THE COLLEGE OF NEW JERSEY
SOLAR SPLASH 2016 TECHNICAL REPORT

June 15, 2016 Boat #10

Team Members:
Joseph DiLorenzo (M.E.)
Timothy Mindnich (M.E.
Matthew Berry (E.E.)
Katherine Cipolla (M.E.)

Faculty Advisors:
Dr. Karen Yan
(Primary Advisor)
Dr. Norman Asper
(Mechanical Advisor)

The College of New Jersey

I. Executive Summary

The IEEE Solar Splash competition is an international intercollegiate boat regatta where teams design and build solar powered boats to compete in a series of events. The competition is composed of a slalom event, designed to test maneuverability, an endurance event, designed to test efficiency, and a sprint event, designed to test maximum power. There is also a qualifying event further testing both maneuverability and power, as well as a technical report and poster presentation. There is a maximum 1000 point total for all events and the team with the most points is declared the winner.

The 2016 TCNJ Solar Splash Team is reverse engineering the 2015 team designs with the goal of being highly competitive throughout the entirety of the competition. The team is improving the longitudinal weight distribution from the previous stern-heavy craft in both configurations.

The location of the endurance motor will be redesigned to minimize the moment distribution at the stern during sprint configuration. In addition, the endurance shaft connection will be redesigned to an angled and offset connection, allowing the endurance propeller to align proportionally with the steering rudders.

To increase the level of anticipated success in the drivetrain, the current student fabricated propeller will be replaced with a professionally manufactured propeller to remove uncertainty in sprint configuration.

The steering rudders will be reconstructed to a hydro airfoil cross-sectional design, allowing the steering system to incorporate hydrodynamic capabilities. Hydro rudders will provide more effective maneuverability and reduce drag forces.

The boat's electrical system will build on prior team's electrical systems to reduce the amount of components needed, and utilize the necessary components more effectively. Following the redesign of the electrical system, will be extensive testing to avoid any uncertainty in the system during competition.

In the final phase of the electrical system design, a real time data acquisition telemetry system will be implemented to allow for constant and consistent data review during competition to increase the team's chances of success.

Table of Contents

II. Overall Project Objectives

The Solar Splash competition is a five-day event in Dayton, Ohio, in which college teams from different parts of the world come together to compete with their solar/electric watercraft. Previous years' designs were reviewed to make improvements and design changes where necessary. In the past, TCNJ teams (with a few exceptions) have been less effective in the sprint competition. This seems to have largely resulted from issues with cavitation. This caused a large loss of efficiency and prevented the boat from achieving its maximum theoretical speed.

Additionally, the longitudinal weight distribution of the craft has led to complications in the mechanical designs. The most previous team incorporated a surface drive design that added a significant load to the stern. This requires making modifications to the locations of certain systems of larger masses.

Another complication in years past has been the efficiency of the steering system. The previous designs incorporated a simplistic cable steering system with a T-bell crank design, incorporating twin rudders. However, in years past, these rudders have provided little hydrodynamic capabilities.

The 2015 team designed and manufactured a new, competitive boat to meet the following objectives:

Hull Design

1. Design hull to be efficient in sprint and endurance competitions
2. Design for lightweight hull
3. Ensure easy configuration changes between events

Steering System

1. Improve maneuverability with new hydrodynamic airfoil design
2. Provide stability for the driver in sprint configuration going at high speeds
3. Achieve a 30° range of motion

Drivetrain

1. Design a modular drivetrain setup to maximize performance across all competition
2. The endurance system must deliver a speed of 500 RPM at the propeller
3. The sprint system must deliver a propeller speed of 4266 RPM

Propeller

1. Surface piercing design to achieve maximum efficiency when craft is at an angle of inclination of 0°
2. Assure manufacturing efficiency by purchasing professionally designed prop

Electrical System

1. Design a motor controller system to maximize the efficiency
2. Integrate the solar panels into the system to power the boat in the endurance race

Telemetry

1. Provide real time data for the solar array voltage & current, battery voltage & current, and propeller RPM

III. Solar System Design

The solar system array consists of two unmodified SCHOTT 240 Watt solar panels. The solar panels will be fixed to the hull with one near the bow and one behind the driver. Each of the 2 solar panels weigh 41.4 lbs for a total solar array weight of 82.8 lbs. and will be positioned such that the weight of the solar panels will offset the weight of the surface drive and drivetrain to make the boat level with the waterline during the endurance event. In past competitions, TCNJ has created a frame out of 80-20 aluminum rails to hold the solar panels between events that allows for easy repositioning of the panels for battery charging. The frame is on wheels, which allows the panels to be easily repositioned on the ground, and can be rotated up or down to align with the sun. The team will be reusing this framework from last year's boat to quickly charge the batteries between events.The technical data regarding the solar panels is located in Appendix I.

Last year's boat to quickly charge the batteries between events. The technical data regarding the solar panels is located in Appendix I.

IV. Electrical system

1. *System Configurations*

The complete electrical schematic as seen in Fig. 1 is relatively similar to last year's electrical system design, with the addition of two SPST relays and one SPDT relay. Having two main electrical mode configurations – sprint and endurance – the electrical panel was designed so as to require minimal team alterations in between competition events, less changing the battery arrays. To do so, the configurations were designed so as to utilize as many concurrent components amongst each other. Both the endurance and sprint configurations utilize bypass sub-modes in order to bypass the motor controller(s) at a certain point for competitive advantage. Wiring for the sprint and sprint bypass configurations utilized 1/0 AWG welding cable as where the endurance and endurance bypass configurations only required #4 AWG wire. Not visible in the schematic below, the two additional SPST solenoids were installed so that the flow of current to the endurance and sprint drivetrain could be controlled from the helm of the craft. The additional SPDT solenoid was integrated into the design so that the positive and negative lead of each MPPT could be isolated from each other.

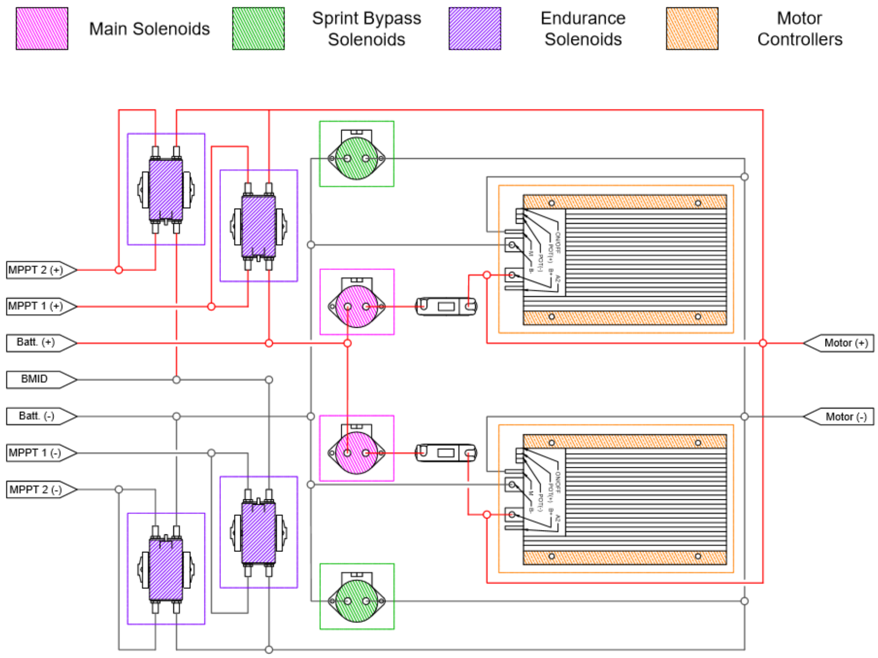


Fig. 1: Electrical Schematic

2. *Motor Controllers*

2.1 Design

Last year's electrical system implemented two Alltrax AXE4855 motor controllers, however due to electrical malfunctions, one of them became damaged to the point of it being irreparable. Fortunately, there were an additional pair of Curtis 1221b controllers available for use. These controllers were chosen for the electrical system design because of their ability to meet our financial and performance needs. During the sprint portion, both controllers are active, but the endurance configuration only uses one of the controllers.

2.2 Analysis of Design

Multiple design alternatives to solve the issue at hand were looked into, however by view of table 1, it becomes clear that few alternatives to the Curtis controllers were worthy of consideration.

Table 1: Design Alternatives

Manufacturer	Model	Nominal Battery Voltage	2 min. Rating Amps	Current Limit (5 sec. boost)	Amp Rating 1 Hr. Later	Price (per controller)
Curtis Intruments	1221B-48xx	24-36	600	600	250	$0.00
Curtis Intruments	1205M-46xx	24-36	500	550	175	$590.00
Alltrax Inc.	AXE4855	24-48	500	500	250	$669.00
Alltrax Inc.	AXE4865	24-48	650	650	250	$674.00

The available pair of Curtis controllers, had better performance specifications that all but one of the possible replacement controllers, came at a cost of nothing, and met the craft's design constraints with ease.

2.3 Design Testing and Evaluation

Both of the two Curtis 1221b controllers worked as intended during preliminary testing in the fall semester as well as during competition testing in April. Capable of handling 800 amps, the controllers also allow for the sprint bypass configuration to be used without fear of damaging the controllers again.

V. Power Electronics System

1. *Current Design*

For the sprint configuration, original power system utilized 2 sets of batteries connected in parallel, with each set of batteries composed of three Odyssey PC680 batteries connected in series for a 36V array. As where the endurance configuration implemented two Interstate MTP-93 batteries connected in series for a 24V array. Both battery arrays did not exceed to 100 lb. weight limit. The endurance battery selection did not change from last year as the batteries were never used due to electrical system issues that prevented the team from competing. However, the sprint battery array was changed to 3 Optima 25 Red Top batteries connected in series. The parameters surround these decisions can be seen in tables 2 and 3.

Table 2: Parameters for Sprint Battery Options

Manufacturer	Model	Volts	Cranking Amps	Weight (lbs.)	Cost (USD)
Odyssey	PC680	12	280	15.4	$0.00
Odyssey	PC625	12	340	13.2	$111.50
Optima	25 Red Top	12	910	31.7	$169.99

Table 3: Parameters for Endurance Battery Options

Manufacturer	Model	Amp Hours Per Battery (20 Ah)	Per Unit MCA (Amps)	Per Unit Voltage (Volts)	Per Unit Weight (lbs)	Per Unit Cost	Array Ah	Array Weight	Array Cost
Interstate	MTP-93	90	850	12	42.9	$0.00	180.00	85.80	$0.00
Trojan	SCS150	100	650	12	50	$142.63	200.00	100.00	$285.26
Interstate	MTP-49/H8	100	910	12	50	$191.95	200.00	100.00	$383.90

2. *Analysis of Design Concepts*

From the Fig.s, it can be seen that the decision to replace the endurance batteries could not be justified from a cost benefit analysis. However, the decision to alter the sprint battery configuration garnered an additional 70 Amps, which translates to an additional 12 kW from the array.

3. *Design Testing and Evaluation*

At this moment in time the newly purchased Optima sprint batteries have not been received by the team, so the evaluation of the decision is not able to be completed at this point in time.

