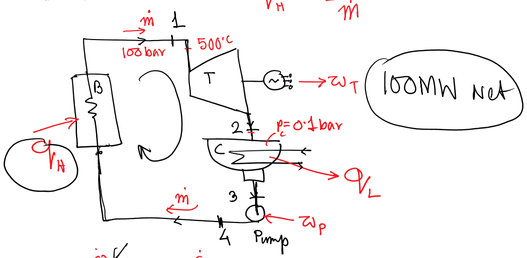
Thursday, December 9, 2021 9:53 AM

$q_H = \frac{\dot{Q}_H}{\dot{m}}$



100MW Net

$q_H = \frac{\dot{Q}_H}{\dot{m}}$, $q_L = \frac{\dot{Q}_L}{\dot{m}}$

$w_T = \frac{\dot{W}_T}{\dot{m}}$, $w_p = \frac{\dot{W}_p}{\dot{m}}$

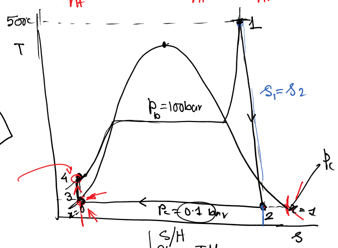
$w_{net} = w_T - w_p$ (specific work output)

q_H = heat input per unit mass of steam/water circulating in the cycle

$\eta = \frac{q_H - q_L}{q_H} = 1 - \frac{q_L}{q_H} = \frac{w_{net}}{q_H} = \frac{w_T - w_p}{q_H}$ ✓

1−2 = isentropic expansion in turbine
2−3 = isobaric condensation in condenser
3−4 = isentropic compression in the pump
4−1 = Const. pr. heating in the boiler

Rankine Cycle



$q_H = (h_1 - h_4)$
$w_T = (h_1 - h_2)$
$q_L = (h_2 - h_3)$
$w_p = (h_4 - h_3)$

Refer to steady flow energy eqn.

water at 3

water at 4

$q_H = (3370 - 202) = 3168$ kJ/kg
$q_L = (2070 - 192) = 1878$ "
$w_T = (3370 - 2070) = 1300$ kJ/kg
$w_p = 10$ kJ/kg.
$w_{net} = 1290$ kJ/kg.

$\eta = \frac{1290}{3168} = 40.7\%$

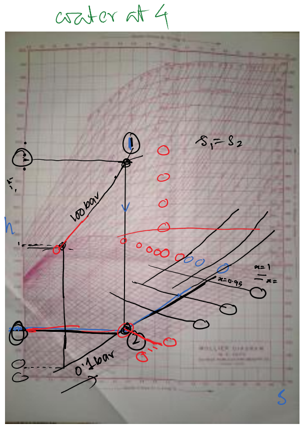
S/H Steam Table

100 bar, 500°C } $h_1 = 3373.7$ kJ/kg. ✓ (Table)

$h_1 = 3370$ kJ/kg
$h_2 = 2070$ "
$x_2 = 0.79$ ✓

$h_3 = h_f|_{0.1 bar} = 191.83$ kJ/kg.

$h_4 = h_3 + v_{f3}(p_4 - p_3) = h_3 + 10 = 201.8$ kJ/kg. (in kPa)



h_2 using steam table

$s_1 = s_2$ → p = 100 bar, t = 500°C
$h_1 = 3374$. kJ/kg
$s_1 = 6.5966$ kJ/kgK

→ $s_2 = 6.5966$ kJ/kgK, $p_2 = 0.1$ bar

Locate the pt. in steam table

what is s_g at 0.1 bar

Sat. table for pr. 0.1 bar

$s_f = 0.6493$ kJ/kgK $s_g = 8.150$ kJ/kgK
$h_f = 191.83$ kJ/kg $h_g = 2584.7$ kJ/kg

For a steady flow in a pump

work done by the pump $w = -\int_3^4 v\,dp = h_3 - h_4$

$\approx -v\int_3^4 dp$ water is incompressible

$= -v_f|_{p=0.1}(p_4 - p_3)$

Work done ON the pump
$w_p = -w = v_f(p_4 - p_3)$

$= 0.001 (100 - 0.1) \times 100$ (kJ/kg)   (kPa/bar)

