การออกแบบระบบผลิตน้ำประปา

1. ชื่อ : พรศักดิ์ สมรไกรสรกิจ

2. ตำแหน่ง : นักวิทยาศาสตร์ 6

3. สถานที่ทำงาน : ฝ่ายควบคุมคุณภาพน้ำ
การประปานครหลวง

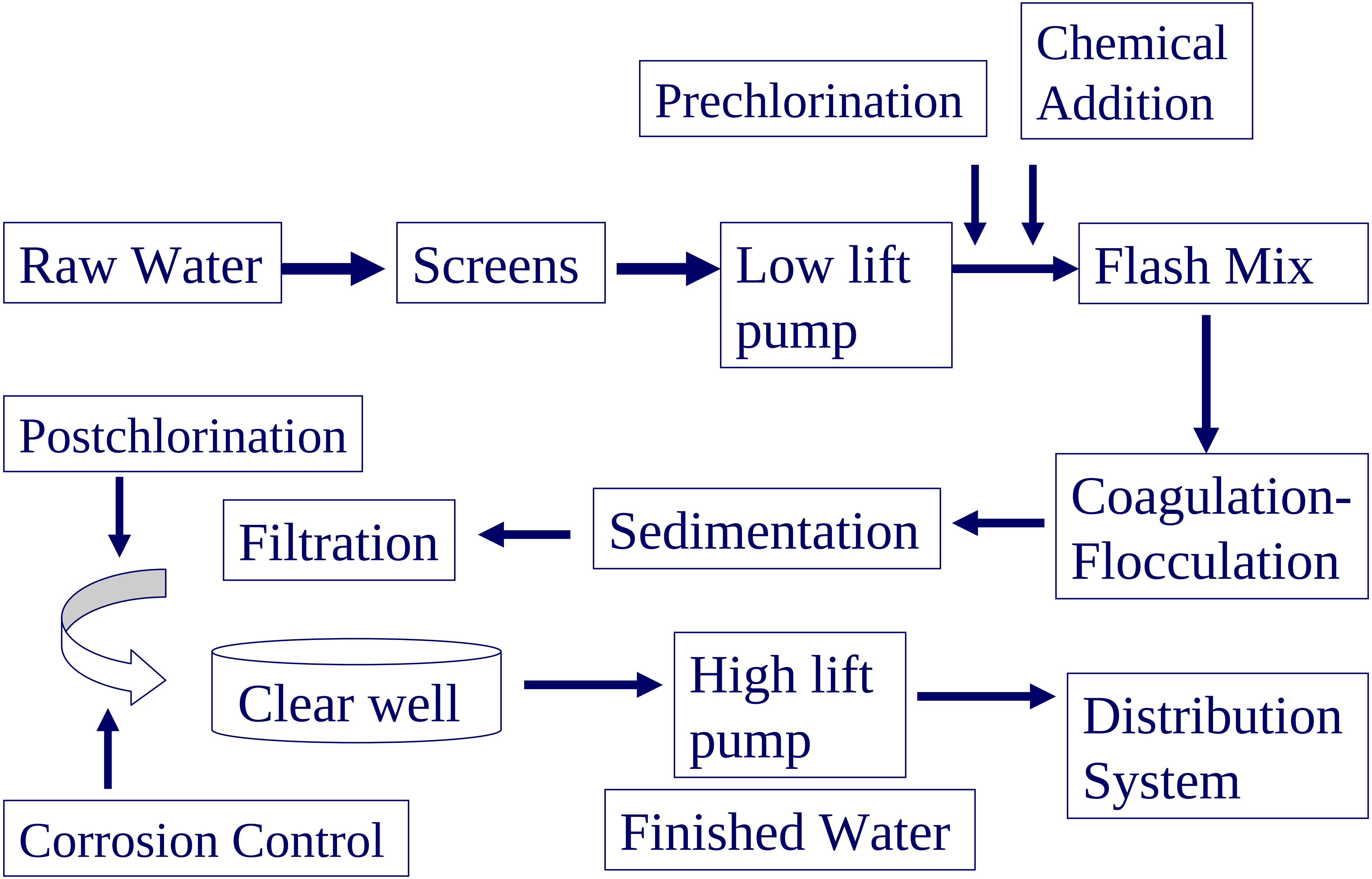
- การศึกษา :

1. ระดับปริญญาตรี สาขา วิทยาศาสตร์สุขาภิบาล จาก มหาวิทยาลัยมหิดล
2. ระดับปริญญาโท สาขา วิศวกรรมสิ่งแวดล้อม จาก มหาวิทยาลัยเกษตรศาสตร์

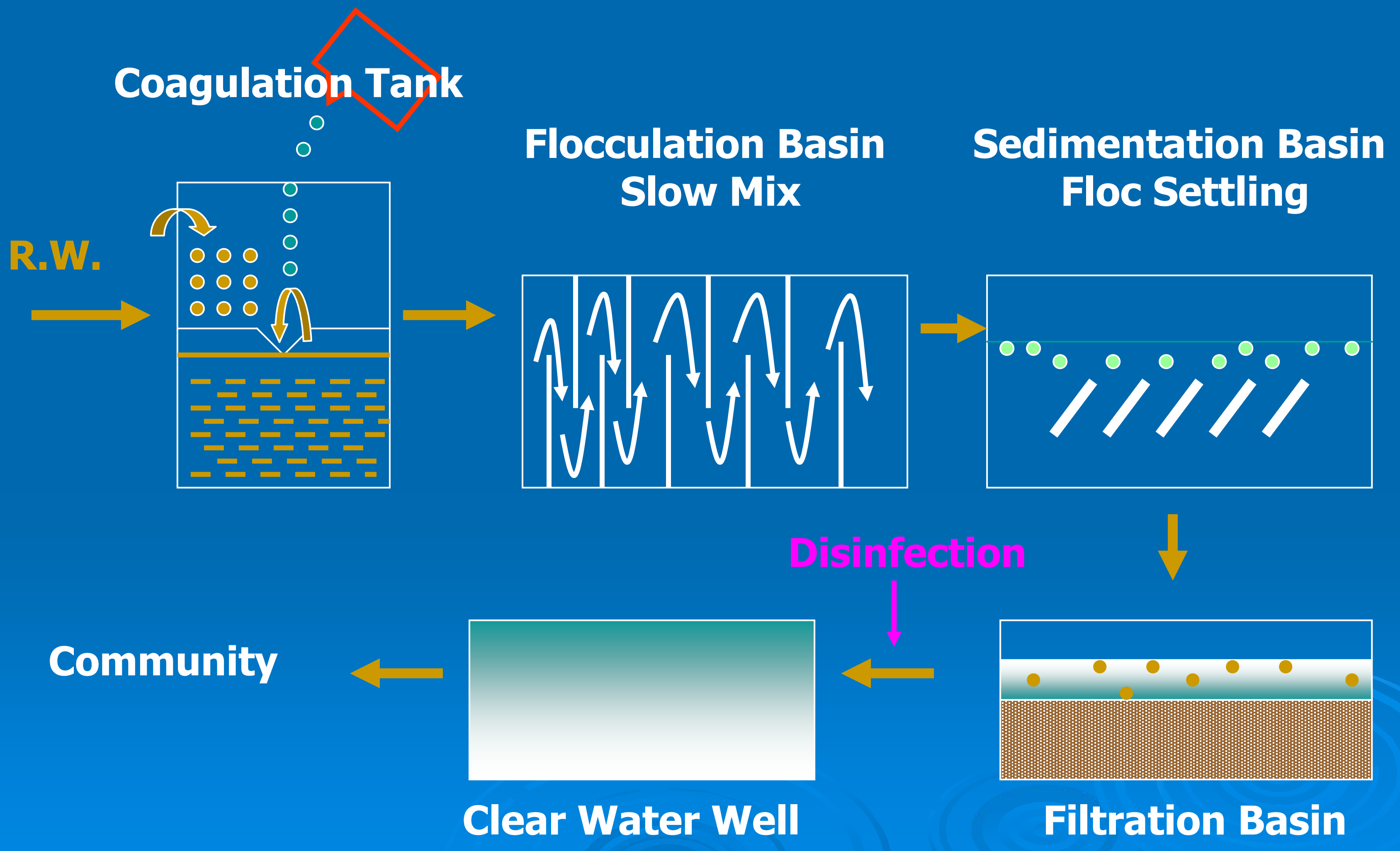
- การฝึกอบรมต่างประเทศ

1. Training course Yokohama Training Program in 2001 in Japan

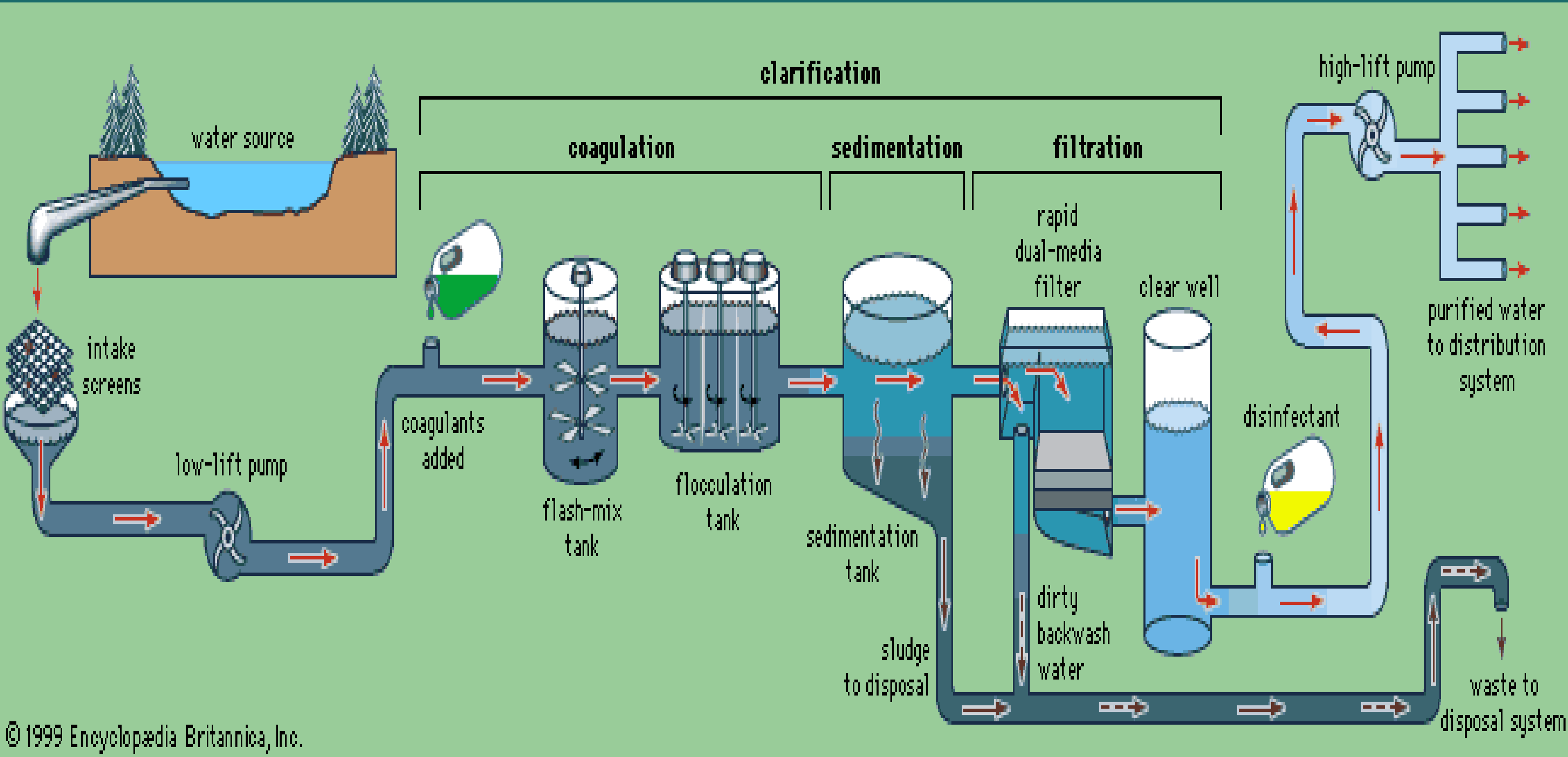
Conventional Surface Water Treatment



Conventional Water Treatment Processes



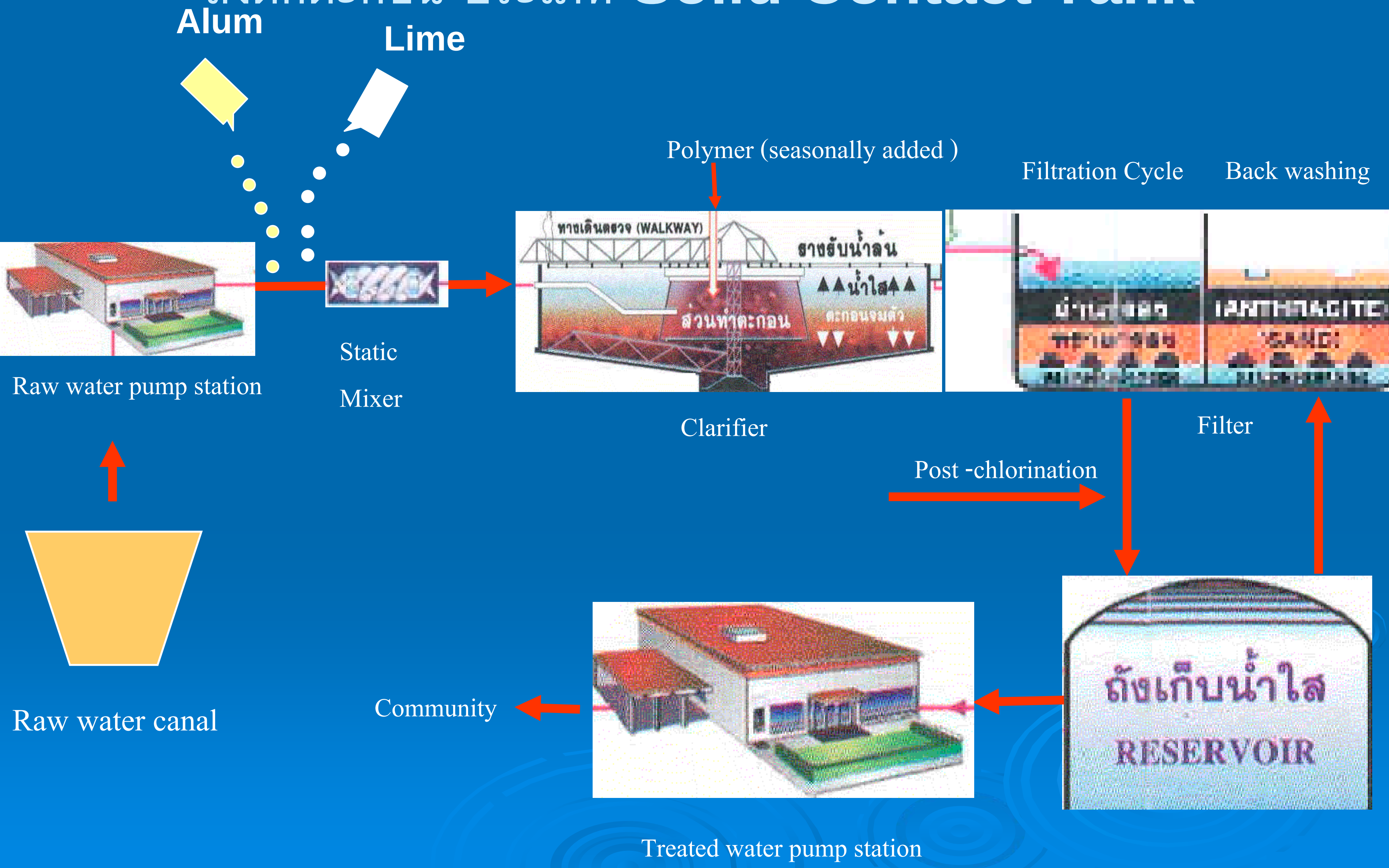
Flocculation and its applications in water treatment



Typical layout of a water treatment plant

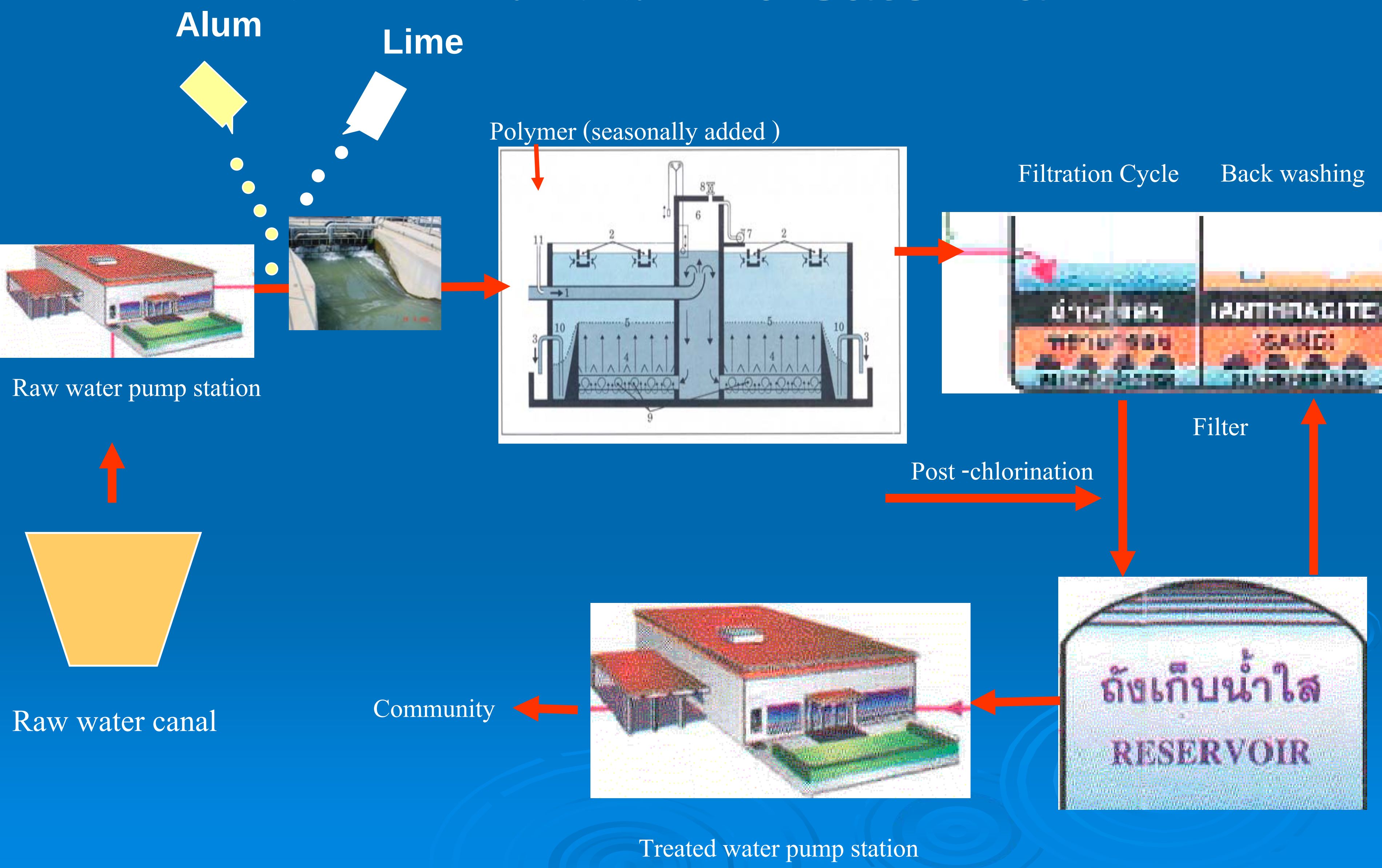
แบบหมุนเวียนสลัดจ์(Sludge Recirculation)

- ถังตกตะกอน ประเภท **Solid Contact Tank**



แบบแบบมีชั้นสลัดจ์(Sludge Blanket)

- ถังตกตะกอน ประเภท **Pulsator Tank**



Coagulation

Rapid Mix

Equations for Design

Camp and Stein Formula

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

where

G = velocity gradient, 1/s (G = 700 to 1,000 per sec)

P = power imparted to the water, N-m/s or watt

V = volume of the basin, m^3

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

Villegas and Letterman

$$G_{opt}^{2.8}T = \frac{44x10^5}{C}$$

where

G_{opt} = velocity gradient, sec^{-1}

T = Mixing Time, sec

C = Optimum dose (Alum, PACl etc.)

Coagulation

Rapid Mix

Type of Mixers

1. Mechanical Mixers

- impeller
- propeller

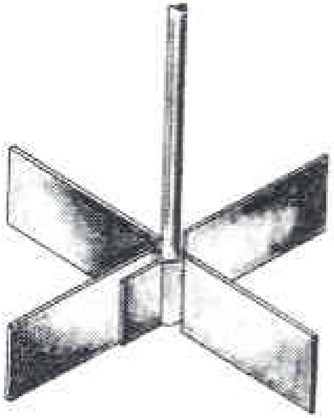
Guideline

Contact time, sec	20	30	40	> 40
Velocity Gradient, sec^{-1}	1,000	900	790	700

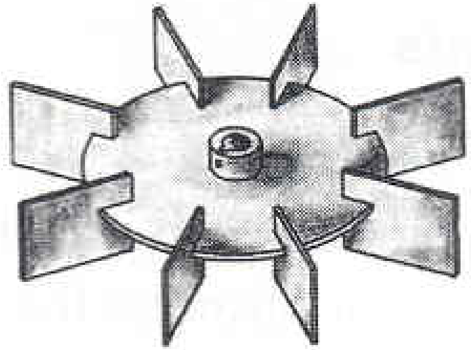
Mechanical Mixer Design Values

Most Common in Larger Plants

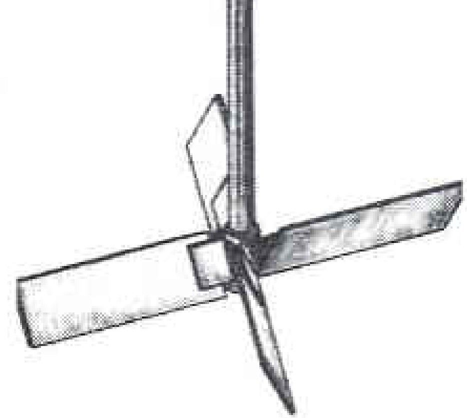
Contact Time (s)	RMS G Value (s^{-1})	GT
20	1000	2×10^4
30	900	3×10^4
40	790	3×10^4
> 40	700	3×10^4



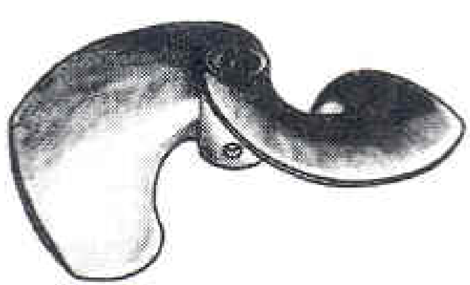
(a)



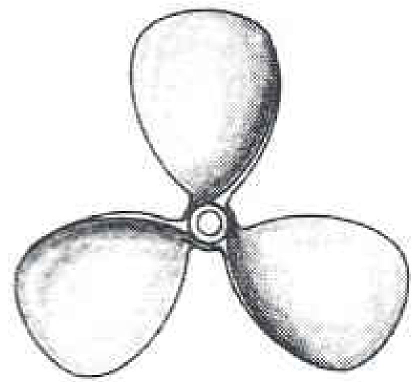
(b)



(c)



(d)



(e)

Power imparted to the water

- Impeller

$$P = 2\pi nT$$

where

n = impeller speed, revolutions per second (rps)

T = impeller shaft torque, N-m

Power imparted to the water

- Impeller & propeller

$$P = N_p \rho n^3 d^5$$

where

N_p = power number of the impeller

d = impeller diameter, m

ρ = mass density of fluid, kg/m^3

n = impeller speed, revolutions per second (rps)

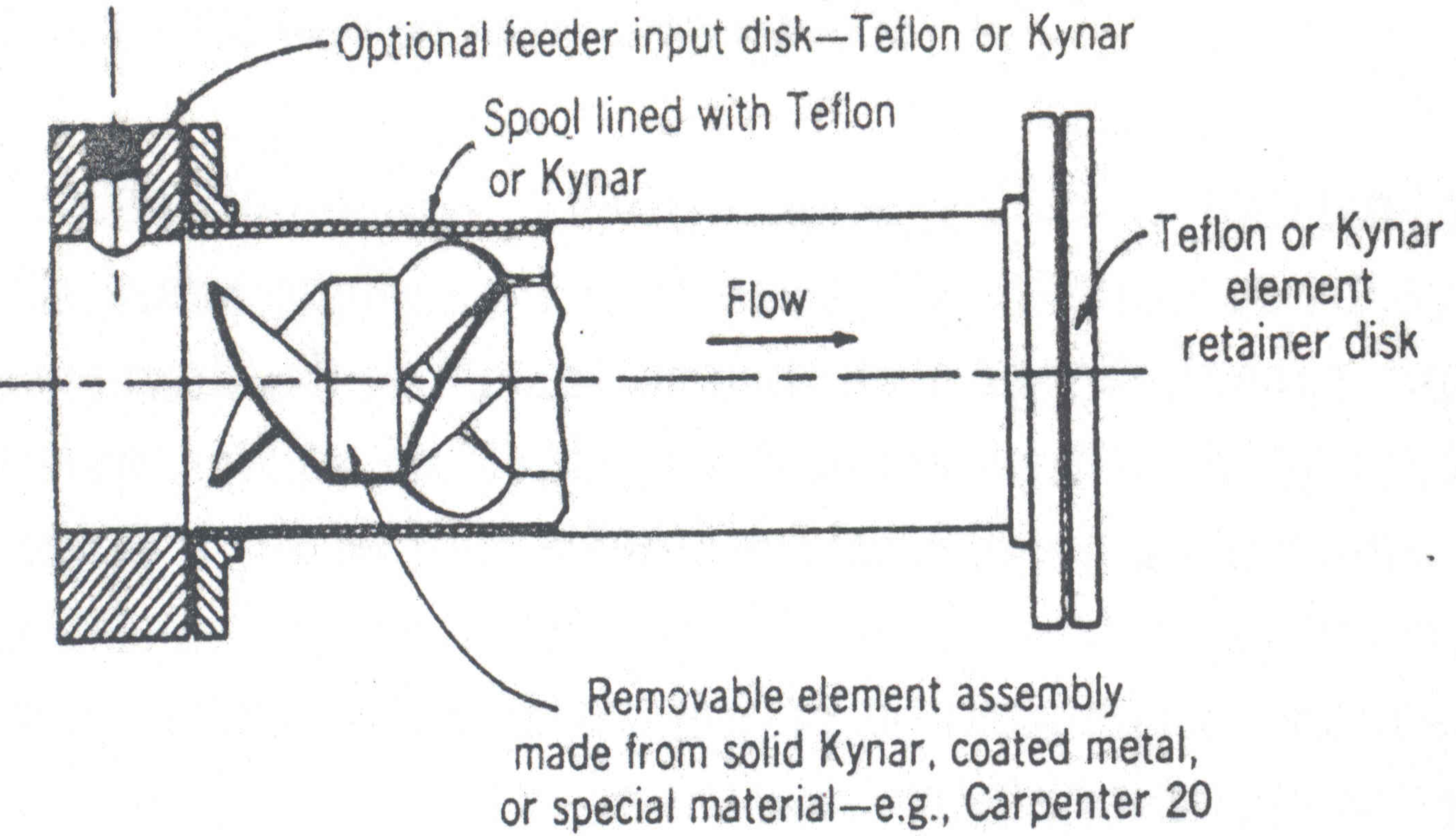
Table 8-5 Power Numbers of Various Rapid-Mix Impellers

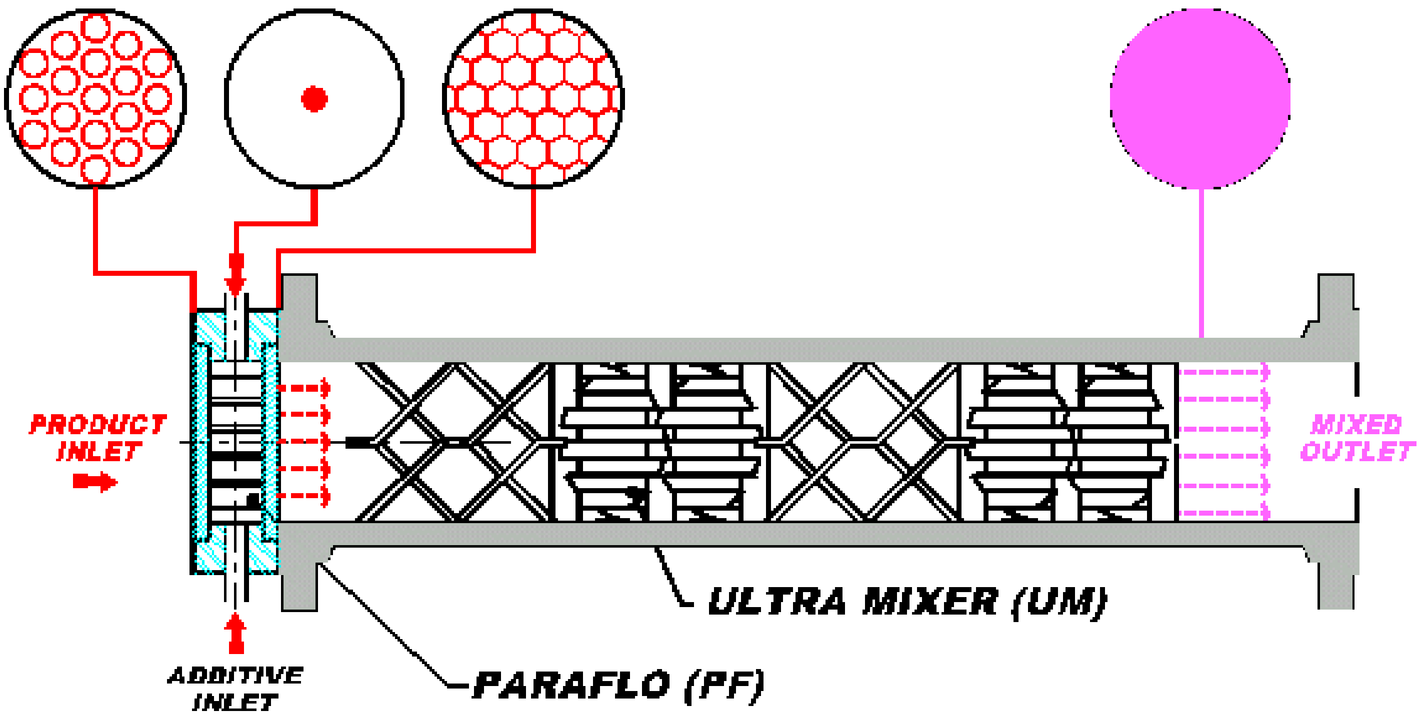
	Power Number, N_p
Radial flow	
Straight blade turbine	
4 blade ($w/d = 0.15$)[a]	2.6
4 blade ($w/d = 0.2$)	3.3
Disc turbine	
4 blade ($w/d = 0.25$)	5.1
6 blade ($w/d = 0.25$)	6.2
Axial flow	
Propeller 1:1 pitch	0.3
Propeller 1.5:1 pitch	0.7
45° Pitched blade	
4 blade ($w/d = 0.15$)	1.36
4 blade ($w/d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

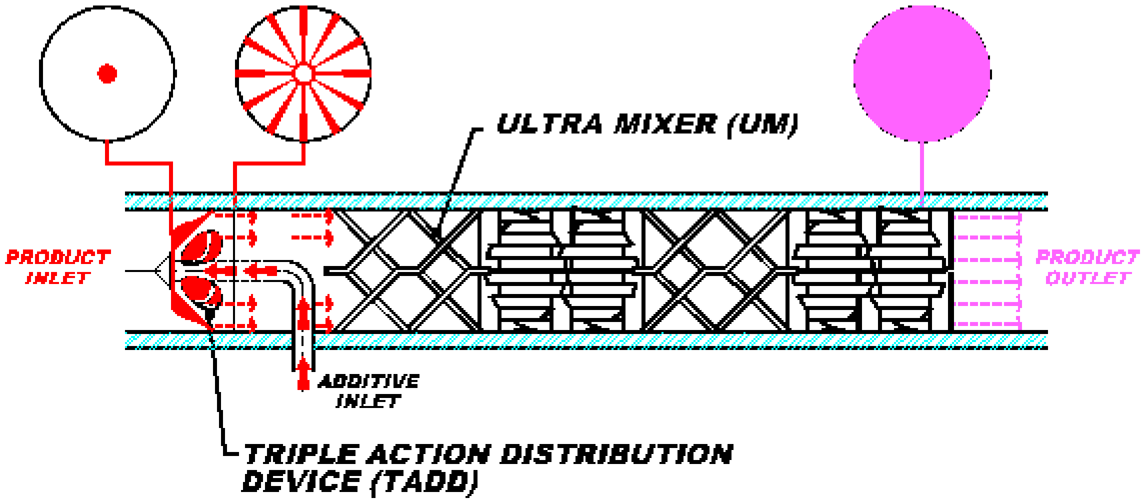
a w/d = blade width-to-diameter ratio.

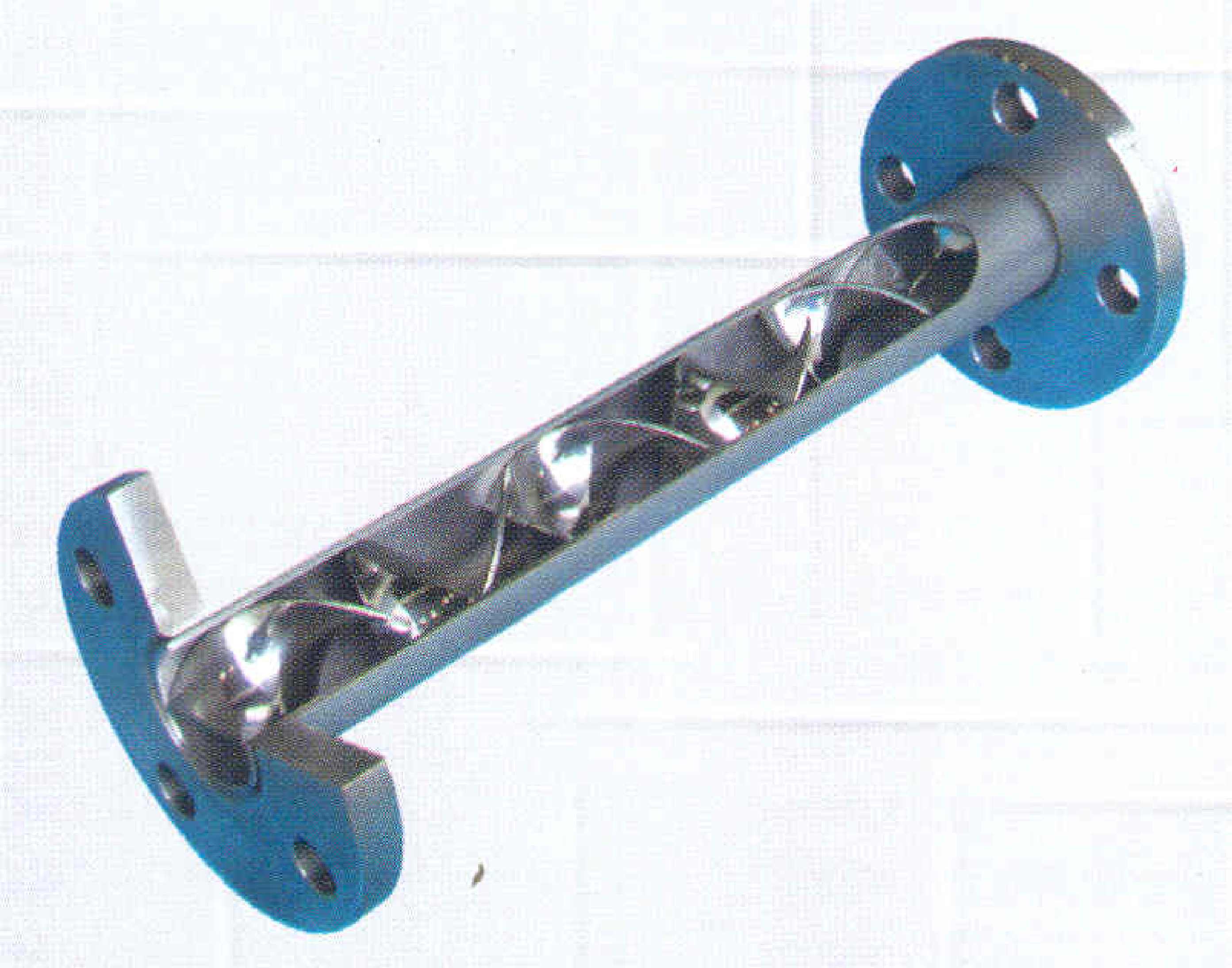
Source: Adapted in part from References 2, 5, 27, and 28.

