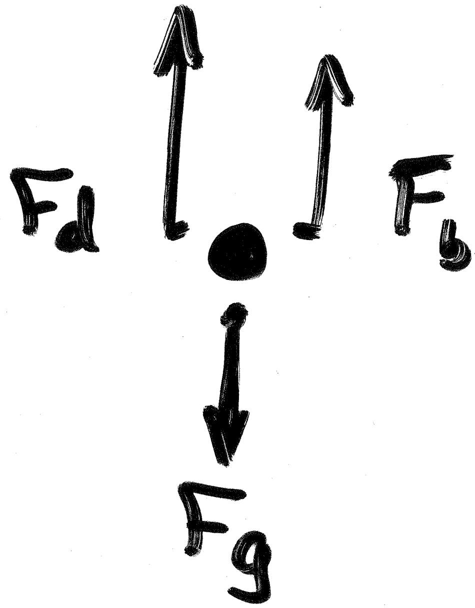
SEDIMENTATION



TERMINAL VELOCITY:

Balance among forces

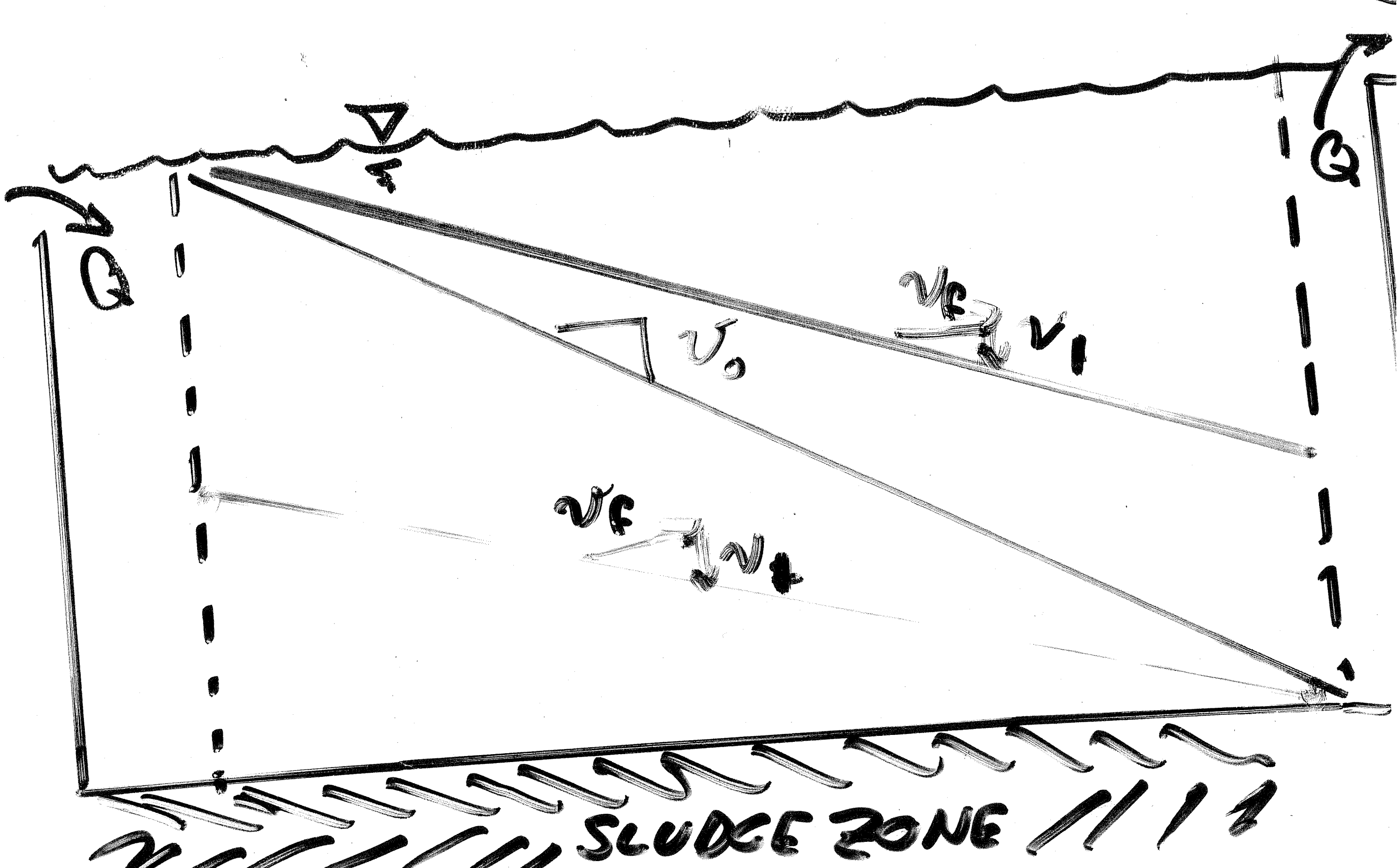
$$v_s = \left(\frac{4}{3} \frac{g d}{C_D} \left(\frac{\rho_p - \rho}{\rho} \right) \right)^{\frac{1}{2}} \quad \text{(Eq. 11.10)}$$

For $Re < 0.5$, $C_D = 24/Re$

Can substitute & simplify:

$$v_s = \frac{g(\rho_p - \rho)\, d^2}{18 \mu} \quad \text{STOKES LAW}$$

TYPE I: DISCRETE SETTLING



PLUG FLOW, DISCRETE SETTLING, CF

$$t_d = \frac{V}{Q} \quad \leftarrow \text{Tank (Vol.)} \qquad v_f = \frac{Q}{A_{xs}} = \frac{Q}{B \cdot H}$$

Must Travel Length: $L = v_f t_d$

" " Depth $H = v_0 t_d$

$$t_d = \frac{L}{v_f} = \frac{H}{v_0}$$

$$\frac{1}{v_0} = \frac{L}{H} \cdot \frac{1}{v_f}$$

$$\rightarrow v_0 = v_f \frac{H}{L} = \frac{Q}{BH} \cdot \frac{H}{L} = \frac{Q}{BL} = \frac{Q}{A_s}$$

SURFACE LOADING RATE

"OVERFLOW RATE"

$$V_0 = \frac{Q}{A} \tag{10.16}$$

A/K/A
- SURFACE SETTLING RATE
- SURFACE LOADING RATE

V_0 = overflow rate, gpd/ft² (m³/m²·d)
Q = average daily flow, gpd (m³/d)
A = surface area of the clarifier, ft² (m²)

