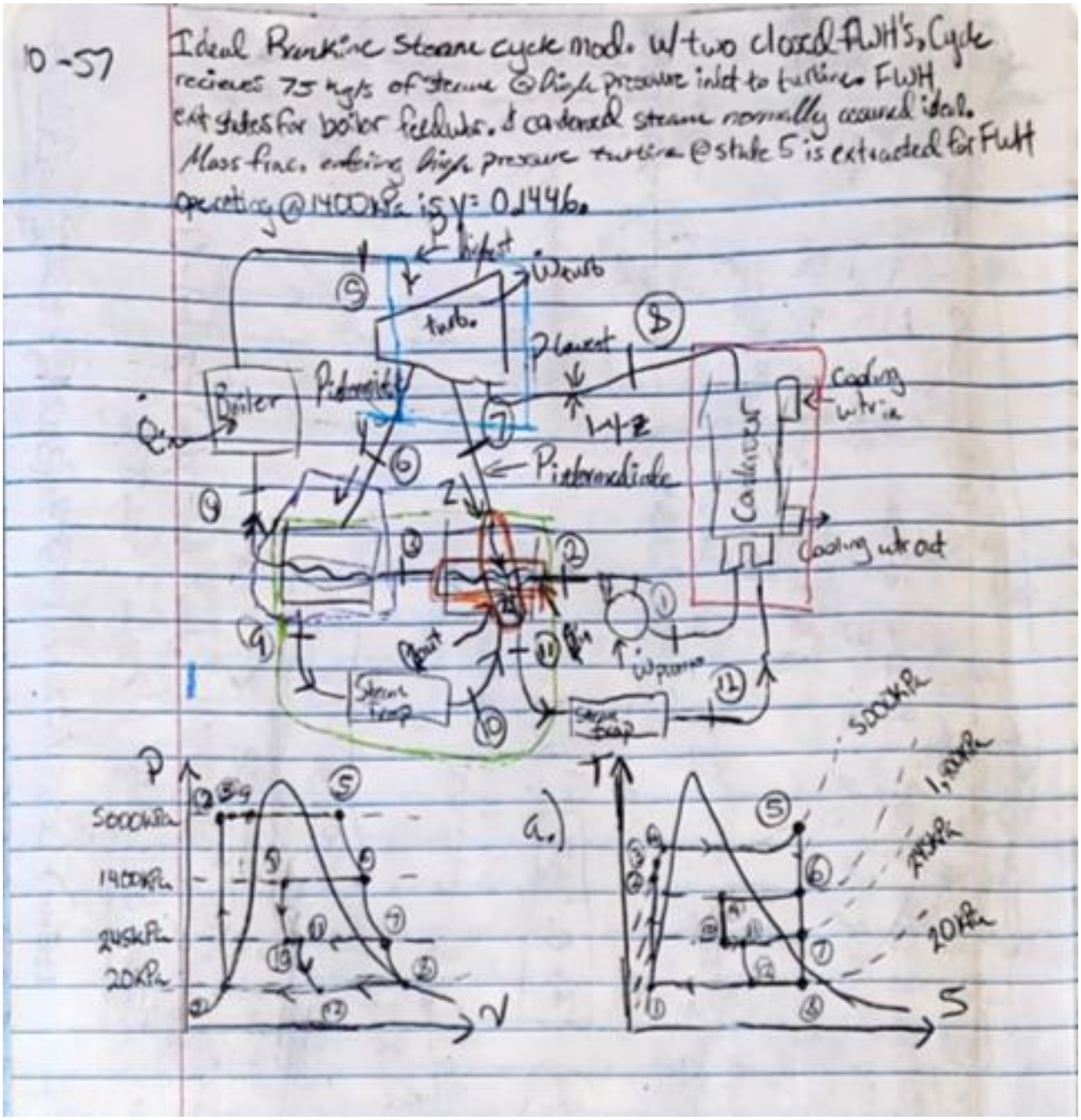
10-57 part 1:


10-57
Ideal Rankine Steam cycle mod. w/ two closed FWH's, Cycle recieves 75 kg/s of steam @ high pressure inlet to turbine. FWH exit states for boiler feedwtr. & condensed steam normally assumed ideal. Mass frac. entering high pressure turbine @ state 5 is extracted for FWH operating @ 1400kPa is y = 0.1446.
P high
W turb
turb.
P lowest
Boiler
P intermediate
Condenser
Cooling wtr in
Cooling wtr out
W pump
Steam trap
Steam trap
5000kPa
1400kPa
245kPa
20kPa
a.)
P
v
T
s
5000kPa
1,400kPa
245kPa
20kPa

10-57 part 2:

1 (Pump) → 2 ($P_{const.}$) → 3 ($P_{const.}$) → 4 ($P_{const.}$) → 5 (Isentr. Turb.) → 6 (Isentr. Turb.) → 7 (Isentr. Turb.) → 8 → 9 (Isenthalpic) → 10 ($P_{const.}$) → 11 (Isenthalpic) → 12 ($P_{const.}$) → 1

State 1: $P_1 = 10kPa$, $x_1 = 0$, $v_1 = .00102\frac{m^3}{kg}$, $T_1 =$, $h_1 = 251\frac{kJ}{kg}$, $s_1 =$

$h_2 = h_1 + v_1(P_2 - P_1) \Rightarrow h_2 = 256.49\frac{kJ}{kg}$

State 2: $P_2 = 5000kPa$, $h_2 = 256.49\frac{kJ}{kg}$

State 3: $P_3 = 5000kPa$, $h_3 = 533\frac{kJ}{kg}$

State 4: $P_4 = 5000kPa$, $h_4 = 830\frac{kJ}{kg}$

State 5: $P_5 = 5000kPa$, $T_5 = 500°C$, $h_5 = 3400\frac{kJ}{kg}$, $S_5 = 7.5\frac{kJ}{kg \cdot K}$

$S_5 = S_6 = S_7 = S_8$

$\dot{m}_5 = 75\frac{kg}{s}$

State 6: $P_6 = 1400kPa$, $h_6 = 3406\frac{kJ}{kg}$

State 7: $P_7 = 245kPa$, $h_7 = 2815\frac{kJ}{kg}$

State 8: $P_8 = 20kPa$, $h_8 = 2477\frac{kJ}{kg}$

State 9: $P_9 = 1400kPa$

$x_9 = \frac{h_9 - h_{f_9}}{h_{fg_9}}$

$h_f @ P_9 = 829.96$

$h_{fg} @ P_2 = 1958.9$

State 10: $x_{10} = 0$, $P_{10} = 245kPa$, $h_9 = h_{10}$, $h_{10} @ P_{10} = 533\frac{kJ}{kg}$

State 11: $P_{11} = 245kPa$, $x_{11} = \ldots$, $h_{11} = h_{12}$

$x_{11} = \frac{h_{11} - h_{f_{11}}}{h_{fg}} \Rightarrow x_{11} = 12.9\%$ (.1289)

State 12: $x_{12} = 0$, $P_{12} = 20kPa$, $h_{12} @ P_{12} = 251.4$

$y = .1446$

$C_p = 4.18$

b.)

$h_3 - h_2 = z(h_7) + y(h_{10}) - (z + y)(h_{11}) \Rightarrow$ **$z = 0.0646$**

Q_{out}

$h_4 - h_3 = y(h_9 - h_6) \Rightarrow h_9 = \frac{(h_4 - h_3)}{y} + h_6 \Rightarrow h_9 =$

$y(h_6) + z(h_7) + h_2 = h_4 + (y - z)(h_1) \Rightarrow$

c.)

