ENVE 301

Environmental Engineering Unit Operations

Chapter 11

Secondary Clarifiers

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SECONDARY CLARIFIERS

Hindered (Zone) settling $\longrightarrow$ refers to suspensions of intermediate concentration

(in which interparticle forces are sufficient to hinder the settling of neighbouring particles)

The particles tend to remain in fixed positions with respect to each other and mass of particles settles as a unit.

.

Because of the high concentration of particles :

- The liquid tends to move up through the interstices of contacting particles

- As a result,the contacting particles tend to settle as a zone or “blanket” maintaining the same relative position with respect to each other.

- As the particles settle, a relatively clear layer of water is produced above the particles in the settling region.

DESIGN CRITERIA

- Overflow rate(surface loading) $= \dfrac{Q}{A}$

- Solids loading $= \dfrac{Q+Q_R}{A} X$ (Where X= MLSS conc. mg/l)

- Weir loading (less critical then overflowrate) $= \dfrac{\mathrm{Q}}{\mathrm{L}}$

-

Table 8-7
Typical design information for secondary clarifiers for the activated-sludge process[a]

Type of treatment	Overflow rate				Solids loading				Depth, m[b]
	gal/ft²·d		m³/m²·d		lb/ft²·h		kg/m²·h		
	Average	Peak	Average	Peak	Average	Peak	Average	Peak	
Settling following air-activated sludge (excluding extended aeration)	400–700	1000–1600	16–28	40–64	0.8–1.2	1.6	4–6	8	3.5–6
Selectors, biological nutrient removal	400–700	1000–1600	16–28	40–64	1.0–1.5	1.8	5–8	9	3.5–6
Settling following oxygen-activated sludge	400–700	1000–1600	16–28	40–64	1.0–1.4	1.8	5–7	9	3.5–6
Settling following extended aeration	200–400	600–800	8–16	24–32	0.2–1.0	1.4	1.0–5	7	3.5–6
Settling for phosphorus removal; effluent concentration, mg/L									3.5–6
Total P = 2	600–800		24–32						
Total P = 1[c]	400–600		16–24						
Total P = 0.2–0.5[d]	300–500		12–20						

[a] Adapted in part from Kang (1987); WEF (1998).
[b] m × 3.2808 = ft.
[c] Occasional chemical addition required.
[d] Continuous chemical addition required for effluent polishing.
Note: Peak is a 2-h sustained peak.

TABLE 11.7 Clarifiers in Wastewater Treatment[a] (Orante, 1997)

Item	Value
Primary Clarifiers[b]	
Overflow rate, $m^3/m^2/d$ ($gal/ft^2/d$)	
For average dry weather flow rate	32–49 (785–1 200)
For peak flow condition	49–122 (1 200–3 000)
Sidewater depth, m (ft)	2.1–5 (6.9–16.4)
Weir loading rate[c], $m^3/m/d$ (gal/ft/d)	125–500 (10 000–40 000)
Secondary Clarifiers	
Overflow rate[d], $m^3/m^2/d$ ($gal/ft^2/d$)	
For average dry weather flow rate	16–29 (393–712)
For peak flow condition	41–65 (1 006–1 595)
Sidewater depth, m (ft)	3.0–5.5 (9.8–18)
Floor slope	Nearly flat to 1 : 12
Maximum diameter, m (ft)	46 (150)

[a]From WEF and ASCE (1992), *Design of Municipal Wastewater Treatment Plants*, vol. 1, WEF, © WEF 1992.

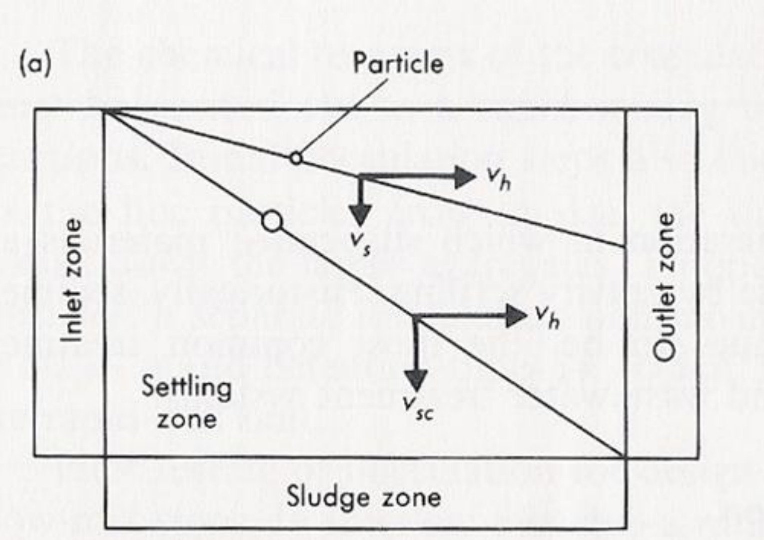
[b]Criteria are based on the maximum ranges specified by a number of firms and agencies reported in WEF and ASCE (1992).

[c]Generally for average flow conditions.

[d]For circular or rectangular tanks.

Sedimentation tanks can be divided into 4 different functional zones;

1. Inlet zone
2. Settling zone
3. Sludge zone
4. Outlet zone



Inlet Structures

- should dissimate influent energy
- distribute the flow
- mitigate density currents
- minimize sludge blanket disturbance

→are designed to uniformly distrubute the influent suspension over the cross section of the settling zone.

For Rectangular Basins

full width inlet channels → effective spreading of flow introduce a vertical velocity component into sludge hopper that may resuspend sludge.

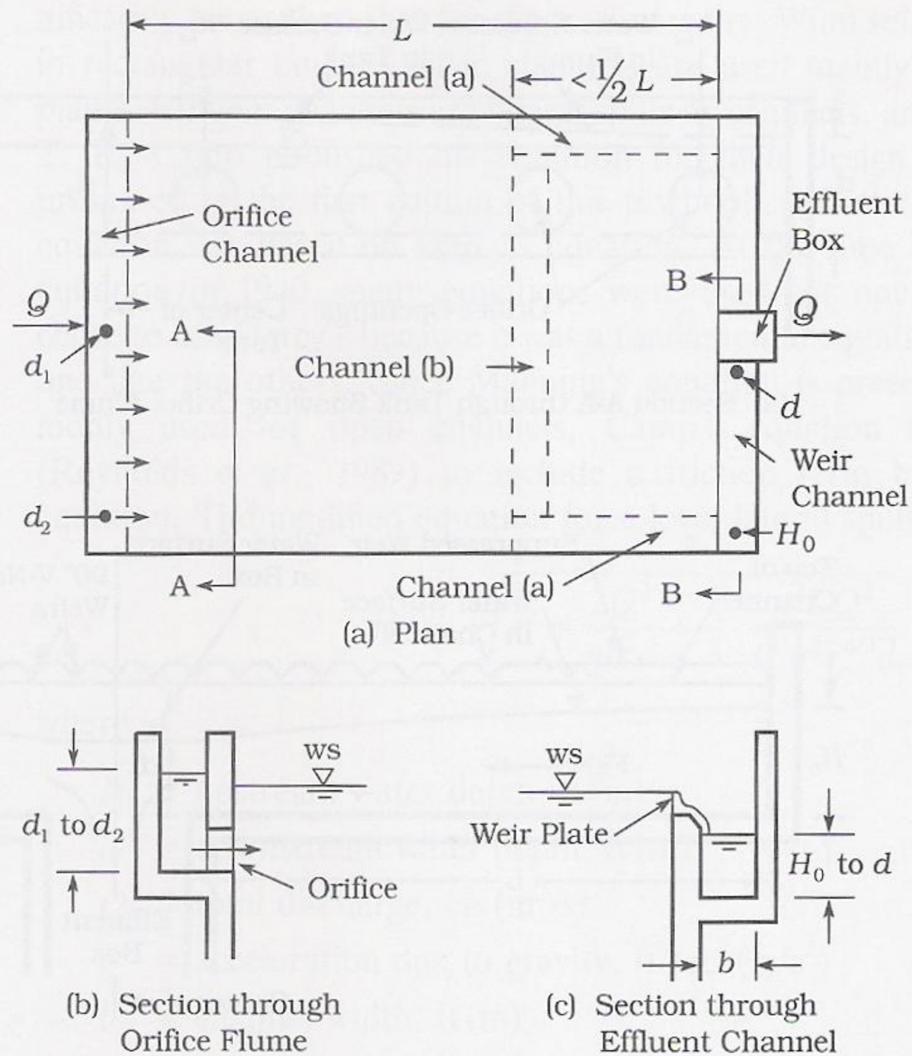


FIGURE 9.44 *Inlet and Outlet Details for a Rectangular Tank*

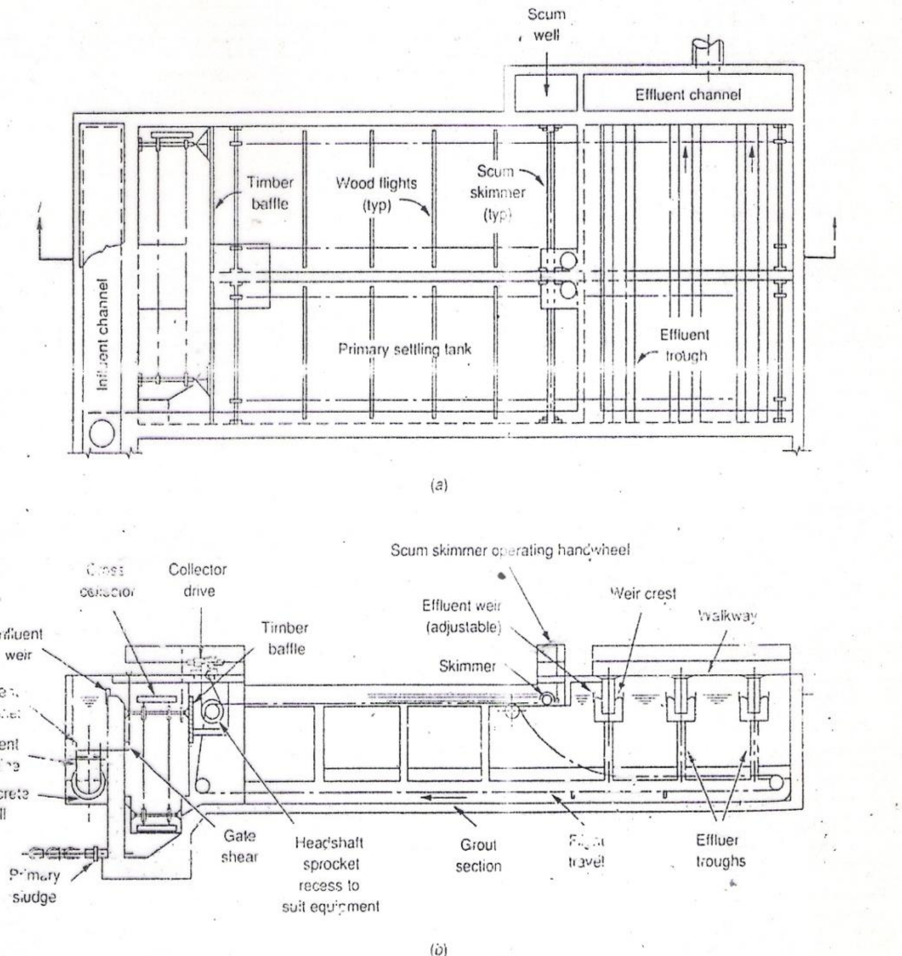


FIGURE 9-16 (Metcalf & Eddy, 1991).
Typical rectangular primary sedimentation tank.

Inlet Structures (continue)

For circular tanks

circular tanks→ radial flow

to achieve a radial flow patterninfluent is introduced →in the center of the tank
or
around the periphery of the tank

Central feed → water enters a circular well designed to distribute the flow equally in all directions

D of feed well = 15-20 % of tank diameter

Depth= 1- 2.5m

Velocity through the orificies on feed well
0.075- 0.15 m/sec

entrance pipe → suspended from bridge OR encased in concrete beneath the tank floor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For peripheral feed (not as uniform as central feed)

orifice channel around periphery of the tank

from the channel the flow discharges through the orifices into sedimentation tank

Sedimentation Facilities

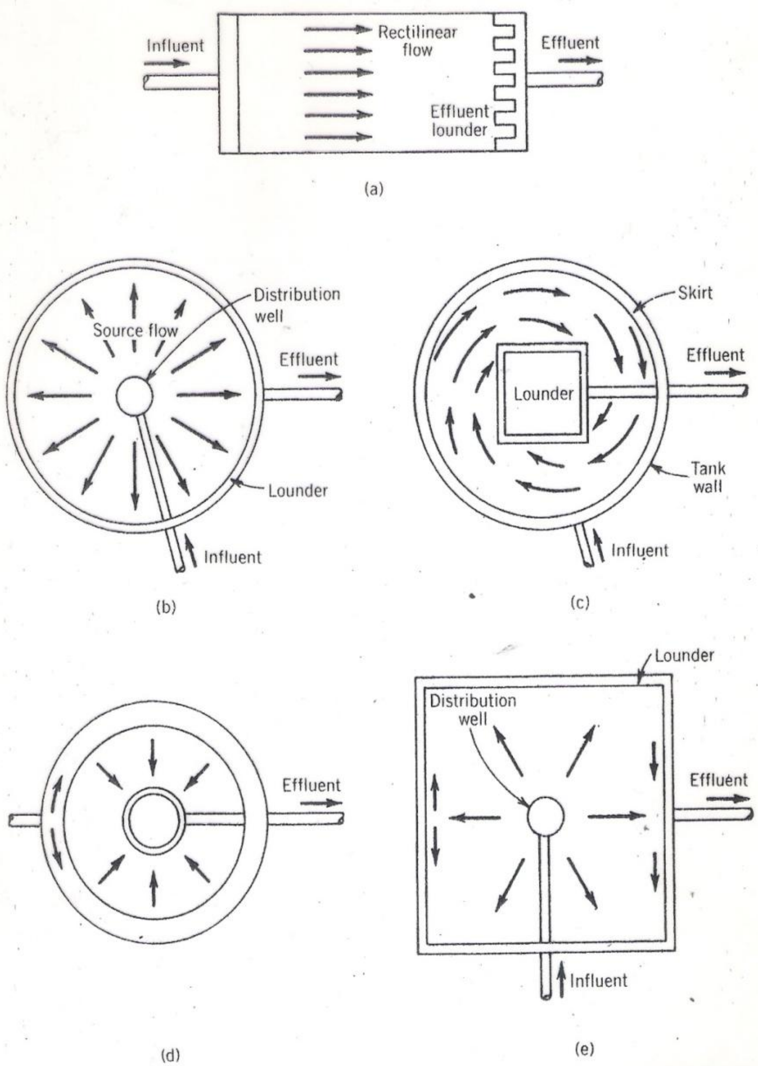


FIGURE 21-22. Flow patterns in sedimentation tanks: (a) Rectangular settling tank; (b) center feed, source flow; (c) peripheral feed, spiral flow; (d) peripheral feed, radial flow; (e) square, radial flow. (Reprinted from *Water Treatment Plant Design*. Copyright 1969, American Water Works Association, Inc.)

