Final Report

Team 7

<u>Personal Hydroelectric Generator</u>

Members:

Joseph Bonfardino	jjb12f@my.fsu.edu
Galen Bowles	gtb12b@my.fsu.edu
Brendan McCarthy	bbm10@my.fsu.edu
Parth Patel	prp12@my.fsu.edu
Shane Radosevich	srr11c@my.fsu.edu
Ilan Sadon	ilanesadon@gmail.com
Brandon Shaw	bs10m@my.fsu.edu
Matthew Vila	mjv11c@my.fsu.edu

Faculty Advisor

Seungyong Hahn, Ph.D.

Sponsor

Michael D. Devine, Ph.D.

Instructors

Nikhil Gupta, Ph.D. & Chiang Shih, Ph.D.

04/08/2016

Table of Contents

Table of Figures

Table of Tables

ABSTRACT

For this project, sponsored by Dr. Devine and the FAMU-FSU College of Engineering, Team 7 is working on developing and marketing a Personal Hydroelectric Generator. A major human problem is inaccessible electricity in remote locations. The team decided to design a product that can easily be transported to different locations to generate electricity through the use of flowing water in streams and rivers. Team 7's designed generator is capable of producing 80-130W of power which can be stored into a battery for use at a remote campsite/house located by a water source. The 40lbs system involves a 4 blade turbine attached to a gearbox and alternator within a waterproof housing that can be fully submerged in a flowing river/stream. Team 7 experimentally tested the system's components to account for issues of waterproofing, heat dispersion, and power output. During the development, precautions were taken to ensure ethical and wildlife/user safety. Team 7 also entered into multiple entrepreneurial contests where they placed top ten amongst hundreds of other projects.

ACKNOWLEDGEMENTS

On behalf of Team 7 we would like to thank the FAMU-FSU College of Engineering for presenting us the opportunity to participate in the 2015-2016 Senior Design.

We would like to personally thank Dr. Devine and Dr. Hahn for their guidance in entrepreneurial engineering and electrical engineering concepts.

Also, much appreciation is given to Dr. Gupta and Dr. Shih for providing the team with supervision and direction on our project progress.

1 Introduction

In modern day, there is a high demand for electricity in the most remote locations. Whether the need is for outdoor enthusiasts going camping or a secluded community in a third-world country, people have a need for lights and heat. To supply this demand, the production of electricity in these types of regions is necessary. Team 7 took on this project to create a mechanism that harnesses the flow of kinetic energy of water and transforms it into usable electricity. Flowing water is not restricted to the time of the day; this provides a continuous duty cycle that generates usable electricity 24 hours a day, 7 days a week, and 365 days a year. In comparison, other renewable energy generators like PV cells only operate under specific conditions, i.e. sunny and non-shaded. The market is for individuals who are located near a flowing river or water source and are in need of electricity when not connected to a power gird. As an entrepreneurial group, this project is orientated to design and build a generator which is light weight and portable and works efficiently in moderately flowing streams and rivers; thus meeting the needs of a personal consumer.

1.1 Problem Statement

This project is an entrepreneurial-based mission sponsored by FAMU-FSU College of Engineering, specifically through Dr. Michael D. Devine. Currently, there are few effective, simple, and quiet ways to get power in remote locations. These remote locations include campsites, mountainsides, and third world countries. In order to supply energy to items such as lights, heaters, or USB chargers, a gas generator is traditionally used. These types of generators are too loud and too heavy to be effectively used in remote locations.

“People in remote locations do not have access to electricity for powering their electrical devices.”

1.2 Constraints

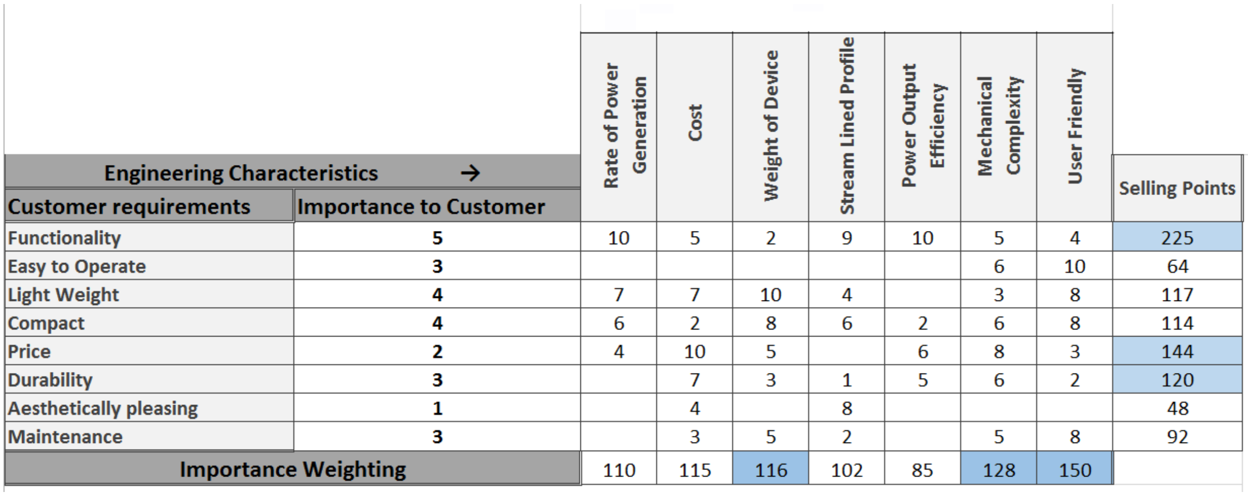
- Device weight must not exceed 70lbs
- Compact (less than 3 ft^3)
- Unidirectional flow
- Water proof to protect the electrical components within the housing

- Durable and corrosion resistant
- Complies with all safety standards and has little/no environmental and human impact

The House of Quality in section 1.2.1 and Customer Discovery Survey in section 1.2.2 allowed for Team 7 to formulate the constraints found above. The device's total weight which includes the housing, turbine, and all the other components cannot exceed 70lbs. The weight has to be manageable and portable for the average person to carry with some assistance. The unit must also be compact for easy transportation by the consumer. The mechanism will assume unidirectional flow of water as flowing rivers usually flow in one direction. High durability will take the force and corrosive properties of the water. A waterproof housing will protect submerged electrical components so the components will not be damaged during use. Safety standards of Senior Design projects must be upheld as to ensure the safety of the operator, producer, and environment.

1.2.1 Quality Function Development

Table 1 - House of Quality



Engineering Characteristics →		Rate of Power Generation	Cost	Weight of Device	Stream Lined Profile	Power Output Efficiency	Mechanical Complexity	User Friendly	Selling Points
Customer requirements	**Importance to Customer**								
Functionality	5	10	5	2	9	10	5	4	225
Easy to Operate	3						6	10	64
Light Weight	4	7	7	10	4		3	8	117
Compact	4	6	2	8	6	2	6	8	114
Price	2	4	10	5		6	8	3	144
Durability	3		7	3	1	5	6	2	120
Aesthetically pleasing	1		4		8				48
Maintenance	3		3	5	2		5	8	92
Importance Weighting		110	115	116	102	85	128	150	

The Quality Function Deployment (QFD) is a method that transforms qualitative user requirements into quantitative design parameters. This process was executed by first determining the Customer Requirements (CR). The CR's were determined by doing background research on the developing field of micro power generation, meeting with the group's financial and academic advisors, and surveying peers and possible consumers. From this point, the group determined critical aspects of design otherwise known as Engineering Characteristics (EC). After defining the relationships between the CR's and EC's it was determined that the most critical aspects of design will be functionality, price, and durability for the customer. This makes sense since customers want a device that is cheap, does its job, and will not easily break during operation. As a company the most important engineering characteristics were determined to be to create a mechanism that is less mechanically complex, user friendly, and low in weight. This is because the company will not want to confuse the consumer with complex systems and not waste excess funding on material and labor.

1.2.2 Customer Discovery Survey

Table 2 - Customer Survey

	< $350	$350 to $550	$550 to $750	>$750
If a generator could sustain all your lighting needs, run a small refrigerator, or power any TV, how much would you spend?	5	5	15	6
	Camping	**Hunting**	**Cabin**	**Fishing Trap**
Where would you mainly use this item?	13	16	4	10
	Power Output	**Price**	**Durability**	**Size**
What is the most important from the following: Power Output, Price, Durability or Size?	8	5	10	8
	Would buy	**Might buy it**	**Wouldn't buy**	**I don't know**
How likely are you to buy a hydroelectric generator if it meets your needs?	14	5	4	8

Table 1 displayed above shows the results of a customer survey given to possible consumers during a hunting trip. The survey has not been tampered with in order to reflect a desired outcome. The outcome of the survey reflects the results seen in the QFD in section 1.2.1. These questions contributed to the characteristics made for the final product in order to add to the value proposition. In other words, these answers helped the team better understand what the customer wants so that it would sell if mass produced.

1.3 Goal Statement & Objectives

Goal Statement:

“Develop a portable device that transforms organic kinetic energy into usable electricity.”

Objectives:

- Produce enough power to satisfy the need of our target consumers.
    - Produce 200W
    - Supplemental emergency power generation
    - Environmentally conscious recreational camper
    - Rurally indigenous communities
- Minimize the weight of the device to ensure portability.
- Produce a device that is safe to operate and leaves negligible ecological consequences.
- Produce a device that is conveniently set up and disassembled.

The desired wattage output is 200W due to background research of what is realistically achievable. Team 7 believes this wattage is capable of satisfying consumer needs because it has the ability to power several necessary components one might want in a remote location. This includes 5 LED lights that are equivalent to a 60W incandescent bulb and an electronic phone/GPS charger. These devices were shown to both consume 50W (totaling less than 200W). The main goal for the power output for our updated design is to effectively charge a battery hooked up to the system.

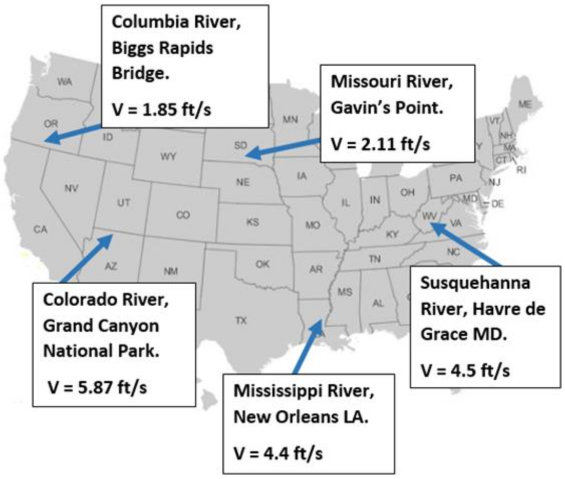


Figure 1 - Velocity of Rivers in Several Locations

Five different locations were chosen based on their geographical location, elevation, width, and depth to provide a variety of realistic flow velocity estimations for calculations to model the group's potential designs. As seen in Figure 1, the five selected rivers were analyzed at specific points based off the above characteristics to represent that area of the initial target market. From this, the velocities were averaged to one single value of 3.75 ft/s for analysis.

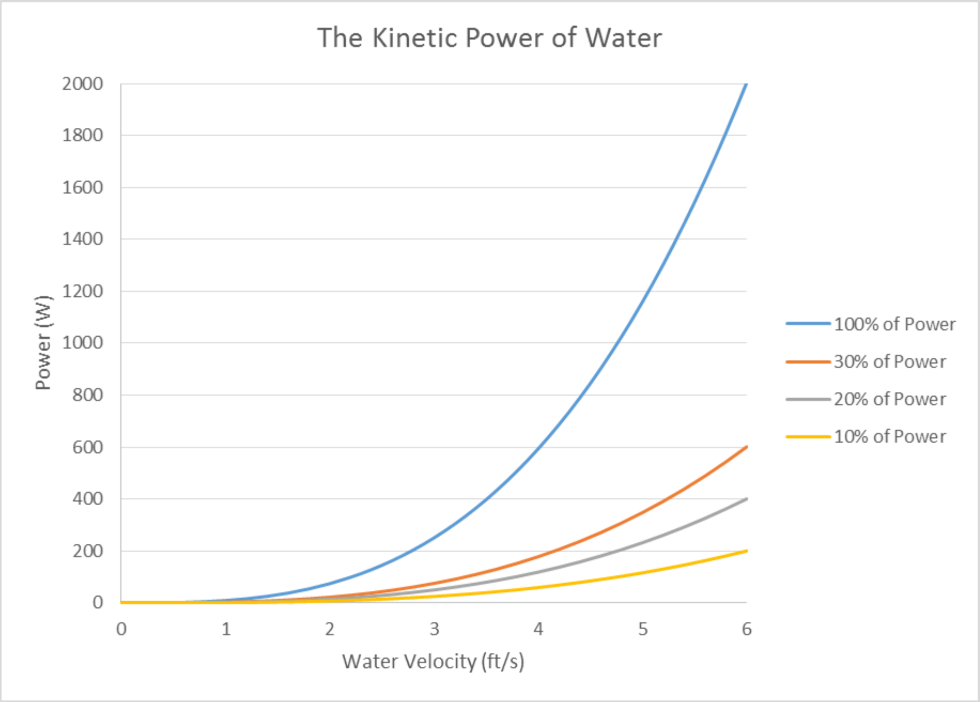


Figure 2 - Kinetic Power of Water

Figure 2 shows that the flow of water running at the average water flow speed calculated is possible of producing at least 200W even at 30% - 20% efficiency. According to Betz law, it is impossible to get over 40% of the total energy of a flowing fluid. This means that 20% is still a realistic amount of power conversion from the water to the generator.

Portability allows for a lightweight system that is easier to transport in the naturally harsh conditions of remote locations. This device is trying to appeal to environmentally conscious individuals who want to use a power source that has no carbon foot print as well as individuals far from conventional power grids. The device also needs to be easy to set up and operate in order to appeal to a non-technical consumer and cut down on assembly time.

2 Background Research

2.1 Fundamentals of Electricity Generation

Several methods for generating electricity have been around for over a century, most of which depend on the use of an electromagnetic generator. Electromagnetic generators work under the principle of electromagnetic induction developed by Michael Faraday in the early 1800's. His principle declares that as a conductor is moved through an electric field a current in produced in the conductor.[1]

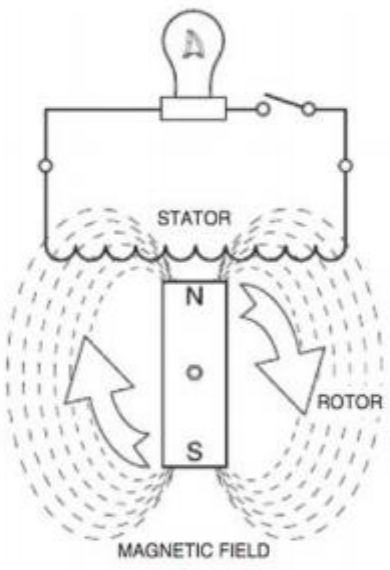


Figure 3 - Stator and Rotor Demonstrating Faraday's Law

Simple, modern day electromagnetics generators have two major components: a stator and a rotor. The stator is composed of a stationary conducting material, usually copper coiling. The rotor has one or multiple north-south permanent magnetics (depicted in Figure 1). A mechanical force is provided to rotate these magnetics, thus producing an electromotive force (EMF) in the stator. This voltage drives a current through the conducting material that can be can directly used or stored in battery.[2]

In order to drive the rotor, some form of mechanical input is necessary. This input can supplied in several ways, by a motor, flowing wind or water, a hand crank, et cetera. When faced with trying to supply this mechanical input in an isolated environment it is beneficial to select a form that is renewable, meaning that it is continuously supplied. For this project, a device shall be developed which transforms the kinetic energy of a flowing water stream into usable electricity. This is referred to as hydroelectric generation. Hydropower (controlling water to perform work) has been around for thousands of years, and in the late 1800's it was first used to generate electricity to power lights.[3] Nowadays hydroelectric power generation is quite common, but most if not all, are in fixed locations like water dams. Thus there is a semi-open market to innovative, portable hydroelectric generating systems.

