University of Colorado – Denver

Solar Boat Team

Boat #14 – The SS Lynx:

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May 9th, 2016

I. EXECUTIVE SUMMARY

The primary goal of the University of Colorado Denver Solar Splash Team 2016 was to build the lightest and most efficient solar-powered-race boat, the SS Lynx. Specifically, as a first generation team, we chose to focus on the endurance aspect of the competition. The endurance race promised the most focus on renewable energy systems, and allowed the team to try a novel approach to harvesting energy from solar powered systems. Renewable energy was of interest because although fossil fuels still seem to be in abundance at this time, it is clear that there is only a finite amount.

Initially the team was to build its own solar panels. However, after attempting to solder 3-tab solar cells, the heat absorbed by the cells was causing problems that could only be solved by using a robotic soldering arm according to industry professionals; this was a machine not available to the team. A 2-tab cell could have been utilized, but due to the lower efficiency, the weight increase of such a panel design would have been significant. Aside from the competition allowance of an additional 10% in power, the only advantage of manufacturing our own panels was the ability to customize the voltage and current. With the help of SBM, Inc. the panels were completely customized for power output, and only resulted in a total weight of 110 N per panel. Therefore, it was decided between the factors of human error, timeline, and professionalism of the finished product that it would be best to have the panels manufactured by an outside source.

To maximize the efficiency and power draw from the panels, the team instituted a novel water-cooling system to keep the panel temperatures as low as possible. The function of the pump is autonomously controlled by the data acquisition system.

As the current draw for the endurance race was significantly different than that of the sprint and slalom races, two battery-bank configurations were chosen. The endurance configuration focused on maximum amp hours, while the other configurations focused on cold-cranking amps. In the system, the current limitation of power consumption now lies with the motor controller which is rated at 400 amps; as this is the case, boosting our voltage from 36 volts to 48 volts could potentially raise our power output by 25% for burst speed. The Lynch motor selected is a 48 volt, therefore the motor itself will run more efficiently at 48 volts than 36 volts.

The design the hull had to be as light weight and hydrodynamic as possible. Utilizing Divnycell foam and a 10 oz. fiberglass composite, the hull weighed in at a full 102 N less than the initial design goal of 445 N. Comsol software confirmed hull thickness and also confirmed that the semi-displacement hull would be best for an all around design.

Due to the complication of using multiple motors, the time allotted for the project, and the lack of an electrical engineer, the fact that the SS Lynx is a first generation project for CU Denver, a single motor configuration was chosen. Noting that other teams used multiple motors, it became clear that a light-weight hull and drivetrain were crucial to success. The drivetrain was designed to be as minimalistic as possible and came in at a weight of 298 Newtons. This weight showed a lot of promise as some previous contenders for Solar Splash have reduced the weight of their drivetrain more than that from one year to another! The steering and shifting systems were both designed as cable systems. The goal here was simplicity. Hydraulics had some appealing characteristics from an engineering perspective, however, there are many problems and complications with this system. The used of a single cable, one for each systems kept the design light, simple, and easy to fix should problems occur.

The data acquisition system was designed primarily for the testing phase of the project. Allowing as much real-time data to be gathered and viewed would allow for fine-tuning of the power systems, and a dictation of what speeds and accelerations were key to performing at the best ability of the boat. Further, having access to this data would allow us to analyze the propellers more effectively to see if any alterations would need to be made prior to the competition.

Though at a disadvantage to other seasoned teams, the design promoted high confidence in success due to the low weight and simplistic designs of all subsystems. This coupled with the novel water-cooling system, the SS Lynx promises to perform well and prove a staunch competitor at the Solar Splash 2016 competition.

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III. OVERALL PROJECT OBJECTIVES

The goal of the University of Colorado Denver team is to build a solar-powered race boat, the SS Lynx. The goals for the solar system are to capture low-angle light, be as lightweight as possible, and implement a water cooling system that will increase the efficiency of the panels. The goals for power electronics are to have two configurations for the different races, maximize burst power in the sprint race, and determine the most efficient speed settings for the boat during all races. The boat hull must be efficient at low speeds yet capable of high speeds. The hull has been designed for an expected weight of no more than 356 N, and ease of manufacturability. The boat is designed for a top speed of 32 km/h with a cruising speed of 18 km/h for peak efficiency. The goal for the outboard motor design is to build around a donated lower unit to integrate the electric motor and gearbox for the propeller. The goals for the steering system are to use lightweight materials in a simple configuration. The goals for the data acquisition system include using real-time data to maximize the efficiency of all subsystems and provide a database for future teams at the University of Colorado Denver.

IV. DESIGN, ANALYSIS, AND TESTING

A. Solar System

1) Design:

Two custom rectangular solar panels were manufactured by SBM Solar, Inc. Each panel will output 235 W resulting in a maximum solar array power output of 470 W. The panels manufactured by SBM are lightweight because the panels do not contain a layer of glass as is typical in most solar panels and a fluoropolymer film was placed on top of the panels to increase the amount of sunlight that reaches the cells. These two reasons make these panels ideal for this competition. The panels contain 50 monocrystalline cells each with an efficiency of 20.30%. Both panels are placed behind the skipper.

Frames for the panels were constructed using an aluminum U-channel. Two corners of the panel frames were welded while the other two were attached using L-brackets. These two processes were used on the frame corners to prevent damage from occurring during the welding process to the panels. To mount the panels to the boat, beam clamps were attached to the panel frame. All-thread rods were extended from the beam clamps to custom brackets on the gunwales of the boat. This mounting system will make it quick and easy to attach and remove the panels in between races. Fig. 1 shows the mounting configuration for the solar panels including the beam clamps, all-thread rods, and custom brackets.

Fig. 1. Mounting configuration for solar panels.

A water-cooling system that utilizes 16 identical nozzles has been implemented to increase the efficiency of the solar panels. The water-cooling system will spray cool lake water onto the back of the panels to remove heat and improve the power output of the solar array. Any excess water will fall into a drain pan directly below the solar panels and will be directed off the side of the boat back into the lake. The pump used for this application is a small pump that will draw less than 10 Watts from the main battery bank.

2) *Analysis of Design Concepts:*

Experiments performed showed that when the difference in temperature between the solar panels and the water being used to cool the panels is between 10° C and 15° C, there is a substantial gain in power increase potential. Fig. 2 shows a plot of the experiment results with power increase percentage versus the temperature delta between the panels and the lake water. As the temperature delta reaches above 10°C, there is a 5-25% power increase.

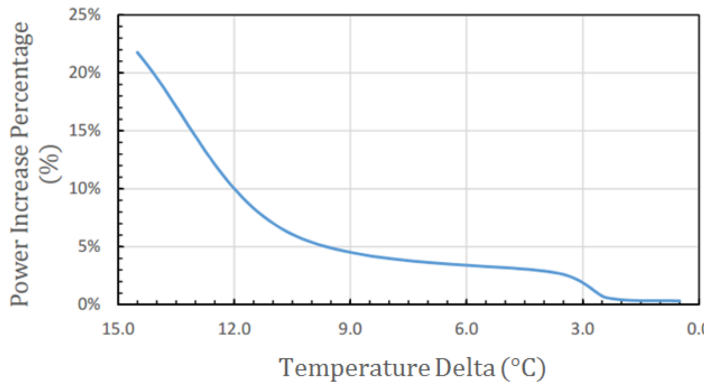

Fig. 2. Power increase percentage versus temperature delta for solar panel water cooling system.

3) *Design Testing and Evaluation*

Implementation and testing of the panels will occur in the month prior to the competition.

B. Power Electronics System

1) *Design:*

The design was to have two panels fabricated by SBM Solar, Inc. as discussed in the Solar Array section of this report. The cells were fabricated such that the voltage was stacked in series resulting in open-circuit voltage potential of 32.95 volts and an operating voltage potential of around 27.7 volts. As with any transfer of energy, it is more efficient to move from a higher potential to a lower potential. The endurance battery bank consists of (2) Vmax XTR3475 12V/75AH batteries. As each panel will be at a close voltage potential to the battery bank, an efficient manipulation and transfer of energy will be realized; this efficiency will only increase as the battery bank voltage potential drops due to power consumption.

Electrical losses along conductors are proportional to amperage due to the heat generation of electrical current. Stacking all of the solar cells in series will allow for the lowest current obtainable, and therefore the lowest losses, in the solar panel array system and associated wiring.

The MPPT will be handled by an off-the-shelf product, the ProStar MPPT-25 amp, which will not only save project timeline, but also cost and complexity. The charge controller selected allows up to only 25 amps, putting our design current very close to the controllers peak efficiency current of 10 amps.

Since the sprint and slalom races will not make use of the solar panels and high current is expected, there will be a different battery bank for these events consisting of (3) XS Power D1200 12 volt batteries. The telemetry battery, which will also power the Rule 25S bilge pump capable of pumping 500 gallons per hour, is a Power Sonic PSH-1255FR 12 Volt 6.0 AH battery. See Appendix A for battery specifications and MSDS.

The manufacturing of the power electronics system has been tested and installed in its final configuration into the boat. Initially a model power station was built to test the system off-boat to curtail any problems before final implementation. The model was built such that the only difference between the model and finished product were length and orientation, organization and professionalism, and proper anchoring of components and wiring. This was deliberately done to ensure as few problems as possible after the final integration into the boat.

As expected, the final integration into the boat worked as modeled. Fig. 3 shows the final placement of the batteries and the motor. Note that this is the endurance configuration.

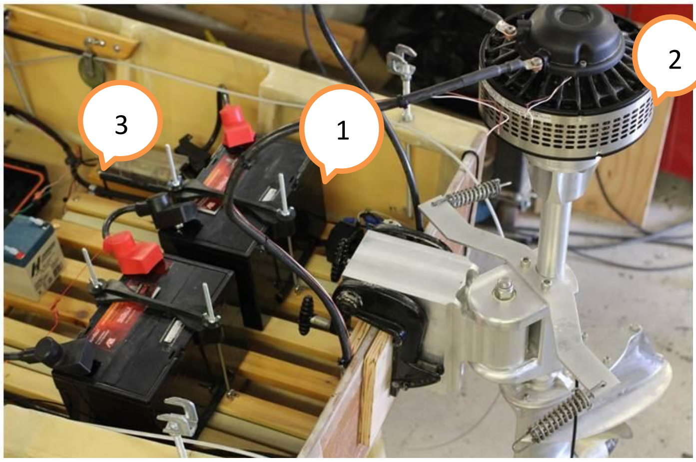

Fig. 3. Endurance batteries with motor setup.

The core of the power electronics system is the battery bank [Label 1]. The battery bank will be either 24 volt for the endurance or 36 volt for the sprint and slalom races. The motor [Label 2] is given extra length of one gauge wire so that the wires do not become stressed or strained as the motor turns for steering. A 500 amp ANL fuse [Label 3] protects the power electronics system from excessive current; this must be located as close as possible to the battery bank.

Though not yet implemented, a 36v to 48v DC/DC boost converter will be installed prior to the competition. Though the rules state that no power source may be above 36 volts, the maximum allowable potential to ground on the boat is 52 volts. This will allow us to extract up to 25% more power out of our motor, which is rated at 48 volts.

