Thermal applications test 1 Ben Smithson

1: purpose : Compare the thermal efficiency of Brayton cycle when the reheater is turned off. Also, to understand the effectiveness of the machine.

Sources: Cengel & Boles, Thermodynamics An Engineering Approach 9th edition

Design considerations: 1) Air behaves as ideal gas
2) Cp & Cv are constant
3) maximum effectiveness
4) regenerator is gone

Data & Variables

9-133 discussed calculations

$T_1 = 290$

$P_1 = 100$ kpa ...

1-4 States the same

$w_{in,1-2} = 141.709$

$w_{in,3-4} = 141.624$

Materials : Air as ideal gas

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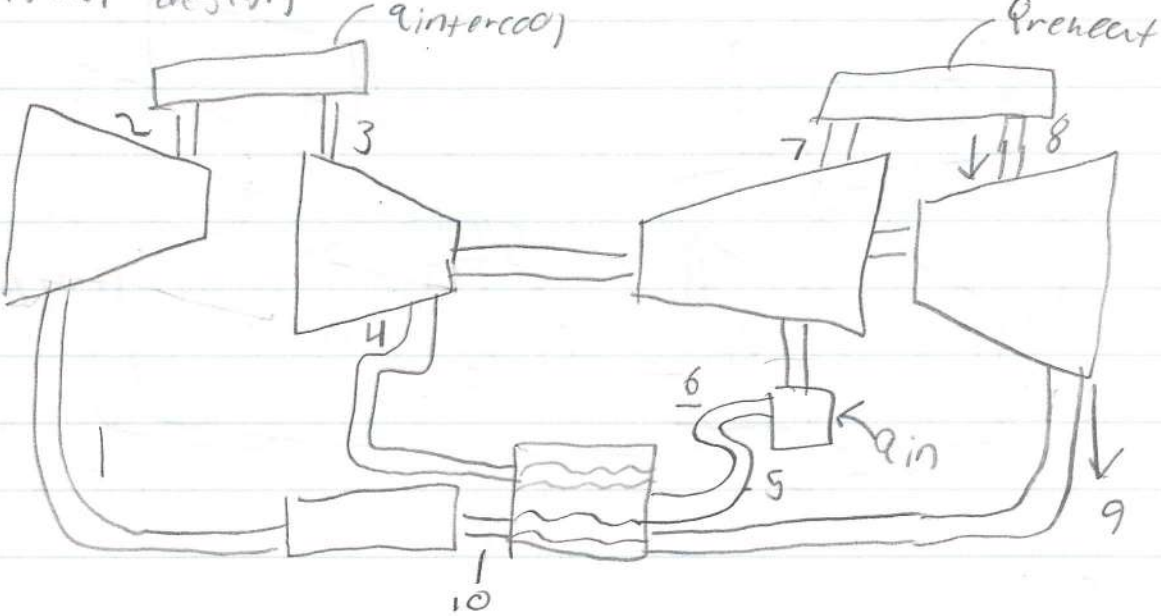
1. Diagrams:

9-133 given info...

