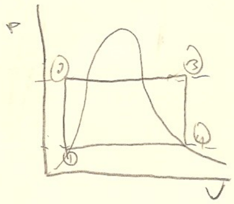
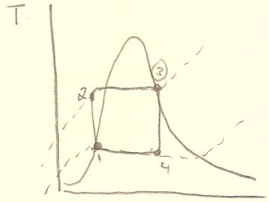
Homework 2.1 | Hannon French | hfren001@odu.edu

18)





Find $\dot{m}_{Boiler}$

$W_{turbine}$

$Q_{in, Boiler}$

η_{therm}

1 — Isen → **2** — P const → **3** — Isen, $\eta = .9$ → **4** — P const →

State 1

$P_1 = P_{min} = 2$ psi

$x = 0 \rightarrow$ See A-5E

$v_f = .01623$ ft³/lbm

$h_f = 94.02$ Btu/lbm

$S_f = .17499$ btu/lbmR

State 2

$P_2 = P_{max} = 1500$ psi

$h_2 = v_1(P_2 - P_1) + h_1$

$= \frac{.01623(1500-2)}{5.404} + 94.02$

$h_2 = 98.5$ btu/lbm

State 3

$P_3 = P_{max} = 1500$ psi

$T_3 = T_{Turbine,in} = 800$°F

Based off A-5E, $T_3 > T_{sat}$ @ 1500 psi, 3 is assumed to be superheated. A-6E @ 15,000 psi & 800°F yields

$h_3 = 1363.1$ btu/lbm

$S_3 = 1.5064$ Btu/lbmR

$V_3 = .4355$ ft³/lbm

State 4

$P_4 = P_{min} = 2$ psi

$S_4 = S_3 = 1.5064$ Btu/lbmR

@ 2psi on A-5E,

$S_f = .17499$ btu/lbmR

$S_{fg} = 1.7444$

$x_4 = \frac{S_4 - S_{f4}}{S_{fg4}}$

$= \frac{1.5064 - .17499}{1.7444}$

$x_4 = .763 \leftarrow$ assume saturated water

$x_4 = \frac{h_4 - h_{f4}}{h_{fg4}} \rightarrow$ solve for h_4, obtaining h_f & h_{fg} from A-5E @ 2psi

$h_4 = x_4(h_{fg4}) + h_{f4}$

$= .763(1021.7) + 94.02$

$h_4 = 873.57$ btu/lbm

$\eta = .90 = \frac{h_3 - h_{4a}}{h_3 - h_{4s}} \rightarrow$ solve for h_{4a}

$h_{4a} = \eta(h_3 - h_{4s}) + h_3$

$= .90(1363.1 - 873.57) - 1363.1$

$h_{4a} = 922.57$ Btu/lbm

$W_{Turbine} = h_3 - h_{4a} = 1363.1$ btu/lbm $- 922.57$ btu/lbm

$\boxed{W_{turbine(out)} = 440.57 \text{ Btu/lbm}}$

$W_{pump,in} = v_1(P_2 - P_1) = \frac{.01623(1500psi - 2psi)}{5.404}$ $W_{pump,in} = 4.5$ Btu/lbm

$W_{net} = W_{out} - W_{in} = 440.57 - 4.5\frac{btu}{lbm} = 436.07$ Btu/lbm

2500 kW = 8530350 Btu/hr

(1 kW = 3412.14 btu/hr)

$\dot{W} = \dot{m}(W_{net})$

$\dot{m} = \frac{\dot{W}}{W_{net}} = \frac{8530350 \text{ btu/hr}}{436.07 \text{ btu/lbm}} =$ $\boxed{\dot{m} = 19561.88 \frac{lbm}{hr} \text{ or } 5.433 \text{ lb/s}}$

$\dot{W}_{out} = \dot{m}(W_{T,out}) = 5.433 \text{ lb/s} (440.57 \text{ btu/lbm})$

