FIELD MANUAL
No. 5-163

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SEWERAGE

APPENDIX A

REFERENCES

A-l. Field Manuals (FM)

5-35 Engineers' Reference and Logistical Data.
21-10 Field Hygiene and Sanitation.

A-2. Technical Manuals (TM)

5-227 Design and Techniques for Military Civic Action.
5-233 Construction Surveying (Mathematical Considerations).
5-301 Engineer Functional Components System Staff Tables of Installations, Facilities, and Equipages.
5-302 Construction in the Theater of Operation.
5-303 Bills of Materials and Equipment of the Engineer Functional Component System.
5-551K Plumbing and Pipefitting.
5-660 Operation of Water Supply and Treatment Facilities at Fixed Army Installations.
5-665 Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations.
5-666 Inspections and Preventive Maintenance Services, Sewage Treatment Plants and Sewer Syetems at Fixed Inatallations.
5-814 (Series) Sanitary Engineering.

ACKNOWLEDGMENTS

Acknowledgment is made to the following companies for their permission to use in this manual the photographs listed below.

Figures 5–1, 5-3, 5-4, 5–5, 5–6, and 5-7 from FMC Corporation, Chicago, Ill.

Figure 5-2 from Clew Corporation, Florence, Ky.

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CHAPTER 1

INTRODUCTION

1-1. Purpose and Relation to Other Manuals

This manual is intended to serve as a guide for personnel who must design waterborne sewage collection, pumping, treatment and disposal facilities in the theater of operations. The manual should be used with the Army Facilities Components System (AFCS), TM 5-301, 5–302, and 5–303. Material in this manual has been drawn from many Department of the Army Field Manuals, Technical Manuals, and commercial publications. References are made to the source of the material throughout the text, and in appendix A. Referenced publications will contain more detailed information and should be referred to in the planning and design for a construction project or operation.

1-2. Changes

Users of this manual are encouraged to submit recommended changes and comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to the Commandant, US Army Engineer School, Fort Belvoir, Virginia 22060.

1-3. Governmental Regulations

Regulations and specifications for the construction and operation of sewage collection and treatment systems, and for the degree of treatment required, may be prescribed by national, state, or local governments. Users of this manual are responsible for complying with such regulations where applicable.

CHAPTER 2

SEWAGE TREATMENT

Section I. PURPOSE

2-1. Introduction

a. In the theater of operations the purpose of sewage treatment is twofold.

(1) It safeguards health by eliminating, to the extent required, the disease-producing organisms. The treatment does not purify the sewage.

(2) It stabilizes the sewage so that it will not overload the disposal media, in lake, stream, or drainfield.

b. Treatment may be of two types, primary and secondary.

(1) Primary treatment is the separation of the settleable and floating solids from the liquid and the stabilization of these solids.

(2) Secondary treatment is the stabilization of the finely-divided sewage solids which remain in the liquid after primary treatment.

c. Specific design criteria given in this section should be used where TM 5-302 designs are not adequate. Use of TM 5-302 designs should be possible in most theater of operation situations.

Section II. SEWAGE CHARACTERISTICS

2-2. General

a. Sewage, the used water together with the solids that are mixed with it, can be of four types. These are—

(1) Sanitary sewage (also called domestic sewage)—the sewage which originates in the sanitary conveniences of houses, barracks, shops, and other areas for work or living.

(2) Industrial sewage—the waste from an industrial process such as dyeing, brewing, or papermaking.

(3) Storm sewage-the water (runoff) from rain and snow and the particles carried with it.

(4) Infiltration-the ground water and the particles carried with it which leak into a sewer through joints or breaks.

b. In theater of operations construction, generally only infiltration and sanitary sewage are allowed in the sewerage system. Wastes from gasoline dispensing systems, wash racks, garages, and shop floor drains must be excluded from sanitary sewers because such wastes deter the natural biological processes which occur during the stabilization of sewage. However, the waste from a laundry may be discharged into the theater of operations sewer system. Storm water runoff from ground surface, pavements, and roofs should not be permitted to enter sanitary sewers. It is difficult to obtain flow conditions in combined sewers (sewers that are designed to carry both sanitary and storm sewage) that are adequate during dry weather to prevent the deposition of sewage solids in the sewer and subsequent septic action. A considerably larger pipe would be required for combined sewers than for sanitary sewers; the cost of installing the larger pipe at the greater depth usually required for sanitary sewers often would equal and sometimes exceed the cost of separate sewer systems. However, where sewage treatment is not required and is not likely to be required, combined sewers may be used if their use results in considerable saving in construction effort and if slopes are available to produce the necessary velocities.

2-3. Composition

a. Physically, sewage is composed of 99.8 to 99.9 percent used water. Thus only .1 to .2 percent of sewage is solid matter. Of this solid matter, 40 to 70 percent is organic matter which will putrefy and give off unpleasant odors. The rest is inorganic matter which is usually harmless.

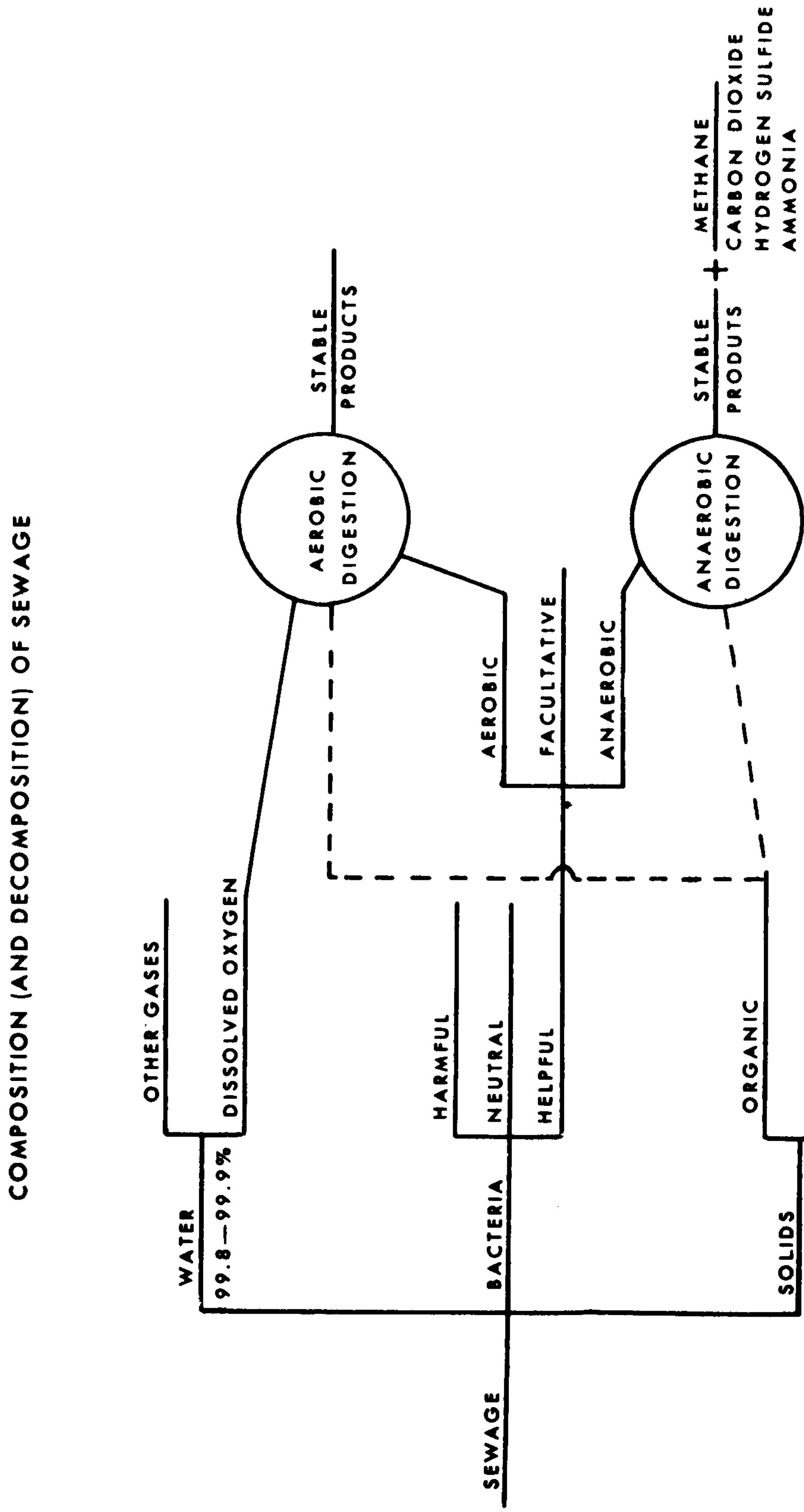


Figure 2–1. Composition and decomposition of sewage.

b. Chemically, sewage contains substances of animal, vegetable, and mineral origin. The first two are called organic matter and are composed largely of the elements carbon, oxygen, hydrogen, and nitrogen.

c. Biologically, sewage contains enormous numbers of living organisms. They are comprised mainly of viruses and phages, bacteria, and other microscopic organisms, listed in order of increasing size. These organisms may be helpful, harmful, or neutral. The harmful ones are those which are pathogenic, that is, disease-producing. The diseases carried in sewage are those normally called "water-borne diseases" such as typhoid fever, cholera, and dysentery. Fortunately, the number of pathogenic organisms decreases rapidly in sewage because they have been removed from the favorable conditions and abundant food supply in the human body. In addition, their ingestion by predatory protozoa, the lack of suitable food in treated sewage, and disinfection by chemicals and by the sun's rays further reduce their number. The helpful organisms are those which are used in the treatment of sewage. Figure 2–1 graphically shows the composition and decomposition of sewage.

2-4. Decomposition

a. Two processes aid the decomposition of sewage: aerobic digestion and anaerobic digestion (fig 2-1).

(1) *Aerobic digestion.* Aerobic digestion requires oxygen and takes place through the combination of dissolved oxygen from the water, aerobic bacteria, and organic solids. This combination results in the formation of a stable product.

(2) *Anaerobic digestion.* Anaerobic digestion does not require oxygen and is a result of the combination of organic solids and anerobic bacteria. From this combination a stable product is found along with some very odorous gases.

b. The final products of aerobic sewage decomposition are compounds formed by oxidation of the original raw sewage components. The amount of oxygen used in the decomposition of a sample of sewage is a measure of the amount of decomposable organic matter present in the sewage, and therefore of its strength. or polluting power.

(1) The biochemical oxygen demand (BOD) is a measure of the polluting power of sewage. BOD is the amount of oxygen required for the biological decomposition of dissolved organic solids to occur under aerobic (dissolved oxygen always present) conditions. The BOD of military sewage is usually taken as 0.20 pounds of oxygen per person per day.

(2) As with any biologically activated process, BOD varies with time and temperature. The standard BOD value is given as oxygen demand per unit (parts per million or pounds per' person) in 5 days at 20 degrees centigrade. This is not meant to say that the biochemical oxygen demand is satisfied in five days, but only that a longer test period becomes impractical. Wherever in this chapter BOD is mentioned with no reference to time or temperature, the standard 5 days at 20°C is to be assumed.

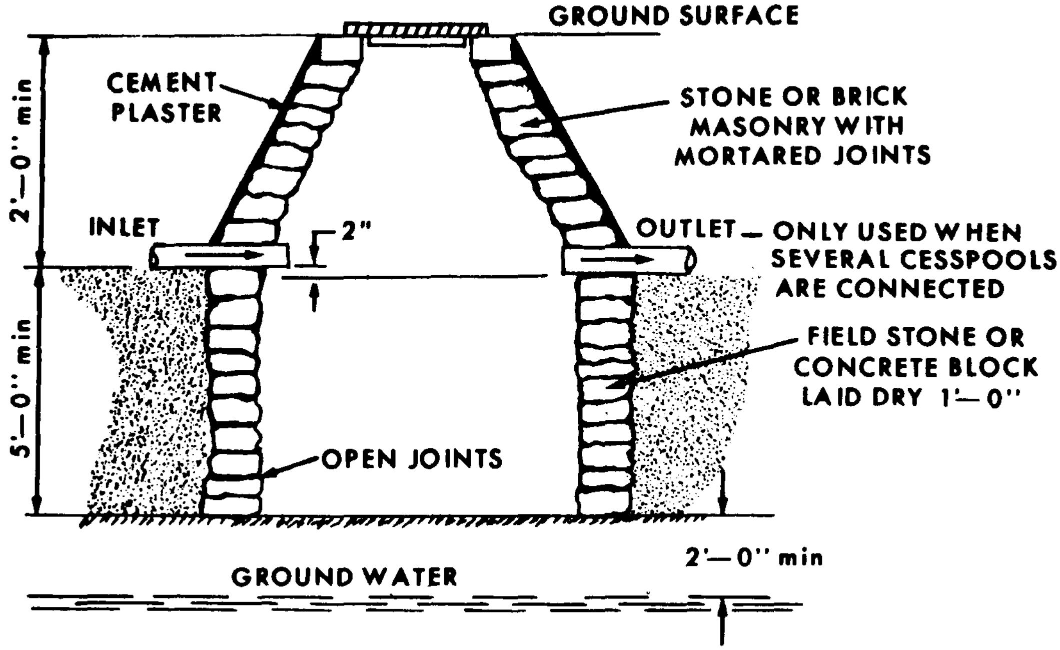
Section III. TREATMENT FACILITIES

2–5. Cesspools

a. Cesspools are usually constructed with open-jointed masonry walls and an unlined bottom through which liquid percolates into the surrounding soil. Solids settle to the bottom and are digested by anaerobic bacteria. The cesspool's ability to function properly ceases when the solids accumulate and clog the soil. When this clogging occurs, a second cesspool should be constructed a minimum of 20 feet away from the existing one and connected to it with an overflow pipe. In this arrangement the first cesspool acts as a settling and digestion pit (septic tank) and the second one acts as a leaching pit.

b. Cesspools may be used where the subsoil is porous to a depth of 8 to 10 feet and where the depth of the cesspool will not pollute or contaminate the ground water. If the bottom of the cesspool is in dry soil at least two feet above the highest ground water table, there is very little danger that it will contaminate the ground water. As a general safety rule the cesspool should be constructed a minimum of 100 meters away and downhill from any water source.

c. The total number and size of cesspools required depends upon the quantity of sewage and the leaching characteristics of the soil. A description of how to conduct a percolation test to determine the leaching characteristics of the soil is given in chapter 3. The allowable application rates and cesspool details are given in figure 2–2. Additional design information is available from TM 5-302.



CESSPOOL — DETAIL

APPLICATION RATES OF SEWAGE FOR CESSPOOLS

TIME IN MINUTES REQUIRED FOR WATER TO FALL ONE INCH IN TEST HOLE	ABSORPTION IN GALLONS PER SQUARE FOOT OF PERCOLATING AREA PER DAY	TOTAL ABSORPTIVE AREA = AREA OF WALLS (BELOW THE INLET) + AREA OF THE BOTTOM TOTAL ABSORPTIVE AREA = (2 π R) (HEIGHT) + π R²		
		DIAMETER	DEPTH Below Inlet	AREA IN SQUARE FEET
1	5.3	5'	5'	99
2	4.3	6'	6'	142
5	3.2	7'	6'	170
10	2.3	8'	6'	201
30	1.1	8'	7'	216
		9'	7'	262
		9'	8'	293
		10'	8'	330
		12'	10'	489

Figure 2–2. Application rates of sewage for cesspools.

2-6. Septic Tanks

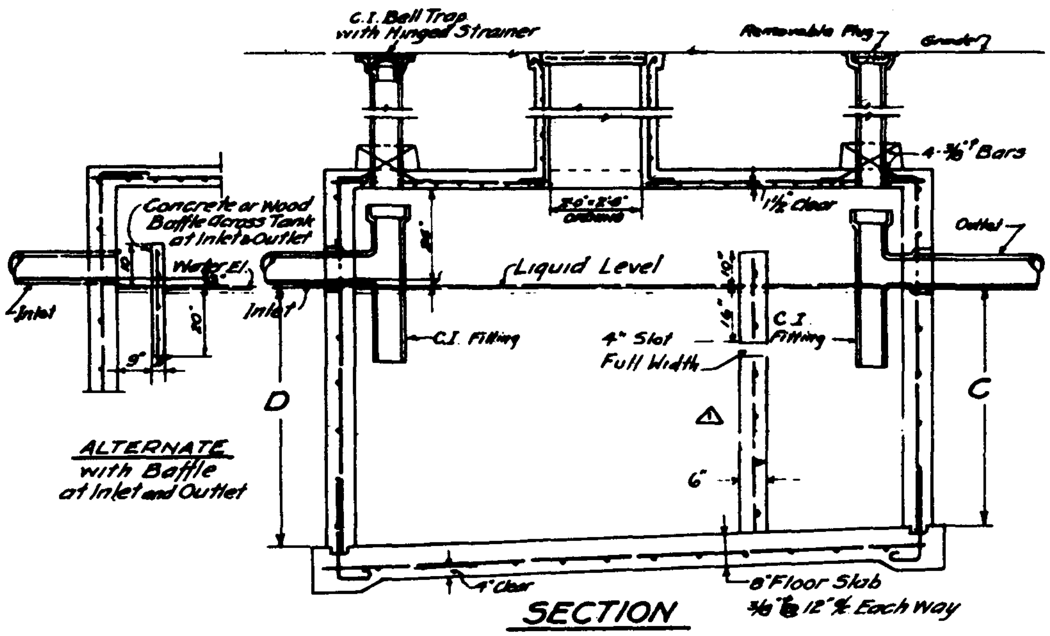
Septic tanks serve small installations where the effluent can be disposed of by dilution, leaching cesspools, leaching trenches, tile fields or artificial subsurface filter systems.

a. The volume of the septic tank should be equal to the peak sewage flow for a period of 16 to 24 hours, plus an additional 25 percent of the total volume for sludge storage. The length of the tank should not be less than two or more than three times the width. Manholes should be provided over the inlet and outlet pipes and over the low points in tanks with hopper-bottoms. These manholes will allow access for inspection and cleaning (fig 2–3). Additional design information may be found in TM 5–302.

b. Although properly designed septic tanks require little operating attention, they must be inspected periodically, frequency being determined by size of tank and population load. Minimum frequency should be once every 2 months at periods of high flow. The inspection must determine that inlet and outlet are free from clogging, that the

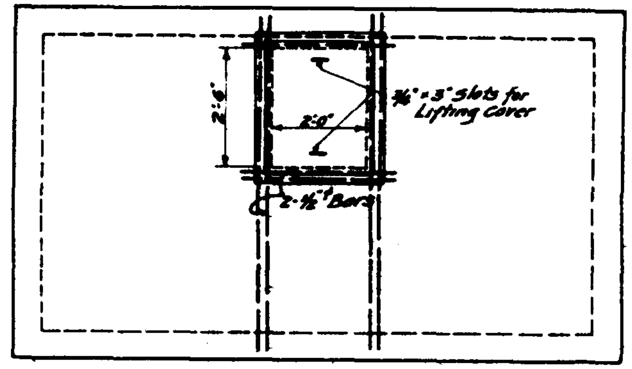
SEPTIC TANK DIMENSIONS & REINF.

CAPACITY GALL'S	CU. FT.	+25%	A	B	C	D	WALL THICKNESS	WALL REINFORCEMENT FOR 1/2"φ HORIZ.	WALL REINFORCEMENT FOR 1/2"φ VERT.	WALL REINFORCEMENT FOR 5/8"φ HORIZ.	WALL REINFORCEMENT FOR 5/8"φ VERTICAL	ROOF SLAB THICKNESS	ROOF SLAB REINF. TRANSVERSE	ROOF SLAB REINF. LONGITUDINAL
500	67	83	6'-8"	3'-0"	4'-3"	4'-9"	7" WALL THICKNESS	1/2"φ @ 12" c/c ALL WALLS	1/2"φ @ 12" c/c ALL WALLS	5/8"φ @ 8" c/c	MIDDLE HALF OF WALL 5/8"φ @ 8" c/c; END QUARTERS OF WALL 5/8"φ @ 12" c/c	3½"	5/8"φ @ 4" c/c	1/2"φ @ 12" c/c ALL SLABS
750	100	125	8'-2"	3'-8"	4'-3"	4'-9"						3½"		
1000	133	166	8'-8"	4'-1"	4'-9"	5'-3"						3½"		
1250	167	208	9'-9"	4'-6"	4'-9"	5'-3"				5/8"φ @ 6" c/c	MIDDLE HALF OF WALL 5/8"φ @ 6" c/c; END QUARTERS OF WALL 5/8"φ @ 8" c/c	4"	5/8"φ @ 3½" c/c	
1500	200	250	10'-6"	4'-9"	5'-0"	5'-6"						4"		
1750	233	292	11'-6"	5'-0"	5'-0"	5'-6"						4½"	1/2"φ @ 6" c/c	
2000	266	332	12'-6"	5'-3"	5'-0	5'-6"						4½"		

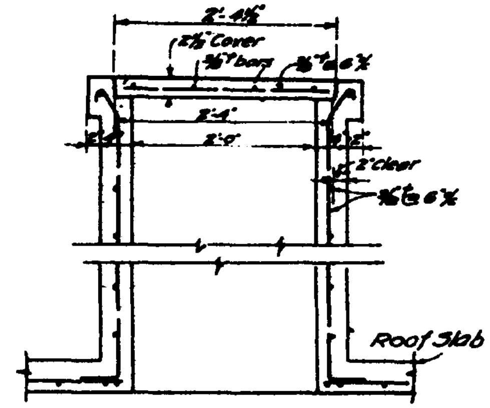


SECTION

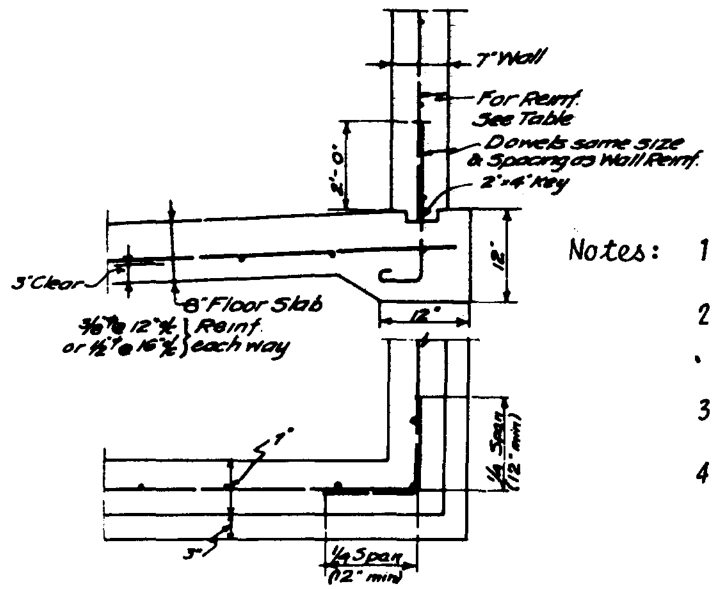
NOTE: For Wall and Roof Slab Reinforcement see Table.



ROOF SLAB PLAN

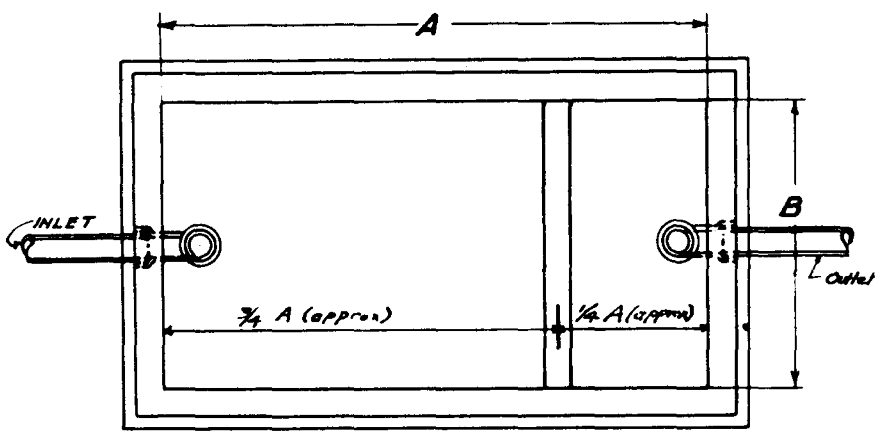


MANHOLE



TYPICAL CORNER REINF.

Notes:
1. Other designs may be used to suit local conditions.
2. The capacities indicated are exclusive of 25% allowance for sludge accumulation.
3. Top of tank may be at grade if conditions permit.
4. Tank may be poured in place, precast elsewhere, or may be fabricated or prefabricated of other approved material.



PLAN

BASIS OF STRUCTURAL DESIGN:

1. Roof slab is designed for an earth load of 300 lbs. plus a live load of 100 lbs. per square foot.
2. Walls are designed for the internal liquid pressure or for an external earth pressure equivalent to a fluid pressure of 33 lbs. per foot of depth, whichever load causes the max. stress.
3. Concrete to have a minimum strength of 3000 lbs. per sq. inch in 28 days, with n = 10; f_s = 20000 lbs. and f_c = 1350 lbs. per sq. inch.

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depth of scum and sludge accumulation is not excessive, and that the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs subsurface disposal facilities. Sludge and scum accumulation cannot exceed one-fourth of tank capacity. Statements, which are sometimes made, that septic tanks liquefy all solids, that they never need cleaning, and that the effluent is pure and free from germs are not true. Perhaps 40 to 60 percent of the suspended solids are retained; the rest are discharged in the effluent.

c. Separating sludge and scum from the liquid in septic tanks is difficult; for small tanks they are customarily mixed. The entire contents should not be removed when the tank is cleaned. A small quantity of sludge should be left in the tank to "seed" future biological processes. The material removed contains fresh or partially digested sewage solids which must be disposed of without endangering public health. Disposal through manholes in the nearest sewerage system, as approved by local authorities, or burial in shallow furrows on open land is recommended.

d. The liquid effluent should be disposed of by dilution or irrigation. See Chapter 3, Disposal, for additional information.

2-7. Sewage Treatment Plant

a. Two types of sewage treatment plants may be constructed from the Engineer Functional Component System:

(1) One plant provides only primary treatment, the removal and stabilization of settleable and floating solids (fig 2-4).

(2) The second type of plant provides complete treatment, both primary and secondary. After primary treatment has been completed, solu-

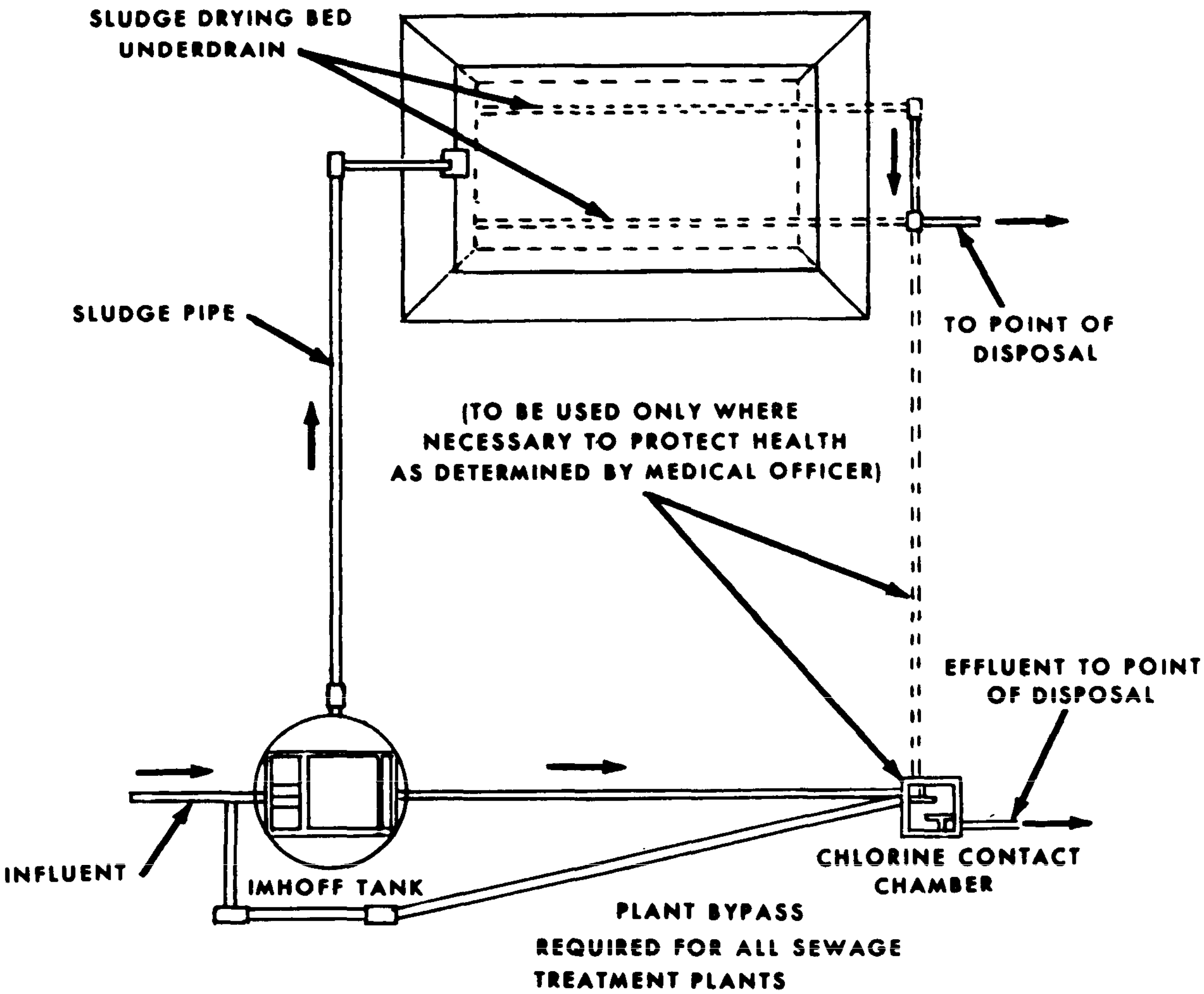


Figure 2-4. Typical primary treatment plant.

