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GAS TURBINE CONVERSION FROM LIQUID TO GASEOUS FUEL

by

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March 2021

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The DOD consumes more energy than any other federal agency to power its many installations and operational assets, prompting the need for robust energy management and solutions. With emerging technologies and a growing reliance on electrical systems, the DOD and DON recognize that energy production, procurement, and usage must be further optimized and secured. This study aims to support research toward a portable and affordable electric generation system capable of supplying power to microgrids. Specifically, it investigates the feasibility of converting liquid-fueled combustion engines to operate with renewable gaseous fuels, namely hydrogen gas. To test this hypothesis, performance measurements and internal inspection were conducted on the JetCat P60-SE turbojet, a small commercial gas turbine engine designed for remote-controlled hobby jets. The results showed that with effective modifications, a liquid-fueled gas turbine has the potential to operate with gaseous fuels. These findings can be used toward larger applications, expanding the application of hydrogen technology to electrical generation.

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GAS TURBINE CONVERSION FROM LIQUID TO GASEOUS FUEL

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ABSTRACT

The DOD consumes more energy than any other federal agency to power its many installations and operational assets, prompting the need for robust energy management and solutions. With emerging technologies and a growing reliance on electrical systems, the DOD and DON recognize that energy production, procurement, and usage must be further optimized and secured. This study aims to support research toward a portable and affordable electric generation system capable of supplying power to microgrids. Specifically, it investigates the feasibility of converting liquid-fueled combustion engines to operate with renewable gaseous fuels, namely hydrogen gas. To test this hypothesis, performance measurements and internal inspection were conducted on the JetCat P60-SE turbojet, a small commercial gas turbine engine designed for remote-controlled hobby jets. The results showed that with effective modifications, a liquid-fueled gas turbine has the potential to operate with gaseous fuels. These findings can be used toward larger applications, expanding the application of hydrogen technology to electrical generation.

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ADC	analog-to-digital converter
AEMRR	Annual Energy Management and Resilience Report
AVG	average
COTS	commercial off-the-shelf
DAQ	data acquisition
DOD	Department of Defense
DON	Department of the Navy
ECU	engine control unit
EGT	exhaust gas temperature
FOD	foreign object debris
FY	fiscal year
GSU	ground support unit
GUI	graphical user interface
HMI	human machine interface
LED	light emitting diode
LiPo	lithium polymer
MEC	microbial electrolysis cell
MPX	multiplex
NI	National Instruments
NPS	Naval Postgraduate School
NTV	non-tactical vehicle
OPTEST	operational test
PEC	photoelectrochemical
PVC	polyvinyl chloride
SFC	specific fuel consumption
SMR	steam methane reforming
STDEV	standard deviation
TPL	Turbo Propulsion Laboratory
USB	universal serial bus
U.S.C.	United States Code

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I. INTRODUCTION

The purpose of this research is to continue the development of a mobile hydrogen-powered gas turbine generator and autonomous hydrogen production, compression, and storage system with a focus on the gas turbine engine. The joint system is designed to address the demands of the U.S. Department of Defense (DOD) and the Department of the Navy (DON) for resilient, reliable, and efficient energy solutions to enhance mission assurance. This research shows that commercial off-the-shelf (COTS) gas turbine engines have the potential to operate with gaseous fuels.

A. MOTIVATION

Because of its many installations and operational assets, the DOD is the highest energy consumer among all U.S. federal agencies, prompting the need for robust energy management and solutions [1]. An analysis performed by the Congressional Research Service in 2019 states that in fiscal year (FY) 2017, "DOD spent approximately $11.9 billion on energy, roughly 76% of the entire federal government's energy expenditures, and roughly 2% of DOD's FY2017 budget" [1]. However, it is important to note that the DOD classifies energy as either "installation" or "operational" [1]. DOD defines installation energy as "energy needed to power fixed installations and enduring locations as well as non-tactical vehicles (NTVs)" [1]. This type of energy "represents roughly 30% of DOD total energy and is subject to federal energy efficiency and conservation requirements" [1]. On the other hand, operational energy is "the energy required for training, moving, and sustaining military forces and weapons platforms for military operations and training—including energy used by tactical power systems and generators at non-enduring locations" [1]. It is not bound by the same requirements, but "DOD does have an operational energy policy to promote readiness of military missions" [1] under Title 10 United States Code (U.S.C.) 2926 [1].

With emerging technologies and growing reliance on electrical systems, the DOD and DON recognize that energy production, procurement, and usage must be further optimized and secured. The DOD explains in its FY19 Annual Energy Management and

Resilience Report (AEMRR) that the key elements of its installation energy strategy are to "maximize efficient energy use," "expand supply for mission assurance," and "enhance energy resilience" [2]. In support of these elements, the DOD tracked installation energy consumption by all DOD components from FY16-FY19 to promote more energy efficiency [2]. Although there was a recent decline in FY19, Figure 1 shows that there was a noticeable upward trend in total electricity consumption from FY16-18 after focusing more towards energy *resilience* investments, rather than energy *efficiency* investments [2].

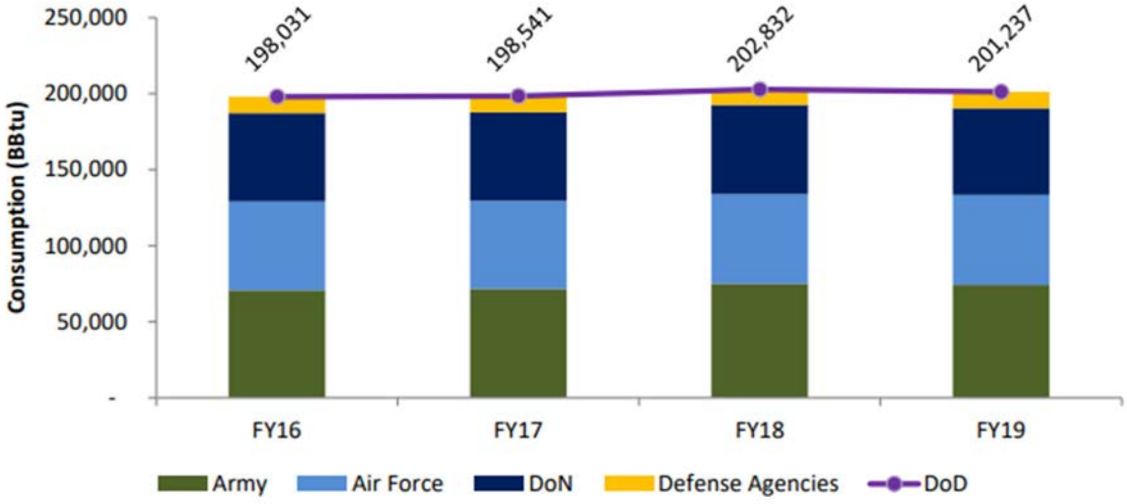


Figure 1. Installation energy consumption by military service (excluding NTV consumption). Source: [2].

Additionally, the DOD has repeatedly fallen short of these renewable energy goals and particularly the U.S. Navy often consumed less renewable energy than other military branches, as illustrated by Figure 2. Despite these shortfalls, the Navy is continually making improvements, such as better energy guidance, awards for outstanding energy projects, more training opportunities for Energy Program staff, and the establishment of an oversight committee to ensure proper accountability and strategic direction [2].

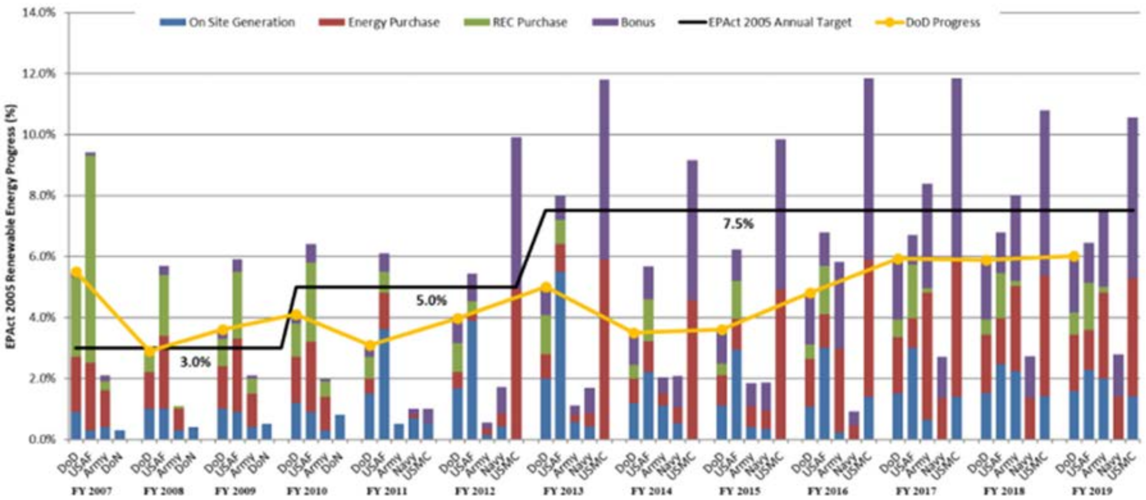


Figure 2. EP Act 2005 renewable energy goal attainment. Source: [2].

The DOD is also working to improve installation energy resilience by pursuing renewable energy options with policies such as the Energy Policy Act (EP Act) of 2005 and Title 10, U.S.C., section 2911(g) [2]. Under the EP Act, the DOD set targets of increased renewable electricity consumption by 7.5% of total facility electricity consumption in FY13 and each FY afterwards [2]. Under Title 10, U.S.C., section 2911(g), the DOD established the goal for increased production or procurement of renewable energy by FY18 and FY25, and each FY thereafter [2]. These goals are illustrated in Table 1.

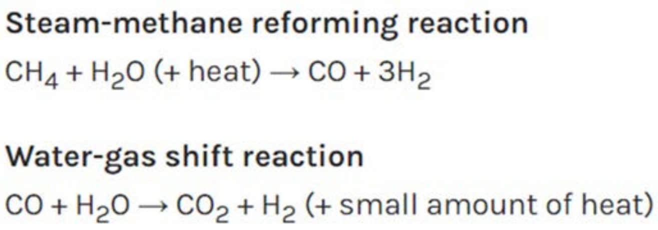
Table 1. DOD energy performance targets. Source: [2].

Target	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY25
Consume More Renewable Energy	+5%	+5%	+7.5%	+7.5%	+7.5%	+7.5%	+7.5%	+7.5%	+7.5%	+7.5%	+7.5%
Produce/Procure More Renewable Energy [1]	-	-	-	-	-	-	-	+15%	-	-	+25%
[1]FY 2018 interim target required by 10 U.S.C. § 2911(g)(2)											

In October 2012, the Deputy Assistant Secretary of the Navy (DASN) Energy Office published the DON’s plans to continue its path towards achieving its “21st century energy objectives,” which include energy security, energy independence, stewardship, and executing renewable energy projects [3]. Similarly, the DASN Energy Office more recently outlined its strategy to achieve and maintain energy security through reliability, resiliency, and efficiency [4]. A joint electricity generation and hydrogen production, compression, and storage system has the potential to offer improved reliability due to the availability of hydrogen and by diversifying the Navy's energy sources, improved resiliency due to its autonomous production and storage capabilities, and improved efficiency due to the higher energy density of hydrogen compared to conventional fuel sources (e.g., petroleum and natural gas).

B. BACKGROUND INFORMATION

Though this research focuses on the application of hydrogen gas as a propulsion fuel, this section is provided to briefly explain different ways hydrogen is produced, its benefits, and an example application. Though the simplest element on Earth, hydrogen has the properties of an energy carrier (not an energy source) with a high specific energy density [5]. Though also the most abundant element, it is not typically available in its pure form, thus it is obtained by thermal, electrolytic, solar, or biological processes [5]. The most prevalent method to produce hydrogen (about 95% of it) is by natural gas reforming, specifically steam methane reforming (SMR) [6]. In general, steam reacts with a hydrocarbon fuel at a high temperature (700°C-1,000°C) to produce hydrogen [6]. During SMR, the reaction between methane (CH_4), steam, and a catalyst occurs when 3–25 bars of pressure (1 bar = 14.5 psi) is applied, producing hydrogen, carbon monoxide, and a small amount of carbon dioxide (Figure 3) [6]. Additionally, the same reaction is repeated using the residual carbon monoxide byproduct, steam, and a catalyst to produce carbon dioxide and more hydrogen in a process called the "water-gas shift reaction" [6]. Thermal processes can also use other hydrocarbon fuels, such as ethanol, propane, or gasoline, to produce hydrogen [6].



Steam-methane reforming reaction

$CH_4 + H_2O$ (+ heat) $\rightarrow CO + 3H_2$

Water-gas shift reaction

$CO + H_2O \rightarrow CO_2 + H_2$ (+ small amount of heat)

Figure 3. Chemical reactions during SMR. Source: [6].

Electrolysis is another common process that uses electricity to disassociate water into hydrogen and oxygen within a unit called an electrolyzer [7]. Within the electrolyzer, the electricity is supplied to a cathode and an anode, which are submerged in water and separated by an electrolyte membrane where hydrogen and/or oxygen ions can pass through (depending on the membrane material) [7].

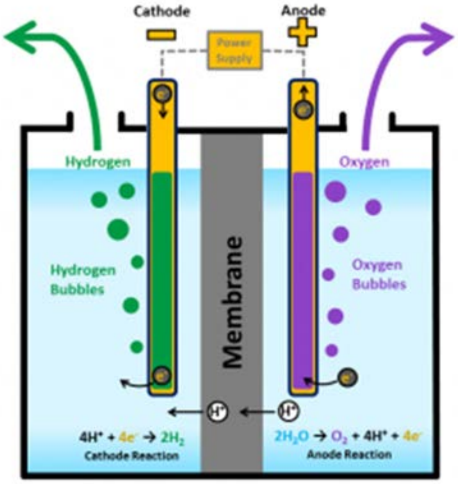


Figure 4. Chemical reactions within an electrolyzer. Source: [7].

Solar processes, also known as photoelectrochemical (PEC) water splitting, use specialized semiconductors (PEC materials) immersed in a water-based electrolyte to disassociate water molecules into hydrogen and oxygen when exposed to sunlight [8]. Two examples of a PEC reactor are in the form of an electrode system (cathode, anode, photoelectrode panel, and electrolyte) or particle system (photocatalyst slurry mixed in an electrolyte) (Figure 5).

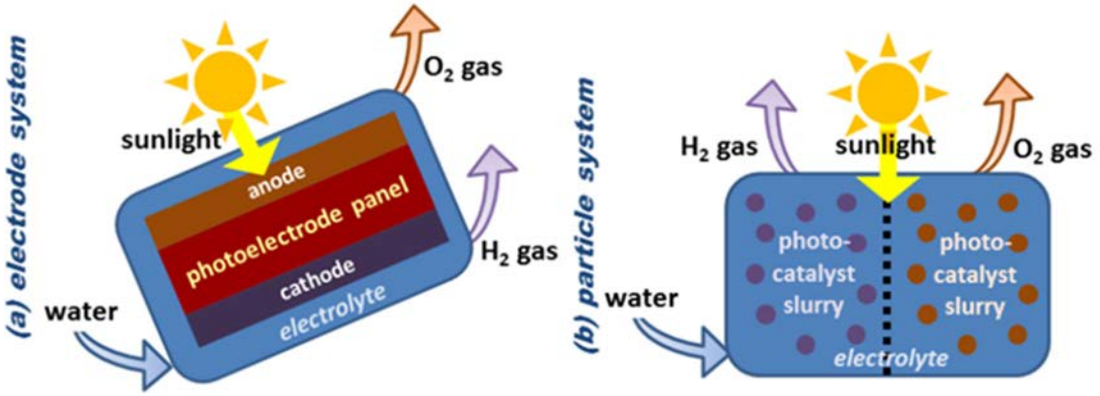


Figure 5. PEC reactor approaches. Source: [8].

Lastly, biological processes, also known as microbial biomass conversion, use fermentation in which microorganisms release hydrogen from the breakdown of biomass or by consuming and digesting organic matter [9]. Alternatively, new devices called microbial electrolysis cells (MECs) capture the electrons and protons released in the breakdown of organic matter to produce hydrogen with some added electricity (Figure 6) [9].

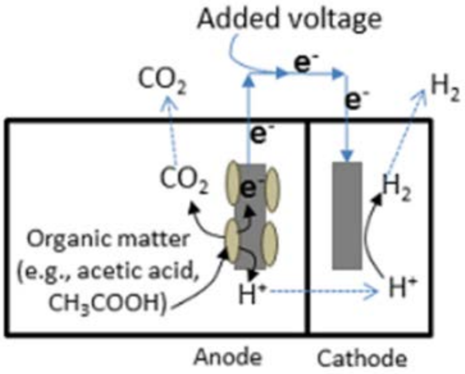


Figure 6. Chemical reaction within a MEC. Source: [9].

After hydrogen is produced and stored, it can be used as a fuel in fuel cell technology, for example. Fuel cells use the chemical energy of a fuel to produce electricity for various applications, including transportation and emergency backup power [10]. Its process can be thought of as the reverse process of an electrolyzer, as explained earlier. A significant benefit to hydrogen fuel cells is that they can generate electricity while only emitting water and heat as byproducts, resulting in zero carbon dioxide emissions, zero air pollutants, and reduced health-related issues due to poor air quality [10]. They can also operate more efficiently (up to 60%) and with less noise than combustion engines [10].

C. LITERATURE REVIEW

Ongoing research into the hydrogen production, compression, and storage system at the Naval Postgraduate School (NPS) Turbo Propulsion Laboratory (TPL) is being performed to support hydrogen fuel testing in gas turbine engines for this project. The system is designed with solar photovoltaic cells that provide electricity to the dehumidifier, electrolyzer, and other electronics to harness water from the ambient air and then split the water into hydrogen and oxygen [11]–[15]. The hydrogen is also passed through filtration and compression systems that remove contaminants and excess moisture before being compressed into storage tanks. It is designed to be fully automated and powered with renewable, zero carbon emission energy.

The commercial off-the-shelf (COTS) engines previously used to test the compressed hydrogen were the Sophia J450 turbojet and the Capstone C30 MicroTurbine. Penley successfully ran the Sophia turbojet with hydrogen, but higher-than-designed fuel pressures were needed to achieve adequate flow, which caused increased internal temperatures [16]. The turbojet could only be operated at approximately 85.3% of its max speed due to the higher temperatures [16]. Penley recommended that a possible solution to obtain proper flow at the designed pressure is to modify the engine with larger fuel nozzles to choke the flow further upstream [16]. The C30 operated at steady state using natural gas and propane (C_3H_8), but not with hydrogen. In a 2019 NPS thesis, Brianna Kaufmann explained that the C30 faulted and performed an automatic shutdown when operated with hydrogen possibly because of a lack of volumetric flow rate or choked flow by the fuel nozzles in the combustion chamber [17]. This project intends to apply these findings towards the gas turbine experiments in order to determine how to redesign the JetCat P60-SE gas turbine engine to run on hydrogen.

D. OBJECTIVE

The primary objective of this research was to determine the feasibility of altering a COTS liquid-fueled gas turbine engine to operate with compressed hydrogen gas. The findings of this research will aid in the development of a mobile, autonomous joint energy generation and hydrogen production, compression, and storage system. Ultimately, the joint system design is meant to be used for shore installations, both large-scale and forward-operating bases, and possibly marine applications. The COTS gas turbine engine used for experimentation was the JetCat P60-SE. The practical challenges and approach to achieve the objective are explained further in Appendix A.

E. CHAPTER OVERVIEW

In the following sections of the paper, Chapter II offers general information on the engine, its associated equipment, and the data acquisition equipment to provide an understanding of what is being tested and how it is being measured. Chapter III discusses the process of verifying and calibrating the data acquisition equipment, as well as learning how to operate the engine. Chapter IV provides the experimental data using liquid fuel (kerosene), GASTURB simulation results, data from testing with propane fuel, and disassembly and observations. Finally, Chapter V contains the discussion of the results, propose modifications, and recommendations.

II. TEST EQUIPMENT

This chapter will provide an overview of the main and data acquisition equipment used to operate the engine and gather data during experiments. Because the engine is used in remote-controlled hobby jets, the main equipment is optimized to be as small as possible. Some parts were replaced with equipment that proved more useful for testing purposes. The data acquisition equipment was effectively used during the Sophia project [16], so the equipment remained mostly the same with minor adaptations for compatibility with the P60-SE.

A. MAIN EQUIPMENT

The main operating equipment, purchased as a set from JetCat, consisted of the gas turbine engine and the control and auxiliary components. The control and auxiliary components included: the engine control unit (ECU), ground support unit (GSU), input/ output (I/O) board, starter gas tank, lithium polymer (LiPo) battery, fuel pump, fuel/ propane shut-off valves, 4 mm and 3 mm diameter transparent polyvinyl chloride (PVC) tubing for fuel and starter gas (respectively), tubing fittings and connectors, electronic data cables, and electrical power cables with connectors. Other equipment that was on-hand or purchased include: a fuel storage tank, a fuel-oil mixing container with attached battery-powered pump, a valve-regulated propane tank adapter, a transmitter and receiver, and a foreign object debris (FOD) screen. The JetCat universal serial bus (USB) interface later replaced the transmitter and receiver to operate the engine more easily and collect more data with a computer using the Jet-tronic software, and the battery was later replaced by a power supply as a more reliable source of power. See Appendix B for photos of the system setup.

1. JetCat P60-SE Gas Turbine Engine

The JetCat P60-SE gas turbine engine was designed by Ingenieurbüro CAT, M. Zipperer GmbH, in Germany for use in remote-controlled hobby jets. The SE series engines produce lower thrust than all JetCat gas turbine engines, except for the P20-SX, and they are also the most affordable models (Table 2).

Table 2. JetCat hobby jet engines. Source: [18].

Engine	P60-SE P80-SE	P20-SX	P130-RX P100-RX P200-RX	P220-RXi	160-RXi-B	P180-NX
Thrust [N]	63 97	24	100 130 210	220	158	175
Cost [€]	1995 1799	2545	2449 2295 4195	3950	2850	3550

Using a low-cost test platform for research was beneficial from a financial and safety perspective because of the potential for engine failure. The project team did not have prior knowledge of the internal design, and altering a liquid-fueled engine to run on gaseous fuel was a difficult task in itself. Additionally, as demonstrated with the Sophia project [16], hydrogen gas burns at a higher temperature, so an engine designed to operate on kerosene may not be able to withstand the operating temperatures while using hydrogen. Therefore, working with a smaller engine in place of a full-scale device reduced risk and lowered cost to a more acceptable and manageable level.

The P60-SE functions similarly to any gas turbine engine: air enters through the intake, is compressed by the compressor, then guided into the combustion chamber where it mixes with fuel and is combusted (some used as cooling air), is expanded through the turbine that is coupled with the compressor impeller, then is exhausted out the rear of the engine to produce thrust. This particular engine is designed to initially spin up the compressor with an electric motor powered by a 7.4V 2-cell LiPo battery, allow propane starter gas into the combustion chamber, then perform ignition via a glow plug before introducing a fuel and oil mixture to sustain the combustion in the chamber as well as lubricate the bearings. The designed fuel is kerosene with 5% synthetic oil by volume, which is 1 liter of oil for every 20 liters of kerosene (or 1 quart of oil for every 5 gallons of kerosene). The project team used Klean Strip 1-K Kerosene and AeroShell Turbine Oil 500 for fuel (see Fuel/Fuel Care section on page 8 in the instruction manual [19]) and Bernzomatic propane camping gas as the starting gas.

The NPS TPL purchased two of these engines with the intention to modify one of them to operate using gaseous fuel. The full list of engine specifications can be found in Appendix C and engine diagrams can be found in Appendix D. A few notable characteristics of the P60-SE engine is that it produces 1 N of thrust at idle speed (50,000 RPM) and up to 63 N of thrust at maximum RPM (165,000 RPM) [19]. It also weighs only 8.29 N, thus having a 7.60:1 thrust-to-weight ratio at maximum RPM.

2. Engine Control Unit

The engine came with several pieces of control and auxiliary equipment. The "brain" of the engine is called the engine control unit (ECU) (Figure 7–Figure 8) and it is a microcomputer that communicates with the receiver, ground support unit (GSU), and engine sensors and automates the engine and auxiliary equipment during startup, operation, and shutdown. The engines were provided with version 6.0 ECUs. Electrical connection diagrams and instructions can be found on pages 6–8 of the instruction manual [19].

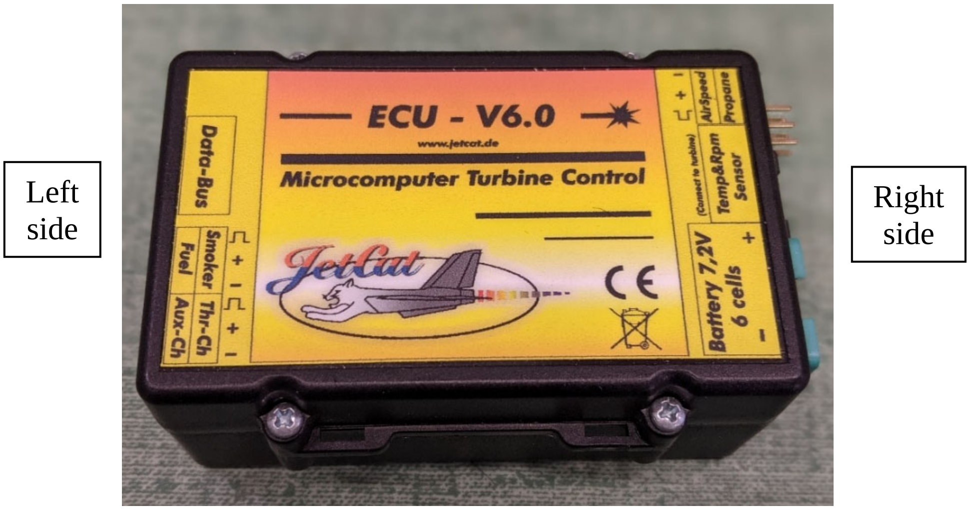


Figure 7. Top of ECU

Figure 8. Bottom of ECU

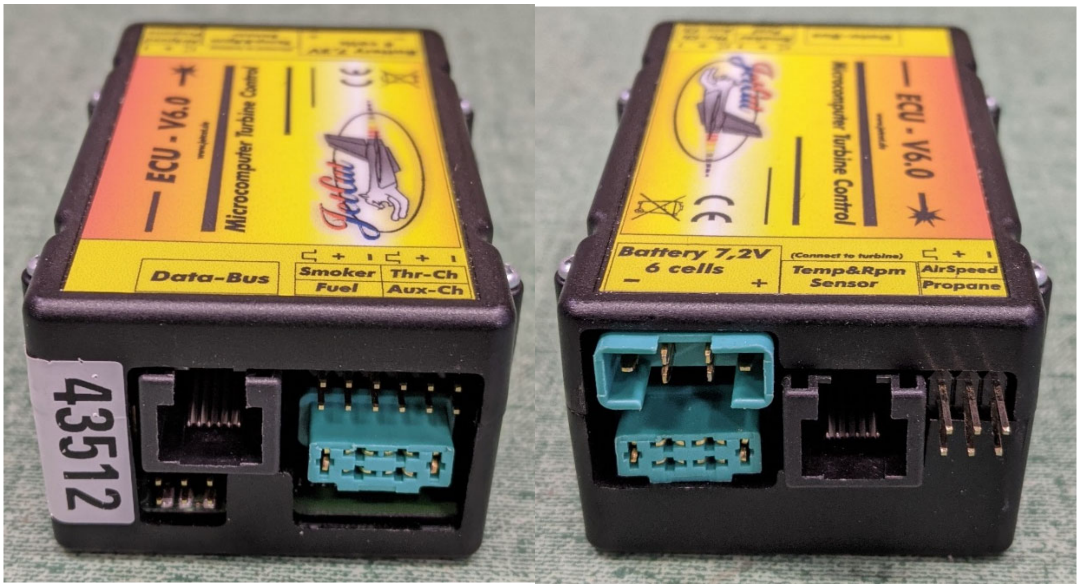


Figure 9. Left and right sides of ECU

3. Ground Support Unit

The GSU (Figure 10) is a handheld device that allows the user to see engine information stored in the ECU, change operational settings, spool the engine, and pair a transmitter to the receiver, and view various engine information (see pages 25–39 in the instruction manual [19]). Primarily, the GSU was used to set the fuel flow rate and to purge air from the fuel line. The GSU has input and output ports for 6-pin data cables above/ behind the screen that are used to connect to the ECU and to another source (if applicable). The engines were provided with version 2.02 GSUs (Figure 11). The GSU is not required to remain connected during operation since these engines were designed to be used in recreational jets.

Figure 10. Front of GSU

Ingenieurbüro CAT, M. Zipperer GmbH
D-79282 Ballrechten-Dottingen
Typ: GSU
Version: V 2.02
Made in Germany

Figure 11. Part information on rear of GSU

4. Input/Output Board

The light emitting diode (LED) input/output (I/O) board (Figure 12) provides the interface between the ECU and GSU via 6-pin data cables. The green, red, and yellow indication lights illuminate in sequence (with corresponding sound from the engine circuit board) to provide engine status just prior to startup. Refer to page 19 of the instruction manual [19] for more details.

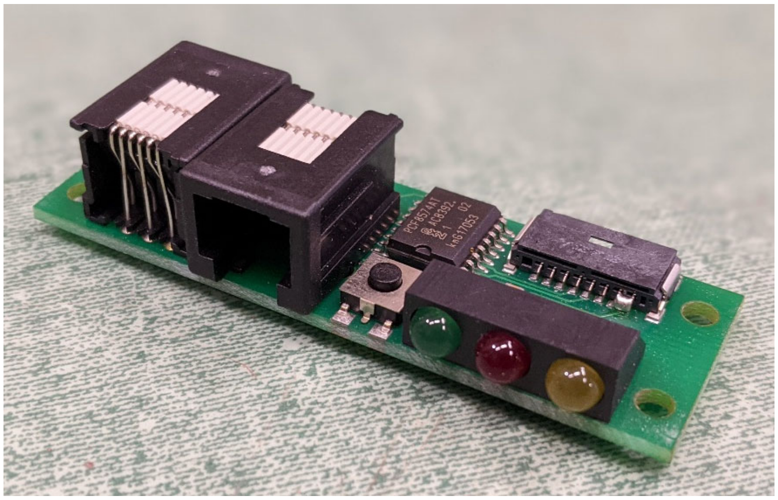


Figure 12. I/O Board

5. Starting Gas Tank

The starting gas tank (Figure 13) provides storage for just enough pressurized propane gas for the initial combustion during startup before shifting to kerosene fuel. The starting gas connection diagram and starting gas filling instruction can be found on pages 14 and 15, respectively, of the instruction manual [19].

Figure 13. Starting gas tank

6. Fuel Storage Tank

The fuel storage tank provides storage for approximately 945 ml (32 oz) of the fuel/oil mixture. The cap was fitted with three brass tubes: two small tubes for fuel inflow and outflow and one longer angled tube for air equalization. Refer to pages 9–13 of the instruction manual [19] for fuel system information and connection diagrams.

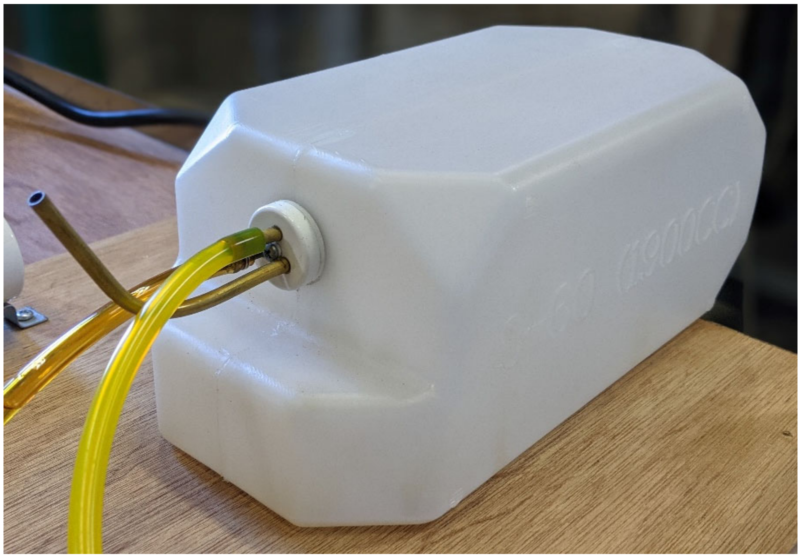


Figure 14. Fuel storage tank

7. Fuel Pump

A 6 VDC fuel pump (Figure 15) was used to pull fuel/oil from the fuel storage tank and pump it through a filter and fuel shut-off valve before entering the engine. It plugs directly into the ECU, which controls the pump rate via voltage. Refer to pages 9–13 of the instruction manual [19] for fuel system information and connection diagrams.

Figure 15. Fuel pump

8. Fuel/Gas Shut-Off Valves

The electronic shut-off valves (Figure 16) allow fuel or gas to flow to the engine. They connect into the ECU and are either in the open or closed position, depending on the input from the ECU. The gas shut-off valve opens and closes during startup, while the fuel shut-off valve opens after initial combustion and closes during engine shutdown.

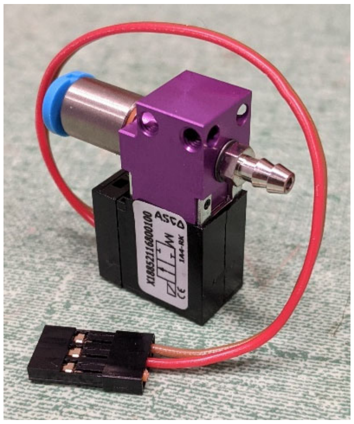


Figure 16. Fuel/gas shut-off valve

9. USB Interface

Because the engine was not going into a model jet, the transmitter and receiver were later replaced with JetCat's universal serial bus (USB) interface (Figure 17) to control the engine and collect ECU performance data directly from a computer (using the Jet-tronic software) [20]. The user is able to view the last 25 operating minutes [20] stored in the ECU, however, it will only record data for successful starts. The ECU does not record startup data for failed starts, but real-time data is viewable on the Jet-tronic human machine interface (HMI) screen. A 6-pin data cable connects the ECU to the USB interface (via the GSU) and a mini-USB to USB-A cable connects the USB interface to a computer. Having the GSU connected in series between the ECU and USB interface allowed access to make changes to the engine settings.

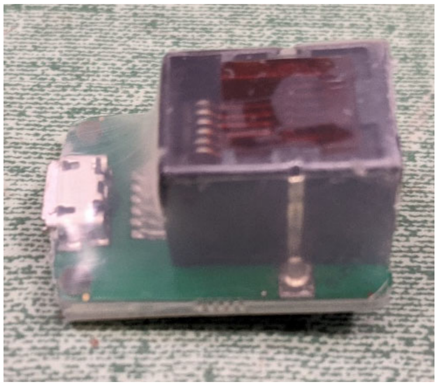


Figure 17. USB interface

10. Power Supply

The power supply provided electricity to the system via the ECU, powering the GSU, fuel pump and valves, and initially spinning the compressor during startup. The LiPo battery was replaced with the BK Precision 1900B power supply (Figure 18-Figure 19) to avoid recharge times and run time limitations. It could provide 1–16 VDC at 0–60A, which was far greater than needed but made ground testing simpler. The ECU operated at about 8 VDC with variable current via the main output plugs on the back of the power supply.

Conductor wires and applicable connectors were soldered together to connect the power supply to the ECU battery port.

Figure 18. Front of power supply

Figure 19. Rear of power supply

11. Miscellaneous Parts and Consumables

Other miscellaneous engine parts are shown in the connection diagram in Appendix D (Figure 99) and Table 3. Other parts and supplies obtained for the system are also included in Table 3. Photos of the system setup, connections, and miscellaneous parts can be seen in Appendix B.

Table 3. Miscellaneous parts and supplies list

Miscellaneous engine parts	**Other parts and supplies**
PVC tubing (4 mm and 3 mm diameter)	Fuel-oil mixing container
Tubing fittings	Valve-regulated propane tank adapter
Electronic data cables	Klean Strip 1-K Kerosene
Fuel and gas filters	AeroShell Turbine Oil 500
	Bernzomatic propane camping gas
	Electrical wires and connectors
	Transmitter and receiver
	FOD screen

B. DATA ACQUISITION EQUIPMENT

The data acquisition equipment used to calibrate the strain gauges and collect thrust measurements from the engine consisted of the thrust beam with bonded strain gauges, calibration pulley, and the National Instruments (NI) data acquisition (DAQ) unit and chassis.

1. Thrust Beam

The thrust beam (Figure 20) provides the mounting interface to the NPS TPL outdoor test stand and the carriage for the engine. It is the same beam used for both the Sophia project [16] and the shrouded gas turbine project [21], so it was already assembled and equipped with strain gauges and wires. The carriage had to be modified to accommodate the smaller diameter of the engine and turbine mounts (Appendix D,

Figure 96) compared to the larger Sophia engine. Small aluminum plates were machined to be secured to the existing thrust beam and provide mounting points to secure the JetCat engine (Figure 21).

Figure 20. Thrust beam

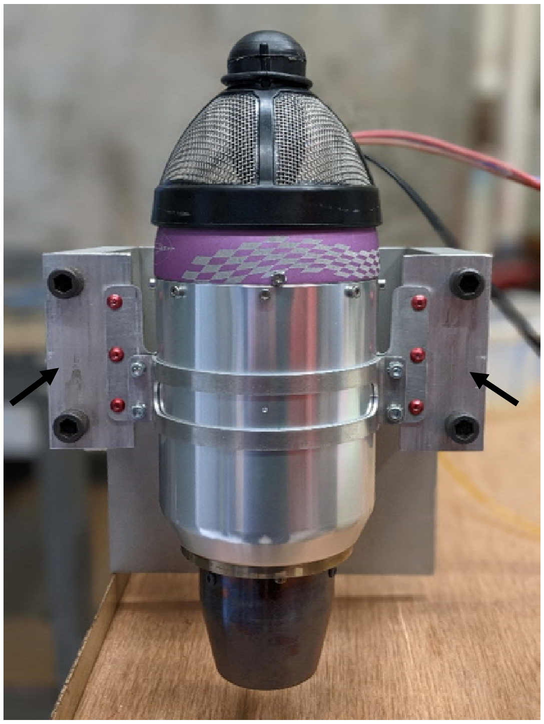


Figure 21. Machined mounting plates

2. Calibration Pulley

The calibration pulley system (Figure 22) provides the means of calibrating the electrical signal from the strain gauges. The pulley was fixed onto the outdoor test stand with vice grips and measured weights were loaded onto the platform while strain gauge readings were recorded. The length from the base of the pulley frame to the wheel itself is about the same length from the base of the thrust beam to the engine mounting points. Thus, the angle of the cable between the thrust beam and the pulley wheel was level.

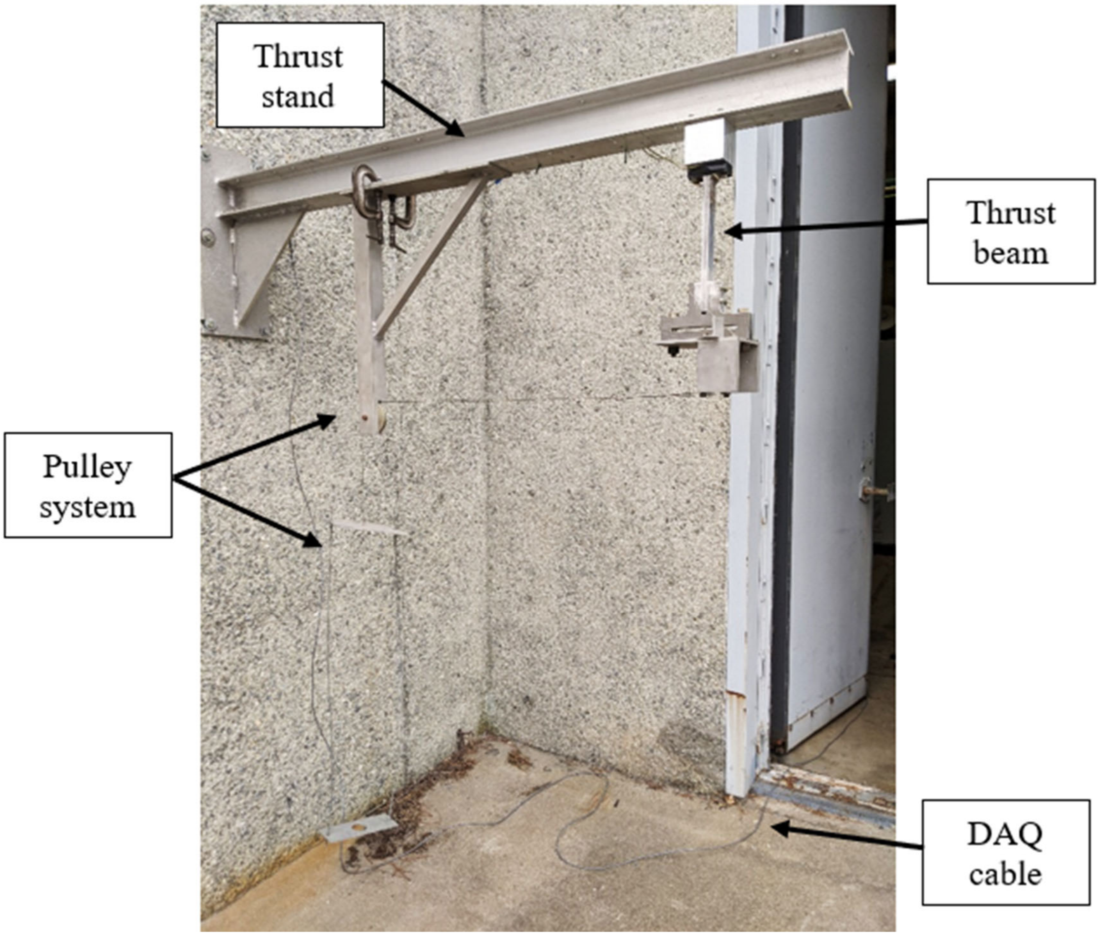
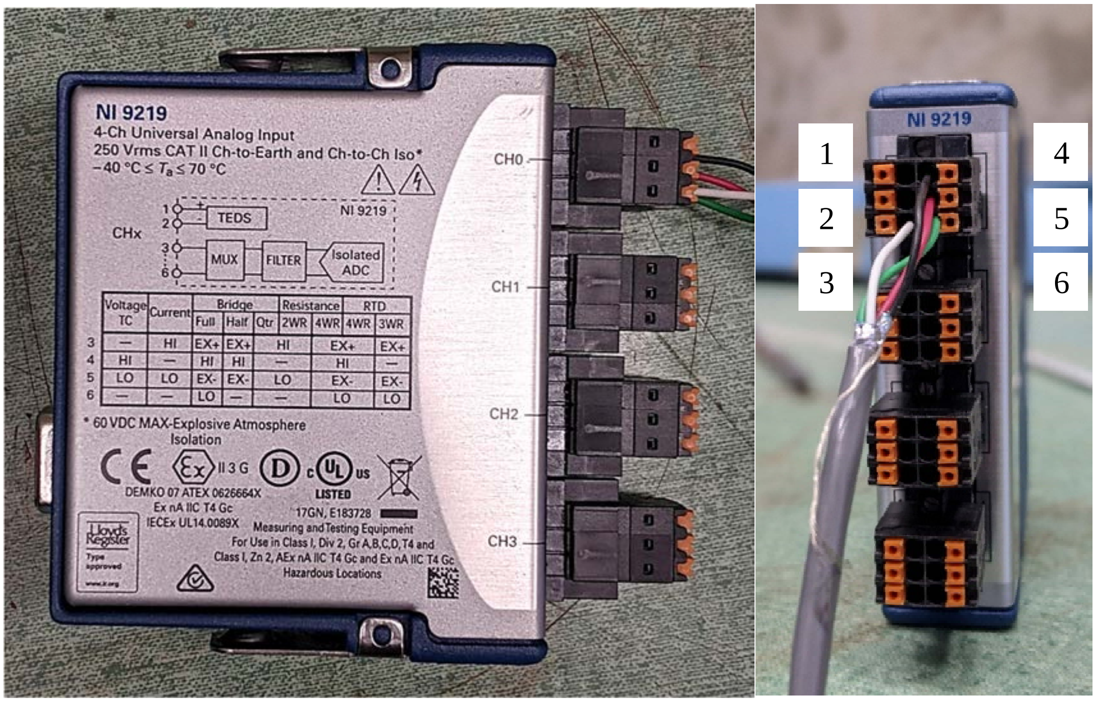


Figure 22. Pulley system attached to thrust beam

3. Data Acquisition Unit

The NI 9219 DAQ unit (Figure 23) is a four-channel analog input and it was used to collect the data from the strain gauges. Each of the four channels has six ports and they are numbered as shown in Figure 23. The back of the NI DAQ also describes what each of the six ports connect to within the unit.



Each channel of the DAQ unit contains six ports numbered as shown in the right photo.

Figure 23. NI 9219 analog input

4. Data Acquisition Chassis

The NI 9219 DAQ unit was seated into a NI 9181 chassis (Figure 24), allowing a computer to access the DAQ unit via ethernet cable. Part information on the chassis is provided in Figure 25.

Figure 24. NI 9181 chassis with attached NI 9219 DAQ unit

M/N: cDAQ–9181
P/N: 150227B–02L
S/N: 17E769D
MAC:00802F145961
PRODUCT OF HUNGARY
N114
KCC–REM–NAT–CDAQ9181
c UL us LISTED
23GF
Measuring and
Testing Equipment

Figure 25. Part information from bottom of chassis

III. EQUIPMENT CALIBRATION AND FAMILIARIZATION

This chapter will provide an overview of the methodology used to verify the effectiveness and calibrate the data acquisition equipment, as well as the process of learning how to operate and record engine data. The engine was mounted onto a cantilever thrust beam, thrust was converted into an electrical signal with the equipped strain gauges, and the NI DAQ unit and NI MAX and MATLAB software were used for strain gauge verification and calibration, respectively.

A. DATA ACQUISITION

The use of strain gauges was an effective data acquisition method for this application because it was simple and inexpensive. A strain gauge (Figure 26) is a strip of conductive metal that can be used to measure applied force based on its change in electrical resistance as long as the tensile or compressive stresses do not exceed the elastic limit of the metal strip and cause plastic deformation [22]. Of note, a single strain gauge is ineffective for measuring lateral forces [22], but these were not important for the experiments of this project.

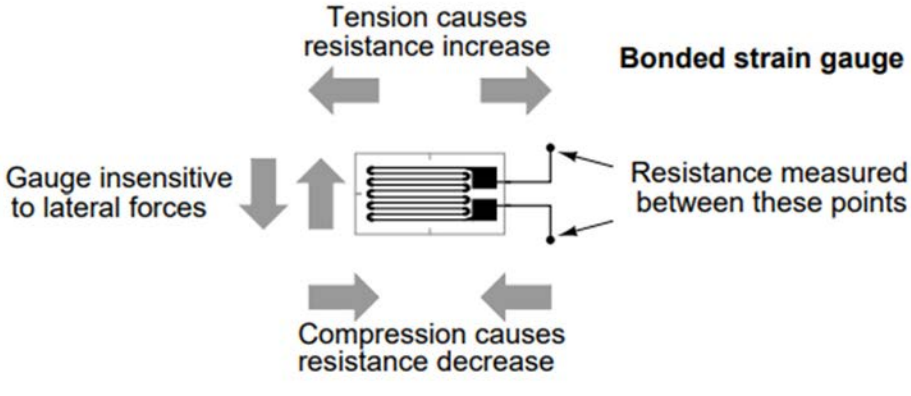
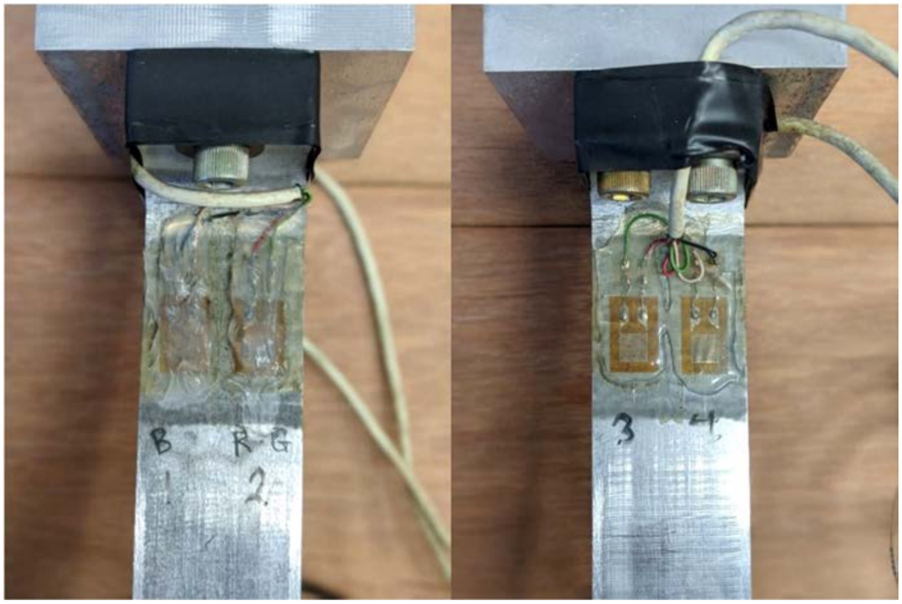


Figure 26. Bonded strain gauge design. Source: [22].

Additionally, strain gauges are considered “bonded gauges” when they are “glued to a larger structure under stress (called the test specimen)” [22]. The test specimen, or "test instrument" in the case of this project, was the thrust beam (explained in the following section).

1. Equipment Verification

Prior to testing the engine, the thrust beam and strain gauges had to be operationally tested, using the NI DAQ unit and NI MAX software, to confirm that the data output will be accurate, consistent, and readable. The original strain gauges and wires soldered to the leads (Figure 27) appeared to be in working condition, so no changes were made. The numbering scheme previously used for the strain gauges also remained unchanged, thus strain gauges 1 and 2 were on the exhaust side of the engine and strain gauges 3 and 4 were on the intake side.



Strain gauges 1 and 2 undergo tension, while strain gauges 3 and 4 undergo compression.

Figure 27. Thrust beam strain gauges

Though it remained unchanged, tests were conducted to verify that the strain gauges would produce an effective signal and that no plastic deformation would occur in the beam or strain gauges. The conductor wires from each of the strain gauges were connected to form a Wheatstone full-bridge arrangement (Figure 28) and were initially tested with a multimeter.

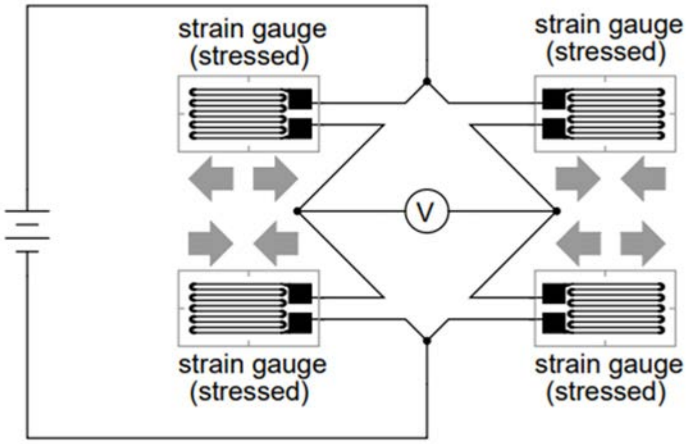


Figure 28. Full-bridge strain gauge circuit undergoing stresses. Source: [22].

A full-bridge configuration is not only more sensitive than a half or quarter-bridge configuration (two or one strain gauge, respectively), but it is also linear [22]. Applied forces will produce a change in output voltage that is directly proportional, assuming that the change in resistance between all four strain gauges are the same [22]. Measurements with a multimeter showed the full-bridge circuit had a resistance of approximately 350 ohms, and a positive and negative voltage output when a force was applied to the beam in one direction or the other. Although Figure 29 is an image of a half-bridge configuration, it shows that the resistance of a strain gauge increases when undergoing tensile stress and decreases under compressive stress, causing the change in voltage output. The experiments for this project used a vertically-oriented test instrument, unlike Figure 29, to measure horizontal, perpendicular loads produced by the P60-SE engine.

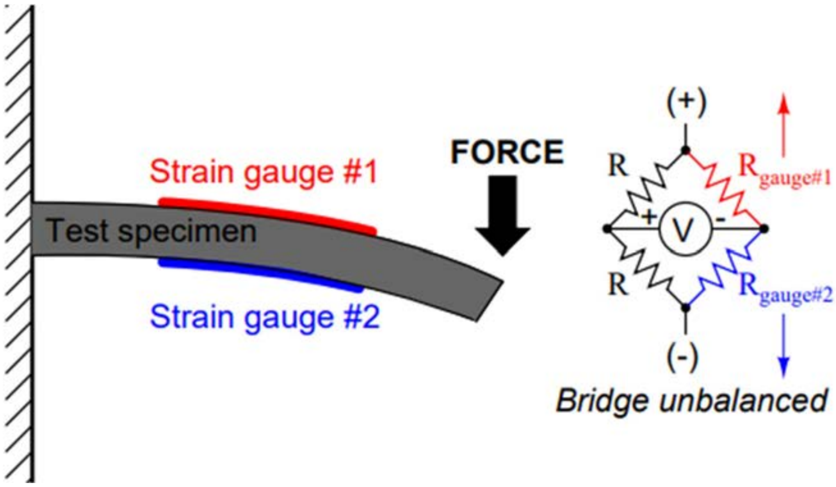


Figure 29. Deflected beam. Source: [22].

After obtaining proper indication that the strain gauges responded to beam deflection, the respective pairs of wires were secured to a four-wire cable with heat shrink (Figure 30), which would be used with the 4-channel NI 9219 DAQ.

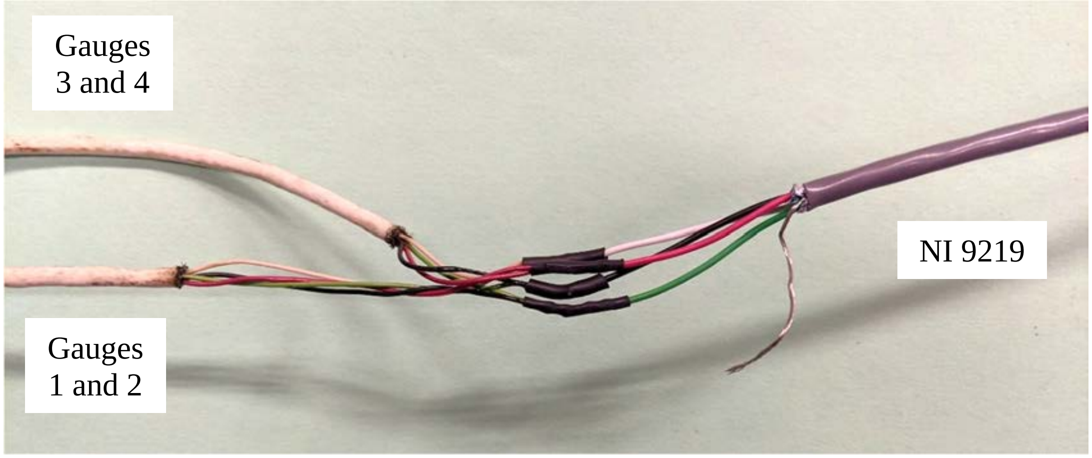


Figure 30. Wire connections for full-bridge configuration

The other (free) ends of the four-wire cable were individually routed into the channel 0 (CH0) port of the NI 9219 DAQ unit, such that the input and output wires coincided with both the full-bridge circuitry connection diagram (Figure 31) and the connection table on the back of the NI 9219 DAQ (Figure 23). To further clarify

Figure 31, the resistors (R1 through R4) on the left of the image represent the strain gauges, which were connected to the NI 9219 DAQ unit. The DAQ unit provided the 2.5 V excitation voltage (EX) and housed the analog-to-digital converter (ADC), which measured and communicated the resulting voltage to the software.

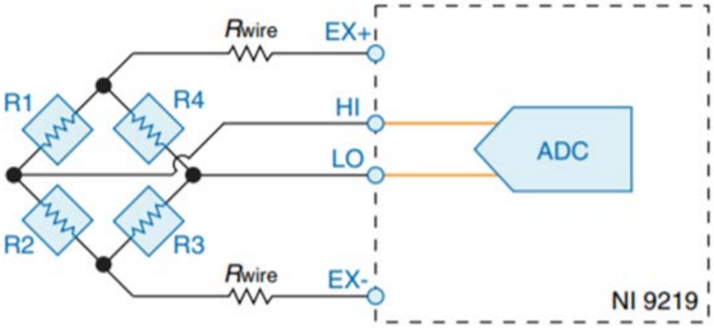


Figure 31. Full-bridge circuitry. Source: [23].

Figure 32 is a colored line connection diagram of the wires and Table 4 summarizes the wire routing path from each strain gauge to the NI 9219 DAQ unit.

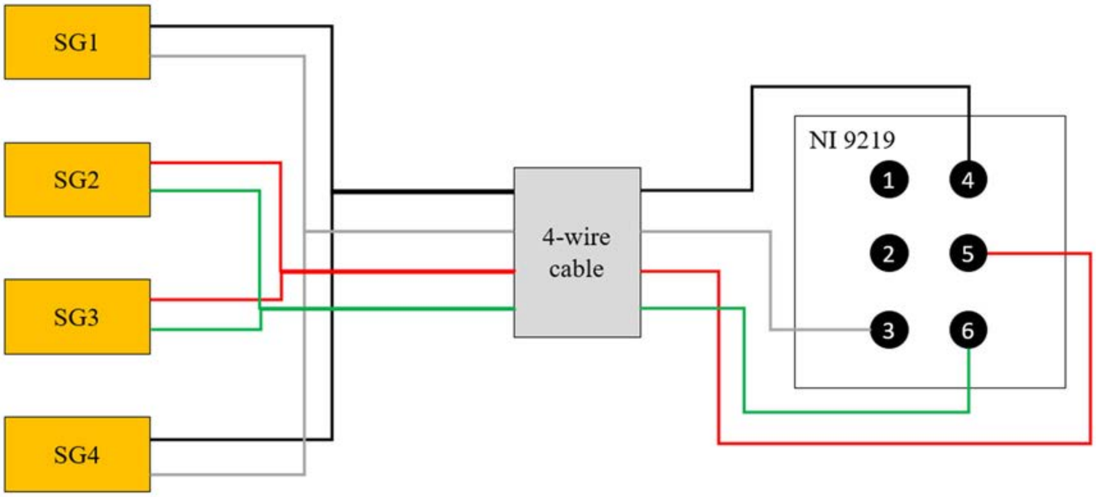


Figure 32. Wire connection diagram

Table 4. Strain gauge-NI DAQ unit connection table

Strain Gauge 1	Strain Gauge 2	Strain Gauge 3	Strain Gauge 4	Cable	NI 9219 Port #
W			W	W	3
	G		B	B	4
	R	R		R	5
B		G		G	6

Abbreviations for the wire color: W for white, B for black, R for red, and G for green.

The NI MAX software provided the computer user interface to obtain samples of the digital signal and produce a plot, verifying that the wires and DAQ unit were connected properly. To configure the software to perform measurements, refer to Appendix E. Operational tests (OPTESTs) successfully produced positive and negative voltages similar to the multimeter and within a tolerable range when the beam was deflected in one direction or the other. Figure 33 shows a test measurement using NI MAX set to obtain 10 samples at a rate of 2 Hz while a light force was applied by hand to the thrust beam in the direction of thrust (positive direction).

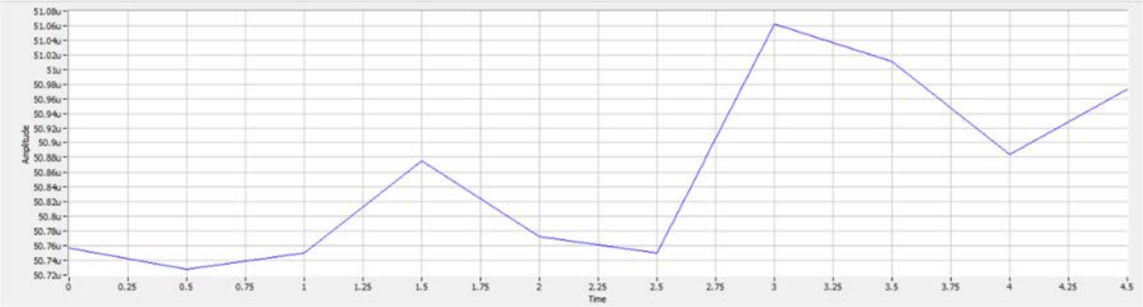


Figure 33. NI MAX amplitude (µV/V) vs. time (s) plot

With these settings, NI MAX produced the plot in Figure 33, showing a sample recorded every 0.5 sec with amplitude output values between 50.72 and 51.08 µV/V. The strain gauges were deemed to be satisfactory to proceed with testing.

2. Equipment Calibration

Although the strain gauges were verified to output a satisfactory signal, it was important to calibrate the electrical signal with a physical applied force to properly correlate voltage readings and to check for the possibility of plastic deformation in the thrust beam. This was accomplished by performing multiple measurements with a pulley and various weights (Figure 34) while the thrust beam was secured to the test stand affixed outside onto building 214 at the NPS TPL.

