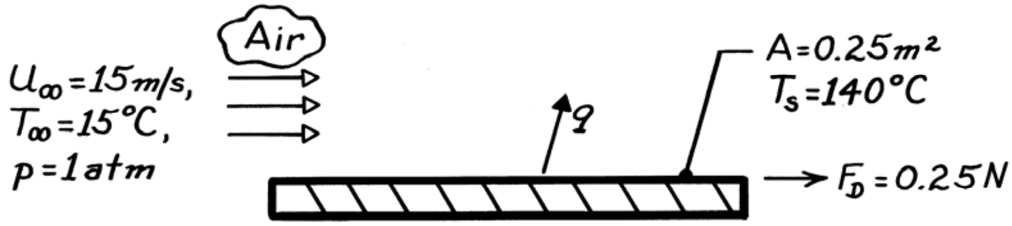
PROBLEM 6.35

KNOWN: Air flow conditions and drag force associated with a heater of prescribed surface temperature and area.

FIND: Required heater power.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Reynolds analogy is applicable, (3) Bottom surface is adiabatic.

PROPERTIES: *Table A-4*, Air (T_f = 350K, 1atm): $\rho = 0.995$ kg/m^3, $c_p = 1009$ J/kg·K, Pr = 0.700.

ANALYSIS: The average shear stress and friction coefficient are

$$\bar{\tau}_s = \frac{F_D}{A} = \frac{0.25\ \text{N}}{0.25\ \text{m}^2} = 1\ \text{N/m}^2$$

$$\bar{C}_f = \frac{\bar{\tau}_s}{\rho\, u_\infty^2/2} = \frac{1\ \text{N/m}^2}{0.995\ \text{kg/m}^3 (15\text{m/s})^2/2} = 8.93 \times 10^{-3}.$$

From the Reynolds analogy,

$$\overline{St} = \frac{\bar{h}}{\rho\, u_\infty c_p} = \frac{\bar{C}_f}{2} Pr^{-2/3}.$$

Solving for $\bar{h}$ and substituting numerical values, find

$$\bar{h} = 0.995\ \text{kg/m}^3 (15\text{m/s})\ 1009\ \text{J/kg}\cdot\text{K}\ \left(8.93\times 10^{-3}/2\right)\ (0.7)^{-2/3}$$

$$\bar{h} = 85\ \text{W/m}^2\cdot\text{K}.$$

Hence, the heat rate is

$$q = \bar{h}\, A\ (T_s - T_\infty) = 85\text{W/m}^2\cdot\text{K}\ \left(0.25\text{m}^2\right)\ (140-15)^\circ\text{C}$$

$$q = 2.66\ \text{kW}.$$ <

COMMENTS: Due to bottom heat losses, which have been assumed negligible, the actual power requirement would exceed 2.66 kW.