Since the entire data acquisition system and the wiring side of the motor controller all must be protected from water, a pelican-style box was selected which was both cost effective and water-proof. Fig. 4 illustrates the final components of the power electronics system including any current safeguards.

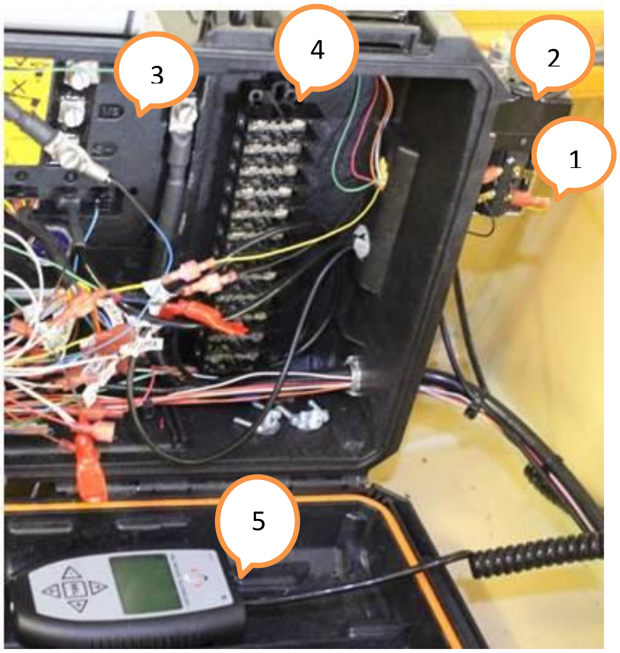

Fig. 4. The safety and control components of the power electronics system.

Located next to the control box is a DC line contactor [Label 1]. The DC line contactor is factory equipped with a magnetic blow-out: a device that uses magnetism to “blow-out” electrical arcs seen in high-current DC systems as the contactor closes. On top of the DC line contactor [Label 2] is a 5 W, 10k Ohm pre-charge resistor. Pre-charge resistors allow a slow charging of the capacitors in motor controllers to prevent arcing on contacts prior to a contactor closing. The next components is the motor controller itself [Label 3]; note that the motor controller is mounted to the power-electronics box such that it is protected from water on the wiring-harness side, while still allowing heat dissipation on the heat-sink side. The motor controller has (3) harness connections which allow a variety of functions, a full schematic of which is detailed in Appendix E. Grounding for marine vehicles must be done with a single conductor routed below the waterline. The terminal strip located in the far right section of the power-electronics box [Label 4] links all 0 volt potentials on the boat to connect together before routing to ground. The final component in the model is the motor controller programmable interface [Label 5]. This interface allows the end user to program the finer points of how the motor controller will run.

In order for the skipper to control all of the various motor functions, a dash was installed in the boat to accommodate various switches and components. Fig. 5 shows the controls available to the skipper.

Fig. 5. The dash and control interface for the skipper.

The key shown is a double pull, single throw switch which will turn on both the power for the power electronics system as well as the data telemetry system discussed later [Label 1]. The switches pictured here allow the skipper to interact with the motor controller; these switches are either safety controls that must be engaged before forward drive is allowed, or used for various preset speeds [Label 2] without needing to utilize the throttle [Label 3]. The LCD display and push button [Label 4] pictured here are discussed in the Data Acquisition Section.

2) Analysis of Design Concepts

The power electronics system did not require analysis because the power electronics were based on installation criterion provided by the motor installation manual.

3) Design Testing and Evaluation

Testing of the power electronics system will be performed during the month leading up to the competition. Testing will involve fine tuning all the speeds and accelerations of the motor for the various races.

D. Hull

1) Design:

There were three criteria guiding the hull design; lightweight, stability, and low resistance in the water. The hull also needed to be economical to build, simple to manufacture, and meet the specifications of Solar Splash 2016. The design process included research, model testing, CAD models, computational fluid dynamics (CFD), and finite element analysis (FEA).

The completed hull is 4.7 m in length, 0.97 m at the widest point, and weighs 343 N. Fig. 6 shows the completed hull.

Fig. 6. Completed hull with motor and solar panels installed.

The hull was made using a foam core composite. The layup schedule consisted of a single layer of 10 oz. fiberglass and epoxy on the inner and outer surfaces of a 9.5 mm thick layer of Divinycell H80 foam. Marine grade plywood was used for the transom. The hull is based on the semi-planing hull shape of a monohull launch boat. The inside of the hull has a system of ribs and stringers to add rigidity and mounting points for decking and the steering and electronics systems. Fig. 7 shows the interior of the boat before installing the cockpit and other subsystems.

Fig. 7. Boat interior before installing the remaining subsystems.

2) Analysis of Design Concepts:

Before selecting a hull shape, five simplified boat models were tested in a drag tank experiment. Fig. 8 shows the five hull shapes used for testing.

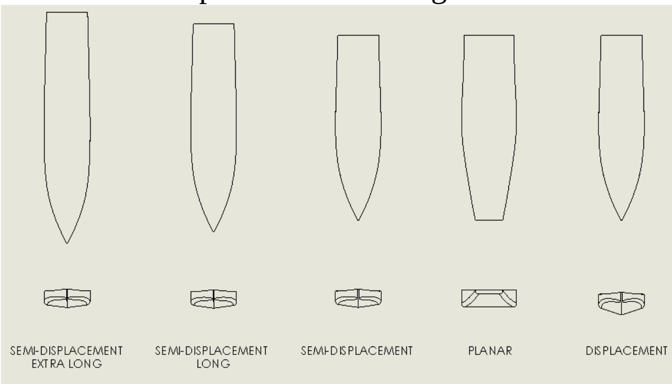

Fig. 8. Diagram of the five model hulls used for testing.

The drag tests showed empirically, that a long semi-displacement hull would have low drag in the water. This verified previous research into basic hull shapes and the limitations posed by hull speed. A CAD model was created in SolidWorks of the full scale design. Buoyancy and stability requirements were verified using data from the Solidworks model and free body diagrams.

A STereoLithography file was exported from Solidworks for use in a Comsol Multiphysics Modeling CFD analysis. A coefficient of drag of 0.065 was calculated using the Comsol data. Fig. 9 shows the mesh used in the analysis.

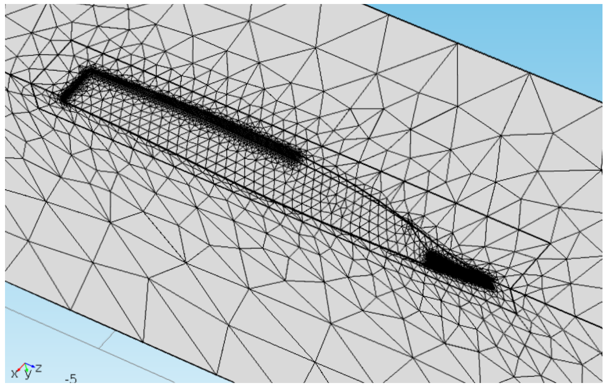

Fig. 9. Mesh used in drag force analysis.

FEA was used to verify the strength of the layup schedule to be used on the hull. A rectangular section of the hull corresponding to the largest unsupported panel on the bottom of the hull was used for the model. Data from the CFD model and buoyancy calculations were used to define the forces on the composite panel. A combination of fixed and immovable constraints were used to allow the model to expand and flex from the forces. Fig. 10A shows the resulting stress plot for the rectangular panel while Fig. 10B shows the resulting stress plot for the boat hull, both from the FEA model.

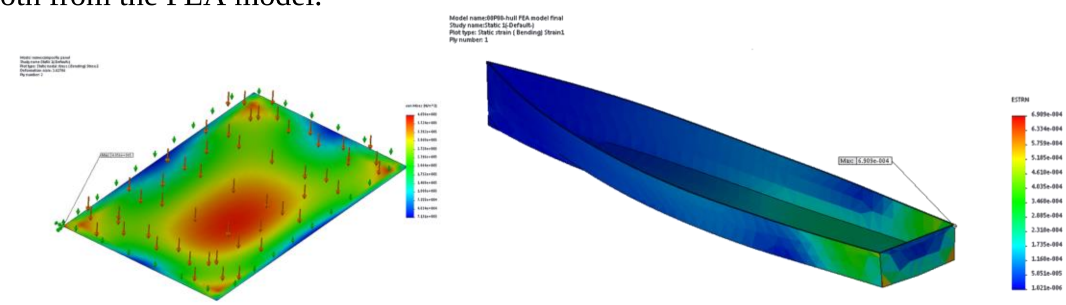

Fig. 10. A. Stress plot of a composite panel and **B.** the boat hull.

After verifying the strength of the layup, FEA was completed on the entire hull. Along with the forces from the water, weights from the drive train, skipper, and batteries were included in the model. A first ply critical strain failure criterion was used to evaluate both models. A factor of safety of greater than 2 was observed in both models.

3) Design Testing and Evaluation:

The hull has met the design criteria of being lightweight because it was below the goal weight of 440 N. Still to be tested is the stability criteria. Once the boat is on the water, stability will be verified using the same testing criteria that will be used during technical inspection at Solar Splash 2016.

E. Drive Train and Steering

1) Design:

The drivetrain for the boat is based on a traditional outboard motor which will be utilized for all events and will be steered by a cable and pulley system. Different propellers will be used for the Sprint and Endurance race.

a) Drivetrain:

The goal for the drivetrain was to create a midsection which could have the electric motor mounted to the top and in line with the driveshaft and enclose the lower unit which was donated to the team. The midsection needed to be lightweight, cost effective due to budget limitations, and such that the team could manufacture it entirely in house. The drivetrain can be seen in Fig. 11.

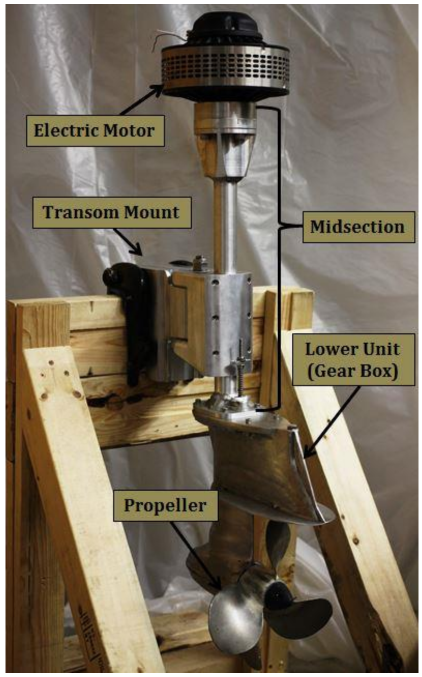

Fig. 11. The completed drivetrain resting on a motor stand.