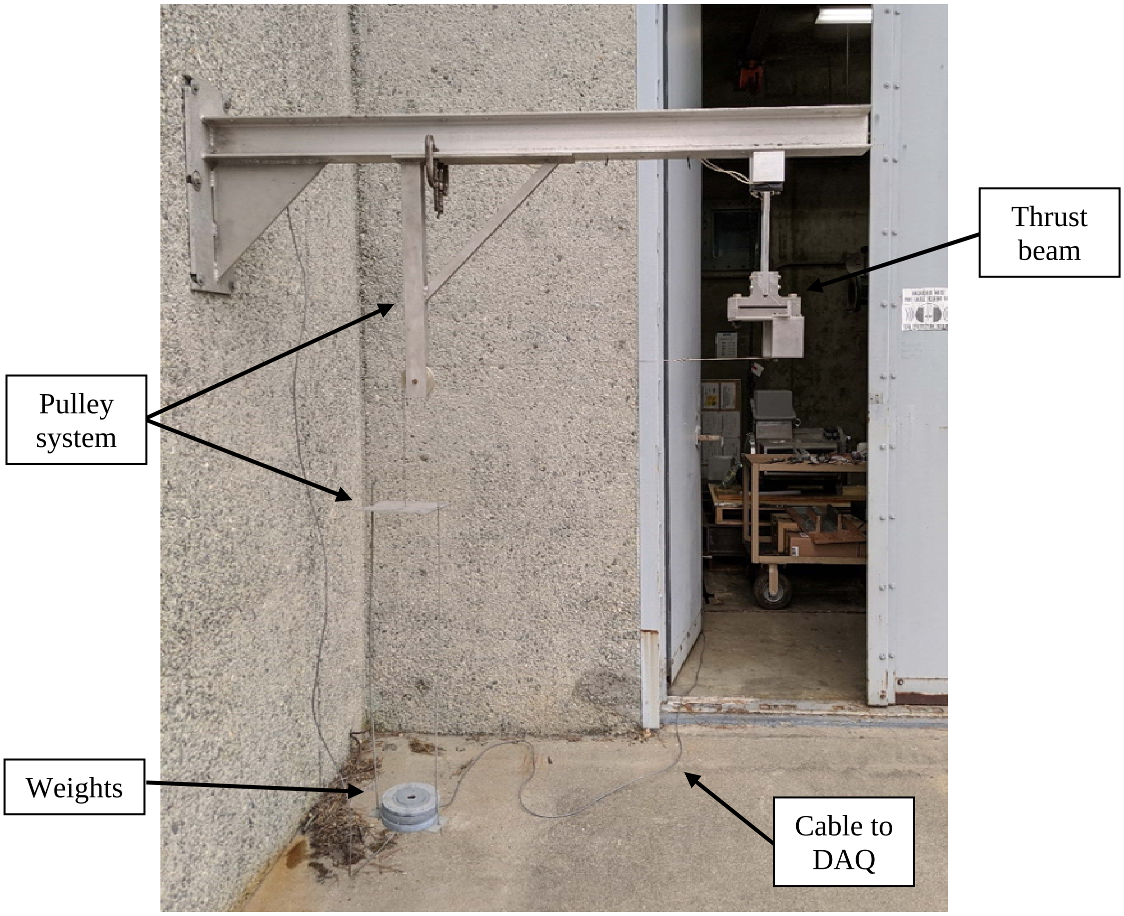


Figure 34. Data acquisition calibration equipment

The engine is rated for 63 N (14.16 lbf) at maximum RPM [24], so to calibrate a sufficient number of loads on the beam, three weights (Figure 35) were used for calibration: 2274 g, 2273 g, and 1138 g (22.31 N, 22.30 N, and 11.16 N, respectively).

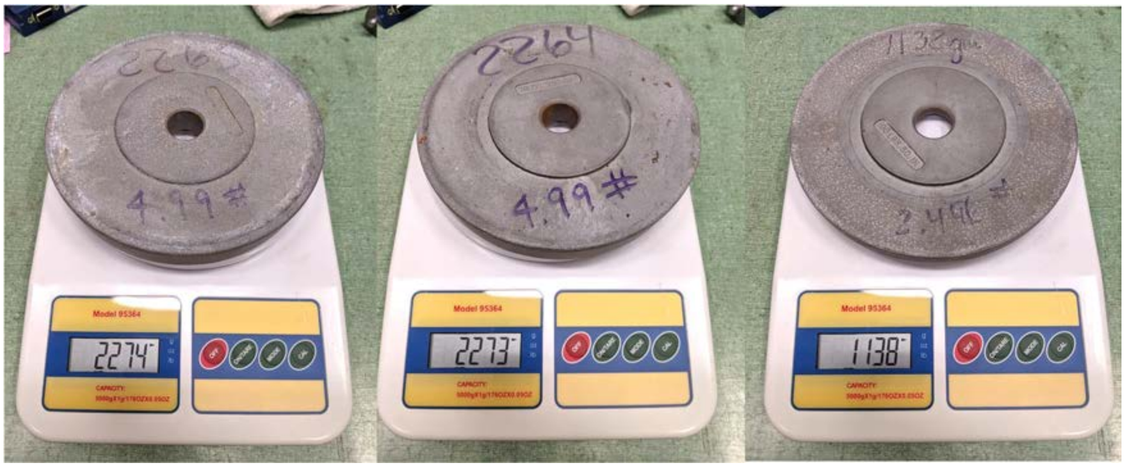


Figure 35. Weights used for strain gauge calibration

Although the pulley was difficult to weigh accurately due to its size and shape, an average of all respective measurements was used, which was 488 g (4.79 N). Thus, the calibration also included data points for an unloaded pulley and with no attached pulley (no load). Three weights and the pulley allowed for up to six calibration points and a max load of 60.56 N (13.61 lbf). All weights were measured using the same metric scale for consistency.

a. Initial Calibration

The MATLAB code from the Sophia project [16] was modified to be compatible with the NI 9219 DAQ and is provided in Appendix F. All calibration tests were set to take samples at a rate of 2 Hz for 5 sec, which resulted in 10 samples in total. The smallest sampling interval that the NI DAQ could perform was 0.5 sec, thus 2 Hz was the maximum frequency. The initial calibration was performed on October 6, 2020. It consisted of three identical calibration tests that each included 11 measurements: an unloaded pulley, incrementally increasing load using the three weights until achieving max load (five combinations), then similarly decreasing the load (four combinations) back to an unloaded pulley. In other words, from 488 g (4.79 N) to 6155 g (60.38 N) and back to 488 g. Measurements without a pulley attached (0 N load) were inadvertently omitted during the initial calibration results. Figure 36 shows the output from MATLAB for an unloaded pulley during test 1.

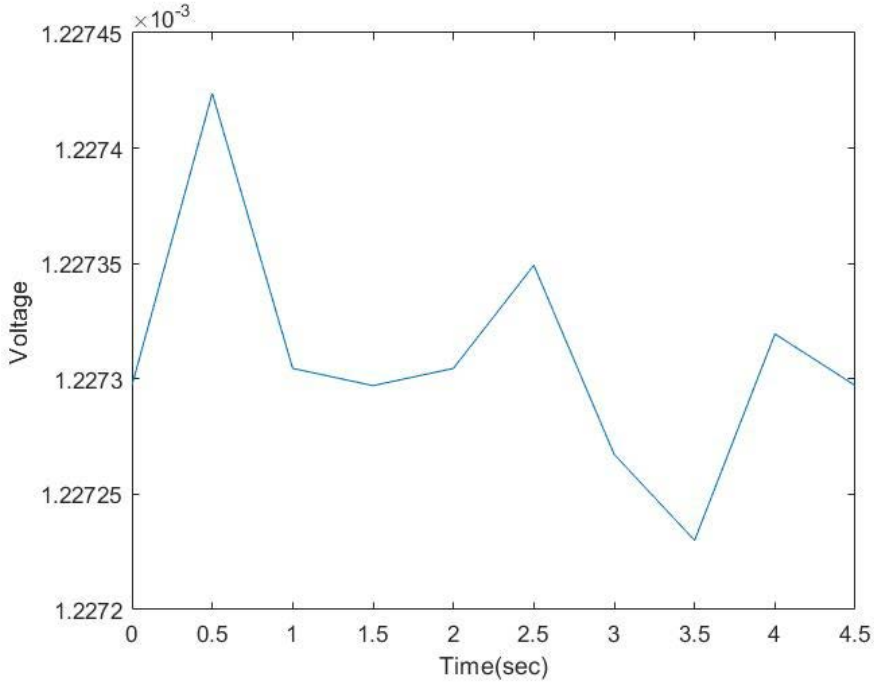


Figure 36. MATLAB output for an unloaded pulley (488 g or 4.787 N) – test 1

The mean voltage of each weight measurement across each calibration test was recorded, including the calculated average and standard deviation between the three tests at various load settings (Table 5). The standard deviation shows that there was little variation between the tests at a specified load. Also, the mean voltage values at the same load are very similar despite increasing or decreasing the weight on the thrust beam. For example, the mean voltage values for an unloaded pulley at the beginning and end of each calibration test are nearly identical. This means that there was no hysteresis or plastic deformation exhibited by the thrust beam over the range of loads.

Table 5. Initial calibration results

		Voltage (mV)				
		Test 1	**Test 2**	**Test 3**	**AVG**	**STDEV**
Load (N)	4.787	1.2273	1.2289	1.2293	1.2285	0.000864
	15.951	1.3485	1.3500	1.3504	1.3496	0.000818
	27.085	1.4697	1.4714	1.4719	1.4710	0.000942
	38.249	1.5907	1.5912	1.5920	1.5913	0.000535
	49.393	1.7109	1.7132	1.7136	1.7126	0.001190
	60.557	1.8328	1.8325	1.8341	1.8331	0.000694
	49.393	1.7132	1.7132	1.7132	1.7132	0.000000
	38.249	1.5915	1.5924	1.5925	1.5921	0.000450
	27.085	1.4697	1.4714	1.4714	1.4708	0.000801
	15.951	1.3500	1.3499	1.3503	1.3501	0.000170
	4.787	1.2290	1.2294	1.2294	1.2293	0.000199

b. Follow-up Calibration

A follow-up calibration was performed on November 5, 2020, to verify whether there were any changes to the thrust beam and/or instrumentation. This calibration was performed with the same method as the initial calibration, but also included measurements with the pulley completely removed (0 N load) at the beginning and end of each test for more accuracy (Table 6). The standard deviation between the three tests did not exceed 0.001 mV (approximately 0.15% difference), and the average voltage values at similar loads did not exceed a difference of 0.0016 mV (approximately 0.11% difference).

Table 6. Follow-up calibration results

		Voltage (mV)				
		Test 1	**Test 2**	**Test 3**	**AVG**	**STDEV**
Load (N)	0	1.1713	1.1718	1.1720	1.1717	0.000272
	4.787	1.2219	1.2221	1.2223	1.2221	0.000184
	15.951	1.3409	1.3410	1.3406	1.3408	0.000193
	27.085	1.4595	1.4603	1.4603	1.4600	0.000377
	38.249	1.5814	1.5795	1.5792	1.5800	0.000983
	49.393	1.6995	1.6988	1.6993	1.6992	0.000294
	60.557	1.8190	1.8179	1.8177	1.8182	0.000572
	49.393	1.7000	1.6996	1.6998	1.6998	0.000163
	38.249	1.5806	1.5807	1.5805	1.5806	0.000062
	27.085	1.4616	1.4618	1.4613	1.4616	0.000227
	15.951	1.3418	1.3418	1.3416	1.3417	0.000085
	4.787	1.2228	1.2227	1.2227	1.2227	0.000047
	0	1.1719	1.1720	1.1719	1.1719	0.000045

A plot of the load compared to the average voltage for both calibrations (Figure 37) shows similar results, both yielding linear relationships. Due to the similarities between the two calibrations, the thrust beam and strain gauges were deemed satisfactory for continued testing.

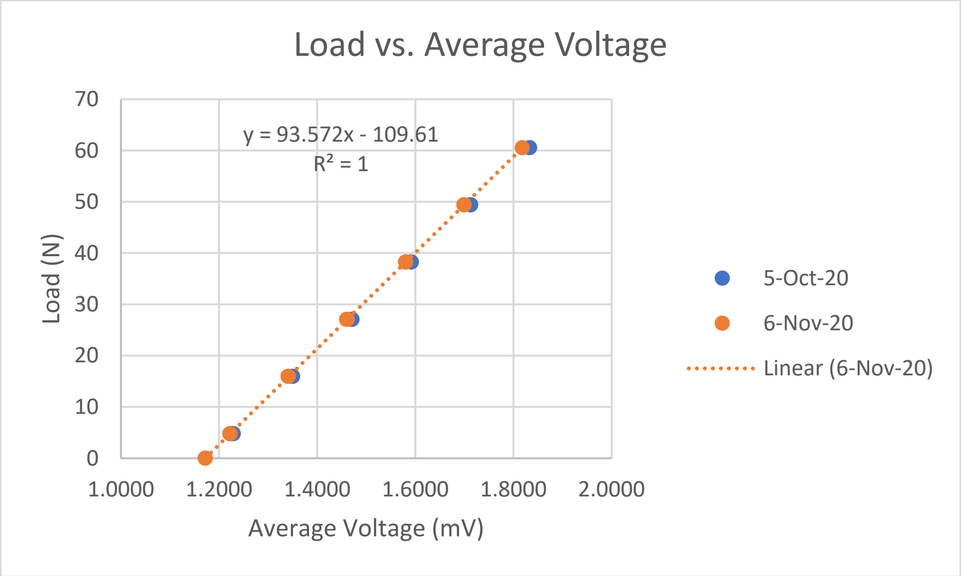


Figure 37. Plot of load vs. average voltage data from Table 5 and Table 6

Calibration spot checks were also performed prior to testing to verify that the data acquisition instrumentation was still effective to use. They consisted of two tests each at different load settings to verify that the voltage output was consistent with the trendline in Figure 37. The data from the spot checks and the differences are shown in Table 7. The spot checks yielded a variability of less than 1.3% with the exception of the spot checks conducted on February 3, 2021, which yielded a variability of up to 2.2%.

Table 7. Spot check data

	Voltage (mV)			
Load (N)	**Calibration**	**2/3/2021**	**2/16/2021**	**2/25/2021**
15.951	1.3408	1.3271	1.33375	1.3411
	Difference →	-0.0137	-0.0071	0.0003
27.085	1.4600	1.4460	1.4522	
	Difference →	-0.0142	-0.0078	
38.249	1.5800			1.5806
	Difference →			0.0006

c. Comprehensive Calibration Check

A more comprehensive calibration check was conducted at the conclusion of this research on March 4, 2021. An additional 2271 g (22.279 N) weight was used to increase the range of loads measured (Figure 38). The results, in 0 and Figure 39, also produced a linear relationship and were still very similar to the calibrations conducted earlier.

Figure 38. Additional 2271g weight

Table 8. Comprehensive pre-check

Load (N)	Mean Voltage (mV)
0	1.1332
4.787	1.1869
15.951	1.3061
27.085	1.4245
38.249	1.5449
49.393	1.6634
60.557	1.7832
71.672	1.9034
82.836	2.0233
71.672	1.9098
60.557	1.7913
49.393	1.6719
38.249	1.5515
27.085	1.4325
15.951	1.3145
4.787	1.1962
0	1.1364

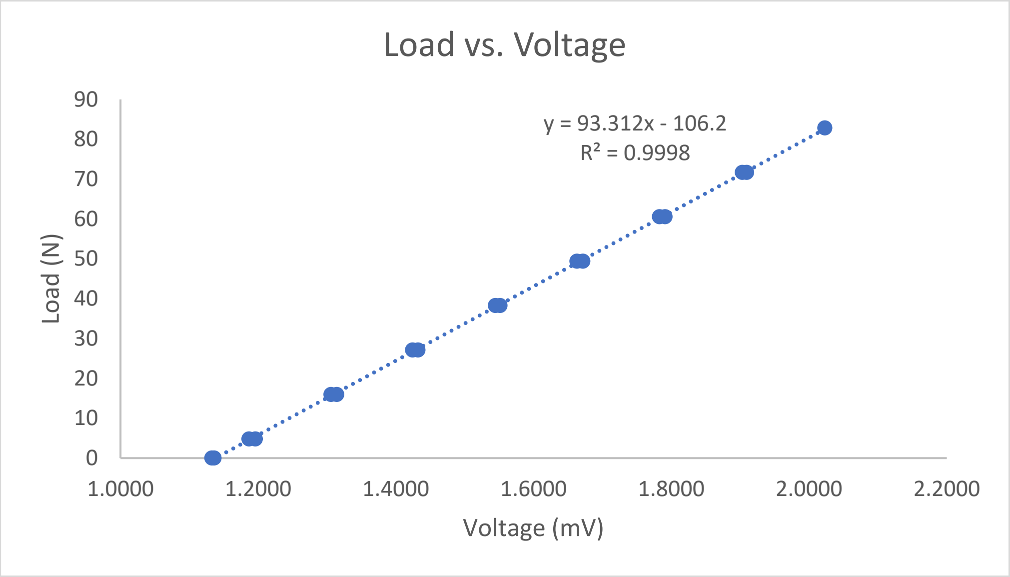


Figure 39. Plot of load vs. voltage data from Table 8

B. ENGINE OPERATION FAMILIARIZATION

Before any data collection occurred, the engines were operated using a battery for power and a transmitter and receiver for control, which were later replaced by a power supply and the USB interface, respectively. As an added precaution during this trial operation phase, the system was initially fastened to a board which was secured to the top of a test stand (Figure 40) to avoid damaging the thrust beam from possible failure of the engine. Additional photos of the system setup and connections can be seen in Appendix B.

Figure 40. Test bench during preliminary tests

The engine manual [19] was referenced for the preparation, light-off, operation, and shutdown procedures. Prior to light-off, safety measures were put in place and safety checks were conducted, including proper placement of fire extinguishers, donning eye and hearing protection, engine setup in an open, well-ventilated area, verifying that the engine intake and fuel and gas lines were clear of any obstructions or hazards, and verifying all connections were secured. Given that the battery was adequately charged beforehand, the battery was plugged into the ECU to power the system. A sufficient amount of mixed fuel-oil was pumped from the mixing container into the fuel storage tank, fuel pump flow rate was verified using the GSU, and the fuel line was purged of air. Then the transmitter was paired to the receiver and tuned according to the instruction manual [19]. If all steps were performed correctly, the LED I/O board provided a light sequence and the engine circuit board sounded an audio sequence indicating the engine was ready to start.

As mentioned earlier, the JetCat P60-SE engine is designed to sustain operation using a kerosene/synthetic oil mixture as a fuel for combustion as well as lubrication of the bearings. Therefore, both engines were operated as designed to gather baseline measurements for comparison to other fuel sources. Both engines were operated through the full range of RPM, but one of the engines proved to have startability and operational issues. More specifically, that particular engine experienced a few failed starts before successfully reaching maximum RPM and occasionally had issues sustaining operation. Due to the inconsistency of that engine, it was no longer operated and only the “good” engine was used for data collection. After receiving the USB interface and power supply, they became the primary means of powering and controlling the system (via the Jet-tronic software) while the battery, transmitter and receiver were kept on-hand as alternative methods. A standard operating procedure for the engine using the USB interface and Jet-tronic software is provided in Appendix G.

IV. TESTING AND DISASSEMBLY

This chapter provides the data gathered from initial operation of the engine with liquid fuel, which was required to obtain baseline measurements for comparison to alternative fuel options, namely gaseous fuels. Photos of the system setup and connections can be seen in Appendix B. The chapter also examines one of the disassembled P60-SE engines, discusses the results, and provides proposals on how to redesign the system. Internal inspection of the engine was necessary to better understand how the engine works. There were limited resources that described the internal design of the engine, and none described it in sufficient detail for the team to decide on how to redesign the engine in advance. The engine that demonstrated startability issues was selected to be disassembled in order to avoid any potential damage to the more consistently operating ("good") engine.

Due to weather changes, the barometric pressure and temperature during each test run were recorded [25]. The collected RPM and thrust data were then corrected to standard atmospheric conditions, where standard atmospheric temperature (T_{STD}) is 60°F (520°R, 15.6℃) and standard atmospheric pressure (P_{STD}) is 1 atm (101.325 kN/m^2, 101.325 kPa, 14.696 psia, 0 psig, 29.92 in Hg) [26]. To correct RPM and thrust, equations 1–4 [27] were used:

$$Pressure\ correction\ factor, \delta = \frac{P}{P_{STD}} \tag{1}$$

$$Temperature\ correction\ factor, \theta = \frac{T}{T_{STD}} \tag{2}$$

$$Corrected\ RPM, N_C = \frac{N}{\sqrt{\theta}} \tag{3}$$

$$Corrected\ thrust, F_C = \frac{F}{\delta} \tag{4}$$

A. LIQUID FUEL BASELINE

It was important to obtain baseline performance data to see the performance characteristics and limits of the engine. Four test runs were conducted using kerosene/ synthetic oil as fuel to measure thrust and fuel consumption relative to RPM. Thrust and RPM data were obtained using the data acquisition equipment and the Jet-tronic software, respectively. The associated MATLAB and Jet-tronic log data tables for each test run can be found in Appendix H. Fuel consumption was later obtained by using a scale and video camera during operation, which can be seen in test run #4. The weather data and correction factors for all test runs are shown in Appendix I. GASTURB 13 was used to perform an off-design study using the default demo turbojet and standard maps. The experimental results were compared to the GASTURB simulation results to determine how the performance of the JetCat P60-SE compares to standard turbojets.

1. Experimental Data

a. Kerosene Test Run #1

The first data collection run performed on October 2, 2020, was conducted to collect thrust and RPM data and test the methodology. The engine was started and slowly increased from idle speed to maximum RPM, then slowly decreased back to idle speed.

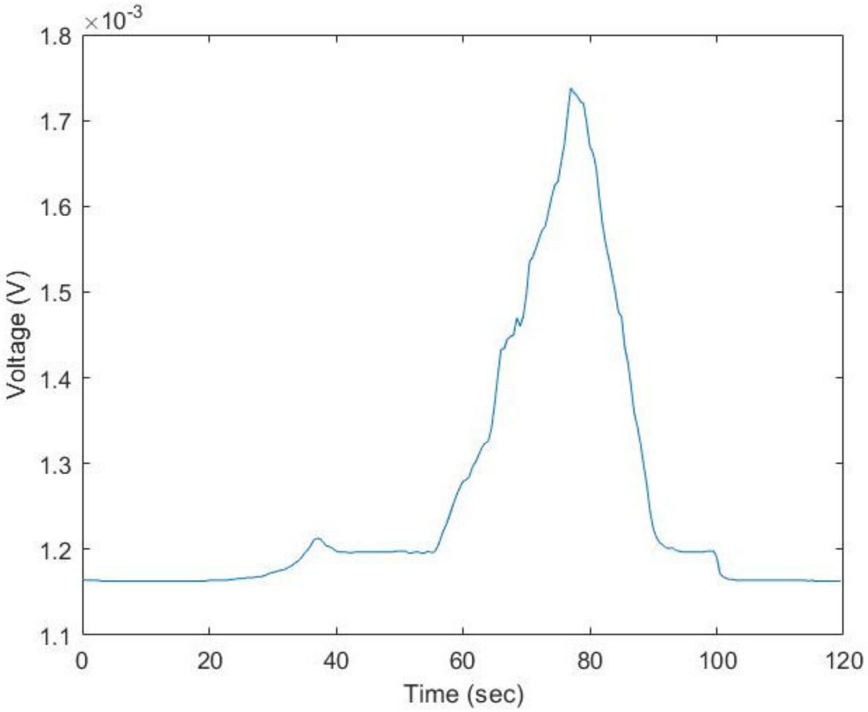


Figure 41. NI DAQ data from kerosene test run #1

Additionally, the Jet-tronic software consolidated the performance data from the ECU into a .log file, which could be exported as plots. Figure 42 shows the Jet-tronic plots for RPM/Set RPM and exhaust gas temperature (EGT) (℃) versus time (sec) and Figure 43 shows plots for throttle stick (%)/auxiliary (AUX) switch (on/off) positions and battery/fuel pump voltage (V) levels versus time (sec). The Jet-tronic software can plot up to the last 500 seconds of data. The data associated with Figure 41 can be seen in Figure 42 from about 180 seconds and on, while the previous run data can be seen before 180 seconds.

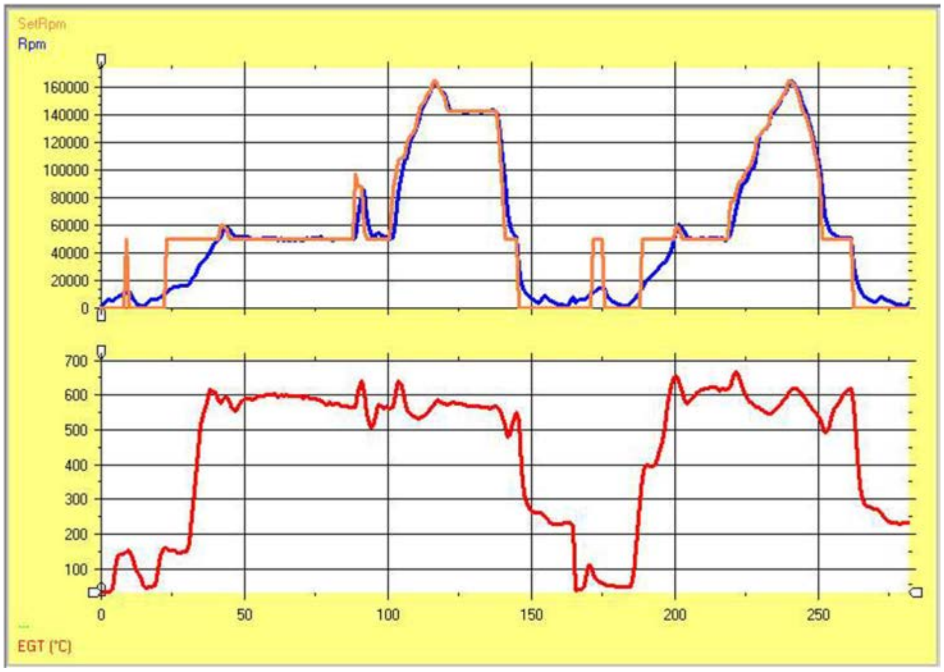


Figure 42. RPM/Set RPM and EGT vs. time Jet-tronic plots – kerosene test run #1 and previous tests

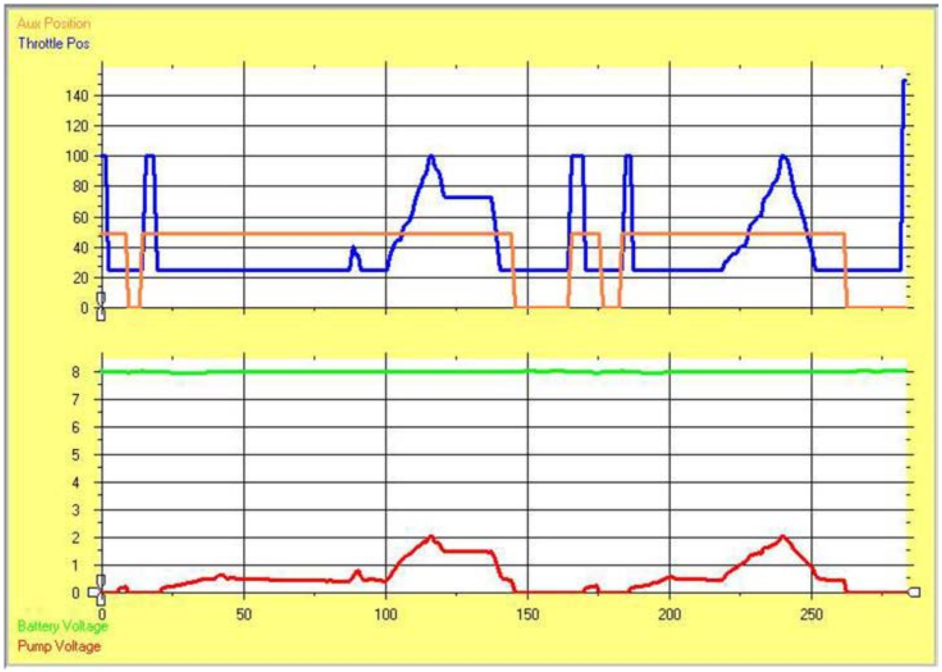


Figure 43. Throttle/aux positions and battery/pump voltage vs. time Jet-tronic plots – kerosene test run #1 and previous tests

With the experimental voltage and RPM data obtained from the NI DAQ and the ECU, and using the linear fit of the calibration data from Table 6, the following plot (Figure 44) was created to show the relationship between corrected thrust and corrected speed.

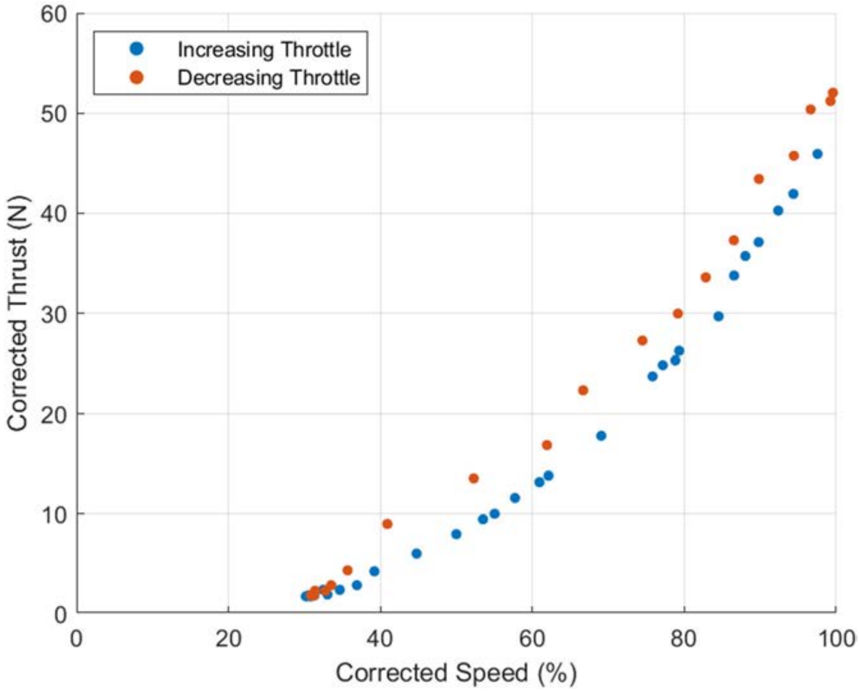


Figure 44. Corrected thrust vs. corrected speed – kerosene test run #1

b. Kerosene Test Run #2

The second test run was performed on October 29, 2020, with the goal to produce steady state results at five evenly spaced RPM settings, starting at idle (50,000 RPM) and incrementing up to maximum RPM (165,000 RPM), then decrementing back to idle (similar to the calibration phase). However, it was difficult to match the throttle to an RPM setting due to how much it fluctuated. Additionally, the speed settings were sustained too long for the amount of fuel stored in the tank, so the experiment was terminated early to prevent engine flame out. Figure 45 shows the data acquired from the NI DAQ and Figure 46 was from the Jet-tronic program. The NI DAQ and ECU log data were correlated together to produce a plot that isolates the steady state data (Figure 47).

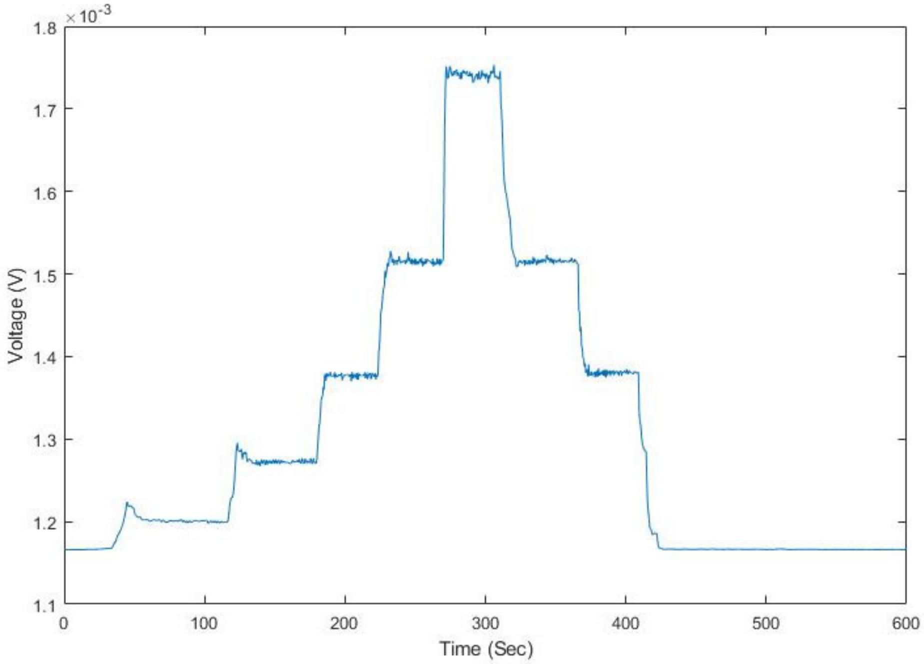


Figure 45. NI DAQ data from kerosene test run #2

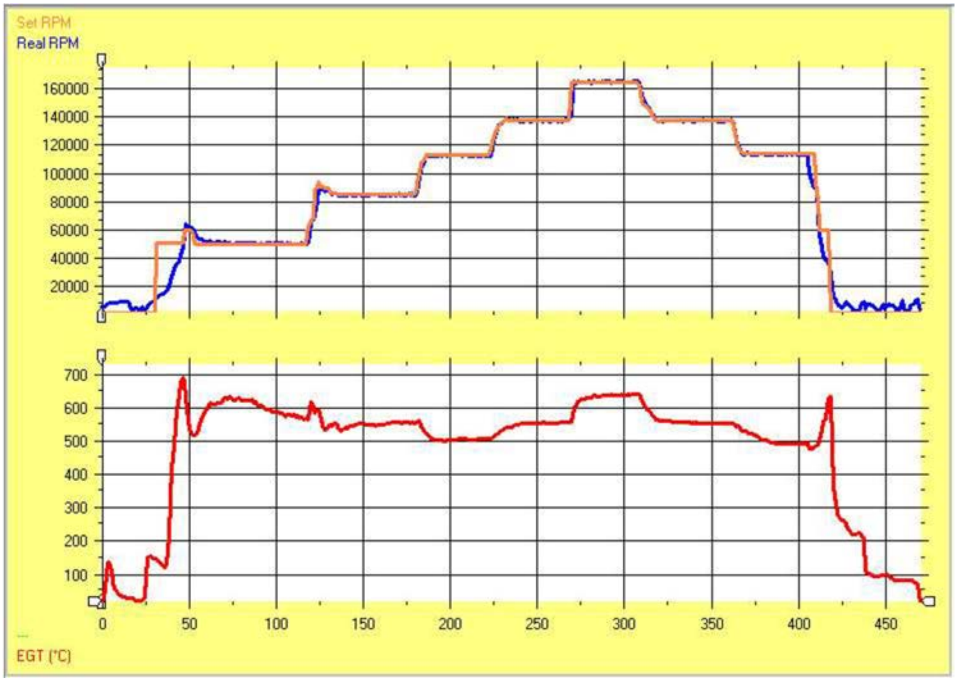


Figure 46. RPM/Set RPM and EGT vs. time Jet-tronic plots – kerosene test run #2

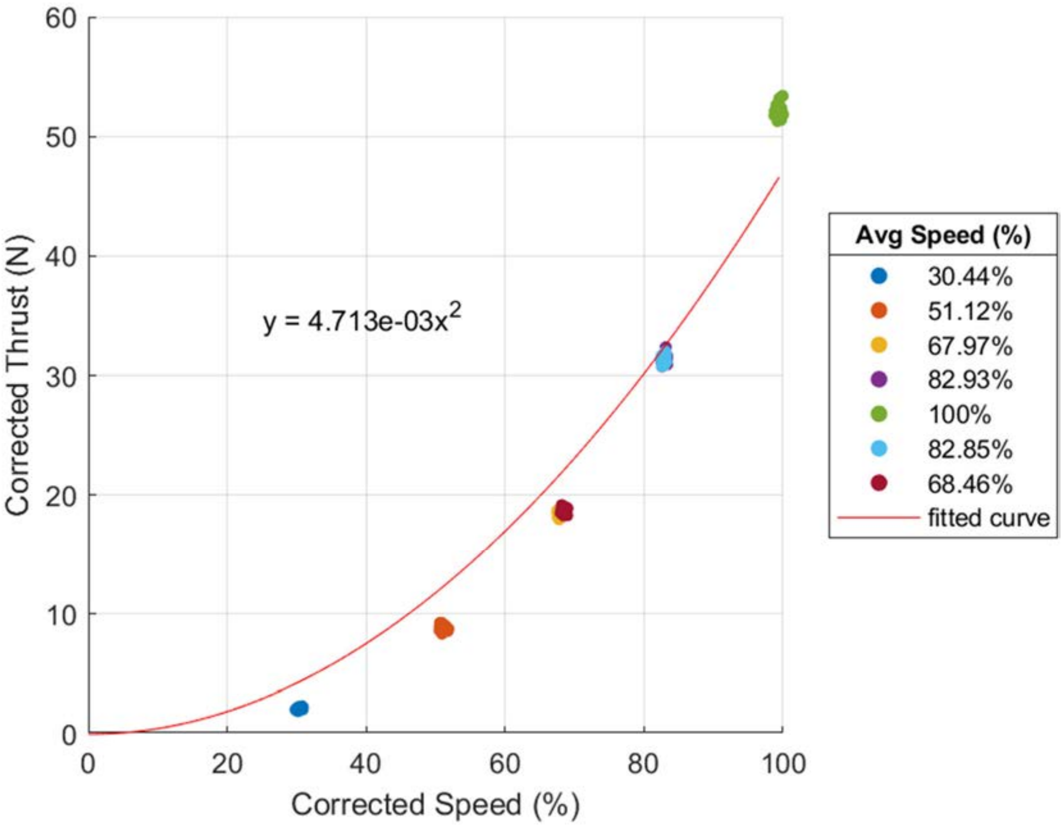


Figure 47. Corrected thrust vs. corrected speed – kerosene test run #2

c. *Kerosene Test Run #3*

The third test run was performed on February 3, 2021, with the goal to produce steady state results at six evenly spaced throttle settings, starting at idle (0% throttle) and incrementing up to 100% throttle, then decrementing back to idle (like the calibration phase). At each throttle increment, the engine was given a few seconds to stabilize before recording roughly ten seconds worth of data. The time at each steady state was shortened to avoid running out of fuel like during test run #2. Figure 48 shows the data acquired from the NI DAQ and Figure 49 was from the Jet-tronic program. The NI DAQ and ECU log data were correlated together to produce a plot that isolates the steady state data (Figure 50).

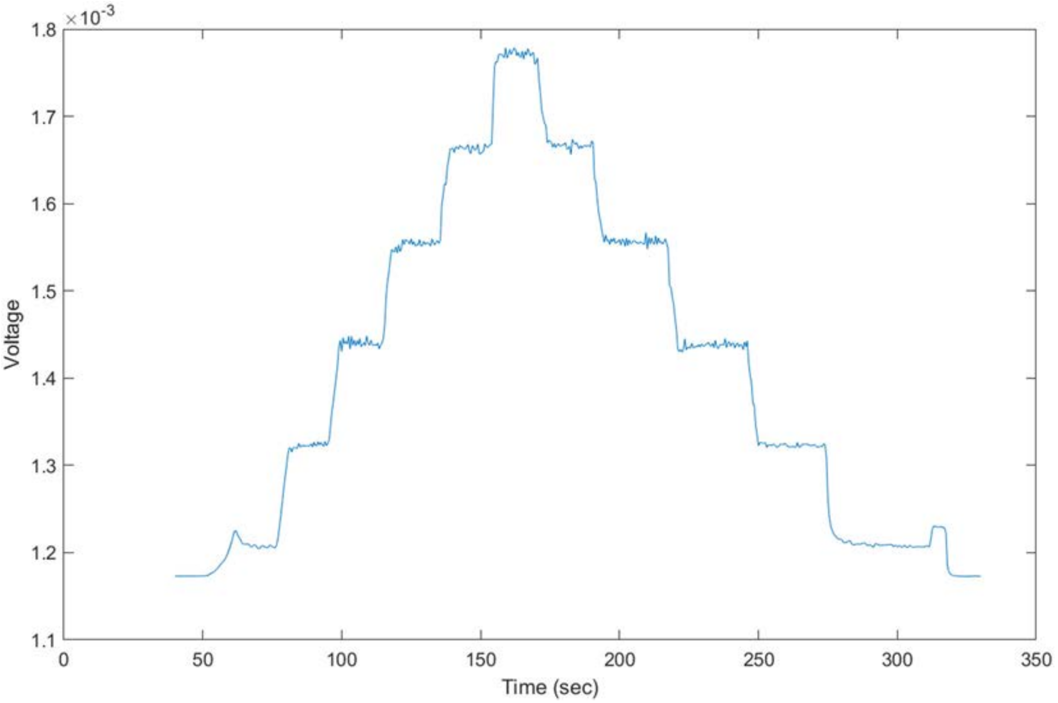


Figure 48. NI DAQ data from kerosene test run #3

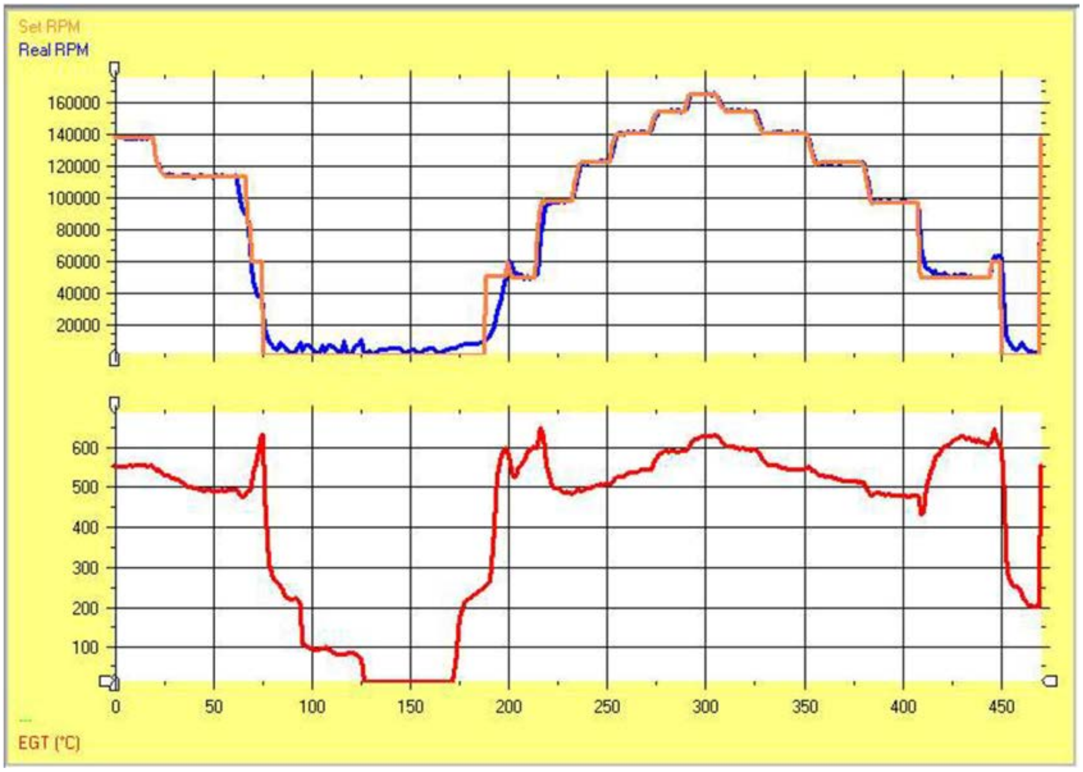


Figure 49. RPM/Set RPM and EGT vs. time Jet-tronic plots – kerosene test run #3

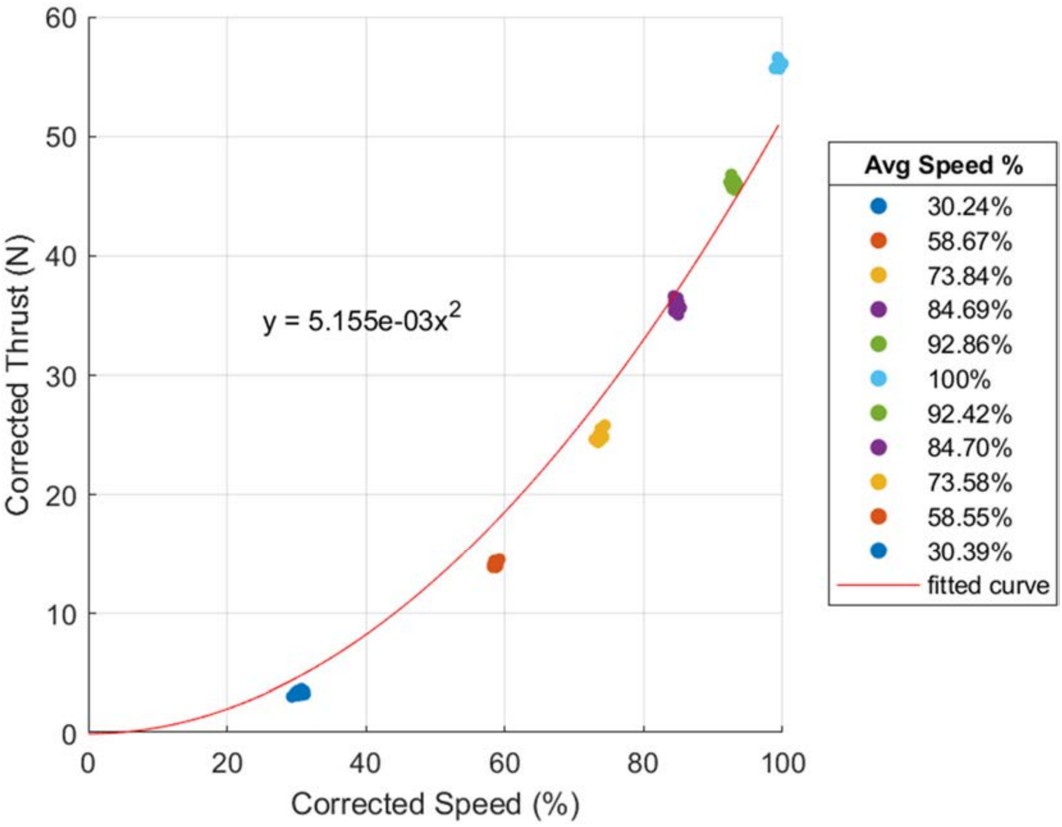


Figure 50. Corrected thrust vs. corrected speed – kerosene test run #3

d. Kerosene Test Run #4

The fourth test run was performed on February 16, 2021, with the main goal to determine fuel consumption at six evenly spaced throttle settings, but also to check for repeatability of the thrust data. Since thrust was not the main parameter being tested, the six evenly spaced throttle settings were only tested starting at 100% throttle then decreased to idle (0% throttle). At each throttle setting, the engine was given a few seconds to stabilize before recording roughly 30 seconds worth of data. Figure 51 shows the data acquired from the NI DAQ and Figure 52 was from the Jet-tronic program. The NI DAQ and ECU log data were correlated together to produce a plot that isolates the steady state data (Figure 53).

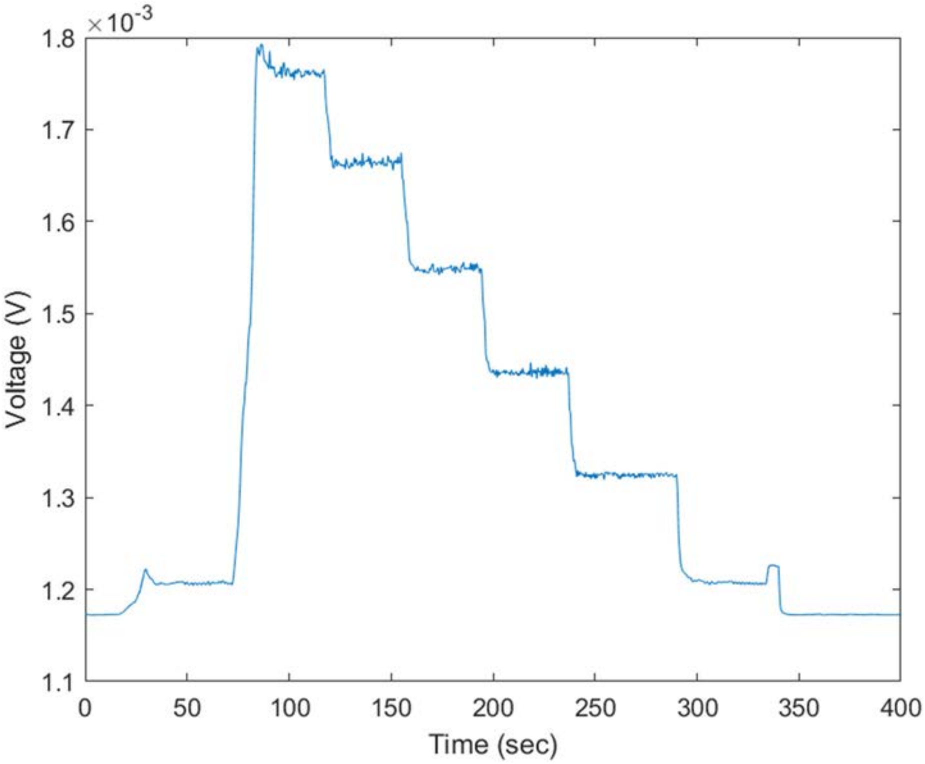


Figure 51. Voltage vs. time – kerosene test run #4

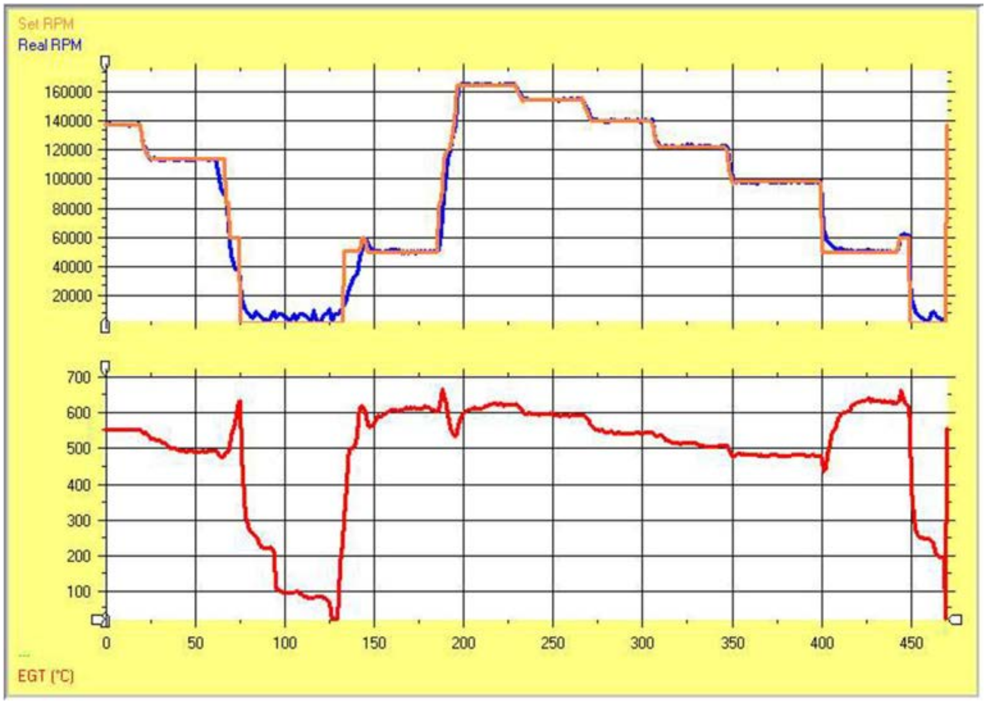


Figure 52. RPM/Set RPM and EGT vs. time Jet-tronic plots – kerosene test run #4

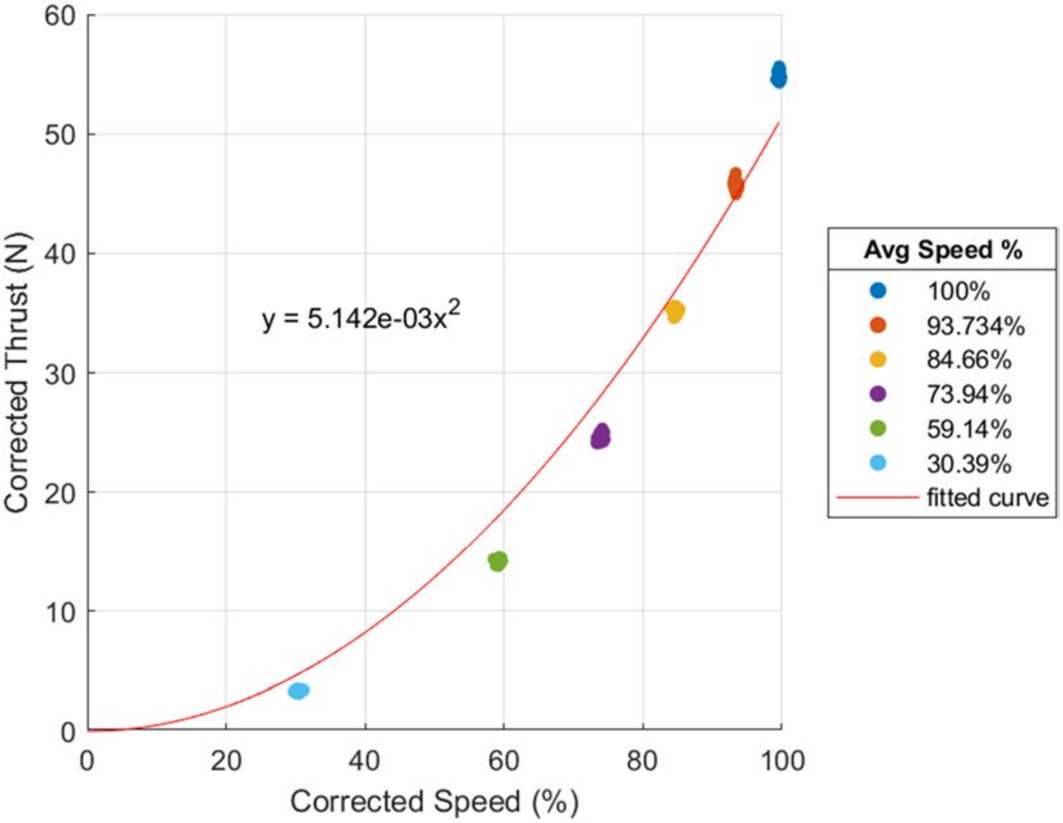


Figure 53. Corrected thrust vs. corrected speed – kerosene test run #4

Since the ECU does not record fuel consumption data, the fuel storage tank was placed on top of a scale and a video camera was used to record the displayed weight on the scale. This has the advantage of being an integral measurement and is thus accurate and stable. Table 9 shows the corrected specific fuel consumption (SFC) vs. corrected thrust at each speed setting and Figure 54 provides a plot of the data.

Table 9. Corrected specific fuel consumption vs. corrected thrust – test run #4

Avg. Speed (%)	Corr. SFC (g/kN-s)	Corr. Thrust (kN)
30.52	234.843	3.33e-3
59.39	132.520	0.0142
74.25	95.514	0.0246
85.02	73.341	0.0351
93.74	66.642	0.0457
100	61.984	0.0549

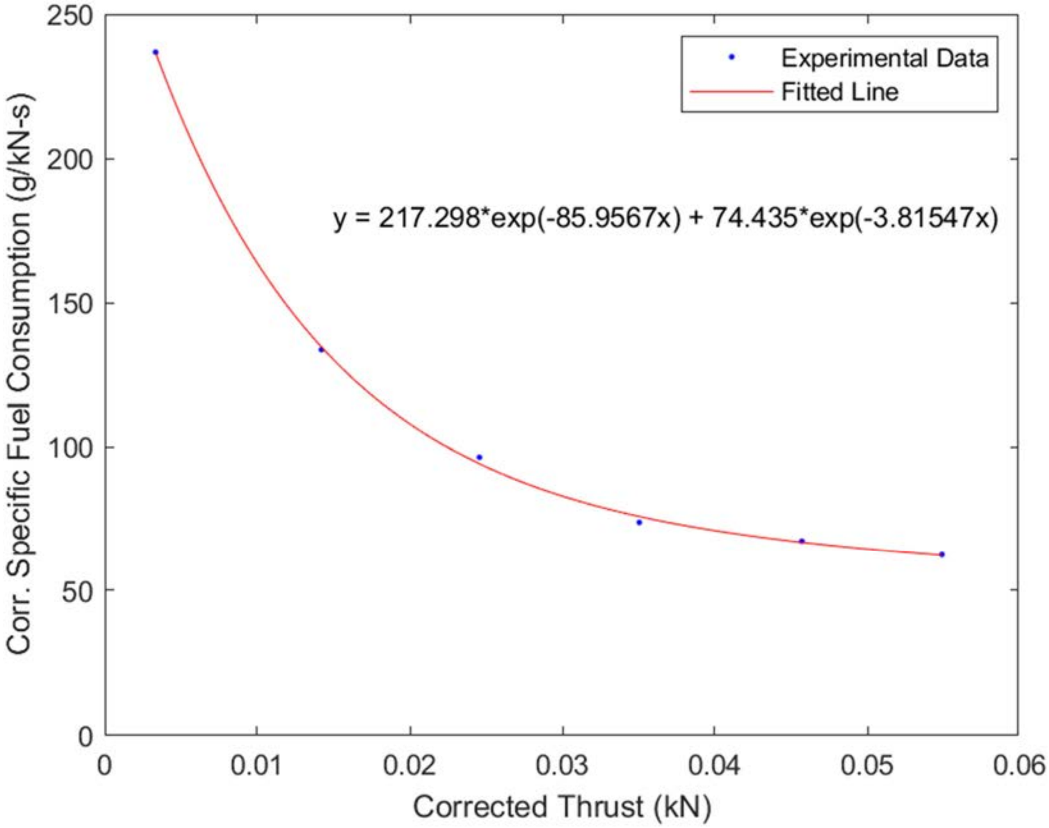
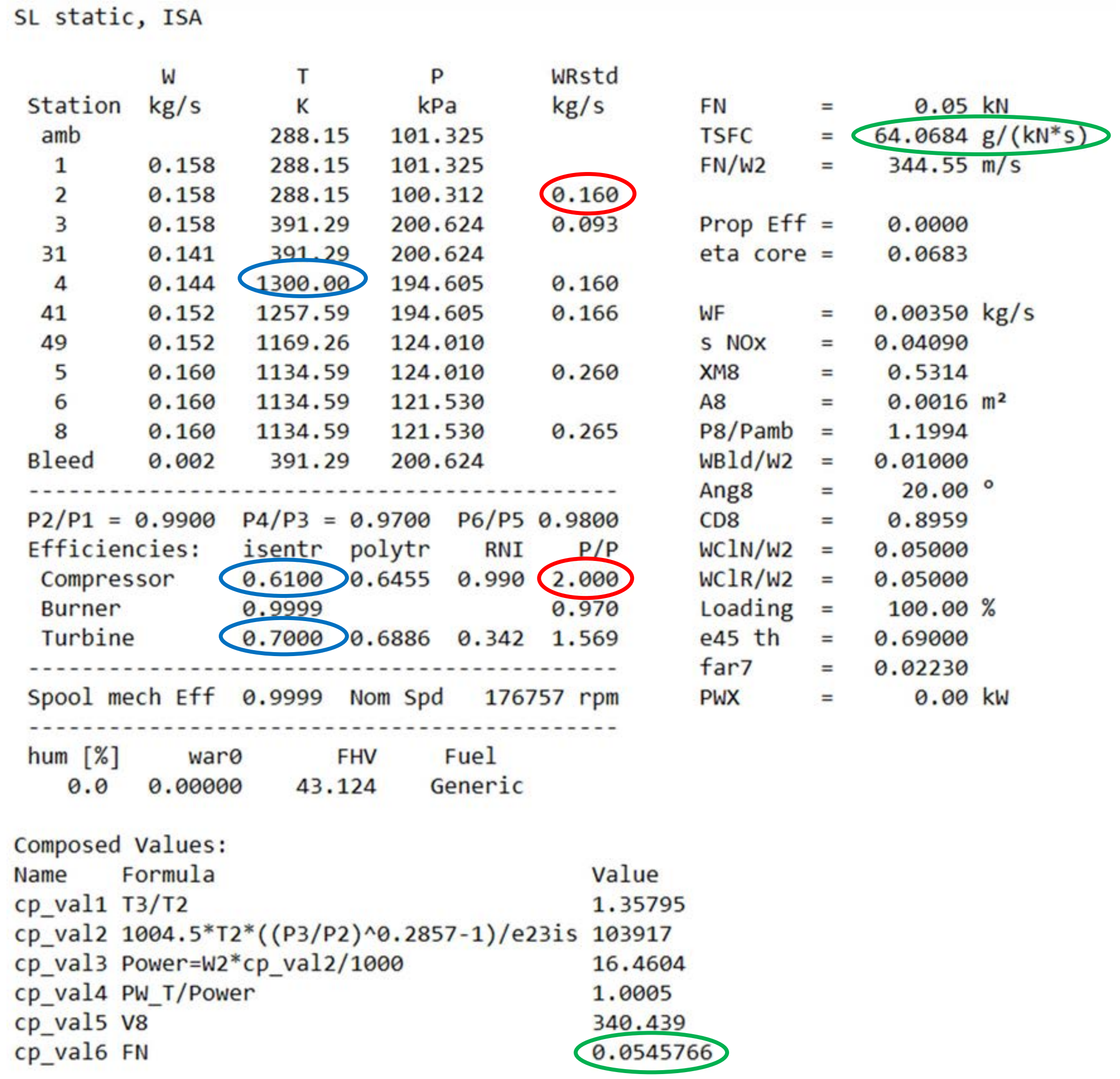


Figure 54. Corrected specific fuel consumption vs. corrected thrust – kerosene test run #4

2. GASTURB Simulations

GASTURB simulations were conducted using the demo turbojet using standard maps for comparison to the P60-SE engine specifications. The demo turbojet did not produce completely representative results primarily due to its multi-stage axial compressor, rather than a radial compressor like the P60-SE. The full results are shown in Appendix J. The mass flow rate and pressure ratio parameters (circled in red in Table 10) were adjusted to match JetCat's engine specifications (Appendix C), then burner exit temperature and compressor and turbine efficiencies (circled in blue in Table 10) were iterated until the thrust specific fuel consumption and net thrust (circled in green in Table 10) closely matched the experimental data at 100% speed (Table 9). These parameters correlated at a burner exit temperature (T4) of 1300 K, compressor efficiency of 61%, and turbine efficiency of 70%.

