Units operation

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Syllabus:

5) Fluid flow through packed column .
6) Flow of particles though fluids .
7) Fluidization .
8) Filtration .
9) Sedimentation .
10) Centrifuge .

Packed Column

A packed bed is a hollow tube, pipe, or other vessel that is filled with a packing material. Packed columns are used for distillation, gas absorption, and liquid-liquid extraction. The gas liquid contact in packed bed column is continuous, as in a plate column. The liquid flows down the column over the packing surface and the gas or vapor, counter-currently ,up the column ,some gas-absorption column are co-current .

DESIGN OF PACKED TOWERS

A common apparatus used in gas absorption and certain other operations is the packed tower, an example of which is shown in Fig. 22.1. The device consists of a cylindrical column, or tower, equipped with a gas inlet and distributing space at the bottom; a liquid inlet and distributor at the top; gas and liquid outlets at the top and bottom, respectively; and a supported mass of inert solid shapes, called *tower packing*. The packing support is typically a screen, corrugated to give it strength, with a large open area so that flooding does not occur at the support. The inlet liquid, which may be pure solvent or a dilute solution of solute in the solvent

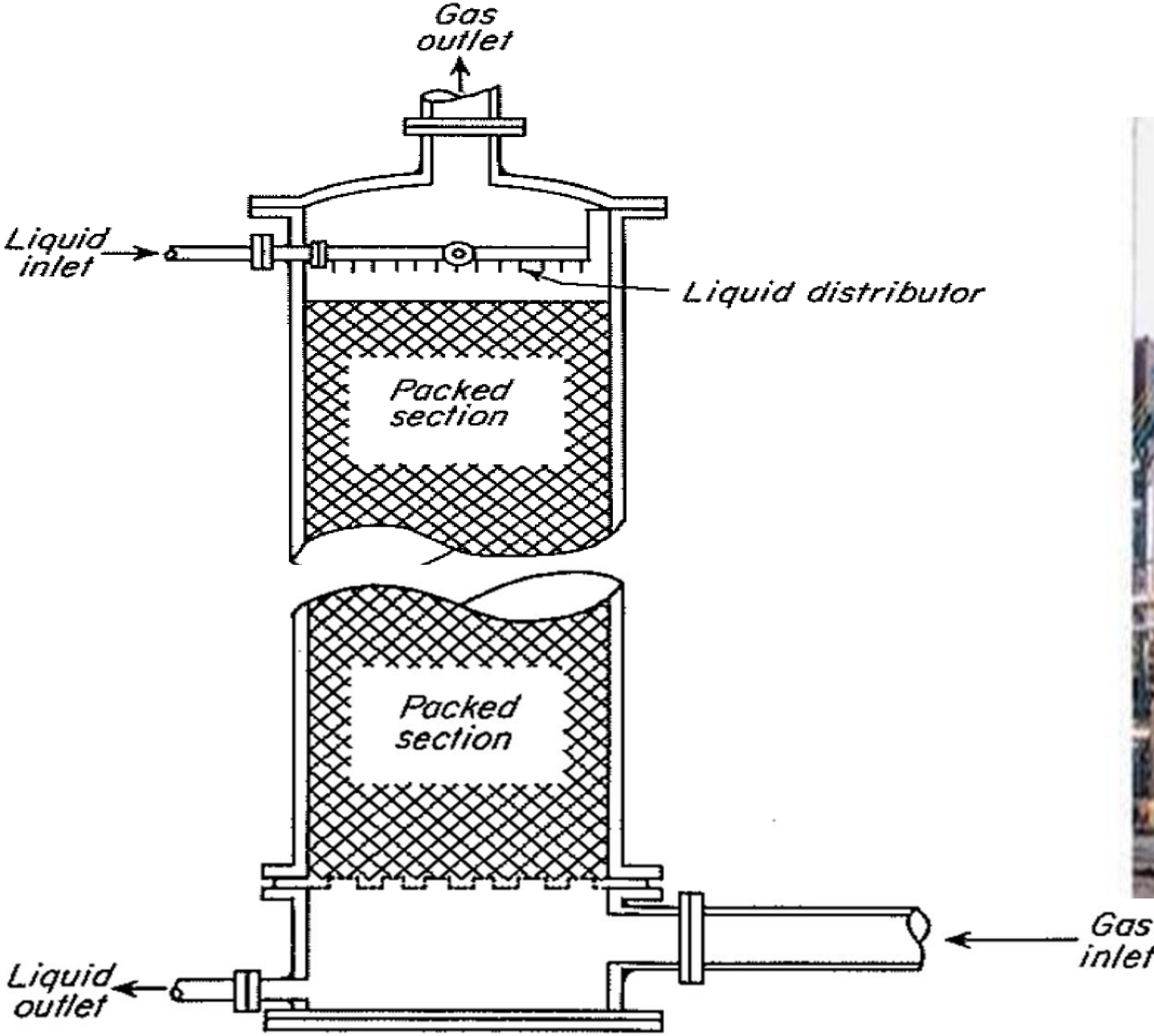

FIGURE 22.1
Packed tower.

and which is called the *weak liquor*, is distributed over the top of the packing by the distributor and, in ideal operation, uniformly wets the surfaces of the packing. The distributor shown in Fig. 22.1 is a set of perforated pipes. In large towers spray nozzles or distributor plates with overflow weirs are more common.

