

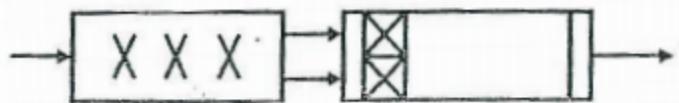
# **Water and Waste water treatment**

**CT 274**

**Dr.Mary Shafeek  
Awadalla**

**Development of chemical sedimentation process**

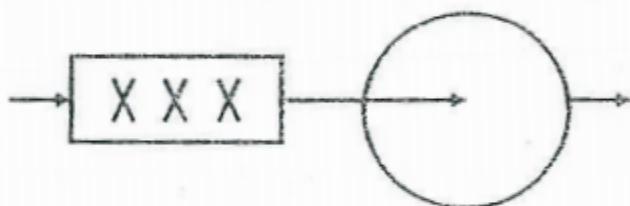
1- Rectangular flocculation tank+ rectangular sedimentation tank



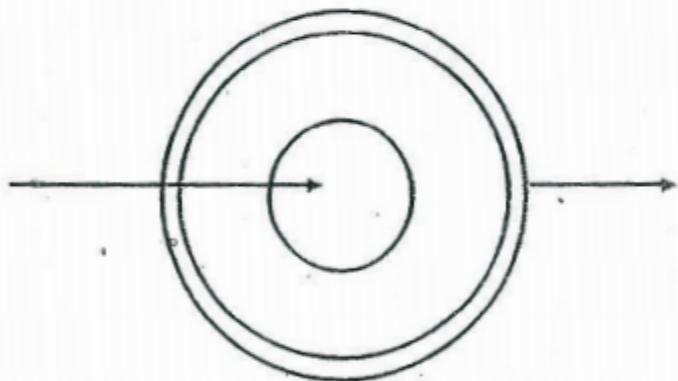
2- Rectangular flocculation sedimentation tank



3- Rectangular flocculation tank+ circular sedimentation tank



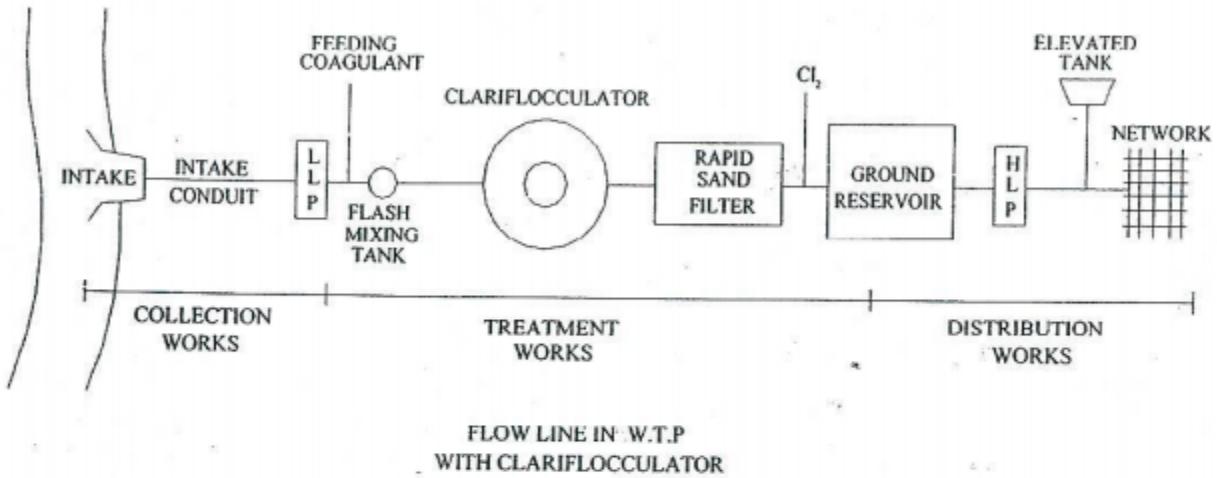
4- Clariflocculation tank



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## Clariflocculator

وهو حوض دائرى يجمع بين كل من Clarifier و Flocculation tank.



