	1.30	2.29

NOTE.—Charges under 50 blocks, add 100 percent; 50 to 200 blocks, add 50 percent; 200 to 500 blocks, add 25 percent; over 500 blocks, add 10 percent.

TABLE CXIX.—*Values which multiplied by L give radii of rupture*

Radius of rupture	Line of crater						
	1-line	1½-line	2-line	3-line	4-line	5-line	6-line
Horizontal	1.0	1.4	1.7	2.4	3.1	3.9	4.7
Vertical	1.0	1.1	1.2	1.4	1.7	2.1	2.6

TABLE CXX.—*Depths of craters in common earth for depth of charge L*

Line of crater	Depth	Line of crater	Depth
2-line	1/3 L.	5-line	4/3 L.
3-line	2/3 L.	6-line	5/3 L.
4-line	L.		

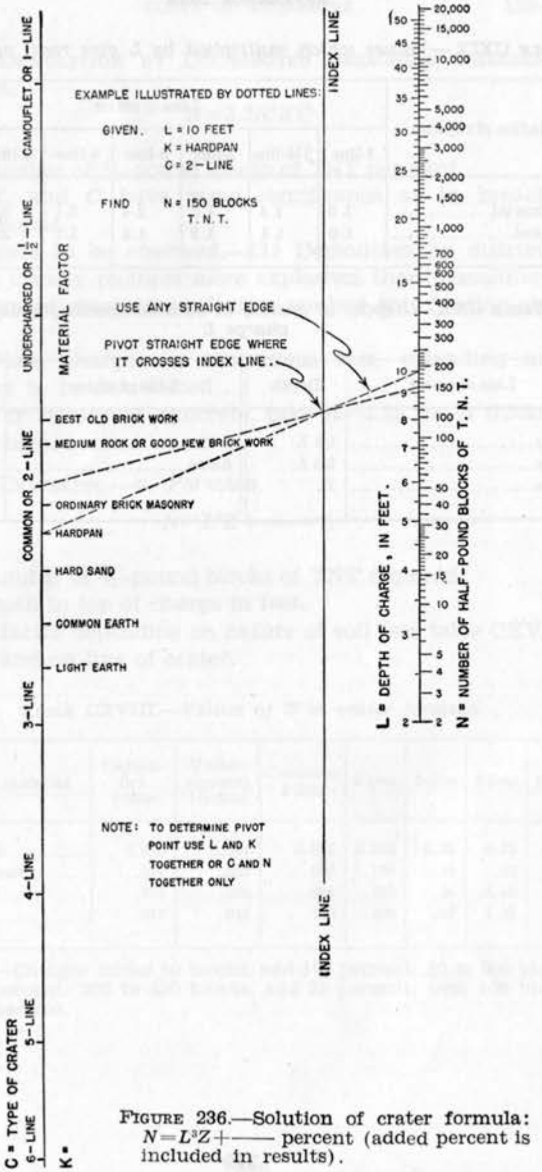


FIGURE 236.—Solution of crater formula: $N=L^3Z+$—— percent (added percent is included in results).

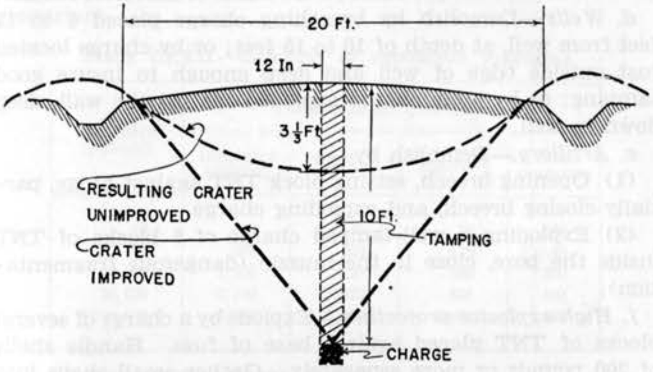
b. Road craters.—(1) Locate in embankments, cuts, fills, causeways, crossroads, or in villages.

(2) Flood, if possible.

(3) For charges placed in culverts, tamp thoroughly for distance at least equal to horizontal radius of rupture.

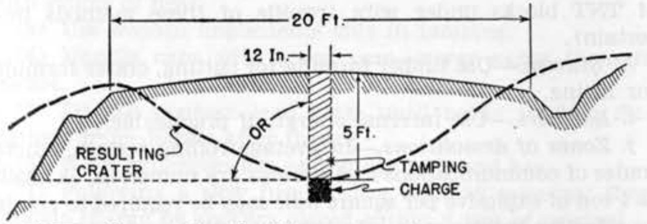
(4) If material falling back can be removed, use a 1½ or 2 lined crater; if not, use a 4 lined crater.

(5) Two or more adjacent charges often will give more effective results (especially for hasty AT obstacles) than the same amount of explosive in one charge which is harder to place.



NOTE.—*Charge:* $N=L^3\times Z+$—— percent
$=10^3\times .10+$—— percent $=100+50$ percent
$=150$ blocks TNT

FIGURE 237.—Road crater, two-lined, to be improved (hardpan).



NOTE.—*Charge:* $N=L^3\times Z+$—— percent
$=5^3\times .67+$—— percent $=83.75+50$ percent
$=126$ blocks TNT

FIGURE 238.—Road crater, four-lined, unimproved (hardpan).

■ 137. **General Demolitions; Various Objects and Structures.**—*a. Tunnels.*—The best points for attack are where the tunnel passes through loose materials (destroy lining for length of 15 to 25 yards by series of breaching charges). Block tunnels by head-on collisions.

b. Telegraph and telephone lines.—Disable by cutting or grounding wires. Destroy completely by burning or demolishing poles and cutting wires.

c. Frame buildings.—Demolish by closing doors and windows and exploding concentrated charge on ground floor (about 1 block TNT per cubic yard volume of first floor rooms).

d. Wells.—Demolish by breaching charge placed 6 to 12 feet from well, at depth of 10 to 15 feet; or by charge located just outside edge of well and deep enough to insure good tamping; or by large charge exploded against the wall, deep down in well.

e. Artillery.—Demolish by—

(1) Opening breech, setting block TNT against hinge, partially closing breech, and exploding charge.

(2) Exploding a well-tamped charge of 5 blocks of TNT inside the bore, close to the muzzle (dangerous fragmentation).

f. High explosive projectiles.—Explode by a charge of several blocks of TNT placed against base of fuze. Handle shells of 200 pounds or more separately. Gather small shells into groups of 200 pounds, place in contact with each other, and detonate one shell (the others detonate by induction). Handle shells carefully—explode only in a trench at least 6 feet deep.

g. Wire entanglement.—Use bangalore torpedo or lay chain of TNT blocks under wire (results of these methods uncertain).

h. Stumps.—Use timber formula for cutting, crater formula for lifting.

i. Boulders.—Use internal charges if practicable.

j. Zones of demolitions.—In average rolling terrain, where routes of communications and streams are numerous, as much as 1 ton of explosive per square mile may be required to create an effective barrier zone. In thickly settled areas, 1.5 tons—and more—may be required per square mile.

Table CXXI.—*Charges for demolition of boulders*

Diameter of boulder (feet)	Number of 1¼- by 8-inch sticks of 50 percent dynamite required		
	Blockhole	Snakehole	Mudcap
1½	¼	1	2
2	¼	1	3
4	¾	4	7

■ 138. **Storage and Handling of Explosives.**—*a. Location of magazines.*

Table CXXII.—*Location of explosives magazine*

Explosive (pounds)	Distance in feet from nearest—			
	Inhabited building	Railway	Highway	Other magazine
50	240	140	70	60
100	360	220	110	80
2,000	1,200	720	360	200
25,000	2,110	1,270	630	300
[1] 100,000	3,630	2,180	1,909	400

[1] Maximum permitted in any 1 magazine.

b. Precautions in handling.—(1) Do not store or transport caps or primers with explosives.

(2) Thaw frozen dynamite slowly, out of direct contact with source of heat.

(3) Use wooden implements only in tamping.

(4) Handle caps with great care—never carry them in pocket.

(5) Do not connect lead wires until ready to fire; disconnect immediately after firing.

(6) Keep explosives dry and under lock and key.

(7) Following a slow fuse misfire, wait 30 minutes; then explode charge by another placed within 2 feet of original.

(8) After an electric cap misfire operate exploder several times; disconnect and separate lead wires off ground. Investigate at once.

Section IV

BARRIERS AND ANTIMECHANIZED DEFENSE

■ 139. Characteristics of Matériel.

Table CXXIII.—*Classification of obstacles*

Criterion	Classification	General purposes	Remarks
Location	Distant—25 miles and more beyond main line of resistance.	Block lines of communication.	Placed by air forces or during raids.
	Outlying—beyond normal antitank (AT) gun range (700 yards).	Impede reconnaissance; delay advance.	Placed by Engineers or other arms.
	Close-in—within normal AT gun range.	Immediate protection of MLR; limit penetration; immediate protection of rear positions and installations; or to prevent escape of mechanized forces that have penetrated positions.	Placed by troops protected by the obstacle, assisted by Engineers.
	Rear area—on line of communications.	Protect supply routes and installations.	Engineers.
			Examples
Time required for erection.	Quick	Block avenues of approach on short notice (matter of minutes).	Wire roll, cables, AT mines, wrecked vehicles, gassed areas.
	Semiquick	Block avenues of approach on fairly short notice (matter of hours).	Mine fields, demolitions, abatis, barricades, craters.
	Deliberate	Block avenues of approach with relatively long time available.	AT ditches, extensive demolitions, inundations.