The solute-containing gas, or rich gas, enters the distributing space below the packing and flows upward through the interstices in the packing countercurrent to the flow of the liquid. The packing provides a large area of contact between the liquid and gas and encourages intimate contact between the phases. The solute in the rich gas is absorbed by the fresh liquid entering the tower, and dilute, or lean, gas leaves the top. The liquid is enriched in solute as it flows down the tower, and concentrated liquid, called *strong liquor*, leaves the bottom of the tower through the liquid outlet.

Tower packings are divided into three principal types: those that are dumped at random into the tower, those that must be stacked by hand, and those known as structured or ordered packings. Dumped packings consist of units 6 to 75 mm ($\frac{1}{4}$ to 3 in.) in major dimension; packings smaller than 25 mm are used mainly in laboratory or pilot-plant columns. In stacked packings the units are 50 to 200 mm (2 to 8 in.) in size. They are much less commonly used than dumped packings and are not discussed here.

Dumped tower packings are made of cheap, inert materials such as clay, porcelain, or various plastics. Thin-walled metal rings of steel or aluminum are sometimes used. High void spaces and large passages for the fluids are achieved by making the packing units irregular or hollow, so that they interlock into open structures with a porosity or void fraction of 60 to 90 percent.

Type of packed column:

- *1. Random Packed Column:*

Random packing is packing of specific geometrical shapes which are dumped into the tower and orient themselves randomly. Random packing has more risk than structured packing and less ability to handle maldistributed liquid.

2. *Structured Packed Column* :

is crimped layers or corrugated sheets which is stacked in the column. Each layer is oriented at 70° to 90°to the layer below. Structured packed offers 30% capacities higher than random packed for equal efficiency up to 50% higher at the same capacity.

3. Grid Packed Column:

- Is systematically arranged packing use an openlattice structure. This device is composed of panels that promote mass transfer and enhance entrainment removal. They have high open area, resulting in high capacity, low pressure drop, and high tolerance to fouling.

TABLE 22.1
Characteristics of dumped tower packings[9,12b,21]

Type	Material	Nominal size, in.	Bulk density,† lb/ft³	Total area,† ft²/ft³	Porosity, ε	Packing factors‡ F_p	Packing factors‡ f_p
Raschig rings	Ceramic	$\frac{1}{2}$	55	112	0.64	580	1.52§
		1	42	58	0.74	155	1.36§
		$1\frac{1}{2}$	43	37	0.73	95	1.0
		2	41	28	0.74	65	0.92§
Pall rings	Metal	1	30	63	0.94	56	1.54
		$1\frac{1}{2}$	24	39	0.95	40	1.36
		2	22	31	0.96	27	1.09
	Plastic	1	5.5	63	0.90	55	1.36
		$1\frac{1}{2}$	4.8	39	0.91	40	1.18
Berl saddles	Ceramic	$\frac{1}{2}$	54	142	0.62	240	1.58§
		1	45	76	0.68	110	1.36§
		$1\frac{1}{2}$	40	46	0.71	65	1.07§
Intalox saddles	Ceramic	$\frac{1}{2}$	46	190	0.71	200	2.27
		1	42	78	0.73	92	1.54

		$1\frac{1}{2}$	39	59	0.76	52	1.18
		2	38	36	0.76	40	1.0
		3	36	28	0.79	22	0.64
Super Intalox saddles	Ceramic	1	—	—	—	60	1.54
		2	—	—	—	30	1.0
IMTP§	Metal	1	—	—	0.97	41	1.74
		$1\frac{1}{2}$	—	—	0.98	24	1.37
		2	—	—	0.98	18	1.19
Hy-Pak	Metal	1	19	54	0.96	45	1.54
		$1\frac{1}{2}$	—	—	—	29	1.36
		2	14	29	0.97	26	1.09

† Bulk density and total area are given per unit volume of column.

‡ Factor F_p is a pressure-drop factor and f_p a relative mass-transfer coefficient.

§ Based on NH_3-H_2O data; other factors based on CO_2-NaOH data.

