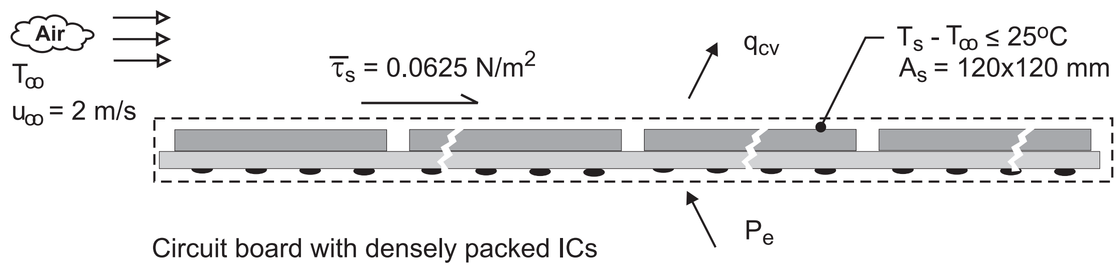
PROBLEM 6.51

KNOWN: Average frictional shear stress of $\overline{\tau}_s = 0.0625\ \text{N/m}^2$ on upper surface of circuit board with densely packed integrated circuits (ICs)

FIND: Allowable power dissipation from the upper surface of the board if the average surface temperature of the ICs must not exceed a rise of 25°C above ambient air temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) The modified Reynolds analogy is applicable, (3) Negligible heat transfer from bottom side of the circuit board, and (4) Thermophysical properties required for the analysis evaluated at 300 K,

PROPERTIES: *Table A-4*, Air (T_f = 300 K, 1 atm): ρ = 1.161 kg/m^3, c_p = 1007 J/kg·K, Pr = 0.707.

ANALYSIS: The power dissipation from the circuit board can be calculated from the convection rate equation assuming an excess temperature (T_s - T_∞) = 25°C.

$$q = \overline{h} A_s \left(T_s - T_\infty\right) \tag{1}$$

The average convection coefficient can be estimated from the Reynolds analogy and the measured average frictional shear stress $\overline{\tau}_s$.

$$\frac{\overline{C}_f}{2} = \overline{St}\ Pr^{2/3} \qquad \overline{C}_f = \frac{\overline{\tau}_s}{\rho\ V^2/2} \qquad \overline{St} = \frac{\overline{h}}{\rho\ V\ c_p} \qquad (2,3,4)$$

With V = u_∞ and substituting numerical values, find $\overline{h}$.

$$\frac{\tau_s}{\rho\ V^2} = \frac{\overline{h}}{\rho\ V c_p} Pr^{2/3}$$

$$\overline{h} = \frac{\overline{\tau}_s\ c_p}{V} Pr^{-2/3}$$

$$\overline{h} = \frac{0.0625\ \text{N/m}^2 \times 1007\ \text{J/kg}\cdot\text{K}}{2\ \text{m/s}} \left(0.707\right)^{-2/3} = 39.7\ \text{W/m}^2\cdot\text{K}$$

Substituting this result into Eq. (1), the allowable power dissipation is

$$q = 39.7\ \text{W/m}^2\cdot\text{K} \times \left(0.120 \times 0.120\right)\text{m}^2 \times 25\ \text{K} = 14.3\ \text{W}$$ <

COMMENTS: For this analysis using the modified or Chilton-Colburn analogy, we found C_f = 0.0269 and St = 0.0170. Using the Reynolds analogy, the results are slightly different with $\overline{h} = 31.5\ \text{W/m}^2\cdot\text{K}$ and q = 11.3 W.