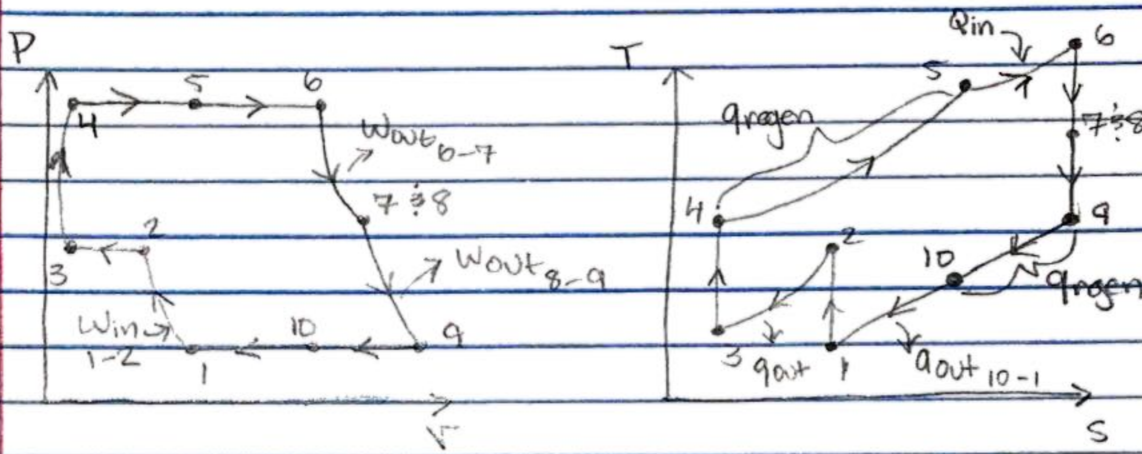
Ethan Kishinevskiy Thermal Applications

1.

Purpose To find the effectiveness of the heat exchanger, compare it with values on the provided graph, then determine efficiency of a system with the reheater disabled.

Drawings & Diagrams



Sources · Textbook · Interpolation calculator
· Professor [illegible]

Design Considerations · Regenerator operates perfectly
· Isentropic, constant c_p, c_v

Data & Variables $P_1 = 100$ kPa $r_p = 4$
$T_1 = 17°C$ $q_{in_{[illegible]}} = 300$ kJ/kg

Procedure 1. Use tables to find enthalpies to determine exchanger efficiency.
2. Compute states for stages.
3. Calculate η_{th} and Power output.

Calculations

$\varepsilon = \frac{h_5 - h_4}{h_9 - h_4}$ → Table in Textbook (interpolation) → $\frac{452.9 - 432.53 \text{ kJ/kg}}{544.93 - 432.53 \text{ kJ/kg}}$

$\varepsilon = 0.181$ or 18.1% : Poor efficency.

1 —Isent.→ 2 —Iso-B→ 3 —Isent.→ 4 —Iso-B

$T_1 = 290.15\text{ K}$, $P_1 = 100\text{ kPa}$ | $T_2 = 431.16\text{ K}$, $P_2 = 400\text{ kPa}$ | $T_3 = T_1 = 290.15\text{ K}$, $P_3 = 400\text{ kPa}$ | $T_4 = 431.08\text{ K}$, $P_4 = 1600\text{ kPa}$

→ 5 —Iso-B→ 6 —Isent.→ 7 —Nothing

T_5: below, $P_5 = 1600\text{ kPa}$ | $T_6 = T_5 + \frac{q_{in\,5\text{-}6}}{c_p}$, $P_6 = 1600\text{ kPa}$ | $P_7 = P_2 = 400\text{ kPa}$, $T_7 = T_6\left(\frac{P_7}{P_6}\right)^{k-1/k}$

→ 8 —Isent.→ 9 —Iso-B→ 10

$T_8 = T_7$, $P_8 = P_7$ | $T_9 = T_8\left(\frac{P_9}{P_8}\right)^{\frac{k-1}{k}}$, $P_9 = 100\text{ kPa}$ | $P_{10} = 100\text{ kPa}$, $T_{10} = T_9 - (T_5 - T_4)$

$$\varepsilon = \frac{T_5 - T_4}{\left(T_5 + \frac{q_{in\,5\text{-}6}}{c_p}\right)\left(\frac{P_7}{P_6}\right)^{k-1/k}\left(\frac{P_9}{P_8}\right)^{k-1/k}}$$

Can show relationship if desired (can derive by hand)

↓

$T_5 = 495.83\text{ K}$ $T_7 = 531.8\text{ K}$ $T_9 = 357.44\text{ K}$

$T_6 = 789.95\text{ K}$ $T_8 = 531.8\text{ K}$ $T_{10} = 292.99\text{ K}$

$\eta_{th} = \frac{w_{net}}{q_{in}}$ → $w_{out\,6\text{-}7} = h_6 - h_7$, $w_{out\,8\text{-}9} = h_8 - h_9$, $w_{in\,1\text{-}2} = h_1 - h_2$, $w_{in\,3\text{-}4} = h_3 - h_4$ → $w_{net} = 167.73 \text{ kJ/kg}$