Table CXXIV.—*Typical tank characteristics*

Characteristics	Light tank	Medium tank
Weight .... tons	12	19
Length .... inches	163	210
Width each tread .... do	12	13
Tread (center to center) .... do	73	81
Clearance at belly .... do	15	17
Fording ability .... do	43	48
Climb vertical bank .... feet	3	6
Cross ditch without jumping, width .... do	8	10
Climb short dry slopes (maximum) .... degrees	45	45
Climb long dry slopes (maximum) .... do	30	30

Note.—Light tanks may weigh from 9 to 15 tons, medium tanks from 18 to 35 tons, and heavy tanks as much as 50 tons. In Europe, tanks weighing 70 to 90 tons have been used in the attack of strongly fortified positions.

Table CXXV.—*Characteristics of antimechanized weapons*

Type	Projectile weight (pounds)	Muzzle velocity (feet per second)	Armor penetration at 600 yards (inches) [1]		Maximum rate of fire (rounds per minute)	Weight of piece in firing position (pounds)
			Normal	30° impact		
Machine gun, caliber .50	0.107	2,700	0.55	0.40	600	130
Antitank gun:						
25-mm	.72	3,000	1.95	1.50	170	1,200
37-mm	1.85	2,600	2.20	1.76	30	850
47-mm	3.50	2,000	1.90	1.45	20	1,120

[1] Penetration of armor cannot be counted upon when angle of impact is greater than 30° from normal. At these larger angles of impact, projectile either ricochets or breaks up.

■ 140. MINE FIELDS.—*a. Description.*—(1) Number of rows in band: 3 to 6.

(2) Distance between rows: 1 to 3 yards.

(3) Least density: 1½ mines per yard of front.

(4) Pattern: varied, nongeometric.

(5) Additional protection: best obtained by additional bands rather than by increasing density of existing ones.

b. Methods of laying.—(1) *Longitudinal.*—Parties move along rows laying one or more rows simultaneously.

(*a*) *Advantage.*—Allows close supervision of work and favors use of trucks.

(*b*) *Disadvantage.*—May leave paths visible from air and ground.

(2) *Crossfield.*—Parties move across field, laying mines in several rows simultaneously.

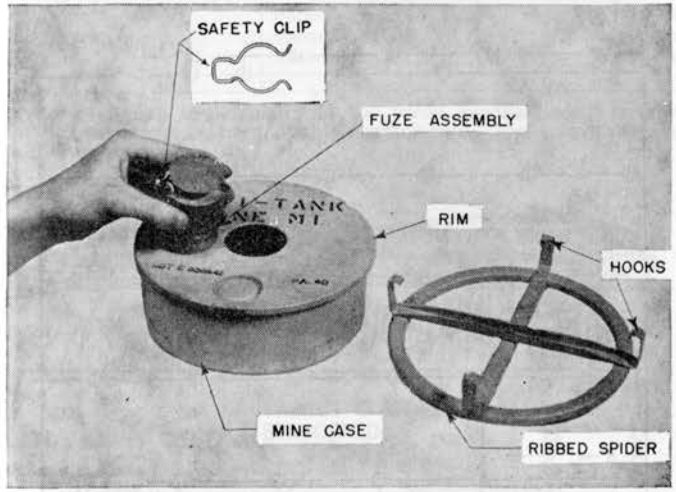
(*a*) *Advantage.*—Adapted to situation where road parallels field and serves as base line.

(*b*) *Disadvantage.*—Not adapted to use of trucks, or to accurate laying, especially at night.

c. Concealment.—(1) *Burying.*—Effective against all forms of observation. Scoop out shallow hole, placing mine at elevation to insure detonation; replace sod or top soil over mine; dispose of spoil.

(2) *Use of terrain.*—Effective against air observation and to some extent against ground observation. Lay mines along natural terrain lines, furrows, old fence lines, roads.

d. Equipment required for erection.—Trucks for transporting mines; bags for carrying away spoil; picks; shovels; tracing tape; measuring stakes; sledges.



NOTE.—For shipment the ribbed spider fits on the bottom of the mine case, and fuzes are carried separately. When ready for use the fuze assembly is inserted and the ribbed spider placed on top so that the hooks are clipped under the rim of the mine case. Until removed, the safety clip prevents the fuze plunger being forced down to fire the mine. This clip can be replaced. A ring handle is attached to the side of the case for carrying purposes.

FIGURE 239.—Antitank mine.

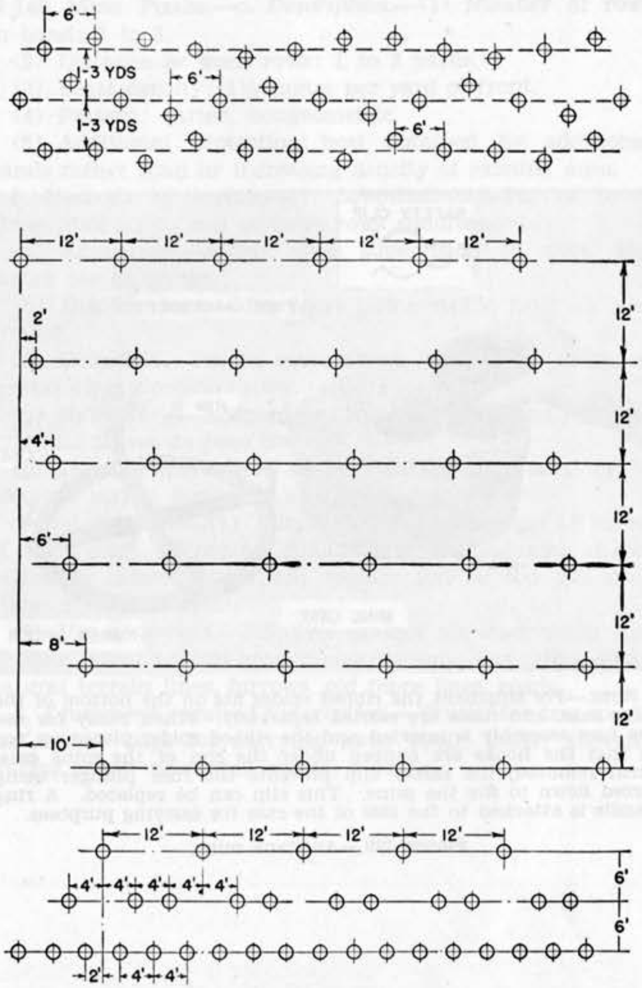


FIGURE 240.—Antitank mine fields showing typical 3- and 6-row patterns.

TABLE CXXVI.—*Typical rates of laying mines for various conditions.*

Method of—		Party (squads)			Total mines laid per man-hour
Transport	Placing	Carrying	Laying	Burying	
Hand carry	Unburied	2	1		40
	Buried	2	1	3	20
Laying from truck	Unburied		1		120
	Buried		1	3	30

NOTE.—8-man squad, carry of 100 yards, medium soil. If tray or carrying sticks are used, double carrying rate. Night work reduces all rates by 50 percent.

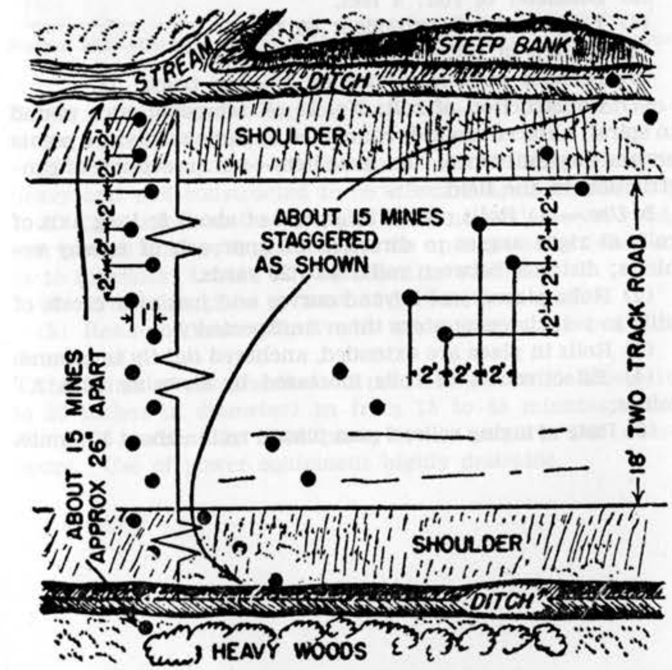


FIGURE 241.—Two typical patterns for antitank mine road block.

e. Removal of mines.—Use pointed sticks or rods as probes to locate buried mines; determine extent of field; separate mines from detonators; be careful of trap mines; use protective clothing against persistent gas; consider clearing only lanes through field, fencing off dangerous area. Average rate of mine removal, daytime, with no gas or enemy interference (reduce rates 50 percent for night work):

(1) *Unburied.*—120 mines per man-hour.

(2) *Buried.*—60 mines per man-hour.

■ 141. WIRE ROLLS.—*a. Description.*—(1) Class of obstacle: quick.

(2) Effective against wheeled vehicles (entangles itself around wheels, axles, brakes, steering mechanism).

(3) Diameter of roll: 4 feet.

(4) Length of roll extended: 40 feet.

(5) Weight of roll: 40 pounds.

(6) Number of rolls carried on 1½-ton truck: 75.

(7) Construction of roll: No. 11 oil tempered wire wound in spiral; adjacent rounds connected by strong clips at 5 points around circumference. An issue item—not susceptible of construction in the field.

b. Use.—(1) Rolls placed in groups of about 6; long axis of rolls at right angles to direction of approach of enemy vehicles; distance between rolls: 5 to 25 yards.

(2) Rolls placed just beyond curves and just over crests of hills so vehicle encounters them unexpectedly.

(3) Rolls in place are extended, anchored *lightly* to ground.

(4) Effectiveness of rolls increased by strewing with AT mines.

(5) Rate of laying rolls: 2 men place 1 roll in about 1 minute.

