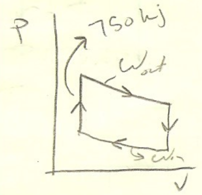
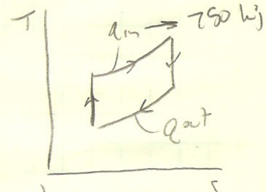
33)





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1 → (Poly) → **2** → (v const) → **3** → (Poly) → **4**

1

$P_1 = 95\ kpa$

$T_1 = 27° + 273$

$T_1 = 300K$

$V_1 = \frac{RT_1}{P_1} = \frac{.287(300)}{95}$

$V_1 = .906\ m^3$

$u_1 = 214.07\ kj/kg$

2

$V_2 = \frac{V_1}{r} = \frac{.906}{8}$

$V_2 = .113\ m^3$

Since variable specific heat,

$\frac{V_2}{V_1} = \frac{V_{r2}}{V_{r1}}$

$\frac{.113\ m^3}{.906\ m^3} = \frac{V_{r2}}{621.2}$

$V_{r2} = 77.65$

from A-17 @ $V_{r2} = 77$, $T_2 = 675K$

$P_2 = \frac{RT_2}{V_2}$

$P_2 = \frac{.287(675K)}{.113}$

$P_2 = 1714\ kpa$

3

$V_3 = .113\ m^3$

$q_{in} = U_3 - U_2$

from A-17 @ $T_2 = 675$

$U_2 \approx 492\ kj/kg$

$750\ kj/kg = U_3 - 492$

$U_3 = 1242\ kj/kg$

from A-17 @ $U = 1242$

$T_3 = 1540K$

$P_3 = \frac{RT_3}{V_3}$

$P_3 = \frac{.287(1540)}{.113}$

$P_3 = 3911.3\ kpa$

4

$V_4 = .906\ m^3$

$\frac{V_4}{V_3} = \frac{V_{r4}}{V_{r3}} \rightarrow V_{r4} = V_{r3}\left(\frac{V_4}{V_3}\right) = 6.569\left(\frac{.906}{.113}\right)$ (from A-17)

$V_{r4} = 52.66$

From A-17 @ $V_{r4} = 52.66$,

$T_4 \approx 770K$

$U_4 \approx 568\ kj/kg$

$P_4 = \frac{RT_4}{V_4} = \frac{.287(770)}{.906}$ $P_4 = 243.9\ kpa$

a) P; T @ end of heat addition – $P_3 = 3911.3\ kpa$ | $T_3 = 1540K$

b) $U_{out} = U_4 - U_1 \rightarrow Q_{out} = 568 - 214.07 = 353.93\ kj/kg$

c) $\eta = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{353.93}{750} = 52.8\%$

d) $MEP = \frac{W_{net}}{V_{max} - V_{min}}$

$\eta = .528 = \frac{W_{net}}{q_{in}} \rightarrow W_{net} = .528(750\ kj/kg)$ $W_{net} = 396.07\ kj/kg$

$MEP = \frac{396.07\ kj/kg}{.906\ m^3 - .113\ m^3}$ $MEP = 499.5\ kpa$

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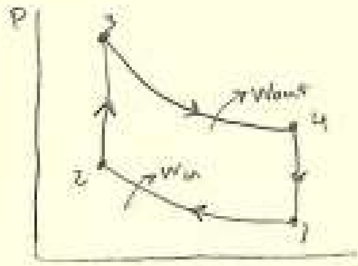
36) Given:

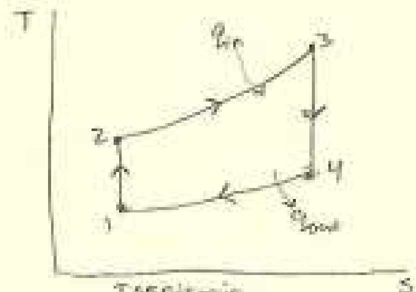
- Ideal
- 6 cylinders
- bore size = 3.5 in
- Stroke dist = 3.9 in
- $V_{min} = V_{max}(.098)$

