MO
MECHANICAL OPERATION

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Thanks to all of You :

Mechanical Operation :-

- ↳ Particulate Solids — Solid characteristics, Size Reduction. S-S separation
- ↳ Dynamics of solids — fluidization, Sedimentation, Elutriation
- ↳ Mining — Mining of solids.

Characteristics of Solid :-

- ↳ Physical property (density, M.P, k)
- ↳ Particle Shape
- ↳ " Size

Particle Shape :-

- ↳ Regular Particles (spherical particles) $\frac{\text{Surface Area}}{\text{Volume}}$ = minimum — It is minimum in only spherical particle
- ↳ Irregular Particles

Sphericity

$$\boxed{\phi = \frac{(S/V)\ \text{sphere having same volume}}{(S/V)\ \text{irregular particle of same Volume}}}$$

assume hypothetical Sphere

$$V_p = \frac{\pi}{6} d_p^3$$

$$S_p = \pi d_p^2$$

$$\boxed{\phi = \frac{(S_p/V_p)_{\text{sphere}}}{(S_p/V_p)_{\text{particle}}}}$$

$$\left(\frac{S_p}{V_p}\right)_{\text{sphere}} = 6/d_p$$

$$\boxed{\phi = \frac{\quad}{S_p/V_p}}$$ same volume

* $\phi < 1$ is less than one for irregular particle [illegible] broken [illegible] sphere [illegible]

* If irregular particle is sphere

$$\rightarrow \boxed{\phi = 1}$$

* $\phi \rightarrow 1$, particle is near to the regularity.

* $\phi \rightarrow 0$, particle is far away from regularity.

Q.) Cube $a \times a \times a$, Sphericity.

$$a^3 = \frac{\pi}{6} d_p^3$$

$$\left(\frac{6a^3}{\pi}\right)^{1/3} = d_p$$

$$\phi = \frac{\cancel{6a}\,6/(6/\pi)^{1/3} a}{6a^2/a^3} = \frac{(6/\cancel{\pi})^{1/3} \cancel{a^2}}{6\,\cancel{a^2}}$$

$$= \frac{6/a \sqrt[3]{6/\pi}}{6a^2/a^3}$$

$$\phi = \sqrt[3]{\frac{\pi}{6}} \simeq 0.806$$

* ϕ is independent of particle size

* <u>Particle Size</u> :—

Dimension occupy by the particle in vector space.

for 1-Dim = linear dimension = diameter.

2-Dim = Planner dimension = Area.

Particle Size Analysis

- Mixed Size Analysis — we calc. sp. S/A
- Average Size Analysis

Average Size Analysis :-

Average diameter:

→ Mean Arithmatic diameter

$$(\bar{D}_N) = \frac{\sum N_i d_{pi}}{\sum N_i}$$

N_i → No. of particles in ith fraction

d_{pi} → Equivalent dia of particle in ith fract

$$\boxed{\bar{D}_N = \frac{1}{N_T} \sum N_i d_{pi}}$$

→ Mean Volume diameter

$$\boxed{\bar{D}_V = \left[\frac{1}{\sum \frac{x_i}{d_{pi}^3}}\right]^{1/3}}$$

x_i = Mass fract of particle in ith fract

→ Mean Mass dia

$$\boxed{\bar{D}_M \text{ or } \bar{D}_W = \frac{\sum x_i d_{pi}}{\sum x_i} = \sum x_i d_{pi}}$$

$\sum x_i = 1$

→ Mean Sauter dia

Used in operation such as, catalytic rxn, adsorptn

$$\boxed{\bar{D}_{VS} \text{ or } \bar{D}_S = \frac{1}{\sum \frac{x_i}{d_{pi}}}}$$

Volume-surface mean dia.

$\bar{D}_V$ & $\bar{D}_M$ or $\bar{D}_W$ is used in

Drying (spray), Evaporation, filtration, fluidization, sedimentation.

Mixed Size Analysis :-

Size	Dimension
Coarse	inches, cm
Fine	mm
Very fine	micro μm, nm
Ultra fine	$\frac{mm^2}{g}$, $\frac{\mu m^2}{g}$

for any fractn (i),

let volume of the fractn V_i

Volume of particle, V_p

$$N_i = \frac{V_i}{V_p}$$

$$N_i = \frac{m_i}{\rho_p \cdot V_p}$$

$\rho = m/V$

$V = m/\rho$

$V_i = m_i/\rho_p$ / Assumption ρ is same for all particles.

total surface of 'i' fractn

$$A_S = N_i \times S_p$$

S_p → S/A of one particle

$$A_S = \frac{m_i \times S_p}{}$$

$$A_{si} = \frac{m_i \times S_p}{\rho_p \times V_p}$$

$$A_{si} = \frac{m_i}{\rho_p} \times \frac{6}{\phi \times d_{pi}}$$

$\because \phi = \frac{6/d_p}{S_p/V_p}$

$S_p/V_p = 6/\phi d_p$.

Assuming ϕ same $\forall$ particle.

Specific Surface Area of i^{th} fracth A_{ss}

$$A_{ssi} = \frac{A_{si}}{m_i} =$$

Total surface Area of Mixture,

$$A_{s\,total} = \Sigma A_{si}$$

$$\boxed{A_{s\,total} = \Sigma \frac{6 m_i}{\phi \rho_p d_{pi}}}$$

$$\boxed{A_{s\,total} = \frac{6}{\phi \rho_p} \Sigma \frac{m_i}{d_{pi}}}$$

Total Sp. S/A of mixture

$$A_{ss} = \frac{A_{s\,total}}{m_{total}}$$

$$= \frac{\frac{6}{\phi \rho_p} \Sigma \frac{m_i}{d_{pi}}}{m_{total}}$$

$$\boxed{A_{ss} = \frac{6}{\phi \rho_p} \Sigma \frac{x_i}{d_{pi}}}$$

Q> The size analysis for a petroleum industry is found to be

avg. dia d_{pi} (mm)	Mass fracth x_i (g/g)	
0.0252	0.088	3.4920
0.0178	0.178	10
0.0126	0.293	23.2539
0.0089	0.194	21.7977
0.0038	0.247	65
		123.54361

find sp. surface A.

$A_{ss} = ?$ & $\bar{D}_s = ?$

if $\phi = 0.5$

S.g = 2.6

$$= \frac{6}{0.5 \times 2.6 \times \frac{1g}{cc} \times \frac{1cc}{1000\,mm^3}} \times 123.54366.$$

$$= 570.201 \times 10^3 \ mm^2/kg$$

$Sp = S \times m = 2.6$

$\rho_p = 2.6 \times 1 \ g/cc = 2.6 g/c.c$

$$\bar{D}_s = \frac{1}{\sum \frac{x_i}{d_{pi}}} = 0.008094, \ mm$$

Surface Shape factor :- ϕ_s

$$\phi_s = \frac{1}{\text{Sphericity}}$$

$$\boxed{\phi_s = \frac{1}{\Phi}}$$

$\boxed{\phi_s > 1}$ $\forall$ all particle

$\boxed{\phi_s = 1}$ sphere

Volume Shape factor :-

$$V \propto d_p^3$$

$$V = a \cdot d_p^3$$

a = proportionality const or Vol. shape factor

$\boxed{a = V/d_p^3}$ V = actual vol^m of solid particle

Q.) find the ϕ_s & a, for a cuboid of $10 \times 5 \times 1$ cm×cm×cm.

$$10 \times 5 \times 1 = \frac{\pi}{6} \times d_p^3$$

$$\frac{50 \times 6}{\pi} = d_p^3$$

$$d_p = 4.57155$$

$$SA_{cuboid} = 2(lb + bh + lh)$$

$$= 2(10 \times 5 + 5 \times 1 + 1 \times 10) = 2(50 + 5 + 10)$$

$$\phi = \frac{71.5785}{130/50}$$

$$\phi_s = \frac{1}{\phi} = \phi_s = 1.981$$

$$a = \frac{V}{dp^3}$$

$$= \frac{50}{\,}$$

$$= 0.52359$$

if we take dp of sphere then volume shape factor $a = \pi/6$ always.

Sep 23/14

* Size Reduction (communition)

Breaking of coarse particles into fine particles

Purpose

- To increase Sp. S/A
- Better handling

Methods for size Reduction

- Impact – used for secondary crushing — hard & brittle
- Compression – " " primary crushing — hard & tough
- Attrition " " tertiary " — Amorphous (crystalline material)
- Cutting.

Coarse crusher → Primary crushers ⟹ Crushed pdt ⟹ (coarse in size) → fine grinder → Secondary grinder (hammer mill, Ball mill) → Crushed pdt (fine particle)

Secondary grinder ⟹ tertiary crusher (Fluid Energy mill) → Ultra fine

Impact :-

Sharp & sudden force for an instantaneous time.

- Dynamic Impact
- Gravity Impact :-

Gravity Impact:
[One object is moving & second object is at rest] eg → Blow of hammer on nails.

Dynamic Impact:–
[When both object is moving] cricket bat & ball.

Q:> for which type of solid material we use impact, compression & Attrition?

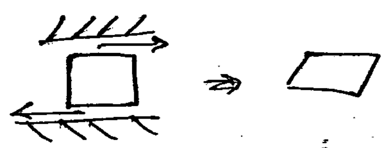
*** Compression :–**

When two continous forces applied on an object in normal dir^n

eg → Jaw crusher, Roll crusher, Gyratory crusher.

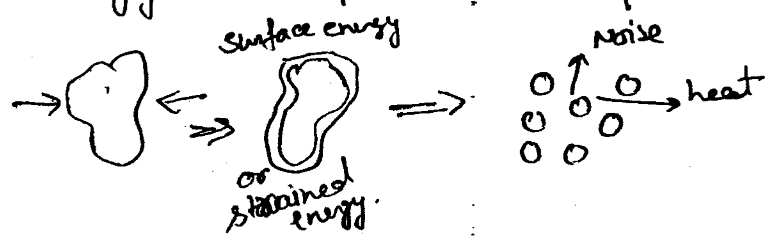
*** Attrition :–**

When two continous forces applied to an object in shear dir^n.



eg → fluid Energy mill,

*** Energy Consumption in Size Reduction**



$\eta_c = 10^{-3} - 10^{-1}$ %.

$$\eta_c = \frac{\text{total Surface Energy Created}}{\text{total Energy absorbed by the Solid}}$$

$$\boxed{\eta_c = \frac{e_s\,(A_{ssb} - A_{ssa})}{W_n}}$$

e_s → Surface Energy factor, J/m^2

A_{ss} → m^2/kg

W_n → J/kg.

$$\eta_m = \frac{\text{total Energy Absorbed by the solid}}{\text{total energy fed}}$$

$$\eta_m = \frac{W_n}{W}$$

$$\boxed{W = \frac{W_n}{\eta_m} = \frac{e_s(A_{ssb} - A_{ssa})}{\eta_c \cdot \eta_m}}$$

Power fed to the Equipment.

$$P = W \times m$$

$$\boxed{P = \frac{e_s(A_{ssb} - A_{ssa}) \cdot m}{\eta_c \eta_m}} \quad W$$

* Laws of Crushing:—

→ Rittinger's Law (1867)

The work required for size Red^n is directly proportional to the new surface area created.

