Solar Splash – Collegiate Solar Boating Design Competition

Boat #6

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Executive Summary

The Solar Splash Competition is a collegiate engineering event where various schools from around the world compete against each other to make the fastest, most agile, and most efficient solar-powered boat. In the past, Wright State University has competed in two of these competitions. In 2021, they received awards for placing third in the endurance race, for Outstanding Rookie Team, and for placing fifth overall. In 2022, they received the Innovation Award, the Outstanding Solar System Design Award, and placed sixth overall. Now, for the 2023 competition, they plan to make even bigger waves. Their goal is to focus on an overall increase in performance compared to previous years while also giving team members the opportunity to gain invaluable engineering project experience.

This year's team consists of three mechanical engineering students and one electrical engineering student. Unfortunately, due to some issues with accidental electrical shorts and malfunctions leading up to and during last year's competition, the team started with a damaged and un-operational boat. To restore the boat to a glory greater than she previously knew, the team began researching electrical systems and diagnosing the issues with the boat. It was concluded that nearly the entire electrical system needed to be replaced. A whole new system was designed. Notably, the decision to switch from a brushless motor to a brushed motor was made. The necessary components, like a new motor, solenoid, and reverse contactor, were purchased. The team already had a brushed motor controller that had been purchased by a past team. There were also some minor scratches and holes in the hull that were patched.

Many of the ordered parts had quite the lead time for delivery so in the meantime, the team sought to make some quality-of-life changes to the boat. The electrical compartment was first to be redesigned. The old plywood battery boxes were replaced with sleek plexiglass boxes fitted with safety switches and quick connect/disconnect terminals. The box that houses all the other components was also redone with plexiglass and mounting positions for the existing and soon to be delivered components were specified. Then, the steering wheel was redesigned, and the dashboard was reorganized and clearly labeled. Everything was in place for the arrival of the new components.

Once the ordered components were delivered and installed into the boat, testing was able to be conducted. Initial tests were conducted in a water tank at the school but as the boat became seaworthy, lake tests were able to be done. The team made several trips to the nearby Eastwood Metro Park Lake to obtain data on things like current draw and top speed. Additionally, these trips allowed the operator of the boat to get acquainted with the controls and the rest of the team to practice launching and reloading the boat. This was also a time where the team could look for further issues with the system. For example, during one trip, it was found that the driveshaft assembly was binding while running. The team then examined the driveshaft and determined that there was a poor seal and that after it was fixed, the assembly needed to be relubricated.

Now that the boat had finally been brought to working order, the team could start making attempts to better performance: settings within the motor controller were explored, battery configurations were examined, different gear ratios were made, and a new propeller was fitted. Each of these redesigns were tested and optimized for each race.

With hopes of making a bigger presence among the veteran schools, Wright State University's 2023 team has completely revamped their boat's system. As the competition draws

nearer, the team seeks further experience with their boat and prepares strategies for each event. Considering the amount of time spent this year getting the boat in working order, it is recommended to next year's team that they focus on system optimization instead of repair. A goal for this year's team is to leave the boat in good condition so that this may be done.

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I. Overall Project Objectives

For the 2023 Solar Splash Competition, the team of students on the Wright State University team modified the existing boat that was used by the previous teams. The goal was to optimize and replace parts within the boat to increase the speed of the boat. After increasing the speed, the goal of the competition was to beat the previous teams time in the sprint and slalom races and number of laps in the endurance races. To increase the speed of the boat, the motor was to be replaced with a better performing one. The motor was to be used in both the sprint and endurance races. The dashboard of the boat was updated to provide the operator with more adjustability while on the water. The update to the dashboard added clearly labeled switches and throttle and newly designed steering wheel. The updated also included an updated and safer dead man switch. The storage compartments of the boat were designed to be lighter and aide in the ability to be removed.

II. Solar System

A. Current Design

In previous years, the WSU Solar Splash team has either used or designed a new set of solar panels. The team for the previous year bought four panels of BougeRV 120-watt solar panels. The BougeRV panels are 12-volt monocrystalline 5 busbar panels. The previous team built a frame to hold the panels with three panels side by side with the fourth panel connected to the center panel of the three. In **Fig. 1** below, the current arrangement of the solar panels from the previous team. The panels were wired in two sets of series panels. The two sets were then wired into a Victron Energy Smart Solar MPPT 75/10 solar charge controller. The solar charger is able to continuously charge the batteries as long as there is sunlight. The charger is able to charge the batteries at complete depletion. The wiring of the solar panels and solar charger is shown in **Fig. 2**.

Fig. 1. *Current Solar Panel Arrangement*

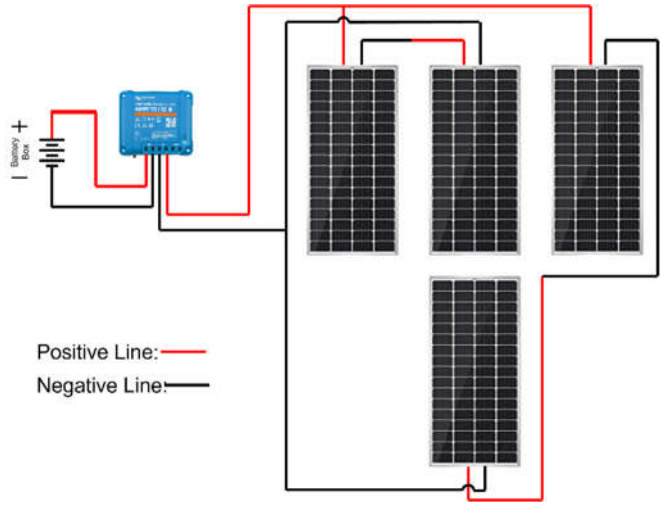

Fig. 2. *Solar Panel Wiring Diagram*

B. Analysis of Design Concepts

The solar array output was checked to see that the output did not exceed the 480 Watts, bought, and 528 Watts student-built [1]. The panels were found to have a max output of 480 Watts under normal conditions. Therefore, it was decided to use the same panels as the previous team. The panels are only 1 to 1.5 years old at the time of competition. This allows for the panels to still be within their maximum output to lifespan. The reuse of panels saves the team money as no additional cost was associated with the solar system.

C. Design Testing and Evaluation

The current solar panel array was evaluated to verify that the solar panels were still in operation. This testing was to attach the panels to the batteries to verify they can still charge them to 100% charge. This was achieved by taking the boat to the lake and running it until the batteries were nearly drained of power. The boat was then taken out of the water and allowed to sit in the sun. The batteries were charged to 100% quickly. This quick charge allowed the team to conclude that the solar panels were in working condition.

III. Electrical System

A. *Wiring*

1) Current Design: The previous team wired the boat such that all of the wiring components are stored in the electrical box in the fourth section of the hull. From the electrical box, there are multiple wires that run along the side of the hull to the front where the skipper resides. The instrumentation on the dashboard of the boat includes a Victron Smart Battery Monitor, an emergency shut off switch, a throttle controller, and a dead-man switch, also known as a DMS.

There was also a switch on the dashboard that had no wiring connecting it to the rest of the system. The electrical equipment is enclosed in a fiberboard box with all sides of the box covered in a layer of carbon fiber. The box has a lid that is attached with hinges. When the lid is closed, the inside of the box is unable to be viewed. This becomes harder when the solar panels are attached to the boat as one of the panels is above the box and preventing the box from being opened to view components. The box had holes cut into the backside of the box. These holes allowed for water that splashed into the boat while in operation to pool inside the electrical box.

All of the existing wiring had little fusing and diodes. Since there was little fusing and diodes, the previous team caused electrical components to short circuit within the boat. These components were removed from the boat and could not be reused in the boat.

