Jet Turbine Engine Project

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Introduction/Summary

Our final project as prospective graduates of Mechanical Engineering Technologies is to design and build a functioning jet turbine engine using an automotive turbocharger. The project will be comprised not only of a physical model but an in depth analysis of the prospective figures of power, thrust and fuel consumption. We will also record and analyze live data collected during the process of running the engine to compare those results with those calculated. We hope to create a successful working model along with learning from and experiencing all that is associated with undertaking a serious and educational project. By applying our knowledge from courses we have taken at Wentworth and technical ability we hope that we will able to build a working jet engine and collect data utilizing various instrumentation devices.

Need/Abstract

Currently there is no need for our turbine project, however if successful, it could be used to provide electrical power and heat efficiently to individuals who can afford it, though turbine generators have not yet been established on a small scale in which people could purchase them for their homes. Large power plants utilize turbines because of their efficiency and power output with low cost operation. We could use the same techniques in which exhaust heat and shaft rotation could provide meaningful sources of power. By illustrating our ability to make a functioning jet engine and devise a system of portability we may then be inspired by ideas for direct application. Because of its size and low cost of operation any energy harnessed from it could be beneficial and economical in many variations.
Objective

The objective of our jet engine project is to successfully design a functional turbine from a turbocharger that was removed from a diesel truck. We will apply what we have learned from our Wentworth education to design a functioning unit and measure a wide variety of critical values such as RPM, exhaust temperature, inlet temperature, thrust, and fuel delivery. We will need to establish a fuel delivery system, oil control and delivery system, combustion chamber, frame, and data acquisition methods and hardware. Our objective has been well thought out and planned which will allow our project to flow smoothly and successfully. Success of our project will determine our ability to demonstrate engineering techniques as well as effectiveness and functionality of our machine as well as our data collection methods.

Budget

The original projected budget was estimated to be in the $300-400 range, this was quickly realized to be a great underestimate. After inquiring about the necessary raw materials that needed to be purchased we realized that in metal alone it was going to cost roughly $300. Fortunately after some brainstorming one group member was able to acquire all of the metal from his current employer, $300 worth of stainless steel was acquired for free, along with other pieces of equipments such as thermocouples and temperature controllers. Also all of the oil burning furnace parts that we decided to use for the project was also generously donated by various oil companies. The turbocharger, the heart and soul of the project, was also acquired at no cost from a fellow class mate, Rick Piermarini. With the majority of the key components acquired for no cost the budget was seriously reduced. The only equipment that was purchased was various miscellaneous parts that were needed to complete the build.
lists the purchased components and the total budget spent on the project, it is obvious that very little money was spent and we are extremely grateful and fortunate as a group to have received so much outside help.

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Quantity</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbocharger</td>
<td>Rick's Truck Center</td>
<td>1</td>
<td>Free</td>
</tr>
<tr>
<td>Fuel Pump</td>
<td>Jim Ravesi</td>
<td>1</td>
<td>Free</td>
</tr>
<tr>
<td>Oil Pump</td>
<td>Jim Ravesi</td>
<td>1</td>
<td>Free</td>
</tr>
<tr>
<td>Fuel Nozzle</td>
<td>AES - BMA</td>
<td>1</td>
<td>Free</td>
</tr>
<tr>
<td>EGT Digital Readout</td>
<td>AES - BMA</td>
<td>1</td>
<td>Free</td>
</tr>
<tr>
<td>Stainless Steel: Tubing and Flanges</td>
<td>AES - BMA</td>
<td>2-3ft</td>
<td>Free</td>
</tr>
<tr>
<td>3/8&quot; Ball Valve</td>
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<td>7.58</td>
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<tr>
<td>Fittings and Rubber Tubing</td>
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<td>Omron Sensor</td>
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<tr>
<td>T25 Exhaust Inlet Flange</td>
<td>Ebay</td>
<td>1</td>
<td>11.25</td>
</tr>
</tbody>
</table>