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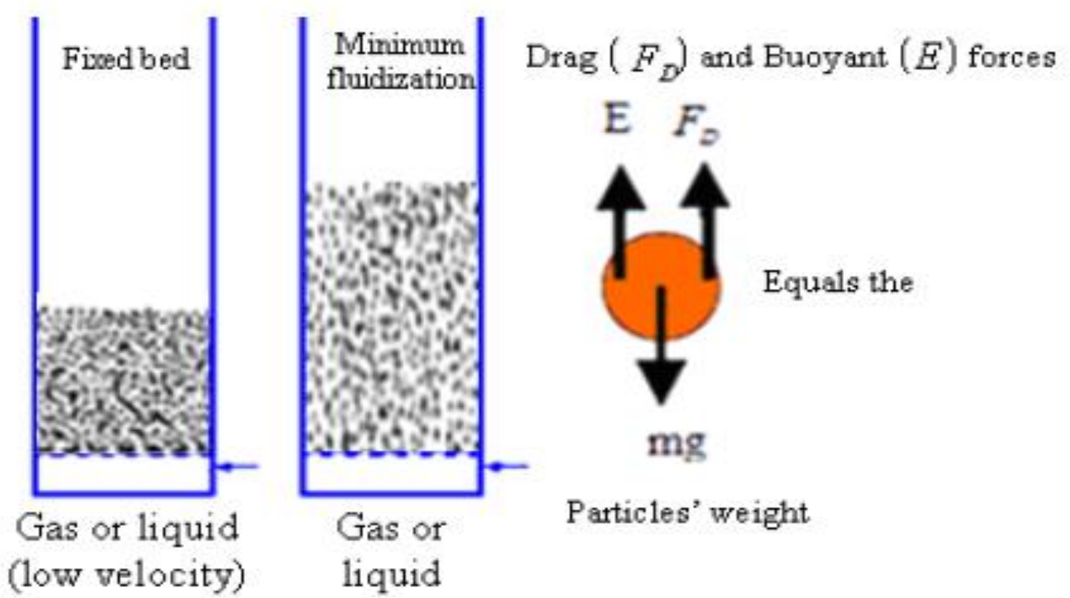
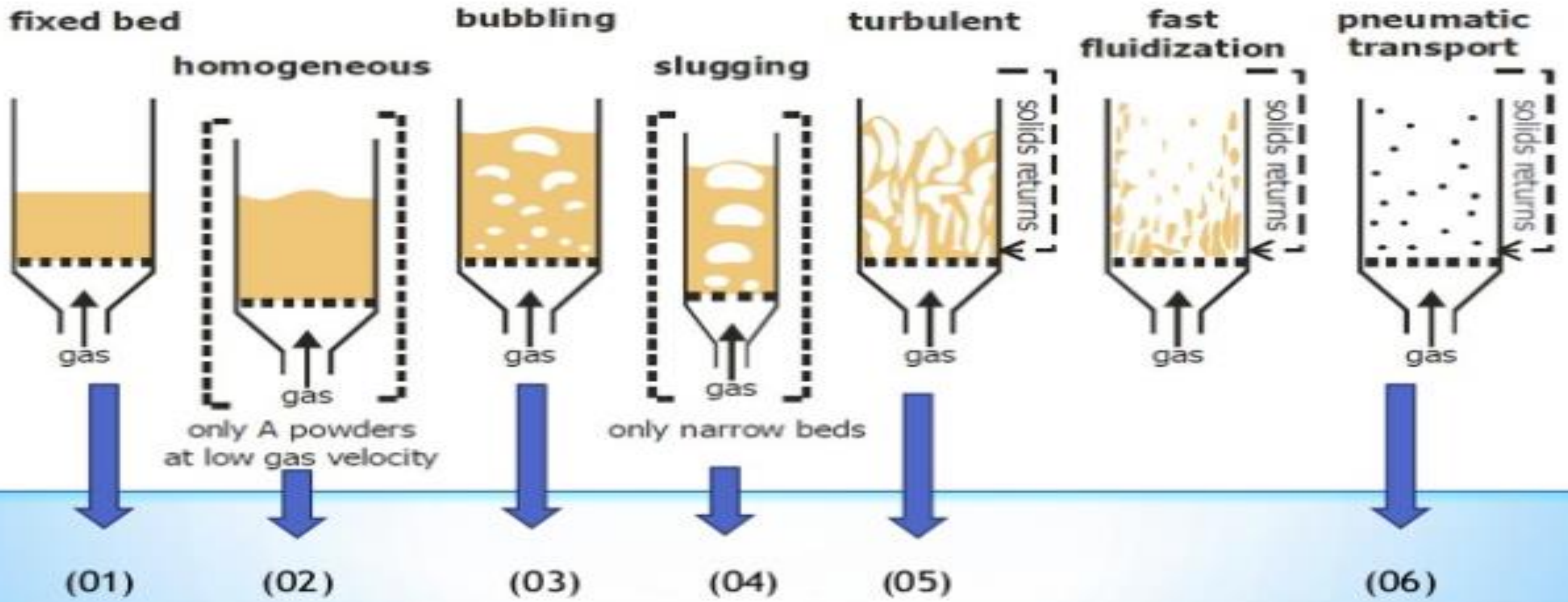
Fluidization

When a fluid is passed upwards through a bed of particles the pressure loss in the fluid due to frictional resistance increases with increasing fluid flow. A point is reached when the upward drag force exerted by the fluid on the particles is equal to the apparent weight of particles in the bed. At this point the particles are lifted by the fluid, the separation of the particles increases, and the bed becomes fluidized.



Fluidization Regimes



- When the flow of a gas passed through a bed of particles is increased continually, a few vibrate, but still within the same height as the bed at rest. This is called a **fixed bed**. (01)

- With increasing gas velocity, a point is reached where the drag force imparted by the upward moving gas equals the weight of the particles, and the voidage of the bed increases slightly: this is the onset of fluidization and is called **minimum fluidization**.(02)

- Increasing the gas flow further, the formation of fluidization bubbles sets in. At this point, a **bubbling fluidized bed** occurs.(03)

- If the ratio of the height to the diameter of the bed is high enough, the size of bubbles may become almost the same as diameter of the bed. This is called **slugging**.(04)

- If the particles are fluidized at a high enough gas flow rate, the velocity exceeds the terminal velocity of the particles. The upper surface of the bed disappears and, instead of bubbles, one observes a turbulent motion of solid clusters and voids of gas of various sizes and shapes. Beds under these conditions are called **turbulent beds**.(05)