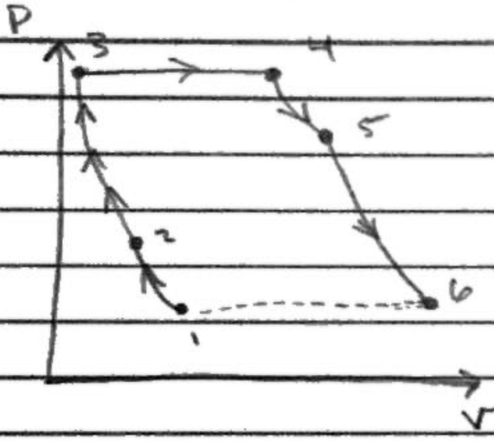
$\eta_{th} = 0.56$ or 56% because less q_{in}

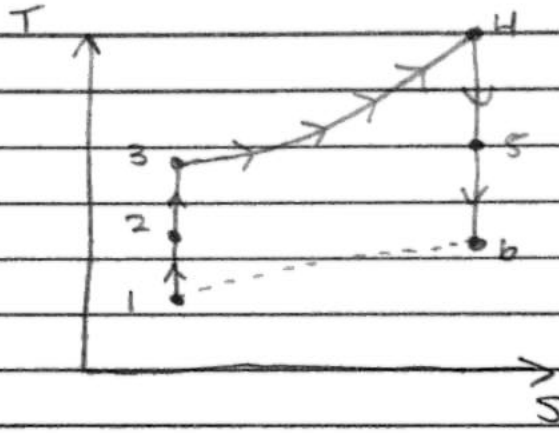
$q_{in} = 300 \text{ kJ/kg}$

Summary	The thermal efficiency improved by removing the reheater from the system.
Materials	• Compressors • Air • Turbines • Heat Exchanger • Pipes • Intercooler • Chamber
Analysis	The design was improved when the reheater was taken out. Increasing pressure ratio should further improve it.

Purpose Calculating efficiency of the jet propulsion cycle and recalculating the propulsion of the jet to compare efficiencies.

Drawings & Diagrams





Sources
- Interpolation Calc.
- Textbook

Design Considerations
- Variable c_p, c_v
- Isentropic processes

Data & Variables

$h_4 = 855.196$ · $V_{aircraft} = 240$ m/s · $T_1 = -13°C$

$h_3 = 608.06$ · $P_1 = 45$ Kpa · $D_{in} = 1.6$m · $r_{cp} = 13$

$T_{in} = 557°C$ · $\eta_c = 0.80$ $\eta_T = 0.85$

Procedure
1. Calculate propulsive efficiency using interpolation and tables
2. Calculate states.
3. Calculate efficiency of new system and compare.

Calculations $\eta_p = {}^{w_p}/_{q_{in}} = \frac{(V_{exit} - V_{inlet}) \cdot V_{aircraft}}{h_4 - h_3} = 0.315$ or 31.5%

1 —Isentropic→ 2 —Isentropic→ 3 —Isobaric→

$P_1 = 45$ kpa
$T_1 = 260.15$ K
$v_1 = 1.659$ m³/kg
$V_1 = 240$ m/s

$V_2 = 0$ m/s
$T_2 = T_1 + {}^{V^2}/_{2c_p}$
$T_2 = 288.81$ K
$P_2 = 64.87$ kpa
$h_2 = 288.97$ kJ/kg

$\eta_c = 0.80 = \frac{h_{3s} - h_2}{h_{3a} - h_2}$
$P_3 = P_2\left(\frac{P_{r3}}{P_{r2}}\right) = r_p P_2 = 843.31$
$P_{r3} =$
$T_3 = 594.87$ K
$h_{3s} = 601.63$ kJ/kg $\therefore h_{3a} = 679.79$ kJ/kg

→ 4 —Isentropic→ 5

$T_4 = 830.15$ K
$P_4 = P_3 = 843.31$ kpa
$h_4 = 855.196$ kJ/kg
$P_{r4} = 55.13$

$W_c = W_T$: $h_4 - h_5 = h_3 - h_2$
$h_5 = h_4 - h_3 + h_2$
$= 855.196 - 601.63 + 288.97$
$= 464.4$ kJ/kg
$T_5 = 462.33$ K ← interpolation on A-17
$P_5 = P_4\left(\frac{P_{r5}}{P_{r4}}\right) = 843.31\left(\frac{6.361}{55.13}\right) = 97.3$ kpa

—Isent.→ 6

Need to improve on var. c_p, c_v ∵

$P_6 = P_1 = 45$ kpa
$T_6 = T_5\left(\frac{P_6}{P_5}\right)^{\frac{k-1}{k}} = 370.91$ K
$V_{exit} = \sqrt{2(h_5 - h_6)} = 13.62$ kJ/kg
→ 1362 m/s

$1\ \frac{kJ}{kg} = 1000\ \frac{m^2}{s^2}$ →

$V_{exit} = 1362$ m/s

$\eta_{th_2} = \frac{(V_{exit} - V_{in}) \cdot V_{aircraft}}{h_4 - h_3} = 1.06$?

Incorrect answer, but η_{th_2} should be higher because of better efficiencies (most turbines run at lower eff.)

Summary

This [illegible] [illegible] an understanding of Brayton cycles and the jet propulsion cycle. For the efficiency it would most likely be [illegible] as the efficiencies of an average comp. and turbine are usually lower.

Materials

- A spare jet engine.

Analysis

The higher the eff. of the turbine and compressor, the better the engine performs. Though my answer is incorrect, the theory holds that an increase in eff. is an increase in turbine and comp. ratios.

This problem was enjoyable until I saw variable cp, cv.