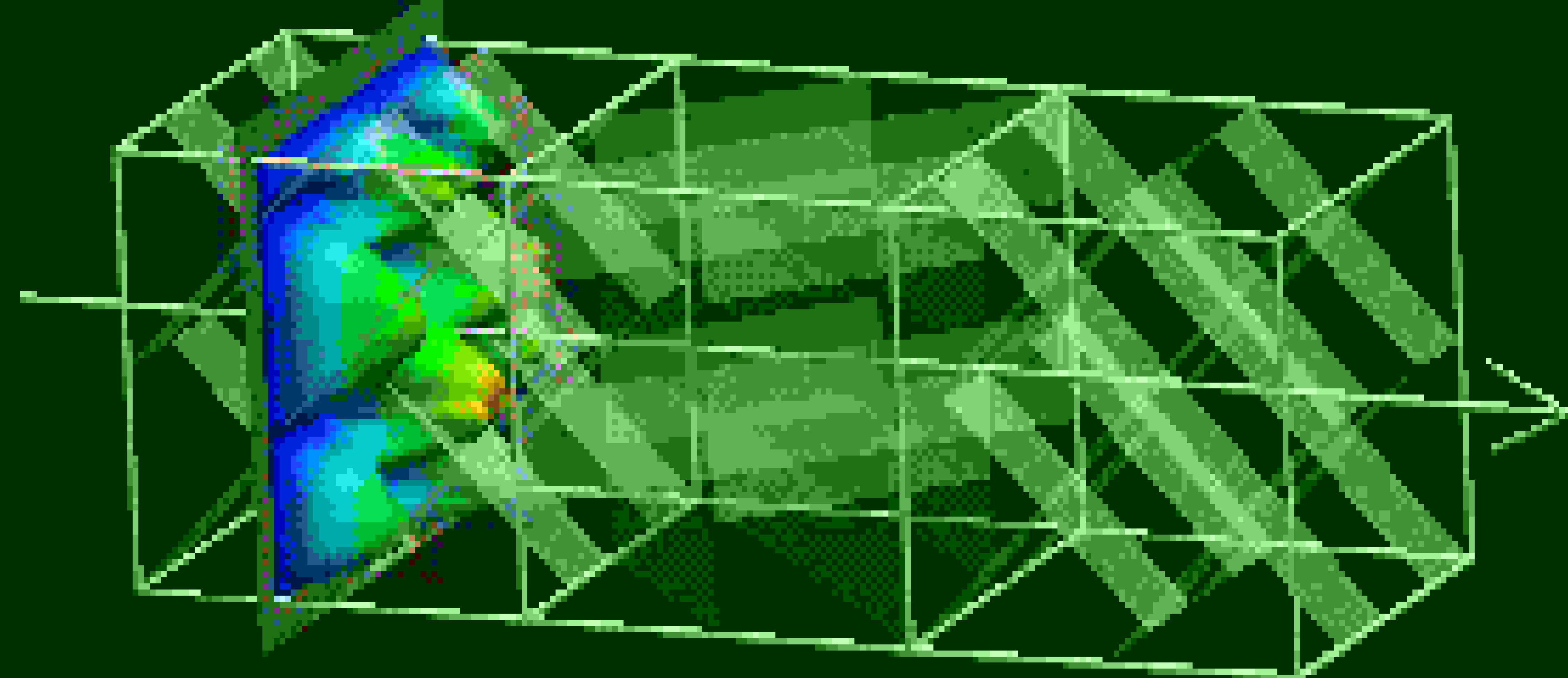
2. Static Mixer

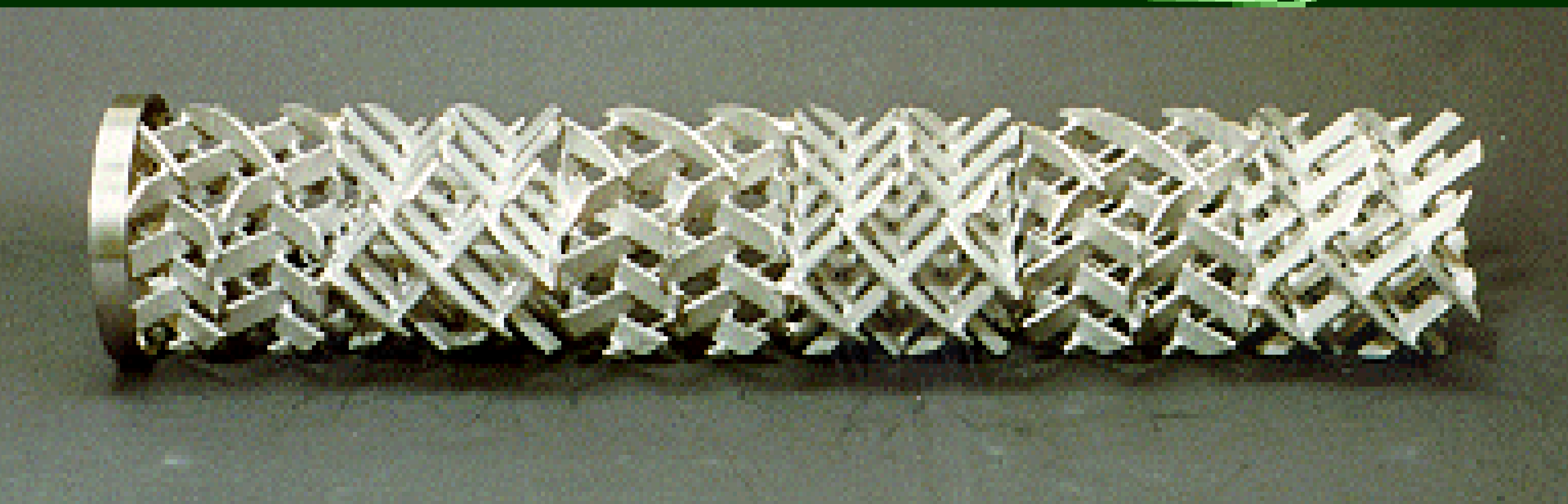


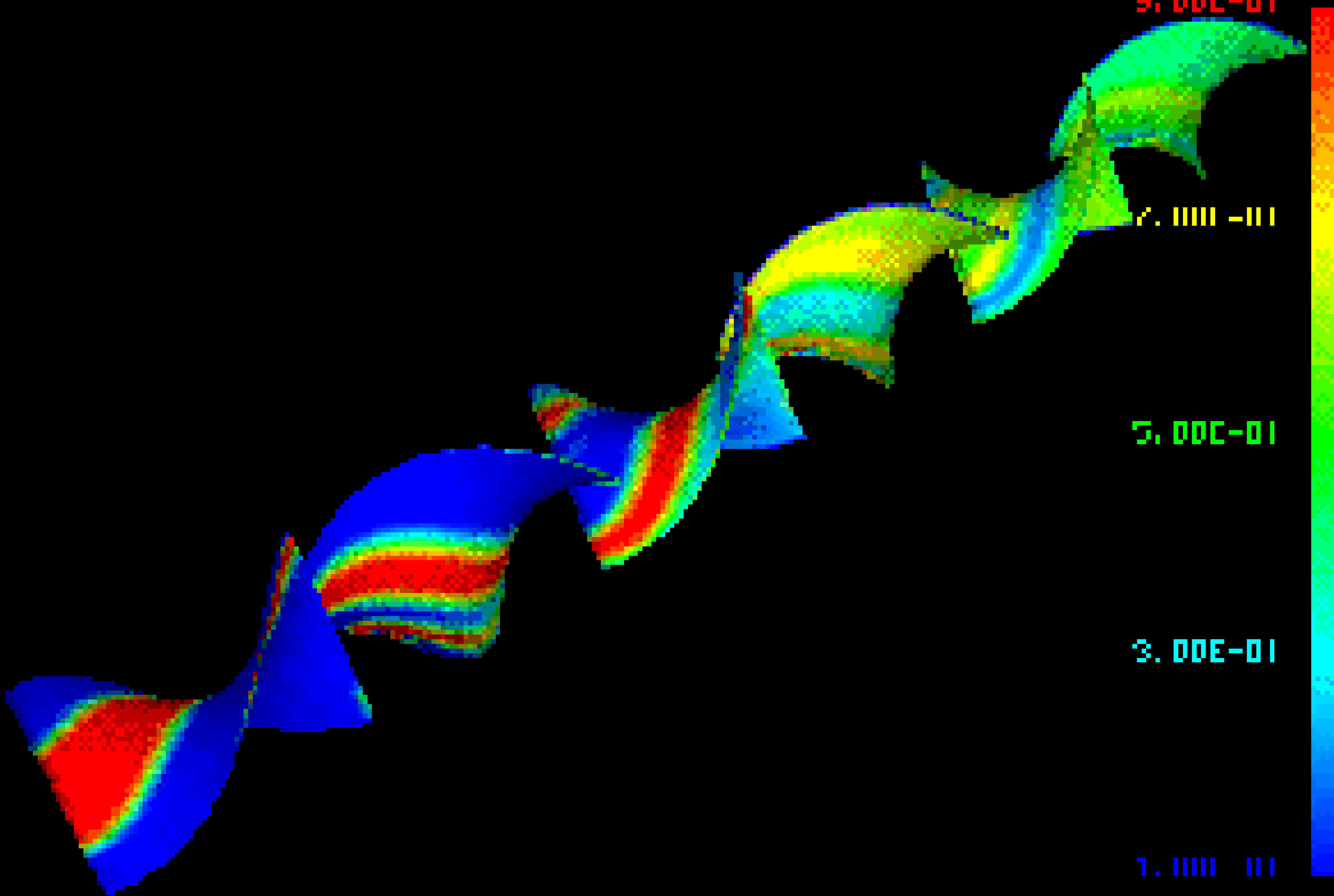

PRODUCT INLET
ADDITIVE INLET
MIXED OUTLET
ULTRA MIXER (UM)
PARAFLO (PF)


ULTRA MIXER (UM)
PRODUCT INLET
PRODUCT OUTLET
ADDITIVE INLET
TRIPLE ACTION DISTRIBUTION DEVICE (TADD)








9.00E-01
5.00E-01
3.00E-01

Design Criteria

- Detention time = 1 – 3 sec

  = 1 – 5 sec

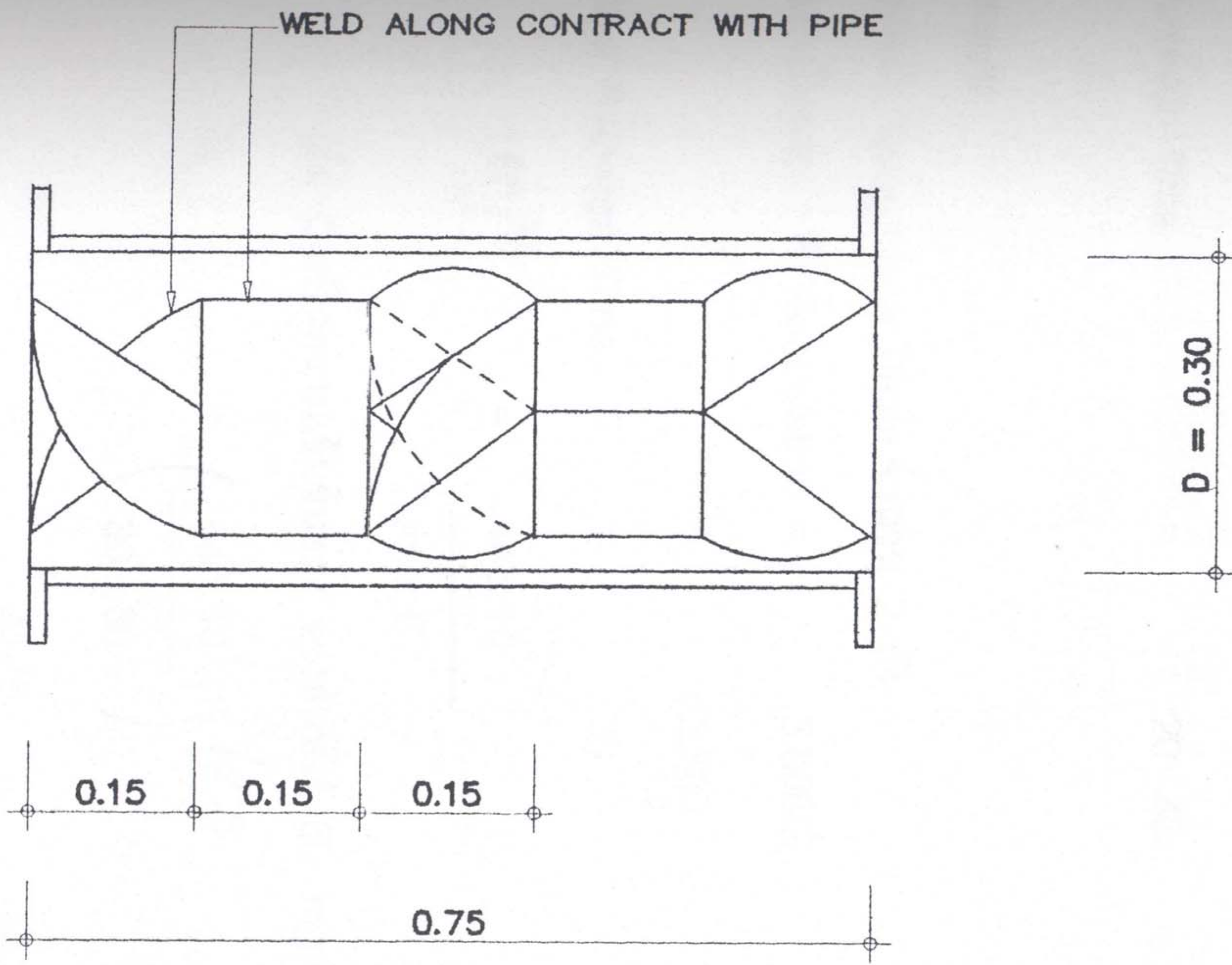
- G value = 500 – 700 s^{-1}

  = 500 – 1,000 s^{-1}

- Gt = 350 – 1,500

  = 350 – 1,700

  = 1,000 – 1,500 (Kawamura)


WELD ALONG CONTRACT WITH PIPE
D = 0.30
0.15
0.15
0.15
0.75

Static mixer Design

2 element

Static mixer length = 1.5 x d x element – 0.5d

3 element

Static mixer length = 1.5 x d x element – d

4 element

Static mixer length = 1.5 x d x element – 1.5d

5 element

Static mixer length = 1.5 x d x element – 2d

6 element

Static mixer length = 1.5 x d x element – 2.5d

7 element

Static mixer length = 1.5 x d x element – 3d

8 element

Static mixer length = 1.5 x d x element – 3.5d

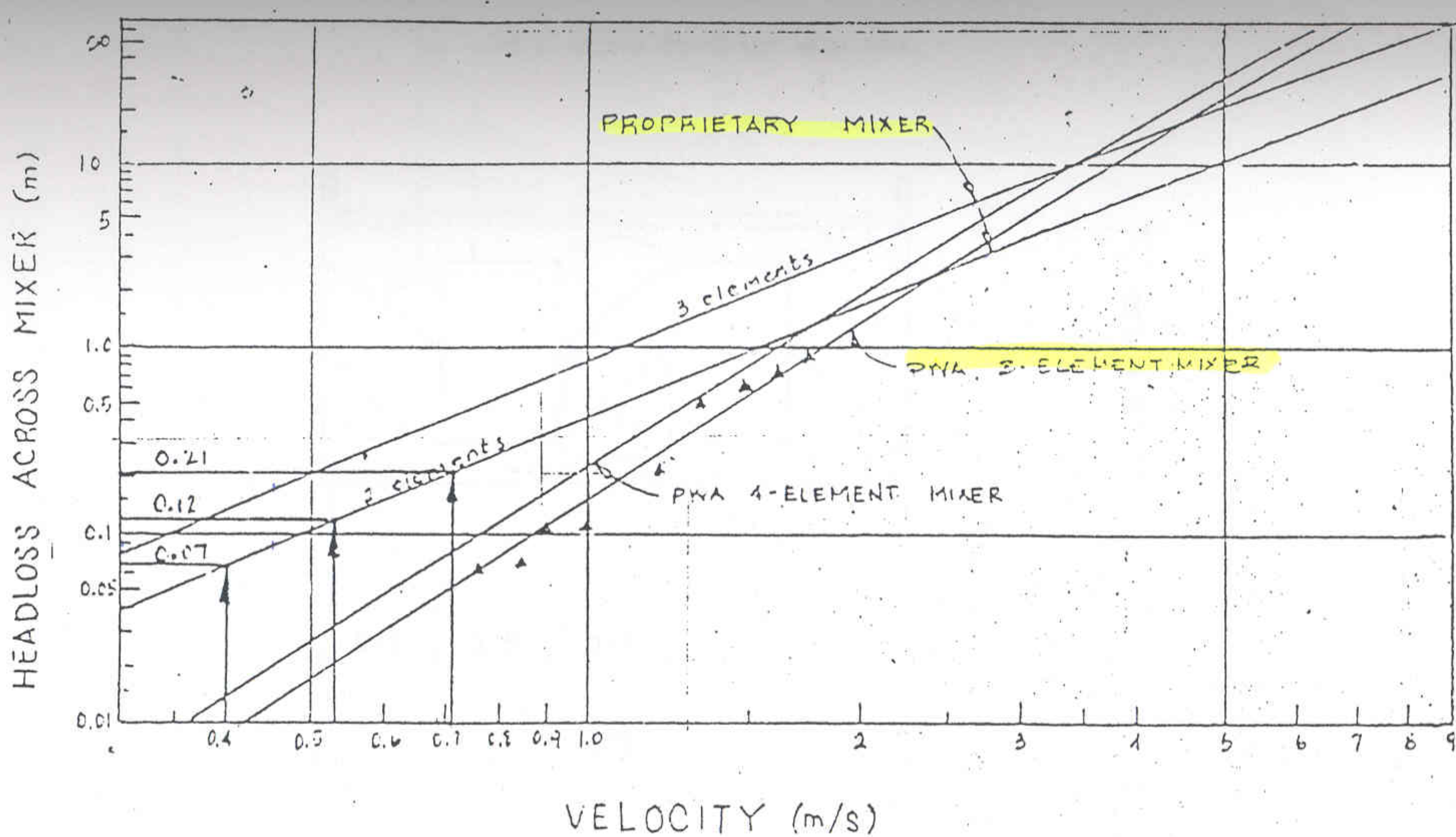
$$Acture \quad Velocity \quad = \frac{Q(m^3/d)}{A(m^2)} \quad m/d$$

$$Acture \quad Velocity \quad = \frac{Q(m^3/d)x4}{\pi D(m)^2 x24x60x60} \quad m/s$$

Check Head loss across Static Mixer from PWA Graph

$$\therefore \quad Detention \quad Time \quad = \frac{Static\ Mixer\ Length(m)}{Acture\,Velocity(m/s)} \quad s$$

HEADLOSS ACROSS MIXER (PWA)



Equations for Design

$$G = \sqrt{\frac{\Delta H x g}{\nu x t}}$$

where

G = velocity gradient, 1/s

ΔH = Head loss across static mixer, m

g = acceleration due to gravity, m/s^2

ν = kinematic viscosity , m^2/s

t = time across static mixer, sec

Equations for Design

1.The Minimum Number of Element

$$R_e = \frac{D_p \rho_L V_s}{\mu}$$

where

R_e = Reynolds number

D_p = pipe diameter. (m)

ρ_L = mass density of water. (kg/m^3)

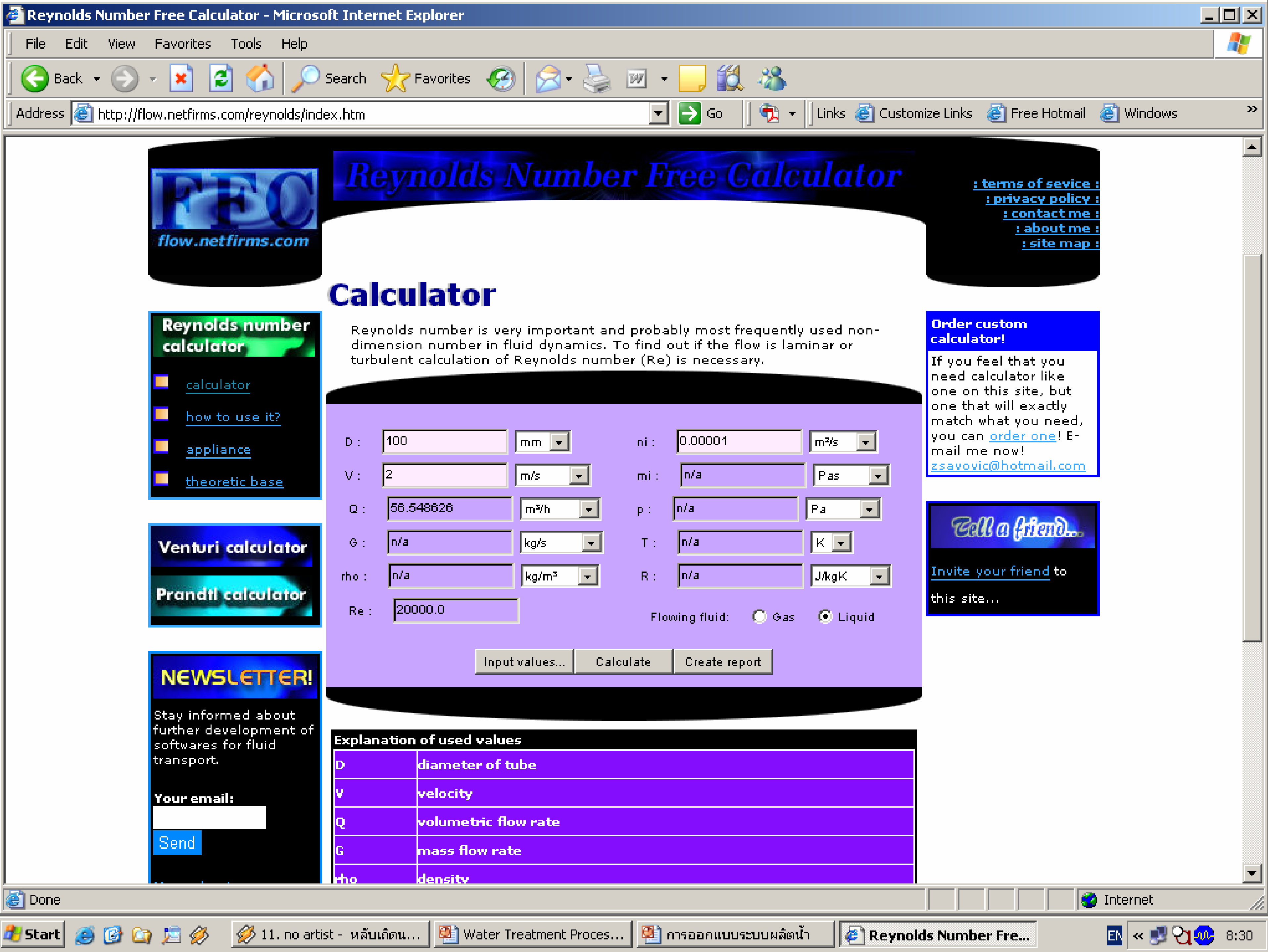
V_s = water velocity. (m/s)

μ = absolute viscosity of water. (kg/m.s)

The Minimum Number of Element

The number of elements recommended are as follows:

Re	Number of Elements
<10	24
10 - 500	18
500 - 1000	12
>1000	6


Reynolds Number Free Calculator - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://flow.netfirms.com/reynolds/index.htm Go Links Customize Links Free Hotmail Windows
FFC
flow.netfirms.com
Reynolds Number Free Calculator
: terms of sevice :
: privacy policy :
: contact me :
: about me :
: site map :
Calculator
Reynolds number calculator
calculator
how to use it?
appliance
theoretic base
Reynolds number is very important and probably most frequently used non-dimension number in fluid dynamics. To find out if the flow is laminar or turbulent calculation of Reynolds number (Re) is necessary.
Order custom calculator!
If you feel that you need calculator like one on this site, but one that will exactly match what you need, you can order one! E-mail me now!
zsavovic@hotmail.com
D : 100 mm
V : 2 m/s
Q : 56.548626 m³/h
G : n/a kg/s
rho : n/a kg/m³
Re : 20000.0
ni : 0.00001 m²/s
mi : n/a Pas
p : n/a Pa
T : n/a K
R : n/a J/kgK
Flowing fluid: Gas Liquid
Input values... Calculate Create report
Venturi calculator
Prandtl calculator
Tell a friend...
Invite your friend to this site...
NEWSLETTER!
Stay informed about further development of softwares for fluid transport.
Your email:
Send
Explanation of used values
D diameter of tube
V velocity
Q volumetric flow rate
G mass flow rate
rho density
Done
Internet
Start
11. no artist - หลับเต็มตื่น...
Water Treatment Proces...
การออกแบบระบบผลิตน้ำ
Reynolds Number Fre...
EN 8:30

Number of Elements	Applications
1 - 4	- Mixing of gas and low viscous fluids
4 - 6	- Mixing of low viscous fluids - Homogenization of high viscous fluids - Uniformization of temperature
6 - 12	- Gas - liquid contraction - Blending of heavy oils - Alkali washing - Aeration
12 - 18	- Mixing of medium viscous fluids - Extraction / emulsification
18 - 24	- Mixing of high viscous fluids - Mixing of two-component resins/adhesives
>24	- Heat exchanger/reactor - Specific purposes

2.Head Loss in Static Mixer

Darcy – Weisbach Equation

$$h_f = f \frac{L}{D} \frac{v^2}{2g}$$

where

h_f = total head loss across static mixer. (m)

f = coefficient of friction (Darcy – Weisbsch)

L = length of static mixer. (m)

D = diameter of pipe. (m)

v = velocity in the pipe. (m/s)

g = acceleration due to gravity. 9.81 m/s^2

For smooth pipe Reynolds number would give the following relationships between f and R_e

$$f = 0.048(R_e)^{-0.20} \qquad 10^4 < R_e < 10^6$$

$$f = 0.193(R_e)^{-0.35} \qquad 3x10^3 < R_e < 10^4$$

$$P = Q\rho g\Delta h$$

where

P = power imparted to the water, ft.lb/sec

Q = pumping rate ft^3/s

ρ = mass density of fluid, 62.4 lb/ft^3

h = pressure drop, ft

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

G = velocity gradient, 1/s

μ = absolute viscosity of the fluid, $lb.s/ft^2$

V = volume of the basin, ft^3

Manufacturer of the static mixer unit

$$\Delta h = \left(\frac{0.009(N-1)Q^2 SM^{0.1}}{D4} \right) N$$

where

Δh = pressure drop, ft

S = specific gravity = 1

M = viscosity, cps

Q = flow rate, gpm

D = pipe diameter, in

N = number of mixing elements

Manufacturer of the static mixer unit

$$\Delta h = \frac{0.007 QxN}{D^{4.4}}$$

where

Δh = pressure drop, psi (1 psi = 70 cm)

Q = flow rate, gpm

D = pipe diameter, in

N = number of mixing elements

การคำนวณค่า Pressure Drop

สูตร

สูตรที่เกี่ยวข้องกับการคำนวณค่า Pressure drop มี 2 สูตร คือ

$$\text{Re.No} = \frac{D\,\bar{u}\,\rho}{\mu} \quad (1)$$

Re.No : Reynold's Number

D : เส้นผ่านศูนย์กลางด้านในของท่อ (mm)

$\bar{u}$: ความเร็วในการเคลื่อนที่ของของเหลว (m/s)

ρ : ความหนาแน่นของของเหลว (Kg/m^3)

μ : ความหนืดของของเหลว (Kg/m.s)

ถ้า Re.No. < 2300 ⇨ Laminar flow

ถ้า Re.No. > 2300 ⇨ Turbulent flow

$$\Delta P = 3.061 \times 10^{-6} f_{NSM} \rho (\bar{u})^2 E$$ → (2)

ΔP : Pressure drop (Kg/cm^2)

f_{NSM} : สัมประสิทธิ์แรงเสียดทานของ Noritake Static Mixer เป็นค่าที่อ่านได้จากตาราง

ถ้าค่า Re.No ต่ำกว่า 0.1 ค่า f_{NSM} จะหาได้จากสูตร

$$f_{NSM} = \frac{16}{Re.No} \times 6$$

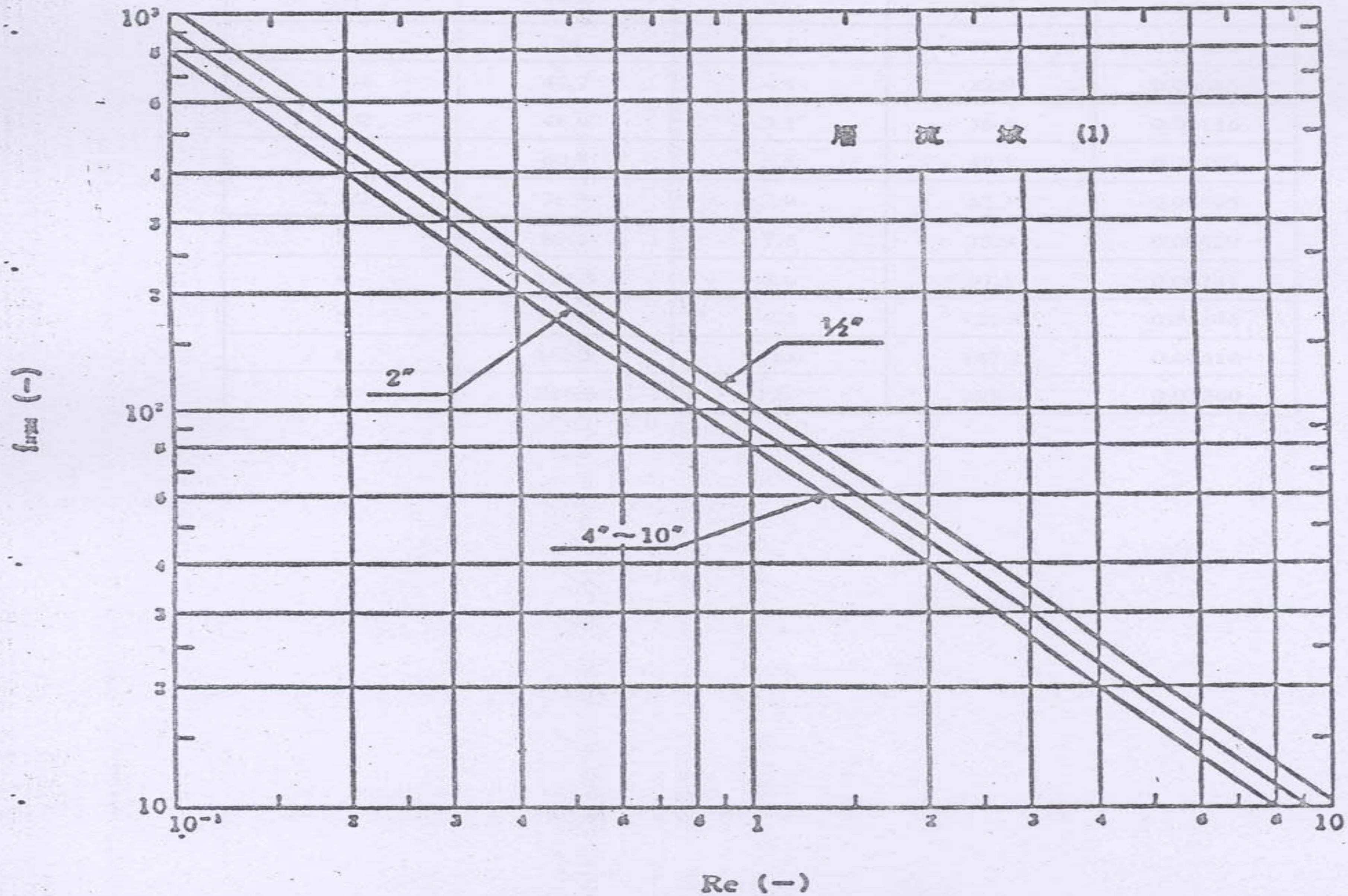
ρ : ความหนาแน่นของของเหลว (g/cm^3)

$\bar{u}$: ความเร็วในการเคลื่อนที่ของของเหลว (cm/s)

