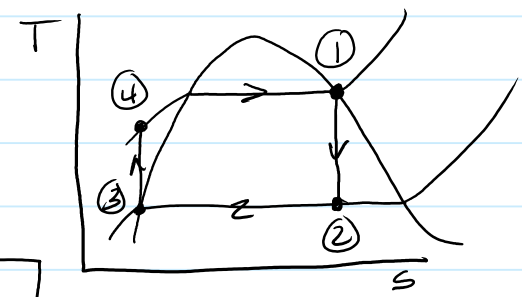
Vapor Power Cycle Example

Given:
- Water in an Ideal Rankine Cycle
- Condenser Pressure = 8 kPa
- Saturated Vapor enters the turbine at 18 MPa

Determine:
- The net work and net heat transfer in kJ/kg
- Thermal Efficiency

State ①	State ②	State ③	State ④
$P_1 = 18$ MPa	$P_2 = 8$ kPa $= 0.008$ MPa	$P_3 = 0.008$ MPa	$P_4 = 18$ MPa
Sat Vapor	$s_2 = s_1$	Sat Liquid	$s_4 = s_3$



1-2

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

Table W-2

@ $P_1 = 18$ MPa

$$\boxed{h_1 = h_{g_1} = 2509.1 \text{ kJ/kg}}$$

$$s_1 = s_{g_1} = 5.1044 \text{ kJ/kg}\cdot\text{K}$$

@ $P_2 = 0.008$ MPa

$h_{f_2} = 173.88$ kJ/kg $h_{g_2} = 2577.0$ kJ/kg

$s_{f_2} = 0.5926$ kJ/kg·K $s_{g_2} = 8.2287$ kJ/kg·K

$s_2 = s_1 = 5.1044$ kJ/kg·K

$$s_2 = s_{f_2} + x_2(s_{g_2} - s_{f_2})$$

$$5.1044 = 0.5926 + x_2(8.2287 - 0.5926)$$

$$x_2 = 0.591$$

$$h_2 = h_{f_2} + x_2(h_{g_2} - h_{f_2})$$

$$= 173.88 + 0.591(2577.0 - 173.88)$$

$$\boxed{h_2 = 1594.1 \text{ kJ/kg}}$$

$$\frac{\dot{W}_t}{\dot{m}} = 2509.1 \text{ kJ/kg} - 1594.1 \text{ kJ/kg}$$

$$\boxed{\frac{\dot{W}_t}{\dot{m}} = 915 \text{ kJ/kg}}$$

2-3

$$\frac{\dot{Q}_{out}}{\dot{m}} = h_2 - h_3 \qquad h_3 = h_{f3} = h_{f2} = 173.88\ KJ/Kg$$

$$\frac{\dot{Q}_{out}}{\dot{m}} = 1594.1\ KJ/kg - 173.88\ KJ/kg$$

$$\boxed{\dot{Q}_{out}/\dot{m} = 1420.22\ KJ/Kg}$$

3-4

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

For a pump => $\left(\frac{\dot{W}_p}{\dot{m}}\right)_{int\ rev} \approx V_3 (P_4 - P_3)$ $\qquad V_3 = V_{f3} = 0.0010084\ m^3/Kg$

$$\frac{\dot{W}_p}{\dot{m}} = (0.0010084\ m^3/Kg)(18 \times 1000\ kPa - 8\ kPa) \qquad \left(\frac{m^3}{Kg}\right)\left(\frac{KN}{m^2}\right) \rightarrow \frac{KN \cdot m}{Kg} \ (KJ)$$

$$\boxed{\dot{W}_p/\dot{m} = 18.14\ KJ/Kg}$$

$$18.14\ KJ/Kg = h_4 - 173.88\ KJ/Kg$$

$$\boxed{h_4 = 192.02\ KJ/Kg}$$

4-1

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

$$= 2509.1\ KJ/Kg - 192.02\ KJ/Kg$$

$$\boxed{\dot{Q}_{in}/\dot{m} = 2317.08\ KJ/Kg}$$

$$\frac{\dot{W}_{cycle}}{\dot{m}} = \frac{\dot{W}_t}{\dot{m}} - \frac{\dot{W}_p}{\dot{m}} = 915\ KJ/Kg - 18.14\ KJ/Kg$$

$$\boxed{\dot{W}_{cycle}/\dot{m} = 896.86\ KJ/Kg}$$

$$\frac{\dot{Q}_{cycle}}{\dot{m}} = \frac{\dot{Q}_{in}}{\dot{m}} - \frac{\dot{Q}_{out}}{\dot{m}} = 2317.08\ KJ/Kg - 1420.22\ KJ/Kg$$

$$\boxed{\frac{\dot{Q}_{cycle}}{\dot{m}} = 896.86\ KJ/Kg} \qquad \dot{W}_{cycle}/\dot{m} = \dot{Q}_{cycle}/\dot{m}\ ✓$$

$$\eta = \frac{\dot{W}_{cycle}/\dot{m}}{\dot{Q}_{in}/\dot{m}} = \frac{896.86\ KJ/Kg}{2317.08\ KJ/Kg} = 0.387$$

$$\boxed{\eta = 38.7\%}$$