It is valid for particle size less than 0.05 mm

$$W_R \propto (A_{ssb} - A_{ssa})$$

$$\boxed{W_R = k \cdot e_s (A_{ssb} - A_{ssa})}$$

$$A_{ss} = \frac{6}{\phi \rho_p} \Sigma \frac{x_i}{d_{pi}}$$

$$A_{ssa} = \frac{6}{\phi \rho_p d_{pa}}$$

Assumption

ϕ is constant & same for feed & product.

$$A_{ssb} = \frac{6}{\phi \rho_p d_{pb}}$$

$$W_R = k\, e_s \left[\frac{6}{\phi \rho_p d_{pb}} - \frac{6}{\phi \rho_p d_{pa}}\right]$$

$$W_R = \frac{6 k e_s}{\phi \rho_p} \left[\frac{1}{d_{pb}} - \frac{1}{d_{pa}}\right]$$

$$\boxed{W_R = \frac{P}{\dot{m}} = K_R \left[\frac{1}{d_{pb}} - \frac{1}{d_{pa}}\right]}$$

Rittinger's No. $R_N = \frac{1}{K_R} = \frac{\phi \rho_p}{6 k e_s}$

* Kick's Law (1885)

valid for particle size Range > 50mm

The work required for crushing is constant for a given mass of material for a constant reduction ratio, irrespective of their initial size

$$\text{Reductio Ratio} = \frac{\text{Avg. dia of feed particles}}{\text{Avg. dia of pdt particles.}}$$

$$\boxed{W_K = \frac{P}{\dot{m}} = K_K \ln\left(\frac{d\bar{P}_a}{d\bar{P}_b}\right)}$$

Reduction ration

300 — 60
500 — 100 > 5

* Bond's Law (1952)

The work required for crushing is directly proportional to the square root of surface area to volume ratio of the pdt particles of diameter dP_b

$$W_B \propto \sqrt{(S_P/V_P)_b}$$

$$W_B = K\sqrt{(S_P/V_P)_b}$$

$$\phi = \frac{6/dP}{S_P/V_P} \Rightarrow \left(\frac{S_b}{V_P}\right)_b = \frac{6}{\phi d\bar{P}_b}$$

$$W_B = K\sqrt{\frac{6}{\phi d\bar{P}_b}} = \sqrt{\frac{6K^2}{\phi}} \cdot \frac{1}{\sqrt{d\bar{P}_b}}$$

$$\boxed{W_B = \frac{P}{\dot{m}} = K_b \frac{1}{\sqrt{d\bar{P}_b}}}$$

Valid for particle size Range

$$0.05\,\text{mm} < dp < 50\,\text{mm}$$

This law is also known as *Universal law of crushing*.

The gross energy required in kWhr/ton for crushing a large size feed upto a size (pdt) such that 80% of the product can passes through a 100 μm mesh screen.

$$w_i = k_b \frac{1}{\sqrt{0.1 (mm)}}$$

$$\boxed{k_B = 0.3162\, w_i}$$

$$\boxed{w_B = \frac{P}{\dot{m}} = 0.3162\, w_i \left(\frac{1}{\sqrt{d_{Pb}}}\right)}$$

$$\boxed{w_B = \frac{P}{\dot{m}} = k_b \left[\frac{1}{\sqrt{d_{Pb}}} - \frac{1}{\sqrt{d_{Pa}}}\right]}$$

$$d_{Pa} >> d_{Pb}$$

$$\frac{1}{\sqrt{d_{Pa}}} << \frac{1}{\sqrt{d_{Pb}}}$$

$$\frac{1}{\sqrt{d_{Pb}}} \approx \left(\frac{1}{\sqrt{d_{Pb}}} - \frac{1}{\sqrt{d_{Pa}}}\right)$$

Rittinger

$$\frac{P}{\dot{m}} = K_R \left[\frac{1}{d_{Pb}} - \frac{1}{d_{Pa}}\right] \rightarrow d \text{ unit } (m)$$

Kick

$$\frac{P}{\dot{m}} = K_K \ln \left(\frac{d_{Pa}}{d_{Pb}}\right) \rightarrow d \text{ (anything) bcz there is ratio}$$

Bond

$$\frac{P}{\dot{m}} = K_b \cdot \left(\frac{1}{\sqrt{d_{Pb}}} - \frac{1}{\sqrt{d_{Pa}}}\right) \rightarrow (mm)$$

Unit of $P \rightarrow kW$ - power required for crushing.

$\dot{m} \rightarrow ton/hr$

Q.> What is the power required for crushing 100 tons/hr of feed if 80% of feed passes through a 2 inch of screen, 80% pdt passes through 1/8 inch screen.

$$k_b = 0.3162 \times w_i$$
$$= 0.3162 \times 12.74$$
$$= 4.028$$

2.54cm = 1in

$$\frac{P}{} = 100 \times 4.028 \left[\frac{1}{\sqrt{\cancel{1/8}}} - \frac{1}{\sqrt{2}}\right]$$

$$= \cancel{4.028}\ 854.467\ \frac{ton}{hr} \times \frac{kWh}{ton} \times \frac{2.54cm}{1in} \times \frac{10mm}{1cm}$$

$$d_{pb} = \frac{1}{8} in \times \frac{25.4mm}{1in}$$

$$d_{pa} = 2 in \times \frac{25.4mm}{1in}$$

$$P = 169.558\ kW$$

$$1HP = 746W$$

$$P = 169.558 \times kW \times \frac{1000W}{1kW} \times \frac{1hp}{746W}$$

$$=$$

Sep 24, 14

Q) Particles of avg. size 50×10^{-4} m are crushed to an avg. pdt size of 10×10^{-4} m at rate of 20 tons/hr. At this rate crusher consumes 40 kW power of which 8 kW is required to run the empty mill. Calculate the power consumption if 12 tons/hr of this pdt is further crushed to an avg. pdt size of 5×10^{-4} m by using rittinger law.

$$\frac{35}{20} = k_R \left[\frac{1}{10 \times 10^{-4}} - \frac{1}{50 \times 10^{-4}}\right]$$

$$k_R = \cancel{7.14 \times 10^{-4}}\ 2.1875 \times 10^{-3}$$

$$\frac{P}{\dot{m}} = \cancel{7.14 \times 10^{-4}}\ 2.1875 \times 10^{-3} \left[\frac{1}{5 \times 10^{-4}} - \frac{1}{10 \times 10^{-4}}\right]$$

$$P = 26.25\ kW$$

Size Reduction equipment :-

Crushers / Grinders

Basis of product

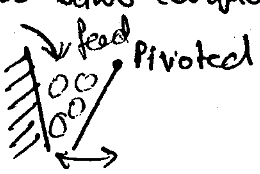
Primary ↳ Coarse Crushers (Pdt size - in, cm, ~~mm~~) eg → Jaw Crusher, Gyratory ", Roll "

Secondary ↳ Fine Grinders (Pdt size - mm, ~~μm~~) eg → Hammer mill, Pebble ", Ball "

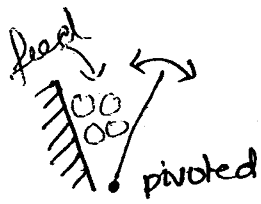
Tertiary ↳ Ultra fine Grinders (Pdt size - nm, μm) eg → Fluid Energy Mill, Attrition "

* Jaw Crusher :- (Compression)

Two Jaws (surface)



Blake Jaw Crusher



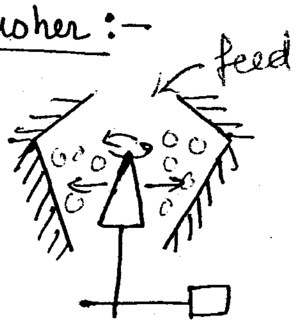
Dodge Jaw Crusher.

Disad. Non-uniform pdt size

Uniform pdt size

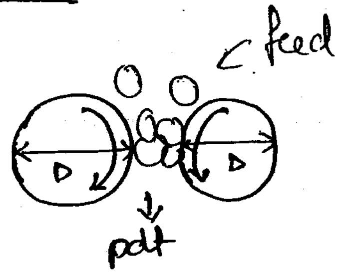
Disad. Block of ~~crushed~~ particles that's y not use in industries.

* Gyratory Crusher :- (compression)



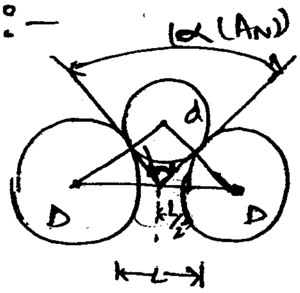
Gyratory Crushers consume less power than jaw crusher. for same capacity.
Gyratory crusher has highest capacity per unit crushing area.

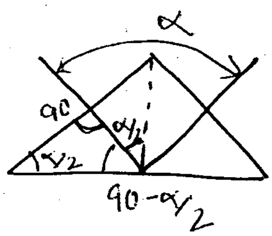
Roll Crushers :- (compression)



pdt size ≈ 1/4 feed size (generally - not for all)

Angle of nip :-





$$\cos\alpha/2 = \frac{Base}{Hyp} = \frac{D/2 + L/2}{D/2 + d/2}$$

$$\boxed{\cos\frac{\alpha}{2} = \frac{D+L}{D+d}}$$

D → roll dia
d → feed dia
L → Max. prod size.

Q.) The feed of 50 mm dia, have to be crushed to a pdt size 'L' such that angle of nip is α = 30° and the roll dias are 1m. Find out the max^m pdt size

$$\cos\frac{30}{2} = \frac{10^3 + L}{10^3 + 50}$$

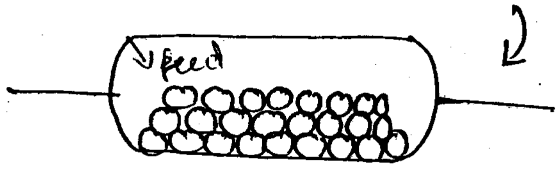
~~L = 149.36 mm~~

L = 14.22 mm

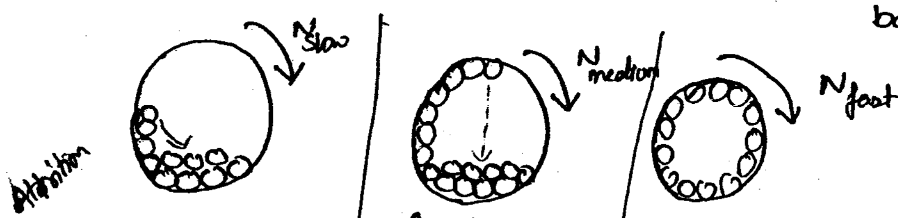
Coefficient of friction μi

$$\boxed{\mu_i = \tan\alpha/2}$$

* Ball Mill :



balls = 30-50% $\frac{\text{Volume}}{\text{volume of ball mill}}$



Cascading Condition	Contracting Condition (operating condition)	Centrifuging condition.

The min rotational speed of ball mill at which the centrifuging condition started (No grinding) is called Critical condition of ball Mill.

$$\boxed{N_{op} = 50\text{–}75\%\ N_c}$$

Critical speed of ball mill (rps) ← $\boxed{N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}}}$ ✓

R = radius of ball mill m

r → radius of balls, m

g → 9.81 m/s²

Q.) What will be the op speed of ball mill would you recommend for the ball mill of 1m dia, charged wid 50mm dia balls

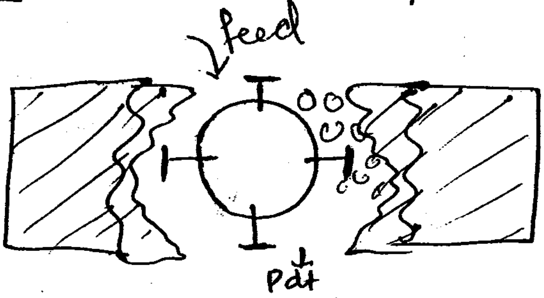
$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{\frac{1}{2} - \frac{50\times10^{-3}}{2}}}$$

$= 0.5114$ rps $\times \frac{1\text{m}}{60\text{s}}$

$= 0.0085$ rpm

$N_c = 43.39$ rpm

* Hammer Mills :- (dynamic impact)



Hammer mills can grind almost anything.

→ semi solid (food, Agricultural)

→ Fibrous Solid (leather, bark)

→ sticky Paste

→ wet solids

→ hard solids, dry.

2010

1.) Sep 26, 14

Mixing -

Dispersion of one component into another.

Purpose

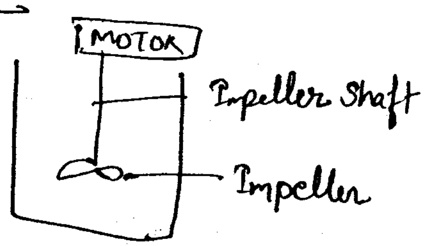
→ To increase the homogenity in the physical property of Mixture. (T, S, C_A).