**Total** $82.50

**Table 1**

**Methods**

Our methods for completing the project in a productive, professional, and effective manner will enable us to produce a unique piece of equipment and successful senior design
project. First we will collaborate with our group members to determine possible projects and alternatives. Once we have chosen a suitable concept we will proceed to obtain approval from our professor. Once this is completed we will continue by going through the engineering design phases which includes stating the problem, generating ideas, selecting a solution, obtaining calculations, performing the engineering, building the item, evaluating our design, and presenting our results. Once we have successfully chosen our solution, it will be important to perform calculations and modeling our design before any constructing can be done. Once this is completed we will also begin collecting materials needed to build all the components of the project. After calculations are checked and modeling has been done to check for any layout issues we can begin machining and assembling components for our design. Once our design is complete we will evaluate and test our design by physically running it and demonstrating its functionality and the data acquisition methods utilized in the design. Refer to Schedule outline table for a rough estimate of the time schedule and the proposed completion process

Qualifications

Our individual skills were an integral part of completing this project successfully. From educational knowledge to hands on experience, our group has many talents that allowed us to converge, create and succeed in finishing this project as a whole. Each member has obviously been active in completing both the many required courses of the mechanical major along with electives which serve as specialized knowledge. Also, there was a high level of hands on fabrication and designing of personal projects completed for the sole purpose of fulfilling one’s hobby interests. These skills included sheet metal fabrication, welding, machining and a deep passion and understanding of the many facets of the automotive field. Each member
contributed to the group in an equal effort which made our project and coordination with group member’s efficient and productive manner.

**Sample Calculations**

Due to the non-conventional nature of our project there are not many hand calculations that can be made. This is mainly due to the fact that all equations and mathematics involving automotive turbochargers are aimed at an application involving coupling the turbocharger to an engine and since our turbocharger was not to be used in such a fashion, much of those equations are useless. Similarly all equations involving jet engines and the Brayton cycle cannot accurately be applied to the project as the turbocharger to jet engine conversion does not mimic a true jet turbine engine in construction, but merely in practice and essential function. The calculations made were to be for analysis purposes and were related to how the engine ran and performed. Some of the intended parameters to be measured and compared were fuel consumption at various pressures and shaft speeds, exhaust gas temperature (EGT) at various combustion pressures, thrust at various combustion pressures, and combustion pressure with respect to shaft speed. One number that had been calculated was the theoretical thrust force that the turbocharger was capable of, which was approximately 23.2 lbs. This value was acquired using a program called “JetSpecs” which is a program that was designed specifically for this exact application of converting a turbocharger into a mock jet turbine engine. The only other calculations made were simply done to determine proper flame tube and combustion chamber dimensions. The flame tube diameter is simply 3 times the diameter of the compressor inducer and the length of the flame tube is 6 times the diameter of the same inducer (see fig. 3). The combustion chamber is merely one to one and half inches larger in
diameter than the flame tube. With the turbocharger disassembled we measured the inducer on the compressor wheel at 1.8335” (46.5mm) therefore our flame tube diameter and length are ~5.5” and ~11” respectively.

**Theoretical Values/Expectations**

Through the use of the JetSpec program mentioned earlier some theoretical values were determined. The JetSpec program was validated due to the fact that it estimated for the Garrett TB28 a maximum rpm of 140,000 and a max flow rate of 0.558 lbs/s which is equal to 33.48 lbs/min. These values are very close to the values published by Garrett. JetSpec also estimated the total thrust output to be 23.2 lbs along with a maximum EGT of 1195F. Unfortunately due to the premature failure of the turbocharger during one of the initial runs none of these values were able to be obtained except for various EGT values that were in excess of 1400F, which could have lead to the premature failure of the turbocharger.

