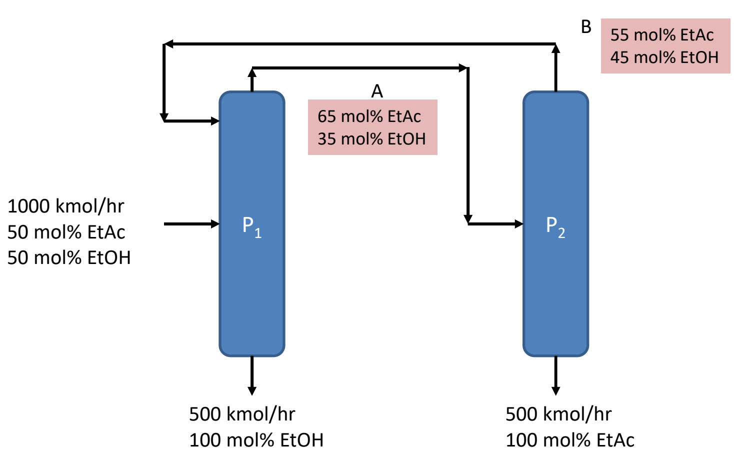
Faith Precedes the Miracle

Story of Brother Wu

1

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.

2

Case Study Teams

Team	Team Leader		
1	Porter Jared William	Dahl Eric Jack	Seaman Adelle
2	Williams Lillian Carrie	Anderson Elaina Dawn	Rodriguez Ceron Ricardo
3	Thomas Catherine	Wallace Callie Rose	Miles Matthew Thomas
4	Bennett Gwendolyn	Shumway Spencer Sawaya	St. Rose Jamoll Jorden
5	Ziegler Masaharu John	Jensen Spencer	Asay Brigham Zachary
6	Smith Benjamin Shumway	Dykes Jenna	Thurston Mark David
7	Sedgwick Mia Camille	Grandon Perez Alejandro	Rappleyea Aaron Dean
8	Stone Douglas	Younger Celeste Nina	Belnap Jake Kristopher
9	Guanuna Ernesto Giovanni	Exon Kaiden Denton	Dobberfuhl Amy Janae
10	Pope Caeden Arding	Varga Jarod Alexander	Sasser Samuel Denver
11	Thompson Ethan Lee	Smith Thomas Bradley	Fenberg Mary Kate
12	Higley Brayden	Bair Brianna Josephine	Klippel Lloyd
13	Tolman Tyson Edward	Fowler Kensley Jade	Jones Olivia
14	Stone Ryan Aaron	Schouten Lydia Camille	Scott Tripp
15	Larson Benjamin Greg	James Nicole Marie	Bregg Eric William
16	Steed Aaron Huber	Dick Schuyler James	

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Teams for Case Study

- Teams are on Learning Suite
  - Under Content>Case Study
- Phone numbers and emails are also on Learning Suite

Please get to know your team members and maybe do HW with them

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Professional Program Application

- Due Nov 18 to ChE Office (sooner is better)
- Must meet with your ChE Faculty Advisor
  - After getting forms approved by Sister Huff
- 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 W'21

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Faculty Advisors

Name	Advisor	Name	Advisor	Name	Advisor
Anderson, Elaina	Argyle	James, Nicole	Baxter	Shumway, Spencer	Bundy
Asay, Zach	Argyle	Jensen, Spencer	Rappleye	Smith, Benjamin	Wheeler
Bair, Brianna	Baxter	Jones, Olivia	Hedengren	Smith, Thomas	Lignell
Belnap, Jake	Seo	Klippel, Turner	Lewis	St. Rose, Jamoll	Fletcher
Bennett, Gwen	Nickerson	Larson, Ben	Lewis	Steed, Aaron	Guymon
Bregg, Eric	Fletcher	Miles, Matt	Pitt	Stone, Doug	Guymon
Dahl, Jack	Fry	Pope, Caeden	Tree	Stone, Ryan	Hedengren
Dick, Schuyler	Lignell	Porter, Jared	Wheeler	Thomas, Catherine	Baxter
Dobberfuhl, Amy	Fletcher	Rappleyea, Aaron	Lignell	Thompson, Ethan	Memmott
Dykes, Jenna	Tree	Rodriguez Ceron, Ricardo	Tree	Thurston, David	Memmott
Exon, Kaiden	Wheeler	Sasser, Sam	Seo	Tolman, Tyson	Hedengren
Fenberg, Mary	Guymon	Schouten, Lydia	Rappleye	Varga, Jarod	Nickerson
Fowler, Kensley	Nickerson	Scott, Tripp	Argyle	Wallace, Callie	Pitt
Grandon Perez, Alejandro	Seo	Seaman, Adelle	Fry	Williams, Lillian	Fry
Guanuna-Lehenbauer, Gio	Pitt	Sedgwick, Mia	Memmott	Younger, Celeste	Lewis
Higley, Brayden	Rappleye			Ziegler, Masa	Bundy

