Electronic Fuel Control for GE-T58 Gas Turbine

2015 University of Idaho Senior Capstone Project

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Executive Summary

The GE-T58 gas turbine currently uses a mechanical fuel controller which controls both a stator vane actuator as well as fuel to the combustion nozzles. The goal of our project is to create a device that is simpler to work on as well as tune. This will require a manifold, a thermodynamic analysis, and a programmed electronic controller. The design consists of a two way valve and a four way valve. These valves provide kerosene to the combustion chamber and stator vane actuator, respectively. The manifold will encompass these valves while bolting into the same place on the turbine as the existing fuel control. The thermodynamic analysis will be done using a gasifier turbine cycle and using Engineering Equation Solver (EES) program software. The electronic controller will be an industrial off the shelf hydraulic controller with pulse-width modulation (PWM) communication.

Appendices

Background

The GE-T58 currently uses a complex mechanical fuel control that provides kerosene to the stator vane actuator and the fuel nozzles. The stator vane actuator controls the first three stages of compressors, which are stationary. These stages of compressors are either open or closed depending on the speed of turbine one (N1). The fuel nozzles inject the kerosene into the combustion chamber to provide combustion gasses to the both turbines, N1 and N2. This mechanical fuel control unit is extremely difficult to service and tune. The rebuild costs have been estimated around $15,000.00, while only a few places have the proper equipment to perform this service. The mechanical fuel control can be seen in figures 1 and 2.

Figure 1. Mechanical fuel control

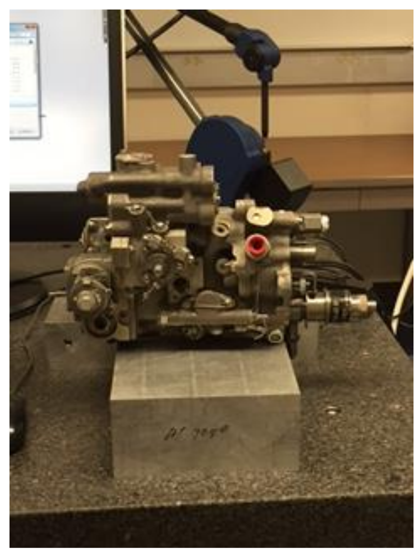

Figure 2. Mechanical fuel control

Problem Definition

As recently stated, the existing fuel control is very complex and expensive to repair. An Electronic fuel control would allow the user to tune, repair and update any hardware on the new fuel controller. This is ideal as it allows the user to attend race days confidently with spare components and very few time needed to make these repairs. The following specs, in Table 1, represent what needs to be done to achieve these benefits.

No.	Component	Need	Imp.
1	Fuel Control	Programmed hydraulic controller	5
2	Fuel Control	2 way valve wired to controller	5
3	Fuel Control	4 way valve wired to controller	5
4	Inputs	Read type K T.C	5
5	Inputs	Read turbine speeds, N1 & N2 - AC Frequency	5
6	Inputs	TPS (0-5v)	3
7	Inputs	Read compressor discharge pressure (0-5v)	1
8	Record	Read RTD inlet temperature	4
9	Outputs	PWM for fuel outlet control	5
10	Outputs	Fuel to compressor guide vane actuator	5
11	Manifold	Bolts in place of existing fuel control	5
12	Manifold	Throttle position sensor mounted	5
13	Manifold	Package sensors	5
14	Manifold	Aluminum	3
15	Manifold	Cap off unnecessary ports	3
16	Manifold	Drawing package	5
17	Manifold	Bypass fuel control (manual)	1

Table 1. Specifications

Plan

The proper equipment needs to be specified to ensure that the valves will provide the correct flow rates and be controlled using an Eaton® HFX-12m hydraulic controller. Equipment will be specified and then will be included into an equipment schematic, which can be seen in Figure 3.

