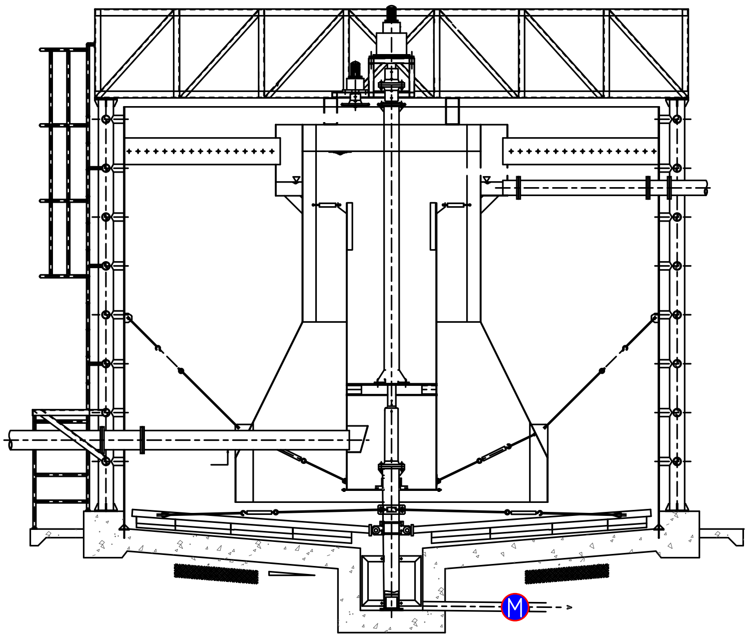
การออกแบบถัง *Solid Contact Clarifier Tank*

(Sludge Recirculation)

สำหรับน้ำประปาขนาด *150* ลูกบาศก์เมตรต่อชั่วโมง



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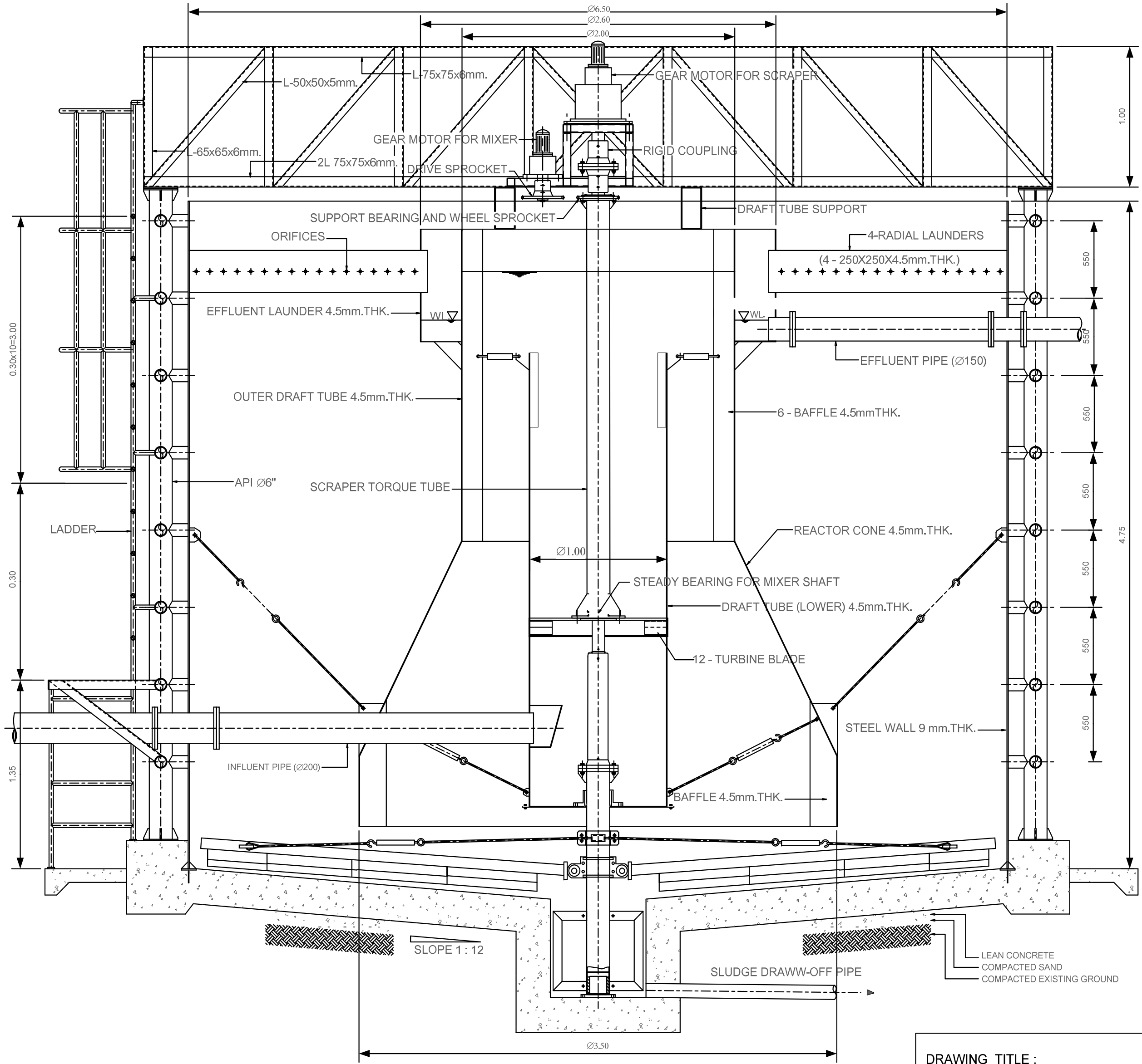
ส่วนวิเคราะห์จัดการสิ่งแวดล้อม กองจัดการสิ่งแวดล้อมและมลพิษ