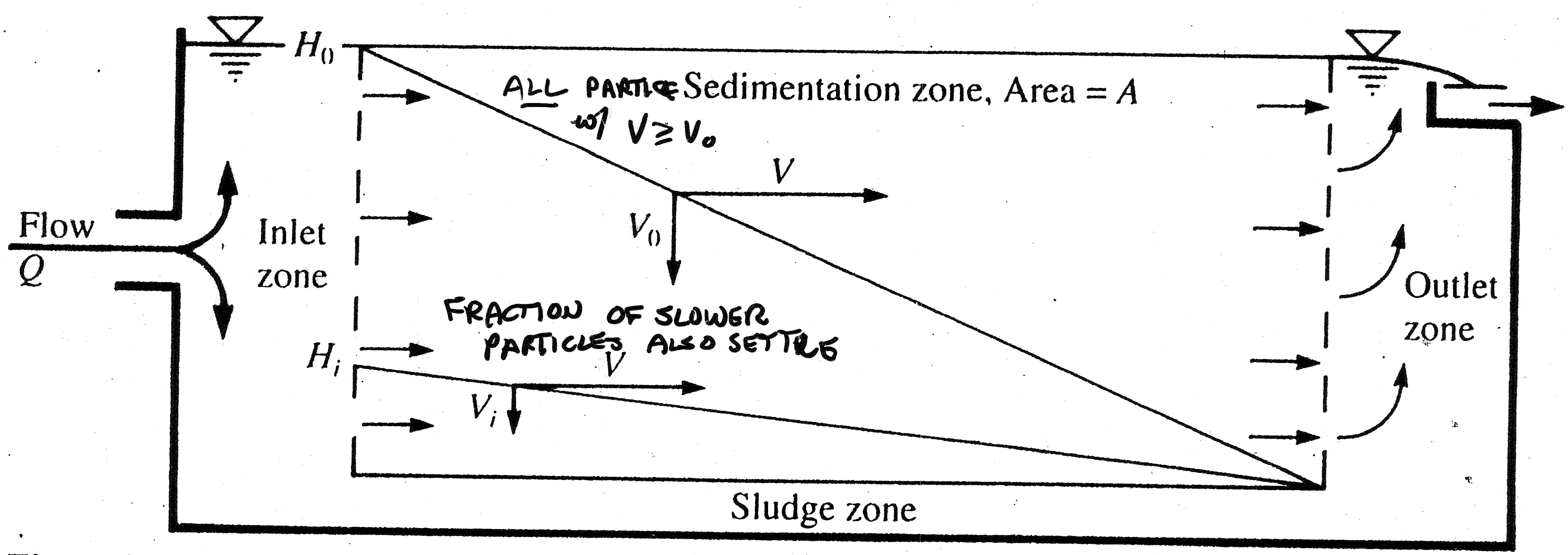


Figure 10.15 An ideal rectangular clarifier settling discrete particles with an overflow rate of $V_0 = Q/A$.

$v < v_0$ ← PARTICLES SLOWER SETTLING THAN v_0

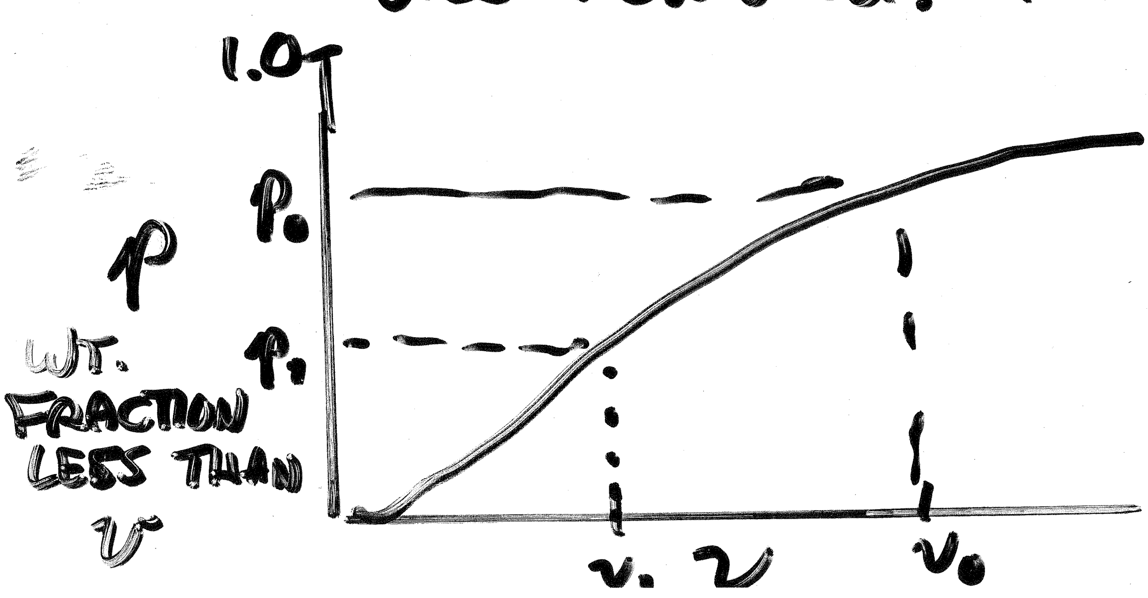
$$h = v t_d$$

$$\frac{h}{H} \leq \frac{v}{v_0}$$ ← SOME FRACTION OF SLOWPOKES STILL REMOVED

FRACTIONAL REMOVAL OF PARTICLE w/ velocity v : $r = \frac{h}{H} = \frac{v}{v_0}$

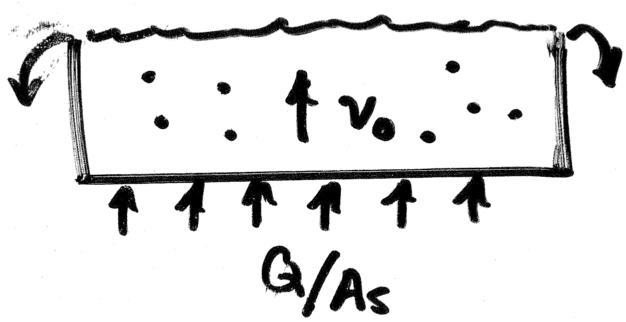
Ex: If $v = 0.5\, v_0$

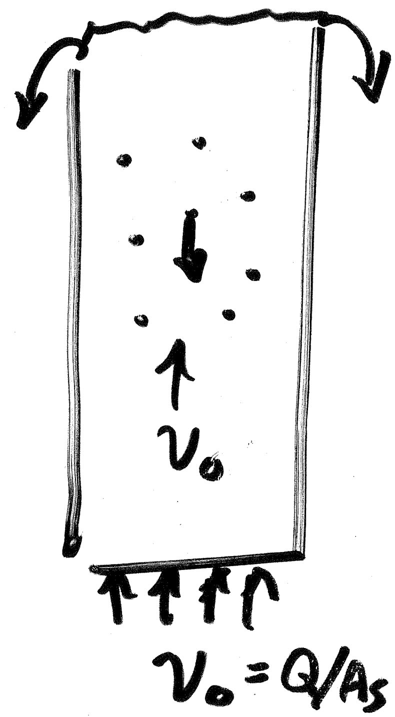
Then 50% of those particles are removed. And so on...



- BASIN DESIGN INDEPENDENT OF DEPTH ; only on Q/A_s

- EFFICIENCY independent of t_d

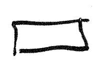
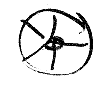




CAN IN PRACTICE HAVE

- UPFLOW

  OR

- HORIZONTAL (RECT. OR RADIAL)

w/ HORIZONTAL <u>some</u> particles w/ $v < v_0$ will be removed if enter at some depth $< H$

OVERALL REMOVAL

R

PARTICLES IN AT $h < H$

$$R = 1 - p_0 + \sum r_i$$

- R ← TOTAL REMOVAL
- p_0 ← FRACTION OF PARTICLES w/ $v \leq v_0$
- $\sum r_i$ ← REMOVAL OF ADDITIONAL PARTICLES WITHIN p_0

E.g.: 30% particles $v \leq v_0$

$$R = 1 - 0.3 + 0.12$$

↑ suppose a total of 12% more due to $h < H$

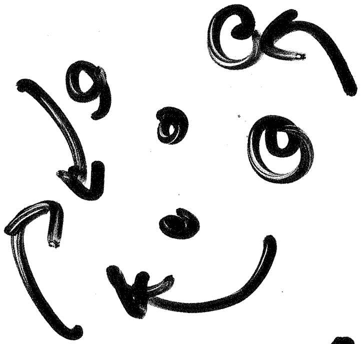
$$R = 0.82$$

82% REMOVAL OF MASS

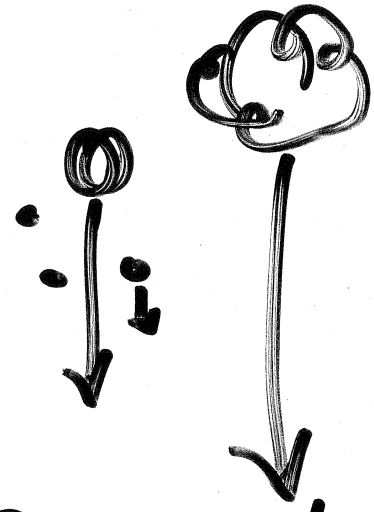
$$\sum r_i = \frac{v_0 + v_1}{2v_0}(p_0 - p_1) + \frac{v_1 + v_2}{2v_0}(p_1 - p_2) + \ldots \text{etc}$$

