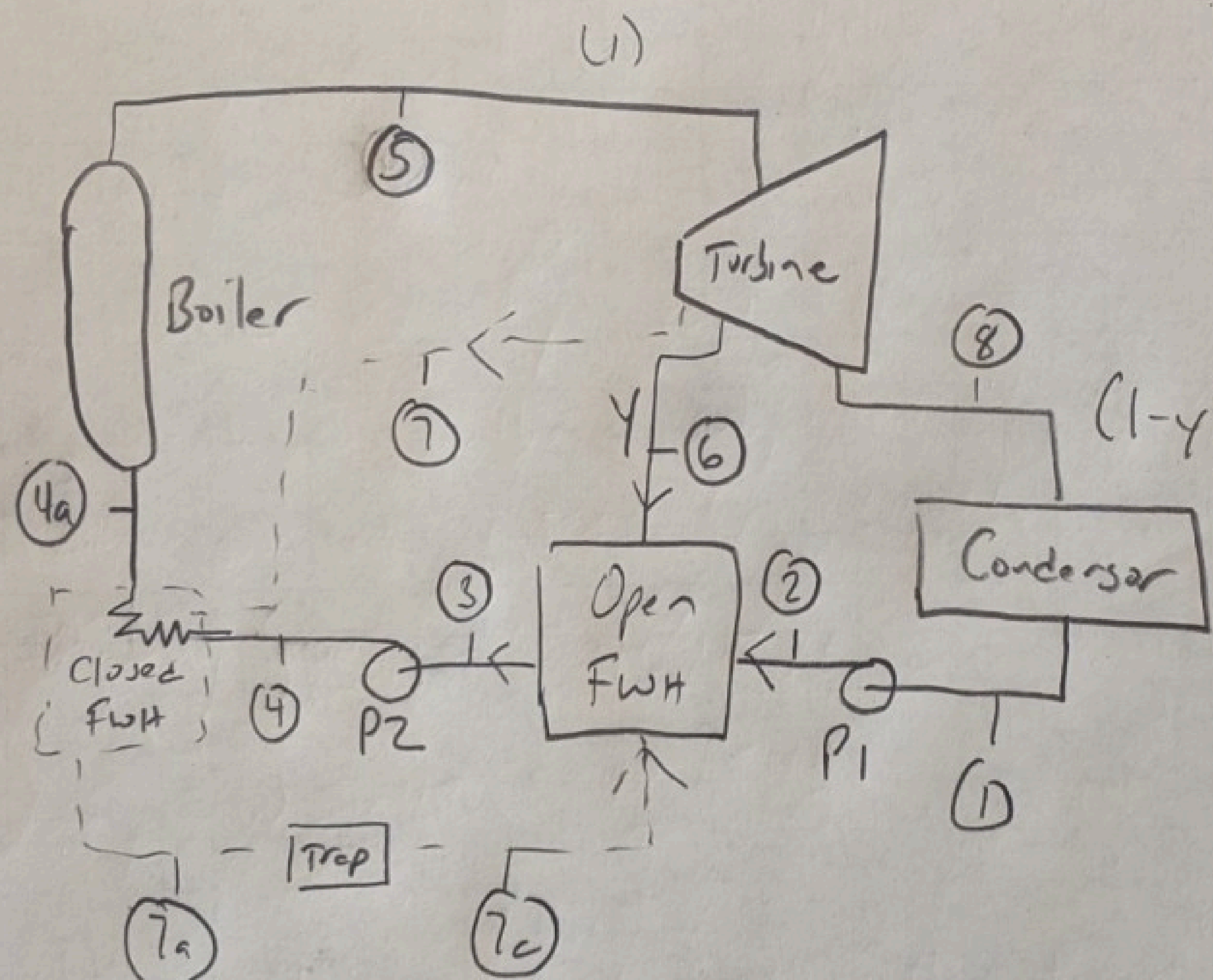
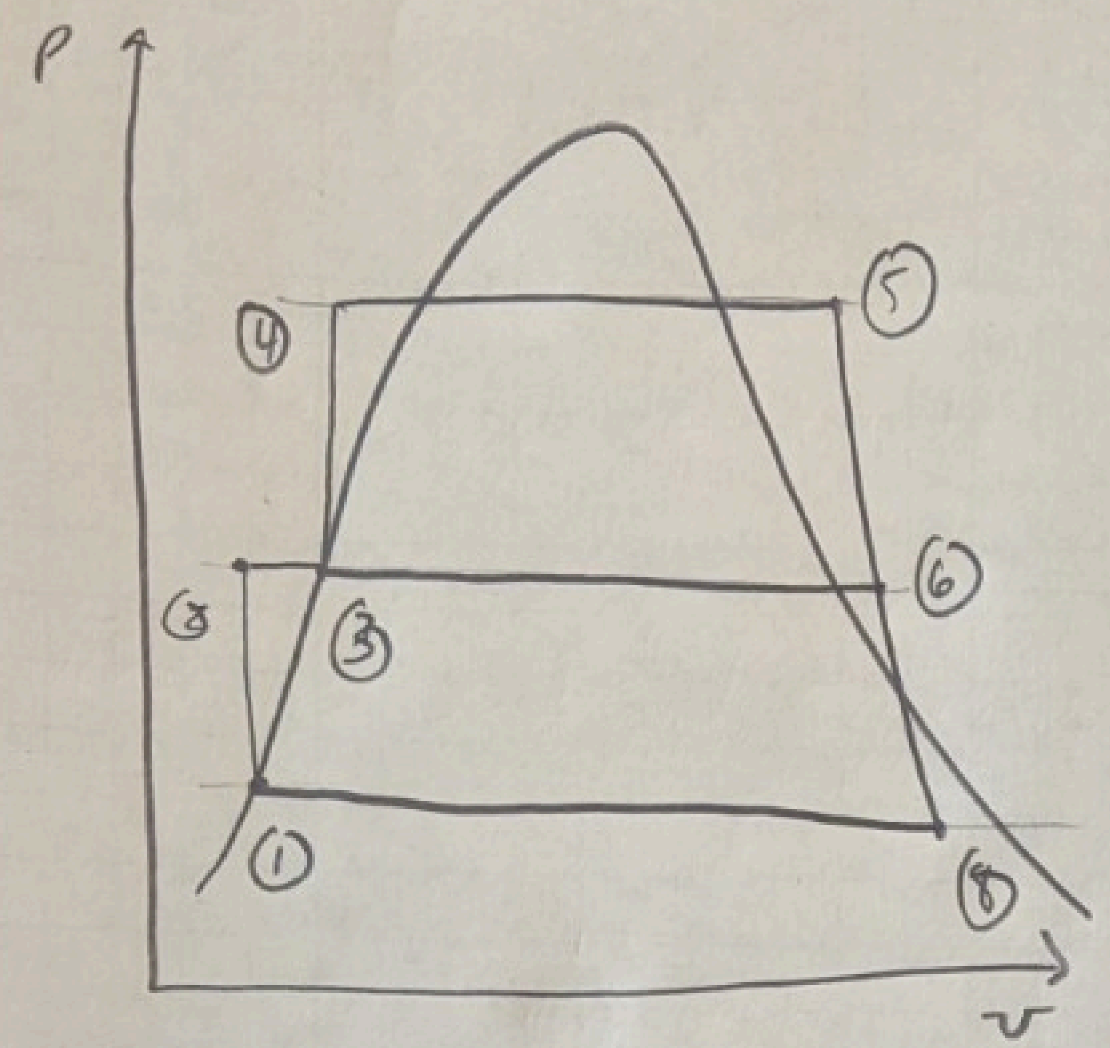
Purpose Calculate thermal efficiency and specific work of an ideal steam regenerative cycle.

