
(P5.1) COP = coef. of performance = $\frac{Q_C}{W_{S,net}}$

Using state numbers of Fig 5.8-5.9. P-H plot will look like Fig 5.9. Use P-H chart and table from Appendix E. Saturated values are from the table:

state 2 is satV at –40C → H_2 = 372 kJ/kg (chart)
state 3, outlet of the reversible compressor is found by following the isentropic line to 40C, where H_3' = 438 kJ/kg.
state 4 is satL at H_4 = 256 kJ/kg (table)
state 1, $H_1 = H_4$

$$Q_C = (H_2 - H_1) = 372 - 256 = 116 kJ/kg$$

$W_S = (H_3 - H_2) = 438 - 372 = 66$ kJ/kg

$$\Rightarrow COP = \frac{\dot{Q}_C}{\dot{W}_S} = \frac{116}{66} = 1.76$$

Q_C = COP (W_S) = 1.76 (9000 J/day) = 16 kJ/day

(P5.2) Methane,. See Fig 5.8-5.9. Methane chart Appendix E.

$$T_{evap} = -280^O F, P = 0.032 MPa$$

$$\Rightarrow H_2^{satV} = 339 Btu/lbm$$

$$S_2^{satV} = 2.35 Btu/lb.^O F$$

Pressure of 3' isn't given, however, it will be the same as the condenser outlet (P_4) since the condenser will be considered to be isobaric. State 4 will be satL at 40F, so P4 = P3' = 2 MPa. Follow isentropic line from the compressor inlet state to 2MPa. At P3'=2MPa, and S3' = 2.35 Btu/lb$_m$F, H3' = 485 Btu/lbm, and T3' = 40F. At the outlet of the condenser, the fluid will be saturated liquid at 2 MPa,

$$T_4 = -160^O F, P_4 = 2 MPa$$

$$\Rightarrow H_4^{satL} = 218 Btu/lbm$$

$$S_4^{sat_{liq}} 1.54 Btu/lb.^O F$$

State	T(°F)	P(MPa)	H(Btu/lb)	S(Btu/lb*°F)
1	-280	0.032	218	
2 Sat'd vap	-280	0.032	339	2.35
3'	**40**	2	**485**	2.35
4	-160	2	218	1.54

$$COP = \frac{H_2 - H_1}{H_3' - H_2} = \frac{Q_C}{W_{S,net}} = \frac{H_2 - H_4}{H_3' - H_2} = \frac{339 - 218}{485 - 339}$$

$$\Rightarrow COP = 0.83$$

(P5.3) Rankine Cycle, Fig 5.2

temperatures $200^O C$ & $99.6^O C$, Sat vapor from Turbine outlet can be found in the Sat Pressure table Appendix E.

The turbine is assumed to be adiabatic and reversible since no other specifications are given. The inlet state will then have the same entropy as the outlet. Since the boiler/superheater outlet is to operate at T_3 = 200 C, and S_3 = 7.3592, we must hunt in the superheated tables to find this combination. This will occur between 0.2 and 0.3 MPa. Interpolating, the value of H can be found. Values are tabulated below:

State	**T^{o}C**	**P(MPa)**	**H(kJ/kg)**	**S(kJ/kg*K)**	**V(m3/kg)**
4' sat vap	99.6	0.098	2675	7.359	
5 sat liq.	99.6	0.098	417	1.3028	0.001043
3	200	0.271	2867	7.3592	
6			417.18		

$$W'_{S,turbine} = (H'_4 - H_3) = 2675 - 2867 = -192 kJ/kg$$

$$\Delta H_{pump} = W_{S,pump} = \int VdP = V\Delta P$$

$$\Rightarrow \Delta H_{pump} = \frac{1043 cm^3 * (0.271 - 0.098)}{kg} * \frac{1J}{cm^3 * MPa} * \frac{kJ}{10^3 J}$$

$$\Rightarrow \Delta H_{pump} = 0.180 kJ/kg.$$

$$\Rightarrow W'_{S,net} = -192 + 0.180 = -191.82 kJ/kg$$

$$\& \, \eta = \frac{-W'_{S,net}}{Q_{boiler}} = \frac{-(-191.82)}{(H_3 - H_6)} = \frac{-(-191.82)}{(2867 - H_6)}$$

$$\Rightarrow H_6 = 417 + 0.18 = 417.18 kJ/kg$$

$$\Rightarrow \eta = \frac{-(-191.82)}{(2867 - 417.18)} = 0.0783$$

$$\Rightarrow \eta = 7.83\%$$

(P5.6) Inlet: 300 psia/14.504 = 20.68 bar; (550 ^{o}F + 460)/1.8-273.15 = 288 ^{o}C = 561.15K
Steam.xls => H1=2993.9; S1 = 6.7004
Outlet: S2 = 1.3072 + 0.95(7.3541 - 1.3072) = 7.053; H2 =419.17+0.95*2256.4=2562.8
W = 2562.8-2993.9 = -431.1
S2' = S1 => q' = (6.7004-1.3072)/(7.3541-1.3072) = 0.8919
H2' =419.17+0.8919*2256.4=2431.7 => W' = 2431.7-2993.9 = -562.2
=> η_E = 431.1/562.2 = 76.7%
(b) Base Rankine cycle on actual turbine => Wp = 1.9J/g; QH = 2993.9-(419.17+1.9) = 2572.8
ηθ = (431.1-1.9)/2572.8 = 16.7%