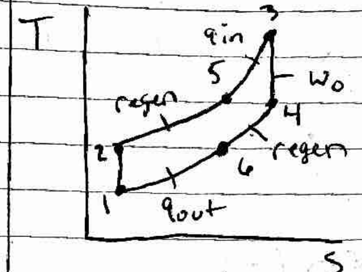
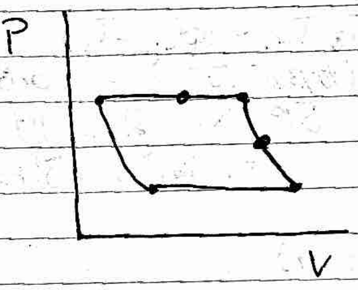
Nick Mason
Thermal Apps
Test 1

Source: Thermo Book | Lectures
Purpose: ~~[illegible]~~.

A





Isent. 1	Pcont. 2	Isent. 3	Pcons. 4	Pcons. 5	6
$T_1 = 303.15°K$	$T_2 = 584.92°K$	$T_3 = 1073°K$	$T_4 = 555.8°K$	$T_5 = 594.92°K$	$T_6 = 565.$
$P_1 = 100\,kPa$	$P_2 = 1000\,kPa$	$P_3 = 1000\,kPa$	$P_4 = 100\,kPa$	$P_5 = P_4$	$P_6 = P_4$

① Find T_2

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

$$T_2/303.15 = \left(\frac{1000}{100}\right)^{\frac{1.4-1}{1.4}}$$

$$= 584.92°K$$

② Find T_4

$$T_4 = T_3 \cdot (1/10)^{\frac{1.4-1}{1.4}}$$

$$= 555.8°K$$

③ $$T_5 = T_2 + \text{Regen}$$
$$= 594.92°K$$

④ $$T_6 = 10 + T_4$$
$$= 565.8°K$$

Find w_{net}

$w_{net} = w_o - w_i$

$$cp(T_3 - T_4) - cp(T_2 - T_1)$$
$$1.005(1073.15 - 555.8) - 1.005(584.92 - 303.15)$$
$$519.93 - 283.17$$
$$= 236.75 \text{ KJ/kg}$$

Heat Addition (+)

$$q_{in} = c_p(T_3 - T_5)$$
$$1.005(1073.15 - 594.92)$$
$$= 480.62°K$$

Heat Rejection (-)

$$q_{out} = c_p(T_6 - T_1)$$
$$1.005(565.8 - 303.15)$$
$$= 263.96°K$$

Effiency

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

$$236.75/480.62$$

$$= .492$$

$$\boxed{49\%}$$

Heat Exchange

$$\frac{h_5 - h_2}{h_4 - h_2} = x$$

$$\frac{602.02 - 591.9}{561.20 - 591.9}$$

$$= -.36$$

$$\boxed{-36\%}$$

This is the reason why the other engineer said this design was bad/major issue.

Const p. → Isent. → Const p → Isent. →

Part B	1	2	3	4
	$T_1 = 303.15$	$T_2 = 584.92$	$T_3 = 1073.15$	$T_4 = 555.8$
	$P_1 = 100$ kPa	$P_2 = 1000$ kPa	$P_3 = 1000$ kPa	$P_4 = 100$ kPa

① $w_{net} = w_o - w_i$

$c_p(T_3 - T_4) - c_p(T_2 - T_1)$

$= 236.75$ kJ/kg

② Heat addition (+)

$q_{in} = c_p(T_3 - T_2)$

$1.005(1073.15 - 584.92)$

$= 490.67°K$

③ Heat Rejection

$q_{out} = c_p(T_4 - T_1)$

$1.005(555.8 - 303.15)$

$= 253.91$

④ Efficiency $= \eta_{th} = w_{net}/q_{in}$

$\eta_{th} = 236.75/490.67$

$= .482$

$\boxed{48\%}$

C	Isent	Pconst	Isent	Pconst	Pconst.	
	1	2	3	4	5	6
	$T_1 = 303.15°K$	$T_2 = 559.95°K$	$T_3 = 1023°K$	$T_4 = 580.61$	$T_5 = 569.95$	$T_6 = 590.61$
	$P_1 = 100kPa$	$P_2 = 858kPa$	$P_3 = 858$	$P_4 = 100kPa$	$P_5 = P_4$	$P_6 = P_4$