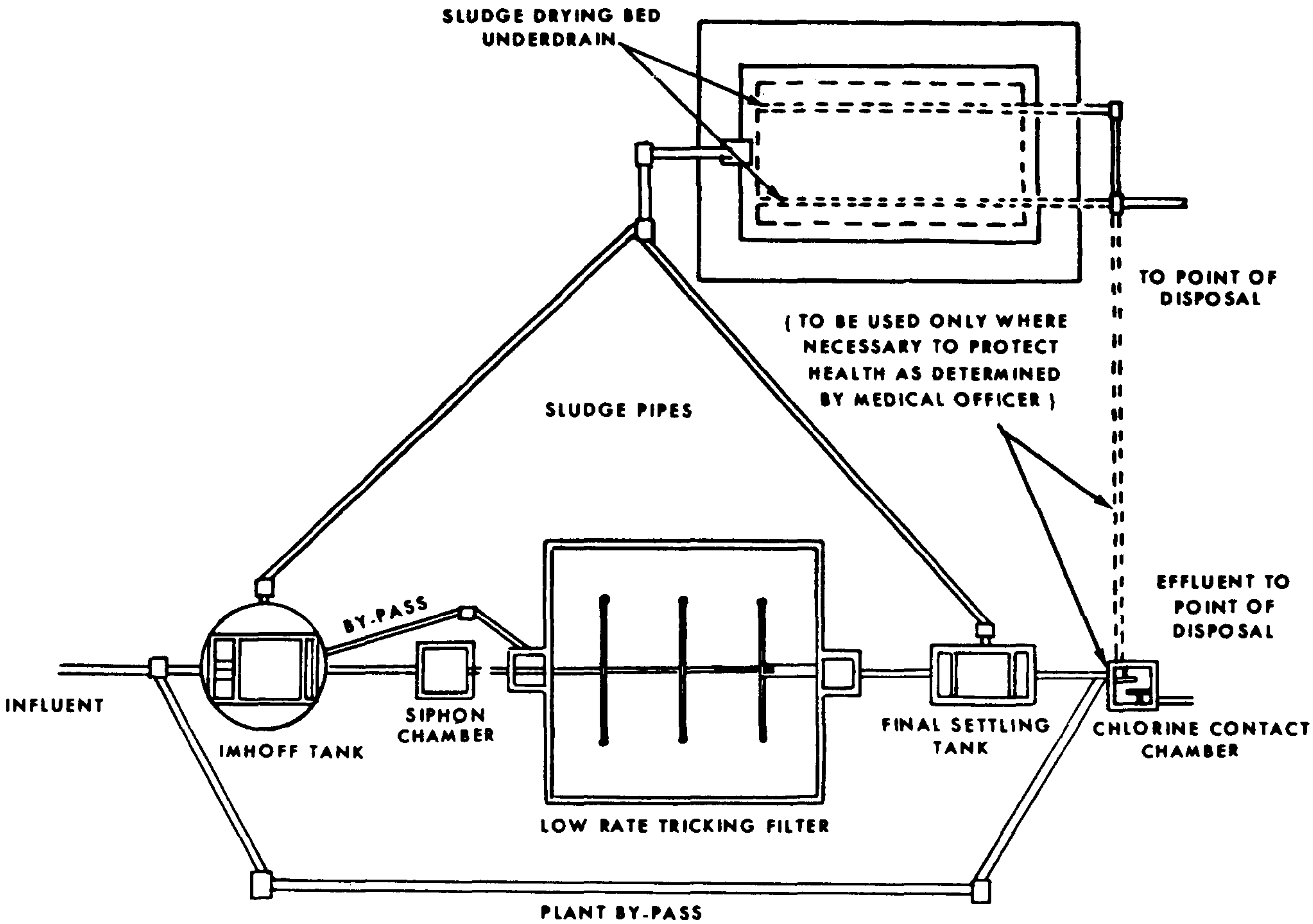


Figure 2–5. Typical primary and secondary treatment plant.

ble or finely divided sewage solids remaining in the liquid are biologically oxidized (fig 2-5).

b. Specific design criteria given in this section are for situations where standard designs from TM 5-302 are not adequate. Standard designs from TM 5-302 should be used whenever possible.

2–8. Facilities for Primary Treatment

a. Bar Screen. A bar screen is used to screen large particles such as rags, rocks and sticks from the sewage. Bar screens are usually required at the inlet to pumping stations and treatment plants. The bar screen is constructed of bars installed longitudinally in a channel, 1 to 1½ inches apart, clear measurement, and should have a slope of about 1:2. One inch screens collect 1 to 3 cubic feet of screenings per million gallons of sewage. The screens should also be constructed with an overflow chamber to prevent stoppages (fig 2-6).

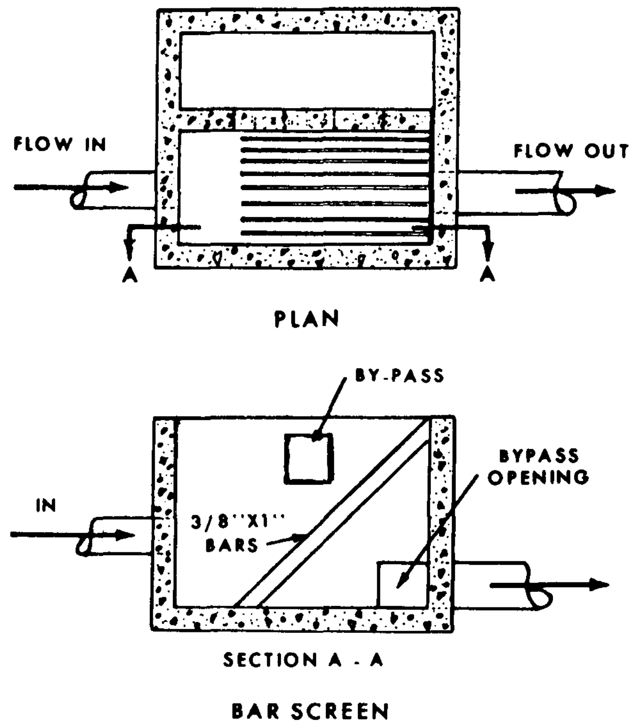


Figure 2–6. Bar screen.

b. Plain Settling Tanks.

(1) The only function of the plain settling tank is to detain the sewage long enough and at a low enough velocity to permit most of the suspended solids to settle out. The settled solids, often

called sludge, are removed from the settling tank daily and transferred to another facility for digestion.

(2) Factors considered in designing settling tanks are the quantity of sewage (average flow), detention time, method of sludge removal, length, width, and depth.

(a) The liquid volume of the tank may be calculated by the formula:

$$V = \frac{2.5}{180} \left[.7 (\text{Des. pop.} \times \text{Ave. Flow}) \; \text{Inf. All} \right]$$

where:

- v = Liquid Volume of the tank in cubic feet
- 2.5 = Recommended detention time in hours
- 180 = (7.5 cubic ft / gal) (24 hours / day)
- Des. Pop. = Design population of the installation
- Ave. Flow = Average water demand in gallons per day per person
- Inf. All. = Infiltration allowance = (length of sewer in feet) (1440 min / day) (infiltration rate or 2 gpm / 1000')

(b) The length and width may be determined by assuming a depth of 10 to 12 feet and dividing this into the tank volume. The resultant will be the surface area in square feet. Based on the ratio that the length of the tank should be equal to 3 times the width, the rectangular dimensions can then be determined. Additional allowances are necessary to provide freeboard, about 12 inches, and space in the bottom for sludge storage (fig 2-7).

(c) Sludge is removed through a sludge draw-off pipe having its inlet about 1 foot above the tank bottom. For design details see TM 5-302.

c. Separate Sludge Digestion Tanks.

(1) Raw sludge from the settling tank is discharged daily into the sludge digestion tank for septic decomposition by anaerobic bacteria. The simplest type of digestion tank is an uncovered earth basin which receives the settled sludge from the settling tank by gravity flow. Digested sludge is drawn off at the bottom, which should be cone-or hopper-shaped to facilitate the outflow of sludge. Concrete lined tanks are preferred, although brick or stone masonry, gunite, sheet-metal, or wood tanks may be used.

(2) The volume of the digester should be equal to 3 cubic feet per capita. In plants that recycle the sludge from the final settling tank to the plain settling tank or directly to the digester, the volume should be equal to 4.5 cubic feet per capita. The depth of the digester should be between 15 and 25 feet.

(3) This design basis allows for a reasonable depth of sludge which, unless stirred, stratifies into 4 layers as follows:

(a) An upper, relatively inactive scum layer,

(b) A central layer of tank liquor, from which solids have settled,

(c) A lower, relatively active layer of digesting solids, and

(d) A bottom, relatively inactive layer of stable solids.

(4) The rate at which digestion and the resulting change in fluidity takes place depends on the temperature and the alkalinity of the sludge. The optimum temperature range is 90 to 100 degrees and the Ph value should be between 6.8 and 7.3.

(5) A more efficient treatment of the sewage can be accomplished by returning the liquor from the central layer of the sludge digestion tank to the plant influent (in the primary settling tank). The liquor can be withdrawn from the sludge digestion tank by tapping 3 or 4 outlets spaced about 2 feet apart vertically, beginning approximately 3 feet below the maximum liquid level.

(6) The digested solids in the bottom of the digestion may be withdrawn in the same manner as the sludge was withdrawn from the plain settling tank or the Imhoff tank. This stable solid may be transferred to the sludge drying beds.

d. Imhoff Tanks.

(1) An Imhoff tank is a sedimentation tank and digestion tank in one (fig 2-8). It consists of an upper compartment for settling out solids from the slowly flowing sewage and a lower compartment for septic digestion of the sludge. The upper compartment forms a channel with an approximately 8-inch slot in the bottom. Sides of the slot have a 1 horizontal to 1½ vertical slope and are overlapped to prevent gases formed by digesting sludge from escaping into the upper or "flowing-through" compartment. With an average flow, solids settle in the upper compartment in 2 to 2½ hours, pass downward through the slot, and settle to the bottom of the lower compartment where they are digested. Accumulated solids are removed periodically through a sludge draw-off pipe having its inlet about 1 foot above the tank bottom.

(2) Design of the upper or "flowing-through" compartment is based on the retention period. (See plain settling tanks.) The lower or digestion compartment is designed to hold 3 cubic feet per

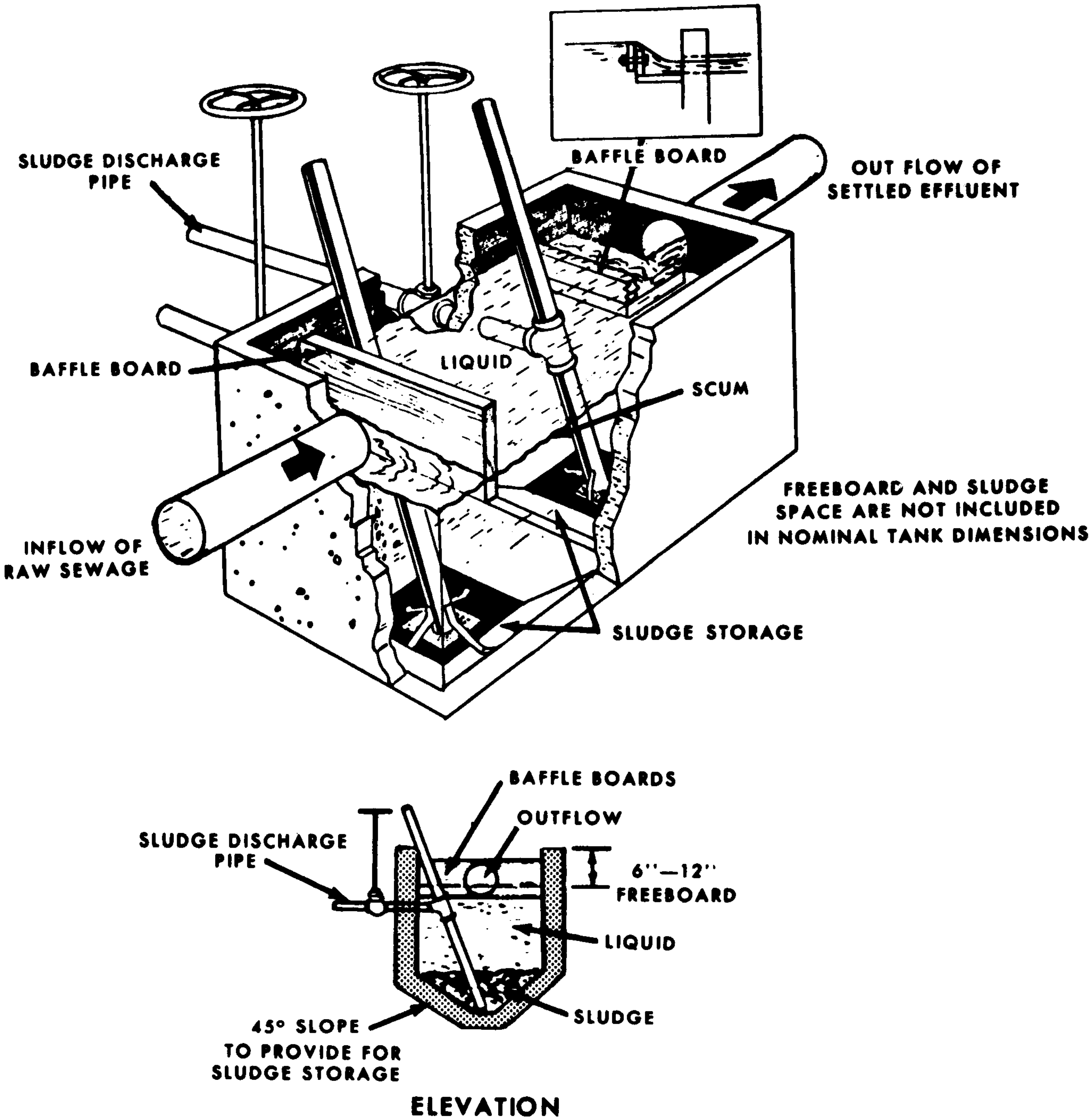


Figure 2–7. Settling tank.

capita below a plane 18 inches beneath the bottom of the slot. If sludge from secondary settling is returned to this compartment for digestion, the capacity of the compartment must be increased to 4½ cubic feet per capita. Construction drawings of Imhoff tanks are given in TM 5–302.

(3) The digested sludge removed from the Imhoff tank should be transferred to the sludge drying beds.

e. Sludge Drying Beds. A common method of preparing digested sludge for disposal is by air drying. There are generally two types of sludge drying beds which can be constructed.

(1) Drying beds without drains: Natural sludge drying beds without underdrains are constructed by building earth dikes. They should provide 3 to 4½ square feet of surface per capita, depending on climate and permeability of the soil. Liquid sludge from the digestion tank is applied about 12 inches deep. When dried, it forms a cake about 4 inches thick. This cake is removed with a fork or shovel and can be used as humus.

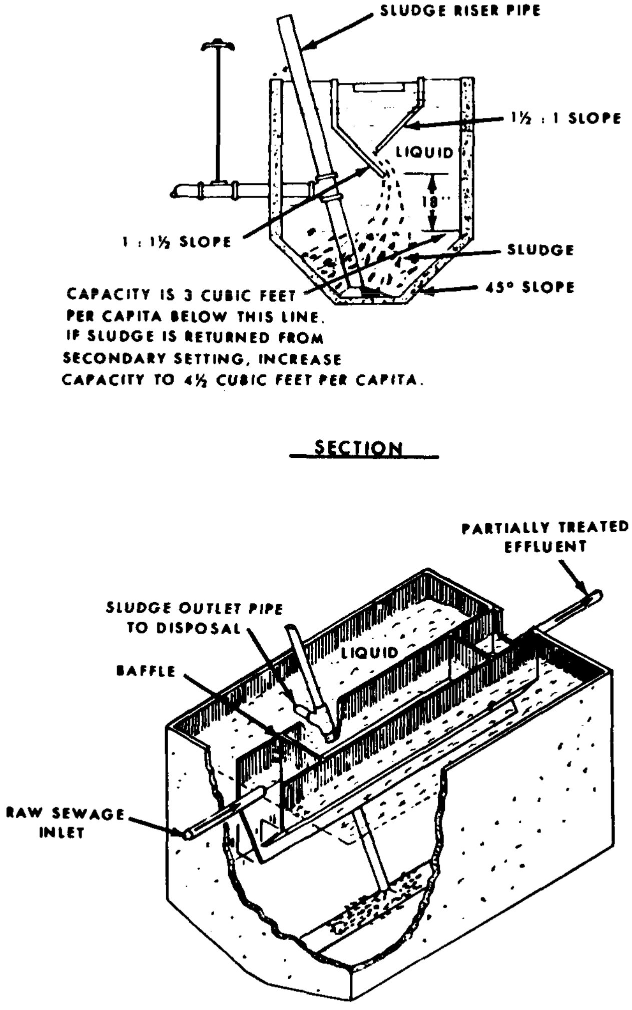


Figure 2-8. Imhoff tank.

(2) Drying beds with drains: Underdrain sludge drying beds consist of a surface layer and sand 6 to 12 inches thick, a 6 to 12 inch layer of gravel below the sand, and underdrains below the gravel layer. The underdrains should be 4 to 6 inch open joint or perforated pipe space 10 to 20 feet apart and should be laid in a V-shaped trench and surrounded with coarse gravel. The required area of a sludge bed is 1 to 1½ square feet per capita; the maximum length is about 100 feet. The bed is subdivided into sections by wood or masonry curbs spaced midway between the drain pipes. Characteristics and handling of sludge are the same as for natural beds. Drying requires 2 to 4 weeks, depending on humidity and rainfall. Sand removed with the sludge must be replaced when the thickness of the sand layer is reduced to 4 inches (fig 2-9).

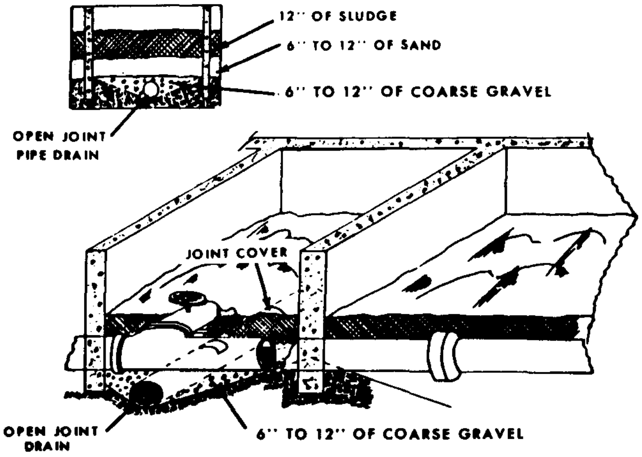


Figure 2-9. Sludge drying bed.

2-9. Secondary Treatment

a. Dosing Tank.

(1) In a conventional treatment plant the dosing tank is a control mechanism which performs two functions, the first of which is to discharge the effluent from the primary treatment facility, at intervals, over a filter media. Its second function is to provide sufficient hydraulic head to distribute the effluent evenly over the filter. Figure 2–10 shows a typical dosing tank. The dosing chamber volume is equal to 15 minutes full flow from the primary treatment unit.

(2) The siphon operates as follows: When the water is cut off at the low water line the liquid will be standing in the discharge pipe at the level A. As the liquid rises in the tank and covers the siphon vent, air is trapped under the dome. As the liquid level approaches the high water level the air under the dome is compressed; the liquid in the discharge pipe is forced down to level B; and the liquid level under the dome is near the upper end of the discharge pipe. Discharge will occur when a slight increase in head causes the water level at B to be depressed so that the compressed air will escape through the vent and overflow pipe. This sudden release of air will allow the water to rush into the discharge pipe and start the siphon action. The siphon action continues until the water level in the tank falls below the air vent, breaking the siphon action.

b. Trickling filters.

(1) Trickling filters, often called sprinkling filters, are beds of crushed rock, crushed slag, or

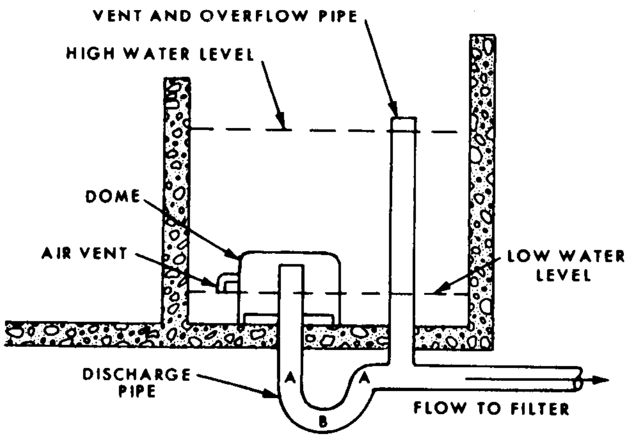


Figure 2–10. Dosing tank.

gravel, to the surface of which primarily treated sewage is applied through rotary distributors or stationary sprays. The sewage then trickles in a thin film over the stones to a system of underdrains (figs 2-11 and 2-12). These beds are not actually filters in the usual sense, but accomplish their function in the treatment of sewage mainly through oxidizing action by aerobic bacteria. The effect is that dissolved and suspended organic matter in the sewage is absorbed by bacterial growth on the stones and converted to more stable compounds. Some of these compounds coagulate and settle in the final settling tank. Others are soluble and pass on with the final effluent sewage. There are two main types of trickling filters,

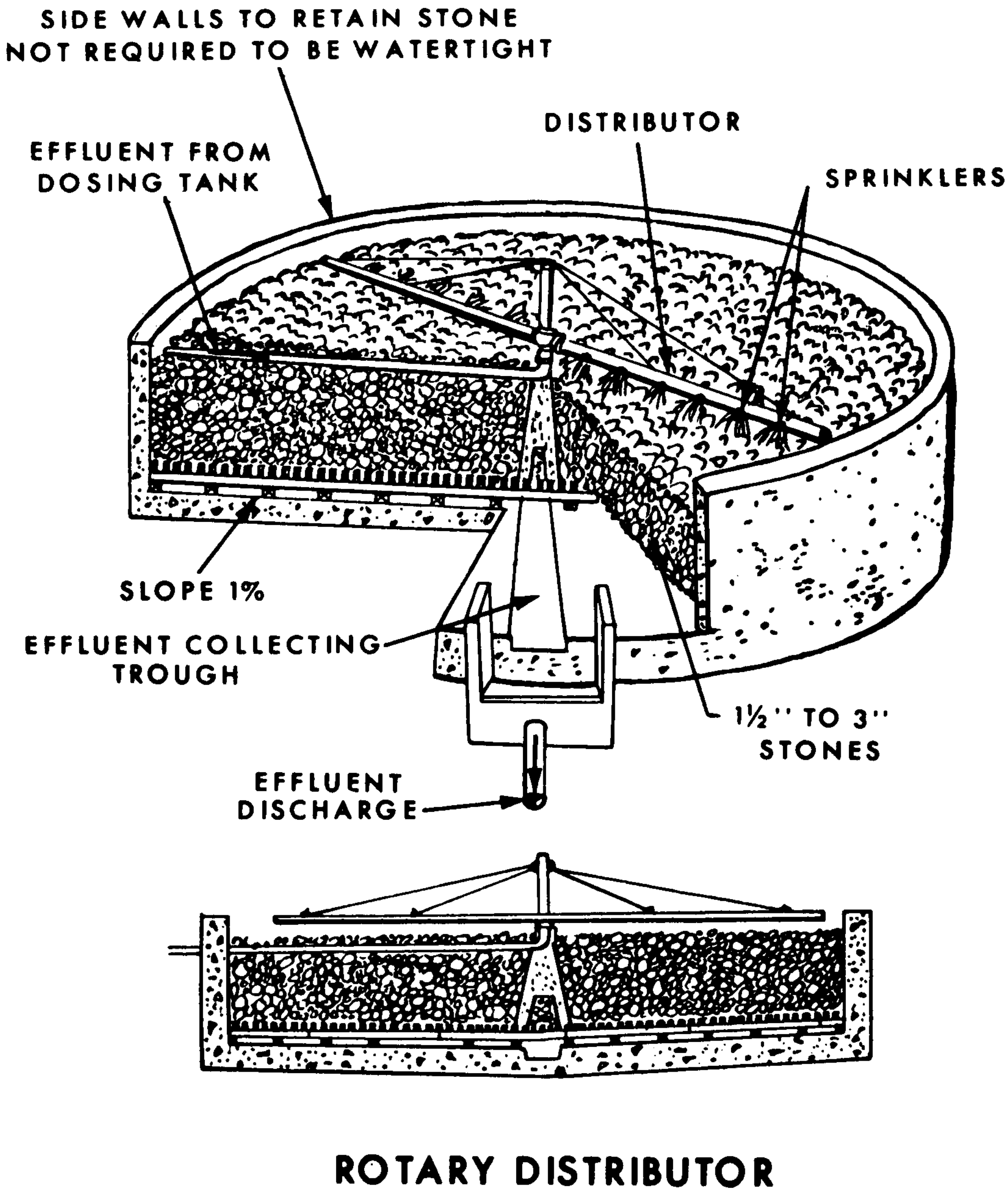
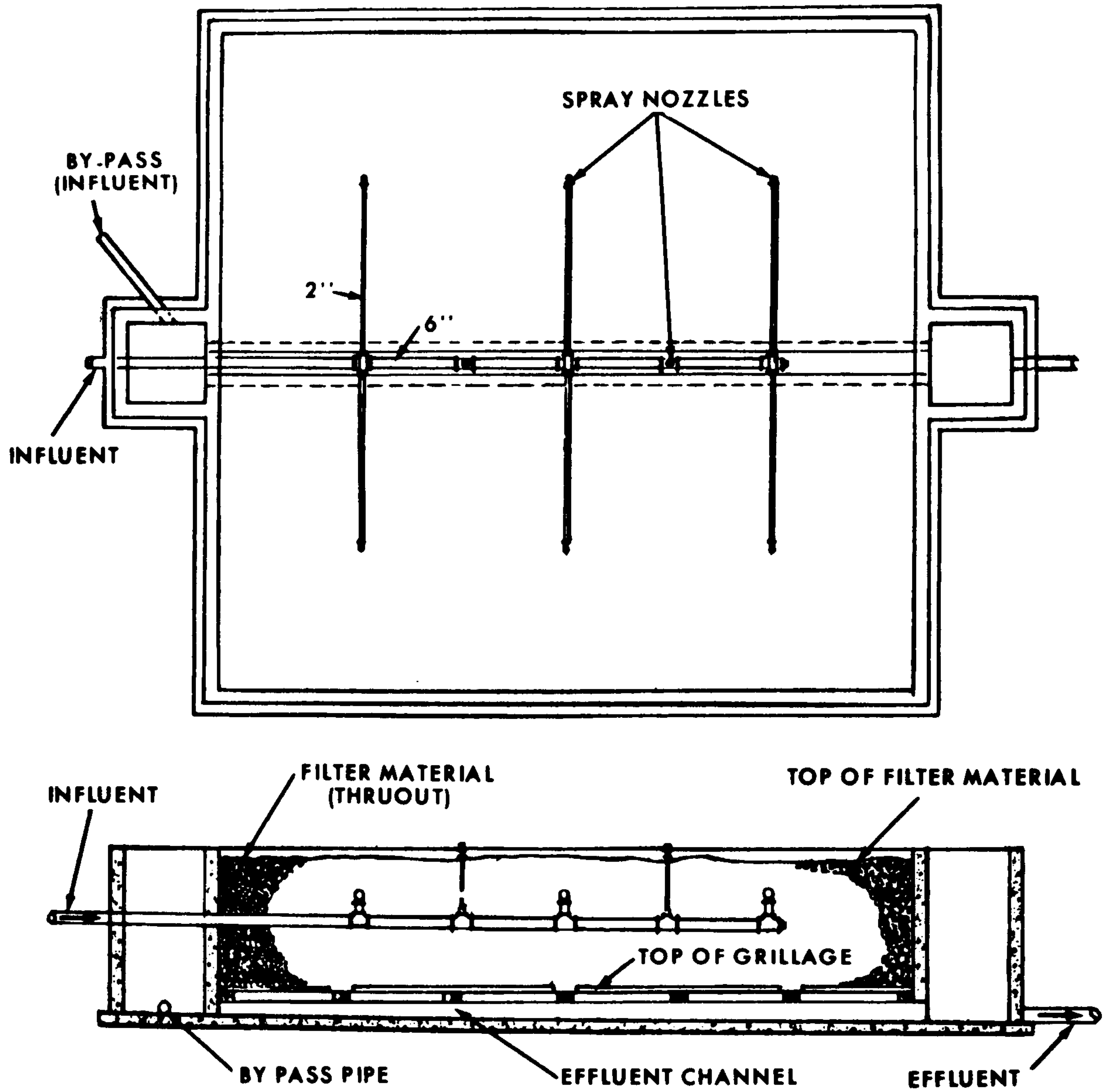


Figure 2–11. Rotary distributor.



FILTER MATERIAL SPECIFICATIONS

MATERIAL FOR FILTER MEDIA SHOULD BE SOUND HARD PIECES, CLEAN AND FREE FROM DUST, SCREENINGS, AND OTHER FINE MATERIAL. IT SHOULD BE AS NEARLY UNIFORM IN SIZE AS POSSIBLE. THE MATERIAL SHOULD NOT DISINTEGRATE UNDER SERVICE CONDITION, EITHER BY BREAKING INTO SMALLER PIECES OR BY CRUMBLING INTO FINE MATERIAL. THE USE OF FLAT ELONGATED OR GLASSY PIECES SHOULD BE AVOIDED. MATERIAL MAY BE GRAVEL, BROKEN STONE, SLAG, OR OTHER HARD DURABLE SUBSTANCE. THE MATERIAL SHALL BE OF A SIZE THAT WILL PASS A 3-INCH SCREEN AND BE RETAINED ON A 1 1/2-INCH ROUND SCREEN. THE SODIUM SULPHATE SOUNDNESS TEST MAY BE USED TO DETERMINE DURABILITY OF STONE.

Figure 2–12. Sprinkler-nozzle system.

standard or low rate and high rate. The application of sewage at higher rates and the recirculation of a portion of the effluent constitute the principal difference between the operation of a high rate filter and that of a standard rate filter. The design procedure is as follows: The size of the filter bed is determined on the basis of about 0.35 cubic yard of stone per capita. Desirable hydraulic head between the lowest liquid level in the dosing chamber and the center of the rotary distributor arm is 10 to 12 inches (fig 2-11). If sprinkler nozzles are used, a 6- to 10-foot head from the high-water level in the dozing tank to the sprinkler-nozzle outlet is required (fig 2-12).

(2) Crushed stone is the best filter material, but gravel, coke, clinker, broken brick, or slag can be used. To permit maximum voids for passage of sewage, and air for ventilation, filter material should be reasonably uniform in size—1½- to 3-inch stone is best. The filter layer should be 5 to 8 feet deep.

(3) Underdrains maybe either whole or half tile laid with open joints, or a grillage of 2- by 4-inch timber laid on edge. The underdrain system must be constructed so all parts of the filter bed are ventilated.

(4) See TM 5-302 for standard plans.

c. Final Settling Tanks. The effluent from trickling filters should be passed through final settling tanks to remove the bacterial gel which forms on the filter stone and peels off into the effluent. Sludge obtained from final settling tanks is about one-half the volume obtained from primary settling tanks. It can be run directly to drying bads or preferably returned to the digestion tank. Final settling tanks should be large enough to provide a 2 to 2½ hour detention period at the average rate of flow. The sludge should be removed daily to prevent septic action. The slope of the hopper bottom is 1 to 1 or steeper. Side water depth of final settling tanks should not be more than 10 feet. Other details of construction are the same as for plain settling tanks. See TM 5-302 for construction drawings.

d. Oxidation Ponds.

