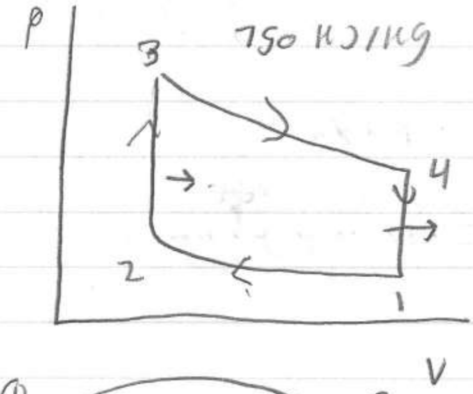
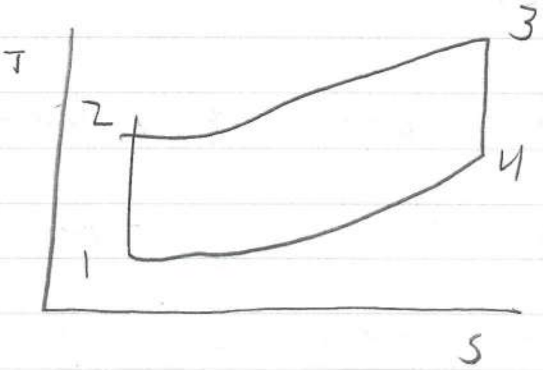
Thermal Applications HW 1.3 Ben Smithson

33, 36, 46, 57, 59, 80

33.





① | ② | ③ | ④

$T_1 = 300\ K$ | $T_2 = 673\ K$ |

$U_1 = 214.07$ | $U_2 = 491.2\ kJ/kg$ | $T_3 = 1539\ K$

$V_{r1} = 621.2$ | $P_2 = 1705\ kPa$ | $V_{r3} = 6.58$

$V_{r2} = \frac{V_2}{V_1} V_{r1} = \frac{1}{r} V_{r1} = \frac{1}{8}(621.2) = 77.65$

$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1} = P_2 = \frac{V_1 T_2}{V_2 T_1} P_1 = 8\left(\frac{673}{300}\right)(95\ kPa) = 1705\ kPa$

constant heat

$q_{2-3,in} = U_3 - U_2 = U_3 = q_2 + q_{2-3\,in} = 491.2 + 750 = 1241.2\ kJ/kg$

A-17 $T_3 = 1539\ K$

$\frac{P_3 V_3}{T_3} = \frac{P_2 V_2}{T_2} = P_3 = \frac{T_3}{T_2} P_2 = \left(\frac{1539 K}{673 K}\right)(1705\ kPa) = 3898\ kPa$

$v_{r4} = \frac{v_1}{v_2} v_{r3} = r v_{r3} = 8(6.58 = 52.7$ $T_4 = 774.5K$

$u_4 = 571.69$ kJ/kg

$q_{out} = u_4 - u_1 = 571.69 - 214.07 = 357.62$ kJ/kg

$w_{net,out} = q_{in} - q_{out} = 750 - 357.62 = 392.4$ kJ/kg

$\eta_{th} = \frac{w_{net,out}}{q_{in}} = \frac{392.4}{750} = 52.3\%$

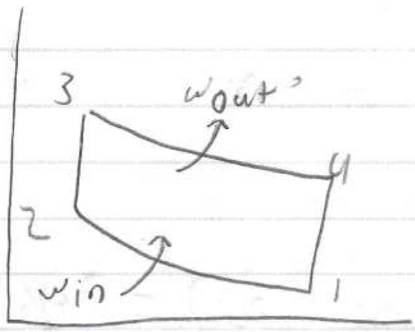
$v_1 = \frac{RT_1}{P_1} = \frac{(0.287 \text{ kPa})(300K)}{95 \text{ kPa}} = 0.906 \text{ m}^3/\text{kg}$

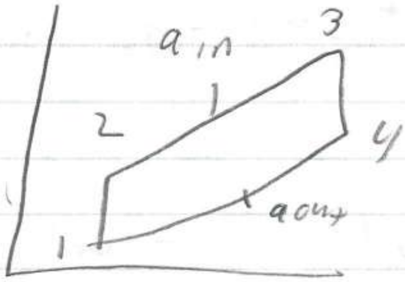
? $v_{min} = v_2 = \frac{v_{max}}{r}$

$MEP = \frac{w_{net out}}{v_1 - v_2} = \frac{w_{net out}}{v_1(1-1/r)} = \frac{392.4}{0.906)(1-1/8)} = 495 \text{ kPa}$