(1) - Find T_2

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

$$\frac{T_2}{303.15} = (8.58)^{.4/1.4}$$

$$= 560.23°K$$

(2) $T_4 = T_3(1/8.58)^{.4/1.4}$

$$= 580.61°K$$

(3) $T_5 = T_2 + \text{Regen}(+)$

$$= 569.95°K$$

(4) $T_6 = 10 + T_4$

$$= 590.61°K$$

(5) $W_{net} = W_o - W_i$

492.39 - 256.95

= 235.44 kJ/kg

(7) Efficiency

$$\eta_{th} = w_{net}/q_{in} = \boxed{45\%}$$

$$= .456$$

(6) Heat Addition (+)

$$q_{in} = c_p(T_3 - T_2)$$

$$= 515.61$$

(8) Heat Exchanger

$$\frac{h_5 - h_2}{h_4 - h_2} = \frac{575.814 - 565.393}{586.789 - 565.393} = \boxed{48\%}$$

	Pc	Isent.	Pc	Isent	Pcon	Pc
	1	2	3	4	5	6
D	$T_1 = 303.15°K$	[illegible]	$T_3 = 1168.63$	$T_4 = 605.28°$	$T_5 = 594$	$T_6 = 615.28$
	$P_1 = 100kPa$	$P_2 = 1000kPa$	$P_3 = 1000kPa$	$P_4 = 100$	$P_5 = P_4$	$P_6 = P_4$
		$T_2 = 584.92$				

(1) $T_3 = 1168.63°K$

(2) $T_4 = T_3 \left(\frac{1}{10}\right)^{.4/1.4}$

605.28°K

(3) $T_6 = T_4 + 10$

$= 615.28°K$

(4) $W_{net} = W_a - W_1$

$(T_3 - T_4) - (T_2 - T_1)$

$(1168.63 - 605.28) - (\overset{584.92}{[illegible]} - 303.15)$

$563.35 - 281.77$

$= [illegible]$ kJ/kg

281.58

(5) Heat (+)

$q_{in} = cp\,(T_3 - T_2)$

$1.005\,(1168.63 - \overset{584.92}{[illegible]})$

$= [illegible]$

586.62°K

(6) Heat (−)

$q_{out} = cp\,(T_4 - T_1)$

$1.005\,(615.28 - 303.15)$

$= 313.69°K$

(7) $Eff = \eta_{th}$

w_{net}/q_{in}

$= [illegible]$ 48%

[illegible]

(8) Heat exchanger

$$\frac{h_5 - h_2}{h_4 - h_2} = \frac{602.05 - 591.56}{612.54 - 591.56}$$

$= 49\%$

Pconst	Isent	Pc	I sent	P con	Pcon	Isent	Pcons
1	2	3	4	5	6	7	8
$T_1 = 303.15°K$	$T_2 = 585.29°K$	$T_3 = 303.15°K$	$T_4 = 585.29$	$T_5 = 595.29°K$	$T_6 = 1073.15°K$	$T_7 = 555.85$	$T_8 = 565.85$
$P_1 = 100KPa$	$P_2 = 1000KPa$	$P_3 = 1000KPa$	$P_4 = r_p P_3$	$P_5 = 10{,}000KPa$	$P_6 = 10{,}000KPa$	$P_7 = 100$	$P_8 = 100 KPa$

(1) Find P_2

$P_2 = P_2/P_1 = 10$

$\frac{T_2}{T_1} = 10^{.4/1.4} \cdot 303.15$

$T_2 = 585.29°K$

(2) $P_4 = 10(1000kPa)$

$10{,}000kPa$

(3) $T_4 = 585.29°K$

(4) $T_5 = 595.29°K$

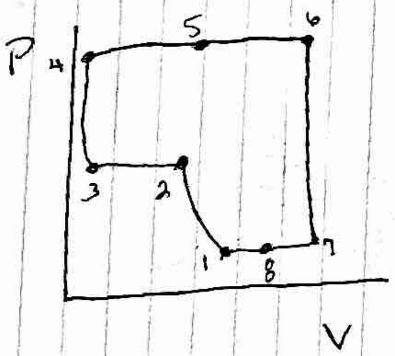
(5) $T_7/T_6 = P_7/P_6$

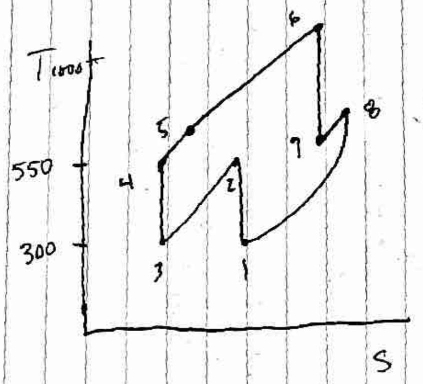
$T_7/1073.15 = \frac{100}{10{,}000}$

$T_7 = 555.85°K$

(6) $T_8 - T_7 = 10$

$T_8 = 565.85°K$





(7) $w_{net} = w_o - w_i$

$$cp(T_6 - T_7) - [cp(T_2 - T_1) - cp(T_4 - T_3)]$$

$$1.005(1073.15 - 555.85) - [1.005(585.29 - 303.15) - 1.005(585.29 - 303.15)]$$

$$519.88 \quad - \quad 283.55 \quad + \quad 283.55$$

$$519.88 - 567.1$$

$$= -47.22 \text{ kJ/kg}$$

(8) Heat (+)