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Class 25

- Prob 22.1 is a steam table problem
- Hint on Prob 22.2
  - Assume 1 bar total pressure
- Hint on 22.3
  - 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
- Prob 22.4 is just like the example we will work in class (so pay attention!)

7

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.

You will learn more about entropy in PChem and in Thermodynamics.
For now, let's call it non-useful work.

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

or for multiple species:

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

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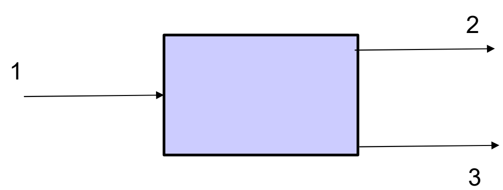
What about multiple streams?



$$\Delta \dot{H} = \dot{H}_{out} - \dot{H}_{in} = \dot{m}_2\hat{H}_2 + \dot{m}_3\hat{H}_3 - \dot{m}_1\hat{H}_1$$

or in general:

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

where j is the index for each stream

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How Do You Calculate Enthalpy?

1. Tables
   - i.e., steam tables, last class
2. Equations
3. Graphs

Refrigerant 22 P-H diagram

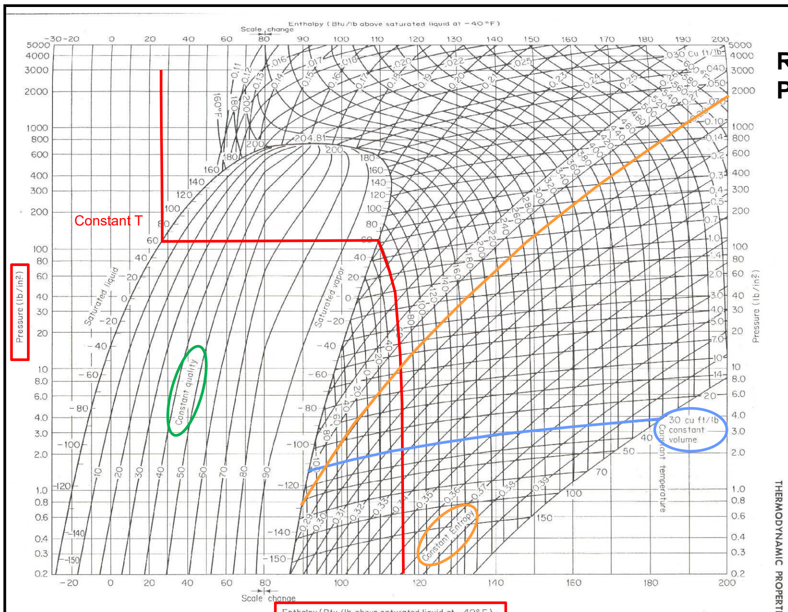

FIG. 3-38. Enthalpy–log pressure diagram for Refrigerant 22. Temperature in °F., volume in cu. ft./lb., entropy in B.t.u./(lb.)