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WAR DEPARTMENT

ENGINEER FIELD MANUAL

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VOLUME II

MILITARY ENGINEERING

(*TENTATIVE*)

PART THREE

CONSTRUCTION AND UTILITIES

ENGINEER FIELD MANUAL

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VOLUME II
MILITARY ENGINEERING
(*TENTATIVE*)

PART THREE
CONSTRUCTION AND UTILITIES

Prepared under the direction of the
CHIEF OF ENGINEERS

UNITED STATES OF AMERICA
WAR OFFICE

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Part Three, Construction and Utilities, Engineer Field Manual, Volume II, Military Engineering (Tentative), is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

DOUGLAS MACARTHUR,
General,
Chief of Staff.

OFFICIAL:
C. H. BRIDGES,
Major General,
The Adjutant General.

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Signal Corps Field Manual. (S. C. F. M.)

Vol. I. *Signal Corps Troops.*
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FOREWORD

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

The manual will be published in three parts as follows:

Part One. Communications:
  Chapter 1. Roads.
    2. Bridges.
    3. Military railways.
    4. Surveys and maps (this chapter will be published when it becomes necessary to revise TM 2180–30 and 2180–37).
Part Two. Defensive measures:
  Chapter 1. Camouflage.
    2. Field fortifications.
    3. Explosives and demolitions.
Part Three. Construction and utilities:
  Chapter 1. General construction.
    2. Water supply.
    3. Light and power.

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ENGINEER FIELD MANUAL,

VOLUME II, MILITARY ENGINEERING

(*TENTATIVE*)

PART THREE

CONSTRUCTION AND UTILITIES

(The matter contained herein supersedes the Engineer Field Manual, Edition of 1918 (Professional Papers of the Corps of Engineers, U. S. Army, No. 29).)

CHAPTER 1

GENERAL CONSTRUCTION

SECTION I

GENERAL PRINCIPLES

1. Simplicity.—All plans for general construction in the theater of operations are of the simplest nature and in general should call for only the most common construction materials and supplies.

2. Economy of materials.—Economy of materials is obtained principally—

a. By recognizing the temporary and emergency character of war-time construction.

b. By limiting all construction to the barest necessities of the situation, eliminating all nonessentials.

c. By utilizing existing structures, which can be adapted for military purposes, rather than to erect new structures.

d. By the use of type plans.

3. Use of type plans.—Efficient utilization of personnel and materials and speed in construction are attained by the use of type plans such as those suggested in this manual. Type plans in detail are prepared in time of peace by the Corps of Engineers. These are the basis for the procurement of materials which are shipped to the theater of operations, and hence the employment of type plans by the field forces is an assurance that the materials called for are of a type and in quantities which are likely to be available.

4. Planning.—In planning construction where large expansion may be required later, projects should be so laid out that expansion is feasible. The actual construction should be carried out so that each usable unit is completed in succession in such a way that it can be used immediately. Construction carried out in this manner will lend itself continually to the military requirements, and a change in the military situation which makes it necessary to stop the construction will not leave a large quantity unused and useless. Work carried on in this manner may not be as economical of labor and materials as when parts requiring similar construction methods are all built at the same time. It must not be inferred from the foregoing that the planning itself should be piecemeal. A construction project, such as a cantonment, storage depot, or base hospital, should be planned in its entirety and the site chosen for the construction should be suitable for the ultimate development of the entire project. In this way, the actual construction which may proceed in a piecemeal manner will, nevertheless, fit into the large scheme.

Section II

REQUIREMENTS

5. Shelter.—*a. Barracks.*—Considering the theater of operations as a whole, a fair assumption is that barracks will have to be provided for 60 per cent of the total force plus 100 per cent of the prisoners. In any particular camp, barracks must be provided for all of the troops and may have to be provided for civilian labor. Barrack space is provided on a basis of 50 men per building, 20 by 100 feet. An air space of 400 cubic feet per man is required as a minimum. Expressed in floor space, this sanitary requirement in a building of average height of 10 feet is from 40 to 60 square feet per man. Bunks should be provided for all men and where space is scarce may be of the double-decker type.

b. Kitchens and mess halls.—In ordinary cantonments, a separate kitchen and mess room should be provided for each company, troop, battery, or similar unit. A standard barrack building will serve as a kitchen and mess for one such unit. In replacement camps, embarkation and debarkation camps, and at other points where large numbers of transients are fed rapidly from one kitchen, other special types of mess rooms may be provided. Rough lumber tables and benches may be provided, but this is a refinement not always necessary.

c. Latrines.—Water-borne sewerage, septic tanks, and other sewage-disposal devices should not be constructed, as materials or labor are seldom available for such purposes. Latrines should be of the simplest type. About one seat to 20 men is desirable, but one seat to 40 men can be made to serve.

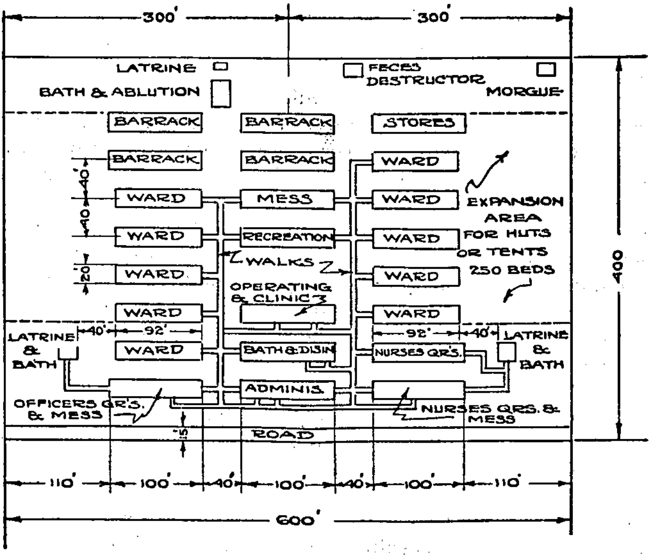


FIGURE 1.—Typical layout for 250-bed station hospital

d. Bathhouses.—Bathhouses should be provided in the ratio of one to each battalion area. This allowance is small and requires good administration and supervision in the use of the bathhouses. If conditions permit, one bathhouse per company, troop, or battery should be provided.

e. Water.—The question of water requirements is discussed in Chapter 2. Where water is piped to separate companies, one faucet per company can be made to serve and no construction for washing face and hands is necessary, although such facilities should be provided if practicable.

f. Electricity.—The question of requirements in electricity is discussed in Chapter 3.

6. Hospitals.—*a. Percentage allowances.*—Hospitalization requirements vary from 5 per cent to as high as 15 per cent or more of the total strength of the command. Under normal healthful conditions 10 per cent should be sufficient. A combination of prolonged fighting and unhealthful conditions may necessitate hospital provision for considerably more than 15 per cent. Station hospitals at training centers should provide facilities for the care of about 5 per cent of the troops in the area.

b. Space allowances.—Space allowances in hospitals must necessarily greatly exceed those for barracks. A minimum allowance of 60 square feet per patient should be provided at each bed. The additional space for administration, supply, operating rooms, etc., and for accommodation of the hospital personnel will require a minimum of 30 to 35 square feet additional per patient. General hospitals are constructed in 1,000-bed units. The capacity of the 1,000-bed units can in emergency be increased to 1,200 beds. Station hospitals are constructed in 250-bed units. Figure 1 shows approximately the space devoted to each facility in a typical layout for a 250-bed station hospital.

c. Water supply.—Water supply for general hospitals should be provided on a minimum basis of 25 gallons per patient per day. For station hospitals this figure may be reduced somewhat if necessary.

d. Electricity.—Electric current should be provided for all station and general hospitals for lights, sterilizing apparatus, dentist tools, X rays, etc. A 250-bed station hospital requires about 5 kilowatts which can be supplied from a single portable 5 kilowatt direct-current generator.

7. Shelter for animals.—Veterinary general hospitals should be provided on a basis of hospitalizing 8 per cent of the animals in the theater of operations. Veterinary station hospitals should be provided at the rate of one per camp, with accommodations for approximately 1 per cent of the animals in the camp. A veterinary hospital is required in close proximity to each remount depot. At each veterinary hospital are required dressing rooms, operating rooms, dipping vats, sulphurizing rooms, horseshoeing shops with forges, and storehouses for equipment and forage. Each large project requires an ample water supply and a standard-gage railroad siding or spur, with facilities for rapidly loading and unloading animals. In general, animals in good condition do not require shelter, but watering troughs, feeding racks with feed boxes and mangers, and picket-line standings may have to be provided.

8. Ports.—*a. Dockage.*—Ordinarily, the problem of port facilities resolves itself into the expansion or adaptation of existing facilities. Requirements in berths for vessels are based upon the tonnage rate passing through the port. Experience shows that about 1.25 tons per day can be unloaded per linear foot of dock frontage. On this basis, assuming supply shipments to be at the rate of 40 pounds per man per day, 16,000 linear feet would be required for a force of 1,000,000 men. In addition, there should be provided several docks for the handling of ammunition, sufficient to receive two lighters at one time or a dock approximately 150 feet long. In addition to dock facilities, there should be planned a liberal use of lighters and barges for handling cargoes and for discharging troops.

b. Cargo-handling apparatus.—At first cargoes may have to be unloaded, using no other devices than ship's tackle. Later, if shipping tonnage is sufficiently plentiful to warrant transporting cargo-handling machines, these may be provided.

c. Trackage.—It is necessary to have tracks along the entire length of the wharves. In the case of a wharf paralleling and near the shore line, with connections to the yards in the rear at each end, there should be at least three tracks with ample cross-overs in the space between the front of the wharf and the warehouses. Depressed tracks should also be placed in the rear of the warehouses and should serve open storage space conveniently. Behind the wharf there should be receiving and departure yards, a coal-storage yard, and facilities for light repairs to cars, requiring for a dockage of 8,000 feet front a total of approximately 70 miles of track. In case the topography and local conditions permit, the base storage depot should be located immediately adjacent to the rear of the wharves, reducing the total trackage requirements for receiving and departure yards, as well as coal-storage yards and car-repair facilities. There are also the reduced labor of operations and the economy effected by the concentration of operations. Generally speaking, the entire wharf and storage space, both open and covered, should be accessible to motor trucks, in order that local necessities may be served by trucks as necessary.

d. Facilities for debarking 10,000 troops per day.—The general facilities for debarking and entraining 10,000 troops per day are a railroad-classification yard and receiving and forwarding yard for freight, a troop-entraining yard, holding tracks, engine and car repair facilities, and a quartermaster depot, the total trackage amounting to about 35 miles. A camp should be provided near by for about 20,000 men, capable of expansion by tents to a 40,000 capacity, with the usual quartermaster warehouse, messing, bathing, and hospital facilities. In general, debarking facilities should be the same as for cargoes; that is, the men should be either disembarked directly on the wharf or transferred from ships to shore by lighters or tenders.

9. **Camps and cantonments.**—*a.* Structural requirements of various kinds for camps and cantonments for units of the several arms can be stated in general terms only, since the precise requirements will depend upon the Tables of Organization current during the war. In the absence of definite information as to the types of units which will occupy a given camp or cantonment, unit installations may be made on the basis of accommodating 500 men per unit and 1,000 men per unit. Combinations of these units can be made to accommodate organizations of varying sizes. In general, every camp or cantonment requires barracks, messes, latrines, baths, administration building, medical building, guardhouses, storehouses, post exchange, officers' mess, and officers' quarters. Shops should be provided for motorized units. Stables, watering troughs, and corrals should be provided for mounted units. In large cantonments one recreation building per regiment or independent battalion is conducive to good morale. (See fig. 2.)

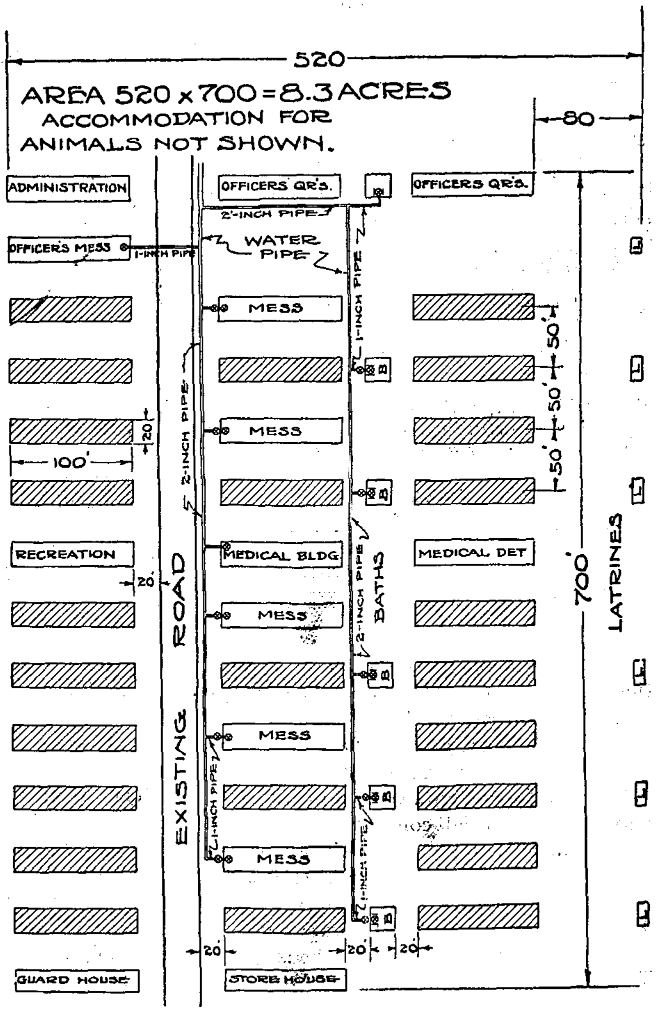


FIGURE 2.—Typical layout of shelter cantonment for 1,000-man unit

TABLE I.—*Approximate areas required for semipermanent camps for an infantry division*

Unit	Depth	Breadth	Acres
	Yards	*Yards*	
Division headquarters and special troops	305	350	22
Infantry brigade headquarters and headquarters company	435	25	2.3
Infantry regiment	435	540	48.5
Infantry brigade	435	1,135	102
Headquarters field artillery brigade and headquarters battery	435	30	2.7
Field artillery regiment (75-mm. gun)	435	500	45
Ammunition train	435	70	6.4
Field artillery brigade	435	1,170	105.2
Engineer combat regiment	300	260	16.1
Division air service (if attached), including landing field	600	600	75
Medical regiment	370	440	33.6
Division train	400	330	27.3
Total for a division			486.1

TABLE II.—*Approximate areas required for semipermanent camps for a field artillery regiment (155-mm. howitzer), for a cavalry regiment and for a squadron, Corps of Engineers*

Unit	Depth	Breadth	Acres
	Yards	*Yards*	
Field artillery regiment (155-mm. howitzer)	435	575	51.7
Cavalry regiment	435	370	33.3
Squadron, Corps of Engineers	280	150	8.6

b. Rule of thumb for camp areas.—A rough rule for determining the area for semipermanent camps of any unit is as follows:

50 square yards per man.
60 square yards per animal.
300 square yards per vehicle.

10. Air Corps construction.—*a. General.*—The Air Corps may require special construction at assembly plants, training centers, depots, and airdromes in addition to shelter for personnel.

b. Assembly plants.—If airplanes are delivered to the theater of operations unassembled, an assembly plant is necessary. This comprises assembly hangars with motor-testing adjuncts, salvage hangar, shops, storage sheds, hangars, and a flying field. The assembly hangars must be large enough to accommodate the largest size of aircraft. Floors are desirable in these hangars, although not absolutely necessary. Salvage hangars are identical in type with assembly hangars. The shop requires a building large enough to accommodate the machinery and power plant and should be located adjacent to the assembly hangar. On account of machinery being used, concrete floors in shops are greatly desired. Storage sheds are standard warehouses containing racks to hold special parts. No floors are necessary. A flying field adjacent to the assembly plant is necessary on which to test aircraft before being turned over to using troops. Hangars are placed on the side of the flying field along the direction of the prevailing wind. Shelter for personnel and administrative offices are required as for other cantonments.

c. Training centers.—Air Corps training centers require shelter for personnel, flying fields with hangars, shops for minor repairs, assembly rooms for class instruction, and administrative buildings. As the training centers are located well to the rear, the layout of the installation is that which best facilitates efficient and economical administration and operation.

d. Depots.—Air Corps depots are usually located separate from general depots, because air supplies do not, in general, follow the same lines of travel as other supplies. An Air Corps depot requires storage sheds without floors, shop buildings for repairs, and a flying field.

11. Airdromes.—*a. General.*—Airdromes in the theater of operations are of two general classes, those in the rear areas and those in the forward areas. Airdromes in the rear areas do not differ materially in characteristics from the army air fields commonly constructed in the zone of the interior in time of peace. Airdromes in the forward areas are used for tactical operations of the Air Corps. These airdromes are temporary in character, and considerations of camouflage, secrecy, and dispersion to minimize casualties from enemy activity profoundly affect their layout.

b. Nature of the terrain.—In selecting a site for a landing field, the following points should be considered:

(1) Field should be clear of brush and stumps. Grass and weeds should not be taller than 15 inches.

(2) The ground surface should be reasonably smooth. A grass field is best. Ridges and furrows cause aircraft to bounce dangerously. Stubble is good. Wet plow is very dangerous. Dry plow, harrowed and rolled, will serve.

(3) The grade of slopes should not be greater than 2½ per cent. Within this limit a gently rolling field is usable.

(4) An ideal condition is that the soil should be so firm and so well drained that aircraft can use the field without the need of especially constructed runways. This condition will often be found where the ground is of a gravelly or sandy nature. The construction of runways other than clearing should be avoided both to economize labor and to minimize the chances of detection from the air.

c. *Size of advanced airdromes.*—The size of a landing field is influenced by the performance characteristics of the aircraft using it. The principal controlling feature is the angle of descent as the aircraft approaches the field in making a landing. The usual angle of descent is 1 to 7. This fixes the location of the runways with reference to trees or other obstacles in the vicinity of the airdrome. For safety, 100 feet should be added to the tallest obstacle in computing the distance from this obstacle to the runway. The runway itself must be of sufficient length to care for the landing and take-off. Experience shows that runways of from 2,500 to 3,000 feet are adequate. The width of the runway should be great enough to permit five aircraft to take off abreast. This requires a minimum of 400 feet to commence operations. This width should be increased as soon as practicable.

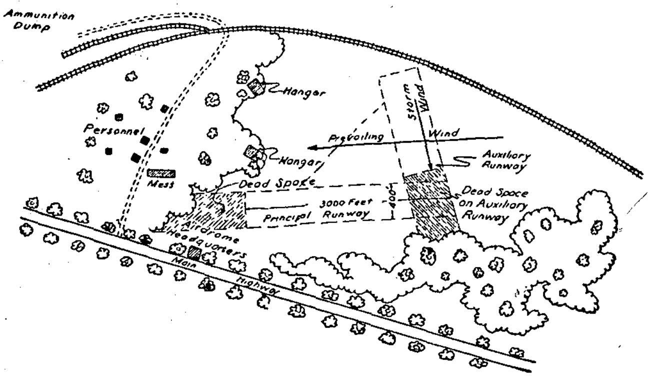


FIGURE 3.—Typical airdrome bombardment aviation forward areas

d. *Direction of runways.*—Where choice is possible, the runways should parallel the prevailing winds. Where the winds are variable, a number of runways may have to be provided lying in several directions. In determining the direction of the prevailing winds a wind-rose diagram should be constructed based upon data collected over a considerable period of time.

e. Layout.—Figure 3 shows the layout of a typical forward airdrome of the L-shape. The longer leg of the L is in the direction of the prevailing wind. The shorter leg gives a take-off for storm winds. A third direction may be developed across the angle. Camouflage considerations and dispersion to minimize losses due to enemy bombings may direct that the buildings be scattered.

f. Construction.—The construction required includes clearing and grading the landing field, construction or maintenance of roads and railways, construction of hangars and shelter for personnel, and utilities, including water supply. Some clearing and grading are usually necessary. Tall brush and trees should be cut down and the débris removed from the site. Stones and boulders must be cleared from the surface and removed or buried. The grading and smoothing of the surface may be accomplished by using plows, harrows, and drags drawn by tractors. Drainage is very important and where necessary must be provided by subsurface drainage pipes. It is necessary that trenches carrying such pipes be filled in and leveled, in order not to provide an obstacle to the ground movements of airplanes.

g. Shelter.—In rear areas shelter must be provided for personnel on the same basis as for other cantonments. In the forward areas tentage suffices. In addition, messes and shelter should be provided for transient personnel using the airdrome, and shelter must be provided for shops and photographic laboratories.

h. Ammunition dump.—An ammunition dump consisting principally of open storage must be provided within reasonable distance of the airdrome for the storage of bombs and other ordnance supplies. If practicable, an ammunition dump should be separated from the airdrome proper by natural defilade to minimize the possibility of damage resulting from explosions.

i. Hangars.—Hangars are made of steel, wood, or canvas. Canvas is the most expedient, but where long use is required, or where extremely wide spans are required, wood or steel is used. Spans under 70 feet can be made with wooden trusses. Greater spans than this make steel almost essential, and even for smaller spans steel may be more expedient. In forward areas hangars are required only to shelter mechanics while making repairs to aircraft, and to conceal lights used by them in making repairs at night. In general, hangars are not necessary for sheltering aircraft from weather.

12. Motor transport construction.—There should be an assembly plant at each base port. The construction work required includes sheds, roads, and storage parks. Sheds are necessary only for work and for storage of spare parts. All vehicles are stored outside. Heavy traffic around motor facilities requires much road work. Drainage is especially important. Storage ground for motor vehicles may be graded and drained, but surfacing with rock or gravel is rarely necessary. Generally, grading for drainage will keep the ground firm enough to permit storage of motor vehicles, and only those portions of a park which are subjected to traffic have to be surfaced with rock.

13. Ammunition depots.—Depots for ammunition other than for small-arms ammunition are constructed apart from general depots, and they are so laid out that each storehouse is located apart from other storehouses so as to localize the effect in case of accidental explosion. Standard warehouses and sheds are used for the storage of ammunition. Much ammunition may be kept in open storage.

14. General storage depots.—*a. Plans and development.*—All supplies other than ammunition, airplanes, and motor vehicles are ordinarily stored in general storage depots whose location depends on conditions. The plan shown in Figure 4 shows a typical layout for a general storage depot. The construction progresses according to immediate and urgent needs. The warehouse area is laid out in sections, each section having a ladder track on each side connected by house tracks about 1,700 feet long, there being one of these to each three warehouses. These tracks are about 150 feet apart, which gives space enough for open storage on the opposite side of the track from the houses, as well as space for firebreaks. A section can be started with a ladder track on one side, a ladder on the other side to be added later.

Variations will have to be made in the layout to take advantage of local topography, but the principle of operation should not be changed. No turntables should be built for military operations; use Y's, or loops.

b. Construction.—In the beginning a space should be laid out for each supply service, and the construction should proceed so that each service can begin storing supplies and expand without mixing up its supplies with those of other services. Different types of storehouses should be distributed on separate tracks so that any one commodity can be stored on separate tracks and so that if desirable the same commodity may be loaded on one track while it is being received on another. No existing road should be closed by warehouses or tracks, as existing roads are very valuable and scarcity of materials may make new road construction impracticable. Each supply service should be provided with one or more storehouses adjacent to roads from which shipments can be made by motor truck.

c. Fire protection.—Warehouses are spaced far enough apart so that fire can not spread from one to another, and groups of warehouses are separated by open storage spaces. No installation of water pipes and hydrants for fire protection is provided because the cost of such a system would exceed any probable loss from fire. Sidings and spurs far removed from other stores are laid for the storage of hay and dynamite, thus localizing fire risk.

d. Warehouses.—A suitable type of storehouse is about 50 feet wide and 400 or 500 feet long, made with wooden frame and corrugated iron roof and sides. (See fig. 5.) For many uses the sides may

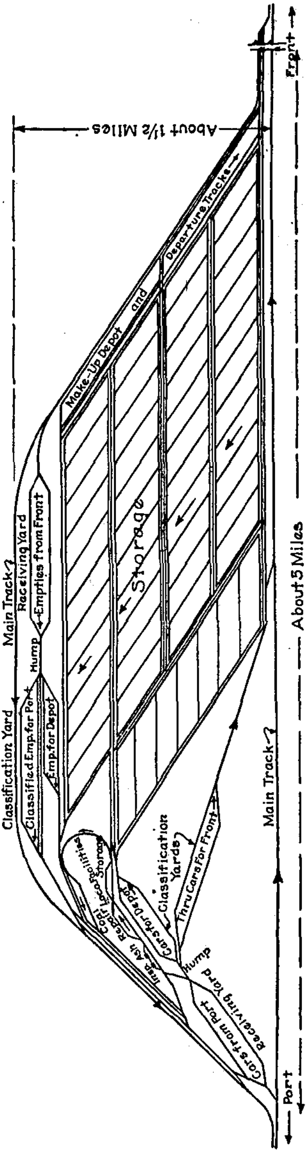


FIGURE 4.—Schematic plan of a typical storage depot layout

be omitted and the structures used as sheds. Sides are necessary only on houses which carry perishable supplies, such as flour or sugar. No windows are needed if the siding is carried up to within 12 or 18 inches of the roof and a continuous opening left at the top which is protected by the eaves. Doors are not essential, canvas being hung over openings where it is necessary to close them. The frames of the buildings may be made of round posts and rough lumber. In general, floors are not necessary. For the preservation of supplies which are very sensitive to water, such as flour and sugar, dunnage consisting of wood poles with rough plank laid on them may be used. Floors at car level are not constructed since they do not warrant the labor, materials, and time necessary.

e. Cold storage.—Cold-storage plants may be required to freeze or store meat between shipments. While such a structure on account of its technical nature must be most carefully constructed, a designer having in mind the military requirements of simplicity, economy of materials, and time, and the absence of necessity for durability, can modify for the better a refrigerating plant designed upon the basis of civil practice.

f. Freight house and small shipments.—The depot will frequently have to make a large number of less-than-carload shipments from the various departments. It is desirable to have a special shipping warehouse for this purpose. This warehouse should be located near a connection to the main line outgoing railroad.

g. Post warehouse.—The post to serve the personnel which operates the depot needs a warehouse for local issue purposes. This warehouse should contain from 20,000 to 25,000 square feet and should be located on a road outside of the depot area, since it is important that post supply functions should not be mixed up with depot operation. This warehouse should be on a railway siding.

h. Offices.—Each supply service operating at the depot needs office space. The standard barrack building is suitable for this purpose. The offices should be located adjacent to the respective storage areas used by the several supply services.

i. Camps.—Camps for operating personnel should be located on existing roads and should be distributed around the depot so that personnel belonging to each supply service is within walking distance of its work.

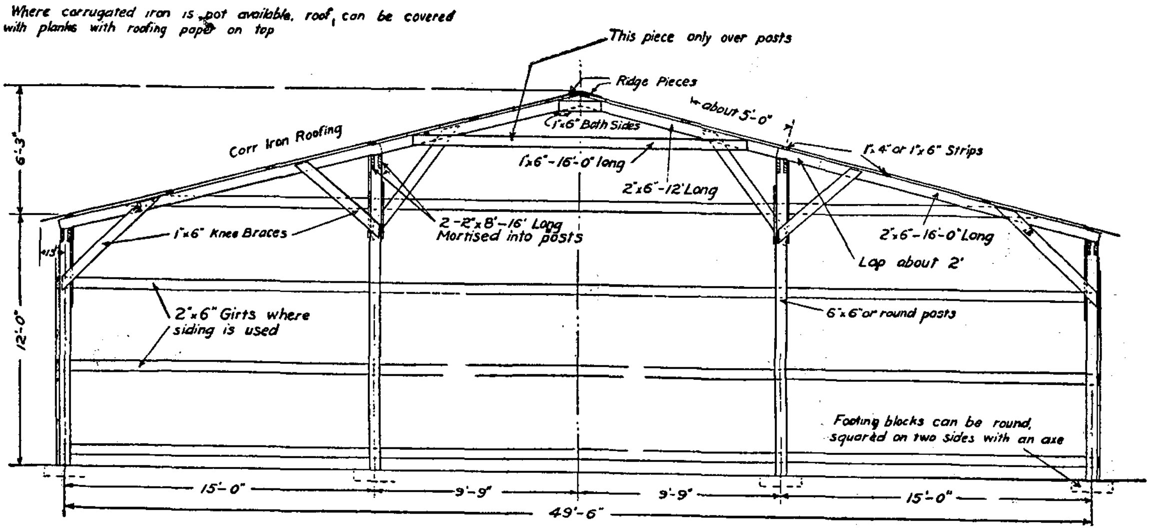


FIGURE 5.—Warehouse

j. Water supply.—In addition to water for personnel, there must be water for locomotives and possibly ice plants and bakeries. A large depot may use about 500,000 gallons per day.

k. Electricity.—Experience has shown that in the intermediate and base depots very little night work is necessary, and so it is unnecessary to install electric lights in the warehouses. On the rare occasions when night work is necessary, portable illuminating sets may be used.

l. Railway facilities.—A general storage depot requires so much railway operation in connection with the depot that engine terminal facilities in immediate proximity to the depot are essential. These do not differ from the engine terminal facilities discussed in Chapter 3, Part One. They are shown in Figure 4. In the storage area, the cars are pushed into the storage track from the ladder on one side and taken out at the other, thus always maintaining a flow in one direction.

SECTION III

RECONNAISSANCE

15. Reconnaissance for general construction.—Reconnaissance for general construction consists principally in the selection of sites for camps or cantonments, hospital areas, storage depots and remount depots. In general, a site for any of these installations should have about the same characteristics. In the selection of sites and in the comparison of the merits of various available sites, aerial photographs, both vertical and oblique, are of much assistance. A map should always be used, if available, in connection with personal reconnaissance of the site.

16. Reconnaissance party.—A reconnaissance party making a preliminary examination of sites should include a general staff officer, an engineer officer, and a medical officer, and where the site is for the especial or principal use of one of the separate arms or services, the party should include a representative of that arm or service. They should be equipped with motor transportation, field glasses, maps, and notebooks. The engineer should carry a compass for general orientation and a pocket level for rough determination of grades. In a foreign country, the reconnaissance party should include an interpreter.

17. Reconnaissance of the site.—*a. General.*—In general, sites chosen for construction should be on well drained, fairly smooth terrain There should be no heavy grades and the amount of excavation and grading necessary in connection with construction on the site should be a minimum.

b. Cantonment sites.—In the selection of a cantonment site the following points should be kept in mind:

(1) A cantonment site should—

(*a*) Be of sufficient size to accommodate the command without crowding.

(*b*) Have an adequate water supply for both men and animals to be encamped thereon.

(*c*) Contain within itself, or be located within convenient distance of, an adequate training area.

(*d*) Contain within itself, or be located within convenient distance of, suitable ground for target practice.

(*e*) Be located upon or near a railroad of sufficient capacity to insure the convenient supply of the command and its prompt movement in case of need.

(*f*) Be one that can be leased (if not already owned or leased by the Government) for one or two years with the option of renewal from year to year for about five years.

(*g*) Be immune from floods and inundations.

(2) The following very desirable features should be secured whenever practicable:

(*a*) Soil of sandy loam with good drainage.

(*b*) Site affording natural bathing facilities, such as streams, lakes, or seas.

(*c*) Site adjacent to a city or large town containing facilities for healthful and attractive recreations.

(3) The following desirable features are not so important as those enumerated above, but they should not be overlooked, as they tend toward efficiency, economy, and the welfare and contentment of the command:

(*a*) Roads good or potentially good.

(*b*) Infrequent interruptions of training by inclement weather.

(*c*) Grazing for animals within convenient distance.

(*d*) Absence of insect pests.

(*e*) Good strategical location.

(*f*) Location central with respect to training area.

(*g*) Material for temporary shelter locally obtainable in sufficient quantities at reasonable prices.

(*h*) Mechanical, skilled, and common labor locally obtainable at reasonable wages.

SECTION IV

STANDARD TYPES

18. General.—This section presents type plans for use in the theater of operations for the construction of shelter and covered storage. The designs are based upon the utmost economy of construction materials, simplicity, and the absence of details requiring skilled personnel to construct. The standard 20 by 100 foot one-story building, with minor adaptations, is used for as many purposes as possible.

19. Standard barrack building.—Figure 6 shows a standard 20 by 100 foot barrack building. This type of building can be used for a great variety of purposes, such as barracks, warehouses, mess halls, administration buildings, infirmaries, hospital wards, etc. It consists essentially of a very lightweight frame covered with a sheathing of wood or corrugated steel. This structure is designed to make the maximum use of standard sizes of lumber, sawed-off end pieces being utilized in making splices or ties between the side frames and the ends. Only such bracing is used as is considered absolutely essential, the stability of the structure depending partly upon the stiffness of the complete assembly of sides and ends. The simplest form of covering is corrugated steel. This should not be used in hospital areas, because it is too hot in summer and too cold in winter. The doors are of the common batten type shown in Figure 10, simple hardware being used. An improvised latch is shown, but any available latch may be used. The same type of door is intended for use on all outside openings of buildings of this type. The doors may be either single or double leaf, and may be covered with either corrugated steel or wood. Screen doors as shown in Figure 9 are for use only on hospital wards, kitchens, and mess halls. The window frame is designed for assembly in the field. It is not intended that glass should be used in the frame, but it should be covered with a translucent material or screened. If mill-made sashes of the proper size are easily available, they may be used instead of the sash shown. Certain uses of this type of building require the installation of ventilators, which may be either of the ridge type or the tubular-metal type.

TABLE III.—*Standard barrack building, 20 by 100 feet, bill of materials*

Type 1				Items
Number of pieces	Size	Length	Feet board measure	
52	2 by 4 inches	12 feet	416	Roof rafters.
77	2 by 4 inches	16 feet	821	Framing, subrafters and toilet box; partition studs also.
550	⅞ by 6 inches	16 feet	4,400	Sheathing, screen doors, drain board, shelves and toilet box.
50	⅞ by 4 inches	12 feet	200	Rafter ties, knee braces, screen-door frames, shelves, supports, and toilet box.
11	⅞ by 3 inches	10 feet	28	Door meeting rails, window sills, and door bolts.
24	⅞ by 3 inches	14 feet	84	Sash frames.
2	⅞ by 8 inches	16 feet	21	Sash frames, corners.
1	⅞ by 2 inches	10 feet	2	Door-bolt guides.
6	⅞ by 1¾ inches	14 feet	12	Window filler strips.
48	⅞ by 1 inch	14 feet	56	Window guide strips and screen-door strips.
24 sq. yards	36 inches wide	72 linear feet	216 square feet	Translucent material and 2½ ounces No. 2 tacks per 100 square feet.
26 rolls	32 inches wide		2,808 square feet	Two-ply "prepared roofing" and nails, cement, and tin caps.
4		3 inches		Hooks and screw eyes, for doors.
50 pounds	20 penny	4 inches		Framing nails.
88 pounds	8 penny	2½ inches		Sheathing nails.
4 pounds	4 penny	1½ inches		Nails for strips.
1	36 inches wide	72 linear feet	216 square feet	Screen wire for windows, 14 by 14 mesh.
1	26 inches wide	28 linear feet	61 square feet	Screen wire for doors, 14 by 14 mesh.
1	26 inches wide	12 linear feet	26 square feet	Cellar window wire for doors, 2 by 2 mesh.
4	¼ inch diameter	16 inches		Coiled wire springs with screw eyes.
8	3½ by 3½ inches	3½ inches		Fast, joint butts with screws, for screen doors.
8		10 inches		T hinges with 1½-inch screws, for exterior doors.
				Strap hinges for toilet box lids and necessary screws.
8 ounces	18 gage	½ inch		Blind staples for screen wire; windows and doors.

