find Joule thomson effect of an Ideal gas.

$\mu \to$ zero

For air standard cycle → P.K. Nag

I.C. Engine

Refrigeration & Air conditioning →

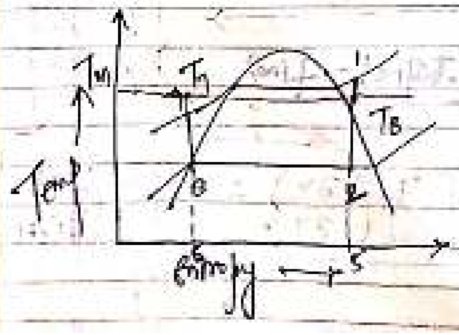
(i) By C.P. Arora

(ii) By R.S. khurmi.

Fluid Mechanics → Som Biswas

Rankine Cycle.

Mean temperature of heat addition.



$Q_{4-1} \Rightarrow$ Pressure = constant

= Area 4,1,2,5,6,3,4

$T_7 = T_8 = T_{mean}$

$\left(\frac{dT}{dP}\right) = 0$

$Q_{add} = Q_{4-1}$ = Area 4-1-5-6-4 (p = c)

Replace process 4-1 by a constant temp process 7-8 such that $Q_{4-1} = Q_{78}$ → Then temp T_m.

$T_7 = T_8$ = mean temp of heat addition (T_m)

$$Q_{78} = \int_7^8 T \cdot ds$$

$$Q_{78} = T[S_8 - S_7]$$

$$Q_{78} = Q_{4-1} = m(h_1 - h_4)$$

If $m = 1$ kg, then

S_8, S_7 → specific entropy.

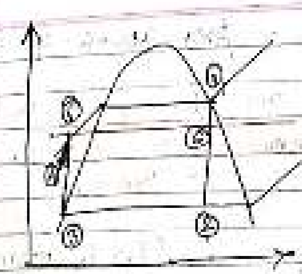
$$h_1 - h_4 = T(S_8 - S_7)$$

$$\boxed{T_m = \frac{h_1 - h_4}{S_8 - S_7}}$$

$S_8 = S_1$, $S_7 = S_4 = S_3$

$$\boxed{T_m = \frac{h_1 - h_4}{S_1 - S_3}}$$

Scanned with CamScanner



Cycle 1·2·3·4·1 → Simple Rankine

$Q_{add} = Q_{4-1}$; $Q_{rej} = Q_{2-3}$

Cycle 5·6·2·3·5 → Carnot cycle

$Q_{add} = Q_{5-6} = Q_{4-1}$

$T_5 = T_6 = T_m$

$\boxed{Q_{rej} = Q_{2-3}}$

$\eta_{1-2-3-4} = \eta_{5-6-2-3-5}$

$$\boxed{\eta_{carnot} = \frac{T_{add} - T_{rej}}{T_{add}}}$$

$$\eta_{carnot} = \frac{T_m - T_{condenser}}{T_m}$$

$$\boxed{\eta_{Rankine} = \eta_{1-2-3-4} = 1 - \frac{T_{cond}}{T_{mean}}}$$

$\boxed{T_{condenser} \gg T_{atm}}$

$T_2 \gg T_0$

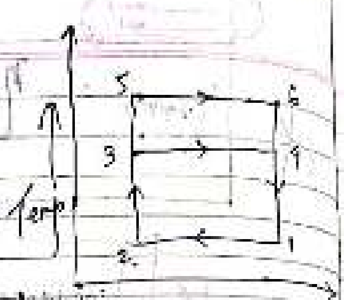
$\boxed{T_2 \geq T_0}$, $T_2 \neq T_0$

$T_0 \neq T_{atm}$

$\boxed{\eta_{Rankine} \propto T_{mean}}$

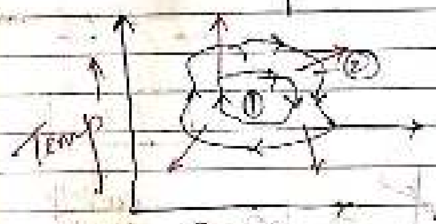
$T_{condenser} = \text{coolant} = T_{atm}$

$\eta_{3612} > \eta_{1234}$



B'coz T_{source} is higher (T_{mean} is higher)

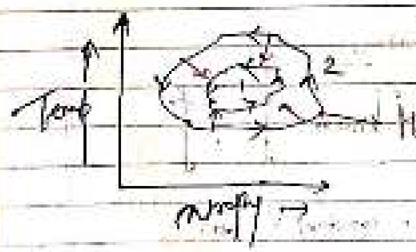
When T_{sink} is same then only we can compare.



$(W_{net})_2 > (W_{net})_1$

Heat Engine

Expansion



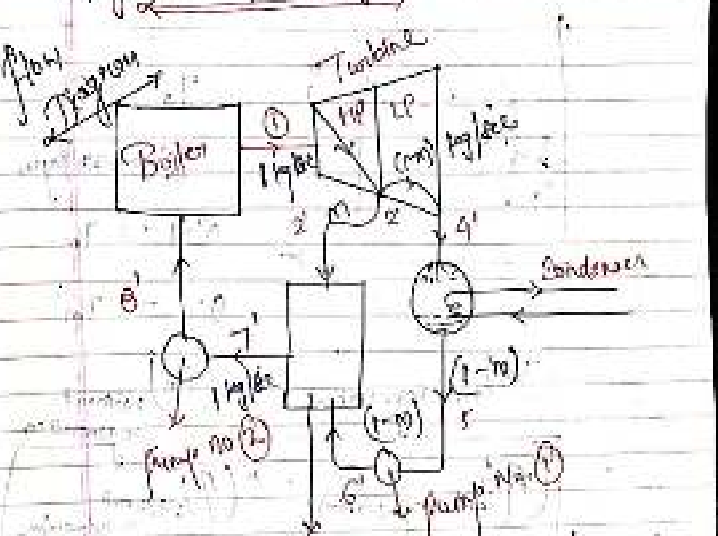
$\boxed{W_1 < W_2}$

Heat pump

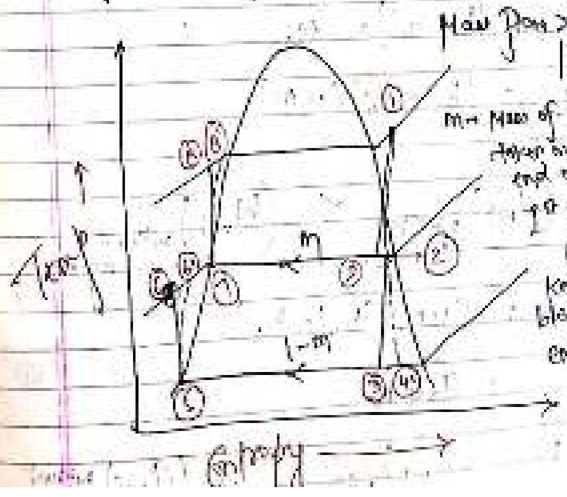
Shrinkage

Regenerative Rankine Cycle

Flow Diagram

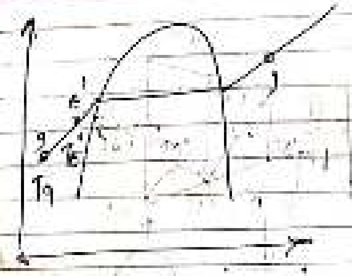


Regenerative or feed water heater or Heat Exchanger



Mass flow rate: 1 kg/sec

m = Mass of steam taken out at the end of I.P or 1st turbine (out of 1 kg) known as bled off or extracted steam



$T_8' > T_9$

$T_8' \to$ with regen.

$8'-1 \to T_m$

$9-1 \to T_m'$

$(T_m)_{\text{with regeneration}} > (T_m)_{\text{without regeneration}}$

$$\boxed{(\eta)_{\text{with regeneration}} > (\eta)_{\text{without regeneration}}}$$

$W_{T,reg} = (h_1 - h_2') = W_{T_1}$

$W_{T,reg,II} = (h_2' - h_4')(1-m)$

$(W_{net})_{\text{with reg}} < (W_{net})_{\text{without regen.}}$

$Q_{rej} = (1-m)(h_4' - h_5)$

$= Q_{rej} \downarrow$

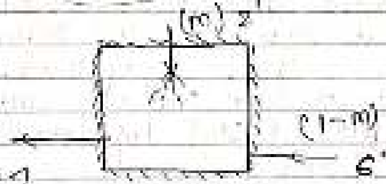
i.e. $(Q_{rej})_{\text{with reg}} < (Q_{rej})_{\text{without regen.}}$

$W_{P_1} = (1-m)(h_6' - h_5)$

$W_{P_2} = 1(h_8' - h_7)$

$Q_{add} = Q_{8'-1} = (h_1 - h_8')$

$(Q_{added})_{\text{with reg}} < (Q_{add})_{\text{without regen.}}$



$$\boxed{m h_2' + (1-m) h_6' = 1 h_7}$$

Steps

(i) $s_1 = s_2 \to x_2 \to h_2 \to \eta_{isen} \to h_2'$

$s_2' \leftarrow x_2' \leftarrow h_2'$

(ii) $s_2' = s_3 \to x_3 \to h_3 \to \eta_{isen} \to h_4'$

(iii) $h_6 = h_5 + v_5(P_6 - P_5)$

$\eta_P \to h_6'$

$h_7 \to$ from Table.