### purpose:

- Give enough time for chemical reaction.
- Give enough time for flocs to grow and entrap suspended solids.
- Removal of 90 → 96% suspended solids.

### Design Criteria:

#### Outer Chamber

$$T_{out} = (2 \rightarrow 4) \text{ hr}$$

$$T_{total} = \left( \frac{1}{3} \rightarrow \frac{1}{2} \right) \text{ hr} + (2 \rightarrow 4) \text{ hr}$$

$$d_{out} = (3 \rightarrow 5) \text{ m}$$

$$\varphi_{max} = 35 \text{ m.}$$

$$n_{out} = n_{in} \geq 2$$

#### Inner Chamber

$$T_{in} = \left( \frac{1}{3} \rightarrow \frac{1}{2} \right) \text{ hr.}$$

$$d_{in} = d_{out} - (0.5 \rightarrow 1 \text{ m})$$

$$\frac{\varphi_{in}}{\varphi_{out}} = \left( \frac{1}{3} \rightarrow \frac{1}{2} \right)$$

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$$\bullet S.L.R = \frac{Q}{S.A_{out} - S.A_{in}} = \frac{Q}{n \frac{\pi}{4} (\phi_{out}^2 - \phi_{in}^2)}$$

$$(25 \rightarrow 40) m^3/m^2/d$$

$$\bullet \text{Hydraulic load} = \frac{\phi}{n} = \frac{\phi}{n \pi \phi_{out}}$$

$$(150 \rightarrow 300) m^3/m^3/d$$

$$\bullet V_{hz} = \frac{\phi}{n \pi (\phi_{in} + 1) d_{out}} \quad \times 0.3 \text{ m/min}$$

### **Example:**

Design a clariflocculator for W.T.P of max monthly discharge = 3000 m<sup>3</sup>/hr.

### **Solution:**

#### **• Outer chamber:**

Assume T<sub>out</sub> = 0.5 + 2.5 = 3 hrs.

$$\begin{aligned} \text{Capacity} &= Q \times T_{out} \\ &= 3000 \times 3 = 9000 \text{ m}^3 \end{aligned}$$

Assume depth = 3 m.

$$S.A_{out} = \frac{\text{cap.}}{d} = \frac{9000}{3} = 3000 \text{ m}^3$$

To get n<sub>min</sub>

$$\phi_{max} = 35 \text{ m.}$$

$$a_{max} = \frac{\pi}{4} (35)^2 = 962 \text{ m}^2$$

$$n_{min} = \frac{S.A_{total}}{a_{max}} = \frac{3000}{962} = 3.11$$

Take n = 4 تقریب للأكبر

$$\therefore n \frac{\pi}{4} \phi_{out}^2 = S.A_{total}$$

(4.1)

$$4 \frac{\pi}{4} \varnothing_{\text{out}}^2 = 3000$$

$$\therefore \varnothing_{\text{max}} = 30.9 \text{ m} \simeq 31 \text{ m}$$

• Inner Chamber:

$$T_{\text{in}} = 0.5 \text{ hr.}$$

$$\begin{aligned} \text{Capacity} &= Q \times T_{\text{in}} = 3000 \times 0.5 \\ &= 1500 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} d_{\text{in}} &= d_{\text{out}} - 0.5 \\ &= 3 - 0.5 = 2.5 \text{ m.} \end{aligned}$$

$$S.A_{\text{in}} = \frac{\text{cap.}}{d_{\text{in}}} = \frac{1500}{2.5} = 600 \text{ m}^2$$

$$\therefore n \frac{\pi}{4} \varnothing_{\text{in}}^2 = 600$$

$$4 \frac{\pi}{4} \varnothing_{\text{in}}^2 = 600$$

$$\therefore \varnothing_{\text{in}} = 13.8 \text{ m}$$

Checks:

