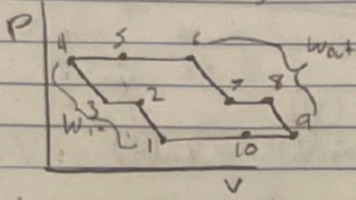
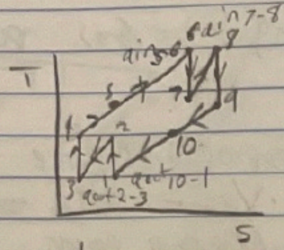
9-123 Nathan Chevrs





$r_p = \frac{P_2}{P_1} = \frac{P_4}{P_3}$

perfect regenerator

$r_p = 4$

const. cp/cv

counterflow

① $\xrightarrow[\text{comp.}]{\text{isent}}$ ② $\xrightarrow{\text{pconst}}$ ③ $\xrightarrow[\text{comp}]{\text{isent}}$ ④ $\xrightarrow{\text{pconst}}$ ⑤ $\xrightarrow{\text{pconst}}$

$P_1 = 100\,kpa$, $T_1 = 290°K$ | $P_2 = 400\,kpa$, $T_2 = 430.94°K$ | $T_3 = 290°K$, $P_3 = 400\,kpa$ | $T_4 = 430.94°K$, $P_4 = 1600\,kpa$ | $T_5 = 450.94°K$, $P_5 = 1600\,kpa$

$q_{in} = 300\,kJ/kg$

⑥ $\xrightarrow[\text{expansion}]{\text{isent}}$ ⑦ $\xrightarrow[300\,kJ/kg]{\text{pconst}}$ ⑧ $\xrightarrow[\text{expansion}]{\text{isent}}$ ⑨ $\xrightarrow{\text{pconst}}$ ⑩ $\xrightarrow{\text{pconst}}$

$P_6 = 1600\,kpa$, $T_6 = 749.45°K$ | $T_7 = 504.34°K$, $P_7 = 400\,kpa$ | $P_8 = 400\,kpa$, $T_8 = 802.85°K$ | $P_9 = 100\,kpa$, $T_9 = 540.28°K$ | $T_{10} = 520.28°K$, $P_{10} = 100\,kpa$

$P_2 = r_p \cdot P_1 \rightarrow P_2 = 4 \cdot 100\,kpa$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow 290°K \cdot (4)^{\frac{0.4}{1.4}} = 430.94°K$

$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \rightarrow 290°K \cdot (4)^{\frac{0.4}{1.4}} = 430.94°K$

$P_4 = r_p \cdot P_3 \rightarrow 4 \cdot 400\,kpa = 1600\,kpa$

$T_5 = T_4 + 20°K \rightarrow 430.94°K + 20°K = 450.94°K$

$\frac{T_9}{T_8} = \left(\frac{P_9}{P_8}\right)^{\frac{k-1}{k}} \rightarrow \left(\frac{1}{4}\right)^{\frac{0.4}{1.4}} \cdot 802.85°K = T_9 = 540.28$

$T_{10} = T_9 - 20°K \rightarrow 540.28°K - 20°K = 520.28°K$

$P_4 = P_5 = P_6$

1st Law $\Rightarrow q_{in} = 300\frac{kJ}{kg} = c_p(T_6 - T_5)$

$300\frac{kJ}{kg} = 1.005\frac{kJ}{kg \cdot k}(T_6 - 450.94°K)$

$T_6 = 749.45°K$

$r_p = \frac{P_6}{P_7} = \frac{P_8}{P_9}$ $\quad \frac{P_6}{r_p} = P_7 =$

$\frac{T_7}{T_6} = \left(\frac{P_7}{P_6}\right)^{\frac{k-1}{k}} = \left(\frac{1}{4}\right)^{\frac{0.4}{1.4}} \cdot 749.45°K = 504.34°K = T_7$

1st law $\rightarrow q_{in} = 300\frac{kJ}{kg} = c_p(T_8 - T_7)$

$504.34°K + \frac{300\frac{kJ}{kg}}{1.005\frac{kJ}{kg \cdot k}} = T_8 = 802.85°K$

$\eta_{th} = \frac{W_{net}}{q_{in}}$ $\quad q_{in} = 2 \cdot 300\frac{kJ}{kg} = 600\frac{kJ}{kg}$