$h_8 = h_7 + v_{f_7}(P_8 - P_7)$

$\eta_{pB} \rightarrow h_8'$

Ques A thermal power plant operates in a regenerative Rankine cycle. Superheated steam at 2.5 MPa, 250°C is fed to turbine and a fraction of steam is extracted at 0.5 MPa and rest of steam is expanded in 2nd turbine upto condenser pressure of 10 kPa.
Find η of cycle, specific output, heat rejected & bled off steam.
Assume turbine efficiency = 90 (for each stage)

If total mass flow rate of steam is 10 kg/sec, find power output, bled off steam in kg/sec.

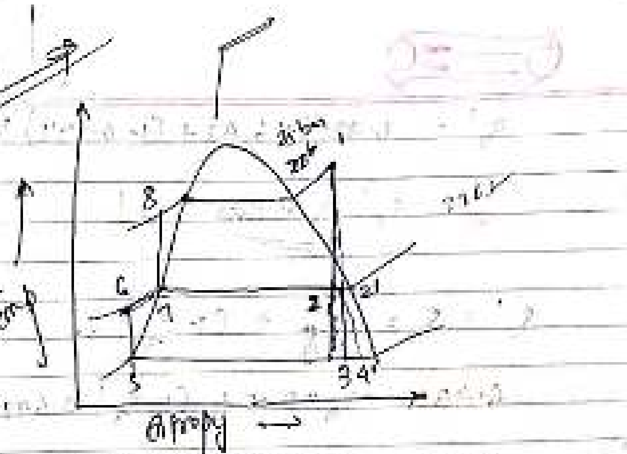
Extract of steam table

(i) 2.5 MPa, 250° → Superheated, $h = 2880$, $s = 6.4085$

(ii) 0.5 MPa, $h_f = 640.2$, $h_{fg} = 2108.5$, $s_f = 1.86$, $s_g = 6.82$, $v_f = 0.001$

(iii) 10 kPa → $v_f = 0.001$, $h_f = 191.8$, $h_{fg} = 2392.8$, $s_f = 0.6493$, $s_g = 8.15$

Soln



$h_1 = 2880$ kJ/kg

$s_1 = 6.4085 = s_2$

$6.4085 = x(6.82) + (1-x)1.86$

$6.4085 = 6.82x + 1.86 - 1.86x$

$\boxed{x_2 = 0.9170}$

$\eta_{turb} = \dfrac{h_1 - h_2'}{h_1 - h_2} = 0.9 = \dfrac{2880 - h_2'}{2880 - h_2}$

$h_2 = 640.2 + 0.9170 \times 2108.5$
$= 2573.6945$ kJ/kg

$0.9 \times (2880 - 2573.6945) = 2880 - h_2'$

$h_2' = 2604.32$ kJ/kg

x_2': $2604.32 = 640.2 + x \times 2108.5$
$x = 0.935$

$s_2' = 0.9315 \times 6.82 + (1-0.9315)\,1.85$

$s_2' = 6.480$

$s_2' = s_3 = x_3 s_g + (1-x_3) s_f$

$6.480 = x_3 \times 8.15 + (1-x_3)\,0.6493$

$\frac{6.480 - 0.6493}{8.15 - 0.6493} = x_3$

$x_3 = 0.7773$

$h_3 = 191.8 + 0.7773 \times 2392.8$

$= 2051.85$ kJ/kg

$0.9 = \frac{h_2' - h_4'}{h_2' - h_3}$

$0.9 = \frac{2604.92 - h_4'}{2604.92 - 2051.85}$

$h_4' = 2107.697$ kJ/kg

$h_5 = \boxed{191.8}$

$h_6 = 191.8 + 0.001(500 - 10) = 192.29$

$h_7 = 640.2$

$h_8 = 640.2 + 0.001[2880 - 500]$

$= 642.2 = h_8'$ #

η of cycle $= \frac{(2880 - 642.2) - (1-m)(2107 - 191.8)}{(2880 - 642.2)}$

$m \times 2604.92 + (1-m)\,192.29 = 640.2$

$m \times 2604.92 + 192.29 - 192.29m = 640.2$

$m = 0.185$ kg/sec

$\eta = 30.30\%$ Ans

Specific output $= 678.0539$ Ans

Heat rejected $= (1-0.185)(2107.697 - 191.8)$

$= 1650.967$ kJ/kg-sec Ans

$m = 0.185$ kg/sec Ans

For mass flow rate $= 10$ kg/sec

Specific power output $= 10 \times 678.0539$

$= 6780.539$ KW

bleed off = 0.185 × 10

= 18.5 kg/sec

Work Ratio = $\frac{678.05}{680.6}$

= 0.996

S.S.C = $\frac{3600}{678.05}$

Specific Steam Consumption = 5.3 kg/kWh

$\boxed{(SSC)_{\text{with heat regeneration}} > (SSC)_{\text{without heat regeneration}}}$

4 stage → No. of Reg = 3
No of pump = 4

N-stage Turbine → Reg = N-1
pump = N

Reheat Rankine Cycle

Main aim of reheating → To increase quality i.e. dryness fraction of steam at exit of turbine.

$\boxed{x_{\text{exit of turbine}} \geq 0.85}$ → To increase life of blade.

$\rho_{vapour} < \rho_{water}$

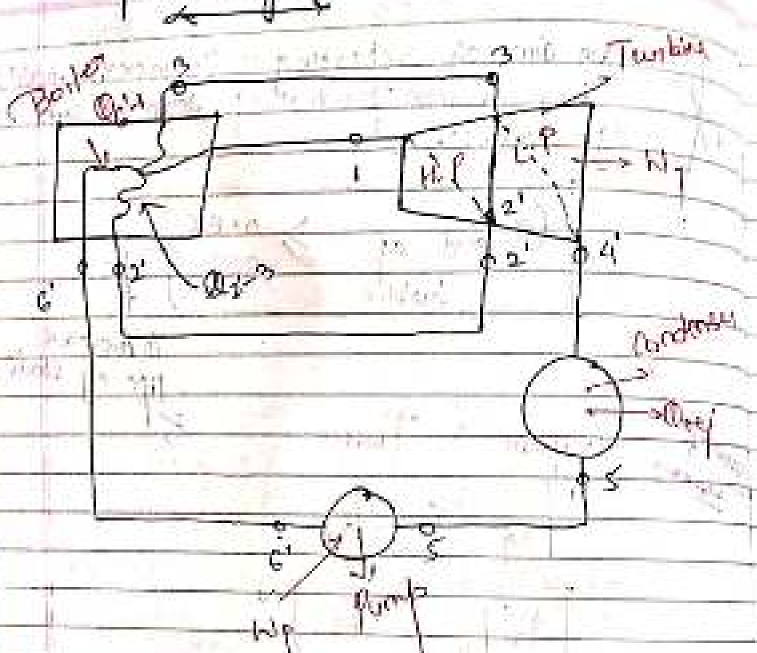
$1/v_g < 1/v_f$

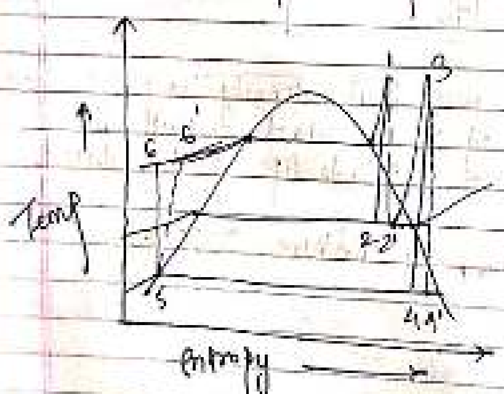
$\boxed{\rho_w/\rho_v \approx 1000}$

B'coz of very high density (compare to vapour) erosion of blade will be higher. → Blade life will reduce.

x_{exit} of turbine ≥ 0.85

Flow Diagram





m kg/sec is steam flow rate through cycle.