$\dot{W}_{out} = 2393.61$ Btu/s $\rightarrow$ 1 hp = .7068 Btu/sec

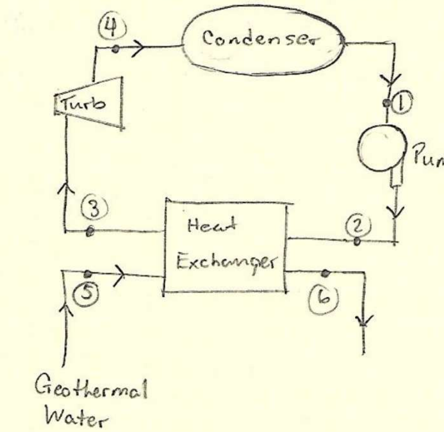
$\boxed{\dot{W}_{out} = 3386.55 \text{ hp}}$

$q_{in} = h_3 - h_2 = 1363.1$ btu/lbm $- 98.5$ btu/lbm $= 1264.6$ btu/lbm $\rightarrow \dot{Q}_{in} = \dot{m}(q_{in}) \rightarrow 5.433\frac{lb}{s}(1264.6)$

$\boxed{\dot{Q}_{in} = 6870.6 \text{ Btu/s}}$

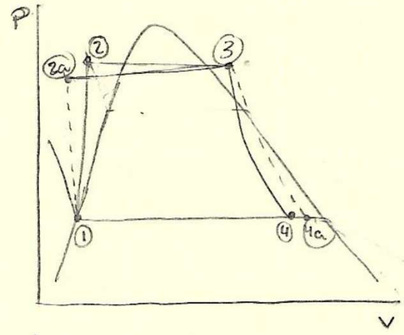
$\eta = \frac{W_{net}}{q_{in}} = \frac{436.07 \text{ btu/lbm}}{1264.6 \text{ btu/lbm}}$ $\boxed{\eta = 34.38\%}$

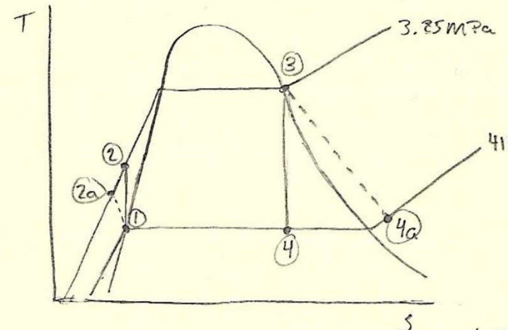
10-25.



Variables

$\eta_{pump} = .9$



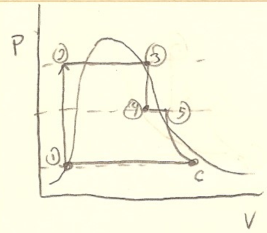


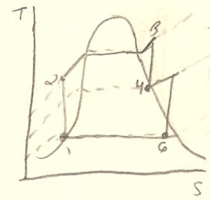
States:

$$① \xrightarrow{\text{Isent}} ② \xrightarrow{\text{Pconst}} ③ \xrightarrow{\text{Isent}} ④ \xrightarrow{\text{P/T const}}$$

①	②	③	④
$P_1 = 410\,kPa$	$P_2 = 3.25\,MPa$	$P_3 = 3.25\,MPa$	$P_4 = 410\,kPa$
$T_1 = 79.5°C$		$T_3 = 147°C$	$T_4 = 79.5°C$
		$\dot{m}_3 = 305.6\,kg/s$	

34)





Points 4 & 6 are saturated zone since we are given $x = 96\%$

1 $\xrightarrow{\text{Isen}}$ **2** $\xrightarrow{\text{P const}}$ **3** $\xrightarrow{\text{Isen}}$ **4** $\xrightarrow{\text{P const}}$ **5** $\xrightarrow{\text{Isen}}$ **6** $\xrightarrow{\text{P const}}$

