UNIT – I

PARTICLE CHARACTERIZATION

Solids, in general are more difficult to handle than liquids or gases. In processing, solids appear in a variety of forms angular pieces, continuous sheets, and finely divided powders. They may be hard and abrasive, tough and rubbery, soft or fragile, dusty, cohesive, free flowing or sticky. Whatever be their forms, means must be found to manipulate the solids as they occur and, if possible, to improve their handling characteristics.

Solids particles are characterized by their size, shape and density. For regular particles size and shape are easily specified such as sphere and cubes. For irregular particles the terms size and shape are to be defined.

Particle Technology deals with the properties, characteristics, behaviour and applications of particles.

Equivalent Diameter:

The equivalent diameter of a non-spherical particle is defined as the diameter of a sphere having the same volume as the particle denoted by Dp.

Sphericity:

The shape of an individual particle is conveniently expressed in terms of the sphericity 'ϕ_s' which is independent of particle size. For a spherical particle $\phi_s = 1$. ϕ_s is defined as the ratio of the surface area of sphere (having equal volume of particle) to the actual surface area of particle.

$$\phi_s = \frac{Area\ of\ sphere}{Area\ of\ particle}$$

Expression for ϕ_s:

Let S_s = surface area of sphere (having equal volume of particle)

V_p = volume of particle (or Volume of sphere).

Consider,

$$\frac{S_s}{V_p} = \frac{\pi D_P^2}{\pi D_P^3 / 6} = \frac{6}{D_p} \quad \text{or } S_s = \frac{6V_p}{D_p} \quad \text{Therefore} \quad \frac{S_s}{Sp} = \frac{6V_p}{S_p D_p}$$

Where,

S_p = surface area of particle

D_p = Equivalent dia. of particle.

For cubes and for cylinders when length equal to the diameter, $\phi_s = 1$.

Proof for above statement:

$$\text{Cubes - } \phi_s = \frac{6V_p}{S_p D_p} = \frac{6 \times a^3}{6a^2 \times a} = 1$$

$$\text{Cylinder } \phi_s = \frac{6 \times \left(\frac{\pi D_P^2}{4} \right) \times D_P}{\left[\underset{\text{surface area}}{\pi D_P^2} + \underset{\text{circularar face}}{2 \frac{\pi D_P^2}{4}} \right] D_P} = \frac{6\pi D_P^2}{6\pi D_P^2} = 1$$

For irregular particles ϕ_s is less than unity, for many crushed materials is is between 0.6 or 0.7 (ϕ_s is always less than unity because surface of sphere is always less for same volume of any other shape).

Shape Factor: It is calculated as the reciprocal of Sphericity:

Particle Size:

Diameter is specified for any equidimensional (proportional dimensions) particles. Particles which are not equidimensional i.e. which are longer in one direction than in others are often characterized by the second longest major dimensions.

Size range of particles (Expressions for size):

Coarse particles – measured in inches / cm.

Fine particles – In terms of screen (mesh) size.

Very fine - Micrometers nanometers

Ultra-fine - In terms of surface area per unit mass.

Standard Screen Series:

Testing sieves- (measurement of size). Standard screen series are used to measure the size and size distribution of particles in the range between 3, 0.0015 inch. Testing sieves are made up of woven wire screens. The openings are square. Each screen is identified in meshes (openings) per linear inch the actual openings are smaller than those corresponding to the mesh numbers.

Ex: 40 mesh, 10 mesh

Some of the standard screen series are.

Tyler Standard Series (TSS), British Standard Series (BSS), Berue of Indian Standards (BIS), American Society of Testing Machines (ASTM) Standards.

Tyler standard screen series (Commonly used):

This set of screens is based on the opening of 200 mesh screen which is established at 0.074 mm. The area of opening in any one screen in the screen series is exactly twice that of the openings in the next smaller screen. The ratio of the actual mesh dimension of any screen to that of the next smaller screen is $\sqrt{2} = 1.414$.

$$\frac{A_n}{A_{n+1}} = 2, \qquad \frac{D_n}{D_{n+1}} = \sqrt{2}$$

For closer sizing, intermediate screens are available, each of which has a mesh dimension $4\sqrt{2}$ or 1.189 times that of the next smaller standard screen. Ordinarily these intermediate screens are not used. These sieves are called sub sieves and the analysis carried out using these sieves are called sub sieve analysis.

Mixed particle sizes and Size analysis:

In a sample of uniform particles of diameter D_P the total volume of the particles is m/ρ_P, where m and $\int_P$ are the total mass of the samples and the density of the particles, respectively. Since the volume of the particle is V_P, the numbers of particles in the sample 'N' is

$$N = \frac{m}{\int_P V_P}$$

S_P is the surface area of the particle then the total surface area of the particle (A) = NS_P,

$$\text{We know, } \phi_S = \frac{6V_p}{S_p D_p} \text{ or } \qquad S_P = \frac{6V_p}{\phi_s D_p}$$

$$\text{Surface area, } A = N S_P = \frac{m}{\int_P V_P} \cdot \frac{6V_p}{\phi_s D_p} = \frac{6m}{\phi_s \int_p D_p}$$

$$\text{Surface area per unit mass} = A/m = \frac{6m}{\phi_s \int_p D_p}$$

To apply above equations to mixtures of particles having various sizes and densities the mixture is sorted into fractions each of constant density and approximately constant size [particle size distribution] .Each fraction can then be weighed, individual particles in it can be counted or measured by microscopic methods. The above equations can then be applied to each fraction and the results added.

Surface area of mixed particles, $A = \frac{6m_1}{\phi_s \int_p \overline{D_{p\,1}}} + \frac{6m_2}{\phi_s \int_p \overline{D_{p\,2}}} + \frac{6m_3}{\phi_s \int_p \overline{D_{p\,3}}} + \frac{6m_4}{\phi_s \int_p \overline{D_{p\,4}}} + \ldots\ldots = \frac{6}{\phi_s \int_p} \sum \frac{m_i}{\overline{D_{p\,i}}}$

Surface area per unit mass = A/m = $A_w = \frac{6x_1}{\phi_s \int_p \overline{D_{p\,1}}} + \frac{6x_2}{\phi_s \int_p \overline{D_{p\,2}}} + \frac{6x_3}{\phi_s \int_p \overline{D_{p\,3}}} + \frac{6x_4}{\phi_s \int_p \overline{D_{p\,4}}} + \ldots\ldots = \frac{6}{\phi_s \int_p} \sum \frac{x_i}{\overline{D_{p\,i}}}$ for differential analysis