$R_{Air} = 0.3704 \frac{psia \cdot ft^3}{lbm \cdot R}$ $R = °F + 459.67$

$C_v = 0.171$ Btu/lbm·R

$k = 1.4$





→ ① —Isentropic→ ② —const v→ ③ —Isentropic→ ④ —const v

①	②	③	④
$T_1 = 564 R$	$T_2 = 1428 R$	$T_3 = 2859.7 R$	$T_4 = 1129.5 R$
$P_1 = 14$ psia	$P_2 =$	$P_3 =$	$P_4 = 28.04$ psia
$V_1 = 14.92$ ft³/lbm	$V_2 =$	$V_3 =$	$V_4 = 14.92$ ft³/lbm

$\frac{\pi d^2}{4}(h) = V_1 = \frac{\pi(3.5)^2}{4}(3.9) = 37.5 in^3$

$V_2 = .098(37.5) = 3.68 in^3$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \Longrightarrow T_2 = (r)^{k-1}(T_1)$ $r = \frac{37.5 in^3}{3.68 in^3} = 10.2$ and $k = 1.4$

$T_2 = (10.2)^{.4}(564) = 1428.2 R$

$T_{max} = T_3 = 2400 + 459.67 = 2859.7 R$

$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{k-1} \Longrightarrow T_3 = T_4(r)^{k-1} \Longrightarrow T_4 = \frac{2859.7}{(10.2)^{.4}} = 1129.5 R$

$V_1 = \frac{RT_1}{P_1} = \frac{(.3704)(564 R)}{14 \text{ Psia}} = 14.92$ ft³/lbm

$P_4 = \frac{RT_4}{V_4} = 28.04$ Psia

36. Continued:

$W_{out} = \Delta u = c_v(T_3 - T_4) = 0.171(2859.5 - 1129.5) = 295.8 \ BTU/lbm$

$W_{in} = \Delta u = c_v(T_2 - T_1) = 0.171(1428 - 564) = 147.74 \ BTU/lbm$

$W_{out} - W_{in} = W_{net} = 148.1 \ BTU/lbm$

$m = \frac{V_d}{V_1}$ (per cyl) $V_d = \frac{\pi(3.5)^2}{4}(3.9) = 37.52 \ in^3 \left(\frac{1 \ ft}{(1728 \ in^3)}\right) = .0217 \ ft^3$

$m = \frac{.0217 \ ft^3}{14.92 \ ft^3/lbm} = .0015 \ lbm$

$m_{tot} = .0087 \ lbm$

$W_{net} = w_{net} m_{tot} = 1.29 \ BTU/cycle$

$\dot{W}_{net} = \frac{W_{net} \dot{n}}{n_{rev}}$ $\quad n_{rev} = 2 \ rev/cycle$

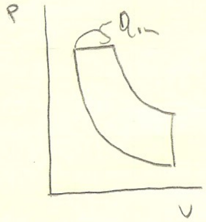
$\dot{n} = 2500 \ rev/m = \frac{2500}{60} = 41.67 \ rev/s$

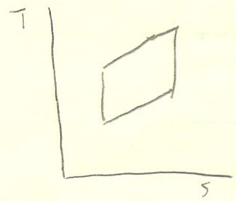
$\dot{W}_{net} = \frac{(1.29 \ BTU/cycle)(41 \ rev/s)}{(2 \ rev/cycle)} = 26.88 \ BTU/s$

$1 \ hp = .7068 \ BTU/s$

$\boxed{\dot{W}_{net} = \frac{26.88}{.7068} = 38.02 \ Hp}$

46)