4. *Configuration*

In past designs, the arrays of batteries place within a series and connected in parallel was done to optimize amps and while meeting motor voltage requirements. However, because both configurations connect the batteries in series, this strategy has little use to the 2016 team. The configurations can be seen in Fig. ( ) and ( ).

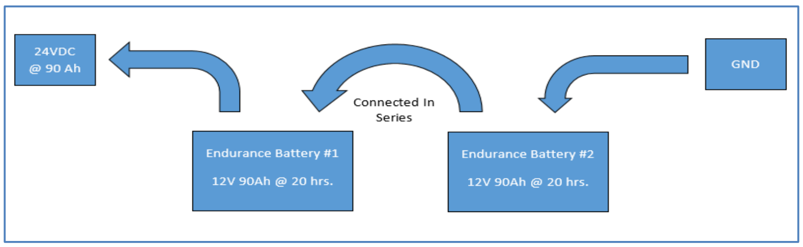


Fig. 2: Endurance Configuration

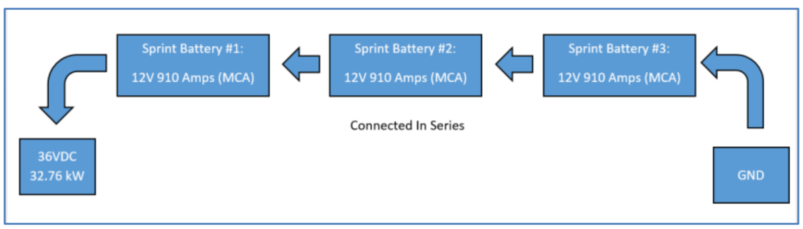


Fig. 3: Sprint Configuration

VI. Hull Design

1. *Current Design*

After viewing the history of past TCNJ team's performances in the Solar Splash competition, the 2015 team noticed that TCNJ had seldom performed to their expectations in the sprint event compared to their strong endurance performance history. Therefore, rather than creating a major innovation in hull design, the team decided to focus on the implementation of a surface-piercing drive system and propeller. The team considered reusing a previously manufactured TCNJ hull to complete this task. Thus, it became necessary to select a hull that could effectively support this design without making major modifications to the already manufactured hull.

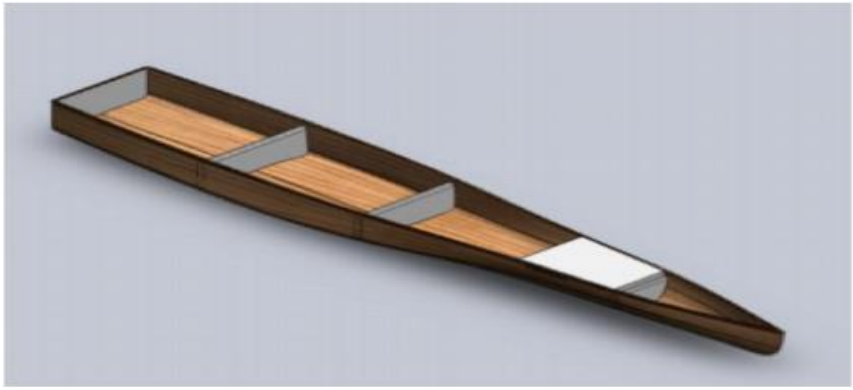


Fig. 4: Solid Works Model of Hybrid Mono-hull

The 2009 hybrid mono-hull, shown in Fig. 3 above, has proved to be successful in previous Solar Splash competitions, which was used again in 2012. It is comprised of fiberglass sandwich with a balsa wood core. As a hybrid hull, it possesses the ability to plane and displace water effectively at their respective critical speeds. This design was concluded to be a promising candidate for the implementation of the surface-piercing propeller.

2. *Analysis & Design Concepts*

2.1 Design Concepts

Due to its effective hybrid planing and water displacement capabilities for the sprint and endurance events, respectively, the 2015 team decided to implement the hybrid monohull hull for their competition. As stated in the Constraints section, the maximum length of the craft must not exceed 19 ft. 8 in. This includes all components that protrude from the hull. A surface-piercing propeller is most efficient at an optimal distance of 36 in. from the back of the hull, which will be discussed in the Propeller section. For these reasons, the 2015 team removed approximately two feet of the boat in the stern, displayed below in Fig. 4, to incorporate the new surface drive design. Consequently, a new transom would be fabricated and reattached using epoxy and fiberglass.

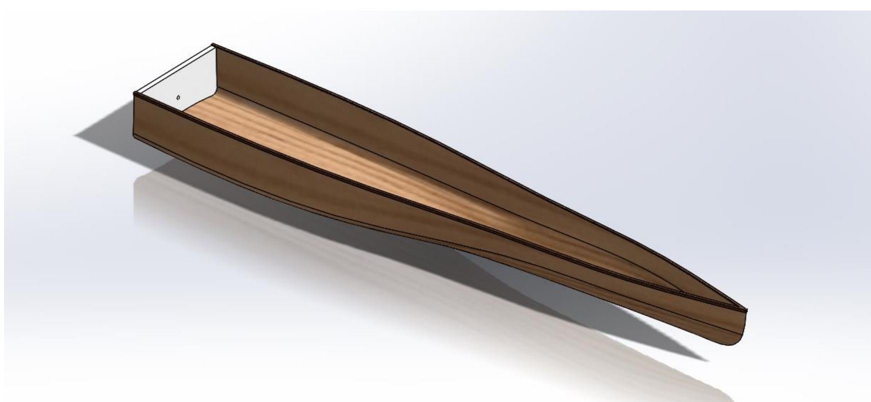


Fig. 5: Modified Solid Works Model of Hybrid Mono-hull w/ Honeycomb Transom

In Fig. 5 below, the most effective sprint weight distribution requires an angle of inclination at 0˚, seen in the Fig. below. This allows the bow to lift out of the water with the incorporation of a strong thrust, allowing the boat to achieve proper planing, with the effective use of its flat bottom at the back of the boat, at higher speeds.

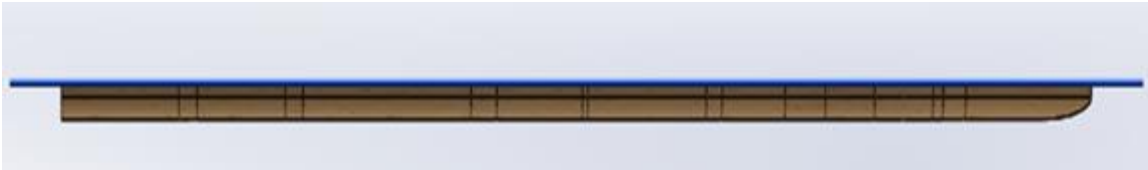


Fig. 6: Sprint Inclination Angle at 0 ˚

However, the most effective endurance weight distribution requires an angle of inclination toward the bow, seen in Fig. 6 below. This means that the center of buoyancy is to the right of the center of gravity. In the slow speed endurance event, this would allow the team to take advantage of the canoe-like, water displacement bow and also reduce the wake as the stern was lifted out of the water. Additionally, the lift of the back of the hull will decrease the vortices created, making this inclination more efficient.

Fig. 7: Endurance Inclination Angle towards the Bow

With the added length for the implementation of the surface drive, approximately 22 inches of the hull was cut from the stern. Polypropylene Honeycomb, an extremely strong, yet lightweight material, was chosen as the material for the transom reconstruction endeavor. With the transom alone holding the weight of the surface drive and steering system, it became necessary for the addition of further support. 8 holes of 1/2” diameter were drilled into the transom so that aluminum spacers, of ½” OD and 3/8” ID, could be placed to help dissipate the load caused by the parallel plates of the surface drive. Fig. 6 shows the integrated honeycomb transom with aluminum spacers.

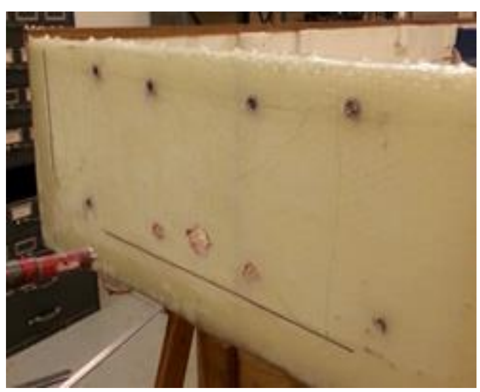


Fig. 8: Aluminum Spacers Placed into the Transom

2.2 Analysis

Analyzing the flotation of the craft is essential to ensure that the boat will float if completely filled with water. For this calculation, the team is required to have a flotation safety factor of 120%. Essentially, this means that ratio of the flotation force to the weight of the boat and all materials included has to be at a ratio of 1.2. The sprint configuration expressed a flotation ratio of 0.708, and in endurance, a ratio of 0.650. These are acceptable numbers, as the team planned to integrate polystyrene foam with epoxy resin fiber-glassed to the craft. This reduced the total volume inside the boat, allowing less water to fill. The calculation of these ratios is located in Appendix B.

When analyzing the flotation of the boat, it was important look at both configurations. Based on both analyses, the endurance configuration has a larger weight, and therefore, required a larger flotation force. With that being said, the flotation safety factor was analyzed in the endurance configuration.

Further calculations (Appendix B) concluded that there is an excess of approximately 3 ft^3 of excess foam integrated onto the boat from previous years. With this foam in place, the flotation safety factor values to 1.61, which fulfills the required safety factor of 1.2.

3. Design Testing & Evaluation

Upon testing, the new sprint configuration, which involved altering the displacement of the endurance motor head during sprint configuration turned out to be bow heavy. The displacement change of the endurance head, after being analyzed from testing, was too close to the bow. The team has proposed several solutions to alter the weight distribution so that the stern will effectively plane during sprint.

- Move the endurance motor head back closer to the stern
- Switch the batteries with the electrical panel, so that the batteries will be placed closer to the stern

Additional calculations will be done for these iterative configurations to form a conclusion of the most efficient.

VII. Propeller Design

1. Current Design

TCNJ has often designed and created custom propellers for use in both the sprint and endurance events. The endurance configuration used in past years has performed well in the competition, thus, the team has decided to reuse the 2014 endurance configuration and focus on improving performance in the sprint portion of the competition. The team elected to implement a surface drive with a surface piercing propeller to maximize top speed in sprint configuration. A surface piercing propeller is only partially submerged, with the waterline located at the center of the hub. The reason for improved performance is two-fold: First, less appendage drag exists due to the propeller being partially submerged; second, cavitation is eliminated as the low pressure bubbles that form on the suction side of each blade are ventilated on each revolution of the propeller. According to *The Propeller Handbook* by David Gerr[7], surface piercing propeller can provide a 10-12% speed increase over conventional submerged propellers and operate most effectively at speeds over 40 knots. The most crucial design constraint is the peak power of the two combined sprint motors is 29.9 HP, with a maximum torque of 43.48 lb-ft and a rated speed of 3600 RPM. The torque and speed of the motor can be adjusted via the gear ratio of the drive train; however, an increase in torque will result in a decrease in speed and vice versa. According to *The Propeller Handbook*[7], the shaft horsepower may be assumed to be 96% of the maximum break horsepower. Therefore the maximum shaft horsepower attainable will be 96% of 29.9, resulting in 28.7 SHP. Last year's team designed and manufactured a surface piercing propeller. The design process and manufacturing of this propeller are found in Appendix F.