And for cumulative analysis, it will be

$$\frac{6}{\phi_s \rho_p} \int_0^1 \frac{d\phi}{D_{Pi}}$$

Particle size distribution methods:

Method	Particle size range
Sieve analysis	**Above 40 micron**
Gravity sedimentation	**1-100 micron**
Centrifugal sedimentation	**0.005-3 micron**
Elutriation under gravity	**5-100 microns**
Centrifugal field	**1-60 micron**
Ultra microscopy	**0.0005-5 microns**
Light scattering	**0.1-10 microns**
X-Ray scattering	**0.005-0.05 microns**

Screen Analysis:

The simplest and most common method of separating mixtures by size alone is to make a screen analysis using series of testing series. In making an analysis a set of standard screens is arranged serially in a stack, with the smallest mesh (opening) at the bottom and the largest(opening) at the top. The sample is placed on top of the screen i.e. on the top screen and stack is shaken mechanically for a definite period of time. The particles retained on each screen are removed and weighed, and the masses of the individual screen increments are converted to mass fraction or mass percentages of the total sample. Any particles that pass the finest screen are caught in a pan at the bottom of the stack.

Screen analysis is of 2 types. They are called Differential screen analysis and Cumulative screen analysis; the difference between the two methods of screen analysis is based on the difference in the tabulation or plotting of the results obtained from the screen analysis.

Since the particles on any one screen are passed by the screen immediately ahead of it, two members are used to specify the size range of an increment, one for the screen

through which the fraction passes and the other on which it is retained. The notation 14 / 20 means "through 14 mesh and on 20 mesh" (i.e. passes through 14 mesh but retained on 20 mesh)

Tabulation in case of Differential Analysis:

Mesh No	Screen Opening Dpi; mm	Mass fraction retained xi	Avg. particle dia. $\overline{D}_{Pi}$ mm
4	4.699	0.000	-
6	3.327	0.0251	4.013
8	2.362	0.1250	2.845
PAN	-	0.0075	0.037

In the above table, the first two columns give the mesh size number and clear opening of screen. The third column is the mass fractions of the total sample that is retained in the designated screen and this fraction is x_i, where i vary from 1-n. The symbol D_{Pi}, means the particle diameter equal to mesh opening of screen i. The last column D_p D_{Pi} is the average diameter of the particles retained on any screen i which is the arithmetic average of the opening of the screen which passes the material and the opening of the mesh which retains the material.

Cumulative Analysis:

A cumulative analysis is obtained from a differential analysis by adding, (cumulatively) the individual differential increments, starting with that retained on the smallest mesh, and tabulating or plotting the cumulative sums against the mesh dimensions of the retaining screen of the last to be added. In the following table the last column gives the cumulative fraction which is smaller than the corresponding value of Dpi. This is called cumulative underflow.

Tabulation e.g. (cumulative Analysis):

Mesh. No	Screen opening Dpi, mm	Mass fraction retained xi	Avg. dia $\overline{D}$pi mm	Cumulative fraction smaller than Dpi	Cumulative fraction larger than Dpi
4	4.699	0.000	-	1.0000	0
6	3.327	0.0250	4.013	0.9749	0.0251
8	2.362	0.1250	2.845	0.8499	0.1501
. . .	. . .	. . .	. . .	. . .	
150	0.104	0.0041	0.126	0.106	0.8940
200	0.074	0.0031	0.089	0.0075	0.9925
PAN	-	0.0075	0.037	0.0000	1.0000

The cumulative fraction x_n is defined as follow

$X_n = x_1 + x_2 + x_3 \ldots\ldots\ldots\ldots\ldots\ldots x_n$

i.e. $x_n = \sum_{i=1}^{n} xi$

Note: Sometimes in screen analysis the cumulative fractions are written starting from the top of the stack, in this case the last column will be "Cumulative fraction larger than Dpi".

Assumption of Differential analysis:

The assumption made is that all particles in a single fraction are equal is size and that the size is the arithmetical mean of the mesh dimensions of the 2 screens that define the fraction.

Eg: The 10 / 14 mesh fraction is $\frac{1.651+1.168}{2}$ = 1.410 mm i.e, Dpi = 1.410 mm. The symbol of Dpi is used for such arithmetic average diameter.

In Cumulative analysis, the graph of x_n v_s D_{pi} is treated as a continuous function. In principle, the method based on the cumulative analysis is more precise than that based on the differential analysis because when the cumulative analysis is used, the assumption that all particles in a single fraction are equal in size in not needed. The graph of x_n v_s D_{Pi} is treated as a continuous function.

Average size of mixture of particles:

Particle size is important as it affects properties such as the surface area per unit volume. When the particle size reduces below critical size the properties that changes are-Optical properties, magnetic properties, thermal properties, mechanical properties, energy, biomedical properties, environmental, surface properties. Particles are three dimensional objects for which three parameters (length, breadth and height) are required in order to provide a complete description. As such it is not possible to describe a particle using a single number that equates to the particle size. Most sizing techniques therefore assume that the material being measured is spherical, as a sphere is the shape that can be described by a single number (the diameter).This equivalent sphere approximation is useful as it simplifies the way particle size is represented.

The simplest shape of a particle is the sphere, because of the symmetry, any question of orientation does not have to be considered, since particle looks exactly the same from whatever direction it is viewed and behaves in the same manner in a fluid, irrespective of its orientation. No other particles have this characteristic. Frequently, the size of a particle of irregular shape is defined in terms of the size of an equivalent sphere although the particle is represented by a sphere of different size according to the property selected. Some of the important sizes of equivalent spheres are

The sphere of the same volume as the particle
The sphere of the same surface area as the particle
The sphere of the same surface area per unit volume as the particle

Based on the above the, following average diameters are defined

Volume surface mean diameter D_S

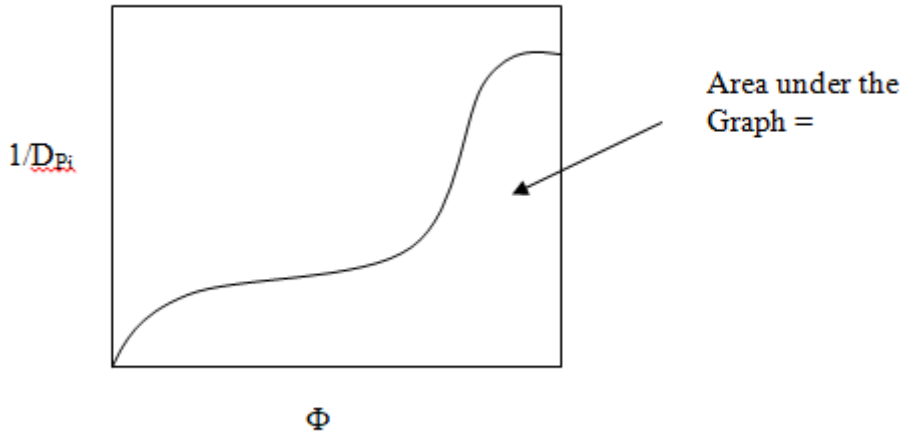
It is defined as $D_S = 6/ \phi_S A_W \int_P$ Substituting for A_W