$W_{net} = 246.335\frac{kJ}{kg} + 263.883\frac{kJ}{kg} - 283.29\frac{kJ}{kg}$

$W_{net} = 226.93\frac{kJ}{kg}$

$\eta_{th} = \frac{226.93\,kJ/kg}{600\,kJ/kg}$ $\boxed{= 0.378}$

$W_{net} = W_{out} - W_{in} \rightarrow$ (6-7) $W_{out_{6-7}} = c_p(T_6 - T_7)$

$246.335\frac{kJ}{kg} = 1.005(749.45°K - 504.34°K)$

(8-9) $W_{out_{8-9}} = c_p(T_8 - T_9)$

$263.883\frac{kJ}{kg} = 1.005(802.85°K - 540.28°K)$

$W_{in} = 2(c_p(T_2 - T_1))$

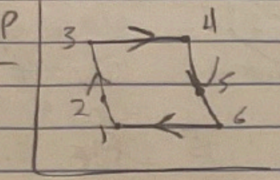
$283.29\frac{kJ}{kg} = 2(1.005(430.94°K - 290°K))$

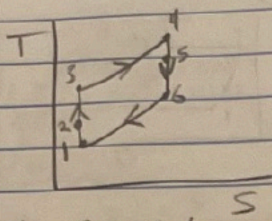
9-129

$r_{p,comp} = 13 = \frac{P_3}{P_2} = \frac{P_4}{P_5}$

Const. C_p/C_v

$c_p = .240 \frac{btu}{lb\cdot R}$





P const $\rightarrow$ (1) $\xrightarrow{\text{isent diffuser}}$ (2) $\xrightarrow{\text{isent compression}}$ (3) $\xrightarrow{\text{p const}}$ (4) $\xrightarrow{\text{isent expansion}}$ (5) $\xrightarrow{\text{isent nozzle}}$ (6) $\rightarrow$

$V_1 = 900\,ft/s$, $P_1 = 7\,psi$, $T_1 = 470°R$

$T_2 = 537.4°R$, $P_2 = 11.189\,psi$

$P_3 = 13 \cdot P_2 = 145.46\,psi$, $T_3 = 1118.32°R$

$T_4 = 2400°R$, $P_4 = 145.46\,psi$

$T_5 = T_2 - T_3 + T_4$, $T_5 = 1819.077°R$, $P_5 = 55.142\,psi$

$T_6 = 1008.65°R$, $P_6 = 7\,psi$, $V_6 = 3120.8\,ft/s$

$$h_2 + \cancel{\frac{V_2^2}{2}} = h_1 + \frac{V_1^2}{2} \rightarrow \frac{V_1^2}{2} - c_p(T_2 - T_1) = 0$$

$$T_2 = \frac{V_1^2}{2} / c_p + T_1 \rightarrow \frac{(900\,ft/s)^2}{2 \cdot 0.24 \frac{btu}{lb\cdot R}} \cdot \frac{1}{25037\,ft^2/s^2} + 470°R = \underline{537.4°R}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow 1.14^{\frac{1.4}{0.4}} \cdot 7\,psi = \underline{11.189\,psi} = P_2$$

$$T_5 - T_4 = T_2 - T_3$$

$$T_5 = 537.4°R - 1118.32°R + 2400°R$$

$$\underline{T_5 = 1819.077°R}$$

$$\frac{T_3}{T_2} = (r_p)^{\frac{k-1}{k}} \rightarrow (13)^{\frac{0.4}{1.4}} \cdot 537.4°R = \underline{1118.32°R}$$

$$\frac{P_5}{P_4} = \left(\frac{T_5}{T_4}\right)^{\frac{k}{k-1}} = \left(\frac{1819.077°R}{2400°R}\right)^{\frac{1.4}{0.4}} \cdot 145.46\,psi$$

$$\boxed{P_5 = 55.142\,psi}$$

$$\frac{T_6}{T_5} = \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}} \rightarrow \left(\frac{7\,psi}{55.142\,psi}\right)^{\frac{.4}{1.4}} \cdot 1819.077°R = \underline{1009.65°R} = T_6$$

$$h_5 + \frac{V_5^2}{2} = h_6 + \frac{V_6^2}{2} \rightarrow V_6 = \sqrt{2 \cdot c_p (T_5 - T_6)}$$

$$= \sqrt{2 \cdot (0.24 \cdot 25037)(1819.077 - 1009.65°R)}$$

$$\boxed{V_6 = 3120.8\,ft/s}$$

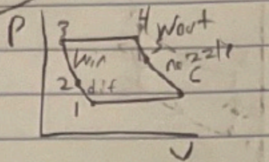
$$\eta_{th} = \frac{w_p}{q_{in}} \Rightarrow w_p = (V_6 - V_1) \cdot V_1 = (3120.8\,ft/s - 900\,ft/s) \frac{900\,ft/s}{25037\,\frac{ft^2}{s^2}} = \underline{79.83 \frac{btu}{lb}}$$