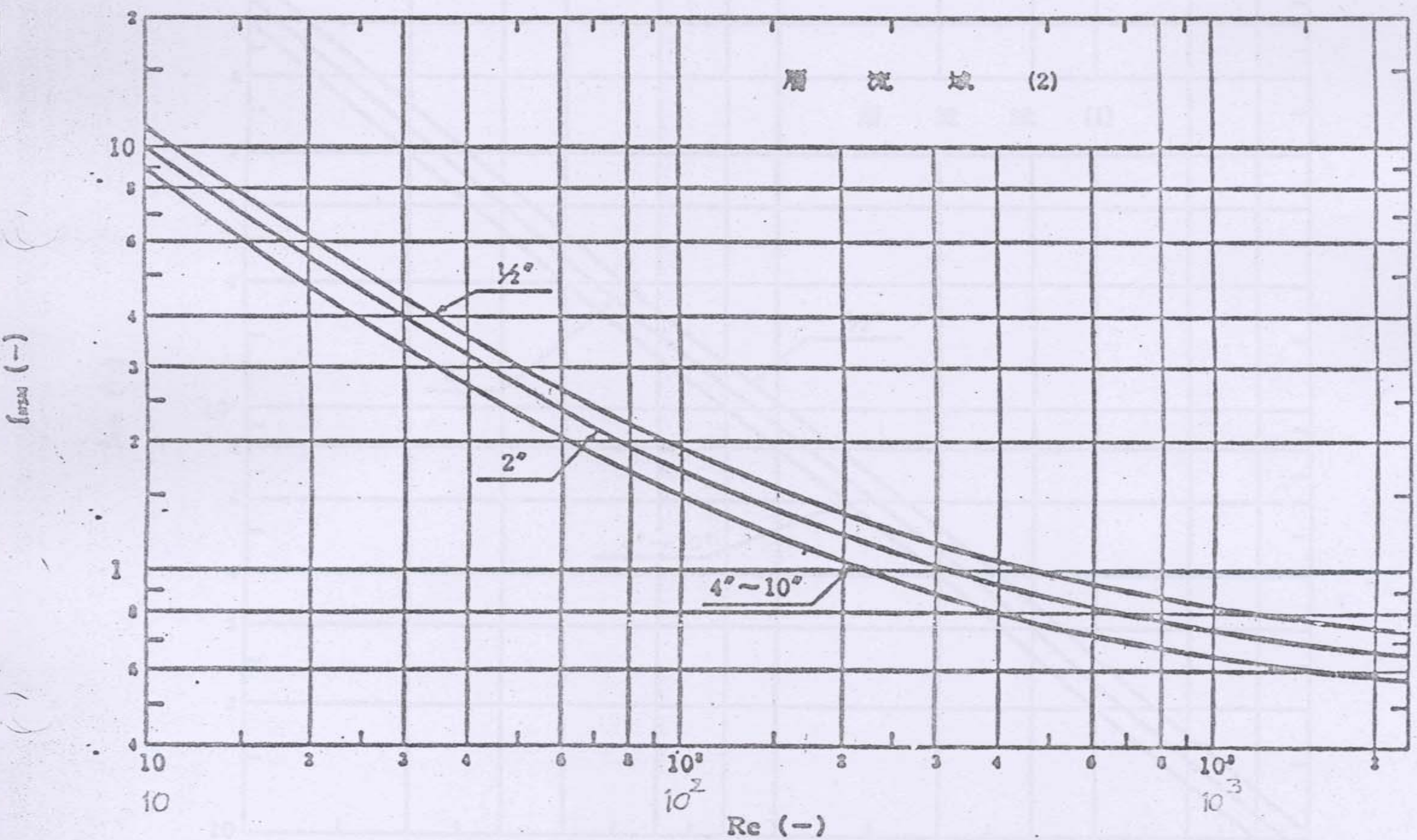
E : จำนวน elements

The quantity of the elements required depend upon the Re.No. , see below for details

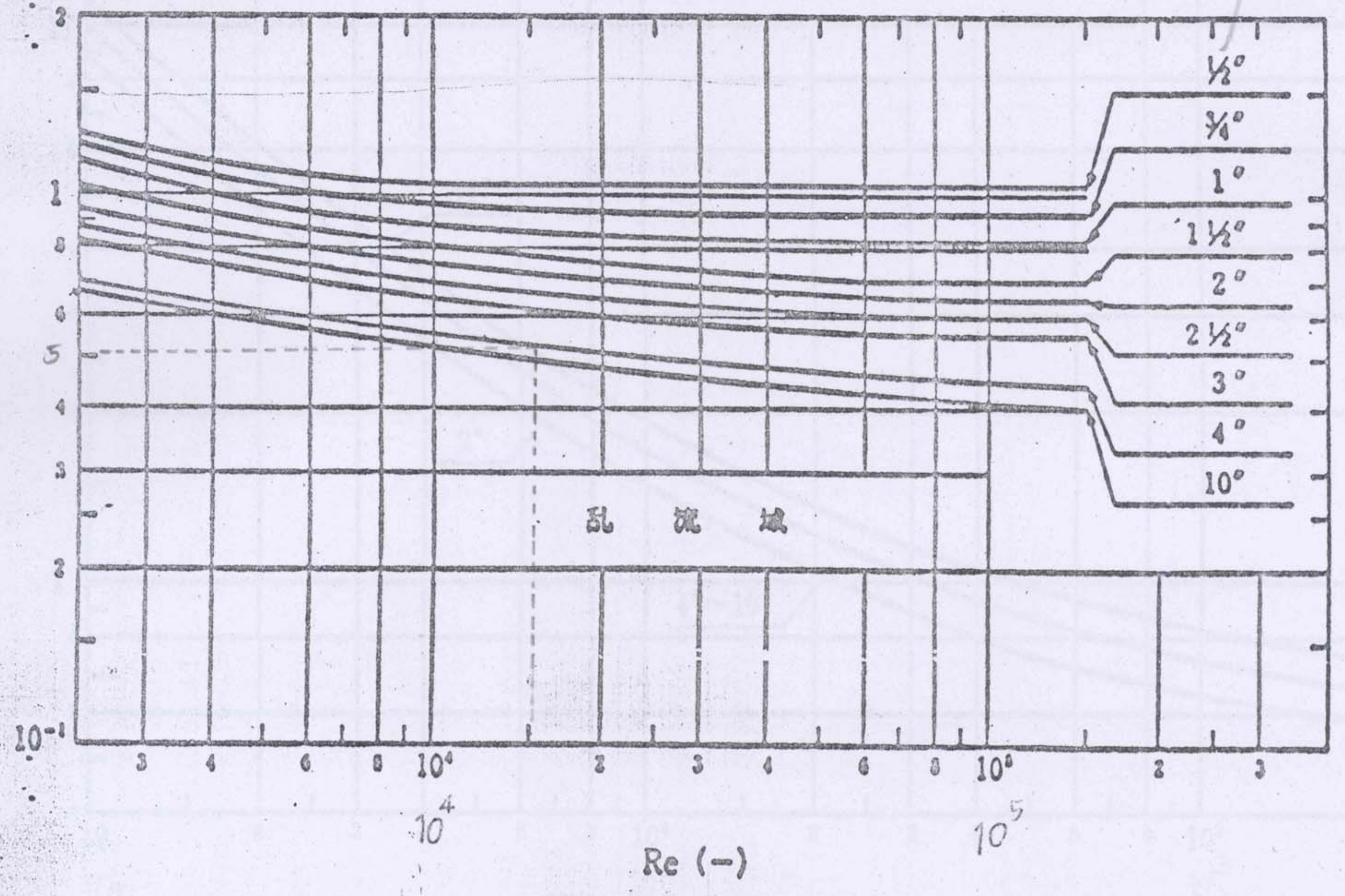
$Re \geq 100{,}000$	....	4 elements
$1{,}000 \leq Re \leq 100{,}000$	....	6 elements
$100 \leq Re \leq 1{,}000$	....	12 elements
$10 \leq Re \leq 100$	....	18 elements
$Re \leq 10$	....	24 - 30 elements



LAMINAR FLOW



LAMINAR FLOW



TURBULENT FLOW

3. Hydraulic Mixing

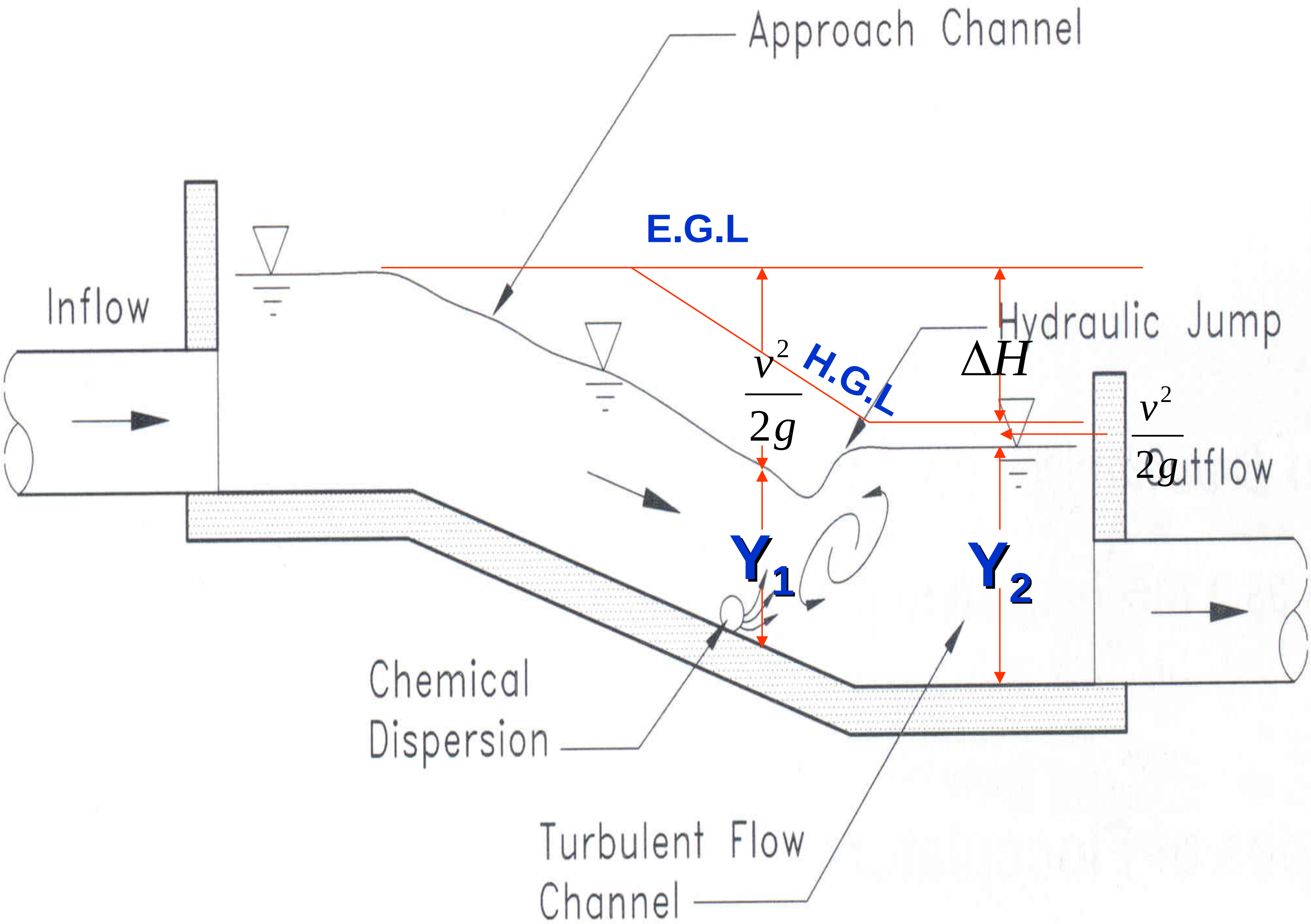
- Hydraulic jump

Guideline

resident time = 2 sec

Velocity Gradient = 800 sec^{-1}

Head loss = 0.3 – 0.4 m



Approach Channel
E.G.L
Inflow
$\frac{v^2}{2g}$
H.G.L
Hydraulic Jump
ΔH
$\frac{v^2}{2g}$
Outflow
Y_1
Y_2
Chemical Dispersion
Turbulent Flow Channel


24 4 2002

Power imparted to the water

- Hydraulic jump

$$P = \rho g Q \Delta H$$

where

ρ = mass density of fluid, kg/m^3

g = acceleration due to gravity, m/s^2

Q = flow rate, m^3/s

ΔH = Head loss, m

Head loss for Hydraulic jump (ΔH)

$$\Delta H = \frac{(Y_2 - Y_1)^3}{4Y_1Y_2}$$

Y_1 and Y_2 mean Critical depth (ความลึกวิกฤต)

$$Y = \sqrt[3]{\frac{q^2}{g}}$$

$$q = \frac{Q}{b}$$

Q = flow rate, m^3/s

b = width of Hydraulic jump, (m)

$$\frac{Y_2}{Y_1} = \frac{1}{2}\left[\sqrt{1+8F_{r1}^{\ 2}} - 1\right]$$

$$F_{r1} = \frac{v_1}{\sqrt{gY_1}}$$

F_{r1} = Freundlicn Number

v_1 = velocity at point 1, (m/s)

Critical state flow	$F_r = 1$
Subcritical state flow	$F_r < 1$
Supercritical state flow	$F_r > 1$

- Weir

Guideline

resident time = 2 - 5 sec

Head loss = 0.3 – 0.6 m

Equations for Design

Grant Formula

1. 90° V-notch weir

$$Q = 1.38 h_w^{5/2}$$

2. 60° V-notch weir

$$Q = 0.78 h_w^{5/2}$$

3. Rectangular weir

$$Q = 1.84 B h_w^{3/2}$$

4. Trapezoidal weir

$$Q = 1.86 B h_w^{3/2}$$

where

Q = flow discharge, m^3/s

h_w = head on weir, m

B = Length of weir, m

5. Outlet Arrangement

$$L = \frac{0.2Q}{Hv_s}$$

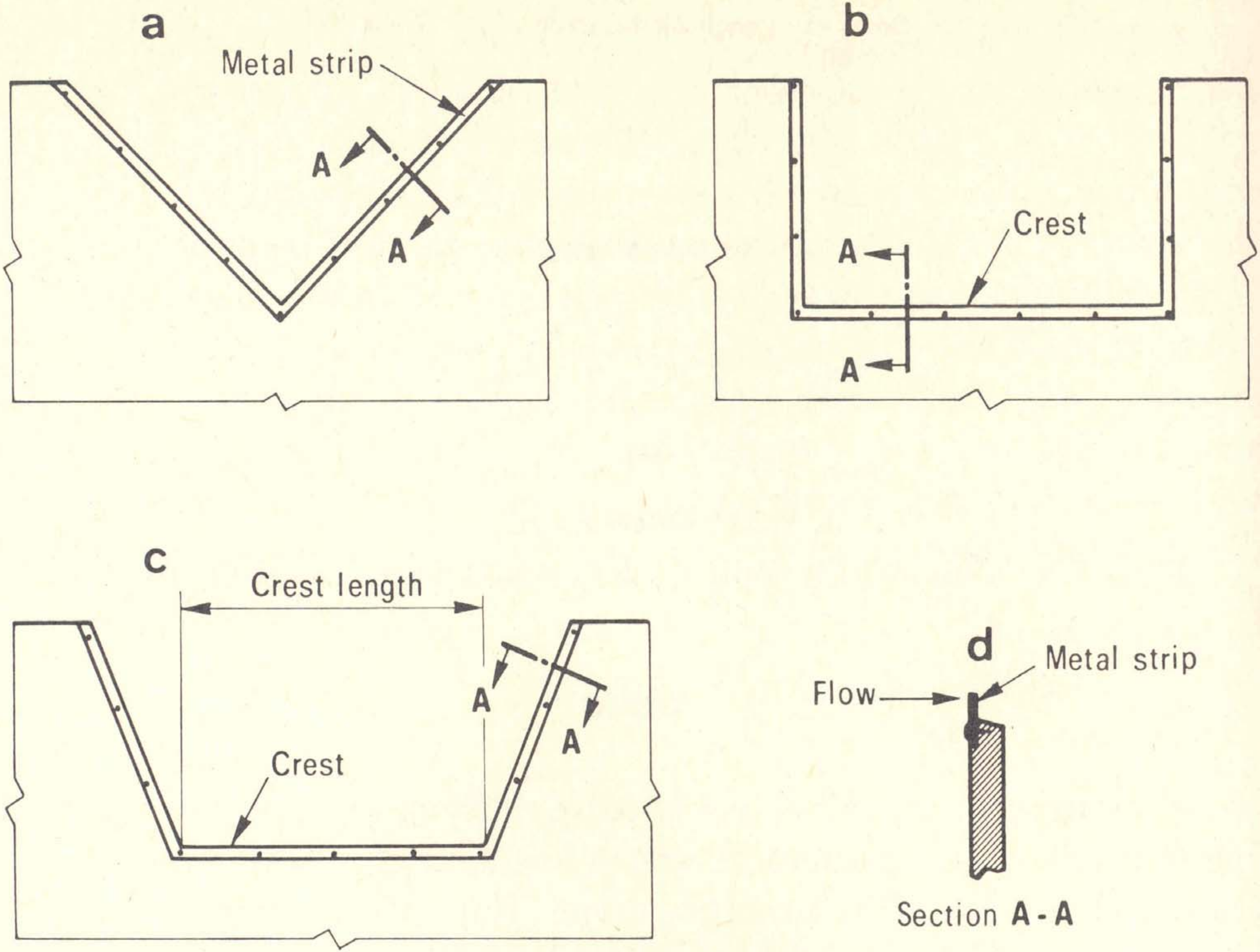
where

L = Combined weir length, m

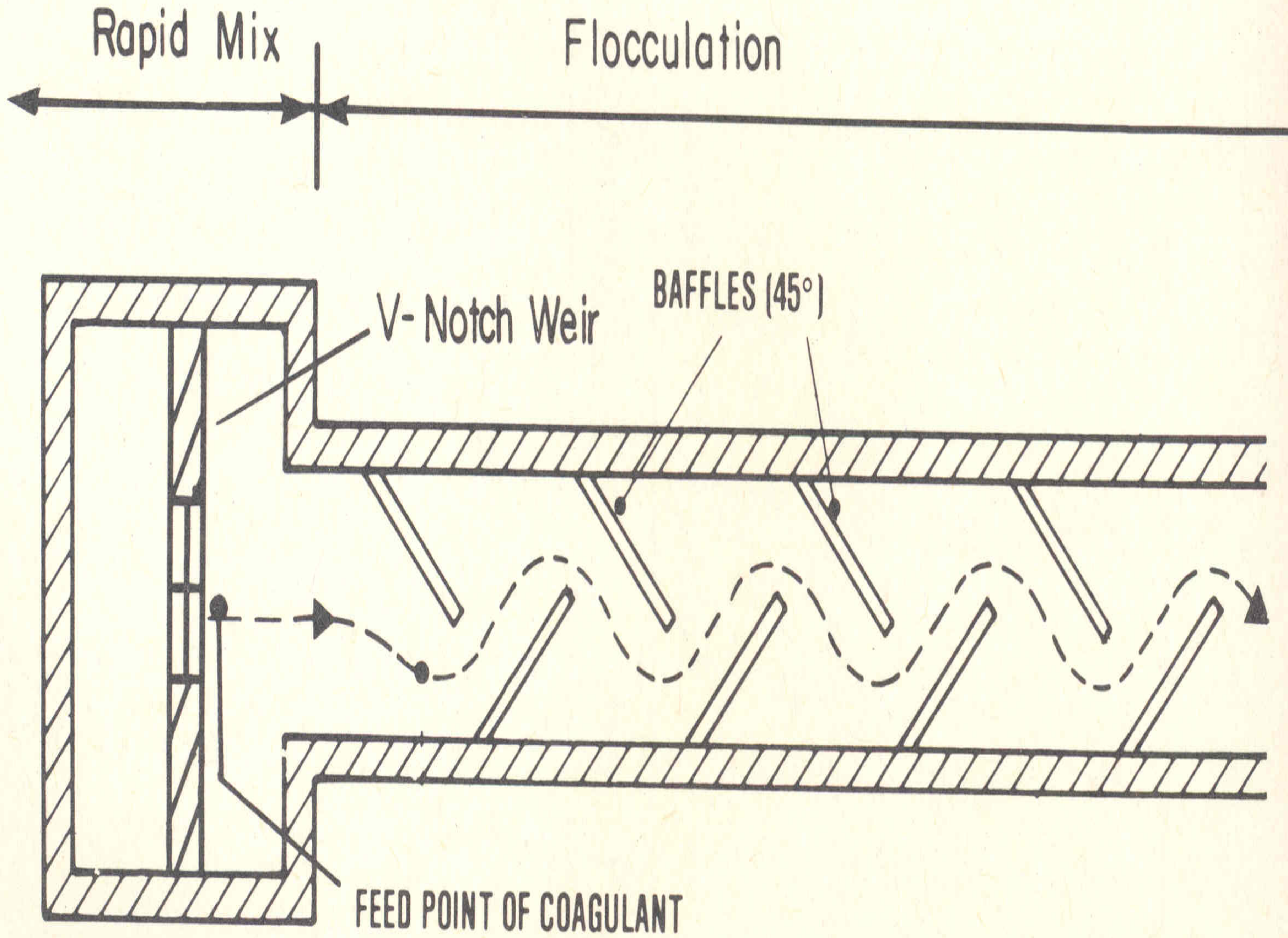
Q = flow rate, m^3/d

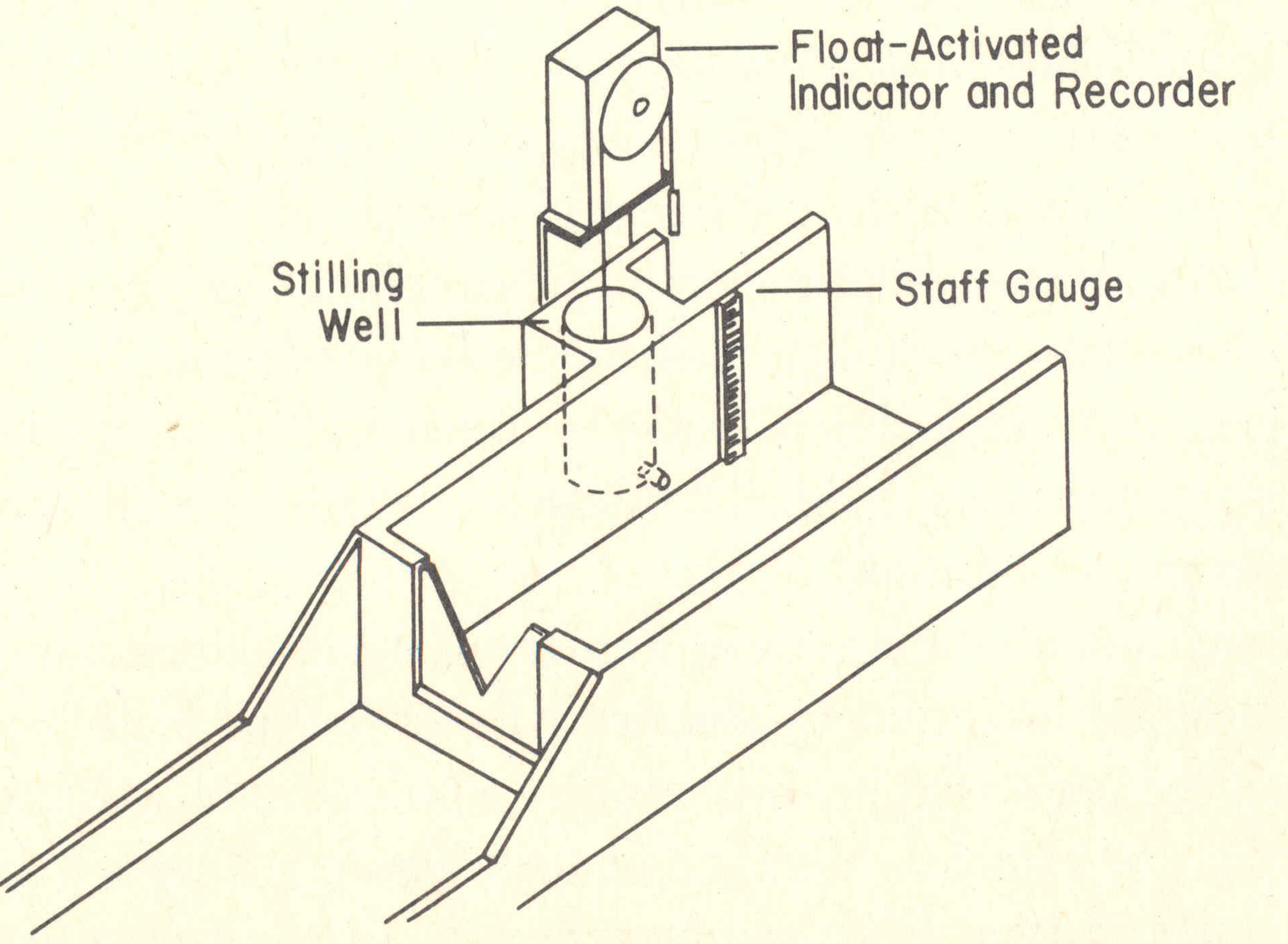
H = depth of tank, m

V_s = settling velocity, m/d



a
Metal strip
A
A
b
Crest
A
A
c
Crest length
Crest
A
A
d
Metal strip
Flow
Section A - A


Rapid Mix
Flocculation
V- Notch Weir
BAFFLES (45°)
FEED POINT OF COAGULANT


Float-Activated
Indicator and Recorder
Stilling
Well
Staff Gauge

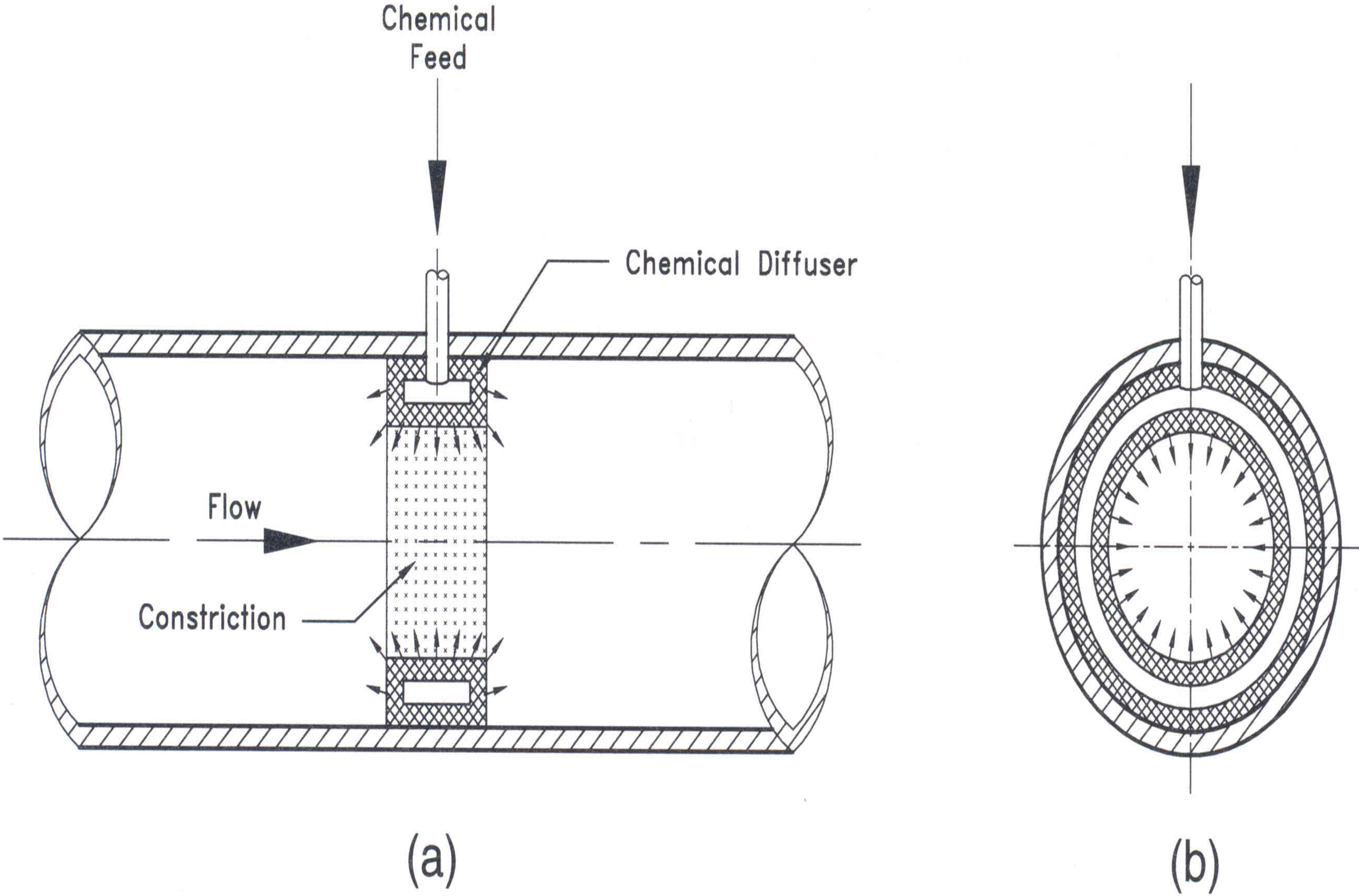
4. Diffusers and injection device

Guideline

Mixing time = 1 sec

Velocity Gradient = 750 – 1,000 sec^{-1}

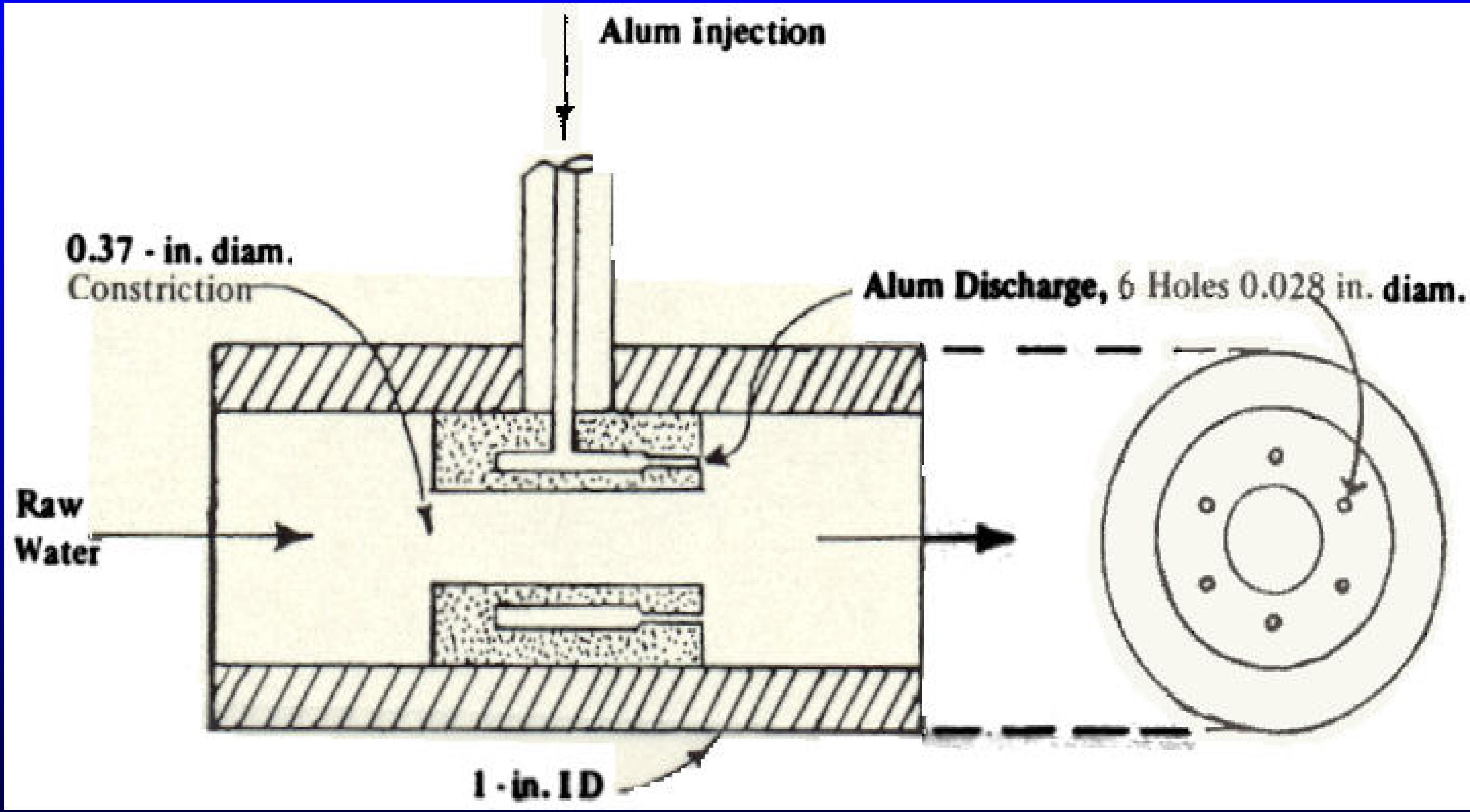
Velocity at injection nozzles = 6 -7.6 m/s


Chemical
Feed
Chemical Diffuser
Flow
Constriction
(a)
(b)

In-Line Blenders

- $T < 30$ s
- $G = 3{,}000$ to $5{,}000\ s^{-1}$
- $GT = 9 \times 10^3$ to 1.5×10^5

Injection Mixer



Data needed for design

1. Raw water analysis ~ best & worst quality

2. Maximum and minimum flow rate

3. Typical Jar test result

Flocculation

1. paddle type mechanical flocculators

$$P = \frac{1}{2} C_D (\Sigma A) \rho (\Sigma v)^3$$

where

P = Power requirement for mixing , Watt (N.m/s)

ρ = mass density of fluid, kg/m^3

A = area of paddles, m^2

v = velocity of the paddle relative to the water, m/s

C_D = coefficient of drag

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

v = velocity of the paddle relative to the water, m/s

$$v = 0.75 v_{paddle}$$

$$v_{paddle} = 2\pi r n$$

n = the rotation speed of paddle (rps)

Design Criteria

1. Velocity Gradient 30 to 80 sec^{-1}

2. Detention Time = 30 – 60 min

$1x10^4 < Gt < 1x10^5$ (Kawamura)

$2x10^4 < Gt < 2x10^5$ (Camp)

2. Baffled type flocculators

For Horizontal units

$$n = \left\{ \left[(2\mu t) / \rho (1.44 + f) \right] \left[(HLG) / Q \right]^2 \right\}^{1/3}$$

For Vertical units

$$n = \left\{ \left[(2\mu t) / \rho (1.44 + f) \right] \left[(WLG) / Q \right]^2 \right\}^{1/3}$$

where

ρ	= mass density of fluid, kg/m^3
n	= number of baffles in the basin
H	= depth of water in the basin (m)
L	= length of the basin (m)
G	= velocity gradient (s^{-1})
Q	= flow rate (m^3/s)
t	= time of flocculation (s)
μ	= dynamic viscosity (kg/m.s)
f	= coefficient of friction of the baffles
W	= width of the basin (m)

Guideline For Horizontal units & Vertical units

1. Water velocity generally varies from 0.1 to 0.3 m/s

2. Detention time varies from 15 to 30 min

3. Velocity gradients vary between 10 to 100 s^{-1}

4. Distance between baffle > 0.45 m

5. Head loss = 0.035 – 0.04 m

$$\Delta H = (n+1)\frac{v_1^2}{2g} + n\frac{v_2^2}{2g}$$

where

ΔH = Head loss, m

n = number of baffle

v_1 = velocity in channel, m/s

v_2 = velocity in slot, m/s

g = acceleration due to gravity, 9.8 m/s^2

$$P = \rho g Q \Delta H$$

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

Design Criteria

$1x10^4 < Gt < 1x10^5$ (Kawamura)

$2x10^4 < Gt < 2x10^5$ (Camp)

Flocculation: cont.