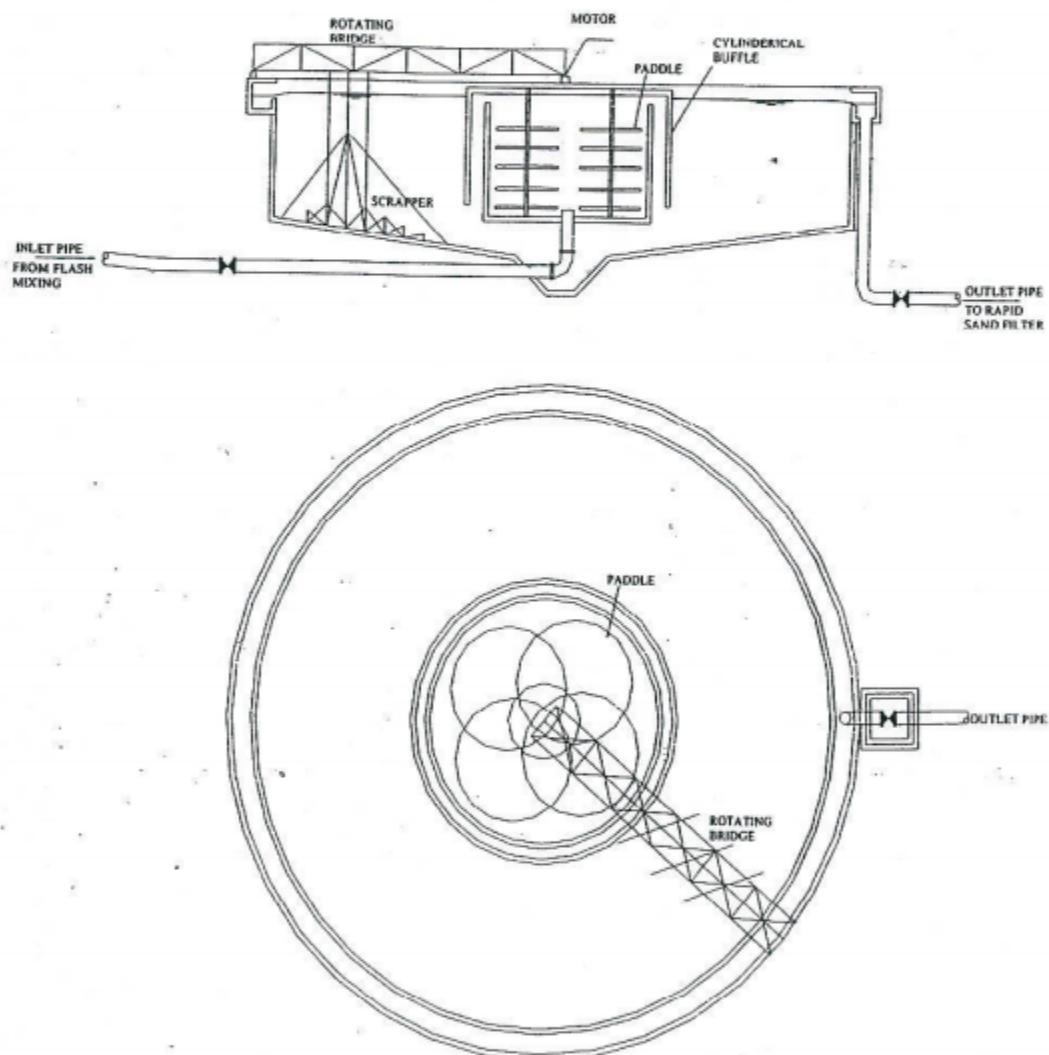
$$\bullet \frac{\varnothing_{\text{in}}}{\varnothing_{\text{out}}} = \frac{13.8}{31} = 0.42 \quad (0.33 \rightarrow 0.5) \quad \text{O.K.}$$