Table III.—*Standard barrack building, 20 by 100 feet, bill of materials*—Continued

CORRUGATED STEEL COVERED

Type 1				Items
Number of pieces	Size	Length	Feet board measure	
102	26 inches wide	8 feet	1,768 square feet	Roofing, corrugated steel, No. 26 gage, black steel.
102	26 inches wide	6 feet	1,326 square feet	Roofing, corrugated steel, No. 26 gage, black steel.
108	2 by 4 inches	8 feet	576	Purlins and braces.
15	⅞ by 4 inches	8 feet	40	Purlin splice plates and overhang brackets.
104	26 inches wide	8 feet	1,803 square feet	Sides and ends, corrugated steel, No. 26 gage, black steel.
24	26 inches wide	5 feet	260 square feet	Sides, corrugated steel, No. 26 gage, black steel.
5 pounds	3/16 inch diameter	⅜ inch		Rivets, for fastening corrugated steel sheets.
5	18 inchesdiameter			Ventilators, galvanized steel "economy type."
12 pounds	No. 10	1½ inches		Nails, barbed, for corrugated steel sheets.

WOOD SHEATHED AND FELT COVERED

21 rolls	32 inches wide	851 linear feet	2,268 square reet	One-ply "prepared roofing," sides, ends, and doors.
5 bundles	¼ by 1½ inches	4 feet		Lath for sides, ends, and doors and 12 ounces, 2 penny nails, per bundle.
5 rolls	32 inches wide	203 linear feet	540 square feet	2-ply "prepared roofing" with nails, tin caps, and cement for louver.
59	⅞ by 6 inches	16 feet	472	Sheathing for louver roof.
25	2 by 4 inches	10 feet	167	Framing for louver.
32	⅞ by 3 inches	12 feet	96	Baffle boards and small brace blocks for louver.
1	8 inches wide	200 linear feet	133 square feet	Screen wire, black, and 8 ounces of ½-inch blind staples per 100 linear feet.

20. Floors.—Figure 11 shows two types of floors which may be used in situations where floors are absolutely essential. For the type-X floor it is merely necessary to bring the ground to some grade. Where necessary to install floors, it is considered desirable to construct them before the main frames of the buildings are erected and use the floors as a level work space for assembly of the building frames in a horizontal position. On an uneven terrain the type-Y floor is used. Buildings should be located, if practicable, so as to avoid excessive use of this type of floor.

21. Bunks.—Figure 12 shows two types of bunks for one or two men. The double-tier bunk is for use where shelter is limited.

22. Latrines.—Figure 13 shows a latrine shelter with roof and sides, and urinal trough and box latrine over a pit. The details of the latrine box are shown in Figure 14. Where materials are scarce, or the latrine is for temporary use, the shelter may be dispensed with and a screen only provided consisting of burlap supported by a frame of 2 by 4 inch studding. For hospitals and for officers' or nurses' quarters, a pail latrine may be used, as shown in Figure 15.

23. Mess halls.—The standard 20 by 100 foot barrack building is adaptable for use as a mess hall. A space 20 by 12 feet suffices for the kitchen, which may be at one end of the building. (See fig. 16.)

24. Mess-hall accessories.—Figure 17 shows a mess table combined with seats, a serving table, and a grease trap.

25. Bathhouse.—Figure 18 shows a bathhouse in a building 20 by 20 feet constructed similarly to the standard 20 by 100 foot barrack building with a floor. Details of the shower outfit are shown in Figure 19.

26. Lavatory.—Figure 20 shows a lavatory with benches and faucets. The building is 12 by 20 feet, constructed in a manner similar to the standard barrack building.

27. Hospital ward.—Figure 21 shows two types of standard hospital wards. These buildings are adaptations of the standard 20 by 100 foot barrack building. They are floored throughout, lined with wall board, ventilated with either galvanized steel or ridge ventilators, heated with stoves, and screened. Each contains a scullery and dietary kitchen, a linen closet, and a wash room with pail latrine. The 92-foot building is suitable for station hospitals. It has a capacity of 25 patients, with a floor space of 60 square feet per patient and an air space of 600 cubic feet per patient. In an emergency, by slight crowding, about 10 additional patients could be provided for in this type ward. The 184-foot building is suitable for general hospitals. In addition to the facilities provided in the smaller-type ward, it has a small room for a special-case ward, an office for the ward surgeon, and a bedpan room. It has a normal capacity of 50 patients, giving each patient 60 square feet of floor space and about 600 cubic feet of air space. In an emergency, by slight crowding, about 16 additional patients could be provided for in this type of ward.

28. Storage shed and horse shelter.—Figure 22 shows an open-sided storage shed suitable for use where commodities are placed under the roof by hand. Where vehicles are to be driven under the roof it would be necessary to increase the height of the roof by making the posts of proper height. This same type of building is suitable for a garage or automotive repair shelter. When combined with mangers and feed racks, this structure makes a satisfactory horse shelter. It may be sheathed on the sides if conditions make this necessary. Figure 23 shows an arrangement of this type of building with a center grain-storage room, feed racks, mangers, and covered picket line.

TABLE IV.—*Bill of materials for standard hospital ward*

92-foot ward building, type 1, normal capacity, 25 patients				184-foot ward building, type 2, normal capacity, 50 patients				Items
Number of pieces	Size	Length	Feet board measure	Number of pieces	Size	Length	Feet board measure	
48	2 by 4 inches.	12 feet	384	96	2 by 4 inches.	12 feet	768	Roof rafters.
98	2 by 4 inches.	16 feet	1,012	192	2 by 4 inches.	16 feet	2,048	Framing, subrafters and toilet box; partition studs also.
540	⅞ by 6 inches.	16 feet	4,320	982	⅞ by 6 inches.	16 feet	7,856	Sheathing, screen doors, drain board, shelves, and toilet box.
53	⅞ by 4 inches.	12 feet	212	88	⅞ by 4 inches.	12 feet	352	Rafter ties, knee braces, screen-door frames, shelves, supports, and toilet box.
12	⅞ by 3 inches.	10 feet	30	19	⅞ by 3 inches.	10 feet	48	Door meeting rails, window sills, and door bolts.
22	⅞ by 3 inches.	14 feet	77	42	⅞ by 3 inches.	14 feet	147	Sash frames.
2	⅞ by 8 inches.	16 feet	21	5	⅞ by 8 inches.	16 feet	53	Sash frames, corners.
2	⅞ by 2 inches.	10 feet	3	2	⅞ by 2 inches.	10 feet	3	Door-bolt guides.
6	⅞ by 1¾ inches.	14 feet	12	11	⅞ by 1¾ inches.	14 feet	23	Window filler strips.
42	⅞ by 1 inch.	14 feet		86	⅞ by 1 inch.	14 feet	100	Window guide strips and screen-door strips.
22	36 inches wide.	— linear feet.		46 square yards.	36 inches wide.	138 linear feet.	414 square feet.	Translucent material and 2½ ounces No. 2 tacks per 100 square feet.
24 rolls	32 inches wide.			47 rolls	32 inches wide.		5,076 square feet.	2-ply "Prepared Roofing" and nails, cement, and tin caps.
6		3 inches		6		3 inches		Hooks and screw eyes, for doors.
45 pounds	20 penny			100 pounds	20 penny	4 inches		Framing nails.
85 pounds	8 penny			180 pounds	8 penny	2½ inches		Sheathing nails.
3 pounds	4 penny			6 pounds	4 penny	1½ inches		Nails for strips.

TABLE IV.—*Bill of materials for standard hospital ward*—Continued

92-foot ward building, type 1, normal capacity, 25 patients				184-foot ward building, type 2, normal capacity, 50 patients				Items
Number of pieces	Size	Length	Feet board measure	Number of pieces	Size	Length	Feet board measure	
1	36 inches wide.	66 linear feet.	198 square feet.	1	36 inches wide.	138 linear feet.	414 square feet.	Screen wire for windows, 14 by 14 mesh.
1	26 inches wide.	28 linear feet.	61 square feet.	1	26 inches wide.	42 linear feet	91 square feet.	Screen wire for doors, 14 by 14 mesh.
1	26 inches wide.	12 linear feet.	26 square feet.	1	26 inches wide.	18 linear feet	39 square feet.	Cellar-window wire for doors, 2 by 2 mesh.
6	¼-inch diameter.	16 inches		6	¼-inch diameter.	16 inches		Coiled wire springs with screw eyes.
12	3½ inches	3½ inches		12	3½ inches	3½ inches		Fast joint butts with screws, for screen doors.
12		10 inches		12		10 inches		T hinges with 1½-inch screws, for exterior doors.
4		8 inches		4		8 inches		Strap hinges for toilet-box lids and necessary screws.
8 *ounces*	18 *gage*	½ *inch*		14 *ounces.*	18 gage	½ inch		Blind staples for screen wire, windows, and doors.
16	48 inches wide.	8 feet	512 square feet.	35	48 inches wide.	8 feet	1,120 square feet.	Wall board and 6 ounces 2-penny nails per 100 square feet.
1 roll	32 inches wide.	40½ feet	108 square feet.	1 roll	32 inches wide.	40½ feet	108 square feet.	Tar paper, 2-ply, for flyproofing toilets.
1	36 inches wide.	5 feet	15 square feet.	1	36 inches wide.	5 feet	15 square feet.	Galvanized steel sheet for toilet pan, No. 26 gauge.
2	¾ inch	16 feet		2	¾ inch	16 feet		Supply pipe with coupling, galvanized.
1	2 inches	16 feet		2	1½ inches	16 feet		Drainpipe, galvanized.
3	½ inch			3	½ inch			Elbows, galvanized.
				2	¾ by ½ inch.			Elbows, galvanized.

2	¾ by ¾ by ½ inch.			2	¾ by ½ inch.			Tees, galvanized.
2	½ inch			2	½ inch			Tees, galvanized.
3	½ inch			4	½ inch			Couplings, galvanized.
1	¾ inch			1	½ inch			Plug, galvanized.
				1	2 inches			Plug, galvanized.
2	½ inch			3	½ inch			Unions, galvanized.
1	18 inches wide.	30 inches		1	18 inches wide.	30 inches		Cast-iron kitchen sink with strainer, trap, and cold-water composition bibb.
2	18 inches wide.	24 inches		2	18 inches wide.	24 inches		Lavatories with fittings and cold-water bibbs.
6	4 by 4 inches.	4 inches		14	4 by 4 inches.	4 inches		Steel butts with 1½-inch screws, for room doors.
3	3¼ inches	4 inches		6	3¼ inches	4 inches		Rim locks with mineral knobs.
2	¾ inch	16 feet		2	¾ inch	16 feet		Supply pipe with coupling, galvanized.
2	2 inches	16 feet		2	2 inches	16 feet		Drainpipe, galvanized.
1	2 inches			1	1½ inches			Plug.
				4	1½ inches			Elbows.
2				2	1½ inches			Tees.
				1	2 by 1½ by 2 inches.			Tees.
				3	2 by 2 by 1½ inches.			Tees.
3	1⅛ by 2 feet 8 inches.	6 feet 8 inches.		7	1⅛ by 2 feet 8 inches.	6 feet 8 inches.		Doors, 5-panel, mill-made. (Cross panels.)

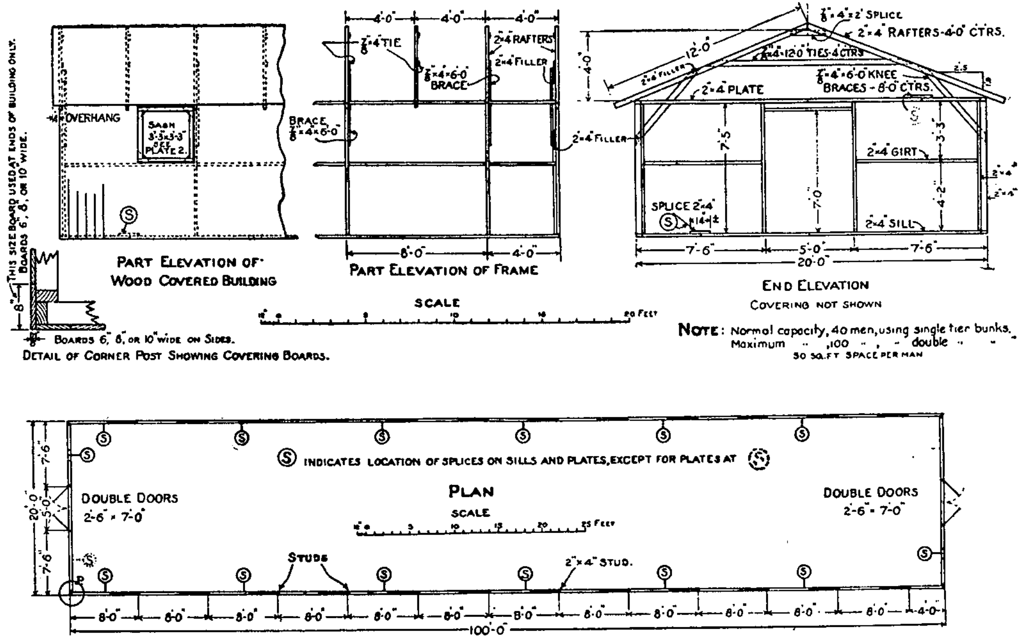
TABLE IV.—*Bill of materials for standard hospital ward*—Continued

CORRUGATED STEEL COVERED

92-foot ward building, type 1, normal capacity, 25 patients				184-foot ward building, type 2, normal capacity, 50 patients				Items
Number of pieces	Size	Length	Feet board measure	Number of pieces	Size	Length	Feet board measure	
94	26 inches wide.	8 feet	1,624 square feet.	186	26 inches wide.	8 feet	3,224 square feet.	Roofing, corrugated steel, No. 26 gauge, black steel.
94	26 inches wide.	6 feet	1,218 square feet.	186	26 inches wide.	6 feet	2,418 square feet.	Roofing, corrugated steel, No. 26 gauge, black steel.
100	2 by 4 inches.	8 feet	533	194	2 by 4 inches.	8 feet	1,035	Purlins and braces.
13	⅞ by 4 inches.	8 feet	35	25	⅞ by 4 inches.	8 feet	67	Purlin splice plates and overhang brackets.
100	26 inches wide.	8 feet	1,728 square feet.	169	26 inches wide.	8 feet	2,929 square feet.	Sides and ends, corrugated steel, No. 26 gauge, black steel.
22	26 inches wide.	5 feet	238 square feet.	43	26 inches wide.	5 feet	466 square feet.	Sides, corrugated steel, No. 26 gauge, black steel.
4 pounds	3⁄16 - inch diameter.	⅜ inch		8 pounds	3⁄16 - inch diameter.	⅜ inch		Rivets, *for* fastening corrugated steel sheets.
5	18-inch diameter.			9	18-inch diameter.			Ventilators, galvanized steel, "economy type."
11 pounds	No. 10	1½ inches		18 pounds	No. 10	1½ inches		Nails, barbed, *for* corrugated steel sheets.

WOOD-SHEATHED AND FELT-COVERED

19 rolls	32 inches wide.	770 linear feet.	2,048 square feet.	39 rolls	32 inches wide.	1,580 linear feet.	4,212 square feet.	1-ply "Prepared Roofing," sides, ends, and doors.
5 bundles	¼ by 1½ inches.	4 feet		8 bundles.	¼ by 1½ inches.	4 feet		Lath for sides, ends, and doors, and 12 ounces 2-penny nails per bundle.
5 rolls	32 inches wide.	203 linear feet.	540 square feet.	9 rolls	32 inches wide.	365 linear feet.	972 square feet.	2-ply "Prepared Roofing," with nails, tin caps, and cement, for louver.
54	⅞ by 6 inches.	16 feet	432	112	⅞ by 6 inches.	16 feet	896	Sheathing for louver roof.
22	2 by 4 inches.	10 feet	147	46	2 by 4 inches.	10 feet	307	Framing for louver.
30	⅞ by 3 inches.	12 feet	90	62	⅞ by 3 inches.	12 feet	186	Baffle boards and small brace blocks for louver.
1	8 inches wide.	180 linear feet.	199 square feet.	1	8 inches wide.	356 linear feet.	237 square feet.	Screen wire, black, and 8 ounces of ½-inch blind staples per 100 linear feet.



NOTE: Normal capacity, 40 men, using single tier bunks.
Maximum " ,100 " , " double " "
50 SQ.FT SPACE PER MAN

Ⓢ INDICATES LOCATION OF SPLICES ON SILLS AND PLATES, EXCEPT FOR PLATES AT Ⓢ

FIGURE 6.—Standard 20 by 100 foot barrack

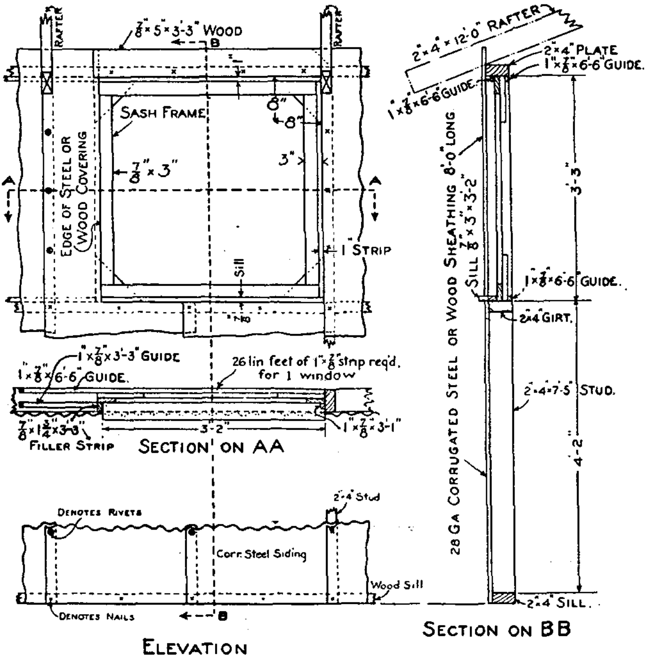


FIGURE 7.—Details of window sash

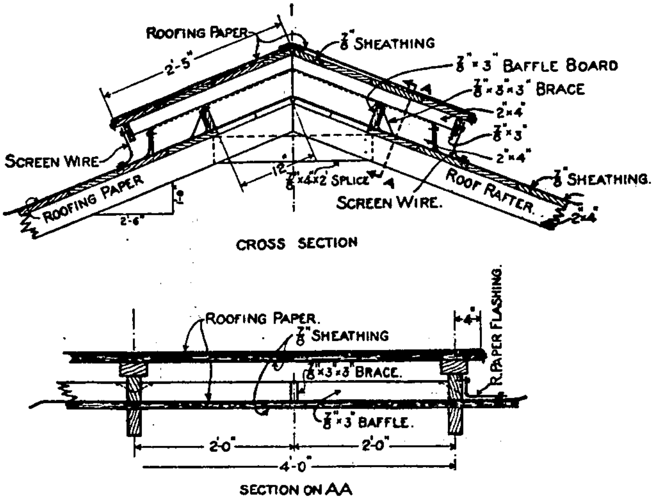
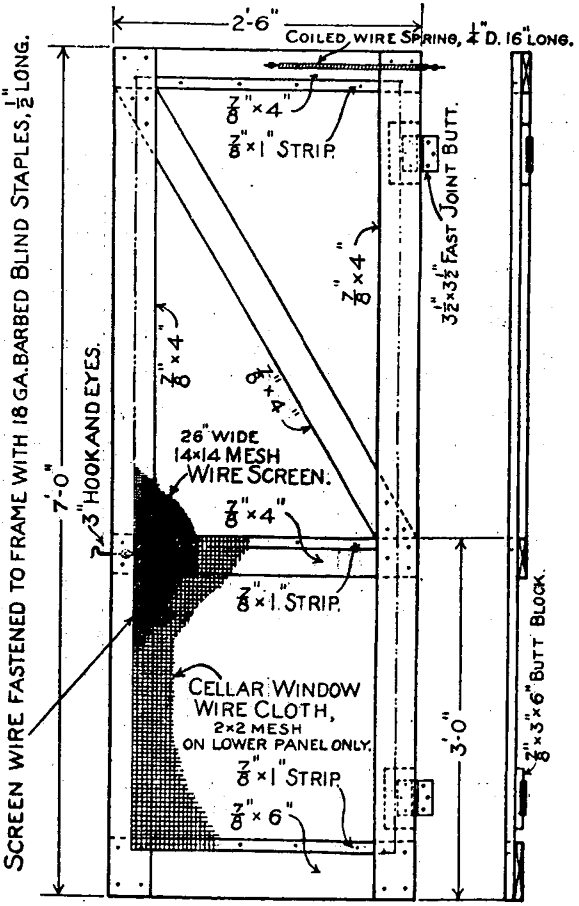


FIGURE 8.—Ridge ventilator



Use 8 D. Wire Nails, and Clinch
Right and Left Handed

Figure 9.—Screen door

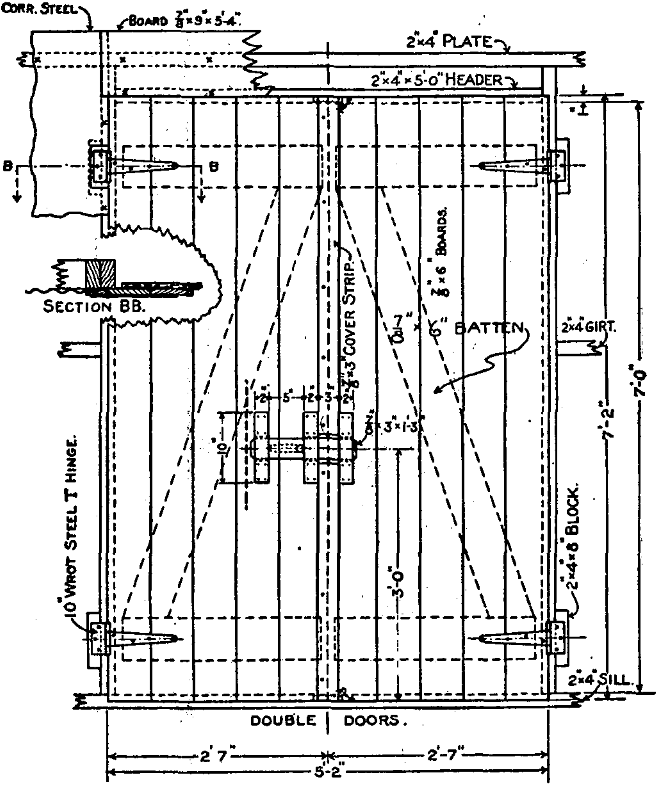
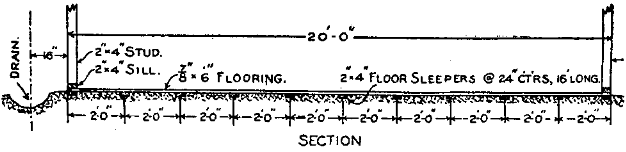


FIGURE 10.—Batten door

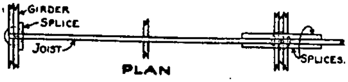


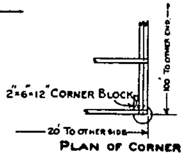
TYPE X FLOOR

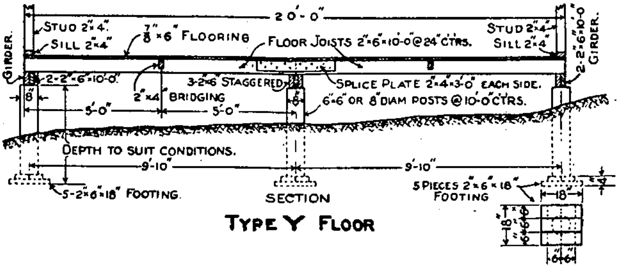
	BILL OF MATERIAL								
	100 FT. BUILDINGS				184 FT. BUILDINGS.				ITEMS
	No. Pcs.	Size	L'gth	Ft. B.M.	No. Pcs.	Size	L'gth	Ft. B.M.	
Type X Fl.	263	7/8"×6"	16'	2,104	483	7/8"×6"	16'	3,864	FLOORING.
	72	2"×4"	16'	768	133	2"×4"	16'	1,419	SLEEPERS
	42 lbs	8 d	2½"		77 lbs	8 d	2½"		NAILS
	4 lbs	20 d.	4"		7 lbs	20 d	4"		NAILS
Type Y Floor.	263	7/8"×6"	16'	2,104	483	7/8"×6"	16'	3,864	FLOORING
	107	2"×6"	10'	1,070	190	2"×6"	10'	1910	JOISTS
	21	2"×4"	10'	140	38	2"×4"	10'	253	BRIDGING
	27	2"×4"	12'	216	48	2"×4"	12'	384	SPLICES
	3	2"×6"	10'	30	6	2"×6"	10'	60	SPLICES
	73	2"×6"	10'	730	136	2"×6"	10'	1360	GIRDERS
	35	6"×6" or 8" ⌀	To suit cond.		62	6"×6" or 8" ⌀	To suit cond.		POSTS
	21	2"×6"	12'	252	38	2"×6"	12'	456	FOOTING
	6	2"×6"	1'	6	6	2"×6"	1'	6	CORNER BLOCKS.
	39 lbs	8 d	2½"		70 lbs	8 d	2½"		NAILS
	95 lbs	20 d	4"		172 lbs	20 d	4"		NAILS

LABOR

	100 FT. BUILDINGS.	184 FT. BUILDINGS
TYPE X	90 MAN HOURS.	318 MAN HOURS.
TYPE Y	270 " "	579 " "

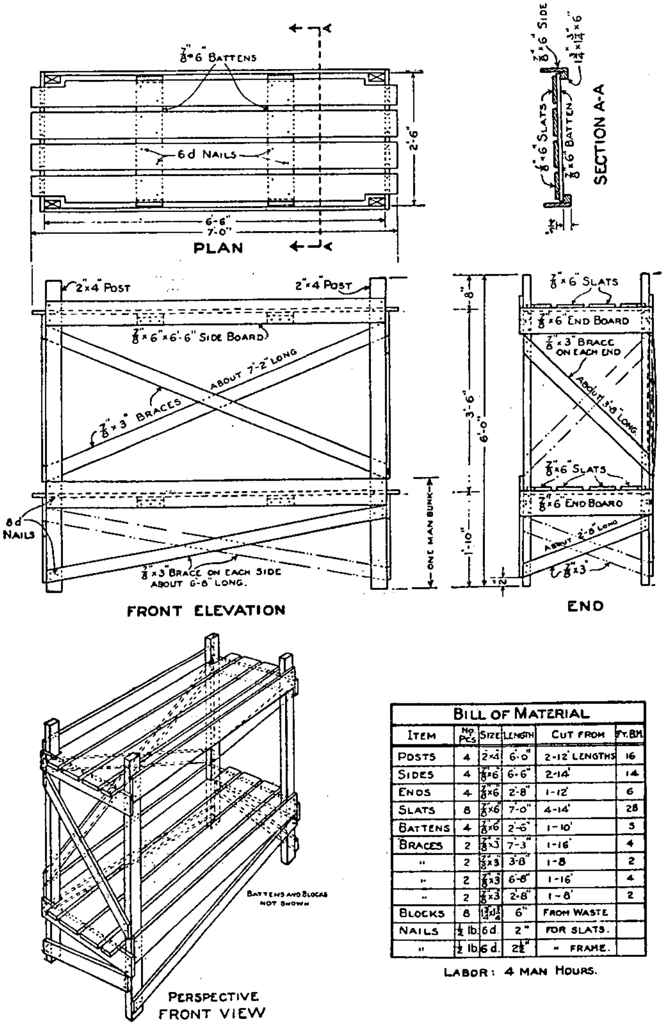






TYPE Y FLOOR

FIGURE 11.—Floors

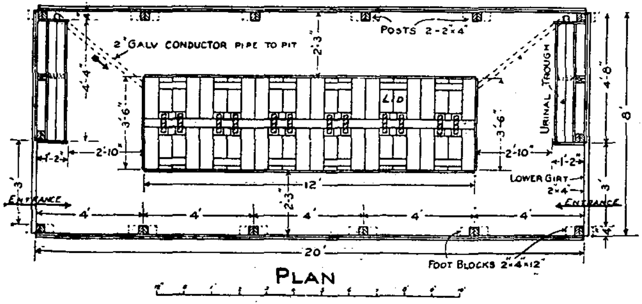


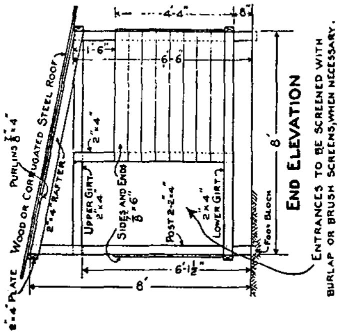
BILL OF MATERIAL

ITEM	NO. PCS	SIZE	LENGTH	CUT FROM	FT. B.M.
POSTS	4	2×4	6'-0"	2-12' LENGTHS	16
SIDES	4	7/8"×6"	6'-6"	2-14'	14
ENDS	4	7/8"×6"	2'-8"	1-12'	6
SLATS	8	7/8"×6"	7'-0"	4-14'	28
BATTENS	4	7/8"×6"	2'-6"	1-10'	5
BRACES	2	7/8"×3"	7'-3"	1-16'	4
"	2	7/8"×3"	3'-8"	1-8	2
"	2	7/8"×3"	6'-8"	1-16'	4
"	2	7/8"×3"	2'-8"	1-8'	2
BLOCKS	8	1 3/4×1 3/4	6"	FROM WASTE	
NAILS	1/2 lb.	6d.	2"	FOR SLATS.	
"	1/2 lb.	6d.	2 1/2"	" FRAME.	

LABOR: 4 MAN HOURS.

FIGURE 12.—Bunk for one or two men

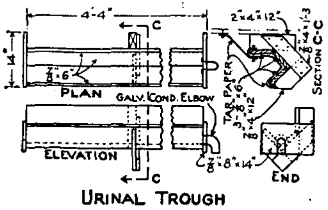




LENGTHS OF SHED
BASED ON 20 MEN PER HOLE.

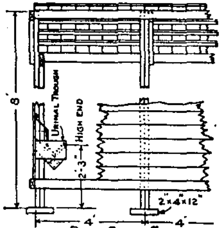
No. HOLES.	No. MEN.	LENGTH.
4	80	12'-0"
8	160	16'-0"
12	240	20'-0"

NOTE:
FOR TEMPORARY LATRINE WITHOUT ROOF COVER, USE SINGLE 2"×4" STUDDING AND COVER WITH LATRINE SCREENS OR BURLAP.



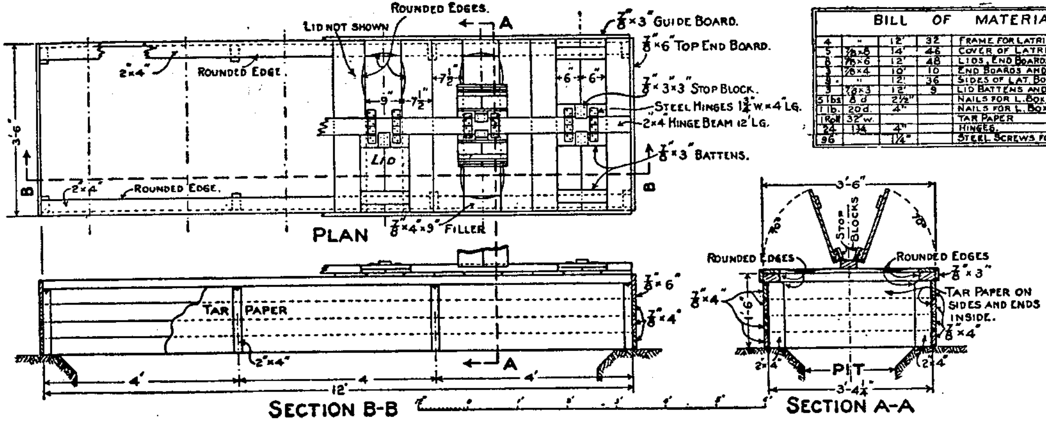
BILL OF MATERIAL

STANDARD TYPE SHELTER WITH ROOF				
No. Pcs.	SIZE	LENGTH	Ft. B.M.	PURPOSE
30	2"×4"	8'	160'	STUDDING AND FOOT BLOCKS.
6	"		32'	GIRTS ON SIDES.
4	"	8'	22	GIRTS ON ENDS.
6	"	10'	40'	ROOF RAFTERS.
16	7/8"×6"	12'	96'	SIDING
16	"	8	64'	SIDING.
50	"	10'		END BOARDS AND ROOFING.
3	7/8"×4"	12'	12'	PURLINS.
3	"	8'	8'	PURLINS.
42	7/8"×3"	10'	105	ROOF JOINT STRIPS.
6 lbs.	20 d	4"		NAILS FOR FRAMING.
12 lbs.	8 d	2½"		NAILS FOR SIDING AND ROOF.
EXTRA MATERIAL IF METAL ROOF IS USED.				
11	26"	9'		CORRUGATED STEEL SHEETS.
1 lb.	4 d	1½"		BARBED ROOFING NAILS.



PART FRONT ELEVATION SHOWING URINAL TROUGH.

FIGURE 13.—Latrine



BILL OF MATERIAL

4	"	12'	32	FRAME FOR LATRINE BOX.
5	7/8×8	14'	46	COVER OF LATRINE BOX.
8	7/8×6	12'	48	LIDS, END BOARDS.
3	7/8×4	10'	10	END BOARDS AND FILLERS.
9	"	12'	36	SIDES OF LAT. BOX
3	7/8×3	12'	9	LID BATTENS AND STOP BLOCKS.
5 lbs	8 d	2½"		NAILS FOR L. BOX
1 lb.	20d.	4"		NAILS FOR L. BOX FRAME.
1 Roll	32" w.			TAR PAPER
24	1 3/4	4"		HINGES.
96		1¼"		STEEL SCREWS FOR HINGES.

