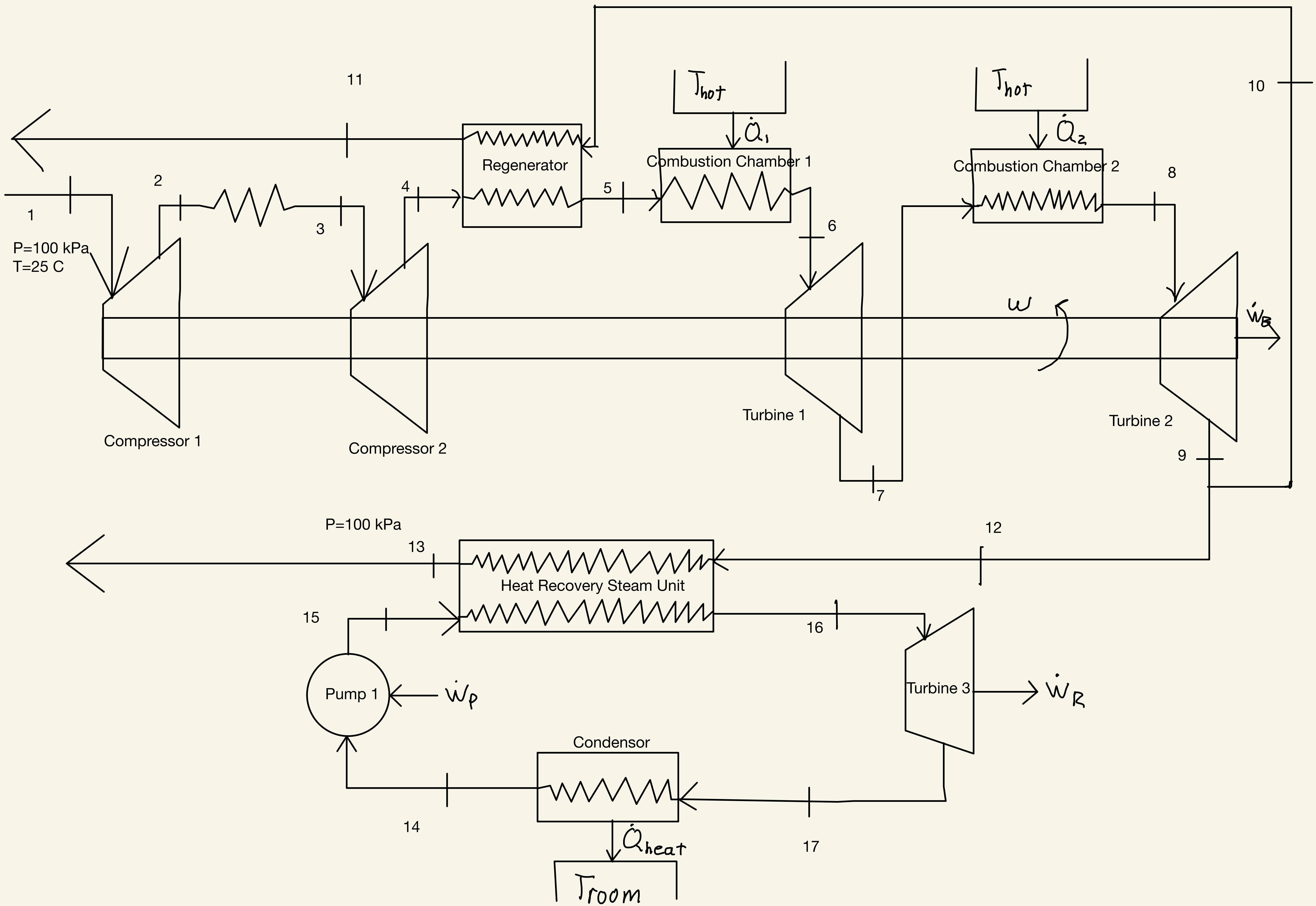

11
10
T_{hot}
$\dot{Q}_1$
T_{hot}
$\dot{Q}_2$
Regenerator
Combustion Chamber 1
Combustion Chamber 2
1
2
3
4
5
6
8
P=100 kPa
T=25 C
ω
$\dot{W}_B$
Compressor 1
Compressor 2
Turbine 1
Turbine 2
9
7
P=100 kPa
13
12
Heat Recovery Steam Unit
15
16
Pump 1
$\dot{W}_P$
Turbine 3
$\dot{W}_R$
Condensor
14
17
$\dot{Q}_{heat}$
T_{room}

Generalized Brayton Cycle Solution
With Constant Specific Heats at 25C

$P_1 = 100\ KPa$

$T_1 = 25°C = 298.15\ K$

$\downarrow$ Isentropic compression

$P_2 = \sqrt{r_p} \cdot P_1 = \sqrt{r_p} \cdot 100 = P_2$

$T_2 = 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} \Rightarrow T_2 = 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}$$