In Fig. 11 the midsection is defined and contains all components necessary to mount the motor, enclose the lower unit, and mount the system to the transom of the boat. The drivetrain is driven by one Lynch LEM200-127 LEMCO 48V electric motor. Details about the Lynch electric motor can be found in Appendix F. The motor is coupled to a driveshaft which runs down to a retrofitted 1960's Evinrude lower unit/gear box. Inside the lower unit the driveshaft drives a beveled gear which transfers power to another beveled gear on the propeller shaft which is perpendicular to the driveshaft. This lower unit has a final drive ratio of 1.75:1. Since the team is using a preexisting lower unit, the gear ratio was not altered and became one of the defining constraints for choosing a propeller. The second constraint for choosing a propeller is based on the expected RPM and power produced by the electric motor during different events.

b) Steering:

The cable-pulley steering system was chosen due to low cost, light weight, and ease of repair. The cable wraps around a drum behind the steering wheel, as the steering wheel turns, it pulls on a handlebar that is attached to the drive train where the midsection clamps to the drive shaft housing. The handlebar is what makes the drivetrain pivot and springs were incorporated to keep the 4.5 mm cable in tension throughout the entire system.

c) Propellers:

Three different propellers were donated to the team this year. Each has a different pitch and diameter and will be tested during the month leading up to the competition to evaluate performance. These propellers will be altered and retested until an ideal pitch and diameter is discovered.

2) Analysis of Design Concepts:

a) Drivetrain:

Adhering to design constraints listed previously began with creating a solid model which led to a quasi-static free body analysis of the entire system under maximum loading conditions.

The maximum loads expected on the system exist during the sprint race. The system was analyzed as a whole and then all components were broken up in order to resolve all forces acting on each component. Fig. 12 is a rendering of the components in the midsection.

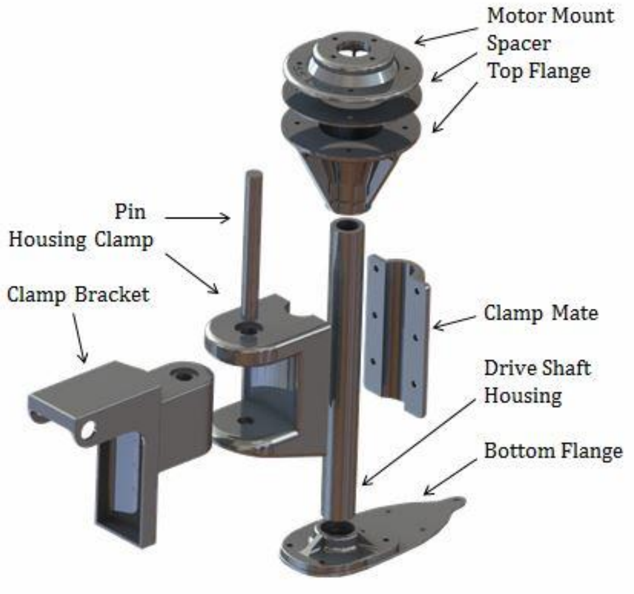

Fig. 12. Rendered model of the midsection with labels.

Knowing all the forces on each component in Fig. 12 led to a finite element analysis (FEA) of each part using SolidWorks.

Using a finite element analysis provided the opportunity to analytically verify that the components would not fail under maximum quasi-static loading with specified materials. The clamp bracket, housing clamp, pin, and motor mount were the main components of concern. The motor mount needed to be able to resist the torque produced by the motor. Both the clamp bracket and housing clamp carry the weight of the system and experience a moment caused by the propulsion force at the propeller. The results of the finite element analysis on the clamp bracket are represented in Fig. 13 and described below.

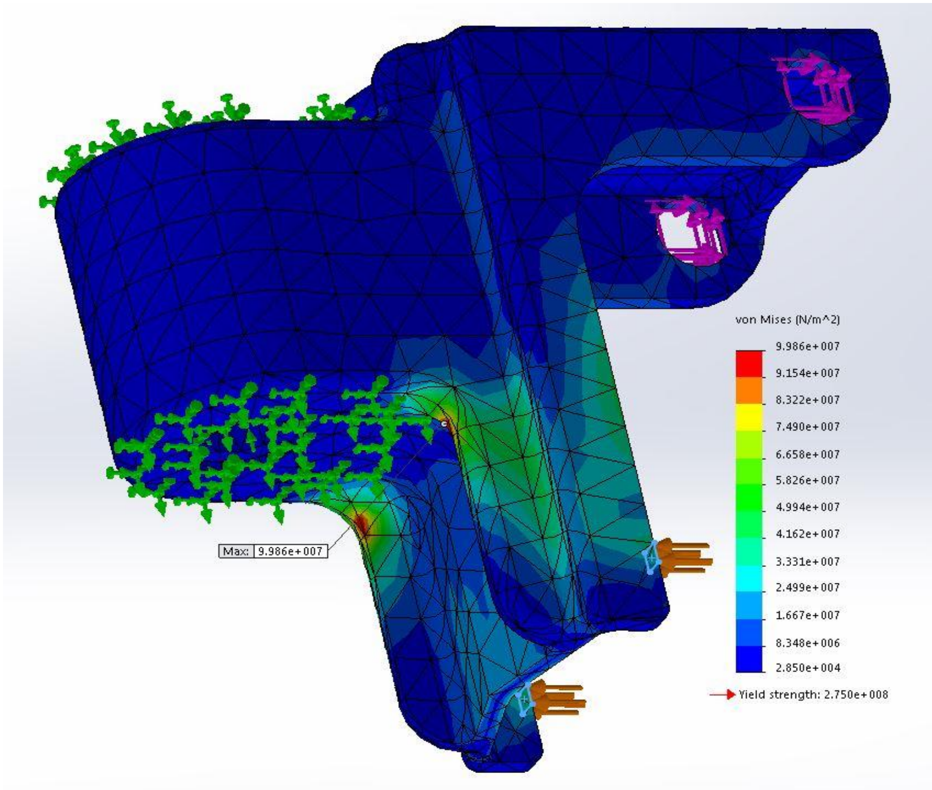

Fig. 13. Quasi-static finite element analysis of the clamp bracket.

The green arrows represent where the clamp bracket is fixed within the housing clamp. The clamp bracket also had a hinged fixture in the cylinder where the pin will sit to allow for steering. Fixing that point like a hinge designated that the part could rotate about this point. The orange arrows represent a total force of 4635 N. The purple arrows pointing right and then up are the total forces 3335 N and 265N, respectively. This analysis on the clamp bracket demonstrated that the design would not fail. Making the part out of 6061-T6 aluminum provides a safety factor of 2.8 when using the maximum stress found in the analysis, which is acceptable.

By analyzing the maximum stress on each component, the design team was able to choose the lightest possible materials while still adhering to the budget limitations. 6061-T6 aluminum was chosen for every part with the exception of the pin which would be made of AISI Type 304 stainless steel.

b) Steering:

FEA analysis was conducted on the handlebars, and it was concluded that using 6065 Aluminum yields a safety factor of 3. The vinyl covered cable and pulleys have safety factors of 6 and 2.2, respectively.

3) Design Testing and Evaluation:

a) Drivetrain:

To date, the drivetrain has not been tested. The team is waiting for time at a local reservoir to put the boat on the water and test the drivetrain. To test the drivetrain, dynameters will be fixed to the propeller shaft to compare the power output at the propeller to the power delivered to the system by the motor. This information will lead to calculating total system efficiency.

b) Steering:

The handlebar was machined out of a 0.25 in. thick 6065 Aluminum plate using the HAAS on campus and can successfully turn the drive train. A full rotation of the steering wheel can pivot the lower unit 45°. The pulleys and cable are still yet to be tested on water.

F. Data Acquisition and/or Communications

1) Design:

The data acquisition system essentially involves the interfacing of various sensors, controls, and a display for manual or autonomous decisions. In lieu of this, a more compact version of the complete data system was constructed before installing it on to the completed boat. Fig. 14 shows the compact version of the entire data acquisition prior to the installation on the boat with appropriate labels for each component.

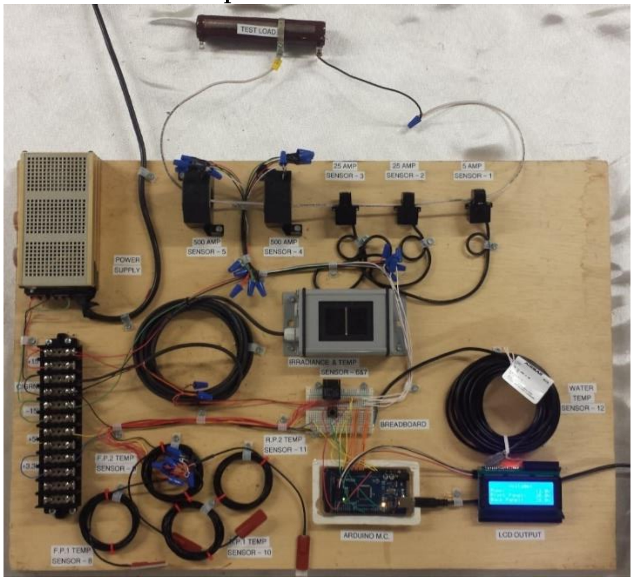

Fig. 14. Current compact version of the data acquisition system to be installed on the boat.

The final installation of the components pictured above are illustrated throughout several figures below. Fig. 15 shows the complete data power center.

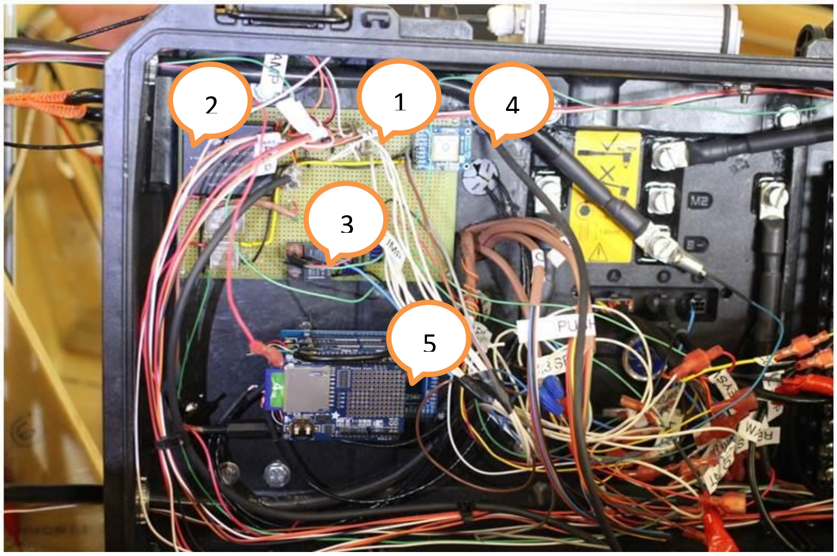

Fig. 15. The main data acquisition control center.

