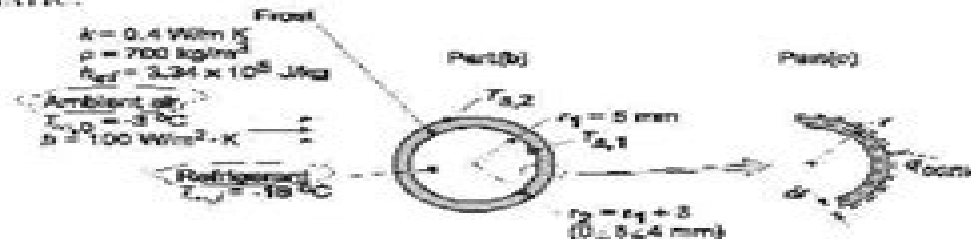


PROBLEM 3-45

KNOWN: Tube diameter and refrigerant temperature for evaporation of a refrigerant system. Convection coefficient and temperature of outside air.

FIND: (a) Rate of heat extraction without frost formation, (b) Effect of frost formation on heat rate, (c) Time required for a 2 mm-thick frost layer to melt in ambient air for which $h = 2 \text{ W/m}^2 \cdot \text{K}$ and $T_{\infty} = 20^\circ\text{C}$.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional, steady-state conduction, (2) Negligible convection resistance for refrigerant flow ($T_{c,w} = T_{c,i}$), (3) Negligible tube wall conduction resistance, (4) Negligible radiation exchange of outer surface.

ANALYSIS: (a) The cooling capacity in the defrosted condition ($\delta = 0$) corresponds to the rate of heat extraction from the outflow. Hence,

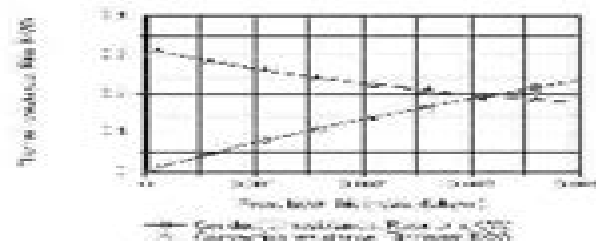
$$\dot{q}' = h_2 \pi (T_{\infty,2} - T_{s,1}) = 100 \text{ W/m}^2 \cdot \text{K} (2\pi \cdot 0.005 \text{ m}) (-5 - 10)^\circ\text{C}$$

$$\dot{q}' = -47.1 \text{ W/m}$$

(b) With the frost layer, there is an additional conduction resistance to heat transfer, and the extraction rate is

$$\dot{q}' = \frac{T_{\infty,2} - T_{s,1}}{R'_{\text{conv}} + R'_{\text{cond}}} = \frac{T_{\infty,2} - T_{s,1}}{1/h_2 \pi r_2 + \ln(r_2/r_1)/\pi k}$$

For $\delta = r_2 - r_1 = 2 \text{ mm}$ and $k = 0.4 \text{ W/m} \cdot \text{K}$, this expression yields



Continued...

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Camilla Rothe



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