FIGURE 14.—Latrine box

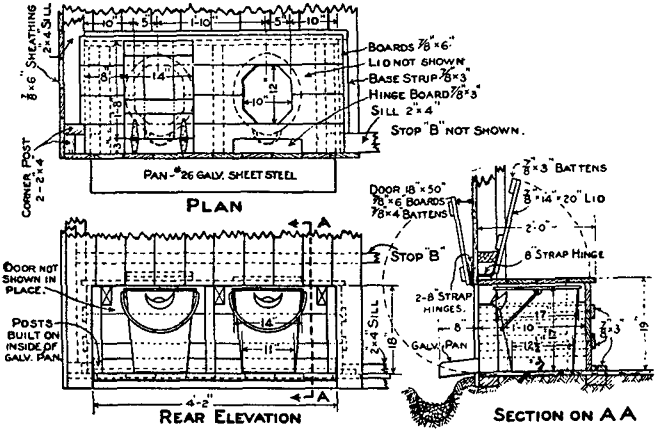
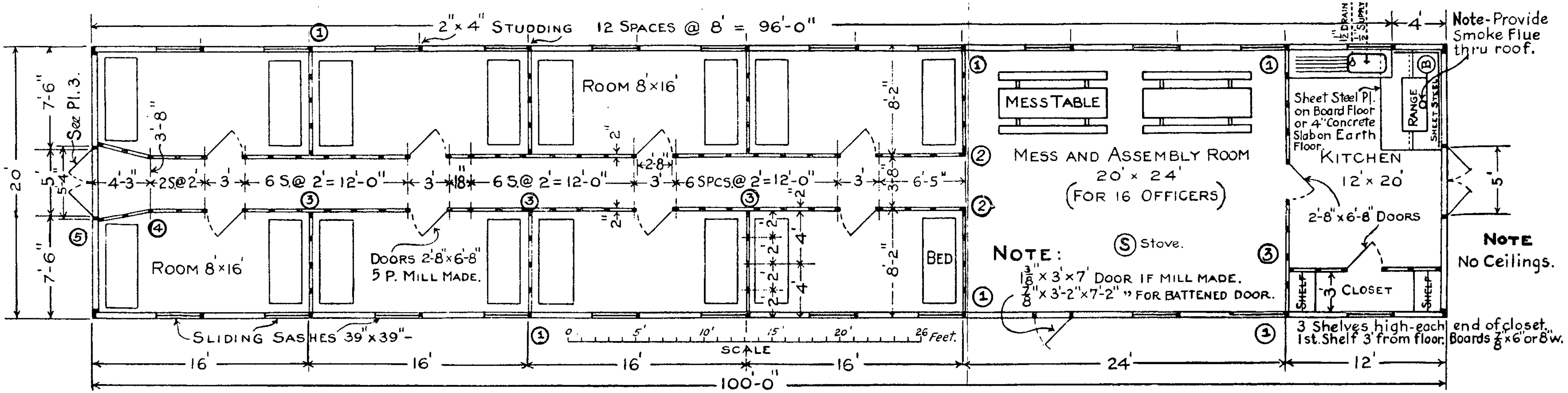
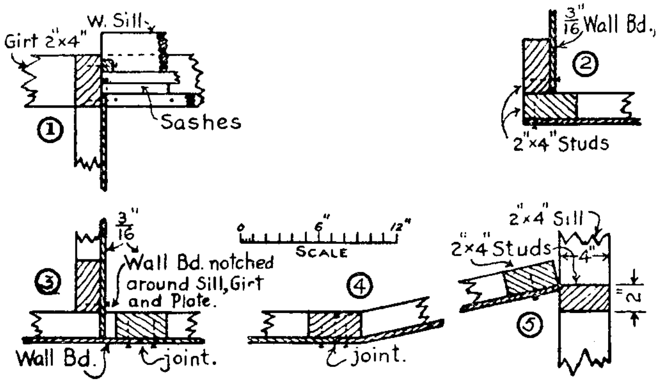


Figure 15.—Pail latrine



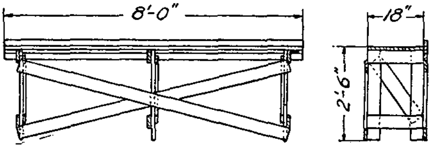


Details of Partition Work

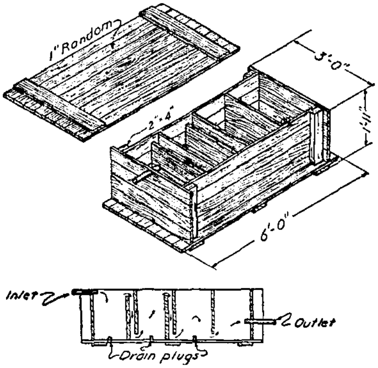
Material for Partition Work Only
Material for St'd. 100 Ft. Bldg

Nº Pcs.	Size	Length	Ft. BM.	Items
102	2"×4"	16'	1088 982	Studs, Girts, Sills, Plates, Ties and Stakes.
9	2"×6"	16'	144 128	Foundation Blocks. 12" and 18" Lengths.
59	48" W.	10'		Wall Board Sheets, Fibre 3/16" thick.
7	2 d.	1"		Nails, Large Headed for Wall Board. 8" Spacing.
10	1⅜×2-8	6'-8"		Doors, 5 Panels, W. Pine-Mill Made.
10	3¼"	4"		Locks, Rim; with Pottery knobs, Strikes, etc.
20	4"×4"	4"		Hinges for Doors, Steel Fast Joint with Screws.
15	⅞×⅞"	16'	20 19	Door Stop Strips.
3	4 d.	1½"		Nails for Door Stop Strips.
16	10 d.	3"		Nails for Partition Framing.
3	⅞×6 or 8"	12'	24 24	Shelves, Kitchen Closet.
3	⅞"×8"	8'	16 16	Drain Board for Sink.
1	18"	30"		Sink, Cast Iron. with Strainer and Trap.
1	½"	12'		C.W. Supply Pipe, W.I. Galv.
1	½"			Bibb, Plain for C.W. Supply. Comp.
1	1½"	12'		Drain Pipe - Black W.I.
3	28" W.	84"		Sheet Steel, Galv. for behind Range.
2	28" W.	84"		Sheet Steel Hearth. -
1	4"×4-6	7'	11 Cu. Ft.	Concrete Hearth Slab.

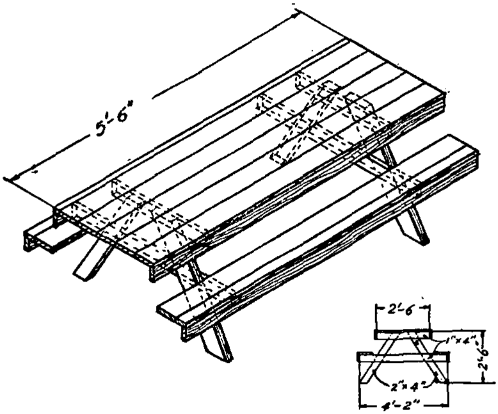
FIGURE 16.—Standard barrack adapted for quarters and mess



SERVING TABLE

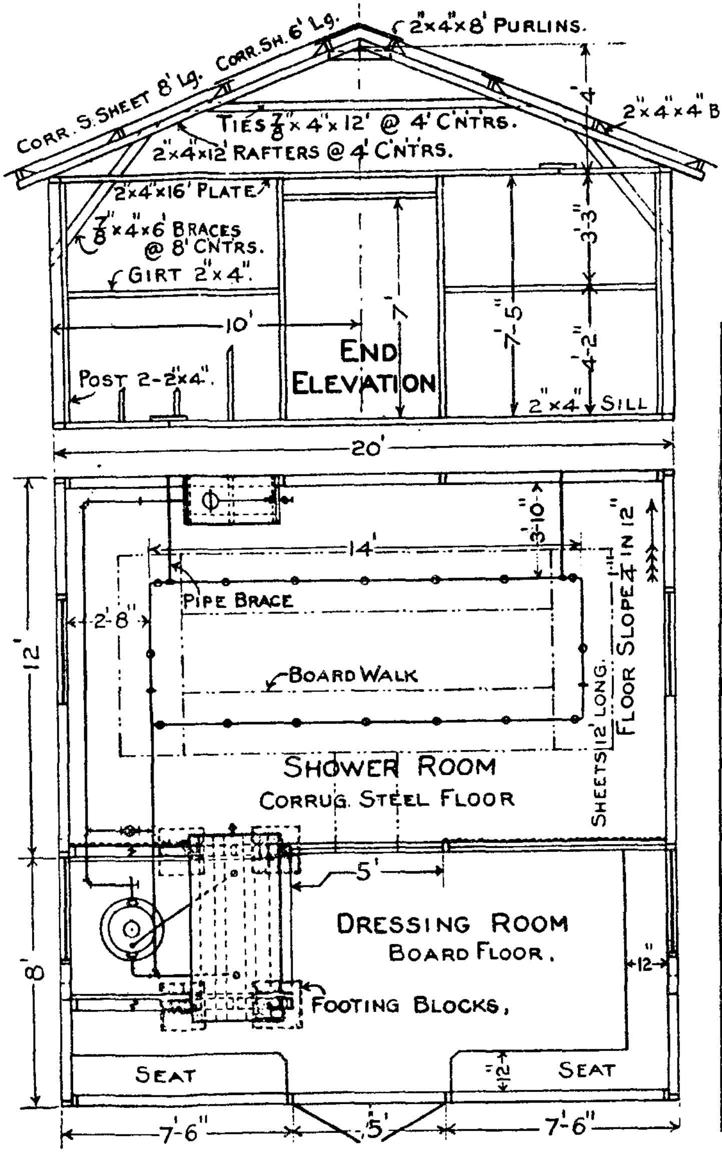


GREASE TRAP



MESS TABLE

Figure 17.—Mess hall accessories



BILL OF MATERIAL				
NO. PCS.	SIZE.	LENGTH	FT. B.M.	ITEMS.
75	2"×4"	16'	800	SILLS, GIRTS, STUDS, PLATES, HEADERS, SHOWER ASSEMB. BEAMS, HANGERS, PURLINS SPLICE BLOCKS, CORNER POSTS, SLEEPERS JOISTS, SEAT SUPPORTS & FILLERS UNDER CORR. ST.
18	2"×4"	12'	144	ROOF RAFTERS, PARTITION DIAGONALS, SMALL TANK BRACES, BLOCKS FOR DOORS.
4	2"×6"	8'	32	FOOTING BLOCKS.
36	⅞"×8"	10'	240	FLOOR BOARDS.
24	⅞"×6"	8'	·96	DOORS & SEATS.
14	⅞"×4"	12'	56	FLOOR SILL IN SHOWER ROOM, TIE BEAMS FOR ROOF RAFTERS & KNEE BRACES.
6	⅞×3"	12'	18	WINDOW SASH; COVER STRIP AND BOLT FOR DOORS.
2	⅞"×2"	10'	3⅓	PROTECTION STRIP FOR COVERING SHARP ENDS OF CORR. STEEL FL'R SHEETS IN SHOWER ROOM.
2	⅞"×1¾	8'	2⅓	WINDOW FILLER STRIPS,
15	⅞"×1"	8'	10	WINDOW GUIDE STRIPS.
4	6"×6"	TO SUIT C.		POSTS. SEE NOTE. 8"Ø MAY BE USED.
11	26"W.	12'	286 □'	CORR. SHEETS FOR FLOOR, SHOWER RM.
56	"	8'	968 □'	" " FOR SIDES, ENDS, & PARTITION.
22	"	8'	381 □'	" " " ROOF.
22	"	6'	286 □'	" " " " .
2	28"W	7'	33 □'	GALV. STEEL SHEETS–UNDER HEATER #26
14	20d.	4"		NAILS, FRAMING.
10	8d.	2½"		NAILS, FOR ⅞" MATERIAL.
4	#10	1½"		NAILS, BARBED ROOFING.
1	4d.	1½"		NAILS, FOR STRIPS.
4		10"		T-HINGES WITH 1½" SCREWS FOR DOOR.
1 LB.	3/16"	⅜"		RIVETS FOR CORR. STEEL SHEETS.
1	⅞"×3"	16'	4' B.M.	WINDOW SILLS.
4		3"		SCREW HOOKS & EYES FOR DOORS.
				✱ THE ABOVE CORR. SHEETS #26 GA.
25	⅞×4	12'	100	BOARDS FOR BOARD WALK.

FIGURE 18.—Bathhouse

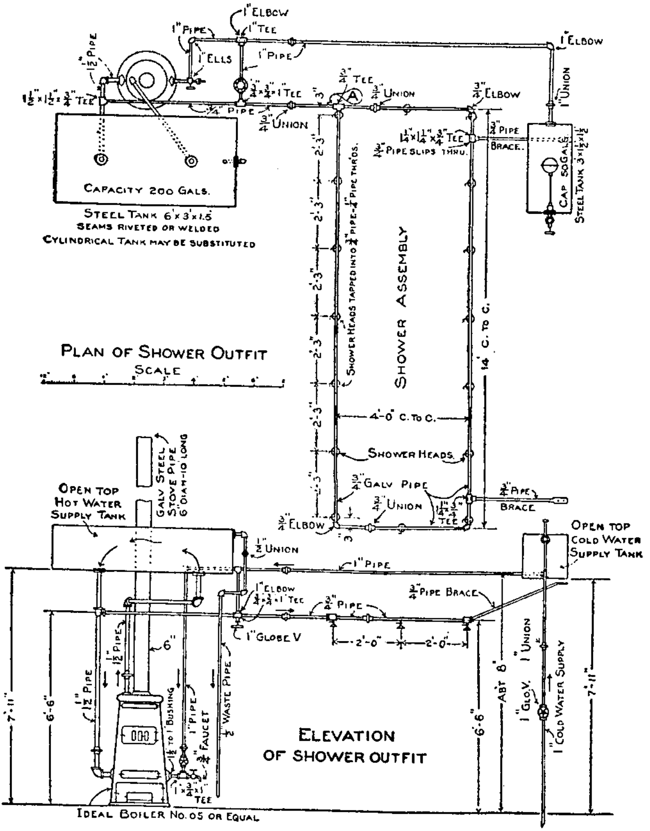
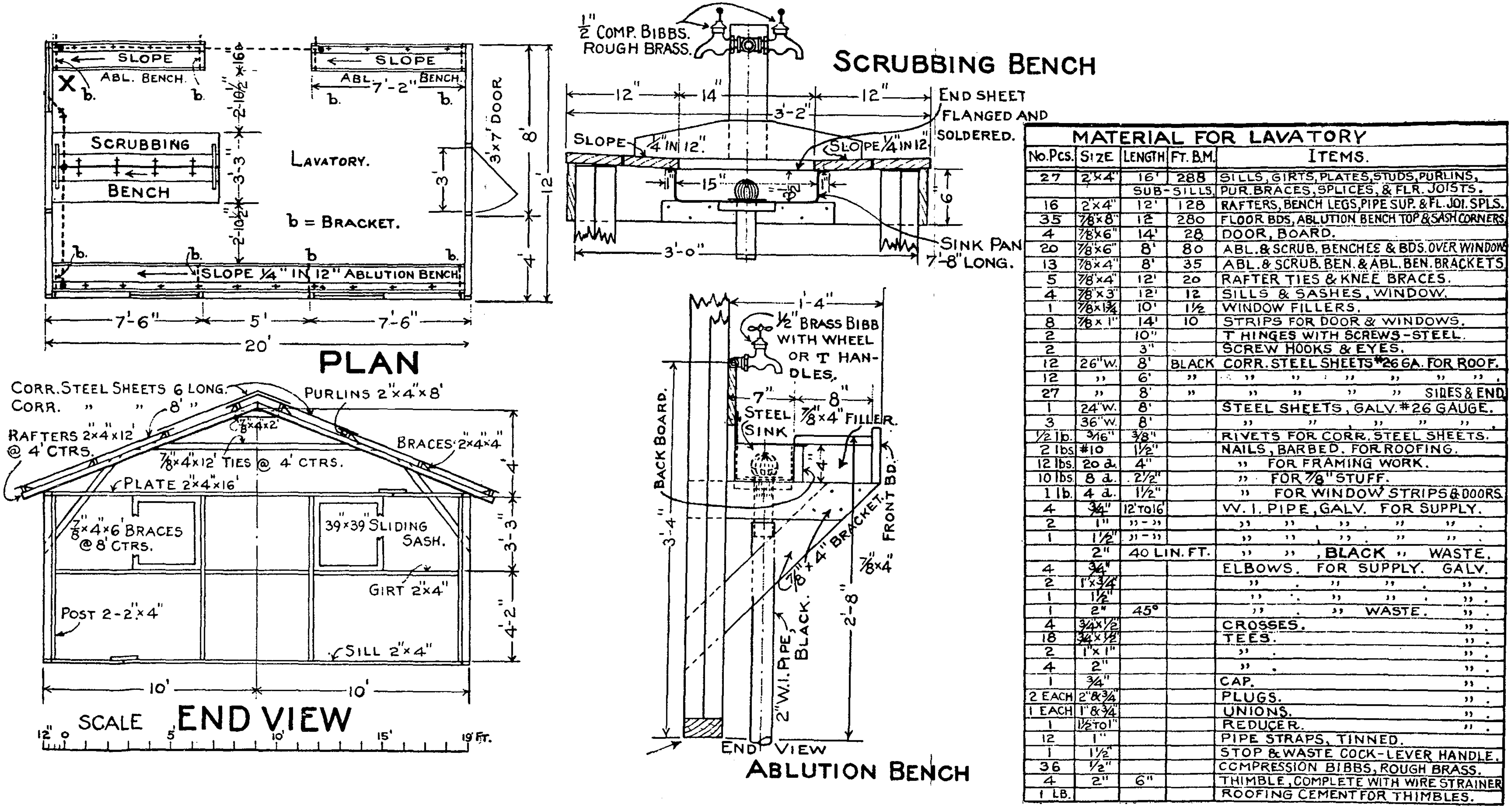


FIGURE 19.—Shower outfit



MATERIAL FOR LAVATORY

No. Pcs.	Size	Length	Ft. B.M.	Items.
27	2"x4"	16'	288	SILLS, GIRTS, PLATES, STUDS, PURLINS,
		SUB-SILLS,		PUR. BRACES, SPLICES, & FLR. JOISTS.
16	2"x4"	12'	128	RAFTERS, BENCH LEGS, PIPE SUP. & FL. JOI. SPLS.
35	7/8"x8"	12'	280	FLOOR BDS, ABLUTION BENCH TOP & SASH CORNERS.
4	7/8"x6"	14'	28	DOOR, BOARD.
20	7/8"x6"	8'	80	ABL. & SCRUB. BENCHES & BDS. OVER WINDOWS
13	7/8"x4"	8'	35	ABL. & SCRUB. BEN. & ABL. BEN. BRACKETS.
5	7/8"x4"	12'	20	RAFTER TIES & KNEE BRACES.
4	7/8"x3"	12'	12	SILLS & SASHES, WINDOW.
1	7/8"x1¾	10'	1½	WINDOW FILLERS.
8	7/8"x1"	14'	10	STRIPS FOR DOOR & WINDOWS.
2		10"		T HINGES WITH SCREWS-STEEL.
2		3"		SCREW HOOKS & EYES.
12	26"W.	8'	BLACK	CORR. STEEL SHEETS #26 GA. FOR ROOF.
12	"	6'	"	" " " " " " .
27	"	8'	"	" " " " SIDES & END.
1	24"W.	8'		STEEL SHEETS, GALV. #26 GAUGE.
3	36"W.	8'		" " , " " " .
½ lb.	3/16"	3/8"		RIVETS FOR CORR. STEEL SHEETS.
2 lbs.	#10	1½"		NAILS, BARBED. FOR ROOFING.
12 lbs.	20 d.	4"		" FOR FRAMING WORK.
10 lbs.	8 d.	2½"		" FOR 7/8" STUFF.
1 lb.	4 d.	1½"		" FOR WINDOW STRIPS & DOORS.
4	¾"	12' TO 16'		W. I. PIPE, GALV. FOR SUPPLY.
2	1"	" - "		" " , " . " .
1	1½"	" - "		" " , " . " " .
	2"	40 LIN. FT.		" " , BLACK " WASTE.
4	¾"			ELBOWS. FOR SUPPLY. GALV.
2	1"x¾"			" . " " . " .
1	1½"			" . " " . " .
1	2"	45°		" . " WASTE. " .
4	¾"x½"			CROSSES. " .
18	¾"x½"			TEES. " .
2	1"x1"			" . " .
4	2"			" . " .
1	¾"			CAP. " .
2 EACH	2" & ¾"			PLUGS. " .
1 EACH	1" & ¾"			UNIONS. " .
1	1½" TO 1"			REDUCER. " .
12	1"			PIPE STRAPS, TINNED.
1	1½"			STOP & WASTE COCK-LEVER HANDLE.
36	½"			COMPRESSION BIBBS, ROUGH BRASS.
4	2"	6"		THIMBLE, COMPLETE WITH WIRE STRAINER
1 LB.				ROOFING CEMENT FOR THIMBLES.

FIGURE 20.—Lavatory with benches

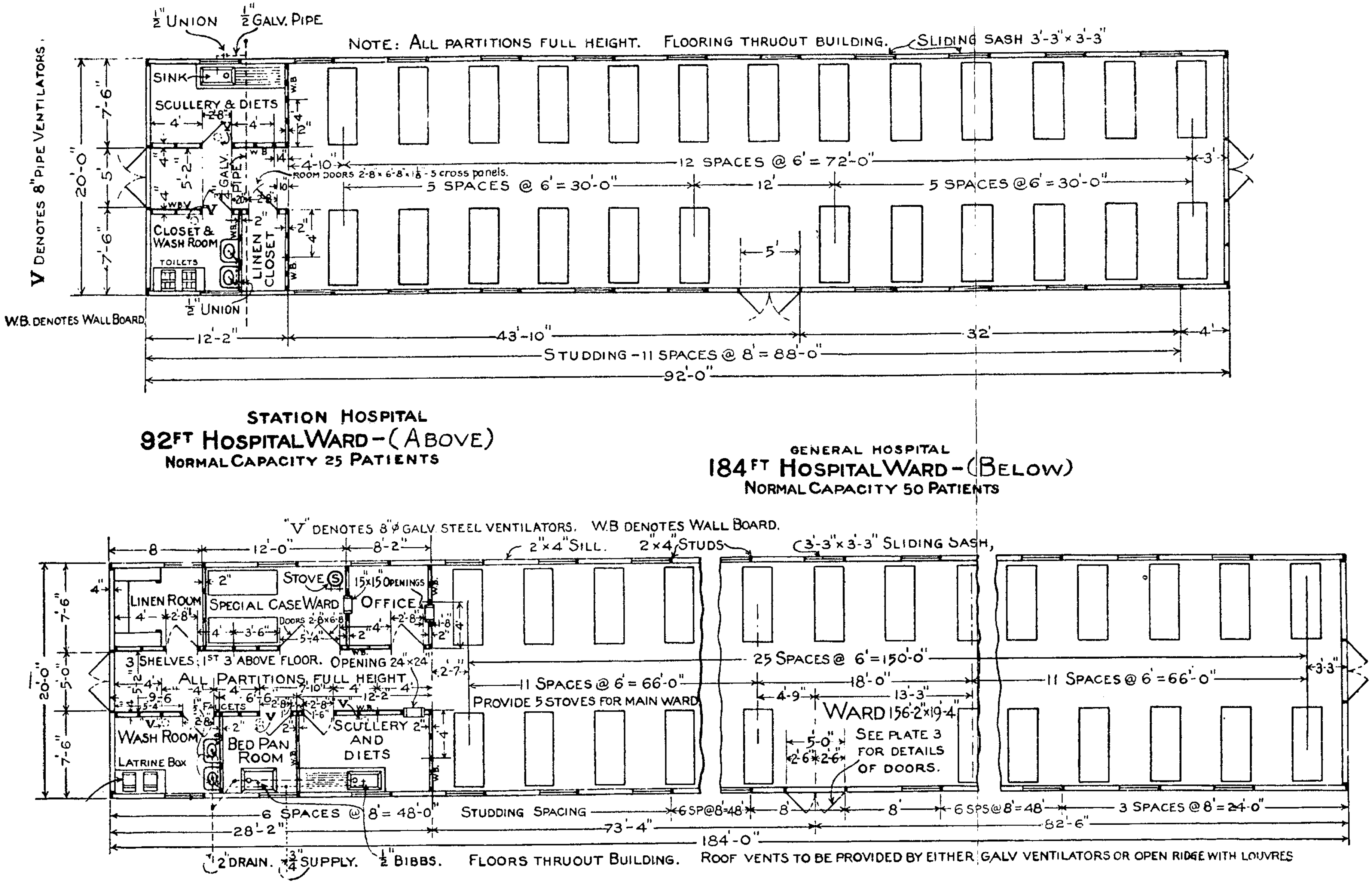


FIGURE 21.—Hospital wards

66590°—32. (Follows p. 41.) No. 2

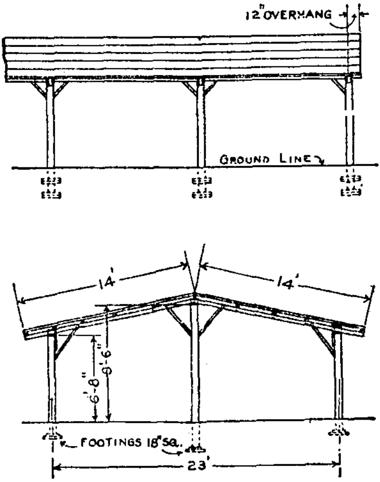


FIGURE 22.—Open-sided storage sheded

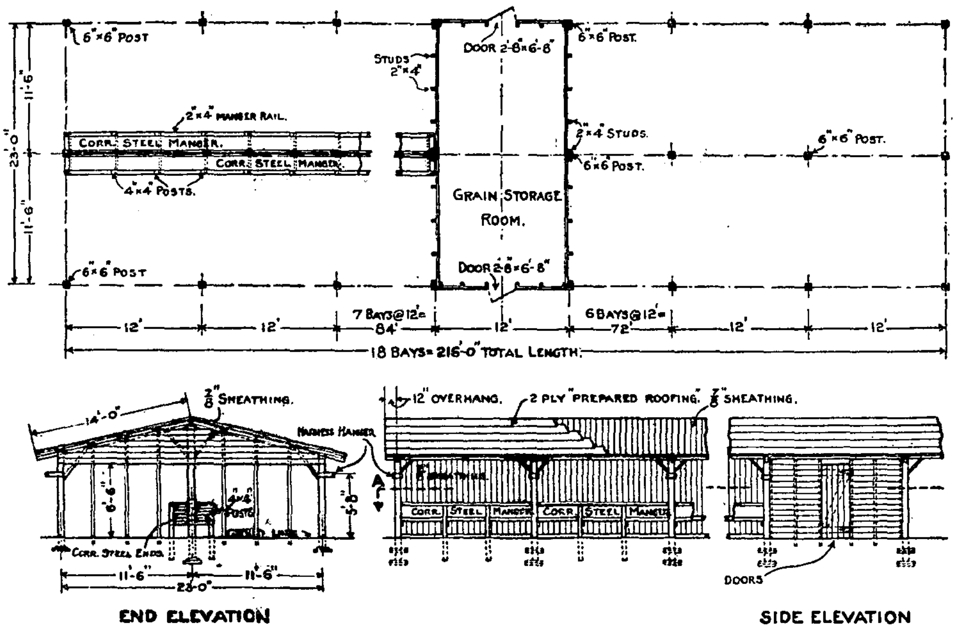


FIGURE 23.—Horse shelter

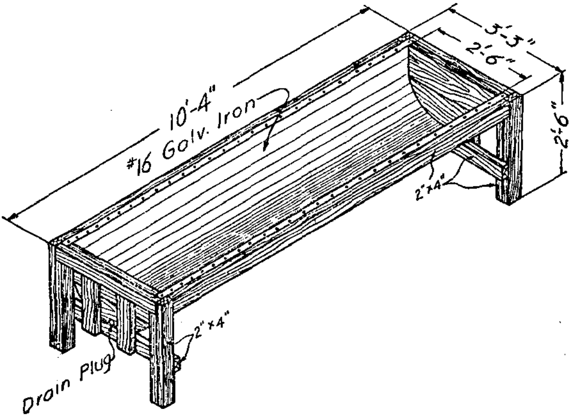


FIGURE 24.—Water trough

SECTION V

CONSTRUCTION METHODS

29. Overhead organization.—The construction of a large project such as a cantonment or supply depot requires an adequate overhead organization. The subdivisions which should be considered in the organization are—

a. Administration.—Handling personnel, correspondence, contracts, project plans and reports, and coordination.

b. Buildings.—Requirements, design, layout and technical supervision of construction.

c. Surveys.—Preparation of maps, giving lines and grades to construction troops.

d. Roads and railroads.—Layout and technical supervision.

e. Water supply.—Requirements, design and technical supervision.

f. Drafting and reproduction.—Preparation of working drawings and blue prints.

g. Supply.—Preparation of requisitions, purchases, and follow-up of supply and finance.

h. Personnel.—Troop and civilian labor.

30. Steps in the development of the project.—The first step in the development of the project is the preliminary reconnaissance and selection of the site; next comes the procurement or making of a detailed topographic survey of the site and the preparation of a map; then the detailed layout of the project. Type plans are a guide only, and in each case the layout must be adapted to local conditions. The general layout of buildings and grounds having been decided upon, the outside utilities are laid out, including roads, water supply, and electric lighting if used. The construction follows the general principles laid down in Section I, with particular reference to making those portions of the project immediately needed available at the earliest moment.

31. Supply.—Occasions when local material will be adequate for the construction of a large project are extremely rare. Supplies must, in general, be procured and transported to the site of the construction. In this connection, consideration should be given to the construction of emergency roads. (See Chs. 1 and 3, Part One.) It may be advisable to erect a sawmill to utilize existing standing timber. At least one woodworking shop should be erected with machinery for the cutting of dimension lumber and special pieces in quantities.

32. Layouts of camps and cantonments.—Take advantage of all local facilities to avoid unnecessary construction. If tents are likely to be changed to barracks, space allowance should be sufficient to permit of the change. Any existing roads should be taken advantage of in order to avoid road construction. Kitchens, warehouses, and stables should be accessible by roads. Stables and incinerators should be located with respect to prevailing winds when possible to minimize annoyance from wind-borne odors. A compact layout is preferable to a straggling one and facilitates administration.

33. Erection of buildings.—*a.* By adopting a form of organization wherein successive crews especially trained in one type of work follow each other over the job, one laying sills, one grading, one framing timber, etc., a high degree of skill is acquired with the result that the construction proceeds rapidly. The actual organization for different kinds of building construction will vary, but the general principles are illustrated by the following procedure in the erection of a standard 20 by 100 foot barrack (see fig. 6). The location of the building is given by the surveyor who establishes corner stakes. The cut lumber, nails, roofing and other materials are delivered to the site. The side frames of the building, including the sheathing, are completely assembled on the ground within the building rectangle by spiking the sills and plates to the studs, and applying the side covering. When completely assembled, the entire side of the building is raised outward to a vertical position and temporarily held in place by braces. The end frames are assembled on the ground outside the building rectangle and are raised into position and spiked to the sides of the building previously erected. The sheathing is applied to the ends after they have been erected. The rafters are assembled on the ground with the rafter ties spiked in place. The rafters then are passed up to men working on the plate, who secure them in their proper places and apply the knee braces. As the erection of the rafters progresses, temporary tie pieces are used to hold them in their places until the roof covering has been applied. Where roofs are of wood and roofing paper, the roof boards should be completely applied before attempting to apply the roofing paper. If wooden floors are used, the floor should be constructed first. The sides can then be assembled on the floor and erected as described above. Doors and window sash can be made up in quantity at the mill and delivered to the building site for hanging. A suitable disposition of personnel for the foregoing operations is—

(1) *Piers and sills.*—One squad (if floors are used).
(2) *Assembly of side frames.*—Two squads.
(3) *Erection of side frames.*—All available men.
(4) *Assembly of end frames.*—Four men at each end.
(5) *Placing rafters and knee braces.*—One squad.
(6) *Applying sheathing.*—Two squads.
(7) *Applying roof boards.*—Two squads.
(8) *Applying composition roofing paper.*—Two squads.
(9) *Hanging doors and windows.*—One squad.

b. The millwork required for the erection of buildings of this type in quantity is shown below:

(1) *Beveling rafters.*—One operator and four helpers.
(2) *Assembling rafter units.*—Two men.
(3) *Cutting and assembling sash.*—One man.
(4) *Cutting and assembling doors.*—One man.
(5) *Cutting sheathing boards.*—One man and four helpers.
(6) *Cutting studs and girts.*—One man and four helpers.

CHAPTER 2

WATER SUPPLY

SECTION I

GENERAL PRINCIPLES

34. Character of water supply work.—The amount and character of the water-supply work that can be carried on in the field vary according to the conditions of the campaign, the mobility of the forces, and the hydrology and transportation facilities of the area occupied. Water must be provided in any area either from surface flow, from subterranean sources, by transportation from a distance, by pipe line, or from existing developments.

35. Sources of water supply.—*a. Surface waters.*—(1) Surface waters constitute the most available source of water supply. In the theater of operations, surface waters usually require purification, but many cases exist in the United States where drainage areas have been protected from pollution and impounding reservoirs supply large cities without purification.

(2) The waters of lakes and ponds are generally good unless polluted from habitations on their shores or tributaries. In these waters, sunlight, aeration and the settling of sediment have a considerable influence on the destruction of bacteria. In small ponds there is less dilution of the impurities washed into them. Decaying leaves may accumulate and with the growth of water organisms give the water a dark color and noticeable taste. Such color does not make the water dangerous nor does the green slime which may collect on the surface, but both are objectionable and may mask dangerous conditions. Bubbles of gas

which rise to the surface when the bottom is disturbed are due to accumulations of decayed vegetable matter and silt. Some small ponds, however, fed from unpolluted springs, are excellent sources of supply. Ponds used by animals should not be used for camp supplies.

(3) Streams in thinly settled regions are usually free from contamination although a tanbark plant or sawmill may lessen their desirability. Acid drainage from mines, particularly coal mines, is always objectionable, but the most common source of pollution is the entrance of sewage and industrial refuse from cities and towns. Although streams become purified naturally to some extent, the use of such water is a common source of typhoid and other intestinal diseases.

b. Springs.—(1) Springs, under favorable conditions, are an ideal source of supply. When coming from considerable depths in the rock or through sand and gravel they are usually free from pollution except where buildings are situated on the hillsides above them or surface waters are allowed to enter. The minerals contained are usually harmless.

(2) A gravity spring is one which flows from loose materials or open passages under the action of gravity, usually where an outcrop of impervious material forces the ground water flow to the surface. They are often formed by a ledge underlying saturated soil or by beds of sedimentary rocks of different porosity. They often flow from passages in glacial deposits or from solution channels in soluble rock. In limestone the passages may be miles in length. If the water is clear, it is usually of good quality, but if found to be muddy after storms, it is liable to pollution from surface drainage.

(3) An artesian spring is one where the waters are confined between impervious layers under hydrostatic pressure. Such springs often flow through faults or fissures and carry considerable amounts of water.

(4) In a seepage spring, the water seeps from sand or gravel deposits. It may emerge above an underlying impervious bed, but usually occurs where valleys cut into water-bearing deposits. They are likely to be found in small swales cut back into a slope, the flow of water being the primary cause of the swale and the swale secondarily tending to concentrate the flow. Areas of diffused seepage may develop into springs by such a process. They are usually marked by vegetation at their outlets and are often colored from vegetable matter or the presence of iron. Coming from no great depth, they are not often very cold.

c. Wells.—(1) Dug wells, usually 3 to 6 feet in diameter, require little labor for the shallow wells, but as commonly sunk are the most dangerous sources of water. They should be protected from surface flows by water-tight curbing with earth banked around it sloping away from the well. They should be protected from pollution by animals, and watering troughs should be a sufficient distance away. Drippings from pumps and containers should be kept out by the use of a water-tight cover. There should be no opportunity for the entrance of small animals.

(2) Driven wells consist of 1½ to 4 inch iron pipes, with open end or point, and a strainer, forced into the ground. The joints are water-tight preventing pollution from waters near the surface. Their use is limited to soft materials. Hard strata or bowlders prevent their use.

(3) Drilled wells 1½ to 12 inches or more in diameter are used in harder materials or where the depth is too great for driving. Sections through soft materials or where undesirable water might enter require an iron casing. Drilled wells may reach a depth of 2,000 feet or more, but in granitic rocks if a supply is not found within 300 feet it is better to try a new locality. The deeper waters contain large amounts of mineral matter which makes them unfit for use in boilers and they usually yield less water than wells nearer the surface.

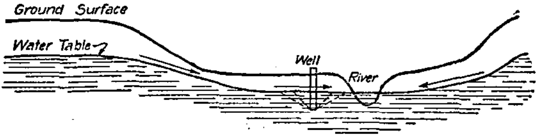


FIGURE 25.—Typical flood plain well

(4) Bored wells are sunk with augers from 2 inches to 3 feet in diameter, rotated and lifted by hand or horsepower.

36. Location and movement of ground waters.—*a.* The ground water has a definite upper surface called the water table (see figs. 25 and 26) which conforms in general with the broader surface irregularities of the ground; but the water table is flatter, often being far below the surface on hills and cutting the surface in the valleys. The movement of ground water is in the direction of the slope of the water table and approximates that of the surface drainage. Low points are the most favorable for open wells, but as polluted water follows the same flow, they are points of danger when sources of contamination exist on the slopes.

b. The occurrence of deep waters depends on the structure and character of rocks far below the surface and the well may usually be located without reference to surface relief, except that where artesian flows are expected it should be located on low ground. Information as to the best location may be obtained from a record of wells in adjacent areas or from a study of the rocks and their structure, which will require a trained geologist.

