Name: Dezmond Banks.

MET 350 Thermal Applications
Dr. Orlando Ayala
Spring 2018
Test 3

Take home – Due Tuesday May 1st 2018 before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. For the technical writing I will follow the attached rubric.

3. There are 2 problems worth (80/2) points each. There is an additional problem worth 10 extra points towards this test. Because of these extra points, there will not be extra points for test reflections and you are given 2 extra days (see due date) to turn in the test to account for the completion of the extra problem. Please note, that you will still have another opportunity for other points towards the final grade if you complete the website (read syllabus).

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me and your partner. I will allow you to partner up with another student for this test. This test can be handled by one person, so if you do not want to partner with someone else, please do not do it. Anyway, call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit only one file and it has to be a pdf file. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University, you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

   IX. PROHIBITED CONDUCT

   A. Academic Integrity violations, including:

   1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

1) A given space is to be maintained at 75 F and a relative humidity of 50%. The total heat gain to the space is 72,000 Btu/hr (this heat is physically passing through the walls, if you want to learn how to calculate this you should take MET440). There is no infiltration of outside air into the space neither there is any source of water inside the space, thus the humidity ratio of the air remains the same between states 2 and 3. Due to a process occurring inside the conditioned space, there is a need of fresh outdoor air in the amount of 500 cfm, which is provided as shown in the sketch. Assume that the air in the cooling and dehumidyfing unit is being constantly mixed so the cooling and dehumidyfing processes follow an ideal behaviour. Also assume that the fan is ideal and does not change the air state condition. The outdoor air has a temperature and relative humidity of 90 F and 60%, respectively. Determine:

   a. The quantity of the air supplied to the space.
   b. The state of the air at each of the points shown in the drawing (provide the dry bulb temperature and the humidity ratio of each state).
   c. Draw all the processes in the attached psychrometric chart.
   d. The required capacity of the cooling and dehumidyfing unit.
   e. The amount of liquid water drained in the cooling and dehumidyfing unit.

2) The cooling and dehumidyfing unit (also known as air handler unit) in the previous problem is part of a air-conditioner equipment that operates on a vapor-compression refrigeration cycle with refrigerant R-134a. You are required to design the equipment knowing that: the waste heat is rejected to the outside air, the refrigerant leaves the evaporator superheated by 2.7 °C and is subcooled by 6.3 °C at the exit of the condenser, and the isentropic efficiency of the compressor is 80%. For the design you must provide:

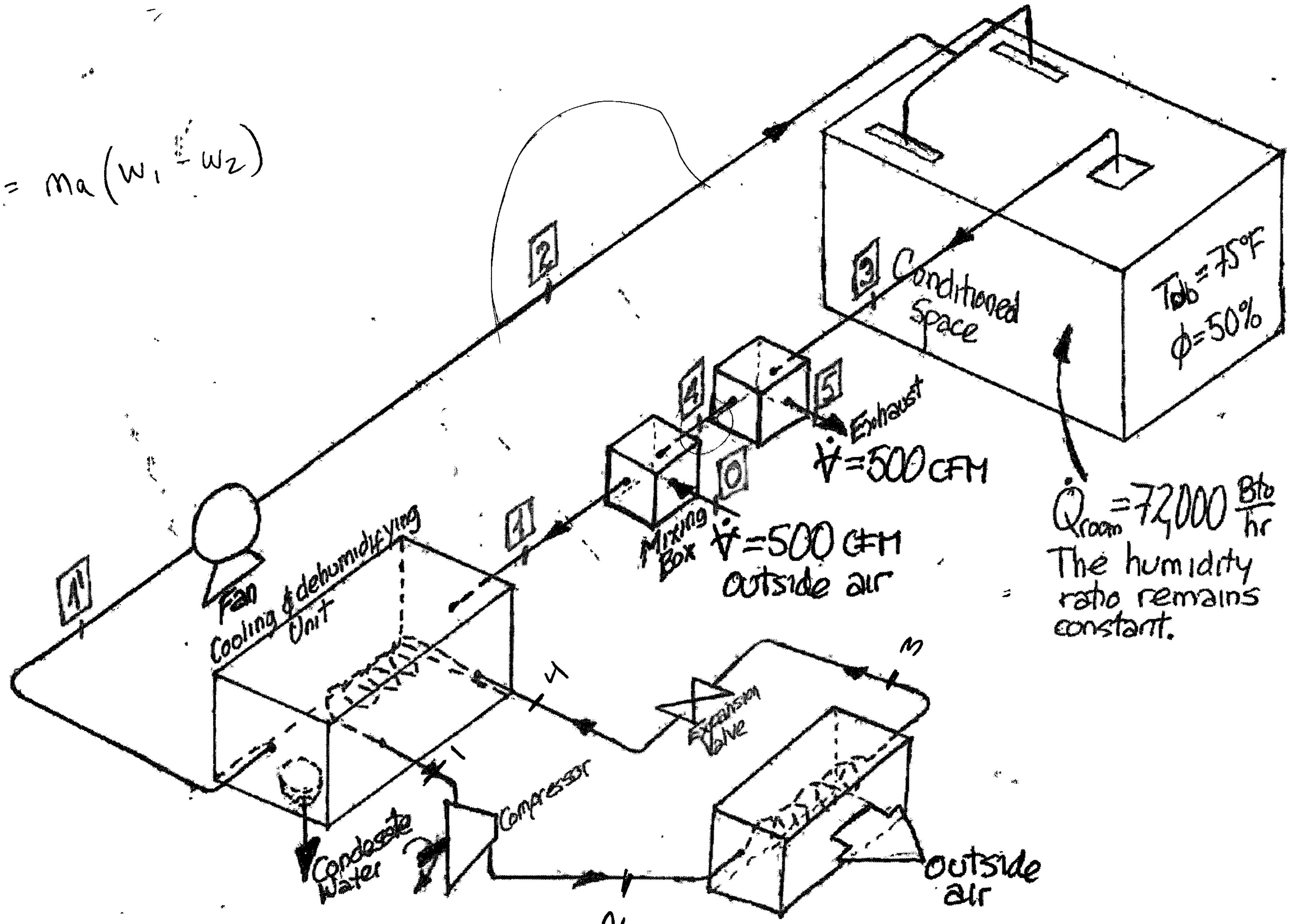
   a. The operating pressure of the evaporator and the condenser. Keep in mind that the temperatures of the refrigerant should be appropriate for the heat transfer to occur. Follow the rule of thumb provided in class.
   b. The state of the refrigerant after each of the elements of the vapor-compression refrigeration cycle (provide pressure, temperature, enthaply, and quality of each state).
   c. The P-v and T-s diagrams.
   d. The COP of your designed cycle.
   e. The required refrigerant mass flow rate.
   f. The power required by the compressor in HP.
   g. The waste heat rate.

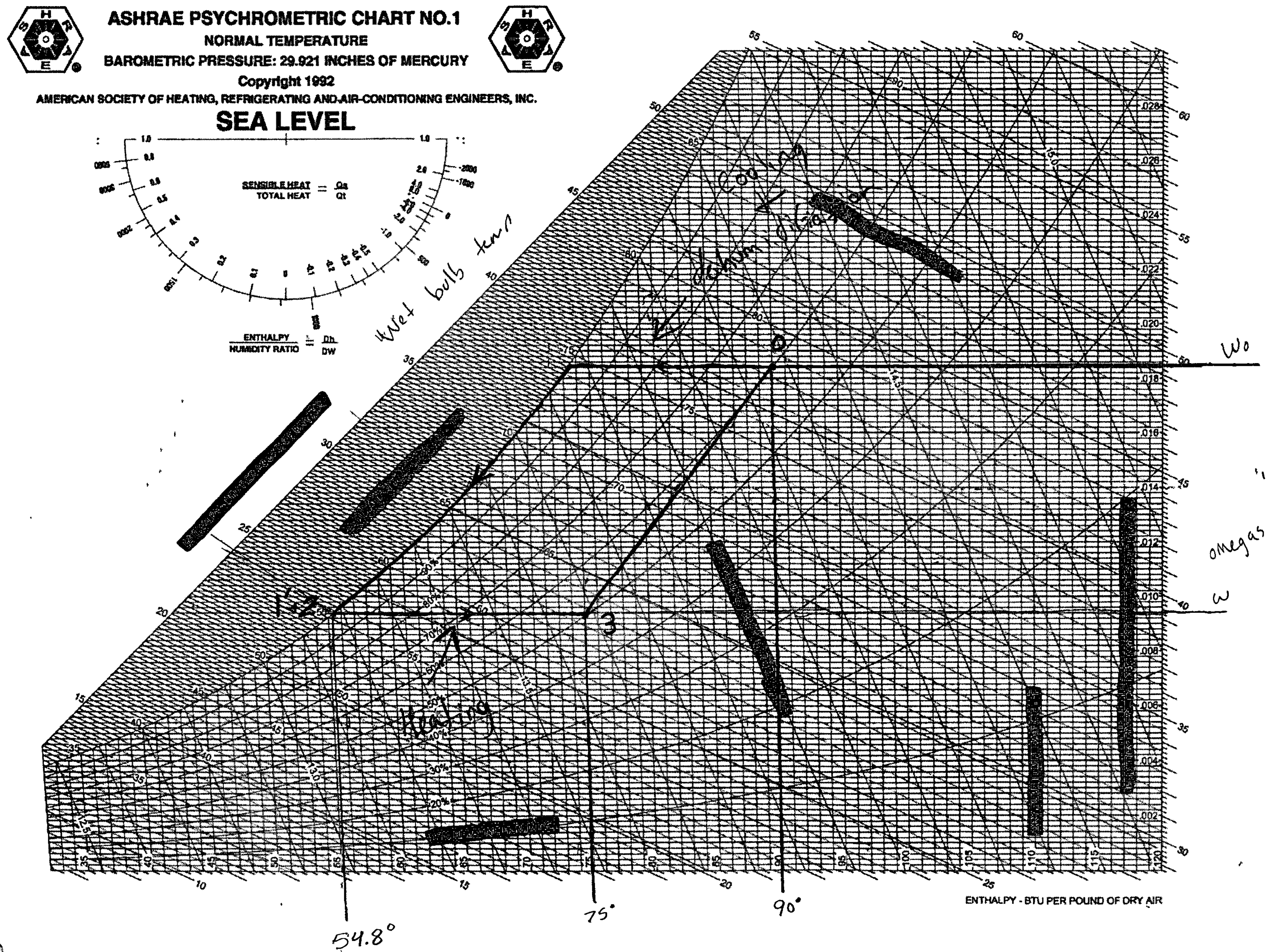
3) For the additional points, you are asked to revise part of your vapor-compression refrigeration cycle design. Your client wants to use water to absorb the waste heat of the cycle instead of rejecting it to the outside air. You must now provide a preliminary design of a cooling tower to cool the water in order to be reused back in the refrigeration cycle. To judge if the idea is feasible, you must provide:

