Team Members:
Erich Brown, WeyAnn Chen, David Sanabria, William Green, Luis Hernandez, Ally Jackman, Aura Jensen-Curtis, Elisabeth Keller, Kevin McConnell, Christopher Murtagh, Cameron Pouncey, Ramon Reyes, Mark Reyna, James Richards, Craig Robertson, Leonardo Rossetti, Ted Sterns, Keith Soules

Faculty Advisors and Instructor
Dr. Jane Lehr
Dr. Peter Vorobieff
Daniel Taylor
EXECUTIVE SUMMARY

This year the University of New Mexico (UNM) is returning to the annual Solar Splash competition for the third time. The previous teams laid down the groundwork, allowing this year's team to pursue bold and innovative new ideas, to lead the pack. To take advantage of the previous project infrastructure, this year the team took on the challenge of two large optimizations. First, a complete reconstruction and design of the original Solar Array done with an emphasis on improving efficiency, assembly, and style. The second optimization was to completely redo the driveline of the boat by upgrading from a single motor to a pair of DC motors, one direct drive and the other belt driven. This year's focus was to improve the endurance performance of the boat without diminishing the slalom sprint performance. Redesign of the solar array will bring a big boost to the overall endurance event.

At UNM there are close ties between the Mechanical Engineering and Electrical Engineering departments. For the previous years the two departments worked side by side to create a mechanically and electrically optimized system. The team considers this union to be a secret weapon, and a key to their success in the previous competitions. This year experienced greater collaboration overall in the aspects of testing and system development. Having both departments allows for more in-depth innovations, giving each student the time to focus on their expertise. Because of this year’s great collaboration massive changes were made to the electrical system and mechanical system. The complete redesign of the driveshaft and solar array was made possible by the focused engineering of the two departments, something that would otherwise be a lengthy and difficult endeavors.

In conclusion it is with great passion that UNM’s team participates in this year’s Solar Splash competition, ready to bring new innovative ideas and improved performance to the course. With only traces of paper work left in the bureaucratic process at the university the UNM Solar Splash team sees great potential in its future. With the improvements to the driveline and the complete redesign of the electrical systems onboard the boat the team is ready. The team’s dreams at the beginning of the project have become a reality and testing has given the team the confidence that this years UNM Solar Splash team will see impressive performance and bring astonishing innovations to the competition.
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I. PROJECT OBJECTIVES

The University of New Mexico (UNM) has been competing in Solar Splash the last two years, this year being the third year. Spring 2018’s team’s primary objective is to place in the top five at competition. This year the team decided to approach the project with two objectives in mind. These objectives were to increase power and increase efficiency. To do so, the mechanical team focused on improving the boat from UNM’s 2017 team with a two-motor setup and a cooling system for the solar panels as the electrical team had groups working on different electrical projects.

The endurance event is the biggest part of the scoring of all the events. By optimizing the boat for this event, the team will be able to gain more points where it counts the most. To optimize the boat, the solar panels are cooled by the cooling system during the endurance. A test on a small number of solar panels showed a four percent efficiency increase through cooling the panels. The cooling system is discussed in further detail in Appendix F.

Establishing a two-motor setup will allow the team to optimize for the different events. For example, the two motors will be utilized in the sprint event to give the most power in the least amount of time. Then for the endurance event, the boat will be set to use one motor, so that the batteries last longer, and the power is more efficiently spread out. See Appendix D for the motor specifications and further details.

II. Solar System

A. Modular Solar Array

The primary design goals for the solar array for this year’s boat were the implementation of a modular design and improving the power density of the array. The decision to make the array modular was based on the failures of solar cells experienced by last year’s team and the resulting loss of solar power output that could not be easily remedied during the competition. The desire to improve the power density was based on the observation that the previous panel did not take full advantage of the power density available from the triple-junction solar cells that were used due to the excessive unused area between cells.

The solar array design is modular in the sense that the array is made up of 29 individual solar modules, each of which consists of 20 series-connected cells affixed to a printed circuit board (PCB) which provides both structure and electrical connectivity for the module. In addition to the solar cells, the module also has bypass diodes for each cell and a reverse current blocking diode. The bypass diodes, which are 20 Volt, 1 Ampere rated Schottky diodes, provide a conduction path around any cell that is not delivering current so that the remaining cells can still provide power. The reverse current blocking diode, which is a 100 V, 5 Ampere Schottky diode, prevents current from flowing into the panel - which could occur in the case of one or more panels being shaded if this diode was not incorporated. Figure 1 is a photograph of a complete module. The cells are affixed to the copper pads on the PCB with 3M 7903 electrically conductive tape. Approximately
13 cm² of tape is used per cell giving a calculate contact resistance of 0.001 Ohms per cell. The top tabs of each cell are connected to the adjacent PCB pads with tinned copper tabbing wire. The entire top surface of each module is coated with a heavy coat of Techspray acrylic conformal coating to provide environmental protection and electrical insulation for the cells and interconnects. This coating was chosen based on tests of various coatings that showed it to have the lowest loss (<1%), easiest application, and a relatively hard, easy to clean finish. Electrical connections to each module are made via a pair of quick-disconnect tabs.

The cells used for the modular array are triple-junction space-rated solar cells manufactured by SolAero Technologies that have an exceptional minimum efficiency of 27.5%. This efficiency, combined with the efficient packing of the cells permitted by the design of the solar modules, enabled a significant reduction in array size compared to the required size for silicone cells. The difference is illustrated in Fig. 2. An additional benefit of these cells is the high open-circuit voltage of 2.6 Volts per cell. This enables the maximum allowable voltage of 52 V DC to be achieved by a series string of only 20 cells. Thus, each module operates at the maximum allowed voltage and the modules can then be connected in parallel - thus allowing for graceful degradation of the solar system in the event of failure of one or more modules. Each cell is rated by the manufacturer at 0.91 W under 1-sun AM 1.5 conditions, thus 29 modules of 20 cells each, for a total of 580 cells produces a rated power of 527.8 W.
B. Cooling System

The cooling system is an innovative new addition to the UNM solar array for this year. Cooling the solar array provides significant improvement in cell efficiency and power output. The cooling system also provides both the structural support for the solar modules as well as the mounting interface for the array to the boat and to the solar tracker when the array is used on shore.

The solar modules are attached to a 1/16\textsuperscript{th} inch thick aluminum top plate. Thermal grease between the sheet and the module increases the heat transfer. Thin aluminum ribs were cut and riveted to the top plate which gave the entire system rigidity while keeping it light weight. The bottom of the ribs are attached to another piece of aluminum sheet that is shaped like a tent, which prevents the water from the cooling system from entering the boat.

The cooling system was routed so that a main line runs up the middle of the ribs and then branches off, as shown in Fig. 3. A hand pump provides the pressure needed to suck water from the lake and through the system. The hose that is used to suck the water from the lake is mounted to the rudder support and then routes the water into the chiller. The chiller consists of a copper coil that is placed in a circular Igloo cooler, which is filled with ice. The lake water is predicted to be around 65°F to 70°F and tests were conducted to determine if it would be worth adding the chiller or not. 1/8\textsuperscript{th} inch holes were drilled in the branches at different angles and adjusted so that maximum water coverage could be achieved. The water ejects out of the holes and interacts with bottom side of the aluminum sheet, the difference in temperature removes heat from the panels, which improves their efficiency.

![Figure 3: Cooling System Schematic](image)

Preliminary tests were conducted to determine the output power increase due to cooling the cells. Figures 4 and 5 show the test setup used. For the initial test, shown in Fig. 4, voltage readings were taken for three minutes where the panel was not cooled followed by one-minute of being cooled with water, Fig. 6 shows the result of the test. At the end of the one-minute cooling period, the voltage output increases from an average of 7.5 V to just over 9 V, which is an increase of roughly 20%. A similar test was conducted with iced water, shown in Fig. 5, allowing for the determination if a chiller would be worth the additional weight for the system. The results of this test show an average increase in power up to 12% of the test conducted with the warmer water, which is shown in Fig. 7.
Figure 4: Test Setup and Initial Test

Figure 5: Test with Iced Water

Figure 6: Solar Panel Cooling Experiment Results
C. Solar Tracker

At last year's competition a solar tracker was used to optimize the amount of charging power between events. The system used an Arduino and a precalculated table of data giving angle of the sun versus time. This table was specific to the location of the competition making the system only work in a small area. To improve the design, the team simplified the system to a closed loop control system. This year’s solar tracker system uses the Arduino UNO, a servo-type motor controller, two light dependent resistors (LDR’s) and two resistors to rotate the solar panel towards the sun. The sun direction sensor works by shading one of the LDR sensors when it is not perpendicular to the sun. This is shown in the Fig. 8 below.
The LDR sensors are mounted on a 3D printed board which can be attached to the tracker frame with screws or double-sided foam tape. The LDR sensor and the 10K Ohm resistor form a voltage divider which outputs a voltage ranging between 0 V and 5 V depending on the irradiance. The output voltage is directly fed into the analog pins on the Arduino and converted to a digital value.

The actuator is controlled by a standard RC ESC (electronic speed controller). The ESC is powered by a 12 V source. A pulse train generated by the Arduino is fed into the ESC. The actuator motor rotation direction can be controlled by varying the pulse width. The actuator, ESC, and light sensors are connected to the Arduino and mounted onto the tracker. The software on the Arduino will detect if one of the light sensors is shaded and adjust the actuator until it perpendicular to the sun. Making the system much simpler and more versatile than last years.

