Design, Fabrication, and Testing of a Bleed-Air Heat Exchanger for the JetCat P100-RX Turbine Engine

Team: Christopher Westmoreland, Brooke Rogachuk, Chloe Nelson, Jackson Annesley, Parker Arnold, Cody Sargent
Advisors: Dr. Christopher Dalton, Dr. Srikanth Bashetty



Objectives

Modify a P100-RX turbojet by designing and integrating a bleed-air heat exchanger system that recovers thermal energy from the engine during operation to heat an external air supply for the Aerospace Propulsion Outreach Program competition. The modified propulsion system will be experimentally tested and evaluated according to the competition's performance, efficiency, and system integration criteria below.

Objective	Target	Scoring
Cycle Analysis		0 - 10
Weight	4lbs	0 - 30
Radial Distance	0 in $\leq$ 4 in	0 - 30
Pressure Test	80 psi	0 - 20
Maximum Correct Thrust	F > 19 lbf	0 -10
Corrected Thrust 80% speed	F > 20 lbf	0 - 30
Pressure Drop	5 $\leq$ ΔP $\leq$ 15 psi	0 - 10
Heat Rate	2700 BTU/hr	0 - 50

Constraints

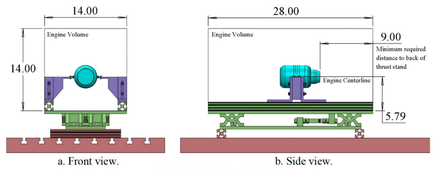


Figure 5: Engine volume

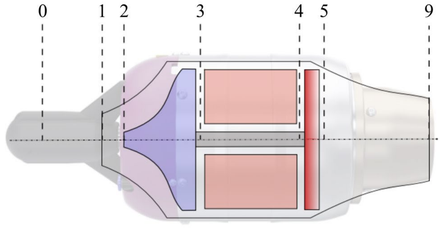
Additional design constraints:

- Adherence to Internal Control Document (ICD) to ensure system compatibility.
- Back-Pressure & Turbine Temperature
- Assembly Temperature Resistance
- Small Feature Design and Manufacturing
- Assembly Mechanical Durability

Engineering Standards

- **14 CFR Part 21,33,34**: Guides engine durability and safety practices
- **FAA AC 20-135**: Engine Temperature Standards
- **ANSI/ASME Y14.5**: Geometric Dimensioning and Tolerancing
- **ANSI Z535, ANSI B11.19**: Safety Signs and Labels
- **NASA-STD-6016**: Material Evaluation, Testing, and Selection

Engine Characteristics

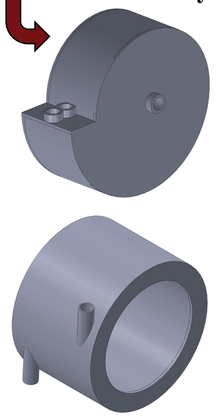


0 – Free Stream
1 – Inlet Entrance
2 – Inlet Exit
3 – Compressor Exit
4 – Combustor Exit
5 – Turbine Exit
9 – Nozzle Exit

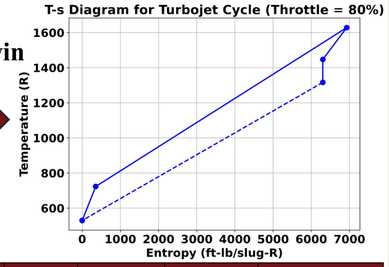
20 lbf of thrust (88.96 N) | Max RPM: 154000 /min | Pressure Ratio: 2.9 | Exhaust temperature: 720° C | Exhaust gas velocity: 1565 km/h | Roughly the size of a football

Design

Preliminary Heat Exchangers



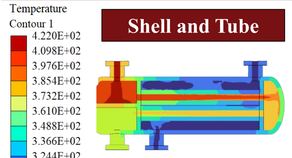
Digital Twin



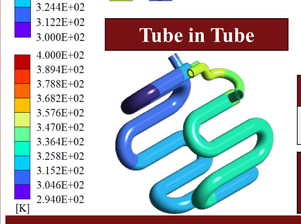
Case	Thr (%)	Bleed (lbm/hr)	Tt4 (R)	Tt5 (R)	M_{Nozz}	Thrust (lbf)
Full Bleed	80	150	1628	1447	0.769	13.2
No Bleed	80	0	1532	1367	0.787	15.1

