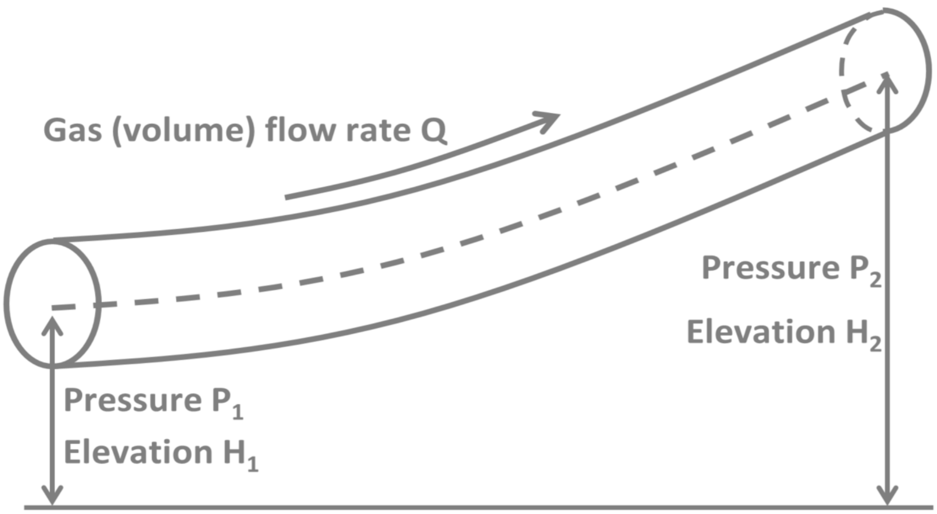
Natural gas pipeline sizing (SI)

This application calculate Gas flow rate as Natual gas pipeline sizing calculation. This calculation is based on General flow equation, AGA, Weymouth, Panhandle A , Panhandle B, and IGT equation. And, The International System of Units is used in this application.



Reference : Gas Pipeline Hydraulics, E. Shashi Menon, 2005

Design parameters

In this section, the gas properties and the geometrical parameters are defined for the calculation later.

Gas properties

Pipeline Inlet pressure $P_1 := 6890\ \mathrm{kPa}$

Pipeline outlet pressure $P_2 := 5500\ \mathrm{kPa}$

Gas pressure at Base condition $P_b := 101.35\ \mathrm{kPa}$

Gas temperature at Base condition $T_{b\_C} := 15\ \mathrm{degC}$

Specific Gravity $G := 0.6$

Average gas flowing temperature $T_{f\_C} := 21\ \mathrm{degC}$

Pipeline parameters

Pipe Length $L := 16.09\ \text{km}$

Pipe inside diameter $D_p := 482.60\ \text{mm}$

Pipe roughness $\epsilon := 0.01778\ \text{mm}$

Upstream elevation $H_1 := 3\ \text{m}$

Downstream elevation $H_2 := 33\ \text{m}$

Pipe efficiency $E := 0.95$
(A decimal value less than or equal to 1.0)

Gas properties

Density, viscosity and compressibility factor of gas can be obtained with the fluid properties specified in the previous section.

Average gas temperature in Kelvin $T_{f\_K} := \text{temperature\_conversion}\left(T_{f\_C}, \text{"degC"}, \text{"K"}\right) = 294.150\ \text{K}$

Gas temperature at Base condition in Kelvin $T_{b\_K} := \text{temperature\_conversion}\left(T_{b\_C}, \text{"degC"}, \text{"K"}\right) = 288.150\ \text{K}$

Note:
The unit of temperature can be converted with temperature_conversion() function defined in the Code region.

Average gas pressure

$$P_{avg} := \frac{2}{3} \cdot \left(P_1 + P_2 - \frac{P_1 \cdot P_2}{P_1 + P_2} \right) = 6220.990\ \text{kPa}$$

Compressibility factor (CNGA method)

$$Z := \frac{1}{1 + \dfrac{\dfrac{P_{avg}}{\text{psi}} \cdot 344400 \cdot 10^{1.785 \cdot G}}{\left(\dfrac{T_{f\_K}}{\text{degR}} \right)^{3.825}}} = 877.54 \times 10^{-3}$$

Viscosity $\mu := 0.000126\ \text{poise}$

Gas flow rate calculation

Gas (volume) flow rate can be calculated with several methods. In this section, these calculations are shown.

General flow equation with Colebrook-White equation of Friction factor

Volume flow rate

$$Q_{GF} := 1.1494 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa}\right)^2 - \left(\frac{P_2}{kPa}\right)^2}{G \cdot \left(\frac{T_{f\_K}}{K}\right) \cdot \left(\frac{L}{km}\right) \cdot Z \cdot f} \right)^{0.5} \cdot \left(\frac{D_p}{mm}\right)^{2.5}$$

Reynolds number

$$Rey_{GF} := 0.5134 \cdot \left(\frac{\frac{P_b}{kPa}}{\frac{T_{b\_K}}{K}} \right) \cdot \left(\frac{G \cdot Q_{GF}}{\frac{\mu}{poise} \cdot \frac{D_p}{mm}} \right)$$

By using above 2 equations, the friction factor can be obtained based on Colebrook-white equation.
And, the final result of Gas flow rate and Reynolds number also can be calculated.

