$$r_2 U_o \left(T_{room} - T_{surface}\right) = \frac{k}{ln\left(\frac{r_2}{r_1}\right)}\left(T_{surface} - T_{water}\right)$$

Substitute and solve for $T_{surface}$. Note the thermal conductivity is given per inch, and the denominator takes care of the thickness of the insulation. $r_2 = 6in$ and $r_1 = 4in$ represent the outer an inner radius of the insulation, respectively, for a nominal $8in$ pipe with $2in$ thick insulation:

$$(6in)\left(2\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)\left(73^\circ F - T_{surface}\right) = \frac{\left(1.8\frac{Btu \cdot in}{hr \cdot ft^2 \cdot {}^\circ F \cdot}\right)}{ln\left(\frac{6in}{4in}\right)}\left(T_{surface} - 48^\circ F\right)$$

Solve algebraically and confirm units along the way.

$$T_{surface} = 66.3^\circ F$$

Answer D

42.8 $60gpm$ of hot water is produced by a steam heat exchanger. $5psig$ saturated steam is provided, and the condensate leaves as a saturated liquid. The flow rate of steam is $2000\frac{lb_m}{hr}$. If cold water enters at $55^\circ F$, what is the temperature of leaving hot water? Neglect losses.

A. $113^\circ F$

B. $116^\circ F$

C. $119^\circ F$

D. $122^\circ F$

All of the heat given up by the steam is added to the water, since losses are to be neglected. Set the heat loss for the steam equal to the heat gain for the water. Write an expression for the steam based on change in enthalpy and an expression for the water using the sensible heating rule of thumb for water:

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

$$\dot{m}_{steam}\Delta h = 500gpm\Delta T$$

Use the table Properties of Saturated Water (by pressure) to look up the enthalpy of saturated steam and saturated liquid at $5psig$:

$$h_f = 196\frac{Btu}{lb}$$

$$h_g = 1156\frac{Btu}{lb}$$

Substitute the given mass flow rate, GPM, and supply water temperature and solve for the leaving hot water temperature:

$$\left(2000\frac{lb}{hr}\right)\left(1156\frac{Btu}{lb} - 196\frac{Btu}{lb}\right) = 500\,(60)\,(T_{hws} - 55°F)$$

$$T_{hws} = 119°F$$

Answer C

42.9 The thermal gradient across the stone wall of an outdoor fireplace is $1000°F$. The stone wall is $10in$ thick and has a thermal conductivity of $0.05\frac{Btu\cdot in}{hr\cdot ft^2\cdot °F}$. What is the rate of heat transfer per unit area?

A. $5\frac{Btu}{hr\cdot ft^2}$

B. $6\frac{Btu}{hr\cdot ft^2}$

C. $50\frac{Btu}{hr\cdot ft^2}$

D. $60\frac{Btu}{hr\cdot ft^2}$

Look up the formula for conduction:

$$\dot{Q}_{conduction} = \frac{kA\Delta T}{L}$$

where k is the thermal conductivity of the stone, A is the area of the stone wall, ΔT is the temperature differential i.e. thermal gradient across the stone wall, and L is the thickness of the wall.

Since the problem asks for heat transfer *per unit area*, divide by area on both sides. Substitute and solve for $\dot{q}$.

$$\dot{q} = \frac{\dot{Q}}{A} = \frac{k\Delta T}{L} = \left(\frac{\left(0.05\frac{Btu\cdot in}{hr\cdot ft^2\cdot °F}\right)(1000°F)}{10in}\right) = 5\frac{Btu}{hr\cdot ft^2}$$

Answer A