

In the field, it has been observed that the detention time reduces much faster with increase in the value of G . Hence the $G.t$ value instead of remaining constant reduces with increase in G value. Equation 7.8 is based on this field experience. Variation in the value of G could be from 300 s^{-1} to 5000 s^{-1} .

7.4.3 SLOW MIXING OR STIRRING

Slow mixing is the hydrodynamic process which results in the formation of large and readily settleable flocs (orthokinetic flocculation) by bringing the finely divided matter into contact with the microflocs formed during rapid mixing. These can be subsequently removed in settling tanks and filters.

TABLE 7.1
RECOMMENDED DETENTION TIME AND NET POWER REQUIRED

Detention Time	Velocity gradient	Net Power input per unit volume	Net Power input per unit discharge
S	s^{-1}	watts/ m^3 of volume	watts/ m^3 of flow/hr
60	300	72	1.2
50	360	104	1.4
40	450	162	1.8
30	600	288	2.4
25	720	415	2.9
20	900	648	3.6

Note: Power calculations are based on water temperature of 30°C ($\mu = 0.8 \times 10^{-3} \text{ N.S./m}^2$)

7.4.3.1 Design Parameters

The rate at which flocculation proceeds depends on physical and chemical parameters such as charges on particles, exchange capacity, particle size and concentration, pH, water temperature, electrolyte concentration, time of flocculation, size of mixing basin and nature of mixing device. The influence of these and other unknown factors which vary widely for different waters, is not yet fully understood. Information on the behaviour of the water to be treated can be had by examination of nearby plants treating similar water and by laboratory testing using Jar Test.

The physical forces of slow mixing of the coagulant fed water and adhesion, controlled by chemical and electrical forces are responsible to a large extent in influencing the flocculation processes.

Slow mixing is meant to bring the particles to collide and then agglomerate. The rate of collision among the particles is dependent upon the number and size of particles in suspension and the intensity of mixing in the mixing chamber.

Since flocculation is a time-rate process, the time provided for flocculation to occur is also significant factor in addition to the intensity of agitation and the total number of particles. The number of collisions is proportional to $G.t$ where t is the detention time of the

flocculation basin. The product $G.t$ is non-dimensional and is a useful parameter for the design and operation of flocculation.

The desirable values of G in a flocculator vary from 20 to 75 s^{-1} and $G.t$ from 2 to 6×10^4 for aluminium coagulants and 1 to 1.5×10^5 for ferric coagulants. The usual detention time, provided, varies from 10 to 30 minutes. Very high G values tend to shear flocs and prevent them from building to size that will settle rapidly. Too low G values may not be able to provide sufficient agitation to ensure complete flocculation.

Another useful parameter is the product of $G.t$ and the floc volume concentration ' C ' (Volume of floc per unit volume of water). This parameter $G.C.t$ reflects to a certain extent the contact opportunity of the particles but the usefulness of this parameter is not yet fully established. The values are of the order of 100.

To ensure maximum economy in the input of power and to reduce possible shearing of particles floc formation, tapered flocculation is sometimes practised. The value of G in a tank is made to vary from 100 in the first stage to 50 or 60 in the second stage and then brought down to 20 s^{-1} in the third stage in the direction of flow.

7.4.3.2 Types Of Slow Mixers

Similar to rapid mixing units, these can be categorised under gravitational or hydraulic, mechanical and pneumatic. The hydraulic type uses the kinetic energy of water flowing through the plant created usually by means of baffles, while mechanical type uses the external energy which produces agitation of water.

(1) Gravitational or Hydraulic Type Flocculators

Several types of gravitational or hydraulic flocculators are used in practice.

(a) Horizontal Flow Baffled Flocculator

Fig. 7.2 shows the plan of a typical horizontal flow baffled flocculator. This flocculator consists of several around-the-end baffles with in between spacing of not less than 0.45 m to permit cleaning. Clear distance between the end of each baffle and the wall is about 1.5 times the distance between the baffles, but never less than 0.6m. Water depth is not less than 1.0 m and the water velocity is in the range of 0.10 to 0.30 m/s. The detention time is between 15 and 20 minutes. The flocculator is well suited for very small treatment plants. It is easier to drain and clean. The head loss can be changed as per requirement by altering the number of baffles. The velocity gradient can be achieved in the range 10-100 s^{-1} .

(b) Vertical Flow Baffled Flocculator

Fig. 7.3 shows the cross section of typical vertical flow baffled flocculator. The distance between the baffles is not less than 0.45 m. Clear space between the upper edge of the baffles and the water surface or the lower edge of the baffles and the basin bottom is about 1.5 times the distance between the baffles. Water depth varies between 1.5 to 3 times the distance between the baffles and the water velocity is in the range 0.1-0.2m/s. The detention time is between 10-20 minutes. This flocculator is mostly used for medium and large size treatment plants.

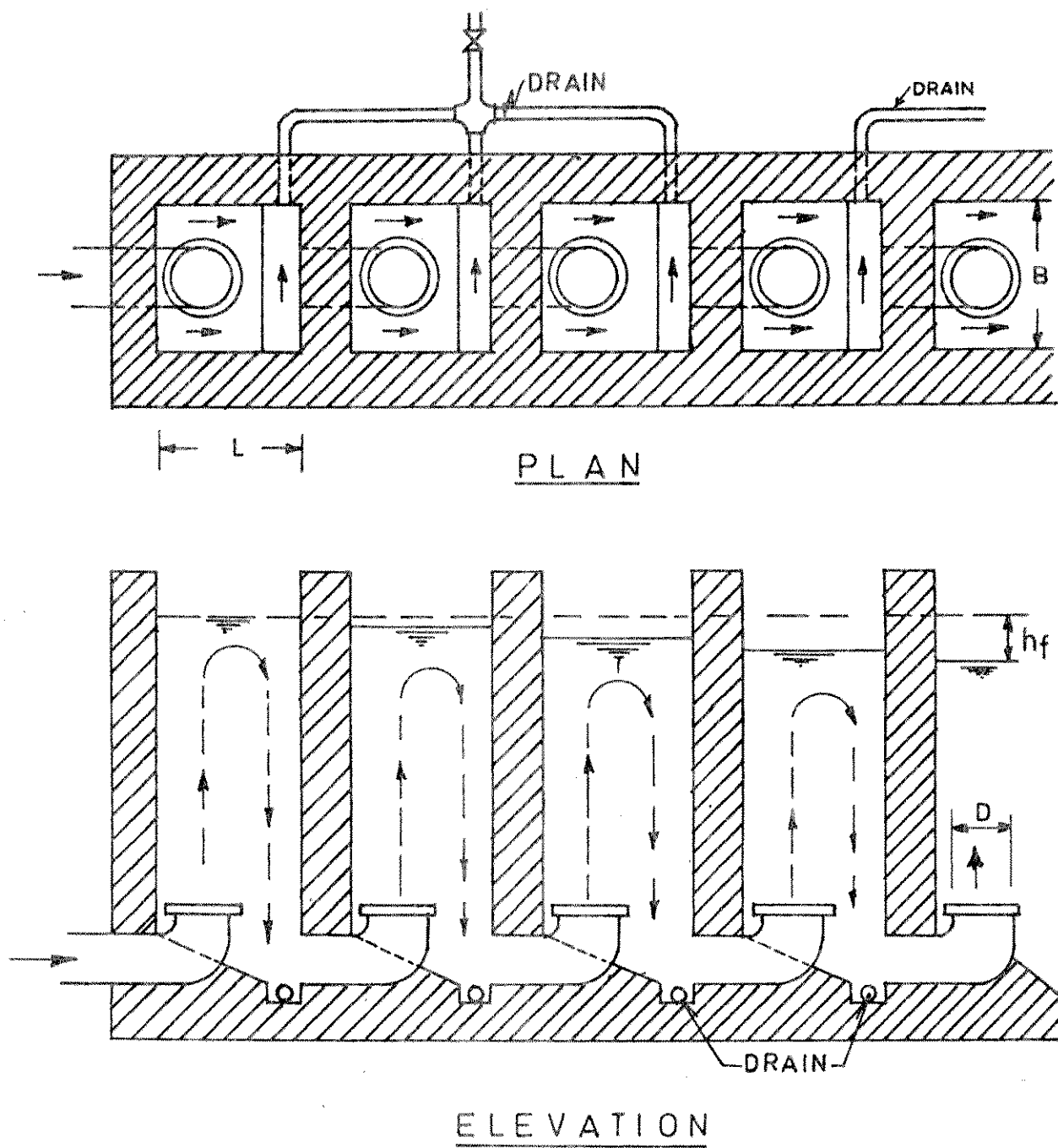
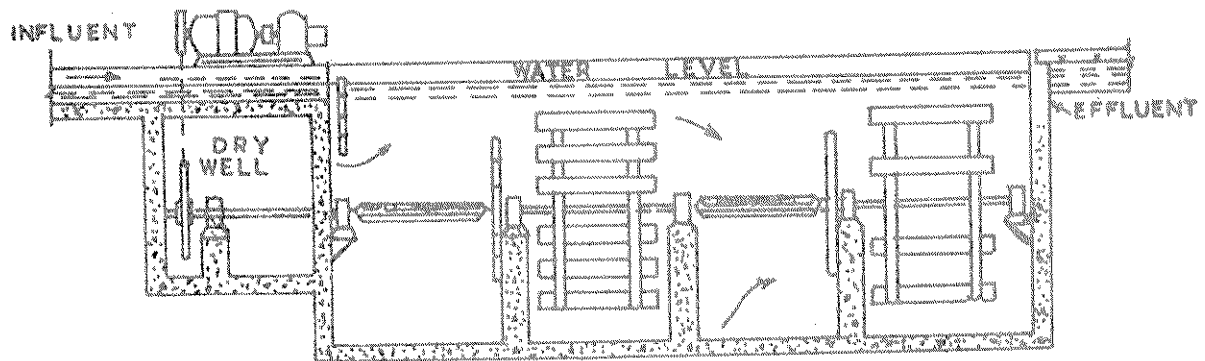
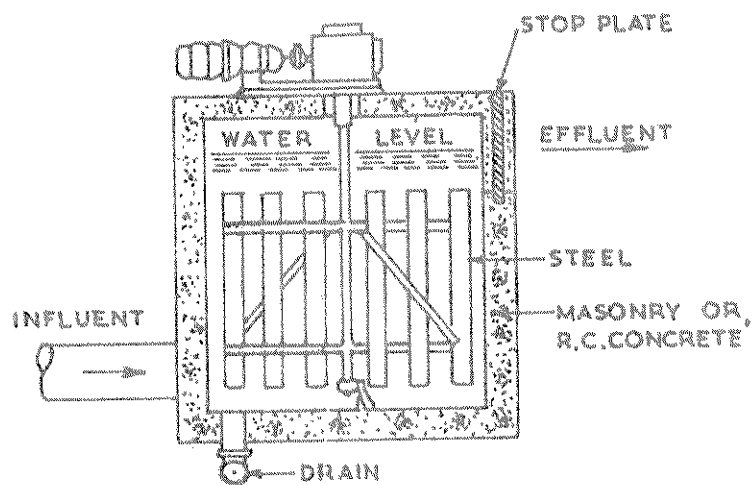