2. Analysis & Design Concepts

Surface piercing propellers are a relatively new technology. Much of the information that exists for surface piercing propellers is proprietary information. One of the major issues in designing this type of propeller is a lack of available data. A disappointing testing of the student-designed and manufactured propeller created uncertainty in the design, leading the team to seek and attain a donation of a professionally manufactured propeller. The old student designed propeller and the new professionally manufactured propeller are shown in Fig. 9.

Fig. 9: Propeller Design Changes

The increased surface area of the new propeller, due to both the additional blade and larger blade size, will allow us to get up to speed quicker. We will be quicker off of the starting line than we were with the old, smaller propeller. A new stainless steel shaft was required to mount the donated propeller. This propeller is a 4 blade semi-cleaver with design specifications of an 11 ½’’ diameter and 18’’ pitch.

3. Design Testing & Evaluation

The professionally manufactured surface piercing propeller allowed the boat to reach a top speed of 11.5 mph. The team is confident that this lower than expected top speed is due to a weight distribution mistake that is currently being corrected. In testing, the bow sat much lower in the water than the team intended. As the propeller climbed out of the water the bow was pushed down instead of up on plane as intended. The team is confident in the new propeller and believe that higher speeds will be achieved once the longitudinal weight distribution is perfected. The steps that will be taken to correct the bow heavy weight distribution can be found in Appendix E.

VIII. Steering Design

1. Current Design

With the implementation of a surface drive, a traditional outboard lower unit fin would not be compatible with this configuration. Additionally, steering the attached endurance unit to the surface drive frame was another challenge the team faced. The steering system was designed using push-pull cables. A twin rudder system was developed to satisfy the length requirement of the craft and allow for successful steering of both the sprint and endurance propellers.

From the bell-crank, the tilling cable runs along the side of the boat through a series of pulleys which do not interfere with other components on the boat. At the bow, it is connected to the steering sprocket at the helm. This design provides the skipper for a 60° range of motion, without requiring any transition between events. Fig. 10 displays the Solid Works model of the steering system with twin hydro airfoil rudders.

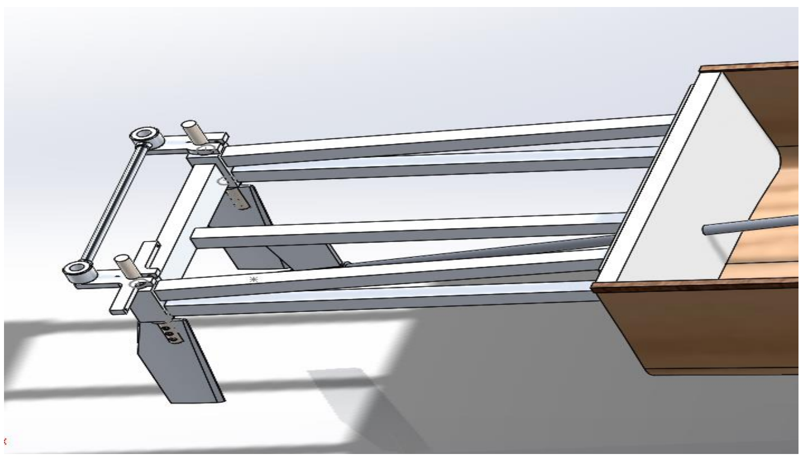


Fig. 10: Solid Works Model of T-Bell Crank Design w/ Surface Drive Design

2. Analysis & Design Concepts

2.1 Steering Design

In order to achieve optimal maneuverability, the primary goal of the steering system is to allow for movement of the rudder, 30 degrees to each side of the center. Additionally, the system must be robust, which is attained by having fewer, reliable components. Therefore, a cable steering system was determined to be the most favorable design.

2.2 Rudder Design

There were several design options for the rudders of the craft. However, the team's concerns were focused with affordability and performance abilities of the design. Additionally, as stated in the hull design section, the competition rules state the boat cannot exceed 6 meters (19 ft. 8 in.) in length. Therefore, this constraint must be considered for the rudders as well.

Table 4: Rudder Design Options

Rudder Design	Advantages	Disadvantages
Single trailing rudder	Only one rudder needed, alignment with centerline of propeller shaft allows for effective steering	Rudder must go behind propeller which adds additional undesired length
Lower unit fin	No rudder necessary	Inapplicable to fixed surface drives
Twin rudders	Reduces length of steering system	More expensive

In order to successfully perform at the competition, it is vital that such critical components, that cannot be easily replaced, do not fail. Thus, material selection was another important consideration of the steering system.

Table 5: Rudder Material Options

Material	Advantages	Disadvantages
Stainless Steel	High strength	Expensive, long machining time, very heavy
Bronze	High strength	Expensive, long machining time, very heavy
Aluminum	Easy to machine, affordable, lightweight	Moderate strength
Wood	Easy to machine, affordable, lightweight	Weak strength

Though the strongest material is preferred, other factors included affordability, manufacturability and weight. Minimizing weight is a reoccurring theme for this project, in order to attain the most efficiency for the boat propulsion. Therefore, aluminum was selected as the material for the twin rudders due its lightweight characteristics, adequate strength, affordability and ease of manufacturing.

The team also designed an airfoil rudder profile to ensure hydrodynamic performance in the water. A hydro airfoil design is integrated on boats that travel at slow or moderate speeds. Fig. 11 provides a display of the symmetrical airfoil cross-section and the Solid Works model of the tapered design. Tapering the rudder provides a consistent cross-section throughout.

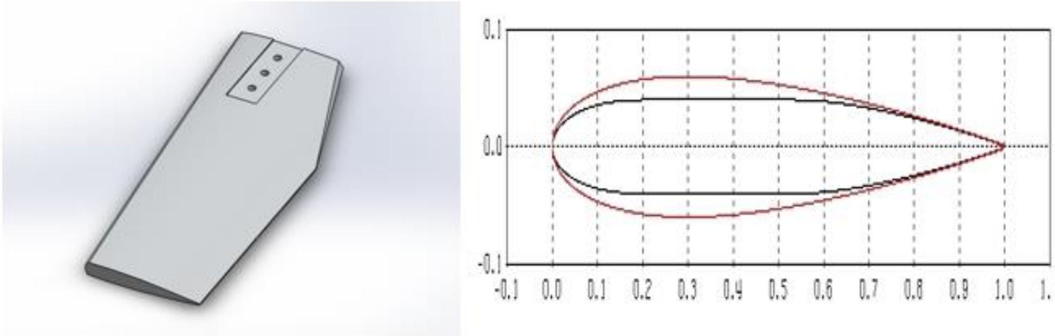


Fig. 11: Rudder Design in Solid Works Model & Coordinates Display

This design will improve the maneuverability of the boat during the endurance and slalom events. There were several design considerations regarding hydro airfoil designs, including aspects like thickness, tapered vs. non-tapered, the advantages of symmetrical camber, shown in table ___.

Table 6: Airfoil Rudder Design Considerations

Design Specification	Advantages	Disadvantages
Thickness = 0.375 in.	• Less drag • Lighter	• More lift with high thickness
Tapering	• Maintain ideal foil section	• Less strength at pivot point
Symmetrical	• More symmetrical control • Necessary for left and right turning	• None

With this rudder the thickest portion will be 25% to 35% along its length (or "chord" as it is called) from the forward or leading edge. The shape is such that fullness is provided along the contours so that they are convex and not straight or concave. This fullness minimizes resistance and provides the necessary lifting forces for turning efficiency.

3. *Design Testing & Evaluation*

Dry testing of the cable steering system concluded that the twin rudders, at maximum turning on both left and right turns, achieve the desired angle of 30 degrees rotation. Further dynamic testing analysis concluded that at an estimated speed of 5 mph, a turning radius of 20 feet completing a 180 degree turn was achieved. Additional dynamic testing will include a simulation of the solar slalom event. This will be an effective way to measure the boat's capabilities during the numerous back and forth turns. In this way, the reaction timing of the boat to the turn of the steering wheel will also be determined. Once these tests are performed, adjustments may be made to ensure the steering system will navigate the craft with proper control and agility.

IX. Surface Drive Design

1. *Current Design*

1.1 Overview

Surface drives are a relatively new type of marine propulsion technology which feature a surface-piercing propeller as well as a framework mounted to the transom designed to transmit power from the inboard motor(s) to the propeller. An example of this type of drive is shown in Fig. 8.

Fig. 12: Fixed Shaft Surface Drive Adapted from Lancing Marine

1.2 Improvements

Surface drives are more beneficial than conventional outboard or inboard drives, because they are more efficient. This is due to the cleaving properties of the propeller and the lack of appendages (propellers or shafts) underneath the hull. A surface drive requires that the centerline of the propeller be level with the bottom of the hull which means that no other appendages or components, aside from the rudder, will be submerged below the hull, this in turn means the boat will experience less drag. Less drag is desirable because it allows the boat to reach higher speed with less horsepower required.

2. *Analysis of Design Concepts.*

2.1 Description

The surface drive design consists of ¼” aluminum plates bolted on each side of the transom to keep the system in place at the 8° angle and 36” length necessary for optimum performance. The rear facing plate is the base for most of the tubing that makes up the surface drive, as well as the base for the pintle, a device designed to hold the outboard drive that will be used for the endurance event in place. Last year’s pintle was placed at a 20 degree angle to the transom in order to allow the outboard drive to tilt out of the water while not in use. This year’s team opted to take the endurance outboard completely off the back of the transom while in sprint configuration and place it in foam cut-outs next to the sprint drivetrain. Fig. 13 shows the surface drive and the new position of the endurance outboard while it is not in use during sprint configuration.

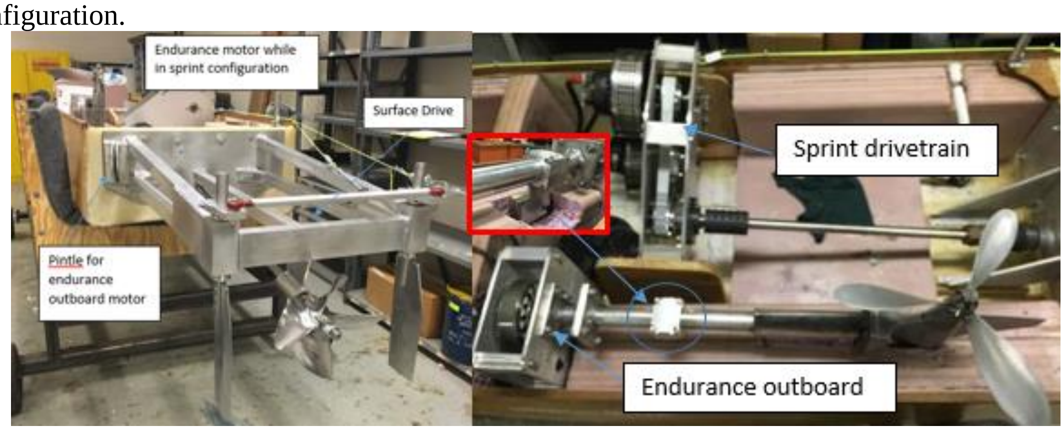


Fig. 13: Endurance Motor Location during Sprint Configuration

The endurance motor will be fastened to the boat while it is not in use, which is shown in the red box in the Fig. above. Moving the resting position of the motor was decided upon based on testing this fall, which displayed a stern heavy sprint configuration. The endurance motor weighing approximately 57 lbs. was the most obvious candidate for weight distribution correction. Sitting next to the sprint drivetrain, the lateral weight distribution is even and the longitudinal distribution is improved. A new pintle connection was designed and manufactured in order to remove the adjustability of the previous year's design. The pintle on the back of the surface drive was kept in place in order to avoid weakening the surface drive. The angle on the pintle connected to the transom was designed around, with the connection to the endurance shaft angled at 15 degrees and offset from center. This angle and offset allows the endurance propeller to sit as close to directly in front of the left steering rudder as possible, in order to increase maneuverability in endurance configuration. The new endurance shaft connection pintle was also lighter than the previous adjustable design. The finished pintle, Solid Works model, and connected endurance motor can be seen in Fig. 14.