2.2 Competitors

The idea of portable hydroelectric systems has been around for a while, and gathered research suggests that there are a couple of other companies and institutions which have built similar devices. One such product currently available on the market is the StreamBee (Figure 4) available by HydroBee Company. The device can use the flow of the water in a stream to create electrical power. Their idea is similar, however their device works on a smaller scale than the market we intend to influence. The power output of this device is a mere 10W. In order to power essential electrical equipment, as our device intends to do, our power output would have to be on a scale of 10-20 times that of the StreamBee. The team's device intends to produce anywhere from 100W to 200W.[4]

Figure 4 - StreamBee

In addition to the StreamBee, another competition on the market exists for a similar type of portable hydroelectric generator. One more closely related to the possible implementation of the team's design, is the Back Pack Power Plant (Figure 5). The Back Pack Power Plant designed by Bourne Energy of California, is a 30lb portable device carried on one's back. The product claims it can generate 600W. Really this device seems like it will conquer all of the obstacles that the team plans to overcome with its design except for some little things. The Back Pack Power Plant needs to be anchored on both sides of a river for proper functionality.[5]

Figure 5 - Back Pack Power Plant

3 Concept Generation

3.1 Initial Concept Generation

The task given to the Senior Design Team 7 was to create a portable device which could harness kinetic energy from a moving body of water and convert it into useable electrical energy. Given just these guidelines the team began the research to decide what kind of realistic prototype they could hope to achieve. Once the preliminary research was completed, the team then developed project constraints for the design.

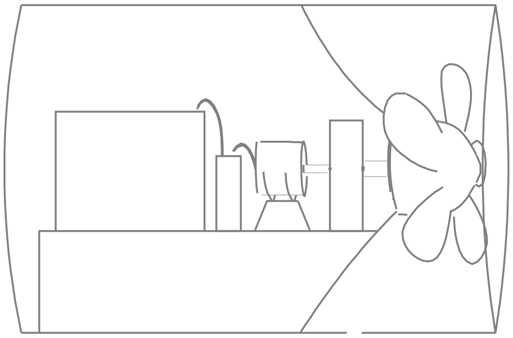


Figure 6 - Initial Concept Design

From here, the team developed a drawing of what the initial design should look like. The initial design would utilize the principles of a unidirectional fluid flow into a turbine with the remaining generation components behind the spinning turbine. The gearbox, alternator, and battery would be placed within a waterproof housing connected to the turbine shaft. The turbine transfers torque and rpm onto the input shaft. Next, a gearbox would be used to increase the speed of rotation coming from the turbine into speeds fast enough for ample electrical production from the alternator. The alternator produces power from this input rotational energy. This power can then be stored in a battery and consumed at the user's desire. After the preliminary idea was drawn up, the team moved on to researching and trying to select the optimal components for the design. These components included turbines, alternators, batteries, gearboxes, housing possibilities, and anchoring styles.

3.2 Turbines

3.2.1 Francis Turbines

Francis turbines are the most commonly used turbines in today's popular hydro systems. They are enclosed within a spiral case with a series of guide vanes to direct flow to the turbine runner (blades). The turbine blades are shaped in a cup like design. The blade efficiency is crucial within the Francis turbine. Usually flow velocity remains constant throughout, and is equal to that at the inlet to the draft tube. Francis turbines may be designed for a wide range of heads (height at which the water falls) and flows. This, along with their high efficiency, has made them the most widely used turbine in the world. The turbines exit tube is shaped to help decelerate the water flow and recover pressure within the turbine. Therefore there is less kinetic or potential energy leaving device. Francis turbines are suitable for medium flow and head. The range of a medium head is 45-400m and flow rate is 10-700m^3 /s.

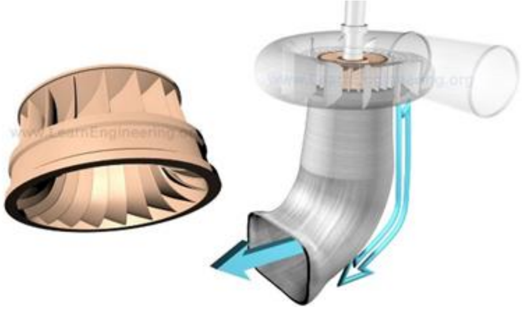


Figure 7 - Francis Turbine

3.2.2 Kaplan Turbines

Kaplan Turbines are used in low head, high flow areas to generate electricity. Often they are installed in areas where large reservoirs of water are present. Water flow is directed into the top of a tube and flows downwards through a propeller. The blades of the propeller can be manipulated to achieve more or less power output based on the flow of the water. The number of propeller blades is related to the head of the flow. Kaplan turbines are traditionally used in areas with a head of 2 - 25 meters. Kaplan turbines are capable of generating 200 MW as seen in dams. One of the challenges associated with a Kaplan turbine is the amount of infrastructure required to run the turbine. Due to the large flow rates handled by Kaplan turbines, they are the largest type if hydroelectric generator. The flow through the turbine is regulated by guide vanes at the top of the tube to ensure uniform flow over the blades. The flow exits through the bottom of the turbine in a draft tube to prevent cavitation. The water flows over the curved blades of the turbine and the reaction to this flow is what spins the shaft and generates power. This is shown by the Figure 8 below.

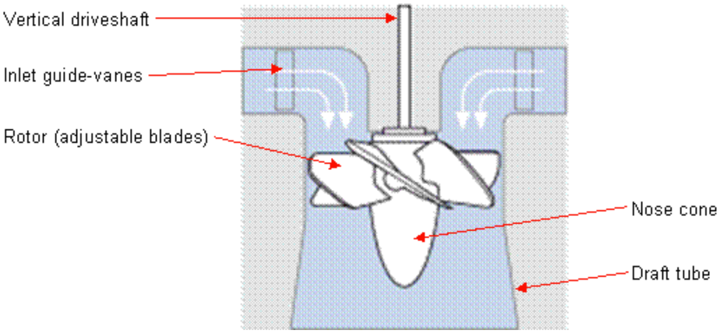


Figure 8 - Kaplan Turbine

3.2.3 Hydrokinetic Turbines

Hydrokinetic turbines are those in which perform efficiently in free-flow environments; meaning that that require little to no head to operate. Instead they are designed to capture the kinetic energy of a flowing fluid. Some examples of these turbines are axial flow rotor turbines and helical turbines. As shown in Figure 10 the axial flow turbines closely resemble that of wind turbine blades and boat propellers. Figure 9 displays a vertical-axis helical turbine. These types of turbines can also be orientated such that their longitudinal axis is in line with the flow.

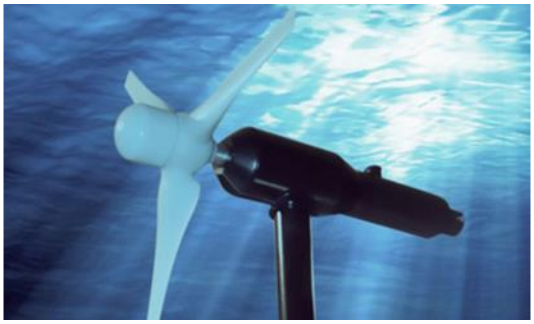


Figure 10 – Axial Flow Rotor Turbine

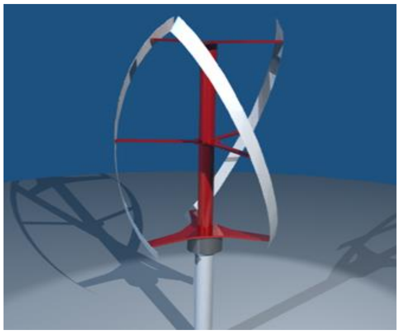


Figure 9 - Vertical-Axis Helical Turbine

Table 3 - Decision Matrix for Turbine Selection

Criteria	*Importance Rating*	*Francis*	*Kaplan*	*Hydrokinetic*
Weight	3	2	3	5
Cost	2	3	2	3
Manufacturability	3	2	2	4
Durability	4	2	3	3
Efficiency	4	3	3	5
Total		38	43	65

The axial flow rotor turbine was eventually selected due to its relatively high efficiency and its ability to be oriented with the flow of the stream. Additionally it is optimized for a low head and high flow application which are the conditions that the Personal Hydroelectric Generator would work upon.

3.3 Alternator

Power generation can be produced through a generator or alternator. Alternators have some advantages over direct-current generators, which makes them simpler, lighter, and more rugged than a DC generator. The stronger construction of alternators allows them to turn at higher speed. The use of brushless alternators will eliminate the hurdle of having a high RPM to generate the power needed for the project. Brushless alternators output a lower amperage but a higher voltage at lower rpm’s.

Alternators use a rotating magnetic field that induces a voltage in the windings. Since the currents in the stator winding vary in step with the position of the rotor, an alternator is a synchronous generator. The magnetic field can be produced by permanent magnets or a field coil electromagnet. A single cycle of alternating current is produced each time a pair of field poles passes over a point on the stationary winding.

Table 4 - Decision Matrix for Generator/Alternator Selection

Criteria	*Importance Rating*	*DC Generator*	*AC Alternator*
Weight	3	2	3
Cost	2	3	3
Safety	3	3	3
Durability	3	2	4
Efficiency	4	2	3
Total		35	48

An alternator was ultimately chosen over a DC generator due to the fact that it is more efficient in producing power under low rpm. Also, alternators by design are lighter than DC generators on a weight per power generation basis. Also when producing the current and voltage by the alternator the use of brushes and slip rings are not needed which are prevalent in dc generators making the generator more cumbersome in maintenance.

3.4 Battery

Being an essential component of many electronic devices, the battery is one of the most researched devices in the field of electricity. It is important to understand that batteries come in many different sizes and designs. They are made of an array of different chemicals, and can store any amount of energy based on size. For the PHG, mainly three types of batteries were looked at including the following: marine batteries (deep cycle), car batteries (starting), and Lithium ion batteries.

As the time passed and the team obtained a better understanding of what was realistically feasible, some aspects of the concept design changed. Most notable, the team removed the internal battery to reduce the weight of the system and to simplify the complexity of encasing a battery within the prototype. Therefore the idea of storing the energy produced would be eliminated. It became apparent that the team would benefit more from allowing the end user to decide upon their own battery. The elimination of the battery allowed the team to use the additional budget to focus on other aspects of the design. It was decided that the final design would consist of a charge controller that would output DC power to any researchable 12V battery the end user decided upon. The charge controller was to be placed inside the housing and the output wires would protrude outside of the housing to be connected to an external battery on land. The team also determined to include a wattmeter, placed before the battery in the circuit. The wattmeter is built to display to the current, voltage, and power produced by the system.

3.5 Gear Train

A gearbox will take the high torque produced by the turbine and convert the energy into a higher rotational speed on the shaft coming out of the gearbox. The desired rotational speed of the alternator is 700 rpm, this is the optimal rotational speed for power generation. The gear type maintains a linear input and output shaft rotation with the use of spur or helical gears. The output shaft would also be able to change orientation with the use of bevel gears.

3.6 Housing

The system would be fully enclosed in a waterproof casing so that the electrical components do not fail and the mechanical components are less likely to corrode. A strong material that will withstand the beating of the current as well as allowing the user to inspect the mechanism would be important for maintenance.

3.7 Anchoring

3.7.1Sinkable Design

Sinkable anchoring systems, or those that use a weight to attach the device to the sea floor have advantages in that they can be placed at virtually any point in a stream of water. In addition they are fairly easy to secure as simply releasing it into the water will suffice. However it should be noted that specific anchors will hold better in different conditions. It is therefore recommended for the greatest anchoring security, you should carry two anchors of different styles. The Danforth style and the plow/scoop variety are shown below and offer different advantages. The type of bottom (mud, grass, sand, coral or rock) will dictate different choices of anchors

.

Figure 11 - Scoop Style Anchor

Figure 12 - Danforth Style Anchor

This type of anchoring system would be geared toward a design such as a floating barge that requires something to prevent it from floating away.

Instead of using a combination of anchors to hold the device to the sea floor, an entire platform can be utilized in order to sink the entire device to a depth that is just above the riverbed. An example of this is shown below. An advantage to this design is in its simplicity. However a disadvantage to this type of riverbed anchoring is that in order to retrieve the device one must dive to the bottom to pull it up or use a rope to drag it out of the water.

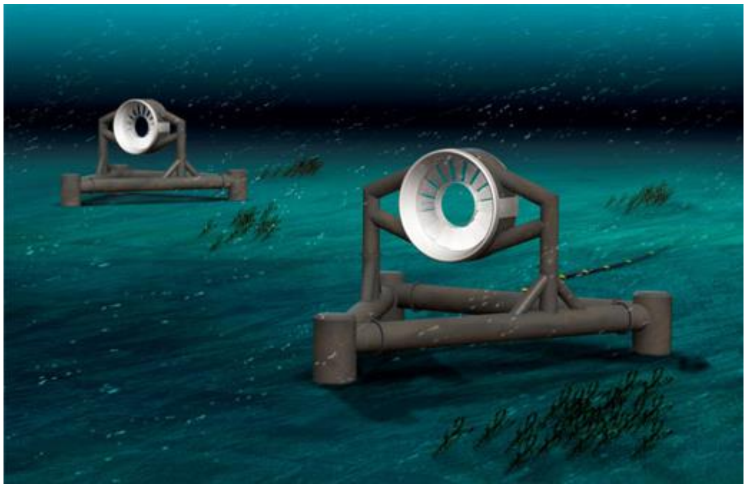


Figure 13 - River Bottom Anchoring Style

3.7.2 Cantilevered Design

The anchoring for this system is achieved by pinning down one side of an elongated light structure to the side of a river bank. The sound foundation is formed by penetrating spikes into the ground. The generator system will be introduced into the water at the other end of the anchoring structure to the desired location as demonstrated in Figure 14. Figure 15 depicts another example of a cantilever system that has the ability to slide out to extend into the body of water. Strong moment forces will be felt by the anchoring structure due to the weight of the alternator and turbine as well as the force due to the flowing river. This design allows for the user to install the generator from one side of the river and does not require the user to enter the water.

Figure 14 - Cantilever style anchoring

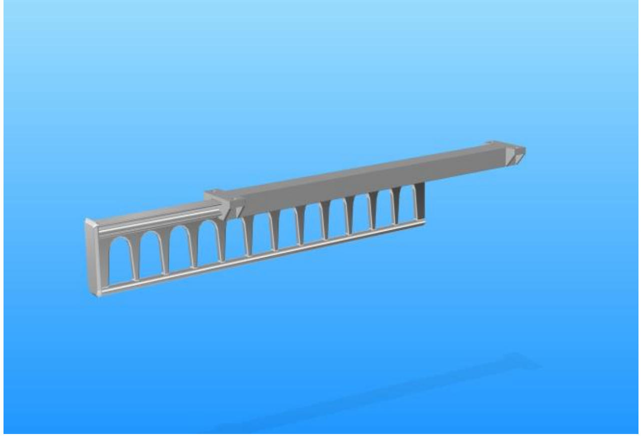


Figure 15 - Cantilever conceptual arm design

4 Final Design

Through research and analyzation over the past year, the team has streamlined the design of the Portable Hydroelectric Generator (PHG) into a workable prototype. The design contains four major components, and one auxiliary one. The main components are the turbine blade, gearbox, alternator, and charge controller, with the auxiliary component being a LCD display wattmeter. In the schematic seen below the design of the PHG can be broken down.