ฝ่ายควบคุมคุณภาพน้ำ



SOLID CONTACT CLARIFIER

DRAWING TITLE :	SUBMITTED :		DATE :
PROJECT :	CHECK :		DATE :
SCALE : DRAWING NO.	Engineer :		DATE :
	Drawing :		DATE :

DESIGN CALIFIER TANK

(SLUDGE BLANKET CLARIFIER TYPE : SLUDGE RECIRCULATION)

1. Flow Rate

Q = 150 m^3/hr

2. Raw Water Quality input

1 Turbidity	=		NTU
2 pH	=	8.3	
3 Alkalinity	=	34	mg/l as $CaCO_3$
4 Temperature	=		^oC
5 Fe	=	2	mg/l
6 Mn	=		mg/l
7 Total Hardness	=	50	mg/l as $CaCO_3$

3. Design Criteria

3.1. Kawamura

3.1.1	Flocculation Time	=	approximate = 20 min
		=	normal = 20 - 40 min
3.1.2	Settling Time	=	1 - 2 hr
3.1.3	Surface Loading	=	2 - 3 m/hr
3.1.4	Weir Loading	=	7.3 - 15 m^3/hr
3.1.5	Upflow Velocity	=	< 10 mm/min
3.1.6	Slurry Circulation rate	=	up to 3 - 5 time the raw water inflow rate
3.1.7	G	=	30 - 50 s^{-1}
3.1.8	MAXIMUM MIXER TIP SPEED	=	0.9 m/s (Baffled Channel)
		=	0.9 m/s (Horizontal Shaft with Paddles)
		=	1.8 - 2.7 m/s (Vertical Shaft with Paddles)
	Equation $mixer\ tip\ speed = \pi DN$		
3.1.9	Free Board is approximate	=	0.6 m
3.1.10	Water Depth	=	4 - 5 m.
3.1.11	Length and Width ratio	=	6 : 1 (minimum 4 : 1) (Rectangular Basin)
3.1.12	Width and Water Depth	=	3 : 1 (maximum 6 : 1) (Rectangular Basin)
3.1.13	Blade area/Rapid Mixing Tank area = 0.1 - 0.2 % (page 121)		
3.1.14	Blade : Diameter Blade/Diameter Mixing Tank = 0.2 - 0.4 (page 121)		
3.1.15	Shaft rpm	=	8 - 12

