CHAPTER 13
ACTIVATED SLUDGE PLANTS

13-1. General considerations.

The activated sludge process has been employed extensively throughout the world in its conventional form and modified forms, all of which are capable of meeting secondary treatment effluent limits. This chapter presents the different modifications of the conventional activated sludge process, including general bases for design, methods of aeration, and design factors for aeration tanks, final sedimentation units and sludge handling systems. Figures 13-1 through 13-4 are schematic diagrams of the conventional and modified processes. The characteristics and obtainable removal efficiencies for these processes are listed in table 3-3. All designed processes will include preliminary treatment consisting of bar screen as a minimum and, as needed, comminutor, grit chamber, and oil and grease removal units. (See Winkler, 1981; Metcalf and Eddy, 1972.)

13-2. Activated sludge processes.

a. Conventional activated sludge. In a conventional (plug-flow) activated sludge plant (fig 13-1), the primary-treated wastewater and acclimated micro-organisms (activated sludge or biomass) are aerated in a basin or tank. After a sufficient aeration period, the flocculent activated sludge solids are separated from the wastewater in a secondary clarifier. The clarified wastewater flows forward for further treatment or discharge. A portion of the clarifier underflow sludge is returned to the aeration basin for mixing with the primary- treated influent to the basin and the remaining sludge is wasted to the sludge handling portion of the treatment plant (chap 16). The portion recirculated is determined on the basis of the ratio of mixed liquor volatile suspended solids (MLVSS) to influent wastewater biochemical oxygen demand which will produce the maximum removal of organic material from the wastewater. Recirculation varies from 25 to 50 percent of the raw wastewater flow, depending on treatment conditions and wastewater characteristics.

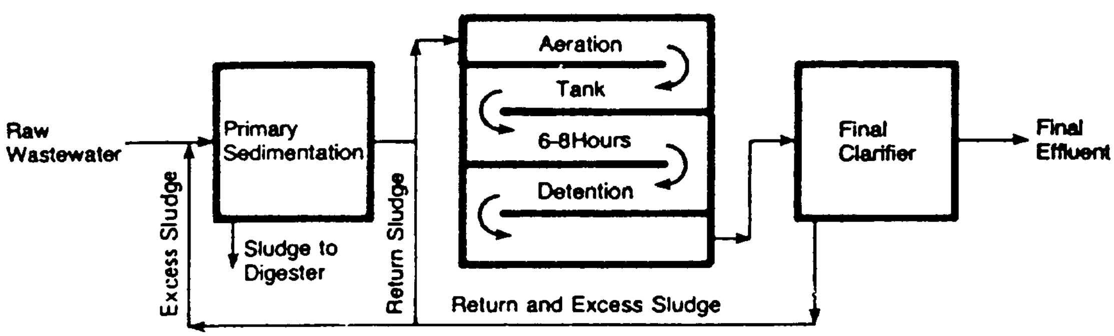

Figure 13–1. Conventional plug flow activated sludge flow diagram.

b. Step aeration. In this process (fig 13-2), the influent wastewater is introduced at various points along the length of the aeration tank. Sludge return varies between 25 and 50 percent. Aeration or the oxygen requirement during step aeration (3 to 7 hours) is about half that required for the conventional process. This results from a more effective biomass utilization in the aeration basin, allowing organic loadings of 30 to 50 pounds biochemical oxygen demand per 1,000 cubic feet per day as compared to loadings of 30 to 40 pounds biochemical oxygen demand per 1,000 cubic feet per day permitted for conventional systems.

