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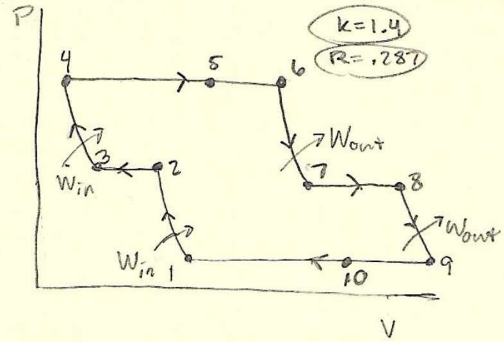
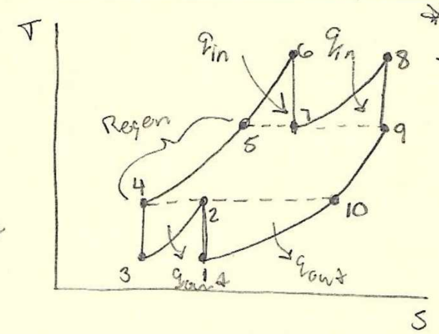
MET350 : Thermo Apps | HW 1.5 | 16-02-2019
Carter Fishback / Hannon French

9-123.)

$k = 1.4$
$R = .287$

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





Processes:

$① \xrightarrow{\text{Isent}} ② \xrightarrow{\text{Const P}} ③ \xrightarrow{\text{Isent}} ④ \xrightarrow[\text{(regen)}]{\text{P const}} ⑤ \xrightarrow[q_{in}]{P_{const}} ⑥ \xrightarrow{\text{Isent}} ⑦ \xrightarrow[q_{in}]{\text{P const}} ⑧ \xrightarrow{\text{Isent}} ⑨ \xrightarrow[\text{(regen)}]{P_{const}} ⑩$

$T_1 = 290k$ $T_2 = 431.16k$ $T_3 = T_1$ $T_4 = T_2$ $T_5 = 451.16k$ $T_6 = 749.67k$ $T_7 = 504.49k$ $T_8 = 803k$ $T_9 = 540.38$ $T_{10} = 520$

$P_1 = 100kPa$ $P_2 = 400kPa$ $P_3 = P_2$ $P_4 = 1600kPa$ $P_5 = P_4$ $P_6 = P_4$ $P_7 = P_2$ $P_8 = P_7$ $P_9 = P_1$ $P_{10} = P_1$

$V_1 = .833$ $V_2 = .31 \frac{m^3}{kg}$ $V_3 = .21 \frac{m^3}{kg}$ $V_4 = .08 \ m^3/kg$ $V_5 = .081 \ m^3/kg$ $V_6 = .134$ $V_7 = .362$ $V_8 = .58$ $V_9 = 1.55$ $V_{10} = 1.4$

* For Reheating & Intercooling Processes *

$$r_{P_{comp}} = 4 = \frac{P_2}{P_1} = \frac{P_4}{P_3} \quad \text{and} \quad r_p = 4 = \frac{P_6}{P_7} = \frac{P_8}{P_9}$$

$$\boxed{\begin{aligned} \text{Const. } C_p &= 1.005 \ kJ/kg \cdot k \\ C_v &= .718 \ kJ/kg \cdot k \end{aligned}}$$

$$V_1 = \frac{RT_1}{P_1} \longrightarrow \frac{(.287)(290.15k)}{100kPa} = \underline{.8327 \frac{m^3}{kg}}$$

$$r_p = \frac{P_2}{P_1} \longrightarrow 4(100kPa) = P_2 = \underline{400 \ kPa}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \longrightarrow T_2 = (4)^{\frac{1.4-1}{1.4}}(290k) = \underline{431.16 \ k}$$

$$V_2 = \frac{(.287)(431.16)}{400} = \underline{.309 \ m^3/kg}$$

$$V_3 = \frac{(.287)(290k)}{400kPa} = \underline{.208 \ m^3/kg}$$

$$\frac{P_4}{P_3} = 4 \longrightarrow P_4 = 4(400kPa) = \underline{1600 \ kPa}$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \longrightarrow T_4 = (290.15)(4)^{\frac{.4}{1.4}} = 431.16 \ k$$