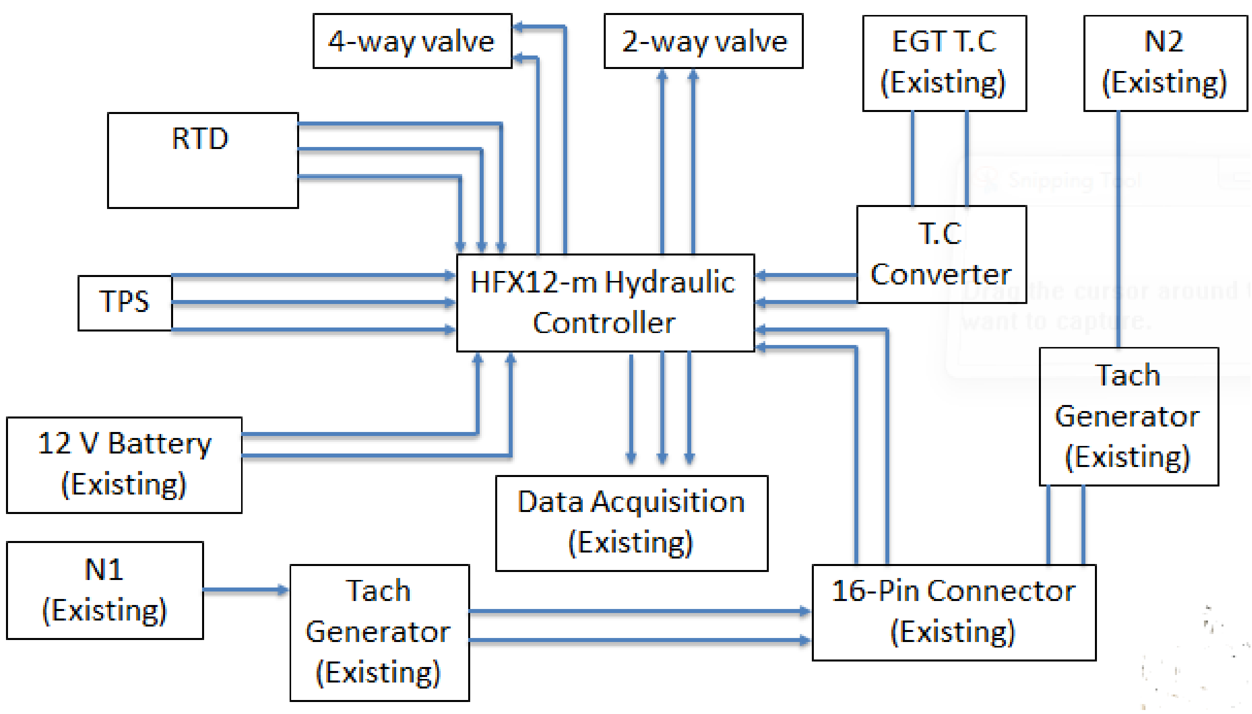

Figure 3. Equipment Schematic

The next step will be setting up a block diagram for the hydraulic controller that shows how the equipment is going to be wired, this can be seen in Figure 4.