- With further increases of gas velocity, eventually the fluidized bed becomes an entrained bed in which we have disperse, dilute or lean phase fluidized bed, which amounts to pneumatic transport of solids. (06)

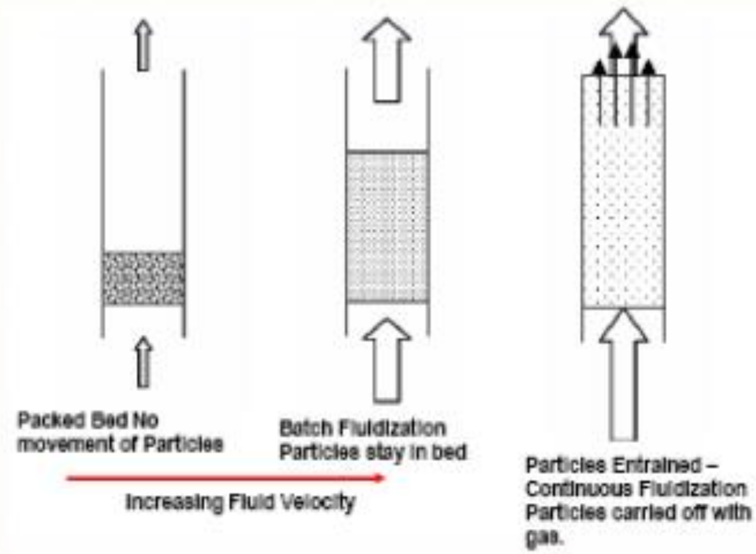
Pressure drop :

As the first approximation, the pressure drop at the starto fluidization can be determined as fallows. The Force obtained from the pressure drop times the cross-sectional area must equal the gravitational force exerted by the mass of the particles minus the buoyant force of displaced fluid .

For a bed of particles of density ρ_p, fluidized by a fluid of density ρ_f to form a bed of depth H and voidage ε in a vessel of cross-sectional area A:-

$$\Delta p = \frac{HA(1-\varepsilon)(\rho_p - \rho_f)}{A}$$

$$\Delta p = H(1-\varepsilon)(\rho_p - \rho_f)g$$



$$\text{pressure drop} = \frac{\text{weight of particles} - \text{Upthrust on particle}}{\text{Bed cross} - \text{sectional area}}$$

Uses for fluidization:

1. Chemical reactors 2. Heat exchange 3. Drying 4. Coating 5. Solidification / granulation 6. Growth of particles 7. Adsorption / desorption 8. Others

Behavior of fluidized beds:

1. Lighter objects float on top of the bed, i.e., objects less dense than the bulk density of the bed.
2. The surface stays horizontal even in tilted fluidized beds.
3. The solids can flow thru and opening in the vessel just likea liquid.
4. The beds have a "static" pressure head due to gravity,given by $\rho g h$

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Minimum fluidizing velocity (U_{mf})

If a fluid in laminar flow is passed upwards through a static packed bed of solid particles , the press. gradient is given by kozeny eq.

$$U = \left(\frac{\Delta P}{L}\right)\left(\frac{1}{K''\mu}\right)\left(\frac{e^3}{(1-e)^2 S^2}\right) \text{ -------- (1) kozeny's eq.}$$

As the fluid velocity is increased appoint reached when the viscous frictional and drag forces on the particles in the fluid stream . This is the start fluidization and a force balance gives :

$$\Delta P = (1-e)(\rho_s - \rho)L.g \text{ ------------------(2)}$$

combine eq.s (1) and (2) to give :

$$U = \left[\frac{(\rho_s-\rho)g}{\mu K''}\right]\left[\frac{e^3}{(1-e)S^2}\right] \text{ ------------------(3)}$$

- There may be some discrepancy between the Calculated and measured minimum velocity for fludization . This may be attributable to :

  1- Channeling, as a result of which the drag force on the bed is reduced .

  2- The action of electostatic forces in the case of gaseous fluidization .

  3- Agglomeration, which is often considerable with small particles .

  4- Friction between the fluid and walls of the containing vessel (it is greats important with the beds of small diameter) .

- **Example :**
- A spherical solid particles having a size of 0.12 mm and a density of 1000 kg/m^3 are to be fluidized using air at 2 atm and 25 $_0$C . The porosity at min. fluidizing condition is 0.42 . If the cross – section of the empty bed is 0.3 m^2 and the bed contains 300 kg of solid , calculate :
- a) The min. height of the fluidized bed .
- b) The pressure. drop at min. fluidizing conditions .
- c) The min. velocity for fluidization .

Take That: μ air = 1.845* 10^{-5} kg/m.s sol.