(1) Oxidation ponds are sometimes used instead of a trickling filter for secondary treatment. This facility is a relatively large shallow pond into which the effluent, from the primary treatment is discharged. Secondary treatment is accomplished here by natural purification under the influence of sunlight and air. Site considerations should include locating the facility far enough from habitation (preferable one-half mile or more) so that odors from the decomposition of organic matter are not objectionable. Ponds should not be constructed in areas where freezes last longer than 10 days.

(2) Capacity of the pond is based on a 30-day storage period. Only the volume of the pond above a 2-foot depth is considered when the total ponding area is 5 acres or less; when the pending area is larger, only the volume above 3-foot depth is considered. For best results, three or more ponds should be used in series. They may be separated by narrow dikes or may be more widely spaced, depending on the terrain and economy of construction. Where it is possible to construct the ponds at different elevations, the flow from one to another should be over a wide, shallow weir to permit maximum aeration and oxidation of the sewage. Where topography permits, a series of weirs, usually called a cascade, is used to insure maximum aeration (fig 2–13).

2-10. Chemical Treatment

a. Disinfectants, such as liquid chlorine or calcium hypochlorite, may be added to sewage in emergencies to safeguard health and prevent odor and fly nuisances. They are sometimes used during periods of low stream flow when there is not enough stream water for proper dilution. They also may be used when a part of a plant is bypassed during cleaning or a breakdown.

b. Since chlorine kills bacteria, it will greatly decrease the decomposition rate of the sewage therefore delaying reduction of the BOD. It sometimes is used to delay the oxygen demand until the sewage reaches a body of water large enough to provide the oxygen required. It is also effective in killing disease-producing organisms if the contact period and the chlorine concentration are sufficient and if all particles are finely enough divided to permit chlorine contact.

c. Should conditions be such that through failure of power or equipment there is a possibility of contaminating a water supply with raw sewage, provisions should be made for chlorinating at a rate of 200 pounds per million gallons at the 4-hour peak rate of sewage flow. In other cases where chlorination is required, provisions should be made for chlorination at a rate of 125 pounds per million gallons at the 4-hour peak rate of sewage flow. The 4-hour peak rate is considered to be 175 percent of the average daily rate of flow. Chlorine can be applied by mechanical chlorinators or by an improvised drum chlorinator.

d. Construction drawings for a chlorine contact chamber may be found in TM 5-302.

2-11. Sewage Lagoons

a. General. Most of the treatment facilities mentioned previously require a considerable amount of engineer effort to construct. Theater of operation situations require that engineer works be constructed to accomplish their mission with the least possible utilization of time, manpower, equipment and material. The sewage lagoon, ap-

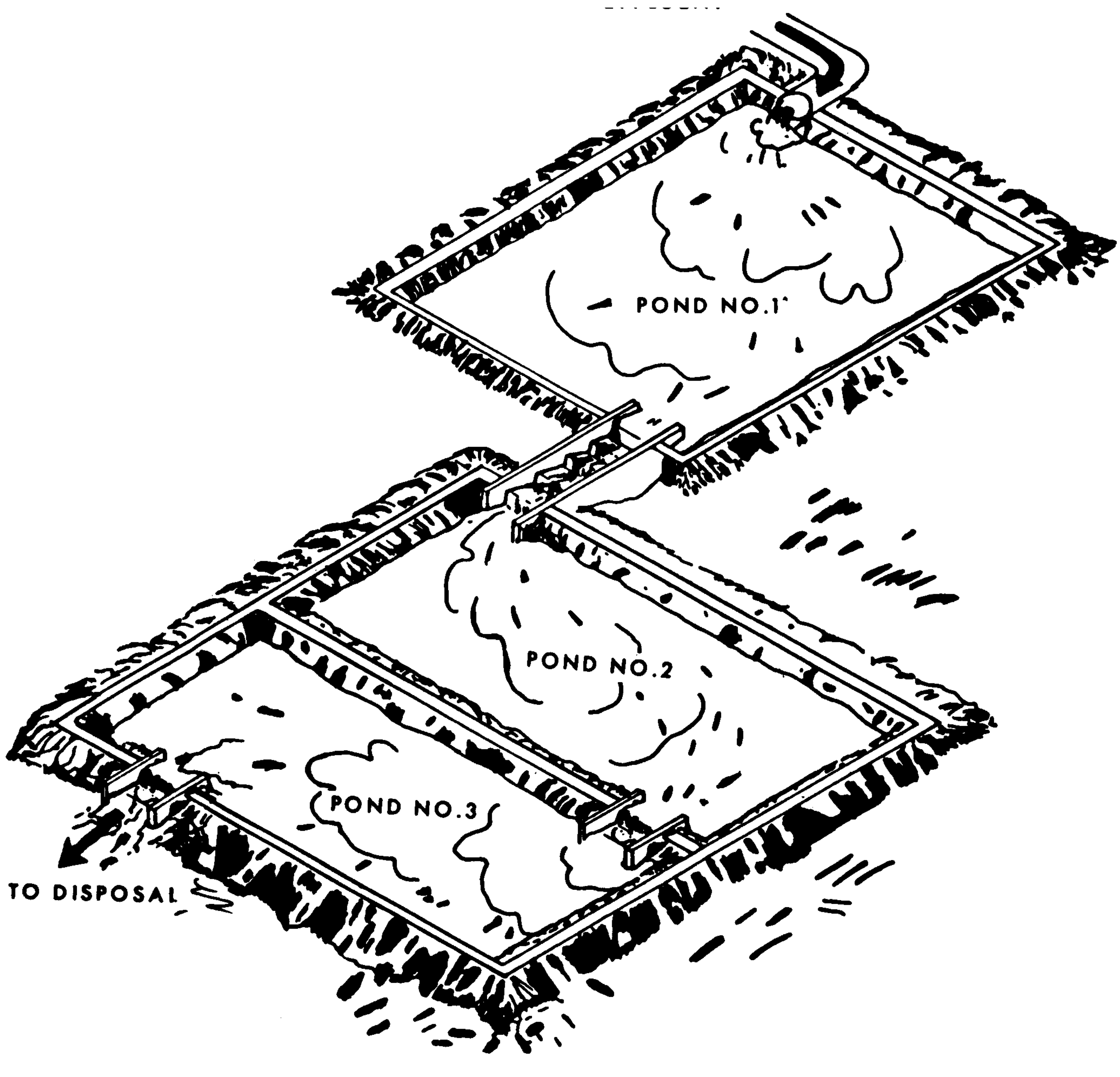


Figure 2-13. Oxidation ponds.

plicable in all but extreme arctic regions, provides an ideal solution to the sewage treatment problem as it gives excellent primary and secondary sewage treatment with an absolute minimum of construction effort.

(1) Primary treatment is accomplished by settling and anaerobic digestion. Secondary treatment is accomplish by aerobic digestion.

(2) Sludge accumulates at a very slow rate allowing many years of efficient service from the lagoon without an appreciable reduction in capacity. Sewage lagoon effluent, as is the case with the effluent from conventional sewage treatment plants, is not necessarily free of pathogenic organisms and may require additional treatment. It should be disposed of by one of the methods described in chapter 3.

b. Lagoon Design Formulus.

(1) The science of lagoon design is not exact. Early designs required a total pond area of one acre for every 100 to 200 persons while later developments and experience led to much higher loadings. In Africa, lagoons are operating satisfactorily today with total pond areas of 1 acre for every

600 to 1,000 persons. However, such rules of thumb can be misleading or even dangerous. So many variables enter the picture that each case should be investigated individually.

(2) In designing a lagoon, it is necessary to establish the capacity which is the area of the lagoon times the depth. To arrive at these figures, the following basic information must be obtained.

(a) The maximum volume of liquid entering the lagoon is the sum of the basic liquid wastewater production of the installation which the lagoon serves, plus liquid entering the system through infiltration, and rainfall.

1. The waste water production of the installation is equal to 70% of the average water demand in gallons per day multiplied by the design population [waste-water (sewage) = .7 (ave. water demand x design population)].

2. Infiltration of water into systems, resulting from poorly constructed and maintained pipes, leaking manholes, etc., may be substantial, and requires an increase in design capacity. In temperate regions, an infiltration rate of 2 gal / min for each 1,000 feet of sewer line should be assumed. In tropical areas, where annual rainy seasons occur, a much higher rate must be assumed to allow for an increase in design. capacity.

(b) Minimum volume of liquid to be retained in the lagoon, which is the basic liquid waste water production minus the loss of liquid from the lagoon from seepage and evaporation.

1. The problem of liquid loss by seepage into the soil is twofold. First, there is the danger of polluting nearby water sources if the lagoon bottom is below or too near the water table at any season. Secondly, under severe conditions, the loss of liquid may be great enough to drop the volume of the water retained to a point below that necessary for efficient aerobic operation. Some loss of liquid is to be expected through percolation in any soil, though the volume of such liquid loss depends upon the soil encountered. A percolation test must be made to allow an accurate estimate of the initial liquid loss, and the relative danger of polluting any nearby water source. The test procedure and a table of relative absorption rates are given in section II of chapter 3. The table also includes a classification of soil types which can be used as a supplement to the percolation test in determining the suitability of a site for lagoon construction. Sludge deposits slowly seal the lagoon bottom, reducing the losses to a negligible point in relatively impervious soils, and drastically reducing percolation in even the worst cases. For example, experience indicates that an initial loss as high as 6 inches per day may gradually decline to as little as ¼ inch to ¾ inch per day. If the percolation test indicates the soil will absorb too much liquid, the bottom of the lagoon should be sealed. The simplest and least costly method of sealing the bottom is to compact the existing soil or add a layer of compacted clay, 6 to 10 inches deep. The use of asphalt cutback or emulsions may also be used.

2. The amount of evaporation at a given moment depends on the temperature, humidity, and wind velocity. As a result, it is difficult to predict with any accuracy the evaporation rate for any short period of time. Fortunately, such losses are only critical on a seasonal basis, for which reasonably accurate averages are known for most regions of the world. Lacking any kind of data, evaporation rates may be roughly estimated using a table such as the one below.

Table 2–1. Evaporation Rates

Climate	Evaporation in inches by month												Total annual evaporation
Above equator	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Below equator	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
Hot	4.0	5.0	6.5	8.0	10.0	12.0	13.0	13.0	11.0	8.5	6.5	5.0	113.0
Moderate	1.0	1.4	2.0	3.0	4.8	6.5	8.5	8.0	6.5	4.6	2.6	1.1	50.0
Cold	0.6	0.7	0.8	1.0	1.3	1.6	2.0	1.9	1.8	1.6	1.1	0.7	15.0
		(lowest)					(highest)						

3. A design bell curve could be developed from the above, assuming single rainy and dry seasons. Where two rainy and dry seasons must be reckoned with, a double bell curve would result and the above sequence of figures would be of little use. In any case there is no substitute for local knowledge. Where no experts are available, local farmers are usually good consultant in outlining seasonal character, though seldom in terms of quantitative figures.

4. To obtain accurate local figures, field tests are made over at least one complete annual cycle, and preferably several. Though these cannot meet immediate needs, they will both facilitate future lagoon design for the region in question and sufficient modifications to allow more efficient operation of the original system. Field measurement of evaporation can be done by the use of a metal pan, 4 feet in diameter and 10 inches deep. This unit is filled to within 2 inches of its rim and is supported to place the water surface a foot or more above ground level. The drop in water level is measured periodically and the unit is refilled from time to time to the original level. The recorded results are multiplied by 70 percent to arrive at a theoretical reservoir evaporation rate. The volume of evaporation for any given time (day, week or month) can be determined by the following formula:

$E = 485\, E_1 A_5$ where:
E = volume of evaporation in gallons
E_1 = estimated evaporation in inches
A_5 = lagoon area in acres

(c) The strength of the sewage in terms of BOD per person per day and the loading of the pond in pounds of BOD per acre per day. For military installations a BOD value of 0.17 to 0.20 lb should be used for design computations. The surface area required for lagoon construction may be determined from the formula:

$$A_s = \frac{\text{(Des. Pop) (BOD Load)}}{20}$$

where:
As = Surface area in acres.
Des. Pop = Design Population of the installation.
BOD Load= Normal BOD Loading (0.17 to 0.20 lb) per person per day.
20 = Design BOD loading of 20 lb per acre per day.

(d) For reasons of economy and efficient operation, the depth of the liquids in lagoons should normally range somewhere between 2 and 6 feet; with minimum depth of 2 to 2½ feet, vegetation is not likely to grow at the bottom of the pond: Shallower ponds (2 to 5 feet) are best in cool climates in order to allow for maximum penetration of sunlight. Because of the higher angle of the sun in tropical climates, deeper sunlight penetration permits deeper ponds (3 to 6 feet). Experience in various parts of Africa indicates that a depth of 4 feet is usually satisfactory.

(e) With the minimum and maximum desired depths established, and using the surface figures calculated above, the volume of the lagoon can be found with the formulas:

Min LC = (A_s) (min. dep.) (43,560) and
Max LC = (A_s) (max. dep.) (43,560)

where:
Min LC = minimum lagoon capacity in cubic feet
Max LC = maximum lagoon capacity in cubic feet
A_s = surface area in acres (see paragraph 2–116(2) (c))
Min. dep = minimum depth of lagoon in feet
Max. dep = maximum depth of lagoon in feet
43,560 = conversion factor to obtain number of square feet in acre.

Because the efficient operation of lagoons depends on maintaining optimum maximum and minimum liquid depths, these must be taken into account in the design of a lagoon.

This will require a careful study of local annual temperature and rainfall data. For example, provision must be made to accommodate the maximum infiltration which generally occurs in the rainy season when usually minimum infiltration and maximum evaporation occur during the same period.

(f) A minimum retention period must be determined in order to induce the reduction of biochemical oxygen demand to a point allowing discharge of effluent into a normal waterway or irrigation system. In the US, lagoons of the flow-through type, receiving raw sewage, normally employ 60 to 90 days retention. In tropical countries this is likely to be reduced but should not be less than 20 to 25 days. A practical retention time is based on the rate of flow balanced against an efficient minimum and economically maximum pond size. If the volume of influent is roughly equal to the volume of liquid remaining after percolation and evaporation losses to keep the lagoon level within acceptable minimum and maximum limits, no effluent will result and the system can be termed balanced. As a balanced lagoon system is sometimes desirable, the lagoon size can be planned within reasonably flexible limits to achieve this end. Operating a lagoon as a closed or balanced system during the dry season, and allowing for effluent at a rate within the desired retention time during the rainy season is one of the several means of operating lagoons in a tropical climate. Both maximum and minimum hydraulic retention times can be determined by the formulas:

$$T\ max = \frac{7.48\ (C\ max)}{G_m}$$

$$\text{and } T\ min = \frac{7.48\ (C\ min)}{G_m}$$

Where:

T max = maximum retention time in days.
T min = minimum retention time in days.
C max = maximum capacity in cubic feet.
C min = minimum capacity in cubic feet.
G_m = gallons per day influent.
7.48 = gallons per cubic foot.

The optimum retention time will depend upon organic loading, as well as hydraulic loading. The lower the loading in pounds of 5 day BOD per acre per day, the greater the volume of liquid. This permits a longer retention period and a correspondingly greater reduction of BOD.

(g) The Army Medical Service is responsible for inspecting waste disposal facilities and operations and recommending changes to protect the health and welfare of the troops. Consequently, the Army Medical Service should be contacted to resolve questions as to whether single or multiple sewage lagoons will be required, retention times required, and other technical advice required.

(h) Though availability of land is a controlling factor, sites at lower elevations than the collection system are economically preferable in order to eliminate the need for costly lift stations. The lagoon layout should always be planned so that the direction of the prevailing wind is never along the line of flow thus short circuiting sewage from inlet to outlet or retarding the normal flow. Obstructions which restrict air movement should be avoided. Wind induces wave action and subsurface currents needed to stimulate oxidation. However, winds in excess of 30 miles per hour may create wave action which may cause erosion along the edges of the lagoon. (US experience indicates that erosion will not be a serious problem unless lagoons reach an area of 30 acres or larger.) To assure a clear sweep for winds, seasonal changes in direction and relative speeds should be known. Again, farmers, fishermen, or others who work outdoors year around are usually excellent sources of general climatic data if local figures are not available. As with evaporation, however, long term observations should be made to broaden background data for future designs and improvements in primary systems. Because local wind conditions are affected by a number of factors, including temperature, obstructions, etc., a generalization concerning clear distances in the immediate vicinity of the lagoon is difficult to make. In the average case, one might allow a clear distance of 5 to 8 times the height of any groups of trees or bushes from the lagoon. In the case of isolated buildings, a clear sweep equal to the height or width of the structure, whichever is greater, is generally sufficient. In any case, a minimum clear sweep of 300 feet free of all but isolated obstructions should provide adequate wave action.

CHAPTER 3

DISPOSAL

3-1. General

Once the treatment process has been carried out to the degree necessary, disposal of the effluent must be performed. There are three basic methods of disposing of the effluent; dilution, evaporation or irrigation.

3-2. Dilution

Dilution is simply the process of adding liquid waste (s) to a body of water. This is, at the present time, the most common method of disposal. However, the sewage which is discharged into lakes or rivers can be stabilized in much the same way that natural sewage treatment occurs in a sewage lagoon. Oxygen is required for this natural stabilization and only a limited quantity of oxygen can be dissolved in any body of water. Lakes and rivers are thus limited in the load of sewage which they may accept without rising to an objectionable level of pollution. A point is reached at which the stream, river or lake is unable to clean itself as fast as pollutants are added. Therefore, if feasible, sewage should be treated prior to dilution.

a. Problems. Even when dealing with treated effluent, disposal by dilution presents basic problems. Great care must be exercised so that the effluent mixture is not a nuisance to the installations adjoining the disposal areas. Water supplies may be contaminated and polluted. Dilution should occur downstream from a water point or installation to prevent those conditions. The less treated the effluent, the more acute the problems become and the more care must be exercised in disposal. Stream flow required for disposal by dilution depends on the strength and quantity of the sewage, the density and nearness of population to stream bank, and" the industrial or domestic use of the stream water below the outfall. A stream overloaded with sewage develops sludge banks and surface scum, is unsightly, and emits an offensive odor. Table 3-1 provides a guide for determining the quantity of sewage that may be discharged into a stream, provided the stream water below the sewage outfall is not for industrial or domestic water supply. Military standards for dilution and sanitary conditions are the same as those used in civilian practice. If military expediency forces substandard sanitary conditions, they must be corrected as rapidly as possible.

b. Procedure. Effluent may be diluted in any body of water; e.g. oceans, lakes, rivers and streams. In general, the procedures for disposal in each of these areas are the same. Discharge points should be as far from the shore as possible. In addition, they should be deep in the water. Meeting these two criteria will allow the sewage to dilute thoroughly before it has the opportunity to rise to the surface. Careful consideration must be made of current directions and strengths in picking the discharge points. In a river or stream the outfall should be in the swift current, not in the slackwater close to shore where little diluting will e place. In ocean waters tide or wind currents, if not considered, may wash the effluents back toward the shore. Where currents vary with the season of the year, care must be taken in placing discharge points.

3-3 Evaporation

Evaporation is sometimes used in sewage disposal. In this process, large surface areas of sewage are exposed to the atmosphere. Since the effluent is 99.8% water, it evaporates easily; but the process is hindered by climatic conditions like rain and cold, and works best in arid climates. Evaporation usually occurs to a certain degree in lagoons and oxidation ponds. Evaporation is not and should not be considered as a primary means of disposal.

3-4. Irrigation

The third method of disposing of the effluent is by irrigation, that is, the spreading of the polluted water onto or through soil. As in dilution, irrigation allows some purification although this is not its primary function. The process is performed in either of two methods; surface irrigation (sewage farming), or subsurface irrigation.

a. Regardless of the type of irrigation involved, the absorptive ability of the soil must be determined before designing or constructing the disposal facility. This property is usually determined by conducting a general-purpose percolation test as follows:

(1) Dig one or more hole(s) 1 foot square and 1 foot deep.

(2) Fill the test hole(s) with water and allow it to soak into the surrounding soil.

(3) After the water has seeped into the soil and the bottom of the hole is still wet, pour water into the hole (s) to a depth of at least 6 inches.

(4) Measure the depth of water and record the time required for all of it to seep out into the surrounding soil.

(5) Calculate the average time required for the water to drop 1 inch by dividing the initial depth of water in the hole by the number of minutes it took for all of the water to seep out. The surface area required for a given volume of sewage per day can be determined by applying this value to the appropriate chart (tables 3–2 through 3-5).

b. Besides the fact that there are different absorption rate charts for surface irrigation, tile drainfields, sewage lagoons, and cesspools, the following test hole conditions should be met:

(1) For tile drainfields, the bottom of the 1 foot square test hole should roughly coincide with the proposed depth of tile.

(2) For cesspools, the 1 foot square test hole should be dug roughly half way between the sewage inlet and the bottom of the proposed cesspool.

(3) For sewage lagoons, the top of the 1 foot square test hole should roughly coincide with the proposed bottom of the lagoon.

(4) Tables to indicate approximate absorption rates for cesspools, tile drain fields, sewage lagoons, and surface irrigation are as listed below in tables 3-2 through 3–5.

Table 3–1. Dilution Rates

Minimum stream flow required for dilution of raw and treated sewage *

Type of treatment	Dilution per 1,000 sewage-contributing population	
	Densely populated areas	Sparsely populated areas
None	20 cfs and over	5 cfs and over
Partial (settling)	12 to 20 cfs	3 to 5 cfs
Complete	6 to 12 cfs	0 to 3 cfs

* Oxidation ponds or irrigation with disposal to ground water can be used if enough water for dilution is not available.

Table 3–2. Application Rates of Sewage in Cesspools

Time (in minutes) required for water level to drop 1 inch in test hole.	*Allowable rate of sewage application in gallons per square foot of percolating area per day.*
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

Note. Soils requiring more than 30 minutes for a fall of 1 inch are unsatisfactory for the installation of cesspools and some other disposal method should be used.

Table 3–3. Subsurface Application Rates of Sewage in Tile Drainfields

Time (in minutes) required for water level to drop 1 inch in test hole.	*Allowable rate of sewage application in gallons per square foot of trench bottom per day.*
1	4.0
2	3.2
5	2.4
10	1.7
30	0.8
60	0.6

Table 3–4. Relative Absorption Rates in Sewage Lagoons

Even though the information listed below is applicable to the same percolation tests as the information in tables 3–2, 3–3, and 3–5, there is an entirely different purpose for conducting the test for lagoons In the cases of cesspools, tile drainfields, and surface irrigation, it is desirable to have a high absorption rate so that the effluent can be disposed of easily. However, absorption from sewage lagoons into the surrounding soil is a problem and should be minimized.

Time (in minutes) required for water level to drop one inch in test hole.	*Relative absorption rate.*	*Classification of the type of soil.*
0–3	Rapid	Coarse sand or gravel
3–5	Medium	Fine sand or sandy loam.
5–30	Slow	Clay, loam or clay with sand.
30–60	Semi-impervious	Dense clay
60 and over	Impervious	Hardpan or rock

Note. The first two types of soil are not suited for lagoon purposes unless water retention is assisted by the installation of a waterproofing skin at the lagoon bottom.

c. Surface irrigation is spreading effluent over plowed fields, allowing the liquid to filter through the ground until it reaches the water table. Disposal rates of sewage by surface irrigation vary with the permeability of the soil, ranging as high as 60,000 gallons per acre per day. This method can assist in the purification of sewage through filtration and aeration. However, to support the purification process, sufficient air must always be in the soil. Therefore, only intermittent irrigation of the soil is possible to permit the soil to "breathe" after each application. This "breathing" restores the oxygen content of the soil and helps maintain aerobic conditions. In addition to intermittent spreading, ground used for surface irrigation must be rested. With use, the surface will clog and must be scraped off. Allowances for resting, recovery, maintenance, and rainfall are included in table 3-5.

Table 3–5. Application Rates of Sewage in Surface Irrigation

Time (in minutes) required for water to fall one inch in test hole.	Allowable rate of sewage application per day. Per acre	Per sq ft
1	57,700	1.3
2	46,800	1.1
5	34,800	0.8
10	25,000	0.6
30	12,000	0.3
60	8,700	0.2

Figures are approximate and are suggested for use as a guide only.

d. Subsurface irrigation is a method of sewage disposal commonly used in conjunction with cesspools or septic tanks at small installations. This method allows sewage to seep directly into the soil or uses tile drainfields with application rates as shown in tables 3-2 and 3-3, respectively.

(1) *Tile drain fields.* The tile drainfield essentially consists of lines of concrete or clay form draintile laid in the ground with open joints. Recently, manufactures have begun to produce concrete pipe with ¼" to 3/8" perforations in the bottom half. Also, a bituminized fiber pipe (Orangeburg Alkacid) with holes bored in the lower portion of the pipe to allow drainage may be used for these drain lines. This pipe is light, easily laid in the trench, and made in sizes between 2 and 8 inches in diameter and 5 and 8 feet in length. These long lengths make it particularly valuable in soil where other types may settle unevenly. Perforated plastic pipe offers the same advantages. Figure 3-1 shows a typical field layout. The following conditions are important for proper functioning of tile fields:

(a) Ground water well below the level of the tile field.

(b) Soil satisfactory leaching characteristics within a few feet of the surface, extending several feet below the tile. Soil leaching tests should be made at the site.

(c) Subsurface drainage away from the field.

(d) Adequate area.

(e) Freedom from possibility of polluting drinking-water supplies, particularly from shallow dug or driven wells in the vicinity.

(f) Length of tile and details of the filter trench generally depend upon the character of the soil.

(g) Minimum widths of trenches on the basis of soils areas follows:

1. Sand and sandy loam, 1 foot.

2. Loam and sand and clay mixture, 2 feet.

3. Clay with some gravel, 3 feet.

(h) Placing tile below the frost line to prevent freezing is not necessary. Tile placed 18 inches below the ground surface operated successfully in New England for many years. Subsurface tile should never be laid below ground-water level.

(i) Design and construction should provide for handling and storage of some solid material, eliminating as much as practicable the opportunity for clogging near pipe joints. Pipe 3 to 6 inches in diameter is recommended. The larger pipe gives greater storage capacity for solids and a larger area at the joint for solids to escape into the surrounding gravel.

(j) To provide for free discharge of solids from the line to the filter trench, the pipe must be laid with 3/8-inch-clear openings. The top of the space is covered with tarpaper or similar material to prevent entry of gravel. Bell and spigot pipe is easily laid to true line and grade. Good practice calls for breaking away two-thirds along the bottom of the bells at the joint and using small wood-block spacers. The pipe is commonly laid at a slope of about 0.5 feet per 100 feet when taking the discharge directly from the septic tank and 0.3 feet per 100 feet when a dosing tank is used ahead of the field.

(k) The tile is laid on a bed of screened coarse gravel 6 inches deep with 3 inches of coarse gravel around and over the pipe. Coarse screened stone passing a 2 1/2-inch mesh and retained on a 3/4-inch mesh is recommended. This gravel bed gives a relatively large percentage of voids into which the solids may pass and collect before the effective leaching area becomes seriously clogged. The soil which fills the trench must not fill the voids in the coarse screened gravel around the pipe. A 3-inch layer of medium screened gravel over the coarse stone and 3 inches of either fine screened gravel or suitable bank-run gravel over the medium stone is recommended.

