INTRODUCTION

Sedimentation, or clarification, is the process of letting suspended material settle by gravity.

Suspended material may be particles, such as clay or silts, originally present in the source water.

More commonly, suspended material or floc is created from material in the water and the chemical used in coagulation or in other treatment processes, such as lime softening.

INTRODUCTION

Sedimentation is accomplished by decreasing the velocity of the water being treated to a point below which the particles will no longer remain in suspension.

When the velocity no longer supports the transport of the particles, gravity will remove them from the flow.

Sedimentation – 2 immiscible liquids or a liquid and a solid, differing density are separated by the action of gravity, so heavier material settles at the bottom. ….is a slow process.

However, centrifugal forces are applied to increase the sedimentation

Filtration – is the separation of solids from liquids, by passing the mixture through fine pores, which are small enough to stop solid particles and large enough to allow liquids.

Sieving – have a barrier through which the large elements cannot pass – used for classification of solid particles.

Separations depends

- Character of the particle and
- Forces acting on the particle

Important characteristics of particle

- Size, shape, and density

Important characteristics of FLUID

- Viscosity, and density

Forces

- Gravitational forces
- Centrifugal forces
- Pressure forces
- Velocity of particles are also important in separation

Fundamental of movement of particle in fluids

- Under const. force, particles in a liquid accelerate for some time then move at a uniform velocity. This maximum velocity at which they reach is called their terminal velocity.
- When a particle moves steadily through a fluid, there are two principal forces acting upon it.

1. External force causing the motion
2. Drag force resisting the motion

- External Force $\mathbf{F_s = V\ a\ (\rho_p - \rho_f)}$

  V = Volume of the particle

  a = Acceleration due to external force

  ρ_p , ρ_f = Density of particle and fluid

- Drag Force $F_c = C\ \rho_f\ v^2\ A/2$

  C = drag co-eff

  ρ_f = density of fluid

  v = velocity of particle

  A = projected area of the particle

  If the particle is spherical, equating Fs & Fc, in that case velocity becomes terminal velocity V_m.

It has been found theoretically that for the streamline motion of spherical particle, the co-eff of drag is $C = 24/R_e$

$V_m = D^2 a (\rho_p - \rho_f) / 18\mu$ this is the fundamental equation for movement of particles in fluids.

Sedimentation

Uses gravitational forces to separate particulate material from fluid.

The particle are usually solids – liquid droplets:

If, particles falling from the rest under the force of gravity, then in the fundamental equation a becomes g.

$V_m = D^2\ g\ (\rho_p - \rho_f) / 18\mu$ is called Stoke's law

It predicts velocities ∞ to sq. of particle dia

Applies to

- Only in streamline flow
- Only to spherical particles
- Only to low concentrations.

Sedimentation of particles in liquid/suspension

Solids will settle in a liquid (whose density is less)

In practical situation the concentration are too high

Uniform suspension – zones; clear liquid, const. composition and sediment

FACTORS AFFECTING SEDIMENTATION

PARTICLE SIZE

The size and type of particles to be removed have a significant effect on the operation of the sedimentation tank.

The shape of the particle also affects its settling characteristics.

All particles tend to have a slight electrical charge.

FACTORS AFFECTING SEDIMENTATION

WATER TEMPERATURE

- When the temperature decreases, the rate of settling becomes slower. The result is that as the water cools, the detention time in the sedimentation tanks must increase.
- In most cases temperature does not have a significant effect on treatment.
- A water treatment plant has the highest flow demand in the summer when the temperatures are the highest and the settling rates the best.
- When the water is colder, the flow in the plant is at its lowest and, in most cases, the detention time in the plant is increased so the floc has time to settle out in the sedimentation basins.

