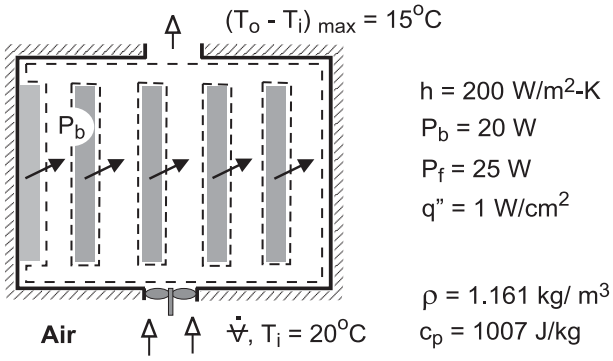
PROBLEM 1.70

KNOWN: Number and power dissipation of PCBs in a computer console. Convection coefficient associated with heat transfer from individual components in a board. Inlet temperature of cooling air and fan power requirement. Maximum allowable temperature rise of air. Heat flux from component most susceptible to thermal failure.

FIND: (a) Minimum allowable volumetric flow rate of air, (b) Preferred location and corresponding surface temperature of most thermally sensitive component.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) Constant air properties, (3) Negligible potential and kinetic energy changes of air flow, (4) Negligible heat transfer from console to ambient air, (5) Uniform convection coefficient for all components.

ANALYSIS: (a) For a control surface about the air space in the console, conservation of energy for an open system, Equation (1.12d), reduces to

$$\dot{m}\left(u_t + pv\right)_{in} - \dot{m}\left(u_t + pv\right)_{out} + q - \dot{W} = 0$$

where $u_t + pv = i$, $q = 5P_b$, and $\dot{W} = -P_f$. Hence, with $\dot{m}\left(i_{in} - i_{out}\right) = \dot{m}c_p\left(T_{in} - T_{out}\right)$,

$$\dot{m}c_p\left(T_{out} - T_{in}\right) = 5\,P_b + P_f$$

For a maximum allowable temperature rise of 15°C, the required mass flow rate is

$$\dot{m} = \frac{5\,P_b + P_f}{c_p\left(T_{out} - T_{in}\right)} = \frac{5 \times 20\ \text{W} + 25\ \text{W}}{1007\ \text{J/kg}\cdot\text{K}\left(15\ ^\circ\text{C}\right)} = 8.28 \times 10^{-3}\ \text{kg/s}$$

The corresponding volumetric flow rate is

$$\forall = \frac{\dot{m}}{\rho} = \frac{8.28 \times 10^{-3}\ \text{kg/s}}{1.161\ \text{kg/m}^3} = 7.13 \times 10^{-3}\ \text{m}^3/\text{s} \qquad <$$

(b) The component which is most susceptible to thermal failure should be mounted at the bottom of one of the PCBs, where the air is coolest. From the corresponding form of Newton's law of cooling, $q'' = h\left(T_s - T_{in}\right)$, the surface temperature is

$$T_s = T_{in} + \frac{q''}{h} = 20^\circ\text{C} + \frac{1 \times 10^4\ \text{W/m}^2}{200\ \text{W/m}^2\cdot\text{K}} = 70^\circ\text{C} \qquad <$$

COMMENTS: (1) Although the mass flow rate is invariant, the volumetric flow rate increases as the air is heated in its passage through the console, causing a reduction in the density. However, for the prescribed temperature rise, the change in ρ, and hence the effect on $\dot{\forall}$, is small. (2) If the thermally sensitive component were located at the top of a PCB, it would be exposed to warmer air (T_o = 35°C) and the surface temperature would be T_s = 85°C.