**How It Works**

Our senior project involved taking an automotive turbocharger and creating a mock turbine jet engine with the turbo at the center of the design/build. There are two main components to our project each containing several sub-components, the two main components are the aforementioned turbocharger and the combustion chamber. The turbocharger is a shaft driven mechanism that runs off of exhaust gases which exit the typical engine after the combustion process. The turbocharger is attached to the exhaust manifold and as the hot exhaust gases travel out of the engine block into the exhaust manifold they spin the exhaust turbine wheel inside of the turbine housing. This turbine wheel is attached to a shaft; on the opposite end of the shaft is another wheel that compresses air. This
compressed air is directed into the engine; this increased air capacity is matched with increased fuel and enters the cylinder. An engine is simply a glorified air pump, the more air that it can consume the more power it can produce. This, as previously explained is the objective of a turbocharger: increase mass air flow to create more power efficiently from what would be unused escaping exhaust gases. Figure 1 graphically represents the above described process. Part 1 is the compressor inlet part of the turbocharger; it is also often referred to as the cold side. Part 7 is the turbine housing, or hot side. Parts 2 through 6 outline the entire cycle, 2 represents the compressed air as it travels within the intake system passing through an intercooler (heat exchanger) at part 3. Part 4 shows the compressed and cooled air traveling into the cylinder and 5 is the exhaust gases exiting the cylinder and traveling through the exhaust manifold. Lastly, part 6 is where these gases are collected and often merged right as they enter the turbine housing spinning the shaft where the process continues and repeats. A turbocharger is similar to a jet engine in that it uses a series of compressor and turbine wheels to produce power in the variation of thrust. In a jet engine hot escaping combustion gases drive and spine turbine wheels which drive compressor wheels collecting increasing flow rates of air. Although a jet engine is far more
complicated than a simple automotive turbocharger, the general principals of how each work internally are similar. Since a turbocharger does not house a combustion chamber within its own housing, as a jet turbine engine does, and there is no motor affixed to it a combustion chamber must be made to complete the cycle, this focused our attention to the second component of the build, the combustion chamber.

**Combustion Chamber**

The designed combustion chamber will essentially house a continuous combustion of diesel fuel, direct its gases to the turbine side of the turbo charger and thus in turn compress the atmospheric air and accept this compressed air into the chamber to continue the cycle. The combustion chamber consists of two main parts while having provisions for both fuel and spark (ignition). There is the outer shell of the combustion chamber which is completely sealed and within that there is a flame tube. Fig. 2 is a SolidWorks illustration of the complete setup. The **RED** casing is the combustion chamber’s outer shell; the **BLUE** tube with the holes drilled is the flame tube. The fuel and ignition system are located at the front (left of the image) of the flame tube. The flame tube’s purpose is to house the combustion process and maintain it. The holes serve the purpose to only allow a precise amount of air to enter the combustion process; too much air and the flame would blow out and too little air and the flame would struggle to ignite. The small **GREEN** pipe connected to a flange is the turbo inlet flange; this simply makes the necessary adaptation to connect to the turbine housing of the turbo. In this specific instance the flange is a T25 flange, which simply denotes a specific size and bolt pattern as there are many different flange types associated with different turbochargers. The **YELLOW** pipe is the intake tube; this takes the compressed air from the turbocharger and directs it into the
combustion chamber. The **PURPLE** portion of the graphic is the turbocharger itself, it can be seen how the turbo is connected as a part of the assembly and how the exhaust and intake sides relate to the chamber.

**Specifications/Parts**

The parts of the combustion chamber were designed in a specific manner in order to appropriately match the size and capabilities of the turbo.

**Flame Tube**

The first component of the combustion chamber is the flame tube, again the blue tube/casing in the previous graphic. The flame was designed with hole sizes in a specific pattern along with the overall dimensions. In order to understand and determine these
dimensions it is necessary to look at a very specific part of the turbocharger, that being the inducer of the compressor wheel (Fig. 3).