If $T_3 = T_1 \rightarrow$ perfect reheating

Steps for finding enthalpy

(i) $S_1 = S_2 \rightarrow x_2 \rightarrow h_2 \rightarrow \eta_{isen} \rightarrow h_2'$

(ii) $S_3 = S_4 \rightarrow x_4 \rightarrow h_4 \rightarrow \eta_{isen} \rightarrow h_4'$

(iii) $h_6 = h_5 + v_{f5}[P_6 - P_5]$

(iv) $\eta_{isen\,pump} = \dfrac{h_6 - h_5}{h_6' - h_5} \rightarrow h_6'$

$W_{Turbine} = W_{T_1} + W_{T_2}$

$= m[(h_1 - h_2') + (h_3 - h_4')]$

$Q_{add} = Q_{6'1} + Q_{2'3}$

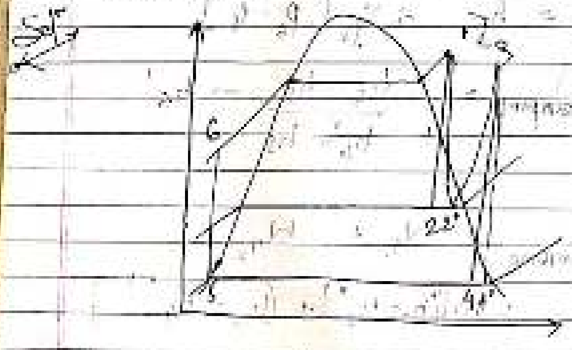
$= m[(h_1 - h_6') + (h_3 - h_2')]$

$Q_{rej} = Q_{4'5} = m[h_4' - h_5]$

Pump Work $= m[h_6' - h_5]$

Ques: Superheated steam at 2.5 MPa, 250°C enter a turbine and leaves at 0.1 MPa. steam is then reheated at 0.5 MPa upto 300°C. Then reheated steam is supplied to 2nd turbine where it expands to 10 kPa. η_{turb} 90% for each. $\eta_{pump} = 100\%$. Find the power output of plant i.e. cycle. If mass flow rate is 10 kg/sec. Also find η, W.R., heat rejected, S.S.C.

Sol:



$h_1 = 2880$ kJ/kg

$S_1 = S_2 = 6.4085$

$6.4085 = x \times 6.82 + (1-x) \times 1.86$

$x = 0.9170 = x_2$

$\eta = \dfrac{h_1 - h_2'}{h_1 - h_2}$

$h_2 = 640.2 + 0.9170 \times 2108.3$

$= 2573.6948$ kJ/kg

$0.9 = \dfrac{2880 - h_2'}{2880 - 2573.6948}$

$h_2' = 2604.32$ kJ/kg

$S_3 = S_4 = 7.2709$

$7.2709 = x \times 8.15 + (1-x)\, 0.6493$

$7.2709 = 8.15x + 0.6493 - 0.6493x$

$\boxed{x = 0.8827}$

$h_4 = 191.8 + 0.8827 \times 2392.8$

$= 2304.158$ kJ/kg

$0.90 = \dfrac{2960.7 - h_4'}{2960.7 - 2304.15}$

$h_4' = 2369.8123$ kJ/kg

$h_5 = 191.8$

$h_6 = 191.8 + 0.001\,[2500 - 10]$

$= 193.49$

$$\eta = \frac{m[h_1 - h_6'] + [h_3 - h_2']m - (h_4' - h_5)m}{m(h_1 - h_6') + m(h_3 - h_2')}$$

$$= \frac{(2880 - 197.29) + (2960.7 - 2043) - (239.803 - 191.8)}{(2880 - 197.29) + (2960.7 - 2441.32)}$$

2367.0783 → 1943

$\eta = 28.40\%$ ✓

power output = 8640.43 kW = 8640.43

Q_{add} = 30420.09 kW = 30420.9

$WR = \frac{W_{net}}{W_T}$ ✓

$= \frac{8640.43}{8667.377}$

$W.R. = 0.9986$

Q_{rej} = 21780.97 kW

$SSC = \frac{3600}{8640.443} = 4.166$ kg/kWh

Between same boiler & condenser pressure.

$(\eta_{th})_{reg} > (\eta_{th})_{reheat}$

$(W_{net})_{reg} < [W_{net}]_{reheat}$

$(SSC)_{Reg} > (SSC)_{reheat}$

Aim of Reheating →

(i) W_{net} ↑

(ii) Improves quality of steam → (main aim)

Gas Power Cycle → Otto, diesel, Dual, Brayton, Carnot, Ericsson, Atkinson, Stirling, etc.

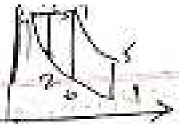
Working fluid → Ideal gas (assumed)

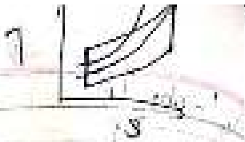
Air standard η : η_{air}

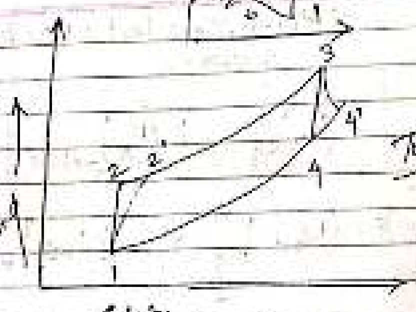
Thermal η or cycle η = η_{th}

Actual η = η_{act}

Relative η = $\eta_{relative}$







Entropy →

1-2-3-4 → Reversible or ideal.

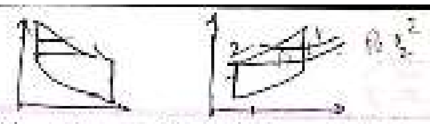
$\eta_{air\text{-}std} = (\eta_{th})_{1\text{-}2\text{-}3\text{-}4}$

Cycle 1-2'-3-4' = η_{th} or η_{actual}

$\eta_{relative} = \dfrac{(\eta_{th})_{1\text{-}2'\text{-}3\text{-}4'}}{(\eta_{th})_{1\text{-}2\text{-}3\text{-}4}}$

Otto cycle (V - Imp) → Used in spark Ignition engine.

D = Diameter of piston
L = Stroke length or stroke
V_c = clearance volume
V_s = stroke volume
$V_s = \pi/4 \times D^2 \times L$ (m^3/stroke)



V_1 = Volume of cylinder = $V_s + V_c$

Compression ratio $(r) = \dfrac{V_1}{V_2} = \dfrac{V_c + V_s}{V_c}$

$Q_{add} = Q_{2\text{-}3} = mC_v(T_3 - T_2)$

$\boxed{\dfrac{\text{Net W.D}}{\text{Stroke Volume}}}$

$T_2/T_1 = (P_2/P_1)^{\gamma-1/\gamma}$

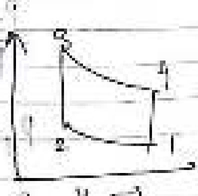
$P_1V_1^{\gamma} = P_2V_2^{\gamma} \rightarrow P_2/P_1 = (V_1/V_2)^{\gamma} = r^{\gamma}$

$Q_{rej} = mC_v(T_4 - T_1)$

Ques: Max temp of otto cycle is 1500°C. Temp of air at inlet is 27°C, Comp. ratio 7.5
(i) find specific power if inlet pressure is 1 bar, find η_{th}
(ii) If comp. curve is not isentropic but polytropic by $pV^{1.35} = C$, find η_{th}

Soln → T_3 = 1773 kelvin, T_1 = 300 kelvin
$r = 7.5$, $P_1 = 100$ kPa

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$



$r^{\gamma} = P_2/100$

$7.5^{1.4} \times 100 = P_2$

P_2 = 1679.13 kPa

$$\frac{P_3 \cancel{V_3}}{T_3} = \frac{P_2 \cancel{V_2}}{T_2}$$

$$\frac{P_3}{T_3} = \frac{P_2}{T_2}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$$

$$T_2 = 300\left[\frac{1679.13}{100}\right]^{1.4-1/1.4}$$

$$\boxed{T_2 = 671.66 \text{ Kelvin}}$$

$$P_3 = \cancel{100}\ \frac{1273 \times 1679.13}{671.66}$$

$$P_3 = 3182.45 \text{ kPa}$$

$$P_3 V_3^{\gamma} = P_4 V_4^{\gamma}$$

$$\frac{P_3}{P_4} = r_p^{\gamma}$$

$$P_4 = P_3 / r^{\gamma}$$

$$P_4 = 3182.46 / 7.5^{1.4} = 187.32 \text{ kPa}$$

$T_3 = 1273$ Kelvin

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} \qquad 1 - \frac{1}{r^{\gamma-1}}$$

