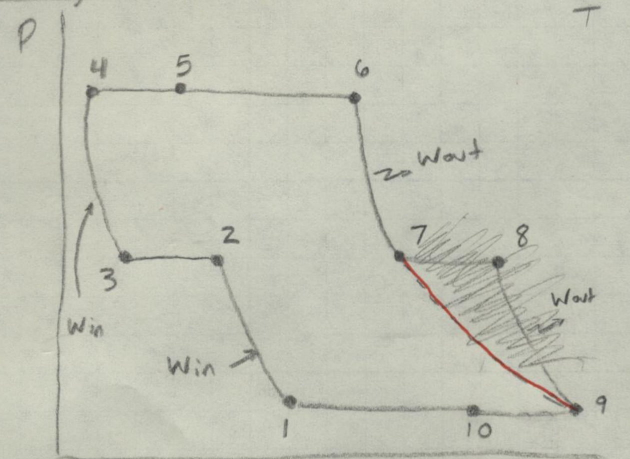
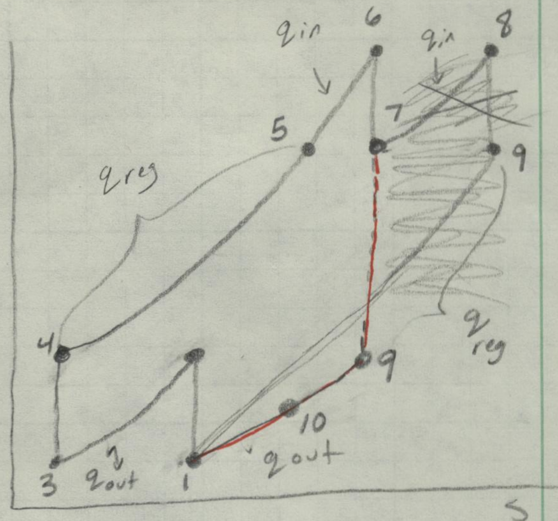
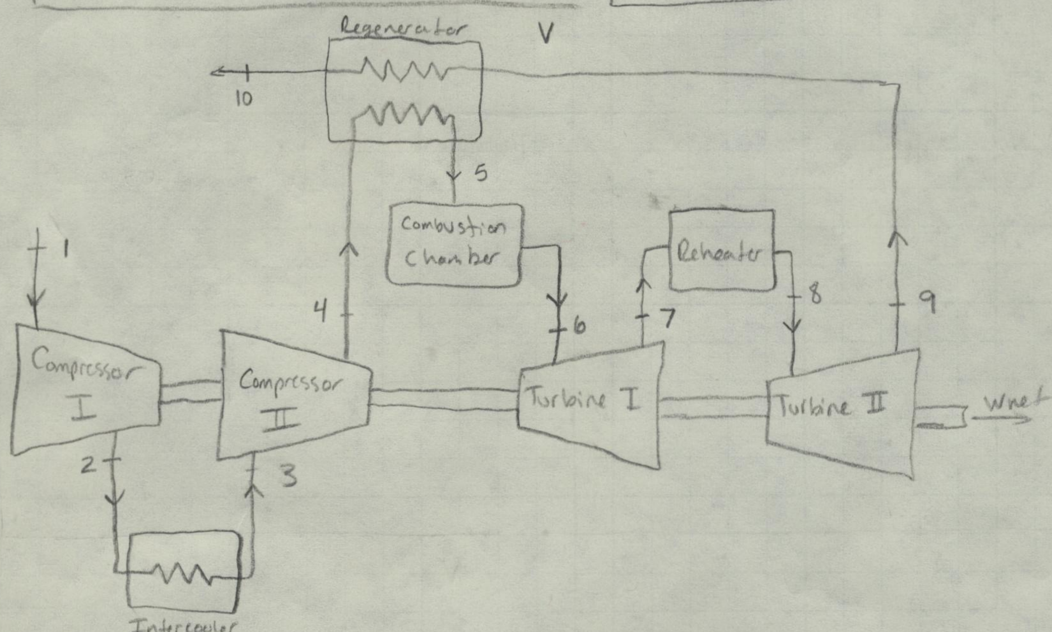
Problem 1	Test 1	Dezmond Banks

Purpose: Calcutate the effectiveness of the heat exchanger problem 9-133 discussed in class. Compare effectiveness against typical values shown in figure. Calculate produced power if reheater is turned off.