Volume surface mean dia. by differential analysis

$$D_s = \frac{1}{\sum\left[x_i / \overline{D_{Pi}}\right]}$$

By cumulative analysis $= \frac{6}{\phi_s \rho_p} \int_0^1 \frac{d\phi}{D_{P_i}}$

The integral is evaluated graphically by drawing a graph of $\frac{1}{D_{Pi}}$ vs ϕ_i



Cumulative analysis of particle size

Find the area under the curve.

$$D_s = \frac{1}{(Area\ under\ the\ curve)}$$

Volume mean dia. by differential analysis

$$D_v = \left[\frac{1}{\sum \left[x_i / \left(\overline{D_{Pi}} \right)^3 \right]} \right]^{1/3}$$

Number of particles by differential analysis

$$N_W = \frac{1}{a\rho_P} \sum_{i=1}^{n} \frac{x_i}{\left(\overline{D_{Pi}} \right)^3}$$

a- Volume shape factor, ρ_p-Density of particles

Mass mean dia. by differential analysis

$$D_W = \Sigma x_i D_{Pi}$$

Mechanical Separations:

Frequently it is necessary to separate the components of a mixture into individual fractions. Procedure for separating the components of mixtures falls into 2 classes.

1. Diffusional Operation (Mass Transfer).

2. Mechanical Separations (M.S)

Mechanical Separations are useful in separating solid particles or liquid drops from fluids.

Different methods of Mechanical Separation are:

1. Screening 2. Filtration 3. Sedimentation 4. Heavy media separation 5. Differential settling 6. High tension methods 7. Magnetic separation.

Mechanical Separations are applicable to **heterogeneous mixtures**. The techniques are based on physical differences between the particles such as size and density. They are applicable for separating solids from gases, liquid drops from gases, solids from solids and solids from liquids. The General methods used for separation are .

1. A sieve, or membrane such as a screen or a filter which retains one component and allows the other to pass through.

2. Utilize the difference in the rate of sedimentation of particles as they move through liquid or gas.

3. Special methods – difference in wettability, electrical and magnetic property of substances.

Screening:

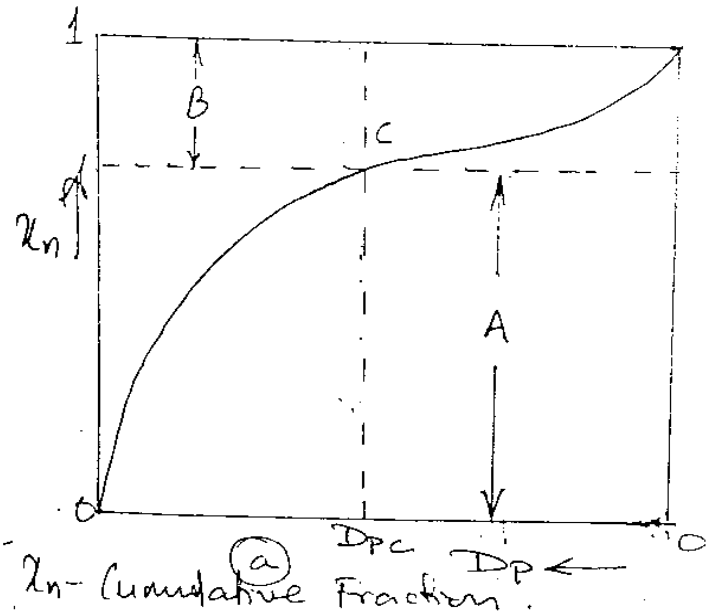
Screening is a method of separating particles according to size alone. In industrial screening the solids are dropped on or thrown against a screening surface. **The undersize or fine pass through the screen openings. Oversize or tails do not.** A single screen can make but a single separation into two fractions. These are called unsized fractions, because although either the upper or lower limit of the particle sizes they contain, is known, the other limit is unknown material passed through a series of screens of different sizes is separated into sized fractions i.e., fractions in which both maximum and minimum particle sizes are known. Screening is occasionally done wet but much more commonly dry.

Ideal screen or Actual Screens:

An ideal screen is one which separates the feed mixture in such a way that the smallest particles in the overflow would be just larger than the largest particle in the underflow. Such an ideal separation defines a cut diameter Dpc, which marks the point of separation between the fractions. Dpc is nearly equal to the mesh opening of the screen.

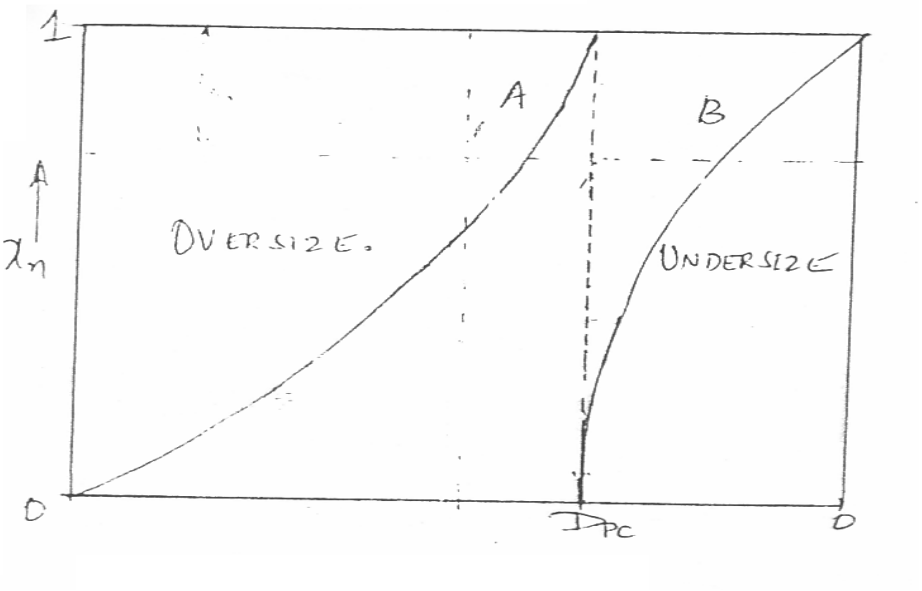
Performance of an ideal screen:

The performance of an ideal screen in terms if the screen analysis of the feed is shown in fig (a). The output is point 'C' in the curve . Fraction A consists of all particles larger than Dpc, and fraction B consists of all particles smaller than Dpc.