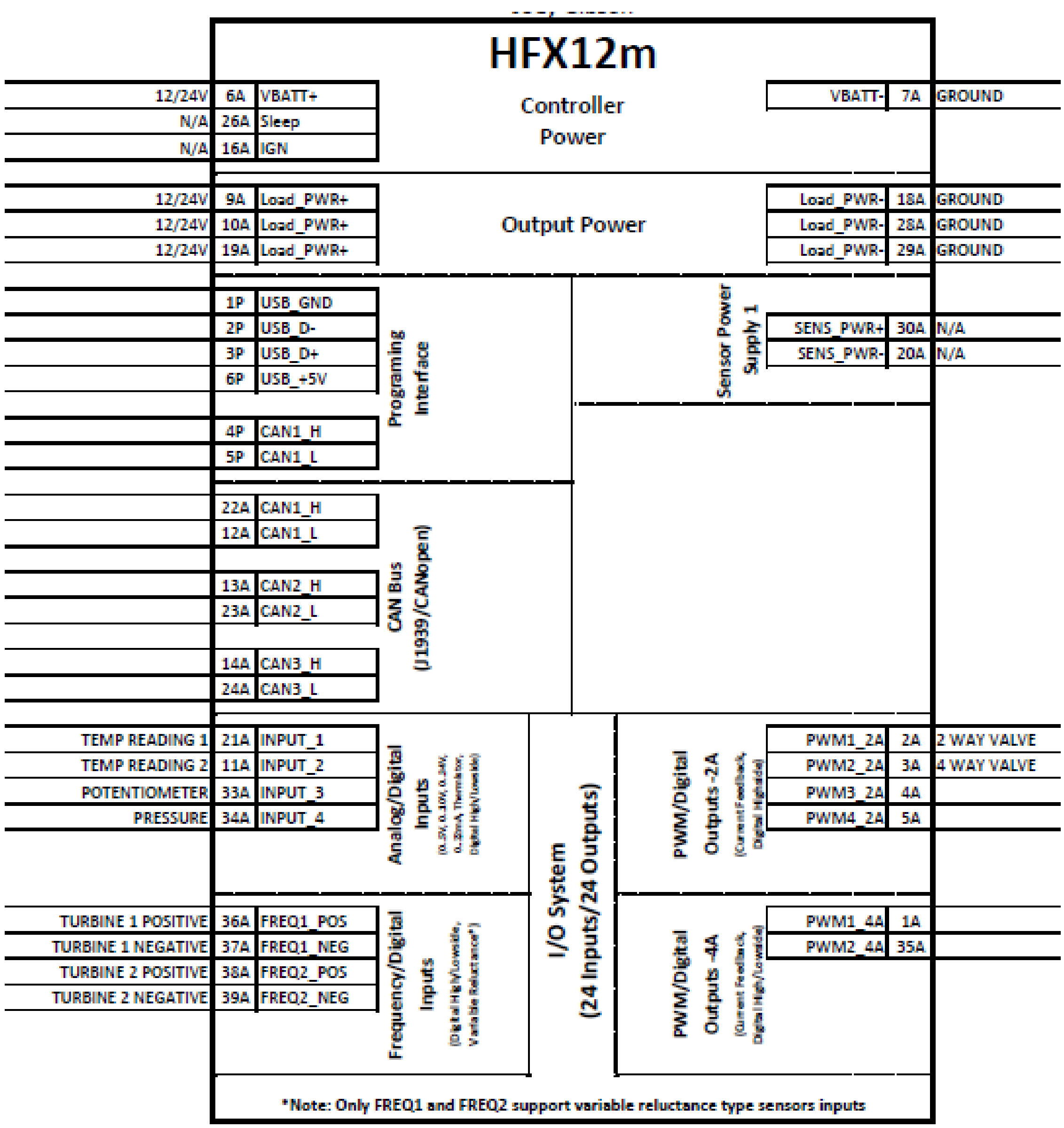

Figure 4. Block Diagram

The next step will be implementing the above figures into a milestone schedule, which can be seen in Table 2.

Milestones	Start date	Completion date
Connect controller to computer	11/11/2014	11/21/2014
order valves, converter, etc.	11/11/2014	11/21/2014
SolidWorks model of manifold (1st iteration)	11/11/2014	11/21/2014
Have Pro-FX software running	11/11/2014	12/5/2014
Control LED's with controller	12/6/2014	12/19/2014
Control valves	12/6/2014	1/30/2015
Have bench test running (Future work?)	12/1/2014	1/30/2015
SolidWorks model of manifold (2nd iteration)	1/15/2015	2/19/2015
Control system tested (correct outputs with varying inputs)	1/15/2015	3/30/2015
Manifold manufactured	2/25/2015	3/27/2015
Testing on turbine	3/30/2015	5/1/2015

Table 2. Milestones

Concept Exploration

A four way valve schematic was necessary to help visualize the design for the fuel supply to the stator vane actuator; this can be seen in Figure 5.

