Class 26

- Hint on Prob 7.41 – Assume 1 bar total pressure (workbook assumes 1 atm)
- Hint on Prob 7.42
  - 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
  - Examples
    - wood (because of grains, wood properties are non-isotropic)

Open System Energy Balance

- At Steady State:
  \[ \Delta H + \Delta E_K + \Delta E_P = \dot{Q} - \dot{W}_S \]

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

where

\[ \Delta H = m \Delta \tilde{H} = m (\tilde{H}_{\text{out}} - \tilde{H}_{\text{in}}) \]

or for multiple species:

\[ \tilde{H}_{\text{out}} = \sum n_{l,\text{out}} \tilde{H}_{l,\text{out}} \]
\[ \tilde{H}_{\text{in}} = \sum n_{l,\text{in}} \tilde{H}_{l,\text{in}} \]

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?

Steam P-H diagram

Air Conditioner

Condenser

Evaporator

Isentropic compressor ($\Delta S = 0$)

Adiabatic expansion ($Q = 0$)
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. $Q_{hot}$

Properties of Each Stream

<table>
<thead>
<tr>
<th>Stream</th>
<th>Phase(s)</th>
<th>T (°F)</th>
<th>P (psia)</th>
<th>H (Btu/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sat’d liq</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Liq + vap</td>
<td>-12</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>Sat’d vapor</td>
<td>-12</td>
<td>30</td>
<td>104</td>
</tr>
<tr>
<td>4</td>
<td>Vapor</td>
<td>130</td>
<td>170</td>
<td>122</td>
</tr>
</tbody>
</table>
Balances

1. From evaporator, find mass flow rate
\[ \Delta H = 0 \]
\[ \Delta H = 0 = 60,000 \text{ Btu/hr} \]
\[ \Delta H = 0 = 104 - 32 = 72 \text{ Btu/lb} \]
\[ \Delta H = 0 = \frac{333}{\text{lb}} \times \frac{122 - 104}{10^{6}} \text{ Btu/hr} \]
\[ \Delta H = -15,000 \text{ Btu/hr} \]
\[ W_s = -5.9 \text{ hp} = -15,000 \text{ Btu/hr} \]
(negative because surroundings do work on system)

2. From compressor, find work required
\[ W_s = m \Delta H = m (R_1 - R_2) \]
\[ W_s = 333 \text{ lb} \times \frac{122 - 104}{10^{6}} \text{ Btu/hr} \]
\[ W_s = 15,000 \text{ Btu/hr} \]
(positive because work is done on the system)

3. From condenser, find cooling rate
\[ \Delta H = 0 = m (R_1 - R_2) \]
\[ \Delta H = 0 = 333 \text{ lb} \times \frac{32 - 122}{10^{6}} \text{ Btu/hr} \]
\[ \Delta H = 0 = 75,000 \text{ Btu/hr} \]
(negative because heat leaves system)

4. Check overall balance
\[ 0 = Q_c + Q_h - W_s \]
\[ 0 = -75,000 + 60,000 - (-15,000) \text{ Btu/hr} \]
Yes!!
Problem 7.42

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

Equal split
98 mol% acetone
2 mol% Ac Acid
65 mol% acetone
35 mol% Ac Acid

Enthalpies given for each species in each stream

65 mol% acetone
35 mol% Ac Acid

15.5 mol% acetone
84.5 mol% Ac Acid

Problem 7.33

Steam
200 kg/min
40 bar
350°C
D_out = 7.5 cm

$Q = 0$

W

25°C
5 bar
D_out = 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., $W$)?