(l) The layout of the tile in the field should be carefully designed. Generally, the length of laterals should not be greater than 75 feet. When tile is laid in sloping ground, the flow must be distributed so each lateral gets a fair portion. Flow

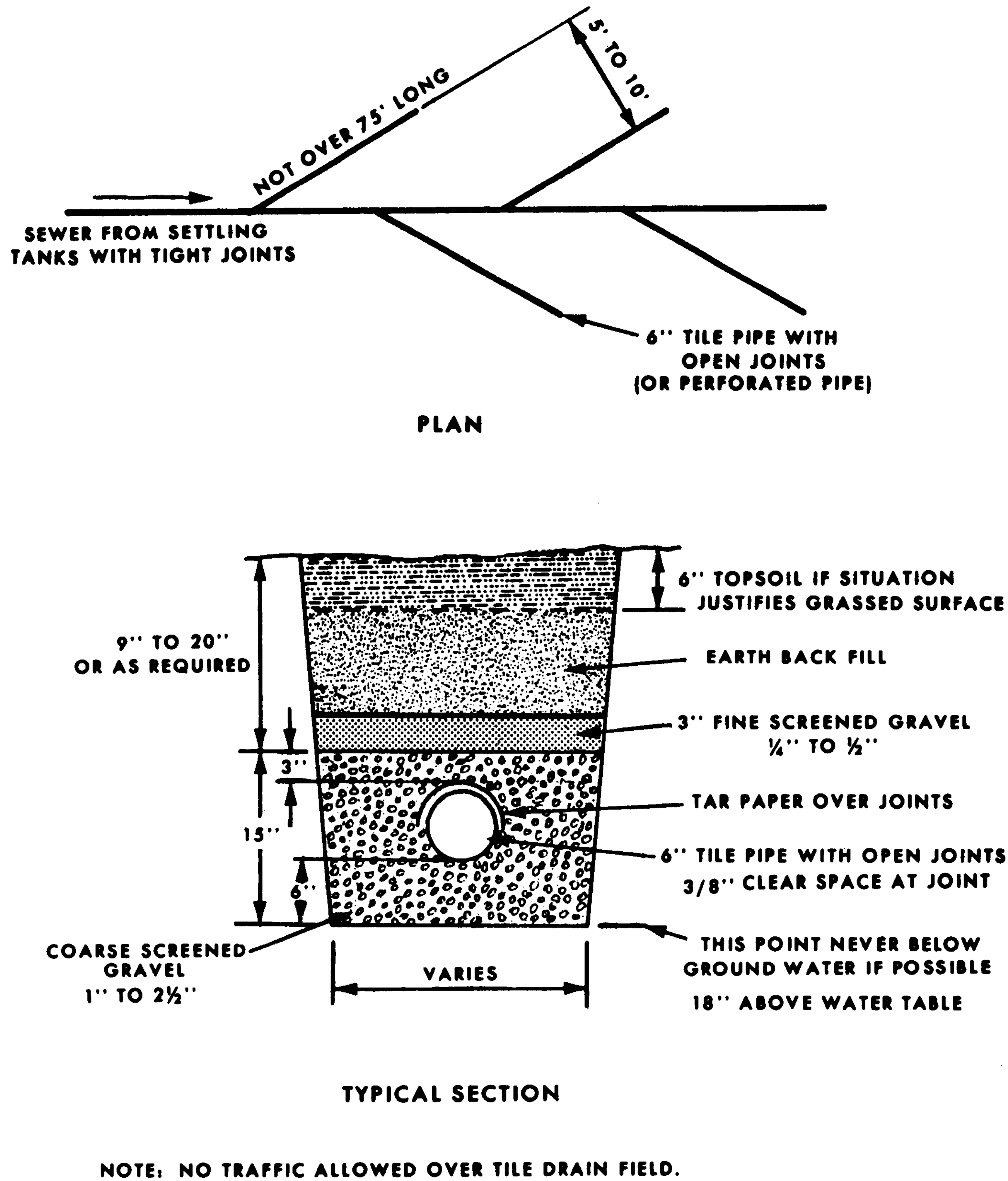


Figure 3–1. Typical layout of a subsurface tile system.

must be prevented from discharging down the slope to the lowest point. Individual lines should be laid parallel to land contours (fig 2-2). Tile fields are commonly laid out either in a herring-bone pattern or with the laterals at right angles to the main distributor. Distance between laterals

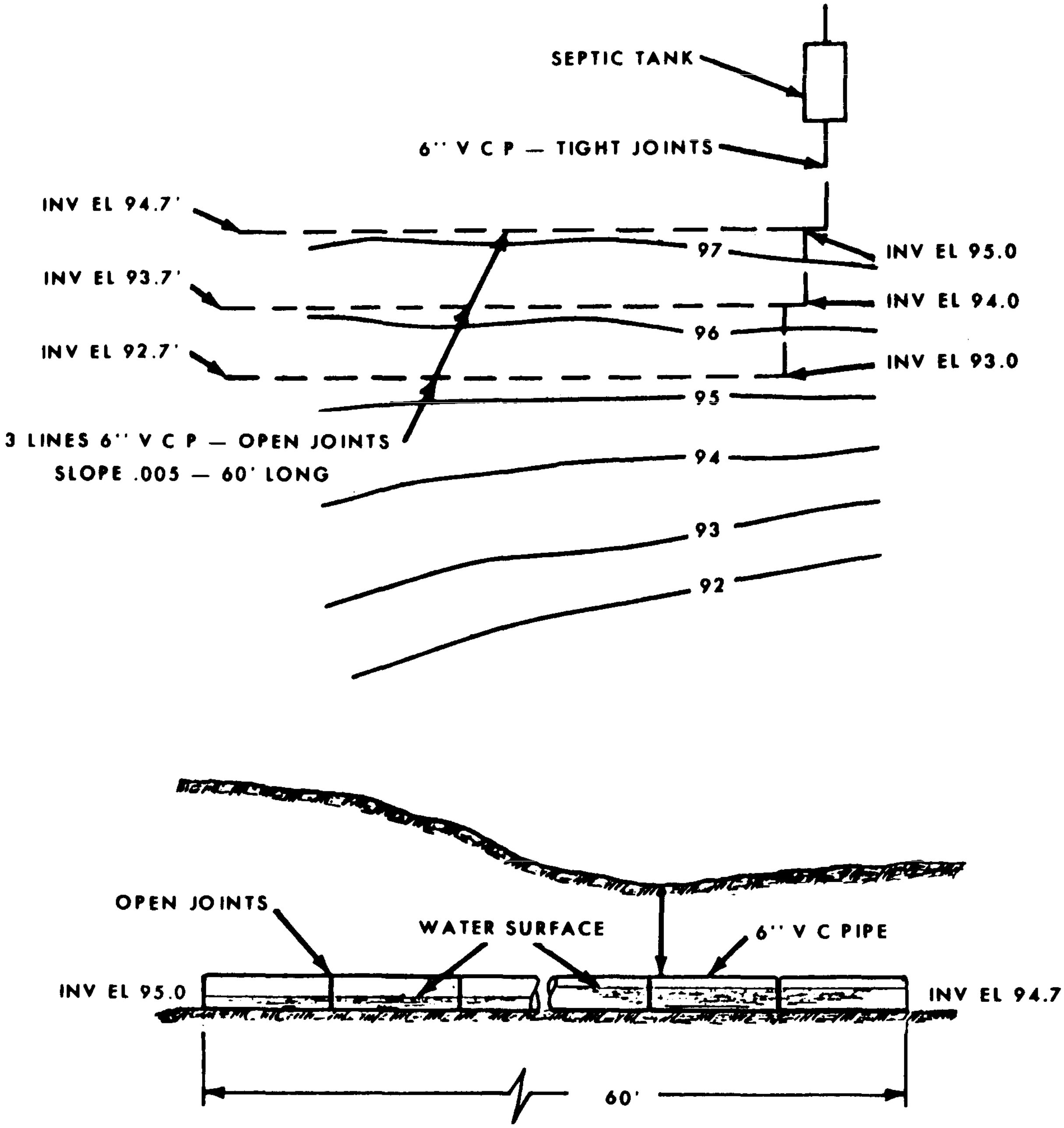


Figure 3–2. Typical layout of tile field in sloping ground.

is 3 times the width of the trench. Distribution boxes to which the laterals are connected may be desirable. Trenches 24 inches wide or more are economical. If a trenching machine is practical on a large installation, the design should be based on the width of trench excavated by the machine.

(m) Once a tile field is constructed, all traffic must be excluded by fencing or posting to prevent crushing the tile. Planting shrubs or trees over the field is not good practice since the roots tend to clog the tile lines; grass over the lines assists in removing the moisture and keeping the soil open. A typical section of a tile filter trench is shown in figure 3-1.

(2) *Subsurface drain field.* Where the soil is so dense and impervious that a subsurface tile-trench system is impractical and where lack of an isolated area prevents use of an open filter, subsurface filter trenches or beds may be required. Underdrains from subsurface filter trenches or beds may be discharged freely to the nearest satisfactory point of disposal such as a small stream, dry stream bed, or on land.

(a) The filter trenches or beds should be designed for a rate of filtration not greater than 1 gallon per square foot per day. The filtering material should be clean, coarse sand all passing a 1/4-inch mesh with an effective size between 0.25 and 9.5 millimeters and a uniformity coefficient not greater than 4.0. Filtering sand should generally be not less than 30 inches deep. Coarse screened gravel should pass a 3 l/2-inch mesh and be retained on a 3/4-inch mesh. A typical section of an underdrained filter trench is shown in figure 3-3. Governing conditions for the field layout are similar to those for the tile fields described above.

(b) A typical plan and section for a subsurface filter bed are shown in figure 3-4. Slope of the distributors should be about 0.3 feet per 100 feet when a dosing tank is used or 0.5 feet per 100 feet when no dosing tank is required. For installations having more than 800 feet of distributors, the filter should be built in two or more sections with alternating siphons to alternate the flow between sections. Distribution pipe lines in beds should be laid on 6-to 10-foot centers; underdrain pipes on 5-to 10-foot centers.

(c) Dosing tanks with automatic sewage siphons should be provided for tile or subsurface fields when the length of distribution tile exceeds 300 feet. Dosing tanks should be designed to discharge a volume equal to 70 to 80 percent of the volumetric capacity of the distribution piping in the tile field or filter. The dosing tank can usually be constructed in the same width and as a part of the septic tank (fig 3-5).

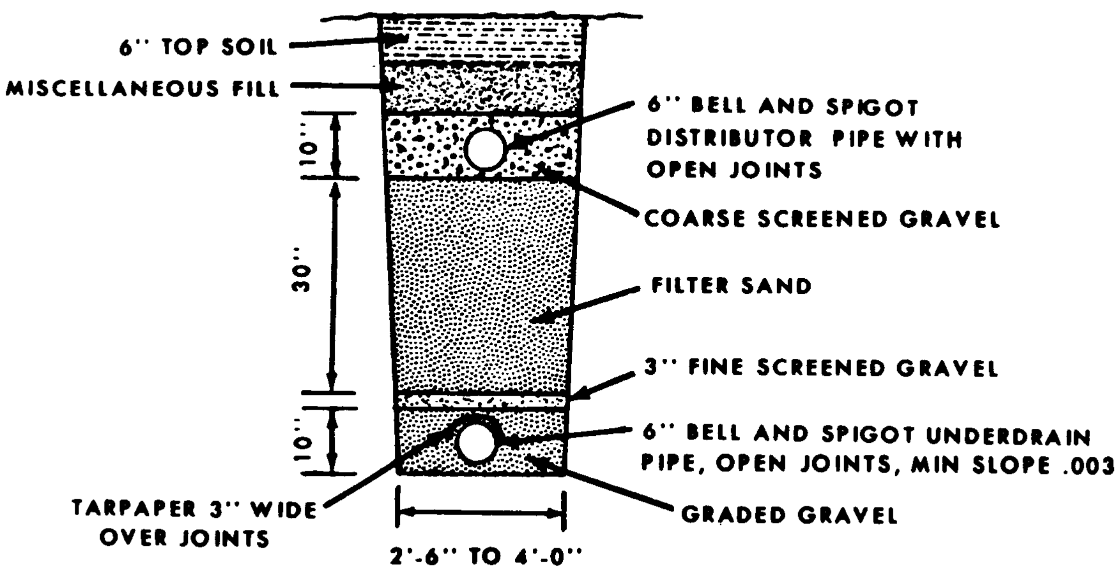


Figure 3-3. Typical section of underdrained filter trench.

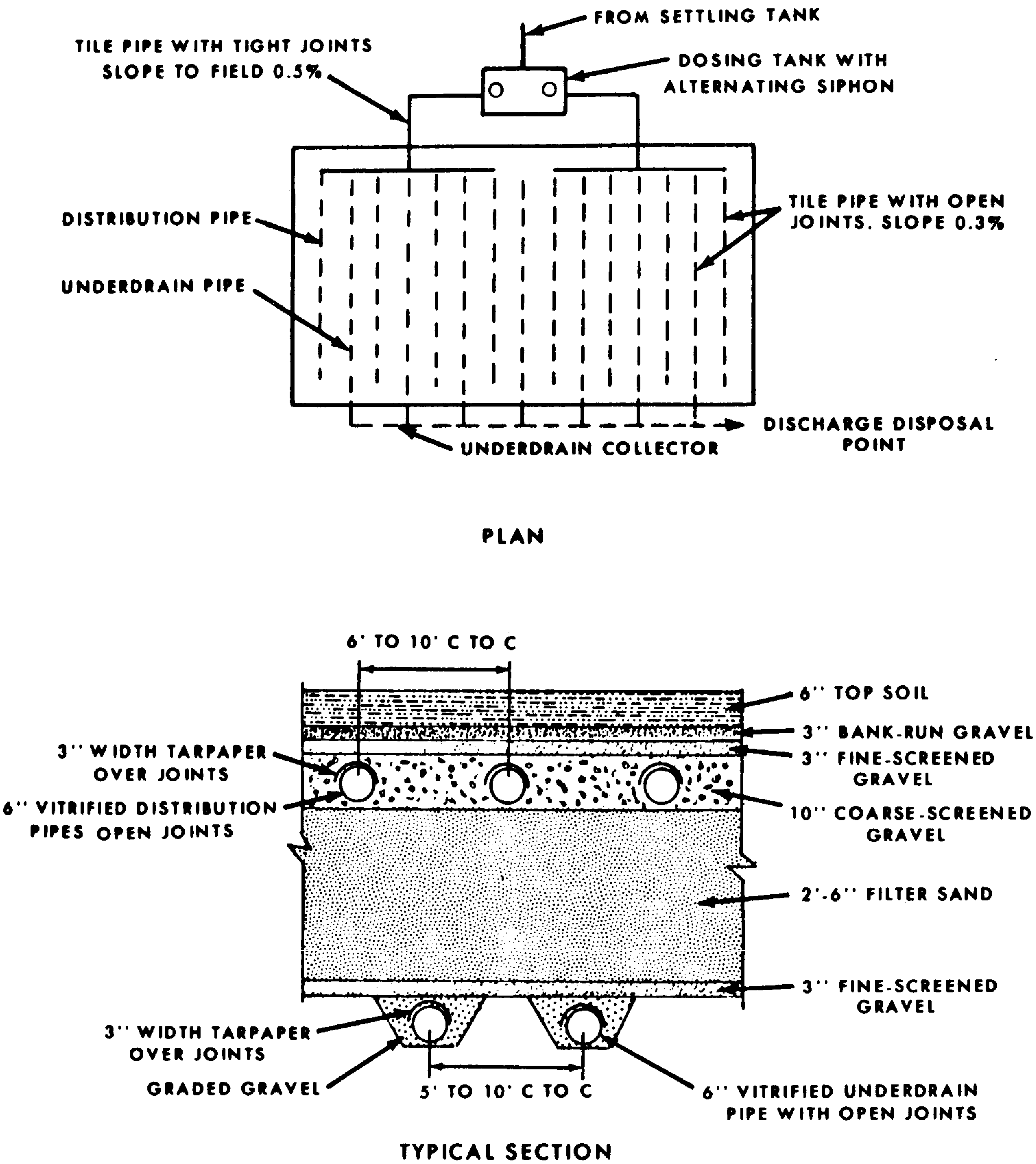


Figure 3-4. Typical plan and section of subsurface sand filter.

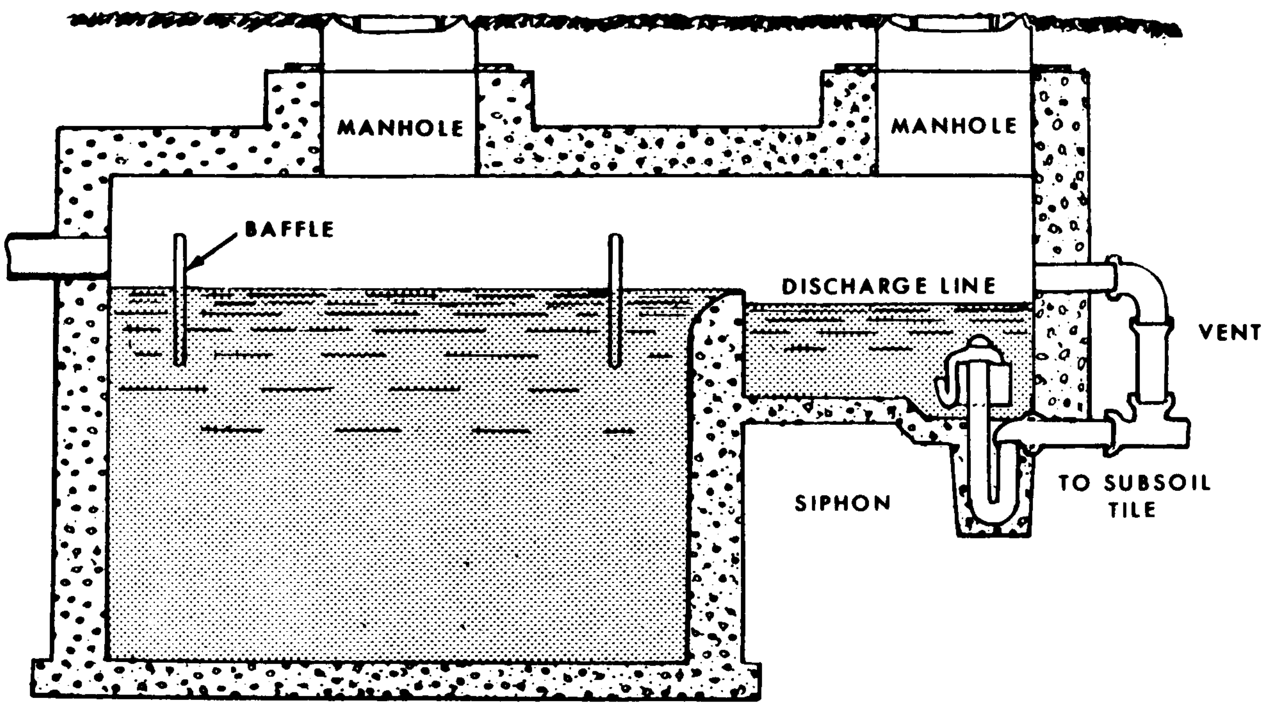


Figure 3–5. Septic tank with dosing siphon.

CHAPTER 4

COLLECTION SYSTEM DESIGN

Section I. COMPONENTS

4-1. General

a. Before sewage can be treated properly it must be collected and transported to a central location. If the installation is built as given in TM 5-302, then the complete sewer system may also be built to conform to the sewage design from TM 5-302. Those installations which have water-borne sewage have the sewer layout given. Thus the only design work necessary is to determine the invert elevations and in some cases the slope of the pipe.

b. If the installation is not laid out as shown in TM 5-302, or if an installation is not given completely, the engineer officer must design the sewer system. An example of a collection system and its nomenclature is given in figure 4-1.

4-2. Grease Trap

A grease trap is required at any facility or installation where grease may be discharged into a sewage system. The presence of grease causes one of the most serious difficulties in sewage treatment. Where sewage is discharged into a stream without treatment grease film on the surface of the water retards reoxygenation. Therefore, as much as possible should be removed to prevent deposits of grease on the walls of the sewer and the formation of film on the surface of the water.

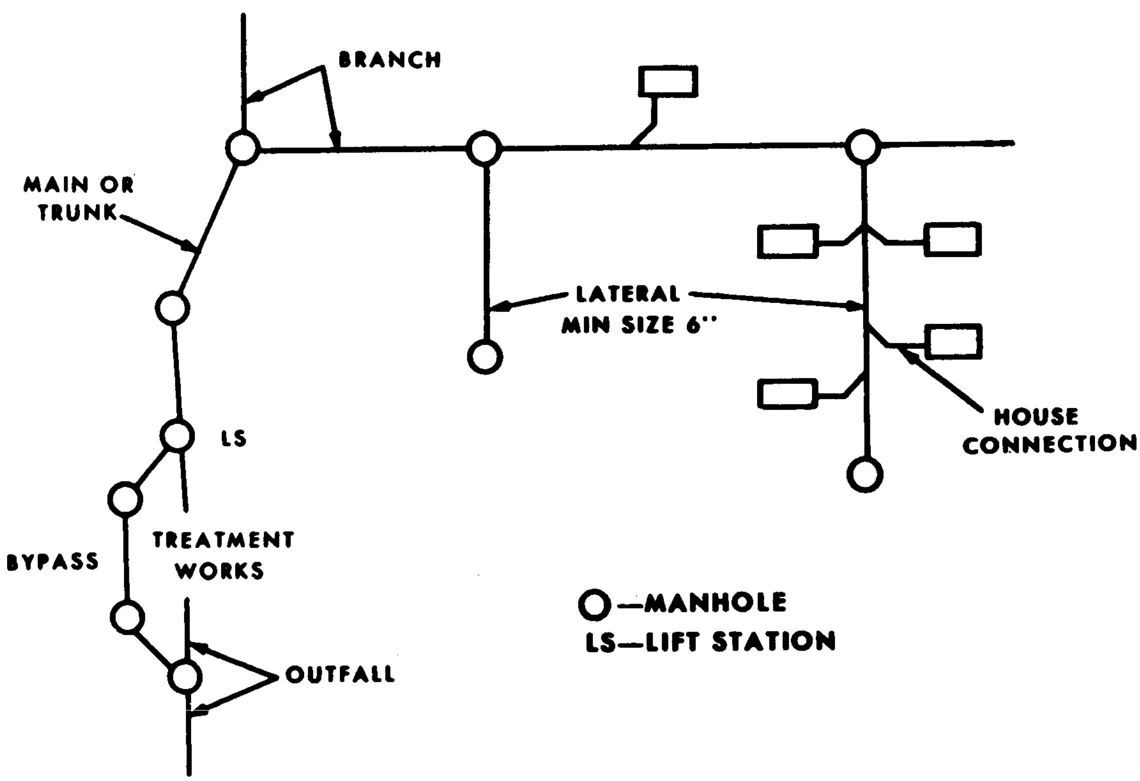


Figure 4-1. Collection system.

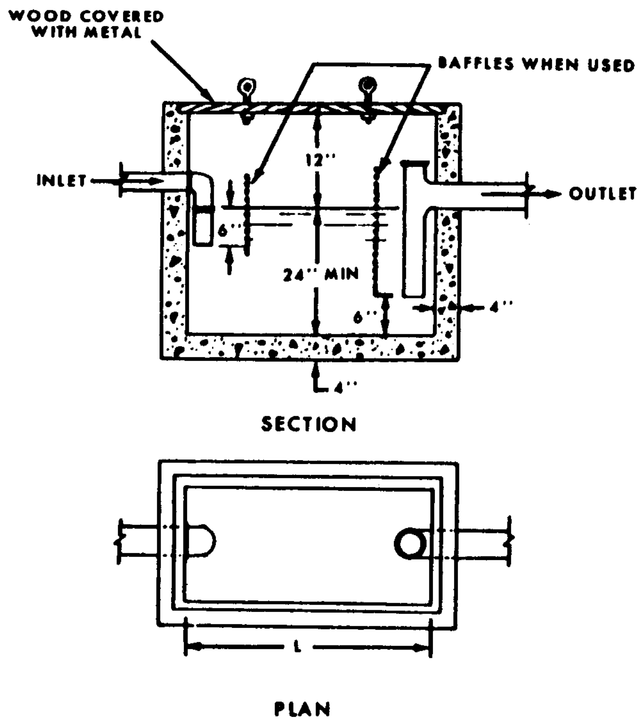


Figure 4-2. Grease trap.

Since grease loses its salvage value after mixing with sanitary sewage, removal at the source is advisable. Grease traps installed as outlined in TM 5-302 achieve this result (fig 4-2).

4-3. House Connections

House connections should be planned to eliminate as many bends as practicable and provide convenience in rodding when required. Generally, connections of house sewers to other sewers should be made directly to the pipe with commercially manufactured fittings rather than through manholes. Manholes may be used, however, if no extra expense would be incurred and should be used if the connection is a greater distance than 150 feet from the nearest cleanout. Where the cleanout inside the building would not be adequate for complete rodding, outside cleanouts, or manholes if cleanouts are impractical, should be provided. For most theater of operations installations, 4-inch diameter sewers on 1% slope will provide adequate capacity. Except where frost or load conditions prevail, one foot of cover will be sufficient for house connections. Figure 4-3 illustrates house connections. Details on this construction are contained in TM 5-302.

4-4. Manholes

a. Standard Manhole. Manholes (fig 4-4) are required at the end of laterals and at each change of direction, slope, or pipe size except for house connections. The distance between manholes should not exceed 400 feet in sewers of less than 18 inches in diameter. For sewers of 18 inch pipe or larger and for outlets from sewage treatment plants, a spacing of 600 feet may be used if the velocity is sufficient to prevent sedimentation. The crown of the outlet pipe from a manhole should be on line with or below the crown of the inlet pipe. Where the invert of the inlet pipe would be more than 18 inches above the manhole floor a drop connection should be provided.

b. Drop Manhole. The only difference between the standard and drop manhole is the difference of elevation of the invert of the manhole. The drop manhole is used to reduce velocities, clear obstacles, and reduce construction effort of ditching along laterals and common sewers (fig 4-5).

4-5. Lift Stations

a. In the theater of operations pumping of sewage should be avoided if possible. However, there are certain conditions under which gravity flow of sewage is impractical or impossible and pumping will be required. Some of the conditions occur when—

(1) The depth of excavation becomes excessive.

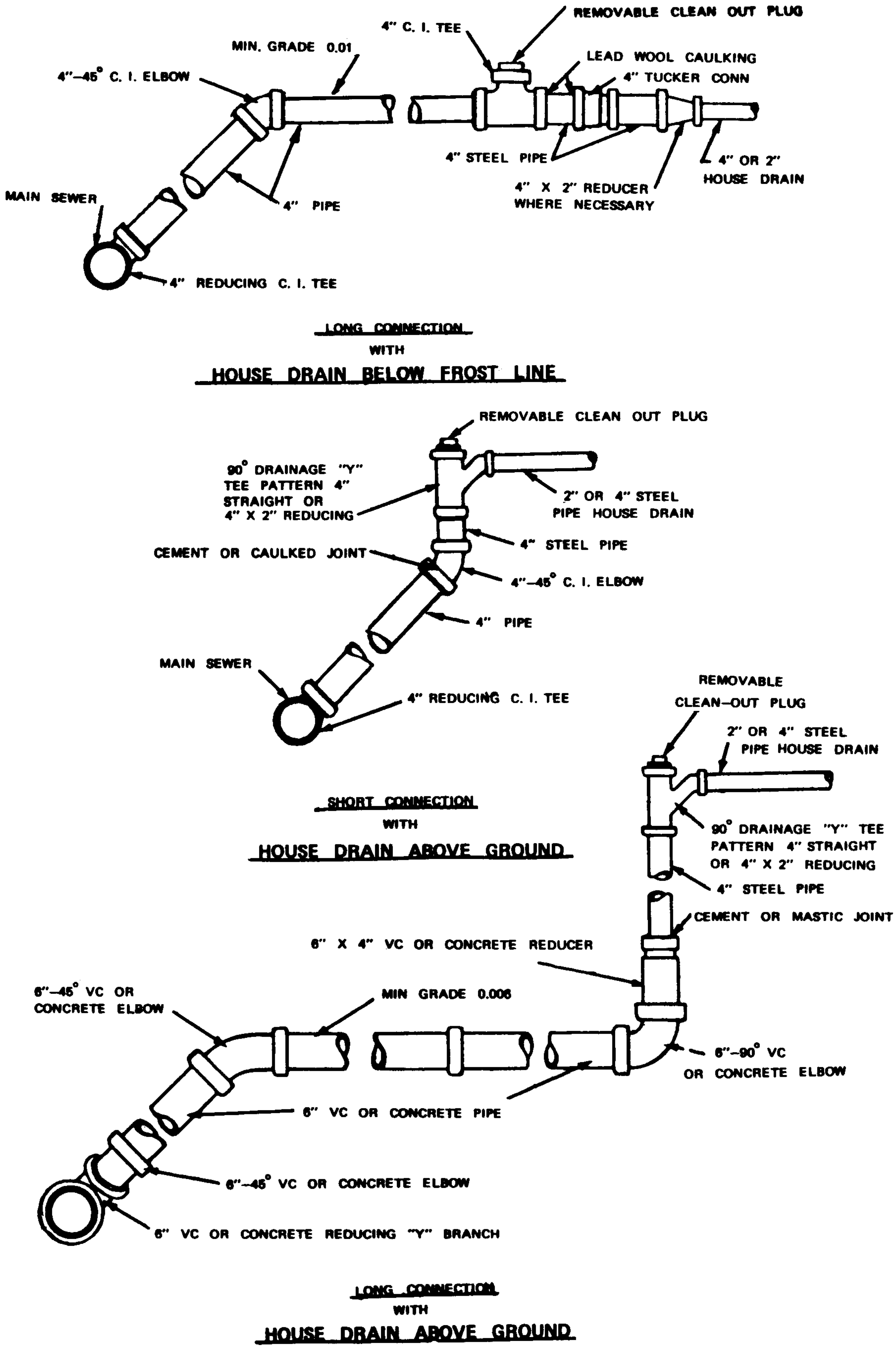


Figure 4–3. Building connections.

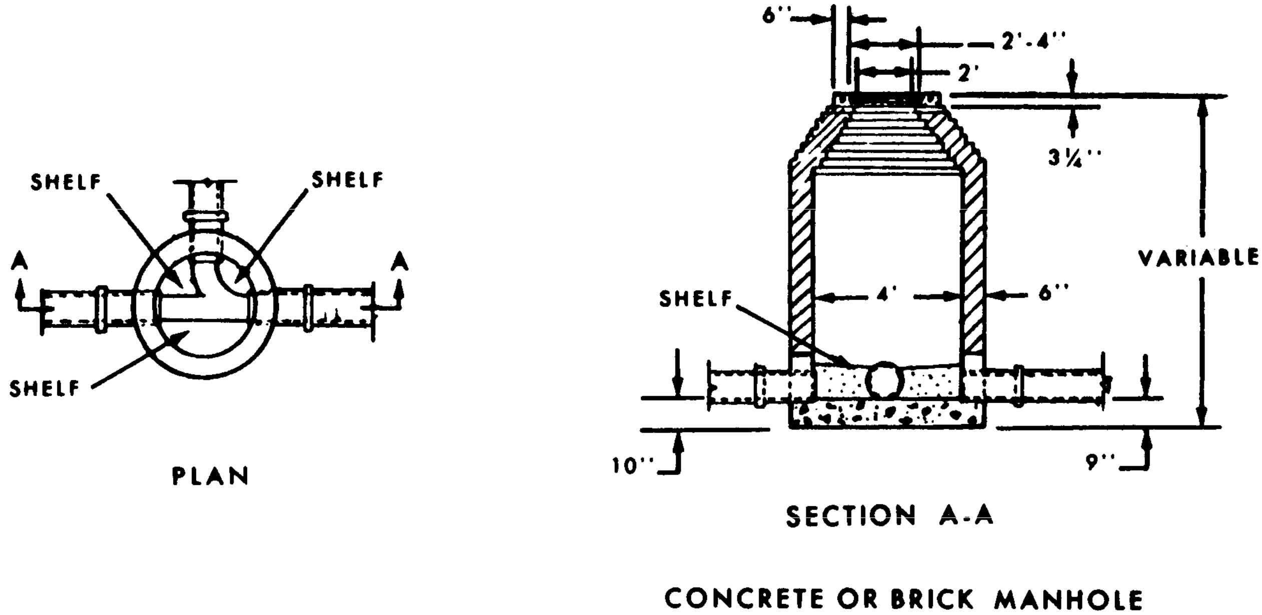


Figure 4–4. Concrete or brick manhole.

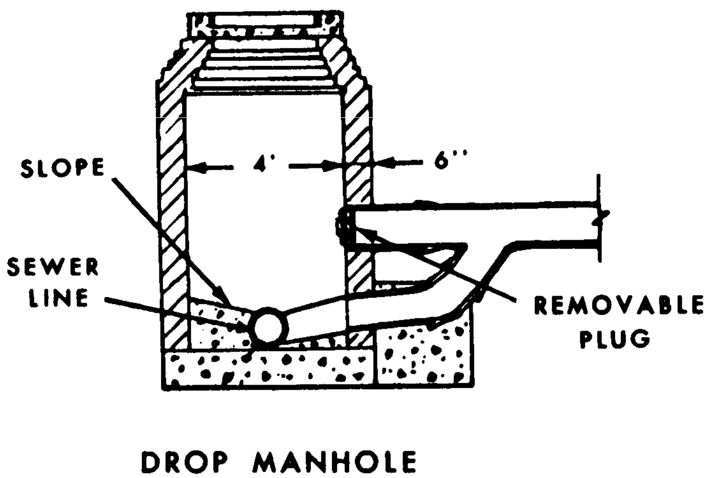


Figure 4–5. Drop manhole.

(2) The sewer outfall is below the level of the receiving stream.

(3) Sewage must be lifted to obtain head for gravity flow through the treatment plant. In all cases the sewage is pumped to a higher elevation and then allowed to continue on by gravity flow.

b. It is necessary to weigh the effort involved in deep excavation versus the cost of the lift station and required maintenance. The situation that would exist if the pumping station failed to operate must also be considered.

c. The lift station is a special design item and must be ordered based on manufacturer's data which are available from the Engineer group. Figure 4-6 shows a typical lift station.