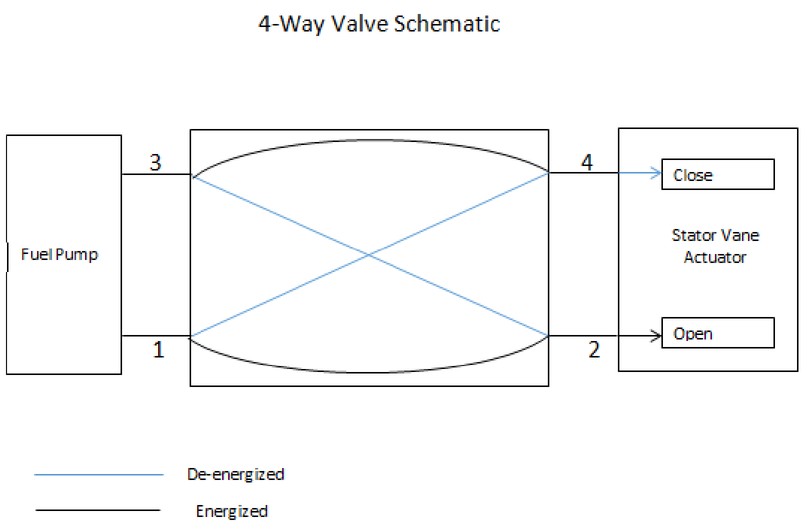

Figure 5. 4-way valve schematic

The next step was creating a manifold which will direct fuel flow, accommodate valves, have mounting brackets for the fuel pump and tach generator and mount the controller along with other hardware. The first iteration of the manifold can be seen in Figures 6-7.

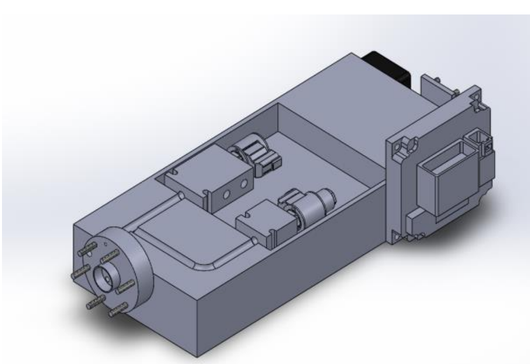

Figure 6. Manifold first iteration

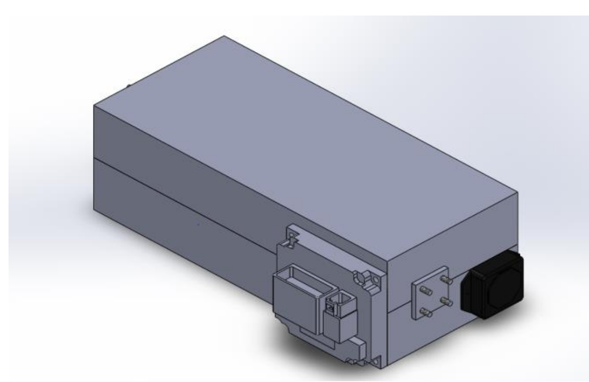

Figure 7. Manifold first iteration

The client gave some input on the first iteration of the manifold about going smaller and adding some shape to the design. The focus on the next iteration was reducing weight and wise use of available space. The second iteration can be seen in Figures 8-9.

