

# University of Dayton Solar Splash 2014 - 2015 Team Boat #4



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## Executive Summary

The University of Dayton (UD) competed in the Solar Splash competition held in Dayton, Ohio last year and achieved great success in the endurance section of the competition. The team struggled last year in the speed section of the competition due to the heavy weight of the boat and the fixed trim tab design, causing the boat to plane out slowly. For the 2014-2015 competition the team was completely reformed with undergraduate students who undertook this boat for their senior design class. The fall team consisted of two electrical engineers and four mechanical engineers. The team focused its efforts over the fall and spring terms to reduce the weight of the boat, implement data logging of the motor controller and photovoltaic (PV) system, and upgrade the PV system to allow for better efficiency. During the fall semester the team focused on creating conceptual designs for implementing a new variable trim tab design to replace the fixed trim tab design from last year's competition. The team also focused its efforts on upgrading the solar panels and solar controllers to increase efficiency and reduce weight by replacing the PV system with thin and lightweight solar panels. During the spring semester a great deal of time was spent on research to determine what solar panels and solar controllers would work best for the competition. Another major research task for the fall term was to determine the best way to monitor/log data from both the motor and PV system.

In the spring semester we lost one electrical and two mechanical engineers but gained back one mechanical and one electrical engineer in the spring senior design class. After this change in personnel we still had three of the original team members to continue the previous semesters work. With the newly formed five person team the mechanical engineers focused their efforts on fabricating the new adjustable trim tab, designing a newer traditional steering design to reduce weight, and designing mounts for the new solar panels and solar controllers. Three new 160W solar panels from Qsolar [1], a leading solar panel supplier headquartered in Canada, were purchased based on their light weight and max wattage that they were able to produce per the rules of the competition. Three new solar controllers from Morningstar [2], the world's leading solar controllers and inverters supplier, were purchased to achieve a design in which each solar panel had its own independent solar controller. The new Morningstar solar controllers were researched to be the optimal choice for the 160W solar panels from QSolar. They were also purchased because they allowed the team to purchase two additional accessories for the controllers. The first new accessory purchased was Morningstar's PC MeterBus Adapter [3], which allowed Morningstar's MSview software to run on a computer to log real time data from the solar panels. Another accessory was Morningstar's Remote Meter [4], which allowed the driver to monitor the solar panel voltage and wattage output in real time with a heads up LED display.

To reduce weight the team decided to remove the bulky steering wheel and dash. The dash and dividers for the motor were previously made of a high gage aluminum and were replaced by light weight polycarbonate. The original dash was removed and the new dash was built into the motor divider to reduce weight. The wiring for the dash remained the same,

however the throttle was redesigned. The  $4.7\text{k}\Omega$  resistor within the throttle was replaced with a  $2.1\text{ k}\Omega$  resistor to allow for more precise throttling. This adjustment allowed the boat to operate at a lower RPM and accelerate more precisely by the operator.

The team decided to keep the original motor kit purchased from The Robot Marketplace [5], a robotics supplier located in Florida, and the original direct drive drivetrain system from Glen-L Marine [6], both of which were used in last year's competition. The twelve degree mounting angle for the driveshaft was also unchanged for this year's competition. The motor was programmed to operate at 36 Volts DC while the wiring for the controller, throttle, E-stop switch, contactor, ignition switch with key, and a forward / reverse selector switch weren't upgraded. Three 12V Optima Batteries [7] that were tested by last year's team showed to have the best power-to-weight ratio and therefore are still being used for this year's competition. All of the previous mentioned items remained unchanged from last year's competition other than the throttle resistor. Since last year's competition the team focused on implementing many new improvements to last year's boat with the goal of creating a sustainable boat that could be modified further for competitions to come.

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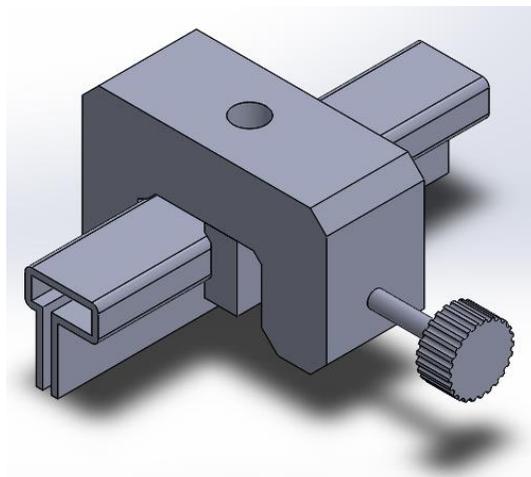
## Overall Project Objectives

The team's main goal is to qualify and compete in the Solar Splash 2015 competition. Given that this is the second year for UD to compete in this competition, the main deliverable for the Spring 2015 term was to improve in overall performance of the boat's speed and power consumption.

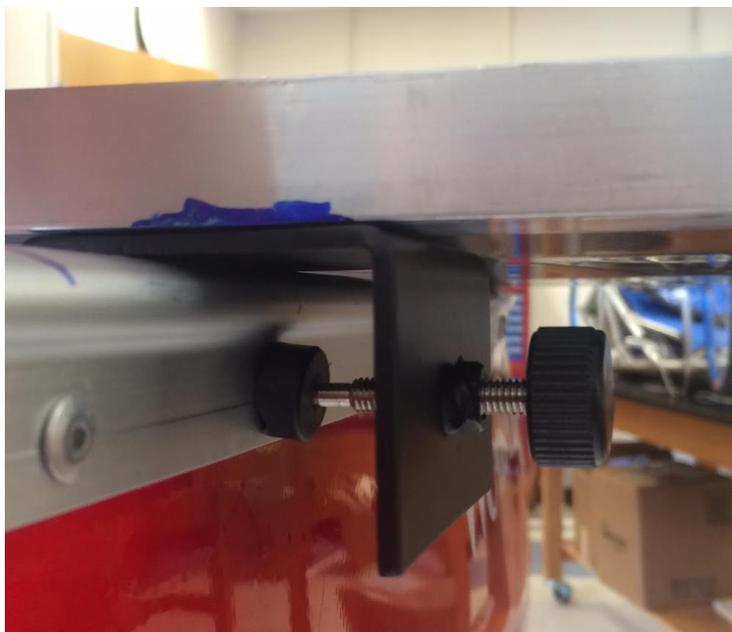
## Solar System Design

Not only were the previous solar panels heavy, the older mounting system was burdensome and overdesigned for the strength needed. Because aluminum railing was used to completely frame the solar panels as well as attach them to the boat, the mounting system was far heavier than needed. In addition, the method used was difficult and time consuming to take on and off. While ease of removability may not be a design criterion for much of the boat, the solar panels do have to be removed and replaced between events and therefore must be able to be removed with some degree of ease.

The mounting system for the new solar panels was designed to accommodate the new thin and light weight panels. Much like the new solar panels the mounting system was designed to make it as light weight as possible. The solar panel mounts featured two aluminum U-channel extrusions which the solar panels were screwed into. Thick polypropylene washers sat within the U-channel on each side of the solar panel to create a snug fit as the screws and nuts completed the assembly. A mount was designed in Solidworks to attach the aluminum U-channel to the aluminum railings of the boat as seen in Fig 1. Similar to the mount the team designed, a microphone mount was later purchased to achieve the teams design goal as seen in Fig. 2. These mounts were chosen because they allowed for ease of use when attaching and detaching the solar panels from the boat. The layout for how the solar panels were mounted to the boat can be seen in Fig. 3.



**Fig. 1: Solar Panel Rail Mount Design**



**Fig. 2: Solar Panel Rail Mount with Solar Panel**

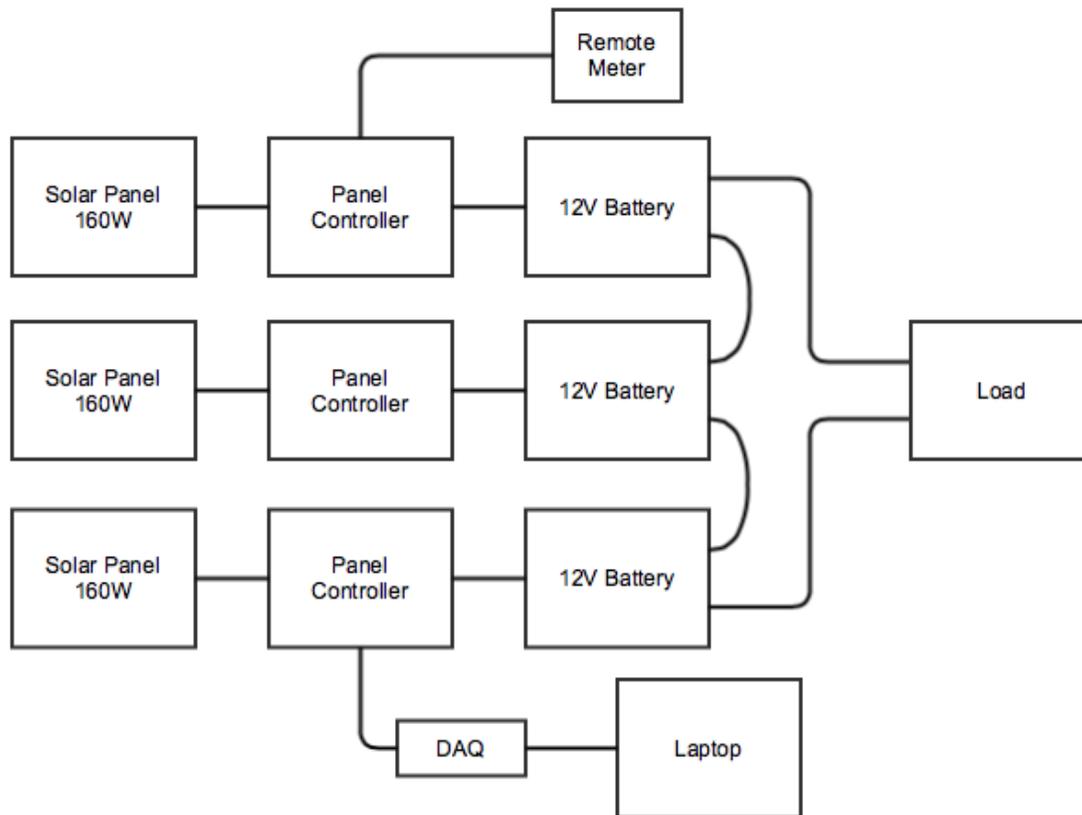


**Fig. 3: Solar Panel Layout**

The solar system for this year has changed slightly from last year's design. Last year's design used two 175W panels and one 100W panel from Solarworld[8], for a total max power generation of 350W. The two 175W panels were wired into a single charge controller, which in turn charged two 12V batteries. The 100W panel had its own solar controller and 12V battery to charge.

The new system, as seen in Fig. 4, is much more symmetric, electrically speaking. Now, the design incorporates three QDRIVE solar panels from Qsolar [1]. Each panel is capable of generating 160 watts maximum power and is rated for up to 63.6 volts. This maximized the power generation capability of the system to 480W. The panel controllers for the new design

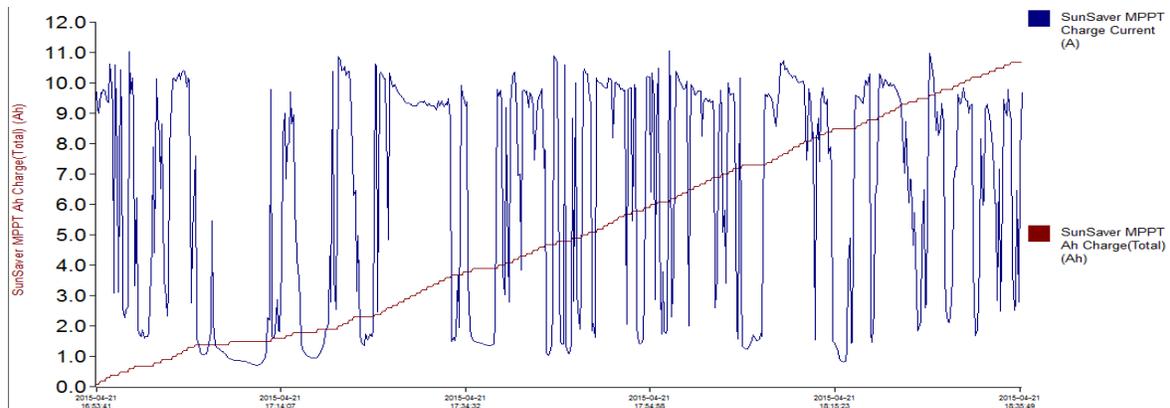
needed to be able to handle up to 70 volts to be safe. A suitable choice for the project was the SunSaver MPPT from Morningstar [2]. Using maximum power point tracking (MPPT), these solar controllers are capable of generating more power for the batteries.