$\dot{m}_5[(1 - z - y)(h_8) + h_{12}(y + z) - h_1] = \dot{m}_{tot} C_p \Delta T \Rightarrow$ **$\dot{m}_{tot} = 3531.133\frac{kg}{s}$**

$C_p \Delta T$

d.) Thermal efficiency

$\dot{W}_{net} = \dot{m}(w_{net})\frac{kJ}{kg}$

$w_{net} = h_5 - y(h_6) - z(h_7) - (1 - y - z)h_8$

$\hookrightarrow w_{net} = 958.71\frac{kJ}{kg}$

$\dot{W}_{net} = 71903.25\frac{kJ}{s}$

$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} \Rightarrow \frac{71903.25\frac{kJ}{s}}{230250\frac{kJ}{s}}$

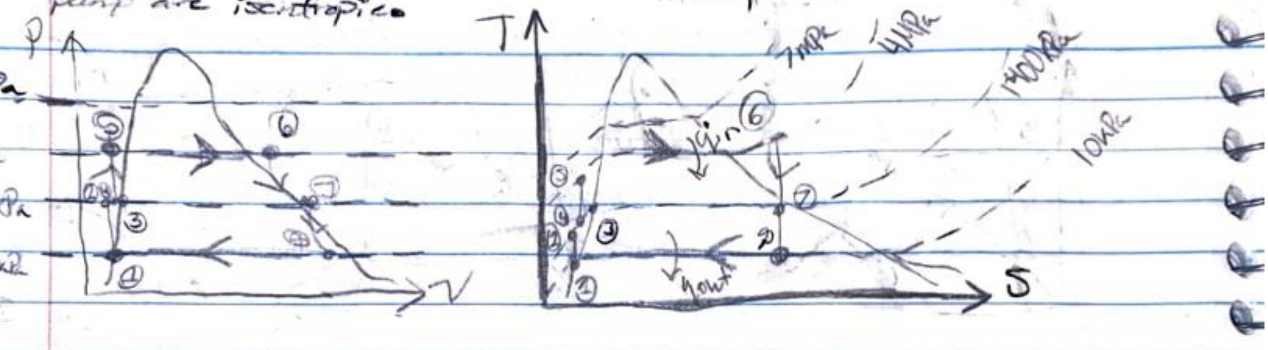
(boiler) $\dot{Q}_{in} = \dot{m}(h_5 - h_4) \Rightarrow 75\frac{kg}{s}(3400\frac{kJ}{kg} - 330\frac{kJ}{kg}) = 230250\frac{kJ}{s}$

$\eta_{th} = .312$ or 31.2%

10-69 part 1:

10-69: Steam enters turbine w/ cogeneration plant @ 4 MPa & 500°C. $\frac{1}{4}$ steam extracted from turbine @ 1200 kPa for heating. Remaining expands to 10 kPa. Extracted steam is then condensed & mixed w/ FWH @ const. pressure & mixture is pumped to boiler pressure @ 7 MPa. $\dot{M}$ through boiler = 55 kg/s. Turbine & pump are isentropic.

$y = .25$



10-69 part 2:

1 —Isent (Pump)→ 2 —Isobaric→ 3 —Isobar→ 4 —Isent (Pump)→ 5 —Isobaric (Boiler)→ 6 —Isentropic (Turbine)→ 7 —Isentropic→ 8 (Condenser) —Isobaric→

$P_1 = 10kPa$, $x_1 = 0$, $v_1 = 0.00101 \frac{m^3}{kg}$, $h_1 = 191.81 \frac{kJ}{kg}$, $s_1 = 0.6492 \frac{kJ}{kg \cdot K}$, $T_1 =$

Pump I: $h_2 - h_1 = v_1(P_2 - P_1)$

$h_2 = 193.214 \frac{kJ}{kg}$

$s_2 = 0.6492 \frac{kJ}{kg}$

$P_2 = 1400kPa$

$P_3 = 1400kPa$, $x_3 = 0$

$h_3 @ P_3 = 829.96 \frac{kJ}{kg}$, $v_3 @ P_3 = 0.001149 \frac{m^3}{kg}$, $s_3 @ P_3 = 2.2835 \frac{kJ}{kg \cdot K}$, $T_3 @ P_3 = 195.04°C$

