CHAPTER 70
SETTLING

71. GENERAL

71.1 Number of Units

Multiple units capable of independent operation are desirable and shall be provided in all plants where design average flows exceed 100,000 gallons/day (379 m^3/d). Plants not having multiple units shall include other provisions to assure continuity of treatment.

71.2 Flow Distribution

Effective flow splitting devices and control appurtenances (i.e. gates, splitter boxes, etc.) shall be provided to permit proper proportioning of flow and solids loading to each unit, throughout the expected range of flows.

72. DESIGN CONSIDERATIONS

72.1 Dimensions

The minimum length of flow from inlet to outlet shall be 10 feet (3 m) unless special provisions are made to prevent short circuiting. The vertical side water depths shall be designed to provide an adequate separation zone between the sludge blanket and the overflow weirs. The side water depths shall not be less than the following values:

Type of Settling Tank	Minimum Side Water Depth ft	(m)
Primary	10	3.0
Secondary tank following activated sludge process*	12	3.7
Secondary tank following fixed film reactor	10	3.0

* Greater side water depths are recommended for secondary clarifiers in excess of 4,000 square feet (372 m^2) surface area (equivalent to 70 feet (21 m) diameter) and for nitrification plants. Less than 12 feet (3.7 m) side water depths may be permitted for package plants with a design average flow less than 25,000 gallons per day (95 m^3/d), if justified based on successful operating experience.

72.2 Surface Overflow Rates

72.21 Primary Settling Tanks

Primary settling tank sizing should reflect the degree of solids removal needed and the need to avoid septic conditions during low flow periods. Sizing shall be calculated for both design average and design peak hourly flow conditions, and the larger surface area determined shall be used. The following surface overflow rates should not be exceeded in the design:

Type of Primary Settling Tank	Surface Overflow Rates at: *	
	Design Average Flow gpd/ft² (m³/m²d)	Design Peak Hourly Flow gpd/ft² (m³/m²d)
Tanks not receiving waste activated sludge **	1,000 (41)	1,500 - 3,000 (60-120)
Tanks receiving waste activated sludge		1200 (49)

* Surface overflow rates shall be calculated with all flows received at the settling tanks. Primary settling of normal domestic wastewater can be expected to remove approximately 1/3 of the influent BOD when operating at an overflow rate of 1000 gallons per day/ft² (41 m³/m²d).

** Anticipated BOD removal should be determined by laboratory tests and consideration of the character of the wastes. Significant reduction in BOD removal efficiency will result when the peak hourly overflow rate exceeds 1500 gallons per day/ft² (61 m³/m²d).

72.22 Intermediate Settling Tanks

Surface overflow rates for intermediate settling tanks following series units of fixed film reactor processes shall not exceed 1,500 gallons per day per square foot (61 m³/m²d) based on design peak hourly flow.

72.23 Final Settling Tanks

Settling tests shall be conducted wherever a pilot study of biological treatment is warranted by unusual waste characteristics, treatment requirements, or where proposed loadings go beyond the limits set forth in this Section.

72.231 Final Settling Tanks - Fixed Film Biological Reactors

Surface overflow rates for settling tanks following trickling filters shall not exceed 1,200 gallons per day per square foot (49 m³/m²d) based on design peak hourly flow.

72.232 Final Settling Tanks - Activated Sludge

To perform properly while producing a concentrated return flow, activated sludge settling tanks must be designed to meet thickening as well as solids separation requirements. Since the rate of recirculation of return sludge from the final settling tanks to the aeration or reaeration tanks is quite high in activated sludge processes, surface overflow rate and weir overflow rate should be adjusted for the various processes to minimize the problems with sludge loadings, density currents, inlet hydraulic turbulence, and occasional poor sludge settleability. The size of the settling tank must be based on the larger surface area determined for surface overflow rate and solids loading rate. The following design criteria shall be used:

Treatment Process	Surface Overflow Rate at Design Peak Hourly Flow* gpd/ft^2 (m^3/m^{2}d)	Peak Solids Loading Rate*** lb/day/ft^2 (kg/d/m^2)
Conventional, Step Aeration, Complete Mix, Contact Stabilization, Carbonaceous Stage of Separate Stage Nitrification	1,200** (49)	50 (245)
Extended Aeration Single Stage Nitrification	1,000 (41)	35 (171)
2 Stage Nitrification	800 (33)	35 (171)
Activated Sludge with Chemical addition to Mixed Liquor for Phosphorus Removal	900**** (37)	As Above

* Based on influent flow only.

** Plants needing to meet 20 mg/l suspended solids should reduce surface overflow rate to 1,000 gallons per day per square foot (41 m^3/m^{2}d).

*** Clarifier peak solids loading rate shall be computed based on the design maximum day flow rate plus the design maximum return sludge rate requirement and the design MLSS under aeration.