Ben Smithson Thermal applications 1.3Hw

9-36





①

$P_1 = 14$ psia

$T_1 = 105°F = 565R$

$V_1 = 14.95 ft^3/lbm$

②

$V_2 = 1.47 ft^3/lbm$

$T_2 = 1430R$

$P_2 = 360$ psia

③

$T_3 = 2859.67R$

$V_2 = V_3$

$V_3 = 1.47 ft^3/lbm$

$P_3 = 721$ psia

④

$V_4 = V_1 = 14.95$

$T_4 = 1130.81$

$P_4 = 27.9$

$$V_1 = \frac{RT_1}{P_1} = \frac{\left(0.3704 \frac{psia \cdot ft^3}{lbm \cdot R}\right)(565R)}{14 \text{ psia}} = 14.95 ft^3/lbm$$

$$r = \frac{V_{max}}{V_{min}} = \frac{V_1}{V_2} = \frac{14.95}{0.98(14.95)} = 10.2$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} = T_2 = \left(\frac{14.95}{1.47}\right)^{0.4} \cdot 565R = 1430R$$

$$P_2 = \frac{RT_2}{V_2} = \frac{\left(0.3704 \frac{psia \cdot ft^3}{lbm \cdot R}\right)(1430R)}{1.47 ft^3/lbm} = 360 \text{ psia}$$

$$\frac{P_2}{P_3} = T_2/T_3 = P_3\left(\frac{2859.6}{1430}\right)(360 \text{ psia}) = 721 \text{ psia}$$

1st law

$_1W_2 = c_v(T_1 - T_2) = 0.1717(565 - 1430\,°R) = -148$ Btu/lbm

$_2W_3 = 0$

$_3W_4 = c_v(T_3 - T_4) = (0.171)(2860 - 1130) = 296$ Btu/lb

$_4W_1 = 0$

$w_{net} = -148 + 0 + 296 + 0 = 148$ Btu/lbm

Rpm $= 2500 \frac{rev}{min} \left(\frac{1\,min}{60\,sec}\right)$

$V = \frac{\pi d^2 h}{4} = \frac{\pi (0.2916)^2 (0.325)}{4} = 0.0217\ ft^3 \cdot 6 = 0.13\ ft^3$

$m = \frac{V}{v_1} = \frac{0.13}{1495} = 0.008695$

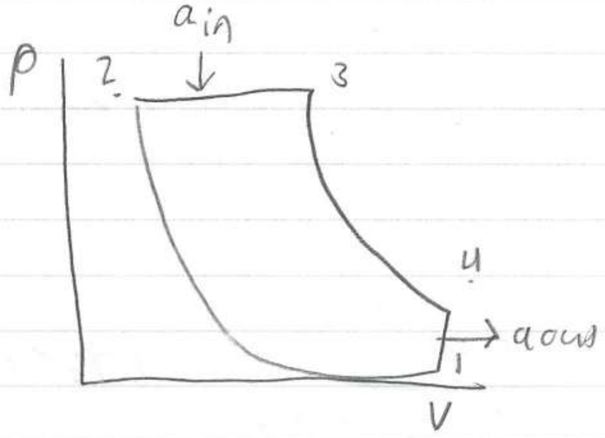
$w_{net} = 148\ (0.00895) = 1.29$ Btu

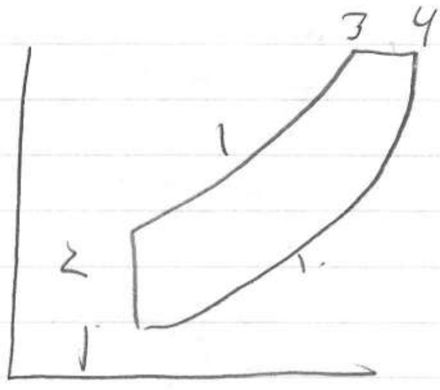
power $= \frac{1.29\ Btu\ (2500)\left(\frac{1}{60\,s}\right)}{2\,rev} = 26.875$ Btu/s $\left(\frac{1.4148\ hp}{1\ Btu/s}\right)$

