NORTHERN ARIZONA UNIVERSITY

College of Engineering, Informatics, and Applied Sciences

# Thermodynamic Demonstration Unit

Jacob Barker Samm Metcalfe Ashley Shumaker
Department of Mechanical Engineering Northern Arizona University

## Abstract

The Brayton Cycle is of particular interest in Thermodynamics as it is the working cycle used in gas turbine engines such as those found in airplanes. Current NAU engineering students are taught the theory and mathematics behind Brayton Cycle, but their exposure to this cycle's applications in the real world is limited to textbook illustrations and online videos. In order to enhance student understanding of the Brayton Cycle, the team was tasked with designing and manufacturing a Brayton Cycle Demonstration Unit which can be used in Thermodynamics courses.

## Engineering Requirements

Table 1: Engineering Requirements and System Testing

| Engineering Requirements | How the system tested |
|---|---|
| 24"x36" | 16"X30" |
| Weight <100 lbs. | 77.6 lbs. |
| Measure pressure and temperature at 4 states | System set up for all measurements |
| Time<15 minutes | Total time= 7 minutes |
| Outer casing must be clear | clear acrylic tube |
| Use 120v AC, 60Hz, and/or compressed air tank | Everything uses standard wall outlets |
| Minimize exposure to dangerous parts | Heat exchanger insulated, Casing latches shut, Pressure release valve |
| Last for 10 semesters | Ran 25 times continuously |

## Compressor

- First component
- Powered by shaft connected to turbine
- Raises pressure for effective combustion
- Rotating blades called rotors with stationary blades called stators
- Area must decrease, design uses an increasing hub diameter with a constant casing diameter

## Combustion Chamber

- Second component
- Adds energy in the form of heat before working fluid goes to turbine
- For typical design air is mixed with fuel then ignited
- With a classroom setting, the system has heated compressed air pumped in
- Dyson Fan design for even air distribution

## Turbine

- Third component
- Mounted on same shaft as compressor
- Rotating rotor blades convert energy from flow into mechanical power
- Stationary guide vanes, or stators, redirect flow between rotor stages
- Mechanical power drives compressor and creates work output (thrust in a turbojet)

