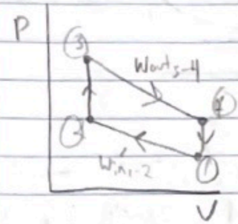
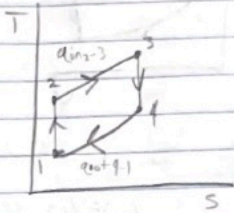
HW 1.2

9-33

Nithan Chernngs




Var. Cp/cv

$q_{in} = 750 \frac{kJ}{kg}$

$r = 8$

$\frac{V_1}{V_2} = r$

$R = 0.287 \frac{kJ}{kg \cdot K}$

isentropic various sh

① $\xrightarrow[\text{compression}]{\text{isentropic}}$ ② $\xrightarrow[\text{combustion}]{\text{V const}}$ ③ $\xrightarrow[\text{expansion}]{\text{isentropic}}$ ④ $\xrightarrow[\text{V-const}]{\text{exhaust}}$

$T_1 = 300°K$

$P_1 = 95 kPa$

$V_1 = \frac{RT_1}{P}$

$V_1 = \frac{0.287 \frac{kJ}{kg \cdot K} \cdot 300K}{95 kPa}$

$V_1 = 0.9063 m^3$

$U_1 = 214.07 \frac{kJ}{kg}$

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

$V_{r1} = 621.2$

$0.125 \cdot 621.2 = V_{r2} = 77.66$ interpolate app for $T_2$

$V_2 = \frac{V_1}{r}$

$V_2 = 0.1133 m^3$

$T_2 = 673.55°K$

$U_2 @ 673.55°K$ interpolate app

$U_2 = 491.58 \frac{kJ}{kg}$

$V_3 = V_2$

$V_3 = 0.1133 m^3$

$T_3 = 1539.1°K$

$V_{r3} = T_3 @$ interpolate @ $T_3$

$V_{r3} = 6.58$

$V_{r3} \cdot \frac{V_4}{V_3} = V_{r4}$

$V_4 = V_1$

$V_4 = V_3 \cdot r$

$V_4 = 0.9063 m^3$

$V_{r4} = 52.656$ ] interpolate app

$T_4 = 774.79 K$

$U_4 = 571.923 \frac{kJ}{kg}$

$q_{in_{2-3}} = U_3 - U_2$

$491.58 + 750 \frac{kJ}{kg} = \underbrace{1241.58 \frac{kJ}{kg} = U_3}_{\text{interpolate for } T_3}$

$\boxed{T_3 = 1539.1°K}$

$PV = RT$

$P_3 = \frac{RT_3}{V_3} = \boxed{3898.7 kPa} = \boxed{P_3}$

$W_{net} = W_{out} - W_{in}$

(1-2) 1st law $\cancel{q_{in}}^0 - \cancel{q_{out}}^0 + W_{in} - \cancel{W_{out}}^0 = \Delta U$

$W_{in} = U_2 - U_1 = 491.58 \frac{kJ}{kg} - 214.07 \frac{kJ}{kg}$

$W_{in} = 277.51$

(3-4) 1st law $\cancel{q_{in}}^0 - \cancel{q_{out}}^0 + \cancel{W_{in}}^0 - W_{out} = \Delta U$

$-W_{out} = U_4 - U_3 = 571.923 \frac{kJ}{kg} - 1241.58 \frac{kJ}{kg}$

$W_{out} = 669.657 \frac{kJ}{kg}$

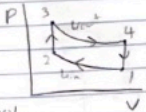
$W_{net} = 669.657 - 277.51$

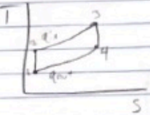
$\boxed{W_{net} = 392.147 \frac{kJ}{kg}}$

$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{392.147 \frac{kJ}{kg}}{750 \frac{kJ}{kg}} = 0.523 = \boxed{52.3\% = \eta_{th}}$

$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{392.147 \frac{kJ}{kg}}{(0.9063 m^3 - 0.1133 m^3)} = \boxed{494.5 kPa = MEP}$

9-36




$R = 0.3704 \frac{psi \cdot ft^3}{lbm \cdot R}$ const cp cv

$c_p = 0.24$

$c_v = 0.171$

$K = 1.4$

① isentropic compression → ② v = const → ③ isentropic expansion → ④ v = const

$P_1 = 14\,psi$

$T_1 = 105°F = 565°R$

$V_1 = \frac{R \cdot T_1}{P_1} = \frac{0.3704 \frac{psi \cdot ft^3}{lbm \cdot R} \cdot 565 R}{14}$