The copper clad perf-board [Label 1] was installed to allow a permanent soldered connection to all components in one central location ensuring sound electrical transmission. In addition to the various wires shown, there are (3) onboard DC/DC converters to deliver stiff voltages of $\pm$15, 12, and 5 volts; these converters are installed on the left hand side of the copper clad perf-board from top to bottom respectively [Label 2]. To the right of the bottom-most converter is a 5 VDC relay used to autonomously control the water-cooling-system pump [Label 3]. Several of the resistors shown on the perf-board are used as voltage dividers to determine power monitoring discussed later. The last component on the perf-board is the GPS chip [Label 4]. Just below the perf-board [Label 5] is the Arduino microcontroller stack. The stack consists of, from lowest to highest: an Arduino Mega 2560 microcontroller, (2) Protovoltaic RTD shields for interaction with the solar-panel temperature sensors, and (1) SD card shield for data storage. The various wires extending from the perf-board and exiting the power-electronics box route to a variety of sensors on the boat. There are 12 sensors in total: (1) irradiance sensor, (1) ambient temperature sensor, (4) solar-panel temperature sensors, (1) water temperature sensor, (5) amperage sensors. The irradiance and ambient temperature sensors are only for data accrual. The solar-panel temperature sensors will be used in conjunction with the water temperature to allow the microcontroller to autonomously turn on the water pump when the temperature delta between the water and the panels is above 30℃, and also to turn the pump off when the temperature delta is below 20℃. In order to determine the power usage on the boat, the amperage sensors, when used with the data from the voltage dividers, will provide real-time power consumption that is both accessible through the LCD screen (discussed below) and storable onto the SD card.

The final components to the Data Acquisition system, the LCD screen and push button, are shown in Fig. 5 [Label 4]. The LCD output will be very instrumental in fine-tuning the boats control systems before the competition in June in addition to providing the skipper with the ability to access any or all of the information at any time.

2) Analysis of Design Concepts:

Analysis of the data acquisition system consisted of iteratively going through the microcontroller programming code to confirm proper operation of various data acquisition components.

3) Design Testing and Evaluation:

Testing of the data acquisition system will be performed in the month leading up to the competition and will consist of calibration of sensors in programming code and confirmation of retrieval of data.

V. PROJECT MANAGEMENT

G. Team Members and Leadership Roles

All team members are undergraduate students of the Mechanical Engineering department. The various components of the project were designated to two or more team members so that each team member had one or more component that they were responsible for working on. It was important to have at least two team members working on each component of the project to increase the chances of catching any mistakes made during design and analysis. The team met as a whole twice a week for at least an hour and a half and each sub-team met various times throughout the duration of the project. The team met with advisors and various faculty members at the University when necessary.

H. Project Planning and Schedule

The planning and scheduling of the project followed the requirements of the Senior Design courses at the University. The schedule allots the fall semester to the design and analysis of the project while the spring semester is for the construction of the project. Each semester required the writing of a midterm report as well as a final report that assisted in keeping the team on track with progress. The team did struggle to keep up with the construction deadlines as many components of the boat were redesigned over the winter break between the fall and spring semesters. Fortunately, the project was about 80% complete by the end of the semester, May 6^{th}.

I. Financial and Fund Raising

The total budget for the project came out to $19,242.12 and the University only provided $2100 towards the funds of this project so it was necessary to perform extensive fund raising. Fortunately, many materials and parts needed for the project were generously donated by vendors and added up to a total of $10,351.89 in donated materials which greatly decreased the amount of money required to complete the project. Fundraising events were held to help bring in additional funds that included an event with a local bar and an event with a local golf course. Fundraising events and fundraising by individual team members brought in a total of $8,193.47.

J. Team Continuity and Sustainability

As we are a first year team competing in Solar Splash, we would like to provide a platform for future teams at the University of Colorado Denver to compete in Solar Splash. The data acquisition system will allow our team to compile data that will be useful for any future Solar Splash teams at our University.

K. Discussion and Self-Evaluation

As a team of strictly Mechanical Engineering students doing this project at our University for the first time, we feel that we have been successful in completing the project. The difficulties we encountered such as not having any Electrical Engineering team members or advisors as well as not having any advisement on performing fluid dynamics evaluations posed noteworthy challenges to the team.

VI. CONCLUSIONS AND RECOMMENDATIONS

L. Conclusions

The goal of the University of Colorado Denver team is to build a solar-powered race boat, the SS Lynx. The solar-array design was able to capture low-angle light, while being lightweight with an integrated water-cooling system. The various configurations of the power electronics and data systems were successful in providing maximum potential to focus on maximum efficiency or burst speed. The boat hull weighed less than expected and was manufactured as intended. It is therefore expected that a top speed of 32 km/h with a cruising speed of 18 km/h for peak efficiency is realistic. The outboard motor was built exceptionally light and mated well with the power electronics system. The steering system and shifter are lightweight and functional. The data acquisition system proved to provide sufficient data to maximize the efficiency of all subsystems and provide a database for future teams at the University of Colorado Denver.

M. Recommendations

While the water cooling system is fully configured, it is still necessary to drill a hole in the bottom of the hull for the pump inlet as well as construct the drain pan. Additionally, further adjustments to the nozzle orientations will assist in determining optimal water coverage across the panels.

The final steps in completing the hull will be to fair the outside using a thickened epoxy with added microspheres and then painting the exterior surface.

With the competition in mind, the drivetrain will undergo a critical evaluation to verify that it complies with all rules laid down by the governing body of the Solar Splash competition. Testing the drivetrain will take place as soon as possible, which should include verifying that the propeller is delivering as much power as was estimated by calculation. This can be done with dynameters placed on the propeller shaft. Knowing the true power output will provide the need information to calculate the true efficiency of the system from power in at the motor to power out at the propeller. Unfortunately the components in between will remain unknown. Last of all and for the sake of aesthetics the entire drivetrain will be polished to give it a more professional look when it arrives in Dayton, OH.

The path forward for steering will be testing the steering to see how much force it takes to turn and what the turn radius will be. It will also be tested to make sure the handling is acceptable for the skipper.

The 36v to 48v DC/DC boost converter will be installed and testing of the systems will need to be completed prior to the competition.

An LCD screen for the dashboard will be wired and live testing of the entire system in the lake will need to be done prior to testing to ensure all system function properly in the same environment as the competition.

VII. REFERENCES

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VIII. APPENDICIES

Appendix A – Battery Documentation

Endurance Battery Bank

- Labels
- New Dealer Package
- Quick Order Form

Home > Marine & RV > Power Boats > XTR34-75 12Volts 75AH Deep Cycle, XTREME AGM Battery.

XTR34-75 12Volts 75AH Deep Cycle, XTREME AGM Battery.

Price

Your Price:$219.99

Availability:

Free Shipping & 10% Off First Order
Part Number:XTR34-75

Quantity 1 Add to Cart
Quantity Pricing
Quantity
Price

- 2 - 3
- $208.99

- 4 - 11
- $197.99
- 12+
- $186.99

Like Be the first of your friends to like this.

- Description

Description

XTR34-75

Nominal Voltage	20Hr Capacity	RC (min)	HCA	Terminal Posts	Dimensions	Weight	Charging Current*	Charging Voltage	Float Voltage
12V	75AH	145	1100A	6mm Hex Screws(included)	10.2"w x 6.6"d x 7.2"h	45lb	5A-20A	14.4-14.9V	13.5V-13.8V

* Warning: Do not use a wet battery constant current charger to recharge any VMAX battery.*

Recommended Charging Options:

- Smart / Microprocessor controlled charger: Battery Charger Guide.
- Vehicle Alternator: 14V-15V.
- RV Converter: 14V-15V.
- Solar Panel: 135W-350W.
- Wind Turbine: 135W-350W.
- Charge Controller: 15A-UP.

Operating Temperature Range:

- Discharge: -4~140F
- Charge: 14~140F
- Storage: -4~140F

Temperature Compensation:

- Cycle use: -30mV/C
- Standby use: -20mV/C

UPC: 804879288152

BCI Group Codes*:
Matching Termination: 34 (+ on L.H.S. & - on R.H.S)

* Matching is based on closest dimensional specifications. Differences in hold downs and termination may require some accommodations and/or the extension of one or both vehicle's battery cables.

Reward Points

VMAXTANKS Material Safety Data Sheet

□ SECTION 1 : PRODUCT IDENTIFICATION

□ SECTION 2: CONTACT

Chemical/Trade name (as used on label)	Chemical Family/Classification
AGM NON-SPILLABLE BATTERY	Electric Storage Battery

□ SECTION 3: HAZARDOUS INGREDIENTS/INDENTITY INFORMATION

□ SECTION 4: PHYSICAL/CHEMICAL CHARACTERISTIC DATA

Material is solid at normal temperatures. Electrolyte

Company Name:	Address:
VMAX USA, LLC.	26300 W. 8 MILE, SOUTHFIELD MICHIGAN 48034, USA Tel: 248-827-1021 Fax: 248-827-2420

Appearance and Odor:

Electrolyte is a clear liquid with an acidic order. (5% diluent's acid,95% is water)

VMAX USA, LLC.

www.vmaxtanks.com

Exposure Limits (Air Exposure Limits(ug/m3) Material %by Wt. CAS Number OSHA AGGIH NIOSH Lead 57 7439-92-1 50 150 100
Lead Oxide 22 1309-60-0 50 150 100
AGM 16 Electrolyte 5 electrolyte5% diluent's acid,95% is water

Page1

Boiling Point: 230°F/110°C Melting Point Lead 327.4°C
Specific Gravity: 1.215-1.350 Vapor Density Not determined
% Volatiles By Weight: Not Applicable Vapor Pressure Not determined
Solubility in Water 100%(electrolyte5% diluent's acid,95% is water) Evaporation Rate Not determined

SECTION 5: HEALTH HAZARD INFORMATION

Under normal operating conditions, the internal material will not be hazardous to your health. Only internally exposed material during production or case breakage or extreme heat (fire) may be hazardous to your health.

SECTION 6: Routes of Entry:

·Installation: Acid mist from formation process may cause respiratory irritation ·Skin Contact: Acid may cause irritation, burns and/or ulceration ·Skin Absorption: Not a significant route of entry. ·Eye Contact: Acid may cause severe irritation, burns, cornea damage and/or blindness ·Ingestion: Acid may cause serve irritation of mouth, throat, esophagus and stomach

SECTION 7: Sign and Symptoms of Over Exposure:

Acute Effects: Over exposure to lead may lead to loss of appetite, constipation, sleeplessness and fatigue. Over exposure to acid may lead to skin irritation, corneal damage of the eyes and upper respiratory system.

Chronic Effects: Lead and its components may cause damage to kidneys and nervous system. Acid and its components cause lung damage and pulmonary conditions.

Potential to Cause Cancer: The International Agency for Research on Cancer has classified "strong inorganic acid mist containing sulfuric acid" as a Category 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 is not generated under normal use of this product. Misuse of the product, such as overcharging, may however result in the generation of sulfuric acid mist.