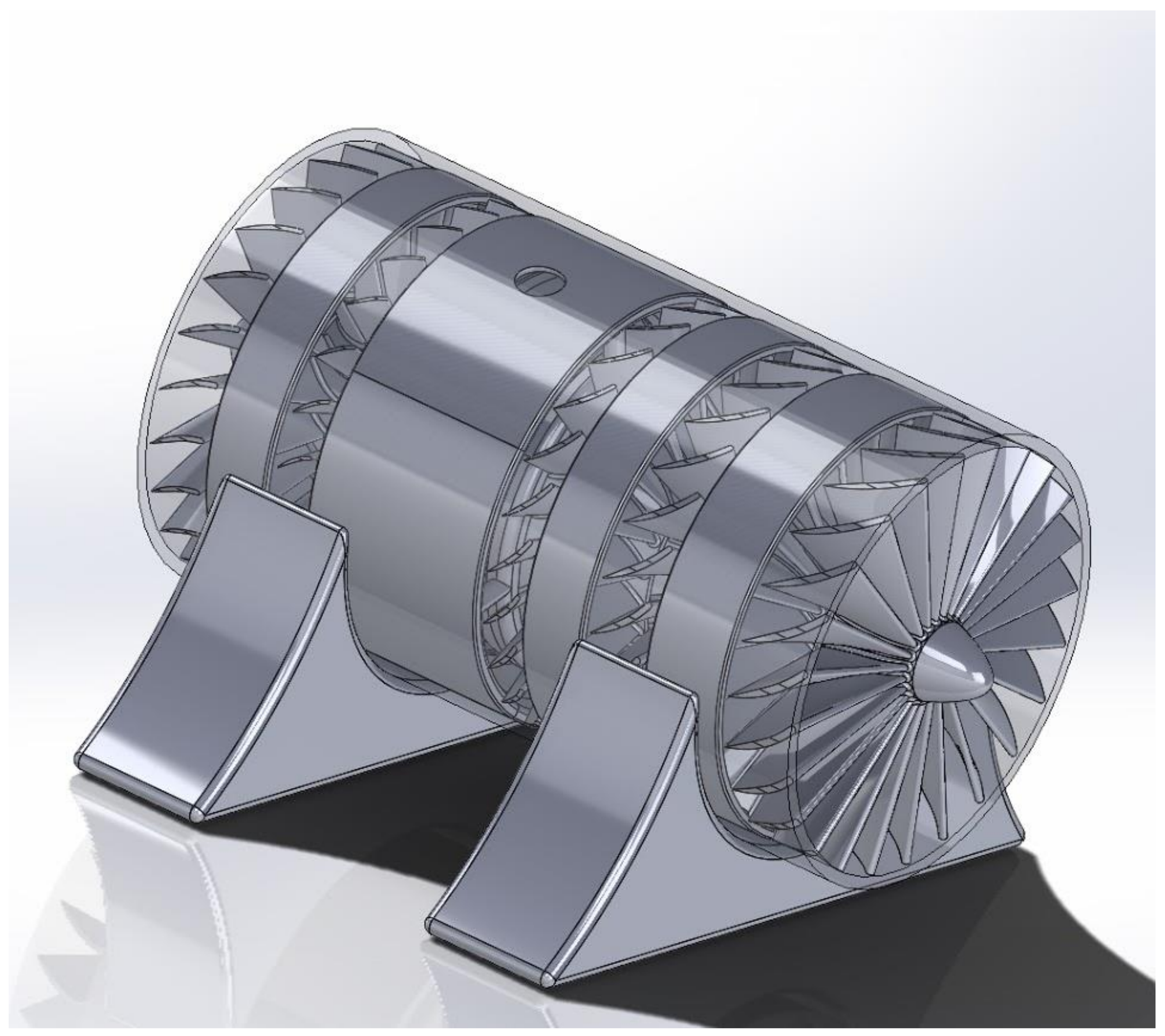

Figure 1: CAD Model of System

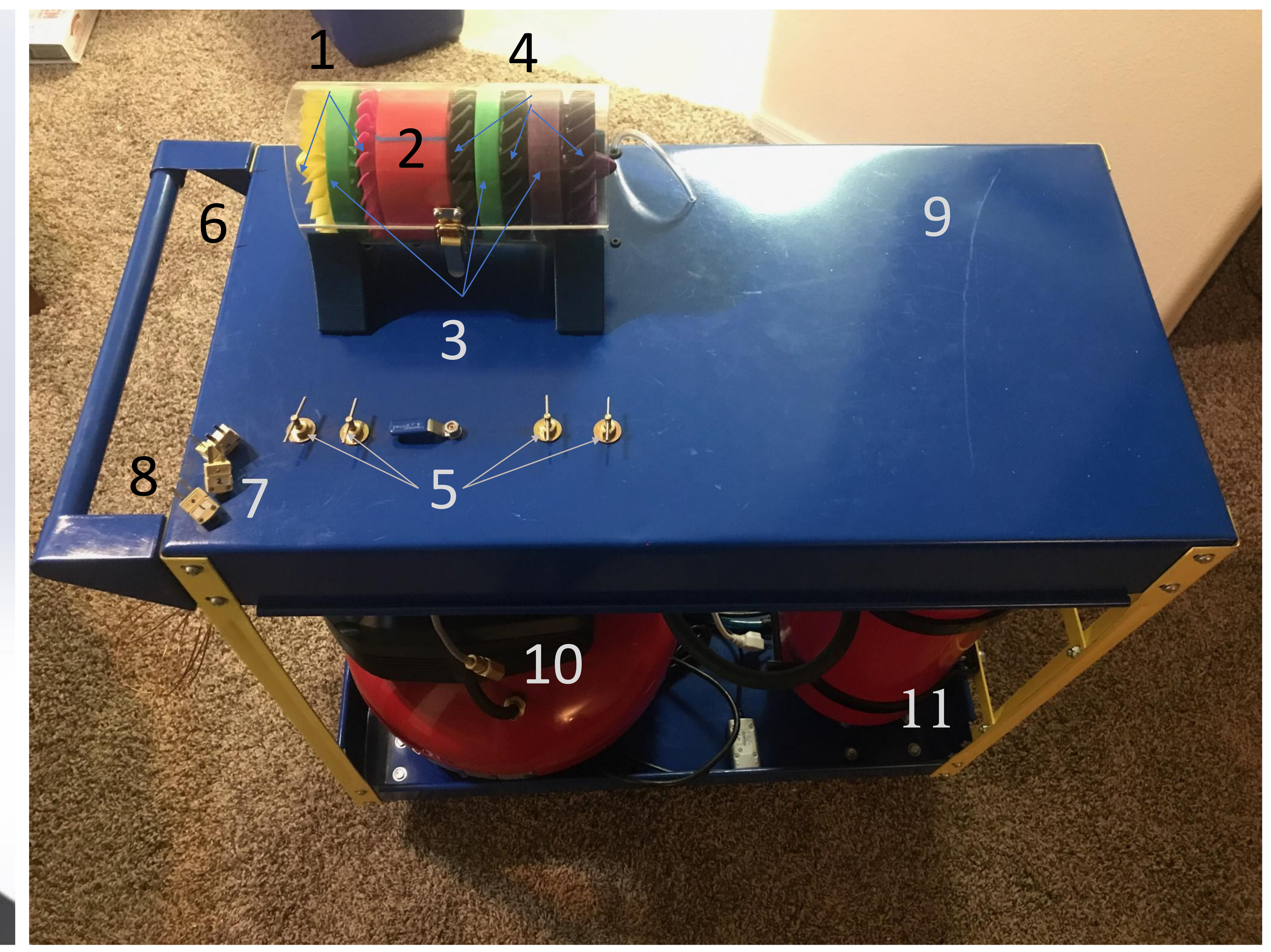


Figure 2: Side View of the System

## Subsystems

1. Compressor Blades
2. Combustion Chamber
3. Stator Blades
4. Turbine Blades
5. Pressure Manifold (tubing not seen under cart)
6. Pressure DAQ (not seen on side)
7. Thermocouple Wires
8. Thermocouple DAQ (not seen on side)
9. Heat Exchanger (not seen under cart)
10. Air Compressor
11. Air Tank

## P-V Diagram

- Diagram showing the work inputs and outputs of a Brayton Cycle
- Heat enters creating energy in the system from stage one to stage 2
- Temperature of the working fluid is decreased from stage 2 to stage three
- Heat taken out of the system using energy from stage 3 to stage 4
- Temperature of the working fluid is raised from stage four to stage one
- Total work created by a system is the area inside the lines

