UNIVERSITY OF ROCHESTER | URSS

SOLAR SPLASH #7

Technical Report 2015

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Executive Summary

The objective of this year's University of Rochester Solar Splash (URSS) team was to increase our scores in every race by at least 50% at the International Solar Splash Competition, and to once again be competitive with the top veteran teams. This competitive spirit has driven a group of engineers at the University of Rochester to become enthusiastic about the application of their studies and solar power as an alternative source of energy. Rochester Solar Splash team members committed thousands of hours and dollars to their fifth iteration of a competitive Solar Splash boat.

Out of consideration for the endurance portion of the competition, URSS aimed to increase the efficiency and power output of the solar panels. To this end, two new lightweight and efficient solar panels by SBM Solar were purchased. These panels are a third the weight of previous year's panels while outputting 35% more power. In addition, these panels are much more durable and long lasting, built with shock resistant coating and rated to run for a minimum of 30 minutes underwater. With these new panels, the URSS boat runs for a longer time with greater power output.

With the intention to submit a much more hydrodynamic and aerodynamic hull design than in previous years, it was determined that the existing hull could not be modified, which called for the construction of a brand new hull design. Taking what was learned from the previous year's competition, the new hull was designed to be much smaller and more agile. The goal was to design a hull that allowed sufficient control at high speeds and around corners with minimal body roll. For compatibility with both the sprint and endurance portions of the competition, this new design is a trimaran with a central planing hull to allow for excellent lift production at high speeds, and tapered side hulls for precise turning. This hull would enjoy the benefits of a surface drive configuration as well as a lift producing airfoil. The hull will be efficient in the sprint portion, as it generates less drag and essentially rides atop the water. The effectively large static surface area is best in the endurance portion of the race, as it does not require the high speeds of a pickle fork catamaran hull to operate. This hull is made from epoxy-coated fiberglass supported by foam core stringers.

The calibration of the throttle to transmit the correct range of voltages to the motor controller increases the usability of the system. The throttle enclosure has also been redesigned to become a gated shifter to allow for minimal strain on the skipper during the endurance race, while lending to overall effective straight ramp acceleration for the sprint race. Other upgrades include the use of a new rudder designed for racing and a new pulley system to increase the responsiveness when turning the boat. These improvements result in easier and more controlled boat handling.

The process of upgrading our Solar Splash boat system has improved the engineering skills of all the students involved in the 2014-2015 University of Rochester Solar Splash Team. We hope to improve our performance this year and believe our improved engineering will allow us to be very successful in Dayton.

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Overall Project Objectives

The University of Rochester's major goals this year include the incorporation and use of a new hull designed for efficiency in both the sprint and endurance portions of the competition. In previous competitions, the hull produced a substantial amount of drag as it did not produce a sufficient lifting force out of the water. Other major improvements include the use of a programmer to set the motor controller's specifications, which will most definitely improve performance. The previous design did not allow for specific control of certain parameters, such as the maximum allowable rpm for the motor. Additionally, the new design incorporates much more efficient and lightweight solar panels than in the previous design. Improvements elsewhere in the steering and circuitry will hopefully raise Rochester's results this June as well.

Analysis of Integral Systems

Solar System

Previous Design

The solar panels used in every previous year were three model SX 170Bs manufactured by BP. Each panel weighs 33.1 lbs., for a total weight of 99.3 lbs., and has an efficiency of 11%, for a total power output of 510W at 32V. In addition, a FlexMax60 MPPT charge controller by Outback Power Systems was used to interface between the solar panels and the batteries. The FlexMax60 is designed to maximize power conversion from the panels to the batteries with a conversion rate of 98.1%. To do this, the FlexMax60 utilizes a Max Power-Point Tracking Algorithm, or MPPT for short.

While this system served us well in past years, there were several shortcomings, specifically with respect to the solar panels. The SX 170B panels were heavy and unwieldy to work with during construction and competition. At almost 100 lbs., the panels required a strong and heavy mounting system to safely secure them to the boat while in use. In addition, the panels were relatively inefficient, having only 11% efficiency and a power-to-weight ratio of 5.2 watts per pound. For this year's competition, a core focus was obtaining more efficient and lighter panels to both increase power output to the motor and reduce overall weight.

Analysis of Design Concepts

This year, two SBM Solar 258W modules were used. Each of these panels has a power output of 258W and weighs only 15lbs. They have a conversion efficiency of 20% or more and output 30V. Both panels were electrically configured in series to output a total of 60V to the FlexMax60 charge controller, which then converts the input provided by the panels to the 36V needed by the battery system.

As previously mentioned, these solar panels are both more efficient and lighter in weight than the panels used in previous years. The most important metric used in deciding to acquire these panels was their power-to-weight ratio of 17.2 Watts per pound, a 330% increase from last year's panels. The lighter weight of the panels required and allowed for a much lighter and more compact mounting system, which is especially important this year given the size of the new hull. Additionally, in accordance with the higher efficiency of the panels, the total panel surface area is lower than last year's – a total of 34.6 sq. ft. compared to the 40.7 sq. ft. of last year's panels. The SBM panels are also much more durable than the previous panels, having a shock resistant coating (IEC 61215) and a rating for a minimum of 30 minutes of runtime when submerged 1 meter underwater (IPX7) while remaining undamaged.

The SBM solar panels outperform our previous panels in every aspect. They provide a total power output of 516 Watts at one third of the weight and 15% less surface area. These panels enable the boat to run for a longer time, giving it a longer endurance and keeping overall weight lower, making the boat faster. In fact, because 516 Watts is over the maximum panel power of 480 Watts, 2.5 sq. ft. of the panels was taped off in order to bring the power output of the panels within regulation. In all, these panels brought great performance improvements this year and should be useful for several years to come. Table 1 summarizes a direct comparison between the new and old solar systems.

	2013-2014 System	**2014-2015 System**
Solar Panels Model	SX 170B by BP	SBM Solar modules
# of Panels	3	2
Panel Surface Area	40.7 sq. ft.	34.6 sq. ft.
Power Output	510W	516W (2.5 sq. ft. taped off to limit to 480W)
Voltage Output	32V	30V
Efficiency	11%	20%
Weight	33.1 lbs. per panel x3 panels	15 lbs. per panel x2 panels
Resistive Power Loss During Sprint	2.3% or 304W	0.8% or 108W

Table 1. Tabulated comparison of previous and current solar panel specifications.

Power Electronics System

<u>Overview</u>

The boat utilizes the Curtis 1238 Motor Controller for its ease in programming to the current design specifications. It is connected to the batteries, which feed a set voltage of 36V and output a various range of voltages and currents depending on user input. The output is connected directly to the motor, which receives the power and converts it into mechanical energy. Other inputs from the motor controller include the dead man switch and the throttle. In previous years, URSS has used battery configurations that utilize of a different set of batteries for each portion of the race – one set each for the sprint and endurance races. As in the previous years, this year's design utilizes three 42Ah batteries and three 44Ah batteries for the endurance and sprint portions of the competition, respectively. All control wires for start-up switches, throttle, and data cables are passed to the back of the boat and to the dashboard. With this configuration all high current wires and components are close together, keeping the high current wires short and resistance losses low, while all the control wires are brought to the pilot, keeping him away from the potential danger of the power electronics.

Previous Design

Last year, many different styles and sizes of wire were used due to lack of resources and poor documentation from previous years. In addition, the wiring harness was not engineered well which introduced inefficiencies and safety hazards. This year, the overarching power electronics system remains the same as in past years. However, there is a substantial improvement in the wiring and wiring harness in terms of uniformity and organization in order to reduce crowdedness in the boat and enable easier troubleshooting.

Analysis of Design Concepts and Design Testing

The Power electronics system currently consists of: the Curtis 1236 motor controller, a 36-48V, 650 Amp controller designed for a wide range of AC electric motor applications; an AC-9 three- phase AC electric motor capable of a peak of 18 HP, a continuous 6HP, and a maximum of 6800 RPMs; three Genesis 42Ah batteries for the endurance competition; and three Optima 8022-091-FFP RedTop Group 75/25 batteries for the sprint competition. Due to propeller specifications, the motor RPMs were reduced to around 3000RPMs for greater efficiency in both motor current consumption and propeller thrust. The schematic for the power side of the electronics system can be seen in Fig. 2.

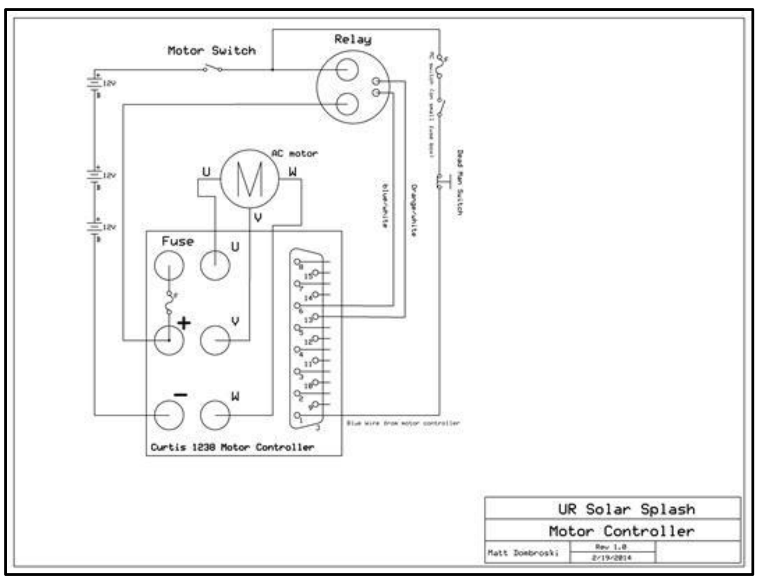

Figure 1. Schematic for the electronic system

The motor controller is fed with 36V from three batteries in series. The low current logic portion of the controller is activated by both a normally open dead man's switch and a low current toggle switch, which were connected in series with a 20 Amp fuse. The logic portion of the controller then activates a high current contactor, which energizes the rest of the power system. This setup allows for less high current wiring, lowering resistance and increasing overall efficiency, while still providing full control over the system and emergency shutoff capability.

This year, the wires for each of the electrical subsystems were standardized and made uniform. All battery-to-battery and battery-to-motor controller connections are made with 1/0 flexible battery cable having a high strand count and heavy duty crimped, soldered, and heat-shrink sealed terminals. The solar charger wiring uses 10 AWG wire with crimped and heat-shrink sealed connections. Finally, the motor controller to motor connection uses the same 4/0 welding cable that had been used in previous years. The improved wiring configuration increases the physical robustness of the wiring system along with increasing the organization and ease of maintenance due to the new standardized layout.

The layout and bus bar system was also updated for this year's design. The layouts of the power electronics subsystems – batteries, motor controller, solar charger, and motor – were concentrated towards the front of the boat in a 3' x 3' area. This allowed for the power feeds to remain short, keeping their overall resistances low. The bus bars this year were also redesigned. Two 3" x 5" x 1.75" aluminum blocks are used as a central connection point for all the main power subsystems: the batteries, motor controller, and solar battery charger. Each of these three subsystems is connected in parallel. These aluminum blocks are much larger than last years' copper bus bars, allowing for more space to attach wire terminals and an overall sturdier and lower-resistance connection point. The team did not take into account dissimilar material corrosion issues due to the short time that the aluminum bus bars would be attached to the copper wires. However, as part of the pre-race and post-race systems validation inspections, the team checks for any sign of oxidation on the bus bars. If oxidation is present, the team takes the necessary steps to remove the surface corrosion before the boat is to be launched again. Aluminum blocks were initially chosen because of their machinability and inexpensive cost compared to brass; a material of which will be utilized in future configurations.

Other improvements this year include vacuum forming water-tight compartments for all the power electronics components. Such compartments keep the power electronics systems dry while also improving organization and maintainability of the systems while reducing safety hazards.

The throttle enclosure was also updated to gated-shifter system so that the throttle can be locked into a particular position. This way the skipper does not need to hold the throttle manually for the entirety of the endurance race, which caused problems in the previous competition. To maintain safety, the gated-shifter mechanism is designed so that the throttle can be quickly pushed sideways and then spring back to the neutral position, causing the motor to stop turning. There is also a dead-man's switch, which if released in an emergency, will immediately cut all power, regardless of the throttle's locked position.

Electrical Systems

Overview of Previous/Current Design

The electrical systems were primarily located on the dashboard. One electrical system was comprised of the safety switches, throttle, and the digital readout display from the motor controller. The other electrical system controlled the bilge pump and distress alarm.

The first electrical system interacted with the motor controller. There were two switches and the throttle on the dashboard that controlled the power to both the motor controller and motor. The circuit diagram detailing this electrical system is outlined in Figure 2 and Appendix J. The switches acted as a redundant system so that the power electronics system could not be accidently activated during testing or set-up. One is a dead man's switch, which was normally open with a clip to hold it closed. This clip was attached via a cord to the skipper so the switch would flip open and deactivate all power to the motor and motor controller immediately should he fall out or another emergency warranted immediate engine cutoff. The second switch is a fused on-switch that is used to turn on the boat during normal operation. A 20A fuse ensured that if there were a malfunction in the motor controller, the fuse would blow and deactivate the power system before more damage could be done. To turn the boat on, this switch provided power to a high current contactor that connected the high current wires from the batteries to the motor controller, thus enabling the power system.

The throttle signal was passed to the motor controller and proportionally set the magnitude of current delivered to the motor. It operated as potentiometer that fed a voltage between 0V and 5V to the motor controller, which was then translated to RPMs from the motor and propeller.

The electrical system also interacted with a digital display monitor. This digital display had the ability to read error codes, approximate battery capacity, approximate rotational speed of the motor, and perform other related motor performance measurements used for data analysis and information on the appropriate boat speed during the endurance race. On the dashboard, a toggle button was included to cycle through the various motor metrics.

The final feature of the electrical system is the forward/reverse switch. This switch allowed for easier navigation in and out of the dock, however, the reverse direction has a limited maximum current to prevent excessive speeds in reverse that could damage the drive train.

The second electrical system, the bilge pump and distress alarm, requires a supplemental battery. The bilge pump battery was selected to be compatible with the 600 gallon per hour bilge pump. This bilge pump required approximately 1.5A. For this reason, a 12V battery with at least a 4 Amps per hour capacity was required. The Powersonic PS-1270 F1 battery was selected because it has a 6A-h capacity for 5 hours of continuous discharge. This selection assumed the bilge pump could run for up to four hours throughout the two, two-hour endurance races. In addition, this battery powers an electronic distress alarm in parallel to the bilge pump. Switches for each the bilge pump and distress alarm are located on the dashboard.

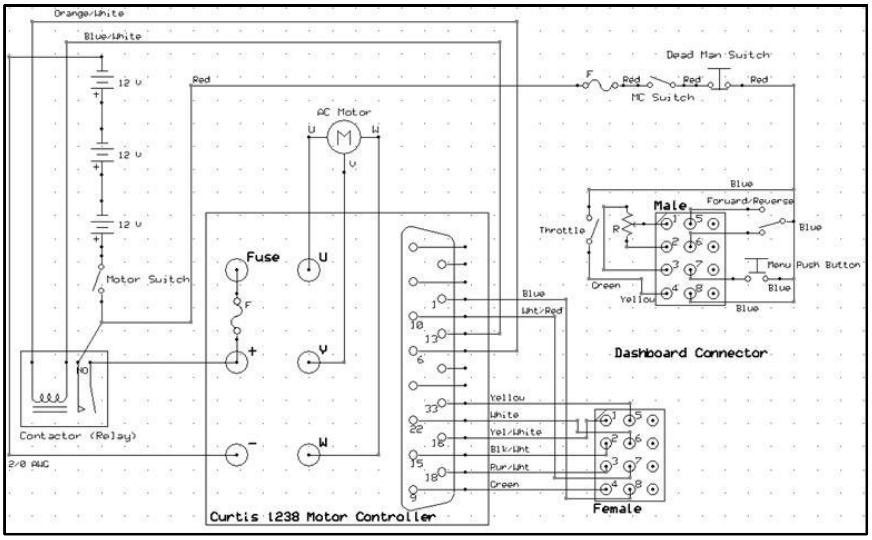

Figure 2. Full schematic of circuit used in electrical system.

Hull Design and Construction Processes

Hull Design: Overall Hull Shape Design Process

Previous Hull Design

The 2013-2014 academic year marked the second year that the University of Rochester team personally manufactured a hull from an Orca3D design. The previous hull design had several issues that limited its success in the competition. The hybrid planing-displacement design worked well in CFD analysis, but in use, the height and weight of the hull was extremely difficult to maneuver in wind. The previous hull was also much thicker than necessary, which lead to a curb weight of approximately 550 lbs. fully loaded, without the skipper. This required an excessive amount of power to move the boat off the starting line. That said, the planing feature of the previous hull performed excellently, effectively lifting the boat out of the water as intended to reduce drag. Even more, imperfections in the hull's water-tightness caused continuous leakage throughout the previous competition. This forced the previous team to improvise with expandable foam, oil seals, and multiple strategically placed bilge pumps.

Analysis of Design Concepts

In an effort to improve the standing in the competition, the University of Rochester's Solar Splash team decided to completely redesign the shape of the hull. The original hull shape was hugely inefficient both in the sprint and endurance portions of the competition, and thus presented the team with a significant opportunity for improvement. Inspired by the pickle-fork racing catamarans of the 1970's, the team aimed to create a hybrid hull shape that would combine both the high-speed performance of a lift-inducing airfoil with the low-speed efficiency of a displacement hull with a large surface area. This concept was achieved by creating core specifications to continuously develop through prototyping and flume analysis.

Using Dassault Systèmes' Solidworks fluids program, multiple revisions of our pickle fork trimaran were created and tested which helped streamline the overall design. In drawing the hull, multiple 3D sketched cross-sections were stitched together to make one solid surface. From our previous experience with a motor placement and shaft angle, it became apparent that a central planing hull was necessary to provide optimal lift conditions. The plane of the transom was fixed at a four-degree offset angle from the neutral vertical axis to allow the propeller shaft to exit at an optimal surface drive height and angle. Each side hull is gently tapered upward towards the stern to give an ideal surface to ride on when the center hull is on plane; all lending towards the lift created from the U-channels between the catamaran hulls. A full schematic of the boat assembly can be seen in Figure 3 and Appendix K.

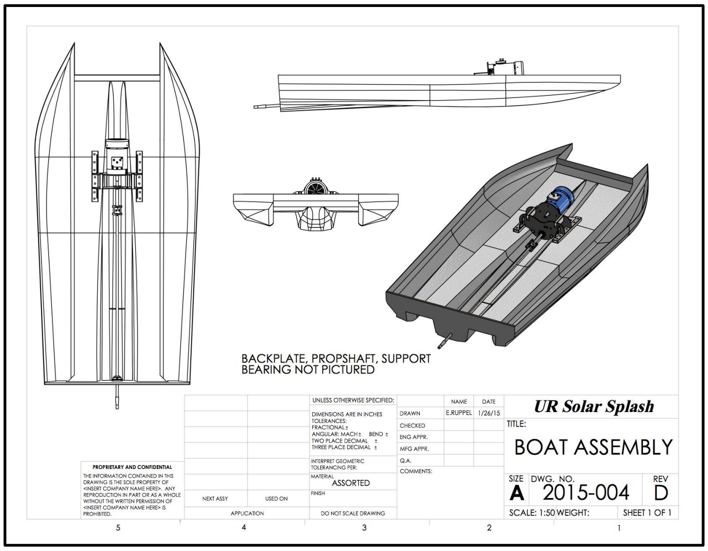

Figure 3. 3D CAD Drawing of hull design.

At the Dayton competition, the most successful boats were the smallest and lightest. Learning from this, the hull was designed to be 10 feet in length, 6.5 feet shorter than the previous design.

Hull Design Testing and Evaluation

The hull design was tested in water to experimentally find the waterline to confirm it displaced the correct amount. After testing, each component of the drive, steering, and electronic systems was placed in the hull without a skipper, causing a 12-degree center of mass angle towards the bow. The design displayed nearly no cavitation in the water, however it was determined that the addition of flaps would benefit the design while turning. Initially, it was determined that 3 layers of fiberglass and resin would be sufficient, but stress and torsion testing revealed that at least 2 additional layers were required to support the stringers.