1

$P_1 = P_{cond} = 20\ kpa$

$x = 0$

Table A-5 @ 20 kpa

$V_f = .001017\ m^3/kg$

$h_{f_1} = 251.42\ kJ/kg$

$S_{f_1} = .832\ kJ/kgk$

2

$P_2 = P_{Boiler} = 5000\ kpa$

$h_2 = V_1(P_2 - P_1) + h_1$

$= .001017(5000-20) + 251.42$

$h_2 = 256.5\ \frac{kJ}{kg}$

3

$P_3 = P_{boiler} = 5{,}000\ kpa$

$S_3 = S_4 = 6.34$

$X_3 = \frac{S_3 - S_{f3}}{S_{fg3}}$

Table A-5 @ 5,000 kpa

$S_{fg} = 3.053$

$S_f = 2.92$

$X_3 = \frac{6.34 - 2.92}{3.053}$

$X_3 = 1.12$

SUPERHEATED

Table A-6 @ 5 mpa... Interpolate between 6.21 & 6.4516 kj/kgk for h_3 & T_3

$h_3 = 3002.6\ kj/kg$

$T_3 = 326.8°c$

4

$P_4 = P_{reheat} = 1200\ kpa$

$x_4 = .96$

find S_4 to find X_3

$X_4 = \frac{S_4 - S_{f4}}{S_{fg4}}$

$S_4 = S_{fg}(x_4) + S_{f4}$

Table A-5

$S_{fg4} = 4.3058\ \frac{kj}{kgk}$

$S_f = 2.2159\ kj/kgk$

$S_4 = (4.3058)(.96) + 2.2159$

$S_4 = 6.34$

$X_4 = \frac{h_4 - h_{f4}}{h_{fg4}}$

$h_4 = h_{fg4}(x_4) + h_{f4}$

Table A-5 @ 1200 kpa

$h_f = 798.33$ $h_{fg} = 1985.4$

$h_4 = 1984.4(.96) + 798.33$

$h_4 = 2703.4\ \frac{kj}{kg}$

5

$P_5 = P_{reheat} = 1200\ kpa$

Assume SUPERHEATED SINCE 3 IS SUPERHEATED

$\therefore S_5 = S_6$

Table A-6 @ 1.2 Mpa Interpolate between 7.3799 & 7.6779 kj/kgk for h_5 & T_5

$h_5 = 3435.2\ \frac{kj}{kg}$

$T_5 = 480.6°c$

6

$P_6 = P_1 = 20\ kpa$

$X_6 = .96$

find S_6 to find S_5

$X_6 = \frac{S_6 - S_{f6}}{S_{fg6}}$

$S_6 = X_6(S_{fg}) + S_{f6}$

from A-5 @ 20 kpa

$S_f = .832\ kj/kgk$

$S_{fg} = 7.0752\ kj/kgk$

$S_6 = .96(7.0752) + .832$

$S_6 = 7.62\ kj/kgk$

$h_6 = h_{fg6}(x_6) + h_{f6}$

Table A-5 @ 20 kpa

$h_{fg} = 2357.5\ kj/kg$

$h_f = 251.2\ kj/kg$

$h_6 = 2357.5(.96) + 251.2$

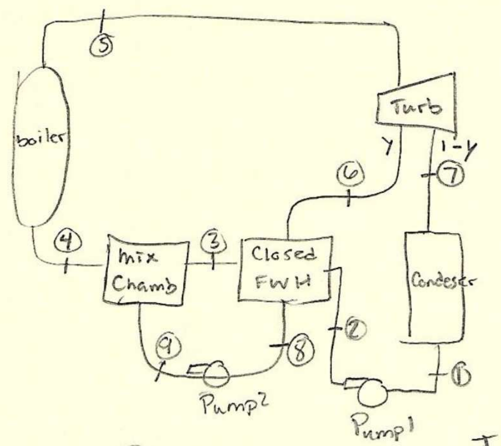
$h_6 = 2514.4\ kj/kg$

Temp @ each turbine inlet = T_3 & T_5 $\rightarrow$ $\boxed{T_3 = 326.8°c \quad T_5 = 480.6°c}$

$$\eta = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{(h_6 - h_1)}{(h_3 - h_2) + (h_5 - h_4)} = 1 - \frac{2514.4 - 251.42\ kj/kg}{(3002.6 - 256.5\ kj/kg) + (3435.2 - 2703.4\ kj/kg)}$$