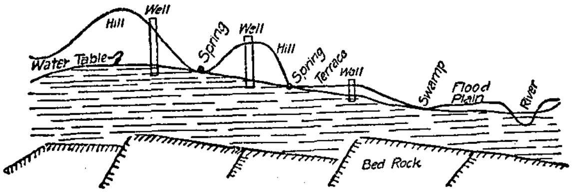


FIGURE 26.—Typical water table

c. It is a widespread belief that water increases with depth and may be had anywhere by going deep enough. This is far from the truth. Rainfall is the source of over 99 per cent of fresh ground water and, neglecting the surface material above the water table, ground water decreases with the depth. The deeper rocks are largely granitic and hold little water. Unless they also constitute the surface rock and are broken by joints it will be of little use to penetrate them. Unless there is some evidence that deep water-bearing beds exist, a deep well should be considered as an experiment, although in sedimentary rocks it may penetrate a number of water strata which furnish in the aggregate an adequate supply, or supply artesian flow.

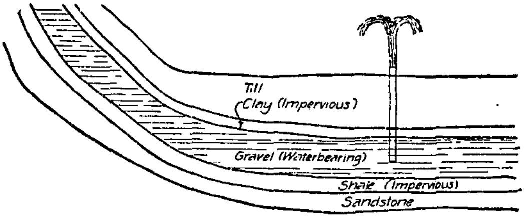


FIGURE 27.—Typical flowing (artesian) well (an artesian well may be nonflowing, the water rising in the well to a height depending on the pressure head in the water-bearing strata)

d. In connection with underground water supplies in dry areas or where deep wells are required, the location of water-bearing strata is almost an exact science to the geologist. Much wasted time and labor can be avoided by utilizing his knowledge. When it is necessary to estimate stream volumes during the dry season, depth of ground water, and the probable location of springs within the enemy lines, his services may be invaluable.

37. Selection of type of wells.—*a.* (1) The yield of a well is largely determined by the character of the water-bearing material. A sand will furnish large supplies while a chalk or clay, although possibly containing more water, will yield little or none. Quicksands contain large amounts of water, but owing to the ready flow of the fine sand through crevices, dug wells are impossible and driven wells with ordinary strainers become clogged. Drilled or driven wells sunk by men familiar with the methods of handling quicksand and equipped with special strainers are usually the only types successful in such material. The strainers may be of brass wire mesh, but are usually cylinders of brass tubing with openings varying from 0.004 inch (0.1 millimeter) upward, depending on the fineness of the strata. Solution passages or joints in rock play an important part in determining yield and may afford excellent supplies where the mass of the rock contains no water.

(2) The facility with which water enters the well depends both on the rock structure and on the type of well. In loose materials, water accumulates most easily in stone-lined uncemented dug wells, and somewhat less in tightly-lined dug wells with open bottoms. If the materials are so consolidated as to prevent their entering the well, water will enter an iron casing open at the bottom. In soft materials perforated casings or screens are necessary. In the harder rocks, casings are unnecessary except to prevent entrance from undesirable levels.

(3) The amount of storage in a well is important when the rate of flow is low. The storage capacity varies as the square of the diameter; a 3-foot well will hold 36 times as much water as a 6-inch well. Dug wells are of advantage in any material where water enters more slowly than it can be lifted by the pumps. In rock, only relatively small-bore holes are practicable and wells should be made as large and as deep as possible below the entrance point of water if the flow is inadequate.

b. It is a common belief that wells in lowlands near a river receive their water from the river. Under normal conditions, as shown in Figure 25, this is not the case, the well being supplied by the ground water; the water table will be lowered as shown by the dotted line and the supply may be drawn from both the ground water and seepage from the river. The arrows indicate the normal ground water movement.

c. The depth of water is of importance in determining the type. A dug well is usually suitable only for depths less than 30 or 40 feet. Driven wells are most suitable at depths of less than 150 feet, although at times are carried to 300 feet or even 500 feet in suitable material. Bored wells are not carried more than 100 feet below the surface. Wells of the California type have been carried to 1,000 feet, and with the percussion drill to far greater depths.

d. The time available often will be important in determining the type. Drilled wells and power pumps require considerable time and equipment for installation and can be used only under favorable conditions in stabilized areas. Dug and driven wells are the types most used in forward areas.

SECTION II

REQUIREMENTS

38. Estimates of water required.—The water supply provided for civil consumption in most regions rarely is sufficient for military needs. During the World War, both French and English estimated minimum water requirements when troops were massed for an advance at about 150,000 gallons per day for every 20 square miles occupied. An Infantry division of 20,000 men has about 7,000 animals. At one gallon per day, the men require 20,000 gallons and at 10 gallons per day the animals require 70,000 gallons, a total of 90,000 gallons per day. The Cavalry division with 7,500 men and 9,500 animals requires 102,500 gallons. The table following gives per capita consumption under average conditions.

TABLE V.—*Water consumption*

	Gallons per capita per day	Remarks
Cities and Army posts (peace).	100–200	Provides for water-borne sewage.
Cantonments, 30,000 to 50,000 troops.	55	Men and animals. Includes water for kitchens, baths, steam heat, toilets, sewers, and stables.
Semipermanent camp in rest area.	30	Includes piped supply for baths, toilets, etc.
Temporary camp	5 10	Men. Animals. For drinking, cooking, washing, disinfecting. No water-borne sewage.
On the march and in bivouac.	1 10	Men (¾ to 1½ gallons). Animals.
In battle, absolute minimum for not over 3 days.	¼–½ 3	Men. Animals (3 to 5 gallons).
Locomotives (standard gage).	--------	7,000 gallons a day or 120 gallons per train-mile with 1 locomotive.
Stationary engine (condensing).	--------	2 gallons per horsepower-hour.
Stationary engine (noncondensing).	--------	4 gallons per horsepower-hour.
Condensing water (waste).	--------	100 gallons per horsepower-hour.
Gasoline engines (cooling water).	--------	¼ to ½ gallon per horsepower-hour.

These estimates must be modified according to circumstances, especially in hot climates. The requirements of the maximum month may exceed those of the average month by from 15 to 40 per cent.

SECTION III

RECONNAISSANCE

39. Sources of information.—Information of the water resources of an area may be obtained from Government or other reports, topographical and geological maps, airplane photographs, by interrogation of the local population or prisoners, and by personal reconnaissance of the ground. In arid countries the assistance of a qualified geologist should be obtained if practicable.

40. Equipment of the reconnaissance party.—In addition to the equipment customarily carried by parties engaged in general reconnaissance, a water supply reconnaissance party should be equipped with a number of clean glass bottles holding from 2 quarts to a gallon each and equipped with a well-fitting stopper or a clean, unbroken cork. A label should be provided for each bottle.

41. Technique of a water reconnaissance.—*a.* Notes should be taken of the location of all resources in the area and attention concentrated on those supplies which appear to be easiest of development. The seasonal variation of supply and areas of possible artesian flow and the localities where shallow wells are likely to be successful should be noted. In locating water supplies the following suggestions may be useful:

(1) Streams in open country are usually bordered by trees.

(2) Spots where the grass is greener in one place than another or the vegetation more abundant are more likely to be near ground water.

(3) Vapor often rises in the early morning or evening from places where springs or ground waters may be found.

(4) Springs are often found at the junction of valleys or at the base of an overhanging cliff.

(5) Areas suitable for shallow wells will usually be found in valleys.

b. The rate of flow for wells is determined by making a pumping test or by local inquiry. The rate of flow of a spring is determined by noting the time to fill a container of known capacity. The rate of flow for streams is determined by the formula $Q=AV$; where Q equals the quantity in cubic feet per second, A equals the area of cross section of the stream, and V equals the velocity of the stream in feet per second. The cross section is determined by estimate or measurement. The velocity may be estimated by noting the velocity of a chip floating on the surface of the stream.

c. The measurement of the yield of flowing wells requires only a foot rule. The following table from data by Slichter requires the measurement of the height of the jet from a *vertical* pipe. The discharge for other sizes can be obtained by remembering that the discharge will vary as the square of the diameter. If the pipe is one-half inch in diameter the discharge will be one-fourth that of a 1-inch pipe for same height of jet. For an 8-inch pipe the discharge will be that of a 4-inch pipe multiplied by 4.

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

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

42. Reports.—*a.* The most important information to be obtained and reported immediately is the location of the water supply and the rate of flow. The location should be shown exactly on the map or by coordinates. The rate of flow should be expressed preferably in gallons per 24 hours. In reporting on animal water points, the number of animals that can be watered at one time should be indicated.

b. In making a report of a water reconnaissance, the use of the following form is helpful:

WATER RECONNAISSANCE

FORM FOR RECONNAISSANCE REPORT

Date________________________
Report by____________________
Grade and organization_____________
1. Location______________________________
____________________Coordinates__________________
2. Source (well, spring, or stream)____________________
3. Character of water: Clearness, ____________________
____________; taste,____________; odor,____________________
4. Result of test (if test impossible take sample of water). (See back of sheet for method of taking samples)____________
5. Possible sources of pollution and location______________
____
6. Rate of flow (for wells, pumping test, local inquiry, or estimate; for springs, time of filling a container of known capacity; for streams, determination of velocity and cross-section area, or flow over a weir): ______________________________
____

7. Existing development:
   - (*a*) Pump: Number, ------------; type, ------------; size, ------------; speed, ------------.
   - (*b*) Engine: Type, ------------; size, ------------; speed, ------------; horse power, ------------.
   - (*c*) Electrical equipment------------------------------
   - (*d*) Storage facilities: Type, ------------; capacity, ----------------; height, ------------.
   - (*e*) Pipe lines: Kind, ------------; size, ------------; length, ------------; head, ------------.
   - (*f*) Present condition or damage----------------------
8. Well or spring:
   - (*a*) Depth of water in well------------------------
   - (*b*) Depth of water below ground surface--------------
   - (*c*) Nature and depth of lining, curbing and cover, and whether water-tight------------------------
   - (*d*) Diameter: Top, ------------; bottom, ------------
   - (*e*) Opportunity for entrance of surface water----------
   - (*f*) Method of raising and delivering water------------
   - (*g*) Temperature of water--------------------------
9. Stream:
   - (*a*) Width, --------; mean depth---------; maximum depth, ----------
   - (*b*) Nature of bed--------------------------------
   - (*c*) Height of banks above water surface--------------
10. (*a*) Proposed development------------------------
    - (*b*) Material available and required--------------------

Report by--------------------
Grade------------------------
Organization--------------------

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

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

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. Pour out a small quantity of water so there is an air space below the stopper.
5. Insert stopper or cork, stretch a clean cloth over it, and tie down the cloth below the flange of the neck.
6. 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 should be held in a clean flame (alcohol torch) and heated 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 flow to waste for a time.

SECTION IV

DEVELOPMENT OF SOURCES

43. Increasing the yield of wells.—*a.* An originally inadequate yield usually results from insufficient supply or the slowness with which the supplies are given up by the water-bearing rock. In clay and the denser varieties of bowlder clay and till, water is given up slowly, and the amount entering is more or less proportional to the area of surface exposed in the well. This area varies with the diameter, six times as much surface being exposed in a 3-foot as in a 6-inch well; hence large wells are desirable. They are also desirable in rocks in which the water occurs in pores, rather than open passages, and at the same time they increase the chance of striking an opening. The depth of dug wells is important in providing increased storage. In some cases where the water table has sunk, the deepening of the well will be sufficient.

b. In deep wells the use of dynamite shatters the surrounding rock and may result in connection with other water-bearing crevices. Dynamite is most effective in hard, brittle rocks, such as limestone, and least effective in soft, tough shales.

c. Packing with gravel is useful when the material is so fine as to clog the flow. Pebbles may sometimes be dropped into the well and forced out into the surrounding clay with a drill until a pocket is produced permitting flow. Yield and specific capacity of wells in unconsolidated sands may often be increased by removing sand from around the strainer and substituting selected graded gravel. A coarse strainer will be used, and the effective diameter of the well becomes that of the gravel pocket. The method consists of pumping out sand through an inner casing and simultaneously feeding in gravel between an inner and an outer casing. This method is most applicable to shallow wells in fine sands.

d. A gradual reduction in the flow of a deep well may be due to a drawing off of the general supply in the area, to deterioration of the well from clogging of the screen, entrance of sand to working parts of a pump or leakage of the well from corrosion of the casing.

e. Emergency equipment for the cleaning out of wells and springs and installing temporary water points can be carried on a 1½ to 2 ton truck, or a 4-mule wagon, if roads are poor is mobile, and may be of great value on the march or during combat. It should usually include a windlass with buckets, shovels, pick mattocks, crowbar, blocks and rope, hand force pumps, carpenters' and plumbers' tools, canvas water troughs and basins, Lyster bags, hypochlorite of lime in 1-gram capsules and in 1-kilogram bottles. The personnel should include an experienced noncommissioned officer, a carpenter, plumber, and laborers. Additional supplies and equipment may be added as required.

44. Development of streams.—*a.* The methods of developing surface streams will depend on the amount of water required and may vary from pumping by means of the mobile purification truck into storage basins to constructing impounding reservoirs for the supply of a cantonment, concentration area, or general hospital.

b. Dams will rarely be required during military operations, but may at times be useful for equalizing the flow of streams to cover variation in draft or flow.

45. Development of springs.—A substantial collecting basin should be constructed. A water-tight timber casing may be used, but will be objectionable if permitted to become old enough to decay. Concrete is preferable. Water-tight walls should extend 1 or 2 feet above and below the surface to prevent the entrance of surface wash. The shape of the springy area should determine the shape of the reservoir. Small springs may be developed by setting a length of large concrete, iron, or vitrified pipe in the ground vertically over the spring. A cover should always be provided to keep out dust, leaves, sticks, and small animals. Every care should be taken to guard against pollution, particularly such as might occur from dipping buckets or dippers into the spring, and the water should be taken by a pipe to the storage tank or point of delivery.

46. Dug wells.—*a.* Dug wells require a considerable expenditure of time and labor. For depths over 20 feet it usually is more economical to use some method of driving or boring. Excavation is with pick and shovel and there is usually room for only one man to work at the bottom. A windlass and bucket must be provided for lifting out the excavated material. The size of the shaft depends on the amount of storage required, the type of lining, and the method of raising the water. Shafts using a windlass and bucket require a diameter of at least 4 feet. Where considerable storage is required in shallow wells, diameters of from 15 to 20 feet may be called for. It is usually desirable during excavation to install the permanent dump for use in removing water.

b. Linings may be of brick, masonry, timber, concrete, or corrugated iron, depending on the diameter of the well, the character of the soil, and the time and material available. For field use timber is the most useful and shafts may be sunk as in mining operations (at least 4 feet square for a shallow well). The top of the well should be secured from contamination by raising the lining above the ground level and covering the opening. For temporary use the top may be of timber with an impervious cover. For semipermanent construction a concrete top should be used. A manhole should be provided with the cover set on a curbing. The pump hole should be protected from waste water by a sleeve and gasket set on a curbing. The lining of the well should be water-tight for at least 6 feet below the ground surface. (See fig. 28.)

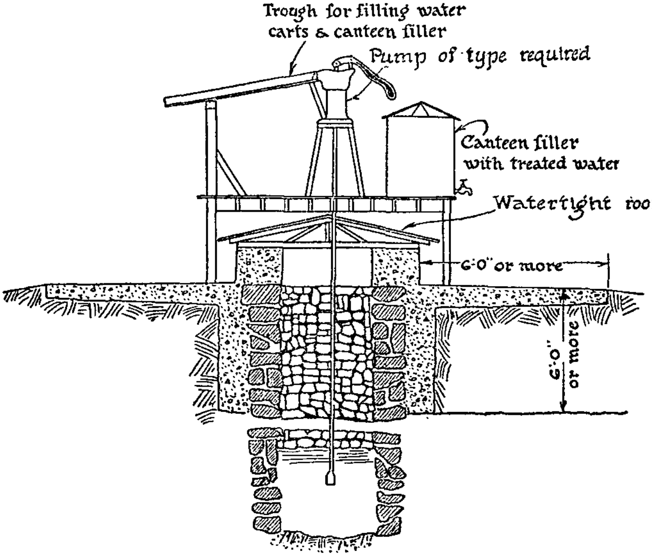


FIGURE 28.—Development of existing well

c. An infiltration gallery is a modification of a dug well in which the ground water at moderate depths is intercepted by galleries across the line of flow. The gallery may range from an open ditch leading the water away, to conduits of masonry, wood, iron, or vitrified pipe provided with openings, surrounded by stone or gravel, to permit the entrance of water. The galleries are usually constructed in an open trench and are arranged to lead the water to a pump well. Similar galleries at right angles to the direction of flow can occasionally be used to increase the yield of dug wells.

47. Driven wells.—*a.* Driven wells are constructed by driving pipes into the ground with a maul or a driving machine, sometimes with the assistance of a jet or "wash drill." In closed-end wells a drive point slightly larger than the pipe is used and above the point is a perforated section. The pipes are usually ¼ to 3 inches in diameter (2-inch is the most common size) and the screens 2 to 4 feet long. New sections are screwed on as the pipe is driven.

Open-end wells are constructed by driving a plain pipe which may or may not have a heavy driving shoe attached. The material inside is removed by a sand pump or by a water jet forced down a small pipe inside the drive pipe. The pipe is perforated either before driving or by special tools after driving. A perforated strainer section about 2 feet long should always be used even if the bottom of the well is open. A portable and very simple arrangement for driving tube wells is illustrated in Figure 29. It is entirely suitable for moderate depths. A hollow cast-iron monkey slides over a bar which is supported vertically by the tube to be driven. By means of two ropes passing over pulleys at the top of the bar, the drop weight may be alternately raised by hand and allowed to descend by gravity, striking a blow on an attached clamp or cap fitted to the upper length of well tubing.

b. Driven wells are suited to loose sand or gravel where caving would interfere with digging. If unsuccessful the pipe may be withdrawn and used again. One disadvantage is that in the smaller tubes the screen may become clogged by mineral matter or silt and another is that grit may be drawn up and score the working parts of the pump. If a well becomes clogged after use it can sometimes be cleaned by forcing water into it under pressure. It may be necessary to pull and redrive the casing, perhaps with a new strainer. Wells of the larger diameters are best adapted to obtaining large supplies from the stratified drift or other sand or gravel deposits. Driven wells are not suited to till because the bowlders make driving difficult and because the yield is insufficient for a satisfactory supply. If several wells are to be driven, they should be in a line across the direction of under-flow so that the maximum yield may be intercepted without interference among the wells. In stratified drift, the wells should be 8 inches or more in diameter with holes one-fourth inch or larger. They should be pumped vigorously for a considerable time with an air lift or centrifugal pump to get out the sand and leave a pocket of clean gravel around the intake.

c. As a safeguard against pollution the casing should be thick enough to resist corrosion, should have tight joints, and should be carried above ground level. If located in a stream valley casings should be carried above flood levels.

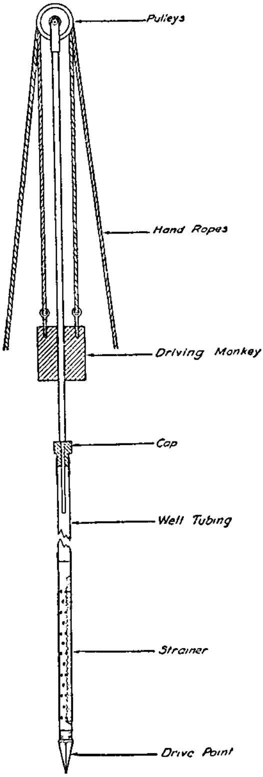


FIGURE 29.—Simple device for driving tube wells

48. Development in advanced areas.—*a*. The extent to which wells can be dug, reclaimed, or driven, or small purification plants installed, depends on the sources available and the intensity of shell fire. Such water points should be developed for filling water carts or buckets and canteens as required, and should always be provided with adequate chlorinating apparatus. For shallow wells a hand force pump may be used, for deeper wells a windlass and bucket or a suitable pump. The windlass and bucket arrangement, however, is usually inadequate and insanitary. If safe water can not be provided at these sources, it is better to carry it from a suitable source farther to the rear. Water taken from shell holes is a source of sickness, particularly after gas shelling. Water tainted by gas can not be purified by boiling.

b. Springs form excellent water points. They should be protected against contamination, provided with chlorinating tanks, hand pumps, and faucets for drawing off the water. Fouling will occur if men are allowed to dip any sort of receptacles in the spring. A popular belief that springs as they issue from the ground are pure has no basis in fact. They are as subject to pollution by drainage from stables, latrines, or sewers as are wells and the source of contamination may be at a considerable distance from the spring.

c. Small filters may often be used which are compact enough to be erected in forward dugouts or shelters. During long periods of position warfare, it will sometimes be possible to dig or drive wells in a dugout in the trench system. Special precautions must be taken to protect them against drainage, and chlorinating arrangements must be provided.

SECTION V

PURIFICATION

49. Requirements as to quality.—*a.* Natural water always contains inorganic and organic matter in suspension, as sand, silt, leaves, animal tissue, algæ, insects; or in solution, as oxygen, nitrogen, carbon dioxide, ammonia, carbonates, bicarbonates, and sulphates of calcium and magnesium, sodium chloride, nitrates, etc. The presence of the carbonates, bicarbonates, and sulphates of calcium and magnesium in solution makes water hard and unsuitable for use with soap. In general, mineral constituents are unobjectionable in water for drinking unless present in sufficient amounts to create an objectionable taste. Two hundred and fifty parts per million of sodium chloride give a salty taste; 60 parts per million may cause boiler trouble. Rain water may have solids as low as 20 parts, while ground waters may have 500 parts per million. Free mineral acids from mill or mine wastes cause corrosion of pipes and fixtures and possible poisoning and can not be allowed in drinking waters. They also render water unsuitable for use in boilers.

b. A bacteriological examination is necessary to determine the character of the water from a disease-carrying point of view. Cholera and typhoid are propagated through drinking water as also are dysentery and other intestinal diseases. Tests for contamination are usually based on a determination of the presence of *Bacillus coli communis* (*B. coli*), which are abundant in the intestines of men and animals and usually indicate contamination by sewage. If organisms of the *B. coli* type are absent and the total number of bacteria is not too high we can definitely say that the water is safe. If *B. coli* are not entirely absent it can not as definitely be said that the water is dangerous, as they may be of animal origin; but if they are persistently present in small amounts of water, as 1 cubic centimeter or less, the water is likely to contain human waste and is certainly unsatisfactory.

c. In any analysis, the following items are usually determined and the figures given are typical. The quantities are expressed in parts per million by weight (milligrams per thousand cubic centimeters). The usual report also gives information concerning the turbidity, sediment, odor, hardness, and acidity of the sample.

	Good water	Sewage
Total solids	50. 0	700. 0
Organic matter (loss on ignition)	30. 0	200. 0
Inorganic matter (fixed residue)	20. 0	500. 0
Chlorine as chlorides	3. 0	40. 0
Free ammonia	0. 010	25. 0
Albuminoid ammonia	0. 100	10. 0
Nitrogen as nitrates	0. 200	0. 1
Nitrogen as nitrites	0. 000	0. 005
Oxygen consumed	0. 5	40. 0
Bacteria in 1 milliliter (1 cubic centimeter)	50. 0	1, 000, 000. 0
Bacteria coli communis in 10 milliliters	0. 0	5, 000. 0

d. The presence of abnormal amounts of chlorine (or sodium chloride) is usually indicative of pollution by human or animal excreta, but in deep ground waters the chlorides may be soluble ingredients of the rocks traversed, and the normal amount is larger in surface waters near the coast than in inland waters. Albuminoid nitrogen is an indication of undecomposed organic matter, animal or vegetable. Free ammonia nitrogen is nitrogen which has passed through the first stages of mineralization. Nitrites are the next step in mineralization. They are unstable and not ordinarily found unless active chemical change is going on. They are always an indication of danger. Nitrates are the final stage of oxidation in which the nitrogen is found in the completely mineralized form. The amount is an indication of past history and is an index of so-called remote pollution. In ground water they may be due to mineral deposits and have no sanitary significance. "Oxygen consumed," serves as a means of comparing relative amounts of carbonaceous organic matter, or other oxidizable constituents of various waters. Analysis of the same water may show different results at different seasons, and a knowledge of the topography and sanitary conditions of the source of supply is absolutely necessary for the interpretation of a chemical analysis.

e. Living organic matter is usually certain species of microorganisms, commonly called algæ, found by microscopic examination, which may produce a fishy or pigpen odor. Suspicion is justified in case of turbidity and unpleasant odor, but the water is not necessarily dangerous, while the most dangerous bacteria may exist in water which is clear and sparkling.

f. Hardness is mainly due to sulphates, carbonates, and bicarbonates of calcium and magnesium. The sulphates give "permanent" hardness which can only be removed by chemical treatment, while the bicarbonates cause "temporary" hardness which can be removed by boiling. Water containing 250 parts per million of hardness producing constituents is unfit for washing or for use in boilers, although waters that are even harder may be suitable for drinking. In boiler use the carbonates of lime and magnesia are precipitated, forming a deposit which can usually be removed by blowing out. The sulphates form a very objectionable hard scale. Softening of water is usually accomplished by precipitation. To remove the carbonates, lime ($Ca(OH)_2$) is added, precipitating calcium or magnesium carbonate. To remove the sulphates, sodium carbonate (Na_2CO_3) is used (lime must be added in case of magnesium sulphate), producing sodium sulphate.

50. Purification by sedimentation.—*a.* Sedimentation may occur by the action of gravity in any quiet body of water. Waters are often clarified in a pond or reservoir in from one to three days. Should the silt be composed of finely divided or colloidal clay it may remain in suspension indefinitely. In water purification it is customary to use a coagulant which, forming precipitates of a gelatinous character, unites the finely divided suspended matter into larger masses, thus facilitating removal by either sedimentation or filtration. Colloidal solutions of clay, vegetable color, etc., can not be removed by filtration unless coagulated.

b. The most commonly used coagulant is aluminum sulphate ($Al_2(SO_4)_3$). If this is introduced into water containing carbonates and bicarbonates of lime and magnesia, it is decomposed, the aluminum uniting with the water and liberating carbonic acid. "Alkalinity" is a measure of the salts that neutralize acids, usually carbonates, bicarbonates, or hydroxides. Water that has been treated with aluminum sulphate or other aluminum compounds should contain a residual alkalinity of at least 10 parts per million. One grain per gallon of the aluminum sulphate requires 5 to 10 parts per million of calcium carbonate alkalinity or its equivalent for complete reaction, and this should ordinarily be allowed. If not present in natural form, soda ash (anhydrous sodium carbonate (Na_2CO_3)) is added to bring about coagulation and prevent undecomposed alum remaining in the treated water. High alkalinity is undesirable as causing a corresponding high degree of soap consumption, and an excess of sodium carbonate may cause the coagulate to redissolve. If a larger amount of the aluminum sulphate is added than can combine with the carbonates present, it will leave an objectionable amount of alum dissolved in the water. The reaction which takes place forms aluminum hydrate ($Al_2(OH)_6$), which acts as the coagulant. Carbonic acid is set free, increasing the corrosive action of the water on unprotected iron or lead. This fact, however, will rarely be a detriment. The amount of aluminum sulphate required varies, with the amount of sediment, from three-fourths grain to 3 or 4 grains per gallon; 2 grains of alum per gallon (28½ pounds per 100,000 gallons) is a common average for surface waters.

c. The rate of sedimentation depends much on the amount of coagulant used. Where sedimentation is to be followed by rapid filtration, two to six hours are usually allowed. Complete clarification is unnecessary and better filtration occurs if a small amount of the coagulant is carried to the filters. If the water is not to be filtered it would be desirable to allow from 12 to 24 hours.

d. Sedimentation basins may be operated by continuous flow or by filling and emptying. The first method, the water moving with a low velocity, is desirable for filter plants. The second is often necessary where basins have to be improvised or the water is chlorinated without filtration. The apparatus for handling alum should have special bronze or hard-rubber fittings and copper, bronze, or lead pipes. Tanks may be of concrete. Particular emphasis must be placed on the reliability of the method of feeding the coagulant in the continuous-flow method, as the efficiency of the rapid filter in removing bacteria depends largely on proper control of the coagulation. The coagulant is introduced into the water as it enters the basin, preferably by a series of perforated tubes distributed over a channel through which the water passes, and the solution in the alum tank must be kept stirred during application to insure uniform strength. (See method of applying hypochlorite in paragraph 52.) A low velocity in the basin (2½ feet per minute) is obtained by increasing the cross-section area and the use of baffles insures thorough mixing. In case the alum is added to the water in a basin, using the method of filling and emptying, sufficient agitation to insure thorough mixing is necessary. A trough directing the incoming water along one side of the basin will assist in maintaining circulation while the tank is being filled. Concrete is desirable for the basin, but timber or tarred canvas or other materials may be used. Laboratory tests are required to determine the amounts of alum and alkalinity required.

51. Purification by filtration.—*a.* Sand filters are of the slow or rapid types. The time required for construction of slow sand filters, in which the total thickness of the filtering layers of sand and gravel averages 4 feet, eliminates any possibility of their being constructed for use during military operations, but where already in use they may be taken over. They operate at from 2,000,000 to 6,000,000 gallons per acre per day. Every three or four weeks the filter must be drained and the top layer scraped off. When the sand bed becomes too thin, sand must be added. The bacterial efficiency does not depend so much on the mechanical effect of the sand as on the bacterial growth in the body of the filter and the film which forms on its surface. The sand should be clean, uniform, and with grains about 0.2 to 0.4 millimeter in size. As the filter becomes clogged the head is increased so as to maintain a uniform discharge.

b. A rapid sand filter is shown in Figures 30 and 31.

(1) The filter medium is a thick layer of selected uniform sand with the artificial surface mat caused by coagulation. The sand, 24 to 30 inches deep, should be nearly pure quartz, preferably with rounded grains and between 0.35 and 0.60 in size. A certain amount of flocculent precipitate from the coagulating basin is necessary to secure proper filtration, and sedimentation for 2 to 6 hours is required. The filter units are usually small tanks of wood, steel (for pressure filters), or concrete (see fig. 31), and require washing every 6 to 24 hours. Washing is accomplished by reversing the flow and should hold the entire sand bed in suspension, care being taken that no sand is washed out through the troughs. It should clear the sand of dirt but some coagulated floc should remain in the water over the filter to form the basis of a new mat. Effective washing requires 7.5 to 15 gallons per minute per square foot applied from three

to eight minutes. Elevated tanks are often used to furnish wash water at the required pressure. Between 1 and 5 per cent of the filtered water may be required for washing. Mechanical agitators are regarded as obsolete. Common filter troubles include the appearance of mud balls, which must be removed, and the clogging of the surface sand with organic matter and mud, which may cause cracks in the surface mat. After washing, a certain amount of the effluent should be wasted. The sand bed is supported on a 10-inch layer of pea-size gravel overlying the underdrain system on filters with brass strainers discharging upward. On other types 12 to 20 inches of graded gravel are used.

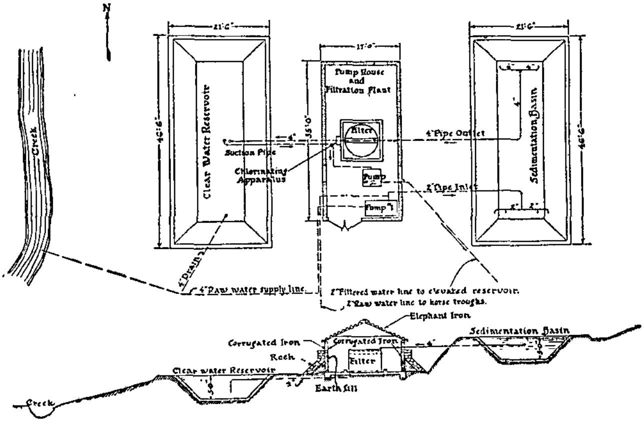


FIGURE 30.—Water-purification plant

(2) There should be at least 10 feet difference in elevation between water surface in the clear water basin and in the filter. This gives the filtering head necessary. A greater head is likely to break the film of coagulant on the sand surface. The pipe to the clear water basin should be trapped against the entrance of air. The head is usually controlled as in the slow sand type by maintaining a constant water level on the filter, preferably the level of the water in the coagulating basin, and automatically or manually varying the pressure head in the effluent pipe by a valve. This valve supplies a means of maintaining a constant rate of filtration. For a capacity of 100,000 gallons per day the tank should be about 7 feet in diameter and

5 feet or more deep. A pipe grid at the bottom with 3/16-inch holes at 2-inch intervals leads off the effluent. An overflow trough should be built about 12 to 30 inches (average 20 inches) above the surface of the sand for taking off the wash water.

(3) The rate of filtration is usually 125,000,000 gallons per acre per day or approximately 1,000,000 gallons per day for each 350 square feet of sand surface. This rate is equivalent to 2 gallons per minute per square foot. Filters usually permit a variation of 25 per cent above or below the normal rate. Any sudden change in the rate of filtration is undesirable.

52. Purification by disinfection.—*a.* It has become standard practice to disinfect water by the application of liquid chlorine. This is the method used in the mobile purification unit. In the liquid chlorine treatment a reliable feed apparatus is essential, the rate of feed being constant, as all of the flowing water must come in contact with the chlorine. The solution of the chlorine is secured by a water jet which thoroughly mixes the chlorine and water. A flow of 1 pound of chlorine per 24 hours or 0.000694 pound per minute treats approximately 300,000 gallons of water per day. In civil practice 0.1 part per million of free chlorine remains in the water. In military practice 0.5 part per million is customary and is the minimum prescribed for the mobile purification unit. The germicidal action is due to the formation of hypochlorous acid (HOCl) on mixing chlorine and water. This reacts with the protein of the bacteria, decomposing and killing them.

b. (1) Chlorination in the field in semipermanent and improvised installations (see fig. 32) is usually by the application of calcium hypochlorite (chlorinated lime or bleaching powder) ($4CaOCl_2 \cdot 2Ca(OH)_2 \cdot 5H_2O$). On dissolving in water hypochlorous acid and calcium bicarbonate are formed. The hypochlorous acid is further decomposed into hydrochloric acid (HCl) and nascent oxygen. The hydrochloric acid combines with carbonate or bicarbonate alkalinity in the water to form calcium chloride, carbon dioxide and water. It has been assumed that the hypochlorite killed bacteria by oxidation, but it is now believed that the germicidal action is due to chlorine or its derivatives rather than to nascent oxygen.

(2) When chlorine or calcium hypochlorite is added to water the reactions may be divided into three types:

(*a*) Oxidation of organic or mineral matter.

(*b*) Direct chlorination of organic matter.

(*c*) Bactericidal action.

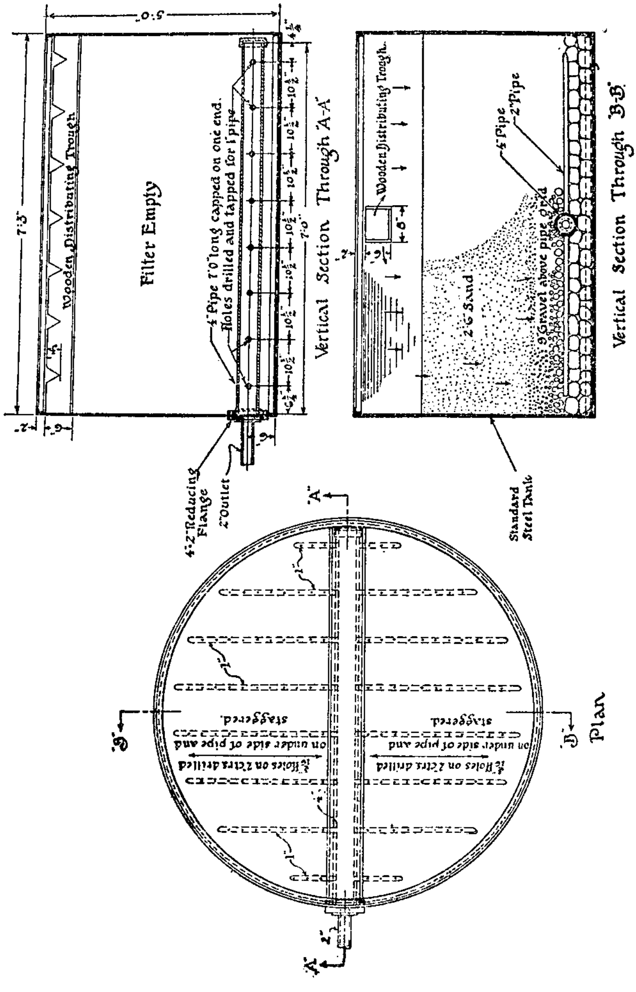


FIGURE 31.—Detail of rapid filter

Usually the greater part of the chlorine added is required for the first reaction and the chlorine demand of this reaction must be satisfied before an excess for the removal of bacteria is available. Five to ten parts per million of caustic alkalinity in the water materially retard the germicidal action. It is common practice to make solutions of 0.5 to 2.0 per cent strength (1 to 4 pounds of hypochlorite to 200 pounds of water). The essential features of its use are (Medical War Manual No. 6, 1918):

1. The powder should be made into a smooth paste by adding a small amount of water.
2. This paste should be kept thoroughly stirred.
3. Solution tanks should be kept covered.
4. Solutions deteriorate but little when standing (about 2 per cent per day).
5. Period of contact with the water should be not less than 20 minutes.
6. A thorough mixture of the hypochlorite and water should be obtained.
7. Solution tanks should have two valves, a sludge valve on the bottom and a discharge valve on the side. The sludge should be removed daily.
8. The strength of the hypochlorite solution must be determined and adjusted with each new charge. If the water is to be filtered the hypochlorite is added after filtration. Any turbidity reduces its efficiency. Concrete tanks with valves of brass or bronze usually are used for dissolving the bleaching powder. Wood can be used, but is rapidly destroyed unless protected. Galvanized pipe is fairly resistant, as are also tin, brass, lead, hard rubber, and paraffin. Wrought iron or steel corrodes rapidly.