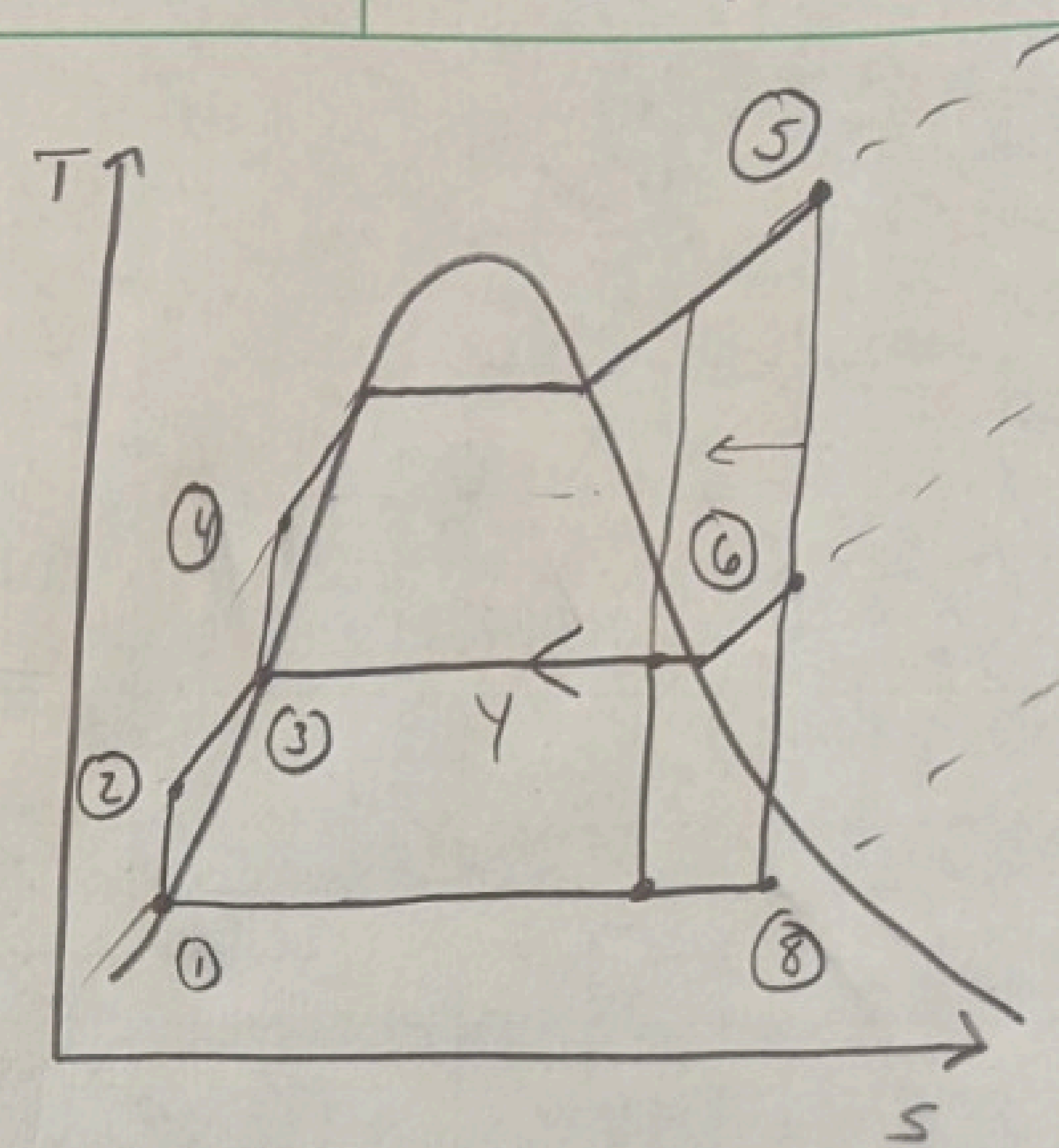
Drawings and diagrams



The steam trap is clogged, therefore no flow through the pipe (7). $\dot{m} = 0 \Rightarrow \dot{Q}_{Closed\ FWH} = 0 = \cancel{\dot{m}}^{0}(\Delta h)$

$\Rightarrow$ <u>Conditions at $4 = 4_a$</u>, assuming no losses to ambiant.





Sources

Cengal + Boles. "Thermodynamics - An Engineering Approach," 8^{th} Edition, McGraw Hill, 2015

Design Considerations

1) Water is pure
2) Pumps and turbines are isentropic
3) Not heat losses in connections, pipes, neither fluid friction losses.

Data and Variables

Steam @ 5 = 3.0 MPa, 400°C
Steam @ 8 = 10 KPa
Steam @ 6 = 100 KPa
Water @ 1, 3, and 4a is saturated liquid. ⇒ $x = 0$

Procedure

① Get states using Tables A-4, A-5, A-6 and the following equations

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

$x_i = \dfrac{s_i - s_f}{s_{fg}}$ $h_i = h_f + x_i h_{fg}$

$y = \dfrac{\dot{m}_6}{\dot{m}_5} = \dfrac{h_3 - h_2}{h_6 - h_2}$

$q_{out} = (1-y)(h_8 - h_1)$

$q_{in} = h_5 - h_{4a}$

$w_{net} = q_{in} - q_{out}$

$\eta_{th} = 1 - \dfrac{q_{out}}{q_{in}}$

P_{const}

Isentopic

$\textcircled{1} \xrightarrow[P1]{\text{Isentopic}} \textcircled{2} \xrightarrow{P_{cont}} \textcircled{3} \xrightarrow[PZ]{\text{Isentopic}} \textcircled{4a} \xrightarrow{P_{const}} \textcircled{5} \xrightarrow{\text{Isentopic}} \textcircled{6} \qquad \textcircled{8} \xrightarrow{P_{const}} \textcircled{1}$

