Refrigerant Selection

If you have not investigated the impact of different refrigerants on the properties of the last 2 cycles you've analyzed, I suggest you do. It makes a big difference!

As we'll find out, refrigerants are <u>everywhere</u>. (Show can of cooking spray)

Some of you may remember the switch from R12 → R134a in automotive AC systems. Before we discuss this, let's talk about the history of refrigerants

→ Pre 20th century the state of the art or "modern" refrigeration used <u>ice</u>.

→ The primary unit of refrigeration is the <u>ton</u>: 1 ton = 3517 W

Which is the amount of cooling provided by melting 1 ton of ice in 1 hour.

→ Think about this for a minute... a building like this could easily have <u>100 tons</u> of AC cooling capacity: 100 tons of ice/hour

$$\rho_{ice} = 916.7\,\frac{kg}{m^3},\quad m_{ice} = 90{,}718\,kg,\quad V_{ice} = 98.96\,m^3$$

football field is 100 yd × 53.5 yd = 1" thick layer of ice melted/hour

basketball court 94 ft × 50 ft ≈ 9" thick layer of ice melted/hour

→ The invention of mechanical refrigeration with compressors

Changed everything! But what to use as refrigerant?

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Good refrigerant characteristics depend on the demands of a specific application:

1) Positive evaporator gauge pressure ⇒ prevents air from leaking into system
2) Moderate condenser pressure ⇒ P_{sat} increases almost exponentially with T_{sat}
3) Triple point & critical point temperatures
4) Low specific volume (high density) @ compressor inlet: $Disp = \frac{\dot{m}}{\rho \eta_{vol}} \Rightarrow \frac{v_1 \dot{m}}{\eta_{vol}}$ $\dot{m}\uparrow \forall v_1\downarrow$
5) high latent heat of vaporization: $h_{fg} = h_g - h_f$
6) high dielectric strength (ability to resist flow of electricity) for cooling electronics
7) Compatability with lubricants
8) Non-toxic
9) Non-flammable
10) Inertness / Stability → prevents degredation of compontes
11) Ozone depletion / Global Warming Potential

→ A Huge list & its difficult to find or make a fluid that addresses all of those

→ Ammonia was used from the late 1800's → 1920 in households, still used in industry

→ 1928 Thomas Midgley Jr. & Charles Franklin Kettering invented freon "R12 @ GM. Problem: toxic

→ also invented leaded gasoline which doubled amount of gas we can make from a barrel of oil → but all of the lead; duh

Invented electronic ignition systems

→ Chlorofluorocarbons

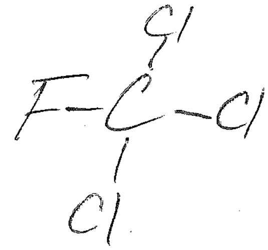
→ This division was later bought out by DuPont. R11 & R12 used until 1989.

We still use the DuPont naming scheme for these refrigerants ME301 Spr 32,3

R_{xyz} — x: # of carbon atoms − 1; y: # of H atoms + 1; z: # of fluorine atoms

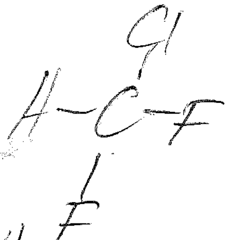
All of these have Chlorine atoms

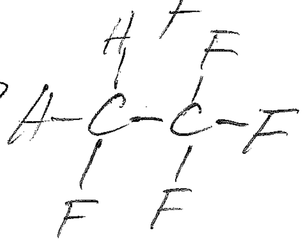
R_{11} is actually R_{011} — 1C, 0H, 1F

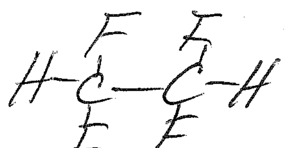


→ CFC → chlorofluorocarbon (Cl, F, C)

- used everywhere, shaving cream, hairspray, refrigerant

$R_{022} = R_{22}$ ⇒  → HCFC → hydrochlorofluorocarbon (H, Cl, F, C)

R_{134a} ⇒  → HFC → hydrofluorocarbon (H, F, C) no $\underline{Cl}$!

↳ other ways to make same combo  ← very different, separation required, we'll talk about this some in statistical mechanics

- Why is Cl bad? → Destroys Ozone O_3 ← protects us from UV radiation
- by making R-11, R-22 etc very stable, it survives up into the highest regions of the atmosphere where cosmic rays break it up, causing reactions $Cl + O_3$
- CFCs outlawed in 1989
- HCFCs will probably be outlawed in next 10 years ← huge costs to changeover equipment
- HFCs have 0 Ozone Depletion Potential (ODP) but some overall GWP ← Global Warming potential
  - See Figure 9.14 in text pgs 578 → 579
- Conclusion: we're using better chemicals with lower ODP & GWP, but we still have to make these systems efficient to reduce CO2 & its GWP.

