8.68 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 V8.5.) The muffler acts as a resistor with a loss coefficient of \( K_r = 8.5 \). Determine the pressure at the beginning of the exhaust system if the flow rate is 0.10 cfs, the temperature is 250 °F, and the exhaust has the same properties as air.

\[
\frac{\rho_1 V_1^2}{2g} + Z_1 = \frac{\rho_2 V_2^2}{2g} + Z_2 + \left( \frac{L}{D} + \Sigma K_L \right) \frac{V^2}{2g}, \quad \text{where} \quad Z_1 = Z_2, \quad \rho_2 = 0, \quad \text{and} \quad V = V_1 = V_2 = \frac{Q_1}{A} = \frac{0.1\text{ ft}^3}{\frac{\pi}{4}(0.125\text{ ft})^2} = 8.15 \text{ ft/s}
\]

Thus,

\[
\rho_1 = \left( \frac{L}{D} + \Sigma K_L \right) \frac{1}{2} \rho V^2, \quad \text{where} \quad \rho = \frac{Q_1}{\mu \frac{\pi}{4} (0.125\text{ ft})^2} = \frac{(14.7 \text{ lb/ft}^3)(144 \text{ in}^2)}{(1716 \text{ lb/ft}^3)(460+250)\text{°R}} = 1.74 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3}
\]

Also \( \xi = \frac{0.000055 \text{ ft}}{0.125 \text{ ft}} = 0.00088 \) (Table 8.1),

so that with \( \Re = \frac{\rho V D}{\mu} = \frac{(1.74 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3})(8.15 \text{ ft})}{0.125 \text{ ft}} = 3770 \text{ we obtain from Fig. 8.20, } f = 0.047
\]

Hence,

\[
\rho_1 = \left( 0.047 \left( \frac{144 \text{ ft}}{0.125 \text{ ft}} \right) + 6(0.3) + 8.5 \right) \left( \frac{1}{2} \right) \left( \frac{1.74 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3}}{1.74 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3}} \right) (8.15 \text{ ft})^2
\]

\[
= 0.899 \frac{\text{lb}}{\text{ft}^2}
\]