Test 2

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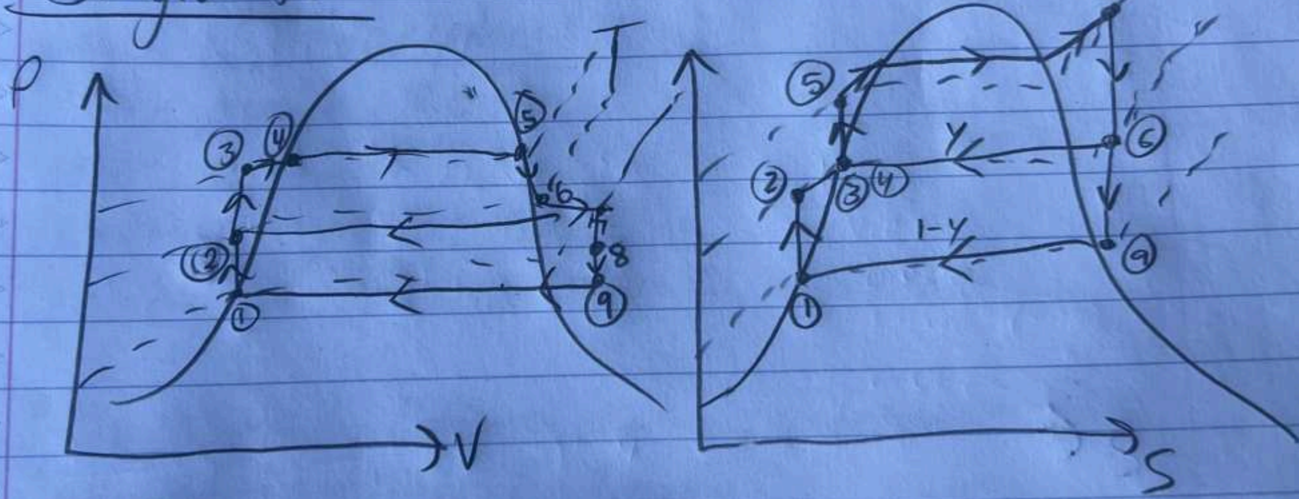
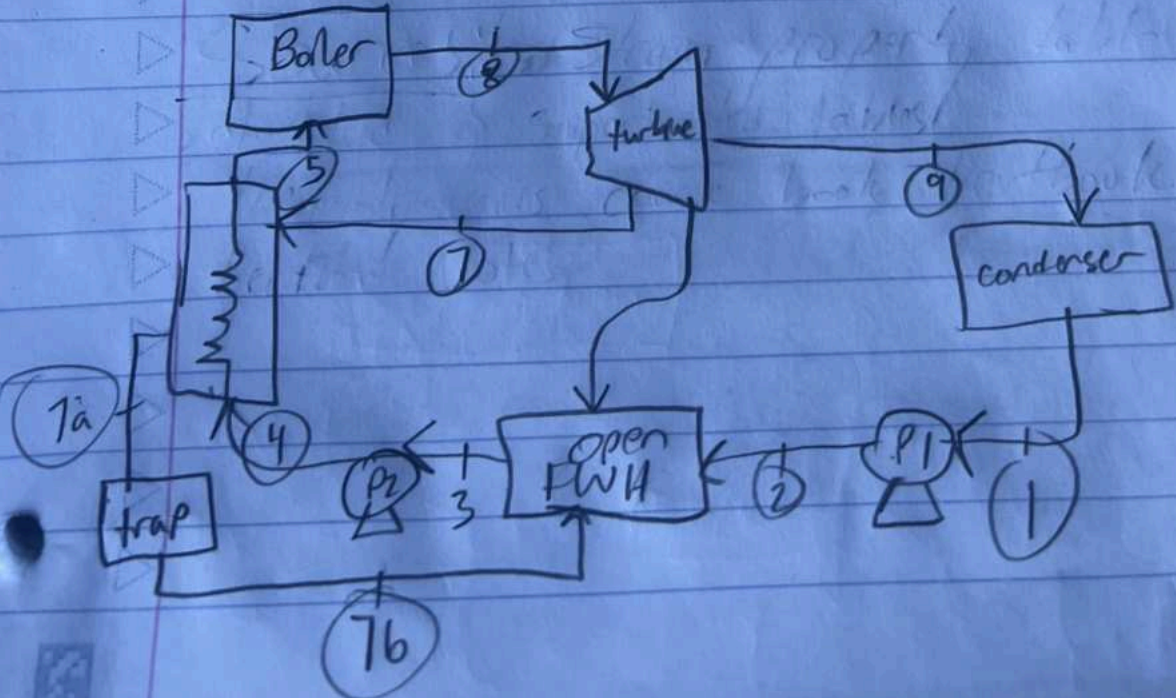
Purpose: The purpose is to analyze the performance of an ideal regenerative rankine cycle with a closed feedwater heater & an open heater. To evaluate how regeneration improves thermal efficiency. Also to examine the effect of a closed feedwater heater failure.

