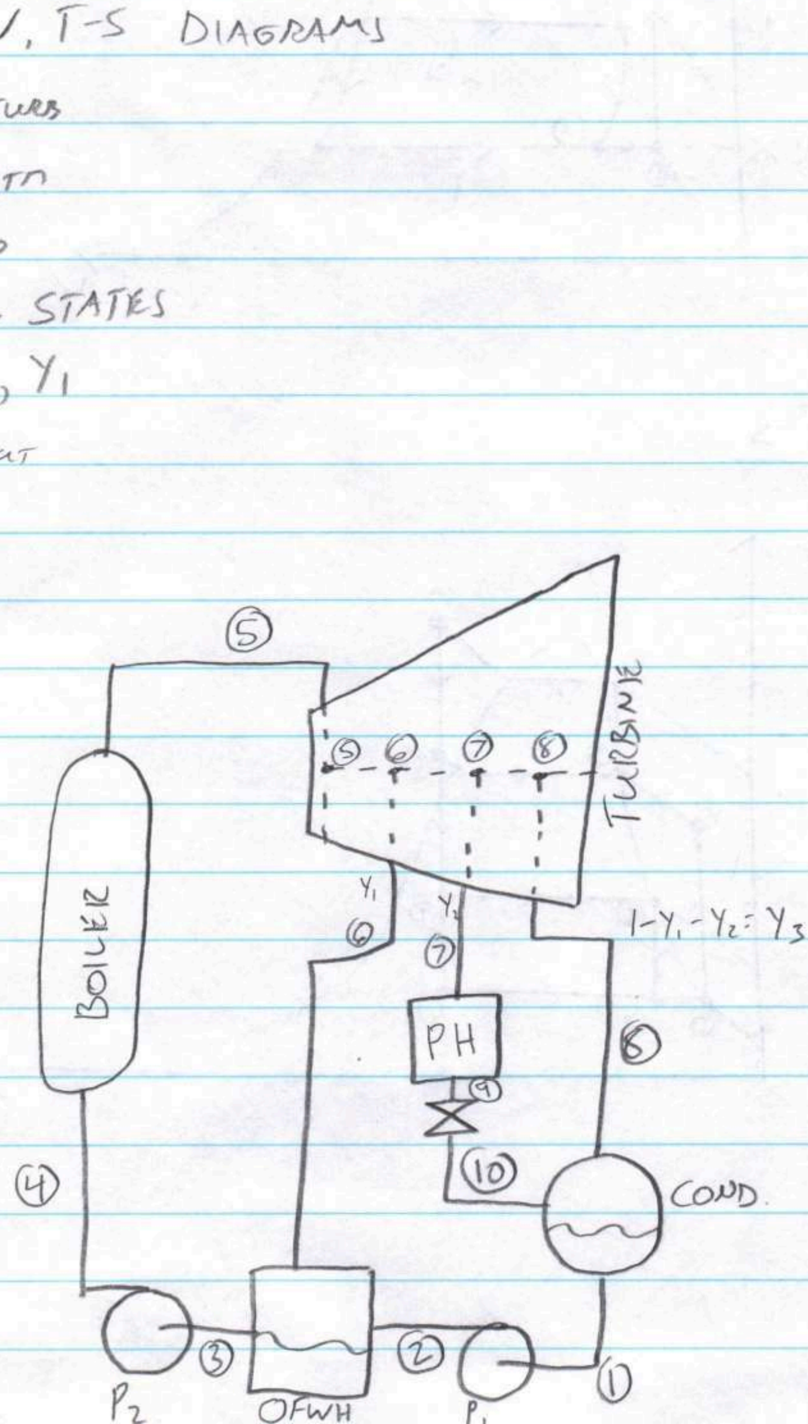
GOLDMAN TEST 2

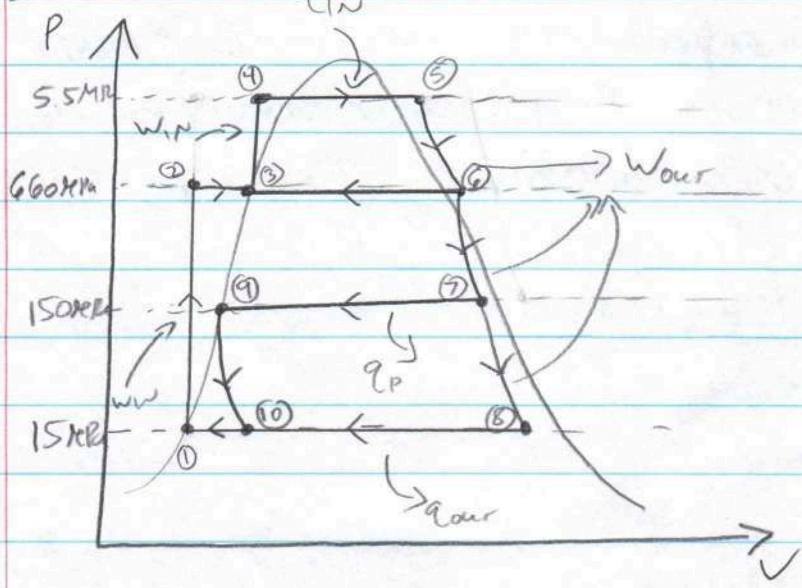
1 PURPOSE: THE PURPOSE OF THIS TEST/PROBLEM IS TO DEMONSTRATE THE ABILITY TO CREATE A SYSTEM FROM A DESCRIPTION, SOLVE FOR EACH STATE, AND OTHER VARIABLES, SPECIFICALLY:

a) ϵ_u
b) P-V, T-S DIAGRAMS
c) W_{TURB}
d) $\dot{m}_{STM}$
e) q_P
f) ALL STATES
g) Y_2, Y_1
h) q_{OUT}

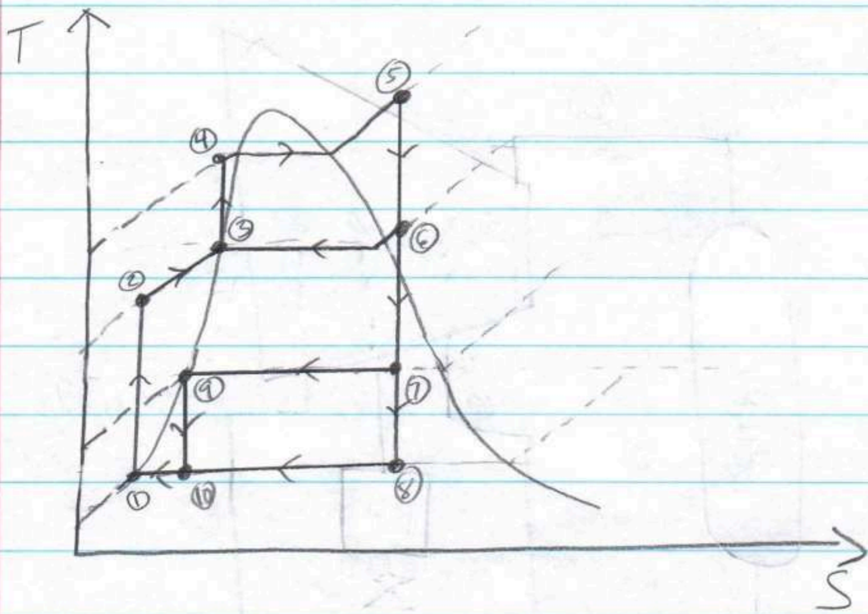
2. DRAWINGS



P–V



T–S



④ SOURCES: "THERMODYNAMICS, AN ENGINEERING APPROACH" 6TH EDITION, YUNUS A. CENGAL MICHAEL A. BOLES

ODU CLASS NOTES.

④ DESIGN CONSIDERATIONS:

ASSUMPTIONS: - ALL LIQUID GOING INTO A PUMP IS SATURATED

- ALL STEAM ENTERING A TURBINE IS SUPERHEATED
- $Y_1 = Y_2$

(F) ⑤ DATA AND VARIABLES.

SAT LIQ. → ① —ISENTROPIC PUMP→ ② → SAT LIQ. ③ —ISENTROPIC PUMP→ ④ → ⑤ —ISENTROPIC→

①	②	③	④	⑤
$P_1 = 15\,kPa$	$P_2 = 660\,kPa$	$P_3 = 660\,kPa$	$P_4 = 5.5\,MPa$	$P_5 = 5.5\,MPa$
$T_1 = 53.9°C$	$h_2 = 226.59\,kJ/kg$	$V_3 = .001105\,m^3/kg$	$h_4 = 692\,kJ/kg$	$T_5 = 500°C$
$V_1 = .001014\,m^3/kg$		$h_3 = 686.66\,kJ/kg$		$h_5 = 3428.9\,kJ/kg$
$h_1 = 225.94\,kJ/kg$				$S_5 = 6.93\,kJ/kg\cdot K$
$S_1 = .7549\,kJ/kg\cdot K$				