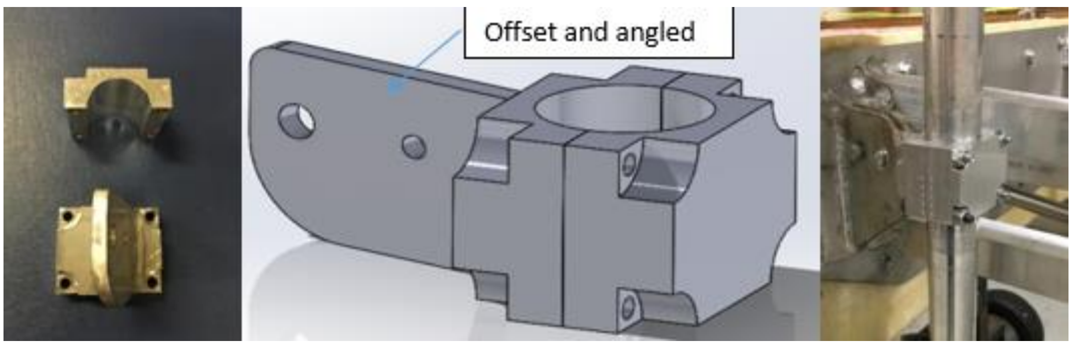


Fig. 14: Solid Works Model of Endurance Motor Modifications

The surface drive was not altered from last year except for the removal of the tilting aspect of the endurance motor. The Solid Works model of the surface drive with old design for the resting endurance motor is shown in Fig. 15.

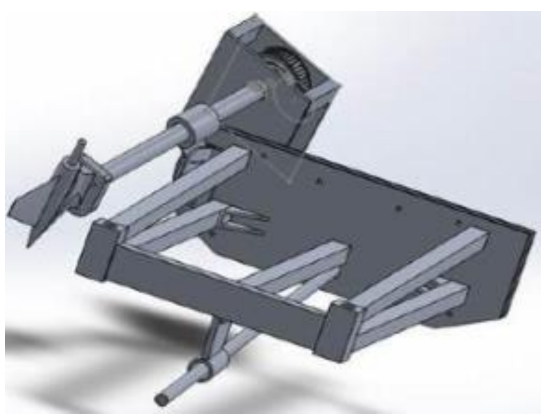


Fig. 15: Solid Works Model of Surface Drive w/ Endurance Motor

The tubing in this design consists of 3 horizontal members welded onto the rear facing aluminum plate. Two angled members are also welded onto the rear facing aluminum plate and are placed directly above the outermost horizontal members. These angled and horizontal tubes are in turn welded onto 4.5" by 2.5" by 2.5" blocks with 1 ¼" inch holes bored through them in order to support the rudder shafts from the steering system. These rudder shaft support blocks are connected by a 3" by 1.5" rectangular tube with 1/8" wall thickness that is oriented perpendicularly to the horizontal square tubing. All square tubing was chosen to be 1.5” by 1.5” tubing with a 3/16” wall thickness and all tubing was required to resist torsion as well as bending stress. To hold the propeller shaft in place, a cutlass bearing is placed in a strut which is attached to the underside of the middle horizontal tube by a slotted bracket welded in place. This bracket allows for the angle of the propeller shaft to be slightly adjusted in the event of any deviations from the 8° angle during fabrication. From the initial analysis, the team decided that the tubing still needed more support, and chose to add triangular supports to the outermost horizontal tubing in order to resist lateral deformation. To resist torsional deformation and keep the frame rigid, the team also added gusset plates on the outside of the outermost tubing.

2.2 Design Choices

The type of surface drive that the team chose to implement is known as a fixed-shaft surface drive, so named because it consists of one fixed propeller shaft which extends from the inboard motor all the way to the propeller. A fixed-shaft surface drive therefore is incapable of turning the boat on its own, requiring the boat to also include a rudder steering system. Similarly, since the propeller shaft is fixed, the propeller cannot raise or lower the trim of the boat, leaving out the benefit of trim adjustment. However, it is much simpler to install and to maintain, since the only components are the propeller, the propeller shaft, and the support frame and bearings that help support the shaft and keep it in place behind the boat. Fewer components will also mean that the drive will be less prone to failure. An example of a fixed shaft surface drive from the *Lancing Marine Pricebook* [9] is shown in Fig. 16.

Fig. 16: Fixed Shaft Surface Drive

Since the main purpose of the surface drive is to deliver power from the motor to the propeller, the team had to consider how to make a sturdy frame that would support the propeller shaft as well as resist any lateral or longitudinal loading such as thrust, lift, and weight. However, the team also had to make the surface drive as light as possible to reduce the amount of weight on the boat, thereby reducing the amount of power needed to propel the boat, as well as increasing the boat’s achievable speed. Finally, the team needed to ensure that the surface drive would resist any corrosion, since it would have to be exposed to both aquatic and standard atmospheric environments. To satisfy these conditions, the team chose to use aluminum 6061-T6 for most of the surface drive components, since it is lightweight, has a high enough tensile strength to resist any loading it might endure. Aluminum 6061-T6 also offers good corrosion resistance and has the added benefit of being a very affordable material. When making this selection, it was important to note that this design required almost every component to be welded to another component. A heavy reliance on welded joints meant that the team had to create a framework that could still be strong enough to resist any loading experienced during the competition with 20% of the yield strength of standard 6061-T6 aluminum. Therefore, instead of having a yield strength of 40 ksi, the welded joints would only have a yield strength of 8000 psi. Finally, square tubing was chosen over circular tubing because the square cross section had both a higher area moment of inertia and a higher polar moment of inertia than the circular cross section. This means that the square tubing is more resistant to bending stress and torsional stress than the circular tubing.

2.3 Analyses of design

The performance of the surface drive was analyzed when the rudders are positioned at their maximum angle of 30° since this was assumed be the most extreme loading case. The loads then determined from the free body diagram included drag forces and transverse forces as well as each of their moments on the rudder shaft support blocks, and weight loading from the outboard drive on the pintle as well as the weight of the surface drive itself. Since drag force would most likely have a negligible effect on the surface drive at only 30°, it was sufficient for each of the drag forces to be overestimated at 100 pounds, causing drag moments of 600 pound-inches if the center of the rudders are located 6” below the rudder support block. The transverse force was more difficult to determine, since it has a large effect on the surface drive, but can vary greatly depending on the speed of the boat, or the angle of attack of the rudders. By using the fastest completion time on the slalom event and the given length of the course, the team determined that an ideal speed for turning would be anywhere from 12 mph to 15 mph since that was the average speed of the winner of that event. The team then set the design goal of being able to turn at an angle of at least 20° at this speed. Realizing that this transverse force is actually a lift force, the group referenced a chart from *Force and Moment Characteristics of Six High-Speed Rudders for Use on High-Performance Craft* [8] that showed the lift coefficients for a NACA 0015 airfoil in a water tunnel with a Reynolds number of 1.02x10^6 vs. different angles of attack from 0° to 35°. This chart is shown in Appendix H and the Reynolds number used was calculated to correspond to about 17 mph using standard freshwater properties. It was also noted that the highest coefficient of lift for the NACA 0015 airfoil in a water tunnel occurred at a 20° angle of attack, meaning that the worst loading case would actually occur at that angle instead of the 30° that was previously assumed to be the worst. Therefore the team could safely assume that the coefficients of lift obtained for each angle of attack on the chart could be applicable to the rudders used by the team. With these lift coefficients, the team could determine the transverse/lift force on the rudders for various angles of attack at a few different speeds in the 10 to 20 mph range using the lift force equation,

$$FL = 12CLV2A \qquad (3)$$

With this equation, the group was able to calculate that at a 20° angle of attack and at 15 mph, the transverse/lift force would be 166.26 lbs. on each rudder. This force corresponded to a moment of about 997.56 pound-inches on each of the rudder shaft support blocks. Using the simulation program ANSYS v.15.0, the team determined that for these loading conditions, the part would experience a maximum stress of 7641 psi, meaning that it could sustain all of the loading conditions experienced during competition, while maintaining structural integrity. This result is shown in Appendix K.

X. Drivetrain Design

A. Current Design.

One goal of the 2015 TCNJ Solar Splash team was to improve in the sprint portion of competition while maintaining competitive in the endurance portion of competition. In order to achieve this, a new surface drive design will be implemented for the sprint event and the team would use an outboard previously designed that has kept TCNJ competitive in the endurance event. With the implementation of a surface drive system, the drivetrain designs for both the endurance and sprint configuration must be compatible with the design of the surface drive. Through research, the team discovered that surface-piercing drive systems are most efficient when the shaft is coming into the hull at an angle of 8°. With that angle in mind, an inboard drivetrain was designed to be placed in the hull at an angle of 82° to allow for the drive shaft to connect to the pulley system at 90°.

The pintle of the outboard drive was re-designed to be integrated on the surface drive on the port side of the hull. To compensate for the weight of the outboard drive, the motors on the inboard drive were placed on the starboard side of the hull.

B. Analysis of Design Concepts

Unlike larger hulls, the solar boat is a light water craft which is powered by smaller motors and solar energy. Since the boat only operates under these forms of power, it is necessary to keep the design of the drivetrain as lightweight as possible. It is also important to keep the design as simple as possible. A simple design will not only be more cost effective but allow for quick and efficient adjustments if needed. In order to keep the mounting of the motors and gearing lightweight, the material chosen for the two plates was aluminum 6061-T6 and the material used for the supports holding the plates at an angle of 82° was chosen to be plywood. The plywood supports will be fiber glassed into the hull to add extra strength to the supports. The belt driven system was also determined with the weight of the system in mind. Belt driven systems are significantly lighter than other systems and offer better adjustability with the use of tensioners.
The inboard drivetrain consists of two ¼” 6061-T6 aluminum plates which are separated by 3” x 2”x 1” aluminum blocks. The two aluminum plates are cut to 18”x 20” and excess aluminum is cut from the top of the plates. The open top allows for the user to have easier access when adjusting the timing belt or pulleys. The motors are mounted on the starboard side of the hull facing the bow. Placing the motors in this position takes advantage of the motor weight to counterbalance the weight of the located endurance unit. Facing the motors towards the bow allows easy access when connecting to the electrical panel when setting up for the sprint event. To compensate for the surface drive shaft coming into the hull at 8°, the two plates are attached to two cut plywood supports which hold the aluminum at an 82° angle. The prototype of this design is shown in Fig. 17.

