ME/NE 312
Winter 2016
Homework Problem Set #3

Due in class on Thursday, January 28, 2015 (submit before class before the exam)

1. Provide the equations for the second law efficiencies for the following components. This problem need not follow the homework format.
   a) Turbine
   b) Pump/compressor
   c) Unmixed heat exchanger
   d) Mixed stream heat exchanger (mixing chamber)

For each of the cycles below, determine the following:
   a) Net power output per mass flow rate
   b) Rate of heat input per mass flow rate
   c) Back work ratio
   d) Carnot efficiency
   e) Thermal cycle efficiency
   f) Second law cycle efficiency

2. (L.O.#1) Consider a standard, ideal Rankine cycle that operates with water and has evaporator and condenser pressures of 100 and 0.1 bars, respectively. The thermal reservoir temperatures are 300 K and 650 K.

3. (L.O.#1) To the cycle in problem #2, replace the ideal pump and turbine with ones having isentropic efficiencies of 95% and 90%, respectively.

4. (L.O.#1) To the cycle in problem #3 replace the evaporator with a superheater that heats the steam to 620 K at 100 bar.

$$\varepsilon_t = \frac{\dot{W}_t / \dot{m}}{\psi_{f1} - \psi_{f2}}$$

(a) $\varepsilon_t = \dfrac{w_t}{\psi_{f1} - \psi_{f2}}$ OR $\dfrac{h_1 - h_2}{\psi_{f1} - \psi_{f2}} = \varepsilon_t$

(b) $\varepsilon_p = \dfrac{\psi_{f1} - \psi_{f2}}{w_p}$

OR

$\varepsilon_p = \dfrac{\psi_{f1} - \psi_{f2}}{h_1 - h_2}$

$\varepsilon_c = \dfrac{\psi_{f1} - \psi_{f2}}{w_c}$ OR $\varepsilon_c = \dfrac{\psi_{f1} - \psi_{f2}}{h_1 - h_2}$

(c) $\varepsilon_{HX} = \dfrac{\dot{m}_c (\psi_{fo} - \psi_{fi})_c}{\dot{m}_H (\psi_{fi} - \psi_{fo})_H}$

(d) $\varepsilon_{MC} = \dfrac{\dot{m}_c (\psi_{fo} - \psi_{fic})}{\dot{m}_H (\psi_{fiH} - \psi_{fo})}$

[K] IDEAL STANDARD H_2O RANKINE

$P_E = 100$ bar $= 10$ MPa

$P_E = 10{,}000$ kPa

$P_c = 0.1$ bar $= 10$ kPa

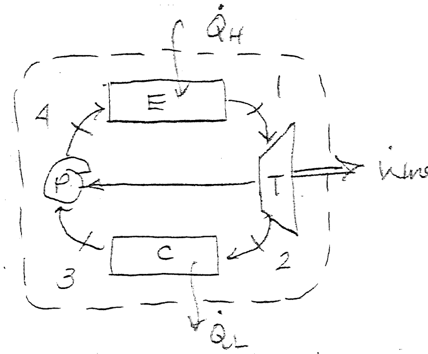
$T_L = 300K$

$T_H = 650K$

$\eta_t = 100\%$

$\eta_p = 100\%$

[S]



[F] (a) $\dot{W}_{net}/\dot{m} = \omega_{NET}$

(b) $\dot{Q}_{IN}/\dot{m} = q_{NET}$

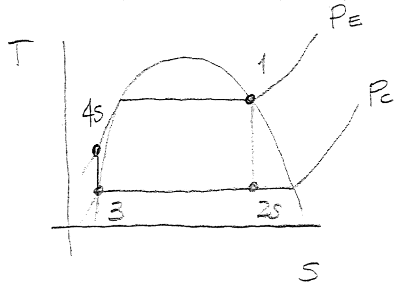
(c) BWR

(d) η_{MAX}

(e) η

(f) ε

[D]



[A1] Δpe & Δke NEGLECTED

$\dot{Q}$ NEGLECTED

[A2] $\dot{W}_{net} = {}_1\dot{W}_2 + {}_3\dot{W}_4$ OR $\dot{W}_{NET} = \dot{Q}_{NET} = {}_4\dot{Q}_1 + {}_2\dot{Q}_3$

C.V. TURBINE: $0 = \dot{m}_1 - \dot{m}_2 \qquad \dot{m}_1 = \dot{m}_2$

$0 = \cancel{\dot{Q}} - {}_1\dot{W}_2 + \dot{m}[h_1 - h_2 + \cancel{\Delta ke} + \cancel{\Delta pe}]$

${}_1\dot{W}_2 = (h_1 - h_{2s})\dot{m}$

C.V. PUMP: ${}_3\dot{W}_4 = (h_3 - h_{4s})\dot{m}$

(a) $\omega_{NET} = h_1 - h_{2s} + h_3 - h_{4s}$

$\omega_{NET} = 939$ kJ/kg

$x_1, P_1 \rightarrow h_1, s_1$

$s_{2s} = s_1, P_2 \rightarrow h_{2s}$

$x_3, P_3 = P_2 \rightarrow h_3, s_3$

$s_{4s} = s_3, P_1 \rightarrow h_{4s}$

EES...