(a) Vol. of solid = 300kg / 1000 kg/m^3

= 0.3 m^3

The height of the solid would be

L_1=0.3m^3 / 0.3m^2 = 1m

Occupy in the bed if e = zero

$$\frac{L_1}{L_{mf}} = \frac{1-e_{mf}}{1-e_1} \gg \frac{1}{L_{mf}} = \frac{1-0.42}{1-0} \gg L_{mf} = 1.72\ m$$

b) $\Delta P = (1\text{-}e_{mf})(\rho_s\text{-}\rho)L_{mf}.g$

$$\rho_{air} = \frac{P.Mwt}{RT} = \frac{2*101.325*29}{8.314*298} = 2.372\ kg/m^3$$

ΔP = (1-0.42)(1000-2.372)*1.72 *9.81

= 9786 N/m^2

(c)

$$U_{mf} = [\frac{(\rho_s-\rho)g}{\mu}]\,[\frac{e_{mf}^3 d^2}{180(1-e_{mf})}]$$

$$U_{mf} = [\frac{(1000-2.372)9.81}{1.845*10^{-5}}]\,[\frac{(0.00012)^2(.42)^2}{180(1-0.42)}]$$

$= 5.42 * 10^{-3}$ m/s

(d) using an operating velocity of 3 times the min. fluidizing velocity estimate the porosity of the bed

Solution:-

$$U_{mf} = [\frac{(\rho_s-\rho)g}{\mu}]\,[\frac{e^3 d^2}{180(1-e)}]$$

$3 * 5.42 * 10^{-3} =$

$e^3 + 0.3832\, e - 0.3832 = 0$

$e = 0.555$

SETTLING AND SEDIMENTATION

- **Sedimentation** is the gravitational accumulation of solids at the bottom of a fluid (air or water)

- **Settling**- a unit operation in which solids are drawn toward a source of attraction. The particular type of settling that will be discussed in this section is gravitational settling. It should be noted that settling is different from sedimentation.

•**Free Settling:-**

if the particle is at a sufficient distance from the walls and from other particles so that its fall is not affected by them, ratio of particle diameter to container is less than (1/200) or if the particle concentration is less than 0.2 vol% in solution.

•**Hindered Settling:-**

Particles are crowded, the settle at lower rate, the separation of a dilute slurry or suspension by gravity settling into a clear fluid and a slurry of higher solid content is called “Sedimentation” .

Factors affecting zone settling velocity:

1. **Suspended solids concentration**
2. **Depth of settling column (or tank)**
3. **Stirring (0.5 – 2 rpm to prevent “arching”)**
4. **Temperature**
5. **Polymer addition (affects matrix structure)**

The main reasons for the modification of the settling rate of particles in a concentrated suspension are as follows:

(a) If a significant size range of particles is present, the large particles are settling relative to a suspension of smaller ones so that the effective density and viscosity of the fluid are increased.

(b) The upward velocity of the fluid displaced during settling is appreciable in a concentrated suspension and the apparent settling velocity is less than the actual velocity relative to the fluid.

(c) The velocity gradients in the fluid close to the particles are increased as a result of the change in the area and shape of the flow spaces.

(d) The smaller particles tend to be dragged downwards by the motion of the large particles and are therefore accelerated.

(e) Because the particles are closer together in a concentrated suspension, flocculation is more marked in an ionised solvent and the effective size of the small particles is increased.

Flocculation.

Agglomeration is sometimes promoted by adding flocculating agents including strong electrolytes, which reduce the repulsive forces between the charged particles, or polymeric flocculants that may be cationic, anionic, or nonionic in character. Flocculation is also carried out by adding inexpensive materials such as lime, alumina, or sodium silicate, which form loose agglomerates that carry fines down with them.

Flocculated particles have different settling characteristics from suspensions of dispersed dense solids. The aggregates have a high porosity and retain a considerable amount of water that accompanies the flocs when they settle. The aggregates are also loosely bonded, and the sludge at the bottom of the settler compresses under the weight of additional solids. Because the size, shape, and effective density of the flocs are not readily definable, it is not possible to **predict** the settling rate or the sludge density from theories or general correlations. The

Batch sedimentation. These are several stages in the settling of a flocculated suspension, and different zones are formed as sedimentation proceeds. Usually, the concentration of solids is high enough that sedimentation of individual particles or flocs is hindered by other solids to such an extent that all solids at a given level settle at a common velocity. At first, the solid is uniformly distributed in the liquid, as shown in Fig. 30.32*a*. The total depth of the suspension is Z_0. After a short time, the solids have settled to give a zone of clear liquid, zone *A* in Fig. 30.32*b*, and a zone *D* of settled solids. Above zone *D* is a transition layer, zone *C*, in which the solids content varies from that in the original pulp to that in zone *D*. In zone *B*, the concentration is uniform and equal to the original concentration, since the settling rate is the same throughout this zone. The boundaries between zones *D* and *C* and between *C* and *B* may not be distinct, but the boundary between zones *A* and *B* is usually sharp.

As settling continues, the depths of zones *D* and *A* increase. The depth of zone *C* remains nearly constant, and that of zone *B* decreases. This is shown in Fig. 30.32*c*. Eventually zone *B* disappears and all the solids are in zones *C* and *D* (see Fig. 30.32*d*). Meanwhile, the gradual accumulation of solid puts stress on the material at the bottom, which compresses solids in layer *D*. Compression breaks down the structure of the flocs or aggregates, and liquid is