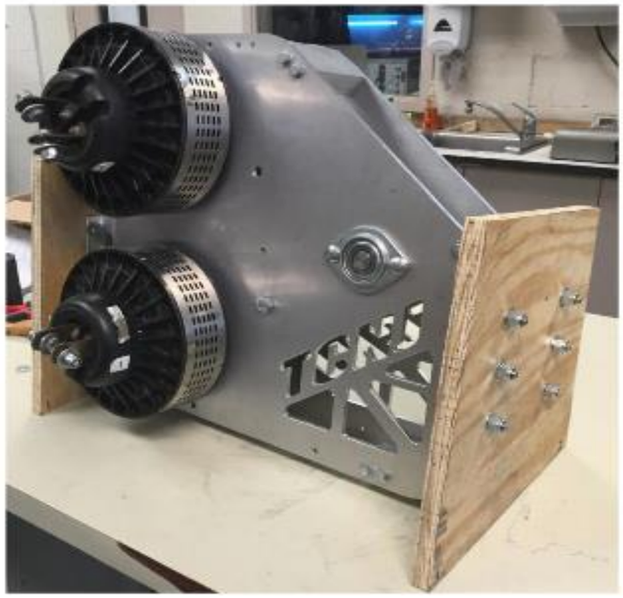


Fig. 17: Sprint Drivetrain

A stub shaft was constructed to connect to the drive shaft using a coupler. The coupler allows the team to disassemble the drivetrain from the surface drive if adjustments must be made.

Through coordination with the propeller designer, an operating speed of 500 RPM was decided for the endurance competition and a speed of 4300 RPM was decided for the sprint configuration, to optimize the performance of the surface -piercing propeller. With the targeted RPM in mind, a spreadsheet was made using nominal sizes of pulleys found in storage and on the BRECOFlex's catalog. The selected pulley's and resulting propeller (prop) RPM are highlighted in Table 7.

Table 7: Motor to Prop RPM

Motor RPM	Driven Gear	Drive Gear	Prop RPM
3600	20	22	3960
3600	20	24	4320
3600	20	32	5760
3600	24	32	4800
3600	27	32	4266.67
3600	30	32	3840

The sprint power head uses two Lynch LEM200 D126 motors, which run a single drive shaft. The motors run at a rated 3600 RPM at a 36V power supply. The motors each have a 32-tooth pulley, which drives a 27-tooth pulley on the drive shaft. The final speed attained is 4266 RPM, which closely models the designed RPM.

The endurance power head uses a PMG132 motor, which applies a speed of 1080 RPM when run at 24V. The motor shaft has a 20-tooth pulley, which drives a 40-tooth pulley on the drive shaft, producing a 1:2 ratio and stepping the RPM down to 540. Through the 14:15 Konny Racing lower unit, the RP Another necessary component in the initial design of the drivetrain was the selection of bearings. Bearings are necessary to constrain the relative movement between two points and will be necessary in keeping the drive shaft aligned while it is being driven by the belt and pulley system. There are various types of bearings but the main bearing considered was a ball bearing. Self-aligning ball bearings have lower friction value and are more forgiving of imperfections in the gearbox construction. Thus, it was determined that self-aligning ball bearings would be the optimal choice. Three ball bearings were selected to be placed on the shafts for the two sprint motors and the stub shaft connected to the drive shaft by a coupler. A 1” medium duty two bolt flange bearing was selected for the drive shaft due to its capability of carrying the thrust loads produced by the surface-piercing propeller.

C. Design Testing & Evaluation

Further testing of the sprint configuration concluded that the functionality of the drivetrain is efficient. However, there is speculation that the proper amount of power expected to be produced is not being fulfilled. This may be contributed to a malfunctioned sprint motor. The team will remove the connecting belt, and dry testing the drivetrain. WIth this, there will be sufficient evidence to support this claim that required power to maximize the surface piercing propeller if not being reached.

XI. Data Acquisition System

1. Current Design

Designed around an Arduino Mega 2560, the data acquisition system needed to get the battery array voltage and current, the solar array voltage and current, and craft speed. These parameters had to then be transmitted to team onshore team as well as display them to the driver in order for the team to make critical decisions during competition. Through use of a differential attenuating circuit seen in Fig. 18, the voltages from the solar and battery array will be obtained. As where current measurements will use current transducers operating on the hall-effect principal. The manner in which speed will be obtained has not been decided on at this point in time. However, the transmittal of data will be done through the use of two Stream 900 MHz RF modems that are capable of wireless data transmittal from up to 7 miles away. The entire data acquisition system is powered through the use of an auxiliary battery as permitted by competition rules.

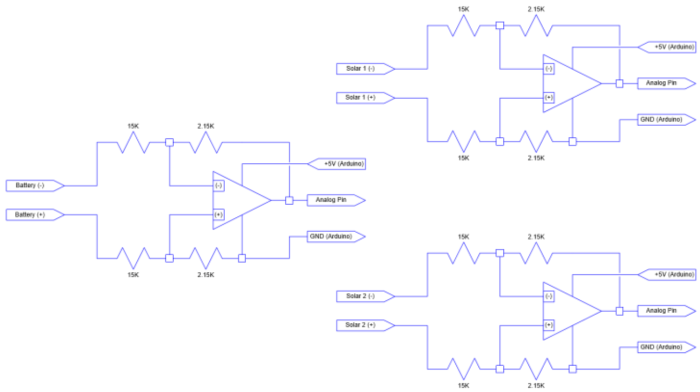


Fig. 18: Differential Attenuating Circuit

2. *Analysis of Design Concepts*

The methods chosen to be used for obtaining current and voltage measurements were decided upon because of their ability to be implemented without disturbing or taking power from the electrical system. A voltage divided and a voltage follower circuit were considered for voltage measurement acquisition, however a follower required 2 analog inputs and although a voltage divider requires only one analog input, it consumes substantially more power than the differential attenuator circuit that was designed. Similarly, the use of hall-effect transducers was decided upon for measuring current because they do not need to interrupt the circuit being measured in any way. The RF modem was chosen because it was already on hand and the microcontroller was easily interfaced with the modem by implementing a level shifter between the two devices.

3. *Design Testing and Evaluation*

The system has yet to be fully fabricated, however the parts that have been prototyped and test thus far have shown promise. Further testing and prototyping will need to be done to ensure a functional system during competition

XII. Project Management

1. *Team Organization & Responsibility*

The College of New Jersey's 2016 Solar Electric Boat team is composed of 4 team members from two engineering disciplines, mechanical engineering and electrical engineering. The four senior team members worked together building one overall system for their Senior Project I and II capstone course, while also planning to compete at the 2016 Solar Splash competition. Each member of the team is responsible for multiple subsystems of the boat. Two mechanical and one electrical and computer engineering faculty members advised the team. The team roster is detailed in Appendix D.

2. *Project Planning & Schedule*

The 2016 team decided that a key to developing a successful project would be to properly plan for it and to create a schedule. The team was first formed in the spring of 2015 and their first official meeting was held in during the following summer. During this meeting the team discussed each of the subsystem designs, initial discussion of integrating each component, and the proper planning required to finish on time with a successful project. To help the team keep on schedule, a Gantt chart was created (Appendix J), which outlined schedules for each subsystem. The team met every Wednesday with the advisors to talk about their designs and any unforeseen complications. All meetings' minutes were thoroughly recorded in a logbook. The team was on schedule throughout the fall, but unfortunately ran into delays starting the construction over the winter due to late material orders and necessary redesigning's of the subsystems. Fortunately, the team was able to get back on schedule and successfully tested within the testing time of April 9th – April 29th. There will be additional tests done, as the results of this testing did not provide the results expected. The team assigned the final 50 days prior to competition as a time where any additional testing can be completed.

3. *Financial & Fund-raising*

Each member of the team is given $300 to start out with in the budget, called seed money. From there, the team completed several budget proposals, including a travel budget and a budget for materials necessary for the project. These budgets are presented to the Dean of the School of Engineering, where it is then either approved or denied, in which case, the team will change the budget, need be. Table 10.1 is the overall budget for the 2016 Solar Boat team.

Table 8: Team Budget Summary

System	Total
Endurance Motor	$50
Propeller Integration	$142.53
Electrical System	$970.89
Telemetry	$48.03
Rudders	$136.57
Travel	$3,386
Miscellaneous	$200
Drive Train	$35
Total	**$4,969**

Currently, the team has been granted $4,000 for the travel budget. The estimate for $3,386 is most likely going to increase because of the price of gas. The 2016 team did not need to present a budget proposal to the Dean, as there was money left over from the previous team.

4. *Strategy for Team Community & Sustainability*

Every year, the TCNJ Solar Boat team is primarily composed of senior students, thus, it is important to pass on all resources used and any documentation collected to future years' teams. This year the team included interested underclassmen during the design phase and construction of the boat. The team has continued using a cloud-based service called Dropbox, which keeps future teams informed about the past projects' successes and any recommendations. It is also fortunate that there is a 2016 team already formed and have helped out through the construction phase, allowing them to understand what needs to be done and to have a better understanding of the scope of the project. Two of next year's team members will be attending this year's competition to gain valuable experience.

XIII. Conclusions & Recommendations

A. Strengths

- Surface drive will improve efficiency and sprint performance
- Hybrid monohull maximizes use of the hull for each configuration
- Outboard drive that has performed well in previous competition
- Proper telemetry system that can help maximize the use of batteries in the endurance event
- Redesigned electrical system that will minimize adjustments when transitioning from one event to the other

B. Weaknesses

- Time limitation on testing of the boat and making changes
- Boat is very difficult to place in the water due to length
- Surface drive and drivetrains concentrate most of the weight of the boat in the back.

C. Recommendations

In the future teams should attempt to begin construction on all systems even sooner than this year's team. This way, the team could more comprehensively test the boat design and make any adjustments necessary. Given more time to complete this project, the team would recommend attempting the implementation of a contra-rotating propeller design for the endurance event. A contra-rotating propeller would increase performance in the endurance portion of the competition because it can deliver the maximum power required with reduced energy loss.

References

1]B.P. Epps, “OpenProp v2.4 Theory Document,”MIT Department of Mechanical Engineering. Technical Report, December 2010.

[2]"Calculating New Waterline." WoodenBoat Forum. N.p., 1 May 2006. Web. 16 Nov. 2014.

[3]"Center of Buoyancy and Center of Gravity." Ask a Scientist!NEWTON, June 2006. Web. 22 Nov. 2014.

[4]"Center of Gravity - Center of Buoyancy." The Engineering Toolbox. N.p., n.d. Web. 14 Oct. 2014.