   a. The volume flow rate of outside air into the cooling tower.
   b. The mass flow rate of the required makeup water.

NOTE: assume the air leaves the cooling tower with a relative humidity of 90%. Also assume that the temperature changes of the water and the air are about 3 F.

$\dot{m}_w = \dot{m}_a(w_1 - w_2)$





ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE: 29.921 INCHES OF MERCURY
Copyright 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Dh / DW
ENTHALPY - BTU PER POUND OF DRY AIR
Wet bulb temp
Cooling
dehum
Heating
Wo
omegas
w
0
1-2
3
54.8°
75°
90°

Test 3 #1 | Dezmond Banks | Daniel Neuhaus

Purpose: Determine: (A) Quantity air supplied
(B) States
(C) Drawings on pschromatic chart
(D) required capacity of cooling and dehumidifying unit
(E) Amount of liquid drained

Drawing:

- See attached

Sources:

Cengel & Boles "Thermodynamics - An Engineering Approach." 8th edition, McGraw Hill 2015.

Design Considerations:

- Constant humidity ratio states 2 & 3
- No infiltration of outside air inside conditioned space
- Cooling and dehumidifying process is ideal
- No source of water inside space

Data Variables:

$\dot{Q}_{in} = 72000$ btu/hr

$\dot{V} = 500$ cfm

@ 90°F $\phi = 60\%$

@ 75°F $\phi = 50\%$

$\dot{Q} = \dot{m}(h_3 - h_2)$

$\dot{V} = V \dot{m}_a$

$m_a = \frac{cfm}{V}$

Procedure:

- Listed given info
- Drew out process on psychrometric chart
- Found all states
- Calculated mass air flow at state 2
- Calculated $\dot{V}$
- Calculated $\dot{m}$ at state 1
- Calculated h_1 and ω_1
- Calculated $\dot{m}_w$ draind from the c+d unit
- Calculated the the required Capacity.