1:
$x_1 = 0$
$P_1 = 10\,kPa$
$T_1 = 45.81$
$v_1 = .001010$
$h_1 = 191.81$
$s_1 = .6492$

2:
$P_2 = 100\,kPa$
$h_2 = 191.90$

3:
$x_3 = 0$
$P_3 = 100\,kPa$
$T_3 = 99.61°C$
$v = .001043$
$h_3 = 417.51$
$s_3 = 1.3028$

4a:
$x = 0$
$P_4 = 3\,MPa$
$h_4 = 420.54$

5:
$P_5 = 3\,MPa$
$T_5 = 400°C$
$v_5 = .09938$
$h_5 = 3231.7$
$s_5 = 6.9235$

6:
$P_6 = 100\,kPa$
$s_6 = s_5 = 6.9235$
$s_f < s_6 < s_g \Rightarrow$ Mix
$s_f = 1.3028$
$s_{fg} = 6.0562$

8:
$P_8 = 10\,kPa$
$s_8 = s_5 = 6.9235$
$s_f < s_8 < s_g \Rightarrow$ Mix
$s_f = .6492$
$s_{fg} = 7.4996$

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

$= 191.81 + .00101(100-10)\,kPa$

$\frac{191.81\,kJ}{kg} + \frac{.0909\,kPa\,m^3}{kg} \Big| \frac{1\,kJ}{1\,kPa\,m^3}$

$h_2 = 191.90$

$h_4 = h_3 + v_3(P_4 - P_3)$

$= 417.51 + .001043(3-.1)$

$h_4 = \frac{417.51\,kJ}{kg} + \frac{.001043\,m^3}{kg} \Big| 2.9\,MPa \Big| \frac{1\,kJ}{1\,kPa \cdot m^3} \Big| \frac{1000\,kPa}{1\,MPa}$

$h_4 = 420.54\,kJ/kg$

$x_6 = \frac{s_6 - s_f}{s_{fg}} = \frac{6.9235 - 1.3028}{6.0562} = .928$

$h_6 = h_f + x_6(h_{fg}) = 417.51 + .928(2257.5) = 2512.67\,kJ/kg$

$x_8 = \frac{s_8 - s_f}{s_{fg}} = \frac{6.9235 - .6492}{7.4996}$

$x_8 = .8366$

$h_8 = h_f + x_8(h_{fg})$

$= 191.81 + .8366(2392.1)$

$h_8 = 2193.1\,kJ/kg$

Control Volume around FWH to solve for y

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

$\Rightarrow y = \frac{h_3 - h_2}{h_6 - h_2} = \frac{417.51 - 191.9}{2512.67 - 191.9} = .097$

MET350

TEST 3-1

ML SUNDERLAND

MET 350 | TEST 3-1 | ML SUNDERLAND | 5

Calculate specific work and thermal efficiency

$$\eta_t = \frac{w_{net}}{q_{in}}$$

$$= \frac{945.28}{2811.16}$$

$$\boxed{\eta_t = 33.63\%}$$

$$w_{net} = w_T - w_{p_1} - w_{p_1}$$

$*\ w_T = h_5 - y h_6 - (1-y) h_8)$

$3231.7 - .097(2512.67) - .930(2193.1)$

$w_t = 948.39\ \text{kJ/kg}$

$*\ w_{p_1} = (1-y)\, h_2 - h_1$

$= .930(191.9 - 191.81)$

$w_{p_1} = .0837\ \text{kJ/kg}$

$*\ w_{p_2} = 1\,(h_4 - h_3)$

$= 420.54 - 417.51$

$w_{p_2} = 3.03\ \text{kJ/kg}$

$*\ w_{net} = 948.39 - .0837 - 3.03$

$$\boxed{w_{net} = 945.28\ \text{kJ/kg}}$$

$q_{in} = h_5 - h_4$

$= 3231.7 - 420.54$

$q_{in} = 2811.16\ \text{kJ/kg}$

MET350	TEST 3-2	M.L. SUNDERLAND	1A

Purpose

Given specifications for a water cogeneration stm cycle calculate the following parameters if stm trap is clogged!

a) rate of heat transfer in Stm Gen.