$$\xrightarrow{\infty} = \frac{1}{v_0}\int_0^{p_0} v\,dp$$

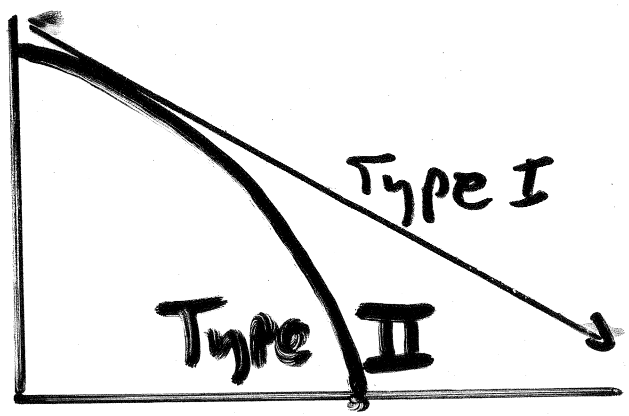
TYPE II: Settling + Coagulation



- TURBULENCE
- BROWNIAN MOTION



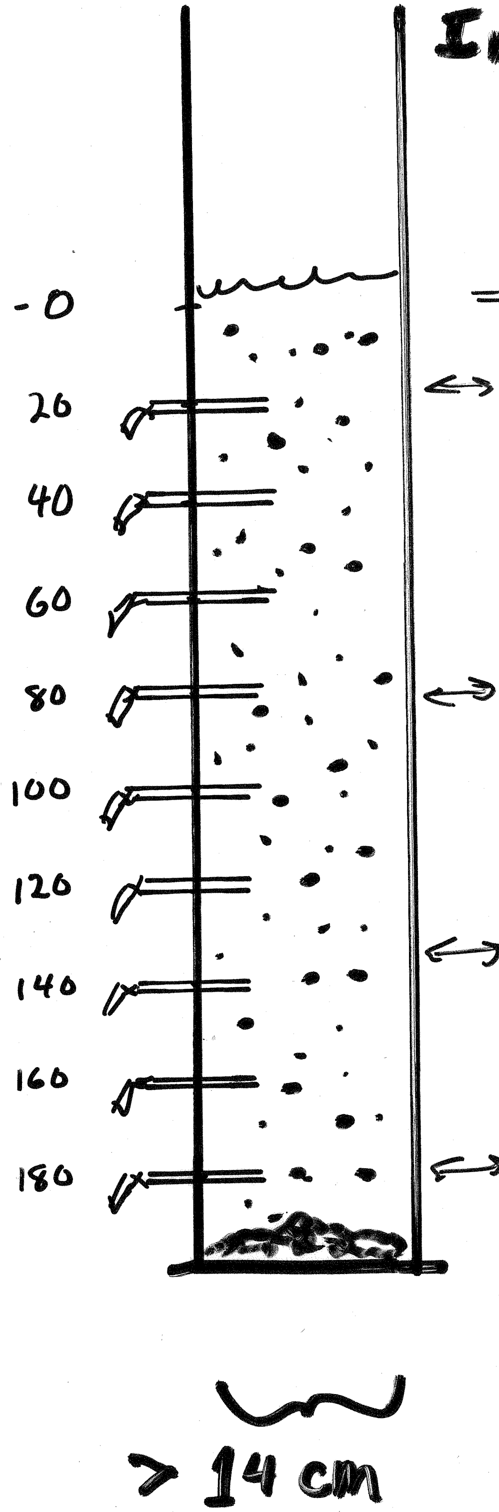
- Differential settling



$$\bar{v} = \frac{H}{t_1}$$ AVERAGE

EXPERIMENTAL SETTLING COLUMN

Initial TSS = 100 mg/L



$t=0$	t_1	t_2 …
100 mg/L (0%)	57 (43%)	52 (48%)
100 (0%)	64 (36%)	60 (40%)
100 (0%)	70 (30%)	66 (34%)
100 (0%)	85 (15%)	70 (30%)

Collect samples at all depths at intervals. Determine TSS or turbidity in each.

TABLE 11.4 Percentage Solids Removed

Time min	Solids removed, % 60 cm (1.97 ft)	120 cm (3.94 ft)	180 cm (5.91 ft)
5	17.0	10.0	7.9
10	28.0	19.5	14.9
20	41.5	30.5	26.0
30	54.0	40.9	33.0
40	62.0	46.5	41.4
50	66.5	54.4	46.0
60	73.0	58.6	52.5
75	75.0	66.7	57.9

EXAMPLE

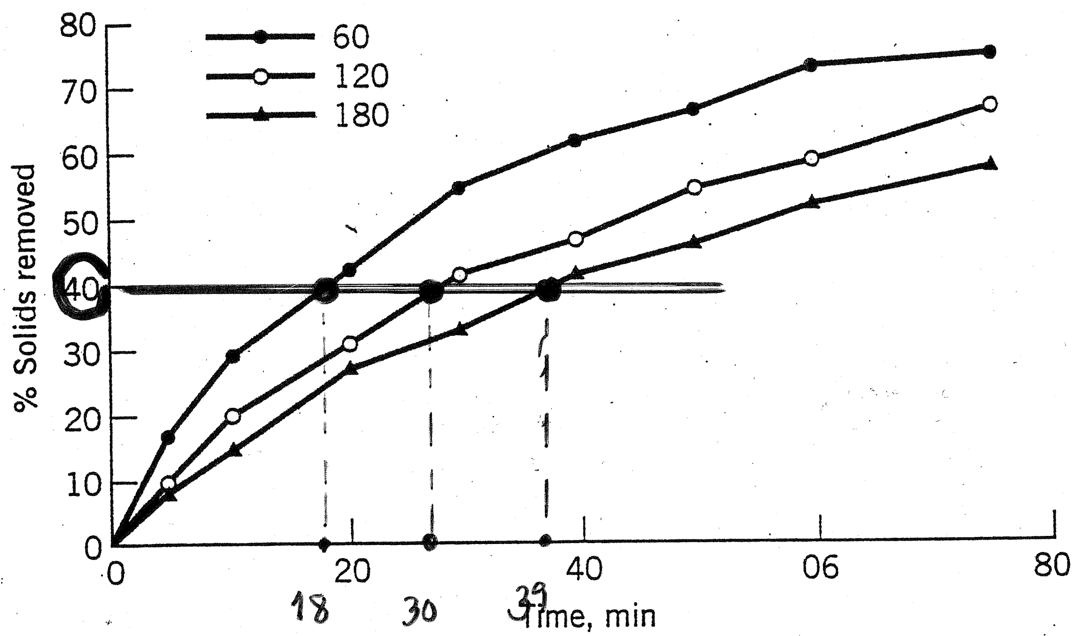


Figure 11.12 Percentage SS removed at each depth.