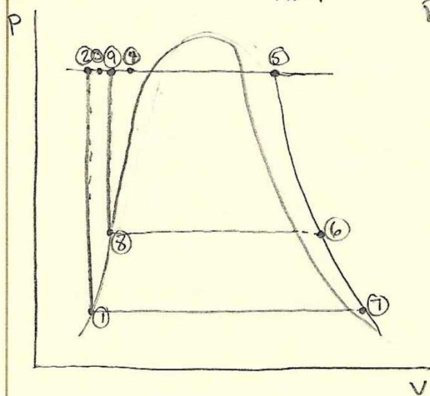
$$\boxed{\eta = 35\%}$$

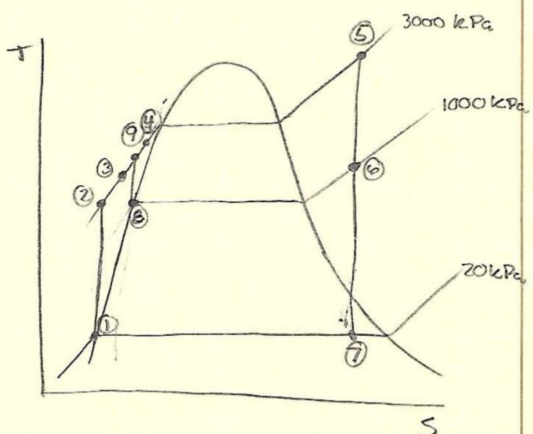
10-48)



Find :

- $W_{Turb} = W_{out}$
- $W_{Pump} = W_{in}$
- heat supply of boiler





States

Pconst Pconst Isenthalpic Isent (y)

$① \xrightarrow[(1-y)]{Isent} ② \xrightarrow[(1-y)]{Pconst} ③ \xrightarrow[(1-y)]{Isenthalpic} ④ \xrightarrow{Pconst} ⑤ \xrightarrow{Isent} ⑥ \quad ⑦ \quad ⑧ \xrightarrow[y]{Isent} ⑨$

①	②	③	④	⑤	⑥	⑦	⑧	⑨
$P_1 = 20\,kPa$	$P_2 = 3000\,kPa$	$P_3 = P_2$	$P_4 = P_3$	$P_5 = P_4$	$P_6 = 1000\,kPa$	$P_7 = 20\,kPa$	$P_8 = P_6$	$P_9 = P_4$
$X_1 = 0$	$h_2 = 254.45\,kJ/kg$	$T_3 = T_8$	$h_4 = 765.194\,kJ/kg$	$T_5 = 350°C$	$S_6 = S_5$	$S_7 = S_6$	$X_8 = 0$	$h_9 = 764.76$
$h_1 = h_{f@20}$	$T_2 \approx 60.06°C$	$h_3 = 765.3$		$S_5 = 6.745$	$h_6 = 2852.86$	$h_7 = 2221.67$	$h_8 = 762.51$	$V_9 \approx .001127$
$h_1 = 251.42$	$V_3 \approx .001017$			$h_5 = 3116.1$	$T_6 = 210.7°C$	$T_7 \approx 60.06°C$	$V_8 = .001127$	$T_9 \approx 179.88$
$V_1 = V_{f@20kPa}$							$T_8 = 179.88°C$	
$V_1 = .001017$								
$T_1 = 60.06°C$								

$v_1(P_2 - P_1) = h_2 - h_1 \longrightarrow h_2 = v_1(P_2 - P_1) + h_1 \longrightarrow h_2 = 254.45\,kJ/kg$

$h_9 = v_8(P_9 - P_8) + h_8 \longrightarrow h_9 = 764.76\,kJ/kg$

$S_6 = S_5 = 6.745$ $\quad S_6 > S_f$ and S_g @ 1000 kPa (so superheated charts)

$$h_6 = \frac{(6.745 - 6.6958)(2943.1 - 2828.3)}{(6.9265 - 6.6956)} + 2828.3 = 2852.86\,kJ/kg$$