b) net power produced by turbines

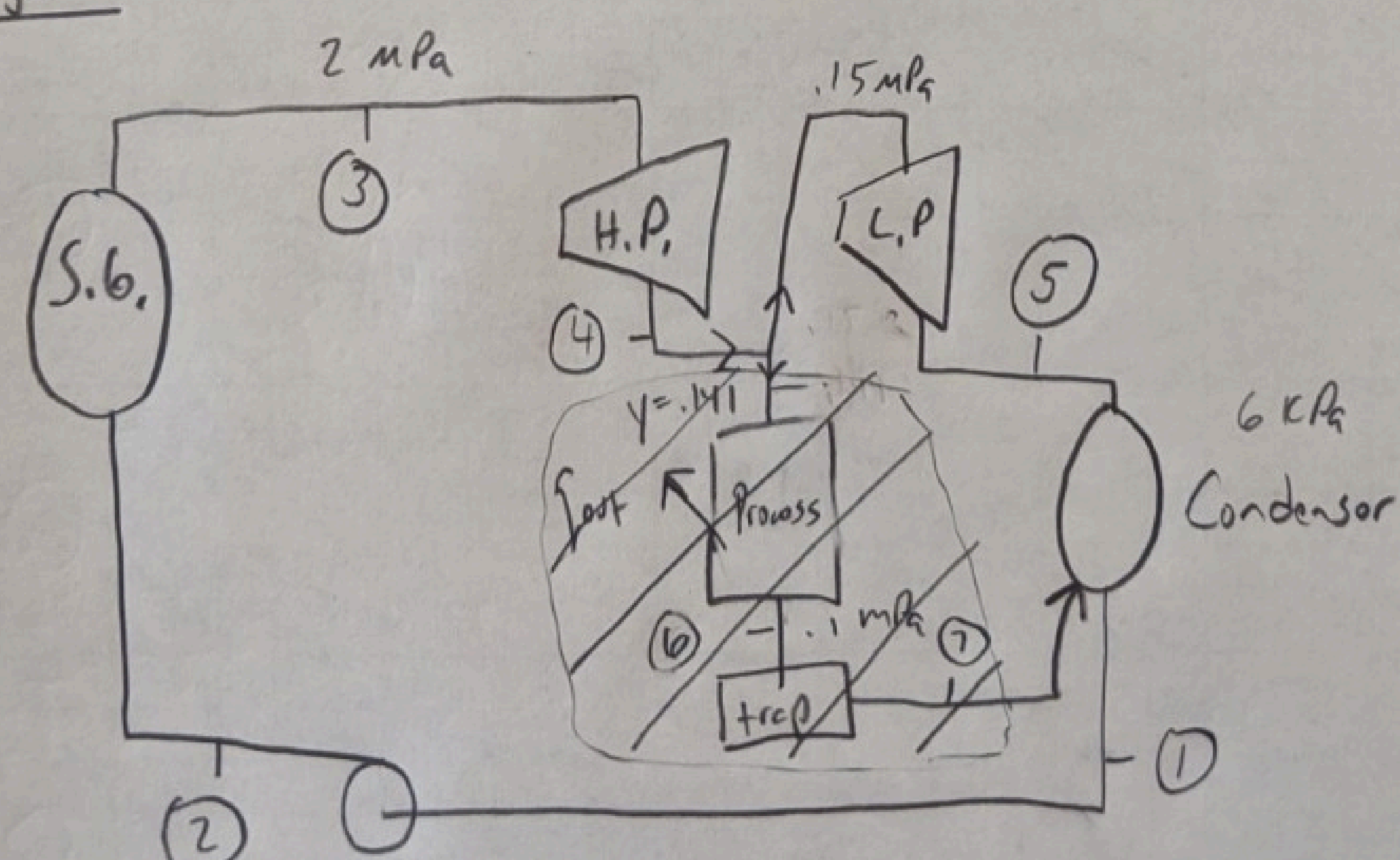
c) rate of heat transfer for building heating