FIGURE 7.5 : ALABAMA TYPE FLOCCULATOR



(a) FLOCCULATOR LONGITUDINAL FLOW



(b) VERTICAL FLOCCULATOR

FIGURE 7.6 : MECHANICAL TYPE FLOCCULATOR WITH PADDLES

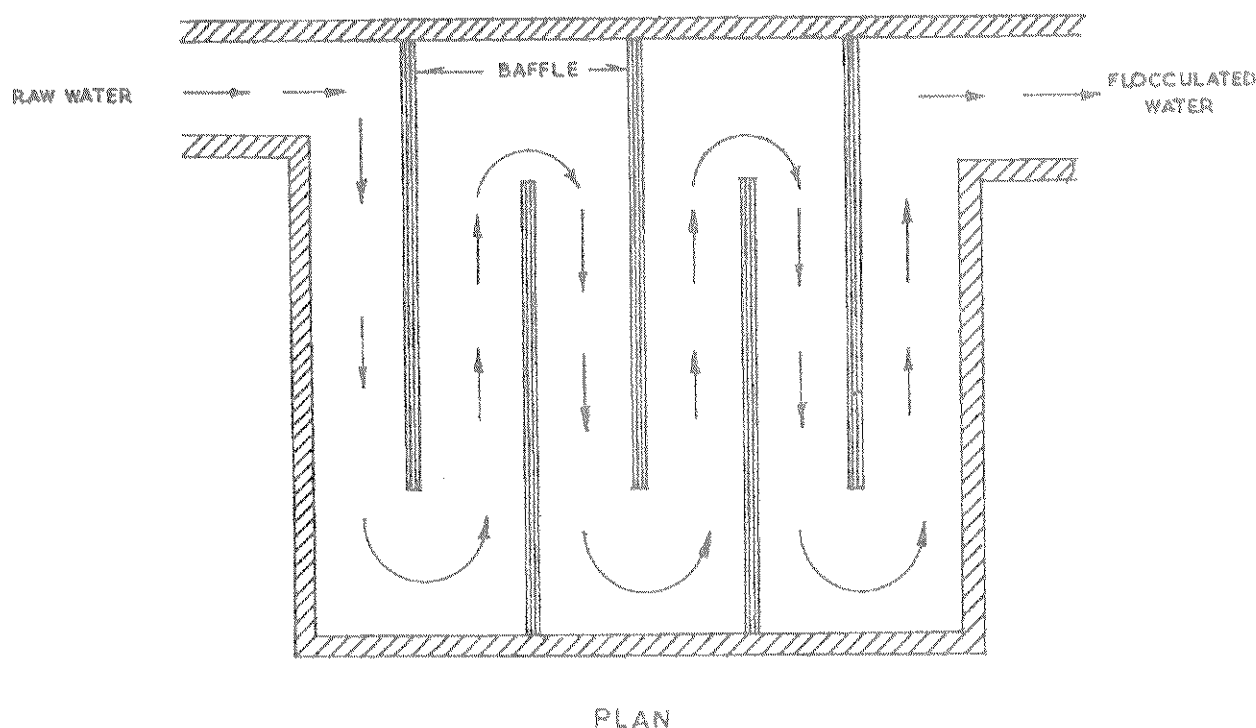


FIGURE 7.2 : HORIZONTAL FLOW BAFFLED FLOCCULATOR

(c) Hydraulic jet Action Flocculator

This is a less known type of hydraulic flocculator and is suitable for small treatment plants.

In one type of jet flocculators, shown in Fig. 7.4, the coagulant (alum) is injected in the raw water using a special orifice device at the inlet bottom of the tank. Water is then let into this hopped tank. Helicoidal-flow (also called tangential-flow or spiral-flow) type as well as staircase type flocculators can also be used.

(d) Alabama-Type Flocculator

An Alabama-type flocculator shown in Fig. 7.5. is a hydraulic flocculator having separate chamber in series, through which the water flows in two directions. Water flows from one chamber to another, entering each adjacent partition at the bottom and through outlets facing upwards. This flocculator was initially developed in Alabama State, U.S.A. (hence the name) and was later introduced in Latin America.