Table 10. GASTURB output summary



```
SL static, ISA

           W          T          P         WRstd
 Station  kg/s        K         kPa        kg/s       FN        =       0.05 kN
  amb               288.15    101.325                TSFC      =    64.0684 g/(kN*s)
   1      0.158     288.15    101.325                FN/W2     =     344.55 m/s
   2      0.158     288.15    100.312      0.160
   3      0.158     391.29    200.624      0.093     Prop Eff =     0.0000
  31      0.141     391.29    200.624                eta core =     0.0683
   4      0.144    1300.00    194.605      0.160
  41      0.152    1257.59    194.605      0.166     WF        =    0.00350 kg/s
  49      0.152    1169.26    124.010                s NOx     =    0.04090
   5      0.160    1134.59    124.010      0.260     XM8       =     0.5314
   6      0.160    1134.59    121.530                A8        =     0.0016 m²
   8      0.160    1134.59    121.530      0.265     P8/Pamb   =     1.1994
 Bleed    0.002     391.29    200.624                WBld/W2   =    0.01000
 -------------------------------------------         Ang8      =      20.00 °
 P2/P1 = 0.9900  P4/P3 = 0.9700  P6/P5 0.9800        CD8       =     0.8959
 Efficiencies:   isentr  polytr    RNI    P/P        WClN/W2   =    0.05000
  Compressor     0.6100  0.6455  0.990  2.000        WClR/W2   =    0.05000
  Burner         0.9999                 0.970        Loading   =     100.00 %
  Turbine        0.7000  0.6886  0.342  1.569        e45 th    =    0.69000
 -------------------------------------------         far7      =    0.02230
 Spool mech Eff  0.9999  Nom Spd   176757 rpm        PWX       =       0.00 kW
 -------------------------------------------
 hum [%]     war0       FHV     Fuel
    0.0   0.00000    43.124    Generic

Composed Values:
Name     Formula                                 Value
cp_val1 T3/T2                                    1.35795
cp_val2 1004.5*T2*((P3/P2)^0.2857-1)/e23is 103917
cp_val3 Power=W2*cp_val2/1000                    16.4604
cp_val4 PW_T/Power                               1.0005
cp_val5 V8                                       340.439
cp_val6 FN                                       0.0545766
```

Additionally, an off-design calculation was performed (Figure 55) and overlayed onto Figure 54 to see how the theoretical specific fuel consumption vs. thrust relationship compares to the experimental results (Figure 56).

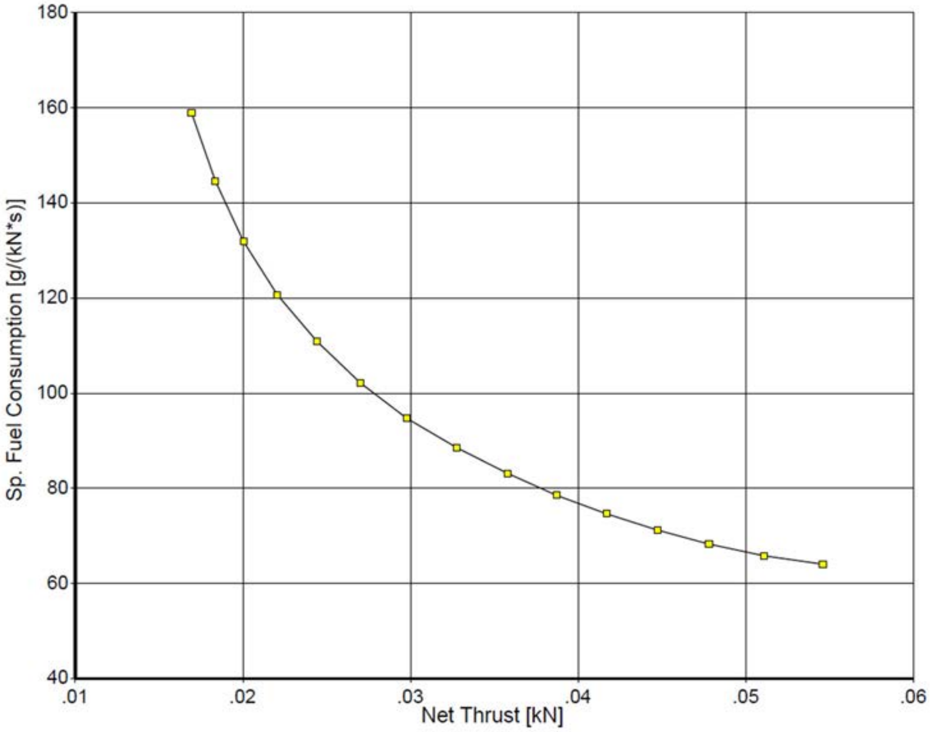


Figure 55. Specific fuel consumption vs. net thrust

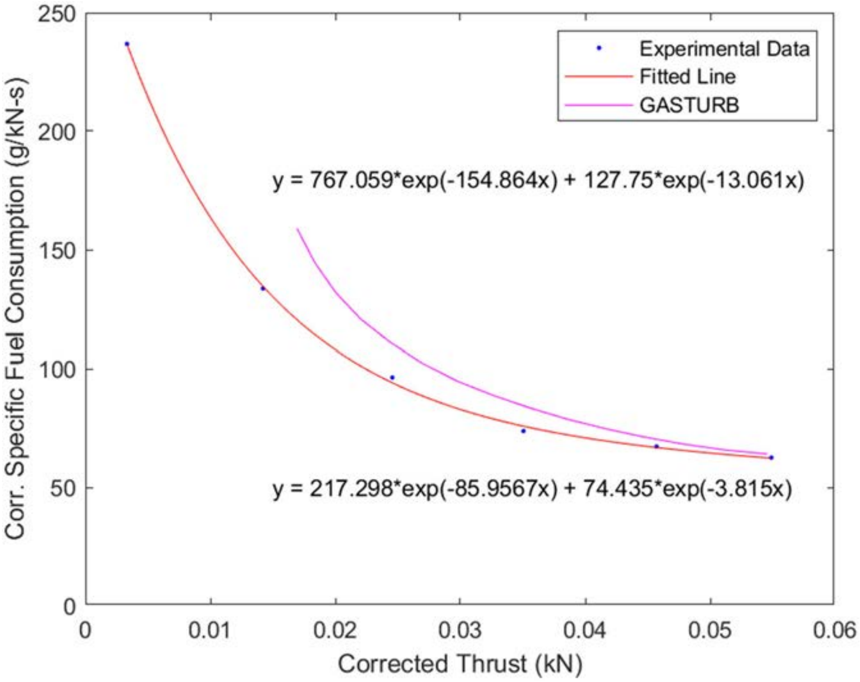


Figure 56. Specific fuel consumption vs. net thrust comparison

The GASTURB results show that the P60-SE is less efficient than standard turbojets, which is typical of very small engines. GASTURB was unable to perform calculations below 0.675 compressor spool speed because its estimations would yield results that were beyond the lower limit of the compressor map.

B. GASEOUS FUEL OPERATION

After sufficient performance data for kerosene fuel was obtained, the focus was shifted to operating the engine using only propane. The goal of each propane run was to test whether the engine can reach idle speed at different set points using the propane bottle valve-regulated adapter purchased from DreamworksRC (Figure 57). After each propane test run, the engine was operated with kerosene/synthetic oil at idle for a short period to lubricate the bearings. Photos of the system setup and connections can be seen in Appendix B.

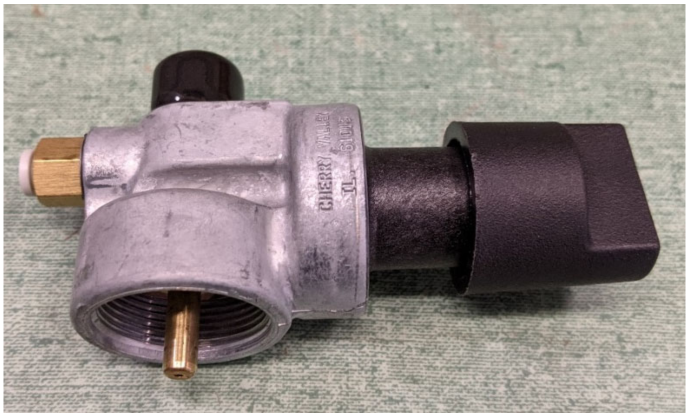


Figure 57. Propane bottle valve-regulated adapter

The adapter has six pressure set points and were measured to be 0.069, 0.414, 0.621, 0.896, 1.103, and 1.31 bar (1, 6, 9, 13, 16, and 19 psig) (Figure 58).

Figure 58. Measured pressure at highest valve setting 1.31 bar (19 psig)

Test runs at the first three pressure set points were performed on February 25, 2021, and were unsuccessful at reaching idle speed, but they demonstrated a noticeable increase in RPM after each test. Two more test runs were conducted on March 4, 2021, at 1.103 bar and 1.31 bar and resulted with similar trends. The ECU did not record the propane runs, rather maximum RPM and EGT values were obtained via HMI screen recordings (discussed in Chapter V). The corrected maximum RPM and EGT during each test is shown in Table 11 and provided as plots in Figure 59 and Figure 60. NI DAQ measurements are in Appendix H and the weather data and correction factors for all test runs are shown in Appendix I.

Table 11. Measured pressure and HMI data for propane test runs

Pressure gauge (bar)	0.069	0.414	0.621	1.103	1.31
Meas. Max RPM	17,000	23,400	26,800	31,900	33,900
Corr. Max RPM	16860.08	23207.40	26579.42	31637.44	33620.98
Max EGT (°C)	222	322	360	458	479

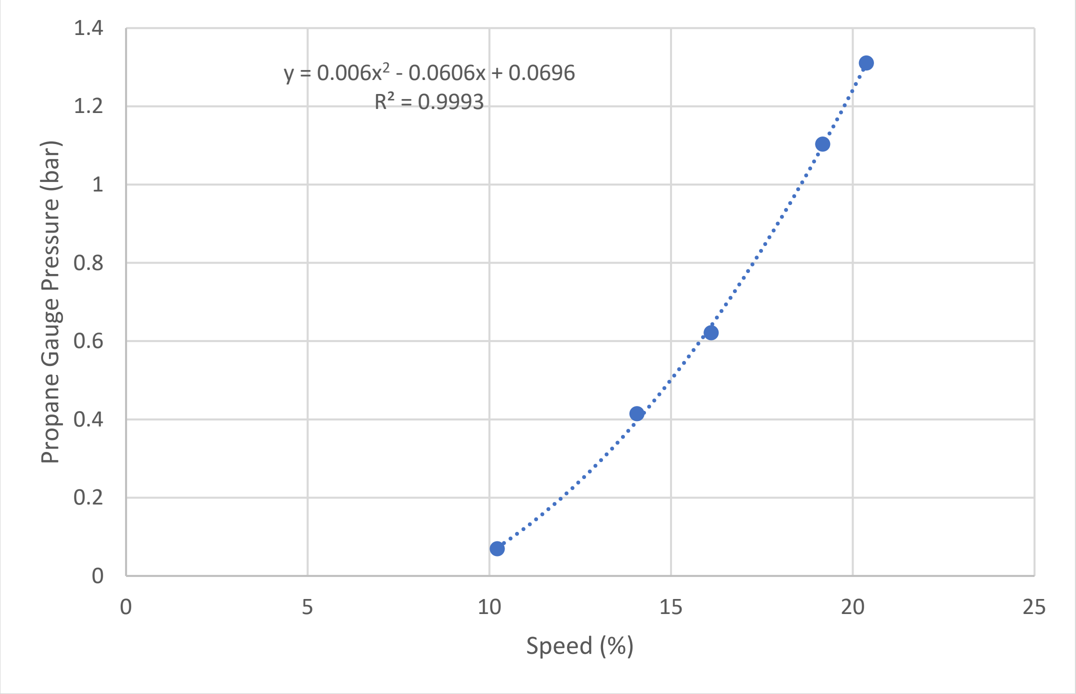


Figure 59. Propane pressure vs. speed

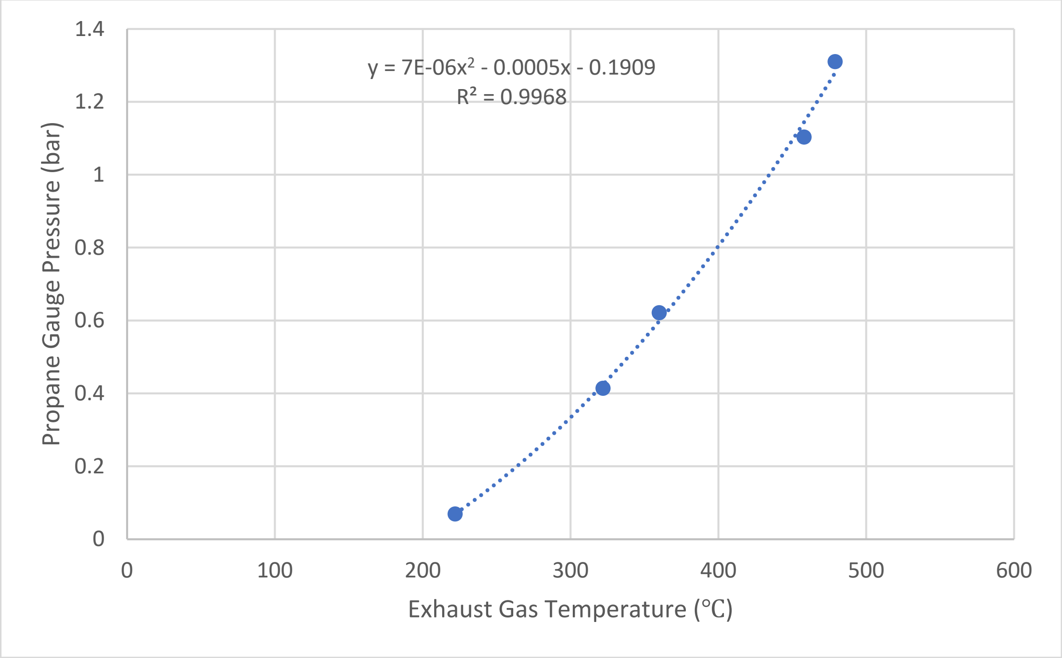


Figure 60. Propane pressure vs. EGT

C. DISASSEMBLY AND OBSERVATIONS

The following section will provide a description and measurements performed on each major section of the P60-SE. Before disassembly, the project team knew that an understanding of the propane starter and fuel/lube oil plumbing would be the top priority because the engine uses propane as starter fuel then sustains the combustion and provides lubrication with a kerosene/synthetic oil mixture. Up front, this posed a significant challenge to modifying this particular engine to operate with gaseous fuel due to the engine start sequence switching from starter gas to liquid fuel automatically. Alteration considerations and recommendations will be discussed in later sections. Figure 61 is an image of the disassembled P60-SE without its casing.

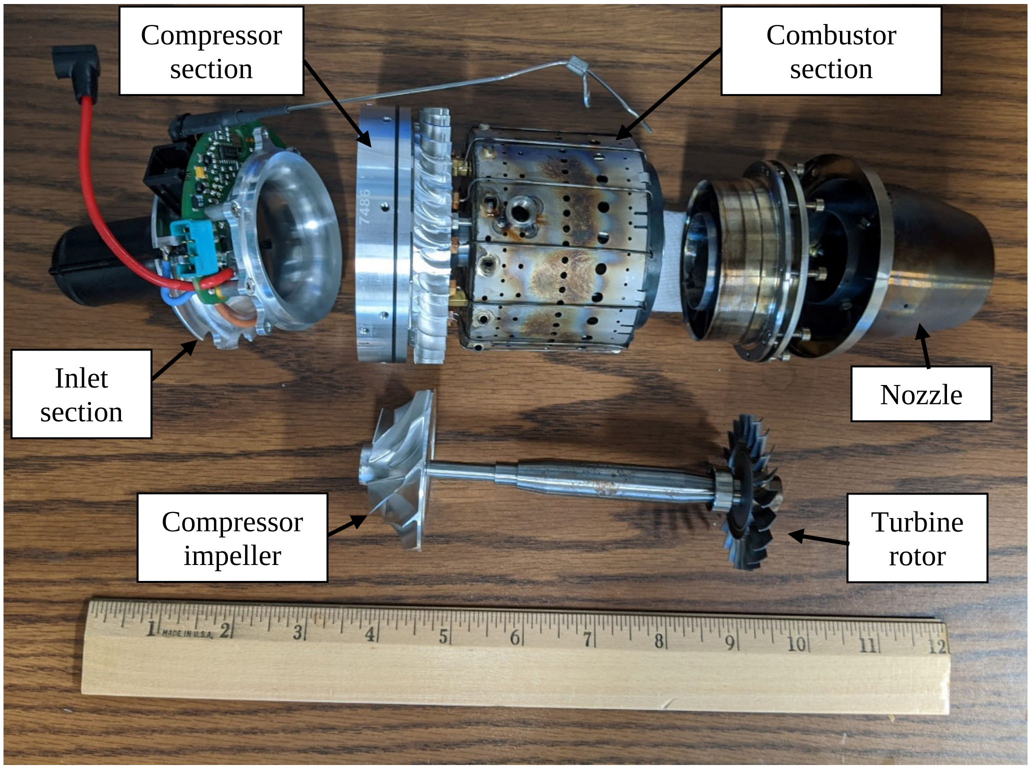


Figure 61. Disassembled JetCat P60-SE

1. Inlet Section

On the inlet section, the engine circuit board is stored just after the inlet within the casing (Figure 62). The circuit board functions include receiving commands from and sending engine status to the ECU via the 6-pin data cable port, storing basic engine characteristics and settings onto a memory chip [24], spinning the compressor via the electric motor, igniting the starter gas with the glow plug, and reading EGT from the attached thermocouple. The diameter of the inlet opening is about 38.5 mm.

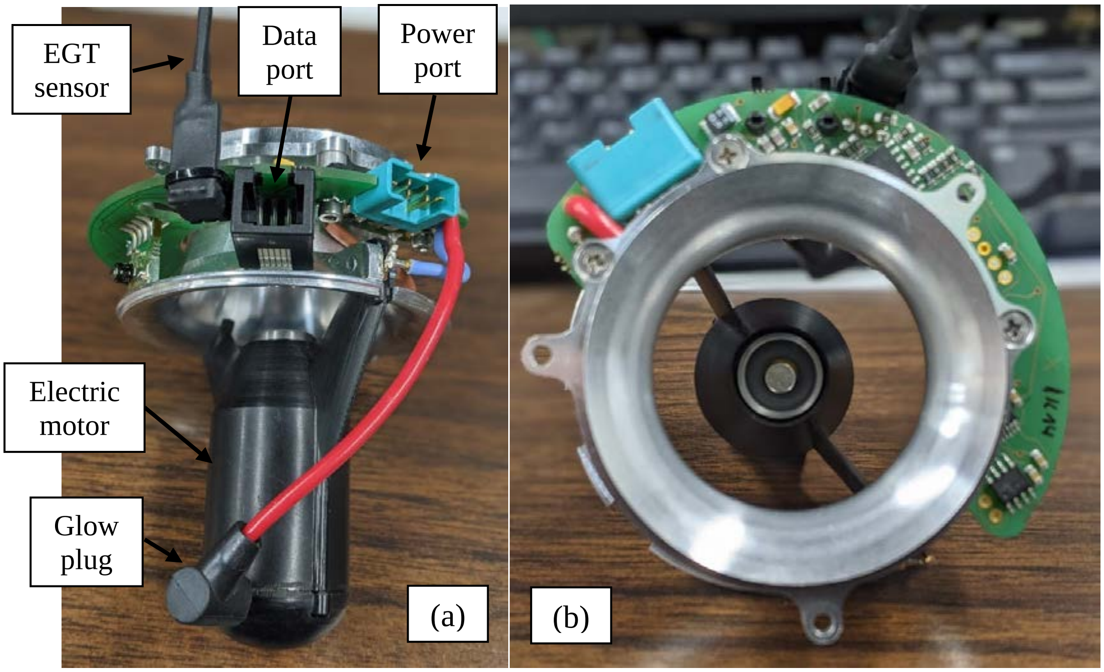


Figure 62. Side view (a) and rear view (b) of inlet section

2. Compressor

After the inlet section, the impeller (Figure 63) of the single-stage radial compressor would be positioned just in front of the fuel manifold, coupled (press-fit) to the shaft shared by the single-stage turbine, which passes through the center of the combustor. A coupler for the electric motor starter secures the impeller to the coupling shaft. The impeller has a total of 10 blades (5 short, 5 long). The air pulled in by the compressor impeller is directed radially outward through 11 radial stator vanes (Figure 64) and then rearward through the guide vanes. Some air enters the inside of the combustion chamber, while the rest of the air cools the outside of the flame tube and the casing. Measurements of the compressor section are in Table 12.

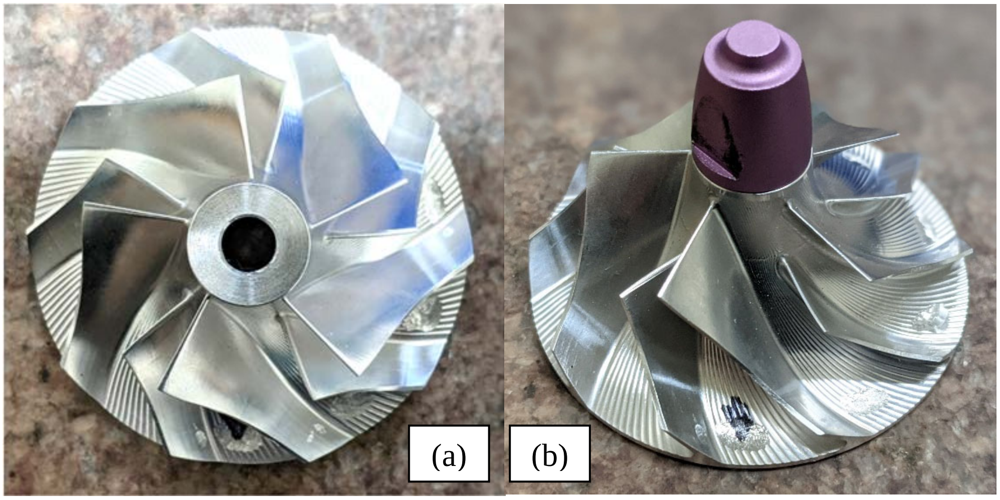


Figure 63. Compressor impeller (a). Impeller with electric motor coupler (b).

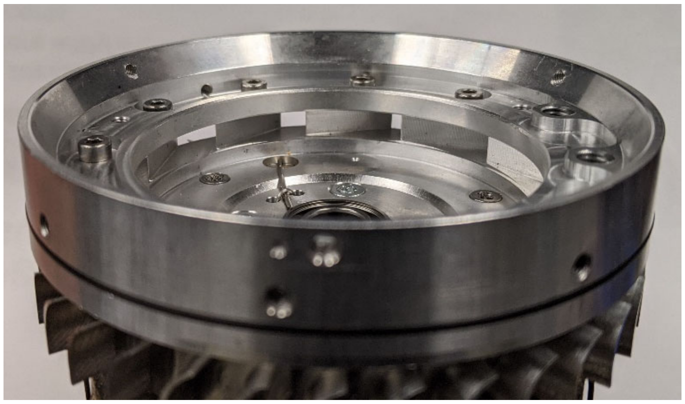


Figure 64. View of compressor radial stator vanes

Table 12. Compressor measurements

Impeller base diameter	54.0 mm
Impeller front diameter	13.5 mm
Impeller length (front to base)	22.7 mm
Radial stator vane (11) axial length	8.3 mm

3. Fuel Manifold

The fuel manifold contains the fuel and gas distribution network. On the front starting at the compressor section, the engine has one inlet port for fuel/oil and a separate inlet port for starting gas (Figure 65). The fuel/oil is distributed to the combustion chamber via the 12 fuel injectors and to the front and rear bearings via the lubrication injector. The starting gas flows into combustion chamber via two injectors (Figure 66). Additionally, inlet guide vanes are fixed around the perimeter of the fuel manifold baseplate to direct incoming air to the combustion chamber. Measurements of the fuel manifold section are in Table 13.

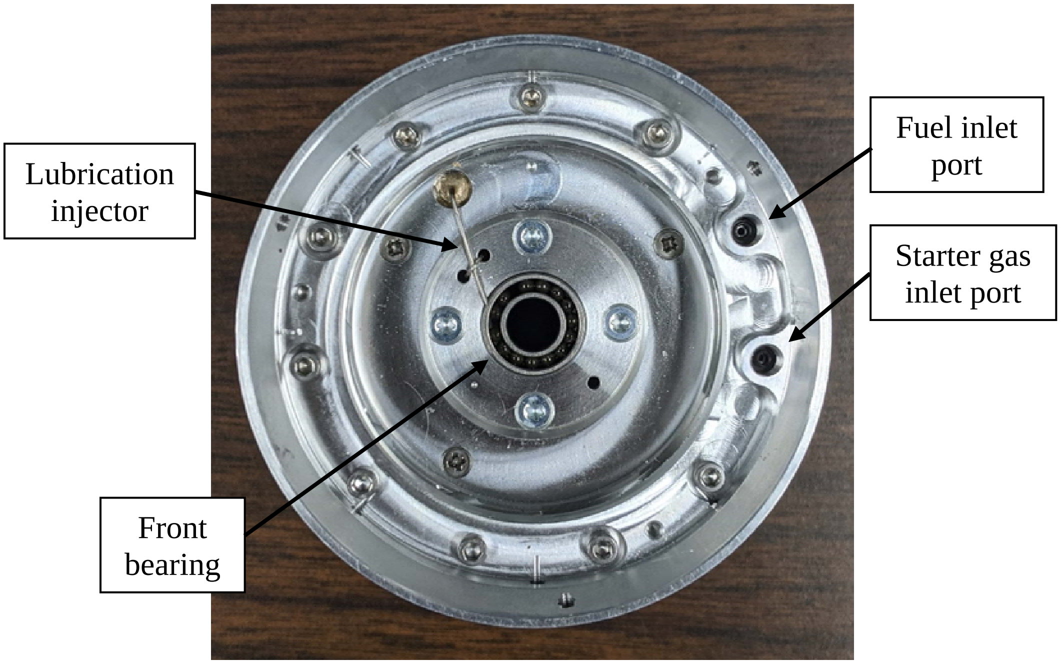


Figure 65. Front view of compressor section and fuel/oil distribution

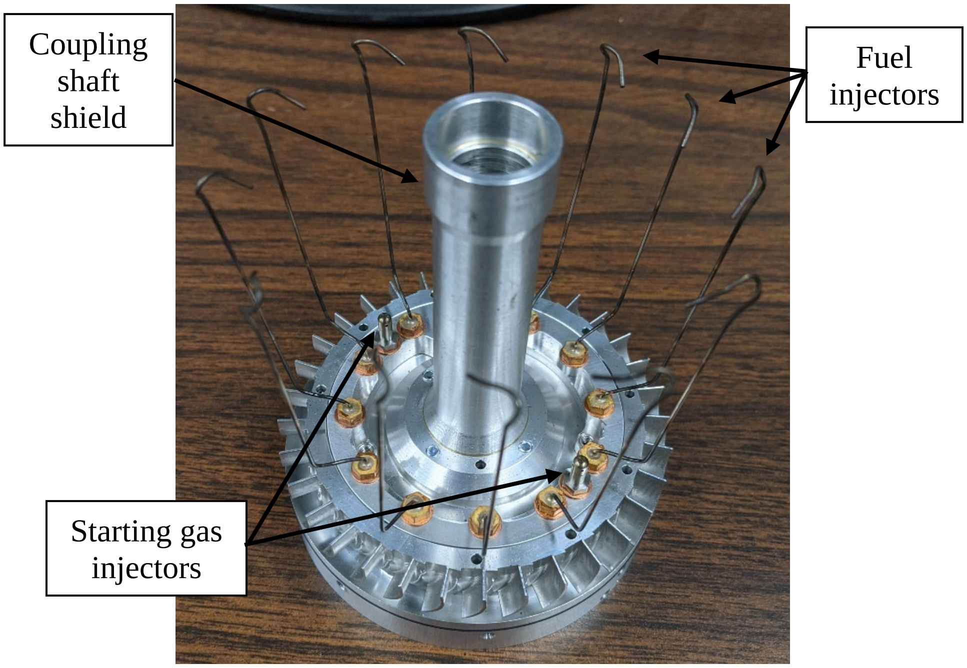


Figure 66. Fuel manifold base plate

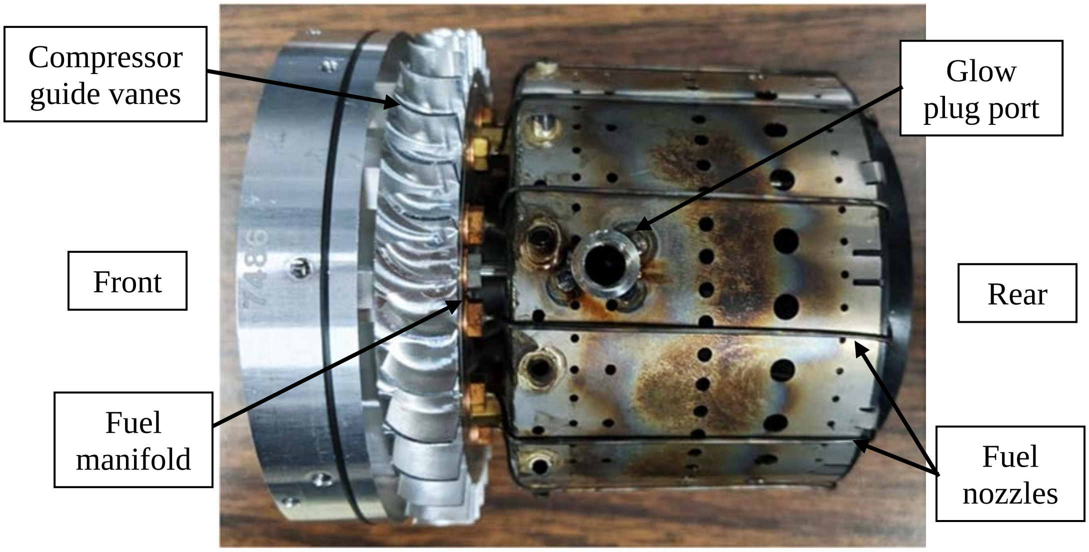


Figure 67. Side view of compressor and combustion chamber

Table 13. Fuel manifold measurements

Fuel injectors (12) outer diameter	0.82 mm
Length of fuel injectors	~52 mm
Starting gas injector (2) outer diameter	2.93 mm
Bearing lubrication injector outer diameter	0.73 mm
Axial length of inlet guide vanes (33)	9.2 mm

4. Combustion Chamber

The combustion chamber appears to be a reverse-flow axial, annular combustor. Air is introduced into the chamber through primary air holes (Figure 68 and Figure 69) and atomized fuel/oil is mixed with the air via the injectors and guide tubes (Figure 70). The guide tubes are used to preheat the atomized fuel before combustion, however, hydrogen gas does not need to be preheated due to its high heat of combustion. Instead, gaseous fuel can be introduced at the front of the combustion chamber, rather than through the fuel nozzles. Figure 69 (b) shows where fuel/oil mixes with the air entering through the primary holes. Each primary hole is tubed into the chamber at an angle to create a swirl effect, presumably. Measurements of the combustion chamber section are in Table 14.

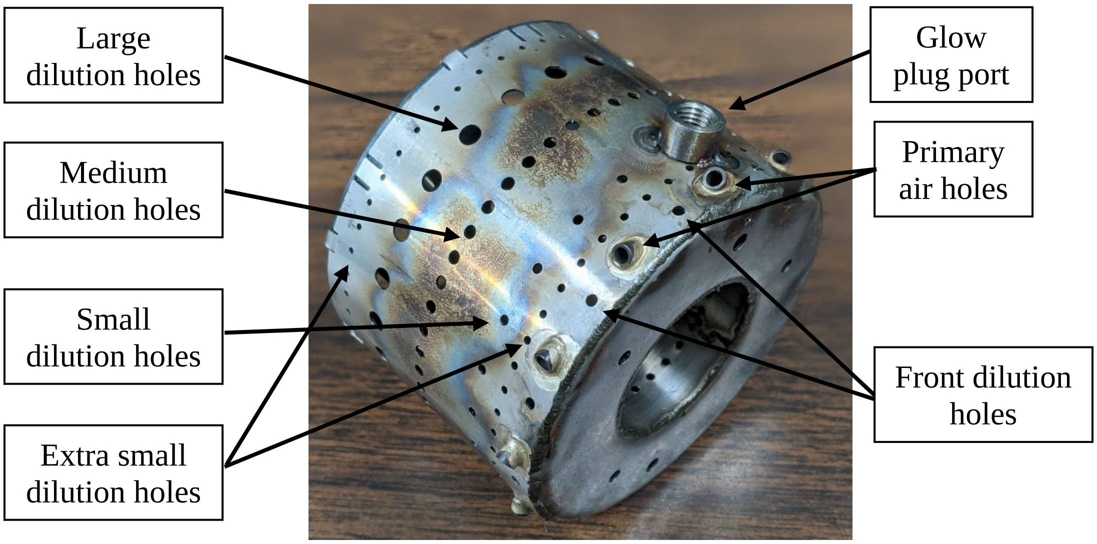


Figure 68. Combustion chamber

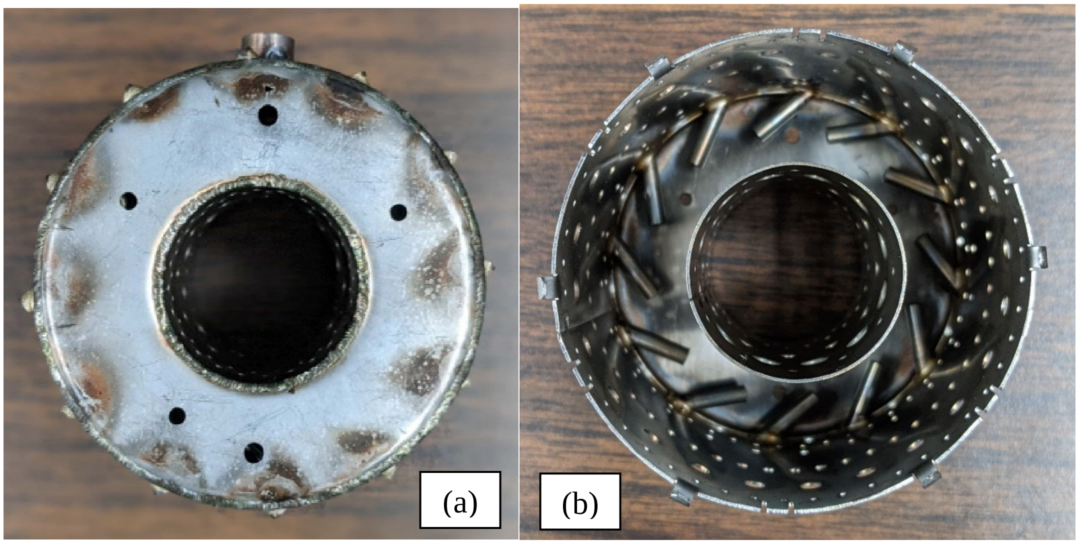


Figure 69. Intake side (a) and exhaust side (b) of combustion chamber

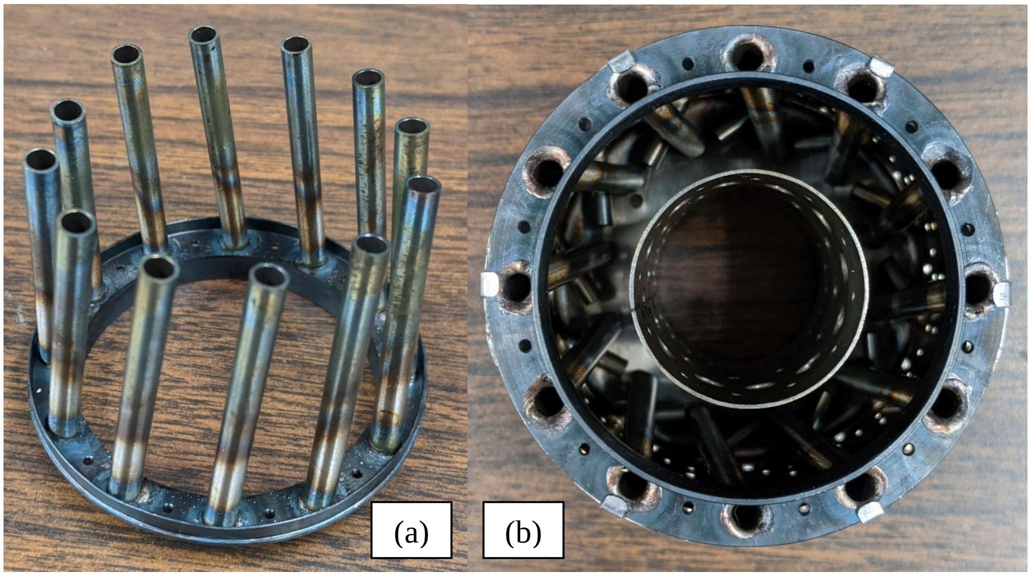


Figure 70. Fuel guide tubes (a). Assembled flame tube and guide tubes (b).

Table 14. Flame tube measurements

Outer diameter	70.0 mm
Rear opening inner diameter	53.47 mm
Shaft tube outer diameter	15.6 mm
Length overall	52.6 mm
Primary air tube holes (12)	2.4 mm
Large dilution holes (48)	3.47 mm
Medium dilution holes (48)	2.14 mm
Small dilution holes (23)	1.8 mm
Extra small dilution holes (47)	1.3 mm
Front dilution holes (12)	1.8 mm

5. Turbine

After the combustion section, the air is expanded through the turbine section. It first passes through the 11-blade stator (Figure 71), where it is directed rearward to the 21-blade rotor (Figure 72). The rotor, in turn, drives the compressor via the coupling shaft, continuing the process. Measurements of the turbine section are in Table 15.

Figure 71. Turbine stator

Figure 72. Rear view of turbine rotor

Table 15. Turbine measurements

Stator inner diameter	32.8 mm
Stator outer diameter	53.45 mm
Stator axial length	13.5 mm
Rotor inner diameter	32.8 mm
Rotor outer diameter	53.45 mm
Rotor blade radial length	20.65 mm

6. Nozzle

The nozzle provides the thrust for the engine by increasing the velocity of the exhaust gases from the turbine and provides a mounting point for the EGT thermocouple (Figure 73). The nozzle converges slightly and has a center body fixed within the nozzle to reduce the exhaust area and increase the thrust (Figure 74). Measurements of the turbine section are in Table 16.

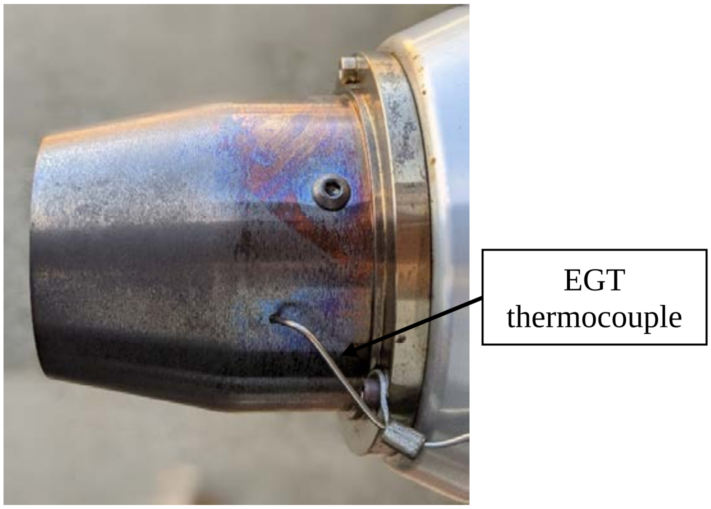


Figure 73. Side view of nozzle

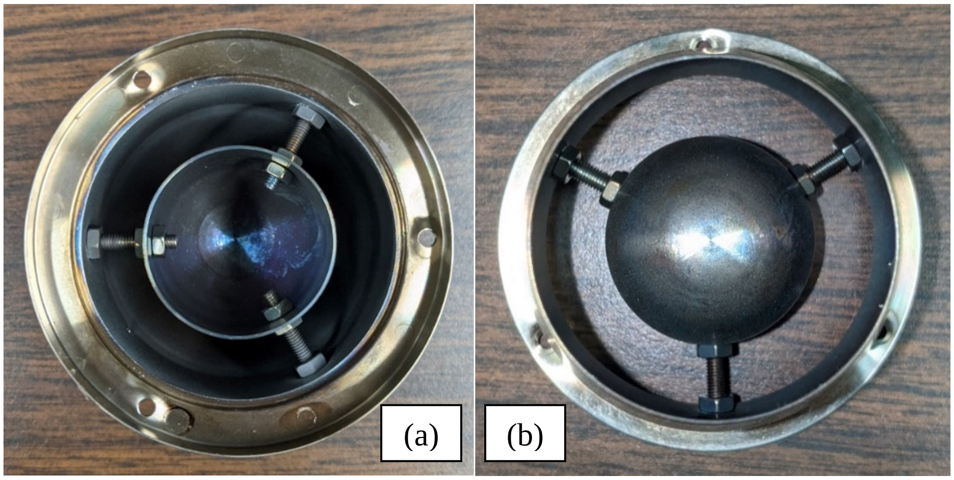


Figure 74. Front/inner view (a) and rear/outer view (b) of nozzle

Table 16. Nozzle measurements

Front inner diameter	52.4 mm
Rear inner diameter	40.2 mm
Center body outer diameter	31.2 mm
Length overall	49.0 mm
Length of straight section	17.9 mm

D. PROPOSED MODIFICATIONS

With the baseline setup and operation completed, further advancements towards a fully operational hydrogen-fueled gas turbine can be pursued. Future work can begin with a system redesign for operating with gaseous fuels. A basic layout of the proposed system redesign is in Appendix K.

One proposed modification would be to isolate the fuel and lubrication plumbing to provide lubrication to the bearings without introducing oil into the combustion chamber. The fuel injectors can be sealed shut and synthetic oil can be pumped into the engine's designed liquid fuel inlet port so that the oil will only be directed out of the bearing lubrication injector. With a dedicated lubrication system, the engine's designed starting gas inlet port would then be used as the gaseous fuel inlet. Another proposal is to modify the fuel and gas manifold to accommodate two more gas injectors to fill the combustion chamber adequately and evenly. In doing so, the ECU would have to be reprogrammed to open and close the shut-off valves accordingly, or different remote-operated valves can be utilized so that the user can open and shut them manually.

With the propane tank valve-regulated adapter, the engine demonstrated increasing RPM with allowable exhaust gas temperatures, but the adapter could not output more than 1.31 bar. Therefore, one proposed modification would be to increase the pressure output from the propane tank using the same voltage signal that is sent from the ECU to the fuel pump. Controlling the pressure of a fluid would allow a user to control the mass flow rate (assuming minimal change in temperature) because pressure is proportional to density (equations 5 and 6) since gas is compressible. Also, velocity can be written in terms of the static-to-stagnation pressure ratio (equation 7).

$$Ideal\ gas\ law: P = \rho RT \qquad (5)$$

$$P \propto \rho$$

where P is pressure, ρ is density, R is the universal gas constant, and T is temperature.

$$Modified\ definition\ of\ density: \rho = \frac{P_o}{RT_o}\left(\frac{P}{P_o}\right)^{\frac{1}{\gamma}} \qquad (6)$$

where P is static pressure, P_o is stagnation pressure, γ is the ratio of specific heats (c_p/c_v).

$$Velocity: v = \sqrt{1 - \left(\frac{P}{P_o}\right)^{\frac{\gamma-1}{\gamma}}}\sqrt{2c_pT_o} \qquad (6)$$

This can potentially be accomplished by using an electropneumatic actuator, such as the Emerson TESCOM ER5000 [29] (Figure 75), connected to a pneumatically actuated regulator. A transducer, such as the TESCOM 100–625 Series Pressure Transducer Transmitter [30], would have to be installed downstream of the regulator to provide feedback to the electropneumatic actuator (Figure 75). Table 16 shows notable specifications of the ER5000. Emerson's proprietary software, TESCOM ERTune, can be used to collect data and to tune the controller.

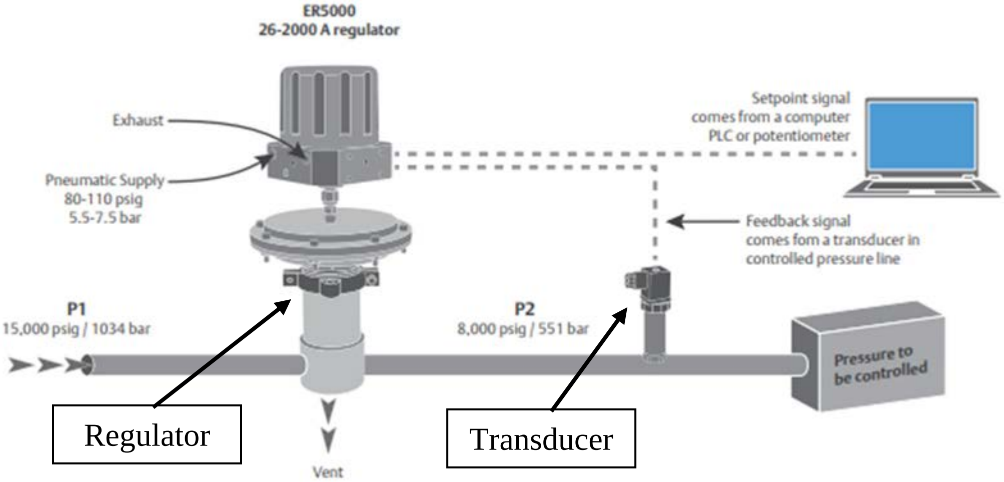


Figure 75. ER5000 typical pressure reducing application. Source: [29].

Table 17. Notable ER5000 specifications. Source: [29].

Specification	Value
Power requirement	22 to 28.5 VDC, 340 mA maximum, 180 mA nominal
Pneumatic supply	"Clean, dry inert gas or instrument grade air" [29] 1-120 psig, 110 psig nominal
Input signal	4-20 mA, 1–5 VDC
Feedback signal	4-20 mA or 1–5 VDC
Gas port (inlet, exhaust and gauge)	1/8 inch - 27 NPTF

Since the required input signal is 1–5 VDC, the ECU signal would have to be amplified because the fuel pump is powered by about 0.4 V at idle and about 2.2 V at maximum RPM, based on the experimental log data (Appendix H). A mass flow controller connected upstream of the pneumatically actuated regulator would allow the user to view and better control fuel flow rate. The Alicat Scientific MC series mass flow controller (Figure 76) has an available flow measurement range of 0.025 SCCM to 5000 SLPM and a maximum operating pressure of 10 bar (145 psig) [31]. It is recommended to install a check valve downstream of the mass flow controller as a precaution if high back pressures are expected.

Figure 76. Alicat mass flow controller. Source: [31].

With all this said, it is important to keep in mind that the engine's liquid fuel inlet port supports tubing with a diameter of 4 mm and its starting gas inlet port supports tubing with a diameter of 3 mm. If compatible adapters of different diameters can be obtained, that would allow more flexibility with the redesign.

E. DISCUSSION

Further testing is required to properly determine whether the engine can fully operate on gaseous fuel. During the kerosene test runs, baseline data was successfully obtained to better understand how the engine performs across its full operating range. The engine performed consistently across all kerosene tests (Figure 77) and demonstrated a wide range of operating speeds (nearly 30.5% of maximum RPM on average when at idle).

Though the propane test runs only produced transient results, the maximum thrust and RPM were recorded and added to Figure 77 as well.

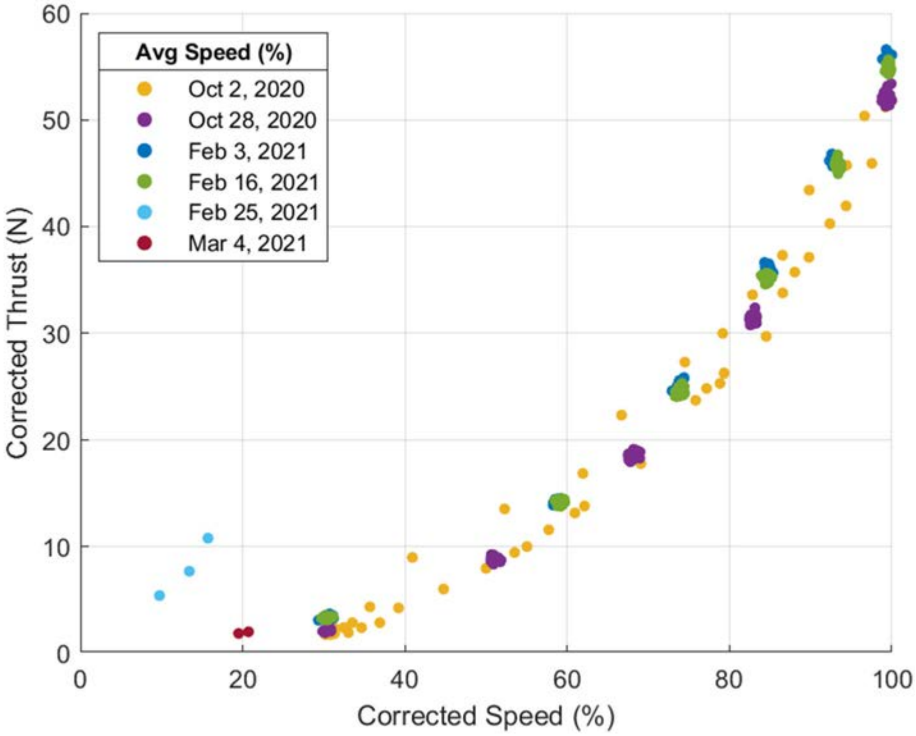


Figure 77. Plot overlay with all test runs

The initial test run produced only transient results which were inadequate, but it helped confirm the data acquisition equipment, test the methodology, and make improvements for future runs. For the second test run, trying to match RPM for steady state measurements was difficult and there was not enough fuel in the tank to complete the full intended test run, but the data appears to follow the same trend as the following tests. The testing method was more refined for the third and fourth test runs, which may have contributed to the two nearly identical results.

Test runs at the various pressure set points on the propane adapter were unsuccessful at reaching idle speed, but they demonstrated a noticeable increase in RPM and EGT with each increase in propane pressure. This shows that the engine has potential to run on gaseous fuel. Since vapor pressure of propane is about 6.42 bar (93 psig) at 15.6℃

(60°F) [28] and the maximum pressure setting on the propane adapter is 1.31 bar (19 psig), there is still a wide range of propane pressures that can be tested. However, the thrust data only partially reflected the same trend, demonstrating inconsistent results between the two days of propane testing. This could be due to an issue with the data acquisition equipment or because the electric starter never disengaged from the compressor.

During all the propane attempts, the ECU integrated data logger did not record engine parameters, rather the RPM and EGT data were collected using the Windows 10 built-in screen recorder (see Appendix G for instructions). The engine never reached idle speed during the propane test runs, so it is likely that the data logger does not start recording until it successfully reaches idle RPM (state 6 or 7 on page 26 of the instruction manual [19]). Another possible reason is that the electric motor never disengaged during the propane test runs, which may be due to lower EGT during startup compared to kerosene. It seems as if the ECU considered the propane attempts as failed starts, rather than operating time.

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V. CONCLUSION

A. SUMMARY

The goal of the thesis was to modify the JetCat P60-SE in order to operate it using gaseous fuel. Although this goal was not fully realized, this research focused on learning how to operate the engine effectively and how the engine is designed internally, gathering performance data, and documenting learning outcomes and findings. It provides a basis for system modifications to perform further testing, so that future work can focus on optimizing processes and implementing the proposed redesigns. The lubrication and fuel plumbing must be modified to only allow lubrication of the bearings, not injection of oil into the combustion chamber. Once that is accomplished, the fuel and gas system can be modified to accommodate higher gas pressures and control the gas and lube oil flows via the ECU.

B. RECOMMENDATIONS

One recommendation is to optimize the system arrangement or layout. To reduce the time it takes to prepare and stow the engine, it would be helpful to mount a weatherproof control box that can house the engine control and auxiliary equipment onto the test stand or onto the building. It would also be helpful to modify the DAQ connections to allow users to operate the engine remotely from the viewing window of test rig #2 within building 214 at the NPS TPL for added safety, especially when running with hydrogen gas. Therefore, the following list is provided with items to obtain:

- Bulk shielded CAT5 cable (at least 400 ft)
- CAT5 plug connectors (at least 4)
- female ethernet-to-male micro-USB adaptor (plugs into the USB interface)
- female ethernet-to-male USB-A adaptor (at least 2 – connects the USB interface and DAQ unit to a computer)
- Alternative: female 6-pin data cable-to-male USB-A adaptor

Though the Jet-tronic software was instrumental in gathering performance data from the ECU, the log data is somewhat limited. It would be valuable to capture the engine performance data even during failed starts when operating with gaseous fuel because the data can demonstrate trends. Also, the fuel consumption rate is not included in the ECU log data output. Either programming the ECU to output those data or manually logging the engine data with HMI screen recordings would be helpful for future test runs. An exhaust air velocity or pressure sensor may be helpful as well because it would allow the user to compare experimental exhaust velocity data to the theoretical exhaust velocity found in the engine specifications.

Finally, it is recommended to modify the MATLAB code to have a graphical user interface (GUI). The estimated total time for recording was entered prior to each engine run and MATLAB continued recording for the preset length of time. A GUI that allows a user to start and stop the data recording and output a file with the date and time of the recording will be helpful. Also, it would be more helpful to automatically output a thrust versus time plot, rather than a voltage versus time plot. Sufficient calibration and periodic checks would have to be conducted due to the possibility of unexpected changes in strain gauge response.

APPENDIX A. CHALLENGES AND APPROACH

One limitation is that the engines were delivered without an instruction manual, so the project team spent weeks using a seemingly outdated instruction manual [19], forums, and videos from the internet to setup and test the engine. Because the manual did not completely match the equipment, the team used shared information from the online community of recreational jet hobbyists and trial-and-error to fully set up and operate the engines. Another challenge was that the engines did not come with all the pieces of equipment to operate the engine, so delays in finding equipment to borrow, processing parts orders, and delivery times also hampered progress, especially for the USB interface, CAT’s proprietary data collection component.

The approach to accomplish the objective included:

1. Testing the effectiveness of the existing cantilever beam and bonded strain gauges (Chapter III.A.1), fabricating a new data acquisition method if ineffective;
2. Adapting the data acquisition code (Appendix F) and calibrating the strain gauge output (Chapter III.A.2);
3. Learning how to properly operate the P60-SE prior to mounting onto the thrust beam (Chapter III.B) and documenting the operating procedures (Appendix G);
4. Mounting then running the P60-SE with liquid fuel (kerosene) and utilizing remote monitoring software to collect baseline measurements (Appendix H);
5. Running software simulations to compare with experimental data and theoretical operation with gaseous fuels (Appendix J);
6. Disassembling the P60-SE and analyzing the internal components (Chapter IV.C);
7. Proposing changes to P60-SE to operate with gaseous fuel (Chapter IV.E).

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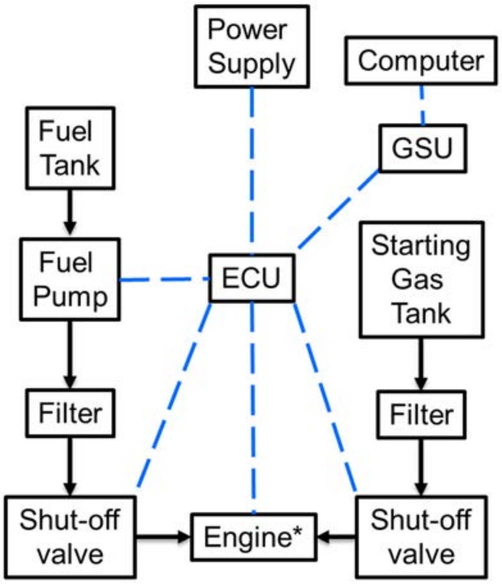
APPENDIX B. SYSTEM SETUP

The system setup was completed using the electrical and fuel connection diagrams and instructions on pages 6–12 of the instruction manual [19] as well as online forums. The photos in this section first provide a top-level view, then progressively show more detailed views of the components and connections. A basic schematic is shown in Figure 78.



*Electric starter, glow plug, data transfer

Figure 78. Basic connection schematic

The main equipment was initially staged on a test bench to avoid causing potential issues with the thrust beam while learning how to operate the engine. Then, the main equipment was mounted to the outdoor test stand with the thrust beam to perform measurements. When aligning the system for propane operation, another gas shut-off valve, gas filter, and PVC tubing were connected via splitter (wye arrangement) with the propane tank line and starting gas line (Figure 88). This arrangement sent propane through both the starting gas and fuel injectors based on ECU logics. The fuel pump remained connected but in a closed loop to make the ECU think that it is fueling the combustion with the fuel pump (Figure 89).

A. SYSTEM SETUP DURING PRELIMINARY TESTING

The equipment used only during preliminary testing included a 2-cell, 7.2 VDC LiPo battery to power the system and a transmitter and receiver to operate the engine. The transmitter and receiver used were the Spektrum DX7s 7-Ch DSMX radio system with AR8000 receiver. The preliminary setup was based on the electrical connection diagram (Figure 79) on page 6 of the instruction manual [19].

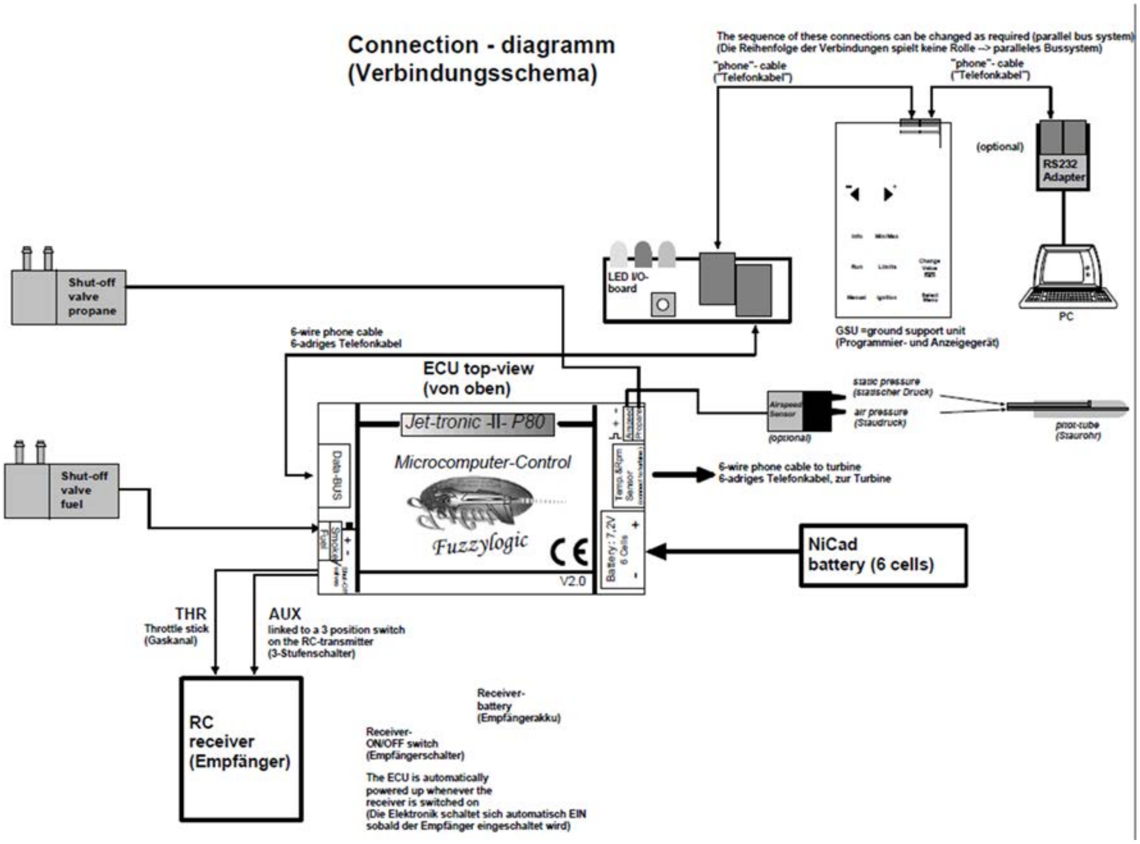


Figure 79. Electrical connection diagram. Source: [19].

