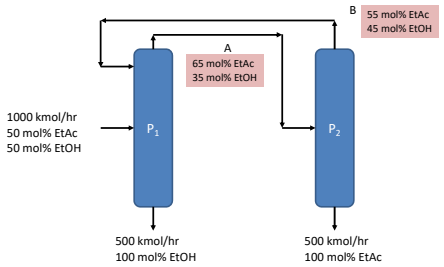
Debate on world's oldest profession

Are You Smarter Than A Senior?

(many of the seniors said that they did not know how to work this problem)



Find the molar flow rates of stream A and stream B.

Professional Program Application

- Due Nov. 17 to ChE Office (2 weeks!)
- Must meet with your ChE Faculty Advisor
  - This is not Brother Oakeson!
- Must update the course planning Excel Spreadsheet
- Must take a shot at your electives
- This is not a contract!
- Allows you to take Fluids (ChE 374) in F'17

Teams for Case Study

Team	Team Leader			
1	Jacobs James Ryan	Horne Benjamin Robert	Baird Jonathan Reese	Benning Alexander Patrick
2	Wallentine Jakob Scott	Van Wagoner Colton Taylor	Holt Cole Joseph	Christensen Alan Spencer
3	Frandsen Jacob Roberts	Rice Taylor Blake	Welling Evelyn Esther	Brady Cassandra Jane (Guffy)
4	Timmerman Brandon David	Lore James David	Sederholm Jarom Glen	De Jesus Arielle Jemima Belza
5	Arment Joshua Randall	Hart Elizabeth Hannah	Wood Benson Reid	Davis Brady Rockwell
6	Schooff Brian Jeffrey	Smith Madison Jane	Van Katwyk Nathan Kirk	Crofts Magdalena Rose
7	Martineau Joshua Michael	Free Tyler Jordan	Potter Kalen Dell	Bourdeau Jefferson Eddy
8	Bailey Paul Widdison	Lee Wan Luan	Ashby James Michael	Jones Harry Orville

Please sit by your team members and exchange cell # and email

Class 26

- Hint on Prob 7.45 (7.41 in 3rd Ed. and workbook)
  - Assume 1 bar total pressure (workbook assumes 1 atm)
- Hint on Prob 7.46 (7.42 in 3rd Ed.)
  - Take a basis of 100 mol/hr instead of just 100 mol
  - You will have to do a total mole balance and a balance on one of the species in order to find the molar flow rates of the two exit streams

More Definitions

- Isentropic = constant entropy ($\Delta S = 0$)
- Isobaric = constant pressure ($\Delta P = 0$)
- Isotropic = no change with direction

Standard textbook definitions of Entropy

- a measure of energy dispersal at a specific temperature.
- a measure of disorder in the universe or of the availability of the energy in a system to do work.
- a measure of a system's thermal energy per unit temperature that is unavailable for doing useful work.

Entropy has often been loosely associated with the amount of order or disorder, or of chaos, in a thermodynamic system.

Open System Energy Balance

- At Steady State:

$$\Delta \dot{H} + \Delta \dot{E}_K + \Delta \dot{E}_P = \dot{Q} + \dot{W}_s$$

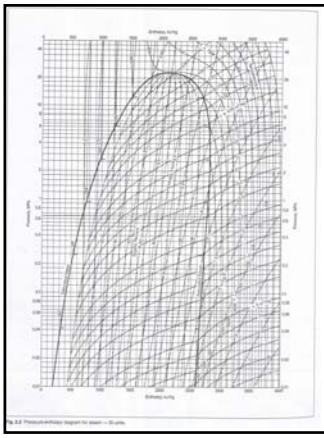
Units: Btu/hr or J/s or kW or cal/min

where

$$\Delta \dot{H} = \dot{m} \Delta \hat{H} = \dot{m}(\hat{H}_{out} - \hat{H}_{in})$$