d) rate of heat transfer in condensor

e) Utilization factor

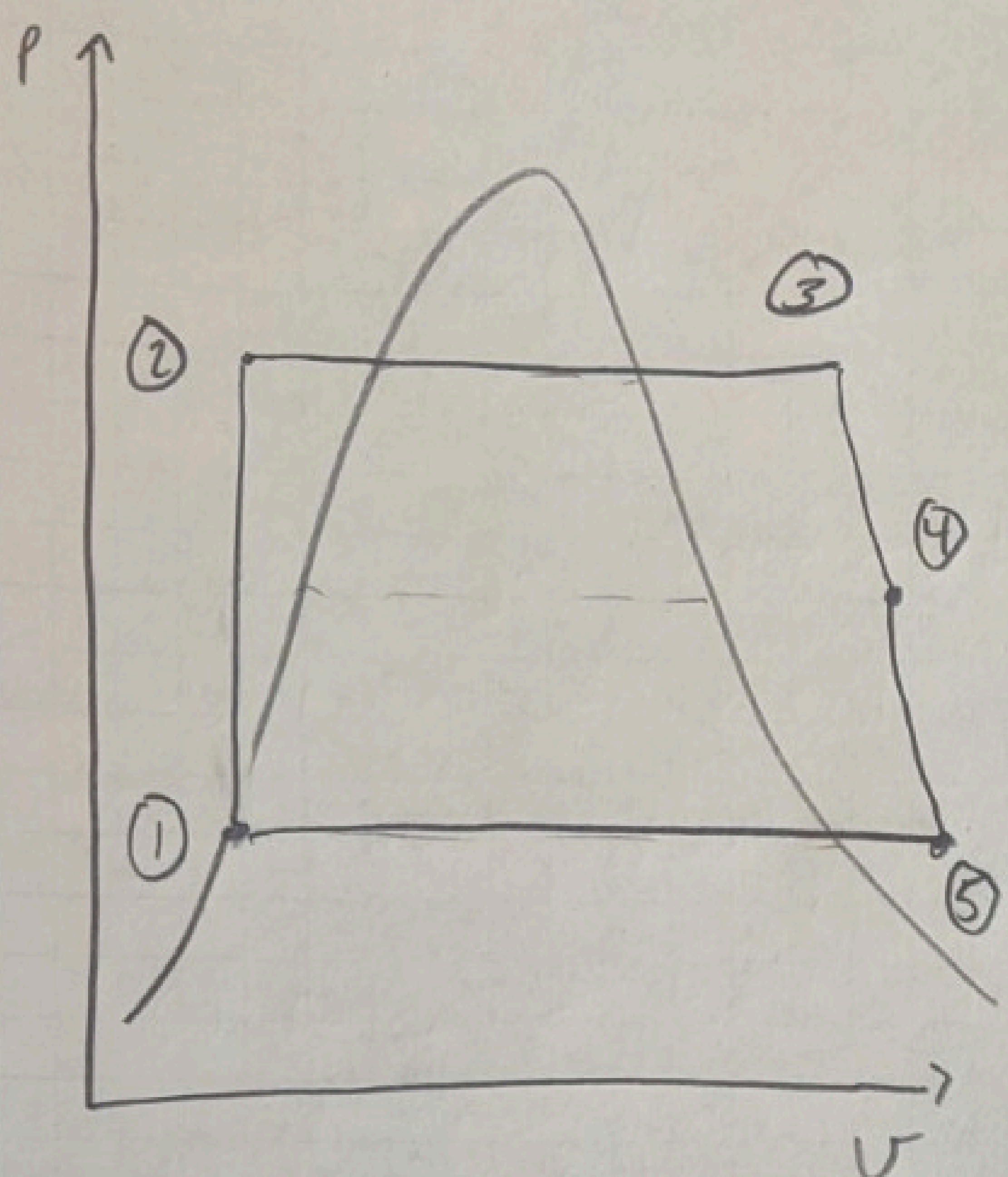
f) Thermal efficiency considering cycle does not heat building. (No stm extracted between HP + LP turbines.