$\dot{Q}_{IN} = {}_4\dot{Q}_1$

CV EVAP: $0 = \dot{m}_4 - \dot{m}_1$

$0 = \dot{Q} - \cancel{\dot{W}} + \dot{m}[h_4 - h_1 + \cancel{\Delta pe} + \cancel{\Delta ke}]$

$h_1 = 2725$ kJ/kg

$h_{2s} = 1775$ "

$h_3 = 191.8$ "

$h_{43} = 201.9$ "

(b) ${}_4q_1 = [h_1 - h_{4s}]$

${}_4q_1 = 2523$ kJ/kg

(c) $BWR = \left| \frac{{}_3\dot{W}_4}{{}_1\dot{W}_2} \right|$ $BWR = \left| \frac{h_3 - h_{4s}}{h_1 - h_{2s}} \right|$

$BWR = 0.0106$

(d) $\eta_{MAX} = 1 - \frac{T_L}{T_H}$ $\eta_{MAX} = 0.539$

(e) $\eta = \frac{\dot{W}_{net}/\dot{m}}{\dot{Q}_{IN}/\dot{m}}$ $\eta = \frac{\omega_{NET}}{q_{IN}}$ $\eta = 0.372$

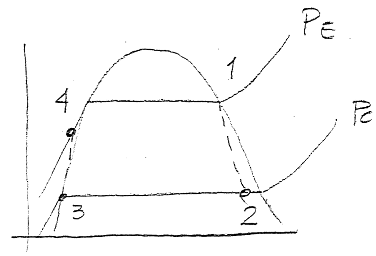
(f) $\varepsilon = \frac{\eta}{\eta_{MAX}}$ $\frac{\omega_{net}}{q_{in}\left(1 - \frac{T_L}{T_H}\right)} = \varepsilon$ $\varepsilon = 0.691$

K

STANDARD
H_2O
RANKINE
$P_E = 10{,}000$ kPa
$P_c = 10$ kPa
$T_L = 300$ K
$T_H = 650$ K
$\eta_t = 0.9,\ \eta_p = 0.95$

S SEE PROBLEM #1

D



F

(a) w_{net}
(b) q_{IN}
(c) BWR
(d) η_{MAX}
(e) η
(f) ε

A1

Δpe & Δke NEGLECTED
$\dot{Q}$ NEGLECTED

A2

(a) $w_{net} = h_1 - h_2 + h_3 - h_4$ $\quad$ $w_{net} = 844$ kJ/kg

$$\eta_t = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

h_1, h_{2s}, h_3, h_{4s} IN PROBLEM #1

$$h_2 = h_1 - \eta_t(h_1 - h_{2s})$$

$h_2 = 1870$ kJ/kg
$h_4 = 202.4$ " $\}$ EES

$$\eta_p = \frac{h_3 - h_{4s}}{h_3 - h_4}$$

$$h_3 - h_4 = \frac{h_3 - h_{4s}}{\eta_p} \qquad h_4 = h_3 - \left[\frac{h_3 - h_{4s}}{\eta_p}\right]$$

(b) $q_{IN} = h_1 - h_4$ $\quad$ $q_{IN} = 2522$ kJ/kg

(c) $BWR = \left|\dfrac{h_3 - h_4}{h_1 - h_2}\right|$ $\quad$ $BWR = 0.0124$

(d) $\eta_{MAX} = 0.539$ $\quad$ SAME AS IN PROBLEM #1

(e) $\eta = \dfrac{w_{NET}}{q_{IN}}$ $\quad$ $\eta = 0.335$

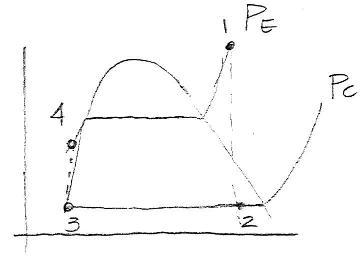
(f) $\varepsilon = \dfrac{\eta}{\eta_{MAX}}$ $\quad$ $\varepsilon = 0.621$

$\{$ w_{net} ↓
q_{IN} NO CHANGE
η ↓

K $T_1 = 620\,K$
$P_E = 10{,}000\,kPa$
$P_C = 10\,kPa$
$T_L = 300\,K$
$T_H = 650\,K$
$\eta_t = 0.9,\ \eta_p = 0.95$

S SEE PROBLEM #1

D



F (a) w_{NET}
(b) q_{IN}
(c) BWR
(d) η_{MAX}
(e) η
(f) ε

A1 SAME AS PROBLEM #2

A2 SAME AS PROBLEM #2

PROPERTIES FROM EES

$h_1 = 2909\ kJ/kg$
$h_{2s} = 1874$ "
$h_2 = 1977$ "
$h_3 = 191.8$ "
$h_{4s} = 201.9$ "
$h_4 = 202.4$ "

$w_{NET} = 922\ kJ/kg$
$q_{IN} = 2707\ kJ/kg$
$BWR = 0.0114$
$\eta_{MAX} = 0.539$
$\eta = 0.341$
$\varepsilon = 0.632$

EVERYTHING BUT η_{MAX} INCREASED OVER REAL RANKINE

PERFORMANCE WORSE THAN IDEAL, STANDARD