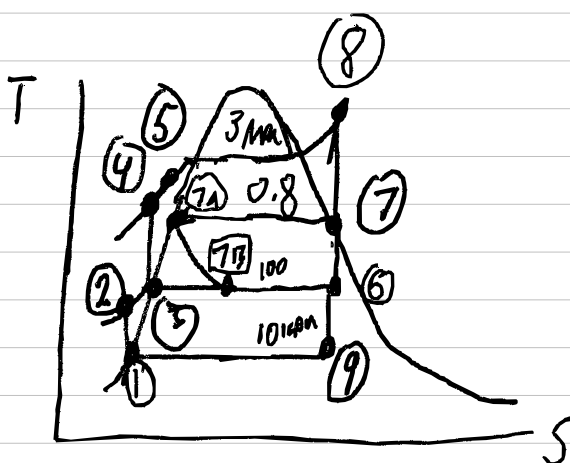
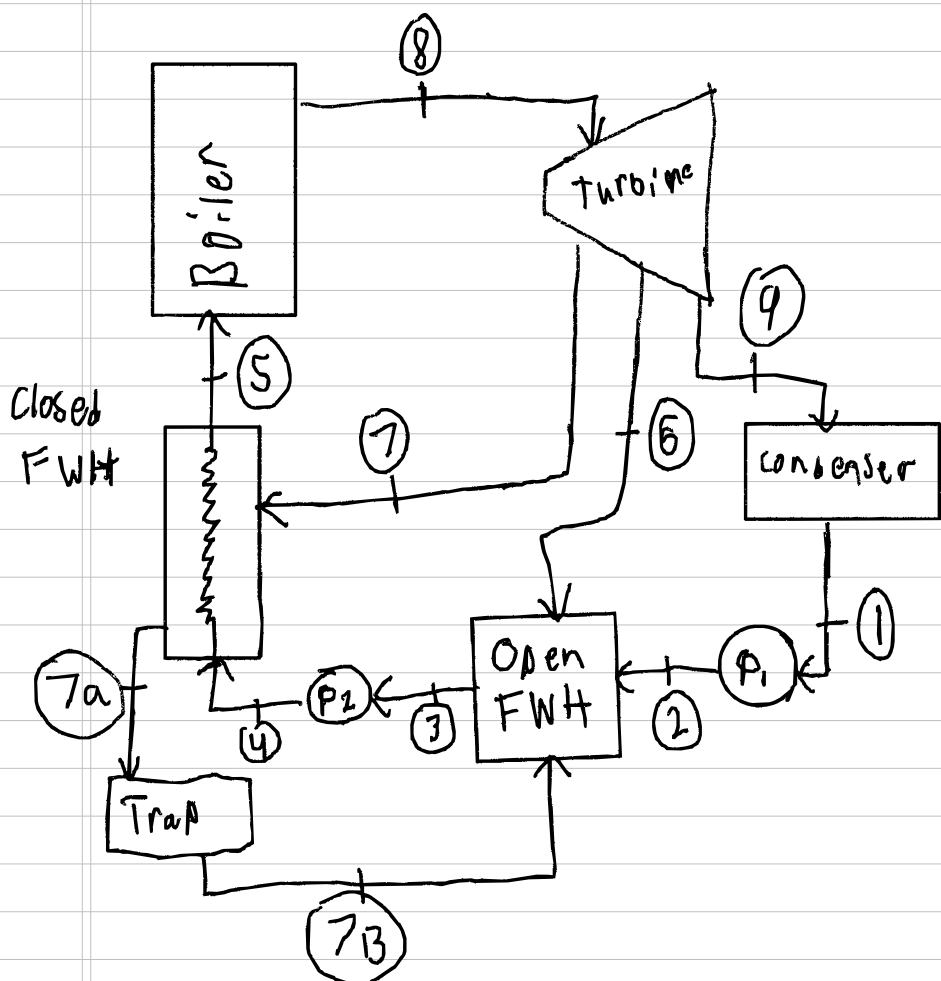


Purpose: To calculate specific net work and thermal efficiency of a ideal steam regenerative cycle and a steam regenerative cycle without a closed FWH and trap.