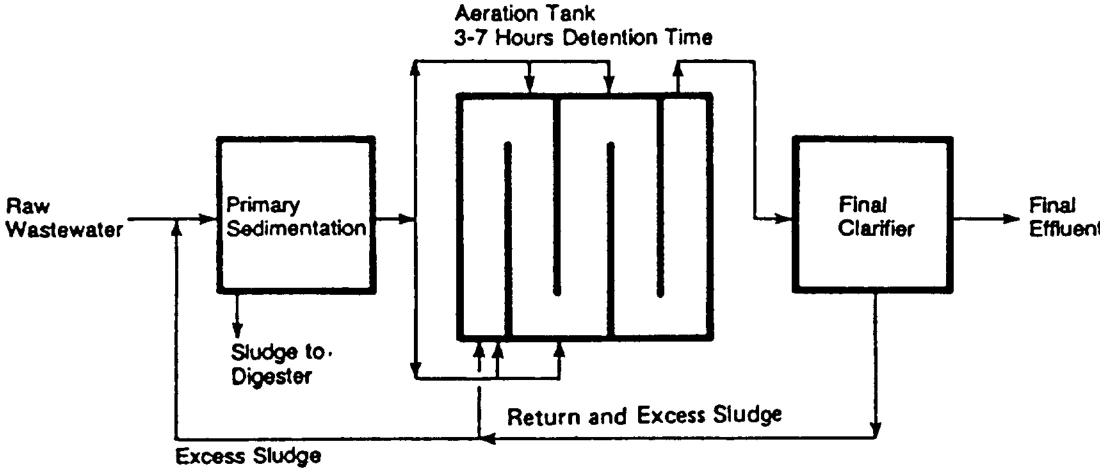

Figure 13–2. Step aeration flow diagram.

c. Contact stabilization. The contact stabilization activated sludge process (fig 13-3) is characterized by a two-step aeration system. Aeration of short duration (½ to 2 hours) is provided in the contact tank where raw or primary-settled wastewater is mixed with the activated sludge in the contact tank. The effluent from the contact tank is then settled in a final settling tank. The settled activated sludge to be recycled from the final clarifier is drawn to a separate re-aeration in a stabilization basin for 3 to 8 hours of aeration time. It is then returned to the contact aeration basin for mixing with the incoming raw wastewater or primary-settled effluent. In addition to a shorter wastewater aeration time, the contact stabilization process has the advantage of being able to handle greater shock and toxic loadings than conventional systems because of the buffering capacity of the biomass in the stabilization tank. During these times of abnormal loadings, most of the activated sludge is isolated from the main stream of the plant flow. Contact stabilization plants will not be used where daily variations in hydraulic or organic loadings routinely exceed a ratio of 3:1 on consecutive days or for plants with average flows less than 0.1 million gallons per day without prior approval of HQDA (CEEC-EB) WASH DC 20314-1000 for Army projects and HQ USAF/LEEE WASH DC 20332 for Air Force projects.

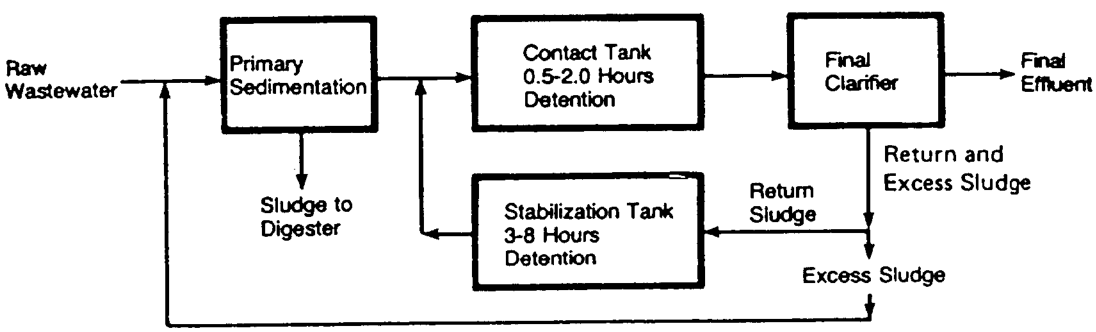

Figure 13–3. Contact stabilization flow diagram.

d. Completely-mixed activated sludge. In the completely-mixed process (fig 13-4), influent wastewater and the recycled sludge are introduced uniformly through the aeration tank. This allows for uniform oxygen demand throughout the aeration tank and adds operational stability when treating shock loads. Aeration time ranges between 3 and 6 hours. Recirculation ratios in a completely-mixed system will range from 50 to 150 percent.