For effective flocculation in each chamber, the outlets are placed at depth of about 2.50 m below the water level. The loss of head is normally about 0.35 to 0.50 m for the entire unit. The range for the velocity gradient is 40 to 50 s^{-1} . The common design criteria are: Rate capacity per unit chamber = 90 to 180 $m^3/m/hr$; velocity at turns = 0.40 to 0.60 m/s; length

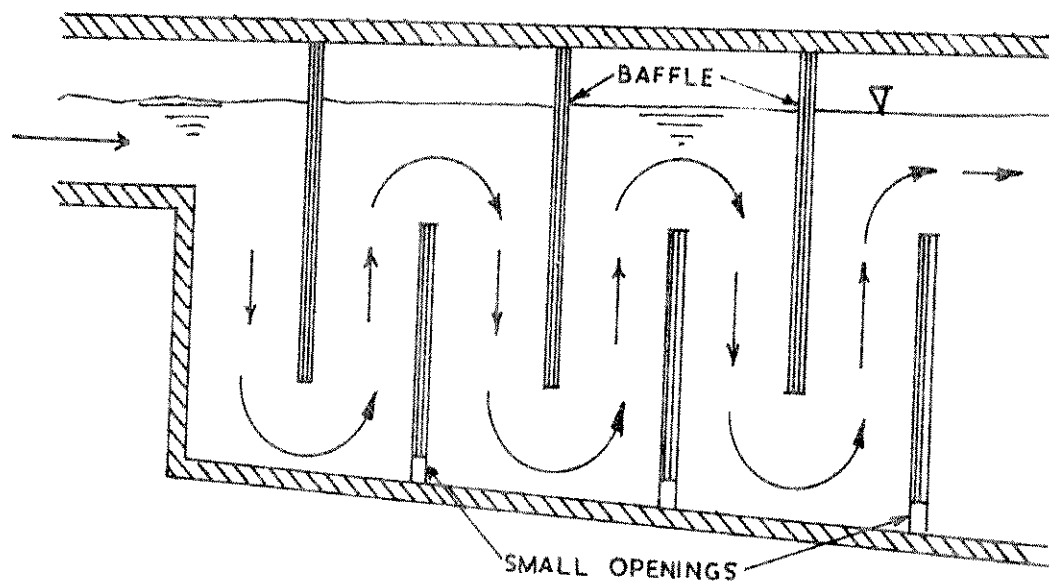


FIG. 7.3 VERTICAL FLOW BAFFLED FLOCCULATOR

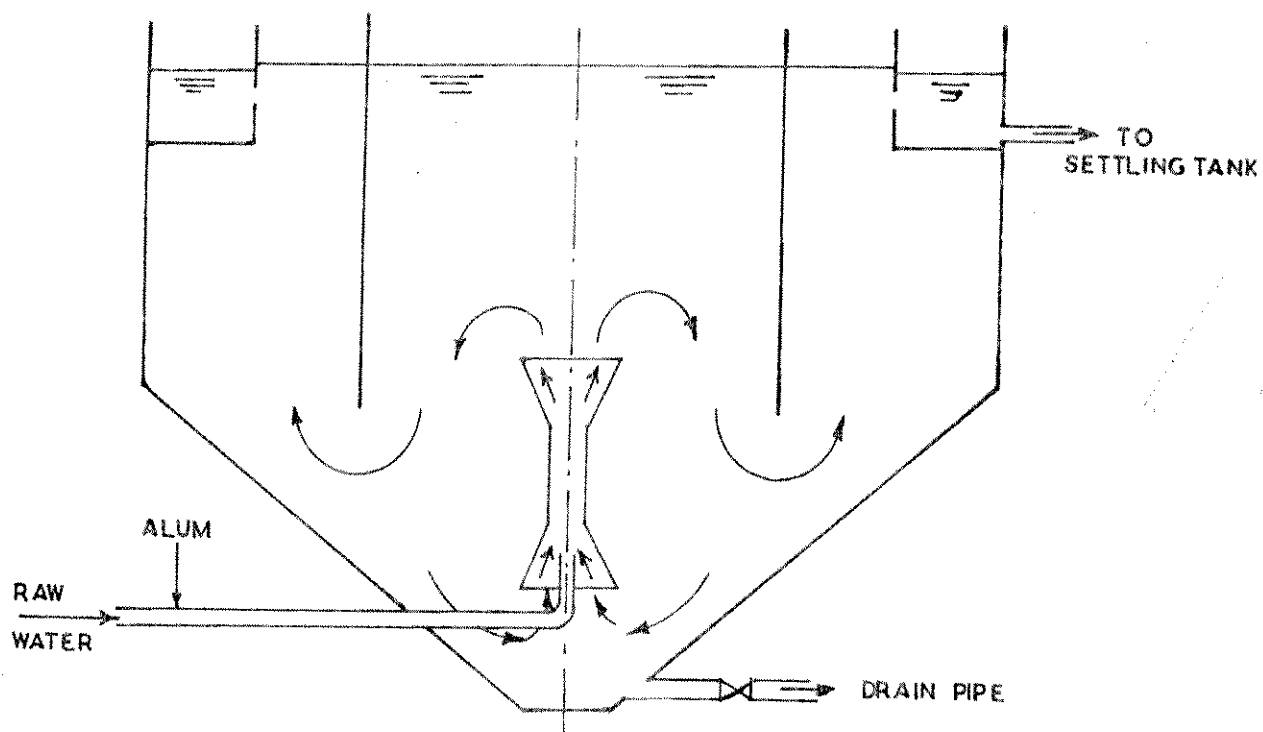


FIGURE 7.4 : JET FLOCCULATOR

of unit chamber = 0.75 to 1.50 m; width = 0.50 to 1.25 m; depth = 2.50 to 3.50 m; and detention time = 15 to 25 min.

(e) *Tangential Flow Type*

Water is introduced tangentially at an inclination in a square tank with chamfered corners to induce a circulatory motion, thus resulting in turbulence and mixing. Chances of short circuiting are high and intimate mixing may not be obtainable.

(f) *Pipe Flocculators*

The turbulence during the flow through a pipe can create velocity gradients leading to flocculation. The mean velocity gradient is calculated from

$$G = \left[\frac{\rho g Q h_f}{Vol(\mu)} \right]^{\frac{1}{2}} \quad (7.9)$$

in which Q = flow rate, m^3/s ; Vol = Volume of pipe of length L in m^3 , and h_f = headloss in pipe of length l ; $h_f = \frac{f l v^2}{2 g d}$

Where v = Velocity, m/s ; f = friction factor for the pipe; d = diameter of pipe, in m .

(2) *Mechanical Type flocculator*

Paddle flocculators are widely used in practice. Fig. 7.6 shows two types of mechanical type flocculator with paddles. The design criteria are: depth of tank = 3 to 4.5 m; detention time, t = 10 to 40 min. normally 30 min; velocity of flow = 0.2-0.8 m/s normally 0.4 m/s ; total area of paddles = 10 to 25% of the cross-sectional area of the tank; range of peripheral velocity of blades = 0.2-0.6 m/s ; 0.3-0.4 m/s is recommended; range of velocity gradient, G = 10 to 75 s^{-1} , range of dimensionless factor Gt = 10^4 - 10^5 and power consumption; 10.0 to 36.0 kw/mld , outlet velocity to settling tank where water has to flow through pipe or channel = 0.15 to 0.25 m/s to prevent settling or breaking of flocs. For paddle flocculator, the velocity gradient is given by

$$G = \left[\frac{1}{2} \cdot \frac{C_D A_p \rho (V_p - V_w)^3}{\mu(vol)} \right]^{\frac{1}{2}} \quad (7.10)$$

In which C_D = coefficient of drag (0.8 to 1.9), A_p = area of paddle (m^2), Vol = volume of water in the flocculator (m^3), V_p = velocity of the tip of paddle (m/s), V_w = Velocity of the water adjacent to the tip of paddle (m/s).

The optimum value of G can be calculated

$$G_{opt}^{2.8} t c = 44 \times 10^5 \quad (7.11)$$

In which G = optimum velocity gradient, s^{-1} , t = time of flocculation, min.; and c = alum concentration (mg/l).