III. Electrical System

A. Skipper Controls and Cruise System

To improve the overall performance of the boat during the endurance race, a cruise control system has been implemented. The system estimates an optimal speed based on power draw from the batteries to guarantee that all stored and generated power during the event will be consumed in the two hours allotted. The hardware for the system is an Arduino UNO running the ATmega328 microcontroller. The total battery energy is calculated by a BMV-712 made by Victron energy, it transmits a value in minutes estimating the time remaining of the batteries known as the Time to Go (TTG). There are two physical inputs to the system, a flip switch and a momentary push button. The flip switch signals the Arduino that the Cruise Control has been enabled and switches the throttle signal from the physical handle to the internal digital throttle, which allows the Arduino to control the motor speed. The momentary push button starts a two-hour countdown, the Internal
Event Timer (IET), after the being pressed for three seconds. The timer should be started at the beginning of the endurance event to give the Arduino a reference time for the event duration.

![Figure 9: Control Box](image)

The software for the cruise control system is written in C++ with the Arduino IDE. A PI (Proportional Integral) control system is used to calculate the optimized motor speed. In a PI control system an error term is calculated by subtracting the PV (Process Variable) from the SP (Set Point). In this system the SP will be the IET and the PV will be the TTG from the BMV-712. This error term is then multiplied by a constant $K_p$, this is the proportional part of the controller. The integral part is a constant $K_I$ which is multiplied by the integration of the error term. These two parts are summed and used to set the motor speed. The ideal operation of the system will optimize the motor to have the PV match the SP.

![Figure 10: Closed Loop Process](image)

**B. Electrical Integration and Wiring**

With all of the new electrical and electronic systems planned for this year’s boat, it was recognized that the wiring and integration of the various systems would be a challenge. Fortunately, the team included an electrical engineering student with extensive experience in
the wiring of aircraft electronics for both commercial and military aviation. An overall block diagram of the electrical system was developed and from that the various interface harnesses were designed. All cable interfaces with the various electrical systems were equipped with suitable connectors to ease installation and maintenance. The wiring harnesses are assembled according to industry best practices with protective sheathing and labels. Spare conductors were included in several of the harnesses to provide for addition of future capabilities. The complete wiring drawing set is included as Appendix J.

IV. Power Electronics System

A. MPPT

To optimize the charging of the batteries the team used a maximum power point tracking (MPPT) controller. Last year, a 150/35 from Victron Energy was purchased. This same MPPT was used because of its quality, ease of use, and to reduce unnecessary spending. The 150/35 MPPT is an excellent product, as it quickly optimizes the maximum power output of the solar array and allows easy configuration of the device. In addition, the purchase included the optional Bluetooth adapter which allows for the viewing of the data in real time and store values for future reference. Specifications about the product can be found in Appendix H.

B. Battery State of Charge Monitors

The performance of the batteries in the last two years has been evaluated based on runtimes of the boat during testing and competition days. These are good determinants to understand the battery performance, however, it lacks precision. To improve the team’s understanding of how the batteries are performing, a Victron Energy BMV-712 was used. This is a battery supply monitoring device designed for solar systems. It gives crucial information such as, voltage, power, state of charge, and an estimated time remaining on the batteries.

C. Batteries

The team’s chosen batteries are deep-cycle marine Odyssey-PC1100 batteries. These batteries are relatively light at 27.5 lbs. each. They are rated at 12 V; therefore, three batteries will be used to power the boat to achieve the 36 V that is the maximum allowable voltage per Solar Splash rules. The specifications are found in Appendix A.

One major change that has been made by this year’s team is the battery boxes. Below is a picture of the battery box used in the 2017 competition.
While the battery box functioned properly in last year’s competition and testing early this year, there was still more to be desired from the battery box. For starters, the battery box was handmade with a locking mechanism that was difficult to secure. The team wanted something sturdier and rated for marine applications. Also, when switching out the batteries, each battery had to be disconnected and removed one by one followed by individual placement and connection of the next three batteries. The team wanted easy transition between battery assemblies. Finally, the original battery box was mounted to the back seat in the hull. Weighing roughly 80 lbs., the placement of the battery box in the boat could affect the boat’s ability to plane. Therefore, the team considered mounting the batteries near the front of the hull.

To accomplish these goals, the team has chosen to use two NOCO Marine Battery Boxes, pictured below.
As it stands, there are two battery boxes with identical battery configurations. Each box is bolted to an aluminum plate which is then mounted to an L-bracket on the front seat of the boat. The placement of the battery boxes helps guide the nose of the boat down at higher speeds which is referred to as planing. Planing helps increase the boat’s performance because it causes the propeller to be working more horizontally to push the boat forward rather than working vertically against gravity. The NOCO Marine battery boxes accomplish the goal of easy transition because there are two boxes with identical setups, meaning addition and removal of the boxes only requires attachment of two bolts and four cables.

There are still changes that the team plans to make to the battery box mounting process. Currently, there is a small space between the sides of the boat and the battery box, making it difficult to reach the bolts and nuts with a ratchet. Also, the aluminum mounting plate has been straight cut which makes sharp edges a hazard for slicing fingers and hands. To eliminate these setbacks, the team plans to implement a new mounting system which is one complete piece, mounted to the top of the boat’s front seat. The new mount design is pictured below.

![Battery Box Mounting CAD Drawing](image)

With this new design, there will be no sharp edges. In fact, there will need to be no handling of the mounting system at all since the mount will be fixed to the boat. This eliminates the risk of cutting hands. This also makes switching battery boxes infinitely easier because the boxes will sit inside the tray, eliminating the need for bolts. A strap will hold the boxes securely in place, protecting them from becoming dislodged due to waves or capsizing of the boat. Also, this mounting design will eliminate the need for the wooden supports in the current design. Therefore, there will be no concern of the wooden supports coming lose due to chatter from the boat experiencing choppy waves.

V. Hull Design

The hull design is the same as that of UNM’s 2017 team. The team chose to continue working with the hull from the year before because it would be the most cost-efficient option as nothing would need to be changed. It is a Gheenoe hull that is 13 feet long and is made of fiberglass and composite materials. The specifications are in Appendix G.
UNM’s 2017 team made a few modifications to the hull. The team had rounded the bottom of the hull to reduce drag as well as removing the seat in the middle. Removing the seat in the middle allowed for the drive train to occupy that space.

VI. Drivetrain and Steering

It was decided early on that the hull and steering from last year was going to be reused and improving the drivetrain was necessary.

The steering mechanism and rudder from last year’s team was fabricated out of aluminum. Aluminum was used for its light weight and structural rigidity. In place of a traditional steering wheel, a long aluminum post was attached to the rudder behind the hull. Pulling the post forward or backward turned the rudder right and left, respectively.

Last year’s drivetrain included an inboard mounted Motenergy PMAC ME1117 motor that had a direct 1” diameter driveshaft. The motor and driveshaft were angled 10° from the horizontal surface of the hull. The motor was mounted along the center with the controller and electrical components in front.

The new system consists of two LEM200-D126 LEMCO motors. Although the new motors are smaller in diameter and width, they weigh close to two pounds more. The compensation of having two motors allow for a faster draw of current resulting in more power. A parallel drive system was considered. The CAD drawing can be seen in Fig. 15. The setup would have accounted in an uneven distribution of torque when a single motor was operating, as well as wiring and relocating the controllers.
The motors were then mounted along the driveshaft. One of the motors was mounted directly to the driveshaft and the other motor was mounted above it. The angle in the driveshaft allowed the motor to sit lower and keep a low center of gravity. The driveshaft had to be extended to fit one motor directly in to the shaft, and the other motor inversely running on a single pulley system. Having the motor run opposite to the first motor removes having multiple pulleys and belts reducing the efficiency losses. The new motor mounting is shown in Fig. 16.

![Figure 16: New Motor Mounting](image)

The control box has a key next to the cruise control. This key allows for a counterclockwise or clockwise turn resulting in operating two or one motor, respectively. The flexibility of having one motor for longer distance versus two motors for a sprint is a major improvement in this year’s Solar Splash team.

The steering mechanism and rudder kept from last year’s team is shown in Fig. 17. The throttle was added at the end of the post. The only modification to the steering components were shortening the post so that the throttle is closer to the skipper.

![Figure 17: Steering and Rudder Mechanisms](image)
VII. Data Acquisition and/or communications

A. Telemetry System

Because the UNM telemetry and autopilot system design for the 2017 Solar Splash competition was judged to be in violation of the rules, a new telemetry system has been designed from the ground up. The requirements for the system fall into five main categories: monitoring the PV system, monitoring the batteries, monitoring the propulsion system, collecting physical data, and the reliability of the system itself. The rationale behind all of these is to increase the performance of the boat, either by increasing speed or by making the use of power more efficient. The total voltage of the PV modules, the current of individual modules and the temperature at six points on the PV system are collected. This allows poorly performing modules to be identified and replaced, as well as assessment of the performance of the PV cooling system. The batteries are monitored through a Victron BMV, which provides battery voltage, current, temperature, state of charge, time remaining at current output, power, and consumed amp-hours, giving data on the health of the batteries and the use of their energy. The propulsion system is monitored through motor temperature sensors and an RPM sensor. The former is a simple method to check that the load on the motors is properly balanced, and the latter provides data to evaluate the efficiency of various system configurations. Physical data, such as ambient temperature, speed, and location, give the team the ability to control for differing conditions in tests and to evaluate the effect on the speed of the boat, which is paramount. Lastly, the system is designed to withstand the demands of operating in a wet environment with EMI produced by the switching power electronics on board.

A high-level schematic of the system is shown in Fig. 18. The main component of the system is a Labjack T-7 Professional. It provides collection of analog and digital signals, communication via Wi-Fi with the shore, and storage using an SD card. An Arduino Uno
communicates with the T-7 via I2C, providing data from both the Victron BMV and an Adafruit Ultimate GPS, both of which use serial communication. The T-7 also receives many analog signals from the PV junction box: 29 differential current signals for individual modules, the total voltage signal, and 6 temperature sensor signals. In addition, the T-7 receives the status of the cruise control system and the status of the throttle from the cruise control system. Finally, the propulsion system sends analog signals for the motor temperatures and a digital signal from the RPM sensor. After the initial design of the telemetry system, analog temperature sensors for the PV module cooling system were added. The last component of the system is a laptop on shore which collects, analyzes, and displays the data using LabVIEW. The choice of the T-7 was driven by two main factors: it is less expensive than alternatives like National Instruments hardware, and it is easily expanded to handle the multitude of signals encompassed by the telemetry system.

