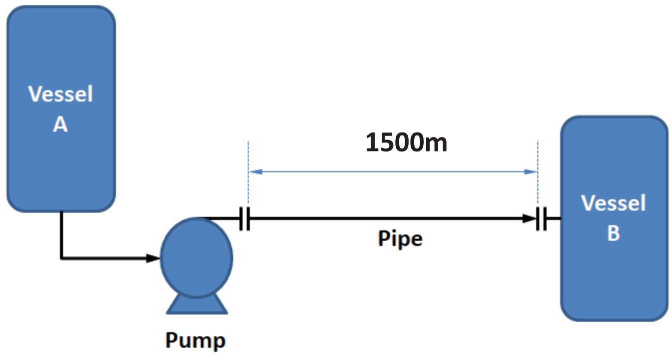
Lesson No. 1 – Pipe Sizing Hydraulics

Hydrocarbon Condensate has to be transported from Vessel A to Vessel B. In order to transport the condensate product from Vessel A, a pump is installed at Vessel A. The distance between the Pump at Vessel A to the nozzle of Vessel B is 1,500 m (Straight Length). The required amount to be transported is 150,000 kg/h. The density of the oil transported is 850 kg/m^3. Viscosity of oil is 0.4 cP. The roughness of the pipe can be taken to be 45.2 μm. The required pressure at Vessel B Inlet Nozzle is 2 bar(g).



Your Task:

1. What would be the minimum Pipe Size (ID) required for an allowable pressure drop of < 0.1 bar/100m across the pipe for a pump flow rate of 150,000 kg/h. Assume your client's requirement of commercial pipe sizes is per ANSI/ASME B36.10M. Use Schedule 40 pipe (Sch 40).
2. For the flow rate of 150,000 kg/h & the pipe size chosen, what is the inlet pressure required at the pipe inlet at Vessel A Pump discharge. (This determines what is the pump discharge pressure required).
3. For various pipe sizes between 4" to 20", Plot a graph, Pressure drop (Y-axis) Vs. Pipe OD (X-Axis) for a flow rate of 150,000kg/h.
4. What is the velocity of the condensate in the pipe for the selected pipe.
5. If Pipe Roughness is 100 μm, what is the pipe size required for an allowable pressure drop of <0.1 bar/100m.

Notes:

1. Work out a full set of hand calculations using ***Equation Editor in MS Word & format it neatly with all equation numbers & step by step calculations***. Use SI/Metric Units for consistency and right answers.

2. For Pressure Drop calculations,

1. If N_{Re} <= 2100 - Use Laminar Flow Friction Factor
2. If 2100 <= N_{Re} <= 4000 - Use Churchill Equation
3. If N_{Re} > 4000 - Use Colebrook Equation
4. Pressure Drop is estimated using Darcy-Weisbach Equation

In case if you think there isn't enough information, try assuming them & also explain why you chose them in the report.

Line Sizing Task - Solution

Given Parameters:

Length of pipe, L= 1500m

Density of fluid, ρ = 850kg/m^3

Flow rate of fluid, Q = 150000kg/hr = $\frac{150000}{850} = 176.47$m^3/hr

Viscosity of fluid, μ = 0.4 cP = 0.0004kg/m.s

Roughness of pipe, ε = 45.2μm = 0.0000452m

Outlet pressure, P_2 = 2 bar(g)

Pump discharge pressure P_1 =?

Allowable pressure drops of < 0.1bar/100m

Pipe Schedule = SCH 40

Solution

Step 1: Assume pipe size

Initial Pipe size assumed = 4";

Corresponding Outer diameter = 4.5"; (read from ASME B36.1 pipe table for 4" SCH 40)

Pipe wall thickness (read from ASME B36.1 pipe table for 4" SCH 40) = 0.237"

Corresponding Inner diameter with SCH 40, D = [4.5 - (2 x 0.237) = 4.026" = 0.1022604m

Step 2: **Calculate Velocity and check whether calculated velocity falls within recommended range (API 14E velocity range of 0.9m/s – 4.5m/s):**

- **If YES, calculate pressure drop and check if it falls within the specified allowable pressure drop in given parameters**
- **If NO, assume a new pipe size and repeat step 2**