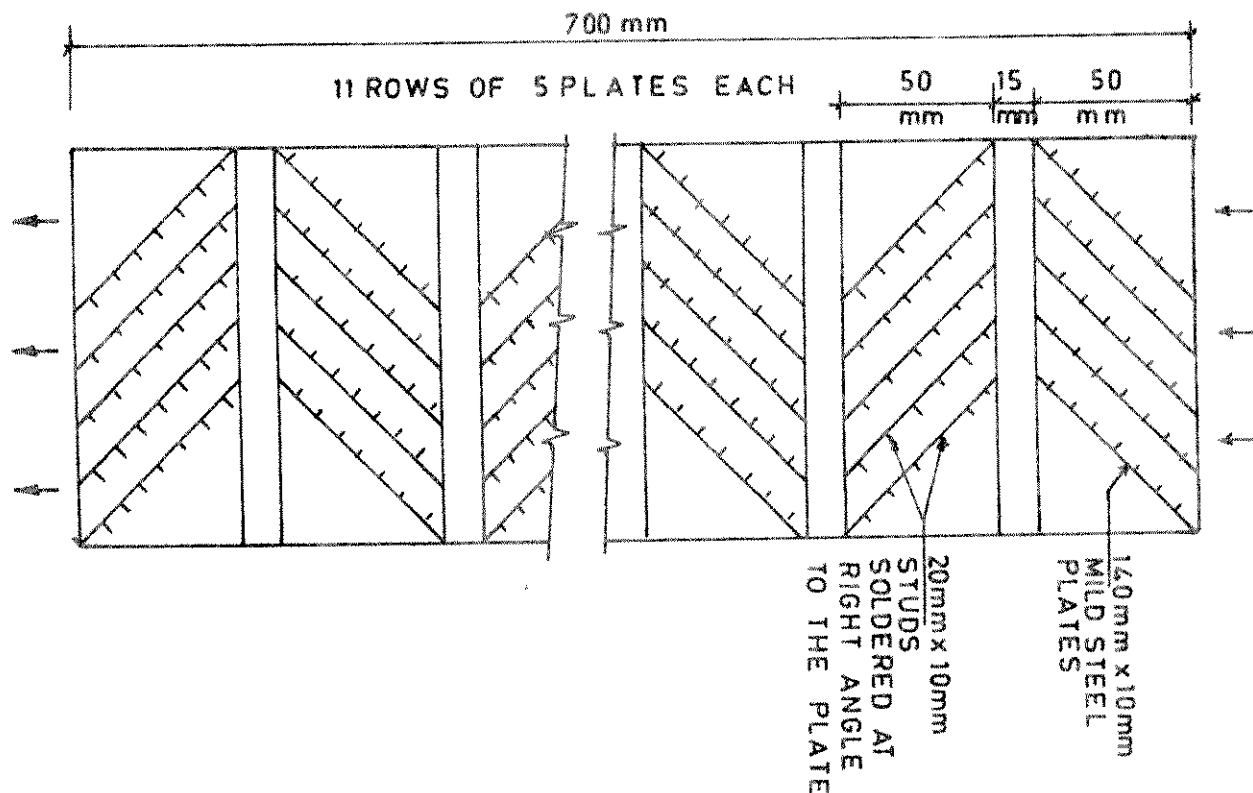


FIGURE 7.7 : SURFACE CONTACT FLOCCULATOR

In large plants, it is desirable to provide more than one compartment in series to lessen the effect of short circuiting. While translating laboratory jar test data to plant scale, it must be borne in mind that the good mixing conditions available in the laboratory cannot be simulated in the plant.

The paddles can be driven by electric motors or by turbines rotated by water fall when sufficient head is available. The direction of flow is usually horizontal moving parallel or at right angles to the paddle shafts. The shape of the container also affects the process of flocculation. For the same volume and height of water in the containers of several shapes such as circular, triangular, square, pentagonal and hexagonal, it was observed that the pentagonal shape gave the best performance.

Introduction of stators in the flocculator helps to improve the performance of flocculation.

(3) Pebble Bed Flocculator

The pebble bed flocculator contains pebbles of size ranging from 1 mm to 50 mm. Smaller the size of the pebbles, better is the efficiency, but faster is the build up of the headloss and vice-versa. The depth of the flocculator is between 0.3 to 1.0 m.

The velocity gradient is given by

$$G = \left[\frac{\rho g Q h_f}{\alpha \mu A} \right]^{\frac{1}{2}} \quad (7.12)$$

In which

h_f = Head loss across the bed (m);

α = Porosity of bed;

A = Area of flocculator (m^2); and

L = Length of the bed (m)

The main advantage of the pebble bed flocculator is that it requires no mechanical devices and electrical power. The operation and maintenance cost is also low. The drawback of this flocculator is that there is gradual build up of the head loss across the pebble bed and therefore needs periodical cleaning by simultaneous draining and hosing.

(4) Fluidized Bed Flocculator

In a fluidized flocculator the sand bed is in the fluidized form. Even a 10% expansion of the sand bed is enough to create the required turbulence without choking the media. The sand size is between 0.2 to 0.6 mm and depth of sand bed is between 0.3 to 0.6 m. The flow of water is upwards. This flocculator also does not require any mechanical equipment or electrical power. Further, there is no build up of the head loss across the bed.

(5) Pneumatic Flocculator

In a pneumatic flocculator, air bubbles are allowed to rise through a suspension. This creates velocity gradient useful for flocculation. The velocity gradient can be calculated from

$$G = 0.236 \frac{g D \rho}{\mu} \left[\frac{\text{Vol}_A}{\text{Vol}} \right]^{\frac{1}{2}} \quad (7.13)$$

In which

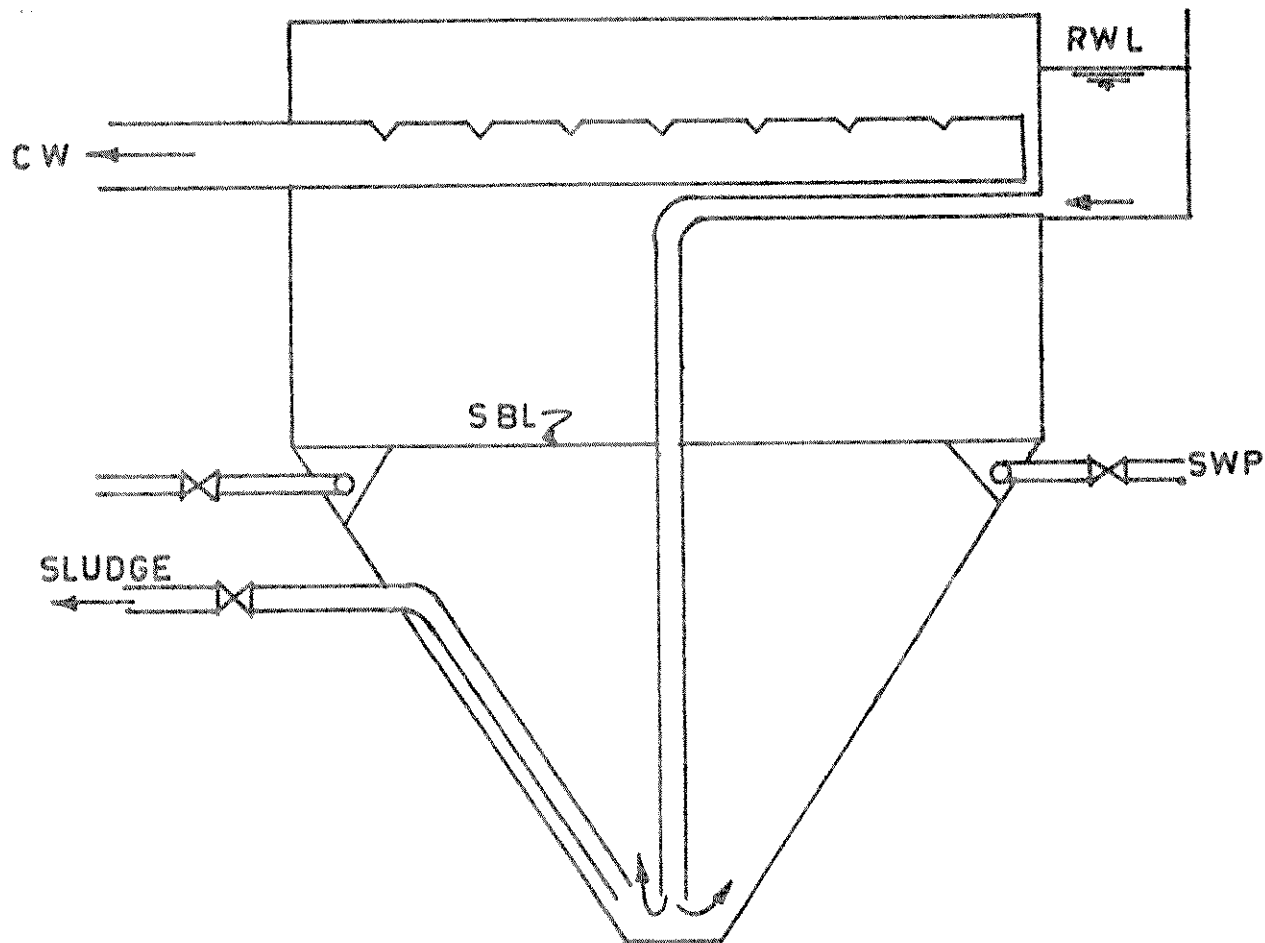
D = diameter of air bubbles (m); and $(\text{Vol}_A/\text{Vol})$ = volume of air supplied per unit water volume.