$$q_{in} = cp(T_6 - T_5)$$

$$1.005(1073.15 - 595.29)$$

$$= 480.26 \text{°K}$$

(9) Heat (−)

$$q_{out} = cp(T_8 - T_1) + cp(T_6 - T_7)$$

$$1.005(565.85 - 303.15) + 1.005(1073.15 - 555.85)$$

$$= -255.86 \text{°K}$$

(10) $Eff = \eta_{th}$

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

$$-47.22/480.26$$

$$= .098$$

$$\boxed{9.8\%}$$

(11) Heat Exchanger

$$\frac{h_5 - h_4}{h_7 - h_4} = \frac{602.07 - 591.98}{561.25 - 591.98}$$

$$\frac{10.49}{-30.33}$$

$$= -.34$$

$$\boxed{-34\%}$$

(12) Interpolate

$$h_7 = \frac{T_{max} - T_{act}}{T_{act} - T_{min}} = \text{Enthalpy} = \frac{h_{max} - h_{act}}{h_{act} - h_{min}}$$

$$\frac{560 - 555.85}{555.85 - 550} = \frac{565.17 - h_9}{h_9 - 555.74}$$

$$h_7 = 561.25$$

$$h_4 = \frac{590 - 585.29}{585.29 - 580} = \frac{596.52 - h_4}{h_4 - 586.04}$$

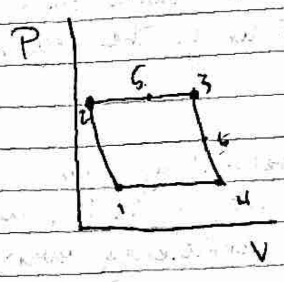
$$h_4 = 591.58$$

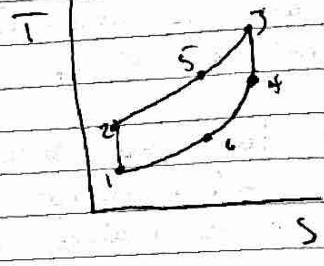
$$h_5 = \frac{T_{max} - T_A}{T_A - T_{min}} = \frac{607.02 - h_5}{h_5 - 596.52}$$

$$h_5 = 602.07$$

(12) Int

Purpose: Solve for the engineers cycle, then state why the second engineer believed the design was not effective.





Procedure:

① 1st draw P-V and T-S diagrams

② Solve for Temp and Pressure for each states

③ find what process is happening between states

④ Find heat addition, heat rejection, and eff.

⑤ find heat exchanger effectiveness. This will determine what and why the 2nd engineer suggests that the heat exchanger should not be used unless changes were made.

5a. Course objective being answered: bullet 2
- apply thermo laws, to gas turbine, reheating regenerating...

5b. The information being indirectly assessed is being built upon understanding practical systems as a foundation

(3)

Design Considerations: With the use of the regenerator we get a heat exchanger effectiveness of negative -36%. which means this is causing the system to work even harder and is decreasing the efficiency. The regenerator should not be used.

Using a two stage compressor with intercooling we get a heat exchanger effectiveness of -34%, which means it is making the system's efficiency even worse.

The best design would be either part C or D.

Summary: We found in part A - the regenerator is hurting the system.

We find in part B this design is 49% efficient

We find in part C with an increase in pressure it increased the system's eff. to +48% out of 100%.

We find in part D with an increase in temperature, it increased the system's eff. to 49.9%

Finally in part E, we find that this design is nearly as bad as the first design with a heat exchanger effectiveness of -34%

Data

:2 Turbo Jet

velocity = 900 km/h → 250 m/s

Temp = -35°c → 238.15°k

$Temp_{Tur}$ = 450°c → 1223.15°k

work = 500 kJ/kg

$n_c = .8$

$n_T = .9$

$\xrightarrow{P_e}$ 1	$\xrightarrow{Isent.}$ 2	$\xrightarrow{Isent.}$ 3	$\xrightarrow{P_e}$ 4	$\xrightarrow{P_e}$ 5	$\xrightarrow{Isen}$ 6 $\xrightarrow{P_e}$
$P_1 = 40 kPa$	$P_2 = 61.42$	$T_3 = 659.01°k$		$T_5 = 733.56$	$P_6 = 40 kPa$
$T_1 = 238.15°k$	$T_2 = 269.42$	$P_3 = 1485.69 kPa$	$P_4 = 1485.69$	$P_5 = 198.21 kPa$	$T_6 = 473.61°k$
$V = 250 m/s$					