2) Analysis of Design Concepts: When looking over the current wiring layout of the hull, it was decided to remove the wiring the previous team created. In **Fig. 3** below, the wiring is shown in its tangled mess of wiring and a portion of the electrical box.

Fig. 3. *Starting Wiring Layout*

The wiring had wires that were cut off and lead to no point or electrical device. In the figure above, the box can be seen having multiple holes cut out of the side of the box. To evaluate if any of the wires worked in the previous setup, the boat was powered on and tried to see if anything would power up. Nothing would turn on using the main battery pack; therefore, the decision was made to remove all the wiring and wiring box from the boat and to restart with the rewiring of the boat. The only device within the boat that still would turn on was the bilge pump since it was on its on circuit and power source.

The box was removed from the boat along with the electrical components within the box. Any of the wires that could be saved and reused were set aside to be used when reinstalling the new box and components. Since the box was falling apart from the years of use, the decision to replace the electrical box was made. The old box has no reuse value to the team and was removed. The new electrical box is made of a wooden base board with plexiglass sides and lid. The new box is able to be inserted and removed from the boat hull at a quicker rate than the previous box. The box is now lighter and sturdier than before.

3) Design Testing and Evaluation: The new wiring was designed such that each wire had a designated label and had a place to be within the wiring diagram. The wiring was then encased in a new electrical box. To support the plexiglass sides, strips of would were run along the corners of the box to mount the plexiglass onto. In **Fig. 4** below, the new electrical box is shown. Inside the electrical box is a new battery box, to be discussed in the next section. The lid of the electrical box allows for the box to be closed and sealed. With the use of the plexiglass, the internals of the box can be viewed while the box is closed, and the solar panels attached to the boat.

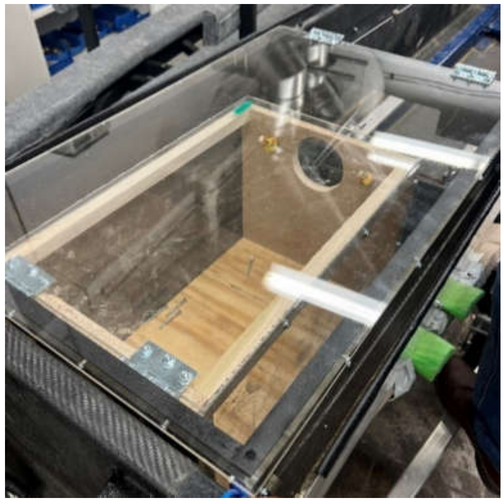

Fig. 4. *New Electrical Box*

After the completion of the electrical box, the new wiring was added to the boat. In **Fig. 5** below, the new wiring schematic is shown. The wiring schematic provides power to the switches in the front of the boat. The wires within the boat are all separate colors and labeled as to what the wires do and where they go. With the newly added wiring, new safety features are added to improve the safety of the boat. New fusing was added to prevent the overcharging and powering of the system were added throughout the system. Along with the fusing, new diodes were added to prevent the back feeding of current between components.

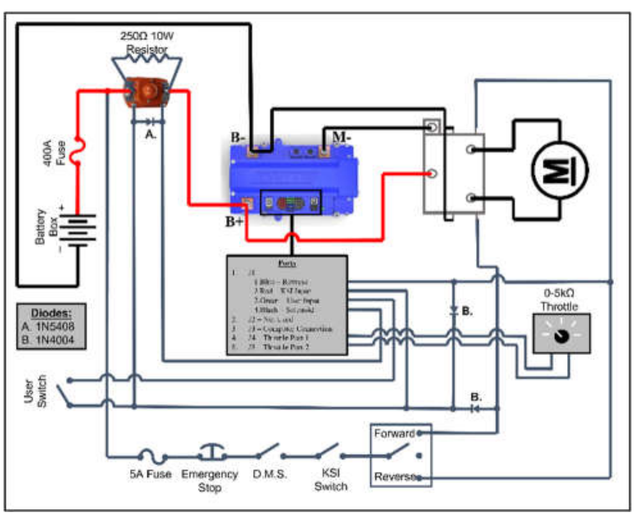

Fig. 5. *New Wiring Diagram*

B. Batteries

1) Current Design: The current batteries in use by the previous team are two sets of four batteries. In each set is two ODYSSEY AGM30E and two ODYSSEY AGM40E. The AGM30E batteries have a voltage of 12 Volts and 32 Amp-Hour [2], and the AGM40E batteries have a voltage of 12 Volts and 43 Amp-Hour [3] as shown in **Appendix A**. The one set of batteries has the two AGM40E batteries in series connected to the two AGM30E batteries, which are in parallel together. This gives the set a total voltage of 36 Volts and 105 Amp-Hours. The other set is a parallel set with one side of the parallel being the two AGM40E in series and the other side of the parallel being the two AGM30E in series. The total for the set has a voltage of 24 Volts and 90 Amp-Hours. The AGM30E and AGM40E batteries used can be found in **Fig. 6** and **Fig. 7** below respectively.

Fig. 6. *ODYSSEY AGM30E (PC950)*

Fig. 7. *ODYSSEY AGM40E (PC1100)*

Each set of batteries had its own battery box. Each battery box was made out of 3/4-inch plywood. Within each box, there was an elevated platform to bring the smaller AGM30E battery top to the same elevation as the AGM40E. The boxes had an open top and two cables extruding from the side of the box for connections to the rest of the electrical system. To connect the battery box to the electrical system of the boat, the two cables that extruded from the box were bolted to the wires of the electrical system. There was no protection from there being arcing between the cables or from an object falling onto the cables creating a short circuit. Below in **Fig. 8** is the battery box designed and created by the previous team. The space between the batteries and the edge of the box is in excess. The batteries were able to slide around while hauling the boat between the testing site and the university. They also shifted when the boat was in motion on the water. The shifting of the batteries within the boxes caused the center of mass of the boat to shift side to side will on the water. When the boxes are empty, they weigh approximately 21 lbs.

Fig. 8. Existing Battery Box

2) Analysis of Design Concepts: When analyzing the current batteries, it was decided to continue to use the existing batteries. The previous team purchased these batteries. The batteries were able to work for the team last year. To evaluate the batteries to verify their performance, they work connected to the new motor and a load applied. It was concluded that two of the batteries needed to be replaced because they were unable to be recharged once they were drained completely dead.

The existing battery boxes were heavy and hard to remove from the boat. The design of the box was looked at to optimize the time it takes to switch out battery packs and reduce weight of the boxes.

3) Design Testing and Evaluation: The new battery configuration used is similar to one of the existing sets. The only change is to the 24 Volt set. The new set continues to utilize two parallel lines of batteries in series. The new change is to that both sides of the parallel set are the same. To accomplish this, a side of the battery is to have an AGM40E battery in series with an AGM30E battery. This change means that both sides of the battery set have the same amp-hour rating. With the new set up the batteries were evaluated such that the batteries still provide enough power to operate the boat.

The decision to rebuild the battery boxes was made to optimize the space within the electrical box. The new boxes provided space between the battery box and the electrical box to run wires and access the wires without the need to remove the battery box. The battery box also has less space within the box for the batteries to shift around. There were also new features added to the batteries that previously were not added. A new power switch dial was added to the side of the box. The switch allows for the de-energization of the entire boat for maintenance. The second addition to the battery boxes is the use of a quick disconnect plug. The new plug allows for quick connection of the boxes when switching boxes. The new battery boxes can be seen in **Fig. 9** below. The new boxes eliminate 9 lbs. This means that the new boxes with the switch and lid have a weight of 12 lbs.