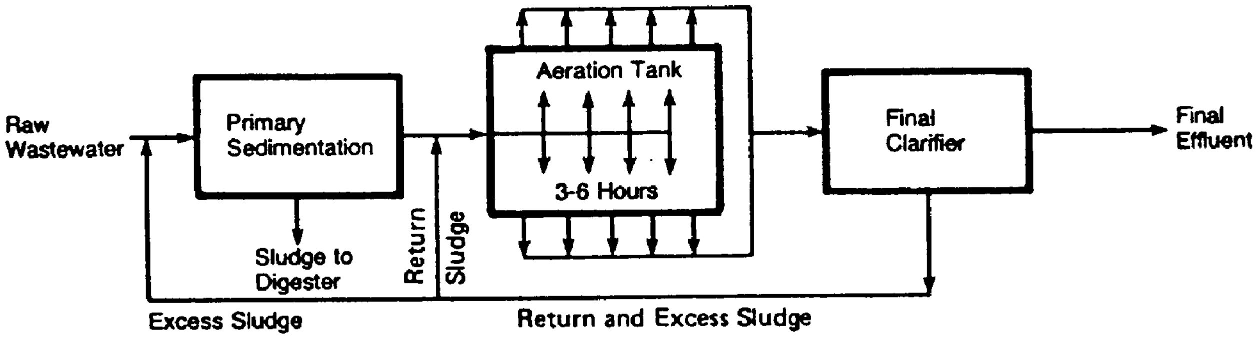

Figure 13–4. Completely–mixed process flow diagram.

e. Extended aeration. Extended aeration activated sludge plants are designed to provide a 24-hour aeration period for low organic loadings of less than 20 pounds biochemical oxygen demand per 1,000 cubic feet of aeration tank volume. This approach, which can be used for treatment plants of less than 0.1 million gallons per day capacity, reduces the amount of sludge being wasted for disposal.

f. Oxidation ditch. The closed-loop reactor, also known as an oxidation ditch (fig 15-5), is a form of the extended aeration process. The wastewater is propelled around an oval racetrack-configured basin by mechanical aerator/mixing devices located at one or more points along the basin. These devices can be either brush aerators, surface aerators or jet aerators. The velocity in the basin is designed to be between 0.8 and 1.2 feet per second. The closed-loop reactor is the preferred type of activated sludge system for Army installations. The design or provision of any other system for Army installations requires prior approval from HQDA (CEEC-EB) WASH DC 20314-1000. Appendix C contains a sample design calculation.