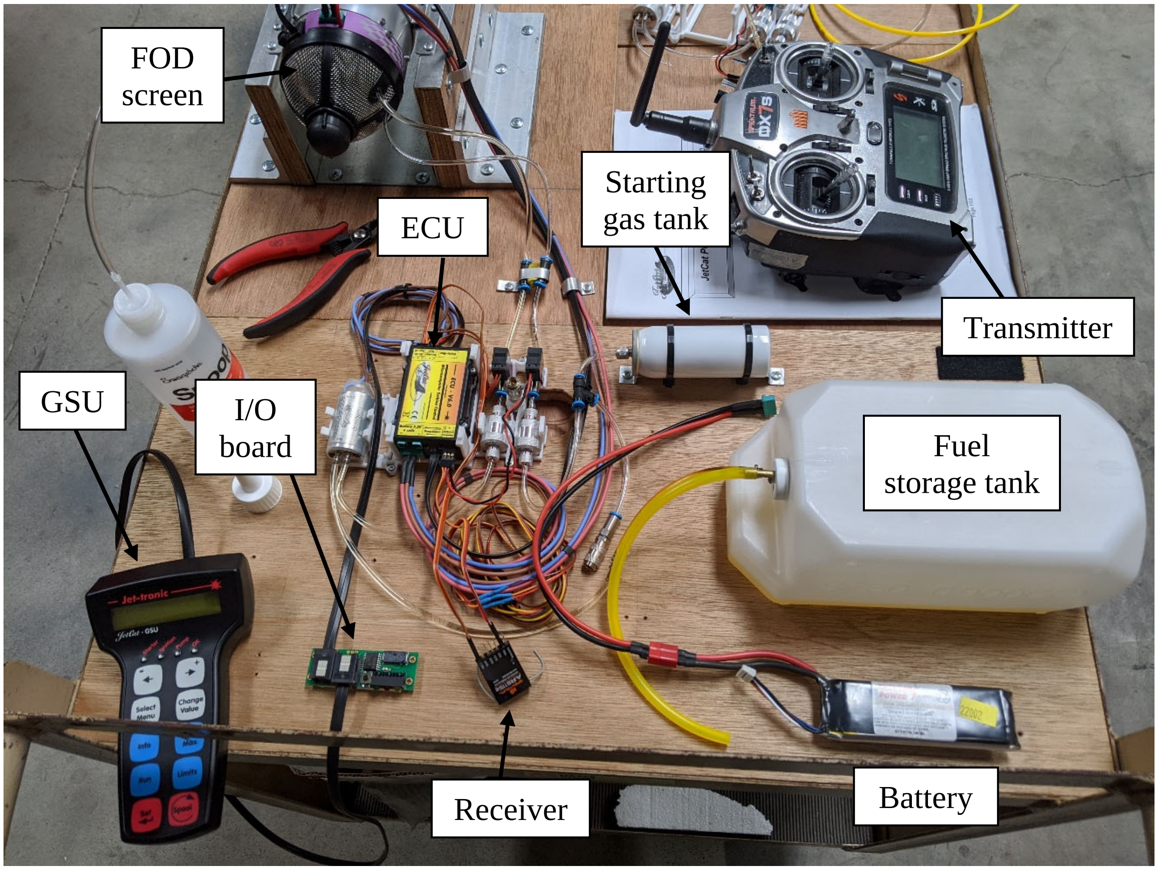


Figure 80. Test bench photo #1

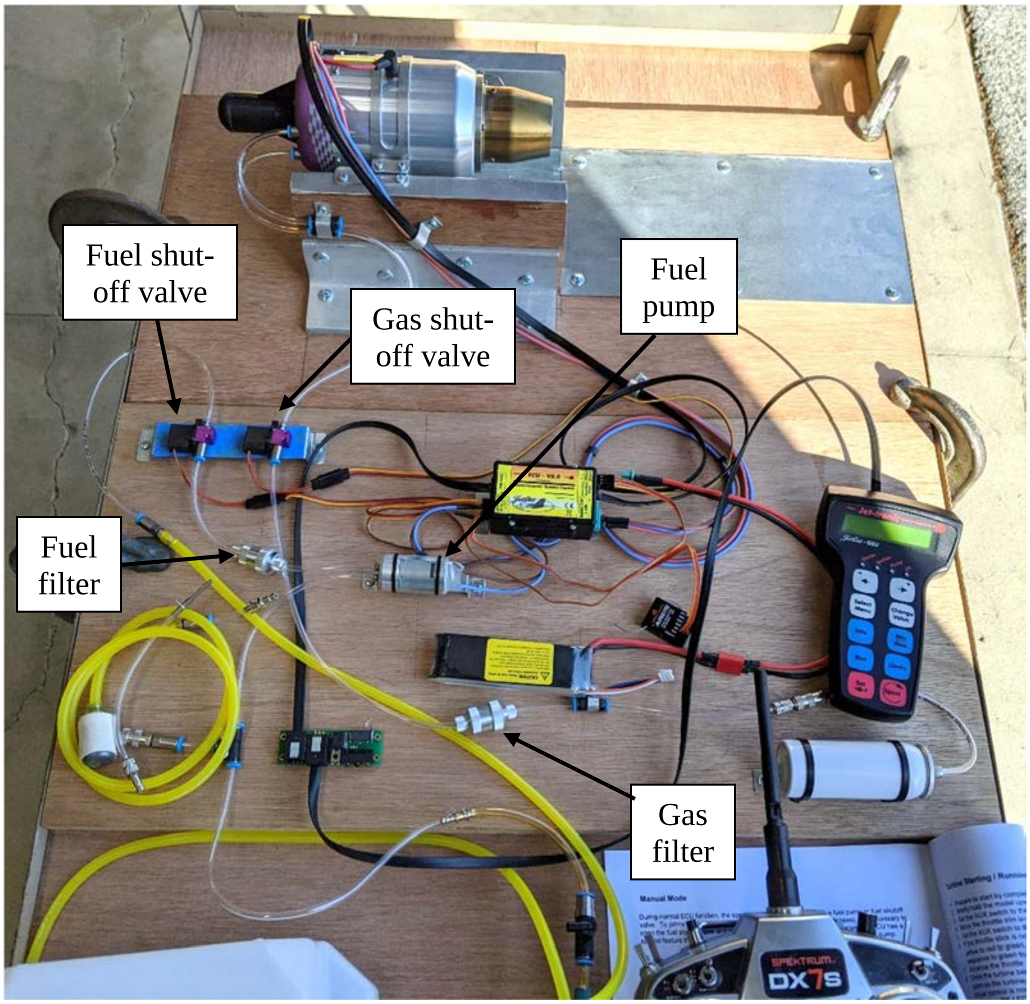


Figure 81. Test bench photo #2

The fuel and starting gas lines were all 4 mm diameter PVC tubing with the exception of the tubing entering the engine's starting gas inlet, which was 3 mm diameter tubing.

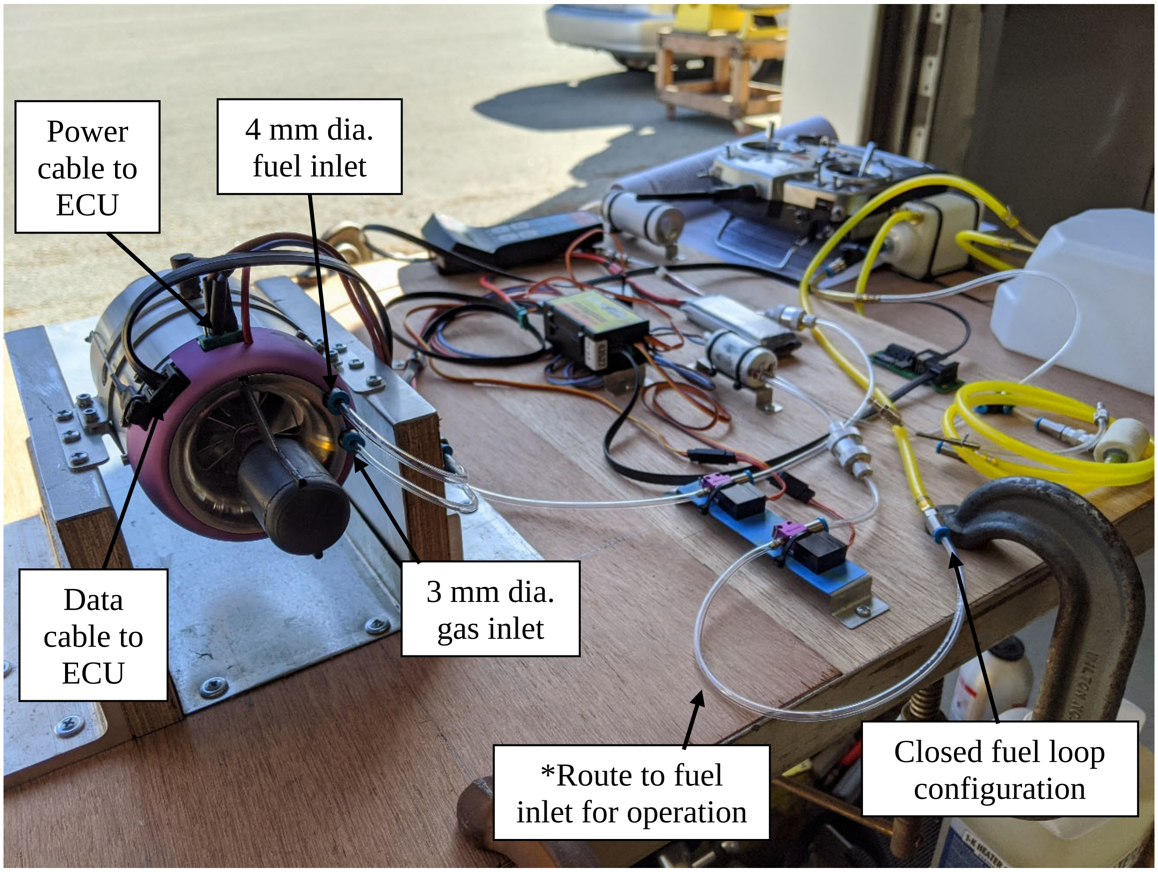


Figure 82. Test bench photo #3

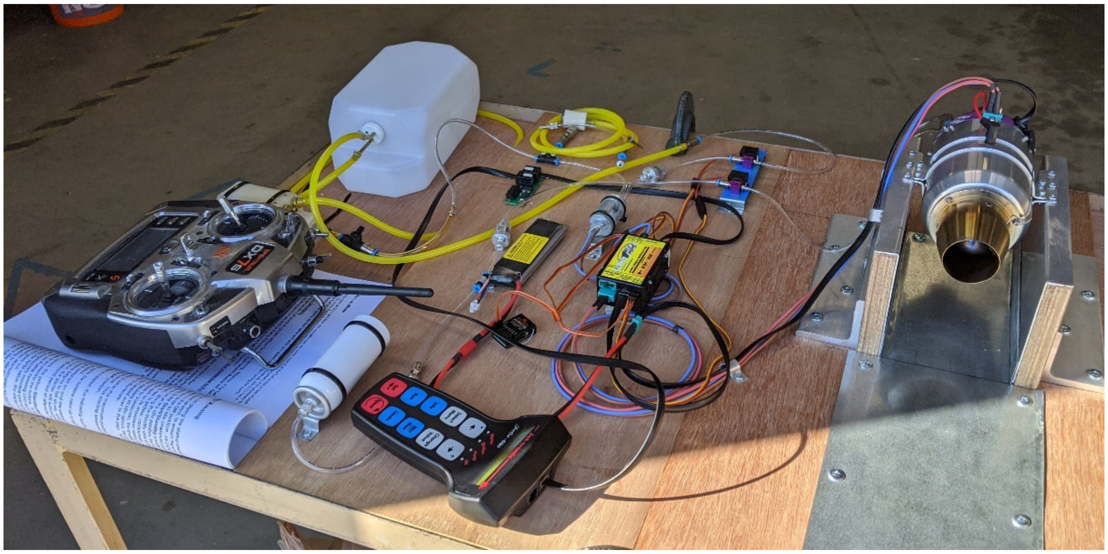


Figure 83. Test bench photo #4

B. SYSTEM SETUP WITH THRUST BEAM

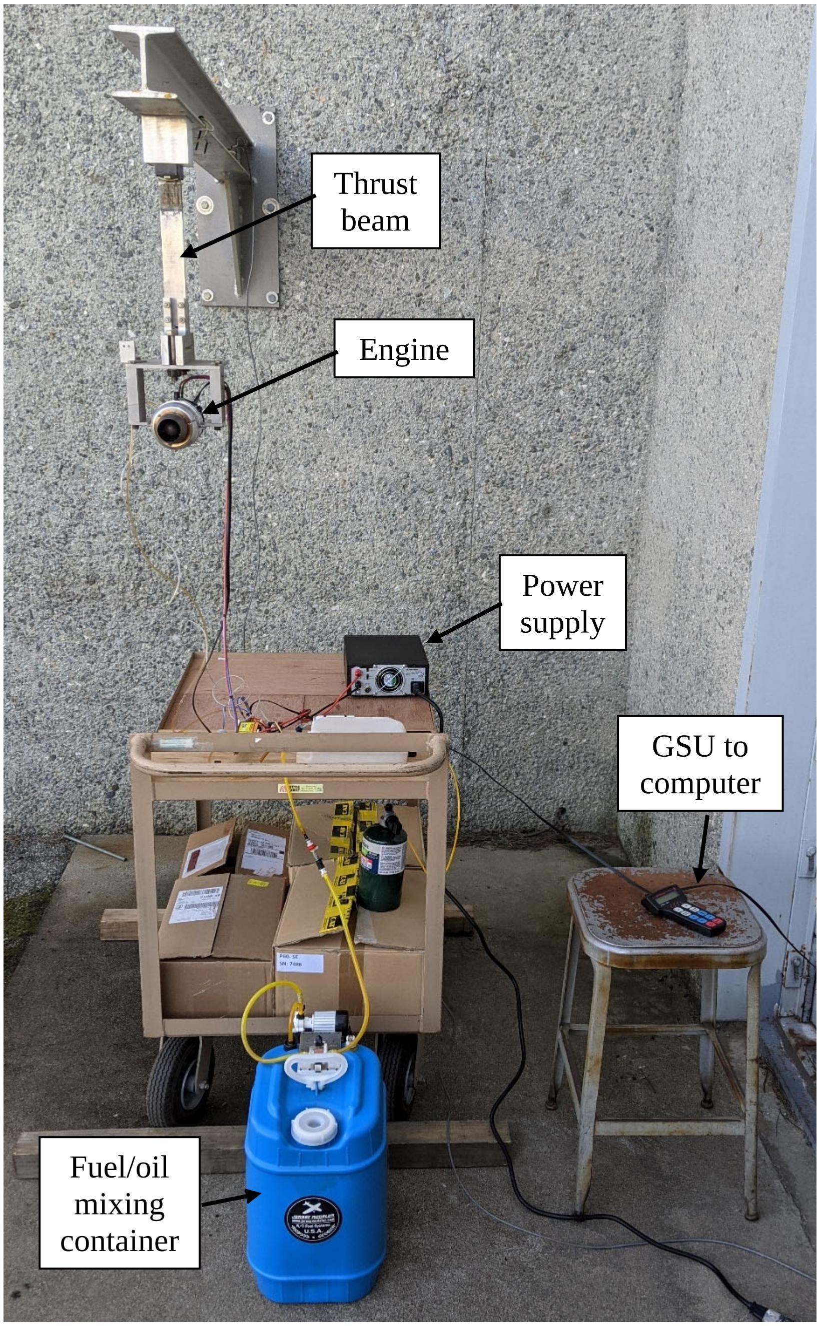


Figure 84. Thrust beam testing setup

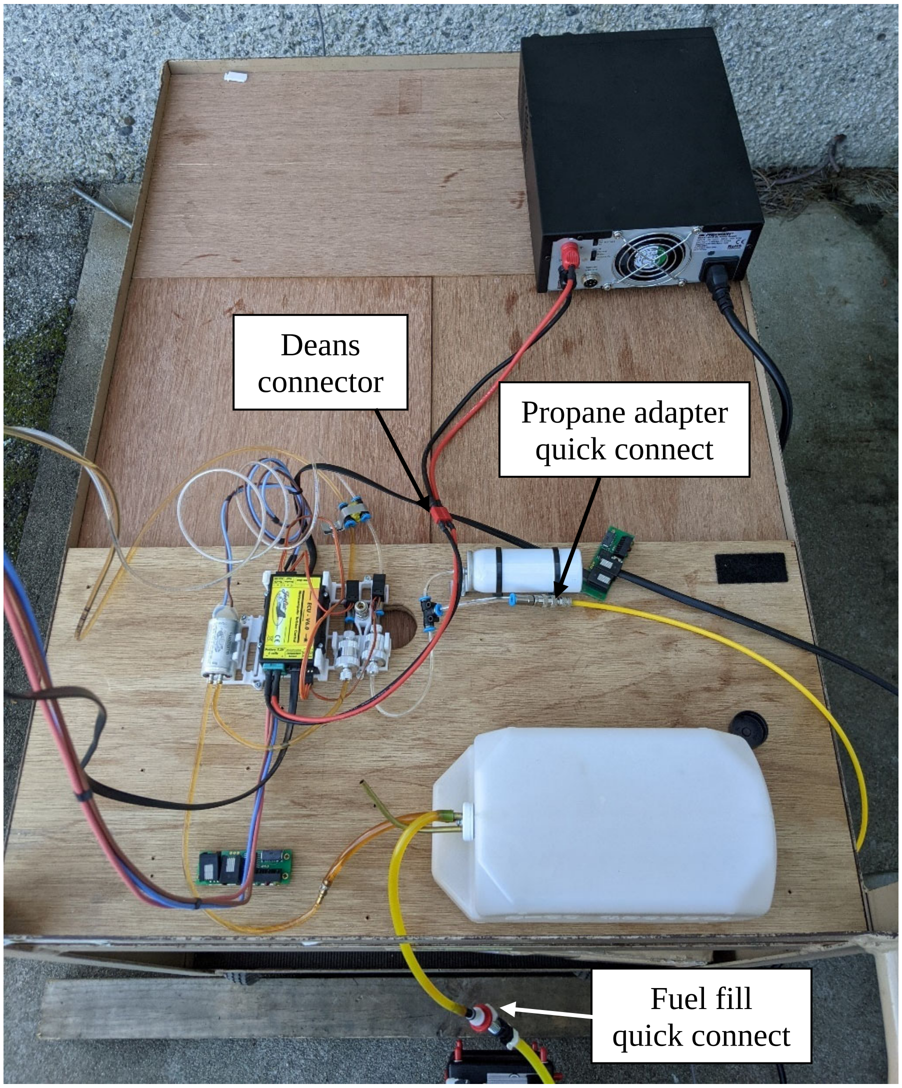


Figure 85. Overall kerosene layout

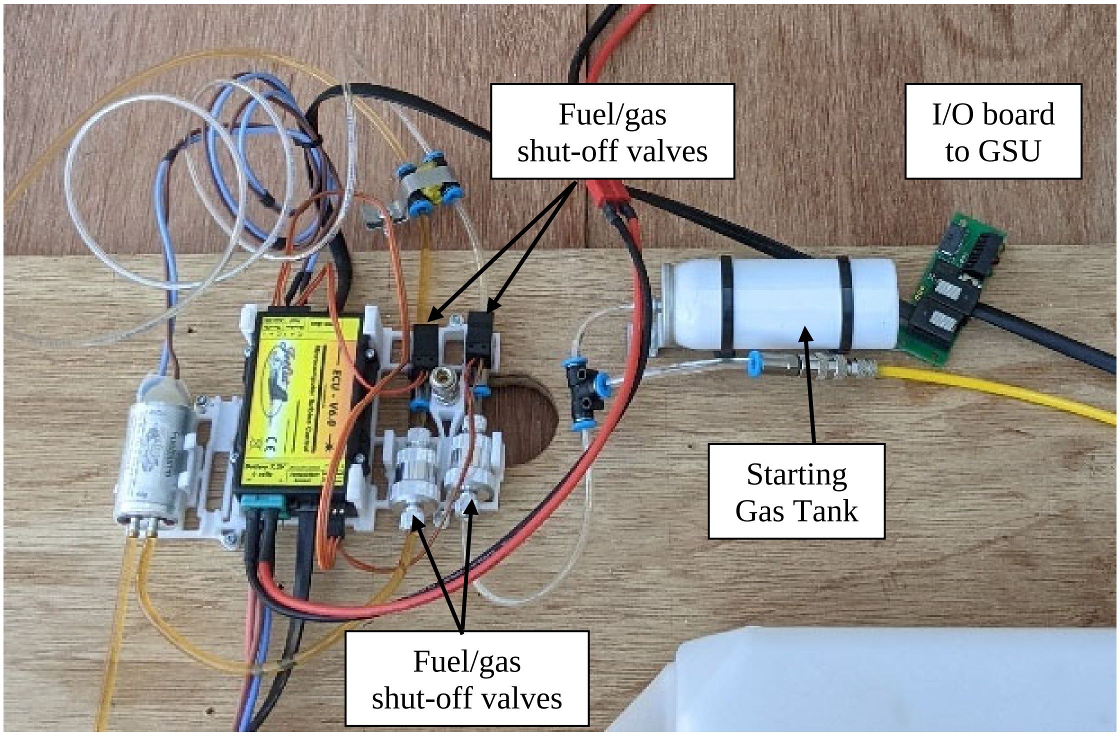


Figure 86. Close-up of overall kerosene layout

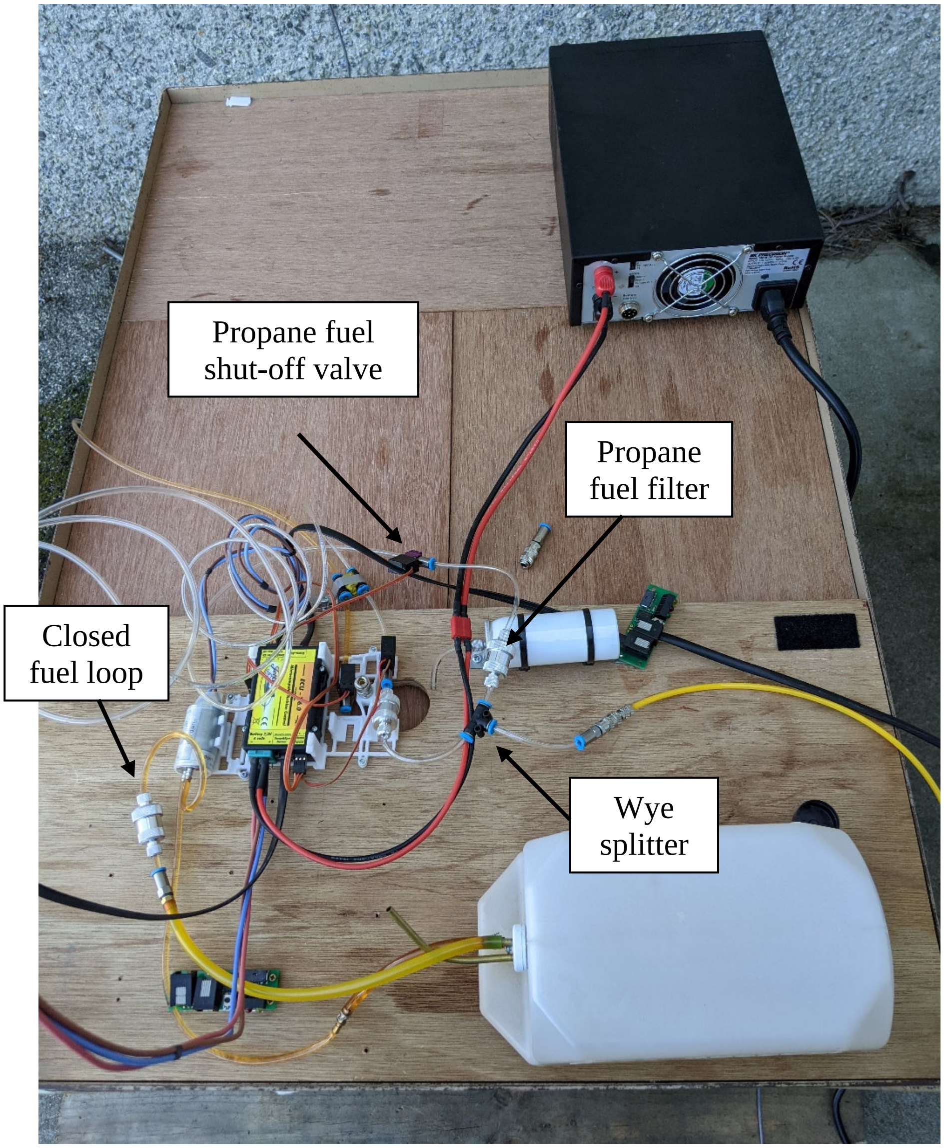


Figure 87. Overall propane layout

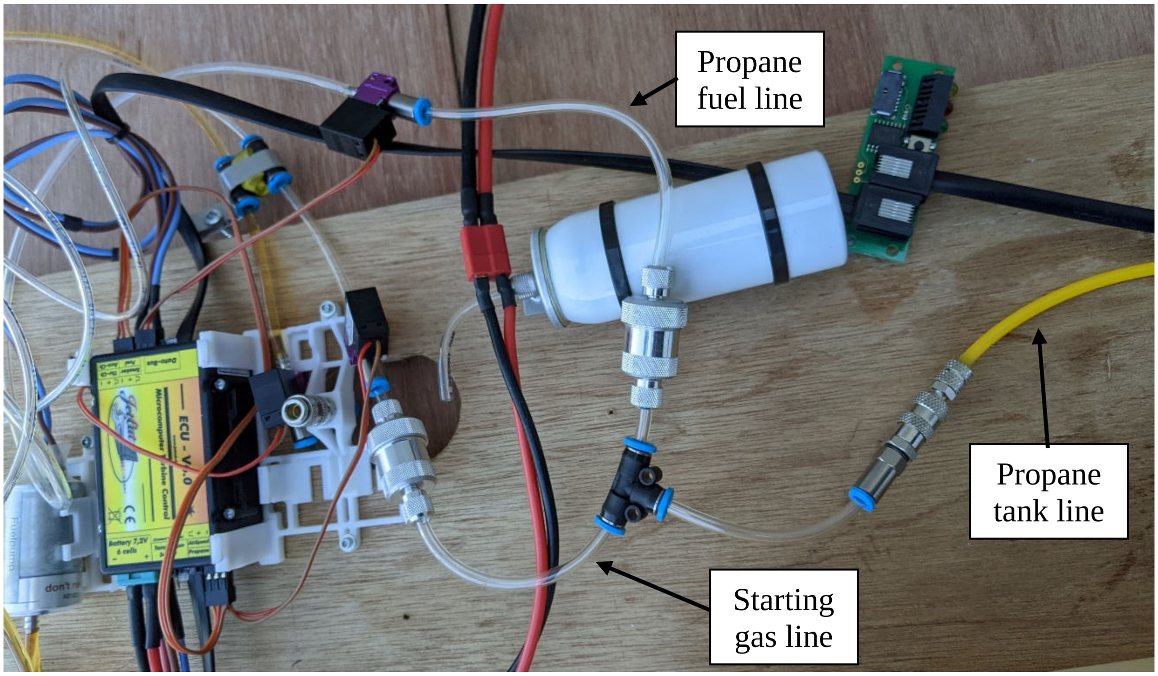


Figure 88. Close-up of propane wye arrangement

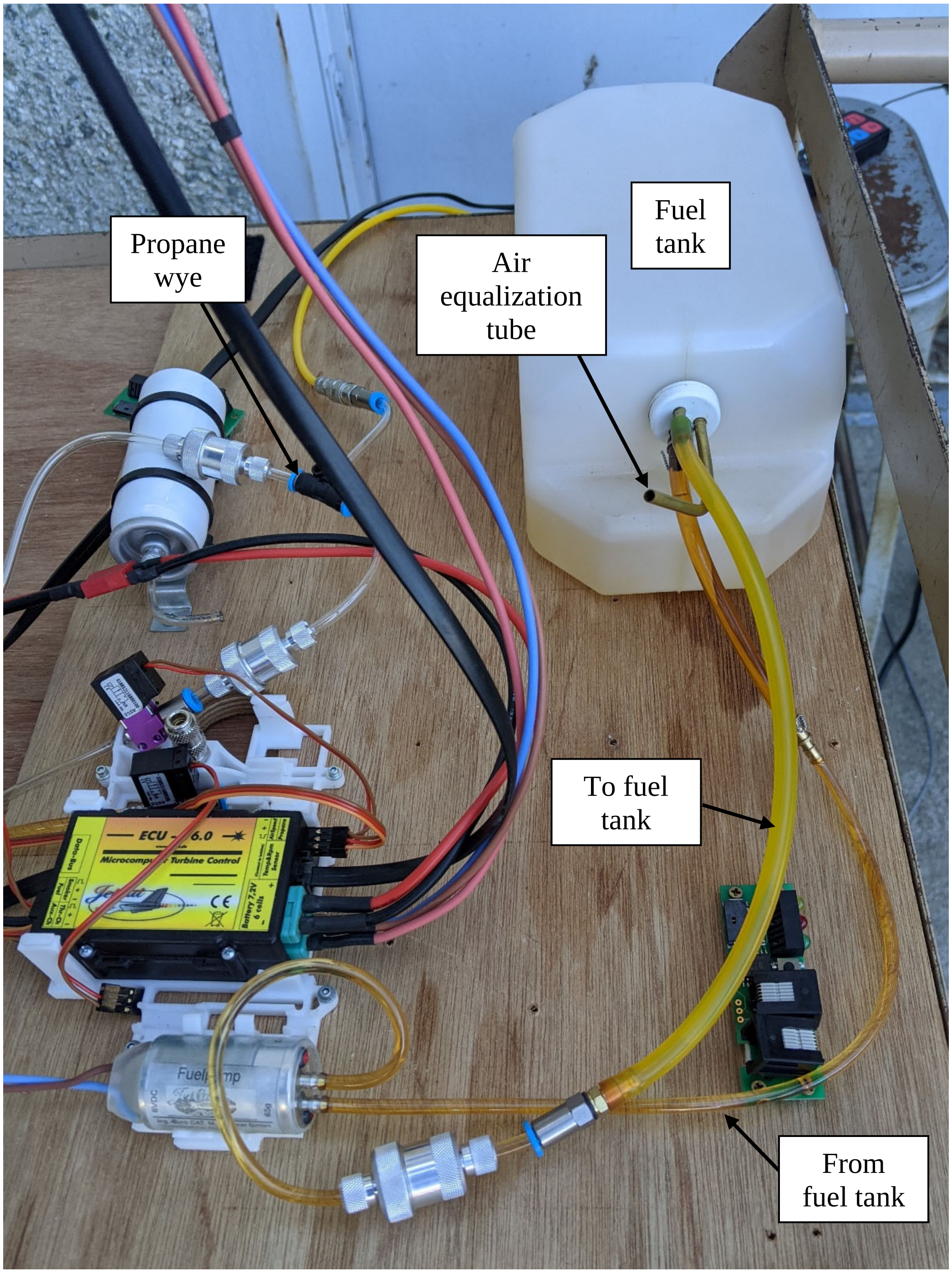


Figure 89. Closed fuel loop for propane layout

C. ADDITIONAL CONNECTION DIAGRAMS

1. Electrical Connections

The connections to the ECU are provided as a numbered list corresponding to the following figures. Electrical connection diagrams are on page 8 and 9 of the instruction manual [19]. Verify the polarity of the 3-prong connections matches the ECU before plugging them in. The Aux-Ch was shorted with the Air Speed connection to bypass an ECU logic that looks for an air speed sensor.

1. Data cable connection to I/O board (6-pin)

2. Fuel shut-off valve connection (3-prong)

3a. Aux-Ch to Air Speed short for computer, or for receiver connection (3-prong)

3b. Thr-Ch for receiver connection (3-prong)

4. Fuel pump power connection (female MPX)

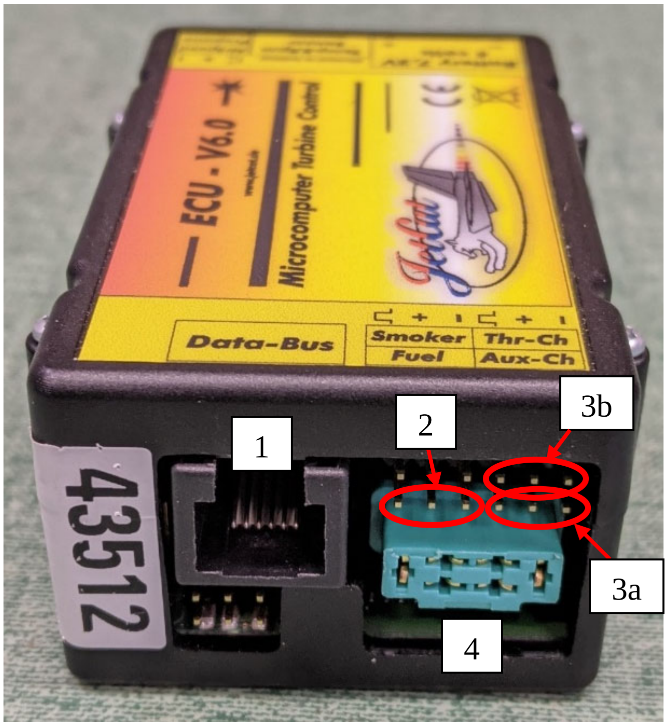


Figure 90. Left side of ECU

5. Power supply connection (male MPX)

6. Engine power connection (female MPX)

7. Data cable connection to engine (6-pin)

8. Propane shut-off valve connection (3-prong)

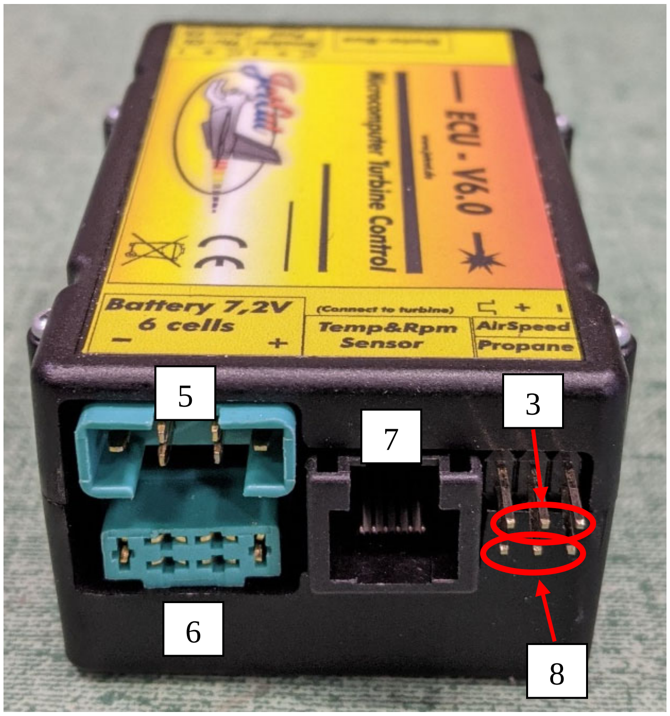


Figure 91. Right side of ECU

2. Fuel and Gas Connections

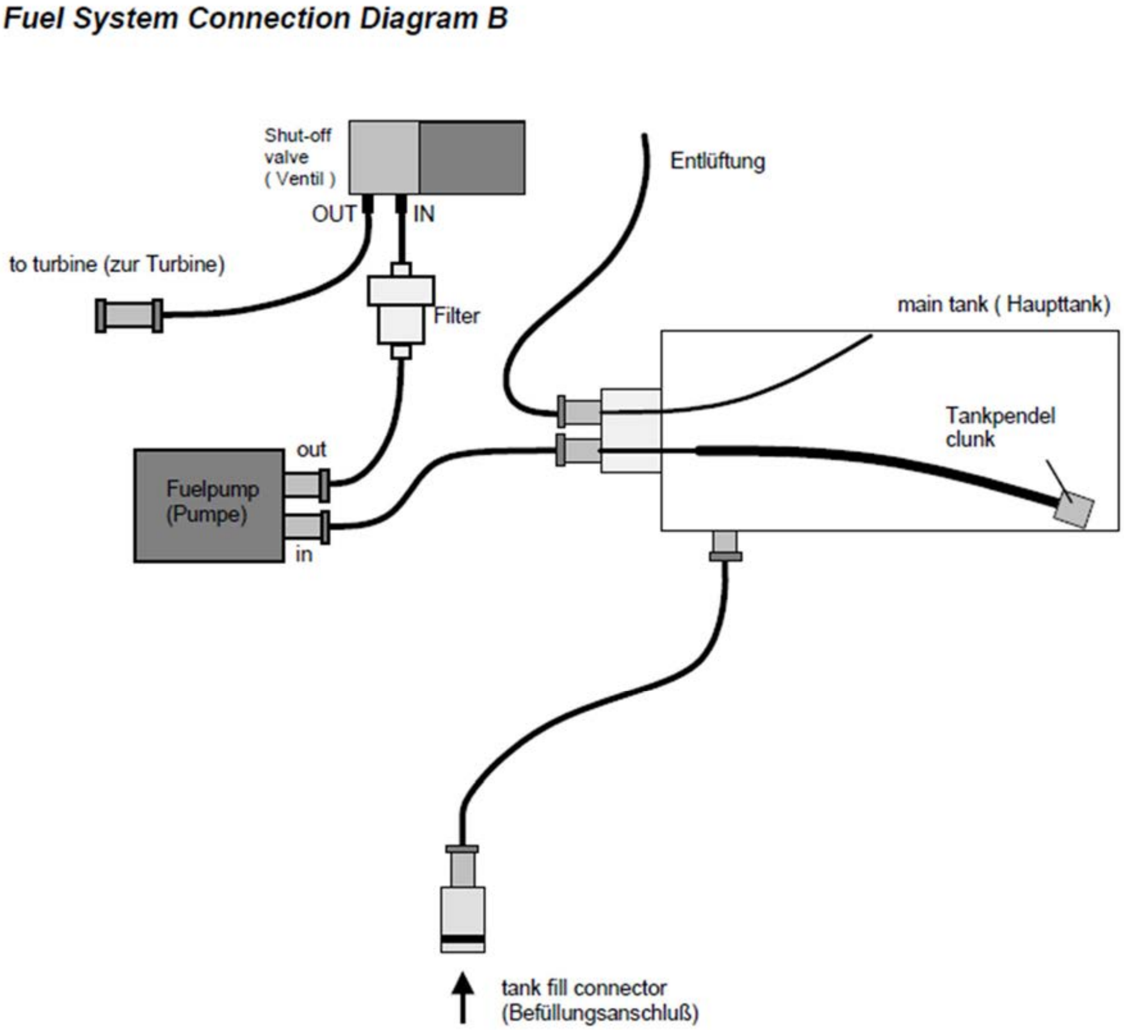


Figure 92. Fuel system arrangement used. Source: [19].

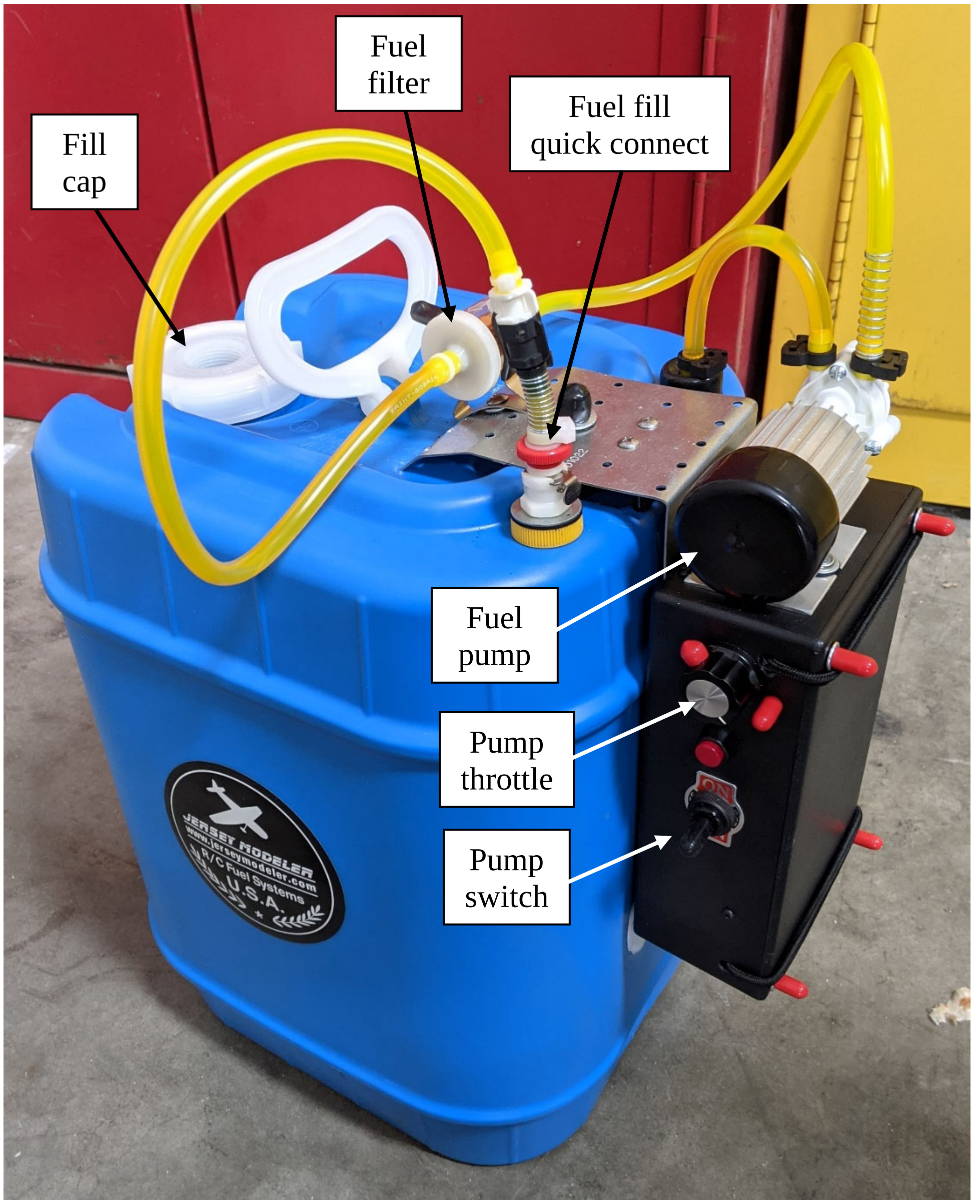


Figure 93. Fuel/oil mixing container

Figure 94. Internal view of mixing container control box

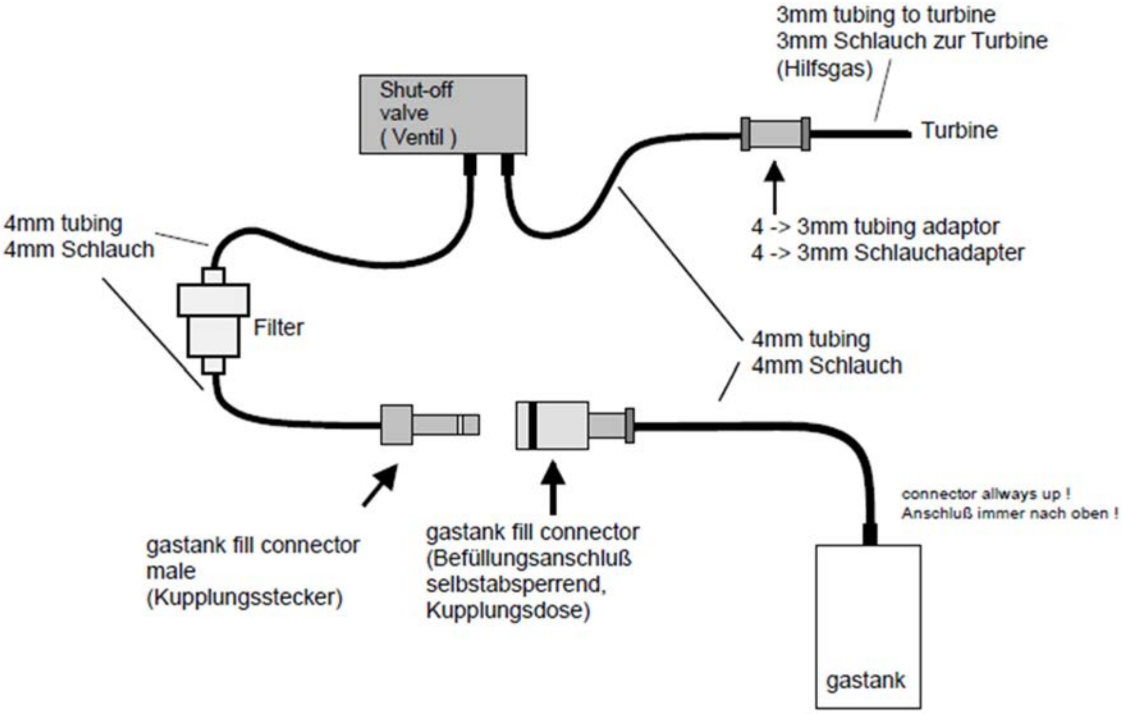


Figure 95. Starting gas connection diagram. Source: [19].

APPENDIX C. ENGINE SPECIFICATIONS

Table 18. JetCat P60-SE specifications. Source: [24].

Specification	**Value**
Pressure ratio	2
Mass flow (kg/s)	0.16
Consumption Full load (ml/min)	240
Consumption idle (ml/min)	70
Weight (g)	845
Dimensions of the diameter (mm)	83
Length (mm)	243
Exhaust gas temperature (°C)	480-730
Idle speed (1/min)	50000
Max rpm (1/min)	165000
Thrust at idle (N)	1
Thrust @ maxRpm (N)	63
Exhaust gas velocity (km/h)	1418
Exhaust gas power output (kW)	12.4
SFC @ maxRpm (kg/Nh)	0.183

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APPENDIX D. ENGINE DIAGRAMS

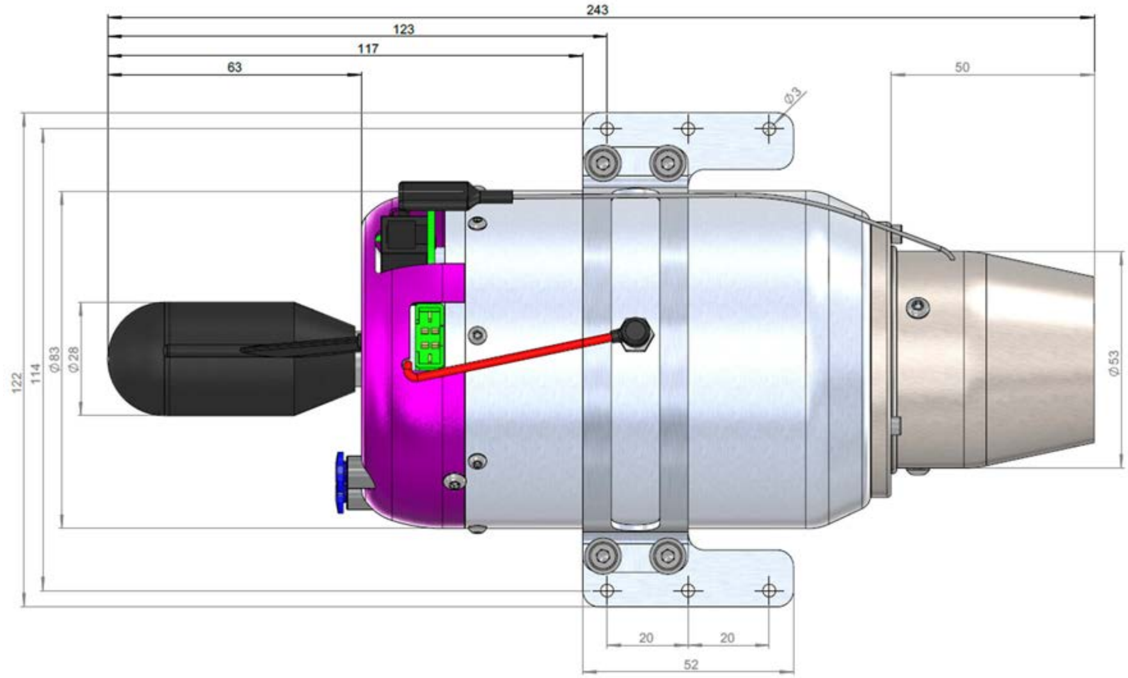


Figure 96. JetCat P60-SE side view and dimensions (mm). Source: [24].

Figure 97. Rear and front views of JetCat P60-SE. Source: [24].

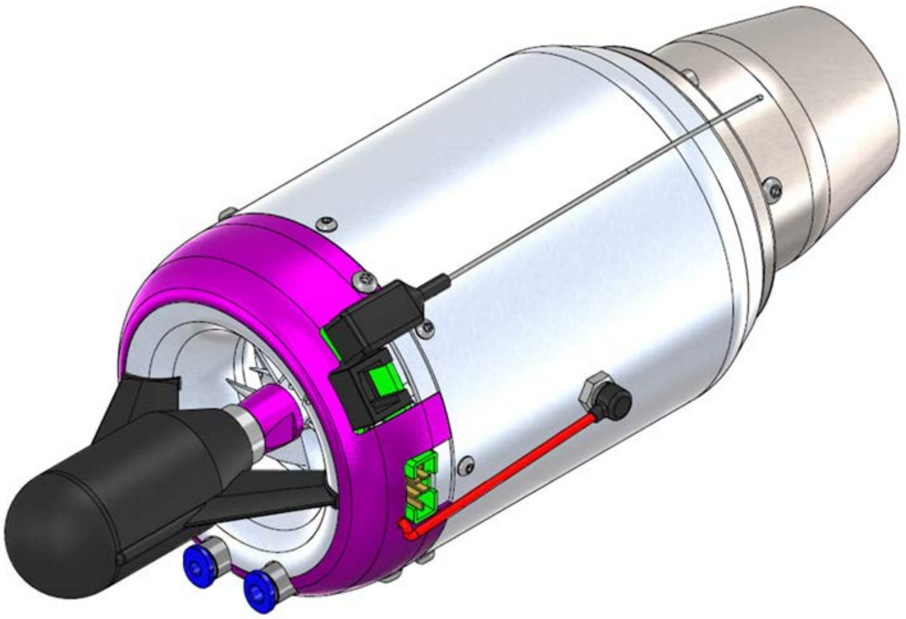
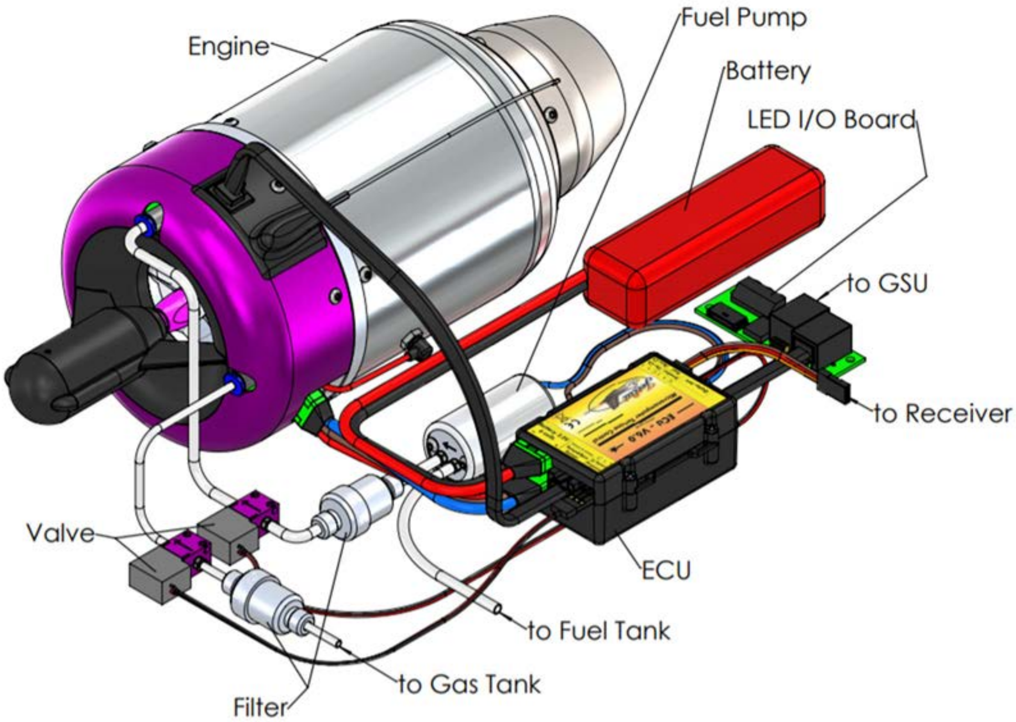


Figure 98. JetCat P60-SE isometric view. Source: [24].



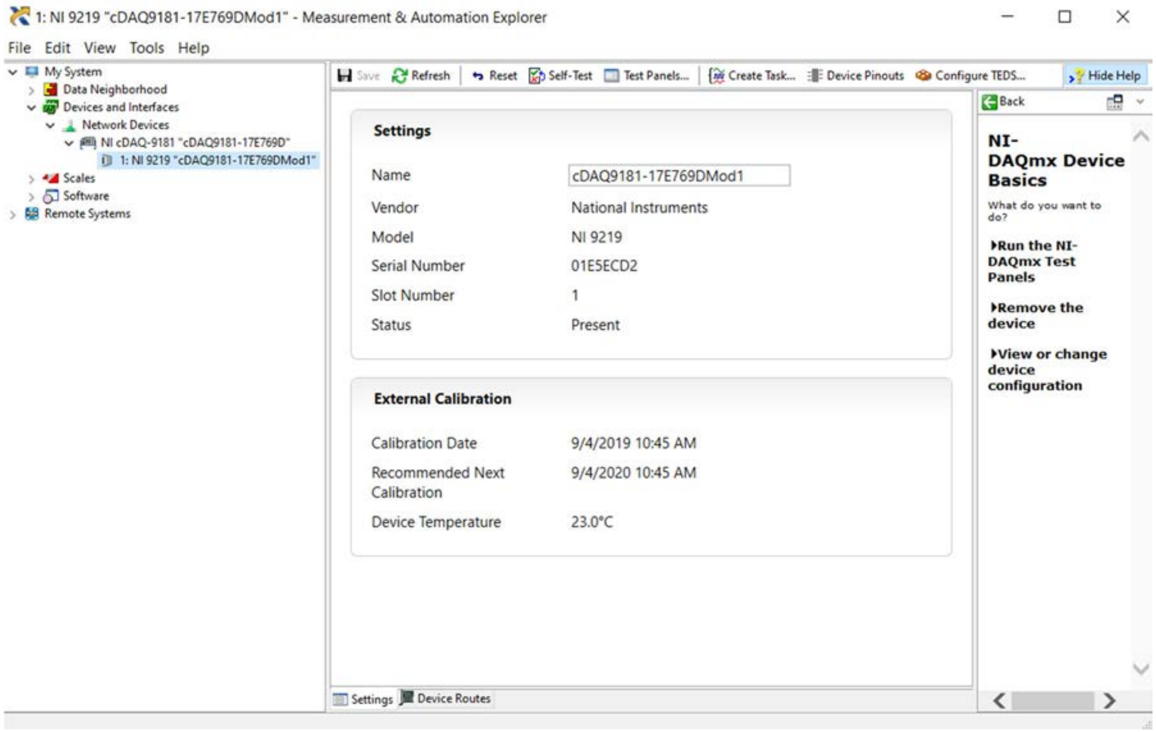
The jet model in the figure is a P80-SE. Port connections for the P60-SE are the same, but oriented differently, as shown in Figure 98. Refer to the instruction manual for more detail.

Figure 99. JetCat SE series connection diagram. Source: [24].

APPENDIX E. NI MAX CONFIGURATION

The NI MAX software and driver were downloaded from the NI website onto a personal laptop and used to verify that the full-bridge circuitry would provide data within sufficient tolerance and consistency. The following steps show how to create a task for testing the sensors:

1. Verify the NI DAQ being used is connected by expanding Devices and Interfaces under My System in the list on the left and confirming the correct unit number. This experiment used an NI 9219 DAQ within an NI 9181 chassis, as shown in Figure 100.



Settings

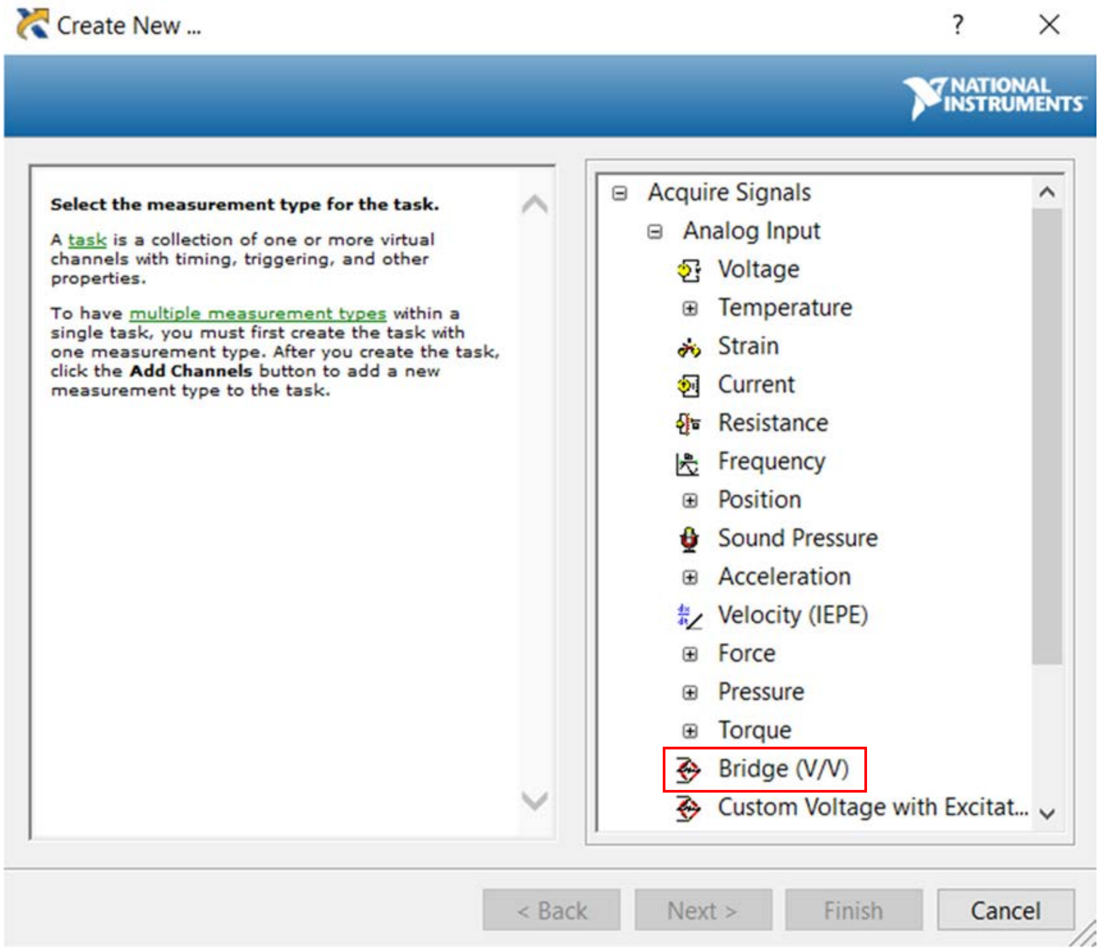
Name: cDAQ9181-17E769DMod1
Vendor: National Instruments
Model: NI 9219
Serial Number: 01E5ECD2
Slot Number: 1
Status: Present

External Calibration

Calibration Date: 9/4/2019 10:45 AM
Recommended Next Calibration: 9/4/2020 10:45 AM
Device Temperature: 23.0°C

Figure 100. NI MAX device menu

2. Create a task for the associated input signal. This experiment converted an analog signal (strain gauges) to a digital signal (NI DAQ) via a full-bridge setup, as shown in Figure 101.



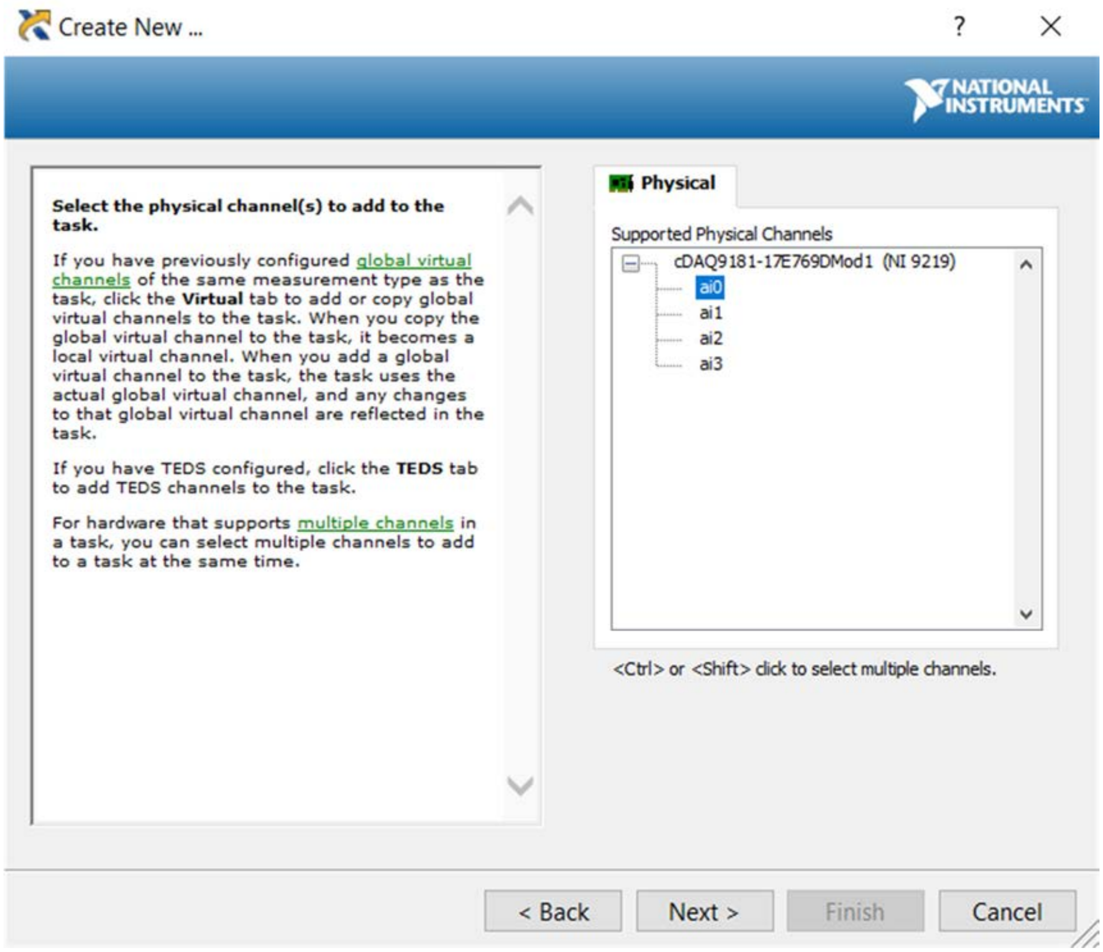
Select the measurement type for the task.

A task is a collection of one or more virtual channels with timing, triggering, and other properties.

To have multiple measurement types within a single task, you must first create the task with one measurement type. After you create the task, click the **Add Channels** button to add a new measurement type to the task.

Figure 101. New task signal selection

3. Verify the DAQ channel to be used and select it in the new task channel selection menu. This experiment used channel 0, as shown in Figure 102.



Select the physical channel(s) to add to the task.

If you have previously configured global virtual channels of the same measurement type as the task, click the **Virtual** tab to add or copy global virtual channels to the task. When you copy the global virtual channel to the task, it becomes a local virtual channel. When you add a global virtual channel to the task, the task uses the actual global virtual channel, and any changes to that global virtual channel are reflected in the task.