FACTORS AFFECTING SEDIMENTATION

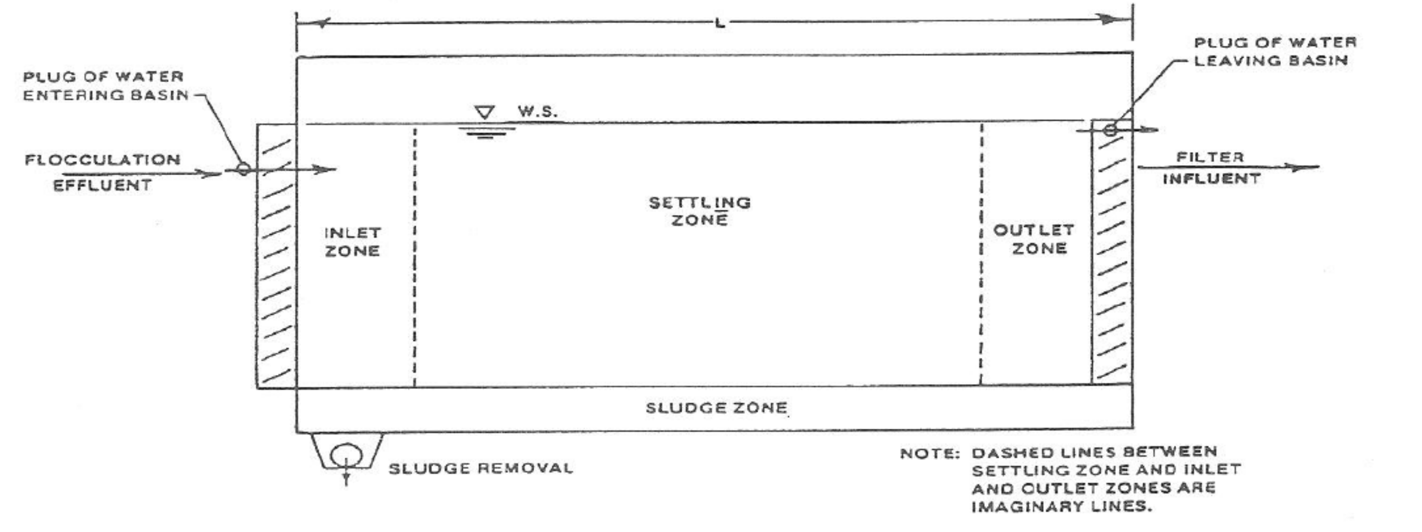
Water Currents

- Several types of water currents may occur in the sedimentation basin:
  - Density currents caused by the weight of the solids in the tank, the concentration of solids and temperature of the water in the tank.
  - Eddy currents produced by the flow of the water coming into the tank and leaving the tank.
- The currents can be beneficial in that they promote flocculation of the particles. However, watercurrents also tend to distribute the floc unevenly throughout the tank; as a result, it does not settle out at an even rate.
- Some of the water current problems can be reduced by the proper design of the tank. Installation of baffles helps prevent currents from short circuiting the tank.

SEDIMENTATION BASIN ZONES

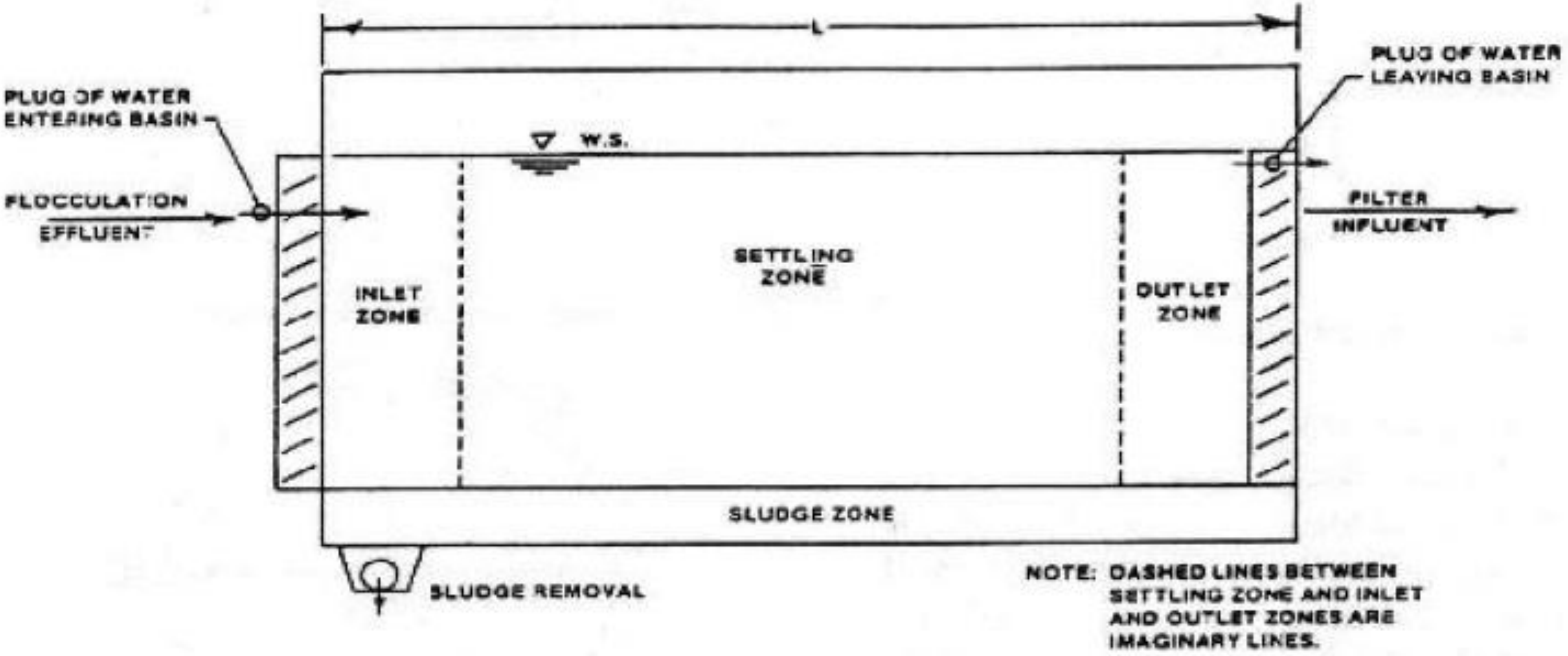
Inlet zone

- The inlet or influent zone should provide a smooth transition from the flocculation zone and should distribute the flow uniformly across the inlet to the tank.
- The baffle could include a wall across the inlet, perforated with holes across the width of the tank.