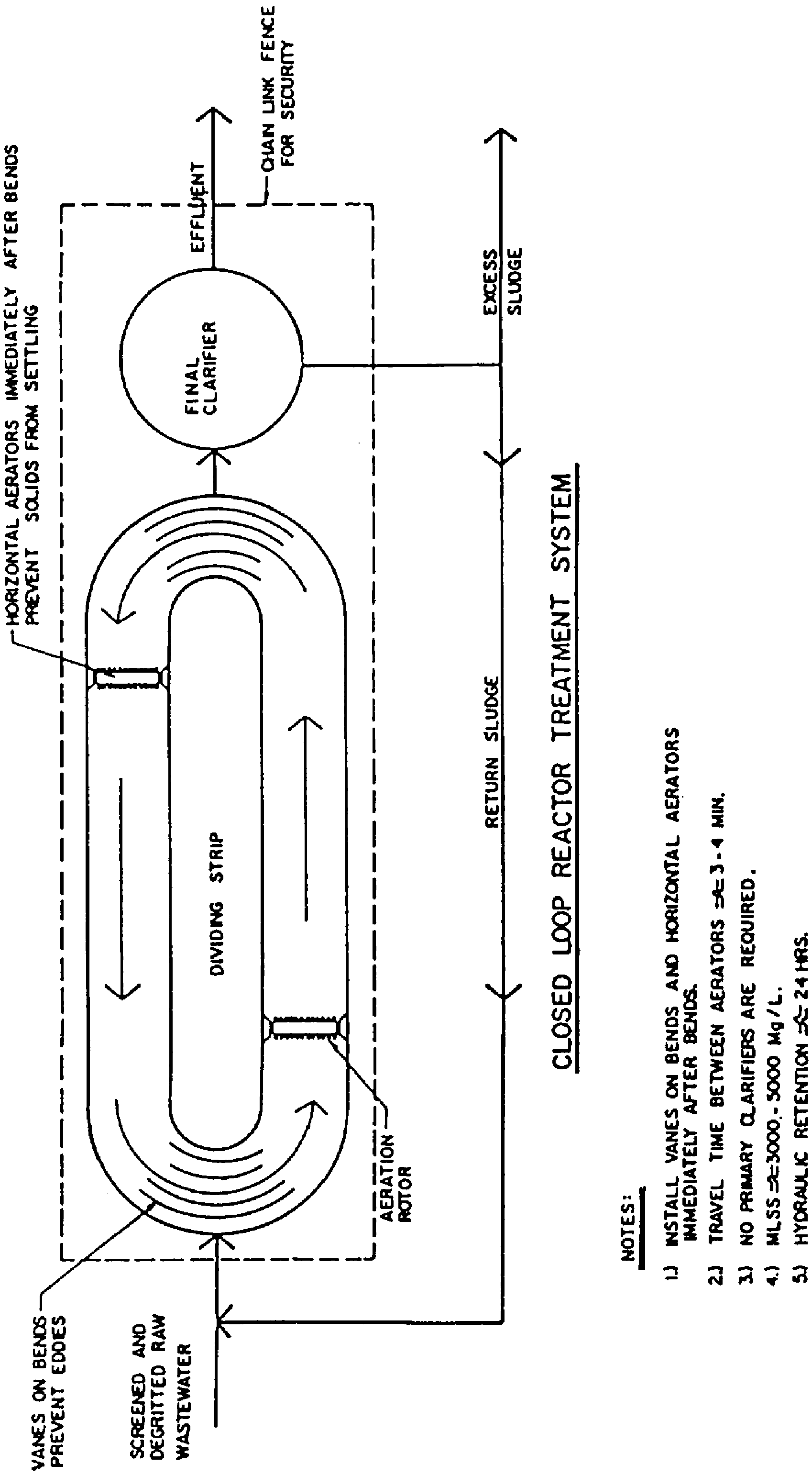

Figure 13–5. Closed–loop reactor treatment system

13-3. Closed-loop reactor design criteria.

a. General. Table 13-1 presents the design criteria to be used for the design of a closed-loop reactor plant.

Table 13-1. Closed–loop reactor design criteria.

Parameter	Value
Primary clarifier	None required
Hydraulic retention time	18–24 hrs
Sludge retention time	20–30 days
Secondary clarifier	
Overflow rate	450 gpd/sq ft
Solids loading rate	15 lb/sq ft/day

b. Aeration tank design. All oxidation ditch plants use looped channels or ditches. A looped channel with a partition in the middle may be shaped like an oval or a concentric ring. The design engineer may adopt a specific channel configuration and flow scheme recommended by the equipment manufacturer or supplier.

(1) **Channel depth**. The number of loops and the channel depth are dependent upon the size of the plant. A shallow channel, less than 14 feet deep, is used for smaller plants with unlimited land area available. A deep channel, greater than 20 feet, should be designed for larger plants or to conserve heat.

(2) **Number of channels**. Multiple-channel or multiple-loop is the preferable design so that part of the plant can be shut down for repair and maintenance.

(3) **Drainage**. A drain should be provided for each channel. This provision allows mixed liquor or accumulated grit material to be drained from the channel without expensive pumping. Many oxidation ditch plants do not have drains in their channels and are having maintenance problems.