$V_1 = 14.951\, ft^3/lbm$

$V_2 = V_1 \cdot 0.098$

$V_2 = 1.465\, ft^3/lbm$

isentropic + const cp/cv

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$

$T_2 = (10.205)^{1.4-1} \cdot 565°R$

$T_2 = 1430.797°R$

$T_3 = 2400°F = 2860°R$

$V_3 = V_2 = 1.465\, ft^3/lbm$

$V_1 = V_4 = 14.95\, ft^3/lbm$

isentropic + const cp/cv

$T_4 = \left(\frac{V_3}{V_4}\right)^{k-1} \cdot T_3$

$= \left(\frac{1.465\, ft^3}{14.95\, ft^3}\right)^{1.4-1} \cdot 2860°R$

$T_4 = 1129.4°R$

1-2

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

$\frac{W_{in\,1-2}}{m} = (U_2 - U_1) \rightarrow U_2 = 252.88 \frac{btu}{lbm}$ $U_1 = 96.3275 \frac{btu}{lbm}$

$156.5525 \frac{btu}{lbm} = w_{in\,1-2} = 252.88 - 96.3275$

3-4

$q_{in} - q_{out} + w_{in} - w_{out} = \Delta U \rightarrow U_3 = 553.748 \frac{btu}{lbm}$ $U_4 = 195.98 \frac{btu}{lbm}$

$-W_{out} = \Delta U = U_4 - U_3 = 195.98 \frac{btu}{lbm} - 553.748 \frac{btu}{lbm}$

$+W_{out} = 357.77$ $W_{net} = W_{out} - W_{in} = 357.77 - 156.5525$

$W_{net} = 201.2175 \frac{btu}{lbm}$

Find work of 2500 cycles

$d = 3.5\,in \rightarrow \frac{1\,ft}{12\,in} = 0.2917\,ft$

$h = 3.9\,in \rightarrow \frac{1\,ft}{12\,in} = 0.325\,ft$

$1\,rev = 2\,cycles$

$2500 \frac{rev}{min} \cdot \frac{1\,min}{60\,s} = 41.667$

$v = \frac{V}{m}$

6 cylinders $\rightarrow 6 \cdot (\pi r^2 \cdot h) = V = 6 \cdot (\pi \cdot 0.14585\,ft^2 \cdot 0.325\,ft) = 0.1303\, ft^3$

$\frac{0.1303\, ft^3}{14.95 \frac{ft^3}{lbm}} = 0.0087168\,lbm \cdot 201.2175 \frac{btu}{lbm} = 1.754\, btu$

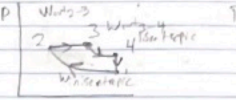
power done $\rightarrow 1.754\, btu \cdot 41.667\, rev \cdot \frac{1\,rev}{2\,cycles} = \boxed{36.54\, btu/cycle = W_{net}/cycle}$

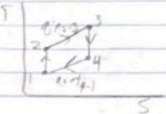
9-46

air standard diesel cycle

$r = 16$ Vary Spheat $R = 0.287\ kJ/kg\cdot K$

$r_c = 2$




$\rightarrow$ 1 $\xrightarrow{\text{isentropic compression}}$ 2 $\xrightarrow{P-\text{constant}}$ 3 $\xrightarrow{\text{isentropic expansion}}$ 4 $\xrightarrow{\text{exhaust}}$

**1**

$P_1 = 95\,kPa$

$T_1 = 300°K$

isentropic compression: $\frac{V_2}{V_1} = \frac{V_{r2}}{V_{r1}}$

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

$PV = RT_1$

$V = \frac{0.287\frac{kJ}{kg\cdot K}\cdot 300°K}{95\,kPa}$

$r = \frac{V_1}{V_2}$

$V_1 = .9063\,m^3/kg$

**2**

$P_2 = P_3$

$V_2 = \frac{V_1}{r} = \frac{0.9063}{16}$

$V_2 = 0.056645\,m^3/kg$

$T_2 = 862.345°K$

$P_2 = 4369.2\,kPa$

$\frac{0.056645\,m^3/kg}{0.9063\,m^3/kg}\cdot 621.2 = V_{r2} = 38.826 \rightarrow$ interpolate app for $T_2$