Hull Construction: Mold-Making Process

Previous Mold-Making Process

The previous hull shape was manufactured by printing cross-sections of the model onto 2-inch-thick slabs of foam. The foam cross-sections were then sandwiched together and used as a mold to lay fiberglass atop. This method was successful in 2011 when constructing the new bow. In contrast to the previous construction process, however, a majority of the original foam mold had to be removed from the fiberglass overlay for the internal components. A reciprocating saw was used to carve out large chunks of foam and then acetone to dissolve any remaining foam. The end result was a thin fiberglass shell, which required additional reinforcement from a core material and internal bracing. Roughly 100 cross-sections were extracted from the computer model, taken at 2-inch intervals along the length of the boat. Each cross section was exported as an image file and then imported into Microsoft PowerPoint. The full-size images were then printed onto paper using a large poster printer. These printed cross section images were glued onto slabs of 2-inch thick insulation foam and cut to shape with a band saw. The paper outlines were then removed and the foam sections were glued sequentially to produce a life-size foam model of the resulting hull. Although this system was accurate and relatively easy, the time that it took to accomplish this task was exponentially larger than the mold making process should be.

Figure 4. In 2013, cross-sections were pasted onto insulation foam and cut.

Analysis of Mold-Making Concepts

Under consideration for the team's significant time constraints, it became apparent that the best and most accurate way to create the hull mold would be to use a CNC router to cut a negative foam mold. Fortunately, the University of Rochester found a vendor in Sunnyvale, CA with a CNC router large enough to cut the design out of expanded polystyrene blocks.

Once the mold arrived, the team took multiple steps to prepare the mold for fiberglass layers. The process first required applying multiple layers of a polymer called Styropoxy, which adhered to the foam surface to create a solid non-permeable surface. This new surface could then be finely sanded smooth. Afterwards, multiple layers of carnauba mold release wax were applied to the styropoxy surface to allow for easy fiberglass removal. After a smooth layer of wax, fiberglass layers infused with epoxy were finally applied to the mold to create the hull. Once the epoxy dried and the fiberglass layers summed to a sufficient thickness, the shell was removed by applying multi-axial pressure, employing the use of airbags between the fiberglass and mold.

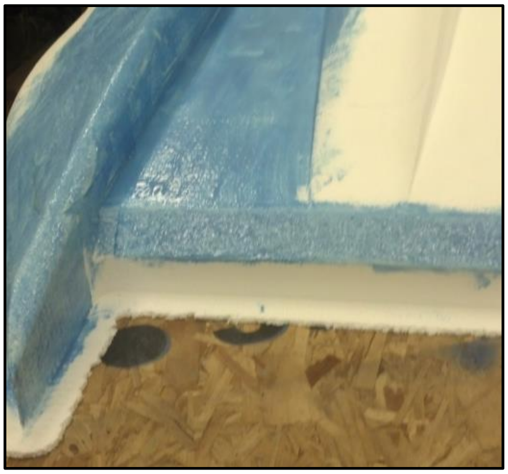

Figure 5. Blue styropoxy applied to the foam hull mold in preparation for fiberglass.

Mold-Making Testing and Evaluation

Although the foam mold was expensive, having a perfect, reusable mold, pictured in Figure 6, was worth it. Both top and bottom sections were molded from the same foam piece, which simplified the hull-building process and cut the expense of having to order a top mold. After molding both portions of the boat, it was obvious that future designs must be drafted at a 10^o inward angle to allow for easy shell removal and effective vacuum bagging. The time in turn wasted in removing the hull from the mold will be cut to a minimum. A CNC-cut mold is definitely the best option to create an advanced design that would be time consuming to put together by classical means. The University of Rochester team is looking to build a personal CNC foam cutter for future designs for prototyping and creating final hull molds.

Figure 6. Negative foam mold of hull design in original shipping crate.

Hull Construction: Composite Structure of Hull Material Cross-Section

Previous Composite Structure

The previous hull was made from multiple layers of fiberglass on either side of Corecell foam with wood flour epoxy as filler at joints. Although this combination of composites creates an outstandingly strong hull, the large amounts of epoxy required makes it extremely heavy.

Analysis of Composite Structure Concepts

This year's hull was constructed without an internal core material. Instead, the team used composite stringers, which were strategically placed throughout the cross-section of the hull material to provide flexural rigidity and shear strength. The construction process was derived from "stitch and glue" boat building and airplane wing construction techniques. After testing different composite thicknesses with MTS machines, the optimal shell combination was created. The composite fiberglass combination was chosen for the boat with consideration for shear strength, weight, and thickness. This composite consists of a layer of 9-oz 45 degree weave, three layers of 6-oz 45-degree weave, then one layer of 4.5-oz weave. The composite also consisted of a 12-oz 45-degree weave with 8-oz matt for all angled and corner sections to lend excellent rigidity in form. All of the stringers are made from Corecell foam backed with 12-oz 45-degree weave that have been attached seamlessly with 12-oz 45-degree weave with 8-oz matt.

Composite Design Testing and Evaluation

To account for the shear stresses on the composites caused by the concentrated loads from the batteries, and electronics, expandable foam, a hot wire foam cutter, and vacuum molded plastic compartments were employed. First, expandable polyurethane foam was poured into each compartment to provide a buffer to distribute the weight of the heavy components. The team built a custom hot wire foam cutter from a variac controlled 1000-Watt power supply and a nichrome wire harness. Before each cut, the nichrome wire is formed in the shape of the object to create 1:1 embedded compartments. The carved foam compartments were then press fit with plastic compartments created by vacuum molding. This process provides a custom waterproof compartment that is vibration dampening and composite preserving. The internal weight of the boat will be mostly concentrated in its center, approximately six feet from the transom. This concentration is accounted for by additional stringers, dampening foam, ¼" thick rubber gaskets, and thick weave fiberglass for rigidity. With most of the weight towards the bow, the boat has a high ability to plow when there is no weight (skipper) in the rear to counter the boat's fixed load. This problem is accounted for by setting the angle of the seat at a rearward 15-degree angle from the neutral vertical axis to move the skipper's weight back.

After extensive on the water evaluation at top speeds of approximately~30 mph, the lab tests have proven to be correct; as a core material was not necessary when in usage with a thick matt backing, stringers and buoyancy foam compartments. At less than half the weight of the previous configuration, it was determined that using stenciled composite stringers coupled with expandable foam dampeners is an excellent way to provide rigidity without excessive weight.

Shaft Support, Drive Train, and Steering Systems

Shaft Log: Overall Shaft Support Configuration

Analysis of Shaft Support Design Concepts

For the 2013-2014 academic year there was no bearing used for mid-shaft support. Although this caused no major damage, this was a risky decision. A mounted bearing is needed to support the middle of the drive shaft and dampen vibrations. Decreasing of vibrations is necessary to provide maximum power and rotation to the propeller. It is also important to keep the drive system stable so that components are not displaced and damaged by torque. The bearing has to support up to 6000 rpm, have a large load capacity, and fit the ¾" inch drive shaft. The original design for the support of this bearing involved a system of 11-gauge stainless steel rectangular tubing. This design involved the use of a pillow block bearing. After some consideration, it was decided this support had an unnecessarily large factor of safety because of the gauge size, and was also time inefficient to manufacture. Using tubing this thick would be extremely. Also, the required height of the mount (to fit the 4 degree angle of the shaft) could not be determined without the drive assembly in the boat, delaying its manufacturing process.

Because of this, the team chose a flange mount bearing that could be bolted down to a piece of plywood. This plywood is fiberglassed midway down the propeller shaft to all sides of the submerged central planing hull. It was then paired up with the bearing after the drive shaft has been placed through the back of the boat, so that the angle was naturally determined. An ABEC-1 Square Cast Iron Mounted Steel Ball Bearing fit the specifications we needed for the bearing. It has a dynamic load capacity of 2,860 lbs. and can handle a max rpm of 8,500.

Design Evaluation

This bearing will satisfy this year's design specifications, but it will be more ideal to purchase mounted roller bearings for future designs. These mounted roller bearings will cost more but are generally capable of withstanding much higher loads. Roller bearings also have more specific applications, which will allow us to design much more specifically to our application.

Shaft Support: Thrust Bearing

Previous Thrust Bearing Configuration

In the previous year, the shaft was supported with oil seals, marine grease, a stuffing box in the rear, and packing rope. This excessive amount of material was inefficient and unsuccessful, given that water still flooded the boat and required three total bilge pumps during competition.

Analysis of Thrust Bearing Design Concepts

To prevent flooding, this year's team was highly focused on perfectly waterproofing and supporting the exit point of the shaft. In doing so, the team utilized the same mounted square bearing, as well as a smaller High-Speed/High-Load Steel Ball Bearing. This bearing has a load capacity of 2595 lbs. and a 6000 max rpm, and was mounted similarly to the casing for the mounted square bearing. Oil seals, marine grease, and two stainless steel plates were also used.

Thrust Bearing Testing and Evaluation

The team tested the support and waterproofing configurations by launching the boat into a local lake. Testing revealed that the bearing allowed seamless rotation of the shaft log and that the team was successful in waterproofing the exit point of the shaft.

Overall Drive System

Previous Drive System Design

The drive shaft and prop shaft system worked well in the previous year, so no major changes were made in this system.

Analysis of Drive System Concepts

The drive shaft is the same as last year's: a 6 foot ¾" diameter stainless steel rod. This is connected to the prop shaft using a Lovejoy coupler. This coupler is held together using a clamp designed in the 2013-2014 academic year. The clamp was remade, this time with filleted corners.

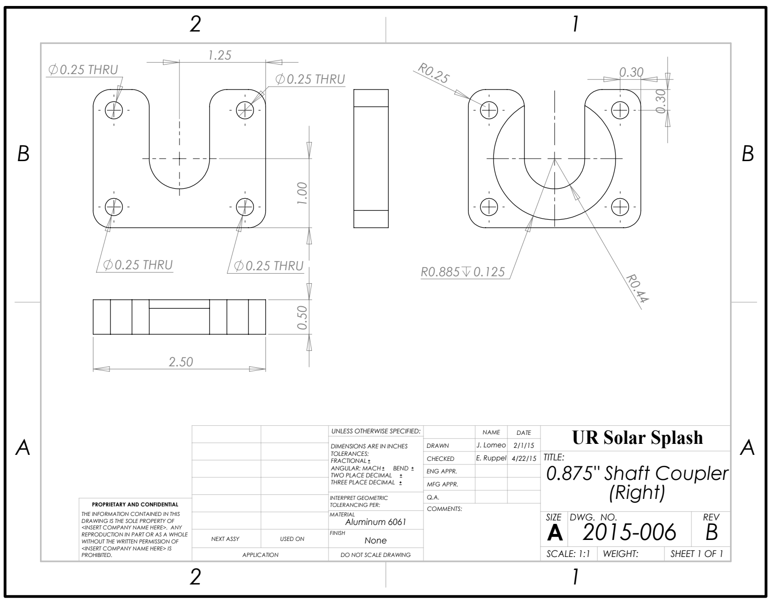

Figure 7. Right side of shaft coupler. This was the same clamp used in last year's design.

The prop shaft from the 2013-2014 year was also reused. The same timing belt pulleys are used, but a new timing belt had to be purchased. The timing belt ratio is 1:1, making the ratio of the power of the motor to the rotation of the propeller also 1:1.

When initially joining the shafts together in the boat, it was obvious that the overall shaft assembly extended farther from the stern than necessary. This would cause excessive vibrations, thus dampening the rotation the propeller receives. It is also important to keep the propeller closest to its support to decrease the bending moment caused by gravity. To resolve this, a hole was cut into the one of the stringers, and the motor mount/motor was slid upwards into this hole. This allowed the team to extend the shaft from the stern at an optimal length, roughly 6 inches.

Drive System Testing and Evaluation

Utilizing many of last year's parts, a much stronger motor mount (discussed below), and adding a mid-shaft bearing should improve the drive system. Vibrations caused by the motor's rotation will be minimal, and the overall system will be extremely sturdy. Potential improvements for the following year include changing the timing belt ratio and designing a gearbox system.

Drive System: Motor Mount

Previous Motor Mount Design

While the motor mount for the previous design worked well, it was square, bulky, heavy, and did not enhance the modularity of design within the boat. Another major problem with the mount was that, the frame twisted after extended on-water usage due to relatively few retaining bolts.

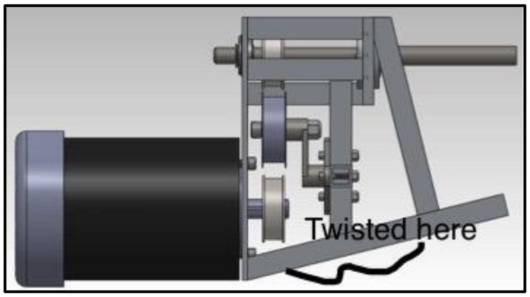

Figure 8. A sketch of the previous motor mount design, showing where deformation occurred.

Analysis of Motor Mount Concepts

The current motor mount was specifically designed using SolidWorks, to fit the shape of the boat. The mount is composed of rounded plates to parallel the center curves of the boat, and these plates are welded to rectangular tubing, which sit on the interior design struts of the boat. The mount includes 7 holes on each side to ensure that it is securely attached to the boat, which will be done using weld nuts, Corecell foam, rubber dampers, and stainless 3/8"-16 bolts. The motor mount sits on a line of fiberglassed Corecell cubes that have the weld nuts embedded within them. The new motor mount design is shown in **Figure x.**

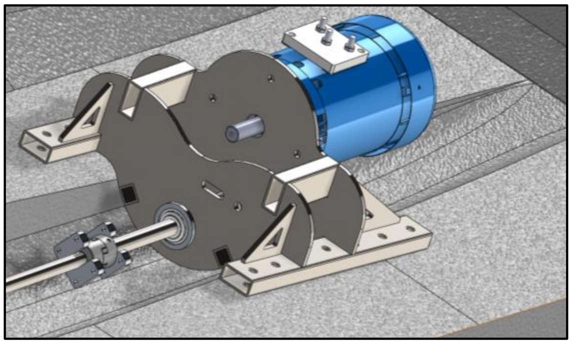

Figure 9. Depiction of the motor mount with the motor embedded into the central planing hull.

Motor Mount Testing and Evaluation

The motor mount has more than enough strength to handle the torque of the motor (up to 4500 ft-lb) and its vibrations. It is a solid design that can likely be used for several years, unless future boats have a hull design with which it does not pair well. The current design, however, is over-engineered for the load it is supporting, which prompts room for improvement next year.

Steering System

Previous Design

The previous design utilized a steering wheel to pull a line that was tied to each end of the rudder. This line was made of 4 mm Dyneema Spectra Line. Essentially when the wheel was turned in one direction, one end of the rope was pulled in toward the boat, rotating the rudder in its direction. Although this system worked, it was difficult to steer due to large quantities of friction that built up within the rope and pulleys it traveled through. Additionally, the rope was exposed at critical locations, making it likely to fray or give someone a rope burn, and due to the fact that it was rope, it was likely to tangle.

Analysis of Design Concepts

This year, the team decided to switch back to the Teleflex NFB Safe T II Mechanical Steering System that was used in the 2012-2013 year. This system was not used in the 2013-2014 year because of space constraints and compatibility with the rest of the boat design. This system works by converting rotational motion of the steering wheel into linear motion of a rod surrounded by a jacket. The rod is flexible and as a result, we can position it at the back of the boat. As the steering wheel turns in one direction, the rod contained within the Teleflex is pushed out the end and as it is turned in the other direction, the rod is pulled back in. Connected by a pin-type joint to end of the rod is a plastic arm. The plastic arm is connected to the rudder so that when the Teleflex extends, the plastic rod pushes the rudder to one side and when the Teleflex is retracted, it pulls the rudder to the other side. The plastic arm has a 90-degree angle in it to change the direction of the motion from parallel to the boat to perpendicular to the rudder as the Teleflex terminates parallel to the boat. This system does solve many of the problems from the previous design, including the fraying due to exposed rope and the friction caused by using rope. See Appendix T for a schematic of the mechanism.

Steering System Testing and Evaluation

The new steering system has been tested in on-the-water evaluation. It has proven to be a much smoother and less prone to problems.

Data Acquisition and Communication

Overview

Last year for data acquisition, the Curtis Spy Glass information display was used as the main readout for data from the motor controller. While this system worked, it was slow and there were only a few pieces of data that could be monitored. This year, the data acquisition system was upgraded to be more advanced, so that data could be read from the CAN port of the motor controller and then forwarded via Bluetooth connection to an Amazon Kindle Fire mounted on the dashboard.

Previous Design

Last year, the Spy Glass was connected to the motor controller via a 4-pin serial connection and received information such as rpm, remaining battery capacity, battery voltage, and amperage draw. While this information was useful in determining remaining run-time and diagnosing problems within the power electronics system, the Spy Glass was cumbersome to use and limited in the amount of information it could provide. The Spy Glass' screen could only fit one line of text, 12 characters long at a time, so that in order to display all of the data, it needed to flip through each piece of data at two second intervals. To view a certain piece of data, for example battery voltage, one had to wait until the Spy Glass cycled through all of the other pieces and got back to the desired data-readout.

Analysis of Design Concepts

This year, a much more advanced real-time data acquisition system was implemented to monitor boat performance both in test runs before the race and during the competition. This new system connected the BAFX OBDII scanning tool to the CAN port of the motor controller to send data via Bluetooth to an Amazon Kindle Fire. We ran the Android app, Torque, on the Kindle to interpret and display the data. Through Torque, the voltage of the batteries, RPMs and amperage draw of the motor, temperature of the batteries and motor, and the remaining battery capacity could be monitored in real time simultaneously from the 7" display screen of the Kindle.

Using a Kindle for obtaining feedback from the system instead of the Spy Glass, provided several advantages. The most significant advantage was that any data value could be viewed at any time, without the processing delay the Spy Glass had. Additionally, feeding the data to a much more computationally powerful device, such as the Kindle, allowed for a more complex analysis of the runtime conditions of the power electronics system. Torque takes into account past data and formulates general trends of the system. For example, Torque can display an estimated remaining runtime in minutes, rather than only the remaining percentage of battery capacity. The Kindle also stores the data in a text file format that can later be uploaded and analyzed by a program such as Excel. These features were helpful in collecting better data and analytics for this year's boat.

To communicate with team member's on-shore, hand-held two way radios were used. They were used to enable the skipper to update those on the shore about the conditions of the boat, so that in case of malfunction or damage, the team on-shore could prepare repairs. The radios were also used to update and advise the skipper while driving.

Project Management

Team Sustainability

University of Rochester Solar Splash is primarily an on-campus club at the University. In an effort to strengthen team organization, nurture the overall cohesion of the team, and become much more competitive in June, this year's team remodeled itself from the ground up. While the current team's president, Edward Ruppel '17, is a sophomore, this team has done a significant amount of research on its previous strengths and weaknesses in order to revitalize the club. The core leaders of this team, which also includes Vice President Matt Dombroski '17, have been tremendously aggressive in reaching out to previous student members and faculty for guidance in order to complete the project within a strict self-prescribed timeline. Spearheaded by Jonah Burstein '17, and the current executive board, a new program has been instituted as well to provide crowdfunding to allow for financial stability and liquid sources of funds for future purchases. Significant changes were made to the team's shop in order to maximize workspace, promote cleanliness, and ensure that all available resources were utilized. The boat was built upon a mobile table, which sat on workhorses with wheels, allowing the team to move the boat when necessary. This now seasoned but young team is well set up for future development and expansion, given that its current leaders will have many years ahead.

Team Organization

This current team's President is Edward Ruppel '17, a biomedical engineering student at the University. The presidents' duties involve recruitment, technical oversight of the project, and task designation. Matt Dombroski '17 is the current Vice President and is responsible for maintaining the team's relationship with the UR Mechanical Engineering Department, Student Association, and other engineering clubs. As the current business manager, Jonah Burstein '17 is responsible for managing all transactions incurred by the club and securing funding from various sponsors. Minsoo Lee '17 is the current Chief Electrical Engineer and is responsible for leading a group of members in configuring all electrical systems on the boat. This year, the construction phase of the new boat was split into three major sections: the hull, mechanical systems, and electrical systems. During the previous academic year, the first semester was dedicated primarily to planning the project, while the second semester and first semester of this academic year were dedicated constructing the hull. Edward Ruppel '17 lead a group of members in designing the boat and employed the help of Matthew Dombroski '18, Josh Lomeo '18, Madeline Hermann '17, and Jacob Krapf '18 to take charge of the construction phase. Josh Lomeo '18 and Edward Ruppel '17 designed the mechanical drive systems. The university machine shop was employed to produce the drivetrain components to military specifications. Weekly team meetings and biweekly executive board meetings allowed regular communication.

