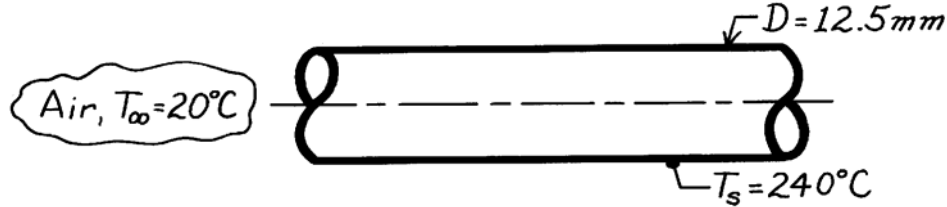


PROBLEM 9.58

KNOWN: Horizontal tube, 12.5mm diameter, with surface temperature 240°C located in room with an air temperature 20°C.

FIND: Heat transfer rate per unit length of tube due to convection.

SCHEMATIC:



ASSUMPTIONS: (1) Ambient air is quiescent, (2) Surface radiation effects are not considered.

PROPERTIES: Table A-4, Air (T_f = 400K, 1 atm): $\nu = 26.41 \times 10^{-6} \text{ m}^2/\text{s}$, $k = 0.0338 \text{ W/m}\cdot\text{K}$, $\alpha = 38.3 \times 10^{-6} \text{ m}^2/\text{s}$, $\text{Pr} = 0.690$, $\beta = 1/T_f = 2.5 \times 10^{-3} \text{ K}^{-1}$.

ANALYSIS: The heat rate from the tube, per unit length of the tube, is

$$q' = \bar{h} \pi D (T_s - T_\infty)$$

where $\bar{h}$ can be estimated from the correlation, Eq. 9.34,

$$\overline{\text{Nu}}_D = \left\{ 0.60 + \frac{0.387 \text{Ra}_D^{1/6}}{\left[1 + (0.559/\text{Pr})^{9/16} \right]^{8/27}} \right\}^2.$$

From Eq. 9.25,

$$\text{Ra}_D = \frac{g\beta(T_s - T_\infty)D^3}{\nu\alpha} = \frac{9.8 \text{ m/s}^2 \times 2.5 \times 10^{-3} \text{ K}^{-1} (240 - 20) \text{ K} \times (12.5 \times 10^{-3} \text{ m})^3}{26.41 \times 10^{-6} \text{ m}^2/\text{s} \times 38.3 \times 10^{-6} \text{ m}^2/\text{s}} = 10,410.$$

$$\text{Hence, } \overline{\text{Nu}}_D = \left\{ 0.60 + \frac{0.387 (10,410)^{1/6}}{\left[1 + (0.559/0.690)^{9/16} \right]^{8/27}} \right\}^2 = 4.40$$

$$\bar{h} = \frac{k}{D} \overline{\text{Nu}}_D = \frac{0.0338 \text{ W/m}\cdot\text{K}}{12.5 \times 10^{-3} \text{ m}} \times 4.40 = 11.9 \text{ W/m}^2 \cdot \text{K}.$$

The heat rate is

$$q' = 11.9 \text{ W/m}^2 \cdot \text{K} \times \pi (12.5 \times 10^{-3} \text{ m}) (240 - 20) \text{ K} = 103 \text{ W/m}. \quad <$$

COMMENTS: Heat loss rate by radiation, assuming an emissivity of 1.0 for the surface, is

$$q'_{\text{rad}} = \varepsilon P \sigma (T_s^4 - T_\infty^4) = 1 \times \pi (12.5 \times 10^{-3} \text{ m}) \times 5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4} \left[(240 + 273)^4 - (20 + 273)^4 \right] \text{ K}^4$$

$$q'_{\text{rad}} = 138 \text{ W/m}.$$

Note that $P = \pi D$. Note also this estimate assumes the surroundings are at ambient air temperature. In this instance, $q'_{\text{rad}} > q'_{\text{conv}}$.