At this point, there have been several successes and failures with the system. The Wi-Fi was the first success, as it was not clear that the range would be great enough for the competition. However, after testing the range on land and then on the boat at a local lake, the range was found to be sufficient. This saved time that would have gone into researching and implementing alternatives such as LoRa. Another success has been the ability to evaluate different props by correlating speed and RPM data. This data showed that a smaller prop would keep the motors running at higher RPM, which is not only more efficient but resulted in much greater speed. The main challenge encountered is the poor performance of the Arduino. It frequently loses its I2C connection with the T-7, causing other software issues. Two solutions are being considered for implementation before the 2018 competition: add more robust error handling to the software or establish direct communication between the T-7 and both the GPS and BMV. Because the error handling does not really solve the problem, direct communication will be attempted first.

The system developed for the 2018 competition is a good base from which to develop next year’s system. In addition to resolving the issues mentioned above, accommodation for expansion of the system to include data from the motor controllers has been made in the telemetry system box and cabling. The LabVIEW vi is also designed to include in the future a mapping feature to show the location of the boat.

VIII. PROJECT MANAGEMENT

A. Team Organization

UNM’s 2018 team is composed of both mechanical and electrical engineering students because of the multidisciplinary nature of the Solar Splash competition. The mechanical engineering team has been focused heavily on the design of the boat and improving its power and efficiency. To do this, the team has considered everything from hull design to motor configuration and even hydrofoils. The mechanical engineering team is responsible for all building and machining of the boat design. The electrical engineering team takes on the role of improving solar power collection and efficient conversion of that power to the boat as well as data collection both before and during the competition. This year, the electrical team revamped the solar array for more
efficient collection, improved the articulating solar tracker, developed a cruise control system, and implemented a telemetry system. Although both teams do not meet for a common class time, both disciplines have been involved in helping every step of the way, allowing all parts of the project to be considered with many points of view as well as making the desired goals more achievable.

The teams also chose delegates responsible for various parts of the mission. This way, tasks could be divided amongst a couple members of the team and everyone could be working on accomplishing different tasks simultaneously. This was extremely efficient in the design process as many different ideas were synthesizing throughout the semester.

An important part of the team organization was allowing team members easy access to the boat and work spaces. This is important since all the team members are also full-time students with busy schedules. Designating a set times would often become difficult tasks, freedom to work on the project at any time improved the speed at which tasks were completed.

B. Project Planning and Timeline

The team first met in January and chose responsibilities and roles at that time. These roles include team leads, shop manager, fundraising leader, purchasing delegate, and social media correspondent. Once these roles were established, the team decided to have a testing day where no changes were made to the previous year’s boat. The testing gave baseline data, so that the team will know if changes improve the performance. This testing day took place on February 10th. Using the baseline data, the team decided what to focus on for this year’s competition. Controllers and motors were ordered as well as other material. These materials were ordered and delivered from February through April. This allowed for the testing to start in late April, leaving roughly six weeks of testing and modification before the competition.

C. Financial Planning

Solar Splash is one of the senior design options at UNM; therefore, the mechanical engineering department supplies a limited amount of funds. Additional funds must be fundraised, donated, or otherwise found. As this is the third year that Solar Splash has been a design option at UNM, there are sponsors in place already.

D. Team Continuity and Legacy

The team considered what to do for the future teams from UNM. Because this is the third year that UNM has competed in Solar Splash, there is a framework in place for the future teams. Relationships between the sponsors and the team have gotten stronger each year and should continue to flourish for the prospective teams as well as the relationship between the two disciplines, mechanical and electrical engineering.

The team worked on making Solar Splash more available to students from every major by making Solar Splash a student organization. This will make it so that the forthcoming teams can
have a broad range of talents and skills available to them. It may also lead to more funds or donations.

When making choices about what to improve for competition, the team chose components that future teams would be able to use and improve upon. For example, the two motors that this team chose were used for an inboard motor whereas the future team will be able to use the motors in an outboard setup. Altogether the groundwork is laid for future teams.

**E. Self-Evaluation**

Looking over the work accomplished and the work that was not accomplished, the team concludes that time management was something that could have been better. When waiting for the materials to arrive, the team could have focused on the aspects that did not depend on those materials. An important aspect to consider is the chain of events that need to be processed. Components on the critical path need to be primary focus to ensure minimal delays in other projects.

**IX. CONCLUSIONS AND RECOMMENDATIONS**

**A. Objectives Completion**

The main objectives were to implement the two-motor setup, the cooling system and the multiple electrical projects. The two-motor setup has successfully been implemented, and the cooling system is not yet finished. It will be finished for competition in June. The new solar array is complete and ready for testing.

**B. Reflections**

Making the decision to focus on a couple big tasks instead of trying to do multiple things was the way to go. By doing this, the team was able to complete their goals by the time competition came around.

The following table displays the strengths and weaknesses of the team.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>Communication</td>
<td>Time Commitment</td>
</tr>
<tr>
<td>Organization</td>
<td>Time Management</td>
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</tbody>
</table>

The following table displays the strengths and weaknesses of the boat.
Table 2: Strengths and Weakness of the Boat

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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</thead>
<tbody>
<tr>
<td>Motors</td>
<td>Hull</td>
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<tr>
<td>Cooling System</td>
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</tbody>
</table>

C. Future Plans

With the success that is expected from this boat design, a future team can focus on manufacturing a hull instead of buying one. This would allow for the team to create a lightweight hull which is still stable. Another design alternative for a future team to explore is the concept of an outboard motor with hydrofoils. The outboard motor can be more efficient than the current inboard motor, and the hydrofoils will reduce the drag of the boat which will allow for more efficient use of the batteries. Another future plan is to optimize many of the electrical projects completed this year such as the, cruise control and telemetry. These systems were implemented from scratch in a limited amount of time. Improvements can be made to ensure that the system is running at its greatest efficiency.

D. Lessons Learned

An important lesson that will be taken away from this project is the time constraint. Having the mechanical team work during the spring semester makes for a challenge to accomplish more difficult tasks. Making the Solar Splash class a two-semester design project allows for more challenging and rewarding designs to be explored. One of the most important lessons learned by the team this year is that legacy information is key to success. Without knowledge of the previous year’s efforts improvements are difficult. That is why this year the team made a focused effort to ensure that proper information about the projects was kept. Lessons learned must be passed on to ensure that every year new lesson can be learned, and new improvements can be made.
REFERENCES

http://www.gheenoe.net/thirteenft.html

http://www.odysseybattery.com/extreme_battery_specs.aspx

APPENDICES

Appendix A: Battery Documentation

The specifications of the batteries used for the Solar Splash craft, seen below, contain information about the dimensions and operating conditions of the PC1100 batteries. A similar specifications sheet is attached for the auxiliary PS12180 battery. The MSDS sheets for both the PC1100 and the PS12180 contains information for the safe use of these batteries.

![Figure A1: Odyssey PC1100 Specifications](image_url)
Figure A2: Odyssey Battery MSDS Sheet (1 of 7)
IV. FIRST AID MEASURES

Inhalation:
Sulphuric Acid. Remove to fresh air immediately. If breathing is difficult, give oxygen. Consult a physician.
Lead. Remove from exposure, gargle, wash nose and lips; consult physician.

Ingestion:
Sulphuric Acid. Give large quantities of water; do not induce vomiting or aspiration into the lungs may occur and can cause permanent injury or death. Consult a physician.
Lead. Wash out stomach and get fresh air; consult physician immediately.

Skin:
Sulphuric Acid. Flush with large amounts of water for at least 15 minutes, remove contaminated clothing completely, including shoes. If symptoms persist, seek medical attention. Wash contaminated clothing before reuse. Discard contaminated shoes.
Lead. Wash immediately with soap and water.

Eye:
Sulphuric Acid and Lead. Flush immediately with large amounts of water for at least 15 minutes while lifting lids.
Seek immediate medical attention if eyes have been exposed directly to acid.

V. FIRE FIGHTING MEASURES

Flash Point: NA

Flammable Limits: LEL = 4.1% (Hydrogen Gas) UEL = 74.3% (Hydrogen Gas)

Extinguishing Media: Carbon dioxide, foam, dry chemical. Avoid breathing vapors. Use appropriate media for surrounding fire.

Special Fire Fighting Procedure:
If batteries are on charge, shut off power. Use positive pressure, self-contained breathing apparatus. Water applied to electrolyte generates heat and causes it to spatter. Wear acid-resistant clothing, gloves, face and eye protection. Note that strings of series connected batteries may still pose risk of electric shock even when charging equipment is shut down.

Unusual Fire and Explosion Hazards:
Highly flammable hydrogen gas is generated during charging and operation of batteries. To avoid risk of fire or explosion, keep sparks or other sources of ignition away from batteries. Do not allow metallic materials to simultaneously contact negative and positive terminals of cells and batteries. Follow manufacturer's instructions for installation and service.

VI. PRECAUTIONS FOR SAFE HANDLING AND USE

Spill or Leak Procedure:
Stop flow of material, contain small spills with dry sand, earth, and vermiculite. Do not use combustible materials. If possible, carefully neutralize spilled electrolyte with soda ash, sodium bicarbonate, lime, etc. Wear acid-resistant clothing, boots, gloves, and face shield. Do not allow discharge of unneutralized acid to sewer. Acid must be managed in accordance with local, state, and federal requirements.
Consult local environmental agency and/or federal EPA.

VII. HANDLING AND STORAGE

Handling:
Unless involved in recycling operations, do not breach the casing or empty the contents of the battery.

There may be increasing risk of electric shock from strings of connected batteries.