$P_2 = \frac{RT_2}{V_2} = 4369.2\,kPa$

**3**

$V_3 = V_2\cdot 2$

$0.1133\frac{m^3}{kg} = 0.056645\cdot 2$

$P_3 = 4369.2\,kPa$

$T_3 = 1724.84°K$

$P_3 V_3 = RT_3$

$\frac{PV}{R} = \frac{4396.2\,kPa\cdot 0.1133\frac{m^3}{kg}}{0.287\frac{kJ}{kg\cdot K}} = 1724.84\,°K$

**4**

$V_4 = V_1$

$V_4 = 0.906\,m^3/kg$

$T_4 = 882.1°K$

$V_{r1} = 621.2$ @ 300K

isentropic expansion $\rightarrow \frac{V_4}{V_3}\cdot V_{r3} = V_{r4} \rightarrow$ interpolate for $T_4$

$\frac{0.9063}{0.1133}\cdot 4.546 = 36.368 \rightarrow T_4 = 882.1°K$

$\boxed{(a)\ T_3 = 1724.84°K}$

(b) $\eta_{th} = \frac{W_{net}}{q_{in}}$

1st law $\cancel{q_{in}} - \cancel{q_{out}} + W_{in} - W_{out} = \Delta U$

(3-4) $-W_{out} = \Delta U_{3-4}$ $U_4 @ 882.1°K = 659.696$

$= 659.696\frac{kJ}{kg} - 1416.1\frac{kJ}{kg}$

(3-4) $W_{out} = -756.404\frac{kJ}{kg}$ $W_{out\,tot} = W_{out\,3-4} + W_{out\,2-3}$

(2-3) $W_{out} = 247.493$ $W_{out\,tot} = 1003.89685$

$W_{net} = W_{out} - W_{in} = 1003.8963\frac{kJ}{kg} - 429.27\frac{kJ}{kg} = 574.6268\frac{kJ}{kg}$

$\eta_{th} = \frac{574.6268\,(kJ/kg)}{1020.253\,(kJ/kg)} = 0.563 = \boxed{56.3\%}$

(c) $W_{net} = MEP(V_{max} - V_{min}) \rightarrow \frac{574.6268\frac{kJ}{kg}}{0.9063 - 0.056645\frac{m^3}{kg}} = \boxed{676.3\,kPa\ MEP}$

(1-2) 1st law $\cancel{q_{in}} - \cancel{q_{out}} + W_{in} - \cancel{W_{out}} = \Delta U_{1-2}$

$W_{in,1-2} = \Delta U$

$U_2 - U_1$ $U_2 @ 862.345°K$

interpolate app $= 643.34\frac{kJ}{kg}$

$U_1 @ 300°K = 214.07$

$W_{in,1-2} = 643.34\frac{kJ}{kg} - 214.07\frac{kJ}{kg}$

$= 429.27\frac{kJ}{kg}$

(2-3) 1st law $q_{in} - \cancel{q_{out}} + \cancel{W_{in}} - W_{out} = \Delta U$

$Q_{in} - W_{out} = \Delta U \rightarrow W_{out} = P(\Delta V)$

$Q_{in} = P(V_3 - V_2) + U_3 - U_2$

$U @ 1724.84 = 1416.1\frac{kJ}{kg}$

$= 4369.2(0.056645) + (1416.1\frac{kJ}{kg} - 643.34)$

$= 247.493\frac{kJ}{kg}$ $772.76\frac{kJ}{kg}$

$q_{in} = 1020.253\frac{kJ}{kg}$

9-57

$V = 2.4\,L \to 2.4\,m^3 \times 10^{-3}$   $r_c = \frac{V_3}{V_2}$

diesel engine   $r = \frac{V_1}{V_2}$

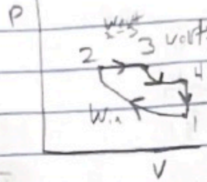
cold air assumptions

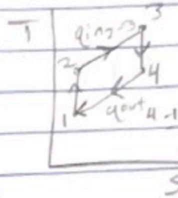
Const cp/cv of air

$cv = 0.718\,\frac{kJ}{kg \cdot K}$

$cp = 1.015\,\frac{kJ}{kg \cdot K}$

$r = 22$   $r_c = 1.8$




(1) isentropic compression → (2) P const → (3) isentropic expansion → (4) exhaust V-const