$= 38.0$ Hp

Ben smithson Thermal applications 1.3 hw

46





① $T_1 = 300\ K$, $u_1 = 214\ kJ/kg$, $V_{r1} = 621.2$

② $T_2 = 862\ K$, $h_2 = 891\ kJ/kg$, $V_{r2} = 38.82$

③ $T_3 = 1724\ K$, $h_3 = 1910\ kJ/kg$, $V_{r3} = 4.54$

④ $V_{r4} = 36.37$, $U_4 = 659.7\ kJ/kg$

$$V_{r2} = \frac{V_2}{V_1} V_{r1} = \frac{1}{16}(621) = 38.82$$

$\downarrow$

$T_2 = 862\ K$

$h_2 = 891\ kJ/kg$

$$P_3 V_3 = \frac{P_2 V_2}{T_2} = T_3 = \frac{V_3}{V_2} T_2 = 2T_2 = (2)(862) = \boxed{1725\ K}$$

h_3, V_{r3}

$$V_{r4} = \frac{V_4}{V_3} V_{r3} = \frac{V_4}{2V_2} V_{r3} = \frac{r}{2} V_{r3} = \frac{16}{2}(4.54) = 36.37$$

V_4

$$q_{in} = h_3 - h_2 = 1910 - 891 = 1019\ kJ/kg$$

$$q_{out} = u_4 - u_1 = 659.7 - 214\ kJ/kg = 445.6\ kJ/kg$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{445.6}{1019} = \boxed{56\ \%}$$

$$w_{net\,out} = q_{in} - q_{out} = 1019 - 445.6 = 574\ kJ/kg$$

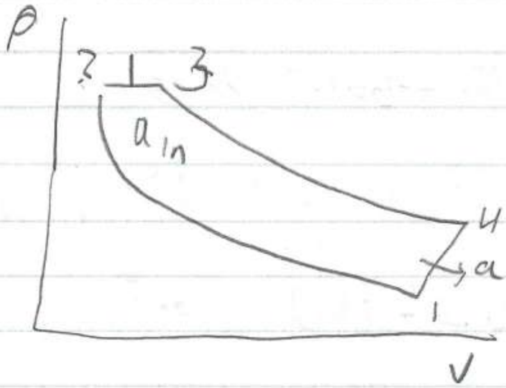
$$V_1 = \frac{RT_1}{P_1} = \frac{(0.287\ kPa \cdot m^3/kg\,K)(300K)}{95\,kPa} = 0.906$$

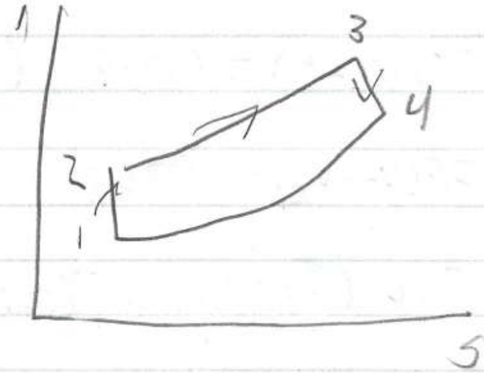
$$V_{min} = V_2 = \frac{V_{max}}{r}$$

$$MEP = \frac{w_{net,out}}{V_1 - V_2} = \frac{W_{net,out}}{V_1(1-1/r} = \frac{574}{(0.906)\,1-1/6} = 675.9\,kPa$$

thermal applications 1.3 HW Ben Smithson

57





(1)
$T_1 = 343K$
$P_1 = 97kPa$
$V_1 = 1.016\ m^3/kg$

(2)
$V_2 = 0.046\ m^3/kg$
$T_2 = 1181K$
$P_2 = 7348\ kPa$

(3)
$P_3 = P_2 = 7348\ kPa$
$V_3 = 0.08303\ m^3/kg$
$T_3 = 2126\ K$

(4)
$T_4 = 7$

$$V_1 = \frac{RT_1}{P_1} = \frac{(0.287\ kJ/kg)(343K)}{97\ kPa} = 1.016\ m^3/kg$$

$$V_2 = \frac{V_1}{2}\left(\frac{1.015}{22}\right) = 0.046$$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{k-1} = (343)(22)^{1.4-1} = 1181K$$

$$P_2 = \frac{RT_2}{V_2} = \frac{(0.287\ \frac{kJ}{kg \cdot K})(1181K)}{(0.016\ m^3/kg)} = 7348\ kPa$$

