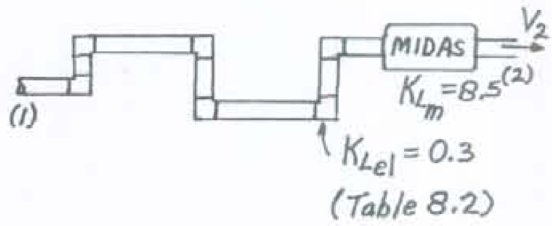
8.76

8.76 Assume a car's exhaust system can be approximated as 14 ft of 0.125-ft-diameter cast-iron pipe with the equivalent of six 90° flanged elbows and a muffler. (See Video V8.12) The muffler acts as a resistor with a loss coefficient of $K_L = 8.5$. Determine the pressure at the beginning of the exhaust system if the flowrate is 0.10 cfs, the temperature is 250 °F, and the exhaust has the same properties as air.



$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + \left(f\frac{\ell}{D} + \Sigma K_L\right)\frac{V^2}{2g},$$ where $z_1 = z_2$, $p_2 = 0$,

and

$$V = V_1 = V_2 = \frac{Q}{A} = \frac{0.1\ \frac{ft^3}{s}}{\frac{\pi}{4}(0.125\,ft)^2} = 8.15\ \frac{ft}{s}$$

Thus,

$$p_1 = \left(f\frac{\ell}{D} + \Sigma K_L\right)\frac{1}{2}\rho V^2,$$ where $$\rho = \frac{p}{RT} = \frac{(14.7\ \frac{lb}{in.^2})(144\ \frac{in.^2}{ft^2})}{(1716\ \frac{ft\cdot lb}{slug\cdot {}^\circ R})(460+250)^\circ R} = 1.74\times10^{-3}\ \frac{slug}{ft^3}$$

Also, $\frac{\varepsilon}{D} = \frac{0.00085\ ft}{0.125\ ft} = 0.0068$ (Table 8.1)

so that with $$Re = \frac{\rho V D}{\mu} = \frac{(1.74\times10^{-3}\ \frac{slug}{ft^3})(8.15\ \frac{ft}{s})(0.125\,ft)}{4.7\times10^{-7}\ \frac{lb\cdot s}{ft^2}} = 3770$$ we

obtain from Fig. 8.20, $f = 0.047$

Hence,

$$p_1 = \left(0.047\left(\frac{14\,ft}{0.125\,ft}\right) + 6(0.3) + 8.5\right)\left(\frac{1}{2}\right)\left(1.74\times10^{-3}\ \frac{slug}{ft^3}\right)\left(8.15\ \frac{ft}{s}\right)^2$$

$$= \underline{\underline{0.899\ \frac{lb}{ft^2}}}$$