$R = 0.287\,\frac{kJ}{kg \cdot K}$

$P_1 = 97\,kPa$

$T_1 = 70°C \to 343°K$

$P_1 V_1 = R \cdot T_1$

$V_1 = \frac{0.287\frac{kJ}{kg \cdot K} \cdot 343°K}{97\,kPa}$

$V_1 = 1.0148\,\frac{m^3}{kg}$

$V_2 = \frac{V_1}{r}$

$0.0461 = \frac{1.0148\frac{m^3}{kg}}{22}$

$\frac{m^3}{kg} = V_2$

$T_2 = 1181.03615°K$

$P2 = 7352.6545\,kPa$

$V_3 = r_c \cdot V_2$

$V_3 = 1.8 \cdot 0.04613\,\frac{m^3}{kg} = 0.083\,\frac{m^3}{kg}$

$P_3 = P2 = 7352.6545\,kPa$

$T_3 = 2126.377°K$

$V_4 = V_1$

$V_4 = 1.0148\,\frac{m^3}{kg}$

$T_4 = 781.123°K$

variable analysis.

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \to (22)^{0.4} \cdot 343°K = 1181.03615°K$

$P2 = \frac{R \cdot T_2}{V_2} = \frac{0.287\frac{kJ}{kg \cdot K} \cdot 1181.03615°K}{0.0461\,m^3/kg} = 7352.6545\,kPa$

$\frac{P_3 V_3}{R} = T_3$

$\frac{7352.6545\,kPa \cdot 0.83\frac{m^3}{kg}}{0.287} = T_3$

$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{k-1} \to \left(\frac{0.83\,m^3/kg}{1.0148\,m^3/kg}\right)^{0.4} \cdot 2126.377°K = T_4 = 781.123°K$

4 cylinder $\cdot (2.4\,m^3 \times 10^{-3})$

$\frac{V\,m^3}{V\,\frac{m^3}{kg}} = m(kg) \to \frac{4(2.4)\,m^3 \times 10^{-3}}{1.0148\frac{m^3}{kg}} = 2.364 \times 10^{-3}$

$W_{net} = W_{out\,2-3} + W_{out\,3-4} - W_{in\,1-2}$

$\Delta U = cv(T_2 - T_1)$

isentropic const

1 cycle = 2 strokes = 1 rev

(2-3) $q_{in} - \cancel{q_{out}} + \cancel{w_{in}} - W_{out} = \Delta U \to cv(T_3 - T_2)$

isobaric $W_{out} = p(V_3 - V_2)$

$W_{out\,2-3} = 271.313\,\frac{kJ}{kg}$

$q_{in} = P(V_3 - V2) + (U_3 - U_2)$

$= 7352.6545\,kPa(0.083 - 0.0461)(0.719)(2126 - 1181°K)$

$q_{in} = 271.313\,\frac{kJ}{kg} + 678.754\,\frac{kJ}{kg}$

$= 950\,\frac{kJ}{kg}$

(3-4) 1st law $\cancel{q_{in}} - \cancel{q_{out}} + \cancel{w_{in}} - W_{out} = \Delta U$

$-W_{out\,3-4} = cv(T_4 - T_3)$

$-W_{out} = 0.718\,\frac{kJ}{kg \cdot K}(781.123°K - 2126.377°K)$

$+W_{out} = +965.89\,\frac{kJ}{kg}$

(1-2) 1st law $\cancel{q_{in}} - \cancel{q_{out}} + w_{in} - \cancel{W_{out}} = \Delta U$

$W_{in\,1-2} = cv(T_2 - T_1)$

$= 0.718\,\frac{kJ}{kg \cdot K}(1181.0361K - 343K)$

$W_{in} = 601.7099\,\frac{kJ}{kg}$

$W_{net} = W_{out} - W_{in} = 271.313\,\frac{kJ}{kg} + 965.89\,\frac{kJ}{kg} - 601.7099\,\frac{kJ}{kg}$

$= 635.49\,\frac{kJ}{kg} \cdot m \to 2.364 \times 10^{-3} = 1.5023\,kJ$

Conversion → & power produced

$\dot{W}_{net} = \frac{(W_{net})(rpm)\left(\frac{1\,min}{60\,s}\right)}{1\,rev/cycle} = (1.502\,kJ)\left(\frac{3500}{60}\right) = \boxed{87.634\,kW}$

