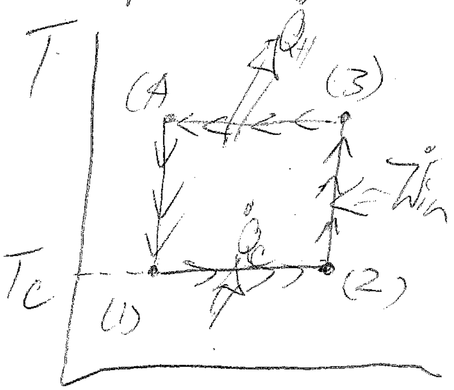
Last time we introduced the Carnot Cycle for refrigeration & showed that any time you have a change in entropy @ constant temperature, you can create a refrigerator. We demonstrated this with rubber bands & could make a Stirling Cycle refrigerator. Today we'll discuss the most common type a refrigerator. Call a Volunteer to take apart fridge while I start,

Vapor Compression Refrigeration Cycles:



Carnot Cycle had

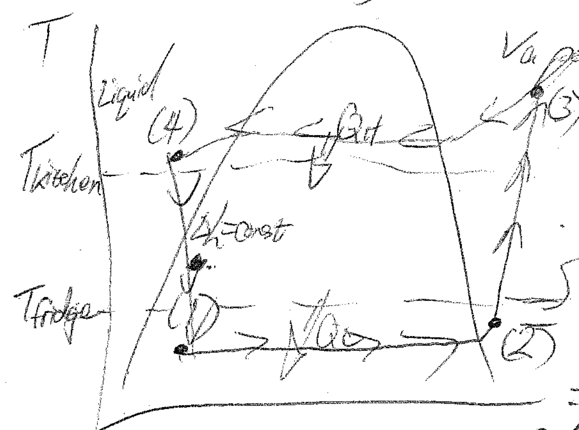
1→2 Expansion @ T_C

2→3 Isentropic Compression to T_H

3→4 Compression @ T_H

4→1 Isentropic Expansion to T_C

★ Similar to the Rankine Cycle for power generation, the vapor Compression refrigeration cycle uses phase change to mimic the constant temperature processes,



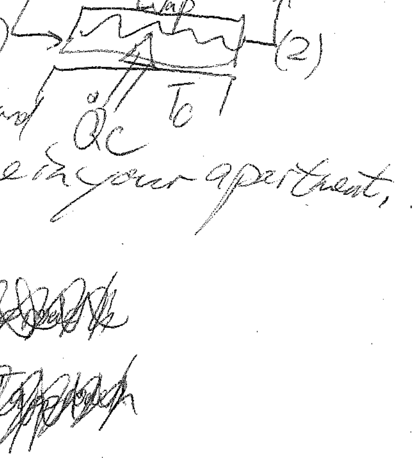
1→2 Evaporation (Expansion in evaporator)

2→3 Compression in Compressor

3→4 Compression in Condenser

4→1 Expansion through throttle

★ Go through Components while are apart, pass around



Example: Let's model a refrigeration system like the one in your apartment,

Fluid R22, $T_C = -10°C$ → freezer temp, $T_H = 27°C$,

Condensor: $\Delta T_{cond}^{approach} = 5k$, $\Delta T_{Subcool} = 3k$, $\Delta P_{Cond} = 200 kPa$, ~~No ΔT approach~~

Evaporator: $\Delta T_{evap}^{approach} = 4k$, $\Delta T_{superheat} = 4k$, $\Delta P_{evap} = 50 kPa$, ~~No ΔT approach~~

Compressor: $\eta_C = 0.75$, Displacement $= 4 \frac{Liter}{min}$, $\eta_{vol/disp} = 0.70$

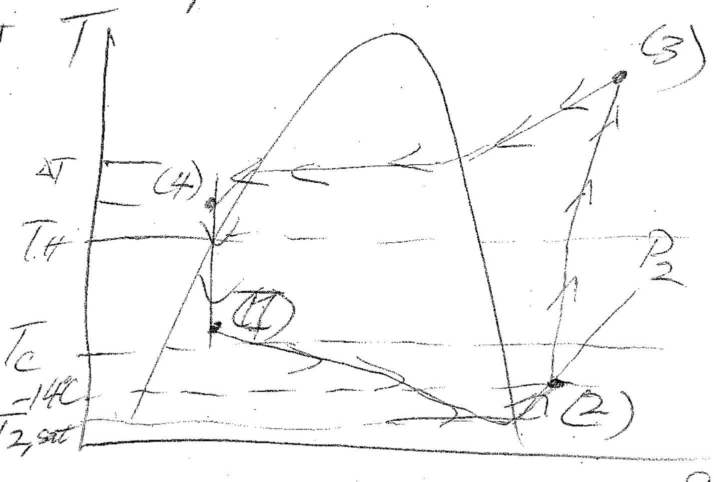
30.2 ME301 Sp2011

Compressors are volumetric devices ⇒ they pull in gas/vapor in fixed volumes

If everything was perfect $\dot{V}_{suction} = \text{Displacement}$

→ because of losses & leakage $\dot{V}_{suction} = \eta_{vol}\,\text{Displacement}$

