## 4.6 Limited Pressure Cycle (or Dual Cycle):

This cycle is also called as the dual cycle, which is shown in Fig.4.6. Here the heat addition occurs partly at constant volume and partly at constant pressure. This cycle is a closer approximation to the behavior of the actual Otto and Diesel engines because in the actual engines, the combustion process does not occur exactly at constant volume or at constant pressure but rather as in the dual cycle.

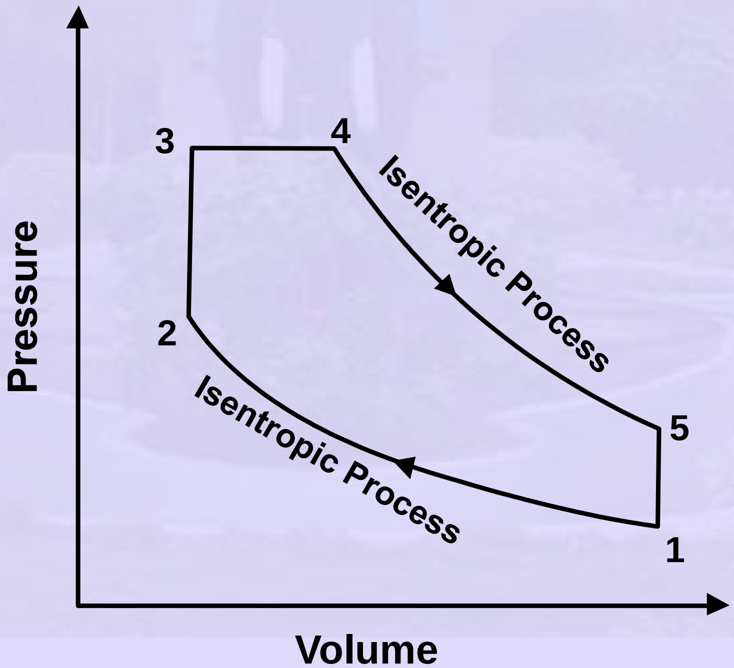
Process 1-2: Reversible adiabatic compression.

Process 2-3: Constant volume heat addition.

Process 3-4: Constant pressure heat addition.

Process 4-5: Reversible adiabatic expansion.

Process 5-1: Constant volume heat rejection.



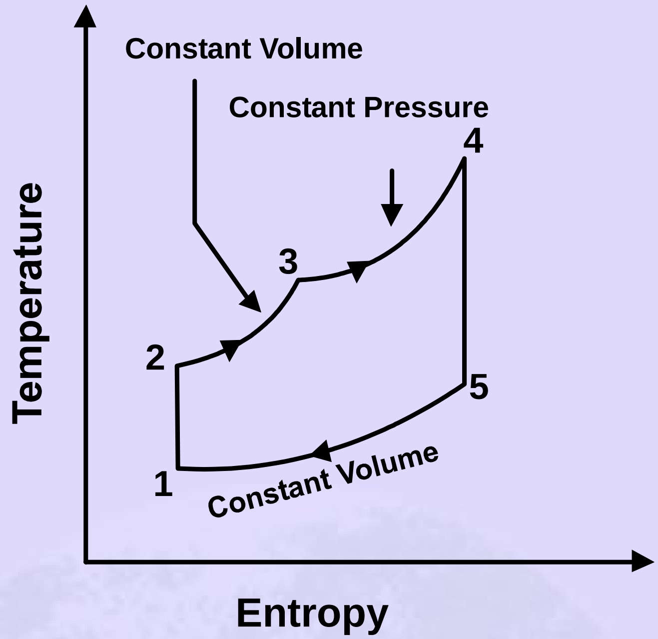



**Fig.4.6. Dual cycle on p-v and T-s diagrams**

## Air Standard Efficiency:

$$\text{Heat supplied} = m\, C_v \left(T_3 - T_2\right) + m\, C_p \left(T_4 - T_3\right)$$