**** When phosphorus removal to a concentration of less than 1.0 mg/l is required.

72.3 Inlet Structures

Inlets shall be designed to dissipate the inlet velocity, to distribute the flow equally both horizontally and vertically and to prevent short circuiting. Channels shall be designed to maintain a velocity of at least one foot per second (0.3 m/s) at one-half of the design average flow. Corner pockets and dead ends shall be eliminated and corner fillets or channeling shall be used where necessary. Provisions shall be made for elimination or removal of floating materials in inlet structures.

72.4 Weirs

72.41 General

Overflow weirs shall be readily adjustable over the life of the structure to correct for differential settlement of the tank.

72.42 Location

Overflow weirs shall be located to optimize actual hydraulic detention time, and minimize short circuiting. Peripheral weirs shall be placed at least one foot from the wall.

72.43 Design Rates

Weir loadings shall not exceed:

Average Plant Capacity	Loading Rate at Design Peak Hourly Flow gpd/lin ft (m^3/md)
equal to or less than 1 MGD (3785 m^3/d)	20,000 (250)
greater than 1 MGD (3785 m^3/d)	30,000 (375)

If pumping is required, the pumps shall be operated as nearly continuous as possible. Also, weir loadings should be related to pump delivery rates to avoid short circuiting.

72.44 Weir Troughs

Weir troughs shall be designed to prevent submergence at design peak hourly flow, and to maintain a velocity of at least one foot per second (0.3 m/s) at one-half design average flow.

72.5 Submerged Surface

The tops of troughs, beams, and similar submerged construction elements shall have a minimum slope of 1.4 vertical to 1 horizontal; the underside of such elements shall have a slope of 1 to 1 to prevent the accumulation of scum and solids.

72.6 Unit Dewatering

Unit dewatering features shall conform to the provisions outlined in paragraph 54.3. The bypass design shall also provide for distribution of the plant flow to the remaining units.

72.7 Freeboard

Walls of settling tanks shall extend at least 6 inches (150 mm) above the surrounding ground surface and shall provide not less than 12 inches (300 mm) freeboard. Additional freeboard or the use of wind screens is recommended where larger settling tanks are subject to high velocity wind currents that would cause tank surface waves and inhibit effective scum removal.

73. SLUDGE AND SCUM REMOVAL

73.1 Scum Removal

Full surface mechanical scum collection and removal facilities, including baffling, shall be provided for all settling tanks. The unusual characteristics of scum which may adversely affect pumping, piping, sludge handling and disposal, shall be recognized in design. Provisions may be made for the discharge of scum with the sludge; however, other special provisions for disposal may be necessary.

73.2 Sludge Removal

Mechanical sludge collection and withdrawal facilities shall be designed to assure rapid removal of the sludge. Suction withdrawal should be provided for activated sludge clarifiers over 60 feet (18 m) in diameter, especially for activated sludge plants that nitrify.

Each settling tank shall have its own sludge withdrawal lines to insure adequate control of sludge wasting rate for each tank.

73.21 Sludge Hopper

The minimum slope of the side walls shall be 1.7 vertical to 1 horizontal. Hopper wall surfaces should be made smooth with rounded corners to aid in sludge removal. Hopper bottoms shall have a maximum dimension of 2 feet (600 mm). Extra depth sludge hoppers for sludge thickening are not acceptable.

92. ACTIVATED SLUDGE

92.1 General

92.11 Applicability

92.111 Biodegradable Wastes

The activated sludge process and its various modifications may be used where wastewater is amenable to biological treatment.

92.112 Operational Requirement

This process requires close attention and competent operating supervision, including routine laboratory control. These requirements shall be considered when proposing this type of treatment.

92.113 Energy Requirements

This process requires major energy usage to meet aeration demands. Energy costs and potential mandatory emergency public power reduction events in relation to critical water quality conditions must be carefully evaluated. Capability of energy usage phasedown while still maintaining process viability, both under normal and emergency energy availability conditions, must be included in the activated sludge design.

92.12 Specific Process Selection

The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of carbonaceous and/or nitrogenous oxygen demand. Choice of the process most applicable will be influenced by the degree and consistency of treatment required, type of waste to be treated, proposed plant size, anticipated degree of operation and maintenance, and operating and capital costs. All designs shall provide for flexibility in operation and should provide for operation in various modes, if feasible.

The fill and draw mode of the activated sludge process commonly termed the Sequencing Batch Reactor may be approved by the reviewing authority on a case by case basis under the provisions of paragraph 53.2. The design must be based on experience at other facilities. Continuity and reliability of treatment equal to that of the continuous flow through modes of the activated sludge process shall be provided. The reviewing authority should be contacted for design guidance and criteria where such systems are being considered.

