Solution: For water at 20°C, take ρ = 1.94 slug/ft^3 and μ = 2.09E−5 slug/ft·s. Let "a" be the small pipe and "b" the larger. For wrought iron, $\varepsilon \approx$ 0.00015 ft, whence ε/da = 0.0018 and ε/db = 0.0009. From the continuity relation,

$$Q = V_a \frac{\pi}{4} d_a^2 = V_b \frac{\pi}{4} d_b^2 \quad \text{or, since } d_b = 2d_a, \quad \text{we obtain } V_b = \frac{1}{4} V_a$$

For pipe "a" there are two minor losses: a sharp entrance, K_1 = 0.5, and a sudden expansion, Fig. 6.22, Eq. (6.101), $K_2 = [1 - (1/2)^2]^2 \approx 0.56$. For pipe "b" there is one minor loss, the submerged exit, $K_3 \approx 1.0$. The energy equation, with equal pressures at (1) and (2) and near zero velocities at (1) and (2), yields

$$\Delta z = h_{f\text{-}a} + \sum h_{m\text{-}a} + h_{f\text{-}b} + \sum h_{m\text{-}b} = \frac{V_a^2}{2g}\left(f_a \frac{L_a}{d_a} + 0.5 + 0.56\right) + \frac{V_b^2}{2g}\left(f_b \frac{L_b}{d_b} + 1.0\right),$$

$$\text{or, since} \quad V_b = V_a/4, \quad \Delta z = 45 \text{ ft} = \frac{V_a^2}{2(32.2)}\left[240 f_a + 1.06 + \frac{120}{16} f_b + \frac{1.0}{16}\right]$$

where f_a and f_b are separately related to different values of Re and ε/d. Guess to start:

$$f_a \approx f_b \approx 0.02: \quad \text{then } V_a = 21.85 \text{ ft/s}, \quad Re_a \approx 169000, \quad \varepsilon/d_a = 0.0018, \quad f_{a\text{-}2} \approx 0.0239$$

$$V_b = 5.46 \text{ ft/s}, \quad Re_b \approx 84500, \quad \varepsilon/d_b = 0.0009, \quad f_{b\text{-}2} \approx 0.0222$$

$$\text{Converges to:} \quad f_a = 0.024, \quad f_b = 0.0224, \quad V_a \approx 20.3 \text{ ft/s},$$

$$Q = V_a A_a \approx \mathbf{0.111\ ft^3/s}. \quad \textit{Ans.}$$

6.104 Reconsider the air hockey table of Problem 3.162, but with inclusion of minor losses. The table is 3 ft by 6 ft in area, with 1/16-in-diameter holes spaced every inch in a rectangular grid (2592 holes total). The required jet speed from each hole is 50 ft/s. Your job is to select an appropriate blower to meet the requirements.

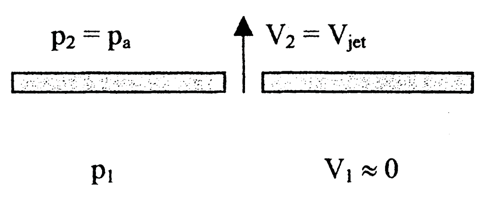

Fig. P3.162

Hint: Assume that the air is stagnant in the manifold under the table surface, and assume sharp-edge inlets at each hole. (a) Estimate the pressure rise (in lbf/in^2) required of the blower. (b) Compare your answer to the previous calculation in Prob. 3.162, where minor losses were ignored. Are minor losses significant?