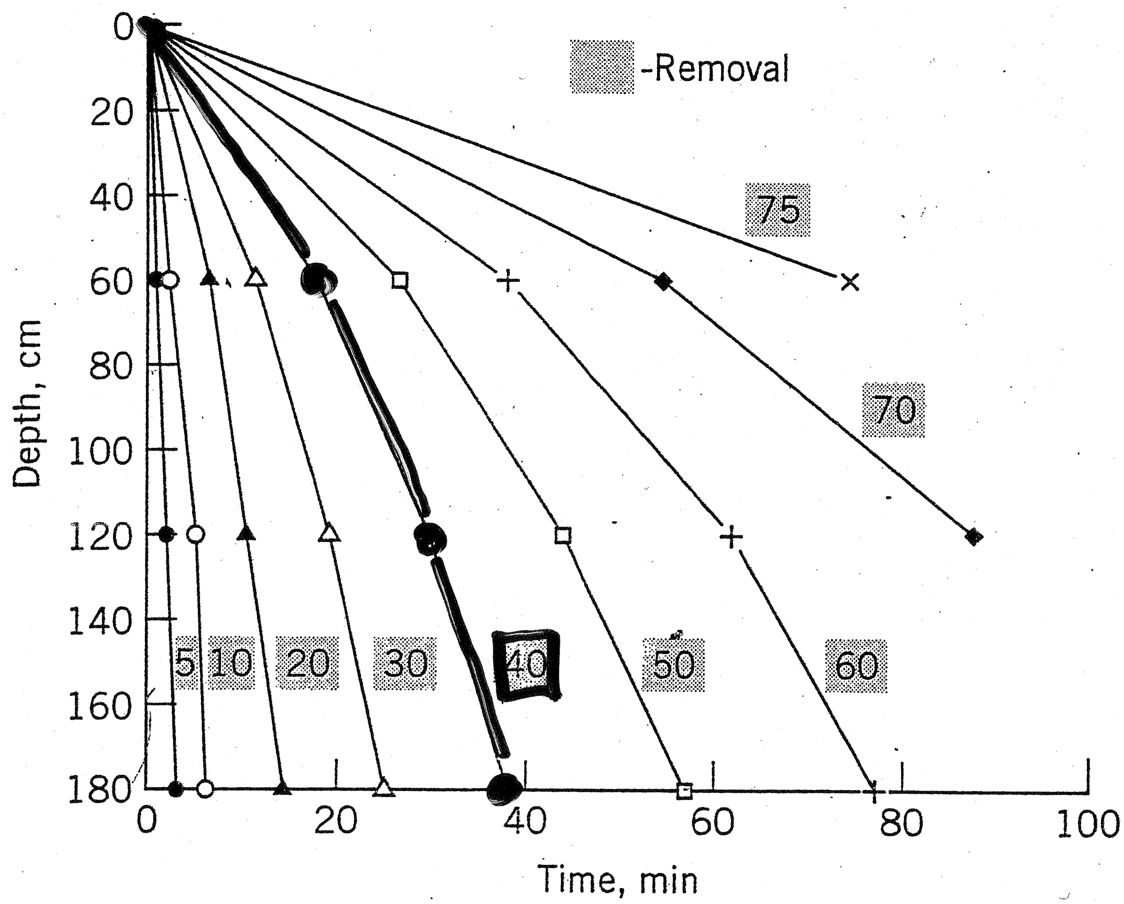
TABLE 11.5 Interpolated Percentage Solids Removed

% SS removed	t, min 60 cm (1.97 ft)	120 cm (3.94 ft)	180 cm (5.91 ft)
5	1.2	2.5	3.7
10	2.5	5.0	6.5
20	6.7	11.0	14.5
30	11.7	19.0	25.0
40	18.0	30.0	39.0
50	27.0	44.0	56.5
60	38.5	61.5	77.5
70	55.0	87.5	.
75	75.0	—	—

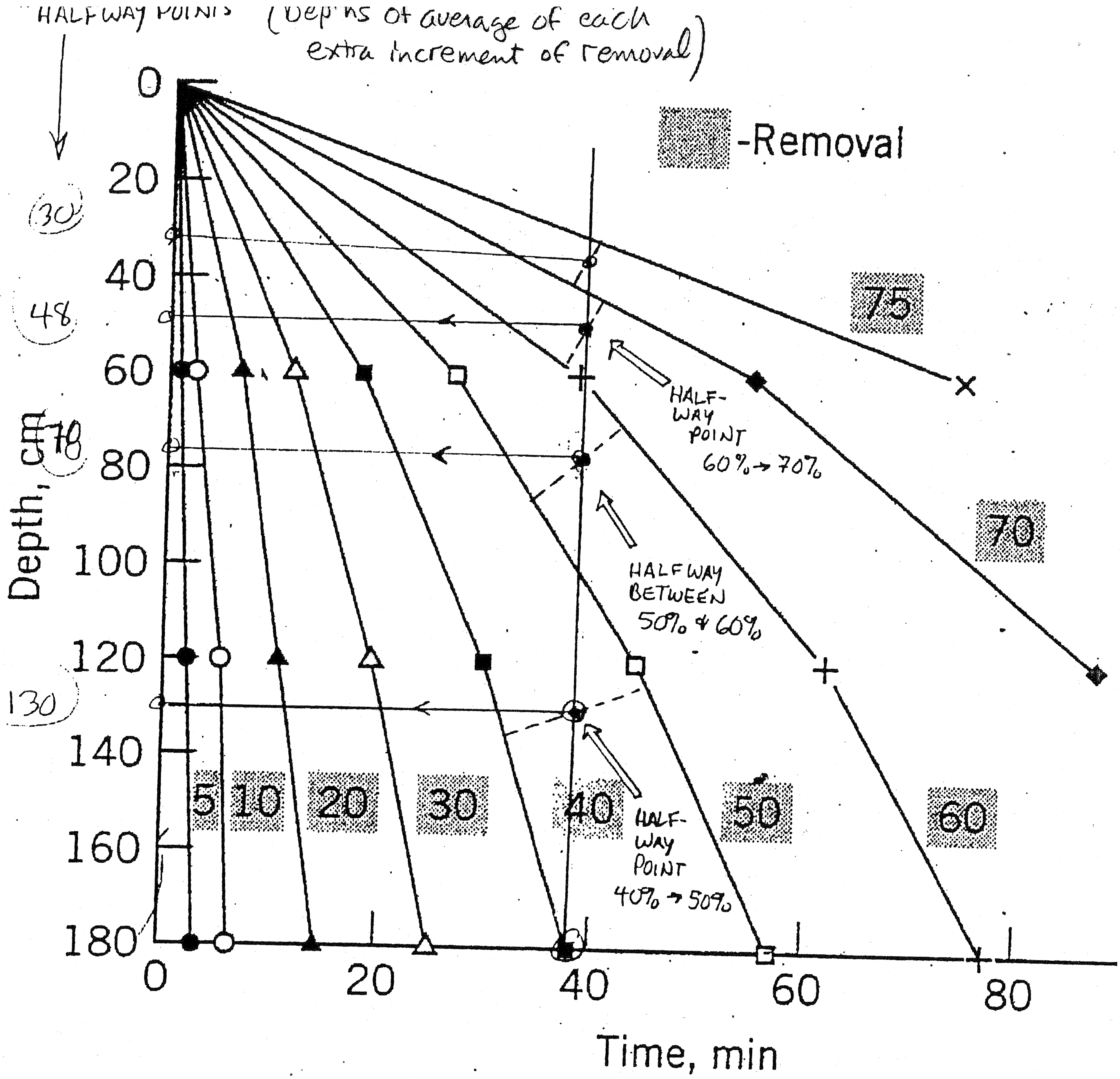
TABLE 11.5 Interpolated Percentage Solids Removed

% SS removed	t, min 60 cm (1.97 ft)	120 cm (3.94 ft)	180 cm (5.91 ft)
5	1.2	2.5	3.7
10	2.5	5.0	6.5
20	6.7	11.0	14.5
30	11.7	19.0	25.0
40	18.0	30.0	39.0
50	27.0	44.0	56.5
60	38.5	61.5	77.5
70	55.0	87.5	—
75	75.0	—	—

EXAMPLE:



Isoconcentration curves.