Project Planning

Weekly meetings were scheduled throughout the year to organize efforts. The first meetings of each semester were geared towards recruiting new members. Subsequent meetings focused on assigning tasks and responsibilities to individuals and groups of club members. This year our goals were focused on the construction of a new hull, and the improvement of the mechanical and electrical systems. Hull improvements were made in the form of a brand new design, so that the boat can be more hydrodynamic and more efficient than previous models. Mechanical improvements made this year include the redesign of the dashboard and the change of the angle in the drive shaft. New solar panels that are more efficient and light weight have been purchased to replace previous year's panels. A new solar panel mount has been designed and built as the previous system was inefficient. The new system has allowed for the easy mounting and un-mounting of the panels through the use of pins that can be clipped and unclipped.

Funding and Finances

The Hajim School at the University of Rochester funded the majority of the project. We received a generous budget of $6,700. Approximately $2,000 was spent on epoxy, fiberglass, paint and other hull materials. Miscellaneous expenses, tools, including belt sanders, acetone and other shop equipment such as metal reinforcements, and organizational equipment are expected to cost at least $2,000. Our expected expenses for the competition will approach about $3,800 dollars, accounting for traveling costs, food and lodging. We were also allotted funds from the UR Student Association, which will be covering a large amount of our traveling expenses.

Sponsorship

In order to generate the largest and most relevant list of potential partners, team members in charge of each project (electrical, steering, motor, hull, etc.) were responsible for creating an initial list of potential partners per system.

The engineers then relayed this information to the business manager, who then did in depth research on each company to find out whether or not there was a clear reason that both Solar Splash and the company would benefit from a partnership.

If any mutual benefits were found, the business manager contacted each company and managed all aspects of any transactions; bringing in the engineers if needed. As of writing the tech report we have contacted CADimensions/Solidworks, Klein Steel as well as SBM Solar; all of whom have agreed to partner with UR Solar Splash.

Conclusions and Recommendations

Hull

Rochester Solar Splash successfully created a competitive hull after experimentation with the previous four iterations. With a pickle fork trimaran, we believe that it will be competitive with other submissions. Although the design is solid, the release from the mold proved to be somewhat of a challenge due to the many design features; i.e. the more surface areas for static adhesion, the more static pressure to release the mold from shell without cracking. Additionally, now that we have two years of familiarity with Dassault Systemes' Solidworks, we are comfortable designing advanced composite monohulls. With upperclassmen and their knowledge of finite element analysis we will be able to minimize weight and maximize hydrodynamic efficiency next year. In terms of construction, using a CNC foam cutter, "stitch and glue" stringers, and vacuum bagging turned out to be successful and not time consuming.

In the future, we will definitely utilize the process we have experimented with this year, taking note that future designs must have no vertical surface for mold release adhesion.

Drive Train and Motors

Using the previous configurations as previous years, we have optimized our drive train system to the motor specifications. Using information from Appendix E, we have determined the optimal rpm of 3000 for our motor and have calibrated it to maintain that level throughout the race. Other improvements include the shaft log and clamp, which has increased the reliability of the drive train system. In future years, a more suitable motor should be used as our current one is not efficient for low current.

Electrical Systems

The wiring was greatly improved this year. All wires were standardized with 1/0 wire for all power systems, 10 AWG for the solar power system, and 18 AWG for all other lower power and/or logic systems. This updated wiring system keeps power loss due to resistance low and also improves the maintainability and safety of the system. Additionally, the solar panels were upgraded to be more efficient and lighter weight, providing more electric power for the motor while keeping the weight of the boat low. We succeeded in reprogramming our motors to allow us to draw maximal power from them in the sprint and the appropriate power to maximize efficiency during the endurance races.

Acknowledgements

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The Boat Locker
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The Ideaboxx LLC
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Alfred Mustardo
Nate Smith
Robert Tuchrelo
Logitech
Thunderstruck Motors

University of Rochester Student Association
Stacey Fisher
Appropriations Committee

University of Rochester Mini Baja

Appendices

Appendix A: Battery Documentation

Endurance

EnerSys
Power/Full Solutions

INFORMATION ONLY - Please read Section X

SECTION I - Product and Manufacturer Identity

Product Identity:
Sealed Lead Battery

Revision Date: July 26, 2011
Supersedes: May 1, 2011
Document #: MSDS 853027
Revised on ECO: 1001036

Cyclon®, Genesis®, SBS, SBS J, Hawker XE™, Odyssey®, Trolling Thunder™ or NexSys™

Manufacturer's Name and Address:
EnerSys Energy Products Inc. (formerly Hawker Energy Products Inc.)
617 North Ridgeview Drive
Warrensburg, MO 64093-9301

Emergency Telephone Number:
(660) 429-2165
Customer Service Telephone Number:
800-964-2837

SECTION II - Ingredients

Hazardous Components	CAS #	OSHA PEL-TWA	% (By weight)
Lead	7439-92-1	50 $\mu g/m^3$	45 - 60 %
Lead Dioxide	1309-60-0	50 $\mu g/m^3$	15 - 25 %
Sulfuric Acid Electrolyte	7664-93-9	1.0 mg/m^3	15 - 20 %
Non-Hazardous Materials	N/A	N/A	5 - 10 %

SECTION III - Physical/Chemical Characteristics

Boiling Point - N/A
Vapor Pressure (mm Hg.) - N/A
Solubility in Water - N/A
Specific Gravity (H_2O=1) - NA
Melting Point - N/A
Appearance & Color - N/A

SECTION IV - Fire & Explosion Hazard Data

Flash Point (Method Used): N/A Flammable Limits: N/A LEL: N/A UEL: N/A
Extinguishing Media: Multipurpose Dry chemical, CO_2 or water spray.
Special Fire Fighting Procedures: Cool Battery exterior to prevent rupture. Acid mists and vapors in a fire are toxic and corrosive.
Unusual Fire and Explosion Hazards: Hydrogen gas may be produced and may explode if ignited. Remove all sources of ignition.

SECTION V- Reactivity Data and Shipping/Handling Electrical Safety

Conditions to Avoid: Avoid shorting, high levels of short circuit current can be developed across the battery terminals. Do not rest tools or cables on the battery. Avoid over-charging. Use only approved charging methods. Do not charge in gas tight containers.

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 anytime online at wwww.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.

SECTION VI - Health Hazard Data

Routes of Entry: N/A
Health Hazards (Acute & Chronic): N/A

Emergency & First Aid Procedures: Battery contains acid electrolyte which is absorbed in the separator material. If battery case is punctured, completely flush any released material from skin or eyes with water.

Proposition 65: 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.

Page 1 of 2

SECTION VII - Precautions for Safe Handling & Use

Steps to be taken in case material is released or spilled:	Avoid contact with acid materials. Use soda ash or lime to neutralize. Flush with water.
Waste Disposal Method:	Dispose of in accordance with Federal, State, & Local Regulations. Do not incinerate. Batteries should be shipped to a reclamation facility for recovery of the metal and plastic components as the proper method of waste management. Contact distributor for appropriate product return procedures.

SECTION VIII - Control Measures - Not Applicable

SECTION IX – Other Regulatory Information

EnerSys Energy Products Inc. batteries are starved electrolyte batteries which means the electrolyte is absorbed in the separator material. The batteries are also sealed.

NFPA Hazard Rating for Sulfuric Acid:

Health (Blue) = 3 Flammability (Red) = 0 Reactivity (Yellow) = 2 Sulfuric Acid is Water Reactive if concentrated.

U.S. DOT: EnerSys Energy Products Inc. batteries are classified as Nonspillable. They have been tested and meet the nonspillable criteria listed in 49 CFR § 173.159(f) and 173.159a(d)(1).
Nonspillable batteries are excepted from 49 CFR Subchapter C requirements, provided that the following criteria are met:

1. The batteries must be securely packed in strong outer packagings and meet the requirements of 49 CFR § 173.159a.
2. The batteries' terminals must be protected against short circuit.
3. Each battery and their outer packaging must be plainly and durably marked "NONSPILLABLE" or "NONSPILLABLE BATTERY".

The exception from 49 CFR, Subchapter C means shipping papers need not show proper shipping name, hazard class, UN number, and packing group and hazardous labels are not required when transporting a nonspillable battery.

IATA: EnerSys Energy Products Inc. batteries have been tested and meet the nonspillable criteria listed in IATA Packing Instruction 872 and Special Provision A67. Nonspillable batteries must be packed according to IATA Packing Instruction 872. This means shipping papers need not show proper shipping name, hazard class, UN number, and packing group and hazardous labels are not required when transporting a nonspillable battery.
These batteries are excepted from all IATA regulations provided that the batteries are packed in a suitable outer packaging and their terminals are protected against short circuits.

IMDG: EnerSys Energy Products Inc. batteries have been tested and meet the nonspillable criteria listed in Special Provision 238. Non-spillable batteries must be packed according to IMDG Packing Instruction P003. This means shipping papers need not show proper shipping name, hazard class, UN number, and packing group and hazardous labels are not required when transporting a nonspillable battery. These batteries are excepted from all IMDG code provided that the batteries are packed in a suitable outer packaging and their terminals are protected against short circuits per PP16.

RCRA: Spent lead-acid batteries are not regulated as hazardous waste by the EPA when recycled, however state and international regulations may vary.

CERCLA (Superfund) and EPCRA:

(a) Reportable Quantity (RQ) for spilled 100% sulfuric acid under CERCLA (Superfund) and EPCRA (Emergency Planning Community Right to Know Act) is 1,000 lbs. State and local reportable quantities for spilled sulfuric acid may vary.
(b) Sulfuric acid is a listed "Extremely Hazardous Substance" under EPCRA, with a Threshold Planning Quantity (TPQ) of 1,000 lbs.
(c) EPCRA Section 302 notification is required if 1,000 lbs. or more of sulfuric acid is present at one site.
(d) EPCRA Section 312 Tier 2 reporting is required for 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.
(e) 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	7664-93-9	15 - 20

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".

SECTION X - Additional Information

The EnerSys Energy Products Inc. sealed lead acid battery is determined to be an "article" according to the OSHA Hazard Communication Standard and is thereby excluded from any requirements of the standard. The Material Safety Data Sheet is therefore supplied for informational purposes only.

The information and recommendations contained herein have been compiled from sources believed to be reliable and represent current opinion on the subject. No warranty, guarantee, or representation is made by EnerSys Energy Products Inc., as to the absolute correctness or sufficiency of any representation contained herein and EnerSys Energy Products Inc. assumes no responsibility in connection therewith, nor can it be assumed that all acceptable safety measures are contained herein, or that additional measures may not be required under particular or exceptional conditions or circumstances.

N/A or Not Applicable - Not applicable for finished product used in normal conditions.

Informational MSDS

GENESIS SELECTION GUIDE

GENESIS PRODUCT FAMILY (All capacities at 10 hr. rate 25°C to 1.67 vpc)

GENESIS EP:

Product (capacity)	Part Number	Internal res. of fully charged battery mΩ @ 25°C	Nominal short circuit current for charged battery	DIMENSIONS Length in. (mm)	Width in. (mm)	Height in. (mm)	Weight lb. (kg)	Brass Terminal (metric)
G13EP (13Ah)	0770-2007	8.5	1,400A	6.910 (175.51)	3.282 (83.36)	5.113 (129.87)	10.8 (4.9)	M6 w/ss hardware
G13EPX (13Ah)	0770-2003	8.5	1,400A	6.998 (177.75)	3.368 (85.55)	5.165 (131.19)	12.0 (5.4)	M6 w/ss hardware
G16EP (16Ah)	0769-2007	7.5	1,600A	7.150 (181.61)	3.005 (76.33)	6.605 (167.77)	13.5 (6.1)	M6 w/ss hardware
G16EPX (16Ah)	0769-2003	7.5	1,600A	7.267 (184.58)	3.107 (78.92)	6.666 (169.32)	14.7 (6.7)	M6 w/ss hardware
G26EP (26Ah)	0765-2001	5.0	2,400A	6.565 (166.75)	6.920 (175.77)	4.957 (125.91)	22.3 (10.1)	M6 w/ss hardware
G26EPX (26Ah)	0765-2003	5.0	2,400A	6.636 (168.55)	7.049 (179.04)	5.040 (128.02)	23.8 (10.8)	M6 w/ss hardware
G42EP (42Ah)	0766-2001	4.5	2,600A	7.775 (197.49)	6.525 (165.74)	6.715 (170.56)	32.9 (14.9)	M6 w/ss hardware
G42EPX (42Ah)	0766-2003	4.5	2,600A	7.866 (199.80)	6.659 (169.14)	6.803 (172.80)	35.1 (15.9)	M6 w/ss hardware
G70EP (70Ah)	0771-2001	3.5	3,500A	13.020 (330.71)	6.620 (168.15)	6.930 (176.02)	53.5 (24.3)	M6 w/ss hardware
G70EPX (70Ah)	0771-2003	3.5	3,500A	13.020 (330.71)	6.620 (168.15)	6.930 (176.02)	56.0 (25.4)	M6 w/ss hardware

GENESIS VP:

Product (capacity)	Part Number	Internal res. of fully charged battery mΩ @ 25°C	Nominal short circuit current for charged battery	DIMENSIONS Length in. (mm)	Width in. (mm)	Height in. (mm)	Weight lb. (kg)	Brass Terminal (metric)
G26VP (26Ah)	0765-3001	5.0	2,400A	6.565 (166.75)	6.920 (175.77)	4.957 (125.91)	22.3 (10.1)	M6 w/ss hardware
G26VPX (26Ah)	0765-3003	5.0	2,400A	6.636 (168.55)	7.049 (179.04)	5.040 (128.02)	23.8 (10.8)	M6 w/ss hardware
G42VP (42Ah)	0766-3001	4.5	2,600A	7.775 (197.49)	6.525 (165.74)	6.715 (170.56)	32.9 (14.9)	M6 w/ss hardware
G42VPX (42Ah)	0766-3003	4.5	2,600A	7.866 (199.80)	6.659 (169.14)	6.803 (172.80)	35.1 (15.9)	M6 w/ss hardware

X denotes metal jacket design for extreme duty
All dimensions, excluding weight, are maximum
EP external case material — V-0 rated non-halogenated flame-retardant
VP external case material — HB flame rated

9

Certificate Number EMS 39520, ISO 14001 Certified
Certificate Number FM 32099, ISO 9001 Certified
Publication No. US-GPL-SG-001 March 2003

Sprint

Battery Model: 75/25
Part Number: 8022-091
Nominal Voltage: 12 volts
NSN: 6140 01 475 9361
Description: High power, sealed lead acid, engine starting battery

Physical Characteristics:

Plate Design:	High purity lead-tin alloy. Wound cell configuration utilizing proprietary *SPIRALCELL®* technology.
Electrolyte:	Sulfuric acid, H_2SO_4
Case:	Polypropylene
Color:	Case: Dark Gray Cover: "OPTIMA" Red
Group Size:	BCI: 75/25

	Standard	Metric
Length:	9.340"	237.24 mm
Width:	6.772"	172.01 mm
Height:	7.697"	195.50 mm (Height at the top of terminals)
Weight:	33.1 lb	15.0 kg

Terminal Configuration: SAE / BCI automotive and GM style side terminal (3/8"-16UNC-2B threaded nut).

Performance Data:

Open Circuit Voltage (Fully charged):	12.8 volts
Internal Resistance (Fully charged):	.0030 ohms
Capacity:	44 Ah (C/20)
Reserve Capacity:	BCI: 90 minutes (25 amp discharge, 80°F (26.7°C), to 10.5 volts cut-off)

Power:

CCA (BCI 0°F):	720 amps
MCA (BCI 32°F):	910 amps

Recommended Charging:

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

Model: 75/25
These batteries are designed for engine starting applications. They are not recommended or warranted for use in deep cycle applications.

Recommended Charging Information:

Alternator:	13.3 to 15.0 volts
Battery Charger (Constant Voltage):	13.8 to 15.0 volts; 10 amps maximum; 6-12 hours approximate
Float Charge:	13.2 to 13.8 volts; 1 amp maximum; (indefinite time at lower voltages)
Rapid Recharge: **(Constant voltage charger)**	Maximum voltage 15.6 volts. No current limit as long as battery temperature remains below 125°F (51.7°C). Charge until current drops below 1 amp. **All limits must be strictly adhered to.**

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

Current	Approximate time to 90% charge
100 amps	35 minutes
50 amps	75 minutes
25 amps	140 minutes

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

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

Always wear safety glasses when working with batteries.

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

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

Shipping and Transportation Information:

OPTIMA batteries can be shipped by AIR. The battery is nonspillable and is tested according to ICAO Technical Instructions DOC. 9284-AN/905 to meet the requirements of Packing Instructions No. 806 and is classified as non-regulated by IATA Special Provision A-48 and A-67 for UN2800. Terminals must be protected from short circuit.

Manufacturing Location:

Enertec Exports S. de R.L. de C.V.
RFC: EEX020516KU2
Avenida. del Parque No. 2155
Monterrey Technology Park
Cienega de Flores, N.L. 65550
MEXICO
Phone: 52 (81) 81542300
Fax: 52 (81) 81542301

BCI = Battery Council International

OPTIMA Batteries
Product Specifications: Model 75/25
December 2006

Supplemental

POWER SONIC

PS-1270 12 Volt 7.0 AH

Rechargeable Sealed Lead Acid Battery

We've Got The Power.™

Features

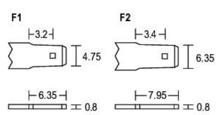
- Absorbent Glass Mat (AGM) technology for superior performance
- Valve regulated, spill proof construction allows safe operation in any position
- Power/volume ratio yielding unrivaled energy density
- Rugged impact resistant ABS case and cover (UL94-HB)
- Approved for transport by air. D.O.T., I.A.T.A., F.A.A. and C.A.B. certified
- U.L. recognized under file number MH 20845

Terminals (mm)

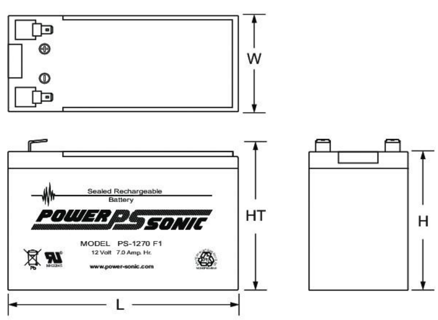
- F1 - Quick disconnect tabs, 0.187" x 0.032"- Mate with AMP. INC. FASTON "187" series

— OR —

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



Physical Dimensions: in (mm)



L: 5.95 (151) **W:** 2.56 (65) **H:** 3.70 (94) **HT:** 3.86 (98)

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.	(350mA to 10.50 volts)	7.00 AH
10-hr.	(650mA to 10.50 volts)	6.50 AH
5-hr.	(1.2A to 10.20 volts)	6.00 AH
1-hr.	(4.5A to 9.00 volts)	4.50 AH
15-min.	(14A to 9.00 volts)	3.50 AH
Approximate Weight		4.80 lbs. (2.18 kg)
Energy Density	(20-hr. rate)	1.49 W-h/in3 (90.95 W-h/l)
Specific Energy	(20-hr. rate)	17.50 W-h/lb (38.58 W-h/kg)
Internal Resistance	(approx.)	23 milliohms
Max Discharge Current	(7 Min.)	21.0 amperes
Max Short-Duration Discharge Current	(10 Sec.)	70.0 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
Power-Sonic Chargers		PSC-12800A, 12800A-C

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

Appendix B: Flotation Calculations

Description	Sprint (lbs.)	Endurance (lbs.)
Batteries	99	99
Engine	50	50
Hull	45	45
Motor Controller	15	15
Solar Arrays	0	50
Cables	20	20
Steering (Including Rudder)	15	15
Passenger	150	150
Miscellaneous (Chair, Safety, etc)	30	30
Shaft and Propeller	25	25
TOTAL (x1.2)	**449 (538.8)**	**499 (598.8)**

The displacement due to the wall thickness of our foam and fiberglass composite will account for part of the flotation. The buoyant force,F_B, is calculated as follows, where $A_b$is the surface area of the hull, t is the thickness of the boat and ρ_{water} is the density of water

$$F_B = A_b t \rho_{water} = 22\ ft^2 \times \frac{0.15\ in}{12\ in/ft} \times 62.2 \frac{lb}{ft^3} = \ 17.105\ lb$$

The remaining buoyant force must be created in another way. 580 lbs. of buoyant force must still be accounted for in order to avoid sinking when capsized.

$$598.8 - 17.105 = 581.695\ lb$$

$$V_D = \frac{581.695\ lb}{62.2\ lb/ft^3} = 9.352\ ft^3$$

Therefore approximately 9.4 cubic feet must be displaced. 3 Optimist sailboat airbags from The Boat Locker, which each hold approximately 2 cubic feet of air, will be distributed strategically along the bottom of the hull (one in the front and one by each gunwale). Buoyancy foam distributed in the front and along the sides of the hull also sums to roughly 4.5 cubic feet in volume. The airbags and buoyancy foam add a total of roughly 10.5 cubic feet of buoyancy, which covers the remaining buoyancy force V_D.