Figure 5-43

Typical energy-dissipating and flow distribution inlet for a center-feed sedimentation tank. The inner ring is used to create a tangential flow pattern. *(Randall, et al., 1992.)*

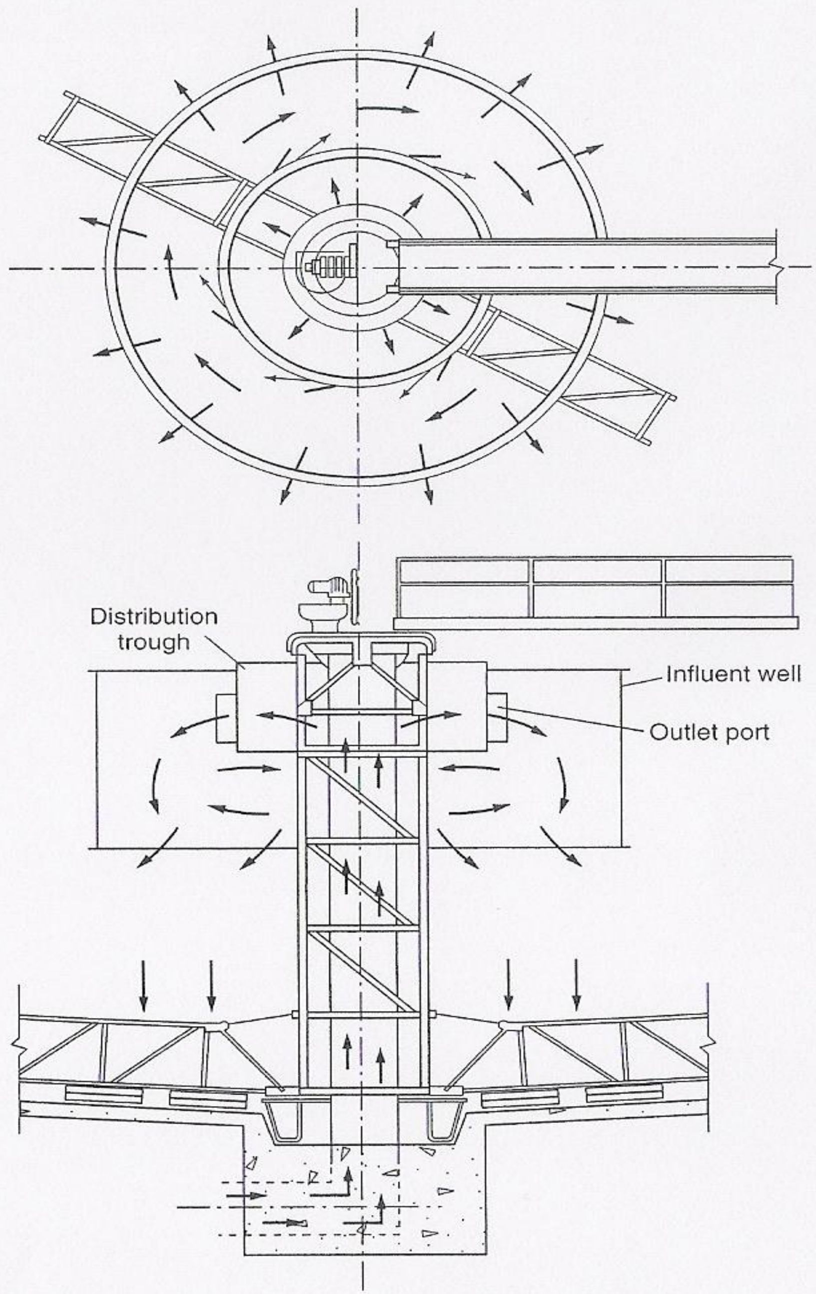


Figure 5-41

Typical circular primary sedimentation tanks: *(a)* center feed and *(b)* peripheral feed. *(Crites and Tchobanoglous, 1998.)*

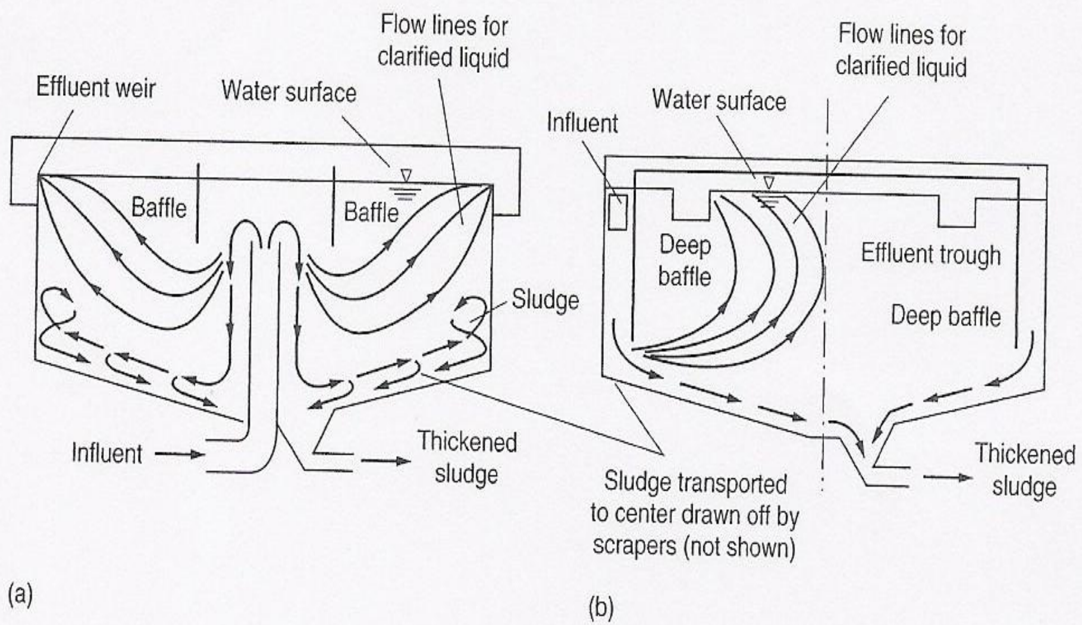
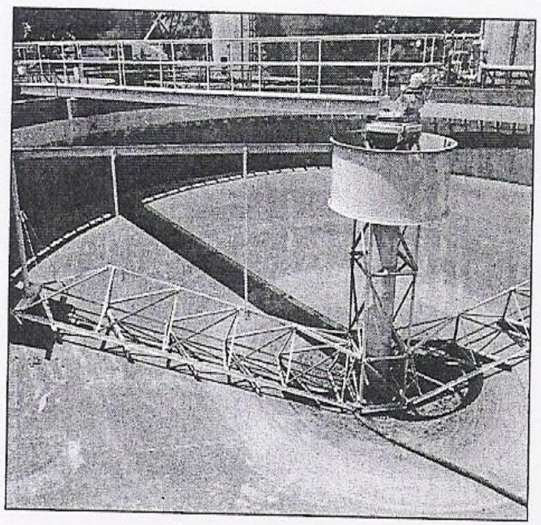


Figure 5-42

Typical circular primary sedimentation tank.



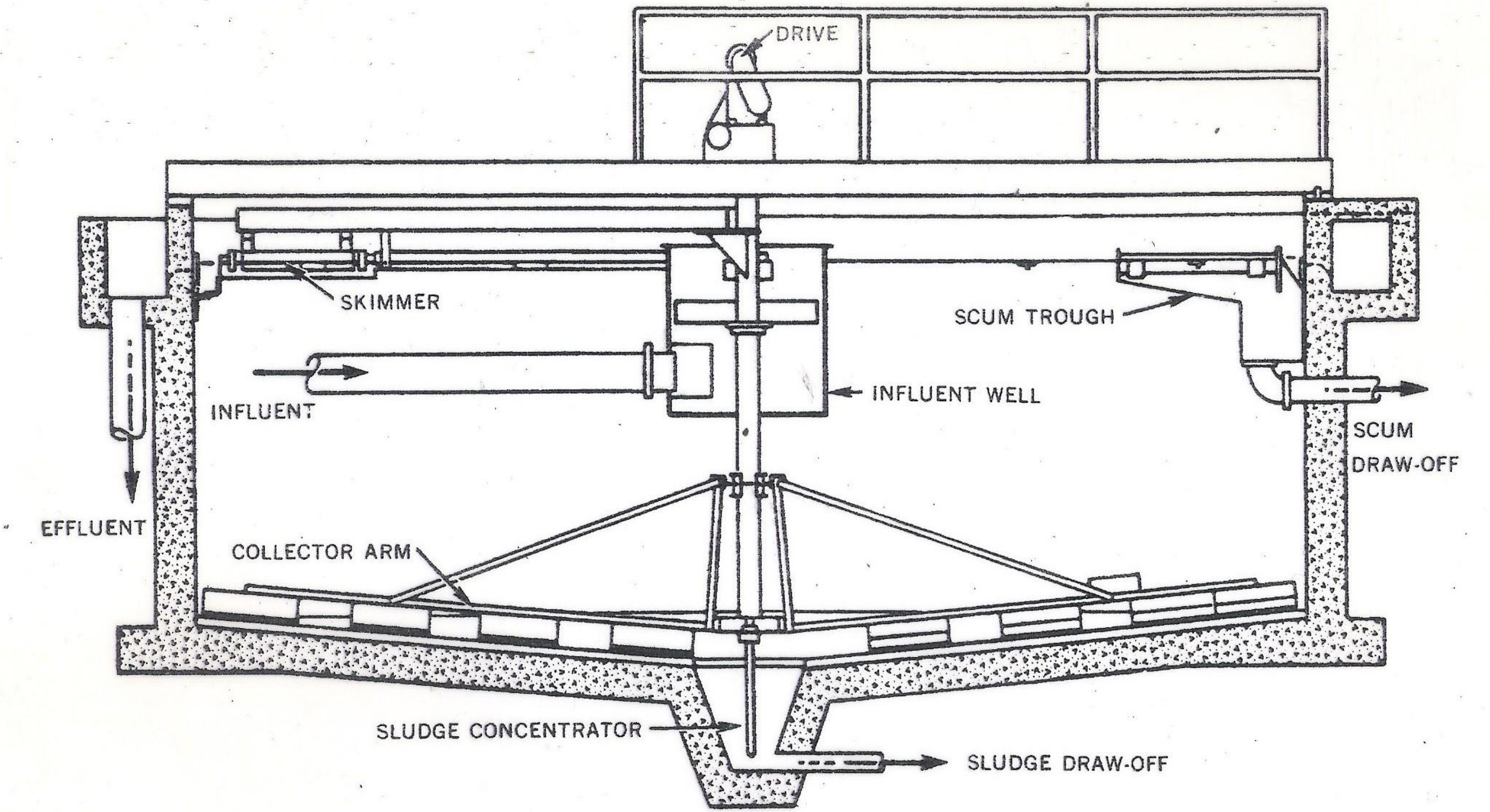


Figure 3–14 Circular clarifier design. (Courtesy of Walker Process equipment.)