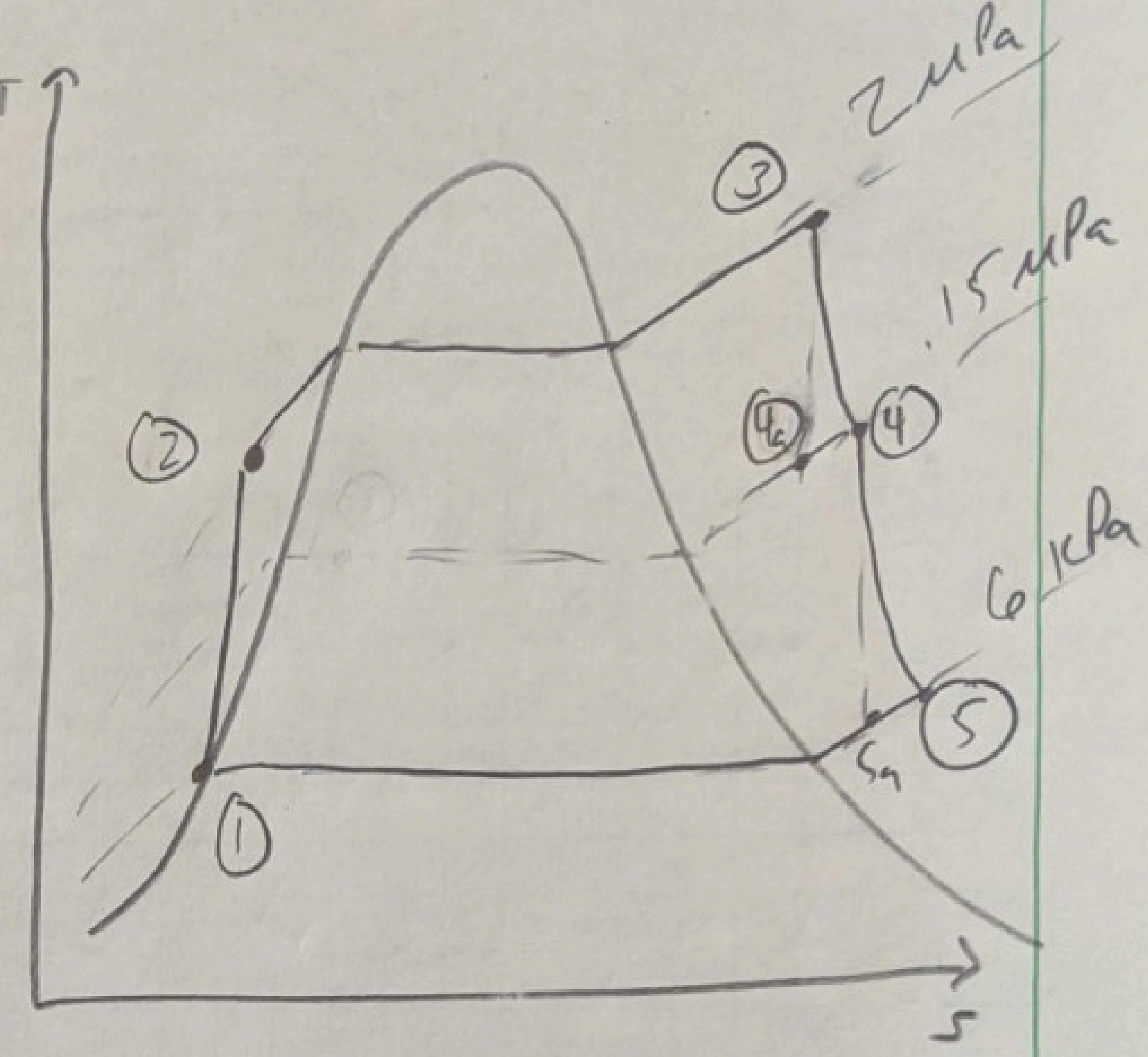
Drawings



MET 350	TEST 3-2	ML SUNDERLAND

B





Because the stm trap is clogged, there is no heat transfer in process and can be ignored in cycle diagrams

Sources

Cengel + Boles, "Thermodynamics - An Engineering Approach," 8th Edition, McGraw-Hill. 2015

Design Considerations

1) Water is pure
2) Pump is isentropic
3) Turbines have $\eta_t = .8$
4) No heat losses in connectors or pipes. Disregard fluid friction losses

MET350	TEST 3-2	ML SUNDERLAND	C

Data + Variables

Boiler produces steam @ 2 MPa, 320°C

$\dot{m}_{stm} = 0.82$ kg/s

P @ HP exhaust = 0.15 MPa

P @ LP exhaust = 6 KPa

$\eta_{turbines} = 80\%$

Trap is blocked

Procedure

Get states using Tables A-4, A-5, A-6

And the following equations

$h_2 = h_1 + v(P_2 - P_1)$ Pump only

$X_i = \dfrac{s_i + s_f}{s_{fg}}$ $\quad h_i = h_f + x_i h_{fg}$

$q_{out} = h_5 - h_1 = q_{cond}$ $\quad q_{in} = h_3 - h_2 = q_{5.6.}$

$\varepsilon_u = \dfrac{\dot{W}_{net} + \cancel{\dot{Q}_{process}}^{\,0}}{\dot{Q}_{in}}$ $\quad \dot{W} = \dot{m} q$