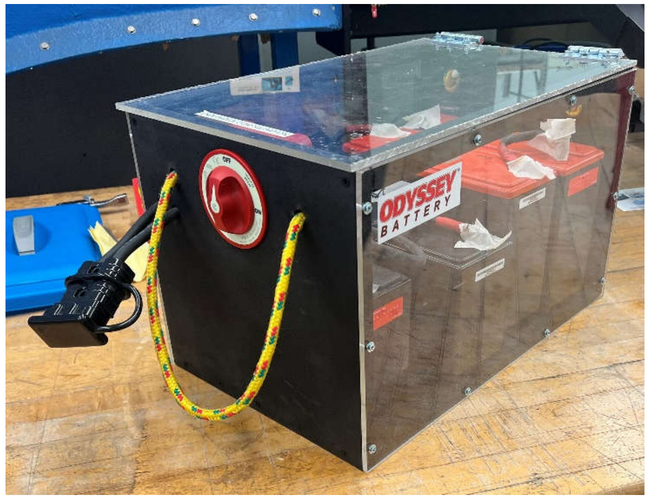

Fig. 9. *New Battery Box*

IV. Power Electronics System

A. *Current Design*

The 2022 team used a TALON HV120 MCU (Motor Control Unit). This was a 3-phase motor controller. The controller functioned as an inverter to convert the DC (Direct Current) power from the battery pack to AC (Alternating Current) power for the motor. This controller was used with the brushless AC motor, which will be discussed in the motor section. The controller was found to be nonfunctional at the end of the 2022 competition. This controller that they were using was purchased before the competition to replace the other controller they had been using. They needed to find a new controller since the previous was fried. The controller was not thoroughly researched and evaluated to see if it would work properly with all the other components and motor in the boat.

They also had an ALLTRAX SR72400 controller that came with the donation of the hull. The team purchased an additional controller. The controller they bought was an ALLTRAX SR48600 controller shown in **Fig. 10** below. This controller was never used as they did not have a brush DC motor to use the controller for.

Fig. 10. *ALTRAX SR48600 Controller*

B. Analysis of Design Concepts

The team decided to use the ALLTRAX SR48600 controller for the design of this year's boat. The controller had not been used so it was still new and had no electrical issues associated with it. The controller had multiple features available with it. The controller has computer software called ALLTRAX Toolkit. The toolkit allows for the customization of the settings built into the controller. The controller has the ability to run any DC brushed motor that runs at 12 to 48 Volts and less than 600 Amps. The use of this controller dictated the choice of motors discussed in the motor section below.

C. Design Testing and Evaluation

No design testing was conducted on the controller prior to the use of a motor.

V. Hull Design

The hull used by the previous teams is a carbon fiber hull. The hull is approximately 19 feet long by 2 feet wide by 2 feet deep. Of the 2 feet depth, 1 foot is above the water line and the other foot is below the water line. This hull was donated to a previous team from Sherbrooke University in Quebec, Canada. The hull is shaped similarly to a kayak. There is an outrigger on both sides of the hull. These outriggers provide a stabilization and buoyancy factor to the boat. The solar panels mentioned previously mount to the top of the hull. In **Fig. 11** below, the hull that was gifted to WSU. The hull is broken up into five sections. From the front of the hull to the back, the first section is the skippers compartment where the skipper sits, and control dashboard are situated. The next section of the hull is the safety compartment. In the safety compartment, there is an air horn, safety flags, anchor, oar, and a fire extinguisher. The next section is the ballast compartment. The ballast compartment sits empty if the skipper is over 70 kg. If the skipper weighs less than 70 kg, a ballast will be added into the compartment to make up the difference [1]. The second to last section is the electrical compartment. This compartment houses all of the boats electrical devices and battery sets. The top of the compartment is open, but as previously discussed the electrical box closes to seal off the compartment. The last section of the hull is the drivetrain compartment. In this area sits the motor and drivetrain belt. The belt and top of the drivetrain shaft is covered with a plexiglass sheet to protect the belt from external forces and to protect the skipper from a blown belt.

The hull that was used has proven to work well in the competition for the previous teams. The hull has little drag acting upon it due to its narrow shape and long design. Due to the size and outriggers of the boat, there is a greater buoyancy force acting upon the boat, as shown in **Appendix B.** The team has decided to reuse the same hull and to make no changes to the design of the hull.

Fig. 11. *Carbon Fiber Boat Hull*

VI. Drive Train and Steering

A. *Motor*

1) Current Design: The boat used a Motenergy ME1306 motor. This was a three-phase brushless motor. During the competition last year, the motor was working for the team, but the motor had a history of overheating during the endurance race. The overheating caused the team to only be able to drive the boat for about 20 to 30 seconds. Then after 20 to 30 seconds, they would have to stop and let the motor cool down. Once the motor cooled down, they were able to repeat the cycle of using the motor for short bursts then stopping.

The constant use then stopping the motor and the motor overheating caused one of the phases in the motor to pop. A brushless DC motor consists of a permanent magnet by the use of three coils in the use as electromagnets. Each electromagnet represents a phase. The electromagnets are powered by short bursts to rotate the permanent magnet [4]. When one of the phases popped, that removed one of the electromagnets. Without the electromagnet, the permanent magnet was able to spin past the first two phases and then stopped at the third phase since there was no polarity to attract or repel the magnet. The motor was no longer able to be used without sending the motor off to have the phase reset.

2) Analysis of Design Concepts: The team decided to look into finding a new motor that would work. This decision was made on the basis that we could get a new motor faster and more cost-efficient than having the motor reset. The new motor would be more cost-efficient since there would be no need to purchase a new motor control unit.

The team researched three motors to be used for the boat. All three of the motors are produced by Motenergy and are brushed DC motors. The reasoning behind the usage of a Motenergy motor was that the previous teams had been using Motenergy motors and the mounting plate for the motor was designed and fabricated to be used for a Motenergy motor. The first motor was a Motenergy ME1004 motor. The next was a Motenergy ME1513. The final motor was a Motenergy ME0909. Each motor was compared to one another in six categories. The categories were the voltage range, continuous running amperage, peak amperage, peak amperage run time, weight, and price. The motors were scored one to three in each category. The scoring always started at one. So, if in a category two motors had the same values, they were given the same score and that the said category only had a score of one and two.

In **Table 1** below, the scores from the comparisons can be seen. For the voltage range comparison, the larger the range of voltages that the motor could hand the higher the score. The next category was the continuous running amperage with the highest amperage receiving the highest score. The next category was the peak amperage and peak amperage time. The higher the peak amperage and longer the peak time receiving the higher score. The next category was the weight with the lightest motor receiving a higher score. The final category was the price. The motor that cost the least was awarded the highest score. The scores were added together and the motor with the highest score was the best motor for the boat.

Table 1: *Motor Comparisons*

Motor (Motenergy)	Voltage Range	Cont. Amps	Peak Amps	Peak Time	Weight	Price	Total
ME1004	2	1	1	1	2	2	9
ME1513	1	2	1	2	3	3	12
ME0909	2	3	2	2	1	1	11

After comparing the scores from the table above, the best motor according to the table was the Motenergy ME1513. When looking to purchase the Motenergy ME1513, the lead time on the motors was a large factor in purchasing the motor. The motor had a large lead time to purchase it. The decision was made to go with the next best motor, the Motenergy ME0909. The motor scored only one point behind the Motenergy ME1513. The ME0909 had the same peak amperage time as the ME1513 but had a higher continuous amperage and peak amperage than the ME1513. The only downside to the ME0909 motor is the weight of the motor and the cost of it. The cost of the motor and weight was much greater than the ME1513. Therefore, the ME0909 motor was purchased for the use for this year's team. In **Fig. 12** below, the ME0909 motor purchased can be seen.