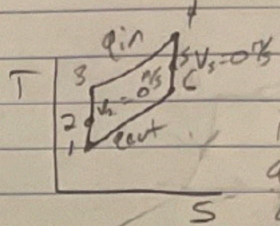
(3-4) $q_{in,3-4} = c_p(T_4 - T_3) = 0.24 \frac{btu}{lb}(2400°R - 1118.32°R) = 307.6032 \frac{btu}{lb}$

$$\eta_{th} = \frac{79.83 \frac{btu}{lb}}{307.6032 \frac{btu}{lb}} = \boxed{0.259 = \eta_{th}}$$

9-135

const cp/cv





$r_p = 9$

Stationary $\Rightarrow$ V

$\dot{m}_{and} = 20 \frac{kg}{s}$

$q_{in} = 42{,}700 \frac{kJ}{kg}$

$\dot{m}_f = 0.5$

P const $\rightarrow$ ① $\xrightarrow[\text{diffuser}]{\text{isent}}$ ② $\xrightarrow[\text{compression}]{\text{isent}}$ ③ $\xrightarrow{\text{P const}}$ ④ $\xrightarrow[\text{expansion}]{\text{isent}}$ ⑤ $\xrightarrow[\text{nozzle}]{\text{isent}}$ ⑥ $\rightarrow$

①	②	③	④	⑤	⑥
$P_1 = 95\,kPa$	$T_2 = 524.56\,K$	$T_3 = 982.74\,K$	$P_4 = 7695\,kPa$	$T_5 = 1586.75\,K$	$P_6 = 95\,kPa$
$T_1 = 280\,K$	$P_2 = 855\,kPa$	$P_3 = 7695\,kPa$	$T_4 = 2044.93\,K$	$V_5 = 0$	$T_6 = 582.634$
$V_1 = 701.117\,m/s$	$V_2 = 0$				$V_6 = 1420.66\,m/s$

1-2

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow (9)^{\frac{0.4}{1.4}} \cdot 280K = 524.56K$

$P_2 = P_1 \cdot r_p \rightarrow 95kPa \cdot 9 = 855kPa$

$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{k-1}{k}} = (9)^{\frac{0.4}{1.4}} \cdot 524.56 = 982.74$

$P_3 = P_2 \cdot r_p = 855kPa \cdot 9 = 7695kPa$

$P_4 = P_3$

1st law $\rightarrow q_{in} = 42{,}700\frac{kJ}{kg} \cdot 0.5\frac{kg}{s} = \dot{m} \cdot c_p (T_4 - T_3)$

$21{,}350 \frac{kJ}{s} = 20\frac{kg}{s} \cdot 1.005\frac{kJ}{kg \cdot K}(T_4 - T_3)$

$21{,}350 \frac{kJ}{s} = T_4$

$982.74K + 1062.19K \Rightarrow T_4 \Rightarrow 2044.93K$

$T_5 = T_4 - (T_3 - T_2) = 2044.93 - (459.18)$

$T_5 = 1586.75K$

$\frac{T_6}{T_5} = \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}} = \left(\frac{1}{9}\right)^{\frac{0.4}{1.4}} \cdot 1091.535K$

$T_6 = 582.634$

$h_1 + \frac{V_1^2}{2} = h_2 \frac{V_2^2}{2} \rightarrow V_1 = \sqrt{2 \cdot c_p (T_2 - T_1)}$

$V_1 = \sqrt{2 \cdot 1.005 \frac{kJ}{kg \cdot K}(524.56K - 280K)}$

$V_1 = 701.117\,m/s$

$V_6 = \sqrt{2 \cdot c_p (T_5 - T_6)}$

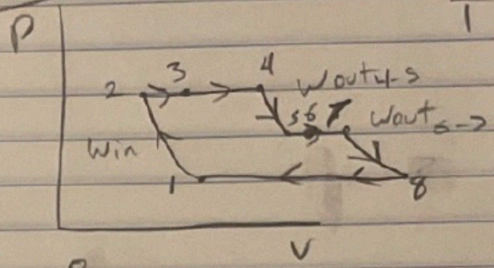
$= \sqrt{2 \cdot 1005 (1586.75K - 582.634K)}$