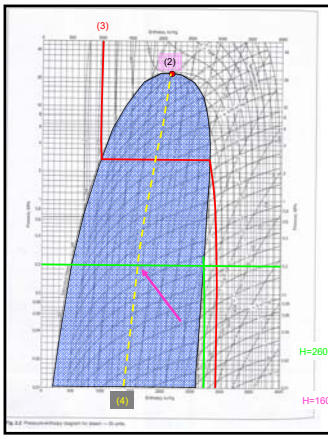
or for multiple species:

$$\dot{H}_{out} = \sum \dot{n}_{i,out} \hat{H}_{i,out}$$
$$\dot{H}_{in} = \sum \dot{n}_{i,in} \hat{H}_{i,in}$$



Steam P-H diagram
(from Steam, by Babcock & Wilcox Company)

1. Identify the 2-phase envelope
2. Label the Critical Point
3. Draw the 500 K isotherm everywhere on chart
4. Draw the line of constant 50% quality steam
5. How many things can we say about a steam-water system at 0.2 MPa and 400 K?
6. What about 0.2 MPa and 50% quality?



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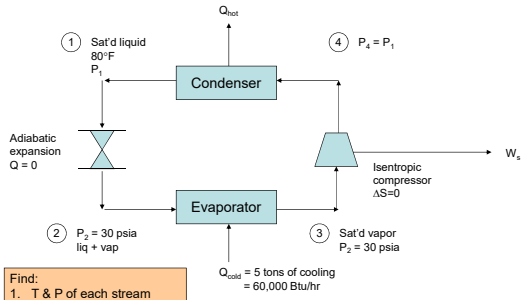
H=2600 kJ/kg V=0.9 m³/kg Above dew pt S=7.2 kJ/kg

6. What about 0.2 MPa and 50% quality?

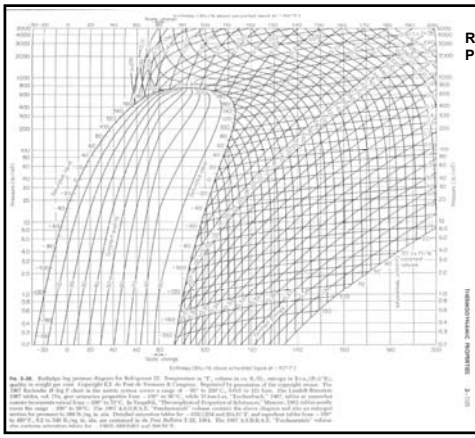
H=1600 kJ/kg V=0.45 m³/kg 2-phase S=4.4 kJ/kg T=395 K

Air Conditioner with Refrigerant 22



Find:
1. T & P of each stream
2. Enthalpies of each stream
3. Mass flow rate
4. W_s
5. Q_{hot}

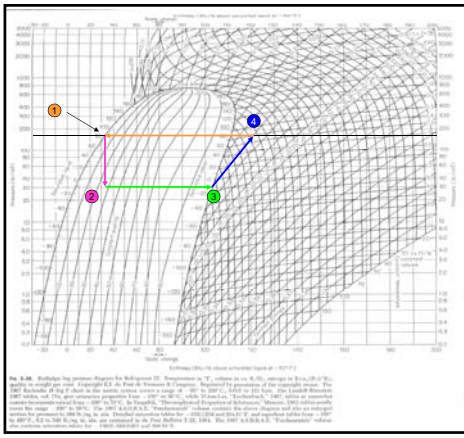
(see P-H diagram on next page)



Refrigerant 22 P-H diagram

Properties of Each Stream

Stream	Phase(s)	T (°F)	P (psia)	H (Btu/lb)
1	Sat'd liq	80		
2	Liq + vap		30	
3	Sat'd vapor		30	
4				



Refrigerant 22
P-H diagram

Properties of Each Stream

Stream	Phase(s)	T (°F)	P (psia)	H (Btu/lb)
1	Sat'd liq	80	170	32
2	Liq + vap	-12	30	32
3	Sat'd vapor, S=.23 Btu/lb-°R	-12	30	104
4	Vapor S=.23 Btu/lb-°R	130	170	122

Balances

- General

  $\Delta H + \Delta E_k + \Delta E_p = Q + W_s$
- Expansion valve

  ~~$\Delta H + \Delta E_k + \Delta E_p = Q + W_s$~~ $\Delta H = 0$
- Evaporator

  ~~$\Delta H + \Delta E_k + \Delta E_p = Q + W_s$~~ $\Delta H = Q$
- Compressor

  ~~$\Delta H + \Delta E_k + \Delta E_p = Q$~~ + W_s $\Delta H = W_s$
- Condenser

  ~~$\Delta H + \Delta E_k + \Delta E_p = Q + W_s$~~ $\Delta H = Q$

Balances

1. From evaporator, find mass flow rate
2. From compressor, find work required
3. From condenser, find cooling rate
4. Check overall balance

Do It!