SECTION 8: Emergency and First Aid Procedures:

·Inhalation: Remove from exposure and apply oxygen if breathing is difficult ·Skin: Wash with plenty of soap and water. Remove any contaminated clothing ·Eyes: Flush with plenty of water immediately for at least 15 minutes. Consult a physician ·Ingestion: Consult a physician immediately

SECTION 9: FIRE AND EXPLOSION HAZARD DATA:

Flash Point: Hydrogen=259°C Auto ignition Temperature: Hydrogen=580°C Extinguishing Media: Dry chemical, foam, CO_2 Unusual Fire and Explosion Hazards: Hydrogen and oxygen gases are produced in the cells during normal battery operation (hydrogen is flammable and oxygen supports combustion). These gases enter the air through the vent caps. To avoid the chance of a fire or explosion, keep sparks and other sources of ignition away from the battery.

SECTION 10: REACTIVITY DATA:

Stability: Stable Conditions to Avoid: Sparks and other sources of ignition Incompatibility: (materials to avoid) 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.

Page2

Hazardous Decomposition Products: Lead/lead compounds: Oxides of lead and sulfur. Battery electrolyte (acid): Hydrogen, sulfur dioxide, and sulfur trioxide. Conditions to Avoid: High temperature. Battery electrolyte (acid) will react with water to produce heat. Can react with oxidizing or reducing agents.

 SECTION 11: CONTROL MEASURES:

Engineering Controls: Store lead/acid batteries with adequate ventilation. Room ventilation is required for batteries utilized for standby power generation. Never recharge batteries in an unventilated, enclosed space. Work Practices: Do not remove vent caps. Follow shipping and handling instruction that are applicable to the battery type. To avoid damage to terminals and seals, do not double-stack industrial batteries.

 SECTION 12: PERSONAL PROTECTIVE EQUIPMENT:

Respiratory Protection: None required under normal handling conditions. During battery formation (high-rate charge condition), acid mist can be generated which may cause respiratory irritation. Also, if acid spillage occurs in a confined space, exposure may occur. If irritation occurs, wear a respirator suitable for protection against acid mist. Eyes and Face: Chemical splash goggles are preferred. Also acceptable are “visor-gogs” or a chemical face shield worn over safety glasses. Hands, Arms, Body: Vinyl coated, VC, gauntlet type gloves with rough finish are preferred. Other Special Clothing and Equipment: Safety shoes are recommended when handling batteries. All footwear must meet requirements of ANSI Z41.1Rev.1972.

 SECTION 13: PRECAUTIONS FOR SAFE HANDLING AND USE:

Hygiene Practices: Following contact with internal battery components, wash hand thoroughly before eating, drinking, or smoking. Respiratory Protection: Wear safety glasses. Do not permit flames or sparks in the vicinity of battery(s). If battery electrolyte (acid) comes in contact with clothing, discard clothing. Protective Measures: Remove combustible materials and all sources of ignition. Cover sills with soda ash (sodium carbonate) or other suitable container. Dispose of a hazardous waste. Wear acid-resistant boots, chemical face shield, chemical splash goggles, and acid-resistant gloves. **Do not release un-neutralized acid.**

Waste Disposal Method: Battery electrolyte (acid): Neutralize as above for a spill, collect residue, and place in a drum or suitable container. Dispose of as hazardous waste. **Do not flush lead contaminated acid to sewer.** Batteries: Send to lead smelter for reclamation following applicable government, province and local regulations.

Product can be recycled along with automotive (SLI) lead acid batteries.

Other Handling and Storage Precautions:

VMAX USA, LLC.

www.vmaxtanks.com

None Required.

□ SECTION 14: NFPA HAZARD RATING:

Sulfuric Acid:

Flammability (Red) =	0
Health (Blue) =	3
Reactivity (Yellow) =	2

□ SECTION 15: DEPARTMENT OF TRANSPORTATION AND INTERNATIONL SHIPPING REGULATIONS:

□ SECTION 16: Comments:

SECTION 16: Comments:

VMAXTANKS batteries are classified as "non-spillable" for the purpose of transportation. They are excepted by the requirements of the DOT's hazardous materials regulations, since they

Proper Shipping Name	Batteries, wet, non-spillable, electric storage UN2800, Class8 PGIII
PRC. DOT(PRC Department of Transportation)	Unregulated
IATA(International Air Transportation Association)/ICAO(International Civil Aviation Administration)	Special Provision S.P.A67
IMO(International Maritime Dangerous Goods)	VMAX AGM batteries meet the non-spillable criteria listed in IMDG Code Special Provision 238 .1 and .2; therefore, are not subject to the provisions of the IMDG Code, provided that the battery terminals are protected against short circuits when packaged for transport.

adhere and meet the requirements of code
49 CFR Section 173.159(D)

VMAXTANKS nonspillable batteries can be safely transported on deck, or under deck stored on either a passenger or cargo vessel as result of passing the Vibration and Pressure Differential Tests as described in the IMDG regulations.

To transport these batteries as "non-spillable", packages must be labeled as "NON-SPILLABLE". They must also be shipped in a condition that would protect them from short-circuits and be securely packaged so as to withstand conditions normal to transportation by a consumer, in or out of a device.

Nonspillable batteries are unregulated thus they require no additional special handling or packaging.

Sprint and Slalom Battery Bank

5/9/2016

SEARCH

HOME / SHOP / STARTING / D SE

TWITTER | FACEBOOK | YOUTUB

http://4xspower.com/shop/d-series/d1200/

Material Safety Data Sheet

Product and Company Identification

Revised: June 6, 2014 **Manufacturer's Name:** XS Power **Address:** 2847 John Deere Dr. Suite 102, Knoxville, TN 37917 **Telephone:** (865) 688-5953 **Web:** www.4xspower.com **Transport Information:** All XS POWER AGM batteries, when transported by air, surface or by vessel are identified as "Battery, Electric Storage, Dry, Nonspillable, Not Regulated".
Chemical / Trade Name (as used on label): Absorbed Electrolite Battery, Sealed Valve Regulated Lead Acid Battery **Chemical Family / Identification:** Electric Storage Battery

Hazardous Ingredients/Identify Information

Note: Inorganic lead and electrolyte (water and sulfuric acid solution) are the primary components of every XS Power battery. Other ingredients may be present dependent upon battery type.

COMPONENTS	APPROXIMATE % BY WEIGHT	CAS #	OSHA PEL	ACGIH TLV	NIOSH
Inorganic Lead/ Lead Compounds	65% _ 75%	7439-92-1	50 g/m3h	150 g/m3h	100 g/m3h
Sulfuric Acid/Battery Electrolyte 1.300sg 40wt%	16% _ 21%	7664-93-9	1 gm/m3	1 gm/m3	1 gm/m3
Case Material: Acrylonitrile, Butadiene, Styrene(ABS)	5% _ 10%	9003-56-9	N/A	N/A	N/A
Fiberglass Separator	5%	_	N/A	N/A	N/A
Tin	<0.5%	7440-31-5	2000 g/m3h	2000 g/m3h	N/A
Calcium	<0.2%	7440-70-2	N/A	N/A	N/A

HEALTH HAZARD INFORMATION Routes of Entry

Lead Compounds: Hazardous exposure can occur only when product is heated, oxi dized or otherwise processed or damaged to create dust, vapor or fume.

Sulfuric Acid: Harmful by all routes of entry.

Inhalation

Lead Compounds: Inhalation of lead dust or fumes may cause irritation of upper respi ratory tract and lungs.

Sulfuric Acid: Breathing of sulfuric acid vapors or mists may cause severe respiratory irritation

Fiberglass Separator: Fiberglass is an irritant to the upper respiratory tract, skin and eyes. For exposure up to 10F°/ use MSA Comfoll with type H filter. Above 10F use Ultra Twin with type H filter. This product is not considered carcinogenic by NTP or OSHA.

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

Lead Compounds: Not absorbed through the skin.

Sulfuric Acid: Severe irritation, burns and ulceration.

Eye Contact

Lead Components: May cause eye irritation. **Sulfuric Acid:** Severe irritation, burns, cornea damage, and blindness.

Effects of Overexposure - Acute

Lead Compounds: Symptoms of toxicity include headache, fatigue, abdominal pain, loss of appetite, muscular aches and weakness, sleep disturbances and irritability.

Sulfuric Acid: Severe skin irritation, damage to cornea, upper respiratory irritation.

Effects of Overexposure - Chronic

Lead Compounds: Anemia; neuropathy, particularly of the motor nerves, with wrist drop; kidney damage; reproductive changes in males and females.

Sulfuric Acid: Possible erosion of tooth enamel, inflammation of nose, throat and bron chial tubes.

Carcinogenicity:

Lead Compounds: Lead is listed as a 2B carcinogen, likely in animals at extreme doses. Proof of carcinogenicity in humans is lacking at present.

Sulfuric Acid: The International Agency for Research on Cancer (IARC) has classified “strong inorganic acid mist containing sulfuric acid” as a Category I carcinogen, a sub stance 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. Misuse of the product, such as overcharging, may result in the generation of sulfuric acid mist.

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 neuralgic diseases.

EMERGENCY AND FIRST AID PROCEDURES

Inhalation

Lead Compounds: Remove from exposure, gargle, wash nose and lips; consult physi cian.
Sulfuric Acid: Remove to fresh air immediately. If breathing is difficult, give oxygen.

Ingestion

Lead Compounds: Consult physician immediately.

Sulfuric Acid: Give large quantities of water; do not induce vomiting; consult physician.

Skin

Lead Compounds: Wash immediately with soap and water.
Sulfuric Acid: Flush with large amounts of water for at least 15 minutes; remove con taminated clothing completely, including shoes.

Eyes

Sulfuric Acid and Lead: Flush immediately with large amounts of water for a least 15 minutes; consult physician.

FIRE AND EXPLOSION HAZARD DATA

FIRE AND EXPLOSIVE PROPERTIES

Hydrogen Flammable Limits in Air (% by Volume): LEL: 4.1 UEL: 74.2
Lower Explosion Limit (LEL), Upper Explosion Limit (UEL)
Hydrogen Flash point: N/A Hydrogen Auto ignition point: 580°C
Special Fire Fighting Procedures: Use Positive Pressure, self-contained breathing ap paratus.
Extinguishing Media: Dry chemical, foam, $CO2$
Unusual Fire and Explosion Hazards:

In operation, batteries generate and release flammable hydrogen gas. They must always be assumed to contain this gas which, if ignited by burning cigarette, naked flame or spark, may cause battery explosion with dispersion of casing fragments and corrosive liquid electrolyte. Carefully follow manufacturer's instructions for installation and service. Keep away all sources of gas ignition and do not allow metallic articles to simultaneously contact the negative and positive terminals of a battery.

PRECAUTIONS FOR SAFE HANDING AND USE

Handling and 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 protec tion 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.

Precautionary Labeling:

POISON - CAUSES SEVERE BURNS DANGER - CONTAINS SULFURIC ACID

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 whenever 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.

Spill or Leak Procedures:

Stop flow of material; contain/absorb 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

Electrolyte:			
Boiling Point:	203-240℉	**Specific Gravity(H2O=1):**	1.300-1.330
Melting Point:	N/A	**Vapor Pressure(mm Hg):**	10
Solubility in Water:	100%	**Vapor Density (AIR = 1):**	3.4
Evaporation Rate: (Butyl Acetate = 1)	Less than 1	**% Volatile by Weight:**	N/A
Appearance and Odor:	Manufactured article; no apparent odor. Electrolyte is a clear liquid with a sharp, penetrating, pungent odor.		

not allow discharge of un-neutralized acid to sewer.