If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

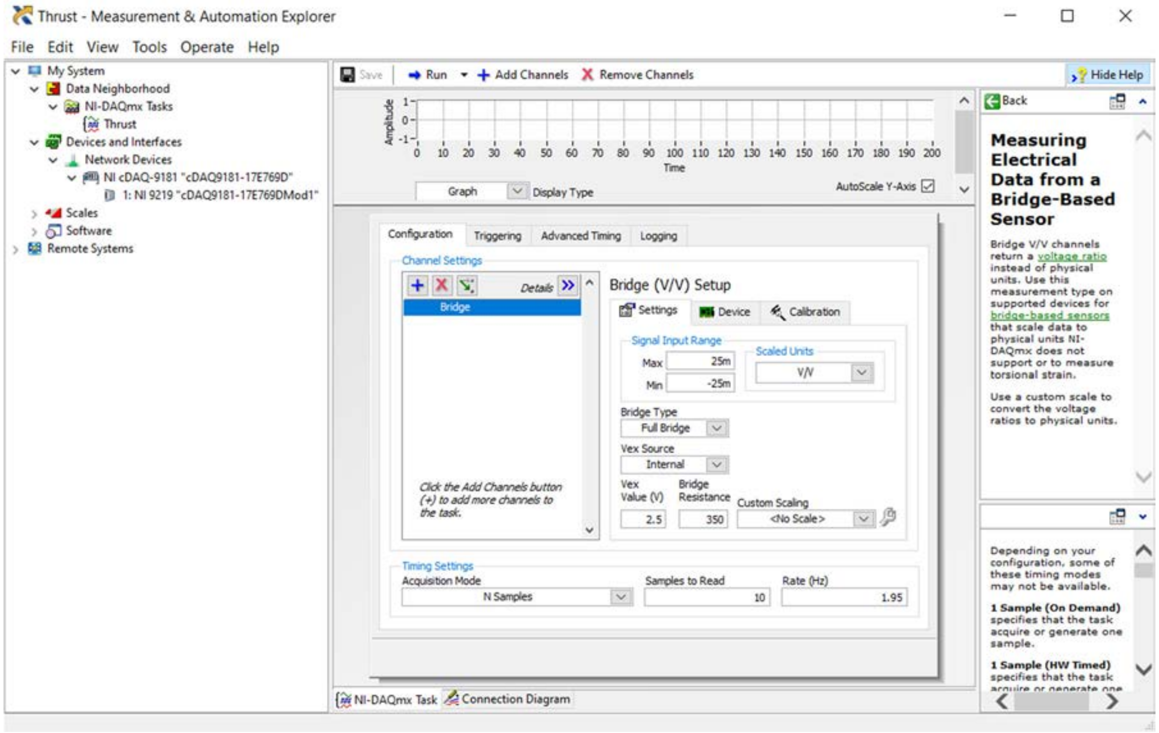
For hardware that supports multiple channels in a task, you can select multiple channels to add to a task at the same time.

<Ctrl> or <Shift> click to select multiple channels.

Figure 102. New task channel selection

4. Enter a name for the task and click Finish. The task for this experiment was named “Thrust.”

5. Enter the signal and bridge parameters into the task menu, as shown in Figure 103.



Display Type: Graph

AutoScale Y-Axis ☑

Bridge

Click the Add Channels button (+) to add more channels to the task.

Signal Input Range
Max 25m
Min -25m

Scaled Units: V/V

Bridge Type: Full Bridge

Vex Source: Internal

Vex Value (V): 2.5

Bridge Resistance: 350

Custom Scaling: <No Scale>

Timing Settings
Acquisition Mode: N Samples
Samples to Read: 10
Rate (Hz): 1.95

Measuring Electrical Data from a Bridge-Based Sensor

Bridge V/V channels return a voltage ratio instead of physical units. Use this measurement type on supported devices for bridge-based sensors that scale data to physical units NI-DAQmx does not support or to measure torsional strain.

Use a custom scale to convert the voltage ratios to physical units.

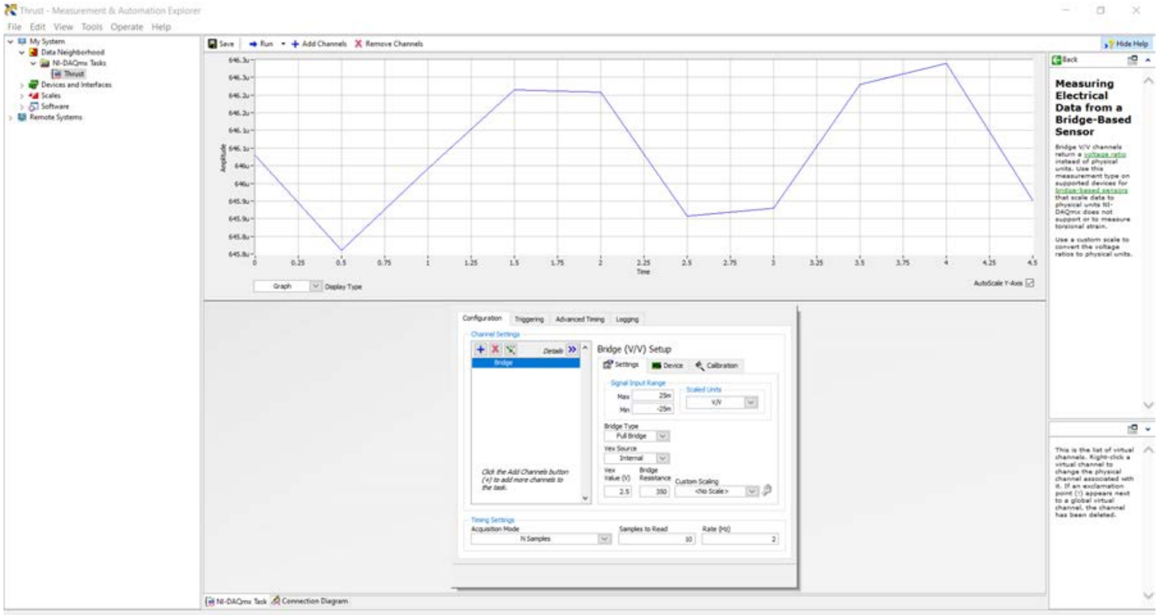
Depending on your configuration, some of these timing modes may not be available.

1 Sample (On Demand) specifies that the task acquire or generate one sample.

1 Sample (HW Timed) specifies that the task acquire or generate one

Figure 103. Task configuration menu

6. Select the **Acquisition Mode**, and input values for **Samples to Read** and **Rate** under the "Timing Settings" at the bottom. This experiment read five samples at 2 Hz for calibration, as shown in Figure 104.



Signal Input Range
Max 25m
Min -25m

Scaled Units V/V

Bridge Type Full Bridge

Vex Source Internal

Vex Value (V) 2.5

Bridge Resistance 350

Custom Scaling <No Scale>

Click the Add Channels button (+) to add more channels to the task.

Timing Settings
Acquisition Mode N Samples

Samples to Read 10

Rate (Hz) 2

Measuring Electrical Data from a Bridge-Based Sensor

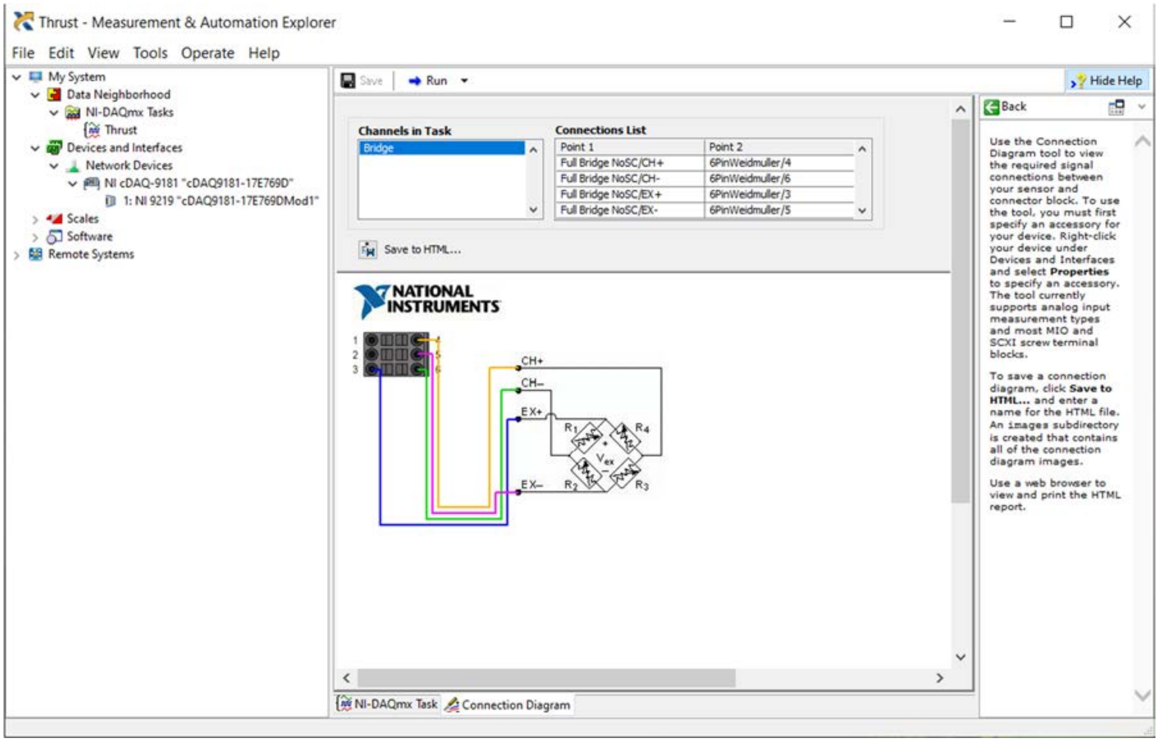
Bridge V/V channels return a voltage ratio instead of physical units. Use this measurement type on supported devices for bridge-based sensors that scale data to physical units NI-DAQmx does not support or to measure torsional strain.

Use a custom scale to convert the voltage ratios to physical units.

This is the list of virtual channels. Right-click a virtual channel to change the physical channel associated with it. If an exclamation point (!) appears next to a global virtual channel, the channel has been deleted.

Figure 104. Measurement of ten samples at 60.4 N (13.6 lb.) of force

Note: NI MAX provides a connection diagram for the selected signal input. The full-bridge connection diagram for this experiment is shown in Figure 105.



Connections List

Point 1	Point 2
Full Bridge NoSC/CH+	6PinWeidmuller/4
Full Bridge NoSC/CH-	6PinWeidmuller/6
Full Bridge NoSC/EX+	6PinWeidmuller/3
Full Bridge NoSC/EX-	6PinWeidmuller/5

Use the Connection Diagram tool to view the required signal connections between your sensor and connector block. To use the tool, you must first specify an accessory for your device. Right-click your device under Devices and Interfaces and select **Properties** to specify an accessory. The tool currently supports analog input measurement types and most MIO and SCXI screw terminal blocks.

To save a connection diagram, click **Save to HTML...** and enter a name for the HTML file. An `images` subdirectory is created that contains all of the connection diagram images.

Use a web browser to view and print the HTML report.

Figure 105. Bridge connection diagram

APPENDIX F. MATLAB CODE

```
%N. Perez, “Gas Turbine Operation on Compressed Hydrogen,” M.S. thesis,
%Mech. Eng. Dept., Naval Postgraduate School, Monterey, CA, USA, 2021.
%[Online] Available: https://calhoun.nps.edu/handle/10945/61244
%Adapted using the MATLAB code from Penley [16]

%NI 9219 Strain Module Connection and Test
close all
clear
clc

%https://www.mathworks.com/help/daq/acquire-data-using-ni-devices.html
%Discover analog input devices
%d = daqlist("ni")

%Create the DAQ Station
devices = daq.getDevices;
s = daq.createSession('ni');
s.Rate = 2; %Sampling rate [Hz]

%Add Strain Gauge Modules to measure strain
%Only connected to ai0 port
% addAnalogInputChannel(s,'cDAQ1Mod1', 0,'Bridge');
addAnalogInputChannel(s,'cDAQ9181-17E769DMod1', 0,'Bridge');

%Set up Channel mode
tc = s.Channels();
tc.BridgeMode = 'Full';
% tc.NominalBridgeResistance = 150;
tc.NominalBridgeResistance = 350;

%Set Scan Duration
s.DurationInSeconds = 5; %for calibration/pre-checks
% s.DurationInSeconds = 600; %for test runs

%Acquires a single scan of data
% data = s.inputSingleScan

[data,timestamps,triggerTime] = startForeground(s);
% returns the data acquired, timestamps relative to the
% time the operation is triggered, and a trigger time
% indicating the absolute time the operation was triggered.

A = [timestamps'; data'];
filename = datestr(now,'yyyy_mm_dd_HHMM');
txtfile = sprintf('%s.txt', filename);
fileID = fopen(txtfile,'w');
fprintf(fileID,'%6s %12s\r\n','time','data');
fprintf(fileID,'%6.2f %15.4e\r\n',A);
```

```
fclose(fileID);
% writetable(A,txtfile);

voltage = max(data)
plot(timestamps,data);
hold on
xlabel('Time (sec)');
ylabel('Voltage (V)');

% remove MATLAB's reservation of DAQ channel
delete(s)
```

Published with MATLAB® R2020a

APPENDIX G. STANDARD OPERATING PROCEDURES

These instructions are derived from the instruction manual [19] and modified for use with a power supply, the USB interface and the Jet-tronic software (driver installation required). It also includes steps for recording data with the data acquisition equipment. Please note that the fuel filters must be checked every ten flights and the engine, ECU, and fuel pump should be returned to CAT for service after approximately 25 hours of total run time (accessed via the GSU Statistic menu), as stated on page 39 of the instruction manual [19].

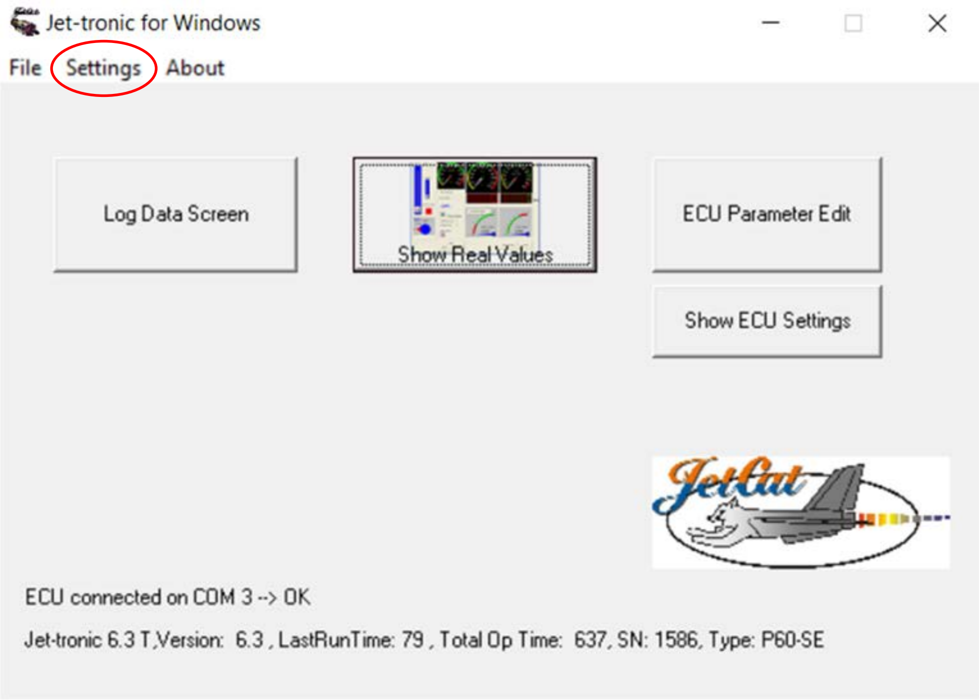
Pre-Light Off Checklist

1. Prepare fire extinguisher(s).
2. Don eye and hearing protection.
3. Verify fuel lines and filter for cleanliness and restrictions.
4. Verify engine intake and exhaust are unobstructed and free of debris.
5. Check the fuel tank vent for obstructions.
6. “Mix 5% oil in fuel (i.e. 1 quart per 5 gallons of kerosene)” [19].
7. “Fill fuel tank(s)” [19].
8. Ensure fuel line is disconnected from engine and purge the fuel line of air. Adjust the fuel pump rate accordingly (see **fuel pump adjustment** on page 13 of manual [19]).
9. “Be certain the starting gas release valve is closed, before filling the starting gas tank” [19].
10. Ensure valve on the propane valve-regulated adapter is shut, then install the propane bottle.
11. Ensure all fuel lines and electronic connections are fully seated.
12. Initialize MATLAB or other strain gauge data collection software.

Turbine Starting / Running

1. Complete Pre-Light Off Checklist.
2. “Briefly hold the model upward to ensure there is no residual fuel in the turbine” [19].
3. Mount the engine and verify all screws are secured.
4. Verify engine intake and exhaust are clear of FOD.
5. Turn on power supply and set it to nominal voltage (8 V) and max current.
    a. Ensure Constant Voltage (C.V.) is illuminated.
6. Plug power supply into ECU.
7. Initialize the Jet-tronic computer application.
    a. If needed, pair USB interface to the ECU by selecting *Settings* in the main menu banner (Figure 106), *COM Settings*, *AutoDetect* (Figure 107).

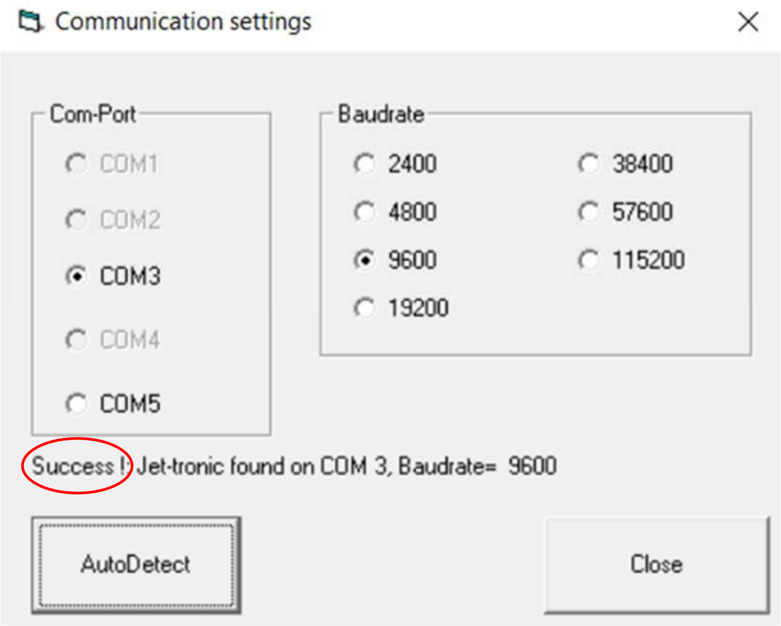
b. Verify *Success* message (Figure 107). If none, check connections and/or restart NI-DAQ and Jet-tronic software.



ECU connected on COM 3 --> OK

Jet-tronic 6.3 T,Version: 6.3 , LastRunTime: 79 , Total Op Time: 637, SN: 1586, Type: P60-SE

Figure 106. Jet-tronic main menu



Com-Port

○ COM1
○ COM2
● COM3
○ COM4
○ COM5

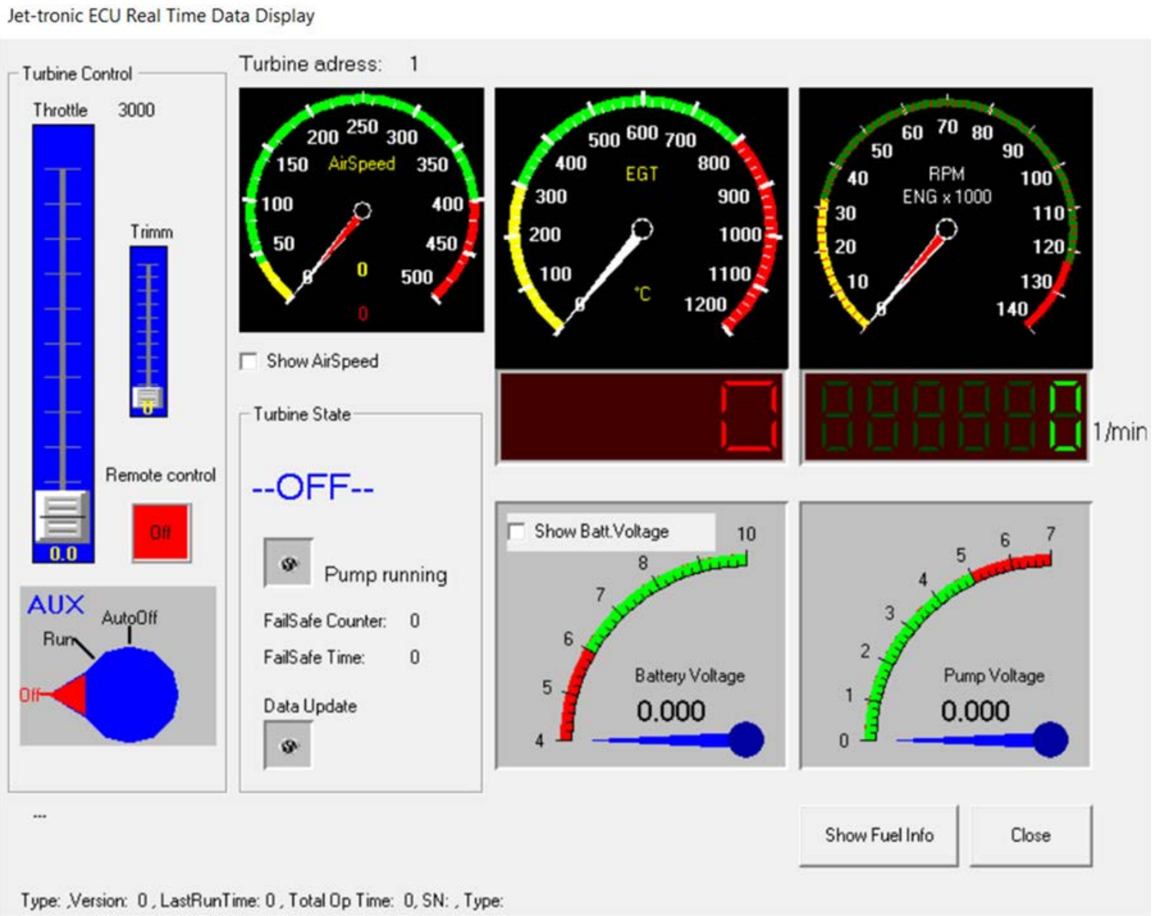
Baudrate

○ 2400
○ 4800
● 9600
○ 19200
○ 38400
○ 57600
○ 115200

Success ! Jet-tronic found on COM 3, Baudrate= 9600

Figure 107. Jet-tronic communication settings menu

8. Open the HMI (Figure 108) by clicking *Show Real Values* on the main menu.



Jet-tronic ECU Real Time Data Display

Turbine adress: 1

Throttle 3000

--OFF--

FailSafe Counter: 0

FailSafe Time: 0

Battery Voltage 0.000

Pump Voltage 0.000

Type: ,Version: 0 , LastRunTime: 0 , Total Op Time: 0, SN: , Type:

Figure 108. Jet-tronic HMI

9. Change *Remote Control* to **On.**
   a. Enable *Show Batt. Voltage* if interested in battery voltage.
   b. Enable *Show Fuel Info* if interested in fuel rate. Fuel level must be set with GSU to read properly.
10. “Set the *AUX* switch to the **Off** position. All LEDs will be off” [19].
11. “Move the throttle trim [control] to idle (maximum) position” [19].
12. “Set the *AUX* switch to the [**Run**] (middle) position” [19].
13. Ensure throttle [control] is at the idle position and the LEDs are blinking in a continuous sequence of green to red to yellow. Turbine is now ready to start.
14. If engine is unable to start with the starter gas tank, the propane valve-regulated adapter can be slightly opened (second setting) to allow flow directly from the propane bottle.

15. Start MATLAB and screen capture recordings (if applicable). To record the HMI screen with Windows 10, click the window and type Win+Alt+R. It can also be accessed with the Game Bar (Win+G).
16. “Advance the throttle to its maximum setting and the turbine will start” [19].
17. “Once the turbine begins to accelerate, the throttle [control] can be returned to idle position” [19]. Refer to instruction manual (page 23) for engine automatic startup actions. “As soon as the turbine stabilizes at idle speed, the green **OK** LED will illuminate…The throttle must be in the idle position for the green **OK** LED to illuminate” [19].

Note: “The starting sequence can be immediately disengaged by moving the *AUX* switch to the **Off** position” [19].

Stopping the Turbine

1. Move the *AUX* switch to the **Auto Off** position.
    a. “The turbine automatically stabilizes at around 55,000 RPM, for approximately six (6) seconds, before shutting down” [19].
2. Allow the turbine to complete its automatic cooldown process (about one minute or until EGT is below 100 °C).
3. Stop MATLAB and screen capture recordings (if applicable).
4. If turbine does not enter its cooldown process, manually shut off the engine by moving the *AUX* switch to the **Off** position or by bringing both the throttle and trim controls to zero.
    a. Engine will not perform its automatic cooling process.

Note: Emergency stopping of the engine can be performed by shutting down power to the ECU, however, this may damage the engine.

5. “Open starting gas valve before storing the model” [19] to release the gas. “Perform this procedure in a safe area” [19].
6. Ensure propane bottle valve-regulated adapter is closed, then remove from propane bottle.
7. Stow fuel and propane in appropriate flammables locker.
8. Log the total run time from the GSU Statistics menu [19].

Downloading the ECU log data

1. Navigate to the Main Menu (Figure 106) and click *Log Data Screen*.
2. On the ECU Turbine Log Data window (Figure 109), click *Read LogData from ECU*.

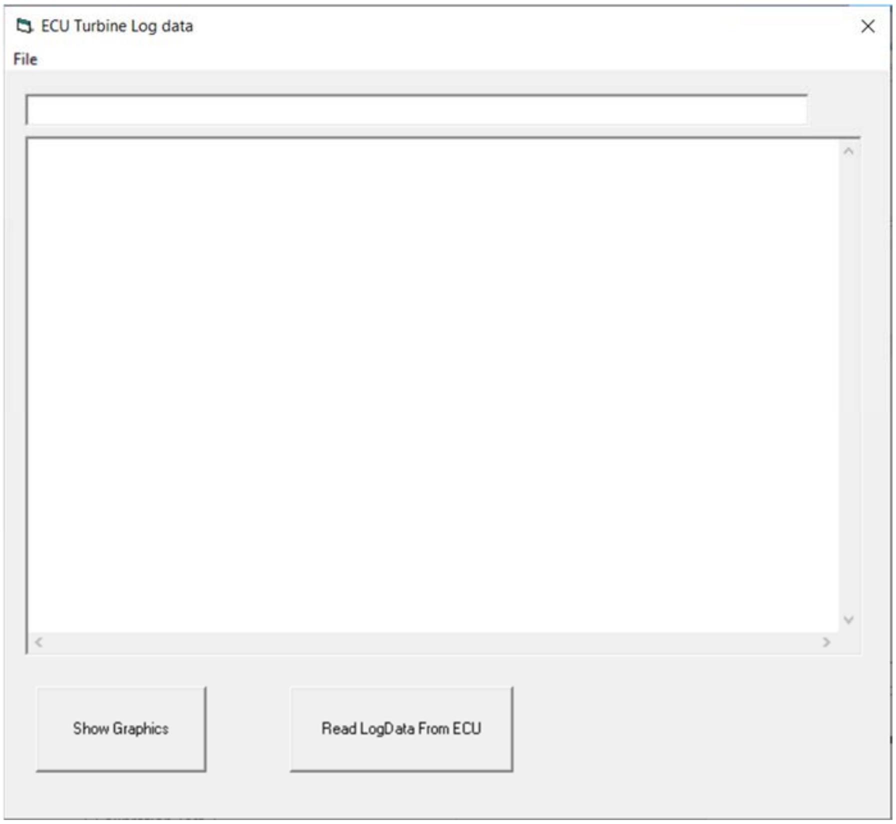


Figure 109. ECU turbine log data window

3. Click *File* > *Save Flight Data*. Data will be saved into a .log file.
4. Click *Show Graphics* to plot the log data using Jet-tronic.

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APPENDIX H. NI DAQ AND JET-TRONIC LOG DATA

The log data from the ECU was acquired with the Jet-tronic software via the USB interface. The data was converted from a .log file to a table for better presentation, and the units for the columns were added for clarity. The SetRPM column is the input RPM relative to the throttle position (THR, where 100% = 165,000 RPM), the Temp column is the EGT, the Pump column is the fuel pump voltage draw, the State column shows the current turbine running state as listed on pages 25–27 of the instruction manual [19], the AUX column shows the position of the auxiliary switch on the transmitter or in the program (49 = engaged, 0 = disengaged), and the Batt column shows battery or power supply voltage at that point in time. There is no air speed or set speed data because air speed sensors were unnecessary for this project (fixed position). Lastly, the inconsistency with the time column appears to be due to the integrated time logger starting as soon as the engine is turned on. This is based on intuition since it is not explained in the instruction manual [19] or product specification [20]. Also, the USB interface is able to only provide data from the last 25 operating minutes [20], which did not hinder data collection since the test runs lasted only a few minutes. Before obtaining the USB interface, the project team was unable to acquire these performance parameters.

One issue with the integrated data logger is that it did not record engine parameters during the propane attempts. The engine never reached idle speed during the propane test runs, so it is likely that the data logger does not start recording until it successfully reaches idle RPM (state 6 or 7). Another possible reason is that the electric motor never disengaged during the propane test runs, which may be due to lower EGT during start up compared to kerosene. It may consider the propane attempts as failed starts, rather than operating time.

A. KEROSENE TEST RUN #1

Table 19. DAQ data table for Figure 41

Time (sec)	Voltage (V)
0	0.001165
0.5	0.001164
1	0.001164
1.5	0.001164
2	0.001164
2.5	0.001164
3	0.001163
3.5	0.001163
4	0.001163
4.5	0.001163
5	0.001163
5.5	0.001163
6	0.001163
6.5	0.001163
7	0.001163
7.5	0.001163
8	0.001163
8.5	0.001163
9	0.001163
9.5	0.001163
10	0.001163
10.5	0.001163
11	0.001163
11.5	0.001163
12	0.001163
12.5	0.001163
13	0.001163
13.5	0.001163
14	0.001163
14.5	0.001163
15	0.001163
15.5	0.001163
16	0.001163
16.5	0.001163
17	0.001163
17.5	0.001163
18	0.001163
18.5	0.001163
19	0.001163
19.5	0.001163
20	0.001164
20.5	0.001164
21	0.001164
21.5	0.001164
22	0.001164
22.5	0.001164
23	0.001164
23.5	0.001165
24	0.001165
24.5	0.001166
25	0.001166
25.5	0.001166
26	0.001167
26.5	0.001167
27	0.001167
27.5	0.001168
28	0.001168
28.5	0.001169
29	0.00117
29.5	0.001172
30	0.001173
30.5	0.001174
31	0.001175
31.5	0.001176
32	0.001177
32.5	0.001179
33	0.001181
33.5	0.001184
34	0.001186
34.5	0.00119
35	0.001195
35.5	0.001199
36	0.001204
36.5	0.001211
37	0.001213
37.5	0.001212
38	0.001208
38.5	0.001204
39	0.001203
39.5	0.001201
40	0.001198
40.5	0.001197
41	0.001197
41.5	0.001197
42	0.001196
42.5	0.001196
43	0.001197
43.5	0.001197
44	0.001197
44.5	0.001197
45	0.001197
45.5	0.001197
46	0.001197
46.5	0.001197
47	0.001197
47.5	0.001197
48	0.001197
48.5	0.001197
49	0.001197
49.5	0.001198
50	0.001198
50.5	0.001198
51	0.001198
51.5	0.001195
52	0.001196
52.5	0.001197
53	0.001197
53.5	0.001195
54	0.001196
54.5	0.001198
55	0.001196
55.5	0.001197
56	0.001203
56.5	0.001213
57	0.001223
57.5	0.001231
58	0.001242
58.5	0.001253

59	0.001263
59.5	0.001272
60	0.001279
60.5	0.001281
61	0.001285
61.5	0.001296
62	0.001302
62.5	0.00131
63	0.001319
63.5	0.001324
64	0.001326
64.5	0.001341
65	0.001369
65.5	0.001402
66	0.001433
66.5	0.001434
67	0.001445
67.5	0.001448
68	0.00145
68.5	0.00147
69	0.00146
69.5	0.001471
70	0.001497
70.5	0.001535
71	0.001541
71.5	0.001551
72	0.001562
72.5	0.001572
73	0.001577
73.5	0.001594
74	0.001611
74.5	0.001625
75	0.001629
75.5	0.001652
76	0.001672
76.5	0.001707
77	0.001738
77.5	0.001732
78	0.001729
78.5	0.001722
79	0.00172
79.5	0.001697
80	0.00167
80.5	0.001662
81	0.001645
81.5	0.00161
82	0.001579
82.5	0.001556
83	0.001539
83.5	0.00152
84	0.0015
84.5	0.001477
85	0.001471
85.5	0.001436
86	0.001418
86.5	0.00139
87	0.001359
87.5	0.001343
88	0.001323
88.5	0.001298
89	0.001274
89.5	0.001244
90	0.001224
90.5	0.001214
91	0.001208
91.5	0.001205
92	0.001202
92.5	0.001201
93	0.001202
93.5	0.001199
94	0.001198
94.5	0.001197
95	0.001197
95.5	0.001197
96	0.001197
96.5	0.001197
97	0.001197
97.5	0.001197
98	0.001197
98.5	0.001198
99	0.001198
99.5	0.001198
100	0.001191
100.5	0.001172
101	0.001168
101.5	0.001166
102	0.001165
102.5	0.001165
103	0.001164
103.5	0.001164
104	0.001164
104.5	0.001164
105	0.001164
105.5	0.001164
106	0.001164
106.5	0.001164
107	0.001164
107.5	0.001164
108	0.001164
108.5	0.001164
109	0.001164
109.5	0.001164
110	0.001164
110.5	0.001164
111	0.001164
111.5	0.001164
112	0.001164
112.5	0.001164
113	0.001164
113.5	0.001164
114	0.001164
114.5	0.001163
115	0.001164
115.5	0.001163
116	0.001163
116.5	0.001163
117	0.001163
117.5	0.001163
118	0.001163
118.5	0.001163
119	0.001163
119.5	0.001163

Table 20. Jet-tronic data table for Figure 42 and Figure 43

Time (sec)	Rpm	SetRpm	Temp (°C)	Pump (V)	State	THR (%)	AUX (49/0)	Batt (V)	AirSpd	SetSpd
13	2020	0	32	0	1	100	49	8.05	0	0
15	3520	0	33	0	2	100	49	8.04	0	0
16	5820	0	35	0	2	100	49	8.03	0	0
17	6470	0	36	0	2	25	49	8.02	0	0
18	6030	0	42	0	2	25	49	8.02	0	0
19	6910	0	98	0	12	25	49	8.01	0	0
20	8360	0	134	0	12	25	49	8.01	0	0
21	9870	0	143	0.22	12	25	49	8.01	0	0
22	10280	0	144	0.22	12	25	49	8.01	0	0
23	11530	50500	151	0.23	3	25	49	8	0	0
24	13080	0	152	0	8	25	0	7.99	0	0
26	7590	0	130	0	8	25	0	8	0	0
27	5110	0	104	0	8	25	0	8.01	0	0
28	3390	0	88	0	0	25	0	8.02	0	0
29	2210	0	81	0	0	25	0	8.03	0	0
74	2200	0	49	0	0	25	49	8.05	0	0
82	3510	0	46	0	2	100	49	8.04	0	0
83	5890	0	48	0	2	100	49	8.03	0	0
84	6700	0	50	0	2	100	49	8.02	0	0
85	6620	0	51	0	2	100	49	8.02	0	0
86	7150	0	97	0	12	25	49	8.02	0	0
87	8790	0	140	0	12	25	49	8.02	0	0
88	10620	0	159	0.22	12	25	49	8.01	0	0

89	11040	50500	162	0.22	3	25	49	8.01	0	0
90	13470	50500	152	0.23	3	25	49	8	0	0
91	15120	50500	152	0.25	3	25	49	7.99	0	0
92	15690	50500	152	0.26	3	25	49	7.98	0	0
93	15990	50500	146	0.28	3	25	49	7.98	0	0
94	16580	50500	146	0.3	3	25	49	7.97	0	0
95	16490	50500	150	0.33	3	25	49	7.97	0	0
96	16560	50500	151	0.35	3	25	49	7.96	0	0
97	18080	50500	170	0.38	3	25	49	7.96	0	0
98	21420	50500	251	0.39	3	25	49	7.96	0	0
99	25260	50500	359	0.41	3	25	49	7.96	0	0
100	29920	50500	443	0.44	3	25	49	7.96	0	0
101	33330	50500	513	0.47	3	25	49	7.97	0	0
102	33920	50500	543	0.51	3	25	49	7.98	0	0
103	37320	50500	576	0.54	3	25	49	7.99	0	0
104	40200	50500	616	0.54	3	25	49	8	0	0
105	44200	50500	613	0.54	3	25	49	8.01	0	0
106	48350	50500	608	0.54	3	25	49	8.01	0	0
107	49160	50500	587	0.55	3	25	49	8.02	0	0
108	51000	60000	575	0.64	4	25	49	8.02	0	0
109	56390	60000	589	0.64	4	25	49	8.02	0	0
110	59880	57200	594	0.6	6	25	49	8.03	0	0
111	57980	50200	579	0.54	6	25	49	8.03	0	0
112	53850	50000	560	0.55	6	25	49	8.03	0	0
113	51880	50000	555	0.55	6	25	49	8.03	0	0
114	52010	50000	568	0.54	6	25	49	8.03	0	0
115	52240	50000	580	0.53	6	25	49	8.03	0	0
116	51980	50000	585	0.52	6	25	49	8.03	0	0

117	52480	50000	590	0.51	6	25	49	8.04	0	0
118	51430	50000	589	0.51	6	25	49	8.04	0	0
119	50300	50000	587	0.52	6	25	49	8.04	0	0
121	50620	50000	592	0.51	11	25	49	8.04	0	0
122	50610	50000	597	0.51	11	25	49	8.04	0	0
123	50740	50000	597	0.51	11	25	49	8.04	0	0
124	50940	50000	598	0.5	11	25	49	8.04	0	0
125	51190	50000	600	0.5	11	25	49	8.04	0	0
126	51390	50000	601	0.5	11	25	49	8.04	0	0
127	51640	50000	602	0.49	11	25	49	8.04	0	0
128	51250	50000	603	0.49	11	25	49	8.04	0	0
129	49860	50000	595	0.49	11	25	49	8.04	0	0
130	50860	50000	600	0.49	11	25	49	8.04	0	0
131	49790	50000	599	0.49	11	25	49	8.04	0	0
132	50790	50000	600	0.48	11	25	49	8.04	0	0
133	49570	50000	599	0.49	11	25	49	8.04	0	0
134	50710	50000	599	0.48	11	25	49	8.04	0	0
135	49760	50000	598	0.49	11	25	49	8.04	0	0
136	50730	50000	597	0.48	11	25	49	8.04	0	0
137	49900	50000	596	0.48	11	25	49	8.04	0	0
138	49760	50000	592	0.49	11	25	49	8.04	0	0
139	50870	50000	596	0.48	11	25	49	8.04	0	0
140	50680	50000	592	0.48	11	25	49	8.04	0	0
141	51010	50000	591	0.47	11	25	49	8.04	0	0
142	51330	50000	589	0.47	11	25	49	8.04	0	0
143	51670	50000	585	0.46	11	25	49	8.04	0	0
144	52030	50000	584	0.46	11	25	49	8.04	0	0
145	50650	50000	580	0.46	11	25	49	8.04	0	0

146	50490	50000	572	0.46	11	25	49	8.04	0	0
147	50800	50000	580	0.45	11	25	49	8.04	0	0
148	49800	50000	573	0.46	11	25	49	8.04	0	0
149	50710	50000	575	0.45	11	25	49	8.04	0	0
150	50100	50000	574	0.45	11	25	49	8.04	0	0
151	49950	50000	570	0.45	11	25	49	8.04	0	0
152	50090	50000	569	0.45	11	25	49	8.04	0	0
153	50190	50000	568	0.45	11	25	49	8.04	0	0
154	50330	50000	566	0.45	11	25	49	8.04	0	0
155	50570	50000	565	0.45	11	25	49	8.04	0	0
156	51010	98000	564	0.62	11	41	49	8.04	0	0
157	66840	88170	607	0.76	11	35	49	8.04	0	0
158	82840	88170	642	0.82	11	35	49	8.04	0	0
159	85460	56750	609	0.61	11	25	49	8.04	0	0
160	67190	50000	547	0.49	11	25	49	8.04	0	0
161	55310	50000	507	0.46	11	25	49	8.04	0	0
162	50670	50000	511	0.5	11	25	49	8.04	0	0
163	52680	50000	541	0.5	11	25	49	8.04	0	0
164	54950	50000	571	0.48	11	25	49	8.04	0	0
165	53040	50000	569	0.47	11	25	49	8.04	0	0
166	52310	50000	563	0.46	11	25	49	8.04	0	0
167	52070	50000	567	0.45	11	25	49	8.04	0	0
168	49980	50000	561	0.46	11	25	49	8.04	0	0
169	51610	87700	566	0.59	11	34	49	8.04	0	0
170	64680	95460	605	0.76	11	38	49	8.04	0	0
171	83110	106770	641	0.95	11	44	49	8.04	0	0
172	98880	109560	625	1.09	11	45	49	8.04	0	0
173	106930	109560	585	1.16	11	45	49	8.03	0	0

174	109090	120490	556	1.27	11	53	49	8.03	0	0
175	119850	124120	547	1.38	11	56	49	8.03	0	0
176	126100	127320	540	1.41	11	58	49	8.03	0	0
177	129270	131430	536	1.48	11	62	49	8.03	0	0
178	134670	140620	533	1.62	11	70	49	8.03	0	0
179	142680	147590	537	1.72	11	78	49	8.03	0	0
180	148160	149390	540	1.77	11	80	49	8.03	0	0
181	152250	155770	548	1.87	11	87	49	8.03	0	0
182	155840	156060	557	1.86	11	88	49	8.03	0	0
183	162060	165000	567	2.09	11	100	49	8.03	0	0
184	165170	165000	583	2.06	11	100	49	8.03	0	0
186	160160	159830	587	1.85	11	93	49	8.03	0	0
187	158500	157970	581	1.83	11	90	49	8.02	0	0
187	155920	153030	574	1.67	11	84	49	8.03	0	0
189	148360	144010	573	1.53	11	74	49	8.03	0	0
190	143890	142780	577	1.53	11	73	49	8.03	0	0
191	143290	142780	578	1.53	11	73	49	8.03	0	0
192	143440	142780	575	1.5	11	73	49	8.03	0	0
193	143280	142780	575	1.5	11	73	49	8.03	0	0
194	142900	142780	575	1.5	11	73	49	8.03	0	0
195	142200	142780	572	1.52	11	73	49	8.03	0	0
196	142530	142780	570	1.51	11	73	49	8.03	0	0
197	142770	142780	569	1.51	11	73	49	8.03	0	0
198	142740	142780	568	1.51	11	73	49	8.03	0	0
199	142780	142780	567	1.51	11	73	49	8.03	0	0
200	142600	142780	567	1.51	11	73	49	8.03	0	0
201	142260	142780	566	1.53	11	73	49	8.03	0	0
202	142720	142780	564	1.51	11	73	49	8.03	0	0

203	142780	142780	564	1.51	11	73	49	8.03	0	0
204	143070	142780	563	1.5	11	73	49	8.03	0	0
205	143500	142780	565	1.48	11	73	49	8.03	0	0
205	142790	142780	567	1.52	11	73	49	8.03	0	0
207	134750	125850	563	1.26	11	56	49	8.03	0	0
208	117990	99640	547	0.99	11	40	49	8.03	0	0
209	92680	50000	514	0.66	11	25	49	8.03	0	0
210	69190	50000	479	0.54	11	25	49	8.03	0	0
211	59130	50000	489	0.5	11	25	49	8.03	0	0
212	55260	50000	522	0.47	11	25	49	8.03	0	0
213	52650	50000	551	0.46	11	25	49	8.03	0	0
214	29240	0	528	0	8	25	0	8.04	0	0
215	17890	0	389	0	8	25	0	8.04	0	0
216	12800	0	315	0	8	25	0	8.04	0	0
217	10100	0	283	0	8	25	0	8.04	0	0
218	7820	0	270	0	8	25	0	8.05	0	0
219	6490	0	265	0	8	25	0	8.05	0	0
220	5290	0	263	0	8	25	0	8.05	0	0
221	4380	0	262	0	8	25	0	8.05	0	0
222	7140	0	260	0	8	25	0	8.04	0	0
223	9300	0	253	0	8	25	0	8.04	0	0
224	7520	0	241	0	8	25	0	8.04	0	0
225	5990	0	234	0	8	25	0	8.04	0	0
226	4880	0	230	0	8	25	0	8.04	0	0
227	4000	0	229	0	8	25	0	8.05	0	0
228	3330	0	229	0	8	25	0	8.05	0	0
229	2790	0	230	0	8	25	0	8.05	0	0
230	2330	0	231	0	8	25	0	8.05	0	0

231	1960	0	233	0	8	25	0	8.05	0	0
232	6190	0	232	0	8	25	0	8.04	0	0
233	8810	0	222	0	8	25	0	8.04	0	0
901	4220	0	37	0	2	100	49	8.04	0	0
902	6750	0	40	0	2	100	49	8.03	0	0
903	7190	0	42	0	2	100	49	8.03	0	0
904	6860	0	54	0	12	100	49	8.02	0	0
905	8640	0	111	0	12	100	49	8.02	0	0
907	10400	0	109	0.22	12	25	49	8.01	0	0
908	11200	50500	86	0.22	3	25	49	8.01	0	0
909	13450	50500	71	0.24	3	25	49	8	0	0
910	14690	50500	63	0.26	3	25	49	7.99	0	0
911	15210	50500	58	0.28	3	25	49	7.98	0	0
912	15260	0	55	0	8	25	49	7.98	0	0
913	8920	0	52	0	8	25	0	8	0	0
914	6690	0	51	0	8	25	0	8.01	0	0
915	5130	0	51	0	8	25	0	8.02	0	0
916	4110	0	50	0	8	25	0	8.03	0	0
917	3360	0	50	0	0	25	0	8.03	0	0
918	2630	0	50	0	0	25	0	8.04	0	0
919	2180	0	50	0	0	25	0	8.04	0	0
927	1150	0	49	0	0	25	49	8.05	0	0
930	4910	0	47	0	2	100	49	8.04	0	0
931	5680	0	84	0	12	100	49	8.04	0	0
932	9040	0	160	0.22	12	100	49	8.03	0	0
933	12580	0	291	0.22	12	25	49	8.03	0	0
934	14810	50500	364	0.23	3	25	49	8.01	0	0
935	18800	50500	397	0.24	3	25	49	8	0	0

936	21200	50500	399	0.26	3	25	49	7.99	0	0
937	23380	50500	396	0.28	3	25	49	7.98	0	0
938	24850	50500	395	0.31	3	25	49	7.98	0	0
939	26910	50500	406	0.34	3	25	49	7.97	0	0
940	29730	50500	432	0.37	3	25	49	7.97	0	0
941	32760	50500	467	0.4	3	25	49	7.97	0	0
942	33470	50500	508	0.44	3	25	49	7.98	0	0
943	36840	50500	572	0.47	3	25	49	7.99	0	0
944	42260	50500	626	0.51	3	25	49	8	0	0
945	49290	50500	652	0.56	3	25	49	8.01	0	0
946	56870	60000	654	0.6	4	25	49	8.01	0	0
947	60950	57900	641	0.57	6	25	49	8.02	0	0
948	57230	50200	606	0.53	6	25	49	8.02	0	0
949	54560	50000	580	0.51	6	25	49	8.03	0	0
950	51690	50000	577	0.51	6	25	49	8.03	0	0
951	51000	50000	583	0.51	6	25	49	8.03	0	0
952	50720	50000	594	0.51	6	25	49	8.03	0	0
954	50840	50000	604	0.51	11	25	49	8.03	0	0
955	50810	50000	611	0.5	11	25	49	8.03	0	0
956	50930	50000	616	0.5	11	25	49	8.03	0	0
957	50620	50000	618	0.5	11	25	49	8.03	0	0
958	50420	50000	619	0.5	11	25	49	8.03	0	0
959	50880	50000	623	0.5	11	25	49	8.04	0	0
960	51270	50000	622	0.49	11	25	49	8.04	0	0
961	51530	50000	621	0.49	11	25	49	8.04	0	0
962	50030	50000	613	0.49	11	25	49	8.04	0	0
963	50990	50000	618	0.48	11	25	49	8.04	0	0
964	49860	50000	614	0.49	11	25	49	8.04	0	0

965	50800	50000	620	0.48	11	25	49	8.03	0	0
966	53620	77650	623	0.62	11	31	49	8.03	0	0
967	64760	77650	662	0.69	11	31	49	8.04	0	0
968	73930	85770	667	0.78	11	34	49	8.04	0	0
969	82560	91740	652	0.87	11	36	49	8.04	0	0
970	88370	91740	628	0.91	11	36	49	8.03	0	0
971	90900	98160	600	0.99	11	39	49	8.04	0	0
972	95320	101430	588	1.06	11	41	49	8.04	0	0
973	100640	102820	581	1.1	11	41	49	8.04	0	0
974	102600	111040	572	1.19	11	46	49	8.04	0	0
975	114080	123410	566	1.39	11	55	49	8.04	0	0
976	125250	124820	565	1.38	11	56	49	8.03	0	0
977	127460	127990	557	1.44	11	59	49	8.03	0	0
978	130190	130800	551	1.46	11	61	49	8.03	0	0
979	131020	130800	547	1.44	11	61	49	8.03	0	0
980	139580	141890	547	1.65	11	72	49	8.03	0	0
981	142960	144530	554	1.68	11	74	49	8.03	0	0
982	145410	146580	560	1.7	11	77	49	8.03	0	0
983	148300	150520	568	1.77	11	81	49	8.03	0	0
984	152560	153340	581	1.8	11	84	49	8.03	0	0
985	155840	157240	592	1.89	11	89	49	8.03	0	0
986	161100	165000	604	2.06	11	100	49	8.03	0	0
987	164450	165000	617	2.05	11	100	49	8.03	0	0
988	163920	163440	619	1.95	11	97	49	8.02	0	0
989	159600	157970	619	1.83	11	90	49	8.02	0	0
990	155960	151630	613	1.67	11	82	49	8.02	0	0
991	148350	143840	602	1.53	11	74	49	8.03	0	0
992	142910	139510	586	1.44	11	69	49	8.03	0	0

993	136800	133090	575	1.33	11	63	49	8.03	0	0
994	130740	126870	566	1.24	11	58	49	8.03	0	0
995	123030	118460	558	1.15	11	51	49	8.03	0	0
996	110150	104500	544	1.02	11	42	49	8.03	0	0
997	102270	91310	534	0.91	11	36	49	8.03	0	0
998	86350	50000	516	0.66	11	25	49	8.03	0	0
999	67570	50000	493	0.55	11	25	49	8.03	0	0
1000	58930	50000	501	0.51	11	25	49	8.03	0	0
1001	55360	50000	531	0.5	11	25	49	8.03	0	0
1002	54100	50000	559	0.48	11	25	49	8.03	0	0
1003	51840	50000	571	0.48	11	25	49	8.04	0	0
1004	51190	50000	584	0.47	11	25	49	8.04	0	0
1005	50940	50000	599	0.47	11	25	49	8.04	0	0
1006	51130	50000	610	0.47	11	25	49	8.04	0	0
1007	51350	50000	615	0.46	11	25	49	8.04	0	0
1008	51640	50000	618	0.46	11	25	49	8.04	0	0
1010	30530	0	573	0	8	25	0	8.04	0	0
1011	18870	0	420	0	8	25	0	8.04	0	0
1012	13890	0	336	0	8	25	0	8.04	0	0
1013	10230	0	301	0	8	25	0	8.04	0	0
1014	8200	0	285	0	8	25	0	8.05	0	0
1015	6750	0	278	0	8	25	0	8.05	0	0
1016	5810	0	275	0	8	25	0	8.05	0	0
1017	4820	0	273	0	8	25	0	8.05	0	0
1018	5290	0	272	0	8	25	0	8.05	0	0
1019	8380	0	267	0	8	25	0	8.04	0	0
1020	8760	0	256	0	8	25	0	8.04	0	0
1021	6900	0	244	0	8	25	0	8.04	0	0

1022	5690	0	237	0	8	25	0	8.04	0	0
1023	4800	0	234	0	8	25	0	8.05	0	0
1024	3930	0	232	0	8	25	0	8.05	0	0
1025	3380	0	231	0	8	25	0	8.05	0	0
1026	2830	0	230	0	8	25	0	8.05	0	0
1027	2430	0	231	0	8	25	0	8.05	0	0
1028	1600	0	233	0	8	25	0	8.05	0	0
1029	4650	0	234	0	8	25	0	8.05	0	0

B. KEROSENE TEST RUN #2

Table 21. DAQ data table for Figure 45

Time (sec)	Voltage (V)
0	0.001166
0.5	0.001166
1	0.001166
1.5	0.001166
2	0.001166
2.5	0.001166
3	0.001166
3.5	0.001166
4	0.001166
4.5	0.001166
5	0.001166
5.5	0.001166
6	0.001166
6.5	0.001166
7	0.001166
7.5	0.001166
8	0.001166
8.5	0.001166
9	0.001166
9.5	0.001166
10	0.001166
10.5	0.001166
11	0.001166
11.5	0.001166
12	0.001166
12.5	0.001166
13	0.001166
13.5	0.001166
14	0.001166
14.5	0.001166
15	0.001166
15.5	0.001166
16	0.001166
16.5	0.001166
17	0.001166
17.5	0.001166
18	0.001166
18.5	0.001166
19	0.001166
19.5	0.001166
20	0.001166
20.5	0.001166
21	0.001166
21.5	0.001166
22	0.001166
22.5	0.001167
23	0.001167
23.5	0.001167
24	0.001167
24.5	0.001167
25	0.001167
25.5	0.001167
26	0.001167
26.5	0.001167
27	0.001167
27.5	0.001167
28	0.001167
28.5	0.001167
29	0.001167
29.5	0.001167
30	0.001167
30.5	0.001168
31	0.001167
31.5	0.001167
32	0.001167
32.5	0.001167
33	0.001167
33.5	0.001168
34	0.001168
34.5	0.00117
35	0.001171
35.5	0.001173
36	0.001174
36.5	0.001176
37	0.001178
37.5	0.00118
38	0.001183
38.5	0.001185
39	0.001186
39.5	0.001187
40	0.001189
40.5	0.001191
41	0.001193
41.5	0.001196
42	0.001198
42.5	0.001202
43	0.001206
43.5	0.00121
44	0.001215
44.5	0.001223
45	0.001224
45.5	0.001219
46	0.001218
46.5	0.001219
47	0.001219
47.5	0.00122
48	0.001218
48.5	0.001217
49	0.001216
49.5	0.001216
50	0.001213
50.5	0.001209
51	0.001208
51.5	0.001207
52	0.001206
52.5	0.001205
53	0.001205
53.5	0.001206
54	0.001206
54.5	0.001205
55	0.001203
55.5	0.001202
56	0.001202

56.5	0.001203
57	0.001202
57.5	0.001202
58	0.001202
58.5	0.001203
59	0.001203
59.5	0.001203
60	0.001201
60.5	0.001201
61	0.0012
61.5	0.001201
62	0.001201
62.5	0.001201
63	0.001202
63.5	0.001202
64	0.001203
64.5	0.001202
65	0.001202
65.5	0.001202
66	0.001202
66.5	0.001201
67	0.001202
67.5	0.001203
68	0.001203
68.5	0.001201
69	0.0012
69.5	0.0012
70	0.001202
70.5	0.001201
71	0.001201
71.5	0.0012
72	0.0012
72.5	0.0012
73	0.001199
73.5	0.0012
74	0.0012
74.5	0.0012
75	0.001201
75.5	0.001201
76	0.001201
76.5	0.001201
77	0.001201
77.5	0.0012
78	0.001201
78.5	0.001201
79	0.001201
79.5	0.001201
80	0.001201
80.5	0.0012
81	0.001201
81.5	0.001201
82	0.001202
82.5	0.001202
83	0.001202
83.5	0.001202
84	0.001202
84.5	0.0012
85	0.001201
85.5	0.001202
86	0.0012
86.5	0.001199
87	0.0012
87.5	0.001201
88	0.001199
88.5	0.001199
89	0.001201
89.5	0.001201
90	0.0012
90.5	0.001199
91	0.0012
91.5	0.0012
92	0.001201
92.5	0.001201
93	0.001201
93.5	0.001201
94	0.001201
94.5	0.001201
95	0.001201
95.5	0.0012
96	0.0012
96.5	0.0012
97	0.001201
97.5	0.001201
98	0.001201
98.5	0.001201
99	0.001201
99.5	0.001201
100	0.001201
100.5	0.001201
101	0.001202
101.5	0.001202
102	0.001201
102.5	0.001198
103	0.001199
103.5	0.0012
104	0.0012
104.5	0.001201
105	0.0012
105.5	0.001199
106	0.0012
106.5	0.001201
107	0.001199
107.5	0.0012
108	0.001201
108.5	0.001199
109	0.001199
109.5	0.0012
110	0.001201
110.5	0.001199
111	0.001199
111.5	0.001199
112	0.001201
112.5	0.0012
113	0.001199
113.5	0.001199
114	0.001199
114.5	0.0012
115	0.0012
115.5	0.0012
116	0.001199
116.5	0.0012
117	0.001205
117.5	0.001213
118	0.001221
118.5	0.001227
119	0.001229
119.5	0.001229
120	0.00123
120.5	0.001235
121	0.001243
121.5	0.001256
122	0.001271
122.5	0.001285
123	0.001293
123.5	0.001295

124	0.001285
124.5	0.001285
125	0.001285
125.5	0.001285
126	0.001288
126.5	0.001284
127	0.001276
127.5	0.001282
128	0.001284
128.5	0.001282
129	0.001283
129.5	0.001284
130	0.001276
130.5	0.001272
131	0.001275
131.5	0.001276
132	0.001276
132.5	0.001274
133	0.001275
133.5	0.001272
134	0.001271
134.5	0.001271
135	0.001271
135.5	0.001271
136	0.001269
136.5	0.00127
137	0.001275

137.5	0.00127
138	0.001268
138.5	0.001273
139	0.001272
139.5	0.001267
140	0.001272
140.5	0.001275
141	0.001271
141.5	0.00127
142	0.001274
142.5	0.001273
143	0.001269
143.5	0.001272
144	0.001275
144.5	0.001269
145	0.001271
145.5	0.001274
146	0.001274
146.5	0.00127
147	0.001272
147.5	0.001274
148	0.00127
148.5	0.001272
149	0.001275
149.5	0.001273
150	0.00127
150.5	0.001274

151	0.001275
151.5	0.00127
152	0.001272
152.5	0.001274
153	0.001274
153.5	0.00127
154	0.001271
154.5	0.001274
155	0.001274
155.5	0.001271
156	0.001272
156.5	0.001273
157	0.001273
157.5	0.001271
158	0.001272
158.5	0.001272
159	0.001272
159.5	0.001271
160	0.001271
160.5	0.001271
161	0.00127
161.5	0.001271
162	0.001271
162.5	0.001274
163	0.001274
163.5	0.001272
164	0.001272

164.5	0.001272
165	0.001272
165.5	0.001274
166	0.001274
166.5	0.001273
167	0.001272
167.5	0.001276
168	0.001272
168.5	0.00127
169	0.001272
169.5	0.001277
170	0.001273
170.5	0.001271
171	0.00127
171.5	0.001276
172	0.001274
172.5	0.001272
173	0.001271
173.5	0.001274
174	0.001272
174.5	0.001271
175	0.001271
175.5	0.001277
176	0.001273
176.5	0.00127
177	0.001272
177.5	0.001277

178	0.001273
178.5	0.001272
179	0.001271
179.5	0.00127
180	0.001276
180.5	0.00129
181	0.001303
181.5	0.001316
182	0.001319
182.5	0.001332
183	0.001347
183.5	0.001351
184	0.001352
184.5	0.001363
185	0.001359
185.5	0.001378
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186.5	0.001371
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187.5	0.001376
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188.5	0.001376
189	0.001377
189.5	0.001381
190	0.001377
190.5	0.001376
191	0.001376

191.5	0.001377
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192.5	0.001381
193	0.001373
193.5	0.001379
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194.5	0.001376
195	0.001376
195.5	0.001378
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196.5	0.001377
197	0.001378
197.5	0.00138
198	0.001371
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199	0.001377
199.5	0.001376
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200.5	0.001378
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202.5	0.001379
203	0.001376
203.5	0.001378
204	0.001378
204.5	0.00137

205	0.001381
205.5	0.001373
206	0.001377
206.5	0.001379
207	0.001375
207.5	0.001375
208	0.00138
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209	0.001381
209.5	0.001372
210	0.001379
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213	0.001377
213.5	0.001378
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215.5	0.001381
216	0.001373
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222.5	0.001378
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225.5	0.001453
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227.5	0.001483
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228.5	0.001504
229	0.001495
229.5	0.001502
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230.5	0.001513
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233.5	0.001514
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234.5	0.001518
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235.5	0.001516
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236.5	0.001517
237	0.001511
237.5	0.001517
238	0.001516
238.5	0.001521
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239.5	0.001513
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240.5	0.001516
241	0.001514
241.5	0.001515
242	0.001516
242.5	0.001516
243	0.001512
243.5	0.001517
244	0.001514
244.5	0.001517
245	0.001527

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246	0.00152
246.5	0.001514
247	0.001512
247.5	0.001519
248	0.001511
248.5	0.001517
249	0.001513
249.5	0.001519
250	0.001511
250.5	0.001518
251	0.001512
251.5	0.001516
252	0.001512
252.5	0.001515
253	0.001518
253.5	0.001518
254	0.001513
254.5	0.00152
255	0.001514
255.5	0.001509
256	0.001516
256.5	0.001514
257	0.001512
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258	0.001513
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259.5	0.001516
260	0.001516
260.5	0.001515
261	0.001514
261.5	0.001514
262	0.001512
262.5	0.001519
263	0.001509
263.5	0.001515
264	0.001511
264.5	0.001514
265	0.001511
265.5	0.001519
266	0.001512
266.5	0.001513
267	0.001519
267.5	0.00151
268	0.001518
268.5	0.001512
269	0.001515
269.5	0.001516
270	0.001518
270.5	0.001596
271	0.00168
271.5	0.001725
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272.5	0.001746
273	0.001737
273.5	0.001737
274	0.001741
274.5	0.001751
275	0.001751
275.5	0.001744
276	0.001742
276.5	0.00174
277	0.001743
277.5	0.001746
278	0.001741
278.5	0.001746
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279.5	0.001748
280	0.00174
280.5	0.001745
281	0.001741
281.5	0.001741
282	0.001736
282.5	0.001745
283	0.001736
283.5	0.001744
284	0.001747
284.5	0.001743
285	0.001746
285.5	0.001742
286	0.001742
286.5	0.001745
287	0.001746
287.5	0.00174
288	0.001742
288.5	0.00174
289	0.001745
289.5	0.001739
290	0.001742
290.5	0.001743
291	0.001732
291.5	0.001734
292	0.001734
292.5	0.001738
293	0.00174
293.5	0.001742
294	0.001742
294.5	0.001735
295	0.001741
295.5	0.001746
296	0.001735
296.5	0.001738
297	0.001737
297.5	0.001747
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298.5	0.001743
299	0.00174
299.5	0.001742
300	0.001737
300.5	0.001743
301	0.001741
301.5	0.001738
302	0.001731
302.5	0.001742
303	0.001737
303.5	0.001741
304	0.001746
304.5	0.001746
305	0.001742
305.5	0.001745
306	0.001754
306.5	0.001741
307	0.001737
307.5	0.001741
308	0.001739
308.5	0.001737
309	0.001736
309.5	0.001739
310	0.001736
310.5	0.001746
311	0.001705
311.5	0.001697
312	0.001675
312.5	0.001648
313	0.001624
313.5	0.001611
314	0.001605
314.5	0.001598
315	0.001597
315.5	0.001588
316	0.001584
316.5	0.001577
317	0.001571
317.5	0.001567
318	0.001554
318.5	0.001542
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319.5	0.001529
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321	0.00152
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322.5	0.001509
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323.5	0.001514
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325	0.001513
325.5	0.001516
326	0.001513