92.13 Winter Protection

In severe climates, protection against freezing shall be provided to ensure continuity of operation and performance. Insulation of the tanks by earthen banks should be considered.

92.2 Pretreatment

Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease, and screening of solids shall be accomplished prior to the activated sludge process.

Where primary settling is used, provision shall be made for discharging raw wastewater directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life.

92.3 Aeration

92.31 Capacities and Permissible Loadings

The size of the aeration tank for any particular adaptation of the process shall be determined by full scale experience, pilot plant studies, or rational calculations based mainly on food to microorganism ratio and mixed liquor suspended solids levels. Other factors, such as size of treatment plant, diurnal load variations, and degree of treatment required, shall also be considered. In addition, temperature, alkalinity, pH, and reactor dissolved oxygen shall be considered when designing for nitrification.

Calculations should be submitted to justify the basis for design of aeration tank capacity. Calculations using values differing substantially from those in the accompanying table should reference actual operational plants. Mixed liquor suspended solids levels greater than 5000 mg/L may be allowed providing adequate data is submitted showing the aeration and clarification system capable of supporting such levels.

When process design calculations are not submitted, the aeration tank capacities and permissible loadings for the several adaptations of the processes shown in the following table shall be used. These values apply to plants receiving diurnal load ratios of design peak hourly BOD_5 to design average BOD_5 ranging from about 2:1 to 4:1. Thus, the utilization of flow equalization facilities to reduce the diurnal design peak hourly BOD_5 organic load may be considered by the appropriate reviewing authority as justification to approve organic loading rates that exceed those specified in the table.

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PERMISSIBLE AERATION TANK CAPACITIES AND LOADINGS

Process	**** Aeration Tank Organic Loading lbs. BOD_5/d/1000 ft^3 ($kg/d/m^3$)***	F/M Ratio lb. BOD_5/day per lb. MLVSS***	MLSS* mg/l
Conventional Step Aeration Complete Mix	40 (0.64)	0.2-0.5	1000-3000
Contact Stabilization	50**(0.80)	0.2-0.6	1000-3000
Extended Aeration Single Stage Nitrification	15 (0.24)	0.05-0.1	3000-5000

* MLSS values are dependent upon the surface area provided for sedimentation and the rate of sludge return as well as the aeration process.

** Total aeration capacity, includes both contact and reaeration capacities. Normally the contact zone equals 30 to 35% of the total aeration capacity.

*** Refer to 11.251(a) for definition of BOD.

**** Loadings are based on the organic load influent to the aeration tank at plant design average BOD_5.

92.32 Arrangement of Aeration Tanks

a. Dimensions

The dimensions of each independent mixed liquor aeration tank or return sludge reaeration tank shall be such as to maintain effective mixing and utilization of air. Ordinarily, liquid depths should not be less than 10 feet (3 m) or more than 30 feet (9 m) except in special design cases. An exception is that horizontally mixed aeration tanks shall have a depth of not less than 5.5 feet (1.7 m).

b. Short-circuiting

For very small tanks or tanks with special configuration, the shape of the tank, the location of the influent and sludge return, and the installation of aeration equipment should provide for positive control to prevent short-circuiting through the tank.

92.321 Number of Units

Total aeration tank volume shall be divided among two or more units, capable of independent operation, when required by the appropriate reviewing authority to meet applicable effluent limitations and reliability guidelines.

92.322 Inlets and Outlets

a. Controls

Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit controlling the flow to any unit and to maintain reasonably constant liquid level. The effluent weir for a horizontally mixed aeration tank system must be easily adjustable by mechanical means and shall be sized based on the design peak instantaneous flow plus the maximum return sludge flow. Refer to paragraph 92.41. The hydraulic properties of the system shall permit the design peak instantaneous flow to be carried with any single aeration tank unit out of service.

b. Conduits

Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleansing velocities or shall be agitated to keep such solids in suspension at all rates of flow within the design limits. Adequate provisions should be made to drain segments of channels which are not being used due to alternate flow patterns.

92.323 Freeboard

All aeration tanks should have a freeboard of not less than 18 inches (460 mm). However, if a mechanical surface aerator is used, the freeboard should be not less than 3 feet (910 mm) to protect against windblown spray freezing on walkways, etc.

92.33 Aeration Equipment

92.331 General

Oxygen requirements generally depend on maximum diurnal organic loading (design peak hourly BOD_5 as described in paragraph 11.25), degree of treatment, and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be capable of maintaining a minimum of 2.0 mg/l of dissolved oxygen in the mixed liquor at all times and provide thorough mixing of the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes shall be 1.1 lbs. O_2/lb. design peak hourly BOD_5 applied to the aeration tanks (1.1 kg O_2/kg design peak hourly BOD_5), with the exception of the extended aeration process, for which the value shall be 1.5 to include endogenous respiration requirements.