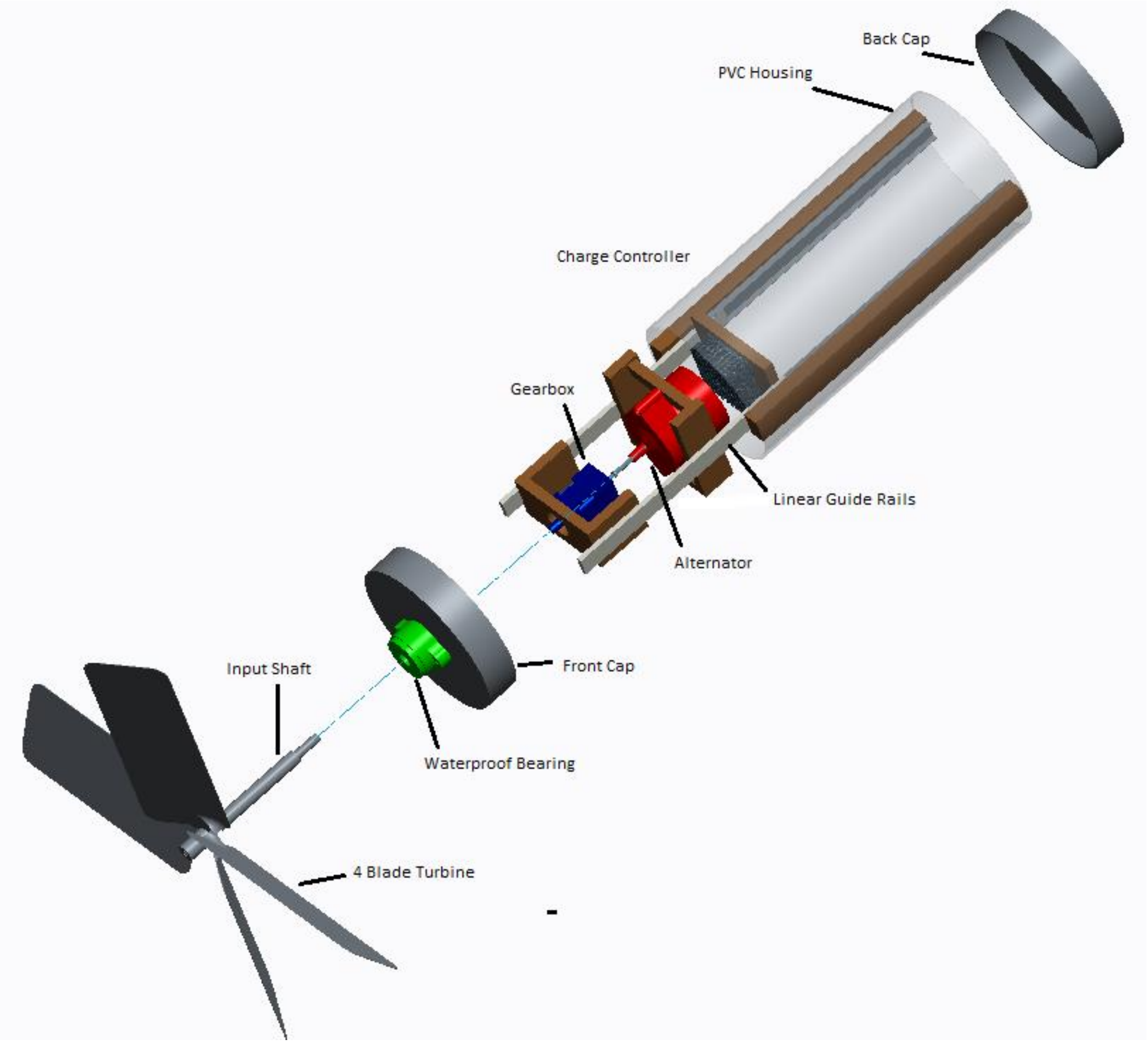


Figure 16 - CAD Schematic

4.1 Main Component Description

The initial component of the design, the turbine blade, is the foremost component of the device. It is put in place to serve as the gatherer of kinetic energy coming from the flowing water. Its job is to spin as the water comes in. The spinning of the turbine blade spins the main shaft of the device which in turn is coupled to the gearbox.

In order to select the best turbine blade setup, it is important to calculate the component's tip-speed ratio.

$$\lambda = \frac{Tip\ speed\ of\ blade}{speed\ of\ water} = \frac{\omega R}{v_{water}}$$

Eq. 1 – Tip-Speed Ratio

Figure 17 - Turbine Blade

This number indicates the ratio of the tangential tip speed of the turbine blade in relation to the speed of the fluid flowing through it. Through research it was determined that the tip-speed ratio of the average 4 blade turbine was 3. Knowing additionally through research that the average speed of water flow in rivers in the United States is 3.75ft/s, the angular velocity of the turbine can be estimated.

$$\omega = \frac{\lambda v_{water}}{R} = \frac{(3)(3.75\frac{ft}{s})}{1.5ft} = 7.5\frac{rad}{s} = 1.194\frac{rev}{s} = \mathbf{71.62\ rpm}$$

Eq. 2 – Angular Velocity of Turbine Blade

This value, 71.62 rpm becomes the speed at which we expect to see the turbine spin in the water with no load attached to it.

The calculations were done based on a four blade turbine do to the fact that the team selected a four blade turbine. Running out of time and budget for a water optimized turbine blade, the team did what they could and bought the best component they could locally. The turbine blade selected is a blade out of an industrial fan. With four blades, a three foot diameter, and a pitch angle of 35^{o}, the turbine blade selected seemed suitable for the job.

In terms of design, the most important component of the prototype to look at is the alternator. The heart of the product, the alternator, is where the device actually generates electricity. The alternator is responsible for converting the mechanical energy of the spinning turbine into electrical energy. Through Faraday's Law, described in the background research section, the spinning rotor of the alternator generates electrical energy.

The DC-540 Windblue Power alternator was selected for its favorable characteristics. Built specifically for wind and hydropower projects, this device outputs power exactly how we want it; three phase AC power. The benefits of three phase over single phase in the team's application is that three phase power can travel significant distances if necessary. It does so smoother and more reliably than single phase power. The three phase power is going to be more consistent, and require less rpm at the alternator than its single phase counterpart.

Figure 18 - DC-540 Alternator

In terms of power output, data provided by the producer shows that at 650 rpm the alternator is capable of producing 83-130W at 48-38V and 1.7-3.3A.

Now, knowing that 650 rpm is ideal to the alternator and the fact that the turbine blade can spin at around 71.62 rpm with the nation's average water velocity, a gearbox has to be selected to convert the speed to out of the alternator into something high enough for the alternator to use. This is where the gearbox comes in. The gearbox chosen was the GBPH-060x-NP-010 planetary gearbox from Anaheim Automation. It was chosen for two main reasons. The real reason this gearbox was purchased was due to the 10:1 gear ratio. At this ratio our input average turbine speed of 71.62 rpm can be increased to 716.2 rpm to the alternator (this is the ideal case with no internal and load resistances). The 10:1 ratio produces more than enough speed to the alternator. Also, since the torque required to turn all of these components will likely increase as the battery becomes more charged, the gear box gives the

Figure 19 - Anaheim Automation: GBPH-0601-NP-010

team room to work with. If the turbine is only spinning at around 50 rpm, the gearbox provides enough speed to the alternator for 500 rpm which is still more than enough.

The charge controller shown in Figure 20, is another major component of the design, its purpose is to take in the three phase power coming from the alternator and convert it into DC power that can be fed into an exterior battery. This enables the end user to harness and consume the electrical energy being generated. This component is built to allow a maximum of 14 volts to be output in DC. By limiting to this voltage, it ensures that the end user will not overcharge any 12 volts battery attached to the system. The charge controller has a built in braking feature that slows down the alternator by applying a high resistance when the battery reaches its full charge. Thus limiting the voltage that can sent to the battery and dissipating the excess energy produced through heat. The charge controller is a critical part of the system without it the system can become dangerous to users due to the volatile state of overcharged batteries.

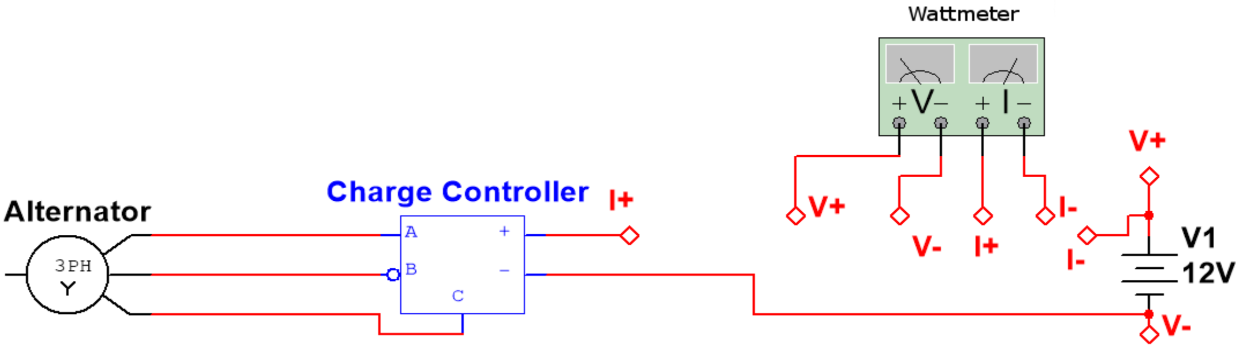


Figure 20 - Electronic Schematic

4.2 Housing

Figure 21 - PVC Housing with sliding rails

With all of these components decided upon, the next step of the final design process was to come up with the proper housing construction that would hold and waterproof all elements of the design. The initial design was to be constructed out of polycarbonate, but this proved to be too difficult and expensive to manufacture so plumbing grade PVC piping was used. The housing has a diameter of 11 inches and a length of 24 inches. The PVC was sized appropriately to contain enough room to house the three internal components: gearbox, alternator, and charge controller.

On the front end cap there is a hole in place for the main drive shaft to be inserted into the gearbox. This shaft spins from the forces acted upon the turbine blades. Due to this being the main connection with the external parts this shaft is inserted through a waterproof spherical flange bearing, shown in Figure 22, which the team purchased from TNN-Jeros. This bearing allows the shaft to rotate inside the housing without allowing any water to penetrate through the input opening.

Additionally, all of the internal components are mounted on sliding linear guide rails as seen in Figure 21. The purpose of using the sliding rail is for the ease of installation and future maintenance. One can slide all the internal components out of the housing with having to unscrew or disassemble anything. All internal components are equipped with their own wooden housings and platforms that are then fixed to these rails.

Figure 22 - Spherical Flange Bearing

4.3 Additional Details

The final design is missing one key component at this time, the anchoring system. Due to the complexity involved, and the team having to focus on other aspects to get a working prototype, the anchoring system had to be overlooked. Time and budget constraints also contributed to the anchoring system being dismissed. However this is still an issue. Without a proper anchoring system the prototype will not be able to stay in the desired position to the flow of water. Thus the probability of the system flowing away or being rotated with the flow of water will increase. Thus anchoring is a major component for future works.

5 Design of Experiments

The following section will cover the testing and results of experiments performed. These experiments were designed to test critical and integral aspects of the Personal Hydroelectric Generator. The experiments were designed with an emphasized focus on mechanical and electrical aspects to prove the functionality of the design.

5.1 Waterproof Testing

Waterproof testing was the most straightforward test performed yet arguably focused on the most critical aspect to prove. The PHG’s modular design includes the capability of dissembling into several components for transportation, replacement or repair. Due to this, it is critical that the system is submersible and has the flexibility incorporated in the design. The testing was conducted at every stage of the designs completion.

The initial testing was conducted by filling the PVC housing end caps with water. This test was considered a failure because the end caps were not capable of containing the water. The problem was resolved by adding a layer of marine grade epoxy to the inner edges, which effectively prevented further leaks. The next phase of testing that was conducted by securing the end caps to the external housing, adding the rubber sleeves and screw-bands, and then submerging the entire housing in a pool. The housing did prove waterproof to this test. The next stage of waterproofing was conducted once the internal housing components were secured to the external housing walls. The holes screwed into the external housing were sealed with a rubber material that acted as a gasket between the washer and housing. This method of sealing proved successful in waterproofing the screw holes. Next, the cap containing the flange bearing for the turbine output shaft was tested for leaks. This iteration of testing was conducted by putting a 25mm diameter section of shaft through the bearing in the cap and watching for water leaks. This test proved waterproof as well.

The final experiment for waterproof testing was conducted after the final assembly was complete. This test was conducted by submerging the finished assembly into a pool. The design was successful by preventing any leaks. Although it was the final assembly, at this specific point in time, the gearbox was slipping, thus no power was generated and therefore, the functionality of the prototype in water was not fully confirmed.

5.2 Heat Dispersion Testing

The heat dispersion test was conducted to verify that no complications would arise from the heat generated during the alternators operation. Since the design of the PHG places an alternator in close proximity to other components such as wiring and the housing walls, the team decided it was important to confirm that heat generation would not be a significant factor to damaging internal components. The advisor instructed the team to conduct the test until you see a plateau in temperature. Therefore by placing the alternator within the housing and connecting its input shaft to a drill, the team was able to spin the alternator at the approximate and much higher rpms then expected in real world application. The alternator being spun at a rate generating 40 volts for a maximum of five minutes, which was well above the desired operating voltage of 12 volts, only generated a max of 76°F which was in a safe operating temperate range as seen below in Figure 23.

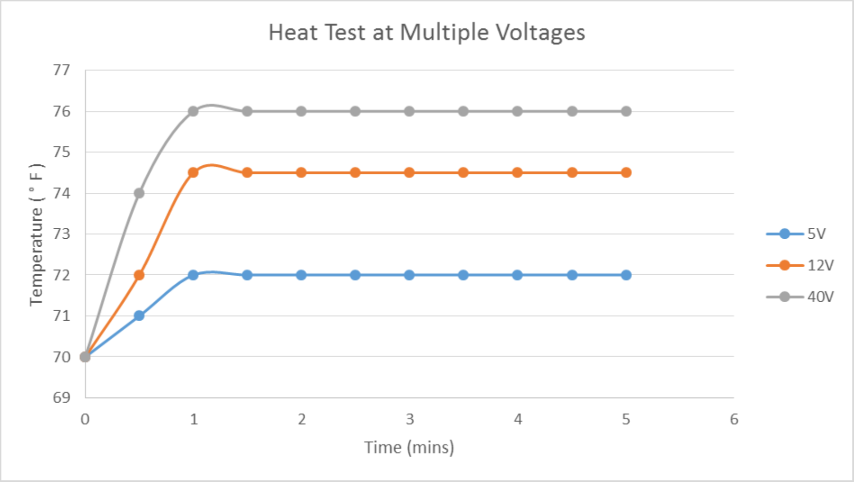


Figure 23. Heat Dispersion Testing Results

5.3 Torque Testing

The torque test was a test designed to test the accuracy of the previous calculations conducted based on assumptions and calculated values. The torque test was conducted by attaching the smallest weight possible such that it generated enough torque to spin the turbine. By doing this it was possible to determine the actual startup torque of the turbine which then would make it possible to find the actual river velocity required to operate the turbine, the turbine's rpm, the alternator rpm and actual power generated.

5.4 Electrical Output Testing

The electrical output test was designed to estimate the performance loses of the system due to the resistances created by external loads. The test was intended to be a proof of operations more than a testing to measure a concept. This test was important to conduct because external loads would create an opposing force onto the system. This test was conducted by connecting an external variable resistor to the leads of the charge controller. The testing results, shown in Figure 24, were consistent with the expected theoretical result: increasing the resistance onto the system increases the input force needed to generate more power. The two ohm testing, representing a low external resistance, achieved 400 rpms which allowed a higher output power by the system. The 168 ohm testing was only able to reach less than 225 rpms therefore a lesser output power could be accomplished. Even though the testing of higher resistance decreases the power output, the system is sufficient to accomplish the intended objective, charging a battery.