Waste Disposal Method:

Spent batteries: Send to secondary lead smelter for recycling.

CONTROL MEASURES

Work Practices:

Handle batteries cautiously to avoid spills. Make certain vent caps are on securely. Avoid contact with internal components. Wear protective clothing when filling or handling bat teries.

Engineering Controls:

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

Eye Protection:

Chemical goggles or face shield.

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.

Protective Gloves:

Rubber or plastic acid-resistant gloves with elbow-length gauntlet.

Other Protection:

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

Emergency Flushing:

In areas where sulfuric acid is handled in concentrations greater then 1%, emergency eyewash stations and showers should be provided, with unlimited water supply.

Physical Data

Reactivity Data

Stability: Stable

Conditions to Avoid:

High temperature, Sparks and other sources of ignition.

Incompatibility (materials to avoid):

Electrolyte (Water and Sulfuric Acid Solution): 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, halogenated, potassium nitrate, permanganate, peroxides, nascent hydrogen, and reducing agents.
Hazardous Byproducts:
Sulfuric Acid: Sulfur trioxide, carbon monoxide, sulfuric acid mist, sulfur dioxide, and hydrogen.
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 generate highly toxic arsine gas.
Ecological Information
Lead and its compounds can pose a threat if released into the environment.
Transport Information
All XS POWER AGM batteries, when transported by air, surface or by vessel are identified as "Battery, Electric Storage, Dry, Nonspillable, Not Regulated". The battery(s) must be identified as above on the Bill of Lading and properly packaged with their terminals protected from short circuit. NA or UN numbers do not apply. XS POWER AGM battery(s) warning label identifies each battery as NONSPILLABLE.
XS POWER AGM battery(s) preprinted cartons identify each battery as NONSPILLABLE. XS POWER AGM battery(s) shipped without XS POWER cartons (bulk packed) need to be Identified as NONSPILLABLE or NONSPILLABLE BATTERY on the outer packaging.
Air: XS POWER AGM batteries meet the conditions in IATA/ICAO Special Provision A67.
Surface: XS POWER AGM batteries meet the conditions for DOT Haz Mat Regulations CFR-Tittle 49 parts 171-189. **Vessel:** XS POWER Batteries meet the conditions of IMDG.
Regulatory Information
See 29 CFR 1910.268(b)(2)
Other Information
The information herein is given is good faith, but no warranty, expressed or implied, is made.

Telemetry Battery

POWER SONIC

PSH-1255FR 12 Volt 6.0 AH

Rechargeable Sealed Lead Acid Battery
HIGH-RATE SERIES

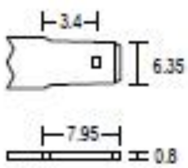
We've Got The Power.™

Features

- Absorbent Glass Mat (AGM) technology for superior performance
- Designed specifically for high-rate discharge (UPS) applications
- 24 Watts/cell for 15 min. of constant power
- Rugged plastic case and cover, flame retardant to UL94 V-0
- Approved for transport by air. D.O.T., I.A.T.A., F.A.A. and C.A.B. certified
- U.L. recognized under file number MH 20845

Terminals (mm)

- F2 - Quick disconnect tabs, 0.250" x 0.032" - Mate with AMP. INC FASTON "250" series



Physical Dimensions: in (mm)

L: 3.54 (90) W: 2.76 (70) H: 3.98 (101) HT: 4.21 (107)

Tolerances are +/- 0.04 in. (+/- 1mm) and +/- 0.08 in. (+/- 2mm) for height dimensions. All data subject to change without notice.

Performance Specifications

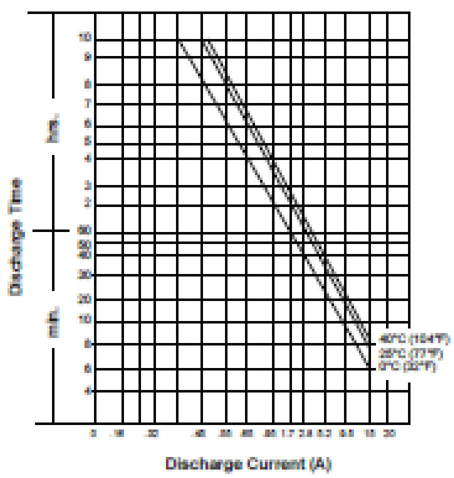
Nominal Voltage		12 volts (6 cells)
Nominal Capacity		
20-hr.	(300mA to 10.50 volts)	6.00 AH
10-hr.	(560mA to 10.50 volts)	5.60 AH
5-hr.	(1.02A to 10.20 volts)	5.10 AH
1-hr.	(3.72A to 9.00 volts)	3.72 AH
15-min.	(11.76A to 9.00 volts)	2.94 AH
Approximate Weight		4.00 lbs. (1.81 kg)
Energy Density	(20-hr. rate)	1.85 W-h/in3 (112.99 W-h/l)
Specific Energy	(20-hr. rate)	18.00 W-h/lb (39.68 W-h/kg)
Internal Resistance	(approx.)	28 milliohms
Max Discharge Current	(7 Min.)	18.0 amperes
Max Short-Duration Discharge Current	(10 Sec.)	60.0 amperes
Shelf Life	(% of nominal capacity at 68°F (20°C))	
1 Month		97%
3 Months		91%
6 Months		83%
Operating Temperature Range		
Charge		-4°F (-20°C) to 122°F (50°C)
Discharge		-40°F (-40°C) to 140°F (60°C)
Case		ABS Plastic (UL94 V-0 flame retardant)
Power-Sonic Chargers		PSC-12500A

To ensure safe and efficient operation always refer to the latest edition of our Technical Manual, as published on our website. All data subject to change without notice.

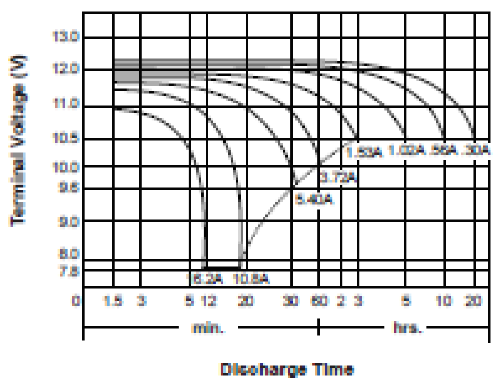
www.power-sonic.com

Constant Power Discharge Ratings								
MODEL	FINAL VOLTAGE	WATTS PER CELL @ 25° C						
		5 MIN	10 MIN	15 MIN	20 MIN	30 MIN	45 MIN	60 MIN
PSH-1255FR	1.75	38	27	22	17	12	9.5	6.4
	1.70	39	28	23	17.5	12.5	9.6	6.5
	1.67	40	29	24	18	13	9.8	6.7

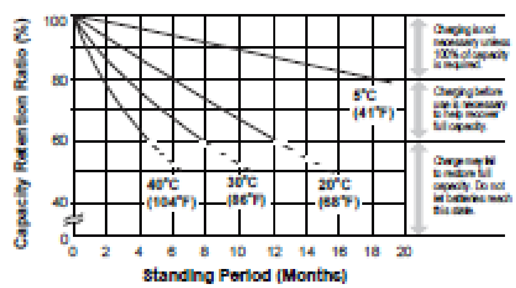
Discharge Time vs. Discharge Current



Discharge Characteristics



Shelf Life & Storage



Charging

Cycle Applications: Limit initial current to 1.8A. Charge until battery voltage (under charge) reaches 14.4 to 14.7 volts at 68°F (20°C). Hold at 14.4 to 14.7 volts until current drops to under 60mA. Battery is fully charged under these conditions, and charger should be disconnected or switched to "float" voltage.

"Float" or "Stand-By" Service: Hold battery across constant voltage source of 13.5 to 13.8 volts continuously. When held at this voltage, the battery will seek its own current level and maintain itself in a fully charged condition.

Note: Due to the self-discharge characteristics of this type of battery, it is imperative that they be charged within 6 months of storage, otherwise permanent loss of capacity might occur as a result of sulfation.

Chargers

Power-Sonic offers a wide range of chargers suitable for batteries up to 100AH. Please refer to the Charger Selection Guide in our specification sheets for "C-Series Switch Mode Chargers" and "Transformer Type A and F Series". Please contact our Technical department for advice if you have difficulty in locating suitable models.

Further Information

Please refer to our website www.power-sonic.com for a complete range of useful downloads, such as product catalogs, material safety data sheets (MSDS), ISO certification, etc.

Contact Information

www.power-sonic.com

DOMESTIC SALES	CUSTOMER SERVICE	TECHNICAL SUPPORT	INTERNATIONAL SALES
Tel: +1-619-661-2020	Tel: +1-619-661-2030	Tel: +1-619-661-2020	Tel: +1-650-364-5001
Fax: +1-619-661-3650	Fax: +1-619-661-3648	Fax: +1-619-661-3648	Fax: +1-650-366-3662
national-sales@power-sonic.com	customer-service@power-sonic.com	support@power-sonic.com	international-sales@power-sonic.com

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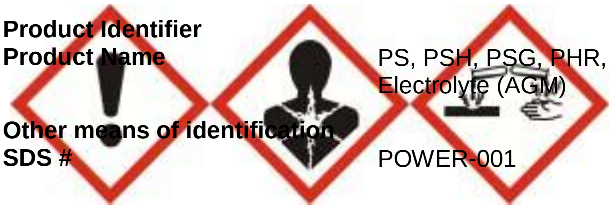
Safety Data Sheet
Issue Date: 01-Jan-2014 **Revision Date:** 26-Jan-2016 **Version** 1



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

Other means of identification
SDS # POWER-001

1. IDENTIFICATION

Recommended use of the chemical and restrictions on use
Recommended Use Battery.
<u>Details of the supplier of the safety data sheet</u> Manufacturer Address
Power-Sonic Corporation 7550 Panasonic Way San Diego, CA 92154
<u>Emergency Telephone Number</u> Company Phone Number 1-619-661-2020 **Emergency Telephone (24 hr)** Chemtrec 1-800-424-9300 (North America) 1-703-527-3887 (International)

2. HAZARDS IDENTIFICATION

<u>EMERGENCY OVERVIEW:</u> 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

Acute toxicity -Oral	Category 4
Acute toxicity -Inhalation (Dusts/Mists)	Category 4
Skin corrosion/irritation	Category 1 Sub-category B
Serious eye damage/eye irritation	Category 1
Reproductive toxicity	Category 1A
Specific target organ toxicity (repeated exposure)	Category 2

the battery, which would only be released during an incident.

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
<u>Precautionary Statements -Prevention</u>
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

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.

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.

Chemical Name	CAS No	Weight-%
Lead	7439-92-1	65-75
Sulfuric Acid	7664-93-9	14-20
Tin	7440-31-5	<.5
Calcium	7440-70-2	<.1
Fiberglass Separator	Proprietary	5
Case material: Acrylonitrile Butadine Styrene (ABS)	Proprietary	5-10

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

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

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.