Sedimentation basin zones

SEDIMENTATION BASIN ZONES



Sedimentation basin zones

SEDIMENTATION BASIN ZONES

Settling Zone

- The settling zone is the largest portion of the sedimentation basin.
- This zone provides the area necessary for the suspended particles to settle.

Sludge Zone

- The sludge zone, located at the bottom of the tank, provides a storage area for the sludge before it is removed for additional treatment or disposal.

SEDIMENTATION BASIN ZONES

- Basin inlets should be designed to minimize high flow velocities near the bottom of the tank.
- If high flow velocities are allowed to enter the sludge zone, the sludge could be swept up and out of the tank.
- Sludge is removed for further treatment from the sludge zone by scraper or vacuum devices which move along the bottom.

SEDIMENTATION BASIN ZONES

Outlet Zone

- The basin outlet zone or launder should provide a smooth transition from the sedimentation zone to the outlet from the tank.
- This area of the tank also controls the depth of water in the basin.
- Weirs set at the end of the tank control the overflow rate and prevent the solids from rising to the weirs and leaving the tank before they settle out.

PARTICLE REMOVAL

- In sedimentation, particles are falling from rest under the force of gravity. Therefore, in sedimentation, fundamental eqn. takes the familiar form of **Stokes' Law**:

$$v_m = D^2 g(\rho_p - \rho_f)/18\mu$$

PARTICLE REMOVAL

- Stoke's Law applies only in streamline flow and strictly only to spherical particles.
- In the case of spheres, the criterion for streamline flow is that (Re) = 2, and many practical cases occur in the region of streamline flow, or at least where streamline flow is a reasonable approximation

PARTICLE REMOVAL

- Stokes' Law applies only to cases in which settling is free, that is where the motion of one particle is unaffected by the motion of other particles.
- Where particles are in concentrated suspensions, an appreciable upward motion of the fluid accompanies the motion of particles downward.

PARTICLE REMOVAL

- So, the particles interfere with the flow patterns round one another as they fall.
- Stokes' Law predicts velocities proportional to the square of the particle diameters.
- In concentrated suspensions, it is found that all particles appear to settle at a uniform velocity once a sufficiently high level of concentration has been reached.
- Where the size range of the particles is not much greater than 10:1, all the particles tend to settle at the same rate.

PARTICLE REMOVAL

- This rate lies between the rates that would be expected from Stokes' Law for the largest and for the smallest particles.
- In practical cases, in which Stoke's Law or simple extensions of it cannot be applied, probably the only satisfactory method of obtaining settling rates is by experiment.

Gravitational Sedimentation of Particles in a Liquid

- Solids will settle in a liquid whose density is less than their own.
- At low concentration, Stokes' Law will apply but in many practical instances the concentrations are too high.

Gravitational Sedimentation of Particles in a Liquid

- In a cylinder in which a uniform suspension is allowed to settle, various quite well-defined **zones** appear as the settling proceeds.
- At the top, is a zone of clear liquid.
- Below this is a zone of more or less constant composition, constant because of the uniform settling velocity of all sizes of particles.
- At the bottom of the cylinder is a zone of sediment, with the larger particles lower down.
- If the size range of the particles is wide, the zone of constant composition near the top will not occur and an extended zone of variable composition will replace it.

Gravitational Sedimentation of Particles in a Liquid

- In a continuous thickener, with settling proceeding as the material flows through, and in which clarified liquid is being taken from the top and sludge from the bottom, these same zones occur.
- The minimum area necessary for a continuous thickener can be calculated by equating the rate of sedimentation in a particular zone to the counter-flow **velocity of the rising fluid**. In this case we have:

Gravitational Sedimentation of Particles in a Liquid

$$v_u = (F - L)(dw/dt)/A\rho$$

where

v_u is the upward velocity of the flow of the liquid,

F is the mass ratio of liquid to solid in the feed,

L is the mass ratio of liquid to solid in the underflow liquid,

dw/dt is the mass rate of feed of the solids,

ρ is the density of the liquid and

A is the settling area in the tank.