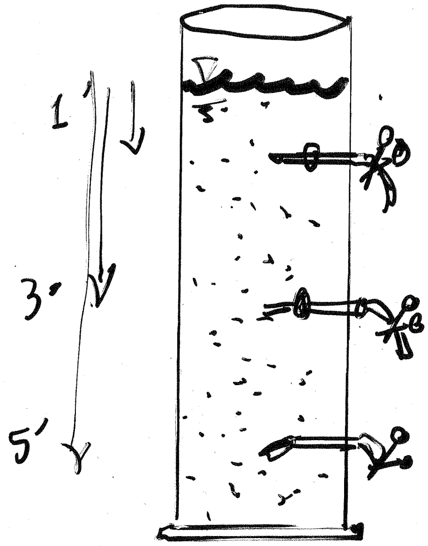


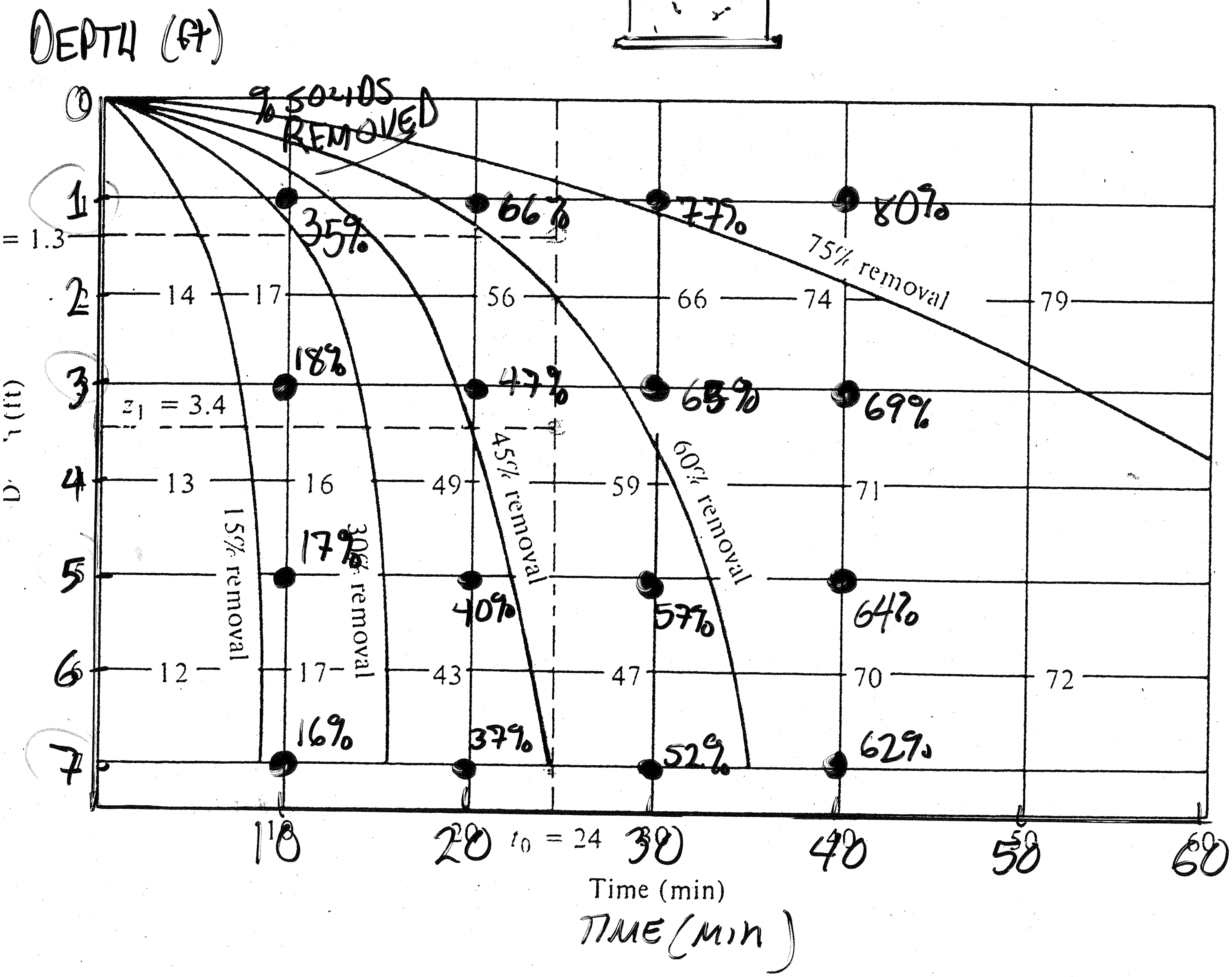
Isoconcentration curves.

e example in the text, using the mean depth found on the curve above

$= 40\% + 10\%(130/180) + 10\%(78/180) + 10\%(48/180) + 10\%($

$= 40\% + 7.2\% + 4.3\% + 2.7\% + 0.8\% = \mathbf{55.0\%}$


1'
3'
5'


DEPTH (ft)
% SOLIDS REMOVED
= 1.3
z_1 = 3.4
15% removal
30% removal
45% removal
60% removal
75% removal
35%
66%
77%
80%
18%
47%
65%
69%
17%
40%
57%
64%
16%
37%
52%
62%
14
17
56
66
74
79
13
16
49
59
71
12
17
43
47
70
72
t_0 = 24
Time (min)
TIME (MIN)

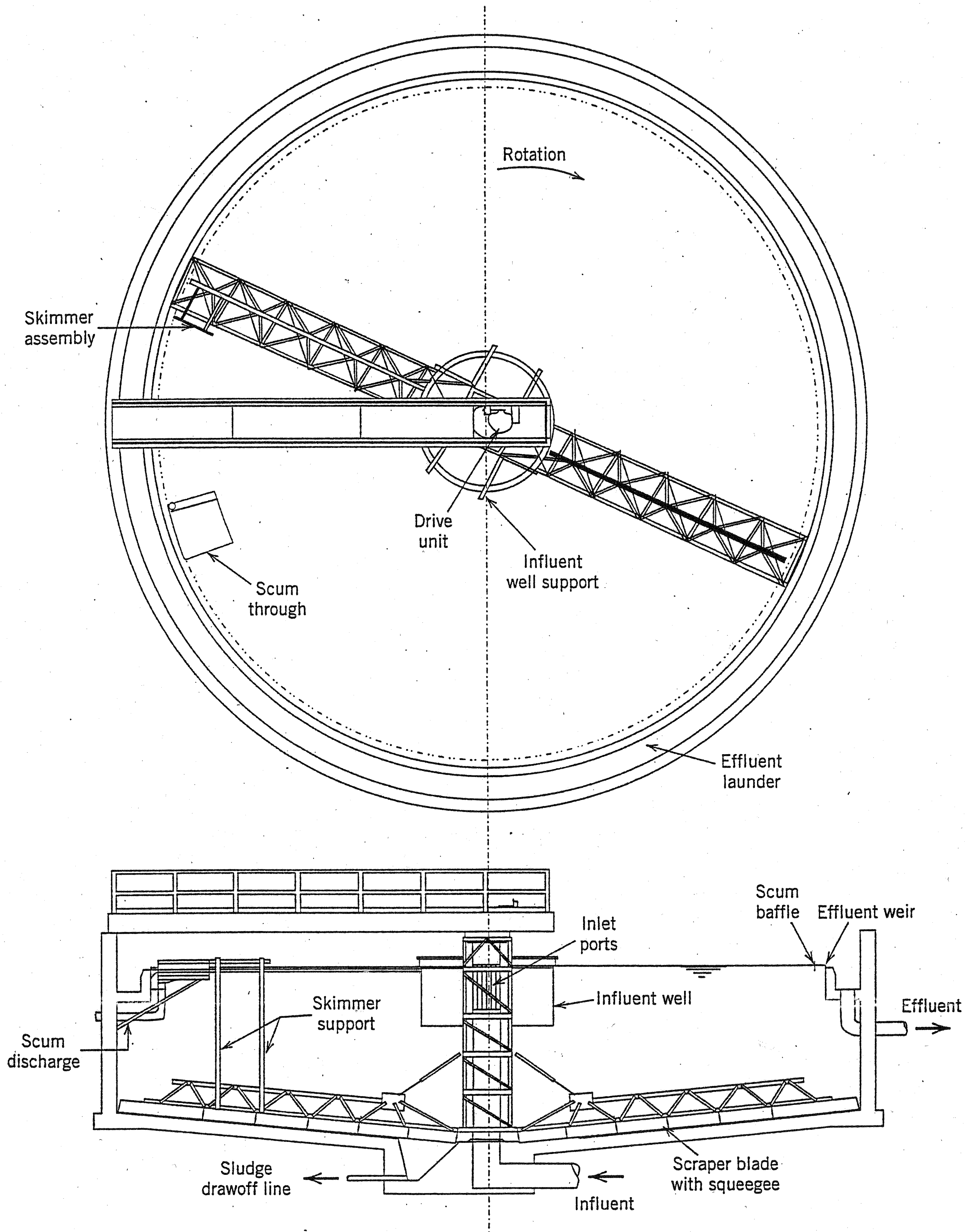


Figure 11.23 Final clarifier for an activated sludge process. Courtesy of Envirex.