![Diagram of turbocharger components](image)

**Fig. 3**

The flame tube dimensions are approximately as followed, the length is six times the diameter of the compressor wheel inducer and the diameter of the flame tube is two and a half times larger than the diameter of the inducer. The inducer diameter of the project specific turbocharger was measured to be 1.829in. The corresponding dimensions of the flame tube were designed to be a length of 11.5in and a diameter of 5in constructed of 1/8in walled 304L stainless steel tubing, this tubing was chosen due to the ability of thick walled tubing’s ability to maintain and withstand high heat. This ability to hold heat within the walls would help maintain heat during the combustion chamber and aid in a more complete burn of the fuel. Exact dimensions for the flame tube were not used, i.e. $2.5 \times 1.829\text{in} = 4.5725\text{in}$ for flame tube diameter, due to the use of typical/nominal tube dimensions. Since the overall dimensions of the flame tube have been determined the next step is to determine the number, sizing and pattern of the holes. As previously stated the holes allow for a controlled burn of the
combustion process and also help direct the combustion process into the hot side of the turbocharger. The holes are categorized by primary, secondary and tertiary holes each having a different set of diameters. To determine the hole size, the use of a program entitled JetSpec was used. This program determines the total area of each set of holes and this again is based off of the inducer diameter but is not a simple as multiplying by a specific factor. The program determined that for our specific turbocharger the total area of the primary holes ought to be 0.788204 in², for the secondary holes the area is 0.525469 in², and lastly the tertiary surface area is 1.31367 in². Specific drill sizes were chosen to aim at resulting in an even number of holes in order to obtain somewhat of a symmetrical hole pattern. Again, exact surface areas were not achieved but very close values were obtained. For the primary holes a number 7 drill was chosen (0.201” diameter) this resulted in a total of 24 primary holes which were drilled and arranged in three rows rotated 45° between rows, one inch apart, of eight for a total surface area of 0.76154 in² (96% of required area). The secondary hole size was chosen to number 4 drill (0.209” diameter). This resulted in a total of 15 holes which were drilled and arranged, again in three rows rotated 72° per row, one inch apart, of five holes for a total surface area of 0.51460 in² (98% of required area). The tertiary holes were drilled using a 9/32” drill (0.28125” diameter), this resulted in a total of 21 holes drilled in three rows in a pattern of six, seven and eight holes in succeeding rows. This was done to provide increasing amounts of air towards the end of the chamber to help burn the fuel mixture as it enters the turbocharger exhaust inlet. This configuration resulted in a total of 1.30465 in² (99% of required area).
**Combustion Shell**

The combustion chamber shell was rather easy and simple to design as it relied mainly on the geometry of the flame tube. The chamber only needs to be roughly one to one and a half inches larger in diameter than the flame tube and only slightly longer to allow thermal expansion of the flame tube along its length. Therefore the combustion chamber for this project was six inches in diameter and 12 inches long, with provision for the intake and exhaust tubes. The combustion shell was constructed of 16 gauge (0.060” thickness) sheet metal which was rolled and TIG welded together.

**Ignition System**

The ignition system was constructed using various components from different specific uses. To deliver the spark a spark plug from a typical forced air heater was used and positioned in the flame tube approximately 1.5 inches from the fuel injector. The spark plug was powered by typical oil burning furnace transformer which inverts 120V to 20,000V. This voltage was sufficient to not only power the spark plug but to create a spark gap in excess of one inch.

**Fuel Delivery System**

The fuel system was essentially a complete system borrowed again from a typical oil burning furnace. It consists of a small DC motor that runs off of 120V connected to a fuel pump via small rubber shaft. The motor spins the pump at 3450rpm creating roughly 100-150psi of fuel pressure; this pressure is fed in a copper fuel line and through an oil burner fuel nozzle. The specific fuel nozzle used was rated at 0.80 gph (Gallons per Hour). This pressure is essential in forcing fuel through the small 0.008” orifice in the nozzle in order to atomize it so that it can easily be ignited. With regards to fuel the project used mainly typical diesel fuel along with
some general testing with gasoline. Both fuels were easily ignited due to proper atomization and ignition.