T_6 = Interpolation

$$S_7 = S_{f_7} + x_7 S_{fg_7} \longrightarrow x_7 = \frac{S_7 - S_{f_7}}{S_{fg_7}} = \frac{(6.745 - .8320)}{7.0752} = .8357$$

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$h_7 = h_{f_7} + x_7 h_{fg_7} \longrightarrow 251.42 + (.8357)(2357.5) = 2221.67$

$h_3 = h_{f@T_8} + (P_3 - P_8)v_3 \longrightarrow h_3 = 763.05 + (3000 - 1000)(.001127) = 765.3\ kJ/kg$

$h_4 = h_3(1-y) + (y)h_9 \longrightarrow h_4 = 765.3(1-.1964) + (.1964)(764.76) = \underline{765.194}$

$y(h_6 - h_8) = (1-y)(h_3 - h_2)$

$y(2852.86 - 762.51) = (1-y)(765.3 - 254.45) \longrightarrow 2601.2\,y = 510.85 \quad y = .1964$

Solutions

$W_{turb} = (h_5 - h_6) + (1-y)(h_6 - h_7) = (3116.1 - 2852.86) + (1-.1964)(2852.86 - 2221.67)$

$\boxed{W_{turb} = 770.46\ kJ/kg}$

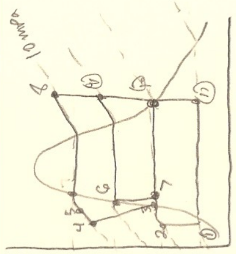
$W_{Pump} = (1-y)(v_1 P_2 - v_1 P_1) + (v_8 P_9 - v_8 P_8) = (1-.1964)[.001017(3000-20)] + [.001127(3000-100$

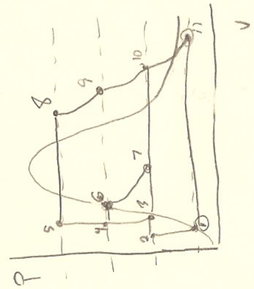
$\boxed{W_{Pump} = 4.69\ kJ/kg}$

$q_{Boiler} = h_5 - h_4 = 3116.1 - 765.19$

$\boxed{q_{Boiler} = 2350.91\ kJ/kg}$

#53)





1	2	3	4	5
$P_1 = 10$ kpa $x=0$ A-5 @ 10 kpa $h_1 = 191.81$ kJ/kg $v_1 = .00101$ m³/kg	$x=0$ $P_2 = .6$ mpa $h_2 = v_1(P_2 - P_1) + h_1$ $= .00101(600-10) + 191.81$ $h_2 = 192.41$ kJ/kg	$x=0$ $P_3 = .6$ mpa Table A-5 @ 600 kpa $h_3 = 670.38$ kJ/kg $v_3 = .001101$	$x=0$ $P_4 = 10$ mpa $h_4 = v_3(P_4 - P_3) + h_3$ ×1000 $= .001101(10-.6)\times1000 + 670.38$ $h_4 = 680.7$ kJ/kg	$P_5 = P_{max} =$ ~~$x=0$~~ $s_5 = s_6$ Interpola[te] Table A-[…] between […] and 2.31[…] for h_5 $h_5 = 808.8$

for closed feed - $\dot{Q}_{in} = \dot{Q}_{out} \Rightarrow \dot{m}_y(h_9 - h_6) = \cancel{\dot{m}_1}(h_5 - h_4)$

$$y = \frac{h_5 - h_4}{h_9 - h_6} = \frac{808.8\text{ kJ/kg} - 680.7\text{ kJ/kg}}{2975.7\text{ kJ/kg} - 798.33} \quad y = \underline{.058}$$

for open feed - $\dot{Q}_{in} = \dot{Q}_{out} = m_{(y)}h_7 + m_{(1-y-z)}h_2 + m_{(z)}h_{10} = m_1 h_3$