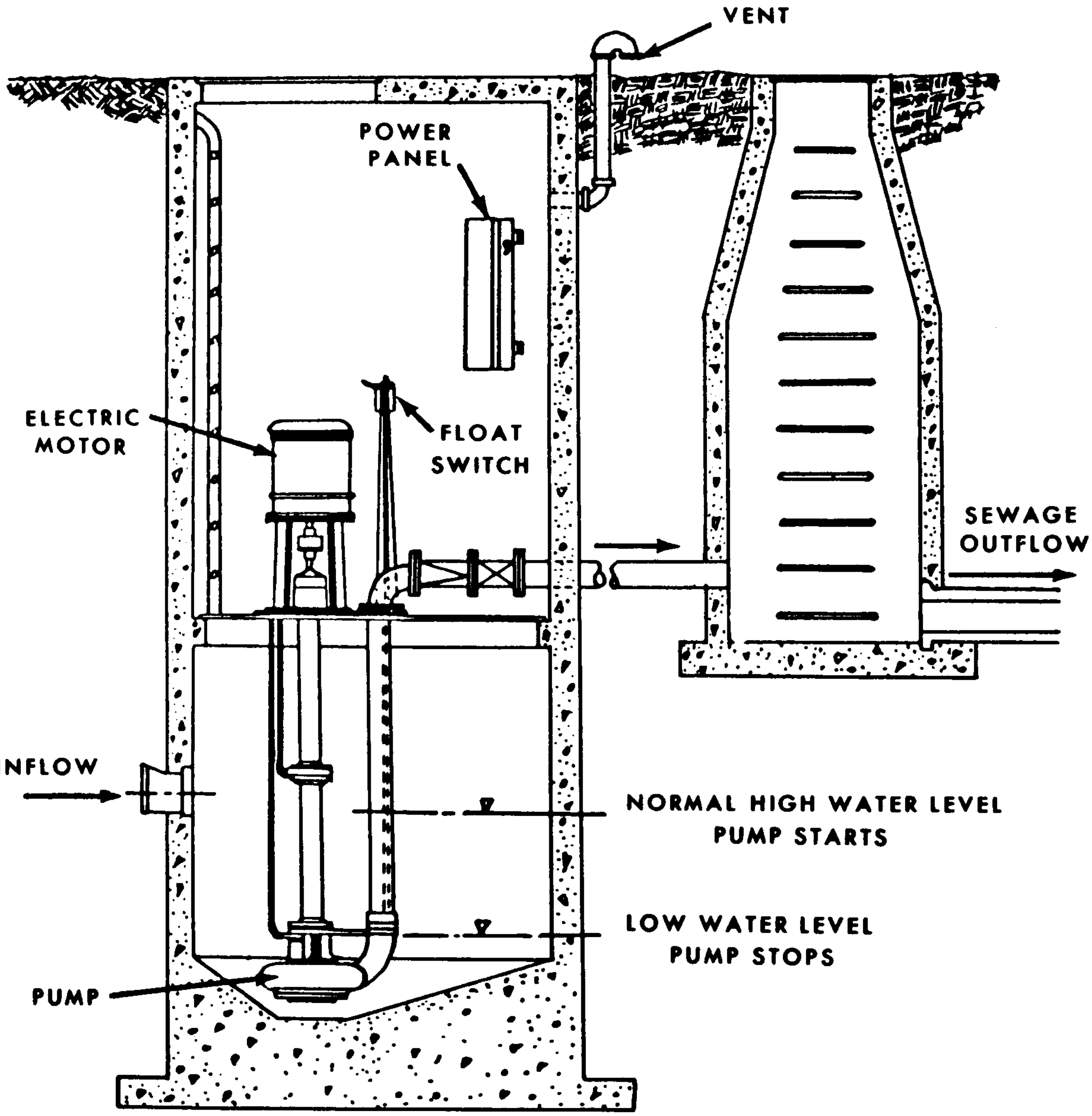


Figure 4–6. Automatic lift station.

Section II. SEWER DESIGN

4-6. General

a. The steps in designing a sewer system are-

(1) Determine sewer layout.
(2) Locate manholes.
(3) Determine flow rates.
(4) Determine slope.
(5) Choose pipe size.
(6) Check actual velocity.
(7) Determine invert elevations.

b. To simplify this process, a worksheet such as the one shown in figure 4–7 should be used. A profile of the sewer system should be drawn as the design proceeds.

4-7. Design Steps

a. Sewer Layout. The development of final sewer plans must await the final site plan, the completion of field surveys and, to some extent, the establishment of floor grades. The development of economical site plans often requires concurrent preliminary planning of the sewer system. The location of lateral and branch sewers will depend not only upon topography, but upon the type and

LATERAL or MAIN		GROUND ELEV.		LENGTH	PEAK FLOW				SLOPE	PIPE SIZE	VELOCITY ANALYSIS					INVERT ELEVATIONS		REMARKS
MAN HOLE																		
FROM	TO	UP	LOW		FLOW INTO	FLOW IN	INFILT	ACTUAL			Q_c	V_c	$\frac{Q_a}{Q_c}$	$\frac{V_a}{V_c}$	V_a	UPPER	LOWER	

Figure 4–7. Sewerage system worksheet.

layout of the housing to be served. Normally, the most practical location would be along one side of the street. In other cases they may be located behind the buildings midway between streets. In still other cases, in closely built-up areas and particularly where the street is very wide or already paved, it may be advantageous and economical to construct laterals on each side of the street. Main, trunk, and outfall sewers should follow the most feasible route to the point of disposal. All sewers should be located outside of roadways as much as possible to reduce the number of roadway crossings. A sewer from one building should not be constructed under another building or remain in service where a building is subsequently constructed over it if any other practical location for the sewer is available. Where no other location is suitable, necessary measures should be taken to assure accessibility for future excavation and complete freedom of the sewer from superimposed building loads. The following safety precautions must be strictly observed in the sewer layout:

(1) No physical connections exist between sewer and water supply systems.

(2) Sewers and water lines will be at least 5 feet apart horizontally, except as permitted by TM 5-814-1, paragraph 6b.

(3) Where conditions require a sewer to cross above a water line, the sewer should be constructed of cast iron, steel, or other pressure pipe for a minimum of 10 feet on each side of the crossing and preferably with no joint within three feet of the crossing.

(4) At crossings of force mains or inverted siphons and water lines, the sewer shall be at least 2 feet below the water line.

b. Manhole Location.

(1) Manholes are required at the end of laterals and at each change in direction or slope. The distance between manholes will not exceed 400 feet for sewers less than 18 inches in diameter. For sewers of 18-inch pipe or larger and for outlets from sewage-treatment plants a spacing of 600 feet may be used provided that the velocity' is sufficient to prevent sedimentation.

(2) Manholes must be located before the rest of the design can be completed since the design method involves finding the pipe size and slope from manhole to manhole.

(3) Once the layout is determined and the manhole locations chosen, each lateral, branch, and main can be designed. It is probably easiest to start with the smallest sewers and work up to the mains.

c. Flow Rates.

(1) General. The flow rate between manholes will be the sum of (1) the flow into the upper manhole, (2) sewage from any house connections between manholes, and (3) infiltration into the sewer. It is assumed that this total flow will exist throughout the whole section of sewer between manholes. This is not strictly true if a house connection exists somewhere along the line (fig 4-8). The flow between manhole 2 and the place where the house connection meets the sewer is 125 gpm, plus some amount of infiltration which can be neglected. The flow in the sewer from the connection to manhole 3 is 155 gpm. Therefore, in designing the sewer from manhole 2 to manhole 3, 155 gpm is assumed to flow in the whole section. Three conditions may prevail:

(a) The flow in the house connection is small compared to the flow in the sewer. In this case, the effect is small and can be neglected.

(b) The flow in the house connection is large compared to the flow in the sewer. In this case, a change in pipe size or slope is necessary and a manhole must be used where the sewer and house connection meet.

(c) The flow is neither so small nor so large that a manhole is necessary. In this case, the sewer should be designed for both flow rates. If one pipe size at a given slope will give an acceptable velocity for both flow rates, then that design is acceptable for the complete sewer section. If one pipe size at the same slope will not give an accepta-

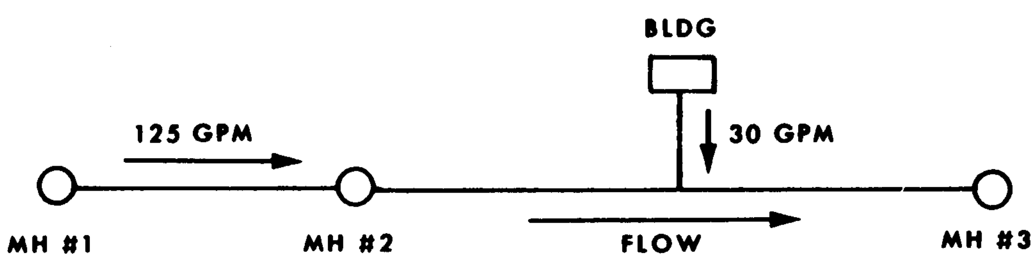


Figure 4–8. Plan view.

ble velocity for both flow rates, then either the pipe size or the slope must be changed at the house connection to the sewer and a manhole placed there.

(2) Quantity of flow. The peak sewage flow from a theater of operations facility is assumed to be 70% of the peak water demand for that facility. The peak flow from all facilities are assumed to occur at the same time. The peak flow in a sewer is the sum of the peak flows from all sewers and house connections discharging into it. Besides this flow, there will be some increase in flow due to infiltration. If nothing is known of the area, a figure of 2 gpm per 1000' of sewer may be assumed for infiltration. Of course, if any information on infiltration in the area is available from other sources (such as sewer systems already in operation nearby), then that value should be used.

d. Pipe Slope.

(1) The natural ground slope is usually used, as a first estimate for pipe slope, to minimize excavation. If this slope is unacceptable, either because it is too small or too great, will not provide an acceptable velocity, or does not meet cover requirements, a new slope must be chosen.

(2) The cover should be at least 2 feet over the crown of the pipe to protect the pipe from superimposed live loads of ordinary traffic and 4 feet for heavy trucks, or extra strength pipe or other pipe structurally capable of supporting the wheel loads with two feet of cover will be used (fig 4-9). All force mains should be buried to a depth such that the top of the pipe will be at the maximum frost penetration. Gravity sewers may be constructed with the bottom of the pipe at the maximum frost penetration when the minimum depths of burial (cover) specified above will not be violated.

(3) Often minimum cover requirements can be maintained by using drop manholes as indicated in figure 4–10, (1) If a standard manhole is used at 11, then a large slope shown by the dashed lines must be used. If a drop manhole is used at 11, then a much smaller slope can be used. This gives two advantages. First, the velocity will be lower between manholes 11 and 10 so there will be less scouring action in the sewer. Secondly, and most important, much less excavation will be required.

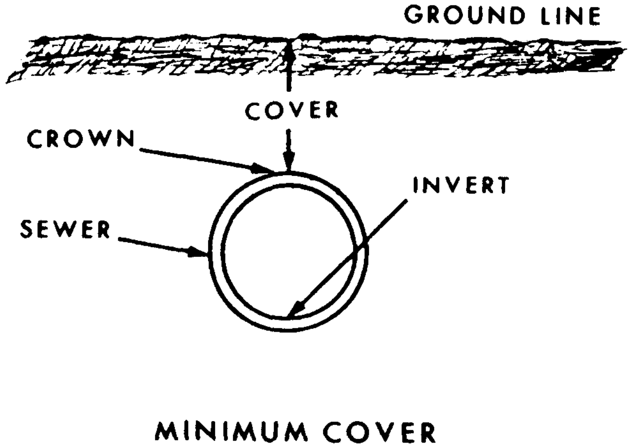


Figure 4–9. Minimum cover.

(4) As a second example, consider figure 4–10, (2). If a design such as this were used, the velocity in the sewer would be so high that the pipe would be rapidly scoured.

(5) Figure 4-10, (3) shows how the slope, and thus the velocity, can be decreased; however, an extreme amount of excavation is necessary.

(6) Figure 4–10, (4) shows how drop manholes can be used to keep both the slope and the excavation to a minimum.

e. Pipe Size.

(1) After a slope is chosen, the pipe size

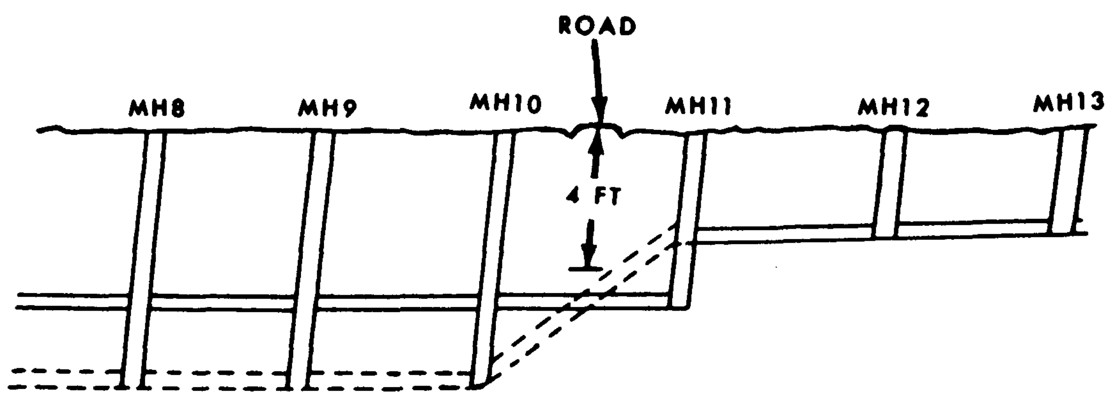


Figure 4–10. Use of drop manholes—(1 of 4).

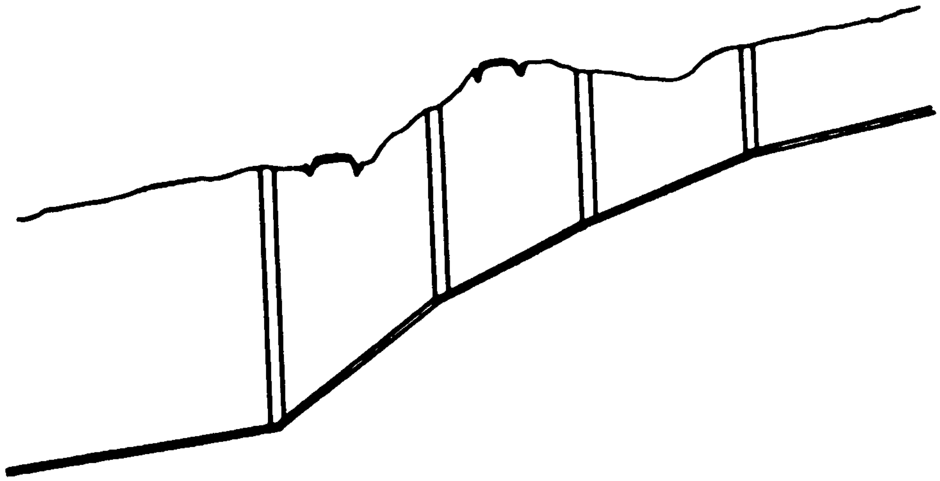


Figure 4–10. Use of drop manholes—Continued—(2 of 4).

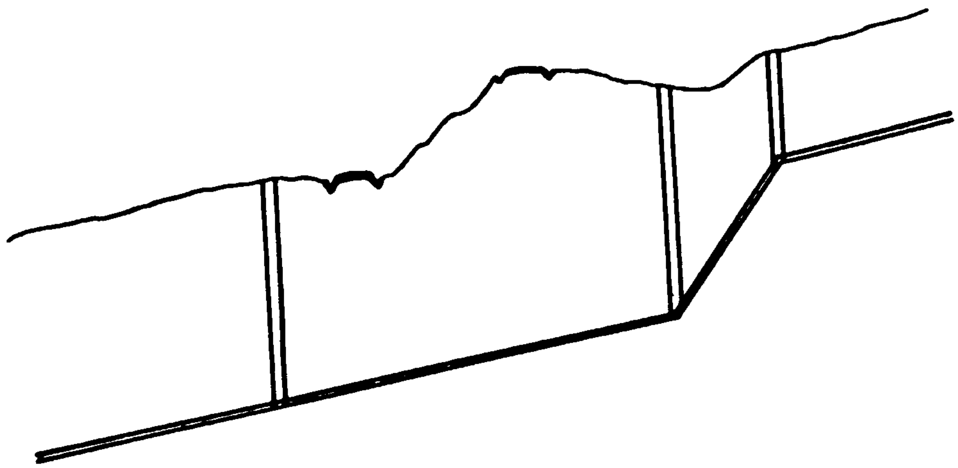


Figure 4–10. Use of drop manholes—Continued—(3 of 4).

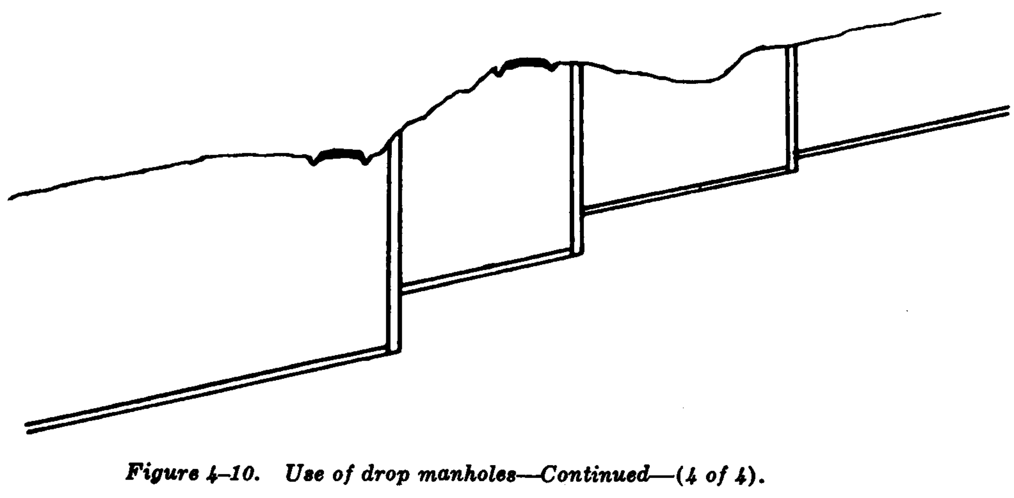


Figure 4–10. Use of drop manholes—Continued—(4 of 4).

necessary can be determined by use of formulas or charts. The formula that has had the widest acceptance among engineers for sewer design in the past is known as Kutter's formula. In the simplified form, usually used in design, it is—

$$V = \frac{\frac{1.81}{n} + 41.66}{1 + \frac{N(41.66}{\sqrt{R} +}} \sqrt{RS}$$

Where—

V = velocity in feet per second

n = a coefficient, dependent primarily upon roughness and, to some extent, upon size and shape of the conduit

R = hydraulic radius in feet

S = slope in feet per foot.

The Manning formula, which uses the same nomenclature and is much simpler in form than Kutter's formula, is-

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

(2) The results obtained by the two formulas are practically the same except that for pipe sizes smaller than 12 inches, the Manning formula requires larger values of n for comparable results. It is recommended that 0.013 be used as the value of n in Kutter's formula for all sizes of pipe and in Manning's formula for pipe larger than 10 inches, and that 0.014 be used in Manning's formula for pipe sizes of 10 inches and smaller. Figures 4–11 and 4–12, respectively, are pipeflow charts based on the two formulas using the values of n, as recommended. Either chart may be used to determine flow rates for pipes running full. MGD stands for million gallons per day; GPM is gallons per minute, and CFS means cubic feet per second. Along the top and bottom of the charts is slope in feet per hundred which is also percent. Inside the chart are lines moving up to the right. These lines are different pipe sizes and range in size from 4-inch to 48-inch diameter. The lines perpendicular to the pipe size lines are velocity lines and range from 1 foot per second (fps) to 12 fps. The pipe chosen must handle at least as great a flow at the chosen slope as the actual flow found in *c* (1) above. To find a pipe size which will do this, enter the chart on the left or right side at the actual flow rate. Draw a horizontal line until the chosen slope is intersected. The pipe size below this point of intersection is too small. The pipe above this point must be used.

(3) As an example, find a pipe size to handle an actual flow of 300 gpm at 1% slope. Use figure 4–11 for this example. Enter the chart at 300 gpm on the right and move horizontally to the left until the 1% slope line is intersected. The point of intersection is above the 6" diameter pipe and below the 8" pipe. Therefore 6" pipe cannot handle 300 gpm at a 1% slope and 8" diameter pipe must be used. The minimum pipe sizes which may be used for theater of operations construction are 4 inch diameter for a house connection and 6 inch diameter pipe for any other sewer.

f. Actual Velocity.

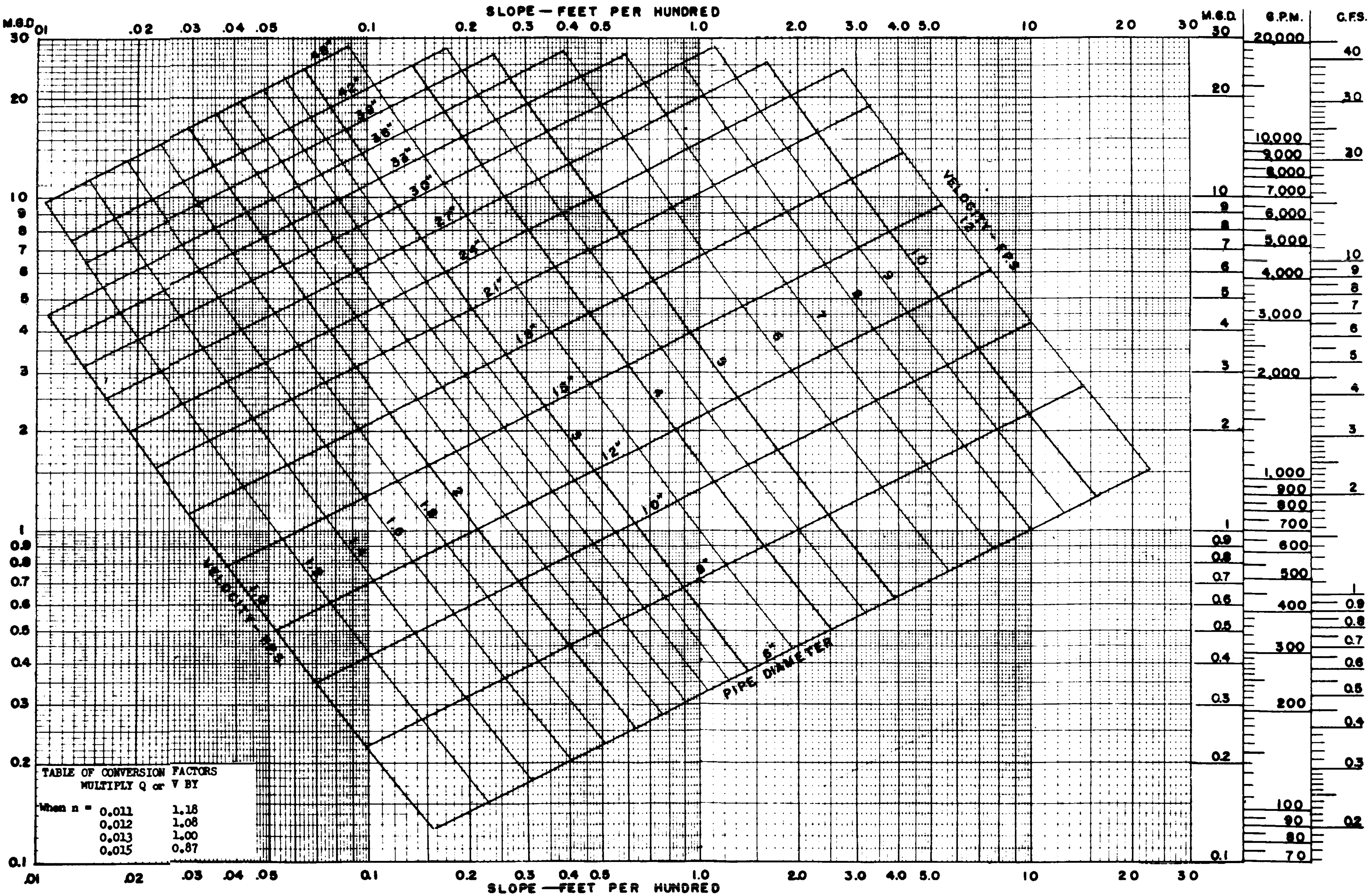
(1) The acceptable limits for the sewage velocity are 2 fps to 10 fps. Velocities lower than this will tend to deposit solids in the sewer and velocities higher will scour out the invert of the sewer. Occasionally, the designer must choose between using a lower velocity than 2 feet per second or of putting in an automatic lift station. If it can be shown that the costs incurred in keeping the sewer clean, and perhaps replacing it, are cheaper over the design life of the system than the procurement and maintenance cost of the lift station or other special facility, then the actual velocity may be decreased to 1.5 fps at peak flow.

(2) The actual velocity is found by the following six steps:

(a) Find the full flow. (Step 1) The full capacity of the sewer is found by entering the chart at the given slope and moving all the way up to the chosen pipe size. Moving horizontally to the right from this point the full capacity can be read. Continuing the example started above, the chart is entered at the 1% slope line. Moving up to the 8" line and reading to the right, a full flow of 500 gpm is obtained.

(b) Find the velocity of full flow. (Step 2) The velocity at full capacity is found by entering the chart at the design slope. Move up vertically until the design pipe size is intersected. (This point of intersection is the same point found in step 1 above). Through this point draw a parallel to the velocity lines. Knowing the velocity value of the line above and below, an estimate of the velocity value of the new line can be made. This is the velocity at full flow. For the example above the chart is entered at 1%. At the intersection of the 1% line and the 8" diameter line, a line is drawn parallel to the velocity lines. The new line lies between the line of 3 fps and 3.5 fps, and by interpolation is 3.2 fps.

(c) Calculate the discharge ratio. (Step 3) The discharge ratio is the ratio of the actual discharge (flow) (QA) to the full discharge (Q.).



PIPE FLOW CHART
KUTTER'S FORMULA (N=.013)

Figure 4–11. Pipe flow chart—Kutter's formula.

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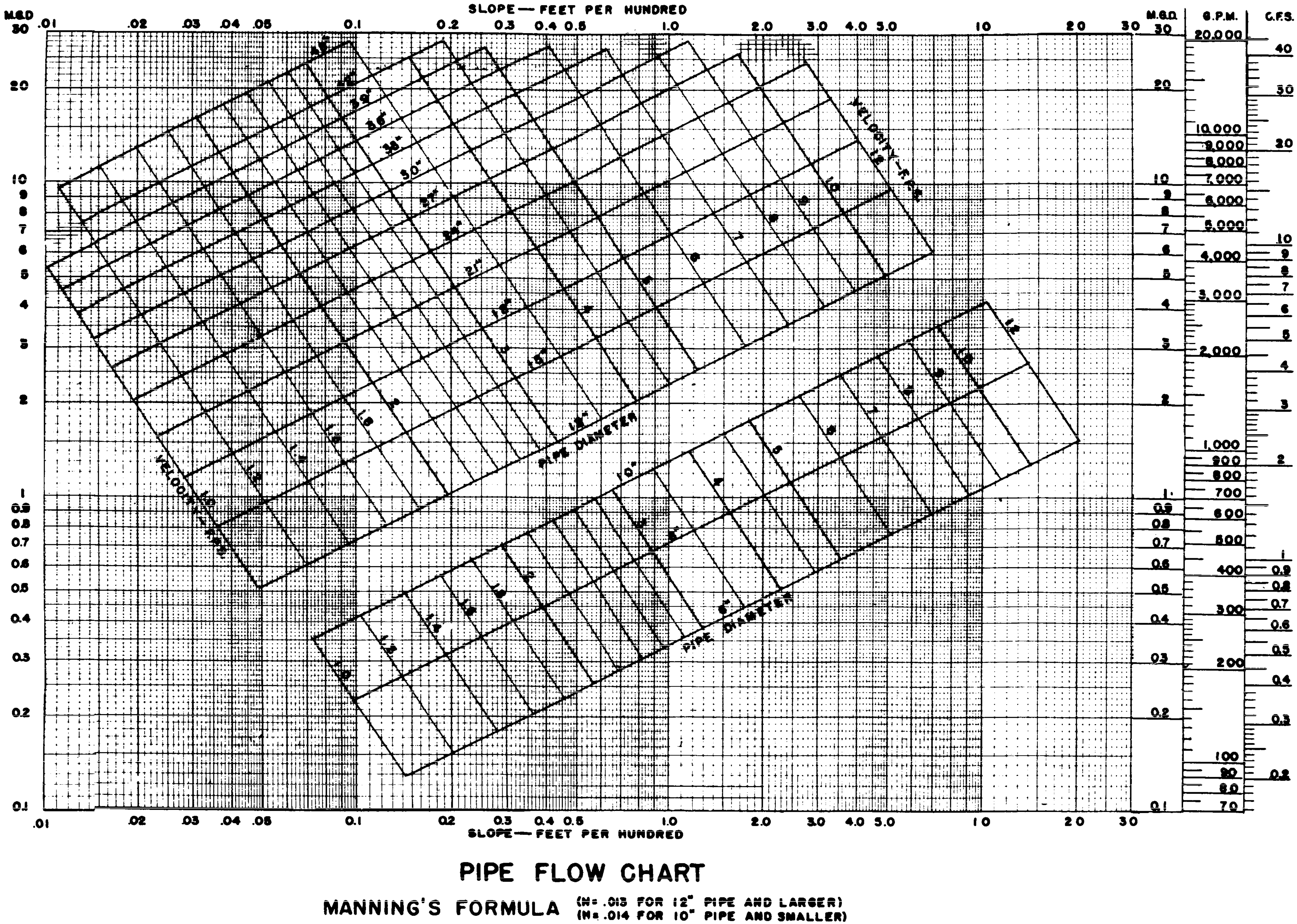

Figure 4–12. Pipe flow chart—Manning's formula.