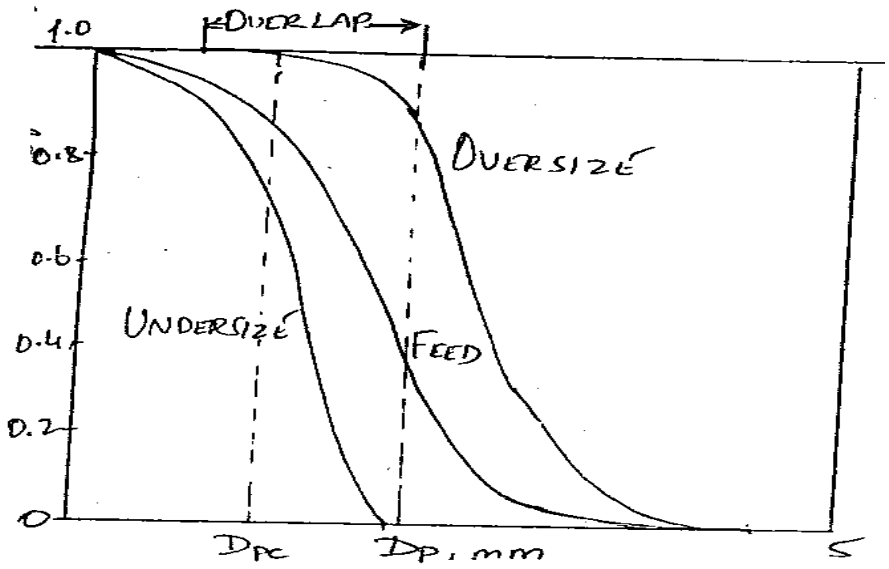
Screen analysis of the fractions A and B are plotted in fig. (b) . The first point on the curve for B has the same abscissa as the last point on the curve for A and there is no

overlap of these curves. (Note: In fig (b) oversize and undersize are taken separately and plotted between 0 to 1 and in fig. (a) the entire mixture is taken and plotted between 0 to 1. Also since it is a plot for ideal screen there is a definite cut off point and separates clearly the undersize and the oversize i.e., there is no overlap.



Actual Screens:

Actual Screens do not give a sharp separation, the overflow has an appreciable content of particles smaller than the designed cut diameter and the underflow has particles larger than the cut diameter. The mass of the 2 leaving streams will not be equal to the individual masses of A and B unless it happens the oversize material in underflow is equal to the undersize in the overflow. The plot of cumulative fraction Vs the particle diameter for actual screens is as shown below.



(Cumulative mass fraction larger than Dpi)

Screen Blindness:

Under the screening action, elongated, sticky, flaky or soft particles may become wedged into the openings of the screens and prevent other particles from passing through. A screen plugged with solid particles is said to be blind.

Screen Effectiveness:

The effectiveness of a screen (often called the screen efficiency) is a measure of the success of a screen in closely separating materials A and B. A common measure of screen effectiveness is the ratio of oversize material A that is actually in the overflow to the amount of A entering with the feed. Similarly the effectiveness based on material B is defined as the mass of B in the underflow to the amount of B entering with the feed. The relation to find the screen efficiency can be derived doing a material balance over the screen as follows:

Let,

F = mass rate of feed. D = mass rate of overflow.

B = mass rate of underflow.

x_F = mass fraction of material A in feed.

x_D = mass fraction of material A in over flow.

x_B = mass fraction of material A in underflow.

$1 - x_F$ = mass fraction of material B in feed.

$1 - x_D$ = mass fraction of material B in overflow.

$1 - x_B$ = mass fraction of material B in underflow.

E_A – Screen effectiveness based on oversize

$$E_A = \frac{D \times D}{F \times F} = \text{Recovery.}$$

E_B – Screen Effectiveness based on undersize.

$$E_B = \frac{B(1 - x_B)}{F(1 - x_F)} = \text{Rejection.}$$

Overall Effectiveness, E = (Recovery). (Rejection).

$$\text{Recovery} = \frac{\textit{Desired mateiral in the topproduct}}{\textit{Desired material in the feed}}$$

Rejection = $\frac{Undesired\ mateiral\ in\ the\ bottomproduct}{Undesired\ material\ in\ the\ feed}$

Overall Effectiveness $E = E_A \times E_B$

$$= \frac{DB\ X_D(1-x_B)}{F^2 x_F(1-x_F)} \qquad (a)$$

The D/F and B/F ratio can be expressed in terms of mass fraction by carrying out material balance around the screen.

$$F = D + B \qquad (1)$$

Desired material A in feed = Desired material A in (product + Reject)

$$Fx_F = Dx_D + Bx_B \qquad (2)$$

From equation (1).

$B = F - D$ Substitute in equation (2)

$Fx_F = D_{xD} + (Fx_B - Dx_{ZB})$

$Fx_F - Fx_B = Dx_D - Dx_B$

$F(x_F - x_B) = D(x_D - x_B)$

$$\frac{D}{F} = \frac{x_F - x_B}{x_D - x_B} \qquad (3)$$ over flow to feed ratio.

From equation (1) D = F – B. Substitute in equation (2).

$Fx_F = Fx_D - Bx_D + Bx_B$

$Fx_D - Fx_F = Bx_D - Bx_B$

$F(x_D - x_F) = B(x_D - x_B)$

$$\frac{B}{F} = \frac{x_D - x_F}{x_D - x_B} \qquad (4)$$ underflow to feed ratio.

Substitute in equation (3) and Equation (4) in equation (a)

$$\left[E = \frac{(x_F - x_B)(x_D - x_F)x_D(1-x_B)}{(x_D - x_B)^2 x_F(1-x_F)} \right]$$

Capacity of Screens:

It is measured by the mass of material that can be fed per unit time to a unit area of the screen.

Capacity and effectiveness are opposing factors. To obtain maximum effectiveness, the capacity must be small, and large capacity is obtained only at the expense of a reduction in effectiveness. In practice, a reasonable balance between capacity and effectiveness is desired.

The capacity of a screen is controlled simply by varying the rate of feed to the unit. The effectiveness obtained for a given capacity depends on the nature of screening operation.