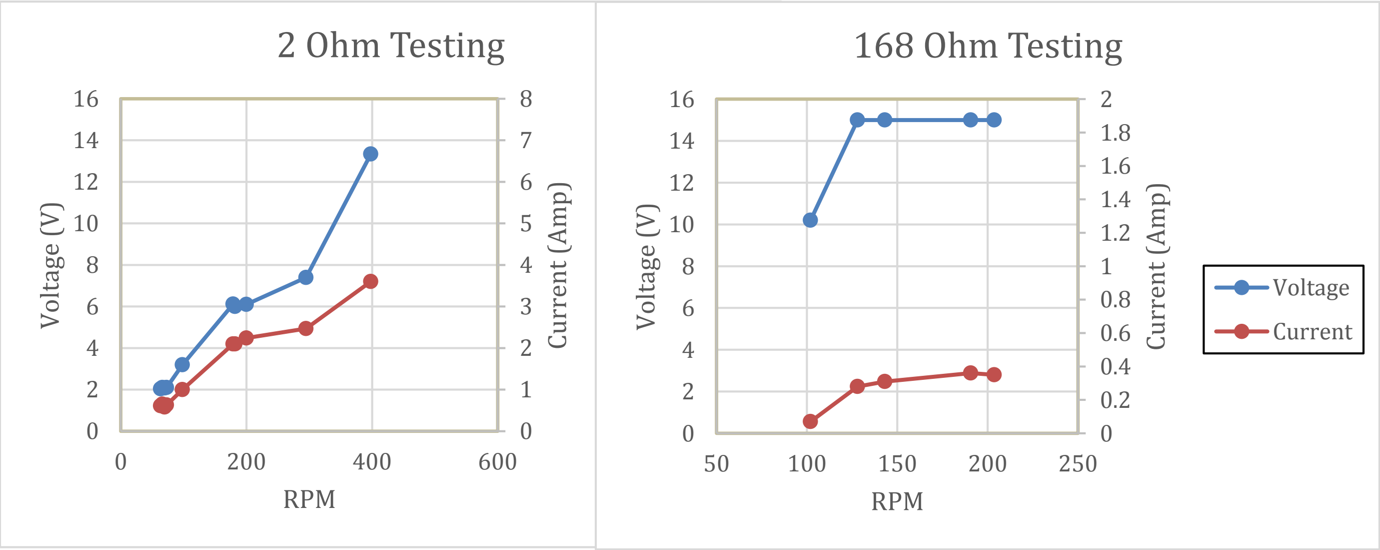


Figure 24 - Electrical Output Testing Result

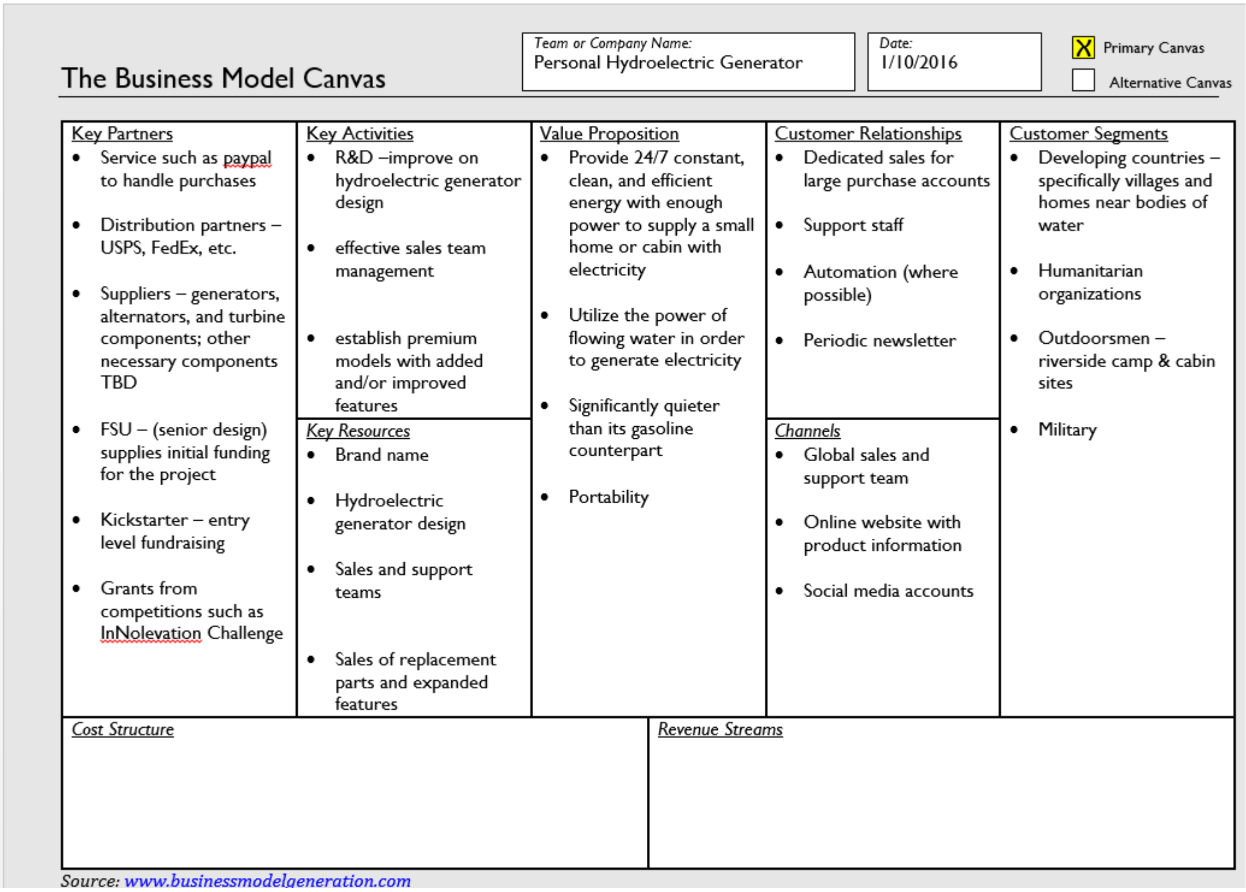
6 Entrepreneurial History

Team 7 has entered into four entrepreneurial competitions during the 2015 – 2016 school year. The first competition being the InNolevation challenge where the goal at the end of the competition after four submissions and elimination rounds was to identify and precisely define the assumptions of the new venture, testing those assumptions in the field, and then pivoting or changing based on the lessons learned. In Stage 1, the purpose is to develop a value proposition, or the value that is delivered to the customer and the problem that is being solved. The value proposition was summarized in that section of the Business Model Canvas.

In Stage 2, participants developed hypotheses, or assumptions, of who the customer was, what the customer wanted, how the customer wanted it, how participants would get it to the customer, and what participants would need to get started. After this round the judges reduced the number of participants to 25.

The hypothesis was then be tested with potential customers in order to see if it is accurate. From that test data, the hypotheses would be adjusted and tested again. In Stage 3, the testing/pivoting that was done will be summarized by reworking the Stage 2 sections of the Business Model Canvas. Judges then selected the top 7 teams to advance into the final round. Unfortunately, the Personal Hydroelectric Generators design team was eliminated during this round.

In Stage 4, participants prepared revenue streams and cost structures based on the work completed to date. The completed Business Model Canvas for the Personal Hydroelectric Generator that was developed for this competition is shown on the next page:



The Business Model Canvas

Team or Company Name: Personal Hydroelectric Generator

Date: 1/10/2016

☒ Primary Canvas

☐ Alternative Canvas

Key Partners
- Service such as paypal to handle purchases
- Distribution partners – USPS, FedEx, etc.
- Suppliers – generators, alternators, and turbine components; other necessary components TBD
- FSU – (senior design) supplies initial funding for the project
- Kickstarter – entry level fundraising
- Grants from competitions such as InNolevation Challenge

Key Activities
- R&D –improve on hydroelectric generator design
- effective sales team management
- establish premium models with added and/or improved features

Key Resources
- Brand name
- Hydroelectric generator design
- Sales and support teams
- Sales of replacement parts and expanded features

Value Proposition
- Provide 24/7 constant, clean, and efficient energy with enough power to supply a small home or cabin with electricity
- Utilize the power of flowing water in order to generate electricity
- Significantly quieter than its gasoline counterpart
- Portability

Customer Relationships
- Dedicated sales for large purchase accounts
- Support staff
- Automation (where possible)
- Periodic newsletter

Channels
- Global sales and support team
- Online website with product information
- Social media accounts

Customer Segments
- Developing countries – specifically villages and homes near bodies of water
- Humanitarian organizations
- Outdoorsmen – riverside camp & cabin sites
- Military

Cost Structure

Revenue Streams

Source: www.businessmodelgeneration.com

Figure 25 - Business Model Canvas

After the InNolevation Challenge was complete, team 7 then entered into the ACC challenge where the design team was selected among 12 others that presented in front of a panel of judges based on a submitted essay detailing the teams design and marketability. After presenting, the design team was then selected to move on to the final 3 participants from Florida State University. The team was unfortunately eliminated after this point. The winner of this competition received a chance to pitch in front of investors competing against other nominees from the other ACC schools which was broadcasted on PBS television and online.

Design team 7's next entrepreneurial endeavor involved entering into Digitech FSU. Here the prototype was displayed along with a poster describing the design. For hours participants and judges walked around the exhibition and asked various questions about the design and commercialization potential. After the display was over representatives from team 7 were responsible for a quick 3 minute pitch about the design to judges in a setting modeled after the television show Shark Tank for the chance to win one thousand dollars towards the business behind the concept. Prizes were awarded at the conclusion of the event of which team 7 won none.

Finally team 7 entered into an engineering shark tank competition put on by the Jim Moran Institute for global entrepreneurship. This competition required the team to pitch a short presentation to a panel of judges that scored participants based on the following criteria:

- Idea. Idea validity, novelty, and potential impact
- Business Model. Value proposition, target customer(s), market size, competitive advantages, etc.
- Entrepreneurship. Team commitment, team expertise and knowledge
- Pitch delivery
- Probability of Success. Commercialization plan and probability of proceeding with the plan

After the initial pitch, team 7 was selected to move on to the next round which is scheduled on April 14 (engineering design day). In order to prepare for this presentation members of the design group attended review and suggestion session in effort to gain advice on pitch delivery and PowerPoint strengths among other things.

Source websites:

http://business.fsu.edu/jmi/students/innolevation-challenge

http://www.eng.fsu.edu/eae/

https://innovation.fsu.edu/events/acc/

7 Considerations for Environment, Safety, and Ethics

7.1 Wildlife Impact

One of the main goals of the project was to create a power generation device that has little to no impact on its surrounding environment. Large scale and even small scale dams require a permanent installation that greatly affects the environment and can give off harmful emissions. The Personal Hydroelectric Generator is small, portable, does not require any permanent structures to operate, and gives off zero emissions.

Another concern is turbines in flowing rivers may interact with the wildlife like fish and snakes. The team spent a short amount of time considering a design that included a screen to keep wildlife from interacting with the spinning blades of the turbine. However, a study showed that with a turbine that reached rotation speeds of 70 rpm in a subtropical river, fish movements were recorded to avoid collision with the turbine. In fact, the study showed that no fish collided with the turbines and only a few specimens passed through the turbine during the testing period. It was shown that fish slowed and then seemed to actively avoid the turbine fixtures.[6]

7.2 Safety

Risks during the design of the project are inevitable. When dealing with electrical equipment, like the alternator and battery, harm can come to the operator if water is introduced to the system. There is also a drowning hazard when the device is being installed in swift currents. While building the system, misuse of equipment like power tools and improper handling of heavy equipment can also be an issue. All of the concerns listed above will be remedied by implementing eye, ear, and hand protection as well as safety flotation devices worn while working on or testing the system in rivers. The use of PPE will help avoid accidents all together. A CPR certified individual will be present during the testing of the system in the case of an accident. All accidents will be dealt with seriously and the proper authorities will be alerted of any accidents during the project.

7.3 Ethics

Due to the entrepreneurial nature of this project, several hours were spent researching current products that Team 7’s design would compete with. The purpose of this research was to ensure that no patented designs would be infringed upon, and that the final design would in fact be a unique and innovative product. The current market for micro hydroelectric power generation is small and consists mostly of small startup projects similar to Team 7’s. This research payed off and the final design is unique in size and power production. Most competitors have extremely small designs with low power output, or they are large devices that need to be permanently installed.

8 Project Management

8.1 Schedule

The Gantt Chart produced at the beginning of the first semester was rewritten and fixed to a more suitable timeline by the end of the first semester. With the unexpected length of time that some aspects took as well as the unexpected machine shop times, the Gantt chart was not necessarily followed directly. Improvising and work on multiple parts at the same time to always be progressing is talked about in the next section. Therefore, the Gantt chart was used more as a guideline tool to make sure Team 7 kept close to their time schedule as far as project completion. Order of completion with specific components was varied.

8.2 Resources

The College of Engineering offers many resources to aid in senior design research and testing. Unfortunately, some of the most important resources needed by these senior design teams are not abundant enough to allow all of the teams to get through their project as planned. Therefore, teams must plan accordingly and learn to be flexible in scheduling with backup plans and multiple target objectives that can be completed simultaneously in case one part cannot be worked on at the desired time.

An example of this problem can be seen with the machine shop. With one major machine shop at the College of Engineering, Team 7 ran into the difficulties described above. In order to stay on task, multiple parts of the design were worked on at the same time so that a portion of the design was always progressing. Also, Team 7 reached out to a machine shop on Florida State University’s main campus and was able to have some parts successfully completed at that location in a timely manner. The machinist at the main campus machine shop knew one of the group members as a coworker at the school. With this connection, he performed the machining free of charge, which allowed for more room in the budget for other components and needs.

A major help to the success of the project was found in the Electrical Engineering Department Lab, where the alternator was able to be tested. This test was completed in the Power and Energy Lab room A310. A synchronous motor, whose speed can be controlled by the input voltage, was coupled to the alternator. Two rubber couples were provided by the lab room. To represent a load on the alternator a variable resistor ranged from $1 - 700\Omega$ was used, which was also available in the lab room. A Fluke 434 was used to measure the resistance, power, voltage, and amperage throughout the system while testing. This was a crucial facility available to the team in complete alternator testing.

A resource needed by Team 7 for easy testing of the turbine system in flowing water was not available and could have been an Infinity Pool or something similar. Testing the Personal Hydroelectric Generator could have been much safer and easier if this was available to the team. The only true alternative to this is to put the device in a river for testing. Testing in the river is both dangerous due to natural hazards and produces data that is not obtained in a controlled environment.

The availability of professors and faculty advisors at the College of Engineering was extremely beneficial for Team 7 during both the design and assembly phases. On many occasions, the team would run into a problem and not be able to find the answer even after more and more research. At this point, the problem would be taken to a professor who specialized in this particular field. The professor helped immensely by pointing the team in the right direction and giving advice on how things work in real world applications compared to theoretical applications.

Team 7 seemed was successful in using the resources available through the College of Engineering as well as outside resources. Professors' advice, available testing devices, and available computer labs and conference rooms helped the team complete the project. With that being said, outside resources such as personal tools and the machine shop on campus also contributed significantly to the completion of the project. The College of Engineering should offer more tools/machinery available to the senior design teams. If Team 7 did not already have many of the tools needed, then most of the assembly would have been more difficult to finish.

8.3 Procurement

The Personal Hydroelectric Generator project is an entrepreneurial project that was funded by the College of Engineering. The initial budget of the project consisted of \$1,500. Towards the end of the assembly phase, certain components showed to be more expensive than initially expected. Therefore, a higher budget was requested and the total budget was increased to \$2,000. Extra parts were purchased during the assembly process that were not used, but these parts were returned and reallocated into the budget to minimize loss.