Keep containers tightly closed when not in use. If battery case is broken, avoid contact with internal components.

Keep vent caps on and cover terminals to prevent short circuits. Place cardboard between layers of stacked automotive batteries to avoid damage and short circuits.

Keep away from combustible materials, organic chemicals, reducing substances, metals, strong oxidizers, and water. Use banding or stretch wrap to secure items for shipping.

Storage:
Store batteries in cool, dry, well-ventilated areas with impervious surfaces and adequate containment in the event of spills. Batteries should also be stored under roof for protection against adverse weather conditions. Separate from incompatible materials. Store and handle only in areas with adequate water supply and spill control. Avoid damage to containers. Keep away from fire, sparks and heat. Keep away from metallic objects which could bridge the terminals on a battery and create a dangerous short-circuit.

Charging:
There is a possible risk of electric shock from charging equipment and from strings of series connected batteries, whether or not being charged. Shut-off power to chargers when not in use and before detachment of any circuit connections. Batteries being charged will generate and release flammable hydrogen gas. Charging space should be ventilated. Keep battery vent caps in position. Prohibit smoking and avoid creation of flames and sparks nearby.

Wear face and eye protection when near batteries being charged.

Figure A3: Odyssey Battery MSDS Sheet (2 of 7)
### INGREDIENTS

<table>
<thead>
<tr>
<th>Chemical Common Name</th>
<th>OSHA PEL</th>
<th>ACGIH</th>
<th>US NIOSH</th>
<th>Quebec PELV</th>
<th>Ontario OEL</th>
<th>EU OEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead and Lead Compounds</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Tin</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sulfuric Acid Electrolyte</td>
<td>1</td>
<td>0.2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>N.E.</td>
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<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Polyethylene</td>
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<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Diethyl Ether</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Acrylonitrile Butadiene</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Styrene</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Glycerol Ether</td>
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<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td>1</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Polycarbonate, Hard Rubber, Polyethylene</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Polyethylene Oxide</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Polycarbonate-Alloy Rubber, Polyethylene</td>
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<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
<tr>
<td>Absorbent Glass Mat</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
<td>N.E.</td>
</tr>
</tbody>
</table>

**NOTES:**

- (b) As inhalable aerosol
- (c) Thoracic fraction

**Engineering Control:**

Store and handle in well-ventilated area. If mechanical ventilation is used, components must be acid-resistant.

Handle batteries cautiously to avoid spills. Make certain vent caps are on securely. Avoid contact with internal components. Wear protective clothing, eye and face protection when filling, charging or handling batteries. Do not allow metallic materials to simultaneously contact both the positive and negative terminals of the batteries. Charge the batteries in areas with adequate ventilation. General dilution ventilation is acceptable.

**Respiratory Protection:**

None required under normal conditions. When concentrations of sulfuric acid mist are known to exceed the PEL, use NIOSH or MSHA-approved respiratory protection.

**Skin Protection:**

If battery case is damaged, use rubber or plastic acid-resistant gloves with elbow-length gauntlets, acid-resistant apron, clothing and boots.

**Eye Protection:**

If battery case is damaged, use chemical goggles or face shield.

**Other Protection:**

Under severe exposure emergency conditions, wear acid-resistant clothing and boots.

---

**EX. PHYSICAL AND CHEMICAL PROPERTIES:**

- Boiling Point: 203 - 240°F
- Specific Gravity (H₂O = 1): 1.215 to 1.330
- Melting Point: N.A.
- Vapor Pressure (max Hg): 10
- Solubility in Water: 100%
- Vapor Density (AIR = 1): Greater than 1
- Evaporation Rate (Butyl Acetate = 1): N.A.
- % Volume by Weight: Less than 1
- pH: 1 to 2
- Flash Point: Below room temperature (as hydrogen gas)
- LEL (Lower Explosive Limit): 4.1% (Hydrogen)
- UEL (Upper Explosive Limit): 74.2% (Hydrogen)
- Appearance and Odor: Manufactured article, no apparent odor. Electrolyte is a clear liquid with a sharp, penetrating, pungent odor.

---

Figure A4: Odyssey Battery MSDS Sheet (3 of 7)
SAFETY DATA SHEET

II. REACTIVITY DATA

Stability: Stable
This product is stable under normal conditions; at ambient temperature.

Condition: To Avoid: Prolonged overcharge, sources of ignition.

Incompatibility: Materials to avoid: 
- Lithium Acid: Contact with combustibles and organic materials may cause fire and explosion. Also reacts violently with strong reducing agents, metals, sulfur trioxide gas, strong oxidizers and water. Contact with metals may produce toxic sulfur dioxide flames and may release flammable hydrogen gas.
- Lead Compounds: Avoid contact with strong acids, bases, halides, halogenates, potassium nitrate, permanganates, peroxides, nascent hydrogen and reducing agents.

Hazardous Decomposition Products:
- Sulfuric Acid: Sulfur trioxide, carbon monoxide, sulfuric acid mist, sulfur dioxide, and hydrogen sulfide.
- Lead Compounds: High temperatures likely to produce toxic metal fume, vapor, or dust. Contact with strong acid or base or presence of nascent hydrogen may produce highly toxic arsenic gas.

Hazardous Polymerization: Will not occur.

III. TOXICOLOGICAL INFORMATION

Route of Entry:
- Sulfuric Acid: Harmful by all routes of entry.
- Lead Compounds: Hazardous exposure can occur only when product is heated, oxidized or otherwise processed or damaged to create dust, vapor or fume. The presence of nascent hydrogen may generate highly toxic arsenic gas.

Inhalation:
- Sulfuric Acid: Breathing of sulfuric acid vapors or mists may cause severe respiratory irritation.
- Lead Compounds: Inhalation of lead dust or fumes may cause irritation of upper respiratory tract and lungs.

Ingestion:
- Sulfuric Acid: May cause severe irritation of mouth, throat, esophagus and stomach.
- Lead Compounds: Acute ingestion may cause abdominal pain, nausea, vomiting, diarrhea and severe cramping. This may lead rapidly to systemic toxicity and must be treated by a physician.

Skin Contact:
- Sulfuric Acid: Severe irritation, burns and ulceration.
- Lead Compounds: Not absorbed through the skin.

Eye Contact:
- Sulfuric Acid: Severe irritation, burns, corneal damage, and blindness.
- Lead Compounds: May cause eye irritation.

Effects of Overexposure - Acute:
- Sulfuric Acid: Severe skin irritation, damage to cornea, upper respiratory irritation.
- Lead Compounds: Symptoms of toxicity include headache, fatigue, abdominal pain, loss of appetite, muscle aches and weakness, sleep disturbances and irritability.

Effects of Overexposure - Chronic:
- Sulfuric Acid: Possible erosion of tooth enamel, inflammation of nose, throat and bronchial tubes.
- Lead Compounds: Anemia, neuropathy, particularly of the motor nerves, with wrist drop; kidney damage; reproductive changes in males and females. Repeated exposure to lead and lead compounds in the workplace may result in nervous system toxicity. Some toxicologists report abnormal conduction velocities in persons with blood lead levels of 50 mcg/100 ml or higher. Heavy lead exposure may result in central nervous system damage, encephalopathy and damage to the blood forming (hemopoietic) tissues.

Carcinogenicity:
- Sulfuric Acid: The International Agency for Research on Cancer (IARC) has classified “strong inorganic acid mist containing sulfuric acid” as a Group 1 carcinogen, a substance that is carcinogenic to humans. This classification does 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. Hence, the product, such as overcharging, may result in the generation of sulfuric acid mist.
- Lead Compounds: Lead is listed as a Group 2A carcinogen, likely in animals at extreme doses. Per the guidance found in OSHA 29 CFR 1910.1200 Appendix F, this is approximately equivalent to GHS Category 1B. Proof of carcinogenicity in humans is lacking at present.

Medical Conditions Generally Aggravated by Exposure:
- Overexposure to sulfuric acid mist may cause lung damage and aggravate pulmonary conditions. Contact of sulfuric acid with skin may aggravate diseases such as eczema and contact dermatitis. Lead and its compounds can aggravate some forms of kidney, liver and neurologic diseases.
### SAFETY DATA SHEET

**Acute Toxicity:**
- Inhalation LD50:
  - LC50 rat: 375 mg/m³; LC50 guinea pig: 510 mg/m³
- Oral LD50:
  - LC50 rat: 2140 mg/kg

**Elemental Lead:**
- Acute Toxicity Point Estimate = 4500 ppmV (based on lead bulb)

**Additional Health Data:**
All heavy metals, including the hazardous ingredients in this product, are taken into the body primarily by inhalation and ingestion. Most inhalation problems can be avoided by adequate precautions such as ventilation and respiratory protection covered in Section 8. Follow good personal hygiene to avoid inhalation and ingestion: wash hands, face, neck and arms thoroughly before eating, smoking or leaving the workplace. Keep contaminated clothing out of non-contaminated areas, or wear cover clothing in such areas. Restrict the use and presence of food, tobacco and cosmetics to non-contaminated areas. Work clothes and work equipment used in contaminated areas must remain in designated areas and never taken home or laundered with personal non-contaminated clothing. This product is intended for industrial use only and should be isolated from children and their environment.

The 18th Amendment to EC Directive 67/548 EEC classified lead compounds, but not lead in metal form, as possibly toxic to reproduction. Risk phrase R1: May cause harm to the unborn child. Applies to lead compounds, especially soluble forms.

### XII. ECOLOGICAL INFORMATION

**Environmental Fate:**
Lead is very persistent in soil and sediments. No data on environmental degradation. Mobility of metallic lead between ecological compartments is slow. Bioaccumulation of lead occurs in aquatic and terrestrial animals and plants but little biomagnification occurs through the food chain. Most studies include lead compounds and not elemental lead.