$P_4 = 1400kPa$

$h_4 @ P_4 = 829.96 \frac{kJ}{kg}$, $v_4 @ P_4 = 0.001149 \frac{m^3}{kg}$, $T_4 @ P_4 = 195.04°C$

$h_5 - h_4 = v_4(P_5 - P_4)$ (Pump II)

$h_5 = 836.3 \frac{kJ}{kg}$

$P_5 = 7MPa$, $h_5 =$, $m_5 = 55 \frac{kg}{s}$

$P_6 = 4MPa$, $T_6 = 500°C$, $s_6 = s_7 = s_8$, $m_6 = 55 kg/s$

$v_6 @ T_6 P_6 = 0.08643$, $h_6 @ T_6 P_6 = 3446$, $s_6 @ T_6 P_6 = 7.0922$

$P_7 = 1400kPa$, $y = .25$

$s_7 = 7.0922 \frac{kJ}{kg \cdot K}$, $m_7 = 13.75 \frac{kg}{s}$, $h_7 @ P_7 = 2780 \frac{kJ}{kg}$

$P_8 = 10kPa$, $s_8 = 7.0922 \frac{kJ}{kg}$, $m_8 = 41.25 \frac{kg}{s}$, $z = 0.75$, $s_{f8} = 0.6492$, $s_{fg8} = 7.4996 \frac{kJ}{kg \cdot K}$

$x_8 = \frac{s_8 - s_{f8}}{s_{fg8}} \Rightarrow x_8 = .86$

$h_{f8} = 191.81 \frac{kJ}{kg}$, $h_{fg8} = 2392.1 \frac{kJ}{kg}$

$h_8 = h_{f8} + x_8(h_{fg8})$

$h_8 = 2249.016 \frac{kJ}{kg}$

$(.25) m_6 = m_7$, $m_7 = 13.75 \frac{kg}{s}$

$m_8 = m_6 - m_7$, $m_8 = 41.25 \frac{kg}{s}$

Boiler: $\dot{Q}_{in} = m_5(h_6 - h_5) \Rightarrow \dot{Q}_{in} = 143528.31W$

$\dot{W}_T = m_7(h_6 - h_7) + m_8(h_6 - h_8)$

$\dot{Q}_P = m_7(h_7 - h_3) \Rightarrow \dot{Q}_P = 26,797.93W$

-Find net power produced:

$\dot{W}_{turb} = m_6(h_6 - h_7) + (y)(h_7 - h_8) = 36275.47W$

$36.3kW = \dot{W}_{turb}$

$W_{net} = \dot{W}_{turb} - (h_8 - h_1)$

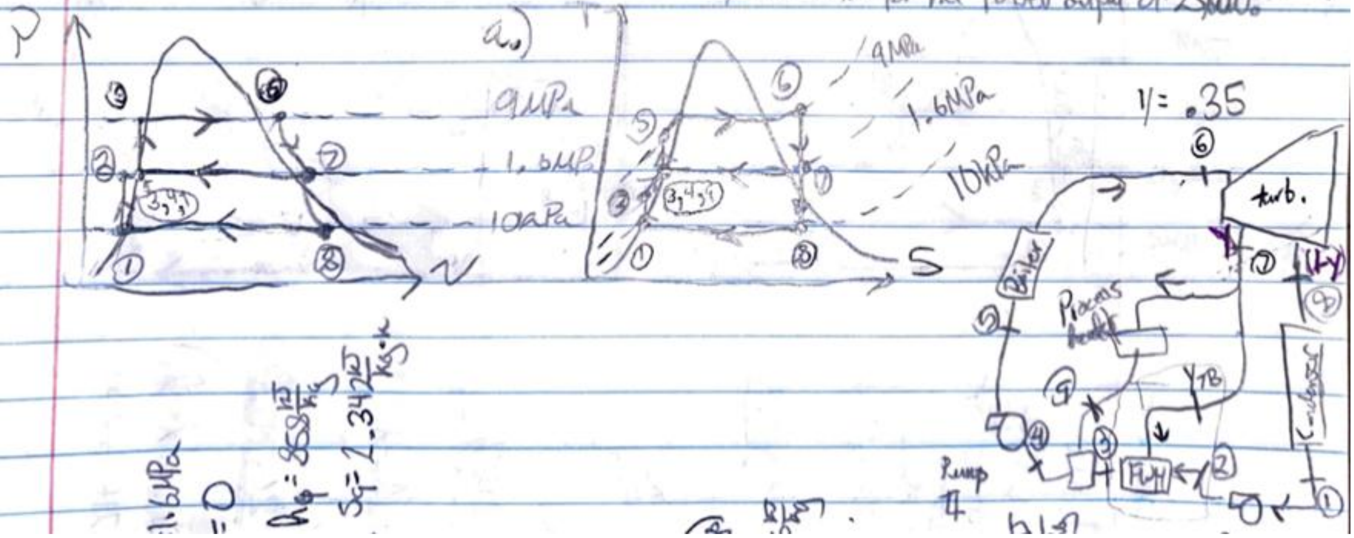
$W_{net} = 34,216.668W$

- Utilization Factor of Plant:

$\varepsilon_u = \frac{W_{net} + \dot{Q}_P}{\dot{Q}_{in}} \Rightarrow \frac{34216.67 + 26797.9}{143528.31} \Rightarrow \varepsilon_u = .425$

10-72 part 1:

10-72 Cogeneration power plant modified w/ regen. Steam enters turbine @9MPa & 400°C & expands to pressure of 1.6MPa. This pressure, 35% of steam is extracted from turbine, & remain expands to 10KPa. Part is used to go Open FWH. Rest of steam goes to process heater, Sat. liquid @1.6MPa. Assuming turbines & pumps are isent. T-S diagram & find extra mass flow rate of steam through the boiler for net Power output of 25MW.



10-72 part 2:

1 Pump | 2 | 3 | 4 Pump | 5 boiler | 6 Turb ($y = .35$) | 7 | 8 | 9

State 1: $P_1 = 10\,kPa$, $x_1 = 0$, $h_1 = 191.81\,\frac{kJ}{kg}$, $s_1 = 0.6492\,\frac{kJ}{kg\cdot K}$, $v_1 = 0.00101\,\frac{m^3}{kg}$

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

$h_2 = 193.42\,\frac{kJ}{kg}$

State 2: $P_2 = 1.6\,MPa$

State 3: $P_3 = 1.6\,MPa$, $x_3 = 0$

$h_3 @ P_3 = 858\,\frac{kJ}{kg}$ (Interp.)

State 4: $P_4 = 1.6\,MPa$, $x_4 = 0$

$h_4 @ P_4 = 858\,\frac{kJ}{kg}$

$v_4 @ P_4 = 0.001159\,\frac{m^3}{kg}$

State 5: $P_5 = 9\,MPa$

$h_5 - h_4 = v_4(P_5 - P_4)$

$h_5 = 866.58\,kJ/kg$

State 6: $P_6 = 9\,MPa$, $T_6 = 400°C$ (A-6)