$$T_4 = \frac{T_3 \times T_1}{T_2}$$

$$= \frac{1008 \times 300}{671.66}$$

$$\boxed{T_4 = \cancel{568.59}\ 446.60 \text{ Kelvin}}$$

∴ Specific power

$$\overset{0.718}{\cancel{1.005}}[1273 - 671.66] - \overset{0.718}{\cancel{1.005}}[568.59 - 300]$$

$$= \cancel{384.44}\ 238.91 \text{ kN}$$

Heat added: $\cancel{604.34}$ ~~kN~~ 431.762 kN

$$\eta = 384.44 / 604.34$$

$$= 55.33\%$$

(b) $7.5^{1.36} \times 100 = P_2$

$$P_2 = 1518.21 \text{ kPa}$$

$$\frac{P_3}{T_3} = \frac{P_2}{T_2}$$

$$T_2 = 300\left[\frac{1518.21}{150}\right]^{0.35/1.35}$$

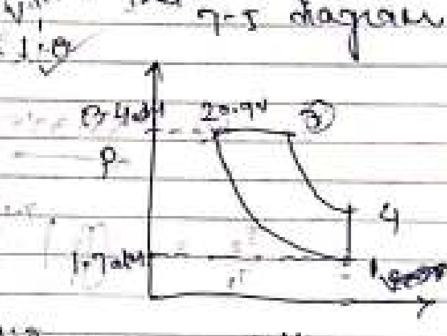
$$T_2 = \underline{607.28\,\text{kelvin}}$$

$$P_3 = \frac{1279 \times 1518.21}{607.28}$$

(iv)

Que. In a diesel cycle the pressure at two points on the compression curve are 1.7 atm & 13.4 atm respectively. Corresponding to the position where $3/10^{th}$ & $9/10^{th}$ of compression stroke have been executed. The comp curve is $pv^{1.38} = C$. ($\gamma = 1.4$). Expansion curve is isentropic. Find $\eta_{air\ std}$, η_{th}, η_{rel}. Draw p-v, T-S diagram. If cutoff ratio = 1.9

Soln



Cutoff Ratio = $\dfrac{\text{Comp. Ratio}}{\text{Expansion Ratio}}$

$$\frac{V_1}{V_2} \times \frac{V_3}{V_4}$$

$V_1 = V_4$

$$\boxed{\text{Cutoff Ratio} = \frac{\text{Comp R.}}{\text{Exp}}}$$

$$\frac{V_3}{V_2} = \frac{V_1}{V_2} \times \frac{V_3}{V_4}$$

Sol^n (i) $T_3 = T_{max} = 1000$ kelvin

$T_1 = 300$ kelvin

$r = 7.5$

$\eta_{otto} = 1 - \frac{1}{r^{\gamma - 1}}$

$= 1 - \frac{1}{7.5^{0.4}}$

$= 55.3\%$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$

$T_2 = 300 \left[7.5\right]^{0.4/1.4}$

$T_2 = 671.66$ Kelvin

Heat added: $\left(\cancel{571.66 - 1000}\right) \times 0.718$ ($1000 - 671.66$)

$= \cancel{266.185}$ 235.7553

$\therefore$ Net Work $= \eta \times Q_{add}$

$= \cancel{147.85 \text{ KW}}$ 130.44 KW

(ii) $P_2 = (7.5)^{1.35} \times 100$

$= 1518.21$ KPa

$T_2 = 300 \left[\frac{1518.21}{100}\right]^{\frac{0.35}{1.35}}$

$T_2 = 607.28$ kelvin

$Q_{2-3} = 0.718 \left[1000 - 607.28\right]$

$= 281.97$ KJ

$Q_{4-1} = 0.718 \left[T_4 - T_1\right]$

$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$

$T_4 = \frac{1000}{(7.5)^{0.4}} = 446.7$ kelvin

$Q_{4-1} = 0.718 \left[446.7 - 300\right]$

$= \cancel{105.33}$ KJ 105.33

$W_{net} = \cancel{\quad}$ KJ 175.3

$\eta = 176.64 / 281.97 = \cancel{62.64\%}$

$$Q = m\left[C_v - \frac{R}{n-1}\right](T_2 - T_1)$$

$$Q = m\left[nC_v - C_v - C_p + C_v\right]\left[\frac{T_2 - T_1}{n-1}\right]$$

$$Q_{1-2} = m\left[\frac{nC_v - C_p}{n-1}\right]\left[T_2 - T_1\right]$$

$$\boxed{Q_{1-2} = mC_v\left[\frac{n-\gamma}{n-1}\right](T_2 - T_1)}$$

(i) 1-2 → compression : $T_2 > T_1$
& if $n > \gamma$ ⟹ Q_{1-2} → +ive
if $n < \gamma$ ⟹ Q_{1-2} → -ive
(ii)

(ii) If 1-2 → expansion $T_2 < T_1$

for I^{st} part

$$W_{net} = P_m [V]_{stroke}$$

$$P_1 V_1 = mRT_1$$

$$100 \times V_1 = 1 \times 0.287 \times 300$$

$$V_1 = 0.861 \text{ m}^3/\text{kg}$$

$$V_2 = 0.861/r = 0.861/7.5$$

$$= 0.1148$$

$$(V_2 - V_1) = 0.7462$$

$$W_{net} = P_m \times V_{stroke}$$

$$130.4 = P_m \times 0.7462$$

$$P_m = 174.75 \text{ kPa}$$

$$\eta_{rel} = \eta_{act} / \eta_{air\ std}$$

$$= 51.3 / 55.3$$

$$= 92.7\ \%$$

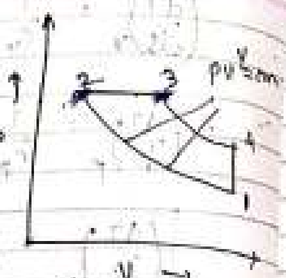
Ans

Diesel cycle

cutoff ratio $\alpha = V_3/V_2$

2 → Beginning of fuel injection

3 → end of fuel injection



$(\alpha)_{otto} = 1$ $\boxed{r = V_1/V_2}$

V_B at $3/10\,[V_1 - V_2]$

$V_A = 7/10\,[V_1 - V_2] + V_2$

$V_B = 1/10\,[V_1 - V_2] + V_2$

$P_A V_A^{1.38} = P_B V_B^{1.38}$

$1.7\,[0.7 V_s + V_c]^{1.38} = 13.4\,[0.1 V_s + V_c]^{1.38}$

$$\left(\frac{1.7}{13.4}\right)^{1/1.38} = \frac{0.1 V_s + V_c}{0.7 V_s + V_c}$$

$0.2240\,[0.7 V_s + V_c] = 0.1 V_s + V_c$

$0.156 V_s + 0.224 V_c = 0.1 V_s + V_c$

$(0.156 - 0.1) V_s = (1 - 0.224) V_c$

$$\boxed{\frac{V_s}{V_c} = 13.66}$$

$r = \frac{V_s + V_c}{V_c} \Rightarrow r = \frac{V_s}{V_c} + 1$

$r = 1 + 13.66$

$\boxed{r = 14.66}$

Air std $\eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\alpha^\gamma - 1}{\gamma(\alpha - 1)}\right]$

Diesel engine

$= 1 - \frac{1}{14.66^{0.4}}\left[14.66^{1.4} - 1\right]$

$T_1 \to$ inlet temp

$Q_{1-2} = m c_v \left[\frac{n-\gamma}{n-1}\right][T_2 - T_1]$

$T_2 = [r^{n-1}] \times T_1$

$T_2 = (14.7)^{0.38} \times T_1 = 2.?? T_1$

$Q_{1-2} = m c_v \left[\frac{n-\gamma}{n-1}\right] T_1 [14.7^{0.38} - 1] = -0.0671\,T_1$

$\dot{Q}_{2-3} = mC_p[T_3 - T_2]$

$= 1.005[4.986 - 2.77]T_1 = 2.2277T_1$

$\frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3}$

$\frac{V_2}{T_2} = \frac{V_3}{T_3}$

$T_2 = T_3\frac{V_2}{V_3}$

$T_3 = T_2 \times \frac{V_3}{V_2}$

$T_3 = 1.8T_2 \Rightarrow 4.986T_1$

$T_3 = 1.8\times(14.7)^{0.38}\times T_1$

$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\gamma-1/\gamma} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$

$\frac{T_3}{T_4} = \left(\frac{V_1}{V_3}\right)^{\gamma-1}$

$\frac{T_3}{T_4} = \left(\frac{V_1}{V_2}\times\frac{V_2}{V_3}\right)^{\gamma-1}$

$\frac{T_3}{T_4} = \left[\frac{14.7}{1.8}\right]^{0.4}$

$T_4 = \left(\frac{1.8}{14.7}\right)^{0.4}\times T_3 = 2.152T_1$

$T_4 = \left(\frac{1.8}{14.7}\right)^{0.4}\times 1.8\times(14.7)^{0.38}\times T_1$