original design



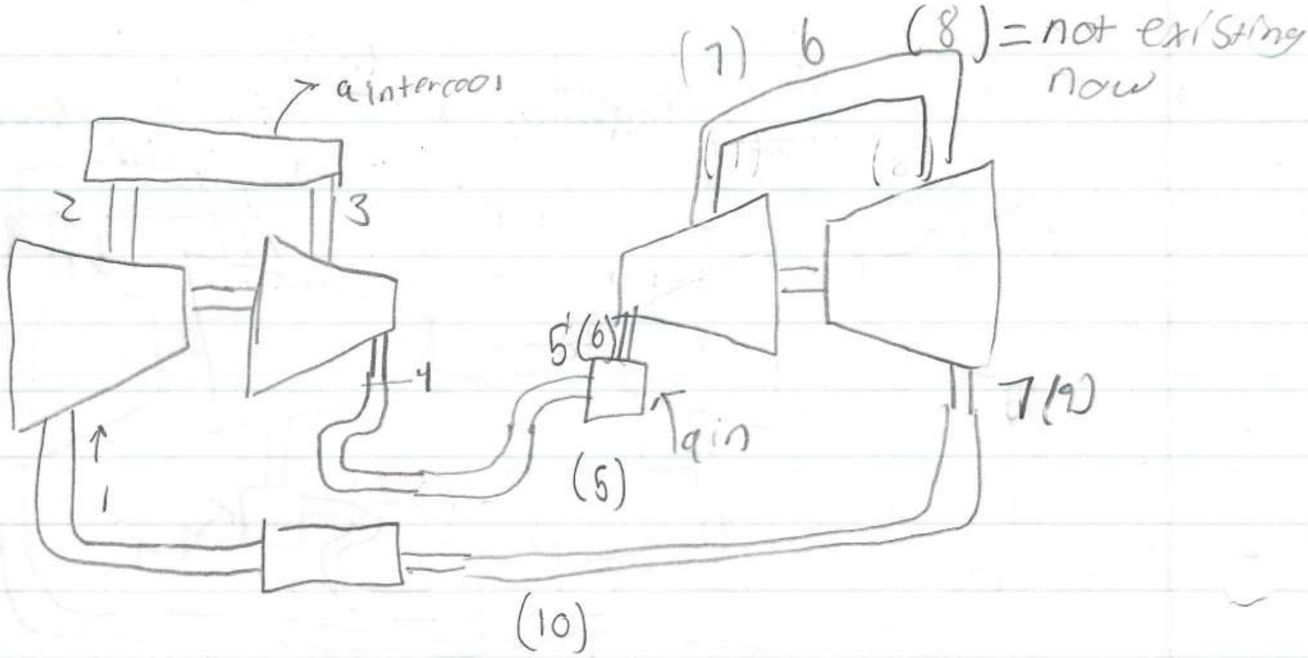
Part 1 question 1: effectiveness of 9-133

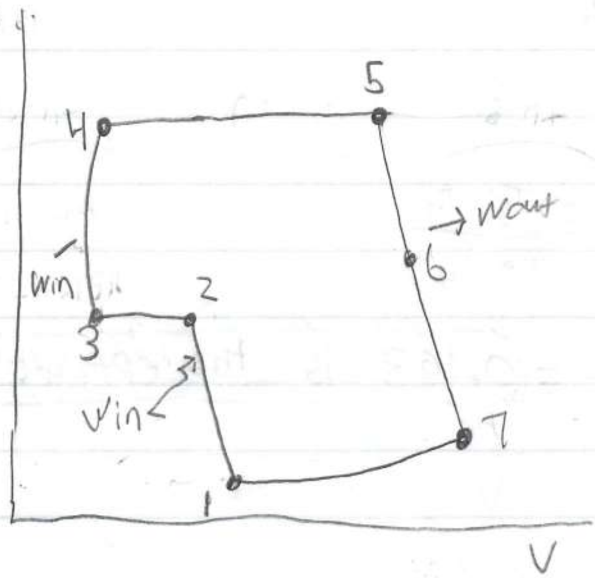
$$\epsilon = \frac{q_{regen,act}}{q_{regen,max}} = \frac{h5 - h_4}{h9 - h_4} \cong \frac{T_5 - T_4}{T_9 - T_4}$$