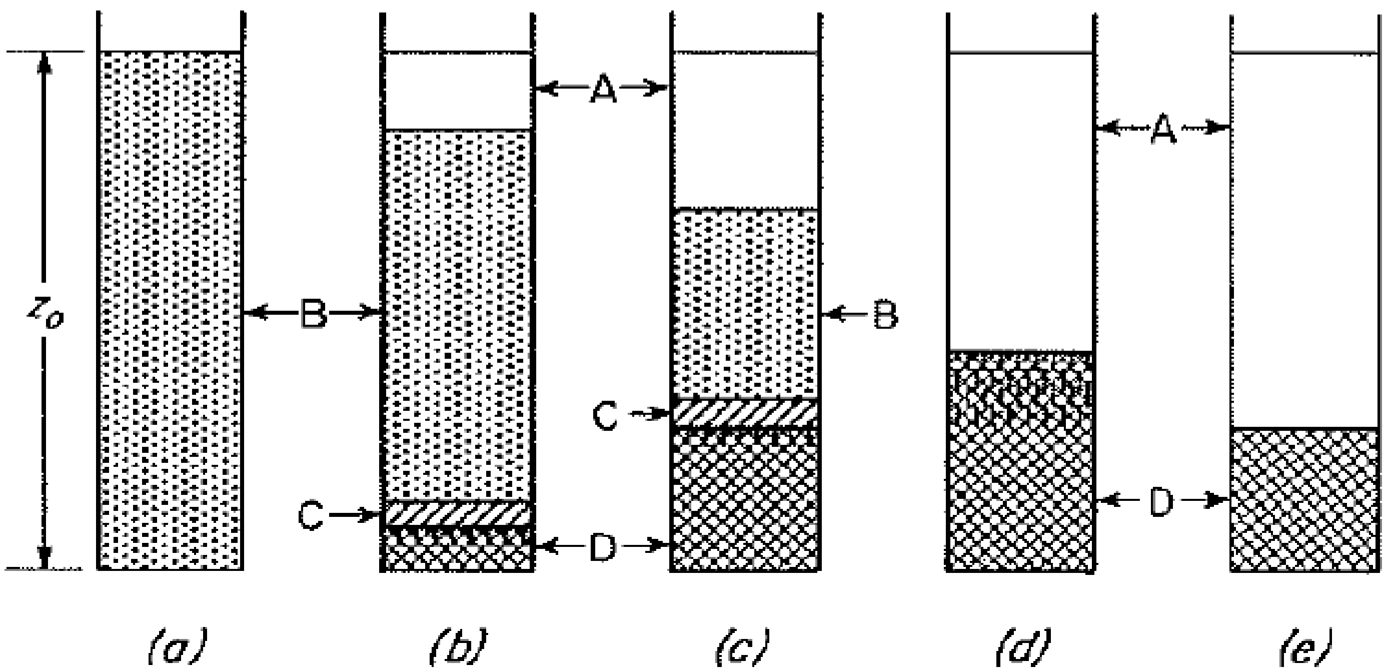

FIGURE 30.32
Batch sedimentation.

expelled into the upper zones. Sometimes liquid in the flocs spurts out of zone *D* like small geysers as layer *D* compresses. Finally, when the weight of the solid is balanced by the compressive strength of the flocs, the settling process stops, as shown in Fig. 30.32*e*. The entire process shown in Fig. 30.32 is called sedimentation.

Factors Affecting Sedimentation

1. Particle size diameter (d)

- $V \alpha d^2$
- Sedimentation velocity (v) is directly proportional to the square of diameter of particle.

2. Density difference between dispersed phase and dispersion media $(\rho_{s-}\rho_o)$

- $V \alpha (\rho_{s-} \rho_o)$
- Generally, particle density is greater than dispersion medium but, in certain cases particle density is less than dispersed phase, so suspended particle floats & is difficult to distribute uniformly in the vehicle.
- If density of the dispersed phase and dispersion medium are equal, the rate of settling becomes zero.

3 **Viscosity of dispersion medium (η)**

$V \alpha 1/\eta_0$

- Sedimentation velocity is inversely proportional to viscosity of dispersion medium.
- So increase in viscosity of medium, decreases settling, so the particles achieve good dispersion system but greater increase in viscosity gives rise to problems like pouring, syringibility and redispersibility of suspensoin.

Applications

- Water Treatment
- Effluent Treatment
- Sewage Treatment

Tube settler produced by our company uses PP, PVC and FRP as its raw material. It was hot-drawn into a hexagonal tube shape by infrared thermal machine and then welded into the using shape with patented technology and high frequency.

Our inclined tube settler can be applied to many kinds of precipitation and sand removing. In decades, it is the most mature water treatment device that widely used in drainage projects. With the advantages of wide application range, high treatment efficiency and small occupation area, it can be used in water inlet degritting, industrial and living water sedimentation, sewage sedimentation, grease and tailing enrichment processing and so on. It not only can be applied to new construction project but also the transformation of existing old tank and you can achieve astounding economic benefit in both occasions.

Filtration

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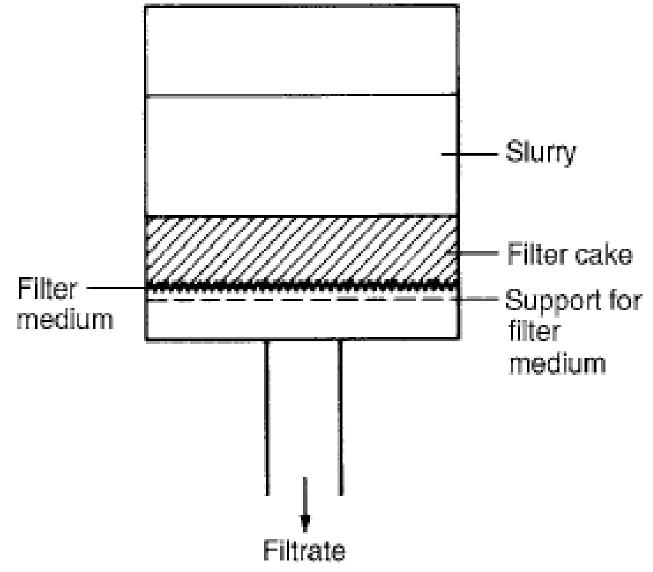
The separation of solids from a suspension in a liquid by means of a porous medium or screen which retains the solids and allows the liquid to pass is termed filtration.