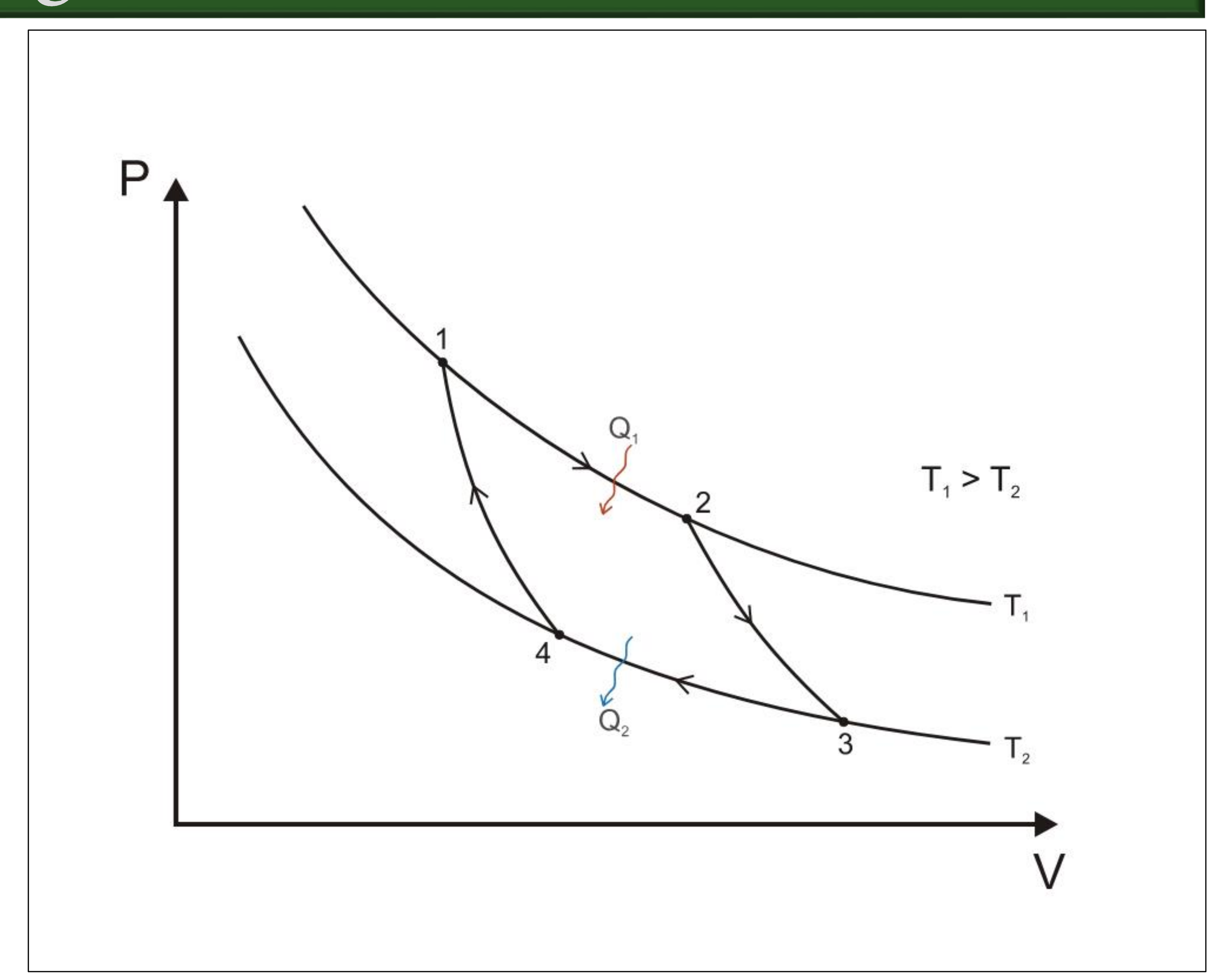


Figure 3: P-V Diagram

## References

1. N. Hall (2015, May 5). Compressors [Online]. Available: https://www.grc.nasa.gov/www/k12/airplane/compress.html.
2. Q. Nagpurwala, Design of Gas Turbine Combustors, Bengaluru: M.S. Ramaiah School of Advance Studies
3. K. Hunecke, "Turbine," in Jet Engines: Fundamentals of Theory, Design, and Operation, Ramsbury, England: The Crowood Press Ltd, 1997, ch. 6, sec. 6.1, pp. 137-145.
4. Moran, Michael J. (2008). Fundamentals of Engineering Thermodynamics. (pp. 530-562), Hoboken, N.J. Wiley
5. Reference for the NAU logo
6. Keta, "Wikimedia.org," 3 April 2006. [Online]. Available: https://commons.wikimedia.org/wiki/File:Carnot_cycle_p-V_diagram.svg.

## Acknowledgements

Thank you to everyone who has made this project possible:

David Willy
Sarah Oman
Thomas Acker
Heidi Feigenbaum