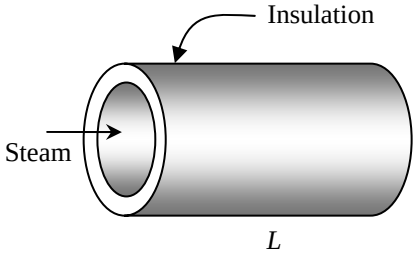
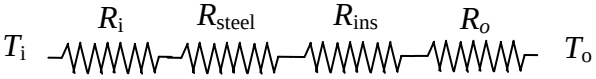
10-70 Steam flows in a steel pipe, which is insulated by gypsum plaster. The rate of heat transfer from the steam and the temperature on the outside surface of the insulation are be determined.

Assumptions **1** Heat transfer is steady since there is no indication of any change with time. **2** Heat transfer is one-dimensional since there is thermal symmetry about the centerline and no variation in the axial direction. **3** Thermal conductivities are constant. **4** The thermal contact resistance at the interface is negligible.

Properties (*a*) The thermal conductivities of steel and gypsum plaster are given to be 50 and 0.5 W/m·°C, respectively.



Analysis The thermal resistances are



$$R_i = \frac{1}{h_i A_i} = \frac{1}{(800\ \text{W/m}^2\cdot\text{°C})\pi(0.06\ \text{m})(20\ \text{m})} = 0.0003316\text{°C/W}$$

$$R_{\text{steel}} = \frac{\ln(D_2/D_1)}{2\pi k_{\text{steel}} L} = \frac{\ln(8/6)}{2\pi(50\ \text{W/m}\cdot\text{°C})(20\ \text{m})} = 0.0000458\text{°C/W}$$

$$R_{\text{ins}} = \frac{\ln(D_3/D_2)}{2\pi k_{\text{ins}} L} = \frac{\ln(16/8)}{2\pi(0.5\ \text{W/m}\cdot\text{°C})(20\ \text{m})} = 0.011032\text{°C/W}$$

$$R_o = \frac{1}{h_o A_o} = \frac{1}{(200\ \text{W/m}^2\cdot\text{°C})\pi(0.16\ \text{m})(20\ \text{m})} = 0.0004974\text{°C/W}$$

The total thermal resistance and the rate of heat transfer are

$$R_{\text{total}} = R_i + R_{\text{steel}} + R_{\text{ins}} + R_o = 0.0003316 + 0.0000458 + 0.011032 + 0.0004974 = 0.011907\text{°C/W}$$

$$\dot{Q} = \frac{T_i - T_o}{R_{\text{total}}} = \frac{(200-10)\text{°C}}{0.011907\ \text{m}^2\cdot\text{C/W}} = \mathbf{15{,}957\ W}$$

(*b*) The temperature at the outer surface of the insulation is determined from

$$\dot{Q} = \frac{T_s - T_o}{R_o} \longrightarrow 15{,}957\ \text{W} = \frac{(T_s - 10)\text{°C}}{0.0004974\ \text{m}^2\cdot\text{°C/W}} \longrightarrow T_s = \mathbf{17.9°C}$$

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