32.12 A vapor-compression chiller using R-134a operates with a condenser pressure of $186 psia$. Refrigerant enters the single-pass counter flow condenser as a saturated vapor and exits as a saturated liquid. The condenser water enters at $74°F$ and leaves at $86°F$. The consenser surface area is $400 ft^2$. The overall heat transfer coefficient for the condenser is $10 \frac{Btu}{hr \cdot ft^2 \cdot °F}$. What is the mass flow rate of refrigerant through the chiller?

A. $720 \frac{lb}{hr}$

B. $1290 \frac{lb}{hr}$

C. $1850 \frac{lb}{hr}$

D. $2410 \frac{lb}{hr}$

Assuming the condenser is 100% efficient, all of the heat removed from the refrigerant is added to the condenser water. Write expressions for the heat removed from the refrigerant and the heat added to the condenser water, and set them equal. Since there is no mass or volume flow rate given for the water side of the heat exhanger, it is not feasible to express the heat gain as $\dot{Q} = \dot{m} c_p \Delta T$ or $\dot{Q} = 500 gpm \Delta T$. Instead, treat the device as a single-pass Heat Exchanger where overall heat transfer coefficient and surface area are known, and the Log Mean Temperature Difference can be determined.

$$\dot{Q}_R = \dot{m} \Delta h$$

$$\dot{Q}_{cw} = U A \Delta T_{lm}$$

$$\dot{Q}_R = \dot{Q}_{cw}$$

$$\dot{m} \Delta h = U A \Delta T_{lm}$$

Look up Refrigerant 134a and scroll down to the table below the chart. At $186 psia$, look up the saturation temperature and enthalpy values.

$$P = 186 psia$$

$$T = 120°F$$

$$h_f = 52.38 \frac{Btu}{lb}$$

$$h_g = 118.26 \frac{Btu}{lb}$$

Calculate the log mean temperature difference. Note the refrigerant is changing phase (condensing from a vapor to a liquid) at *constant temperature*. Only the condenser water experiences a change in temperature i.e. *sensible heating*. Draw the single pass counterflow heat exchanger and label the temperatures.

$$Cold\,Fluid:\ 74°F \longrightarrow 86°F$$

$$Hot\,Fluid:\ 120°F \longleftarrow 120°F$$

Define one *physical* side of the heat exchanger as 'A' and the other side as 'B' and determine the respective temperature differences. Conveniently, the assignment of labels A and B turns out to be arbitrary. However, the *direction* of the flows is critical.

$$\Delta T_A = 120°F - 74°F = 46°F$$

$$\Delta T_B = 120°F - 86°F = 34°F$$

Use the formula below to calculate the log mean temperature difference.

$$LMTD = \frac{\Delta T_A - \Delta T_B}{ln\left(\frac{\Delta T_A}{\Delta T_B}\right)}$$

$$LMTD = \frac{46°F - 34°F}{ln\left(\frac{46°F}{34°F}\right)} = 39.7°F$$

Solve for the mass flow rate of refrigerant.

$$\dot{m} = \frac{UA\Delta T_{lm}}{\Delta h}$$

$$\dot{m} = \frac{\left(10\frac{Btu}{hr\cdot ft^2\cdot °F}\right)\left(400ft^2\right)(39.7°F)}{118.26\frac{Btu}{lb} - 52.38\frac{Btu}{lb}} = 2410\frac{lb}{hr}$$

Answer D