Q4 2001

i) $\eta = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{mC_v(T_5 - T_1)}{mC_v(T_3 - T_2) + mC_p(T_4 - T_3)}$

$\eta = 1 - \frac{C_v(T_5 - T_1)}{C_v(T_3 - T_2) + C_p(T_4 - T_3)}$

NB HEAT REJECTED AT CONST. VOL (5-1)
HEAT INPUT AT CONST VOL (2-3)
AND CONST. PRESSURE (3-4)

ii) $r_c = 10$

$P_1 = 1$ bar $T_1 = 290$K $m_a = 0.05$kg/s
$\dot{Q}_{in} = 50$kw

$\dot{Q}_{in}$ 2-3 = 25kw
$\dot{Q}_{in}$ 3-4 = 25kw

Highest P and T is at point (4)

$\gamma = C_p/C_v = 1.004/0.717 = 1.4$

$T_2 = T_1 (r)^{\gamma-1} = 290 \times 10^{0.4}$

$290 \times 2.512 = 728.4$K

Const Vol Heating
25kw $= m C_v (T_3 - T_2)$

$25 = 0.05 \times 0.717 (T_3 - 728.4)$

$T_3 = 697.35 + 728.4 = 1425.8$K

Constant Pressure Heating

$$25 = 0.05 \times 1.004 (T_4 - 1425.8)$$

$$T_4 = 498 + 1425.8 = \underline{1923.8\ K}$$

$P_3 = P_4 =$ Highest Press

$$P_3 = \frac{P_1 V_1}{T_1} \times \frac{T_3}{V_3} = \frac{1}{290} \times \frac{10}{1} \times 1425.8$$

$$P_3 = P_4 = 49.16\ bar$$

$$P_{nett} = Q_{in} - Q_{out}$$

$$Q_{out} = m c_v (T_5 - T_1)$$

$$\frac{P_4 V_4}{T_4} = \frac{P_3 V_3}{T_3}$$

$$\frac{V_3}{V_4} = \frac{P_4}{P_3} \times \frac{T_3}{T_4} = 1 \times \frac{1425.8}{1923.8} = 0.74$$

$$\frac{V_4}{V_3} = 1.35$$

$$T_5 = T_4 \left(r \right)^{0.4}_{V_4/V_1}$$

$$\frac{V_5}{V_4} = \frac{V_5}{V_3} \times \frac{V_3}{V_4} = 10 \times .74 = 7.4$$

$$T_5 = 1923.8 \times \left(\frac{1}{7.4}\right)^{.4} = 863.9\,K$$

$$\phi_{out} = 0.05 \times 717 \,(863.9 - 290)$$

$$= 20.57\ kw$$

$$P(net) = 50 - 20.57 = 29.43\ kw$$

$$\eta = \frac{29.43}{50} = 58.9\%$$