Appendix C: Proof of Insurance

ACORD®

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY) 05/10/2013

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
MARSH USA INC.
70 LINDEN OAKS
STE 310
ROCHESTER, NY 14625
Attn: UniversityofRochester.certrequest@marsh.com
30008 -MAIN-MAST-12-13

CONTACT NAME:
PHONE (A/C, No, Ext): FAX (A/C, No):
E-MAIL ADDRESS:

INSURER(S) AFFORDING COVERAGE		NAIC #
INSURER A :	United Educators Ins Risk Ret. Grp.	10020
INSURER B :	N/A	N/A
INSURER C :	N/A	N/A
INSURER D :	N/A	N/A
INSURER E :		
INSURER F :		

INSURED
UNIVERSITY OF ROCHESTER
ATTN: MARY GOLDENBERG
OFFICE OF COUNSEL
P. O. BOX 278979
ROCHESTER, NY 14627-8979

COVERAGES CERTIFICATE NUMBER: NYC-005691214-11 REVISION NUMBER: 7

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 INSR	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	GENERAL LIABILITY			BLX201200037000	07/01/2012	07/01/2013	EACH OCCURRENCE	$ 500,000
	X COMMERCIAL GENERAL LIABILITY						DAMAGE TO RENTED PREMISES (Ea occurrence)	$ INCLUDED
	CLAIMS-MADE X OCCUR						MED EXP (Any one person)	$ EXCLUDED
	X Retention: $500,000 occurrence						PERSONAL & ADV INJURY	$ INCLUDED
	Liquor Liability - Included						GENERAL AGGREGATE	$ 2,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER:						PRODUCTS - COMP/OP AGG	$ INCLUDED
	X POLICY PRO-JECT LOC							$
	AUTOMOBILE LIABILITY						COMBINED SINGLE LIMIT (Ea accident)	$
	ANY AUTO						BODILY INJURY (Per person)	$
	ALL OWNED AUTOS / SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS / NON-OWNED AUTOS						PROPERTY DAMAGE (Per accident)	$
								$
	UMBRELLA LIAB / OCCUR						EACH OCCURRENCE	$
	EXCESS LIAB / CLAIMS-MADE						AGGREGATE	$
	DED RETENTION $							$
	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY						WC STATU-TORY LIMITS / OTH-ER	
	ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH) Y / N	N / A					E.L. EACH ACCIDENT	$
	If yes, describe under DESCRIPTION OF OPERATIONS below						E.L. DISEASE - EA EMPLOYEE	$
							E.L. DISEASE - POLICY LIMIT	$

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (Attach ACORD 101, Additional Remarks Schedule, if more space is required)
EVIDENCE OF COVERAGE FOR SOLAR SPLASH 2013

CERTIFICATE HOLDER
AMERICAN SOCIETY OF MECHANICAL ENGINEERS
UNIVERSITY OF SOUTH CAROLINA
MECHANICAL ENGINEERING DEPARTMENT
COLUMBIA, SC 29208

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
of Marsh USA Inc.
Annette M. Smith Annette M. Smith

ACORD 25 (2010/05) The ACORD name and logo are registered marks of ACORD

IMPORTANT

If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must be endorsed. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

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).

DISCLAIMER

This Certificate of Insurance does not constitute a contract between the issuing insurer(s), authorized representative or producer, and the certificate holder, nor does it affirmatively or negatively amend, extend or alter the coverage afforded by the policies listed thereon.

Acord 25 (2009/01)

Appendix D: Team Roster

Kevin Bonko '17 is currently pursuing a degree in Mechanical Engineering. He is the Shop Master and is responsible for machining parts and teaching safety within the shop.

Jonah Burstein '17 is currently pursuing a Business degree and serves as the team's Business Manager. His main responsibilities involve securing sponsors, managing all expenses, and recording all transactions.

Kelly Chang '17 is currently pursuing degrees in Mechanical Engineering and Business as well as a Mathematics minor. Her key responsibility was to compile and finalize the Technical Report.

Jonavelle Cuerdo '18 is currently pursuing a degree in Biomedical Engineering. She assisted with the boat's steering system.

Matthew Dombroski '17 is currently pursuing a degree in Electrical and Computer Engineering. He is the current Vice President and is responsible for maintaining the equipment and work environment. He is also responsible for all electrical systems of the boat; including the solar system, power electronics system, and telemetry system.

Madeline Hermann '17 is currently pursuing a degree in Statistics. She has been indispensable in her knowledge of fiberglass composite manufacturing.

Brianna Herron '18 is currently pursuing an Electrical and Computer degree. She is the current Fundraising Chair and is helping with the electronics systems of the boat.

Jake Krapf '18 is currently pursuing a Biomedical Engineering degree. He is the Chief Engineer and is responsible for supervising the Chief Electrical and Chief Mechanical Engineers.

Minsoo Lee '16 is currently pursuing a degree in Electrical and Computer Engineering with a concentration in robotics and control system. He is the current Chief Electrical Engineer.

Josh Lomeo '18 is currently pursuing a degree in Mechanical Engineering. He is the Chief Mechanical engineer and is responsible for designing and testing mechanical systems of the boat.

Nicole Munz '18 is currently pursuing a degree in Mechanical Engineering. She is the Communications Chair, which includes secretarial duties.

Breanna O'Reilly '17 is currently pursuing a degree in Biomedical Engineering with a concentration in Cell and Tissue Engineering. She is the teams Social Chair and is responsible for campus and community outreach.

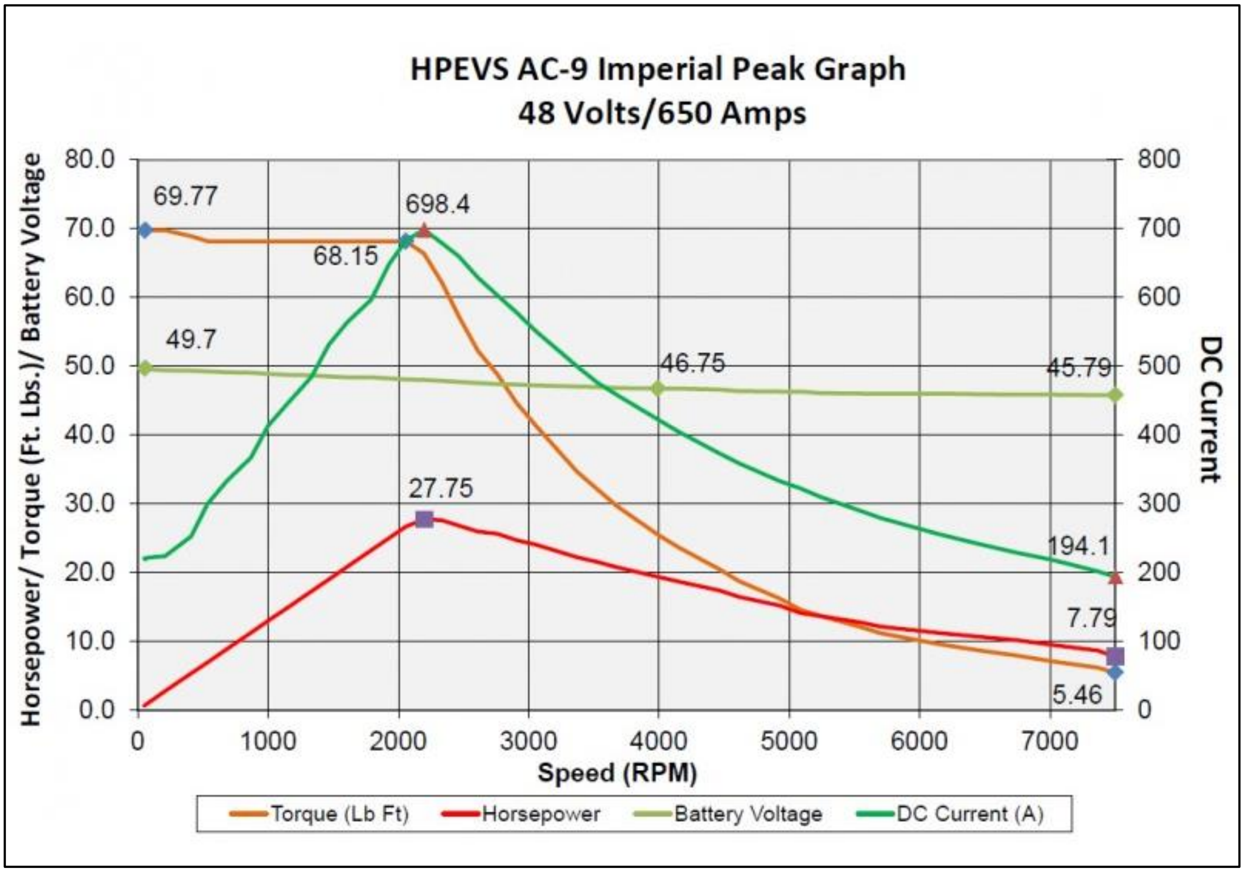
Teddy Reiss '18 is currently pursuing a degree in Electrical and Computer Engineering. He is primarily responsible with the steering system as well as helping with the rest of the boat.

Edward Ruppel ’17 is currently pursuing a Biomedical Engineering degree. He is the current President and is responsible for establishing a timeline, designating tasks to other members, overseeing the project, organizing all aspects of the clubs processes, and communicating with faculty. He is also responsible for all aspects of the mechanical drive systems, the hull design, modernization of the UR Solar Splash shops, and competition logistics.

Nitish Sardana ’17 is currently pursuing a Biomedical Engineering degree. He has been mainly responsible for assisting in the construction phase of the boat.

Steven Tau ’16 is currently pursuing a degree in Chemical Engineering. Having served as President in the past, he has continued to advise current leadership in multiple areas of the design, construction, and refinement processes.

Appendix E: ThunderStruck AC-9 Motor Torque Performance



Appendix F: Sprint Electrical Losses and Power Consumption

The sprint motor configuration has a peak of 18 HP, which is equivalent to 13.4 kW:

$$18\ Hp \times \frac{745\ W}{1\ HP} = 13410\ W$$

At a peak voltage of 36 V

$$P = IV = 13410 = (36)(I) \rightarrow I = 372.5\ A$$

The current will therefore be on the order of 350-400 A flowing from the batteries depending on the internal impedances. Our batteries can produce 720 cold cranking amps, and therefore approximately 700 cranking amps, ample current for this application.

However at these great currents, come significant power losses in the electrical system. 1/0 Gage Copper wire has an impedance of 0.09827 Ω per 1000 ft. We used 8 feet of this wire that will carry the current of this wire, the voltage drop across the wire is approximately 0.29 V and the power loss is about 6% of our original.

$$R = 8ft \times \frac{.09827\Omega}{1000ft} = 7.86 \times 10^{-4}\Omega$$
$$V = IR = 372.5(7.86 \times 10^{-4}) = .29\ \mathrm{V}$$
$$P = I^2R = .29 \times 372.5 = 108\ W$$
$$\%\ Power\ Loss = 100 \times \frac{108\ W}{13410\ W} \approx 0.8\ \%$$

This is 3 times better than the 2.3% estimated loss last year.

Appendix G: Solar Panel Specifications

SBM Solar

SBM 258W Module

WHY SBM SOLAR?

- Lightweight
- Shatterproof
- Strong & Durable
- High Transparency
- Low Glare
- High Efficiency
- MADE IN USA

UL CERTIFICATION

SBM's 140W non-glass, crystalline PV, rigid modules are UL1703 certified

IEC CERTIFICATION

SBM 140W Module has been certified for Hail Impact Resistance based on the IEC61215 Testing Standards from TUV Rheinland PTL, LLC

For more information please visit us at: www.sbmsolar.com

SBM SOLAR, INC.
8000 Poplar Tent Rd
Suite C
Concord, NC 28027
Phone 704.788.2881
Fax 704.793.1909

Available with black or white back sheet behind cells
*Shown in black

Specifications

Maximum Power (Pmax)	258W
Rated Voltage (Vmp)	31.62V
Rated Current (Imp)	8.16A
Open Circuit Voltage (Voc)	37.38V
Short Circuit Current (Isc)	8.72A
Max Fuse Rating	15 A
Weight lbs (kg)	27 lbs (12.3kg)
Power to Weight Ratio: Watts Per Lb/(kg)	9.5W (21W)
Dimensions (inches)	38.67 x 65.06
Module Area ft^2 (m^2)	17.3 ft^2 (1.61 m^2)
Power Output: Watts per ft^2 (m^2)	14.9W (160.5W)
Diodes per module	4
Mono Crystalline Solar Cells	60 cells
Cell Efficiency	~19%

SBM Solar, Inc., founded 2002, is one of the first manufacturers of a UL certified, non-glass, non-EVA and crystalline PV solar module. The module's multi-layered structure provides excellent environmental and chemical protection, better moisture resistance. The encapsulating package is the combination of a Fluoropolymer film provided by *DuPont* and the adhesive encapsulating material, by *The Dow Chemical Company*, performs superior comparing to commonly used EVA. This non-glass PV module is manufactured in the USA.

LIGHTWEIGHT

SBM's solar modules are 40-50% lighter than glass panels. This makes easier for shipping, handling, and installation, and save cost.

SHATTERPROOF/DURABLE

When the glass module is shattered, its entire module will be subsequently loss of power. SBM's non glass modules are completely shatterproof. It is able to withstand the hazardous environmental conditions (hail, rain, wind, heat, cold, and humidity). They are **IEC 61215** certified for hail impact resistance.

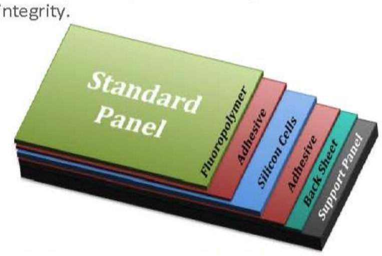
HIGH TRANSPARENCY / LOW GLARE

Blinding glare associated with glass panels can be dangerous and unsafe in certain applications. SBM's solar module utilizes its advanced material property to reduce the reflection. This makes SBM solar modules perfect for applications where glare becomes a critical safety issue such as in military, airport, and highways.

HIGH EFFICIENCY C-Si SOLAR CELLS

SBM Solar modules have over twice the wattage per square foot compared to thin film. They have over 19% cell efficiency and 14.7 watts per square foot compared to thin film's 6-8% module efficiency and 5 watts per square foot.

Besides our standard panels, SBM also develops customized and / or building integrated solar applications. This provides architects and engineers optimal architectural flexibility which preserves design and aesthetic integrity.



All components are made and manufactured in USA

GO GREEN & DEMAND THE BEST!

Appendix H: Outback FLEXmax60 Charge Controller Specifications

FLEXmax Specifications

	FLEXmax 80 - FM80-150VDC	FLEXmax 60 - FM60-150VDC
Nominal Battery Voltages	12, 24, 36, 48, or 60 VDC (Single model - selectable via field programming at start-up)	12, 24, 36, 48, or 60 VDC (Single model - selectable via field programming at start-up)
Maximum Output Current	80 amps @ 104º F (40ºC) with adjustable current limit	60 amps @ 104º F (40ºC) with adjustable current limit
Maximum Solar Array STC Nameplate	12 VDC systems 1250 Watts / 24 VDC systems 2500 Watts / 48 VDC systems 5000 Watts / 60 VDC Systems 7500 Watts	12 VDC systems 900 Watts / 24 VDC systems 1800 Watts / 48 VDC systems 3600 Watts / 60 VDC Systems 4500 Watts
NEC Recommended Solar Array STC Nameplate	12 VDC systems 1000 Watts / 24 VDC systems 2000 Watts / 48 VDC systems 4000 Watts / 60 VDC Systems 5000 Watts	12 VDC systems 750 Watts / 24 VDC systems 1500 Watts / 48 VDC systems 3000 Watts / 60 VDC Systems 3750 Watts
PV Open Circuit Voltage (VOC)	150 VDC absolute maximum coldest conditions / 145 VDC start-up and operating maximum	150 VDC absolute maximum coldest conditions / 145 VDC start-up and operating maximum
Standby Power Consumption	Less than 1 Watt typical	Less than 1 Watt typical
Power Conversion Efficiency	97.5% @ 80 Amps in a 48 VDC System - Typical	98.1% @ 60 Amps in at 48 VDC System voltage - Typical
Charging Regulation	Five Stages: Bulk, Absorption, Float, Silent and Equalization	Five Stages: Bulk, Absorption, Float, Silent and Equalization
Voltage Regulation Set points	10 to 60 VDC user adjustable with password protection	10 to 60 VDC user adjustable with password protection
Equalization Charging	Programmable Voltage Setpoint and Duration - Automatic Termination when completed	Programmable Voltage Setpoint and Duration - Automatic Termination when completed
Battery Temperature Compensation	Automatic with optional RTS installed / 5.0 mV per °C per 2V battery cell	Automatic with optional RTS installed / 5.0 mV per °C per 2V battery cell
Voltage Step-Down Capability	Can charge a lower voltage battery from a higher voltage PV array - Max 150 VDC input	Can charge a lower voltage battery from a higher voltage PV array - Max 150 VDC input
Programmable Auxilary Control Output	12 VDC output signal which can be programmed for different control applications (Maximum of 0.2 amps DC)	12 VDC output signal which can be programmed for different control applications (Maximum of 0.2 amps DC)
Status Display	3.1" (8 cm) backlit LCD screen - 4 lines with 80 alphanumeric characters total	3.1" (8 cm) backlit LCD screen - 4 lines with 80 alphanumeric characters total
Remote Display and Controller	Optional Mate or Mate2 with RS232 Serial Communications Port	Optional Mate or Mate2 with RS232 Serial Communications Port
Network Cabeling	Proprietary network system using RJ45 Modular Connectors with CAT 5e Cable (8 wires)	Proprietary network system using RJ45 Modular Connectors with CAT 5e Cable (8 wires)
Data Logging	Last 128 days of Operation - Amp Hours, Watt Hours, Time in Float, Peak Watts, Amps, Solar Array Voltage, Max Battery Voltage Min Battery Voltage and Absorb for each day along with total Accumulated Amp Hours, and kW Hours of production	Last 128 days of Operation - Amp Hours, Watt Hours, Time in Float, Peak Watts, Amps, Solar Array Voltage, Max Battery Voltage Min Battery Voltage and Absorb for each day along with total Accumulated Amp Hours, and kW Hours of production
Hydro Turbine Applications	Consult factory for approved Turbines	Consult factory for approved Turbines
Positive Ground Applications	Requires two Pole Breakers for switching both positive and Negative Conductors on both Solar Array and Battery Connections (HUB 4 and HUB 10 can not be used for use in positive ground applications)	Requires two Pole Breakers for switching both positive and Negative Conductors on both Solar Array and Battery Connections (HUB 4 and HUB 10 can not be used for use in positive ground applications)
Operating Temperature Range	Minimum -40° to maximum 60° C (Power capacity of the controller is automatically derated when operated above 40° C)	Minimum -40° to maximum 60° C (Power capacity of the controller is automatically derated when operated above 40° C)
Environmental Rating	Indoor Type 1	Indoor Type 1
Conduit Knockouts	One 1" (35mm) on the back; One 1" (35mm) on the left side; Two 1" (35mm) on the bottom	One 1" (35mm) on the back; One 1" (35mm) on the left side; Two 1" (35mm) on the bottom
Warranty	Standard 5 year / Available 10 Year	Standard 5 year / Available 10 Year
Weight - Unit	12.20 lbs (5.56 kg)	11.65 lbs (5.3 kg)
- Shipping	15.75 lbs (7.10 kg)	14.55 lbs (6.4 kg)
Dimensions - Unit	16.25" x 5.75" x 4" (41.3 x 14 x 10 cm) - (H x W x D)	13.5 x 5.75 x 4" (40 x 14 x 10 cm)
- Shipping	21" x 10.5" x 9.75" (53 x 27 x 25 cm)	18 x 11 x 8" (46 x 30 x 20 cm)
Options	Remote Temperature Sensor (RTS), HUB 4, HUB 10, MATE, MATE 2	Remote Temperature Sensor (RTS), HUB 4, HUB 10, MATE, MATE 2
Menu Languages	English & Spanish	English & Spanish
Certifications	ETL Listed to UL1741, CSA C22.2 No. 107.1	ETL Listed to UL1741, CSA C22.2 No. 107.1

*Specifications subject to change without notice

OutBack POWER

Main Office:
19009 62nd Avenue NE
Arlington, WA 98223 USA
Phone: (360) 435.6030
Fax: (360) 435.6019

European Office:
BARCELONA, España
Phone: +34.93.654.9568

www.outbackpower.com

Available From:

980-0016-01-00 REV B

Appendix I: Solar Panel Area Reduction Calculations

Calculations for Reducing Solar Panel Output

$$\frac{Power}{Area} = \frac{258\ W}{17.3\ ft^2} = \frac{14.9\ W}{ft^2}$$

The above equation indicates the average power generated from each square mm of the solar panel.

$$Total\ Power\ from\ PV\ array = (2\ panels)(258\ W) = 516\ W$$

The maximum allowed power from the PV array is 480W. We want to evenly reduce the power on each solar panel so that our PV array output is within the 480W limit.