(°R.), quality in weight per cent. Copyright E.I. du Pont de Nemours & Company. Reprinted by permission of the copyright owner. The 1967 Karlsruhe *H*–log *P* chart in the metric system covers a range of −90° to 250°C., 0.035 to 121 bars. The Landolt-Börnstein 1967 tables, vol. IVa, give saturation properties from −100° to 96°C., while D'Ans-Lax, "Taschenbuch," 1967, tables at somewhat coarser increments extend from −100° to 70°C. In Vargaftik, "Thermophysical Properties of Substances," Moscow, 1963, tables mostly cover the range −100° to 50°C. The 1967 A.S.H.R.A.E. "Fundamentals" volume contains the above diagram and also an enlarged section for pressures to 300 lb./sq. in. abs. Detailed saturation tables for −155(1)204 and 204.81°F. and superheat tables from −150° to 480°F., 0.2 to 540 lb./sq. in. abs. are contained in *du Pont Bulletin* T-22, 1964. The 1967 A.S.H.R.A.E. "Fundamentals" volume also contains saturation tables for −150(5)-100(2)204 and 204.81°F.

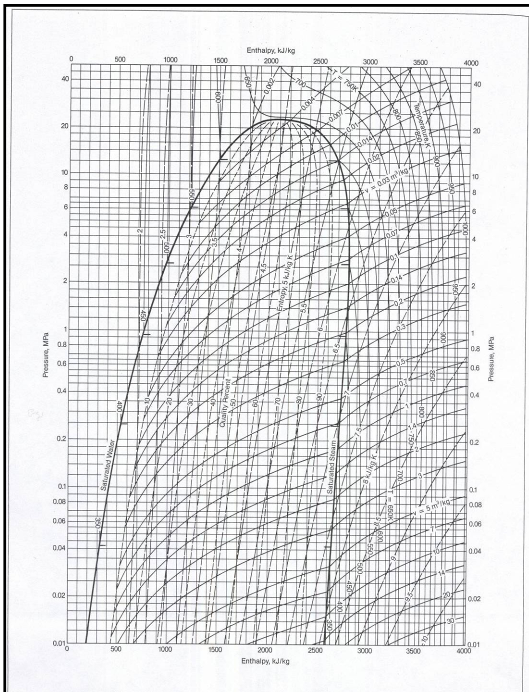

Fig. 2.2 Pressure-enthalpy diagram for steam — SI units.

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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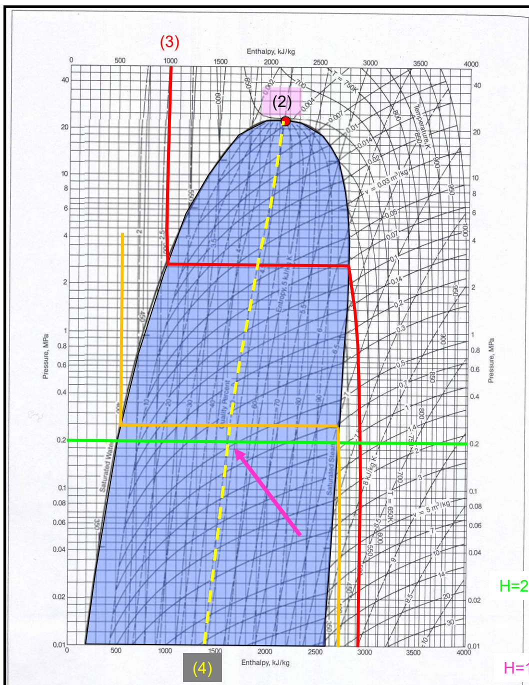

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2. Label the Critical Point
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5. How many things can we say about a steam-water system at 0.2 MPa and 400 K?

H=2600 kJ/kg V=0.9 m^3/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 m^3/k 2-phase S=4.4 kJ/kg T=395 K

