Pressure Drop Calculations for Designing Pneumatic Conveying System

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

Particle Drag Coefficient :

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

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

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

Actual Solids Velocity

$u_{ig} = \dfrac{u_{sg}}{\varepsilon} = 1.5\, u_{salt}/\varepsilon$

Interstitial Gas Velocity

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

Superficial Solids Velocity

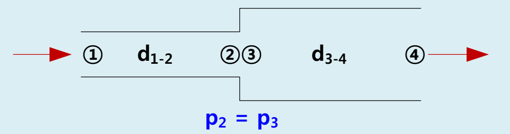
$u_{sg} = Q_g/A \cong 1.5 \times u_{salt}$

Superficial Gas Velocity

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

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

12. Pipe Diameter Stepping



$$u_3 = \frac{4 p_0 \dot{V}_0 T_3}{\pi d^2_{3-4} p_3 T_0}\, m/s = 0.448 \frac{\dot{V}_0 T_3}{d^2_{3-4} p_3}$$

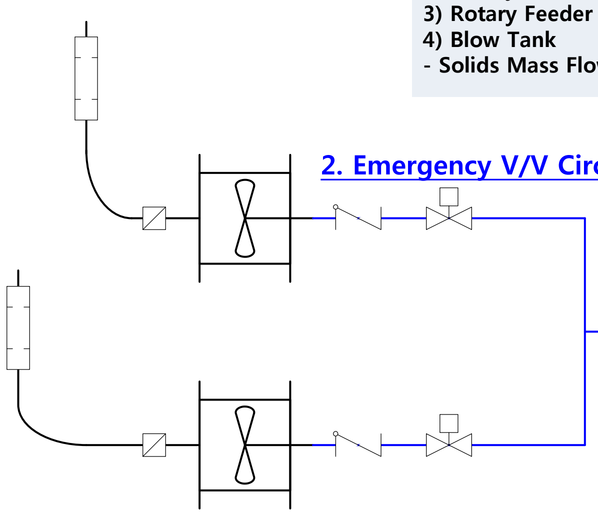
$$p_3 = \frac{4 p_0 \dot{V}_0 T_3}{\pi d^2_{3-4} T_0 u_3} = 0.448 \frac{\dot{V}_0 T_3}{d^2_{3-4} u_3}$$

4. Material Properties

1) Mean Particle Size : d_p
2) True Density of a Particle : ρ_p

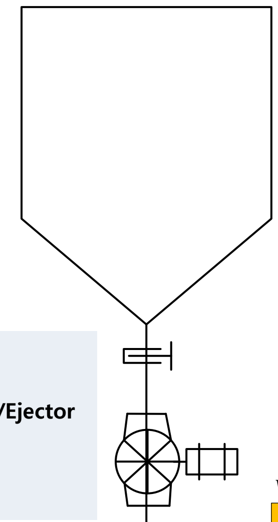
1. Gas Mover:

1) Fan & Blower
2) Compressor
3) Plant Air or Gas
-Density of Gas: ρ_g
-Dynamic Viscosity of Gas : δ_g



5. Feeder

1) Rotary Air Lock
2) Rotary Feeder or Screw Feeder/Ejector
3) Rotary Feeder / Double Flap
4) Blow Tank
- Solids Mass Flow Rate : m_p



2. Emergency V/V Circuit

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

8. Conveying Line: Inner Diameter- " D "

7. Acceleration Length:

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

$$L_a = D \times 0.527 \left(\frac{D}{d_p} \right)^{-1.26} (1-\phi) \mathrm{Re}_d$$: Eq. by Enick & Klinzing, Marcus

ϕ : Loading Ratio, Re_d : Drag Reynolds Number

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

$$= \left[0.5 \rho_g u^2 \right] + \left[2 f_g \rho_g u^2 \frac{(L_{gh} + L_{gv})}{D_g} \right] + \left[\rho_g g L_{gv} \sin 90^0 \right]$$

Gas Acceleration — Gas Friction — Gas Static Head

Gas Reynolds Number : $\mathrm{Re}_f = \dfrac{u D_g \rho_g}{1,000 \delta_g}$, δ_g :Dynamic Viscosity of Gas(Pa.s)

Gas Friction Factor : $f_g = 2\left(0.0396 \mathrm{Re}_f^{-0.25}\right)$

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

ρ_g : Density of Gas, u : Gas Velocity in only L_g

9. Pressure Drop in All Vertical Pipe Line

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

By Solids Friction = $0.057 \times m_{pf} L_V \sqrt{\dfrac{g}{D}}$

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

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

By Gas Static Head = $\rho_a \varepsilon g L_V \sin 90^o$

10. Pressure Drop in All Horizontal Pipe Line

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

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

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

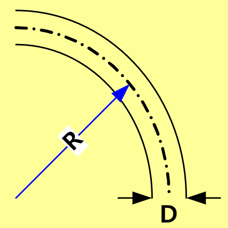
By Gas Friction= $2 f_g \rho_a \varepsilon u_{sg}^2 L_H / D$

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

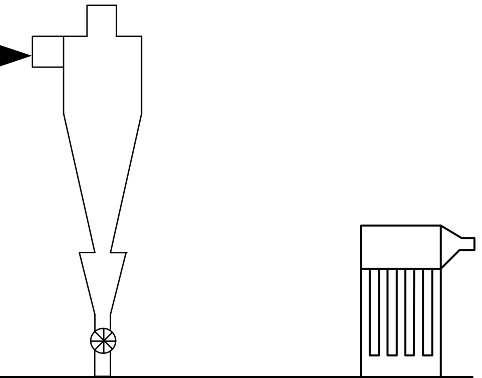
11. Pressure Drop in All Bends

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

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

1) Filtration
2) 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(m_g: kg/sec.)
P: Absolute Pressure
T : Temperature

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