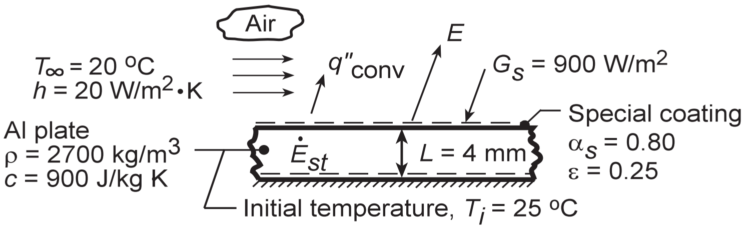
PROBLEM 1.35

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. 1.11a, 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.

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

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

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

$$dT/dt = \left(2700\ kg/m^3 \times 0.004\ m \times 900\ J/kg \cdot K\right)^{-1} \times$$

$$\left[0.8 \times 900\ W/m^2 - 0.25 \times 5.67 \times 10^{-8}\ W/m^2 \cdot K^4\left(298\ K\right)^4 - 20\ W/m^2 \cdot K\left(25 - 20\right)^\circ C\right]$$

$$dT/dt = 0.052^\circ\ C/s\ .$$ <

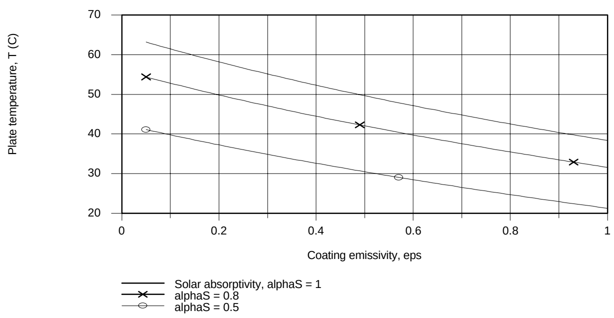
(b) Under steady-state conditions, $\dot{E}_{st} = 0$, and the energy balance reduces to

$$\alpha_S G_S = \varepsilon\sigma T^4 + h\left(T - T_\infty\right) \qquad (2)$$

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

The solution yields T = 321.4 K = 48.4°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.