Power input

$$G = \left(\frac{P/V}{\mu} \right)^{0.5}$$

Tank volume

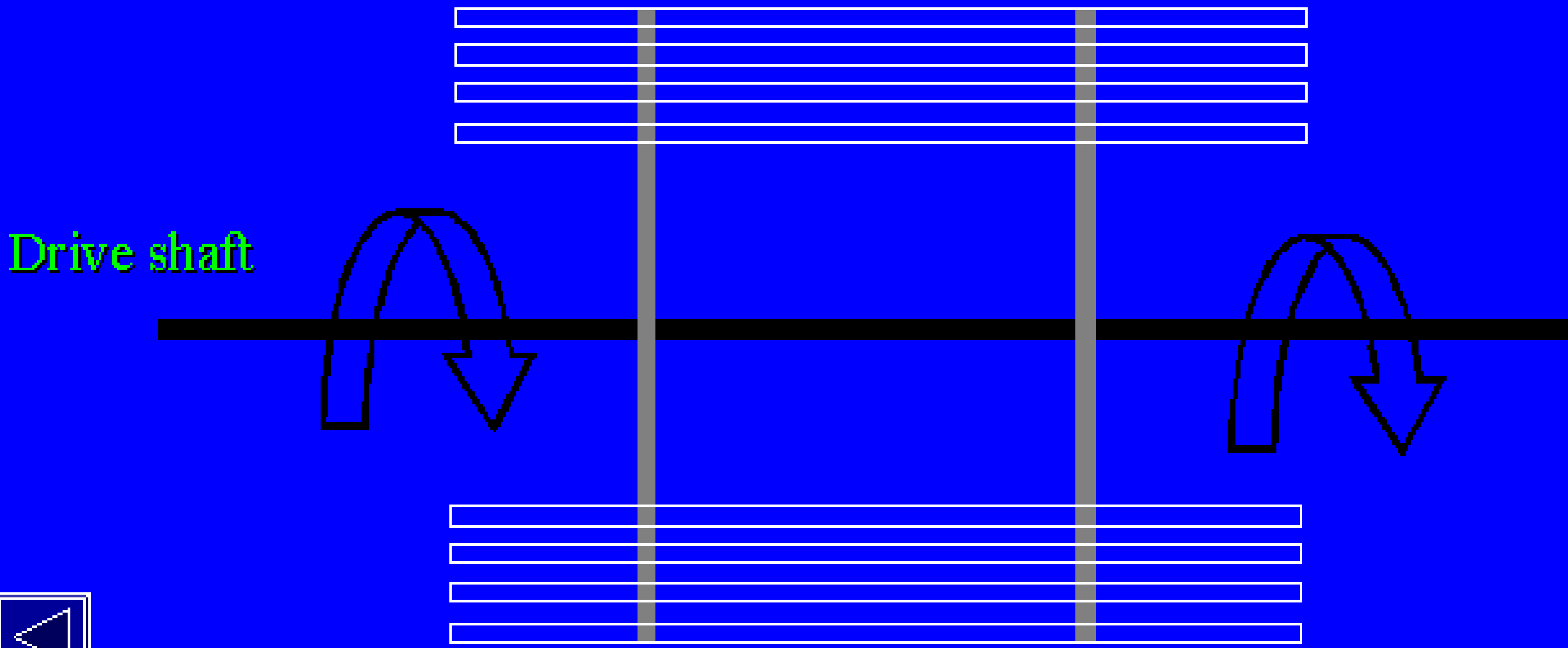
Dynamic viscosity

Extent of Mixing = Gt

Flocculation: Purpose

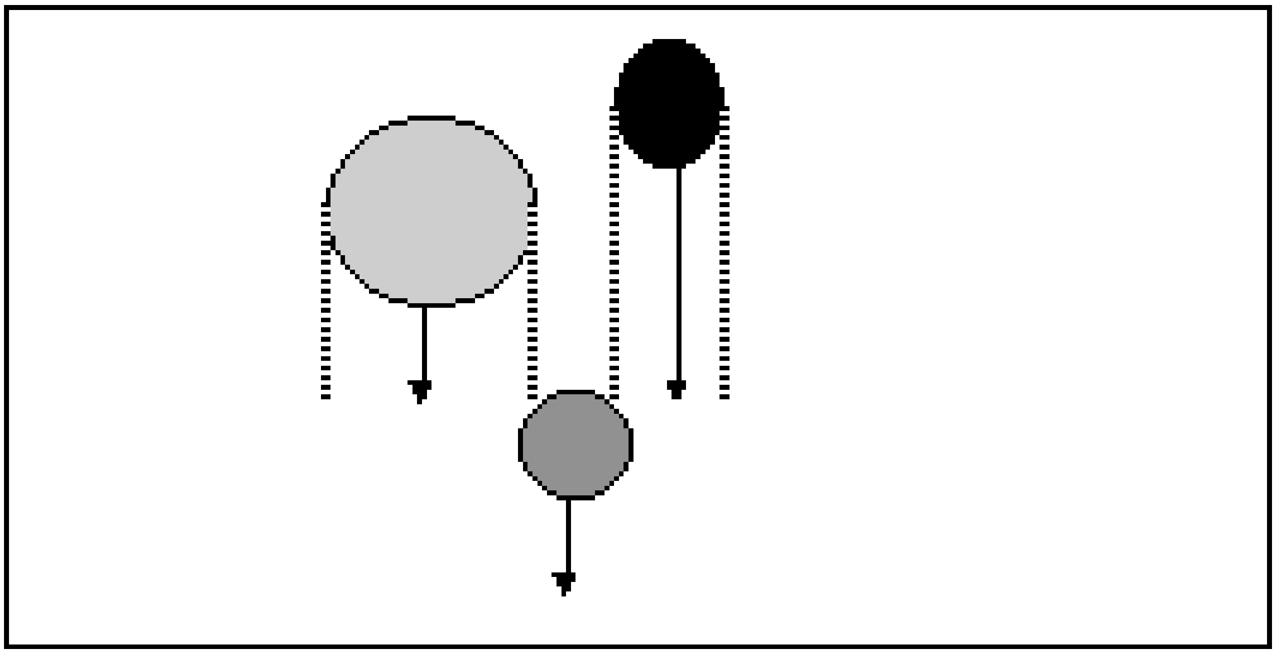
- Promote agglomeration of particles into larger floc
- Units often designed on the basis of mixing intensity as described by the velocity gradient, G
  - some mixing is needed to keep particles in contact with other particles
  - too much mixing can cause floc break-up

Flocculators



Usually 4 arms with 3-4 slats per arm

Differential Settling



$$\beta(d_i, d_j) = \left(\frac{\pi g}{72\mu}\right)(\rho_p - \rho_f)(d_i + d_j)^3 (d_i - d_j)$$

Flocculation: Design

- Flow through velocity: 0.5 to 1.5 ft/min
- variable speed paddle flocculators
  - peripheral velocities of 0.5-2.0 ft/sec
  - horizontal shaft: slower, best for conventional
  - vertical shaft: faster, best for direct filtration
- typical dimensions
  - 12 ft deep
  - length/width = 4
  - 30 min detention time

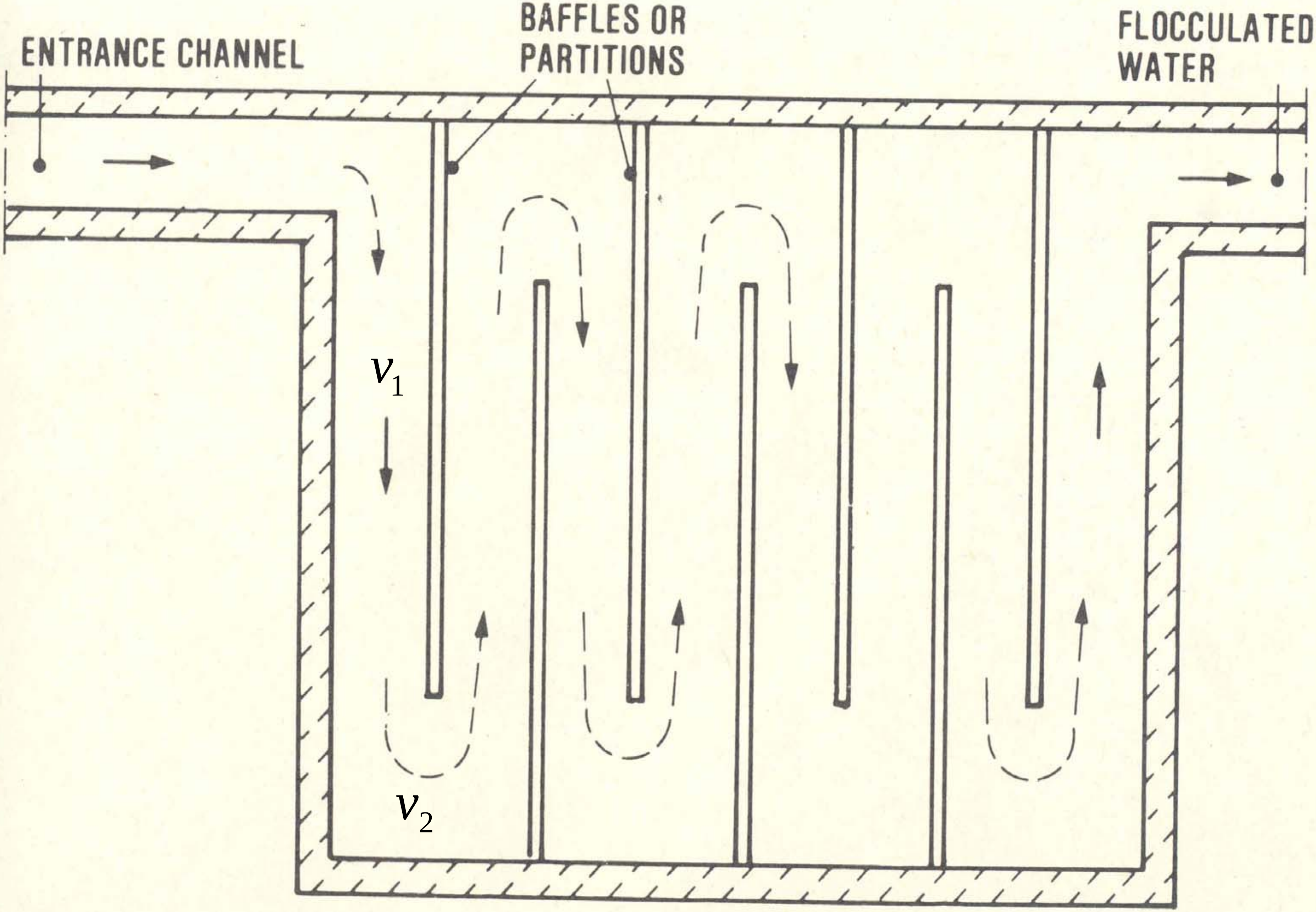


Figure 6.2. Horizontal-flow baffled channel flocculator (plan). *Source*: IRC, 1981b.

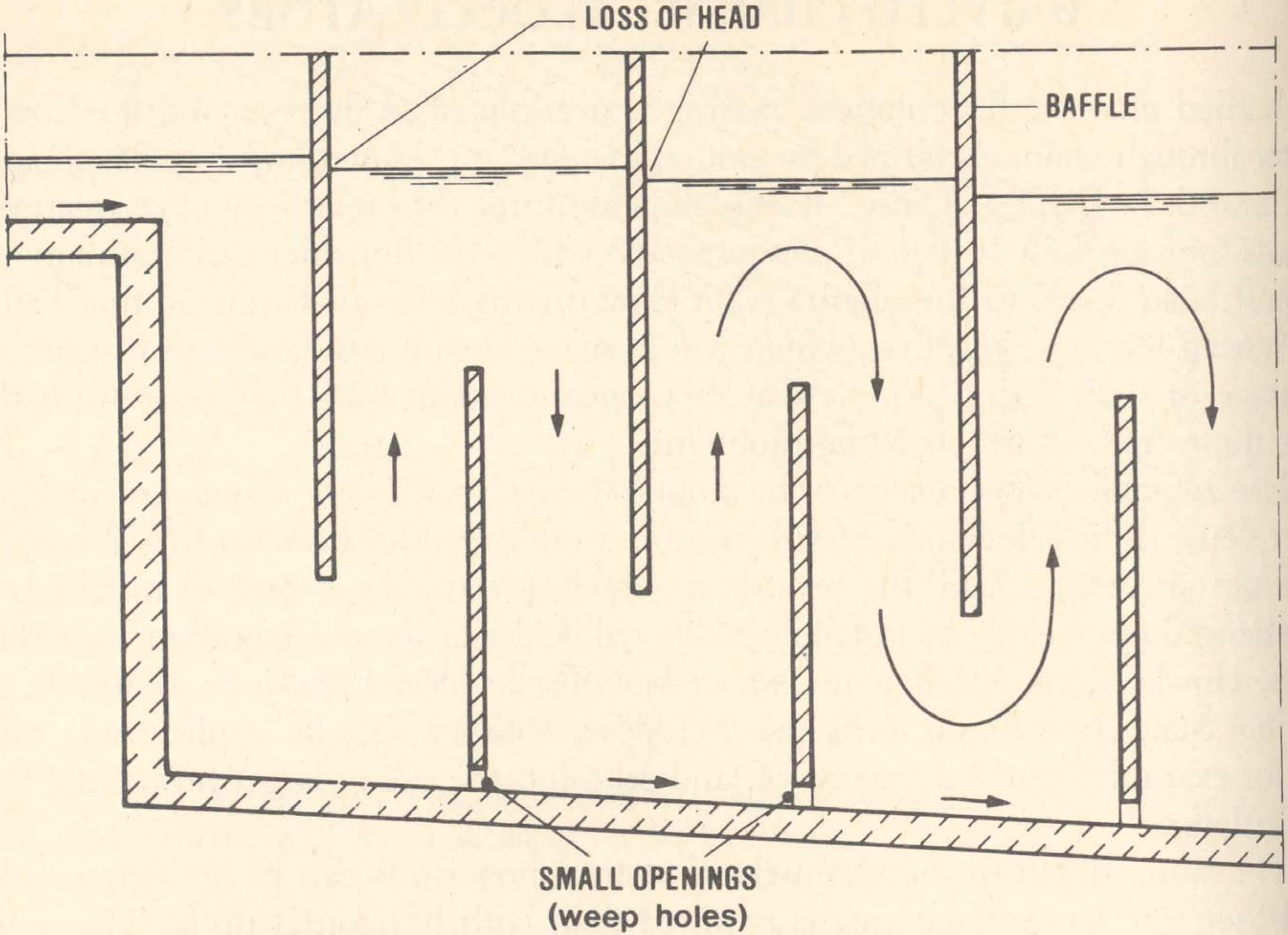


Figure 6.3. Vertical-flow baffled channel flocculator (cross-section). *Source:* IRC, 1981b.

Flocculation

Choose between sufficient energy and shearing the floc

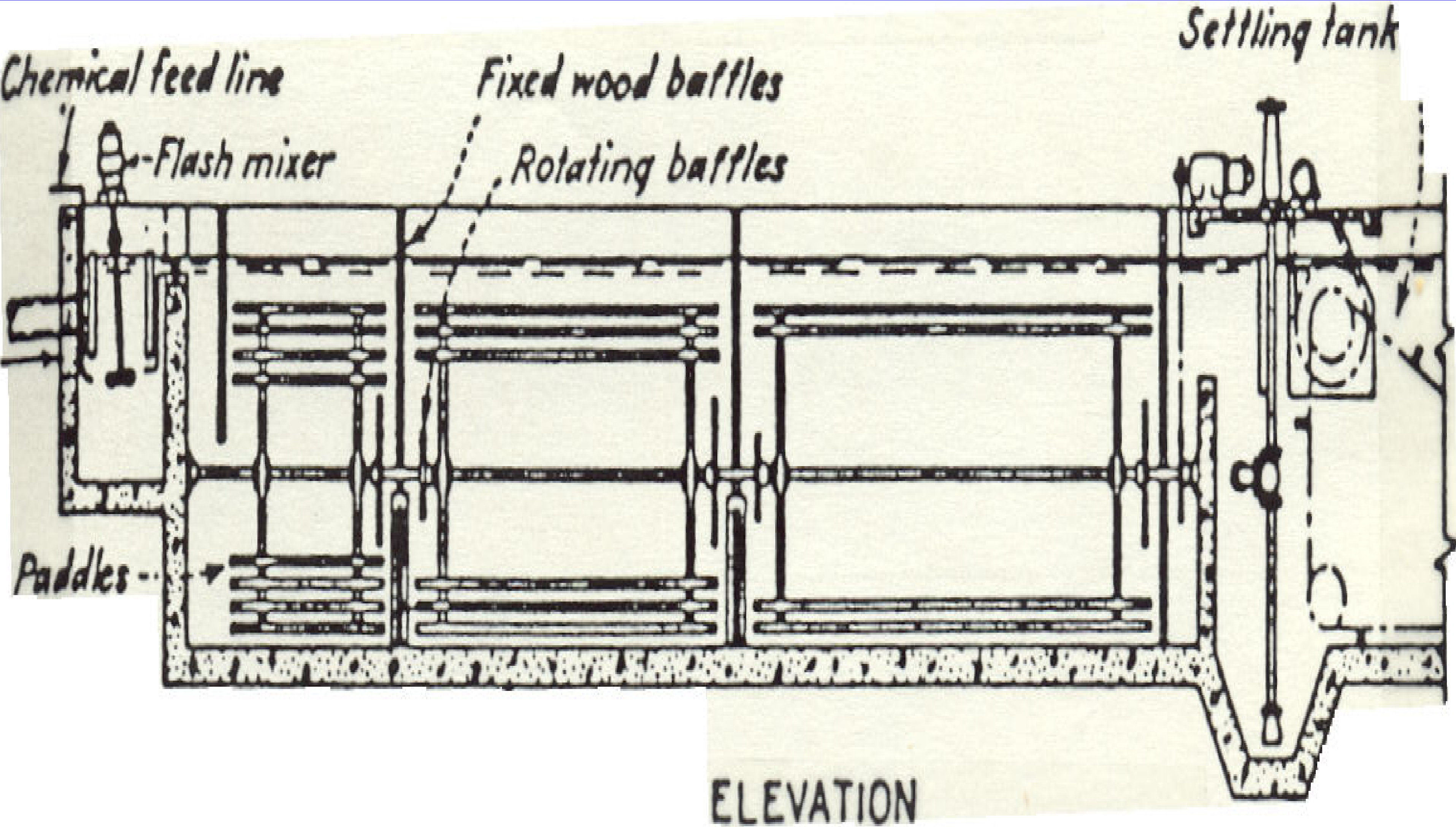
Range of RMS G Values

- G = 10 to 75 s^{-1}
- Most Common Range of G = 30 to 60 s^{-1}
- Single Value of G = 50 s^{-1}
- Time of Flocculation is also important !!!!!!
- Theoretically as G increases Time of Flocculation would decrease. However the limit of G = 75 s^{-1}
- Flocculation Time is limited by basin size. Flocculation Times less than 10 minutes should be avoided.

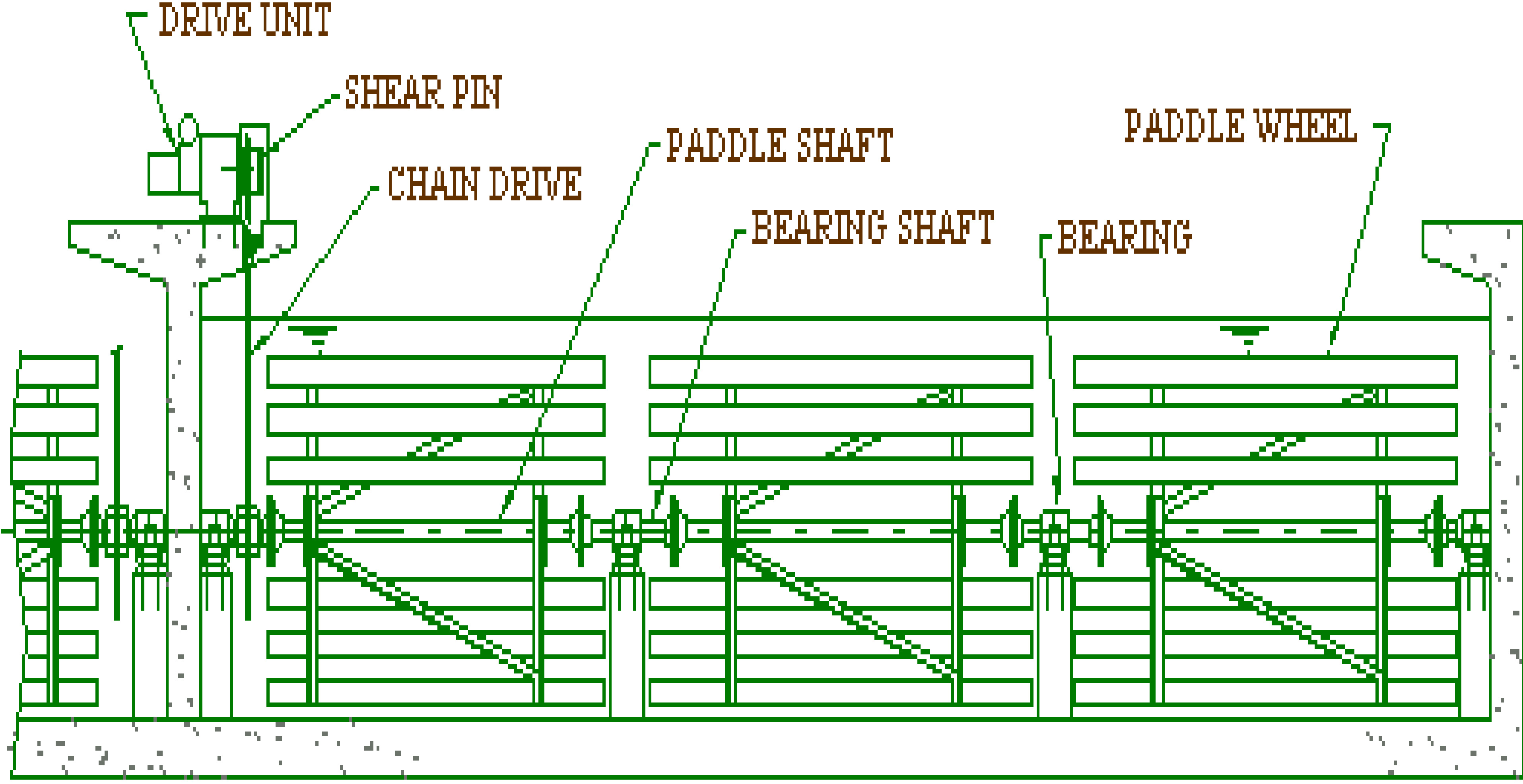
A Dimensionless Design Parameter (GT)

- G = Root Mean Square Velocity Gradient
- T = Flocculation Basin Detention Time
- Range of GT Values = 10^4 to 10^5
- Engineers prefer dimensionless numbers.

Paddle Flocculator Schematic

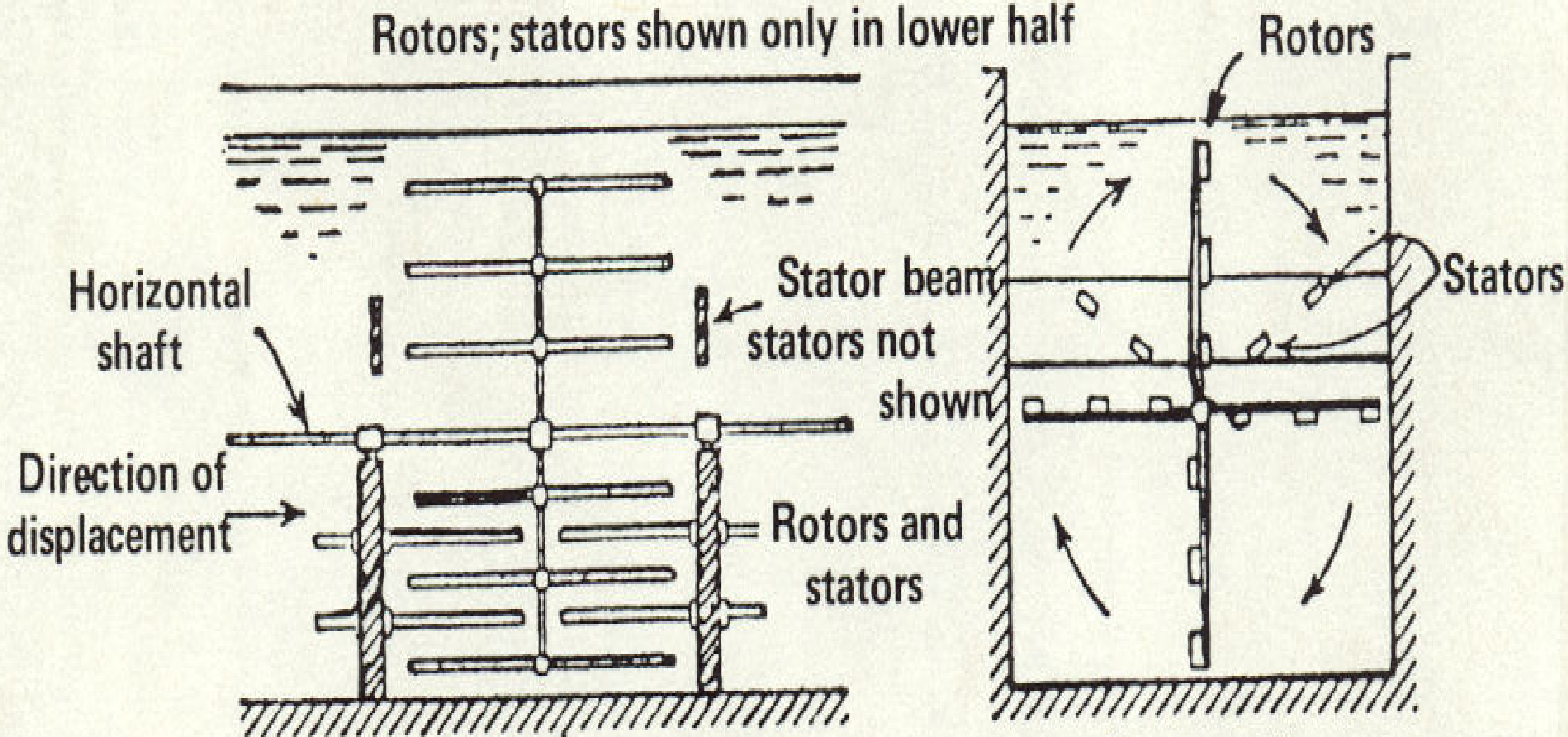


Paddle Flocculator Schematic



HORIZONTAL FLOCCULATOR TYPE FHPP

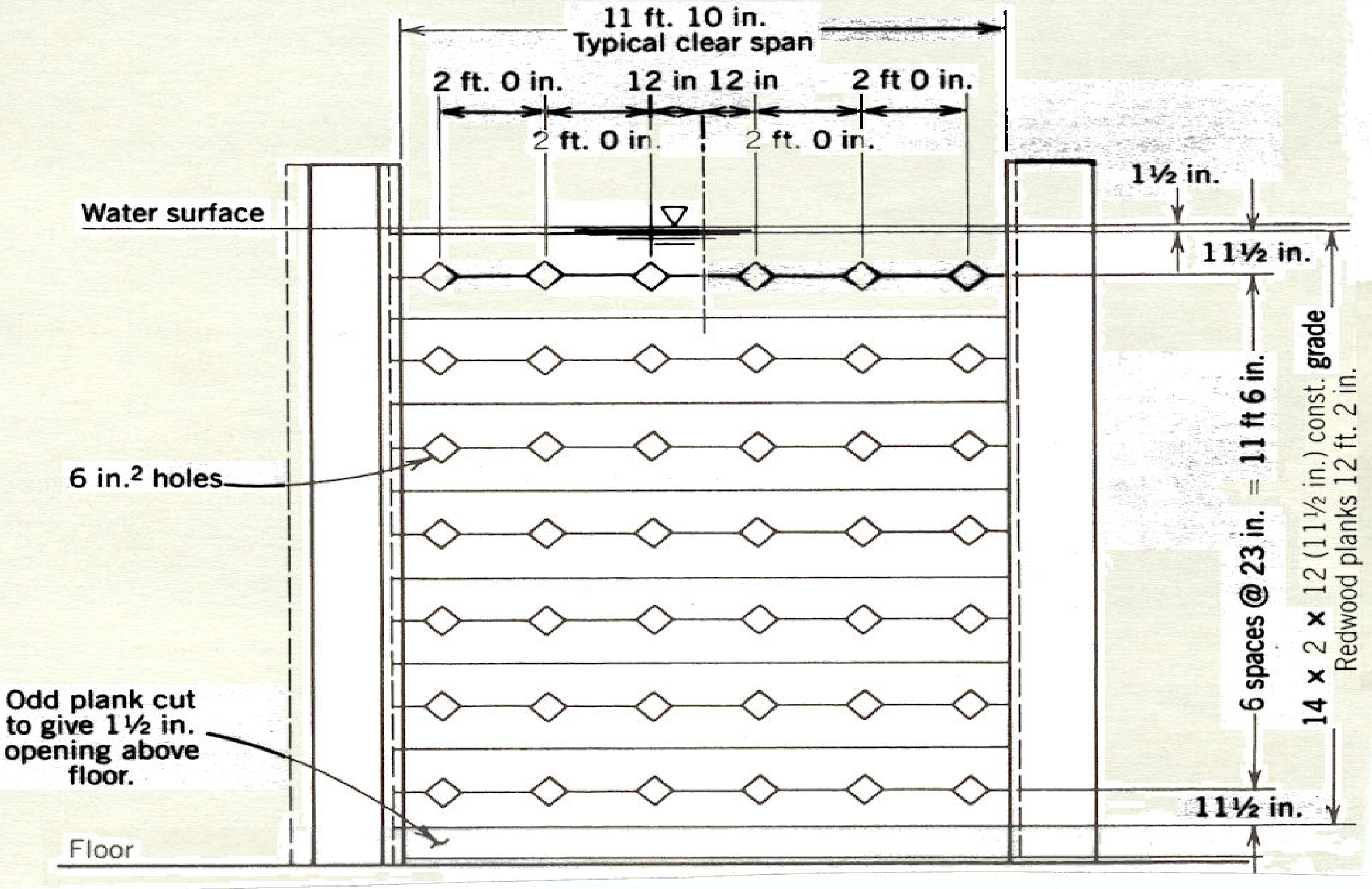
Rotors and Stators



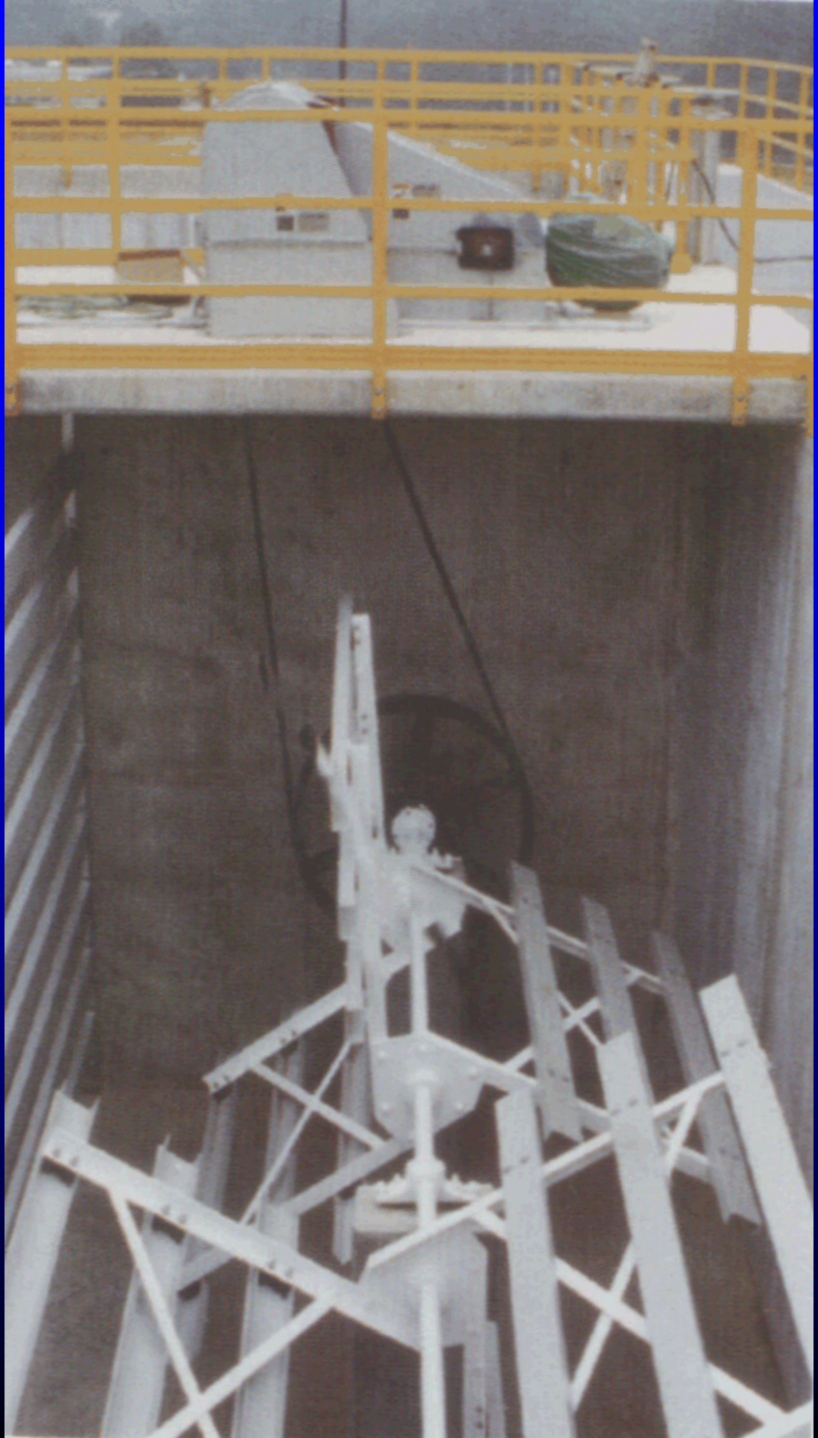
Longitudinal section; stators not shown in upper half

