19 sept
Monday

Pnuematic transport

↳ use of gas for transport.

dilute phase pnuematic transport:

Particles are distributed uniformly and this method is used for small distance, Require high gas velocity.

↳ $u_{fluid} > U_{salting\ velocity}$

$u_f > U_{chocking\ velocity}$

salting → minimum fluid velocity at which horizontal pnuematic transport happen

$G \rightarrow \frac{\text{Mass flow rate}}{\text{crossectional area}}$

chocking → minimum fluid velocity at which verticle pnuematic transport happen.

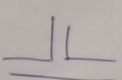
Since terminal velocity is size dependent and we will never have uniform particles that's why we have defined salting and chocking velocities.

Bends and T-Joint

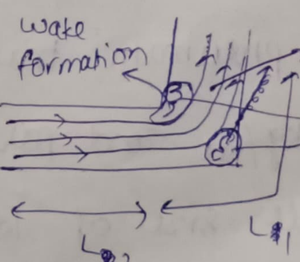
TO Join two pipe line we use Bends and T-Joints.

Bends: curved Joints

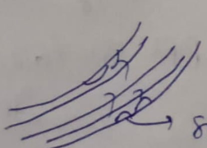
T-Joints: If Joint is perfect 90° then it is T Joint



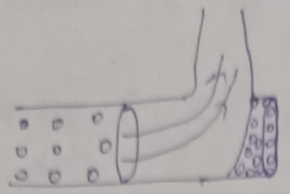
Energy loss
⇓
Pressure drop (ΔP)



Energy loss will be much more higher in L_1 than L_2 because of wake formation.



Blind T-Joints



friction ~~to~~ depends on fluid and wall

so less energy loss
- Less friction loss { As there will be less friction ~~loss~~ b/w particle-2 interaction }
- very less wake formation

for fluid transports bends are more preferable. but in pneumatic transport Blind T-Joints are used

$$\frac{M_p \; (\text{mass flow rate})}{\rho_f \, U_{salting} \, A} = \left(\frac{1}{10^{1440x+1.96}}\right)\left(\frac{U_{salt}}{\sqrt{gD}}\right)^{(1100x+2.5)}$$

Salting velocity

ρ_f = density of fluid, A = Area, x = particle size (mean particle size)

Chocking velocity

unknowns: $U_{chocking}$, $\varepsilon_{chocking}$

$$\frac{U_{chocking}}{\varepsilon_{chocking}} - U_{Terminal} = \frac{G}{\rho_{particle}(1-\varepsilon_{CH})}$$

$G = \dfrac{\text{mass flow Rate}}{\text{Area}}$

$$\rho_f^{0.77} = \frac{2250\,D\,(\varepsilon_{CH}^{-4.7} - 1)}{\left(\frac{u_{CH}}{\varepsilon_{CH}} - u_t\right)^2}$$

D = Diameter of particle

Q. A dilute phase pneumatic transport system is employed to transport 900 kg/hr sand particles having density of 2500 kg/m³ and mean particle size of 100 µm between two points in a plant seperated by 30 m horizontal distance using ambient air. Estimate the salting velocity. o Diameter of pipe is 76.2 mm or 3 inch.

$$\frac{M_p}{\rho_f U_{salt} A} = \frac{1}{10^{1440x+1.96}} \left(\frac{U_{salt}}{\sqrt{gD}} \right)^{(1100x+2.5)}$$

air	water
$\rho = 1\,kg/m^3$	$\rho = 1000\,kg/m^3$
viscosity 0.01 cp	viscosity 1 cp

centipoise

$M_p = 900\,kg/hr = \frac{900\,kg}{3600\,s}$

$\rho_f = 1\,kg/m^3$

$\rho_p = 2500\,kg/m^3$

$x = 100\mu m = 10^{-4} m$

$L = 30\,m$

$D = 76.2 \times 10^{-3}\,mm$

$A = \frac{\pi D^2}{4} = \frac{\pi}{4}(0.0762)^2$

Put all information in the formulla.