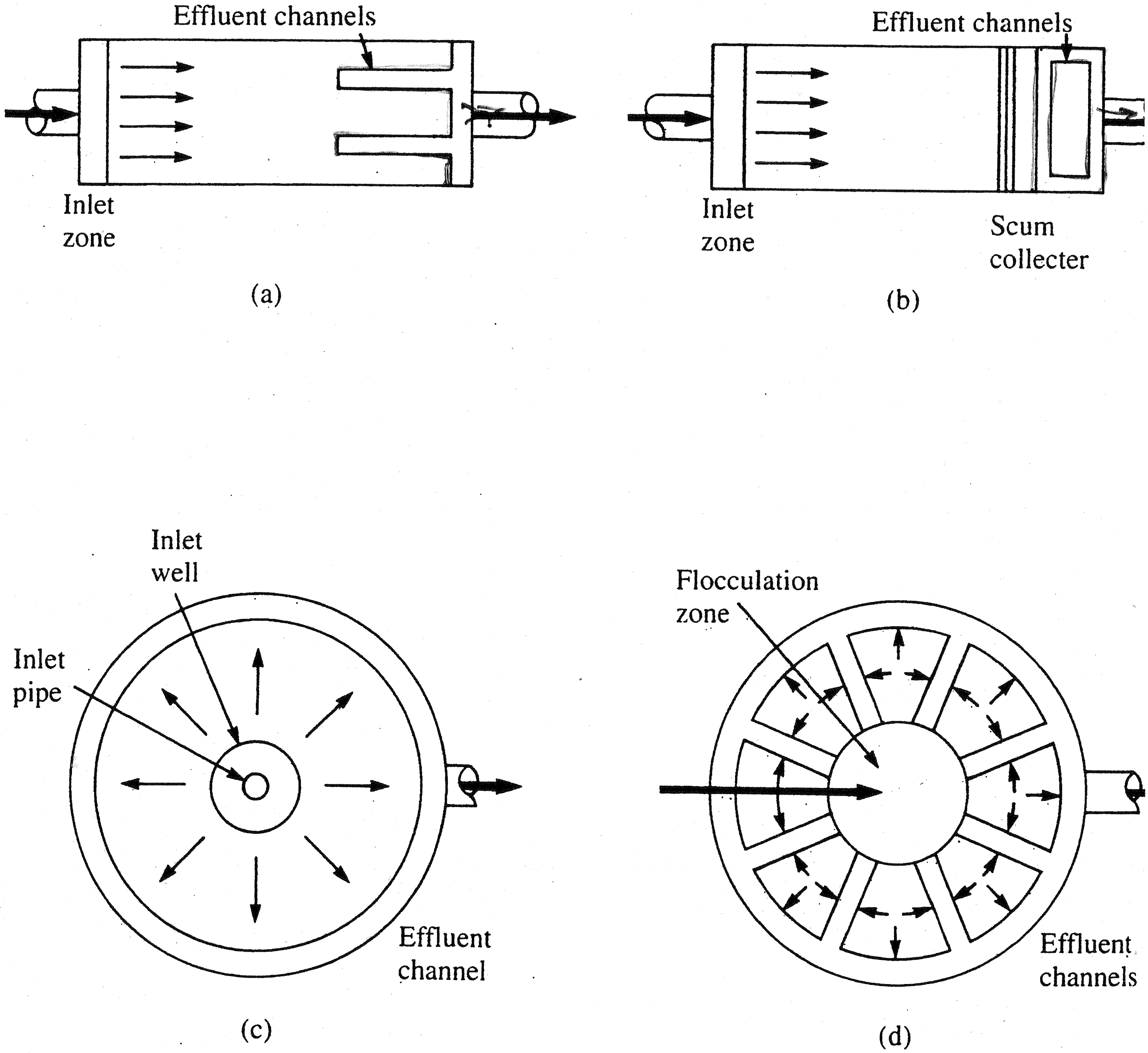


Figure 10.16 Diagrams of various clarifier shapes shown with flow patterns. (a) Rectangular clarifier with horizontal flow to effluent "finger" channels extending into the tank from the outlet end. (b) Rectangular clarifier with a scu collector and effluent channels located at the outlet end. (c) Circular clarifier wi central feed well and radial flow to a peripheral effluent channel. (d) Circular flocculator–clarifier with water flowing up to radial effluent channels in the settling zone surrounding the submerged hood of the flocculation zone.

Fig. 10.16(d) diagrams the plan view of a flocculator–clarifier that is illustrat Fig. 10.23. The flocculation zone is under a central cone-shaped hood that exten

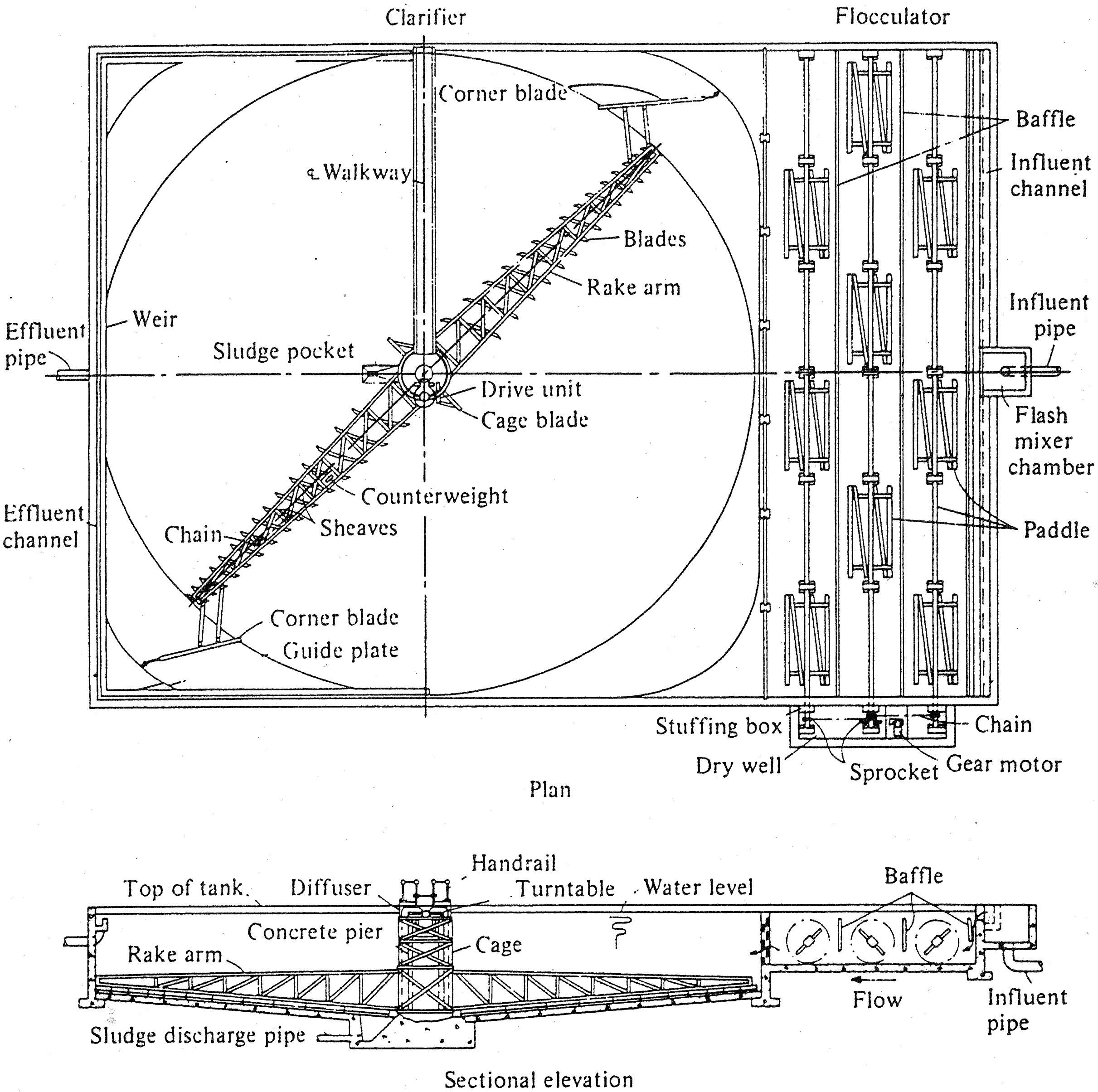


Figure 10.22 Flocculator and square sedimentation tank for water clarification, illustrating cross-flow operation. (Courtesy of Dorr-Oliver, Inc.)