Capacity of Actual Screens:

In practice several complicating factors appear that cannot be treated theoretically. Some of the disturbing factors are the interference of the particles with the motion of any one; blinding, cohesion of particles to each other; the adhesion of particles to the screen surface and the oblique direction of approaches of the particles to the surface when large and small particles are present. The large particles tend to segregate next to the screen and so prevent the smaller particles from reaching the screen. All these factors tend to reduce capacity and lower effectiveness. Moisture content of the feed is especially important. Either dry particles or particles moving in a stream of water screen more readily than damp particles which are prone to stick to the screen surface and to each other. As the particle size is reduced, screening becomes more difficult, and the capacity and effectiveness are in general, low for particle sizes smaller than about 150 mesh.

Screening Equipment:

Many varieties of screens are available for different purposes and only a few representative types are used here. In most screens the particles drop through the openings by gravity. In few designs they are pushed through the screen by a brush using centrifugal force. If fine particles are more the screen surface must be agitated insome way such as by shaking, gyrating or unbarring it mechanically or electrically. Typical screen motions are illustrated in fig.

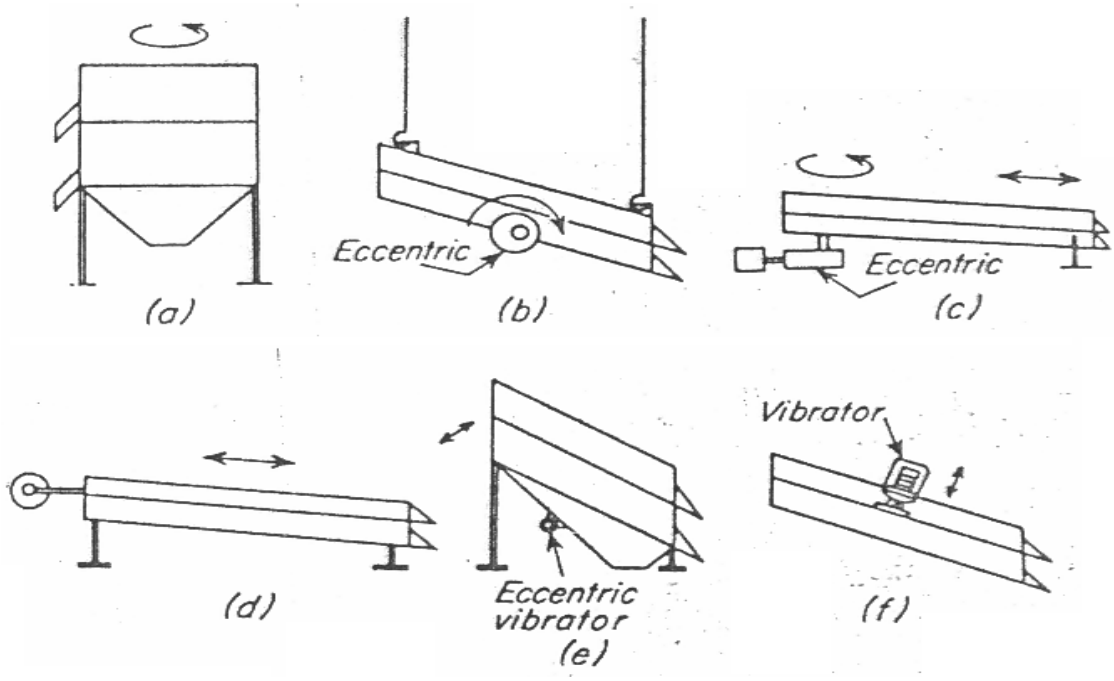
Industrial Screening Equipment:
Various types of screening equipments have been developed, differing largely in ruggedness, method of moving of the material across them, and materials of construction. A classification based largely on size of material and as follows.

1. Grizzlies are used for coarse screening of large lumps and are of rugged construction.

2. Trommels are rotating screens used for fairly large particles.

3. Shaking and Vibrating screens are used for fine sizing. Industrial screens are made from woven wire, silk or plastic cloth, metal bars, perforated or slotted metal plates or

wires that are wedge shaped in cross sections. Various metals are used, with steel and stainless steel the most common.

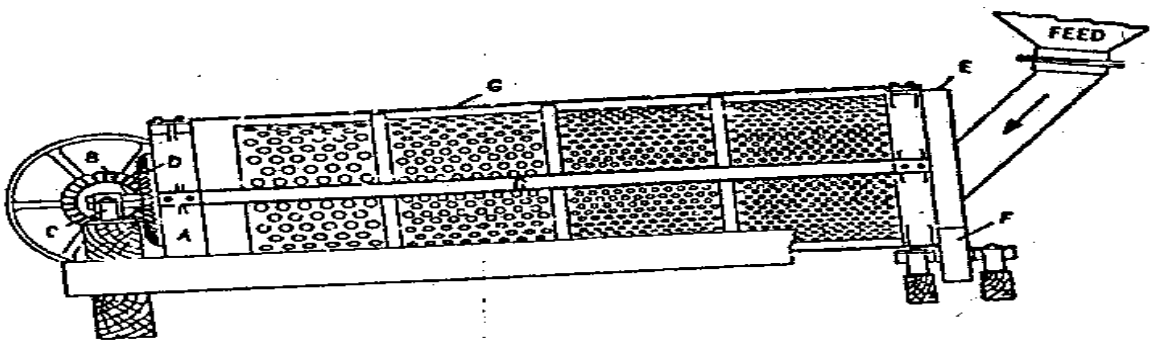


1. Grizzlies:

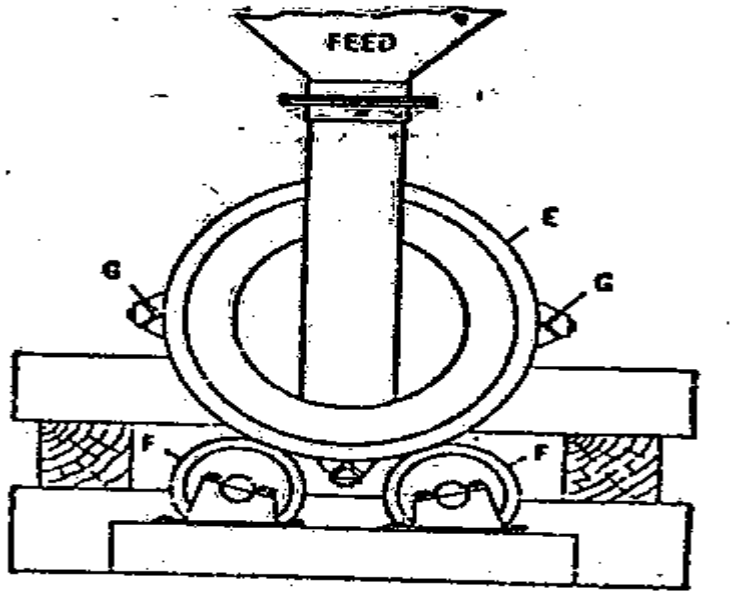
A Grizzly is a simple device consisting of a grating made up of Bars, usually built on a slope, across which material is passed. The slope and hence the path of the material is parallel to the length of the bars. The bar is usually so sloped that the top is wider than the bottom, so that the bar can be made fairly deep for strength without being choked by particles passing past way through. The grizzly is often constructed in the form of a short endless belt so that the oversize is dumped over the end which the sized materials passes through. In this case the bar length is transverse to the path of the material. The grizzly is used out for the coarsest and roughest separation.