→ To promote the HT^r & MT^r.

→ To enhance the chem. rxn rate.

→ To increase the homogenity in b/w two immissible phases.

Agitator



Agitation - The generation of flow of current.

Mixing equipments :-

Impeller

↳ on the basis of flow current

→ Axial flow Impeller

→ Radial flow Impeller

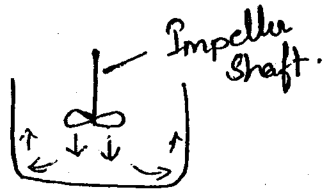
↳ On the basis of Viscosity of mixture

→ Propeller

→ turbine

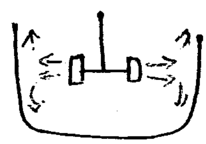
→ Highly efficient Impeller.

Axial flow impeller :-



→ Its blades makes angle ≤90° to the driving shaft to produce current in liquids parallel to the impeller shaft.

Radial flow impeller



→ Its blades are parallel to the axis of driving shaft to produce current in radial or tangential directn in liq.

Propeller :-

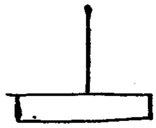
It is used for the Low Viscosity fluids.

→ Axial flow impeller

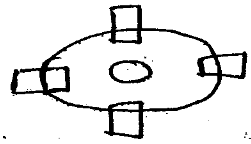
Turbine

→ Used for Moderate viscosity fluids.

→ Radial flow impeller



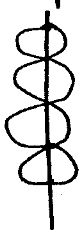
Straight blade turbine



Disc blade turbine

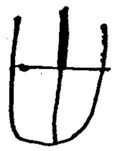
highly Efficient Impeller

Helical tube Impeller



$\mu > 20$ Pa. Sec

Anchor blade Impeller.



$\mu = 50$ Pa. Sec

* Power Consumption in Mixing

$$\frac{P}{\rho N^3 D_i^5} = f\left(\underbrace{\frac{\rho N D_i^2}{\mu}}_{*}, \underbrace{\frac{N^2 D_i}{g}}_{\#}, \frac{D_v}{D_i} \ldots\right)$$

P = Power reqd., W

ρ = fluid density kg/m3

N → Impeller speed rps.

Di = Impeller dia

Dv = Vessel dia.

Power No.

$N_{P_0} = \frac{P}{\rho N^3 D_i^5}$

$\underbrace{\quad}_{*}$ = Reynolds no. of mixing

$$N_{Re} = \frac{\rho N D_i^2}{\mu}$$

$\underbrace{\quad}_{\#}$ = Froude No.

Physical Significance

Q.) If flat blade plate turbine is installed in a 1.8 m dia tank which is filled wid a mixture to a gas depth of 1.8 m. The turbine is 60cm in dia & is operating at 90 rpm. The tank is fitted with 4 baffles. Calculate the power consumption for this tank. If ρ of mixture is 1450 kg/m3 & viscosity = 10 Cp.

N_{Re}	N_{Po}
30000	5.5
50000	5.8
70000	5.9
80000	6.0

1 centi Poise = 10^{-2} P

1 P = 10^{-1} Pa·Sec

$$N_{Re} = \frac{\rho N D_i^2}{\mu} = \frac{1450 \times \frac{90}{60} \times (60\times10^{-2})^2}{10\times10^{-3}}$$

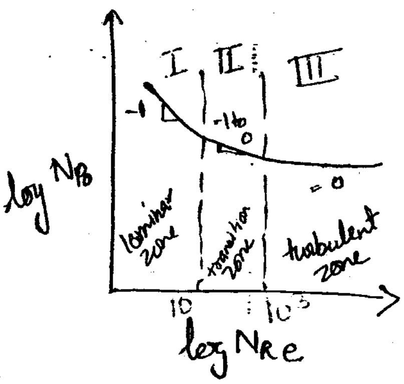
$$N_{Re} = 78300$$

$$N_{Po} \simeq 6 = \frac{P}{\rho N^3 D_i^5}$$

$$6 = \frac{P}{1450 \times \left(\frac{90}{60}\right)^3 \times (60\times10^{-2})^5}$$

$$\boxed{P = 2283.228 \text{ W}}$$

$$\boxed{hp = 7.716 \text{ HP}}$$



for high Reynolds no N_{Re}, Power no. N_P is constant.

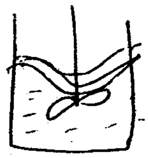
$$N_{Fr} = \frac{N^2 D_i}{g}$$

when there is huge vortex formation. only then N_{Fr} no. is introduce.

$N_{Re} > 300$

~~if Reynolds no is less than vortex formation~~

If there is no vortex formation we neglect the froude no.



whenever there is vortex the mixing will be ~~actheater~~ affected & the degree of mixing is reduced

If we use baffles:-

vortex Removed.

Re ↑

N_{Fr} neglect

* Blending

~~at~~ mixing of solids & liquids.

(mixind at fixed proportion)

Q.7 53.

Gr-2004

P_{In} = const.

N_{Po} = const

D_i = 20%.

S_l =

$$\frac{P}{\rho N^3 D_i^3} = \frac{\cancel{0.20P}+P}{\rho(N_1^3)(D_i^3+0.2D_i)^3}$$

$$\frac{1}{N^3 D_i^3} = \frac{}{(N_1^3)(1.2)D_i)^5}$$

$$\frac{(1.2)^5 \cancel{D_i^5}}{N^3 \cancel{D_i^5}} = \frac{1}{N'^3}$$

$$N'^3 = (1.2)^5 N^3$$

$$N' = (1.2)^{5/3} N$$

$$\boxed{\frac{1.7281}{N^3} = \frac{1}{N_1^3} \quad N'^3 = N^3(0.578) \quad N' = 0.760}$$

Gr-2005

Q-18

2004-53
2005-18
2009-8
2008-42
2006-61
2012-13

Solid-liquid Separation :-

purpose :-
↳ to purify liquid.
↳ to prevent the solid losses
↳ to reduce the solid concn & content in the S-L mixture..

Types
Size of Solid particles
↳ Filtration Coarse solid particles.

↳ Sedimentation separation of fine solid particles.

Sedimentation :-

We want to separate fine solid particles from S-L mixture.

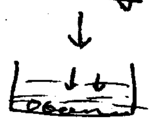
Dewatering Separation of S-L mix into 2 parts → one (rich is in liq), second (rich in solid).

Draining removal of liquid from coarse solid particle.

Classification When we want to separate clear liq from S-L mix by sedimentation.

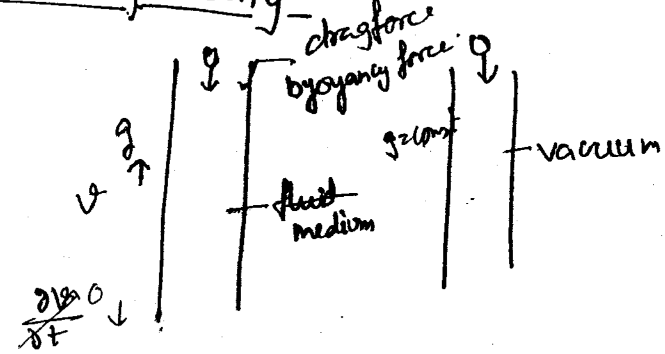
Thickening Separation of thick solid content from S-L mix by sedimentation.

Settling & Suspension. → Separation of fine solid particles in S-L mixtures by settling processes.



Settling of S particles
liq is in rest.

Terminal Settling Velocity -



gr force = Resistive force
terminal settling velocity = const.

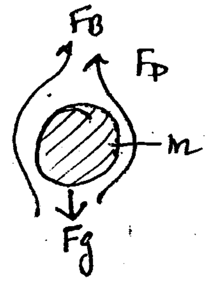
Sedimentation theory :—

Assumption

↳ the particle is regular

↳ the fluid is incompressible & viscosity is constant.

↳ Infinite height medium.



$$m\frac{dv}{dt} = F_g - F_B - F_D$$

coeff of drag; projected area of particle

$$= mg - m_f . g - C_D \frac{\times A_p \times \rho_f \times v^2}{2}$$

$$V_p = m/\rho_p$$

$$m_f = V_f . \rho_f$$

$$m_f = (m_p/\rho_p) . \rho_f$$

$$m.\frac{dv}{dt} = mg - \left(\frac{m}{\rho_p}\right).\rho_f g - \frac{C_D \times A_p \times \rho_f \times v^2}{2}$$

At terminal settling velocity.

$$\frac{dv}{dt} = 0$$

$$0 = mg - \frac{m}{\rho_p}.\rho_f g - \frac{C_D \rho_f A_p v_t^2}{2}$$

$$\boxed{V_t = \sqrt{\frac{2mg(\rho_p - \rho_f)}{C_D . A_p \rho_p \rho_f}}}$$

$$\frac{m}{A_p \rho_p} = \frac{V_p}{A_p} = \frac{\pi/6 \, d_p^3}{\pi/4 \, d_p^2}$$

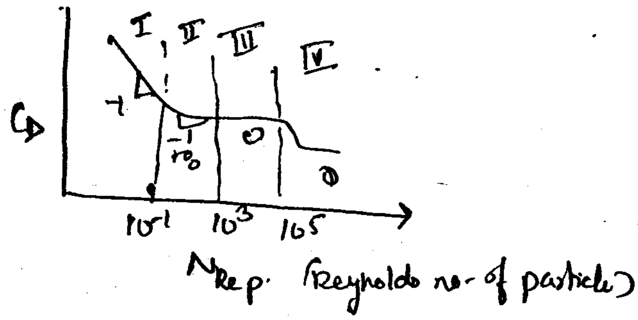
$$\frac{m}{A_p \rho_p} = 2/3 \, d_p$$

$$\boxed{V_t = \sqrt{\frac{4 D_p (\rho_p - \rho_f) g}{3 C_D \rho_f}}}$$

$$\boxed{N_{Re\,p} = \frac{D_p \rho_f v}{\mu_f}}$$

v = velocity of par.

D.. - dia



I $10^{-4} < N_{Rep} < 10^{-1}$

Laminar Regime or Stoke's Law Regime.

$$\boxed{C_D = \frac{24}{N_{Rep}}}$$

$$C_D = \frac{24}{\frac{D_p v_t \rho_f}{\mu_f}}$$

$$V_t = \sqrt{\frac{4 D_p(\rho_p - \rho_f)g}{3\rho_f\left(\frac{24}{\frac{D_p \rho_f V_t}{\mu_f}}\right)}}$$

$$v_t = \sqrt{\frac{4 D_p(\rho_p - \rho_f) \times g \times D_p \times \rho_f \times V_t}{3 \times 24\, \rho_f\, \mu_f}}$$

$$\boxed{V_t = \frac{D_p^2(\rho_p - \rho_f)g}{18\,\mu_f}}$$

II transition Regime

$10^{-1} < N_{Rep} < 10^{3}$

$$\boxed{C_D = \frac{24}{N_{Rep}} + 0.44}$$

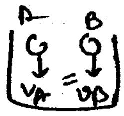
III turbulent Regime, Newton's Law Regime

$$\boxed{C_D = 0.44}$$

IV High turbulent Regime

$$\boxed{C_D \simeq 0.10}$$

Settling Particle :-
Equal



$$\frac{D_{PA}}{D_{PB}} = \text{Settling Ratio.}$$

I

$$V_t = \frac{D_p^2 g(\rho_p-\rho_f)}{10\mu_f}$$

$$V_{tA} = V_{tB}$$

$$\frac{D_{PA}^2 g(\rho_{PA}-\rho_f)}{18\mu_f} = \frac{D_{PB}^2 g(\rho_{PB}-\rho_f)}{18\mu_f}$$

$$\boxed{\frac{D_{PA}}{D_{PB}} = \sqrt{\frac{\rho_{PB}-\rho_f}{\rho_{PA}-\rho_f}}}$$

III

$$v_t = \sqrt{\frac{4D_p(\rho_p-\rho_f)g}{3C_D\rho_f}}$$

$$V_{tA} = V_{tB}$$

$$\sqrt{\frac{4D_{PA}g(\rho_{PA}-\rho_f)}{3C_D\rho_f}} = \sqrt{\frac{4D_{PB}g(\rho_{PB}-\rho_f)}{3C_D\rho_f}}$$

$$\boxed{\frac{D_{PA}}{D_{PB}} = \frac{\rho_{PB}-\rho_f}{\rho_{PA}-\rho_f}}$$

$$\frac{D_{PA}}{D_{PB}} = \left(\frac{\rho_{PB}-\rho_f}{\rho_{PA}-\rho_f}\right)^n$$

$n = 0.5$ for stoke's law Regime.

