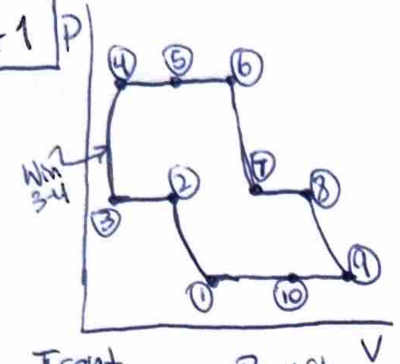
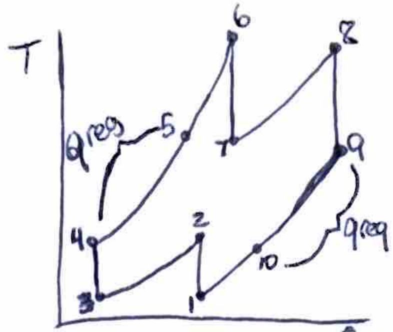
Ramzie Abbas
Met 350 - Test 1





$\varepsilon = 9$

$P = 800\,kW$

$r = \dfrac{C_{min}}{C_{max}}$

$C_p = 1.004926$

$C_v = 0.717926$

$K = 1.39998$

$r_p = 4$

1 →(Isent)→ 2 →(Pconst)→ 3 →(Isent)→ 4 →(Pconst regen)→ 5 →(Pconst)→ 6 →(Isent)→ 7 →(Pconst)→ 8 →(Isent)→ 9 →(Pconst regen)→ 10 →(Pconst)→

State	P	T	V
1	$P_1 = 100\,kpa$	$T_1 = 290.15\,K$	$V_1 = 0.833\,\frac{m^3}{kg}$
2	$P_2 = 400\,kpa$	$T_2 = 431.16\,K$	$V_2 = 0.31\,\frac{m^3}{kg}$
3	$P_3 = 400\,kpa$	$T_3 = 290.15\,K$	$V_3 = 0.21\,\frac{m^3}{kg}$
4	$P_4 = 1600\,kpa$	$T_4 = 431.08\,K$	$V_4 = 0.077\,\frac{m^3}{kg}$
5	$P_5 = 1600\,kpa$	$T_5 = 451.08\,K$	$V_5 = 0.081\,\frac{m^3}{kg}$
6	$P_6 = 1600\,kpa$	$T_6 = 749.61\,K$	$V_6 = 0.134\,\frac{m^3}{kg}$
7	$P_7 = 400\,kpa$	$T_7 = 504.55\,K$	$V_7 = 0.326\,\frac{m^3}{kg}$
8	$P_8 = 400\,kpa$	$T_8 = 808.08\,K$	$V_8 = 0.576\,\frac{m^3}{kg}$
9	$P_9 = 100\,kpa$	$T_9 = 540.51\,K$	$V_9 = 1.551\,\frac{m^3}{kg}$
10	$P_{10} = 100\,kpa$	$T_{10} = 520.51\,K$	$V_{10} = 1.494\,\frac{m^3}{kg}$

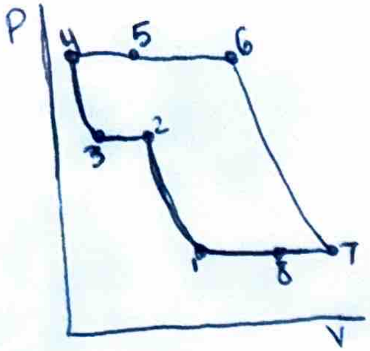
$C_{min} = C_{max} = \dot{m} C_p$ will be the same as the C_p & C_V are assumed constant

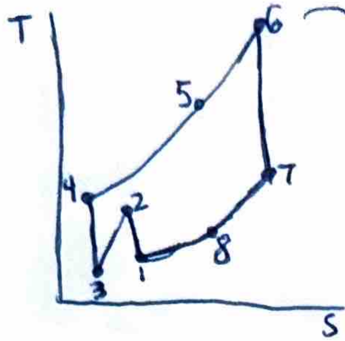
$$\frac{C_{min}}{C_{max}} = 1 \qquad \varepsilon = \frac{C_{hot}(T_{hi} - T_{ho})}{C_{min}(T_{hi} - T_{ci})} = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}}$$

$T_{hi} = T_9 = 540.51\,K \qquad T_{ho} = T_{10} = 520.51\,K \qquad T_{ci} = T_4 = 431.08\,K$

$$\varepsilon = \frac{540.51 - 520.51}{540.51 - 431.08} = 0.18276$$

Corresponding $C_{min}/C_{max} = 1$ maximum effectiveness is around 0.58, higher than the actual obtained from data available. This is because in an actual case, heat losses are taking place.