1

$P_1 = 95\ kpa$

$T_1 = 27^{\circ}C + 273k$

$T_1 = 300k$

$V_1 = \frac{RT_1}{P_1} = \frac{.287(300k)}{95\ kpa}$

$V_1 = .906\ m^3$

$u_1 = 214.07\ kj/kg$

2

$V_2 = \frac{V_1}{r} = \frac{.906m^3}{16}$

$V_2 = .0566m^3$

$V_{r_2} = \frac{V_2}{V_1}(V_{r_1})$

from A-17 @ 300k

$V_{r_1} = 621.2$

$V_{r_2} = \frac{.0566m^3}{.906m^3}(621.2)$

$V_{r_2} = 38.82$

Interpolate between 360k ; 380k

$T_2 = 862.03k$

$U_2 = 643.08\ kj/kg$

$P_2 = \frac{RT_2}{V_2} = \frac{.287(862.03)}{.0533m^3}$

$P_2 = 4641.7kpa$

3

$P_3 = 4641.7kpa$

$r_c = \frac{V_3}{V_2} \rightarrow V_3 = r_c(V_2)$

$V_3 = 2(.0566) = .1132m^3$

$T_3 = \frac{V_3}{V_2}T_2 = T_3 = (2)(862.03)$

$T_3 = 1724.06k$

Interpolate Between 1700 ; 1750k

$U_3 = 1415.36\ kj/kg$

4

$V_4 = V_1 = .906m^3$

$V_{r_4} = \frac{V_4}{V_3}(V_{r_3})$

Interpolate for $V_{r_3} = 4.55$

$V_{r_4} = \frac{.906m^3}{.1132m^3}(4.55)$

$V_{r_4} = 36.42$

Interpolate between 880k ; 900k

$T_4 = 881.65\ k$

$U_4 = 659.33\ kj/kg$

a) Temp after heat addition - $\boxed{T_3 = 1724.06k}$

b) $\eta = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{U_4 - U_1}{U_3 - U_2} = 1 - \frac{659.3\ kj/kg - 214\ kj/kg}{1415.36\ kj/kg - 643.5\ kj/kg}$

$\boxed{\eta = 42.3\%}$

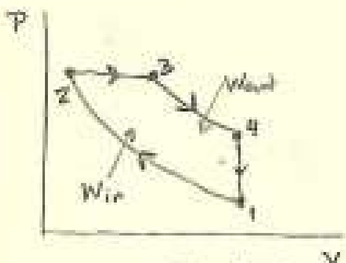
c) $MEP = \frac{W_{net}}{V_{max} - V_{min}}$ $\quad W_{net} = \eta(Q_{in}) \rightarrow .423(1415.36 - 643.08)$

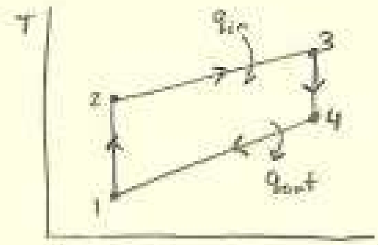
$W_{net} = 326.67\ kj/kg$

$MEP = \frac{326.67}{.906m^3 - .0566m^3}$ $\boxed{MEP = 384.6\ kpa}$

57.) Given:

- 4 Cylinders
- Compression Ratio = 22
- Cutoff Ratio = 1.8





→ ① —Isentropic→ ② —Isobaric→ ③ —Isentropic→ ④ —V = Const→

①	②	③	④
$T_1 = 343\ k$	$T_2 = 1181.04\ k$	$T_3 = 2125.9\ k$	$T_4 = 780.9\ k$
$P_1 = 97\ kPa$	$P_2 = 7352.68\ kPa$	$P_3 = 7352.68\ kPa$	$P_4 = 220.8\ kPa$
$V_1 = 1.015\ m^3/kg$	$V_2 = .0461\ m^3/kg$	$V_3 = .083\ m^3/kg$	$V_4 = 1.015\ m^3/kg$

$r = \frac{V_1}{V_2} = 22 \quad k = 1.4 \quad R = .2870\ kJ/kg\cdot k = .287\ \frac{kPa \cdot m^3}{kg \cdot k}$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \Longrightarrow T_2 = T_1(r)^{k-1} = 343(22)^{.4} = 1181.04\ k$

$V_1 = \frac{RT_1}{P_1} = \frac{(.2870)(343)}{97} = 1.015\ m^3/kg$

$V_2 = \frac{1.015}{22} = .0461\ m^3/kg$

$P_2 = \frac{RT_2}{V_2} = \frac{(.287)(1181.04)}{.0461} = 7352.68\ kPa$

$\frac{V_3}{V_2} = \frac{T_3}{T_2} \Longrightarrow r_{co} = \frac{T_3}{T_2} \Longrightarrow r_{co} T_2 = T_3 = 1.8(1181.04) = 2125.9\ k$