Friction factor

$$f_{GF\_res} := \text{fsolve}\left(\frac{1}{\sqrt{f}} = -2 \cdot \log10\left(\frac{\epsilon}{3.7 \cdot D_p} + \frac{2.51}{Rey_{GF} \cdot \sqrt{f}} \right), f \right) = 10.17 \times 10^{-3}$$

Volume flow rate

$$Q_{GF\_res} := 1.1494 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa}\right)^2 - \left(\frac{P_2}{kPa}\right)^2}{G \cdot \left(\frac{T_{f\_K}}{K}\right) \cdot \left(\frac{L}{km}\right) \cdot Z \cdot f_{GF\_res}} \right)^{0.5} \cdot \left(\frac{D_p}{mm}\right)^{2.5} \cdot \frac{m^3}{day}$$

$$Q_{GF\_res} = 1.309 \times 10^{7} \ \frac{m^3}{d}$$

$$Rey_{GF\_res} := 0.5134 \cdot \left(\frac{\frac{P_b}{kPa}}{\frac{T_{b\_K}}{K}} \right) \cdot \left(\frac{G \cdot \frac{Q_{GF\_res}}{\frac{m^3}{day}}}{\frac{\mu}{poise} \cdot \frac{D_p}{mm}} \right) = 2.333 \times 10^{7}$$

General flow equation with American Gas Association (AGA) equation of Transmission factor

Pipe drag factor $D_f := 0.95$

Volume flow rate

$$Q_{AGA} := 1.1494 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa}\right)^2 - \left(\frac{P_2}{kPa}\right)^2}{G \cdot \left(\frac{T_{f\_K}}{K}\right) \cdot \left(\frac{L}{km}\right) \cdot Z \cdot f} \right)^{0.5} \cdot \left(\frac{D_p}{mm}\right)^{2.5}$$

Reynolds number

$$Rey_{AGA} := 0.5134 \cdot \left(\frac{\frac{P_b}{kPa}}{\frac{T_{b\_K}}{K}} \right) \cdot \left(\frac{G \cdot Q_{AGA}}{\frac{\mu}{poise} \cdot \frac{D_p}{mm}} \right)$$

Von Karman smooth pipe transmission factor

$$F_{t\_res} := solve\left(F_t = 4 \cdot \log10\left(\frac{Rey_{AGA}}{F_t}\right) - 0.6, F_t \right)$$

Transmisson factor

$$F_{AGA} := \min\left(4 \cdot \log10\left(\frac{3.4 \cdot D_p}{\epsilon}\right), 4 \cdot D_f \cdot \log10\left(\frac{Rey_{AGA}}{1.4125 \cdot F_{t\_res}}\right) \right)$$

Therefore, friction factor can be obtained with above equations, and Gas flow rate and Reynolds number can be calculated as follow.

Friction factor

$$f_{AGA} := solve\left(F_{AGA} = \frac{2}{\sqrt{f}}, f \right) = 10.14 \times 10^{-3}$$

Volume flow rate

$$Q_{AGA\_res} := 1.1494 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa}\right)^2 - \left(\frac{P_2}{kPa}\right)^2}{G \cdot \left(\frac{T_{f\_K}}{K}\right) \cdot \left(\frac{L}{km}\right) \cdot Z \cdot f_{AGA}} \right)^{0.5} \cdot \left(\frac{D_p}{mm}\right)^{2.5} \cdot \frac{m^3}{day}$$

$$Q_{AGA\_res} = 1.311 \times 10^7 \frac{m^3}{d}$$

$$Rey_{AGA} := 0.5134 \cdot \left(\frac{\frac{P_b}{kPa}}{\frac{T_{b\_K}}{K}} \right) \cdot \left(\frac{G \cdot \frac{Q_{AGA\_res}}{\frac{m^3}{day}}}{\frac{\mu}{poise} \cdot \frac{D_p}{mm}} \right) = 2.336 \times 10^7$$

Weymouth equation

Elevation adjustment parameter

$$s_{el} := 0.0684 \cdot G \cdot \left(\frac{\frac{H_2}{m} - \frac{H_1}{m}}{\frac{T_{f\_K}}{K} \cdot Z} \right) = 0.005$$