(3) For waters overtreated with calcium hypochlorite or chlorine, sodium thiosulphate (sodium hyposulphite), which is available in tubes containing 1 gram, can be used to remove the excess of chlorine. This is needed only in cases where the taste of chlorine is so objectionable to troops as to cause them to drink from unpurified sources. Dechlorination is always inadvisable until the water has passed all stages where contamination is possible. There is no reason to believe that any amounts of free chlorine obtained by methods used in the purification of water are in the slightest degree harmful. It is desirable, however, to keep the free chlorine down to two parts per million or less. Where tests are possible it can easily be kept below one part per million.

(4) Twenty-five pounds of hypochlorite (30 per cent chlorine) are required to sterilize 1,000,000 gallons of water by applying one part per million of available chlorine. The standard strength requires not less than 30 per cent of available chlorine in the hypochlorite. Either storage or contact with air or light may bring about reactions liberating oxygen and chlorine and reducing their efficiency. The hypochlorite is usually supplied by the manufacturer in sheet steel drums 39 inches high by 29½ inches diameter (gross weight 750 pounds, net weight 690 pounds). It is also available in smaller containers. The loss of available chlorine is approximately 1 per cent per month in hot weather and 0.3 per cent in cold weather.

c. Either hypochlorite or alum solution is usually applied to water entering a sterilizing or sedimentation basin by maintaining a constant head with a float valve on a varying size orifice. The usual head is one foot. Several orifices may be available in the chemical tank and that one used which gives the desired discharge. The orifices should be made in a plane surface and beveled so that the inner surface has a sharp edge. (See Table XI.)

53. Tests for free chlorine.—*a.* (1) Where water is disinfected with calcium hypochlorite, a test to determine the amount of free chlorine acts as a protection against the use of deteriorated chemicals, and such tests should be applied in all cases. Orthotolidin is the reagent ordinarily used (a 0.1 per cent solution made by dissolving 1 gram of orthotolidin in one liter of a 10 per cent solution of hydrochloric acid) and the usual test is to add one cubic centimeter of the orthotolidin solution to 100 cubic centimeters of the water to be tested. (If the free chlorine exceeds three parts per million it will be necessary to add more of the reagent.) Small amounts of free chlorine give a yellow and larger amounts an orange to red color after standing five minutes. By comparing with color standards the amount of free chlorine can be readily estimated. This is the official test of the American Public Health Association.

(2) The oxidation of organic or mineral matter requires 10 minutes, and the test should not be made until the chlorine has been in contact with the water for 10 minutes. Rarely orthotolidin added to raw water produces a yellow color (as when manganese is present). It is, therefore, desirable to test a sample of the water before the application of chlorine. The presence of organic matter in the water sometimes causes a false

color reaction after 10 minutes and readings should be made in five minutes or less, after adding the reagent. In very alkaline waters a blue or green color may be produced instead of yellow. Slightly increasing the amount of orthotolidin eliminates this trouble. Standard color solutions should be kept away from the light.

b. A method of determining the amount of chlorine needed for sterilization is as follows:

(1) Rinse a canteen cup, which holds approximately 1 pint, with water, leaving a few drops in the cup. Mix a 1-gram tube of hypochlorite into a paste with the few drops of water. Fill the cup to within 1 inch of the top (500 cubic centimeters) and mix by pouring into another cup and back. This solution should contain 0.3 gram of available chlorine.

(2) Rinse four canteen cups with the water to be tested and fill to within 1 inch of the top. With a pipette or hypodermic syringe add 0.2 cubic centimeter of the hypochlorite solution to the first cup of water, 0.4 cubic centimeter to the second, 0.6 cubic centimeter to the third, and 0.8 cubic centimeter to the fourth. Mix the solution with the water in each cup by pouring into another cup and back and allow them to stand 30 minutes. Fifteen minutes is sufficient if time is important.

(3) Test each cup by adding 1 cubic centimeter of the orthotolidin solution. The cup that contains the smallest amount of hypochlorite solution capable of giving an orange color contains the amount of chlorine necessary to sterilize the water.

54. Water-sterilizing or Lyster bag.—The water-sterilizing or Lyster bag, as issued to the service, is intended as a convenient receptacle for the disinfection and storage of small quantities of water, from which the water may be drawn by the individual consumer. The bag, when filled to the white mark, contains 36 gallons, or 288 pints.

55. Sterilization of well water.—*a.* The amount of calcium hypochlorite solution required can be computed by the orthotolidin test and added to all containers taken from the well. Or the hypochlorite solution may be added to the well itself until the tests show a sufficient amount of free chlorine. Frequent tests must be made to determine when additional hypochlorite is needed.

b. Wells can also be treated by placing 4 grams potassium permanganate and 10 cubic centimeters hypochloric acid in the well and leaving 24 hours. If the water has lost its pink color, more must be added. Pump until well is clear. The action is probably weakly germicidal except against cholera.

c. In one instance a well in France which had been badly fouled by the enemy with excrement was cleaned carefully and about 3 pounds of hypochlorite added. This was left some hours and then the well pumped vigorously for some time and the treatment repeated. After four days the water was found to be of good quality.

56. Small purification plants.—Small purification plants can be improvised as shown in Figure 32. Alum solution of the required strength is made up in tank *A* and added to the water as it is pumped into tank *B* from the stream so as to be thoroughly mixed. Let stand for about eight hours. Draw off clear water into tank *C* and add the required amount of hypochlorite solution, mixing thoroughly. After standing 30 minutes the water can be pumped to the storage tank *D*. Tests for free chlorine should be applied. The outlet pipe of tank *B* should be 4 inches above the bottom of the tank. There should be a depression at one end, *S*, to act as a sump for cleaning, and the tank should slope slightly in that direction. Sludge can be removed with a hand pump and a little water. The standard canvas basin can be used for all tanks and connections made with hose or pipe. If the water requirements are greater than 4,000 gallons in eight hours, additional sedimentation tanks can be used.

SECTION VI

DISTRIBUTION

57. Distribution systems.—*a.* A distribution system consists of the following:

(1) A source of supply.
(2) Means of conveying water.
(3) Storage.
(4) Distribution.

b. (1) In the direct system of distribution, the mains are supplied by gravity or by pumping directly into the pipe lines. In the indirect system, water is pumped into a raised reservoir from which the system receives supply by gravity. Direct pumping has many objections and should preferably not be employed. In case it is necessary, a relief valve must be placed at the pumping station to provide for the possibility of valves being shut on the line. Storage should usually be provided in the form of a raised tank or reservoir to provide a constant head, to prevent water hammer, and to provide for variations in the demand. If pumps are used duplicate sets should be provided for use in case of breakdown. Telephone connections are essential to the efficient working of a long pipe line.

(2) One-inch, 2-inch, and 4-inch pipes have a large use and should be standard. The 4-inch size can easily supply a division with 100,000 gallons a day and by repumping the water can be carried forward indefinitely. With trained men 4 miles of 4-inch pipe can be laid in a day, which is as fast as an army would be likely to advance against resistance, and the pipe can later be buried. The 2-inch and 1-inch sizes are suitable for laterals to water points, and other distribution. Occasional need may arise for 6-inch and, in rare instances, for larger sizes in bringing supplies for a large camp a considerable distance. Screw-joint steel or wrought-iron pipe was largely used in France. Universal joint and bell-and-spigot cast-iron pipe with lead-wool joints was used to some extent. Screw-joint pipe was found to be satisfactory except that occasional trouble developed from crossed threads or insufficient screwing when laid by unskilled men. Special fittings vary greatly with conditions, but should include 45° and 90° elbows, tees, bushings, plugs, nipples, valves, couplings, and saddles.

c. (1) Pumping stations should be easy to install and simple to operate. Steam is rarely useful because of the heavy equipment required and the fact that the smoke is easily picked up by the enemy air service. Electricity has many advantages where its use is possible, but the standard fuel in the theater of operations is gasoline. The pumps should be housed in a shelter large enough for two men and with such heating as required to prevent water jackets from freezing. It is usually possible to locate repair shops and needed supplies at the station.

(2) In forward areas, where natural protection is not available, splinter-proof and, in some instances, bomb-proof construction is desirable.

d. Storage should be provided both at the source of supply and at the point of distribution. The amount depends on the variation of supply and demand. In case water is moved forward by tank truck or light railway and the supply is sufficient for the average demand, storage must be sufficient to supply the difference between the average and the maximum. In all cases some form of storage is necessary for efficiently supplying water, whether to tank truck, water cart, or canteen, and in many instances for regulating the flow of small streams.

e. (1) Transport of water during a forward movement is normally by the 500-gallon tank truck from rear to forward areas pending a development of local supplies or supplementing them. In rapid forward movements, tank trains may be assigned to divisions and corps, or may operate under army control from water sources to water points established by the division or corps. The corps and division engineers are equipped to exploit existing resources and place water suitable for use at points convenient of access to the water carts of corps and division troops. The engineers concerned should chlorinate supplies at the water point as a matter of standard practice unless it is known that no pollution exists. Following the advance, water-supply troops will move forward to make available captured supplies and develop new sources.

(2) When suitable conditions exist, light railway tank cars of 2,000-gallon capacity may be used.

58. Water points.—*a.* Water points are points for storage and distribution to organizations. They should be as far forward as is consistent with concealment from artillery fire and, if possible, from air observation and may be located at varying distances from the front lines, at times actually in the trench system and under other conditions as far back as 5 to 7 miles. They should be located near the center of gravity of military population of the area to be supplied. Near the front, they make use of the mobile purification units, canvas reservoirs and horse troughs, hand pumps, and small power pumps as required. Farther to the rear, steel or wood storage tanks may be used or supplies may be piped. Their capacity is generally limited by the source or the number of troops to be supplied. Both men and animals must be supplied and separate facilities should usually be provided. The water point should be near a main road but not on it, and traffic should enter and leave without turning.

b. Figures 33 and 34 give typical arrangement of canvas basins and troughs for a water cart and canteen filling point and a horse water point. The standard canvas basin is a flat waterproofed canvas. If used in a rectangular timber frame with a base 12 feet square and sides 4 feet high, its capacity is about 4,000 gallons. These can be elaborated, or adjusted to available material, as conditions may dictate. Timber, steel, or concrete can be used for the tanks and troughs if a more permanent installation is desired.

c. Tank cart fillers in the simplest form may be a hose and hand pump delivering by pumping from a canvas basin sunk in the ground. If used in this way, a support should be constructed for the hose to keep it from becoming soiled. The canvas basin should be covered with canvas or some other type of roofing, such as timber, tarred paper, or corrugated iron, to keep out dust and other forms of pollution, and to prevent reflection visible from the air. The canvas for the basins should be waterproofed, but unwaterproofed canvas, although leaking considerably at first, will gradually tighten up. The road at the filling point should be paved with gravel, rock, or timber and the area adequately drained. Suitable methods of disinfecting the water for the troops should be installed if necessary. Faucets of canteen fillers should be small enough to fit into the canteens.

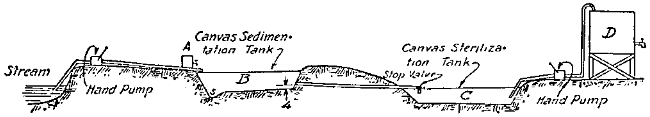


FIGURE 32.—Improvised purification plant

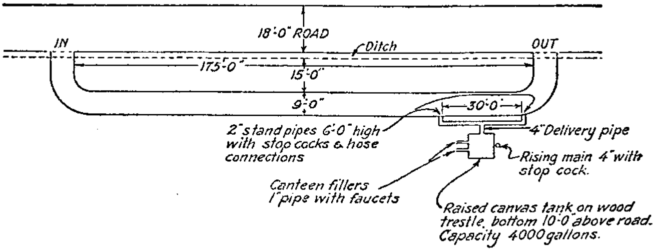


FIGURE 33.—Typical water point

d. Horse troughs (see fig. 35) need not be supplied with disinfected water, although clean water is desirable. Streams are used, when available, by pumping into the troughs. The ground in front of the troughs should be paved for about 12 feet. Guard rails are essential, and chicken wire can be used to prevent animals from gnawing wooden frames or canvas. In estimating the troughing required, allow 4 feet frontage per horse and five minutes for each animal to water.

e. In stabilized situations water may be supplied for laundries, lavatories, and baths. The lavatories usually consist of a pipe with faucets at intervals of 2 to 2½ feet placed over a shelf and V-shaped waste trough. Large, centrally located bath and delousing plants are operated by the Quartermaster Corps, but there are many opportunities to set up the 8-head showers, with heater and piping, which should be available in the army dump.

f. If possible, all hospitals should receive piped supplies available at kitchens, operating rooms, and baths. Veterinary evacuation hospitals and veterinary convalescent hospitals are army units requiring relatively large amounts of water, which should be piped if the permanence of the location will permit.

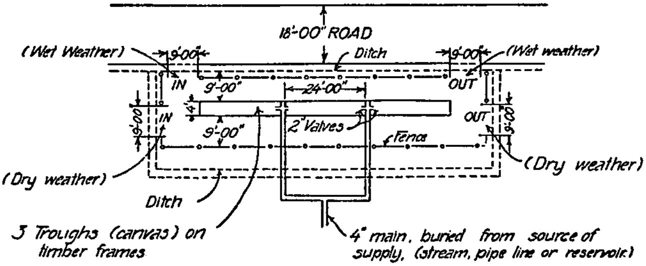


FIGURE 34.—Typical water point for animals

g. Railway watering points must be provided at engine houses and sorting yards. For watering engines on main traffic lines, points should be provided where trains will stop for traffic requirements and where engines will not have to be taken from the trains for watering. Watering points for yards should be off of the main lines so as not to obstruct traffic.

Filling stations for locomotives and tank cars should be of about 25,000-gallon capacity and so arranged that the time for filling may be reduced to a minimum and that engines can water without being detached from their trains. Locomotive filling tanks should be about 10 or 15 miles apart on main lines, at engine terminals and yards. Side tracks must be provided so that tank cars can be filled without impeding main-line traffic. Tanks are usually of steel or timber, the circular tank of 3-inch timber with iron binding rods and turnbuckles being particularly suitable, as it can be knocked down for shipment. Posts for such a tank should be 8 by 8 inches. Four or six inch piping should be used and hose connections for filling tank cars and locomotives provided. The bottom of the tank should be about 16 or 17 feet above track level.

h. Water discipline is of the highest importance. Guards should be available to superintend the filling of storage basins and tanks and canteen fillers, to see that water is chlorinated, to prevent waste, and to control traffic in the absence of military police. Discipline at animal-watering points should provide for admission at one time of sufficient animals to utilize the full length of the trough, to see that bits are removed, and to see that no animals attached to vehicles are permitted to water.

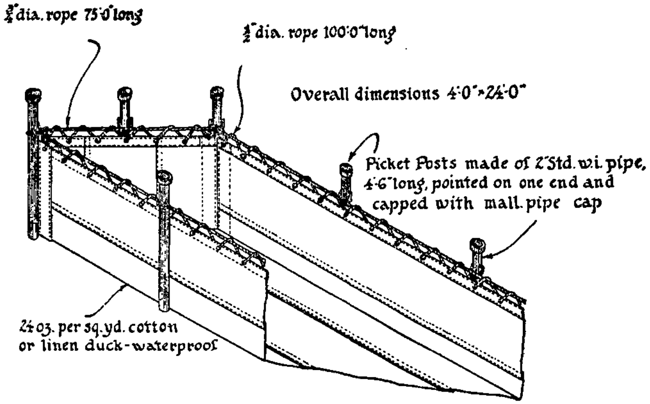


FIGURE 35.—Canvas horse trough

i. Proper use of signs in connection with water-distributing points is of the greatest importance, and they should be placed at road junctions and other points within a radius of from 500 to 2,000 yards as well as at the water point.

SECTION VII

WATER SUPPLY MACHINERY

59. Pumps.—*a.* The windlass with one or two buckets is the most common method of raising water. It is subject to the objection that it facilitates contamination of the water in the well. Hand force pumps may be used for shallow wells. For deep wells, if the water rises high enough, the best method for raising water is the electrically driven centrifugal pump, either fixed on supports across the well or in a chamber cut within the suction lift of the water; otherwise some type of deep well plunger, air lift, or vertical centrifugal pump set well below water level must be used. Power can be furnished by a portable gasoline engine.

b. A canvas-belt elevator can be quickly installed in an open well. An endless 8-inch canvas belt weighing 0.346 pound per yard is used, running over a 15-inch belt drum, the bottom loop immersed in the water 6 inches from the bottom of the well when at rest. Water is taken off by a scraper at the top or at high speeds by centrifugal force. These elevators were used by the British forces for delivering 1,000 to 2,000 gallons per hour at depths of 40 to 200 feet. The chief disadvantage was a lack of durability in the belts. Slip can be avoided by tacking a 4-inch strip of canvas around the middle of the pulley and for the shallower wells using two or more belts superimposed. A 3 to 5 horsepower gas engine is suitable for power. The amount of water that can be lifted by a plunger pump depends on the diameter and the stroke as well as the speed. With a 6-inch hole, a 4-inch rising main and a 3¾-inch pump barrel can be used, giving 200 gallons per minute. With a 6-inch rising main and 5¾-inch barrel, 500 gallons per minute may be obtained. Pumps have been built to handle 1,400 gallons per minute against a head of 150 feet. It often happens that it is difficult to keep sand and grit out of the pump barrel with ordinary strainers, and considerable damage and loss of efficiency can result from this cause. For moderate ease of installation 250 feet is the maximum depth of pump barrel below the surface. The suction lift should never be greater than 20 feet. Under some conditions it is necessary to change the elevation of the pump to adjust to varying levels of water; the practicable speed decreasing as the depth increases. The stroke of reciprocating pumps varies from 6 inches to 40 inches with speeds up to 40 revolutions per minute. Owing to shock and vibration maintenance charges are high.

c. (1) A centrifugal pump consists of a set of vanes mounted on a shaft and inclosed in a pump case. When the shaft is rotated, water admitted at the base of the vanes along the shaft is given a radial motion; and as it is confined by the pump case, this motion is converted into pressure and water discharged.

(2) The pump may be of either the horizontal or the vertical shaft type. The horizontal is the standard form and should be

used when possible. (See fig. 36.) The vertical type has the advantage that a short belt or direct drive can be used on the surface and power transmitted down to the pump by the shaft. It will operate under water, and this is convenient where large fluctuations of the water table occur, but a considerable loss of efficiency takes place in friction losses in the bearings supporting the shaft.

(3) When electrical power is available centrifugal pumps are usually directly connected to the motor. A saving in power is effected by discarding the belt; but as the motor has a fixed speed, it must be designed to fit the conditions under which it is to work.

(4) Centrifugal pumps are rated according to the size of the discharge openings in inches. The capacity varies with the total head (including suction lift), the speed, and the design of the impeller. Small pumps run at higher speed than the larger ones, and the same pump must run at a higher speed for greater heads. Average figures for a single-stage belt-driven pump are as follows:

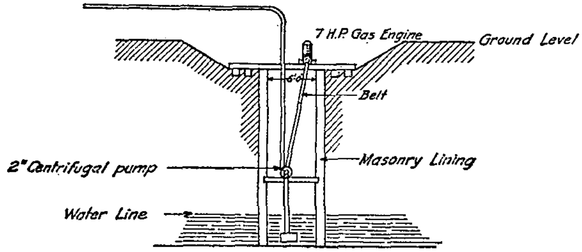


FIGURE 36.—Typical centrifugal pump installation

TABLE VII.—*Centrifugal pump data*

Size of suction and discharge in inches	Normal capacity in gallons per minute at 40 feet total head	Recommended horse power for each foot of lift at normal capacity
1	20	0.02
2	100	.06
2½	150	.085
3	225	.114
4	400	.20

(5) The efficiency reported by manufacturers is rarely attained under field conditions. A centrifugal pump is not ordinarily operated under more than a 17-foot suction lift; and as greater lifts are difficult to avoid if horizontal pumps are used and there is much fluctuation of the water table, it may be necessary to reset the pump from time to time to keep it within 17 feet of the water level. A 10 or 12 foot suction lift (or less when possible) results in more satisfactory operation. If a centrifugal pump, taking its supply from a reservoir, can be installed below the level of the water so as to have a positive head on the suction of the pump, its operation is more satisfactory and certain than where there is a suction lift.

(6) It is necessary to prime centrifugal pumps either by extracting the air from the top of the pump casing or by admitting water under pressure when the pump is not running and allowing the air to escape through a valve at the top of the casing. If pumping from driven wells, a vacuum chamber should be inserted in the suction pipe with an ejector for exhausting the air from the top of the chamber. Dissolved air will separate from the water and stop the pump unless this precaution is taken for its removal. In temporary field installations, where such provision is impracticable, it may be necessary to stop the pump from time to time and remove the accumulated air.

(7) In a recent form of centrifugal pump, called the deep-well turbine, the shafting is inclosed in the discharge pipe and the apparatus designed to fit inside a well casing. As the impellers are small, a number of stages are provided—one for each 20 or 30 feet of lift. It is of the turbine type, supported at the ground and hangs free in the well. Power may be applied by a belt or directly by a vertical motor.

d. The air-lift pump is adapted to supplying large amounts of water from great depths. Compressed air is forced down an air pipe and delivered near the bottom of a discharge pipe, where it expands and rises bringing water with it. The length of the submerged portion of the air pipe should be from 30 to 70 per cent of the distance from the bottom of the air pipe to the point of discharge. It is preferable to have 70 per cent submergence of the eduction pipe. The pressure used ranges from 20 to 100 pounds per square inch and is usually one-fifth to one-fourth pound per foot of lift. There are no moving parts to wear, and it may be operated from a distant air compressor, but the efficiency is not high.

60. General suggestions for the use of portable pumping sets.—*a. Setting up for operation.*—The pump should be brought to the nearest level spot to the water hole, sump, or stream from which water is to be pumped. Although a pump head will lift from 10 to 20 feet, it is always advisable to shorten suction lift as much as possible. Every unnecessary additional foot of suction lift cuts down the discharge volume and pressure accordingly. An added foot of suction lift will decrease the possible discharge head at least five times that amount. Attach the suction hose securely to the suction port of the pump, making sure there are no air leaks. Attach the strainer to the other end of the suction hose. If the suction lift is over 10 feet, it is advisable to use a check valve or foot valve at the end of the suction hose so that the pump may be readily primed if stopped for any reason during the operation. Attach the suction strainer to this foot valve if the foot valve has no strainer on it. If a swing check valve is used as a foot valve, the suction strainer should be attached to it. Keep the strainer well under the surface of the water, but *do not allow it to rest on the bottom of the water hole and do not permit it to come in contact with grit or fine rock.* Place a stick or rock underneath to keep the strainer off the bottom or float it from a block on the surface of the water. Grit and sand will cut the pump and cause it to lose its suction and efficiency.

b. No specific rules can be laid down for the use of hose lines because of the wide variation in the nature of the terrain elevation and topography of the various localities in which pumping sets are used. However, it is the general purpose to reach either the longest distance the most easily or cover the widest area with the least amount of hose. The Siamese connection used in connection with pumping sets is a valuable part of pumping equipment. It allows two or more hose lines to be used, permitting the extension of the hose to a wide front or to both sides of a fire or area to which water has to be brought. A Siamese connection used at the pump outlet, as in Figure 37, will handle four discharge nozzles by connecting two additional Siamese connections on the two primary lines. It is suggested that gate or stop valves be used at every point in connection with these Siamese connections so that the water may be closed down at one point while hose is being changed. A Siamese connection in the line with a valve may be used to take water from the line for any purpose.

c. Relay pumping.—It is often necessary and many times desirable to place water at an elevation above the pumping set, impossible to reach with a single unit. It is practical and simple to connect two or more pumps in series and relay the water to elevations up to 1,500 feet through a mile of hose line. The simplest means is to pump from the lower pump to an elevation of about 200 feet into a canvas tank partly buried in the ground or suspended; placing the suction of the second pump at that elevation into this tank or pump and pumping to a second elevation. Another very practical way of relay pumping where tanks are not available is through the use of Siamese connections. In order to supply the second pump in a relay series, the plant at the source of the water should be connected up as usual. The second plant should have a Siamese connection put on at the suction end with a valve on one side of the Siamese. The regular discharge hose from the first pump should be connected into the open end of the Siamese on the suction of the second unit. The valve on the other side of the Siamese should be left open and the first pump started. When the water reaches the second unit and starts to run out of the valve, the second pump should be started and the valve closed. This same connection may be repeated on the pumps above. (See fig. 37.) By this method relay tanks are done away with.

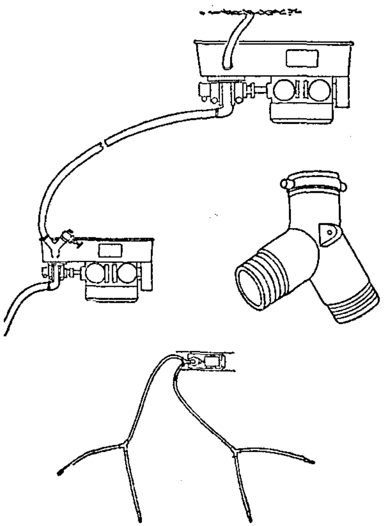
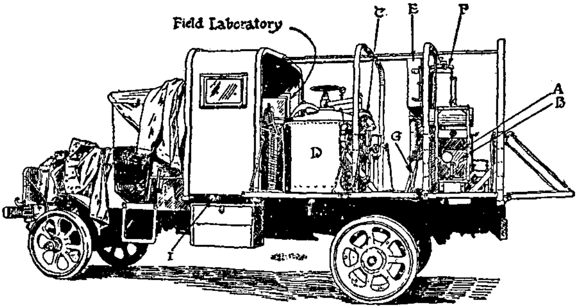


FIGURE 37.—Siamese connection used with portable pump

61. Mobile purification unit.—*a.* (See fig. 38.) The entire equipment of this unit is mounted on a 3½-ton truck and consists essentially of a modified truck body; a single-stage, 2-inch, double-suction, horizontal centrifugal pump, directly coupled to a 4-cylinder gasoline engine of 20 to 25 horsepower; a 42-inch rapid sand pressure filter, 5 feet high, with a hand agitator; a 5-way control valve; a direct dry feed or a solution feed chlorinator; an alum pot; a 12-gallon soda ash tank with appropriate feeds; a 32-gallon contact tank; a venturi meter; and a simple laboratory for making acidity, alkalinity, free chlorine, color, and turbidity tests. In some models slight modifications in the above have been made including the substitution of a power take-off from the truck engine in lieu of a special engine for the pump.

b. (See fig. 39.) (1) The water is drawn in through the suction line by the centrifugal pump and forced to the 5-way valve, which can be set to normal filtering, filter to waste, washing filter, by-passing the filter (i. e. from pump to contact tank), or closed.



A Pump
B Engine
C Five-way valve
D Filter
E Chlorinator
F Soda-ash Apparatus
G Alum pot
I Contact tank

FIGURE 38.—Mobile purification truck

(2) Chlorine is fed into the suction line and is thoroughly mixed with the water while passing through the pump and filter. Sufficient chlorine as determined by tests with orthotolidin is applied to leave a minimum of 0.5 part per million of free chlorine in the effluent. The chlorine is supplied in steel cylinders containing 1.1 cubic feet or approximately 100 pounds of the liquefied gas. A solution of alum also is fed into the suction line and reacts with the alkali in the water to form a flocculent precipitate which is deposited in a layer on the top of the sand in the filter. If the water is normally acid, neutral, or has insufficient alkalinity this precipitate does not form and

it is necessary to add a certain amount of alkali (2 or 3 per cent sodium carbonate) by means of the soda-ash system, feeding likewise into the pump suction. Sufficient alum is used to remove the turbidity and leave a residual alkalinity of 10 parts per million in the effluent. In general, one grain of alum per gallon reduces the alkalinity five parts per million. The correct amount is determined by the difference in alkalinity between the raw and filtered water. If ferrous iron is present, it will be precipitated after filtration as a reddish ferric iron. The addition of hydrated lime through the alkalinity device changes the ferrous to ferric iron, which is then removed by the filter.

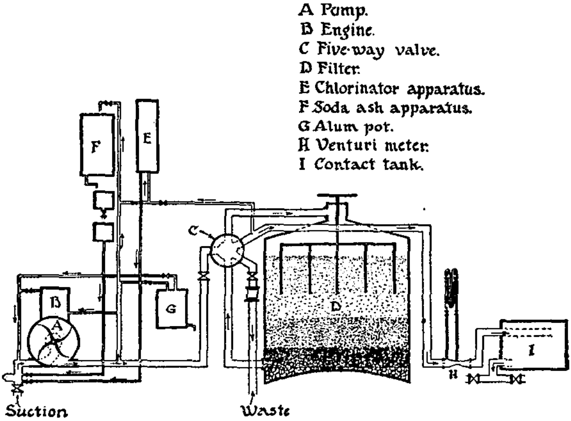


FIGURE 39.—Diagram piping system of mobile purification unit

(3) After passing through the filter the water normally goes to the contact tank, where it is retained for a brief time to permit the chemical action of the chlorine and to furnish a small reservoir for the laboratory water supply. The discharge lines lead from the contact tank at both sides of the truck.

(4) The pump has a rated capacity of 100 gallons per minute against a 75-foot head when operating at 1,150 revolutions per minute. It may be operated as a simple pumping unit, as a pumping and chlorinating unit or as a pumping and filter unit with or without chlorination.

SECTION VIII

FORMULAS AND TABLES

62. Symbols used.

v = velocity in feet per second
p = pressure in pounds per square foot
w = weight of 1 cubic foot of water = 62.4 pounds
g = acceleration due to gravity = 32.2 feet per second—per second (average)
h = total head in feet
H = hydrostatic head
h_f = friction head (head lost on account of friction)
l = length of pipe line in feet
d = diameter of pipe in feet
f = friction factor
Q = discharge in cubic feet per second
a = area in square feet

$$r = \text{hydraulic radius} = \frac{\text{area of wet cross section}}{\text{wetted perimeter}}$$

$$= \text{(for circular pipes flowing full) } \frac{d}{4}$$

$$s = \frac{\text{head in feet}}{\text{length in feet}} = \frac{h}{l}$$

$\frac{v^2}{2g}$ = theoretic head required to produce a given velocity

63. Flow of water in pipes.—The fundamental statement of hydrodynamics is the Bernoulli theorem, which may be expressed as follows: At any section of a pipe or tube under steady flow without friction the sum of the velocity head $\left(\frac{v^2}{2g}\right)$ and the pressure head $\left(\frac{p}{w}\right)$ equals the hydrostatic head (H) that obtains when there is no flow. The expression p/w or pressure head is the head which gives rise to the pressure p. In Figure 40 a sloping pipe is connected to a reservoir. At points A and B on the pipe are inserted vertical tubes open at the top. If the flow in the pipe is shut off at the lower end, water will rise in both vertical tubes to the level of the water surface in the reservoir. Evidently the head at A is H_1, and at B it is H_2. If flow is again permitted in the pipe and we assume that it takes place without friction loss, we can establish certain relations between the hydrostatic pressure and velocity heads at any particular point. While flow is taking place, water in the vertical tube at A, for example, will not rise to the water surface level of the reservoir but to some point lower than this. The extent to which it does rise in the tube is a measure of the pressure head (p/w) at the point and the difference between the hydrostatic head and the pressure head is evidently the head that produces the velocity of flow in the pipe—

$$H_1-\frac{P_1}{W}=\frac{V_1^2}{2g}$$

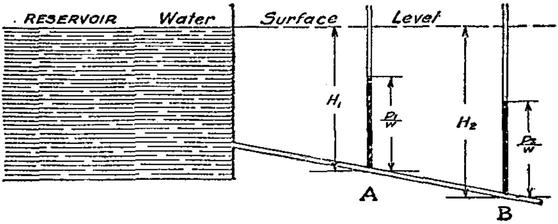


FIGURE 40.—Flow of water in pipes

This expresses Bernoulli's theorem in equation form. Similarly at point B—

$$H_2=P_2/W+V_2^2/2g$$

From the above it is apparent that the pressure head at any section decreases when the velocity increases. At the outlet where the pressure head is zero—

$$H_b=V_b^2/2g$$

But in steady flow with friction, the total hydrostatic head on the outlet (h) equals the sum of the head which produces the velocity of discharge and the head required to overcome friction between the reservoir and the outlet. Then

$$h=v^2/2g+h_f \qquad (1)$$

Considering points other than the top and bottom of the pipe, a general statement of the law governing the flow in pipes may be given as follows: The total head at any section is equal to that at any subsequent section plus the head lost on account of friction between the two sections.

If, as explained below, the lost head (h_f) is expressed in terms of V, equation (1) becomes the general equation for the solution of problems concerning pipe flow, losses other than those due to friction being neglected.

64. Lost head.—In a straight pipe of uniform section the only losses of head of importance are the head lost at entrance and that lost in friction. Sudden changes in direction or diameter or obstruction to the flow by partially closed valves introduce losses which need not be considered here. The friction factor, f, decreases as the velocity increases and as the diameter increases; it increases with the roughness of the pipe. The friction head is directly proportional to the length of pipe, is inversely proportional to the diameter, increases nearly as the square of the velocity, increases with the roughness and is independent of the pressure.

$$\text{Head lost by friction} = h_f = \frac{fl}{d} \times \frac{v^2}{2g}$$

Disregarding the loss of head at entrance and substituting the above value for h_f in equation (1)

$$h = v^2/2g + f\,\frac{l}{d}\,v^2/2g \tag{2}$$

That is, the head necessary to give a desired discharge at the outlet must be sufficient to overcome in addition the friction in the pipe line. But in a long pipe—that is, where the length is at least 500 times the diameter—the loss by friction will take up practically the whole available head. For example in a 12-inch pipe line 4,000 feet long with the reservoir surface 100 feet above the discharge, 98 per cent of the head is lost in friction. In such pipe lines we may even disregard the head necessary to give the discharge velocity. For practical purposes (2) may be written

$$h = h_f = \frac{fl}{d} \times \frac{v^2}{2g}$$

$$v = \sqrt{\frac{2ghd}{fl}} = 8.02\sqrt{hd/fl} \tag{3}$$

For rough computations, f may be assumed to have a value of 0.02.