**Turbocharger**

The central component of the entire project was the specific turbocharger used during the experiment and build. The turbocharger was removed from a Nissan UD120 Box truck and is manufactured by Honeywell/Garrett Turbo. The turbo is more specifically a TB28 turbo with a cold side air ratio (A/R) of 0.60 and a hot side A/R of 0.86. These air ratios are not important to our project, rather they serve to demonstrate the size of the turbo which is more commonly used when trying to match a proper turbo to a specific automobile engine. To better understand the turbo and its capabilities, referencing the compressor map (fig. 4) is the best way to determine a turbocharger’s size and more importantly its flow characteristics. Figure 4 displays the compressor map for the Garrett TB28, as this information was taken directly from the Honeywell/Garrett official site. The Y axis represents the pressure ratio which is simply derived from the following equation.

\[
PR = \frac{\text{Atmospheric Pressure} + \text{Compressor Pressure}}{\text{Atmospheric Pressure}}
\]
The x axis represents the corresponding mass flow rate of air which the compressor is capable of producing at the corresponding pressure ratio. The plotted data points on the graph that resemble a topographical map are called the efficiency islands with the inner most island being the most efficient area for the turbo to operate i.e. at X flow rate and Y pressure. The somewhat horizontal lines that sweep across the efficiency islands are the rpms at which the turbo can operate. Again, these values do not necessarily pertain to the project at hand but they outline that the turbocharger can essentially flow up to approximately 35 lbs of air per minute and can obtain a rotational shaft speed of 144,000 rpms, also where the turbo is most efficient. These values are important when monitoring the turbocharger during operation so that excess speeds are not reached and the turbocharger can be regulated within specific efficiency regions and gather data based on these parameters.

**Instrumentation**

In order to successfully complete any experiment whether elaborate or simple, it is necessary to use and determine specific instruments that will aid in proper execution as well as facilitated data collection. The first bit of equipment used is the Omron E3X-A21 photoelectric sensor. The Omron is simply a sort of photo interrupter that returns a signal/frequency count; it is used in this project to return the shaft speed of the turbocharger in Hz which is converted to rpm by simply multiplying Hz by 60. The specific way the sensor functions is by shooting an infrared signal at the nut that secures the compressor wheel to the turbine shaft. The nut is painted half black and half white, the white half reflects the signal back to the sensor, and the black half does not, thus interrupting the signal. This interruption represents one revolution of the shaft. The signal output is connected to a multimeter capable of reading frequency and this
is how shaft speed is determined. The Omron was chosen due to its capacity to record up to 5,000 cycles per second (Hz) which could specifically measure up to 300,000 rpms which is over double what is needed for the specific project.

The next two instruments work together in measuring temperature, specifically exhaust gas temperature. For temperature sensing a type J thermocouple, which has a range of -40F - 1500F, was used along with a Love Series 40t Digital Thermocouple/RTD Temperature Switch which automatically converted the voltage difference across the thermocouple into a digital temperature in degrees Fahrenheit. The refresh rate on the thermocouple and controller were rather fast and at times ramped a few hundred degrees in just a couple of seconds.

An analog pressure gauge was inserted into the compressor housing to measure the pressure created by the compressor wheel which enters the combustion chamber. With these values observed they could be referenced to the previously mentioned compressor map to determine efficiency of the turbo along with a general knowledge of where the turbocharger is operating within its parameters. The pressure gauge was simply a standard tire pressure gauge that measures from 0 to 60 psi.