$$V_4 = \frac{.287(431.16)}{1600} = \underline{.077 \ m^3/kg}$$

Regen: $T_5 = T_4 + 20°k \longrightarrow \underline{T_5 = 451.16k}$

$$V_5 = \frac{.287(451.16)}{1600} = \underline{.081 \ m^3/kg}$$

$$q_{in_{5-6}} = C_p(T_6 - T_5) \longrightarrow T_6 = \frac{q_{in}}{C_p} + T_5 \longrightarrow T_6 = \frac{300}{1.005} + 451.16 = \underline{749.67k}$$

$$V_6 = \frac{(.287)(749.67)}{1600} = \underline{.134 \ m^3/kg}$$

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9-123) $\frac{T_7}{T_6} = \left(\frac{P_7}{P_6}\right)^{\frac{k-1}{1.4}} \longrightarrow T_7 = (749.67)(.25)^{\frac{.4}{1.4}} = \underline{504.49\ K}$

$P_7 = \frac{P_6}{4} = \underline{400\ kPa}$

$V_7 = \frac{.287(504.49)}{400} = \underline{.362\ m^3/kg}$

$q_{in} = C_p(T_8 - T_7) \longrightarrow T_8 = \frac{q_{in}}{C_p} + T_7 \longrightarrow T_8 = \frac{300}{1.005} + 504.49 = \underline{802.997\,K}$

$V_8 = \frac{.287(802.997)}{400} = .58\ m^3/kg$

$\frac{T_9}{T_8} = \left(\frac{P_9}{P_8}\right)^{\frac{k-1}{k}} \longrightarrow T_9 = T_8\left(\frac{1}{4}\right)^{\frac{.4}{1.4}} = 540.38\ K$

$V_9 = \frac{.287(540.38)}{100} = 1.55\ m^3/kg$

$T_{10} = T_9 - T_{regen} = T_9 - 20°K = \underline{520.38\ K}$

$V_{10} = \frac{.287(520.38)}{100} = 1.49\ m^3/kg$

$W_{net} = \Sigma W_{out} + \Sigma W_{in}$ # Open Sys so C_p #

$= [(h_6 - h_7) + (h_8 - h_9)] + [(h_2 - h_1) + (h_4 - h_3)]$

$= C_p[(T_6 - T_7) + (T_8 - T_9) - (T_2 - T_1) + (T_4 - T_3)]$

$\underline{W_{net} = 226.91\ kJ/kg}$

$q_{in} = q_{in_{5-6}} + q_{in_{7-8}} = 300\ kJ/kg + 300\ kJ/kg = \underline{600\ kJ/kg}$

$\eta_{TH} = \frac{W_{net}}{q_{in}} = \frac{226.91}{600} = \boxed{.378 \text{ or } 37.8\%}$

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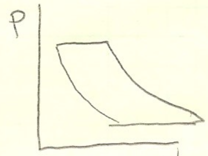
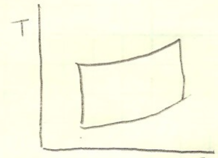
#129) $V_{aircraft} = 900$ ft/s @ 29,000 ft $P_1 = 7$ psi $T_1 = 10°F$ $r_p = 13$

$T_{turbine,inlet} = 2400R$ Assume Constant specific heats Find: P_{exit}, $V_{exhaust}$, η_{prop}





1 $\xrightarrow{Isen}$ 2 $\xrightarrow{Isen}$ 3 $\xrightarrow{P_{const}}$ 4 $\xrightarrow{Isen}$ 5 $\xrightarrow{Isen}$ 6 $\xrightarrow{P_{const}}$