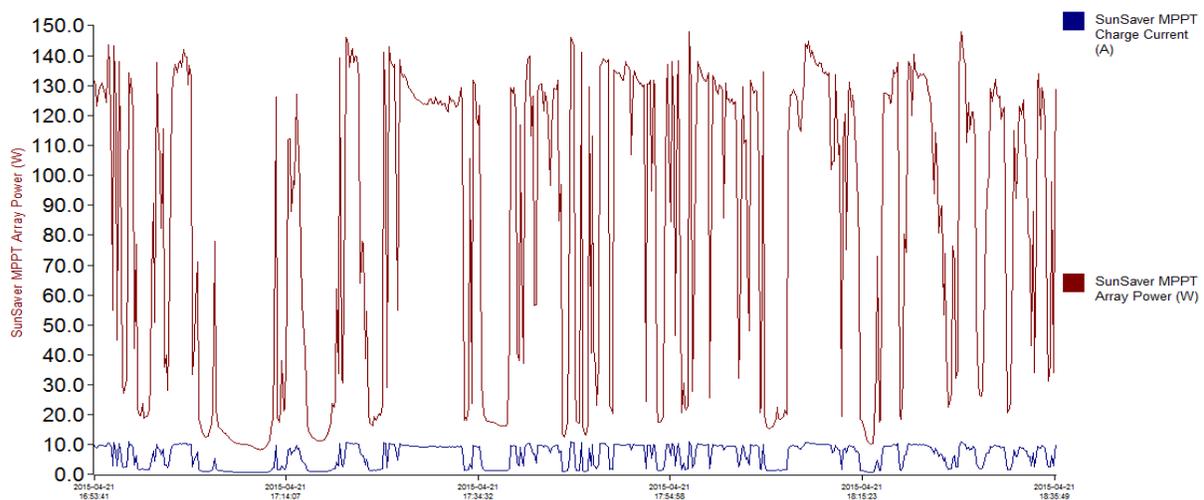
**Fig. 4: New Solar System Design**

To collect detailed information about the performance of the solar panels, controllers, and batteries over time, a PC MeterBus Adapter [3] was also added to the system. The adapter connects the solar controllers to a computer via a small black adapter box. Using software called MSview, provided by Morningstar, a number of characteristics about the solar panel, battery, and controller can be tracked over time. All the data can be stored on a computer for further analysis. An individual solar panel system was used to run preliminary testing using the MSview software, consisting of one solar panel, one solar controller, and one 12V battery. On the day of testing it was a partly cloudy day, with alternating periods of direct sunlight and cloud coverage. The system was left outside for about 2 hours, collecting data samples on a number of system parameters every ten seconds. The system parameters included the charge current, total charge in Ah, array power, battery voltage, and panel voltage. The plots seen in Fig. 5 and 6 display the performance of the solar panel over the testing period. Fig. 5 shows the variation in the charge current due to the changing cloud conditions. When in the direct sight of the sun, the panel generates anywhere from 9-11 amps. However, when a cloud is directly blocking the sun, the panel drops to a 1-2 amp charge rate. At the max charging current of 11amps, the batteries will

take approximately 3.5 hours to fully charge in direct sunlight. Fig. 6 shows the power being generated by the array over the testing period. The 2 hour tests proved that the panel is almost reaching its max power potential of 160W.



**Fig. 5: MSview – Battery Rate of Charge**



**Fig. 6: MSview – Solar Panel Power Output**

In order to track the power being generated by the solar panels in real time, a Morningstar's Remote Meter [4] was also added to the system. The remote meter is able to display the current voltage across the connected panel, the battery voltage, and current being delivered to the battery. The remote meter connects to one of the solar panel controllers, and monitors the data for the connected panel and battery only to provide the driver with real time information.

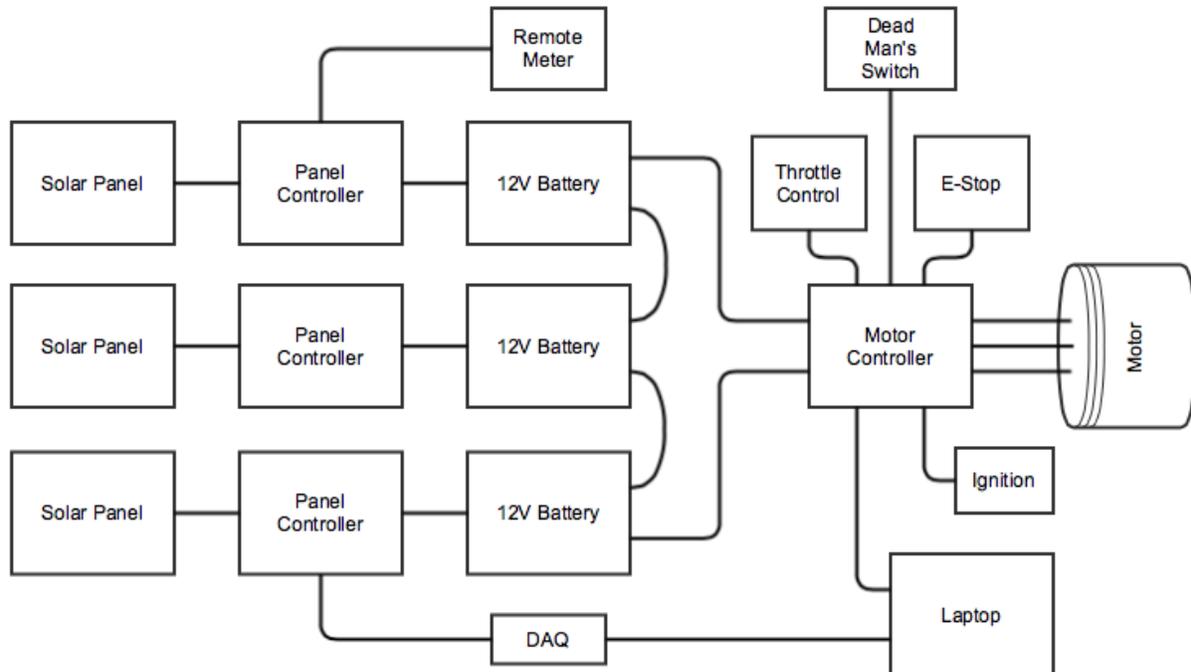
## Electrical System

The complete electrical system, as seen in Fig. 7, is an extension of the solar power system described in the previous section. As mentioned earlier, the batteries are connected in series, producing an overall voltage to the motor controller of 36 volts. Each battery is an Optima

Yellow Top [7]. The total battery weight cannot exceed 100 lbs, and each Optima Yellow Top only weighs 26 lbs, meeting the requirement. Each battery has a nominal voltage of 12.7 volts and a capacity of 38Ahours.

The onboard motor controller is the Gen4 AC motor controller from Sevcon [5]. The inputs to the motor controller are the two power lines from the battery, the voltage signal from the throttle lever, the E-stop signal, the “dead man’s switch” signal, and the ignition signal. The outputs from the motor controller are the three motor cables.

One change from last semester to this semester, is that the motor controller configuration software has been obtained. Now it is possible to change various performance parameters of the motor, as well as track its performance over time. Various performance characteristics, such as throttle level, voltage being supplied, and current draw from the motor can all be monitored using an onboard laptop. This is most useful in the testing phase, when hard data can be collected while the boat is actually running in the water. This is explained further in the data acquisition section. In case of emergency, the team kept the same bilge pump and VMAX Battery[9] on a separate loop.



**Fig. 7: Electrical Design Layout**

## Power Electronics System

The team members kept the Mars Brushless PMAC motor kit [5] to power the boat. The motor’s specifications are shown below in Fig. 8. The team chose this motor because the motor can be programmed for either 36 or 48 volts, and all of the components of the wiring harness can operate within that voltage range. The motor is being controlled by a Sevcon Gen4 Size 2 motor controller [5], included in the original motor kit, which is shown below in Fig. 9.

Mars Brushless PMAC Motor: Model #: ME1117  
Motor Specifications:  
Voltage: 24-48 VDC  
HorsePower: 15 Hp peak/ 6 Hp cont  
Efficiency: 90%  
Diameter: 8"  
Bore Diameter: 7/8"  
Keyway: 3/16"  
Weight: 22 Lbs  
Output Torque Constant: 1.20" lbs/ Amp  
Max motor current: 300A/1 min

Controller Specifications  
Gen4 Controller: 36 to 48 VDC  
Continuous Current Rating: 110 A  
Peak current (120s) Rating: 275 A  
Boost (10s) Rating: 330 A

Pot box throttle: 0 to 5K ohm  
Forward/Reverse Selector Switch  
Ignition key  
Contactor :  
Albright single acting solenoid contactor model: SW80B-6  
24VDC, can operate at a continuous 100 Amp load.

**Fig. 8: Motor, Controller, and Wiring Specifications**



**Fig. 9: Sevcon Gen4 Motor Controller**

The team chose to not modify the motor position or the mount [10] that the motor was

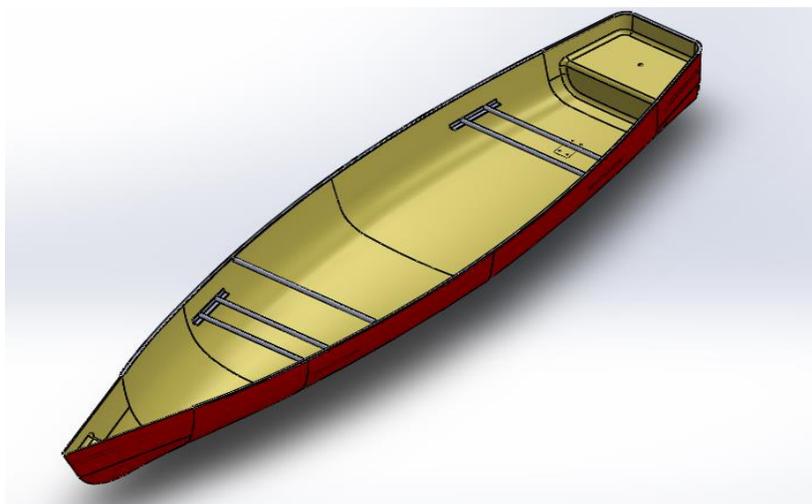
attached to. In Fig. 10 you can see that the motor is mounted to aluminum extrusion bars that can be adjusted, as well as being bonded to the bottom of the hull.



**Fig. 10: Motor Mounted to the Hull of the Boat**

### Hull Design

The hull from last year's boat design, a Backwater model manufactured by Wenonah Canoes [11], made of Kevlar reinforced fiberglass is being used again for this year's competition due to its light weight and sturdiness. The team decided that the original tandem canoe was the best choice for this year's competition since the motor and drive shaft installed by the previous team weren't being upgraded for this year's competition. Fig. 11 is the Solidworks model from the previous team of the original hull before any modifications. Fig. 12 is a photo of the boat supplied by Wenonah canoes which gives the dimensions of the boat, showing that it's within the width and length requirements put in place by the competition.



