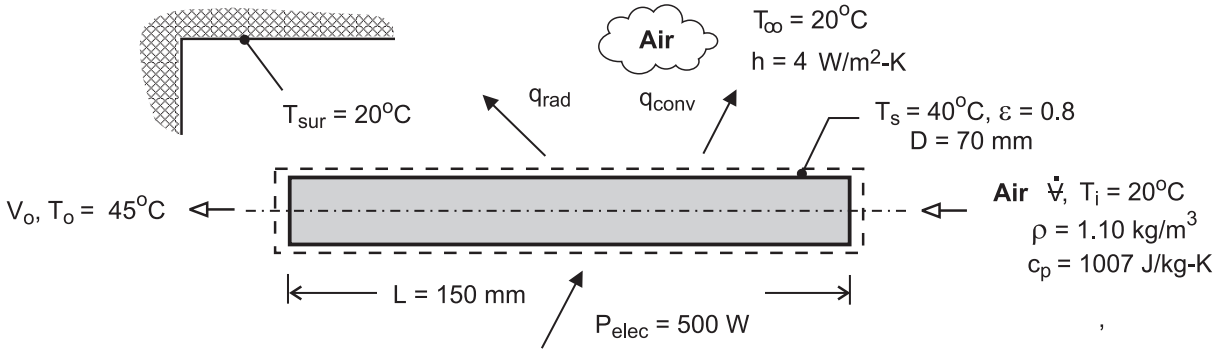
PROBLEM 1.52

KNOWN: Power consumption, diameter, and inlet and discharge temperatures of a hair dryer.

FIND: (a) Volumetric flow rate and discharge velocity of heated air, (b) Heat loss from case.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) Constant air properties, (3) Negligible potential and kinetic energy changes of air flow, (4) Negligible work done by fan, (5) Negligible heat transfer from casing of dryer to ambient air (Part (a)), (6) Radiation exchange between a small surface and a large enclosure (Part (b)).

ANALYSIS: (a) For a control surface about the air flow passage through the dryer, conservation of energy for an open system reduces to

$$\dot{m}\left(u + pv\right)_i - \dot{m}\left(u + pv\right)_o + q = 0$$

where u + pv = i and $q = P_{elec}$. Hence, with $\dot{m}\left(i_i - i_o\right) = \dot{m}c_p\left(T_i - T_o\right)$,

$$\dot{m}c_p\left(T_o - T_i\right) = P_{elec}$$

$$\dot{m} = \frac{P_{elec}}{c_p\left(T_o - T_i\right)} = \frac{500\ W}{1007\ J/kg \cdot K\left(25^\circ C\right)} = 0.0199\ kg/s$$

$$\dot{\forall} = \frac{\dot{m}}{\rho} = \frac{0.0199\ kg/s}{1.10\ kg/m^3} = 0.0181\ m^3/s \qquad <$$

$$V_o = \frac{\dot{\forall}}{A_c} = \frac{4\dot{\forall}}{\pi D^2} = \frac{4 \times 0.0181\ m^3/s}{\pi\left(0.07\ m\right)^2} = 4.7\ m/s \qquad <$$

(b) Heat transfer from the casing is by convection and radiation, and from Equation (1.10)

$$q = hA_s\left(T_s - T_\infty\right) + \varepsilon A_s\sigma\left(T_s^4 - T_{sur}^4\right)$$

where $A_s = \pi DL = \pi\left(0.07\ m \times 0.15\ m\right) = 0.033\ m^2$. Hence,

$$q = 4 W/m^2 \cdot K\left(0.033\ m^2\right)\left(20^\circ C\right) + 0.8 \times 0.033\ m^2 \times 5.67 \times 10^{-8}\ W/m^2 \cdot K^4\left(313^4 - 293^4\right)K^4$$

$$q = 2.64\ W + 3.33\ W = 5.97\ W \qquad <$$

The heat loss is much less than the electrical power, and the assumption of negligible heat loss is justified.

COMMENTS: Although the mass flow rate is invariant, the volumetric flow rate increases because the air is heated in its passage through the dryer, 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.