Gravitational Sedimentation of Particles in a Liquid

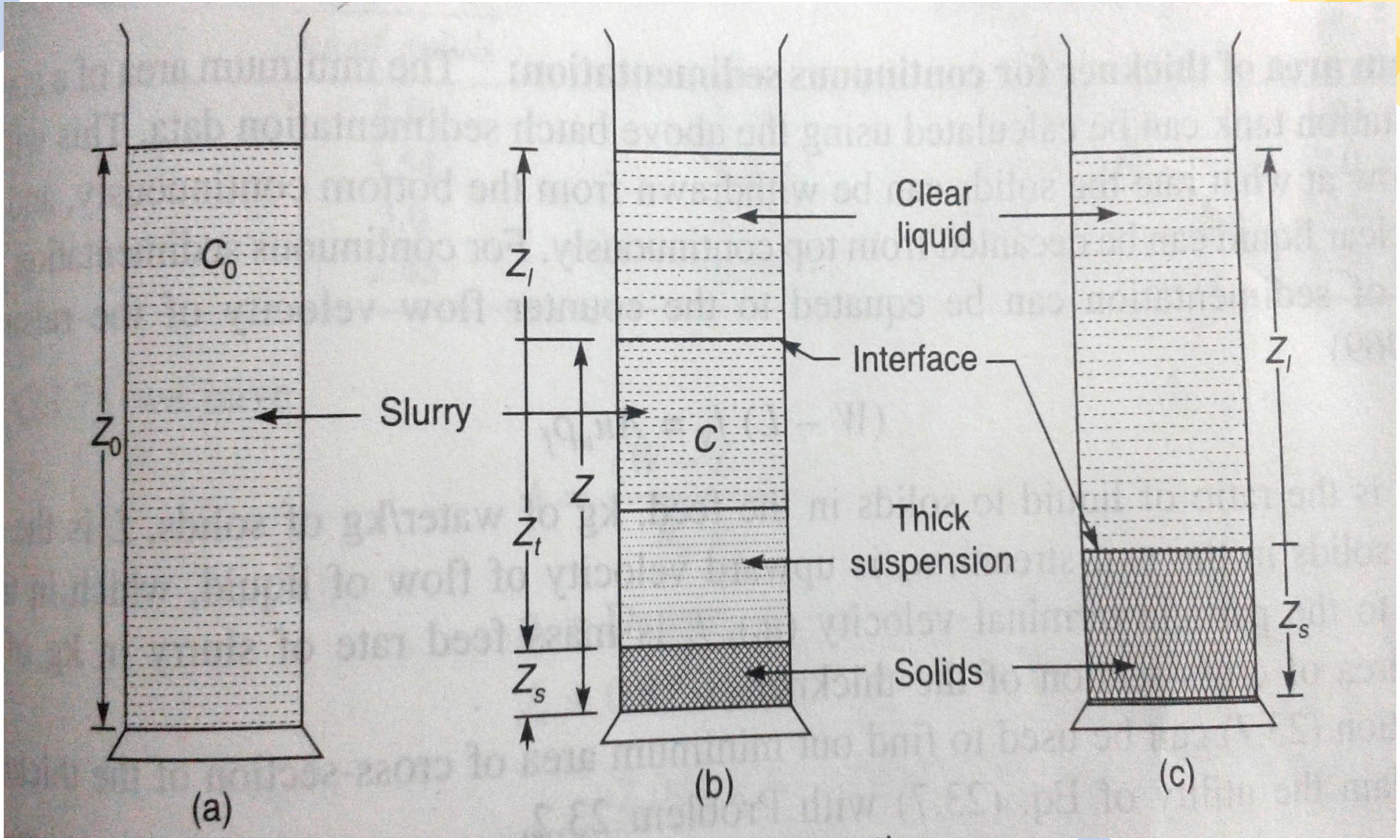
- If the settling velocity of the particles is v, then $v_u = v$ and, therefore:

$$A = (F - L)(\mathrm{d}w/\mathrm{d}t)/v\rho$$

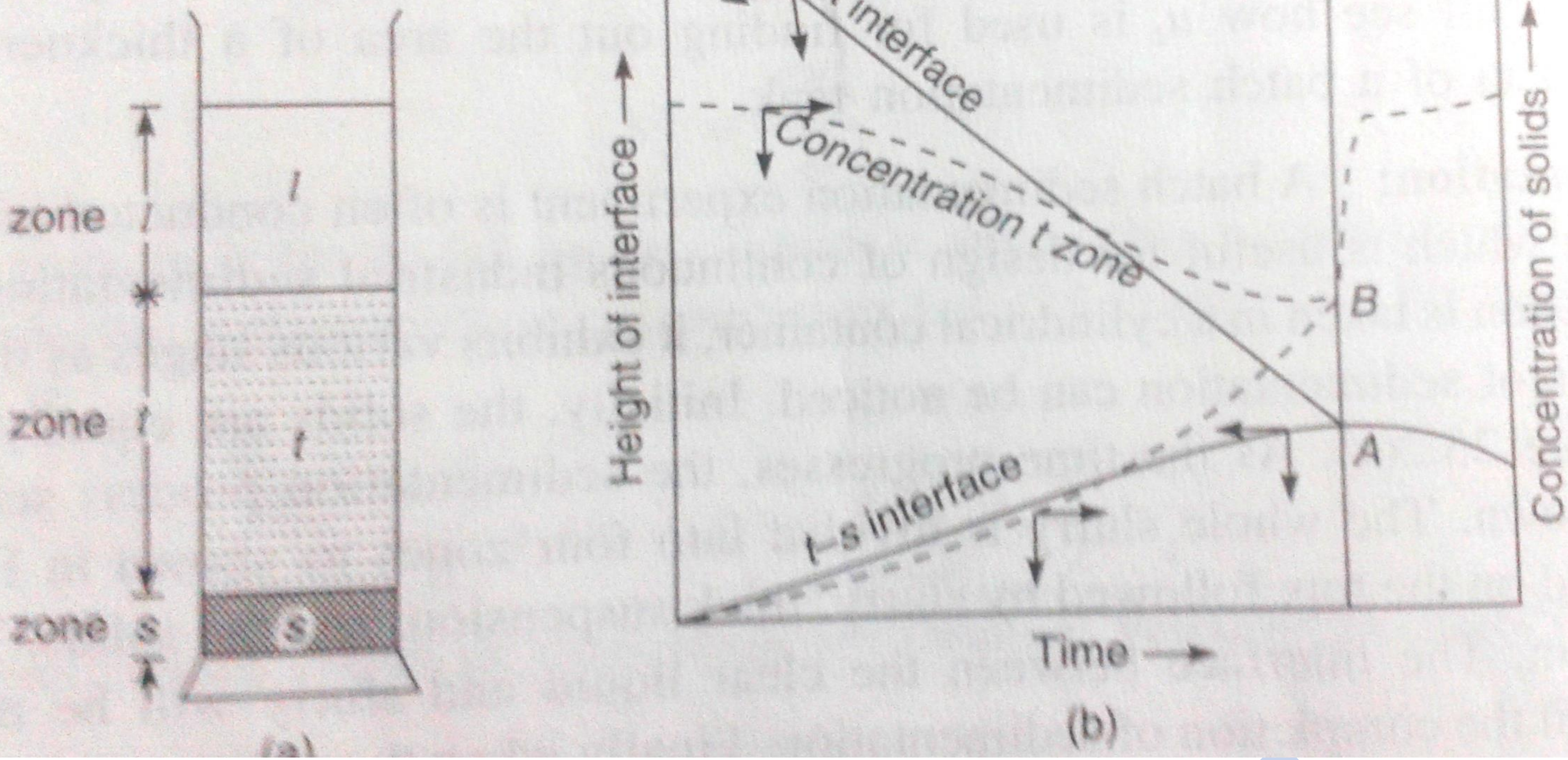
- The same analysis applies to particles (droplets) of an immiscible liquid as to solid particles.
- Motion between particles and fluid is relative, and some particles may in fact rise.

