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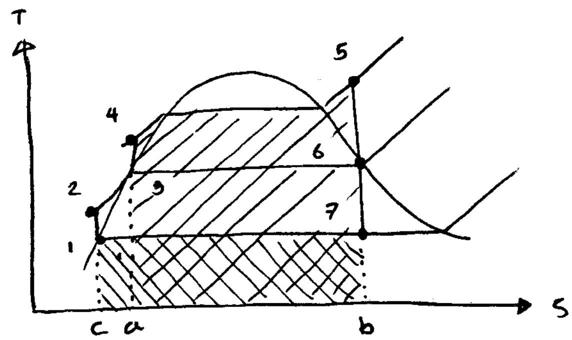
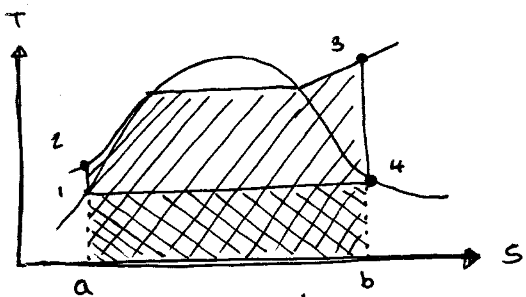
Feedwater heaters :



$A_{a45b} = Q_H$

$A_{c17b} = Q_L$



$Q_H = A_{a23b}$

$Q_L = A_{a14b}$

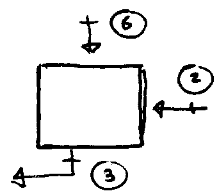
→ Standard Rankine Cycle

Example :
↳ (9.40)

FWH recieves steam at 1 MPa, 200 °C - From the turbine @ 1 MPa, 100 °C water From the Feed water line. Required Fraction of extraction Flow?

