ENVE 301
Environmental Engineering Unit Operations

Lecture 13
High Rate Settlers

SPRING 2014

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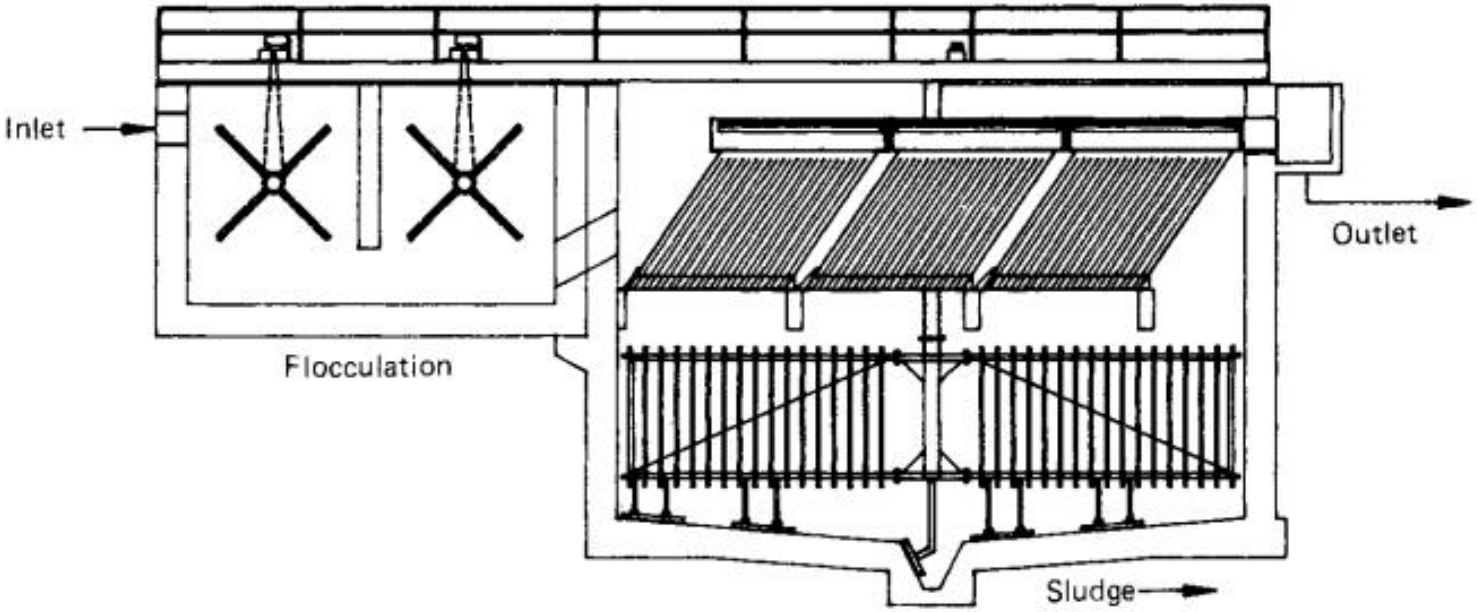
High Rate Clarification

- Refers to all processes that can be loaded at higher rate than its typically used in conventional clarifiers.
- Principal types of units used:
  - Tube settlers
  - Plate settlers
  - Solids contact units
  - Sludge blanket clarification
  - Dissolved air floatation
  - Contact clarification

Inclined Settlers

- Equal flow distribution in each channel is very important



Ref: American Water Works Association. Water Quality and Treatment: A handbook of community water supplies. 5th ed. McGraw Hill, 1999

Inclined Settlers

- Counter Current Settlers:
  - Suspension is fed below the settling modules
  - Suspension flow is up the channels
  - Solids settle onto the lower surface in each channel
  - If the angle is sufficient, solids move down the surface counter to the flow of liquid
  - Tube settlers are mostly counter current

Inclined Settlers

- Cocurrent Settlers:
  - Suspension is fed above the settling modules
  - Settled solids move down the surface in the same direction as the liquid
- Cross Flow Settlers:
  - Suspension flows horizontally between the inclined surfaces
  - Settled solids move downwards
  - Resuspension of settled solids is a less concern compared to that of Countercurrent or cocurrent settlers

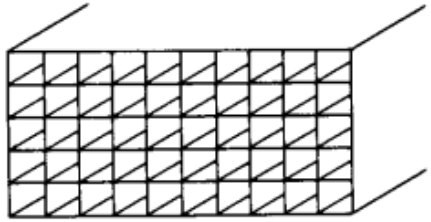
High Rate Settlers

- High rate settler units (tubes, plates etc) achieve effective settling in detention times less than 20 min (conventional sedimentation tank ~ 2 h)
- Existing sedimentation tanks can be modified to include such units

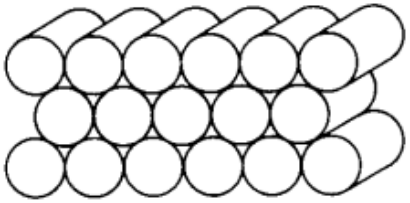
Tube Settlers

- Theoretically shallow basin should be effective in terms of settling efficiency (short settling distance)
- Shallow, parallel tubes increase surface area and reduce settling distance
- Tubes are placed at 50° - 60°→ efficient settling, self cleaning of surfaces occur
- Typical separation distance between inclined surfaces = 50 mm, with an inclined length of 1-2m

