High Purity Oxygen Aeration: This method requires the use of bottled or manufactured oxygen which is introduced to closed aerating tanks in place of atmospheric air. Mechanical mixing is needed to take full advantage of the oxygen.

Intermediate Clarifiers: Sedimentation tanks located between trickling filter stages (see figure 8.12) or between a filter and subsequent aeration are known as *intermediate clarifiers*. Recommended standards are:

- maximum overflow rate 1000 gpd/ft^2
- minimum water depth 7 feet
- maximum weir loading 10,000 gpd/ft (plants 1 MGD or less)
  15,000 gpd/ft (plants over 1 MGD)

Final Clarifiers: Final sedimentation in secondary treatment is done in final clarifiers. The purpose of final clarifiers is to collect sloughed off filter material (trickling filter processes) or to collect sludge and return it for aeration (activated sludge processes).

General characteristics for clarifiers following trickling filters are:

- BOD removal See equation 8.30
- minimum depth 7 feet
- maximum overflow rate 800 gpd/ft^2
- maximum weir loading Same as for intermediate clarifiers, but lower preferred.

If the final clarifier follows an activated sludge process, the sludge should be removed rapidly from the entire bottom of the clarifier. Characteristics of clarifiers following an activated sludge process are given in table 8.15.

D. ADVANCED TERTIARY TREATMENT

Suspended Solids: Suspended solids are removed by microstrainers or polishing filter beds.

Phosphorus Removal: Phosphorus can be removed by chemical precipitation. Aluminum and iron coagulants, as well as lime, are effective in removing phosphates.

Nitrogen Conversion and Removal: In the *ammonia stripping* (*air stripping*) method, lime is added to water to increase its pH to above 10. The water is then passed through a packed tower into which air is blown. The air (at the rate of approximately 400 ft^3/gallon) strips the ammonia out of the water. Recarbonation follows to remove the excess lime.

$$NH_4 + OH^- \underset{pH<10}{\overset{pH\geq 11}{\rightleftharpoons}} NH_4OH \xrightarrow{\text{air}} H_2O + NH_3 \qquad 8.54$$

In the *nitrification and denitrification process*, bacteria oxidize ammonium ions to nitrate and nitrite in an aeration tank kept at low BOD. Nitrate and nitrite ions do not absorb further oxygen and may be discharged.

$$NH_3^+ \xrightarrow[\text{oxygen}]{\text{bacteria}} NO_2^- + NO_3^- \qquad 8.55$$

Table 8.14
Representative Operating Conditions for Aeration

type of aeration	plant flow rate (MGD)	t_A (hrs)	oxygen required (lbm/lbm BOD removed)	waste sludge (lbm/lbm BOD removed)	total plant BOD load (lbm/day)	aerator BOD load, L_{BOD} (lbm/1000 ft^3-day)	$R_{F/M}$ (lbm/lbm)	MLSS (mg/l)	R_R (%)	η_{BOD} (%)
conventional	0-0.5	7.5	0.8-1.1	0.4-0.6	0-1000	30	0.2-0.5	1500-3000	30	90-95
	0.5-1.5	7.5-6.0			1000-3000	30-40				
	1.5 up	6.0			3000 up	40				
contact stabilization	0-0.5	3.0*	0.8-1.1	0.4-0.6	0-1000	30	0.2-0.5	1000-3000*	100	85-90
	0.5-1.5	3.0-2.0*	0.4-0.6		1000-3000	30-50				
	1.5 up	1.5-2.0*	0.4-0.6		3000 up	50				
extended	0-0.05	24	1.4-1.6	0.15-0.3	all	10.0	0.05-0.1	3000-6000	100	85-95
	0.05-0.15	20				12.5				
	0.15 up	16				15.0				
high rate	0-0.5	4.0	0.7-0.9	0.5-0.7	2000 up	100	1.0 or less	4000-10,000	100	80-85
	0.5-1.5	3.0								
	1.5 up	2.0								
step aeration	0-0.5	7.5			0-1000	30	0.2-0.5	2000-3500	50	85-95
	0.5-1.5	7.5-5.0			1000-3000	30-50				
	1.5 up	5.0			3000 up	50				
high purity oxygen		1.0-3.0				above 120	0.6-1.5	6000-8000	50	90-95

* in contact unit only