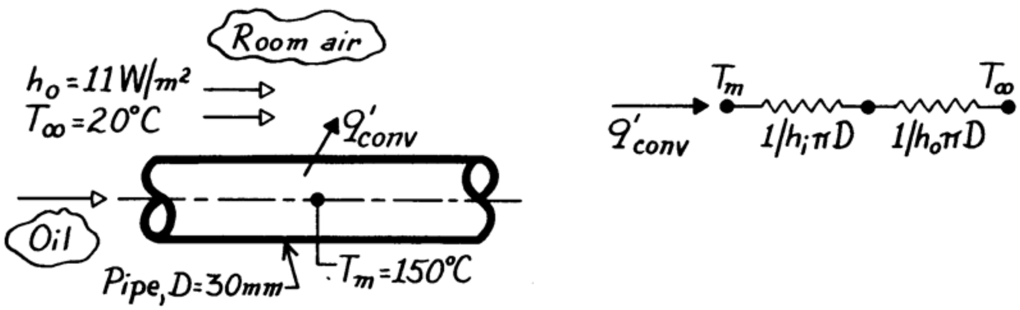
PROBLEM 8.58

KNOWN: Oil flowing slowly through a long, thin-walled pipe suspended in a room.

FIND: Heat loss per unit length of the pipe, q'_{conv}.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Tube wall thermal resistance negligible, (3) Fully developed flow, (4) Radiation exchange between pipe and room negligible.

PROPERTIES: *Table A-5*, Unused engine oil (T_m = 150°C = 423K): k = 0.133 W/m·K.

ANALYSIS: The rate equation, for a unit length of the pipe, can be written as

$$q'_{conv} = \frac{\left(T_m - T_\infty\right)}{R'_t}$$

where the thermal resistance is comprised of two elements,

$$R'_t = \frac{1}{h_i \pi\ D} + \frac{1}{h_o \pi\ D} = \frac{1}{\pi\ D}\left(\frac{1}{h_i} + \frac{1}{h_o}\right).$$

The convection coefficient for internal flow, h_i, must be estimated from an appropriate correlation. From practical considerations, we recognize that the oil flow rate cannot be large enough to achieve turbulent flow conditions. Hence, the flow is *laminar*, and if the pipe is very long, the flow will be *fully developed*. The appropriate correlation is

$$Nu_D = \frac{h_i D}{k} = 3.66$$

$$h_i = Nu_D\ k/D = 3.66 \times 0.133 \frac{W}{m \cdot K} / 0.030\ m = 16.2\ W/m^2 \cdot K.$$

The heat rate per unit length of the pipe is

$$q'_{conv} = \frac{(150-20)^\circ\ C}{\dfrac{1}{\pi(0.030m)}\left(\dfrac{1}{16.2} + \dfrac{1}{11}\right)\dfrac{m^2 \cdot K}{W}} = 80.3\ W/m.$$ <

COMMENTS: This problem requires making a judgment that the oil flow will be laminar rather than turbulent. Why is this a reasonable assumption? Recognize that the correlation applies to a constant surface temperature condition.