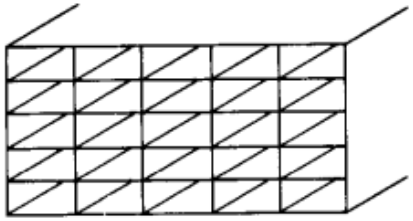
Tube Settlers



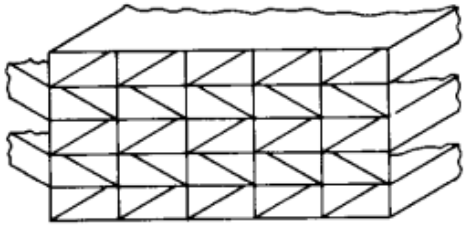
Square tubes



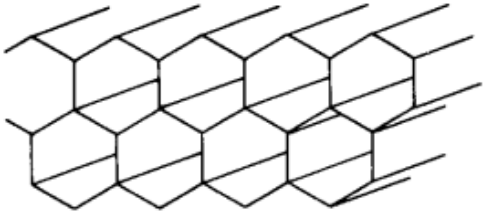
Tubes



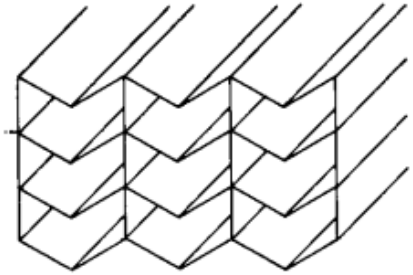
Rectangular tubes



Rectangular, layers alternating direction



Hexagonal



Chevron

FIGURE 7.21 Various formats for tube modules.

Ref: American Water Works Association. Water Quality and Treatment: A handbook of community water supplies. 5th ed. McGraw Hill, 1999

Inclined Settlers

- Counter Current Settlers:
  - Suspension is fed below the settling modules
  - Suspension flow is up the channels
  - Solids settle onto the lower surface in each channel
  - If the angle is sufficient, solids move down the surface counter to the flow of liquid
  - Tube settlers are mostly counter current

Tube Settlers – Desing Criteria

- Designed based on the total projected surface area of tubes
- Surface loading rate of 1.2 m/h for aluminum, iron based coagulants (range from 1-2 m/h)
- Inlet conditions:
  - Turbulence causes uneven flow distibution to the tubes
  - Sludge falling from the tubes must be able to settle to the tank bottom (high velocities cause high shear)

Tube Settlers – Desing Criteria

- Inlet conditions:
  - To avoid turbulence stilling zone of 25% of the total basin area should be left (stilling zone: distance between the inlet and the settlers)
  - A minimum depth of 3 m should be left below the tubes
- Effluent Design:
  - A clear space of 2-3 m above the tubes must be provide
  - Launders should be spaced less than 1.5m centers
- Solids removal:
  - Solids can be removed with same type of equipment as used in the conventional sedimentation unit