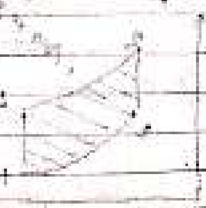
$\dot{Q}_{4-1} = 0.718[2.152T_1 - T_1]$

$= 0.827T_1$

$\eta = \frac{2.2277T_1 - [0.0671 + 0.827]T_1}{2.2277T_1}$

$\eta = 59.84\%$

$\eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho\alpha^{\gamma}-1}{\alpha-1}\right]$



for otto (S.I. Engine), Diesel (C.I. engine)

Indicated power $= \dfrac{K \times (IMEP) \times (L \times A \times N)/n}{60}$

where IMEP = kPa

L = stroke (m)

$A = \pi/4 \, D^2 \; (m^2)$

K = No. of cylinders in engine

N = rpm

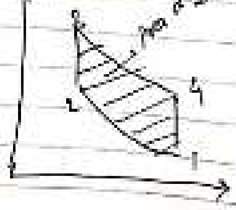
n = 1 for 2-stroke engine

n = 2 for 4-stroke engine

Brake power $= \dfrac{P_{mb} \times L \times A \times N}{n \times 60}$ kW

P_{mb} = Brake mean eff pressure

$$\boxed{\eta_{mech} = B.P / I.P.}$$

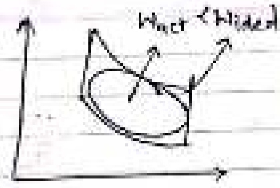


p-v diagram → Indicator diagram

Area 1-2-3-4 → W_{net}

If W_{net} is in kJ/sec. It is power = I.P.

$W_{act} < W_{ideal}$

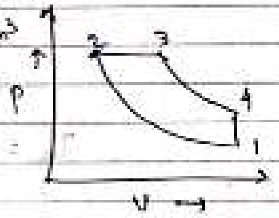


Que. An ideal 4-stroke diesel engine with comp ratio 17 & Clearance volume of $0.002 m^3$, takes in air at 1atm, 60°C, max cycle temp is 1420 kelvin. find (a) Result Work done / cycle

(b) Brake power and BMEP, when engine runs at 1500 rpm. η_{mech} = 87%

Sol. $P_1 = 101 \; kPa$, $V_2 = 0.002 m^3$

$T_1 = 333 K$



$r = \dfrac{V_1}{V_2} \Rightarrow 17 = \dfrac{V_1}{0.002}$

$V_1 = 0.028 \; m^3$

$100 \times 0.028^{1.4} = P_2 \times 0.002^{1.4}$

$P_2 = 4078.27 \; kPa$

$\dfrac{P_2 V_2}{T_2} = \dfrac{P_3 V_3}{T_3}$

$T_2 = T_1 \left[\dfrac{4078.27}{100}\right]^{0.4/1.4}$

$T_2 = 956.969$ kelvin

$\dfrac{0.002}{956.969} = \dfrac{V_3}{1420} \Rightarrow V_3 = 2.96 \times 10^{-3} \; m^3$

$V_1 = V_4 = 0.028\ m^3$

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

$$\frac{P_1 V_1}{T_1} = \frac{P_4 V_4}{T_4}$$

$$P_4 = P_1 \times \frac{T_4}{T_1}$$

$$= 101.325 \times \frac{1420}{333}$$

$P_4 = 432.07$ kPa

$$T_4 = 1420 \Big/ \left(\frac{4076.97}{432.07}\right)^{0.4/1.4}$$

$T_4 = 749.98$ K

$$\frac{1.005 \times (1420 - 956.963)}{} = 0.718\,(749.98 - 333)$$

$W_{net} = 187.99$

$$\eta = \left[1 - \frac{1}{r^{0.4}}\left[\frac{1.48^{1.4} - 1}{1.4\,(1.48 - 1)}\right]\right]$$

$\eta = 62.13\%$

$$\eta_{th} = \frac{W}{Q}$$

$Q = 1.005\,[1420 - 956.963]$

$W_{net} = 0.6213 \times 1.005\,(1420 - 956.963)$

$= 289.14$ kJ / kg cycle $= 8.583$ kJ

$W_{net} = P\,(V_s) \qquad \frac{V_s}{V_c} = 13$

$V_s = 0.026$

$8.583 = P \times 0.026$

$P = 330.128$ kPa

$$I.P = \frac{330.128 \times 0.026 \times 1500}{2 \times 60}$$

$= 107.29$ kW

$B.P = 0.83 \times 107.29 = 89.05$ kW

$101.325 \times 0.028 = m \times 0.287 \times 333$

$\boxed{m = 0.029 \text{ kg / cycle}}$

No of cycles / sec $= 1500 / 2 \times 60$

$\therefore$ Power $= \dfrac{1500}{2 \times 60} \times 8.58$

$= 106.29$

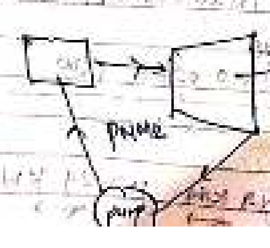
B.P $= 0.83 \times 106.29$

$= 89.04$

$89.04 = \dfrac{P_B \times 0.028 \times 1500}{2 \times 60}$

$\boxed{P_B = 273.97 \text{ kPa}}$

Whether condenser is must in Rankine ?



Not possible

violates 2nd law.

Dual cycle ⟹ 1 or 2 problem → P.K. Nag

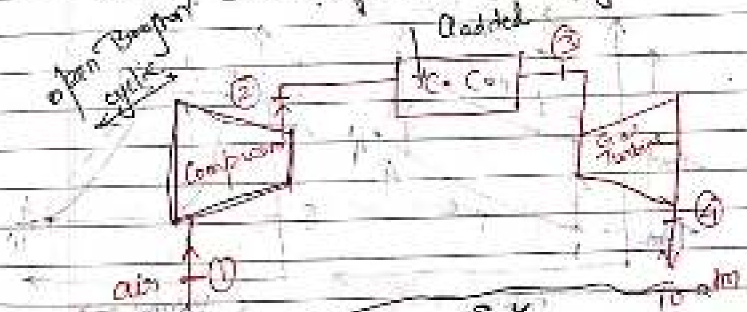
Otto, Diesel → P.K. Nag → Do more que (solved + unsolved) + Ganeshan.

Brayton cycle / Joule cycle

(Gas Turbine cycle)

Use → Gas Power plant.

Working fluid (system) – Ideal gas (assume)



SmK atm

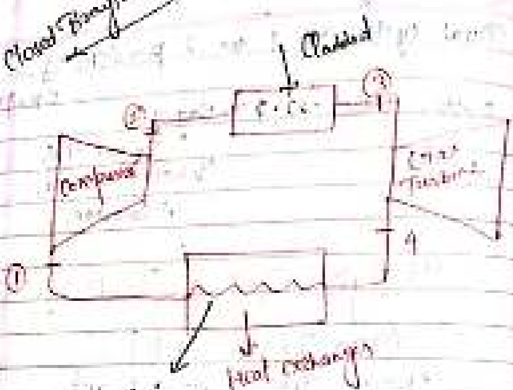
Brayton cycle.

→ open Brayton

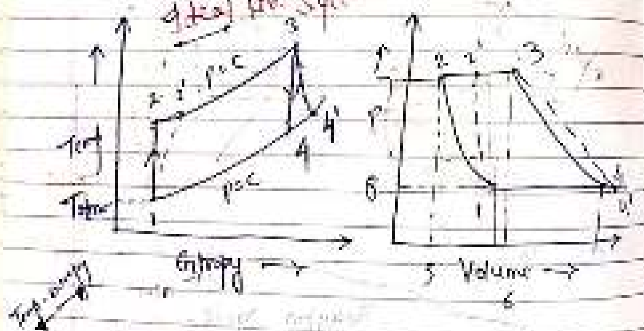
→ closed Brayton

Flow process → Work Done $= \int V.dP$

Closed Brayton cycle



Ideal Gas. Cycle



Area 1-2-3-6 → Work Done → flow process

For cycle (1-2'-3-4'-1) → Irrev. actual Brayton cycle.

$\eta_{12341} > \eta_{1-2'-3-4'-1}$

Air standard η

Comp. process 1-2' → Irrev. adiabatic in compressor.

$Q_{1-2'} = 0, \quad W_{1-2'} = ?$

m_a = mass flow rate.

Neglecting KE & PE.