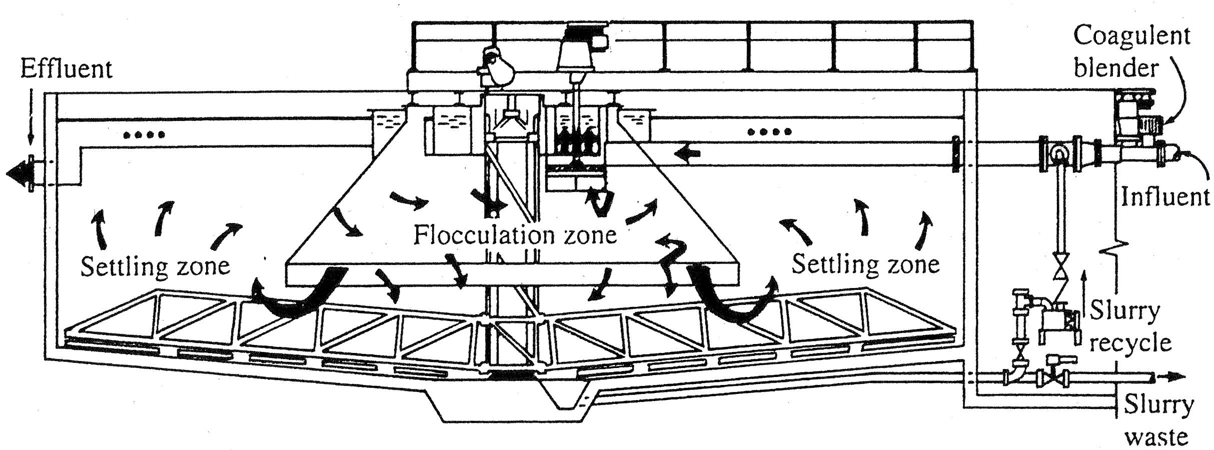
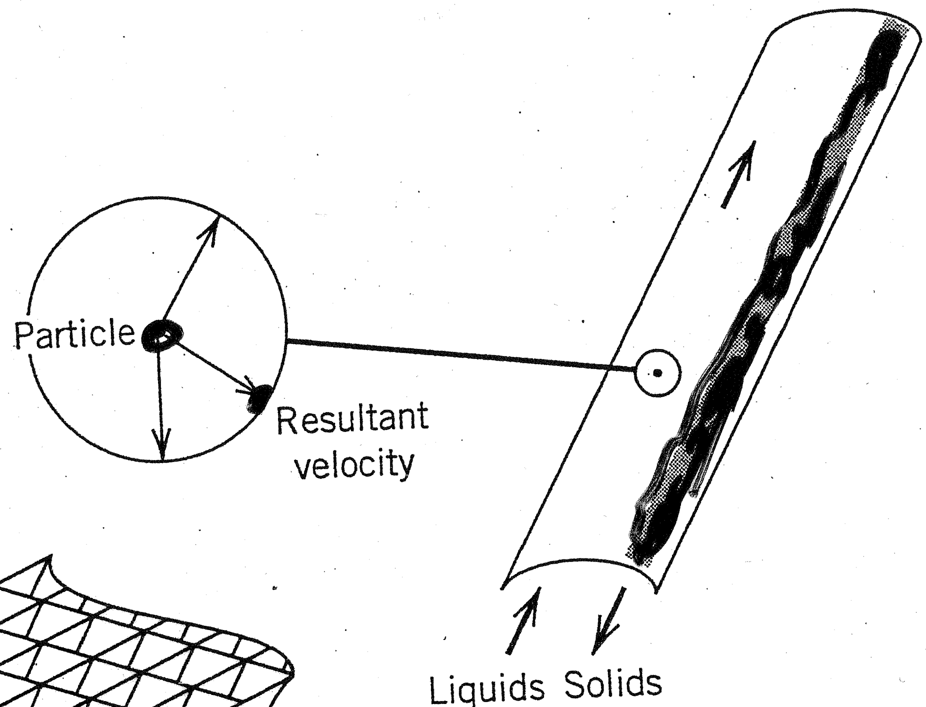
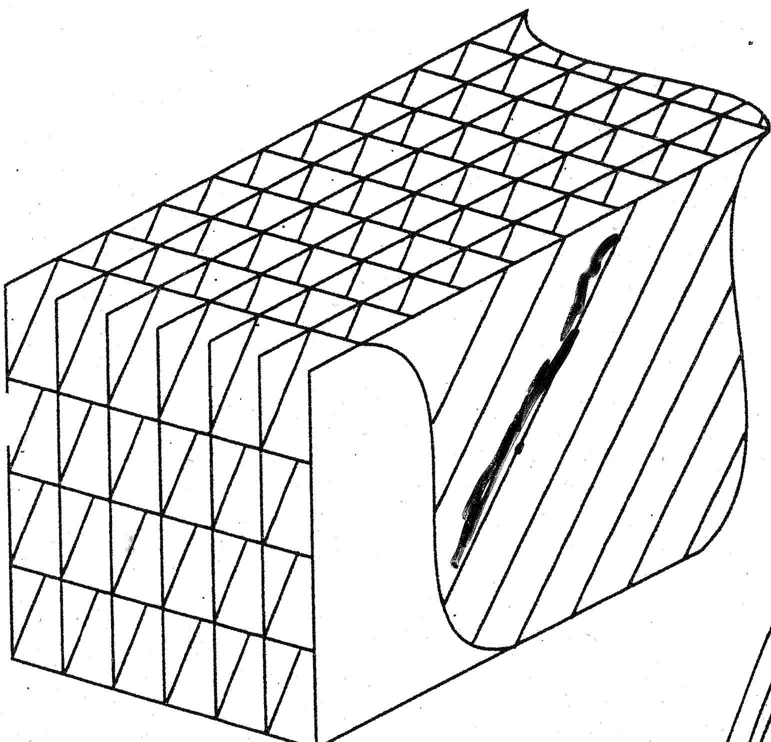
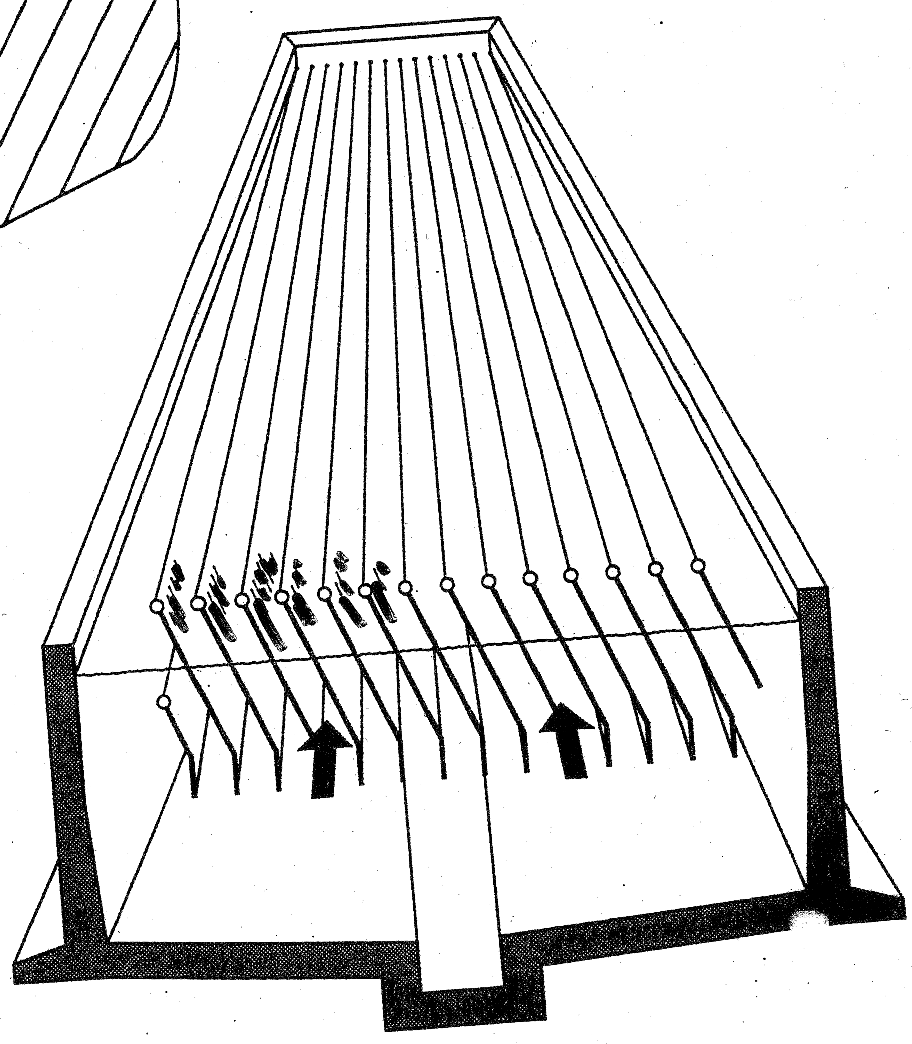