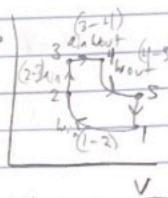
9-59

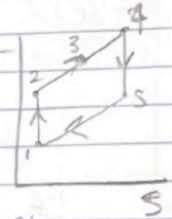
ideal dual cycle

$R = 0.3704 \frac{psi \cdot ft^3}{lbm \cdot R}$ $\quad r = 15 \quad r = \frac{V_1}{V_2}$

const sh at room temp $\quad r_c = 1.4 \quad r_c = \frac{V_4}{V_3}$

$r_p = 1.1 \quad r_p = \frac{P_3}{P_2}$




states

① $\xrightarrow{\text{isentropic compression}}$ ② $\xrightarrow{\text{v - const combustion}}$ ③ $\xrightarrow{\text{P - const expansion}}$ ④ isentropic expansion

$P_1 = 14.2\,psi$ $\quad V_2 = 0.9303 \frac{ft^3}{lbm}$ $\quad V_3 = 0.9303$ $\quad P_4 = 692.1989\,psi$

$T_1 = 75°F = 535°R$ $\quad T_2 = 1580.48°R$ $\quad P_3 = 692.1989\,psi$ $\quad V_4 = 1.30242 \frac{ft^3}{lbm}$

$V_1 = 13.955 \frac{ft^3}{lbm}$ $\quad P_2 = 629.2717\,psi$ $\quad T_3 = 1738.533°R$ $\quad T_4 = 2433.946°R$

V const

⑤

$K = 1.401$ $\quad V_5 = 13.955 \frac{ft^3}{lbm}$

$cp = 0.24 \frac{btu}{lbm \cdot R}$ $\quad T_5 = 942.58°R$

$cv = 0.171$

① $P_1 V_1 = R \cdot T_1 \quad \frac{0.3704 \frac{psi \cdot ft^3}{lbm \cdot R} \cdot 535°R}{14.2\,psi} = 13.955 \frac{ft^3}{lbm} = V_1$

② $V_2 = V_3 \quad \frac{V_1}{r} = V_2 = \frac{13.955 \frac{ft^3}{lbm}}{15} = 0.9303 \frac{ft^3}{lbm}$

isentropic const cp

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{K-1} = 15^{0.4} \cdot 535°R = T_2 = 1580.48°R$

$P_2 = \frac{R \cdot T_2}{V_2} = \frac{0.3704 \frac{psi \cdot ft^3}{lbm \cdot R} \cdot 1580.48°R}{0.9303 \frac{ft^3}{lbm}} = P_2 = 629.2717\,psi$

③

$\frac{P_3}{P_2} = r_p \quad r_p \cdot P_2 = P_3 = 1.1 \cdot 629.2717 = 692.1989\,psi$

$\frac{P_3 V_3}{R} = T_3 = \frac{692.1989\,psi \cdot 0.9303 \frac{ft^3}{lbm}}{0.3704 \frac{psi \cdot ft^3}{lbm \cdot R}} = 1738.533°R$

④ $\quad$ ⑤

$\frac{V_4}{V_3} = r_c \quad r_c \cdot V_3 = V_4 = 1.4 \cdot 0.9303 = 1.30242 \frac{ft^3}{lbm}$ $\quad V_1 = V_5 = 13.955 \frac{ft^3}{lbm}$

$\frac{P_4 V_4}{R} = T_4 = \frac{692.1989\,psi \cdot 1.30242\,ft^3}{0.3704 \frac{psi \cdot ft^3}{lbm \cdot R}} = 2433.946°R$ $\quad$ isentropic 4-5

$\frac{T_5}{T_4} = \left(\frac{V_4}{V_5}\right)^{K-1}$

$T_5 = \left(\frac{1.30242 \frac{ft^3}{lbm}}{13.955 \frac{ft^3}{lbm}}\right)^{0.4} \cdot 2433.946°R = 942.58R$

$W_{net} = W_{out} - W_{in} \rightarrow (W_{out\,3-4} + W_{out\,4-5}) - W_{in\,1-2} =$

$W_{out\,3-4}$ → isobaric → $P_3(V_4 - V_3) \rightarrow 692.1989\,psi \cdot (1.30242 - 0.9303) = 257.58 \frac{btu}{lbm}$

$W_{out\,4-5}$ → isentropic → $\frac{R(T_5 - T_4)}{1-k} \rightarrow \frac{0.06855 \frac{btu}{lbm \cdot R}(942.58°R - 2433.946°R)}{-0.4} = 255.58 \frac{btu}{lbm}$

$W_{in\,1-2}$ → isentropic → $\frac{R(T_1 - T_2)}{k-1} \rightarrow \frac{0.06855 \frac{btu}{lbm}(1580.48°R - 535°R)}{-0.4} = -179.169 \frac{btu}{lbm}$ $\quad \boxed{W_{net} = 334 \frac{btu}{lbm}}$