$m_a(h_1) + 0 = m_a(h_2') + W_{1-2'}$

$m_a[h_1 - h_2'] = W_{1-2'}$

$\boxed{W_{1-2'} = m_a c_{p_a}[t_1 - t_2]}$

$P_1 = P_{atm}$ (for open cycle)

$P_1 \geq P_{atm}$ (for closed cycle)

$\frac{P_2}{P_1} = r_p$ = pressure ratio

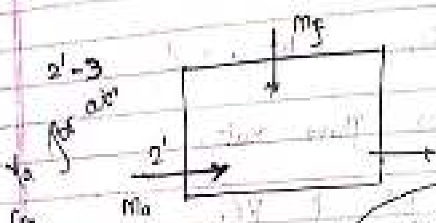
$\frac{V_2}{V_1}$ = comp ratio

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$[\eta_{isen}]_{comp} = \frac{W_{1-2}}{W_{1-2'}} \to \frac{h_2-h_1}{h_2'-h_1} = \frac{T_2-T_1}{T_2'-T_1}$

$\boxed{[\eta_{isen}]_{comp} \to \frac{T_2-T_1}{T_2'-T_1}}$

$2'$-$3 \rightarrow$ $p = c$, Heat addition in combustion chamber. $\rceil$ $W = 0$



$\rightarrow 3 \; (m_a + m_f) = m_g$ gas

m_g (kg/sec) = $(m_a + m_f)$ kg/sec

$\rightarrow \gamma_g \; , \; c_{pg}$

$\boxed{Q = m_f \times C.V.}$

Take $\gamma_g = \gamma_a$ $\}$ When Data for
$c_{pg} = c_{pa}$ $\}$ gas is not given

$$m_a h_2' + \eta_{cc} \, m_f (C.V.) = (m_a + m_f) h_3$$

open cycle η_{cc} = $\frac{\text{Actual Heat transfer}}{\text{Theoretical heat transfer } (m_f \times C.V.)}$

$$\boxed{m_a c_{pa} T_2' + \eta_{cc} m_f \cdot C.V = (m_a + m_f) c_{pg} T_3}$$ open cycle

$\frac{m_a}{m_f} = \frac{A}{F} = 50$ to 100

\# $\boxed{m_a h_2' + \eta_{cc} \, m_f [C.V] = m_a h_3}$ $\leftarrow$ for closed cycle

for closed
for open cycle

process $\rightarrow$ 3-4' (Turbine) $\rceil$ given adiabatic

$$W_{3-4'} = (m_a + m_f) \, c_{pg} \, (T_3 - T_4')$$

$$= m_a \, c_{pg} \, (T_3 - T_4')$$ $\rightarrow$ for $m_f << m_a$ $\rightarrow$ for closed cycle

process 4'-1 : $p = c$ heat rejection.

$$Q_{4'-1} = (m_a + m_f) c_{pg} (T_1 - T_4')$$

$$Q_{rej} = (m_a + m_f) c_{pg} (T_4' - T_1)$$

$$Q_{rej} = m_a \, c_{pg} (T_4' - T_1)$$ $\rightarrow$ for closed cycle $\rightarrow$ $m_f << m_g$

$$(\eta_{isen})_{turb} = \frac{h_3 - h_4'}{h_3 - h_4}$$

$$= \frac{T_3 - T_4'}{T_3 - T_4}$$

$$\eta_{thermal} = \frac{W_{net}}{Q_{add}} = \frac{Q_{add} - Q_{rej}}{Q_{add}}$$

$$\boxed{(\eta_{th})_{1234} = 1 - \frac{1}{(r_p)^{\gamma-1/\gamma}}}$$

P_2/P_1

$1 - \frac{1}{(r_p)^{\gamma-1/\gamma}}$ Work ratio $\Rightarrow \frac{W_{net}}{W_{Turbine}}$

Que (A) Find the air fuel ratio in gas turbine cycle whose turbine and comp η are 85% & 80% resp. Max cycle temp is 875°C. Working fluid is air, which enters the compressor at 1 atm & 27°C & $r_p = 4$. Calorific value of fuel is 43MJ, $\eta_{cc} = 90\%$. Also find specific power output for $m_a = 1$ kg/sec, work ratio, η_{th}, $\eta_{air\ std}$, $\eta_{relative}$, Q_{rej}.

(B) If mass of fuel is negligible compared to air. Recalculate all the data.

(C) If cycle is closed brayton cycle, recal. all the data.

$\frac{A}{f} = \frac{m_a}{m_f} = 56.11$

$0.85 = \frac{1148 - T_4}{1148 - 772.546}$

$\frac{1148}{T_4} = (4)^{0.4/1.4}$

$T_4 = \frac{1148}{(4)^{0.4/1.4}}$

$T_4 = 772.546$

$T_4' = 828.86$ Kelvin

$W_{Turbine} = m_a C_{pg} (T_3 - T_4')$

$= (1.005)(1148 - 828.86)$

$= 326.7357$ KN

$W_{comp} = m_a C_{pa} (T_1 - T_2')$

$= 1 \times 1.005 \times 1.00 (90 - 482.25)$

$= -183.1625$

0.7
0.72
0.8

$W_{net} = W_{turb} - W_{comp}$

$= 326.7357 - 183.1625$

$= 143.08$ KN

Work ratio $= \frac{143.08}{326.7357} = 0.436$

Heat added $= 0.0178 \times 43000 \times 0.9$

$= 688.9$ KW

$\eta_{th} = \frac{143.08}{0.0178 \times 43000 \times 0.9}$

$= 0.2077 = 20.79\%$

$\eta_{air} = 1 - \frac{1}{r^{0.4/1.4}} = 1 - \frac{1}{4^{0.4/1.4}}$

$= 32.70\%$

$\eta_{rel} = \frac{\eta_{th}}{\eta_{air}} = 63.95\%$

$Q_{rej} = 688.9 - 143.08 = 545$ KW

(ii) When $\dot{m}_f < 5 = \dot{m}_g$

W_{heater}

$m_g \times 1.005 \times 482.23 + 0.9 \times 43600 \times m_f =$

$1.005 \times 1148 \times m_g$

$\frac{m_g}{m_f} \times 1.005 \times 482.23 + 0.9 \times 43600 = \frac{m_g}{m_f} \times 1.005 \times 1148$

$$\boxed{\frac{m_g}{m_f} = 57.83}$$ Ans

$W_{turbine} = 1 \times 1.005 \times (1148 - 828.86)$

$= 320.7357 \, kW$ Ans

$W_{comp} = 1 \times 1.005 \times (300 - 482.74)$

$= 183.16 \, kW$ Ans

$W_{net} = 320.7357 - 183.16$

$= 137.57 \, kW$ Ans

$Q_{add} = 0.9 \times m_f \times C.V.$

$= 0.9 \times \frac{1}{57.83} = 669.201 \, kW$ Ans

$\eta_{thermal} = 20.56\%$ Ans

$(\eta)_{cc} = 32.7\%$ Ans

$(\eta)_{rel} = \frac{20.56}{32.70}$

$= 0.6289$

$= 62.94\%$ Ans

$W.R = \frac{137.57}{320.7357}$

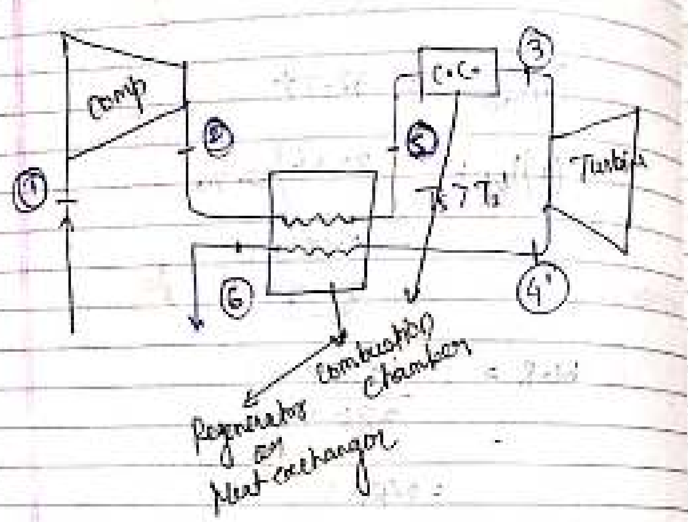
$= 0.4289$ Ans

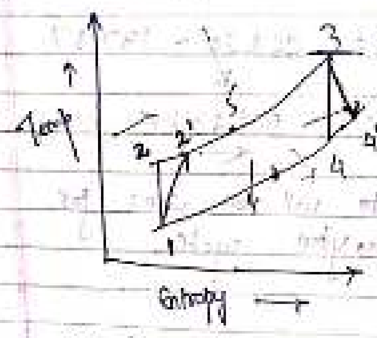
$\text{Heat rejected} = 669.20 - 137.57$