⑥ —ISENTROPIC→ ⑦ —ISENTROPIC→ ⑧ SAT LIQ. ⑨ —ISENTHALPIC→ ⑩

⑥	⑦	⑧	⑨	⑩
$P_6 = 660\,kPa$	$P_7 = 150\,kPa$	$P_8 = 15\,kPa$	$P_9 = 150\,kPa$	$P_{10} = 15\,kPa$
$S_6 = 6.93\,kJ/kg\cdot K$	$S_7 = 6.93\,kJ/kg\cdot K$	$S_8 = 6.93\,kJ/kg\cdot K$	$h_9 = 467.13\,kJ/kg$	$h_{10} = 467.13\,kJ/kg$
$h_6 = 2882.77\,kJ/kg$	$h_7 = 2581.83\,kJ/kg$	$h_8 = 2242.4\,kJ/kg$		

6) PROCEDURE: - SOLVE STATES

7 - ANSWER PROBLEM ASKED.

7. CALCULATIONS:

STATE 1 FOUND USING SAT LIQUID TABLE.

$\Rightarrow T_1 = 53.9°C$

$V_1 = .001014 \, m^3/kg$

$h_1 = 225.94 \, kJ/kg$

$S_1 = .7549 \, kJ/kg \cdot K$

FROM 1ST LAW:

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

$$h_2 = .001014 \, m^3/kg(660 kPa - 15 kPa) + 225.94 \, kJ/kg$$

$$h_2 = 226.59 \, kJ/kg$$

STATE 3 FOUND USING SAT LIQUID TABLE

$\Rightarrow V_3 = .001105 \, m^3/kg$

$h_3 = 686.66 \, kJ/kg$

STATE 5 FOUND USING SUPERHEATED TABLES.

$\Rightarrow h_5 = 3428.9 \, kJ/kg$

$S_5 = 6.93 \, kJ/kg \cdot K$

STATE 5 → 6 → 7 → 8 ARE ISENTROPIC

$\Rightarrow S_5 = S_6 = S_7 = S_8$

I NEED TO FIND THE QUALITIES OF THESE STATES.

$$S_6 = S_F + X S_{FG}$$

$$6.93\,kJ/kg\cdot K = 1.9682\,kJ/kg\cdot K + X(4.75898\,kJ/kg\cdot K)$$

$X_6 = 1.04 \Rightarrow$ SUPERHEATED

$$S_7 = S_F + X S_{FG}$$

$$6.93\,kJ/kg\cdot K = 1.4337\,kJ/kg\cdot K + X(5.7894\,kJ/kg\cdot K)$$

$X_7 = .95 \Rightarrow$ MIX

$$S_8 = S_F + X S_{FG}$$

$$6.93\,kJ/kg\cdot K = .7549\,kJ/kg\cdot K + X(7.2522\,kJ/kg\cdot K)$$

$X_8 = .85 \Rightarrow$ MIX

h_6 FOUND USING INTERPOLATION AND ONLINE CALCULATOR.

$$h_6 = 2882.77\,kJ/kg$$

$h_7 = h_F + X h_{FG}$

$h_7 = 467.13\,kJ/kg + (.95)\,2226\,kJ/kg$

$h_7 = 2581.83\,kJ/kg$

$h_8 = h_F + X h_{Fg}$

$h_8 = 225.94 \text{ kJ/kg} + (.85)\, 2372.3 \text{ kJ/kg}$

$h_8 = 2242.4 \text{ kJ/kg}$

STATE 9 FOLLOWS USING SAT LIQUID TABLES

$h_9 = 467.13 \text{ kJ/kg}$

STATE 10 IS AFTER A THROTTLE VALVE.
THIS DOES NOT AFFECT h (ISENTHALPIC)

$\Rightarrow h_9 = h_{10}$

$h_{10} = 467.13 \text{ kJ/kg}$

$h_4 = V_3 (P_4 - P_3) + h_3$

$h_4 = .001105 \text{ m}^3/\text{kg} (5500 - 660) \text{kPa} + 686.66 \text{ kJ/kg}$

$h_4 = 692 \text{ kJ/kg}$

NOW WE NEED TO FIND Y_1, Y_2.