$n = 1$ for Newton's Law Regime.

Types of Settling :-

↳ Free Settling :- solid concⁿ < 1%, particles can achieve there V_t.

$$\boxed{v_h = v_t \cdot \varepsilon^k}$$

$\frac{\text{Vol. of voids}}{\text{total vol}^m}$ = ε → porosity of Suspension. (vol^m fraction of liquids in S-L mixture.

k → Zaki Richardson Index.

Sep 30, 14

Q.) Find the terminal settling velocity of a particle of 40 μ size having a sp. gravity 2.6 flowing through still water If the settling zone is laminar. all particles may be assume to spherical & the wall effect to be neglected.

Sol^n

$$V_t = \frac{D_p^2 (\rho_p - \rho_f) g}{18 \mu}$$

1 cp = 10^{-3} P s

$$V_t = \frac{(40 \times 10^{-6})^2 (2600 - 1000) \times 9.81}{18 \times 10^{-3}}$$

$$V_t = \frac{40 \times 40 \times 1.6 \times 9.81 \times 10^{-6}}{18}$$

$$\boxed{V_t = 0.0013952 \ m/sec}$$

Q.) Find the drag coeff. for a bacteria moving in water at 15 mm/sec. The size of bacteria is 2μ & $\nu_{bout} \Rightarrow 10^{-6} m^2/sec$

$D = 2 \times 10^{-6}$ m

$\frac{\mu}{\rho} = 10^{-6} m^2/sec$

$V \Rightarrow 15 mm/sec$

$$Re = \frac{\rho V D}{\mu} \Rightarrow \frac{VD}{\mu} \Rightarrow \frac{15 \times 10^{-3} \times 2 \times 10^{-6}}{10^{-6}}$$

Re ⇒ 0.03 ⇒ stokes Low regime

$$C_D = \frac{24}{0.03} \Rightarrow 800$$

Q) In the suspension of galena particle settling under gravity in a water tank. If the density of particle is 7500 kg/m³ $D_p = 0.0002m$ Find the upward velocity of water. If the porosity of suspension is 0.5 & Zaki richarson index is 4.5.

$$\boxed{V_{upward} = \frac{V_h(1-\varepsilon)}{\varepsilon}}$$

for concn soln
↓
Always Stokes region

$$V_h = V_t \cdot \varepsilon^k$$

$$V_t = \frac{D_p^2(\rho_p - \rho_f)g}{18\mu}$$

$$V_t = \frac{(2\times10^{-4})^2 \times (7500-1000)\times 9.81}{18\times10^{-3}}$$

$$V_t = 0.1417 \text{ m/sec}.$$

$$V_h = 0.1417(0.5)^{4.5}$$

$$V_h = 6.26\times10^{-3}$$

$$V_{up} = V_h \times \frac{1-\varepsilon}{\varepsilon} \Rightarrow 6.26\times10^{-3} \text{ m/sec}.$$

Q) Gate 2004

15) $W = B + D$

2005 ⇒ 56)

$D = 1\times10^{-4}$ | $\rho_p = 2800$ $\rho_f = 1000$

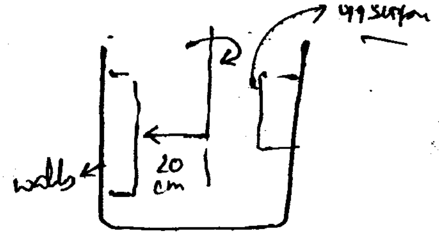
$\mu = 10^{-3}$ $g = 10$

$$V_t = \frac{D_p^2(\rho_p - \rho_f)g}{18\mu} = \frac{10^{-8}\times1800\times10}{18\times10^{-3}}$$

$$\frac{1.8\times10^{-1}}{18} = \frac{0.18}{18} = 10^{-2} \text{ m/sec}.$$

2001 Q) 40)

$$V_t = \frac{\omega^2 r (\rho_p - \rho_f) d_p^2}{18\mu}$$



$$\frac{dr}{dt} \Rightarrow \frac{\omega^2 r (\rho_p - \rho_f) d_p^2}{18\mu}$$

$$\mu = \frac{dr}{\omega^2 r (\rho_p - \rho_f) d_p^2}$$

$$t = \frac{18\mu}{\omega^2 d_p^2 (\rho_p - \rho_f)} \ln \frac{25}{20}$$

$d_p = 0.0001$
$Sp \cdot gr = 2.5$

$$t = \frac{18 \times 10^{-3}}{(6.28)^2 \times 10^{-8} (1500)} \ln (1.25)$$

$$t = \frac{1800}{(6.28)^2 \times 1.5} \times \ln 1.25 = 30.42 \ln 1.25$$

$$\boxed{t = 6.788 \text{ Sec}}$$

2008 41)

$\rho_A = \rho_B$ fluid $\Rightarrow \rho$

$$\frac{V_A}{V_B} = \sqrt{\frac{\rho_A - \rho}{\rho_B - \rho}}$$

2001 32)

$d_p = 6mm$ $\rho_p = 2500$
$V_t = 100\ \mu m/s$ $\rho_f = 1500$ $g = 9.81$

$\mu = ?$

$$V_t = \frac{D_p^2 (\rho_p - \rho_f) g}{18\mu}$$

$$\mu = \frac{(6 \times 10^{-3})^2 \times (1000) \times 9.81}{18 \times 100 \times 10^{-6}} = 196.2 \text{ Pa.s}$$

Oct 04/11

Gate 2013

34) 100 ton/hr

80% feed → 2.54 mm

80% prod → 1.27 mm

100 kW

100 ton/hr

5.08 mm

↳ 2.54 mm

P_2 ? using Bond's law

$P_2 = 70.79$ kW

$$\Rightarrow \frac{P}{\dot{m}} = K_b \left(\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}} \right)$$

$$\frac{100 \text{ kW}}{100 \text{ ton/hr}} = K_b \left(\frac{1}{\sqrt{1.27}} - \frac{1}{\sqrt{2.54}} \right)$$

$$\frac{P \text{ kW}}{100 \text{ ton/hr}} = K_b \left(\frac{1}{\sqrt{2.54}} - \frac{1}{\sqrt{5.08}} \right)$$

$P = 70.79$

$P = 71$ (Nearest integer value)

* Solid Gas Separation :—

Separation of solid from S-G mixture

Purpose ↳ To purify the Gas

↳ To ~~present~~ prevent the loss of solid.

↳ To maintain ~~pol~~ enviornmental policies for the safety of enviornment.

Gas – Solid

↳ Gravitational force

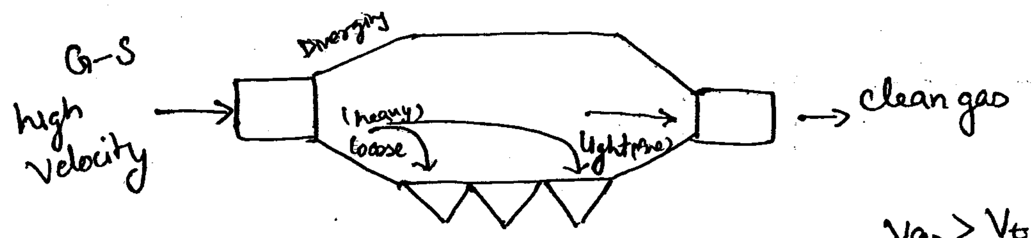
↳ Centrifugal force

↳ Filtration

↳ Electrostatic force

↳ Wet Scrubbing

* Gravity Settling Chamber :-



$V_{gas} > V_t$

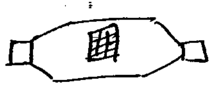
Advantages

→ No power Consumption
→ Simple in Construction
→ low maintaince Cost.

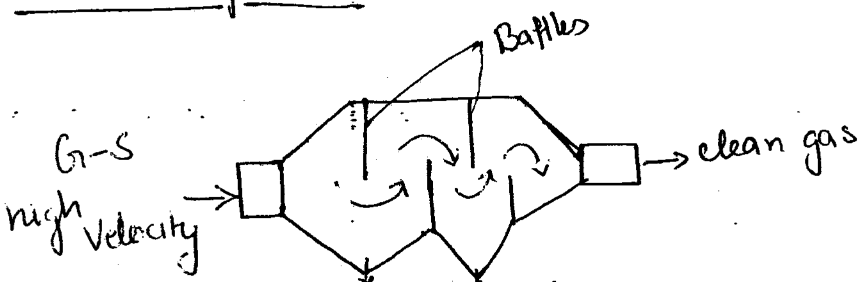
Disadvantage

→ No sharp separation
→ Very low efficiency.
→ Very large space requirement

Modification



* Inertia Separator :-



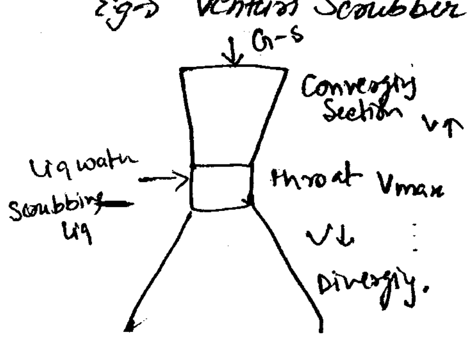
$F_c \propto m$

$F_c \propto m_s$ ↑ high.

* Wet Scrubbers :-

Use third liquid water stream to separate solid from G-S stream

Eg→ Venturi Scrubber.



⇒ Converging section is short & diverging section is long

⇒ Velocity at throat is 60–120 m/s

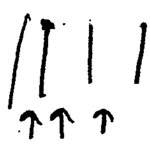
Principle

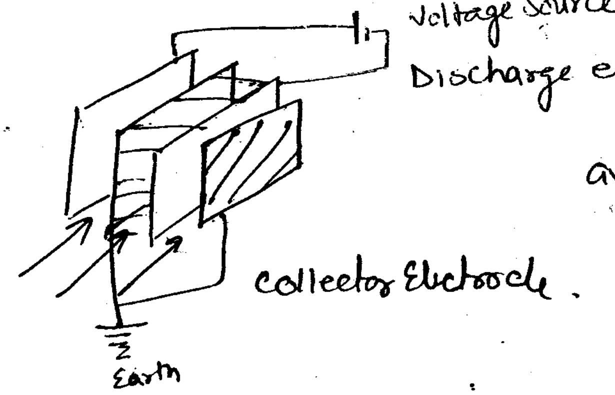
⇒ Kinetic energy of gas-solid stream is utilized to atomised the Scrubbing liquid.

* ESP (Electrostatic precipitator) :—

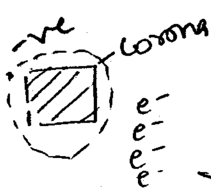
Purpose

↳ Separation of fine solid particles by using Electrostatic force.





avg G-S stream industry 1–3 m/s

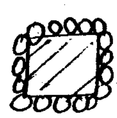


G-S

Ⓢ Ⓢ

Ionised

$S + e \rightarrow S^-$

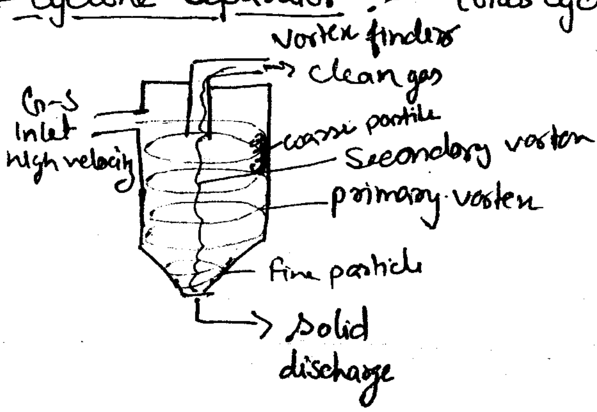


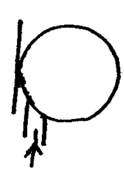
$\tau = 0.1 = 0.2$ sec

Residence tym = 2 sec.