65. Solution of pipe problems.—*a.* The common formula for flow in open channels, the Chezy formula, may also be used in computations for long pipes. This formula is

$$v = C\sqrt{rs}. \tag{4}$$

The term "r" is the hydraulic radius and equals the area of the wet cross section divided by the length of the wetted perimeter. For a circular pipe flowing full $r=d/4$. The term "s" (slope) $=h/l$. The values of C for various conditions have been determined by experiment and may be obtained from Table VIII. The mean value of C for new pipes is 114. Most pipe problems can be solved with sufficient accuracy for ordinary military conditions by using Chezy's formula and the following:

$$Q=av.$$

Results need not in any case be carried to more than three significant figures. A common problem in pipe flow is: Having h, l, and d given, find v and Q. For example, assume that $h=100$ feet, $d=12$ inches, and $l=4{,}000$ feet, and, as a trial, assuming a value of $C=115$ we have in equation (4)—

$$v=115\sqrt{rs}$$

$$\text{here } \sqrt{r}=\sqrt{1/4}=0.5$$

$$\sqrt{s}=\sqrt{\frac{100}{4{,}000}}=\sqrt{0.025}=0.158$$

$$v=115\times0.5\times0.158$$

$$=9.1 \text{ ft. per second.}$$

Taking 9 feet per second as sufficiently close, we find the value of C from Table VIII to be about 115, so no recomputation is necessary. If it should be found that the velocity computed does not correspond with a value of C in the table substantially equal to that assumed, a value of C corresponding to the velocity in the trial computation may be taken from the table and the formula recomputed for a new value of v.

Finally:

$$Q=av=0.785\times9 \quad (a=0.785d^2)$$

$$=7.06 \text{ cu. ft. per second.}$$

b. The usual method of finding the diameter necessary to deliver a certain amount of water, having h, l, and Q given, requires finding the fifth root. It is generally easier to assume a diameter and solve equation (4) for v and Q. An estimate can then be made of the necessary amount to increase or reduce the trial diameter so that the equation will give the required value of Q. Here it may be useful to note that the discharge varies about as $d^{2.5}$. Since the velocity increases with the diameter, a direct relationship does not exist.

Example: To compute the diameter necessary to discharge 9 second-feet with a head of 50 feet in a distance of 2 miles. For a trial assume $d=10$ inches and $C=110$. Then

$$\begin{aligned} v &= 110\sqrt{rs} \\ &= 110\times 0.456\times 0.0688 \\ &= 3.45 \text{ feet per second} \end{aligned}$$

$$\text{and } Q=av=0.545\times 3.45=1.88 \text{ second-feet.}$$

The value required, 9 second-feet, is about five times the result obtained. Inasmuch as the velocity is somewhat larger with a larger pipe, make a second trial with a pipe having an area about 4 times that of a 10-inch pipe or one having a diameter the square of which would be about 4×10^2, namely, a 20-inch pipe. With a 20-inch pipe—

$$C=113$$

$$\begin{aligned} \text{and } v &= 113\sqrt{rs} \\ &= 113\times 0.646\times 0.0688 \\ &= 5.0 \text{ feet per second} \\ Q &= 2.18\times 5.0 \\ &= 10.9 \text{ second-feet.} \end{aligned}$$

This is satisfactory. The next smaller size, 18-inch, will give a discharge less than $\frac{18^2}{20^2}\times 10.9=8.8$, and this will be too small.

TABLE VIII.—*Values of C for iron pipes*

[By Williams, American Civil Engineers Pocket Book, p. 1089]

Diameter in inches	Velocities in feet per second							
	For new pipe				For old pipe			
	1	3	6	10	1	3	6	10
3	95	98	100	102	63	68	71	73
6	96	101	104	106	69	74	77	79
9	98	105	109	112	73	78	80	84
12	100	108	112	117	77	82	85	88
15	102	110	117	122	81	86	89	91
18	105	112	119	125	86	91	94	97
24	111	120	126	131	92	98	101	104

c. At times it will be necessary to determine the size required and then compute the number of pipes of a smaller size which discharge the required amount. Based on the fact that relative discharge varies as the 5/2 power of the diameter, Table IX supplies means of determining this for the sizes commonly used. Example: To find size of pipe necessary to supply 28 branches of 1-inch pipe, read down column headed "1" for a number larger than 28—in this case 29—and find answer in column 1 at the left which gives diameter of pipe required as 4-inch.

d. The greater number of military pipe problems may be solved with sufficient accuracy by Table X for long pipes. It applies to new straight cast or wrought iron pipes, and may be used to advantage for problems involving the sizes given; it applies equally to steel or wood. The discharge coefficient for riveted steel is 10 to 25 per cent less than for smooth new iron.

Example: Given a 6-inch pipe 3,000 feet long with a total head of 36 feet, find the velocity and the discharge: Assuming that the velocity head is so small as to be negligible, the friction head per 100 feet will be $100\times36/3000=1.2$. From the table, for 6-inch pipe, the velocity is found to be 4 feet per section and the discharge 352 gallons per minute. For old pipe, enter the table with only one half the available head. If the above problem were for old pipe, the friction head used would be 0.6 per 100 feet, the velocity would be 2.8 feet per second, and the discharge 247 gallons per minute. Similarly, if the velocity is given, the actual friction head for an old pipe may be obtained by multiplying the tabular value by 2. For a velocity of 4 feet per second, the friction head in an old 6-inch pipe is 2.4 feet per 100 feet. The discharge must be reduced to allow for the age of any pipe which has been, or is expected to be, in service more than one or two years. The term "old pipe" as used here applies to an age of 10 years or more.

To find the diameter necessary to furnish a given discharge with a given head and length of pipe:

Example: Find the diameter of a pipe to discharge 4 gallons per minute under a head of 21 feet in a pipe line 1,000 feet long. Here the friction head is 2.1 feet per 100 feet. The table shows a discharge of 4.4 gallons per minute under 1-inch pipe with a velocity of 1.8 feet per second and the 1-inch pipe could be used. In connection with branching pipes, it is usually necessary to compute each branch separately, but note may be made of the fact that the friction head in a pipe discharging uniformly throughout its length is about one-third that of a pipe discharging only at its end.

e. If a check computation is desired on the application of the Chezy formula, $v=C\sqrt{rs}$, or on data taken from Table X, equation (3), paragraph 64, can be used with a value of f based on the following equations of Darcy:

$$\text{New pipe—}f=0.02+\frac{0.02}{12d}$$

$$\text{Old pipe—}f=0.04+\frac{0.04}{12d}$$

As f varies with the velocity, the values are not exact but they are sufficiently so for use here. (d=diameter in feet and $12d$ here=pipe diameter in inches.)

f. The calculating diagram (fig. 41) for cast-iron pipe given below may be used in arriving at results quickly in pipe problems. If any two of the quantities shown on the four vertical lines are known, the other two may be read directly from the diagram. This eliminates the necessity of trial computations.

The results from the diagram may not agree in every case with results derived from the use of formulas, but the values from the calculating diagram provide some margin of safety.

66. Pipe line with pump.—If a pump lifts water from one reservoir to another it requires power not only to lift the water through the height, h, but also to overcome the friction head, h_l, in the suction and discharge piping so that the pump works against a head $h+h_l$. The expression h_l includes the velocity head of discharge. The power of a pump is—

$$\text{Foot-pounds per second}=\frac{w\ (h+h_l)}{e}$$

where w=number pounds lifted per second
e=efficiency.

To raise 20 cubic feet per second 16 feet with a pump efficiency of 0.62 and a friction head of 4 feet,

$$\frac{20\times 62.4\times(16+4)}{0.62}=40{,}260 \text{ foot-pounds per second.}$$

This divided by 550 gives 73.2 horsepower.

If a complete vacuum could be produced below the plunger of a pump, and if there were no friction, the suction lift would be equal to the atmospheric pressure (in feet of water) or about 34 feet. In practice the suction lift is limited to 24 feet or preferably less than this.

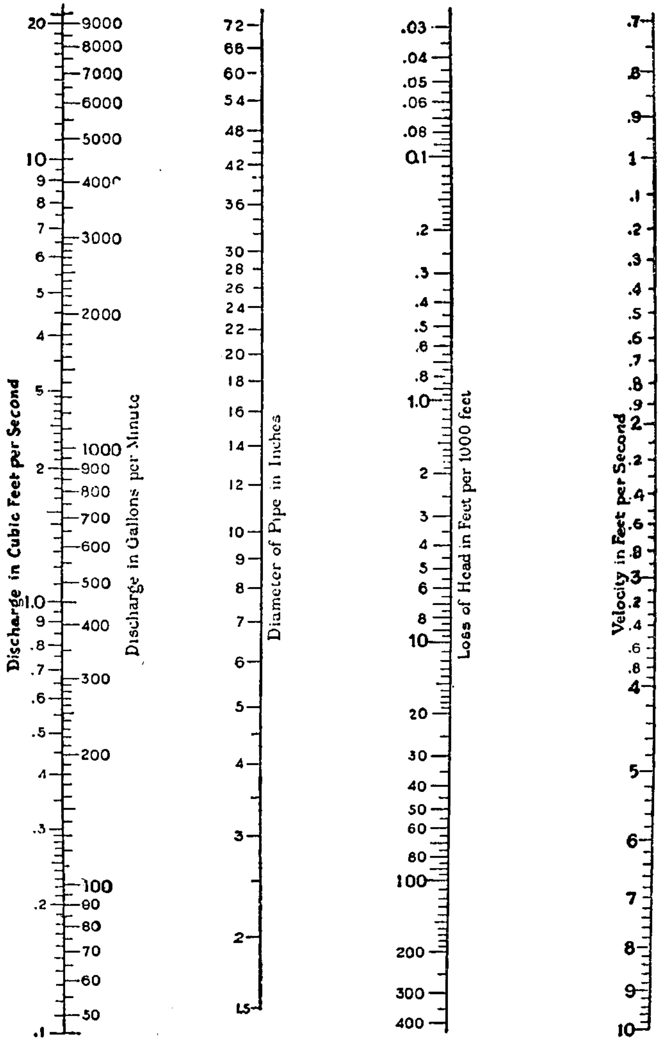


FIGURE 41.—Diagram for calculating cast-iron pipes

TABLE IX.—*Relative capacity of pipes of different diameters*

Diameter (inches)	1	2	4	6	8	10	12	15
1	1.0	0.18	0.034	0.012	0.0062	0.0035	0.0022	0.0012
2	5.5	1.0	.19	.067	.034	.019	.012	.0068
4	29.0	5.3	1.0	.36	.18	.10	.067	.036
6	80.0	15.0	2.8	1.0	.77	.29	.18	.10
8	160.0	29.0	5.5	2.0	1.0	.56	.36	.20
10	282.0	52.0	10.0	3.5	1.8	1.0	.62	.34
12	443.0	81.0	15.0	5.5	2.8	1.6	1.0	.56
15	806.0	148.0	28.0	10.0	5.0	2.9	1.8	1.0

TABLE X.—*Discharge and friction head for clean iron pipes*

[From values of *f* by Merriman]

	1-inch pipe			2-inch pipe		
Velocity (feet per second)	Second-foot	Gallons per minute	Friction head-feet per 100 feet	Second-foot	Gallons per minute	Friction head-feet per 100 feet
1.0	0.00545	2.44	0.7	0.0218	9.78	0.33
1.2	.00655	2.94	1.0	.0262	11.8	.46
1.4	.00764	3.43	1.4	.0305	13.7	.60
1.6	.00873	3.92	1.7	.0349	15.6	.77
1.8	.00982	4.41	2.1	.0393	17.6	.93
2.0	.0109	4.89	2.5	.0436	19.6	1.1
2.2	.0120	5.38	3.0	.0480	21.5	1.3
2.4	.0131	5.88	3.5	.0524	23.5	1.6
2.6	.0142	6.37	4.0	.0567	25.4	1.8
2.8	.0153	6.87	4.5	.0611	27.4	2.0
3.0	.0164	7.36	5.2	.0655	29.4	2.3
3.2	.0175	7.85	5.9	.0698	31.3	2.6
3.4	.0185	8.32	6.5	.0742	33.3	2.9
3.6	.0196	8.80	7.1	.0785	35.2	3.2
3.8	.0207	9.28	7.9	.0829	37.2	3.6
4.0	.0218	9.78	8.7	.0873	39.2	4.0
4.2	.0229	10.3	9.3	.0916	41.1	4.3
4.4	.0240	10.8	10.2	.0960	43.1	4.7
4.6	.0251	11.3	11.1	.100	45.0	5.1
4.8	.0262	11.8	12.0	.105	47.0	5.6
5.0	.0273	12.3	13.0	.109	48.9	6.0
5.2	.0284	12.7	14.0	.113	50.9	6.4
5.4	.0295	13.2	15.0	.118	52.9	6.8
5.6	.0305	13.7	16.0	.122	54.8	7.3
5.8	.0318	14.2	17.0	.127	56.8	7.8
6.0	.0327	14.7	18.0	.131	58.8	8.4
6.2	.0338	15.2	19.0	.135	60.7	8.9
6.4	.0349	15.6	20.0	.140	62.8	9.5
6.6	.0360	16.2	22.0	.144	64.6	10.0
6.8	.0371	16.7	23.0	.148	66.5	10.5
7.0	.0382	17.1	24.0	.153	68.5	11.0
7.2	.0393	17.6	25.0	.157	70.4	11.6
7.4	.0404	18.1	27.0	.161	72.4	12.2
7.6	.0415	18.6	28.0	.166	74.4	12.9
7.8	.0425	19.1	29.0	.170	76.3	13.4
8.0	.0436	19.6	31.0	.175	78.3	14.2
8.2	.0447	20.1	32.0	.179	80.3	14.9
8.4	.0458	20.6	34.0	.183	82.2	15.5
8.6	.0469	21.0	35.0	.188	84.2	16.4
8.8	.0480	21.5	37.0	.192	86.2	16.7
9.0	.0491	22.0	38.0	.196	88.1	17.0
9.2	.0502	22.5	40.0	.201	90.1	18.0
9.4	.0513	23.0	41.0	.205	92.0	19.0
9.6	.0524	23.5	43.0	.209	94.0	20.0
9.8	.0535	24.0	45.0	.214	96.0	21.0

TABLE X.—*Discharge and friction head for clean iron pipes*—Con.

[From values of *f* by Merriman]

Velocity (feet per second)	4-inch pipe			6-inch pipe		
	Second-feet	Gallons per minute	Friction head feet per 100 feet	Second-feet	Gallons per minute	Friction head feet per 100 feet
1.0	0.0873	39.2	0.14	0.196	88	0.087
1.2	.105	47.0	.20	.235	106	.13
1.4	.122	54.8	.27	.275	123	.17
1.6	.140	62.7	.34	.314	141	.21
1.8	.157	70.5	.41	.353	159	.27
2.0	.175	78.3	.50	.393	176	.34
2.2	.192	86.2	.60	.432	194	.39
2.4	.209	94.0	.71	.471	212	.46
2.6	.227	102	.82	.510	229	.53
2.8	.244	110	.94	.550	247	.60
3.0	.262	118	1.07	.589	264	.70
3.2	.279	125	1.2	.628	282	.79
3.4	.297	133	1.3	.668	300	.88
3.6	.314	141	1.4	.707	317	.97
3.8	.332	149	1.6	.746	335	1.08
4.0	.349	157	1.8	.785	352	1.2
4.2	.367	164	1.9	.825	370	1.3
4.4	.384	172	2.1	.864	388	1.4
4.6	.401	180	2.3	.903	405	1.5
4.8	.419	188	2.5	.942	423	1.6
5.0	.436	196	2.7	.982	441	1.8
5.2	.454	204	2.9	1.02	458	1.9
5.4	.471	212	3.1	1.06	476	2.0
5.6	.489	219	3.4	1.10	494	2.2
5.8	.506	227	3.6	1.14	511	2.3
6.0	.524	235	3.9	1.18	529	2.4
6.2	.541	243	4.1	1.22	546	2.6
6.4	.558	251	4.4	1.26	564	2.8
6.6	.576	258	4.6	1.30	582	2.9
6.8	.593	266	4.9	1.34	599	3.1
7.0	.611	274	5.1	1.38	617	3.2
7.2	.628	282	5.4	1.41	634	3.4
7.4	.646	290	5.7	1.45	652	3.6
7.6	.663	298	6.0	1.49	670	3.8
7.8	.681	305	6.3	1.53	687	3.9
8.0	.698	313	6.6	1.57	705	4.1
8.2	.716	321	6.9	1.61	723	4.3
8.4	.733	329	7.2	1.65	740	4.5
8.6	.750	337	7.5	1.69	758	4.7
8.8	.768	345	7.8	1.73	776	4.9
9.0	.785	352	8.1	1.77	793	5.1
9.2	.803	360	8.5	1.81	811	5.3
9.4	.820	368	8.8	1.85	828	5.5
9.6	.838	376	9.1	1.88	846	5.7
9.8	.855	384	9.4	1.92	863	6.0

67. Convenient data for hydraulic calculations.

Area of circle $=\pi r^2=\frac{1}{4}\pi d^2=0.7854d^2$
π $=3.1416$
g (average) $=32.2$ feet per second
v (theoretical velocity) $=\sqrt{2gh}=8.02\sqrt{h}$
h (theoretical velocity head) $=v^2/2g=0.0155v^2$
1 atmosphere =29.92 inches mercury
=33.90 feet of water
=14.7 pounds per square inch
=760 millimeters mercury
1 meter =3.281 feet
=39.37 inches
1 foot =0.3048 meter
1 inch =25.4 millimeters
1 kilometer =0.6214 statute mile
1 mile =1.609 kilometers
1 gram =15.43 grains
=weight of 1 cubic centimeter of water
1 kilogram =2.20 pounds av.
1 grain per gallon =17.1 parts per million
1 part per million =0.0584 grain per gallon
1 pound (av.) =7,000 grains
Grains per gallon/7 =pounds per 1,000 gallons
1 ton water =32.0 cubic feet
1 imperial gallon =1.20 gallons (United States)
1 gallon (United States) =231 cubic inches
=0.1337 cubic foot
=3.785 liters
=8.345 pounds (av.) of water
1 gallon per minute =0.002228 cubic foot per second
1 cubic foot =62.43 pounds water (average)
=7.480 gallons (United States)
=28.32 liters
1 cubic foot per second =448.8 gallons per minute
=0.0864 million cubic feet per day
=646,317 gallons per day
1,000,000 gallons per day =1.547 cubic feet per second
=694.4 gallons per minute
1 acre =43,560 square feet
1 barrel (oil) =42 gallons (United States)
1 pound per square inch =2.31 feet water

1 foot water =0.434 pound per square inch
1 inch on 1 square mile =2.323 million cubic feet
1 foot on 1 square mile =27.88 million cubic feet
1 kilowatt =1.34 horsepower
1 horsepower =550 foot-pounds per second—-0.746 kilowatt
=3,954 foot-gallons per minute
=5,694,120 foot-gallons per day
1 sterilizing bag =36 gallons (to the white mark)
Cart, water =180 gallons
Trailer, tank, water =180 gallons
Truck, tank, water-supply battalion =500 gallons
1 light railway tank car =2,000 gallons
1 standard railway tank car =8,000 to 10,000 gallons
1 canvas water basin (20 by 20) =4,000 gallons (approximate)
1 canteen =1 quart
=950 cubic centimeters (approximate)
1 canteen cup =700 cubic centimeters (approximate)
1 canteen top =8 cubic centimeters (approximate)
=2 teaspoonfuls

TABLE XI.—*Discharge in United States gallons through a circular orifice—head 1 foot. Coefficient of discharge=0.62*

Diameter (inch)	Area (square inch)	Gallons per minute	Gallons per day	Diameter (inch)	Area (square inch)	Gallons per minute	Gallons per day
0.05	0.002	0.0304	43.81	0.30	0.071	1.096	1,578
0.10	.008	.1217	175.3	0.35	.096	1.491	2,147
0.15	.018	.2739	394.3	0.40	.126	1.947	2,804
0.20	.031	.4869	701.1	0.45	.159	2.464	3,549
0.25	.049	.7607	1,096	0.50	.196	3.043	4,381

TABLE XII.—*Friction of water in hose*

Friction loss in pounds pressure per square inch, for each 100 feet of length in different size cotton rubber lined hose discharging given quantities of water per minute.

Gallons per minute	¾ inch	1 inch	1¼ inch	1½ inch	2 inch	2½ inch	3 inch
5	--------	0.84	0.310	0.12	--------	--------	--------
10	3.3	3.16	1.050	.47	0.12	--------	--------
15	13.0	6.98	2.380	.97	--------	--------	--------
20	28.7	12.30	4.070	1.66	.42	--------	--------
25	50.4	19.00	6.400	2.62	--------	0.21	0.10
30	78.0	27.50	9.150	3.75	.91	--------	--------
35	--------	37.00	12.40	5.05	--------	--------	--------
40	--------	48.00	16.10	6.52	1.60	.51	.20
45	--------	--------	20.20	8.15	--------	.61	--------
50	--------	--------	24.90	10.00	2.44	.81	.35
75	--------	--------	56.10	22.40	5.32	1.80	.74
100	--------	--------	--------	39.00	9.46	3.20	1.31
125	--------	--------	--------	--------	14.90	4.89	1.99
150	--------	--------	--------	--------	21.20	7.00	2.85

CHAPTER 3

LIGHT AND POWER

SECTION I

GENERAL PRINCIPLES

68. Military considerations.—*a. Military applications of electricity.*—The military applications of electrical engineering devices consist principally of lighting systems for headquarters, hospitals, shelters, depots, and schools, and power systems for operating shop or portable electrical machinery, for charging batteries, and for operating pumping and ventilating systems.

b. Sources of electricity.—As a general rule, the Army makes use of commercial sources of electrical energy whenever they are available within a reasonable distance and when the characteristics of the local power supply are such that the power is adaptable to the kinds of electrical machinery employed by the military forces.

c. Equipment.—The items of electrical equipment procured and stocked for the use of the field forces are limited to a few standard commercial items, including generating sets, ranging from 1½ to about 750 kilowatts, motors ranging from one-fourth to about 30 horsepower, single-phase transformers ranging from 5 to about 200 kilovolt-amperes, and the common articles of miscellaneous electric equipment. Both alternating-current and direct-current machines are used, depending principally upon the availability of suitable current and machines, although for certain special purposes such as searchlights, direct current is essential.

d. Character of installations.—The installation of large power plants in the combat zone is unusual because of the long time required to install the necessary machinery and because of the uncertainty as to the duration of the need for the plant. As a general rule, military requirements call for the immediate use of a small amount of power, the demands increasing from week to week. Such requirements usually can best be met by the installation of a small generating set, to be augmented by other small sets from time to time, in accordance with the need for electrical service. Military electrical installations may, therefore, seem uneconomical from the point of view of civil practice and will probably be most successful when the piecemeal character of their establishment renders them suitable for the immediate needs without much regard to the ultimate economy of the resulting system.

e. Scope of treatment.—The scope of this chapter is limited to information useful to the engineer in the installation and operation of equipment most likely to be used in the combat zone. The brief treatment of the theory of electricity here presented is just sufficient to afford a practical understanding of the principles most often applied in the field.

SECTION II

FUNDAMENTALS OF PRACTICAL ELECTRICITY

69. **Amperes.**—The ampere is the unit of measure of the current or rate of flow of electricity along a conductor. One ampere represents a flow of one unit of electricity per second.

70. **Volts.**—The volt is the unit of electromotive force. One volt is the force or pressure required to cause a current of 1 ampere in a circuit containing one unit of resistance.

71. **Ohms.**—The ohm is the unit of electrical resistance. A circuit has a resistance of 1 ohm when a pressure of 1 volt will force a current of 1 ampere through it.

72. **Direct current.**—A direct current is one which flows in a single direction in a conductor. Certain types of electric generating machines provide direct current.

73. **Alternating current.**—An alternating current is one that reverses in direction at regular intervals of time. Its value changes from zero to a maximum in one direction, returns to zero, and passes to a maximum in the reverse direction and returns to zero again. A complete set of these values through

which an alternating current repeatedly passes is called a *cycle*. The number of cycles per second is the *frequency* of the current. Common frequencies of alternating currents are 60 cycles per second and 25 cycles per second. The voltage of an alternating current also reverses periodically, just as does the current itself, but the corresponding values of voltage and current are not necessarily reached at the same instant. This is illustrated in Figure 42 which shows a curve of values of an alternating current and its corresponding voltage in a typical case where the current and voltage do not reach corresponding values at the same instant. In such a case the current and voltage are said to be out of *phase*. A similar phase difference exists between the several currents in a 2-phase or 3-phase alternating current system. Thus in a 3-phase circuit, carried on three wires, there

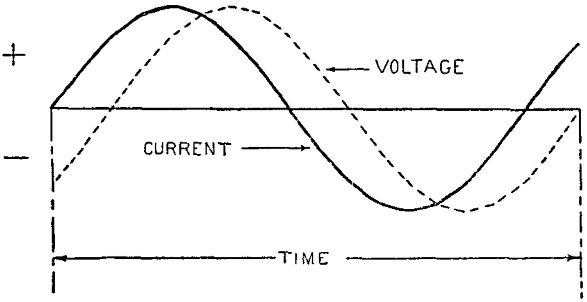


FIGURE 42.—Curves of alternating current and voltage

are three separate alternating currents, one flowing in each pair of the wires. These three currents are out of phase with each other by exactly one-third of a cycle. The practice has grown up of calling the current in each pair of wires a "phase." An alternating current circuit having but one current is called a *single-phase* circuit. One having more than one current is called a *polyphase* circuit. Alternating currents are provided by certain types of electric generating machines called *alternators*. Currents coming from transformers are also alternating currents. If necessary, an alternating current can be changed over to direct current by the use of a machine called a rotary converter. Batteries do not provide alternating currents, and alternating currents, unless rectified, can not be used to charge batteries.

74. Comparison of alternating and direct current.—The chief advantage of alternating current is that power in alternating current circuits may be transformed without material loss to higher voltages, permitting transmission over long distances to the point of consumption, where it can be transformed back to a lower voltage suitable for lamps and other uses. Direct current can not be so transformed and is therefore not easily distributed over a wide area. However, small direct-current generators are much simpler than alternating-current generators and most small portable sets in commercial use generate direct current. The question, then, as to which type of current to use will depend very largely upon the type which is available. From the point of view of the consuming end there is little difference. Machines designed to use direct current are not ordinarily usable with alternating current, and vicè versa, but incandescent lamps may be operated with either type of current.

75. Watts.—*a. Definition.*—The watt is the unit of electrical power.

b. Power in direct-current circuits.—In a direct-current circuit, the power is equal to the current in amperes multiplied by the pressure in volts. It can be determined by measuring the volts with a voltmeter and the amperes with an ammeter and multiplying their values. Thus, in a direct-current circuit:

$$W = EI$$

Where W = the power in watts
E = volts as measured with a voltmeter
I = current im amperes as measured with an ammeter.

c. Power in alternating-current circuits.—In alternating currents the foregoing rule for computing power does not apply since the voltage and current are generally not in phase with each other. The product of the volts and amperes in an alternating-current circuit gives what is called the *apparent power*. The *true power* in such a circuit may be measured with an instrument called a wattmeter. The ratio between the true power and the apparent power is called the *power factor*. When the power factor of a circuit is known, the true power may be obtained by multiplying the apparent power by the power factor. The power factor is usually expressed in per cent and is never greater than 100 per cent. The foregoing relations are expressed by the following formula for power in a single-phase alternating-current circuit or in any one phase of a polyphase alternating-current circuit:

$$W = p.f. \times E \times I$$

Where W = the true power in watts in a single-phase circuit or in any one phase of a polyphase circuit as measured with a wattmeter

E = the volts as measured with a voltmeter

I = the current as measured with an ammeter

$p.f.$ = the power factor, a percentage determined as described in paragraph 80.

76. Kilowatts and kilovolt amperes.—*a. Kilowatts.*—A kilowatt equals 1,000 watts and is a unit of electrical power sometimes more convenient to use than the watt. The relation of kilowatts to watts is shown in the following formulas:

$$\text{Kilowatts} = \frac{\text{watts}}{1{,}000}$$

$$\text{Kilowatts} \times 1{,}000 = \text{watts.}$$

b. Kilovolt-amperes.—The kilovolt-ampere (*kva*) is the customary unit of measure of the apparent power in an alternating-current circuit. Its value is expressed in the following formula:

$$\text{Kilovolt-amperes} = \frac{\text{volts} \times \text{amperes}}{1{,}000}$$

The relations between the kilovolt-amperes (*kva*), kilowatts (*kw*), and power factor (*p. f.*) of an alternating-current circuit are given in the following formulas:

$$\text{Kilovolt-amperes} = \frac{\text{volts} \times \text{amperes}}{1{,}000}$$

$$\text{Kilowatts} = \text{kilovolt-amperes} \times \text{power factor}$$

$$kva = \frac{kw}{p.\ f.}$$

$$p.\ f. = \frac{kw}{kva}$$

77. Horsepower.—Horsepower (*h. p.*) is the unit which measures the rate of doing mechanical work. One horsepower is the work required to raise 33,000 pounds vertically 1 foot in one minute. One horsepower is the equivalent of 746 watts, or 0.746 kilowatt. For either direct or alternating currents these relations are expressed by the following formulas:

$$h.\ p. = \frac{\text{watts}}{746} \qquad \text{watts} = 746 \times h.\ p.$$

$$h.\ p. = \frac{\text{kilowatts} \times 1{,}000}{746} \qquad \text{kilowatts} = \frac{746 \times h.\ p.}{1{,}000}$$

78. Ohm's law for direct current.—Ohm's law is a formula expressing the relation existing between electromotive force in volts, current in amperes, and resistance in ohms. This formula is the basis of many electrical computations. It may be expressed in several ways:

a. Current flow equals the electromotive force divided by the resistance.

$$I = \frac{E}{R}$$

b. Electromotive force equals the current flow multiplied by the resistance.

$$E = I \times R$$

c. Resistance equals the electromotive force divided by the current flow.

$$R = \frac{E}{I}$$

These relations hold good for circuits carrying direct current. For circuits carrying alternating currents, certain modifications are necessary, as explained in paragraph 79.

79. Ohm's law for alternating currents.—*a.* Alternating-current circuits have characteristics, such as inductance and capacitance, which affect the application of Ohm's Law. The theory of these characteristics of alternating-current circuits is beyond the scope of this manual to discuss, but the following formulas permit of practical calculations for the majority of alternating-current work likely to be met in the combat zone.

b. Single-phase circuits.—The relations between current, voltage, power, and power factor in a single-phase circuit are given by the following equations:

$$I = \frac{W}{E \times p.f.} \qquad E = \frac{W}{I \times p.f.} \qquad W = \frac{E \times I}{p.f.}$$

$$p.\ f. = \frac{\text{true power}}{\text{apparent power}} = \frac{W}{E \times I} = \frac{h.\ p. \times 746}{\text{volts} \times \text{amperes}} = \frac{h.\ p. \times 746 \times 1{,}000}{kva}$$

Where

I = current as measured with an ammeter
E = voltage as measured with a voltmeter
W = true power as measured with a wattmeter
$p.\ f.$ = power factor
$h.\ p.$ = horsepower
kva = kilovolt-amperes.

c. *Two-phase circuits.*—Two-phase circuits are so unusual that formulas therefor are omitted.

d. *Three-phase circuits.*—(1) The relations of current, voltage, power, and power factor in a 3-phase, 3-wire circuit furnishing current to lights only (noninductive load) are given by the following equations. In such a circuit the power factor equals unity and is therefore not shown in the equations.

$$I=\frac{W}{1.73\times E}$$

$$E=\frac{W}{1.73\times I}$$

$$W=1.73\times E\times I$$

Where I and E have the same meanings as in *b* above
W = the total true power of all three circuits.

(2) The relations of the voltage, current, power, and power factor in a 3-phase, 3-wire system carrying a mixed load of lights and motors (inductive load) are given by the following equations:

$$p.\ f.=\frac{\text{true power}}{\text{apparent power}}=\frac{W}{1.73\times I\times E}$$

$$=\frac{kw}{kva}$$

$$=\frac{h.\ p.\times 746\times 1{,}000}{kva}$$

$$kva=\frac{kw}{p.\ f.}$$

$$E=\frac{W}{1.73\times I\times p.\ f.}$$

$$W=1.73\times I\times E\times p.\ f.$$

Where I, E, W, $p. f.$, $h. p.$, kw, kva, have the same meanings as in *b* and (1) above.

80. Power factor.—*a.* The power factor (see par. 75*c*) in an alternating-current circuit is of much practical importance and must be carefully considered when putting a load upon a generator if damage to equipment and operating failures are to be avoided. The power factor is fixed by the nature of the load. Thus, a load consisting of induction motors, not utilized to their full capacity, causes a low power factor, the practical effect of which is to cause the generating machine to generate current which circulates without producing useful power, causing the overheating of conductors both within the generator and out on the power line, with resulting loss of efficiency. The obvious remedy in such a case is to substitute smaller motors which would be taxed more nearly to their capacity, thus giving a high power factor. Good power factor is anything above 75 per cent. When a number of machines are to be installed the power factor of the total load should be computed by one of the following formulas:

$$
\begin{aligned}
p.\,f. &= \frac{\text{true power}}{\text{apparent power}} = \frac{W}{1.73 \times I \times E} \\
&= \frac{kw \text{ of the total load}}{kva \text{ of the total load}} \\
&= \frac{\text{horsepower of the total load} \times 746}{kva \text{ of the total load} \times 1{,}000}
\end{aligned}
$$

Where I = the current requirements of all the motors

E = the voltage of the motors

W = the total power in watts of the motors as shown on the name plates. Usually the power is given in horsepower in which case the last form of the equation is used.

If the motors are not all of the same voltage the *kw* for each voltage group is computed separately and then all are added together to get the total *kw* of the load. Similarly, the *kva* for each voltage group is computed separately and then added to get the *kva* of the total load.

b. *Power factor of typical loads.*—Incandescent lights have 100 per cent power factor. Alternating-current arc lamps have a low power factor (average, 70 per cent). Single-phase induction motors, squirrel-cage rotor, have power factors ranging from an average of 68 per cent for less than 1 horsepower to an average of about 82 per cent for 1 to 10 horsepower. Polyphase induction motors, squirrel-cage rotor, have power factors averaging 85 per cent for 1 horsepower to 10 horsepower and 89 per cent for 10 horsepower to 50 horsepower. In general, induction motor loads have power factors ranging from 60 to 85 per cent, depending upon whether motors are carrying their rated loads.

c. Power factor does not have to be considered in direct-current circuits, because in such circuits the voltage and current are always in phase with each other.

81. Magnetism.—*a.* If an insulated wire is coiled around a soft-iron core, as in Figure 43, and a current is passed through the wire, the coil and its core become a magnet. Such an arrangement is called an *electromagnet.* One end is the north pole; the other end is the south pole. When the current is turned off the magnetism disappears. The strength of the magnetic field depends upon the amount of current flowing in the wire and also upon the number of turns the wire makes around the core. The coils of wire in electric generators and motors are electromagnets.

b. Another principle of magnetism applied in electric machines is that when a conductor moves rapidly across a magnetic field an electromotive force is set up (induced) in the conductor. The faster the conductor moves the greater the induced electromotive force. If the conductor forms a closed circuit, this induced electromotive force causes a current to flow in the conductor. This is the basic principle of the electric generator.

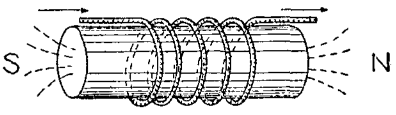


FIGURE 43.—Electromagnet

82. Properties of conductors.—*a. Definition.*—A conductor is a wire or other metallic path along which an electric current flows. Copper, aluminum, and iron make good conductors and are in common use. When a current flows in a conductor, a certain amount of heat is generated, and if the conductor is not large enough to carry the current, the heat may become excessive and cause it to become very hot. It is therefore necessary to determine carefully the size of conductor to be used in practical installations in order to avoid fire hazard as well as losses of power due to heat dissipation.

b. Characteristics.—The resistance of a conductor varies directly with its length and inversely with its cross section. It follows by Ohm's law that for a given voltage, the smaller a conductor is, and the longer it is, the less the current. For any given size of conductor, the further we get from the source of power the lower will be the voltage. Such a decrease in voltage is called the *line drop* or the *voltage loss.*

c. Mils and circular mils.—Wire conductors are usually circular in cross section. The unit of measure of the area of cross section in common use is the *circular mil.* The area of cross section of a wire in circular mils equals the square of its diameter in mils. A mil equals one one-thousandth of an inch.