Drawings:







Sources:

Cengel & Boles. Thermodynamics - An Engineering Approach 4th edition McGraw Hill. 2002

Struchtrup, Henning, Thermodynamics and Energy Conversion. Springer, 2016

Problem 1	Test 1	Dezmond Banks

Design Considerations:

- At full load the engine Produces 800 KW of power
- To service a partial load, the heat addition in both or one of the combustion chambers is reduced.
- regenerator effectiveness stays constant
- modifications to the flow route might occur.
- Isentropic compression + expansion
- Air enters turbine with 2 stages of compression and 2 stages of expansion
- C_p & C_v constant at room temp. (298.15 K)
- 300 kJ/kg heat added to air in each combustion chamber
- regenerator operates perfectly. Increases T of cold air by 20°C

Data & Variables:

$r_p = 14$ $\quad T_1 = 17°C = 290\,K$ $\quad \dot{W} = \dot{m}(w_{net})$ $\quad \eta_{th} = \frac{w_{net}}{q_{in}}$

$P_1 = 100\,kPa$ $\quad C_p = 1.004926\ kJ/kg\cdot K$ $\quad w_{net} = w_{out_{6-7}} + w_{out_{7-9}} - w_{in_{1-2}} - w_{in_{3-4}}$

$C_v = 0.717926\ kJ/kg\cdot K$ $\quad K = 1.39998$ $\quad w_{out_{7-9}} = C_p(T_7 - T_9)$

$\epsilon \cong \frac{T_5 - T_4}{T_9 - T_4}$ $\quad w_{net} = 226.801\ kJ/kg$ $\quad \frac{T_9}{T_7} = \left(\frac{P_9}{P_7}\right)^{\frac{K-1}{K}}$

Procedure:

For this problem the first thing I did was solve part one. In part one I calculated the effectiveness of the heat exchanger using the formula $\epsilon \cong \frac{T_5 - T_4}{T_9 - T_4}$. Next I used the Power to calculate my "$\dot{m}$". After finding "$\dot{m}$" I then began finding my new states from 7-10 not including the reheater. After that I solved for $w_{out\,7-9}$. Once I got my $w_{out\,7-9}$ I calculated w_{net}. Next I used the formula $\dot{W} = \dot{m}(w_{net})$ to find the Power produced. Lastly I solved for my Thermal efficiency.

Calculations:

① —Isent→ ② —Pconst→ ③ —Isent→ ④ —Pconst→ ⑤ —Pconst→ ⑥ —Isent→ ⑦ —Pconst→ ⑧ —Isen→ ⑨ —Pconst→ ⑩ —Pconst→

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
$P_1 = 100\,kPa$	$P_2 = 400\,kPa$	$P_3 = P_2$	$P_4 = r_p P_3$	$P_5 = P_4$	$P_6 = P_5$	$P_7 = 400\,kPa$	$P_8 = P_7$	$P_9 = P_{10}$	$P_{10} = P_1$
$T_1 = 290.15K$	$T_2 = 431.16K$	$P_3 = 400\,kPa$	$P_4 = 1600\,kPa$	$P_5 = 1600\,kPa$	$P_6 = 1600\,kPa$	$T_7 = 504.55K$	$P_8 = 400\,kPa$	$P_9 = 100\,kPa$	$P_{10} = 100\,kPa$
$v_1 = .0833\,\frac{m^3}{kg}$	$v_2 = .31\,m^3/kg$	$T_3\ 290.15K$	$T_4 = 431.08$	$T_5 = T_4 + 20$	$q_{in_{5-6}} = 300\,\frac{kJ}{kg}$	$v_7 = .362\,\frac{m^3}{kg}$	$T_8 = 803.08K$	$T_9 = 540.51K$	$T_{10} = 520.51K$
				$T_5 = 451.08$	$T_6 = 744.61K$		$v_8 = .576\,\frac{m^3}{kg}$	$v_9 = 1.551\,\frac{m^3}{kg}$	$v_{10} = 1.494\,\frac{m^3}{kg}$
				$v_5 = .081\,m^3/kg$	$v_6 = .134\,\frac{m^3}{kg}$				