Cross sectional area of discharge electrode is less than that of the collector

* Cyclone Separator :— (Gas Cyclone)





tangential velocity (v)

$S = V^2/rg$

$S \propto 1/r$

Cyclone large, separation ↓

Cyclone small, Separation ↑

Separation factor

$$S = \frac{F_e}{F_g} = \frac{mv^2/r}{mg}$$

$$\boxed{S = \frac{v^2}{rg}}$$

$v \rightarrow$ tangential velocity of input stream
$r \rightarrow$ radius of cyclone

Advantage

Efficiency is more than 99% for the particles of size range 0.1–2mm.

Cyclone Efficiency :-

Overall cyclone

$$\boxed{\eta = \Sigma x_i \eta_i}$$

x_i = mass fraction of solid in feed for i^{th} stream.

$$\eta_i = \frac{\text{mass of solid collected in collector for } i^{th} \text{ stream}}{\text{mass of solid present in feed for the } i^{th} \text{ stream}}$$

eg1 →

	Size	mass in feed	mass collect	x_i
1	1mm	2g	1.1	2/20
2	2mm	3g	2.1	3/20
3	3 "	4g	3.2	4/20
4	4 "	5g	4.6	
5	5 "	6g	5.7	
		20g		

$$\eta_i = \frac{\text{mass collect}}{\text{mass in feed}},$$

2004
Q14.)

$$S = \frac{V^2}{rg}$$

$$= \frac{15^2}{0.1 \times 9.81} = 229.35 \simeq 230.$$

2013
Q15)

$g = 10 m/s^2$, $S = $ ~~[illegible]~~ $d = 0.5 m$
$V = 20 m/s$

$$S = \frac{20 \times 20}{0.25 \times 10} \frac{m^2/s^2}{m \times m/s^2}$$

$$= 160$$

Q.) A dust loaded gas stream enters the pipe of 2cm dia connected to a cyclone separator with the flow rate of 100 kg/hr what will be the separation factor if dia of cyclone is nearly 0.5 m.

<u>Data given</u> :- $\rho_{mix} = 3 kg/m^3$

$d = 2 cm = 1 \times 10^{-2} m$

$\rho = \frac{m}{V}$

$V = \frac{100}{3}$

$\frac{100 \cancel{kg}}{3 \cancel{kg}} \times \frac{m^3}{hr}$

$$= \frac{\left(\frac{100}{3 \times 0}\right)^2}{\cancel{1 \times 10^{-2}} \times 9.81}$$
0.25

$V = q / A_{pipe}$

$V = 29.48 \; m/sec$

$= \frac{\pi}{4} d^2 , \frac{\frac{m^o}{\rho}}{A_{pipe}}$

$S = 354.19$

Q)
2011

Size range (μm)	wt. of feed (g)	wt. of collected (mg)	x_i	n_i	$x_i n_i$
1–5	2	0.1	2/20 = 0.1	0.05	
5–10	3	0.7	3/20 = 0.15	0.233	
10–15	5	3.6	5/20 = 0.25	0.72	
15–20	6	5.5	6/20 = 0.3	0.916	
20–25	3	2.9	3/20 = 0.15	0.966	
25–30	1	1	1/20 = 0.05	1	0.6896
	20				

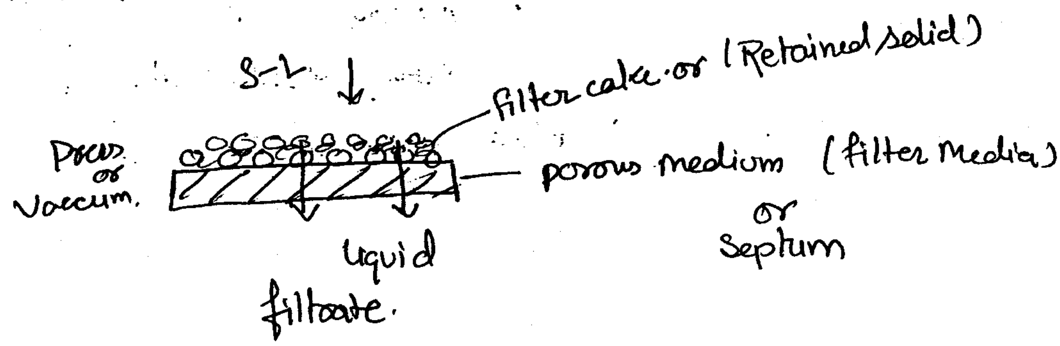
η.

$\eta = \Sigma x_i n_i \Rightarrow \boxed{\eta = 68.96\%}$

* Solid-liquid Separation :-

filtration :-

It may be defined as solid-liquid separation process carried out either under pressure or vaccum, resulting in the separation of undissolved solid particles from a solid-liquid mixture by passage of most of the liquid through a porous medium that retain the solids on it.



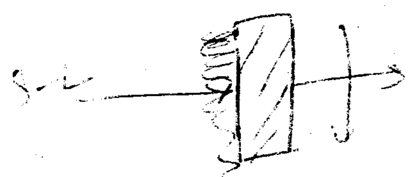
Types of filtration

↳ on the basis of driving force :-
- → Press.
- → Vacuum
- → Gravitational force
- → Centrifugal force.

↳ on the basis of operating Mode
on the basis of discharge of retained solid.
- → Batch
- → Continous.

↳ On the basis of filtration Mechanism
- → Cake filtration  filter cake
-  deep filter bed media → Deep bed filtration low concn of solid
- → Cross flow filtration. high [illegible] solid

Rate of filteration :-



the volumetric flow

* Filtration equipment

- ↳ Batch Pressure filters — filter press.
- ↳ Batch Vacuum filters — vaccum leaf filters, Nutsche filter.
- ↳ Continous press filter. — Rotary drum filter.
- ↳ Continous vaccum — Rotary drum filter & Rotary disk filter
- ↳ Centrifuges. — Batch as well as continous.

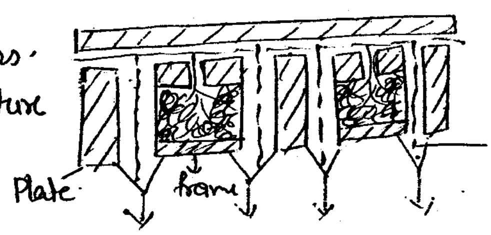
* Filter Presses

- ↳ Plate & frame filter press.
- ↳ Recessed plate ~~filter~~ press.

Plate & frame Filter Press :—

1> S-L fed at high press.

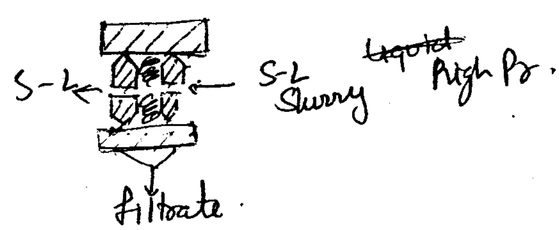
1- high press. S-L mixture



2> washing water ⇒ to remove impurities dissolved from the cake.

3> Compressed air ⇒ to dry the cake.

Recessed plate filter Press

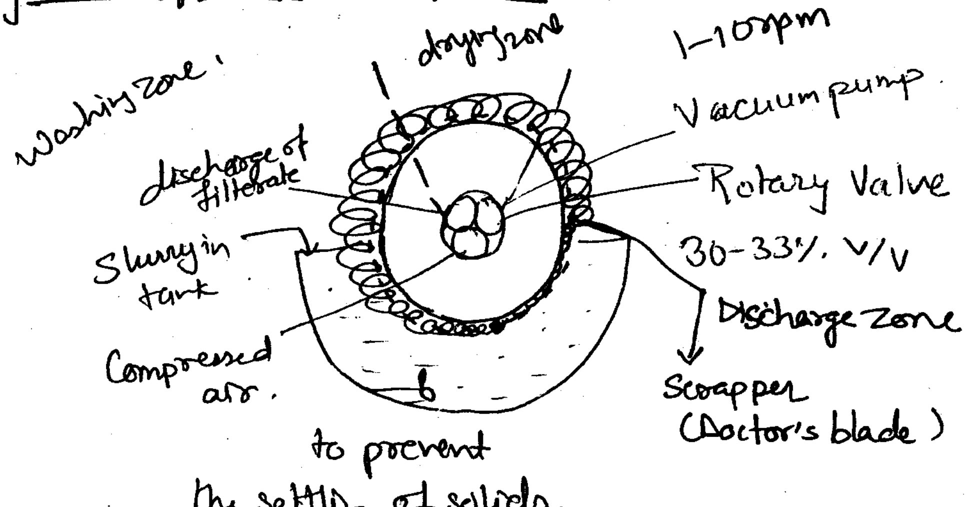


same procedure as above

Advantages

→ operate at high press.
→ large filtration area per space requirement.
→ No power requirement.

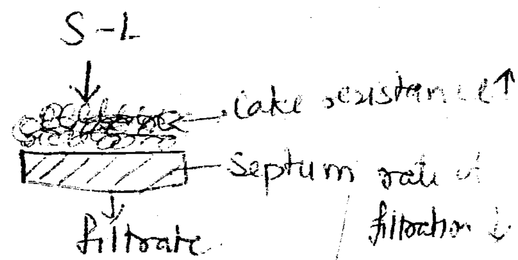
Rotary drum filter under Vacuum :—



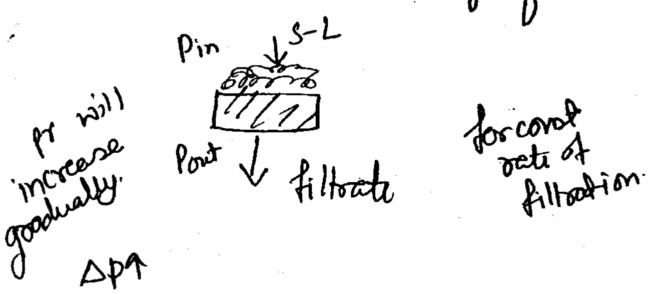
Advants

→ large capacity.
→ desired thickness of cake can be obtained.
→ Continous opr

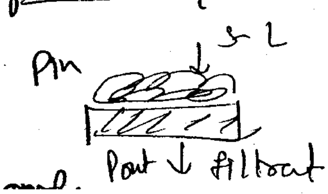
* Principle of Cake filteration :—



↳ Constant Rate of filteration



↳ Constant Pressure filteration



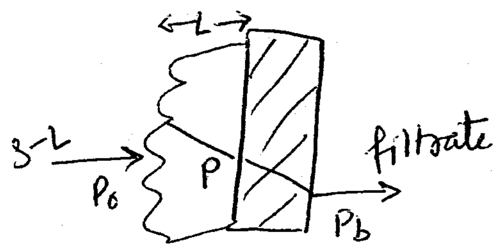
* filter Aid :- (diatomaceous Silica particles)

Expanded particles

↳ By precoating (disadv. by flow of S-L mix it will be depleted)

↳ By Mixing with feed slurry.

* Pressure drop Calculation for Constant press. cake filtration



dv volume of filtrate is passing at time dt,

$$\Delta P_{overall} = (P_a - P_b)$$

$$= (P_a - P') + (P' - P_b)$$

$$\boxed{\Delta P = \Delta P_c + \Delta P_m}$$

Assumptions

→ Uniform dia solid.

→ Incompressible fluid.

→ density of solid is constant.