$\downarrow$ constant pressure heat rejection

$P_3 = P_2 = \sqrt{r_p} \cdot P_1 = \sqrt{r_p} \cdot 100$

$T_3 = T_1 = 298.15\ K$

$\downarrow$ Isentropic compression

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{K-1}{K}} \Rightarrow T_4 = T_3 \cdot \left(\frac{r_p \cdot 100}{\sqrt{r_p} \cdot 100}\right)^{\frac{K-1}{K}} = T_3 \cdot \sqrt{r_p}^{.4/1.4}$$

$P_4 = r_p \cdot P_1 = r_p \cdot 100$

$T_4 = 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}$

$$T_5 = \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}$$

$\downarrow$

$P_5 = P_4 = r_p \cdot 100$

$T_5 = \frac{\dot{m}_{10} T_{10} - \dot{m}_{10} T_4 + \dot{m}_B T_4}{\dot{m}_B}$

T_5:

$${}_4Q_5 = \dot{m}_B \cdot c_p [T_5 - T_4] = \dot{m}_{10} \cdot c_p \cdot [T_{10} - T_{11}]$$

$$\dot{m}_B [T_5 - T_4] = \dot{m}_{10} [T_{10} - T_4]$$

$$\dot{m}_B T_5 - \dot{m}_B T_4 = \dot{m}_{10} T_{10} - \dot{m}_{10} T_4$$

$$\dot{m}_B T_5 = \dot{m}_{10} T_{10} - \dot{m}_{10} T_4 + \dot{m}_B T_4$$

$$T_5 = \frac{\dot{m}_{10} T_{10} - \dot{m}_{10} T_4 + \dot{m}_B T_4}{\dot{m}_B}$$

$\downarrow$ Constant pressure heat addition

$T_6 = 2200°F = 1477.594$

$P_6 = P_5 = r_p \cdot 100$

$\downarrow$ Isentropic expansion

$$\frac{T_7}{T_6} = \left(\frac{P_7}{P_6}\right)^{\frac{K-1}{K}} \Rightarrow T_7 = 1477.594\ K \cdot \left(\frac{\sqrt{r_p} \cdot 100}{r_p \cdot 100}\right)^{\frac{.4}{1.4}}$$

$P_7 = \sqrt{r_p} \cdot 100$

$T_7 = 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}$

$7 \downarrow$ Constant Pressure heat addition

$T_8 = T_6 = 1477.594\,K$

$P_8 = P_7 = \sqrt{r_p} \cdot 100$

$\downarrow$ Isentropic expansion

$T_9 = 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}$

$P_9 = 100\,kPa$

$$\frac{T_9}{T_8} = \left(\frac{P_9}{P_8}\right)^{\frac{K-1}{K}} \Rightarrow T_9 = 1477.594K \cdot \left(\frac{\cancel{100}}{\sqrt{r_p} \cdot \cancel{100}}\right)^{.4/1.4}$$

Now component analysis:

$$\dot{W}_{C_1} = \dot{W}_{C_2} = \dot{m}_B\,(h_2 - h_1) = \dot{m}_B \cdot \int_1^2 C_p\,dT = \dot{m}_B \cdot C_p \cdot [T_2 - T_1] = \dot{m}_B \cdot C_p \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right]$$

$$\boxed{\dot{W}_{C_1} = \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right] = \dot{W}_{C_2}}$$

$$\dot{W}_{T_1} = \dot{W}_{T_2} = \dot{m}_B \cdot (h_6 - h_7) = \dot{m}_B \cdot C_p \cdot [T_6 - T_7] = \boxed{\dot{m}_B \cdot C_p \cdot \left[1477.594 - 1477.594 \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{W}_{T_2} = \dot{W}_{T_1}}$$

$$\dot{Q}_1 = \dot{m}_B \cdot (h_6 - h_5) = \dot{m}_B \cdot C_p \cdot [T_6 - T_5] = \boxed{\dot{m}_B \cdot C_p \cdot \left[1477.594 - \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}\right] = \dot{Q}_1}$$

$$\dot{Q}_2 = \dot{m}_B \cdot (h_8 - h_7) = \dot{m}_B \cdot C_p \cdot [T_8 - T_7] = \boxed{\dot{m}_B \cdot C_p \cdot \left[1477.694 - 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{Q}_2}$$

$$\dot{W}_{C_1} = \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right] = \dot{W}_{C_2}$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.594 - 1477.594 \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{W}_{T_2} = \dot{W}_{T_1}$$

$$\dot{W}_{net} = \Sigma \dot{W}_T - \Sigma \dot{W}_C = 2 \cdot \dot{m}_B \cdot 1.004 \cdot \left[1477.594 - 1477.594 \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] - 2 \cdot \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right]$$

$$\dot{W}_{net} = 2 \cdot \dot{m}_B \cdot 1.004 \cdot \left[\left(1477.594 - 1477.594 \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right) - \left(298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right)\right]$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.594 - \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}\right] = \dot{Q}_1$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.694 - 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{Q}_2$$

$$\dot{Q}_{net}^{in} = \dot{Q}_1 + \dot{Q}_2 = \dot{m}_B \cdot C_p \cdot \left[\left(1477.594 - \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}\right) + \left(1477.594 - 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right)\right]$$

$$\dot{Q}_{out_B} = \dot{m}_{12} \cdot C_p \cdot \left[1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - T_{15}\right]$$