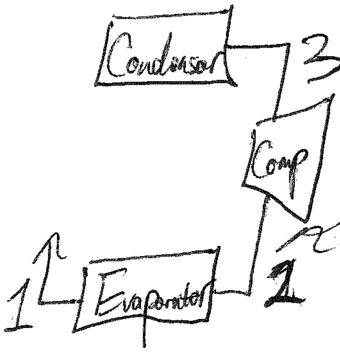
~~18.7~~ ME301 Sp2011

32.3

Vapor Compression Cycle Modifications

Assign 9.A→13

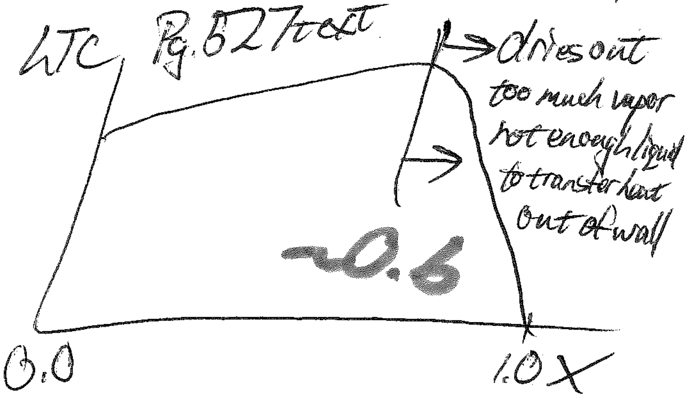
or superheated vapor



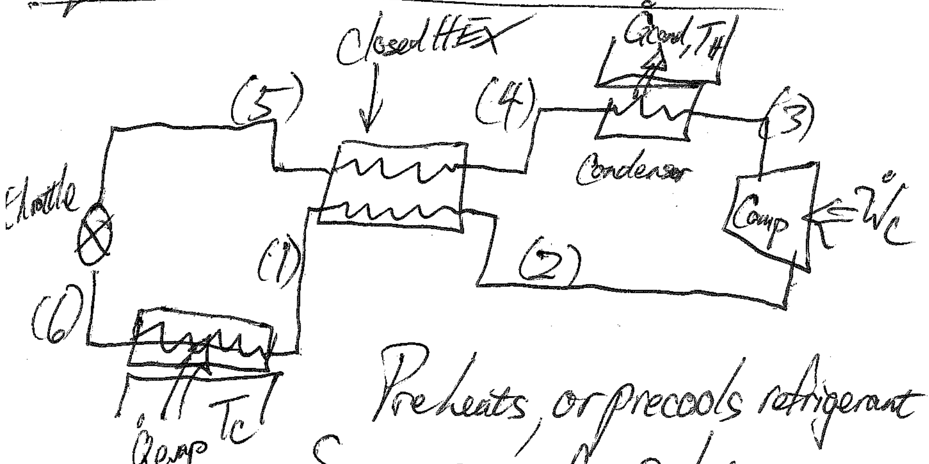
We want saturated vapor @ evaporator exit.

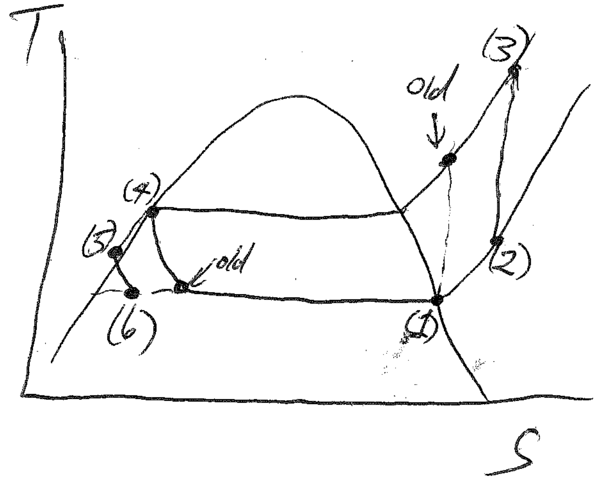
$x \rightarrow 1.0$

But, heat transfer effects that we have been ignoring in this class play a factor ← will be covered in ME564



Liquid Suction HEX Modification

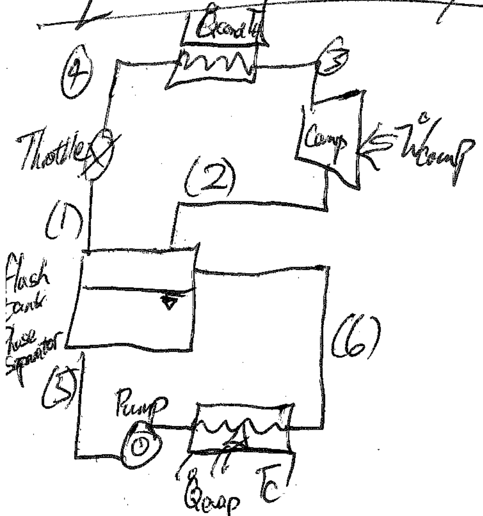


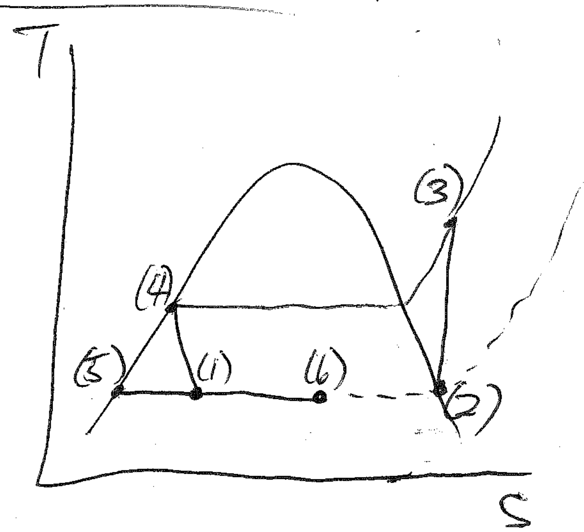


Preheats, or precools refrigerant

Same game for solving

Liquid Overfed System Modification





Multiple compressor cycles & combinations of these modifications. More complexity, still the same game of defining all of the states, then analyzing.

Can change pump speed to increase ε_{evap}, could also connect several evaps to this.