PNEUMATIC TRANSPORT

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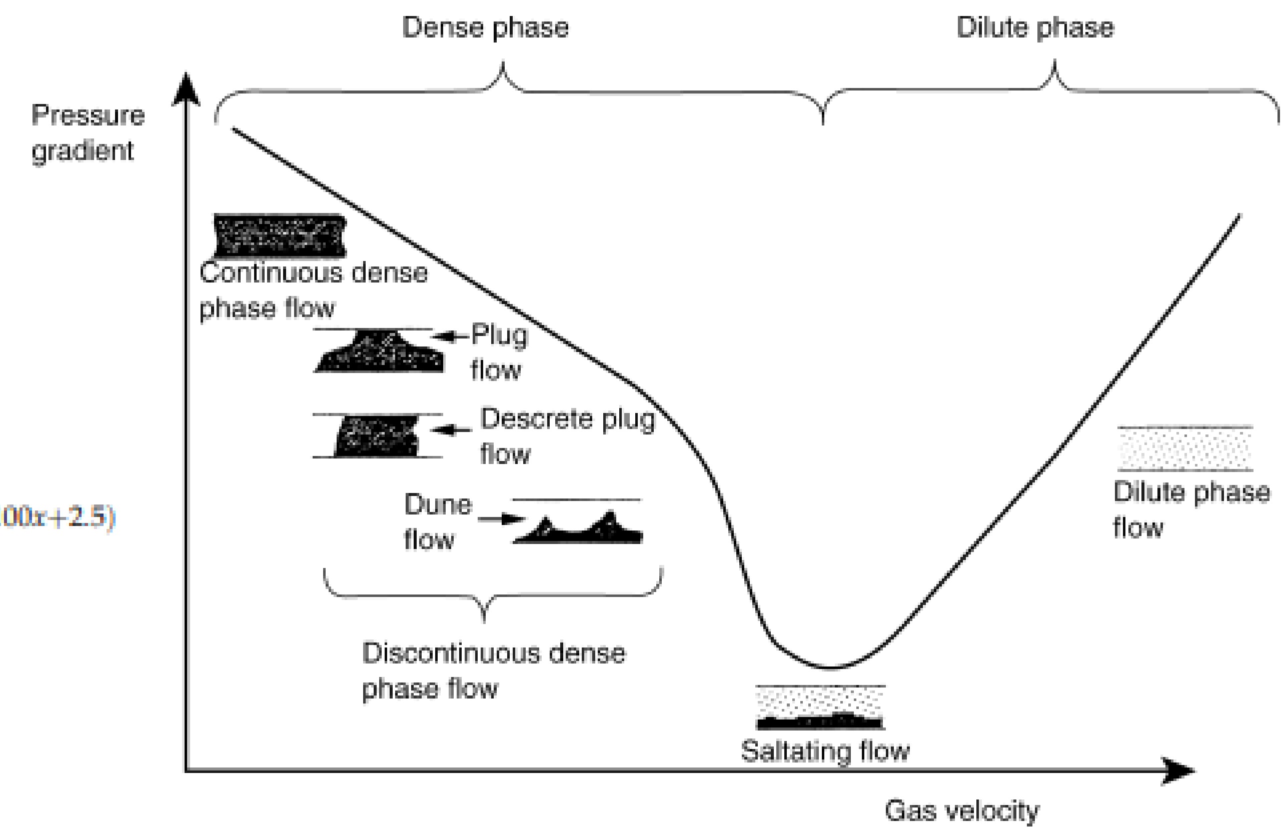
PNEUMATIC TRANSPORT

- Dilute phase
  - Vertical
  - Horizontal
- Dense phase
- Horizontal dilute transport
  - Saltation velocity