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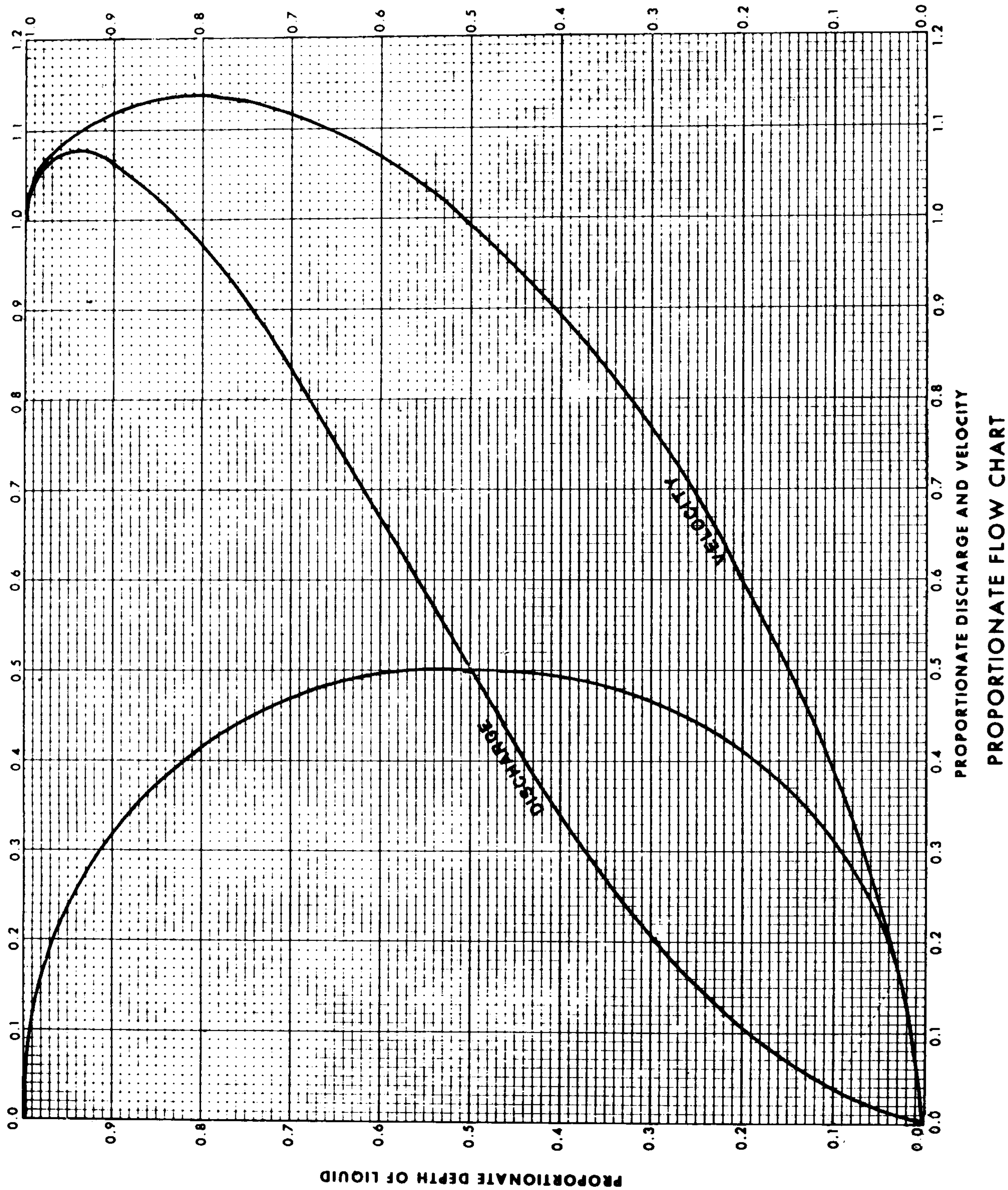

Figure 4–13. Proportionate flow chart.

Thus the discharge ratio is found by dividing the actual flow by the full flow. For the example started above, the actual flow is 300 gpm and the full flow is 500 gpm. Therefore, the discharge ratio is $\frac{300}{500} = 0.6$.

(d) Find the velocity ratio. (Step 4) The velocity ratio is the ratio of the actual velocity (V_a) to the velocity at full flow (V_c). The velocity ratio is found by the use of the proportionate flow chart shown in figure 4-13. The semicircle shown on the graph depicts a pipe cross section. This is used with the other two curves to show how the discharge and velocity ratios depend on the depth of the liquid in the pipe. The graph shows that the maximum velocity (velocity curve) does not occur at the maximum discharge (discharge curve) value. This is due to the fact that, at maximum discharge, the cross-sectional area of pipe being used is larger; therefore, the velocity losses due to friction are greater. The chart is used by entering along the top or bottom of the value of the discharge ratio. Move vertically along the discharge ratio value until the discharge curve is intersected. From this point move horizontally to the right until the velocity curve is intersected. At this point move vertically up or down and read the velocity ratio at the top or the bottom of the chart. Continuing the example, the chart is entered along the bottom at the value of ratio 0.6. Moving up to the discharge curve across to the velocity curve and down to the bottom a value of 1.045 is read. The velocity ratio is 1.045. The only case where this method of using chart 3 gives an incorrect answer is when the discharge ratio is 1.0. In this case, the actual velocity must be equal to the full flow velocity because the pipe is flowing full. Since the velocities must be equal, the velocity ratio is 1.0.

(e) Calculate the actual velocity. (Step 5) The velocity ratio is the actual velocity divided by the full flow velocity. Therefore, the actual velocity can be determined by multiplying the velocity ratio by the full velocity. Continuing the example, the full flow velocity was found to be 3.2 fps and the velocity ratio 1.045. Therefore the actual velocity will be (3.2 x 1.045) = 3.34 fps.

(f) Check the actual velocity. (Step 6) The actual velocity must be between 2 and 10 fps. There is a greater probability that suspended solids will settle and clog the sewer at velocities less than 2 fps. The sewage must be kept flowing toward the treatment facilities so it will not become septic. However, high velocities must be avoided to prevent scouring the sewer.

g. Determine Invert Elevations. Invert elevations can be determined once the slope is known. The elevation of the invert at the lower manhole is the elevation of the invert of the upper manhole less the product of the slope multiplied by the length of the sewer between manholes. The invert elevations of the upper manhole will be known for each section except the first. The invert at the first manhole will usually be made as close to the ground level as possible while still maintaining minimum cover (fig 6-4).

CHAPTER 5

SEWAGE PUMPS AND LIFT STATIONS

Section I. TYPES AND CHARACTERISTICS

5-1. General

Pumps for lifting sanitary sewage, storm water, and plant-unit effluents are usually high-capacity, low-head types with large openings and low velocities to allow passage of large particles of solid material. The types in most common use are the centrifugal, axial-flow propeller, turbine, and ejector. A detailed description of pumps and their operation is given in TM 5-660.

a. Desirable characteristics in sewage pumps are freedom from clogging and resistance to wear. Most installations provide for pump protection by adequate screens or grinders which either remove the larger solids or cut them to a size which can easily pass the pump openings. Because rags and strings, which cause stoppage, are most troublesome, provision is usually made in the pump casing for their ready removal.

b. Sewage pumps may be powered either by electric motors or internal-combustion engines. Gas from sewage digesters is sometimes used as a fuel.

5-2. Centrifugal Pumps

Centrifugal pumps are used to pump sanitary sewage because of their comparative simplicity, ease and efficiency of operation, and small dimensions. The type used for sewage is single-stage slow-speed (about 1,150 rpm), mounted either horizontally or vertically. Figure 5-1 shows a typical single-stage horizontal type pump and figure 5-2 a close-up of the centrifugal sewage pump. Figures 5-2 and 5-4 show a vertical submerged type with float control.

a. Starting Operation. The centrifugal pump must be filled completely with sewage before it is

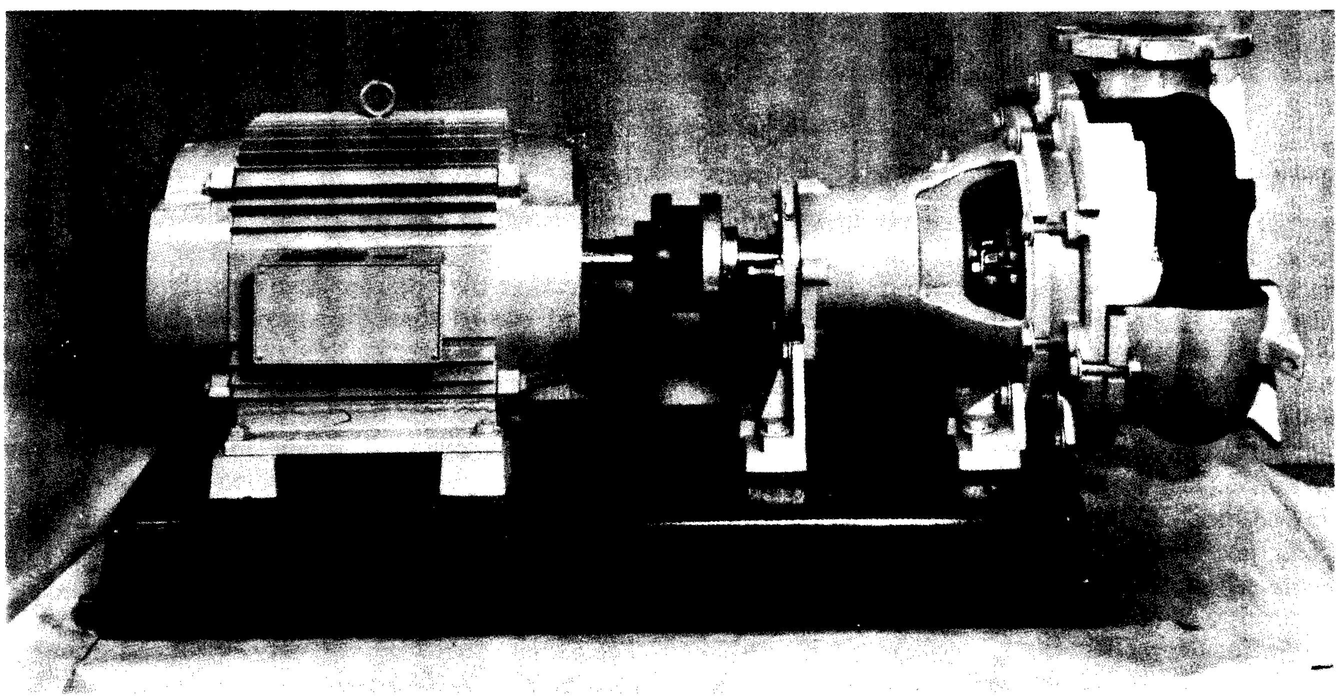

Figure 5–1. Horizontal type centrifugal pump for sewage.

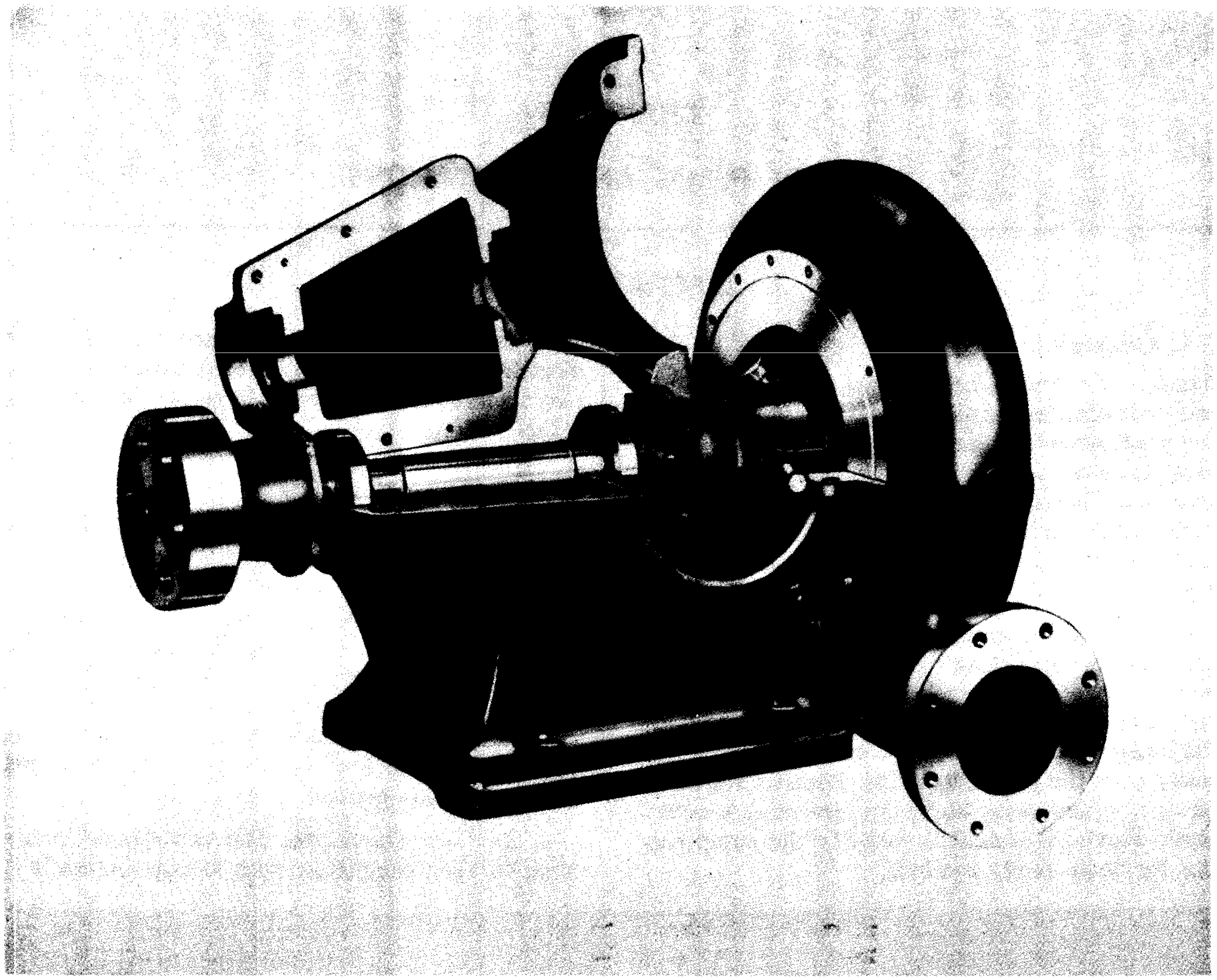

Figure 5-2. Closeup of horizontal type centrifugal pump.

started to remove air from the casing and provide water for lubrication. If the pump is set above water level, priming devices are required. The pumps are usually set either in the well from which the sewage is pumped or in a dry well outside and below the sewage elevation of the wet well. The suction lift must not be excessive, 15 feet being considered maximum; all piping on the suction side of the pump must be airtight to avoid air binding. If the pump characteristics differ from the requirements, the motor may overload and overheat. The manufacturer may be contacted concerning pump characteristics and recommendations for alterations.

b. Flush-Kleen Type. Flush-kleen centrifugal pumps are widely used for sewage pumping to avoid some of the difficulties with clogging (fig 5-5). Sewage enters the discharge line of this type rather than discharging directly into the wet well; it passes through a strainer just ahead of the impeller where the solids are removed; sewage flows through the pump to the well. The pump lifts sewage from the well through the screen, forcing the retained solids into the discharge main. These pumps are installed in duplicate.

5-3. Axial-Flow Pumps

Axial-flow propeller type pumps are described in TM 5-660. This high-capacity, low-head pump is used largely for recirculating treatment-unit effluents and for pumping storm water.

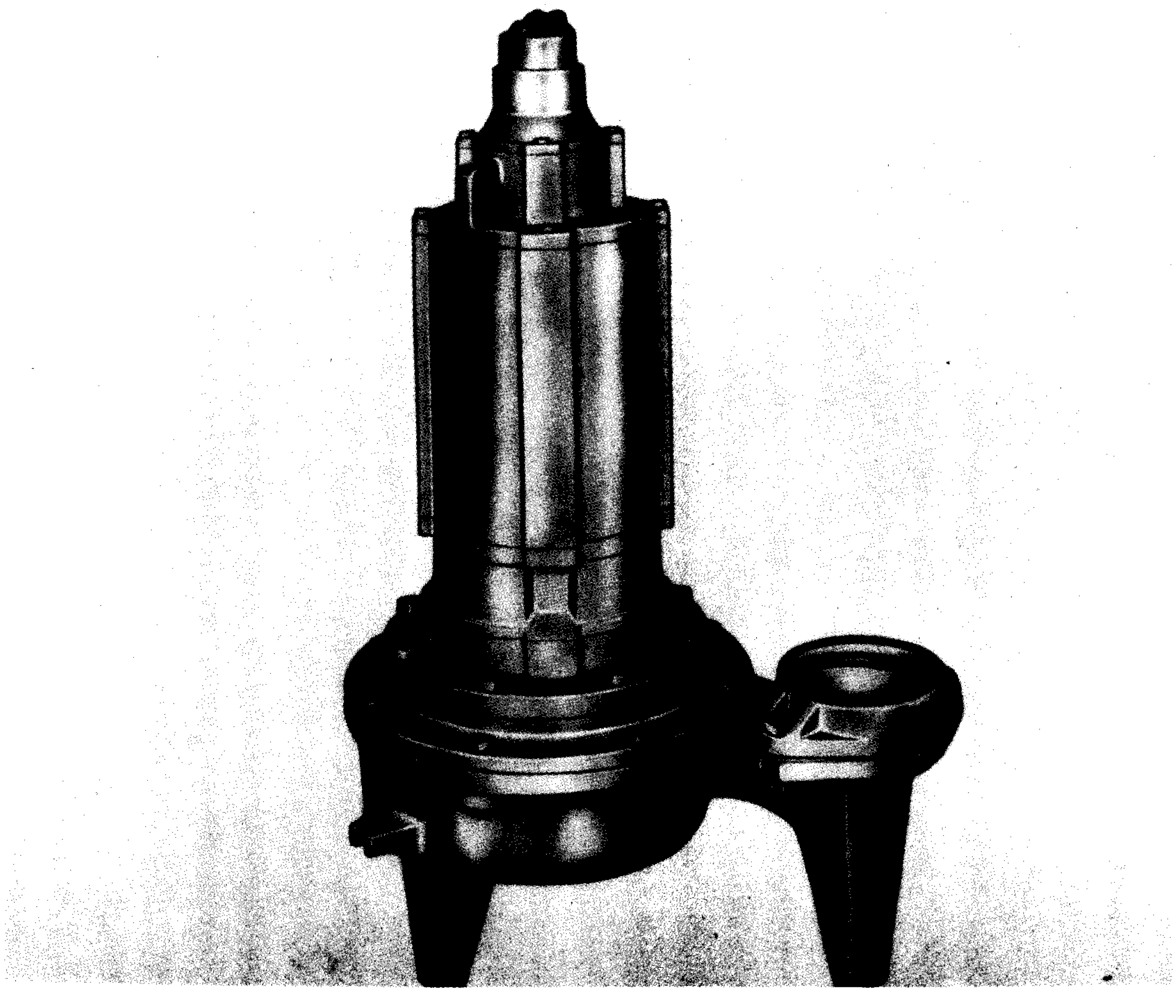

Figure 5–3. Vertical submerged type centrifugal pump for sewage.

5-4. Turbine Pumps

Turbine type pumps, described in TM 5-660, are used to pump large volumes of storm water.

5-5. Sewage Ejectors

The sewage ejector is used to avoid the trouble of cleaning screens and clearing material from pumps. The sewage flows into a metal chamber; when the chamber is full, an automatic control admits compressed air which forces the sewage out through the discharge line. This installation requires air compressors, air tanks, and other items which make the system expensive. The efficiency is low, seldom attaining 15 percent. Sewage ejectors are better than centrifugal pumps for lifting sewage from basements of buildings into the main sewer because the relatively small flow requires a pump so small that it clogs easily. Figure 5-6 shows a typical installation lifting sewage from a manhole on a sewage line to a higher sewer. Figure 5-7 is a cross section of an ejector.

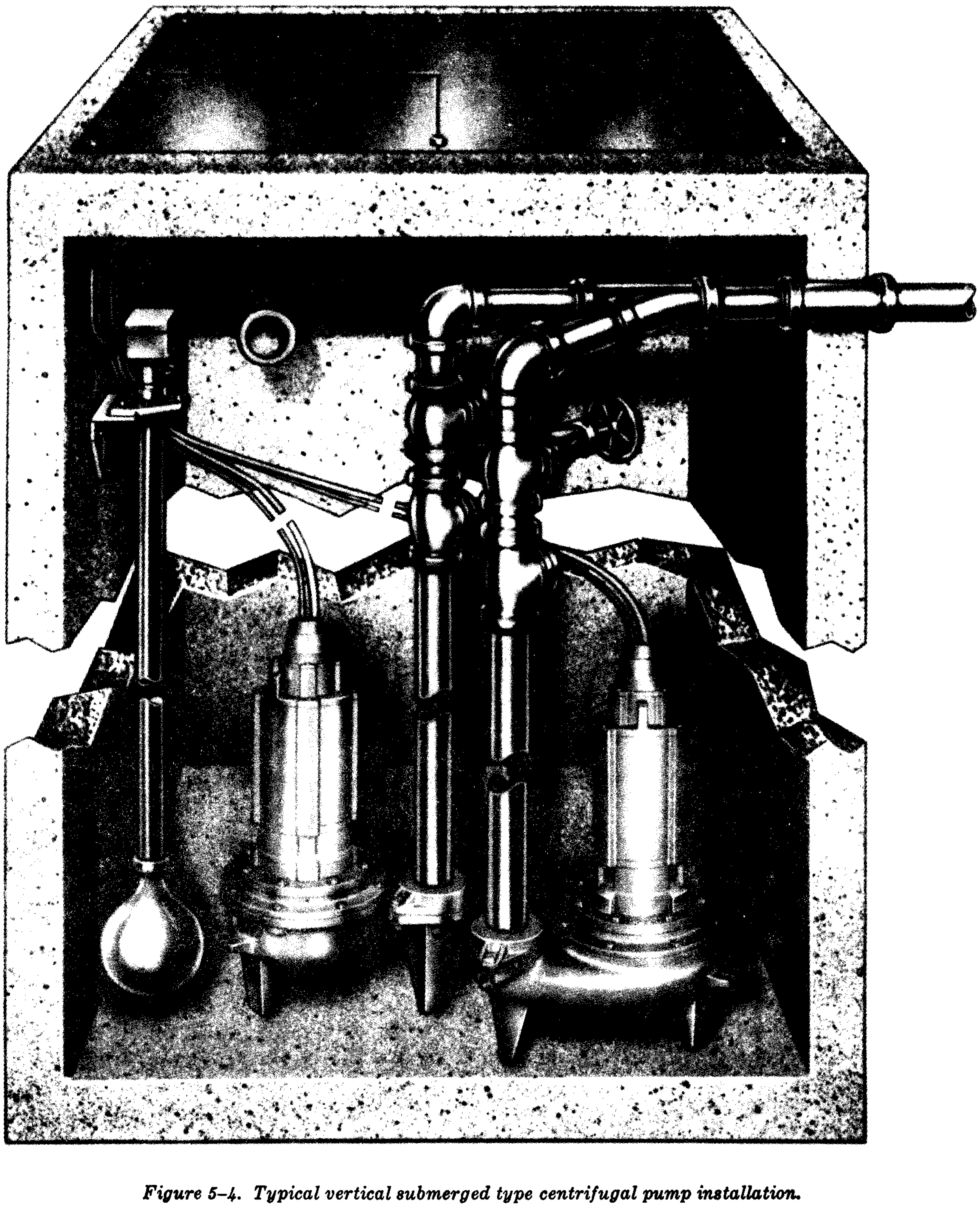

Figure 5–4. Typical vertical submerged type centrifugal pump installation.

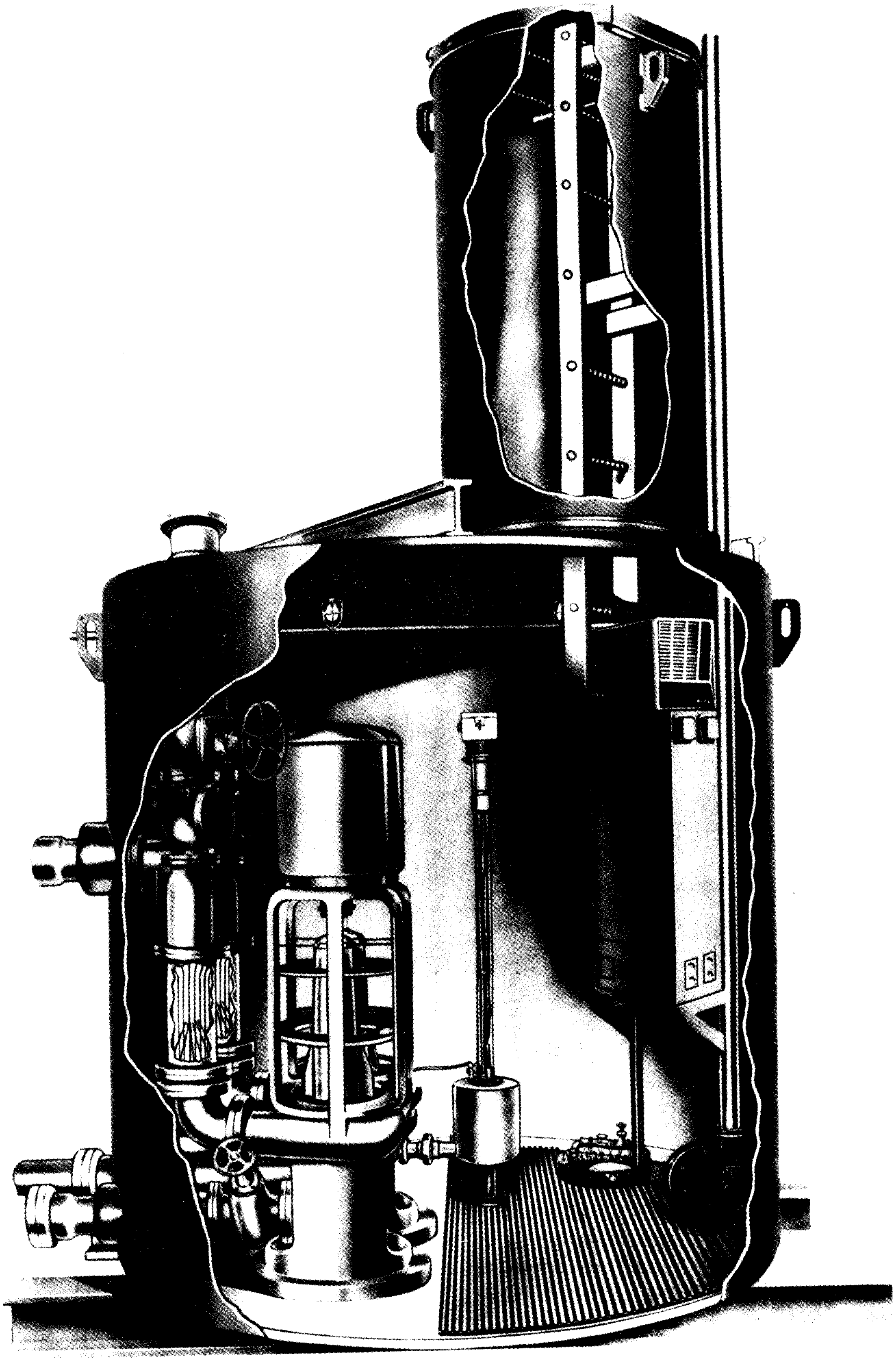

Figure 5–5. Flush-kleen centrifugal pumps.

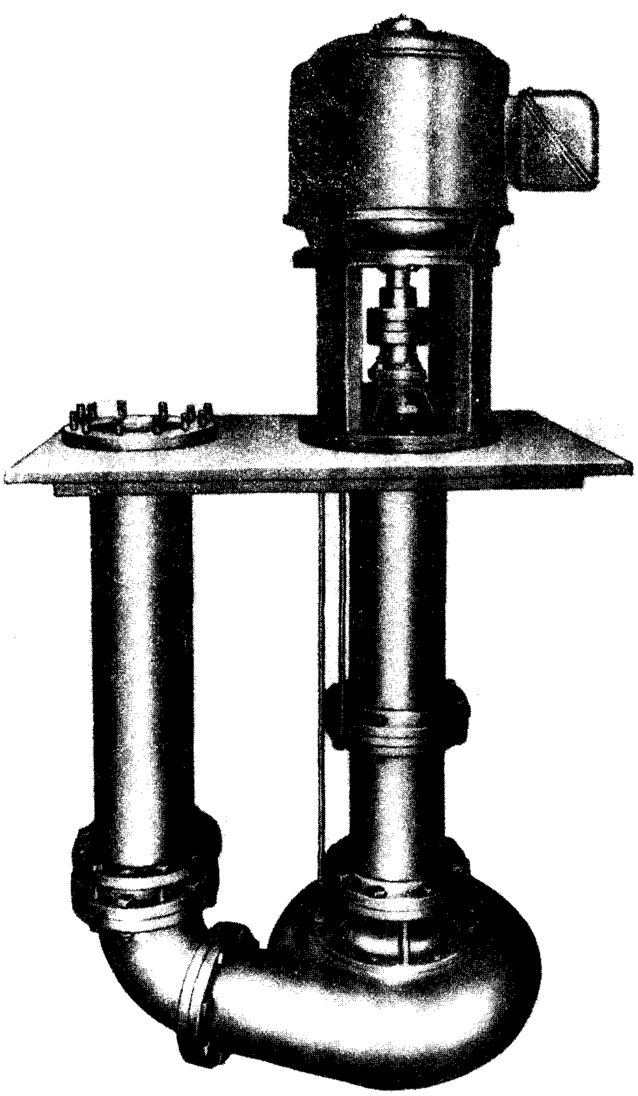

Figure 5–6. Typical installation of sewage ejector.

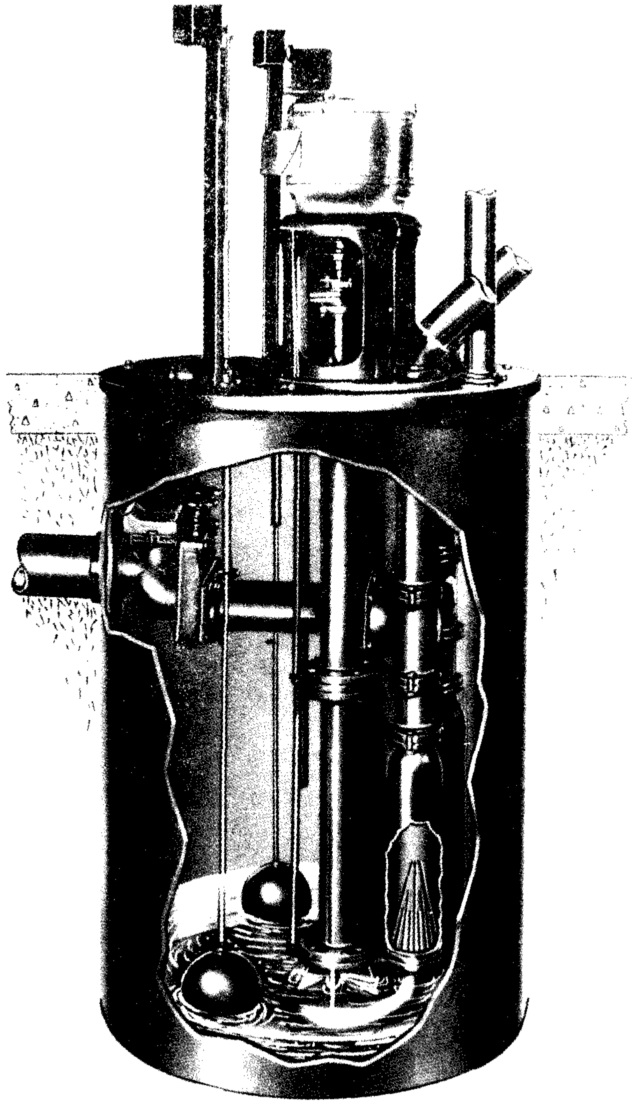

Figure 5–7. Cross section of a sewage ejector.