1

$V_1 = 900$ ft/sec

$P_1 = 7$ psi

$T_1 = 10°F + 459.67$

$= 469.67R$

2

$V_2 \approx 0$

$T_2 = T_1 + \frac{V_1^2}{2C_p}$

$C_p = .24$ Btu/lbm

1 btu/lbm = 25,037 ft²/s²

$T_2 = 469.67 + \frac{900 ft/s}{2(.24 \times 25037)}$

$T_2 = 537.07R$

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

$P_2 = \sqrt[\frac{k-1}{k}]{\frac{T_2}{T_1}}(P_1)$

$= \sqrt[\frac{1.4-1}{1.4}]{\frac{537.07}{469.67}}(7)$

$P_2 = 11.2$ psi

3

$V_3 \approx 0$

$P_3 = 13P_2 = 13(11.2)$

$P_3 = 145.6$ psi

$\frac{T_3}{T_2} = (r_p)^{\frac{k-1}{k}}$

$T_3 = 537.07(13)^{\frac{1.4-1}{1.4}}$

$T_3 = 1117.6R$

4

$V_4 \approx 0$

$T_4 = T_{turbine} = 2400R$

$P_4 = P_3 = 145.6$ psi

5

$V_5 \approx 0$

from $W_T = W_c$

$T_4 - T_5 = T_3 - T_2$

$T_5 = T_4 - T_3 + T_2$

$= 2400 - 1117.6 + 537.07$

$T_5 = 1819.5R$

$P_5 = \sqrt[\frac{1.4-1}{1.4}]{\frac{T_5}{T_4}}(P_1)$

$= \left(\sqrt[\frac{1.4-1}{1.4}]{\frac{1819.5}{2400}}\right)145.6$

$P_5 = 55.24$ psi

6

$P_6 = P_1 = 7$ psi

$\frac{T_6}{T_5} = \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}}$

$T_6 = \left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}}(T_5)$

$= \left(\frac{7}{55.24}\right)^{\frac{1.4-1}{1.4}}(1819.5)$

$T_6 = 1008.37R$

$C_pT_1 + \cancel{\frac{V_1^2}{2}} = C_pT_2 + \frac{V_2^2}{2}$

$V_2^2 = 2(C_pT_5 - C_pT_6)$

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

$= \sqrt{2(.24 \times 25037)(1819.5 - 1008.37)}$

$V_6 = 3122.2$ ft/s

1) P @ Turbine exit = $\boxed{P_5 = 55.24 \text{ psi}}$

2) V of exhaust = $\boxed{V_6 = 3122.2 \text{ ft/s}}$

3) $\eta_{prop} = \frac{W_p}{Q_{in}} = \frac{(V_6 - V_1)(V_1)}{C_p(T_4 - T_3)} = \frac{(3122.2 - 900)900}{.24(25037)(2400 - 1117.6)}$ $\boxed{\eta = 26\%}$

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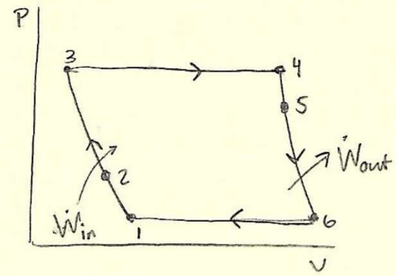
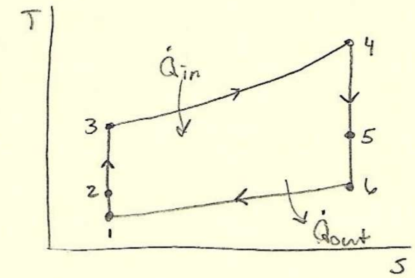
9-135





Given :

- $r_p = 9$
- $\dot{m}_{fuel} = .5\ kg/s$
- $\dot{m}_{Air} = 20\ kg/s$
- $H_v = 42{,}700\ \frac{kJ}{kg}$
- $T_1 = 280.15\ k$ $P_1 = 95\ kPa$
- Variable C_p and C_v

* NO DIFFUSER *

process 2 = irrelevant

Processes :

$V_2 = 0\ m/s$ $V_5 = 0\ m/s$

$(1) \xrightarrow[\text{diffuser}]{\text{Isent}} (2) \xrightarrow{\text{Isent}} (3) \xrightarrow{P_{const}} (4) \xrightarrow[W_C = W_T]{\text{Isent}} (5) \xrightarrow[\text{Nozzel}]{\text{Isent}} (6)\ P_{const}$