3.2. Q'Sim

3.2.1	Detention Time	=	2 Hr
3.2.2	Surface Loading	=	2 - 4 m/hr
3.2.3	Weir Loading	=	7.1 m^3/m.hr

3.3. Sheet Master Degree of Environmental Engineering

3.3.1 Weir Loading = 7.1 m^3/m.hr

3.3.2 Surface Loading

- Q < 0.35 m^3/min = 0.5 - 1.0 m/hr
- Q > 0.35 m^3/min = 1.25 - 1.85 m/hr

3.3.3 Water Depth = 3 - 5 m.

3.3.4 Paddle radius = 65 - 75% of radius for Flocculator

3.3.5 Detention Time = 1 - 3 Hr

3.3.6 Diameter Tank < 45 m

3.3.7 Paddle at bottom tank high bottom = 15 - 30 cm

3.3.8 Paddle Velocity = 2 - 3 rpm

3.3.9 Effective Paddle Area = 10 % Sweep area of the fllocculator

3.4. Water Work Engineering Book

3.4.1 Flocculation

2.4.1.1 Detention Time = 20 - 60 min

2.4.1.2 Velocity Gradient = 15 - 60 S^{-1}

2.4.1.3 GT = $1x10^4$ - $15x10^4$

2.4.1.4 Periperal Velocity of Paddle = 0.3 - 0.6 m/s

2.4.1.5 Shaft rotation speed = 1.5 - 5 rpm

3.4.2 Sedimetation (Coagulation)

2.4.2.1 Detention Time = 2 - 8 hr

2.4.2.2 Surface Loading = 20 - 40 m^3/m^2.day

2.4.2.3 Weir Loading = 200 - 300 m^3/m.day

3.4.3 Sedimentation (Softening)

2.4.3.1 Detention Time = 1 - 6 Hr

2.4.3.2 Surface Loading = 40 - 60 m^3/m^2.day

2.4.3.3 Weir Loading = 250 - 350 m^3/m.day

3.5 Clarifier Design (Water Poluttion Control Federation 1985)

3.5.1 Detention Time Flocculator central well = 20 - 30 min

3.5.2 Weir Loading (outlet) = 100 to 150 m^3/m^2.day

3.5.3 Radial inner feed well = 10 to 13% of the tank radius

3.5.4 velocity gradient = 30 - 50 S^{-1}

4 GiveContact Time in Hopper inside (Flocculation Zone)	=	40	min	
Contact Time ZONE 1	=	20	min	(Criteria 20 - 30 min)
Contact Time outside (ZONE 2 + ZONE 3) + ZONE 4	=	20	min	
5 Flow Rate	=	150	m^3/hr	
6 Volume in inside Hopper	=	$Q \times t$		
	=	100	m^3	
7 Give Detention Time in outside Hopper(Sedimentation Zone)	=	1.7	Hr	
8 Volume in outside Hopper	=	$Q \times t$		
	=	255	m^3	

9 Calculation Diameter Hopper inside

9.2 ZONE 1 (Circular Basin)

	Volume in ZONE 1	=	$Q \times t$	
∴	Volume in ZONE 1	=	50	m^3
	Give D1	=	4	m
	Surface Area	=	$\frac{\pi D^2}{4}$	m^2
∴	A_1	=	12.5664	m^2
∴	Depth in ZONE 1	=	3.97887	m

9.2 ZONE 2 (Circular Basin)

	Give D2	=	5	m	
	Surface Area	=	$\frac{\pi D^2}{4}$	m^2	
∴	A_2	=	19.635	m^2	
	Depth in ZONE2	=	3.22887	m	(safety 0.25 m)
∴	Volume ZONE2	=	63.3988	m^3	

9.3 ZONE 3 (Conical Basin)

Give D3	=	7	m
Give Depth in ZONE 3	=	1	m

Surface area on Top = $\frac{\pi D^2}{4}$

∴ Surface area on Top (A3) = 19.635 m^2

Surface area on Bottom = $\frac{\pi D^2}{4}$

∴ Surface area on Bottom (A4) = 38.4845 m^2

$$Volume = \frac{d}{6} x(A_1 + A_2 + \sqrt{A_1 x A_2})$$

∴ Volume ZONE 3 = 14.2681 m^3

9.4 Outside Volume ZONE 2 andZONE 3 = Volume ZONE 2 + ZONE 3 - Volume ZONE 1

= 27.6669 m^3

9.5 ZONE 4 (Circular Basin)

∴ Volume in ZONE 4 = Total Volume in Hopper inside - (Volume ZONE2+ ZONE3)