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



PNEUMATIC TRANSPORT

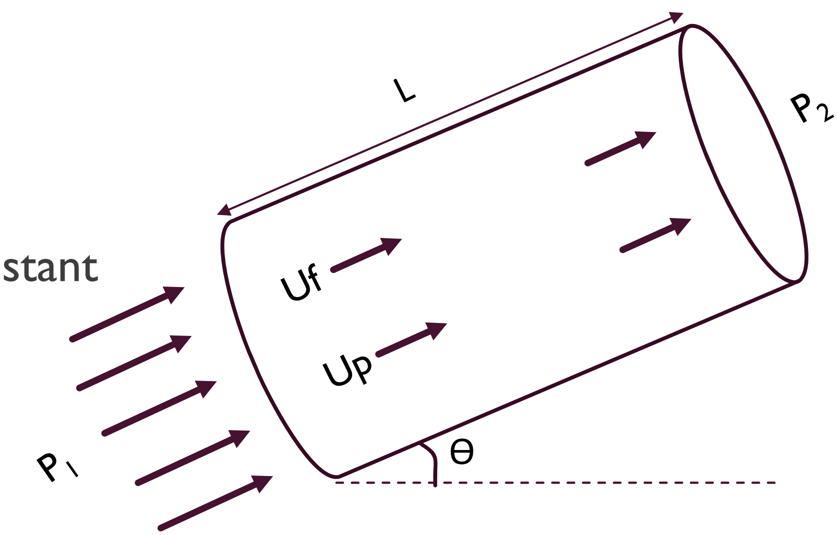
- Vertical Dilute phase transport
  - Choking velocity -

$$\frac{U_{\mathrm{CH}}}{\varepsilon_{\mathrm{CH}}} - U_{\mathrm{T}} = \frac{G}{\rho_{\mathrm{p}}(1 - \varepsilon_{\mathrm{CH}})}$$

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

PRESSURE DROP

Bernoulli Equation:



Pressure energy + potential energy + kinetic energy = Constant

$$\boxed{P1 - P2 + \rho L g\, sin\theta + \frac{1}{2}\rho(U_1^2 - U_2^2) = const}$$

If loss of energy due to friction is considered

Pressure energy + potential energy + kinetic energy = loss of energy due to friction

Gas Solids

Gas Solids

Gas and Wall Solids and Wall

PRESSURE DROP

- Net pressure force = ΔP
- Net gas-wall frictional forces = F_{fw} A ΔL
- Net solid-wall frictional forces = F_{pw} A ΔL
- Gravitation forces = Gravitation force offered by gas + Gravitation force offered by gas

  = mass of gas in the element * g + mass of particles in the element * g

  = $A * \Delta L * \varepsilon * \rho_f * g \sin \Theta + A * \Delta L * (1-\varepsilon) * \rho_p * g * g \sin \Theta$
- Rate of increase in momentum of gas = change in $M_f \, (\dot{m}) U_f = A \, U_f \, \varepsilon \, \rho_f \, \Delta U_f$
- Rate of increase in momentum of particles = $A \, U_p (I - \varepsilon) \, \rho_p \, \Delta U_p$
- Substituting all these in the momentum balance expression:

$$- A \Delta P - F_{fw} A \Delta L - F_{pw} A \Delta L - A * \Delta L * \varepsilon * \rho_f * g \sin \Theta - A * \Delta L * (1-\varepsilon) * \rho_p * g * g \sin \Theta = A \, U_f \, \varepsilon \, \rho_f \, \Delta u_f + A \, U_p (I - \varepsilon) \, \rho_p \, \Delta U_p$$

$$\boxed{P1 - P2 = FfwL + FpwL + \rho_f L \varepsilon g \sin\theta + \rho_p L (1-\varepsilon) g \sin\theta + \varepsilon \rho_f \frac{1}{2} U_f^2 + (1-\varepsilon) \rho_p \frac{1}{2} U_p^2}$$

PRESSURE DROP

Pressure energy + potential energy + kinetic energy = loss of energy due to friction

Potential energy:

- Gas: $\rho_f L \varepsilon g\ sin\theta$
- Solids: $\rho_p L(1-\varepsilon)g\ sin\theta$

Kinetic energy:

