Stroke IV :- Adiabatic Compression of gas from V_4 to V_1

(i) Heat given out = 0

(ii) Work done on the system $W_4 = C_v (T_2 - T_1)$

Now the net heat absorbed (q) by the ideal gas in the whole cycle is given by

$$q = (q_2) + (-q_1) = RT_2 \ln \frac{V_2}{V_1} + RT_1 \ln \frac{V_4}{V_3} \quad \text{— 8}$$

$$= RT_2 \ln \frac{V_2}{V_1} - RT_1 \ln \frac{V_3}{V_4} \quad \text{— (4)}$$

On the basis of Adiabetic expansion the following equation Can be Obtained

$$C_v \ln \frac{T_2}{T_1} = R \ln \frac{V_3}{V_2} \quad (\text{For stage II})$$

$$C_v \ln \frac{T_2}{T_1} = R \ln \frac{V_4}{V_1} \quad (\text{For stage IV})$$

Or, $R \ln \frac{V_3}{V_2} = R \ln \frac{V_4}{V_1}$

or, $\frac{V_3}{V_4} = \frac{V_2}{V_1}$

Now net heat absorbed is q,

$$q = (q_2) + (-q_1) = RT_2 \ln \frac{V_2}{V_1} - RT_1 \ln \frac{V_3}{V_4}$$

$$= RT_2 \ln \frac{V_2}{V_1} - RT_1 \ln \frac{V_2}{V_1} \quad \left[\because \frac{V_3}{V_4} = \frac{V_2}{V_1}\right]$$

$$\therefore q = R(T_2 - T_1) \ln \frac{V_2}{V_1} \quad \text{— (5)}$$

Again Net work done by gas :-

$$W = (-W_1) + (-W_2) + (W_3) + (W_4)$$

On Substituting the value of $-W_1, -W_2, W_3$ and W_4, we have

$$W = RT_2 \ln \frac{V_2}{V_1} - C_v (T_2 - T_1) + RT_1 \ln \frac{V_4}{V_3} + C_v (T_2 - T_1)$$

$$W = RT_2 \ln \frac{V_2}{V_1} - RT_1 \ln \frac{V_3}{V_4} \quad \left[\because \frac{V_3}{V_4} = \frac{V_2}{V_1}\right]$$

$$\therefore W = RT_2 \ln \frac{V_2}{V_1} - RT_1 \ln \frac{V_2}{V_1} = R(T_2 - T_1) \ln \frac{V_2}{V_1} \quad \text{— (6)}$$

It follows from eqn (5) and (6) that $q = W$, thus essential Condition for a Cyclic process that the net work done is equal to the net heat absorbed is fully satisfied.

Relation between W, q_2 and higher temperature T_2.

$$\because W = R(T_2 - T_1) \ln \frac{V_2}{V_1} \quad \text{— (6)}$$

$$\text{and } q_2 = RT_2 \ln \frac{V_2}{V_1} \quad \text{— (1)}$$

On dividing eqn (6) by eqn (1) we have

$$\frac{W}{q_2} = \frac{T_2 - T_1}{T_2}$$

$$\text{or } W = q_2 \frac{(T_2 - T_1)}{T_2} \quad \text{— (7)}$$

Efficiency of a Heat engine: → The fraction of heat absorbed by an engine, that it can Convert in to work gives the efficiency (η) of the engine.

Efficiency $\eta = \frac{W}{q_2} = \frac{T_2 - T_1}{T_2}$, If $T = 0$, Efficiency = 1

The net heat absorbed by the System is q, then work $W = q_2 - q_1$ — 8

From eqn (7) and (8) $\frac{q_2 - q_1}{q_2} = \frac{T_2 - T_1}{T_2} = \eta$ (Efficiency of heat engine) — (9)