∴ Volume in ZONE 4 = 22.3331 m^3

∴ Depth in ZONE 4 = $\frac{Volume\ Zone\ 4}{\pi D^2} x4$

= 0.58032 m

Check Detention Time Outside ZONE2 and ZONE3 + ZONE4 = 0.33333 hr

= 20 min

∴ Water Depth = 4.80919 m

(Design Criteria 3 - 5 m,Kawamura,page161)

Free Board from Design Criteria = 0.6 m (Kawamura)

∴ Solid Contact Clarifier Tank Height = 5.40919 m

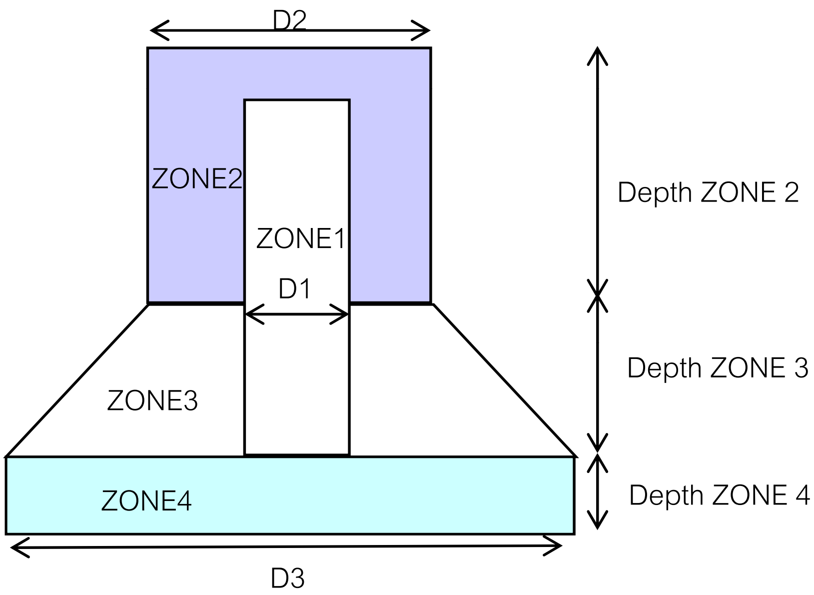
10 Calculation Diameter Solid Contact Clarifier

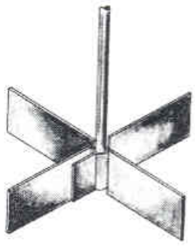
Total Volume = Volume inside Hopper + Volume outside Hopper

= 355 m^3

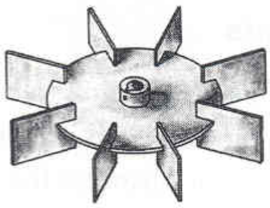
Diameter Solid Contact Clarifier = $\sqrt{\frac{4xVolume}{\pi x water\ depth}}$

= 9.69468 m


D2
ZONE2
ZONE1
D1
Depth ZONE 2
ZONE3
Depth ZONE 3
ZONE4
Depth ZONE 4
D3



(a)



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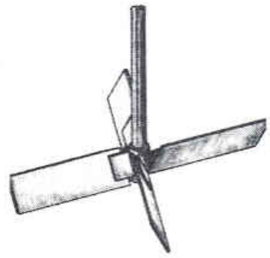

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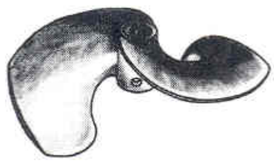
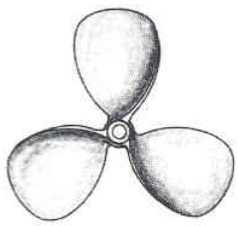


(d)



(e)

1. Rapid Mixing by Radial and Axial Impellers

Theory $G = \sqrt{\frac{P}{\mu V}}$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

The motor power of the mixer is the power to drive the speed reduction gears. The powe imparted to the water by a mixer is calculated from

Theory $P = 2\pi nT$

Where :

n = Impeller speed, revolutions per second (rps)

T = Impeller shaft torque, N-m.