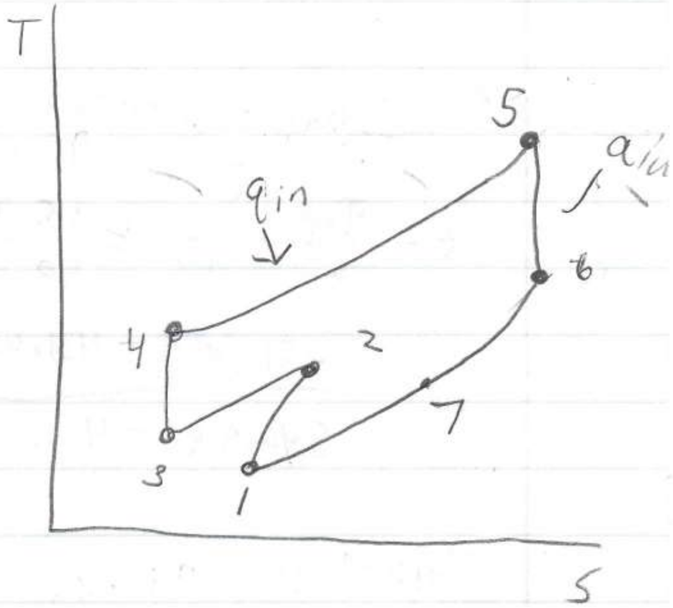
$$= \frac{461.08K - 431.08K}{540.51K - 431.08K} = \boxed{0.183 \text{ is the effectiveness}}$$

The effectiveness ...

New machine w/o regenerator & reheater turned off.







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Calculations:

States

P const	1 — isent —	2 — P const —	3 — isent —	4 — P const —	5 — isent —	6 — isent —	7 — pconst
	$P_1 = 100kPa$	$P_2 = 400kPa$	$P_2 = P_3$	$P_4 = 1600kPa$	$P_5 = 1600kPa$	$P_6 = 400kPa$	$P_7 = 100kPa$
	$T_1 = 290.15K$	$T_2 = 431.16K$	$P_3 = 400kPa$	$T_4 = 431.08K$	$T_5 = 730.89K$	$T_6 = 491.6$	$T_7 = 330K$
	$V_1 = \frac{RT_1}{P_1} = 0.833 \frac{m^3}{kg}$	$V_2 = \frac{RT_2}{P_2} = 0.31$	$V_3 = 0.21$	$V_4 = 0.077$	$V_5 = 0.131$		
			$T_3 = 290.15K$				

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 290.15\left(\frac{400kPa}{100kPa}\right)^{\frac{0.4}{1.4}} = 431.16K$$

$$rP = 4 \quad \frac{P_2}{P_1} = \frac{P_4}{P_3} = 4(100kPa) = 400kPa = P_2$$

$$T_3 = T_1 = 290.15K$$

$$V_3 = \frac{RT_3}{P_3} = 0.21 \frac{m^3}{kg}$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = 290.15\left(\frac{1600}{400}\right)^{\frac{0.4}{1.4}} = 431.08K$$

$$P_4 = r_P P_3 = 4(400kPa) = 1600 kPa$$

$$V_4 = \frac{RT_4}{P_4} = 0.077 = \frac{0.287 \cdot 431.08}{1600} = 0.077 m^3/kg$$

$P_4 = P_5$

$q_{in} = c_p(T_5 - T_4$

$q_{in} = 1.004926 \frac{kJ}{kgK} (T_5 - T_4)$

$T_5 = T_4 + \frac{q_{in}}{c_p} = 431.8 + \frac{300 \text{ kJ/kg}}{1.004926} = 730.329$

$V_5 = \frac{RT_5}{P_5} = \frac{0.287 (730.329)}{1600 \text{ kPa}} = 0.131$

$P_5 / r_p = P_6 = 1600/4 = 400 \text{ kPa}$

$\frac{T_6}{T_5} = \frac{P_6}{P_5} \left(\frac{k-1}{k}\right) = T_6 = 730.329 \left(\frac{400}{1600}\right)^{\frac{0.4}{1.4}} = 491.47 \text{ K}$

$\frac{T_7}{T_6} = T_7 = T_6 \left(\frac{P_7}{P_6}\right)^{\frac{k-1}{k}} = 330.73 \text{ K}$

$w_{net} = w_{out\,5-6} + w_{out\,6-7} - w_{in\,1-2} - w_{in\,3-4}$

$w_{out\,5-6} = c_p(T_6 - T_7) = 1.004926 (730.329 - 491.47) = 240.035 \text{ kJ/kg}$