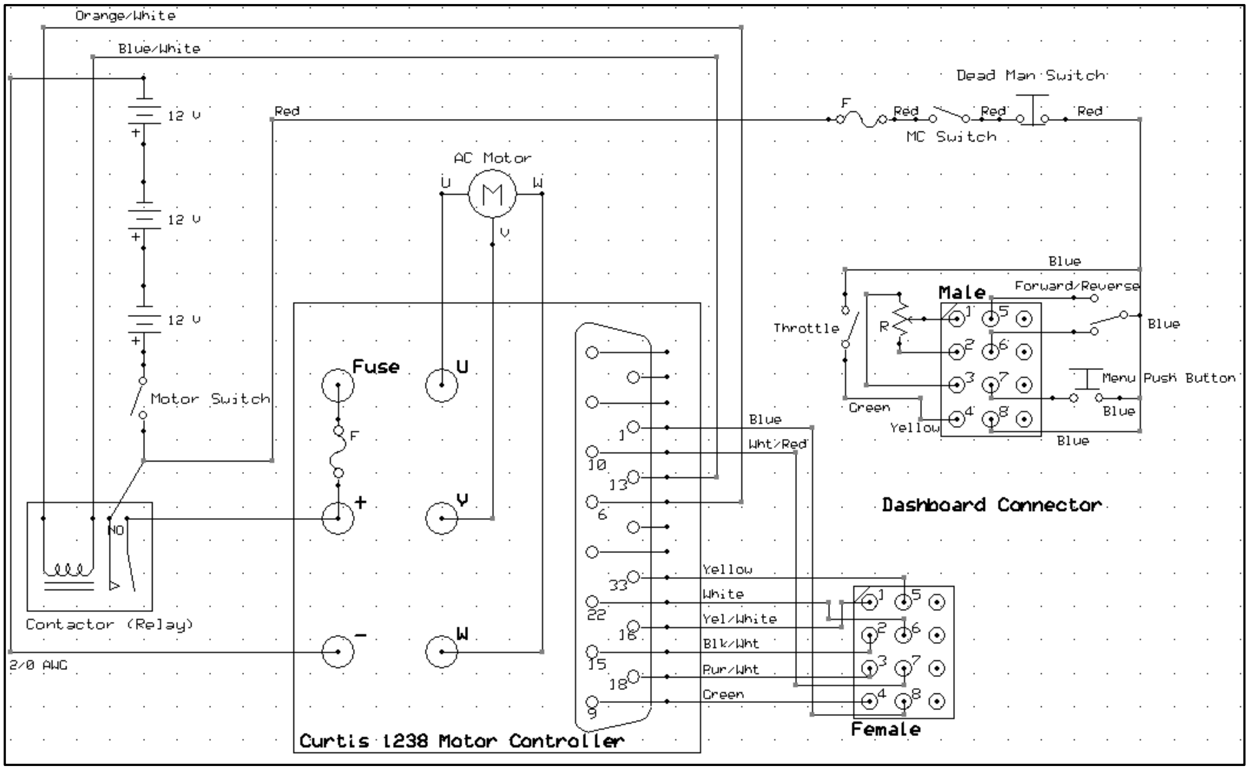
$$Reduction\ in\ Power\ for\ Each\ Panel = \frac{516\ W - 480W}{2\ Panels} = \frac{18\ W}{Panel}$$

To reduce the total power of the PV array, we will cover an area of necessary to reduce each panel power output by 18W.

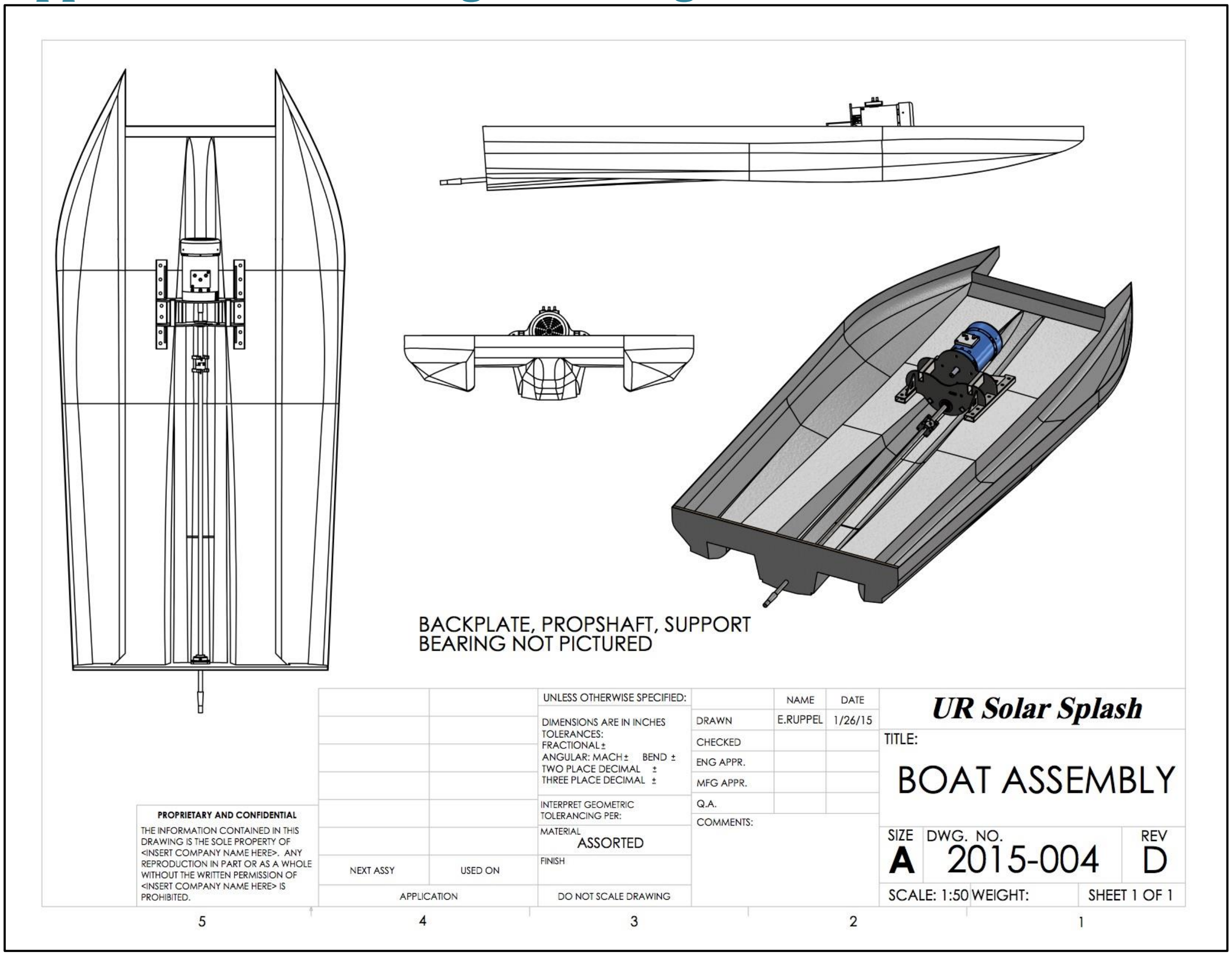
$$Area\ Covered = \frac{18W}{258W} \times 17.3 ft^2 = 1.2\ ft^2$$

The calculations above show the area of each solar panel that needs to be covered in order to reduce the power output of the PV array by 36W. We will be covering each solar panel with reflective material such as aluminum foil.

Appendix J: Circuit Schematic



Appendix K: Hull Design Drawings



Appendix L: Bearings Used in Drive System

High-Speed/High-Load Steel Ball Bearing with Shaft Collar

for 3/4" Shaft Diameter, 1-3/4" OD with Retaining Ring

Each | ADD TO ORDER

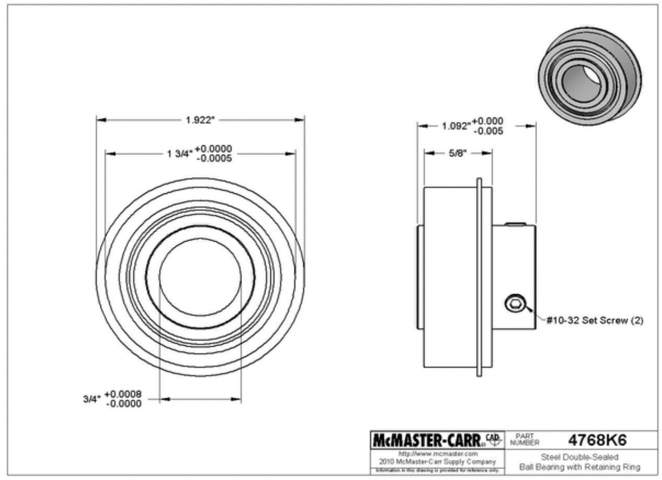
In stock
$34.80 Each
4768K6

You ordered 1 each on 04/16/15.

Bearing Type	Ball
Ball Bearing Style	Double Sealed
Bearing Material	Steel
Seal Material	Synthetic Rubber
Temperature Range	-20° to 250° F
Bearing No.	7612
For Shaft Diameter	3/4"
For Shaft Diameter Tolerance	-0" to +0.0008"
OD	1 3/4"
OD Tolerance	-0.0005" to +0"
Bearing Width	5/8"
Overall Width	1.092"
Overall Width Tolerance	-0.005" to +0"
Dynamic Load Capacity	2,595 lbs.
Maximum rpm	6,000
Feature	Retaining Ring

Great for high speeds and high loads, these bearings have an extended inner ring that acts as a built-in shaft collar to save you time and space when mounting. All are double sealed with synthetic rubber seals that block out dirt, preserve lubricants, and reduce noise. They also have a retaining-ring groove. Temperature range is –20° to 250° F. Two set screws for secure mounting are included.

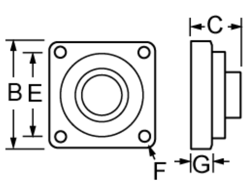
Available with and without a retaining ring, which holds the bearing in the housing.



The information in this 3-D model is provided for reference only. Details

Cast Iron Flange-Mounted Steel Ball Bearing

4-Bolt Square-Flange, for 3/4" Shaft Diameter



Each | ADD TO ORDER

In stock
$42.63 Each
5967K82

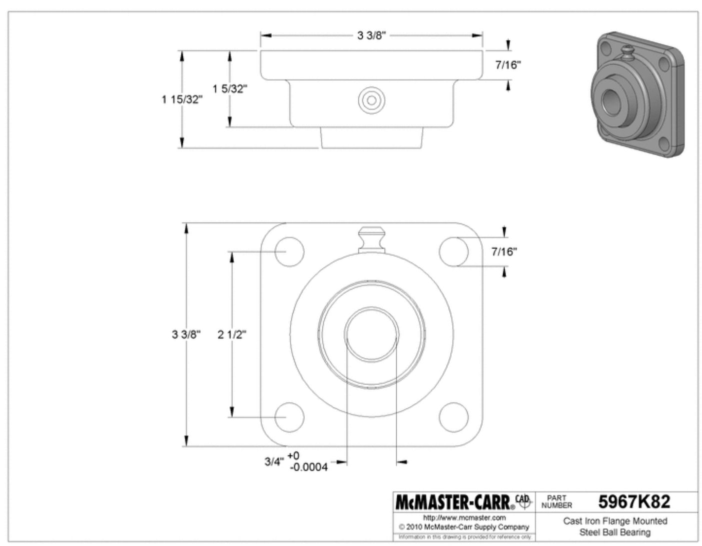
You ordered 2 each on 04/16/15.

Bearing Type	Ball
Ball Bearing Style	Double Sealed
Mount Type	Flange
Flange Type	Square
Shaft Attachment	Set Screw
Temperature Range	-4° to 248° F
For Shaft Diameter	3/4"
For Shaft Diameter Tolerance	-0.0004" to +0"
Dynamic Load Capacity	2,860 lbs.
Maximum rpm	8,500
Square Size (B)	3 3/8"
Overall Height (C)	1 15/32"
Center-to-Center (E)	2 1/2"
Bolt Hole Size (F)	7/16"
Thickness (G)	7/16"
RoHS	Compliant

These rugged cast iron bearings are made to ABEC-1 dimensional tolerance standards. All have a deep-grooved ball bearing insert and are double sealed. Bearings also have a grease fitting for easy lubrication. Ball bearing components are steel; they can accommodate 2° of shaft misalignment. Temperature range is –4° to 220° F.

Bearings with set-screw lock include two set screws to secure the bearing to the shaft.

Also Available: Replacement ball bearing inserts. Please ask for 6361K888 and specify the part number of the bearing for which you need an insert.



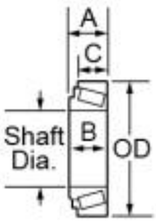
The information in this 3-D model is provided for reference only. Details

Steel Tapered-Roller Bearing

Roller Assembly for 3/4" Shaft Diameter, #09067

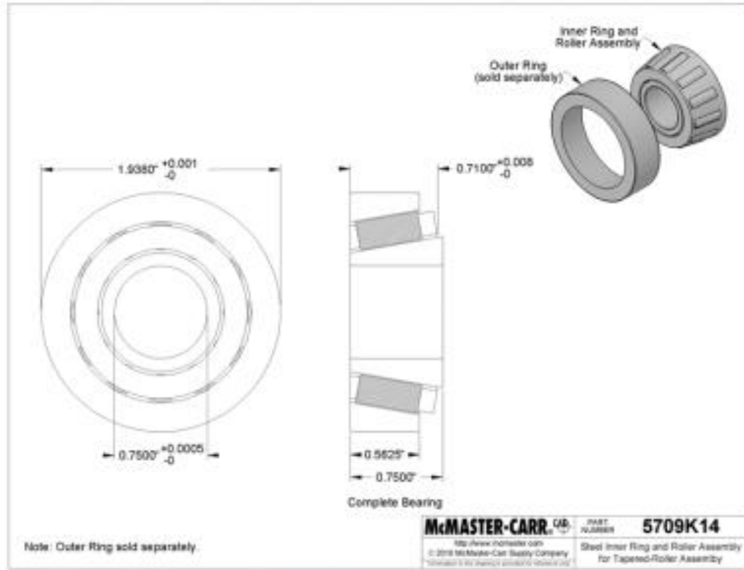
Each — ADD TO ORDER — In stock $36.76 Each 5709K14

You ordered 1 each on 02/12/15



Bearing Type	Tapered Roller
Bearing Component	Inner Ring and Roller Assembly
Bearing Material	Steel
Temperature Range	-65° to 200° F
For Shaft Diameter	3/4"
For Shaft Diameter Tolerance	-0" to +0.0005"
OD	1 15/16"
OD Tolerance	-0" to +0.001"
Bearing No.	09067
Roller Assembly Width (A)	45/64"
Roller Assembly Width Tolerance	-0" to +0.008"
Inner Ring Width (B)	3/4"
Dynamic Load Capacity, lbs.	
Radial	2,310
Thrust	1,050
RoHS	Compliant

Also known as Timken bearings, these tapered-roller bearings handle both radial (perpendicular to the shaft) and thrust (parallel to the shaft) loads, so you can use them virtually anywhere wheels and shafts turn. They have a two-piece design, which offers easy assembly and more accurate adjustments. A complete bearing consists of an inner ring and roller assembly plus an outer ring (sold separately). For best results, replace the outer ring whenever you change the inner ring and roller assembly. All components are made to Class 2 tolerances. Temperature range is –65° to 200° F.



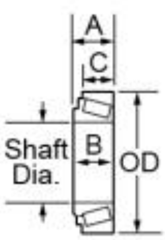
The information in this 3-D model is provided for reference only. Details

Steel Tapered-Roller Bearing

Outer Ring for 3/4" Shaft Diameter, 09195 Bearing #

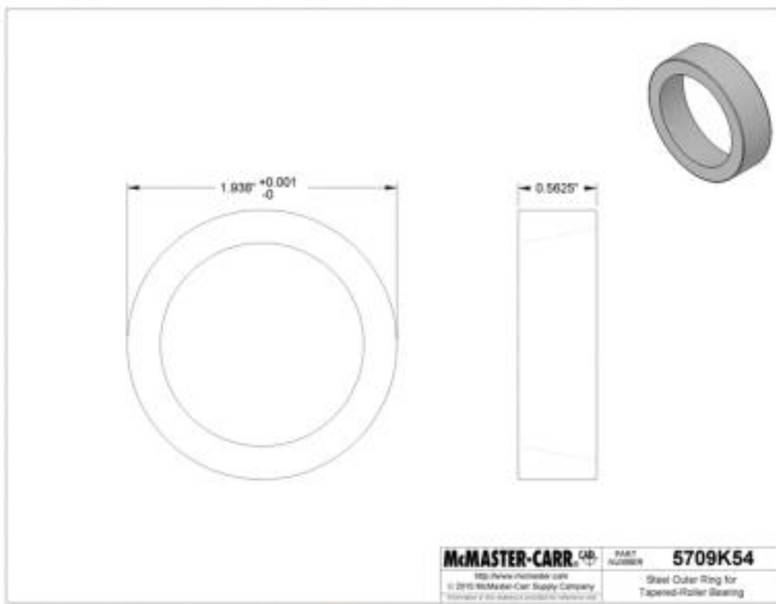
Each — ADD TO ORDER — In stock $12.64 Each 5709K54

You ordered 1 each on 02/12/15



Bearing Type	Tapered Roller
Bearing Component	Outer Ring
Bearing Material	Steel
Temperature Range	-65° to 200° F
For Bearing No.	09067
For Shaft Diameter	3/4"
OD	1 15/16"
OD Tolerance	-0" to +0.001"
Ring Number	09195
Outer Ring Width (C)	9/16"
RoHS	Compliant

Also known as Timken bearings, these tapered-roller bearings handle both radial (perpendicular to the shaft) and thrust (parallel to the shaft) loads, so you can use them virtually anywhere wheels and shafts turn. They have a two-piece design, which offers easy assembly and more accurate adjustments. A complete bearing consists of an inner ring and roller assembly plus an outer ring (sold separately). For best results, replace the outer ring whenever you change the inner ring and roller assembly. All components are made to Class 2 tolerances. Temperature range is –65° to 200° F.



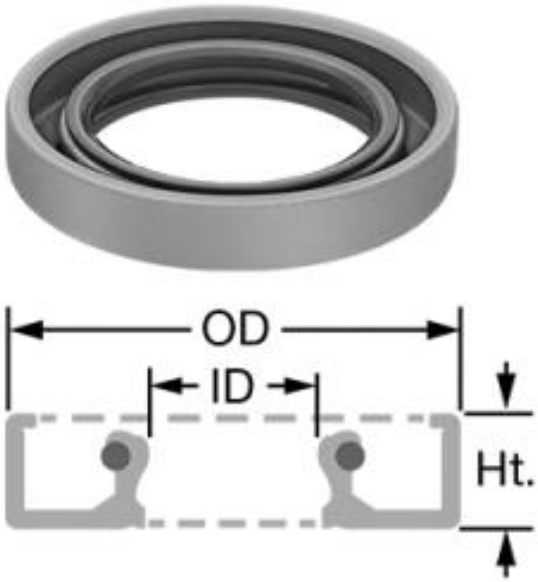
The information in this 3-D model is provided for reference only. Details

Appendix M: Steel Shaft Oil Seal

This seal was used to seal the juncture where the shaft meets the motormount.

Steel Shaft Seal

Spring-Loaded Double Lip, 3/4" ID, 1-1/4" OD



Each

ADD TO ORDER

In stock
$4.47 Each
5154T35

You ordered 5 each on 04/16/15.