$P_3 = P_2$

$$V_2 = \frac{V_3}{V_2} = 1.8$$

$$V_3 = V_c V_2 = 1.8(0.046) = 0.08303\ \frac{m^3}{kg}$$

$$T_3 = \frac{P_3 V_3}{R} = (7348)(0.08303)/0.287 = 2126K$$

$$\left(\frac{T_4}{T_3}\right) = \left(\frac{V_3}{V_4}\right)^{k-1} = T_4 = T_3\left(\frac{V_3}{V_4}\right)^{k-1} = 2126K)\left(\frac{0.08303}{1.015}\right)^{0.4} = 7$$

1st law

$_1W_2 = C_v(T_1 - t_2) = (0.718)(343 - 1181 = -601.7 \ kJ/kg$

$_2W_3 = P(V_3 - V_2) = (7348 \ kPa)(0.08303 - 0.046) = 271.1 \ kJ/kg$

$_3W_4 = C_v(T_3 - T_4) = (0.718)(2126 - 781) = 965.7$

$W_{net} = {_1W_2} + {_2W_3} + {_3W_4} + {_4W_1}$

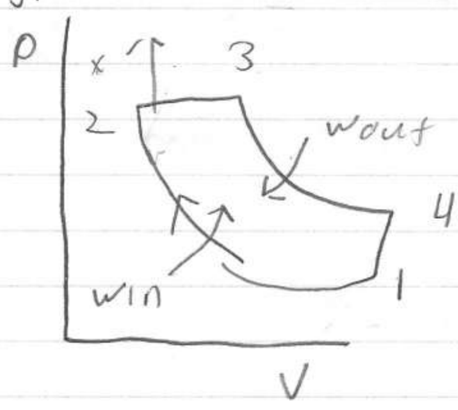
$W_{net} = (-601.7) + (271.1) + (965.7) + 0) = 635.1 \ kJ/kg$

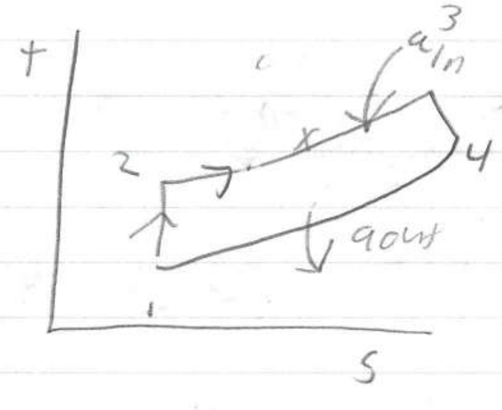
$$W_{net} = \frac{w_{net} \cdot n}{n_{rev}} = \frac{(635.1 \ kJ/kg)(3500 \ \frac{rev}{min} (\frac{1 min}{60 s})}{1 rev}$$

$W_{net} = 37,047.5$?

Thermal applications HW 1.3 Ben Smithson

59





(1)	(2)	(x)	(3)	(4)
$P_1 = 14.2$ PSIa	$V_2 = V_x$	$P_x = 692.1$ PSIa	$P_3 = P_x$	V_4
$T_1 = 534.6R$	$T_2 = 1579.5R$	$T_x = 1737.4R$	$P_3 = 692.1$ PSIa	V_4
$V_1 = 2.58$ ft	$P_2 = 629.2$ PSIa		$T_3 = 2432.4R$	T_4
	$V_2 = 0.172$ ft/lbm		$V_3 = 0.241$ ft^3/lbm	

$r = \frac{V_{max}}{V_{min}} = \frac{V_1}{V_2} = 15 \qquad r = \frac{V_3}{V_x} = 1.4$

$R = 0.06855$ Btu/lbmR $\qquad V_2 = \frac{RT}{P} = 0.1721$ ft^3/lbm

$\frac{P_x}{P_2} = r_P = 1.1$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} = T_2 = (15)^{1.4-1}(534.6R) = 1579.5R$

$P_2 = \frac{k-1}{k}\sqrt{\frac{T_2}{T_1}}\ (P_1 = \left(0.285\sqrt{\frac{1579.5}{534.67}}\right)(14.2\text{ Psia}) = 629.2$