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.

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

Skin and Body Protection None needed under normal conditions. If battery case is damaged use rubber or plastic elbow length gauntlets. In case of damaged or broken battery use an acid resistant apron. Under severe exposure or emergency conditions wear acid resistant clothing.

Respiratory Protection None required under normal conditions. If battery is overcharged and concentrations of sulfuric acid are known to exceed PEL use NIOSH or MSH approved respiratory protection.

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 product 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

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.

Chemical Name	ACGIH TLV	OSHA PEL	NIOSH IDLH
Lead 7439-92-1	TWA: 0.05 mg/m^3 Pb	TWA: 50 µg/m^3 Pb	IDLH: 100 mg/m^3 Pb TWA: 0.050 mg/m^3 Pb
Sulfuric Acid 7664-93-9	TWA: 0.2 mg/m^3 thoracic fraction	TWA: 1 mg/m^3 (vacated) TWA: 1 mg/m^3	IDLH: 15 mg/m^3 TWA: 1 mg/m^3
Tin 7440-31-5	TWA: 2 mg/m^3 Sn except Tin hydride	TWA: 2 mg/m^3 Sn except oxides (vacated) TWA: 2 mg/m^3 Sn except oxides	IDLH: 100 mg/m^3 Sn TWA: 2 mg/m^3 except Tin oxides Sn

General Hygiene Considerations Handle batteries carefully to avoid damaging the case. Do not allow metallic articles to contact the battery terminals during handling. Avoid contact with the internal components of the battery.

9. PHYSICAL AND CHEMICAL PROPERTIES

10. STABILITY AND REACTIVITY

Reactivity

Not reactive under normal conditions.

Chemical Stability

Stable under recommended storage conditions.

<u>**Possibility of Hazardous Reactions**</u>

None under normal processing. **Hazardous Polymerization** Hazardous polymerization does not occur.

Conditions to Avoid

Keep out of reach of children.

<u>**Incompatible Materials**</u>

Sulfuric acid: Contact with combustibles and organic materials may cause fire and explosion.

Information on basic physical and chemical properties

Physical State Solid containing liquid Battery Not determined **Odor Odor Threshold** Characteristic Not determined

Appearance Color

Property pH Melting Point/Freezing Point Boiling Point/Boiling Range Flash Point Evaporation Rate Flammability (Solid, Gas) Upper Flammability Limits Lower Flammability Limit Vapor Pressure Vapor Density Specific Gravity Water Solubility Solubility in other solvents Partition Coefficient Auto-ignition Temperature Decomposition Temperature Kinematic Viscosity Dynamic Viscosity Explosive Properties Oxidizing Properties

This product is a battery and typical physical/chemical properties do not apply. Remarks • Method Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined 1.3 Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined Not determined

Product Information

Eye Contact Causes severe eye damage.

Skin Contact Causes severe skin burns.

Inhalation Harmful by inhalation.

Ingestion Harmful if swallowed.

Component Information

Chemical Name	Oral LD50	Dermal LD50	Inhalation LC50
Sulfuric Acid 7664-93-9	= 2140 mg/kg (Rat)	-	= 510 mg/m^3 (Rat) 2 h
Tin 7440-31-5	= 700 mg/kg (Rat)	-	-

Also reacts violently with strong reducing agents, metals, sulfur trioxide gas, strong oxidizers, and water. Contact with metals may product 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.

<u>**Hazardous Decomposition Products**</u>

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

<u>**Information on likely routes of exposure**</u>

<u>**Information on physical, chemical and toxicological effects**</u>

Symptoms Please see section 4 of this SDS for symptoms.

<u>**Delayed and immediate effects as well as chronic effects from short and long-term exposure**</u>

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.

Legend
ACGIH (American Conference of Governmental Industrial Hygienists)
A2 -Suspected Human Carcinogen A3 -Animal Carcinogen

Chemical Name	Algae/aquatic plants	Fish	Toxicity to microorganisms	Crustacea
Lead 7439-92-1		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		600: 48 h water flea µg/L EC50
Sulfuric Acid 7664-93-9		500: 96 h Brachydanio rerio mg/L LC50 static		29: 24 h Daphnia magna mg/L EC50

IARC (International Agency for Research on Cancer)
Group 1 -Carcinogenic to Humans Group 2A -Probably Carcinogenic to Humans ***NTP (National Toxicology Program)***
Known -Known Carcinogen Reasonably Anticipated -Reasonably Anticipated to be a Human Carcinogen
OSHA (Occupational Safety and Health Administration of the US Department of Labor)
X -Present
Reproductive toxicity May damage fertility or the unborn child.
STOT -repeated exposure Causes damage to organs through prolonged or repeated exposure. **Numerical measures of toxicity**
Not determined

12. ECOLOGICAL INFORMATION

Ecotoxicity
Very toxic to aquatic life with long lasting effects.

Chemical Name	ACGIH	IARC	NTP	OSHA
Lead 7439-92-1	A3	Group 2A	Reasonably Anticipated	X
Sulfuric Acid 7664-93-9	A2	Group 1	Known	X

Persistence/Degradability
Not determined.
Bioaccumulation
Not determined.
Mobility
Not determined

Other Adverse Effects

Not determined

California Hazardous Waste Status

Chemical Name	California Hazardous Waste Status
Lead 7439-92-1	Toxic
Sulfuric Acid 7664-93-9	Toxic Corrosive

This product contains one or more substances that are listed with the State of California as a hazardous waste

.

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.

Chemical Name	RCRA	RCRA -Basis for Listing	RCRA -D Series Wastes	RCRA -U Series Wastes
Lead 7439-92-1		Included in waste streams: F035, F037, F038, F039, K002, K003, K005, K046, K048, K049, K051, K052, K061, K062, K069, K086, K100, K176	5.0 mg/L regulatory level	

15. REGULATORY INFORMATION
International Inventories

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 872 and Special Provision A67
The batteries have been tested in accordance with the vibration and pressure differential tests found in Packing Instruction 872 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.

Chemical Name	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	IECSC	KECL	PICCS	AICS
Lead	Present	X		Present		Present	X	Present	X	X
Sulfuric Acid	Present	X		Present		Present	X	Present	X	X
Tin	Present	X		Present			X	Present	X	X

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

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Chemical Name	Hazardous Substances RQs	CERCLA/SARA RQ	Reportable Quantity (RQ)
Lead 7439-92-1	10 lb		RQ 10 lb final RQ RQ 4.54 kg final RQ
Sulfuric Acid 7664-93-9	1000 lb	1000 lb	RQ 1000 lb final RQ RQ 454 kg final RQ

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

Chemical Name	CAS No	Weight-%	SARA 313 -Threshol Values %
Lead -7439-92-1	7439-92-1	65-75	0.1
Sulfuric Acid -7664-93-9	7664-93-9	14-20	1.0

Chemical Name	CWA -Reportable Quantities	CWA -Toxic Pollutants	CWA -Priority Pollutants	CWA -Hazardous Substances
Lead		X	X	

CWA (Clean Water Act)

US State Regulations

California Proposition 65

This product contains the following Proposition 65 chemicals.

Chemical Name	California Proposition 65
Lead -7439-92-1	Carcinogen Developmental Female Reproductive Male Reproductive
Sulfuric Acid -7664-93-9	Carcinogen

U.S. State Right-to-Know Regulations

16. OTHER INFORMATION

NFPA HMIS	**Health Hazards** 3 **Health Hazards** Not determined	**Flammability** 0 **Flammability** Not determined	**Instability** 2 **Physical Hazards** Not determined	**Special Hazards** - **Personal Protection** Not determined

Issue Date: 01-Jan-2014
Revision Date: 26-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 Rev.1.1

Chemical Name	New Jersey	Massachusetts	Pennsylvania
Lead 7439-92-1	X	X	X
Sulfuric Acid 7664-93-9	X	X	X
Tin 7440-31-5	X	X	X
Calcium 7440-70-2	X	X	X

Appendix B – Floatation Calculations

Using SolidWorks, the surface area of the hull was determined to be 11.77 m^2. The thickness of the hull was measured using a pair of digital calipers and came out to be 0.013 m.

$F_{B,hull} = (11.77\ m^2 * 0.013\ m) * \left(998\ \frac{kg}{m^3}\right)$*(9.81 m/s^2)

$F_{B,hull} = 1498\ N$

The buoyancy force of the hull alone, $F_{B,hull}$, was determined by multiplying the volume of the hull itself by the density of water and acceleration due to gravity. This resulted in a hull buoyancy force of 1498 N. Taking into account the smallest battery bank weight of 400 N that will contribute to the buoyancy force of the boat, a total buoyancy force of 1898 N will be expected. Giving a 20% safety allowance, the total buoyancy force to be compared to total weight is 1518 N. The weights of all components are as follows:

Sprint Race:

- Solar panels: 0 N
- Power Electronics: 502 N
- Hull: 343 N
- Drivetrain: 298 N
- Data Acquisition: 13 N
    - Total Weight: 1156 N

Endurance Race:

- Solar panels: 222 N
- Power Electronics: 458 N
- Hull: 343 N
- Drivetrain: 298 N
- Data Acquisition: 13 N
    - Total Weight: 1334 N

Based on these calculations, we can be sure that our hull can support itself as well as a safety factor because the total weights of 1186 N and 1334 N did not exceed the 20% safety factor buoyancy force of 1518.4 N.

Appendix C – Proof of Insurance

ACORD

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY): 10/4/2015

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.

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).

PRODUCER
Arthur J. Gallagher Risk Management Services, Inc.
6399 S. Fiddlers Green Cir
Suite 200
Greenwood Village CO 80111

CONTACT NAME: Anita Bruner
PHONE (A/C, No, Ext): 303-889-2574 FAX (A/C, No): 303-889-2575
E-MAIL ADDRESS: anita_bruner@ajg.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Princeton Excess & Surplus Lines In	10786
INSURER B : Arch Insurance Canada Ltd.	
INSURER C :	
INSURER D :	
INSURER E :	
INSURER F :	

INSURED
Board of Regents of University of Colorado
University of Colorado Denver
University Risk Management
Aurora CO 80045

COVERAGES CERTIFICATE NUMBER: 424280320 REVISION NUMBER:

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.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY			N3A3RL000001009	10/1/2015	10/1/2016	EACH OCCURRENCE	$1,000,000
	CLAIMS-MADE X OCCUR						DAMAGE TO RENTED PREMISES (Ea occurrence)	$Excluded
	X Educ Legal Liab.						MED EXP (Any one person)	$Excluded
	X SIR - $1,250,000						PERSONAL & ADV INJURY	$Included
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$None
	X POLICY PRO-JECT LOC						PRODUCTS - COMP/OP AGG	$Included
	OTHER:							$
A	AUTOMOBILE LIABILITY			N3A3RL000001009	10/1/2015	10/1/2016	COMBINED SINGLE LIMIT (Ea accident)	$Included
	X ANY AUTO						BODILY INJURY (Per person)	$InAbove
	ALL OWNED AUTOS SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS NON-OWNED AUTOS						PROPERTY DAMAGE (Per accident)	$
	X SIR Limit X $1,250,000							$
	UMBRELLA LIAB OCCUR						EACH OCCURRENCE	$
	EXCESS LIAB CLAIMS-MADE						AGGREGATE	$
	DED RETENTION $							$
B	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N	N/A		WCX002954807	10/1/2015	10/1/2016	X PER STATUTE OTH-ER	
	ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH)						E.L. EACH ACCIDENT	$2,000,000
	If yes, describe under DESCRIPTION OF OPERATIONS below						E.L. DISEASE - EA EMPLOYEE	$2,000,000
							E.L. DISEASE - POLICY LIMIT	$2,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
For WC Coverage - SIR - $1,500,000.