$y h_7 + (1-y-z)(h_2) + z(h_{10}) = h_3$

$.058(798.33) + (1-.058-z)(192.41) + z(2821.8) = 6[…]$

$(.942 - z)(192.41) + z2821.8 = 6240$

$z\,2629.38 = 442.82$

$z = \underline{.168}$

te on
-5
2.1271 kj/kg
74 kj/kgk

kj/kg

70.38 kj/kg

7

10 mpa

6

$X_6 = 0$

$P_6 = 1.2$ Mpa

Table A-5 @ 1.2 mpa

$\underline{h_6 = 798.3 \text{ kj/kg}}$

$S_f = 2.2159$

$S_{fg} = 4.3058$

$X_6 = \frac{S_6 - S_{f6}}{S_{fg6}}$

Solve for S_6

$S_6 = S_{fg}(X) + S_f$

$S_6 = S_f = 2.2159 \text{ kj/kgk}$

7

$P_7 = .6$ mpa

$h_7 = h_6 = 798.3$ kj/kg

8

$P_8 = 10$ mpa

$T_8 = T_{max} = 600\,°c$

$x = >1$

A-6 @ 10 mpa @ 600 °c

$\underline{h_8 = 3625.8 \text{ kj/kg}}$

$S_8 = 6.9045$ kj/kg

9

$P_9 = 1.2$ MPa

$S_8 = S_9$

from A-5 @ 1.2 mpa

$S_f = 2.2159$ $S_{fg} = 4.3058$

$X_9 = \frac{S_9 - S_f}{S_{fg}}$

$X_9 = \frac{6.9045 - 2.2159}{4.3058}$

$X_9 = 1.09 \rightarrow$ A-6

Interpolate on A-6 @ 1.2 mpa between 6.8313 ; 7.0335 kj/kgk for h_9

$\underline{h_9 = 2975.7 \text{ kj/kg}}$

10

$P_{10} = .6$ Mpa

$S_8 = S_{10} = 6.9045$

$X_{10} = \frac{S_{10} - S_f}{S_{fg}}$

from A-5 @ .6 mpa

$S_f = 1.9308$

$S_{fg} = 4.8285$

$X_{10} = \frac{6.9045 - 1.9308}{4.8285}$

$X_{10} = 1.03 \leftarrow$ SUPER HEATED

Interpolate on A-6 between 6.7593 ; 6.9683 kj/kgk for h_{10}

$\underline{h_{10} = 2821.8 \text{ kj/kg}}$

11

$P_{11} = 10$ kpa

$S_8 = S_{11} = 6.9045$ kj/kg

$x_{11} = \frac{S_{11} - S_{f11}}{S_{fg11}}$

from A-5 @ 10 kpa

$S_f = .6492$ kj/kgk

$S_{fg} = 7.4996$ kj/kg

$X_{11} = \frac{6.9045 - .6492}{7.4996}$

$X_{11} = .834 \leftarrow$ SATURATED

from A-5 @ 10 kpa

$h_f = 191.81$ kj/kg $h_{fg} = 2392.1$ kj/kg

$x_{11} = \frac{h_{11} - h_{f11}}{h_{fg11}}$

$h_{11} = x_{11}(h_{fg11}) + h_{f11}$

$= .834(2392.1) + 191.81$

$\underline{h_{11} = 2186.82 \text{ kj/kg}}$

$q_{out} = (1 - y - z)(h_{11} - h_1)$

$= 1 - .058 - .168(2186.82 - 191.81)$

$q_{out} = 1544.14$ kj/kg

$q_{in} = h_8 - h_5 = 3629.8 - 808.8$ kj/kg

$q_{in} = 2821$ kj/kg

$w_{net} = q_{in} - q_{out} = 2821 - 1544.14 = 1276.86$ kj/kg

$\dot{W} = \dot{m}(w_{net})$

$400(1000) = \dot{m}(1276.86)$

$\boxed{\dot{m} = 313.3 \text{ kg/s}}$

$\eta = \frac{w_{net}}{q_{in}} = \frac{1276.86}{2821}$

$\boxed{\eta = 45.3\%}$