47.40 A $25 ft$ long hot water pipe with a $3 in$ O.D. has an an average surface temperature of $175°F$ in a room with an ambient temperature of $60°F$. The convection coefficient is $2\frac{Btu}{hr \cdot ft^2 \cdot °F}$. What is the total heat loss from the pipe, assuming all surfaces are considered to be black, and no insulation is used?

A. $3000\frac{Btu}{hr}$

B. $4500\frac{Btu}{hr}$

C. $7500\frac{Btu}{hr}$

D. $15,000\frac{Btu}{hr}$

Consider both Convection and Radiation. The total heat loss is found by combining the two.

$$\dot{Q}_{combined} = \dot{Q}_{convection} + \dot{Q}_{radiation}$$

Write the formula for convection found by searching Newton's Law of Cooling. The convection coefficient is given. The surface area of the pipe is defined as $A = \pi DL$. The temperatures are known. Substitute and solve for the heat loss due to convection.

$$\dot{Q}_{conv} = hA\Delta T$$

$$\dot{Q}_{conv} = \left(2\frac{Btu}{hr \cdot ft^2 \cdot °F}\right)\left[\pi\left(\frac{3}{12}ft\right)(25ft)\right](175°F - 60°F) = 4516\frac{Btu}{hr}$$

Write the formula for radiation. Since all surfaces are black, assume $\varepsilon = 1$. σ is the Stefan-Boltzmann Constant. Surface area is the same as in the convection analysis. Temperatures must be in absolute terms i.e. Rankine.

$$\dot{Q}_{rad} = \varepsilon\sigma A\left(T_1^4 = T_2^4\right)$$

$$\dot{Q}_{rad} = (1)\left(0.1713 \times 10^{-8}\frac{Btu}{hr \cdot ft^2 \cdot °R^4}\right)\left(\left[\pi\left(\frac{3}{12}ft\right)(25ft)\right]\right)\left[(635°R)^4 - (520°R)^4\right] = 3009\frac{Btu}{hr}$$

Solve for the combined heat loss by taking the sum of the heat loss due to convection and radiation.

$$\dot{Q}_{combined} = 4516\frac{Btu}{hr} + 3009\frac{Btu}{hr} = 7525\frac{Btu}{hr}$$

Answer C

47.41 Saturated steam at $300psia$ enters a closed feedwater heater and heats entering water with a temperature of $60°F$. The steam leaves as a saturated liquid. If the mass flow rate of water is 10 times the mass flow rate of steam, what is the exit temperature of the water?

A. $99°F$

B. $101°F$

C. $139°F$

D. $141°F$

Assuming 100% efficiency, all of the heat provided by the steam is added to the water. Set the heat removed from the steam equal to the heat gained by the water.

$$\dot{Q}_{steam} = \dot{Q}_{water}$$

Write an expression for the steam based on mass flow rate and the change in enthalpy, and express the heat gain by the water using mass flow rate, specific heat capacity, and change in temperature.

$$\dot{m}_{steam}\Delta h = \dot{m}_{water}c_p\Delta T$$

Since the mass flow rate of water is 10 times the mass flow rate of steam, substitute for the mass flow rate of water, then cancel $\dot{m}_{steam}$ on both sides.

$$\dot{m}_{water} = 10\dot{m}_{steam}$$

$$\dot{m}_{steam}\Delta h = 10\dot{m}_{steam}c_p\Delta T$$

$$\Delta h = 10c_p\Delta T$$

Solve for ΔT. Use the Properties of Saturated Water and Steam table by pressure to obtain the change in enthalpy for $300psia$ steam. The steam enters as saturated steam and therefore has enthalpy h_g, and leaves as saturated liquid and therefore has enthalpy h_f. For convenience, recall that the change in enthalpy is provided in the table directly, and $h_{fg} = h_g - h_f$.

$$\Delta T = \frac{\Delta h}{10c_p} = \frac{h_g - h_f}{10c_p} = \frac{h_{fg}}{10c_p} = \frac{809.42\frac{Btu}{lb}}{10\left(1\frac{Btu}{lb\cdot°F}\right)} = 80.9°F$$

Expand the water ΔT and solve for the leaving water temperature, T_2.

$$\Delta T = T_2 - T_1$$

$$T_2 = T_1 + \Delta T$$

$$T_2 = 60°F + 80.9°F = 140.9°F$$

Answer D