- Gas: $\varepsilon\rho_f \frac{1}{2}U_f^2$
- Solids: $(1-\varepsilon)\rho_p \frac{1}{2}U_p^2$

Loss of energy due to friction:

- Gas and Wall: $F_{fw}L$
- Solids and Wall: $F_{pw}L$

$$\boxed{P1\ - P2 = FfwL + FpwL + \rho_f L\varepsilon g\ sin\theta + \rho_p L(1-\varepsilon)g\ sin\theta + \varepsilon\rho_f \frac{1}{2}U_f^2 + (1-\varepsilon)\rho_p \frac{1}{2}U_p^2}$$

PRESSURE DROP

Solid – wall frictional forces per unit volume

- Konno – Saito correlation for vertical dilute pneumatic transport : $F_{pw}L = 0.057GL\sqrt{\frac{g}{D}}$
- For horizontal dilute pneumatic transport : $F_{pw}L = \frac{2f_p(1-\varepsilon)\rho_p U_p^2 L}{D}$
- Hinkle correlation for U_p : $U_p = U(1 - 0.0638x^{0.3}\rho_p^{0.5})$
- Hinkle correlation for f_p : $f_p = \frac{3}{8}\frac{\rho_f}{\rho_p}\frac{D}{x}C_D\left(\frac{U_f - U_p}{U_p}\right)^2$

$$\begin{array}{rl} Re_p < 1 & C_D = 24/Re_p \\ 1 < Re_p < 500 & C_D = 18.5Re_p^{-0.6} \\ 500 < Re_p < 2 \times 10^5 & C_D = 0.44 \end{array}$$

$$Re_p = \frac{\rho_f(U_{fH} - U_{pH})x}{\mu}$$

PRESSURE DROP

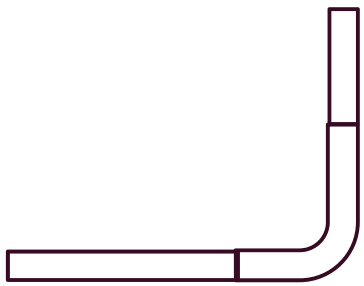
- Gas – Solid frictional forces:

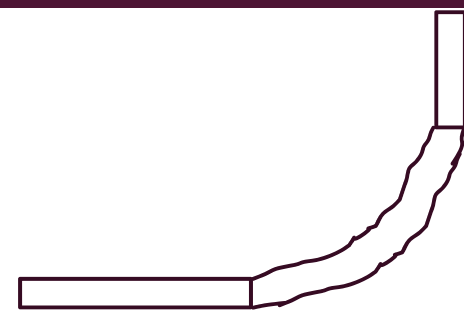
  Assuming the low concentration of particles, presence of particles effects can be neglected in estimating $F_{fw}L$