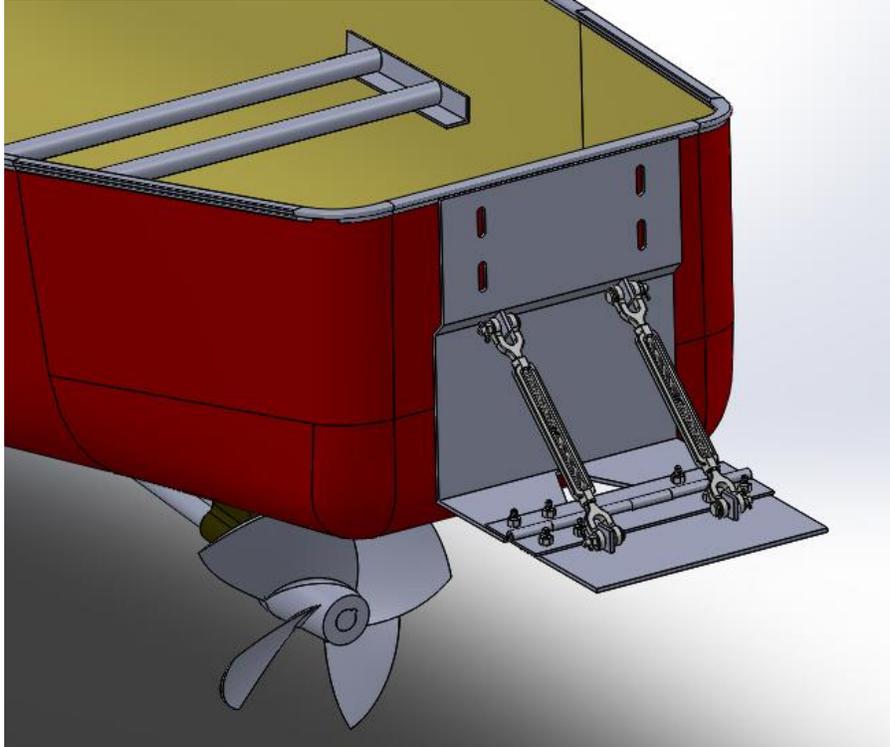
**Fig. 11: Solidworks 3D Model of the Boat**



**Fig. 12: Wenonah Backwater Canoe with Dimensions [11]**

In order to improve the boat's acceleration and time for the speed and slalom portion of the competition the team focused on replacing the fixed trim tab from last year's competition. Last year's team had problems with the boat taking a long time to fully plane out which made the boat's acceleration very slow, increasing the boat's overall time in the speed and slalom trials. The past year's team designed and implemented a "fixed" trim tab to help fix this problem but it wasn't a very efficient design due to the depth that the boat sat in the water and how the angle in which water deflected was fixed. Another problem with the previous design was the thickness of the 6061 Aluminum sheeting used in the implementation of the design. The 0.125" aluminum trim tab which was fixed with a 90 degree angle began to bend away from the boat creating a gap between the two mounting surfaces. This slight bend in the aluminum allowed water to rush into the gap between the trim tab and boat hull which created a great deal of drag during boat operation. Another problem was the depth in which the trim tab set in the water. The trim tab set too deep in the water which caused water to rush over the trim tab, meaning less water was being deflected downward.

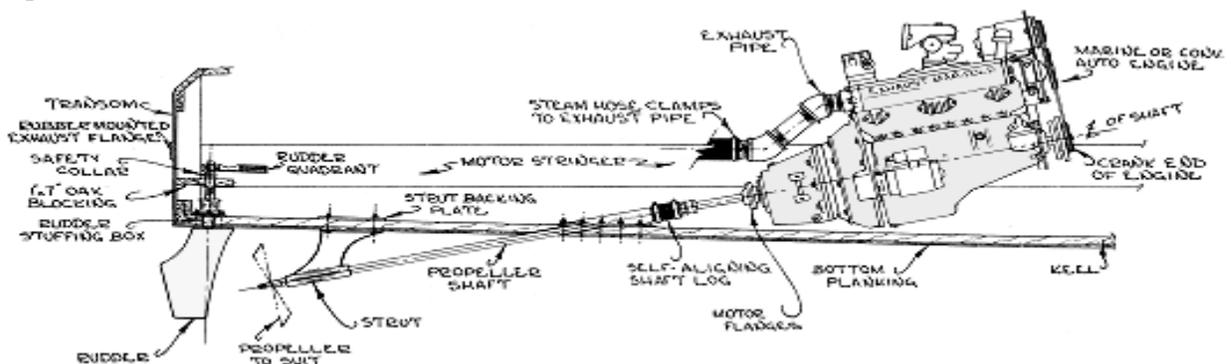
To fix this the team came up with a new design to maximize efficiency and increase acceleration. To fix the issues with the previous design the team created an "adjustable" trim tab which allows the operator to change the angle in which the water is deflected. Making this angle of deflection adjustable allows for on the water adjustments to create the optimal planing speed for the boat. The new design was also raised 1" to sit higher up in the water while the thickness of the 6061 Aluminum sheeting was increased to .1875" to increase the material's rigidity. The previous "fixed" trim tab was designed into an "adjustable" trim tab with the addition of a piano hinge and two turnbuckles as seen in Fig. 13. The adjustable tabs are interchangeable which will allow for future testing of the different shapes and sized tabs in the future. Future testing will be completed at various angles of deflection in order to determine the optimal angle for the "variable" trim tab to deflect the water.



**Fig. 13: Assembled “Variable” Trim Tab**

## Drive Train

For this year the team didn't change the drive train in any way. The team was happy with the performance of the drive train in last year's competition so we left it in that exact state. The unchanged drivetrain layout with its simple design can be seen in Fig 14. The drivetrain is centrally located on the boat where the motor is connected through a Lovejoy jaw coupler to the drive shaft that connects the motor to the propeller. The previous team that installed the drivetrain used *Boat Builder's Notebook* [12] to be able to correctly position the drive train components in the boat.



**Fig. 14: Drivetrain Configuration**

The team also used the previous team's propeller which was determined using the Victoria Propeller LTD Calculator [13] in order to calculate the size of the propeller based on the

specific data of the boat and the engine such as the weight and length of the boat and the power and speed of the engine along with other factors. Last year's team came to the conclusion that of a 3 blade, 12" diameter, 15 pitch bronze propeller along with a 12 degree strut from Glen-L. A 1" diameter and 66" long shaft from last year's boat was still used to connect the motor to the propeller. The calculations for the appropriate diameter shaft from last year can be seen in Appendix G.

### Steering and Dashboard

In an effort to reduce the overall weight of the boat in any way possible, the old steering system was removed leaving only the rudder and tiller arm. This included a large piece of angled aluminum, a steering wheel, cables, and two 4' PVC cable guards. This in total weighed 55 lbs. The steering system was replaced by a welded, L-shaped piece of aluminum tubing that was attached to the tiller arm. This piece extends to the right side of the skipper so that the skipper may directly steer the boat. This idea was based off of how one would steer a small boat with an outboard motor. This would also allow for an increase in the range of motion of the rudder as compared with the previous steering system. Because some of the dashboard was incorporated into the angled sheet of aluminum, modifications needed to be made to create a new dashboard. The rest of the dashboard was located on an aluminum plate that protected the skipper from the motor. Therefore, continuing with theme of weight reduction, that plate was removed. It was replaced with a polycarbonate sheet which also contains the entire dashboard. There was also a similar aluminum plate that protected the batteries from the motor closer to the bow of the boat that was replaced with polycarbonate sheeting. These changes allowed for a total weight reduction of 30 lbs. (too be added to when steering is completed). The new steering system is shown below in Fig. 15.



**Fig. 15: Steering Lever**

## Data Acquisition and/or Communications

The team found that the Sevcon Gen4 motor controller, which came with the PMAC motor, can be interfaced with using the Sevcon DVT Customer software [14] via an IXXAT CAN-to-USB adapter [15], shown in Fig. 16. The adapter is connected to the motor controller by a DB9 connector and only three pins are used. A schematic of the connection can be seen in Fig. 17 below. The DVT Customer software can be used to log real time data from the motor controller as well as tuning the motor. The team chose to focus on gaining access to the data that can be logged by the software. The logged data is exported as a comma separated value file so it can be opened up in Microsoft Excel as soon as logging is stopped. The tuning of the motor was determined to be tabled for discussion until the next year as there was not enough time to learn exactly what was needed to properly tune the motor. The main graphic user interface (GUI) of the Sevcon software shows real time data, in hexadecimal format, on the current status of the motor. If the motor has experienced any sort of fault, it will be shown here. Fig. 18 shows the logging window of the software. These are the data variables that can be logged by the current setup of the software, and are of the most use to the team. This is where the team will get the real time values from the motor for RPM, battery voltage draw, and battery current draw. The acquisition of the real time data from the motor controller will allow the team to get the best performance under the current battery and weather conditions while in operation. The team performed a test while the motor was unloaded and recorded the resulting data using the logging ability of the software. The throttle was slowly increased until the motor was at max RPM and then the throttle was slowly decreased. The team did this three times so that there would be three curves to show. Fig. 19 shows the RPM data recorded from the unloaded test, while Fig. 20 shows the resulting wattage draw while performing the same test.



Fig. 16: IXXAT CAN-to-USB Adapter

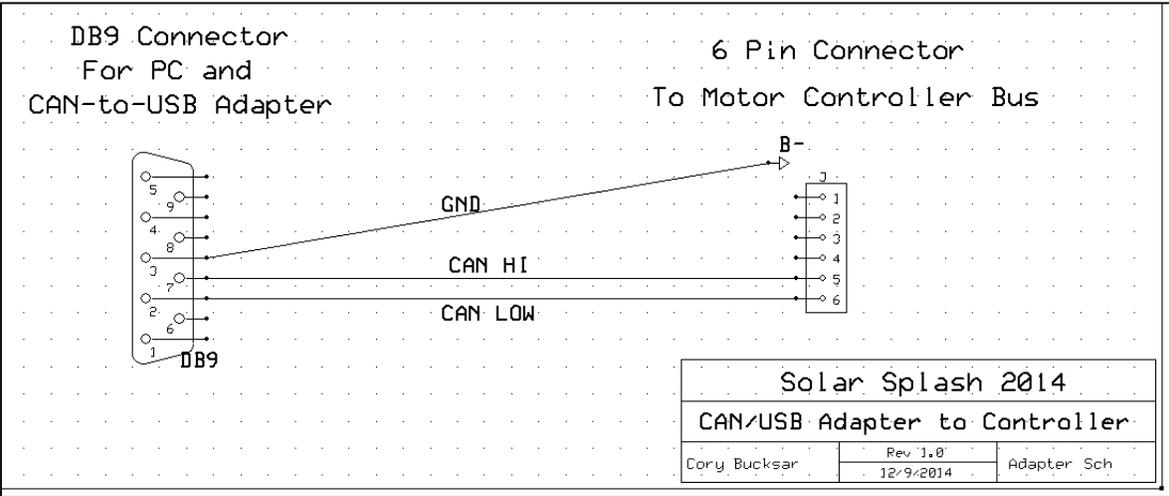
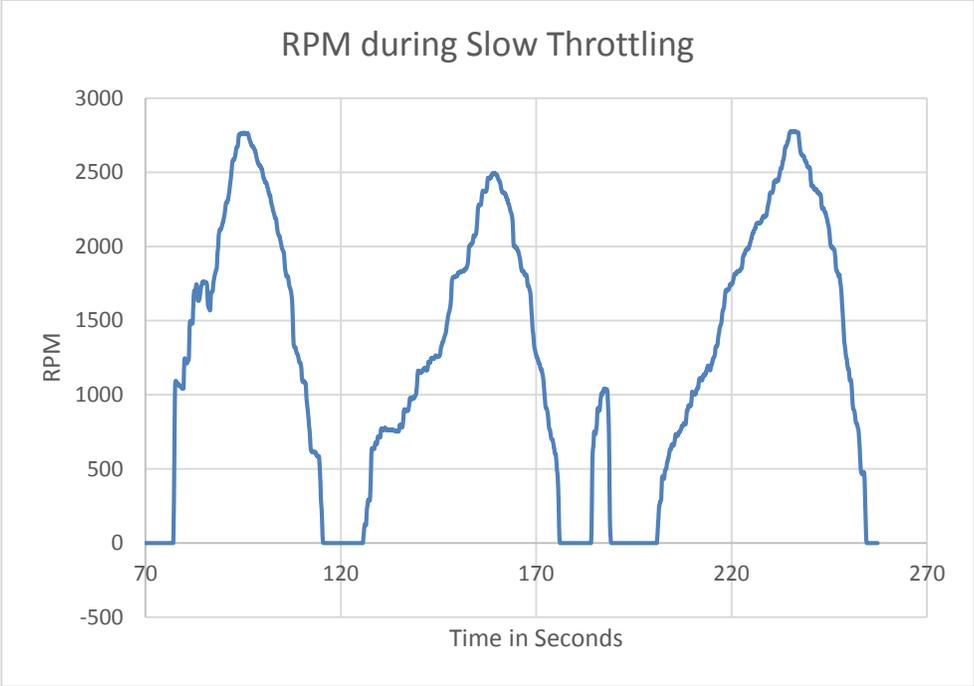