	T(°C)	P(kPa)	x	h	s	h_s	s_s
1 Evaporator	✓	$=P_2+\Delta P_{evap}$	✓	$=h_4$	✓		—
2 Compressor	−14°C ~~259K~~	✓	NA	✓	✓	—	
3 Condenser	✓	$=P_4+\Delta P_{cond}$	NA	✓		✓	$=s_2$
4 Throttle	32°C ~~281K~~	✓	NA	✓	✓	—	



What do we know to start? $T_C = -10°C$ $\Delta T_{approach\,evap} = 4K$ $T_2 = T_C - \Delta T_{approach\,evap}$

$T_2 = -10°C - 4°C = T_2 = -14°C$

How can we find pressure @ state 2? $T_{2,s} = T_2 - \Delta T_{superheat} \Rightarrow T_{2,s} = -14°C - 4°C = -18°C$

$P_2 = P_{2,s} = P_{sat}(F\#, T = T_{2,sat})$

What can we find from this? $P_1 = P_2 + \Delta P_{evap}$ What do we know about throttles $h_1 = h_4$

So what do we know about State 4? $T_4 = T_H + \Delta T_{approach\,cond} = 27°C + 5°C = 32°C$

How to find P_4? $T_{4,s} = T_4 + \Delta T_{subcool} = 32°C + 3°C = T_{4,s} = 35°C$

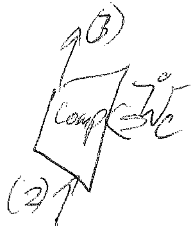
$P_4 = P_{4,s} = P_{sat}(F\#, T = T_{4,sat})$

What can we find from this? $P_3 = P_4 + \Delta P_{cond}$ ← What else for State 3?

$\eta_c = \frac{W_{ideal}}{W_{actual}} = \frac{h_{3s} - h_2}{h_3 - h_2}$ use $s_2 = s_{3s}$ & $h_{3s} = \text{enthalpy}(F\#, P = P_3, s = s_{3s})$

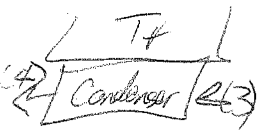
All States fixed, what is $\dot{m}$? $\dot{m} = \frac{\dot{V}_{suction}}{v_2} = \frac{\text{Displacement}\,\eta_{vol}}{v_2}$

Let's Look @ Each Component



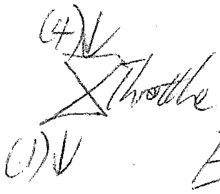
Energy: $\dot{E}_{in} = \dot{E}_{out} + \frac{dE_{stored}}{dt}$; $\dot{m}h_2 + \dot{W}_C = \dot{m}h_3$

Entropy: $\dot{S}_{in} + \dot{S}_{Gen} = \dot{S}_{out} + \frac{dS_{stored}}{dt}$; $\dot{m}s_2 + \dot{S}_{Gen\,2,3} = \dot{m}s_3$



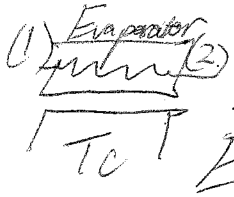
Energy: $\dot{E}_{in} = \dot{E}_{out}$; $\dot{m}h_3 = \dot{Q}_{cond} + \dot{m}h_4$

Entropy: $\dot{S}_{in} + \dot{S}_{Gen} = \dot{S}_{out} + \frac{dS_{stored}}{dt}$; $\dot{m}s_3 + \dot{S}_{Gen\,3,4} = \frac{\dot{Q}_{cond}}{T_H} + \dot{m}s_4$



Energy: $h_4 = h_1$

Entropy: $\dot{m}s_4 + \dot{S}_{Gen\,4,1} = \dot{m}s_1$



Energy: $\dot{m}h_1 + \dot{Q}_{evap} = \dot{m}h_2$

Entropy: $\dot{m}s_1 + \frac{\dot{Q}_{evap}}{T_C} + \dot{S}_{Gen\,1\to 2} = \dot{m}s_2$ Plugging everything into EES

$\dot{Q}_{evap} = 26.58\,W$, $\dot{W}_C = 11.06\,W$, $COP = \frac{\dot{Q}_{evap}\ \text{want}}{\dot{W}_{C\ \text{payed}}} = 2.402$

You won't see a typical COP listed in a store on a fridge, you'll see

Energy Efficiency Ratio instead: $EER = \frac{\dot{Q}_{evap}}{\dot{W}_C}$ in $\frac{Btu}{W\,hr} = 8.197$ usually $8 \to 12$

$3.412 \times COP$ in $\frac{W}{W}$