

$$Nu_D = 0.3 + \frac{0.62 Re_D^{1/2} Pr^{1/3}}{[1 + (0.4/Pr)^{2/3}]^{1/4} \left[1 + \left(\frac{Re_D}{282000} \right)^{5/8} \right]^{4/5}} = 1.0 \times 10^4$$

$$Re_D = \frac{V D}{\nu} \Rightarrow V_{min} = \frac{Re_D \nu}{D} \Rightarrow \frac{(1.0 \times 10^4)(1.748 \times 10^{-6})}{0.06985} = 0.26 \text{ m/s}$$

$$V_{design} = 0.30 \text{ m/s}$$

Actual h_o , U , and Preliminary cooling time

$$V = 0.30 \text{ m/s}$$

$$Re_D = 1.17 \times 10^4$$

$$Nu_D = 173.8$$

$$h_o = \frac{Nu_D k}{D} \Rightarrow \frac{(173.8)(0.552)}{0.06985} = 1374 \text{ W/m}^2 \cdot \text{K}$$

$$U_{actual} = \left(\frac{1}{210} + \frac{1}{1374} \right)^{-1} = 182 \text{ W/m}^2 \cdot \text{K}$$

$$t = - \frac{m c_p}{U A} \ln \left(\frac{T_f - T_{\infty}}{T_i - T_{\infty}} \right) = 266 \text{ s}$$

$$t_{ideal} = \boxed{4.43 \text{ min}} < 5.00 \text{ min}$$

Pump flow requirement

$$\Delta T_c = 3^\circ \text{C}$$

$$\dot{Q} = \dot{m}_c c_p \Delta T_c \Rightarrow \dot{m}_c = \frac{742}{(4184)(3)} = 0.0591 \text{ kg/s}$$

$$\dot{V}_{min} = 213 \text{ L/hr}$$

$$\dot{V}_{design} \geq 300 \text{ L/hr}$$

$$\dot{V}_{nominal} = 2(240) = \boxed{480 \text{ L/hr}} > 300 \text{ L/hr}$$

Ice energy requirement

$$h_f = 334 \text{ kJ/kg}$$

$$m_{ice, min} = \frac{Q_c}{h_f} \Rightarrow \frac{222.6}{334} = 0.67 \text{ kg}$$