Equivalent length

$$L_e := \frac{L \cdot \left(e^{s_{el}} - 1 \right)}{s_{el}} = 16.128 \, km$$

Flow velocity

$$Q_w := 3.7435 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa} \right)^2 - e^{s_{el}} \cdot \left(\frac{P_2}{kPa} \right)^2}{G \cdot \left(\frac{T_{f\_K}}{K} \right) \cdot \left(\frac{L_e}{km} \right) \cdot Z} \right)^{0.5} \cdot \left(\frac{D_p}{mm} \right)^{2.667} \cdot \frac{m^3}{day}$$

$$Q_w = 1.200 \times 10^7 \, \frac{m^3}{d}$$

Transmission factor

$$F_w := 6.521 \cdot \left(\frac{D_p}{mm} \right)^{\frac{1}{6}} = 18.263$$

Friction factor

$$f_w := \text{solve}\left(F_w = \frac{2}{\sqrt{f}}, f \right) = 11.99 \times 10^{-3}$$

Panhandle A equation

Elevation adjustment parameter

$$s_{el} := 0.0684 \cdot G \cdot \left(\frac{\frac{H_2}{m} - \frac{H_1}{m}}{\frac{T_{f\_K}}{K} \cdot Z} \right) = 0.005$$

Equivalent length

$$L_e := \frac{L \cdot \left(e^{s_{el}} - 1 \right)}{s_{el}} = 16.128 \, km$$

Flow velocity

$$Q_{pA} := 4.5965 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right)^{1.0788} \cdot \left(\frac{\left(\frac{P_1}{kPa} \right)^2 - e^{s_{el}} \cdot \left(\frac{P_2}{kPa} \right)^2}{G^{0.8539} \cdot \left(\frac{T_{f\_K}}{K} \right) \cdot \left(\frac{L_e}{km} \right) \cdot Z} \right)^{0.5394} \cdot \left(\frac{D_p}{mm} \right)^{2.6182} \cdot \frac{m^3}{day}$$

$$Q_{pA} = 1.610 \times 10^7 \, \frac{m^3}{d}$$

Transmission factor

$$F_{pA} := 11.85 \cdot E \cdot \left(\frac{\left(\frac{Q_{pA}}{\frac{m^3}{day}} \right) \cdot G}{\frac{D_p}{mm}} \right)^{0.07305} = 23.209$$

Friction factor

$$f_{pA} := solve\left(F_{pA} = \frac{2}{\sqrt{f}}, f \right) = 7.43 \times 10^{-3}$$

Panhandle B equation

Elevation adjustment parameter

$$s_{el} := 0.0684 \cdot G \cdot \left(\frac{\frac{H_2}{m} - \frac{H_1}{m}}{\frac{T_{f\_K}}{K} \cdot Z} \right) = 0.005$$

Equivalent length

$$L_e := \frac{L \cdot \left(e^{s_{el}} - 1 \right)}{s_{el}} = 16.128\ km$$

Flow velocity

$$Q_{pB} := 1.002 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right)^{1.02} \cdot \left(\frac{\left(\frac{P_1}{kPa} \right)^2 - e^{s_{el}} \cdot \left(\frac{P_2}{kPa} \right)^2}{G^{0.961} \cdot \left(\frac{T_{f\_K}}{K} \right) \cdot \left(\frac{L_e}{km} \right) \cdot Z} \right)^{0.51} \cdot \left(\frac{D_p}{mm} \right)^{2.53} \cdot \frac{m^3}{day}$$

$$Q_{pB} = 1.522 \times 10^6\ \frac{m^3}{d}$$

Transmission factor

$$F_{pB} := 19.08 \cdot E \cdot \left(\frac{\left(\frac{Q_{pB}}{\frac{m^3}{day}} \right) \cdot G}{\frac{D_p}{mm}} \right)^{0.01961} = 21.017$$

Friction factor

$$f_{pB} := solve\left(F_{pB} = \frac{2}{\sqrt{f}}, f \right) = 9.06 \times 10^{-3}$$

Institue of Gas Technology (IGT) equation

Elevation adjustment parameter

$$s_{el} := 0.0684 \cdot G \cdot \left(\frac{\frac{H_2}{m} - \frac{H_1}{m}}{\frac{T_{f\_K}}{K} \cdot Z} \right) = 0.005$$

Equivalent length

$$L_e := \frac{L \cdot \left(e^{s_{el}} - 1 \right)}{s_{el}} = 16.128 \, km$$

Flow velocity

$$Q_{IGT} := 1.2822 \cdot 10^{-3} \cdot E \cdot \left(\frac{\frac{T_{b\_K}}{K}}{\frac{P_b}{kPa}} \right) \cdot \left(\frac{\left(\frac{P_1}{kPa} \right)^2 - e^{s_{el}} \cdot \left(\frac{P_2}{kPa} \right)^2}{G^{0.8} \cdot \left(\frac{T_{f\_K}}{K} \right) \cdot \left(\frac{L_e}{km} \right) \cdot \left(\frac{\mu}{poise} \right)^{0.2}} \right)^{0.555} \cdot \left(\frac{D_p}{mm} \right)^{2.667} \cdot \frac{m^3}{day}$$

$$Q_{IGT} = 1.591 \times 10^7 \, \frac{m^3}{d}$$