Plate Settlers

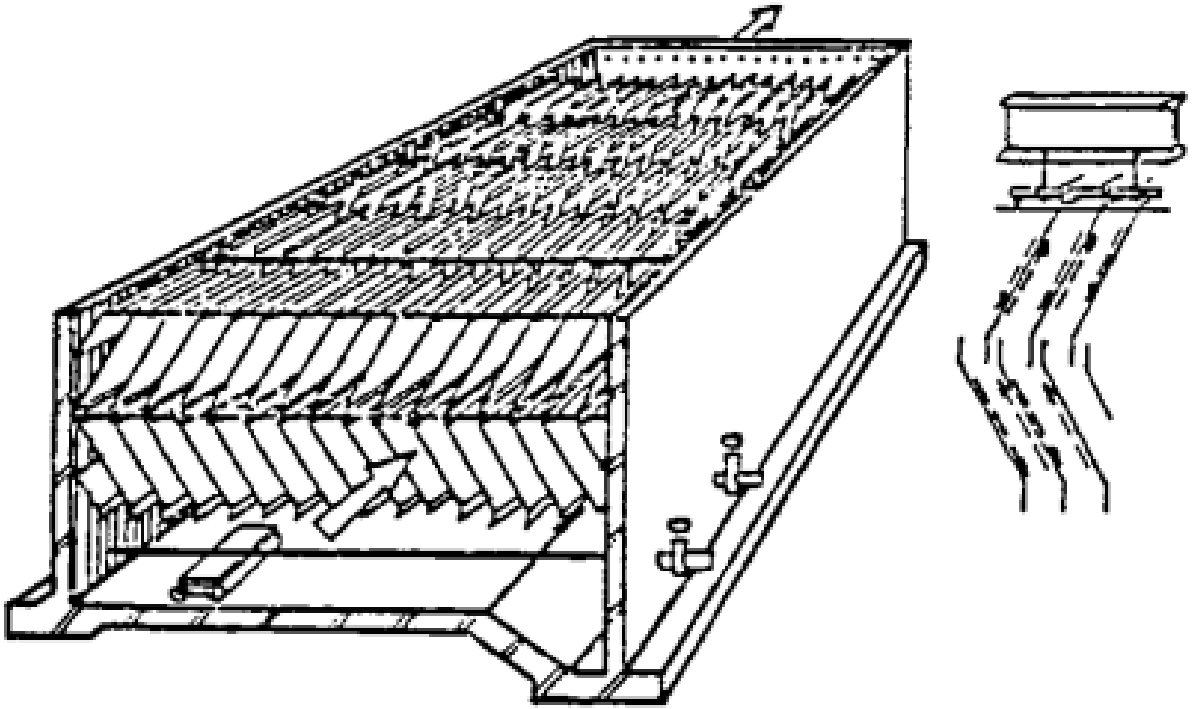
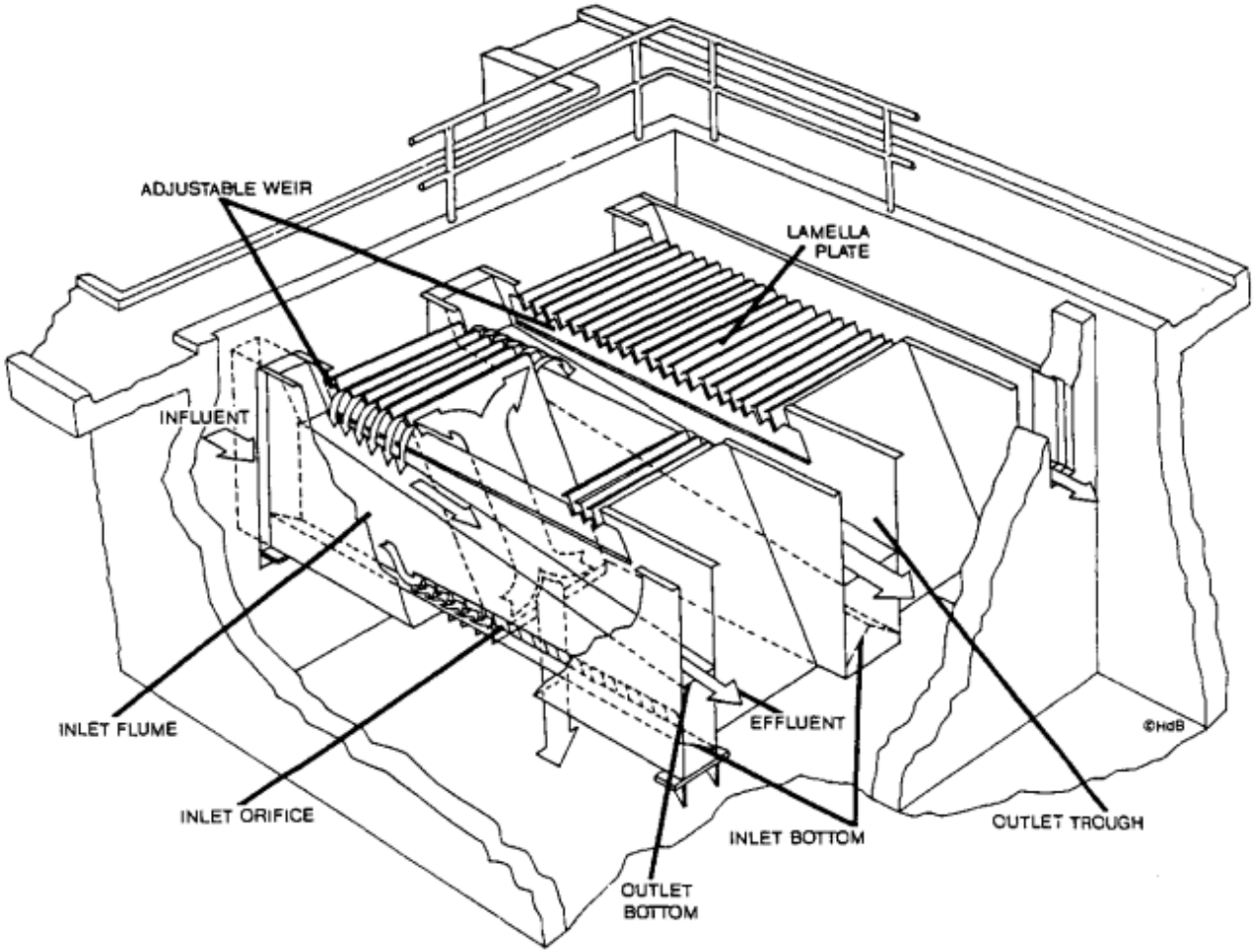


FIGURE 7.22 Alternating cross-flow lamella settler. [*Source:* Gomella, Co. Clarification avant filtration; ses progres recents (Rapport General 1). Int'l Water Supply Assoc. Int'l Conf., 1974.]

Ref: American Water Works Association. Water Quality and Treatment: A handbook of community water supplies. 5th ed. McGraw Hill, 1999

Plate (Lamella) Settlers



Ref: American Water Works Association. Water Treatment Plan Desing 4th ed. McGraw Hill, 1998

Plate (Lamella) Settlers

- Typical Loading rates range from 0.7-1.7 m/h, which corresponds to 5-15 m/h for overall basin loading
- Cocurrent flow is applied
- Inlet distribution is critical
- Launders should be placed on the order of 1.8 m
- Submerged orifices should be designed to create headloss– to enable good flow distribution
- Orifice velocity of 46-76 cm/s is adequate
- Chain and flight or bottom tract units are generally used for sludge collection