Cross-section of channel

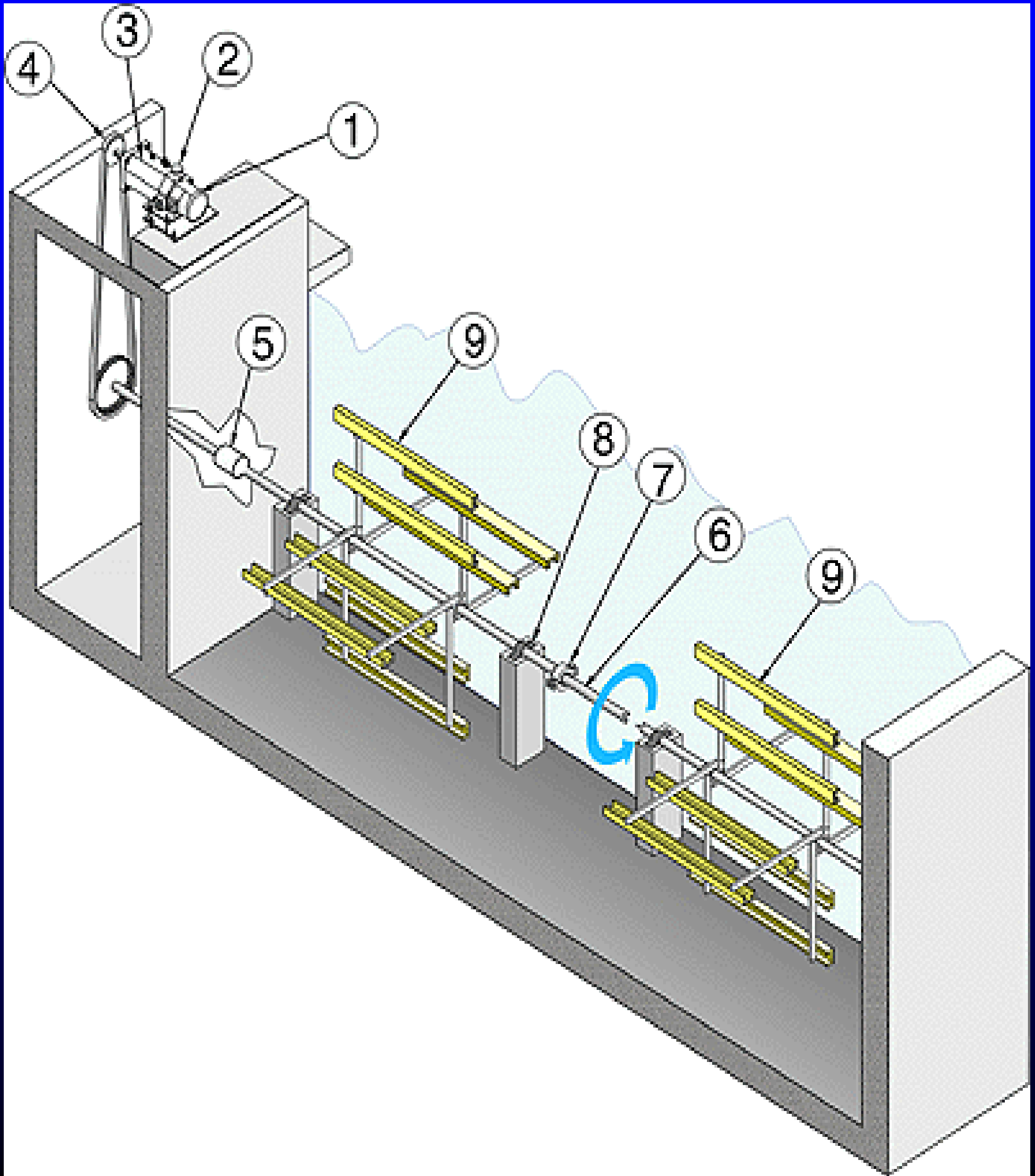
Baffled Flocculator



Flocculators



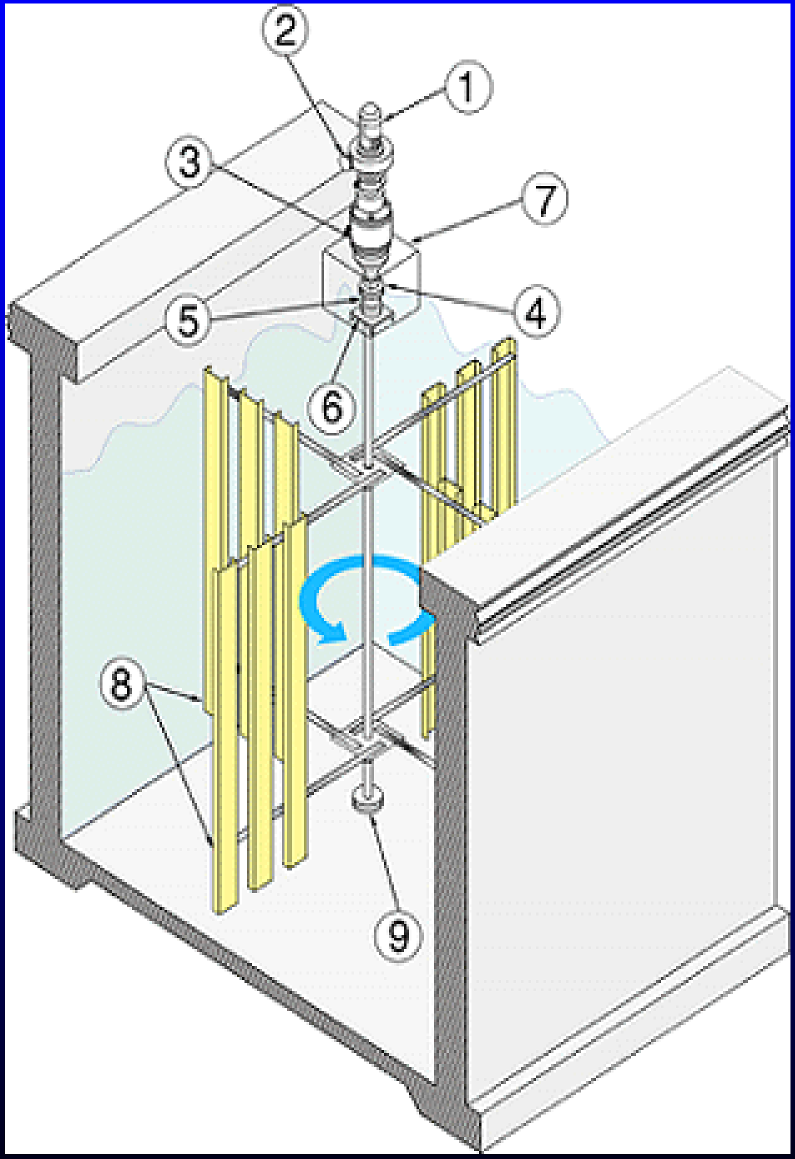
Horizontal Paddle Flocculator



Flocculator Paddle Wheel

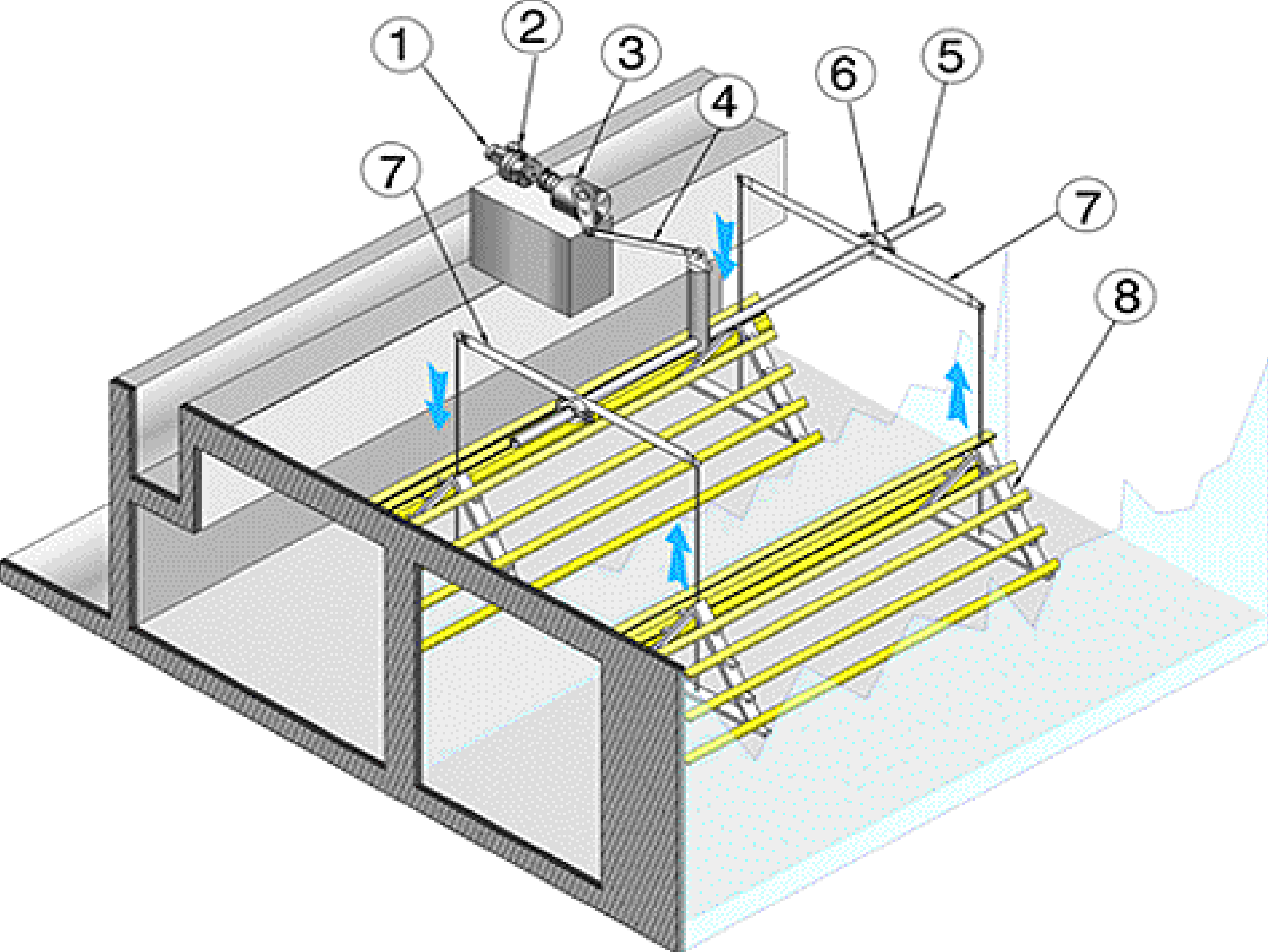
Flocculator Paddle Wheel

Vertical Paddle Flocculator



Vertical Paddle Flocculator Wheel

Coagulation/Floccuation and Sedimentation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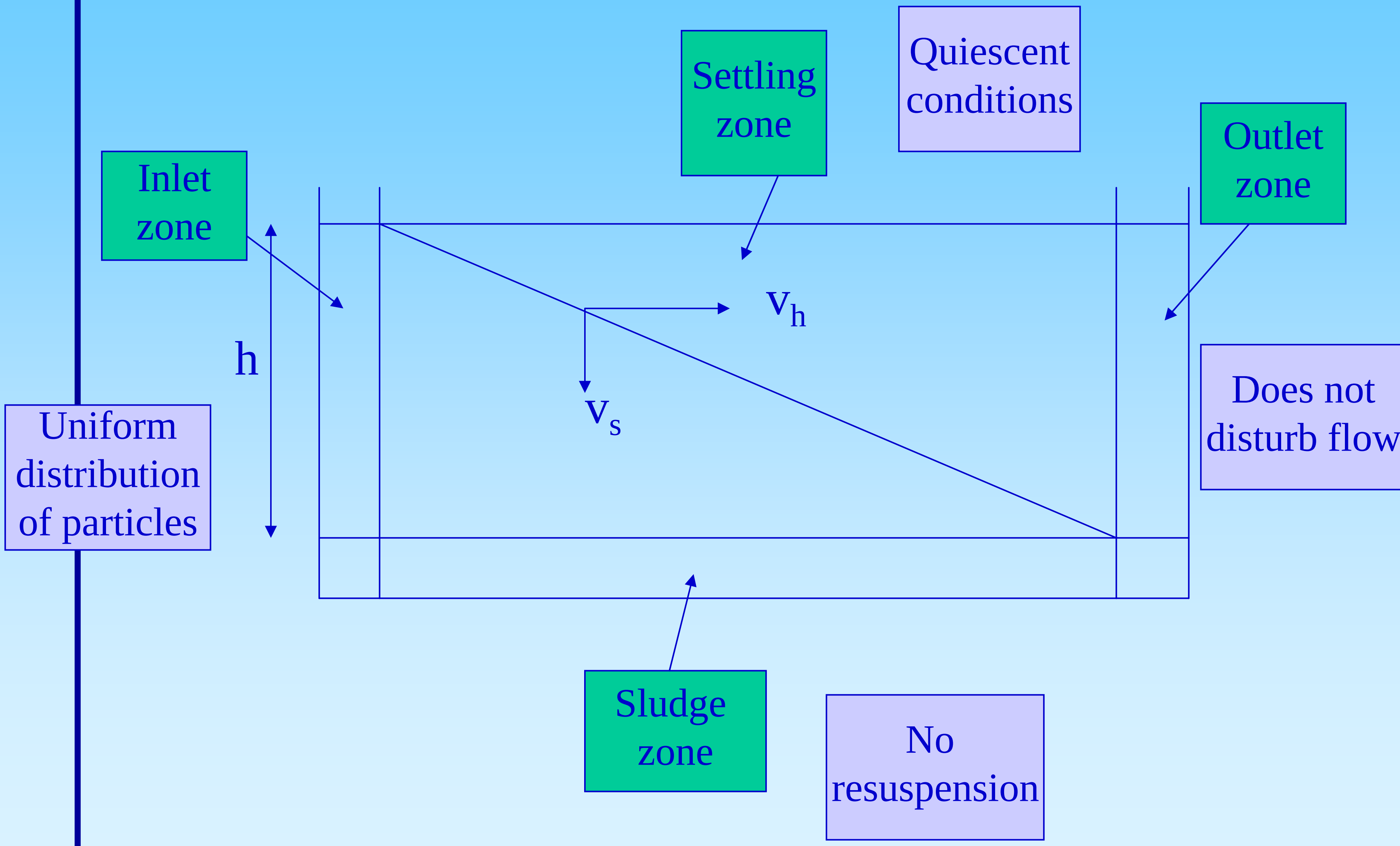
H_2O

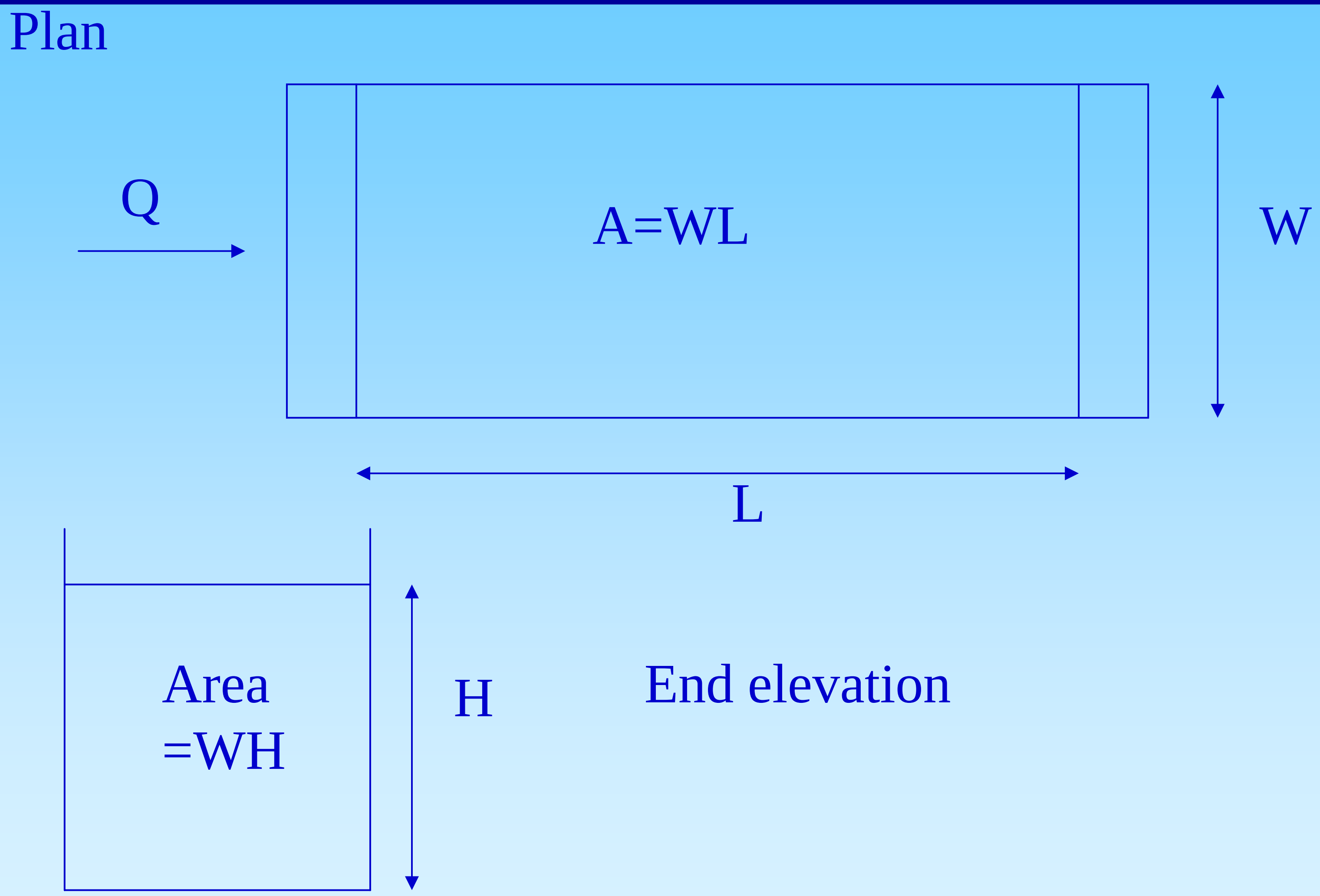
Water Treatment

Settling Tank Design

Ideal Settling Tank(1)



Ideal Settling Tank(2)



Ideal Settling Tank (3)

Residence time $t_r = \frac{L}{v_h}$

Horizontal velocity $v_h = \frac{Q}{HW}$ ⇒ $t_r = \frac{HWL}{Q}$

Consider a particle entering at water level.

Needs to fall a distance H in time $\leq t_r$

$$\Rightarrow \quad v_s \geq \frac{H}{t_r} = \frac{QH}{HWL} = \frac{Q}{WL} = \frac{Q}{A}$$

Q/A is the *surface loading*, or *overflow rate*

In theory, all particles with v_s exceeding Q/A will be removed

H_2O

Design Considerations

- Generally used:
  - Older and smaller installations
  - Raw water with high solids
  - Quick solution
- Main features
  - Length 3 times width – stability of flow
  - Surface loading up to 2.5 mh^{-1}.
  - Inlet and outlet design
  - Sludge removal by mechanical means

H_2O

Typical parameters

- Discrete settling (Type 1)
  - 2.5-3m deep
  - 1.0-2.5 m/h overflow rate
  - Horizontal flow < 36 m/h
  - Weir overflow rate <14 m^3/h per m of weir
- Flocculent suspension (Type 2)
  - 3-4m deep
  - 0.6-1.0 m/h overflow rate
  - Horizontal flow < 9 m/h
  - Weir overflow rate <6 m^3/h per m of weir

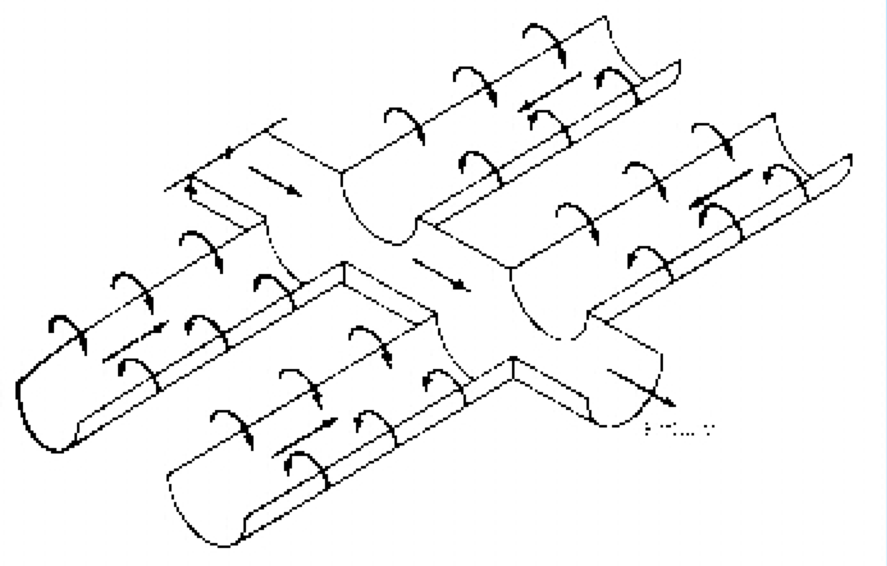
Residence Time

- Ideal tank
  - Assumes plug flow
- Reality
  - Short circuiting
  - Disturbances
  - Currents

H_2O

Overflow Weirs

- Need to prevent excessive velocities
- Light flocs
  - 6 m^3/h per meter of weir
- Discrete particles
  - 14 m^3/h per meter of weir



H_2O

Other Design Factors

- At least 2 tanks
  - Cope with maintenance and breakdowns
- Width no more than 12m
  - Sludge removal equipment
- Length
  - 3-4 times width
  - 10-20 times depth
- Sludge zone
  - 0.5 m
- Slope – approx 1/100

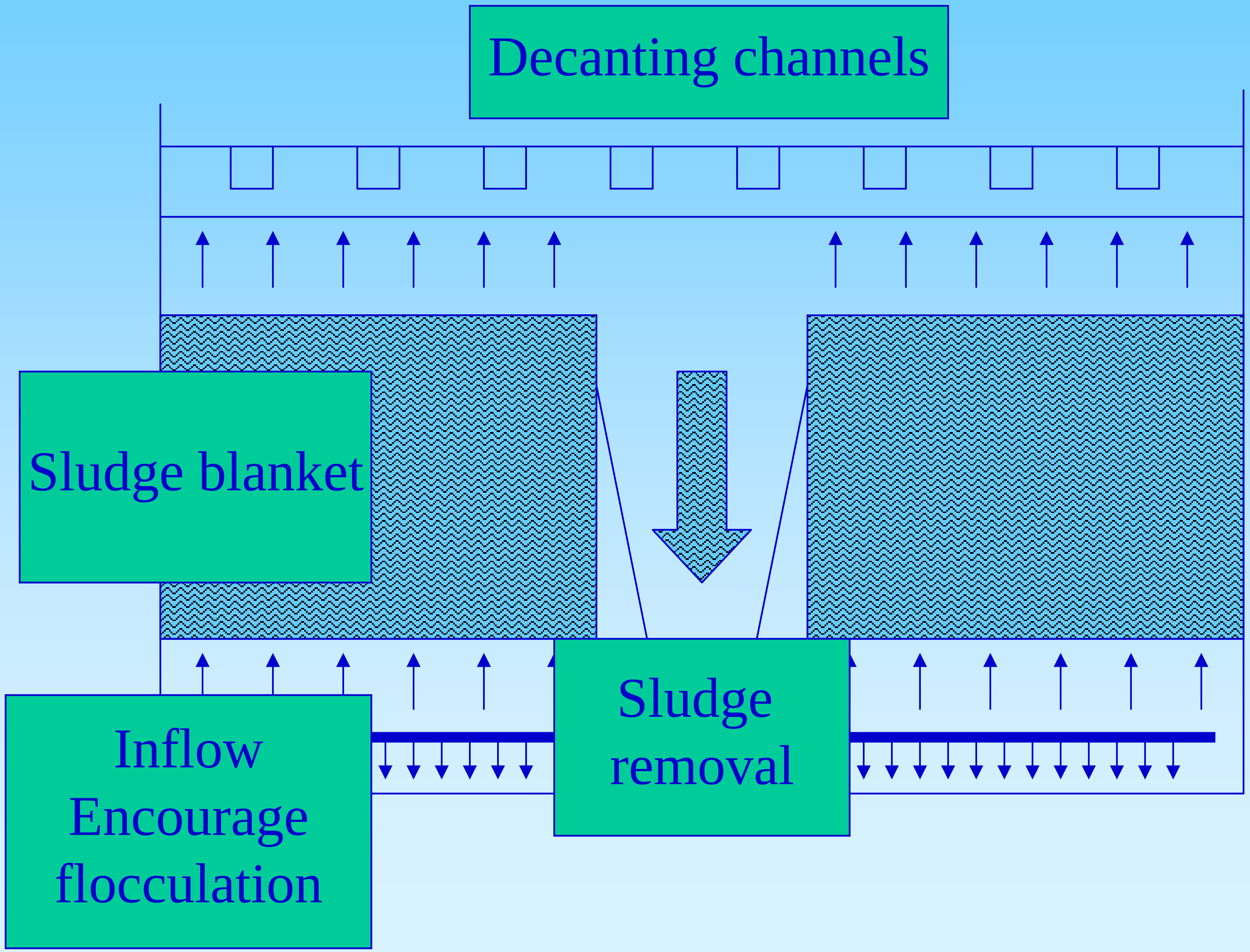
H_2O

Other Types of Clarifiers

- Sludge blanket clarifiers
- Inclined plate and tube settlers
- Flotation

H_2O

Sludge Blanket Clarifier



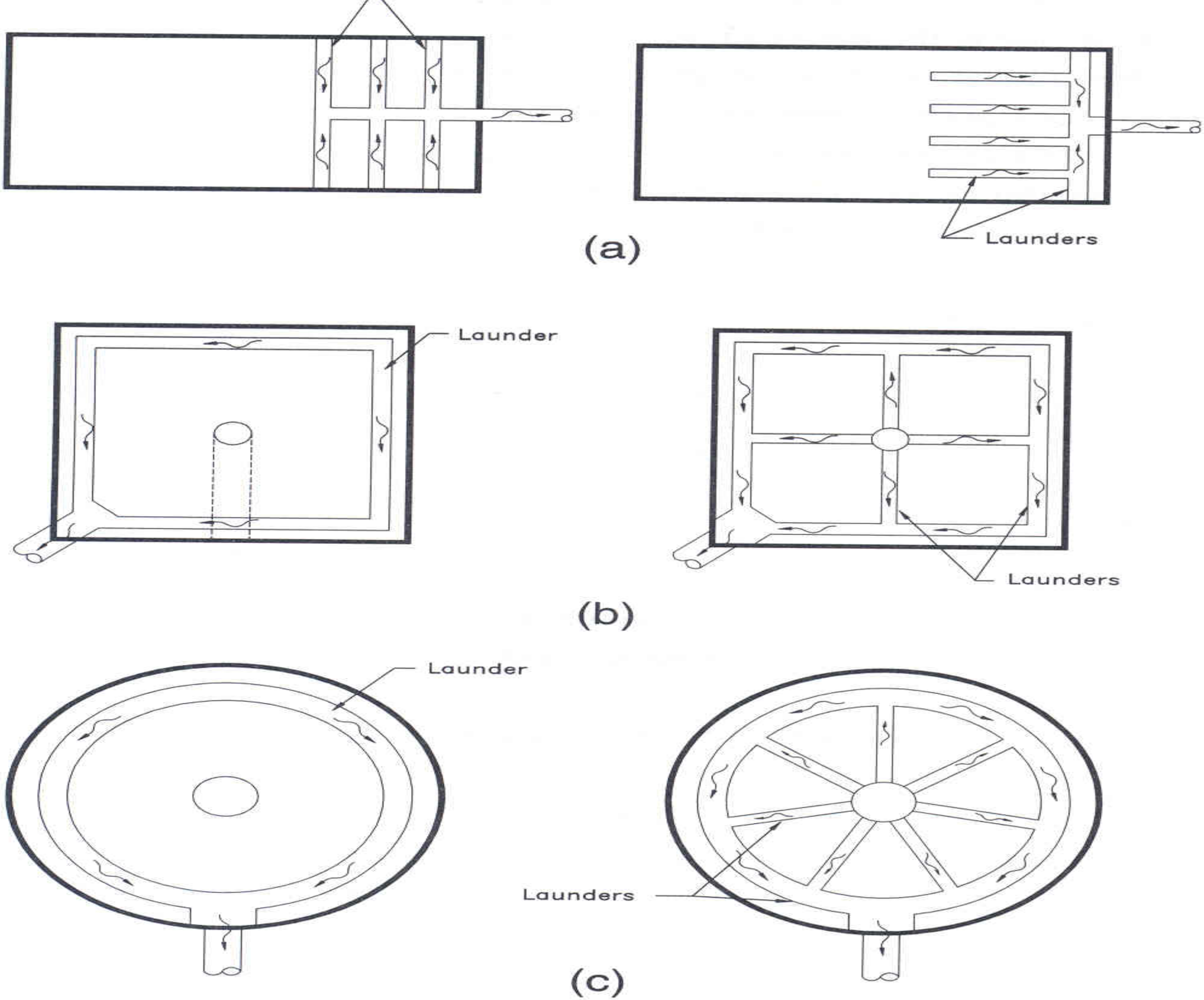
Type of Clarifier	Design Criteria
1. Rectangular basin (Horizontal flow)	- Surface loading 0.83 – 2.5 m/h - Water depth 3 – 5 m - Detention time 1.5 – 3 h - Width/Length > 1/5 - Weir loading < 11 m^3/h.m
2. Upflow type (Radial- Upflow)	Circular or square in shape - Surface loading 1.3 – 1.9 m/h - Water depth 3 – 5 m - Settling time 1 – 3 h - Weir loading 7 m^3/h.m

Type of Clarifier	Design Criteria
3. Reactor Clarifiers	- Flocculation time : approx 20 min - Settling time 1 – 2 h - Surface loading 2 – 3 m/h - Upflow velocity < 50 mm/min - Weir loading 7.3 – 15 m^3/h.m
4. Sludge Blanket Clarifier	- Flocculation time : approx 20 min - Settling time 1 – 2 h - Surface loading 2 – 3 m/h - Upflow velocity < 10 mm/min - Weir loading 7.3 – 15 m3/h.m - Slurry circulation rate : up to 3 – 5 times the raw water inflow rate

Table 9-6 Typical Water Treatment Sedimentation Design Parameters

	Detention Time, h	Surface Loading Rate, $m^3/m^2 \cdot d$ (gpd/ft^2)	Weir Loading Rate, $m^3/m \cdot d$ (gpd/ft)
Rectangular basins			
Coagulation	4–8	20–40 (50–1000)	250 (20,000)
Softening	2–6	40–60 (1000–1500)	250 (20,000)
Solids contact units			
Coagulation	2	40–60 (1000–1500)	170 (14,000)
Softening	1	60–100 (1500–2500)	350 (28,000)
Upflow basins			
Coagulation	2	40–60 (1000–1500)	170 (14,000)
Softening	1	60–1000 (1500–2500)	350 (28,000)

Source: Adapted in part from References 3, 6, 7 and 9.


Launders
(a)
Launder
Launders
(b)
Launder
Launders
(c)

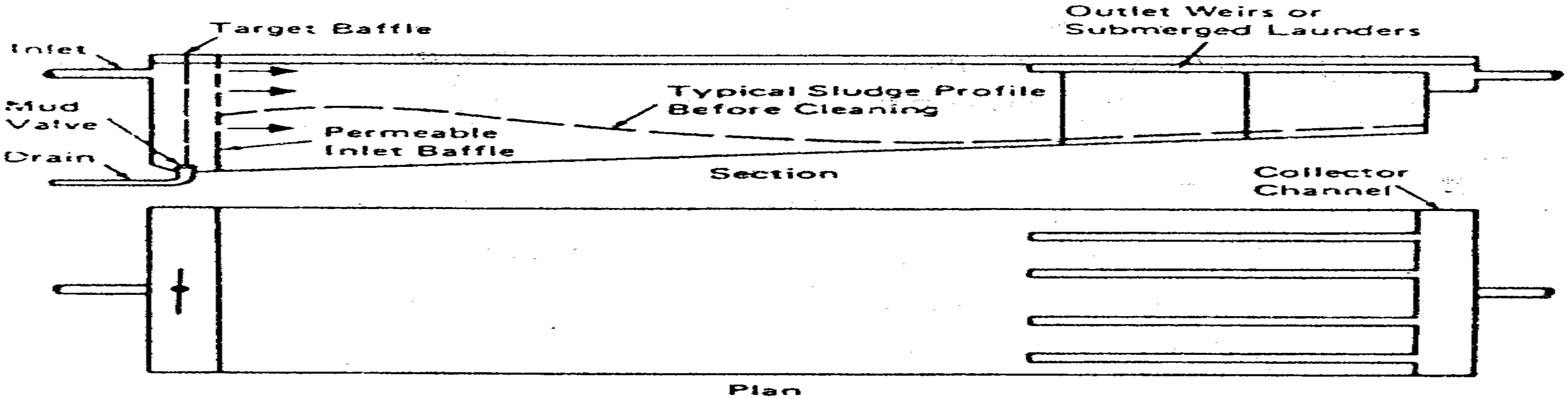
ถังตกตะกอน (Clarifier Tank)

ประเภทของถังตกตะกอน แบ่งออกเป็น 3 ประเภทคือ

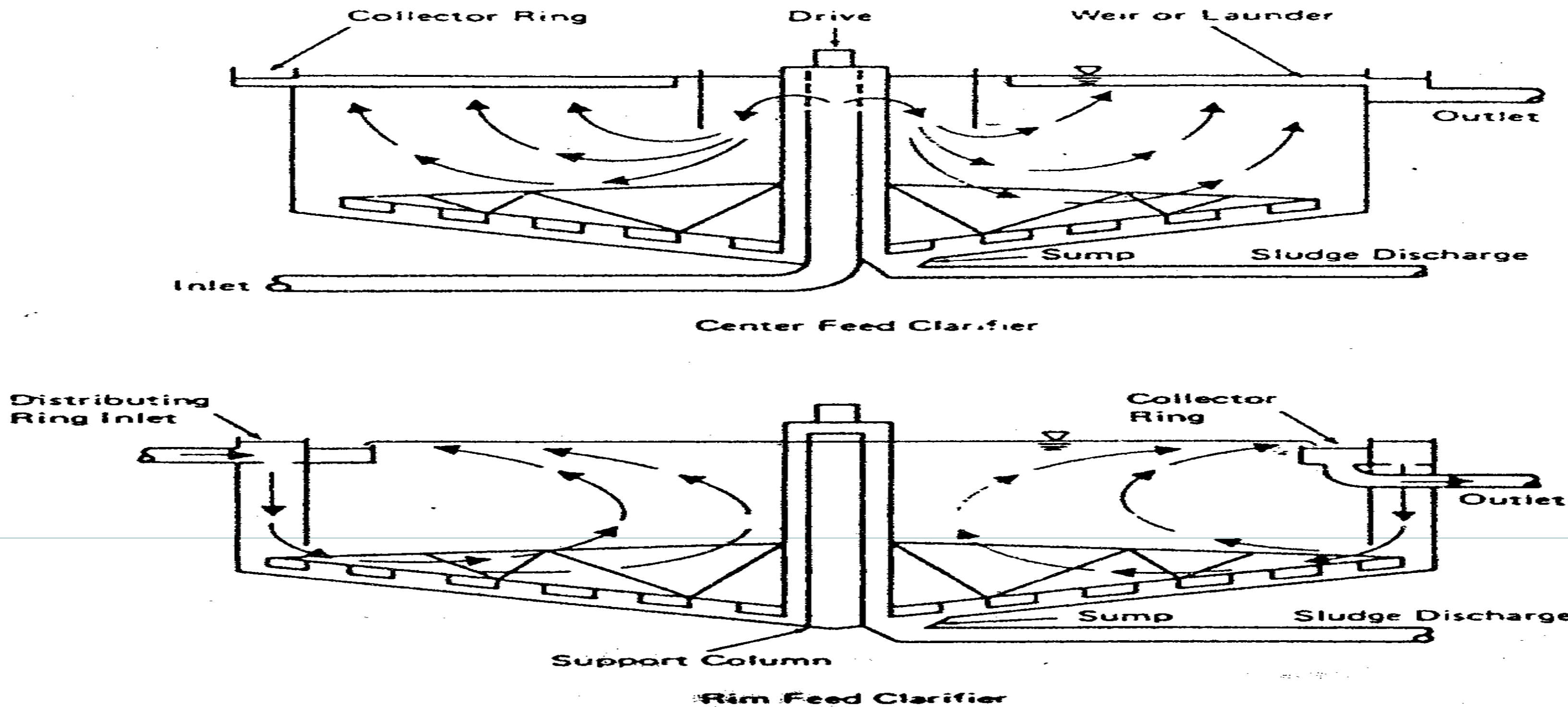
1. ถังตกตะกอนแบบธรรมดา (Conventional Sedimentation Tank)

ลักษณะถังเป็นบ่อขนาดใหญ่ สามารถแบ่งออกได้ 2 แบบ คือ

- แบบไหลในแนวระดับ (Horizontal Flow)
- แบบไหลในแนวดิ่ง (vertical Flow)



ก) รูปสี่เหลี่ยมผืนผ้า

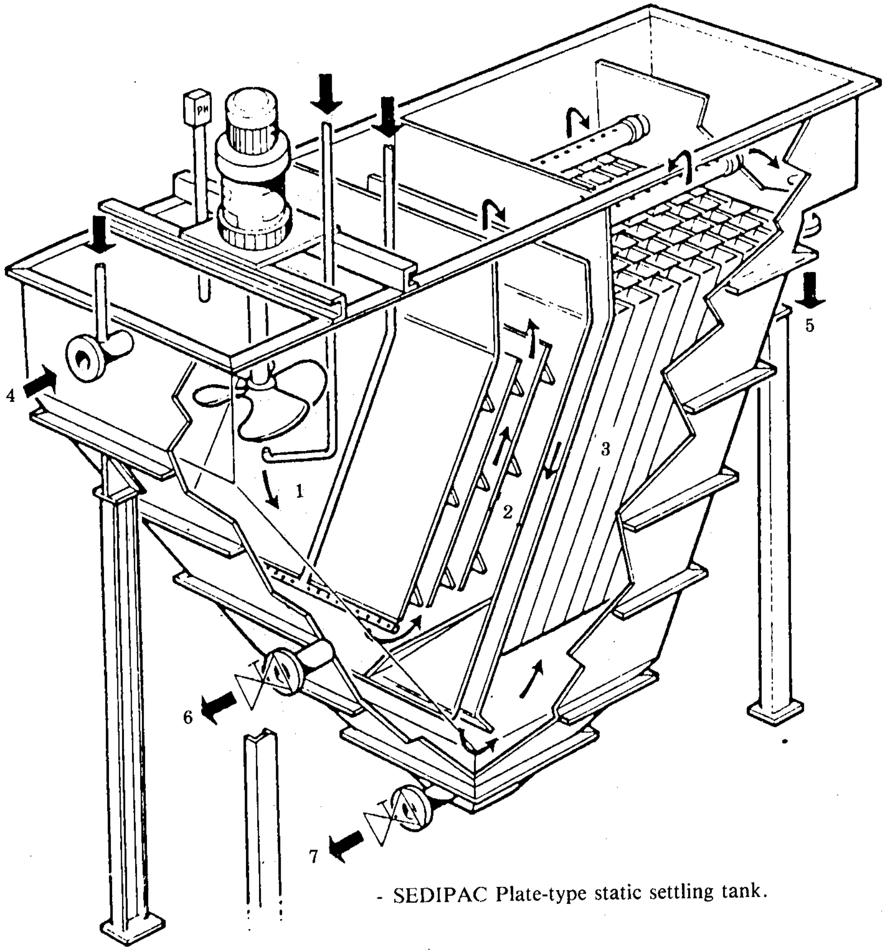


ข) รูปทรงกลม

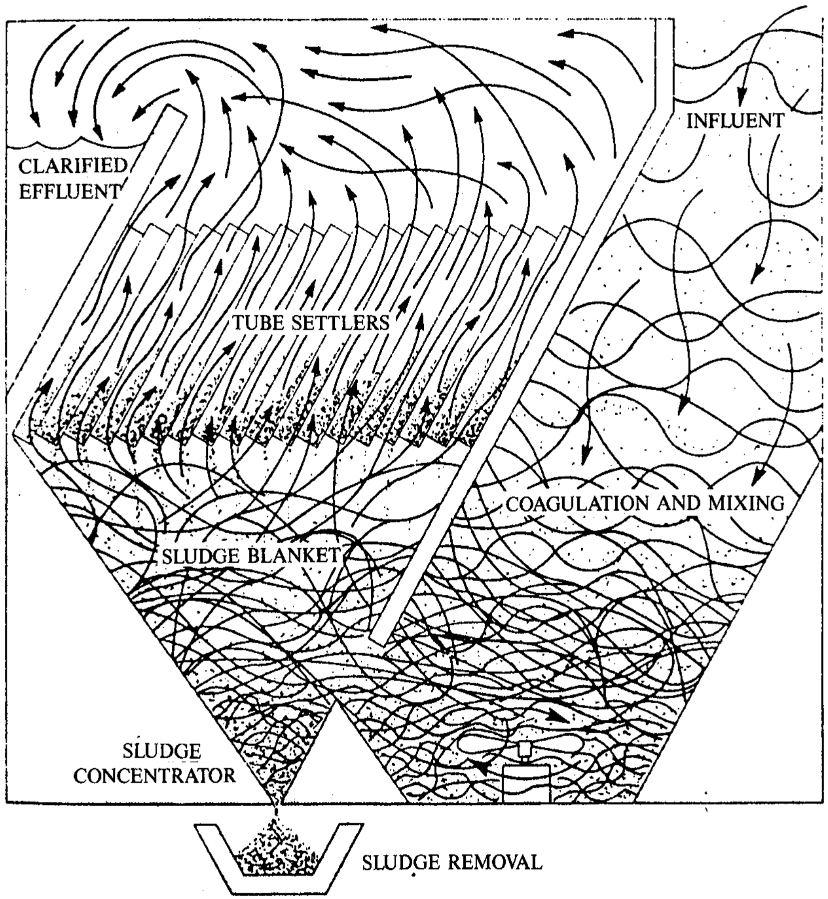
2. ถังตกตะกอนแบบท่อ **(Tube Settler)** ติดตั้งท่อขนาดเล็กใส่ลงในถังเพื่อให้มีระยะเวลาการตกตะกอนนานขึ้น

- แบบท่อลาดชันต่ำ **(Horizontal Tube settler)** ติดตั้งท่อทำมุมประมาณ 5 องศากับแนวระดับ

- แบบท่อลาดชั้นสูง **(Inclined Tube Settler)** ติดตั้งท่อทำมุมประมาณ 45-60 องศากับแนวระดับ



- SEDIPAC Plate-type static settling tank.