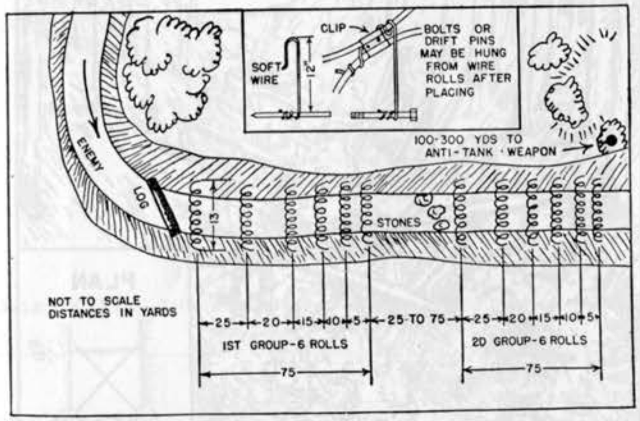


FIGURE 242.—Groups of wire roll obstacles placed in a cut for concealment and surprise.

■ 142. ABATIS.—*a. Description and use.*—(1) Class of obstacle: usually semiquick.

(2) Effective against wheeled and track vehicles (must be heavy and well constructed to be effective against latter).

(3) Construction: tree or poles felled at angle across road, tips toward enemy; trees or poles on opposite sides felled so as to interlock; trunks left attached to stumps.

(4) Trees should be at least 12 inches in diameter.

(5) Rendered more effective by using trap mines and persistent gas.

(6) *Rates of construction.*—2 men can fell single trees (10 to 20 inches in diameter) in from 15 to 45 minutes; road abatis 75 yards deep (100 heavy trees) requires 260 man-hours. Use of power equipment highly desirable.

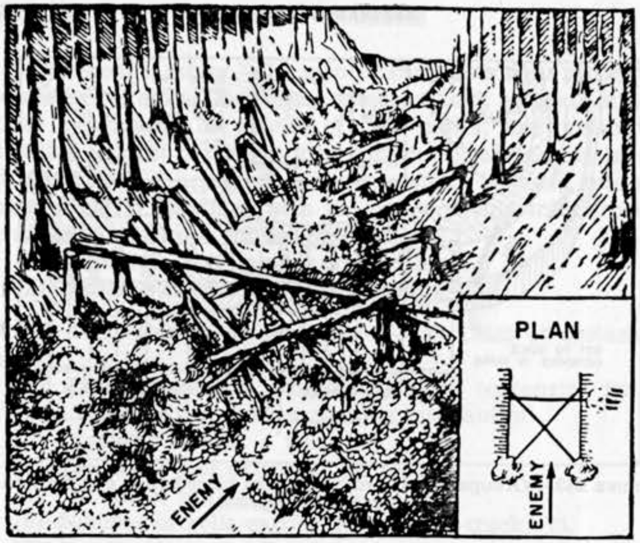


FIGURE 243.—Abatis constructed of interlaced trees in defile.

■ 143. ANTITANK DITCHES.—Triangular ditch more economical; trapezoidal ditch traps tank.

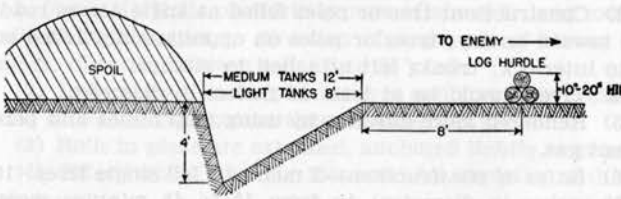


FIGURE 244.—Triangular ditch.

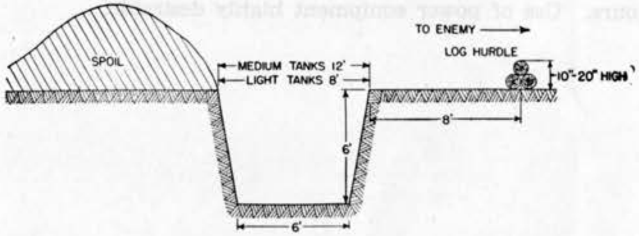


FIGURE 245.—Trapezoidal ditch.

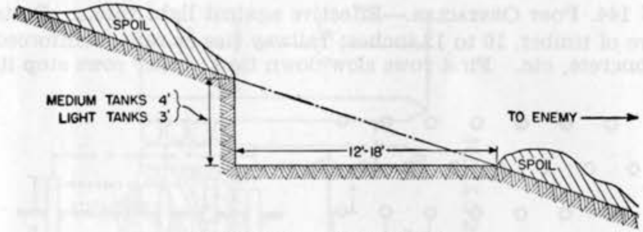


FIGURE 246.—Sidehill cut.

TABLE CXXVII.—*Estimated time to construct 100 feet of antitank ditch (8 hrs. to a shift).*

Size of working party (excluding supervision)	Type of soil	Total time required: Triangular ditch, 8 feet wide	Triangular ditch, 12 feet wide	Trapezoidal ditch, 8 feet wide	Trapezoidal ditch, 12 feet wide
32 workers with hand tools.	Light	2 hours	3½ hours	1 shift	1 shift plus 1½ hours.
	Average	3 hours	5½ hours	1 shift plus 1½ hours.	1 shift plus 6 hours.
	Hard	5½ hours	1 shift plus ½ hour.	2 shifts	2 shifts plus 3½ hours.
7½-ton shovel with 2 shovel operators and 3 to 10 finishers.	Light	1½ hours	2 hours	3 hours	4 hours.
	Average	2½ hours	4 hours	7 hours	1 shift plus 1 hour.
	Hard	4 hours	5 hours	1 shift plus 1½ hours.	1 shift plus 4 hours.

■ 144. **Post Obstacles.**—Effective against light tanks. Posts are of timber, 10 to 12 inches; railway ties or rails; reinforced concrete, etc. First rows slow down tank; other rows stop it.

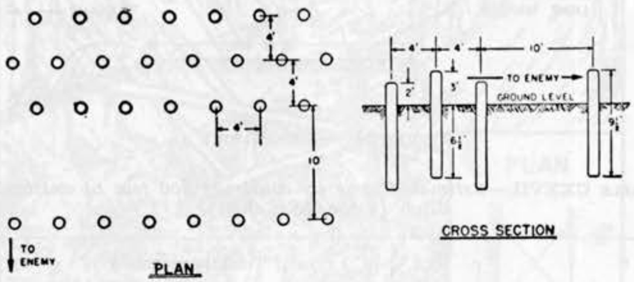


Figure 247.—Typical post obstacle.

Table CXXVIII.—*Rates of construction of post obstacles*

Method of placement	Operating crew	Pointing capping crew	Rate of placement of posts per hour in— Soft soil	Medium soil	Hard soil
Pile driver (drop or air hammer) using 7½-ton mobile crane.	1 NCO, 8 men	1 NCO, 8 men	7	4	(1)
Power earth auger, hand tamping.	1 NCO, 8 men		35	25	17
Hand labor	1 engineer company 100 workers.		30	20	9

[1] Unsatisfactory.

■ 145. **Miscellaneous Obstacles.**—(For road craters see section III.) Logs, ditches, large stones, and log hurdles (see figs. 242, 244, and 249) should be placed in one line or staggered 8 to 30 feet in front of every obstacle to slow down or throw out of control rapidly approaching vehicles.

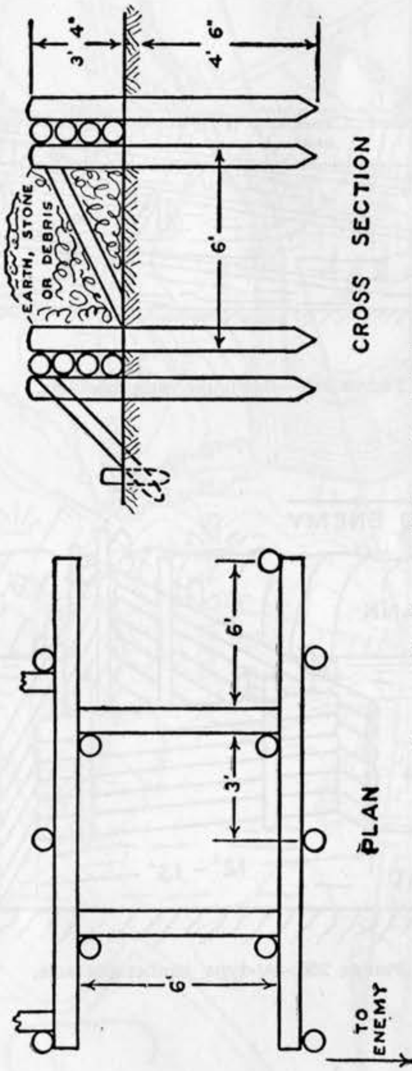


Figure 248.—Log or timber crib obstacle.

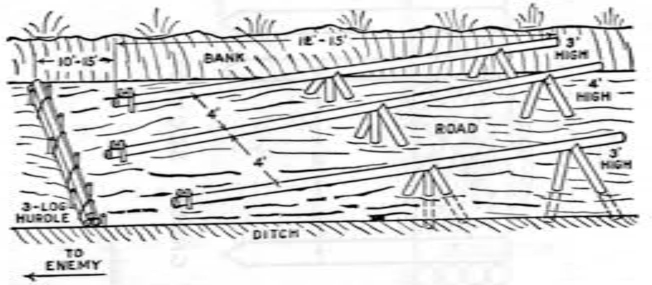


FIGURE 249.—Sawhorse ramp obstacle.