Rankine Cycle Solution: This final solution only shows one pressure choice, to arrive at this pressure choice in the rankine cycle, 9 different pressures were considered and evaluated. The pressure choice here is 30MPa.

$$\frac{20000\,\#m}{hr}\cdot\frac{1\,hr}{3600\,sec}\cdot\frac{.453592\,kg}{1\,\#m}$$

$$\boxed{\dot{m}_R = 2.51996\ \frac{kg}{s}}$$

$P_{14} = 205.967$ kPa

$V = .001061\ m^3/kg$

$T_{14} = 250°F = 121.7°C = T_{14}$

$x_{14} = 0$

$S_{14} = 1.53943\ \frac{KJ}{kg\,K}$

$h_{14} = 508.417\ \frac{KJ}{kg}$

↓ Isentropic Compression

$P_{15} = 30000$ kPa $\quad S_{15} = S_{14} = 1.53943\ \frac{KJ}{kg\,K}$

$h_{15} = 540.114\ \frac{KJ}{kg}$

$T_{15} = 123.628°C$

↓ Constant pressure heat addition

$P_{16} = 30000$ kPa

$T_{16} = 921.405°C$

$h_{16} = 4348.17\ \frac{KJ}{kg}$

$S_{16} = S_{17} = 7.11772\ \frac{KJ}{kg\,K}$

↓ Isentropic expansion

$S_{17} = S_{16} = 7.11772\ \frac{KJ}{kg\,K}$

$P_{17} = 205.967$ kPa

$h_{17} = 2707.92$

$T_{17} = 121.7°C$

$x_{17} = 1$

↓ Constant pressure heat rejection

Now back to State 1

Component Analysis:

$$\dot{W}_C = \dot{m}_R\left[h_{15} - h_{14}\right] = 2.51196\left[540.114 - 508.417\right] = \boxed{79.6216\ kW = \dot{W}_C}$$

$$\dot{W}_T = \dot{m}_R\left[h_{16} - h_{17}\right] = 2.51196\left[4348.17 - 2707.92\right] = \boxed{4120.24\ kW = \dot{W}_T}$$

$$\dot{W}_{net} = \dot{W}_T - \dot{W}_C = \boxed{4040.62\ kW = \dot{W}_{net\,R}}$$

$$\dot{Q}_{in} = \dot{m}_R\left[h_{16} - h_{15}\right] = 2.51196\left[4348.17 - 540.114\right] = \boxed{9565.68\ kW = \dot{Q}_{in}}$$

$$\dot{Q}_{heat} = \dot{m}_R\left[h_{17} - h_{14}\right] = 2.51196\left[2707.92 - 508.417\right] = \boxed{5525.06\ kW = \dot{Q}_{heat}} = \dot{Q}_{out}$$

Check: $\dot{Q}_{in} - \dot{Q}_{heat} = \dot{W}_{net}$

$9565.68 - 5525.06 = 4040.62$

$4040.62 \overset{\checkmark}{=} 4040.62$

Now with rankine cycle solved and brayton cycle solved generally, we can start doing some computations on the brayton cycle:

$$T_{16} = T_{12} = 921.405^{\circ}C = 1194.56K = T_9 = 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} \Rightarrow \boxed{r_p = 4.4304}$$

$$\dot{Q}_{inR} = 9565.68\ KW = \dot{Q}_{out\,B} = \dot{m}_{12} \cdot C_p \cdot \left[1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - T_{15}\right]$$

$$9565.68 = \dot{m}_{12} \cdot 1.004 \left[1477.594 \cdot \left(\frac{1}{\sqrt{4.4304}}\right)^{.4/1.4} - 396.778\right] \Rightarrow \boxed{\dot{m}_{12} = 11.9427\ \frac{kg}{s}}$$

$$\dot{W}_{net\,R} = 4040.62KW \Rightarrow \dot{W}_{net\,B} = 10000 - 4040.62 = \boxed{5959.38KW = \dot{W}_{net\,B}}$$

$$\dot{W}_{net\,B} = 2 \cdot \dot{m}_B \cdot 1.004 \cdot \left[\left(1477.594 - 1477.594\left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right) - \left(298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right)\right]$$

$$5959.38 = 2 \cdot \dot{m}_B \cdot 1.004 \cdot \left[\left(1477.594 - 1477.594\left(\frac{1}{\sqrt{4.4304}}\right)^{.4/1.4}\right) - \left(298.15 \cdot \left(\sqrt{4.4304}\right)^{.4/1.4} - 298.15\right)\right] \Rightarrow \boxed{\dot{m}_B = 13.9731\ \frac{kg}{s}}$$

$$\dot{m}_B = \dot{m}_{10} + \dot{m}_{12} \Rightarrow \boxed{\dot{m}_{10} = 2.03045\ \frac{kg}{s}}$$

$$\dot{Q}_{net\,in\,B} = \dot{Q}_1 + \dot{Q}_2 = \dot{m}_B \cdot C_p \cdot \left[\left(1477.594 - \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}\right) + \left(1477.594 - 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right)\right]$$