Example: What is the size in circular mils of a wire one-fourth inch in diameter?

Answer: 1 inch equals 1,000 mils. One-fourth inch $= {}^{1000}/_{4}$ mils $= 250$ mils. This is the diameter of the wire in mils; 250 squared $= 250 \times 250 = 62{,}500$. This is the cross sectional area of the wire in circular mils.

d. Wire gage.—Wire sizes are referred to by gage numbers. The Brown & Sharpe gage is the standard for American practice. The gage numbers of wires commonly used range from 0000, which is very heavy, to 14, which is the smallest size for Army use in the field. (See Table XVIII.)

Section III

INSTRUMENTS

83. **General.**—The measuring instruments in common use are the ammeter, the voltmeter, and the wattmeter. These are all small instruments and may be either portable or mounted upon a switchboard. The range of readings on the dials of electrical instruments varies according to the uses for which the instruments are designed. In selecting an instrument for any given purpose, take one whose highest reading is about 25 per cent greater than the expected load. In general, instruments designed for direct-current circuits are not interchangeable with those designed for alternating-current circuits.

84. **The ammeter.**—The ammeter is used to measure the flow of current in a circuit. It is generally connected in series with the load in the circuit, the entire current in the circuit passing through the instrument. An ammeter must never be connected across the terminals of an open circuit. For measuring very large currents use is made of a shunt which permits only a known proportion of the current in the circuit to pass through the ammeter. This shunt is provided especially for each particular instrument, and the instrument is so calibrated that when its shunt is used with it, the dial shows directly the amount of current flowing in the main.

85. **The voltmeter.**—The voltmeter is an instrument for measuring the electric pressure between any two points in a circuit. It is connected between the two points and indicates the

electromotive force in the circuit in volts. The voltmeter has a high internal resistance which permits only a very slight current to flow through the instrument. It must not, therefore, be connected in series with the load, since to do so would cut off the current in the circuit. Voltmeters are made to measure over a variety of ranges.

86. The wattmeter.—The wattmeter is an instrument for measuring the power in a circuit. It really is a combination of a voltmeter and an ammeter. The voltmeter side of the instrument has small binding posts which are to be connected across the circuit. The ammeter side of the instrument has large binding posts which are to be connected in series in the circuit. (See fig. 44.) Some wattmeters indicate power in watts, while others indicate power in kilowatts.

87. The rheostat.—The rheostat is a device used to introduce resistance into an electrical circuit. It usually consists of a number of coils of special wire of varying resistance with a handle to regulate the amount of resistance introduced. Rheostats are frequently mounted on switchboards.

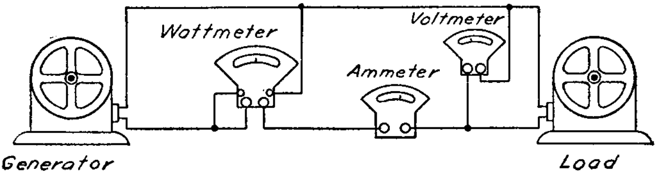


FIGURE 44.—Ammeter, wattmeter, and voltmeter connections

SECTION IV

GENERATORS AND MOTORS

88. General.—The electrical machines in common use consist of generators which convert mechanical power into electrical energy and motors which convert electrical energy into mechanical power. An electrical machine, whether a generator or a motor, consists essentially of two parts: A magnetic field, produced by electromagnets and an armature formed of a number of loops or coils of wire wound upon an iron core. These parts are so arranged that one of them may revolve, thus causing the magnetic lines of force of the field to be cut by the coils of the armature, thus producing an electromotive force or a mechanical torque, depending upon whether the machine is acting as a generator or as a motor. These machines may be constructed for either alternating or direct current. A machine having but one pair of field coils, called the N-pole and the S-pole, in its field structure is said to be bipolar. Where there are more than two poles in the field structure, the machine is said to be multipolar. In addition to the field coils, some machines have coils called interpoles, which are connected in series with the armature to improve the performance of the machine under heavy load. They are attached to the yoke of the machine in the intervals between the field coils.

89. Direct-current generators.—Direct-current generators are classified according to their field windings, as series wound, shunt wound, and compound wound. (See fig. 45.)

a. In a series-wound generator, the field coils are wound with heavy insulated copper wire connected in series with the armature and the external circuit. A series generator is adapted to furnishing approximately constant current at a variable voltage. The power output of a series generator is controlled through a field rheostat, which is connected in parallel with the series field and controls the current in the field magnets and consequently the strength of the field. In starting a series generator it should at first be short-circuited, so that the current generated in the armature will pass through the field magnets, energizing them and strengthening and building up the field. When the voltage of the current reaches its maximum, the short-circuiting switch is opened, permitting the current to flow through the external circuit. The external circuit should never be open-circuited; that is, the load should never be disconnected, as this causes damage to the generator. For this reason, use is made of jumpers which close the circuit whenever the load becomes disconnected. Series generators are little used except as boosters in long lines and for arc lights.

b. The shunt-wound generator has field coils made of fine wire, which are connected in series across the brushes in parallel with the armature. As the generated current leaves the armature, one part flows through the field coils while another part, the larger portion, flows through the external circuit. The output of a shunt generator is controlled through a field rheostat connected in series with the shunt field circuit and in parallel with the armature. The shunt generator is suitable for circuits requiring fairly constant voltage and variable current. It is suitable for lighting circuits and for charging batteries, as the voltage remains practically constant while the current varies under the load. There is a certain maximum load current which a shunt generator is capable of delivering at constant voltage. Beyond that the voltage decreases as the load increases until the generator weakens its field and delivers no more current. It is, therefore, not adapted to supplying current to motor loads. The shunt generator should never be short-circuited, as the resulting rush of current through the armature will cause it to burn out.

c. In a compound-wound generator, the field magnetism is produced from two field windings. One of these is the shunt field winding made of fine insulated wire connected in series and across the brushes in parallel with the armature. The other is the series field winding, which is wound outside the shunt field winding and is made of heavy insulated wire, the separate coils of the series field being connected in series with each other and in series with the armature and the external circuit. The series field is therefore directly affected by the load current, and thus compensates automatically for the internal losses of the generator, keeping the voltage practically constant under varying loads. Compound generators, therefore, give better voltage regulation on constant voltage circuits than can be obtained from shunt generators. The power output of a compound generator is controlled through a field rheostat connected in series with the shunt field winding and in parallel with the armature or in parallel with the series field and armature. A compound generator will maintain the desired voltage at approximately the speed for which it is designed. Compound generators are adapted for incandescent lighting and for supplying motor loads with power for arc lights and for charging batteries. When a short circuit occurs in the line, it overloads this type of machine excessively, and unless

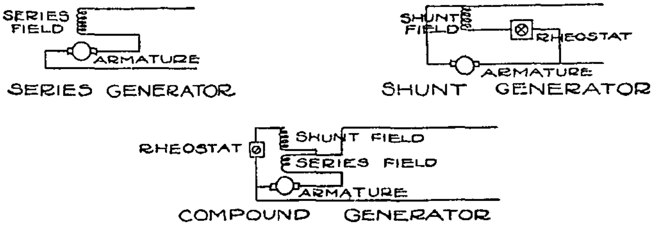


FIGURE 45.—Direct current generators (diagrammatic)

the generator is protected by circuit breakers or fuses the armature will be damaged. The compound generator is the best type of direct-current generator for general military purposes.

90. Practical installation of direct-current generators.—*a. General.*—Portable generating sets connected to the prime movers are already connected to the switchboard when delivered by the manufacturer and present, therefore, no special problem in their installation. When a new installation is to be made of a generator which is not a part of a portable electric set, the names of the leads can generally be read from ferrules placed upon them by the manufacturer. If these are not provided or have been lost it will be necessary to trace out the interior circuits of the generator and determine which leads are the armature leads and which the series and shunt field leads. Having determined these things, the generator is connected to the switchboard as shown in Figures 46, 47, and 48.

b. Direct-current generators in series.—When a voltage higher than that of one generator is necessary, the generators may be operated in series as shown in Figure 49. Such a connection causes the voltage in the external circuit to equal the sum of voltages of the two generators. This is called the series Edison 3-wire connection. The voltage between the two outside wires is double that of a single generator, while the voltage between the middle or neutral wire and either outside wire is the voltage of one generator. This permits the service of mixed loads; that is, loads consisting partly of lamps or other devices requiring one voltage and partly of lamps or other devices requiring another voltage.

c. Direct-current generators in parallel.—When it is desired to increase the current output without increasing the voltage, two or more generators are operated in parallel, as shown in Figure 48. This connection requires that the generators be of the same type and of the same current output and voltage. A compound generator can not be thus paralleled with a shunt generator, but two compound generators will operate satisfactorily when connected with an equalizer bar as shown in Figure 48.

91. Direct-current motors.—*a. General.*—A motor is a machine for converting electrical power into mechanical power; that is, it performs the converse function of a generator. Direct-current generators and motors are always interchangeable in function, although a machine which is designed specifically for a motor would not make a first-class generator, and vice versa.

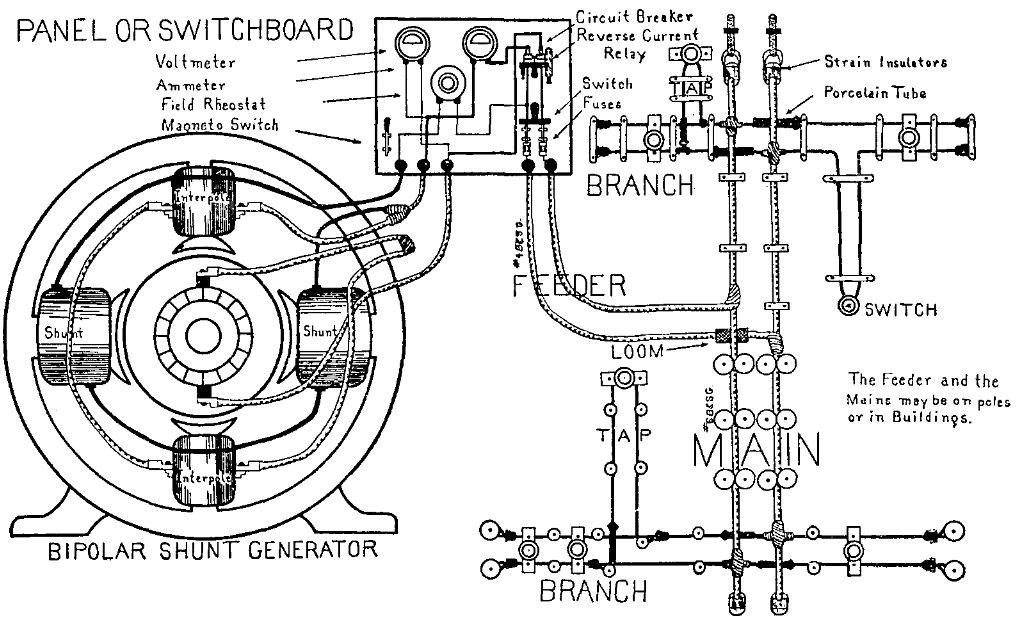


FIGURE 46.—Shunt generator (d. c.) connected to panel and typical lighting circuit

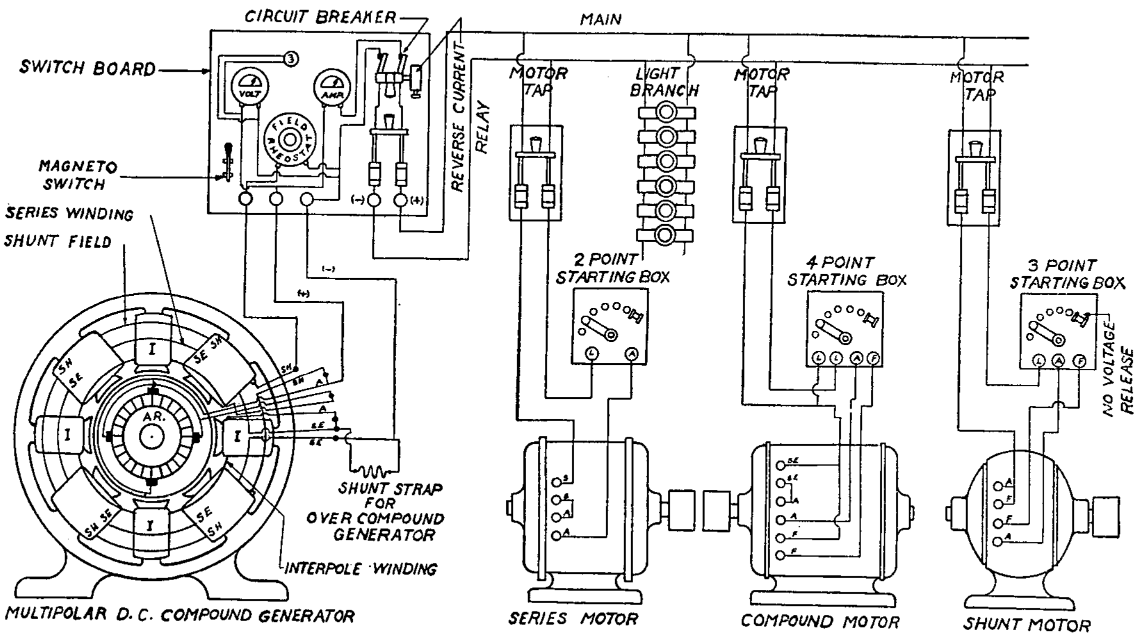
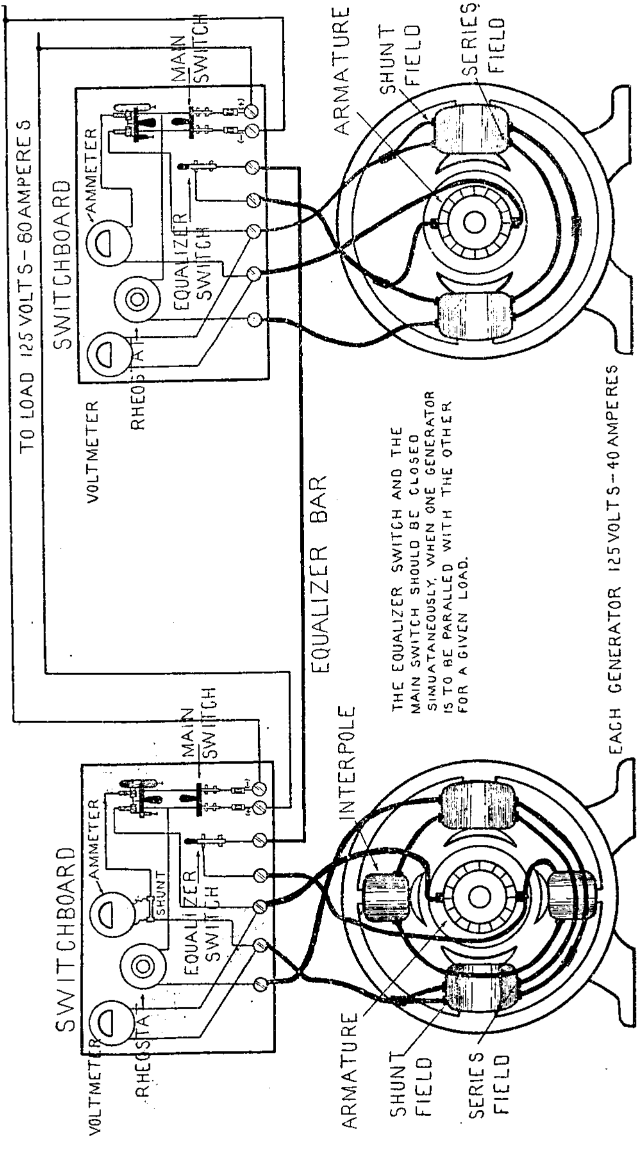


FIGURE 47.—Multipolar direct-current compound generator connected to panel and typical external circuits



THE EQUALIZER SWITCH AND THE MAIN SWITCH SHOULD BE CLOSED SIMUATANEOUSLY, WHEN ONE GENERATOR IS TO BE PARALLED WITH THE OTHER FOR A GIVEN LOAD.

EACH GENERATOR 125 VOLTS - 40 AMPERES

FIGURE 48.—Two direct-current compound generators connected for parallel operation, each generator 125 volts, 40 amperes

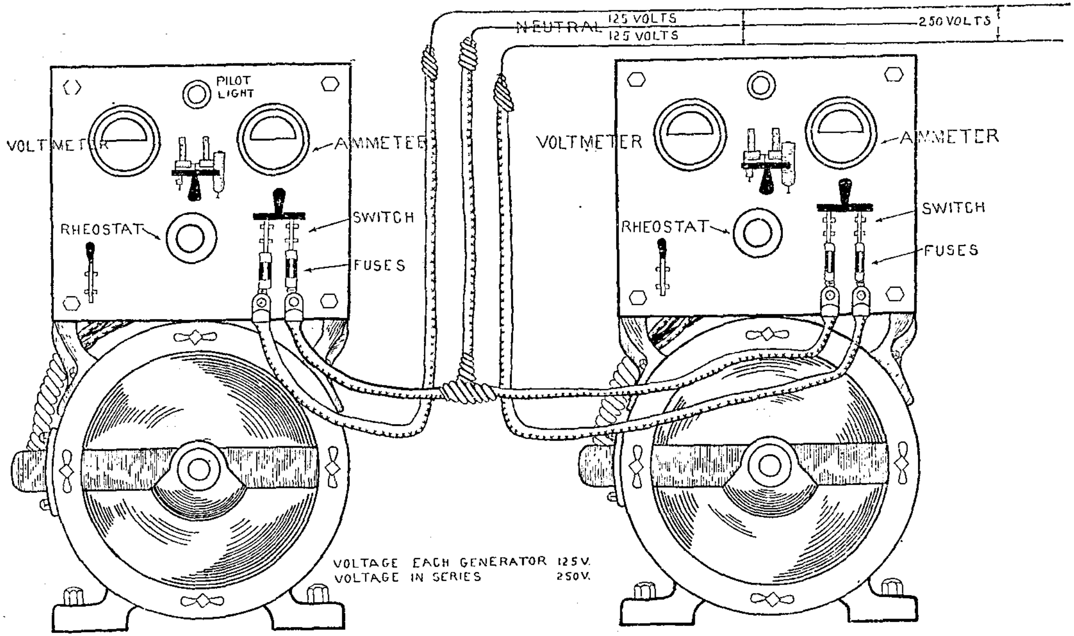


FIGURE 49.—Two direct-current generators connected for 3-wire Edison service—voltage each generator, 125 volts; voltage in series, 250 volts

b. Classification.—There are three principal types of direct-current motors, differentiated by their characteristics and the connection of the exciting windings. (See fig. 50.)

(1) *Series motor.*—This motor has only one exciting winding, which is connected in series with the armature so that all the current flows through the field as well as the armature. The field winding consists of a few turns of wire on each pole and the windings on all poles are connected in series. The current in the armature, and hence in the field, depends upon the mechanical load the motor is carrying and is thus large with heavy load and small with light load. The resistance of the field winding is purposely made low so that the loss of voltage and power in that circuit will be small. The characteristic of a series motor is speed varying with every change in load—high speed at light load and low speed at heavy load. The efficiency is high throughout a wide range of speed. The speed will be dangerously high at no load. Thus, a series motor must always be mechanically connected rigidly to its load. Since the torque is high at low speeds, this motor is particularly adapted to work requiring frequent starting.

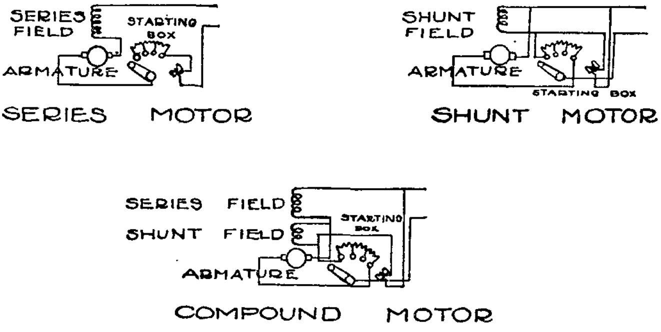


FIGURE 50.—Direct-current motors (diagrammatic)

(2) *Shunt motor.*—This motor has only one exciting winding, which is connected across the armature and is thus in parallel or in shunt with the armature. The field winding consists of a large number of turns of fine wire on each pole, and usually the windings on all the poles are connected in series in one circuit. The resistance of the field winding is purposely made high so that the field current may be kept between 1 and 5 per cent of the full-load current of the motor. The characteristic of the

shunt motor is a fairly constant speed for all reasonable values of load.

(3) *Compound or accumulative motor.*—This motor has both a series winding and a shunt winding on each pole, wound and connected so that the two windings assist each other in the production of magnetism. It is a combination of a shunt and a series motor designed to give the good starting qualities of the series motor and to avoid the danger of excessive speed at light loads.

c. Voltage and current.—Usual values of voltage for direct-current motors will vary, being 110 to 125 volts for small motors on lighting circuits and 220 to 250 volts for motors in factories, shops, etc., on power mains or on the outside mains of a 3-wire system. The current required for any motor is found by the following formula:

$$\text{Current}=\frac{\text{Output in horsepower}\times 0.746}{\text{Efficiency}\times \text{voltage}}$$

d. Application of motors.—The chief applications of direct-current motors are the following:

(1) *Shunt motor* for driving shafting, machine tools, blowers, reciprocating pumps, and generators.

(2) *Series motors* for hoists, cranes, and transportation work.

(3) *Compound motor* for centrifugal pumps, hoists, and machinery that must be started often and where better regulation is required, especially smooth speed.

e. Starting, speed control, and reversal.—Direct-current motors of less than 3 horsepower can be started directly on the line, but motors of greater horsepower should have starting boxes. The speed of a direct-current motor is controlled through a field rheostat. To reverse a direct-current motor, change the position of the brushes on the commutator or reverse the leads connecting to the brush holders.

f. Efficiency of motors.—The average efficiency varies according to conditions, but for purposes of approximation may be taken as 85 per cent.

TABLE XIII.—*Efficiencies of direct-current motors on 110 and 220 volts*

Horsepower	½	1	2	3	5	7½	10	15	20	25	50
Efficiency	73	77	82	83	84	86	86	86	87	89	91

g. Practical installations of direct-current motors.—When installing a direct-current motor, it is necessary to provide a starting box for the same voltage, horsepower, and current as that shown on the name plate of the motor. The starting box should be installed as close to the motor as possible. Motors of 3 horsepower or less can be installed without a starting box. Each direct-current motor should be equipped with a 2-pole single-throw knife switch with fuses and a starter with low voltage release magnet. If the installation is such that at times it is necessary to reverse the direction of rotation, a double-pole, double-throw knife switch, without fuses, should be added to the equipment. When the motor is not over 100 feet distant from the source of power, using the ampere rating on the name plate of the motor, a wire of proper current carrying capacity can be selected from Table XIV. If the motor is over 100 feet distant from the source of power, it is necessary to compute the circular mils of the proper conductor to be used to supply the motor with current, using the following formula for direct-current motors:

$$\text{Circular mils} = \frac{\text{Hp} \times .746 \times L \times 22 \times 1.25}{E \times e \times \text{efficiency}}$$

P = Rating in horsepower of motor

L = Distance in feet to motor

e = Voltage drop in line—usually 5 per cent

E = Line voltage.

The above formula allows 25 per cent excess current.

TABLE XIV.—*Wiring table for direct-current motors*

Horsepower	Voltage	Approximate full load current	Size of fuses	Size of switches	Size of wire Brown & Sharp gage
½	115	2.5	6	30	14
	230	1.2	3	30	14
	500	.5	3	30	14
1	115	8.5	15	30	14
	230	4.3	6	30	14
	500	1.8	3	30	14
2	115	17.0	30	30	12
	230	8.5	15	30	14
	500	3.7	6	30	14
3	115	24.0	30	30	10
	230	12.0	20	30	12
	500	5.3	10	30	14
3½	115	28.0	40	60	8
	230	14.0	20	30	12
	500	6.0	10	30	14
5	115	40.0	50	60	6
	230	20.0	30	30	10
	500	8.0	15	30	14
7½	115	60.0	75	100	4
	230	30.0	40	60	8
	500	13.5	20	30	12
10	115	80.0	100	100	2
	230	40.0	50	60	6
	500	17.5	30	30	12
15	115	120.0	150	200	0
	230	60.0	75	100	4
	500	26.3	40	60	8
20	115	154.0	200	200	000
	230	77.0	100	100	2
	500	34.0	50	60	8
25	115	192.5	250	400	0000
	230	96.3	150	200	0
	500	42.5	60	60	6
30	115	232.0	300	400	250,000
	230	116.0	150	200	0
	500	50.8	75	100	4
35	115	270.0	350	400	400,000
	230	135.0	200	200	00
	500	59.2	75	100	4
40	115	310.0	400	400	400,000
	230	155.0	200	200	000
	500	67.8	100	100	2
50	115	377.0	500	600	500,000
	230	188.5	250	400	0000
	500	83.0	100	100	2
60	115	452.0	600	600	700,000
	230	226.0	300	400	250,000
	500	99.5	150	200	0

92. Alternating-current generators.—*a. General.*—Alternating-current generators, frequently called alternators, are essentially direct-current machines without commutators, the armature circuit being connected directly to the outside circuit.

through slip rings. An electromotive force is produced at the machine which varies in cycles, as described in paragraph 73. As alternating currents are not suitable for producing the magnetic fields of the machine, an alternating-current generator must be assisted by a direct-current source to excite the field coils. Usually small separate generators (called exciters) are used for this purpose. On account of the necessity for much accessory equipment, the use of alternating-current generators as portable sets for military purposes is not desirable. It will be unusual for the engineer in the combat zone to use alternating-current generators, his use of alternating current being limited to the employment of such current supplied by existing commercial plants.

b. Types of alternating-current generators.—The most common forms of alternating-current generators are of two classes, those with revolving armatures and those with revolving fields. In the revolving-armature type the armature is the moving member and the field is stationary, current being delivered from the armature to the circuit by means of brushes resting on the revolving rings. In the revolving-field type, the field is the moving member, while the armature is stationary and is directly connected to external circuit. Alternating-current generators are also classified according to the number of circuits in the armature. A single-phase generator has only one circuit in its armature and the current is led from the generator on two wires. In a 2-phase generator there are two circuits, the current coming from the generator on four wires. The 2-phase generator is not in very common use. In a 3-phase generator there are three circuits and the current is led from the generator on three wires. Each pair of these wires carries one phase of the current.

c. Power control.—The power output of an alternating-current generator is regulated through the exciter supplying the field current. It should be remembered that the power output of alternating-current generators is affected by the power factor of the load. When a load with a lower power factor is connected to such a generator, the power output is greatly reduced. (See par. 80.)

93. Practical installation of alternating-current generators.—Alternating-current generators when used for short-distance distribution are directly connected to the distributing system. When used for long-distance distribution systems, the power from the generator is passed through transformers which step up the voltage and thus make long-distance distribution feasible. Alternating-current generators can be connected in parallel when they can be properly synchronized. The size of wire feeders and the capacity of fuses used in alternating-current generator installations may be determined from Table XV.

94. Alternating-current motors.—*a.* The stationary frame of an alternating-current motor is known as the *stator* and the windings in it are called the primary windings. The revolving member carrying the pulley is known as the *rotor*, and its windings are called the secondary windings. There are two important types of alternating-current motors, the synchronous and the induction-repulsion.

(1) A synchronous motor is essentially an alternating-current generator operated as a motor. It has to be brought up to synchronous speed (the speed at which it would run if operated as a generator at the line frequency) by external means before it can be connected to the line. It will operate only at synchronous speed.

TABLE XV.—*Alternating-current motors. Approximate amperes per terminal for induction motors*

[For determining size of wires, capacity of fuses, and setting of circuit breakers]

Horsepower of motor	110 volts			220 volts		
	1-phase	2-phase	3-phase	1-phase	2-phase	3-phase
0.5	6.6	3.3	3.7	2.4	1.7	1.8
1	12.0	6	6.5	6	3	3.2
2	21.0	10.5	12.0	10	5	6
3	30	15	17	15	7.5	9
5	54	27	30	26	13	15
7.5	76	38	44	40	20	22
10	88	44	50	50	25	29
15	132	66	76	70	35	41
20	176	88	102	96	48	55
25	222	111	129	108	54	62
30	268	134	154	140	70	81
40	356	178	204	190	95	109
50	408	204	236	200	100	127

When starting without load, the current given in the table should be multiplied by 1.4 and when starting at full load the values should be multiplied by 1.8.

(2) There are two forms of induction-repulsion motors, the squirrel-cage form, in which the winding of the rotor consists of heavy copper bars short-circuited on each other, and with no

external electrical connection; and the slip-ring form, the rotor of which is a regular polyphase distributed winding, into the phases of which the current is connected through the slip rings on the shaft. The induction-repulsion type is the most commonly used single-phase motor. When induction motors are loaded to a certain definite amount called the breaking load they stop. If an induction motor is connected directly to the line when starting, it will take a current two to four times the normal full-load running current. To avoid the disturbance which this would produce in the system, it is customary to start at a reduced voltage which is attained by means of a device called a compensator.

b. Speed control.—The speed of polyphase induction motors can be regulated by use of a rheostat. There is no speed control for a single-phase induction-repulsion motor.

c. Reversal of alternating-current motors.—To reverse the rotation of a single-phase, induction-repulsion motor it is only necessary to shift the position of the brushes as indicated on the motor itself. This is done while the machine is not in operation. After the brushes have been shifted to the reverse position, the motor is started. In order to reverse a 3-phase induction motor the two outside wires of the 3-phase circuit of the motor terminal are interchanged. This is done while the motor is not in operation.

95. Alternating-current and direct-current motors.—Some motors are so designed that they may be operated on either alternating current or direct current. Such universal motors are built in sizes ranging from one-fourth to 1 horsepower and operate on 110 and 220 volts. They are in common use for portable tools such as drills, saws, fans, etc. They operate best on direct current. There is no speed control.

96. Operation and care of portable electric generating sets.—*a. Location.*—A portable electric generating set should be located as near as possible to the load it supplies, near a supply of water, and if possible within a shelter wherein the attending personnel can live and do the work necessary to maintain the equipment.

b. Unloading.—To unload a 5-kilowatt set from a vehicle, a good method is as follows: Procure two wooden beams about 20 feet long and about 5 by 5 inches in cross section, similar to ponton bridge balk; a pulley block with 100 feet of 1-inch rope; a towing chain; and four 1½-inch rollers 1½ feet long. About six men are required to unload the set. Put the set on rollers. Fasten the towing chain to the front of the truck and put it over the driver's seat to the interior of the body of the truck. Between the ends of the chain and the skids of the generating set insert the block and tackle. Push the set off the truck and down the beams to the ground, controlling the speed of movement by paying out on the tackle. To load the set reverse this operation. Experience has shown that in this manner a set can be quickly loaded or unloaded, whereas without such a plan, the sets are difficult to handle. Place the generating set on the level ground or floor free from dust and moisture.

c. Operation.—When the engine is used for the first time, prime the oil pump and fill all grease cups, fill the radiator, fill the gas tank, and prime the vacuum tank. The engine is now ready for operation. To start generating current, turn the rheostat in a clockwise direction, thus inserting all the resistance of the rheostat in the field circuit of the generator so that the generator will not generate current. This makes it easier to crank the engine. After the engine is started close the circuit breaker and turn the field rheostat handle in an anticlockwise direction until the voltmeter indicates the operating voltage of 125 volts. To stop the generator, turn the field rheostat handle in a clockwise direction, reducing the voltage output to 50 volts, open the circuit breaker and switches, and close the magneto switch to stop the engine.

97. Generator and motor troubles and remedies.—*a. Excessive sparking of brushes.*—Sometimes vibration will cause the brush-holder yoke to shift its position. This results in reducing the voltage and power output of a generator or in reducing the speed and mechanical power output of a motor. It is indicated by excessive sparking at the brushes. The remedy is to shift the brush-holder yoke back and forth while the machine is in operation until a position of minimum sparking is reached. Excessive sparking may also be caused when the brushes are not properly trimmed, are not in line and do not make good contact with the commutator. To remedy, smooth the commutator by applying a piece of sandpaper the same width as the commutator with the sand towards the brushes, working the sandpaper back and forth, thus reseating the brushes on the commutator. If the brushes do not make good contact with the commutator, see that they are working freely in the brush holders and that they are of the proper length and that there is proper tension in the springs. Excessive sparking is also caused by a rough commutator which may have resulted from the copper bars of the commutator being worn down by the brushes. To remedy, polish the commutator with No. 00 sandpaper. If the mica insulation between the commutator bars sticks up higher than the commutator bars it should be undercut with a 3-cornered file. When a commutator has become so badly worn that it can not be straightened by the use of a sandstone while the machine is in operation, the armature must be removed from the motor frame and the commutator turned down on a lathe. A commutator in good operation is a brownish-black color and is smooth and glossy.

b. Failure to operate.—Look for burned-out fuses. If the field connections between the field coils or on the field rheostat are broken, there results a weak magnetic field which in a motor causes excessive speed with excessive sparking and in a generator causes reduced power output. To locate the cause of such a trouble, test for open circuits by connecting a battery and an ammeter in each circuit and noting whether the ammeter registers the passage of a current. Sometimes when all connections are correct, there is not enough permanent magnetism in the core of the field coils to enable the generator to build up its field. Procure a small storage battery or three or four dry cells and connect them in the shunt field circuit. This will give the necessary start to the field, after which it will build up very easily from its own field winding. On a compound-wound generator this result may be obtained by short-circuiting the terminals of the generators for a few seconds, which starts the field to building up.

c. Overheating of parts.—The parts of an electrical machine will overheat if subjected to excessive current. A generator will overheat when overloaded, a condition which can be corrected by reducing the load. Overheating may also be due to grounds and leakage through short circuits on the line, the remedy for this condition being to locate the short circuit or ground and remove it. If excessive voltage is impressed upon a motor, it will cause an increase in speed and power accompanied by sparking and overheating of the motor. To remedy, use a motor of proper voltage. A motor will be overloaded if a pulley of too large a diameter is attached to its shaft.

d. Armature troubles.—Carbon, copper dust, solder, or other metallic substances which form a contact between commutator bars cause the armature to heat. This is indicated by a ring of fire formed of sparks around the commutator. To remedy, see that the clamping rings are perfectly free and insulated from the commutator bars and that there is no copper dust, carbonized oil or other conductor that will cause an electric leakage. See that the brush holders are clean and properly insulated from the yoke. Short circuits in motors are indicated by the armature becoming locked. This is true of both direct-current and alternating-current motors. A method to test for short circuits in a generator armature is to run the generator on a full load for a few minutes and then stop the machine and feel of the armature. A section which has been short-circuited will be found to be very hot. Moisture in armatures is sometimes the cause of trouble. It can be evaporated by gentle heat in an oven or by running the generator at reduced voltage without a load for 15 to 30 minutes before adjusting to the operating voltage.

98. Protective devices.—*a. Fuses and circuit breakers.*—Fuses are generally used for the protection of small electrical equipment against heavy currents and high voltages. They are connected between the source of supply and the equipment it serves with electrical power. Where heavy currents are generally used, both circuit breakers and fuses are installed so that in case one of these devices fails to work the circuit will still be broken if necessary. Such devices are generally installed on switchboard panels that control generators, feeders and mains, or motors that use heavy currents.

b. Lightning arrestors and grounds.—Lightning arrestors are installed on long lines about two to the mile, including one at each end of the circuit. These arrestors are connected to ground usually by a ground rod driven about 4 or 5 feet in the ground or a metallic plate about 1 foot square, connected with a wire not smaller than No. 8 placed under the pole when the pole is set. Motor and generator frames, transformer cases, and all other metal parts of machines or wiring devices not carrying current should be grounded. A good method of grounding is to connect these parts to water pipes that are carrying water, if available. Otherwise, provide a ground similar to that described for lightning arrestors.