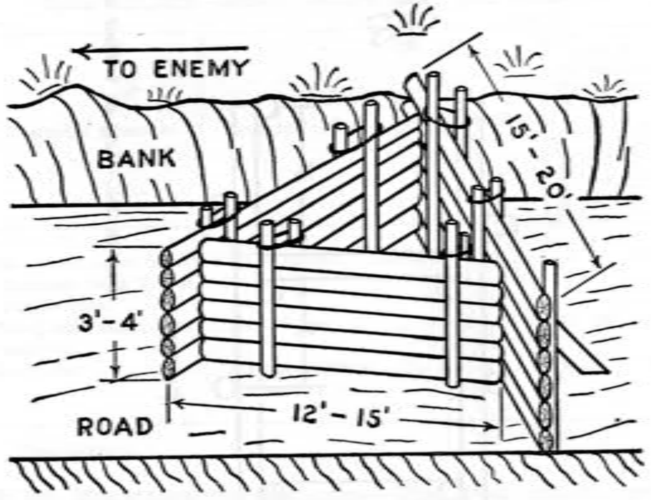


FIGURE 250.—V-type timber obstacle.

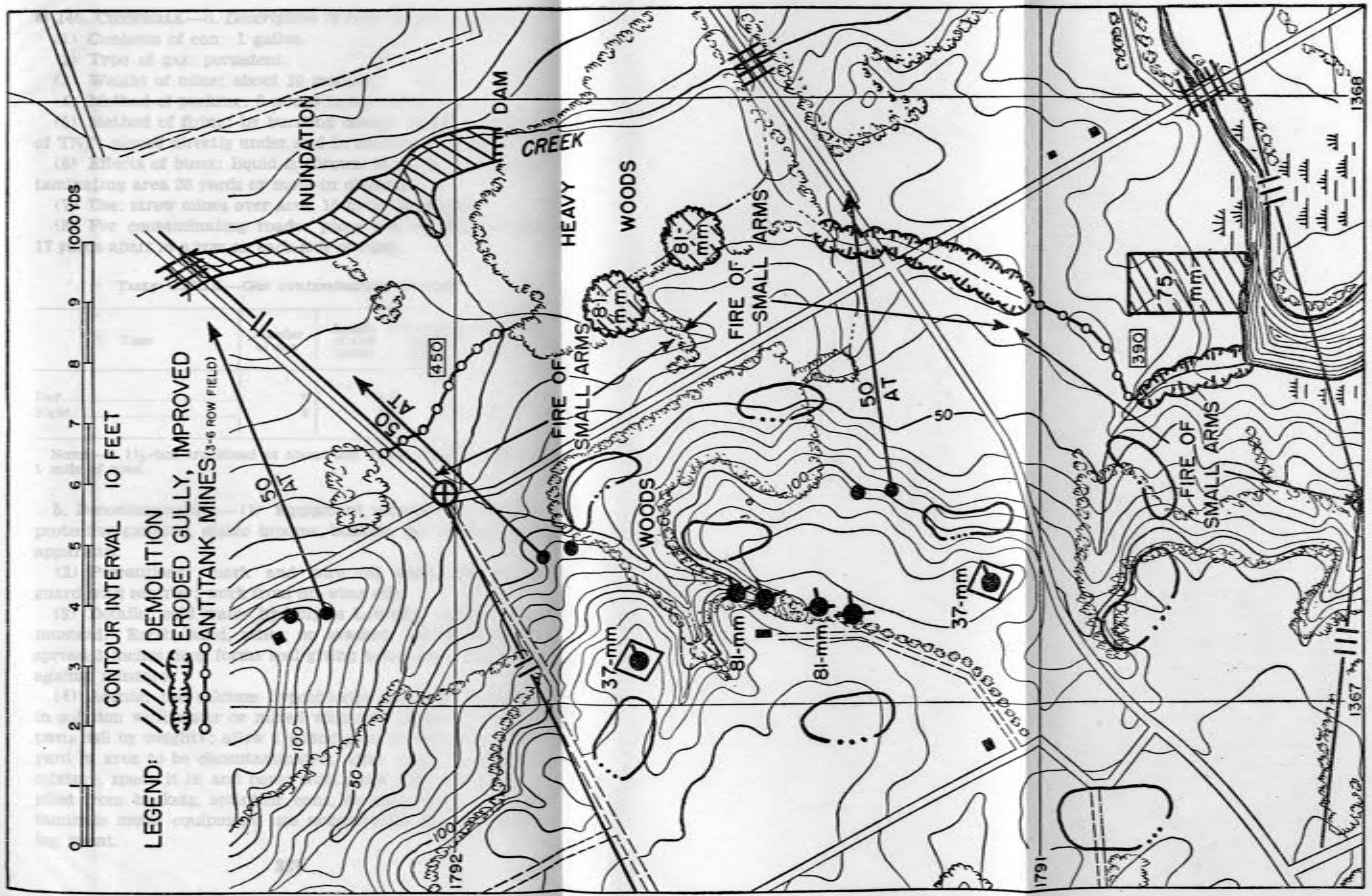


FIGURE 251.—Obstacles against tanks in a defensive position.

282786°—41 (Face p. 336)

■ 146. CHEMICALS.—*a. Description of issue chemical mine.*

(1) Contents of can: 1 gallon.

(2) Type of gas: persistent.

(3) Weight of mine: about 10 pounds.

(4) Method of packing: 6 mines in box crate.

(5) Method of firing: by bursting charge (special or block of TNT) placed directly under and in contact with mine.

(6) Effects of burst: liquid is thrown 10 yards in air, contaminating area 20 yards or more in diameter.

(7) Use: strew mines over area, 15 to 20 yards apart.

(8) For contaminating roads: place row of mines about 17 yards apart in a row on each side of road.

TABLE CXXIX.—*Gas contamination of roads*

Time	Number of men	Length of road (miles)	Time fuse ignition (hours)	Electrical ignition (hours)
Day	8	1	1	2
Night	8	1	1½	3

NOTE.—A 1½-ton truckload at about 200 mines will contaminate 1 mile of road.

b. Decontamination.—(1) Equipment required: gas masks, protective clothing, stable brooms, buckets, decontamination apparatus.

(2) Precautions: mark and wire off dangerous areas; guard with sentries; work from up-wind side.

(3) Details: cold water hydrolyzes Lewisite, washes away mustard. Earth, sand, ashes, or sawdust (preferably wet) spread 3 inches deep forms seal giving temporary protection against mustard.

(4) Agents: use calcium hypochlorite (bleaching powder) in solution with water or mixed with soil (1 part powder, 3 parts soil by weight); allow 1 pound pure powder per square yard of area to be decontaminated; after using powder-soil mixture, spade it in and cover with fresh soil; solution applied from buckets, sprinkler cans, or sprayers; to decontaminate metal equipment, use noncorrosive decontaminating agent.

(5) Roads: wash down with water; wash with bleaching powder paste; coat with thin layer of sodium silicate (water glass) or hot asphalt. Renew coating as required.

c. Field collective protector.—This equipment, which supplies dugouts with air from which gases have been filtered, has been standardized. The canister and gasoline engine blower, both mounted on a base, and a length of flexible hose can be transported on a truck. The unit can supply about 200 cubic feet of purified air per minute.

CHAPTER 4

MISCELLANEOUS DATA

SECTION I

MATHEMATICAL AND PHYSICAL DATA

TABLE CXXX.—*Factors for conversion of units*

[To convert A to B, multiply A by C. To convert B to A, multiply B by D]

Unit A	Factor C	Factor D	Unit B
Length:			
Miles	[1] 63,360.0	0.00001578	Inches.
Do	[1] 5,280.0	.0001894	Feet.
Do	1.609	.6214	Kilometers.
Meters	3.281	.3048	Feet.
Kilometers	3,281.0	.0003048	Do.
Inches	2.540	.3937	Centimeters.
Surface:			
Square miles	[1] 27,878,400.0	.00000003587	Square feet.
Do	[1] 640.0	.001563	Acres.
Do	2.59	.3861	Square kilometers.
Acres	[1] 43,560.0	.00002296	Square feet.
Do	4,046.9	.0002471	Square meters.
Hectares	2.471	.4047	Acres.
Do	[1] 10,000.0	[1] .0001	Square meters.
Square inches	6.452	.1550	Square centimeters.
Square meters	10.76	.09290	Square feet.
Volume:			
Cubic feet	[1] 1,728.0	.0005787	Cubic inches.
Cubic inches	16.39	.06102	Cubic centimeters.
Cubic meters	35.31	.2832	Cubic feet.
Cubic feet	7.481	.1337	U. S. gallons.
Do	6.229	.1605	Imperial gallons.
Do	28.32	.03531	Liters.

[1] Exact values.

TABLE CXXX.—*Factors for conversion of units*—Continued

Unit A	Factor C	Factor D	Unit B
Volume—Continued.			
U. S. gallons	[1] 231. 0	0. 004329	Cubic inches.
Do	3. 785	. 2642	Liters.
Imperial gallons	1. 200	. 8331	U. S. gallons.
U. S. bushels	1. 244	. 8036	Cubic feet.
Fluid ounces	1. 805	. 5541	Cubic inches.
Acre-feet	[1] 43, 560. 0	. 00002296	Cubic feet.
Millions U. S. gal	133, 700. 0	. 000007481	Do.
Flowing water:			
Second-feet	[1] 60. 0	. 01667	Cubic feet per minute.
Do	448. 8	. 002228	U. S. gallons per minute.
Do	1. 984	. 5042	Acre-feet per 24 hours.
Cubic feet per minute	7. 481	. 1337	U. S. gallons per minute.
Velocities:			
Miles per hour	1. 467	. 6818	Feet per second.
Meters per second	3. 281	. 3048	Do.
Do	2. 237	. 4470	Miles per hour.
Pressure:			
Atmospheres (mean)	33. 90	. 02950	Feet of water.
	14. 70	. 0680	Pounds per square inch.
	29. 92	. 03342	Inches of mercury.
Pounds per square inch.	2. 036	. 4912	Do.
Feet of water	62. 42	. 01602	Pounds per square foot.
Weight:			
Pounds	[1] 7, 000. 0	. 0001429	Grains.
Kilograms	2. 205	. 4536	Pounds.
Long tons	[1] 1. 120	. 8929	Short tons.
Power:			
Horsepower	[1] 550. 0	. 001818	Foot-pounds per second.
Kilowatts	1. 341	. 746	Horsepower.