W/ $r_p = 4.4304$ $\quad \dot{m}_B = 13.9731$

$\dot{m}_{12} = 11.9427\ kg/s$ $\quad \dot{m}_{10} = 2.03045$

$$\dot{Q}_{net} = 17842.7\ KW$$

$$\eta_{Th} = \frac{\dot{W}_{net} + \dot{Q}_{heat}}{\dot{Q}_{in\,B}} = \frac{10000 + 5525.06}{17842.7} = .870106 = \boxed{87.0106\% = \eta_{Th}}$$

$P_1 = 100\,KPa$
$T_1 = 25°C = 298.15\,K$

↓ Isentropic Compression

$P_2 = 210.485\,KPa$
$T_2 = 368.794\,K$

↓ constant pressure heat rejection

$P_3 = 210.485\,KPa$
$T_3 = 298.15\,K$

↓ Isentropic Compression

$P_4 = 443.04\,KPa$
$T_4 = 368.794\,K$

↓ constant pressure heat addition

$P_5 = 443.04\,KPa$
$T_5 = 488.786\,K$

↓ Constant pressure heat addition

$P_6 = 443.04\,KPa$
$T_6 = 1477.594\,K$

↓ Isentropic expansion

$P_7 = 210.485\,KPa$
$T_7 = 1194.55\,K$

↓ Constant pressure heat addition

$P_8 = 210.485\,KPa$
$T_8 = 1477.594\,K$

↓ Isentropic expansion

$P_9 = 100\,KPa$
$T_9 = 1194.55\,K$

Now we can calculate pressure and temperature at each state in the brayton cycle. Once this is done, we can assemble a complete diagram with isentropic values. Then its on to inefficiencies in components.

$T_{10} = T_9 = 1194.55\,K$
$P_{10} = P_9 = 100\,KPa$

↓ Constant pressure heat rejection

$T_{11} = T_5 = 448.786\,K$
$P_{11} = P_{10} = 100\,KPa$

$T_{12} = T_9 = 1194.55\,K$
$P_{12} = P_9 = 100\,KPa$

↓ Constant pressure heat rejection

$T_{13} = T_{15} = 396.778\,K$
$P_{13} = 100\,KPa$

$$\dot{W}_{C_1} = \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right] = \dot{W}_{C_2}$$

$$\boxed{\dot{W}_{C_1} = \dot{W}_{C_2} = 991.064\ KW}$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.594 - 1477.594\left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{W}_{T_2} = \dot{W}_{T_1}$$

$$\boxed{\dot{W}_{T_1} = \dot{W}_{T_2} = 3970.75\,KW}$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.594 - \frac{\dot{m}_{10} \cdot 1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - \dot{m}_{10} \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} + \dot{m}_B \cdot 298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4}}{\dot{m}_B}\right] = \dot{Q}_1$$