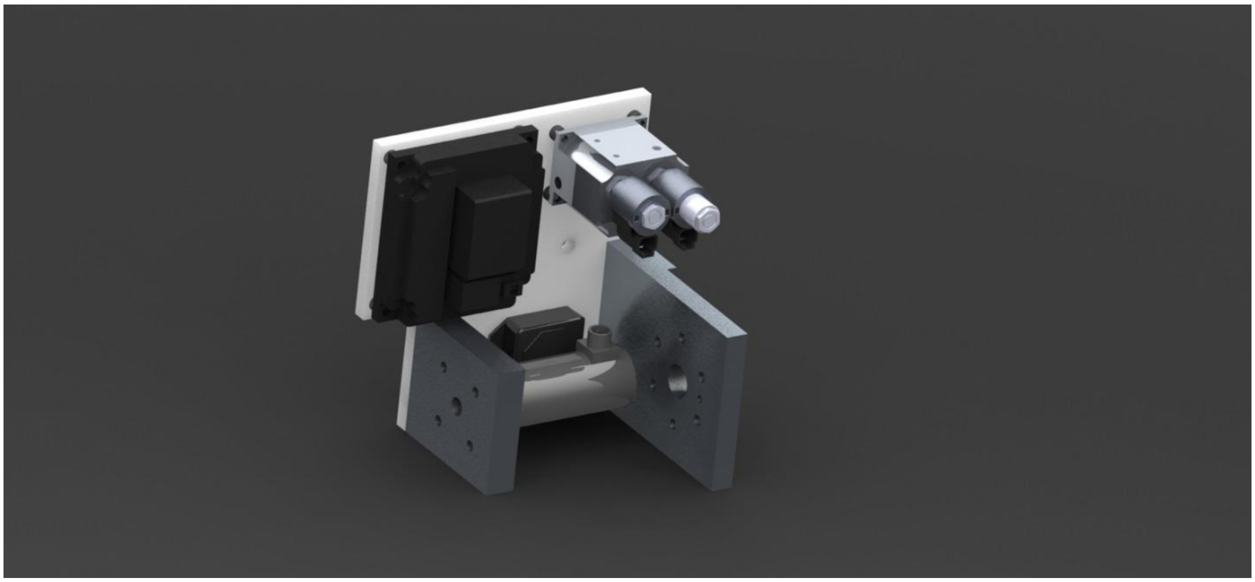

Figure 8. Manifold second iteration

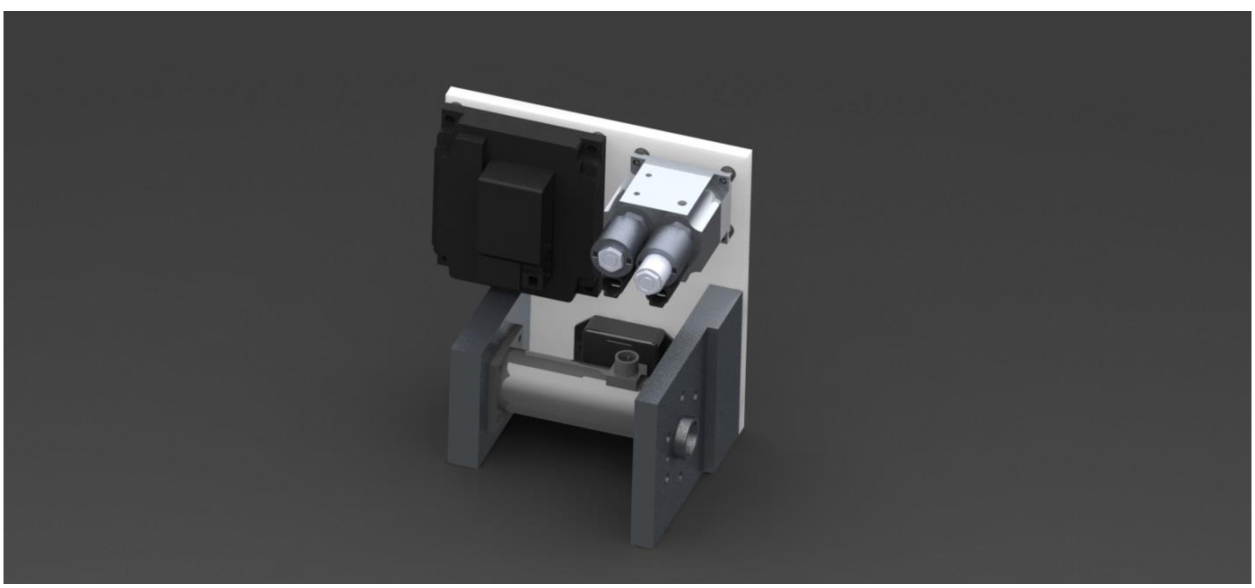

Figure 9. Manifold second iteration

System Design

A valve schematic with fuel flow direction is mandatory to design a manifold that will direct fuel flow to the correct location. The valve schematic can be seen in Figure 10.