The flocculator needs air compressor and the problem of clogging of diffuser is quite common. It is less efficient than the paddle-flocculator and therefore not commonly used.

(6) Surface Contact Flocculator

The surface contact flocculator was studied experimentally in India to overcome the inherent problem of choking, which increases the head loss over a period of time in pebble bed flocculators.

The surface contact flocculators consist of studded plates, placed in a zigzag form along the direction of flow. An experimental flocculator, shown in Fig. 7.7, comprised of 55 mild steel plates, 140 mm x 60 mm in size, arranged in 11 rows of 5 plates each. These plates were fixed at 45° to a base plate in zigzag fashion. The flocculator was tested in a continuous



LEGEND

RWL	RAW WATER LEVEL
CW	CLEAR WATER
SBL	SLUDGE BLANKET LEVEL
SWP	SLUDGE WASTE PIPE

FIGURE 7.8(A) : SLUDGE BLANKET CLARIFIER

downflow system with velocity of flow ranging from 5 m/h to 25 m/h and turbidity ranging from 50 to 1600 NTU. Further work in this direction is necessary.

Another type of surface contact flocculator is made of PVC Pipes. These pipes either square or circular in cross-section are cut longitudinally in two equal pieces, length of each piece being 1m. These pieces are then tied with copper wire in perpendicular directions in alternate layers. Suitable gaps are provided between the pieces. The whole assembly of the pipes can be called as floc module. The depth of the module can be between 2.0 to 2.5 m to provide about 15 to 20 minutes of detention time. The modules are housed in a square or rectangular chamber with hopper bottoms. The top of the module is about 200 to 300 mm below the water level in the chamber. The modules can be supported by mild steel grating fabricated from 50 mm x 50 mm mild steel flats welded in vertical positions to mild steel angle frame of 55 mm x 50 mm x 5 mm size angles. The grating can be placed 200 mm above the top of hopper level. The settled sludge can be periodically removed from the hopper.

(7) Inline Flocculator

An Inline static flocculator, or an inline static mixer is a relatively recent device. it is housed in a gravity main and is static. The head loss in an inline flocculator is comparatively less and the maintenance cost is also almost negligible. Only occasional flushing is necessary since deposition of some flocs takes place. The capitalized cost of typical inline flocculator is one-third of the capitalized cost of conventional mixing impellers. Laboratory experiments show that twisted aluminium plates as static mixer in the pipeline give better performance compared to the semicircular plates or the inclined plane plates.

(8) Sludge Blanket Clarifier

A sludge Blanket clarifier includes both flocculation and clarification. Flocculators are generally independent of the settling tanks that follow. They can also be installed such that both the functions are performed in a single unit, though in different zones. In the case of rectangular tanks, the bottom portion can be used for flocculation and the top for sedimentation. In circular tanks, flocculators are at the centre and the flow is vertical.

The more common form of the combination unit is the up-flow clarifier which combines one of flocculation or solids contact unit of either a sludge blanket filtration (also called contact filtration) or a slurry recirculation type with sedimentation. Though there are differences amongst them, all of them seek to take advantage of the mass action effect of floc formation in the presence of previously formed masses of floc. In such basins which are usually deep, vertical flow is induced from the bottom and the decanted water is skimmed out from the top. For floc build-up, inlet and sludge zones are in close contact and the flocculation zone is occupied in part or as a whole by a blanket of flocs. Rising flocs come into contact with both the settling flocs and the stationary blanket of flocs which is in equilibrium with the hydraulic environment. Agglomeration of flocs thus takes place by direct contact.

The bottom section is devoted to mixing of incoming water with chemicals. In the sludge blanket type, chemicals are directly fed into the blanket. All chemical reactions occur in the

blanket so that the newly formed insoluble salts precipitate directly on the sludge particles already present. In this manner a completely flocculated system is constantly maintained and a type of sludge is produced which settles very rapidly and results in completely "cracked" water. At the same time, the filtering action of the blanket traps the finer particles.

The clarification zone extends from the top of the sludge blanket to the surface of the liquid. Upon emergence from the sludge blanket, the water passes through this clarification zone and is collected for use.

From time to time the excess sludge is withdrawn either by gravity or by pumping. For larger tanks, it is advisable to provide mechanical scrapers for removal of the settled solids.

Several designs of the "Solids Contact Units" are available and they are fundamentally similar in design in that they combine solids contact mixing, flocculation, solids liquid separation and continuous removal of sludge in a single basin. The general design features are:

- i) Rapid and complete mechanical mixing of chemicals, raw water and suspension of solids;
- ii) Provision of mechanical means for constant circulation of large volumes of liquid containing the solids being used for contact. This is achieved either inside the tank by an impeller in the inner compartment or in the outer compartment used for settlement. In other types, the solids from the clarification zone are removed and mixed with the raw water in a chamber located outside. Rapid sludge recirculation ensures quick mixing with incoming water; and
- iii) Operation at higher than conventional flow rates.

As the efficiency of this type depends on the formation of a sludge blanket, skilled and delicate operation for control is needed. The turbidity of raw water that can be applied to the Solids Contact Unit is limited to 700 to 1000 NTU. These are not advisable for the high algae laden water. A typical sketch of the plant is shown in Fig. 7.8 (a). The different problems involved in the conventional clarifier are in connection with the dosing and mixing, desludging and the stability of the blanket. An attempt was made in India to overcome these inherent defects, through a modified sludge blanket clarifier, shown in Fig. 7.8 (b).

The velocity gradient of the sludge blanket can be calculated from

$$G = \left[\frac{\rho g}{\mu} (S_s - 1)(1 - \alpha)h / \frac{Vol}{Q} \right]^{\frac{1}{2}} \quad (7.14)$$

In which S_s = specific gravity of flocs; α = porosity of blanket; h = depth of blanket (m); Vol. = capacity of clarifier (m^3); and Q = rate of flow (m^3/s).

(9) Tapered Velocity Gradient Flocculator

In a tapered velocity gradient flocculator, the water is initially subjected to a high velocity gradient and finally to a low velocity gradient, thus generating dense, large size and tough flocs which in turn settle more quickly.