Fig. 12. *Motenergy ME0909 DC Motor*

3) Design Testing and Evaluation: The motor was able to be placed into the boat upon its arrival. The motor was run under no load at the continuous amperage of 100 Amps and the peak amperage of 300 Amps to verify the motor was able to run. After the confirmation that the wiring was hooked up correctly, testing of the motor and system was performed. To evaluate the system in house, the use of a tank built by the previous team was filled with water and the back end of the boat was set into the tank. The motor was then powered on and run under 100 Amps of continuous load.

With the use of the two finned propeller used by last year's team, to be discussed in the propeller section below, we found that we were able to obtain a rotational speed of approximately 400 RPMs when the motor is loaded. From this testing, it was determined to purchase a backup motor of the same one in case of an emergency.

B. Gears and Gear Ratios

1) Current Design: The boat currently used a set of two gears being the same profile. They are both meant for the use of a HTD 8M timing belt. The gears have 27 teeth on them. They allow the driveshaft and motor to spin at the same rate. This setup does not allow for there to be any change in the torque or speed between the motor and driveshaft. The belts have been shredded so there are spare belts laying around for use with the gears. From the gear at the top of the driveshaft to the propeller, the gear ratio was a 1 to 1 ratio.

2) Analysis of Design Concepts: To allow for changes to the gear ratio, it was decided to create new gears. The new gears would still utilize the 8M timing belt tooth profile. The use of the 8M timing belt allows for the use of the existing gears and the new gears. The gears being made would have 18 teeth and 36 teeth. The new gears give us additional gear ratios on top of the existing 1 to 1. The new ratios would be 3 to 2, 4 to 3, and 2 to 1. The gears were analyzed to have the max force applied to the gear for the max speed of the motor with the highest current. In **Fig. 13** below, the stress analysis for the gears is shown. The torque being applied by the motor was divided by the radius of the gear teeth to find the force being applied to the gear. On one side of each tooth of the gear the max force was applied. The gear was meshed, and simulation ran.

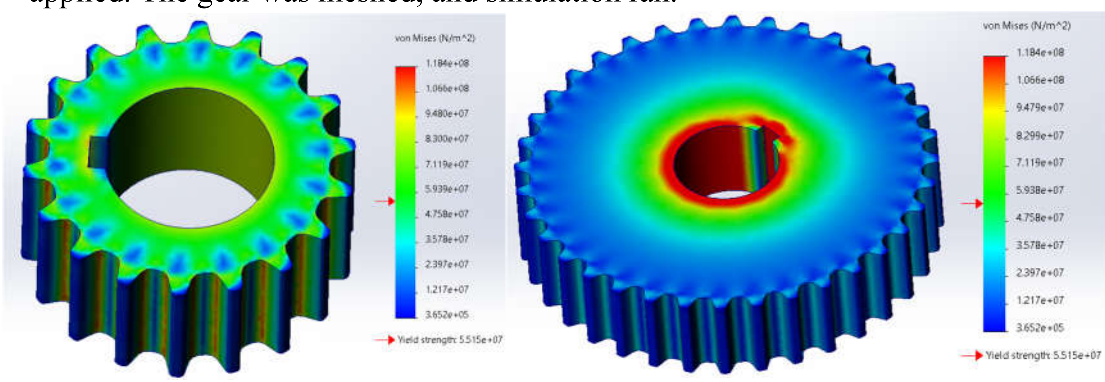

Fig. 13. *Stress Analysis of Gears*

The 18-tooth gear shown on the left side of **Fig. 13** has its highest stress concentration at the base of the teeth. Then in the center of the gear where the gear connects to the shaft, there is a high stress above the yield strength. The 36-tooth gear shown on the right side of **Fig. 13** has its highest stress concentration at center of the gear, where the stress above the yield strength. There is also a slightly elevated stress concentration at the base of the teeth, but the stress concentration is below the yield strength of the material. The stresses shown in the figure above represents the highest stress due to the highest torque. It was found that the motor does not reach its max rotational speed when put on a load. Therefore, it was decided that since the motor does not reach its max speed that the analysis passed.

An additional goal was to take apart the driveshaft and casing. After taking apart the driveshaft and casing, the goal was to rebuild the driveshaft and gear ratios. The layout was to rebuild the driveshaft such that the power input is going directly into a single spinning shaft to prevent the power loss of a spinning shaft with nothing attached. The second shaft causes additional stress points in the gearing within the driveshaft and additional friction from the sealing gaskets and O-rings.

3) Design Testing and Evaluation: The gears were printed out of ABS prior to fabrication. The printed gears were used to evaluate the concept of the gears. The teeth of the gears matched the belt profile. The gear ratios with the larger gear on the motor increased the speed of the driveshaft. After confirming that the gears provided a higher speed on the shaft, the gears were manufactured in house. The 3D printed gears were able to be used for some time, but due to the material being soft the material started wearing away with every cycle. The gears needed to be manufactured out of a material that was suitable to last repeated use. The materials selected were aluminum due to its cost efficiency and the majority of the material were available without additional purchasing. The 36-tooth gear was cut using an EDM to cut the profile of the teeth was cut out of an aluminum disc. The 18-tooth gear was cut from a rod of HTD 8M Timing Belt stock material. The gears were then topped with a 1/4-inch plate aluminum on both sides of the gear. In **Fig. 14** below, the gears that were cut made out of aluminum and steel can be seen.

Fig. 14. *36-Tooth Gear (Left) & 18-Tooth Gear (Right)*

C. Propeller

1) Current Design: The boat previously utilized two propellers, or props for short. One of the props used was a large 18-inch diameter and a pitch of 20-inches, as shown in **Fig. 15** below. The prop has proven to work well in the endurance races as it moves slowly and steady to get through the water. The other prop that has been used is a set of two counter-rotating four finned props. These props have been proven to eliminate the twisting torque from the resting position. They did not provide any additional benefits to the boat and have not been used often.

Fig. 15. *20-Inch Prop.*

2) Analysis of Design Concept: N/A

3) Design Testing and Evaluation: The team had a propeller donated to it. The prop is a 10-inch diameter and a pitch of 10-inches mixing prop, shown in **Fig. 16** below. The prop was donated by DAP. The propeller needed to be modified so that it would fit on the propeller shaft. The propeller's center bore hole was bored to a larger diameter and replaced the set screw with one that sat below the surface. The prop was evaluated against the existing prop. The existing prop was able to accelerate the boat up to approximately 6 MPH (or 2.68m/s) and the new prop reached a speed of approximately 10 MPH (or 4.47 m/s). It was decided to use the new prop in combination with the new gear ratios for the sprint race. The existing prop was going to continue being used for the endurance race.

Fig. 16. *10-Inch Prop.*

D. Steering

1) Current Design: The boat utilizes two separate rudders. One rudder for steering the boat in the maneuverability race and one for the endurance and sprint races. The rudder for the maneuverability race consists of a long and wide rudder. The long and wide rudder provide more surface area to allow for easy and fast change in direction. The rudder used in the endurance and sprint races is a short and narrow rudder. The rudder is short and narrow to provide less surface area. The less surface area provides less area for there to be drag acting upon to slow the boat down. The rudders have functioned well for the previous teams, so no changes were made to the rudders other than resealing the maneuverability rudder.

The rudders are controlled by a pulley system that is attached to a steering wheel at the front of the boat. The previous team was using the steering wheel that was attached to the boat. The steering wheel was shaped similarly to that of a gaming system controller. The steering wheel had triggers attached to the backside that provided no functionality to the boat and a thumb throttle controller that also provided no functionality. The decision was made to replace the steering wheel with a new circular shaped wheel similar to that of a car steering wheel.