Diagrams:



Sources:

Cengel & Boles, Thermodynamics - An Engineering Approach 8th edition
Mc Graw Hill, 2015

Design considerations:

- Saturated liquid
- Pumps are Isentropic
- $\Delta KE = 0 / \Delta PE = 0$

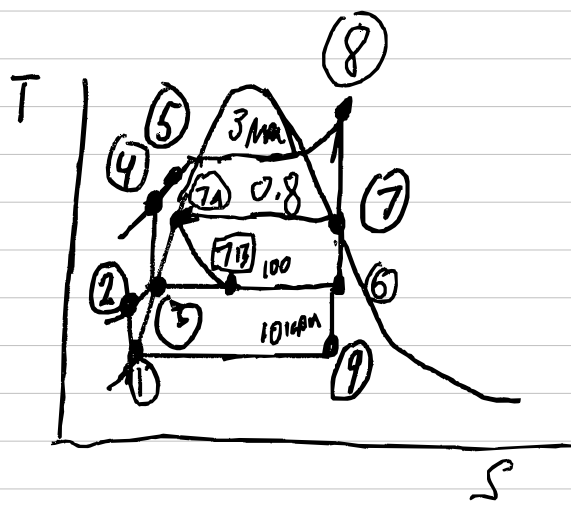
Data and Variables

$$P_1 = 10 \text{ kPa} \quad P_8 = 3 \text{ MPa} \quad T_8 = 400^\circ\text{C}$$

$$P_2 = 100 \text{ kPa} \quad P_7 = 0.8 \text{ MPa}$$

$$P_{7A} = 0.8 \text{ MPa}$$

Procedure and calculations



$$(1) P_1 = 10 \text{ kPa}$$

$$h_1 = 191.81 \text{ kJ/kg}$$

$$v_1 = 0.001$$

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

$$h_2 = 191.81 + 0.001(100 - 10) = 191.9 \text{ kJ/kg}$$

$$(3)$$

$$P_3 = 100 \text{ kPa}$$

$$w_{p2} = v_3(P_4 - P_3)$$

$$h_3 = 417.51 \text{ kJ/kg}$$

(tables)

$$v_3 = 0.001043 \text{ m}^3/\text{kg}$$

$$w_{p2} = 0.001043(3000 - 100)$$

$$w_{p2} = 3.0247 \text{ kJ/kg}$$

$$(4) h_4 = h_3 + w_{p2} = 417.51 + 3.0247$$

$$h_4 = 420.53 \text{ kJ/kg}$$

$$(7A)$$

$$P_{7A} = 0.8 \text{ MPa}$$

$$T_{7A} = T_5 \rightarrow h_5 = 720.87 \text{ kJ/kg}$$

$$h_{7A} = 720.87 \text{ kJ/kg}$$

(tables)

$$T_{7A} = 170.41^\circ\text{C}$$

$$h_{7B} = 720.87$$

$$(8)$$

$$P_8 = 3 \text{ MPa}$$

$$h_8 = 3231.7 \text{ kJ/kg}$$

$$T_8 = 400^\circ\text{C}$$

$$s_8 = 6.4235 \text{ kJ/kg}\cdot\text{K}$$

$$(7)$$

$$P_7 = 0.8 \text{ MPa}$$

$$h_7 = 2917.13 \text{ kJ/kg}$$

$$s_7 = s_8$$

(Steam interpolation calculator)

$$(6)$$

$$P_6 = 100 \text{ kPa}$$

$$x = \frac{6.4235 - 1.3028}{7.3589 - 1.3028}$$

$$s_6 = s_8$$

$$x = 0.93$$

$$h_6 = h_f + x(h_g - h_f) = 417.51 + 0.93(2675.0 - 417.51)$$

$$h_6 = 2516.98 \text{ kJ/kg}$$

$$(9)$$

$$P_9 = 10 \text{ kPa}$$

$$x_9 = \frac{8.9235 - 0.6492}{7.4996}$$

$$s_9 = s_8$$

$$x_9 = 0.8366$$

$$h_9 = h_f + x_{11} h_{fg} = 191.81 + (0.8366)(2392.1)$$

$$h_9 = 2193.041 \text{ kJ/kg}$$

All (h) calculated

Now solve for wet and η_{th}

$$Y = \frac{h_5 - h_4}{h_7 - h_{7A}} = \frac{720.87 - 420.53}{2917.13 - 720.87}$$

$$Y = 0.137$$

$$\Delta E = 0 \quad \dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_{10} h_{10} = \dot{m}_3 h_3$$