$$\epsilon \cong \frac{T_5 - T_4}{T_9 - T_4}$$

$$\epsilon \cong \left(\frac{451.08 - 431.08}{540.51 - 431.08}\right)$$

$$\boxed{\epsilon \cong .1827}$$

$$W = \dot{m}(w_{net})$$

$$\frac{400\,kW}{226.801} = \frac{\dot{m}\,(226.801\ kJ/kg)}{226.801}$$

$$\underline{\dot{m} = 3.53}$$

$$w_{net} = w_{out_{6-7}} + w_{out_{7-9}} - w_{in_{1-2}} - w_{in_{3-4}}$$

$w_{out_{6-7}} = 246.267\ kJ/kg$

$w_{out_{7-9}} = ?$

$w_{in_{1-2}} = 141.705\ kJ/kg$

$w_{in_{3-4}} = 141.624\ kJ/kg$

$$w_{out\,7-9} = C_p(T_7 - T_9)$$
$$= C_p(504.55 - 339.53)$$

$$\underline{w_{out\,7-9} = 165.833\ kJ/kg}$$

⑦ ——→ ⑨ ——→ ⑩

⑦	⑨	⑩
$P_7 = 400\,kPa$	$P_9 = P_{10}$	$P_{10} = P_1$
$T_7 = 504.55K$	$P_9 = 100\,kPa$	$P_{10} = 100\,kPa$
$v_7 = .362\,\frac{m^3}{kg}$	$T_9 = 339.53$	$T_{10} = 319.53$

$$w_{net} = (246.267) + (165.833) - (141.705) - (141.624)$$

$$\underline{w_{net} = 128.771}$$

$$W = \dot{m}(w_{net})$$
$$W = (3.53)(128.771)$$
$$\boxed{W = 455\,KW}$$

$$q_{in} = q_{in_{5-6}}$$

$$\underline{q_{in} = 300\,\frac{kJ}{kg}}$$

$$\frac{T_9}{T_7} = \left(\frac{P_9}{P_7}\right)^{\frac{k-1}{k}}$$

$$T_9 = T_7\left(\frac{P_9}{P_7}\right)^{\frac{k-1}{k}}$$

$$T_9 = 504.55K\left(\frac{100\,kPa}{400\,kPa}\right)^{\frac{.4}{1.4}}$$

$$\underline{T_9 = 339.53}$$

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

$$T_{10} = 339.53 - \underset{(20)}{(451.08 - 431.08)}$$

$$\underline{T_{10} = 319.53}$$

$$\eta_{th} = \frac{w_{net}}{q_{in}}$$

$$\eta_{th} = \frac{128.771}{300} = \underline{.429}$$

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Problem 1	Test 1	Dezmond Banks

Summary:

The purpose for this problem was broken up into two parts. The first part was to find the effectiveness of the heat exchanger. The second part was to calculate the power produced when the reheater was turned off. In the end the amount of power produced decreased by nearly half and the thermal efficiency increased.

Materials:

- Compressor I
- Compressor II
- Intercooler
- Regenerator
- Combustion Chamber
- Turbine I
- Turbine II
- Reheater in part one
  Part two reheater is switched off

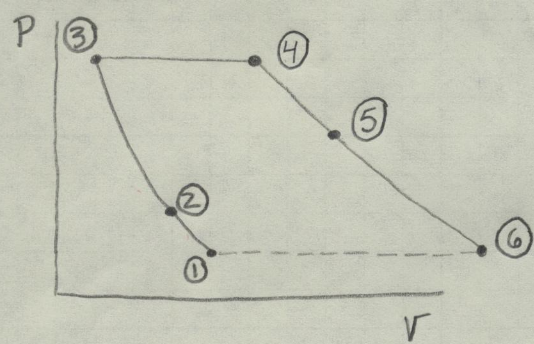
Analysis:

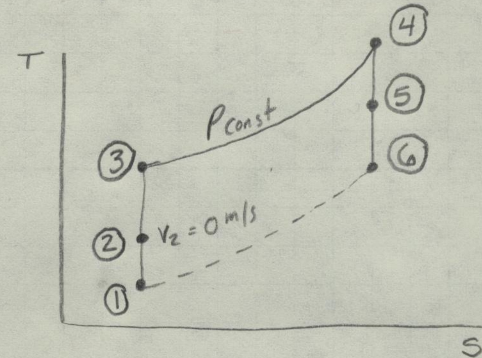
After completing the problem it was apparent that the power produced decreased, but the thermal efficiency increased. The thermal efficiency increased because the reheater normaly negatively impacts the thermal efficiency by increasing the average temperature at which heat is rejected. So by removing the reheater the thermal efficiency automatically increased.

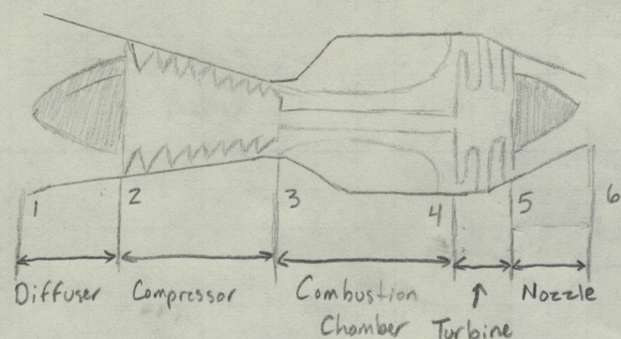
Problem 2 | Test 1 | Dezmond Banks

Purpose: Calculate the Propulsive efficiency of the Jet propulsion cycle Solved in class. Repeat using compressor efficiency of 80% and a turbine efficiency of 85% using C_p and C_v Variable. Calculate the propulsion efficiency of the Jet Propulsion cycle and compare to the previous one.

Drawings:







Sources:

Cengel & Boles. Thermodynamics - An Engineering Approach. 4th edition McGraw Hill. 2002

Design Considerations:

Compressor efficiency 80 %

Turbine efficiency 85 %

C_p and C_v are variable

Pure Jet engine

Materials:

- Jet engine
- Air
- Diffuser
- Compressor
- Turbine
- Nozzle
- Combustion chamber

Problem 2 continued	Test 1	Dezmond Banks

Data & Variables:

- $D_{engine\ inlet}$: 1.6m - r_p (compressor) = 13 - V_1 = 240 m/s
- $T_{inlet\ turb}$: 830K - $F = \frac{V_1}{v_1}\frac{\pi D^2}{4}(V_6 - V_1)$ - $\eta_p = \frac{W_P}{Q_{in}}$ - $W_p = (F)V_{aircraft}$
- Turbine Efficiency: $\eta_{th} = \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$ - Compressor Efficiency: $\eta_{th} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$ - $Q_{in} = \dot{m}(T_4 - T_3)$
- Interpolation $y = y_1 + (y_2 - y_1)\left(\frac{x - x_1}{x_2 - x_1}\right)$ - $V_6 = \sqrt{2(h_5 - h_6)}$

Procedure:

For part one of the problem, I calculated W_p by multiplying F from the problem done in class with the initial velocity of the aircraft. I then calculated Q_{in} by multiplying $\dot{m}$ with $(T_4 - T_3)$. After finding both W_p and Q_{in} I calculated original propulsive efficiency of part one. Next for part two I found my new states using given values and interpolation formulas. I then incorporated my new efficiencies using to find my actual h actuals. After getting my h_{5a} I used the formula $V_6 = \sqrt{2(h_5 - h_6)}$ to find my exit velocity. After getting my V6 I found my new "F" by using the formula $F = \dot{m}(V_6 - V_1)$. I then used my "F" to find my new W_p by multiplying "F" to the initial velocity of the aircraft. After calculating my new W_p I calculated the Q_{in} using $Q_{in} = \dot{m}(T_4 - T_3)$. Once I calculated both my new W_p and Q_{in} I then used them both to calculate the propulsion efficiency using the formula $\eta_p = \frac{W_p}{Q_{in}}$

