42.2 During winter operation, a cooling plant reduces energy use by using a parallel flow plate and frame heat exchanger instead of its chillers. The system consists of two loops, (1) an open condenser water loop which is fed by cooling towers outside, and (2) a closed chilled water loop which is distributed throughout the facility. If the condenser water enters the heat exchanger at $40°F$ and leaves at $46°F$ and the chilled water enters at $60°F$ and leaves at $48°F$, what is the log mean temperature difference?

A. $8°F$

B. $9°F$

C. $10°F$

D. $11°F$

Look up Log Mean Temperature Difference or LMTD in the Reference Handbook. Consider memorizing the simpler version below rather than using either of the two equations shown, and learning how to apply it rather than risking a mistake when assigning the variables to the given information. Recall:

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

where ΔT_A is the temperature difference between the two fluids on one side of the heat exchanger and ΔT_B is the temperature difference between the two fluids on the other side of the heat exchanger.

Since this is a parallel flow heat exchanger, the temperature difference between the two fluids upon entering, ΔT_A, is as large as it is ever going to be; i.e. the warm fluid is at is warmest and the cold fluid is at its coldest. Therefore:

$$\Delta T_A = 60°F - 40°F = 20°F$$

The temperature difference between the two fluids upon leaving, ΔT_B, is as small as it is ever going to be; i.e. the warm fluid has cooled, the cool fluid had warmed, and the temperatures approach one another from either side, never crossing for a parallel flow heat exchanger, but potentially becoming quite close in most cases.

$$\Delta T_B = 48°F - 46°F = 2°F$$

Solve the $LMTD$. It may be faster and easier to use the natural log, ln, rather than $2.3 \times log_{10}$ as suggested in the handbook. (Mathematically they are equivalent.)

$$T_{lm} = \frac{20°F - 2°F}{ln\left(\frac{20°F}{2°F}\right)} = \frac{18°F}{ln\,(10)} = 7.8°F$$

Answer A

42.3 $10gpm$ **of water is heated from** $60°F$ **to** $125°F$ **in a feedwater heater by steam. The steam side of the feedwater heater operates at** $5psig$**. Steam enters at** $350°F$ **and leaves as a saturated mixture with 95% quality. What is the required mass flow rate of steam?**

A. $5\frac{lb}{min}$

B. $50\frac{lb}{min}$

C. $120\frac{lb}{min}$

D. $360\frac{lb}{min}$

A feedwater heater is simply a steam heat exchanger that makes hot water. The heat added to the water comes entirely from the heat given up by the steam, minus any losses. This problem statement makes no mention of losses or efficiency, so losses may be neglected. Start by establishing the energy balance between the steam and the water. Then use the sensible heating rule of thumb to calculate how much heat is added to the water.

$$q_{steam} = q_{water} = 500gpm\Delta T = 500\,(10)\,(125-60) = 325,000\frac{Btu}{hr}$$

The steam side of the energy equation can be expressed as:

$$q_{steam} = \dot{m}\,(h_1 - h_2)$$

where state 1 corresponds to the entering condition, state 2 corresponds to the leaving condition, and the mass flow rate is unknown.

Look up the superheated steam table by searching Properties of Superheated Steam in the Reference Handbook and find the enthalpy for the entering steam condition. Note $5psig \approx 20psia$. If you were to check the saturated steam table first by searching Properties of Saturated Water (by pressure), you would observe the saturation temperature for $20psia$ steam is $\sim 228°F$. The entering temperature $350°F > 228°F$, confirming that the entering steam is superheated.

$$P_1 = 20psia$$

$$T_1 = 350°F$$

$$h_1 = 1215\frac{Btu}{lb}$$

The question states that the exiting condition is a saturated mixture, so use the Properties of Saturated Water table again. The pressure is implied to be constant. Use the quality to calculate the enthalpy for state 2:

$$P_2 = 20psia$$

$$\chi_2 = 0.95$$