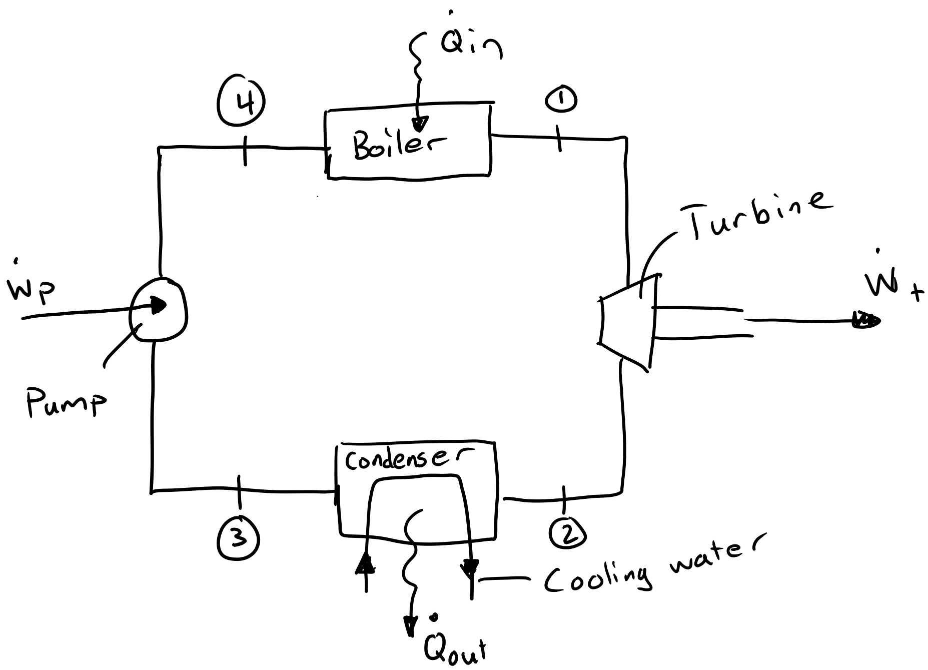
Vapor Power System: Fluid is alternately vaporized and condensed

Ideal Rankine Cycle



Process 1-2 (Turbine)

Isentropic Expansion from saturated vapor to the condenser pressure

$$0 = \dot{Q}_{cv}^{\nearrow 0} - \dot{W}_{cv} + \dot{m}\left(h_1 - h_2 + \Delta KE^{\nearrow 0} + \Delta PE^{\nearrow 0}\right)$$

$$\dot{W}_{cv} = \dot{W}_t$$

$$\boxed{\frac{\dot{W}_t}{\dot{m}} = h_1 - h_2}$$

Process 2-3 (Condenser)

Constant pressure heat transfer to saturated liquid (condensation)

$$0 = \dot{Q}_{cv} - \dot{W}_{cv}^{\nearrow 0} + \dot{m}\left(h_2 - h_3\right)$$

$$\dot{Q}_{cv} = -\dot{Q}_{out}$$ (out of the system)

$$\boxed{\frac{\dot{Q}_{out}}{\dot{m}} = h_2 - h_3}$$

Process 3-4 (Pump)

Isentropic compression to the boiler pressure

$$0 = \cancel{\dot{Q}_{cv}}^{0} - \dot{W}_{cv} + \dot{m}(h_3 - h_4)$$

$$\dot{W}_{cv} = -\dot{W}_p$$

$$\boxed{\frac{\dot{W}_p}{\dot{m}} = h_4 - h_3}$$

Note: For a pump,

$$\left(\frac{\dot{W}_p}{\dot{m}}\right)_{\substack{int\\rev}} \approx v_3(P_4 - P_3) \Rightarrow \text{Avoids Double Interpolation}$$

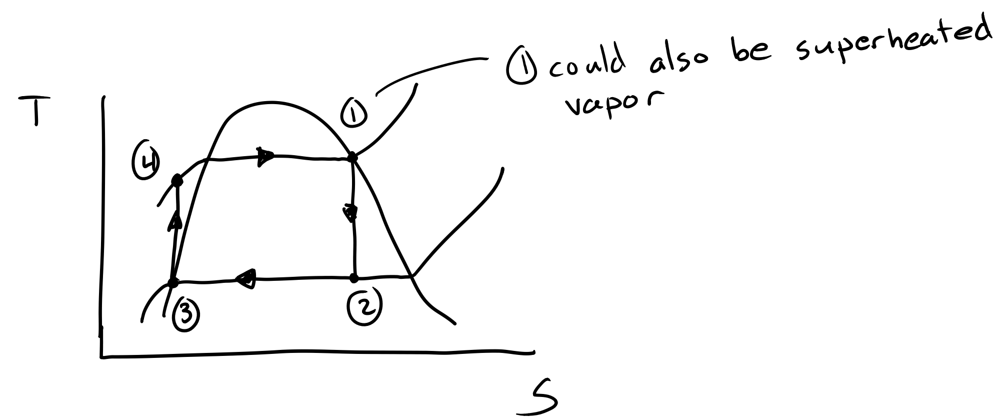
Process 4-1 (Boiler)

Constant pressure heat transfer to saturated vapor (expansion)

$$0 = \dot{Q}_{cv} - \cancel{\dot{W}_{cv}}^{0} + \dot{m}(h_4 - h_1)$$

$$\dot{Q}_{cv} = \dot{Q}_{in}$$

$$\boxed{\frac{\dot{Q}_{in}}{\dot{m}} = h_1 - h_4}$$



Thermal Efficiency

$$\eta = \frac{\dot{W}_{cycle}/\dot{m}}{\dot{Q}_{in}/\dot{m}} = \frac{\dot{W}_t/\dot{m} - \dot{W}_p/\dot{m}}{\dot{Q}_{in}/\dot{m}} = 1 - \frac{\dot{Q}_{out}/\dot{m}}{\dot{Q}_{in}/\dot{m}}$$

$$\dot{W}_{cycle} = \dot{Q}_{cycle}$$

Heat Rate

$$\text{Heate Rate} = 1/\eta$$

Back Work Ratio

$$bwr = \frac{\dot{W}_p/\dot{m}}{\dot{W}_t/\dot{m}}$$

Comparison of the Rankine Cycle to the Carnot Cycle

- Carnot is more efficient

But,

- For the boiler, the temperature for Rankine Cycle starts below T_H, while the Carnot cycle starts at T_H
- For the pump, the Rankine Cycle uses all liquid, while the Carnot Cycle uses a Two-Phase Liquid-Vapor mixture