3. ถังตกตะกอนแบบใช้ชั้นตะกอน (Solid Contact Tank)

หมายถึงถังตกตะกอนที่มีกระบวนการโคแอกกูเลชันและการตกตะกอนรวมอยู่ภายในถังเดียวกันจึงมีข้อดีคือสามารถลดขนาดของระบบลงได้

แบ่งออกได้ 2 ชนิดคือ

1. แบบหมุนเวียนสลัดจ์(Sludge Recirculation)
2. แบบมีชั้นสลัดจ์(Sludge Blanket)

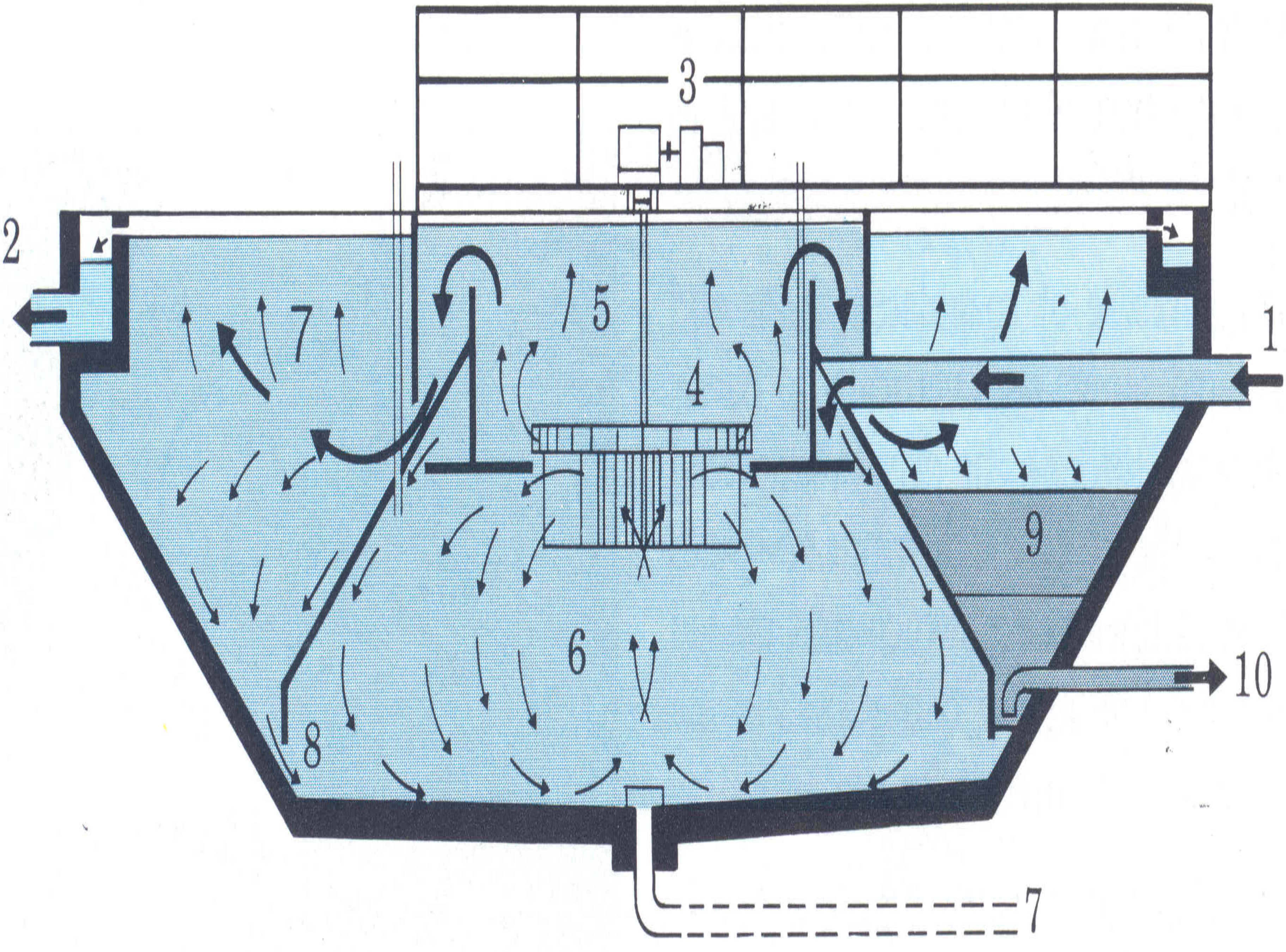
การประปานครหลวงใช้ประเภทที่ 3

แบบหมุนเวียนสลัดจ์(**Sludge Recirculation**)

- ถังตกตะกอน ประเภท **Solid Contact Tank**

แบบมีชั้นสลัดจ์(**Sludge Blanket**)

- ถังตกตะกอน ประเภท **Pulsator Tank**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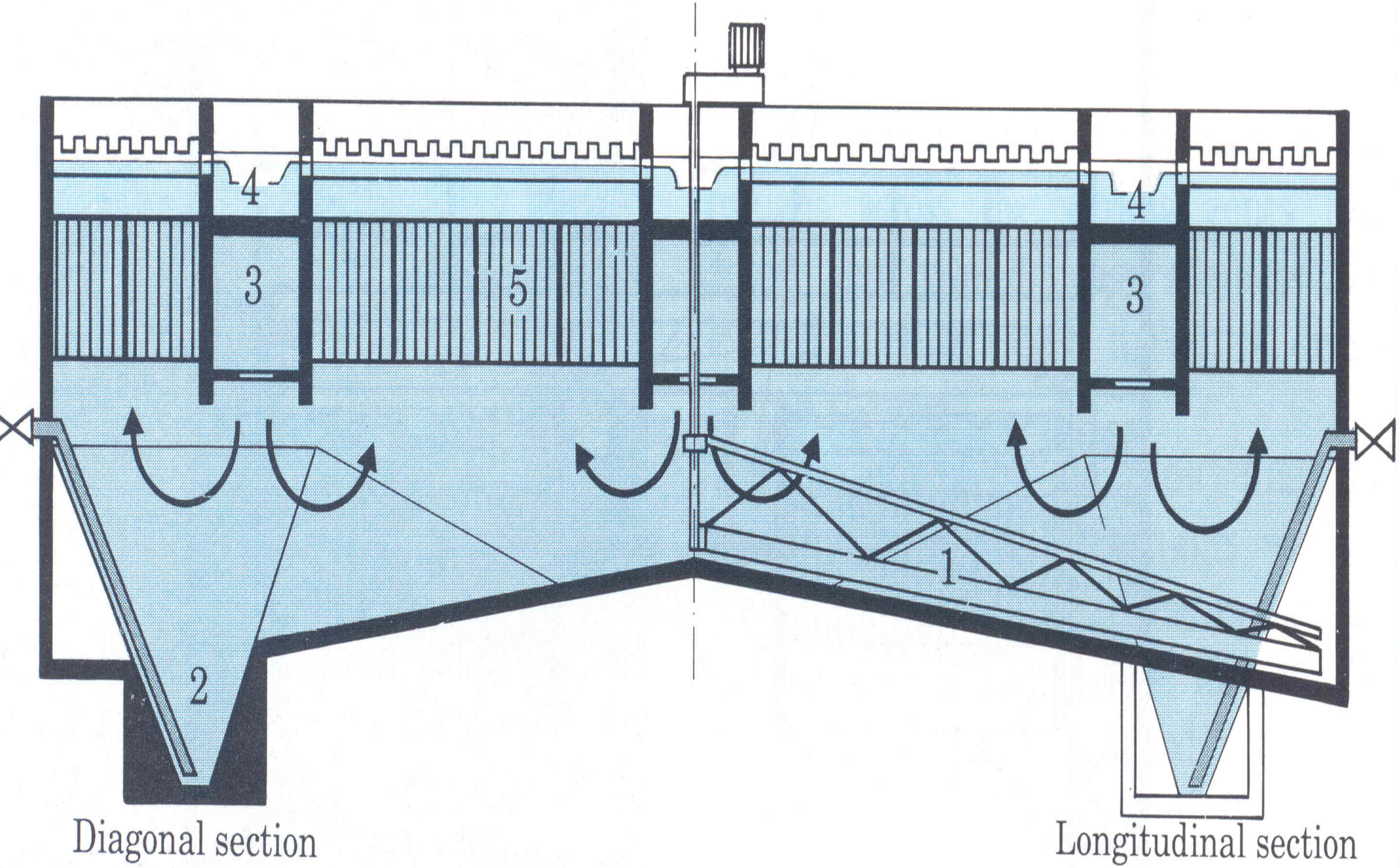
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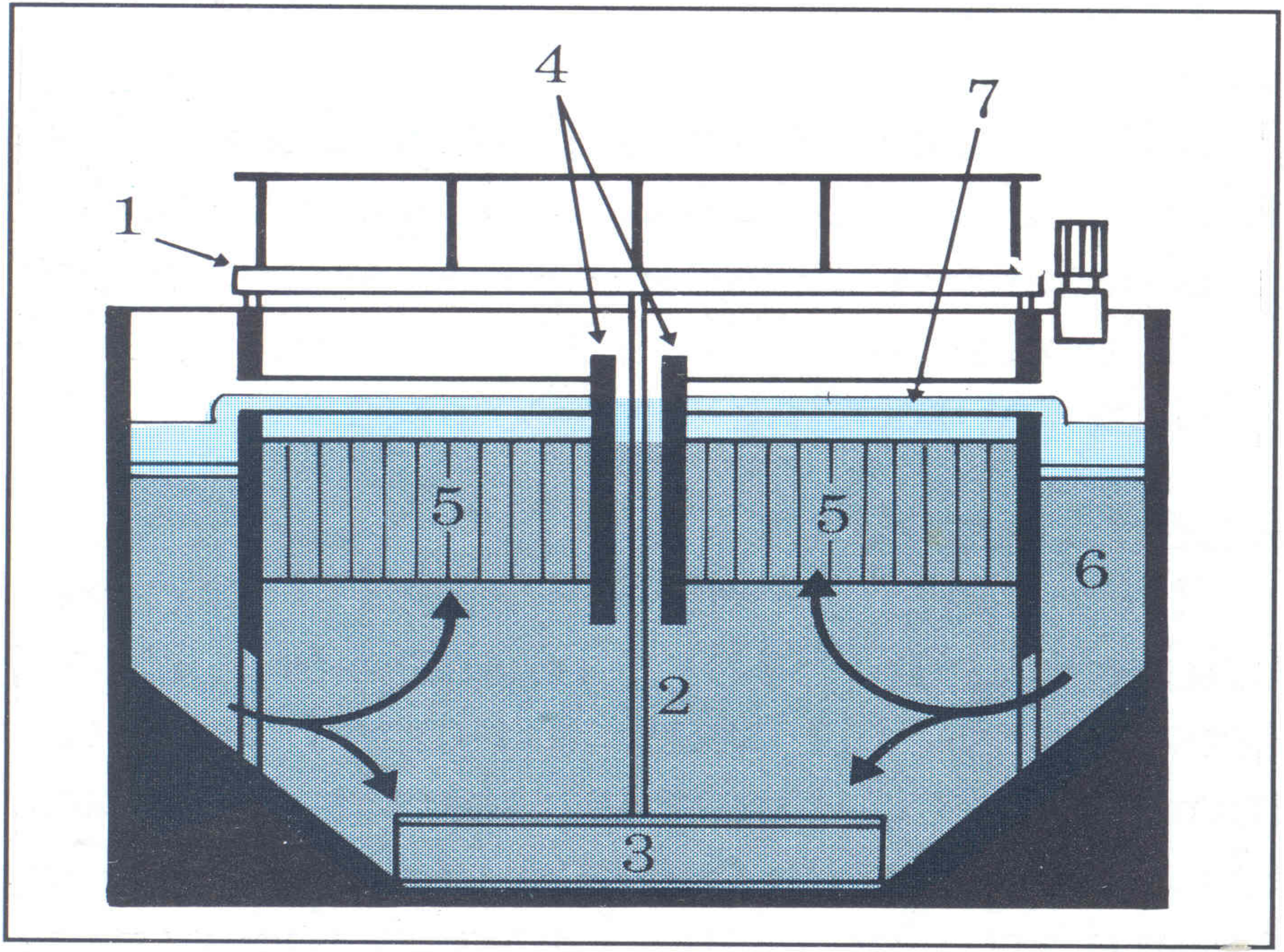
Diagonal section
Longitudinal section



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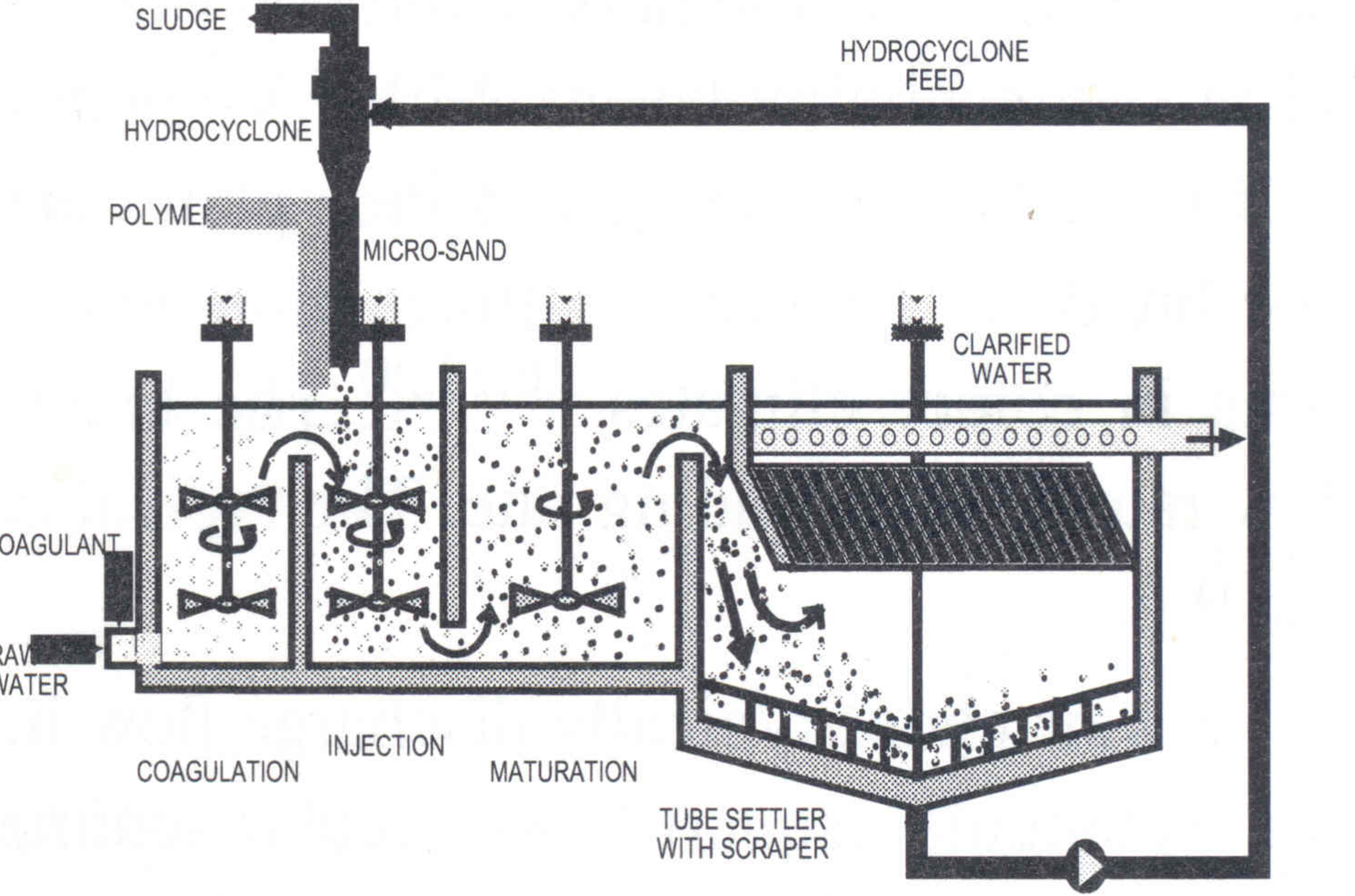
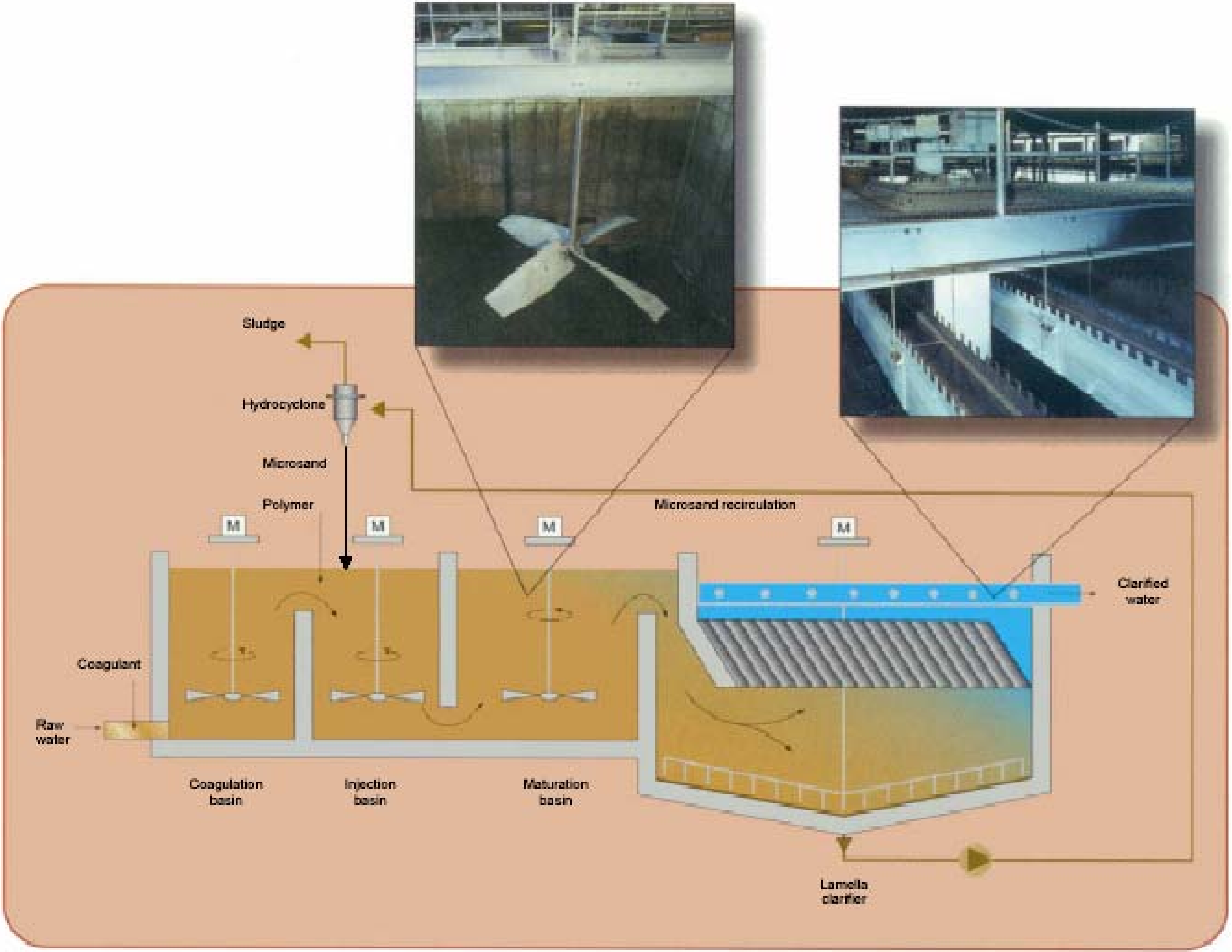

SLUDGE
HYDROCYCLONE FEED
HYDROCYCLONE
POLYMEI
MICRO-SAND
CLARIFIED WATER
OAGULANT
RAW WATER
INJECTION
COAGULATION
MATURATION
TUBE SETTLER WITH SCRAPER



Sludge
Hydrocyclone
Microsand
Polymer
Microsand recirculation
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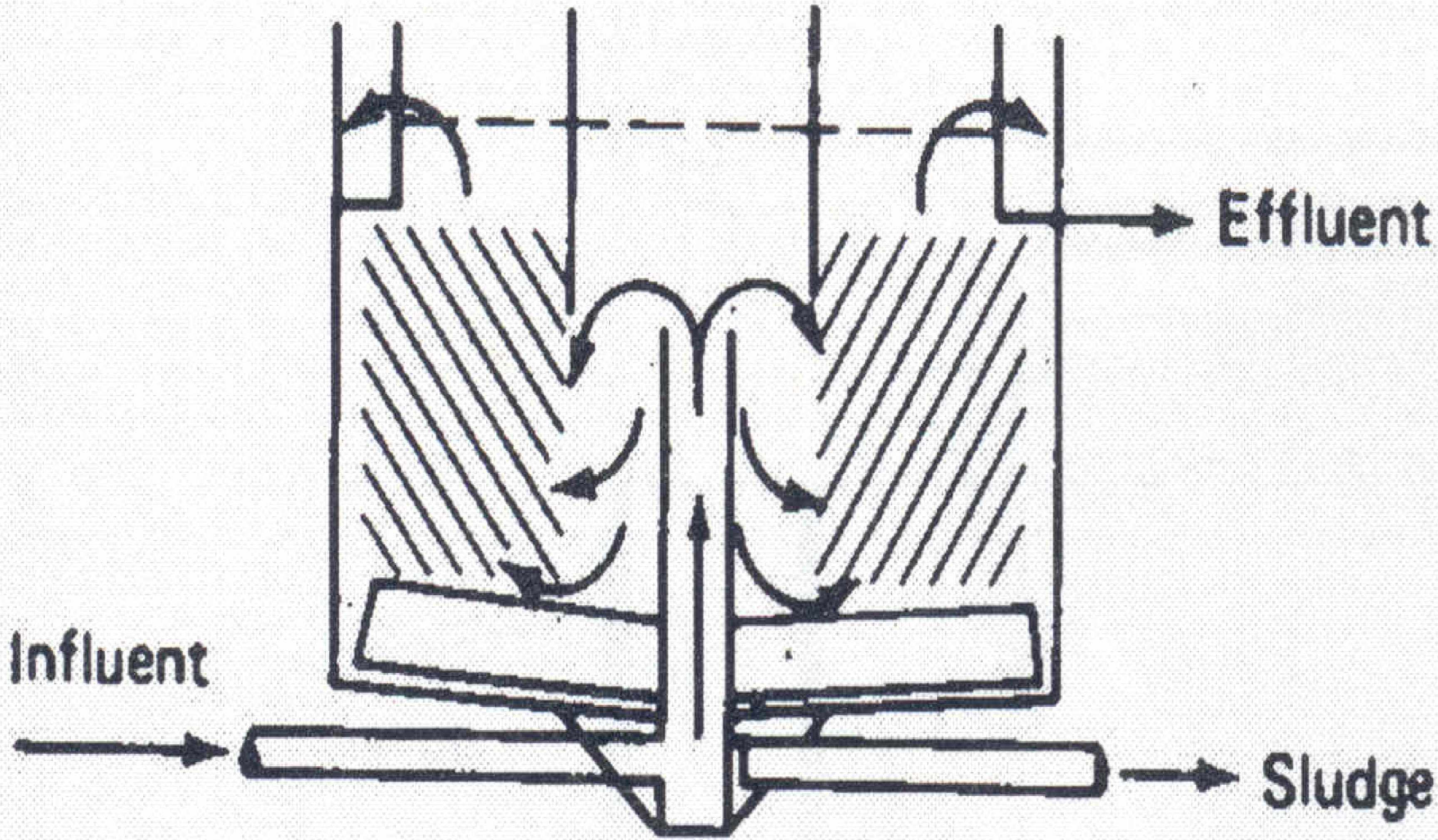
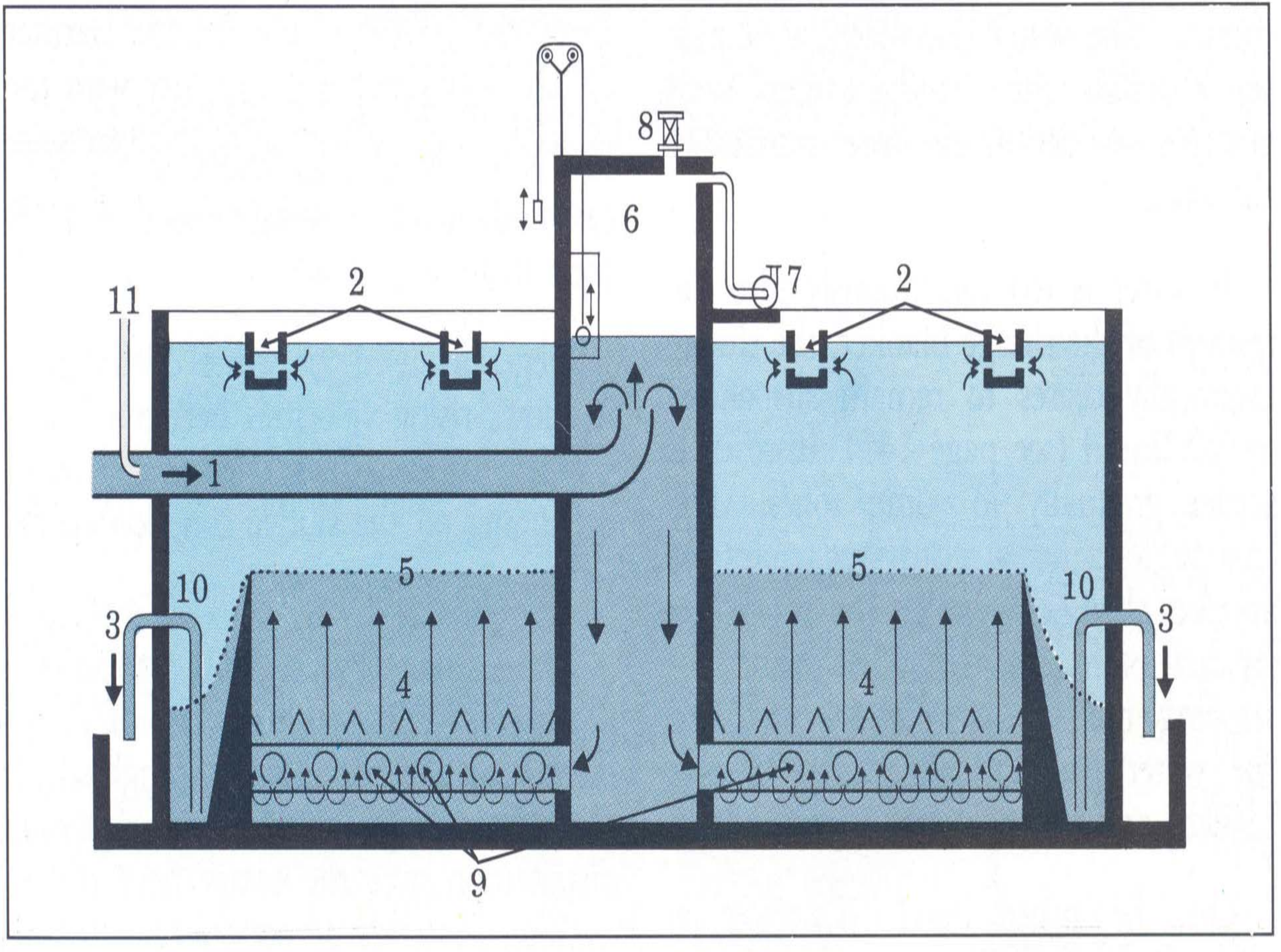
Coagulant
Raw water
Clarified water
Coagulation basin
Injection basin
Maturation basin
Lamella clarifier