Diagrams:





Sources: . Steam property tables

. saturated & superheated tables

. Thermodynamics course book textbook

. Lectures

Design Considerations:

Turbine & pumps are isentropic
No heat losses to surroundings
Open water heater is saturated liquid
Closed water heater is saturated liquid
Condenser pressure is fixed at 10 kpa

Data & Variables:

Boiler pressure : 3.0 Mpa
inlet temp: 400°c
Condenser pressure: 10 kpa
Extraction pressure: 0.8Mpa & 100kpa

Materials: Steam tables, Calculator, equation sheet, & Pencil

Procedure & Calculations:

1) state identification, label all states in cycle

2) Determine enthalpy & entropy

Pump work calculations $h_{out} = h_{in} + v(P_{out} - P_{in})$

4) Turbine expansion $s_{in} = s_{out}$

5) work calculations

6) heat input

7) Efficiency

① → ② → ③ → ④ → ⑤ → ⑥ ← ⑦ ← ⑧ ; ⑥ → ⑨

$h_1 = 191.8$ kJ/kg
$v_1 = 0.00101$

$h_2 = 191.8 + 0.091$
$h_2 = 191.9$

$h_3 = 417$

$h_4 = 419 + 3$
$h_4 = 422$

$h_5 = 420.46$

$h_6 = 419 + 0.88(2257)$
$h_6 = 2512.61$

$h_7 = 720 + 0.94(2046)$
$h_7 = 2635$

$h_8 = 3231.57$ kJ/kg

$h_9 = 191.8 + 0.80(2392)$
$h_9 = 2105$

Calculations:

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

$h_3 = h_2 - yh_2 + yh_6$

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

$$\frac{h_3 - h_2}{h_6 - h_2} = \frac{417.44 - 191.9}{2512.61 - 191.90}$$

$y = 0.0972$

$Q_{in} = h_8 - h_5$

$= 3231.57 - 420.46$

$Q_{in} = 2811.11$ kJ/kg

$Q_{out} = (h_9 - h_1)(1 - y)$

$Q_{out} = (2192.98 - 191.81)(1 - 0.0972)$

$Q_{out} = 1806.66$ kJ/kg

$\eta_{th} = 1 - \frac{Q_{out}}{Q_{in}}$

$= 1 - \frac{1806.66}{2811.11}$

$\eta_{th} = 0.3573$

$\boxed{\eta_{th} = 35.73\%}$

$W_{net} = Q_{in} - Q_{out}$

$= 2811.11 - 1806.66$

$\boxed{W_{net} = 1004.45 \text{ kJ/kg}}$

Summary: A regen Rankine cycle significantly improves thermal efficiency by preheating feedwater. The system achieved a 35.73% efficiency. Although the system produced more work, it required more heat input, making less efficient. Feedwater heaters play a critical role in improving overall plant performance.

Analysis: The feedwater heater improves cycle performance by increasing the average temp at which heat is added, which enhances thermal efficiency. In the full system, steam extraction reduces the mass flow through the turbine, decreasing turbine work but lowering the heat input required. This highlights the trade off between maximizing work output & improving thermal efficiency.