Section II. CONTROLS AND OPERATION OF PUMP STATIONS

5-6. Controls

Pumping cycles controlled by float and sequence switches are adjusted, if possible, to avoid large fluctuations of flow to the treatment plant. Where pumps of different capacity are installed, the smaller pump is set to cut out when the larger pump starts, both pumps operating only at peak periods. Where two pumps of identical capacity are provided, their use is alternated frequently to provide equal wear. Standby pumps are operated manually once a week to maintain proper operating condition. Since sewage pumps usually have automatic operation, the float control requires frequent attention. The float may be connected to the electric switch either by a push rod or a chain running over pulleys with a counterweight to balance the float. Floats hanging unprotected are likely to be moved sideways by the sewage, causing the rod to bend; some guiding device must be provided to prevent such damage. Proper protection must be provided to eliminate building up ice on the rods exposed to the weather.

5-7. Operation of Pump Stations

Because pumping costs are often a major operating expense in a sewage treatment plant and sewage system, maintaining normal efficiency of all pumping units is extremely important. Partly clogged pumps, worn impellers, and other inefficient conditions may greatly increase the power consumption and cost of repairs. In addition, breakdowns may cause health hazards by backing up sewage in buildings or flooding low areas. Pumping stations are often located in housing areas where odors caused by lack of cleanliness are especially objectionable. Proper maintenance and frequent inspection can insure continuous and efficient operation of pumping stations.

a. Although most sewage pumping stations are equipped to operate automatically, daily attention is required. Accumulation of solids in the wet well must be prevented.

b. The sewage level is drawn to minimum elevation daily; walls and bottom are thoroughly flushed with a heavy stream of water. This operation may require manual operation of pumps. Any air trapped in the pump can be bled by hand, following this operation, if an automatic air-relief valve is not provided. If the potable water system is used for flushing, the hose must be physically disconnected from the well to prevent contaminating the water supply.

c. Grit accumulations are removed periodically by bucket and shovel if flushing is not effective.

d. Slopes in the bottom of the wet well may be increased by laying concrete in the corners of the well sloping to the pump suction. Slopes of 1:2 or 1:1 are desired to prevent accumulations.

e. Grease accumulation in float tubes is removed by daily flushing and scrapping with a homemade hoe-shaped tool, when necessary. Replacement of float tubes with open guides of vertical-steel angle iron eliminates grease clogging.

f. Bar screens and basket screens installed at pumping stations must be cleaned daily, or more often if necessary, to prevent obstruction to flow or overflow of basket.

g. Water accumulations in the dry well are removed daily by the sump suction valve of a sewage pump. If a separate sump pump is available, this operation is done automatically by a float switch. The dry-well floor should slope toward the sump.

h. Structures housing pumping equipment require careful maintenance to prevent rapid deterioration.

i. Pumping-station floors, walls, and windows must be kept clean to avoid odor nuisance and unsightliness.

j. Acid-laden condensation from sewage which severely corrodes concrete and masonry structures, steelwork, window sashes, and settings, may be relieved by adequate ventilation. Forced ventilation is necessary in underground installations without surface structures. Where required, paints specially manufactured to protect masonry are applied. All metal must be protected with paint.

k. Sewage gas and explosive vapors are likely to accumulate in the wet well. Daily flushing and removal of solids reduces the production of gas.

l. In some cases, particularly where the lift is high and discharge pipes are long, check-valve slam occurs, which may fracture the pipe or loosen the joints. Remedial measures must be taken by installing the following:

(1) Slow-closing check valves.

(2) Large air chambers with small compressors to replenish air in the chamber.

(3) Hydraulic shock eliminators.

m. Maintenance of pumps and auxiliary equipment is covered in TM 5-666.

CHAPTER 6

CONSTRUCTION OF SEWER SYSTEMS

Section I. SEWER MATERIALS

6-1. Pipe

a. Sanitary Sewers. Vitrified-clay sewer pipe may be used in all sizes that are readily available. Bituminized-fiber sewer pipe of the 6-inch and 8-inch sizes may be used in house connections except in connections to boiler blowdown tanks and laundries. Concrete pipe, unlined asbestos-cement pipe, and cast iron soil pipe may be used except where the acid waste would be insufficiently diluted with akaline sewage to prevent corrosion and where unalterable conditions, such as high sulphate content, high temperature, and low velocity of the sewage, would be conducive to the formation and liberation of hydrogen sulphide. Asbestos-cement pipe may be used under these conditions if adequately lined with a corrosion-resisting plastic. In areas where sulphate concentrations in soil or water are in ranges of 0.10 to 0.20 percent as water soluble SO_4 in soil samples and of 150 to 1000 parts per million as SO_4 in water samples, the cement used in the manufacture of concrete pipe or construction of manholes or other structures will be type II portland cement; and where SO_4 concentrations exceed these maximum limits, the type V cement will be used. Asbestos-cement pipe used under either of these conditions will be type I or II and adequately protected with an outer coating. Where pressure pipe is required, as in force mains or inverted siphons, the pipe may be cast iron, steel or asbestos-cement pressure pipe adequately protected against interior and exterior corrosion as conditions indicate. Therefore, a study will be made of the soil and expected sewage conditions and specifications will be prepared accordingly. Pipe of any material will conform to the requirements of OCE guide specifications.

b. Industrial-Wade Sewers. As the mission of, or the processes used in military industrial installations are subject to change, pipe made of materials subject to attack by acids will not be included in specifications for industrial-waste sewers. Vitrified-clay pipe conforming to Federal Specifications SS-P-361 normally will be specified. Conditions seldom exist at military installations requiring discharge of acid in such concentrations that vitrified-clay pipe would not be suitable. Where it is known that such conditions will occur frequently, special acid-resistant pipe will be specified. In such cases the specifications will state the concentrations and type (nitric, sulfuric, etc.) of acids that will be encountered and whether the waste will contain mixtures of acids.

6-2. Joints

The joints of nonpressure bell-and-spigot sewer pipe normally should be made with hot poured bituminous material, poured in place or precast as rings inside the bells and as collars on the spigots. This type of joint reduces infiltration and the entrance of roots into the pipe. Portland cement mortar and certain cold-applied bituminous jointing compounds are satisfactory materials for sewer joints if the annular space is properly filled entirely around the pipe (fig 6-1). The problem with these materials is that the lower part of the joint is more difficult to fill and defects are more difficult to detect. It is primarily for this reason

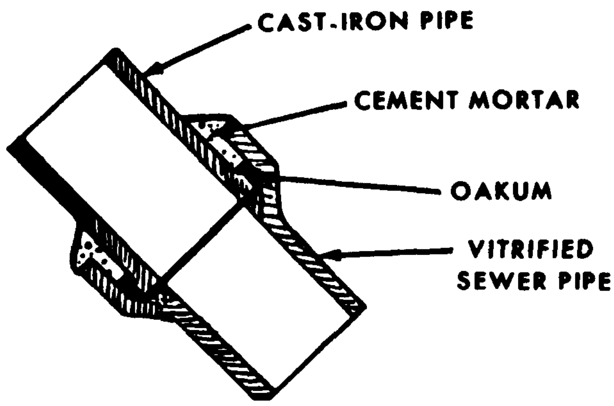

Figure 6–1. Cast-iron pipe and vitrified sewer pipe joint.

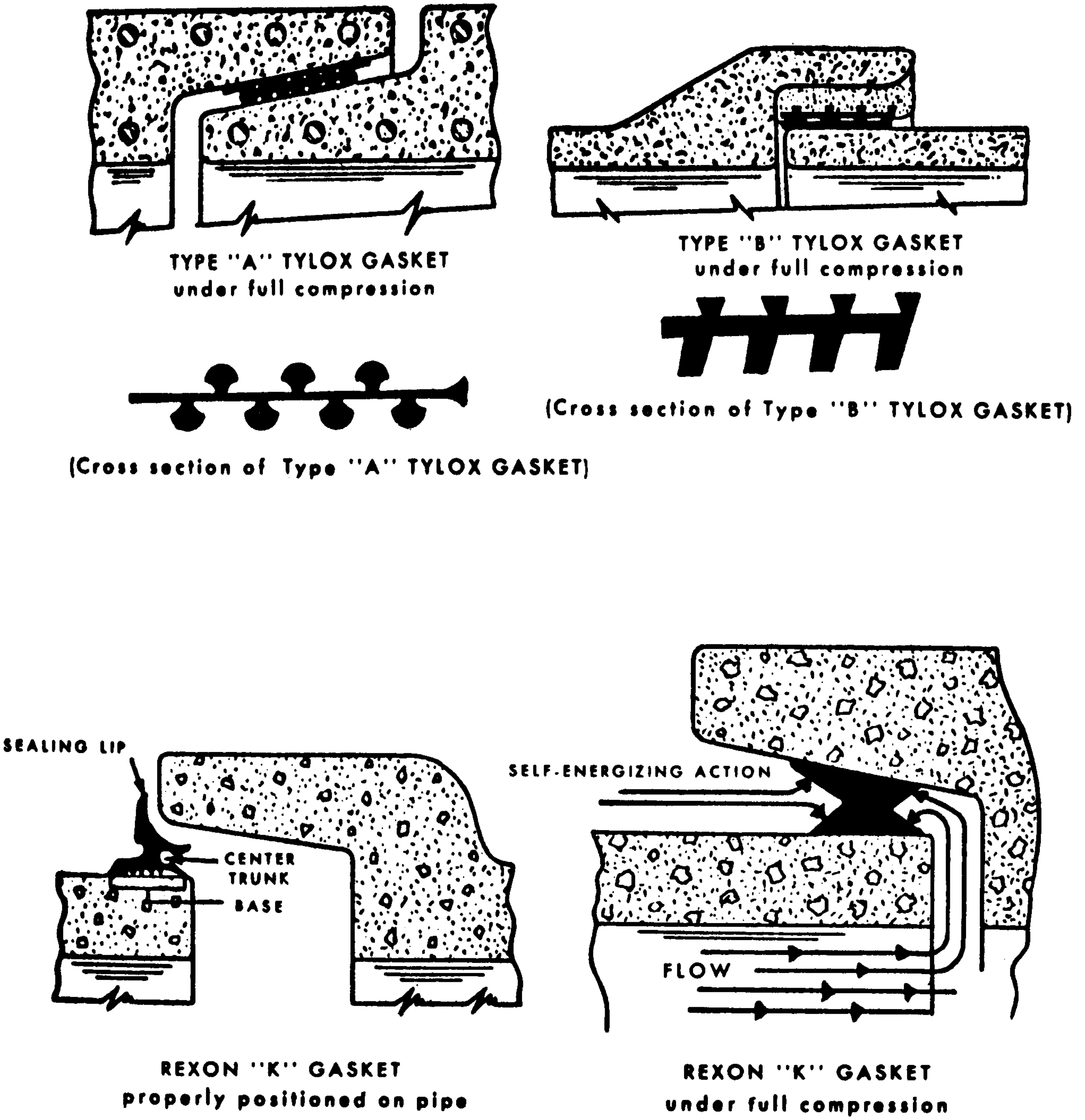

Figure 6-2. Tylox rubber gasket couplings.

that hot poured bituminous joints are preferred in bell-and-spigot pipe. Cement mortar or cold-applied compound would be required for the mortised or tongue-and-groove type of concrete pipe. Also, cement joints should be used in house connections to boiler blowdown tanks and laundries.

Slip joints with rubber gaskets are produced commercially and, because of the ease of installation, should be used when available. Figure 6-2 shows several types of slip joints with rubber gaskets. TM 5-551K and TM 5-814-1 provide additional information on sewer-pipe joints.

Section II. INSTALLATION

6-3. General

The construction of the sewerage system requires careful planning and organization. A thorough knowledge of existing conditions, careful scheduling of work, and use of men and machines will keep the actual length of sewer being worked on at any one time at a minimum. Local conditions influence the methods of construction, such as sheeting and bracing requirements and type of excavating equipment.

6-4. Line Location

a. Before staking out the sewer, a plan and profile view should be prepared to show—

(1) The horizontal location of each line in the system.

(2) The invert elevation of the upper and lower edge of each manhole.

(3) The slope of each line.

b. The stakeout consists of setting hubs and stakes to mark the alinement and indicate the depth of the sewer. The alinement may be marked by a row of offset hubs and a row of centerline stakes. Cuts may be shown on cut sheets (also called grade sheets or construction sheets) or may be marked on the stakes or both. The cuts shown on the centerline stakes guide the backhoe or ditcher operator; they are usually shown to tenths; they generally represent the cut from the surface of the existing ground to the bottom of the trench, taking into account the depth to the invert, the barrel thickness, and the depth of any sand or gravel bed. The cuts marked on the stakes next to the hubs are generally shown to hundredths and usually represent the distance from the top of the hub to the invert. Hubs and/or stakes are generally set at 25-foot intervals, though 50-foot and even 100-foot intervals are adequate. Sewer hubs are usually offset from 5 to 8 feet from the centerline. Figure 6-3 is a sewer stakeout plan view showing a line running through two manholes. The dotted lines are offsets (greatly exaggerated for clarity) to points where hubs will be set. Note that at stations 5 + 75 and 1 + 70.21 two hubs are set, one for the invert in and the other for the invert out. The invert elevations at the manholes are given on the profile.

c. An example of determining invert elevation is shown in figure 6-4.

d. One method of using these hubs to dig the trench to grade is to erect a batter board across

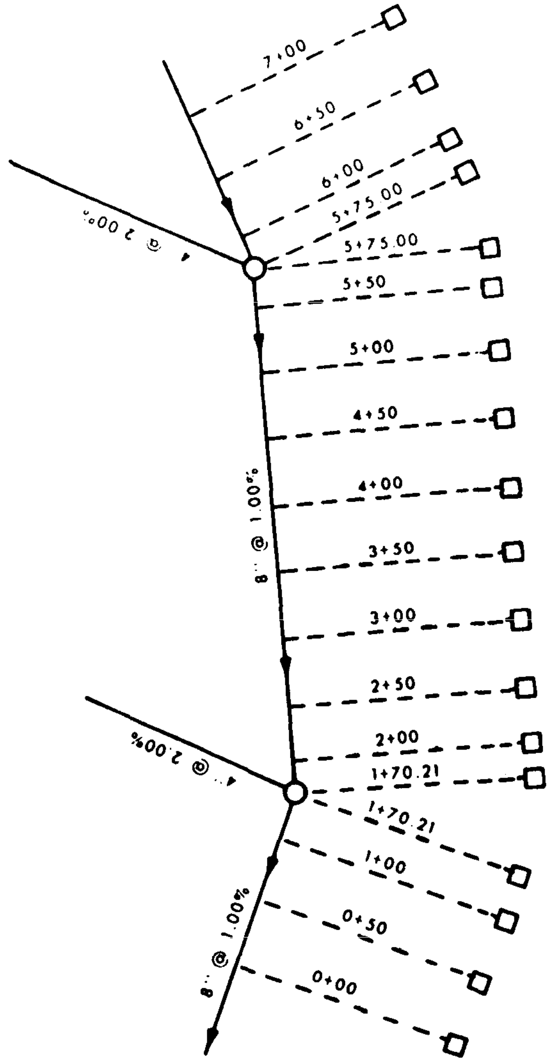

Figure 6-3. Sewer stakeout plan.

the trench at each hub. The elevation of the batter board is at a set distance above the invert and a string line is laid parallel to the pipe along the centerline. The finished grade of the trench or the invert of the pipe may be checked by using a grade pole, as shown in figure 6-5.

6-5. Excavation

a. Excavation may be done by hand labor or with equipment. Table 6-1 lists typical construction rates for hand labor.

b. Ditching equipment may be used to dig the trench to within inches of the final grade. The bottom of the trench is then shaped by hand labor as pipelaying progresses. Machine excavation is done by use of continuous bucket excavators, overhead

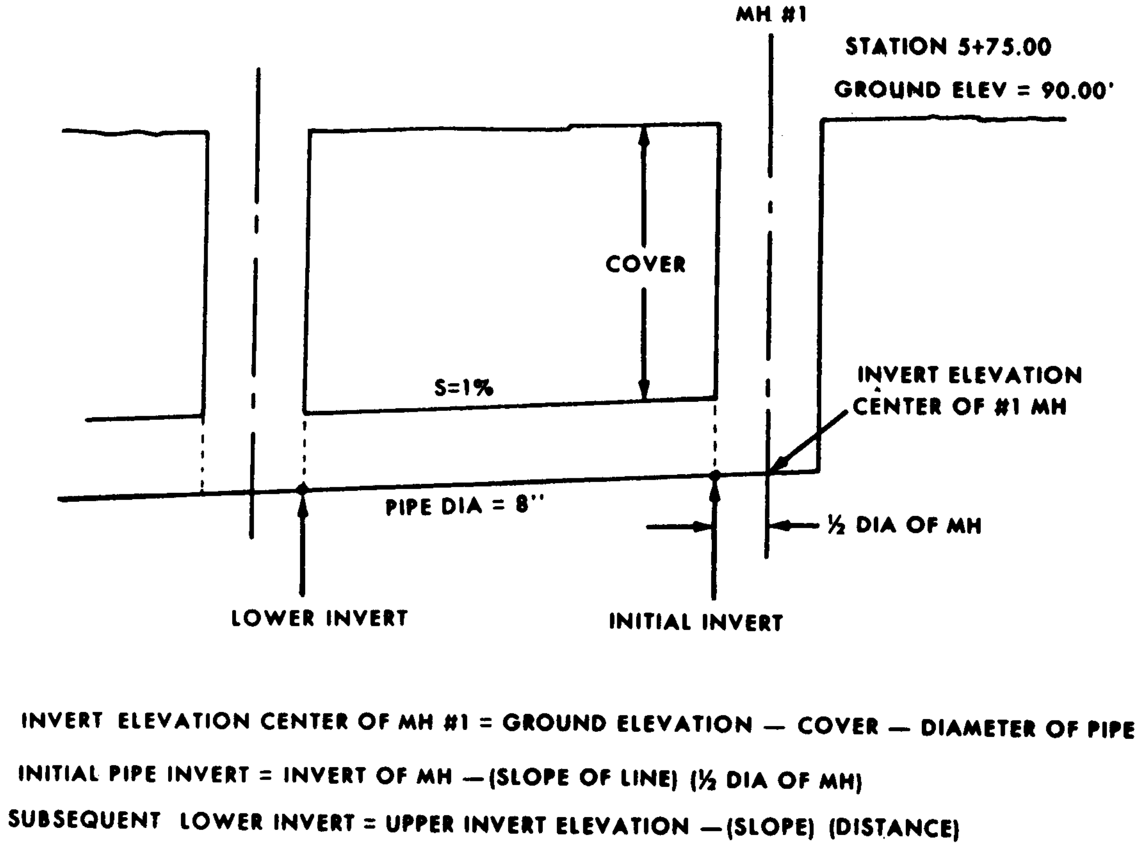

Figure 6–4. Determining invert elevation.

Table 6–1. Sewer Construction by Hand Labor (Man-Hours per 100 Feet)

Size of pipe	Depth to top of pipe								
	2 feet			4 feet			6 feet		
	Soft	Medium	Heavy	Soft	Medium	Heavy	Soft	Medium	Heavy
6 inch	50	76	94	80	125	158	110	176	224
8 inch	58	87	108	90	142	169	124	198	252
10 inch	69	103	129	106	163	206	141	221	282
12 inch	77	119	148	119	181	232	157	248	313
15 inch	94	138	171	137	208	262	182	278	347
18 inch	122	177	217	169	254	315	215	301	419

Note 1. Operation includes excavation to width of 16 inches plus pipe diameter, shaping bottom of trench, laying pipe, preparing joints, back fill, tamping to top of pipe, and back fill of trench. A normal method of determining trench width is to add 12 inches to 1.5 times the pipe diameter.

Note 2. Soil classifications are as follows: Soft-sandy silt or silt; medium—average solid; requiring some picking, gravelly; heavy—heavy clay or gravelly clay.

cableway excavators, track excavators, power shovels or boom and bucket excavators. Trapezoidal-shaped trenches help to keep the walls from caving in. However, the entire trench should be as narrow as possible with the bottom dimension equal to 1.5 times the pipe diameter plus 12 inches to permit proper bedding and construction of the joints.

c. Sheeting and bracing is used in trenches to prevent caving in of the wall and entrance of ground water. For shallow trenches where only limited support is needed, skeleton sheeting (fig 6-6) or poling boards may be used. These basically consist of wooden staves laid vertically against the face of the wall and braced to support the soil For deep trenches where greater support is required, box sheeting (horizontal staves) or vertical sheeting (fig 6-7) may be used. Vertical sheeting is the strongest since the staves are dug into the ground and braced. However, this sheeting is difficult and more time consuming to construct. Most sheeting is made of wood. However, metal is becoming more popular. The latter costs more but the sheeting can be used many more times than wood.

d. Proper embedment is essential in increasing the structural capacities of the sewer. When rock, shale and hard clay are encountered, the excavation should be carried to a minimum of 4 inches below the grade and a good granular material

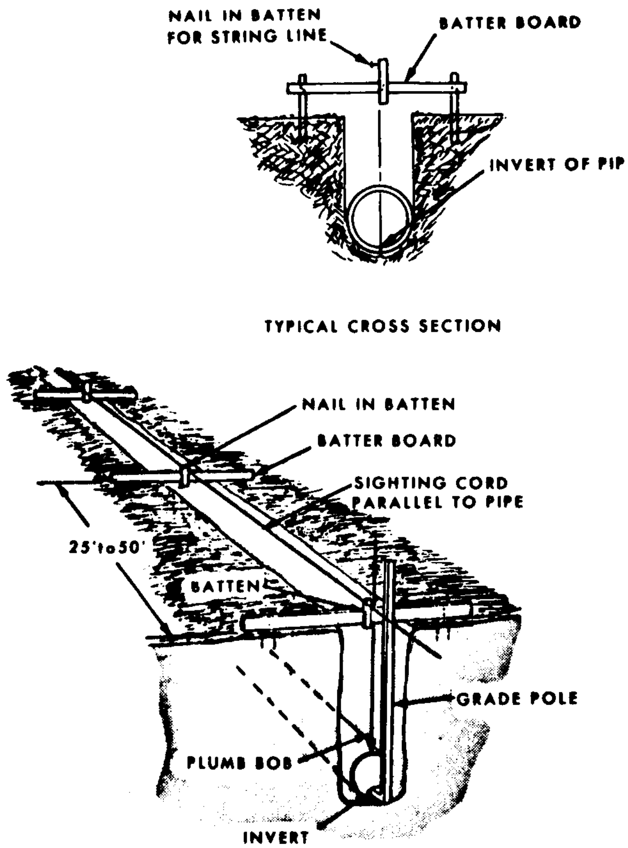

Figure 6–5. Setting sewer line to grade.

used as backfill. When the foundation for pipe sewers is in soft but stable clay soil, without excessive water, little attention will be required provided the trench width and bottom shape conform to the dimensions of the pipe. Careful trimming of the trench bottom to the shape of the pipe is

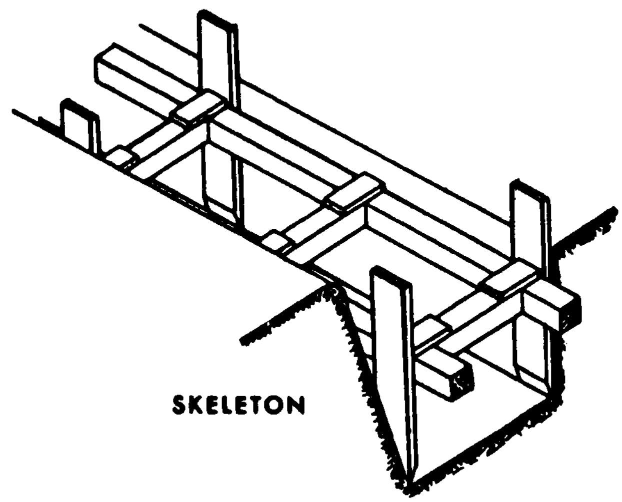

Figure 6–6. Skeleton sheeting.

however, costly in manpower and there is a growing (civilian) practice of overexcavation, followed by backfilling with granular material to provide uniform bedding of the pipe. Pea gravel or roofer's gravel is a good material for this purpose. In the theater of operations, construction on unstable soil should be avoided due to the requirement for additional effort in the form of concrete cradles or piling. In some cases, soft trench bottoms can be stabilized by overexcavating and adding coarse rock or gravel. Figure 6-8 shows four types of bedding.

e. Additional information may be found in TM 5-551K, Plumbing and Pipefitting.

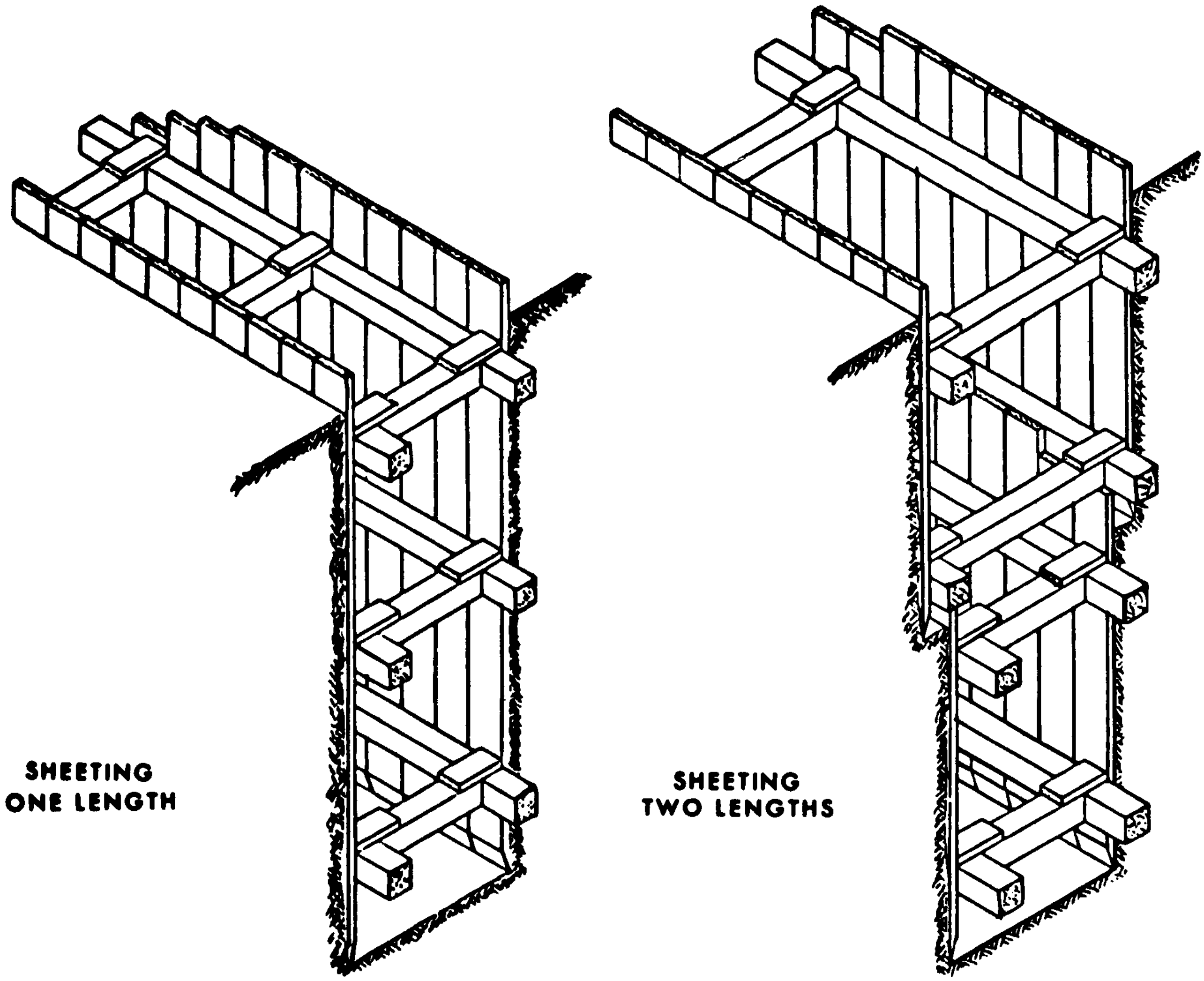

Figure 6-7. Typical vertical sheeting.