Other expression for the power imparted to the water are given by :

Theory $P = N_p \mu n^2 d^3$ is used for the Laminar-flow range (Reynolds number N_R < 10)

$P = N_P \rho n^3 d^5$ is used for the Turbulent-flow range (Reynolds number NR > 10,000)

Where :

N_P = Power number of the impeller (power numbers for different types of impellers are give in table 8 - 5

d = impeller diameter, m

ρ = mass density of fluid, kg/m^3

μ = absolute viscosity of water, N-s/m^2

The Reynolds number for Rapid mixers is given by :

Theory $$N_R = \frac{d^2 n\rho}{\mu}$$

The velocity gradient for a mixing basin utilizing flow - induced turbulence can be calculated from :

$$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

Where :

h_L = total head loss through the mixer,m

t = detention time, s

Detention time in Rapid-Mix Basin

Theory $$t = \frac{V}{Q}$$

Where :

t = average detention time, min

Q = flow rate, m^3/min

V = volume of the tank, m^3

Check Mixer Tip Speed

Theory

$$Tip\ Speed = \pi D n$$ m/s

Where :

D = Diameter of Impeller (m.)

n = Impeller speed, revolutions per second (rps)

Rapid Mix

Tip Speed > 1 m/s

Slow Mix

1.Baffle Channel < 0.9 m/s

2.Mechanical Flocculators

- Horozontal Shaft with Paddle < 0.9 m/s
- Vertical Shaft with Blade < 1.8 m/s to 2.7 m/s

1. Power Number for Impeller

Table 8-5 Power Numbers of Various Rapid-Mix Impellers

	Power Number, N_p
Radial flow	
Straight blade turbine	
4 blade ($w/d = 0.15$)[a]	2.6
4 blade ($w/d = 0.2$)	3.3
Disc turbine	
4 blade ($w/d = 0.25$)	5.1
6 blade ($w/d = 0.25$)	6.2
Axial flow	
Propeller 1:1 pitch	0.3
Propeller 1.5:1 pitch	0.7
45° Pitched blade	
4 blade ($w/d = 0.15$)	1.36
4 blade ($w/d = 0.2$)	1.94

a w/d = blade width-to-diameter ratio.
Source: Adapted in part from References 2, 5, 27, and 28.

2. Coefficient of Drag for Paddle

Table 8-6 Coefficient of Drag (C_D) for Paddle-Wheel Flocculator, Based on Length-to-Width Ratio of the Paddle

Length-to-Width Ratio (L/W)	C_D
5	1.20
20	1.50
∞	1.90

Impeller Mixing

Give

1 Flow rates = 150 m^3/hr

2 Volume of the ZONE 1 = 50.000 m^3

μ = = 0.000895 Kg/m.s at $25^{o}C$

ρ = = 997.1 Kg/m^3 at $25^{o}C$

Theory

$$G = \sqrt{\frac{P}{\mu V}}$$

Where :

G = Velocity gradient, sec^{-1}

P = Power Imparted to the water, N-m/s or Watt or $kg.m^2/s^3$

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, $N\text{-}s/m^2$

Give Velocity Gradient (G) = 70 s^{-1} (Design Criteria Kawamora)

3 Power Imparted to the water, P = 219.3 N-m/s or Watt or $kg.m^2/s^3$

= 0.2193 kWatt

P is the power imparted to the water. The power of the driver(P') is calculated by diving P by the efficiency of the gearbox, which is typically around 80 percent

∴ Power Imparted to the water, P' = 0.2741 kWatt

1 HP = 0.7457 kWatt

∴ Power Imparted to the water, P' = 0.3676 HP

∴ Use Standard motor of P' = HP, rpm =

and efficiency = 80 percent

4 Impeller Design

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type.Experience shown that radial-flow mixers perform batter than axial-flow mixers in a vertical-flow basin

Use Disc Turbine 6 Blade

Blade width-to-Diameter ratio = 0.25

N_P = 6.2 (Table 8.5 Power Number)