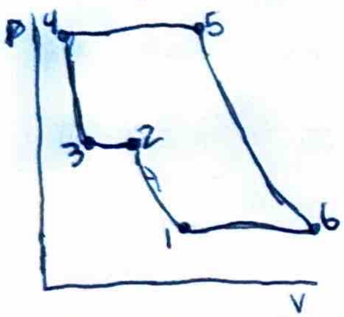
1 → 2 → 3 → 4 → 5 → 6 → 7 → 8

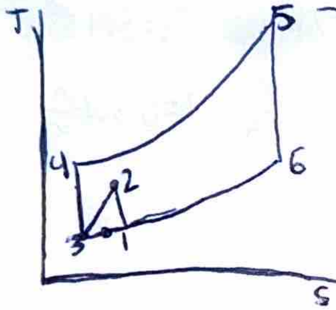
$T_1 = 290.15K$ $T_2 = 431.18K$ $T_3 = 290.15K$ $T_4 = 431.08$ $T_5 = 451.08K$ $T_6 = 749.61K$ $T_7 = 339.47K$

$$T_7 = T_6\left(\frac{1}{16}\right)^{\frac{k-1}{k}}$$

$T_7 = 339.47K$

As T_7 is than the exit temp of the compressor, the heat transfer direction will be reversed, which will require more heat addition in combustion process & reduces the thermal efficiency. So now we will bypass the regenerator & run the cycle w/o regeneration whenever the outlet temp. of the cycle goes below the exit temp. of compressor during partial load.





1 → 2 → 3 → 4 → 5 → 6

$T_1 = 290.15K$ $T_2 = 431.18K$ $T_3 = 290.15K$ $T_4 = 431.18K$ $T_5 = 729.609$ $T_6 = 330.421K$

$$T_5 = \frac{300}{1.004926} + T_4 \qquad T_6 = T_5\left(\frac{1}{16}\right)^{\frac{k-1}{k}}$$

$T_5 = 729.609$ $\qquad T_6 = 330.4214K$

$W = C_p(T_5 - T_6)$

$= 1.004926 \times (729.609 - 330.421)$

$W = 401.15$

$W_{net} = 401.15 - 141.7 - 141.62$

$W_{net} = 117.82$

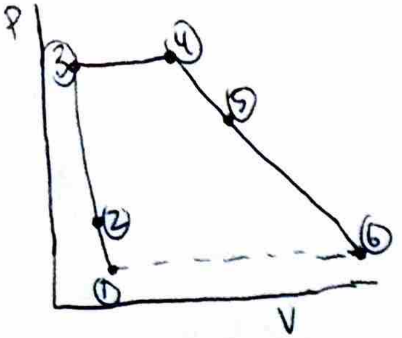
$P = \dot{m} \times W_{net}$

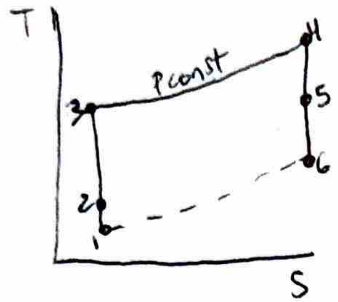
$P = 415.61\ kW$

$$\eta_{th} = \frac{117.82}{300}$$

$\eta_{th} = 0.39275$

At part load condition the power output of the engine is reduced & the efficiency is increased. This is because the heat taken by the air to the surroundings is reduced & the exit temp of air ($T_{10} = 520.51K$) is higher than when reheat is turned off ($T_6 = 330.42K$). Which leads to an increase in efficiency.





