Dense Phase CO_2 Pipeline Case Study Using ProMax Properties

Input data:

$kmole := 1000mole$ $lbmole := 453.4mole$

$MW := 44\frac{lb}{lbmole}$ $cP := \frac{poise}{100}$ $C := 5.7\cdot 10^{-4}\frac{MPa}{K}$ $R_g := 8.314\cdot\frac{Pa\cdot m^3}{mole\cdot K}$

$Q_S := 160\cdot 10^6\frac{SCF}{D}$ $Q_{Std} := Q_S\frac{ft^3}{day}$

CO2 Critical Properties $T_C := 304K$ $P_C := 7.38MPa$ $MW = 44.019\frac{kg}{kmole}$

$mass := Q_S\frac{ft^3}{day}\cdot\frac{lbmole}{379.5\cdot ft^3}\cdot MW$ $mass = 97.39\frac{kg}{s}$ $mass = 214.707\cdot\frac{lb}{s}$

$MoleRate := Q_{Std}\cdot\left(\frac{lbmole}{379.5ft^3}\right)$ $MoleRate = 1.757\times 10^4\cdot\frac{lbmole}{hr}$ $MoleRate = 7.965\times 10^3\cdot\frac{kmole}{hr}$

$Length := 100\cdot mile$ $Length = 160.934\cdot km$ $Dia := 395mm$ $Dia = 15.551\cdot in$

$Area := \frac{\pi}{4}\cdot Dia^2$ $Area = 0.12254\,m^2$ $Area = 1.319\cdot ft^2$

Standard Condition: $P_S := 101.325\cdot 10^3 Pa$ $T_S := (15 + 273)K$

$\rho_S := \frac{P_S\cdot MW}{R_g\cdot T_S}$ $\rho_S = 1.863\cdot\frac{kg}{m^3}$

$Q_{Std} := MoleRate\cdot\left(23.64\frac{m^3}{kmole}\right)$ $Q_{Std} = 52.303\cdot\frac{m^3}{s}$ $Q_{Std} = 4.519\times 10^6\cdot\frac{m^3}{day}$

$T := (40 + 273)K$ $T = 313\,K$ $T = 563.4\,R$

Solution for one segment

$P_{in} := 140bar$ $P_{in} = 14\cdot MPa$ $P_1 := P_{in}$ $P_{out} := 9.815MPa$ (Assumed Value)

$P_{Avg} := \frac{P_{in} + P_{out}}{2}$ $P_{Avg} = 119.075\cdot bar$ $P_{in} = 2.0305\times 10^3\cdot psi$

$Pavg := \frac{P_{Avg}}{MPa}$ $Pavg = 11.908$ $P_{Avg} = 11.908\cdot MPa$

Density and Viscosity Correlation Coefficients

$$DA := \begin{pmatrix} -4722.2000 \\ 1217.5000 \\ -94.0780 \\ 2.4694 \end{pmatrix} \qquad VA := \begin{pmatrix} -0.180207558 \\ 4.5871475418E-02 \\ -3.1836754072E-03 \\ 7.7928525288E-05 \end{pmatrix}$$

$\rho := \left(DA_4\cdot Pavg^3 + DA_3\cdot Pavg^2 + DA_2\cdot Pavg + DA_1\right)\cdot\frac{kg}{m^3}$ $\rho = 605.202\frac{kg}{m^3}$ $\rho = 37.782\cdot\frac{lb}{ft^3}$

$Vel := \frac{mass}{Area \cdot \rho}$ $Vel = 1.313 \frac{m}{s}$ $Vel = 4.308 \cdot \frac{ft}{s}$ $Z := \frac{P_{Avg} \cdot MW}{\rho \cdot R_g \cdot T}$ $Z = 0.333$

$\mu := \left(VA_4 \cdot Pavg^3 + VA_3 \cdot Pavg^2 + VA_2 \cdot Pavg + VA_1\right) \cdot cP$ $\mu = 0.046 \cdot cP$

$\mu = 4.617 \times 10^{-5} \frac{kg}{m \cdot s}$ $\mu = 3.102 \times 10^{-5} \frac{lb}{ft \cdot s}$

Calculate the Reynolds Number

$Re := \frac{\rho \cdot (Vel) \cdot (Dia)}{\mu}$ $Re = 6.8 \times 10^6$

$\varepsilon/D := 0.001$ Roughness factor or relative roughness

Calculate the friction factor using Colburn formula by trial and error

$f := 0.02$ Use this value as initial guess

Given Find friction factor by find option of MathCad

$\frac{1}{\sqrt{f}} = -2 \log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re \cdot \sqrt{f}}\right)$ $f := Find(f)$ $f = 0.0197$ This is calculated value

Liquid Phase Pressure Drop Calculations

$\Delta P_{Liquid} := f \cdot \frac{Length}{Dia} \cdot \frac{Vel^2}{2} \cdot \rho$ $\Delta P_{Liquid} = 4.185 \cdot MPa$ $\Delta P_{Liquid} = 606.9 \cdot psi$

$P_{LiqOut} := P_{in} - \Delta P_{Liquid}$ $P_{LiqOut} = 9.815 \cdot MPa$ $P_{LiqOut} = 1423.6 \cdot psi$

Gas Phase Pressure Drop Calculations

$P_{out} := \sqrt{P_{in}^2 - C \cdot f \cdot Length \cdot Z \cdot T \cdot \rho_S \cdot \frac{Q_{Std}^2}{Dia^5}}$ $P_{out} = 9.815 \cdot MPa$ $P_{out} = 1423.5 \cdot psi$

$\Delta P_{Gas} := P_{in} - P_{out}$ $\Delta P_{Gas} = 4.185 \cdot MPa$ $\Delta P_{Gas} = 607 \cdot psi$