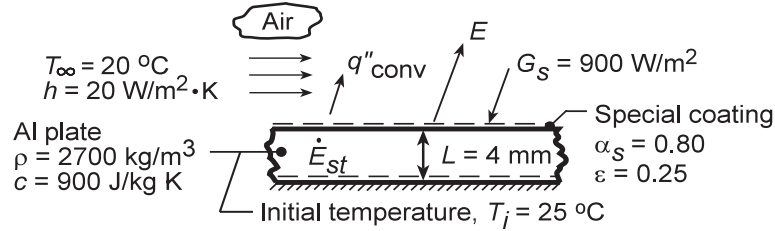


PROBLEM 1.45

KNOWN: Thickness and initial temperature of an aluminum plate whose thermal environment is changed.

FIND: (a) Initial rate of temperature change, (b) Steady-state temperature of plate, (c) Effect of emissivity and absorptivity on steady-state temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Negligible end effects, (2) Uniform plate temperature at any instant, (3) Constant properties, (4) Adiabatic bottom surface, (5) Negligible radiation from surroundings, (6) No internal heat generation.

ANALYSIS: (a) Applying an energy balance, Eq. 1.12c, at an instant of time to a control volume about the plate, $\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st}$, it follows for a unit surface area.

$$\alpha_S G_S (1 \text{ m}^2) - E (1 \text{ m}^2) - q''_{conv} (1 \text{ m}^2) = (d/dt)(McT) = \rho (1 \text{ m}^2 \times L) c (dT/dt).$$

Rearranging and substituting from Eqs. 1.3 and 1.5, we obtain

$$dT/dt = (1/\rho Lc) \left[\alpha_S G_S - \epsilon \sigma T_i^4 - h(T_i - T_\infty) \right].$$

$$dT/dt = \left(2700 \text{ kg/m}^3 \times 0.004 \text{ m} \times 900 \text{ J/kg} \cdot \text{K} \right)^{-1} \times \left[0.8 \times 900 \text{ W/m}^2 - 0.25 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 (298 \text{ K})^4 - 20 \text{ W/m}^2 \cdot \text{K} (25 - 20)^\circ \text{C} \right]$$

$$dT/dt = 0.052^\circ \text{C/s}.$$

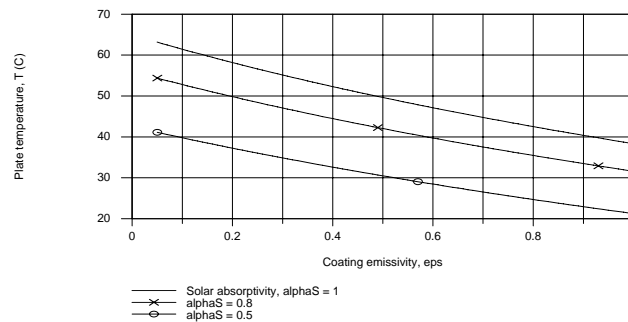
(b) Under steady-state conditions, $\dot{E}_{st} = 0$, and the energy balance reduces to

$$\alpha_S G_S = \epsilon \sigma T^4 + h(T - T_\infty) \quad (2)$$

$$0.8 \times 900 \text{ W/m}^2 = 0.25 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 \times T^4 + 20 \text{ W/m}^2 \cdot \text{K} (T - 293 \text{ K})$$

The solution yields $T = 321.4 \text{ K} = 48.4^\circ \text{C}$.

(c) Using the IHT *First Law Model* for an *Isothermal Plane Wall*, parametric calculations yield the following results.



COMMENTS: The surface radiative properties have a significant effect on the plate temperature, which decreases with increasing ϵ and decreasing α_S . If a low temperature is desired, the plate coating should be characterized by a large value of ϵ/α_S . The temperature also decreases with increasing h .