[5]Doane, Charles. "MODERN SAILBOAT DESIGN: Quantifying Stability."Sailfeed. N.p., 16 May 2013. Web. 29 Oct. 2014.

[6]"Flotation - Basic Flotation." Boating Safety Resource Center. N.p., n.d. Web. 22 Nov. 2014.

[7]Gerr, Dave. Propeller Handbook: The Complete Reference for Choosing, Installing and Understanding Boat Propellers. Camden, Me.: International Marine, 2001. Print.

[8]Gregory, D. L. "Force and Moment Characteristics of Six High-Speed Rudders for Use on High-Performance Craft." - NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER (1974): n. pag. Web. www.dtic.mil/dtic/tr/fulltext/u2/772098.pdf

[9]"Lancing Marine Pricebook 2014 P39, Sterndrives. Surface Dri ves." Lancing Marine. N.p., n.d. Web. 21 Nov. 2014.<http://www.lancingmarine.com/pricebook2013/page39.html>.

[10]Lautrup, Benny. "Buoyancy and Stability." Physics of Continuous Matter(2010): 41-56. Print.

[11]Maritime New Zealand. "A Guide to Fishing Vessel Stability." Vessel Stability Guidelines (2011): 1-32. Print.

[12]"Sailing Boats' Stability, STIX and Old Ratios." Boat Design Forums RSS. N.p., n.d. Web. 27 Nov. 2014.

Appendix A: Battery Documentation

The following is the technical and safety data for the Optima 25 Red Top.

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 <u>not</u> 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 2008

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

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

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

II. Hazardous Ingredients

Material	% by Wt.	CAS Number	Eight Hour Exposure Limits		
			OSHA PEL	**ACGIH TLV**	NIOSH REL
Specific Chemical Identity **Lead & lead compounds**	63-81	7439-92-1	50 µg/m³	150 µg/m³	100 µg/m³
Specific Chemical Identity **Sulfuric Acid (35%)** **Common Name** **Battery Electrolyte (Acid)**	17 - 25	7664-93-9	1mg/m³	0.2 mg/m³ (respirable thoracic fraction)	1 mg/m³
Common Name **Case Material Polypropylene**	2-6	9010-79-1	--	--	--
Common Name **Separator/Paster Paper Fibrous Glass**	1-4	65997-17-3	--	--	--

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

III. Physical Data

Material is (at normal temperatures) **☑Solid ☑Liquid**		Appearance and Odor **Battery Electrolyte (acid) is a clear to cloudy liquid with slight acidic odor. Acid saturated lead oxide is a dark reddish-brown to gray solid with slight acidic odor.**
Boiling Point (at 760 mm Hg) **Lead 1755°C Batt. Electrolyte (Acid) 110-112°C**	Melting Point **Lead 327.4°C**	
Specific Gravity (H_2O =1) **Battery Electrolyte (Acid) 1.210 - 1.300**		Vapor Pressure ☑(mm Hg at 20°C) Ž(PSIG) **Battery Electrolyte (Acid) 11.7**
Vapor Density (Air =1) **Battery Electrolyte (Acid) 3.4**		Solubility is H_2O **Lead and Lead Dioxide are not soluble. Battery Electrolyte (acid) is 100% soluble in water.**
% Volatile By Weight **Not Determined**		Evaporation rate (Butyl Acetate = 1) **Not Determined**

IV. Health Hazard Information

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

V. Fire and Explosion Data

Flash Point (test method)	Autoignition Temperature	Flammable Limits in Air, % by Vol.
Hydrogen - 259°C	**Hydrogen 580°C**	**Hydrogen LEL - 4.1 UEL - 74.2**

Extinguishing Media
Dry chemical, foam, or CO_2

Special Fire Fighting Procedures
Use positive pressure, self-contained breathing apparatus.

Unusual Fire and Explosion Hazard
The sealed lead acid battery is not considered flammable, but it will burn if involved in a fire. A short circuit can also result in a fire. Acid mists, smoke and decomposition products may be produced. Remove all ignition sources. Cool battery(s) to prevent rupture.

VI. Reactivity Data

Stability	Conditions to Avoid
☐ Unstable ☑ Stable	**Sparks and other sources of ignition may ignite hydrogen gas.**

Incompatibility (materials to avoid)
Lead/lead compounds: Potassium, carbides, sulfides, peroxides, phosphorus, sulfur.
Battery electrolyte (acid): Combustible materials, strong reducing agents, most metals, carbides, organic materials, chlorates, nitrates, picrates, and fulminates.

Hazardous Decomposition Products
Lead/Lead compounds: Oxides of lead and sulfur
Battery electrolyte (acid): Hydrogen, sulfur dioxide, sulfur trioxide

Hazardous Polymerization	Conditions to Avoid
☐ May Occur ☑ Will Not Occur	**High temperature. Battery electrolyte (acid) will react with water to produce heat. Can react with oxidizing or reducing agents.**

VII. Control Measures

Engineering Controls
Store sealed lead acid batteries at ambient temperature. Never recharge batteries in an unventilated, enclosed space. Do not subject product to open flame or fire. Avoid conditions that could cause arcing between terminals.

Work Practices
Do not carry battery by terminals. Do not drop battery, puncture or attempt to open battery case. Avoid contact with the internal components of a battery.

PERSONAL PROTECTIVE EQUIPMENT

Respiratory Protection
None required for normal handling of finished product.

Eyes and Face
None required under for finished product under normal conditions of use. If necessary to handle broken product, chemical splash goggles are recommended.

Hands, Arms, and Body
None required for normal handling of finished product. If necessary to handle broken product, Vinyl-coated, PVC, gauntlet-type gloves with rough finish are recommended..

Other Special Clothing and Equipment
Safety footwear meeting the requirements of ANSI Z 41.1 – 1991 is recommended when it in necessary to handle the finished product.

VIII. Safe Handling Precautions

Hygiene Practices

Wash hands thoroughly before eating, drinking, or smoking after handling batteries.

Protective Measures to be Taken During Non-Routine Tasks, Including Equipment Maintenance

Do not carry battery by terminals. Do not drop battery, puncture or attempt to open battery case. Do not subject product to open flame or fire and avoid situations that could cause arcing between terminals.

Protective Measures to be Taken if Material is Released or Spilled

Remove combustible materials and all sources of ignition. Avoid contact with acid materials. Use soda ash, baking soda or lime to neutralize any acid that may be released.

If battery is broken, wear chemical goggles and acid-resistant gloves for handling the parts.

DO NOT RELEASE UNNEUTRALIZED ACID!

Waste Disposal Method

Battery Electrolyte (Acid): Neutralize as above for a spill, collect residue, and place in a drum or suitable container. Dispose of as a hazardous waste.

DO NOT FLUSH LEAD-CONTAMINATED ACID INTO SEWER.

Send spent or broken batteries to a lead recycling facility or smelter that follows applicable Federal, State and Local regulations for routine disposition of spent or damaged batteries. The distributor / user is responsible for assuring that these "spent" or "damaged" batteries are disposed of in an environmentally sound way in accordance with all regulations. OPTIMA batteries are 100% recyclable by any licensed reclamation operation..

LEAD RETURN
RECYCLE

SUPPLEMENTAL INFORMATION

Proposition 65 Warning (California) Proposition 65 Warning: The state of California has listed lead as a material known to cause cancer or cause reproductive harm (July 9, 2004 California List of Chemicals Known to Cause Cancer or Reproductive Toxicity) Battery posts, terminals and related accessories contain lead and lead compounds. Batteries also contain other chemicals known to the State of California to cause cancer. Wash hands after handling.

TSCA Registry: Ingredients listed in the TSCA Registry are lead, lead compounds, and sulfuric acid.

Transportation: Sealed Lead Acid Battery is not a DOT Hazardous Material.

Other: Per DOT, IATA, ICAO and IMDG rules and regulations, these batteries are exempt from "UN2800" classification as a result of successful completion of the following tests:

1) **Vibration Tests**
2) **Pressure Differential Tests**
3) **Case Rupturing Tests (no free liquids)**

US MILITARY NATIONAL STOCK NUMBER (NSN)

Model Number	P/N	NSN
34/78	8004-003	6140-01-374-2243, 6140-01-457-4339
34	8002-002	6140-01-378-8232, 6140-01-493-1962
34R	8003-151	6140-01-475-9357
34VX	8008-158	6140-01-534-6466
25	8025-160	
35	8020-164	
75/25	8022-091	6140-01-475-9361
78	8078-109	
850/6 -1050 SLI	8010-044	6140-01-475-9414
DS46B24R	8171-767	
850/6 - 950 (DC)		
D51	8071-167	6140-01-523-6288
D51R	8073-167	6140-01-529-7226
D35	8040-218	
D75/25	8042-218	

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

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

The following is the technical and safety data for the Odyssey PC680 sprint batteries. This is provided in case the team does not obtain the new Optima batteries in time for competition and is forced to used batteries from last year's team.

PC 680 Specs:

- 680 cranking amps for 5 seconds
- 595 cranking amps for 10 seconds
- 525 cranking amps for 20 seconds
- 17 amp hours
- Short circuit current over 1800A
- 25 minute reserve capacity with 25amp load
- Female brass terminal w/M6 SS bolt
- Length 7 1/16"
- Width 3"
- Height 6 9/16"
- Weighs less than 15 lbs

Odyssey design:

- 2 year full warranty
- Rugged Drycell sealed design
- Military grade
- Vibration resistant
- 60% more starting power
- Deep discharge reserve power
- 2 year storage life
- 8-12 year design life
- Can be mounted flat or upright

EnerSys
Powering Full Solutions

Revision Date: June 6, 2013
Supersedes: July 26, 2011
Document #: MSDS 853027
Revised on ECO: 1001294

INFORMATION ONLY - Please read Section X

SECTION I - Product and Manufacturer Identity

Product Identity:

Sealed Lead Battery

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

Stability: Stable

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 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.

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. 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. 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. Hazardous labels are not required when transporting a nonspillable battery. These batteries are excepted from all IMDG codes 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.

The following is the technical and safety data for the Interstate MTP-93 endurance batteries.

MEGA-TRON PLUS 93 AUTOMOTIVE BATTERY SIX-YEAR PERFORMANCE 850 CCA

Get long life and premium performance in any cold to moderate climate with Interstate Batteries' Mega-Tron 93. With 30-month free replacement and six-year performance, this 850 CCA will meet or exceed your vehicle's starting requirements.

5.0

Sugg Retail Price: $163.95
List Price: $186.95
Dealer prices will vary

Please enter a ZIP/Postal code below:

LOCATE YOUR STORE

VIEW CANADIAN PRICING

Available In Stores Only!
CALL TOLL FREE 888-772-3600

Only Available at Authorized Dealers
Due to regulations, this product cannot be shipped to you directly. The information and specifications above are for your reference. Please use the dealer locator to find a location near you. Dealer prices may vary.