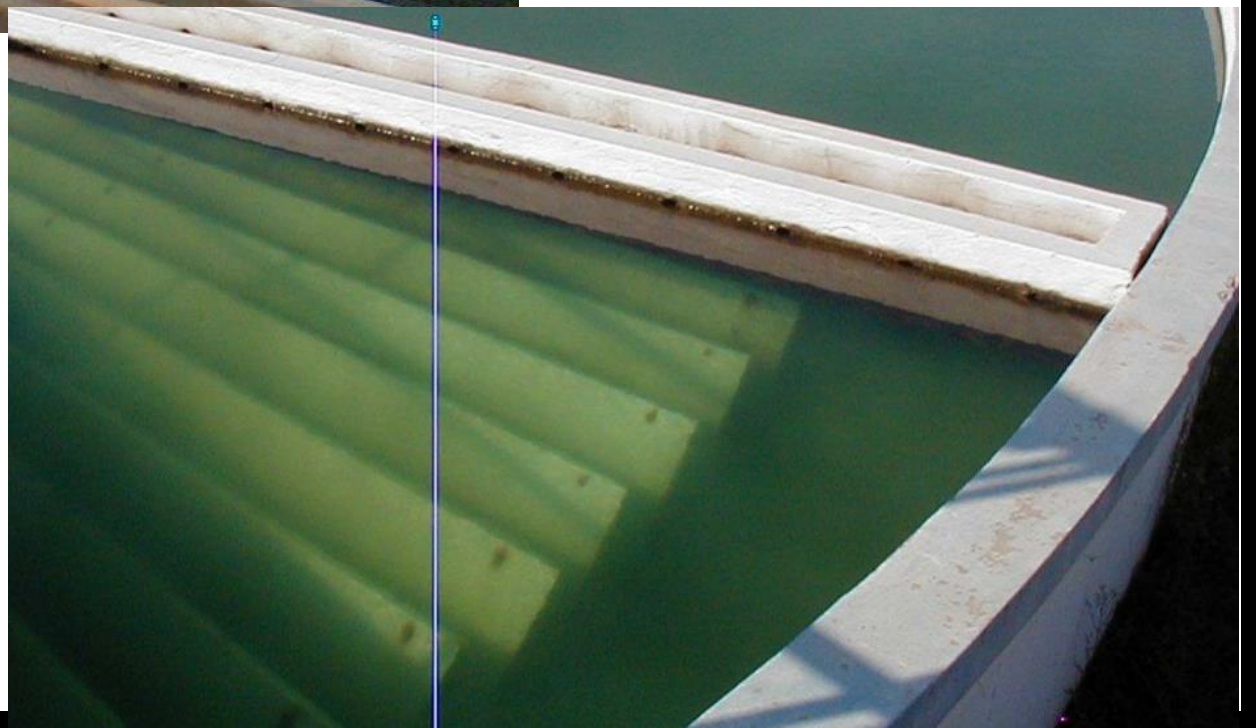


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TABLE 10-6
Typical design criteria for high-rate settler modules

Parameter	Typical range of values	Comment
Inlet zone		
Distance to diffuser	≤ 2 m	
Diffuser hole diameter	0.10–0.20 m	
Settling zone		
Overflow rate	60–180 $m^3/d \cdot m^2$	Alum floc
Side water depth (SWD)	3–5 m	
Length	60 m	Chain-and-flight
Width	0.3 m increments	Chain-and-flight
	6 m maximum per train	Chain-and-flight
	24 m maximum = 3 trains per drive	Chain-and-flight
Settler		
Fraction of basin covered	< 0.75	For plates ≤ 0.95
Height	0.5–2.0 m	For plates ≥1.0 m
Plate angle	≥55°	
Tube angle	≥60°	
Tube hydraulic diameter	0.05–0.08 m	
Tube velocity	0.0025–0.0033 m/s	
Approach velocity	0.010 m/s	Horizontal, mean
Reynolds number	< 50	
Froude number	$> 10^{-5}$	
Outlet zone		
Launder length	Equal to length of settler	
Launder spacing	1.5 m on centers	
Launder elevation	0.6–1.0 m above top of settler	For plates = to top
Launder weir loading	< 300 $m^3/d \cdot m$	
Sludge zone		
Depth	0.6–1 m	Equipment dependent
Slope	1:600	Mechanical cleaning
Sludge collector speed	0.3–0.9 m/min	

Sources: Kawamura, 2000, MWH, 2005, Willis, 2005.

Ref: Davis M.L. *Water and Wastewater Treatment: Design Principles and Practice*. 2010. McGrawHill

Upflow Clarifiers (Solids Contact Units)