Q = vA; 176.47 = $v\frac{\pi D^2}{4}$; $v =$ (4 x 176.47)/ (π x 0.1022604^2 x 3600) = 5.9685m/s (does not fall within API 14 E recommended range of between 0.9m/s and 4.5m/s)

We assume new pipe size

New assumed Pipe size = 6" (I assumed a higher pipe size than the previous, because to get a velocity lower than 5.9685, pipe size must increase)

Corresponding Outer diameter = 6.625”; (read from ASME B36.1 pipe table for 6” SCH 40)

Pipe wall thickness (SCH 40) = 0.28” (read from ASME B36.1 pipe table for 6” SCH 40)

Corresponding Inner diameter with SCH 40, D = [6.625 - (2 x 0.28) = 6.065” = 0.154051m

Checking for velocity compliance with API 14E:
Q = vA; 176.47 = $v\frac{\pi D^2}{4}$; $v =$ (4 x 176.47)/ (π x 0.154051^2 x 3600) = 2.62996m/s (Complies with API 14 E velocity of between 0.9m/s and 4.5m/s)

Step 3: Calculate pressure drop and check if it falls within the specified allowable pressure drop in given parameters (<0.1bar/100m)

- **If YES, then select pipe size**
- **If No, then assume a new pipe size and repeat from step 2**

Checking if chosen diameter (6”) meets the allowable pressure drop criteria:

Reynold number, $R_e = \frac{\rho v D}{\mu}$ = $\frac{850 \times 2 \cdot 62996 \times 0 \cdot 154051}{0.0004}$ = 860939.431915 (turbulent flow)

Since flow is turbulent, Colebrook Equation will be used

$$\frac{1}{\sqrt{f}} = -2\, log_{10}\left[\frac{\varepsilon}{3 \cdot 7D} + \frac{2 \cdot 51}{Re\sqrt{f}}\right]$$

Substituting values and solving iteratively for f gives f = 0.015711

Pressure drop $\Delta P = \frac{\rho f L v^2}{2D}$ = $\frac{850 \times 2 \cdot 62996 \times 2 \cdot 62996 \times 0 \cdot 015711 \times 1500}{2 \times 0.154051}$ = 4.9699bar = 0.2998bar/100m (does not meet pressure drop criteria of < 0.1bar/100m)

Since pressure drop criteria is not met with pipe size 6”, we choose a higher pipe size and check for both velocity and pressure drop criteria

New assumed Pipe Size = 8”

Corresponding Outer diameter = 8.625”; (read from ASME B36.1 pipe table for 8” SCH 40)

Pipe wall thickness (SCH 40) = 0.322” (read from ASME B36.1 pipe table for 8” SCH 40)

Corresponding Inner diameter with SCH 40, D = [8.625 - (2 x 0.322) = 7.981” = 0.2027174m

Checking for velocity compliance with API 14E:

Q = vA; 176.47 = $v\frac{\pi D^2}{4}$; $v =$ (4 x 176.47)/ (π x 0.2027174^2 x 3600) = 1.51879m/s (Complies with API 14 E (between 0.9m/s and 4.5m/s))

Checking if chosen diameter (8") meets the allowable pressure drop criteria

Reynold number, $R_e = \frac{\rho v D}{\mu}$ = $\frac{850 \times 1.51879 \times 0.20271174}{0.0004}$ = 654256.217 (turbulent flow)

Since flow is turbulent, Colebrook Equation will be used again

$$\frac{1}{\sqrt{f}} = -2\,log_{10}\left[\frac{\varepsilon}{3 \cdot 7D} + \frac{2 \cdot 51}{Re\sqrt{f}}\right]$$

Substituting values and solving iteratively for f gives f = 0.015319

Pressure drop $\Delta P = \frac{\rho f L v^2}{2D}$ = $\frac{850 \times 1.51879 \times 1.51879 \times 0 \cdot 015319 \times 1500}{2 \times 0.2027174}$ = 1.111277bar = 0.0741bar/100m (Meets pressure drop criteria of < 0.1bar/100m)

Therefore,

1.) The minimum pipe size (ID) required = 8 inches (8")
2.) For Pump discharge pressure required:
    Pressure drop = $\Delta P =$ P_1 - P_2;
    1.111277 = P_1 – 2;
    P_1 = 3.1111277bar(g) = 3.1 bar(g)
4.) Velocity of Condensate, v = 1.51879m/s = 1.52m/s