

# Pressure Drop Calculations for Designing Pneumatic Conveying System

Particle Reynolds Number :  $Re_p = d_p u_{slip} \rho_g / \delta_g$

Particle Drag Coefficient :

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

## 4. Material Properties

- Mean Particle Size :  $d_p$
- True Density of a Particle :  $\rho_p$

## 1. Gas Mover:

- Fan & Blower
  - Compressor
  - Plant Air or Gas
- Density of Gas :  $\rho_g$   
- Dynamic Viscosity of Gas :  $\delta_g$

## 5. Feeder

- Rotary Air Lock
  - Rotary Feeder or Screw Feeder/Ejector
  - Rotary Feeder / Double Flap
  - Blow Tank
- Solids Mass Flow Rate :  $m_p$

## 2. Emergency V/V Circuit

## 3. Pressure Drop for Only Gas Pipe Line ( $L_g$ )

$$= [0.5 \rho_g u^2] + \left[ 2 f_g \rho_g u^2 \frac{(L_{gh} + L_{gv})}{D_g} \right] + [\rho_g g L_{gv} \sin 90^\circ]$$

Gas Acceleration

Gas Friction

Gas Static Head

Gas Reynolds Number :  $Re_f = \frac{uD_g \rho_g}{1,000 \delta_g}$ ,  $\delta_g$ : Dynamic Viscosity of Gas (Pa.s)

Gas Friction Factor :  $f_g = 2(0.0396 Re_f^{-0.25})$

$L_{gh}$  : Horizontal Length of Gas Pipeline,  $L_{gv}$  : Vertical Length of Gas Pipeline

$\rho_g$  : Density of Gas,  $u$  : Gas Velocity in only  $L_g$

$$u_{slip} = u_{ig} - u_{sp} = u_{terminal}$$

$$u_{ap} = \frac{4 \times 1000 \times m_p}{(\pi D^2)(1 - \epsilon)}$$

Actual Solids Velocity

$$u_{ig} = \frac{u_{sg}}{\epsilon} = 1.5 \frac{u_{salt}}{\epsilon}$$

Interstitial Gas Velocity

$$u_{sp} = u_{sg}(1 - 0.638 d_p^{0.3} \rho_p^{0.5})$$

Superficial Solids Velocity

$$u_{sg} = Q_g / A \cong 1.5 \times u_{salt}$$

Superficial Gas Velocity

where  $\alpha = 1440 d_p + 1.96$ ,  $\beta = 1100 d_p + 2.5$

$$u_{salt} = \left[ \frac{4 m_p \times 10^{\alpha} \times g^{\beta/2} \times D \left( \frac{\beta-2}{2} \right)}{\pi \rho_a} \right]^{\frac{1}{\beta+1}}$$

## 6. @Feed Point: Saltation Velocity- " $u_{salt}$ "

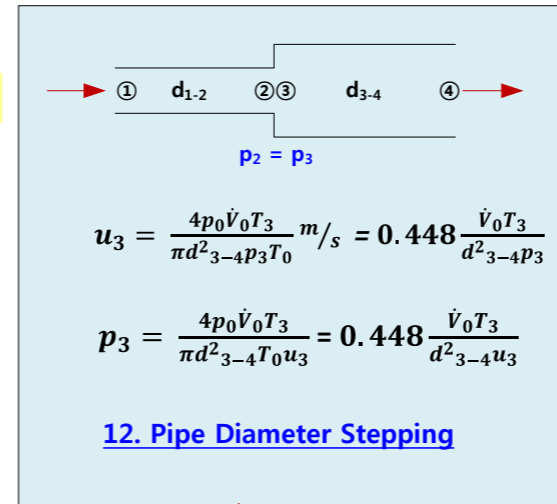
## 8. Conveying Line: Inner Diameter- "D"

## 7. Acceleration Length:

$$L_a = D \times 5.7 \left( \frac{m_p}{\rho_g g^{0.5} D^{2.5}} \right)^{0.36} \left( \frac{d_p}{D} \right)^{-0.16} \left( \frac{\rho_p}{\rho_g} \right)^{0.18} \quad \text{; Eq. by Rose & Duckworth}$$

$$L_a = D \times 0.527 \left( \frac{D}{d_p} \right)^{-1.28} (1 - \phi) Re_d \quad \text{; Eq. by Enck & Klinzing, Marcus}$$

$\phi$  : Loading Ratio,  $Re_d$  : Drag Reynolds Number



## 9. Pressure Drop in All Vertical Pipe Line

Vertical Solids Friction Factor :  $f_{vp} = \frac{0.057 D}{2 u_{sp}} \sqrt{\frac{g}{D}}$

By Solids Friction =  $0.057 \times m_p f L_V \sqrt{\frac{g}{D}}$

By Gas Friction =  $2 f_g \rho_a \epsilon u_{ig}^2 L_V / D$

By Solids Static Head =  $\rho_p (1 - \epsilon) g L_V \sin 90^\circ$

By Gas Static Head =  $\rho_a \epsilon g L_V \sin 90^\circ$

## 10. Pressure Drop in All Horizontal Pipe Line

Horizontal Solids Friction Factor :  $f_{hp} = \frac{3 \rho_g}{8 \rho_p} C_D \frac{D}{d_p} \left( \frac{u_{slip}}{u_{sp}} \right)^2$

By Gas Acceleration =  $0.5 \rho_a \epsilon u_{ig}^2$

By Solids Acceleration =  $0.5 \rho_p (1 - \epsilon) u_{sp}^2$

By Gas Friction =  $2 f_g \rho_a \epsilon u_{sg}^2 L_H / D$

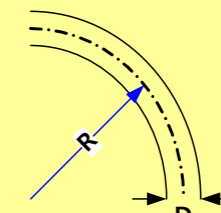
By Solids Friction =  $2 f_{hp} \rho_p (1 - \epsilon) u_{sp}^2 L_H / D$

## 11. Pressure Drop in All Bends

$$\Delta p_b = B(1 + \phi) \frac{\rho_g u_{sg}^2}{2g}$$

B value Selection :

- R/D > 6 : B = (R/D)/2
- R/D = 4 : B = 0.75
- R/D = 2 : B = 1.5



• Major source of wear/attrition

• Pressure loss associated with re-acceleration of gas and solids

• Bends usually specified by a ratio of the bend radius to pipe diameter R/D

• Typical in conveying R/D = 6 to 12

• B : Bend loss coefficient

## 13. Gas/Solids Separator

- Filtration
- Cyclone

### Cyclone Radial Velocity (m/sec.)

$$u_{rad} = \frac{(\rho_p - \rho_g) r w^2 d_p^2}{18 \delta_g}$$

r : Radial Distance (m)  
w : Rotational Velocity (radian/sec.)

### Cyclone Pressure Drop (Pa)

$$\Delta P_{cyclone} = \frac{3950 K Q^2 P \rho_g}{T}$$

K : Proportionality Factor  
Q : Gas Flow Rate (mg; kg/sec.)  
P : Absolute Pressure  
T : Temperature