Theory $P = N_P \rho n^3 d^5$

$$n = \left(\frac{P}{\rho N_P d^5} \right)^{1/3}$$

Diameter of mixing tank (D) = 4.000 m = Width of Rapid Mixing Tank

Diameter of impeller (d) = 0.2 to 0.4D use 0.3 D

∴ Diameter of impeller (d) = 1.200 m

∴ n = 0.261188569 rps

= 15.67131412 rpm

∴ use gear box to convert rpm(standard motor) to 15.67131 rpm

5 Check Reynolds number for turbulent flow

Theory $$N_R = \frac{d^2 n \rho}{\mu}$$

∴ N_R = 419,018 > 10,000 OK

Therefore this equation is Valid

6 Dimentions of impeller are as follow

- Diameter of impeller (d) = 120.0 cm.
- Width of impeller (W) = 30.0 cm.

7 Check Impeller shaft torque

Theory $P = 2\pi n T$

∴ T = 133.6827314 N-m

∴ choose motor gear = 15.67131412 rpm.

Shaft torque = 133.6827314 N-m

Use Standard motor of P' = 0.3676 HP

8 Head loss through the mixer

Theory $G = \dfrac{g\rho\sqrt{h_L}}{t\mu}$

∴ h_L = 4.078534E-05 m.

9 Check Mixer Tip Speed

Theory $Tip\ Speed = \pi Dn$ m/s

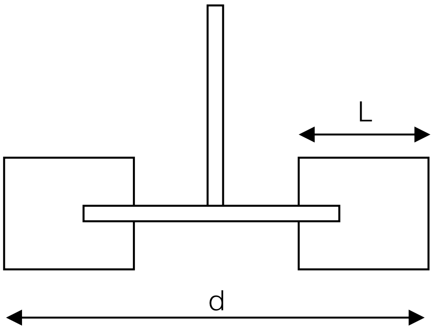
∴ Tip Speed = 0.985 m/s (0.9 m/s m/s,Kawamura)

(Horizontal Shaft with Paddles)

10 Check Blade area/Tank area = 0.09 (Design Criteria 0.1 - 0.2)

(Horizontal Shaft with Paddles)

Bladed Disk Turbine



Where : D = Diameter of Mixing Tank (m)

d = Diameter of Bladed Disk Turbine (m)

L = Long of single bladed (m)

W = Width of single bladed (m)

Equation : $d = 0.2 \quad to \quad 0.4D$

$$L = \frac{d}{4}$$

$$W = \frac{d}{5}$$

sourec : Water Treatment Process : Simple Option (S.Vigneswaran)

Outlet Clarifier Tank

Weir Loading = 7.3 - 15 m^3/m.hr

From Diameter Tank = 9.694676462 m.

Minus outlet hole 2 side = 1 m. (Launders 2 side)

$\therefore$ *Length of weir* = 8.694676462 m.

Theory

$$Length\ of\ weir = \frac{Q(m^3/hr)}{Weir\ Loading\,(m^3/m.hr)}$$

Weir Loading = 17.25193579 m^3/m.hr OK.

Give Diameter of Orifice = 0.5 in. = 0.0127 m.

Give 1 m. of outlet weir have orifice = 25 pores/side

$\therefore$ 2 side = 50 pores

Length of Orifice = 0.635 m./ 1 m. weir

$\therefore$ 1 side = 0.3175 m./ 1 m. weir

Then Free Space of weir = 0.6825 m./ 1 m. weir

$\therefore$ Space between orifice to orifice = 0.0273 m.

= 2.73 cm.