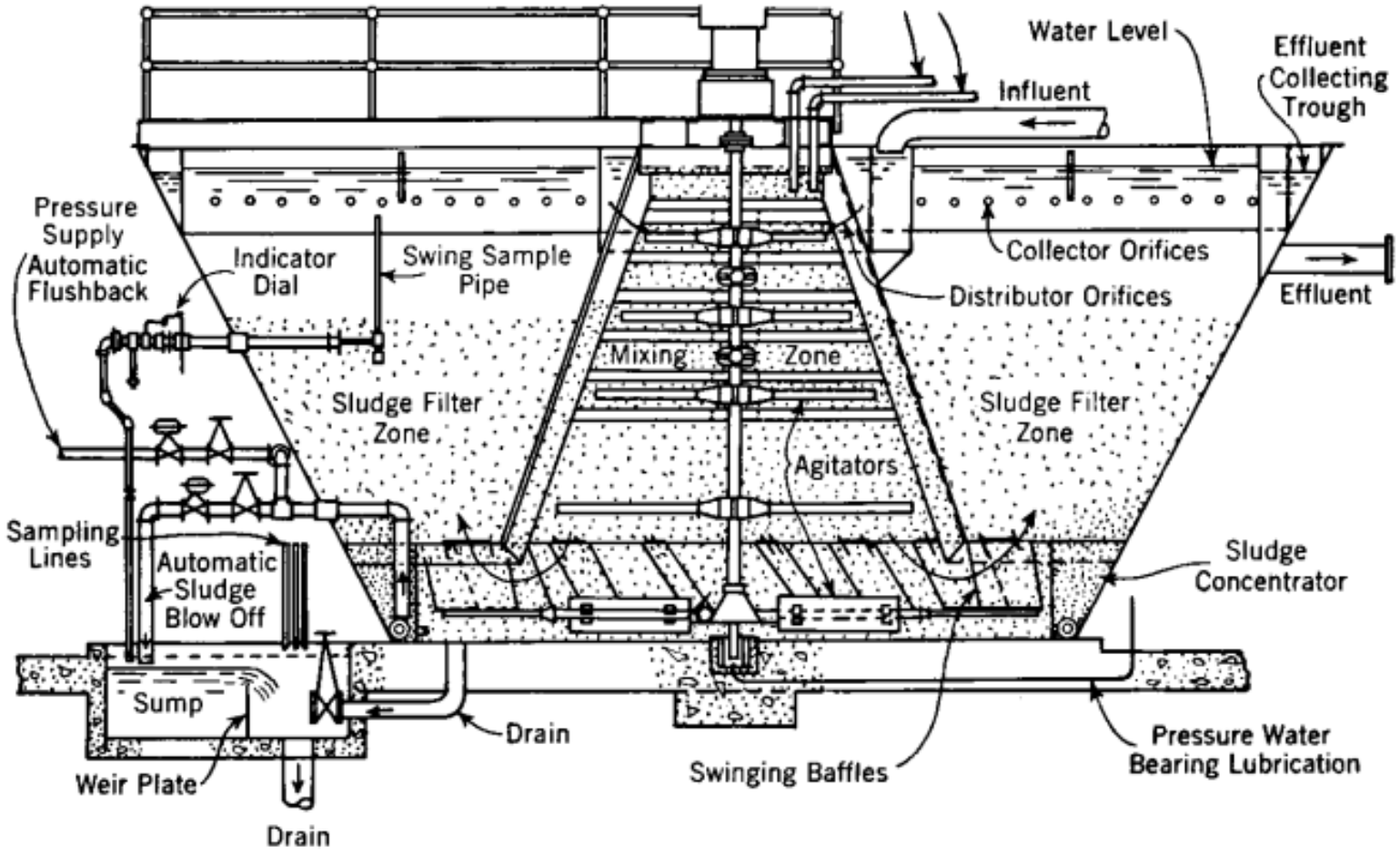
- Flocculation and sedimentation takes place in a single unit
- Some units operate with chemical feed directly into the pipe
- Upflow solids contact clarifiers combine; mixing, coagulation, flocculation, liquid/solid separation, sludge removal in a single tank
- Two types of solids contact units
  - Premix
  - Premix-recirculation

Upflow Clarifiers

- Types of Upflow Clarifiers
  - Solids Contact
  - Sludge Blanket

- Two types of solids contact units
  - Premix
  - Premix-recirculation

Premix Solids Contact Unit



Ref: American Water Works Association. Water Quality and Treatment: A handbook of community water supplies. 5th ed. McGraw Hill, 1999