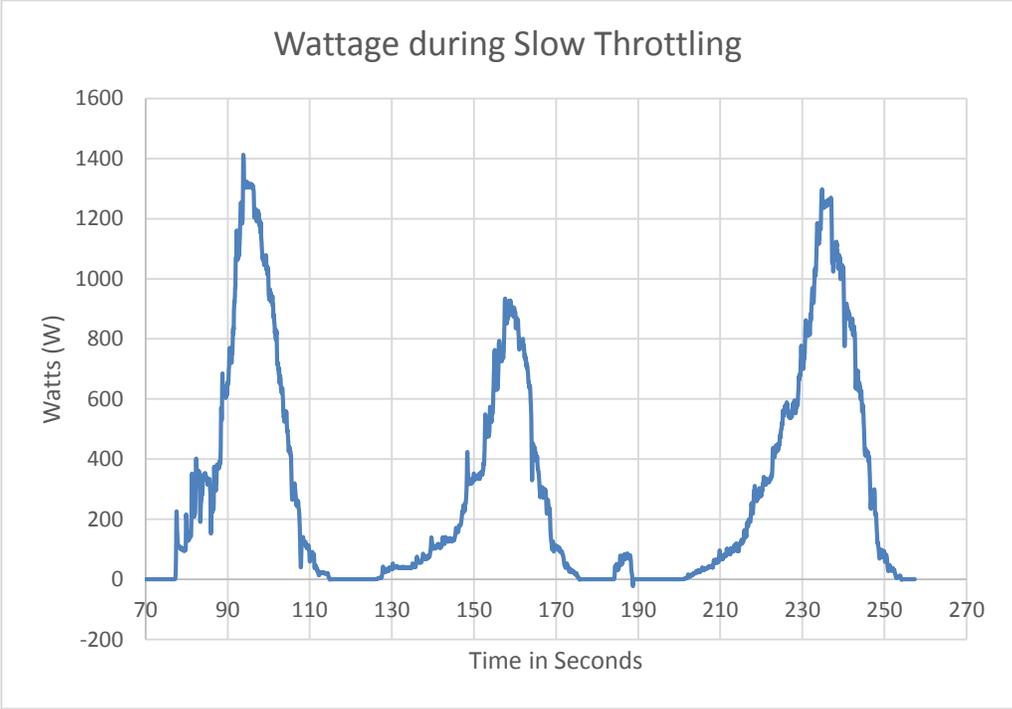
Fig. 17: Motor Controller and Adapter Connection Schematic



Fig. 18: Vehicle Interface Logging Window



**Fig. 19: Unloaded RPM Testing**



**Fig, 20 Unloaded Wattage Draw**

## Peripheral / Auxiliary Components

Several other items were placed in the boat, with many being safety requirements to compete. These items included:

Air Horn: Shoreline Marine SL52417

Oar: Caviness O1000 Series Aluminum Synthetic Boat Oar

2-Way Radio: Midland LXT535VP3

Bilge Pump: Rule Model 25S

Auxiliary Battery: Vmax Tank 64, 15 Ah

Life Preserver: Class 2 or 3

Fire Extinguisher: Kidde Mariner PWC

Tow Rope: 20 feet in length

Orange Skier in the water flag: Accurate Liners: Skier Down Flag, Heavy Duty Vinyl 12" x 12"

## Project Management

*Project management of a multi-disciplinary project is a challenge that requires a focused effort to be successful. What were your challenges; your successes? Think of the "success" of your team in terms of both the technical performance of your boat and the performance of your team.*

The team had many challenges and successes while upgrading the original boat for this year's competition. Unlike last year's team, this year's team had a fully functional boat to begin with so the hardest part was determining what parts of the boat the team wanted to focus on upgrading and improving.

One of the hardest struggles the team faced was becoming familiar with the boat and how it was wired. The team from last year left recommendations for this year's team which was a great help to get us started. The main struggle for the mechanical engineers of the group was designing a mounting system for the PV panels. The solar panel order was delayed over 3 months due to customs issues and therefore we didn't have very much time for designing a mounting system or for testing. When we finally received the new solar panels the team was pushed hard to come up with a design which it could effectively implement. However, one area in which the mechanical engineers had great success was the design, fabrication, and implementation of a new "variable" trim tab. The team's design worked successfully and improved the boat's acceleration and planing time drastically.

The electrical engineer struggled and succeeded in many ways as well. After months and months of trying Sevcon, the manufacturer of the boat's motor controller, provided the team with proprietary software to monitor and log motor outputs. This goal wasn't achieved until the middle of the spring semester which left almost no time for testing. This challenge limited their

setup and acquire data from the motor controller. One great success that the electrical engineers achieved was the implementation of the new solar controllers and solar controllers. They successfully wired and tested the solar panels to make sure they were ready for the competition.

Although the team faced many setbacks due to the lack of receiving several orders on time, the team managed to overcome all of the obstacles that stood in their way. In wait of some of these delayed orders the team focused its efforts on other parts of the boat such as steering and reconfiguring the dash to reduce weight. These changes led to great success and improved the overall speed, handling, and efficiency of the boat. Although the roles of each team member were divided, the team worked well together to help each other out to stay on track. Assigning different tasks to team members that fit their major and skillset greatly improved the efficiency of the team throughout the project.

*What did you learn about managing an engineering project/team during this year?*

Team clarity and communication was the hardest learning curve that this team had to face. Losing three team members from the fall semester and gaining back two new team members for the spring semester caused a lot of wasted time to be spent trying to bring the new team members up to speed on the various projects and tasks the team was currently working on from last semester. Overall, we all learned quickly how some members of the team excelled in particular roles due to their skill set which made dividing tasks up down the road a lot easier. Although this project challenged the skills sets of each team member, learning from others was by far the most worthwhile experience. The team learned quickly from one another while staying focused on the specific goals that were established from the beginning of the project. The team aimed to achieve better efficiency through various improvements that were drawn up in the preliminary design stage. The team worked hard to stick to the timeline in order to achieve our end goal of having a fully functional boat that meets the competitions requirements. A budget was formed and kept while weekly progress reports were written and emailed to our sponsors on how the team was doing and what exactly we had achieved since the last status report. This kept our sponsors up to date on what the team was doing and what we hoped to achieve and deliver for the competition.

*How did you handle the design efforts of the different sub-systems?*

The design efforts of the different sub-systems were separated among the team members based on interests and abilities. Since there were two electrical engineers and three mechanical engineers on the team, the electrical engineers took charge of the data collection from the motor controller and the charge controllers. The mechanical engineers then took charge of the mechanical improvements of the boat such as the trim tab, the weight reduction, and the steering system changes. Although we seemed to split things into individual projects, everybody consulted on all decisions made. This helped to ensure the best decision was made and that the group continued to stay on the same page.

*What initiatives/approaches to project management did you apply and how effective were they?*

Project management was expressed through the cooperation our team had. Everyone was equal and there was no “head” of the team. Each team member was “in charge” of one part of the

project and we consulted each other on all decisions made. This was a very effective way to handle the project for our team. Because no one was “in charge,” no team member was reluctant to share any ideas that they had.

There was also a team advisor and a team sponsor that managed us as a team. There was a weekly meeting with the sponsor, Dr. Kelley Kissock (Chair of the Mechanical Engineering Department), worked well for managing the team's time and progress. The team made improvements to the agenda for the meetings which helped guide efforts and maintain focus on the tasks at hand. This was also a very effective way to manage the project as the team received good advising without an extreme amount of oversight.

*How did you finance your project?*

The team originally had a \$2500 budget for the project. Records of all the purchases were kept in a Microsoft Excel file to ensure the team did not go over budget. The team also sought to have businesses donate machining time and some machining materials if the business were willing. Since the team's goal was to modify the existing system, the funds from the original budget were sufficient.

*Do you have recommendations for financing sources and fund raising approaches?*

The team would recommend that the primary financing sources be found through the Mechanical Engineering department as well as the Innovation Center for the Engineering Design student class. The team was able to continue the relationship with the Mechanical Engineering department from the previous years and would recommend pursuing that path in the future. Because the team was focused on primarily modifying the systems, fundraising was not required for this year. However if the need for more financing were to occur, the team would suggest presenting to the Electrical Engineering department to pursue funds.

*How are you addressing the sustainability of the boat team in future years?*

All changes to the system were focused around making minimally intrusive changes to the boat. Past designs for the boat have focused largely on sustainability of the installed systems, and any new systems, such as the new electronic speed controller mounts, should not impair that sustainability.

The main change that was made to improve the sustainability of the design is a new steering system. The old system was unwieldy and complicated, and likely to break in the near future. Instead, a much simpler design was installed.

*Did you have focused recruiting and succession planning efforts for your project?*

This year, the team did not explicitly focus on recruiting for next year. The team is open to any Engineering student. The team will continue to be filled with students from the Senior Design capstone course. Due to the past successes of the team, there is still interest in the future performance of the project by students at the University.

## Conclusions and Recommendations

Next year's team will likely use the same hull, drivetrain, solar panels, solar controllers, and data logging equipment in next year's competition. Some recommendations for next year's team would be to focus on improving the steering the boat. Although a newer simple and lightweight design was implemented for this year's competition, the team wasn't ecstatic about the results. To further weight reduction, improve performance, and improve steering, alternative materials should be researched to see if the bronze rudder and propeller can be replaced. Further research into motor optimization could also be completed to improve performance and efficiency through the Sevcon software's capabilities. Another suggestion would be to design a custom gearbox to allow for fine tuning of torque and rpm.

Overall this past year getting the boat ready was of great success. Since this will be UD's second time competing in the Solar Splash our design process was structured in a way that the team was able to meet its established deliverables and deliver an upgraded boat with increased performance and efficiency. Our research process allowed the team to find great lightweight solar panels, data acquisition software for both the motor controller and solar panels, and more efficient solar controllers. The team did run into some issues with the delivery of the solar panels being delayed but that only pushed us harder to design the mounts and get the boat ready for the competition. Throughout this process the team showed both growth and team unity which allowed us to meet our goals.

**REFERENCES**

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## **APPENDICES**

Appendix A: Battery Documentation

Appendix B: Flotation Calculations

Appendix C: Proof of Insurance

Appendix D: Team Roster

Appendix E: Solar Splash Gantt Chart

Appendix F: Power Calculations

Appendix G: Shaft Diameter Calculations

### **APPENDIX A: Battery Configuration**

Per the technical report requirements, the product information and MSDS sheets for the batteries are posted in this section.

