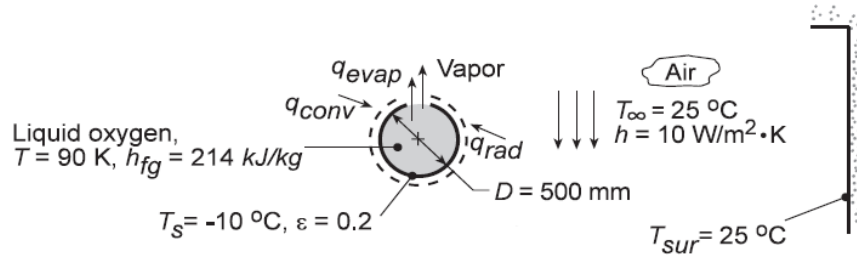


## PROBLEM 1.42

**KNOWN:** Boiling point and latent heat of liquid oxygen. Diameter and emissivity of container. Free convection coefficient and temperature of surrounding air and walls.

**FIND:** Mass evaporation rate.

**SCHEMATIC:**



**ASSUMPTIONS:** (1) Steady-state conditions, (2) Temperature of container outer surface equals boiling point of oxygen.

**ANALYSIS:** (a) Applying mass and energy balances to a control surface about the container, it follows that, at any instant,

$$\frac{dm_{st}}{dt} = -\dot{m}_{out} = -\dot{m}_{evap} \quad \frac{dE_{st}}{dt} = \dot{E}_{in} - \dot{E}_{out} = q_{conv} + q_{rad} - q_{evap} \quad (1a,b)$$

With  $h_f$  as the enthalpy of liquid oxygen and  $h_g$  as the enthalpy of oxygen vapor, we have

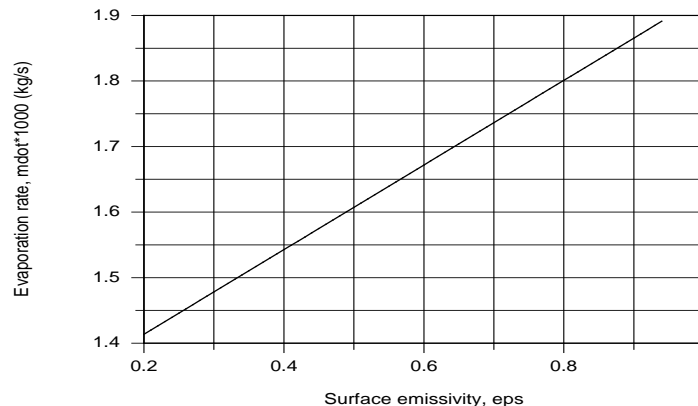
$$E_{st} = m_{st} h_f \quad q_{evap} = \dot{m}_{out} h_g \quad (2a,b)$$

Combining Equations (1a) and (2a,b), Equation (1b) becomes (with  $h_{fg} = h_g - h_f$ )

$$\begin{aligned} \dot{m}_{out} h_{fg} &= q_{conv} + q_{rad} \\ \dot{m}_{evap} &= (q_{conv} + q_{rad}) / h_{fg} = \left[ h(T_{\infty} - T_s) + \varepsilon \sigma (T_{sur}^4 - T_s^4) \right] \pi D^2 / h_{fg} \quad (3) \\ \dot{m}_{evap} &= \frac{\left[ 10 \text{ W/m}^2 \cdot \text{K} (298 - 263) \text{ K} + 0.2 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 (298^4 - 263^4) \text{ K}^4 \right] \pi (0.5 \text{ m})^2}{214 \text{ kJ/kg}} \end{aligned}$$

$$\dot{m}_{evap} = (350 + 35.2) \text{ W/m}^2 (0.785 \text{ m}^2) / 214 \text{ kJ/kg} = 1.41 \times 10^{-3} \text{ kg/s} \quad <$$

(b) Using Equation (3), the mass rate of vapor production can be determined for the range of emissivity 0.2 to 0.94. The effect of increasing emissivity is to increase the heat rate into the container and, hence, increase the vapor production rate.



**COMMENTS:** To reduce the loss of oxygen due to vapor production, insulation should be applied to the outer surface of the container, in order to reduce  $q_{conv}$  and  $q_{rad}$ . Note from the calculations in part (a), that heat transfer by convection is greater than by radiation exchange.