$y = \dot{m}_6 / \dot{m}_5$

$\dot{m}_7 = (1-y)\dot{m}_5$



$\dot{m}_3 = \dot{m}_5$

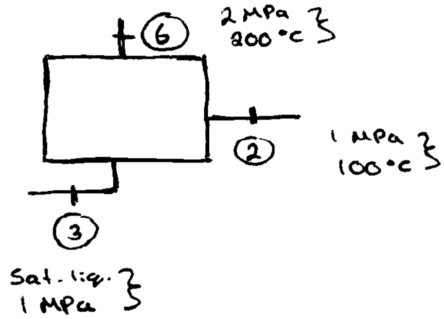
$\dot{m}_2 = \dot{m}_7$

$\dot{m}_2 h_2 + \dot{m}_6 h_6 = \dot{m}_3 h_3$

$(1-y)\cancel{\dot{m}_5} h_2 + y\cancel{\dot{m}_5} h_6 = \cancel{\dot{m}_5} h_3$

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

$$\Rightarrow \quad y = \frac{h_3 - h_2}{h_6 - h_2}$$



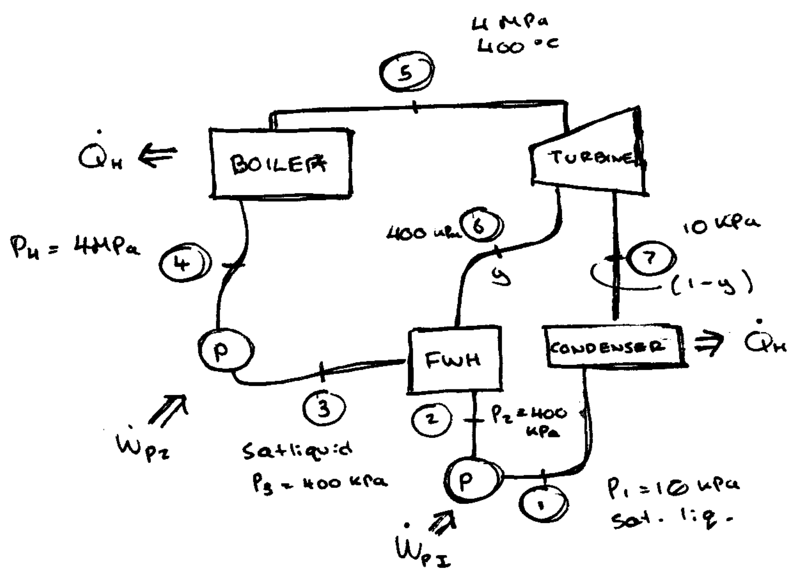
$y = ?$

$$y = \frac{h_3 - h_2}{h_6 - h_2}$$

$$y = \frac{(762.79 - 419.02)}{(2827.86 - 419.02)} = 0.1427$$

$\dot{m}_5 = 1\ kg/s \longrightarrow \dot{m}_6 = 0.1427(1) = 0.1427\ kg/s$

Example: Steam leaves boiler and enters the turbine at 4MPa, 400°C. After expansion to 400 kPa, some of the steam is extracted from the turbine to open FWH. FWH pressure is 400 kPa water leaving is Sat. liquid at 400 kPa, liquid from condenser : 10 kPa



$\eta_{th} = ?$

$$w_{PI} = v(P_2 - P_1) = 0.00101(400-10) = 0.4 \text{ kJ/kg}$$

$$w_{PI} = h_2 - h_1 \Rightarrow h_2 = h_1 + w_{PI} = 191.8 + 0.4 = 192.2 \text{ kJ/kg}$$

Turbine:

$$\dot{m}_5 h_5 = \dot{m}_6 h_6 + \dot{m}_7 h_7 + \dot{W}_T$$

$$h_5 = y h_6 + (1-y) h_7 + w_t$$

$$w_t = h_5 - y h_6 (1-y) h_7$$

h_5 : P_5, T_5 : $h_5 = 3213.51$

h_6 : P_6, $S_6 = S_5$: $h_6 = 2685.60$

h_7 : P_7, $S_7 = S_5$: $h_7 = 2144.10$ $\quad w_t = 980.06$ kJ/kg

$$w_t = 3213.51 - y(2685.6) - (1-y)(2144.1)$$

FWH: $\dot{m}_6 h_6 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \Rightarrow y = \dfrac{h_3 - h_2}{h_6 - h_2}$

$$y = \frac{(604.7 - 192.2)}{(2685.6 - 192.2)} \Rightarrow y = 0.165$$

$$w_{net} = w_t - w_{pII} - (1-y)w_{pI}$$

$$w_{net} = 980.06 - (-3.9) - (1 - 0.165)(0.4) = 975.8 \text{ kJ/kg}$$

$$w_{pII} = v_3(P_3 - P_4) \Rightarrow (0.001084)(400 - 4000) = -3.9 \text{ kJ/kg}$$

$$w_{pII} = h_3 - h_4 \Rightarrow h_4 = 608.6 \text{ kJ/kg}$$

Boiler:

$$q_H = h_5 - h_4 \Rightarrow 3213.51 - 608.6 = 2605 \text{ kJ/kg}$$

$$\eta_{th} = \frac{w_{net}}{q_H} = \frac{975.8}{2605} = 0.375 \text{ or } 37.5\%$$

$$\eta_{th} = \frac{w_{net}}{q_H} = \frac{q_H - (1-y)q_L}{q_H}$$

/END

$\boxed{\text{Example}}$ – From picture

Deviation of actual cycles from ideal cycles

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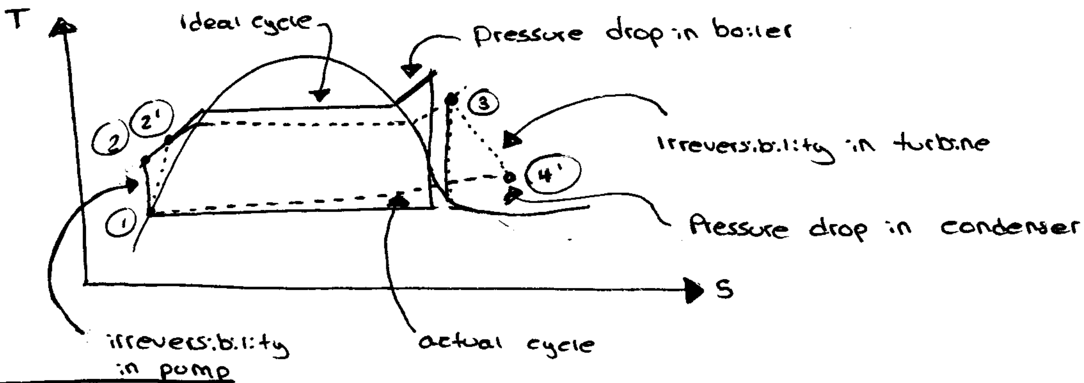


Ex. (9.5) $\boxed{\text{Example:}}$ A steam power plant operates on a cycle w/ pressures and temp. as designed in figure. Thermal efficiency is 86%, efficiency of pump is 80%. Determine the thermal efficiency of this cycle.

