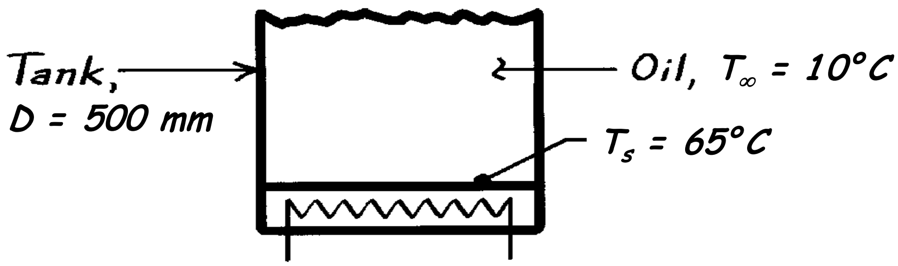
PROBLEM 9.28

KNOWN: Electric heater at bottom of tank of 500 mm diameter maintains surface at 65°C with engine oil at 10°C.

FIND: Power required to maintain 65°C surface temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Oil is quiescent, (2) Quasi-steady state conditions exist.

PROPERTIES: *Table A-5*, Engine Oil ($T_f = (T_\infty + T_s)/2 = 310K$): $\nu = 288 \times 10^{-6}\ m^2/s$, $k = 0.145\ W/m\cdot K$, $\alpha = 0.847 \times 10^{-7}\ m^2/s$, $\beta = 0.70 \times 10^{-3}\ K^{-1}$.

ANALYSIS: The heat rate from the bottom heater surface to the oil is

$$q = \bar{h}A_s\left(T_s - T_\infty\right)$$

where $\bar{h}$ is estimated from the appropriate correlation depending upon the Rayleigh number Ra_L, from Eq. 9.25, using the characteristic length, L, from Eq. 9.29,

$$L = \frac{A_s}{P} = \frac{\pi D^2/4}{\pi D} = \frac{D}{4} = \frac{0.5m}{4} = 0.125m.$$

The Rayleigh number is

$$Ra_L = \frac{g\beta\left(T_s - T_\infty\right)L^3}{\nu\alpha}$$

$$Ra_L = \frac{9.8m/s^2 \times 0.70 \times 10^{-3}K^{-1}\left(65-10\right)K \times 0.125^3 m^3}{288 \times 10^{-6} m^2/s \times 0.847 \times 10^{-7} m^2/s} = 3.02 \times 10^7.$$

The appropriate correlation is Eq. 9.31 giving

$$\overline{Nu}_L = \frac{\bar{h}L}{k} = 0.15\,Ra_L^{1/3} = 0.15\left(3.02 \times 10^7\right)^{1/3} = 46.7$$

$$\bar{h} = \frac{k}{L}\overline{Nu}_L = \frac{0.145\,W/m\cdot K}{0.125m} \times 46.7 = 54.2\,W/m^2\cdot K.$$

The heat rate is then

$$q = 54.2\,W/m^2\cdot K\left(\pi/4\right)\left(0.5m\right)^2\left(65-10\right)K = 585\,W.$$ <

COMMENTS: Note that the characteristic length is D/4 and not D; however, A_s is based upon D. Recognize that if the oil is being continuously heated by the plate, T_∞ could change. Hence, here we have analyzed a quasi-steady state condition.