$V_3 = \frac{RT_3}{P_3} = \frac{(.287)(2125.9)}{7352.68} = .08298\ m^3/kg$

$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{.4} = T_4 = \left(\frac{.083}{1.015}\right)^{.4}(2125.9) = 780.9\ k$

$P_4 = \frac{RT_4}{V_4} = \frac{(.287)(780.9)}{1.015} = 220.8\ kPa$

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57 Continued

$$W_{out} = W_{3\to4} = C_v(T_3 - T_4) = 0.718\,(2125.9 - 780.9) = 965.7\ kJ/kg$$

$$W_{in} = W_{1\to2} = C_v(T_2 - T_1) = .718\,(1181.04 - 343) = 601.7\ kJ/kg$$

$$W_{net} = 965.7 - 601.7 = 364.0\ kJ/kg$$

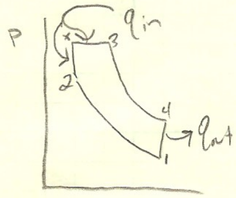
2.4 L = .0024 m³

$$PV = nRT \Longrightarrow n = \frac{PV}{RT} \Longrightarrow \overbrace{n_{mass}}^{state\ 1} = \frac{(97\,kPa)(.0024\ m^3)}{(.287)(343\ k)} = .00236\ kg$$

$$W_{net} = 601.7\ kJ/kg\,(.00236\ kg) = 1.42\ kJ$$

$$\dot{W}_{net} = \frac{W_{net}\,(\dot{n})}{n_{rev}} = \frac{(1.42\ kJ)(3500\ \frac{rev}{min})(\frac{1\ min}{60\ s})}{1\ rev/cycle} = \boxed{83.01\ kW}$$

59)



$R = .3704$
$C_p = .24$
$C_v = .171$
$k = 1.4$

$w_{net} = ?$
$q_{in} = ?$
$\eta = ?$

1 → (Isentropic, Compression ratio) → 2 → (V const, Pressure ratio) → x → (P const, cutoff ratio) → 3 → 4

1

$P_1 = 14.2\ psi$

$T_1 = 75\ °F + 459.67$

$T_1 = 534.67\ R$

$V_1 = \frac{RT_1}{P_1} = \frac{.3704(534.67)}{14.2\ psi}$

$V_1 = 13.94\ in^3$

2

$\frac{T_2}{T_1} = \frac{V_1}{V_2}^{(1.4-1)}$

$\frac{T_2}{534.67} = 15^{(1.4-1)}$

$T_2 = 1579.5\ R$

$V_2 = \frac{V_1}{r} = \frac{13.94\ in^3}{15}$

$V_2 = .929\ in^3$

$\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \frac{V_1}{V_2}^{(1.4-1)}$

$P_2 = \sqrt[\frac{k-1}{k}]{\frac{V_1}{V_2}^{(1.4-1)}}\ P_1$

$P_2 = \left(\sqrt[.285]{\frac{13.94}{.929}^{1.4-1}}\right)14.2\ psi$

$P_2 = 629.56\ psi$

41.9

x

$\frac{T_x}{T_2} = \frac{P_2}{P_1}$

$T_x = 1579.5(1.1)$

$T_x = 1737.45\ R$

$V_2 = V_x = .929\ in^3$

$\frac{P_x}{P_2} = r_{pressure}$

$P_x = 629.56(1.1)$

$P_x = 692.51\ psi$

3

$\frac{T_3}{T_x} = \frac{V_3}{V_x}$

$T_3 = 1737.45(1.4)$

$T_3 = 2432.3\ R$

$\frac{V_3}{V_x} = 1.4 \Rightarrow V_3 = V_x(1.4)$

$V_3 = 1.3\ in^3$

$P_x = P_3 = 692.51\ psi$

4

$P_1 = P_4 = 14.2\ psi$

$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}}$

$T_4 = T_3\left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}}$

$= 2432.3\ R\left(\frac{14.2}{692.5}\right)^{\frac{1.4-1}{1.4}}$

$T_4 = 801.1\ R$

a) $q_{in} = C_v(T_x - T_2) + C_p(T_3 - T_x) = .171(1737.45\ K - 1579.5\ K) + .24(2432.3\ R - 1737.45\ R)$