BATCH SEDIMENTATION

- Initially solids in suspension equally distributed in container.
- Time progresses sedimentation process sets in.
- Whole slurry can be divided in to 4 zones:
- Clear liquid- at top
- Interface
- Slurry-thick suspension
- Solids-at the bottom



C_0
Z_0
Slurry
Clear
liquid
Z_l
Z
C
Z_t
Z_s
Interface
Thick
suspension
Solids
(a)
(b)
(c)


zone l
l
zone t
t
zone s
s
(a)
l–t interface
Concentration t zone
B
A
t–s interface
Height of interface →
Time →
Concentration of solids →
(b)

- Increasing in time, the boundary between the clear liquid and thick suspension(l-t zone) will be falling down.
- The boundary between the thick suspension and solids will be increasing.
- The two will merge after sometime at a point A.
- The concentration of solids in l-t zone will be falling.
- t- s zone will be building up.
- They meet at point B.
- Beyond this point zone t disappears.

Batch equipment

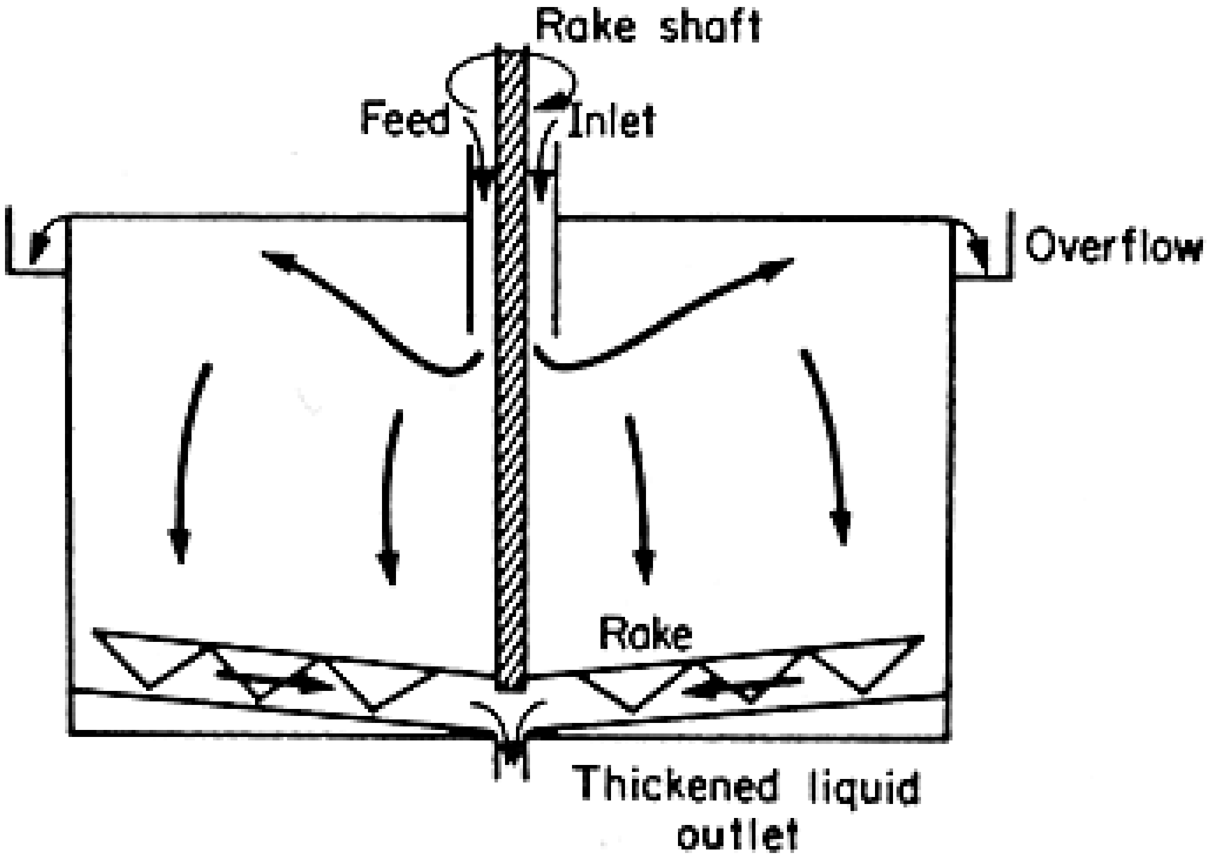
- A tank with slight conical bottom
- Suspension is filled and left for some time for settling.
- After settling clear liquid at top decanted.
- The thickened liquid at bottom is removed.
- Sedimentation can be enhanced by adding flocculating agents.
- Which flocculates smaller suspended particle to lumps.