$\eta_{th} = \frac{w_{net}}{q_H}$; $w_{net} = \underset{(actual)}{w_{turbine}} - \underset{(actual)}{w_{pump}}$

$\eta_{turbine} = 0.86$ $\rightarrow$ $\eta_{turbine} = \frac{w_{t,a}\ (actual)}{w_{t,s}\ (isentropic)} = \frac{h_5 - h_{6a}}{h_5 - h_{6s}}$

$\eta_{pump} = 0.80$

$w_{ta} = \eta_{turbine}(h_5 - h_{6s})$

From table, $h_5 = 3169.1$ kJ/kg

$S_5 = S_{6s} = 6.7235$ kJ/kg

@10 kPa: $S_{6s} = S_f|_{10kPa} + x_6 S_{fg}|_{10kPa}$

$x_6 = 0.8098$

$h_{6s} = h_f|_{10kPa} + x_6 h_{fg}|_{10kPa}$

$h_{6s} = 2129.5$ kJ/kg

$w_{t,ac} = 0.86(3169.1 - 2129.5)$

$w_{t,ac} = 894.1$ kJ/kg

$\eta_{pump} = \frac{w_{ps}}{w_{pa}} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$ / $w_{pa} = \frac{h_{2s} - h_1}{\eta_{pump}} = \frac{v_1(P_2 - P_1)}{\eta_{pump}}$

$\Rightarrow \frac{0.00101(5000 - 10)}{(0.8)} = 6.3$ kJ/kg

$w_{net,ac} = w_{t,ac} - w_{p,ac} \Rightarrow 894.1 - 6.3$ kJ/kg

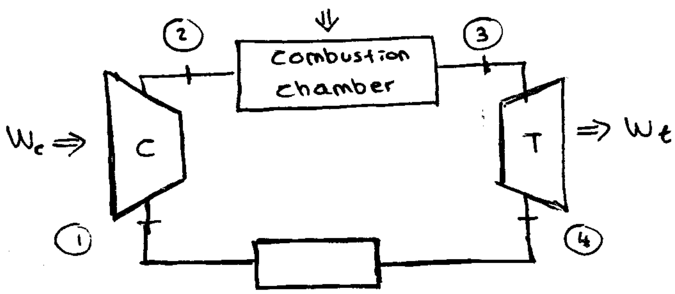
$q_H = h_4 - h_3 = 3213.6 - 171.8 = 3041.8$ kJ/kg

$\eta_{th} = w_{net}/q_H = 29.2\%$

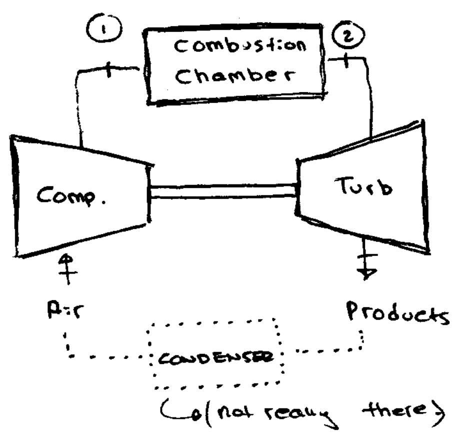
2) (From previous example)

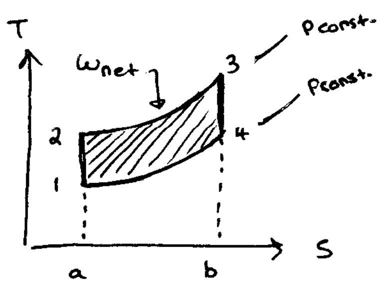
For ideal Rankine Cycle works between same pressures, $\eta_{th} = 35.3\%$