$$\begin{aligned} \bullet \text{S.L.R.} &= \frac{Q}{n \frac{\pi}{4} (\varnothing_{\text{out}}^2 - \varnothing_{\text{in}}^2)} \\ &= \frac{3000 \text{ m}^3/\text{hr}}{4 \frac{\pi}{4} (31^2 - 13.8^2)} = 1.24 \text{ m}^3/\text{m}^2/\text{hr} = 29.7 \text{ m}^3/\text{m}^2/\text{d} \end{aligned}$$

$$\begin{aligned} \bullet V_{\text{hz}} &= \frac{\varnothing}{n \pi (\varnothing_{\text{in}} + 1) d_{\text{out}}} \\ &= \frac{3000 \text{ m}^3/\text{hr}}{n \pi (13.8 + 1) 3} \\ &= 5.4 \text{ m/hr} \div 60 \\ &= 0.09 \text{ m/min.} \quad < 0.3 \text{ m/min.} \quad \text{O.K.} \end{aligned}$$

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$$\begin{aligned}
 \bullet \text{ Hydraulic load} &= \frac{\emptyset}{n \pi \emptyset_{\text{out}}} \\
 &= \frac{3000 \times 24}{4 \pi 31} = 154 \text{ m}^3/\text{m}^2/\text{d} \\
 (150 \rightarrow 300) \text{ m}^3/\text{m}^2/\text{d} &\quad \text{O.K.}
 \end{aligned}$$



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## ADVANCED EXAMPLES

### Example:

A W.T.P. contains 2 clariflocculators each of:

- outer diameter = 25m.      • outer depth = 3m.
- inner diameter = 10m.      • inner depth = 2.5m.

Calculate maximum capacity of this plant.

#### • Solution:

1) Q for max S.L.R.

assume max. S.L.R =  $40 \text{ m}^3/\text{m}^2/\text{d}$ .

$$\text{S.L.R} = \frac{Q}{\text{S.A}_{\text{out}} - \text{S.A}_{\text{in}}}$$

$$Q = \text{S.L.R} (\text{S.A}_{\text{out}} - \text{S.A}_{\text{in}})$$

$$Q_1 = 40 \times 2 \times \frac{\pi}{4} (25^2 - 10^2) = 32987 \text{ m}^3/\text{d}.$$

2) Q for max Hydraulic load

Assume max hydraulic load =  $300 \text{ m}^3/\text{m}^2/\text{d}$ .

$$\text{Hyd. load} = \frac{Q}{n\pi \varnothing_{\text{out}}}$$

$$Q = \text{hyd. Load} (n\pi \varnothing_{\text{out}})$$

$$Q_2 = 300 \times 2 \times \pi \times 25 = 47124 \text{ m}^3/\text{d}.$$

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**Example:**

An existing W.T.P with three clarifiers, 32 m diameter, 3 m. deep and working 16 h/d., Determine the maximum population that can be served by this plant if the average water consumption is 200 l/c/d.

**Solution:**

1) Q for max S.L.R

assume max S.L.R =  $40 \text{ m}^3/\text{m}^2/\text{d}$ .

$$Q = \text{S.L.R} \times \text{S.A} = \text{S.L.R} \times n \cdot \frac{\pi}{4} \cdot \varnothing^2$$

$$Q_1 = 40 \times 3 \times \frac{\pi}{4} (32)^2 = 96510 \text{ m}^3/\text{d.}$$

$$= 96510 / 24$$

$$= 4021 \text{ m}^3/\text{hr.}$$

2) Q for max hydraulic load

Assume max hydraulic load =  $300 \text{ m}^3/\text{m}^2/\text{d}$ .

$$Q = \text{hyd. load} \times n \times \pi \times \varnothing$$

$$Q_2 = 300 \times 3 \times \pi \times 32 = 90478 \text{ m}^3/\text{d.}$$

$$= 90478 / 24$$

$$= 3770 \text{ m}^3/\text{hr.}$$

3) Q for max horizontal velocity

$$Q = V_{\text{hz}} \times n \times \pi \left( \frac{\varnothing}{2} \right) d$$

Assume max velocity = 0.3 m/min.