≈ 10 kJ/kg

$h_4 = h_3 + 10$ kJ/kg

$s_f < s_2 < s_g$ @ 0.1 bar (at 0.1 bar)

$s_2 = s_f|_{at\ 0.1 bar} + x_2 s_{fg}|_{0.1 bar}$

$6.5966 = 0.6493 + x_2(8.150 - 0.6493)$

$x_2 = \frac{6.5966 - 0.6493}{8.150 - 0.6493} = 0.793$

$h_2 = h_f + x_2 h_{fg}|_{0.1 bar} = 191.83 + 0.793(2584.7 - 191.8)$
$= 2089.4$ kJ/kg

* If the Power plant has a capacity of 100 MW, find the steam flowrate & the Coal supply rate, if coal has a calorific value of 12000 kJ/kg

$q_H =$

$\dot{W}_{net} = 100 \times 1000$ kW $= \dot{m}\, w_{net}$

$\Rightarrow \dot{m} = \frac{100 \times 10^3}{1290}$ kg/s $= 77.5$ kg/s $= 279$ T/h

1T = 1000 kg

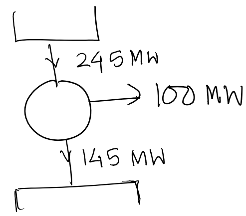
$\dot{Q}_H = q_H \times \dot{m} = 245501.4$ kW

$= 1290$

$$\dot{Q}_H = q_H \times \dot{m} = 245581.4 \text{ kW}$$

$$= 245 \text{ MW}$$

1T = 1000 kg

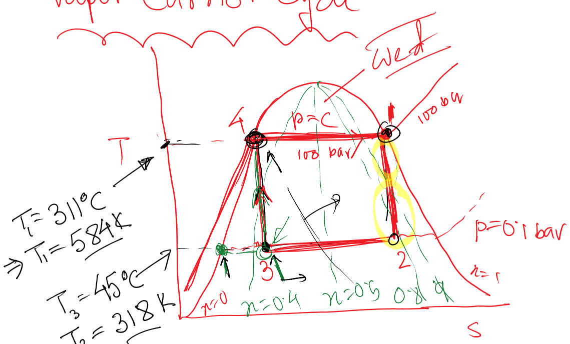


$$\dot{m}_{coal} \times CV = \dot{Q}_H$$

$$\dot{m}_{coal} = \frac{245\times 10^3}{12\times 10^3} \quad \frac{kJ}{s} \times \frac{}{kJ/kg} = \frac{kg}{s}$$

$$= 20.4 \text{ kg/s} = 73.6 \text{ T/hr.}$$

Vapor Carnot cycle

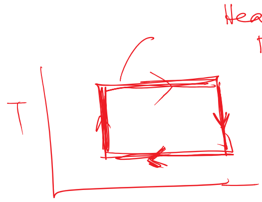


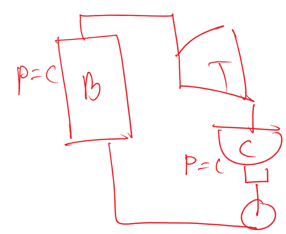
$T_1 = 311°C \Rightarrow T_1 = 584K$

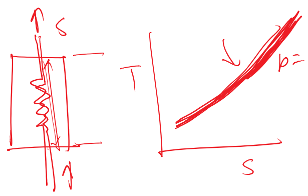
$T_3 = 45°C$, $T_3 = 318K$

Carnot vapor power cycle

Heat is added in Boiler → Const. pr. Heating







$h_1 = h_g|_{at\ 100\ bar} = 2724 \text{ kJ/kg}$

Find

- $h_1 = 2724$ kJ/kg
- $h_2 = 1770$ kJ/kg
- $h_3 = 1055.65$ kJ/kg
- $h_4 = 1407$ kJ/kg

$q_H = (h_1 - h_4) = h_{fg}|_{at\ 100\ bar} = 1317.5$ kJ/kg.

$w_T = (h_1 - h_2) = (2724 - 1770) = 954$ kJ/kg.