Balances

1. From evaporator, find mass flow rate

$$\Delta \dot{H} = \dot{Q}$$
$$\dot{m}\,\Delta\tilde{H} = \dot{Q} = 60{,}000\ Btu/hr$$
$$\Delta\tilde{H} = \tilde{H}_3 - \tilde{H}_2 = 104 - 32 = 72\ Btu/lb_m$$
$$\dot{m} = \frac{60{,}000\ Btu/hr}{Btu/lb_m} = 833\frac{lb_m}{hr}\ of\ Ref\ 22$$

2. From compressor, find work required

$$\dot{m}\,\Delta\tilde{H} = W_s = \dot{m}\,(\tilde{H}_4 - \tilde{H}_3)$$
$$W_s = \left(833\frac{lb_m}{hr}\right)\left(122 - 104\frac{Btu}{lb_m}\right) = +15{,}000\frac{Btu}{hr}\left(\frac{1.34\times10^{-3}\ hp}{9.486\times10^{-4}\frac{Btu}{s}}\right)\left(\frac{hr}{3600\ s}\right)$$

W_s = +5.9 hp = +15,000 Btu/hr
(positive because surroundings do work on system)

(negative according to convention in 3rd Ed.)

Balances

3. From condenser, find cooling rate

$$\Delta \dot{H} = \dot{Q}_c = \dot{m}\,(\tilde{H}_1 - \tilde{H}_4)$$
$$\dot{Q}_c = \left(833\frac{lb_m}{hr}\right)\left(32 - 122\frac{Btu}{lb_m}\right) = -75{,}000\ Btu/hr$$

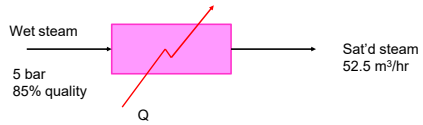
(negative because heat leaves system)

4. Check overall balance

$$0 = \sum \dot{Q} + \dot{W}_s$$

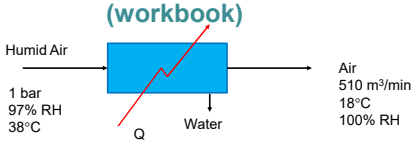
$0 = Q_c + Q_h + W_s$
0 = -75,000 + 60,000 + (+15,000) Btu/hr yes!!

Problem 7.36 (7.32 in 3rd Ed.)



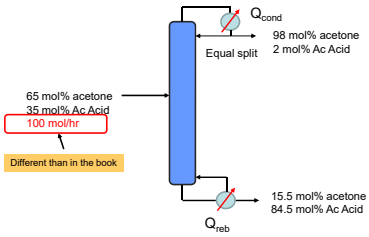
Find:
(a) T, $\hat{H}_{\text{wet steam}}$, $\hat{H}_{\text{dry steam}}$, $\dot{m}_{\text{total}}$
(b) Q

Problem 7.45 (7.41 in 3rd Ed.) (workbook)



Find:
(a) $\dot{m}_{\text{water}}$
(b) Q

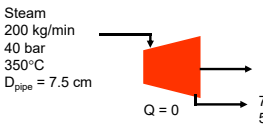
Problem 7.46 (7.42 in 3rd Ed.)



Enthalpies given for each species in each stream

Find:
(a) Q_{overall} (= $Q_{\text{condenser}}$ + Q_{reboiler})
(b) Q_{cond}, Q_{reb}

Problem 7.33



75°C
5 bar
D_{pipe} = 5 cm
Wet Steam? Water? Dry Steam?

(a) If outlet stream is wet steam, what would the temperature be instead of 75 °C?
(b) Net energy transfer to or from turbine (i.e., W_s)?