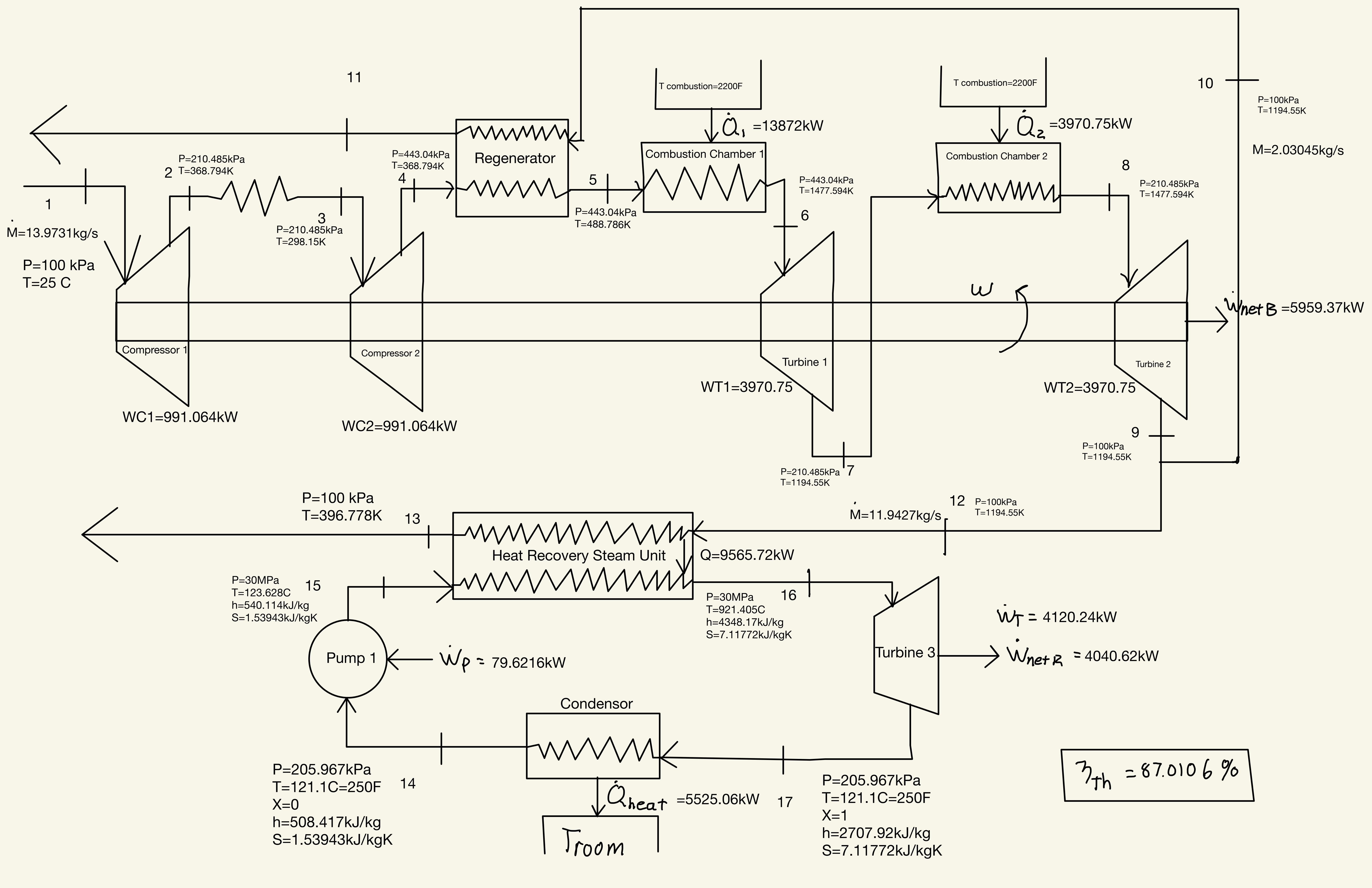
$$\boxed{\dot{Q}_1 = 13872\ KW}$$

$$\dot{m}_B \cdot C_p \cdot \left[1477.694 - 1477.594 \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right] = \dot{Q}_2$$

$$\boxed{\dot{Q}_2 = 3970.75\,KW}$$

$$\dot{Q}_{out_B} = \dot{m}_{12} \cdot C_p \cdot \left[1477.594K \cdot \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4} - T_{15}\right]$$

$$\boxed{\dot{Q}_{out_B} = 9565.72\,KW}$$


11
10
P=100kPa
T=1194.55K
M=2.03045kg/s
T combustion=2200F
$\dot{Q}_1$ =13872kW
T combustion=2200F
$\dot{Q}_2$ =3970.75kW
Regenerator
Combustion Chamber 1
Combustion Chamber 2
P=210.485kPa
T=368.794K
2
P=443.04kPa
T=368.794K
4
5
P=443.04kPa
T=488.786K
P=443.04kPa
T=1477.594K
6
8
P=210.485kPa
T=1477.594K
1
3
P=210.485kPa
T=298.15K
M=13.9731kg/s
P=100 kPa
T=25 C
ω
$\dot{W}_{net B}$ =5959.37kW
Compressor 1
Compressor 2
Turbine 1
Turbine 2
WC1=991.064kW
WC2=991.064kW
WT1=3970.75
WT2=3970.75
9
P=100kPa
T=1194.55K
7
P=210.485kPa
T=1194.55K
P=100 kPa
T=396.778K
13
M=11.9427kg/s
12
P=100kPa
T=1194.55K
Heat Recovery Steam Unit
Q=9565.72kW
P=30MPa
T=123.628C
h=540.114kJ/kg
S=1.53943kJ/kgK
15
P=30MPa
T=921.405C
h=4348.17kJ/kg
S=7.11772kJ/kgK
16
$\dot{W}_T$ = 4120.24kW
Turbine 3
$\dot{W}_{net R}$ = 4040.62kW
Pump 1
$\dot{W}_P$ = 79.6216kW
Condensor
P=205.967kPa
T=121.1C=250F
X=0
h=508.417kJ/kg
S=1.53943kJ/kgK
14
$\dot{Q}_{heat}$ =5525.06kW
Troom
17
P=205.967kPa
T=121.1C=250F
X=1
h=2707.92kJ/kg
S=7.11772kJ/kgK
η_{th} = 87.0106 %

Now considering inefficiencies

$P_{14} = 205.967\ kPa$ $\quad v = .001061\ m^3/kg$

$T_{14} = 250°F = \underline{121.7\ °C = T_{14}}$

$x_{14} = 0$ $\quad S_{14} = 1.53943\ \frac{kJ}{kg\,K}$

$h_{14} = 508.417\ \frac{kJ}{kg}$

$\downarrow$ compression (85% efficient)

$P_{15} = 30000\ kPa$

$h_{15} = 545.589\ \frac{kJ}{kg}$

$T_{15} = 132.49°C = 405.64\ K$

$\downarrow$ constant pressure heat addition

$P_{16} = 30000\ kPa$

$T_{16} = 857.974°C = 1131.12\ K$

$h_{16} = 4179.46\ \frac{kJ}{kg}$

$S_{16} =$

$\downarrow$ expansion (90% efficient)