All events batteries - (three 12-volt batteries)

Optima YellowTop - Model: D51/D51R

Specifications and MSDS attached - nominal weight of 26.0 lb each (total 78.0 lb)

Auxiliary Battery - (one 12-volt battery)

VMAX Battery - Model: MB-64 15 AH Mobility Battery

Specifications and MSDS attached - nominal weight of 10.0 lb



Battery Model: D51  
 Part Number: 8071-167  
 Nominal Voltage: 12 volts  
 NSN: 6140 01 523 6288  
 Description: High power, dual purpose engine start and deep cycle, sealed lead acid battery



Battery Model: D51R  
 Part Number: 8073-167  
 Nominal Voltage: 12 volts  
 NSN: Number applied for, product currently available  
 Description: High power, dual purpose engine start and deep cycle, sealed lead acid battery

#### Physical Characteristics:

Plate Design: High purity lead-tin alloy. Wound cell configuration utilizing proprietary *SPIRALCELL*™ technology.  
 Electrolyte: Sulfuric acid, H<sub>2</sub>SO<sub>4</sub>  
 Case: Polypropylene  
 Color: Case: Light Gray  
           Cover: "OPTIMA" Yellow  
 Group Size: BCI: 51

	Standard	Metric
Length:	9.272"	235.51 mm
Width:	5.024"	127.61 mm
Height:	8.885"	225.68 mm (Height at the top of terminals)
Weight:	26.0 lb	11.8 kg

Terminal Configuration: SAE / BCI automotive.

#### Performance Data:

Open Circuit Voltage (Fully charged): 13.1 volts  
 Internal Resistance (Fully charged): 0.046 ohms  
 Capacity: 38 Ah (C/20)  
 Reserve Capacity: BCI: 66 minutes  
                           (25 amp discharge, 80 °F (26.7 °C), to 10.5 volts cut-off)

#### Power:

CCA (BCI 0°F): 450 amps  
 MCA (BCI 32°F): 575 amps

**Fig1. of Appendix A: Sprint and Endurance Battery Specifications - Optima YellowTop D51 (1 of 2)**

**Recommended Charging:**

The following charging methods are recommended to ensure a long battery life: (Always use a voltage regulated charger with voltage limits set as described below.)

**Model: D51 and D51R**

These batteries are designed for starting and deep cycle applications and for use in vehicles with large accessory loads.

**Recommended Charging Information:**

<b>Alternator:</b>	13.65 to 15.0 volts
<b>Battery Charger (Constant Voltage):</b>	13.8 to 15.0 volts; 10 amps maximum; 6-12 hours approximate
<b>Float Charge:</b>	13.2 to 13.8 volts; 1 amp maximum; (indefinite time at lower voltages)
<b>Rapid Recharge:</b>	Maximum voltage 15.6 volts. No current limit as long as battery temperature remains below 125°F (51.7°C). Charge until current drops below 1 amp.
<b>(Constant voltage charger)</b>	
<b>Cyclic or Series String Applications:</b>	14.7 volts. No current limit as long as battery temperature remains below 125°F (51.7°C). When current falls below 1 amp, finish with 2 amp constant current for 1 hour. <b>All limits must be strictly adhered to.</b>

**Recharge Time:** (example assuming 100% discharge – 10.5 volts)

Current	Approximate time to 90% charge
100 amps	25 minutes
50 amps	65 minutes
25 amps	130 minutes

Recharge time will vary according to temperature and charger characteristics. When using Constant Voltage chargers, amperage will taper down as the battery becomes recharged. When amperage drops below 1 amp, the battery will be close to a full state of charge.

(All charge recommendations assume an average room temperature of 77°F (25°C).

Always wear safety glasses when working with batteries.

Always use a voltage regulated battery charger with limits set to the above ratings. Overcharging can cause the safety valves to open and battery gases to escape, causing premature end of life. These gases are flammable! You cannot replace water in sealed batteries that have been overcharged. Any battery that becomes very hot while charging should be disconnected immediately.

Not fully charging a battery can result in poor performance and a reduction in capacity.

**Fig1. of Appendix A: Sprint and Endurance Battery Specifications - Optima YellowTop D51 (2 of 2) [12]**

	Title:	Date:	Rev:	Page:	File Name:
	Material Safety Data Sheet for All Optima Batteries	10/17/11	M	1 of 5	MSDS battery

MSDS No. L 8A
Date Issued Feb. 20, 1990
Date Revised Oct. 17, 2011

Chemical/Trade Name (Identify used on label) Sealed Lead Acid Battery/ OPTIMA BATTERY 12V		Chemical Family/Classification Electric Storage Battery	HMIS Rating for Sealed, Lead Acid Battery 0 0 0; For sulfuric acid 3 0 2
Synonym/Common Name Sealed Lead Acid Battery		DOT, IATA and IMO Description Non-Spillable Battery, Exempt from UN2800 Classification	
Company Name OPTIMA Batteries, Inc.		Address 5757 N. Green Bay Avenue Milwaukee, WI 53209	
Division or Department Wholly-owned subsidiary of Johnson Controls Inc.			
CONTACT		TELEPHONE NUMBER	
Questions Concerning MSDS OPTIMA Batteries, Environmental, Health & Safety Department		Day: (800) 333-2222, Ext. 3138	
Transportation Emergencies CHEMTREC		24 Hours: (800) 424-9300 International: (703) 527-3887 (Collect)	

NOTE: The OPTIMA sealed lead acid battery is considered an article as defined by 29 CFR 1910.1200 © OSHA Hazard Communication Standard. The information on this MSDS is supplied at customer's request for information only.

#### II. Hazardous Ingredients

Material	% by Wt	CAS Number	Eight Hour Exposure Limits		
			OSHA PEL	ACGIH TLV	NIOSH REL
Specific Chemical Identity Lead & lead compounds	6381	7439-92-1	50 µg/m <sup>3</sup>	150 µg/m <sup>3</sup>	100 µg/m <sup>3</sup>
Specific Chemical Identity Sulfuric Acid (35%) Common Name Battery Electrolyte (Acid)	17 - 25	7664-93-9	1 mg/m <sup>3</sup>	0.2 mg/m <sup>3</sup> (respirable fraction)	1 mg/m <sup>3</sup>
Common Name Case Material Polypropylene	2-6	9010-79-1	--	--	--
Common Name Separator/Paster Paper Fibrous Glass	1-4	66667-17-3	--	--	--

NOTE: The contents of this product are toxic chemicals that are subject to the reporting requirements of section 302 and 313 of the Emergency Planning and Community Right-To-Know Act of 1986 (40 CFR 355 and 372).

#### III. Physical Data

Material is (at normal temperatures) <input checked="" type="checkbox"/> Solid <input type="checkbox"/> Liquid		Appearance and Odor Battery Electrolyte (acid) is a clear to cloudy liquid with slight acidic odor. Acid saturated lead oxide is a dark reddish-brown to gray solid with slight acidic odor.
Boiling Point (at 760 mm Hg) Lead 1755°C Batt. Electrolyte (Acid) 110-112°C	Melting Point Lead 327.4°C	
Specific Gravity (H <sub>2</sub> O = 1) Battery Electrolyte (Acid) 1.210 - 1.300	Vapor Pressure (kmm Hg at 20°C) (PSIG) Battery Electrolyte (Acid) 11.7	
Vapor Density (Air = 1) Battery Electrolyte (Acid) 3.4	Solubility in H <sub>2</sub> O Lead and Lead Dioxide are not soluble. Battery Electrolyte (acid) is 100% soluble in water.	
% Volatile by Weight Not Determined	Evaporation rate (Butyl Acetate = 1) Not Determined	

Fig.2 of Appendix A: Optima MSDS Sheets (1 of 5).

## IV. Health Hazard Information

NOTE: Under normal conditions of use, this product does not present a health hazard. The following information is provided for battery electrolyte (acid) and lead for exposure that may occur during battery production or container breakage or under extreme heat conditions such as fire.
<b>ROUTES AND METHODS OF ENTRY</b>
<b>Inhalation:</b> Acid mist may be generated during battery overcharging and may cause respiratory irritation. Seepage of acid from broken batteries may present inhalation exposure in a confined area.
<b>Skin Contact:</b> Battery electrolyte (acid) can cause severe irritation, burns and ulceration.
<b>Skin Absorption:</b> Skin absorption is not a significant route of entry.
<b>Eye Contact:</b> Battery electrolyte (acid) can cause severe irritation, burns, and cornea damage upon contact.
<b>Ingestion:</b> Hands contaminated by contact with internal components of a battery can cause ingestion of lead/lead compounds. Hands should be washed prior to eating, drinking, or smoking.
<b>SIGNS AND SYMPTOMS OF OVEREXPOSURE</b>
<b>Acute Effects:</b> Acute effects of overexposure to lead compounds are GI (gastrointestinal) upset, loss of appetite, diarrhea, constipation with cramping, difficulty in sleeping, and fatigue. Exposure and/or contact with battery electrolyte (acid) may lead to acute irritation of the skin, corneal damage of the eyes, and irritation of the mucous membranes of the eyes and upper respiratory system, including lungs.
<b>Chronic Effects:</b> Lead and its compounds may cause chronic anemia, damage to the kidneys and nervous system. Lead may also cause reproductive system damage and can affect developing fetuses in pregnant women. Battery electrolyte (acid) may lead to scarring of the cornea, chronic bronchitis, as well as erosion of tooth enamel in mouth breathers in repeated exposures.
<b>POTENTIAL TO CAUSE CANCER</b>
The National Toxicological Program (NTP) and The International Agency for Research on Cancer (IARC) have classified "strong inorganic acid mist containing sulfuric acid" as a Category 1 carcinogen, a substance that is carcinogenic to humans. The ACGIH has classified "strong inorganic acid mist containing sulfuric acid" as an A2 carcinogen (suspected human carcinogen). These classifications do not apply to liquid forms of sulfuric acid or sulfuric acid solutions contained within a battery. Inorganic acid mist (sulfuric acid mist) is not generated under normal use of this product. Misuse of the product, such as overcharging, may result in the generation of sulfuric acid mist.
The NTP and the IARC have classified lead as an A3 carcinogen (animal carcinogen). While the agent is carcinogenic in experimental animals at relatively high doses, the agent is unlikely to cause cancer in humans except under uncommonly high levels of exposure. For further information, see the ACGIH's pamphlet, <i>1996 Threshold Limit Values and Biological Exposure Indices</i> .
<b>EMERGENCY AND FIRST AID PROCEDURES</b>
<b>Inhalation:</b> Not expected for product under normal conditions of use. However, if acid vapor is released due to overcharging or abuse of the battery, remove exposed person to fresh air. If breathing is difficult, oxygen may be administered. If breathing has stopped, artificial respiration should be started immediately. Seek medical attention immediately.
<b>Skin:</b> Exposure not expected for product under normal conditions of use. However, if acid contacts skin, flush with water and mild soap. If irritation develops, seek medical attention immediately.
<b>Eyes:</b> Exposure not expected for product under normal conditions of use. However, if acid from broken battery case enters eyes, flush with water for at least 15 minutes. Seek medical attention immediately.
<b>Ingestion:</b> Not expected due to physical form of finished product. However, if internal components are ingested: Lead/Lead compounds: Consult a physician immediately for medical attention. Battery Electrolyte (Acid): Do not induce vomiting. Refer to a physician immediately for medical attention.
<b>MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE</b>
Inorganic lead and its compounds can aggravate chronic forms of kidney, liver, and neurologic diseases. Contact of battery electrolyte (acid) with the skin may aggravate skin diseases such as eczema and contact dermatitis.

Fig.2 of Appendix A: Optima MSDS Sheets (2 of 5).

