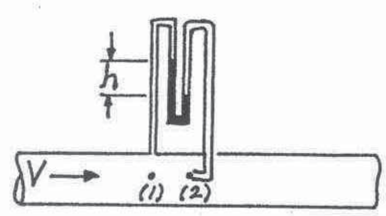
3.24

3.24 A Pitot-static tube is used to measure the velocity of helium in a pipe. The temperature and pressure are 40 °F and 25 psia. A water manometer connected to the Pitot-static tube indicates a reading of 2.3 in. Determine the helium velocity. Is it reasonable to consider the flow as incompressible? Explain.



$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

with $z_1 = z_2$, $V_1 = V$, and $V_2 = 0$

Thus,

$$V_1 = \sqrt{2g\frac{(p_2 - p_1)}{\gamma}} = \sqrt{\frac{2(p_2 - p_1)}{\rho}}$$

where

$$\rho = \frac{p}{RT} = \frac{25\frac{lb}{in.^2}\left(144\frac{in.^2}{ft^2}\right)}{\left(1.242\times10^4\frac{ft\cdot lb}{slugs\cdot{}^\circ R}\right)(460+40)^\circ R} = 5.80\times10^{-4}\frac{slugs}{ft^3}$$

and since $\gamma_{H_2O} \gg \gamma_{He}$

$$p_2 - p_1 = \gamma_{H_2O}h = 62.4\frac{lb}{ft^3}\left(\frac{2.3}{12}ft\right) = 11.96\frac{lb}{ft^2}$$

Thus,

$$V_1 = \sqrt{\frac{2\left(11.96\frac{lb}{ft^2}\right)}{5.80\times10^{-4}\frac{slugs}{ft^3}}} = \underline{\underline{203\frac{ft}{s}}}$$

Note: $Ma = \frac{V}{c}$ where $c = \sqrt{kRT}$

Thus,

$$c = \left[1.66(1.242\times10^4)\frac{ft\cdot lb}{slug\cdot{}^\circ R}(460+40)^\circ R\right]^{1/2} = 3210\frac{ft}{s}$$

or

$$Ma = \frac{203\frac{ft}{s}}{3210\frac{ft}{s}} = 0.063 \ll 0.3$$

Thus, the flow can be considered incompressible.