Give 1 m. of outlet weir have orifice = 25 pores/side

$\therefore$ 2 side = 50 pores

Then total orifice = 435 pores

Then sum area of orifice = 0.06 m^2

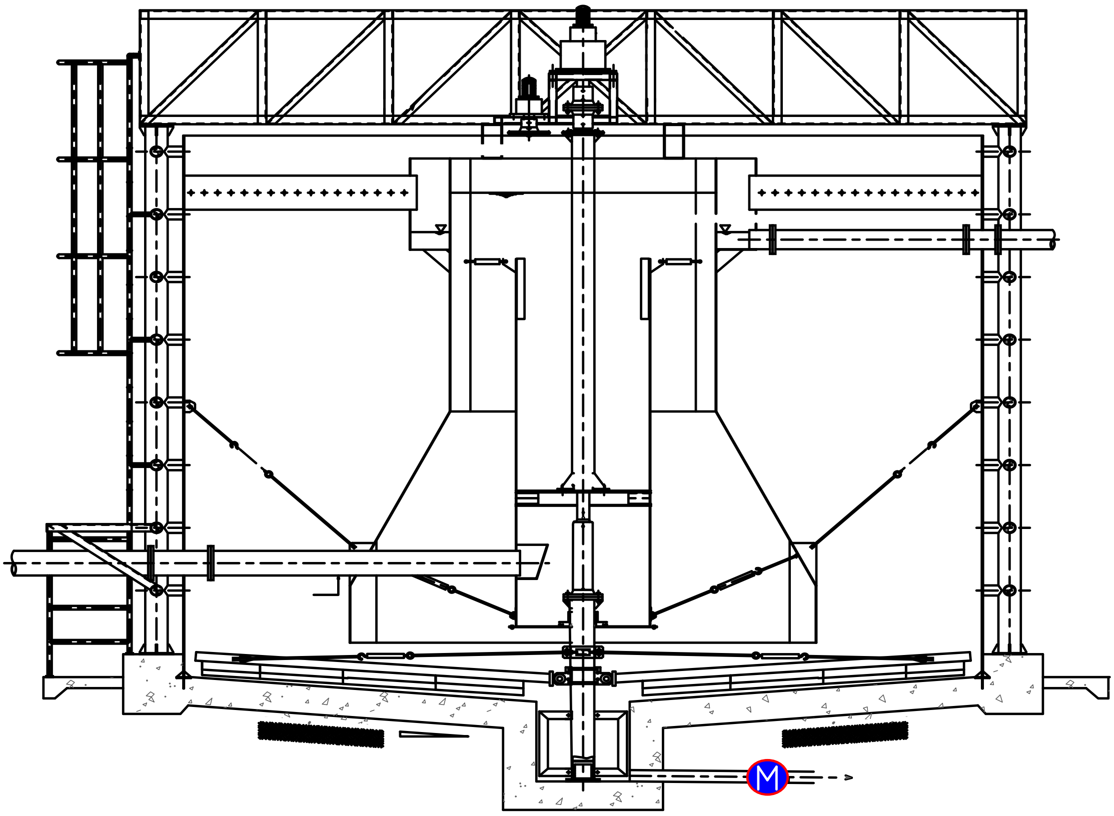
22 Flow Rate pass through 1 orifice = 0.345 m^3/hr

Each of orifice area = $\frac{\pi D^2}{4}$

$\therefore$ Each of orifice area = 0.0001267 m^2

Theory $$Q = Av$$

$\therefore$ Velocity pass through each orifice = 0.756603 m/s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23 Inlet Structure

From Static Mixer Design criteria velocity pass through static mixer = 1 - 2 m/s

Select velocity = 1.5 m/s

Theory $Q = Av$

Area $= \frac{Q}{v}$ m^2

$= 0.027778$ m^2

Circular pipe area $= \frac{\pi D^2}{4}$

$D^2 = 0.035368$

$D = 0.188063$ m.

$= 7.404063$ in. $\approx$ 7 in.

24 Calculation Surface Loading (Sedimentation Zone)

Surface Area at Sedimentation Zone $= \frac{\pi D_{outside}^2}{4} - \frac{\pi D_{inside+2xLaunderswidth}^2}{4}$

$D_{outside} = 9.694676$ m.

$D_{inside+(2xLaunders\ width)} = 6$ m.

∴ Surface Area at Sedimentation Zone = 45.54269 m^2

∴ Surface Loading $= \frac{Q}{A}$

$= 3.293613$ m/hr.

Design Criteria 1.3 - 1.9 m/hr upflow (radial upflow type)

Text Book (Chularrongkron University < 4.2 m/hr.)

Water Works Engineering 0.8333 - 1.6666 m/hr

Kawamura 2 - 3 m/hr