326.5	0.001514
327	0.001515
327.5	0.001517
328	0.00151
328.5	0.001517
329	0.001512
329.5	0.001514
330	0.001512
330.5	0.001517
331	0.001513
331.5	0.001511
332	0.001517
332.5	0.001513
333	0.001515
333.5	0.001512
334	0.001521
334.5	0.001513
335	0.001519
335.5	0.001514
336	0.001516
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339	0.001513
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341	0.001516
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343	0.001514
343.5	0.001523
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344.5	0.001517
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347	0.001516
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348	0.001519
348.5	0.001512
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361	0.001518
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363	0.001514
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364	0.001515
364.5	0.001516
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365.5	0.001514
366	0.001511
366.5	0.001457
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367.5	0.00143
368	0.001436
368.5	0.001412
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370	0.001398
370.5	0.001388
371	0.001392
371.5	0.00138
372	0.001385
372.5	0.001381
373	0.001376
373.5	0.001391
374	0.001378
374.5	0.001377
375	0.001378
375.5	0.001382
376	0.001376
376.5	0.00138
377	0.00138
377.5	0.001381
378	0.001375
378.5	0.001382
379	0.001376
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384.5	0.001384
385	0.001376
385.5	0.001384
386	0.001375
386.5	0.001384
387	0.001378
387.5	0.001382
388	0.001379
388.5	0.001383
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415	0.001247
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416.5	0.001204
417	0.001194
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Table 22. Jet-tronic data table for Figure 46 and Figure 47

Time (sec)	Rpm	SetRpm	Temp (°C)	Pump (V)	State	THR (%)	AUX (49/0)	Batt (V)	AirSpd	SetSpd
416	5710	0	19	0	2	100	49	8.01	0	0
417	5880	0	18	0	2	100	49	8.01	0	0
418	5430	0	30	0	2	100	49	8	0	0
419	6090	0	95	0	12	100	49	8	0	0
420	7500	0	136	0	12	100	49	8	0	0
421	8010	0	137	0	12	25	49	8	0	0
422	8350	0	110	0	12	25	49	8	0	0
423	8520	0	81	0	12	25	49	8	0	0
424	8690	0	62	0	12	25	49	8	0	0
425	8600	0	50	0	12	25	49	8	0	0
426	8680	0	44	0	12	25	49	8	0	0
427	8780	0	39	0	12	25	49	8	0	0
428	8820	0	36	0	12	25	49	8	0	0
429	8890	0	34	0	12	25	49	8	0	0
431	9010	0	33	0.22	12	25	49	8	0	0
432	9060	0	31	0.22	12	25	100	8	0	0
434	9400	0	30	0	8	0	49	7.99	0	0
435	4740	0	29	0	8	0	0	8	0	0
435	2910	0	29	0	0	0	0	8.01	0	0
438	3620	0	29	0	0	0	0	8.02	0	0
647	4360	0	21	0	2	100	49	8.03	0	0
648	5130	0	22	0	2	100	49	8.03	0	0
649	4100	0	22	0	2	100	49	8.02	0	0
650	3230	0	22	0	2	100	49	8.02	0	0
651	5530	0	22	0	2	100	49	8.02	0	0

652	2970	0	35	0	12	100	49	8.02	0	0
653	3750	0	94	0	12	100	49	8.02	0	0
654	5940	0	150	0	12	100	49	8.01	0	0
655	7440	0	156	0	12	100	49	8.01	0	0
656	8620	0	155	0	12	25	49	8.01	0	0
658	9490	0	150	0.22	12	25	49	8.01	0	0
659	9700	0	147	0.22	12	25	49	8	0	0
660	11270	50500	147	0.23	3	25	49	8	0	0
661	13000	50500	144	0.24	3	25	49	7.99	0	0
662	14030	50500	136	0.26	3	25	49	7.98	0	0
663	14560	50500	129	0.28	3	25	49	7.97	0	0
664	14810	50500	125	0.31	3	25	49	7.97	0	0
665	15190	50500	123	0.34	3	25	49	7.97	0	0
666	16430	50500	134	0.37	3	25	49	7.96	0	0
667	20170	50500	212	0.4	3	25	49	7.96	0	0
668	23430	50500	325	0.44	3	25	49	7.96	0	0
669	27090	50500	419	0.48	3	25	49	7.96	0	0
670	31570	50500	486	0.52	3	25	49	7.96	0	0
671	34070	50500	541	0.56	3	25	49	7.97	0	0
672	35850	50500	590	0.6	3	25	49	7.98	0	0
673	38450	50500	637	0.65	3	25	49	7.99	0	0
674	41810	50500	677	0.66	3	25	49	8	0	0
675	46790	50500	693	0.66	3	25	49	8.01	0	0
676	57070	60000	675	0.69	4	25	49	8.02	0	0
677	64310	60000	629	0.65	4	25	49	8.02	0	0
678	61700	60000	564	0.65	4	25	49	8.02	0	0
679	61990	60000	536	0.64	4	25	49	8.03	0	0
680	61740	60000	527	0.63	4	25	49	8.03	0	0

681	60820	56500	519	0.61	6	25	49	8.03	0	0
682	59030	50200	521	0.57	6	25	49	8.03	0	0
683	55500	50000	518	0.55	6	25	49	8.03	0	0
684	54090	50000	536	0.54	6	25	49	8.03	0	0
685	53590	50000	554	0.53	6	25	49	8.03	0	0
686	53930	50000	572	0.51	6	25	49	8.03	0	0
687	52400	50000	580	0.51	6	25	49	8.04	0	0
688	51790	50000	588	0.51	6	25	49	8.04	0	0
689	51800	50000	599	0.5	6	25	49	8.04	0	0
691	51640	50000	604	0.5	11	25	49	8.04	0	0
692	52310	50000	614	0.48	11	25	49	8.04	0	0
693	51160	50000	611	0.48	11	25	49	8.04	0	0
694	51040	50000	610	0.48	11	25	49	8.04	0	0
695	51140	50000	612	0.48	11	25	49	8.04	0	0
696	51440	50000	614	0.47	11	25	49	8.04	0	0
697	51470	50000	615	0.47	11	25	49	8.04	0	0
698	50830	50000	615	0.47	11	25	49	8.04	0	0
699	51170	50000	621	0.46	11	25	49	8.04	0	0
700	51820	50000	629	0.45	11	25	49	8.04	0	0
701	50670	50000	629	0.45	11	25	49	8.04	0	0
702	50980	50000	626	0.45	11	25	49	8.04	0	0
702	51110	50000	635	0.45	11	25	49	8.04	0	0
704	50160	50000	629	0.45	11	25	49	8.04	0	0
705	49420	50000	623	0.45	11	25	49	8.04	0	0
705	49810	50000	623	0.45	11	25	49	8.04	0	0
707	50520	50000	628	0.45	11	25	49	8.04	0	0
708	51050	50000	629	0.45	11	25	49	8.04	0	0
709	51140	50000	627	0.44	11	25	49	8.04	0	0

710	50910	50000	623	0.44	11	25	49	8.04	0	0
711	51080	50000	623	0.44	11	25	49	8.04	0	0
712	50630	50000	623	0.44	11	25	49	8.04	0	0
713	50400	50000	621	0.43	11	25	49	8.04	0	0
714	50910	50000	623	0.43	11	25	49	8.04	0	0
715	51030	50000	623	0.43	11	25	49	8.04	0	0
716	51170	50000	625	0.42	11	25	49	8.03	0	0
717	50340	50000	615	0.43	11	25	49	8.04	0	0
718	50370	50000	617	0.42	11	25	49	8.04	0	0
719	50100	50000	608	0.42	11	25	49	8.04	0	0
720	49510	50000	608	0.43	11	25	49	8.04	0	0
721	50840	50000	606	0.42	11	25	49	8.04	0	0
722	50110	50000	606	0.42	11	25	49	8.04	0	0
723	49910	50000	596	0.42	11	25	49	8.04	0	0
724	50520	50000	596	0.42	11	25	49	8.04	0	0
725	51010	50000	596	0.42	11	25	49	8.04	0	0
726	51140	50000	595	0.41	11	25	49	8.04	0	0
727	50840	50000	593	0.41	11	25	49	8.04	0	0
728	50270	50000	587	0.41	11	25	49	8.04	0	0
728	50630	50000	587	0.41	11	25	49	8.04	0	0
730	51060	50000	589	0.4	11	25	49	8.04	0	0
731	51040	50000	587	0.4	11	25	49	8.04	0	0
732	51080	50000	584	0.4	11	25	49	8.04	0	0
733	51160	50000	583	0.39	11	25	49	8.04	0	0
734	50070	50000	581	0.4	11	25	49	8.04	0	0
735	49700	50000	573	0.4	11	25	49	8.04	0	0
736	50850	50000	580	0.39	11	25	49	8.04	0	0
737	49750	50000	581	0.4	11	25	49	8.04	0	0

738	50610	50000	579	0.39	11	25	49	8.04	0	0
738	49750	50000	576	0.4	11	25	49	8.04	0	0
740	50260	50000	579	0.39	11	25	49	8.04	0	0
741	50220	50000	573	0.39	11	25	49	8.04	0	0
742	50120	50000	578	0.39	11	25	49	8.04	0	0
743	49640	50000	570	0.39	11	25	49	8.04	0	0
744	50370	50000	574	0.39	11	25	49	8.04	0	0
745	49840	50000	568	0.39	11	25	49	8.04	0	0
746	50020	50000	566	0.39	11	25	49	8.04	0	0
747	50120	50000	568	0.39	11	25	49	8.04	0	0
748	50360	62170	566	0.5	11	27	49	8.04	0	0
749	58030	63980	592	0.53	11	27	49	8.04	0	0
750	65470	65710	620	0.52	11	28	49	8.04	0	0
751	67290	68130	603	0.53	11	28	49	8.04	0	0
752	70570	87700	585	0.64	11	34	49	8.04	0	0
753	79670	90430	591	0.74	11	36	49	8.04	0	0
754	89270	94250	597	0.82	11	37	49	8.04	0	0
755	90700	90870	581	0.78	11	36	49	8.04	0	0
756	89100	90870	548	0.82	11	36	49	8.04	0	0
756	89230	90870	538	0.83	11	36	49	8.03	0	0
758	87100	89540	535	0.84	11	35	49	8.03	0	0
759	88980	89540	538	0.84	11	35	49	8.03	0	0
760	88260	89540	547	0.86	11	35	49	8.03	0	0
761	87110	85770	548	0.82	11	34	49	8.03	0	0
762	85490	85770	545	0.84	11	34	49	8.03	0	0
763	86030	85770	554	0.83	11	34	49	8.03	0	0
764	85680	85770	555	0.83	11	34	49	8.03	0	0
765	84400	84780	547	0.84	11	33	49	8.03	0	0

766	84300	84780	534	0.85	11	33	49	8.03	0	0
767	84110	84780	532	0.85	11	33	49	8.03	0	0
768	85030	84780	533	0.85	11	33	49	8.03	0	0
769	83870	84780	537	0.86	11	33	49	8.03	0	0
770	85050	84780	541	0.85	11	33	49	8.03	0	0
771	84450	84780	539	0.86	11	33	49	8.03	0	0
772	84700	84780	546	0.85	11	33	49	8.03	0	0
773	85250	84780	546	0.85	11	33	49	8.03	0	0
774	83910	84780	547	0.86	11	33	49	8.03	0	0
774	85500	84780	549	0.85	11	33	49	8.03	0	0
776	84230	84780	548	0.87	11	33	49	8.03	0	0
777	85350	84780	554	0.85	11	33	49	8.03	0	0
778	84960	84780	554	0.86	11	33	49	8.03	0	0
779	84090	84780	553	0.87	11	33	49	8.03	0	0
780	85560	84780	552	0.85	11	33	49	8.03	0	0
781	84250	84780	549	0.87	11	33	49	8.03	0	0
782	85350	84780	551	0.85	11	33	49	8.03	0	0
783	84620	84780	548	0.86	11	33	49	8.03	0	0
784	85270	84780	551	0.85	11	33	49	8.03	0	0
785	84820	84780	548	0.86	11	33	49	8.03	0	0
786	84870	84780	550	0.86	11	33	49	8.04	0	0
787	84770	84780	547	0.86	11	33	49	8.03	0	0
787	84690	84780	548	0.86	11	33	49	8.03	0	0
789	84510	84780	548	0.87	11	33	49	8.03	0	0
790	84410	84780	549	0.87	11	33	49	8.03	0	0
790	84300	84780	549	0.87	11	33	49	8.03	0	0
792	84170	84780	550	0.88	11	33	49	8.03	0	0
793	84390	84780	552	0.88	11	33	49	8.03	0	0

794	84900	84780	555	0.88	11	33	49	8.03	0	0
795	84510	84780	555	0.88	11	33	49	8.03	0	0
796	84590	84780	557	0.88	11	33	49	8.03	0	0
797	84680	84780	557	0.88	11	33	49	8.04	0	0
798	85440	84780	556	0.87	11	33	49	8.03	0	0
799	84330	84780	556	0.88	11	33	49	8.03	0	0
800	85880	84780	557	0.87	11	33	49	8.03	0	0
801	84370	84780	556	0.88	11	33	49	8.03	0	0
802	85530	84780	555	0.87	11	33	49	8.03	0	0
803	84450	84780	556	0.88	11	33	49	8.03	0	0
804	85280	84780	556	0.87	11	33	49	8.03	0	0
805	84340	84780	558	0.88	11	33	49	8.03	0	0
806	85950	84780	559	0.87	11	33	49	8.03	0	0
807	83980	84780	555	0.89	11	33	49	8.03	0	0
808	85820	84780	556	0.87	11	33	49	8.03	0	0
809	84400	84780	555	0.88	11	33	49	8.04	0	0
810	84360	85770	555	0.9	11	34	49	8.04	0	0
811	91080	97780	561	1.02	11	39	49	8.04	0	0
811	97940	98910	562	1.02	11	39	49	8.03	0	0
813	103560	107720	547	1.13	11	44	49	8.04	0	0
814	106500	108340	536	1.14	11	45	49	8.03	0	0
814	109050	109860	527	1.15	11	46	49	8.03	0	0
816	112900	112780	527	1.17	11	47	49	8.03	0	0
817	112150	112780	519	1.2	11	47	49	8.03	0	0
818	112440	112780	513	1.19	11	47	49	8.03	0	0
819	111940	112780	509	1.2	11	47	49	8.03	0	0
819	113170	112780	507	1.18	11	47	49	8.03	0	0
821	112240	112780	504	1.19	11	47	49	8.03	0	0

821	112200	112780	504	1.2	11	47	49	8.03	0	0
823	112300	112780	505	1.19	11	47	49	8.03	0	0
824	113320	112780	505	1.17	11	47	49	8.03	0	0
825	112460	112780	502	1.19	11	47	49	8.03	0	0
826	112760	112780	501	1.18	11	47	49	8.03	0	0
827	112950	112780	501	1.18	11	47	49	8.03	0	0
828	112370	112780	502	1.18	11	47	49	8.03	0	0
829	112690	112780	502	1.18	11	47	49	8.03	0	0
830	112980	112780	505	1.18	11	47	49	8.03	0	0
831	112930	112780	505	1.17	11	47	49	8.03	0	0
831	112790	112780	504	1.18	11	47	49	8.03	0	0
832	112850	112780	505	1.17	11	47	49	8.03	0	0
834	113040	112780	506	1.16	11	47	49	8.03	0	0
835	113430	112780	506	1.16	11	47	49	8.03	0	0
836	112960	112780	508	1.17	11	47	49	8.03	0	0
836	112400	112780	508	1.18	11	47	49	8.03	0	0
838	112800	112780	506	1.17	11	47	49	8.03	0	0
839	113390	112780	506	1.16	11	47	49	8.03	0	0
840	112950	112780	505	1.17	11	47	49	8.03	0	0
841	112500	112780	505	1.18	11	47	49	8.03	0	0
842	112460	112780	505	1.18	11	47	49	8.03	0	0
842	112320	112780	504	1.18	11	47	49	8.03	0	0
844	113330	112780	505	1.16	11	47	49	8.03	0	0
845	112980	112780	506	1.17	11	47	49	8.03	0	0
845	112060	112780	508	1.19	11	47	49	8.03	0	0
847	113230	112780	509	1.17	11	47	49	8.03	0	0
848	111990	112780	508	1.19	11	47	49	8.04	0	0
849	112890	112780	507	1.17	11	47	49	8.03	0	0

850	112280	112780	506	1.18	11	47	49	8.03	0	0
851	113340	112780	508	1.16	11	47	49	8.03	0	0
852	112650	112780	507	1.18	11	47	49	8.03	0	0
853	112480	117680	507	1.25	11	51	49	8.03	0	0
854	119600	121720	510	1.3	11	54	49	8.03	0	0
855	126900	128430	514	1.36	11	59	49	8.03	0	0
856	128820	129730	518	1.37	11	60	49	8.03	0	0
857	132250	132470	522	1.38	11	63	49	8.03	0	0
858	135340	135100	525	1.4	11	65	49	8.03	0	0
859	135010	136080	529	1.45	11	66	49	8.03	0	0
860	136850	136860	533	1.43	11	67	49	8.03	0	0
860	137520	137820	537	1.45	11	68	49	8.03	0	0
862	139270	139140	542	1.45	11	69	49	8.03	0	0
863	137580	137440	544	1.43	11	67	49	8.03	0	0
864	138100	137440	543	1.4	11	67	49	8.03	0	0
865	137890	137440	543	1.41	11	67	49	8.03	0	0
865	138140	137440	546	1.4	11	67	49	8.03	0	0
867	137190	137440	548	1.42	11	67	49	8.03	0	0
868	138170	137440	549	1.39	11	67	49	8.03	0	0
869	137550	137440	550	1.41	11	67	49	8.03	0	0
870	136760	137440	552	1.43	11	67	49	8.03	0	0
871	136980	137440	552	1.42	11	67	49	8.03	0	0
872	137040	137440	553	1.42	11	67	49	8.03	0	0
873	137300	137440	553	1.41	11	67	49	8.03	0	0
874	137850	137440	553	1.41	11	67	49	8.03	0	0
875	137900	137440	554	1.4	11	67	49	8.03	0	0
876	137070	137440	553	1.42	11	67	49	8.03	0	0
877	137740	137440	553	1.4	11	67	49	8.03	0	0

878	137370	137440	553	1.41	11	67	49	8.03	0	0
879	137710	137440	554	1.4	11	67	49	8.03	0	0
880	137600	137440	554	1.4	11	67	49	8.03	0	0
881	137770	137440	553	1.39	11	67	49	8.03	0	0
881	137780	137440	555	1.39	11	67	49	8.03	0	0
883	136970	137440	556	1.42	11	67	49	8.03	0	0
884	137970	137440	556	1.39	11	67	49	8.03	0	0
884	137440	137440	554	1.4	11	67	49	8.03	0	0
886	137240	137440	555	1.41	11	67	49	8.03	0	0
887	136990	137440	554	1.42	11	67	49	8.03	0	0
888	137290	137440	555	1.41	11	67	49	8.03	0	0
889	137460	137440	555	1.41	11	67	49	8.03	0	0
890	137530	137440	554	1.4	11	67	49	8.03	0	0
891	137210	137440	554	1.41	11	67	49	8.03	0	0
892	136910	137440	555	1.42	11	67	49	8.03	0	0
893	137540	137440	556	1.4	11	67	49	8.03	0	0
894	137050	137440	556	1.42	11	67	49	8.03	0	0
894	137370	137440	556	1.4	11	67	49	8.03	0	0
896	138140	137440	556	1.38	11	67	49	8.03	0	0
897	137960	137440	557	1.38	11	67	49	8.03	0	0
898	138120	137440	557	1.38	11	67	49	8.03	0	0
899	140010	165000	558	1.71	11	100	49	8.03	0	0
900	159570	165000	578	1.97	11	100	49	8.03	0	0
901	165250	165000	601	1.95	11	100	49	8.03	0	0
902	164000	165000	610	1.98	11	100	49	8.03	0	0
903	165210	165000	617	1.94	11	100	49	8.03	0	0
904	164980	165000	622	1.95	11	100	49	8.02	0	0
905	164250	165000	625	1.98	11	100	49	8.02	0	0

906	164720	165000	627	1.96	11	100	49	8.02	0	0
907	164630	165000	628	1.97	11	100	49	8.02	0	0
908	164970	165000	631	1.95	11	100	49	8.02	0	0
909	165350	165000	631	1.93	11	100	49	8.02	0	0
910	164620	165000	630	1.95	11	100	49	8.02	0	0
911	163790	165000	631	1.98	11	100	49	8.02	0	0
912	165150	165000	636	1.93	11	100	49	8.02	0	0
913	164610	165000	637	1.95	11	100	49	8.02	0	0
914	164830	165000	635	1.93	11	100	49	8.02	0	0
915	164740	165000	635	1.94	11	100	49	8.02	0	0
916	164920	165000	635	1.93	11	100	49	8.02	0	0
917	165440	165000	637	1.91	11	100	49	8.02	0	0
918	164240	165000	637	1.96	11	100	49	8.02	0	0
919	165400	165000	637	1.9	11	100	49	8.02	0	0
920	165320	165000	637	1.9	11	100	49	8.02	0	0
921	165200	165000	638	1.91	11	100	49	8.02	0	0
922	163830	165000	640	1.96	11	100	49	8.02	0	0
923	164990	165000	638	1.93	11	100	49	8.02	0	0
924	164620	165000	638	1.94	11	100	49	8.02	0	0
925	165260	165000	637	1.91	11	100	49	8.02	0	0
926	165450	165000	638	1.91	11	100	49	8.02	0	0
927	165260	165000	638	1.91	11	100	49	8.02	0	0
928	165130	165000	640	1.91	11	100	49	8.02	0	0
929	165830	165000	639	1.88	11	100	49	8.02	0	0
930	165030	165000	638	1.9	11	100	49	8.02	0	0
931	164510	165000	639	1.93	11	100	49	8.02	0	0
932	164680	165000	640	1.93	11	100	49	8.02	0	0
933	164780	165000	639	1.93	11	100	49	8.02	0	0

934	164980	165000	640	1.91	11	100	49	8.02	0	0
935	165700	165000	640	1.88	11	100	49	8.02	0	0
936	165140	165000	641	1.9	11	100	49	8.03	0	0
937	165130	165000	640	1.89	11	100	49	8.03	0	0
938	164540	161660	641	1.77	11	95	49	8.03	0	0
939	160490	158260	633	1.73	11	91	49	8.03	0	0
940	154510	150520	624	1.57	11	81	49	8.03	0	0
941	150650	148410	609	1.52	11	79	49	8.03	0	0
942	149160	148080	600	1.52	11	78	49	8.03	0	0
943	148530	147590	594	1.5	11	78	49	8.03	0	0
944	146650	145400	592	1.45	11	75	49	8.03	0	0
945	144200	143490	586	1.43	11	73	49	8.03	0	0
946	141730	139510	577	1.34	11	69	49	8.03	0	0
947	139710	138760	570	1.35	11	68	49	8.03	0	0
948	138790	138200	566	1.34	11	68	49	8.03	0	0
949	136730	137050	564	1.35	11	67	49	8.03	0	0
950	136750	137050	562	1.35	11	67	49	8.03	0	0
951	137460	137440	562	1.35	11	67	49	8.03	0	0
952	136910	137440	562	1.36	11	67	49	8.03	0	0
953	137130	137440	563	1.36	11	67	49	8.03	0	0
954	137350	137440	563	1.36	11	67	49	8.03	0	0
955	137190	137440	563	1.36	11	67	49	8.03	0	0
956	137320	137440	560	1.36	11	67	49	8.03	0	0
957	137410	137440	558	1.36	11	67	49	8.03	0	0
958	137740	137440	557	1.35	11	67	49	8.03	0	0
959	137150	137440	556	1.37	11	67	49	8.03	0	0
960	137400	137440	557	1.37	11	67	49	8.03	0	0
961	137720	137440	556	1.36	11	67	49	8.03	0	0

962	137800	137440	556	1.37	11	67	49	8.03	0	0
963	137510	137440	556	1.37	11	67	49	8.03	0	0
964	136960	137440	556	1.39	11	67	49	8.03	0	0
965	137510	137440	556	1.38	11	67	49	8.03	0	0
966	137280	137440	556	1.38	11	67	49	8.03	0	0
967	137630	137440	556	1.38	11	67	49	8.03	0	0
968	137600	137440	555	1.38	11	67	49	8.03	0	0
969	136760	137440	556	1.4	11	67	49	8.03	0	0
970	136740	137440	555	1.4	11	67	49	8.03	0	0
971	137320	137440	556	1.39	11	67	49	8.03	0	0
972	137510	137440	554	1.39	11	67	49	8.03	0	0
973	137780	137440	552	1.38	11	67	49	8.03	0	0
974	137640	137440	553	1.38	11	67	49	8.03	0	0
975	138000	137440	553	1.37	11	67	49	8.03	0	0
976	137520	137440	553	1.39	11	67	49	8.03	0	0
977	137550	137440	553	1.38	11	67	49	8.03	0	0
978	137340	137440	553	1.39	11	67	49	8.03	0	0
979	137590	137440	552	1.38	11	67	49	8.03	0	0
980	137390	137440	554	1.39	11	67	49	8.03	0	0
981	137290	137440	554	1.39	11	67	49	8.03	0	0
982	137800	137440	553	1.38	11	67	49	8.03	0	0
983	137250	137440	555	1.4	11	67	49	8.03	0	0
984	137040	137440	555	1.4	11	67	49	8.03	0	0
985	137460	137440	555	1.39	11	67	49	8.03	0	0
986	136990	137440	555	1.4	11	67	49	8.03	0	0
987	137070	137440	555	1.4	11	67	49	8.03	0	0
988	137740	137440	554	1.38	11	67	49	8.03	0	0
989	137410	137440	553	1.39	11	67	49	8.03	0	0

990	137560	137440	553	1.38	11	67	49	8.03	0	0
991	138010	137440	554	1.37	11	67	49	8.03	0	0
992	137330	137440	553	1.38	11	67	49	8.03	0	0
993	129300	128430	549	1.28	11	59	49	8.03	0	0
994	123660	123410	542	1.25	11	55	49	8.03	0	0
995	121210	119480	546	1.18	11	52	49	8.03	0	0
996	116780	116090	541	1.16	11	50	49	8.03	0	0
997	115520	115550	532	1.15	11	49	49	8.03	0	0
998	113080	113900	529	1.15	11	48	49	8.03	0	0
999	113500	113620	529	1.13	11	48	49	8.03	0	0
1000	115220	113620	529	1.11	11	48	49	8.04	0	0
1001	113880	113620	524	1.13	11	48	49	8.03	0	0
1002	113920	113620	524	1.13	11	48	49	8.04	0	0
1003	113200	113620	522	1.15	11	48	49	8.04	0	0
1004	112980	113620	521	1.15	11	48	49	8.04	0	0
1005	113170	113620	518	1.16	11	48	49	8.04	0	0
1006	113180	113620	515	1.16	11	48	49	8.04	0	0
1007	114300	113620	511	1.14	11	48	49	8.04	0	0
1008	113900	113620	507	1.15	11	48	49	8.04	0	0
1009	113890	113620	503	1.15	11	48	49	8.04	0	0
1010	114040	113620	502	1.15	11	48	49	8.04	0	0
1011	113430	113620	502	1.16	11	48	49	8.04	0	0
1012	113210	113620	501	1.17	11	48	49	8.04	0	0
1013	112760	113620	499	1.18	11	48	49	8.04	0	0
1014	113030	113620	496	1.18	11	48	49	8.04	0	0
1015	113480	113620	496	1.17	11	48	49	8.04	0	0
1016	114010	113620	495	1.16	11	48	49	8.04	0	0
1017	114030	113620	494	1.16	11	48	49	8.04	0	0

1018	113220	113620	491	1.18	11	48	49	8.04	0	0
1019	113820	113620	493	1.17	11	48	49	8.04	0	0
1020	113040	113620	494	1.18	11	48	49	8.04	0	0
1021	113250	113620	494	1.18	11	48	49	8.04	0	0
1022	113770	113620	492	1.17	11	48	49	8.04	0	0
1023	112880	113620	492	1.18	11	48	49	8.04	0	0
1024	113880	113620	492	1.17	11	48	49	8.04	0	0
1025	113670	113620	492	1.17	11	48	49	8.04	0	0
1026	113520	113620	492	1.17	11	48	49	8.04	0	0
1027	114350	113620	493	1.16	11	48	49	8.04	0	0
1028	113600	113620	492	1.17	11	48	49	8.04	0	0
1029	113550	113620	492	1.17	11	48	49	8.04	0	0
1030	113340	113620	493	1.18	11	48	49	8.04	0	0
1031	113210	113620	493	1.19	11	48	49	8.04	0	0
1032	113700	113620	495	1.18	11	48	49	8.04	0	0
1033	113510	113620	494	1.18	11	48	49	8.04	0	0
1034	113890	113620	493	1.18	11	48	49	8.04	0	0
1035	110250	113620	495	1.23	11	48	49	8.04	0	0
1036	100030	113620	478	1.28	11	48	49	8.04	0	0
1037	95010	113620	481	1.22	11	48	49	8.04	0	0
1038	91370	113620	477	1.18	11	48	49	8.04	0	0
1039	89950	113620	481	1.17	11	48	49	8.04	0	0
1040	89450	83240	490	0.96	11	33	49	8.04	0	0
1041	70880	83760	490	0.98	11	33	49	8.04	0	0
1042	57310	60000	502	0.63	10	33	100	8.04	0	0
1043	47740	60000	533	0.63	10	33	100	8.04	0	0
1044	41650	60000	558	0.63	10	33	100	8.04	0	0
1045	38070	60000	570	0.63	10	33	100	8.04	0	0

1046	37860	60000	595	0.63	10	33	100	8.04	0	0
1047	38320	60000	632	0.63	10	33	100	8.04	0	0
1049	28810	0	633	0	8	33	0	8.04	0	0
1050	18110	0	483	0	8	33	100	8.04	0	0
1051	12720	0	367	0	8	33	100	8.04	0	0
1052	9720	0	310	0	8	33	100	8.04	0	0
1053	7750	0	285	0	8	33	100	8.04	0	0
1054	6330	0	273	0	8	33	100	8.04	0	0
1055	5410	0	267	0	8	33	100	8.04	0	0
1056	4540	0	263	0	8	33	100	8.04	0	0
1057	6500	0	260	0	8	33	100	8.04	0	0
1058	9180	0	253	0	8	33	100	8.03	0	0
1059	7570	0	240	0	8	33	100	8.03	0	0
1060	6040	0	230	0	8	33	100	8.03	0	0
1061	4860	0	224	0	8	33	100	8.03	0	0
1062	3950	0	222	0	8	33	100	8.04	0	0
1063	3320	0	221	0	8	33	100	8.04	0	0
1064	2670	0	221	0	8	33	100	8.04	0	0
1065	2180	0	223	0	8	33	100	8.04	0	0
1066	4490	0	225	0	8	33	100	8.03	0	0
1067	7810	0	218	0	8	33	100	8.03	0	0
1068	9020	0	204	0	8	33	100	8.03	0	0
1102	4200	0	108	0	2	33	0	8.03	0	0
1103	7010	0	107	0	2	33	0	8.02	0	0
1104	7440	0	104	0	2	33	0	8.02	0	0
1105	7120	0	101	0	2	33	0	8.02	0	0
1106	6290	0	98	0	2	33	0	8.02	0	0
1107	5190	0	96	0	2	0	0	8.02	0	0

1108	4200	0	95	0	2	0	0	8.03	0	0
1109	2940	0	95	0	2	0	0	8.03	0	0
1110	3120	0	95	0	2	0	0	8.03	0	0
1111	4170	0	97	0	2	0	0	8.03	0	0
1112	7440	0	98	0	2	0	0	8.02	0	0
1113	3670	0	99	0	2	0	0	8.02	0	0
1115	4460	0	101	0	2	0	0	8.02	0	0
1116	7010	0	98	0	2	0	0	8.02	0	0
1117	7420	0	94	0	2	0	0	8.02	0	0
1118	6920	0	89	0	2	0	0	8.01	0	0
1119	6130	0	86	0	2	0	0	8.01	0	0
1120	5090	0	84	0	2	0	0	8.01	0	0
1121	3930	0	82	0	2	0	0	8.01	0	0
1122	3380	0	82	0	2	0	0	8.02	0	0
1123	3730	0	83	0	2	0	0	8.02	0	0
1124	10250	0	83	0	2	0	0	8.02	0	0
1125	5360	0	84	0	2	0	0	8.02	0	0
1126	1690	0	85	0	2	0	0	8.02	0	0
1127	2160	0	85	0	2	0	0	8.02	0	0
1129	2040	0	85	0	2	0	0	8.02	0	0
1130	5280	0	85	0	2	0	0	8.02	0	0
1131	7260	0	82	0	2	0	0	8.01	0	0
1132	7340	0	79	0	12	0	0	8.01	0	0
1133	8770	0	76	0	12	0	0	8.01	0	0
1134	11030	0	71	0.22	12	0	0	8.01	0	0

C. KEROSENE TEST RUN #3

Table 23. DAQ data table for Figure 48

Time (sec)	Voltage (V)
0	0.0011727
0.5	0.0011726
1	0.0011726
1.5	0.0011726
2	0.0011726
2.5	0.0011726
3	0.0011727
3.5	0.0011727
4	0.0011726
4.5	0.0011727
5	0.0011726
5.5	0.0011726
6	0.0011726
6.5	0.0011726
7	0.0011727
7.5	0.0011727
8	0.0011726
8.5	0.0011727
9	0.0011727
9.5	0.0011728
10	0.0011726
10.5	0.0011727
11	0.0011727
11.5	0.0011727
12	0.0011727
12.5	0.0011726
13	0.0011728
13.5	0.0011727
14	0.0011728
14.5	0.0011729
15	0.0011729
15.5	0.0011729
16	0.0011728
16.5	0.0011729
17	0.0011729
17.5	0.0011728
18	0.0011728
18.5	0.0011732
19	0.0011731
19.5	0.001173
20	0.0011729
20.5	0.0011728
21	0.0011727
21.5	0.0011729
22	0.0011733
22.5	0.0011729
23	0.0011728
23.5	0.0011727
24	0.0011726
24.5	0.0011727
25	0.0011726
25.5	0.0011727
26	0.0011729
26.5	0.0011732
27	0.0011731
27.5	0.0011731
28	0.001173
28.5	0.001173
29	0.001173
29.5	0.0011731
30	0.001173
30.5	0.001173
31	0.0011729
31.5	0.0011729
32	0.0011729
32.5	0.0011729
33	0.0011729
33.5	0.001173
34	0.0011731
34.5	0.001173
35	0.0011729
35.5	0.001173
36	0.001173
36.5	0.001173
37	0.0011731
37.5	0.0011732
38	0.0011731
38.5	0.001173
39	0.0011731
39.5	0.0011732
40	0.0011732
40.5	0.0011733
41	0.0011732
41.5	0.0011732
42	0.0011732
42.5	0.0011731
43	0.0011731
43.5	0.0011732
44	0.0011732
44.5	0.0011731
45	0.0011731
45.5	0.0011732
46	0.0011733
46.5	0.0011733
47	0.0011732
47.5	0.0011733
48	0.0011733
48.5	0.0011733
49	0.0011733
49.5	0.0011733
50	0.0011733
50.5	0.0011734
51	0.0011736
51.5	0.0011736
52	0.001174
52.5	0.0011753
53	0.0011762
53.5	0.001177
54	0.0011781
54.5	0.0011795
55	0.0011811
55.5	0.0011828
56	0.0011848

56.5	0.001187
57	0.0011887
57.5	0.0011902
58	0.0011928
58.5	0.0011958
59	0.0011993
59.5	0.0012039
60	0.0012086
60.5	0.0012135
61	0.0012203
61.5	0.0012249
62	0.0012248
62.5	0.0012205
63	0.0012173
63.5	0.0012155
64	0.0012115
64.5	0.0012098
65	0.0012098
65.5	0.0012098
66	0.0012099
66.5	0.0012099
67	0.0012074
67.5	0.0012062
68	0.0012079
68.5	0.0012092
69	0.0012084
69.5	0.0012058
70	0.0012048
70.5	0.0012047
71	0.0012072
71.5	0.001208
72	0.0012069
72.5	0.0012062
73	0.0012057
73.5	0.001206
74	0.0012083
74.5	0.0012082
75	0.0012069
75.5	0.0012059
76	0.0012054
76.5	0.0012083
77	0.0012152
77.5	0.001227
78	0.0012406
78.5	0.0012544
79	0.0012696
79.5	0.0012834
80	0.0012952
80.5	0.0013094
81	0.0013192
81.5	0.0013203
82	0.0013152
82.5	0.0013202
83	0.0013209
83.5	0.0013194
84	0.0013197
84.5	0.0013253
85	0.0013212
85.5	0.001322
86	0.0013229
86.5	0.0013223
87	0.0013221
87.5	0.0013229
88	0.0013218
88.5	0.0013225
89	0.0013247
89.5	0.0013211
90	0.0013268
90.5	0.0013225
91	0.0013224
91.5	0.0013271
92	0.0013231
92.5	0.0013263
93	0.0013233
93.5	0.0013219
94	0.0013275
94.5	0.0013225
95	0.0013252
95.5	0.0013297
96	0.0013466
96.5	0.0013626
97	0.0013736
97.5	0.0013878
98	0.0014003
98.5	0.0014149
99	0.0014359
99.5	0.0014434
100	0.0014305
100.5	0.0014464
101	0.0014393
101.5	0.0014421
102	0.0014391
102.5	0.0014482
103	0.0014332
103.5	0.001448
104	0.0014375
104.5	0.0014437
105	0.0014365
105.5	0.0014432
106	0.0014381
106.5	0.0014455
107	0.0014358
107.5	0.0014382
108	0.0014409
108.5	0.0014371
109	0.0014483
109.5	0.0014402
110	0.0014376
110.5	0.0014436
111	0.0014382
111.5	0.0014375
112	0.0014384
112.5	0.0014376
113	0.0014401
113.5	0.0014332
114	0.0014381
114.5	0.00144
115	0.0014457
115.5	0.001462
116	0.001494
116.5	0.0015113
117	0.0015215
117.5	0.0015365
118	0.0015477
118.5	0.0015457
119	0.0015442
119.5	0.0015507
120	0.0015434
120.5	0.0015526
121	0.0015449
121.5	0.0015492
122	0.001559
122.5	0.0015529
123	0.001559
123.5	0.0015568

124	0.0015568
124.5	0.0015535
125	0.0015597
125.5	0.0015528
126	0.0015565
126.5	0.0015512
127	0.0015531
127.5	0.0015525
128	0.001559
128.5	0.0015512
129	0.001552
129.5	0.0015572
130	0.0015529
130.5	0.0015552
131	0.0015547
131.5	0.0015541
132	0.0015511
132.5	0.0015597
133	0.0015551
133.5	0.0015525
134	0.001556
134.5	0.0015576
135	0.0015542
135.5	0.0015582
136	0.0015977
136.5	0.0016096
137	0.0016225
137.5	0.0016215
138	0.0016419
138.5	0.0016506
139	0.0016625
139.5	0.0016623
140	0.0016639
140.5	0.0016584
141	0.0016649
141.5	0.0016644
142	0.0016622
142.5	0.0016668
143	0.0016644
143.5	0.0016645
144	0.0016624
144.5	0.0016626
145	0.001665
145.5	0.0016678
146	0.0016597
146.5	0.001657
147	0.0016666
147.5	0.0016639
148	0.0016612
148.5	0.0016627
149	0.0016682
149.5	0.0016572
150	0.0016571
150.5	0.0016589
151	0.0016597
151.5	0.0016685
152	0.0016654
152.5	0.0016639
153	0.0016662
153.5	0.0016675
154	0.0016685
154.5	0.0017144
155	0.0017564
155.5	0.0017632
156	0.0017617
156.5	0.0017705
157	0.0017713
157.5	0.0017709
158	0.0017695
158.5	0.001767
159	0.0017786
159.5	0.0017666
160	0.0017706
160.5	0.0017769
161	0.0017707
161.5	0.0017743
162	0.0017783
162.5	0.0017772
163	0.0017692
163.5	0.0017735
164	0.0017686
164.5	0.0017675
165	0.0017747
165.5	0.0017654
166	0.0017743
166.5	0.0017699
167	0.0017777
167.5	0.0017732
168	0.001769
168.5	0.001772
169	0.0017732
169.5	0.0017596
170	0.001762
170.5	0.0017668
171	0.0017421
171.5	0.0017265
172	0.0017066
172.5	0.0016996
173	0.0016915
173.5	0.0016903
174	0.0016695
174.5	0.001672
175	0.0016717
175.5	0.0016695
176	0.0016645
176.5	0.001669
177	0.0016642
177.5	0.0016667
178	0.0016688
178.5	0.0016659
179	0.001666
179.5	0.0016675
180	0.0016677
180.5	0.0016699
181	0.0016626
181.5	0.0016625
182	0.0016659
182.5	0.001656
183	0.0016735
183.5	0.0016704
184	0.0016679
184.5	0.00167
185	0.0016654
185.5	0.0016628
186	0.0016665
186.5	0.0016633
187	0.0016656
187.5	0.0016672
188	0.0016651
188.5	0.0016669
189	0.0016664
189.5	0.0016647
190	0.0016719
190.5	0.001669
191	0.0016287

191.5	0.001624
192	0.0016041
192.5	0.0015898
193	0.0015815
193.5	0.0015719
194	0.0015628
194.5	0.0015556
195	0.0015642
195.5	0.0015568
196	0.0015585
196.5	0.0015531
197	0.0015596
197.5	0.0015561
198	0.0015606
198.5	0.0015545
199	0.0015558
199.5	0.0015564
200	0.0015589
200.5	0.0015524
201	0.0015595
201.5	0.0015579
202	0.0015507
202.5	0.0015605
203	0.0015519
203.5	0.0015585
204	0.0015538
204.5	0.0015548
205	0.0015573
205.5	0.0015575
206	0.0015553
206.5	0.0015547
207	0.0015544
207.5	0.0015563
208	0.0015551
208.5	0.0015536
209	0.0015535
209.5	0.001567
210	0.0015477
210.5	0.0015616
211	0.0015537
211.5	0.0015609
212	0.0015548
212.5	0.0015533
213	0.0015632
213.5	0.001553
214	0.0015608
214.5	0.001555
215	0.0015565
215.5	0.0015535
216	0.0015562
216.5	0.0015597
217	0.001554
217.5	0.0015477
218	0.0015055
218.5	0.0015042
219	0.0014931
219.5	0.001484
220	0.001468
220.5	0.001455
221	0.0014324
221.5	0.0014304
222	0.001433
222.5	0.0014297
223	0.0014329
223.5	0.0014452
224	0.0014322
224.5	0.0014354
225	0.001435
225.5	0.0014343
226	0.00144
226.5	0.001435
227	0.001435
227.5	0.001437
228	0.0014356
228.5	0.0014385
229	0.0014355
229.5	0.0014391
230	0.0014371
230.5	0.0014368
231	0.0014382
231.5	0.0014393
232	0.0014409
232.5	0.0014375
233	0.0014366
233.5	0.00144
234	0.0014346
234.5	0.0014434
235	0.0014357
235.5	0.0014338
236	0.0014376
236.5	0.0014389
237	0.0014382
237.5	0.0014379
238	0.0014453
238.5	0.0014347
239	0.0014402
239.5	0.0014419
240	0.0014363
240.5	0.00144
241	0.0014401
241.5	0.0014344
242	0.0014389
242.5	0.0014402
243	0.0014358
243.5	0.0014386
244	0.0014378
244.5	0.0014326
245	0.0014416
245.5	0.0014358
246	0.0014428
246.5	0.0014166
247	0.0014032
247.5	0.0013945
248	0.0013721
248.5	0.0013678
249	0.0013463
249.5	0.0013354
250	0.0013225
250.5	0.0013262
251	0.0013262
251.5	0.0013253
252	0.0013254
252.5	0.0013261
253	0.0013205
253.5	0.0013236
254	0.001323
254.5	0.0013232
255	0.0013227
255.5	0.0013245
256	0.0013232
256.5	0.0013207
257	0.0013213
257.5	0.0013224
258	0.0013248
258.5	0.0013239

259	0.0013239
259.5	0.0013254
260	0.0013236
260.5	0.0013217
261	0.0013214
261.5	0.0013208
262	0.0013217
262.5	0.0013218
263	0.0013207
263.5	0.0013209
264	0.0013263
264.5	0.0013214
265	0.0013206
265.5	0.0013236
266	0.0013239
266.5	0.0013246
267	0.001324
267.5	0.0013246
268	0.0013236
268.5	0.0013227
269	0.0013227
269.5	0.0013228
270	0.0013237
270.5	0.001323
271	0.0013213
271.5	0.0013207
272	0.0013217
272.5	0.0013218
273	0.0013218
273.5	0.0013249
274	0.0013231
274.5	0.0013085
275	0.0012612
275.5	0.0012411
276	0.001231
276.5	0.0012257
277	0.0012223
277.5	0.0012192
278	0.0012185
278.5	0.0012158
279	0.0012155
279.5	0.0012155
280	0.0012149
280.5	0.0012121
281	0.0012113
281.5	0.0012116
282	0.0012123
282.5	0.0012136
283	0.0012136
283.5	0.0012106
284	0.0012087
284.5	0.0012091
285	0.0012096
285.5	0.0012099
286	0.0012098
286.5	0.0012096
287	0.0012101
287.5	0.0012105
288	0.0012112
288.5	0.0012108
289	0.0012085
289.5	0.0012078
290	0.0012095
290.5	0.0012083
291	0.0012068
291.5	0.0012065
292	0.00121
292.5	0.0012101
293	0.0012088
293.5	0.0012088
294	0.0012083
294.5	0.0012086
295	0.0012085
295.5	0.001209
296	0.0012089
296.5	0.001209
297	0.001209
297.5	0.0012092
298	0.0012096
298.5	0.001207
299	0.0012079
299.5	0.0012083
300	0.0012063
300.5	0.001208
301	0.0012078
301.5	0.0012059
302	0.0012068
302.5	0.0012086
303	0.0012068
303.5	0.0012059
304	0.0012066
304.5	0.0012085
305	0.0012071
305.5	0.0012063
306	0.0012064
306.5	0.0012065
307	0.0012065
307.5	0.001207
308	0.0012067
308.5	0.0012067
309	0.0012065
309.5	0.0012065
310	0.001207
310.5	0.001208
311	0.0012069
311.5	0.0012067
312	0.0012137
312.5	0.0012254
313	0.0012303
313.5	0.00123
314	0.0012297
314.5	0.0012294
315	0.0012294
315.5	0.0012295
316	0.0012295
316.5	0.0012288
317	0.0012282
317.5	0.0012223
318	0.0011855
318.5	0.0011783
319	0.0011758
319.5	0.0011745
320	0.0011739
320.5	0.0011736
321	0.0011735
321.5	0.0011732
322	0.001173
322.5	0.001173
323	0.001173
323.5	0.0011729
324	0.0011729
324.5	0.0011728
325	0.0011728
325.5	0.0011728
326	0.0011728

326.5	0.0011729
327	0.0011731
327.5	0.0011732
328	0.0011732
328.5	0.0011731
329	0.001173
329.5	0.0011729
330	0.0011728
330.5	0.0011728
331	0.0011728
331.5	0.0011728
332	0.0011727
332.5	0.0011727
333	0.0011727
333.5	0.0011727
334	0.0011727
334.5	0.0011726
335	0.0011726
335.5	0.0011727
336	0.0011727
336.5	0.0011729
337	0.0011734
337.5	0.0011733
338	0.0011731
338.5	0.0011729
339	0.001173
339.5	0.0011731
340	0.0011731

Table 24. Jet-tronic data table for Figure 49

Time (sec)	**Rpm**	**SetRpm**	**Temp (°C)**	**Pump (V)**	**State**	**THR (%)**	**AUX (49/0)**	**Batt (V)**	**AirSpd**	**SetSpd**
1012	2860	0	14	0	2	100	49	8.03	0	0
1013	3200	0	15	0	2	100	49	8.03	0	0
1014	3350	0	14	0	2	100	49	8.02	0	0
1015	2670	0	14	0	2	100	49	8.02	0	0
1017	2310	0	14	0	2	96	49	8.02	0	0
1018	3320	0	15	0	2	25	49	8.02	0	0
1018	3920	0	14	0	2	25	49	8.02	0	0
1020	4460	0	15	0	2	25	49	8.02	0	0
1021	4670	0	15	0	2	25	49	8.01	0	0
1022	4890	0	15	0	2	25	49	8.01	0	0
1023	5100	0	14	0	2	25	49	8.01	0	0
1024	5120	0	14	0	2	25	49	8.01	0	0
1025	5220	0	14	0	2	100	49	8.01	0	0
1026	5290	0	15	0	2	100	49	8.01	0	0
1027	5340	0	14	0	2	100	49	8.01	0	0

1028	5430	0	14	0	2	100	49	8.01	0	0
1029	5490	0	14	0	2	100	49	8.01	0	0
1030	5240	0	14	0	2	100	49	8.01	0	0
1031	4630	0	14	0	2	100	49	8.01	0	0
1032	3510	0	14	0	2	100	49	8.01	0	0
1033	2340	0	14	0	2	25	49	8.01	0	0
1034	2670	0	15	0	2	25	49	8.02	0	0
1036	3720	0	14	0	2	25	49	8.01	0	0
1037	4310	0	14	0	2	25	49	8.01	0	0
1038	4720	0	14	0	2	25	49	8.01	0	0
1038	5040	0	14	0	2	25	49	8.01	0	0
1040	2520	0	15	0	0	150	0	8.02	0	0
1080	2300	0	14	0	2	100	49	8.02	0	0
1081	3080	0	15	0	2	100	49	8.02	0	0
1082	3960	0	14	0	2	100	49	8.01	0	0
1083	4630	0	15	0	2	100	49	8	0	0
1084	4950	0	15	0	2	100	49	8	0	0
1085	5310	0	14	0	2	100	49	8	0	0
1086	5510	0	15	0	2	25	49	7.99	0	0
1087	5380	0	15	0	2	25	49	7.99	0	0
1088	5030	0	14	0	2	25	49	7.99	0	0
1089	4030	0	15	0	2	25	49	8	0	0
1090	2940	0	15	0	2	25	49	8	0	0
1092	2210	0	15	0	2	25	49	8.01	0	0
1093	3470	0	15	0	2	25	49	8.01	0	0
1094	4210	0	14	0	2	25	49	8.01	0	0
1095	4770	0	14	0	2	25	49	8.01	0	0

1096	5110	0	14	0	2	25	49	8.01	0	0
1097	5450	0	15	0	2	25	49	8.01	0	0
1098	5640	0	15	0	2	25	49	8	0	0
1099	5590	0	32	0	12	25	49	8	0	0
1100	6030	0	87	0	12	25	49	8	0	0
1101	6580	0	141	0	12	25	49	8	0	0
1102	7190	0	176	0	12	25	49	8	0	0
1103	7620	0	195	0	12	25	49	8	0	0
1104	7950	0	207	0	12	25	49	8	0	0
1105	8140	0	215	0	12	25	49	8	0	0
1106	8200	0	219	0	12	25	49	8	0	0
1107	8360	0	224	0	12	25	49	8	0	0
1108	8470	0	228	0	12	25	49	8	0	0
1109	8530	0	231	0	12	25	49	8	0	0
1110	8640	0	234	0	12	25	49	8	0	0
1111	8760	0	237	0	12	25	49	8	0	0
1112	8880	0	240	0	12	25	49	8	0	0
1114	9360	0	245	0.22	12	25	49	8	0	0
1115	9380	0	250	0.22	3	25	49	8	0	0
1116	10570	50500	253	0.23	3	25	49	7.99	0	0
1117	11830	50500	256	0.25	3	25	49	7.99	0	0
1118	12770	50500	262	0.27	3	25	49	7.98	0	0
1119	15220	50500	302	0.29	3	25	49	7.98	0	0
1120	19190	50500	395	0.31	3	25	49	7.97	0	0
1121	23900	50500	472	0.35	3	25	49	7.97	0	0
1122	28580	50500	528	0.38	3	25	49	7.96	0	0
1123	33870	50500	565	0.41	3	25	49	7.97	0	0

1124	36960	50500	576	0.44	3	25	49	7.98	0	0
1125	43070	50500	589	0.48	3	25	49	7.99	0	0
1126	50090	50500	598	0.52	3	25	49	8	0	0
1127	57650	60000	593	0.56	4	25	49	8.01	0	0
1128	61210	56500	579	0.51	6	25	49	8.01	0	0
1129	57700	50000	544	0.49	6	25	49	8.02	0	0
1130	54250	50000	525	0.47	6	25	49	8.02	0	0
1131	52540	50000	525	0.46	6	25	49	8.03	0	0
1132	52400	50000	540	0.46	6	25	49	8.03	0	0
1133	51020	50000	551	0.46	6	25	49	8.03	0	0
1135	51750	50000	554	0.45	11	25	49	8.03	0	0
1136	50160	50000	567	0.45	11	25	49	8.03	0	0
1137	48780	50000	567	0.46	11	25	49	8.03	0	0
1138	50700	50000	587	0.45	11	25	49	8.03	0	0
1139	49710	50000	594	0.45	11	25	49	8.03	0	0
1140	49520	50000	592	0.46	11	25	49	8.03	0	0
1141	51040	50000	603	0.45	11	25	49	8.03	0	0
1142	49750	50000	598	0.45	11	25	49	8.03	0	0
1143	51470	79980	597	0.58	11	32	49	8.03	0	0
1144	62600	88630	630	0.69	11	35	49	8.03	0	0
1145	75950	93430	651	0.8	11	37	49	8.03	0	0
1146	86400	99280	629	0.91	11	40	49	8.03	0	0
1147	94200	97780	590	0.98	11	39	49	8.03	0	0
1148	95380	97780	556	0.99	11	39	49	8.03	0	0
1149	96560	97780	530	1	11	39	49	8.03	0	0
1149	96270	97780	516	1.01	11	39	49	8.03	0	0
1151	97220	97780	506	1.01	11	39	49	8.03	0	0

1151	96910	97780	498	1.02	11	39	49	8.03	0	0
1153	96980	97780	497	1.03	11	39	49	8.03	0	0
1154	97210	97780	497	1.03	11	39	49	8.03	0	0
1155	98030	97780	493	1.03	11	39	49	8.03	0	0
1156	97750	97780	488	1.04	11	39	49	8.03	0	0
1157	96990	97780	488	1.05	11	39	49	8.03	0	0
1157	97770	97780	490	1.04	11	39	49	8.03	0	0
1159	97890	97780	488	1.04	11	39	49	8.03	0	0
1160	98480	97780	486	1.03	11	39	49	8.03	0	0
1161	97760	97780	485	1.04	11	39	49	8.03	0	0
1162	102930	108340	487	1.16	11	45	49	8.03	0	0
1163	109460	113060	492	1.23	11	48	49	8.03	0	0
1164	114380	119990	496	1.31	11	52	49	8.03	0	0
1165	122030	122690	492	1.35	11	54	49	8.03	0	0
1165	121070	122690	492	1.38	11	54	49	8.03	0	0
1167	122450	122690	495	1.35	11	54	49	8.03	0	0
1167	122580	122690	497	1.35	11	54	49	8.02	0	0
1169	122010	122690	498	1.35	11	54	49	8.02	0	0
1170	122650	122690	499	1.33	11	54	49	8.02	0	0
1171	122290	122690	501	1.33	11	54	49	8.02	0	0
1172	122630	122690	503	1.32	11	54	49	8.02	0	0
1173	122790	122690	505	1.31	11	54	49	8.02	0	0
1174	122730	122690	505	1.31	11	54	49	8.02	0	0
1175	123670	122690	507	1.29	11	54	49	8.02	0	0
1176	123350	122690	506	1.3	11	54	49	8.02	0	0
1177	122530	122690	507	1.31	11	54	49	8.02	0	0
1178	123330	122690	508	1.29	11	54	49	8.02	0	0

1179	122440	122690	509	1.3	11	54	49	8.02	0	0
1180	123030	122690	509	1.28	11	54	49	8.02	0	0
1181	125820	132060	510	1.4	11	62	49	8.02	0	0
1182	133620	136860	518	1.49	11	67	49	8.02	0	0
1183	137760	139880	523	1.54	11	70	49	8.02	0	0
1184	139860	139880	525	1.5	11	70	49	8.02	0	0
1185	140320	139880	525	1.49	11	70	49	8.02	0	0
1186	140750	139880	525	1.47	11	70	49	8.02	0	0
1187	140110	140800	528	1.52	11	71	49	8.02	0	0
1188	140630	140800	533	1.5	11	71	49	8.02	0	0
1189	141120	140800	535	1.48	11	71	49	8.02	0	0
1189	140810	140800	537	1.48	11	71	49	8.02	0	0
1191	140680	140800	538	1.48	11	71	49	8.02	0	0
1192	141050	140800	539	1.46	11	71	49	8.02	0	0
1193	140370	140800	539	1.48	11	71	49	8.02	0	0
1193	140840	140800	539	1.46	11	71	49	8.02	0	0
1195	140850	140800	541	1.46	11	71	49	8.02	0	0
1195	141140	140800	543	1.45	11	71	49	8.02	0	0
1197	141300	140800	543	1.44	11	71	49	8.02	0	0
1198	140780	140800	545	1.45	11	71	49	8.02	0	0
1199	140250	140800	545	1.46	11	71	49	8.02	0	0
1200	140800	140800	544	1.45	11	71	49	8.02	0	0
1201	142260	146250	545	1.57	11	76	49	8.02	0	0
1202	147630	149390	556	1.62	11	80	49	8.02	0	0
1203	150040	151160	567	1.64	11	82	49	8.02	0	0
1204	152780	154260	578	1.71	11	86	49	8.02	0	0
1205	153820	154260	585	1.69	11	86	49	8.02	0	0

1206	153860	154260	586	1.69	11	86	49	8.02	0	0
1207	153900	154260	588	1.69	11	86	49	8.02	0	0
1208	154020	154260	590	1.69	11	86	49	8.02	0	0
1209	154490	154260	591	1.67	11	86	49	8.02	0	0
1210	154200	154260	589	1.68	11	86	49	8.02	0	0
1211	154870	154260	590	1.65	11	86	49	8.02	0	0
1212	154550	154260	592	1.66	11	86	49	8.02	0	0
1213	154210	154260	592	1.67	11	86	49	8.02	0	0
1214	155340	154260	589	1.63	11	86	49	8.02	0	0
1215	154840	154260	589	1.64	11	86	49	8.02	0	0
1216	153480	154260	590	1.69	11	86	49	8.02	0	0
1217	154100	154260	591	1.67	11	86	49	8.02	0	0
1218	154150	154260	591	1.67	11	86	49	8.02	0	0
1219	154690	160400	590	1.79	11	93	49	8.02	0	0
1220	163120	165000	598	1.95	11	100	49	8.02	0	0
1221	164230	165000	611	1.95	11	100	49	8.02	0	0
1222	164640	165000	616	1.95	11	100	49	8.02	0	0
1223	165100	165000	619	1.94	11	100	49	8.02	0	0
1224	165010	165000	619	1.94	11	100	49	8.02	0	0
1225	165410	165000	622	1.93	11	100	49	8.02	0	0
1226	165140	165000	626	1.95	11	100	49	8.02	0	0
1227	165410	165000	629	1.92	11	100	49	8.02	0	0
1228	165500	165000	627	1.91	11	100	49	8.02	0	0
1229	165690	165000	628	1.9	11	100	49	8.02	0	0
1230	165360	165000	628	1.91	11	100	49	8.02	0	0
1231	165130	165000	628	1.91	11	100	49	8.02	0	0
1232	164330	165000	629	1.94	11	100	49	8.02	0	0

1233	166260	165000	630	1.87	11	100	49	8.02	0	0
1234	163320	163710	629	1.92	11	98	49	8.02	0	0
1235	163090	161660	628	1.82	11	95	49	8.02	0	0
1236	159560	157830	622	1.73	11	90	49	8.02	0	0
1237	157230	156660	614	1.74	11	88	49	8.02	0	0
1238	155320	154710	609	1.69	11	86	49	8.02	0	0
1239	154770	154560	604	1.69	11	86	49	8.02	0	0
1240	154580	154560	602	1.68	11	86	49	8.02	0	0
1241	155240	154560	601	1.66	11	86	49	8.02	0	0
1242	154930	154560	601	1.66	11	86	49	8.02	0	0
1243	154550	154560	601	1.67	11	86	49	8.02	0	0
1244	153960	154560	600	1.69	11	86	49	8.02	0	0
1245	154820	154560	597	1.65	11	86	49	8.02	0	0
1246	154670	154560	596	1.65	11	86	49	8.02	0	0
1247	154220	154560	599	1.68	11	86	49	8.02	0	0
1248	154620	154560	599	1.66	11	86	49	8.02	0	0
1249	154930	154560	595	1.65	11	86	49	8.02	0	0
1250	154110	154560	594	1.68	11	86	49	8.02	0	0
1251	154520	154560	594	1.66	11	86	49	8.02	0	0
1252	153950	154560	593	1.69	11	86	49	8.02	0	0
1253	153970	154560	594	1.69	11	86	49	8.02	0	0
1254	153940	151630	596	1.58	11	82	49	8.02	0	0
1255	150170	146920	593	1.47	11	77	49	8.02	0	0
1256	145670	144010	585	1.46	11	74	49	8.02	0	0
1257	143600	141530	575	1.4	11	71	49	8.02	0	0
1258	141030	140800	567	1.42	11	71	49	8.02	0	0
1259	140680	140800	562	1.42	11	71	49	8.02	0	0