[1] Exact values.

TABLE CXXXI.—*Functions of numbers*

Number	Square	Cube	Square root	Logarithm	Number	Square	Cube	Square root	Logarithm
1	1	1	1. 0000	0. 00000	36	1296	46656	6. 0000	1. 55630
2	4	8	1. 4142	. 30103	37	1369	50653	6. 0828	1. 56820
3	9	27	1. 7321	. 47712	38	1444	54872	6. 1644	1. 57978
4	16	64	2. 0000	. 60206	39	1521	59319	6. 2450	1. 59106
5	25	125	2. 2361	. 69897	40	1600	64000	6. 3246	1. 60206
6	36	216	2. 4495	. 77815	41	1681	68921	6. 4031	1. 61278
7	49	343	2. 6458	. 84510	42	1764	74088	6. 4807	1. 62325
8	64	512	2. 8284	. 90309	43	1849	79507	6. 5574	1. 63347
9	81	729	3. 0000	. 95424	44	1936	85184	6. 6332	1. 64345
10	100	1000	3. 1623	1. 00000	45	2025	91125	6. 7082	1. 65321
11	121	1331	3. 3166	1. 04139	46	2116	97336	6. 7823	1. 66276
12	144	1728	3. 4641	1. 07918	47	2209	103823	6. 8557	1. 67210
13	169	2197	3. 6056	1. 11394	48	2304	110592	6. 9282	1. 68124
14	196	2744	3. 7417	1. 14613	49	2401	117649	7. 0000	1. 69020
15	225	3375	3. 8730	1. 17609	50	2500	125000	7. 0711	1. 69897
16	256	4096	4. 0000	1. 20412	51	2601	132651	7. 1414	1. 70757
17	289	4913	4. 1231	1. 23045	52	2704	140608	7. 2111	1. 71600
18	324	5832	4. 2426	1. 25527	53	2809	148877	7. 2801	1. 72428
19	361	6859	4. 3589	1. 27875	54	2916	157464	7. 3485	1. 73239
20	400	8000	4. 4721	1. 30103	55	3025	166375	7. 4162	1. 74036
21	441	9261	4. 5826	1. 32222	56	3136	175616	7. 4833	1. 74819
22	484	10648	4. 6904	1. 34242	57	3249	185193	7. 5498	1. 75587
23	529	12167	4. 7958	1. 36173	58	3364	195112	7. 6158	1. 76343
24	576	13824	4. 8990	1. 38021	59	3481	205379	7. 6811	1. 77085
25	625	15625	5. 0000	1. 39794	60	3600	216000	7. 7460	1. 77815
26	676	17576	5. 0990	1. 41497	61	3721	226981	7. 8102	1. 78533
27	729	19683	5. 1962	1. 43136	62	3844	238328	7. 8740	1. 79239
28	784	21952	5. 2915	1. 44716	63	3969	250047	7. 9373	1. 79934
29	841	24389	5. 3852	1. 46240	64	4096	262144	8. 0000	1. 80618
30	900	27000	5. 4772	1. 47712	65	4225	274625	8. 0623	1. 81291
31	961	29791	5. 5678	1. 49136	66	4356	287496	8. 1240	1. 81954
32	1024	32768	5. 6569	1. 50515	67	4489	300763	8. 1854	1. 82607
33	1089	35937	5. 7446	1. 51851	68	4624	314432	8. 2462	1. 83251
34	1156	39304	5. 8310	1. 53148	69	4761	328509	8. 3066	1. 83885
35	1225	42875	5. 9161	1. 54407	70	4900	343000	8. 3666	1. 84510

TABLE CXXXI.—*Functions of numbers*—Continued

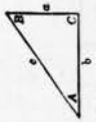
Number	Square	Cube	Square root	Logarithm	Number	Square	Cube	Square root	Logarithm
71	5041	357911	8.4261	1.85126	86	7396	636056	9.2736	1.93450
72	5184	373248	8.4853	1.85733	87	7569	658503	9.3274	1.93952
73	5329	389017	8.5440	1.86332	88	7744	681472	9.3808	1.94448
74	5476	405224	8.6023	1.86923	89	7921	704969	9.4340	1.94939
75	5625	421875	8.6603	1.87506	90	8100	729000	9.4868	1.95424
76	5776	438976	8.7178	1.88081	91	8281	753571	9.5394	1.95904
77	5929	456533	8.7750	1.88649	92	8464	778688	9.5917	1.96379
78	6084	474552	8.8318	1.89209	93	8649	804357	9.6437	1.96848
79	6241	493039	8.8882	1.89763	94	8836	830584	9.6954	1.97313
80	6400	512000	8.9443	1.90309	95	9025	857375	9.7468	1.97772
81	6561	531441	9.0000	1.90849	96	9216	884736	9.7980	1.98227
82	6724	551368	9.0554	1.91381	97	9409	912673	9.8489	1.98677
83	6889	571787	9.1104	1.91908	98	9604	941192	9.8995	1.99123
84	7056	592704	9.1652	1.92428	99	9801	970299	9.9499	1.99564
85	7225	614125	9.2195	1.92942	100	10000	1000000	10.0000	2.00000

TABLE CXXXII.—*Inches to decimals of a foot*

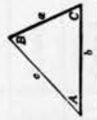
	0	1	2	3	4	5	6	7	8	9	10	11
0	0	0.0833	0.1667	0.2500	0.3333	0.4167	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1/8	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
15/16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948

TABLE CXXXIII.—*Trigonometric solution of triangles*

TRIGONOMETRIC SOLUTION OF TRIANGLES



$a^2=b^2+c^2-2bc\cos A$ $b^2=a^2+c^2-2ac\cos B$ $c^2=a^2+b^2-2ab\cos C$ $s=\frac{a+b+c}{2}$



RIGHT TRIANGLE

Given	To Find: A	B	C	a	b	c	Area
a, b	$\tan A=\frac{a}{b}$	$\tan B=\frac{b}{a}$	90°			$\sqrt{a^2+b^2}$	$\frac{ab}{2}$
a, c	$\sin A=\frac{a}{c}$	$\cos B=\frac{a}{c}$	90°		$\sqrt{c^2-a^2}$		$\frac{a\sqrt{c^2-a^2}}{2}$
A, a		$90°-A$	90°		$a\cot A$	$\frac{a}{\sin A}$	$\frac{a^2\cot A}{2}$
A, b		$90°-A$	90°	$b\tan A$		$\frac{b}{\cos A}$	$\frac{b^2\tan A}{2}$
A, c		$90°-A$	90°	$c\sin A$	$c\cos A$		$\frac{c^2\sin 2A}{4}$

OBLIQUE TRIANGLE

Given	To Find: A	B	C	a	b	c	Area
a, b, c	$\cos\frac{1}{2}A=\sqrt{\frac{s(s-a)}{bc}}$	$\cos\frac{1}{2}B=\sqrt{\frac{s(s-b)}{ac}}$	$\cos\frac{1}{2}C=\sqrt{\frac{s(s-c)}{ab}}$				$\sqrt{s(s-a)(s-b)(s-c)}$
a, A, B			$180°-(A+B)$		$\frac{a\sin B}{\sin A}$	$\frac{a\sin C}{\sin A}$	
a, b, A		$\sin B=\frac{b\sin A}{a}$				$\frac{b\sin C}{\sin B}$	
a,b,C	$\tan A=\frac{a\sin C}{b-a\cos C}$					$\sqrt{a^2+b^2-2ab\cos C}$	$\frac{ab\sin C}{2}$

TABLE CXXXIV.—*Natural trigonometric functions*

Angle	Sin.	Cosec.	Tan.	Cotan.	Sec.	Cos.	
0°	0.000	....	0.000	....	1.000	1.000	90°
1°	.017	57.30	.017	57.29	1.000	1.000	89°
2°	.035	28.65	.035	28.64	1.001	.999	88°
3°	.052	19.11	.052	19.08	1.001	.999	87°
4°	.070	14.34	.070	14.30	1.002	.998	86°
5°	.087	11.47	.087	11.43	1.004	.996	85°
6°	.105	9.567	.105	9.514	1.006	.995	84°
7°	.122	8.206	.123	8.144	1.008	.993	83°
8°	.139	7.185	.141	7.115	1.010	.990	82°
9°	.156	6.392	.158	6.314	1.012	.988	81°
10°	.174	5.759	.176	5.671	1.015	.985	80°
11°	.191	5.241	.194	5.145	1.019	.982	79°
12°	.208	4.810	.213	4.705	1.022	.978	78°
13°	.225	4.445	.231	4.331	1.026	.974	77°
14°	.242	4.134	.249	4.011	1.031	.970	76°
15°	.259	3.864	.268	3.732	1.035	.966	75°
16°	.276	3.628	.287	3.487	1.040	.961	74°
17°	.292	3.420	.306	3.271	1.046	.956	73°
18°	.309	3.236	.325	3.078	1.051	.951	72°
19°	.326	3.072	.344	2.904	1.058	.946	71°
20°	.342	2.924	.364	2.747	1.064	.940	70°
21°	.358	2.790	.384	2.605	1.071	.934	69°
22°	.375	2.669	.404	2.475	1.079	.927	68°
23°	.391	2.559	.424	2.356	1.086	.921	67°
24°	.407	2.459	.445	2.246	1.095	.914	66°
25°	.423	2.366	.466	2.145	1.103	.906	65°
26°	.438	2.281	.488	2.050	1.113	.899	64°
27°	.454	2.203	.510	1.963	1.122	.891	63°
28°	.469	2.130	.532	1.881	1.133	.883	62°
29°	.485	2.063	.554	1.804	1.143	.875	61°
30°	.500	2.000	.577	1.732	1.155	.866	60°
31°	.515	1.942	.601	1.664	1.167	.857	59°
32°	.530	1.887	.625	1.600	1.179	.848	58°
33°	.545	1.836	.649	1.540	1.192	.839	57°
34°	.559	1.788	.675	1.483	1.206	.829	56°
35°	.574	1.743	.700	1.428	1.221	.819	55°
36°	.588	1.701	.727	1.376	1.236	.809	54°
37°	.602	1.662	.754	1.327	1.252	.799	53°
38°	.616	1.624	.781	1.280	1.269	.788	52°
39°	.629	1.589	.810	1.235	1.287	.777	51°
40°	.643	1.556	.839	1.192	1.305	.766	50°
41°	.656	1.524	.869	1.150	1.325	.755	49°
42°	.669	1.494	.900	1.111	1.346	.743	48°
43°	.682	1.466	.933	1.072	1.367	.731	47°
44°	.695	1.440	.966	1.036	1.390	.719	46°
45°	.707	1.414	1.000	1.000	1.414	.707	45°
	Cos.	Sec.	Cotan.	Tan.	Cosec.	Sin.	Angle

TABLE CXXXV.—*Useful formulae*

a. Areas.