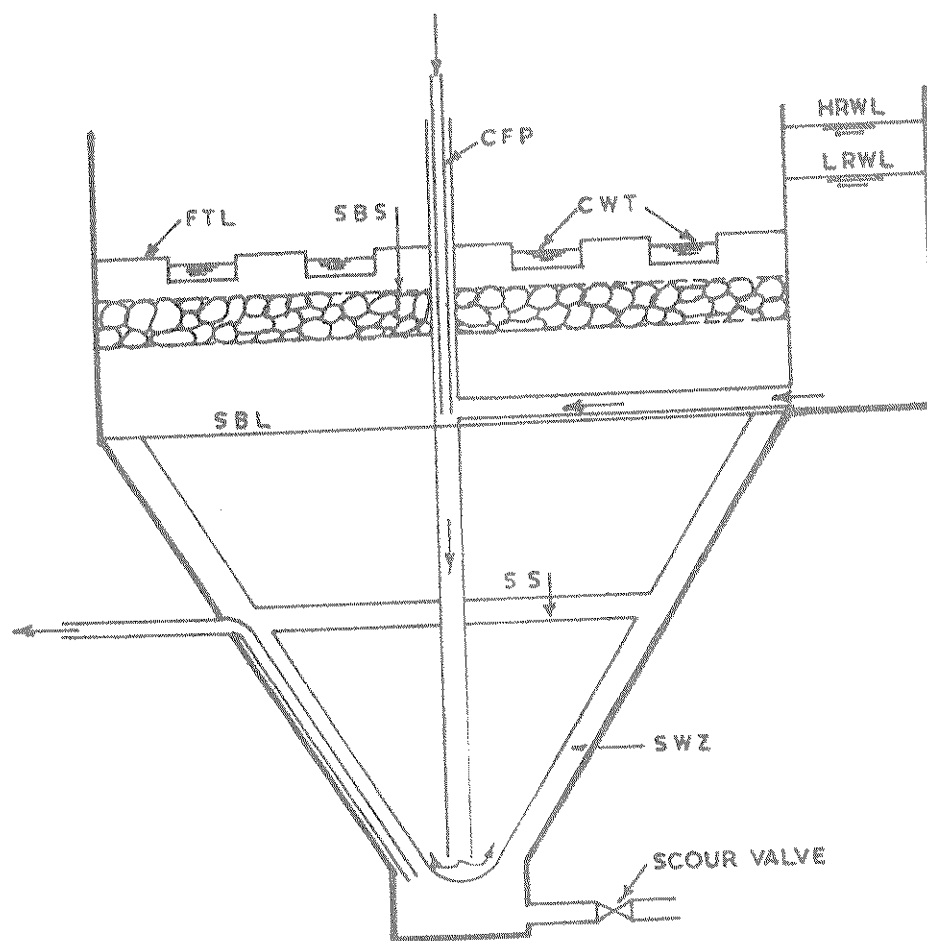


FIGURE 7.8(B) : MODIFIED SLUDGE BLANKET CLARIFIER

Recent studies indicated that the efficiency of a tapered velocity gradient flocculator increases when (a) there is increase in the range of the velocity gradient, the mean value of G remaining the same (b) there is gradual decrease in the velocity gradient and no sudden change of velocity gradient along the direction of flow, and (c) dual tapering, i.e. tapering in velocity gradient as well as time of flocculation is achieved, i.e. highest velocity gradient for the shortest time, followed by little lower value of G , velocity gradient, for a little more time and so on, so that in the end the value of the velocity gradient is the least with the maximum time of flocculation.

7.5 SEDIMENTATION

Sedimentation is the separation from water by gravitational settling of suspended particles that are heavier than water. It is one of the most commonly used unit operation in the flow sheet of conventional water treatment. Sedimentation (settling or clarification) is used to remove readily settling sediments such as sand and silt, coagulated impurities such as colour and turbidity and precipitated impurities such as hardness and iron. When suspended solids

are separated from the water by the action of natural forces alone i.e. by gravitation with or without natural aggregation, the operation is called plain sedimentation. Plain sedimentation is usually employed as a preliminary process to reduce heavy sediment loads from highly turbid raw waters prior to subsequent treatment processes such as coagulation/filtration. Finely divided solids and colloidal particles, which cannot be removed by plain sedimentation within commonly used detention periods of few hours, are converted into settleable flocs by coagulation and flocculation and subsequently settled in sedimentation tanks.

The factors that influence sedimentation are :

- a) Size, shape, density and nature (discrete or flocculent) of the particles ;
- b) Viscosity, density and temperature of water;
- c) Surface over flow rate;
- d) Velocity of flow;
- e) Inlet and outlet arrangements;
- f) Detention period; and
- g) Effective depth of settling zone.

7.5.1 TYPES OF SUSPENDED SOLIDS

In water treatment practice, three main types of suspended particles are to be separated from water. The first type of suspended particles are finely divided silt, silica and clay having specific gravities ranging from 2.65 for sand and 1.03 for flocculated mud particles containing 95 percent water. The grain size may be 0.002 mm or more. Alum and iron flocs constitute the second type of suspended solids. These absorb and entrain water and specific gravities for alum and iron flocs may range from 1.18 and 1.34 respectively to as little as 1.002. Floc particles range in size from submicroscopic to 1 mm or more. The third type is the precipitated crystals of calcium carbonate obtained from limesoda softening operations. Their specific gravity is 2.7 with particle size of 15 to 20 μm . However, due to absorption of water upto 75 %, the specific gravity reduce to 1.2 and formation of cluster of crystals increases the size to a typical value of 0.1 mm.

Suspended particles may settle either as discrete or flocculant particles. Discrete particles do not change their size, shape or weight during settling. The settling velocity of discrete particles can be computed by well-defined mathematical relationships as described in section 7.5.2. On the contrary, flocculent particles tend to agglomerate forming clusters of different size, shape and weight. Though the density of these floc clusters decreases due to entrapment and absorption of water, they settle faster due to increased size.

7.5.2 SETTLING VELOCITY OF DISCRETE PARTICLES

The following equations may be used in arriving at settling velocity of discrete spherical particles;

Law	Equation	Applicable for range of	
		Reynolds Number, N_R	Particle size in mm for specific gravity of 2.65 and temp. of 20°C
Stock's (Laminar)	$V_s = \frac{g}{18} \left(\frac{\rho_s - \rho}{\mu} \right) d^2$	1	Upto 0.1
Hazen's (Transition)	$V_s = \left[\frac{4}{3} \frac{g}{C_D} \left(\frac{\rho_s - \rho}{\rho} \right) \right]^{0.5}$	1-1000	0.1-1.0
Newton's (Turbulent)	$V_s = \left[3.3g \left(\frac{\rho_s - \rho}{\rho} \right) d \right]^{0.5}$	10^3 - 10^4	Greater than 1

Where,

- V_s = Settling velocity of particle, (L/T)
 ρ_s = Mass density of the particle, (M/L³)
 ρ = Mass density of water, (M/L³)
 g = Acceleration due to gravity, (L/T²)
 d = Diameter of the particle, (L)
 C_D = Dimensionless drag coefficient defined by

$$C_D = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34 \quad (7.15)$$

$$N_R = \text{Reynolds number} = \frac{V_s d \rho}{\mu}$$

dimensionless

$$\mu = \text{Absolute or dynamic viscosity of water} \left(\frac{M}{LT} \right)$$

7.5.3 REMOVAL EFFICIENCIES OF DISCRETE AND FLOCCULENT SUSPENSIONS

The removal efficiency of a unisize discrete suspension settling in an ideal settling tank is given by the ratio of settling velocity of the particles, v_s , and the surface overflow rate (SOR) which is numerically equal to flow divided by the plan area of the basin. For an ideal

sedimentation tank, SOR represents the velocity of settling of those particles which covers the depth of the basin in time equal to the theoretical detention period or the settling velocity of the slowest settling particles which are 100 percent removed.

When water contains discrete particles of different sizes and densities, the overall removal, R , of suspended particles is given by

$$R = (1 - P_0) + \frac{1}{V_0} \int_0^{P_0} V_S dp \quad (7.16)$$

Where P_0 is portion of particles with a settling velocity $\leq V_0$, the surface overflow rate.

Flocculent particles coalesce during settling increasing the mass of particles which settle faster. The degree of flocculation depends on the contact opportunities which in turn are affected by the surface overflow rate, the depth of the basin, the concentration of the particles, the range of particle sizes and the velocity gradients in the system. To determine the removal efficiency of a flocculent suspension, no adequate mathematical equation exists and settling column analyses are to be performed.

Settling analyses of flocculent suspensions are performed in column at least 300 mm in diameter and having depth equal to that of proposed basin. The column usually has ports at 0.6 m interval for withdrawal of samples. The flocculent suspension for which the settling characteristics are to be determined is introduced into the column in such a way that a uniform distribution of particle size occurs from top to bottom. The settling is allowed to occur under quiescent conditions and at constant temperature to eliminate convection currents. Samples are withdrawn at various selected time intervals from different depths and analysed to determine the suspended solids concentrations. The percentage removals of suspended solids are computed at different times and depths and the percentage removal is plotted as a number against time and depth. The iso-percent removal curves are drawn in a similar manner as contours are drawn from spot levels.

A generalized plot is given in Fig. 7.9. The percentage removal for a given time, t , can be computed from the relationship:

$$\text{Percentage removal} = \frac{(R_1 + R_2)}{2} \cdot \frac{\Delta h_4}{h} + \frac{(R_2 + R_3)}{2} \cdot \frac{\Delta h_3}{h} + \frac{(R_3 + R_4)}{2} \cdot \frac{\Delta h_2}{h} + \frac{(R_4 + R_5)}{2} \cdot \frac{\Delta h_1}{h} \quad (7.17)$$

where, R_1, R_2, R_3, R_4 and R_5 are percent removals and R_1 is the percent removal at time t and at 100% depth.

The curves can also be used to determine the detention period, depth and surface overflow rate required to obtain a given percentage removal of flocculent particles.

7.5.4 TYPES OF TANKS

The tanks may be categorized into horizontal flow tanks or vertical flow tanks on the basis of direction of flow of water in the tank. The tanks may be rectangular, square or circular in plan.