**Environmental Toxicity:**
- Aquatic Toxicity:
  - Sodium hydroxide: 24-hr LC50, freshwater fish (Brachydanio rerio): 12 mg/L
  - Sodium hydroxide: 96-hr LOEC, freshwater fish (Cyprinus carpio): 22 mg/L
  - Lead: 48-hr LC50 (modelled for aquatic invertebrates): <1 mg/L (based on lead bulb)

**Additional Information:**
- No adverse effects on freshwater fish observed.
- Volatile organic compounds: 0% (by Vehmaa).
- Water Endangering Class (WEC): NA.

### XIII. DISPOSAL CONSIDERATIONS (UNITED STATES)

**Spent batteries:**
- Lead and secondary lead useless for recycling. Spent lead-acid batteries are not regulated as hazardous waste when the requirements of 40 CFR Section 264.30 are met. This should be managed in accordance with approved state and federal requirements. Consult state environmental agency and on federal EPA.

**Electrolyte:**
- Place neutralized slurry into sealed containers and handle as applicable with state and federal regulations. Large water-diluted spills, after neutralization and wetting, should be managed in accordance with approved local, state and federal requirements. Consult state environmental agency and on federal EPA.

Following local, state/provincial, and Federal/State regulations applicable to end-of-life characteristics will be the responsibility of the end-user.

---

Figure A6: Odyssey Battery MSDS Sheet (5 of 7)
### SAFETY DATA SHEET

#### XV. TRANSPORT INFORMATION

**U.S. DOT:**
Excepted from the hazardous materials regulations (HMR), because the batteries meet the requirements of 49 CFR 173.159(a) and 49 CFR 173.159a of the U.S. Department of Transportation's HMR. Battery and outer package must be marked "NONSPILLABLE" or "NONSPILLABLE BATTERY". Battery terminals must be protected against short circuits.

**IATA Dangerous Goods Regulations (DG):**
Excepted from the dangerous goods regulations because the batteries meet the requirements of Packing Instruction 862 and Special Provisions A67 of the International Air Transportation Association (IATA) Dangerous Goods Regulations and International Civil Aviation Organization (ICAO) Technical Instructions. Battery terminals must be protected against short circuits.

**IMDG:**
Excepted from the dangerous goods regulations for transport by sea because the batteries meet the requirements of Special Provision 338 of the International Maritime Dangerous Goods (IMDG CODE). Battery terminals must be protected against short circuits.

**Requirements for Safe Shipping and Handling of Cyclion Cells:**

- **Warning:** Electrical Fire Hazard - Prevent against shorting. Terminals shall short and cause a fire if not insulated during shipping. Cyclion product must be labeled "NONSPILLABLE" during shipping. Follow all federal shipping regulations. See section IX of this sheet and CFR 49 Parts 711 through 180, available online at www.gpoaccess.gov.

**Requirements for Shipping Cyclion Product as a Single Cell:**
Protective caps or other durable insert material must be used to insulate each terminal of each cell unless cells are shipping in the original packaging from EnerSys, in full box quantities. Protective caps are available for all cell sizes by contacting EnerSys Customer Service at 1-800-964-2837.

**Requirements for Shipping Cyclion Product Assembled Into Multicell Batteries:**
Assembled batteries shall have short circuit protection during shipping. Exposed terminals, connectors, or lead wires must be insulated with a durable insert material to prevent exposure during shipping.

#### XV. REGULATORY INFORMATION

**UNITED STATES:**

- **EPA SARA Title III:**
  - Section 302 EPCRA Extremely Hazardous Substance (EHS):
  - Sulfuric acid is a listed Extremely Hazardous Substance under EPCRA, with a Threshold Planning Quantity (TPQ) of 1,000 lbs.
  - EPCRA Section 302 notification is required if 1000 lbs or more of sulfuric acid is present at one use (40 CFR 370.10). For more information consult 40 CFR Part 355. The quantity of sulfuric acid will vary by battery type. Contact your EnerSys representative for additional information.

- **Section 304 CERCLA Hazardous Substance:**
  - Reportable Quantity (RaQ) for spilled 100% sulfuric acid under CERCLA (Superfund) and EPCRA (Emergency Planning and Community Right-to-Know Act) is 1,000 lbs. State and local reportable quantities for spilled sulfuric acid may vary.

- **Section 311/313 Hazard Categories:**
  - EPCRA Section 312 Tier Two reporting is required for non-automotive batteries if sulfuric acid is present in quantities of 500 lbs or more and/or if lead is present in quantities of 10,000 lbs or more. For more information contact 40 CFR 370.10 and 40 CFR 370.40.

- **Section 313 EPCRA Toxic Substances:**
  - 40 CFR section 372.34(b) states: If a toxic chemical is present in an article at a covered facility, a person is not required to consider the quantity of the toxic chemical present in that article when determining whether an applicable threshold has been met under §372.25, §372.27, or §372.28 or determining the amount of release to be reported under §372.30. This exemption applies whether the person received the article from another person or the person produced the article. However, this exemption applies only to the quantity of the toxic chemical present in the article.

**Suppliers Notification:**
This product contains toxic chemicals, which may be reportable under EPCRA Section 313 Toxic Chemical Release Inventory (Form R) requirements. If you are a manufacturer facility under SIC codes 20 through 39, the following information is provided to enable you to complete the required report:

<table>
<thead>
<tr>
<th>Toxic Chemical</th>
<th>CAS Number</th>
<th>Approximate % by Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>7439-92-1</td>
<td>45 - 60</td>
</tr>
<tr>
<td>Sulfuric Acid Electrolyte (Sulfuric Acid/Water)</td>
<td>7664-93-9</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Tin</td>
<td>7440-31-5</td>
<td>0.1 - 0.2</td>
</tr>
</tbody>
</table>

See 40 CFR Part 370 for more details.

If you distribute this product to other manufacturers in SIC Codes 20 through 39, this information must be provided with the first shipment of each calendar year.

The Section 313 supplier notification requirement does not apply to batteries, which are "consumer products".

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Figure A7: Odyssey Battery MSDS Sheet (6 of 7)
Figure A8: Odyssey Battery MSDS Sheet (7 of 7)
Figure A9: PowerSonic PS-12180 Specification Sheet (1 of 2)
Figure A10: PowerSonic PS-12180 Specification Sheet (2 of 2)
# Safety Data Sheet

**Issue Date:** 01-Jan-2014  
**Revision Date:** 26-Jan-2016  
**Version:** 1

## 1. IDENTIFICATION

**Product Identifier**  
**Product Name:** PS, PSH, PSG, FHR, PG, PDC and DCG Valve Regulated (VRLA) Batteries Absorbed Electrolyte (AGM)

**Other means of identification**  
**SDS #:** POWER-001

**Recommended use of the chemical and restrictions on use**  
**Recommended Use:** Battery.

**Details of the supplier of the safety data sheet**  
**Manufacturer Address:**  
Power-Sonic Corporation  
7550 Panasonic Way  
San Diego, CA 92154

**Emergency Telephone Number:**  
1-619-661-2020  
Chemtrec 1-800-424-9300 (North America) 1-703-527-3887 (International)

## 2. HAZARDS IDENTIFICATION

**EMERGENCY OVERVIEW:** This product is a nonspillable lead acid battery. The information below is intended for repeated and prolonged contact with the battery contents in an occupational setting. In the absence of an incident or accident, is not likely to apply to normal product use. However, this Safety Data Sheet (SDS) contains valuable information critical to the safe handling and proper use of this product. This SDS should be retained and available for employees and other users of this product. Always be aware of the risk of fire, explosion, or burns. Do not short circuit the (+) and (-) terminals with any other metals. Do not disassemble or modify the battery. Do not solder a battery directly. Keep away from fire or open flame.

**Appearance:** Battery  
**Physical State:** Solid containing liquid  
**Odor:**  
**Characteristic:**

**Classification:**  
This product is a battery. The classification below is based on the battery acid contained in the battery, which would only be released during an incident.

<table>
<thead>
<tr>
<th>Acute toxicity - Oral</th>
<th>Category 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute toxicity - Inhalation (Dusts/Mists)</td>
<td>Category 4</td>
</tr>
<tr>
<td>Skin corrosion/irritation</td>
<td>Category 1 Sub-category B</td>
</tr>
<tr>
<td>Serious eye damage/eye irritation</td>
<td>Category 1</td>
</tr>
<tr>
<td>Reproductive toxicity</td>
<td>Category 1A</td>
</tr>
<tr>
<td>Specific target organ toxicity (repeated exposure)</td>
<td>Category 2</td>
</tr>
</tbody>
</table>

**Signal Word:**  
**Danger**

---

Figure A11: PowerSonic MSDS Sheet (1 of 10)
Hazard Statements
Harmful if swallowed
Harmful if inhaled
Causes severe skin burns and eye damage
May damage fertility or the unborn child
May cause damage to organs through prolonged or repeated exposure

Precautionary Statements - Prevention
Obtain special instructions before use
Do not handle until all safety precautions have been read and understood
Use personal protective equipment as required
Wash face, hands and any exposed skin thoroughly after handling
Do not eat, drink or smoke when using this product
Use only outdoors or in a well-ventilated area
Do not breathe dust/fume/gas/mist/vapors/spray

Precautionary Statements - Response
Immediately call a POISON CENTER or doctor/physician for all exposures
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
Wash contaminated clothing before reuse
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
IF SWALLOWED: Rinse mouth. DO NOT induce vomiting

Precautionary Statements - Storage
Store locked up

Precautionary Statements - Disposal
Dispose of contents/container to an approved waste disposal plant

Other Hazards
Very toxic to aquatic life with long lasting effects

3. COMPOSITION/INFORMATION ON INGREDIENTS

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS No</th>
<th>Weight-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>7439-92-1</td>
<td>65-75</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>7664-93-9</td>
<td>14-20</td>
</tr>
<tr>
<td>Tin</td>
<td>7440-31-5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Calcium</td>
<td>7440-70-2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Fiberglass Separator</td>
<td>Proprietary</td>
<td>5</td>
</tr>
<tr>
<td>Case material: Acrylonitrile Butadine Styrene (ABS)</td>
<td>Proprietary</td>
<td>5-10</td>
</tr>
</tbody>
</table>

"If Chemical Name/CAS No is "proprietary" and/or Weight-% is listed as a range, the specific chemical identity and/or percentage of composition has been withheld as a trade secret." Inorganic lead and electrolyte (sulfuric acid) are the main components of every Valve Regulated Lead Acid battery supplied by Power-Sonic Corporation. Other ingredients may be present dependent upon the specific battery type. For additional information contact Power-Sonic Corporation Technical Department.