Premix-Recirculation Solids Contact Unit

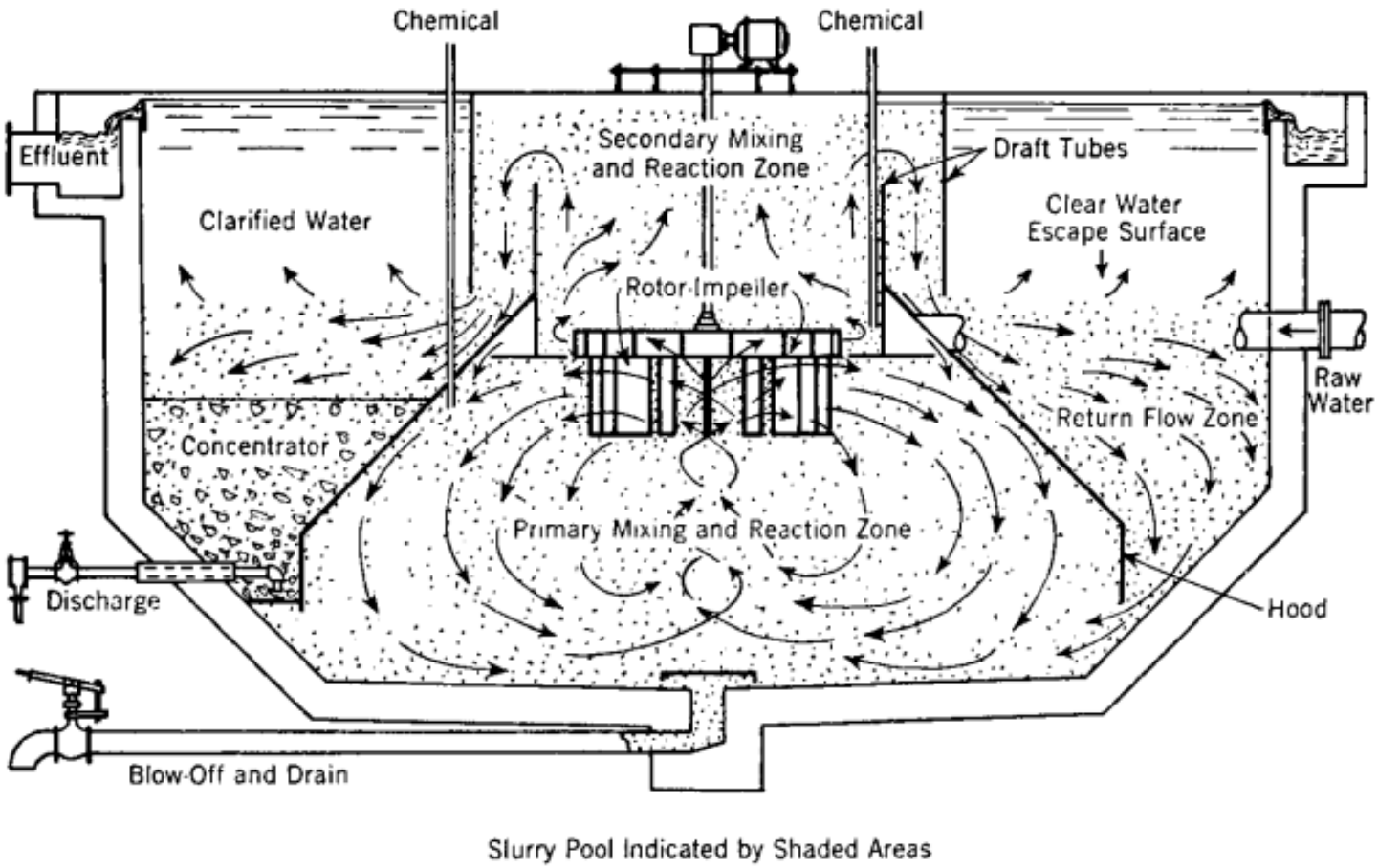


FIGURE 7.23 The Accelator solids contact clarifier. (*Source:* Hartung, 1951.)

Ref: American Water Works Association. Water Quality and Treatment: A handbook of community water supplies. 5th ed. McGraw Hill, 1999

Solids Contact Units – Design Criteria

- Surface loading rates: 1.2-3.7 m/h
- Flocculation contact zone: 30 min detention time
- To provide good flow distribution units are **circular** and have a diameter up to 46 m