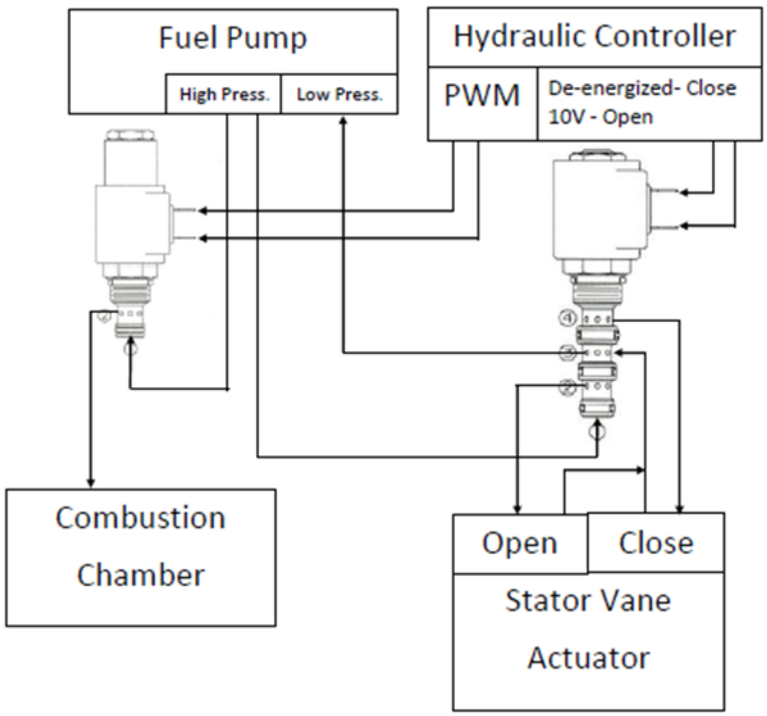

Figure 10. Valve schematic

The next step was designing the right manifold that would accommodate these valves along with their passageways. The final manifold can be seen in Figures 11-14.

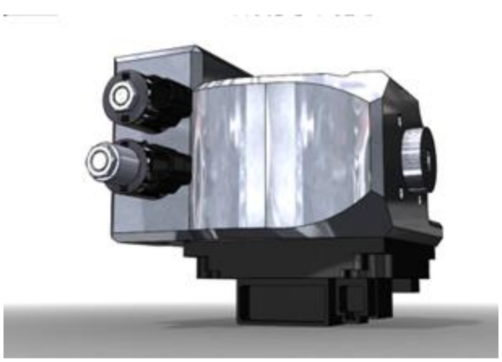

Figure 11. Final manifold

Figure 12. Final manifold

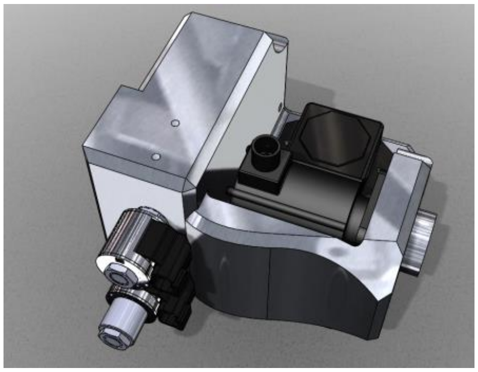

Figure 13. Final manifold

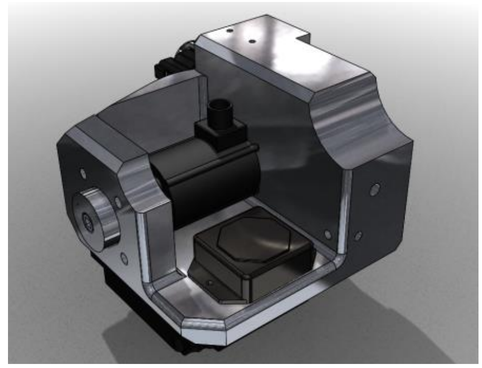

Figure 14. Final manifold

The final manifold was machined using a solid block of aluminum and has complex internal passageways for fuel.

Implementation and Testing

A fueling equation needed to be created and programmed into the hydraulic controller. To start, a thermodynamic analysis needed to be done on the turbine. A gasifier turbine cycle, Figure 15., was used to analyze the turbine.

