PROBLEM 1.82
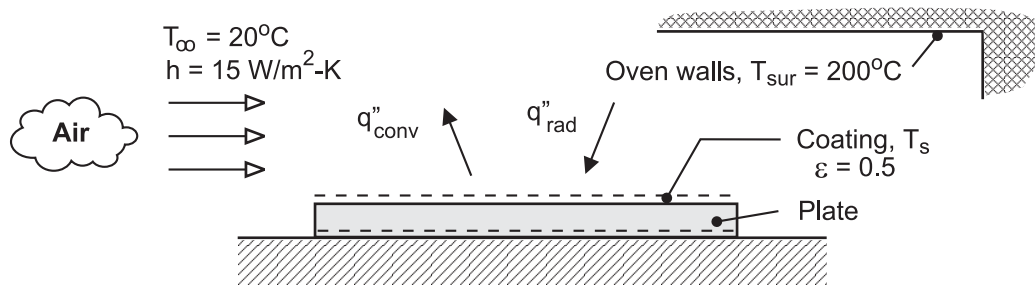
KNOWN: Hot-wall oven, in lieu of infrared lamps, with temperature $T_{sur} = 200°C$ for heating a coated plate to the cure temperature. See Example 1.9.

FIND: (a) The plate temperature T_s for prescribed convection conditions and coating emissivity, and (b) Calculate and plot T_s as a function of T_{sur} for the range $150 \le T_{sur} \le 250°C$ for ambient air temperatures of 20, 40 and 60°C; identify conditions for which acceptable curing temperatures between 100 and 110°C may be maintained.

SCHEMATIC:

ASSUMPTIONS: (1) Steady-state conditions, (2) Negligible heat loss from back surface of plate, (3) Plate is small object in large isothermal surroundings (hot oven walls).

ANALYSIS: (a) The temperature of the plate can be determined from an energy balance on the plate, considering radiation exchange with the hot oven walls and convection with the ambient air.

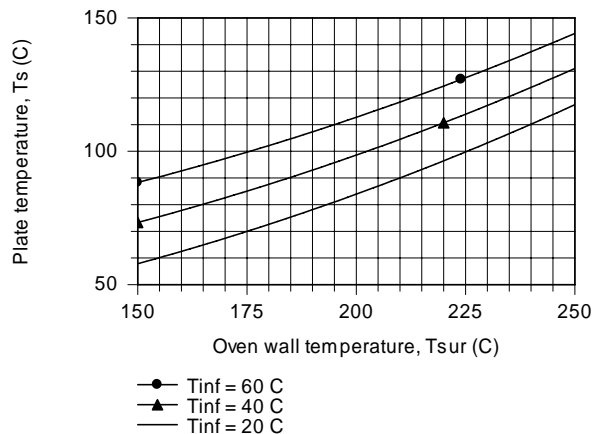$$\dot{E}''_{in} - \dot{E}''_{out} = 0 \qquad \text{or} \qquad q''_{rad} - q''_{conv} = 0$$

$$\varepsilon\sigma\left(T^4_{sur} - T^4_s\right) - h\left(T_s - T_\infty\right) = 0$$

$$0.5 \times 5.67 \times 10^{-8} \, W/m^2 \cdot K^4 \left(\left[200 + 273\right]^4 - T^4_s\right) K^4 - 15 \, W/m^2 \cdot K\left(T_s - \left[20 + 273\right]\right) K = 0$$

$$T_s = 357 \text{ K} = 84°C \qquad\qquad <$$

(b) Using the energy balance relation in the Workspace of IHT, the plate temperature can be calculated and plotted as a function of oven wall temperature for selected ambient air temperatures.

COMMENTS: From the graph, acceptable cure temperatures between 100 and 110°C can be maintained for these conditions: with $T_\infty = 20°C$ when $225 \le T_{sur} \le 240°C$; with $T_\infty = 40°C$ when $205 \le T_{sur} \le 220°C$; and with $T_\infty = 60°C$ when $175 \le T_{sur} \le 195°C$.