① → ② → ③ → ④ → ⑤ → ⑥

① $P_1 = 45kpa$, $T_1 = 260.15k$, $v_1 = 1.659 \frac{m^3}{kg}$, $V_1\ 240 m/s$

② $T_2 = 288.23K$, $P_2 = 64.41kpa$

③ $P_3 = 837.45kpa$, $T_3 = 599.803K$

④ $T_4 = 830.15K$, $P_4 = P_3 = 837.45kpa$

⑤ $T_5 = 559.07K$, $P_5 = 209.921kpa$

⑥ $P_6 =$, $T_6 = 386.244K$, $V_6 = 691.708 m/s$

$Cp(T=260.15k) = 1.005 \frac{kJ}{kg \cdot K}$

(Table A-9)

$Cp(T=288.81K) = 1.007 \frac{kJ}{kg \cdot K}$

$$h_1 + \frac{V_1^2}{2} = h_2$$

$$CpT_1 + \frac{V_1^2}{2} = CpT_2$$

$$1.005 \times 260.15 + \frac{240^2}{2000} = 1.007 \times T_2$$

$$\eta_{isen/compr} = \frac{T_3 - T_2}{T_3' - T_2}$$

$$T_3' = \frac{T_3 - T_2}{\eta_{isen}} + T_2$$

$$= \frac{599.803 - 288.23}{0.8} + 288.23$$

$$T_3' = 677.69K$$

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

$$P_2 = 64.41kpa$$

$$P_3 = r_p P_2$$

$$P_3 = 13 \times 64.41$$

$$P_3 = 837.45kpa$$

compr work = turbine work

$Cp(T=288.81k) = 1.007$

$Cp(T=599.803K) = 1.005 \frac{kJ}{kg\,K}$

$Cp(T=830.15K) = 1.104 \frac{kJ}{kg \cdot K}$

$Cp(T=520K) = 1.033 \frac{kJ}{kgK}$

$$-1.007 \times 288.81K + 1.05 \times 599.803$$

$$= 1.104 \times 830.15 - 1.033 \times T_5$$

$$T_5 = 559.075k$$

$$\frac{T_3}{T_2} = (r_p)^{\frac{k-1}{k}}$$

$$T_3 = 599.803k$$

Isentropic Effiency of turbine 85%

$$\eta_{isen/turbine} = \frac{T_5' - T_4}{T_5 - T_4}$$

$$T_5' = \eta_{isen/turbine} \times (T_5 - T_4) + T_4$$

$$= 0.85 \times (559.075 - 830.15) + 830.15$$

$$T_5' = 599.736K$$

$$\frac{P_4}{P_5} = \left(\frac{T_4}{T_5}\right)^{\frac{k}{k-1}} = P_5 = 209.921kpa$$

$$\left(\frac{P_5'}{P_6'}\right)^{\frac{k-1}{k}} = \frac{T_5'}{T_6} =$$

$$T_6' = T_5' \left(\frac{P_6'}{P_5'}\right)^{\frac{k-1}{k}}$$

$$T_6' = 386.244k$$

$$h_5' = h_6' + \frac{V_6'^2}{2}$$

$Cp(T=599.736) = 1.05 \frac{kJ}{kgK}$

$Cp(T=386.244k) = 1.011 \frac{kJ}{kgK}$

$$1.05 \times 599.736 = 1.011 \times 386.244 + \frac{V_6'^2}{2000} =$$

$$V_6 = 691.708 m/s$$

$$\eta_p = \frac{\cancel{\dot m}(V_1 - V_6) \times V_1}{\frac{\cancel{\dot m}(V_1^2 - V_6^2)}{2}} = \frac{2V_1(V_1 - V_6)}{V_1^2 - V_6^2}$$

a) η_p in previous case w/o comp & turbine effiency w/ isentropic process

$V_1 = 240\ m/s \quad V_6 = 564.52\ m/s$

$$\eta_p = \frac{2 \times 240(240 - 564.52)}{240^2 - 564.52^2} = 0.5966$$

$\eta_p = 59.66\%$

b) η_p in the case w/ isentropic compr & turbine effiency.

$$\eta_p = \frac{2 \times 240(240 - 691.708)}{240^2 - 691.708^2} = 0.5152$$

$\eta_p = 51.52\%$

Propulsion efficiency has reduced from 59.66% to 51.52% due to unreversibility involved in the compr & expansion of air in the compressor & turbine who by considering the variable air property the specific heat of air is higher, which consumes more energy for the same temperature drop.