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Calculations:

(1')

(0)

$\dot{V} = 500$ CFM

$T = 90°F$

$\phi = 60\%$

$h_f = 41.8 \frac{Btu}{lbm}$

$T_{WB} = 78.2 °F$

$\omega = .0182 \frac{lbm\ water}{lb\ air}$

$V_1 = 14.25\ ft^3/lb$

$\dot{m}_0 = \frac{CFM}{V}$

$m_0 = 35.09$

(1)

$m_0 + m_4 = m_1$

$\phi = 100\%$

$m_1 = 248.54 \frac{lb}{min}$

$h_1 = 30.03 \frac{Btu}{lbm}$

$\omega_1 = .01047 \frac{lb\ water}{lb\ air}$

$V_1 = 35.2$

$T_1 = 65.5°F$

Needs to be 100% so cooling coils can condense

(2)

$\phi_2 = 100\%$

$\omega_2 = .0092$

$T_{DB} = 54.8°F$

$V = 13.18\ ft^3/lb$

$h_f = 23.3 \frac{Btu}{lb}$

$\dot{V}$ 3295 CFM

$m_2 = 250 \frac{lbm}{min}$

(3) ← Same → **(4)**

(3)

$T_3 = 75°F$

$\phi = 50\%$

$T_{WB} = 62.5°F$

$\omega = .0092 \frac{lb\ water}{lb\ air}$

$h_f = 28.1\ Btu/lbm$

$V_3 = 13.68\ ft^3/lb$

$m_3 = m_2 = 250 \frac{lbm}{min}$

(4)

$T_{DB} = 75°F$

$\phi = 50\%$

$T_{WB} = 62.5°F$

$\omega = .0092 \frac{lb\ water}{lb\ air}$

$V = 13.68\ ft^3/lb$

$m_4 = 213.45 \frac{lbm}{min}$

(5)

$\dot{V} = 500$ CFM

$\phi = 50\%$

$T_{WB} = 62.5 F$

$\omega = .0092 \frac{lb\ water}{lb\ air}$

$h_f = 28.1\ Btu/lbm$

$V = 13.68$

$\dot{V}_{out} = 500$ CFM

$m_5 = 36.55$

$$\dot{Q} = \dot{m}(h_3 - h_2)$$

$$\frac{72000}{4.8} = \frac{\dot{m}(28.1 - 23.3)}{4.8}$$

$$\dot{m} = 15000 \frac{lb}{hr} \times \frac{1\ hr}{60\ min}$$

$$\dot{m} = 250 \frac{lb\ air}{min}$$

$\dot{V} = V_2\, \dot{m}_{a}$

$\dot{V} = (13.18\ ft^3/lb)(250 \frac{lb}{min})$

$\dot{V} = 3295$ CFM

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Calculations:

$$m_4 = m_3 - m_5 = 250 \frac{lbm}{min} - 36.55 \frac{lbm}{min} = 213.45 \frac{lbm}{min}$$

$$m_1 = m_4 + m_0 = 213.45 \frac{lbm}{min} + 35.09 \, lb/min$$

$$m_1 = 248.54 \frac{lbm}{min}$$

$$h_1 = \frac{m_4 h_4 + m_0 h_0}{m_1} \qquad h_1 = \frac{\left(213.45 \frac{lbm}{min}\right)\left(28.1 \frac{Btu}{lbm}\right) + \left(35.09 \frac{lb}{min}\right)\left(41.8 \frac{Btu}{lbm}\right)}{248.54 \frac{lbm}{min}}$$

$$h_1 = 30.03 \frac{Btu}{lbm}$$

$$\omega_4 m_4 + \omega_0 m_0 = \omega_1 m_1$$

$$\omega_1 = \frac{(.0092)(213.45) + (.0182)(35.09)}{248.54}$$

$$\omega_1 = .01047 \frac{lb\ water}{lb\ air}$$

$$m_w = m_1 (\omega_1 - \omega_{1'})$$

$$m_w = 248.54 (.01047 - .0092)$$

$$m_w = .3156 \frac{lb}{min}$$

$$Q_{C+D} = \dot{m}_1 (h_1 - h_{1'})$$

$$Q_{C+D} = \left(250 \frac{lbm}{min}\right)(30.03 - 23.3) \frac{Btu}{lbm}$$

$$Q_{C+D} = 1682.5 \frac{Btu}{min}$$

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Summary:

The purpose of this problem was to test the students knowledge on cooling and dehumidifying systems. For this problem we had to determine the quantity of air supplied, the states at each point, the required capacity of the cooling and dehumidifying unit, the amount of liquid drained, from the unit and draw all of the processes on the chart.

Materials:

- Conditioned Space
- air
- Mixing box
- Cooling & dehumidifying unit
- Fan

Analysis:

Analyzing the problem I realize that by drawing out all of the processes on the psychrometric chart we were able to better understand what was happening during each process and find the states. After finding the states we were able to calculate the the mass air flow of the states which made it possible to calculate the quantity of air supplied to the space. After this was all calculated the rest of the tasks were easy to calculate.