Table 5 - Bill of Materials

<table>
<tr><td colspan="5">Team 7</td></tr>
<tr><td colspan="5">Personal Hydroelectric Generator</td></tr>
<tr><td colspan="5">Date: 04/08/2016</td></tr>
<tr><th>Item(s)</th><th>Vendor</th><th>Quantity</th><th>Price per Unit ($)</th><th>Total ($)</th></tr>
<tr><td>DC 540 Alternator</td><td>WindBlue Power</td><td>1</td><td>239</td><td>239</td></tr>
<tr><td>12V/25A Charge Controller</td><td>WindBlue Power</td><td>1</td><td>44</td><td>44</td></tr>
<tr><td>60V/100A Watt Meter</td><td>WindBlue Power</td><td>1</td><td>24</td><td>24</td></tr>
<tr><td>5' of 11" PVC Pipe</td><td>Commercial Ind. Supply</td><td>1</td><td>170</td><td>170</td></tr>
<tr><td>External PVC End-Caps</td><td>Commercial Ind. Supply</td><td>3</td><td>74.8</td><td>224.4</td></tr>
<tr><td>Water-Proof Bearing</td><td>TNN-JEROS</td><td>1</td><td>101.36</td><td>101.36</td></tr>
<tr><td>Turbine Blade</td><td>Lowes</td><td>1</td><td>235.43</td><td>235.43</td></tr>
<tr><td>1' Aluminum Shaft</td><td>Grainger</td><td>1</td><td>16.17</td><td>16.17</td></tr>
<tr><td>Linear Guide Rails</td><td>HomeDepot</td><td>1</td><td>21.76</td><td>21.76</td></tr>
<tr><td>Assembly Hardware</td><td>HomeDepot</td><td>1</td><td>65.61</td><td>44.23</td></tr>
<tr><td>Assembly Hardware</td><td>HomeDepot</td><td>1</td><td>15.72</td><td>15.72</td></tr>
<tr><td>Windblue Shipping</td><td></td><td>1</td><td>17.16</td><td>17.16</td></tr>
<tr><td>Bearing Shipping</td><td></td><td>1</td><td>15.88</td><td>15.88</td></tr>
<tr><td>Pipe Shipping</td><td></td><td>1</td><td>25.97</td><td>25.97</td></tr>
<tr><td>Gearbox</td><td>Anaheim Automation</td><td>1</td><td>330</td><td>330</td></tr>
<tr><td>Gearbox shipping</td><td></td><td>1</td><td>43.39</td><td>43.39</td></tr>
<tr><td>Input Shaft Coupling</td><td>Grainger</td><td>1</td><td>20.16</td><td>20.16</td></tr>
<tr><td>Gearbox-Alternator Coupling</td><td>Lowes</td><td>1</td><td>6.24</td><td>6.24</td></tr>
<tr><td>LED Lighting</td><td>AutoZone</td><td>1</td><td>21.49</td><td>21.49</td></tr>
<tr><td colspan="3" rowspan="3"></td><td>Total</td><td>1616.36</td></tr>
<tr><td>Amount Over Initial Budget</td><td>116.36</td></tr>
<tr><td>Available Budget - Total</td><td>383.64</td></tr>
</table>

The final budget report shows everything purchased in the project. In conclusion, it is Team 7’s opinion that the budget was planned out and spent effectively. Although, there was an increase in the budget, not all of the extra $500 was used in the final assembly. The finances of the project were successfully handled because of the constantly updated bill of materials and financial status. By doing this, the team was always aware of what was available and conscientious of what needed to be prioritized. Below is a final pie chart of Team 7’s expenses to show an easier visual of how the budget was utilized.

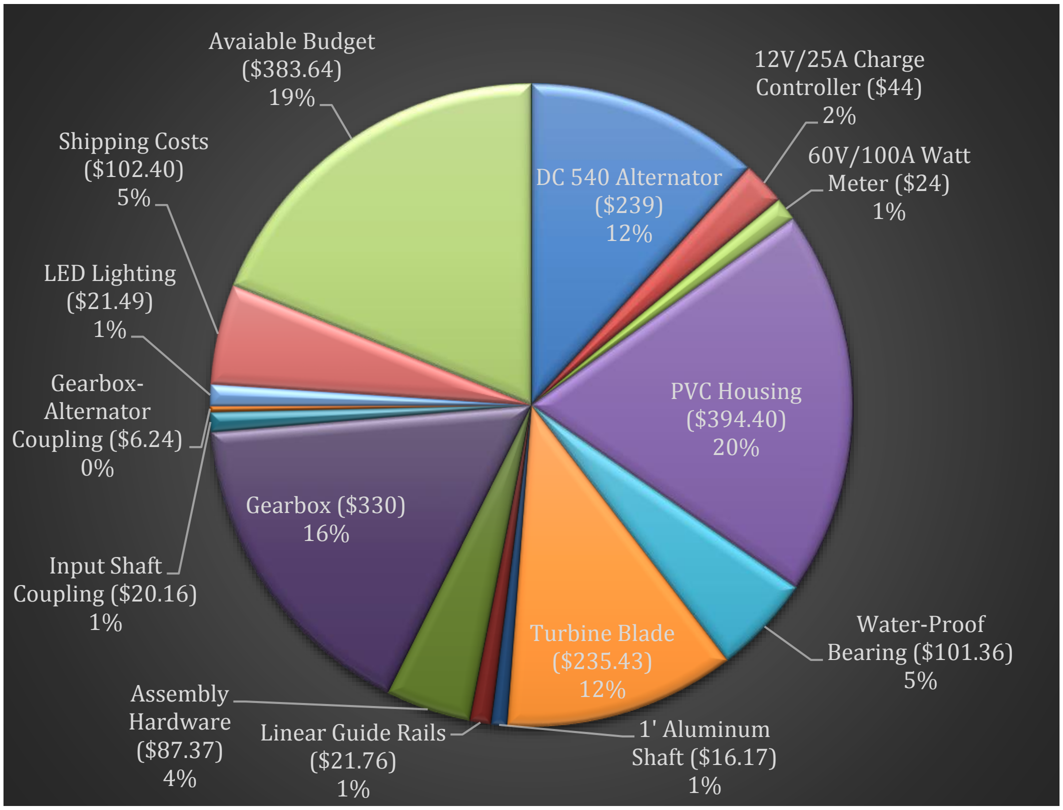


Figure 26 - Budget Breakdown

8.4 Communications

The main form of communication between Team 7 members was through *GroupMe*, a phone application. This application allowed all of the members of the group to be able to communicate similar to a group phone text. Members were able to instantaneously give others information. The other main form of communication between group members consisted of email. Email allowed for easy transmission of documents, pictures, and data.

Team 7 never had any communication problems with either the sponsor or the faculty advisor assigned. The sponsor, Dr. Devine, and the faculty advisor, Dr. Hahn, were both extremely attentive to their emails and usually responded within a couple of hours. Specifically, Dr. Hahn was invited to all presentations, but was mainly used as a tool for difficult questions and advice during the design phase. Dr. Devine was also invited to all presentations, but was more hands-on during the semesters for several reasons. First, being an entrepreneurial project, he was in charge of our budget and was looked to for approval on some of the major purchases. Also, Dr. Devine wanted the team to be involved in a total of four entrepreneurial competitions. Dr. Devine is experienced in the entrepreneurial side of engineering and helped Team 7 through these competition. With all of this involvement, at least one person from the team was in his office meeting about something on a weekly basis.

9 Design for Manufacturing, Reliability, and Economics

9.1 Manufacturing

Manufacturing of the components for this project are dealt with through third party companies. Once all the parts where obtained it becomes a logical method of assembly. The parts are listed as follows:

1. PVC housing, and end caps
2. Sliding rails
3. Wood-for mounting internal components
4. Gearbox
5. Alternator
6. Charge Controller
7. Shaft and coupling mechanism
8. Water-proof bearing on front end cap
9. Turbine Blade
10. Wattmeter
11. Electrical Wiring
12. Conduit to protect wiring

Once all of these parts are obtained, the manufacturing procedure used by the senior design team can be laid out in a simple to follow step by step process.

1. Obtain the PVC housing and drill holes equally spaced on the sides to mount the sliding rails.
2. Mount the sliding rails onto the housing by lining them up and screwing the rails in place where the holes are.
3. On the top of the PVC housing a hole is drilled, this is where the wiring and conduit will go.
4. The housings for the gearbox, alternator, and charge controller are assembled (For the prototype these are made out of wood). These housings will all be mounted onto the rails.

5. Once the housings are constructed, the alternator, charge controller, and gearbox are mounted to their respected housings.
6. The guide rails are extended out and the components are mounted appropriately. With the turbine at the front of the system, the charge controller is in the back, alternator in the middle, and gearbox in front
7. Wires attached to the output of the charge controller should at this point be extended through the opening previously made at the top of the housing.
8. All the shafts for these components need to be manufactured to fit properly to couple the gearbox and alternator together.
9. The front end cap should be drilled to fit the shaft diameter, holding the turbine on the outside.
10. Two holes need to be drilled equidistantly on the sides of the front end cap hole for the waterproof bearing to be mounted.
11. Then, the main shaft is affixed through the hole of the front end cap and coupled to the gearbox.
12. Here the front end cap is fixed onto the housing and sealed.
13. The water-proof bearing is now placed over the shaft on the outside of the end cap to water-proof the product.
14. Now the turbine is affixed to the exterior part of the shaft.
15. Next, the conduit protection is set over the protruding wires to secure and water proof the exterior of the device.
16. The wattmeter is separate and should be manufactured with proper plugs to attach the protruding wires on land.
17. The wattmeter has leads which are connected to a battery; the product is complete.

About five to six months were needed in order to complete the research and determine which components were best for the product. Assembly time was relatively quick. In about a week of all the parts being received, the device was put together. The PVC housing and end caps were drilled with their required holes in one day. In that same day the guide rails were attached. Construction of the housings for all the internal components were also done in one day. With proper measurements, the two shafts needed for the prototype were constructed by FSU’s machine shop in a day as well. Promptly, the prototype was finalized when these shafts were received. By the next day, all pieces were put together and the prototype was complete.

The complexity of the design is fairly simple. There is not much in the design that would be deemed unnecessary. Every component has a needed function. However, given more time and research, it is probable that some components of the design should be replaced. The alternator and gearbox have startup torques that are not optimally small. This added force that the flowing water needs to overcome is not ideal and better components can be chosen to improve the devices production. Also, the turbine was chosen merely for its availability and does not have optimal characteristics. There are better turbines that can be used with optimal pitches to grasp more energy from the flowing water. It would not be necessary to add or remove parts, only optimize.

9.2 Reliability

In the coming week, the device will be ready for testing and the team will begin to be more suited to answer questions about reliability.

There are a number of things that will be looked at for reliability testing; the most important being waterproofing. With ample amount of sealant in every crevice and a failsafe sponge put into the housing, the device should be able to stay fully submerged in water over long periods of time. After initial testing, how well the device does in avoiding any type of water damage is important.

Next, the device will have to be looked at mechanically to see how the components do when under the actual conditions of a flowing body of water. The speed of the turbine determines the power production of the rest of the machine. Thus, the team needs to see how fast the turbine will spin when placed in water, as well as any components not accounted for previously which would affect the turbine’s performance. For example, will the turbine spin hard and fast enough in the water to compensate for the starting torques of both the gearbox and alternator? Will the water have enough force to spin the turbine on its own at all? These are questions the team needs to look out for to determine reliability.

Electrical components will be looked at in initial testing to see how much power the device is producing in real world application. It is important for the team to gather electrical data to see if the device is even experimentally worth using. Does the power production exceed the minimum required for keeping a handful of LED lights running for hours on end? Is the production constant, or does it decrease over time? Does internal resistance in the wiring affect the power production, or is it negligible? These are questions the team needs to address from an electrical standpoint to determine how the device will fair electronically. Once the preliminary tests are run, it will be possible to determine what kind of longevity the device will see.

10 Operations Manual

10.1 Project Assembly

10.1.1 Mechanical Components

Due to the modular design of the hydroelectric generator, assembly of the device is simple and straightforward. The first step in assembling the generator is to connect the alternator and gearbox by inserting the shaft of the alternator into the output of the gearbox. Both the alternator and the gearbox have frames that make it easy to attach the two of them to the sliding rails inside of the housing. The wiring on the back of the alternator should then be run through the waterproof conduit on the back end of the housing. Once the alternator/gearbox assembly is attached to the rail system, the turbine shaft should be fed through the waterproof bearing on the front cap, and attached via coupler to the input shaft of the gearbox. Using the set screw on the fan blade, connect the blades to the rest of the assembly. The front cap then needs to be sealed by placing it over the rubber seal and tightening the screw clamps.

10.1.2 Electrical Components

Outside of the hydroelectric generator the electronic components consist of the wattmeter, wiring, and battery that is provided by the user. The wattmeter is conveniently attachable at the ends of the positive and negative cables coming outside the hydroelectric generator. As can be seen in the schematic, the wattmeter goes in between the cables out of the charge controller and the battery. For convenience, the wattmeter will plug into two 2 ft. long positive and negative leads that can be connected to any battery the user desires. Coming out of the PVC pipe is a hollow conduit made out of PVC and steel that will serve to waterproof electrical wiring coming out of the device. They will be adorned with fittings that will allow them to easily be screwed into the PVC housing of the hydroelectric generator. The wires will be housed in the conduit for twenty feet outside of the hydroelectric generator. On land, the wires in the conduit will be plugged into the wattmeter. From the wattmeter, wires will be plugged into the 2ft. long leads that shall go to the user’s battery.

10.2 Operations Instructions

10.2.1 Transport

The personal hydroelectric generator is unique in that it has a compact design that makes transporting the device much easier. The entire apparatus will fit easily into the bed of a pickup truck or on a small trailer, with plenty of space for other supplies to be packed. Removing the turbine blades by loosening the set screw on the hub of the turbine will allow the user to save more space. When loading and unloading the generator, take caution to avoid bending the turbine blades or unplugging wires/conduit.

10.2.2 Installation

Once the generator has been unloaded, determine the best location in which to install the device. Proceed cautiously into the water near the location in which electricity is desired. To give the turbine blades room to spin without risk of impacting the river/creek bottom, the device needs to be placed at a depth of at least four feet. Due to the length of the electrical conduit, the device also needs to be within 15 feet of dry land. Find a location that satisfies these two constraints, and ensure that there are no underwater obstructions or hazards. Before placing the generator in the flowing water, check thoroughly that both end caps are secured tightly and that the set screw of the turbine blade is tightened. Ensure that the conduit will not snag on anything and cautiously enter the water. It is important to keep the blades of the turbine above the water when maneuvering to the installation location. If the turbine blades enter the water, they may begin to rotate and present a hazard to the user. Be sure to point the turbine directly into the current, as this maximizes the amount of power that can be harnessed, and reduces the risk that the device will shift or come loose in the water.

10.2.3 Power Generation

Once the device has been installed in the river, connect the cables from the end of the conduit to a battery. When the turbine is spinning and the wattmeter is properly connected to the wiring and battery, the user will see the proper readings for amperage, voltage, and wattage to the battery.

This allows the user to easily monitor what is going on electronically. It is imperative that the generator should not be used if the charge controller is not in place. Because the charge controller is set to output a maximum of 14V, it is important that the user only use a 12V battery in the system. The cutoff at 14V will ensure that the voltage in the battery never gets too high to cause damage. If a user installs a battery with a voltage that is too low or high, it is possible that the battery will overcharge or never reach its full capacity.

10.2.4 Deconstruction

When the user is finished using the Personal Hydroelectric Generator at the desired location and wants to remove it from the flowing stream for transportation, deconstruction must take place. The user must be mindful of the electrical attachments and be sure that the wires connected to the battery are disconnected and grounded. When the user begins removing the generator from the water, the user must remove it slowly and carefully to allow the turbine to slow or stop before being moved onto land for transportation.

11 Troubleshooting

Throughout the lifetime of any device, there are bound to be some small issues or problems that occur. The purpose of this section is to help the user with some of the more common issues that might be faced during the lifetime of the product.

11.1 Water is leaking into the housing

The introduction of water into the housing of the hydroelectric generator is the greatest threat to the operation of the device. If too much water leaks into the housing, the electrical components could be severely damaged and require replacement. At the first sign of any water leaking into the generator housing, the device should be immediately disconnected from any batteries or other electrical equipment. Remove the PVA sponge from the housing, then wring it out until it is dry. If the leak is significant, the source needs to be found and addressed immediately. Remove the interior components by taking the sliding rails off of their tracks. Place the housing and end caps in water to locate the leak, and use marine grade epoxy to repair the leaks.

11.2 The turbine is spinning, but no power is being generated

If the turbine blades are rotating and no power is being produced, this means that there is a problem with either the wiring in the device or the shaft connections. See Figure 8 to ensure that everything is connected properly inside and outside of the device. Improper connections will disrupt the flow of electricity and no power will be produced. Also, make sure all set screws to the shaft couplings are tightened.

11.3 The turbine blades will not spin

Without rotation of the turbine blades, no power can be produced. First, check the charge of the battery to ensure that it is not completely discharged. A dead battery puts a very large internal resistance on the alternator, which therefore requires much more torque to spin. Next, check the set screw on the turbine blade hub to verify that it is indeed tightened. If not, tighten the set screw to connect the turbine blades and the input shaft. Lastly, if the blades still do not turn, it is likely that the water is not moving fast enough to provide the required torque to spin the alternator. The only remedies to this problem are to either find a new location with faster flowing water, or wait for the flow at the current location to increase.