$= 531.63 \, kW$ Ans

(c) All the data will be same for closed brayton cycle

Regenerative Brayton Cycle





$\boxed{T_5 - T_2'}$ → Degree of regeneration

Effectiveness of regenerator:

$$\epsilon_R = \frac{T_5 - T_2'}{T_4' - T_2'}$$

Ideally $\epsilon_R = 1$ then $T_5 = T_4'$

$Q_{add} = Q_{3-5} = (m_a + m_f) c_{pg} T_3 - m_a c_{pa} T_5$

$W_{turbo} = (m_a + m_f) c_{pg} (T_3 - T_4')$

$W_{comp} = m_a c_{pa} (T_2' - T_1)$

$W_{net} = W_T - W_C$

$Q_{rej} = Q_{6-1}$

$$\boxed{\therefore (\eta)_{reg\ bray} > (\eta)_{reg\ bray.}}$$

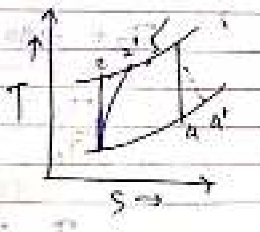
Heat lost by gas = Heat gain by air ($p = c$)

$(m_a + m_f) c_{pg} (T_4' - T_6) = m_a c_{pa} (T_5 - T_2')$

If $T_4' < T_2'$

$Q_{added} \uparrow_{reg}$

$\eta \downarrow_{\text{dec}}$



If $T_4' > T_2'$ use a reg to increase η.

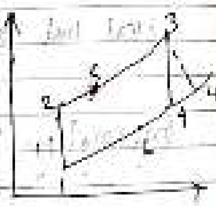
$\boxed{T_4' = T_2'}$ Using reg → η_{th} remain constant. → Don't use regenerator

$T_4' < T_2'$; using Reg. will dec. η

↳ Don't use regenerator

Que. In a regenerative brayton cycle, pressure ratio is 5. Air enters the compressor at 1 bar, 300 kelvin and leaves at 490K. Max temp of cycle is 1000 kelvin. Effectiveness of regenerator = 0.8, η_t = 0.8, find the cycle η & power output if air flow is 5 kg/sec. find work.

Ans. $P_1 = 100\ kPa$



$P_2 = 500\ kPa$

$T_1 = 300\ K$

$T_2 = 490K$, $T_3 = 1000$ kelvin

$$\frac{T_3}{T_4} = (5)^{0.4/1.4}$$

$$T_4 = 1000\left|\frac{1}{5}\right|^{0.4/1.4}$$

$= 631.38$ kelvin

$$\eta = \frac{1000 - T_4'}{1000 - 631.38} = 0.8$$

$T_4' = 705.104$ kelvin

$$\epsilon_R = \frac{T_5 - T_2}{T_4' - T_2}$$

$$0.8 = \frac{T_5 - 490}{705.104 - 490}$$

$T_5 = 662.08$ kelvin

$\cancel{m}\times \cancel{c_p}\times(T_4' - T_6) = \cancel{m}\, \cancel{c_p}\ (T_5 - T_2')$

$T_6 = T_4' - T_5 + T_2'$

$= 705.164 - 662.08 + 490$

$= 533.024$

$Q_{add} = 5\times 1.005\ (1000 - 662.08)$

$= 1698.048$ Ans.

$Q_{rej} = 5\times 1.005\ (533.024 - 300)$

$= 1170.9456$ Ans.

$\eta = 31.04\%$ Ans.

Power = 0.3104×1698.08

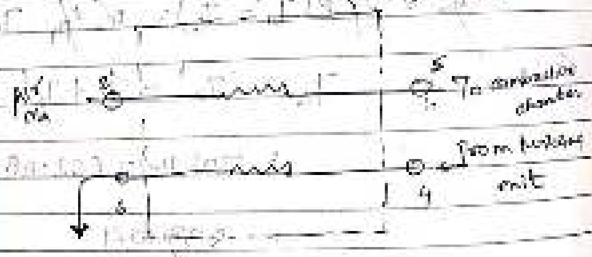
$= 527.1024$ kW

$W_{turbine} = 5 \times 1.005 \times (1580 - 905.104)$

$= 1481.8324$ kW

$W.R. = \frac{W_{net}}{W_{turb}} = \frac{527.1024}{1481.8324}$

$= 0.3557$



(i) $T_4' < T_2'$, $T_5' < T_2'$

DON'T USE REGENERATOR

(ii) $T_4' = T_2'$ ⟹ No heat transfer between air & gas.

η_{th} will remain constant i.e.

$(\eta_{th})_{without} = (\eta_{th})_{with\ regen}$

No need to use a regenerator.

$T_{exit\ turbine} \le T_{exit\ comp}$

NO NEED TO USE REGENERATOR

$T_{exit_{Turb}} > T_{exit_{comp}}$

$(\eta_{th})_{with\ reg} > (\eta_{th})_{without\ reg}$

Use a regenerator

Que. A closed cycle ideal gas turbine plant operates b/w temp limits of 800°C & 30°C and produces a power of 100 kW. The plant is designed in such a way that there is no need of regenerator. Calorific value of fuel is 45000 kJ/kg. Find the mass flow rate of air into the plant & also the fuel supplied rate in kg/sec. Also find W.R., S.F.C. (specific fuel consumption), A:F, η_{th}, $\eta_{overall}$.

for ideal Brayton (open / closed)

$$\boxed{\text{If } r_p = \left(\frac{T_3}{T_1}\right)^{\gamma/2(\gamma-1)}}$$

No need of regeneration

If $r_p < \left(\frac{T_3}{T_1}\right)^{\gamma/2(\gamma-1)} \rightarrow$ Use regenerator

$r_p > \left(\frac{T_3}{T_1}\right)^{\gamma/2(\gamma-1)} \longrightarrow$ Don't use regen.

$150 = M \times 1.005 (870.15 - 303) +$
$M \times 1.005 (1073 - 540.15)$

$m_a = 0.425$ kg/sec

$m_f = 0.0049$ kg/sec

Ans

W.R. = 0.4658 = $\frac{W_{net}}{W_{turbine}}$

$= \frac{100}{0.425 (1.005)(1073 - 540.45)}$

$= 0.4658$

Ans

S.f.C = $\frac{0.0049 \times 3600}{100}$ Ans

$= 0.1764$ kg/kW-hr

S.A.C = 15.33 kg/kW hr Ans

$\eta_{th} = \frac{W_{net}}{Q_{add}} = \frac{100}{0.0049 \times 45000}$

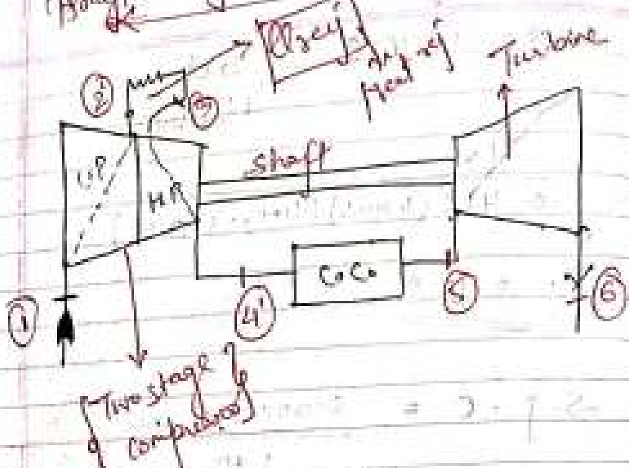
$= 45.35\% = \eta_{overall}$ Ans

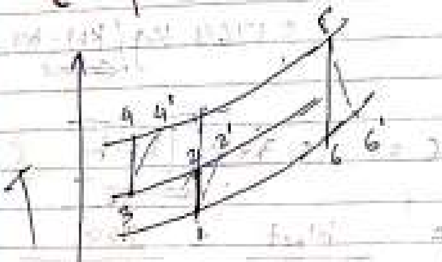
$$\boxed{\frac{S.A.C.}{S.f.C.} = \frac{A}{F}}$$

$r_{p_{opt}} = \left(\frac{T_{max}}{T_{min}}\right)^{\gamma/2(\gamma-1)}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$

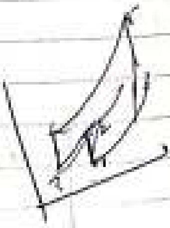
Brayton cycle with Intercooling





$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$

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



$\frac{T_2'}{T_4} = \left(\frac{P_2'}{P_4}\right)$

$Q = 2'-3 \rightarrow$ Heat rejection at $p = c$ in intercooler.