Ansys Simulation

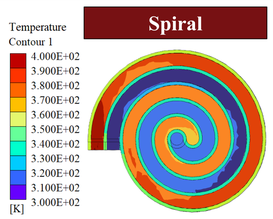
Shell and Tube



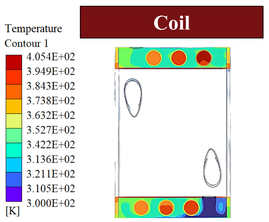
Tube in Tube



Spiral

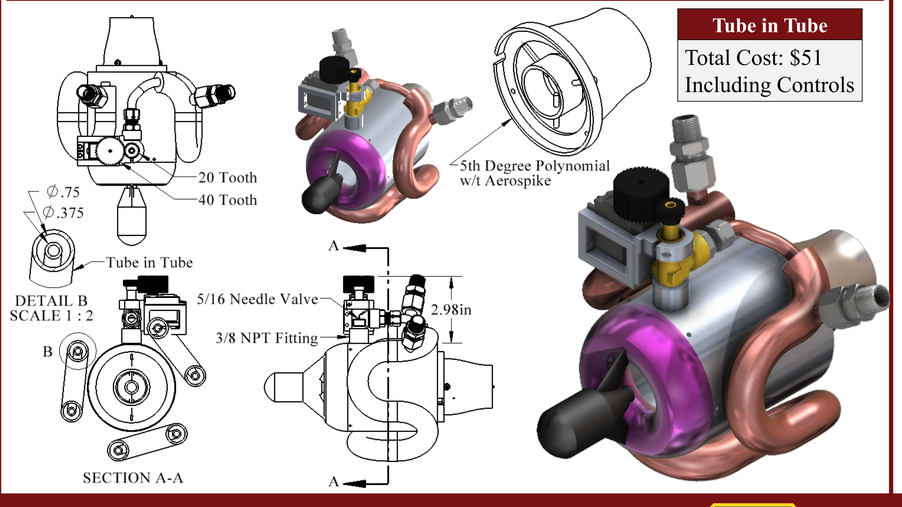


Coil



Finalized Inputs	Shell and Tube	Spiral	Coil	Tube in Tube
$\dot{Q} = \dot{m}c_p\Delta T$				
Heat Transfer Rate (BTU/hr)	3768	3628	3871	2670

Final Design



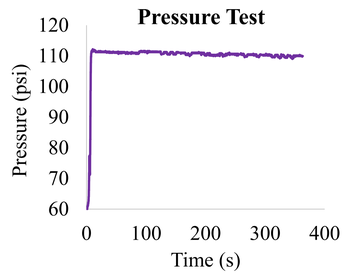
Tube in Tube

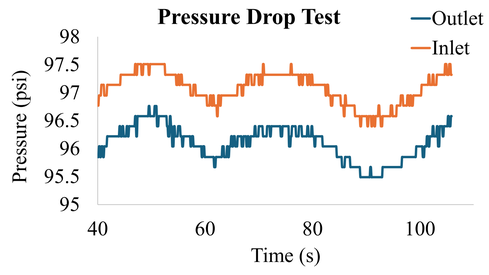
Total Cost: $51
Including Controls

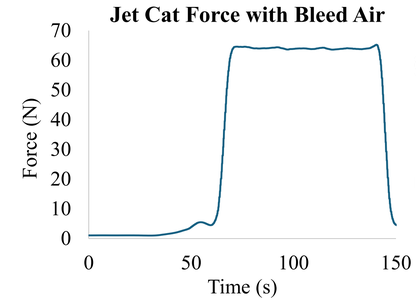
Manufacturing

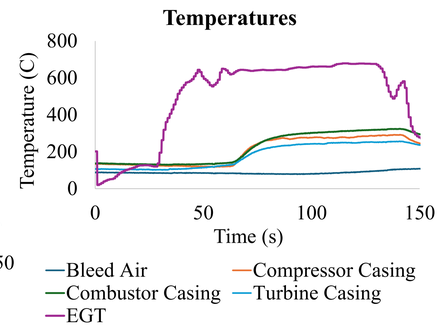


Test Results











Future Work

- Manufacture of high thrust 5th deg nozzle
- Use 5/8" outer copper tube to improve heat rate
- Continue to refine copper bending techniques
- Research new ways of lowering radial distance
- Fix engines to continue future testing

Objective	Target	Scoring
Cycle Analysis	Complete	10
Weight	5.85lbs	20.75
Radial Distance	3.37in	4.725
Pressure Test	80psi	20
Maximum Correct Thrust	19.6lbf	11.5
Corrected Thrust 80% speed	16.6lbf	19.8
Pressure Drop	0psi	10
Heat Rate	1360BTU/hr	0
Manufacturing Bonus	In-House	+5
	Estimated Score	101.78/190pts

GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF AEROSPACE AND MECHANICAL ENGINEERING
The UNIVERSITY *of* OKLAHOMA

NORTHROP GRUMMAN
AIR FORCE RESEARCH LABORATORY
U.S. AIR FORCE
UNITED STATES SPACE FORCE
AFRL THE AIR FORCE RESEARCH LABORATORY