SECTION V

POWER TRANSMISSION AND LIGHTING

99. Direct-current distribution.—*a. Practicable distance.*—Direct-current distribution at low voltages (110 and 220 volts) is not suitable for covering large areas or for delivering current at a great distance from the generator. The reason for this is that in order to prevent power losses and excessive voltage drop, it would be necessary to use a very heavy wire conductor for distributing current which would be difficult to install as well as difficult to transport. For general military purposes, transmission of direct current should not ordinarily be to a greater distance along the wire from the generator than 200 feet for 110 volts or about 350 feet for 220 volts. If necessary to place the generator at a greater distance, the usable load would be reduced accordingly. It follows as a general principle that in installing direct-current generators they should be located as near as possible to the point where the current is to be used.

b. Distribution from portable sets.—In supplying current from portable lighting sets to an extensive area such as a large camp or supply depot, it is not good to concentrate the sets as a central power station in any one location. The best method is to distribute the portable sets over the area, each furnishing current to an allotted number of buildings. In this way, the generating units are located close to the point of consumption and excessive line loss is avoided. Often it will be advantageous to wire warehouses for electric lights without connecting the buildings to any source of current. When the necessity for lights arises, a portable set can be sent to any warehouse to provide current for the necessary time.

100. Alternating-current distribution.—*a. General.*—Alternating currents are frequently available for military purposes where existing commercial central stations supply power to an area. Alternating current is adaptable for distribution over a large area and at long distances from the central station. This is made possible by the ease with which alternating currents can be stepped up to high voltages at which transmission to long distances is feasible without excessive line losses and without the employment of heavy conductors. This high voltage is attained by passing the current through a step-up transformer at the central station. Transmission voltages on overhead lines in towns vary from 2,300 to 16,000 volts. Near the point of consumption the current is again passed through a transformer called a step-down transformer, which reduces the voltage. Distribution from the substation to the consumer generally involves a second reduction in voltage, which is accomplished by a small transformer usually placed on a pole near the point where the current is to be used. From these transformers to the point of consumption, alternating-current lighting circuits do not differ from direct-current circuits.

b. Transformers.—A transformer is a device for transforming power of low voltage and high amperage to the same amount of power at a high voltage and low amperage and vice versa. This permits a large quantity of power to be carried over small wires without undue loss. A transformer has no moving parts and its efficiency is very high. It consists of two windings about a laminated core. The high-tension winding consists of fine insulated wire. The low-tension winding consists of heavy wire. The terminals of both windings lead to the outside of the transformer. When a current at a given voltage passes through the high-tension winding, it causes a corresponding current at a lower voltage to flow in the low-tension winding. The high-tension and low-tension coils are immersed in a special oil which keeps the coils cool and insulates them. The whole is contained in an iron case covered by a bolted iron cover, making a weather-proof device. The high-tension terminals are generally to be found either to the rear or on top of the case; the low-tension terminals are found at the front of the transformer. The transformer terminals that are connected to the source of current are called the primary leads. The terminals through which a transformer delivers current are known as secondary leads. Transformers are rated in kilovolt-amperes (kva). When the power factor of the load is unity, as in the case where only incandescent lamps are being supplied with power, the *kva* is equivalent to the kilowatts. Distribution transformers for military purposes are generally single-phase transformers. Various ways of connecting single-phase transformers separately or in banks of two or three are shown in Figures 51 to 55, inclusive.

c. Practical installation of transformers.—Single-phase transformers are connected in banks of twos and threes mounted on platforms or on poles or in an inclosure on the ground. Transformers should be as close to the load they serve as possible, in order to eliminate line loss on the secondary lines. For lighting purposes, single-phase transformers should be scattered through the area to be lighted and mounted on the same poles which carry the high-tension lines. While there are many methods of connecting transformers depending upon the ratio of transformation and the kind of service, the most common connections are as shown in the following figures.

(1) *Connections for one single-phase transformer.*

(*a*) Figure 51 shows a 2-wire circuit at 110 volts.

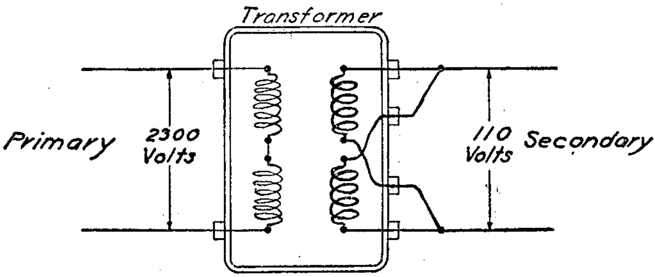


FIGURE 51.—Transformer connections

(*b*) Figure 52 shows a 2-wire circuit at 220 volts.

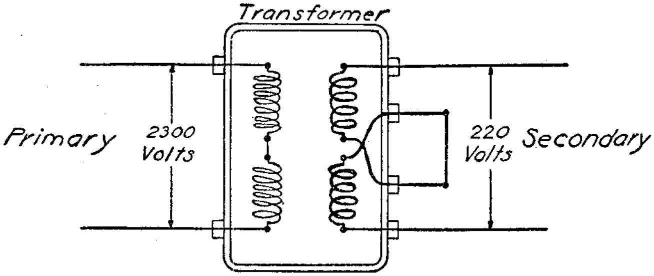


FIGURE 52.—Transformer connections

(*c*) Figure 53 shows a 3-wire Edison circuit giving 110 volts between neutral and the two outside wires and 220 volts between the two outside wires. This is commonly used for mixed single-phase load; that is, a load consisting of lamps or other devices some of which require each voltage.

(2) *Connections for two single-phase transformers.*—Figure 54 shows the connections when two single-phase transformers are used to give 3-phase service.

(3) *Connections for three single-phase transformers.*—Figure 55 shows the connections for three single-phase transformers, giving 3-phase service at 220 volts. If 110-volt service were desired the connections would be similar except that the secondary leads from each transformer would be connected together as shown in Figure 51. Figure 55 shows what is called a delta-connected primary and a delta-connected secondary. This delta to delta connection is the one most generally used. It has the advantage that in case one transformer of the bank burns out or becomes overloaded, the remaining two transformers can carry the load without interrupting the service until another transformer is substituted. This is the reason why single-phase transformers are best for general military use.

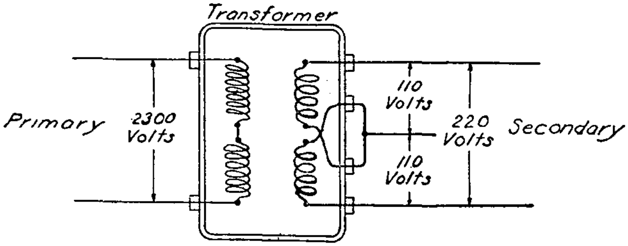


FIGURE 53.—Transformer connections

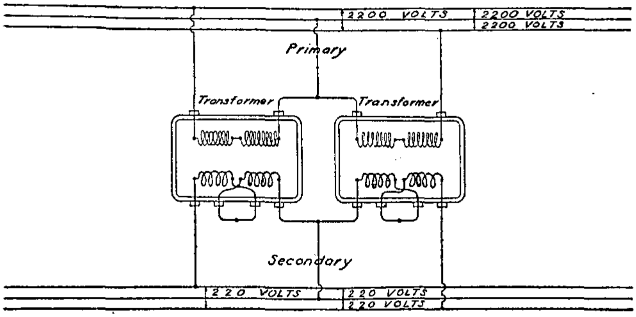


FIGURE 54.—Transformer connections

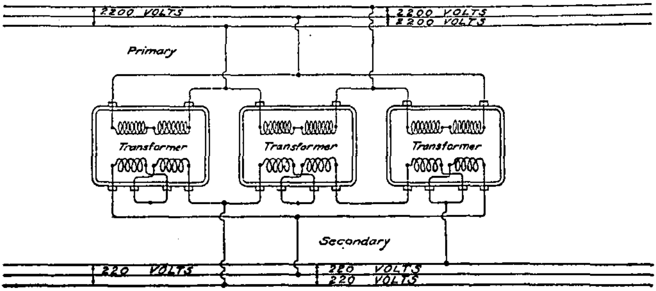


FIGURE 55.—Transformer connections

TABLE XVI.—*Material for one mile of 2,300-volt transmission line, single-phase*

10 poles, 25 feet, 6-inch top.
50 poles, 30 feet, 6-inch top.
50 cross arms, 4-pin, 3¼ by 4½ inches by 4 feet.
50 bolts, cross arm, ⅝ by 12 inches.
100 braces, cross arm, 28 by 1¼ by ¼ inch.
100 pins, locust, standard.
100 insulators, glass, 2,300-volt.
20 insulators, strain, 6,600-volt.
100 bolts, carriage, with washers, ⅜ by 4½ inches.
50 bolts, lag, ½ by 3½ inches.
10 anchors (either log or patent anchors).
10 rods, anchor, ⅝ inch by 6 feet.
20 clamps, 3-bolt, for 5/16-inch messenger.
300 feet strand, galvanized, 5/16-inch.
2 arrestors, lightning, 2,300-volt.
2 ground rods, ⅝ by 6 inches.
12,000 feet wire, No. 4 B. & S. gage, weatherproof.

For 3-phase transmissions, add the following items to above list:

6,000 feet wire, No. 4 B. & S. gage, weatherproof.
50 pins, locust.
50 insulators, glass, 2,300-volt.

TABLE XVII.—*Transformers*

[Single-phase: 2,300-volt primaries; 230–115 volt secondaries; 60 cycles]

Transformer		Material and labor to install									
Rating, (kilovolt-amperes)	Net weight in pounds	Cross arms 3¼ by 4¼	Transformer oil (gallons)	Primary fuse wire (amperes)	Number of men required to install	Time required to install (hours)	Tape, pounds	Solder, pounds	Lightning arrester, 2,300-volt	Primary cut-out	No. 6 wire (feet)
5	200	2-pin 4-pin	5¼	3	3	3	1	1	1	2	30
7½	275	2-pin 4-pin	8¼	5	3	4	1	1	1	2	30
10	350	2-pin 4-pin	14½	5	4	4	1	1	1	2	30
15	375	4-pin 4-pin	19	10	4	4	1	1	1	2	30
25	670	4-pin 6-pin	23½	15	6	6	1	1	1	2	30
50	1,200	4-pin 6-pin	34	25	6	6	1	1	1	2	50
100	2,100	4-pin 6-pin	44	50	6	8	1	1	1	2	50
200	3,900	4-pin 6-pin	135	100	8	10	1	1	1	2	50

d. Size of transformer to use.—To determine the size of transformer to use for any given situation, compute the kilovolt-amperes of the total load to be placed upon the transformers and use one or more transformers whose total *kva* rating equals or exceeds the load. For example, if the kilovolt-amperes of all the motors and lights in a given building equal 45 *kva*, use either two 22½-*kva* single-phase transformers, or three 15-*kva* single-phase transformers to supply the power for this building.

101. Calculation of wire sizes for distribution systems.—*a. The problem.*—Given a source of current, either a generator or a transformer, it is necessary to determine the proper size of wire to conduct the electricity from this source to the location of the motors or lamps served. The wire must be of such a size that it will carry the electricity to the point where it is to be used without an excessive drop or loss of voltage, and that the current will not heat the wire to a temperature which would destroy the insulation or cause a fire. Unless a proper size of distribution wire is used, the electric service will be unsatisfactory because lamps will be dim and motors will lack power. Wires of large size or short length have greater current-carrying capacity than wires of small size or of great length. The formulas in this paragraph, together with the data given in Table XVIII, permit the selection of a size of distributing wire which will give satisfactory service. For transmission of current a distance of 100 feet or less, the numerical calculations may be dispensed with and a proper size of wire to carry a given number of amperes may be determined directly from the table. If, as may frequently happen in the military service, the required size of wire is not available, a conductor of the same current-carrying capacity may be improvised by using two or more smaller wires to make up a cable, the current-carrying capacity of which will equal the sum of the capacities of the wires so used.

Example: How many strands of No. 8 wire must be used to improvise a cable of equivalent current-carrying capacity to a No. 1 wire?

Answer: From Table XVIII a No. 1 wire with weatherproof insulation will carry 150 amperes. A No. 8 wire will carry 50 amperes. Therefore $\frac{150}{50}$ = three No. 8 wires which must be used.

b. Calculation of wire sizes for direct-current distribution.—The proper size of copper wire necessary to carry a direct current a given distance with a given drop in voltage is determined by the following formula:

$$c.\ m. = \frac{L \times I \times 22}{e}$$

Where,

$c.\ m.$ = circular mils of cross section of the wire

L = length of run in feet from source of power to the load center, one way only (not both sides of circuit)

I = current in amperes required for the total load

e = volts lost or voltage drop on the line.

The distance to the load center may be determined by multiplying the amperes used by each receiver by its distance from the starting point of the circuit, adding together all the products thus found, and dividing this sum by the total amperes in the circuit.

The current I in amperes is determined from the nature of the load by use of the following formula:

$$I = \frac{W}{E},$$

Where,

W = the sum of the watts of all the lamps and motors in the circuit

E = the voltage between the mains at the load center.

The volts lost e are determined from the following formula:

$$e=\frac{E\times p}{100-p}$$

Where,

e=permissible voltage drop on the line

E=the voltage between the mains on the delivery end of the line

p=the permissible percentage drop of voltage on the line.

For circuits in which there are both motors and incandescent lights, the percentage voltage loss p may be taken as 3. For circuits in which there are incandescent lights only, p may be taken as 5.

Example: What size of wire is required from a direct-current generator to a building 150 feet distant in which there are seventy-five 40-watt, 115-volt lamps?

Answer: The current equals

$$\frac{75\times 40}{115}=26 \text{ amperes.}$$

The voltage drop equals

$$\frac{115\times 5}{100-5}=6.5 \text{ volts.}$$

Substituting in the formula we have

$$\frac{150\times 26\times 22}{6.5}=13{,}200 \text{ circular mils.}$$

Referring to Table XVIII, we see that the nearest size of wire is No. 9, which has 13,594 circular mils area of cross section. Good practice requires that the next larger size of wire be used. Hence a No. 8 wire is adopted.

In computing wire size for a balanced 3-wire direct-current system with a central neutral wire, compute the size of the outside wires as for a 2-wire system disregarding the neutral wire, and then make the central wire the same size as that computed for the two outside wires.

c. *Calculation of wire size for alternating-current distribution.*—The calculation for wire sizes for alternating-current circuits involves factors which do not exist with direct-current circuits. The principal one of these is the effect of the power factor of inductive loads such as motors. There is no simple method of calculating alternating-current circuits that takes into account these effects and is accurate under all conditions. The following formulas give approximate results which are practical for military purposes.

(1) *Calculation of wire size for single-phase alterna circuit.*—Use the following formula:

$$c.\ m. = \frac{L \times I \times 22}{e}$$

Where,

$c.m.$ = circular mils of cross section of the wire

L = length of run in feet from source of power, one way only (not both sides of circuit) on name plate of motors or as computed

I = current in amperes as shown below

e = volts lost or voltage drop.

The current in amperes I is determined by using the following formula:

$$I = \frac{W}{E \times p.f.}$$

Where

W = the sum of the watts of the entire load

E = the voltage at the delivery end of the mains or at the load center

$p.\ f.$ = the power factor of the load.

It should be noted that the power factor of a load consisting entirely of incandescent lamps is unity.

Table XVIII.—*Electrical characteristics of copper wire*

Brown & Sharpe (B. & S.) gauge	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	144.23	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	89.38	2.5908	15	20

Sizes marked * are not used for electrical work.

For aluminum wire the carrying capacity of any given size should be taken as 84 per cent of the value given in above table.

If current exceeds the safe current-carrying capacity of the largest wire, two or more wires should be used.

(2) *Calculation of wire sizes for 3-phase, 3-wire alternating-current circuits.*—The following formula can safely be used for ordinary branch circuits and for short mains:

$$c.\ m. = \frac{L \times I \times 19}{e}$$

Where

c. m., L, and e have the same meanings as before, and the current in amperes, I, is computed by the following formula:

$$I = \frac{W}{E \times p.f. \times 1.73}$$

Where

W = the sum of the watts of the entire load
E = the voltage at the delivery end of the mains
$p.\ f.$ = the power factor of the load.

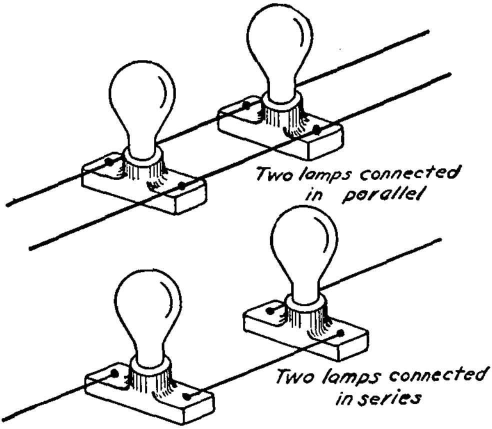


FIGURE 56.—Comparison of parallel and series circuits

102. Interior lighting.—*a.* On account of the fire hazards from electrical installations on the interior of buildings, civilian practices have been hedged in by legal restrictions which insure safety. These restrictions require many refinements which, in the temporary installations made for military purposes, are generally disregarded. The military installations are characterized by extreme simplicity. All wiring is exposed; that is, it is not concealed in partitions. There are two principal types of lighting circuits, the series circuit and the parallel circuit.

b. The series circuit.—In the series circuit (see fig. 56) the current passes consecutively through all of the lamps in the series. The current is the same throughout the entire circuit. The voltage of the circuit equals the sum of the voltages of all the lamps. Thus, if there were 10 lamps in the circuit, each requiring 30 volts, the voltage at the generator would have to be 10×30= 300 volts. In such a circuit, all of the lamps must be turned on and off at the same time, since if one lamp be disconnected, the circuit is broken and none of the lamps in the circuit receive the current. Series circuits are seldom used in interior lighting circuits.

c. Parallel circuits.—In the parallel circuit (see fig. 56) the lamps are connected across the wires. In such a circuit, the voltage at each lamp is the same. The current in amperes supplied by the generator equals the sum of amperes flowing in all of the lamps. The switching on or off of any lamp does not affect the others. Turning out one-half the lamps would reduce the current by one-half without affecting the voltage at the remaining lamps. The circuits usually employed in interior lighting systems are parallel circuits.

d. Practical installations.—Entering the building, the supply line goes to a panel box in which are located an entrance cut-out switch and fuse which control the current to the entire building, and the safety fuses which blow out whenever a short circuit occurs inside the building. From the panel box, No. 14 Brown & Sharpe gage, rubber insulated wire is used to distribute the current to the lamps. Larger wire may be used if No. 14 is not at hand, but smaller than No. 14 should not be used. Wires are suspended either on cleats or knobs, and where they pass through partitions or where they cross each other are insulated by porcelain insulators or loom. Lamps may be connected directly to the distribution line or they may be suspended by drop cords. Lamps of 40-watt rating are adequate for practically all office uses. In hospitals, higher wattage (75 to 100 watts) may be required. Wherever wires are spliced, the joints must be soldered and taped with rubber splicing tape, with suitable friction tape over this. Snap switches are mounted where desirable 4 feet from the floor on switch bases provided for them or else on knobs.

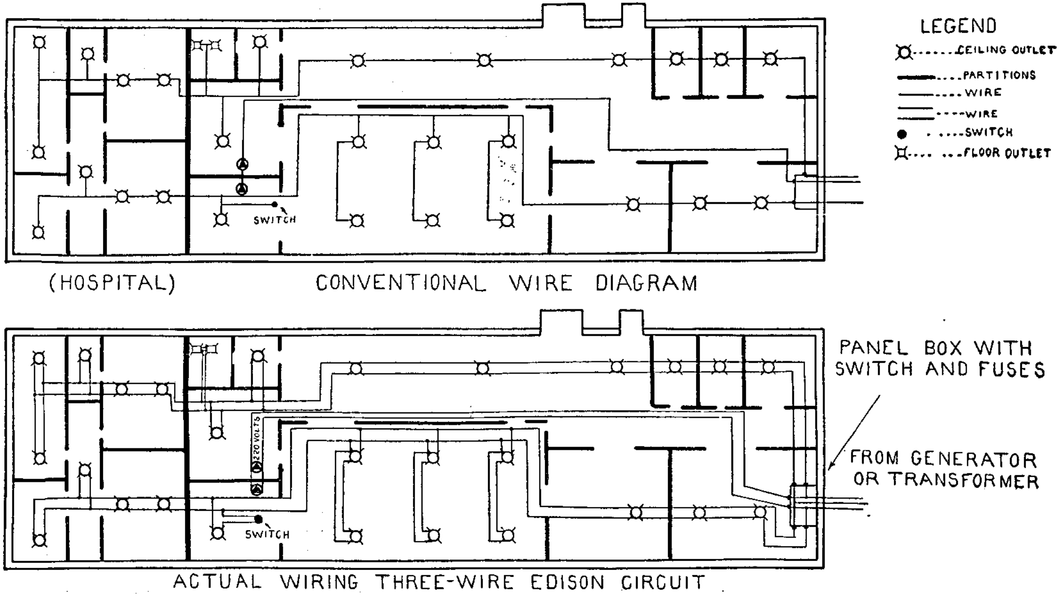


FIGURE 57.—Comparison of conventional diagram with actual wiring in typical building

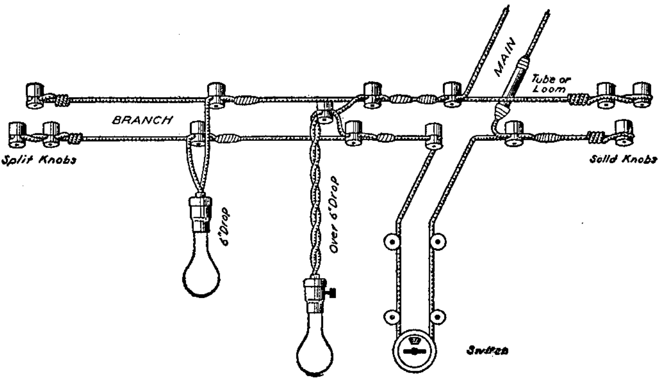


FIGURE 58.—Lighting installation using porcelain knobs

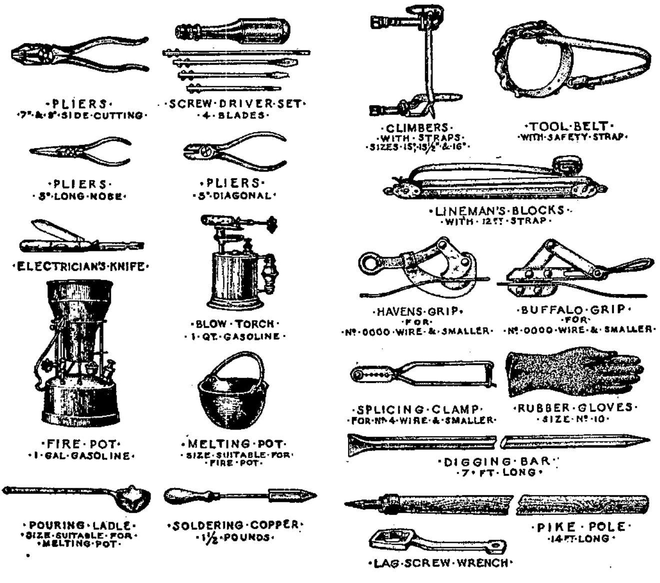


FIGURE 59.—Electrician's tools

TABLE XIX.—*Tools for party of four men for electrical wiring, external and internal*

4 pairs climbers, with straps.
4 tool belts, with safety strap.
4 pairs splicing clamps for No. 000 and smaller sizes wire and for copper sleeving.
4 pairs side cutting pliers, 8-inch.
4 screw drivers, 8-inch.
4 screw drivers, 6-inch.
4 screw drivers, 3-inch.
4 hammers, claw.
4 pairs longnose pliers.
4 blowtorches, 1 quart.
4 pounds friction tape.
4 rolls rubber tape.
4 pounds solder, half-and-half.
1 pound soldering paste.
4 awls, scratch.
4 knives, electricians'.
4 carpenter's brace-and-bit sets.
4 hatchets.
4 carpenter's ripsaws.
2 lineman's blocks with 12-foot strap.
1 2-sheave 4-inch block with 100 feet of ½-inch manila rope.
2 come-alongs (1 havens grip for No. 000 wire and smaller, and 1 buffalo grip for No. 0000 wire and smaller).
4 pairs high-tension gloves, No. 10.
2 digging bars, 7 feet long.
4 pike poles, 14 feet long.
4 spoons, 7 feet long.
4 lag screw wrenches.
4 bars soldering copper, 1½ pounds.
4 diagonal pliers.
1 fire pot, 1 gallon gasoline.
1 pouring ladle.

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

Electric lamps, 40 watts, 110 volts	4
Sockets, screw base, medium cap opening ⅜-inch	4
Reflectors, 8-inch cone, enameled tin	4
Shade holders for reflectors, 2¼ inches	4
Wire No. 14 B. & S. gage, single braid, rubber covered, solid conductor ... feet	220
Lamp cord No. 18 B. & S. gage, cotton covered, twisted ... feet	16
Tubes, porcelain, 5/16-inch by 6-inch	2
Cleats, porcelain, 3 wire (see note 1)	30
Cleats, rosette	4
Switch combination, double-pole, 30 amperes, 110 volts	1
Fuses, plug, 15 amperes, 110 volts	2
Rubber bushings for brass sockets, ⅜-inch outside diameter	4
Porcelain bushings for panel box	4
Nails, 12-penny wire, with leather heads (see note 2) ... nails	66
Screws, bright wood, 1¼ inches, No. 8	12
Screws, bright wood, 1½ inches, No. 10	4
Tape, ¾ inch, black, friction	1
Tape, ¾ inch, rubber, splicing	1
Solder, half-and-half, wire ... pound	1
Paste, soldering ... ounces	4
Panel box, 4 by 4 by 9 inches	1

NOTE 1.—If not available, substitute with 66 split knobs.

NOTE 2.—If not available, substitute with 66 2½-inch, No. 8 wood screws.

103. Storage battery charging circuits.—Storage batteries are charged on direct-current circuits. They can not be charged on alternating-current circuits unless some form of rectifier is used to change the alternating current to direct current. A simple device called a bank of lamps is used to regulate the current flowing through batteries while on charge. (See fig. 60.) In this figure a bank of lamps connected in parallel is shown arranged on some convenient base or on the wall of a building. By turning one or more of the snap switches the amount of current flowing in the circuit can be regulated to meet the needs of the batteries. Thus, by turning the switch on row of lamps No. 2, the current flowing through the batteries is equal to that flowing through four lamps. If snap switches 2 and 4 are turned on, the current flowing through the batteries is equal to that flowing through 11 lamps, and so on. Any other form of variable resistance may be used instead of the bank of lamps shown in the diagram. The batteries have their positive terminals connected to the positive side of the line and their negative terminals connected to the negative side of the line. The positive and negative terminals may be distinguished by using a voltmeter, the direction of movement of the indicator giving a clue as to which is the positive and which the negative terminal of the battery. If no voltmeter is available, the terminals may be distinguished by connecting them to short wires, the ends of which are immersed in a glass of salt water. Bubbles of hydrogen will gather on the negative conductor. Before putting batteries on charge see that the plates within the batteries are covered with distilled water. The charging rates of common storage batteries when constant current and voltage are maintained are as follows:

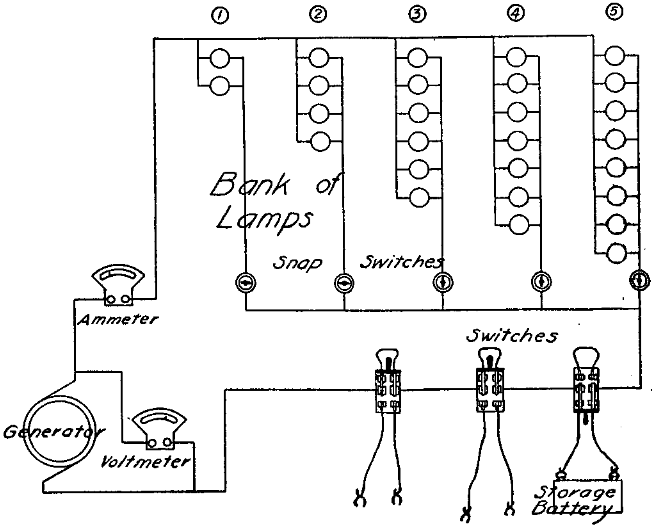


FIGURE 60.—Arrangement for charging storage batteries

	Charging rate, amperes
6-volt, 11 to 13 plates (Ford size)	8
6-volt heavy-duty Willard	17
6-volt Cadillac	15

When the cells bubble and gas freely, it is an indication that they are taking the charge properly, while if no such indication is present there is probably an internal short circuit. The charge of a light storage battery is indicated by the specific gravity of the fluid in the battery. The specific gravity is measured with a hydrometer syringe. Fully charged batteries have a specific gravity of 1,250 to 1,300 at room temperature. A specific gravity of 1,175 or less indicates that the battery is dead. The voltage of a charged cell is 2 volts. If instruments are not available, the state of charge of the battery may be judged by taking a short piece of cable and short-circuiting the battery for a moment. If a bright blue, snapping spark is produced, the battery is fully charged; a reddish yellow spark or flame indicates that the battery is dead.

Section VI

MILITARY REQUIREMENTS

104. Lights for camps, barracks, and recreation halls.—Where electric power and materials for lighting are available, it is a convenience to have electric lights in camp and they may be installed. However, in the theater of operations installations are made only when facilities for their construction are easily available. When camps are lighted there need not be more than four 40-watt lights per barrack (20 by 100 feet) and one 40-watt light per officer. Camp headquarters needs about seventy-five 40-watt lamps. In general, electric lights should be provided in recreation halls, if at all possible, as the attractiveness of these places is intimately related to the morale of the troops. Lights should be provided at writing tables and general illumination within the hall should be liberal. Outside illumination is not provided.

105. Lights for division headquarters.—The forward echelon of an Infantry division headquarters requires about 75 incandescent lamps of 40 to 60 watt rating. This imposes a load of from 3 to 4½ kilowatts depending on the actual wattage of the lamps used. One portable 5-kilowatt gasoline-electric generating set is adequate to supply this requirement, providing from 2 to 6 lamps each for the commanding general, the sections of the general and technical staffs and the message center.

106. Lights for corps, army, and GHQ.—Experience in the World War indicates that for higher echelons the requirements in electric lighting are about as follows:

TABLE XXI.—*Electric-light requirements for headquarters*

Headquarters	Approximate number of lamps, 40 to 60 watt	Power in kilowatts
Corps	75	5
Army	150	10
GHQ	600	40
Communications zone	600	40

107. Power and lights for hospitals.—A 10,000-bed hospital requires 150 kilowatts of power for lights, sterilizing apparatus, dentists' tools, X ray, etc. This is the equivalent of the power output of six 25-kilowatt generating sets. The sets may be installed from time to time as the hospital is constructed and the need for electricity grows. They should preferably be distributed about the hospital area. If possible, commercial sources of power should be used.

SECTION VII

RECONNAISSANCE

108. Reconnaissance party.—*a. Personnel.*—The personnel of a party for making electrical reconnaissance need not be large. A qualified leader and from three to six assistants are sufficient to reconnoiter the area normally occupied by a division. The party should include at least one person familiar with transmission lines, one familiar with primary power plants, and one familiar with electric-power central station installations. Such personnel is generally classified as electrical engineers, general electricians, linemen, gas enginemen, and stationary enginemen.

b. Equipment.—The party should have transportation consisting of either an automobile or several motor cycles. They should be provided with maps of the area to be reconnoitered, paper and pencils for making reports, report blanks, and the following lineman's equipment: Pole climbers with straps, tool belt with safety strap, splicing clamp, 8-inch side-cutting pliers, a

24-inch bolt cutter, screw driver, hatchet, claw hammer, wrecking bar, hack saw, and high-tension gloves.

c. Employment.—The party should, in general, seek first the central station from which power to the area is obtained. After observing the power station, the lines emanating therefrom should be examined. Notes and photographs should be taken showing the installations reported upon in the reconnaissance. Blanks similar to the example shown in paragraph 112 should be filled out.

109. General reconnaissance of a new area.—The electrical reconnaissance of a new area—that is, one not hitherto occupied by our forces and not subjected to the destructive activities of the enemy—should determine first the local supply of electricity for power and light and the amount of additional load which the existing facilities can provide for. In order that the military electrical equipment may be used, it is essential that the frequencies of the local source be the same as that for which the military equipment has been designed. A reconnoitering party should therefore determine the frequencies used in the local supply, if alternating current is used, and whether facilities exist for modifying this frequency, if necessary, in order to adapt it to the military equipment. The potential (voltage) at which the power is transmitted should be determined as well as the condition of the local installations and the system of operation and control. A very important consideration is to determine whether the local fuel situation is satisfactory, and if not, what steps are necessary to supply fuel to the local plant. The location and inventory of existing stocks of electrical supplies in the area should be determined, including wire and cable, incandescent lamps, motors, generators, poles, and accessories. If possible, a diagram should be obtained or made showing the distribution of electrical power throughout the area. An estimate should be made of the requirements in power in the new area and recommendation should be made covering the allocation of portable equipment, the installation of new equipment, and regulations for the consumption of light and power.

110. Reconnaissance of a location for portable lighting sets.—When a division, corps, or army headquarters is moved into a new area, a reconnaissance is made to determine the location for the portable electric-lighting equipment carried by the engineers for the illumination of these headquarters. The requirements for the location of these sets are that they be near enough to the center of distribution so that the line losses will be as small as possible and so located that the noise of the operation of the machine and the exhaust gases will not interfere with the headquarters personnel. The ideal location is in the basement of the building occupied by the headquarters or in a near-by shed. Note must be made of the method of permitting the escape of exhaust gases to the outer air and provision must be made for the supply of gasoline to the set without undue fire hazard. The operating personnel should be sheltered near by and preferably should live in the same room with the generating machinery.

111. Reconnaissance of captured terrain.—The reconnaissance of an area captured from the enemy is similar to that described above for the general reconnaissance of a new area, except that the enemy may be expected to destroy or damage the electrical installations prior to his departure. However, they should be carefully examined, since one usable installation may be made up from undamaged parts taken from several demolished plants. Particular note should be taken of the location and size of the conductors of any distribution lines remaining intact, as by making use of such systems the reestablishment of electric service in the captured area may be made in minimum time. Electric supplies left in abandoned dumps should be inventoried.

112. Blank form.—The following blank form is suggested for use by a reconnaissance party both in making an electrical reconnaissance and in reporting the results.

Form for electrical reconnaissance

ELECTRICAL RECONNAISSANCE

Reconnaissance party:
....
....
....

Area ....
Map ....

Date ....
Photographs ....

Prime movers

Type: .... (Steam, internal combustion, water wheel).

Fuel: .... (Coal, oil, gas)

.... (Amount on hand)

.... (Feed)

Horsepower.....................

Lubricants .... (Kind and amount on hand).

Water supply .... (Character and amount).

General condition.....................
....
....
....
....

Generators

Type .... (Alternating or direct current)

Number of machines.......

K.V.A...... KW... Volts...

Amperes... Power factor...

Frequency... R.P.M.......

Horsepower... Maker......

General condition..........
....
....
....
....
....
....
....

SWITCHBOARD

Instruments...............
Interconnections..........
Condition.................

Transmission lines

Type .... (2-wire; 3-wire Edison; 1, 2, 3, phase A. C.)

Current..... Voltage...... (A. C. or D. C.)

Conductors .... (Size and material)

Location .... (On poles or below ground)

Transformers...............

Substation............... (Whether transformer or synchronous converter).

Condition...............
....

ELECTRICAL SUPPLIES

Location...............
General kind...............
Inventory...............
....

Recommendation..
....

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