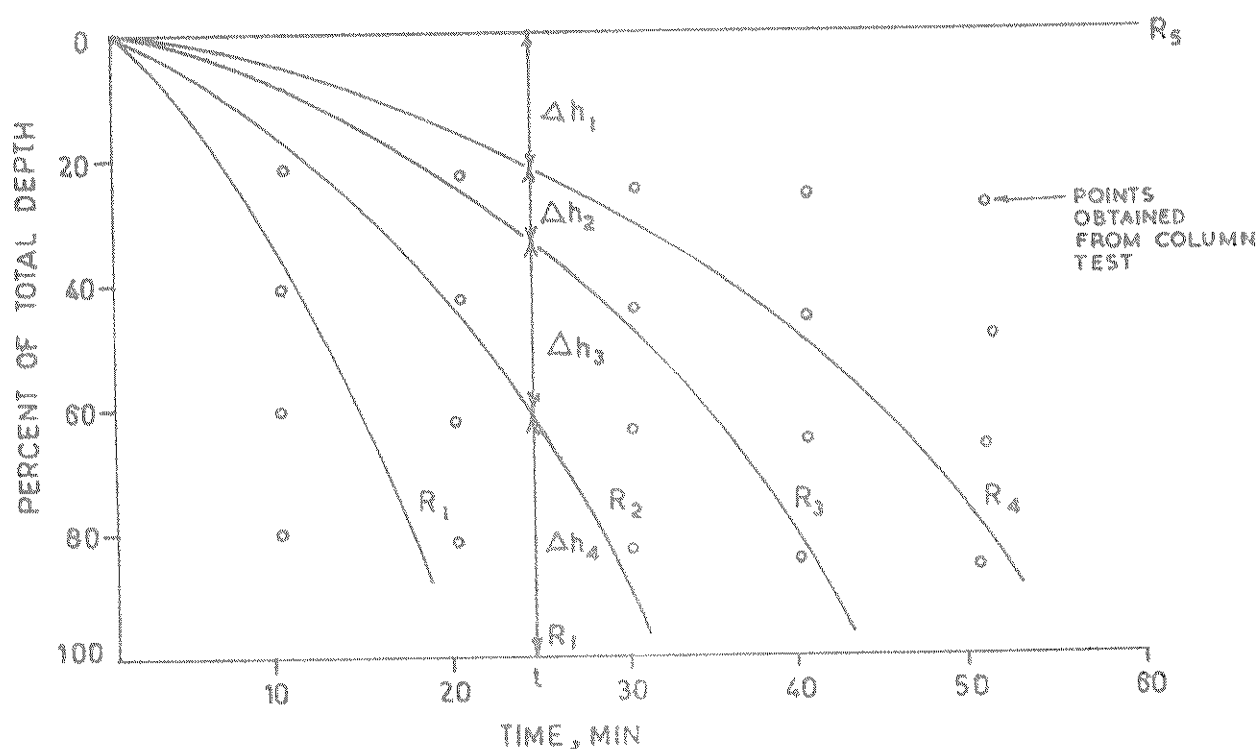
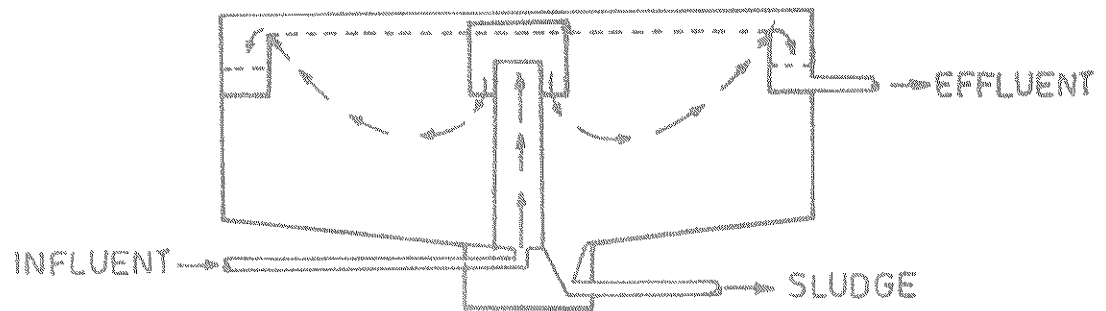


FIGURE 7.9 : SETTLING OF FLOCCULENT SUSPENSION

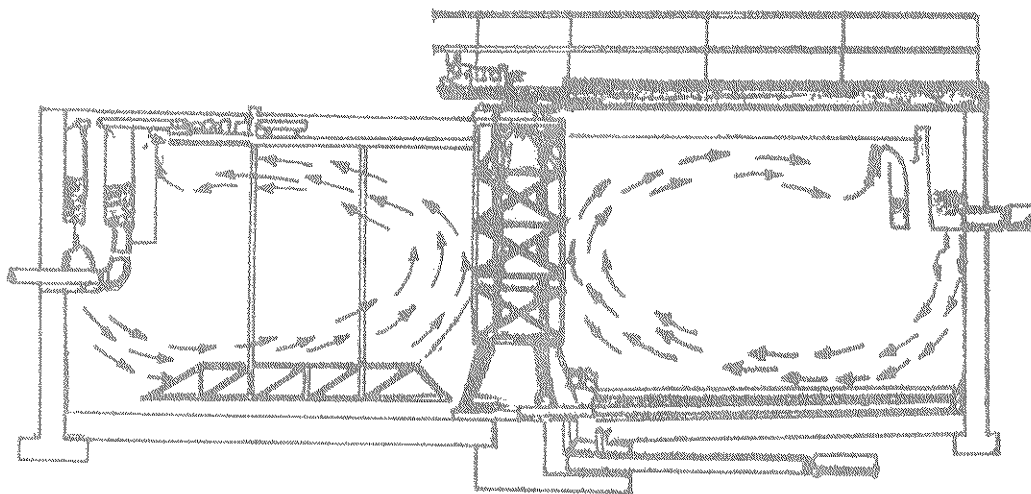
7.5.4.1 Horizontal Flow Tanks

In the design of a horizontal flow tank, the aim is to achieve as nearly as possible the ideal conditions of equal velocity at all points lying on each vertical line in the settling zone. The direction of flow in the tanks is substantially horizontal. Among the representative designs of the horizontal flow settling tanks, the following may be mentioned:

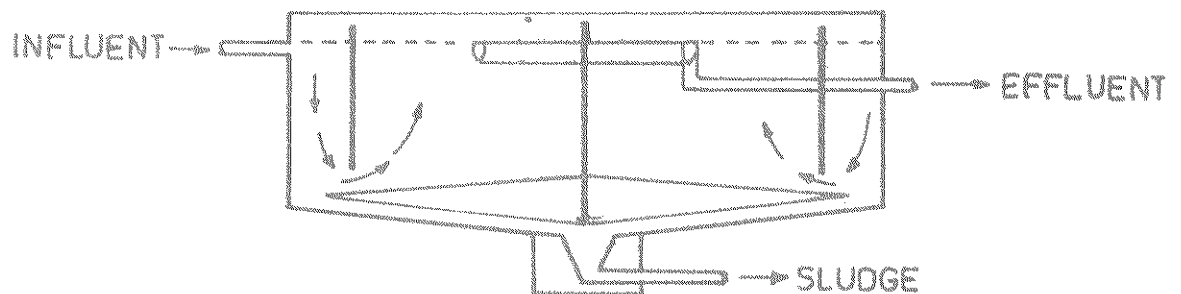
- Radial flow circular tank with central feed. The water enters at the center of the tank and emanates from multiple ports of circular well in the centre of tank to flow radially outwards in all directions equally. The aim is to achieve uniform radial flow with decreasing horizontal velocity as the water flows towards the periphery and is withdrawn from the tank through effluent structure. The sludge is plowed to central sump mechanically and continuously and is withdrawn during operation. The sludge removal mechanism consists of scraper blades mounted on two or four arms revolving slowly.
- Radial flow circular tanks with peripheral feed. These tanks differ from the central feed circular tanks in that the water enters the tank from the periphery or the rim. It has been demonstrated that the average detention time is greater in peripheral feed basins leading to better performance.



