Pressure Drop Calculations for Designing Pneumatic Conveying System

Particle Reynolds Number:

\[ Re_p = d_p \frac{u_{slip} \rho_f}{\delta_g} \]

Particle Drag Coefficient:

\[ C_D = \frac{24}{Re_p} \]

\[ Re_p < 1 \quad C_D = 24 \]

\[ 1 < Re_p < 500 \quad C_D = 18.58 \cdot Re_p^{-0.6} \]

\[ 500 < Re_p < 2 \times 10^5 \quad C_D = 0.44 \]

\[ \delta = \frac{4 \times 10^6 \cdot m_f}{\rho_f (0.17 + \beta) \cdot d_p^2} \]

Actual Solids Velocity

\[ u_{slip} = u_{gslip} = u_{terminal} \]

Interstitial Gas Velocity

\[ u_i = \frac{u_{gslip}}{1.5} \]

Superficial Solids Velocity

\[ u_s = u_{gslip} - 0.628 \delta_i u_{gslip} \]

Superficial Gas Velocity

\[ u_g = \frac{Q_g}{A} \geq 1.5 \times u_{smax} \]

5. Feeder

1) Rotary Air Lock
2) Rotary Feeder or Screw Feeder/Ejector
3) Rotary Feeder/Double Flap
4) Blow Tank
5) Solids Mass Flow Rate: \( m_v \)

4. Material Properties

1) Mean Particle Size: \( d_p \)
2) True Density of a Particle: \( \rho_v \)
3) Dynamic Viscosity of Gas: \( \delta_g \)
4) Density of Gas: \( \rho_g \)
5) Dynamic Viscosity of Gas: \( \delta_g \)

2. Emergency V/V Circuit

3. Pressure Drop for Only Gas Pipe Line (Lg)

\[ \Delta P_{gas} = \frac{4 \rho G u_{gf}^2}{\pi^3 D_g^4} \]

\[ u_{gf} = \frac{Q_g}{\pi D_g^2} \]

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11. Pressure Drop in All Bends

\[ \Delta P_B = B \left( 1 + \frac{\rho_f u_{term}^2}{\delta_g} \right) \]

\[ B = \frac{(K - 1) \rho_f u_{term}^2}{\delta_g} \]

B value Selection:

- \( K \geq 6 \): B \( = 0.5 \rho_f u_{term}^2 \)
- \( K = 2 \): B \( = 2 \rho_f u_{term}^2 \)
- \( K = 4 \): B \( = 4 \rho_f u_{term}^2 \)

• 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

13. Gas/Solids Separator

1) Filtration
2) Cyclone

- Cyclone Radial Velocity (m/sec.)

\[ \omega_{rad} = \frac{(\rho_v - \rho_g) r u_2^2}{18 \rho_g} \]

- Radial Distance (m)
- Rotational Velocity (radian/sec.)

- Cyclone Pressure Drop (Pa)

\[ \Delta P_{cyclone} = \frac{3950 Q_g^2 \rho_f}{\pi D_g^2} \]

K: Proportionality Factor
Q: Gas Flow Rate (m^3 kg/sec.)
P: Absolute Pressure
T: Temperature

9. Pressure Drop in All Vertical Pipe Line

Vertical Solids Friction Factor:

\[ f_s = \frac{0.557}{(1 - \epsilon) \rho_s} \]

\[ \epsilon = \frac{1}{1 + \frac{D_g}{0.527} \left( \frac{1}{R_s} \right)^{3/2}} \]

\[ R_s : \text{Radius of Solids} \]

\[ L_g : \text{Length of Gas Pipeline} \]

\[ L_e : \text{Vertical Length of Gas Pipeline} \]

\[ \rho_s : \text{Density of Solids} \]

\[ \rho_v : \text{Density of Gas} \]

\[ u : \text{Gas Velocity in only } L_g \]

12. Pipe Diameter Stepping

1) Rotary Air Lock
2) Rotary Feeder or Screw Feeder/Ejector
3) Rotary Feeder/Double Flap
4) Blow Tank
5) Solids Mass Flow Rate: \( m_v \)


7. Acceleration Length:

\[ L_a = \frac{L_g + L_e}{1.5 \cdot \delta_s} \]

\[ L_s : \text{Horizontal Length of Gas Pipeline} \]

\[ L_e : \text{Vertical Length of Gas Pipeline} \]

\[ \delta_s : \text{Dynamic Viscosity of Gas(Pa.s)} \]

6. Feed Point: Saltation Velocity: “u_salt”

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