$$\text{Heat rejected} = m\, C_v \left(T_5 - T_1\right)$$

$$\text{Net work done} = m\, C_v \left(T_3 - T_2\right) + m\, C_p \left(T_4 - T_3\right) - m\, C_V \left(T_5 - T_1\right)$$

$$\eta_{th} = \frac{m\, C_v \left(T_3 - T_2\right) + m\, C_p \left(T_4 - T_3\right) - m\, C_v \left(T_5 - T_1\right)}{m\, C_v \left(T_3 - T_2\right) + m\, C_p \left(T_4 - T_3\right)}$$

$$\eta_{th} = 1 - \frac{T_5 - T_1}{\left(T_3 - T_2\right) + \gamma\left(T_4 - T_3\right)}$$

$$\text{Let, } \frac{P_3}{P_2} = r_p \; ; \; \frac{v_4}{v_3} = r_c \; ; \; \frac{v_1}{v_2} = r$$

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

$$T_3 = T_2\, r_p = T_1\, r^{\gamma - 1}\, r_p$$

$$T_4 = T_3\, r_c = T_1\, r^{\gamma - 1}\, r_p\, r_c$$

$$\frac{T_5}{T_4} = \left(\frac{v_4}{v_5}\right)^{\gamma - 1} = \left(\frac{v_4}{v_2}.\frac{v_2}{v_5}\right)^{\gamma - 1} = \left(\frac{r_c}{r}\right)^{\gamma - 1}$$

$$T_5 = T_4\left(\frac{r_c}{r}\right)^{\gamma - 1} = T_1\ r_p\ r_c^{\gamma}$$

$$\eta_{th} = 1 - \frac{T_1\ r_p\ r_c^{\gamma} - T_1}{\left\{\left(T_1\ r^{\gamma - 1}\ r_p - T_1\ r^{\gamma - 1}\right) + \gamma\left(T_1\ r^{\gamma - 1}\ r_p\ r_c - T_1\ r^{\gamma - 1}\ r_p\right)\right\}}$$

$$= 1 - \frac{\left(r_p\ r_c^{\gamma} - 1\right)}{\left\{\left(r_p\ r^{\gamma - 1} - r^{\gamma - 1}\right) + \gamma\left(r_p\ r_c\ r^{\gamma - 1} - r_p\ r^{\gamma - 1}\right)\right\}}$$

$$\eta_{th}\ 1 - \frac{1}{r^{\gamma - 1}}\left\{\frac{r_p\ r_c^{\gamma} - 1}{\left(r_p - 1\right) + \gamma r_p\left(r_c - 1\right)}\right\}$$

From the above equation, it is observed that, a value of $r_p > 1$ results in an increased efficiency for a given value of $r_c$ and $\gamma$. Thus the efficiency of the dual cycle lies between that of the Otto cycle and the Diesel cycle having the same compression ratio.

## Mean Effective Pressure:

$$\text{mep} = \frac{\text{Workdone}}{\text{Displacement volume}}$$

$$= \frac{m\,C_v\left(T_3 - T_2\right) + m\,C_p\left(T_4 - T_3\right) - m\,C_v\left(T_5 - T_1\right)}{v_1 - v_2}$$

$$v_1 - v_2 = \frac{m\,C_v\left(\gamma - 1\right)T_1}{p_1}\left(\frac{r - 1}{r}\right)$$

$$\text{mep} = \frac{p_1\ r}{(r-1)(\gamma-1)}\left\{\frac{T_3 - T_2}{T_1} + \frac{\gamma(T_4 - T_3)}{T_1} - \frac{T_5 - T_1}{T_1}\right\}$$

$$= \frac{p_1\ r}{(r-1)(\gamma-1)}\left\{r^{\gamma-1}(r_p - 1) + \gamma\ r^{\gamma-1}\ r_p\,(r_c - 1) - \left(r_p\ r_c^{\gamma} - 1\right)\right\}$$

$$= \frac{p_1\ r}{(r-1)(\gamma-1)}\left\{r^{\gamma-1}\left\{(r_p - 1) + \gamma\ \ r_p\,(r_c - 1)\right\} - \left(r_p\ r_c^{\gamma} - 1\right)\right\}$$