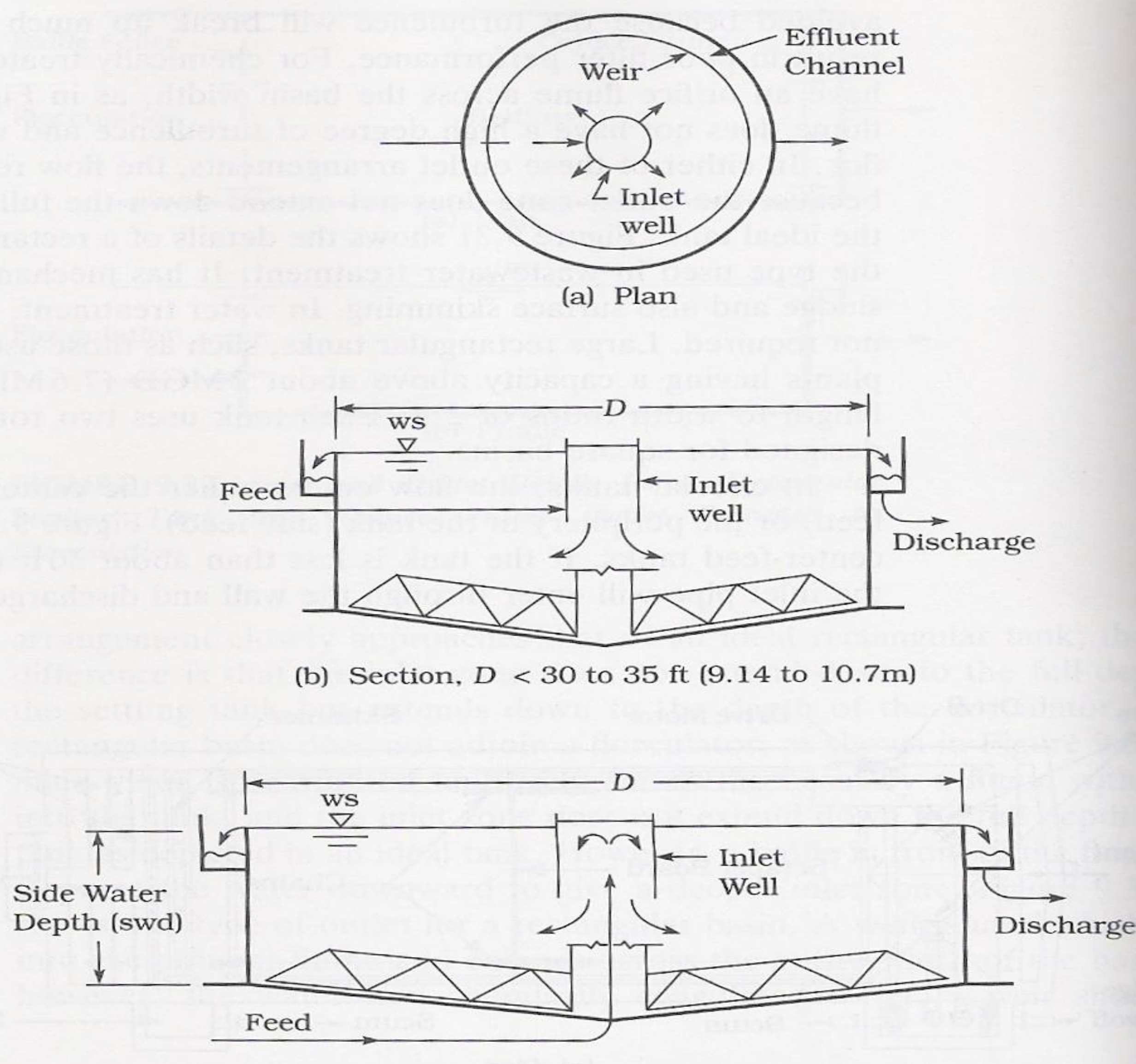
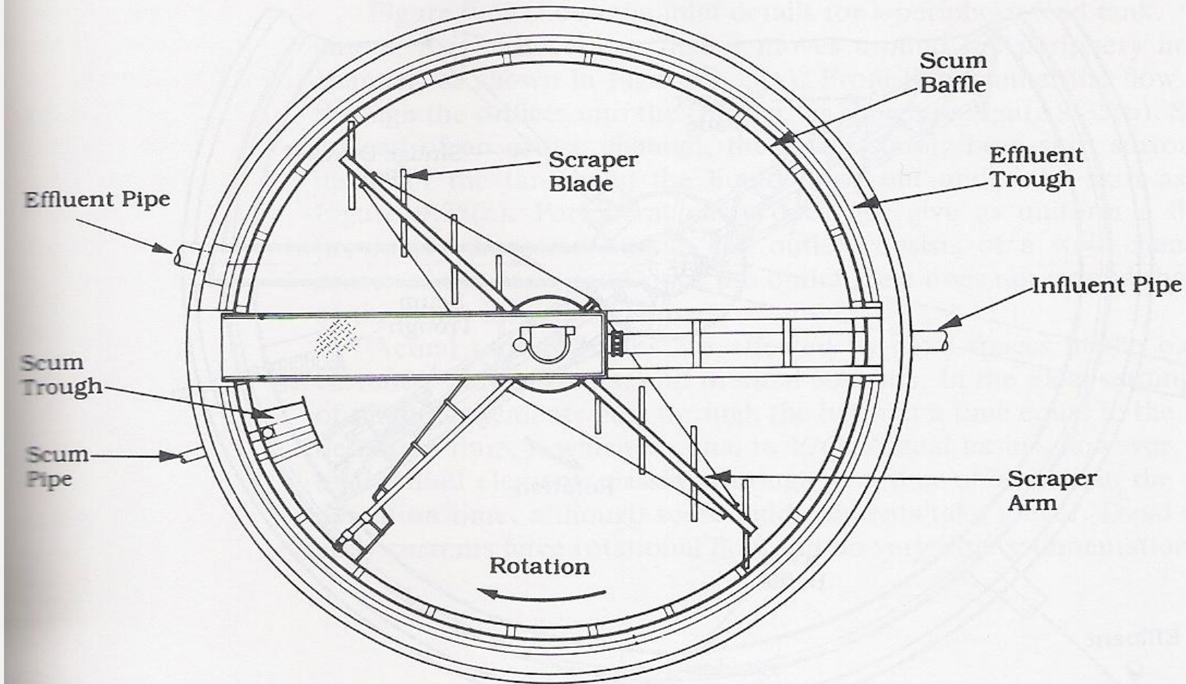
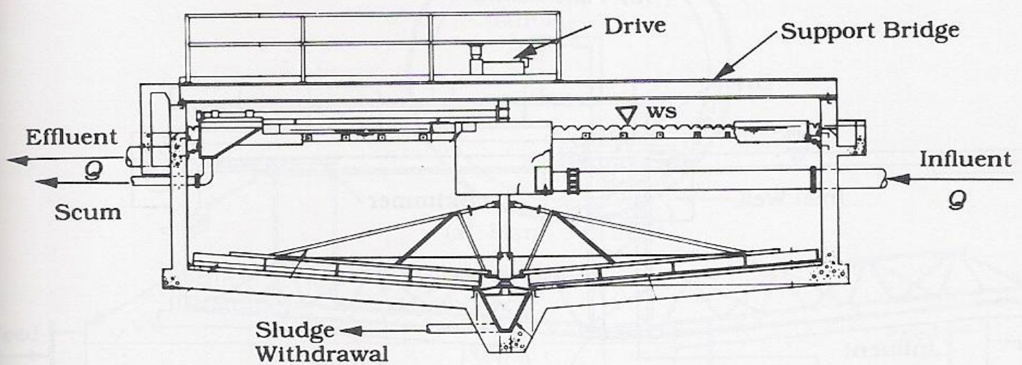


FIGURE 9.32 *Inlet and Outlet Details for Circular Tanks (Center Feed)*



(a) Plan



(b) Elevation

FIGURE 9.33 *Circular Settling Tank (Center Feed by Pipe through Wall)*

Courtesy of Infilco Degremont, Inc.

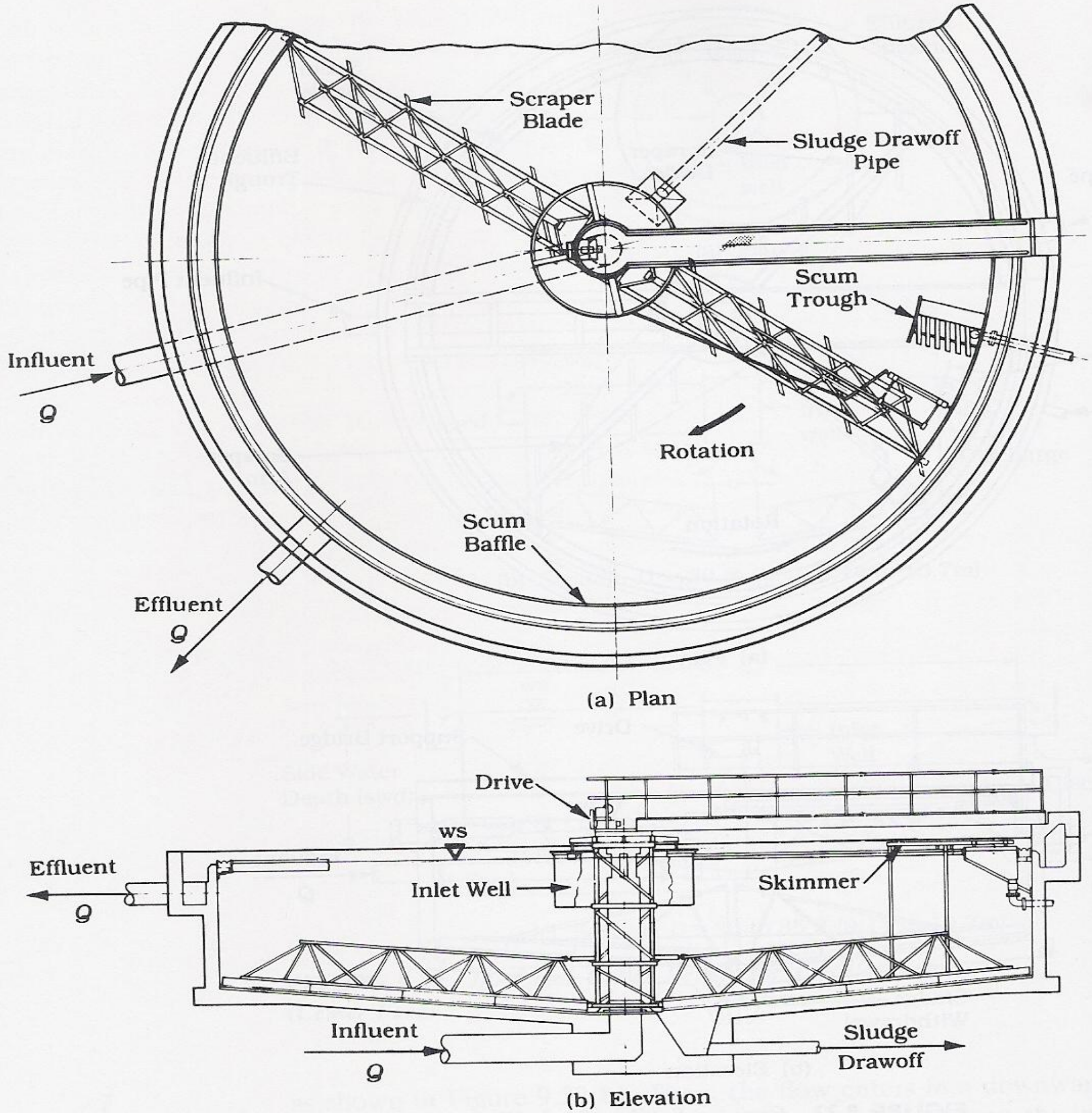


FIGURE 9.34 *Circular Settling Tank (Center Feed by Pipe under Tank Bottom)*

Courtesy of Infilco Degremont, Inc.

