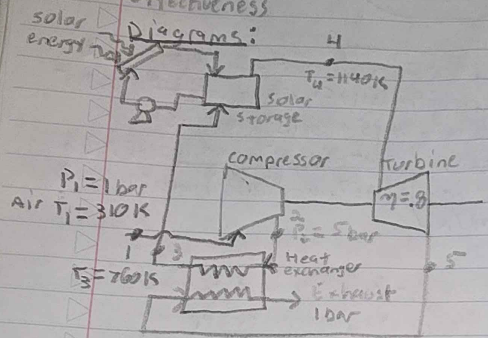
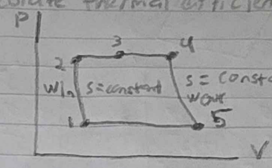
Test 1 Daniel Martinez MET 350

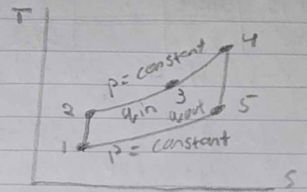
1) **Purpose**: Calculate thermal efficiency, heat exchanger effectiveness, and air mass flow rate. Then calculate thermal efficiency at 100% effectiveness

Diagrams:





1-2 and 4-5 are isentropic



Sources: Cengel and Boles. Thermodynamics - An Engineering Approach 8th edition McGraw Hill, 2015

Design Considerations

I assume the following:

1) air behaves as an ideal gas. $R = .287$ KJ/kg·K
2) C_p and C_v are constant and evaluated at 25°C = 298.15K
3) Isentropic efficiencies of the compressors and turbines is .78
4) no heat losses in connecting pipes, neither fluid flow friction losses
5) $C_p = 1.00493 \frac{KJ}{kg \cdot K}$ $C_v = .71793$ $K = \frac{C_p}{C_v} = 1.3998$

Data and Variables

$T_1 = 310K$ $P_1 = 1$ bar $P_2 = 5$ bar $T_3 = 760K$ $T_4 = 1140K$

$\eta_T = 0.8$ exhaust = 1 bar

Procedures, Calculations, Summary

1 $\xrightarrow{\text{Diffuser}}$ 2 $\xrightarrow{\text{isentropic}}$ 3 $\xrightarrow{P\ \text{const}}$ 4 $\xrightarrow[\text{isentropic}]{W_c = W_T}$ 5 $\xrightarrow[\text{isentropic}]{\text{Nozzle}}$ 6

$V_1 = 900\ \frac{KM}{h}$ $V_2 = \frac{KM}{h}$ $V_3 = 0\ \frac{KM}{h}$ $V_4 = 0\ \frac{KM}{h}$ $V_5 = 0\ \frac{KM}{h}$

$P_1 = 40\,KPa$

$T_1 = 238.15\,K$

$P_4 = P_3$

$T_4 = 1223.15$

$P_6 = P_1$

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

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

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

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

$$\frac{T_3}{T_2} = \frac{P_3}{P_2}^{\frac{k-1}{k}}$$

$$W_T = W_C \Rightarrow h_4 - h_5 = h_3 - h_2 \Rightarrow \cancel{C_p}(T_4 - T_5) = \cancel{C_p}(T_3 - T_2)$$

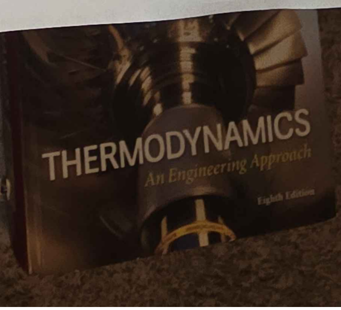
$$T_4 - T_5 = T_3 - T_2$$

$$\frac{T_5}{T_4} = \frac{P_5}{P_4}^{\frac{k-1}{k}}$$

$$F = \dot{m}(V_{exit} - V_{inlet})$$

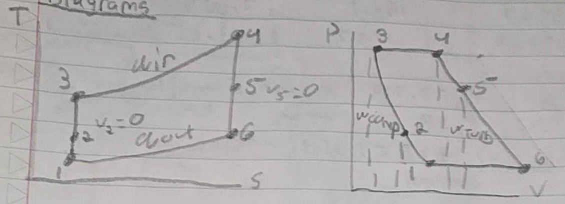
Analysis

This data and calculations show the steps between an engine fuel stage and it combusting and providing thrust. Changes to inlet diameter can reduce velocity by increasing or increase velocity by decreasing diamete



2) __Purpose__: Determine pressure of combustion gases at turbine exit, the velocity of gases at nozzle exit, and thrust of the engine for different inlet diameter.