V. Fire and Explosion Data		
Flash Point (test method)	Autoignition Temperature	Flammable Limits in Air, % by Vol.
Hydrogen - 259°C	Hydrogen 580°C	Hydrogen LEL - 4.1 UEL - 74.2
<b>Extinguishing Media</b> Dry chemical, foam, or CO <sub>2</sub>		
<b>Special Fire Fighting Procedures</b> Use positive pressure, self-contained breathing apparatus.		
<b>Usual Fire and Explosion Hazard</b> The sealed lead acid battery is not considered flammable, but it will burn if involved in a fire. A short circuit can also result in a fire. Acid mists, smoke and decomposition products may be produced. Remove all ignition sources. Cool battery(s) to prevent rupture.		
VI. Reactivity Data		
<b>Stability</b> <input type="checkbox"/> Unstable <input checked="" type="checkbox"/> Stable	<b>Conditions to Avoid</b> Sparks and other sources of ignition may ignite hydrogen gas.	
<b>Incompatibility (state risks to avoid)</b> Lead/Lead compounds: Potassium, carbides, sulfides, peroxides, phosphorus, sulfur. Battery electrolyte (acid): Combustible materials, strong reducing agents, most metals, carbides, organic materials, chlorates, nitrates, picrates, and fulminates.		
<b>Hazardous Decomposition Products</b> Lead/Lead compounds: Oxides of lead and sulfur Battery electrolyte (acid): Hydrogen, sulfur dioxide, sulfur trioxide		
<b>Hazardous Polymerization</b> <input type="checkbox"/> May Occur <input checked="" type="checkbox"/> Will Not Occur	<b>Conditions to Avoid</b> High temperature. Battery electrolyte (acid) will react with water to produce heat. Can react with oxidizing or reducing agents.	
VII. Control Measures		
<b>Engineering Controls</b> Store sealed lead acid batteries at ambient temperature. Never recharge batteries in an unventilated, enclosed space. Do not subject product to open flame or fire. Avoid conditions that could cause arcing between terminals.		
<b>Work Practices</b> Do not carry battery by terminals. Do not drop battery, puncture or attempt to open battery case. Avoid contact with the internal components of a battery.		
<b>PERSONAL PROTECTIVE EQUIPMENT</b>		
<b>Respiratory Protection</b> None required for normal handling of finished product.		
<b>Eyes and Face</b> None required under for finished product under normal conditions of use. If necessary to handle broken product, chemical splash goggles are recommended.		
<b>Hands, Arms, and Body</b> None required for normal handling of finished product. If necessary to handle broken product, Vinyl-coated, PVC, gauntlet-type gloves with rough finish are recommended..		
<b>Other Special Clothing and Equipment</b> Safety footwear meeting the requirements of ANSI Z 41.1 – 1991 is recommended when it is necessary to handle the finished product.		
VIII. Safe Handling Precautions		
<b>Hygiene Practices</b> Wash hands thoroughly before eating, drinking, or smoking after handling batteries.		
<b>Protective Measures to be Taken During Non-Routine Tasks, Including Equipment Maintenance</b> Do not carry battery by terminals. Do not drop battery, puncture or attempt to open battery case. Do not subject product to open flame or fire and avoid situations that could cause arcing between terminals.		

Fig.2 of Appendix A: Optima MSDS Sheets (3 of 5).

<b>Protective Measures to be Taken if Material is Released or Spilled</b>		
Remove combustible materials and all sources of ignition. Avoid contact with acid materials. Use soda ash, baking soda or lime to neutralize any acid that may be released.		
If battery is broken, wear chemical goggles and acid-resistant gloves for handling the parts.		
<b>DO NOT RELEASE UNNEUTRALIZED ACID!</b>		
<b>Waste Disposal Method</b>		
Battery Electrolyte (Acid): Neutralize as above for a spill, collect residue, and place in a drum or suitable container. Dispose of as a hazardous waste.		
<b>DO NOT FLUSH LEAD-CONTAMINATED ACID INTO SEWER.</b>		
Send spent or broken batteries to a lead recycling facility or smelter that follows applicable Federal, State and Local regulations for routine disposition of spent or damaged batteries. The distributor / user is responsible for assuring that these "spent" or "damaged" batteries are disposed of in an environmentally sound way in accordance with all regulations. OPTIMA batteries are 100% recyclable by any licensed reclamation operation.		
		
<b>SUPPLEMENTAL INFORMATION</b>		
<p><b>Proposition 65 Warning (California) Proposition 65 Warning:</b> The state of California has listed lead as a material known to cause cancer or cause reproductive harm (July 9, 2004 California List of Chemicals Known to Cause Cancer or Reproductive Toxicity) Batteryposts, terminals and related accessories contain lead and lead compounds. Batteries also contain other chemicals known to the State of California to cause cancer. Wash hands after handling.</p> <p><b>TSCA Registry:</b> Ingredients listed in the TSCA Registry are lead, lead compounds, and sulfuric acid.</p> <p><b>Transportation:</b> Sealed Lead Acid Battery is not a DOT Hazardous Material.</p> <p><b>Other:</b> Per DOT, IATA, ICAO and IMDG rules and regulations, these batteries are exempt from "UN2800" classification as a result of successful completion of the following tests:</p> <ol style="list-style-type: none"> <li>1) Vibration Tests</li> <li>2) Pressure Differential Tests</li> <li>3) Case Rupturing Tests (no free liquids)</li> </ol>		
<b>US MILITARY NATIONAL STOCK NUMBER (NSN)</b>		
Model Number	P/N	NSN
34/78	8004-003	6140-01-374-2243, 6140-01-467-4339
34	8002-002	6140-01-378-8232, 6140-01-493-1962
34R	8003-151	6140-01-475-9357
34vX	8008-158	6140-01-534-6466
25	8025-160	
35	8020-164	
75/25	8022-091	6140-01-475-9361
78	8078-109	
850/6 -1050 SLI	8010-044	6140-01-475-9414
DS46B24R	8171-767	
850/6 - 950 (DC)		
D51	8071-167	6140-01-523-6288
D51R	8073-167	6140-01-529-7226
D35	8040-218	
D75/25	8042-218	

Fig.2 of Appendix A: Optima MSDS Sheets (4 of 5).

D34	8012-021	6140-01-450-0141
D34/78	8014-045	6140-01-441-4272
D27F	8037-127	
D31T	8050-160	6140-01-457-5469
D31A	8051-160	6140-01-502-4973
34M	8006-006	6140-01-441-4280, 6140-01-526-2605
D34M	8016-103	6140-01-475-9355
D27M	8027-127	6140-01-589-0622
D31M	8052-161	6140-01-502-4405

**Disclaimer:** This information has been compiled from sources considered to be dependable and is, to the best of our knowledge and belief, accurate and reliable as of the date compiled. However, no representation, warranty (either express or implied) or guarantee is made to the accuracy, reliability or completeness of the information contained herein. This information relates to the specific material designated and may not be valid for such material used in combination with any other materials or in any process. It is the user's responsibility to satisfy himself as to the suitability and completeness of this information for his own particular use. We do not accept liability for any loss or damage that may occur, whether direct, indirect, incidental or consequential, from use of this information.

**Fig.2 of Appendix A: Optima MSDS Sheets (5 of 5) [12]**

### **MB64**

Superior Plates with an expected life span of 3 to 5 years in float service applications.

VOLTS 12V  
 AMP HOURS 15AH  
 WEIGHT 10LB  
 SIZE : L=5.94" W=3.86" H=3.74"  
 MAX. CHARGING CURRENT: 4.8A  
 MAX. CHARGING VOLTAGE: 14.7V  
 RECOMMENDED: 1.5A, 14.5V  
 CHARGER: SMART/MICROPROCESSOR CONTROLLED CHARGER

**Fig.3 of Appendix A: Vmax MB - 64 Battery Specification [13]**

# Material Safety Data Sheet

**Stafac 10, Stafac 20, Stafac 50, V-Max 50**

## 1. Product and company identification

**Product name** : Stafac 10, Stafac 20, Stafac 50, V-Max 50  
**Synonym** : Virginiamycin  
**Trade name** : Stafac, V-Max  
**Material uses** : Antibiotic agent.  
**Manufacturer** : Phibro Animal Health  
 65 Challenger Rd.  
 3rd Flr, Ridgefield Park,  
 NJ 07660-2103, USA  
 Tel: (201) 329-7300  
 Toll free: (888) 475-7355  
 Fax: (201) 329-7070  
  
**Code** : 8814 000, 8813 000, 8805 000, 8803 000, 8804 000, 8815 000, 8812 000  
**MSDS authored by** : KMK Regulatory Services Inc.  
**In case of emergency** : 1-800-345-4735  
**Product type** : Solid.

## 2. Hazards identification

**Color** : Brown.  
**Physical state** : Solid. [Granulated powder, free flowing, free from visible impurities.]  
**Odor** : Characteristic fermentation odor.  
**Signal word** : CAUTION!  
**Hazard statements** : MAY CAUSE EYE IRRITATION. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA.  
  
**Precautions** : No known significant effects or critical hazards. Avoid prolonged contact with eyes, skin and clothing. Handling and/or processing of this material may generate a dust which can cause mechanical irritation of the eyes, skin and clothing. Wash thoroughly after handling.  
  
**OSHA/HCS status** : This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).  
**Routes of entry** : Dermal contact. Eye contact. Inhalation. Ingestion.  
**Potential acute health effects**  
**Inhalation** : Exposure to airborne concentration above statutory or recommended exposure limits may cause irritation of the nose, throat and lungs.  
**Ingestion** : No known significant effects or critical hazards.  
**Skin** : No known significant effects or critical hazards.  
**Eyes** : Exposure to airborne concentration above statutory or recommended exposure limits may cause irritation of the eyes.  
  
**Potential chronic health effects**  
**Chronic effects** : Repeated or prolonged exposure to the substance can produce liver damage. Repeated or prolonged inhalation of dust may lead to chronic respiratory irritation.

**Fig 4. of Appendix A: Vmax MSDS Sheets (1 of 7).**

## 2. Hazards identification

Carcinogenicity	: Studies to evaluate the chronic toxicity and/or carcinogenic potential of virginiamycin have been conducted in mice and rats. In a 2-year oral toxicity study in mice, virginiamycin was given in the diet at dose levels of 25, 75 or 1000 mg/kg/day. No drug-related effects were observed in the mortality, physical observations, body weight, blood or clinical chemistry data or gross or microscopic pathology. The NOAELs for toxicity and carcinogenicity in this study were determined to be 1000 mg/kg/day. In rats, virginiamycin was administered orally in the diet at doses of 25, 50 or 250 mg/kg/day for males and 25, 50 or 300 mg/kg/day for females for 24 months. At dose levels greater than 50 mg/kg/day, reduced body weights, increased food consumption values, and changes in some clinical chemistry parameters were observed in males, but not in females. There were no neoplastic or non-neoplastic findings noted at any dose level that were of toxicological or oncogenic significance. Based on these findings, the NOAEL for toxicity in this study was determined to be 50 mg/kg/day. The NOAEL for carcinogenicity was determined to be greater than 300 mg/kg/day.
Mutagenicity	: Virginiamycin was not mutagenic in the Ames test, unscheduled DNA synthesis (UDS), sister chromatid exchange (SCE), or micronucleus tests. It was, however, mutagenic in the mouse lymphoma test and the Chinese hamster ovary assay.
Teratogenicity	: Virginiamycin teratogenicity was evaluated in rats at dose levels of 25, 65 or 200 mg/kg/day and in mice at doses of 25, 160 or 1000 mg/kg/day on days 6 through 15 of gestation. In rats, the high-dose (200 mg/kg/day) reduced maternal weight gains and was slightly embryotoxic, affecting pre-implantation loss, but was neither fetotoxic nor teratogenic. No evidence of maternal, embryo or fetotoxicity or teratogenicity was observed at doses of 25 and 75 mg/kg. The maternal and the fetal NOAELs were 75 mg/kg/day or greater. In mice, no evidence of maternal toxicity or effects on resorption incidence, fetal weight or external, visceral or skeletal development of fetuses were observed at any dose level. The maternal and the fetal NOAELs were 1000 mg/kg/day or greater.
Developmental effects	: The subchronic toxicity of virginiamycin was evaluated in rats for three months and in dogs for three and six months. No apparent drug-related effects were seen at any dose level in either species upon administration of virginiamycin at doses of 5, 22.5 and 100 mg/kg for 3 months; the NOAEL in these two studies was 100 mg/kg/day. In a six month toxicity study virginiamycin was given to dogs once daily at dose levels of 25, 200 or 750 mg/kg. No treatment-related effects were seen for the low and middle dose groups. In the high-dose group, treatment-related effects were vomiting, reduced body weight gain and food consumption, blood parameters changes, and reversible proliferated bile duct epithelium adjacent to the liver. The NOAEL in this study was 200 mg/kg/day.
Fertility effects	: In a two-generation oral reproductive toxicity study in rats, virginiamycin was administered in the diet at dose levels of 25, 65 or 3000 mg/kg/day for ten weeks prior to mating, through out the mating, gestation and lactation, and during the rest interval between litters. (The high-dose (300 mg/kg/day) was reduced to 100 mg/kg/day in both sexes during mating and in females throughout gestation and lactation as well). No treatment-related effects were observed on survival, mating or pregnancy indexes for adult animals, litter data, pup viability or pup survival. The NOAEL for reproductive effects in this study was 100 mg/kg/day.
Other potential effects	: Individuals sensitive to this material or other materials in its chemical class may develop allergic reactions.
<u>Target organs</u>	: May cause damage to the following organs: liver.
<u>Over-exposure signs/symptoms</u>	
Inhalation	: No specific data.
Ingestion	: No specific data.
Skin	: No specific data.
Eyes	: Adverse symptoms may include the following: irritation, watering, redness

Fig 4. of Appendix A: Vmax MSDS Sheets (2 of 7).