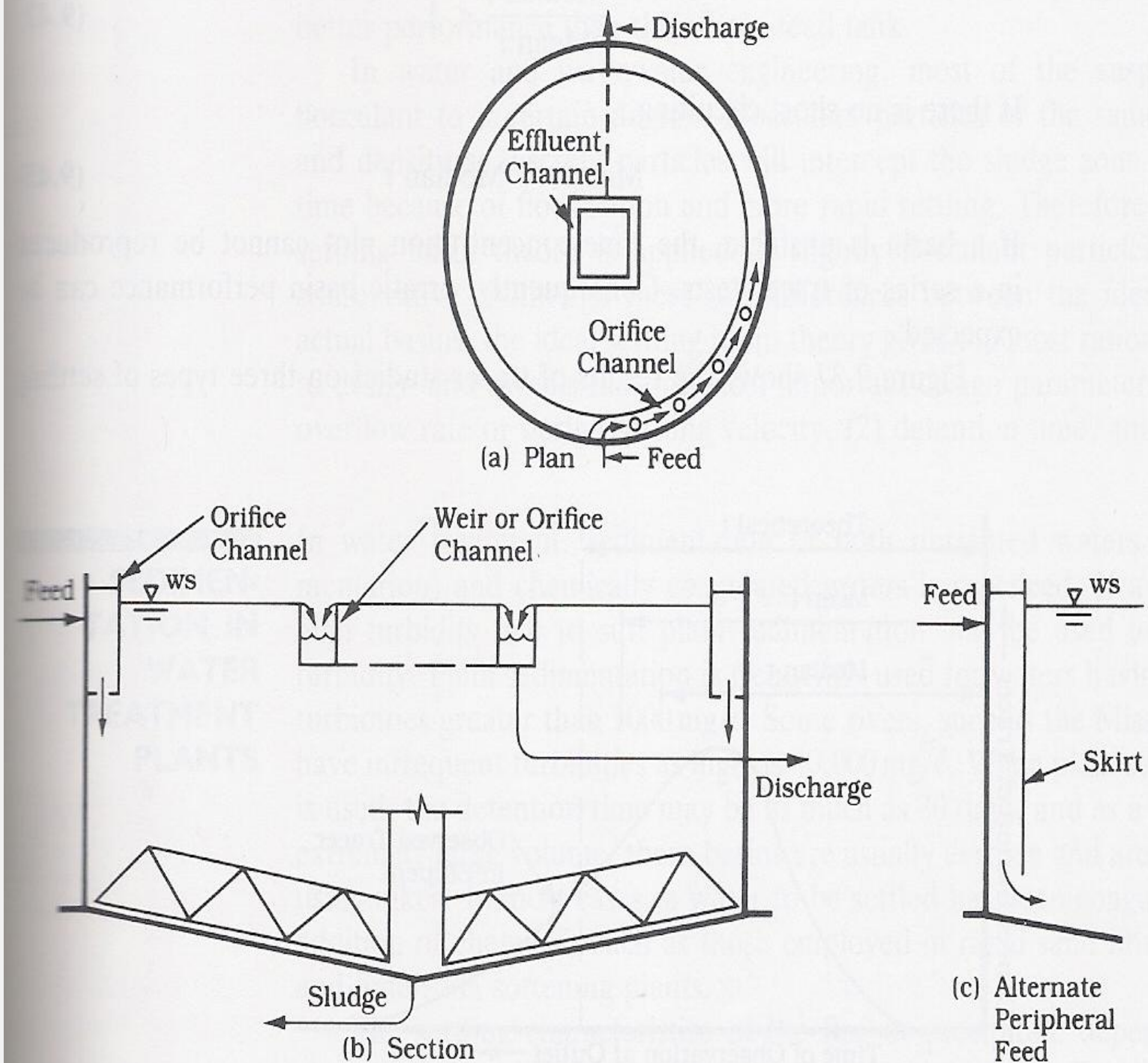
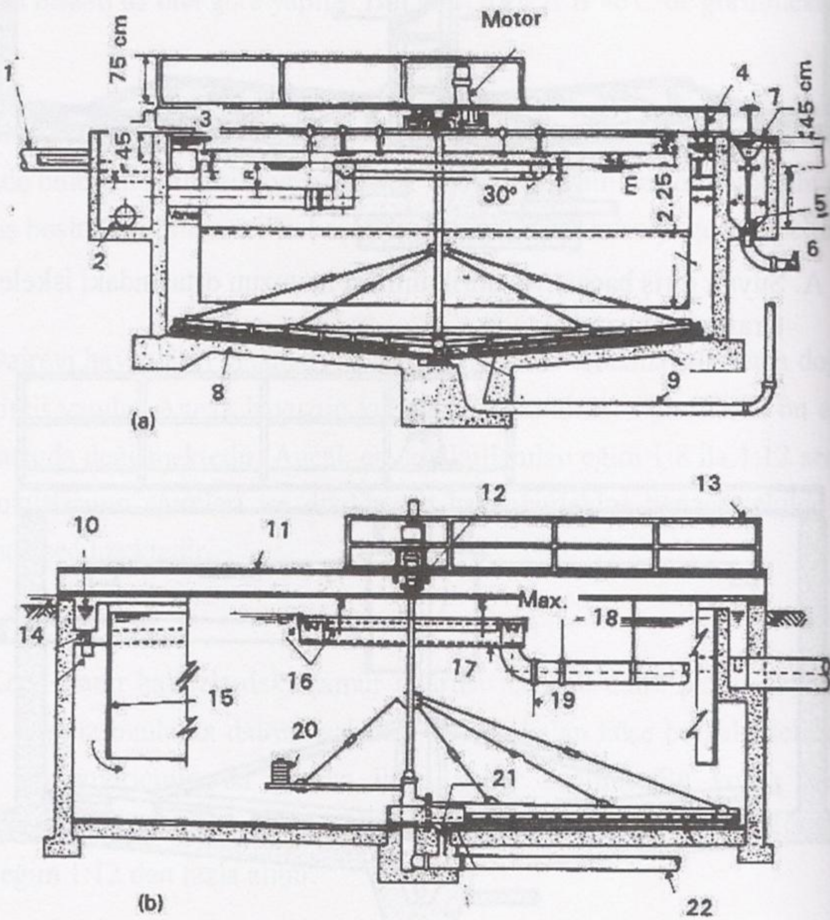


FIGURE 9.35 *Inlet and Outlet Details for a Circular Tank (Peripheral Feed)*

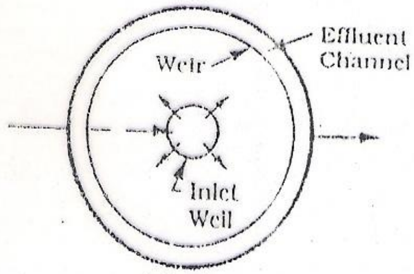


1. Giriş, 2. Çıkış, 3. Giriş oluğu, 4. Elle çalıştırılan köpük borusu, 5. Köpük vanası, 6. Köpük borusu, 7. 10 cm kanal, 8. Taban eğilimi %6, 9. Çamur borusu, 10. Giriş kanalı, 11. Köprü, 12. Sonsuz vida, 13. Korkuluk, 14. Orifis, 15. Dalgıç perde, 16. Ayarlanabilen savak, 17. Çıkış kanalı, 18. EYSS, 19. Çıkış borusu, 20. Karşı ağırlık, 21. Dren, 22. Çamur çıkışı

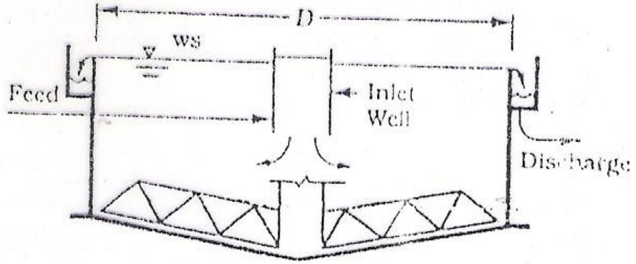
Şekil 6.21. Çevreden beslenen dairesel çöktürme havuzları

Figure 3.28. Inlet and Outlet Details for Circular Tanks (Center Feed)

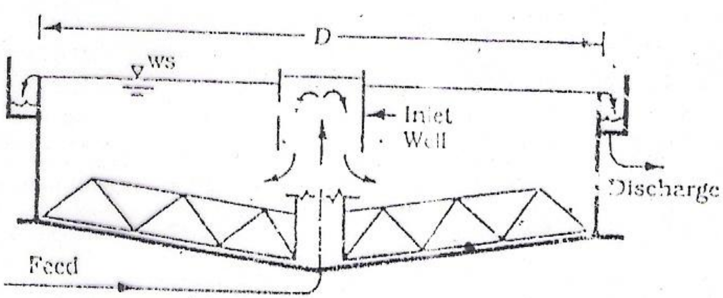
(Reynolds, 1982)



(a) Plan

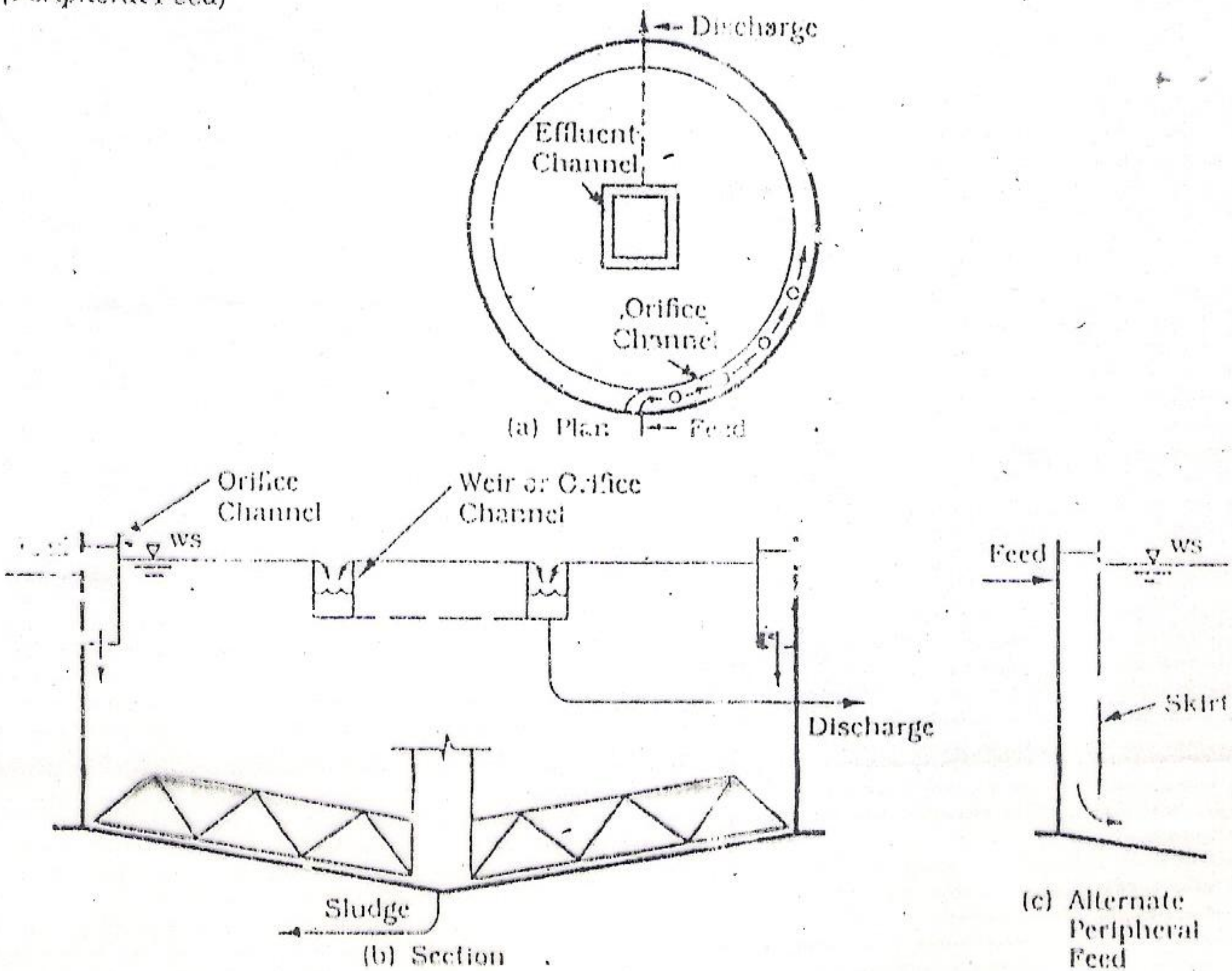


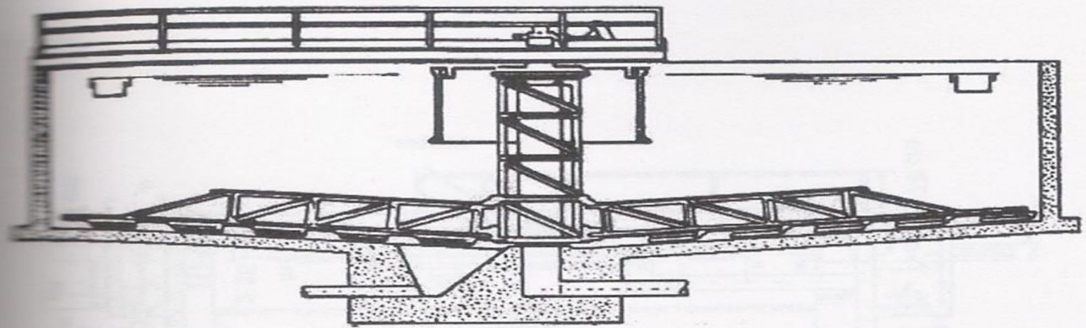
(b) Section, D < 30 to 35 ft



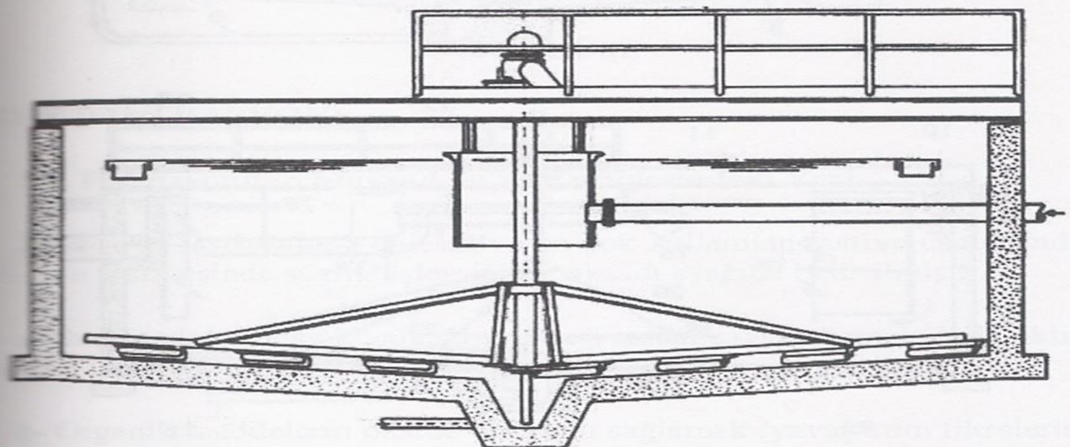
(c) Section, D > 30 to 35 ft

Figure 3.31. Inlet and Outlet Details for a Circular Tank (Peripheral Feed) (Reynolds, 1982)

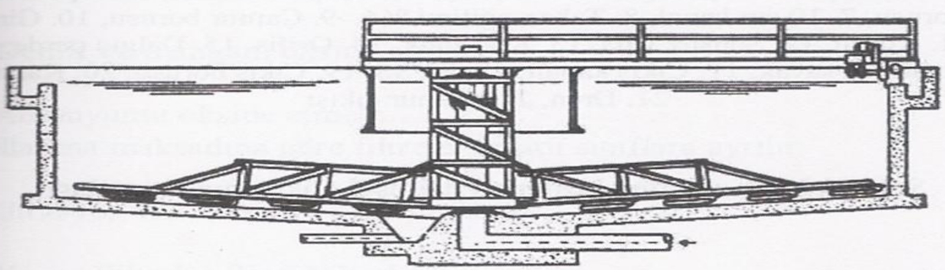




A. Suyun giriş bacası ve tahrik ünitesi havuzun ortasındaki iskele tarafından taşınmaktadır.



B. Suyun giriş bacası ve tahrik ünitesi köprü tarafından taşınmaktadır.



C. Cer makinası çevrede olup çamur toplayıcısı merkezdeki iskele tarafından taşınmaktadır.

Şekil 6.20. Dairevi çöktürme havuzu kesitleri

Settling Zone

It depends on the following desing parameters:

→ Settling characteristics of the suspended matter

→ Surface loading (over flowrate)

→ Width / length ratio OR diameter

→ Detention time

Sludge Zone

Rectangular tanks → the bottom is slightly sloped to facilitate sludge scraping

a pair of endless conveyor chains

bridge – type mechanism

continously pulls the settled material into a sludge hopper where it is pumped out periodically.