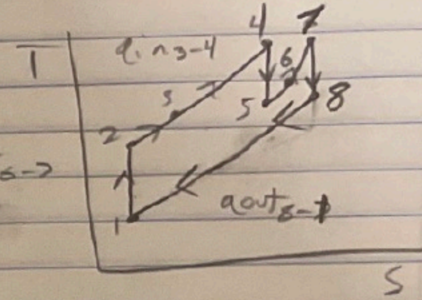
$F = \dot{m}(V_6 - V_1)$

$F = 20\frac{kg}{s}(1420.66\,m/s - 701.117\,m/s)$

$\boxed{F = 14390.8\,N}$

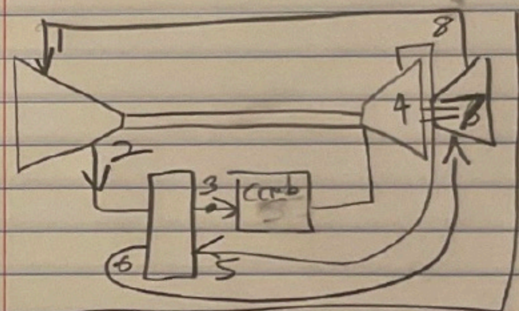
9-167





$r_p = \frac{P_4}{P_5} = \frac{P_7}{P_8}$ const cp/cv

$\xrightarrow{\text{pconst}} (1) \xrightarrow[\text{comp.}]{\text{isent}} (2) \xrightarrow[\text{pconst}]{\text{qpreheat}} (3) \xrightarrow[\text{combust}]{\text{pconst}} (4) \xrightarrow[\text{isent expansion}]{\text{Wout}} (5) \xrightarrow[\text{regen}]{\text{pconst}} (6) \xrightarrow[\text{exhaust}]{\text{pconst}} (7) \xrightarrow[\text{expansion}]{\text{isent}} (8) \rightarrow$



$P_5 = \frac{P_4}{r_p}$ $\quad P_6 = P_5 \quad P_7 = P_5 \quad P_8 = P_1$

$P_8 = \frac{P_7}{r_p}$

$P_1 = P_8 \quad P_2 = P_3 \quad P_3 = P_4 \quad P_4 = r_p \cdot P_5$

$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{w_{out} - w_{in}}{q_{in}} = \frac{(w_{out\,4-5} + w_{out\,7-8}) - (w_{in\,1-2})}{q_{in}}$

$w_{in\,1-2}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$

$w_{out\,4-5} = \frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}}$ $\quad w_{out\,7-8} = \frac{T_8}{T_7} = \left(\frac{P_8}{P_7}\right)^{\frac{k-1}{k}}$ $\quad q_{in\,3-4} = c_p(T_4 - T_3)$

$c_p(T_4 - T_5) + c_p(T_7 - T_8) - c_p(T_2 - T_1)$

$2r_p = r_{p\,compressor}$

$$\frac{\cancel{c_p}\left(\left(r_p^{\frac{k-1}{k}} \cdot T_5\right) - \left(\frac{1}{r_p}^{\frac{k-1}{k}} \cdot T_4\right)\right) + \cancel{c_p}\left(\left(r_p^{\frac{k-1}{k}} \cdot T_7\right) - \left(\frac{1}{r_p}^{\frac{k-1}{k}} \cdot T_8\right)\right) - \cancel{c_p}\left(\left(2r_p^{\frac{k-1}{k}} \cdot T_1\right) - \left(\frac{1}{2r_p}^{\frac{k-1}{k}} \cdot T_2\right)\right)}{\cancel{c_p}\left(\left(r_p^{\frac{k-1}{k}} \cdot T_5\right) - \left(\left(\frac{1}{r_p}\right)^{\frac{k-1}{k}} \cdot T_3\right)\right)}$$

$r_p = \frac{P_2}{P_1}$

$$\boxed{\eta_{th} = 1 - \frac{r_p^{-2\frac{k-1}{k}} - 1}{-r_p^{\frac{k-1}{k}}}}$$