- Launders designed with low loading rates (248L/min/m). Spacing is about 4.6-6.1m
- Rakes are used for solids removal

Sludge Blanket Clarification

- Variation of solids contact clarifier
- Flocculated water flows up through a blanket of previously formed solids
- Blanket depth should be 0.5-1m
- When blanket depth reaches the design depth, portion of the blanket next to the hopper settles into the hopper.
- Sludge is periodically removed from the hopper by gravity

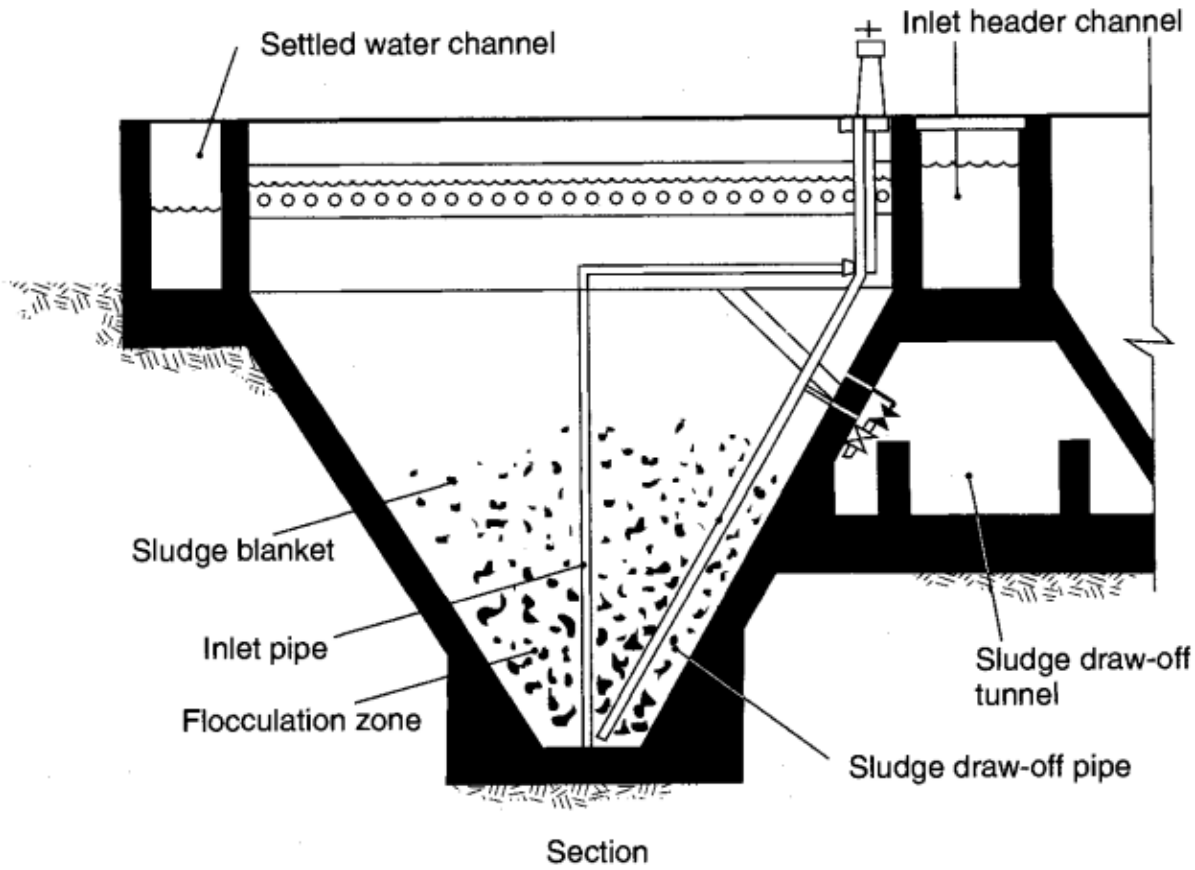
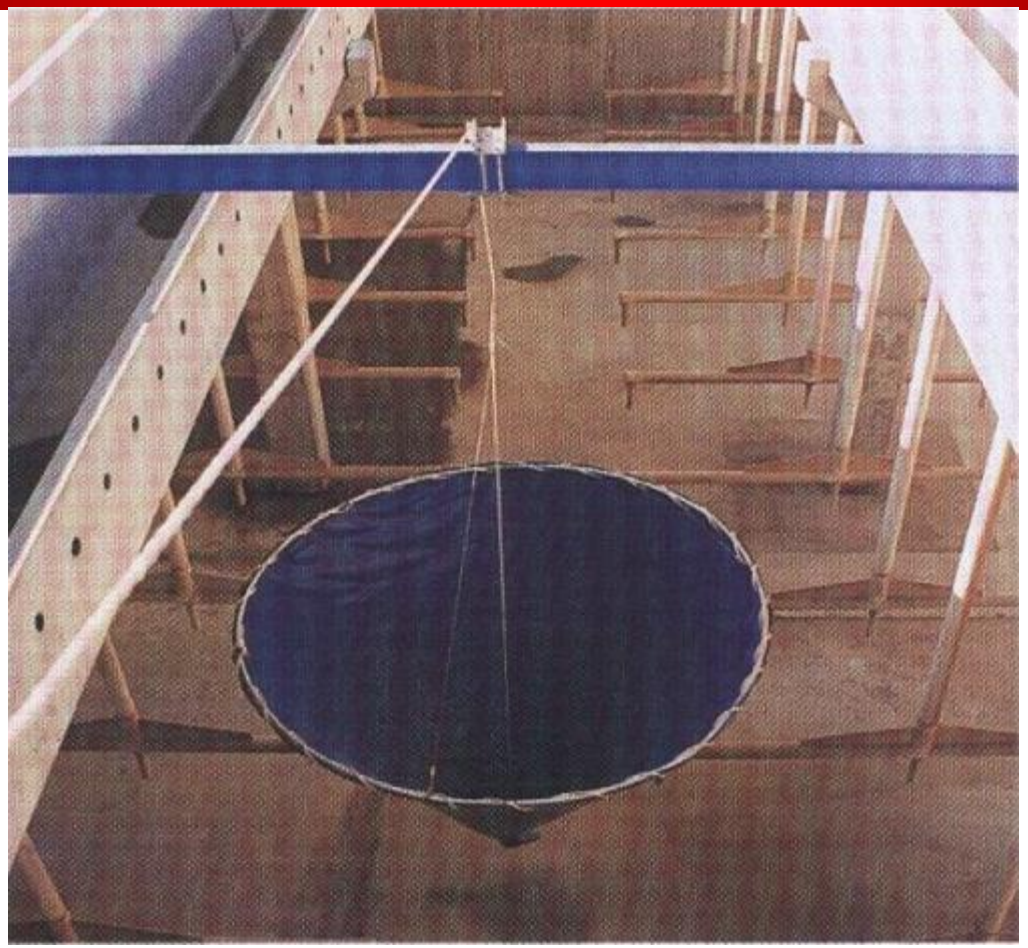