$q_{in}$ 1st law (3-4) $q_{in\,3-4} - W_{out\,3-4} = \Delta U \rightarrow q_{in\,2-3} = cv(T_4 - T_3) + 257.58 \frac{btu}{lbm}$

$\boxed{q_{in\,3-4} = 376.49 \frac{btu}{lbm}}$ $= 0.171(2433.946°R - 1738.533°R) + 257.58$

$\eta_{th} = \frac{W_{net\,total}}{q_{in\,total}} = \frac{334 \frac{btu}{lbm}}{412.01 \frac{btu}{lbm}} = \boxed{0.81}$

$q_{in\,2-3}$ (2-3) $q_{in} - \cancel{q_{out}} + \cancel{W_{in}} - \cancel{W_{out}} = \Delta U$

$U_3 @ 1738.533°R = 313.84 \frac{btu}{lbm}$

$U_2 @ 1580.48°R = 278.32 \frac{btu}{lbm}$

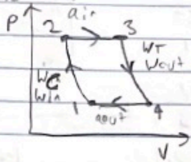
$q_{in\,2-3} = 35.52 + 376.49 = \boxed{q_{in\,total} = 412.01 \frac{btu}{lbm}}$

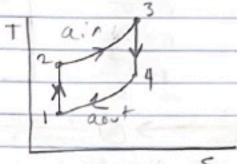
9-80

Brayton cycle   Var. Specific heat

$r_p = 10$

use enthalpy → constant p system → collect in table A17




→ ① compression isentropic → ② P-const → ③ expansion isentropic → ④ P-const →

$T_1 = 520°R$   $\boxed{T_2 = 996.48°R}$   $T_3 = 2000°R$   $T_4 = 1099.3103°R$

$h_1 = 124.27 \frac{btu}{lbm}$   $h_2 = 240.107 \frac{btu}{lbm}$   $h_3 = 504.71 \frac{btu}{lbm}$   Table A-17 → $h_4 = 265.826 \frac{btu}{lbm}$

$\frac{P_2}{P_1} = r_p$   $pr_1 @ 520°R = 1.2147$   $pr_3 @ 2000°R = 174.0$

$\frac{P_2}{P_1} = \frac{Pr_2}{Pr_1} \rightarrow Pr_2 = (r_p)(pr_1) = 10 \cdot 1.2147$   $pr_3 \cdot \frac{P_3}{P_4} = \frac{Pr_3}{Pr_4}$ $\cancel{pr_3} = \frac{1}{10} \cdot 174.0 = 17.4 = pr_4$

$pr_2 = 12.147$ → interpolate up for $T_2$

(1-2) 1st law $\cancel{q_{in}} - \cancel{q_{out}} + w_{in} - \cancel{w_{out}} = \Delta U \rightarrow (h_2 - h_1)$

$w_{in\,1-2} = 240.107 \frac{btu}{lbm} - 124.27 \frac{btu}{lbm} = 115.8 \frac{btu}{lbm}$

$BWr \rightarrow r_{BC} = \frac{W_c}{W_T} = \frac{115.8 \frac{btu}{lbm}}{238.884 \frac{btu}{lbm}}$

$\boxed{r_{bc} = 0.48475}$

(3-4) 1st law

$\overset{0}{q_{in}} - \overset{0}{q_{out}} + \overset{0}{w_{in}} - w_{out} = (h_4 - h_3)$

$-w_{out\,3\text{-}4} = 265.826 \frac{btu}{lbm} - 504.71 \frac{btu}{lbm} = 238.884 \frac{btu}{lbm}$

$W_{net} = W_{out} - W_{in}$

$W_{net} = 238.884 \frac{btu}{lbm} - 115.8 \frac{btu}{lbm} = 123.084$

(2-3) 1st law

$q_{in} - \overset{0}{q_{out}} + \overset{0}{w_{in}} - \overset{0}{w_{out}} = h_3 - h_2$

$q_{in} = 504.71 \frac{btu}{lbm} - 240.107 \frac{btu}{lbm} = 264.603 \frac{btu}{lbm}$

$\eta^{th} = \frac{W_{net}}{q_{in}} = \frac{123.084 \frac{btu}{lbm}}{264.603 \frac{btu}{lbm}}$

$\eta^{th} = 0.46516$

$\boxed{\eta^{th} = 46.5\%}$