1260	140410	140800	560	1.42	11	71	49	8.02	0	0
1261	140160	140800	557	1.43	11	71	49	8.02	0	0
1262	140570	140800	554	1.42	11	71	49	8.02	0	0
1263	141070	140800	555	1.4	11	71	49	8.02	0	0
1264	140170	140800	556	1.42	11	71	49	8.02	0	0
1265	141390	140800	554	1.38	11	71	49	8.02	0	0
1266	141120	140800	552	1.39	11	71	49	8.02	0	0
1267	141200	140800	549	1.4	11	71	49	8.02	0	0
1268	140640	140800	547	1.42	11	71	49	8.02	0	0
1269	140840	140800	547	1.41	11	71	49	8.02	0	0
1270	140310	140800	546	1.43	11	71	49	8.02	0	0
1271	140260	140800	545	1.44	11	71	49	8.03	0	0
1272	140660	140800	546	1.43	11	71	49	8.02	0	0
1273	141920	140800	546	1.4	11	71	49	8.02	0	0
1274	140710	140800	545	1.44	11	71	49	8.02	0	0
1275	141200	140800	546	1.42	11	71	49	8.02	0	0
1276	140550	140800	544	1.44	11	71	49	8.02	0	0
1277	140310	140800	544	1.45	11	71	49	8.02	0	0
1278	140310	140800	545	1.45	11	71	49	8.02	0	0
1279	141240	140800	546	1.42	11	71	49	8.02	0	0
1280	140250	140800	547	1.45	11	71	49	8.02	0	0
1281	135890	133090	551	1.29	11	63	49	8.02	0	0
1282	132200	130800	543	1.29	11	61	49	8.02	0	0
1283	127830	127100	541	1.27	11	58	49	8.02	0	0
1284	123410	120740	540	1.17	11	53	49	8.02	0	0
1285	122210	121230	536	1.18	11	53	49	8.02	0	0
1286	121500	121970	532	1.22	11	54	49	8.02	0	0

1287	122200	122450	532	1.23	11	54	49	8.02	0	0
1288	121740	122450	530	1.25	11	54	49	8.02	0	0
1289	122190	122450	528	1.25	11	54	49	8.02	0	0
1290	122030	122450	528	1.25	11	54	49	8.02	0	0
1291	121750	122450	527	1.26	11	54	49	8.03	0	0
1292	121850	122450	527	1.27	11	54	49	8.03	0	0
1293	121970	122450	525	1.27	11	54	49	8.03	0	0
1294	122620	122450	523	1.26	11	54	49	8.03	0	0
1295	122220	122450	522	1.27	11	54	49	8.03	0	0
1296	122050	122450	521	1.28	11	54	49	8.02	0	0
1297	121210	122450	520	1.3	11	54	49	8.02	0	0
1298	122310	122450	517	1.27	11	54	49	8.02	0	0
1299	122320	122450	515	1.28	11	54	49	8.02	0	0
1300	122370	122450	515	1.28	11	54	49	8.02	0	0
1301	122900	122450	516	1.27	11	54	49	8.02	0	0
1302	122240	122450	516	1.29	11	54	49	8.03	0	0
1303	122450	122450	516	1.28	11	54	49	8.03	0	0
1304	122450	122450	517	1.28	11	54	49	8.03	0	0
1305	122030	122450	515	1.29	11	54	49	8.03	0	0
1306	122570	122450	513	1.28	11	54	49	8.03	0	0
1307	122640	122450	515	1.28	11	54	49	8.03	0	0
1308	122710	122450	514	1.28	11	54	49	8.02	0	0
1309	121560	118970	514	1.21	11	52	49	8.03	0	0
1310	115430	113060	502	1.15	11	48	49	8.03	0	0
1311	109000	104170	487	1.04	11	42	49	8.03	0	0
1312	102830	99640	484	1.02	11	40	49	8.03	0	0
1313	97980	96250	478	0.99	11	38	49	8.03	0	0

1314	97960	97020	483	0.99	11	39	49	8.03	0	0
1315	98010	97400	486	0.98	11	39	49	8.03	0	0
1316	97360	97400	486	0.99	11	39	49	8.03	0	0
1317	97610	97400	486	0.99	11	39	49	8.03	0	0
1318	97590	97400	484	0.99	11	39	49	8.03	0	0
1319	97020	97400	482	0.99	11	39	49	8.03	0	0
1320	97110	97400	480	1	11	39	49	8.03	0	0
1321	97640	97400	484	0.99	11	39	49	8.03	0	0
1322	97700	97400	484	0.98	11	39	49	8.03	0	0
1323	97170	97400	481	0.99	11	39	49	8.03	0	0
1324	97060	97400	481	1	11	39	49	8.03	0	0
1325	97170	97400	480	1	11	39	49	8.03	0	0
1326	96940	97400	478	1.01	11	39	49	8.03	0	0
1327	97370	97400	481	1	11	39	49	8.03	0	0
1328	97600	97400	480	1	11	39	49	8.03	0	0
1329	97630	97400	481	1	11	39	49	8.03	0	0
1330	97950	97400	480	0.99	11	39	49	8.03	0	0
1331	97420	97400	477	0.99	11	39	49	8.03	0	0
1332	97390	97400	477	1	11	39	49	8.03	0	0
1333	97210	97400	479	1	11	39	49	8.03	0	0
1334	96880	97400	478	1.01	11	39	49	8.03	0	0
1335	97100	97400	479	1.01	11	39	49	8.03	0	0
1336	97360	97400	480	1	11	39	49	8.03	0	0
1337	88570	55400	476	0.75	11	25	49	8.03	0	0
1338	68630	50000	433	0.63	11	25	49	8.03	0	0
1339	61150	50000	435	0.58	11	25	49	8.03	0	0
1340	57810	50000	470	0.55	11	25	49	8.03	0	0

1341	55780	50000	501	0.53	11	25	49	8.03	0	0
1342	55770	50000	528	0.51	11	25	49	8.03	0	0
1343	53350	50000	541	0.51	11	25	49	8.03	0	0
1344	53050	50000	555	0.5	11	25	49	8.03	0	0
1345	54210	50000	575	0.48	11	25	49	8.04	0	0
1346	51820	50000	580	0.48	11	25	49	8.03	0	0
1347	51470	50000	582	0.48	11	25	49	8.04	0	0
1348	52140	50000	593	0.47	11	25	49	8.04	0	0
1349	51880	50000	599	0.47	11	25	49	8.04	0	0
1350	52330	50000	604	0.46	11	25	49	8.04	0	0
1351	51610	50000	607	0.46	11	25	49	8.04	0	0
1352	51060	50000	603	0.45	11	25	49	8.04	0	0
1353	50250	50000	611	0.45	11	25	49	8.04	0	0
1354	50920	50000	613	0.45	11	25	49	8.04	0	0
1355	51420	50000	622	0.44	11	25	49	8.04	0	0
1356	50940	50000	621	0.44	11	25	49	8.04	0	0
1357	51080	50000	625	0.44	11	25	49	8.04	0	0
1358	51410	50000	627	0.43	11	25	49	8.04	0	0
1359	51580	50000	628	0.43	11	25	49	8.04	0	0
1360	51850	50000	628	0.42	11	25	49	8.04	0	0
1361	50550	50000	622	0.43	11	25	49	8.04	0	0
1362	50010	50000	623	0.43	11	25	49	8.04	0	0
1363	50580	50000	623	0.42	11	25	49	8.04	0	0
1364	50180	50000	616	0.42	11	25	49	8.04	0	0
1365	50160	50000	621	0.42	11	25	49	8.04	0	0
1366	50120	50000	615	0.42	11	25	49	8.04	0	0
1367	50220	50000	620	0.42	11	25	49	8.04	0	0

1368	49640	50000	613	0.42	11	25	49	8.04	0	0
1369	49950	50000	612	0.42	11	25	49	8.04	0	0
1370	50030	50000	612	0.42	11	25	49	8.04	0	0
1371	49850	50000	608	0.42	11	25	49	8.04	0	0
1372	50330	50000	607	0.42	11	25	49	8.04	0	0
1373	50190	50000	608	0.42	11	25	49	8.04	0	0
1374	57220	60000	616	0.54	10	25	100	8.04	0	0
1375	63560	60000	647	0.54	10	25	100	8.04	0	0
1376	62960	60000	625	0.54	10	25	100	8.03	0	0
1377	63290	60000	609	0.54	10	25	100	8.03	0	0
1378	63230	60000	603	0.54	10	25	100	8.03	0	0
1379	62700	0	600	0	8	0	100	8.03	0	0
1381	24420	0	472	0	8	0	0	8.04	0	0
1382	15540	0	343	0	8	0	0	8.04	0	0
1383	11260	0	288	0	8	0	100	8.04	0	0
1384	8650	0	267	0	8	0	100	8.04	0	0
1385	6910	0	258	0	8	0	100	8.04	0	0
1386	5750	0	254	0	8	0	100	8.04	0	0
1387	4770	0	252	0	8	0	100	8.04	0	0
1388	5000	0	251	0	8	0	100	8.03	0	0
1389	7730	0	246	0	8	0	100	8.03	0	0
1390	8970	0	234	0	8	0	100	8.03	0	0
1391	7200	0	222	0	8	0	100	8.03	0	0
1392	5870	0	213	0	8	0	100	8.03	0	0
1393	4880	0	208	0	8	0	100	8.03	0	0
1394	4090	0	205	0	8	0	100	8.03	0	0
1395	3480	0	204	0	8	0	100	8.03	0	0

1396	3030	0	203	0	8	0	100	8.03	0	0
1397	2550	0	203	0	8	0	100	8.03	0	0
1398	2130	0	204	0	8	0	100	8.04	0	0
1399	5410	0	203	0	8	0	100	8.03	0	0

D. KEROSENE TEST RUN #4

Table 25. DAQ data table for Figure 51

Time (sec)	Voltage (V)
0	0.0011726
0.5	0.0011727
1	0.0011727
1.5	0.0011724
2	0.0011724
2.5	0.0011723
3	0.0011723
3.5	0.0011724
4	0.0011723
4.5	0.0011723
5	0.0011724
5.5	0.0011724
6	0.0011724
6.5	0.0011724
7	0.0011725
7.5	0.0011725
8	0.0011725
8.5	0.0011724
9	0.0011724
9.5	0.0011725
10	0.0011726
10.5	0.0011727
11	0.0011728
11.5	0.0011729
12	0.0011728
12.5	0.0011729
13	0.0011729
13.5	0.0011728
14	0.0011728
14.5	0.0011728
15	0.001173
15.5	0.0011729
16	0.0011728
16.5	0.001173
17	0.0011734
17.5	0.001174
18	0.0011745
18.5	0.0011752
19	0.0011762
19.5	0.0011773
20	0.0011784
20.5	0.0011797
21	0.0011809
21.5	0.0011817
22	0.0011828
22.5	0.0011837
23	0.0011845
23.5	0.0011859
24	0.0011854
24.5	0.0011869
25	0.0011887
25.5	0.0011912
26	0.0011944
26.5	0.001196
27	0.0011995
27.5	0.0012044
28	0.001209
28.5	0.0012134
29	0.0012189
29.5	0.001222
30	0.0012219
30.5	0.0012175
31	0.0012153
31.5	0.0012135
32	0.0012114
32.5	0.0012114
33	0.0012112
33.5	0.0012082
34	0.0012068
34.5	0.0012054
35	0.0012054
35.5	0.0012057
36	0.0012059
36.5	0.0012055
37	0.0012074
37.5	0.0012072
38	0.0012059
38.5	0.0012062
39	0.0012058
39.5	0.0012057
40	0.0012056
40.5	0.0012057
41	0.0012061
41.5	0.0012059
42	0.0012067
42.5	0.0012068
43	0.0012067
43.5	0.0012071
44	0.0012073
44.5	0.0012075
45	0.001208
45.5	0.0012081
46	0.0012081
46.5	0.0012083
47	0.0012082
47.5	0.0012082
48	0.0012085
48.5	0.0012077
49	0.0012052
49.5	0.0012067
50	0.0012082
50.5	0.001206
51	0.0012046
51.5	0.0012053
52	0.0012072
52.5	0.0012069
53	0.0012043
53.5	0.0012062
54	0.0012075
54.5	0.0012066
55	0.0012048
55.5	0.0012061
56	0.0012074

56.5	0.0012065
57	0.0012048
57.5	0.0012064
58	0.0012075
58.5	0.0012072
59	0.001205
59.5	0.0012059
60	0.0012076
60.5	0.001209
61	0.0012049
61.5	0.0012055
62	0.0012072
62.5	0.0012078
63	0.0012074
63.5	0.0012065
64	0.0012076
64.5	0.0012074
65	0.0012064
65.5	0.0012086
66	0.0012087
66.5	0.0012066
67	0.0012083
67.5	0.0012098
68	0.001208
68.5	0.0012063
69	0.0012079
69.5	0.0012078
70	0.0012054
70.5	0.0012063
71	0.0012073
71.5	0.001206
72	0.0012052
72.5	0.0012091
73	0.0012185
73.5	0.0012312
74	0.0012451
74.5	0.0012565
75	0.0012688
75.5	0.0012888
76	0.0013148
76.5	0.0013488
77	0.0013746
77.5	0.0013941
78	0.0014019
78.5	0.001421
79	0.0014261
79.5	0.0014449
80	0.0014702
80.5	0.0014842
81	0.0014879
81.5	0.0015189
82	0.0015556
82.5	0.0016198
83	0.0016847
83.5	0.0017463
84	0.0017769
84.5	0.0017895
85	0.0017839
85.5	0.00178
86	0.0017906
86.5	0.0017933
87	0.0017905
87.5	0.00178
88	0.001774
88.5	0.0017743
89	0.0017707
89.5	0.0017699
90	0.0017658
90.5	0.0017853
91	0.0017659
91.5	0.0017689
92	0.0017657
92.5	0.0017686
93	0.0017629
93.5	0.0017568
94	0.0017582
94.5	0.0017615
95	0.0017628
95.5	0.0017597
96	0.0017688
96.5	0.0017557
97	0.0017692
97.5	0.001773
98	0.0017622
98.5	0.0017575
99	0.0017665
99.5	0.0017668
100	0.0017632
100.5	0.0017575
101	0.0017611
101.5	0.001757
102	0.0017632
102.5	0.0017538
103	0.0017651
103.5	0.001762
104	0.0017604
104.5	0.0017667
105	0.0017629
105.5	0.0017632
106	0.0017564
106.5	0.0017587
107	0.0017585
107.5	0.0017583
108	0.0017642
108.5	0.0017636
109	0.0017599
109.5	0.0017644
110	0.0017592
110.5	0.0017601
111	0.0017625
111.5	0.0017634
112	0.0017652
112.5	0.0017595
113	0.0017628
113.5	0.0017574
114	0.0017608
114.5	0.0017613
115	0.0017562
115.5	0.0017574
116	0.0017624
116.5	0.0017609
117	0.0017652
117.5	0.0017565
118	0.0017316
118.5	0.0017178
119	0.0017121
119.5	0.0017016
120	0.001692
120.5	0.0016668
121	0.0016716
121.5	0.0016588
122	0.0016579
122.5	0.0016654
123	0.0016677
123.5	0.0016598

124	0.0016655
124.5	0.0016632
125	0.0016609
125.5	0.0016624
126	0.0016604
126.5	0.0016608
127	0.0016622
127.5	0.0016569
128	0.0016685
128.5	0.0016637
129	0.00166
129.5	0.0016576
130	0.0016602
130.5	0.0016641
131	0.0016596
131.5	0.0016608
132	0.0016697
132.5	0.0016634
133	0.0016678
133.5	0.0016608
134	0.0016617
134.5	0.0016654
135	0.0016653
135.5	0.0016592
136	0.0016746
136.5	0.001661
137	0.0016644

137.5	0.0016654
138	0.0016667
138.5	0.001665
139	0.0016712
139.5	0.0016623
140	0.0016689
140.5	0.0016581
141	0.001664
141.5	0.0016642
142	0.0016656
142.5	0.0016617
143	0.0016614
143.5	0.0016647
144	0.0016638
144.5	0.0016656
145	0.0016616
145.5	0.0016634
146	0.0016696
146.5	0.0016603
147	0.001663
147.5	0.0016608
148	0.0016606
148.5	0.0016717
149	0.0016664
149.5	0.0016643
150	0.0016669
150.5	0.001662

151	0.0016555
151.5	0.0016662
152	0.0016639
152.5	0.001667
153	0.0016627
153.5	0.0016707
154	0.0016632
154.5	0.0016643
155	0.0016748
155.5	0.0016465
156	0.001645
156.5	0.001626
157	0.0016148
157.5	0.0016009
158	0.0015985
158.5	0.0015765
159	0.0015588
159.5	0.0015557
160	0.0015534
160.5	0.0015529
161	0.0015509
161.5	0.0015497
162	0.0015462
162.5	0.0015475
163	0.0015514
163.5	0.0015464
164	0.0015473

164.5	0.0015462
165	0.0015478
165.5	0.0015472
166	0.001544
166.5	0.0015481
167	0.0015448
167.5	0.0015445
168	0.001545
168.5	0.0015437
169	0.0015494
169.5	0.0015474
170	0.0015527
170.5	0.0015539
171	0.0015457
171.5	0.0015452
172	0.0015453
172.5	0.0015471
173	0.00155
173.5	0.0015417
174	0.0015454
174.5	0.0015509
175	0.0015439
175.5	0.0015484
176	0.0015493
176.5	0.0015481
177	0.001549
177.5	0.0015497

178	0.0015497
178.5	0.0015492
179	0.0015507
179.5	0.0015523
180	0.0015464
180.5	0.0015468
181	0.0015518
181.5	0.0015436
182	0.0015512
182.5	0.0015491
183	0.0015476
183.5	0.0015453
184	0.0015446
184.5	0.0015522
185	0.0015513
185.5	0.0015561
186	0.0015478
186.5	0.0015498
187	0.0015483
187.5	0.0015488
188	0.0015498
188.5	0.0015477
189	0.001555
189.5	0.001547
190	0.0015542
190.5	0.001546
191	0.0015536

191.5	0.0015479
192	0.0015548
192.5	0.0015506
193	0.001549
193.5	0.0015436
194	0.0015492
194.5	0.0015455
195	0.0015149
195.5	0.0015016
196	0.0014908
196.5	0.0014551
197	0.0014483
197.5	0.0014485
198	0.0014424
198.5	0.0014375
199	0.0014362
199.5	0.0014358
200	0.0014394
200.5	0.0014355
201	0.0014329
201.5	0.0014387
202	0.0014304
202.5	0.0014383
203	0.0014323
203.5	0.0014362
204	0.0014357
204.5	0.0014363

205	0.0014358
205.5	0.0014386
206	0.0014344
206.5	0.0014383
207	0.0014354
207.5	0.001436
208	0.0014358
208.5	0.0014328
209	0.0014387
209.5	0.0014357
210	0.0014331
210.5	0.0014354
211	0.0014349
211.5	0.0014371
212	0.0014326
212.5	0.001435
213	0.0014325
213.5	0.0014378
214	0.0014344
214.5	0.0014407
215	0.0014346
215.5	0.0014358
216	0.0014344
216.5	0.0014351
217	0.0014329
217.5	0.0014374
218	0.0014332

218.5	0.0014467
219	0.0014309
219.5	0.0014372
220	0.001439
220.5	0.0014348
221	0.0014391
221.5	0.0014291
222	0.0014412
222.5	0.0014362
223	0.0014376
223.5	0.0014316
224	0.0014412
224.5	0.0014317
225	0.001441
225.5	0.0014343
226	0.0014442
226.5	0.001431
227	0.0014406
227.5	0.0014338
228	0.0014366
228.5	0.0014378
229	0.0014312
229.5	0.0014388
230	0.0014313
230.5	0.0014418
231	0.0014342
231.5	0.0014395

232	0.0014339
232.5	0.0014404
233	0.0014339
233.5	0.0014372
234	0.0014371
234.5	0.0014335
235	0.001435
235.5	0.0014342
236	0.0014416
236.5	0.0014332
237	0.0014353
237.5	0.0013958
238	0.0013914
238.5	0.0013593
239	0.0013544
239.5	0.0013391
240	0.0013408
240.5	0.0013318
241	0.0013224
241.5	0.0013296
242	0.0013234
242.5	0.0013282
243	0.0013252
243.5	0.0013267
244	0.0013237
244.5	0.0013254
245	0.0013215

245.5	0.0013276
246	0.0013225
246.5	0.0013247
247	0.0013223
247.5	0.0013253
248	0.00132
248.5	0.0013253
249	0.0013219
249.5	0.0013268
250	0.0013203
250.5	0.0013257
251	0.0013209
251.5	0.0013255
252	0.0013246
252.5	0.0013241
253	0.0013262
253.5	0.0013261
254	0.0013248
254.5	0.0013194
255	0.0013278
255.5	0.0013267
256	0.001328
256.5	0.0013247
257	0.0013271
257.5	0.0013262
258	0.0013257
258.5	0.0013268

259	0.0013233
259.5	0.0013275
260	0.0013259
260.5	0.0013237
261	0.0013256
261.5	0.0013204
262	0.0013238
262.5	0.0013199
263	0.0013253
263.5	0.0013225
264	0.0013267
264.5	0.0013223
265	0.001325
265.5	0.0013245
266	0.0013228
266.5	0.0013268
267	0.0013232
267.5	0.0013225
268	0.0013255
268.5	0.0013232
269	0.0013265
269.5	0.0013207
270	0.0013241
270.5	0.0013215
271	0.0013232
271.5	0.0013263
272	0.0013215
272.5	0.0013262
273	0.0013263
273.5	0.0013218
274	0.001325
274.5	0.001326
275	0.0013262
275.5	0.0013246
276	0.001326
276.5	0.0013227
277	0.0013261
277.5	0.0013207
278	0.0013243
278.5	0.0013264
279	0.0013215
279.5	0.0013239
280	0.0013258
280.5	0.0013266
281	0.0013267
281.5	0.0013224
282	0.0013258
282.5	0.0013264
283	0.0013255
283.5	0.0013229
284	0.0013251
284.5	0.0013257
285	0.0013273
285.5	0.0013241
286	0.0013226
286.5	0.0013246
287	0.0013246
287.5	0.0013255
288	0.0013252
288.5	0.0013226
289	0.001322
289.5	0.0013239
290	0.0013253
290.5	0.0013068
291	0.0012587
291.5	0.0012419
292	0.0012283
292.5	0.0012231
293	0.00122
293.5	0.001219
294	0.0012173
294.5	0.0012166
295	0.0012156
295.5	0.0012132
296	0.0012126
296.5	0.0012131
297	0.0012124
297.5	0.0012094
298	0.0012081
298.5	0.0012093
299	0.0012099
299.5	0.0012094
300	0.001209
300.5	0.00121
301	0.0012106
301.5	0.0012099
302	0.0012095
302.5	0.0012088
303	0.001209
303.5	0.0012082
304	0.0012066
304.5	0.0012073
305	0.0012087
305.5	0.0012071
306	0.0012056
306.5	0.0012055
307	0.0012084
307.5	0.0012083
308	0.0012068
308.5	0.0012062
309	0.0012065
309.5	0.0012064
310	0.0012071
310.5	0.0012088
311	0.0012079
311.5	0.0012074
312	0.0012077
312.5	0.0012078
313	0.0012082
313.5	0.0012083
314	0.001208
314.5	0.0012079
315	0.0012082
315.5	0.0012082
316	0.0012085
316.5	0.0012087
317	0.0012091
317.5	0.0012081
318	0.0012059
318.5	0.0012074
319	0.0012083
319.5	0.0012069
320	0.0012059
320.5	0.0012083
321	0.0012071
321.5	0.0012054
322	0.0012075
322.5	0.0012082
323	0.0012059
323.5	0.0012055
324	0.0012078
324.5	0.0012069
325	0.0012055
325.5	0.0012075
326	0.001207

326.5	0.0012053
327	0.0012064
327.5	0.0012076
328	0.0012055
328.5	0.0012057
329	0.0012079
329.5	0.0012065
330	0.0012051
330.5	0.0012063
331	0.0012073
331.5	0.0012052
332	0.0012061
332.5	0.0012073
333	0.0012059
333.5	0.0012051
334	0.0012072
334.5	0.0012144
335	0.0012229
335.5	0.001226
336	0.0012262
336.5	0.0012262
337	0.0012264
337.5	0.0012262
338	0.0012263
338.5	0.0012256
339	0.0012252
339.5	0.001225

340	0.0012249
340.5	0.0011964
341	0.0011798
341.5	0.0011763
342	0.001175
342.5	0.0011742
343	0.0011738
343.5	0.0011733
344	0.0011732
344.5	0.0011729
345	0.0011728
345.5	0.0011728
346	0.0011728
346.5	0.0011726
347	0.0011726
347.5	0.0011725
348	0.0011725
348.5	0.0011726
349	0.0011725
349.5	0.0011725
350	0.0011725
350.5	0.0011725
351	0.0011725
351.5	0.0011725
352	0.0011725
352.5	0.0011725
353	0.0011726

353.5	0.0011727
354	0.0011728
354.5	0.001173
355	0.0011728
355.5	0.0011728
356	0.0011727
356.5	0.0011727
357	0.0011728
357.5	0.0011726
358	0.0011732
358.5	0.0011728
359	0.001173
359.5	0.0011731
360	0.0011733
360.5	0.0011732
361	0.0011726
361.5	0.0011724
362	0.001172
362.5	0.0011724
363	0.0011723
363.5	0.0011725
364	0.0011727
364.5	0.0011729
365	0.001173
365.5	0.001173
366	0.001173
366.5	0.001173

367	0.0011728
367.5	0.0011727
368	0.0011726
368.5	0.0011728
369	0.0011727
369.5	0.0011726
370	0.0011726
370.5	0.0011727
371	0.0011726
371.5	0.0011725
372	0.0011726
372.5	0.0011725
373	0.0011726
373.5	0.0011727
374	0.0011727
374.5	0.001173
375	0.0011731
375.5	0.0011729
376	0.0011729
376.5	0.0011729
377	0.0011728
377.5	0.0011727
378	0.0011727
378.5	0.0011726
379	0.0011726
379.5	0.0011726
380	0.0011726

380.5	0.0011726
381	0.0011726
381.5	0.0011726
382	0.0011726
382.5	0.0011725
383	0.0011726
383.5	0.0011727
384	0.0011728
384.5	0.0011728
385	0.001173
385.5	0.0011728
386	0.0011727
386.5	0.0011727
387	0.0011728
387.5	0.0011728
388	0.0011727
388.5	0.0011727
389	0.0011727
389.5	0.0011726
390	0.0011725
390.5	0.0011725
391	0.0011728
391.5	0.0011725
392	0.0011725
392.5	0.0011725
393	0.0011724
393.5	0.0011725

394	0.0011725
394.5	0.0011725
395	0.0011724
395.5	0.0011724
396	0.0011725
396.5	0.0011726
397	0.0011724
397.5	0.0011724
398	0.0011725
398.5	0.0011725
399	0.0011725
399.5	0.0011725
400	0.0011724

Table 26. Jet-tronic data table for Figure 52

Time (sec)	Rpm	SetRpm	Temp (°C)	Pump (V)	State	THR (%)	AUX (49/0)	Batt (V)	AirSpd	SetSpd
972	137510	137440	554	1.39	11	67	49	8.03	0	0
973	137780	137440	552	1.38	11	67	49	8.03	0	0
974	137640	137440	553	1.38	11	67	49	8.03	0	0
975	138000	137440	553	1.37	11	67	49	8.03	0	0
976	137520	137440	553	1.39	11	67	49	8.03	0	0
977	137550	137440	553	1.38	11	67	49	8.03	0	0
978	137340	137440	553	1.39	11	67	49	8.03	0	0
979	137590	137440	552	1.38	11	67	49	8.03	0	0
980	137390	137440	554	1.39	11	67	49	8.03	0	0
981	137290	137440	554	1.39	11	67	49	8.03	0	0
982	137800	137440	553	1.38	11	67	49	8.03	0	0
983	137250	137440	555	1.4	11	67	49	8.03	0	0
984	137040	137440	555	1.4	11	67	49	8.03	0	0
985	137460	137440	555	1.39	11	67	49	8.03	0	0
986	136990	137440	555	1.4	11	67	49	8.03	0	0
987	137070	137440	555	1.4	11	67	49	8.03	0	0
988	137740	137440	554	1.38	11	67	49	8.03	0	0
989	137410	137440	553	1.39	11	67	49	8.03	0	0

990	137560	137440	553	1.38	11	67	49	8.03	0	0
991	138010	137440	554	1.37	11	67	49	8.03	0	0
992	137330	137440	553	1.38	11	67	49	8.03	0	0
993	129300	128430	549	1.28	11	59	49	8.03	0	0
994	123660	123410	542	1.25	11	55	49	8.03	0	0
995	121210	119480	546	1.18	11	52	49	8.03	0	0
996	116780	116090	541	1.16	11	50	49	8.03	0	0
997	115520	115550	532	1.15	11	49	49	8.03	0	0
998	113080	113900	529	1.15	11	48	49	8.03	0	0
999	113500	113620	529	1.13	11	48	49	8.03	0	0
1000	115220	113620	529	1.11	11	48	49	8.04	0	0
1001	113880	113620	524	1.13	11	48	49	8.03	0	0
1002	113920	113620	524	1.13	11	48	49	8.04	0	0
1003	113200	113620	522	1.15	11	48	49	8.04	0	0
1004	112980	113620	521	1.15	11	48	49	8.04	0	0
1005	113170	113620	518	1.16	11	48	49	8.04	0	0
1006	113180	113620	515	1.16	11	48	49	8.04	0	0
1007	114300	113620	511	1.14	11	48	49	8.04	0	0
1008	113900	113620	507	1.15	11	48	49	8.04	0	0
1009	113890	113620	503	1.15	11	48	49	8.04	0	0
1010	114040	113620	502	1.15	11	48	49	8.04	0	0
1011	113430	113620	502	1.16	11	48	49	8.04	0	0
1012	113210	113620	501	1.17	11	48	49	8.04	0	0
1013	112760	113620	499	1.18	11	48	49	8.04	0	0
1014	113030	113620	496	1.18	11	48	49	8.04	0	0
1015	113480	113620	496	1.17	11	48	49	8.04	0	0
1016	114010	113620	495	1.16	11	48	49	8.04	0	0

1017	114030	113620	494	1.16	11	48	49	8.04	0	0
1018	113220	113620	491	1.18	11	48	49	8.04	0	0
1019	113820	113620	493	1.17	11	48	49	8.04	0	0
1020	113040	113620	494	1.18	11	48	49	8.04	0	0
1021	113250	113620	494	1.18	11	48	49	8.04	0	0
1022	113770	113620	492	1.17	11	48	49	8.04	0	0
1023	112880	113620	492	1.18	11	48	49	8.04	0	0
1024	113880	113620	492	1.17	11	48	49	8.04	0	0
1025	113670	113620	492	1.17	11	48	49	8.04	0	0
1026	113520	113620	492	1.17	11	48	49	8.04	0	0
1027	114350	113620	493	1.16	11	48	49	8.04	0	0
1028	113600	113620	492	1.17	11	48	49	8.04	0	0
1029	113550	113620	492	1.17	11	48	49	8.04	0	0
1030	113340	113620	493	1.18	11	48	49	8.04	0	0
1031	113210	113620	493	1.19	11	48	49	8.04	0	0
1032	113700	113620	495	1.18	11	48	49	8.04	0	0
1033	113510	113620	494	1.18	11	48	49	8.04	0	0
1034	113890	113620	493	1.18	11	48	49	8.04	0	0
1035	110250	113620	495	1.23	11	48	49	8.04	0	0
1036	100030	113620	478	1.28	11	48	49	8.04	0	0
1037	95010	113620	481	1.22	11	48	49	8.04	0	0
1038	91370	113620	477	1.18	11	48	49	8.04	0	0
1039	89950	113620	481	1.17	11	48	49	8.04	0	0
1040	89450	83240	490	0.96	11	33	49	8.04	0	0
1041	70880	83760	490	0.98	11	33	49	8.04	0	0
1042	57310	60000	502	0.63	10	33	100	8.04	0	0
1043	47740	60000	533	0.63	10	33	100	8.04	0	0

1044	41650	60000	558	0.63	10	33	100	8.04	0	0
1045	38070	60000	570	0.63	10	33	100	8.04	0	0
1046	37860	60000	595	0.63	10	33	100	8.04	0	0
1047	38320	60000	632	0.63	10	33	100	8.04	0	0
1049	28810	0	633	0	8	33	0	8.04	0	0
1050	18110	0	483	0	8	33	100	8.04	0	0
1051	12720	0	367	0	8	33	100	8.04	0	0
1052	9720	0	310	0	8	33	100	8.04	0	0
1053	7750	0	285	0	8	33	100	8.04	0	0
1054	6330	0	273	0	8	33	100	8.04	0	0
1055	5410	0	267	0	8	33	100	8.04	0	0
1056	4540	0	263	0	8	33	100	8.04	0	0
1057	6500	0	260	0	8	33	100	8.04	0	0
1058	9180	0	253	0	8	33	100	8.03	0	0
1059	7570	0	240	0	8	33	100	8.03	0	0
1060	6040	0	230	0	8	33	100	8.03	0	0
1061	4860	0	224	0	8	33	100	8.03	0	0
1062	3950	0	222	0	8	33	100	8.04	0	0
1063	3320	0	221	0	8	33	100	8.04	0	0
1064	2670	0	221	0	8	33	100	8.04	0	0
1065	2180	0	223	0	8	33	100	8.04	0	0
1066	4490	0	225	0	8	33	100	8.03	0	0
1067	7810	0	218	0	8	33	100	8.03	0	0
1068	9020	0	204	0	8	33	100	8.03	0	0
1102	4200	0	108	0	2	33	0	8.03	0	0
1103	7010	0	107	0	2	33	0	8.02	0	0
1104	7440	0	104	0	2	33	0	8.02	0	0

1105	7120	0	101	0	2	33	0	8.02	0	0
1106	6290	0	98	0	2	33	0	8.02	0	0
1107	5190	0	96	0	2	0	0	8.02	0	0
1108	4200	0	95	0	2	0	0	8.03	0	0
1109	2940	0	95	0	2	0	0	8.03	0	0
1110	3120	0	95	0	2	0	0	8.03	0	0
1111	4170	0	97	0	2	0	0	8.03	0	0
1112	7440	0	98	0	2	0	0	8.02	0	0
1113	3670	0	99	0	2	0	0	8.02	0	0
1115	4460	0	101	0	2	0	0	8.02	0	0
1116	7010	0	98	0	2	0	0	8.02	0	0
1117	7420	0	94	0	2	0	0	8.02	0	0
1118	6920	0	89	0	2	0	0	8.01	0	0
1119	6130	0	86	0	2	0	0	8.01	0	0
1120	5090	0	84	0	2	0	0	8.01	0	0
1121	3930	0	82	0	2	0	0	8.01	0	0
1122	3380	0	82	0	2	0	0	8.02	0	0
1123	3730	0	83	0	2	0	0	8.02	0	0
1124	10250	0	83	0	2	0	0	8.02	0	0
1125	5360	0	84	0	2	0	0	8.02	0	0
1126	1690	0	85	0	2	0	0	8.02	0	0
1127	2160	0	85	0	2	0	0	8.02	0	0
1129	2040	0	85	0	2	0	0	8.02	0	0
1130	5280	0	85	0	2	0	0	8.02	0	0
1131	7260	0	82	0	2	0	0	8.01	0	0
1132	7340	0	79	0	12	0	0	8.01	0	0
1133	8770	0	76	0	12	0	0	8.01	0	0

1134	11030	0	71	0.22	12	0	0	8.01	0	0
25	1470	0	19	0	1	100	49	8.03	0	0
26	5210	0	20	0	2	100	49	8.03	0	0
27	6930	0	21	0	2	100	49	8.02	0	0
28	6910	0	22	0	2	100	49	8.02	0	0
29	7560	0	85	0	12	100	49	8.02	0	0
31	9050	0	176	0.22	12	100	49	8.02	0	0
32	11210	0	236	0.22	12	100	49	8.01	0	0
32	13320	50500	298	0.23	3	100	49	8	0	0
34	17040	50500	394	0.24	3	100	49	8	0	0
35	21620	50500	466	0.26	3	25	49	7.99	0	0
35	25080	50500	498	0.28	3	25	49	7.98	0	0
37	28900	50500	501	0.31	3	25	49	7.98	0	0
38	32010	50500	501	0.33	3	25	49	7.97	0	0
39	32390	50500	504	0.36	3	25	49	7.99	0	0
40	34760	50500	535	0.4	3	25	49	8	0	0
41	39600	50500	586	0.43	3	25	49	8	0	0
42	46070	50500	615	0.47	3	25	49	8.01	0	0
43	52520	60000	621	0.52	4	25	49	8.01	0	0
44	59000	60000	614	0.52	4	25	49	8.02	0	0
45	58460	55100	594	0.5	6	25	49	8.02	0	0
46	55760	50000	569	0.47	6	25	49	8.03	0	0
46	53880	50000	560	0.46	6	25	49	8.03	0	0
48	52780	50000	566	0.45	6	25	49	8.03	0	0
49	50190	50000	565	0.45	6	25	49	8.03	0	0
50	49890	50000	572	0.45	11	25	49	8.03	0	0
51	50200	50000	585	0.45	11	25	49	8.03	0	0

52	50560	50000	595	0.45	11	25	49	8.03	0	0
53	50190	50000	591	0.45	11	25	49	8.03	0	0
54	49940	50000	591	0.45	11	25	49	8.04	0	0
55	50060	50000	594	0.45	11	25	49	8.04	0	0
56	50370	50000	598	0.45	11	25	49	8.04	0	0
57	50520	50000	601	0.45	11	25	49	8.04	0	0
58	50850	50000	603	0.44	11	25	49	8.04	0	0
59	51300	50000	607	0.44	11	25	49	8.04	0	0
60	51510	50000	608	0.43	11	25	49	8.04	0	0
61	51590	50000	609	0.43	11	25	49	8.04	0	0
62	51710	50000	610	0.42	11	25	49	8.04	0	0
63	50070	50000	605	0.43	11	25	49	8.04	0	0
64	51250	50000	608	0.42	11	25	49	8.04	0	0
65	49150	50000	605	0.43	11	25	49	8.04	0	0
66	50700	50000	610	0.42	11	25	49	8.04	0	0
67	49170	50000	611	0.43	11	25	49	8.04	0	0
68	50800	50000	615	0.42	11	25	49	8.04	0	0
69	49180	50000	613	0.43	11	25	49	8.04	0	0
70	50740	50000	616	0.42	11	25	49	8.04	0	0
71	49360	50000	613	0.43	11	25	49	8.04	0	0
72	50620	50000	616	0.42	11	25	49	8.04	0	0
73	49250	50000	611	0.43	11	25	49	8.04	0	0
74	50550	50000	613	0.42	11	25	49	8.04	0	0
75	49370	50000	614	0.43	11	25	49	8.04	0	0
76	50470	50000	614	0.42	11	25	49	8.04	0	0
77	49390	50000	614	0.43	11	25	49	8.04	0	0
78	50560	50000	619	0.42	11	25	49	8.04	0	0

79	50100	50000	617	0.43	11	25	49	8.04	0	0
80	49720	50000	617	0.43	11	25	49	8.04	0	0
81	50670	50000	611	0.42	11	25	49	8.04	0	0
82	49370	50000	610	0.43	11	25	49	8.04	0	0
83	50640	50000	610	0.42	11	25	49	8.04	0	0
84	49520	50000	606	0.43	11	25	49	8.04	0	0
85	50090	50000	609	0.42	11	25	49	8.04	0	0
86	50550	81100	606	0.53	11	32	49	8.04	0	0
87	63190	85770	646	0.64	11	34	49	8.04	0	0
88	75550	95060	669	0.74	11	38	49	8.04	0	0
89	87880	114180	649	0.94	11	48	49	8.04	0	0
90	104890	118200	628	1.12	11	51	49	8.03	0	0
91	113980	119990	595	1.22	11	52	49	8.04	0	0
92	120120	121480	562	1.27	11	54	49	8.03	0	0
93	125580	127770	547	1.36	11	58	49	8.03	0	0
94	130570	131640	542	1.4	11	62	49	8.03	0	0
95	137860	149230	533	1.61	11	80	49	8.03	0	0
96	151690	165000	542	1.95	11	100	49	8.03	0	0
97	162790	165000	567	2.08	11	100	49	8.03	0	0
98	165540	165000	586	2.02	11	100	49	8.03	0	0
100	165440	165000	594	2.02	11	100	49	8.03	0	0
101	165790	165000	601	1.95	11	100	49	8.03	0	0
102	165110	165000	603	1.96	11	100	49	8.02	0	0
103	165390	165000	607	1.94	11	100	49	8.02	0	0
104	165220	165000	610	1.95	11	100	49	8.02	0	0
105	164970	165000	612	1.95	11	100	49	8.02	0	0
106	164820	165000	614	1.96	11	100	49	8.02	0	0

107	165470	165000	615	1.91	11	100	49	8.02	0	0
108	165110	165000	614	1.93	11	100	49	8.02	0	0
109	165350	165000	613	1.92	11	100	49	8.02	0	0
110	165030	165000	612	1.93	11	100	49	8.02	0	0
111	165450	165000	614	1.91	11	100	49	8.02	0	0
112	164650	165000	615	1.95	11	100	49	8.02	0	0
113	165130	165000	619	1.93	11	100	49	8.02	0	0
114	165090	165000	620	1.92	11	100	49	8.02	0	0
115	165250	165000	624	1.92	11	100	49	8.02	0	0
116	165220	165000	625	1.91	11	100	49	8.02	0	0
117	164630	165000	627	1.93	11	100	49	8.02	0	0
118	164870	165000	628	1.93	11	100	49	8.02	0	0
119	165010	165000	626	1.92	11	100	49	8.02	0	0
120	164840	165000	625	1.92	11	100	49	8.02	0	0
121	165270	165000	628	1.9	11	100	49	8.02	0	0
122	164760	165000	626	1.93	11	100	49	8.02	0	0
123	164410	165000	621	1.94	11	100	49	8.02	0	0
124	165360	165000	623	1.9	11	100	49	8.02	0	0
125	165050	165000	623	1.91	11	100	49	8.02	0	0
126	165240	165000	624	1.9	11	100	49	8.02	0	0
127	165610	165000	624	1.89	11	100	49	8.02	0	0
128	165200	165000	624	1.9	11	100	49	8.02	0	0
129	165220	165000	624	1.9	11	100	49	8.02	0	0
130	164700	165000	627	1.92	11	100	49	8.02	0	0
131	161570	160400	625	1.8	11	93	49	8.02	0	0
132	159640	158550	617	1.76	11	91	49	8.02	0	0
133	157740	154710	611	1.61	11	86	49	8.02	0	0

134	155030	153650	603	1.62	11	85	49	8.02	0	0
135	155390	154710	598	1.63	11	86	49	8.02	0	0
136	155680	154710	599	1.61	11	86	49	8.02	0	0
137	154940	154710	600	1.63	11	86	49	8.02	0	0
138	154440	154710	600	1.66	11	86	49	8.02	0	0
139	154610	154710	599	1.64	11	86	49	8.02	0	0
140	154630	154710	597	1.64	11	86	49	8.02	0	0
141	154660	154710	597	1.64	11	86	49	8.02	0	0
142	154810	154710	596	1.64	11	86	49	8.02	0	0
143	154790	154710	595	1.65	11	86	49	8.02	0	0
144	154580	154710	596	1.65	11	86	49	8.02	0	0
145	154460	154710	597	1.66	11	86	49	8.02	0	0
146	154520	154710	597	1.65	11	86	49	8.03	0	0
147	154530	154710	596	1.65	11	86	49	8.03	0	0
148	154750	154710	598	1.64	11	86	49	8.02	0	0
149	154680	154710	600	1.65	11	86	49	8.02	0	0
150	154980	154710	598	1.64	11	86	49	8.02	0	0
151	154640	154710	596	1.65	11	86	49	8.02	0	0
152	154680	154710	595	1.65	11	86	49	8.02	0	0
153	154220	154710	594	1.66	11	86	49	8.02	0	0
154	154170	154710	592	1.67	11	86	49	8.02	0	0
155	154660	154710	591	1.65	11	86	49	8.02	0	0
156	154840	154710	592	1.65	11	86	49	8.02	0	0
157	155110	154710	594	1.63	11	86	49	8.02	0	0
158	154380	154710	594	1.67	11	86	49	8.02	0	0
159	154740	154710	594	1.65	11	86	49	8.02	0	0
160	155390	154710	591	1.63	11	86	49	8.02	0	0

161	155230	154710	595	1.64	11	86	49	8.02	0	0
162	154880	154710	596	1.66	11	86	49	8.02	0	0
163	154820	154710	595	1.65	11	86	49	8.02	0	0
164	155390	154710	594	1.64	11	86	49	8.02	0	0
165	155290	154710	594	1.64	11	86	49	8.02	0	0
166	154990	154710	593	1.65	11	86	49	8.02	0	0
167	154610	156660	592	1.74	11	88	49	8.03	0	0
168	152870	151310	592	1.57	11	82	49	8.02	0	0
169	149720	148740	588	1.54	11	79	49	8.02	0	0
170	147090	145050	583	1.45	11	75	49	8.02	0	0
171	144290	141530	576	1.36	11	71	49	8.03	0	0
172	142250	140440	565	1.35	11	70	49	8.03	0	0
173	141310	140440	560	1.36	11	70	49	8.03	0	0
174	140830	140440	558	1.37	11	70	49	8.03	0	0
175	140710	140440	554	1.38	11	70	49	8.03	0	0
176	140370	140440	553	1.39	11	70	49	8.03	0	0
177	140300	140440	551	1.4	11	70	49	8.03	0	0
178	140030	140440	554	1.41	11	70	49	8.03	0	0
179	140000	140440	551	1.41	11	70	49	8.03	0	0
180	139560	140440	547	1.43	11	70	49	8.03	0	0
181	140600	140440	546	1.41	11	70	49	8.03	0	0
182	139110	140440	546	1.46	11	70	49	8.03	0	0
183	140640	140440	548	1.41	11	70	49	8.03	0	0
184	140330	140440	545	1.42	11	70	49	8.03	0	0
185	141180	140440	544	1.39	11	70	49	8.03	0	0
186	140470	140440	544	1.41	11	70	49	8.03	0	0
187	139930	140440	546	1.42	11	70	49	8.03	0	0

188	140500	140440	545	1.41	11	70	49	8.03	0	0
189	140200	140440	543	1.43	11	70	49	8.03	0	0
190	140530	140440	542	1.41	11	70	49	8.03	0	0
191	140660	140440	542	1.41	11	70	49	8.03	0	0
192	140310	140440	543	1.42	11	70	49	8.03	0	0
193	141330	140440	543	1.4	11	70	49	8.03	0	0
194	140590	140440	543	1.42	11	70	49	8.03	0	0
195	140000	140440	544	1.43	11	70	49	8.03	0	0
196	140270	140440	544	1.44	11	70	49	8.03	0	0
197	140200	140440	546	1.45	11	70	49	8.03	0	0
198	140660	140440	546	1.43	11	70	49	8.03	0	0
199	140340	140440	545	1.44	11	70	49	8.03	0	0
200	139570	140440	544	1.46	11	70	49	8.03	0	0
201	140070	140440	543	1.45	11	70	49	8.03	0	0
202	140680	140440	545	1.43	11	70	49	8.03	0	0
203	140370	140440	545	1.45	11	70	49	8.03	0	0
204	140360	140440	546	1.44	11	70	49	8.03	0	0
205	139990	140440	547	1.45	11	70	49	8.03	0	0
206	140660	138390	546	1.35	11	68	49	8.03	0	0
207	133010	133090	542	1.37	11	63	49	8.03	0	0
208	127150	125510	535	1.25	11	57	49	8.03	0	0
209	125480	123410	533	1.21	11	55	49	8.03	0	0
210	123130	122450	538	1.23	11	54	49	8.03	0	0
211	122360	122450	537	1.25	11	54	49	8.03	0	0
212	122190	122450	534	1.25	11	54	49	8.03	0	0
213	123020	122450	528	1.23	11	54	49	8.03	0	0
214	122560	122450	524	1.25	11	54	49	8.03	0	0

215	122310	122450	523	1.26	11	54	49	8.03	0	0
216	122410	122450	520	1.26	11	54	49	8.03	0	0
217	122740	122450	518	1.25	11	54	49	8.03	0	0
218	122570	122450	517	1.26	11	54	49	8.03	0	0
219	122250	122450	518	1.27	11	54	49	8.03	0	0
220	121550	122450	516	1.29	11	54	49	8.03	0	0
221	122130	122450	515	1.28	11	54	49	8.03	0	0
222	122450	122450	513	1.28	11	54	49	8.03	0	0
223	122610	122450	515	1.27	11	54	49	8.03	0	0
224	122520	122450	516	1.28	11	54	49	8.03	0	0
225	123170	122450	517	1.26	11	54	49	8.03	0	0
226	123430	122450	516	1.26	11	54	49	8.03	0	0
227	123330	122450	517	1.26	11	54	49	8.03	0	0
228	123460	122450	517	1.25	11	54	49	8.03	0	0
229	122510	122450	517	1.28	11	54	49	8.03	0	0
230	121820	122450	517	1.3	11	54	49	8.03	0	0
231	121790	122450	512	1.3	11	54	49	8.03	0	0
232	122780	122450	511	1.28	11	54	49	8.03	0	0
233	122920	122450	509	1.27	11	54	49	8.03	0	0
234	122410	122450	509	1.28	11	54	49	8.03	0	0
235	123250	122450	508	1.26	11	54	49	8.03	0	0
236	123170	122450	507	1.27	11	54	49	8.03	0	0
237	123370	122450	507	1.26	11	54	49	8.03	0	0
238	122920	122450	505	1.27	11	54	49	8.03	0	0
239	122230	122450	506	1.29	11	54	49	8.03	0	0
240	121920	122450	507	1.29	11	54	49	8.03	0	0
241	121520	122450	507	1.31	11	54	49	8.03	0	0

242	122360	122450	507	1.28	11	54	49	8.03	0	0
243	121950	122450	508	1.29	11	54	49	8.03	0	0
244	122160	122450	509	1.28	11	54	49	8.03	0	0
245	123180	122450	508	1.26	11	54	49	8.03	0	0
246	122790	122450	509	1.27	11	54	49	8.03	0	0
247	122900	122450	510	1.27	11	54	49	8.03	0	0
248	121650	118460	508	1.18	11	51	49	8.03	0	0
249	113480	107090	497	1.07	11	44	49	8.03	0	0
250	105170	100370	482	1	11	40	49	8.03	0	0
251	102520	97020	477	0.96	11	39	49	8.03	0	0
252	98610	97400	479	0.98	11	39	49	8.03	0	0
253	98070	98160	484	0.99	11	39	49	8.03	0	0
254	98290	98160	487	0.98	11	39	49	8.03	0	0
255	98620	98160	487	0.97	11	39	49	8.03	0	0
256	98040	98160	485	0.98	11	39	49	8.04	0	0
257	97630	98160	486	0.98	11	39	49	8.04	0	0
258	97550	98160	485	0.98	11	39	49	8.04	0	0
259	97980	98160	483	0.98	11	39	49	8.04	0	0
260	98130	98160	483	0.98	11	39	49	8.04	0	0
261	97940	98160	484	0.98	11	39	49	8.04	0	0
262	97510	98160	482	0.99	11	39	49	8.04	0	0
263	97830	98160	482	0.99	11	39	49	8.04	0	0
264	97890	98160	483	0.98	11	39	49	8.04	0	0
265	96950	98160	482	1	11	39	49	8.04	0	0
266	98400	98160	480	0.98	11	39	49	8.04	0	0
267	98280	98160	482	0.98	11	39	49	8.04	0	0
268	98320	98160	480	0.98	11	39	49	8.04	0	0

269	98840	98160	478	0.97	11	39	49	8.04	0	0
270	98740	98160	478	0.97	11	39	49	8.04	0	0
271	98250	98160	481	0.98	11	39	49	8.04	0	0
272	97660	98160	482	0.99	11	39	49	8.04	0	0
273	97590	98160	483	0.99	11	39	49	8.04	0	0
274	97510	98160	483	0.99	11	39	49	8.04	0	0
275	98120	98160	483	0.98	11	39	49	8.04	0	0
276	98040	98160	482	0.98	11	39	49	8.04	0	0
277	98370	98160	480	0.98	11	39	49	8.04	0	0
278	97520	98160	479	0.99	11	39	49	8.04	0	0
279	98180	98160	478	0.98	11	39	49	8.04	0	0
280	97560	98160	479	0.99	11	39	49	8.04	0	0
281	97360	98160	480	0.99	11	39	49	8.04	0	0
282	98970	98160	479	0.97	11	39	49	8.04	0	0
283	98610	98160	480	0.98	11	39	49	8.04	0	0
284	97910	98160	482	0.99	11	39	49	8.04	0	0
285	98320	98160	484	0.98	11	39	49	8.04	0	0
286	98520	98160	485	0.98	11	39	49	8.04	0	0
287	98400	98160	484	0.98	11	39	49	8.04	0	0
288	97620	98160	483	0.99	11	39	49	8.04	0	0
289	98810	98160	483	0.97	11	39	49	8.04	0	0
290	98150	98160	482	0.99	11	39	49	8.04	0	0
291	98500	98160	483	0.98	11	39	49	8.04	0	0
292	97850	98160	480	0.99	11	39	49	8.04	0	0
293	97870	98160	480	0.99	11	39	49	8.04	0	0
294	97560	98160	481	0.99	11	39	49	8.03	0	0
295	98430	98160	483	0.98	11	39	49	8.03	0	0

296	97400	98160	482	1	11	39	49	8.04	0	0
297	98120	98160	480	0.99	11	39	49	8.04	0	0
298	98290	98160	480	0.99	11	39	49	8.03	0	0
299	97390	98160	479	1.01	11	39	49	8.03	0	0
300	98420	97780	481	0.99	11	39	49	8.03	0	0
301	82060	50000	471	0.7	11	25	49	8.04	0	0
302	65990	50000	437	0.6	11	25	49	8.04	0	0
303	59590	50000	445	0.56	11	25	49	8.04	0	0
304	57130	50000	482	0.53	11	25	49	8.04	0	0
305	56250	50000	514	0.51	11	25	49	8.04	0	0
306	54250	50000	533	0.5	11	25	49	8.04	0	0
307	54250	50000	548	0.48	11	25	49	8.04	0	0
308	51680	50000	555	0.49	11	25	49	8.04	0	0
309	52140	50000	568	0.48	11	25	49	8.04	0	0
310	51810	50000	581	0.47	11	25	49	8.04	0	0
311	52450	50000	592	0.46	11	25	49	8.04	0	0
312	51990	50000	596	0.46	11	25	49	8.04	0	0
313	51850	50000	600	0.45	11	25	49	8.04	0	0
314	50200	50000	600	0.46	11	25	49	8.04	0	0
315	51220	50000	605	0.45	11	25	49	8.04	0	0
316	49450	50000	605	0.46	11	25	49	8.04	0	0
317	51250	50000	613	0.45	11	25	49	8.04	0	0
318	50280	50000	623	0.45	11	25	49	8.04	0	0
319	49860	50000	622	0.45	11	25	49	8.04	0	0
320	50570	50000	626	0.45	11	25	49	8.04	0	0
321	50790	50000	631	0.45	11	25	49	8.04	0	0
322	50800	50000	631	0.44	11	25	49	8.04	0	0

323	51050	50000	635	0.44	11	25	49	8.04	0	0
324	50840	50000	636	0.44	11	25	49	8.04	0	0
325	50990	50000	636	0.43	11	25	49	8.04	0	0
326	51420	50000	639	0.43	11	25	49	8.04	0	0
327	51650	50000	640	0.42	11	25	49	8.04	0	0
328	50050	50000	632	0.43	11	25	49	8.04	0	0
329	50850	50000	639	0.42	11	25	49	8.04	0	0
330	50440	50000	633	0.42	11	25	49	8.04	0	0
331	49580	50000	636	0.43	11	25	49	8.04	0	0
332	50770	50000	634	0.42	11	25	49	8.04	0	0
333	49270	50000	633	0.43	11	25	49	8.04	0	0
334	50490	50000	635	0.42	11	25	49	8.04	0	0
335	50210	50000	632	0.42	11	25	49	8.04	0	0
336	49570	50000	633	0.43	11	25	49	8.04	0	0
337	50620	50000	632	0.42	11	25	49	8.04	0	0
338	49450	50000	630	0.43	11	25	49	8.04	0	0
339	50290	50000	633	0.42	11	25	49	8.04	0	0
340	49820	50000	627	0.43	11	25	49	8.04	0	0
341	49740	50000	630	0.42	11	25	49	8.04	0	0
342	50500	50000	628	0.42	11	25	49	8.04	0	0
343	49440	50000	627	0.44	10	25	100	8.04	0	0
344	54930	60000	634	0.52	10	25	100	8.04	0	0
345	61540	60000	665	0.52	10	25	100	8.04	0	0
346	61860	60000	648	0.52	10	25	100	8.04	0	0
347	61960	60000	631	0.52	10	25	100	8.04	0	0
348	61730	60000	623	0.52	10	25	100	8.04	0	0
349	61550	60000	620	0.52	10	25	100	8.04	0	0

350	31220	0	559	0	8	25	0	8.04	0	0
351	18260	0	391	0	8	25	0	8.04	0	0
352	12670	0	309	0	8	25	0	8.04	0	0
353	9640	0	276	0	8	3	0	8.04	0	0
354	7590	0	261	0	8	0	0	8.04	0	0
355	6190	0	255	0	8	0	0	8.04	0	0
356	5260	0	252	0	8	0	0	8.04	0	0
357	4380	0	250	0	8	0	0	8.04	0	0
358	3730	0	249	0	8	0	0	8.04	0	0
359	3120	0	248	0	8	0	0	8.04	0	0
360	2720	0	248	0	8	0	0	8.04	0	0
361	3340	0	248	0	8	150	0	8.03	0	0
362	7060	0	245	0	8	150	0	8.03	0	0
363	9190	0	232	0	8	150	0	8.03	0	0
364	7290	0	216	0	8	150	0	8.03	0	0
365	5870	0	205	0	8	150	0	8.03	0	0
366	4830	0	199	0	8	150	0	8.03	0	0
367	4040	0	196	0	8	150	0	8.03	0	0
368	3410	0	194	0	8	150	0	8.04	0	0
369	2860	0	193	0	8	150	0	8.04	0	0

E. PROPANE TEST RUN #1

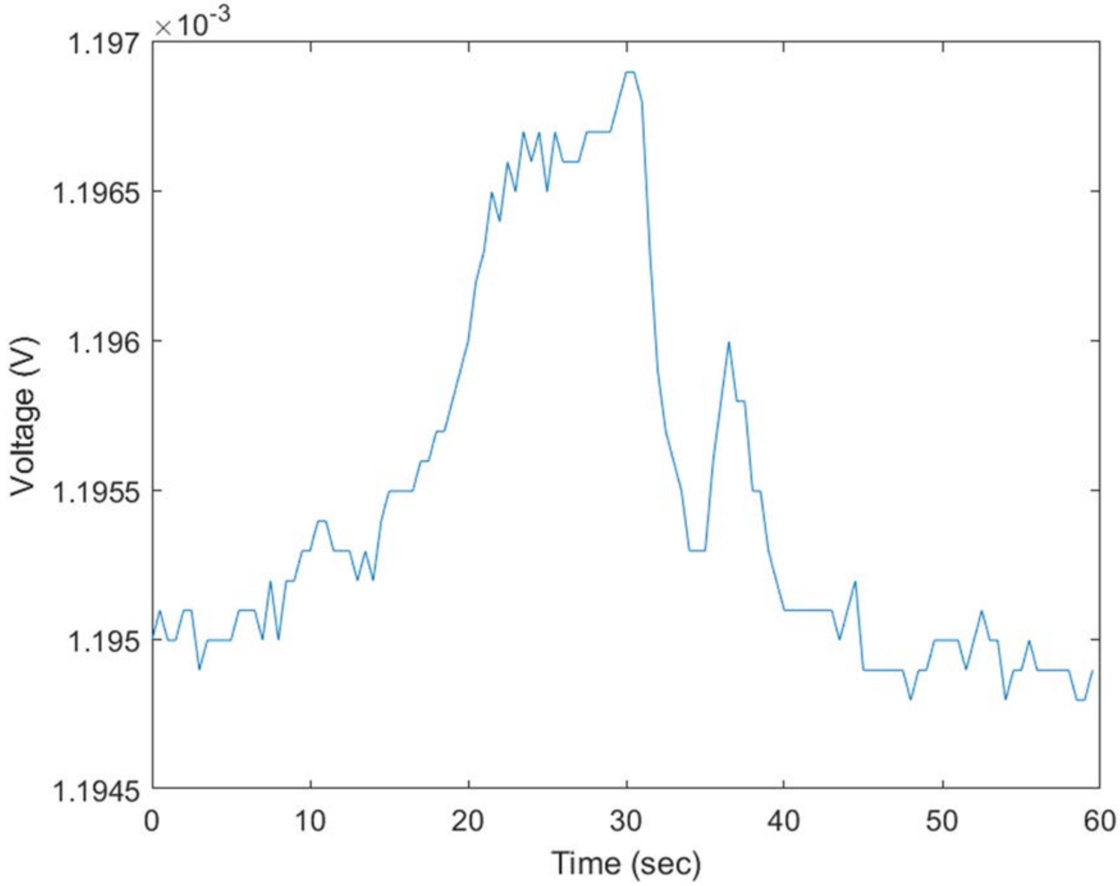

Figure 110. NI DAQ data from propane test run #1

Table 27. DAQ data table for propane test run #1

Time (sec)	Voltage (V)
0	0.001195
0.5	0.0011951
1	0.001195
1.5	0.001195
2	0.0011951
2.5	0.0011951
3	0.0011949
3.5	0.001195
4	0.001195
4.5	0.001195
5	0.001195
5.5	0.0011951
6	0.0011951
6.5	0.0011951
7	0.001195
7.5	0.0011952
8	0.001195
8.5	0.0011952
9	0.0011952
9.5	0.0011953
10	0.0011953
10.5	0.0011954
11	0.0011954
11.5	0.0011953
12	0.0011953
12.5	0.0011953
13	0.0011952
13.5	0.0011953
14	0.0011952
14.5	0.0011954
15	0.0011955
15.5	0.0011955
16	0.0011955
16.5	0.0011955
17	0.0011956
17.5	0.0011956
18	0.0011957
18.5	0.0011957
19	0.0011958
19.5	0.0011959
20	0.001196
20.5	0.0011962
21	0.0011963
21.5	0.0011965
22	0.0011964
22.5	0.0011966
23	0.0011965
23.5	0.0011967
24	0.0011966
24.5	0.0011967
25	0.0011965
25.5	0.0011967
26	0.0011966
26.5	0.0011966
27	0.0011966
27.5	0.0011967
28	0.0011967
28.5	0.0011967
29	0.0011967
29.5	0.0011968
30	0.0011969
30.5	0.0011969
31	0.0011968
31.5	0.0011963
32	0.0011959
32.5	0.0011957
33	0.0011956
33.5	0.0011955
34	0.0011953
34.5	0.0011953
35	0.0011953
35.5	0.0011956
36	0.0011958
36.5	0.001196
37	0.0011958
37.5	0.0011958
38	0.0011955
38.5	0.0011955
39	0.0011953
39.5	0.0011952
40	0.0011951
40.5	0.0011951
41	0.0011951
41.5	0.0011951
42	0.0011951
42.5	0.0011951
43	0.0011951
43.5	0.001195
44	0.0011951
44.5	0.0011952
45	0.0011949
45.5	0.0011949
46	0.0011949
46.5	0.0011949
47	0.0011949
47.5	0.0011949
48	0.0011948
48.5	0.0011949
49	0.0011949
49.5	0.001195
50	0.001195
50.5	0.001195
51	0.001195
51.5	0.0011949
52	0.001195
52.5	0.0011951
53	0.001195
53.5	0.001195
54	0.0011948
54.5	0.0011949
55	0.0011949
55.5	0.001195
56	0.0011949
56.5	0.0011949
57	0.0011949
57.5	0.0011949
58	0.0011949
58.5	0.0011948
59	0.0011948
59.5	0.0011949
60	0.0011949

