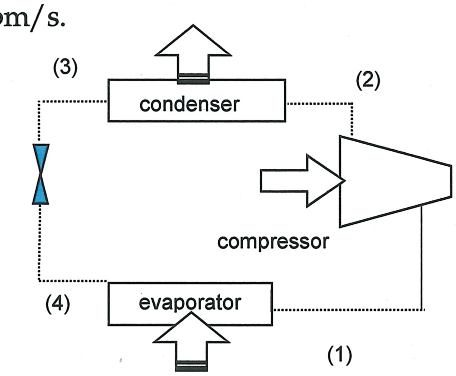
ROSE-HULMAN Institute of Technology
Department of Mechanical Engineering

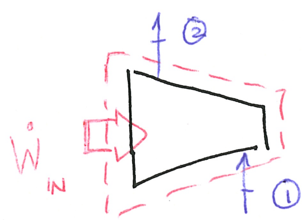
Example

An ideal vapor-compression refrigeration cycle uses R-134a as a working fluid in an air-conditioning system. The refrigerant enters the compressor as a saturated vapor at 40°F and leaves the condenser as a saturated liquid at 130°F. The mass flow rate of the refrigerant is 1.5 lbm/s.



(a) Find the power into the compressor, in B/s.
(b) Find the heat transfer rate out of the condenser, in B/s.
(c) Find the heat transfer rate into the evaporator, in B/s.
(d) Find the COP for the cycle.
(e) Find the quality of the refrigerant at the exit of the valve.
(f) Repeat with an isentropic efficiency for the compressor of η_C=0.85.

(a)



Cons of energy

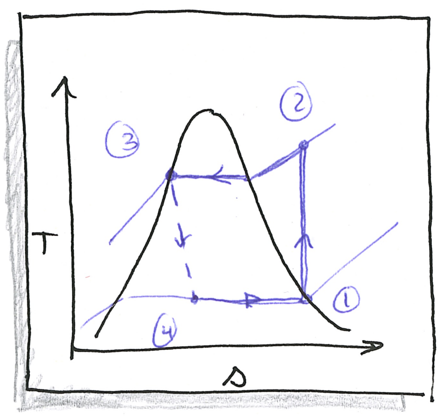
$$\cancel{0} = \cancel{0} + \dot{W}_{IN} + \dot{m}(h_1 + \ldots) - \dot{m}(h + \ldots)$$

$$\dot{W}_{IN} = \dot{m}(h_2 - h_1)$$

$$h_1 = h(T_1, x_1 = 1) = 108.8 \text{ B/lbm}$$

$$s_1 = s(T_1, x_1 = 1) = 0.2219 \text{ B/lbm·°R}$$

$$h_2 = h(P_2 ?, s_2 = s_1)$$



T-s diagram

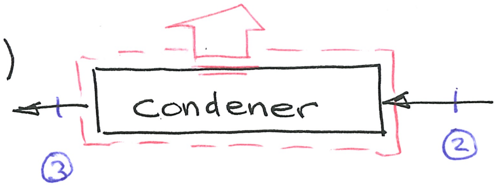
TO find P_2 use state ③

$$P_2 = P_3 = P_{SAT}(T_3) = 213.5 \text{ psia}$$

$$\therefore h_2 = 121.8 \text{ B/lbm}$$

$$\dot{W}_{IN} = 1.5 \frac{\text{lb}}{\text{s}}\left((121.8 - 108.8)\frac{\text{B}}{\text{lbm}}\right) = \boxed{19.5 \text{ B/s}}$$

(b)



C.O.E

$$0 = -\dot{Q}_{OUT} + 0 + \dot{m}(h_2 + ..) - \dot{m}(h_3 + ..)$$

$$\dot{Q}_{OUT} = \dot{m}(h_2 - h_3)$$

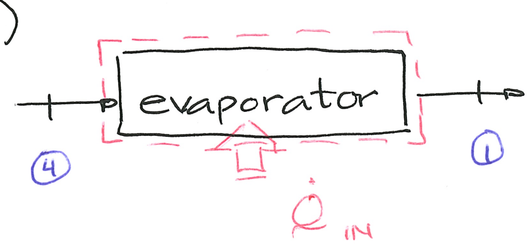
$$h_3 = h(T_3, x_3 = 0)$$

$$= \underline{56.09\ B/lbm}$$

$$\dot{Q}_{OUT} = 1.5\ \frac{lbm}{s}(121.8 - 56.09)\frac{B}{lbm}$$

$$= \boxed{98.6\ B/s}$$

(c)



$\dot{Q}_{IN}$

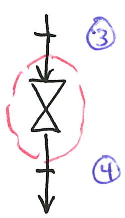
C.O.E

$$0 = \dot{Q}_{IN} + 0 + \dot{m}(h_4 + ..) - \dot{m}(h_1 + ..)$$

$$\dot{Q}_{IN} = \dot{m}(h_1 - h_4)$$

$$h_4 = h(T_4 = T_1 = \quad , ?)$$

Don't have a second property @ ④ to find h_4. What to do?



C.O.E. for valve

$$0 = 0 + 0 + \dot{m}(h_3 + \ldots) - \dot{m}(h_4 + \ldots)$$

$$h_4 = h_3 = 56.09\ B/lbm$$

$$\dot{Q}_{IN} = 1.5\ \frac{lbm}{s} \cdot (108.8 - 56.09)\frac{B}{lbm}$$

$$= \boxed{79.1\ B/s}$$

(d) $COP_R = \beta = \dfrac{\dot{Q}_{IN}}{\dot{W}_{IN}}$

$$= \frac{79.1 \text{ B/s}}{19.5 \text{ B/s}} = \boxed{4.06}$$

(e) $h_4 = (1 - x_4) h_f + x_4 h_g$

$$x_4 = \frac{h_4 - h_f}{h_g - h_f} = \ldots = \boxed{0.372}$$