(4) **Channel lining.** Deep channels are to be built exclusively with reinforced concrete. A concrete liner can be placed against the earth backing in shallow channels by pouring concrete or gunite (shotcrete) to a thickness of 3 to 4 inches. The concrete or gunite should provide a minimum compressive strength of 3,000 pounds per square inch in 28 days.

c. Aeration. Depending on the width and depth of the channel, various types of aerators can meet the oxygenation and mixing requirements.

(1) **Rotor aerator**. A rotor aerator is a horizontal shaft with protruding blades which rotates, thereby transferring oxygen into the wastewater and propelling it around the ditch. Figure 13-6 illustrates a typical horizontal-shaft aerator. The minimum length of shaft is 3 feet; the maximum length of shaft is 30 feet. This type of aerator is suitable for shallow channels.

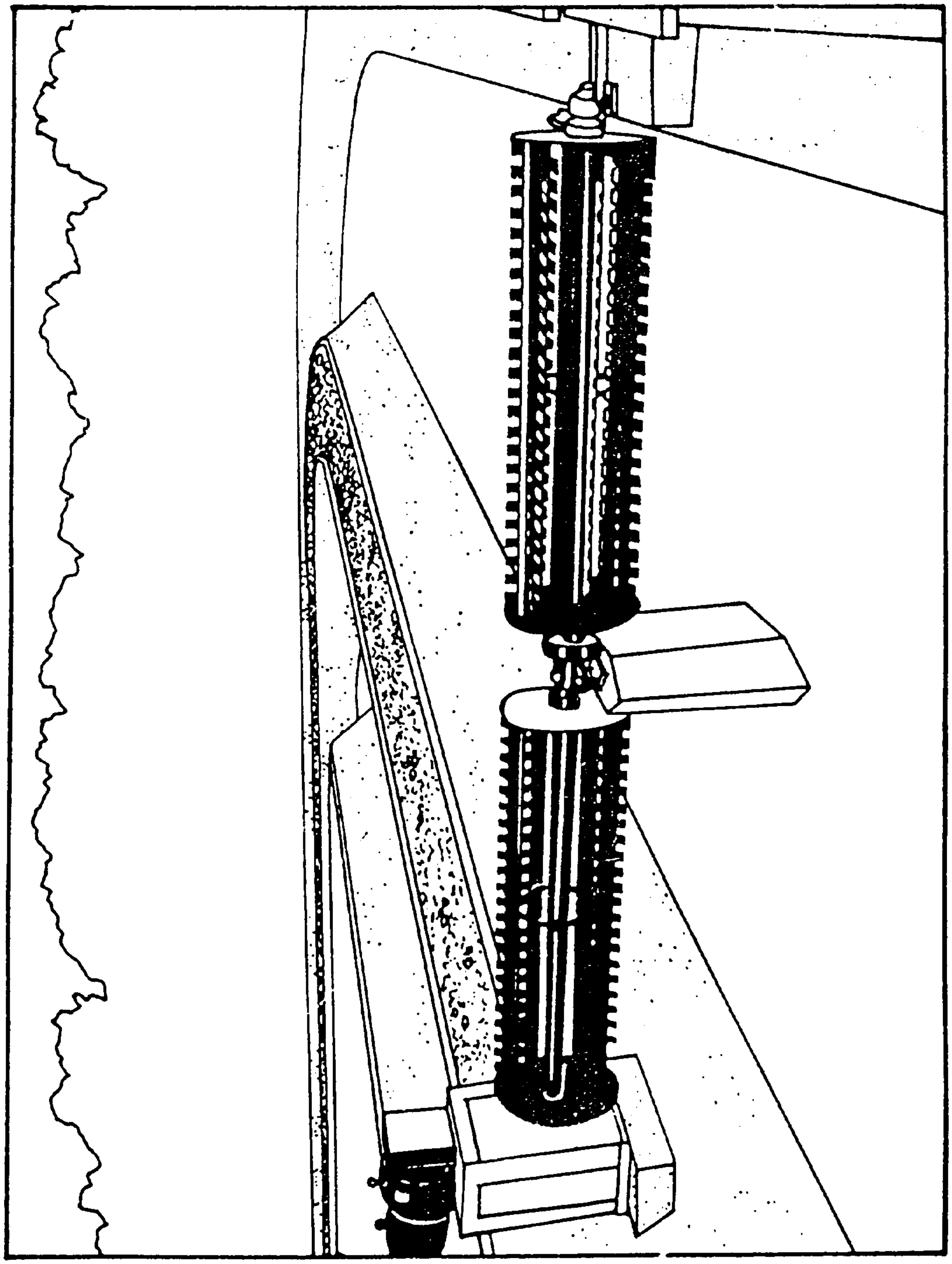

Figure 13–6. Horizontal–shaft aerator.

(2) **Induction aerator**. This type of aerator, which is available in various sizes, draws the mixed liquor and air down a U-tube and discharges it for a distance downstream in the channel. Compressed air at low pressure can be injected near the top of the down-draft tube to enhance oxygenation. A bulkhead (which should be partially opened at the bottom) is required to separate the channel to maintain the flow circulation. This type of aerator is suitable for shallow to moderately deep channels.

(3) **Jet aeration**. Jet aeration is specifically designed for deep channels. Both air and the mixed liquor are pressurized (by aspirator pumping) into a mixing chamber from where the mixture is discharged as a jet stream into the surrounding channel liquid. Deep channels are used to take advantage of better oxygen transfer. Figure 13-7 illustrates a jet aerator, among various other types of aerators.