Air Standard Power Cycles



Brayton Cycle
(ideal cycle for gas)

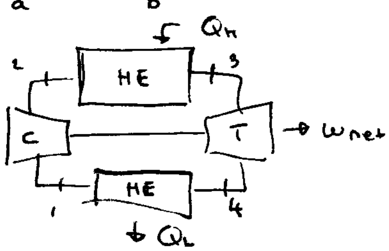


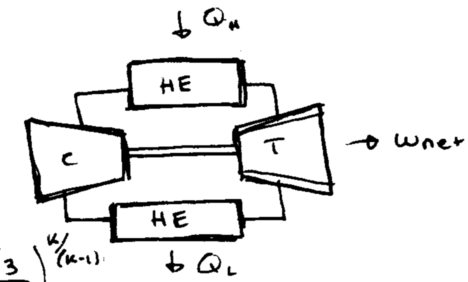


$$A_{a23b} = q_H$$
$$A_{a14b} = q_L$$

$$\eta_{th} = 1 - \frac{q_L}{q_H} = 1 - \frac{h_4 - h_1}{h_3 - h_2}$$

$$\approx 1 - \frac{C_p(T_4 - T_1)}{C_p(T_3 - T_2)} = 1 - \frac{(T_1(T_4/T_1 - 1))}{(T_2((T_3/T_2 - 1))}$$





$$\frac{P_3}{P_4} = \frac{P_2}{P_1}$$

$$\left(\frac{T_2}{T_1}\right)^{k/(k-1)} = \left(\frac{P_3}{P_4}\right) = \left(\frac{T_3}{T_4}\right)^{k/(k-1)}$$

$$\frac{T_3}{T_4} = \frac{T_2}{T_1} \rightarrow \frac{T_3}{T_2} = \frac{T_4}{T_1} \rightarrow \frac{T_3}{T_2} - 1 = \frac{T_4}{T_1} - 1$$

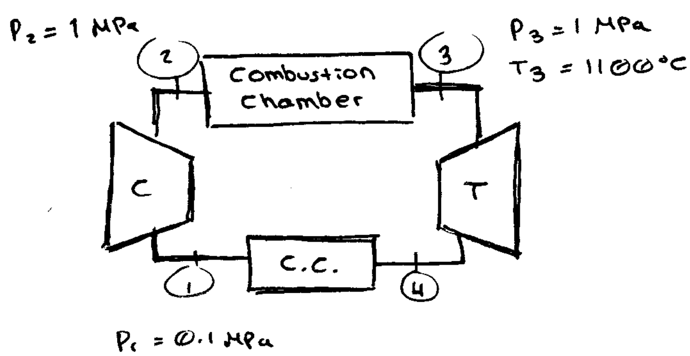
$$\eta_{th} = 1 - T_1/T_2 = 1 - \left[\frac{1}{(P_2/P_1)^{(k-1)/k}}\right]$$

$\boxed{\text{Example:}}$ Air-standard Brayton cycle enters @ 0.1 MPa and 15°C. Leaves compressor @ 1.0 MPa. Maximum temp is 1100°C.

→ Pressure + temp at each point

→ Comp. work
turb. work
cycle efficiency

(in Brayton, max temp is always @



$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \Rightarrow \left(\frac{1}{0.1}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 288.2 \times 10^{0.286} = 556.8 \text{ K}$$

$$\left(\frac{T_4}{T_3}\right) = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \Rightarrow T_4 = T_3\left(P_4/P_3\right)^{k-1/k}$$

$$\rightarrow T_4 = 710.8 \text{ K}$$

$$w_c = C_p(T_2 - T_1) = (1.004 \text{ kJ/kg}\cdot\text{K})(556.8 - 288.2) = 269.5 \text{ kJ/kg}$$

$$w_t = C_p(T_3 - T_4) = (1.004)(1372.2 - 710.8) = 664.7 \text{ kJ/kg}$$

$$w_{net} = w_t - w_c = 395.2 \text{ kJ/kg} \quad ; \quad q_H = h_3 - h_2 = C_p(T_3 - T_2) = 819.3$$

$$\eta_{th} = (395.2)/(819.3) = 48.2\ \%$$