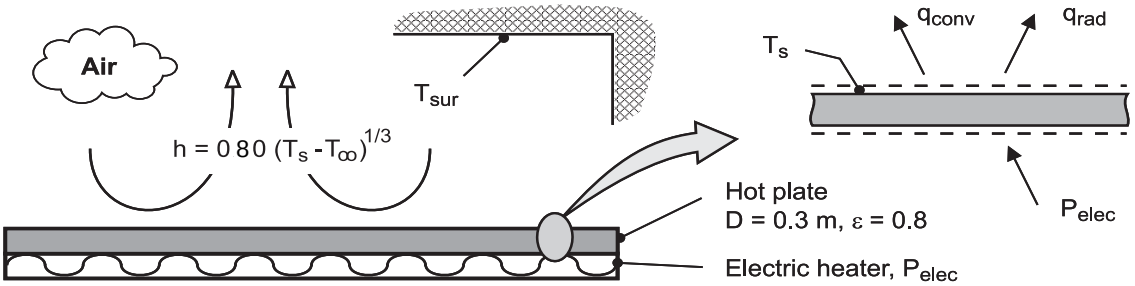
PROBLEM 1.83

KNOWN: Surface temperature, diameter and emissivity of a hot plate. Temperature of surroundings and ambient air. Expression for convection coefficient.

FIND: (a) Operating power for prescribed surface temperature, (b) Effect of surface temperature on power requirement and on the relative contributions of radiation and convection to heat transfer from the surface.

SCHEMATIC:



ASSUMPTIONS: (1) Plate is of uniform surface temperature, (2) Walls of room are large relative to plate, (3) Negligible heat loss from bottom or sides of plate.

ANALYSIS: (a) From an energy balance on the hot plate, $P_{elec} = q_{conv} + q_{rad} = A_p \left(q''_{conv} + q''_{rad}\right)$.

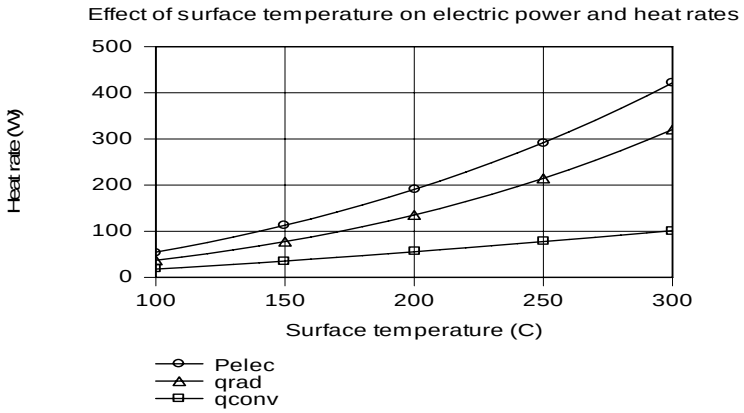
Substituting for the area of the plate and from Eqs. (1.3a) and (1.7), with $h = 0.80 (T_s - T_\infty)^{1/3}$, it follows that

$$P_{elec} = \left(\pi D^2/4\right)\left[0.80\left(T_s - T_\infty\right)^{4/3} + \varepsilon\sigma\left(T_s^4 - T_{sur}^4\right)\right]$$

$$P_{elec} = \pi\left(0.3\text{m}\right)^2/4\left[0.80\left(175\right)^{4/3} + 0.8\times 5.67\times 10^{-8}\left(473^4 - 298^4\right)\right] \text{ W/m}^2$$

$$P_{elec} = 0.0707 \text{ m}^2\left[783 \text{ W/m}^2 + 1913 \text{ W/m}^2\right] = 55.4 \text{ W} + 135.2 \text{ W} = 190.6 \text{ W} \quad <$$

(b) As shown graphically, both the radiation and convection heat rates, and hence the requisite electric power, increase with increasing surface temperature.



However, because of its dependence on the fourth power of the surface temperature, the increase in radiation is more pronounced. The significant relative effect of radiation is due to the small convection coefficients characteristic of natural convection, with $3.37 \le h \le 5.2$ W/m^2·K for $100 \le T_s < 300$°C.

COMMENTS: Radiation losses could be reduced by applying a low emissivity coating to the surface, which would have to maintain its integrity over the range of operating temperatures.