$P_x = r_P(P_2) = 1.1(629.2\text{ PSIa}) = 692.1$ PSIa

$\frac{T_x}{T_2} = \left(\frac{P_x}{P_2}\right) = T_x = \left(\frac{692.1}{629.2}\right) = 1579.5R) = 1737.4R$

$\frac{V_1}{V_2} = \frac{T_1}{T_2} = T_3\left(\frac{V_3}{V_x}\right)T_x = 1.4(1737.4R) = 2432.4R$

$V_1 = V_4$

$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{k-1}$ $V_1 = \frac{(0.06855)(534.67)}{14.2 \text{ psia}} = 2.58 \text{ ft}^3/\text{lbm}$

$V_3 = \frac{(0.06855)(2432.4)}{692.1} = 0.241 \text{ ft}^3/\text{lbm}$

$T_4 \left(\frac{0.241}{2.58}\right)^{1.4-1} (2432.4 R) = 942 R$

$w_{net} = {}_xw_3 + {}_3w_4 - {}_1w_2$

${}_xw_3 = P(V_3 - V_x) = 47.7 \text{ Btu/lbm}$

${}_3w_4 = \frac{R(T_4 - T_3)}{1-k} = 255.4 \text{ Btu/lbm}$

${}_1w_2 = R(T_1 - T_2)/1-k = 179.1 \text{ BTU/lbm}$

$w_{net} = 47.7 + 255.4 - 179.1 = \boxed{124 \text{ Btu/lbm}}$

2-x

~~$q_{in} - q_{out} - w_{out}$~~ $w_{in} = \Delta U$

$q_{in} = c_v(T_x - T_2 = 0.171 (1737.4 - 1579.5) = 27 \text{ Btu/lbm}$

$q_{in} = c_v(T_3 - T_2) + w_{out\, x-3}$

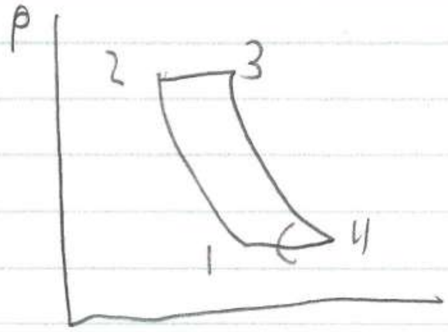
$0.171 (2432.4 - 1737.4) cr + 47.7 = 166.5 \text{ Btu}$

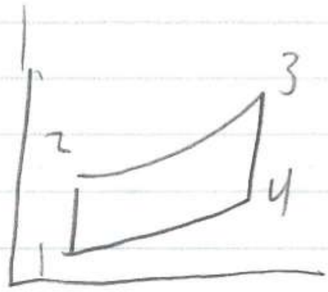
$q_{in} = 166.5 + 27 = \boxed{193.5 \text{ Btu/lbm}}$

$\eta_t = \frac{w_{net}}{q_{in}} = \frac{124}{193.5} = \boxed{0.64}$

Thermal applications HW 1.3 Ben Smithson

80





① $T_1 = 520°R$, $h_1 = 124.27$ BTU/lbm, $Pr_1 = 1.214$

② $P_{2S} = 12.14$, $h_2 = 240.1$ BTU/lbm, $T_2 = 996.48$

③ $T_3 = 2000°R$, $h_3 = 504.7$, $Pr_3 = 174$

④ $P_{4S} = 17.4$, $h_4 = 265.8$ BTU/lbm, $T_4 = 1099.3\ °R$

$$\frac{P_{S2}}{Pr_1} = 10$$

$$P_{S2} = 10 \cdot Pr_1 = 10 \cdot 1.214 = 12.14$$

$\to h_2, T_2$

$$\frac{Pr_3}{P_{S4}} = \frac{Pr_3}{10} = 174/10$$

$$w_T = h_3 - h_4 = 504.7 - 265.8 = 238.8 \text{ Btu/lbm}$$

$$w_C = (h_2 - h_1) = 240.11 - 124.27 = 115.8 \text{ Btu/lbm}$$

$$\text{back work ration} = \frac{w_C}{w_T} = 115.8 / 238.8 = \boxed{0.484}$$

$$\eta_{th} = \frac{w_{net}}{Q_S} = \frac{w_T - w_C}{h_3 - h_2} = \frac{238.8 - 115.8}{504.7 - 240.11} = 45.3\%$$