$U_{salting} = 10.4434\,m/s$

$U_{superfical} = 1.5 \times U_{salting} = 15.6651\,m/s$

pneumatic transport system should be operated at 1.5 times the salting velocity

Q It is required to use an existing 50mm inside diameter verticle smooth pipe as lift line to transfer 2000 kg/h of sand of mean particle size 270 μm and $\rho_{particle}$ 2500 kg/m3 to a process 50m above the solids feed point. Determine chocking velocity. Pipe diameter = 50mm and pipe length = 50m and $U_T = 0.52\,m/s$

$\rho_p = 2500\,kg/m^3$

$x = 270\mu m = 0.27 \times 10^{-3} m.$

$L = 50\,m$

$D = 50mm = 0.05m$

$A = \frac{\pi (0.05)^2}{4}$

$M_p = 2000\,kg/hr = \frac{2000}{3600} = 0.56\,kg/s$

$\rho_f = 1\,kg/m^3$

$U_T = 0.52\,m/s$

$$\frac{U_{CH}}{\varepsilon_{CH}} - U_T = \frac{G}{\rho(1-\varepsilon_{CH})}$$

$$G = \frac{M_p}{A} = \frac{0.56}{0.00196} = 282.94\,kg/m^3$$

$$\rho_f^{0.77} = \frac{2250D(\varepsilon_{CH}^{-4.7} - 1)}{\left(\frac{U_{CH}}{\varepsilon_{CH}} - U_T\right)^2}$$

Put $\frac{U_{CH}}{\varepsilon_{CH}} - U_T$ from eq^n 1 in eq^n 2

$1 - \varepsilon_{CH} = \frac{G}{\rho_p (RHS)}$

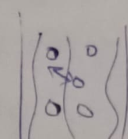
$1-$

$$\rho_f^{0.77} = \frac{2250\, D\,(\varepsilon_{CH}^{-4.7} - 1)}{\left(\frac{G}{\rho_p(1-\varepsilon_{CH})}\right)^2}$$

or

$$\frac{G}{\rho_p(1-\varepsilon_{CH})} = \underbrace{\left(\frac{2250\, D\,(\varepsilon_{CH}^{-4.7} - 1)}{\rho_f^{0.77}}\right)^{\frac{1}{2}}}_{RHS}$$

ε_{CH} will be always greater than 0.9 in pneumatic transport



Void fraction (ε_{CH}) will be higher

Initial guess ε_{CH} 0.9 $\quad \underbrace{LHS \quad RHS}_{\text{calculate}}$

$$\varepsilon_{CH} = \boxed{1 - \frac{G}{\rho_p [RHS]}}_{calc}$$

ε_{CH} assumed	, ε_calc
0.9	0.9975
0.93	0.9905 12
0.971	0.974
0.972	0.97156

So, $\varepsilon_{CH} = 0.972$

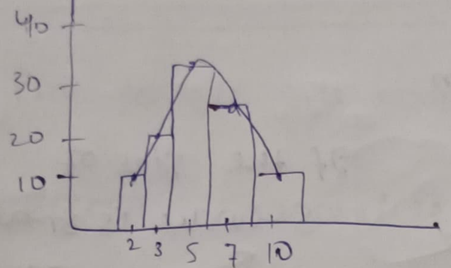
Now

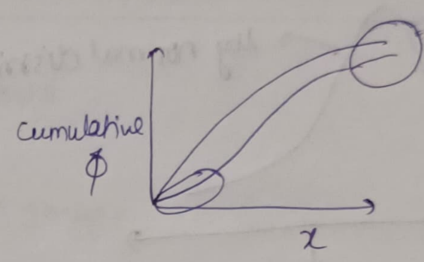
$$\frac{U_{CH}}{0.92} - 0.52 = \frac{282.94}{2500(1-0.972)}$$

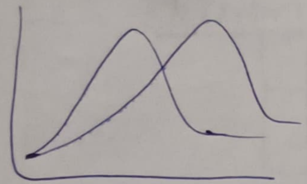
Fine particle characterization:

Size distribution

Particle size	wt%. ($d\phi$)	cumulative distn. (ϕ)
$1 \to 3$ { 2	10	10
$3 \to 5$ { 3	20	30
5	35	65
7	25	90
10	10	100

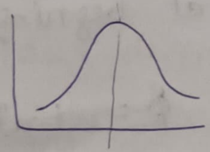


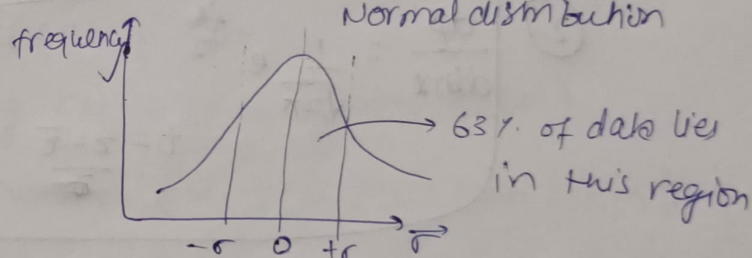




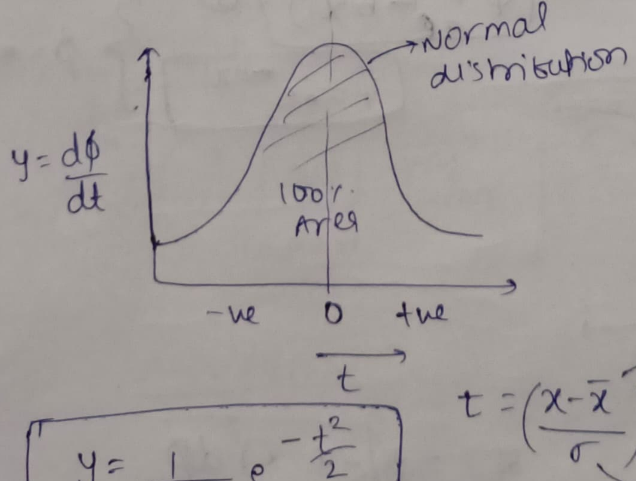
$\Downarrow$

Normal distribution





$$f = \frac{1}{\sqrt{2\pi}} e^{-\frac{\sigma^2}{2}}$$



$$t = \left(\frac{x - \bar{x}}{\sigma}\right)$$

$\bar{x}$ → avg

σ → standard deviation

$$\boxed{y = \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}}$$

Particle size analysis
by T. Allen

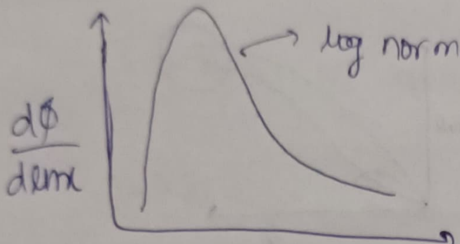
$$\frac{d\phi}{dt} = \frac{1}{\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}}$$

$$t = \frac{x-\bar{x}}{\sigma}$$

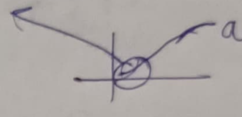
$$\sigma t = x - \bar{x}$$

$$\sigma\, dt = dx$$

$$\boxed{\frac{d\phi}{dx} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}}} \quad (1)$$



If the size of. S-curve is small at begning and large at end



(2)

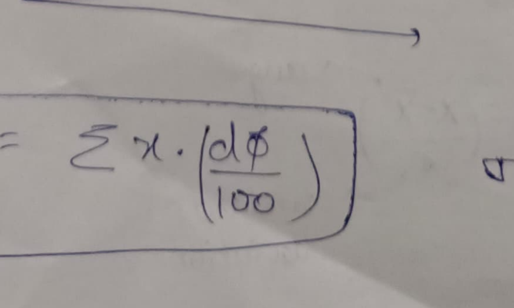
$$\boxed{\frac{d\phi}{d\ln x} = \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} \qquad t = \frac{z-\bar{z}}{\sigma} \qquad z = \ln x}$$

