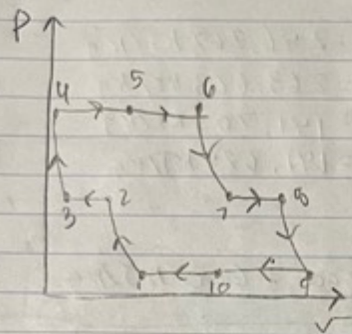
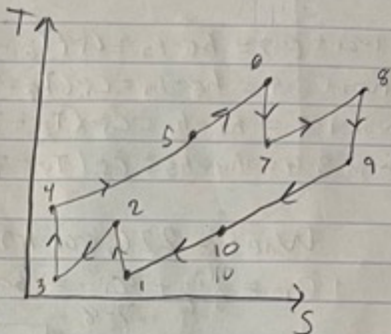
Colby Watts
Professor Ayala
MET 350 HW 1.5
2/13/2024

Hw 1.5 Chap 9

9.123 –

$r_p = 4 = \frac{P_2}{P_1} = \frac{P_4}{P_3}$





$\rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 8 \rightarrow 9 \rightarrow 10 \rightarrow$

1: $P_1 = 100\,kPa$, $T_1 = 290.15\,K$, $v_1 = \frac{RT_1}{P_1} = 0.433\ m^3/kg$

2: $P_2 = r_p P_1$, $P_2 = 400\,k$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = T_2 = 436.16\,K$

$v_2 = \frac{RT_2}{P_2} = 0.31\ m^3/kg$

3: $P_3 = P_2$, $T_3 = T_1$, $T_3 = 290.15\,K$

$v_3 = \frac{RT_3}{P_3} = 0.21\ m^3/kg$

4: $P_4 = r_p P_3$, $P_4 = 1600\,kPa$

5: $P_5 = P_4$, $T_5 = T_4 + 20$, $T_5 = 451.60\,K$, $v_5 = 0.081\ m^3/kg$

6: $P_6 = P_5$

$q_{in\,5\text{-}6} = c_p = T_6 - T_5$

$q_{in\,5\text{-}6} = 300\ kJ/kg$

$T_6 = T_5 + \frac{q_{in\,5\text{-}6}}{c_p}$

$T_6 = 749.61\,K$

7: $P_7 = \frac{P_6}{r_p}$, $P_7 = 400\,kPa$

$\frac{T_7}{T_6} = \left(\frac{P_7}{P_6}\right)^{\frac{k-1}{k}}$

$T_7 = 504.55\,K$

$v_7 = 0.362\ m^3/kg$

8: $P_8 = P_7$, $P_8 = 400\,kPa$

$T_8 = T_7 + \frac{q_{in\,7\text{-}8}}{c_p}$

$T_8 = 803.08\,K$

$v_8 = 0.576\ m^3/kg$

9: $P_9 = P_{10}$, $P_9 = 100\,kPa$

$\frac{T_9}{T_8} = \left(\frac{P_9}{P_8}\right)^{\frac{k-1}{k}}$

$T_9 = 540.51\,K$

$v_9 = 1.551\ m^3/kg$

10: $P_{10} = P_1$, $P_{10} = 100\,kPa$

$h_{10} - h_9 = h_5 - h_4$

$T_{10} = T_9 - \frac{(T_5 - T_4)}{20}$

$T_{10} = 520.51\,K$

$v_{10} = 1.494\ m^3/kg$

Cont. 123 $\quad \eta_{th} = \frac{W_{net}}{q_{in}}$

$W_{net} = W_{out\,6-7} + W_{out\,8-9} - W_{in\,1-2} - W_{in\,3-4}$

$W_{out\,6-7} = h_6 - h_7 = C_P(T_6 - T_7) = 246.267$ kJ/kg
$W_{out\,8-9} = h_8 - h_9 = C_P(T_8 - T_9) = 263.863$ kJ/kg
$W_{in\,1-2} = h_2 - h_1 = C_P(T_2 - T_1) = 141.705$ kJ/kg
$W_{in\,3-4} = h_4 - h_3 = C_P(T_4 - T_3) = 141.624$ kJ/kg