2) Analysis of Design Concepts: The new steering wheel was modeled in SolidWorks so that it would be able to attach to the existing steering wheel frame and mounting bracket. The new steering wheel was to be printed in house out of ABS and the reuse of the aluminum mounting bracket. The model was analyzed for an extreme torque applied while turning the wheel. The stress analysis can be found in **Fig. 17** below. In the stress analysis a force applied at the quarter points of the steering wheel acting in a clockwise direction around the center. The part was meshed, and simulation ran. The stress was compared to the maximum allowable stress. The new steering wheel did not experience any stress near the allowable stress. The two halves of the model were sent off to be manufactured. In **Fig 18** below the existing steering wheel is shown in comparison to the newly manufactured steering wheel.

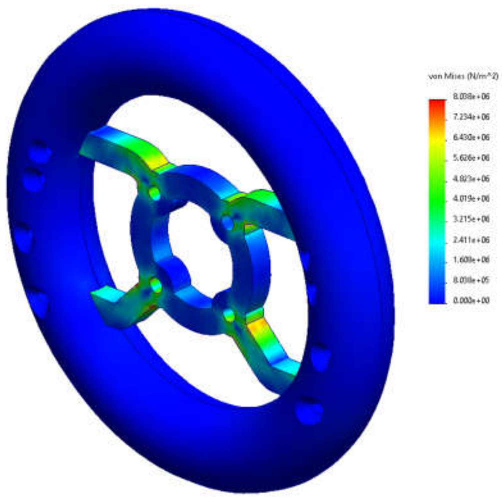

Fig. 17. *Stress Analysis of Steering Wheel*

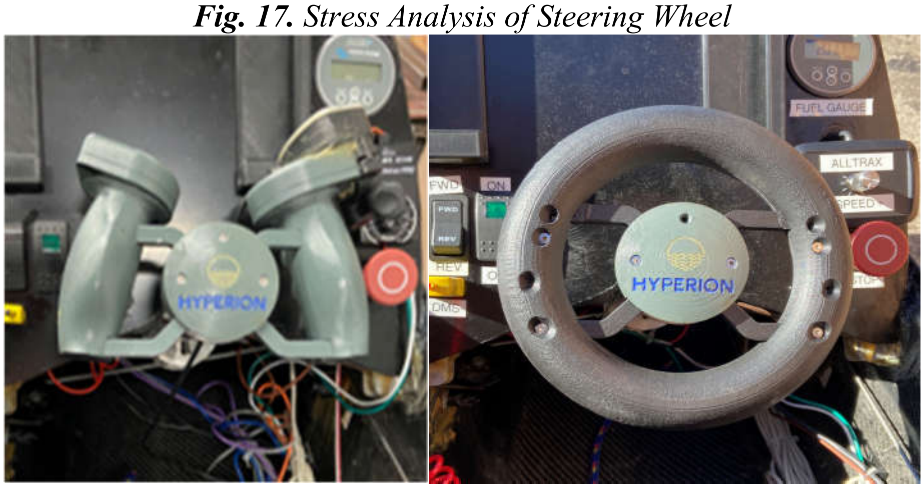

Fig. 18. *Existing Steering Wheel (Left) & New Steering Wheel (Right)*

VII. Data Acquisition and/or Communications

The current data acquisition for the boat consists of the use of a Galaxy tablet connected via Bluetooth to a Victron Smart Battery shunt inside the battery boxes and the Victron Energy Smart Solar MPPT 75/10 solar charge controller. This allows for the skipper to view the live current draw, solar panel power, and battery life. This data is then relayed to the team on shore through a pair of Walkie-Talkies. It was decided that there would be no change to this system other than to use a hotspot on the boat to live stream the tablet screen to the shore for the team to be able to see the same data as the skipper without relying on the skipper. In addition to the tablet, a USB tachometer was added to the drive shaft. The USB tachometer connects to an app on the tablet to give what speed the motor and driveshaft are spinning at.

VIII. Project Management

The Wright State University Solar Splash team is a senior design project. The team consists of four seniors supervised by two academic advisors. The team this year consists of three mechanical engineering students and one electrical engineering student (refer to **Appendix D**). To be on the team the student applies to for the project through their senior design class. The students are then divided into projects. If placed on the Solar Splash team, students must create the goals for the project and work for funding. The students meet with their advisors weekly and their classroom advisor at least once a month.

The team is funded by a grant won from the Ohio Space Grant Consortium (OSGC). The grants stipulation for the winning university to match half the award amount. The total funding available was used in the purchasing of equipment and materials. The team then received additional funding from Dr. Menart and the AES for the purchasing of batteries for renewable energy research. Funding provided per source can be found in **Table 3** in **Appendix E**.

To design each sub-system of the project, each member of the team was given a role to focus their attention on along with doing background research on the project and system. Evan oversaw the reuse of the propellers and possible new propellers. Chase and Brice oversaw the development of the motor and gears. Bryar oversaw the development and analysis of the electrical systems. All of the other sub-systems were overseen by anyone who completed or were in a break from their system. Evan, Chase, and Brice did the manufacturing of the new boxes. The gears being made were done by Brice. Chase and Brice completed purchasing.

To help future teams working on the project, the team is available to be contacted for any questions or advice. The teams will also have access to all research and receipts from the report.

IX. Conclusion and Recommendations

The WSU Solar Splash team performed maintenance on the 2022 boat to get it back into working condition. After getting the boat into working condition classroom lessons were used to modify the boat to increase the speed and efficiency of the boat. The focus to improve the boat happened in the motor and drivetrain. There were lessons in the project and time management of the project. The team worked as one unit to obtain a common goal of improving the solar splash boat and to improve the future of renewable energy and transportation. The team wanted to take apart the driveshaft, but due to time restraints, the driveshaft was not touched. If a future team is able to remove the existing driveshaft and replace it with a new one, in theory there should be less power lose due to the two shafts.

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Acknowledgements

We would like to take the time to thank the following groups and people who helped contribute to this year's Wright State Solar Splash.

The following groups provided funding for to the team:

The Ohio Space Grant Consortium (OSGC)

Wright State University Mechanical and Materials Engineering Department

Without these groups, we would not have been able to fund the development of the Solar Splash boat or been able to compete at the competition.

We would also like to thank Dr. James Menart and the AES for donating the funds to purchase new batteries to replace the bad batteries.

Appendix A: Battery Documentation

A. ODS-AGM30E (PC950)

ODYSSEY BATTERY

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Information correct at time of exporting PDF. Please check website for updates.

Technical Data Sheet

ODS-AGM30E

(PC950)

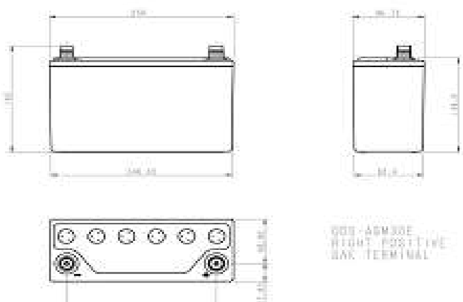
Battery Type

- Up to 400 cycles at 80% depth of discharge
- Absorbed Glass Mat (AGM) with Thin Plate Pure Lead (TPPL)
- Advanced dual purpose battery for engine start and deep cycle use

Power and Performance

Voltage	12V
Pulse (5 second) Hot Cranking Amps (PHCA)	950A
Cold Cranking Amps (CCA)	400A
HCA	600A
MCA	500A
20Hr Nominal Capacity (Ah)	34Ah
10Hr Nominal Capacity (Ah)	32Ah
Reserve Capacity Minutes	60 mins
Terminal	M6 Stud
Torque Spec in-lbs (Nm max)	35 (3.9)
Internal Resistance (mΩ)	7.1 mΩ
Short Circuit (A)	1700A

Drawings & Terminal Position



Dimensions and Weight

Length	9.8 in / 249 mm
Width	3.8 in / 97 mm
Height (terminals included)	6.1 in / 155 mm
Height (container)	5.8 in / 147 mm
Weight	20 lbs / 9.1 kg

Handling and Storage

- Can be mounted or stored in any orientation except inverted
- 2-years storage life at 77°F (25°C) without needing to charge. Recharge when the OCV is <12.2V (50% SOC).
- Classified as non-spillable and approved as non-hazardous cargo for ground, sea and air transportation in accordance with the requirements of IMDG (International Maritime code for Dangerous Goods) and ICAO (International Civil Aviation Organisation)

Temperature

Operating temperature range	-40°F / -40°C to 113°F / +45°C
Optimum storage temperature	68°F / +20°C

Accreditations

The management systems governing the manufacture of this product are ISO 9001 and ISO 14001 certified.