In general, the pores of the medium are larger than the particles which are to be removed, and the filter works efficiently only after an initial deposit has been trapped in the medium .



Slurry: It is a suspension to be filtered.

Filter medium: It is a porous medium used to retain the solids

Filter cake: The solids which are present on the filter

Filtrate: Clear liquid passing through the filter.

Filter cake can be divided into two classes:-

(1) Incompressible cakes.
(2) Compressible cakes.

(1) Incompressible cakes:

The resistance to flow of a given volume of cake is not affected either by the pressure difference across the cake or by the rate of deposition of material (i.e. constant ε and S).

(2) Compressible cakes:

Increase of the pressure difference or of the rate of flow causes the formation of a denser cake with a higher resistance.

The most important factors on which the rate of filtration then depends will be:

(a) The drop in pressure from the feed to the far side of the filter medium.

(b) The area of the filtering surface.

(c) The viscosity of the filtrate.

(d) The resistance of the filter cake.

(e) The resistance of the filter medium and initial layers of cake .

The Objectives of Filtration

The objectives for performing filtration usually fall into one of the following categories:

1. clarification for liquor purification,
2. separation for solids recovery,
3. separation for both liquid and solids recovery, and/or
4. separation aimed at facilitating or improving other plant operations.

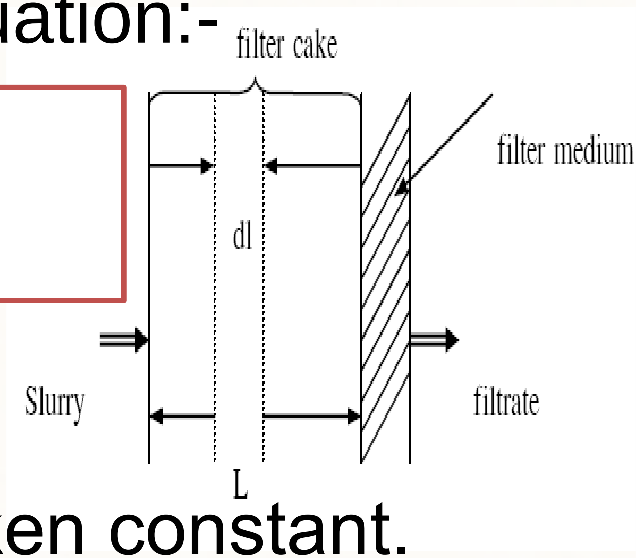
Rotary Drum Filter

The drum is supported by a large diameter trunion on the valve end and a bearing on the drive end. The drum face is divided into circumferential sectors each forming a separate vacuum cell. The internal piping that is connected to each sector passes through the trunion and ends up with a wear plate having ports that correspond to the number of sectors.

Horizontal belt or band filters In the horizontal belt or band filter, an endless belt can be provided with side walls to contain the feed slurry and wash liquors, or a flat belt can be used in conjunction with rigid static walls, against which the belt slides. Rubber, or similar, wiper blades which drag against the cake surface can be used to isolate the filtration and washing zones from each other. In some designs the belts move continuously, in others the belts are moved along in stages.

Theory of Filtration

It is depend on Carmen-Kozeny Equation:-



$$u = \frac{1}{A}\cdot\frac{dV}{dt} = \frac{1}{K}\cdot\frac{\varepsilon^3}{(1-\varepsilon)^2 s^2}\cdot\frac{(-\Delta p)}{l}\cdot\frac{1}{\mu} \qquad (1)$$

K:- Kozeny constant=5

For Filtration:-

For incompressible cake, ε could taken constant.

$$\frac{1}{r} = \frac{\varepsilon^3}{5(1-\varepsilon)^2 s^2}$$

were 1/r=specific resistance.

$$u = \frac{1}{A}\cdot\frac{dV}{dt} = \frac{1}{r}\cdot\frac{(-\Delta p)}{l}\cdot\frac{1}{\mu} \qquad (2)$$

Where:-

V is volume of filtrate passed in time t, A is total cross-sectional area of filter cake, u is superficial velocity of filtrate(m/s), *l* is cake thickness(m), S is specific surface area of particles(m^2/ m^3), ε is porosity, μ is viscosity of filtrate(Pa.s), Δp is applied pressure difference(N/ m^2), ρ is fluid density(kg/m^3), and ρ_s is solid density(kg/m^3).

$$\frac{1}{A}\frac{dV}{dt} = \frac{-\Delta P}{r\,\mu\,l} \qquad (3)$$

Basic filtration Equation

Rate of filtration= driving force/resistance

Centrifugal Separations

INTRODUCTION

There is now a wide range of situations where centrifugal force is used in place of the gravitational force in order to effect separations. The resulting accelerations may be several thousand times that attributable to gravity. Some of the benefits include far greater rates of separation; the possibility of achieving separations which are either not practically feasible, or actually impossible, in the gravitational field; and a substantial reduction of the size of the equipment.