4. FIRST-AID MEASURES

First Aid Measures
**General Advice**
Immediately call a poison center or doctor/physician. Provide this SDS to medical personnel for treatment.

**Eye Contact**
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

**Skin Contact**
IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower. Wash contaminated clothing before reuse.

**Inhalation**
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.

**Ingestion**
IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.

**Most important symptoms and effects**
Symptoms
Harmful if swallowed. Harmful if inhaled. Causes severe skin burns and eye damage. May damage fertility or the unborn child. May cause damage to organs through prolonged or repeated exposure.

**Indication of any immediate medical attention and special treatment needed**

**Notes to Physician**
Treat symptomatically

### 5. FIRE-FIGHTING MEASURES

**Suitable Extinguishing Media**
Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

**Unsuitable Extinguishing Media** Not determined.

**Specific Hazards Arising from the Chemical**
Not determined.

**Hazardous Combustion Products**
Sulfuric acid: Sulfur trioxide, carbon monoxide, sulfuric acid mist, sulfur dioxide, and hydrogen sulfide.
Lead Compounds: High temperatures above the melting point are likely to produce toxic metal fume, vapor, or dust; contact with strong acid or base or presence of nascent hydrogen may generate highly toxic arsine gas.

**Protective equipment and precautions for firefighters**
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

### 6. ACCIDENTAL RELEASE MEASURES

**Personal precautions, protective equipment and emergency procedures**

**Personal Precautions**
Use personal protective equipment as required.

**Methods and material for containment and cleaning up**

**Methods for Containment**
There is no release of material unless the case is damaged or battery is misused/overcharged. If release occurs stop flow of material, contain/absorb all spills with dry sand, earth, or vermiculite. Do not use combustible materials. Neutralize spilled material with soda ash, sodium bicarbonate, lime, etc. Wear acid-resistant clothing, boots, gloves, and face shield. Dispose of as hazardous waste. Do not discharge acid to sewer.

---

Figure A13: PowerSonic MSDS Sheet (3 of 10)
Methods for Clean-Up

Spent Batteries - send to secondary lead smelter for recycling. Follow applicable federal, state and local regulations. Neutralize as in preceding step. Collect neutralized material in sealed container and handle as hazardous waste as applicable. A copy of this SDS must be supplied to any scrap dealer or secondary lead smelter with the battery.

7. HANDLING AND STORAGE

Precautions for safe handling

Advice on Safe Handling

Handle in accordance with good industrial hygiene and safety practice. Obtain special instructions before use. Do not handle until all safety precautions have been read and understood. Use personal protective equipment as required. Wash face, hands, and any exposed skin thoroughly after handling. Do not eat, drink or smoke when using this product. Use only outdoors or in a well-ventilated area. Do not breathe dust/fume/gas/mist/vapors/spray. Due to the battery’s low internal resistance and high power density, high levels of short circuit current can be developed across the battery terminals. Do not rest tools or cables on the battery. Use insulated tools only. Follow all installation instructions and diagrams when installing or maintaining battery systems.

Conditions for safe storage, including any incompatibilities

Storage Conditions
Store batteries in a cool, dry, well ventilated area that are separated from incompatible materials and any activities which may generate flames, sparks, or heat. Keep clear of all metallic articles that could contact the negative and positive terminals on a battery and create a short circuit condition.

Incompatible Materials
Sulfuric acid: Contact with combustibles and organic materials may cause fire and explosion. Also reacts violently with strong reducing agents, metals, sulfur trioxide gas, strong oxidizers, and water. Contact with metals may produce toxic sulfur dioxide fumes and may release flammable hydrogen gas.
Lead Compounds: Avoid contact with strong acids, bases, halides, halogenates, potassium nitrate, permanganate, peroxides, nascent hydrogen, and reducing agents.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Guidelines

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>ACGIH TLV</th>
<th>OSHA PEL</th>
<th>NIOSH IDLH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>TWA: 0.05 mg/m³ Pb</td>
<td>TWA: 50 µg/m³ Pb</td>
<td>IDLH: 100 mg/m³ Pb, TWA: 0.050 mg/m³ Pb</td>
</tr>
<tr>
<td>Sulfuric Acid 7664-93-9</td>
<td>TWA: 0.2 mg/m³ thoracic fraction (vacated) TWA: 1 mg/m³</td>
<td>TWA: 1 mg/m³</td>
<td>IDLH: 15 mg/m³, TWA: 1 mg/m³</td>
</tr>
<tr>
<td>Tin 7440-31-5</td>
<td>TWA: 2 mg/m³ Sn except Tin hydride</td>
<td>TWA: 2 mg/m³ Sn except oxides (vacated) TWA: 2 mg/m³ Sn except oxides</td>
<td>IDLH: 100 mg/m³ Sn, TWA: 2 mg/m³ except Tin oxides Sn</td>
</tr>
</tbody>
</table>

Appropriate engineering controls

Engineering Controls
Store and handle batteries in a well ventilated area. If mechanical ventilation is used, components must be acid resistant.

Individual protection measures, such as personal protective equipment

Eye/Face Protection
None needed under normal conditions. If handling damaged or broken batteries use chemical splash goggles or face shield.

Figure A14: PowerSonic MSDS Sheet (4 of 10)
### 9. PHYSICAL AND CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical State</td>
<td>Solid containing liquid</td>
</tr>
<tr>
<td>Appearance</td>
<td>Battery</td>
</tr>
<tr>
<td>Color</td>
<td>Not determined</td>
</tr>
<tr>
<td>Odor</td>
<td>Odor Threshold</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Not determined</td>
</tr>
<tr>
<td>pH</td>
<td>Not determined</td>
</tr>
<tr>
<td>Melting Point/Freezing Point</td>
<td>Not determined</td>
</tr>
<tr>
<td>Boiling Point/Boiling Range</td>
<td>Not determined</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Not determined</td>
</tr>
<tr>
<td>Evaporation Rate</td>
<td>Not determined</td>
</tr>
<tr>
<td>Flammability (Solid, Gas)</td>
<td>Not determined</td>
</tr>
<tr>
<td>Upper Flammability Limits</td>
<td>Not determined</td>
</tr>
<tr>
<td>Lower Flammability Limit</td>
<td>Not determined</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>Not determined</td>
</tr>
<tr>
<td>Vapor Density</td>
<td>Not determined</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.3</td>
</tr>
<tr>
<td>Water Solubility</td>
<td>Not determined</td>
</tr>
<tr>
<td>Solubility in other solvents</td>
<td>Not determined</td>
</tr>
<tr>
<td>Partition Coefficient</td>
<td>Not determined</td>
</tr>
<tr>
<td>Auto-ignition Temperature</td>
<td>Not determined</td>
</tr>
<tr>
<td>Decomposition Temperature</td>
<td>Not determined</td>
</tr>
<tr>
<td>Kinematic Viscosity</td>
<td>Not determined</td>
</tr>
<tr>
<td>Dynamic Viscosity</td>
<td>Not determined</td>
</tr>
<tr>
<td>Explosive Properties</td>
<td>Not determined</td>
</tr>
<tr>
<td>Oxidizing Properties</td>
<td>Not determined</td>
</tr>
</tbody>
</table>

### 10. STABILITY AND REACTIVITY

**Reactivity**
- Not reactive under normal conditions.

**Chemical Stability**
- Stable under recommended storage conditions.

**Possibility of Hazardous Reactions**
- None under normal processing.
  - Hazardous Polymerization: Hazardous polymerization does not occur.

**Conditions to Avoid**
- Keep out of reach of children.

Figure A15: PowerSonic MSDS Sheet (5 of 10)
Incompatible Materials
Sulfuric acid: Contact with combustibles and organic materials may cause fire and explosion. Also reacts violently with strong reducing agents, metals, sulfur trioxide gas, strong oxidizers, and water. Contact with metals may produce toxic sulfur dioxide fumes and may release flammable hydrogen gas.
Lead Compounds: Avoid contact with strong acids, bases, halides, halogenates, potassium nitrate, permanganate, peroxides, nascent hydrogen, and reducing agents.

Hazardous Decomposition Products
Sulfuric acid: Sulfur trioxide, carbon monoxide, sulfuric acid mist, sulfur dioxide, and hydrogen sulfide.
Lead Compounds: High temperatures above the melting point are likely to produce toxic metal fume, vapor, or dust; contact with strong acid or base or presence of nascent hydrogen may generate highly toxic arsine gas.

11. TOXICOLOGICAL INFORMATION

Information on likely routes of exposure

Product Information
Eye Contact Causes severe eye damage.
Skin Contact Causes severe skin burns.
Inhalation Harmful by inhalation.
Ingestion Harmful if swallowed.