$h_6 = 3118.8\,kJ/kg$

$s_6 = 6.2876\,\frac{kJ}{kg\cdot K}$

State 7: $P_7 = 1.6\,MPa$, $s_7 = 6.2876$

$s_{f7} = 2.342\,\frac{kJ}{kg\cdot K}$

$s_{fg7} = 4.0720\,\frac{kJ}{kg\cdot K}$

$x_7 = \frac{s_7 - s_{f7}}{s_{fg7}}$

$x_7 = .967$

$h_{f7} = 858\,\frac{kJ}{kg}$

$h_7 = h_{f7} + x_7(h_{fg7})$

$h_7 = 2729.64\,kJ/kg$

State 8: $P_8 = 10\,kPa$, $s_8 = 6.2876$

$s_{f8} = 0.6492\,\frac{kJ}{kg\cdot K}$

$s_{fg8} = 7.4996\,kJ/kg\cdot K$

$x_8 = \frac{s_8 - s_{f8}}{s_{fg8}}$

$x_8 = .752$

$h_{f8} = 191.81\,\frac{kJ}{kg}$

$h_{fg8} = 2392.1\,\frac{kJ}{kg}$

$h_{fg} = 1934.6\,\frac{kJ}{kg}$

$h_8 = h_{f8} + x_8(h_{fg8})$

$h_8 = 1990.26\,\frac{kJ}{kg}$

State 9: $P_9 = 1.6\,MPa$, $x_9 = 0$

$h_9 = 858\,\frac{kJ}{kg}$

$s_9 = 2.342\,\frac{kJ}{kg\cdot K}$

First Law: $\Rightarrow \Delta h \Rightarrow (y_{7}(h_7) + (1-y)(h_2) - 1(h_3)$

Find y_{7}

$y_{7} = 0.26365$

b) Mass flow rate of steam through boiler w/ Net power 25 MW.

$\dot{W}_{net} = \dot{m}_T(w_{net})$ (or $\dot{m}_5$; $w_{net} = w_{out} - w_{in}$)

$25000\,\frac{kJ}{s} = \dot{m}_T(389.16 + 480.6 - 1.047 - 8.58)\,\frac{kJ}{kg}$

$\dot{m}_T = 29.065\,kg/s$

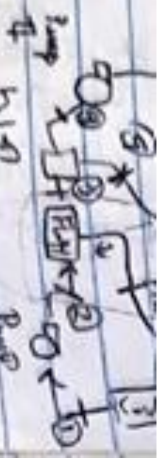
Pump: $w_{in,1-2} = (1-y)(h_2 - h_1) = 1.0465\,\frac{kJ}{kg}$

$w_{in,4-5} = h_5 - h_4 \Rightarrow 8.58\,kJ/kg$

Turb: $w_{out,6-7} = h_6 - h_7 \Rightarrow 389.16\,kJ/kg$

$w_{out,7-8} = (1-y)(h_7 - h_8)$

$w_{out,7-8} = 480.6\,kJ/kg$



10-72 part 3/ extra credit:

Extra Credit Section:

C. Find flow rates at every state:

$\dot{m}_T$ or $\dot{m}_5 = 29.065\ kg/s$

Conservation of mass: $\dot{m}_5 = \dot{m}_6 = 29.065\ kg/s$

$\dot{m}_7 = (0.35)\dot{m}_6 \Rightarrow \dot{m}_7 = 10.173\ kg/s$

$\dot{m}_8 = \dot{m}_6 - \dot{m}_7 = 18.892\ kg/s = \dot{m}_8$

Assume steady state: $\dot{m}_8 = \dot{m}_1 \Rightarrow \dot{m}_1 = 18.892\ kg/s$

Assume conservation of mass for Pump I & II: $\dot{m}_1 = \dot{m}_2 \Rightarrow 18.892\ kg/s$ & Conservation of mass: Pump II: $\dot{m}_6 = \dot{m}_4 = 29.065\ kg/s$

$\dot{m}_3 = \dot{m}_7 + \dot{m}_2 \Rightarrow 29.065\ kg/s = \dot{m}_3$

$\dot{m}_4 = \dot{m}_3 = \dot{m}_9 \Rightarrow \dot{m}_9 = 29.065\ kg/s$

$\dot{m}_1 = 18.892\ kg/s$
$\dot{m}_2 = 18.892\ kg/s$
$\dot{m}_3 = 29.065\ kg/s$
$\dot{m}_4 = 29.065\ kg/s$
$\dot{m}_5 = 29.065\ kg/s$
$\dot{m}_6 = 29.065\ kg/s$
$\dot{m}_7 = 10.173\ kg/s$
$\dot{m}_8 = 18.892\ kg/s$
$\dot{m}_9 = 29.065\ kg/s$