$q_{in} = 27.01 + 166.76$ $\quad q_{in} = 193.8\ Btu/lbm$

$q_{out} = C_v(T_4 - T_3) = .171(801.1\ R - 534.67\ R)$ $\quad q_{out} = 45.6\ Btu/lbm$

$w_{net} = q_{in} - q_{out} = 193.8\ Btu/lbm - 45.6\ Btu/lbm$

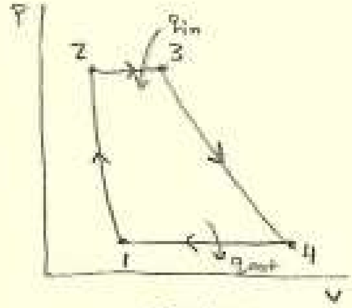
$\boxed{w_{net} = 148.24\ Btu/lbm}$

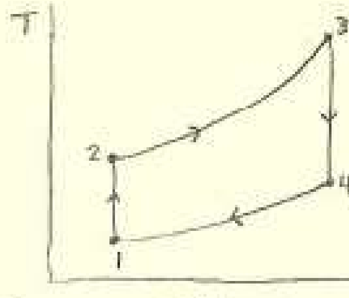
b) Specific heat addition $= \boxed{q_{in} = 193.8\ Btu/lbm}$

c) $\eta = \frac{w_{net}}{q_{in}} = \frac{148.24\ Btu/lbm}{193.8\ Btu/lbm}$ $\boxed{\eta = 76.5\%}$

80. Given: - Variable C_p and C_v

Fluid Pressure Ratio = 10





→ (1) —Isentropic→ (2) —Isobaric→ (3) —Isentropic→ (4) —Isobaric

(1)	(2)	(3)	(4)
$P_1 =$	$P_2 =$	$P_3 =$	$P_4 =$
$T_1 = 520R$	$T_2 = 940R$	$T_3 = 2000R$	$T_4 = 1160R$
$V_1 =$	$V_2 =$	$V_3 =$	$V_4 =$
$h_1 = 124$ BTU/lbm	$h_2 = 226.11$ BTU/lbm	$h_3 = 504$ BTU/lbm	$h_4 = 281.14$ BTU/lbm
$P_{r1} = 1.2147$		$P_{r3} = 174.0$	
$V_{r1} = 158.58$		$V_{r3} = 4.258$	

(1) compressor in (3) Turbine in

(2) compressor out (4) Turbine out

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} \Longrightarrow 8 = \frac{P_{r2}}{P_{r1}} \Longrightarrow 8(1.2147) = P_{r2} = 9.72 \longrightarrow T_2 = 940R.$$

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}} \Longrightarrow \left(\frac{1}{8}\right) = \frac{P_{r4}}{174.0} \Longrightarrow P_{r4} = 21.75 \longrightarrow T_4 = 1160R$$

temp @ compressor Exit = 480.3°F

$$r_{bw} = \frac{W_{comp,in}}{W_{turb,out}}$$

$W_{comp,in} = h_2 - h_1 = 226.11 - 124 = 102.11$ BTU/lbm

$W_{turb,out} = h_3 - h_4 = 504 - 281.14 = 222.86$ BTU/lbm

$$\boxed{r_{BW} = \frac{102.11}{222.86} = .46}$$

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$q_{in} = h_3 - h_2 = 504 - 226.11 = 237.89$ BTU/lbm

$W_{net} = W_{out} - W_{in} = 222.86 - 102.11 = 120.75$ BTU/lbm

$\eta = \frac{W_{nt}}{q_{in}} = \frac{120.75}{237.89} = .51 \longrightarrow \boxed{\eta = 51\%}$