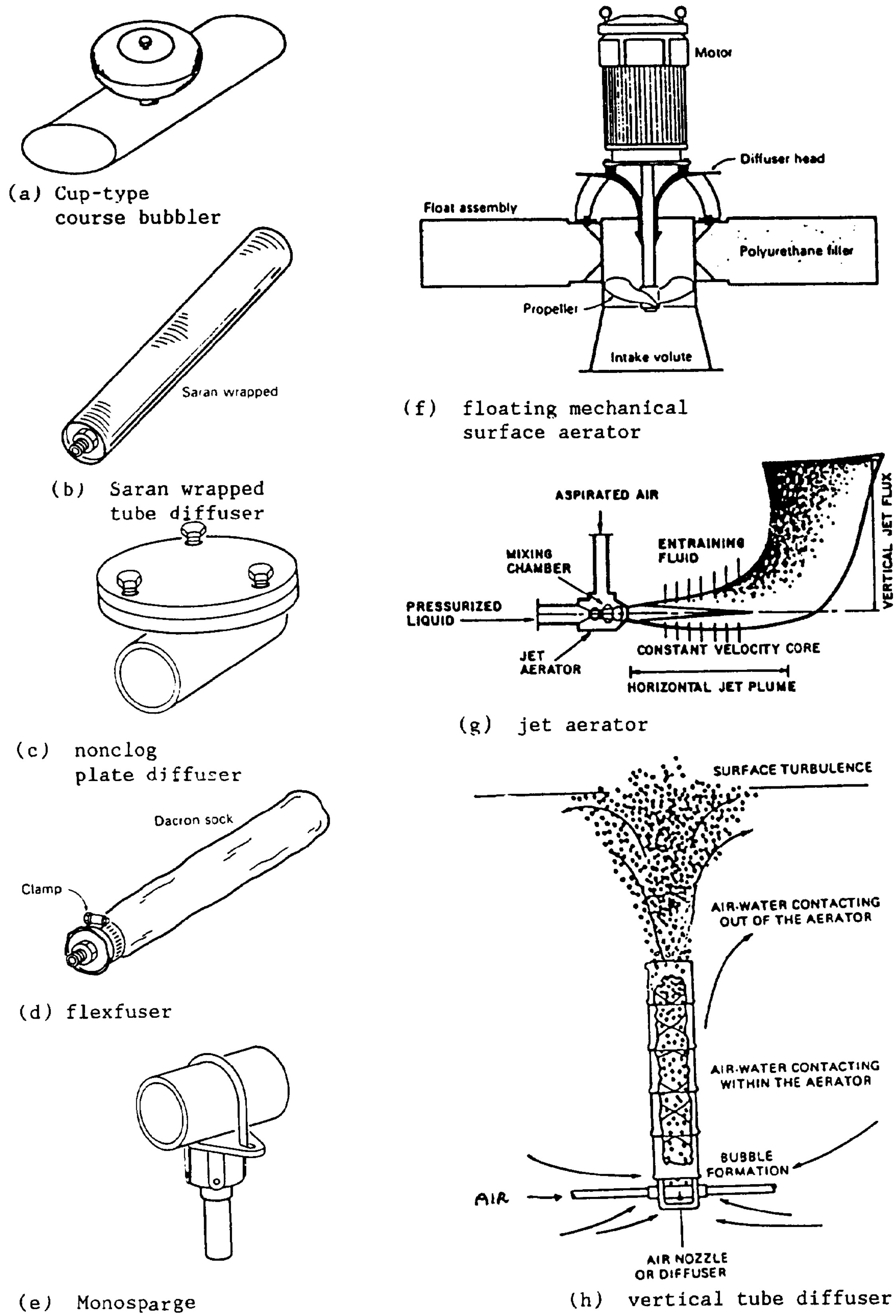

Figure 13-7. Aerators.

(4) **Diffused aeration plus slow mixer**. This type of aeration is more suitable for deep channels. Air bubbles are introduced into the mixed liquor through a pipe grid system with diffusers to provide oxygenation while a slow propeller mixer provides the flow circulation and mixing.

(5) **Aerator sizing.** Aerators should be sized to provide adequate mixing and oxygenation. However, the same size rotor provides different levels of mixing and oxygenation depending on the degree of its submergence. First, the oxygen requirement must be calculated for a level that will satisfy the carbonaceous biochemical oxygen demand removal as well as nitrification-denitrification (if needed). Oxidation ditch equipment manufacturers provide tables or charts for selecting the aerator size for any given speed and submergence (immersion) based on the calculated oxygen requirement. The aerator size should also be checked against the mixing requirement set by the manufacturers. Preferably, more than one aerator should be used per channel; they should be placed at different locations so that if one breaks down, the channel will still function. The procedure for selecting the jet aerator size is similar except there is no submergence factor. The sizing of the induction aerator and the diffused air plus slow mixer units is not precise. Design data for these new aeration systems are not yet available. One reason for this is that the amount of energy required for mixing relative to the energy required for oxygenation is uncertain since it depends a great deal on the channel geometry, which varies among plants. More testing data must be collected before a design criterion can be established.