*Cold Start Performance S.A.E J537 Apr 2016

Charging and Self-Discharge

Type of charging curve	IUU
Charger voltage at 68°F (20°C)	14.4V to 14.8V
Self-discharge per month at 68°F (20°C)	1.25%
Self-discharge per month at 104°F (40°C)	5%
80% depth of discharge cycles	400

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152 Beach Road
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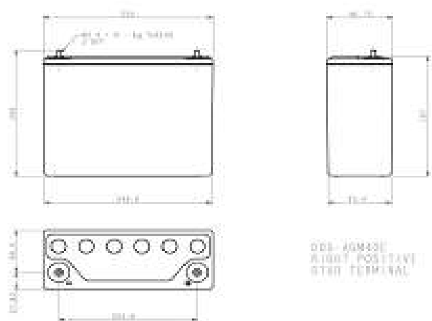
B. ODS-AGM40E (PC1100)

ODYSSEY BATTERY

Drawings & Terminal Position



Handling and Storage

- Can be mounted or stored in any orientation except inverted
- 2-years storage life at 77°F (25°C) without needing to charge. Recharge when the OCV is <12.2V (50% SOC).
- Classified as non-spillable and approved as non-hazardous cargo for ground, sea and air transportation in accordance with the requirements of IMDG (International Maritime code for Dangerous Goods) and ICAO (International Civil Aviation Organisation)

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Type of charging curve	IUU
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Self-discharge per month at 104°F (40°C)	5%
80% depth of discharge cycles	400

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Technical Data Sheet

ODS-AGM40E

(PC1100)

Battery Type

- With M6 SS studs
- Absorbed Glass Mat (AGM) with Thin Plate Pure Lead (TPPL)
- Advanced dual purpose battery for engine start and deep cycle use

Power and Performance

Voltage	12V
Pulse (5 second) Hot Cranking Amps (PHCA)	1100A
Cold Cranking Amps (CCA)	500A
HCA	800A
MCA	650A
20Hr Nominal Capacity (Ah)	45Ah
10Hr Nominal Capacity (Ah)	43Ah
Reserve Capacity Minutes	87 mins
Terminal	M6 Stud
Torque Spec in-lbs (Nm max)	35 (3.9)
Internal Resistance (mΩ)	5.1 mΩ
Short Circuit (A)	2450A

Dimensions and Weight

Length	9.8 in / 249 mm
Width	3.8 in / 97 mm
Height (terminals included)	8.1 in / 206 mm
Height (container)	7.7 in / 196 mm
Weight	27.5 lbs / 12.5 kg

Temperature

Operating temperature range	-40°F / -40°C to 113°F / +45°C
Optimum storage temperature	68°F / +20°C

Accreditations

The management systems governing the manufacture of this product are ISO 9001 and ISO 14001 certified.

*Cold Start Performance S.A.E J537 Apr 2016

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C. SDS for ODYSSEY Batteries

EnerSys
Power/Full Solutions

SAFETY DATA SHEET

Form #: SDS 853027
Revised: AH
Supersedes: AG
ECO #: 1002485

I. PRODUCT IDENTIFICATION

Chemical Trade Name (as used on label):
Cyclon*, Odyssey, Genesis®, SBS, XE*, Armsafe Plus*, MILPC, Nexsys, or Large TPPL.

Chemical Family/Classification:
Sealed Lead Battery

Synonyms:
Sealed Lead Acid Battery, VRLA Battery

Manufacturer's Name/Address:
EnerSys Energy Products Inc.
617 N. Ridgeview Drive
Warrensburg, MO 64093-9301

Canada Corporate Office
3-61 Parr Boulevard
Bolton, Ontario
L7E 4E3

Telephone:
For information and emergencies, contact EnerSys Energy Products Environmental, Health & Safety Dept. at 660-429-2165

24-Hour Emergency Response Contact:
CHEMTREC DOMESTIC: 800-424-9300 CHEMTREC INT'L: 703-527-3877

II GHS HAZARDS IDENTIFICATION

HEALTH		ENVIRONMENTAL	PHYSICAL
Acute Toxicity (Oral/Dermal/Inhalation)	Category 4	Aquatic Chronic 1	Explosive Chemical, Division 1.3
Skin Corrosion/Irritation	Category 1A	Aquatic Acute 1	
Eye Damage	Category 1		
Reproductive	Category 1A		
Carcinogenicity (lead compounds)	Category 1B		
Carcinogenicity (acid mist)	Category 1A		
Specific Target Organ Toxicity (repeated exposure)	Category 2		

GHS LABEL:

HEALTH	ENVIRONMENTAL	PHYSICAL

Hazard Statements	Precautionary Statements
DANGER!	Wash thoroughly after handling.
Causes severe skin burns and serious eye damage.	Do not eat, drink or smoke when using this product.
May damage fertility or the unborn child if ingested or inhaled.	Wear protective gloves/protective clothing, eye protection/face protection.
May cause cancer if ingested or inhaled.	Avoid breathing dust/fume/gas/mist/vapors/spray.
Causes damage to central nervous system, blood and kidneys through prolonged or repeated exposure.	Use only outdoors or in a well-ventilated area.
May form explosive air/gas mixture during charging.	Contact with internal components may cause irritation or severe burns. Avoid contact with internal acid.
Explosive, fire, blast, or projection hazard.	Irritating to eyes, respiratory system, and skin.
May cause harm to breast-fed children	Obtain special instructions before use.
Harmful if swallowed, inhaled, or contact with skin	Do not handle until all safety precautions have been read and understood
Causes skin irritation, serious eye damage.	Avoid contact during pregnancy/while nursing
	Keep away from heat./sparks/open flames/hot surfaces. No smoking

III. COMPOSITION/INFORMATION ON INGREDIENTS

Components	CAS Number	Approximate % by Weight
Inorganic Lead Compound:		
Lead	7439-92-1	45 - 60
Lead Dioxide	1309-60-0	15 - 25
Tin	7440-31-5	0.1 - 0.2
Sulfuric Acid Electrolyte (Sulfuric Acid/Water)	7664-93-9	15 - 20
Case Material:		5 - 10
Polypropylene	9003-07-0	
Polystyrene	9003-53-6	
Styrene Acrylonitrile	9003-54-7	
Acrylonitrile Butadiene Styrene	9003-56-9	
Styrene Butadiene	9003-55-8	
Polyvinylchloride	9002-86-2	
Polycarbonate, Hard Rubber, Polyethylene	9002-88-4	
Polyphenylene Oxide	25134-01-4	
Polycarbonate/Polyester Alloy	--	
Other:		
Absorbent Glass Mat	--	1 - 2

Inorganic lead and sulfuric acid electrolyte are the primary components of every battery manufactured by EnerSys Energy Products.

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There are no mercury or cadmium containing products present in batteries manufactured by EnerSys Energy Products.

IV. FIRST AID MEASURES

Inhalation:

Sulfuric 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:

Sulfuric 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: Consult physician immediately.

Skin:

Sulfuric 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.