(1) Circle: $A=\pi r^2=\frac{\pi d^2}{4}$

(2) Triangle: $A=\frac{1}{2}bh$

(3) Trapezoid (one pair of opposite sides parallel): $A=\frac{1}{2}h(b+c)$

(4) Ellipse: $A=\pi lf$

(5) Sphere: $A=4\pi r^2$

r=radius
d=diameter
b=base
h=altitude
b and c=parallel sides
l and f=semiaxes
π=3.1416

b. Volumes.

(1) Prism or cylinder: $V=A_b h$

(2) Pyramid or cone: $V=\frac{1}{3}A_b h$

(3) Frustrum of pyramid or cone: $V=\frac{1}{3}(A_1+A_2+\sqrt{A_1\times A_2})h$

(4) Sphere: $V=\frac{4}{3}\pi r^3$

A_b=area of base
h=height
A_1 and A_2=areas of bases
r=radius

c. Trigonometry.

(1) $\text{sine}\ \theta=\frac{1}{\text{cosecant}\ \theta}$

(2) $\text{cosine}\ \theta=\frac{1}{\text{secant}\ \theta}$

(3) $\text{tangent}\ \theta=\frac{1}{\text{cotangent}\ \theta}=\frac{\text{sine}\ \theta}{\text{cosine}\ \theta}$

(4) sine $(90°\pm\theta)$=cosine θ

(5) cosine $(90°\pm\theta)$=sine θ

(6) tangent $(90°\pm\theta)$=cotangent θ

(7) $\text{sine}\frac{\theta}{2}=\pm\sqrt{\frac{1-\text{cosine}\ \theta}{2}}$

(8) $\text{cosine}\frac{\theta}{2}=\pm\sqrt{\frac{1+\text{cosine}\ \theta}{2}}$

θ=angle

d. Mechanics.

(1) Rectilinear motion:

$v=\frac{s}{t}$

$a=\frac{v}{t}$

$s=v_o t+\frac{1}{2}at^2$

v=velocity in feet per second
s=distance in feet
t=time in seconds
a=acceleration in feet per second
v_o=initial velocity in feet per second

(2) Kinetics:

$F=m\,a$

$I=F\,t$
$M=m\,v$
$W=F\,s$
$W=\frac{1}{2}m\,v^2$

F=force in pounds
$m=\frac{w}{g}$=weight in pounds divided by acceleration due to gravity (32.2)
I=impulse in pound-seconds
M=momentum in pound-feet per second
W=work in foot-pounds

(3) Beams:

$f=\frac{M\,y}{I}=\frac{M}{S}$

f=intensity of stress in tension or compression in pounds per square inch
M=bending moment in inch-pounds
y=distance in inches of fiber from center of gravity of section
I=moment of inertia of section in inches ^{4}
S=section modulus in inches $^3=\frac{I}{y}$

e. Hydraulics.

(1) Manning's formula for flow in open channels:

$v=\frac{1.486}{n}r^{\frac{2}{3}}s^{\frac{1}{2}}$

v=velocity in feet per second
r=hydraulic radius in feet
s=hydraulic slope
n=coefficient of roughness (for values of n see table CXXXVI)
d=diameter of pipes in inches

TABLE CXXXV.—*Useful formulae*—Continued

e. Hydraulics—Continued.

(2) Manning's formula for flow in pipes:

$v=\frac{0.590}{n}d^{\frac{2}{3}}s^{\frac{1}{2}}$

(3) Rectangular weir (Francis formula):

$Q=3.33L(1-0.1n)[(H+h)^{3/2}-h^{3/2}]$

Q=discharge in cubic feet per second
L=length of weir in feet
H=head on weir in feet
h=velocity head in feet
n=number of end contractions (taken as zero when $L>H\times10$)

f. Electricity.

(1) Direct current:

$E=IR$
$W=EI$

E=electromotive force in volts
I=current in amperes
R=resistance in ohms

(2) Alternating current:

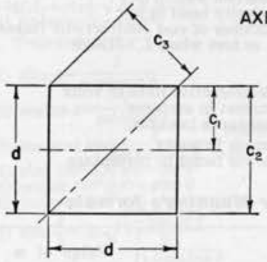
$W=(pf)\,EI$

W=power in watts
pf=power factor in percentage

TABLE CXXXVI.—*Values of n for Manning's formula*

Type of channel	Value of n
Flow in open channels:	
Well-planed timber	0.009
Neat cement	.010
Cement mortar with one-third sand	.011
Unplaned timber	.012
Ashlar and well-laid brick	.013
Rough brickwork	.015
Rubble masonry	.017
Canals in firm ground	.020
Canals and rivers:	
In good condition	.025
With stones and weeds	.030
In bad condition	0.035 to .040
Flow in pipes:	
Clean uncoated cast-iron	.011 to .015
Clean coated cast-iron	.010 to .014
Dirty or tuberculated cast-iron	.015 to .035
Riveted steel	.013 to .017
Lock-bar and welded	.010 to .013
Galvanized-iron	.012 to .017
Brass	.009 to .013
Wood-stave	.010 to .014
Concrete	.010 to .017
Vitrified sewer	.010 to .017
Common clay drainage tile	.011 to .017

TABLE CXXXVII.—*Properties of sections*



AXIS OF MOMENTS THROUGH CENTER

$A = d^2$

$c_1 = \frac{d}{2}$

$I = \frac{d^4}{12}$

$S = \frac{d^3}{6}$

$r = \frac{d}{\sqrt{12}} = .2887\,d$

AXIS OF MOMENTS ON BASE

$A = d^2$

$c_2 = d$

$I = \frac{d^4}{3}$

$S = \frac{d^3}{3}$

$r = \frac{d}{\sqrt{3}} = .5774\,d$

AXIS OF MOMENTS ON DIAGONAL

$A = d^2$

$c_3 = \frac{d}{\sqrt{2}} = .7071\,d$

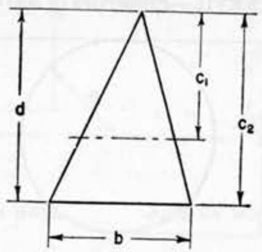
$I = \frac{d^4}{12}$

$S = \frac{d^3}{6\sqrt{2}} = .1179\,d^3$

$r = \frac{d}{\sqrt{12}} = .2887\,d$

Properties of sections—Square.

TABLE CXXXVII.—*Properties of sections*—Continued



AXIS OF MOMENTS THROUGH CENTER OF GRAVITY

$A = \frac{bd}{2}$

$c_1 = \frac{2d}{3}$

$I = \frac{bd^3}{36}$

$S = \frac{bd^2}{24}$

$r = \frac{d}{\sqrt{18}} = .2357d$

AXIS OF MOMENTS ON BASE

$A = \frac{bd}{2}$

$c_2 = d$

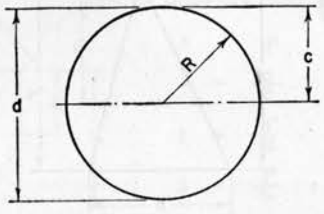
$I = \frac{bd^3}{12}$

$S = \frac{bd^2}{12}$

$r = \frac{d}{\sqrt{6}} = .4082\,d$

Properties of sections—Triangle.

TABLE CXXXVII.—*Properties of sections*—Continued



AXIS OF MOMENTS THROUGH CENTER

$$A = \frac{\pi d^2}{4} = \pi R^2 = .7854\,d^2 = 3.1416\,R^2$$

$$c = \frac{d}{2} = R$$

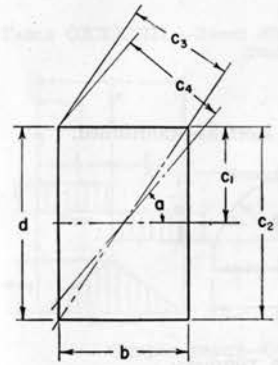
$$I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4} = .0491\,d^4 = .7854\,R^4$$

$$S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4} = .0982\,d^3 = .7854\,R^3$$

$$r = \frac{d}{4} = \frac{R}{2}$$

Properties of sections—Circle.