$W_{net} = 226.801$ kJ/kg
$q_{in} = q_{in\,5-6} + q_{in\,7-8} = 300 + 300 = 600$ kJ/kg

$\boxed{\eta_{th} = .378 \text{ or } 37.8\%}$

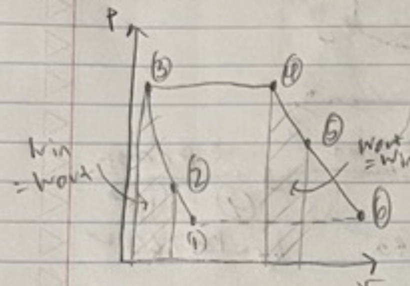
9.129 $V = 900\ ft/s$

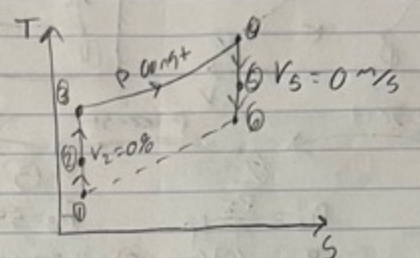
Altitude 20,000 ft

$r_p = 13$ Temp at Turbine inlet 2400 R

need to find $V_{exhaust}$ = Pressure at turbine exit =

Propulsive efficiency = $\eta_P = \dfrac{\text{Propulsive power}}{\text{Energy input rate}} = \dfrac{W_P}{Q_{in}}$





$$① \xrightarrow{\text{Isent}} ② \xrightarrow{\text{Isent}} ③ \xrightarrow{\text{P const}} ④ \xrightarrow{\text{Isent}} ⑤ \xrightarrow{\text{Isent}} ⑥$$

$P_1 = 7\ psia$, $T_1 = 470\ R$

$T_2 = 537.4\ R$ ✓, $P_2 = 11.19\ psia$

$P_3 = 145.5\ psia$ ✓, $T_3 = 1118.3\ R$ ✓

$T_4 = 2400\ R$

$P_5 = 55.2\ psia$ ✓, $T_5 = 1819.1\ R$ ✓

$T_6 = 1008.4\ R$ ✓

$$T_2 = T_1 - \frac{V_2^2 - V_1^2}{2c_P} = 470 + \frac{900^2}{2(0.24)} \cdot \frac{1}{25{,}037} = 537.4 ✓$$

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{r-1}{r}} = 7\left(\frac{537.4}{470}\right)^{\frac{1.4-1}{1.4}} = 11.9\ psia ✓$$

$$P_3 = P_4 = r_P - P_2 = 145.5\ psia ✓$$

$$T_3 = T_2 \left(\frac{P_3}{P_2}\right)^{\frac{k-1}{k}} = 1118.3\ R ✓$$

$$P_5 = P_3 \left(\frac{T_5}{P_2}\right)^{\frac{k-1}{k}} = 55.2\ psia ✓$$

$$T_5 = T_4 - T_3 + T_2 = 1819.1\ R ✓$$

$$T_6 = T_5 \left(\frac{P_1}{P_5}\right)^{\frac{k-1}{k}} = 1008.4\ R ✓$$

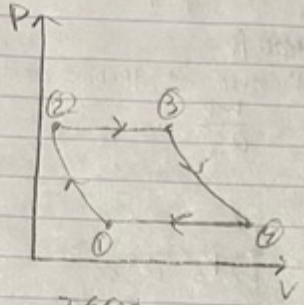
$$\sqrt{V_6^2} = \sqrt{2c_P(T_5 - T_6)}$$