WE know $Y_1 = Y_2$

AND $1 - Y_1 - Y_2 = Y_3$

AND $Y_1 + Y_2 + Y_3 = 1$

WE CAN USE 1ST LAW TO GATHER EQUATIONS

$$\dot{m}h_3 = \dot{m}_{Y_1}h_6 + \dot{m}_{Y_2+Y_3}h_2$$
$$h_3 = Y_1h_6 + (Y_2+Y_3)h_2$$
$$h_3 = Y_1h_6 + h_2Y_2 + h_2Y_3$$
$$h_3 = Y_1h_6 + h_2Y_2 + h_2(1-Y_1-Y_2)$$
$$h_3 = Y_1h_6 + h_2Y_2 + h_2 - h_2Y_1 - h_2Y_2$$
$$h_3 = Y_1h_6 + h_2 - Y_1h_2$$
$$h_3 - h_2 = Y_1(h_6 - h_2)$$
$$Y = \frac{h_3-h_2}{h_6-h_2} = \frac{(686.66-226.59)\,kJ/kg}{(2882.77-226.59)\,kJ/kg}$$
(g) $\boxed{Y_1 = .17}$

$Y_1 = Y_2$

$\boxed{Y_2 = .17}$

AND $Y_3 = 1 - Y_1 - Y_2 = 1 - .17 - .17$

$Y_3 = .66$

$$\epsilon_u = \frac{\dot{W}_{net} + \dot{Q}_P}{\dot{Q}_{IN}} = \frac{W_{net} + q_P}{q_{IN}}$$

$$W_{net} = W_{TURB} - W_{pump1} - W_{pump2}$$
$$W_{TURB} = (h_5-h_6) + (1-Y_1)(h_6-h_7) + (1-Y_1-Y_2)(h_7-h_8)$$
$$W_{TURB} = ((3428.9-2882.77) + (1-.17)(2882.77-2581.83) + (1-.17-.17)(2581.83-2242.4))\,kJ/kg$$
$$W_{TURB} = (546.13 + 249.78 + 224.02)\,kJ/kg$$
(c) $\boxed{W_{TURB} = 1019.93\,kJ/kg}$ $\dot{W}_{TURB} = 50292.75\,kW$

$W_{pump1} = (h_2 - h_1)(1 - Y_1) = (1 - .17)(226.59 - 225.94)$ kJ/kg
$W_{pump1} = .54$ kJ/kg

$W_{pump2} = (h_4 - h_3) = (692 - 686.66)$ kJ/kg
$W_{pump2} = 5.34$ kJ/kg

$W_{net} = (1019.93 - .54 - 5.34)$ kJ/kg
$W_{net} = 1014.05$ kJ/kg

$q_p = (h_7 - h_9)Y_2 = (.17)(2581.83 - 467.13)$ kJ/kg
$q_p = 359.5$ kJ/kg

$q_{IN} = h_5 - h_4 = (3428.9 - 692)$ kJ/kg
$q_{IN} = 2736.9$ kJ/kg

$$\epsilon_u = \frac{W_{net} + q_p}{q_{IN}} = \frac{1014.05 \text{ kJ/kg} + 359.5 \text{ kJ/kg}}{2736.9 \text{ kJ/kg}}$$

(a) $\boxed{\epsilon_u = .502}$

$\dot{W}_{net} = \dot{m} W_{net}$
$50000 \text{ kW} = \dot{m}(1014.05 \text{ kJ/kg})$
(d) $\boxed{\dot{m} = 49.31 \text{ kg/s}}$

$\dot{Q}_P = \dot{m} q_P$

$\dot{Q}_P = 49.31 kg/s (359.5 kJ/kg)$

(e) $\boxed{\dot{Q}_P = 17725.95 kW}$

$q_{out} = h_8(1-Y_1-Y_2) + h_{10}(Y_1) - h_1(1-Y_1)$

$q_{out} = (2242.4(.66) + 467.13(.17) - 225.94(.83))\ kJ/kg$

(h) $\boxed{q_{out} = 1371.86 kJ/kg}$

$\dot{Q}_{out} = \dot{m} q_{out} = (49.31 kg/s)(1371.86 kJ/kg)$

$\boxed{\dot{Q}_{out} = 67646.7 kW}$

8. SUMMARY: AFTER DETERMING THAT THE SYSTEM HAD AN OPEN FWH, ANALYSIS WAS STRAIGHT FORWARD. ALSO, STUDYING WAS REQUIRED TO SURMIZE THAT 2 PUMPS WERE NEEDED IN THE SYSTEM TO PROVIDE PROPER PRESSURE TO THE BOILER.

9. MATERIALS: MATERIALS WERE NOT A CONSIDERED FACTOR IN THIS TEST.

10. ANALYSIS,: HAD THE STUDENT INCORRECTLY ASSUMED A CFWH, THE PROBLEM WOULD BECOME MUCH MORE DIFFICULT. THE STUDENT WAS REQUIRED TO NOTICE THAT 2 PUMPS WOULD BE REQUIRED w/ AN OFWH. ALSO, UNDERSTANDING THAT A THROTTLE VALVE IS ISENTROPIC IS ALSO CRUCIAL TO SOLVING THIS TEST.