$\eta_t = \dfrac{h_3 - h_4}{h_3 - h_{4a}}$

MET 350

TEST 3-2

M L SUNDERLAND

$\textcircled{1} \xrightarrow[\text{Pump}]{\text{isentropic}} \textcircled{2} \xrightarrow{P_{const}} \textcircled{3} \xrightarrow{\eta_T = .8} \textcircled{4} \quad \textcircled{4a} \quad \textcircled{5} \quad \textcircled{5a}$

isent

$\eta = .8$

isent

①
$P_1 = 6$ kPa
$x_1 = 0$
$v_1 = .0010062$ m³/kg
$h_1 = 150.15$ kJ/kg

②
$P_2 = 2$ MPa
$h_2 = 152.16$ kJ/kg

③
$P_3 = 2$ MPa
$T_3 = 320°C$
$h_3 = 3069.6$ kJ/kg
$s_3 = 6.8444$

④
$P_4 = .15$ MPa
$h_4 = 2651.94$
$s_4 = 7.2231$

④a
$s_{4a} = s_3 = 6.8444$
$h_{4a} = 2547.52$ kJ/kg
$P_{4a} = .15$ MPa

$$X_{4a} = \frac{s_{4a} - s_f}{s_{fg}} = \frac{6.8444 - 1.4337}{5.7894}$$

$X_{4a} = .9346$

$h_{4a} = h_f + x_{4a}(h_{fg})$

$= 467.13 + .9346(2226)$

$h_{4a} = 2547.52$ kJ/kg

⑤
$P_5 = 6$ kPa
$h_5 = 2308.11$

⑤a
$s_4 = s_{5a} = 7.2231$
$P_{5a} = 6$ kPa
$s_f = .51624$
$s_{fg} = 7.82008$
$h_f = 150.15 \quad h_{fg} = 2415.92$

$$X_{5a} = \frac{s_{5a} - s_f}{s_{fg}} = \frac{7.2231 - .51624}{7.82008}$$

$X_{5a} = .8576$

$h_{5a} = h_f + x_{5a}(h_{fg})$

$= 150.15 + .8576(2415.92)$

$h_{5a} = 2222.15$ kJ/kg

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

$$= 150.15 + \frac{.0010062 \text{ m}^3}{\text{kg}} \left| \frac{1994 \text{ kPa}}{} \right| \frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}$$

$h_2 = 152.16$ kJ/kg

HP Turbine

$$\eta_T = \frac{h_3 - h_4}{h_3 - h_{4a}}$$

$h_4 = h_3 - \eta_T(h_3 - h_{4a})$

$h_4 = 2651.94$

LP Turbine

$h_5 = h_4 - \eta_T(h_4 - h_{5a})$

$= 2651.94 - .8(2651.94 - 2222.15)$

$h_5 = 2308.11$ kJ/kg

$$\dot{Q}_{s/g} = \dot{m}_{stm}(h_3 - h_2)$$

$$= .82\,\frac{kg}{s}\left|\frac{(3069.6 - 152.16)\,kJ}{kg}\right.$$

a) $\boxed{\dot{Q}_{s/g} = 2392.3\ kW}$

$$\dot{W}_{net} = \dot{m}\,w_{net}$$

$$= .82\,\frac{kg}{s}\left|\frac{759.48\,kJ}{kg}\right.$$

b) $\boxed{\dot{W}_{net} = 622.77\ kW}$

c) $\boxed{\dot{Q}_{process} = 0\ kW}$

$w_{net} = w_{out} - w_{in}$

$w_{net} = 761.49 - 2.01 = \underline{759.48\ kJ/kg}$

$w_{out} = w_{T_1} + w_2$

$= h_3 - \cancel{h_4} + \cancel{h_4} - h_5$

$= h_3 - h_5 = 3069.6 - 2308.11$

$w_{out} = 761.49\ kJ/kg$

$w_{in} = h_2 - h_1 = 152.16 - 150.15$

$w_{in} = 2.01\ kJ/kg$

d) $\dot{Q}_{cond} = \dot{m}(h_5 - h_1)$

$$= .82\,\frac{kg}{s}\left|\frac{(2308.11 - 150.15)\,kJ}{kg}\right.$$

$\boxed{\dot{Q}_{cond} = 1769.53\ kW}$

e) $\varepsilon_u = \dfrac{\dot{W}_{net} + \cancel{\dot{Q}_{process}}^{\,0}}{\dot{Q}_{in}} = \dfrac{622.77}{2392.3} = .26 \Rightarrow \boxed{26\ \%}$

f) $\eta_t = \dfrac{\dot{W}_{net}}{\dot{Q}_{in}} = \boxed{26\ \%}$