Eyes:

Sulfuric 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: N/A | **Flammable Limits:** LEL = 4.1% (Hydrogen Gas) UEL = 74.2% (Hydrogen Gas)

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

Special Fire Fighting Procedures:

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. ACCIDENTAL RELEASE MEASURES

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 not allow discharge of unneutralized acid to sewer. Acid must be managed in accordance with local, state, and federal requirements.
Consult state 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 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.

VIII. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Limits (mg/m3) Note: N.E.= Not Established

INGREDIENTS (Chemical/Common Names)	OSHA PEL	ACGIH	US NIOSH	Quebec PEV	Ontario OEL	EU OEL
Lead and Lead Compounds (inorganic)	0.05	0.05	0.05	0.05	0.05	0.15 (b)
Tin	2	2	2	2	2	N.E
Sulfuric Acid Electrolyte	1	0.2	1	1	0.2	0.05 (c)
Polypropylene	N.E	N.E	N.E	N.E	N.E	N.E
Polystyrene	N.E	N.E	N.E	N.E	N.E	N.E
Styrene Acrylonitrile	N.E	N.E	N.E	N.E	N.E	N.E
Acrylonitrile Butadiene Styrene	N.E	N.E	N.E	N.E	N.E	N.E
Styrene Butadiene	N.E	N.E	N.E	N.E	N.E	N.E
Polyvinylchloride	N.E	N.E	N.E	N.E	1	N.E
Polycarbonate, Hard Rubber, Polyethylene	N.E	N.E	N.E	N.E	N.E	N.E
Polyphenylene Oxide	N.E	N.E	N.E	N.E	N.E	N.E

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Polycarbonate/Polyester Alloy Rubber, Polyethylene	N.E	N.E	N.E	N.E	N.E	N.E
Absorbent Glass Mat	N.E	N.E	N.E	N.E	N.E	N.E

NOTES:
(b) As inhalable aerosol
(c) Thoracic fraction

Engineering Controls (Ventilation):
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 (NIOSH/MSHA approved):
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 gauntlet, 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.

IX. PHYSICAL AND CHEMICAL PROPERTIES

Properties Listed Below are for Electrolyte:

Boiling Point:	203 - 240° F	Specific Gravity (H2O = 1):	1.215 to 1.350
Melting Point:	N/A	Vapor Pressure (mm Hg):	10
Solubility in Water:	100%	Vapor Density (AIR = 1):	Greater than 1
Evaporation Rate: (Butyl Acetate = 1)	Less than 1	% Volatile by Weight:	N/A
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.		

X. STABILITY AND REACTIVITY

Stability: Stable X Unstable ___

This product is stable under normal conditions at ambient temperature

Conditions To Avoid: Prolonged overcharge; sources of ignition

Incompatibility: (Materials to avoid)
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 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.

Hazardous Polymerization:
Will not occur

XI. TOXICOLOGICAL INFORMATION

Routes 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 arsine 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, cornea damage, and blindness.
Lead Components: 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.

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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 50mcg/100 ml or higher. Heavy lead exposure may result in central nervous system damage, encephalopathy and damage to the blood-forming (hematopoietic) 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. Misuse of 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.

Acute Toxicity:

Inhalation LD50:

Electrolyte: LC50 rat: 375 mg/m3; LC50: guinea pig: 510 mg/m3

Elemental Lead: Acute Toxicity Point Estimate = 4500 ppmV (based on lead bullion)

Oral LD50:

Electrolyte: rat: 2140 mg/kg

Elemental Lead: Acute Toxicity Estimate (ATE) = 500 mg/kg body weight (based on lead bullion)

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 worksite. Keep contaminated clothing out of non-contaminated areas, or wear cover clothing when 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 19th Amendment to EC Directive 67/548/EEC classified lead compounds, but not lead in metal form, as possibly toxic to reproduction. Risk phrase 61: 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 bioaccumulation occurs through the food chain. Most studies include lead compounds and not elemental lead.

Environmental Toxicity: Aquatic Toxicity:

Sulfuric acid:	24-hr LC50, freshwater fish (Brachydanio rerio): 82 mg/l.
	96 hr- LOEC, freshwater fish (Cyprinus carpio): 22 mg/l.
Lead:	48 hr LC50 (modeled for aquatic invertebrates): <1 mg/L, based on lead bullion

Additional Information:

- No known effects on stratospheric ozone depletion.
- Volatile organic compounds: 0% (by Volume)
- Water Endangering Class (WGK): NA

XIII. DISPOSAL CONSIDERATIONS (UNITED STATES)

Spent batteries: Send to secondary lead smelter for recycling. Spent lead-acid batteries are not regulated as hazardous waste when the requirements of 40 CFR Section 266.80 are met. This should be managed in accordance with approved local, state and federal requirements. Consult state environmental agency and/or 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 testing, should be managed in accordance with approved local, state and federal requirements. Consult state environmental agency and/or federal EPA.

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

XIV. TRANSPORT INFORMATION

CLASSIFICATION:

UN Number:	UN2800
Shipping Name:	BATTERIES, WET, NON-SPILLABLE
Primary Class:	8
Packing Group:	

U.S. DOT:

Excepted from the hazardous materials regulations (HMR) because the batteries meet the requirements of 49 CFR 173.159(f) 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 DGR:

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EnerSys
Power/Full Solutions

SAFETY DATA SHEET

Form #: SDS 853027
Revised: AH
Supersedes: AG
ECO #: 1002485

Excepted from the dangerous goods regulations because the batteries meet the requirements of Packing Instruction 872 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.

The words "NOT RESTRICTED", SPECIAL PROVISION A67" must be provided when the air waybill is issued.

IMDG:

Excepted from the dangerous goods regulations for transport by sea because the batteries meet the requirements of Special Provision 238 of the International Maritime Dangerous Goods(IMDG CODE). Battery terminals must be protected against short circuits.

Requirements for Safe Shipping and Handling of Cyclon Cells:

Warning – Electrical Fire Hazard – Protect against shorting. Terminals can short and cause a fire if not insulated during shipping. Cyclon product must be labeled "NONSPILLABLE" during shipping. Follow all federal shipping regulations. See section IX of this sheet and CFR 49 Parts 171 through 180, available online at www.gpoaccess.gov.

Requirements for Shipping Cyclon Product as Single Cells:

Protective caps or other durable inert 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 Cyclon Product Assembled Into Multicell Batteries:

Assembled batteries must have short circuit protection during shipping. Exposed terminals, connectors, or lead wires must be insulated with a durable inert material to prevent exposure during shipping.

XV. REGULATORY INFORMATION

UNITED STATES:

EPA SARA Title III:

Section 302 EPCRA Extremely Hazardous Substances (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 site (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 Substances:

Reportable Quantity (RQ) 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 311/312 Hazard Categorization:

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 consult 40 CFR 370.10 and 40 CFR 370.40

Section 313 EPCRA Toxic Substances:

40 CFR section 372.38 (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 such 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.

Supplier 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 manufacturing facility under SIC codes 20 through 39, the following information is provided to enable you to complete the required reports:

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

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".

TSCA:

TSCA Section 8b – Inventory Status: All chemicals comprising this product are either exempt or listed on the TSCA Inventory.

TSCA Section 12b (40 CFR Part 707.60(b)) No notice of export will be required for articles, except PCB articles, unless the Agency so requires in the context of individual section 5, 6, or 7 actions.

TSCA Section 13 (40 CFR Part 707.20): No import certification required (EPA 305-B-99-001, June 1999, Introduction to the Chemical Import Requirements of the Toxic Substances Control Act, Section IV.A)

RCRA:

Spent Lead Acid Batteries are subject to streamlined handling requirements when managed in compliance with 40 CFR section 266.80 or 40 CFR part 273. Waste sulfuric acid is a characteristic hazardous waste; EPA hazardous waste number D002 (corrosivity) and D008 (lead).