For flow of gas through pipe: $F_{fw}L = 2 f_g \rho_g U_f^2 L / D$

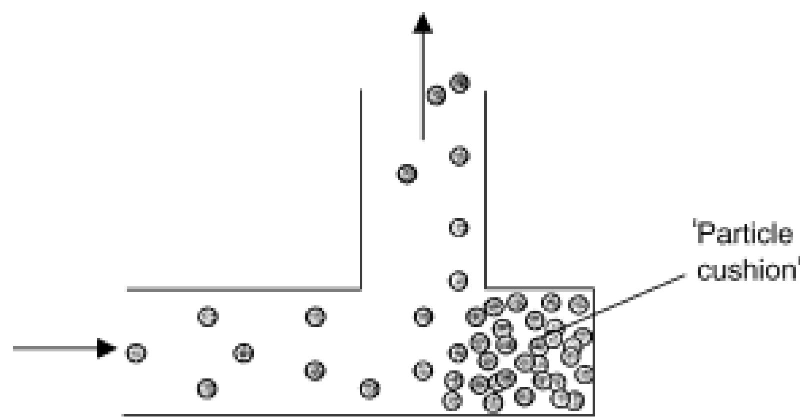
f_g = fanning friction factor

BENDS



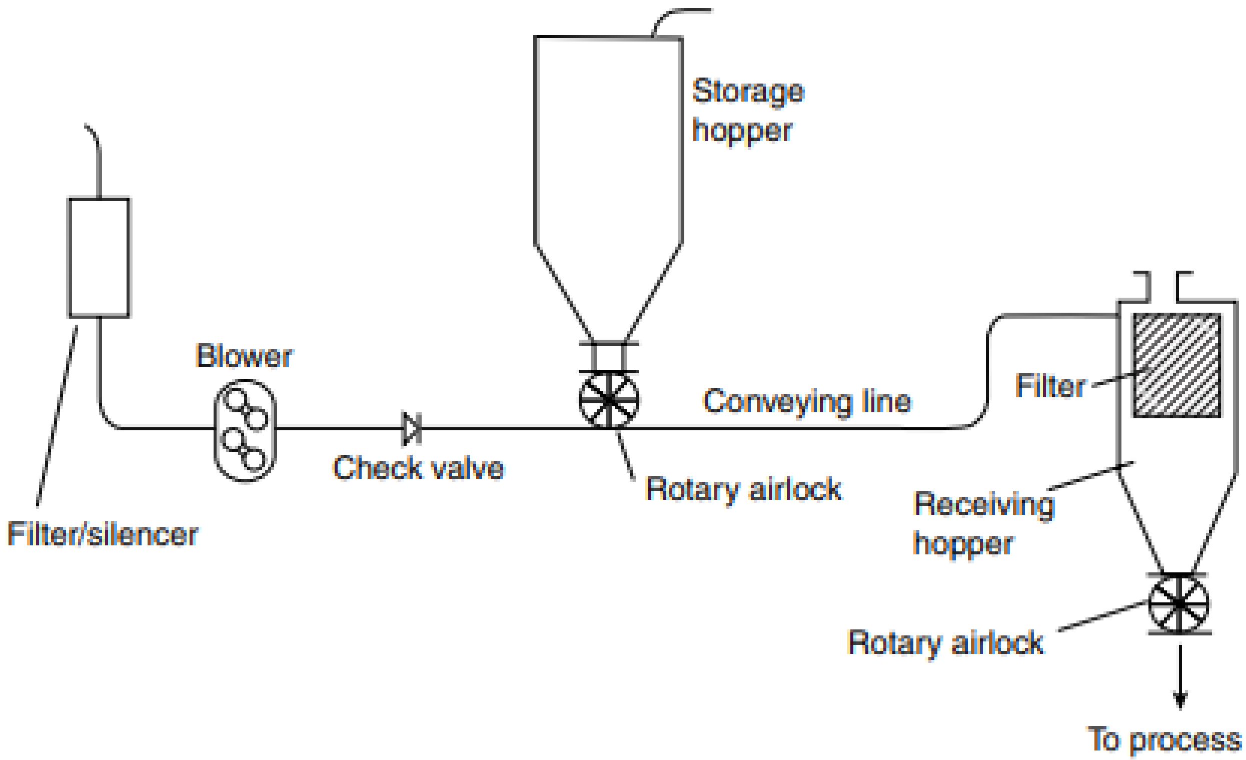


- Zenz (1964) proposed to use blind tees:

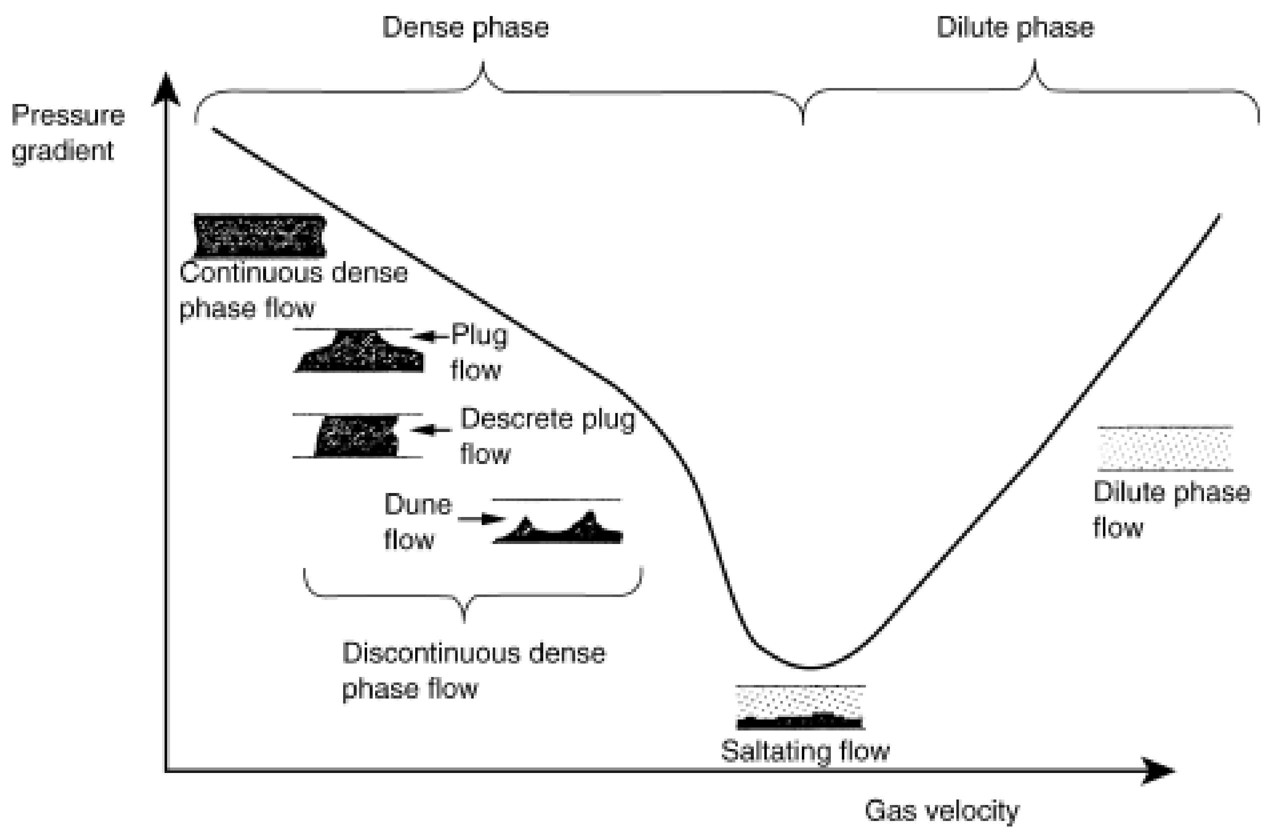


Pressure drop in the bends = 7.5 times the vertical section pressure drop

TYPICAL DILUTE PNEUMATIC TRANSPORT



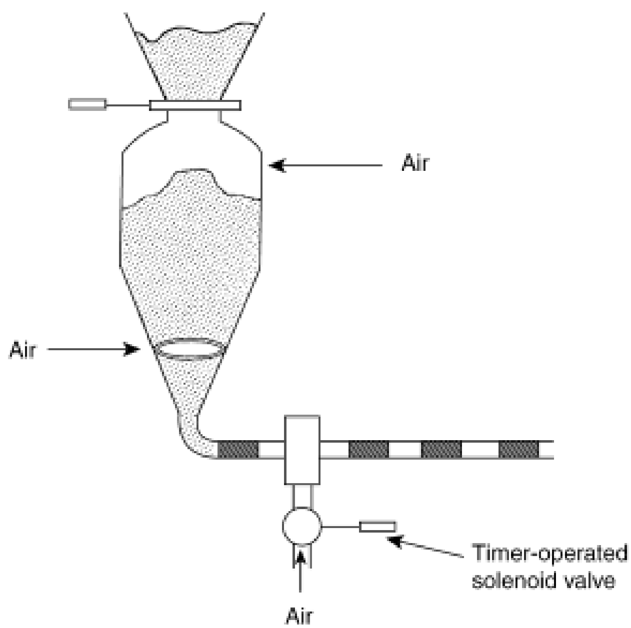