F. PROPANE TEST RUN #2

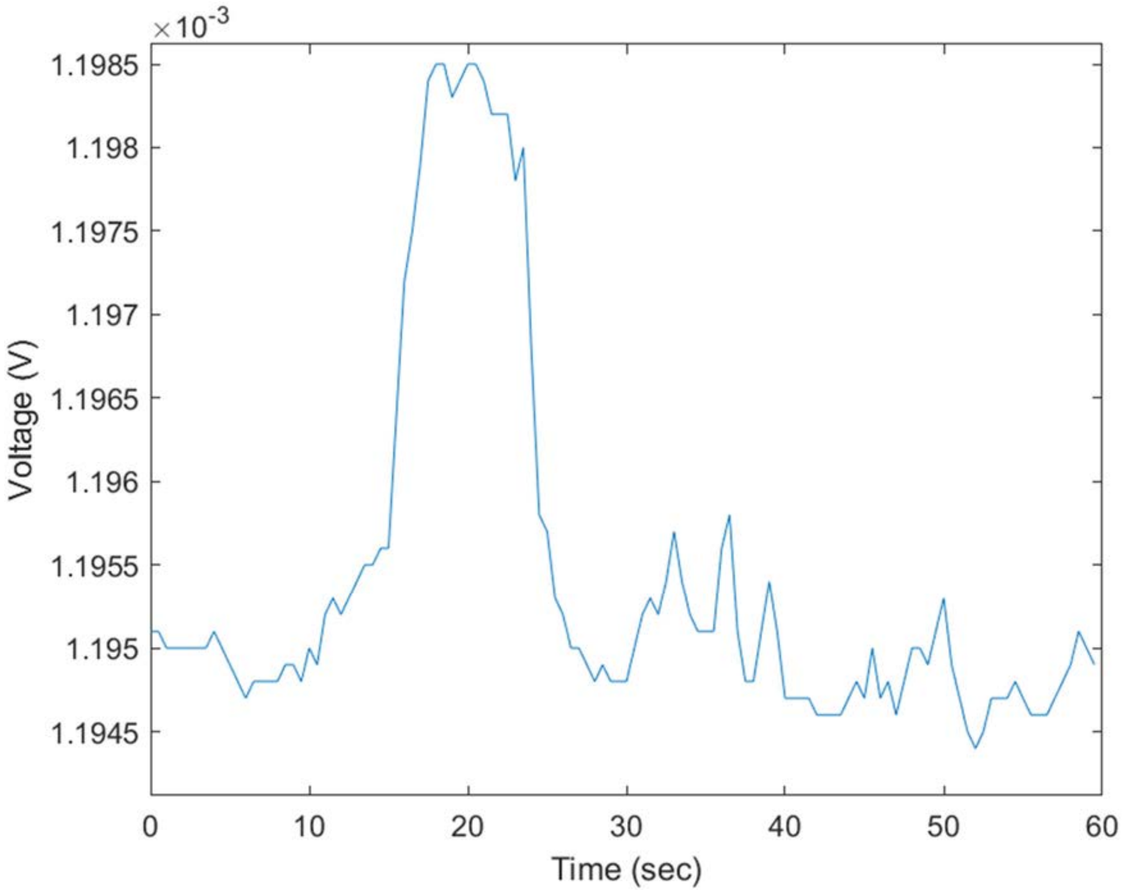

Figure 111. NI DAQ data from propane test run #2

Table 28. DAQ data table for propane test run #2

Time (sec)	Voltage (V)
0	0.0011951
0.5	0.0011951
1	0.001195
1.5	0.001195
2	0.001195
2.5	0.001195
3	0.001195
3.5	0.001195
4	0.0011951
4.5	0.001195
5	0.0011949
5.5	0.0011948
6	0.0011947
6.5	0.0011948
7	0.0011948
7.5	0.0011948
8	0.0011948
8.5	0.0011949
9	0.0011949
9.5	0.0011948
10	0.001195
10.5	0.0011949
11	0.0011952
11.5	0.0011953
12	0.0011952
12.5	0.0011953
13	0.0011954
13.5	0.0011955
14	0.0011955
14.5	0.0011956
15	0.0011956
15.5	0.0011964
16	0.0011972
16.5	0.0011975
17	0.0011979
17.5	0.0011984
18	0.0011985
18.5	0.0011985
19	0.0011983
19.5	0.0011984
20	0.0011985
20.5	0.0011985
21	0.0011984
21.5	0.0011982
22	0.0011982
22.5	0.0011982
23	0.0011978
23.5	0.001198
24	0.0011968
24.5	0.0011958
25	0.0011957
25.5	0.0011953
26	0.0011952
26.5	0.001195
27	0.001195
27.5	0.0011949
28	0.0011948
28.5	0.0011949
29	0.0011948
29.5	0.0011948
30	0.0011948
30.5	0.001195
31	0.0011952
31.5	0.0011953
32	0.0011952
32.5	0.0011954
33	0.0011957
33.5	0.0011954
34	0.0011952
34.5	0.0011951
35	0.0011951
35.5	0.0011951
36	0.0011956
36.5	0.0011958
37	0.0011951
37.5	0.0011948
38	0.0011948
38.5	0.0011951
39	0.0011954
39.5	0.0011951
40	0.0011947
40.5	0.0011947
41	0.0011947
41.5	0.0011947
42	0.0011946
42.5	0.0011946
43	0.0011946
43.5	0.0011946
44	0.0011947
44.5	0.0011948
45	0.0011947
45.5	0.001195
46	0.0011947
46.5	0.0011948
47	0.0011946
47.5	0.0011948
48	0.001195
48.5	0.001195
49	0.0011949
49.5	0.0011951
50	0.0011953
50.5	0.0011949
51	0.0011947
51.5	0.0011945
52	0.0011944
52.5	0.0011945
53	0.0011947
53.5	0.0011947
54	0.0011947
54.5	0.0011948
55	0.0011947
55.5	0.0011946
56	0.0011946
56.5	0.0011946
57	0.0011947
57.5	0.0011948
58	0.0011949
58.5	0.0011951
59	0.001195
59.5	0.0011949
60	0.0011947

G. PROPANE TEST RUN #3

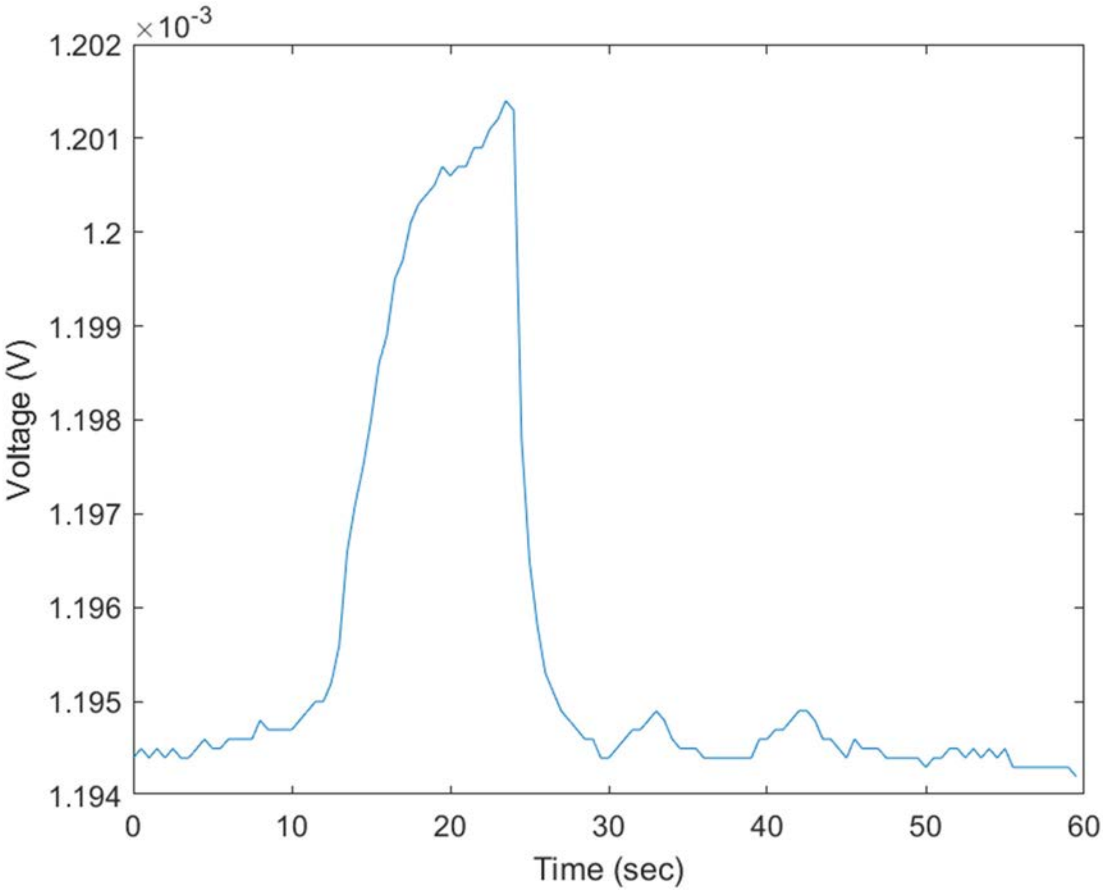

Figure 112. NI DAQ data from propane test run #3

Table 29. DAQ data table for propane test run #3

Time (sec)	Voltage (V)
0	0.0011944
0.5	0.0011945
1	0.0011944
1.5	0.0011945
2	0.0011944
2.5	0.0011945
3	0.0011944
3.5	0.0011944
4	0.0011945
4.5	0.0011946
5	0.0011945
5.5	0.0011945
6	0.0011946
6.5	0.0011946
7	0.0011946
7.5	0.0011946
8	0.0011948
8.5	0.0011947
9	0.0011947
9.5	0.0011947
10	0.0011947
10.5	0.0011948
11	0.0011949
11.5	0.001195
12	0.001195
12.5	0.0011952
13	0.0011956
13.5	0.0011966
14	0.0011971
14.5	0.0011975
15	0.001198
15.5	0.0011986
16	0.0011989
16.5	0.0011995
17	0.0011997
17.5	0.0012001
18	0.0012003
18.5	0.0012004
19	0.0012005
19.5	0.0012007
20	0.0012006
20.5	0.0012007
21	0.0012007
21.5	0.0012009
22	0.0012009
22.5	0.0012011
23	0.0012012
23.5	0.0012014
24	0.0012013
24.5	0.0011978
25	0.0011965
25.5	0.0011958
26	0.0011953
26.5	0.0011951
27	0.0011949
27.5	0.0011948
28	0.0011947
28.5	0.0011946
29	0.0011946
29.5	0.0011944
30	0.0011944
30.5	0.0011945
31	0.0011946
31.5	0.0011947
32	0.0011947
32.5	0.0011948
33	0.0011949
33.5	0.0011948
34	0.0011946
34.5	0.0011945
35	0.0011945
35.5	0.0011945
36	0.0011944
36.5	0.0011944
37	0.0011944
37.5	0.0011944
38	0.0011944
38.5	0.0011944
39	0.0011944
39.5	0.0011946
40	0.0011946
40.5	0.0011947
41	0.0011947
41.5	0.0011948
42	0.0011949
42.5	0.0011949
43	0.0011948
43.5	0.0011946
44	0.0011946
44.5	0.0011945
45	0.0011944
45.5	0.0011946
46	0.0011945
46.5	0.0011945
47	0.0011945
47.5	0.0011944
48	0.0011944
48.5	0.0011944
49	0.0011944
49.5	0.0011944
50	0.0011943
50.5	0.0011944
51	0.0011944
51.5	0.0011945
52	0.0011945
52.5	0.0011944
53	0.0011945
53.5	0.0011944
54	0.0011945
54.5	0.0011944
55	0.0011945
55.5	0.0011943
56	0.0011943
56.5	0.0011943
57	0.0011943
57.5	0.0011943
58	0.0011943
58.5	0.0011943
59	0.0011943
59.5	0.0011942
60	0.0011942

H. PROPANE TEST RUN #4

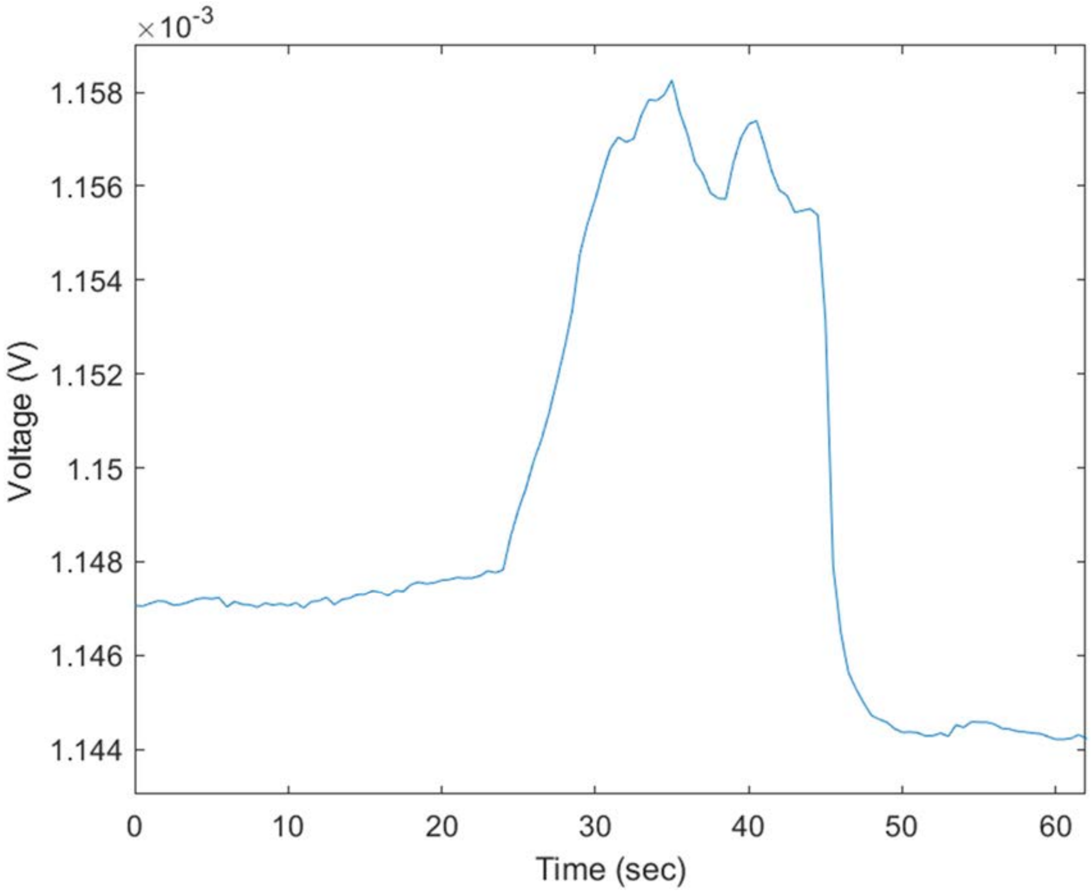

Figure 113. NI DAQ data from propane test run #4

Table 30. DAQ data table for propane test run #4

Time (sec)	Voltage (V)
0	0.0011471
0.5	0.001147
1	0.0011471
1.5	0.0011472
2	0.0011471
2.5	0.0011471
3	0.0011471
3.5	0.0011471
4	0.0011472
4.5	0.0011472
5	0.0011472
5.5	0.0011472
6	0.001147
6.5	0.0011471
7	0.0011471
7.5	0.0011471
8	0.001147
8.5	0.0011471
9	0.0011471
9.5	0.0011471
10	0.0011471
10.5	0.0011471
11	0.001147
11.5	0.0011471
12	0.0011472
12.5	0.0011472
13	0.0011471
13.5	0.0011472
14	0.0011472
14.5	0.0011473
15	0.0011473
15.5	0.0011474
16	0.0011473
16.5	0.0011473
17	0.0011474
17.5	0.0011474
18	0.0011475
18.5	0.0011476
19	0.0011475
19.5	0.0011476
20	0.0011476
20.5	0.0011476
21	0.0011477
21.5	0.0011477
22	0.0011477
22.5	0.0011477
23	0.0011478
23.5	0.0011478
24	0.0011478
24.5	0.0011486
25	0.0011491
25.5	0.0011496
26	0.0011502
26.5	0.0011506
27	0.0011512
27.5	0.0011518
28	0.0011526
28.5	0.0011533
29	0.0011546
29.5	0.0011552
30	0.0011557
30.5	0.0011563
31	0.0011568
31.5	0.001157
32	0.0011569
32.5	0.001157
33	0.0011575
33.5	0.0011578
34	0.0011578
34.5	0.0011579
35	0.0011583
35.5	0.0011576
36	0.0011571
36.5	0.0011565
37	0.0011563
37.5	0.0011559
38	0.0011557
38.5	0.0011557
39	0.0011565
39.5	0.001157
40	0.0011573
40.5	0.0011574
41	0.0011569
41.5	0.0011563
42	0.0011559
42.5	0.0011558
43	0.0011554
43.5	0.0011555
44	0.0011555
44.5	0.0011554
45	0.0011531
45.5	0.0011479
46	0.0011465
46.5	0.0011456
47	0.0011453
47.5	0.001145
48	0.0011447
48.5	0.0011446
49	0.0011446
49.5	0.0011444
50	0.0011444
50.5	0.0011444
51	0.0011444
51.5	0.0011443
52	0.0011443
52.5	0.0011443
53	0.0011443
53.5	0.0011445
54	0.0011445
54.5	0.0011446
55	0.0011446
55.5	0.0011446
56	0.0011445
56.5	0.0011444
57	0.0011444
57.5	0.0011444
58	0.0011444
58.5	0.0011443
59	0.0011443
59.5	0.0011443
60	0.0011442

I. PROPANE TEST RUN #5

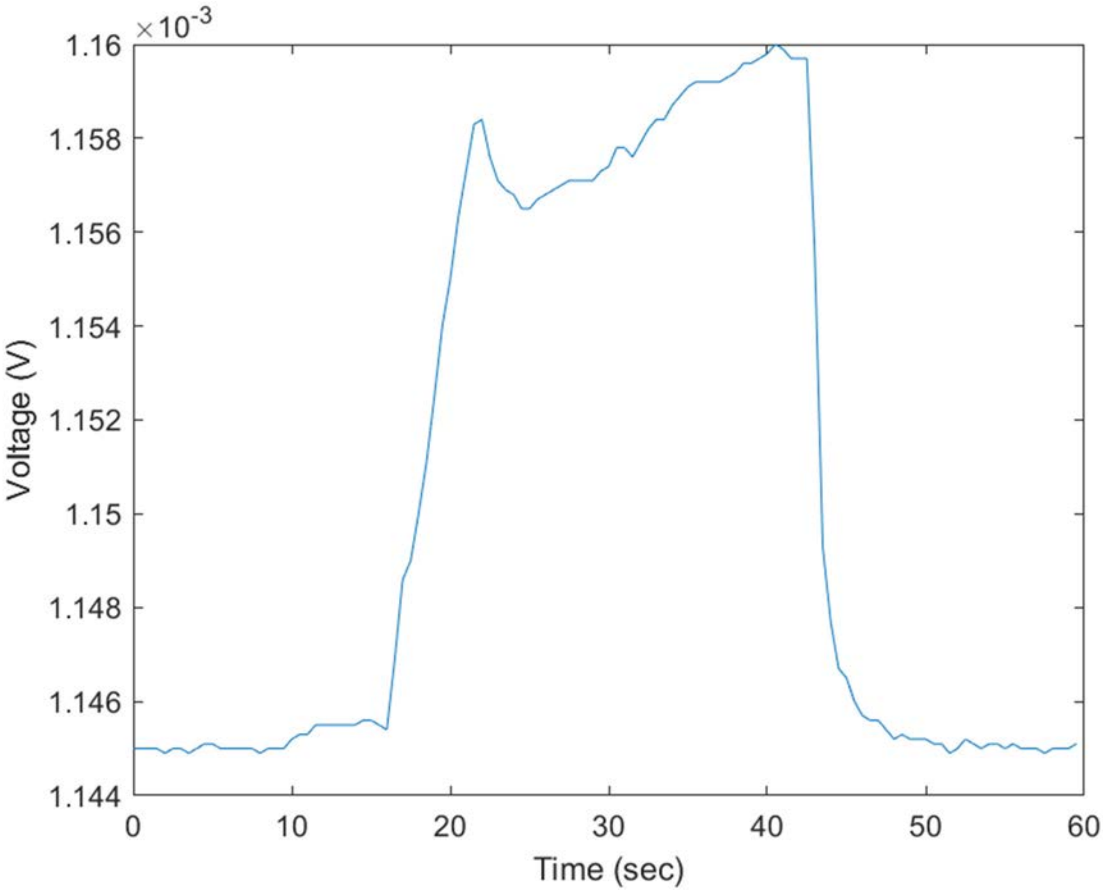

Figure 114. NI DAQ data from propane test run #5

Table 31. DAQ data table for propane test run #5

Time (sec)	Voltage (V)
0	0.001145
0.5	0.001145
1	0.001145
1.5	0.001145
2	0.0011449
2.5	0.001145
3	0.001145
3.5	0.0011449
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4.5	0.0011451
5	0.0011451
5.5	0.001145
6	0.001145
6.5	0.001145
7	0.001145
7.5	0.001145
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8.5	0.001145
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9.5	0.001145
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11.5	0.0011455
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12.5	0.0011455
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13.5	0.0011455
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14.5	0.0011456
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15.5	0.0011455
16	0.0011454
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17.5	0.001149
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18.5	0.0011511
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58.5	0.001145
59	0.001145
59.5	0.0011451
60	0.0011451

APPENDIX I. WEATHER DATA AND CORRECTION FACTORS

Weather data in Table 32 and Table 33 are the values at the time of each test.

Table 32. Weather data and correction factors for kerosene test runs. Source: [25].

Test run	Barometric pressure (in Hg)	Temperature (°F)	Temperature correction factor (θ)	Pressure correction factor (δ)
1	29.75	75	1.250	0.994
2	29.80	63	1.050	0.996
3	30.04	55	0.917	1.004
4	30.16	51	0.850	1.008

Table 33. Weather data and correction factors for propane test runs. Source: [25].

Test run	Barometric pressure (in Hg)	Temperature (°F)	Temperature correction factor (θ)	Pressure correction factor (δ)
1	30.27	67	1.117	1.012
2	30.27	67	1.117	1.012
3	30.25	64	1.067	1.011
4	30.26	59	0.983	1.011
5	30.27	59	0.983	1.012

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APPENDIX J. GASTURB RESULTS

A. DESIGN POINT CALCULATION

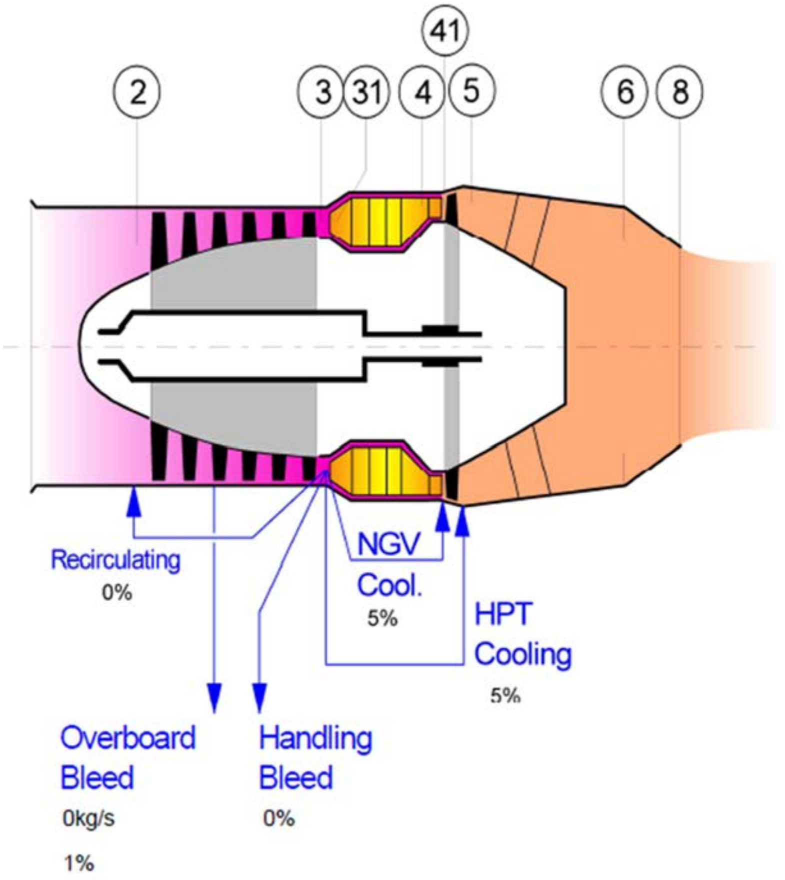
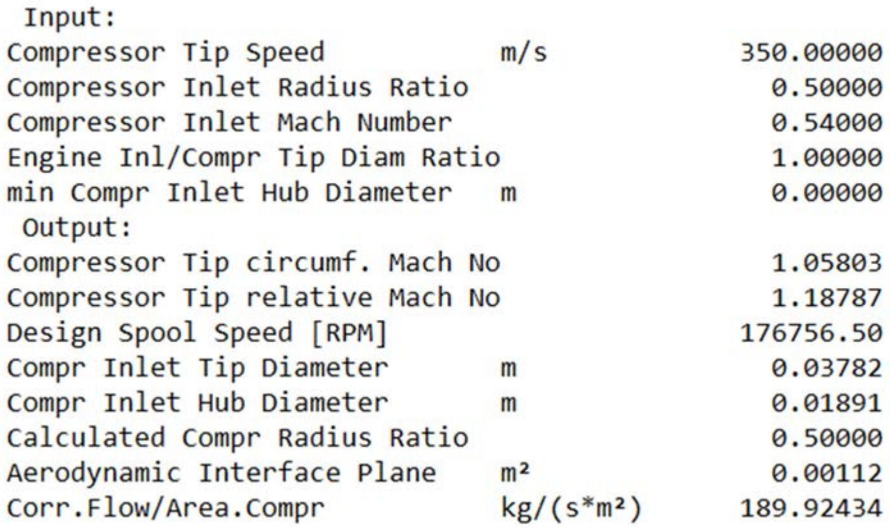


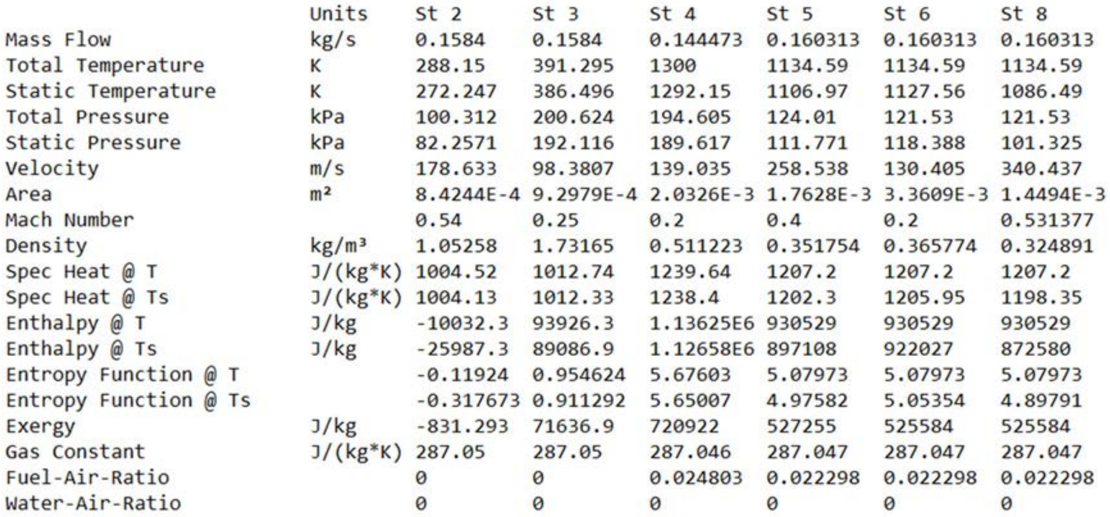
Figure 115. Demo turbojet air system

Table 34. Compressor data using inputs from Table 10



```
 Input:
Compressor Tip Speed           m/s            350.00000
Compressor Inlet Radius Ratio                   0.50000
Compressor Inlet Mach Number                    0.54000
Engine Inl/Compr Tip Diam Ratio                 1.00000
min Compr Inlet Hub Diameter   m                0.00000
 Output:
Compressor Tip circumf. Mach No                 1.05803
Compressor Tip relative Mach No                 1.18787
Design Spool Speed [RPM]                      176756.50
Compr Inlet Tip Diameter       m                0.03782
Compr Inlet Hub Diameter       m                0.01891
Calculated Compr Radius Ratio                   0.50000
Aerodynamic Interface Plane    m²               0.00112
Corr.Flow/Area.Compr           kg/(s*m²)      189.92434
```

Table 35. Station data using inputs from Table 10



	Units	St 2	St 3	St 4	St 5	St 6	St 8
Mass Flow	kg/s	0.1584	0.1584	0.144473	0.160313	0.160313	0.160313
Total Temperature	K	288.15	391.295	1300	1134.59	1134.59	1134.59
Static Temperature	K	272.247	386.496	1292.15	1106.97	1127.56	1086.49
Total Pressure	kPa	100.312	200.624	194.605	124.01	121.53	121.53
Static Pressure	kPa	82.2571	192.116	189.617	111.771	118.388	101.325
Velocity	m/s	178.633	98.3807	139.035	258.538	130.405	340.437
Area	m²	8.4244E-4	9.2979E-4	2.0326E-3	1.7628E-3	3.3609E-3	1.4494E-3
Mach Number		0.54	0.25	0.2	0.4	0.2	0.531377
Density	kg/m³	1.05258	1.73165	0.511223	0.351754	0.365774	0.324891
Spec Heat @ T	J/(kg*K)	1004.52	1012.74	1239.64	1207.2	1207.2	1207.2
Spec Heat @ Ts	J/(kg*K)	1004.13	1012.33	1238.4	1202.3	1205.95	1198.35
Enthalpy @ T	J/kg	-10032.3	93926.3	1.13625E6	930529	930529	930529
Enthalpy @ Ts	J/kg	-25987.3	89086.9	1.12658E6	897108	922027	872580
Entropy Function @ T		-0.11924	0.954624	5.67603	5.07973	5.07973	5.07973
Entropy Function @ Ts		-0.317673	0.911292	5.65007	4.97582	5.05354	4.89791
Exergy	J/kg	-831.293	71636.9	720922	527255	525584	525584
Gas Constant	J/(kg*K)	287.05	287.05	287.046	287.047	287.047	287.047
Fuel-Air-Ratio		0	0	0.024803	0.022298	0.022298	0.022298
Water-Air-Ratio		0	0	0	0	0	0

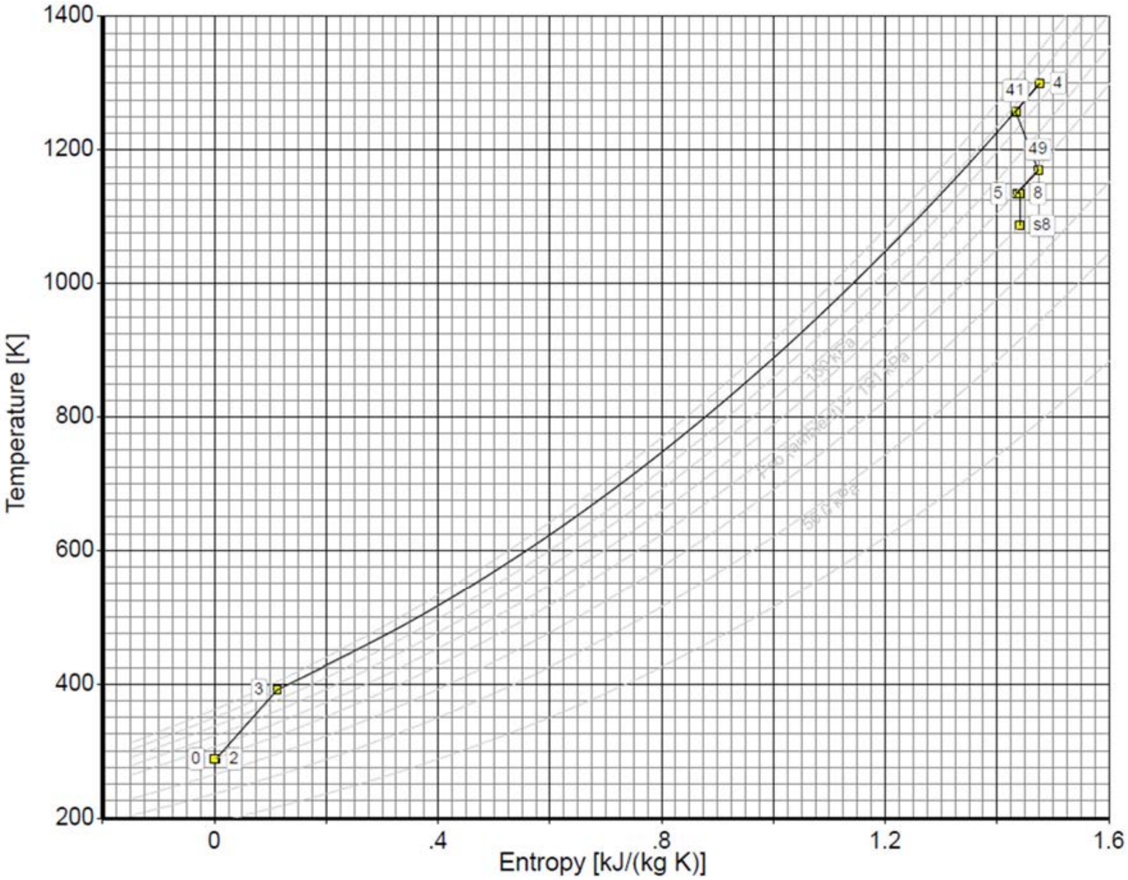


Figure 116. Temperature vs. entropy diagram

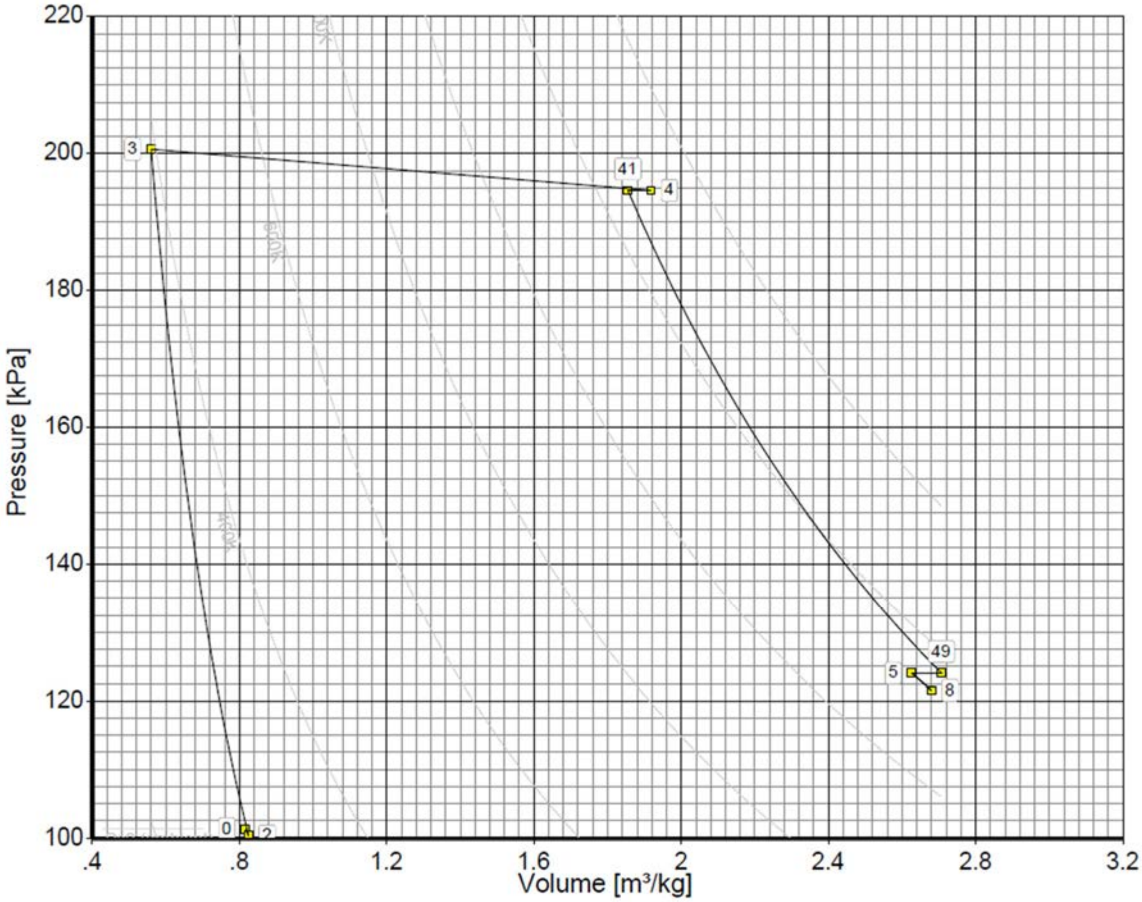


Figure 117. Pressure vs. specific volume diagram

B. OFF-DESIGN CALCULATION

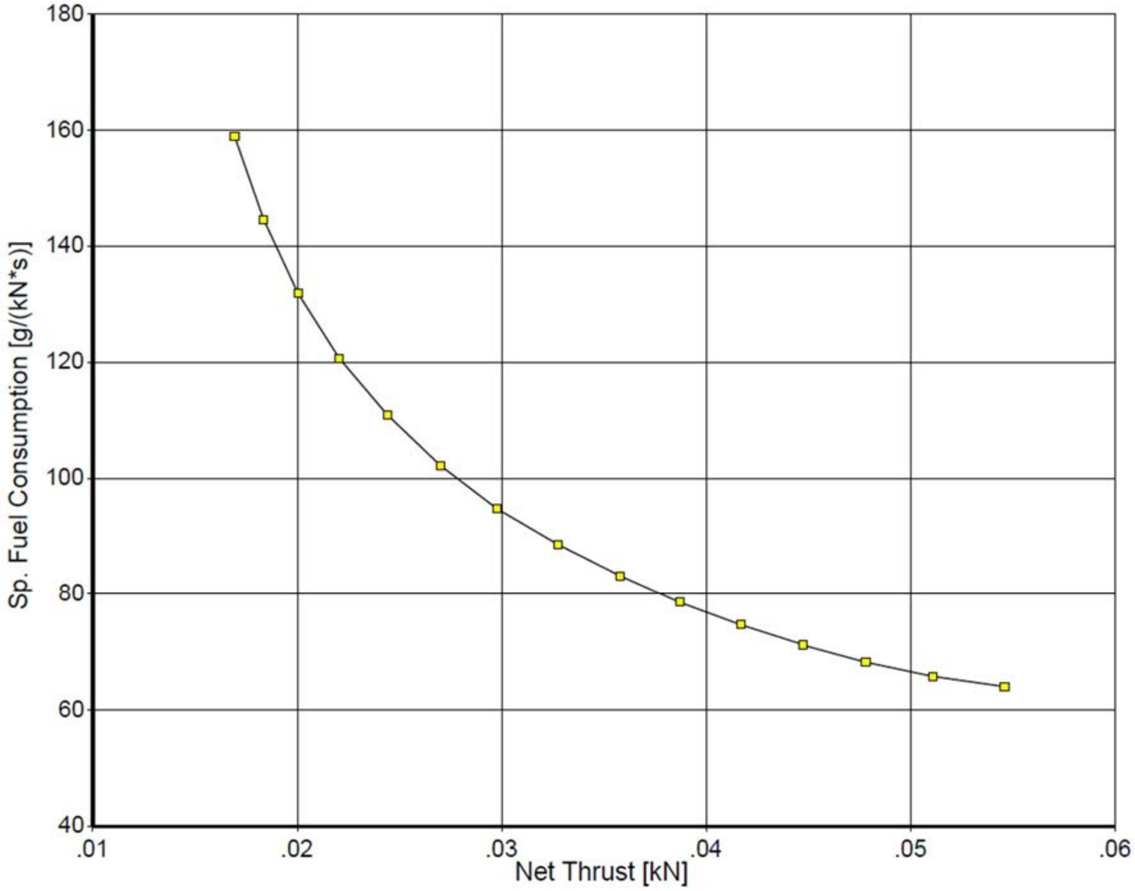


Figure 118. Specific fuel consumption vs. net thrust

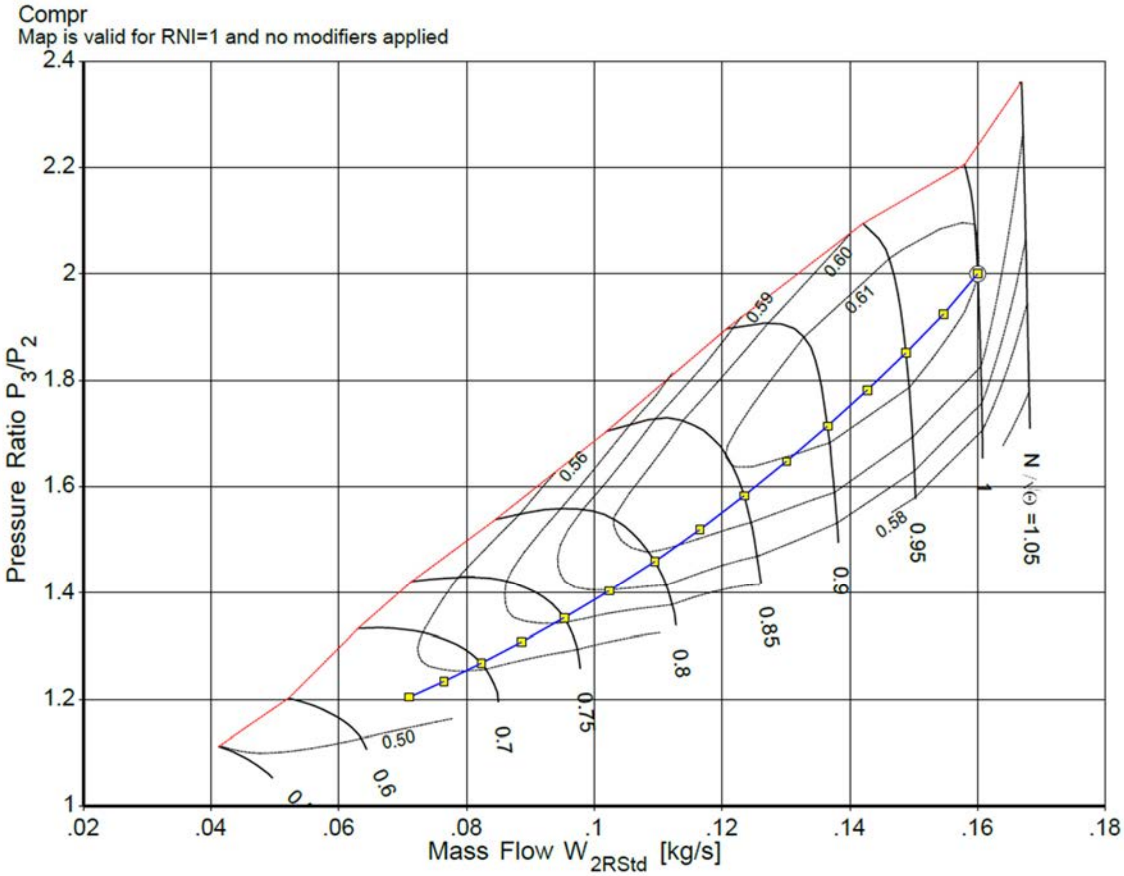


Figure 119. Compressor pressure ratio vs. corrected mass flow

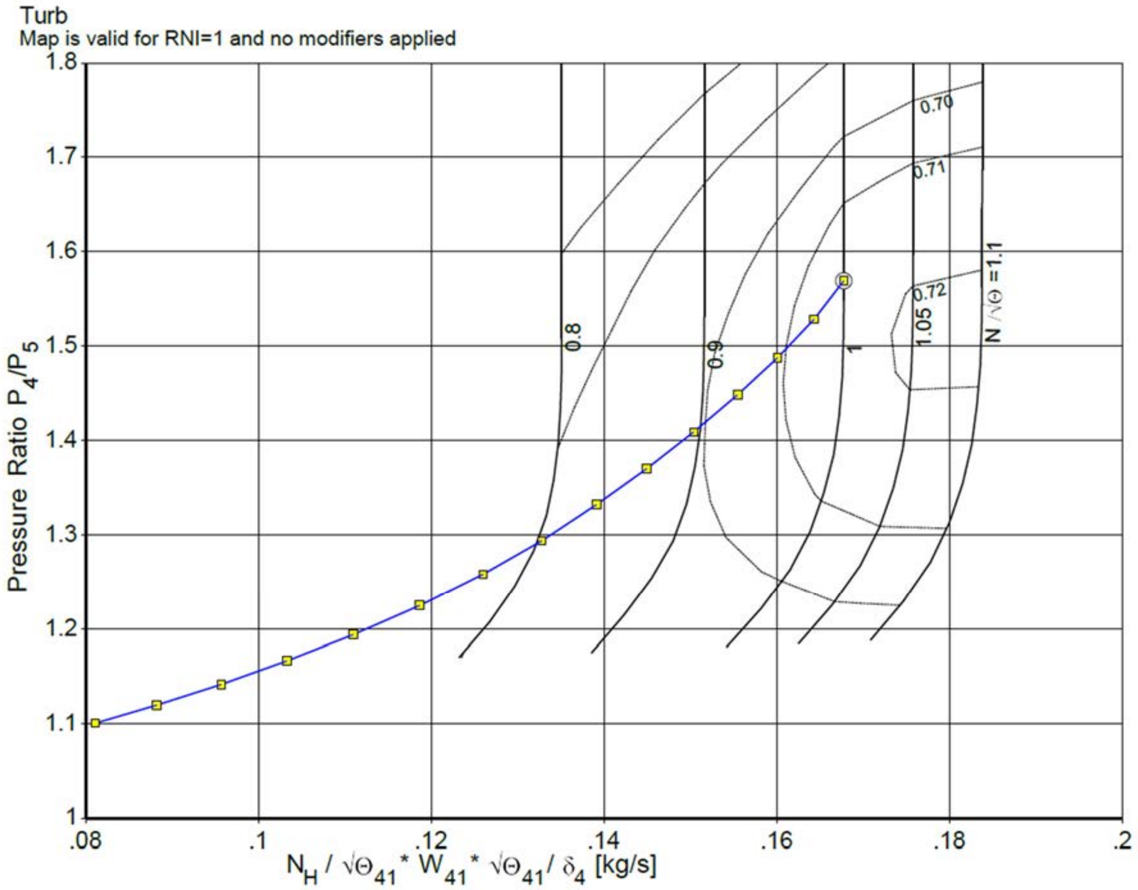


Figure 120. Turbine pressure ratio vs. the product of corrected flow and corrected speed

C. PARAMETRIC STUDY FOR OTHER FUELS

A parametric study was conducted using other fuels offered in GASTURB: generic (jet), natural gas, and hydrogen for comparison.

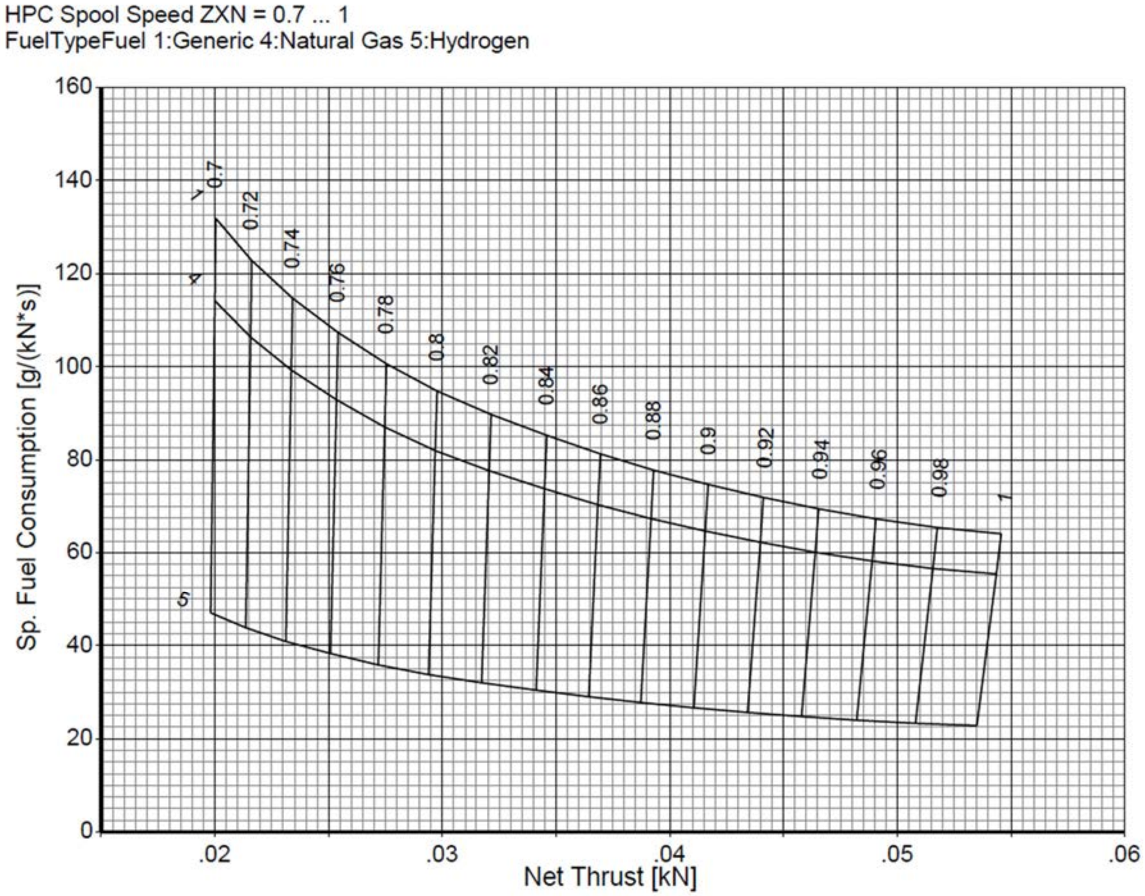


Figure 121. Specific fuel consumption vs. net thrust

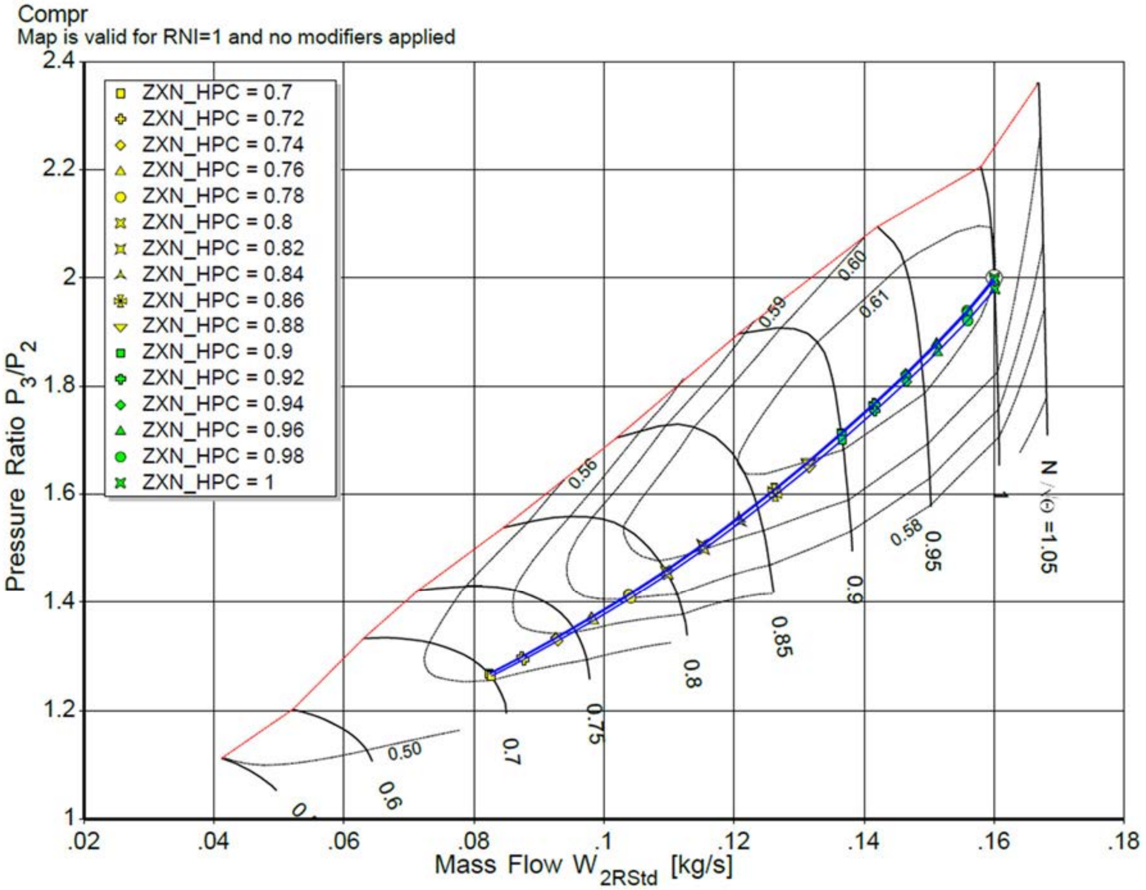


Figure 122. Compressor pressure ratio vs. corrected mass flow

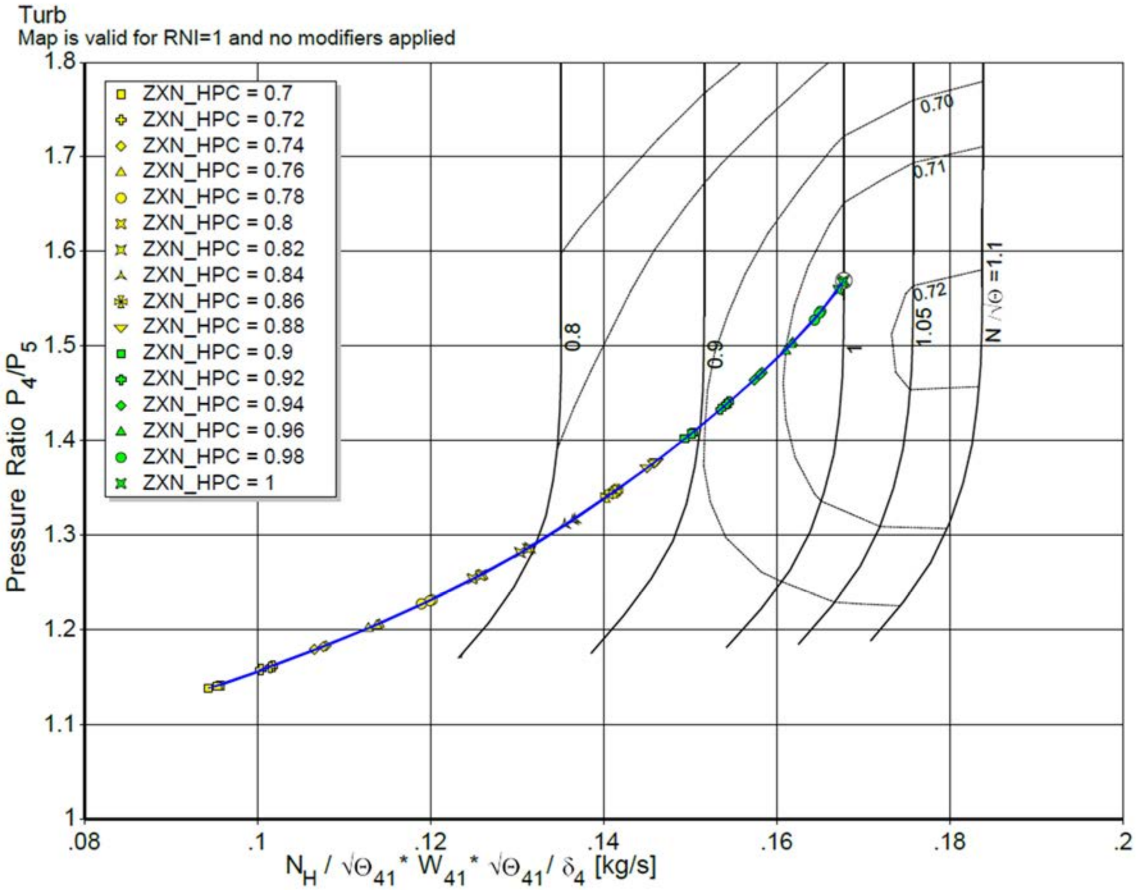


Figure 123. Turbine pressure ratio vs. the product of corrected flow and corrected speed

APPENDIX K. PROPOSED SYSTEM REDESIGN

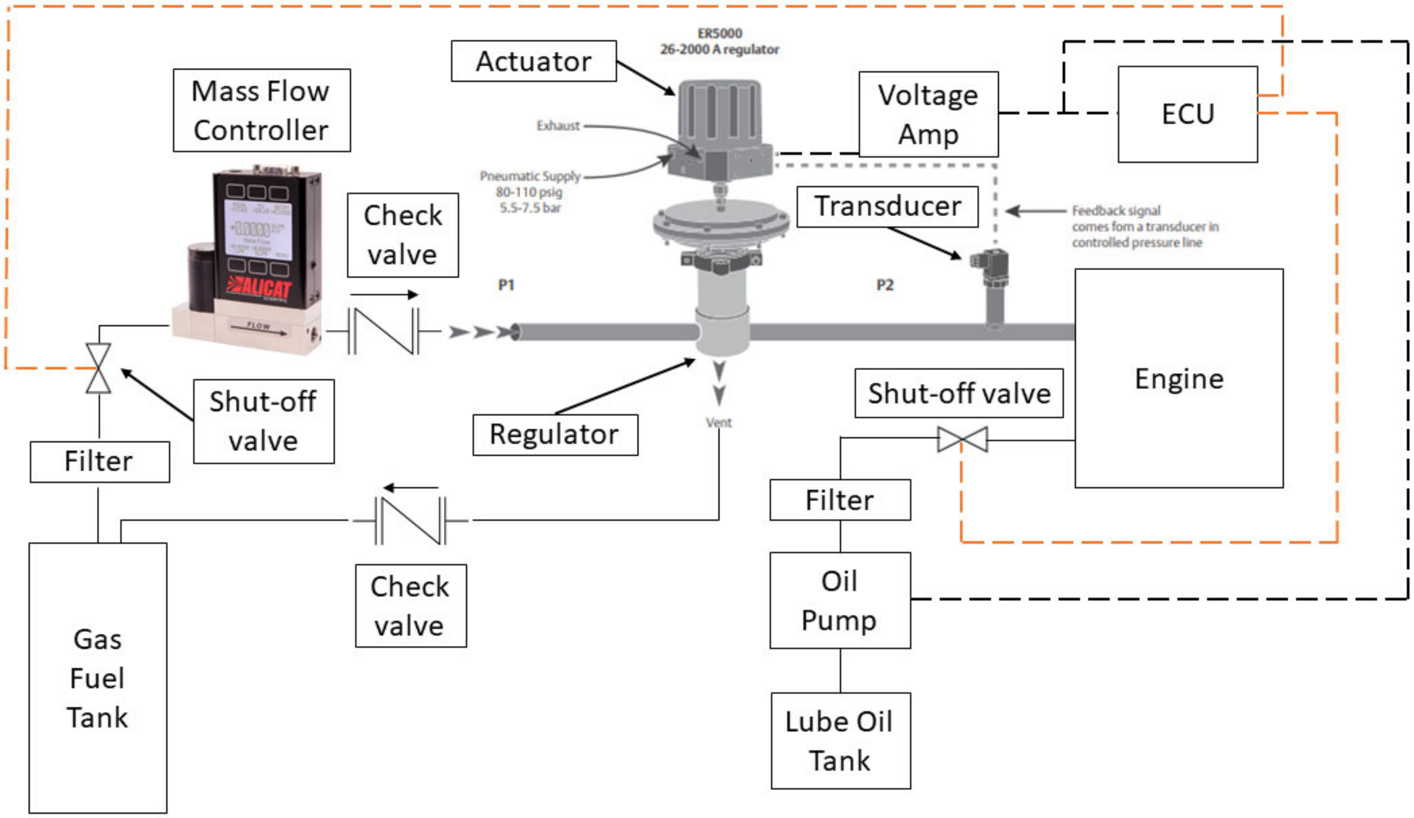


Figure 124. Proposed system redesign. Source: [29] and [31].

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