Motion of scraper →momentarily resuspend lighter particles a few cm above the scraper blades

Excessive horizontal velocity
(for the case of rectangular basins) → move these materials towards outlet zone.

To prevent this,

horizontal velocity -→ < 9 m/hr for light flocculant suspensions
≈ 36 m/hr for heavier discrete suspensions

Bridge type mechanism → travels up and down the tank

one or more scraper blades are suspended from the bridge

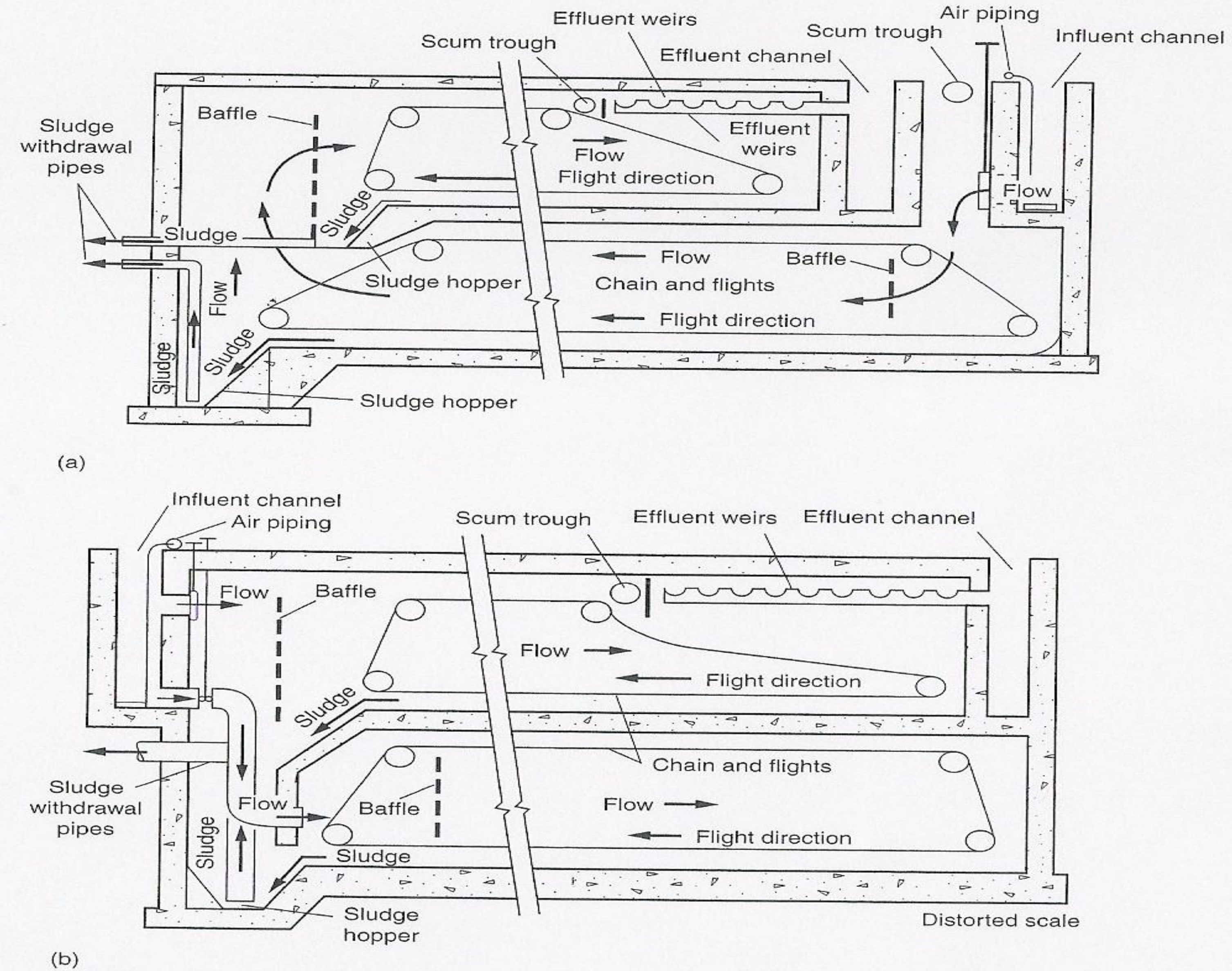

Effluent weirs
Scum trough
Effluent channel
Scum trough
Air piping
Influent channel
Baffle
Sludge withdrawal pipes
Effluent weirs
Flow
Flight direction
Flow
Sludge
Sludge
Sludge
Flow
Baffle
Sludge hopper
Chain and flights
Flight direction
Flow
Sludge
Sludge
Sludge hopper
(a)
Influent channel
Air piping
Scum trough
Effluent weirs
Effluent channel
Flow
Baffle
Flow
Flight direction
Sludge
Chain and flights
Sludge withdrawal pipes
Flow
Baffle
Flow
Flight direction
Sludge
Sludge
Sludge hopper
Distorted scale
(b)

Figure 5–45

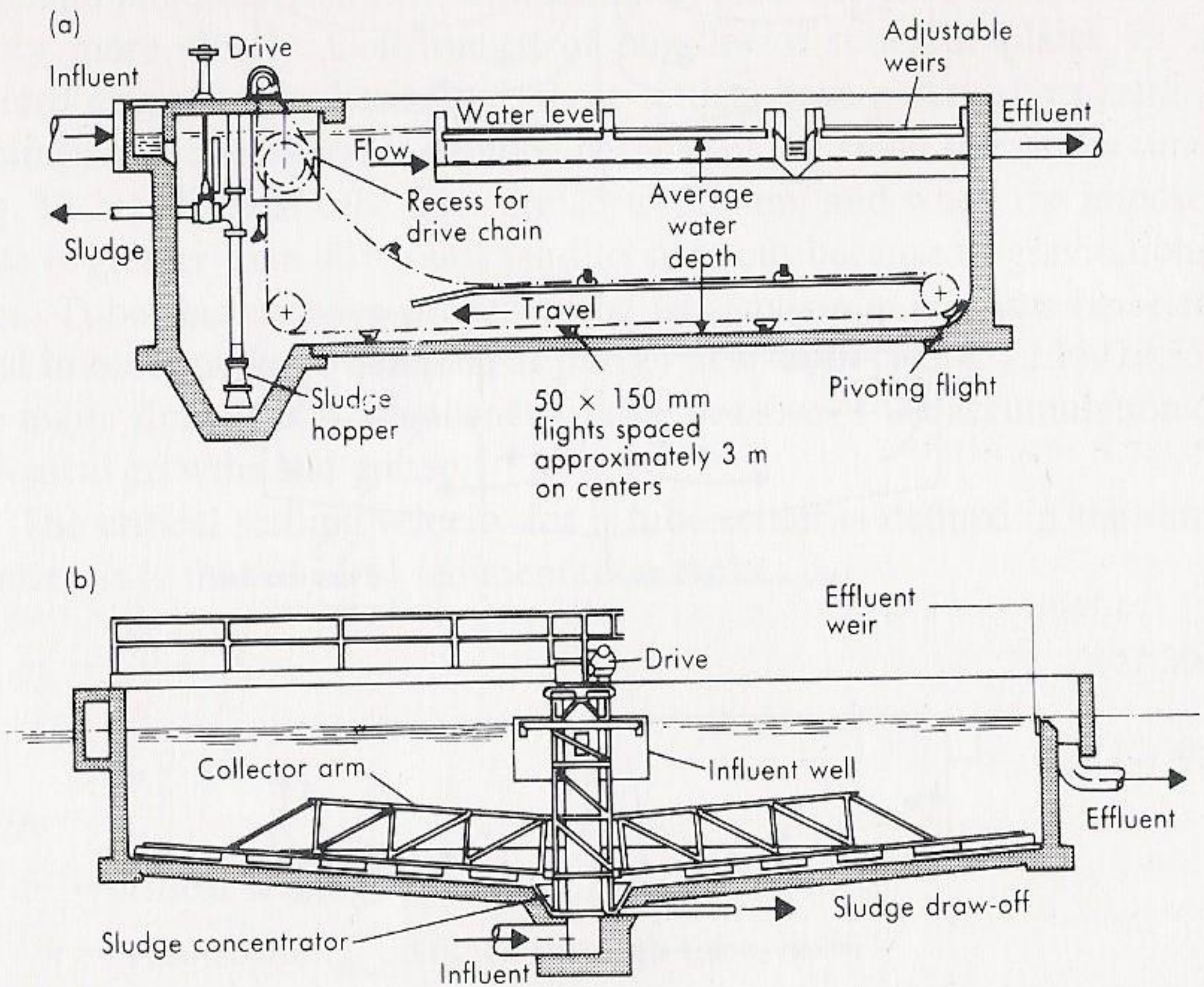


FIGURE 12.19

Typical sedimentation tanks: (a) rectangular (longitudinal section without skimmer)

Source: Courtesy of Walker Process.

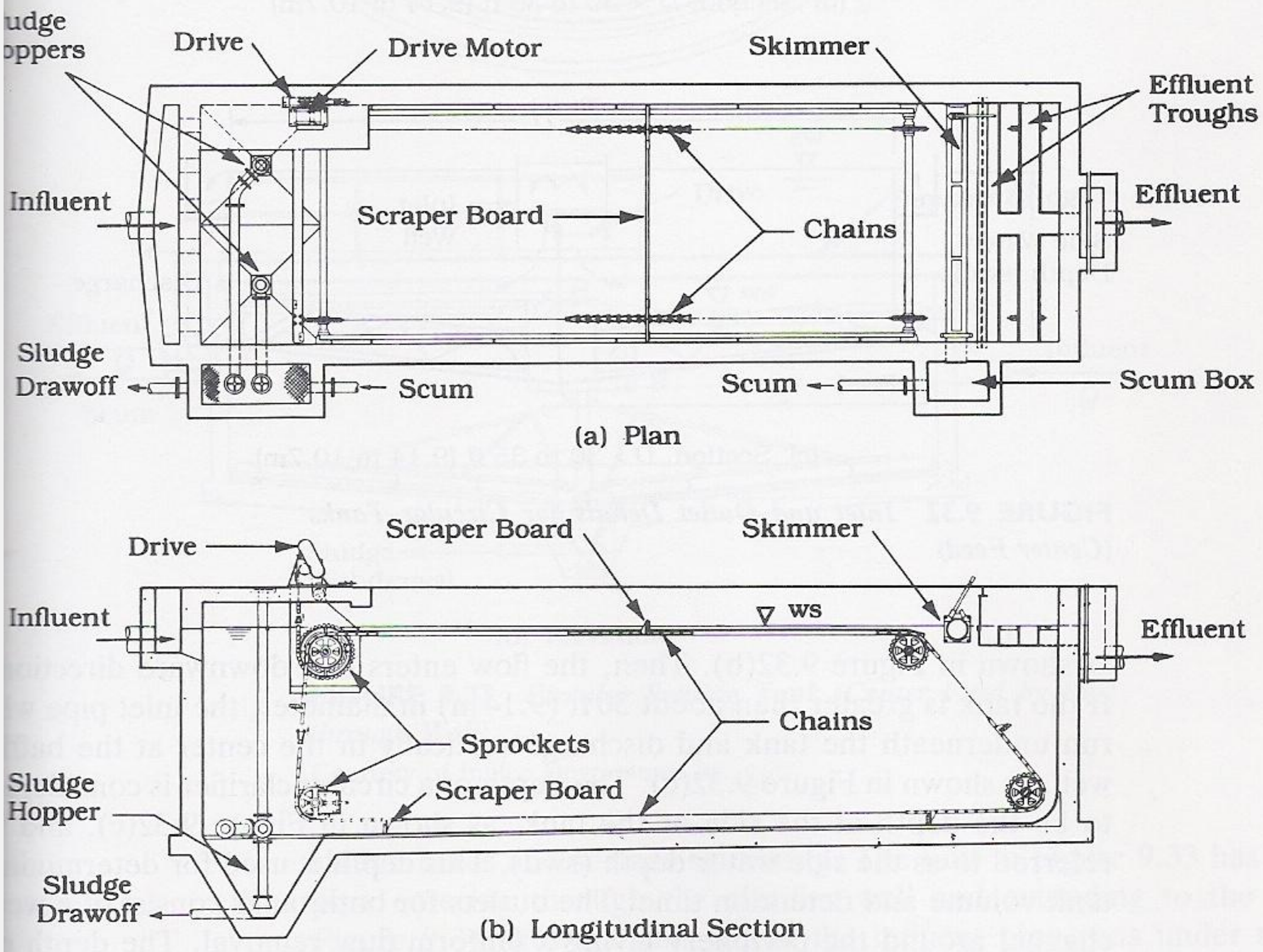


FIGURE 9.31 *Rectangular Settling Tank*

Courtesy of Walker Process Equipment, Division of McNish Corporation.

