47.74 A R-134a refrigeration cycle has a cooling capacity of 30 tons. Refrigerant enters the compressor at $20°F$ saturated and is discharged at $110psia$. There is no subcooling. What is the mass flow rate of refrigerant through the cycle?

A. $91\frac{lb}{min}$

B. $95\frac{lb}{min}$

C. $104\frac{lb}{min}$

D. $110\frac{lb}{min}$

Draw a typical refrigeration cycle on a Pressure-Enthalpy diagram. Consider the entering compressor condition as State 1, the compressor exit condition as State 2, the condenser exit as State 3, and the evaporator entering condition as State 4. The cooling capacity corresponds to the heat absorbed by the exaporator, $\dot{Q}_{evap}$, which depends on the difference in enthalpy between State 1 and State 4, $h_1 - h_4$.

Start by analyzing State 1. The temperature is given and the refrigerant is known to be a saturated vapor. Use the Refrigerant 134a table to look up the enthalpy, h_1.

$$T_1 = 20°F\ (saturated\,vapor)$$

$$h_1 = 106.056\frac{Btu}{lb}$$

Next analyize State 3, after the condenser prior to expansion. The pressure is given and there is no sub-cooling. Therefore, the refrigerant is a saturated liquid. Use the table again to obtain the enthalpy at State 3. It is not necessary to gain additional precision by interpolating in this case.

$$P_3 = 110psia\,(saturated\,liquid)$$

$$h_3 \approx 39.9\frac{Btu}{lb}$$

Since the expansion process from State 3 to State 4 for is isenthalpic, the enthalpy at State 4 may also be specified.

$$h_4 = h_3 = 39.9\frac{Btu}{lb}$$

Express the heat absorbed by the evaporator as the product of the mass flow rate of refrigerant, $\dot{m}_R$, and the change in enthalpy through the evaporator.

$$\dot{Q}_{evap} = \dot{m}_R\,(h_1 - h_4)$$

Rearrange for the mass flow rate, $\dot{m}_R$, substitute, and solve.

$$\dot{m}_R = \frac{\dot{Q}_{evap}}{h_1 - h_4} = \frac{(30tons)\left(12,000\frac{Btu}{hr\cdot ton}\right)\left(\frac{1hr}{60min}\right)}{\left(106.056\frac{Btu}{lb} - 39.9\frac{Btu}{lb}\right)} = 90.7\frac{lb}{min}$$

Answer A

47.75 A room is maintained at $74°F$ and 50% relative humidity by supplying $8000cfm$ of $60°F$ supply air. The room has a sensible heat load of $150,000\frac{Btu}{hr}$ and a sensible heat ratio of 0.75. $1000cfm$ of air is exhausted from the space and a corresponding volume of outside air at $92°F$ db / $74°F$ wb is introduced. What is the wet bulb temperature of the supply air?

A. $50°F$

B. $53°F$

C. $55°F$

D. $58°F$

Sketch the system and label with given information. Apply the Sensible Heat Ratio to determine the total heat load in the room.

$$SHR = \frac{\dot{Q}_s}{\dot{Q}_t}$$

$$\dot{Q}_t = \frac{\dot{Q}_s}{SHR} = \frac{150,000\frac{Btu}{hr}}{0.75} = 200,000\frac{Btu}{hr}$$

Determine the enthalpy of the room/return condition using the Psychrometric Chart.

$$T_{room} = 74°F\,db\,/\,50\%\,RH$$

$$h_{room} = 27.56\frac{Btu}{lb}$$

Draw a system boundary around the room and the supply/return air only. Ignore the exhaust air, outside air, and mixing prior to the cooling coil. Use the total cooling rule of thumb for air to determine the enthalpy of the supply air, which depends on the total heat load in the room as previously calculated, the enthalpy of the room/return condition, and the supply airflow.

$$\dot{Q}_t = 4.5cfm\Delta h = 4.5cfm\left(h_{room} - h_{supply}\right)$$

$$h_{supply} = h_{room} - \frac{\dot{Q}_t}{4.5cfm} = 27.56 - \frac{200,000}{(4.5)\,(8000)} = 22\frac{Btu}{lb}$$

Use the Psychrometric Chart again to determine the supply wet-bulb temperature corresponding to the enthalpy.

$$T_{supply,wb} = f\left(h_{supply}\right) \approx 53°F$$

Answer B