Continuous sedimentation equipment

- It is also called continuous thickner
- Best known Dorr thickners supplied by Dorr-Oliver.
- It consist of flat bottomed tank with feeding provision from centre.
- A slowly rotating stirrer called Raker .
- Feed is admitted about 0.3 to 1m.
- After settlement solids at the   bottom are scraped by the raker continuously.

Cont. thickener

- For separation of solid particle
- Provides sufficient time, space
- Permits overflow, under flow
- Slow sedimentation
- Large chamber



- In cont. thickner, materials flows in, clarified liquid and sludge being taken out.
- Min. area reqd for cont. thickner can be calculated by equating the rate of sedimentation to counter flow velocity of rising fluid.

$$v_u = (F - L)(\mathrm{d}w/\mathrm{d}t)/A\rho$$

F = mass ratio of liquid to solid in the feed

L = mass ratio of liquid to solid in the underflow

d*w*/d*t* = mass rate of feed of the solids

A = settling area; ρ = den. of liquid

- If rising fluid velocity v_u = settling velocity V

$$A = (F - L)(\mathrm{d}w/\mathrm{d}t) / v\ \rho$$

Settling under combined forces

Convenient to combine more than one force

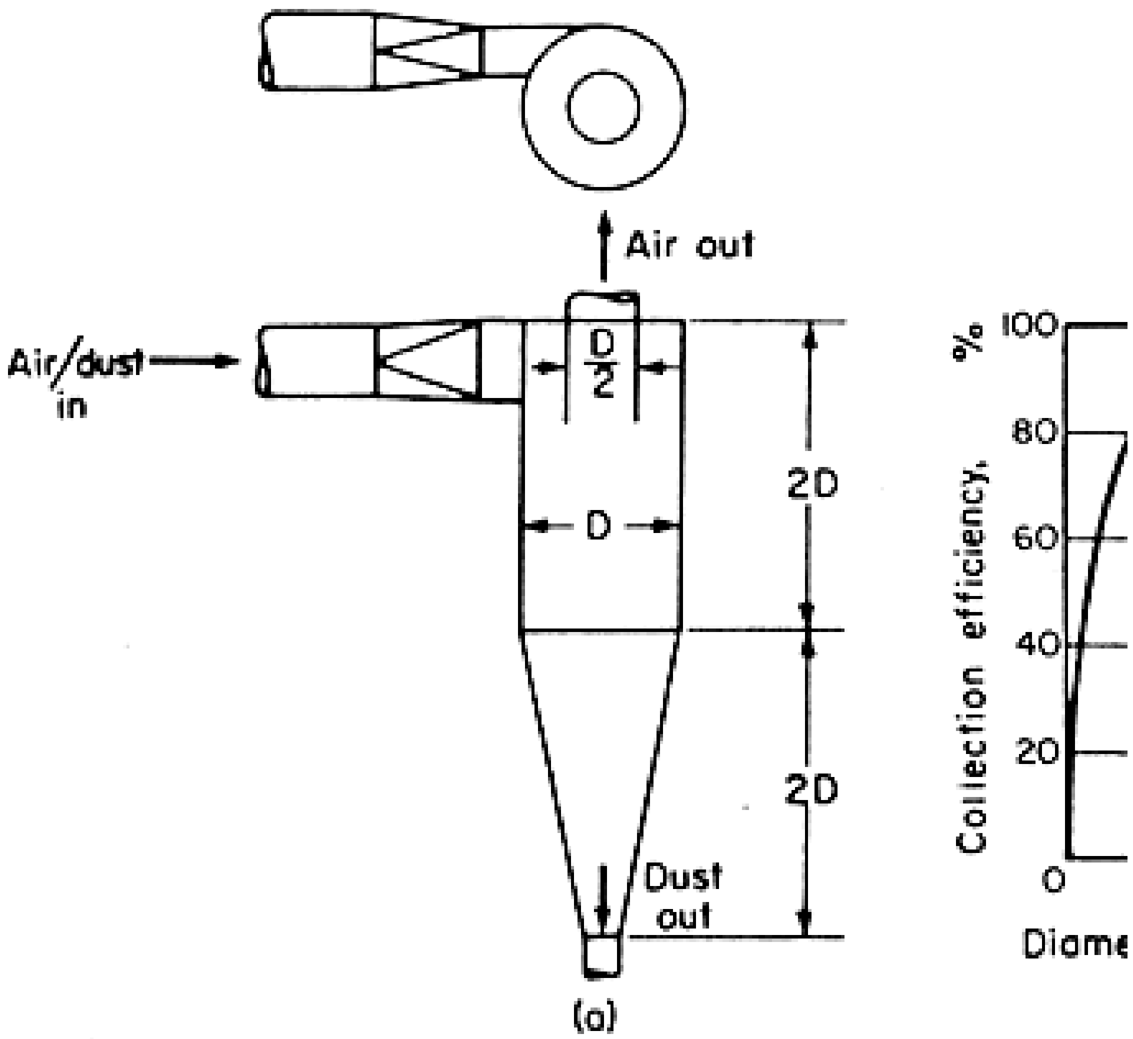
Gravitational + centrifugal

Common applications are

- Cyclones
- Impingement separator
- Classifiers