$$\Delta E_{in} = \Delta E_{out} \quad Y h_7 + (1 - Y - Z) h_2 + Z h_{10} = h_3$$

$$Z = \frac{(h_3 - h_2) - Y(h_{10} - h_2)}{h_{10} - h_2}$$

$$Z = \frac{(417.5 - 191.9) - (0.137)(720.87 - 191.9)}{(2516.98 - 191.9)}$$

$$Z = 0.0659$$

$$q_{in} = h_8 - h_5 = 3231.7 - 720.87 = 2510.83 \text{ kJ/kg}$$

$$q_{out} = (1 - Y - Z)(h_9 - h_1) = (1 - 0.137 - 0.0659) \cdot (2193.041 - 191.81)$$

$$q_{out} = 1595.181 \text{ kJ/kg}$$

$$W_{net} = q_{in} - q_{out} = 2510.83 - 1595.181$$

$$W_{net} = 915.649 \text{ kJ/kg}$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1595.181}{2510.83}$$

$$\eta_{th} = 0.364 \cdot 100 = 36.47\%$$

②

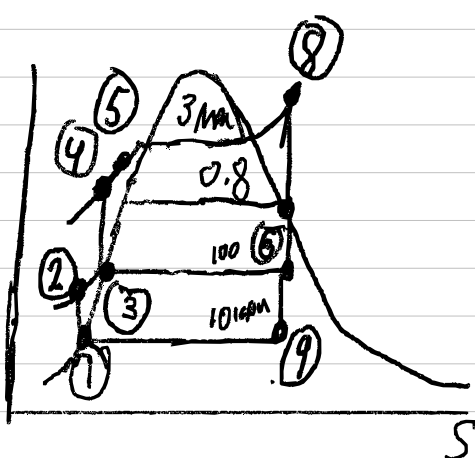
$$h_1 = 191.81 \frac{\text{kJ}}{\text{kg}}$$

$$h_2 = 191.9 \frac{\text{kJ}}{\text{kg}}$$

$$h_3 = 417.51 \frac{\text{kJ}}{\text{kg}}$$

$$h_4 = 420.53 \frac{\text{kJ}}{\text{kg}}$$

~~$$h_5 = 720.87 \frac{\text{kJ}}{\text{kg}}$$~~



- Find W_{net}

$$h_6 = 2516.98 \frac{\text{kJ}}{\text{kg}}$$

- Find η_{th}

~~$$h_7 = 2917.13 \frac{\text{kJ}}{\text{kg}}$$~~

~~$$h_{7A} = 720.87 \frac{\text{kJ}}{\text{kg}}$$~~

~~$$h_{7B} = 720.87$$~~

$$h_8 = 3231.7 \frac{\text{kJ}}{\text{kg}}$$

$$h_9 = 2193.041 \frac{\text{kJ}}{\text{kg}}$$

Find z : $(1-z)h_2 + zh_6 = 0.1h_3$

$$h_2 - zh_2 + zh_6 = h_3$$

$$191.9 - z(191.9) + z(2516.98) = 417.51$$

$$191.9 + 2325.08z = 417.51$$

$$\frac{2325.08z}{2325.08} = \frac{225.61}{2325.08}$$

$$z = 0.097$$

$$q_{in} = h_8 - h_4 = 3231.7 - 420.53$$

$$q_{in} = 2811.17 \frac{\text{kJ}}{\text{kg}}$$

$$q_{out} = (1-z)(h_9 - h_1) = (1-0.097)(2193 - 191.81)$$

$$q_{out} = 1807.07 \frac{\text{kJ}}{\text{kg}}$$

$$W_{net} = q_{in} - q_{out} = 2811.17 - 1807.07$$

$$W_{net} = 1004.1 \frac{\text{kJ}}{\text{kg}}$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1807.07}{2811.17}$$

$$\eta_{th} = 0.357 \cdot 100 = 35.7\%$$

Summary:

Table of W_{net} and η_{th} for Both Setups

	W_{net}	η_{th}
Setup 1	$915.649 \frac{\text{kJ}}{\text{kg}}$	36.47%
Setup 2	$1004.1 \frac{\text{kJ}}{\text{kg}}$	35.7%

Analysis:

With the closed FWH and the steam trap it had less specific net work but a greater thermal efficiency than the setup without the closed FWH and steam trap. It was roughly a 100 kJ/kg difference in specific net work and a roughly 1% difference in thermal efficiency.