## 2. Hazards identification

**Medical conditions aggravated by over-exposure** : Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (Section 11)

## 3. Composition/information on ingredients

Name	CAS number	%
Calcium carbonate	471-34-1	Trade secret
Vigilamycin	11005-76-1	2 - 13
Mixeralcol, light	8042-47-5	Trade secret

There are no additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

## 4. First aid measures

- Eye contact** : Immediately flush eyes with plenty of water for at least 20 minutes, occasionally lifting the upper and lower eyelids. Get medical attention if symptoms occur.
- Skin contact** : In case of contact, immediately flush skin with plenty of water for at least 20 minutes. Get medical attention if symptoms occur.
- Inhalation** : Move exposed person to fresh air. Get medical attention if symptoms occur.
- Ingestion** : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention if symptoms occur.
- Notes to physician** : No specific treatment. Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.

## 5. Fire-fighting measures

- Flammability of the product** : No specific fire or explosion hazard.
- Extinguishing media**
- Suitable** : Use an extinguishing agent suitable for the surrounding fire.
  - Not suitable** : None known.
- Hazardous thermal decomposition products** : Decomposition products may include the following materials:  
carbon dioxide  
carbon monoxide
- Special protective equipment for fire-fighters** : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

## 6. Accidental release measures

- Personal precautions** : Put on appropriate personal protective equipment (see Section 8).
- Environmental precautions** : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).
- Methods for cleaning up**
- Spill** : Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Fig 4. of Appendix A: Vmax MSDS Sheets (3 of 7).

## 7. Handling and storage

- Handling** : Put on appropriate personal protective equipment (see Section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking.
- Storage** : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

## 8. Exposure controls/personal protection

Ingredient	Exposure limits
<p><b>Virgibamycin</b></p> <p><b>Micelolol, bit</b></p>	<p>ACGIH TLV (United States) TWA: 3 mg/m<sup>3</sup></p> <p>ACGIH TLV (United States, 2010) TWA: 5 mg/m<sup>3</sup> (8 hour). Form: Inhalable fraction. See Appendix C, paragraph A. Inhalable Particulate Mass TLVs (PM-TLVs) for those materials that are hazardous when deposited anywhere in the respiratory tract.</p> <p>NIOSH REL (United States, 62005) TWA: 5 mg/m<sup>3</sup> (8 hour). Form: Mist STEL: 10 mg/m<sup>3</sup> (15 minute). Form: Mist</p> <p>OSHA PEL (United States, 112006) TWA: 5 mg/m<sup>3</sup> (8 hour).</p>
<b>Calcium Carbonate</b>	<p>NIOSH REL (United States) TWA: 10 mg/m<sup>3</sup> (8 hour).</p>

Consult local authorities for acceptable exposure limits.

- Recommended monitoring procedures** : Personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.
- Engineering measures** : No special ventilation requirements. Good general ventilation should be sufficient to control worker exposure to airborne contaminants.
- Hygiene measures** : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period.
- Respiratory** : Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. Not required under normal conditions of use. Recommended:
- Hands** : Use gloves appropriate for work or task being performed. Not required under normal conditions of use. Recommended: Disposable vinyl gloves.
- Eyes** : Safety eyewear should be used when there is a likelihood of exposure. Not required under normal conditions of use. Recommended: Safety glasses with side shields.
- Skin** : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.
- Environmental exposure controls** : Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation.

## 9. Physical and chemical properties

- Physical state** : Solid. [Granulated powder, free flowing, free from visible impurities.]
- Color** : Brown.
- Odor** : Characteristic fermentation odor.
- Density** : 35 lbs/cwt.
- Solubility** : Insoluble in the following materials: cold water and hot water.

Fig 4. of Appendix A: Vmax MSDS Sheets (4 of 7).

## 10. Stability and reactivity

Chemical stability	: The product is stable.
Conditions to avoid	: No specific data.
Materials to avoid	: Reactive or incompatible with the following materials: oxidizing materials and alkalis.
Hazardous decomposition products	: Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Possibility of hazardous reactions	: Under normal conditions of storage and use, hazardous reactions will not occur.
Hazardous polymerization	: Under normal conditions of storage and use, hazardous polymerization will not occur.

## 11. Toxicological information

### Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
Calcium carbonate Virginiamycin	LD 50 Oral	Rat	6450 mg/kg	-
	LD 50 Oral	Rat	10000 mg/kg	-
	LD 50 Oral	Mouse	> 5000 mg/kg	-
	LD 50 Oral	Dog	> 4000 mg/kg	-

Chronic toxicity : No specific data.

## 12. Ecological information

Environmental effects : Not established

### Aquatic ecotoxicity

Product/ingredient name	Result	Species	Exposure
Calcium carbonate	Acute LC50 > 95000000 ug/L fresh water	Fish - Gambusia affinis - Adult	96 hours

## 13. Disposal considerations

Waste disposal : The generation of waste should be avoided or minimized wherever possible. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Empty containers or liners may retain some product residues. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor.

Disposal should be in accordance with applicable regional, national and local laws and regulations.

Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.

## 14. Transport information

DOT/MDG/ATA : Not regulated.

## 15. Regulatory information

HCS Classification : Not regulated.

U.S. Federal regulations : TSCA 8(a) IUR: Cellulose, carboxymethyl ether, sodium salt; Mineral oil, light United States inventory (TSCA 8b): Not determined.

SA RA 302/304/311/312 extremely hazardous substances: No products were found.

SA RA 302/304 emergency planning and notification: No products were found.

SA RA 302/304/311/312 hazardous chemicals: Cellulose, carboxymethyl ether, sodium salt

SA RA 311/312 MSDS distribution - chemical inventory - hazard identification:

Cellulose, carboxymethyl ether, sodium salt: Delayed (chronic) health hazard

Clean Water Act (CWA) 307: No products were found.

Fig 4. of Appendix A: Vmax MSDS Sheets (5 of 7).

## 15 . Regulatory information

	Clean Air Act (CAA)112 accidental release prevention: No products were found.
	Clean Air Act (CAA)112 regulated flammable substances: No products were found.
	Clean Air Act (CAA)112 regulated toxic substances: No products were found.
Clean Air Act Section 112(b) Hazardous Air Pollutants (HAPs)	: Not listed
Clean Air Act Section 602 Class I Substances	: Not listed
Clean Air Act Section 602 Class II Substances	: Not listed
DEA List I Chemicals (Precursor Chemicals)	: Not listed
DEA List II Chemicals (Essential Chemicals)	: Not listed
State regulations	: Connecticut Carcinogen Reporting: None of the components are listed. Connecticut Hazardous Material Survey: None of the components are listed. Florida substances: None of the components are listed. Illinois Chemical Safety Act: None of the components are listed. Illinois Toxic Substances Disclosure to Employee Act: None of the components are listed. Louisiana Reporting: None of the components are listed. Louisiana Spill: None of the components are listed. Massachusetts Spill: None of the components are listed. Massachusetts Substances: None of the components are listed. Michigan Critical Material: None of the components are listed. Minnesota Hazardous Substances: None of the components are listed. New Jersey Hazardous Substances: None of the components are listed. New Jersey Spill: None of the components are listed. New Jersey Toxic Catastrophe Prevention Act: None of the components are listed. New York Acutely Hazardous Substances: None of the components are listed. New York Toxic Chemical Release Reporting: None of the components are listed. Pennsylvania RTK Hazardous Substances: None of the components are listed. Rhode Island Hazardous Substances: None of the components are listed.
<a href="#">California Prop. 65</a>	No products were found.
<a href="#">International regulations</a>	
<a href="#">International lists</a>	: Australia inventory (AICS): Not determined. China inventory (IECSC): Not determined. Japan inventory: Not determined. Korea inventory: Not determined. New Zealand Inventory of Chemicals (NZIoC): Not determined. Philippines inventory (PICCS): Not determined.

## 16 . Other information

Label requirements	: MAY CAUSE EYE IRRITATION. MAY CAUSE TARGET ORGAN DAMAGE, BASED ON ANIMAL DATA.
Hazardous Material Information System (U.S.A.)	: Health : 1 Flammability : 0 Physical hazards : 0

**Fig 4. of Appendix A: Vmax MSDS Sheets (6 of 7).**

## 16 . Other information

Caution: HMI9® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks. Although HMI9® ratings are not required on MSDSs under 29 CFR 1910.1200, the preparer may choose to provide them. HMI9® ratings are to be used with a fully implemented HMI9® program. HMI9® is a registered mark of the National Paint & Coatings Association (NPCA). HMI9® materials may be purchased exclusively from J. J. Keller (800) 327-6868.

The customer is responsible for determining the PPE code for this material.

**National Fire Protection Association (U.S.A.)** : **Health :** 1      **Flammability :** 0      **Instability :** 0

**References** : ANSI Z400.1, MSDS Standard, 2004. - Manufacturer's Material Safety Data Sheet. - 29CFR Part 1910.1200 OSHA MSDS Requirements. - 49CFR Table List of Hazardous Materials, UN#, Proper Shipping Names, P.G.

**Date of issue** : 12/01/2010

**Date of previous issue** : 05/01/2010

**Version** : 1.1

### Notice to reader

**To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.**

**Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.**

Stafac, V-Max, Healthy Animals, Healthy Food, Healthy World, are trademarks of Phibro Animal Health Corporation.

**Fig 4. of Appendix A: Vmax MSDS Sheets (7 of 7). [13]**

## Appendix B: Floatation Calculations

Below is Table 1 of the floatation calculations performed by the students.

