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Test 3

Question 1

Purpose: The purpose of the question is to calculate the a) quantity of the air supplied to the space, b) the states at each point, c) the processes on the psychrometric chart, D) the required capacity of the cooling and dehumidifying unit, and E) Amount of water drained in the units.

Diagrams:
Attached Below

Design Considerations:
- humidity ratio stays constant from 2-3
- No outside air in the system or water

Data and Variables
$Q_{in} = 7{,}200\ Btu/hr$ $\quad \dot{V} = 500\ cfm$
$\phi = 50\%$ @ $75°F$ $\quad \phi = 60\%$ @ $90°F$

Procedures:
- Drew the states on a psychrometric chart
- Calculated each of the states starting with 3
- Found mass air flow
- Found $\dot{V}$
- Found m_1
- Found ω_1
- Found h_1
- Found $\dot{m}_{water}$

Calculations:

State 3 $T_{db3} = 75°F$ $\phi_3 = 50\%$ @ 75°F

$\omega_3 = 0.0093$ lb water/lb dry air

$h_3 = 28$ Btu/lb dry air

$v_3 = 13.7$ ft³/lb dry air

State 2 Assuming 20°F temp difference

$\omega_2 = \omega_3 = 0.0093$ $T_{db2} = 75°F - 20°F = 55°F$

$h_2 = 23$ Btu/lb dry air $v_2 = 13.1$ ft³/lb dry air

$$\dot{m}_{dry} = \frac{Q}{h_3 - h_2}$$

$$m_{dry} = \frac{\cancel{72000} \text{ Btu/hr}}{28-23 \text{ Btu/lb dry air}}$$

$$\dot{m}_{dry} = \frac{14400 \text{ Btu/hr}}{60 \text{ Btu/lb dry air}}$$

$\dot{m}_{dry} = 240$ lb/min

$\dot{V}_2 = m_{dry} v_2$

$\dot{V}_2 = 240 \cdot 13.1$

$\dot{V}_2 = 3144$ cfm $\dot{V}_2 = \dot{V}_3$

State 4 $T_{db4} = T_{db3} = 75°F$ $\omega_4 = 0.0093$ $v_4 = 13.7$

$h_4 = 28$

$\dot{V}_4 = \dot{V}_3 - \dot{V}_5$

$= 3144$ cfm $- 500$

$V_4 = 2644$ cfm

$\dot{V}_4 = \dot{m}_4 \cdot v_4$

$\dot{m}_4 = \frac{\dot{V}_4}{v_4} = \frac{2644}{13.7}$

$\dot{m}_4 = 193$ lb/min

State 5

$T_{db5} = 75°F$ $\omega_3 = 0.043$

State 0

$T_{db0} = 90°F$ · $\omega_0 = 0.018$ $v_0 = 14.1$ $\dot{V}_0 = 500$ cfm $h_0 = 41.5$

$$m_0 = \frac{500 \text{ cfm}}{14.1}$$

$m_0 = 35.5$ lb/min

State 5

$T_{db_5} = 75°F \quad \omega_5 = .0093$

state 0

$T_{db} = 90°F \quad \omega_0 = .018 \quad v_0 = 14.1 \quad \dot{V}_0 = 500\,cfm \quad h_0 = 41.5$

$$\dot{m}_0 = \frac{500\,cfm}{14.1}$$

$$\dot{m}_0 = 35.5 \text{ lb/min}$$

State 1

$$\dot{m}_1 = \dot{m}_4 + \dot{m}_0$$

$$= 193 + 35.5$$

$$\dot{m}_1 = 228.5$$

$$\dot{m}_1 \omega_1 = \dot{m}_4 \omega_4 + \dot{m}_0 \omega_0$$

$$\omega_1 = \frac{\dot{m}_4 \omega_4 + \dot{m}_0 \omega_0}{\dot{m}_1}$$

$$\omega_1 = \frac{193(.0093) + 35.5(.018)}{228.5}$$

$$\omega_1 = .0106$$

$$\dot{m}_1 h_1 = \dot{m}_4 h_4 + \dot{m}_0 h_0$$

$$h_1 = \frac{\dot{m}_4 h_4 + \dot{m}_0 h_0}{\dot{m}_1}$$

$$= \frac{193(28) + 35.5(41.5)}{228.5}$$

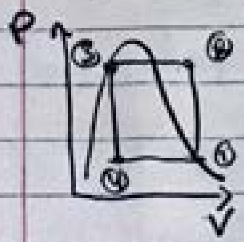
$$h_1 = 30.1$$

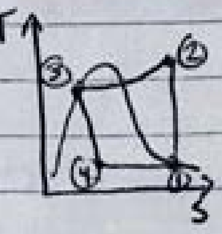
$$T_{db_1} \approx 77°F$$

Question 2

Purpose: The purpose of the question is to calculate a) the operating of the evaporator and condensor, B) state of the refrigerant; C) P-V/T-S diagrams, D) COP of the cycle, E) required refrigerant mass flow rate, f) power required, and g) the waste heat rate.