→ Viscosity of fluid is constant.

$$N_{Re} < 1000$$

u = superficial velocity

$U_{bed} = u \cdot \varepsilon$

$$\frac{\Delta P}{L} = \frac{150\, \mu u (1-\varepsilon)^2}{(\phi_s \cdot D_p)^2 \cdot \varepsilon^3}$$ Kozney-Carman Eqn

μ → Viscosity of fluid

ε → porosity.

D_p → dia

ϕ_s → sphere

u → superficial velocity.

$$\phi_s = \frac{6/d_p}{S_p/V_p}$$

$$\phi_s \cdot d_p = \frac{6}{S_p/V_p}$$

$$\frac{\Delta P_c}{L} = \frac{150\, \mu u (1-\varepsilon)^2}{\left(\frac{6}{S_p/V_p}\right)^2 \cdot \varepsilon^3}$$

$$\frac{\Delta P_c}{L} = \frac{k' \mu u (1-\varepsilon)^2}{\frac{\varepsilon^3}{(S_p/V_p)^2}} \quad \text{--- (1)}$$

$$u = \frac{dV/dt}{A} \quad \text{--- (2)}$$

mass of solid particles in bed $m_c = \rho_p \cdot V_b (1-\varepsilon)$

$$= \rho_p \cdot A \cdot L (1-\varepsilon)$$

V volume filtrate collecting after total filtration time.

$$C = \frac{\text{mass of solid particles retained}}{\text{Volume of filtrate Collected}}$$

$$C = \frac{m_c}{V}$$

$$C = \frac{\rho_p A L (1-\varepsilon)}{V}$$

$$L = \frac{C \cdot V}{\rho_p A (1-\varepsilon)} \quad \text{--- (3)}$$

$$u = \frac{\Delta P_c}{k' \mu (1-\varepsilon)^2 L \frac{(S_p/V_p)^3}{\varepsilon^3}}$$

$$u = \frac{\Delta P_c}{\frac{k' \mu (1-\varepsilon)^2 (S_p/V_p)^2}{\varepsilon^3} \frac{C V}{\rho_p A (1-\varepsilon)}}$$

$$u = \frac{\Delta P_c}{\left(\frac{k'(1-\varepsilon)(S_P/V_P)^2}{\rho_p \varepsilon^3}\right)\frac{\mu c V}{A}}$$

$$\boxed{u = \frac{\Delta P_c}{\frac{\alpha \cdot \mu c V}{A}}} \quad \text{--- (A)} \qquad \& \quad \alpha = \frac{k'(1-\varepsilon)(S_P/V_P)^2}{\rho_p \varepsilon^3}$$

$\alpha \Rightarrow$ Sp. cake Resistance (m/kg)

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Filtration :-

Medium Resistance

$$R_m = \frac{\Delta P_m}{\mu u A} \quad \text{--- (B)}$$

from eq^n (A) & (B)

$$\Delta P_c = \frac{\alpha u \mu c V}{A}$$

$$\Delta P_m = R_m \cdot \mu u A$$

$$\Delta p = \Delta P_c + \Delta P_m$$

$$\Delta p = \frac{\alpha u \mu c V}{A} + R_m \cdot \mu u A$$

$$\boxed{u = \frac{\Delta p}{\left(\frac{\alpha \mu c V}{A} + R_m \mu A\right)}} \quad \text{--- (4)}$$ Superficial velocity

$$u = \frac{dV/dt}{A}$$

$$\frac{dV}{A\,dt} = \frac{\Delta P}{\left(\frac{\alpha \mu c V}{A} + R_m \cdot \mu A\right)}$$

$$\boxed{\frac{dV}{dt} = \frac{\Delta P}{\left(\frac{\alpha \mu c V}{A^2} + R_m \mu\right)}}$$ Rate of filtration.

$$\frac{dt}{dV} = \frac{\frac{\alpha \mu c V}{A^2} + R_m \cdot \mu}{\Delta p}$$

filtration Eqn

$$\boxed{\frac{dt}{dV} = \frac{\alpha \mu c V}{\Delta p \cdot A^2} + \frac{R_m \mu}{\Delta p}}$$

$\alpha = f(\Delta p, L)$ Compressible cake

$\alpha \neq f(\Delta p, L)$ Incompressible cake.

for incompressible cake

$$K_p = \frac{\alpha \mu c}{\Delta p A^2}$$

$$B = \frac{R_m \cdot \mu}{\Delta p}$$

$$\boxed{\frac{dt}{dV} = K_p V + B}$$

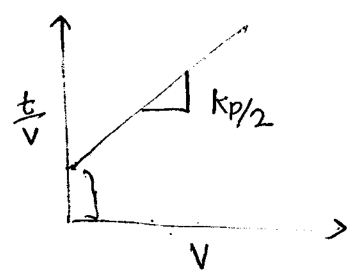
filtration Eqn
Constant pr. filtration & Incompressible cake.

$$\int \frac{dt}{\cancel{dv}} = \int (K_p V + B)\, dV$$

$$t = K_p \frac{V^2}{2} + BV$$

$$\boxed{\frac{t}{V} = \frac{K_p}{2} V + B}$$

$y = mx + c$



units of

$B = s/m^3$

$K_p = s/m^6$

$$\frac{dt}{dV} = K_p V + B$$

$$\int_0^{t_f} dt = \int_0^{V_F} (K_p V + B)\, dV$$

Assembling + filtration + Washing + Open

$$\boxed{t_c = t_F + t_w + t_D}$$

filtration tym

Tym Required for Washing :-

$$= \frac{\text{Volume of washing water}}{\text{Rate of washing.}}$$

$$\text{Rate of Washing} = (\text{Rate of filtration})_{t \to t_F}$$

$$\left(\frac{dV}{dt}\right)_{t_F} = \left(\frac{1}{K_pV + B}\right)_{V_F}$$

Q.) A leaf filter wid $1 m^2$ of filtering area is operating at const press of 1.8 bar and filtration eqn is given as.

$$\frac{dt}{dV} = 45V + 78 \ s/m^3$$

find tym required for washing the cake formed at the of 60 mins of filtration at the same pressure using 3KL of water.

$A = 1 m^2$

$P = 1.8$ bar.

$K_p = 45 \quad , \quad B = 75$

$$\frac{dV}{dt} = \frac{1}{K_pV + B} = \left(\frac{1}{45V + 75}\right)_{V_F}$$

$$\int_0^{3600} \frac{dt}{dV} = \int_0^{V_F} (45V + 75)\, dV$$

$$3600 = \frac{45V_F^2}{2} + 75V \Big|^{V_F}$$

$1 kl = 1000 l = m^3$

$$3600 = \frac{45}{2} V_f^2 + 75 V_f$$

$$\cancel{245}\ \frac{45}{2} V_f^2 + 75 V_f - 3600 = 0$$

$$V_f = 11.09 \ m^3$$

$$\text{rate of filtration} = \left(\frac{1}{45V+75}\right)_{11.09\ m^3}$$

$$= 0.00174 \ m^3/s$$

$$\text{Rate of washing} = 0.00174 \ m^3/s$$

$$t_w = \frac{V_w}{\text{Rate of washing}}$$

$$= \frac{3m^3}{0.00174 \ m^3/s}$$

$$t_w = 1722.28 \text{ sec.}$$

8.)

$V_f = 8m^3$ — 30 min

$t_f = \cancel{30 \ min}$, $V_f = 11.3 m^3$

$t_w = ?$

$V_w = 11.3 m^3$

$$\int_0^{t_f} dt = t = K_p \frac{V^2}{2}$$

$$30 = K_p \frac{\cancel{11}.8^2}{2}$$

$\cancel{K_p = 7.9918}$

$$\cancel{30}\ K_p = 0.9375 = \frac{min}{m^6}$$

$$\text{Rate of washing} = (\text{Rate of filtration}) = \left(\frac{1}{K_p V}\right)_{V_f}$$

$$\text{Rate of filtration} = \frac{1}{\ldots} = 0.09439 \ m^3/min$$

$$t_w = \frac{V_w}{\text{Rate of fil}}$$

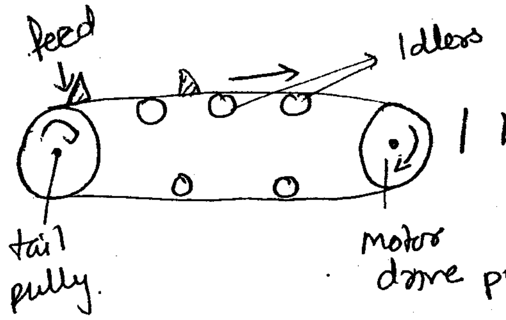
$$= \frac{11.3}{0.0943}$$

$$t = 119.7 \text{ min}$$

* Transportation of Solid :-

⇒ Conveyors (widin industry)

Belt Conveyors:-



if belt ——— → ‿] sagging.

⇒ No. of idlers are more at the top part of belt due to the wt. of feed

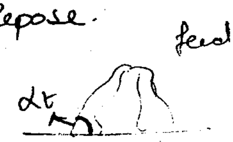
⇒ Dry solid materials,

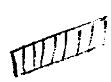
⇒ Granular "

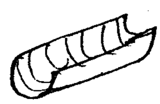
⇒ hard solid "

Types of Belt conveyor

α_t ⇒ angle of Repose.

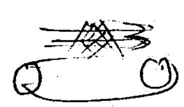


↳ Flat belt Conveyor  α_t high (lyk sticks)

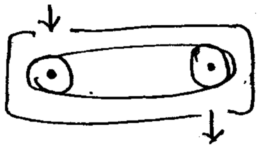
↳ troughed belt Conveyor  α_t low (lyk grains, dust particles)

Disadvantage

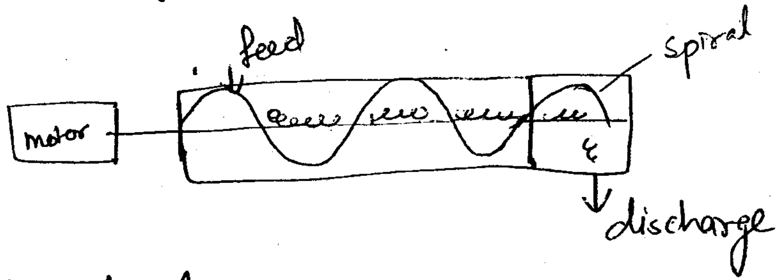
Loss of material due to air.



* Pipe conveyor

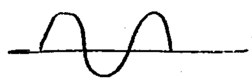


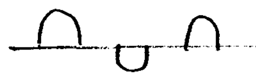
* Screw Conveyor

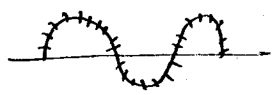


- → Sticky Material
- → Dry Solid
- → Granular
- → Muddy
- → Wet solid
- → Semi solid

Types of Spiral

↳ Continous  sticky materials, wet solids muddy solids

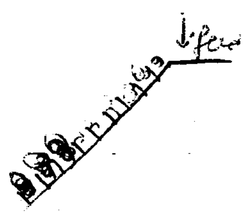
↳ Discontinous  Granular materials, dry solids.

↳ Bladed  required ~~for~~ mixing at the tym of transportation. Suspended slurries.

* Apron Conveyer

(metal plates) Apron plates.

used for $< 30^\circ$ inclination angle. (just lyk esclators)

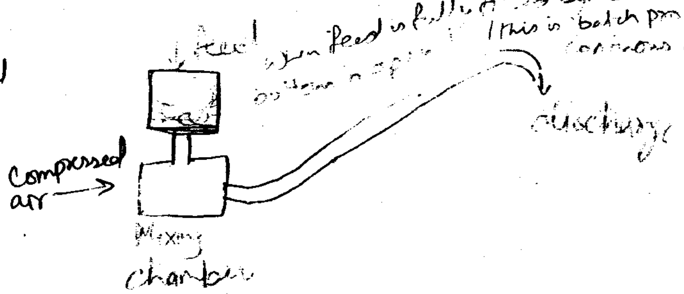


apron plates stands and drags upwards

used for dry & hard solids, metals, ores,

* Pneumatic Conveyor

Transportation of solid wid help of air.