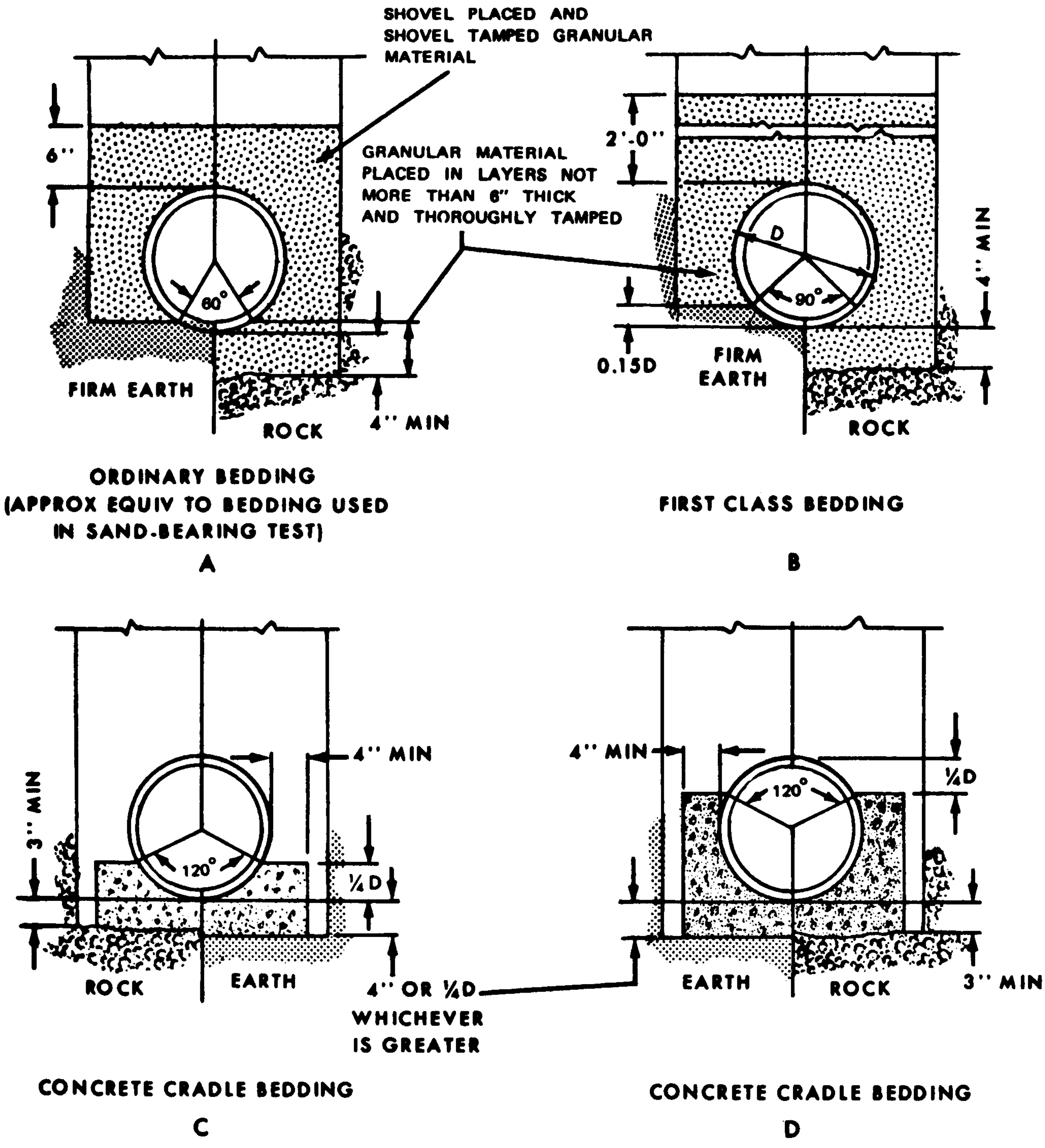

FIGURE	TYPE OF BEDDING	LOAD SUPPORTING RATIO*
(A)	ORDINARY	1.0
(B)	FIRST CLASS	1.25
(C)	CONCRETE CRADLE	1.5
(D)	CONCRETE CRADLE	2.0

*NOTE: THESE RATIOS ARE RELATIVE VALUES AND SHOULD NOT BE CONFUSED WITH FACTOR OF SAFETY

Figure 6–8. Four types of bedding for trenches.

GLOSSARY

Acre-foot— Volume of water (stone in a trickling filter) required to cover 1 acre 1 foot deep. Equals 43,560 cubic feet.

Activated sludge— Sludge settled out of aerated sewage.

Activated-sludge process— Sewage treatment in which sewage is brought into contact with air and with biologically active sludge. Tht sludge is separated by sedimentation, leaving a clear effluent.

Adsorption— Adhesion in a thin layer of molecules of gases, dissolved substances, or liquids to the surfaces of solid bodies. Results in a relatively high concentration of gas or liquid on the surfaces.

Aeration— The process of adding air to a liquid, either by passing finely divided liquid through the air or by passing diffused air through a liquid.

Algae— Small plants, generally one-celled, which may give water a color, taste, odor, or turbidity when present in large numbers. They do not cause human disease but do affect the dissolved oxygen content of the body of water in which they exist.

Alternating device— Used in a sewage treatment plant to deliver sewage automatically or manually into different parallel treatment units according to a predetermined cycle.

Alum— Common name for aluminum sulfate, a chemical used for coagulation in purifying water and sewage.

Anaerobic— Able to live in absence of free oxygen.

Average flow— The amount of sewage that will be produced by an individual or facility during a given period of time. It is used as a criteria for design of the treatment works.

Backfill— The process of refilling an excavation, usually after some object has been placed in it. Also the material placed in such an excavation.

Bacteria—

Pathogenic— Bacteria causing disease.

Saprophytic— Bacteria living on dead organic matter.

Baffles— Wood, metal, or masonry deflectors that divert, guide, or agitate the flow of liquid.

Bell-and-spigot-joint— A joint made by inserting the small end (spigot) of one pipe into the flared end (bell) of another. Calking is tamped around the spigot in the bell to seal the joint.

Biochemical action— Chemical action from the activity of living organisms.

Biochemical oxygen demand— Quantity of oxygen required for biochemical oxidation in a given time at a given temperature, usually for 6 days at 20° C.

Bleach— Chloride of lime, an unstable material of indefinite composition. Term sometimes applied incorrectly to calcium hypochlorite.

Blowoff— A waste gate or valve for discharging tank content or emptying a depressed sewer.

Branch— Special forms of vitrified sewer tile and cast-iron pipe for connecting to a sewer or water main.

Capacity factor— A multiplier used with the authorized population to obtain the design population.

Catch basin— Chamber or well designed to keep grit and debris out of a sewer.

Centigrade— Temperature scale with 0° as the freezing point and 100° as the boiling point of water.

Centrifuge— A device which separates a mixture of solids and liquids by rapid rotation.

Cesspool— Pit into which sewage or other liquid waste is discharged and out of which the liquid seeps into surrounding soil.

Chamber— General term for a space inclosed by walls; a compartment. Often prefixed by a descriptive word, as *grit* or *screen* to indicate contents, or *discharge* or *flushing* in indicate purpose.

Diversion— Chamber containing a device for diverting all or part of the flow through it.

Flowing through— Upper story or compartment of a two-story sewage-sedimentation tank.

Screen— Chamber in a sewage treatment plant containing screens.

Settling— Sometimes used to designate the sedimentation compartment of two-story tank, as in the case of the Imhoff tank.

Sludge digestion— Any chamber used for the digestion of sludge; lower story of an Imhoff tank.

Chlorination— Treatment with chlorine or chlorine compounds to disinfect or oxidise matter or retard its decomposition.

Chlorinator— Device for adding dissolved chlorine to sewage.

Chlorine liquid— Chlorine gas which has been liquefied under pressure.

Clarification— Process of removing suspended and colloidal matter from a turbid liquid.

Coagulation— Flocculation of colloidal material.

Coefficient— Number used in a formula to express the relationship of variables such as temperature and pressure under the conditions to which a formula applies.

Coefficient of discharge— Coefficient applied to formulas for discharge of water over or through weirs, orifices, or other hydraulic measuring devices to modify the theoretical formula to fit actual test results.

Collecting system— A system of sewers and appurtenances for the collection and transportation of sewage.

Colloid— Any substance finely dispersed so it will not settle from a liquid but not soluble in the liquid. It can be precipitated by chemical treatment or by contact with solid surfaces.

Contact aerator— Aeration tank holding asbestos plates, broken stone, coke, brushwood, or other media through which the sewage flows.

Contamination— Introduction of pathogenic bacteria into water, making it unfit for human consumption.

Cradle— Support for pipe laid above the surface of the ground or in soft earth.

Cubic foot per second— The flow of 1 cubic foot of water past a given point in 1 second. Also termed second-foot.

Debris— Floating trash, suspended sediment or bed load moved by a stream.

Design population— The population obtained by multiplying the authorised military and tributary population by the proper capacity factor.

Detritus tank or chamber— Settling tank of short detention period, primarily for removing heavy settling solids. Detention chamber, larger than grit chamber, usually designed so sediment can be removed without interrupting sewage flow.

Diffuser— Porous plate or other device through which compressed air enters sewage.

Digestion— Biochemical decomposition of organic matter to form mineral and simpler organic compounds.

Dilution— Method of disposing of sewage or effluent by discharging into a stream or other body of water. Ratio of volume of flow of a stream to the volume of sewage or effluent discharged into it.

Discharge capacity— Maximum rate of flow of water passing through a conduit, channel, or other hydraulic structure.

Disinfection— Partial destruction, ordinarily by chemicals, of micro-organisms likely to cause disease.

Distributor— Used to apply sewage to the surface of a filter.

Fixed— Perforated pipes, notched troughs, slopping boards, or sprinkler nozzles.

Movable— Rotating or reciprocating perforated pipes or troughs that supply spray or a thin sheet of sewage.

Division box— Installed in a conduit to divide the flow equally or in various proportions to other channels.

Drying sludge— Process of reducing the moisture content of sludge by drainage or evaporation through exposure to air, application of heat, or other methods.

Effluent— Partly or completely treated sewage flowing out of a sewage treatment device.

Examination of water or sewage—

Bacterial— Examination of water to determine contamination which might affect the sanitary quality of the water; an examination to determine the effectiveness of previous treatment.

Chemical— Determining the character and composition of material in solution or suspension.

Microscopic— Determining the presence of microscopic organic growth which might be objectionable or harmful.

Physical— Determining physical characteristics such as temperature, turbidity, settleable solids, color, taste and odor.

Facultative bacteria— Bacteria that can live in the presence or absense of oxygen.

Filter—

Sand— Filter in which sand is the filtering medium.

Sprinkling— Trickling filter in which sewage is applied by spray.

Trickling— Filter having an artificial bed of coarse material over which sewage is distributed and through which it trickles to underdrains, permitting oxidation of organic matter by biochemical agencies.

Filtering media— Materials through which liquid applied to a filter must pees.

Filtration— Procees of passing a liquid through a porous medium to remove suspended and colloidal matter and oxidize the dissolved organic matter. Sometimes loosely applied to removal of solids and liquid organic matter by treatment beds.

Find-settling tank— Tank through which effluent of a trickling filter or other oxidizing device passes for removal of settleable solids.

Fines— Finer-grained particles of soil, sand, or gravel.

Floc— Small gelatinous particles suspended in sewage. They are formed from colloidal solids, bacterial masses, and precipitated chemicals.

Flocculation— Formation of floe either by biochemical action or slow stirring, with or without addition of chemicals.

Flow— Movement of water, silt, sand, or other mobile material. Quantity of water carried by a stream or pipe, expressed in terms of volume per unit of time. Stream of water that is moving or flowing.

Dry-weather— Flow in a sewer during dry weather. such flow consists entirely of sewage and wastes and does not include storm water. Flow of water in a stream during dry weather, usually entirely ground water.

Radial— Flow of liquid across a tank, either from the center to the periphery, or vice versa.

Flume— Open conduit of wood, masonry, or metal constructed on a uniform grade.

Flushing— Removing material deposited in a sewer or basin by washing out with a large flow of water or sewage.

Freeboard— Vertical distance from normal maximum level of liquid surface to the top of the channel or tank

Fungi— Small nonchlorophyll plants which may cause disagreeable tastes and odors in water when they decompose.

Gauge—

Differential— Device that measures difference in pressure between two points in a pipe or receptacle containing a liquid.

Float— Device for measuring elevation of the surface of a liquid. Actuating element is a buoyant float.

Hook— Pointed U-shaped hook, attached to a staff or vernier scale, used to measure elevation of water surface accurately.

Indicator—- Device that chows by a pointer the instantaneous value of such quantities as depth, pressure, velocity, stage, discharge, or movements and positions of water-controlling devices.

Pressure— Device for registering pressure of liquids or gases. It may be graduated in pounds per square inch or in equivalent feet of head.

Recording— Device that makes a continuous record, either graphical or in tabular form. Also called a *register.*

Staff— Graduated rod or board used to determine elevation of water surface in a stream channel, conduit, or tank.

Water level— Device indicating water level in a reservoir or other receptacle.

Gas Vent— Passage for escape of gases from decomposition. Opening in digestion chamber of Imhoff tank to allow liberated gas to escape without passing through sewage in the settling Chamber.

Grade— Elevation of the invert of a pipe line, canal, culvert, or sewer.

Hydraulic— Line joining the elevations to which water would rise in freely vented pipes from a closed conduit or water-bearing stratum under pressure. A line that coincides with the surface of the flowing water in an open channel flowing less than full and not under pressure.

Gravity system— System in which all sewage flows on descending grades from source; one requiring no pumping.

Grit chumber— A small detention chamber, or an enlargement of a sewer, designed to reduce sewage velocity enough to let the heaviest solid matter settle.

Head— Height of free surface of a body of water above a specified point.

Friction— Head or energy lost by water flowing in a stream or conduit because of disturbances set up by contact between moving water and its conduit and also because of intermolecular friction. Head losses from bends, expansions, obstructions, and impact are commonly included under this term.

Pressure— Head on any point in a conduit represented by the height of the hydraulic grade line above that point.

Static— Elevation of a motionless body of water above a specified point.

Total— Sum of static, friction, and velocity heads.

Velocity— Elevation required to impart a specified velocity to water. It is equal to the vertical distance a body must fall freely to acquire that velocity.

Weir— Vertical difference in elevation between the crest of a weir (apex of a triangular weir) and the water surface in the channel above the weir. It does not include the head corresponding to the velocity of approach, unless so specified.

Hydraulics— Science concerned primarily with the mechanics of fluids, especially water.

Hydraulic gradient— Surface slope of liquid in a sewer.

Hydrogen ion concentration (pH)— Index of the acidity or alkalinity of a liquid. The greater the hydrogen ion concentration, the greater the acidity of the liquid. A pH value of 7 is neutral; values below 7.0 are acid; values above 7.0 are alkaline. The pH value of a liquid is determined either by potentiometer measurement or by comparison with color standards after adding certain reagents. (A rough check can be quickly made with litmus paper.)

Imhoff tank— Deep two-story tank having an upper, continuous-sedimentation chamber and a lower, sludge-digestion chamber. The floor of the upper slopes steeply to trapped slots through which solids settle into the lower. The lower chamber does not receive fresh sewage directly but has gas vents and means of taking out digested sludge near the bottom.

Infiltration— Leaching of water from ground into a sewer.

Influent— Sewage, raw or partially treated, flowing into any sewage treatment device.

Inlet— Surface connection to a closed drain; structure at the diversion end of a conduit; upstream end of any structure through which water may flow; connection between surface of ground and sewer for admitting surface or storm water.

Intermittent filter— Natural or artificial bed of sand or other fine-grained material to which sewage is applied in doses. Sewage flowing through is filtered, and the organic matter is oxidized.

Invert— Refers to floor, bottom, or lowest point in the internal cross section of a sewer.

Irrigation—

Broad— Irrigation of crops with. sewage. Differs from *sewage* farming because sewage disposal is the primary object of broad irrigation with the raising of crops incidental.

Subsurface— Process of applying sewage to land by distributing it beneath the surface through open-jointed pipes or drains.

Surface— Process of distributing sewage over surface of ground.

Lamphole— Refers to pipe connecting to sewer with a wye or tee connection which permits inspection and flushing of the sewer by fire hose to clear it of heavy obstructions.

Leaching— Escape of water or sewage from a dry well or cesspool into surrounding permeable soil.

Manhole— Shaft into a sewer large enough to admit a man.

Drop— Manhole having an influent sewer from which sewage falls to a lower level.

End— Manhole at upstream end of a sewer.

Junction— Manhole at junction of two or more sewers.

Line— Manhole in sewer at place where no other sewers connect. It may be where the sewer changes direction either in line or grade.

Manhole cover—

Tight— Cover without openings.

Ventilated— Manhole cover with ventilation openings.

Manometer— U-shaped tube that contains a liquid. The surface of the liquid in one end of the tube moves up or down proportionally with increase or decrease in pressure on the liquid in the other end.

Micro-organism— Small living organisms which can be seen only under a microscope.

Nozzle— Short conical-shaped tube used as an outlet for a hose or pipe. Velocity of the emerging stream of water is increased because of the reduced cross-sectional area of the nozzle.

Sprinkler— Nozzle used to apply sewage as spray to a trickling filter.

Overflow— Device that discharges excess storm flow from a combined sewer.

Oxygen deficiency— Difference between the amount of oxygen in water and total amount of oxygen needed to satisfy the biochemical demand. Usually expressed in parts per million.

Parshall flume— Special flume used to measure water flow in open conduits.

Peak flow— The largest amount of sewage that will flow through the sewer at any given time. It is used as a criteria for the design of the sewer size.

Percolation— Flow or trickling of a liquid through a relatively coarse filtering medium. Liquid usually does not completely fill the pores of the medium.

Pipe—

Suction— Inlet of a pump through which water is lifted by suction from the water level to the pump.

Vitrified-clay— Clay pipe having glazed surface that makes it watertight. Principally used for sewage.

Pneumatic ejector— Compressed-air device for lifting liquids or sludge. Liquid passes through an inlet check valve into a chamber. When the chamber is full, a float opens the compressed-air valve. Compressed air ejects the liquid through the outlet check valve into a discharge pipe.

Pollution— Introduction into water of any substance (s) that make it objectionable to the senses of sight, taste, or smell.

Potable— Term describing clean, relatively pure water considered satisfactory for domestic consumption.

Precipitation— Term applied to rainfall or snowfall; the passing of a substance out of solution into solid form.

Chemical— Precipitation of a substance in solution, caused by adding chemicals. Accelerating sedimentation of sewage solids by adding chemicals that coagulate the suspended or colloidal matter. Process of softening hard water by adding lime or sodium carbonate.

Priming— Starting the flow in a pump or siphon.

Protozoa— One-celled animals, the lowest and simplest form of animal life. Some types found in water are similar to algae, which are plants.

Pump—

Air-chamber— Displacement pump with an air chamber in which air is alternately compressed and expanded by water which the pump displaces, resulting in a more even rate of discharge.

Centrifugal— Impeller pump having straight or curved vanes fixed radially on a shaft and inclosed in a casing. Water enters near the center of the vanes. Rotating velocity imparted to water is converted to pressure.

Impeller—Any pump that moves water by application of power from a mechanical agency or medium.

Reciprocating— Displacement pump with one or more closed cylinders. Each cylinder contains a piston or plunger that draws liquid into the cylinder through the inlet valve and forces it out through the outlet valve. When only one end of the cylinder acts on the liquid, the pump is *single acting;* when both ends act on the liquid, it is *double acting.*

Purification— Removal, by natural or artificial methods, of objectionable matter from water or sewage.

Degree of— Measure of how completely such impurities as bacteria and organic matter are destroyed or removed from sewage.

Self— Destruction of objectionable impurities from water or sewage by natural means.

Putrefaction— Decomposition of organic matter with ill-smelling products. Occurs under conditions of oxygen deficiency.

Putrescibility— Susceptibility of waste waters, sewage, effluent, or sludge to putrefaction. The relative tendency of organic matter to decompose in the absence of oxygen.

Rainfall— Amount of rain, usually expressed as depth in inches on a unit area, that reaches the surface of the earth.

Reagents— Substances which are added to a liquid to detect or measure the pH valve by means of the reaction (color) which they cause.

Relative stability— Ratio, expressed in percentage, of oxygen available to oxygen *required* for complete biochemical oxidation of organic matters in waste water, sewage, effluent or diluted sewage.

Reoxygenation— Recombine oxygen with a liquid, such as the liquid portion of sewage.

Riparian right— Common-law right of the owner of land abutting upon a natural body of water to use such water "undiminished in quantity and unaffected in quality." This right has been abrogated in a number of western States and greatly modified in others. In general, each riparian owner may make reasonable use of water, extent of use being governed by reason. able requirements of other riparian owners and by quantity of water available.

Sanitary survey— A study of the environmental conditions of a water source that might affect its use for domestic consumption.

Saturation— Condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Saturation deficit— Difference, expressed in percentage, between the amount of dissolved oxygen in a stream and the amount needed to produce oxygen saturation under given conditions.

Screen— Device used to retain coarse sewage solids. The screening element may consist of grating, wire mesh, perforated plate, or parallel bars, rods, or wires. Screen openings may have any shape, usually circular or rectangular slots.

Bar— Screen having parallel bars or rods. placed over an opening to prevent entrance of large solids.

Coarse— Screen least dimension whose openings are usually larger than 1 inch.

Fine— Screen whose least dimension openings are 1/4 inch or less.

Screening— Process of removing, by racks or screens, the relatively coarse and suspended solids in water, sewage, and racks.

Screenings— Material removed from sewage by screens and racks.

Scum— Sewage solids floating at the surface buoyed up by entrained gas, grease, or other substance.

Second-foot (cfs)— Term used to express rate of flow of water. Equals 1 cubic foot per second.

Sediment— Any material carried in suspension by water which settles to bottom when water loses motion.

Sedimentation— Settling of suspended matter in a liquid by gravity.

Sedimentation tank— Tank or basin in which sewage is retained until suspended matter settles.

Separate system— System of sewers in which sew. age and storm water are carried in separate conduits.

Septic tank— Settling tank that retains the sludge in immediate contact with the sewage that flows through the tank. Sludge is retained long enough to secure satisfactory decomposition of organic solids by anaerobic bacterial action.

Settleable solids— Suspended solids which settle in quiescent sewage within a reasonable period.

Settling— See sedimentation.

Settling chamber— Sometimes used to designate the sedimentation compartment of a two-story tank, as in the case of the Imhoff tank. (See *sedimentation tank.*)

Sewage— Wash water and water-carried animal, culinary, and industrial wastes. Liquid waste containing human excreta and other matter flowing in or from a house drainage system or sewer, excreta including. feces, urine, secretions from the skin, and expectoration. Liquid wastes from institutions, stables, and business buildings. Combination of liquid wastes with such ground, surface, and storm water as may enter the sewers.

Dilute— Sewage containing a relatively small quantity of organic matter.

Domestic— Sewage derived principally from dwellings, business buildings, institutions, and like sources. It may or may not contain ground water, surface water or storm water, and may contain a small proportion of industrial wastes. Somewhat more general term than sanitary sewage.

Filtered— Effluent of a sewage filter.

Fresh— Sewage of recent origin which still contains dissolved oxygen.

Industrial sewage— Sewage from industrial processes.

Sanitary— Sewage from the sanitary conveniences of a dwelling, business building, factory, or institution. The water supply of a community after it has been used and discharged into a sewer.

Septic— Sewage undergoing putrefaction in the absence of oxygen.

Settled— Sewage from which some of the solids have settled out in a tank.

Stale— Sewage containing little or no oxygen but free from putrefaction.

Storm— Liquid flowing in combined or storm sewers as a result of rainfall.

Strong— Sewage containing organic matter in excess of the normal quantity.

Treated— Sewage that has received more or less complete treatment.

Sewage disposal— Riddance of sewage by any method.

Sewage treatment— Any artificial process for removing or altering the objectionable constituents of sewage and rendering it less offensive or dangerous.

Sewage treatment works— Treatment plant and means of disposal of sewage.

Sewer— Pipe or conduit, generally closed but not normally flowing full, for carrying sewage and other waste liquids.

Branch— Sewer receiving sewage from a relatively small area (usually from two or more laterals).

Building— Pipe conveying sewage from a single building to a common sewer or point of immediate disposal.

Combined— Used to carry domestic, sanitary sewage, or industrial waste, and storm sewage.

Depressed— Sewer that usually crosses beneath a valley or water course. It runs full at greater than atmospheric pressure because its profile is below the hydraulic grade line. Commonly called *inverted siphon*.

Force main— A sewer in which the sewage is under pressure.

House connection— The pipe carrying sewage from the building to a common sewer. Also called a Building Sewer or House Sewer.

Intercepting— Sewer cutting transversely a number of other sewers to intercept the flow.

Lateral— Sewer that discharges into a branch or other sewer and has no other common sewer tributary to it.

Main— Sewer receiving the discharge of many tributary branches. Also called trunk sewer.

Outfall— Sewer that receives sewage from the treatment plant or collection system and conducts it to the point of final discharge or disposition.

Relief— Sewer installed to relieve an existing sewer of inadequate capacity.

Sanitary— Sewer that carries sanitary sewage and excludes as far as possible the storm sewage, surface water, and ground water. Usually used to carry industrial wastes from the area served.

Storm-overflow— Sewer used to carry excess of storm flow from a main or intercepting sewer to an independent outlet.

Sewerage system— Collecting system of sewers and appurtenances.

Sewerage works— Term applied to facilities for collecting, treating, and disposing of sewage.

Silt— Fine particles of earth, sand, or soil carried in suspension by flowing water. The term sometimes includes material rolled along the bed of the stream.

Siphon— Inverted U-shaped tube, one end longer than the other, used to transfer liquids from a higher to a lower level over an intermediate elevation.

Inverted— See *depressed sewer.*

Sleek— Thin oily film on the surface of water.

Sludge— A semiliquid mass formed by mixing water with solids. Sewage suspended solids that have settled out in tanks or basins.

Conditioning— Chemical treatment of liquid sludge before dewatering.

Humus— sludge deposited in final or secondary-settling tanks after' sewage has passed through a trickling filter or other oxidizing device. Sludge that resembles humus in appearance.

Liquid— Sludge containing enough water, usually more than 80 percent, to permit it to flow by gravity.

Spadable— Sludge dry enough, usually under 70 percent moisture, to be shoveled from the drying bed.

Sludge bed— Natural or artificial layers of porous material upon which sludge is dried by drainage or evaporation.

Sludge cake— Mass resulting from sludge pressing or vacuum filtering.

Sludge concentration— Process of reducing water content of sludge, leaving it still a liquid.

Sludge dewatering— General term for removing part of the water in sludge, with or without heat, by draining, pressing, centrifuging, exhausting, passing between rollers, or acid flotation. The process involves reducing sludge from liquid to spadable sludge.

Sludge drying— Process of drying sludge by drainage, evaporation, exposure to air, or application of heat.

Specific gravity— Ratio of the weight of a unit volume of any substance to an equal volume of water under standard conditions.

Spiral-flow tank— Tank used in the activated sludge process. Sewage is given a spiral motion in its flow through the tank by introducing air through a line of diffusers located at one side near the bottom.

Stability— Ability of sewage, effluent, or digested sludge to resist putrefaction.

Sterilization— Destruction of all micro-organisms by heat or chemical action.

Stilling well— Pipe, chamber, or compartment with closed sides and bottom, used to check pulsations or surges while permitting the water level to rise and fall with the major fluctuations of the main body of water.

Storm water— That portion of the rainfall which runs off the surface during and immediately after a storm.

Stream— Body of water flowing in a natural surface channel. Body of water flowing in an open or closed conduit. Jet of water issuing from an opening such as a nozzle or a fissure in rock.

Discharge— Rate of flow of water, usually expressed as cubic feet per second.

Gauging— Measuring velocity of a stream of water.

Suspended matter— Solids physically suspended in sewage.

Tank— Any artificial receptacle through which liquids pass or in which they are held.

Dortmund— Vertical-flow sedimentation tank with a hopper bottom. Sewage enters near the bottom, rises and overflows at the surface, and the sludge is removed from the bottom.

Dosing— Tank used to accumulate raw or partially treated sewage for discharge to contact beds or filters. The discharge is regulated for correct distribution essential to subsequent treatment.

Horizontal-flow— Tank or basin, with or without baffles, in which the direction of flow is generally horizontal.

Imhoff— See *Imhoff tank.*

Multiple dosing— Two or more dosing tanks of equal capacity. Each is equipped with a dosing device, interconnected to fill and discharge tanks alternately or in rotation. Two tanks, so arranged, are called twin dosing tanks.

Settling— See sedimentation tank.

Skimming— Chamber arranged to floating matter rises and remains on the surface until removed. The liquid flows out continuously under partitions, curtain walls, or scum boards.

Trap— Device used to prevent liquid from reversing its direction of flow in a conduit or from passing a given point. Device preventing sewer air or gases from backing up and escaping through a plumbing fixture.

Grease— Device by which grease in sewage is held at the surface of a basin so it can be skimmed off.

Tributary— Stream or other body of water, surface or underground, that contributes its water to another and larger stream or body of water.

Turbidity— Condition of water when it contains visible material in suspension. Such material does not have to be large enough to be seen as individual particles by the naked eye, but the cloudiness in the water must be caused by material in suspension, not in solution.

Turbulence— State of flow of water in which the water is agitated by "cross currents and eddies. Opposed to quiet or quiescent flow.

Vacuum— Condition existing when the pressure in closed space is much lower than the surrounding atmospheric pressure. Strictly speaking, the term applies to a condition within an inclosed space from which all air, gas, vapor, or other substance has been exhausted. In general use, the term is applied to any space where less than atmospheric pressure exists.

Valve— Device installed in a pipe line for controlling the magnitude and direction of flow.

Air— Valve that either releases air from a pipe line automatically without loss of water or introduces air into a line automatically if the internal pressure becomes less than atmospheric pressure.

Automatic— Valve that opens or closes when predetermined conditions are reached.

Check— Valve that prevents reversal in direction of flow.

Flap— Valve that opens and shuts by rotating around hinge on-one edge.

Foot— Valve in the bottom of the pump suction pipe. It opens to let water enter the suction pipe, but closes to prevent water from passing out at the bottom.

Gate— Valve with flat disk that slides over the opening through which water passes and fits tightly against it.

Needle— Valve with circular outlet through which flow is controlled by a tapered needle extending through the outlet. Needle reduces outlet area as it is advanced and enlarges area as it is withdrawn.

Pump— Opening through which water enters and leaves cylinders of a displacement pump.

Rotary— Valve having approximately a cylindrical-shaped casing with an opening of same diameter as the pipe line. When the interior gate, which turns through a 90° angle, is opened fully, liquid flows through valve without construction or appreciable resistance.

Safety— Valve that automatically opens when predetermined conditions, usually of pressure, are exceeded in a pipe line or other closed receptacle containing liquids or gases. It prevents damage that might occur if conditions exceeded safe limitations.

Velocity—

Approach— Average velocity of water flowing in a channel of approach to a weir or tank inlet.

Mean— Average velocity of a stream flowing in a channel or conduit at a given cross section. It equals the discharge divided by the cross-sectional area of the section.

Ventui meter— Device for measuring flow of liquid through closed conduits or pipes. It consists of a Venturi tube and a flow-registering device.

Water-borne disease— Disease caused by organisms carried in water. The most common water-borne diseases are typhoid fever, Asiatic cholera, dysentery, and other intestinal diseases. Also, anthrax germs and some parasitic worms can be carried by water.

Weir—

Contructed— A weir with its crest extending only part way across the channel. The crest is terminated by partitions in the same plane as the crest which rise above the water level on the upstream side of the weir and produce a contraction in the width of the stream of water as it leaves the notch.

Free— Weir that is not submerged. Either the tail water is below the weir crest or the flow is not affected by tail water.

Measuring— Device to measure rate of flow of water. It generally consists of a rectangular, trapezoidal, triangular, or other notch in a thin vertical plate. The water flows through the notch, and its depth of overflow (head) is an index of the rate of flow.

Parabolic— Measuring weir with a notch shaped as a vertical parabola designed so the discharge of the weir is directly proportional to the head.

Rectangular— Measuring weir with a rectangular notch.

Submerged— Weir placed in a stream so the downstream water level is equal to or higher than the weir crest.

Suppressed— Weir with one or both sides or bottom flush with the channel of approach. This prevents contradiction of the nappe (sheet of water above the weir crest) adjacent to the flush side or bottom. Suppression may be on one end, both ends, bottom, or any combination.

Triangular— Measuring weir with a triangular notch. Usually used to measure small flows. Also called V *-notch* weir.

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