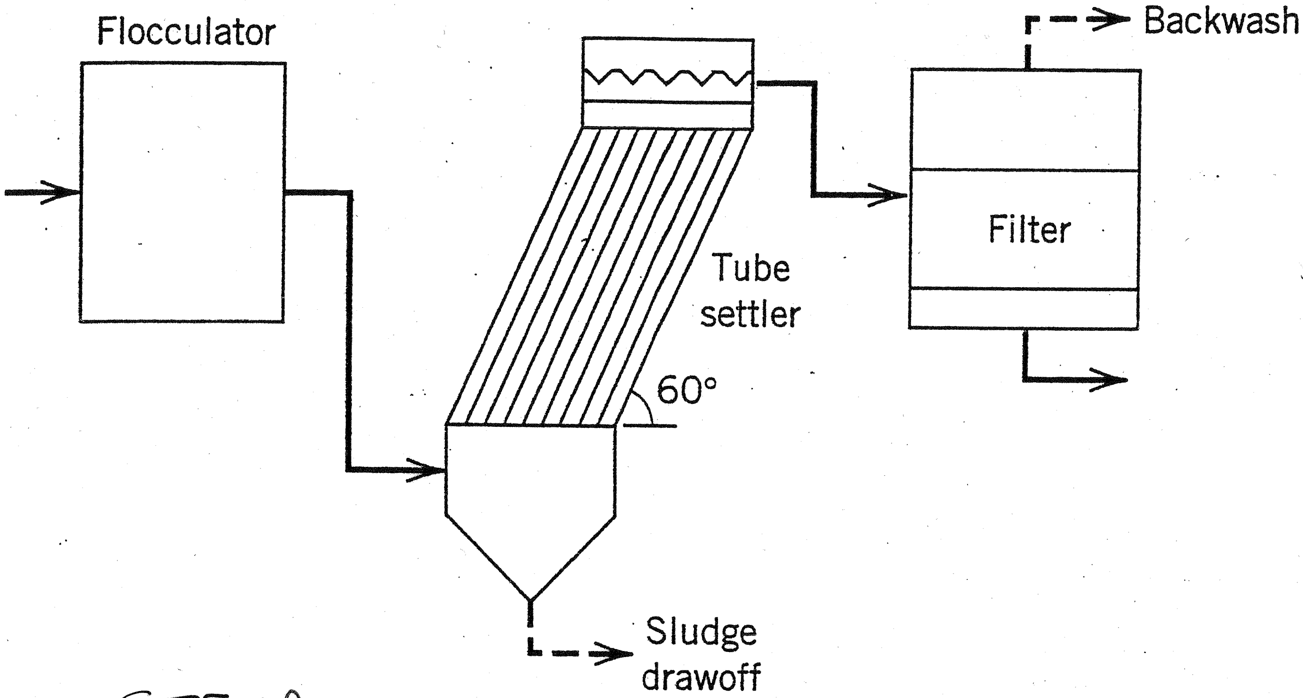
Figure 10.23 Flocculator–clarifier provides mixing, flocculation, and sedimentation in a compartmented concentric circular tank. (Courtesy of Walker Process Equipment Division of McNish Corp.)



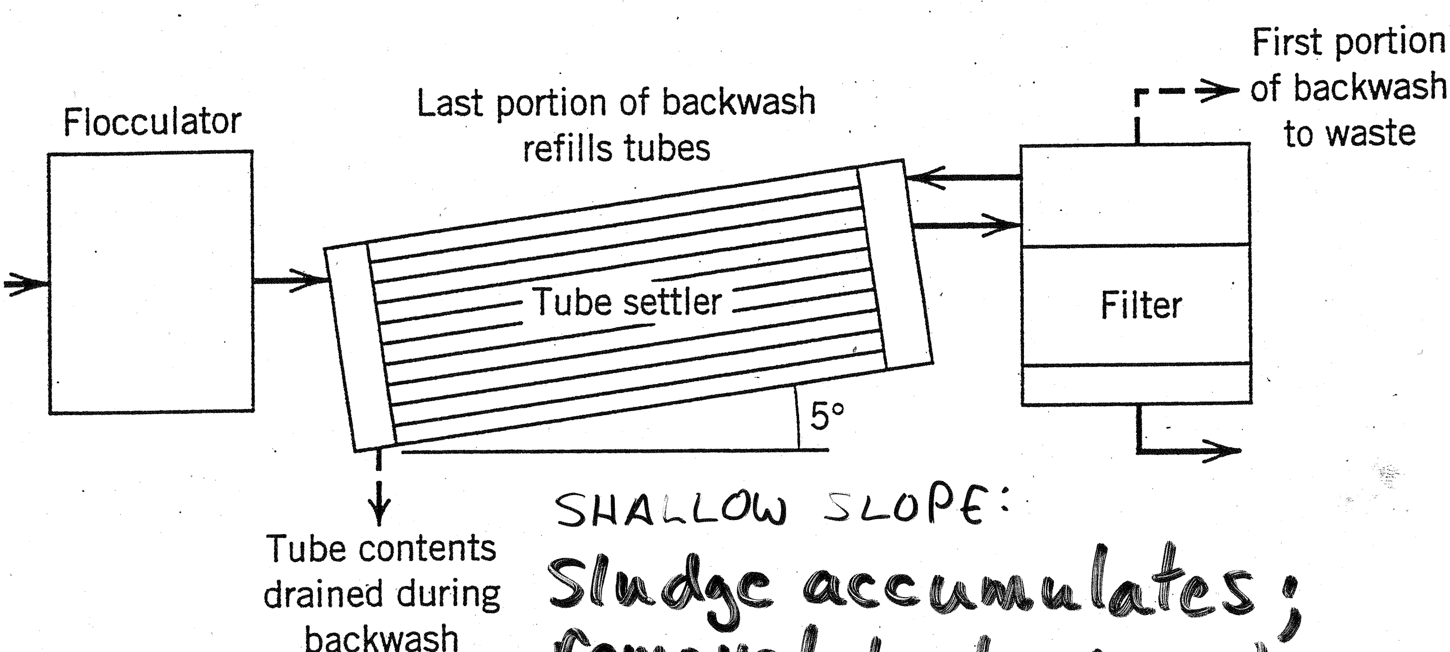
Tube clarifier.







STEEP SLOPE: Gravity clears sludge continously



SHALLOW SLOPE: Sludge accumulates; removed by backwash