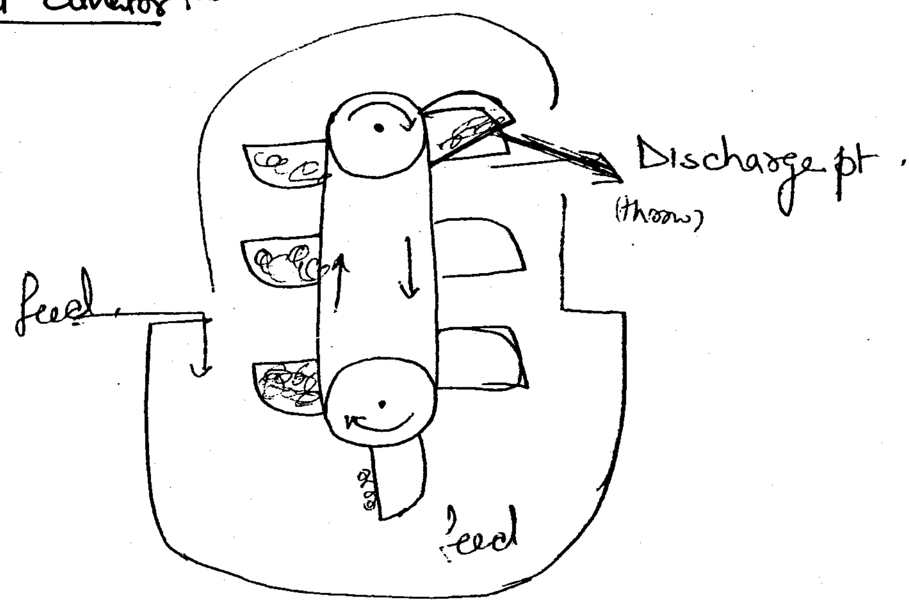


when feed is filled in box ... This is batch process, for making it continous we use another feed box.

Agricultural & ...

used for transportation from bottom to top.

Bucket Elevator :-



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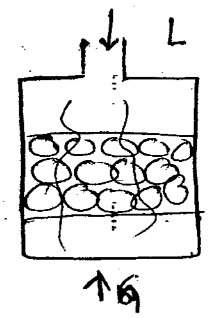
Fludization :-

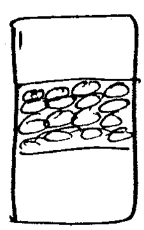


Bed Columns

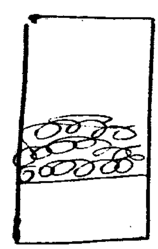
Fixed Bed   Moving Bed

Fixed bed :-

Used for const pr. drop.



Fixed height



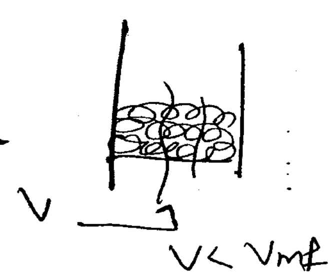
height not fixed.

Moving bed :- Used for Var. press. drop

Fludised bed :-

Case I $V < V_{mf}$

height of bed remain const so Fixed bed condition —



Case -II. $V_{mf} < V < V_{ts}$:—

Fluid will drag particle with this then height of bed increases

* So It is expended bed condition.

Case -III. $V > V_{ts}$

* The particle of solid will leave the column bcz the velocity of fluid is very high.
* known as Elutriation Conditions.

Vmf (minimum fludisation Velocity):—

Minimum velocity of fluids at which the bed starts to expands.

Case -II

* When expanded bed behave like a fluid, then fluidized bed condition.
* hydrostatic law is applicable for fluid
* Lighter density object float on the top of bed
* The tops layer of bed is horizontally formed even if column is tilted.
* When $\rho_f = \rho^o$, Then bed is known as homogeneous fluidised bed.
  ρ_f = dens

Oct 09, 14

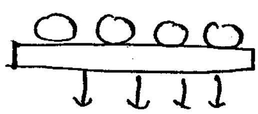
Solid - Solid Separation

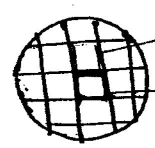
→ basis of their size → Sizing.

→ basis of their density → Sorting.

* On basis of size

⇒ Screening :-

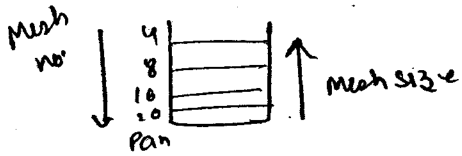




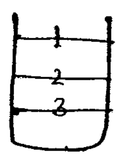
Purpose
↳ Uniform size
↳

Screens are characterized on the basis of mesh no.

$$\text{Mesh no} = \frac{\text{No. of Mesh connected}}{\text{Inch}}, \quad \frac{\text{No. of Mesh}}{\text{Inch}^2}$$



Taylor's standard Screen



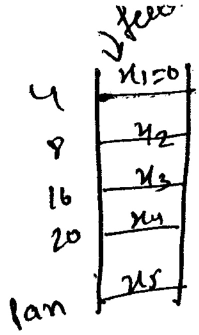
$A_1 = 2A_2$

$l_1^2 = 2l_2$

$\boxed{l_1 = \sqrt{2}\, l_2}$

Screening
↳ Dry Screening — Separation of s-s particles on dry basis.

↳ wet Screening — we feed s-s mixture + water to the screens to remove the undissolved impurities like dust clay.

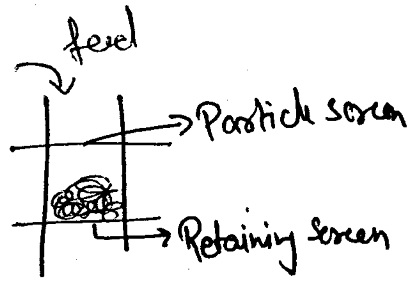


Mesh no	(mm)	retained	of retained dpi part
4	0.43	—	$\frac{0.43+0.36}{2}$
8	0.36	x_2	$\frac{0.36+0.32}{2}$
10	0.32	x_3	$\frac{0.32+0.27}{2}$
16	0.27	x_4	$\frac{0.27+0}{2}$
Pan	0	x_5	

Types of Screen :–

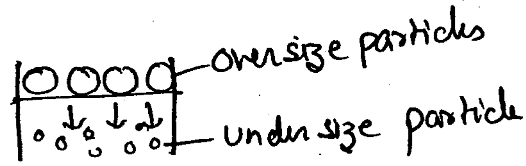
↳ Based on particle retained

- ↳ Limiting Screens (–) Representation
- ↳ Retaining Screens (+)



Types of particle

↳ on basis of screen



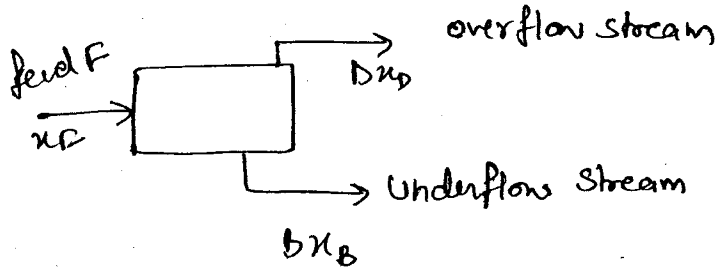
$-20+26 = x_1$

> 20 mesh passed
> 26 Mesh Retain

20/26

* Screen Effectiveness

$$E = \text{Recovery} \times \text{Rejection}$$



desired pdt = Oversize particle.

$$\text{Recovery} = \frac{\text{Amt of desired material in overflow}}{\text{Amt of desired material in feed}} = \frac{D x_D}{F \cdot x_F}$$

$$\text{Rejection} = \frac{\text{Amt of Undesired material in underflow}}{\text{A " " " " " feed}}$$

$$= \frac{B(1-x_B)}{\ldots}$$

$$E = \frac{D}{F} \cdot \frac{x_D}{x_F} \times \frac{B}{F} \frac{(1-x_B)}{(1-x_F)}$$

Overall MB

$$F = D + B$$

Component MB

$$F x_F = D x_D + B x_B$$

$D x_F + B x_F = D x_D + B x_B$

$D(x_F - x_D)$

$B x_F + x_B$

$$\boxed{\frac{D}{F} = \frac{x_F - x_B}{x_D - x_B}}, \quad \boxed{\frac{B}{F} = \frac{x_D - x_F}{x_D - x_B}}$$

$$\boxed{E = \frac{(x_F - x_B)(x_D)(1-x_B)(x_D - x_F)}{x_F(1-x_F)(x_D - x_B)^2}}$$

$$\boxed{E' = 1 - E}$$

Screen effective based on

E = oversized particle

E' = undersized particle.

* Screen Capacity

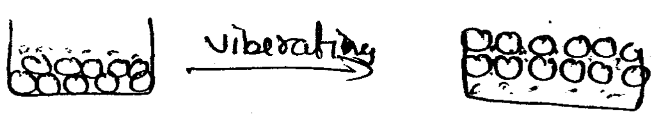
Mass passing through screen per unit screening area per unit tym

$$\frac{kg}{m^2 \cdot s}$$

capacity ↑ , Effectiveness ↓

Capacity ↓ , Effectiveness ↑

* Screening Mechanism :-



Separation probability = K the small particles pass [illegible]

Stratification orientation of particles.

* Types of Screening equipment

on basis of operating mode
- ↳ Stationary
- ↳ Moving.

on basis of particle size
- ↳ Coarse Screens
- ↳ Intermediate
- ↳ fine Screens.

Stationary :—

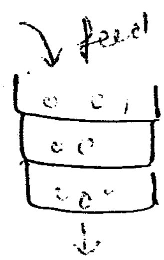
due to gravity,

Less effective
good for separation of coarse particle.

Moving :-
- ↳ Vibrating
- ↳ Gyratory
- ↳ Circular Motion
- ↳ Revolving
- ↳ Shaking.

* Grizzly Screens

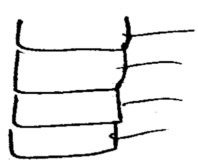
In industry Deck ≃ Screen



Adv
- → Simple construction
- → No power consumption.

D/d
- Efficiency ↓
- Capacity ↓
- No sharp separation
- Blinding (screen ki opening block ho jana)

* Vibrating Screens

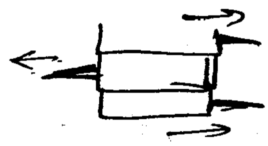


Vibrating motion are created.

Adv
- ~~Hig~~ Max^m efficiency
- fine size particles are separated.

Power Requirements are high.

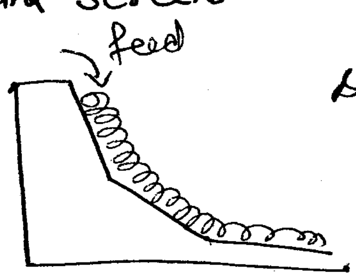
* Gyratory Screens (maxm 4 decks can be used)



→ Separation high
⇒ Capacity maxm

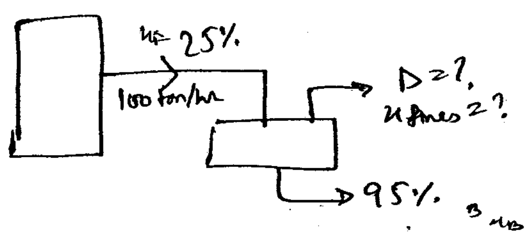
Efficiency Low
Power requirement high
Maintainace Cost high.

* Banana Screens



Slope is decreasing
gravitational force.