The last set of instrumentation relates to fuel and the fuel delivery. A standard plumbing 3/8” ball valve was placed in the fuel line to control the amount of fuel entering the combustion chamber. After the ball valve a liquid filled fuel pressure gauge was used to determine the fuel pressure entering the combustion chamber. The fuel pump used supplied 100psi of fuel pressure and that is to be considered fuel throttle, the ball valve controls the fuel and the gauge measures the resultant fuel pressure. The fuel gauge was rated from 0-100 psi since the upper limit of our fuel deliver cannot exceed 100 psi.
Data

No data was able to be collected due to the premature failure of our turbocharger jet turbine engine. As the turbocharger we sourced failed during the very early stages of completion and running of the engine.

Evaluation/Results

Our project would be evaluated based on how our knowledge from courses taken at Wentworth and how it was applied to our senior design project. Our original evaluation was to be based off the functionality of our design and whether it could possibly be implemented in present day applications. Due to premature detonation of our machine this goal is no longer completely attainable. We have shifted our evaluation from data collection to what we may have done differently or what could be done to make our project more successful and how to increase the efficiency of our turbine if we were given more time to rebuild.

Discussion of Results

Originally our projects goals included formulating an engineering plan, designing our turbine, testing our turbine, and collecting experimental data. Because of our turbine failure we can no longer collect the valuable data that we were expecting to obtain. As a substitute we have concluded several possible explanations for our turbine malfunction as well as preventative methods for future design practices. Causes for failure include excessive heat expanding the hot side turbine blades so that they interfered with the housing walls, exceeding the limits of the turbine, and not having an emergency shutdown plan in case of encountered problems.
**Project Optimization**

There are several possible causes for failure which include excessive heat expanding the hot side turbine blades so that they interfered with the housing walls, exceeding the limits of the turbine, and not having an emergency shutdown plan in case of an emergency. First it is possible that rate of heat increase resulted in the metal turbine blades expanding and coming in contact with the housing wall. A solution to this problem would have been installing a valve with better regulation to have more control of the fuel delivery to better control engine RPM and rate of startup. Another possible cause for failure could have been running the turbine at such a high rate of speed that the inconel blades could no longer hold together and therefore shattered. If this project was done over and we had time for further research it is likely that you could find out at which RPM the metal is likely to fail based on the force and mass of the blades. Then, using instrumentation you could limit the maximum RPM in such a way that this would not happen again. Lastly, under further analysis of video documentation it is likely that excessive RPM was induced when overuse of our starting mechanism was applied. Unfortunately, when an attempt of fuel cutoff failed due to siphoning of our fuel pump we had no way to slow our turbine down. If we were to further design our engine we would need to design a way to stop or slow operation in a situation of emergency. In conclusion optimization of our project would include more research, full instrumentation during all testing phases, and an emergency system to stop or slow our turbine in case of a mishap.

**Future Direction**

Upon successful completion of our project we may attempt to integrate it to an electrical generation unit. Do to the fuel efficiency, power, and high speed of turbine engines
this could easily be a useful and practical source of power generation on small scale. Turbine engines have long durability, relatively low maintenance, and fuel efficient qualities which make them desirable and practical for larger scale power plants as well. The future direction of our project may also result in the propulsion of recreational vehicles such as go karts. Although rather impractical, this would be a unique way to power a highly advanced vehicle. In some current circumstances especially in racing applications such as drag boats turbine engines produce a large amount of power for their weight.

For our specific project the immediate direction will include a rebuild of the damaged turbo and a continued effort to get the engine running properly and more efficient. This will remain a hobby based project for the members of the group as much was learned during the course of the project and we thoroughly enjoyed the project to the point where we want to see it continue for our own personal gratification.