$S_{17} = S_{16} = 7.11772\ \frac{kJ}{kg\,K}$

$P_{17} = 205.967\ kPa$

$h_{17} = 2707.92$

$T_{17} = 121.7°C$

$x_{17} = 1$

$\downarrow$ Constant pressure heat rejection

Now back to State 1

$79.6216\ kW = \dot{W}_{C\,Isen}$

$$.85 = \frac{\dot{W}_{C\,Isen}}{\dot{W}_{actual}} \Rightarrow \boxed{\dot{W}_{C\,actual} = 93.6725\ kW}$$

$$\dot{W}_{CA} = \dot{m}_R(h_{15} - h_{14}) \Rightarrow 93.6725 = 2.51996(h_{15} - 508.417) \Rightarrow h_{15} = 545.589\ \frac{kJ}{kg}$$

$\dot{W}_{T\,Isen} = 4120.24\ kW$

$$.90 = \frac{\dot{W}_{TA}}{\dot{W}_{T\,Isen}} \Rightarrow \boxed{\dot{W}_{TA} = 3708.22\ kW}$$

$$\dot{W}_{TA} = \dot{m}_R(h_{16} - h_{17}) \Rightarrow 3708.22 = 2.51996(h_{16} - 2707.92) \Rightarrow h_{16} = 4179.46\ \frac{kJ}{kg}$$

$$\dot{W}_{net\,A} = \dot{W}_{TA} - \dot{W}_{CA} = \boxed{3614.55\ kW = \dot{W}_{net\,A}}$$

$$\boxed{\dot{Q}_{out} = 5525.06\ kW}$$

$$\dot{Q}_{in} = \dot{m}_R(h_{16} - h_{15}) = 2.51996(4179.46 - 545.589) = \boxed{9157.21\ kW = \dot{Q}_{in}}$$

First, evaluate heat recovery steam unit

Assume $T_{16} = T_{12}$ and $T_{15} = T_{13}$
but only .9 of $\dot{Q}_{outB}$ is transferred to rankine cycle:

$$.9 = \frac{\dot{m}_R(h_{16} - h_{15})}{\dot{m}_{12}(h_{12} - h_{13})} = \frac{9157.21}{\dot{m}_{12} \cdot C_p \cdot [T_{12} - T_{13}]} = \frac{9157.21}{\dot{m}_{12} \cdot 1.004 \cdot [1131.12 - 405.64]} \Rightarrow 10174.7 = \dot{m}_{12} \cdot 1.004 [725.48]$$

$$\boxed{\dot{m}_{12} = 13.9689 \text{ kg/s}}$$

if Turbines are 90% eff
and Compressors 85%

$$\boxed{\dot{W}_{T_2A} = .9 \cdot \left[\dot{m}_B \cdot 1.004 \left[1477.594 - 1477.594 \left(\frac{1}{\sqrt{r_p}}\right)^{.4/1.4}\right]\right] = \dot{W}_{T_1A}}$$

$\dot{m}_B$ cancels

$\Rightarrow \boxed{r_p = 8.27169}$

$$\boxed{347.86 \cdot \dot{m}_B = \dot{W}_{T_2A}}$$

Temps are known

$$\dot{W}_{T_2A} = \dot{m}_B \cdot C_p \cdot [T_8 - T_9] = \dot{m}_B \cdot 1.004 \cdot [1477.594 - 1131.12] = \dot{W}_{T_2A}$$

$$\dot{W}_{C_1 Isen} = \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right]$$

$$\boxed{\dot{W}_{C_1A} = \frac{\dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right]}{.85} = \dot{W}_{C_2A}}$$

$$\boxed{2 \cdot [\dot{W}_{T_2A} - \dot{W}_{C_1A}] = 6385.45}$$

w/ known r_p:

$$2 [347.86 \cdot \dot{m}_B - 124.082 \dot{m}_B] = 6385.45$$

$$\boxed{\dot{m}_B = 14.2674 \text{ kg/s}}$$

$$\dot{m}_B = \dot{m}_{10} + \dot{m}_{12}$$

$$14.2674 = \dot{m}_{10} + 13.9689$$

$$\boxed{\dot{m}_{10} = .298457 \text{ kg/s}}$$

$P_1 = 100\,kPa$
$T_1 = 25°C$
$\downarrow$ compression
$P_2 = \sqrt{r_p} \cdot P_1 = 287.605\,kPa$
$T_2 = 421.737\,K$
$\downarrow$ constant pressure heat rejection
$P_3 = P_2 = 287.605\,kPa$
$T_3 = T_1 = 298.15\,K$
$\downarrow$ compression
$P_4 = 827.169\,kPa$
$T_4 = 421.737\,K$
$\downarrow$ constant pressure heat addition
$P_5 = 827.169\,kPa$
$T_5 = 435.093\,K$
$\downarrow$ constant pressure heat addition
$P_6 = 827.169\,kPa$
$T_6 = 1447.594\,K$
$\downarrow$ expansion
$P_7 = 287.605\,kPa$
$T_7 = T_9 = 1131.12\,K$
$\downarrow$ constant pressure heat addition
$P_8 = 287.605\,kPa$
$T_8 = 1477.594\,K$
$\downarrow$ expansion
$P_9 = 100\,kPa$
$T_9 = 1131.12\,K$