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Applications of Centrifugation

- *Separating chalk powder from water*
- *Removing fat from milk to produce skimmed milk*
- *Separating particles from an air-flow using cyclonic separation*
- *The clarification and stabilization of wine*
- *Separation of urine components and blood components in forensic and research laboratories*

SEPARATION OF IMMISCIBLE LIQUIDS OF DIFFERENT DENSITIES

The separation of one component of a liquid-liquid mixture where the liquids are immiscible but finely dispersed ,

For example, if two liquids, one of which is twice as dense as the other, are placed in a bowl and the bowl is rotated about a vertical axis at high speed , the centrifugal force per unit volume will be twice as great for the heavier liquid as for the lighter. The heavy liquid will therefore move to occupy the annulus at the periphery of the bowl and it will displace the lighter liquid towards the centre .

If g streamline flow occurs in a centrifuge we can write ,

$$u_0 = \frac{D_p{}^2\, r(2\pi N/60)^2(\rho_p - \rho\ )}{18\mu}$$

$$u_0 = \frac{D_p{}^2\, r\, N^2(\rho_p - \rho\ )}{1640\ \mu} \qquad (3)$$

A force balance on a sector of fluid in the rotating bowl, the pressure gradient at a radius r:

$$\frac{\partial P}{\partial r} = \rho\omega^2 r \qquad (4)$$

Integration of equation (4) at a given height gives the pressure P exerted by the liquid on the walls of the bowl of radius R when the radius of the inner surface of the liquid is r_0 as:

$$P = \frac{1}{2}\rho\omega^2(R^2 - r_0^2) \qquad (5)$$

$$\rho_2\, \omega^2 (r_s^2 - r_w^2)/2 = \rho_1\, \omega^2 (r_s^2 - r_i^2)/2 \qquad (8)$$

$$r_s^2 = (\rho_2\, r_w^2 - \rho_1\, r_i^2) / (\rho_2 - \rho_1) \qquad (9)$$

where

ρ_2 is the density of the heavier liquid

ρ_1 is the density of the lighter liquid .

Equation (9) shows that as the discharge radius for the heavier liquid is made smaller , then the radius of the neutral zone must also decrease . When the neutral zone is nearer to the central axis, the lighter component is exposed only to a relatively small centrifugal force compared with the heavier liquid. The feed to a centrifuge of this type should be as nearly as possible into the neutral zone so that it will enter with the least disturbance of the system. This relationship can , therefore , be used to place the feed inlet and the product outlets in the centrifuge to get maximum separation .

Centrifuges Classification

Centrifuges are classified according to the mechanism used for solids separation:

(a) Sedimentation centrifuges: in which the separation is dependent on a difference in density between the solid and liquid phases (solid heavier) .

Centrifuges are extensively used for separating fine solids from suspension in a liquid. As a result of the far greater separating power compared with that available using gravity, fine solids and even colloids may be separated. Furthermore,

Centrifuges may be used for batch operation when dealing with small quantities of suspension although, on the large scale, arrangements must sometimes be incorporated for the continuous removal of the separated constituents. Some of the methods of

Ex. :

If a cream separator has discharge radii of 5 cm and 7.5 cm and if the density of skim milk is 1032 kg/m^3 and that of cream is 915 kg/m^3, calculate the radius of the neutral zone so that the feed inlet can be designed.

Solution

For skim milk , r_w = 0.075m , ρ_2 =1032 kg/m^3,

cream r_i = 0.05 m , ρ_1 = 915 kg/m^3

$$r_s^2 = (\rho_2 r_w^2 - \rho_1 r_i^2) / (\rho_2 - \rho_1)$$

$r_s^2 = [1032 \times (0.075)^2 - 915 \times (0.05)^2] / (1032 - 915)$

$= 0.03\ m^2$

r_s = 0.17 m = 17 cm

EXAMPLE

A dispersion of oil in water is to be separated using a centrifuge. Assume that the oil is dispersed in the form of spherical globules 51 μ m diameter and that its density is 894 kg/m^3. If the centrifuge rotates at 1500 rev/min and the effective radius at which the separation occurs is 3.8 cm , calculate

(a) the velocity of the oil through the water .

(b) the centrifugal acceleration . Take the density of water to be 1000 kg/m^3 and its viscosity to be 0.7×10^{-3} N s/m^2 .

Solution

(a) the rate of settling under gravity

$$u_0 = \frac{D_p{}^2\, r\, N^2(\rho_p - \rho_c)}{1640\,\mu}$$

$u_0 = (5.1x10^{-5})^2\ x1500^2\ x\ 0.038(1000\text{-}894)/(1640x0.7x10^{-3})$

$u_0 = 0.02\ m/s$

Checking that it is reasonable to assume Stokes' Law

Re = $(Dv\rho/\mu) = (5.1\ x10^{-5}\ x\ 0.02\ x\ 1000)/(7.0\ x\ 10^{-4}) = 1.5$

so that the flow is streamline and it should obey Stokes' Law.

(b)

$g = 0.011\ rN^2 = 0.011\ x\ 0.038\ x\ 1500^2$

$g = 940.6\ m^2/s$