__Diagrams__



__Sources__: Cengel and Boles. Thermodynamics - An Engineering Approach 8th edition McGraw Hill. 2015

__Design Considerations__

I assume the following:

1) air behaves as an ideal gas $R = .287\ kJ/kg \cdot K$
2) no heat losses in connecting pipes neither fluid flow friction losses

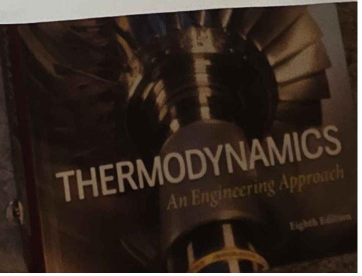
__Data and variables__

$v_1 = 900\ km/h$ $P_1 = 40\ kPa$ $T_1 = -35°C$ $T_4 = 950°C$ $w_{turb} = 520\ kJ/kg$

$\eta_C = 80\%$ $\eta_T = 90\%$

__materials__

air as an ideal gas, diffuser, nozzle, variable Cps



Procedure and calculations/Summary

	1	2	3	4	5
T (K)	310 K	489	760	1140	490.5
P (kPa)	100	500	500	500	100
Pr	1.5546	7.773	39.27	193.1	7.854
h (kJ/kg)	310.24	491.72	778.18	1207.57	493.25

$\frac{P_2}{P_1} = \frac{Pr_2}{Pr_1} \Rightarrow \frac{500}{100} = \frac{Pr_2}{1.5546}$ $Pr_2 = 7.773$ through interpolation $T_2 = 489K$

$P_3 = P_2$ $P_5 = P_1$

$\frac{P_3}{P_5} = \frac{Pr_3}{Pr_5} \Rightarrow \frac{Pr_3}{(P_3/P_5)} = Pr_5 \Rightarrow \frac{39.27}{(500/100)} = 7.854$

interpolation 1

$x_1 = 7.268$ $y_1 = 480$

$x_2 = 7.824$ $y_2 = 490$

$x = 7.773$ $y = 489$

interpolation 2

$x_1 = 7.824$ $y_1 = 490$

$x_2 = 8.411$ $y_2 = 500$

$x = 7.854$ $y = 490.5$

$w_{net} = w_{4-5} - w_{1-2} = (h_4 - h_5) - (h_2 - h_1) = c_p(T_4 - T_5) - c_p(T_2 - T_1)$

$w_{net} = 1.00493(1140 - 490.5) - 1.00493(760 - 489) = 381.7$ kJ/kg

$q_{out} = c_p(T_4 - T_5) = 1.00493(1140 - 490.5) = 652.7$

$\eta_{th} = 1 - \left(\frac{T_1}{T_4}\right)(r_p)^{(k-1/k)} = 1 - \left(\frac{310}{1140}\right)(5)^{(1.4-1/1.4)} = .564$ or 56.4%

$e = \frac{T_3 - T_2}{T_5 - T_2} = \frac{760 - 489}{490.5 - 489} = 180.7 \rightarrow$ Does not make sense

b) $\dot{W}_{net} = \dot{m} w_{net} \Rightarrow \dot{m} = \frac{\dot{W}_{net}}{w_{net}} = \frac{500 \text{ kW}}{} \left| \frac{\text{kg}}{381.7 \text{ kJ}} \right| \frac{1000 \text{ W}}{1 \text{ kW}} \left| \frac{.001 \text{ kJ}}{1 \text{ W} \cdot \text{s}} \right. = 1.31$ kg/s

c) a 100% effective HX would transfer 100% of outgoing heat to incoming for increased effectiveness, making the thermal efficiency dependent on rp. increased pressure increases efficiency

Analysis

The thermal efficiency with solar panels is high and provides a path for extra heat input with no additional work