Seal	
Type	Spring-Loaded Double Lip
Material	Steel with Buna-N Lip
ID	3/4"
OD	1 1/4"
Height	1/4"
RoHS	Compliant

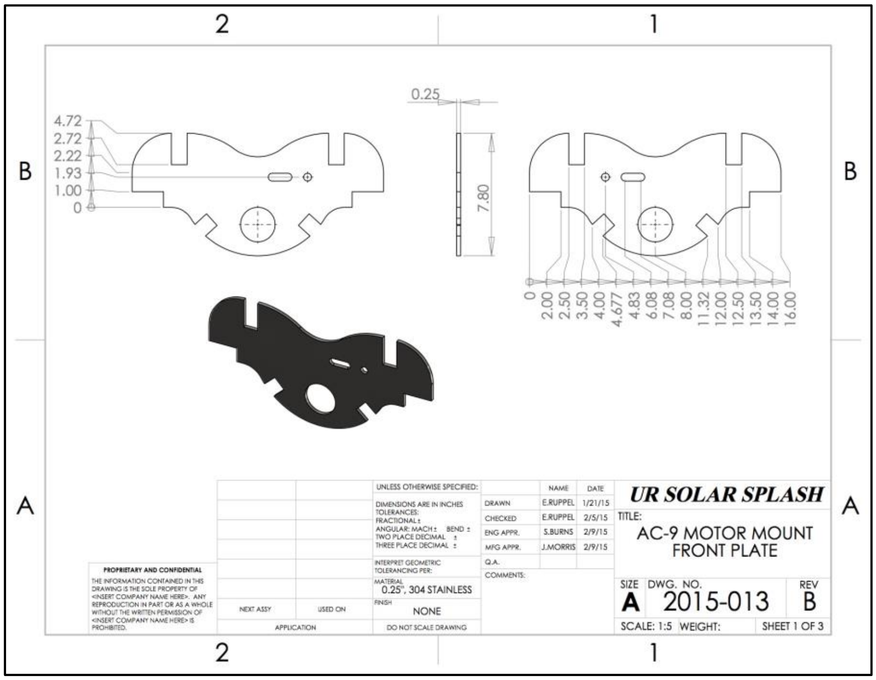
Use these seals on rotating shafts in motors, pumps, and gearboxes. They have Buna-N lips that resist grease, animal and vegetable oils, and most mineral oils. The Buna-N has a durometer hardness of A75 (medium). Temperature range is -40° to 210° F. The seals with spring-loaded lips are also called oil seals; the spring keeps the lip engaged at low pressures to prevent leakage.

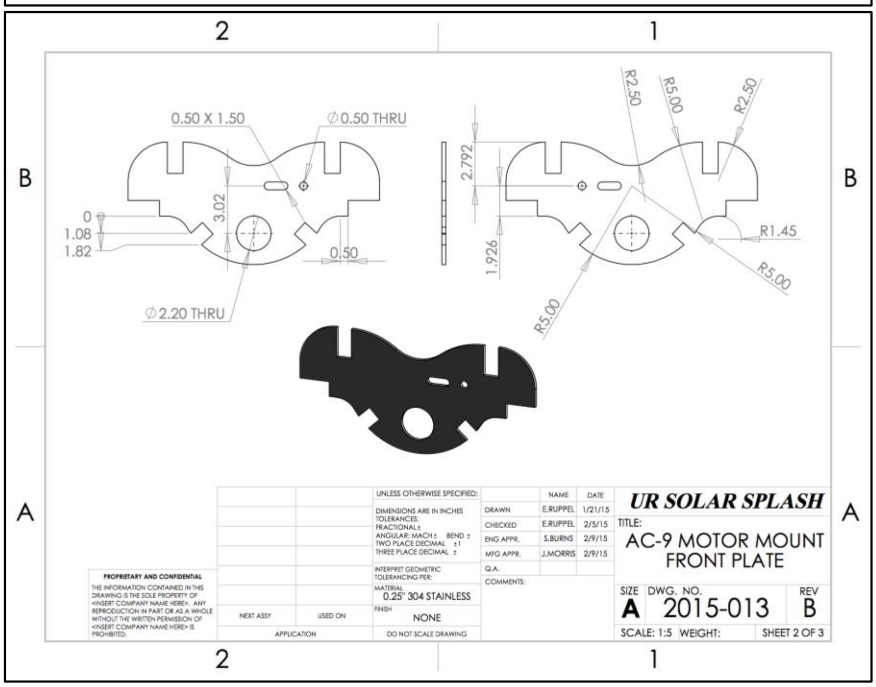
Seals have a green coating on the OD that smooths surface imperfections to ensure a tight seal.

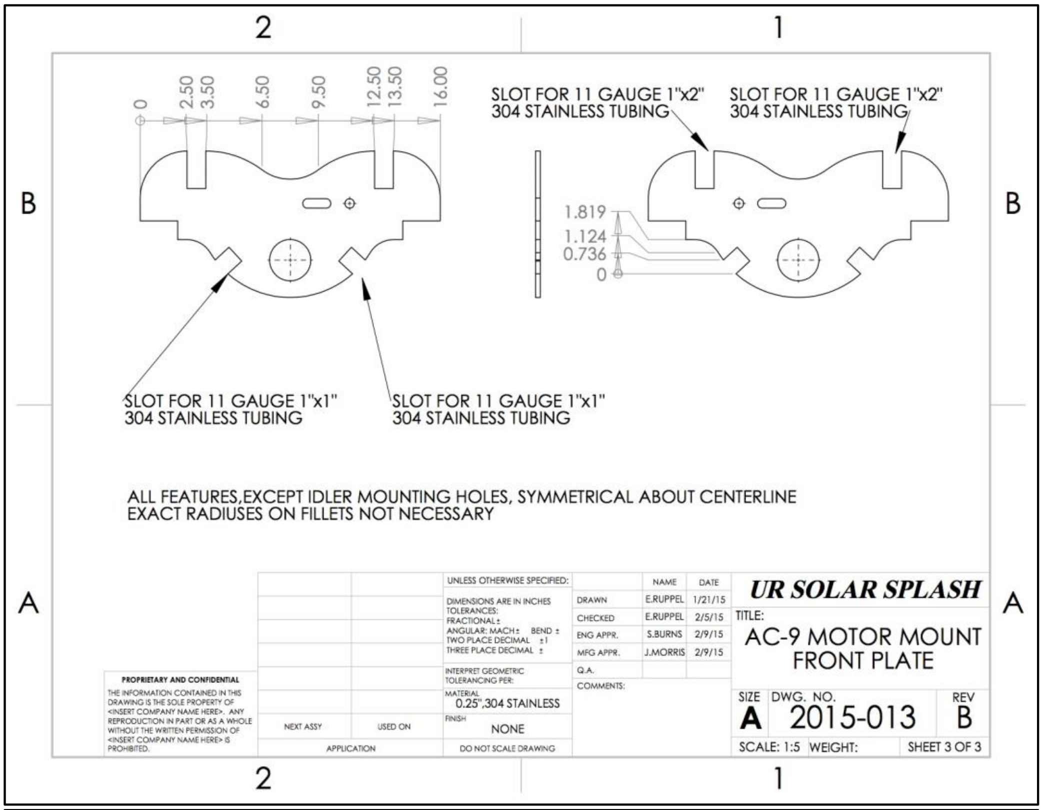
(2) Spring-loaded double lip seals have a second lip that blocks contaminants from the main lip. Maximum pressure is 10 psi at 0-1,000 fpm; 5 psi at 1,001-2,000 fpm; and 0 psi at 2,001-3,600 fpm.

Appendix N: Motor Mount Plates, Assembly, and Placement

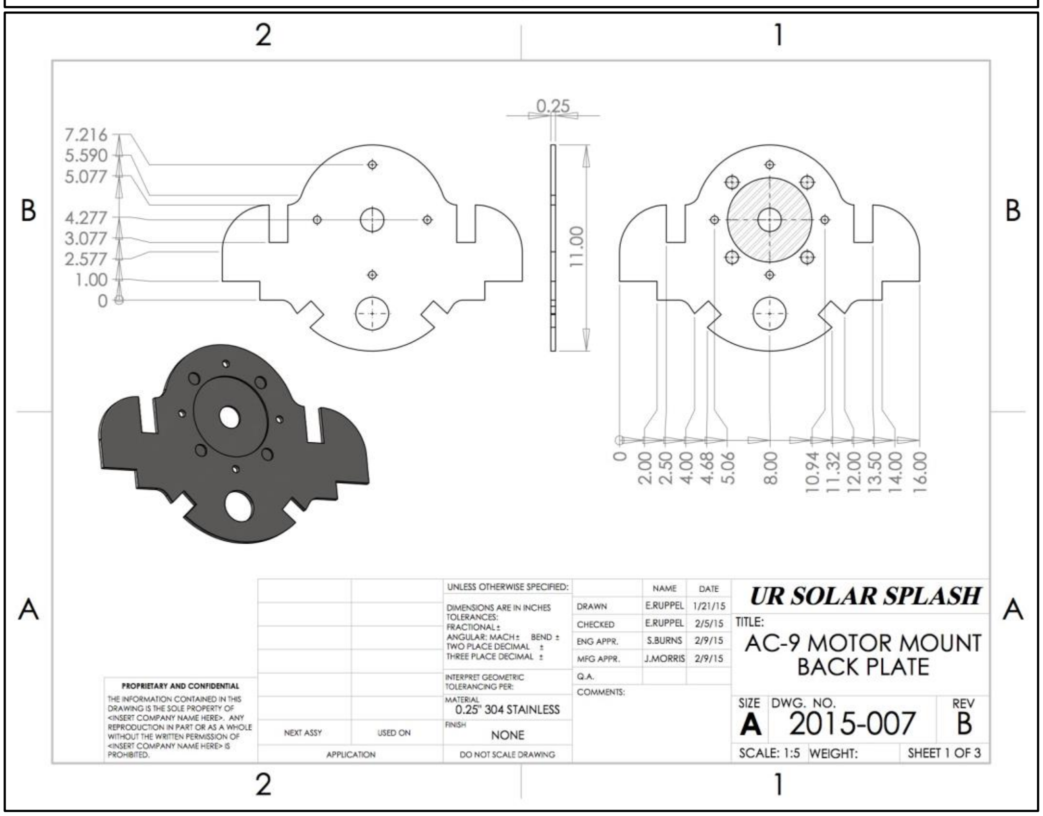
These figures depict the new motor mount design and the way it is specifically configured in the hull. Note that the curves of the back plate on the motor mount conform neatly to the cavity formed by the central planing hull. Round cuts decreased amount of required material without sacrificing rigidity and strength in stress and strain. All cuts and welds for the motor mount plates were contracted to John Miller.



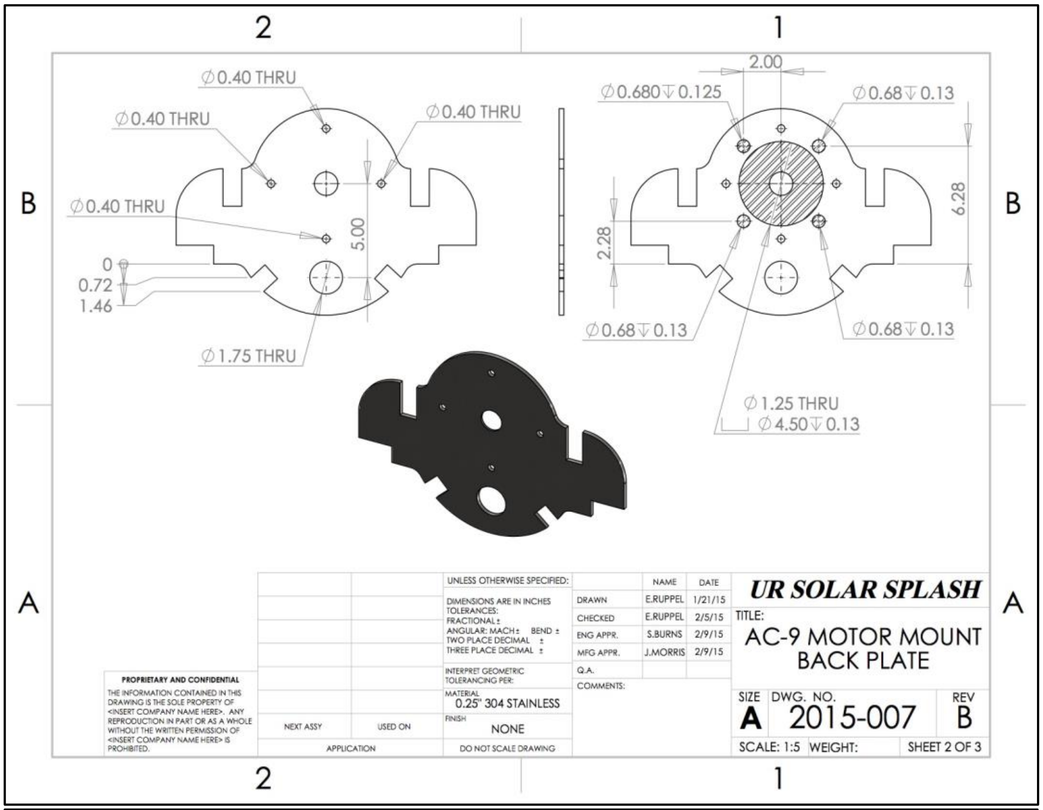




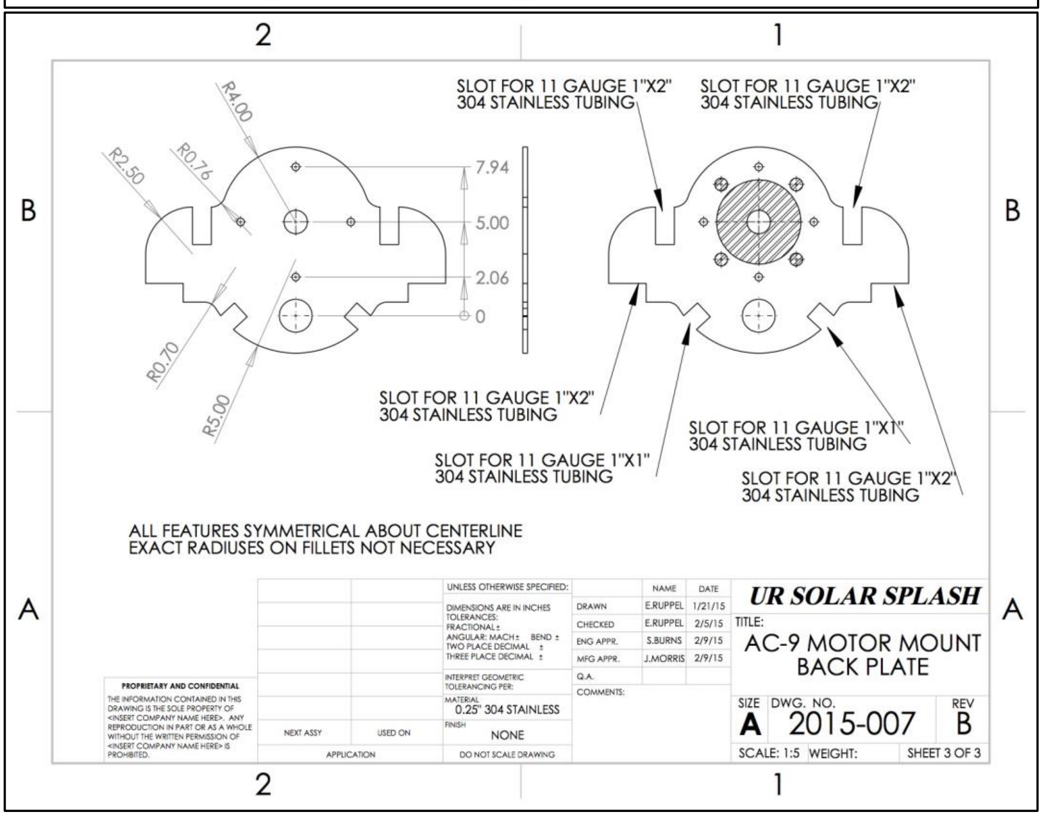
SLOT FOR 11 GAUGE 1"x2" 304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"x2" 304 STAINLESS TUBING
0
2.50
3.50
6.50
9.50
12.50
13.50
16.00
1.819
1.124
0.736
0
SLOT FOR 11 GAUGE 1"x1" 304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"x1" 304 STAINLESS TUBING
ALL FEATURES,EXCEPT IDLER MOUNTING HOLES, SYMMETRICAL ABOUT CENTERLINE
EXACT RADIUSES ON FILLETS NOT NECESSARY
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN E.RUPPEL 1/21/15
CHECKED E.RUPPEL 2/5/15
ENG APPR. S.BURNS 2/9/15
MFG APPR. J.MORRIS 2/9/15
MATERIAL 0.25",304 STAINLESS
FINISH NONE
UR SOLAR SPLASH
TITLE: AC-9 MOTOR MOUNT FRONT PLATE
SIZE A DWG. NO. 2015-013 REV B
SCALE: 1:5 WEIGHT: SHEET 3 OF 3



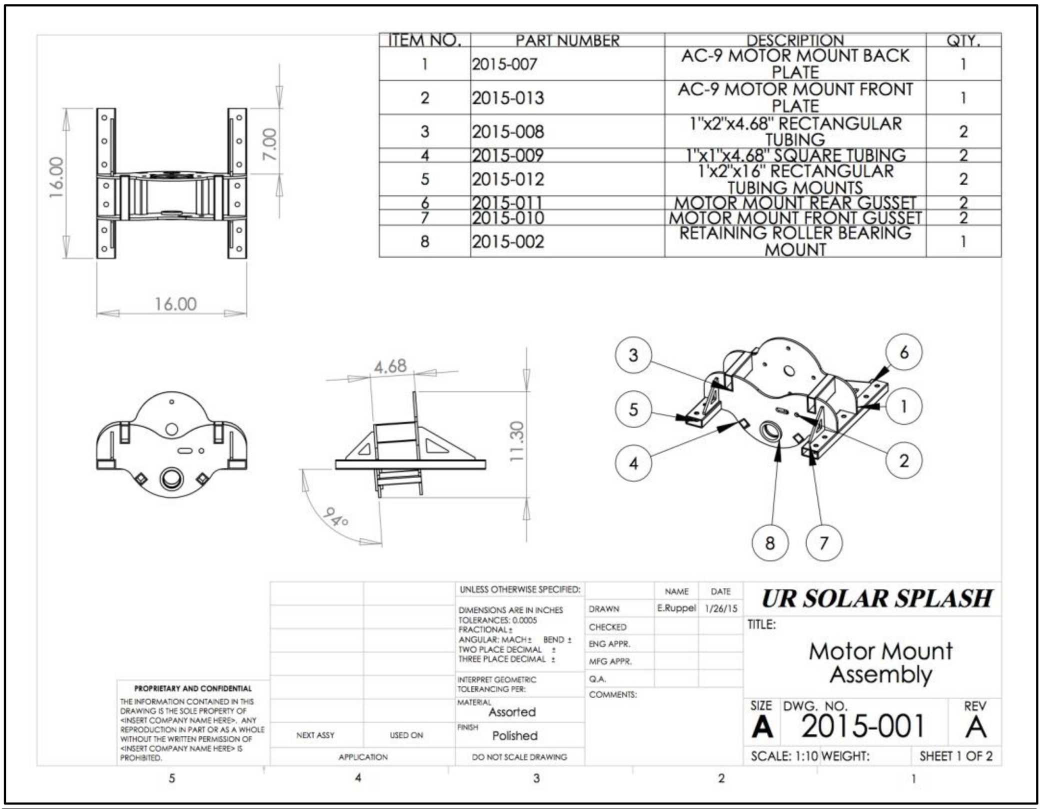
0.25
7.216
5.590
5.077
4.277
3.077
2.577
1.00
0
11.00
0
2.00
2.50
4.00
4.68
5.06
8.00
10.94
11.32
12.00
13.50
14.00
16.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN E.RUPPEL 1/21/15
CHECKED E.RUPPEL 2/5/15
ENG APPR. S.BURNS 2/9/15
MFG APPR. J.MORRIS 2/9/15
MATERIAL 0.25" 304 STAINLESS
FINISH NONE
UR SOLAR SPLASH
TITLE: AC-9 MOTOR MOUNT BACK PLATE
SIZE A DWG. NO. 2015-007 REV B
SCALE: 1:5 WEIGHT: SHEET 1 OF 3