TABLE CXXXVII.—*Properties of sections*—Continued



AXIS OF MOMENTS THROUGH CENTER

$$A = bd$$

$$c_1 = \frac{d}{2}$$

$$I = \frac{bd^3}{12}$$

$$S = \frac{bd^2}{6}$$

$$r = \frac{d}{\sqrt{12}} = .2887\,d$$

AXIS OF MOMENTS ON BASE

$$A = bd$$

$$c_2 = d$$

$$I = \frac{bd^3}{3}$$

$$S = \frac{bd^2}{3}$$

$$r = \frac{d}{\sqrt{3}} = .5774\,d$$

AXIS OF MOMENTS ON DIAGONAL

$$A = bd$$

$$c_3 = \frac{bd}{\sqrt{b^2+d^2}}$$

$$I = \frac{b^3d^3}{6(b^2+d^2)}$$

$$S = \frac{b^2d^2}{6\sqrt{b^2+d^2}}$$

$$r = \frac{bd}{\sqrt{6(b^2+d^2)}}$$

AXIS OF MOMENTS ANY LINE THROUGH CENTER OF GRAVITY

$$A = bd$$

$$c_4 = \frac{b \sin a + d \cos a}{2}$$

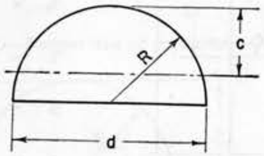
$$I = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$$

$$S = \frac{bd(b^2 \sin^2 a + d^2 \cos^2 a)}{6(b \sin a + d \cos a)}$$

$$r = \sqrt{\frac{b^2 \sin^2 a + d^2 \cos^2 a}{12}}$$

Properties of sections—Rectangle.

TABLE CXXXVII.—*Properties of sections*—Continued.



AXIS OF MOMENTS THROUGH CENTER OF GRAVITY

$$A = \frac{\pi R^2}{2} = 1.5708\ R^2$$

$$c = R\left(1 - \frac{4}{3\pi}\right) = .5756\ R$$

$$I = R^4\left(\frac{\pi}{8} - \frac{8}{9\pi}\right) = .1098\ R^4$$

$$S = \frac{R^3}{24}\,\frac{(9\pi^2 - 64)}{(3\pi - 4)} = 1907\ R^3$$

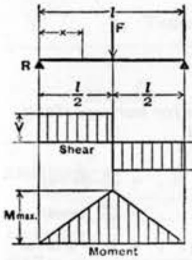
$$r = R\,\frac{\sqrt{9\pi^2 - 64}}{6\pi} = .2643\ R$$

NOTE:
TRANSFER OF AXES: TO FIND THE MOMENT OF INERTIA (I_x) OF ANY AREA A ABOUT ANY AXIS IN TERMS OF THE MOMENT OF INERTIA I_0 ABOUT A PARALLEL AXIS THROUGH THE CENTER OF GRAVITY OF THE AREA, IF X_0 IS THE DISTANCE BETWEEN THE TWO AXES:

$$I_x = I_0 + AX_0^2$$

Properties of sections—Half circle.

TABLE CXXXVIII.—*Beam diagrams and formulas for various static loading conditions*



$R = V$ . . . . $= \frac{F}{2}$

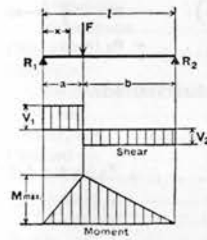
$M_{max.}$ (at point of load) . . . . . . $= \frac{Fl}{4}$

M_x (when $x < \frac{l}{2}$) . . . . . . $= \frac{Fx}{2}$

$\Delta max.$ (at point of load) . . . . . . $= \frac{Fl^3}{48EI}$

Δx (when $x < \frac{l}{2}$) . . . . . . $= \frac{Fx}{48EI}(3l^2 - 4x^2)$

Simple beam—Concentrated load at center.



$R_1 = V_1$ (max. when $a < b$) . . . . . . $= \frac{Fb}{l}$

$R_2 = V_2$ (max. when $a > b$) . . . . . . $= \frac{Fa}{l}$

$M_{max.}$ (at point of load) . . . . . . $= \frac{Fab}{l}$

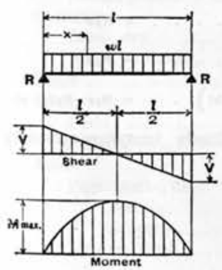
M_x (when $x < a$) . . . . . . $= \frac{Fbx}{l}$

$\Delta max.$ (at $x = \sqrt{\frac{a(a+2b)}{3}}$ when $a > b$) $= \frac{Fab(a+2b)\sqrt{3a(a+2b)}}{27EIl}$

Δa (at point of load) . . . . . . $= \frac{Fa^2b^2}{3EIl}$

Δx (when $x < a$) . . . . . . $= \frac{Fbx}{6EIl}(l^2 - b^2 - x^2)$

Simple beam—Concentrated load at any point.



$R = V$ . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

$M_{max.}$ (at center) . . . . . . $= \frac{wl^2}{8}$

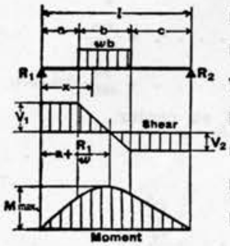
M_x . . . . $= \frac{wx}{2}(l - x)$

$\Delta max.$ (at center) . . . . . . $= \frac{5wl^4}{384EI}$

Δx . . . . $= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

Simple beam—Uniformly distributed load.

TABLE CXXXVIII.—*Beam diagrams and formulas for various static loading conditions*—Continued.



$R_1 = V_1$ (max. when $a < c$) . . . $= \frac{wb}{2l}(2c+b)$

$R_2 = V_2$ (max. when $a > c$) . . . $= \frac{wb}{2l}(2a+b)$

V_x (when $x < a$ and $> (a+b)$) . . $= R_1 - w(x-a)$

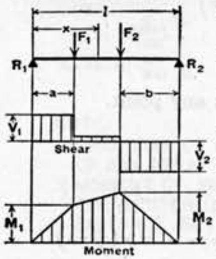
$M_{max.}$ (at $x = a + \frac{R_1}{w}$) . . . . . $= R_1\left(a + \frac{R_1}{2w}\right)$

M_x (when $x < a$) . . . . . . $= R_1 x$

M_x (when $x > a$ and $< (a+b)$) . . $= R_1 x - \frac{w}{2}(x-a)^2$

M_x (when $x < (a+b)$) . . . . $= R_2(l-x)$

Simple beam—Uniform load partially distributed.



$R_1 = V_1$ . . . . $= \frac{F_1(l-a) + F_2 b}{l}$

$R_2 = V_2$ . . . . $= \frac{F_1 a + F_2(l-b)}{l}$

V_x (when $x > a$ and $< (l-b)$) . . $= R_1 - F_1$

M_1 (max. when $R_1 < F_1$) . . . . $= R_1 a$

M_2 (max. when $R_2 < F_2$) . . . . $= R_2 b$

M_x (when $x < a$) . . . . $= R_1 x$

M_x (when $x > a$ and $< (l-b)$) . . $= R_1 x - F_1(x-a)$

Simple beam—Two unequal concentrated loads unsymmetrically placed.

SECTION II

DATA ON MATERIALS

TABLE CXXXIX.—*Weights of materials*

Material	Weight per cubic foot (pounds)	Material	Weight per cubic foot (pounds)
Aluminum:		Earth—Continued	
Cast	160	Sand—Continued	
Wire	168	Wet	118–128
Asphaltum	69– 94	Gravel, clay mixed:	
Brass	510–542	Compact, dry	100
Brick	110–130	Wet	115
Bronze	545–555	Gravel:	
Coal:		Loose	82–125
Anthracite	97	Rammed	90–145
Bituminous	84	Ice	56
Charcoal	17– 35	Iron:	
Concrete:		Grey cast	439–445
Reinforced	150	Wrought	487–492
Stone	140–150	Lead	710
Copper, cast	549–558	Lime	53– 75
Crushed—		Masonry:	
Gravel	95–104	Mortar rubble	155
Granite	90	Dry rubble	125
Limestone	94	Rock:	
Earth:		Granite	125–187
Clay:		Gravel, clean	100
Dry, compact	100	Shale	162
Damp, plastic	110	Soapstone	162–175
Common—		Trap	187–190
Loose, dry	70	Salt	129–131
Moist, rammed	100	Snow:	
Loam	65– 88	Fresh fallen	5– 12
Mud, wet:		Wet compact	15– 20
Fluid	104–120	Steel	474–494
Pressed	110–130	Tin	455
Sand:		Water:	
Pure quartz, dry:		Fresh	62.4
Loose	87–106	Sea	64.0
Rammed	100–120	Wood	[1]
Natural, loose	80–110	Zinc	438

[1] See table CXL.

TABLE CXL.—*Weights of wood*

Kind	Pounds per cubic foot		Pounds per 1,000 board feet (83⅓ cubic feet)	
	Green	Air dry[1]	Green	Air dry[1]
Ash:				
White	48	41	4,000	3,450
Black	52	34	4,350	2,850
Beech	55	44	4,600	3,650
Cedar:				
Eastern red	37	33	3,100	2,750
Western red	27	23	2,250	1,920
Cottonwood, eastern	49	29	4,100	2,400
Cypress, southern	51	32	4,250	2,700
Douglas fir	38	34	3,200	2,850
Hemlock:				
Eastern	49	28	4,100	2,350
Western	42	28	3,500	2,350
Hickory	64	51	5,350	4,250
Larch, western	48	36	4,000	3,000
Oak:				
Red	63	44	5,250	3,700
White	62	48	5,200	4,000
Pine:				
Long leaf	51	41	4,250	3,400
Short leaf	51	38	4,250	3,200
Western yellow	45	28	3,750	2,350
Redwood	54	30	4,500	2,500
Spruce, red or white	34	27	2,850	2,250
Tamarack	47	37	3,900	3,100
Walnut, black	58	39	4,840	3,250

[1] Indicates 12 percent moisture content.

