

5.95

5.95 Oil ($SG = 0.9$) flows downward through a vertical pipe contraction as shown in Fig. P5.95. If the mercury manometer reading, h , is 100 mm, determine the volume flowrate for frictionless flow. Is the actual flowrate more or less than the frictionless value? Explain.

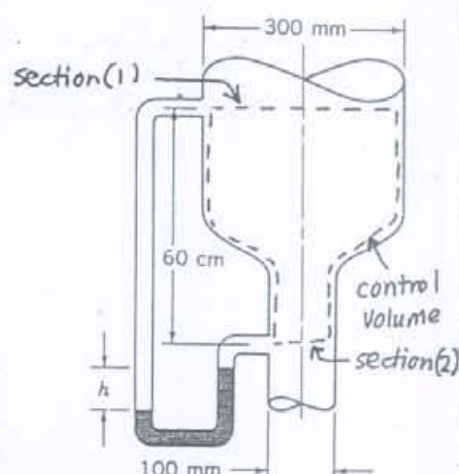


FIGURE P5.95

The volume flowrate may be obtained with

$$Q = A_1 V_1 = A_2 V_2 = \frac{\pi D_1^2}{4} V_1 = \frac{\pi D_2^2}{4} V_2 \quad (1)$$

To determine either V_1 or V_2 we apply the energy equation (Eq. 5.82) to the flow between sections (1) and (2). Thus,

$$\frac{P_2}{\rho} + \frac{V_2^2}{2} + g z_2 = \frac{P_1}{\rho} + \frac{V_1^2}{2} + g z_1 + \underbrace{w_{\text{shaft}}}_{\text{net in}} - \underbrace{\text{loss}}_{\text{neglect}} \quad (2)$$

Combining Eqs. 1 and 2 we obtain

$$\frac{V_2^2}{2} \left[1 - \left(\frac{D_2}{D_1} \right)^4 \right] = \frac{P_1 - P_2}{\rho} + g(z_1 - z_2) \quad (3)$$

To determine $\frac{P_1 - P_2}{\rho}$ we use the manometer equation from Section 2.6 to obtain

$$\frac{P_1 - P_2}{\rho} = gh \left(\frac{SG_{\text{Hg}}}{SG_{\text{oil}}} - 1 \right) - g(z_1 - z_2) \quad (4)$$

Combining Eqs. 3 and 4 we get

$$V_2 = \sqrt{\frac{2gh \left(\frac{SG_{\text{Hg}}}{SG_{\text{oil}}} - 1 \right)}{1 - \left(\frac{D_2}{D_1} \right)^4}}$$

or

$$V_2 = \sqrt{\frac{(2)(9.81 \frac{\text{m}}{\text{s}^2})(0.1 \text{ m}) \left(\frac{13.6}{0.9} - 1 \right)}{1 - \left(\frac{100 \text{ mm}}{300 \text{ mm}} \right)^4}} = 5.29 \frac{\text{m}}{\text{s}}$$

and from Eq. 1 we have

$$Q = \frac{\pi (0.1 \text{ m})^2 (5.29 \frac{\text{m}}{\text{s}})}{4} = \underline{\underline{0.042 \frac{\text{m}^3}{\text{s}}}}$$

Actual flowrate would be less than the frictionless value because the loss would be greater than the zero amount used above.