CAA:

EnerSys supports preventative actions concerning ozone depletion in the atmosphere due to emissions of CFC's and other ozone depleting chemicals (ODC's), defined by the USEPA as Class I substances. Pursuant to Section 611of the Clean Air Act Amendments (CAAA) of 1990, finalized on January 19, 1993, EnerSys established a policy to eliminate the use of Class I ODC's prior to the May 15, 1993 deadline.

STATE REGULATIONS (US):

Proposition 65:

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Warning: Battery posts, terminals and related accessories contain lead and lead compounds, chemicals known to the State of California to cause cancer and reproductive harm. Batteries also contain other chemicals known to the State of California to cause cancer. Wash hands after handling.

INTERNATIONAL REGULATIONS:

Distribution into Quebec to follow Canadian Controlled Product Regulations (CPR) 24(1) and 24(2).

Distribution into the EU to follow applicable Directives to the Use, Import/Export of the product as-sold.

Article 33 (1) of the REACH regulation (Reg. EC 1907/2006), which entered into force on 1st of June 2007 in the European Union, requires that manufacturers communicate the presence of Substances of Very High Concern (SVHC) in articles (lead batteries) in concentration greater than 0.1% by weight.

Effective the 27th of June 2018, the European Chemical Agency (ECHA) updated the Candidate List with the inclusion of Lead Metal (CAS No.: 7439-92-1). This inclusion of Lead as an SVHC applies to all of EnerSys Lead based battery products regardless of the design (Flooded, Gel, AGM, etc…).

XVI. OTHER INFORMATION

Revised: **1/10/2023**

NFPA Hazard Rating for Sulfuric Acid:

Flammability (Red) = 0	Reactivity (Yellow) = 2
Health (Blue) = 3	Sulfuric acid is water-reactive if concentrated.

DISCLAIMER

This Safety Data Sheet is created by the manufacturer to comply with the requirements of 29 CFR 1910.1200. To the extent allowed by law, the manufacturer hereby expressly disclaims any liability to any third party, including users of this product, including, but not limited to, consequential or other damages, arising out of the use of, or reliance on, this Safety Data Sheet.

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Appendix B: Flotation Calculations

For the 2023 competition, the weight of the boat is approximately 320 pounds and 365 pounds in the sprint and endurance configurations, respectively. Per the Solar Splash Rules, a factor of safety of 1.2 must be included in the flotation calculations [1]. Therefore, the sprint configuration needs a buoyancy of 384 pounds and the endurance configuration is 438 pounds. The buoyant force for the boat is calculated using the Archimedes Principle. The properties of water used was for water at 65°F. Using **Equation 1** below, the buoyant force can be calculated.

$$F_b = V * \rho_W \tag{1}$$

The hull was measured to have a volume of 4.98 ft^3. The boat also has outriggers to help stabilize the boat, they provide an additional buoyancy force. Their buoyancy value will be added to the total buoyancy force. The batteries are attached to the hull when the boat is in motion, and they are watertight. This means that each battery would have a buoyancy force acting upon it. The volume for ODYSSEY AGM30E and AGM40E were calculated per the specifications in **Appendix A**. From **Equation 1**, the buoyancy was calculated and collected in **Table 2** below.

Table 2: *Buoyancy Forces*

Object	Volume, ft^3	Buoyancy Force, lbs.	Quantity	Total Buoyancy Force, lbs.
Hull	4.98	310.87	1	310.87
Stabilizers	0.8476	52.89	2	105.77
AGM30E	0.1315	8.20	2	16.41
AGM40E	0.1746	10.90	2	21.79

From the table the total buoyant force acting upon the hull is 454.84 lbs. This is greater than both the required values for the sprint and endurance configurations. The current buoyancy force gives the sprint configuration a factor of safety of 1.42. the endurance configuration has a factor of safety of 1.24.

Appendix C: Proof of Insurance

ACORD®

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY): 7/6/2022

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 have ADDITIONAL INSURED provisions or 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.
2850 Golf Road
Rolling Meadows IL 60008

CONTACT NAME: Jennifer Webber
PHONE (A/C, No, Ext): 630-773-3800 FAX (A/C, No): 630-285-4062
E-MAIL ADDRESS: Jennifer_Webber@ajg.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Inter University Council - Insurance Consortium	
INSURER B :	
INSURER C :	
INSURER D :	
INSURER E :	
INSURER F :	

INSURED INTECOU-13
Wright State University
3640 Colonel Glenn Highway
Dayton, OH 45435

COVERAGES CERTIFICATE NUMBER: 931225798 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			IUCIC-GL-JULY 2022-2023	7/1/2022	7/1/2023	EACH OCCURRENCE	$ 5,000,000
	CLAIMS-MADE X OCCUR						DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 100,000
							MED EXP (Any one person)	$ Not Covered
							PERSONAL & ADV INJURY	$ 5,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$ 5,000,000
	X POLICY PRO-JECT LOC						PRODUCTS - COMP/OP AGG	$ 5,000,000
	OTHER:							$
A	AUTOMOBILE LIABILITY			IUCIC-AL-JULY 2022-2023	7/1/2022	7/1/2023	COMBINED SINGLE LIMIT (Ea accident)	$ 5,000,000
	X ANY AUTO						BODILY INJURY (Per person)	$
	OWNED AUTOS ONLY / SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS ONLY / NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
								$
	UMBRELLA LIAB / OCCUR						EACH OCCURRENCE	$
	EXCESS LIAB / CLAIMS-MADE						AGGREGATE	$
	DED RETENTION $							$
	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N						PER STATUTE / OTH-ER	
	ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH)	N / A					E.L. EACH ACCIDENT	$
	If yes, describe under DESCRIPTION OF OPERATIONS below						E.L. DISEASE - EA EMPLOYEE	$
							E.L. DISEASE - POLICY LIMIT	$
A	ELL/Professional Liability (Claims Made)			IUC-IC ELL JULY 2022-2023	7/1/2022	7/1/2023	Limit	$5,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)

Requesting entity is included as additional insured where required by written contract entered into prior to loss.

CERTIFICATE HOLDER

Evidence of Coverage

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 (2016/03) The ACORD name and logo are registered marks of ACORD

Appendix D: Team Roster

Dr. Craig Baudendistel.. craig.baudendistel@wright.edu	Faculty Advisor
Dr. Mitch Wolff .... mitch.wolf@wrigh.edu	Faculty Advisor
Evan Hannon .... hannon.9@wright.edu	2023 Mechanical Engineering
Chase Mansell... mansell.6@wright.edu	2023 Mechanical Engineering
Bryar Powell .... powell.253@wright.edu	2023 Electrical Engineering
Brice Prigge .... prigge.2@wright.edu	2023 Mechanical Engineering

Appendix E: Budget

A) Starting Funds

Table 3: *WSU Solar Splash Budget*

Funding Source	Funding
Starting Budget	$0.00
OSGC Grant	$5,000.00
Wright State University Mechanical & Materials Engineering	$2,500.00
AEP & Dr. Menart	$1,200.00
Total Budget	$8,700.00

B) Current Spending at Time of Submission

Table 4: *Current Budget Spending*

Item(s)	Cost
Battery Charger	$150.00
New Motors	$1,200.00
New Batteries	$1,400.00
Electrical Components	$1,100.00
Hardware And Materials	$700.00
Data Equipment	$500.00
Tools	$150.00
Manufacturing Fee	$300.00
Entry Fee	$900.00
Total	$6,400.00

C) Remaining Funds and Plans

At the time of the submission of this report. There is currently $2,300.00 remaining in the WSU Solar Splash budget. The remaining budget will be used to purchase new safety equipment, such as a new life jacket and fire extinguisher. The remaining money will be used in the purchasing of spare parts and electrical components.