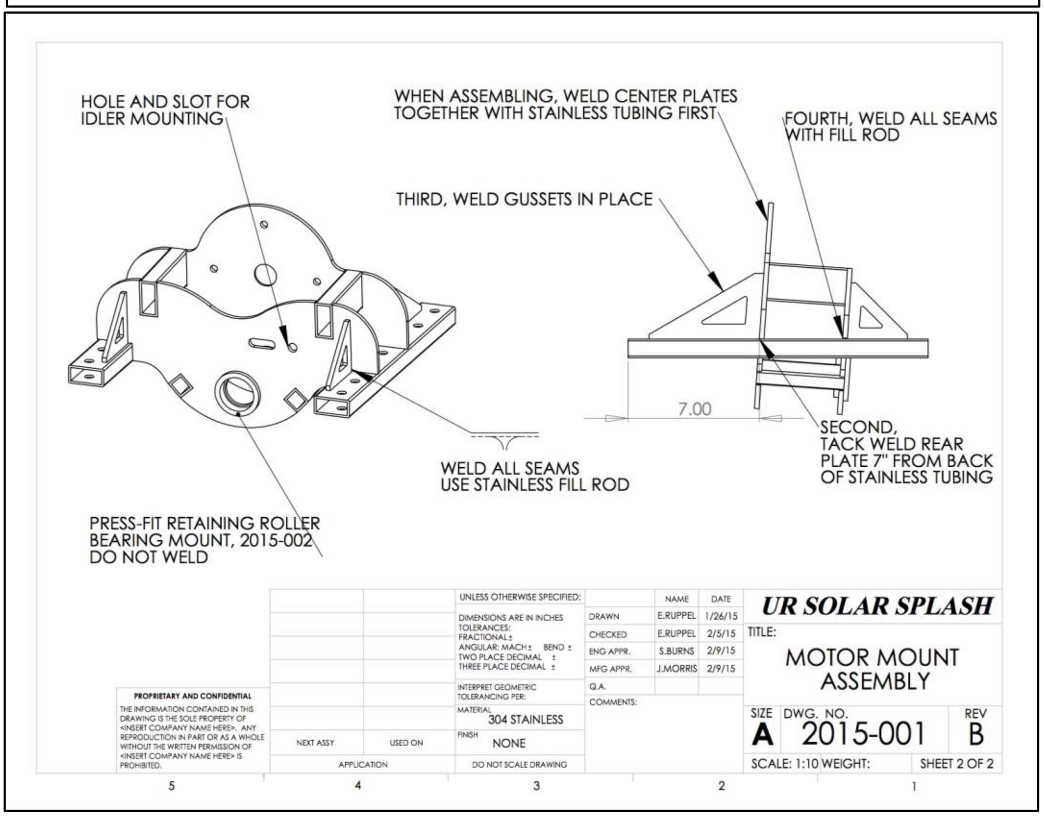


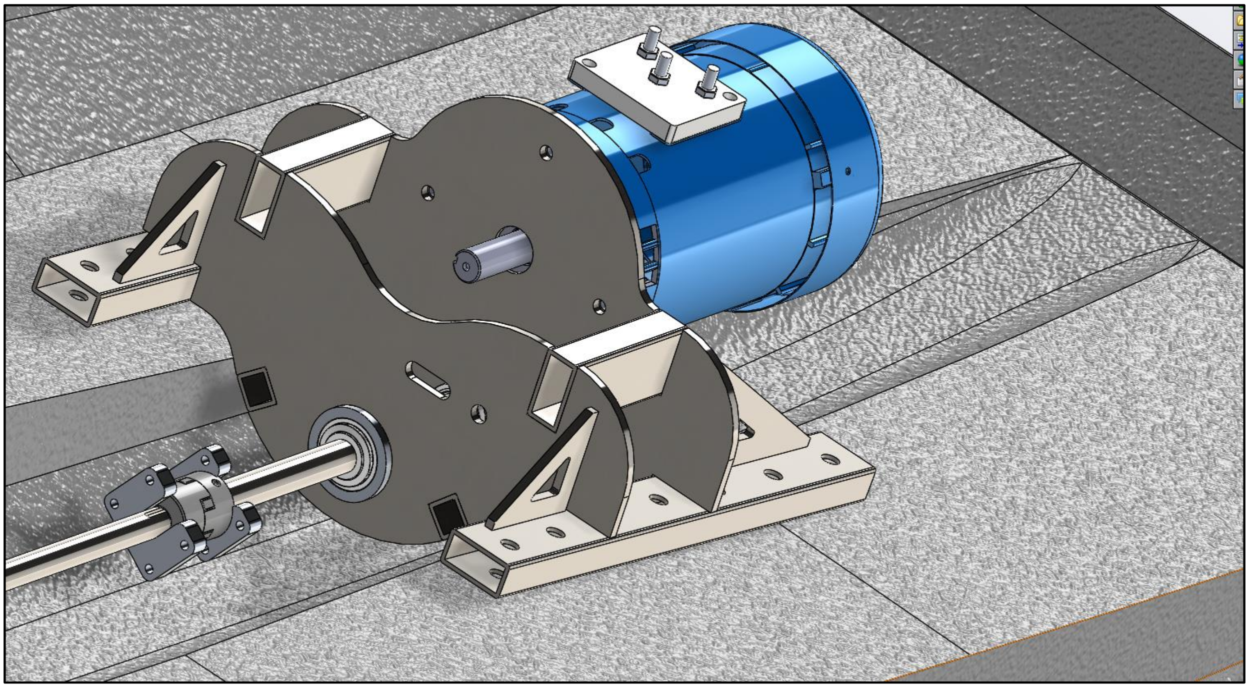
∅0.40 THRU
∅0.40 THRU
∅0.40 THRU
∅0.40 THRU
∅1.75 THRU
0
0.72
1.46
5.00
2.00
∅0.680 ↧ 0.125
∅0.68 ↧ 0.13
6.28
2.28
∅0.68 ↧ 0.13
∅0.68 ↧ 0.13
∅1.25 THRU
⌴ ∅4.50 ↧ 0.13
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
0.25" 304 STAINLESS
FINISH
NONE
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
DRAWN E.RUPPEL 1/21/15
CHECKED E.RUPPEL 2/5/15
ENG APPR. S.BURNS 2/9/15
MFG APPR. J.MORRIS 2/9/15
UR SOLAR SPLASH
TITLE:
AC-9 MOTOR MOUNT
BACK PLATE
SIZE A
DWG. NO. 2015-007
REV B
SCALE: 1:5
WEIGHT:
SHEET 2 OF 3

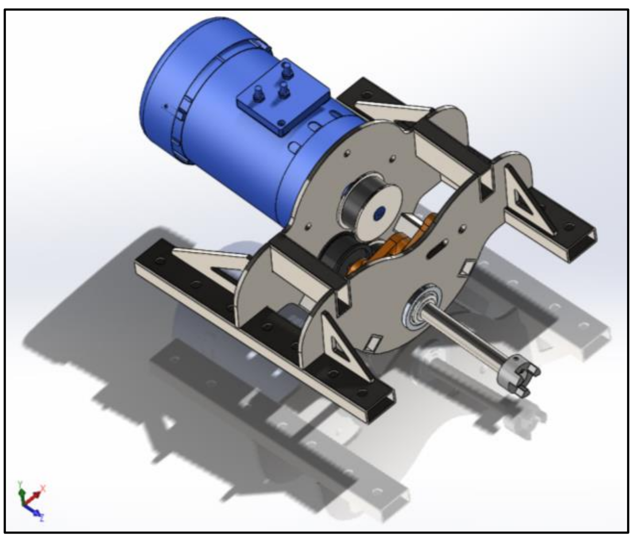


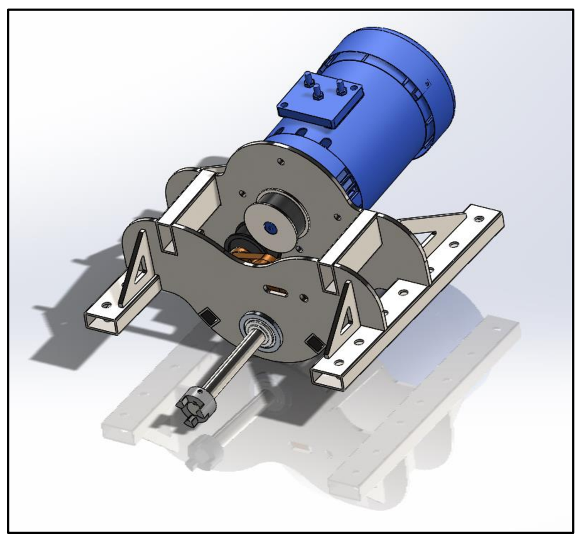
R4.00
R2.50
R0.76
R0.70
R5.00
7.94
5.00
2.06
0
SLOT FOR 11 GAUGE 1"X2"
304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"X2"
304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"X2"
304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"X1"
304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"X1"
304 STAINLESS TUBING
SLOT FOR 11 GAUGE 1"X2"
304 STAINLESS TUBING
ALL FEATURES SYMMETRICAL ABOUT CENTERLINE
EXACT RADIUSES ON FILLETS NOT NECESSARY
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
0.25" 304 STAINLESS
FINISH
NONE
DO NOT SCALE DRAWING
DRAWN E.RUPPEL 1/21/15
CHECKED E.RUPPEL 2/5/15
ENG APPR. S.BURNS 2/9/15
MFG APPR. J.MORRIS 2/9/15
UR SOLAR SPLASH
TITLE:
AC-9 MOTOR MOUNT
BACK PLATE
SIZE A
DWG. NO. 2015-007
REV B
SCALE: 1:5
WEIGHT:
SHEET 3 OF 3


ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
1 2015-007 AC-9 MOTOR MOUNT BACK PLATE 1
2 2015-013 AC-9 MOTOR MOUNT FRONT PLATE 1
3 2015-008 1"x2"x4.68" RECTANGULAR TUBING 2
4 2015-009 1"x1"x4.68" SQUARE TUBING 2
5 2015-012 1'x2"x16" RECTANGULAR TUBING MOUNTS 2
6 2015-011 MOTOR MOUNT REAR GUSSET 2
7 2015-010 MOTOR MOUNT FRONT GUSSET 2
8 2015-002 RETAINING ROLLER BEARING MOUNT 1
16.00
7.00
16.00
4.68
11.30
94°
UR SOLAR SPLASH
TITLE:
Motor Mount Assembly
DRAWN E.Ruppel 1/26/15
MATERIAL Assorted
FINISH Polished
SIZE A
DWG. NO. 2015-001
REV A
SCALE: 1:10
WEIGHT:
SHEET 1 OF 2


HOLE AND SLOT FOR IDLER MOUNTING
WHEN ASSEMBLING, WELD CENTER PLATES TOGETHER WITH STAINLESS TUBING FIRST
FOURTH, WELD ALL SEAMS WITH FILL ROD
THIRD, WELD GUSSETS IN PLACE
7.00
SECOND, TACK WELD REAR PLATE 7" FROM BACK OF STAINLESS TUBING
WELD ALL SEAMS USE STAINLESS FILL ROD
PRESS-FIT RETAINING ROLLER BEARING MOUNT, 2015-002 DO NOT WELD
UR SOLAR SPLASH
TITLE:
MOTOR MOUNT ASSEMBLY
DRAWN E.RUPPEL 1/26/15
CHECKED E.RUPPEL 2/5/15
ENG APPR. S.BURNS 2/9/15
MFG APPR. J.MORRIS 2/9/15
MATERIAL 304 STAINLESS
FINISH NONE
SIZE A
DWG. NO. 2015-001
REV B
SCALE: 1:10
WEIGHT:
SHEET 2 OF 2







Appendix O. Drive Train Concept Analysis

Concept 1 (Worm Gear) Calculations:

$$\text{Efficiency-worm} = \frac{\cos \alpha_n - \mu \tan \gamma}{\cos \alpha_n + \mu \cot \gamma}$$

α_n = Normal pressure angle = 20° as standard
γ = Worm lead angle = $(180/\pi)\tan^{-1}(z_1/q)$(deg)
z_1 = Number of threads (starts) on worm
μ = coefficient of friction (for lubricated steel on steel)
q = diameter factor

Worm shaft made large enough to survive its own stresses		
Torque	1800	ft-lb
Shaft diameter	1.6875	in
Shaft diameter	0.140625	ft
2nd AM = pi*d^4 / 64	1.91964E-05	ft^4
Radius c	0.0703125	ft
Shear stress Tc/J	6593029.278	psf
Shear stress Tc/J	45784.92554	psi

17-4 stainless	140000	psi
Safety factor	3.057774985	(unitless)

Safety Factor Calculations for Worm Gear Teeth, with load fatigue		
Sult	140000	psi
Se	70000	psi
Kl (for 18E6 cycles)	0.9	
Kt	1	
Kr	1	
Sf	63000	psi
J(Table 12-11)	0.36	
F	0.125	in
Pd	12	
Kb	1	
Ki	1.42	
Ks	1	
Kv	0.9	
Ka	1	
Km	1.6	
Wt	11675.67568	lb
Sig	7859891.892	psi
SF	0.008015377	

Concept 2 (Spur Gear) Calculations:

Spur System After Gearing		
Incoming torque	90	ft-lb
Gear ratio	1.4	lb-lb
Outgoing torque	126	ft-lb
Shaft diameter	0.875	in
Shaft diameter	0.072916667	ft
2nd AM = pi*d^4 / 64	1.38764E-06	ft^4
Radius c	0.036458333	ft
Shear stress Tc/J	3310474.37	psf
Shear stress Tc/J	22989.40534	psi
8620 steel	87000	psi
Safety factor	3.784351909	(unitless)

Appendix P: Drivetrain Stress Analysis

Drive Shaft:

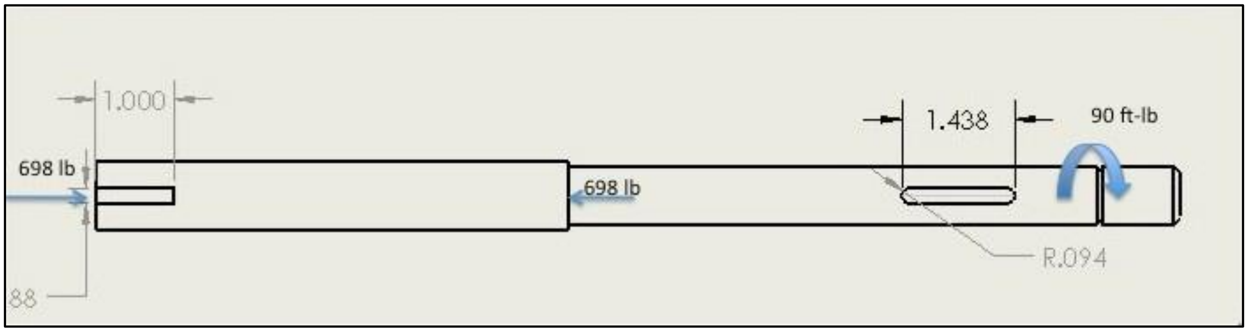


Figure P1: Drive Shaft FBD

The drive shaft was analyzed at the point where it most likely to fail, the interface between the 1'' and the ¾'' diameter which is located at the thrust bearing. This area creates a stress concentration which increases the chance of failure. The axial loads, 698 lbs., are well within the critical load for buckling (on the order of 15x10^3 psi) so the factor of safety wasn't considered for this scenario. Using a bending moment of 19 ft.lb (mostly from the shafts own weight) and an applied torque of 90 ft.lb, we were able to calculate the factor of safety for the shaft. Other parameters considered were the stress concentration at the bearing interface, which we found to be 1.7, and the material properties of 1040 steel. The factor of safety for the beam using these parameters was calculated to be 4.5.

Front Thrust Plate:

The thrust load from the propeller is supported by a thrust bearing. We ensure that the loads are transferred to the bearing by tapering the propeller shaft from 1'' diameter to ¾'' at the bearing interface. The bearing itself is discusses elsewhere, but assuming a solid bolted fit, the thrust forces will be transferred from the thrust bearing to the thrust plate. We initially had two options for the plate, one at 0.125'' thickness and another at 0.25'' thickness. Both designs were 4''x 7.5'' we analyzed the stresses and displacements in each option to determine if the plate would deform beyond the tolerance of our system (near 0.02 inches to ensure the roller bearing's safety).

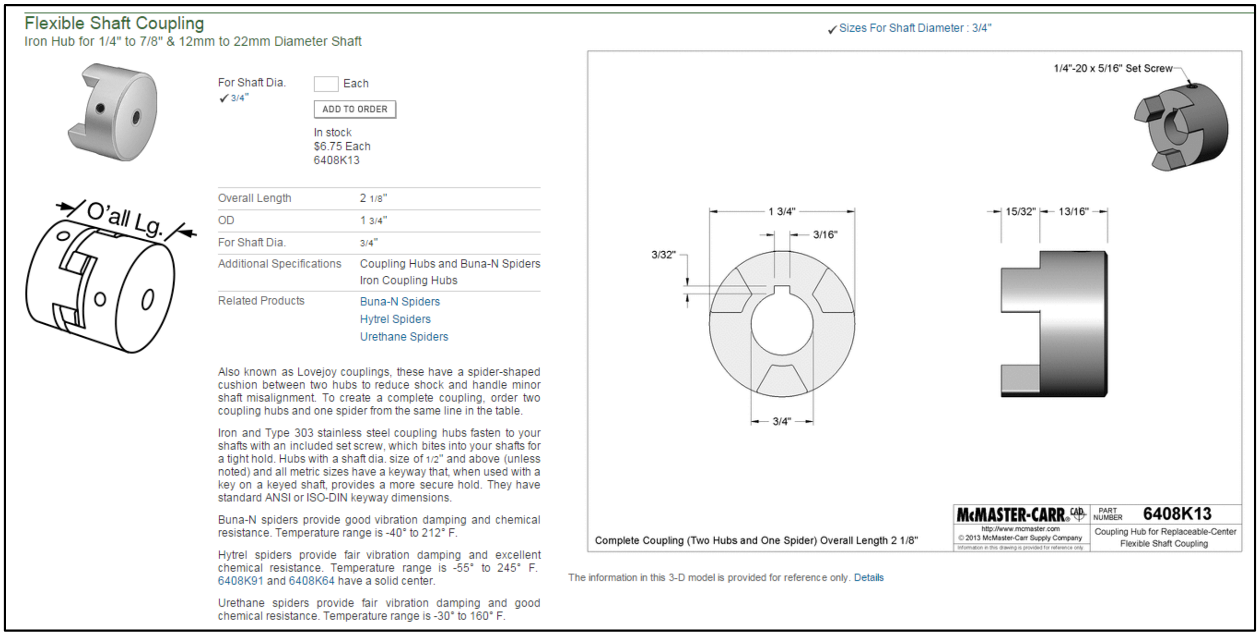
The 0.125'' design was analyzed in Patran, with non-displacement conditions at the interfaces between the 1 inch^2 stainless support bars and the corners of the plate. The load was estimated as a 698 lb. thrust load. The load was conservatively estimated by assuming that the 100% of the motor's peak power output (~33,000 ft. lbs.) is transferred to the propeller, the thrust force is the peak power divided by the foreword velocity. The maximum speed of the boat is near 28 knots/hour, thus we calculate the maximum thrust load to be 698 lbs. We divided the load in equal sections across an area 0.05 square inches around each bolt hole.