CERTIFICATE HOLDER

Evidence of Insurance

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

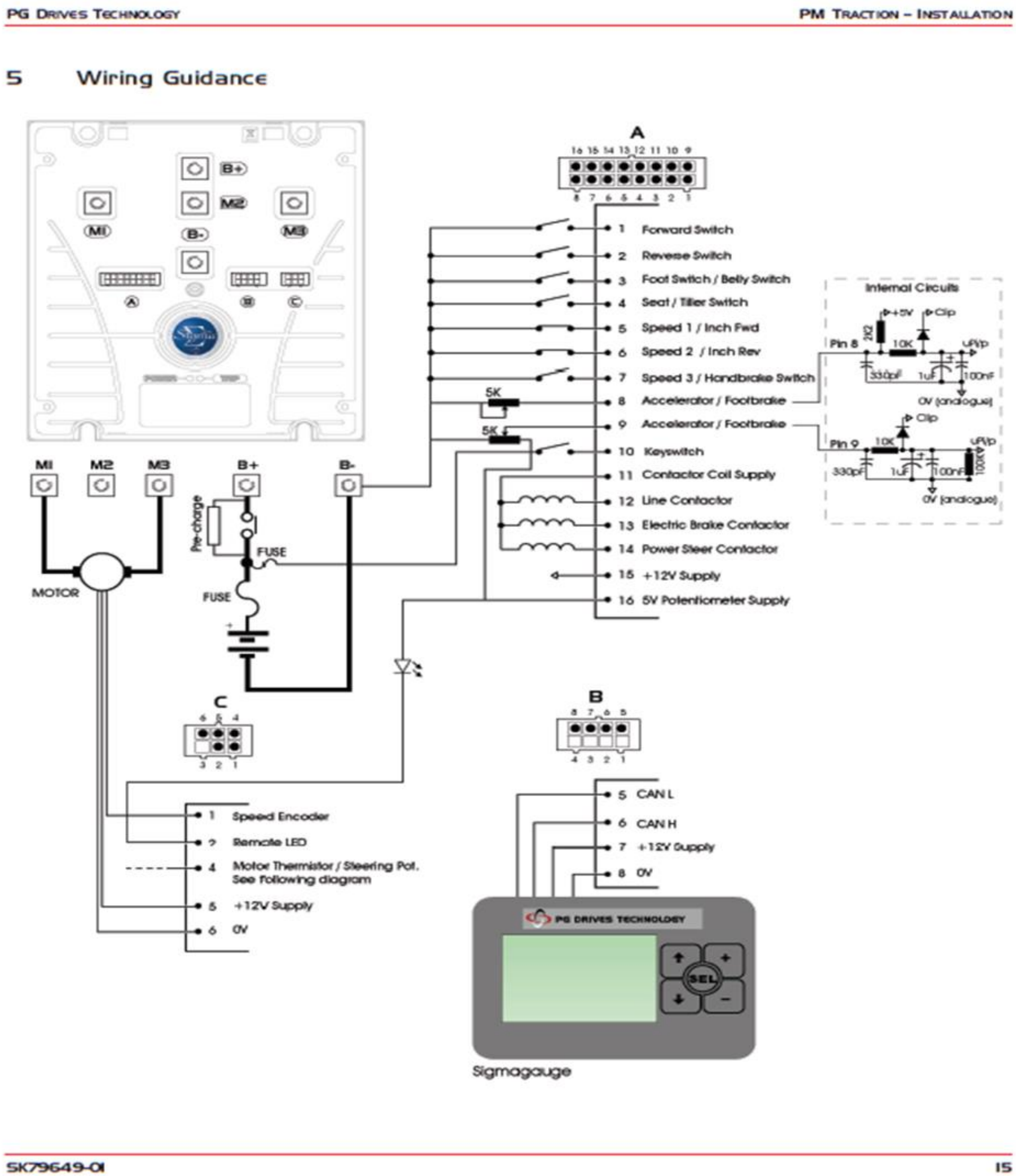
AUTHORIZED REPRESENTATIVE

ACORD 25 (2014/01)

Appendix D – Team Roster

Aaron Anderson – BSME, Senior
Responsible for drive train system.
Alba Avitia – BSME, Senior
Responsible for solar panel research/design and steering system.
Jenna Burnett – BSME, Senior
Responsible for hull analysis/construction and design/analysis of solar panel water cooling system.
Victoria Dorr – BSME, Senior
Responsible for solar panel research/design and financial/budgeting.
Luke Froelich – BSME, Senior
Responsible for research/design of hull and steering system.
Mike Sargent – BSME, Senior
Responsible for hull design/analysis/construction.
Mike Wolfe – BSME, Senior
Responsible for power electronics and data acquisition.

Appendix E – Full Schematic of Motor Controller



Appendix F – Lynch LEM200-127 LEMCO 48V Electric Motor

LMC GENERATING MOVEMENT EFFICIENTLY

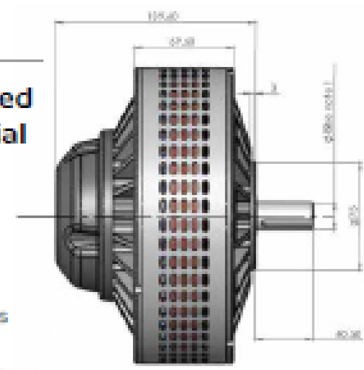
MOTORS LEM-200

Overview

The LEM-200 is an axial gap DC brushed motor suitable for traction and industrial applications.

Example applications include grass cutters, Go-Karts, motorcycles, golf carts, scissor lifts, lightweight vehicles, boats and generators.

The LEM-200 is available in 95, 126, 127 and 135 strip armatures with magnet grade selection dependant on application.

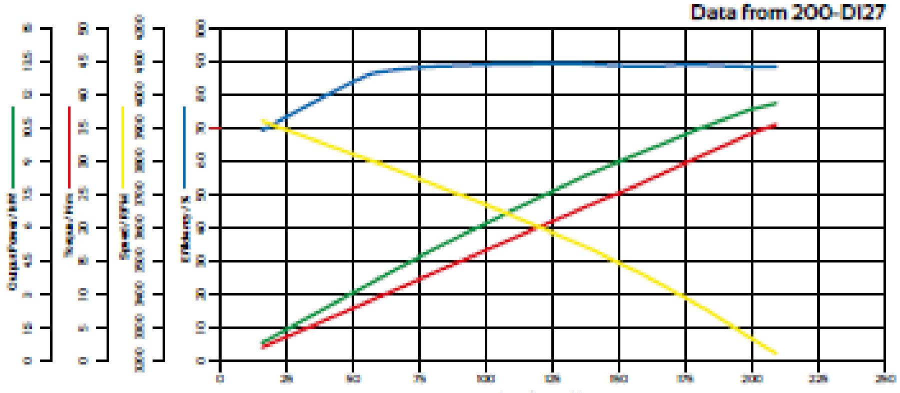


Features

- High efficiency (up to 93%)
- Lightweight design (11kg)
- Simple electronic control
- Long brush Life
- Interchangeable Shaft
- Rugged Construction
- CE Marked
- Ip20 rating
- Available from 12 to 110v
- Speed proportional to voltage

Typical Technical Data Curve

Data from 200-D127

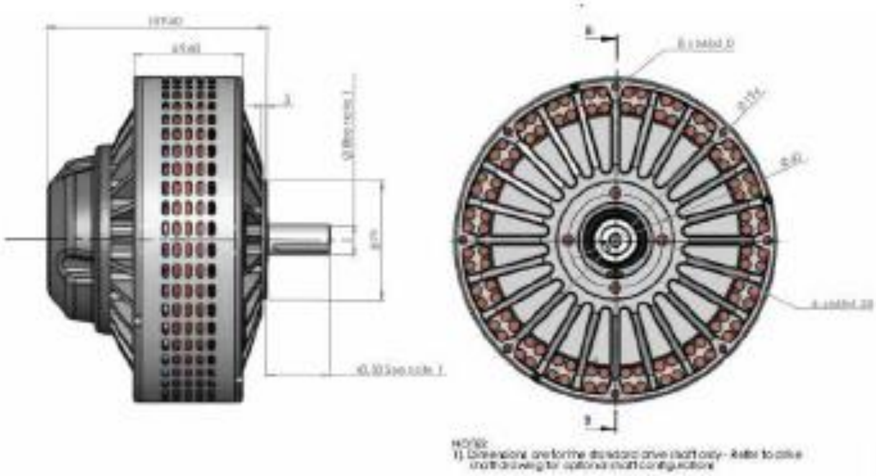


Important

Any model of the LEM-200 can be made up into the 2X2 version. This is 2 motors married together on a single shaft see 2X2 installation drawing for details on our website. This can also be supplied in a V-Twin layout which gives the same performance.

Technical Data

Motor	No Load Current	Torque Constant	Speed Constant	Armature Resistance DC	Armature Inductance @ 1 kHz	Armature Inertia	Peak Power	Peak Efficiency	Peak Current	Rated Power	Rated Speed	Rated Voltage	Rated Current	Rated Torque
	A	Nm/A	Rpm/V	mΩ	µH	Kgm²	kW	%	A	kW	Rpm	V	A	Nm
95	6	0.113	81	21.5	22	0.0238	18	92	400	10	3888	48	250	28
126	10	0.0737	105	17.5	6	0.0234	7.59	83	400	5.06	2520	24	270	19.2
127	5	0.15	54	22.5	23	0.0236	16.08	89	400	8.55	2592	48	215	31.5
D95B	6	0.14	76	20.5	11	0.0238	28.50	92	400	15.00	6000	72	210	30
D126	5	0.0748	100	13.8	5	0.0234	11.14	81	400	6.91	3600	36	250	18.3
D127	4	0.17	50	17.5	13	0.0236	25.38	92	400	12.56	3600	72	200	33.3
D135	3.5	0.185	45	16.75	16	0.0236	29.04	93	400	14.39	3780	84	200	36.4
D135 RAG	7.36	0.207	42	16.95	16	0.0238	34.32	93	400	16.84	4032	96	200	39.9
D135 RAGS	7.45	0.21	40	16.95	16	0.0238	36.00	93	400	18.00	4400	110	200	42.0



GENERATING MOVEMENT EFFICIENTLY

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