Component Information

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Oral LD50</th>
<th>Dermal LD50</th>
<th>Inhalation LC50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfuric Acid 7064-03-9</td>
<td>= 2140 mg/kg (Rat)</td>
<td>-</td>
<td>= 510 mg/m³ (Rat) 2h</td>
</tr>
<tr>
<td>Tin 7449-01-5</td>
<td>= 700 mg/kg (Rat)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Information on physical, chemical and toxicological effects

Symptoms Please see section 4 of this SDS for symptoms.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Carcinogenicity
The table below indicates whether each agency has listed any ingredient as a carcinogen. However, the product as a whole has not been tested. IARC has classified "strong inorganic acid mist containing sulfuric acid" as a category 1 carcinogen, substance that is carcinogenic to humans. This classification does not apply to liquid forms of sulfuric acid or sulfuric acid solutions contained within a battery. Inorganic 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. Hazardous exposure to lead can occur only when product is heated, oxidized, or otherwise processed or damaged to create dust, vapor, or fume.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>ACGIH</th>
<th>IARC</th>
<th>NTP</th>
<th>OSHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>A3</td>
<td>Group 2A</td>
<td>Reasonably Anticipated</td>
<td>X</td>
</tr>
<tr>
<td>Sulfuric Acid 7664-03-9</td>
<td>A2</td>
<td>Group 1</td>
<td>Known</td>
<td>X</td>
</tr>
</tbody>
</table>

Legend
ACGIH (American Conference of Governmental Industrial Hygienists)
A2 - Suspected Human Carcinogen
A3 - Animal Carcinogen
IARC (International Agency for Research on Cancer)
Group 1 - Carcinogenic to Humans
Group 2A - Probably Carcinogenic to Humans
12. ECOLOGICAL INFORMATION

Ecotoxicity
Very toxic to aquatic life with long lasting effects.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Algae/aquatic plants</th>
<th>Fish</th>
<th>Toxicity to microorganisms</th>
<th>Crustacea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td></td>
<td>0.44: 96 h Cyprinus carpio mg/L LC50 semi-static 1.17: 96 h Oncorhynchus mykiss mg/L LC50 flow-through 1.32: 96 h Oncorhynchus mykiss mg/L LC50 static</td>
<td>600: 48 h water flea mg/L EC50</td>
<td></td>
</tr>
<tr>
<td>Sulfuric Acid 7664-32-9</td>
<td></td>
<td>500: 96 h Brachydanio rerio mg/L LC50 static</td>
<td>29: 24 h Daphnia magna mg/L EC50</td>
<td></td>
</tr>
</tbody>
</table>

Persistence/Depgradability
Not determined.

Bioaccumulation
Not determined.

Mobility
Not determined.

Other Adverse Effects
Not determined

13. DISPOSAL CONSIDERATIONS

Waste Treatment Methods

Disposal of Wastes
Spent Batteries - send to secondary lead smelter for recycling. Follow applicable federal, state and local regulations. Neutralize as in preceding step. Collect neutralized material in sealed container and handle as hazardous waste as applicable. A copy of this SDS must be supplied to any scrap dealer or secondary lead smelter with the battery.

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

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>RCRA</th>
<th>RCRA - Basis for Listing</th>
<th>RCRA - D Series Wastes</th>
<th>RCRA - U Series Wastes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td></td>
<td>Included in waste streams: F035, F037, F038, F039, K002, K003, K005, K046, K049, K051, K052, K061, K062, K089, K086, K100, K179</td>
<td>5.0 mg/L regulatory level</td>
<td></td>
</tr>
</tbody>
</table>
California Hazardous Waste Status: This product contains one or more substances that are listed with the State of California as a hazardous waste.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>California Hazardous Waste Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-02-1</td>
<td>Toxic</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Toxic Corrosive</td>
</tr>
</tbody>
</table>

### 14. TRANSPORT INFORMATION

**Note.**

Powersonic's nonspillable lead acid batteries are regulated as Class 8 Corrosive hazardous materials / dangerous goods by the U.S. Department of Transportation (DOT) and international dangerous goods regulations referenced below (i.e., IATA Dangerous Goods Regulations and IMDG Code). However, Powersonic's nonspillable batteries are excepted from these regulations because the batteries meet all of the testing, packaging and marking requirements found in the U.S. and international dangerous goods regulations. Therefore, the batteries do not need to be shipped and transported as fully-regulated Class 8 Corrosive hazardous materials / dangerous goods when packaged in accordance with these regulations.

**UN Number**

2800

**DOT.**

49 CFR 173.159(f) and 49 CFR 173.159a

The batteries have been tested in accordance with the vibration and pressure differential tests found in 49 CFR 173.159(f) and "crack test" found at 49 CFR 173.159a; When offered for transport, the batteries must be protected against short circuits and securely packaged in accordance with 49 CFR 173.159a; and The batteries and outer packaging must be marked NONSPILLABLE BATTERY as required by 49 CFR 173.159a.

**IATA.**

Packing Instruction 972 and Special Provision A67

The batteries have been tested in accordance with the vibration and pressure differential tests found in Packing Instruction 972 and "crack test" found in Special Provision A67 of the International Air Transport Association (IATA) Dangerous Goods Regulations When offered for transport, the batteries must be protected against short circuits and securely packaged in accordance with Special Provision A67.

**IMDG.**

Special Provision 238.1 and 238.2

The batteries have been tested in accordance with the vibration and pressure differential tests and "crack test" found in Special Provision 238.1 and 238.2. When offered for transport, the batteries must be protected against short circuits and securely packaged in accordance with Special Provision 238.1 and 238.2.

### 15. REGULATORY INFORMATION

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>TSCA</th>
<th>DSL</th>
<th>NDSL</th>
<th>EINECS</th>
<th>ELINCS</th>
<th>ENCS</th>
<th>IECSC</th>
<th>KECL</th>
<th>PICCS</th>
<th>AICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Present</td>
<td></td>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td></td>
<td></td>
<td></td>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
<td></td>
<td></td>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Legend:
- TSCA - United States Toxic Substances Control Act Section 8(b) Inventory
- DSL/NDSL - Canadian Domestic Substances List/Non-Domestic Substances List
- EINECS/ELINCS - European Inventory of Existing Chemical Substances/European List of Notified Chemical Substances
- ENCS - Japan Existing and New Chemical Substances
- IECSC - China Inventory of Existing Chemical Substances
- KECL - Korean Existing and Evaluated Chemical Substances
- PICCS - Philippines Inventory of Chemicals and Chemical Substances
- AICS - Australian Inventory of Chemical Substances

US Federal Regulations

**CERCLA**

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Hazardous Substances RQs</th>
<th>CERCLA/SARA RQ</th>
<th>Reportable Quantity (RQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>10 lb</td>
<td>RQ 10 lb final RQ</td>
<td></td>
</tr>
<tr>
<td>Sulfuric Acid 7664-93-9</td>
<td>1000 lb</td>
<td>RQ 1000 lb final RQ</td>
<td></td>
</tr>
</tbody>
</table>

**SARA 313**

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product contains a chemical or chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS No</th>
<th>Weight-%</th>
<th>SARA 313 - Threshold Values %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>7439-92-1</td>
<td>65-75</td>
<td>0.1</td>
</tr>
<tr>
<td>Sulfuric Acid 7664-93-9</td>
<td>7664-93-9</td>
<td>14-20</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**CWA (Clean Water Act)**

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CWA - Reportable Quantities</th>
<th>CWA - Toxic Pollutants</th>
<th>CWA - Priority Pollutants</th>
<th>CWA - Hazardous Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

US State Regulations

**California Proposition 65**

This product contains the following Proposition 65 chemicals.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>California Proposition 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>Carcinogen</td>
</tr>
<tr>
<td></td>
<td>Developmental</td>
</tr>
<tr>
<td></td>
<td>Female Reproductive</td>
</tr>
<tr>
<td></td>
<td>Male Reproductive</td>
</tr>
<tr>
<td>Sulfuric Acid 7664-93-9</td>
<td>Carcinogen</td>
</tr>
</tbody>
</table>

**U.S. State Right-to-Know Regulations**

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>New Jersey</th>
<th>Massachusetts</th>
<th>Pennsylvania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 7439-92-1</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sulfuric Acid 7664-93-9</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Tin 7440-31-5</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Calcium 7440-70-2</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Figure A19: PowerSonic MSDS Sheet (9 of 10)
### Figure A20: PowerSonic MSDS Sheet (10 of 10)

<table>
<thead>
<tr>
<th>NFPA</th>
<th>Health Hazards</th>
<th>Flammability</th>
<th>Instability</th>
<th>Special Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HMIS</th>
<th>Health Hazards</th>
<th>Flammability</th>
<th>Physical Hazards</th>
<th>Personal Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not determined</td>
<td>Not determined</td>
<td>Not determined</td>
<td>Not determined</td>
</tr>
</tbody>
</table>

**Issue Date:** 01-Jan-2014  
**Revision Date:** 20-Jan-2016  
**Revision Note:** New format

**Disclaimer:**

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

End of Safety Data Sheet
Appendix B: Flotation Calculations

The Gheenoe comes with some built in flotation. The flotation in the Gheenoe is foam that sits inside of the two benches that go across the boat. The volume of the foam is calculated by using the dimensions of the respective benches. The calculation of buoyancy from the foam in the front bench is shown in Eqn. B.1 below.

\[
B.1 \quad B_1 = V_1 \times \rho_{water} = \frac{10 \text{ in} \times 31 \text{ in} \times 11 \text{ in}}{1728 \text{ in}^3} \times 62.4 \ \frac{\text{lb}}{\text{ft}^3} = 123.14 \ \text{lb}
\]

\(B_1\) is the buoyant force provided by the bench located toward the front of the boat. The buoyant force for the second bench located further back is shown below in Eqn. B.2.

\[
B.2 \quad B_2 = V_2 \times \rho_{water} = \frac{10 \text{ in} \times 34 \text{ in} \times 11 \text{ in}}{1728 \text{ in}^3} \times 62.4 \ \frac{\text{lb}}{\text{ft}^3} = 135.05 \ \text{lb}
\]

\(B_2\) is the buoyant force provided by the second bench in the craft. There is also foam that runs down both sides of the hull in a triangular shape. This buoyant force is calculated using Eqn. B.3.