**Table 1: Floatation Calculations**

Components	Weight (lbs)
Batteries	88
Motor	22
PV System	25
Drive Train	30
Hull	64
Miscellaneous	10
Total	239

Constants	
Conversion Factor (K)	0.85
Density of Water (lb/ft <sup>3</sup> )	62
Density of Hull Material (lb/ft <sup>3</sup> )	33.7
Density of Components (lb/ft <sup>3</sup> )	0

$$\begin{aligned} \text{Safety Factor} &= (\text{Total Weight} * 0.2) + \text{Total weight} \\ &= 286.8 \end{aligned}$$

$$\text{Flotation of the Boat } F_b = \frac{\text{Dry weight of hull} * K}{\text{Buoyancy of 1 ft}^3 \text{ of flotation material (B)(lbs)}}$$

$$B = \text{Density of fresh water} - \text{density of hull material} = 62 - 33.7 = 28.3 \frac{\text{lb}}{\text{ft}^3}$$

$$F_b = \frac{64 * 0.85}{28.3} = 1.9 \text{ ft}^3$$

$$\text{Flotation of Machinery } F_p = \frac{G}{B}$$

$G$   
 = 75% of the installed weight of the engine, drive and battery (inboard), or the engine, outdrive  
 and battery

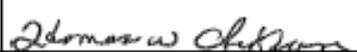
$$G = 0.75 * (88 + 22 + 25 + 30 + 10) = 131.25 \text{ lbs}$$

$$B = \text{Density of Fresh water} - \text{Density of components} = 62 \frac{\text{lb}}{\text{ft}^3}$$

$$F_p = \frac{131.25}{62} = 2.17 \text{ ft}^3$$

$$\begin{aligned} \text{Total flotation} &= F_b + F_p + \text{Factor of Safety} \\ &= 290.8 \text{ ft}^3 \end{aligned}$$

Appendix C: Proof of Insurance

Client#: 1130297		UNIVEDAY1					
<b>ACORD™</b>		<b>CERTIFICATE OF LIABILITY INSURANCE</b>					
			DATE (MM/DD/YYYY) 4/14/2015				
<p><b>THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.</b></p>							
<p><b>IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).</b></p>							
<b>PRODUCER</b> USI Midwest C/L Dayton 131 N Ludlow Suite 700 Dayton, OH 45402 937 223-8891		<b>CONTACT NAME:</b> Patty Isaacs <b>PHONE (A/C No. Ext.):</b> 937 913-1313 <b>FAX (A/C No.):</b> 866-972-6309 <b>E-MAIL ADDRESS:</b> patty.isaacs@USI.BIZ					
		<b>INSURER(S) AFFORDING COVERAGE</b>					
		<b>INSURER A:</b> Genesis Insurance Company					
		<b>INSURER B:</b>					
		<b>INSURER C:</b>					
		<b>INSURER D:</b>					
		<b>INSURER E:</b>					
		<b>INSURER F:</b>					
<b>INSURED</b> University of Dayton 300 College Park Dr. Dayton, OH 45469-1660		<b>NAIC #</b> 36962					
<b>COVERAGES</b>		<b>CERTIFICATE NUMBER:</b>					
		<b>REVISION NUMBER:</b>					
<p>THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.</p>							
LINE	TYPE OF INSURANCE	ADDITIONAL INSURER	SUBJECT	POLICY NUMBER	POLICY EFF. (MM/DD/YYYY)	POLICY EXP. (MM/DD/YYYY)	LIMITS
A	GENERAL LIABILITY <input checked="" type="checkbox"/> COMMERCIAL GENERAL LIABILITY <input type="checkbox"/> CLAIMS-MADE <input type="checkbox"/> OCCUR <input checked="" type="checkbox"/> BIPD Ded: 500000 GEN'L AGGREGATE LIMIT APPLIES PER: <input type="checkbox"/> POLICY <input type="checkbox"/> PRO-JECT <input type="checkbox"/> LOC			YXB301103G	08/01/2014	08/01/2015	EACH OCCURRENCE \$1,000,000 DAMAGE TO RENTED PREMISES (EA OCCURRENCE) \$None MED EXP (Any one person) \$None PERSONAL & ADV INJURY \$1,000,000 GENERAL AGGREGATE \$3,000,000 PRODUCTS - COMP/OP AGG \$Included \$
	AUTOMOBILE LIABILITY <input type="checkbox"/> ANY AUTO <input type="checkbox"/> ALL OWNED AUTOS <input type="checkbox"/> SCHEDULED AUTOS <input type="checkbox"/> HIRED AUTOS <input type="checkbox"/> NON-OWNED AUTOS						COMBINED SINGLE LIMIT (EA ACCIDENT) \$ BODILY INJURY (Per person) \$ BODILY INJURY (Per accident) \$ PROPERTY DAMAGE (Per accident) \$ \$
	UMBRELLA LIAB <input type="checkbox"/> OCCUR EXCESS LIAB <input type="checkbox"/> CLAIMS-MADE DED    RETENTION \$						EACH OCCURRENCE \$ AGGREGATE \$ \$
	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY ANY PROPRIETOR/PARTNER/EXECUTIVE/OFFICER/MEMBER EXCLUDED? (Mandatory in NH) If yes, describe under DESCRIPTION OF OPERATIONS below		N/A				<input type="checkbox"/> WC STATUTORY LIMITS <input type="checkbox"/> OTHER E.L. EACH ACCIDENT \$ E.L. DISEASE - EA EMPLOYEE \$ E.L. DISEASE - POLICY LIMIT \$
DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (Attach ACORD 101, Additional Remarks Schedule, if more space is required) Verification of Insurance regarding Solar Splash Event being held June 10 - 14, 2015.							
<b>CERTIFICATE HOLDER</b>				<b>CANCELLATION</b>			
Solar Splash Headquarters c/o Jeffrey Morehouse, PhD. PE 309 Newridge Road Lexington, SC 29072				SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.			
				AUTHORIZED REPRESENTATIVE 			

## Appendix D: Team Roster

### 2014-2015 Team Members:

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Tyler Edwards: Graduate Aerospace Engineering Student

E-mail: [tyben7805@gmail.com](mailto:tyben7805@gmail.com)

### 2014-2015 Advisors:

Dr. Kelly Kissock, Project Sponsor

John Hageman, Senior Design Professor

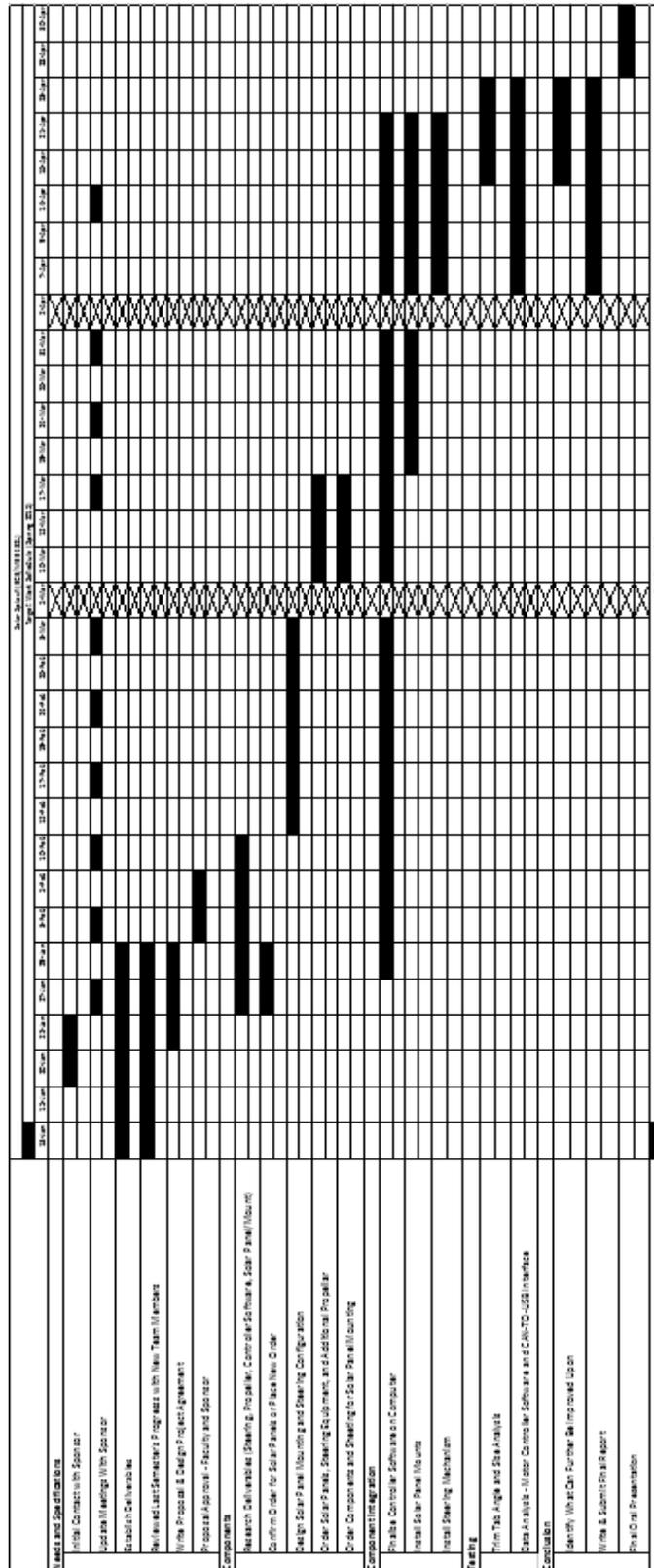
Harold Linville, Senior Design Professor

Sean Powers, Senior Design Faculty

Don Schenck, Senior Design Faculty

Weisong Wang, Senior Design Professor

Appendix E: Gantt Chart for 2014-2015 Team



## Appendix F: Power Calculations

At 36 volts: Power = 10 hp

$$T = \frac{\text{Power} * 5252}{\text{Speed}}$$

$$\text{Speed} = \frac{70 \text{ rpm}}{v} \quad 36 \text{ v} = 2520 \text{ rpm}$$

$$T = 20.8 \text{ ft. lb}$$

Assuming a %100 propeller efficiency

$$\frac{F_{\text{out}}}{T_{\text{in}}} = \frac{2 * \pi * \text{efficiency}}{l}$$

$l$  = linear distance screw travels per 1 revolution

$$F_{\text{thrust } x\text{-direction}} = \frac{2 * \pi * 1 * 20.8 \text{ ft. lb} * 12" / 1'}{14.7" / \text{rev}} = 106.71 \text{ lbs}$$

$$\sum F_x = 106.7 - F_{\text{mount-x}} = 0$$

$$F_{\text{mount-x}} = 106.7 \text{ lbs}$$

$$\sum M_{\text{strut}} = 0 = 108.4 \sin 12 (4.59) - 106.7(4.75 \sin 12) - ([54 - 4.75] \sin 12) 106.7 + F_{\text{mount-y}} ([54 - 4.75] \cos 12)$$

$$F_{\text{mount-y}} = 22.7 \text{ lbs}$$

$$\sum F_y = F_{\text{mount-y}} - F_{\text{strut}} + F_{\text{thrust-y}} = 0$$

$$F_{\text{thrust-y}} = 22.7 + 108.4 \sin 12 = 45.2 \text{ lbs}$$

## Appendix G: Shaft Diameter Calculations

### Nomenclature

$d$	Outer diameter (in.)
$hp$	Horsepower
$k_{ts}$	Endurance limit modification factor for a machined surface
$rpm$	Revolutions per minute
$S_u$	Ultimate tensile strength (kpsi)
$S_e$	Endurance Strength (kpsi)
$T$	Torque (in.-lbs.)
$\tau$	Torsional Stress (psi)

Using 10 horsepower as the estimated motor output at 36 Volts and the no load rpm of 5400, the Torque was calculated using Equation 1.

$$T = \frac{63000hp}{rpm} \quad (1)$$

The expected torque load on the shaft equals 117 in.-lbs. The torsional stress expected in the shaft was calculated using Equation 2. Where  $d$  is the outside diameter of a solid shaft. A shaft diameter of 1 in. was used due to its relatively small size and high availability of components compared to other small shaft sizes.

$$\tau = \frac{16T}{\pi d^3} \quad (2)$$

The torsional stress was calculated to be 5900 psi. The theoretical maximum stress for failure of 304 stainless steel, the material of the proposed shaft, is 73000 psi assuming static or constant loading (<http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MQ304A>). The endurance strength considering the stress concentration factor for shear stress in a machined 304 stainless steel shaft and infinite life, was calculated to be 33400 psi using Equations 3 and 4.

$$k_{ts} = 1.34S_u^{-0.085} \quad (3)$$

$$S_e = \frac{1}{2}S_u k_{ts} \quad (4)$$

Considering a safety factor of 2 the stress was calculated to be 68000 psi. This is less than the ultimate or failure strength of 73000 psi indicating that a 1 in. shaft machined from 304 stainless is acceptable for use.