

Actual Pump flow may be lower than rated flow because of tubing and system losses. Small ice pieces are assumed to increase the available water to ice surface area, and the warmer return water is directed through the ice rich section of the cooler before recirculation.

Data / Variables:

$$T_i = 85^\circ\text{F} = 29.44^\circ\text{C}$$

$$T_f = 40^\circ\text{F} = 4.44^\circ\text{C}$$

$$T_{ice} = 18^\circ\text{F} = -7.78^\circ\text{C}$$

$$t_{max} = 300\text{ s}$$

$$m = 0.355\text{ kg/cm}$$

$$c_p = 4184\text{ J/(kg}\cdot\text{K)}$$

$$D = 0.06985\text{ m}$$

$$L = 0.12065\text{ m}$$

$$h_i = 210\text{ W/(m}^2\cdot\text{K)}$$

$$k_w = 0.522\text{ W/(m}\cdot\text{K)}$$

$$v_w = 1.788 \times 10^{-6}\text{ m}^2/\text{s}$$

$$Pr = 13.6$$

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

Procedure:

First, calculate the amount of heat that must be removed from one beverage and then from all 6 beverages. Divide total heat by 5 min cooling time to determine required avg heat removal rate. Next, calculate the surface area of one can and use transient cooling eq to determine the minimum overall heat transfer coeff needed to reach 40°F in 300 s. Select a slightly larger design value for margin. Use the thermal resistance relationship to determine the required outside convection coeff. Then use Reynolds, Prandtl, and Nusselt #'s with the Churchill-Bernstein correlation to determine the coolant velocity required around the cans. Recalculate actual overall heat transfer coeff and predicted cooling time. Next, use an energy balance to determine the required pump flow and ice mass. Finally, determine how much circulating water warms while cooling the cans and perform an additional water to ice convection check before calculating the final predicted cooling time.