DENSE PHASE PNEUMATIC TRANSPORT



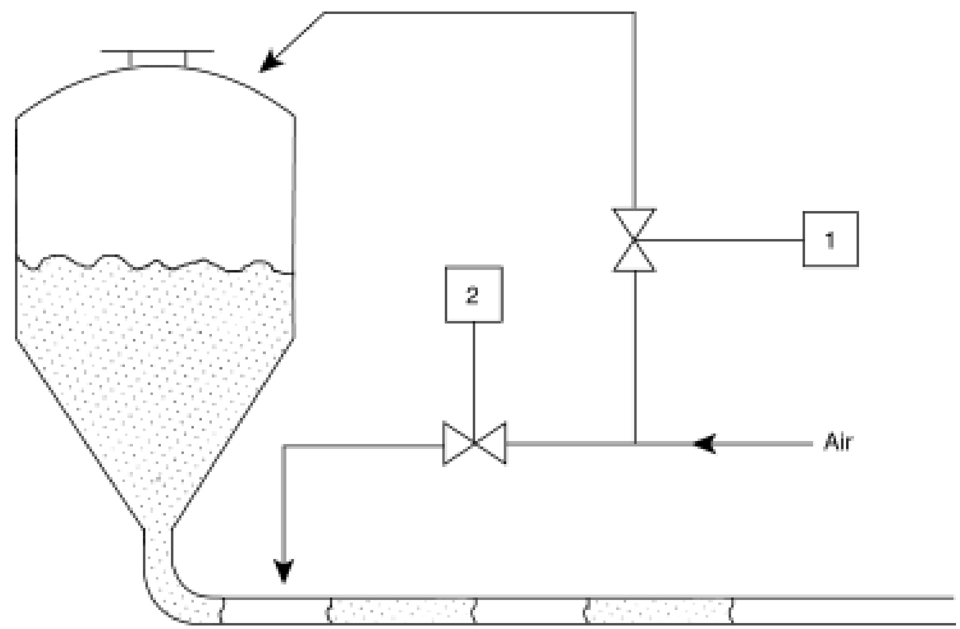
TACKLING THE PLUG FORMATION

- Forming a stable plugs

Time operated air knife



Alternating air valve



STABLE PLUGS – WHICH TYPE OF PARTICLES?