SPECIFICATIONS | CUSTOMER REVIEWS | ALSO FITS

Product ID:	MTP-93
Cranking Amps:	850
Cold Cranking Amps:	850
Voltage:	12
Termination:	Common Code A
Weight:	42.9
Width:	6.88
Length:	14.38
Height:	6.88
WET/DRY:	W

JOHNSON CONTROLS

MATERIAL DATA SAFETY SHEET

Section 1: PRODUCT AND COMPANY IDENTIFICATION

Johnson Controls Battery Group Inc.
Automotive Systems Group
5757 Green Bay Avenue
Glendale, Wisconsin

EMERGENCY PHONE: 24 hours – (800) 424-9300 (CHEMTREC)

INFORMATION PHONE: (800) 333-2222 ext. 3138

PRODUCT NAME: Lead/acid Battery, Wet, filled with acid

MSDS NUMBER: L8

REVISON NUMBER: 1

DATE OF PREPARATION/REVISION: 12/20/07

Section 2: COMPOSITION/INFORMATION INGREDIENTS

Material	% by Wt.	CAS Number	Eight Hour Exposure Limits		
			OSHA PEL	ACGIH TLV	NIOSH REL
Lead	34	7439-92-1	50 µg/m³	150 µg/m³	100 µg/m³
Lead Oxide	31	1309-60-0	50 µg/m³	150 µg/m³	100 µg/m³
Lead Sulfate (Anglesite)	<1	7446-14-2	50 µg/m³	150 µg/m³	100 µg/m³
Battery Electrolyte (Sulfuric Acid (35%)	34	7664-93-9	1mg/m³	0.2 mg/m³ (respirable thoracic fraction)	1 mg/m³

Section 3: HAZARDS IDENTIFICATION

NOTE: Under normal conditions of battery use, internal components will not present a health hazard. The following information is provided for battery electrolyte (acid) and lead for exposure that may occur during battery production or container breakage or under extreme heat conditions such as fire.

EMERGENCY OVERVIEW:

Acid filled battery. Contact with the electrolyte will cause burns to the eyes and skin. Contains lead. Absorption of lead potentially may cause poisoning and reproductive effects.

ROUTES OF ENTRY:

EYE CONTACT: Contact with the battery electrolyte can cause severe irritation, burns, and cornea damage upon contact.
SKIN CONTACT: Battery electrolyte (acid) can cause severe irritation, burns and ulceration.
SKIN ABSORPTION: Not a significant route of entry.

INHALATION: Acid mist generated during battery charging or spillage of the electrolyte in a confined area may cause respiratory irritation.
INGESTION: Hands contaminated by contact with internal components of a battery can cause ingestion of lead/lead compounds. Ingestion of battery electrolyte will cause severe burns to mouth and gastrointestinal tract.

ACUTE HEALTH EFFECTS:

Acute effects of overexposure to lead compounds are GI (gastrointestinal) upset, loss of appetite, diarrhea, constipation with cramping, difficulty in sleeping, and fatigue. Exposure and/or contact with battery electrolyte (acid) may lead to acute irritation of the skin, corneal damage of the eyes, and irritation of the mucous membranes of the eyes and upper respiratory system, including lungs

CHRONIC HEALTH EFFECTS:

Lead and its compounds may cause chronic anemia, damage to the kidneys and nervous system. Lead may also cause reproductive system damage and can affect developing fetuses in pregnant women. Battery electrolyte (acid) may lead to scarring of the cornea, chronic bronchitis, as well as erosion of tooth enamel in mouth breathers in repeated exposures.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:

Inorganic lead and its compounds can aggravate chronic forms of kidney, liver, and neurological diseases. Contact of battery electrolyte (acid) with the skin may aggravate skin diseases such as eczema and contact dermatitis.

Section 4: FIRST AID MEASURES

EYE CONTACT: Immediately rinse with cool running water for at least 15 minutes. Seek medical attention immediately after rinsing.
SKIN CONTACT: Wash thoroughly with soap and water. If acid is splashed on clothing, remove and discard. If acid is splashed in shoes, remove them immediately and discard. Acid cannot be removed from leather.
INHALATION: Remove from exposure and consult a physician if any of the acute effects listed above develop.
INGESTION: Lead: Consult a physician. Battery Electrolyte: Do not induce vomiting. Refer to a physician immediately.

Section 5: FIRE FIGHTING MEASURES

FLASHPOINT: For Hydrogen – N/A as this is a gas. **TEST METHOD:** N/A
AUTOIGNITION TEMPERATURE: Hydrogen - 580°C
FLAMABLE LIMITS: For Hydrogen - **LEL - 4.1** **UEL - 74.2**
EXTINGUISHING MEDIA: Dry chemical, foam, or CO_2
SPECIAL FIRE FIGHTING PROCEDURES: Use positive pressure, self-contained breathing apparatus.
UNUSUAL FIRE AND EXPLOSION HAZARD: Hydrogen and oxygen gases are produced in the cells during normal battery operations, hydrogen is flammable and oxygen supports combustion. These gases enter the air through the vent caps. To avoid the chance of a fire or explosion, keep sparks and other sources of ignition away from the battery.

Section 6: ACCIDENTAL RELEASE MEASURES

Remove combustible materials and all sources of ignition. Contain spill by diking with soda ash (sodium carbonate) or quicklime (calcium oxide). Cover spill with either chemical. Mix well. Make certain the mixture is neutral, and then collect residue and place in a drum or other suitable container. Dispose of as a hazardous waste. Wear acid-resistant boots, chemical face shield, chemical splash goggles, and acid-resistant gloves.
DO NOT RELEASE UNNEUTRALIZED ACID!

Section 7: HANDLING And STORAGE

WORK PRACTICES: Make certain vent caps are on tightly. Place a minimum of two layers of corrugated cardboard between layers of batteries. When stacking in trailer, stack no more than three layers high. Use a battery carrier to lift a battery or place hands at opposite corners to avoid spilling acid through the vents. Avoid contact with internal components of the batteries. Wash hands thoroughly before eating, drinking or smoking after handling batteries.

SPECIAL PECAUTIONS: Keep open flames and sparks away from charging batteries.

STORAGE: Store lead acid batteries with adequate ventilation. Room ventilation is required for batteries utilized for standby power generation. Never recharge batteries in an unventilated, enclosed space.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

VENTILATION: Store lead acid batteries with adequate ventilation. Room ventilation is required for batteries utilized for standby power generation or in area designated for battery charging.

RESPIRATORY PROTECTION: None required under normal handling conditions. During battery formation (high-rate charge condition), acid mist can be generated, which may cause respiratory irritation. If irritation occurs, wear a respirator suitable for protection against acid mist.

GLOVES: Vinyl-coated, PVC, gauntlet-type gloves with rough finish.

EYE PROTECTION: Chemical splash goggles are preferred. Also acceptable are "Visor-Gogs" or a chemical face shield worn over safety glasses with solid side shields.

OTHER PROTECTIVE EQUIPMENT: Safety shoes worn with rubber or neoprene boots or steel-toed rubber or neoprene boots worn over socks. Place pants legs over boots to keep acid out of boots.

Section 9: PHYSICAL And CHEMICAL PROPERTIES

PHYSICAL STATE: Battery is solid case with solid and liquid internal components.

APPEARANCE AND ODOR: Battery Electrolyte (acid) is a clear to cloudy liquid with slight acidic odor. Acid saturated lead oxide is a dark reddish-brown to gray solid with slight acidic odor.

pH: electrolyte – 1.0
BOILING POINT: Lead - 1755°C electrolyte – 110-112°C
MELTING POINT: Lead 327°C
SOLUBILITY IN WATER: electrolyte – 100%
COEFFICIENT WATER/OIL: N/A

SPECIFIC GRAVITY: electrolyte – 1.210-1.300
VAPOR PRESSURE: electrolyte – 11.7
VAPOR DENSITY: electrolyte – 3.4
PERCENT VOLATILE: Not determined.
EVAPORATION RATE: Not determined

Section 10: STABILITY And REACTIVITY

STABILITY:

☐ Unstable ☑ Stable

CONDITIONS TO AVOID:

Sparks and other sources of ignition may ignite hydrogen gas.

INCOMPATABILITY: Lead/lead compounds: Potassium, carbides, sulfides, peroxides, phosphorus, sulfur. Battery electrolyte (acid): Combustible materials, strong reducing agents, most metals, carbides, organic materials, chlorates, nitrates, picrates, and fulminates.

HAZARDOUS DECOMPOSITION PRODUCTS: Lead/Lead compounds: Oxides of lead and sulfur Battery electrolyte (acid): Hydrogen, sulfur dioxide, sulfur trioxide.

HAZARDOUS POLYMERIZATION: Will not occur.

CONDITIONS TO AVOID: High temperature. Battery electrolyte (acid) will react with water to produce heat. Can react with oxidizing or reducing agents.

Section 11: TOXICOLOGICAL INFORMATION

ACUTE TOXICITY DATA: Lead/lead compounds: No data is available.
Sulfuric Acid: LD50 oral rat: 2140 mg/kg
LD50 inhalation: 510 mg/m^3/2 hour

CARCINOGENICITY: The National Toxicological Program (NTP) and The International Agency for Research on Cancer (IARC) have classified "strong inorganic acid mist containing sulfuric acid" as a Category 1 carcinogen, a substance that is carcinogenic to humans. The ACGIH has classified "strong inorganic acid mist containing sulfuric acid" as an A2 carcinogen (suspected human carcinogen). These classifications do not apply to liquid forms of sulfuric acid or sulfuric acid solutions contained within a battery. Inorganic acid mist (sulfuric acid mist) is not generated under normal use of this product. Misuse of the product, such as overcharging, may result in the generation of sulfuric acid mist.

The NTP and the IARC have classified lead as an A3 carcinogen (animal carcinogen). While the agent is carcinogenic in experimental animals at relatively high doses, the agent is unlikely to cause cancer in humans except under uncommonly high levels of exposure. For further information, see the ACGIH's pamphlet, *1996 Threshold Limit Values and Biological Exposure Indices.*

REPRODUCTIVE TOXICITY: Lead is known to cause birth defects in human and animals.
TERATOGENICITY: Lead is known to cause birth defects in human and animals.
MUTAGENICITY: Lead has been found to be mutagenic.
SYNERGISTIC EFFECTS: Other heavy metals (arsenic, cadmium, mercury) may cause additive toxic effects.

Section 12: ECOLOGICAL INFORMATION

EFFECTS OF MATERIALS ON PLANTS OR ANIMALS: Lead and its compounds may cause an adverse effect to animals and plants that come into contact with them.

EFFECTS ON AQUATIC LIFE: Lead and its compounds may cause an adverse effect to animals and plants in an aquatic environment that come into contact with them.

Section 13: DISPOSAL

Battery Electrolyte (Acid): Neutralize as above for a spill, collect residue, and place in a drum or suitable container. Dispose of as a hazardous waste.

DO NOT FLUSH LEAD-CONTAMINATED ACID INTO SEWER.

Batteries: Send to lead smelter for reclamation following applicable Canadian, provincial, and local regulations.

LEAD RETURN RECYCLE

Section 14: TRANSPORTATION INFORMATION

US DOT SHIPPING NAME: Batteries, Wet, Filled with acid, Class 8, UN 2794, PG, III.
DOT LABEL: Corrosive

IATA SHIPPING NAME: Batteries, Wet, Filled with acid, Class 8, UN 2794, PG, III.
IATA LABEL: Corrosive.