Cyclones

- Used for removal of particles from air stream or from liquids, droplets from gases.
- Settling chamber in the form of vertical cylinder, particles spirals round the cylinder to create Centrifugal forces.
- Throw the particles towards wall



- Added with gravitational forces gives rapid settlement rates

$$F_c = (mv^2)/r$$

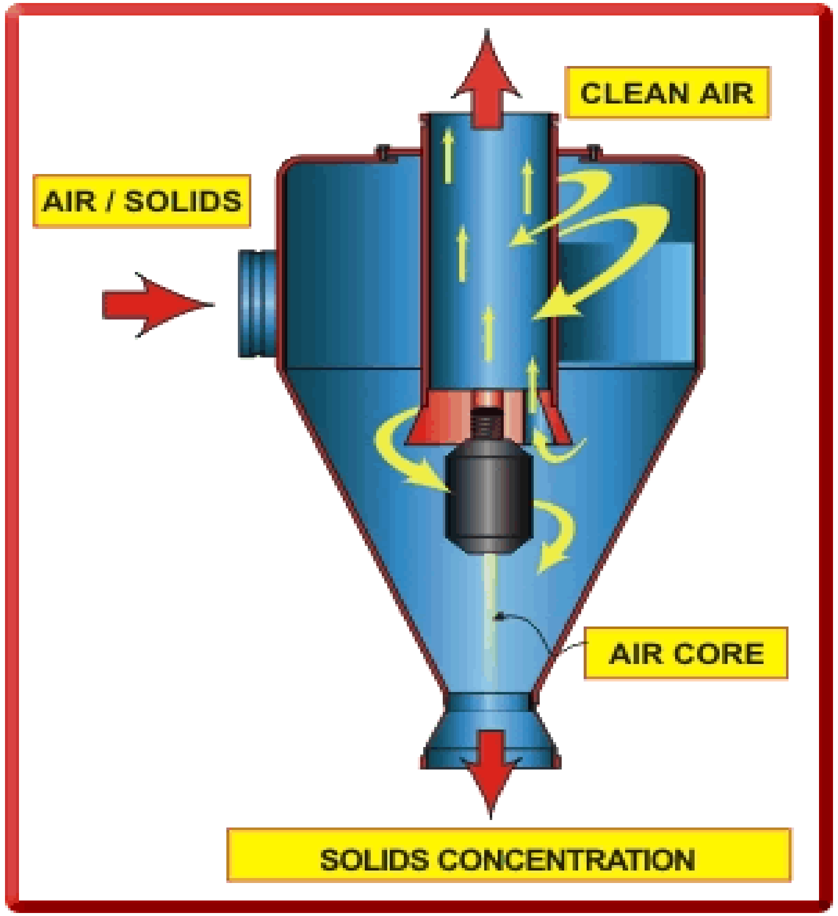
Centrifugal force = F_c

Mass of the particle = m

Velocity of the particle = v

Radius of the cyclone = r

This equation shows that the force on the particle increases as radius decreases….



CYCLONE SEPARATOR

Principal type of gas-solids separator.

Gas cyclones are widely used in industry for the separation of particles from gas and air streams

Water cyclones, also known as hydrocyclones, are used for the separation of fluids of differing densities

Available in a wide range of materials of construction: cast iron, ductile iron, carbon steel, stainless steel.

Suitable for separating particles about 5 µm in diameter; smaller particles down to about 0.5 µm can be separated where agglomeration occurs.

Basic Principles

The flow stream enters the body of the separator tangentially through the inlet at the top and it begins to swirl due to the circular design of the chamber until it reaches the bottom.