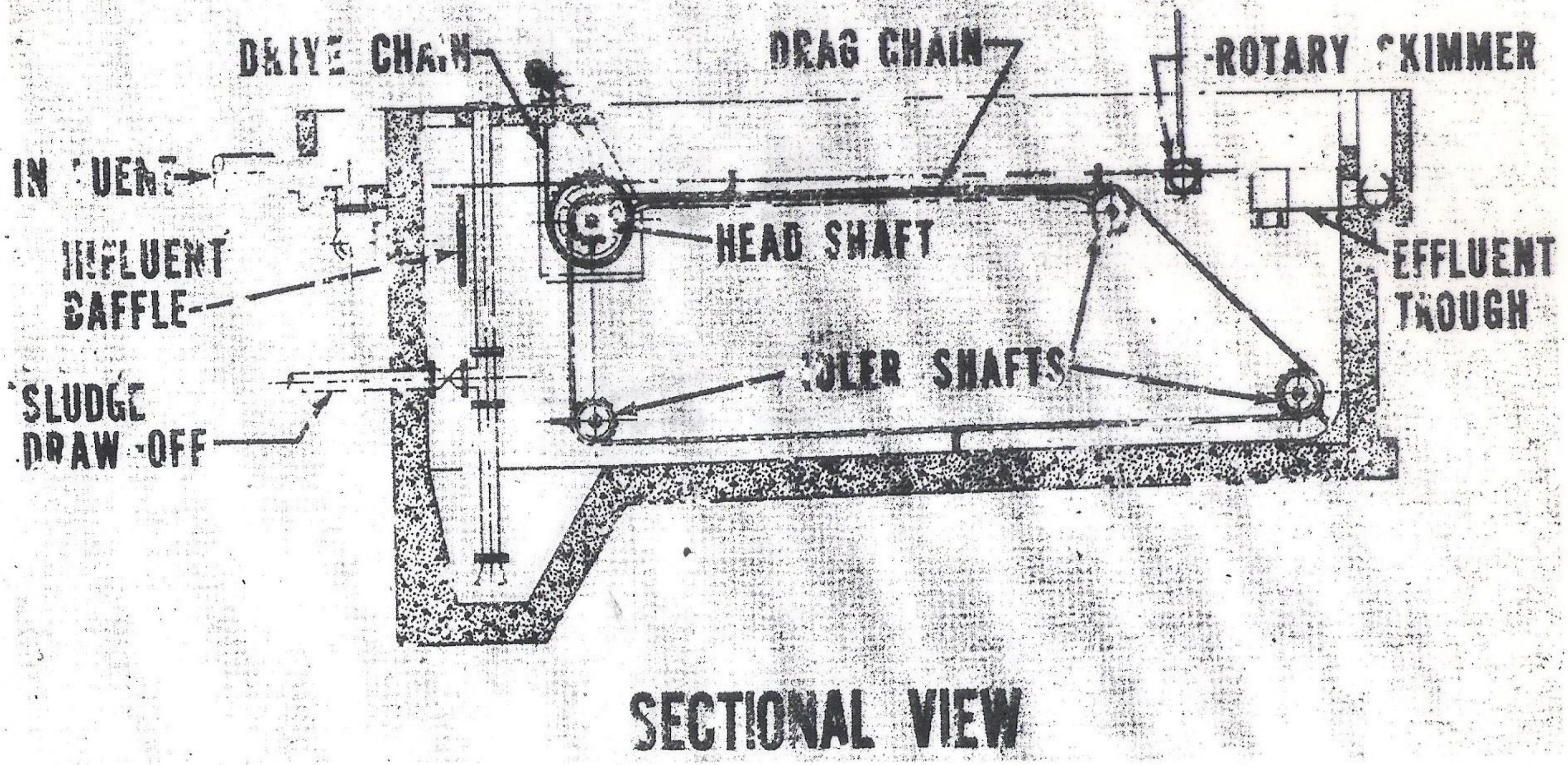
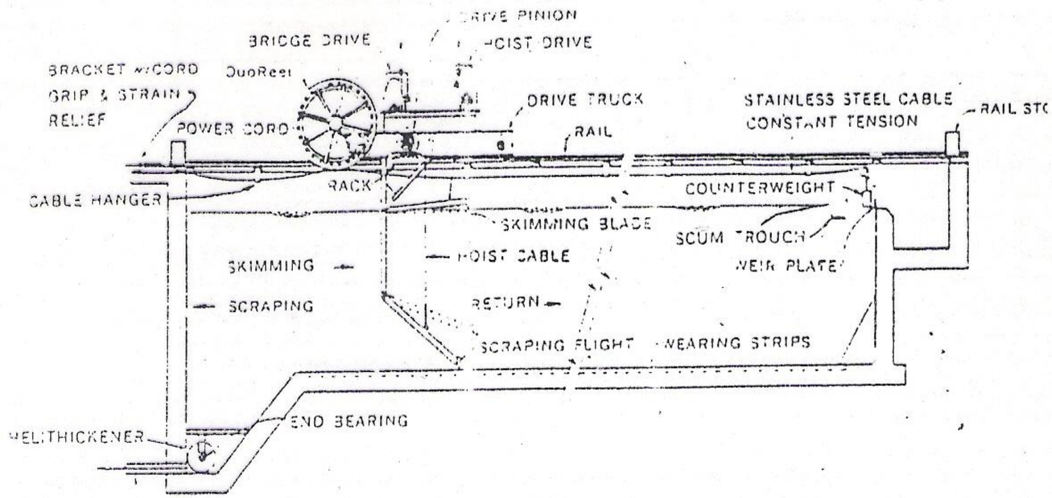


Figure 3–15 Rectangular clarifier design. (Courtesy of Clow Corporation.)

(Montgomery, 1985)



SIDE SECTIONAL ELEVATION

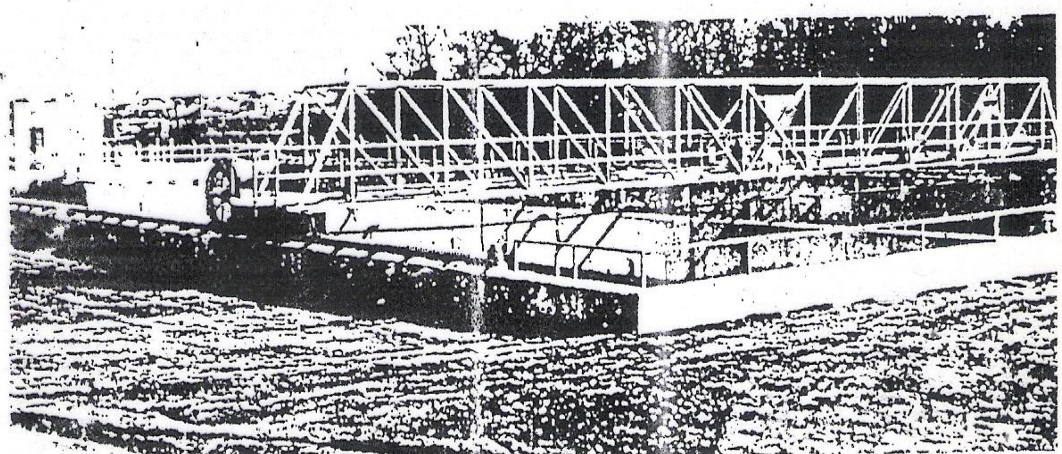


FIGURE 21-25. Traveling bridge sludge collector. (Courtesy of Walker Process.)

Circular tanks

The bottom of the tank is sloped to form an inverted cone and the sludge is scraped to a relatively small hopper located near the center of the tank

Velocity or scraper → important

Very high velocty → resuspension of settled particles (<5mm/sn)

Travelling bridge with sludge suction headers and pumps → not very good

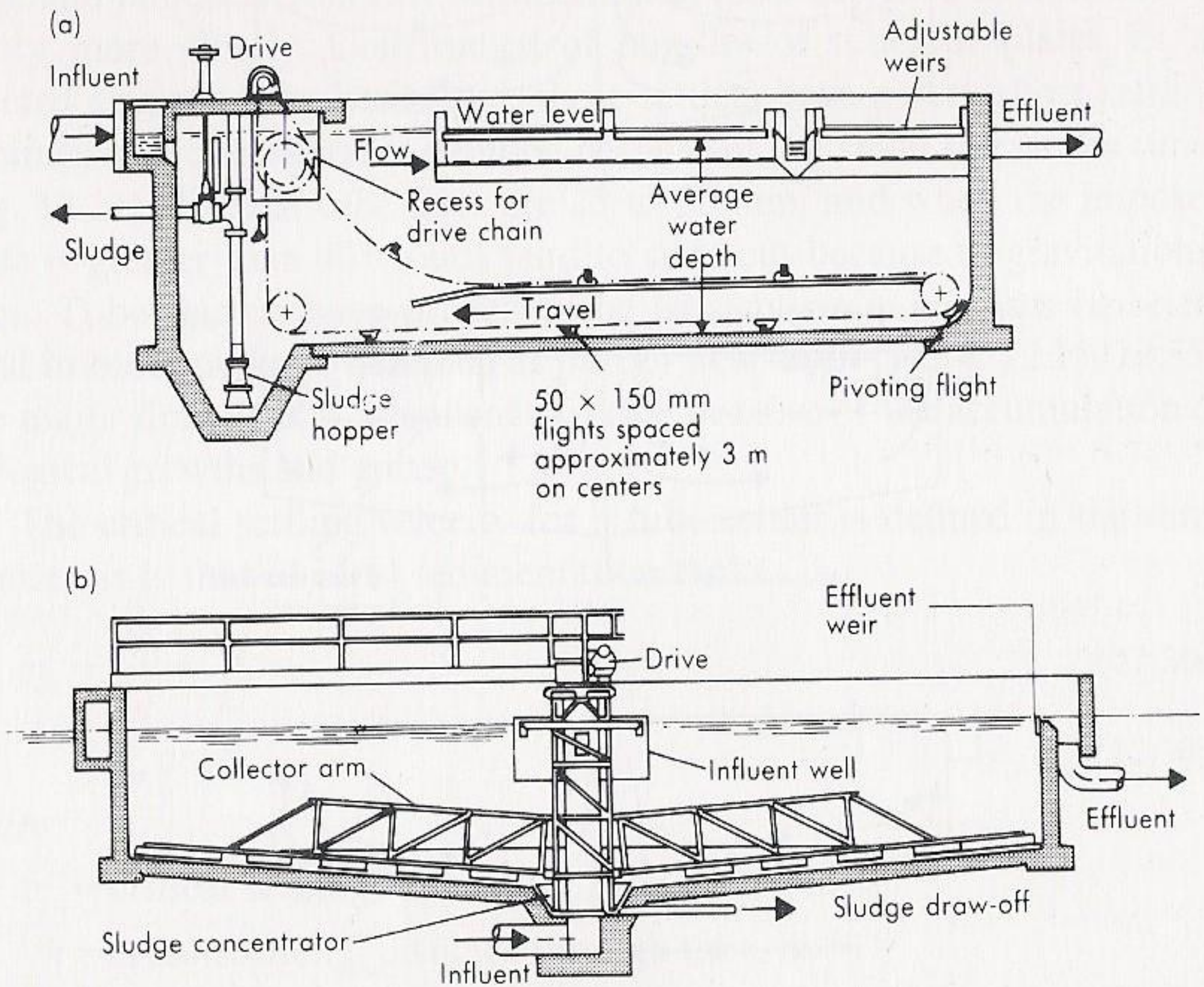


FIGURE 12.19

Typical sedimentation tanks:
circular radial flow.