If the size of S-curve is small at begning and small at the end then

<u>Rosin-Ramler</u> ~~$\phi = e^{-bx^n}$~~

Eq^n ⇒ $\boxed{\phi = e^{(-bx^n)}}$ (3)

$$\left.\begin{array}{l}\boxed{\phi = e^{(-bx^n)}} \\ \boxed{\phi = e^{-bx^n}}\end{array}\right\} \phi = e^{-bx^n}$$



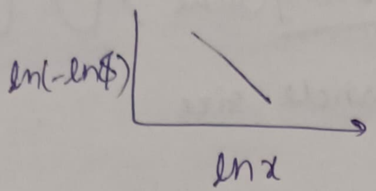
$$\boxed{\bar{x} = \sum x \cdot \left(\frac{d\phi}{100}\right)}$$

$$\sigma = \sqrt{\sum \frac{(x-\bar{x})^2\, d\phi}{100}}$$

$\phi = e^{-bx^n}$ here ϕ is fraction or $\frac{\text{cumulative \%}}{100}$

$\ln(\phi) = -bx^n$

$$\underbrace{\ln(-\ln(\phi))}_{y} = \underbrace{\ln b}_{c} + \underbrace{n \ln x}_{mx}$$



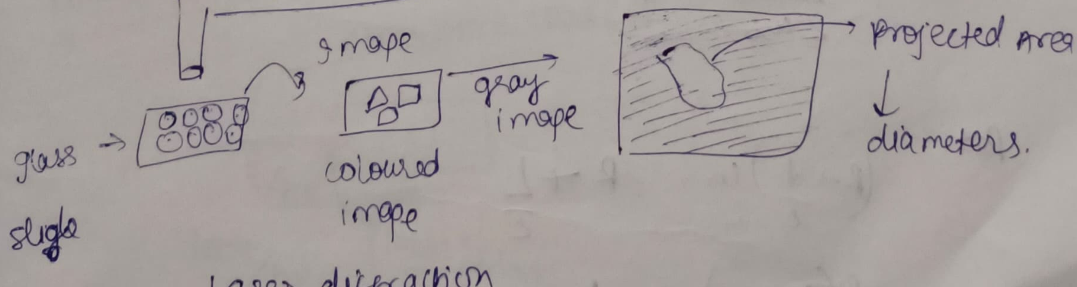
Fine particle size measurement

1. microscopic → visualize → image
   - → light (3–150 μm)
   - → Electron microscope (EM)
     - → scanning EM – SEM (upto 10nm)
     - → Transmission EM – TEM (less than 10nm)
   - → Atomic force microscope

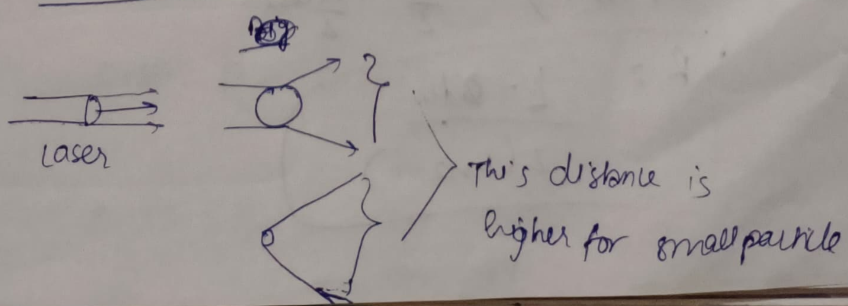
2. laser diffraction

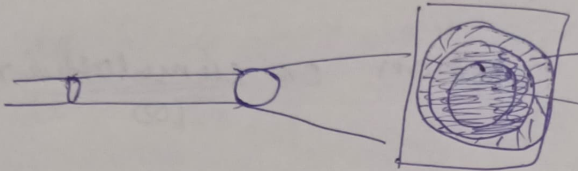
3. Light scattering (DLS)

Light microscope

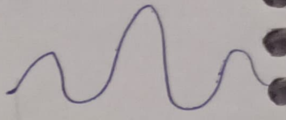


Laser diffraction





→ small particle will have bigger fringe

from these fringes we calculate Intensity curve 

↓

particle size