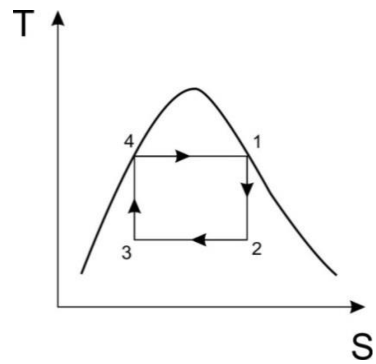
Example 1

A steam power plant operates between a boiler pressure of 42bar and condenser pressure of 0.035bar. Calculate for these limits the cycle efficiency, the work ratio, and the specific steam consumption, SSC.

a) A Carnot cycle using wet steam



$T_{1@42bar} = 526.2K$ (refer steam table)
$T_{2@0.035bar} = 299.7K$ (refer steam table)

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{299.7}{526.2} = 0.4304 = 43.04\%$$

$q_{in} = h_1 - h_4 = h_{fg@42bar} = 1699.2(kJ/kg)$ (refer steam table)

$$\eta_{Carnot} = \frac{W}{q_{in}} \Rightarrow W = q_{in}\eta_{Carnot} \Rightarrow 1699.2 \times 0.4304 = 731.34\,kJ/kg$$

Assume ;
$s_1 = s_2 \Rightarrow s_{1,g@42bar} = s_2 = 6.05\,kJ/kgK$ (refer steam table)
$h_1 = 2799.6\,kJ/kg$

$s_2 = s_{f2@0.035bar} + x_2 s_{fg2}$
$6.05 = 0.391 + x_2 8.13$ where $s_{g2} = 8.5223 kJ/kg$ $(8.5223 - 0.391 = 8.13 kJ/kg)$
$x_2 = 0.696$

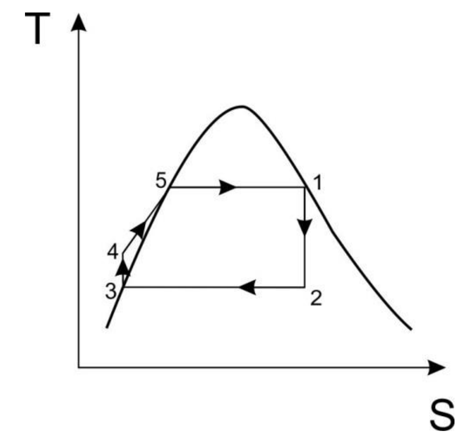
$h_{f2} = 111.8\,kJ/kg\,; h_{g2} = 2550.33 kJ/kg$ $(h_{fg2} = 2550.33 - 111.8 = 2438.58 kJ/kg)$
$h_2 = h_{f2} + x_2 h_{fg2} = 111.8 + (0.696 \times 2438.53) = 1809.02\,kJ/kg$

$W_{12} = h_1 - h_2 = 2799.6 - 1809.02 = 990.58\,kJ/kg$

$$\text{Work ratio} = \frac{\text{Nett work}}{\text{Gross work}} = \frac{W_{in}}{\text{Wout}} = \frac{731.34}{990.58} = 0.738$$

$$\text{SSC} = \frac{3600}{W} = \frac{3600}{731.34} = 4.92\,\text{kg/kWhr}$$

b) A Rankine cycle with dry saturated steam enter the turbine



$h_{1@g} = 2799.6\,\text{kJ/kg}$
$h_{2fg} = 1809.02\,\text{kJ/kg}$
$h_{3@hf0.035bar} = 111.8\,\text{kJ/kg}$

$$\text{Pump work input} = v_f(P_4 - P_3) = h_4 - h_3 = 0.001(42 - 0.035)\frac{10^5}{10^3} = 4.2\,\text{kJ/kg} \quad \text{(conversion from bar to SI unit)}$$

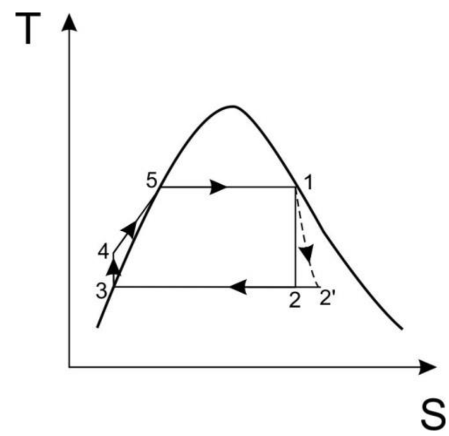
$h_4 = 4.2 + 111.8 = 116\,\text{kJ/kg}$
$W_{12} = h_1 - h_2 = 2799.6 - 1809.02 = 990.58\,\text{kJ/kg}$

$$\eta_{Rankine} = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)} = \frac{(2799.6 - 1809.02) - (116 - 111.8)}{(2799.6 - 116)} = \frac{(990.58) - (4.2)}{(2687.8) - (4.2)} = 0.3676 = 36.76\%$$

$$\text{Work ratio} = \frac{W_{out} - W_{in}}{W_{out}} = \frac{990.58 - 4.2}{990.58} = 0.996$$

$$\text{SSC} = \frac{3600}{W} = \frac{3600}{990.58 - 4.2} = 3.65\,\text{kg/kWhr}$$

c) A Rankine cycle with an <u>irreversible expansion process</u> has an isentropic efficiency 80%



Isentropic efficiency $= \dfrac{h_1 - h_{2'}}{h_1 - h_2} = \dfrac{W_{12'}}{W_{12}}$

$\therefore 0.8 = \dfrac{W_{12'}}{990.58} \Rightarrow W_{12'} = 792.46\,\text{kJ/kg}$

Cycle efficiency $= \dfrac{W_{net}}{\text{Gross heat supplied}} = \dfrac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)} = \dfrac{[0.8 \times (2800 - 1808)] - ((112 + 4.2) - 112)}{(2800 - (112 + 4.2))} = 0.294 @ 29.4\%$

Work ratio $= \dfrac{\text{Net work output}}{\text{Gross work output}} = \dfrac{W_{12'} - \text{pump work}}{W_{12'}} = \dfrac{792.46 - 4.2}{792.46} = 0.995$

$\text{SSC} = \dfrac{3600}{W_{net}} = \dfrac{3600}{792.46 - 4.2} = 4.56\,\text{kg/kWhr}$