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$$Q_3 = 0.3 \times 60 \times 3 \pi \times \left(\frac{32}{2}\right) \times 3 \\ = 8143 \text{ m}^3/\text{hr}$$

4) Q for min Retention time

Assume R.T = 2 hr.

$$Q_4 = \frac{\text{capacity}}{\text{R.T}} = \frac{n \frac{\pi}{4} \varnothing^2 d}{\text{R.T}} \\ = \frac{3 \frac{\pi}{4} (32)^2 3}{2} = 3619 \text{ m}^3/\text{hr.}$$

Take the least Q

$$\therefore Q_{\max} = 3619 \text{ m}^3/\text{hr.} \\ = 3619 \times 16 = 57904 \text{ m}^3/\text{d.}$$

$$Q_{\max} = 1.4 \times \text{avg W.C.} \times \text{max pop.}$$

$$\therefore \text{Max pop.} = \frac{57904 \times 1000}{1.4 \times 200} = 206800 \text{ cap.}$$

ملحوظه هامة:

لم نستخدم إلا في آخر خطوة فقط working period

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### Example

It is required to design the clari-flocculator units for a water treatment plant of hourly capacity  $3,000 \text{ m}^3$ ,

Sol<sup>n</sup>

$$Q_d = 3000 \text{ m}^3/\text{hr}$$

Outer chamber	Inner chamber
$T_o = 3 \text{ hr} + 0.5 \text{ hr} = 3.5 \text{ hrs}$ $C_o = 3000 \cdot 3.5 = 10500 \text{ m}^3$  ass $d_o = 3 \text{ m}$ $SA_o = 10500/3 = 3500 \text{ m}^2$ $SA_o = n \pi \Phi_o^2 / 4$  For $n_{\min}$ ass $\Phi_o = 35 \text{ m}$ $n\pi(35^2/4) = 3500 \text{ m}^2$ $\Rightarrow n_{\min} = 3.6 \Rightarrow \text{take } n = 4$  $\Rightarrow \Phi_{oact} = 33.4 \text{ m}$	Ass $T_i = 0.5 \text{ hr}$ $C_i = 3000 \cdot 0.5 = 1500 \text{ m}^3$  $d_i = d_o - (0.5 - 1) \text{ m}$ $= 3 - 0.75 = 2.25 \text{ m}$ $SA_i = 1500/2.25 = 666.67 \text{ m}^2$  $SA_i = n \pi \Phi_i^2 / 4$  $\Phi_i = 14.6 \text{ m}$

### Checks

- 1) S.L.R. =  $Q (\text{m}^3/\text{hr}) \times 24 / (n\pi/4 \times (\Phi_o^2 - \Phi_i^2))$   
 $= 3000 \times 24 / (4\pi(33.4^2 - 14.6^2)/4) = 25.4 \text{ m}^3/\text{m}^2/\text{d}$ --OK
- 2) HI velocity =  $Q (\text{m}^3/\text{hr}) / (n\pi(\Phi_i + 1)d_o \times 60)$   
 $= 3000 / (4\pi \times 15.6 \times 3 \times 60) = 0.085 \text{ m/min} < 0.3 \text{ m/min}$
- 3) Hydraulic load on weir =  $Q (\text{m}^3/\text{hr}) \times 24 / (n\pi \Phi_o)$   
 $= 3000 \times 24 / 4\pi (33.4) = 171.5 \text{ m}^3/\text{m}'\text{/d} < 300 \text{ m}^3/\text{m}'\text{/d}$ --ok
- 4)  $\Phi_i / \Phi_o = 14.6 / 33.4 = 0.44 \Rightarrow (1/3 - 1/2) \text{ ok}$

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### Example

It is required to find the max Pop to be served by 4 clariflocculators with the following data:

$$d_o = 3 \text{ m}, \varnothing_o = 30 \text{ m}$$

$$d_i = 2.5 \text{ m}, \varnothing_o = 12 \text{ m}$$

if max wc 300 L/c/d and wp=20 h/d.