TABLE CXLI.—*Safe bearing power of soils*

Soil	Safe bearing power	
	Pounds per square inch	Tons per square foot
Quicksand and alluvial soil	6.9	½
Soft clay	13.9	1
Clean, dry sand	27.8	2
Medium dry clay	27.8	2
Compact sand	55.6	4
Dry clay	55.6	4
Rock (poor)	69.5	5
Cemented gravel	111.2	8
Rock (solid and first quality)	139-347	10-25

TABLE CXLII.—*Allowable compressive stresses for masonry*

Material	Stress (pounds per square inch)
Coursed rubble, portland cement mortar	200
Ordinary rubble, portland cement mortar	100
Coursed rubble, lime mortar	120
Ordinary rubble, lime mortar	60
First-class granite masonry, portland cement mortar	600
First-class limestone and sandstone masonry, portland cement mortar	400
Paving brick masonry, portland cement mortar	350
Selected hard common brick masonry, portland cement mortar	200
Common brick masonry:	
Lime mortar	100
Portland cement mortar	175

TABLE CXLIII.—*Allowable stresses for timber* [1]

Variety and grade of lumber	Extreme fiber bending	Horizontal shear	Compression: Perpendicular to grain	Compression: Parallel to grain	Modulus of elasticity E
	Pounds per square inch				
Douglas fir					1,600,000
Dense select structural	2,400	145	500	1,700	
Select structural	2,100	125	450	1,600	
Select merchantable	1,600	125	425	1,300	
Yellow pine, long leaf or dense short leaf					1,600,000
Select structural	2,600	[3] 165	500	1,900	
Structural square edges and sound	2,100	[3] 165	500	1,700	
No. 1 structural [2]	1,600	[3] 165	500	1,600	
Redwood					1,200,000
Prime structural	2,000	105	350	1,600	
Select structural	1,700	90	350	1,450	
Heart structural	1,500	70	350	1,300	
Southern cypress					1,200,000
Select structural	1,700	125	400	1,450	
Common structural	1,400	105	400	1,150	
Eastern hemlock					1,100,000
Select structural	1,450	90	400	900	

[1] Figures are for a factor of safety of 3. For green timber use 60 percent of values given.

[2] Basis of Engineer Board designs for H-15 timber trestle bridge.

[3] For long leaf yellow pine, this figure is 130.

TABLE CXLIV.—*Allowable stress for steel* [1]

	Pounds per square inch
Direct axial tension on net section	18,000.
Direct axial compression, maximum for short columns	14,000.
Compression in columns [2]	$18{,}000-70\frac{L}{r}$.
Fiber stress in flexure, in tension, or in compression when the unsupported length (L) is not more than 15 times the breadth (b).	18,000.
Compressive fiber stress in flexure for value L/b between 15 and 40.	$22{,}000-270\frac{L}{b}$
Fiber stress in pins	27,000.
Bearing on plane faced or rolled surfaces	27,000.
Shear in gross section of webs of girders and rolled shapes in which (d), the unsupported depth between flanges or the distance between stiffeners, if less, divided by (t) (the thickness of web) does not exceed 43.	12,000.
Shear when d/t exceeds 43	$15{,}000-70\frac{d}{t}$.
Shear in power-driven rivets or in pins	13,500.
Shear in hand-driven rivets or in rough bolts	10,000.
Bearing upon power-driven rivets or in pins subjected to single shear on one side of the bearing in question.	24,000.
Bearing upon power-driven rivets or on pins when the bearing metal lies between two planes of shear of opposite character immediately adjacent.	30,000.
Bearing upon hand-driven rivets or on rough bolts subjected to single shear on one side of the bearing in question.	16,000.
Bearing upon hand-driven rivets or on rough bolts when the bearing metal lies between two planes of shear of opposite character immediately adjacent.	20,000.

[1] For design, all values in this table may be increased 25 percent.

[2] Compression stresses in columns, computed by the formulas for column design, may not exceed in any case the maximum for direct axial compression short columns. L=length of column; r=least radius of gyration.

TABLE CXLV.—*Contents of lumber*

[Number of board feet in various sizes for lengths given]

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
2 by 4	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2 by 6	10	12	14	16	18	20	22	24
2 by 8	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2 by 10	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2 by 12	20	24	28	32	36	40	44	48
2 by 14	23⅓	28	32⅓	37⅓	42	46⅔	51⅓	56
2 by 16	26⅔	32	37⅔	42⅔	48	53⅓	58⅔	64
3 by 6	15	18	21	24	27	30	33	36
3 by 8	20	24	28	32	36	40	44	48
3 by 10	25	30	35	40	45	50	55	60
3 by 12	30	36	42	48	54	60	66	72
3 by 14	35	42	49	56	63	70	77	84
3 by 16	40	48	56	64	72	80	88	96
4 by 4	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 by 6	20	24	28	32	36	40	44	48
4 by 8	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4 by 10	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 by 12	40	48	56	64	72	80	88	96
4 by 14	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
4 by 16	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
6 by 6	30	36	42	48	54	60	66	72
6 by 8	40	48	56	64	72	80	88	96
6 by 10	50	60	70	80	90	100	110	120
6 by 12	60	72	84	96	108	120	132	144
6 by 14	70	84	98	112	126	140	154	168
6 by 16	80	96	112	128	144	160	176	192
6 by 18	90	108	126	144	162	188	198	216
6 by 20	100	120	140	160	180	200	220	240
8 by 8	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8 by 10	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8 by 12	80	96	112	128	144	160	176	192
8 by 14	93⅓	112	130⅔	149⅓	168	186⅔	205⅓	224
10 by 10	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10 by 12	100	120	140	160	180	200	220	240
10 by 14	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10 by 16	133⅓	160	186⅔	213⅓	240	266⅔	293⅓	320
12 by 12	120	144	168	192	216	240	264	288
12 by 14	140	168	196	224	252	280	308	336
12 by 16	160	192	224	256	288	320	352	384
14 by 14	163⅓	196	228⅔	261⅓	294	326⅔	359⅓	392
14 by 16	186⅔	224	261⅓	298⅔	336	373⅓	410⅔	448

TABLE CXLVI.—*Safe slopes for cuts and fills*

Material	Climatic conditions					
	Combined rain and heavy frost		Rain, not much frost		Arid regions, not much frost	
	Cut	Fill	Cut	Fill	Cut	Fill
Sand	1½:1	2:1	1½:1	2:1	2:1	4:1
Gravel	1½:1	1½:1	1:1	1½:1	1:1	1½:1
Loam	1½:1	1½:1	1½:1	1½:1	1¼:1	1½:1
Clay	2:1	4:1	1:1	3:1	1:1	1½:1
Boulders, earth	1½:1	1½:1	1:1	1½:1	1:1	1½:1
Rocks, slab buried in earth	1:1	1½:1	¾:1	1½:1	¾:1	1½:1
Broken rock and shale	½:1	1½:1	½:1	1½:1	½:1	1¼:1
Solid rock	¼:1	1:1	¼:1	1:1	¼:1	1:1

TABLE CXLVII.—*Sizes of threaded, round bars, bolts, nuts, and washers (U. S. standard)*

Diameter of bar (inches)	Net diameter (inches)	Net cross-sectional area at base of thread (square inches)	Short diameter of nuts (inches)	Washers		
				Diameter of bolt hole (inches)	Diameter of washer (inches)	Thickness of washer (inch) (approximate)
¾	0.620	0.30	1¼	13/16	2	0.134
⅞	.731	.42	1 7/16	15/16	2¼	.15
1	.838	.55	1⅝	1 1/16	2½	.15
1⅛	.939	.69	1 13/16	1¼	2¾	.15
1¼	1.064	.89	2	1⅜	3	.15
1⅜	1.158	1.05	2 3/16	1½	3½	.15
1½	1.283	1.29	2⅜	-----	-------	-------
1⅝	1.389	1.51	2 9/16	-----	-------	-------
1¾	1.490	1.74	2¾	-----	-------	-------
1⅞	1.615	2.05	2 15/16	-----	-------	-------
2	1.711	2.30	3⅛	-----	-------	-------
2¼	1.961	3.02	3½	-----	-------	-------
2½	2.175	3.72	3⅞	-----	-------	-------

TABLE CXLVIII.—*Sizes of wire nails*

Size (d-penny)	Length (inches)	Number per pound	Size (d-penny)	Length (inches)	Number per pound
2-d	1	900	20-d	4	29
3-d	1¼	615	30-d	4½	23
4-d	1½	322	40-d	5	17
5-d	1¾	250	50-d	5½	13½
6-d	2	200	60-d	6	10½
7-d	2¼	154	70-d	7	7
8-d	2½	106	80-d	8	6
9-d	2¾	85	90-d	9	5
10-d	3	74	100-d	10	4
12-d	3¼	57	120-d	12	3
16-d	3½	46			

TABLE CXLIX.—*Sizes of fence staples*

Size (inches)	Number per pound	Size (inches)	Number per pound	Size (inches)	Number per pound
1	108	1¼	87	1¾	65
1⅛	96	1½	72	2	58

SECTION III

TROOP MOVEMENT DATA

TABLE CL.—*Average rates and lengths of march under favorable conditions (see also FM 101–10)*

Type of unit	Rates of march (miles per hour)				Length of march (miles per day)
	On roads		Across country		
	Day	Night[1]	Day	Night	
Foot troops	2½	2	1½	1	15
Horse-drawn artillery	3½	3	3	2	20
Pack artillery	3½	3	3	2	20
Tractors	3½	3½	3	2	30
Horse cavalry	6	5	5	4	35
Truck-drawn heavy artillery	15	15-10	8	5	100
Truck-drawn medium artillery	20	20-10	8	5	140
Tanks or combat cars	25	25-10	15	5	150
Truck-drawn light and antiaircraft artillery	25	25-10	8	5	175
Trucks	25	25-10	8	5	175
Armored cars and scout cars	35	35-10	10	5	200
Passenger cars and motorcycles	35	35-10	10	5	250

[1] Smaller figure in 2-figure groups is for rates of march without lights.

TABLE CLI.—*Basic road spaces (for motor vehicles see FM 25–10)*

	Yards
Animals:	
In column of fours .... per animal	1
In column of twos .... do	2
Single file .... do	4
Foot troops:	
In column of twos .... per man	1
In column of threes .... do	⅔
In column of fours .... do	½

INDEX

NOTES AND MEMORANDA

The following pages are provided for individual users to paste or write in such data as may be requisite for their particular needs.