(i)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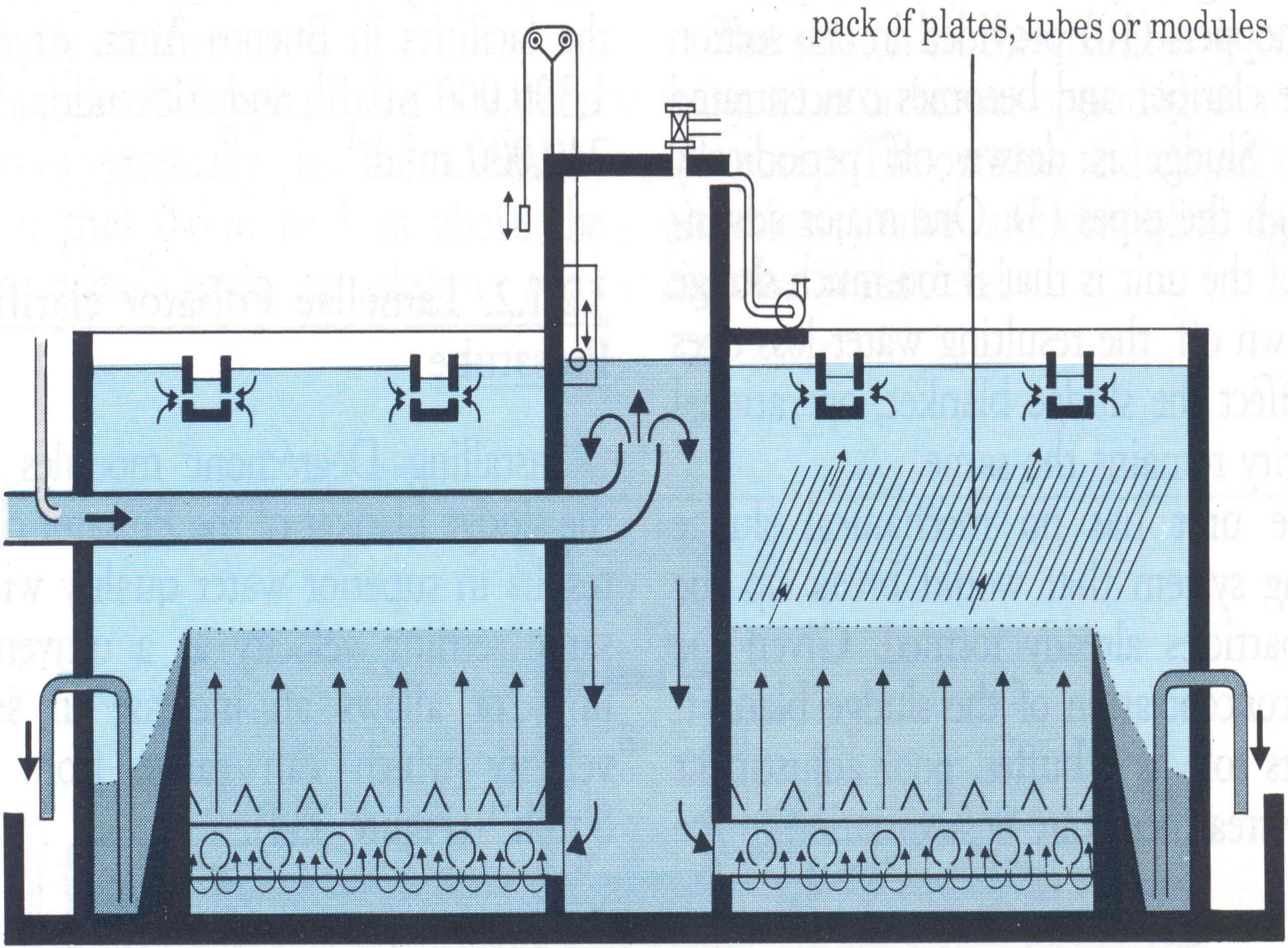
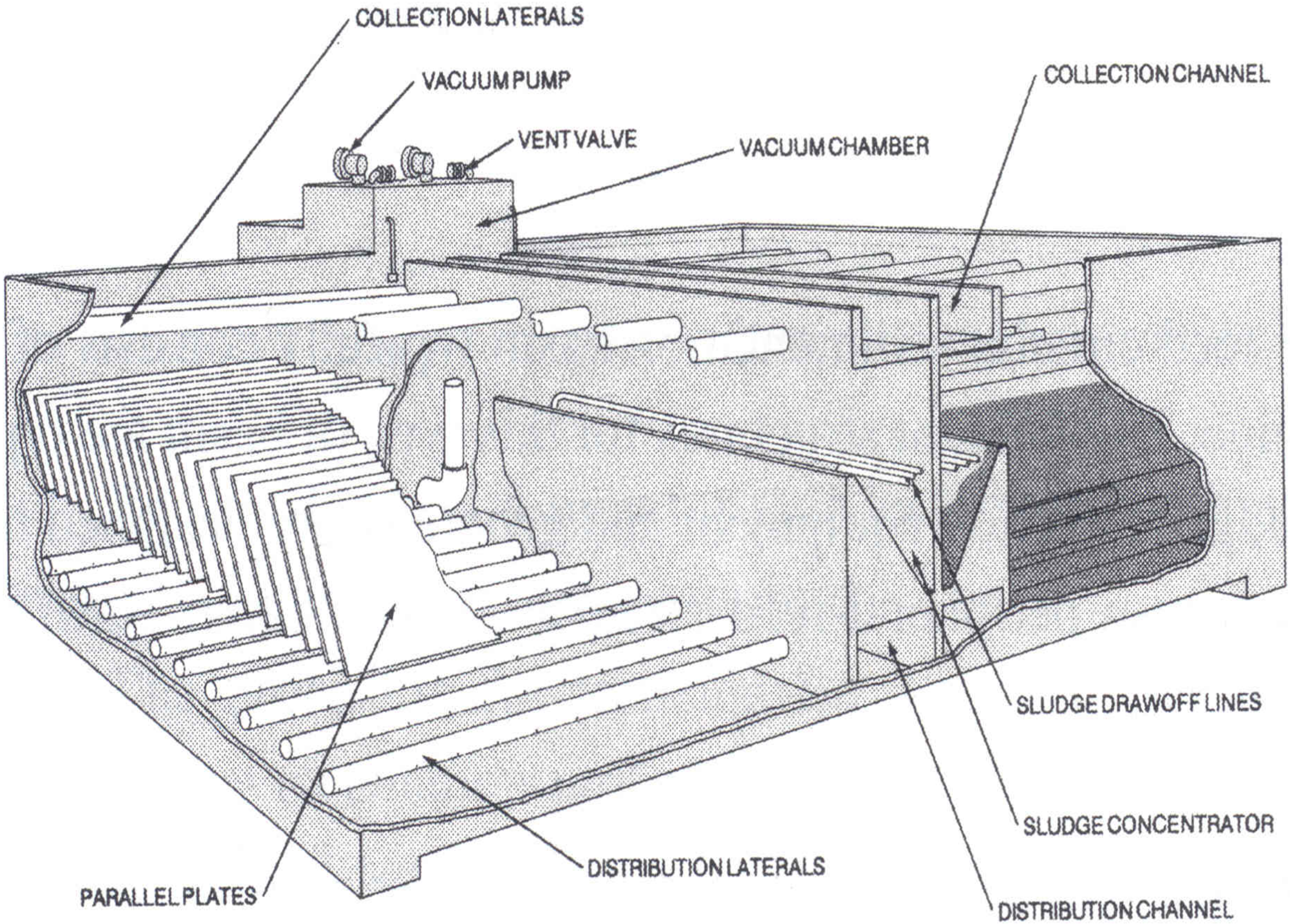

pack of plates, tubes or modules


COLLECTION LATERALS
VACUUM PUMP
VENT VALVE
VACUUM CHAMBER
COLLECTION CHANNEL
SLUDGE DRAWOFF LINES
SLUDGE CONCENTRATOR
DISTRIBUTION LATERALS
PARALLEL PLATES
DISTRIBUTION CHANNEL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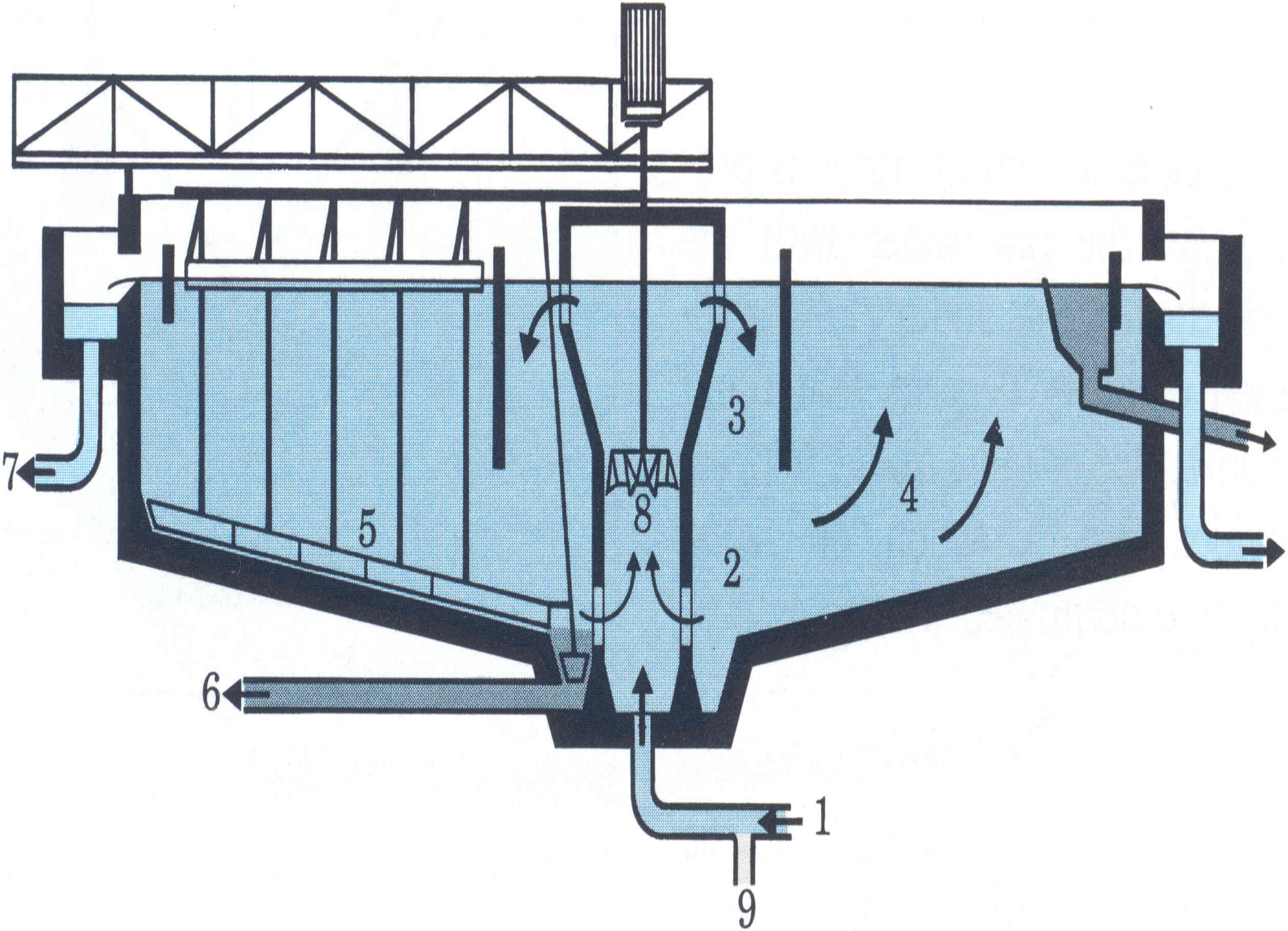

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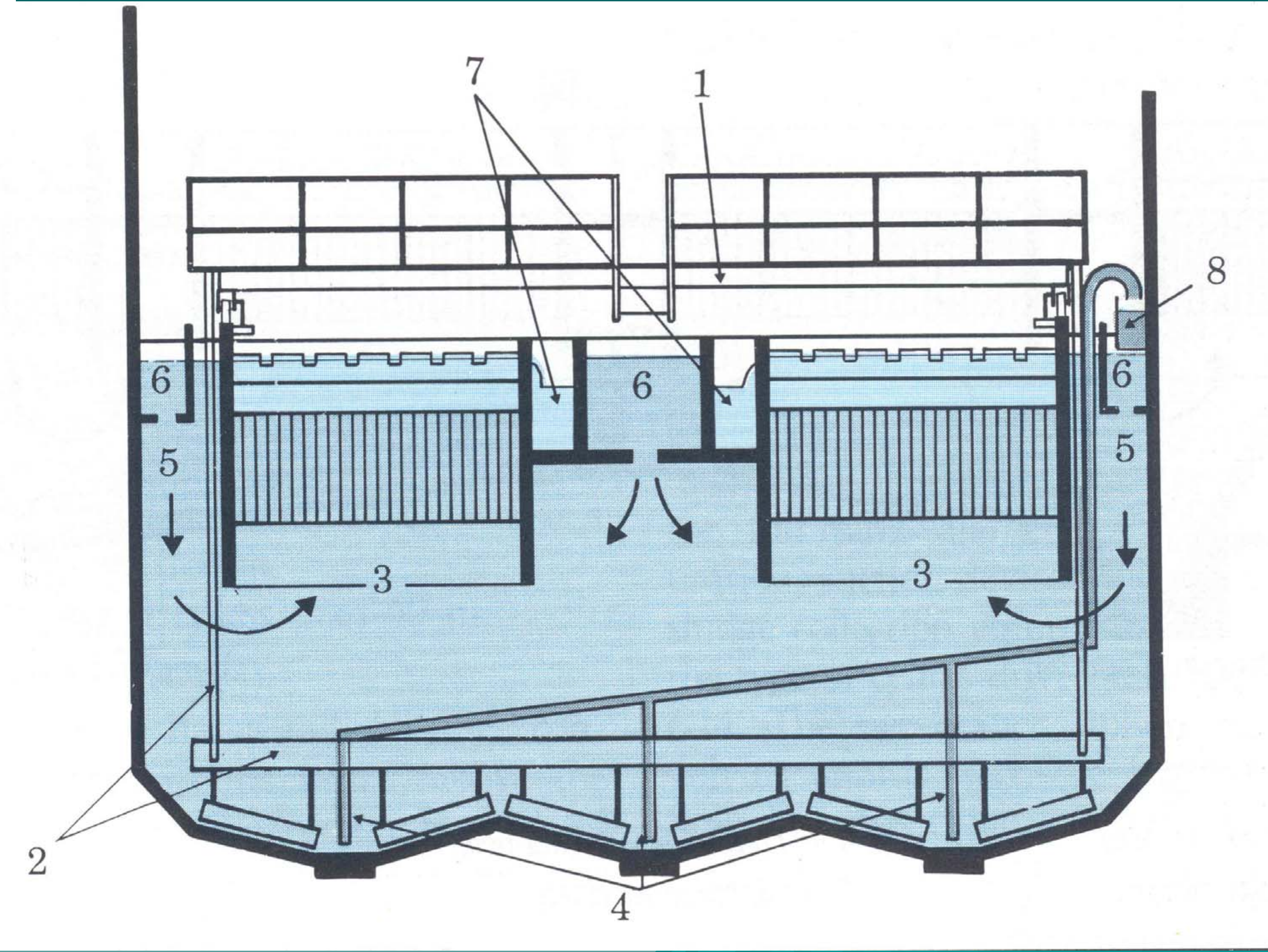

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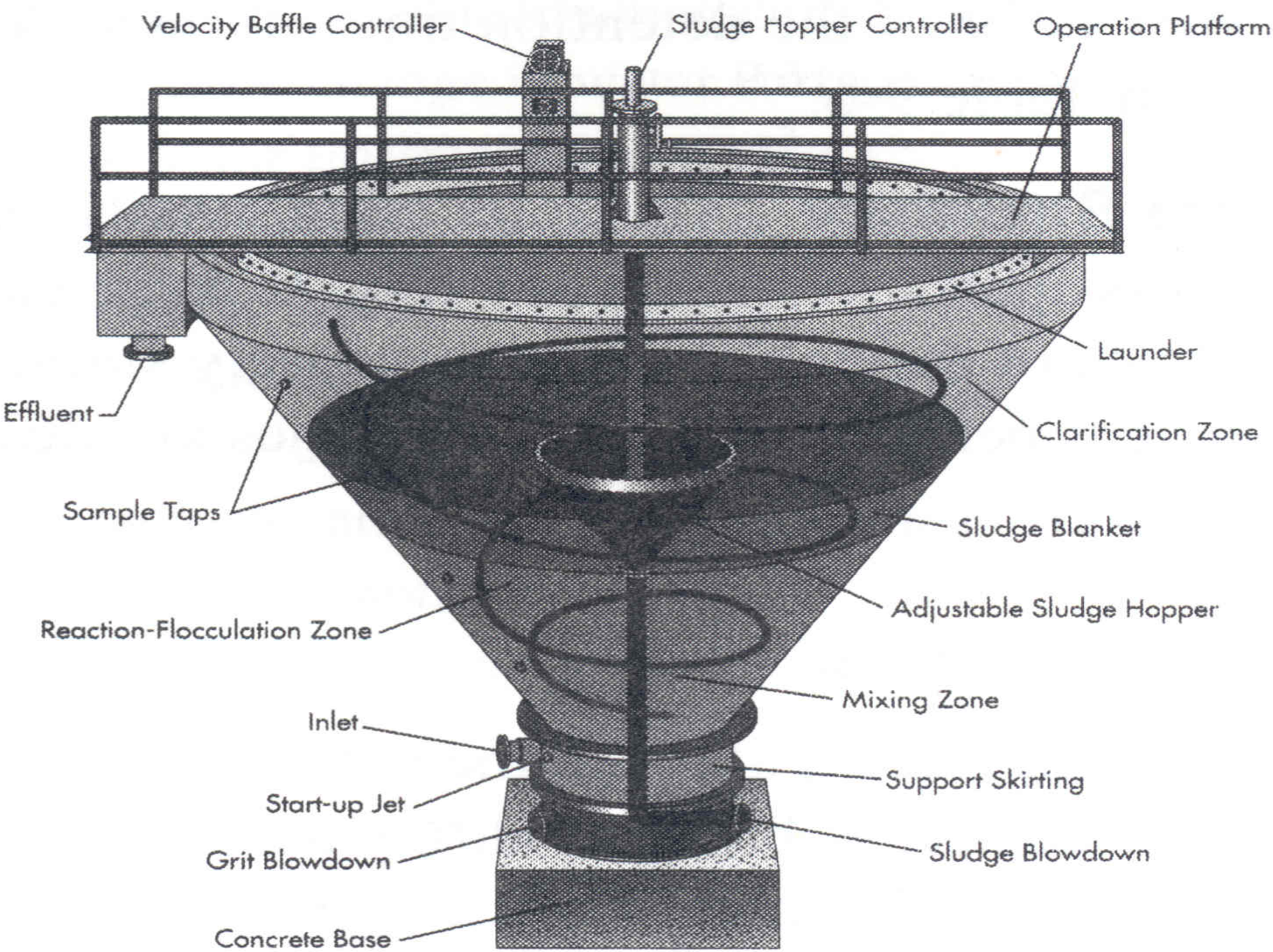
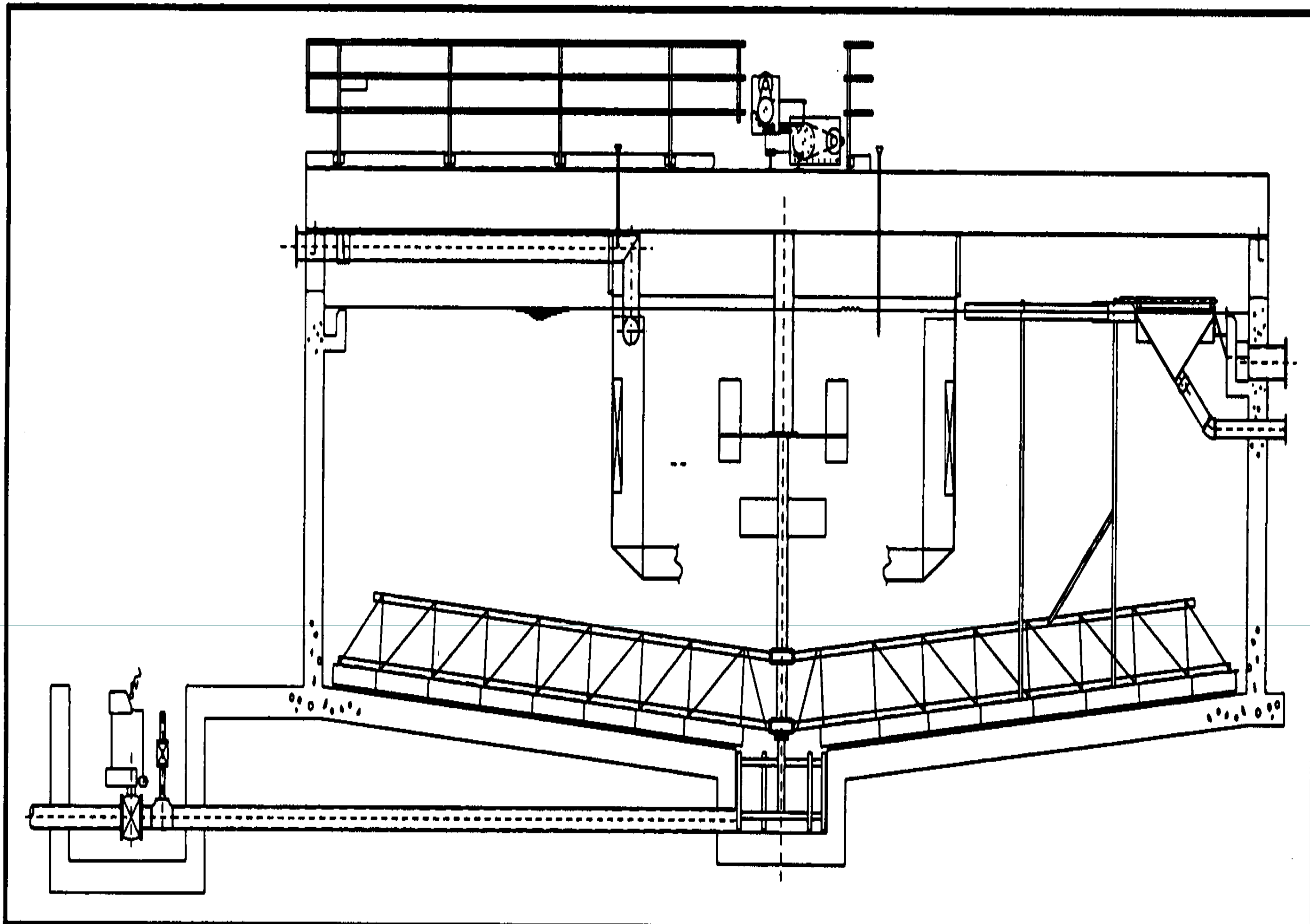

Velocity Baffle Controller
Sludge Hopper Controller
Operation Platform
Launder
Effluent
Clarification Zone
Sample Taps
Sludge Blanket
Adjustable Sludge Hopper
Reaction-Flocculation Zone
Mixing Zone
Inlet
Support Skirting
Start-up Jet
Grit Blowdown
Sludge Blowdown
Concrete Base



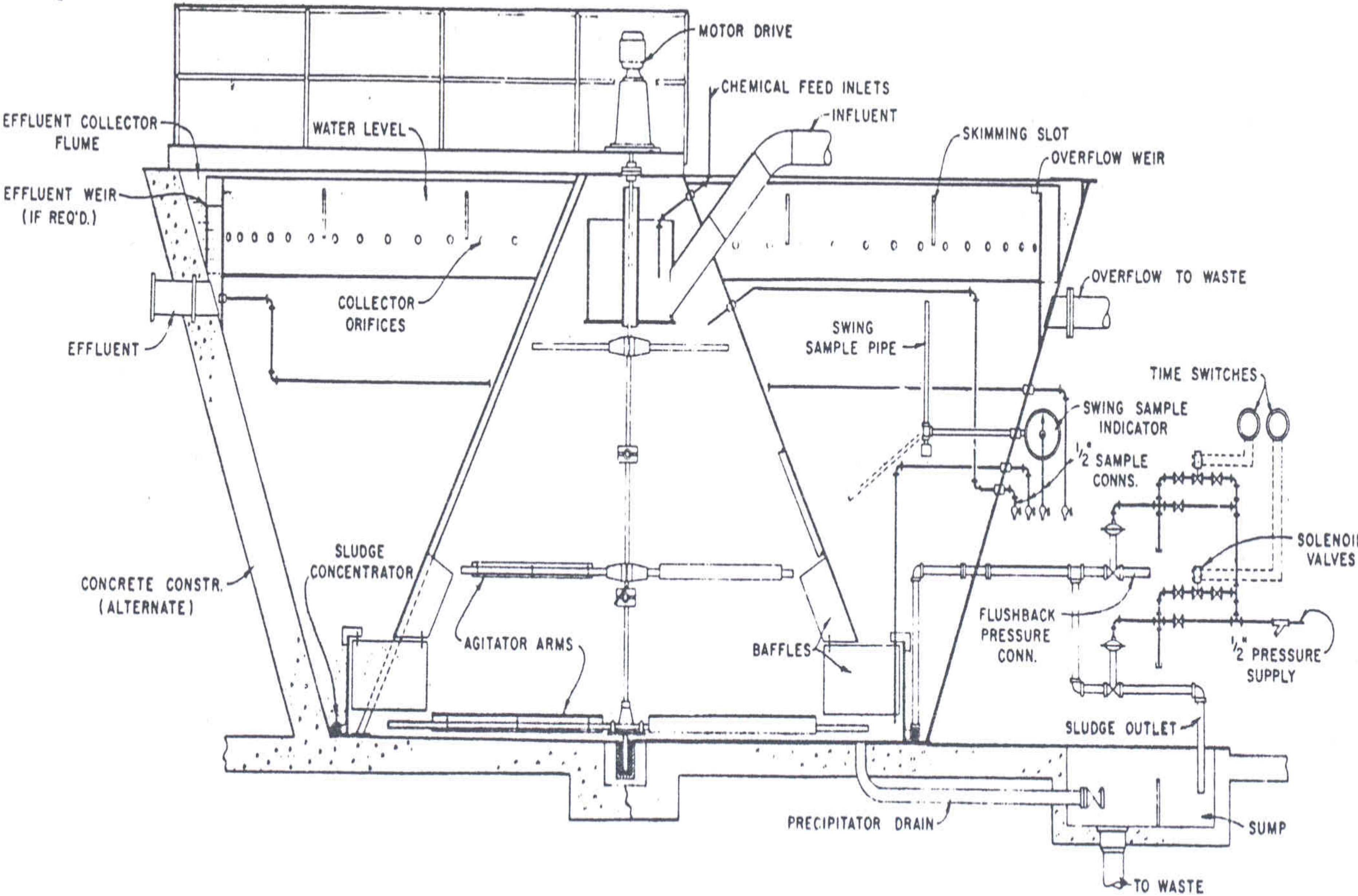


Figure 2. Vertical sludge blanket clarifier.

ถังกรอง (Filter Tank)

ประเภทของถังกรอง แบ่งตามสภาพการไหลผ่านเครื่องกรองดังนี้

1. แบบแรงโน้มถ่วง **(Gravity Filter)**

- เครื่องกรองช้า **(Slow Sand Filter)**
- เครื่องกรองเร็ว **(Rapid Sand Filter)**
- **เครื่องกรองล้างกลับอัตโนมัติ (Self Back Washing)**

2. แบบใช้ความดัน **(Pressure Filter)**

- แบบตั้ง **(Vertical Pressure Filter)**
- แบบนอน **(Horizontal Pressure Filter)**

Design of Filtration

1. Type, Size and Number of Filters

Type of Filters

1.1 Filter Classified by Filtration Rate

1.1.1 Slow Sand Filter – velocity 0.1 – 0.3 m^3/m^2.hr

Biological Layer เรียกว่า Schmutdecke ≈ 5 – 10 cm.

1.1.2 Rapid Sand Filter – velocity 5 – 20 m^3/m^2.hr

1.1.3 High - Rate Filter – velocity > 20 m^3/m^2.hr

Small installation in industry

1.2 Filter Classified by Driving Force

1.2.1 Gravity Filter

1.2.2 Pressure Filter

1.3 Filter Classified by Direction of Flow

1.3.1 Down Flow

1.3.2 Up Flow

Size

Practically < 100 m^2

Number of Filter

For Large Plants minimum 4 Filter

For Small Plants minimum 2 Filter

2. Filtration rate and Terminal Headloss

2.1 Selected by analyzing filter size

2.2 Operating Head

For gravity filter available headloss < 3 m

For pressure filter > 3 m

2.3 Filter Run

2.4 Effluent quality requirements

3. Filter Flow Control Scheme

Basic type of Filter rate control

3.1 Constant rate filtration

- 3.1.1 Effluent controlled constant rate filter
- 3.1.2 Influent controlled constant rate filter

3.2 Declinig rate filtration

- 3.2.1 Influent controlled Decling rate filter
- 3.2.2 Effluent controlled Decling rate filter

3.3 Constant Pressure filtration

4. Media Depth, Size and material

- Pilot Plant Studies

-Existing data from filtration facilities treating similar waters

Size of each Filter

1. Ordinary Gravity Filters

Width of a filter cell	10 – 20 ft (16 ft average) (3 – 6 m)
Length to width ratio	2 : 1 to 4 : 1 (3 : 1 average)
Area of a filter cell	250 – 1,000 ft^2 (600 ft^2 average) (25 – 100 m^2)
Depth of the filter cell	12 – 20 ft (17 ft average) (3.2 – 6 m)

Size of each Filter

2. Self - Backwash Filters (Gravity Filter)

Width of a filter cell	10 – 20 ft (16 ft average) (3 – 6 m)
Length to width ratio	2 : 1 to 4 : 1
Area of a filter cell	250 – 800 ft^2 (25 – 80 m^2)
Depth of the filter cell	18 – 25 ft (22 ft average) (5.5 – 7.5 m)

Size of each Filter

3. Automatic Backwash Filters (Harding Type)

Width of a filter cell	Standard 16 ft (5 m)
Length of a filter	Up to approximately 120 ft (37 m)
Depth of the filter cell	7– 11 ft (2.1 – 3.3 m)
Width of each cell	8 – 25 in (0.2 – 0.64 m)
Depth of the filter bed	11 – 48 in (16 in standard) (0.25 – 1.2 m)

Size of each Filter

4. Pressure Filter

Diameter of a filter cell	4 - 20 ft (10 ft average) (1.2 – 6 m)
Length of a filter cell	8 – 15 ft (20 ft average)
Depth of the filter bed	2 – 3 ft (0.6 – 0.9 m)

Note

Both horizontal and vertical cells are available. However, the vertical cells are more common for large sized units because they are cleaned to a greater extent during filter washing. The multicell (four-cell) horizontal units have the following advantages: a self – backwash system, space-saving features, and cost effectivess

Circular Tank (gravity or pressure filter tank)

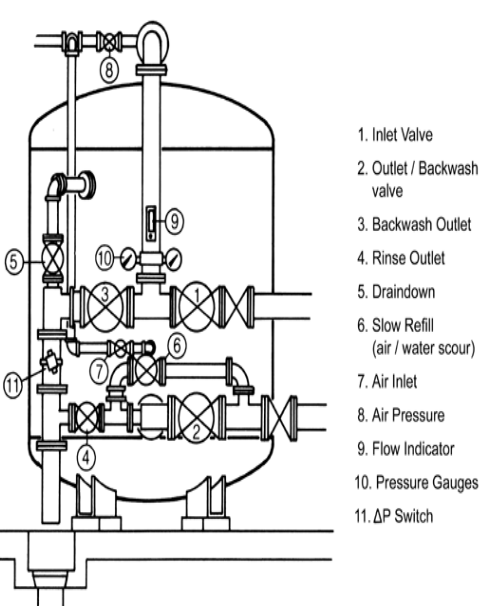
$$Acture\ \ Velocity = \frac{Q(m^3/hr)}{A(m^2)} \qquad m/hr$$

$$Acture\ \ Velocity = \frac{Q(m^3/d)x4}{\pi D(m)^2 x60x60} \qquad m/s$$

$$Flow\ Rate(Q) = \frac{V(m^3)}{t(hr)} \qquad m^3/hr$$

$$Flow\ Rate(Q) = \frac{\pi D(m)^2 xh(m)}{4xt(hr)} \qquad m^3/hr$$

$$Bed\ \ Depth(h) = v(m/s)xt(s) \qquad m$$



Filter Bed

1. $\frac{L}{d_e} \geq 1,000$ For ordinary mono sand and dual media beds

2. $\frac{L}{d_e} \geq 1,250$ For tri media (coal, sand, and garnet) and coarse monomedium beds

3. $\frac{L}{d_e} \geq 1,250 – 1,500$ For very coarse monomedium beds ($2 \text{ mm} > d_e > 1.5 \text{ mm.}$)

Where

L = depth of the filter bed in mm.

d_e = effective size of the filter media. = d_{10}

Types of Filtration Media

- Silica Sand
- Anthracite Coal
- Garnet
- Diatomaceous Earth
- Activated Carbon

Table 10-1 Typical Media Design Values for Various Filters

Parameter	Single-medium Filters	Dual-media Filters	Mixed-media Filters
Anthracite layer			
Effective size, mm	0.50–1.5	0.70–2.0	1.0–2.0
Uniformity coefficient	1.2–1.7	1.3–1.8	1.4–1.8
Depth, cm	50–150	30–60	50–130
Sand layer			
Effective size, mm	0.45–1.0	0.45–0.60	0.40–0.80
Uniformity coefficient	1.2–1.7	1.2–1.7	1.2–1.7
Depth, cm	50–150	20–40	20–40
Garnet layer			
Effective size, mm			0.20–0.80
Uniformity coefficient			1.5–1.8
Depth, cm			5–15

Source: Adapted in part from References 3, 5 and 6.

Table 10-2 The Ratio of the Depth of the Media (l) to the Effective Size of the Media (d_e)

Filter Type	Material	Effective Size (d_e), mm	Media Depth (l), cm	Uniformity Coefficient	l/d_e
Small dual-media	Anthracite	1.00	50.8	1.5	1016
	Sand	0.50	25.4	1.3	
Intermediate dual-media	Anthracite	1.48	76.2	1.5	1023
	Sand	0.75	38.1	1.2	
Large dual-media	Anthracite	2.00	101.6	1.5	1016
	Sand	1.00	50.8	1.3	
Mixed-media	Anthracite	1.00	45.7	1.5	1306
	Sand	0.42	22.9	1.5	
	Garnet	0.25	7.6	1.3	
Mono-medium	Anthracite	1.00	101.6	1.4	1016

Filter Medium	Type of Filter	Medium Design Criteria
Fine sand	Slow sand filter 0.13 – 0.42 m/h (filtration rate)	Effective size : 0.25 – 0.35 mm. Uniformity coefficient : 2 – 3 Depth : 1.0 – 1.2 m S.G. $\geq$ 2.63
Medium sand	Rapid sand filters 5 – 10 m/h (filtration rate)	Effective size : 0.45 – 0.65 mm. Uniformity coefficient : 1.4 – 1.7 Depth : 0.6 – 0.75 m S.G. $\geq$ 2.63
Coarse sand	High – rate filters 10 – 30 m/hr (filtration rate)	Effective size : 0.8 – 2.0 mm. Uniformity coefficient : 1.4 – 2.0 Depth : 0.8 – 2.0 m S.G. $\geq$ 2.63

Filter Medium	Type of Filter	Medium Design Criteria
Multimedia coal sand dual or coal-sand-garnet trimedia	High rate filters 10 – 25 m/h (filtration rate)	**Sand** Effective size : 0.8 – 2.0 mm. Uniformity coefficient : 1.4 – 1.7 Depth : 0.3 m **Anthracite coal** Effective size : 0.9 – 1.4 mm. Uniformity coefficient : 1.4 – 1.7 Depth : 0.45 m S.G. $\geq$ 1.5 to 1.6 **Garnet** Effective size : 0.25 – 0.3 mm. Uniformity coefficient : 1.2 – 1.5 Depth : 0.0075 m S.G. $\geq$ 4.0 – 4.1

Filter Medium	Type of Filter	Medium Design Criteria
Granular activated carbon (GAC)	Removal of organic contaminants 7.5 – 15 m/hr (filtration rate) Contact time : 15 – 30 min	Effective size : 0.5 – 1.0 mm. Uniformity coefficient : 1.5 – 2.5 Depth : 1.8 – 3.6 m S.G. $\geq$ 1.35 – 1.37
Proprietary type media	Variety of types, including green sand and synthetic media	Depends on the purpose

Headloss Across the Filter

Total Headloss Across Each Filter

1. Ordinary gravity filters	9 – 15 ft (average 12 ft) (2.7 – 4.5 m.)
2. Pressure filters	50 – 100 ft (average 75 ft) (15 – 30 m.)
3. Automatic backwash filters	2 – 3 ft (0.6 – 0.9 m.)

Headloss Across the Filter

Net Headloss Available for Filtration

1. Ordinary gravity filters	6 – 12 ft (9 ft average) (1.8 – 3.6 m.)
2. Pressure filters	25 – 50 ft (7.5 – 15 m.)
3. Automatic backwash filters	0.5 – 1.0 ft (0.15 – 0.3 m.)