$T_3 < T_2'$

$T_3 \geq T_1$

$$\boxed{\text{effectiveness of comp} = \frac{T_2' - T_3}{T_2' - T_1}}$$

If $T_3 = T_1 \longrightarrow$ perfect intercooling (Ideal)

If $P_2 = P_2' = \sqrt{P_1 P_4}$ and intercooling is perfect, then compressor will consume MINIMUM WORK

Since $\Rightarrow$ $W_{comp} \downarrow$, $W_{Turbine} \rightarrow$ same $\Big\}$ $W_{net} \uparrow$

$(Q_{add})_{\text{without intercooler}} < (Q_{add})_{\text{with intercooler}}$

$(\eta_{th})_{\text{with intercooler}} < (\eta_{th})_{\text{without intercooler}}$

so, $Q_{rej} = \cancel{\text{same}}\ Q_{6'-1} + Q_{2'-3}$

Que. Overall pressure ratio 5

$T_1 = 300$ Kelvin, $I.P = \sqrt{5}$

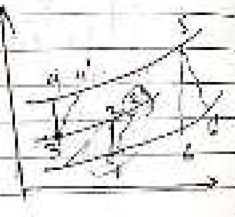
$\eta_{intercooler} = 80\%$

η_{isen} comp $= 0.9$ for both

η_{isen} turbine $= 0.85$, max temp $= 1000$ Kelvin

find power out put if $m_a = 10$ kg/sec.

η_{th}, W_{net}, Q_{add}



Soln $T_1 = 300$ Kelvin

$$\frac{T_2}{T_1} = (\sqrt{5})^{0.4/1.4}$$

$$T_2 = 300 \times (\sqrt{5})^{0.4/1.4}$$

$$\boxed{T_2 = 377.573 \text{ Kelvin}}$$

$$0.9 = \frac{T_2 - T_1}{T_2' - T_1}$$

$$0.9 = \frac{T_2 - T_1}{T_2' - T_1}$$

$$\frac{377.54 - 300}{T_2' - 300} = 0.9$$

$T_2' = 386.155$ Kelvin

$$\frac{T_4}{T_3} = (\sqrt{5})^{0.4/1.4}$$

$$\frac{377.54 - T_3}{377.574 - 300} = 0.8$$

$$\boxed{T_3 = 315.506 \text{ Kelvin}}$$

$$T_4 = 315.506 (\sqrt{5})^{0.4/1.4}$$

$T_4 = 397.066$ Kelvin

$$0.9 = \frac{397.066 - 315.506}{T_4' - 315.506}$$

$T_4' = 406.128$ Kelvin

$$\frac{T_5}{T_6} = (\sqrt{5})^{0.4/1.4} \Rightarrow T_6 = \frac{1000}{(\sqrt{5})^{0.4/1.4}} = \frac{631.385}{}$$

$T_6 = 794.597$

$$0.85 = \frac{1000 - 794.597}{1000 - T_6'}$$

$T_6' = 686.67$ K

Neglecting mass of fuel w.r.t. mass of air

$10 \times 1.005 \times (1000 - 686.67) = W_T$

$W_T = 3148.90$ KW Ans

$W_C = 10 \times 1.005 \times (356.135 - 300) +$

$10 \times (1.005)(406.128 - 310.24)$

$W_C = 1776.5385$ KW Ans

Net power = $3148.90 - 1776.538$

$= 1372.3615$ KW Ans

$Q_{add} = 10 \times 1.005 \times (1000 - 406.128)$

$= 5968.4136$ KW Ans

% η

$\eta_{th} = \frac{1372.3615}{5968.4136}$

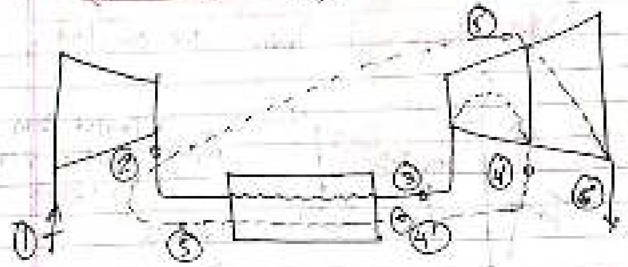
$= 23\%$ Ans

$Q_{rej} = 5968.4136 - 1372.3615$

$= 4596.0521$ KW Ans

Reheat Brayton Cycle

Reheat Brayton Cycle

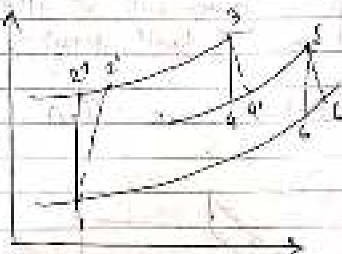


If $T_5 = T_3$ → Perfect intercooling

$\frac{P_3}{P_4'} = \frac{P_4}{P_6} = P_4 = \sqrt{P_3 P_6}$

$P_4 = P_4' = P_5$

$P_6 = P_6' = P_1$



$Q_{add} \uparrow = Q_{2'-3} + Q_{4'-5}$

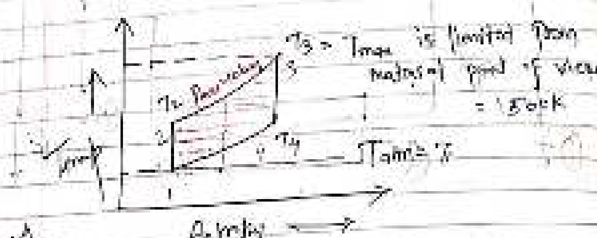
$W_{Turbine} \uparrow$ more, W_C = same

$W_{net} \uparrow$ less, η_{th} decreases

Brayton cycle

Condition for max power

When T_{max} & T_{min} are constant.

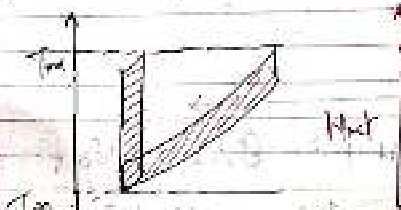


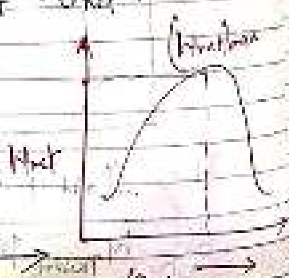
$(T_{max})_{Rankine} = 600°C$

$(P_{max})_{Rankine} = 200$ bar.

Higher temp → lower will be ultimate tensile strength.

Area 1-2-3-4-1 is W_{net} = Q_{net}.





$W_{net} = m_a c_{pa} [(T_3 - T_4) - (T_2 - T_1)]$

$T_3 = T_4 \, r_p^{\gamma-1/\gamma}$

$T_2 = T_1 \, r_p^{\gamma-1/\gamma}$

$\frac{\partial W_{net}}{\partial r_p} = 0$

Ideal cycle

$$\boxed{(r_p)_{optimum} = \left(\frac{T_3}{T_1}\right)^{\gamma/2(\gamma-1)}}$$

For actual cycle W_{net} to be max.

$$\boxed{(r_p)_{opt} = \left(\eta_t \times \eta_c \times \frac{T_3}{T_1}\right)^{\gamma/2(\gamma-1)}}$$

Que. Find the max output and corresponding η of a Joule Brayton cycle under following cond.

$T_{max} = 1200 = T_1$

$T_{min} = 300 = T_3$

$(\eta_{isen})_{turb} = 0.9$

$(\eta_{isen})_{comp} = 0.8$

Soln $r_{opt} = \left(0.9 \times 0.8 \times \frac{1200}{300}\right)^{1.4/2(1.4-1)} = 7.858 \quad 6.35$

$T_4 = 1200 \left(\frac{1}{6.36} \right)^{0.4/1.4} = 707.33$ Kelvin

$T_2 = 300 \times 6.36^{0.4/1.4} = 508.9$ Kelvin

W_{net} 1.005(

$\frac{T_2 - T_1}{T_2' - T_1} = 0.8$

$\frac{508.9 - 300}{T_2' - 300} = 0.8$

$T_2' = 561.5$ Kelvin

$\frac{1200 - T_4'}{1200 - 707.33} = 0.9$

$T_4' = 756.6$ Kelvin

$W_{net} = 1.005[(T_3 - T_4') - (T_2' - T_1)]$

$= 1.005[1200 - 756.6 - 561.5 + 300]$

$= 182.7$ kW/kg

$\eta_{th} = \frac{182.7}{1.005(T_3 - T_2')}$

$\boxed{\eta_{th} = 28.5\%}$

$\eta_{air\ std} = 1 - \frac{1}{(r_p)^{\gamma-1/\gamma}}$

$\boxed{\eta_{air\ std} = 41\%}$

Scanned with CamScanner