Calculations: Part 1

① —Isent→ ② —Isent→ ③ —P const→ ④ —Isent→ ⑤ —Isent→ ⑥

1	2	3	4	5	6
P_1 = 45 kPa	P_2 = 64.87 kPa	P_3 = 843.31 kPa	P_4 = 843.81	V_5 = 0 m/s	P_6 = 45 kPa
T_1 = 260.15 K	T_2 = 288.81 K	T_3 = 600.99 K	T_4 = 830.15 K	P_5 = 161.715 kPa	T_6 = 359.41 K
v_1 = 1.659 m³/kg	v_2 = 1.278 m³/kg	v_3 = 0.205 m³/kg	v_4 = 0.283 m³/kg	T_5 = 517.97 K	v_6 = 2.29 m³/kg
V_1 = 240 m/s	V_2 = 0 m/s				V_6 = 564.52 m/s

$\dot{m} = \frac{V_1}{v_1}\frac{\pi D^2}{4}$

$\dot{m} = 290.79$

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

$F = 94392.21 N$

$Q_{in} = \dot{m}(T_4 - T_3)$

$Q_{in} = 290.79(830.15 - 600.99)$

$Q_{in} = 64116.7$

$W_p = (F)V_{aircraft}$

$W_p = 22654.13$ kW

$\eta_p = \frac{W_p}{Q_{in}}$

$\eta_p = 35.3\%$

Calculations: Part 2

①	②	③	④	⑤	⑥
$P_1 = 45$ Kpa	$P_2 = 64.91$ KPa	$P_3 = P_4$	$T_4 = 830$ K	$P_5 = 783.95$	$P_6 = 45$ KPa
$T_1 = 260.15$ K	$T_2 = 288.88$ K	$T_3 = 668.8$ K	$P_4 = 843.8$ KPa	$T_5 = 583.08$	$T_6 = 260.12$ K
$V_1 = 240$ m/s	$V_2 = 0$	$P_3 = 843.8$ Kpa			$V_6 =$
$v_1 = 1.659\ \frac{m^3}{kg}$					

* Used @ Appendix A-17 for interpolation formulas. Sub hi and low for the higher value and lower value of my target x.

- $h_1 = h_{@260} + (h_{@270} - h_{@260})\left(\frac{T_1 - T_{@260}}{T_{@270} - T_{@260}}\right)$

$h_1 = 260.24$ kJ/kg

- $P_{r_1} = P_{r\,low} + (P_{r\,high} - P_{r\,low})\left(\frac{T_1 - T_{low}}{T_{hi} - T_{low}}\right)$

$P_{r_1} = .84228$

- $h_2 = h_1 + \frac{1}{2}V_1^2$

$h_2 = 289.04$ kJ/kg

- $P_{r_2} = P_{r\,low} + (P_{r\,hi} - P_{r\,low})\left(\frac{h_2 - h_{low}}{h_{hi} - h_{low}}\right)$

$P_{r_2} = 1.215$

- $P_2 = P_1\left(\frac{P_{r_2}}{P_{r_1}}\right)$

$P_2 = 64.91$ kpa

- $P_3 = r_p(P_2)$

$P_3 = 843.8$

- $P_{r_3} = (P_{r_2})\left(\frac{P_3}{P_2}\right)$

$P_{r_3} = 15.79$

- $h_3 = h_{low} + (h_{hi} - h_{low})\left(\frac{P_{r_3} - P_{r\,low}}{P_{r\,hi} - P_{r\,low}}\right)$

$h_3 = 601.7$

- $h_4 = h_{low} + (h_{hi} - h_{low})\left(\frac{T_4 - T_{low}}{T_{hi} - T_{low}}\right)$

$h_4 = 855.03$

- $T_2 = T_{low} + (T_{hi} - T_{low})\left(\frac{h_2 - h_{low}}{h_{hi} - h_{low}}\right)$