(1)	(2)	(3)	(4)	(5)	(6)
$P_1 = 95\ kPa$	$P_2 =$	$P_3 = 855\ kPa$	$P_4 = P_3$	$P_5 = 461.77\ kPa$	$P_6 = P_1$
$T_1 = 280.15\ k$	$T_2 =$	$T_3 = 521.69\ k$	$T_4 = 1464.35\ k$	$T_5 =$	$T_6 =$
$P_{r1} = 1.0889$	$P_{r2} =$	$P_{r3} = 9.8001$	$P_{r4} = 537.1$	$P_{r5} = 291.1$	$P_{r6} = 59.68$
$h_1 = 280.13\ kJ/kg$	$h_2 =$	$h_3 = 525.38\ kJ/kg$	$h_4 = 1592.88\ kJ/kg$	$h_5 = 1347.63\ kJ/kg$	$h_6 = 874.49$

$$\frac{P_{r3}}{P_{r1}} = \frac{P_3}{P_1} \longrightarrow P_{r3} = (1.0889)(9) = 9.8001$$

$$T_3 = \frac{(9.8001 - 9.684)(530 - 520)}{(10.37 - 9.684)} + 520 = 521.69k \qquad h_3 = \frac{(521.69 - 520)(533.98 - 523.63)}{(530 - 520)} + 523.6$$

$$h_3 = 525.38\ kJ/kg$$

$$P_3 = \left(\frac{9.8001}{1.0889}\right)(95) = 855\ kPa$$

$$V_3 = \frac{(.287)(521.69)}{855} = .175\ m^3/kg$$

$$\dot{Q}_{in} = kJ/s = kW \longrightarrow q_{in} = kJ/kg$$

$$\dot{Q}_{in_{3-4}} = \dot{m}_{fuel} H_v = (.5\ kg/s)(42700\ kJ/kg) = 21350\ kJ/s = 21350\ kW$$

$$q_{in_{3-4}} = \frac{\dot{Q}_{in_{3-4}}}{\dot{m}_{Air}} = \frac{21350\ kJ/s}{20\ kg/s} = 1067.5\ kJ/kg$$

$$q_{in} = h_4 - h_3 \qquad h_4 = 1067\ kJ/kg + 525.38\ kJ/kg = 1592.88\ kJ/kg$$

$$T_4 = \frac{(1592.88 - 1587.63)(1480 - 1460)}{(1611.79 - 1587.63)} + 1460 = 1464.35k$$

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9-135 $W_C = W_T \longrightarrow (h_4 - h_5) = (h_3 - h_1) \longrightarrow h_5 = 1592.88 - (525.38 - 280.13) = 1347.63$

$$P_{r5} = \frac{(1347.63 - 1324.93)(290.8 - 272.3)}{(1348.55 - 1324.93)} + 272.3 = 290.1$$

$$P_5 = \left(\frac{P_{r5}}{P_{r4}}\right) P_4 \longrightarrow P_5 = \left(\frac{290.1}{537.1}\right)(855\ kPa) = 461.77\ kPa$$

$$P_{r6} = \left(\frac{P_6}{P_5}\right)(P_{r5}) = \left(\frac{95}{461.77}\right)(290.1) = 59.68$$

$$h_6 = \frac{(59.68 - 57.60)(888.27 - 866.08)}{(63.09 - 57.60)} + 866.08 = 874.49\ kJ/kg$$

$V_5 \to 0$

$$\boxed{\frac{\cancel{V_5}^2}{2} + h_5 = \frac{V_6^2}{2} + h_6} \longrightarrow V_6 = \sqrt{2(h_5 - h_6)} = \sqrt{2(1347.63 - 874.49)}$$

$$V_6 = 30.76\ m/s$$

$$F = \dot{m}_{Air}(V_{exit} - \cancel{V_{inlet}}^{\,0})$$

$$= (20\ kg/s)(30.76\ m/s) = \boxed{615.168\ N}$$