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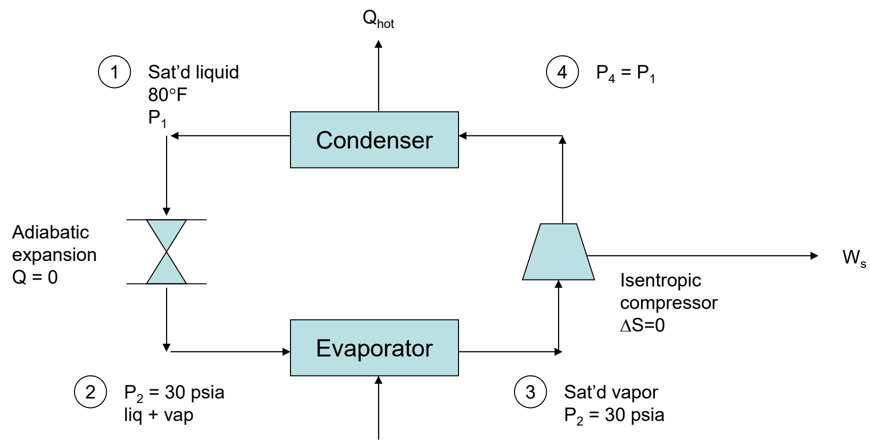
Air Conditioner with Refrigerant 22



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)

Properties of Each Stream

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

Refrigerant 22 P-H diagram

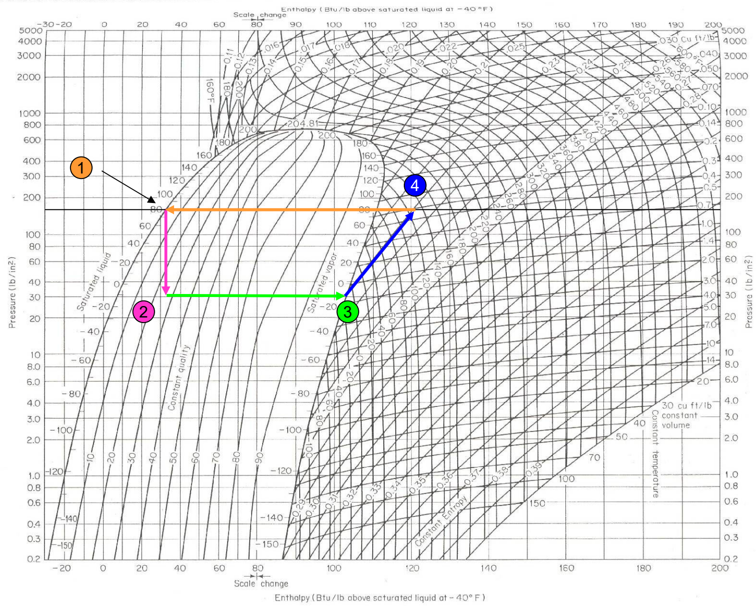


Fig. 3-38. Enthalpy–log pressure diagram for Refrigerant 22. Temperature in °F., volume in cu. ft./lb., entropy in B.t.u./(lb.)(°R.), quality in weight per cent. Copyright E.I. du Pont de Nemours & Company. Reprinted by permission of the copyright owner. The 1967 Karlsruhe *H*–log *P* chart in the metric system covers a range of −90° to 250°C., 0.035 to 121 bars. The Landolt-Börnstein 1967 tables, vol. IVa, give saturation properties from −100° to 96°C., while D'Ans-Lax, "Taschenbuch," 1967, tables at somewhat coarser increments extend from −100° to 70°C. In Vargaftik, "Thermophysical Properties of Substances," Moscow, 1963, tables mostly cover the range −100° to 50°C. The 1967 A.S.H.R.A.E. "Fundamentals" volume contains the above diagram and also an enlarged section for pressures to 300 lb./sq. in. abs. Detailed saturation tables for −155(1)204 and 204.81°F. and superheat tables from −150° to 480°F., 0.2 to 540 lb./sq. in. abs. are contained in *du Pont Bulletin* T-22, 1964. The 1967 A.S.H.R.A.E. "Fundamentals" volume also contains saturation tables for −150(5)-100(2)204 and 204.81°F.