① A-17 @ 238.15°k

$Pr_1 = .619257$

$V_1 = 62.5 kJ/kg$

1st law $h_1 + \frac{V_1^2}{2} = h_2 + \cancel{\frac{V_2^2}{2}}$ 0

$h_2 = 269.42\ kJ/kg$

② $T_2 = 269.42$ A-17

$Pr_2 = .9508$

$P_2 = P_1\left(Pr_2/Pr_1\right)$

$P_2 = 61.42\ kPa$

$\frac{P_3}{P_2} = \frac{Pr_3}{Pr_2}$

③ 1st law for T_3

$T_3 =$

$w_c = \frac{h_3 - h_2}{n_c}$

$w_c = h_3 - h_2 \cdot n_c$

$500 = h_3 - 269.42 \cdot .8$

$h_3 = 669.42\ kJ/kg$

$T_3 = 659.01°k$

$Pr_3 = 23$

$P_3 = 1485.69$

④ 1st law T_4

$w_T = n_T(h_4 - h_5)$

$h_5 = h_4 - w_T/n_T$

$h_5 = 749.47\ kJ/kg$

$T_5 = 733.56°k$

$\frac{P_5}{P_4} = \frac{Pr_5}{Pr_4}$

$P_5 = 198.21 kPa$

⑤ $\frac{P_6}{P_5} = \frac{Pr_6}{Pr_5}$ $Pr_6 = 6.932$

$T_6 = 473.61°k$

(6)

$$\eta_c = \frac{h_3 - h_2}{h_{3A} - h_2}$$

$h_{3A} = 769.42\ \text{kJ/kg}$

$T_3 = 751.96\ °K$

(7)

$$\eta_T = \frac{h_4 - h_5}{h_{4A} - h_5}$$

$h_{4A} = 800.03\ \text{kJ/kg}$

$T_4 = 780\ °K$

A $P_{exit} = P_5 = 198.12\ \text{kPa}$

B V_N = 1st law

$$h_{5A} + \cancel{\frac{V_{5A}^2}{2}}^{\,0} = h_6 + \frac{V_6^2}{2}$$

$$V_N = \sqrt{2(h_{5A} - h_6)}$$

$805.1\ \text{m/s}$

(10)

C Thrust

$$F = \frac{V_1 P_1}{R T_1} \cdot \pi/4 \cdot D^2 (V_6 - V_1)$$

$F = 163.29\ \text{kN}$

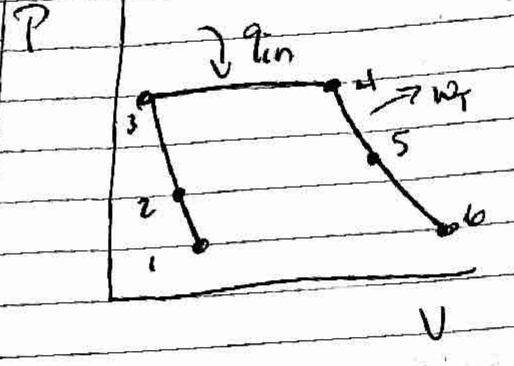
Summary: Pressure at the turbine exit is 198.12 KPa.
Velocity at the nozzle is 805.1 m/s.
Thrust is 163.29 KN.

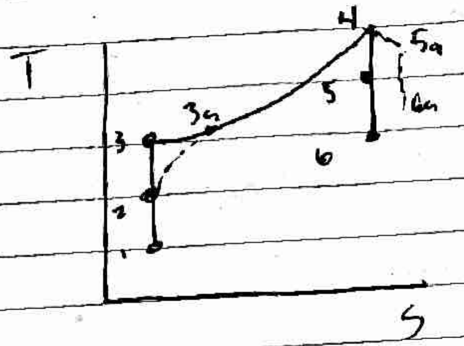
Analysis: Propulsive power is...

$$\dot{W}_p = F V_A = 163.29\,kN \cdot 250\,m/s$$
$$= 40.82\,MW$$

then heat is provided

$$\dot{Q}_{in} = \dot{m}(h_4 - h_3) = \frac{V_1 P_1}{RT_1} \pi/4\, D^2 (h_4 - h_{3a})$$
$$= 157.55\ MW$$





Purpose: Determine pressure of combustion gases at the turbine exit, find velocity of gases at the nozzle exit, and find thrust for this engine if diffuser inlet diameter = 1.6m

Source: Thermo Book and lectures

Design Consideration
- c_p & c_v are variables
- constant pressure through combustion
- Ideal gas
- Efficiency Isentropic$_C$ 80% & Isentropic$_T$ 90%