2. Trommels:

A trommel consists of a rotating cylinder of perforated sheet metal or wire screen. It is open at one or both ends, and the axis of the cylinder is horizontal or slightly inclined, so that the material is advanced by the rotation of the cylinder.



Trommel: *A*, discharge-end casting; *B*, stub shaft; *C*, bearing box; *D*, drive *E*, tire; *F*, supporting rolls; *G*, angle-iron braces.



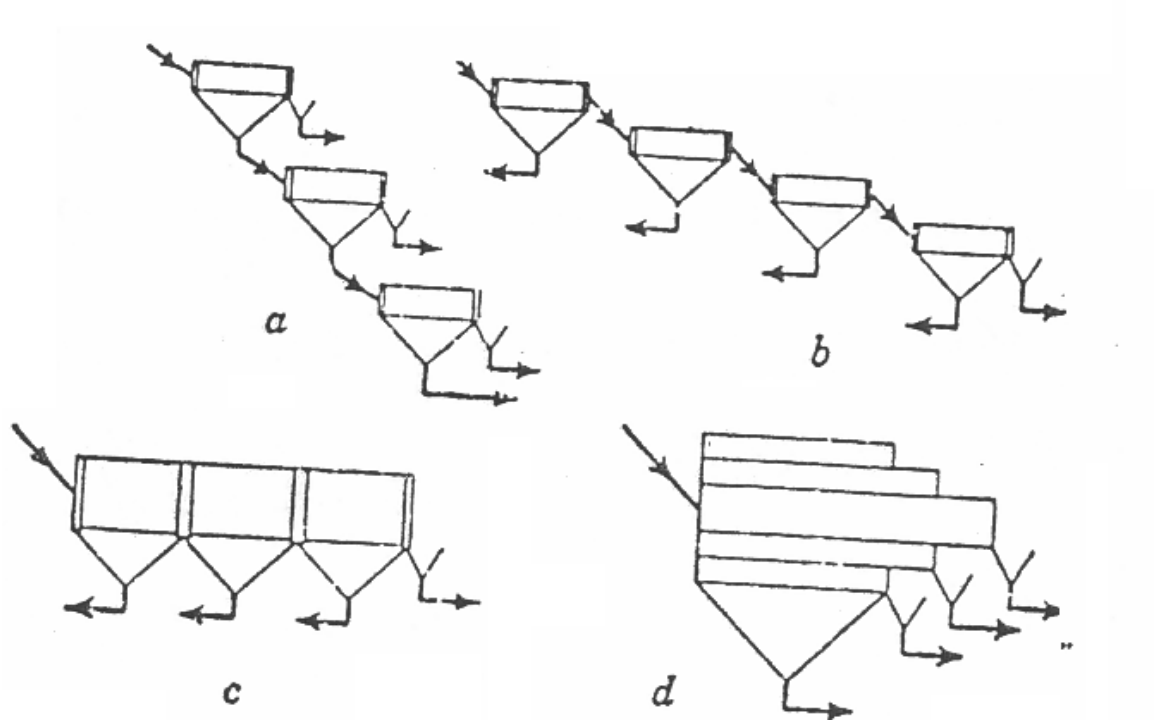
It is best suited for relatively course material (1/2 inch or over). There is considerable variation in trommel construction and arrangement. Several different arrangements of trammels are shown diagrammatically in the following page. The simple case is when the perforations are uniform over the whole length of the cylinder the oversize passes out the lower end into a hopper or chute. If the given material is to be separated into several size fractions, several trommel are operated in series. Some trommel arrangement.

Fig (a). The Ist trommel has the coarsest perforations and the undersize is delivered to the next trommel and it is most convenient to place the trommel one above the other.

Fig.(b) The Ist trommel has the smallest perforations, the oversize passes to the next trommel and the successive screens are out in a line end to end.

Fig (c) An arrangement consisting of a single cylinder with perforations ranging from the finest desired at the feed end to the coarsest at the discharge end. In this case a separate hopper is placed under each belt of sizes. This has the disadvantage that the plate or screens with the finest openings is the weakest and at the same time is subjected to the heaviest wear.

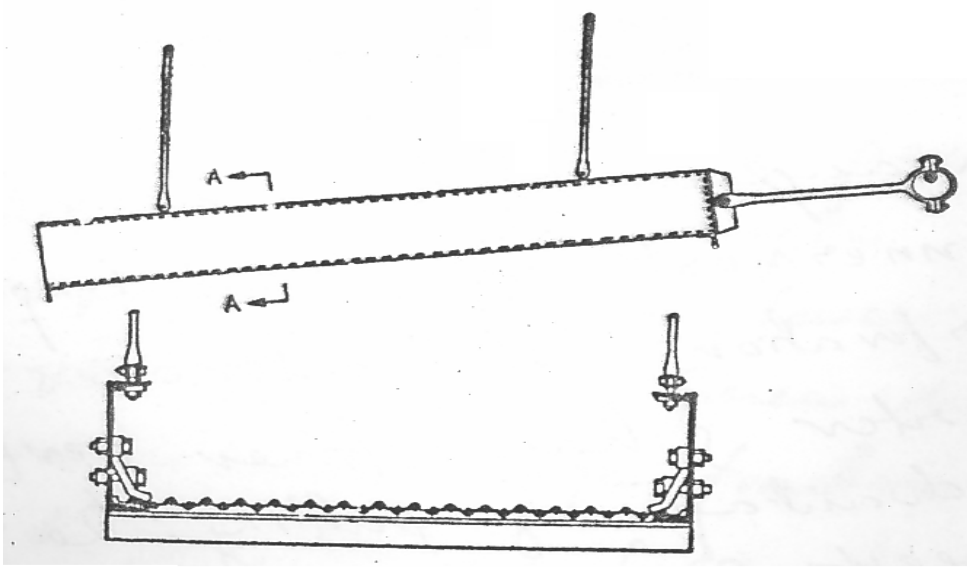
Fig.(d) The arrangement has several concentric cylinders. The innermost one is the longest and has the coarsest perforations. The outer ones are successively shorter and hence finer perforations. This has the advantage of putting the greatest load on the strongest screen, but calls for more complicated and expensive construction.