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Properties of Each Stream

Stream	Phase(s)	T (°F)	P (psia)	$\widehat{H}$ (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

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Balances

- General

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

- Expansion valve

$\Delta H + \cancel{\Delta E_k} + \cancel{\Delta E_p} = \cancel{Q} + \cancel{W_s}$ $\quad \Delta H = 0$

- Evaporator

$\Delta H + \cancel{\Delta E_k} + \cancel{\Delta E_p} = Q + \cancel{W_s}$ $\quad \Delta H = Q$

- Compressor

$\Delta H + \cancel{\Delta E_k} + \cancel{\Delta E_p} = \cancel{Q} + W_s$ $\quad \Delta H = W_s$

- Condenser

$\Delta H + \cancel{\Delta E_k} + \cancel{\Delta E_p} = Q + \cancel{W_s}$ $\quad \Delta H = Q$

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Balances

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

Let's Do It!

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Balances

1. From evaporator, find mass flow rate

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

2. From compressor, find work required

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

W_s = +5.9 hp = +15,000 Btu/hr

(positive because surroundings do work on system)

(would be negative according to convention in 3rd Ed.)

Balances

3. From condenser, find cooling rate

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

(negative because heat leaves system)

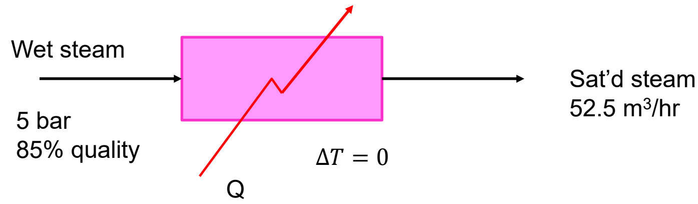
4. Check overall balance

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

$0 = Q_c + Q_h + W_s$

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

Problem 22.1



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

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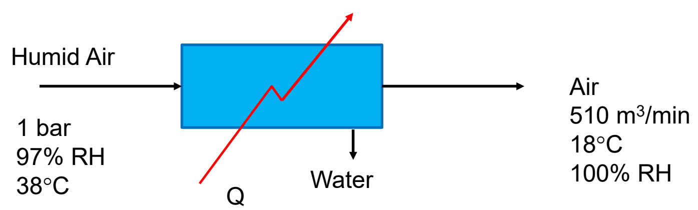
Problem 22.2



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

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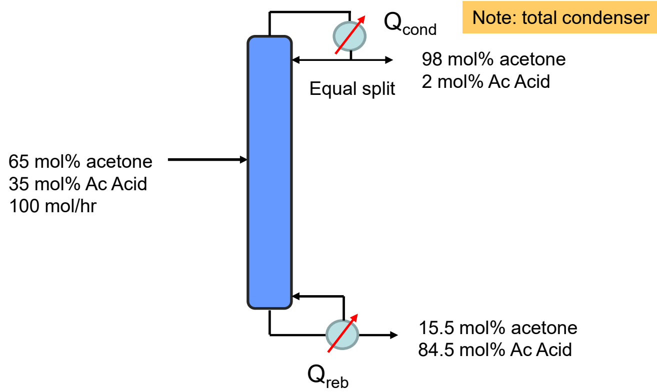
Problem 22.3



Enthalpies ($\hat{H}$) given for each species in each phase in each stream

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

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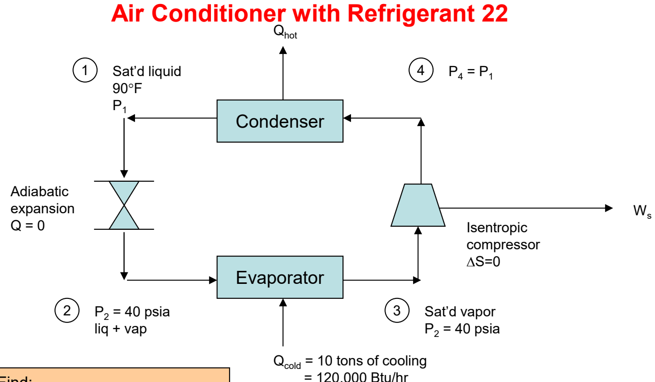
Problem 22.4

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}

(Just like in class, but with different T's and P's)

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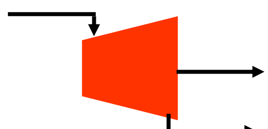
Problem 7.33

Steam
200 kg/min
40 bar
350°C
D_{pipe} = 7.5 cm



W_s

Q = 0

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)?

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