$w_{out\,6-7} = c_p(T_7 - T_6) = 1.004926 (491.4) - 330.73) = 161.631$

$w_{in\,1-2}$ = given = 141.765 kJ/kg

$w_{in\,3-4}$ = given = 141.624 kJ/kg

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1. cont

$w_{net} = 240.035 + 161.53 - 141.705 - 141.624 = \boxed{118.236 \ kJ/kg}$

$q_{in} = q_{in_{4-5}} = 300 kJ/kg$

$\eta_{th} = \frac{w_{net}}{q_{in}} = 0.394 = \boxed{39.4\%}$

Summary: The efficiency changes to a higher value because there are less machines for the air to travel through so it can be more efficient. Also, the effectiveness is lower than most on the graph so it is less effective.

1, Analysis: Since the effectiveness is less than the ones on the graph, we can conclude the machine overall isn't too effective. Also after seeing, the new efficiency, by taking out the reheater and heat exchanger in this case, these two objects in the machine were creating a less efficient system. The new system has a better efficiency with the same effectiveness.

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2: purpose: to compare the propulsive efficiency of the jet propulsion cycle with ideal conditions compared to the compressor working at 80% and the turbine at 85%. Also, when the heats change from constant to variable, what does this affect.

Sources: Cengel & Boles, Thermodynamics An engineering approach, 9th edition

Design considerations:

1) C_p, C_v are variable
2) compressor = 80%
3) Turbine = 85%
4) Original is ideal jet propulsion.

Data & variables

9-142 discussed calculations

$P_1 = 45\,kPa$

$T_1 = 260\,K$

$V_1 = 240\,m/s$

$T_4 = 830\,K$

materials: Jet propulsion turbine engine w/ air as ideal

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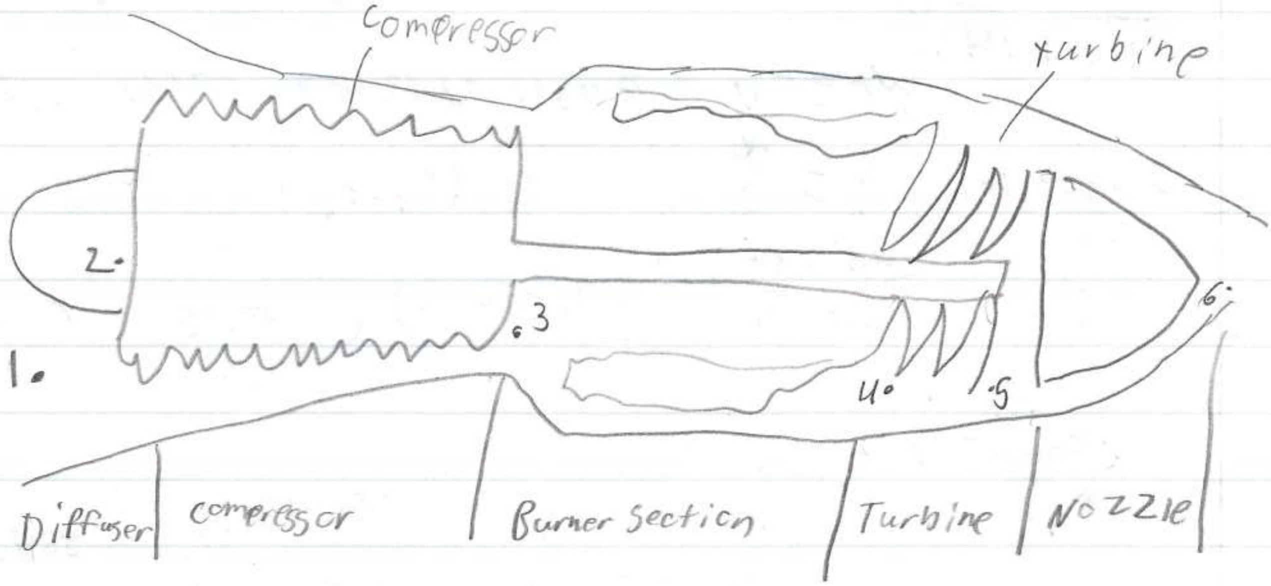
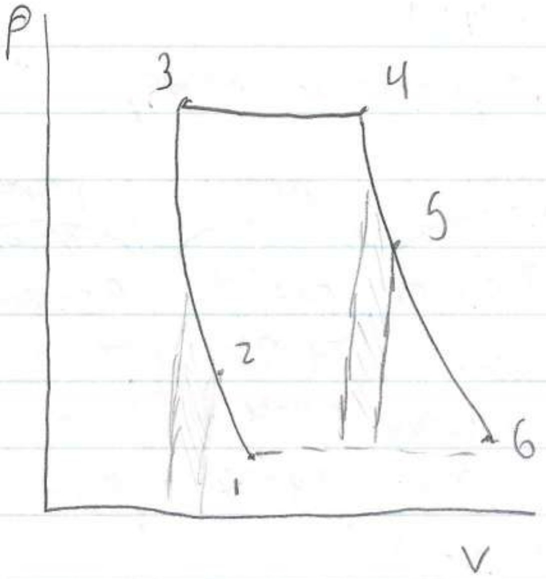
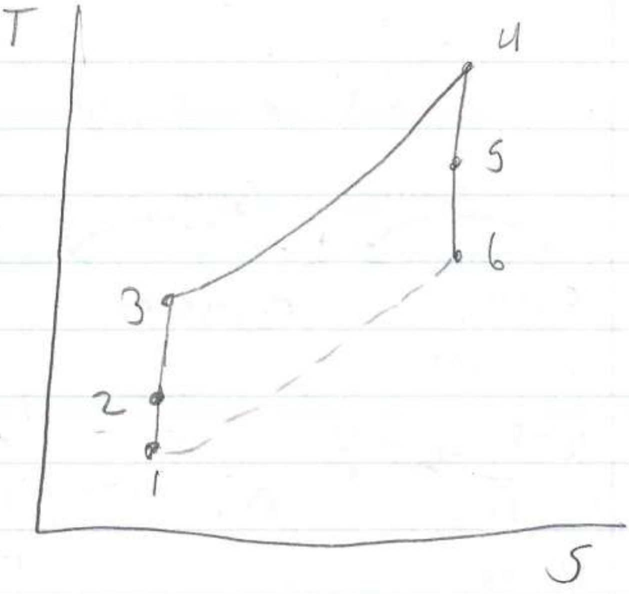
2. Diagrams:







Propulsive efficiency $= \dfrac{\text{propulsive power}}{\text{Energy input rate}} = \dfrac{W_P}{q_{in}}$

Propulsive power from 9-142 $= W_P = \dot{m}\,(V_6 - V_1)V_1$

$$W_P = \rho_1 V_1 A_1 (V_6 - V_1)V_1 = \frac{V_1}{v_1}\,\frac{\pi}{4} D^2 (V_6 - V_1) V_1$$

Calculations:

$$W_p = \frac{240}{1.659}\,\frac{\pi}{4}\,1.6^2\,(564.52 - 240)(240) = 22654131.2$$

$$W_p = F V_1 = 94392.21\,(240) = 22654131.2$$

$$Q_{in} = \dot{m}\,(h_4 - h_3) = \frac{V_1}{v_1}\,\frac{\pi}{4}\,D^2\,(c_p)(T_4 - T_3)$$

$$Q_{in} = \frac{240}{1.659}\,\frac{\pi}{4}\,1.6^2\,(1.004926)\,(830.15K - 600.99K)$$

$= 66983.46$

$$\text{Propulsive efficiency} = \frac{W_p}{Q_{in}} = \frac{22564131.2}{66983.46} = \boxed{338.20}$$

New states efficiency A-17, variable heats,

1 —(Isent, Diffuser)→ 2 —(Isent)→ 3 —(Pconst)→ 4 —(Isent)→ 5 —(Isent, Nozz)→ 6

1	2	3	4	5	6
$P_1 = 45\,kPa$	$P_2 = 585\,kPa$	$P_3 = 7605\,kPa$	$P_4 = 7605$	$P_5 = 1846.57$	$P_6 = 45$
$T_1 = 260.15K$	$h_2 = 541.88$	$h_3 = 1114.86$	$T_4 = 830K$	$T_5 = 1948.62$	$P_{r6} =$ 0.8405
$v_1 = \frac{RT_1}{P_1} = 1.659\,\frac{m^3}{kg}$	$T_2 = 537.62$	$P_{r3} = 142.044$	$P_{r4} = 142.04$	$h_5 = 2187.98$	
$V_1 = 240\,m/s$	$P_{r2} = 10.9265$	$h_{3a} = 1258.503$	$h_4 = 856.07$	$P_5 = 98867$	
$P_{r1} = 0.8405$		$T_{3a} = 1118.03\,K$			
$h_1 = 260.09\,\frac{kJ}{kg}$					

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A-17 $P_{r2} = \frac{P_2}{P_1} P_{r1} = 13(0.8405) = 10.9265$

$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} = \frac{P_2}{45} = \frac{10.9265}{0.8405}$

$P_2 = 585$ kPa

$h_2 = 541.885$ (interpolate)

$T_2 = 531.623$ (interpolate)

$\eta_c = \frac{w_s}{w_a} \cong \frac{h_3 - h_2}{h_{3a} - h_2}$

$0.80 = \frac{1114.86 - 541.885}{h_{3a} - 541.885} = 1258.103 = h_{2a}$

$T_{3a} = 1118.03$ K

$P_3 = r_p P_2 = 13(585) = 7605$ kPa

$h_3 = 1114.86$ (close)

$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}} = \frac{7605}{585} = \frac{P_{r3}}{10.9265}$

$P_{r3} = 142.0445$

$P_4 = P_3 = 7605$

$T_4 = 830$ K $h_4 = 855.030$

$v_4 = \frac{RT_4}{P_4} = \frac{0.287 \cdot 830}{7605} = 0.0313\ m^3/kg$

$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}} = \frac{7605}{7605} = P_{r4} = P_{r3} = 142.0445$

$h_4 = 855.03$

$P_{r5} = 13(142.0445) = 1846.5785$

$\frac{P_{r5}}{P_{r4}} = \frac{P_5}{P_4} = \frac{1846.57}{142.04} = \frac{P_5}{7605}$

$P_5 = 98867.6$

$T_5 = 1948.624$ K (interpolate)

$h_5 = 2187.985$ K (interpolate)

$$n_t = \frac{h_4 - h_{5a}}{h_4 - h_5}$$

$$.85 = \frac{855.03 - h_{5a}}{855.03 - 2187.985} = 1988.04 = h_{5a}$$

$$T_{5a} = 1787.634 \text{ K}$$

$P_6 = P_1$

$P_6 = 45 \text{ kPa}$

$$\frac{P_{r6}}{P_{r5}} = \frac{P_6}{P_5} \Rightarrow \frac{P_{r6}}{1846.57} = \frac{45}{98867.67} \quad P_{r6} = 0.8404$$

$$w_{out} = h_4 - h_{5a} = 855.03 - 1988.04 = 1133.01$$

$$w_{in} = h_{3a} - h_2 = 1258.103 - 541.885 = 716.218$$

$$w_{net} = w_{out} - w_{in} = 1133.01 - 716.218 = \boxed{416.792 \text{ kJ/kg}}$$

$$q_{in} = h_4 - h_3 = 855.03 - 1114.86 = 259.83 \text{ kJ/kg}$$

prop $$\text{efficiency} = \frac{w_p}{q_{in}} = \frac{416.792}{259.83} = \boxed{1.604}$$

Analysis: The jet propulsion efficiency was significantly less when the compressor and turbine were working at a less efficient rate. This makes sense because in an ideal situation where the turbine and compressor are 100% efficient, then they can work to make the jet propell at a better rate. Also when the heat and pressures are changing (variable), then the machine isn't going to work as well as when heats are constant. This is because the changing heats and pressures make the machine work harder to adjust. overall this problem shows the logical efficiency of a a jet engine.