- Geldart's Chart

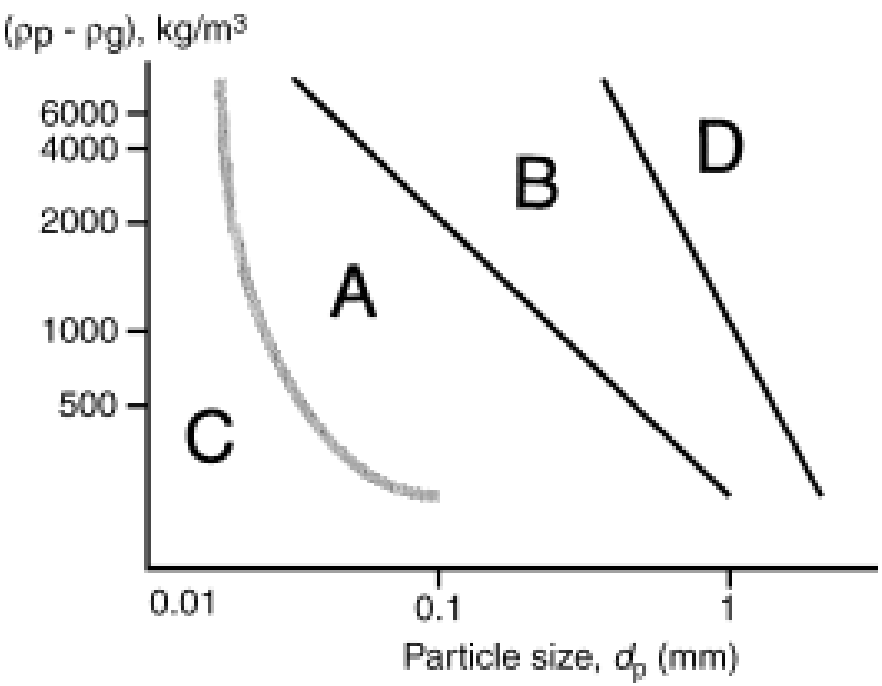


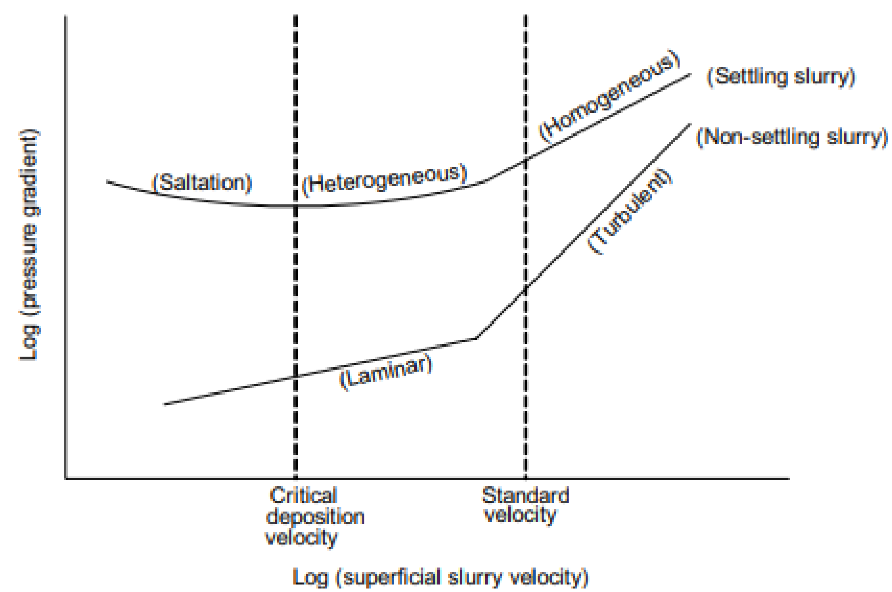
Table 7.1 Geldart's classification of powders

	Group C	Group A	Group B	Group D
Most obvious characteristic	Cohesive, difficult to fluidize	Ideal for fluidization. Exhibits range of non-bubbling fluidization	Starts bubbling at U_{mf}	Coarse solids
Typical solids	Flour, cement	Cracking catalyst	Building sand	Gravel, coffee beans

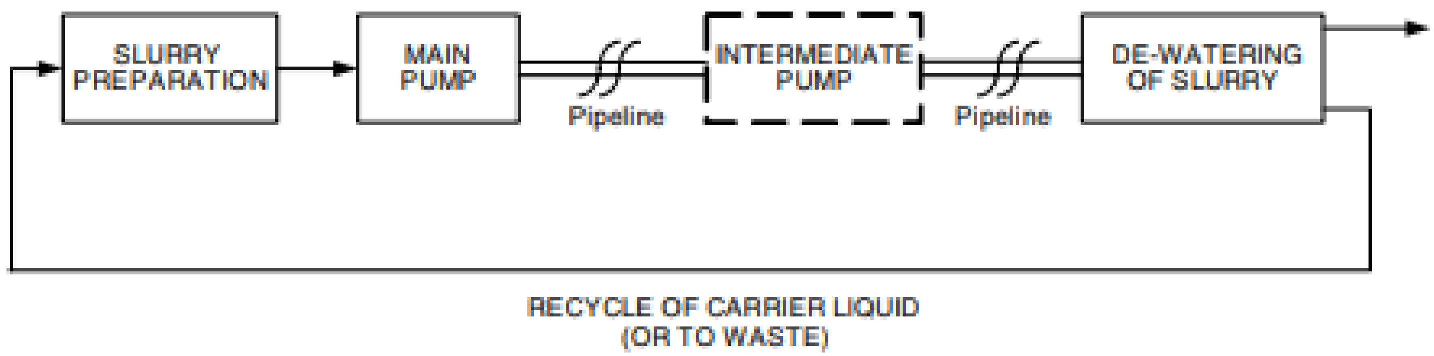
Group A and D powder can tend to form stable plugs and are suitable for Dense phase pneumatic transport