Diagrams:





Design Considerations:

- Same unit as Q1
- R-134a
- Vapor compression system

Data and Variables:

- R-134a @ 2.7°C to 6.3°C
- Isentropic efficiency @ 85%

Procedure:

- Draw PV / Ts diagrams
- Find Condensor Variables
- Find the states
- Find enthalpy 2
- Find Wcompressor
- Find COP of cycle

Calculations:

Summary:

This problem had us calculate the operating pressure, state of refrigerant, COP, required flow rate, power required, and waste heat rate.

Materials:

- R-134a
- Cooling/dehumidifier unit

Analysis

After completing the problem we saw that the COP was relatively high for the system. Also we found the other variables needed to calculate the mass flow rate of the refrigerant, the waste heat, and power required by the compressor.

Evaporator

55°F $\quad (55-32)(5/9) = 12.8°C$

$12°C - 10°C = 2.7 \approx 2°C \quad P_{evapor} = 314.84\ kPa$

condensor

90°F $\quad (90-32)(5/9) = 32.2°C$

$32.2°C + 10°C = 42.2°C \approx 42$

$P_{cond} = 1072.8$

$1 \rightarrow 2 \rightarrow 3 \rightarrow 4$

$T_1 = 2°C + 2.7°C = 4.7°C$

$P = 314.84\ kPa$ $\quad s_1 = .937$

$h_1 = 253.94$

T_2 $\quad -25$

$s_{2s} = .927$

$1072.8\ kPa \quad T_2 = 42°C$

$s_2 = .9140$

$h_{2s} = 272.7\ kJ/kg$

$$\eta_s = \frac{h_{2s} - h_1}{h_2 - h_1}$$

$$h_2 = h_1 + \frac{h_{2s} - h_1}{\eta_s}$$

$$= 253.94 + \frac{272.7 - 253.94}{.80}$$

$h_2 = 277.39$

$T_{cond} = 42^{\circ}C - 6.3 = 35.7^{\circ}C$

$P_2 = P_3 = 1072.8$ kPa

$X_3 = 0$

$h_3 = 101.9$

$s_3 = .3747$

$h_4 = h_3 = 101.9$ kJ/kg $\quad T_4 = T_1 = 2^{\circ}C$

$P_1 = P_4 = 314.84$ kPa

$h_f = 54.498$

$h_g = 251.651$

$$x_4 = \frac{h_4 - h_f}{h_g - h_f}$$

$$x_4 \quad \frac{101.9 - 54.498}{251.651 - 54.498}$$

$x_4 = .2404$

$\dot{W}$

W_{c}

$Q_{cool} = \dot{m}_r (h_1 - h_4) \qquad 109{,}440 \to kW = 32.1$ kW

$$\dot{m}_r = \frac{Q_{cool}}{(h_1 - h_4)}$$

$$\dot{m}_r \quad \frac{32.1}{253.4 - 101.9}$$

$\dot{m}_r = .211$ kg/s

$W_{comp} = \dot{m}_r (h_2 - h_1) \qquad = 4.95\text{ kW}\left(\frac{1}{.7457}\right) = 6.64\text{ HP}$

Waste heat

$Q = \dot{m}_r (h_2 - h_3)$
$.211 (277.93 - 101.9)$
$= 37.14$ Kw

$COP = \frac{Q_{cool}}{W_{comp}}$

$\frac{32.1}{4.95}$
$COP = 6.48$

Part 3 $37.14 \doteq 126726$ Btu/hr

$Q = \dot{m}_{dry} (h_{out\,air} - h_{in\,air}) = \dot{m}_w (h_{out\,water} - h_{in\,water})$

Water in
$90° + 10° = 100$
Water out @100 $h = 68.03$ btu/lb
$100 - 3 = 97°F$ $h = 65.04$

air in
$T_{db} = 90°F$ 60%
$\omega_{in} = .018$ lb wtr/lb dry air
$h = 40.1$
air out
98° 60%
$\omega_{out} = .0205$
$h = 44$

Question 3

Purpose: The question required us to design a new custom cooling tower for a refrigeration cycle.

Design Considerations:

- Asorb waste heat
- Reuse waste water
- Use varibles from Q1 / Q2

Data / Variables

- Relative humitity = 90%
- Temp change = 3°F

Procedure:

- Find Q
- Find Win
- Find air in
- Find air out
- Find mass flow rate

Calculations:

$126726 = \dot{m}_{air}(h_{out} - h_{in})$

$\frac{126726}{44 - 40.1} = \dot{m}_{air}$

32493.85 lb/hr

541 lb/min

$\dot{V}_{air} = 541(14.1)$

$\dot{V}_{air} = 7628$ cfm

$\dot{m}_w = (W_{out} - W_{in})\dot{m}_a$

$(.0205 - .018)(541)$

$\dot{m}_w = 1.35$ lb/min

$= 81.15$ lb/hr

Summary:

The work done for this problem evaluates the cooling and dehumidifying process. To calculate each part the different states had to be evaluated aswell as the required capacity. For the units.

Materials:

- Dehumidifier/cooler
- Compressor
- Air conditioned space

Analysis:

Once the states were calculated the operation of the system became clear. Using each state we were able to Extrapolate what requirements the system needed. and the byproducts.