## **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:** 

$$\begin{array}{c} U_{\infty}=15 \, m/s, \\ T_{\infty}=15 \, ^{\circ}\mathrm{C}, \\ p=1 \, at \, m \end{array} \xrightarrow{f_{2}} f_{2} \\ \end{array} \xrightarrow{f_{2}} F_{p}=0.25 \, N \end{array}$$

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

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

ANALYSIS: The average shear stress and friction coefficient are

$$\overline{\tau}_{s} = \frac{F_{D}}{A} = \frac{0.25 \text{ N}}{0.25 \text{ m}^{2}} = 1 \text{ N/m}^{2}$$
$$\overline{C}_{f} = \frac{\overline{\tau}_{s}}{\rho u_{\infty}^{2}/2} = \frac{1 \text{ N/m}^{2}}{0.995 \text{ kg/m}^{3} (15 \text{ m/s})^{2}/2} = 8.93 \times 10^{-3}.$$

From the Reynolds analogy,

$$\overline{S}t = \frac{\overline{h}}{\rho u_{\infty}c_{p}} = \frac{\overline{C}_{f}}{2} Pr^{-2/3}.$$

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

$$\overline{h} = 0.995 \text{ kg/m}^3 (15 \text{m/s}) \ 1009 \text{ J/kg} \cdot \text{K} \left( 8.93 \times 10^{-3} / 2 \right) \ (0.7)^{-2/3}$$
  
$$\overline{h} = 85 \text{ W/m}^2 \cdot \text{K}.$$

Hence, the heat rate is

q = 
$$\overline{h} A (T_s - T_\infty) = 85 W/m^2 \cdot K (0.25m^2) (140 - 15)^\circ C$$
  
q = 2.66 kW.

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

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