FIGURE 7.19 Pyramid-type sludge blanket clarifier. (*Source: Monk and Willis, 1987.*)

Ref: American Water Works Association. Water Treatment Plan Desing 4th ed. McGraw Hill, 1998



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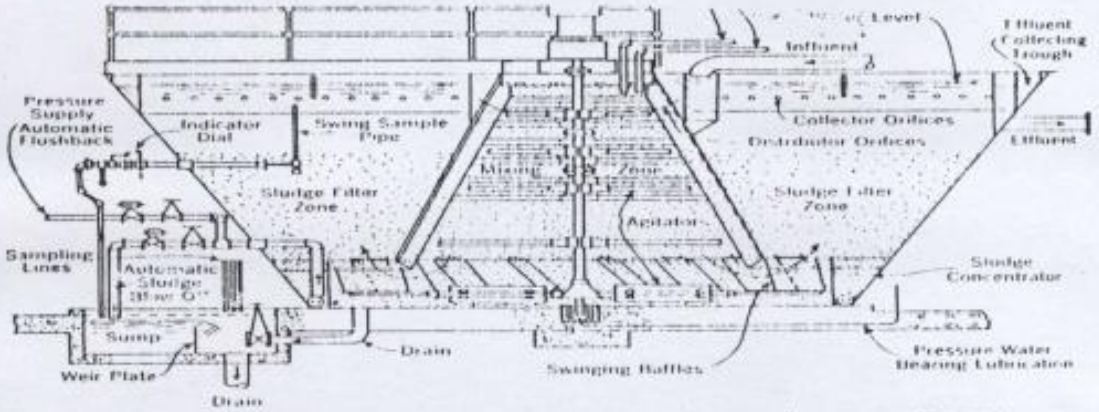
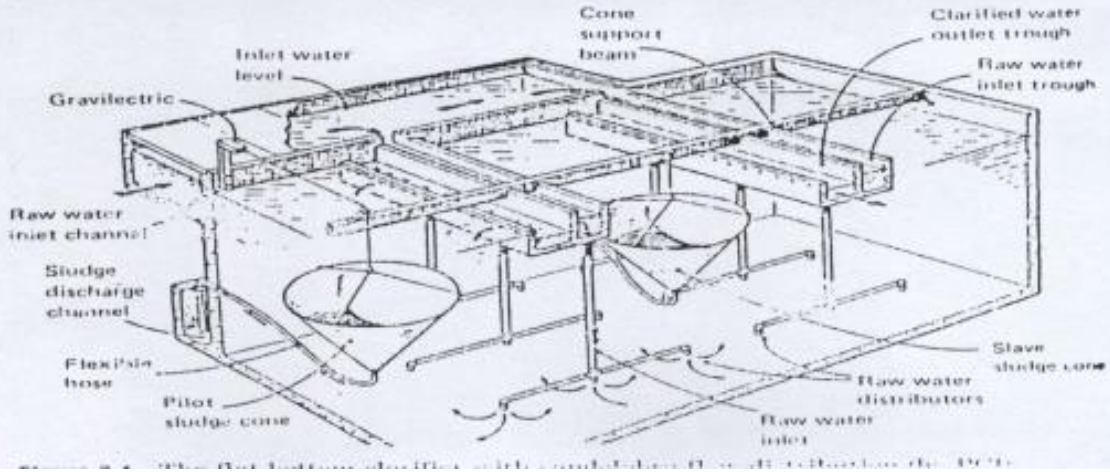
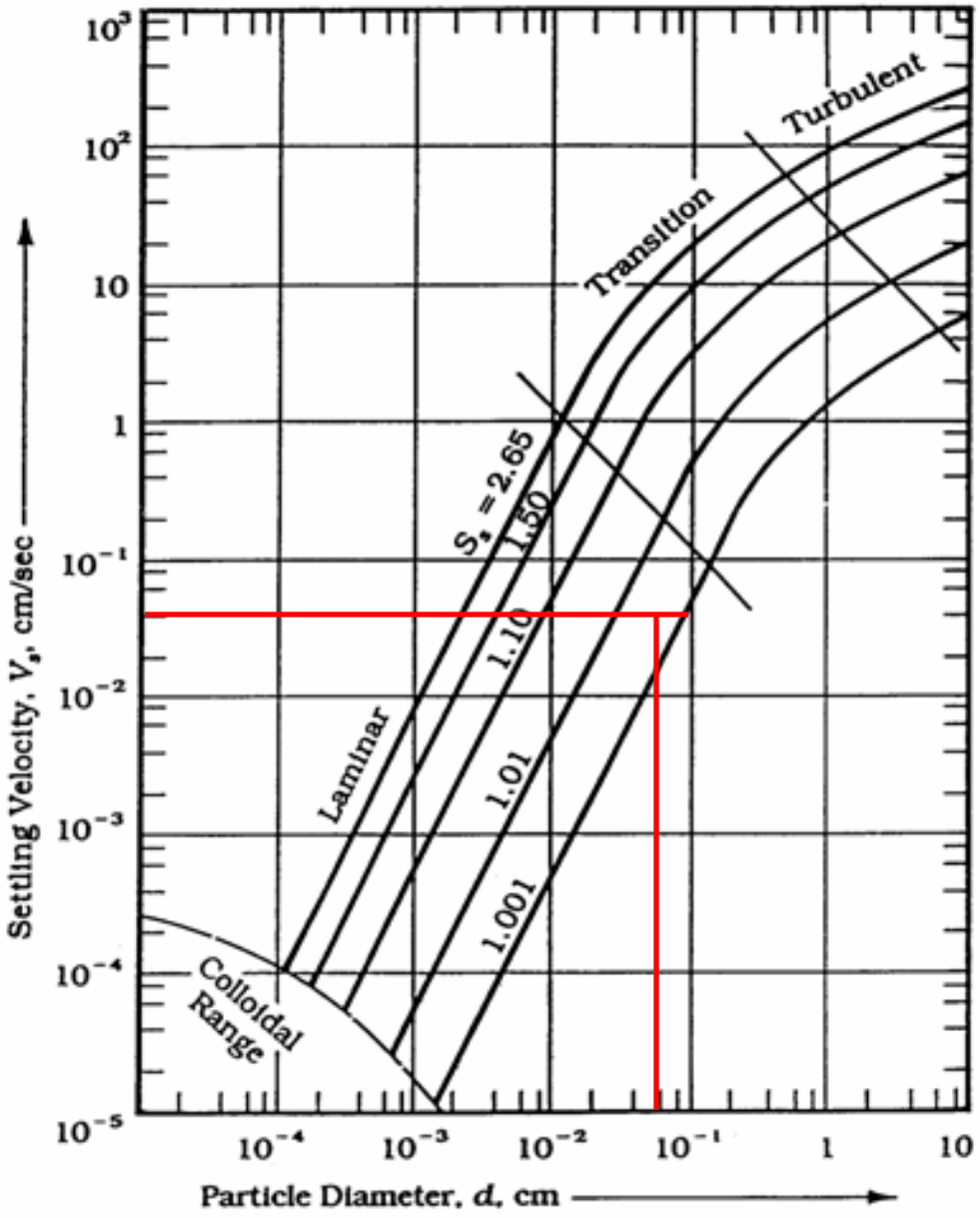


Figure 7.3 The Spaulding Precipitator solids-contact clarifier." (*Source: H. O. Hartung, Committee Report: Capacity and Loadings of Suspended Solids Contact Units, Journal AWWA, vol. 43, no. 4, April 1951, p. 268.*)



Problem session



Ref: Reynolds, T. D., and P. A. Richards. Unit Operations and Processes in Environmental Engineering. 2nd ed. Boston, MA: PWS Publishing Company, 1996.