12 Regular Maintenance and Spare Parts

12.1 Maintenance

In order to extend the life of the device, it is imperative that routine maintenance is performed. Every time the device is removed from the water, check the interior for any signs of leakage and clean up any water that may have entered. Allowing water to collect inside of the housing will create fatal issues with the alternator and render the part useless. Check the PVA sponge regularly and dry it out to maintain its absorbent properties.

Check all connections, ports, and wires before each use to check for any corrosive damage that may have occurred. Damage to these components may disrupt current flow and prevent any energy from being produced. Disconnect the battery before doing any maintenance on any electrical components of the device.

Routinely check the turbine blades to make sure they have not suffered any damage. Any major nicks or bends in the blades will result in a loss of power production, so that is important to try to protect the blades at all times.

12.2 Spare Parts

The personal hydroelectric generator was designed so that it will operate with minimal user work required, however, it may be necessary to replace certain parts at various intervals. Some parts that may be useful to keep on hand are listed below. The bill of materials for the personal hydroelectric generator prototype is found in the appendix.

- Bolts for interior housing
- Rubber gaskets for end cap
- Screw Clamps
- Wiring

13 Conclusion

Team 7 produced a Personal Hydroelectric Generator capable of producing 80-130W of power while still being lightweight enough to be transported into a flowing system of water. The designed product took components comprised of a turbine, gearbox, and alternator placed inside a waterproof housing. Issues involving waterproofing, heat dispersion, and power production were dispelled through testing during development of the system. The final design involved a completed generator able to produce power but anchoring of the system was not completed by Team 7 and may be a future endeavor. Throughout the entire program, ethical and safety issues with users/operators/wildlife were taken seriously and upheld. Team 7 also entered into many entrepreneurial competitions where they placed 3rd in the ACC Innovation Competition amongst 77 other projects. Team 7 was able to complete the project on schedule and keep within the budget of $2,000.

14 References

[1] How Does a Generator Create Electricity? (2013). Retrieved from Diesel Service & Supply: http://www.dieselserviceandsupply.com/How_Generators_Work.aspx

[2] Generator Fundamentals. (2011, 08 19). Retrieved from Aurora Generators Inc.: http://www.auroragenerators.com/news/29-products/generator-controllers/29-generator-fundamentals

[3] History of Hydropower. (n.d.). Retrieved from Energy.gov: http://energy.gov/eere/water/history-hydropower

[4] Products. (2015). Retrieved from HydroBee: http://hydrobee.com/products/

[5] BackPack Power Plant. (2014). Retrieved from Bourne Energy: http://www.bourneenergy.com/futuremain.html

[6] Hammar L, Andersson S, Eggertsen L, Haglund J, Gullström M, Ehnberg J, et al. (2013) Hydrokinetic Turbine Effects on Fish Swimming Behaviour. PLoS ONE 8(12): e84141. doi:10.1371/journal.pone.0084141

15 Biography

Joseph Bonfardino:

Joseph is a native of a small city in Central Florida called Spring Hill. From a young age he always had an inquiring mind wondering how and why things work the way they do, and this lead to a thirst for knowledge. Joseph graduated from Central High School in 2012 with his Associates of Arts Degree, and then moved to Tallahassee, FL to further his education. Currently, he is a Florida State Senior studying Mechanical Engineering with a technical track in Thermal Fluids. Upon graduation in May 2016, he plans to start his career in a renewable energy industry.

Galen Bowles:

Galen Bowles is a senior mechanical engineering student at Florida State University with a focus in Thermal Fluids. Galen was born in Alexandria, Louisiana but grew up in Panama City, Florida where he graduated from the local state college, Gulf Coast State College. After Florida State, Galen plans to remain in the Florida panhandle and continue work and research on renewable energy conversion systems.

Brendan McCarty:

Born in Kansas City, Brendan moved to South Florida at a young age and loved working on the family boat with his father. A senior at FSU, Brendan plans to graduate in the Spring of 2016 with a Bachelor of Science in Mechanical Engineering. Currently taking classes in the Material Science track, Brendan plans to get a job in the same field, hopefully somewhere in the Southeast.

Parth Patel:

Parth is a senior at Florida State University pursuing a Bachelor’s degree in Electrical Engineering. Born in Atlanta, Georgia but my upbringings can be credited to Tallahassee, Florida. Growing up his fascination in how electronics and power tools were designed played a big role in pursuing an engineering degree. Since January of 2015 he has been working at Florida State University’s Utilities and Engineering services, learning and managing the power distribution network within the university.

Shane Radosevich:

Shane Radosevich is a senior in Mechanical Engineering at Florida State University completing his final year. He plans on working after graduation for himself or in a management position for a large company. He hopes to combine his real world experiences with knowledge gained from his mechanical engineering degree to creatively design solutions to problems in life. Born in Allentown Pennsylvania and having lived up and down the east coast Shane has many experiences and real world knowledge about culture having traveled over most of the United States and numerous other countries.

Ilan Sadon:

Ilan is a senior graduating in May of 2016 with his BS in Electrical Engineering. He spawns from the wetlands of Miami Beach, FL. The man is one of the two electrical engineers on the project bringing his expertise in the subject to the team. Ilan's interest into the field began as a sophomore in his Physics II class, when he realized how much more electromagnetics appealed to him than the civil engineering track.

Brandon Shaw:

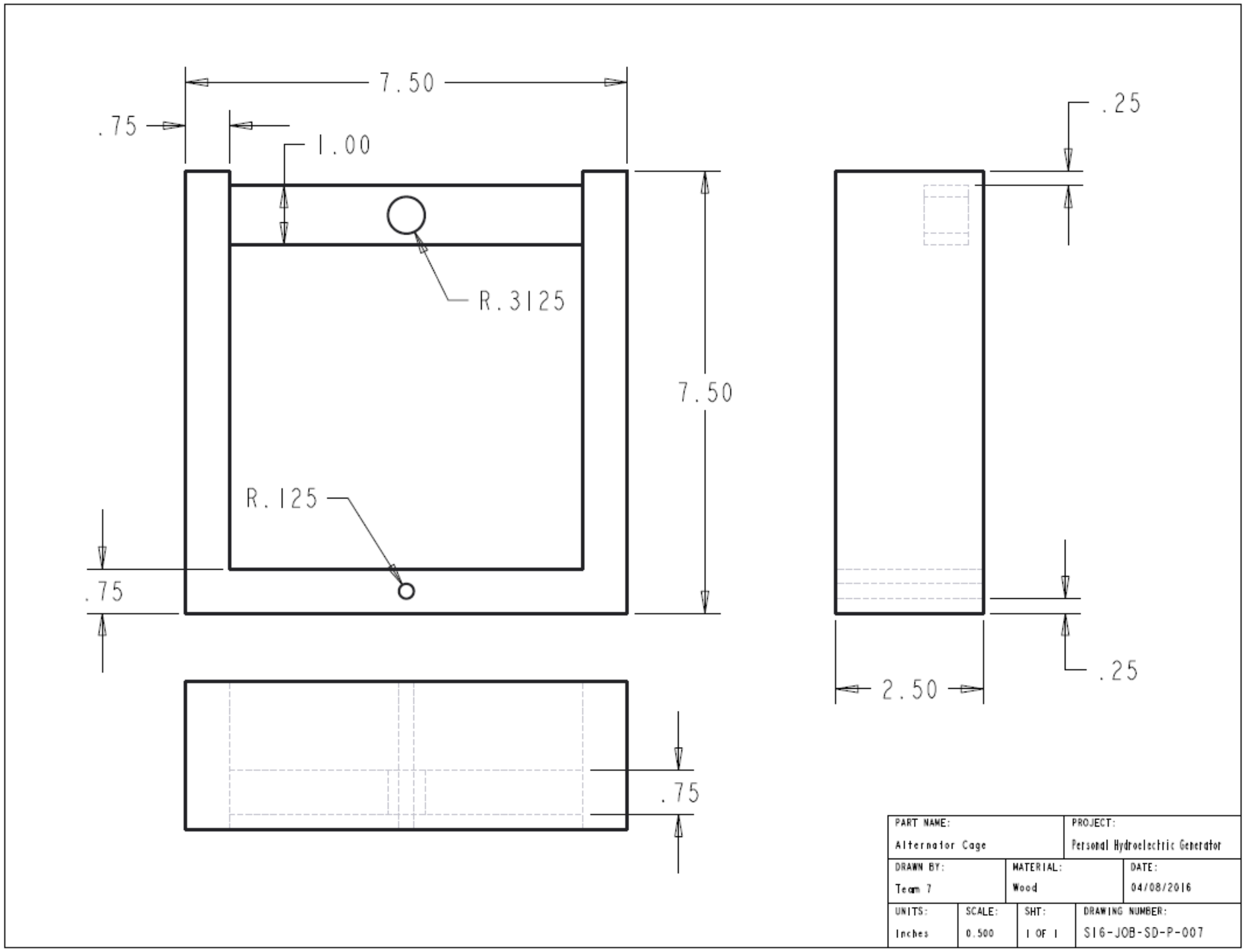
Brandon Shaw is a senior mechanical engineering student at Florida State University. Brandon was born and raised in Saint Johns, Florida until his move to Tallahassee for college. He has a held a sales management role since arriving in Tallahassee and continues to work at Ring Power Corporation in the heavy equipment parts department. Brandon has also had three internships during summers to further his understanding of the mechanical engineering field. These internships include the following: mechanical engineering intern at Phoenix Products which is the power systems division of Ring Power Corporation, a reliability and maintenance engineering internship at CEMEX USA, and a technical research and marketing internship with Polston Applied Technologies. Brandon’s future career will involve either engineering sales or project management.

Matthew Vila:

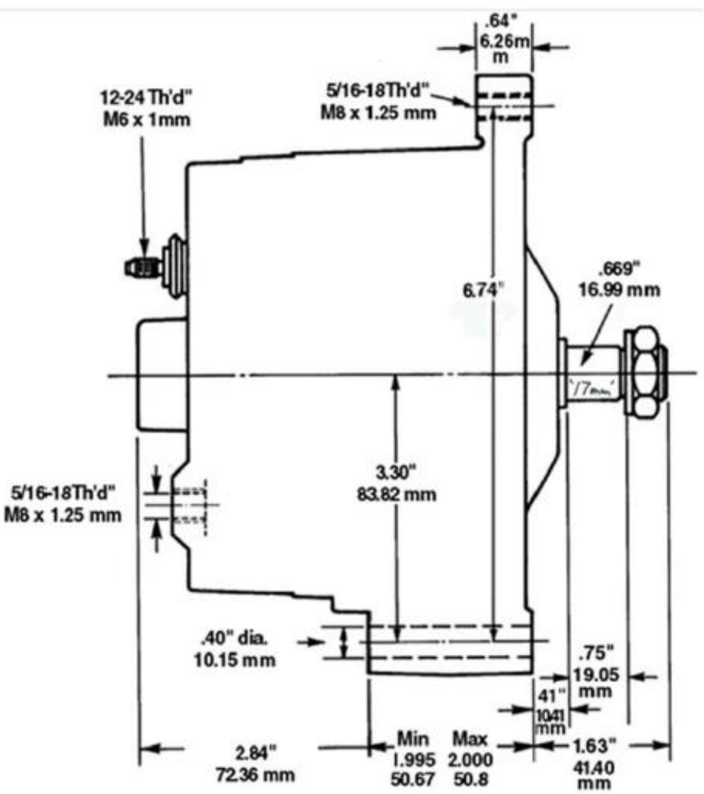
Matthew is a born and raised Floridian who grew up in the South Miami area. He is a representative for the American Society of Mechanical Engineers (ASME) at the FAMU-FSU College of Engineering. His focus is on Materials Engineering and plans on working in the medical field with prosthetics and joint replacement design.