Q) An industry uses a 5mm screen to separate oversize from undersize fines. The screen analysis for a furnance output was found to contain 25% fines. The screen efficiency was known to be 50%. The underflow from the screen contains 95% fines. If furnance prodn rates is 100 tons/hr. Find the pdt rate and % of fines present in it.



as in question all feed data is given on undersize basis

so, ⇒ $x_B = 1 - 0.95$
$x_F = 1 - 0.25$

$E = 0.5$

$$= \frac{D}{F}\frac{x_D}{x_F} \times \frac{B}{F}\frac{(1-x_B)}{1-x_F}$$

$$0.5 = \frac{(x_F - x_B)(x_D)\ (1-x_B)\ (x_D - x_F)}{x_F\ (1-x_F)\ (x_D - x_B)^2}$$

$$0.5 = \frac{(0.25 - 0.95)x_D\ (1-0.95)\ (x_D - 0.25)}{0.25\ (1-0.25)\ (x_D - 0.95)^2}$$

$$0.5 = -0.7 \times 0.05\ (x_D^2 - 0.25\, x_D)$$

$$2.6785\,(x_D^2-0.95)^2 = (x_D^2-0.25x_D)$$

$$2.6785\,(x_D^2+0.9025-1.9x_D) = x_D^2-0.25x_D)$$

$$1.6785\,x_D^2-1.65x_D+0.9025=0$$

Ans.
$x_D = 0.055$
$D = 86.6$ ton

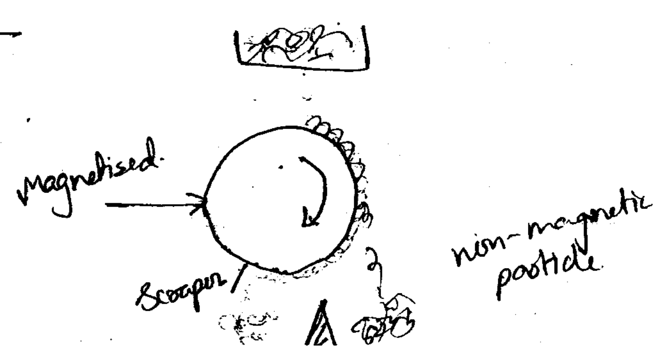
$$0.5 = (1-0.25-1+0.95)\,x_D\,(1-1+0.95)\,(x_D-1-$$

$1.65 \pm \sqrt{}$

Magnetic Susceptibility

* Magnetic Characteristics :—
  - ↳ Ferro magnetic → very strong affection towards magnetic field (Fe, Ni, Co)
  - ↳ Para magnetic → weak affection towards magnetic field (Claycarbonate, SO_4^{2-})
  - ↳ Dia magnetic → Zero attraction towards " " (Bi, Ag, Au) or repelled — Gold

* Magnetic Drum Separator :—



* Classification with water :—

separation s-s mixture on the basis of

↳ settling velocity.

Oct 10, 14

Principles

↳ free

↳ Hindered.

* Laws of classification –

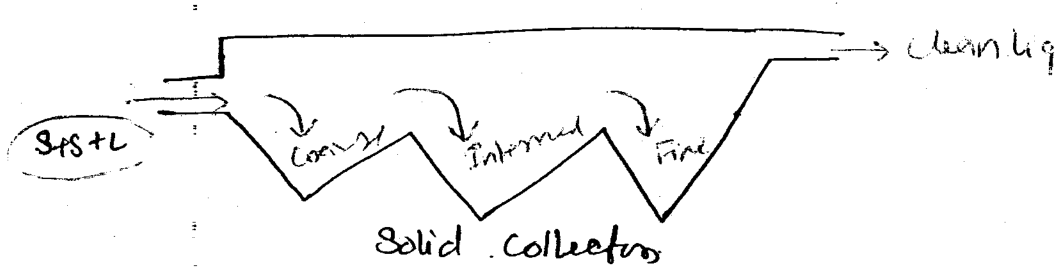
⇒ The regular particles have relatively high settling velocity than the irregular particles of same size and ~~shape~~ density

⇒ The heavy gravity particles have relatively faster settling velocity than the low gravity particles of the same size & shape

⇒ Coarse particles have relatively faster settling velocity of same density & shape.

⇒ The settling velocity of particles increases as the viscosity of fluid decreases.

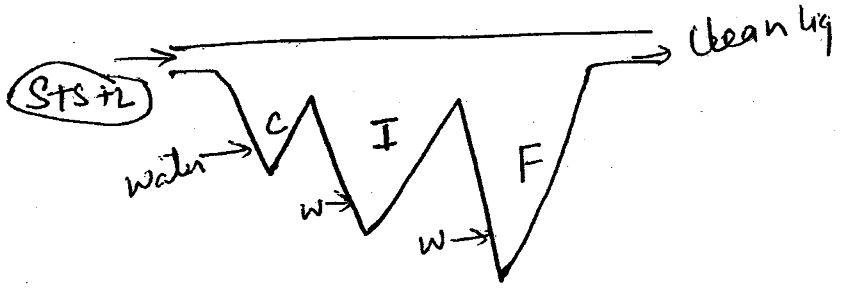
⇒ Gravity Settling Classifier :—



Disadvan

⇒ No sharp separation.

→ Spitzkasten classifier

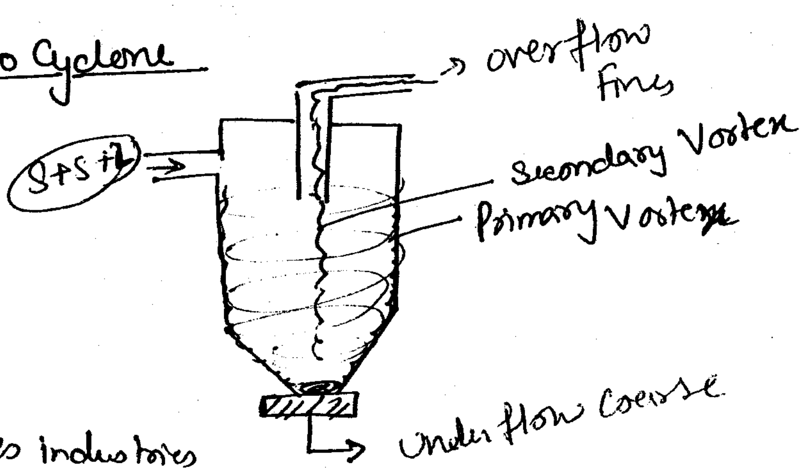


volm of chamber is continuously increasing bcz

→ liquid hold up capacity increases.

→ Minimise the disturbance.

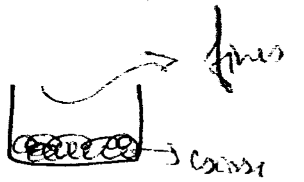
→ Hydro Cyclone



→ Ores industries

→ Steel industries

Elutriation :-



P-103
Q-67

$$\cos \alpha/2 = \frac{D+L}{D+d}$$

$$\cos 15 = \frac{1000+12}{1000+d}$$

$d = 47.6$ mm.

$L = 12$ mm

$D = 1000$ mm

$Sp.G = 2.35$

$\alpha = 30°$

Storage of solids

- Silo
- Bin

> permanent storage. (Inventory)

- Hopper

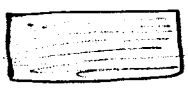
Silos

H = heigh
D = dia

H > D

Hard materials are stored. (

Bins



D ≥ H

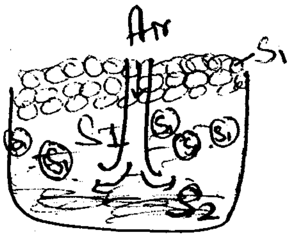
Hoppers

Temporary storage.

Floatation :—

S–S high ρ diff.

froth floatation



S_1 hydrophobic (No water wet)

hydrophillic (water wet) S_2

Coagulation & Flocculation :—

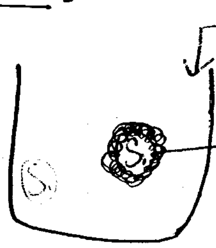
Coagulant ↓ destabilized

coagulato <

S_1 S_2 S_3

hydrophobic

Floculation agent



destabilized floc

Size agglomeration of destabilized particles is flocculation.

* Flow meters

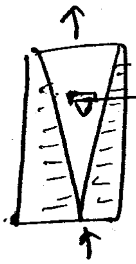
↳ Constant head flow meters → Rotameter

↳ Constant Area flow meters.

↳ Venturimeter

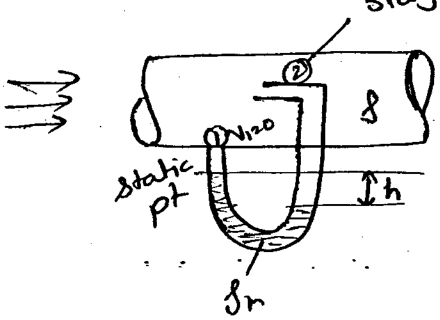
↳ orifice meter

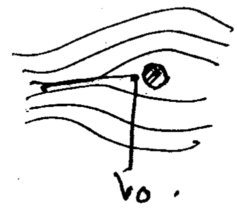
↳ pitot tube



flow rate measure

* Pitot tube





$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$Z_1 \approx Z_2$$

$$V_2 = 0$$

$$\left(\frac{P_2 - P_1}{\rho g}\right) = \frac{V_1^2}{2g}$$

$$V_2 = \sqrt{\frac{2(P_2 - P_1)}{\rho}}$$

$$A\left(P_1 + \rho_m g h\right) = \left(P_2 + \rho g h\right) A$$

$$(P_2 - P_1) = (\rho_m - \rho)gh$$

$$V = \sqrt{2(\rho_m - \rho)gh}$$

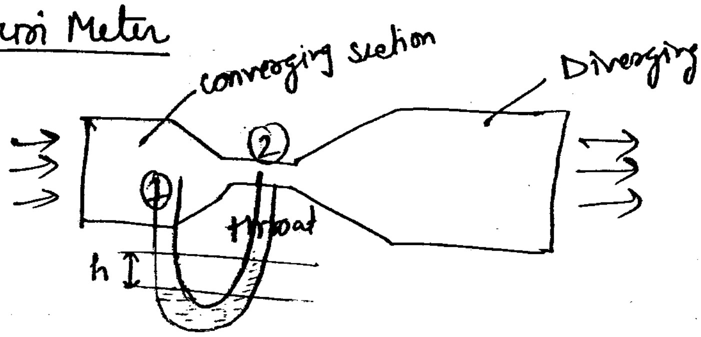
$$V_{act} = C_v \cdot V_{th}$$

$$\boxed{V_{act} = C_v \cdot \sqrt{\frac{2(\rho_m - \rho)\, g h}{\rho}}}$$

C_v = coefficient of velocity.

It cann't be used for the low pressure fluid or gases.

* Venturi Meter



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + \cancel{Z_1} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + \cancel{Z_2}$$

$$\frac{D\rho}{Dt} = \rho \nabla \cdot u$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho}{\partial x} + \frac{\partial \rho}{\partial y} + \frac{\partial \rho}{\partial z} =$$

$$A_1 V_1 = A_2 V_2$$

$$V_1 = A_2 / A_1 \, V_2$$

$$V_1 = \frac{d_2^2}{d_1^2} \cdot V_2$$

$$\frac{P_1}{\rho g} + \left(\frac{d_2}{d_1}\right)^2 \frac{V_2^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\boxed{V_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho \left\{1 - \left(\frac{d_2}{d_1}\right)^4\right\}}}}$$

diameter ratio

$\beta = \frac{d_2}{d_1}$

$$\boxed{V_2 = \sqrt{\frac{2(P_1-P_2)}{\delta(1-\beta^4)}}}$$

$$\boxed{q_2 = A_2 V_2 = A_2\sqrt{\frac{2(P_1-P_2)}{\delta(1-\beta^4)}}}$$

$$q_{actual} = C_D \cdot q_{theo.}$$

$$\boxed{q_{act} = C_D A_2 \sqrt{\frac{2(P_1-P_2)}{\delta(1-\beta^4)}}}$$

$$W = J/s = \frac{N \cdot m}{s}.$$

$$\boxed{\text{Power} = (P_1 - P_2) V_2}$$

Pressure Recovery is approx 99%.

$$\boxed{C_D \approx 0.99}$$