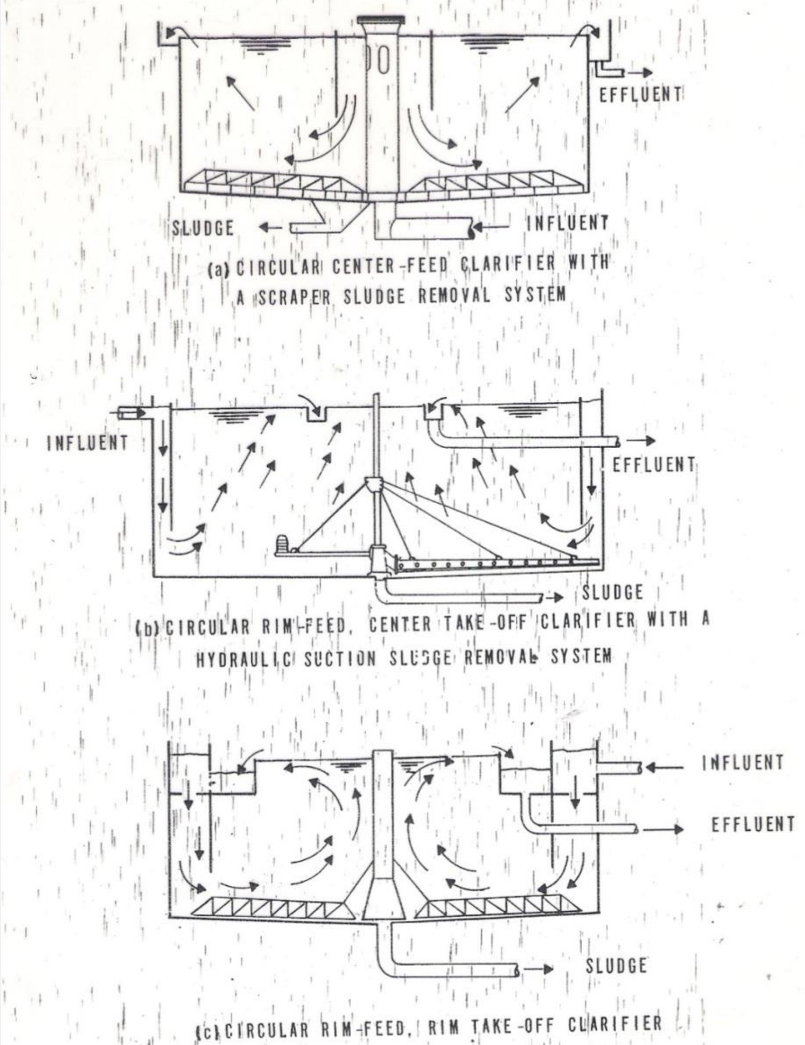


FIGURE 7-2

TYPICAL CLARIFIER CONFIGURATIONS

Outlet Zone

weir channels are used

Checked by weir loading (m^3/m.day) $\frac{Q}{L}$

Large weir loading → resuspension of particles settled near to effluent launders

Effluent weirs → placed as far from the inlet as possible to increase weir length (i.e to decrease weir loading)→ double-sided weirs can be used

Typical weirs → 90^o V notch metal plates bolted onto the effluent collection through

May be placed

→ **at the opposite and of the rectangular basins**

through the entire width of tank

through the length of the tank

if the weir loading causes the required weir length to be greater than tank width

the channel may be extended to a length of 1/3 the basin length (Reynolds)

→ **around the perimeter of center – feed circular tanks**

→ **at the center of peripheral feed circular tanks**

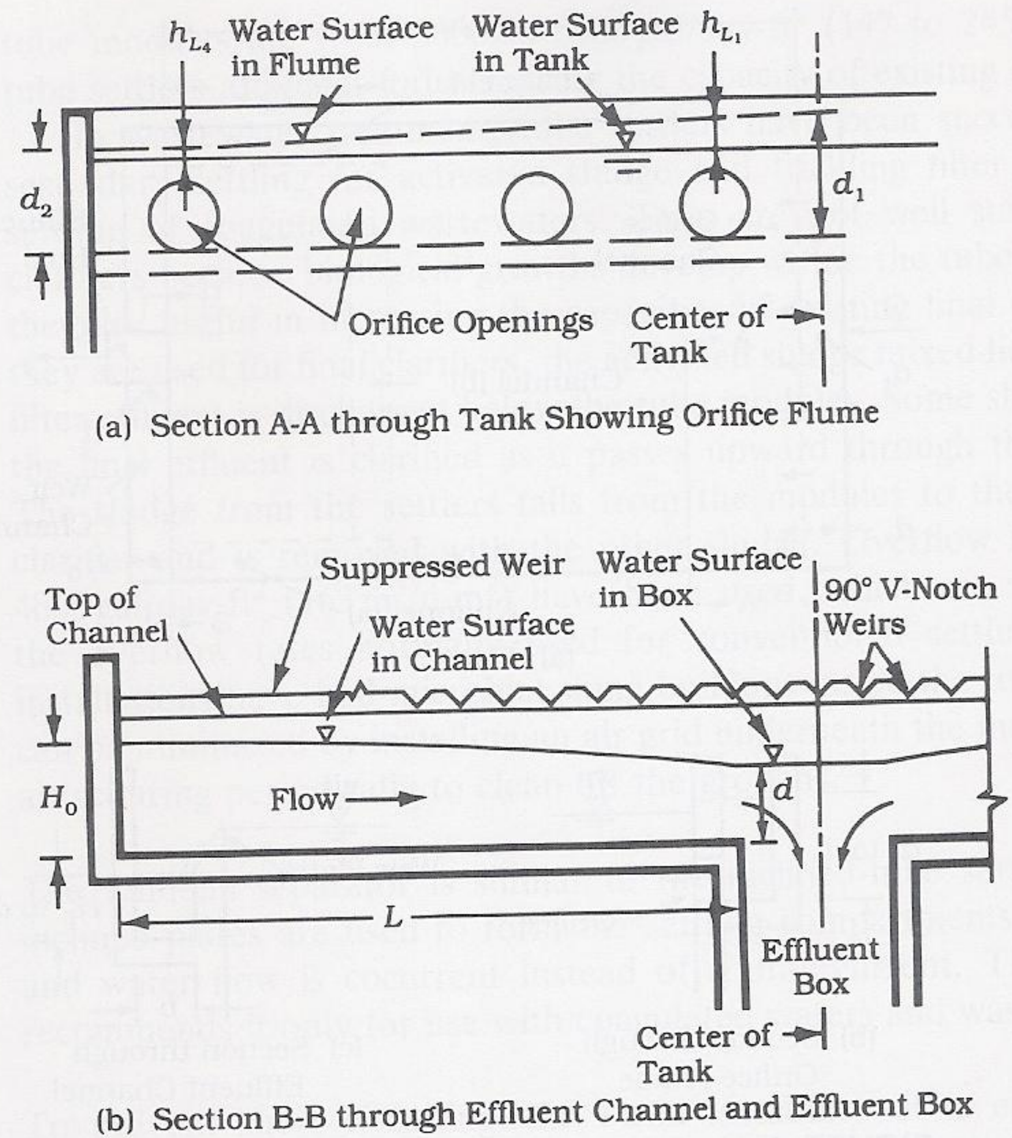


FIGURE 9.45 *Sections through Orifice Flume and Effluent Channel*

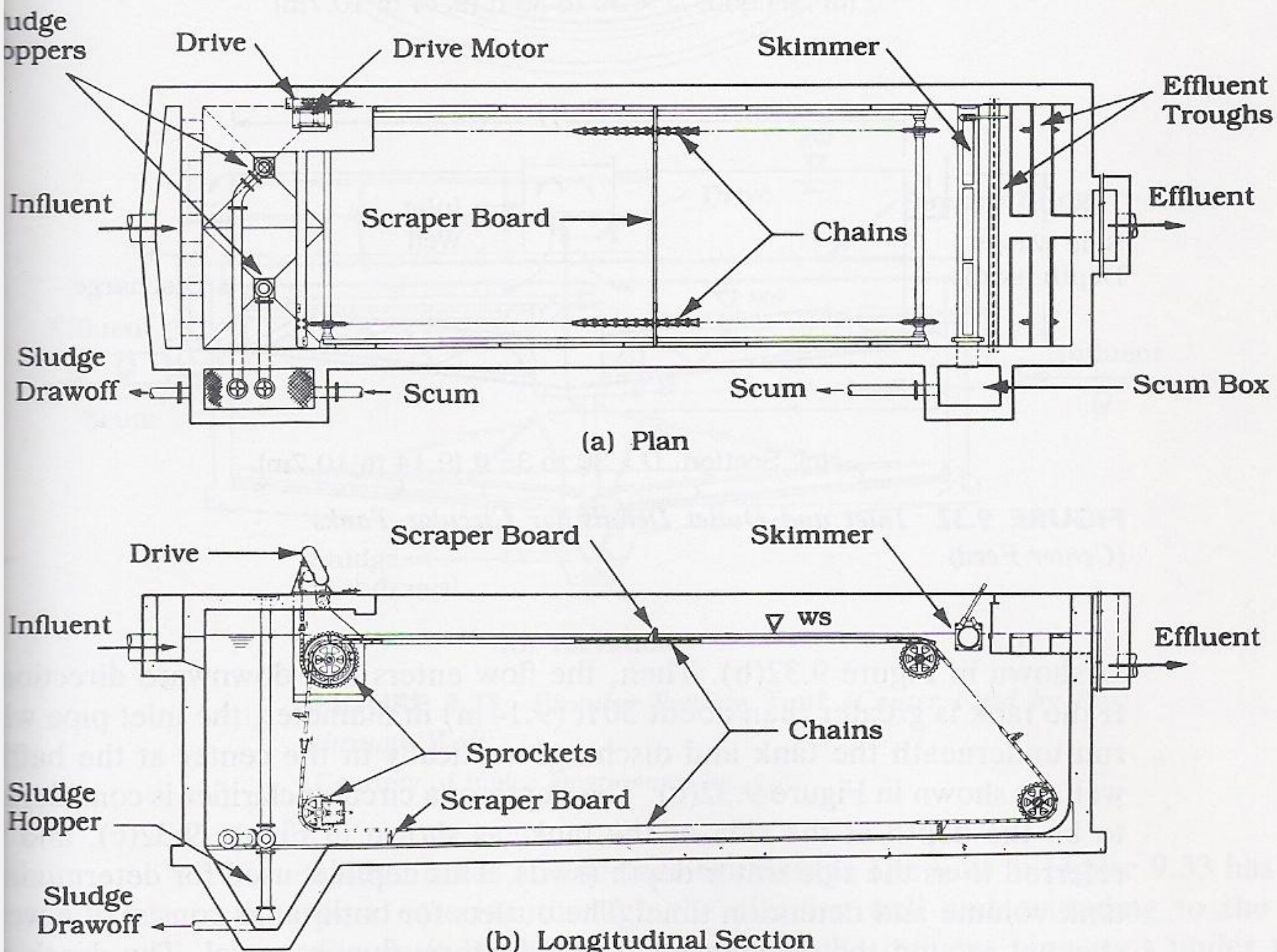
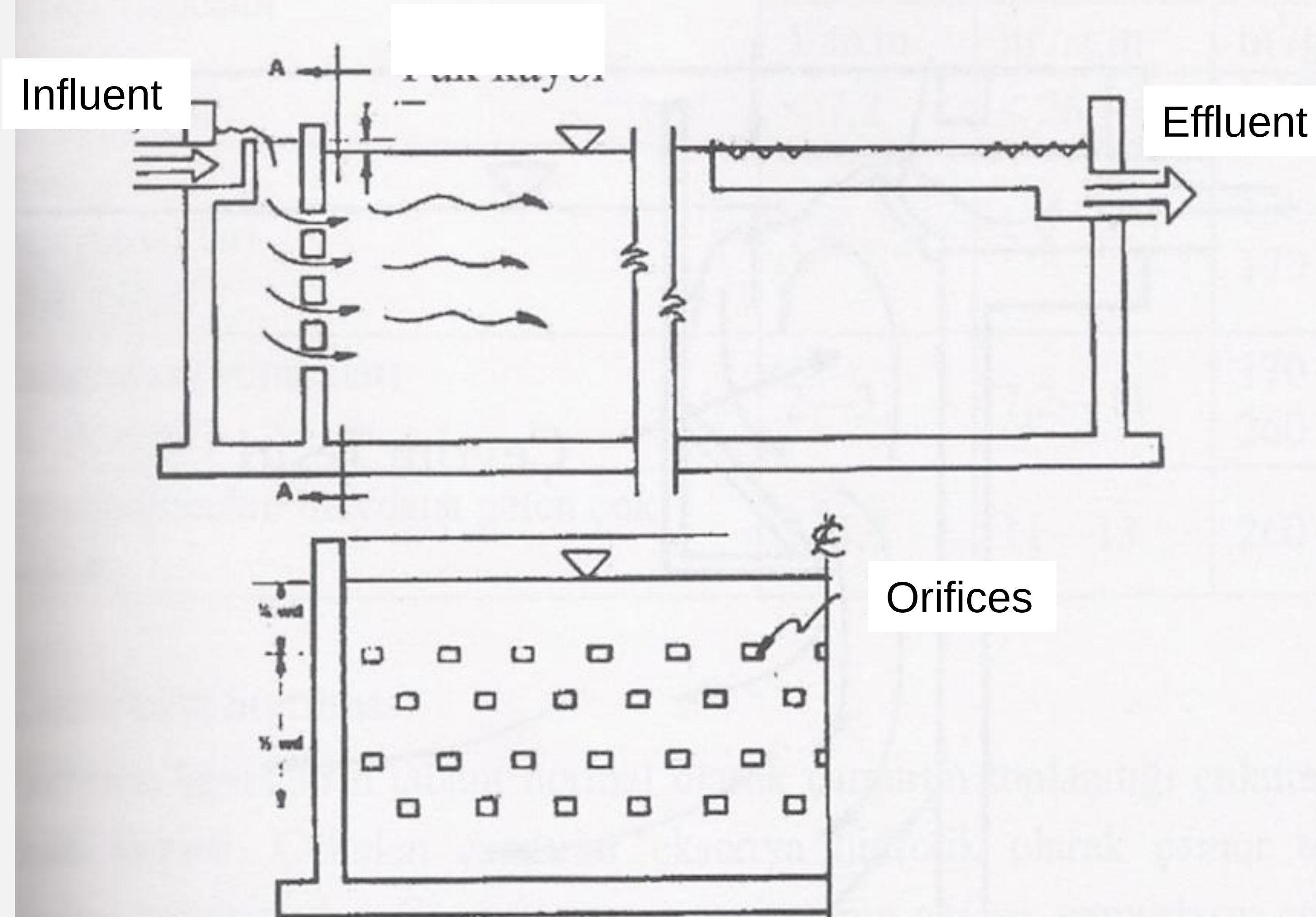


FIGURE 9.31 *Rectangular Settling Tank*

Courtesy of Walker Process Equipment, Division of McNish Corporation.