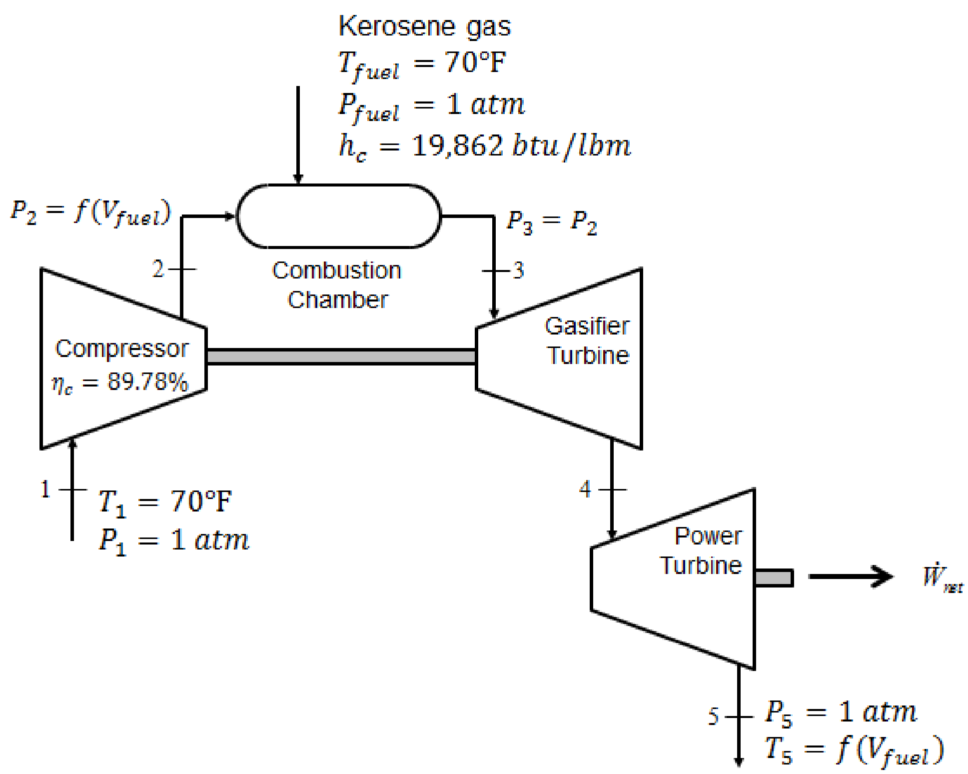

Figure 15. Gasifier turbine cycle

The analysis was done using inputs from a provided dynamometer run. The results are listed in blue in Table 3.

1..11	RPM [Rev/min]	P_2 [psia]	T_5 [F]	n_1	$\dot{V}_f$ [gal/hr]	$dutycycle_{\%}$ [%]	TPS
Run 1	4000	79.4	1090	91.59	46.78	25.99	85.03
Run 2	4100	81.42	1104	92.3	50.72	28.18	85.21
Run 3	4200	83.62	1117	92.96	54.39	30.22	85.39
Run 4	4300	85.47	1120	93.32	56.4	31.33	85.48
Run 5	4400	85.4	1114	93.21	55.79	30.99	85.45
Run 6	4500	85.47	1118	93.24	55.95	31.08	85.46
Run 7	4600	84.89	1112	92.98	54.51	30.28	85.39
Run 8	4700	84.68	1115	93.05	54.9	30.5	85.41
Run 9	4800	84.93	1120	93.1	55.17	30.65	85.42
Run 10	4900	85.47	1126	93.33	56.45	31.36	85.48
Run 11	5000	85.89	1117	93.25	56.01	31.12	85.46

Table 3. Gasifier turbine cycle analysis results

Equipment Cost Summary

An equipment cost summary is provided below in Table 4. This includes both the components purchased and the components needed to complete the design.

Component	Purchased/Recommended	Cost
Aluminum block	Provided	
Hydraulic controller	Provided	
2 way valve	Purchased	$76.65
4 way valve	Purchased	$43.21
Connectors	Purchased	$2.00
Thermocouple Amplifier	Purchased	$78.25
Hardware (plugs, studs, etc.)	Purchased	$58.55
RTD	Recommended	$100
TPS	Recommended	$199.95
Square hole sleeve	Recommended	$17.79
	Total	**$576.40**

Table 4. Equipment Cost Summary

Recommendations

After a long 9 months of working thoroughly on this project we have strongly noted where the weak spots exist in this project. For future work we would like to see two mechanical engineering students, who have taken applied thermodynamics, working in collaboration with two computer science students. This would be strongly beneficial for software coding and debugging. We would also like to see moist intake air be taken into account during the thermodynamic analysis. This will help get more accurate results while being realistic. Local moisture in the air will significantly change the fueling equation, which will add another component (relative humidity sensor) to the design. Another year in this project would allow a strong code to be developed along with a more thorough analysis for the fueling equation and to be tested on the turbine. A bench test setup is strongly recommended as well, which could be used to vary hypothetical inputs and record outputs. For production, screens being placed in the valve cavities would be a recommendation to help valves last longer. After installing the first iteration of the manifold, we have recommendations for manufacturing as well. We recommend shaving 1/16” off of the N_2 boss as well as cutting off any extra corners to save weight.