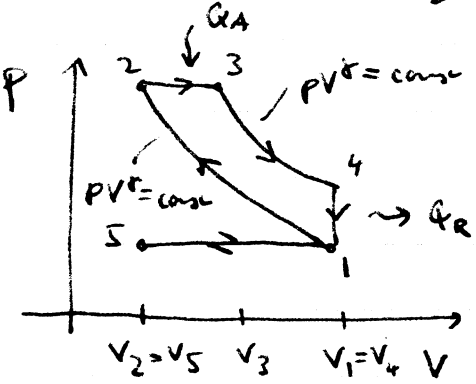
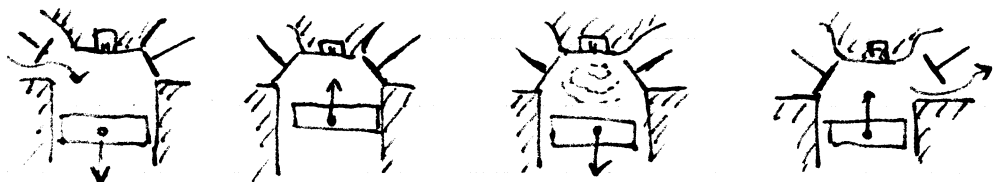
T12 — 16. Unified Fall 07

Diesel engine: $r = \frac{V_1}{V_2} = 15$, $r_c = \frac{V_3}{V_2} = 2$, $T_1 = 288\,K$, $p_1 = 1\,bar$

a)



5 → 1: intake stroke (inlet valve open)
1 → 2: compression stroke (adiabatic rev.)
2 → 3: heat addition (after compression ignition, $p = const$)
3 → 4: power stroke (a.d. reversible)
4 → 1: heat rejection at const. volume
1 → 5: exhaust stroke (exhaust valve open)



2 shaft revs per cycle:
1 – 2 – 3 – 4 – 1
1 – 5 – 1

b) $\eta_{th}^D = 1 - \frac{Q_R}{Q_A} = 1 - \frac{c_v(T_4 - T_1)}{c_p(T_3 - T_2)} = 1 - \frac{1}{\gamma}\frac{T_1}{T_2}\frac{\left(\frac{T_4}{T_1} - 1\right)}{\left(\frac{T_3}{T_2} - 1\right)}$; 1→2, 3→4 a.d. rev: $\frac{T_1}{T_2} = \left(\frac{V_1}{V_2}\right)^{1-\gamma}$

2–3 isobar: $\frac{T_3}{T_2} = \frac{V_3}{V_2}$; 4–1 isochor: $V_1 = V_4$; $\frac{T_4}{T_3} = \left(\frac{V_4}{V_3}\right)^{1-\gamma} = \left(\frac{V_1}{V_3}\right)^{1-\gamma} = \left(\frac{V_1}{V_2}\right)^{1-\gamma}\left(\frac{V_2}{V_3}\right)^{1-\gamma}$

$\frac{T_4}{T_3} = \frac{T_4}{T_1}\frac{T_1}{T_2}\frac{T_2}{T_3} = \frac{T_4}{T_1}\left(\frac{V_1}{V_2}\right)^{1-\gamma}\left(\frac{V_2}{V_3}\right)$ so $\frac{T_4}{T_1} = \left(\frac{V_3}{V_2}\right)^{\gamma}$ use: $r = V_1/V_2$, $r_c = V_3/V_2$

$\eta_{th}^D = 1 - \frac{1}{\gamma} r^{1-\gamma}\frac{r_c^{\gamma} - 1}{r_c - 1}$; $\eta_{th}^D = 0.60$

c) $T_2 = T_1 r^{\gamma - 1}$; $T_2 = 851\,K$

d) $N = 2000$ rpm, $n_{dias} = 4 \cdot \frac{2000}{2} = 4000 \frac{dias}{minute}$
(4 ↑ no. cyl; 2 ↑ 2 revs/dias)

e) $\dot{W} = W \cdot \frac{n_{dias}}{60}$, $W = 2.8\,kJ$ per cycle ; $W = m c_p(T_3 - T_2) - m c_v(T_4 - T_1)$

$W = m c_p T_1\left(\frac{T_3}{T_2}\frac{T_2}{T_1} - \frac{T_2}{T_1} - \frac{1}{\gamma}\frac{T_4}{T_1} + \frac{1}{\gamma}\right)$; $W = m c_p T_1\left(r^{\gamma-1}(r_c - 1) - \frac{1}{\gamma}(r_c^{\gamma} - 1)\right)$

$m = 0.0054\,kg$; $m = \rho_1 V_1$ so $V_1 = \frac{mRT_1}{p_1}$, $V_1 = 0.0045\,m^3$

$V_D = V_1(1 - \frac{1}{r}) \cdot 4 = 16.6\,l$ (rather large for 250 HP!)