**Conclusion**

Although our project encountered an element of failure, we do not view any aspect of our project as a failure. Part of designing and building something new is the attempts that are not 100% successful and learning the lessons that they present. We have learned so much both individually and as a group during the entire course and process of our project that we view everything as a positive. We further understand the risks involved in building something related to fuel and energy and the future precautions that need to be taken into consideration. We are extremely satisfied with the project we undertook and all of its challenges that we encountered along with our path and accomplishments as a group. Ideally we would have hoped to have completed the project to its full potential but its failure did not deprive us of any
knowledge or insight, but rather gave us a greater knowledge an understanding of what a serious project involves. Lastly we would like to thank our professors and institute for allowing us the opportunity to undertake such a project that is unique to our group and allowing us the freedom to direct our senior project as we wished.
# Schedule Outline

<table>
<thead>
<tr>
<th>Week #</th>
<th>Job ID</th>
<th>Detailed Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Project</td>
<td>Come up with options for possible projects. Choose one to present during meeting number one.</td>
</tr>
<tr>
<td>2</td>
<td>Approval</td>
<td>Present best option for project and obtain approval for design concept and begin background research.</td>
</tr>
<tr>
<td>3</td>
<td>Work Plan</td>
<td>Determine work plan and attainable / reasonable work schedule. Plan costs of materials and equipment.</td>
</tr>
<tr>
<td>4</td>
<td>Materials</td>
<td>Begin gathering materials that are required to complete the project such as steel tubing, electric motors, and fuel injection components.</td>
</tr>
<tr>
<td>5</td>
<td>Modeling / Details</td>
<td>Complete gathering materials like steel and electrical components. Commence assembly of the machine.</td>
</tr>
<tr>
<td>6</td>
<td>Assembly</td>
<td>Assembly of engine and revise the design as necessary. Follow assembly prints. Solid modeling.</td>
</tr>
<tr>
<td>7</td>
<td>Assembly</td>
<td>Continue with assembly of engine and determine data acquisition methods. Continue Solidworks modeling.</td>
</tr>
<tr>
<td>8</td>
<td>Assembly</td>
<td>Continue and finalize assembly of engine as well as test functionality of DAQ systems. Complete Solidworks modeling.</td>
</tr>
<tr>
<td>9</td>
<td>Testing / Debugging</td>
<td>Test the machine and modify as necessary within reason. Stick as close to the design as possible. Debug in order to function correctly.</td>
</tr>
<tr>
<td>10</td>
<td>Revising</td>
<td>Make final ramifications to the turbine system. Resume testing and further documentation.</td>
</tr>
<tr>
<td>11</td>
<td>Finalize Documentation</td>
<td>Video tape the engine. Utilize DAQ systems and perform data analysis and compare to calculations.</td>
</tr>
<tr>
<td>12</td>
<td>Presentation of Data</td>
<td>Begin assembling documentation, blueprints, and video tape into a presentation for the class.</td>
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Technical Drawings

Notes:
1. Material: 316 Stainless Steel
2. 16 ga. sheet cut to size, rolled and TIG welded seam

Turbocharger Jet Engine Project
Combustion Shell

A

1:1 Scale
Sheet 1 of 6
Notes:
1. Material: 316 Stainless Steel
2. .25" Plate CNC Laser cut
3. To be welded to end of combustion shell
Notes:
1. Material: 316 Stainless Steel
2. .25" Plate CNC Laser Cut
3. To be welded to end of combustion shell
4. Holes for 1/4-20 Bolt clearence

Turbocharger Jet Engine Project

Combustion End Flange

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SCALE: 1:2
WEIGHT: 
SHEET 3 OF 6
Notes:
1. Material: 304 Stainless Steel
2. .125" Wall
3. 9 Rows of holes all 1" inch apart
4. 3 rows of each hole diameter

Turbocharger Jet Engine Project
Flame Tube

<table>
<thead>
<tr>
<th>DRAWN</th>
<th>DATE</th>
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<td>TLC</td>
<td>4/06/19</td>
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SIZE | DWG. NO. | REV
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A   | -        | A

SCALE: 1/16
WEIGHT:  
SHEET 4 OF 6
Notes:
1. Material: 316 Stainless Steel
2. .25" Plate CNC Laser cut
3. .625" Hole clearance for spark plug
4. .500" Hole clearance for fuel nozzle
5. .260" Holes clearance for 1/4-28 bolts
6. To be welded concentrically to end of flame tube
Bibliography