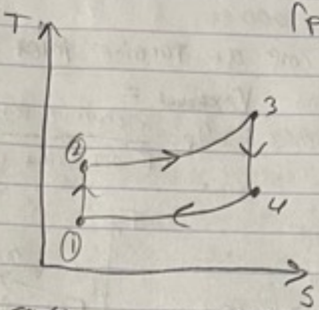
$$V_6 = \sqrt{2(0.24)(1819.1 - 1008.6)\left(\frac{25037}{1}\right)}$$

$$\boxed{V_6 = 3121\ ft/s}$$

9.135

$r_p = 9$





$$① \xrightarrow{\text{Isent}} ② \xrightarrow{\text{P const}} ③ \xrightarrow{\text{Isent}} ④ \xrightarrow{\text{P const}}$$

$T_1 = 280K$

$P_1 = 95 kPa$

$P_{r_2} = \frac{P_2}{P_1} r_p$

$P_{r_2} = (9)(1.0889) = 9.8001$

$P_{r_3} = 543.83$

$h_4 = 1347.63$

$h_3 = 1592.88$

$\dot{m} = 20 \ kg/s$ Table $h_2 = 525.381$

$h_1 = 280.13$

$P_{r_1} = 1.0889$

$$Q_{in} = \dot{m}_f \cdot HV = (0.5)(42700) = 21350$$

$$q_{in} = \frac{Q_{in}}{\dot{m}} = \frac{21350}{20} = 1067.5$$

$W_C = W_T - h_4 = h_3 - h_2 + h_1$ $\qquad h_3 = Q_{in} + h_2 = 1067.5 + 525.381 = 1592.889 \ kJ/kg$

$W_C = W_T = 1592.88 - 525.381 + 280.13 = 1347.63$

$h_5 = 877.5$

$$P_{r_5} = P_{r_3}\left(\frac{1}{r_p}\right) = 60.4255$$

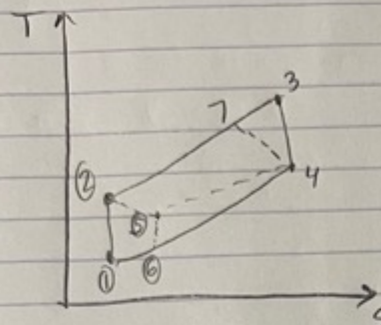
$$h_4 + \frac{1}{2} V_{in}^2 = h_5 + \frac{1}{2} V_{out}^2$$

$$V_{out} = \sqrt{2(h_4 - h_5)}$$

$$V_{out} = \sqrt{2(1347.63 - 877.5)} = 969.6659 \ m/s$$

$$BF = \dot{m}(V_{out} - V_{in}) = 20(969.665 - 0) = \boxed{19{,}370 \ N}$$

9.167



$$\xrightarrow{} (1) \xrightarrow{\text{isent}} (2) \xrightarrow{\text{P const}} (3) \xrightarrow{\text{Isent}} (4) \xrightarrow{\text{P const}} (5) \xrightarrow{\text{I sent}} (6) \xrightarrow{}$$

$$T_5 = T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = T_1\, r_p^{\frac{k-1}{k}}$$

$$T_7 = T_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = T_3 \left(\frac{1}{\sqrt{r_p}}\right)^{\frac{k-1}{k}} = T_3\, r_p^{\frac{1-k}{2}}$$

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

$$q_{in} = h_3 - h_7 = C_p(T_3 - T_7) = C_p T_3 \left(1 - r_p\right)^{\frac{1-k}{2k}}$$

$$q_{out} = h_6 - h_1 = C_p(T_6 - T_1) = C_p T_1 \left(r_p^{\frac{k-1}{2k}} - 1\right)$$

$$\eta_{th} = 1 - \frac{T_1}{T_3}\, r_p^{\frac{k-1}{2k}} \quad \text{(regeneration cycle)}$$

A regeneration cycle with 2 stages would have a higher thermal efficiency than the standard regeneration cycle.