$q_L = (h_2 - h_3) = (1770 - 1055.6) = 714.34$

$w_p = (h_4 - h_3) = (1407 - 1055.65) = 351.35$

$w_{net} = 954 - 351.35 = 602.65$

$\eta = 602.65/1317.5 = 45.74\% = \left(1 - \frac{T_L}{T_H}\right) = 1 - \frac{318}{584} = 45.54\%$

$s_3 = s_4 = s_f|_{100\ bar} = 3.3596$ kJ/kg.K

$s_3 = s_f|_{p=0.1} + x_3\, s_{fg}|_{0.1\ bar}$

$3.3596 = 0.6493 + x_3 \times (8.150 - .6493)$

$\Rightarrow x_3 = \frac{3.3596 - 0.6493}{8.150 - 0.6493} = 0.361$ (36%)

$h_3 = h_f|_{0.1\ bar} + x_3\, h_{fg}|_{0.1\ bar} = 191.83 + .361 \times (2584.7 - 191.83)$

$= 1055.65$ kJ/kg.

Work Ratio
→ $r_{w,carnot} = w_{net}/w_T = \frac{602.65}{954} = 0.63$
→ $r_{w,Rankine} = \frac{1290}{1300} = 0.992$

Specific Steam Consumption

Carnot: $\frac{1}{w_{net}} = \frac{1}{602.65}$ $\frac{kg}{kW}$

Rankine: $\frac{1}{w_{net}} = \frac{1}{1290}$ $\frac{kg}{kW}$

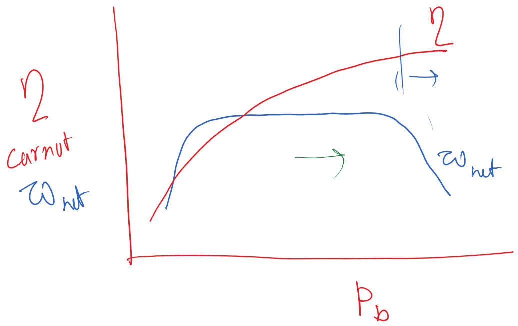
Carnot cycle eff 45.5%
Rankine " " 40.7%

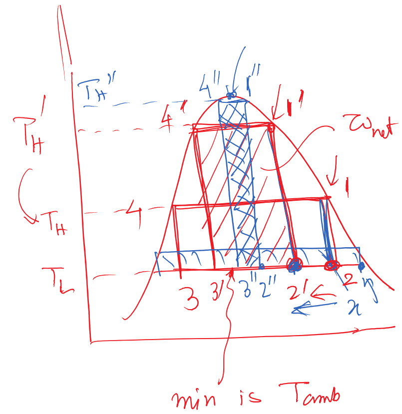
Which cycle to use?

T_H" 4" 1"

Rankine " " 40.7 %

$\eta = 1 - \frac{T_L}{T_H}$



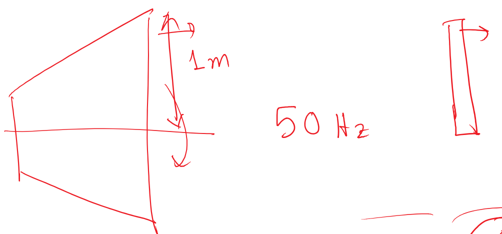


Other problems of a Carnot cycle

1) T_{max} is limited by T_{crit} → 374°C

2) Sp. work output decreases drastically at p approaching critical pr.

3) Turbine exhaust steam dryness faction reduces as we increase the boiler pr.

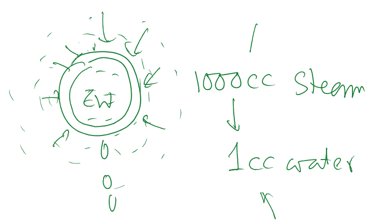


$v = \omega r = 2\pi \, 50 \times 1$

$= 100\pi$ m/s

Erosion in Turbine blade

To avoid erosion in Turbine blade x at the Turbine exit must be above 88%



4) Compression of wet vapor-water mixture is challenging. (cavitation will occur)