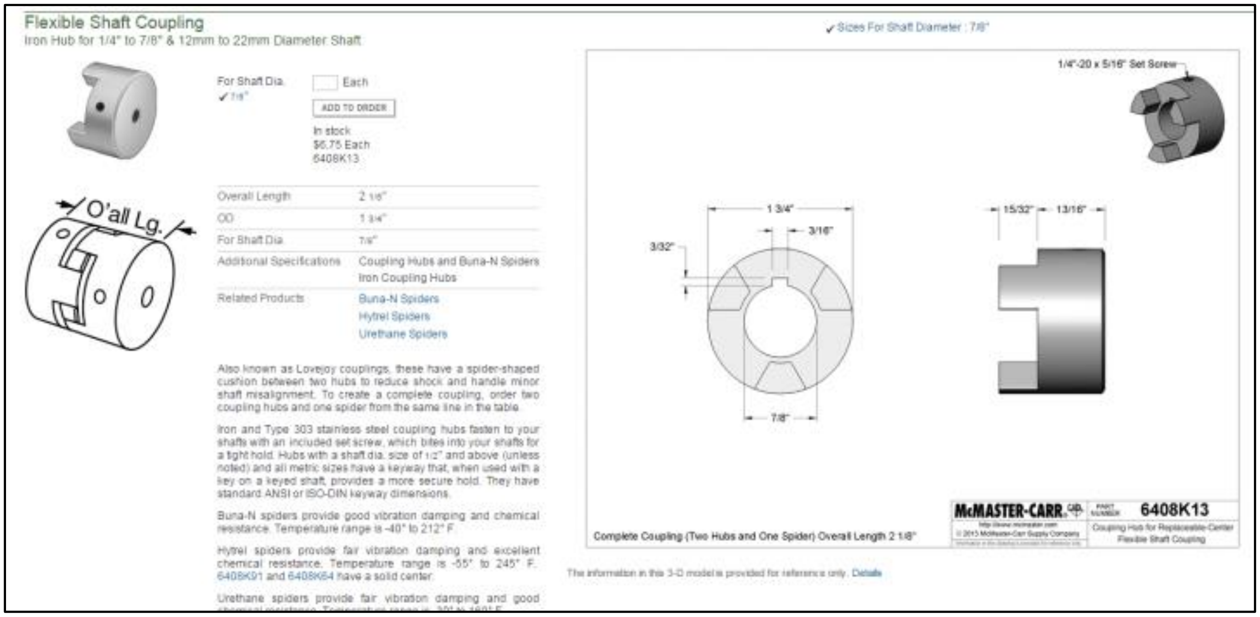
We saw that the deformation on the plate in the z-direction (thrust direction) was too small (3.23×10^{-4} inches) to disrupt the function of the roller bearing. The peak stresses within the plate were satisfactory, as 23,100 psi gave us a safety factor of 2.87. We then analyzed a 0.25'' plate in Nastran to examine its deformations. We used similar boundary conditions as before, but since the thrust bearing is being connected with a mounting plate this time, we used a distributed force around the edge of the inner circle to model the thrust force.

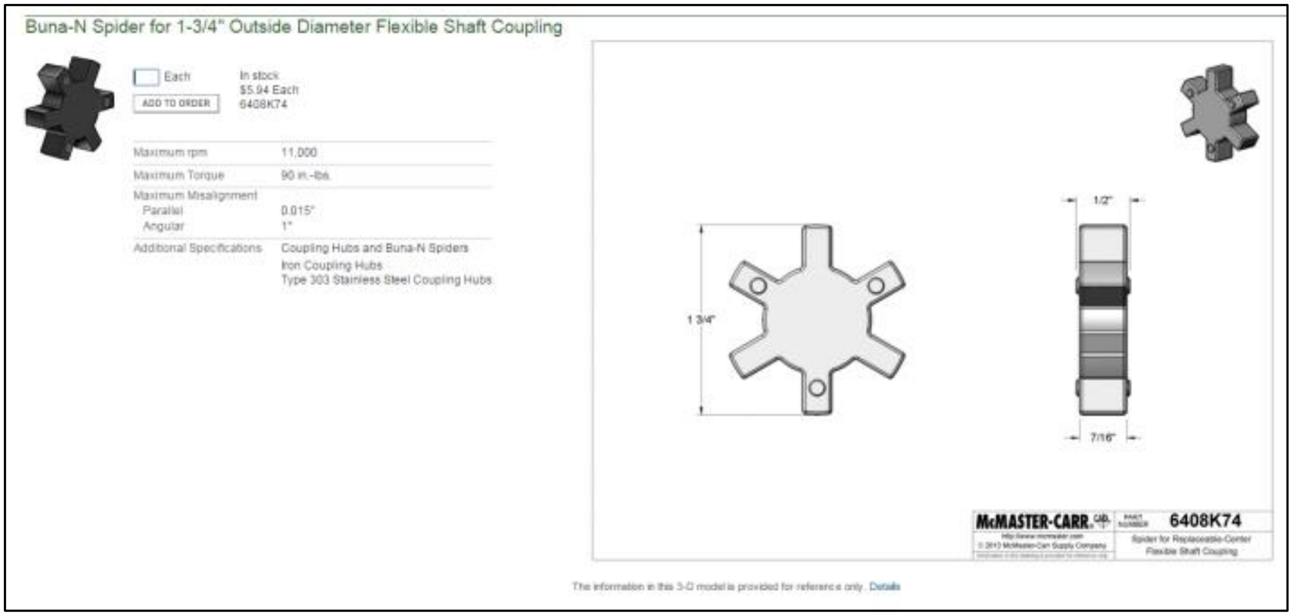
The model showed that the plate held up to the forces much more robustly. Its maximum deformation was only 0.000183 inches, within our tolerance and the max stress was 2910 psi. For 304 stainless this gives the design a safety factor of 21.3. The entire drive train is encased within the boat so elemental factors were no taken into account. The thicker plate's improved performance and safety factor enticed our group to use the thicker plate design.

Appendix Q: Shaft Coupling Parts

The shaft coupling used in joining the drive shafts used the following parts.





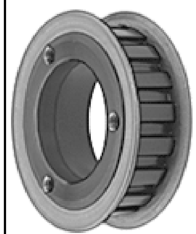

Buna-N Spider for 1-3/4" Outside Diameter Flexible Shaft Coupling
Each
ADD TO ORDER
In stock
$5.94 Each
6408K74
Maximum rpm 11,000
Maximum Torque 90 in.-lbs.
Maximum Misalignment
Parallel 0.015"
Angular 1°
Additional Specifications Coupling Hubs and Buna-N Spiders
Iron Coupling Hubs
Type 303 Stainless Steel Coupling Hubs
1/2"
1 3/4"
7/16"
McMASTER-CARR
6408K74
Spider for Replaceable-Center
Flexible Shaft Coupling
The information in this 3-D model is provided for reference only. Details

Appendix R: Motor Belt and Pulley

This motor belt and neoprene timing belt were used in the motor.

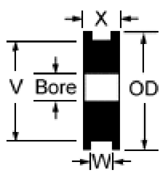
L and H Series Timing Belt Pulley

H-Series, Fit 3/4" & 1" Wide Belt, 3.11" OD, SH Bushing



Each
ADD TO ORDER

In stock
$39.47 Each
6495K513



OD	3.11"
Number of Teeth	18
Bushing	
Style	SH
Bore	1.871"
Pitch Diameter (V)	2.865"
(W)	1 1/16"
(X)	1 5/16"
Additional Specifications	Pulleys for H (Heavy) Timing Belts—1/2" Pitch Fit 3/4" and 1" Belt Wd.

For fast installation and removal, use these pulleys with Quick-Disconnect (QD) Bushings (sold separately). All of the pulleys are made of machined steel (unless noted). They are flanged (unless noted) and have a quick-disconnect bushing bore.

View our offering of L series and H series timing belts.

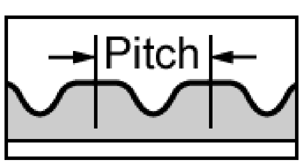
Trapezoidal Tooth Neoprene Timing Belt

1/2" Pitch, Trade Size 210H, 21" Outer Circle, 1" Wide

Each
ADD TO ORDER

In stock
$21.56 Each
6484K401

You ordered 1 each on 04/23/15.



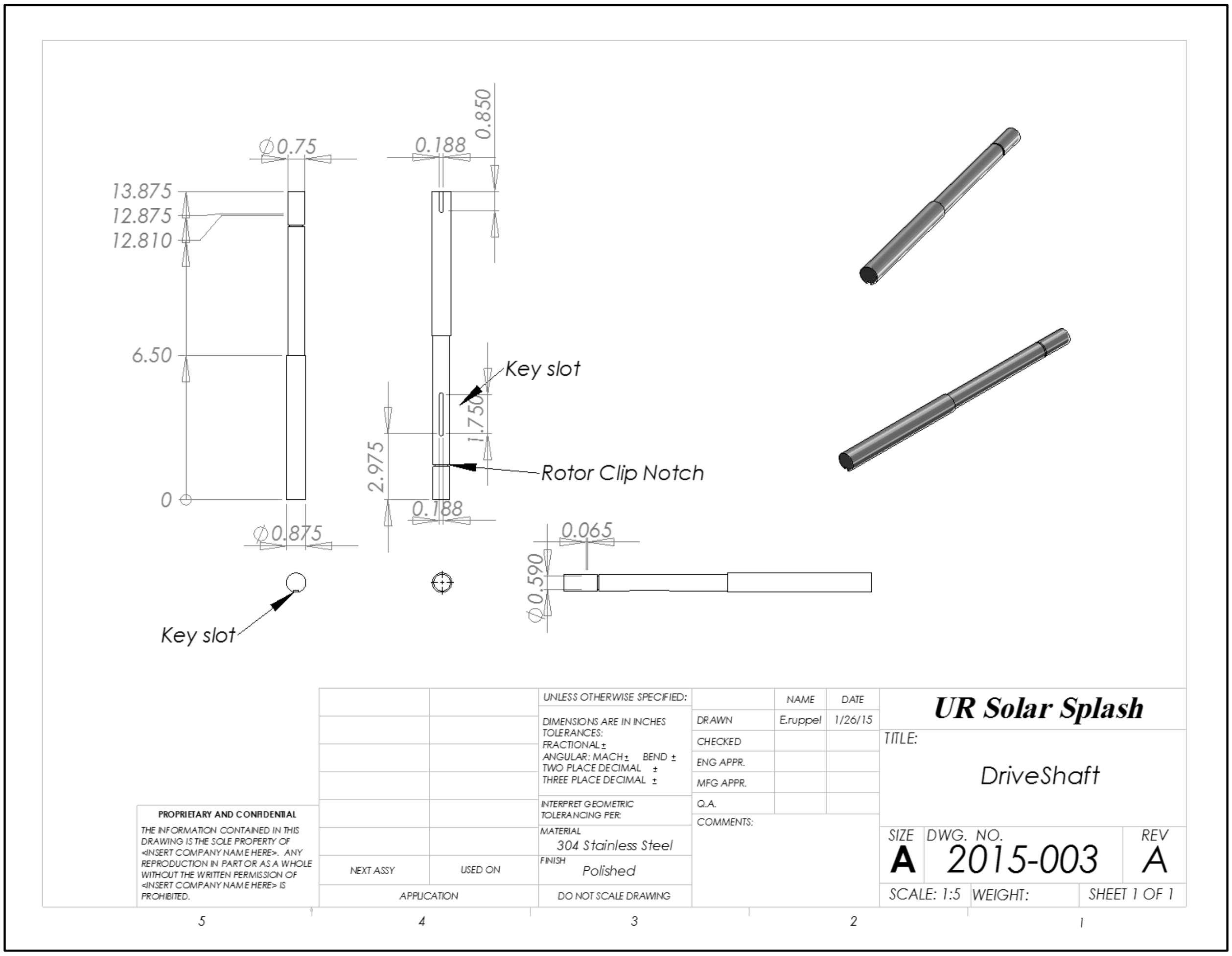
Trade Size	210H
Outer Circle	21.0"
Number of Teeth	42
Additional Specifications	1" Wide Neoprene—Reinforcing cords are fiberglass.

These trapezoidal-tooth H (Heavy) belts mate with grooves in timing-belt pulleys. For use in a fully synchronized drive system. Have a 1/2" pitch. Color is black, unless otherwise indicated.

Neoprene—Run quieter than urethane.

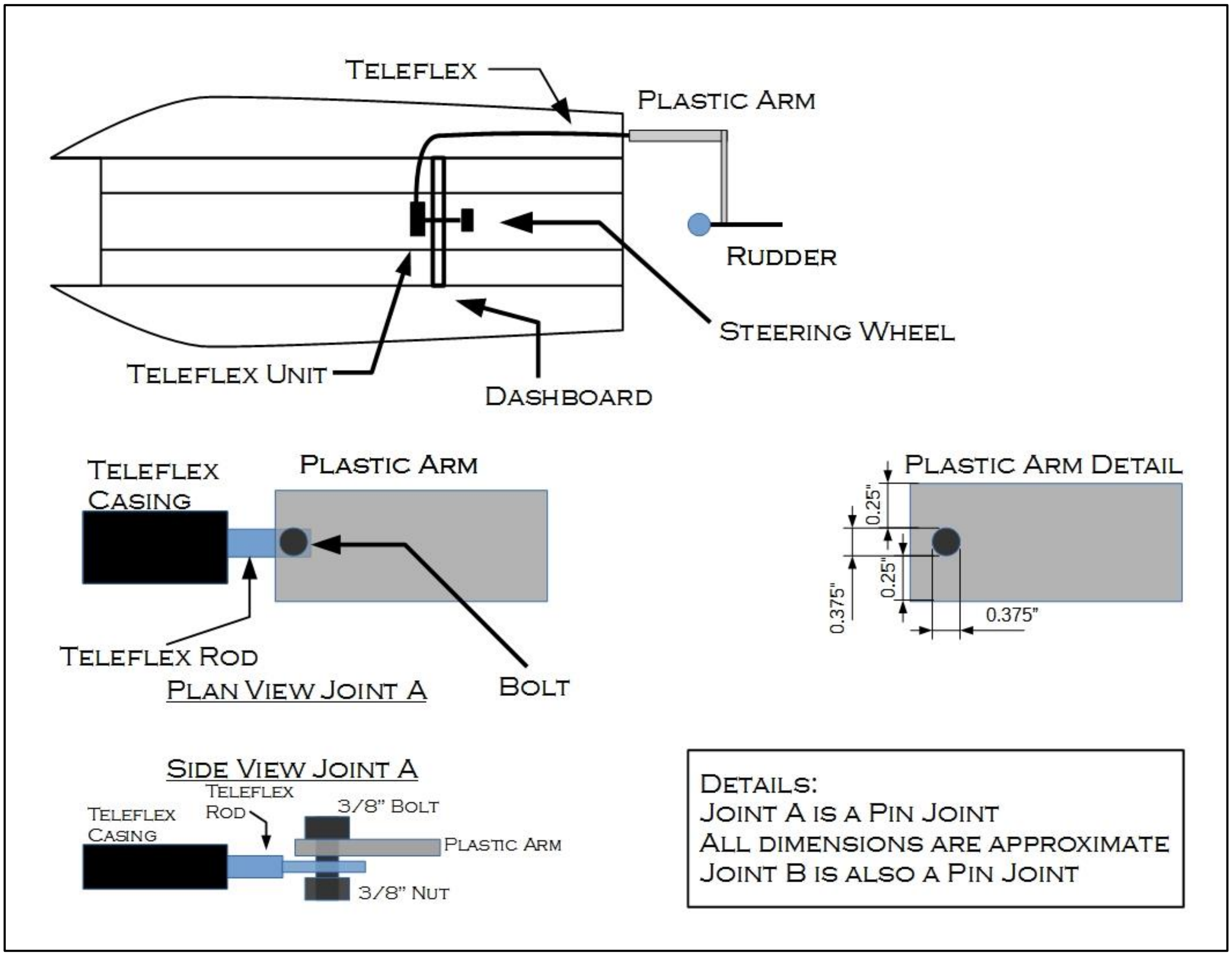
Appendix S: Drive Shaft Specifications

Specifications for the drive shafts used in the boat.



Appendix T: Steering Mechanism

This is a schematic of the steering mechanism used in this year's design.



Appendix U: Corecell Technical Data

Material specifications for Corecell foam used as central interface material within stringer construction.

Gurit

Corecell™ A-Foam

Structural Core Material

- **Exceptional impact tolerance**
- **Suitable for dynamically-loaded structures**
- **Superior styrene and temperature resistance to linear PVC foam**
- **Highly thermoformable**
- **Ideal for resin infusion**

Introduction

Corecell A-Foam shares the benefits of SAN chemistry common to all **Core**cell products.
Built in toughness – Very high ductility and damage tolerance
Environmental stability – High tolerance for heat and chemical exposure
Fine cell size – Resin absorbtion is very low, saving both weight and cost
Superior uniformity – Low density variation
Compatibility – Suitable for use with all polyester, vinylester and epoxy resins
Handling – Tough and easy to machine
No inhibition - **Core**cell does not inhibit epoxy curing mechanisms

Corecell A-Foam is the original **Core**cell material, developed because of frustrations with inadequate PVC core technology in marine sandwich structures. **Core**cell A-Foam is well known for it's incredible toughness and resistance to cracking, which comes from its high ductility. **Core**cell A-Foam can elongate up to 65% in shear before failure, making core shear failure in a laminate almost impossible. Tests and experience show that **Core**cell A-Foam is the most reliable core material for dynamic loading situations where PVC and balsa may fail due to poor shear elongation properties. This reliability has made **Core**cell A-Foam the preferred choice amongst offshore yachtsmen for twenty years.

For the manufacturer, **Core**cell A-Foam offers the benefit of high resistance to styrene and other chemicals and better thermal stability than linear-PVC foam. **Core**cell A-Foam is also highly thermoformable, which is useful in many applications where cutting the core material is undesirable.

Corecell A-Foam is available in every resin infusion format and is compatible with polyester, vinylester and epoxy resin systems. The low resin absorption characteristics of **Core**cell and it's unique knife-cut formats deliver higher performing infusions, low resin cost and low weight. Gurit's global technical team have 10 years experience in resin infusion and offer on-site support for **Core**cell customers. This combination makes **Core**cell a key part of a reliable package.

Approvals
- Accepted for DNV Slamming and Fatigue Applications
- Approved by the US Coast Guard for use as buoyancy foam
- Approved by the US Coast Guard for use as sandwich core material in the structures of integral diesel fuel tanks
- Type approved by: The American Bureau of Shipping, Germanischer Lloyd, Det Norske Veritas

Gurit

Type	Test Method	Units	A400	A450	A500	A550	A600	A800	A1200
Nominal Density		kg/m^3	69	81	92	103	116.5	150	210
		lb/ft^3	4.3	5.0	5.7	6.4	7.3	9.3	13.1
Density Range		kg/m^3	64-74	75-86	87-97	98-108	109-124	140-160	200-220
		lb/ft^3	4.0-4.6	4.7-5.4	5.4-6.0	6.1-6.7	6.8-7.7	8.7-10.0	12.5-13.7
Compression Strength	ASTM D1621	MPa	0.6	0.8	0.9	1.1	1.4	2.1	3.9
		psi	90	112	135	161	197	308	564
Compressive Modulus	ASTM D1621b	MPa	41	53	64	72	83	117	217
		psi	5950	7620	9290	10450	12040	16980	31490
Shear Strength	ISO 1922	MPa	0.7	0.8	1.0	1.1	1.2	1.6	2.6
		psi	102	123	144	157	176	229	373
Shear Modulus	ISO 1922	MPa	22	24	26	30	34	47	76
		psi	3190	3480	3770	4350	4930	6820	11030
Shear Elongation	ISO 1922	%	63%	63%	69%	66%	64%	50%	46%
Tensile Strength	ASTM C-297	MPa	0.9	1.1	1.3	1.6	1.8	2.5	3.9
		psi	135	165	194	225	264	364	560
Tensile Modulus	ASTM C-297	MPa	50	65	81	97	120	183	321
		psi	7260	9430	11750	14080	17410	26560	46580
Thermal Conductivity	ASTM C518	W/mK	0.03	0.03	0.04	0.04	0.04	0.04	0.05
Dimensional Stability	DIN 53424	°C	63	63	63	63	63	63	63
		°F	145	145	145	145	145	145	145

* Peak change rate under static load

Intermediate densities may be available on request, subject to minimum order quantities.

Please Note

:Data quoted is average data at each product s nominal density, and is derived from our regular testing of production materials.

Statistically derived minimum value data, satisfying the design requirements of various classification societies, is available on request.

Notice

All advice, instruction or recommendation is given in good faith but Gurit AG (the company) only warrants that advice in writing is given with reasonable skill and care. No further duty or responsibility is accepted by the Company. All advice is given subject to the terms and conditions of sale (the Conditions) which are available on request from the Company or may be viewed at the Company's Website: www.gurit.com/termsandconditions_en.html.

The Company strongly recommends that Customers make test panels and conduct appropriate testing of any goods or materials supplied by the Company to ensure that they are suitable for the Customer's planned application. Such testing should include testing under conditions as close as possible to those to which the final component may be subjected. The Company specifically excludes any warranty of fitness for purpose of the goods other than as set out in writing by the Company. The Company reserves the right to change specifications and prices without notice and Customers should satisfy themselves that information relied on by the Customer is that which is currently published by the Company on its website. Any queries may be addressed to the Technical Services Department.

Gurit are continuously reviewing and updating literature. Please ensure that you have the current version, by contacting Gurit Marketing Communications or your sales contact and quoting the revision number in the bottom right-hand corner of this page.

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