$$\dot{W}_{C_1\,Isen} = \dot{m}_B \cdot 1.004 \cdot \left[298.15 \cdot \left(\sqrt{r_p}\right)^{.4/1.4} - 298.15\right]$$

$$\dot{W}_{C_1\,Isen} = 1504.77\,KW$$

$$\dot{W}_{C_1 A} = \frac{1504.77}{.85} = \boxed{1770.32\,KW = \dot{W}_{C_1 A}} = \dot{W}_{C_2 A}$$

$$\dot{W}_{C_1 A} = \dot{m}_B \cdot C_p \cdot [T_2 - T_1]$$

$$1770.32 = 14.2674 \cdot 1.004 [T_2 - 298.15] \Rightarrow T_2 = 421.737\,K$$

$\eta = .9 \rightarrow$ regenerator:

$$.9 = \frac{\dot{m}_B \cdot C_p \cdot [T_5 - T_4]}{\dot{m}_{10} \cdot C_p \cdot [\underbrace{T_{10}}_{=T_9} - \underbrace{T_{11}}_{=T_4}]} = \frac{14.2674 \cdot 1.004 [T_5 - 421.737]}{.298457 \cdot 1.004 [1131.12 - 421.737]} = .9 \Rightarrow T_5 = 435.093\,K$$

$$\dot{Q}_1 = \dot{m}_B \cdot C_p \cdot [T_6 - T_5] = 14.2674 \cdot 1.004 \cdot [1477.594 - 435.093] = \boxed{14933.3\,KW = \dot{Q}_1}$$

$$\dot{W}_{T_1 A} = \dot{W}_{T_2 A} = 347.86 \cdot \dot{m}_B = 347.86 \cdot 14.2674 = \boxed{4963.06\,KW = \dot{W}_{T_1} = \dot{W}_{T_2}}$$

$$\dot{Q}_2 = \dot{m}_B \cdot C_p \cdot [T_8 - T_7] = 14.2674 \cdot 1.004 \cdot [1477.594 - 1131.12] = \boxed{4963.06\,KW = \dot{Q}_2}$$

$$\dot{W}_{net} = 2[\dot{W}_T - \dot{W}_C] = 2[4963.06 - 1770.32] = \boxed{6385.47\,KW = \dot{W}_{net\,B}}$$

$$\dot{Q}_{net} = \dot{Q}_1 + \dot{Q}_2 = \boxed{19896.4\,KW = \dot{Q}_{net}}$$

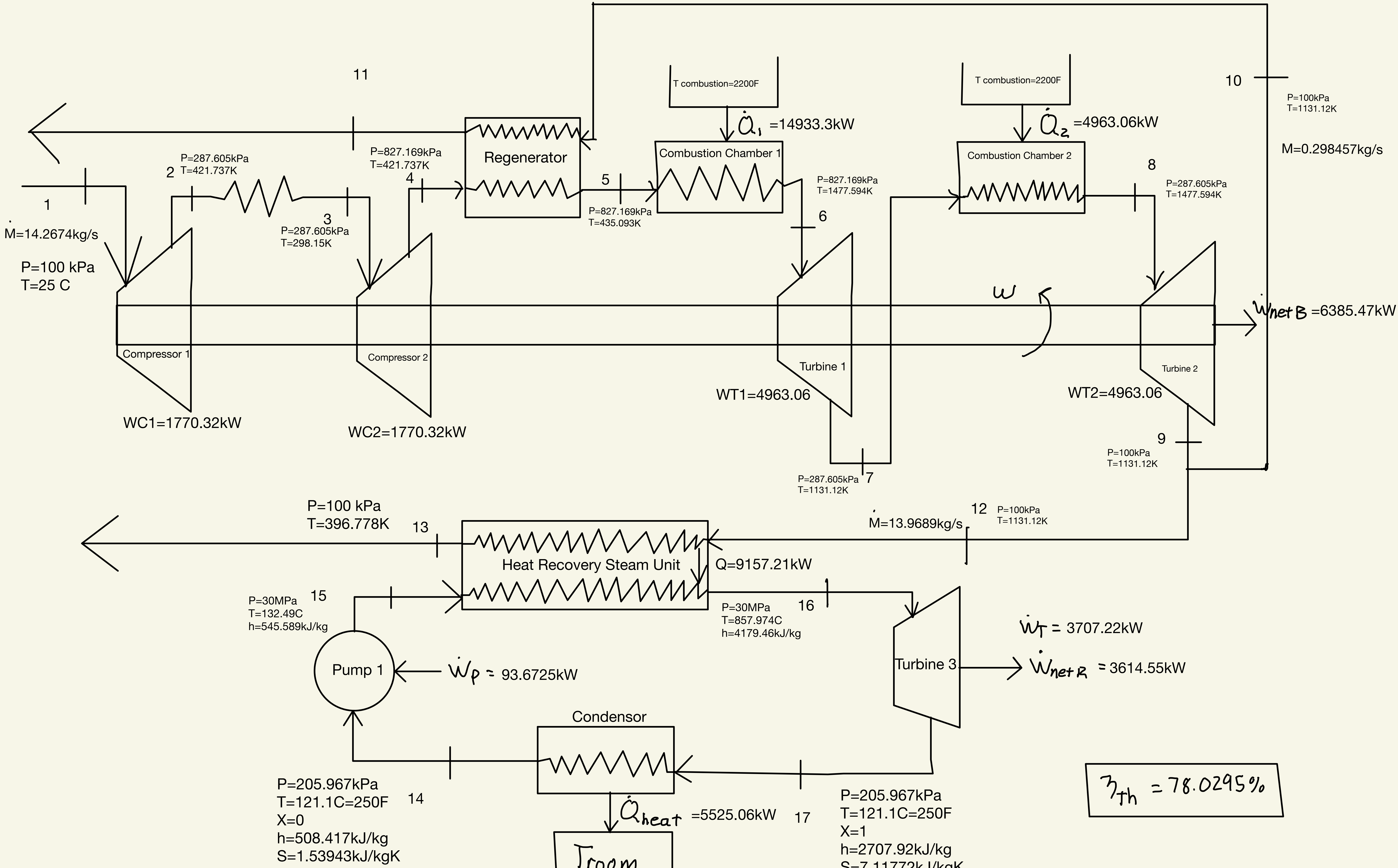
$$\eta_{Th} = \frac{\dot{W}_{net} + \dot{Q}_L}{\dot{Q}_H} = \frac{10000 + 5525.06}{19896.4} = .780295 = \boxed{78.0295\% = \eta_{Th}}$$