### Given

$$n=4$$

$$d_o = 3 \text{ m}, \varnothing_o = 30 \text{ m}$$

$$d_i = 2.5 \text{ m}, \varnothing_o = 12 \text{ m}$$

max wc 300 L/c/d

$$wp=20$$

### Required

Q<sub>max</sub> & P<sub>max</sub>

### Solution

$$Q_1 = C_i/T_i = (4 \pi (12^2)/4 \times 2.5) / (0.33) = 3393 \text{ m}^3/\text{hr}$$

$$Q_2 = C_o/T_o = (4 \pi (30^2)/4 \times 3) / (2.33) = 3641 \text{ m}^3/\text{hr}$$

$$Q_3 = SLR \times SA = 40/24 \times (4 \pi (30^2 - 12^2)/4) = 3958 \text{ m}^3/\text{hr}$$

$$Q_4 = \text{Hyd load} \times L_w = 300/24 \times 4 \pi (30) = 4712 \text{ m}^3/\text{hr}$$

$$Q_5 = V \cdot h_l \times XA = 0.3 \times 60 \times (4 \pi \times 13 \times 3) = 8143 \text{ m}^3/\text{hr}$$

$$Q_d = Q_{mm} = 3393 \text{ m}^3/\text{hr} = 3393 \times 20 = 67860 \text{ m}^3/\text{d}$$

$$Q_{max} = 67860 \text{ m}^3/\text{d} = P \times 300 / 1000 \rightarrow P = 226200 \text{ c}$$