SLURRY TRANSPORT

- A slurry is a mixture of a liquid and solid particles.
- 'sludge' typically refers to a highly concentrated slurry containing fine particulate material.
- Slurries are often used to transport coal, phosphates and minerals.
- In most slurries, the liquid phase is water. However, coal–oil and coal–methanol fuels are examples of slurries made up with liquids other than water
- Flow behaviour – non-Newtonian fluids



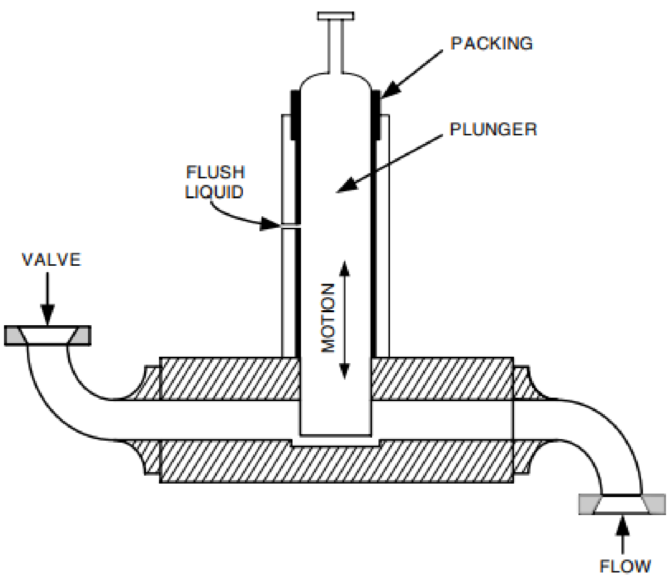
SLURRY CONVEYING SYSTEM



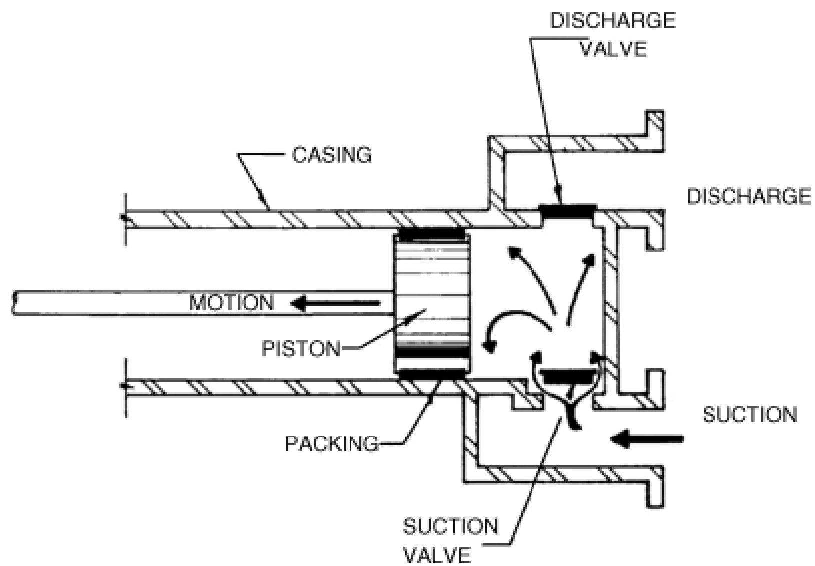
PUMPS

- If the discharge pressure is less 45 bar – centrifugal pumps are preferred.
- If the discharge pressure is greater than 45 bar – positive displacement pumps or reciprocating pumps

Plunger Pump



Single Acting Piston Pump



Thank you