$$\boxed{r_p = 8.27169}$$

$$\boxed{\dot{m}_{12} = 13.9689\,kg/s}$$

$$\boxed{\dot{m}_{10} = .298457\,kg/s}$$

$$\boxed{\dot{m}_B = 14.2674\,kg/s}$$



11
10
T combustion=2200F
T combustion=2200F
$\dot{Q}_1$ =14933.3kW
$\dot{Q}_2$ =4963.06kW
P=100kPa
T=1131.12K
M=0.298457kg/s
Regenerator
Combustion Chamber 1
Combustion Chamber 2
P=287.605kPa
T=421.737K
2
P=827.169kPa
T=421.737K
4
5
P=827.169kPa
T=1477.594K
8
P=287.605kPa
T=1477.594K
1
3
P=287.605kPa
T=298.15K
P=827.169kPa
T=435.093K
6
M=14.2674kg/s
P=100 kPa
T=25 C
w
$\dot{W}_{net\,B}$ =6385.47kW
Compressor 1
Compressor 2
Turbine 1
Turbine 2
WT1=4963.06
WT2=4963.06
WC1=1770.32kW
WC2=1770.32kW
9
P=100kPa
T=1131.12K
P=287.605kPa
T=1131.12K
7
P=100 kPa
T=396.778K
13
M=13.9689kg/s
12
P=100kPa
T=1131.12K
Heat Recovery Steam Unit
Q=9157.21kW
P=30MPa
T=132.49C
h=545.589kJ/kg
15
P=30MPa
T=857.974C
h=4179.46kJ/kg
16
$\dot{W}_T$ = 3707.22kW
Pump 1
$\dot{W}_p$ = 93.6725kW
Turbine 3
$\dot{W}_{net\,R}$ = 3614.55kW
Condensor
P=205.967kPa
T=121.1C=250F
X=0
h=508.417kJ/kg
S=1.53943kJ/kgK
14
$\dot{Q}_{heat}$ =5525.06kW
17
Troom
P=205.967kPa
T=121.1C=250F
X=1
h=2707.92kJ/kg
S=7.11772kJ/kgK
η_{Th} = 78.0295%

Fuel required computations:

Isentropic components:

$\dot{Q}_{in\,Total} = 17842.8\ KW$

80% Combustion efficiency

Actual components:

$\dot{Q}_{in\,Total} = 19896.4\ KW$

natural gas energy density $= \dfrac{37\ MJ}{m^3}$

$$\frac{17842.8 \cdot 10^3\ J}{s}\Bigg|\frac{3600\ s}{1\ hr}\Bigg|\frac{24\ hr}{1\ day} = \frac{1.54161 \cdot 10^{12}\ J}{day}\Bigg|\frac{m^3}{37 \cdot 10^6\ J} = \frac{41665.2\ m^3}{day} \div .8 = \frac{52081.5\ \cancel{m^3}}{day}\cdot\frac{\$.141259}{\cancel{m^3}}$$

$$= \boxed{\$7356.98/day}$$

$$\frac{19896.4 \cdot 10^3\ J}{s}\Bigg|\frac{3600\ s}{1\ hr}\Bigg|\frac{24\ hr}{1\ day} = \frac{1.71905 \cdot 10^{12}\ J}{day}\Bigg|\frac{m^3}{37 \cdot 10^6\ J} = \frac{46460.8\ m^3}{day} \div .8 = \frac{58076\ \cancel{m^3}}{day}\Bigg|\frac{\$.141259}{\cancel{m^3}}$$

$$= \boxed{\$8203.75/day}$$

natural gas cost: $\dfrac{\$4.00}{1000\ ft^3}\Bigg|\dfrac{1000\ ft^3}{28.3168\ m^3} = \dfrac{\$.141259}{m^3}$