$T_2 = 288.88$

- $\eta_C \cong \frac{h_{3s} - h_2}{h_{3a} - h_2}$

$h_{3a} = \frac{h_{3s} - h_2 + h_2 \eta_C}{\eta_C}$

$h_{3a} = 679.86$

- $h_5 = h_4 - h_3 + h_2$

$h_5 = 542.37$

- $\eta_T \cong \frac{h_{5a} - h_4}{h_{5s} - h_4}$

$h_{5a} = \eta_T(h_{5s} - h_4) + h_4$

$h_{5a} = 589.27$

- $T_3 = T_{low} + (T_{hi} - T_{low})\left(\frac{h_{3a} - h_{low}}{h_{hi} - h_{low}}\right)$

$T_3 = 668.8$ K

- $T_5 = T_{low} + (T_{hi} - T_{low})\left(\frac{h_{5a} - h_{low}}{h_{hi} - h_{low}}\right)$

$T_5 = 583.08$ K

- $P_{r_5} = P_{r\,low} + (P_{r\,hi} - P_{r\,low})\left(\frac{T_5 - T_{low}}{T_{hi} - T_{low}}\right)$

$P_{r_5} = 14.67$

- $P_{r_4} = \frac{P_4}{P_3} P_{r_3}$

$P_{r_4} = 1 \times 15.79$

$P_{r_4} = 15.79$

- $P_5 = \frac{P_{r_5}}{P_{r_4}} P_4$

$P_5 = \frac{14.67}{15.79} * 843.8$

$P_5 = 783.95$

- $P_{r_6} = \frac{P_6}{P_5} P_{r_5}$

$P_{r_6} = .842$

- $T_6 = T_{low} + (T_{hi} - T_{low})\left(\frac{P_{r_6} - P_{r\,low}}{P_{r\,hi} - P_{r\,low}}\right)$

$T_6 = 260 + (270 - 260)\left(\frac{.842 - .8405}{.959 - .8405}\right)$

$T_6 = 260.13$

Problem 2 cont. | Test 1 | Dezmond Banks

Calculations:

$$h_6 = h_{low} + (h_{hi} - h_{low})\left(\frac{T_6 - T_{low}}{T_{hi} - T_{low}}\right)$$

$$h_6 = 260.09 + (270.11 - 260.09)\left(\frac{260.12 - 260}{270 - 260}\right)$$

$$\underline{h_6 = 260.21}$$

$$V_6 = \sqrt{2(h_5 - h_6)}$$

$$V_6 = \sqrt{2(589.27 - 260.21)}$$

$$\underline{V_6 = 811.25}$$

$$\dot{m} = \frac{V_1}{v_1}\frac{\pi D^2}{4}$$

$$\underline{\dot{m} = 290.79}$$

$$Q_{in} = \dot{m}(T_4 - T_3)$$

$$Q_{in} = (290.79)(830 - 668.8)$$

$$\underline{Q_{in} = 46875.3}$$

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

$$F = (290.79)(811.25 - 240)$$

$$F = 166113.79\ N$$

$$W_p = (F)V_{aircraft}$$

$$W_p = (166113.79\ N)(240\ m/s) * .001$$

$$\underline{W_p = 39867.31}$$

$$\eta_p = \frac{W_p}{Q_{in}}$$

$$\eta_p = \frac{39867.31}{166113.79\ N} = .24$$

$$\boxed{\eta_p = 24\%}$$

Summary:

The purpose of this experiment was to calculate the propulsive efficiency of a Jet Turbine engine. In part one I calculated the propulsive efficiency of the engine when cp and cv were constant. In part two I had to calculate the propulsive efficiency using cp and cv variable.

Analysis:

After conducting the experiment in part one my calculations gave me a propulsive efficiency of 35.3% with Constant cp and Cv values. In part two my calculations gave me a propulsive efficiency of 24%. Judging by my calculations the engines propulsive efficiency is higher when the cp and cv values were constant. This Could be because in part one the Turbine and compressor efficiency wasn't taken into consideration.