16 Appendix

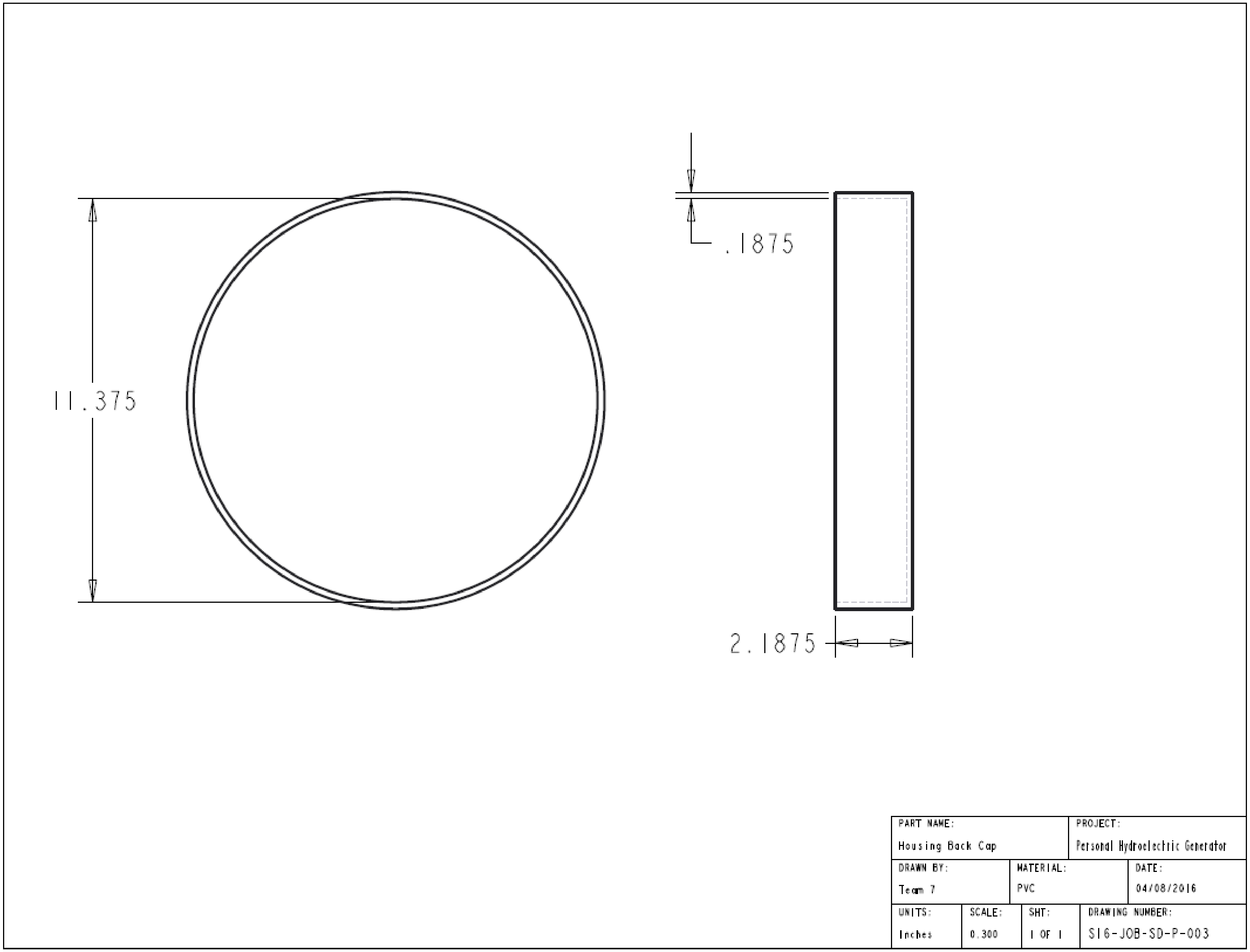
16.1 Engineering CAD Drawings



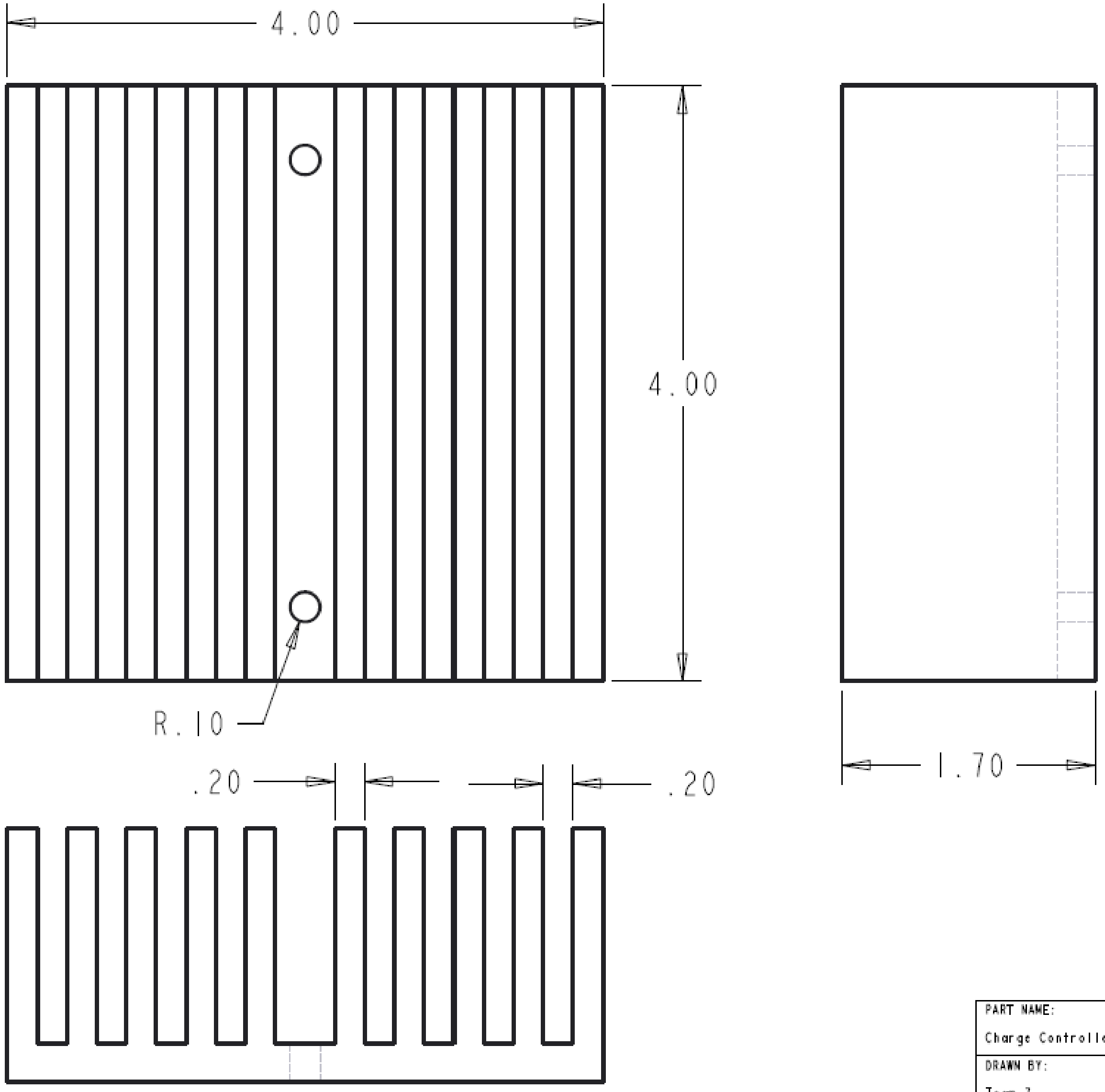
PART NAME: Alternator Cage		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: Wood	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.500	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-007



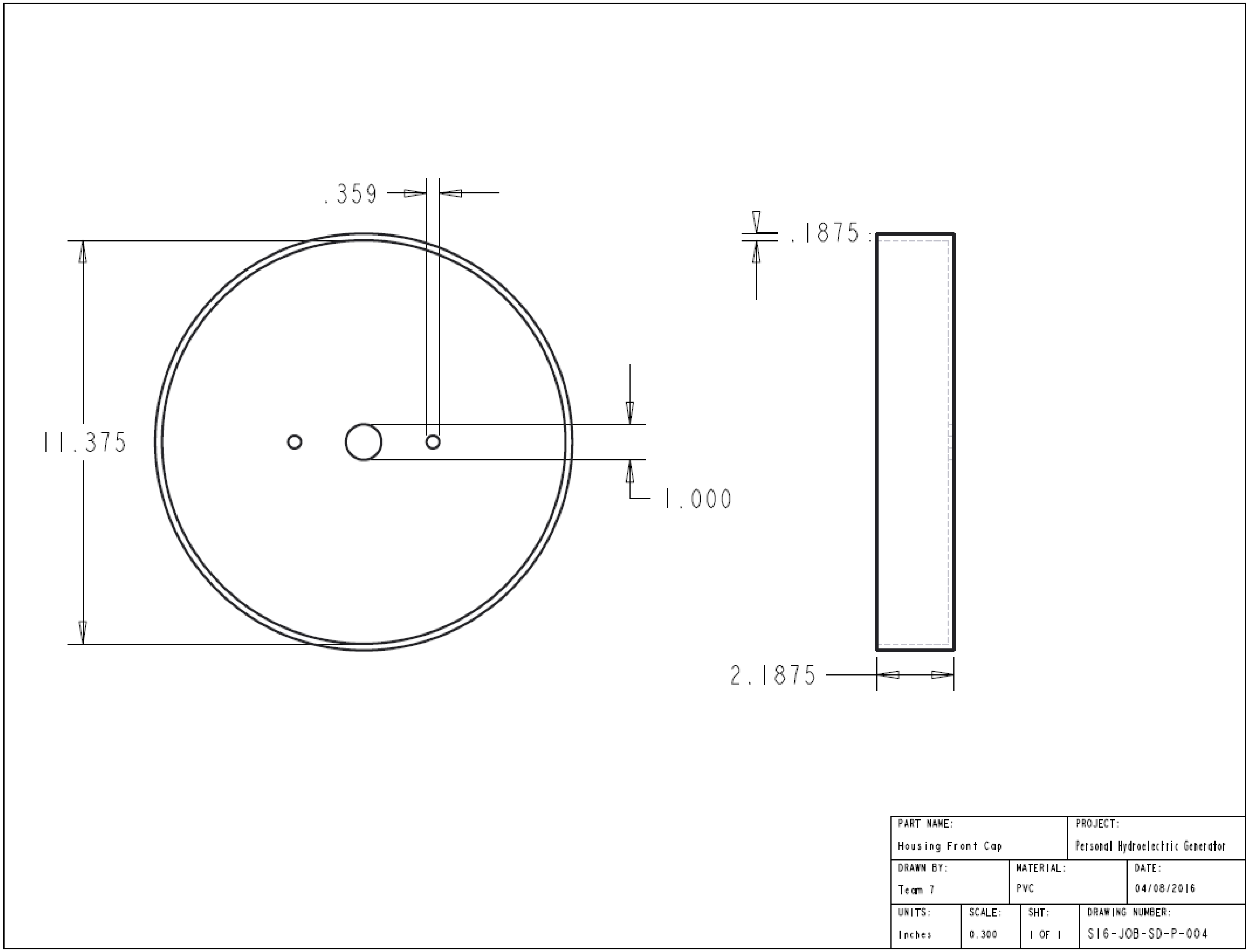
PART NAME: Alternator		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: Steel	DATE: 04/08/2016	
UNITS: mm	SCALE: n/a	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-010



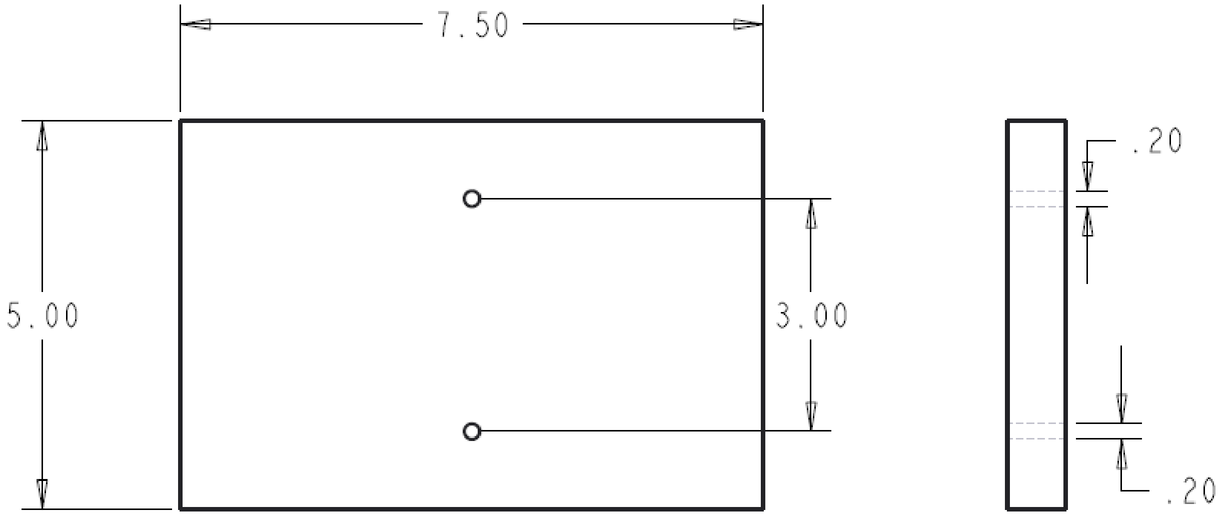
PART NAME: Housing Back Cap		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: PVC	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.300	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-003



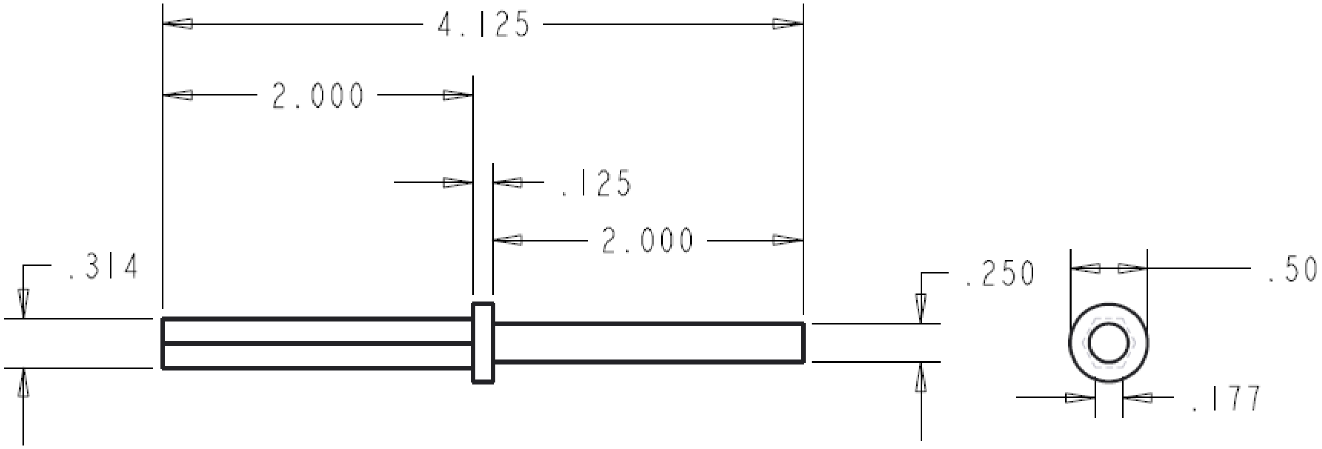
PART NAME: Charge Controller		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: n/a	DATE: 04/08/2016	
UNITS: Inches	SCALE: 1.000	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-012



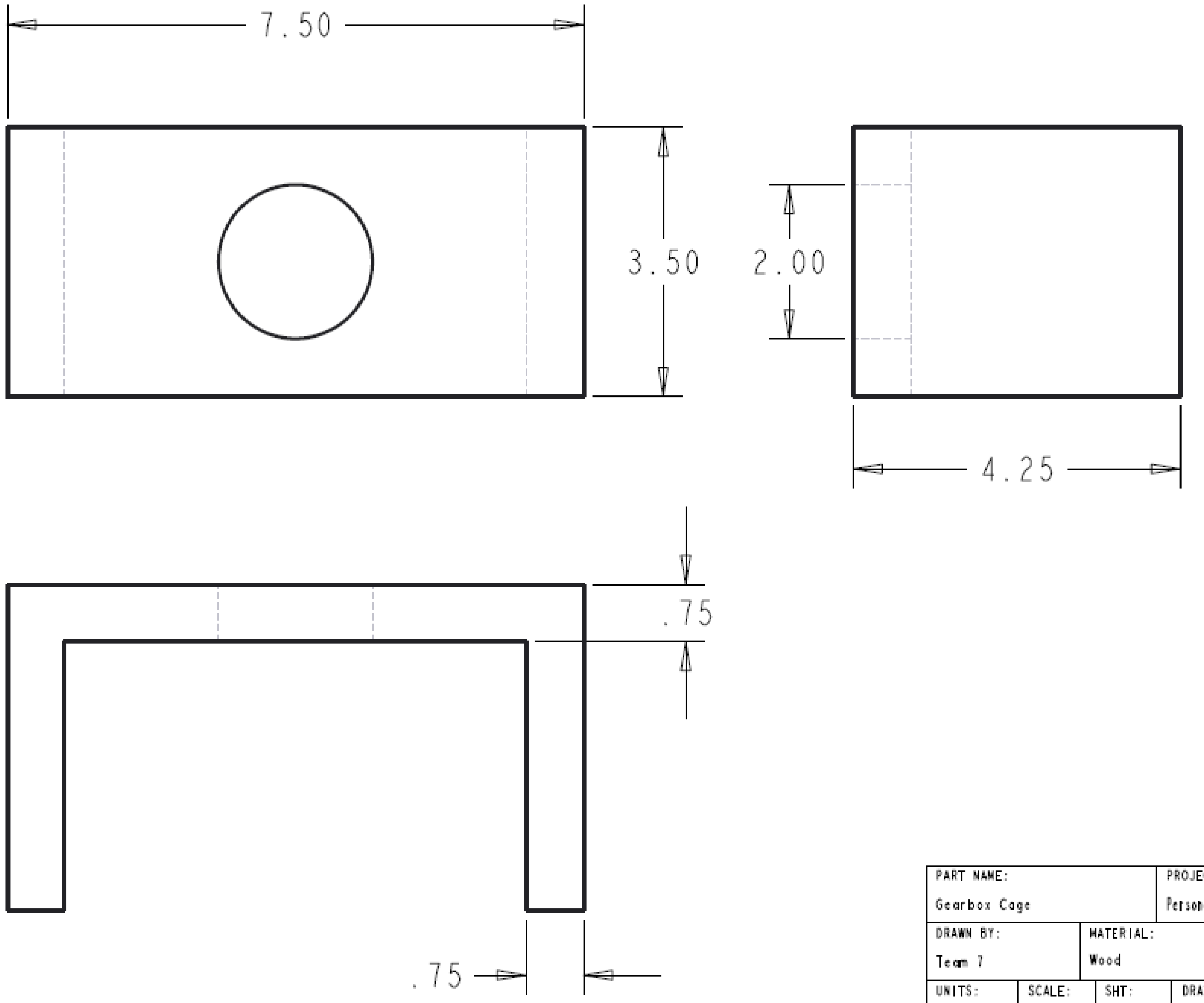
PART NAME: Housing Front Cap		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: PVC	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.300	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-004