Pressure Drop and Head Loss

Filtration Type	Pressure Drop (Bar)	Head Loss (m. of water)
Pressure Filtration	0.2 – 0.34	2.1 – 3.5
Gravity Filtration	0.18 – 0.24	1.8 – 2.5
Self - Backwash Filters (Gravity Filter)	0.12 – 0.15	1.2 – 1.5
Granular activated carbon	0.21 – 0.34	2.1 – 3.5

Filter Washing

Backwash Rate

1. Ordinary rapid sand filters	0.6 – 0.74 m/min
2. Ordinary dual media bed (trimedia included)	0.74 – 0.9 m/min
3. Ordinary GAC bed	0.5 – 0.65 m/min

Surface wash Rate

1. Fixed nozzle type – flow rate 0.12 – 0.16 m/min
   – pressure 8 – 12 psi

Surface wash Rate

2. Rotating Arm type	– flow rate	0.02 – 0.03 m/min
(single arm)	– pressure	70 – 100 psi
3. Rotating Arm type	– flow rate	0.05 – 0.06 m/min
(dual arms)	– pressure	80 – 100 psi

Air – Scour Backwash

1. Air Scour stage for ordinary beds	0.08 – 0.16 m/min
2. Air Scour stage for coarse deep beds	0.3 – 0.4 m/min
3. Rinse stage for ordinary beds	0.4 – 0.5 m/min
4. Rinse stage for coarse deep beds	0.65 – 1.0 m/min

Conditions	Possible Causes
1. High head loss through a filter unit, or filter runs too short	Filter bed in need of backwashing
	Air binding (เกิดฟองอากาศอุดตันบริเวณช่องว่างของเม็ดทราย)
	Mud balls in the filter bed (เกิดการรวมตัวเป็นก้อนของเม็ดทรายคล้ายลูกบอล)
	Improper rate-of-flow controller operation (เกิดความผิดพลาดในการควบคุมอัตราการไหล)
	Clogged underdrains (เกิดการอุดตันบริเวณท่อรับน้ำสะอาดใต้ถังกรอง)
	Improper media design: too small, or too deep (เลือกขนาดของสารกรองผิดพลาด)
	Floc strength too strong—will not penetrate media (ฟล็อคมีความแข็งแรง)
2. High effluent turbidity	Filter bed in need of backwashing
	Rate of flow too high (อัตราการกรองสูงกว่าที่ออกแบบไว้)
	Improper rate-of-flow controller operation (เกิดความผิดพลาดในการควบคุมอัตราการไหล)
	Disturbed filter bed (ชั้นกรองรับภาระมากเกินไปแล้วไม่ล้างทำความสะอาด)
	Mud balls in the filter bed (เกิดการรวมตัวเป็นก้อนของเม็ดทรายคล้ายลูกบอล)
	Air binding (เกิดฟองอากาศอุดตันบริเวณช่องว่างของเม็ดทราย)
	Inappropriate media size or depth (เลือกขนาดและความสูงของสารกรองผิดพลาด)
	Low media depth (caused by loss during backwash) (ชั้นสารกรองลดลง)
	Floc too small or too weak caused by improper chemical pretreatment (ฟล็อคมีขนาดเล็กเนื่องจากระบบการเติมสารเคมีผิดพลาดทำให้ลอดผ่านชั้นกรอง)

Equations for Design

1. The surface area of filter media per unit of filter plan area

$$\sum a = 6\frac{(1-f)}{\phi}\frac{L}{d}$$

where

$\sum a$ = surface area of filter media per unit of filter plan area, m^2

d = average diameter of filter media grain, mm

ϕ = measure of sphericity (0.7, 0.8-1)

f = porosity of bed (sand = 0.45)

L = filter depth, m

For ordinary high – rate filters, f = 0.45, ∅ = 0.8 and L/d = 950 (all approximate)

2. Number of Filter

$$N = 1.2Q^{0.5}$$

where

N = total number of filter

Q = maximum plant flow rate, mgd

Empirical formula for trough

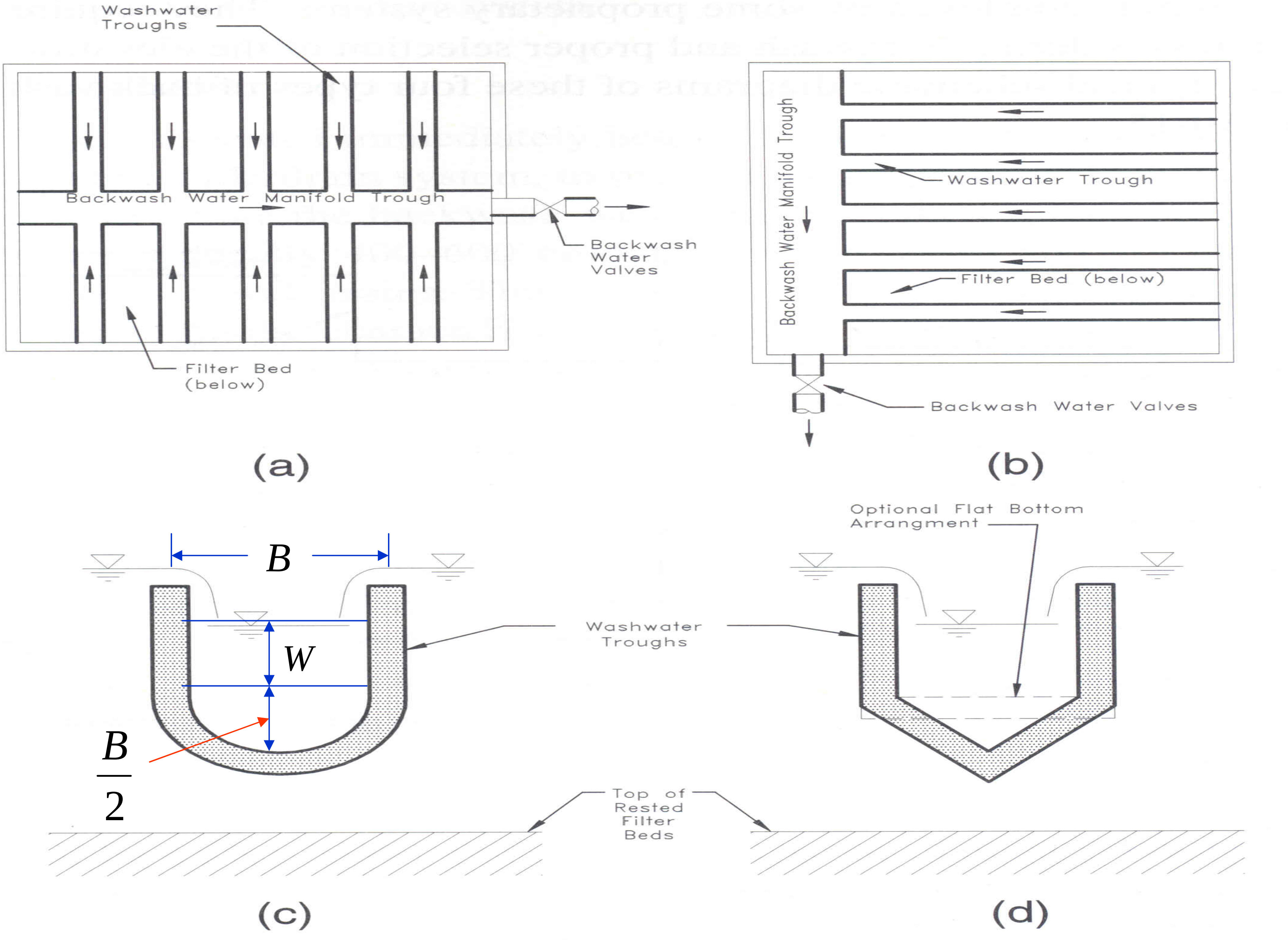
$$\textit{Minimum trough height}(P) = \left(\frac{Q}{1.4B}\right)^{2/3} + \textit{free board}$$

where

Q = total flow rate of discharge (m^3/s)

B = inside width of the trough (m)

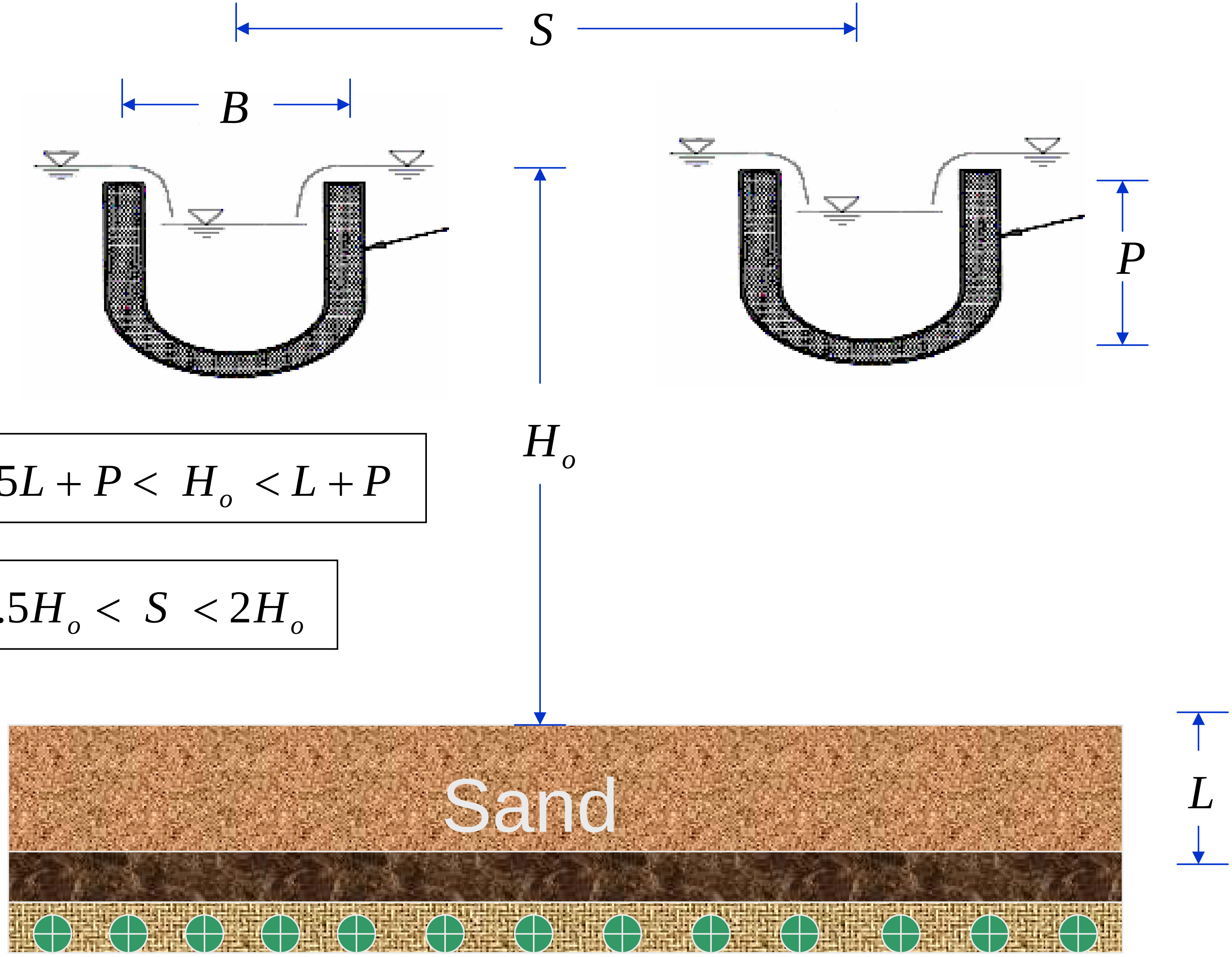
free board = minimum = 0.05 m



Washwater Troughs
Backwash Water Manifold Trough
Backwash Water Valves
Filter Bed (below)
(a)
Backwash Water Manifold Trough
Washwater Trough
Filter Bed (below)
Backwash Water Valves
(b)
B
W
B/2
Washwater Troughs
Optional Flat Bottom Arrangment
Top of Rested Filter Beds
(c)
(d)

$$Minimum\ trough\ height(P) = W + \frac{B}{2} + free\ board$$

$$W + \frac{B}{2} = \left(\frac{Q}{1.4B}\right)^{2/3}$$



$$0.75L + P < H_o < L + P$$

$$1.5H_o < S < 2H_o$$

Head loss in Filter

1. Head loss in Clean Filter
2. Head loss in Clogged filter
3. Miscellaneous Head losses
   - Piping Systems
   - Gravel Beds
   - Underdrain System
   - Washwater Collection Launders

Head loss in Piping Systems

Calculated from Darcy – Weisbach or Hazen – Williams

1. Darcy - Weisbach

$$h_f = f \frac{L}{D} \frac{v^2}{2g}$$

SI unit

2. Hazen - Williams

$$h_f = 6.81 \left(\frac{v}{C} \right)^{1.85} \left(\frac{L}{D^{1.167}} \right)$$

SI unit

$$v = 0.85CR^{0.63}S^{0.54}$$

$$v = 0.355CD^{0.63}S^{0.54}$$

$$Q = 0.278CD^{2.63}S^{0.54}$$

where

h_f = total friction head loss in suction or discharge pipes, m

v = Velocity in the pipe, m/s

Q = flow rate, m^3/s

f = coefficient of friction

C = coefficient of roughness

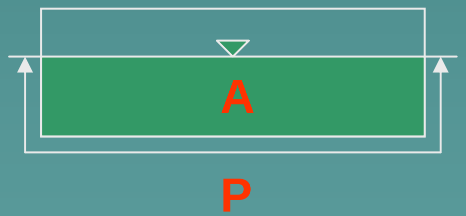
D = diameter of the pipe, m

L = Length of pipe, m

S = slope of energy grade line, (h_f / L)

R = hydraulic radius, m (ft)

$$R = \frac{A(surface\ area, m^2)}{P}$$



$$R = \frac{A}{P} = \frac{\frac{\pi D^2}{4}}{\pi D} = \frac{D}{4}$$

Head loss through clean filter beds

1. Carmen - Kozeny

$$h_L = \frac{f}{\phi}\left(\frac{1-e}{e^3}\right)\frac{L}{d}\frac{v^2}{g}$$

2. Fair - Hatch

$$h_L = k^2 \gamma s^2 \frac{(1-e)^2}{e^3}\frac{L}{d^2}\frac{v}{g}$$

3. Rose

$$h_L = \frac{1.067}{\phi} C_d \frac{1}{e^4} \frac{L}{d} \frac{v^2}{g}$$

4. Hazen

$$h_L = \frac{1}{C} \frac{(5.2x10^6)}{(T+10)} \frac{L}{{d_{10}}^2} v$$

5. Friction factor

$$f = 150\frac{(1-e)}{N_R} + 1.75$$

6. Reynolds number

$$N_R = \frac{d\rho_w v}{\mu}$$

7. Coefficient of drag

$$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$

where

- C = coefficient of compactness (600 – 1,200)
- C_d = coefficient of drag
- d = media grain diameter, m
- d_{10} = media effective size, mm
- e = porosity ratio (usually 0.4 to 0.5)
- f = friction factor
- g = acceleration due to gravity (9.81 m^2/s)
- h_L = head loss, m
- k = filtration constant
- L = media depth, m
- N_R = Reynolds number

S = Shape factor (6.0 – 8.5)

T = temperature, ^{o}F

v = filtration velocity, m/s

μ = absolute viscosity, N-s/m^2 (kg/m.s)

γ = kinematic viscosity, m^2/s

ρ_w = density of water, kg/m^3

ϕ = particle shape factor (usually 0.85 to 1.0)

Head loss through the underdrain

$$h_L = \frac{f}{\phi}\frac{(1-e)}{e^3}\frac{L}{d}\frac{v^2}{g}$$

$$N_R = \frac{d_p \rho_L v_s}{\mu}$$

$$f = 150\frac{(1-e)}{N_R} + 1.75$$

Filter Cleaning or Backwashing

To ensure proper operation of the filter, the design engineer must consider

1. the settling velocity of the media
2. the backwash flow rate
3. the head loss during backwash
4. the duration of the backwash cycle
5. the quality of water required to backwash each filter

1. the settling velocity of the media

- Calculated from Newton's Law

$$v_s = \sqrt{\frac{4}{3}\frac{d_p g}{C_d}\frac{(\rho_s - \rho_L)}{\rho_L}}$$

or

$$v_s = \sqrt{\frac{4}{3}\frac{d_p g}{C_d}(S_g - 1)}$$

- Calculated from Strokes Law

$$v_s = \frac{g}{18\mu}(\rho_s - \rho_L)d_p{}^2$$

or

$$v_s = \frac{g}{18\gamma}(s_g - 1)d_p{}^2$$

where

v_s = settling velocity, m/s

d_p = particle diameter, m

g = acceleration due to gravity = 9.81 m/s^2

C_d = drag coefficient, dependent on Reynolds number

$$C_d = \frac{24}{N_R}$$ (Laminar rang, $N_R < 1$)

$$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$ (Transition rang, $1 < N_R < 10^4$)

S_g = specific gravity of the particle

ρ_s = density of solids, kg/m^3

ρ_L = density of water, kg/m^3

γ = kinematic viscosity, m^2/s

N_R = Reynolds number $N_R = \dfrac{d_p \rho_L v_s}{\mu}$

Calculate the size of the media grains with different specific gravity

$$d_2 = d_1 \left(\frac{S_{g1} - 1}{S_{g2} - 1} \right)^{2/3}$$

where

d_2 = effective size of the media with a specific gravity of S_{g2}, mm

d_1 = effective size of the media with a specific gravity of S_{g1}, mm

2. Backwash flow rate

$$v_s = 10d_{60}$$ (sand)

$$v_s = 4.7d_{60}$$ (anthracite)

where

v_s = terminal settling velocity of the media, m/min

d_{60} = size of the standard sieve opening that will pass 60 percent by weight of the media (mm)

$$d_{60} = d_{10}\ x\ uniformity\ coefficient$$

Backwash rates equal approximate 10 percent of the media terminal settling velocities

$$U_b = d_{60}$$ (sand)

$$U_b = 0.47 d_{60}$$ (anthracite)

where

U_b = backwash rate, m/min

3. Head loss during backwash

h_L = Volume of media grains x (density of media grains – density of water)

or

$$h_L = L(1-e)(S_g-1)$$

where

h_L = head loss through the media bed during backwash, m

e = porosity of the clean stratified bed at rest (not fluidized)

L = depth of stratified bed at rest, m

S_g = specific gravity of the media

4. Surface wash

$$G_{sw} = \left(\frac{\Delta h g v_s \rho_w}{\mu \alpha L_e} \right)^{1/2}$$

where

G_{sw} = velocity gradient give by water-jet-type surface wash, s^{-1}

v_s = surface backwash rate, m/s

Δh = head applied to the media by surface wash system, m

α = coefficient 0.25 for surface wash, 0.5 for dual-arm surface wash

L_e = depth of expanded bed, m

μ = absolute viscosity of water, $N\text{-}s/m^2$ (or kg/m.s)

ρ_w = density of water, kg/m^3

5. Washwater Collection

$$\frac{v'_s \pi}{U_b} < \frac{S}{D} < \pi$$

where

v'_s = settling velocity of the floc, m/s

U_b = backwash rise including surface wash rate, $m^3/m^2.s$

S = center to center spacing of the troughs, m

D = distance between top of the fluidized bed and water surface, m

6. Calculate the porosity of the expanded bed

$$e_{eb} = \left(\frac{U_b}{v_s}\right)^{0.22} = \left(\frac{U_b}{v_s} = \frac{d_{60}}{10d_{60}}\right)^{0.22} = (0.1)^{0.22} = 0.6$$

where

e_{eb} = porosity of the expanded bed

v_s = media settling velocity, m/s

U_b = backwash rise including surface wash rate, $m^3/m^2.s$

7. Calculate expanded bed depth

$$L_{fb} = \frac{(1-e)L}{(1-e_{eb})}$$

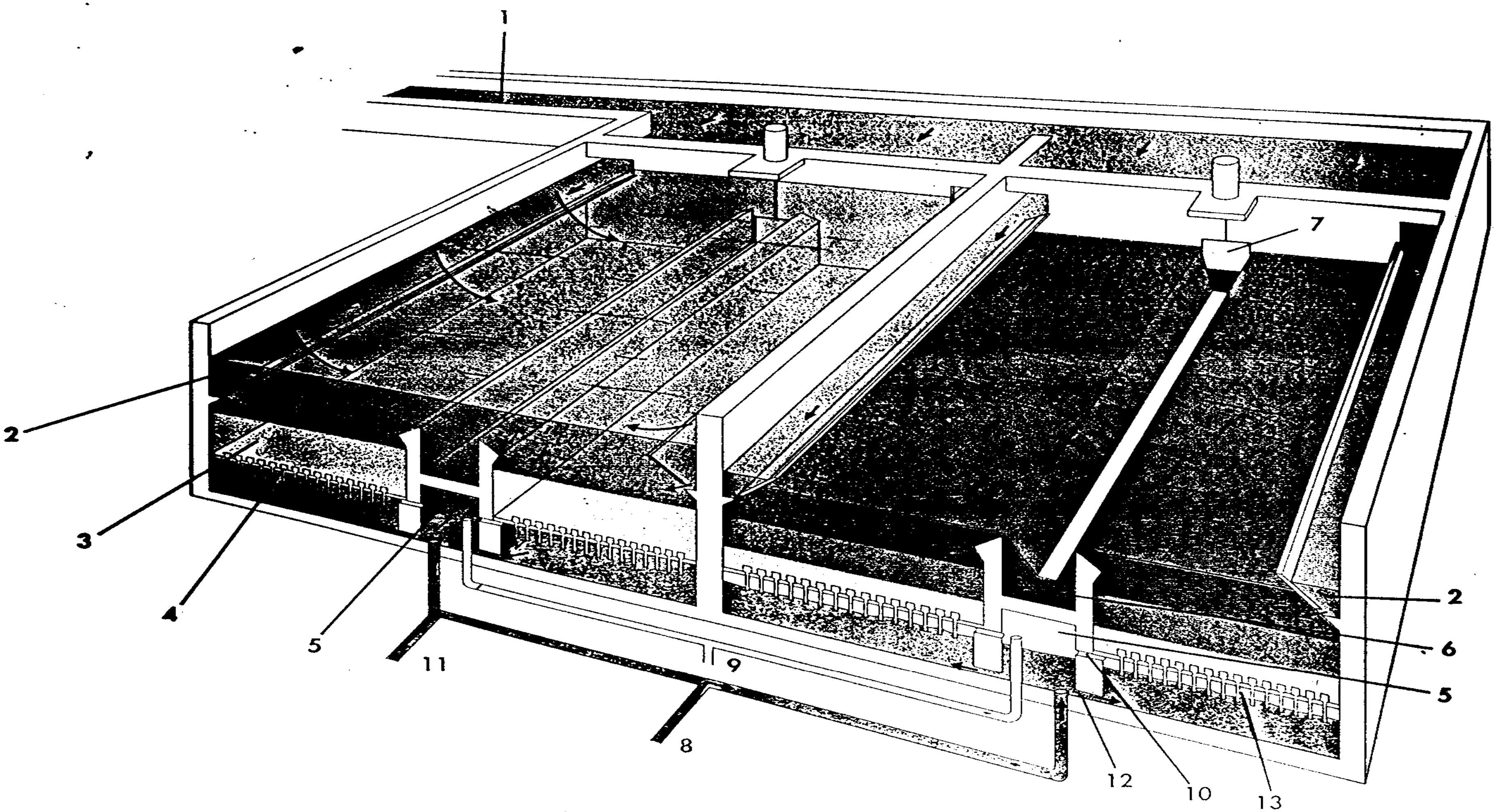
where

L_{fb} = expanded bed depth, m

L = bed depth at rest, m

e_{eb} = porosity of the expanded bed

e = porosity of the clean stratified bed at rest (not fluidized)



Rapid sand filter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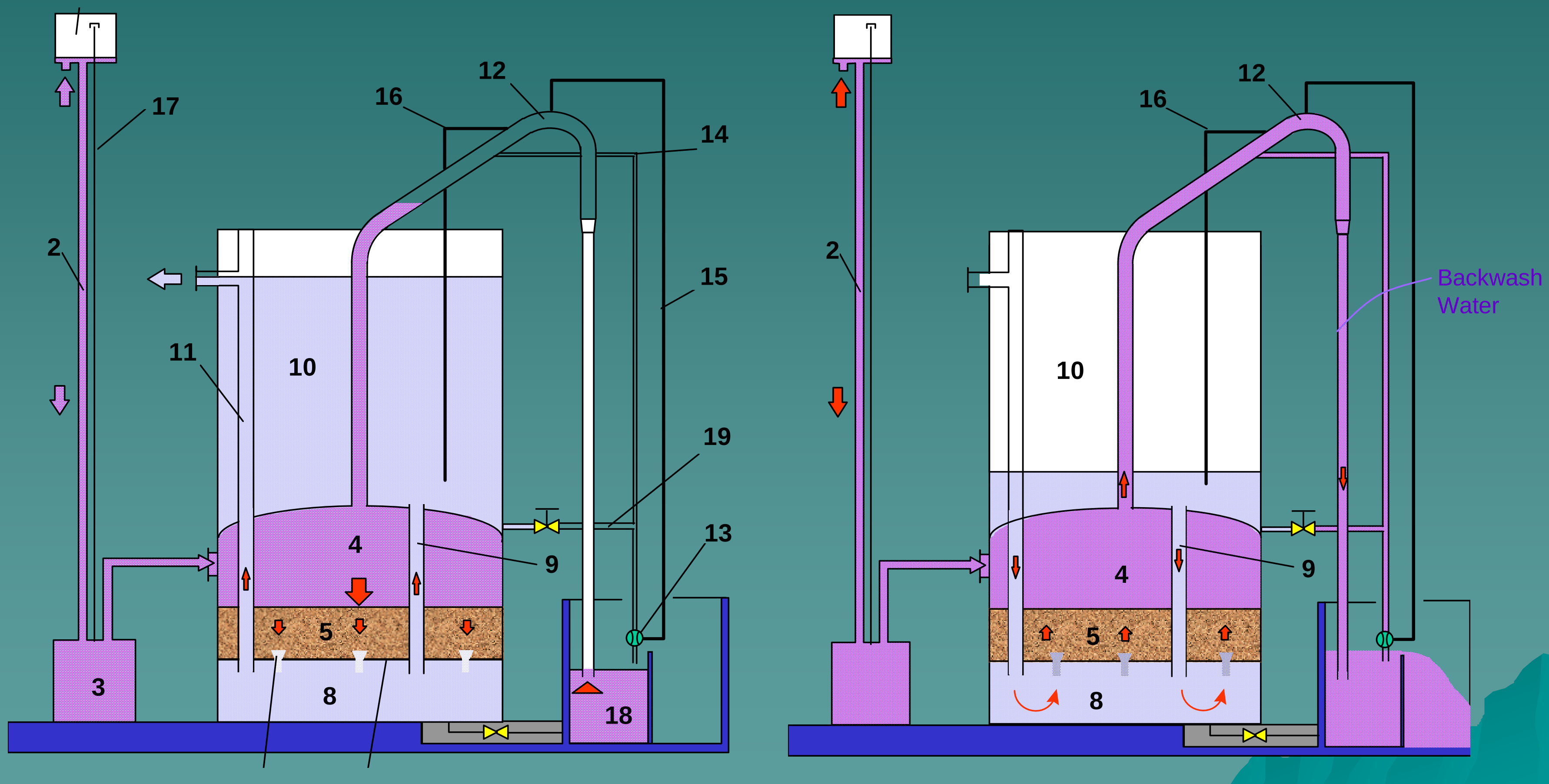
Interfilt® SK

Gravity Filters - Function Principal



Filtering mode

Backwash mode

Interfilt® SK

Application examples: Filtration of the effluent of Amper water treatment plant (135.000 eq. inhabitants)

sewage

Pretreatment

Biology

Sedimentation

Filtration

effluent

Perpetuum mobile: Self-cleaning gravity filters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Interfilt® SK - S

Raw water

↓

Coagulation

↓

Flocculation

↓

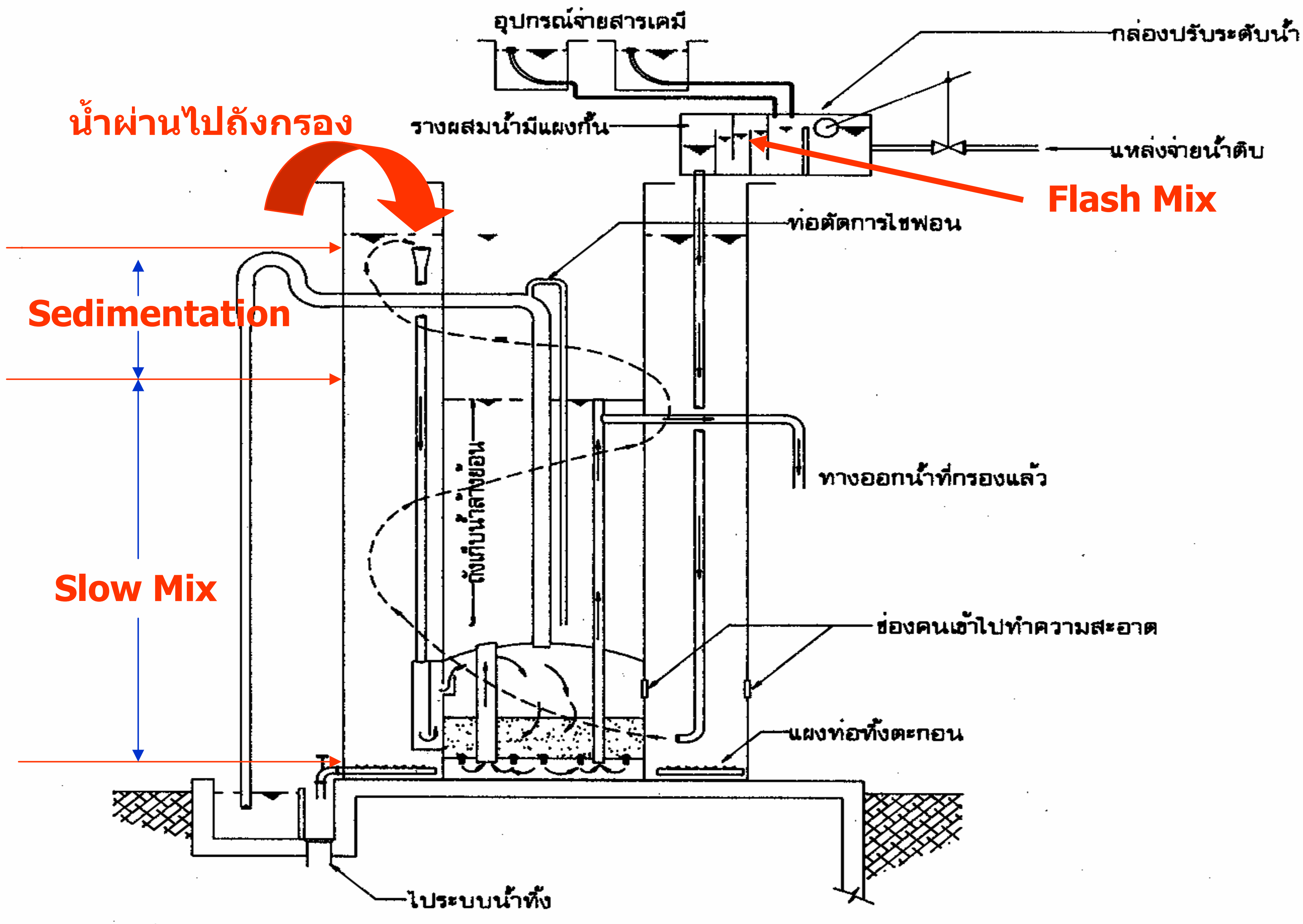
Sedimentation

↓

Filtration

↓ Disinfection

Clear water tank


อุปกรณ์จ่ายสารเคมี
กล่องปรับระดับน้ำ
น้ำผ่านไปถังกรอง
รางผสมน้ำมีแผงกั้น
แหล่งจ่ายน้ำดิบ
Flash Mix
ท่อตัดการไซฟอน
Sedimentation
ถังเก็บน้ำล้างย้อน
ทางออกน้ำที่กรองแล้ว
Slow Mix
ช่องคนเข้าไปทำความสะอาด
แผงท่อทิ้งตะกอน
ไประบบน้ำทิ้ง

Vertical Pressure sand filter

Horizontal Pressure sand filter

ข้อได้เปรียบเสียเปรียบของ Slow sand filter

ข้อได้เปรียบ

1. การออกแบบและก่อสร้างไม่ยุ่งยาก
2. ไม่ต้องใช้ทักษะมากในการควบคุมระบบ
3. ถ้ามีวัสดุกรองที่หาได้ในท้องถิ่นจะช่วยให้ค่าก่อสร้างต่ำ
4. สิ้นเปลืองค่าสารเคมีน้อยกว่าระบบ Rapid sand filter

ข้อได้เปรียบ(ต่อ)

5. ตะกอนที่เกิดขึ้นมีปริมาณน้อยกว่าและไม่ยุ่งยากต่อการกำจัด
6. สิ้นเปลืองพลังงานเดินเครื่องน้อยกว่าระบบ Rapid sand filter
7. มีอุปกรณ์ควบคุมเครื่องน้อยกว่าและเรียบง่ายกว่าระบบ Rapid sand filter
8. Headloss ในถังจะน้อยกว่าระบบ Rapid sand filter

<u>ข้อเสียเปรียบ</u>

1. ใช้พื้นที่มากกว่าระบบ Rapid sand filter ที่อัตราการกรองเท่ากัน
2. ใช้ปริมาณสารกรองมากกว่า
3. ถ้ามีความขุ่นเพิ่มขึ้นโดยทันทีจะทำให้กลไกการกรองน้ำเสียไป
4. การนำทรายกรองมาล้างนอกถังต้องหยุดระบบกรอง ทำให้สิ้นเปลืองเวลามาก

ข้อเสียเปรียบ (ต่อ)

5. เกิดสาหร่ายในถังกรองได้ง่ายถ้ามีแสงแดดและสารอาหารในน้ำดิบมากพอ
6. ต้องใช้เวลาปรับสภาพการกรองในตอนเริ่มทำการกรองค่อนข้างนาน

ข้อได้เปรียบเสียเปรียบของ Rapid sand filter

<u>ข้อได้เปรียบ</u>

1. ใช้พื้นที่น้อยกว่า Slow sand filter
2. ไม่ต้องอาศัยจุลชีพมาเป็นกลไกในการกองจึงไม่ต้องเสียเวลาปรับสภาพในตอนเริ่มต้น
3. การลงทุนในขั้นแรกจะต่ำกว่าระบบ Slow sand filter
4. ใช้ปริมาณสารกรองน้อยกว่า Slow sand filter

ข้อได้เปรียบ(ต่อ)

5. การล้างหน้าทรายทำได้เร็ว
6. สามรถปรับอัตราการกรองให้สอดคล้องกับคุณภาพน้ำดิบได้ง่าย
7. กำจัดสีได้ดีกว่า
8. โอกาสที่จะมีสาหร่ายในถังกรองเป็นไปได้ยาก

ข้อเสียเปรียบ

1. สิ้นเปลืองสารเคมีในการลดความขุ่นด้วยการสร้างแกนตะกอน
2. ตะกอนที่เกิดขึ้นในระบบจะมีปริมาณมากและกำจัดได้ยาก
3. ผู้ควบคุมต้องมีความรู้และทักษะในการควบคุมถังทรายกรองและระบบทั้งหมด
4. ใช้น้ำล้างหน้าทรายในปริมาณที่มากกว่าระบบ Slow sand filter

ข้อเสียเปรียบ(ต่อ)

5. Headloss ในถังกรองจะมีค่าสูง

Chemical use in water treatment plant

Alum

Polyaluminum Chloride (PACl)

Chlorine

Lime

Polymer

PAC(powdered activated carbon)

เงื่อนไขการ Operate ระบบผลิตน้ำ

1. น้ำออกจากถังตกตะกอน **(Clarifier Tank)**

- **Turbidity** 7 $\pm$ 3 NTU
- **pH** 6.5 – 8.5
- **Alkalinity** $\geq$ 50 mg/l