(d) CIRCULAR CLARIFIER WITH CENTRE FEED



(b) PERIPHERAL FEED CIRCULAR CLARIFIER WITH EFFLUENT AND INFLUENT CHANNELS SEPARATED BY A SKIRT



(c) PERIPHERAL FEED CIRCULAR CLARIFIER WITH EFFLUENT WEIRS NEAR THE CENTRE OF BASIN

FIGURE 7.10 : VARIOUS TYPES OF CIRCULAR CLARIFIERS

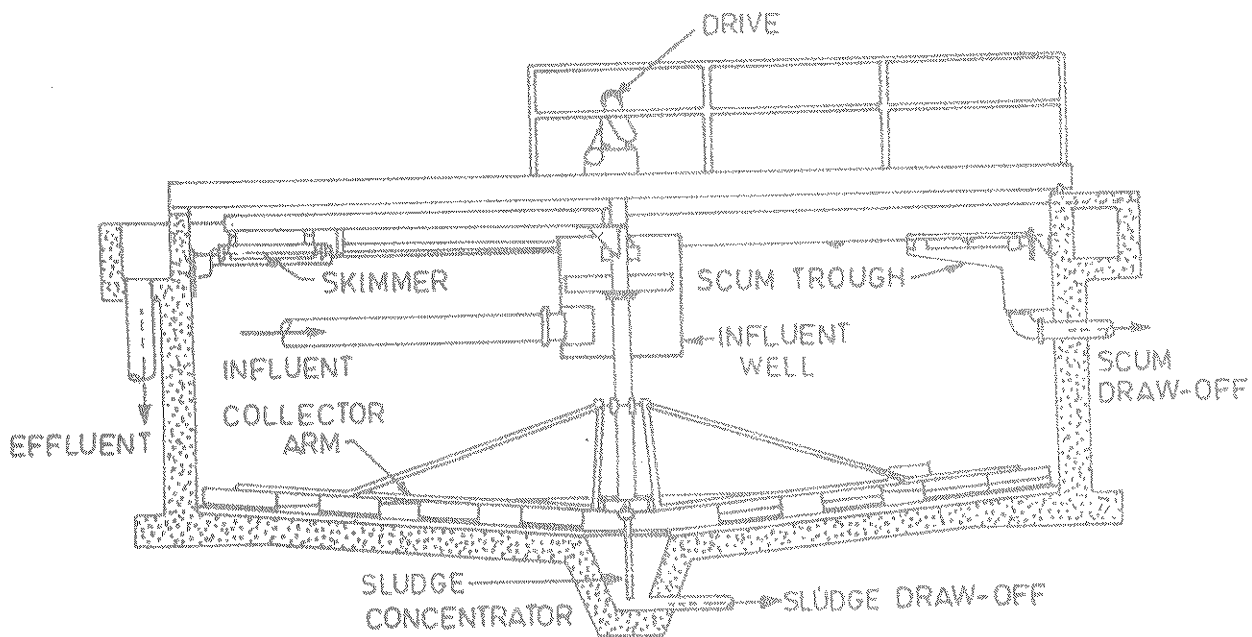


FIG. 7.11 CIRCULAR CLARIFIER DESIGN

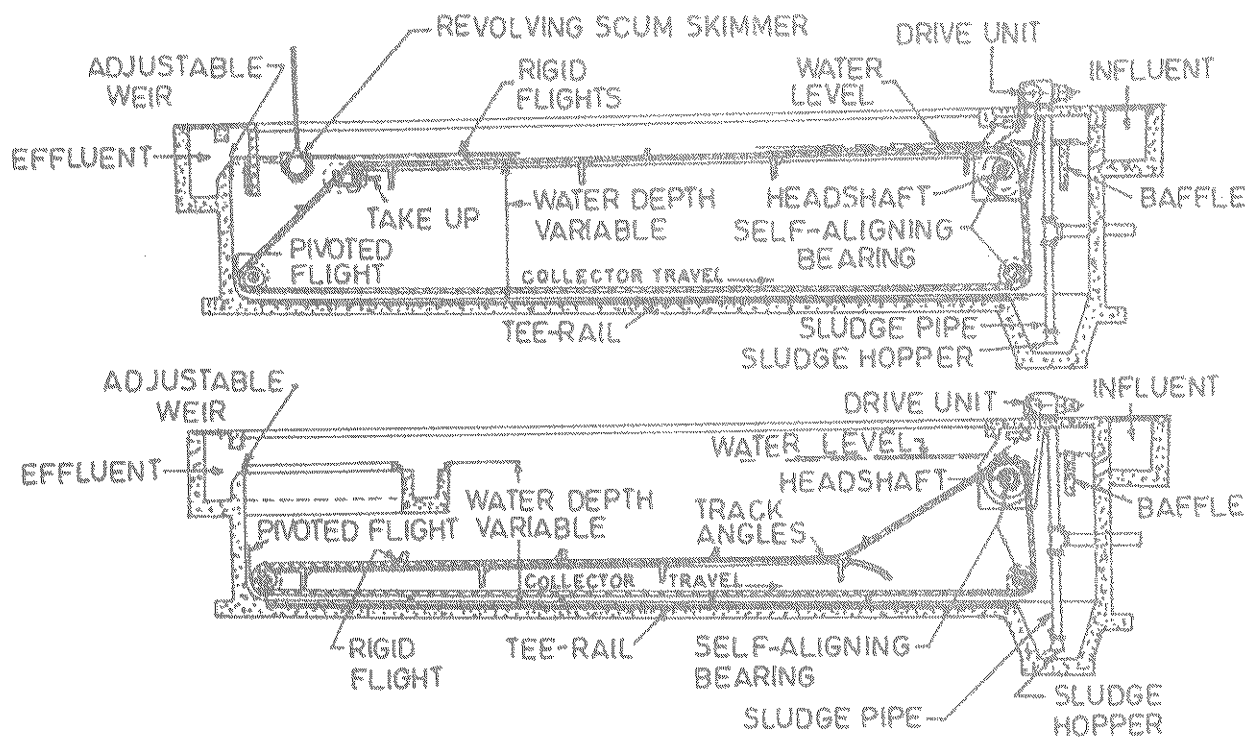


FIGURE 7.12 : RECTANGULAR CLARIFIERS

- c) Rectangular tanks with longitudinal flow where the tanks are cut out of operation for cleaning. The solids are flushed to sump for removal from the dewatered tank.
- d) Rectangular tanks with longitudinal flow where sludge is mechanically scraped to the sludge pit located usually towards the influent end and removed continuously or periodically without disrupting the operation of the tanks.

7.5.4.2 Vertical Flow Tanks

Vertical flow tanks normally combine sedimentation with flocculation. These tanks are square or circular in plan and may have hopper bottoms. The influent enters at the bottom of the unit where flocculation takes place as particles cojoin into aggregates. The upflow velocity decreases with increased cross sectional area of the tank. There is a formation of blanket of floc through which the rising floc must pass. Because of this phenomenon, these tanks are also called as upflow sludge blanket clarifier. The clarified water is withdrawn through circumferential or central weir.

These tanks have no moving parts and except for a few valves, require no mechanical equipment. They are compact units requiring less land area.

7.5.4.3 Clariflocculators

Clariflocculators are widely used in the country in water and wastewater treatment. The coagulation and sedimentation processes are effectively incorporated in a single unit in the clariflocculator.

All these units consist of 2 or 4 flocculating paddles placed equidistantly. These paddles rotate on their vertical axis. The flocculating paddles may be of rotor-stator type rotating in opposite direction around this vertical axis. The clarification unit outside the flocculation compartment is served by inwardly raking rotating blades. The water mixed with chemicals is fed in the flocculation compartment fitted with paddles rotating at slow speeds.

The flocculated water passes out from the bottom of the flocculation tank to the clarifying zone through a wide opening, the area of the opening being large enough to maintain a very low velocity. Under quiescent conditions in the annular settling zone the floc embedding the suspended particles settle to the bottom and the clear effluent overflows into the peripheral launder.

7.5.5 TANK DIMENSIONS

The settling basins may be long and narrow rectangular tanks, square or almost square tanks and circular tanks. The rectangular tanks have lengths commonly upto 30 m but larger lengths upto 100 m have also been adopted. The length to width ratio of rectangular tanks should preferably be from about 3: 1 to 5: 1. The narrower the tank, the less chance there is for setting up of cross currents and eddies due to wind action, temperature changes and other factors involved. In very large size tanks where the depth is necessarily great, it may be advisable to provide longitudinal baffles to confine the flow to definite straight channels. These walls could be of thin sections since the pressure on both sides will be the same.