d. Sludge dewatering and disposal. Sludge from oxidation ditch plants operating in the extended aeration mode (sludge retention time of 20 to 30 days) can be wasted directly to open drying beds. It can also be wasted directly to tank trucks which spread the liquid sludge on the plant grounds or on adjacent land. The degree of sludge stabilization in the oxidation ditch is equivalent to that of a conventional activated sludge plant operated at a 10-day sludge retention time followed by aerobic digestion of the sludge for 7 to 15 days. In most climates, 1.0 square foot of drying bed surface area per population equivalent (0.17 pound biochemical oxygen demand per capita per day) should be used. This capacity can accept 2.2 cubic feet of wasted sludge per 100 capita per day, which is typical for domestic wastewater treatment. Double units of drying beds should be used so that half of them can be taken out of service for maintenance.

e. Cold climate. In moderately cold areas, ice buildup on clarifier scum collection boxes can cause problems and eventually jam the skimmer mechanisms. Therefore, final clarifiers should be covered. In cold areas, the spray from surface aerators will freeze on adjacent structures, bearings, gear reducers, etc., making maintenance difficult. Drive components and walkways near the aerators should be covered to shield them from spray, or mounted in isolated compartments. In very cold areas, heated covers for surface aerators should be provided. Ice fences should be installed across the channel upstream of brush-type aerators to prevent chunks of ice from breaking the brushes.