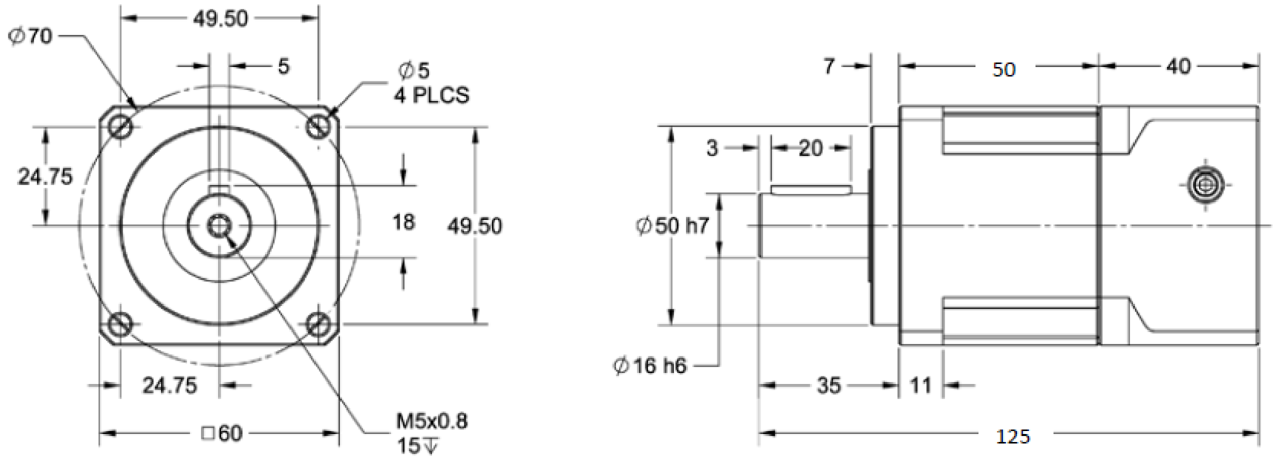
PART NAME: Charge Controller Cage
PROJECT: Personal Hydroelectric Generator
DRAWN BY: Team 7
MATERIAL: Wood
DATE: 04/08/2016
UNITS: Inches
SCALE: 0.500
SHT: 1 OF 1
DRAWING NUMBER: S16-JOB-SD-P-013



PART NAME: Gear-Alternator Shaft		PROJECT: Personal Hyrdoelectric Generator	
DRAWN BY: Team 7	MATERIAL: Steel	DATE: 04/08//2016	
UNITS: Inches	SCALE: 1.000	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-005

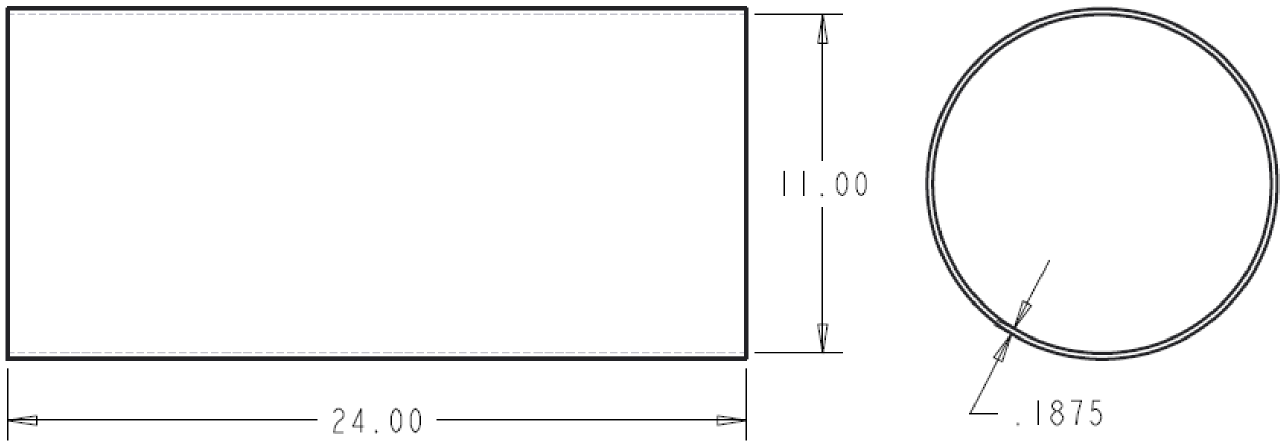


PART NAME: Gearbox Cage
PROJECT: Personal Hydroelectric Generator
DRAWN BY: Team 7
MATERIAL: Wood
DATE: 04/08/2016
UNITS: Inches
SCALE: 0.500
SHT: 1 OF 1
DRAWING NUMBER: S16-JOB-SD-P-008



PART NAME: Gearbox		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: n/a	DATE: 04/08/2016	
UNITS: mm	SCALE: n/a	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-0014

I



PART NAME: Housing

PROJECT: Personal Hyrdroelectric Generator

DRAWN BY: Team 7

MATERIAL: PVC

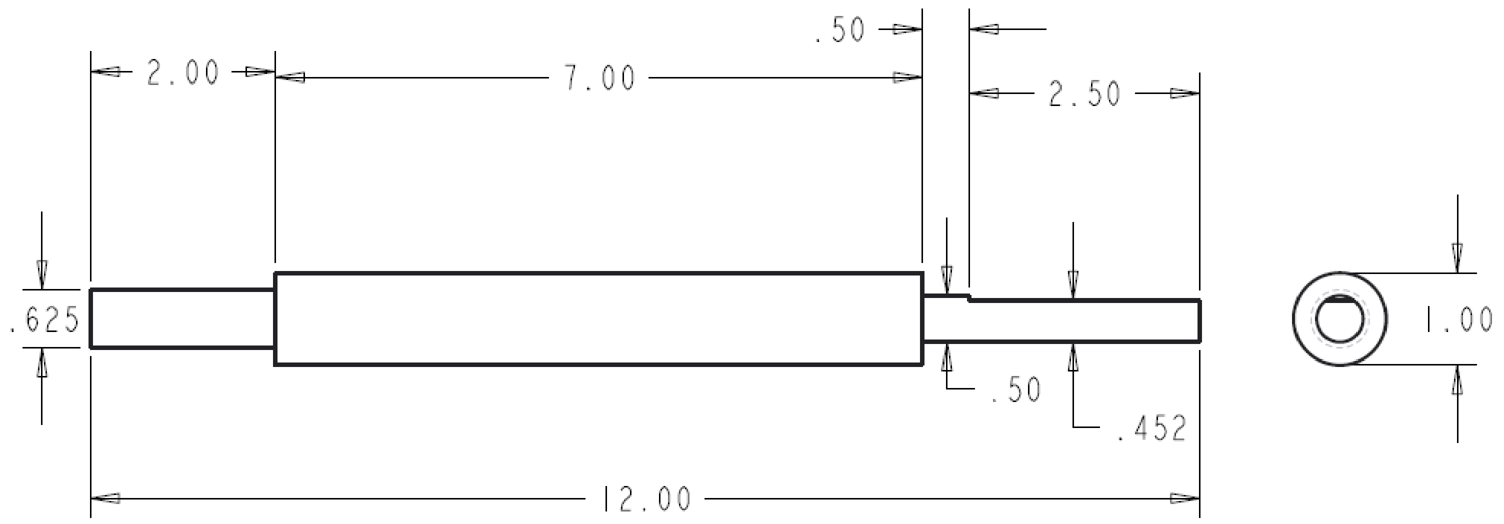
DATE: 04/08/2016

UNITS: Inches

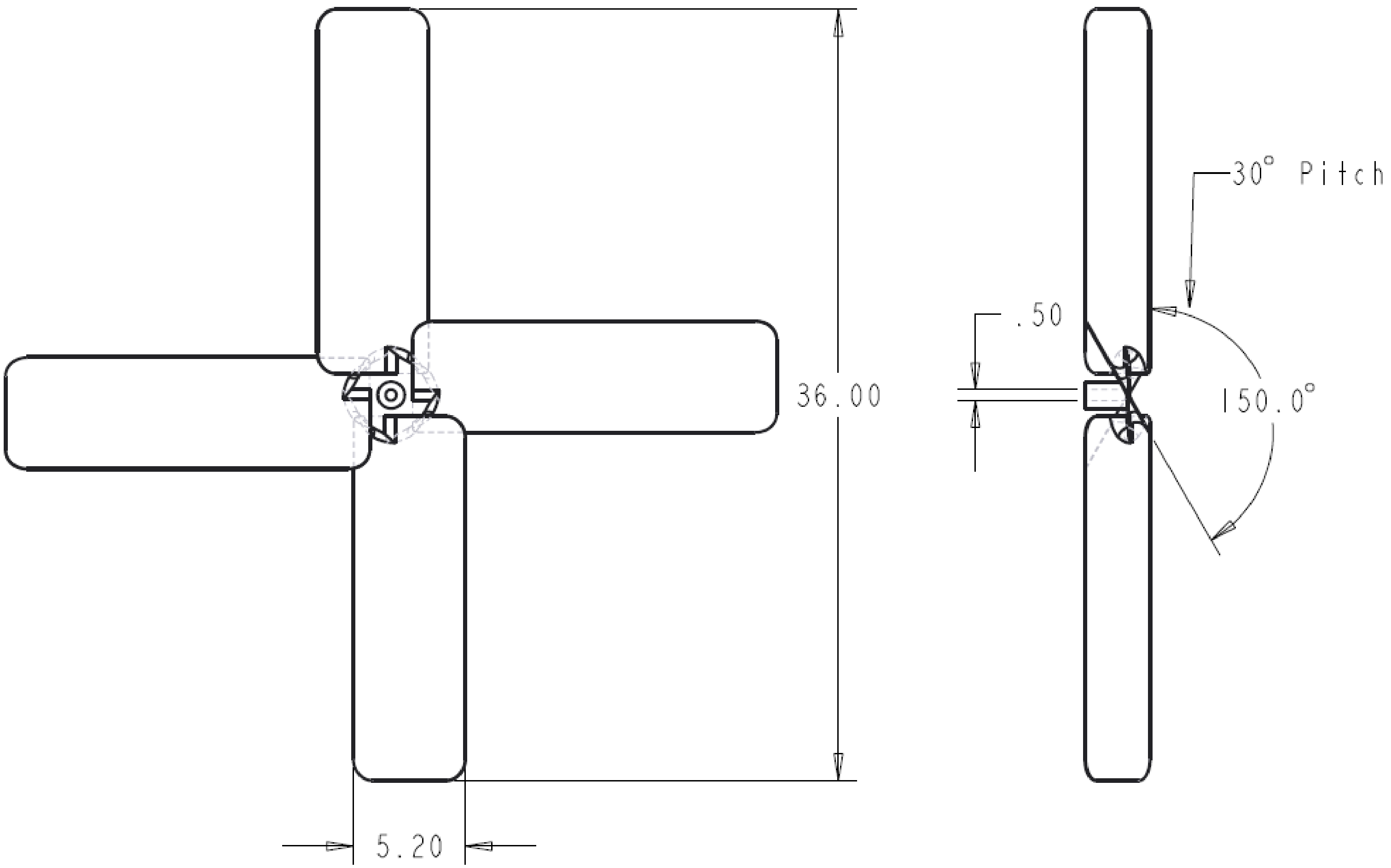
SCALE: 0.200

SHT: 1 OF 1

DRAWING NUMBER: S16-JOB-SD-P-001

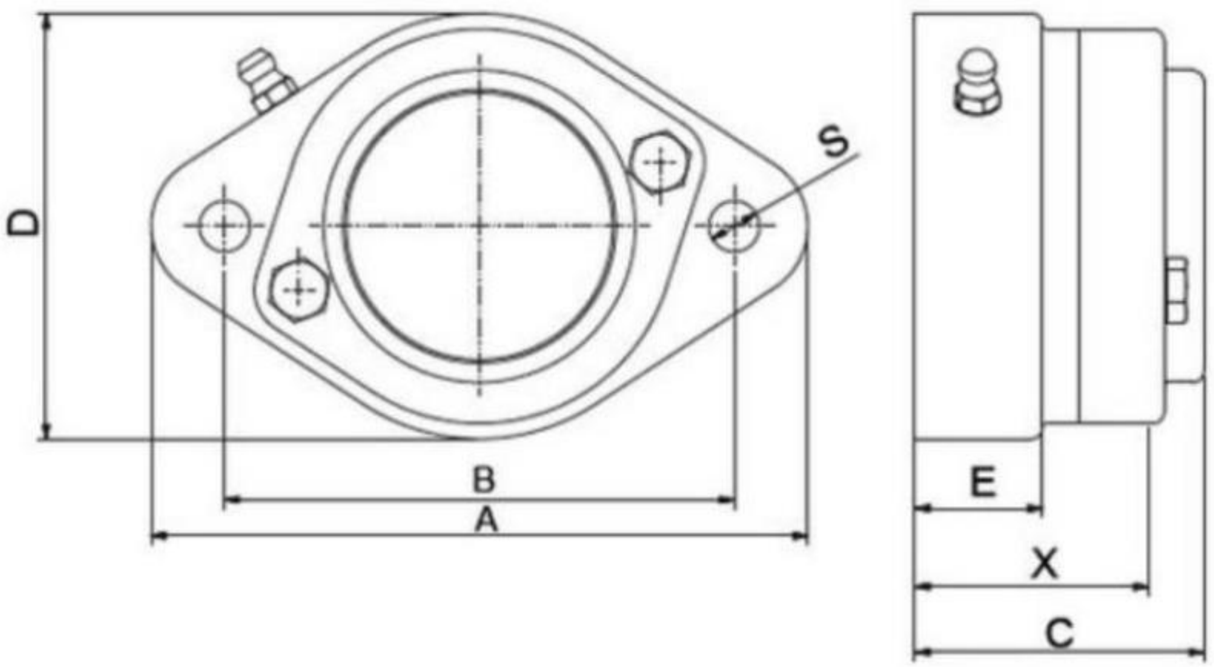


PART NAME: Input Shaft	PROJECT: Personal Hydroelectric Generator		
DRAWN BY: Team 7	MATERIAL: Aluminum	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.600	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-006



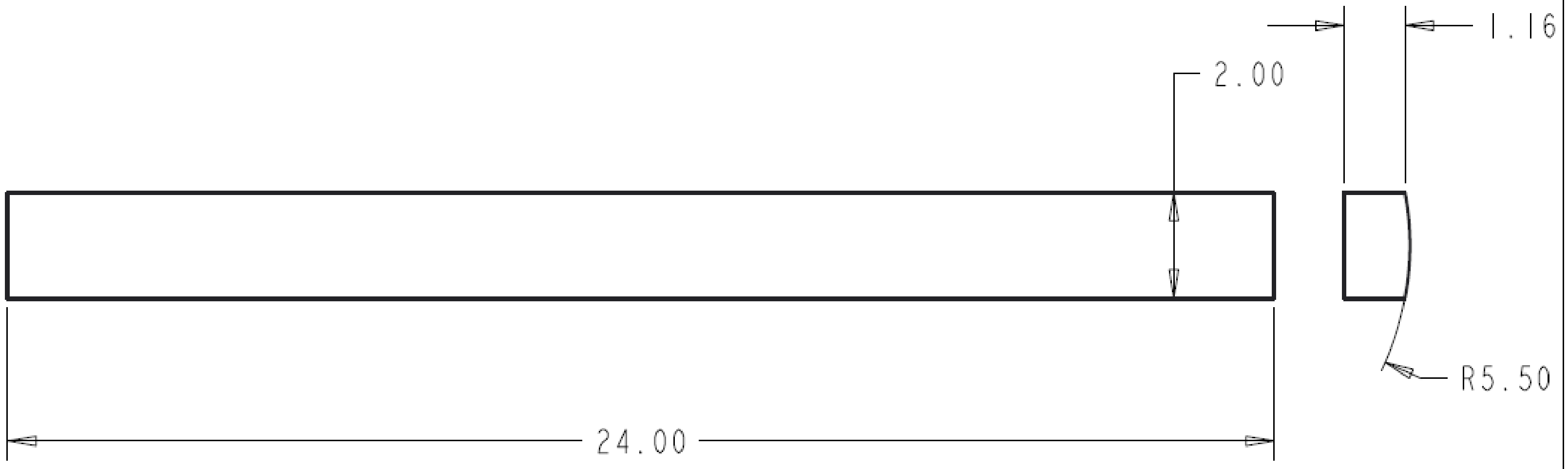
PART NAME: Turbine		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: Aluminum	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.150	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-002

L



Type F2 Flange bearing	Catalog No. closed cover	Catalog No. open cover	A	B	C	D	E	S	X	Weight [kg]
Ø25 mm	NG25F20	NG25F21	123mm	99mm	52 mm	79mm	22.5 mm	9 mm	44mm	0.51

PART NAME: Waterproof Bearing		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: n/a		DATE: 04/08/2016
UNITS: mm	SCALE: n/a	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-011



PART NAME: Wooden Rail		PROJECT: Personal Hydroelectric Generator	
DRAWN BY: Team 7	MATERIAL: Wood	DATE: 04/08/2016	
UNITS: Inches	SCALE: 0.350	SHT: 1 OF 1	DRAWING NUMBER: S16-JOB-SD-P-009

16.2 CAD Schematics