Materials that are denser than the carrier medium are separated from the stream during this downward flow and can be removed through the outlet at the bottom of the cone.

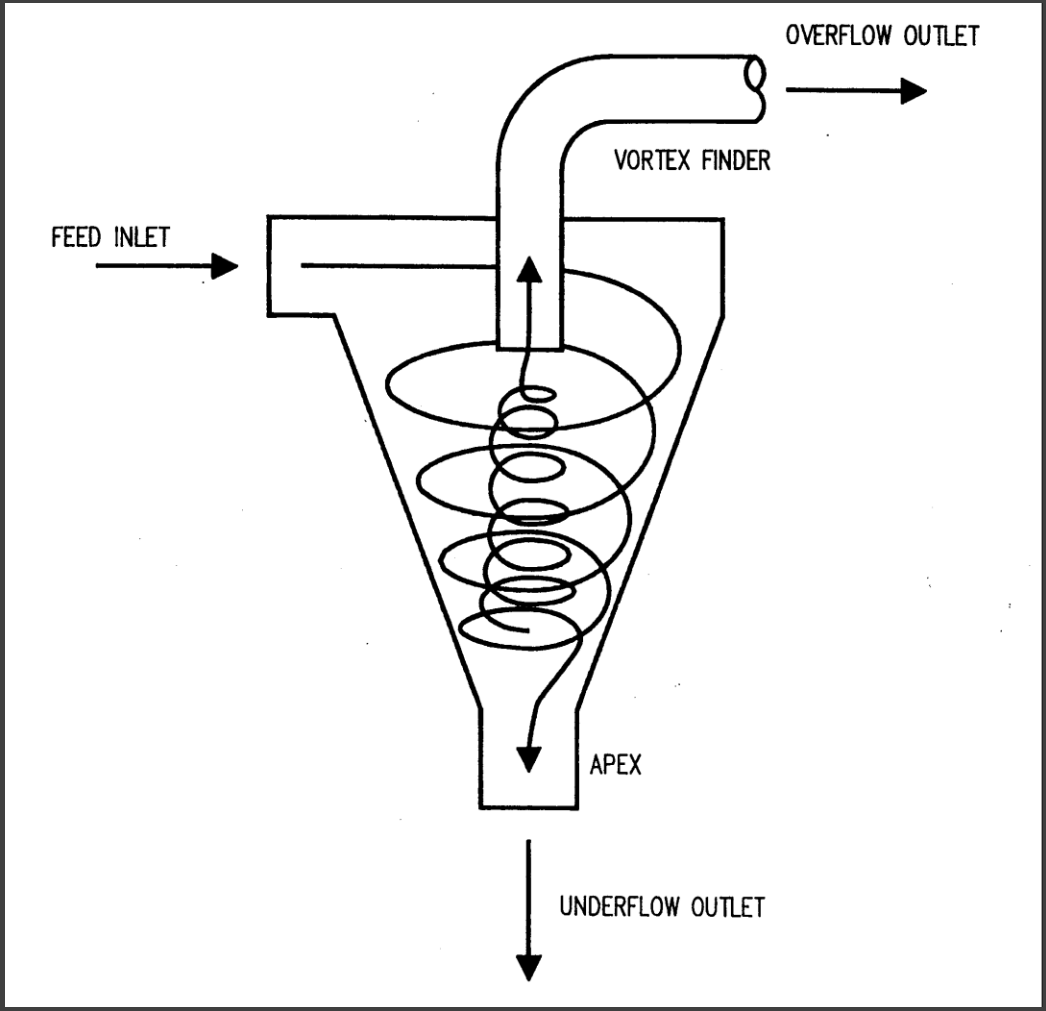
As the mixture is circulating down the funnel it creates a "*whirlpool effect*" in the middle of the cone. This causes a vortex in the center of the cone through which the lighter flow stream rises.

As the fluid or vapor reaches the top of the vortex, it is passing by the difference in pressure through a tube that sticks down into the center of the funnel. This tube is called a vortex finder.

OPERATION

- The gas enters the top chamber tangentially- spirals down to the apex of the conical section- moves upward in a second, smaller diameter spiral, and exits at the top through a central vertical pipe.

- The solids move radially to the walls, slide down the walls, and are collected at the bottom.



Advantages

- Simple and inexpensive to manufacture, require little maintenance
- Contains no moving parts
- Has the ability to operate at high temperatures and pressures
- Unlike the slow setting within a settling tank, the pump and cyclone separator system yields fast separation and utilizes less space.

Two main types of cyclone separators:

- *Axial*-the material enters from the top of the cyclone and is forced to move tangentially by a grate at the top
- *Tangential*-the material enters from an inlet on the side which is positioned tangentially to the body.

Cyclone separator is used :

- for removal of dust particles from emissions from cotton gins, grain elevators, tractors, grain mixers, and other agricultural machinery.
- in the food industry for the separation of agglomerated particles and for the separation of starch and protein.
- For cleaning flue gases from Power Plants.

Impingement separators

- Particles in gas uses the principle of impingement, means…change direction rapidly whereupon their inertia causes them to collide with a surface, thus separating them form the gas stream.
- Deflector plates or rods, abruptly changes the direction of flow