When finer separations are to be made in a device of this type, the cylinder may be covered with fine wire or silk cloth instead of punched plate or course wire screen. Such an apparatus is normally called a REEL. These REELS must be equipped with some device or the other to prevent blinding.

3. Shaking Screens:

Many size separations in which the product may be from ½ inch down to most finest sizes that can be handled by screens, may be performed by means of flat or slightly inclined screens that are given a reciprocating motion. Fig. Below shows such a screen made of single mechanical elements.



The frame is of channel irons and is suspended by layer rods so that it can move freely. It is shaken by means of an ordinary eccentric on a rotating shaft. The screen cloth may be riveted directly to the frame, or it may be soldered. Over a light, removable frame bolted into place. Another method of attachment is to provide a light angle that can be bolted to the inside of the frame. The edge of the screen cloth is drawn up between this angle and the man structure.

4. Vibrating Screens:

Screens that are rapidly vibrated with small amplitude are less likely to blind than are gyrators screens. The vibrations may be generated mechanical or electrically. Mechanical vibrations are usually transmitted from single speed eccentrics to the casing of the unit and from there to steeply inclined screens. Electrical vibrations from heavy duty solenoids are transmitted to the casing or directly to the screens.

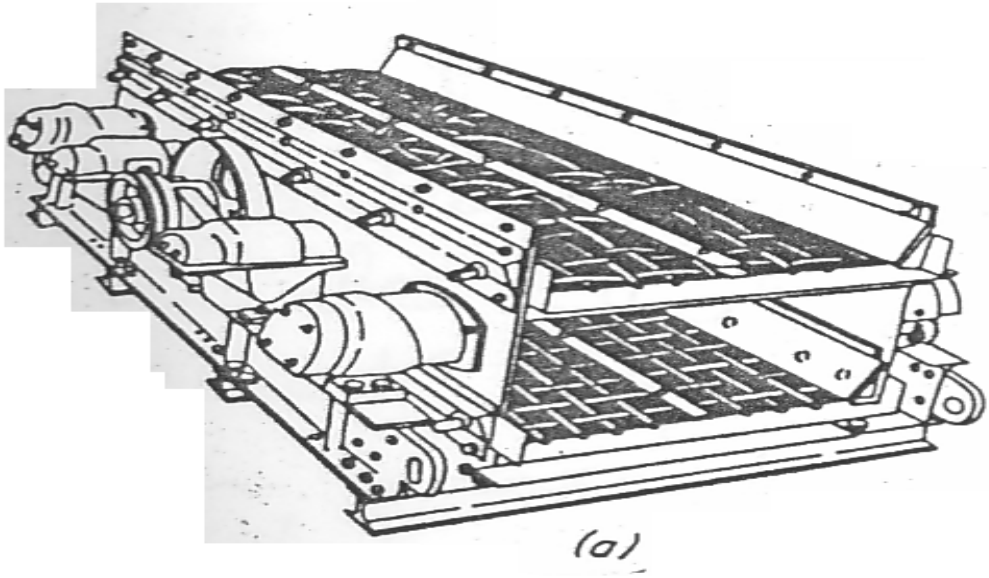
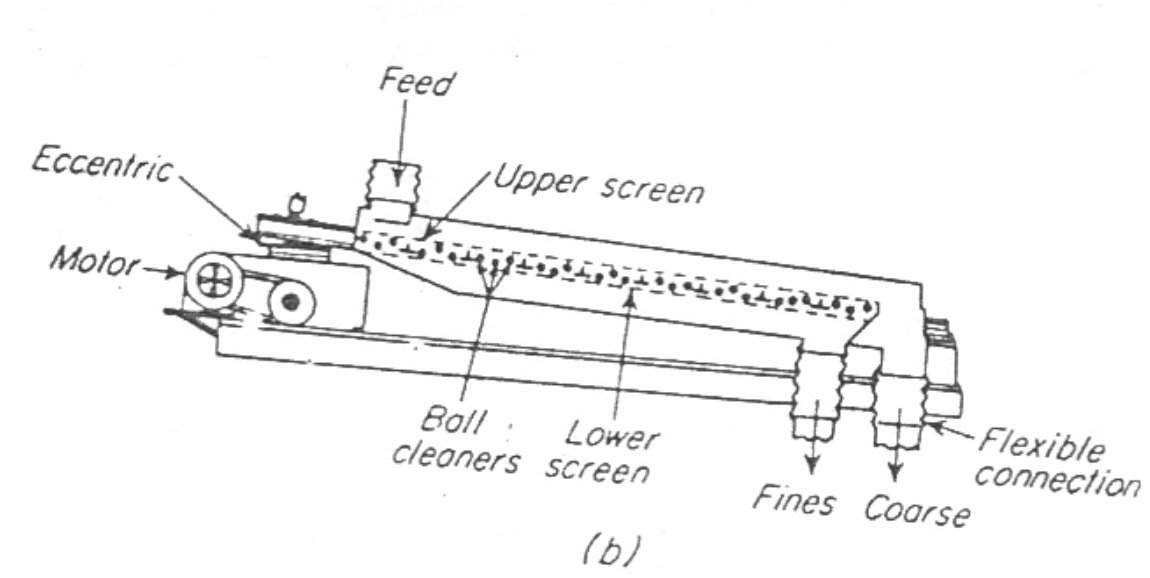


Fig. Shows a directly vibrated unit. Ordinarily no more than 3 decks are used in vibrating screens. Between 1800 to 3600 librations per minute are usual.



Sub-Sieve Analysis:
The analysis are done using settling techniques. The methods used in general are sedimentation. Air permeating method and Elutriation methods.

ICI Sedimentation:

This is a method developed by imperial chemical industries, U.K for the size distribution of a powder sample and to calculate the average size. In this method different sizes of particles are assumed to be present and the settling velocities are calculated assuming free settling under stokes region. The time of settling of different particles are calculated using settling velocities and the mixture of particles are separated into different fraction by allowing the particles to settle for different calculated times.

