STUDY GUIDE
Energy and Flow #1

Linear Analysis

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Energy and Flow: PART A

- ***Water at 40F flows through the coil of heat exchanger as shown with 0.5" copper pipe (drawn tubes) at rate of 0.9 gal/min. Determine the pressure drop between the inlet and outlet.***
- ***Convert flow to base units:***

$$Q = 0.9\frac{gal}{\min}231\frac{in^3}{gal}\frac{1\,ft^3}{1728in^3}\frac{1\min}{60s} = 0.002\frac{ft^3}{s}$$

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi D^2}{4}} = \frac{Q}{\pi\left(\frac{0.5}{12}\right)^2} = 1.47\,ft/s$$

- ***Apply Energy Equation***

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}+\cancel{h_p} = \cancel{h_T}+\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+\sum_j f_j\frac{L_j}{D_j}\frac{V_j^2}{2g}+\sum_i K_{L_i}\frac{V_i^2}{2g}$$

$$\Delta P = P_1 - P_2 = \left(\cancel{\frac{V_2^2}{2g}-\frac{V_1^2}{2g}}+\sum_j f_j\frac{L_j}{D_j}\frac{V_j^2}{2g}+\sum_i K_{L_i}\frac{V_i^2}{2g}\right)\gamma$$

$$\Delta P = P_1 - P_2 = \left(\sum_j f_j\frac{L_j}{D_j}\frac{V_j^2}{2g}+\sum_i K_{L_i}\frac{V_i^2}{2g}\right)\gamma$$

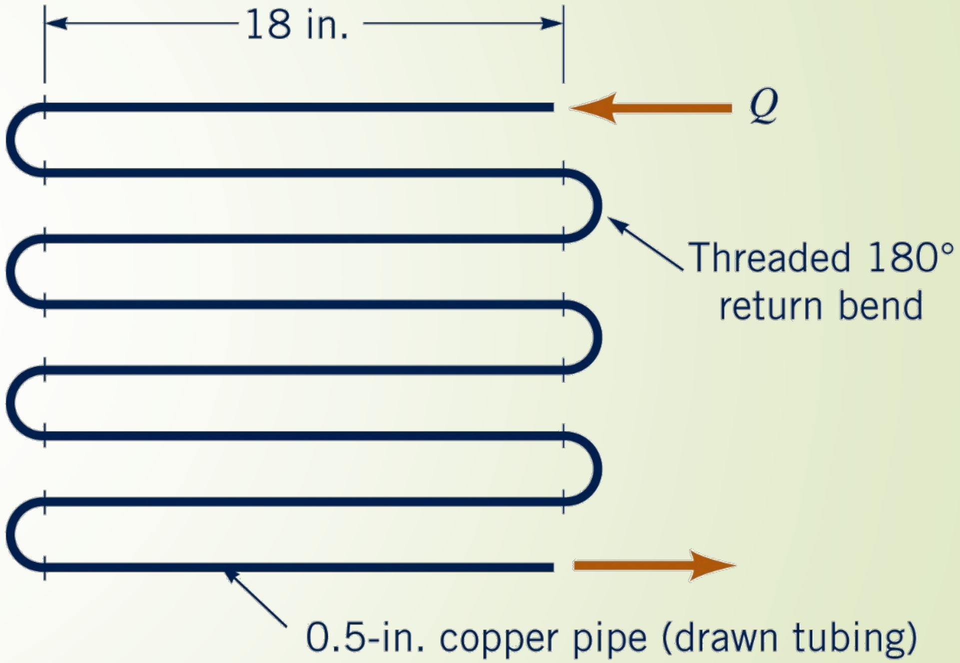

Figure P8.81

Frictional Losses

- **Minor Frictional Losses**

Regular 180^0 Threaded Return Bends (n=7)

Table 8.2, K=1.5

$$\sum K_L = 7 \bullet 1.5 = 10.5$$

$$\sum_i K_{L_i} \frac{V_i^2}{2g} = 10.5 \frac{V^2}{2g}$$

- **Major Losses**

Relative Roughness, Table 8.2

$$\varepsilon = 0.000005\,ft$$

$$\frac{\varepsilon}{D} = \frac{0.000005\,ft}{\frac{0.5}{12}ft} = 1.2x10^{-4}$$

$$l = 8 \bullet \frac{18}{12}ft = 12\,ft$$

$$\sum_j f_j \frac{L_j}{D_j}\frac{V_j^2}{2g} = f\frac{L}{D}\frac{V^2}{2g} = f\frac{12\,ft}{\frac{0.5\,ft}{12}}\frac{V^2}{2g} = 288 f \frac{V^2}{2g}$$

Energy Flow Equation

$$\Delta P = P_1 - P_2 = \left(\sum_j f_j \frac{L_j}{D_j}\frac{V_j^2}{2g} + \sum_i K_{L_i}\frac{V_i^2}{2g}\right)\gamma$$

$$\Delta P = \left[(10.5 + 288 f)\frac{V^2}{2g}\right]\gamma$$

Note: Constant Diameter Pipe Means Same Velocity For Pipe and Components

- **Total**

$$\sum_i K_{L_i}\frac{V_i^2}{2g} + \sum_j f_j \frac{L_j}{D_j}\frac{V_j^2}{2g} = \left(\sum_i K_{L_i} + \sum_j f_j\right)\frac{V^2}{2g} = (10.5 + 288 f)\frac{V^2}{2g}$$

Friction Factor

- Reynolds Number

$$f = F(\mathrm{Re}_D, \frac{\varepsilon}{D})$$

$$\mathrm{Re}_D = \frac{VD}{\frac{\mu}{\rho}} = \frac{1.47\,ft/s \bullet \frac{0.5}{12}\,ft}{1.66x10^{-5}\,ft^2/s} = 3690$$

$$\frac{\varepsilon}{D} = 1.2x10^{-4}$$

- Haaland Equation

$$\frac{1}{\sqrt{f}} = -1.8\log_{10}\left(\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\mathrm{Re}}\right)$$

$$\frac{1}{\sqrt{f}} = -1.8\log_{10}\left(\left(\frac{1.2x10^{-4}}{3.7}\right)^{1.11} + \frac{6.9}{3690}\right) = 4.90638$$

$$f = 0.04154$$

$$\Delta P = \left[(10.5 + 288f)\frac{V^2}{2g}\right]\gamma$$

$$\Delta P = \left[(10.5 + 288 \bullet 0.041)\frac{1.47^2\,ft^2/s^2}{2 \bullet 32.2\,ft/s^2}\right]62.4lb/ft^3$$

$$\Delta P = 47\frac{lbf}{ft^2} = 0.3266PSIG$$

PUMP Power

- Power needed to overcome pressure drop due to losses.

$$
\begin{aligned}
\dot{W}_p &= \gamma Q h_{Loss} \\
&= \gamma Q \frac{\Delta P}{\gamma} \\
&= Q\Delta P = 0.002\frac{ft^3}{s} \bullet 47\frac{lbf}{ft^2} \\
&= 0.094\frac{lbf-ft}{s} \bullet \frac{1hp}{550\frac{lbf-ft}{s}} \\
&= 1.7x10^{-4}\,hp
\end{aligned}
$$