\[
B.3 \quad B_3 = V_3 \times \rho_{water} = \frac{2 \times (0.5 \times 3 \text{ in} \times 2 \text{ in}) \times 156 \text{ in}}{1728 \text{ in}^3} \times 62.4 \ \frac{\text{lb}}{\text{ft}^3} = 33.8 \ \text{lb}
\]

\(B_3\) is the buoyant force provided by the foam that runs down the sides of the hull. The buoyancy also benefits from the fiberglass coating on the surface area of the bottom of the hull. This coating sits 1.25 inches in the water. The hull has a bottom surface area of 41.075 square feet, which is the equivalent of 5914.8 square inches. The buoyant force provided by the hull is shown in Eqn. B.4.

\[
B.4 \quad B_H = V_3 \times \rho_{water} = \frac{1.25 \text{ in} \times 5914.8 \text{ in}^2}{1728 \text{ in}^3} \times 62.4 \ \frac{\text{lb}}{\text{ft}^3} = 266.99 \ \text{lb}
\]

\(B_H\) represents the buoyant force provided by the hull. The total buoyancy of the boat is shown in Eqn. B.5 below.

\[
B.5 \quad B_{total} = B_1 + B_2 + B_3 + B_H = 123.14 \ \text{lb} + 135.05 \ \text{lb} + 33.80 \ \text{lb} + 266.99 \ \text{lb} = 558.98 \ \text{lb}
\]

The weight of the hull is shown below in Table B.1. This is the heaviest the boat will be, since the solar array will only be on the boat during the endurance event, meaning the minimum buoyancy required to keep the boat afloat is 430 pounds. With a 1.2 factor of safety, the new required buoyancy is 516 pounds, still smaller than the actual buoyant force of 558.98 pounds.
### Table A1: Boat Weight

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull</td>
<td>120</td>
</tr>
<tr>
<td>Motors and Controllers</td>
<td>60</td>
</tr>
<tr>
<td>Drivetrain</td>
<td>30</td>
</tr>
<tr>
<td>Solar Array (Including Cooling System)</td>
<td>90</td>
</tr>
<tr>
<td>Batteries with box</td>
<td>80</td>
</tr>
<tr>
<td>Other Structural Components</td>
<td>15</td>
</tr>
<tr>
<td>Rudder and Steering</td>
<td>20</td>
</tr>
<tr>
<td>Safety Equipment</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>430</strong></td>
</tr>
</tbody>
</table>
Appendix C: Proof of Insurance

As per Solar Splash’s rule, 2.9 on insurance, the following document is proof of general liability insurance from UNM spanning over July 1st, 2017 to July 1st, 2018.

Figure A21: Proof of Insurance
## Appendix D: Team Roster

The following table displays the names, degree programs, school year, and team role of everyone who participated.

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree Program</th>
<th>Year</th>
<th>Team Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Jane Lehr</td>
<td>Electrical Engineering</td>
<td>N/A</td>
<td>Faculty Advisor</td>
</tr>
<tr>
<td>Dr. Peter Vorobieff</td>
<td>Mechanical Engineering</td>
<td>N/A</td>
<td>Faculty Advisor</td>
</tr>
<tr>
<td>Daniel Taylor</td>
<td>Mechanical Engineering</td>
<td>Senior Graduate</td>
<td>Instructor</td>
</tr>
<tr>
<td>Erich Brown</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Cooling System</td>
</tr>
<tr>
<td>WeyAnn Chen</td>
<td>Electrical Engineering</td>
<td>Undergraduate Senior</td>
<td>Module Assembly</td>
</tr>
<tr>
<td>David Sanabria</td>
<td>Electrical Engineering</td>
<td>Undergraduate Senior</td>
<td>Telemetry System</td>
</tr>
<tr>
<td>William Green</td>
<td>Electrical Engineering</td>
<td>Undergraduate Senior</td>
<td>Telemetry System</td>
</tr>
<tr>
<td>Luis Hernandez</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Motors</td>
</tr>
<tr>
<td>Ally Jackman</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Finance</td>
</tr>
<tr>
<td>Aura Jensen-Curtis</td>
<td>Computer Engineering</td>
<td>Undergraduate Senior</td>
<td>Software Development</td>
</tr>
<tr>
<td>Elisabeth Keller</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Organization</td>
</tr>
<tr>
<td>Kevin McConnell</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Cooling System</td>
</tr>
<tr>
<td>Christopher Murtagh</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Battery Box</td>
</tr>
<tr>
<td>Cameron Pouncey</td>
<td>Electrical Engineering</td>
<td>Graduate</td>
<td>Solar Panels</td>
</tr>
<tr>
<td>Ramon Reyes</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Battery Box</td>
</tr>
<tr>
<td>Mark Reyna</td>
<td>Electrical Engineering</td>
<td>Undergraduate Senior</td>
<td>Telemetry System</td>
</tr>
<tr>
<td>James Richards</td>
<td>Electrical Engineering</td>
<td>Graduate</td>
<td>Solar Tracker</td>
</tr>
<tr>
<td>Craig Robertson</td>
<td>Electrical Engineering</td>
<td>Graduate</td>
<td>Boat Wiring</td>
</tr>
<tr>
<td>Leonardo Rossetti</td>
<td>Electrical Engineering</td>
<td>Graduate</td>
<td>Cruise Control</td>
</tr>
<tr>
<td>Ted Sterns</td>
<td>Electrical Engineering</td>
<td>Undergraduate Senior</td>
<td>Telemetry System</td>
</tr>
<tr>
<td>Keith Soules</td>
<td>Mechanical Engineering</td>
<td>Undergraduate Senior</td>
<td>Motors</td>
</tr>
</tbody>
</table>
Appendix E: Motor

This Appendix displays the motor specifications.

Figure A22: LEM-200 Motor

Figure A23: Technical data on the Motors
Appendix F: Gheenoe Hull

The following figures display the hull and the hull specifications.

Figure A24: Gheenoe Hull, Unchanged

Figure A26: Gheenoe Hull Specifications
Appendix G: Maximum Power Point Tracker (150/35)

The MPPT specifications are shown below.

Figure A27: MMPT Specification
Appendix H: Propeller Analysis

Another decision the team must make is whether to modify the propeller properties or increase the size of the propeller altogether. There are three propeller properties that the team would be able to change if the data indicated changes were needed. The first is the propeller diameter. Smaller propeller diameters are useful in Deepwater applications because water pressure is higher, and the small propellers can displace a decent amount of water. In shallow water conditions, smaller propellers may cause cavitation behind the blades, causing the blades to slip. This would mean that the propeller is spinning but not doing as much work as it is capable of. If this is the case, larger propeller diameter would be desired to displace a larger amount of water and allow the motors to maximize their work. The team will be able to make this decision when telemetry data is acquired telling the team if the motors are drawing maximum power from the batteries. If they are not, the team will know the propeller has begun to slip and is not operating efficiently.

Two more properties of propellers the team could change are pitch and rake. The pitch of the propeller is the theoretical distance the propeller would travel if rotated in a solid medium. If telemetry data shows that the motors are maximizing power output, increasing pitch could help the boat get the most distance out of each blade rotation. Rake is the angle from the hub to the tip of a blade. Higher rakes lead to increased thrust from the propeller, so the team may also consider increasing rake. This would be extremely helpful when the boat is planing, because the propeller would be working to push the boat horizontally and not vertically. However, this is all dependent on telemetry data to be collected during testing. If the data shows that the amperage draw from the batteries is not a maximum, the team will be sure that changes to the propeller could increase its performance.
Appendix I: Battery Monitor (BMV-712)

Figure A28: BMV-712 Specifications
Appendix J: Wiring Diagram

1. The symbol □ denotes a splice.
2. All colors to be denoted on the diagram.
3. All shields are to be grounded at each termination end where possible.
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NOTES:
1. ALL UNSHIELDED WIRING TO CONFORM TO M22759/16/0000 SPEC WHERE XX IS AWG AND YY IS COLOR.

USE SWITCHCRAFT P/N DEAF SERIES (FEMALE).

USE SWITCHCRAFT P/N A4M SERIES (MALE).

4. ALL SHIELDED WIRING TO CONFORM TO M27500 SPEC 22.

5. USE RING TERMINALS (#10) DUGKEY P/N A1002TR-10

6. USE RING TERMINALS (#0) DUGKEY P/N 2-320372-2

CRUISE CONTROL

PROPELLER SYSTEM

INT 7
NOTES:
1. ALL WIRING TO BE TO 2/0 600V WELDING CABLE BETWEEN BATTERY BANK AND MOTOR CONTROLLER.
2. USE RING TERMINALS 1/2" to 1/4" TO CRIMP 2/0 600V WELDING CABLE TO THE MOTOR CONTROLLER.
3. USE RING TERMINALS 2/0 5/8 TO 3/4" TO CRIMP 2/0 600V WELDING CABLE WIRING TO THE MOTOR.
NOT IMPLEMENTED THIS REVISION

NOTES:
1. ALL WIRING TO CONFORM TO MX7500 SPEC 22 AWG AND WHITE COLOR.
2. CONNECTORS SHALL CONFORM TO XXXX CONTACTS SHALL CONFORM TO XXXX
3. CONNECTORS SHALL CONFORM TO XXXX CONTACTS SHALL CONFORM TO XXXX
4. USE <MANUFACTURER> CONNECTOR P/N XXXXXXXX

INT 20
NOTES:
1. ALL WIRING TO CONFORM TO M27500 SPEC 22 AWG AND WHITE COLOR.

CONNECTORS SHALL CONFORM TO DB-25F, CONTACTS SHALL CONFORM TO M24801/4-39F

CONNECTORS SHALL CONFORM TO DB-25M, CONTACTS SHALL CONFORM TO M39029/64-369

TERMINATED TO THE SENSORS VIA SPLICES TO THE COMPONENTS

TELEMERTY SYSTEM

COOLING SYSTEM

INT 24