The settling velocities are calculated using the equation $u_t = \frac{gD_P^2(\int_P - \int)}{18\mu}$

$$\text{Time of Settling} = \frac{height\ of\ settling}{Ter\min al\ settling\ velocity}$$

Weigh a known quantity of sample. Prepare thick slurry of the sample with water and take it in the left limb (Settling limb) of the sedimentation apparatus. Add water to the right limb up to some known height and make up the slurry in the left limb and equalize the level in the limbs to the known height. To keep the slurry agitated and keep it uniform blow air through the rubber tube provided at the bottom. Assume that the particles present area of sizes 60μ, 60/√2 μ, 30 μ, 30 / √2μ and calculate the times of settling for each of them. After making the slurry uniform stop blowing of air, start the stop watch and allow the solids to settle for the calculated time of 60 μ particles. At this moment, close the stop cock in the left limb. Open the outlet at the bottom of the left limb and also open the stop cock in the right limb to flush the settled solids out. Filter the slurry in a previously weighed filter paper, wash the solids present, dry and weigh. Repeat the procedure for the other sizes also and tabulate the values as rough weights W_1, W_2, W_3 and W_4. Calculate the connected weights using the formula

$$X_1 = W_1 - W_2, \qquad X_2 = 2\,W_2 - W_3, \qquad X_3 = 2W_3 - W_4$$

$$X_4 = \text{Total} - X_1 - X_2 - X_3.$$

Calculate the average size of the particles by differential or cumulative methods of analysis and report.

Air Permeability:

Specific area of a given sample powder can be determined by Air permeability.

Specific surface area is defined as the surface area per unit mass of powder sample. This is a characteristic of the size of the material. Surface area can be obtained from the resistance offered to the flow of fluid through a head of given powder sample.

Fluid (air) is allowed to pass through the bed of solids under laminar flow conditions and Kozeny Carman Equation is used. The modified form of Kozeny Carman Equation for finding the specific surface area is.

$$S_W = \left[\frac{\varepsilon^3 \Delta P}{5(1-\varepsilon)^2 \mu \int_S^2 \bar{V}_O L} \right]^{1/2} \textbf{ m}^2\textbf{/ Kg.}$$

Where S_W – Specific surface Area, m^2 / Kg.

ε = Porosity of bed = $\frac{Void\ Volume}{Bed\ Volume}$

$$= \frac{1/\int_b - 1/\int_b}{1/\int_b}$$

$\int_b$ = density of bed of solids.

$$= \frac{mass\ of\ sample}{volume\ of\ bed}, \text{ kg/ m}^3.$$

Volume of bed = C/S area of bed × height of bed, m^3

μ = Viscosity of fluid (Air) = 18.325×10^{-6} NS / m^2.

$\int_S$ = Density of solid.

$\bar{V}_O$ = Superficial velocity of fluid flowing (air) m/s.

$$= \frac{volume\ of\ water\ collected}{Time\ of\ collections\ C/S\ Area\ of\ \ bed}$$

L – Hight of bed, m

$\Delta P = R_m \int g$, Pressure drop for the flow of fluid, N/m^2.

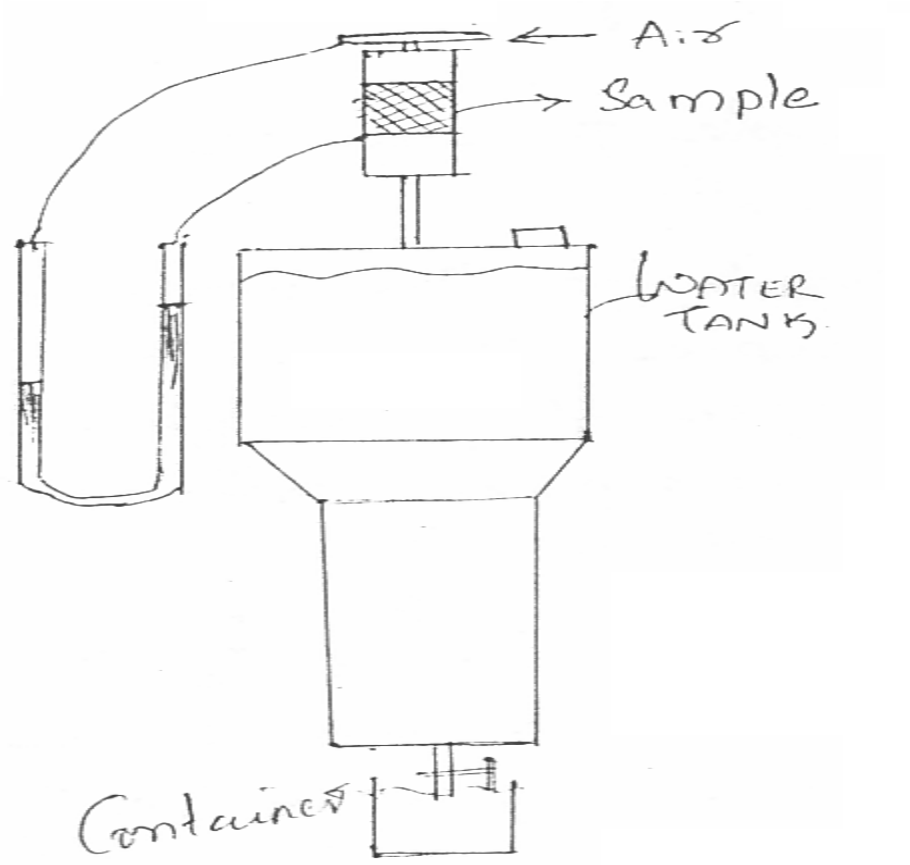
R_m – manometer reading

$\int$ - density of manometric fluid (water) = 1000 kg/m^3.

G – Acceleration due to gravity. 9.81 m/s^2.

Experiment Procedure:

Weigh 10 gm of $CaCO_3$ powder and place it in a sample holder of the apparatus and measure the height of bed with the help of plunger provided. Remove the plunger and give the manometer connections. Conduct experiment by collecting water at the bottom of the drum for different flow rate of water. Note the corresponding manometer reading.



Repeat the experiment with different weight of sample. The average specific surface area of the sample is reported.

Elutriators use the velocity of an ascending stream of fluid to affect separation. The feed mixture containing solid particles of different sizes is fed from the top and the fluid (normally water or air) is sent up from the bottom. Particles whose free settling velocity is more than the upward velocity of fluid settle down and are collected as the underflow from the bottom of the chamber, whereas particles whose free sterling is less than the upward velocity of fluid air carried over by the ascending fluid are carried over and are collected in the over flow at the top of the column. By using a number of elutriation columns of increasing cross-sectional area in series, several fractions of solids can be sorted.