Influent
Effluent
A
A
Orifices

Sedimentation Facilities

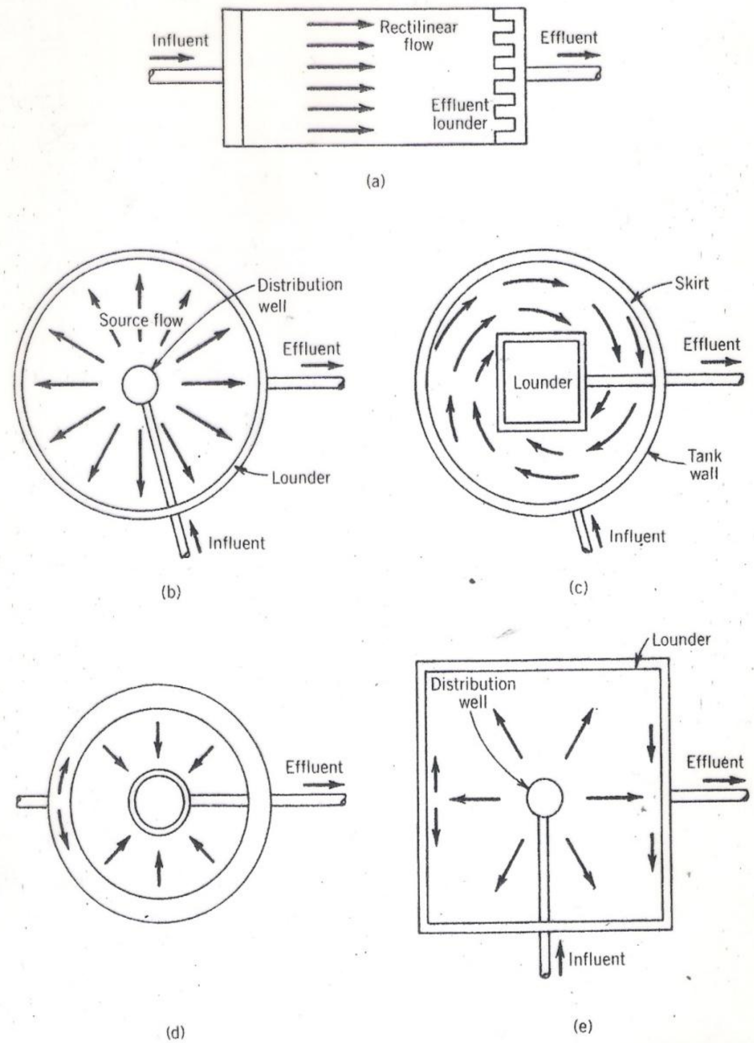


FIGURE 21-22. Flow patterns in sedimentation tanks: (a) Rectangular settling tank; (b) center feed, source flow; (c) peripheral feed, spiral flow; (d) peripheral feed, radial flow; (e) square, radial flow. (Reprinted from *Water Treatment Plant Design*. Copyright 1969, American Water Works Association, Inc.)

Figure 3.31. Inlet and Outlet Details for a Circular Tank (Peripheral Feed) (Reynolds, 1982)

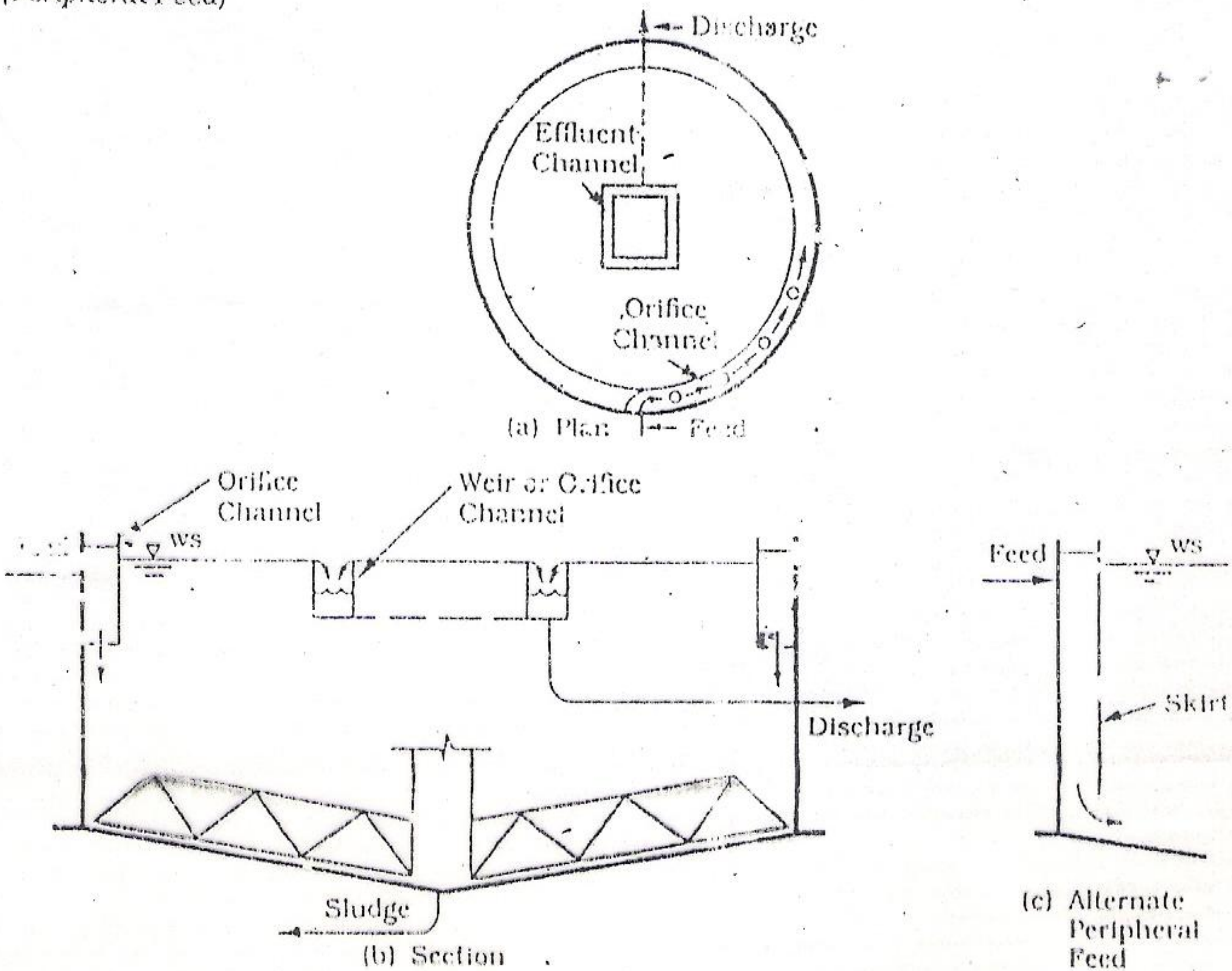


TABLE 12.4

Typical Dimensions of Sedimentation Tanks

	VALUE	
	Range	Typical
Rectangular		
Depth, m	3–5	3.5
Length, m	15–90	25–40
Width, m	3–24	6–10
Circular		
Depth, m	3–5	4.5
Diameter, m	4–60	12–45
Bottom slope, mm/m	60–160	80

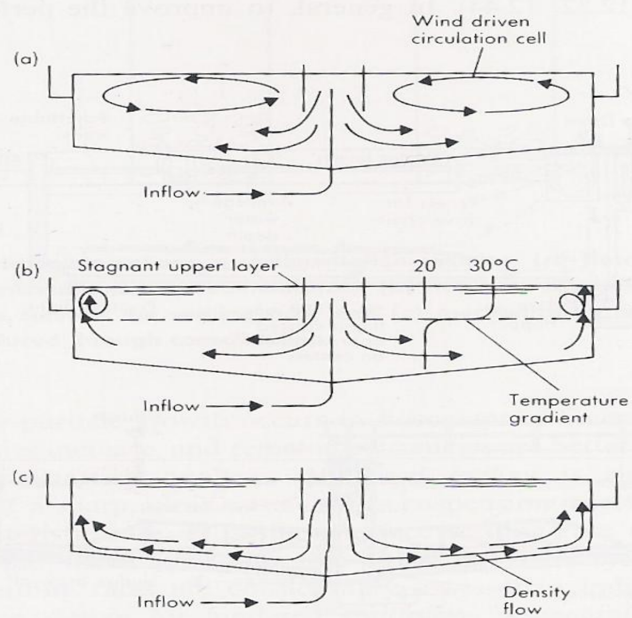


FIGURE 12.20

Nonideal conditions in circular sedimentation tanks: (a) formation of wind-driven circulation cells, (b) thermal stratification, and (c) density currents. To improve the effluent quality, the discharge weir should be placed in the dead zone.





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Example:

Design circular secondary clarifiers for an extended aeration activated sludge system receiving a flow of 250 000 m3/d average, 375 000 m3/d peak flow. The activated sludge system has MLSS concentration of 4160 mg/l. Return activated sludge recycle ratio is 1

Operational problems in secondary clarifiers

1)Bulking sludge

2)Rising sludge

3)Nocardia foam

Bulking sludge

MLSS with poor settling characteristics.

In a bulking sludge condition ,the MLSS floc does not compact or settle well, and floc particles one discharged in the clarifier effluent.

Filamenteous bulking

caused by the growth of filamenteous organisms

predominant form of bulking

low DO, low F/M, complete mixing conditions favor the growth of filamentous organisms

Viscous bulking

caused by an excessive amount of extracellular biopolymer, which produces a sludge with a slimy,jellylike consistency)

Usually found with nutrient limited systems or in a very high loading condition with wastewater having a high amount of rbCOD

Checklist in the control of bulking

1)Wastewater characteristics

The nature of components found in wastewateror the absence of certain components, such as trace elements.

2) DO concentration

Limited DO oxygen

3)Process loading / Reactor configuration

Low F /M, complete mix systems with long SRT

4) Internal plant overloading

Recycle loads

(centrate or filtrate from sludge dewatering, supernatant from digesters)

5) Clarifier operation

Poor settling is a problem in center-feed circular tanks

Where sludge is removed from tank directly under the point where the mixed liquor enters

Sludge may actually be retained in the tank many hours rather than desired retention time $\longrightarrow$ cause localized septic condition

Temporary control measures

$\longrightarrow$ Chlorination of return sludge

for low θ (5 to 10 hr) systems $\longrightarrow$ 0.002 -0.008 $\dfrac{kg\,Cl_2}{kg\,MLSS\,d}$

Good solution:

Use of selectors $\longrightarrow$ specific bioreactor

favors the growth of floc-forming bacteria instead of filamenteous bacteria.

Selectors $\longrightarrow$ high F/M ratio

small tank (20-60 min contact time)

a series of tanks in which the incoming wastewater is mixed with return sludge.

Selectors $\longrightarrow$ kinetics based (high F/M selector)

$\longrightarrow$ metabolic based selectors(anoxic anaerobic)

Kinetics based selectors:

Filamenteous bacteria $\longrightarrow$ more efficient for substrate utilizaiton at low substrate conc.

Floc- forming bacteria $\longrightarrow$ have higher growth rates at high soluble substrate concentration

A series of reactors at relatively low θ values is used to provide high soluble substrate conc.

Metabolic based selectors:

Anoxic or anaerobic metabolic conditions

favor growth of floc-forming bacteria.

Filamenteous bacteria can not use NO_2 , NO_3 for an electron acceptor

yielding a significant advantage to denitrifiying floc-forming acteria

Filamenteous bacteria do not store polyphosphate

can not consume acetate in the anaerobic contact zone giving an advantage for substrate uptake and growth to PAOs

Rising Sludge

Sludge that has good settling characteristics will be observed to rise or float to the surface after a relatively short settling period

The most common cause $\longrightarrow$ Denitrification

As N_2 gas is formed in the sludge layer sludge mass becomes buoyant and rises or floats to the surface.

Rising Sludge (continue)

Rising sludge can be differentiated from bulking sludge by noting the presence of small gas bubbles attached to the floating solids.

Common in short SRT systems where the temperature encourages the initiation of nitrification and the mixed liquor is very active due to low θ_c .

Rising sludge problem may be overcome by :

- Increasing the RAS withdrawal rate from the clarifier to reduce the detention time of sludge in clarifier.
- Increasing speed of the sludge collecting mechanism in settling tank.
- Decreasing the SRT to bring the active sludge out of nitrification
- Pre-anoxic (Anoxic → Aerobic) process is preferred for denitrification

Nocardia Foam

Two bacteria genera → Nocardia

→ Microthix parcivella

are associated with extensive foaming in activated sludge process

These organisms have hydrophobic cell surfaces and attach to air bubbles, where they stabilize the bubbles to cause foam

More pronounced with diffused air systems.

Methods that can be used to control Nocardia foam :

- avoiding trapping foam in the secondary treatment process
- avoiding the recycle of skimmings into the secondary treatment process.
- using chlorine spray on the surface of the nocardia foam.
- addition of small conc of cationic polymer.
- reducing the oil and grease content from discharges to collection systems from restaurant etc.