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## Notes

1) if given

Retention time in sedimentation zone = 2.5 hr

Retention time in flocculation zone = 0.5 hr

$$\rightarrow T_i = 0.5 \quad \& \quad T_o = 2.5 + 0.5 = 3 \text{ hr}$$

2) if given S.L.R. should not exceed  $32 \text{ m}^3 / \text{m}^2 / \text{d.}$

$\rightarrow$  assume S.L.R. ( $25-32$ )  $\text{m}^3/\text{m}^2/\text{d.}$

OR

$\rightarrow$  check it between ( $25 - 32$ )  $\text{m}^3/\text{m}^2/\text{d.}$

3) If given S.L.R. =  $32 \text{ m}^3 / \text{m}^2 / \text{d.}$

$\text{Ass } T_o = 0.5 + 0.5 \text{ hr} = 3 \text{ hr}$ $C_o = Q_d \cdot T_o = \dots \text{ m}^3$	$\text{Ass } T_i = 0.5 \text{ hr.}$ $C_i = Q_d \cdot T_i = \dots \text{ m}^3$
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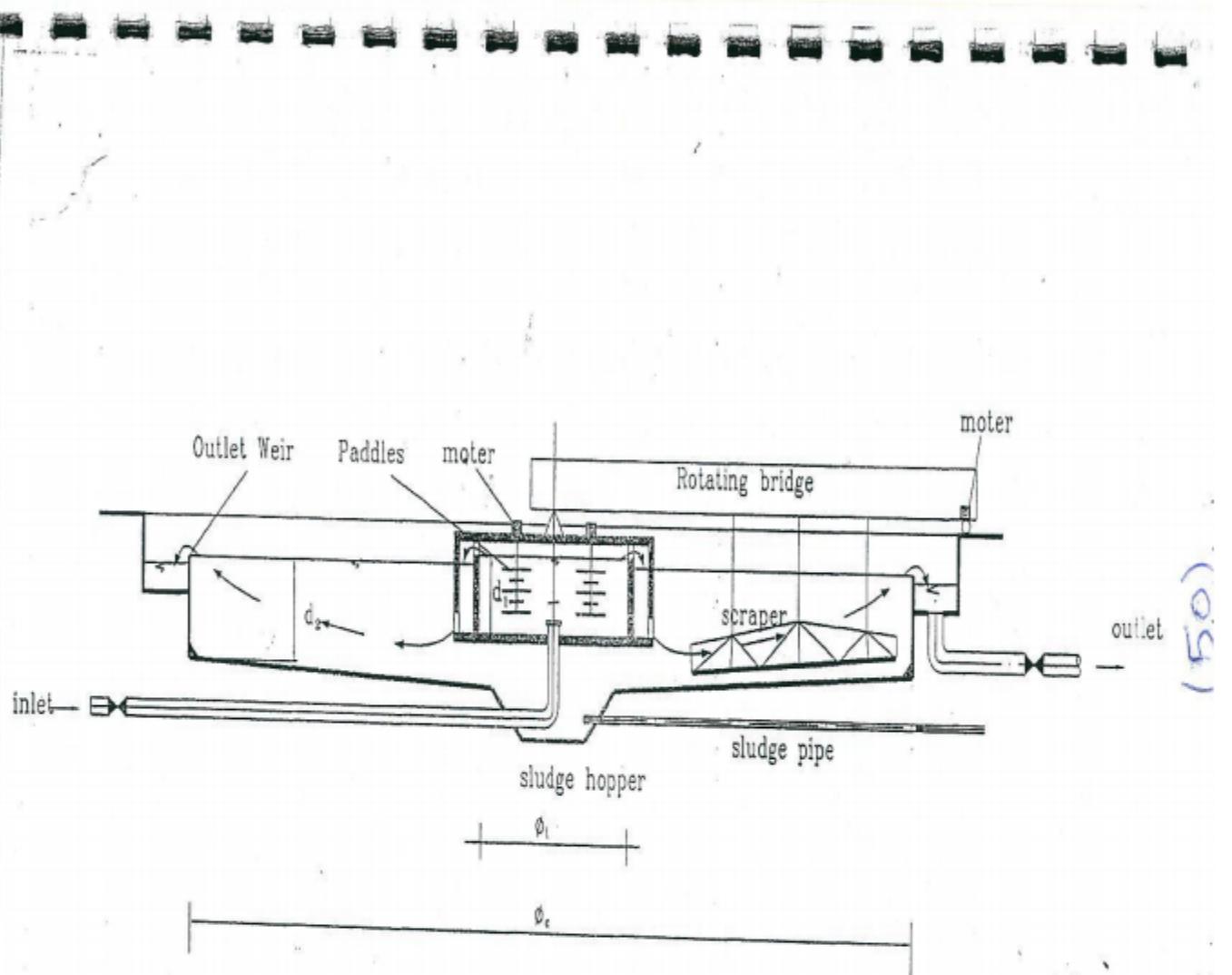
Take S.L.R. =  $32 = Q \text{ m}^3/\text{hr} \cdot 24 / (n \pi / 4 (\Phi_o^2 - \Phi_i^2))$ ,  
 ass  $\Phi_i = (0.33 - 0.5) \Phi_o \rightarrow \Phi_i = (0.4) \Phi_o$

$$32 = Q \text{ m}^3/\text{hr} \times 24 / (n \pi / 4 \times (\Phi_o^2 - 0.16 \Phi_o^2))$$

Then ass  $\Phi_o$  max =  $\frac{35}{50}$  m get  $n_{\min} \rightarrow$  get  $n, \Phi_o$  act

$$\text{From S.L.R.} = 32 = Q \text{ m}^3/\text{hr} \times 24 / (n \pi / 4 (\Phi_o^2 - \Phi_i^2)) \rightarrow \text{get } \Phi_i$$

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Clariflocculator