TRANSPORT OF CANADA TRANSPORTATION OF DANGEROUS GOODS REGULATION
SHIPPING NAME: Batteries, Wet, Filled with acid, Class 8, UN 2794, PG, III.
LABEL: Corrosive

Section 15: REGULATORY INFORMATION

TSCA REGISTRY: Ingredients listed in the TSCA Registry are lead, lead oxide, lead sulfate and sulfuric acid.

CALIFORNIA PROPOSITION 65 WARNING: The state of California has listed lead as a material known to cause cancer or cause reproductive harm (July 9, 2004 California List of Chemicals Known to Cause Cancer or Reproductive Toxicity)

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

CANADIAN ENVIRONMENTAL PROTECTION ACT: These products are manufactured articles and are exempt from regulation.

CANADIAN WHMIS CLASSIFICATION: This product has been classified according to the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

Section 16: OTHER INFORMATION

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

Appendix B: Flotation Calculations

Endurance Configuration

Section	Volume (in^3)	Weight (lbs)	1 lb of Foam to Volume (in^3)	Foam NEEDED (ft^3)	EXCESS Foam (ft^3)
Front of Bow (Triangle Shape)	2854.875	3.146850869	907.21649	5.88903759	3.051555581
Seat	1732.5	1.90968751	907.21649		
Side Walls	791.25	0.8721733001	907.21649		
Under Panel	2830.5	3.119982971	907.21649		
Middle Wall	1048.44	1.155666824	907.21649		
Under Endurance Motor	3864	4.259181841	907.21649		
Side Wall in Back	1502.91	1.656616713	907.21649		
Back Floor	824.87	0.9092317094	907.21649		
Total Volume (in^3) -->	15449.345				
Total Volume (ft^3) -->	8.940593171				
Total Weight (lbs) --->	17.02939174				
Foam in the Back of Boat					
Under Endurance Motor	3864	Total Volume (Back Foam) (in^3)	6191.78		
Side Wall in Back	1502.91	Total Volume (Back Foam) (ft^3)	3.583206019		
Back Floor	824.87	Total Weight (Back Foam) (lbs)	6.825030264		

This table above concludes that there is excess foam on the current integrated boat design, by a value of approximately $3ft^3$, as shown in the column far right.

The current flotation force in this configuration was calculated to be 942.86 lb. This results in a flotation safety ratio of 1.61.

Sprint Configuration

Part	Volume (in^3)	Weight (lbs)	Buoyant Force (lb)	Flotation Ratio	Required Buoyant Force (lbs)	Volume Necessary (ft^3)	Current Volume (ft^3)	Foam Needed
Hull	7100	100	357.8197639	0.7057589031	608.4	9.75	5.734291088	4.015708912
Steering Helm	0	20						
Front Solar	0	0						
Middle Solar	0	0						
Electrical Panel	1508.38	43						
Batteries	779.625	90						
Sprint Drive Train	520.85	80						
Endurance Motor	0	57						
Surface Drive	0	90						
Steering System	0	27						
Total Volume (in^3) -->	9908.855							
Total Volume (ft^3) -->	5.734291088							
Total Weight (lbs) -->	507							
* Parts with volume = 0 do not apply in volume calculations								
* Parts with weight = 0 do not apply in configuration								

The team concluded that this configuration was not necessary to analyze in concluding the flotation safety factor. To ensure this, calculations were made anyway.

Appendix C: Proof of Insurance

THE COLLEGE OF NEW JERSEY

STATEMENT ON LIABILITY INSURANCE

As an agency of the State of New Jersey, The College of New Jersey is bound by the same statutory provisions. Any agreement signed on behalf of the State of New Jersey by a State official shall be subject to all of the provisions of the New Jersey Tort Claims Act N.J.S.A. 59:1-1 et. seq., the New Jersey Contractual Liability Act N.J.S.A. 59:13-1 et. seq., and the availability of appropriations.

The State of New Jersey does not carry public liability insurance, but the liability of the State and the obligation of the State to be responsible for tort claims against its employees, is covered under the terms and provisions of the New Jersey Tort Claims Act. The State shall be liable for injury proximately caused by the acts or omissions of its employees within the scope of their employment, pursuant to N.J.S.A. 59:2-2. The other party shall be responsible for the acts and omissions of its employees within the scope of the performance of their job duties, as well as for the maintenance, safety and upkeep of their facilities.

The Act also creates a special self-insurance fund and provides for payment of claims under the Act against the State of New Jersey or against its employees for which the State is obligated to indemnify against tort claims which arise out of the performance of their duties.

Claims against the State of New Jersey or its employees arising out of the use of your facility should be referred for handling to the Department of Treasury, Bureau of Risk Management, PO Box 620, Trenton, New Jersey 08625.

Authorized Representative

Curt Heuring
Vice President for Administration

2012

Appendix D: Team Roster

Timothy Mindnich, 2016 Mechanical Engineer
- Endurance motor
- Sprint propeller integration

Joseph DiLorenzo, 2016 Engineering Management (Mechanical)
- Steering and Rudder design
- Weight Distribution

Matthew Berry, 2016 Engineering Management (Mechanical)
- Electrical System
- Telemetry

Kali Cippola, 2016 Mechanical Engineer
- Drivetrain
- Captain

Last year's contributors:

Edward Han, 2015 *M.E.*
- Project Manager
- Hull Modification
- Steering System

Kevin Butterhof, 2015 *M.E.*
- Propeller Design

Elias Davila, 2015 *M.E.*
- Surface Drive Design

Julian Daum, 2017 *E.E*
- Electrical System
- Telemetry System

Appendix E: Solutions to weight distribution issue

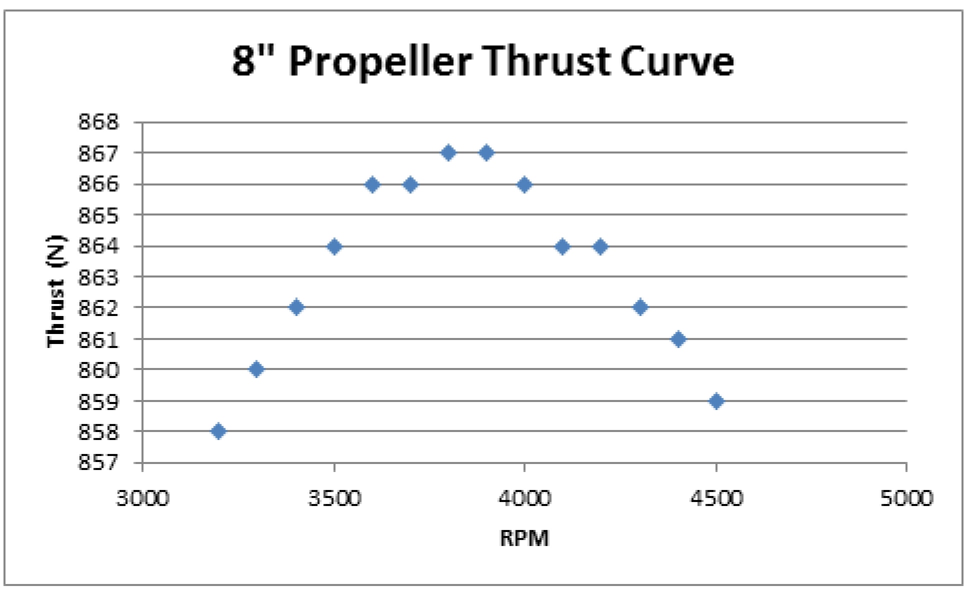
After a disappointing test in sprint configuration the team brainstormed solutions to our weight distribution issue. The following iterative plan is currently being implemented. The first step take will be to flip the resting position of the endurance motor. This will move the 40 lb powerhead about 3 feet toward the stern. The motor is the heaviest object with the greatest moment that can be most easily shifted. If the swapping of the motor position does not raise the bow out of the water as much as the team would like, the position of the panel and batteries will swapped. The panel would have to be condensed to fit in the skinnier part of the hull. This would move 90 lbs. batteries to the stern side of the center of gravity.

Appendix F: Previous Year's Propeller Design

The first step in designing the propeller was to choose a suitable diameter, number of blades, and operating speed using open-source software Open Prop v.3.3.4. The program uses a number of input parameters, such as ship speed, required thrust, diameter, RPM, number of blades, etc. to calculate required torque, horsepower, and propeller efficiency.

Determining the optimal number of blades, diameter, and operating speed was a highly iterative process. The parameters for ship speed and power were fixed at 40 knots and 28.7 HP respectively, while the experimental parameters, number of blades, diameter, and rotational speed were varied over a large range of values. The goal of the analysis was to determine which combination of experimental parameters would produce the highest thrust without exceeding the available shaft horsepower. Each iteration was manually inputted into Open Prop and the data was collected in an Excel file. The results of the of the parametric analysis showed that a three-bladed, 8" propeller operating at 3900 RPM would provide the highest thrust at 83.2% efficiency.

Table 9: Propeller Thrust Curve



The thrust curve for the 8” propeller shown in Table 9 revealed that over the range of 3200-4500 RPM the thrust varied by only 10 Newtons. It was for this reason that an operating speed of 4266 RPMs was chosen as the required pulleys and gears to achieve this output speed were already in the team’s possession.

The team was able to verify the chosen diameter and speed using *The Propeller Handbook*[7], as a reference. Equation 1, adopted from Gerr, can be used to find the diameter of a three bladed propeller of standard elliptical contour and flat faced section, with blade widths of about 0.33 mean-width ratio

$$D = \frac{632.7 * SHP^{0.2}}{RPM^{0.6}}$$

where: D = propeller diameter in inches; SHP = shaft horsepower at the propeller; RPM = shaft RPM at the propeller.

Substituting 28.7 SHP and 4266 RPM into equation1, results in a diameter of 8.22 inches, which is very close to the results obtained using Open Prop. The handbook also states that surface piercing propellers are usually about 30-40 percent larger in diameter than comparable standard propellers. Erring on the side of a larger diameter, the team chose to increase the propeller diameter by 40%. A 40% increase in the calculated 8.22 inch diameter results in a diameter of 11.5 inches.

With a boat speed of 40 knots and an engine speed of 4266 RPM, the pitch that will give the same forward distance traveled per minute as the boat will travel at 40 knots can be calculated. The boat speed in knots converted to feet per minute (FPM) is 4050.7 FPM. Dividing 4050.7 FPM by 4266 RPM results in a pitch of 0.949 feet (11.39 inches) per revolution. This calculated pitch assumes no slip occurs between the propeller and the water, such is not the case. In order to calculate the required pitch, slip must be a factor. Slip can be calculated using the following:

$$Slip = \frac{1.4}{Kts^{0.57}}$$

With a boat speed of 40 knots, the slip is calculated to be 17.1%. Increasing the slip without pitch by 17.1% yields a pitch of 13.34 inches.

To determine the necessary maximum blade thickness of the propeller blades, an ANSYS structural analysis was performed. There were a number of difficulties in performing a structural analysis on the blades due to the unknown nature of the forces acting on the blade as the propeller impacts the water surface. To address this issue, an assumption was made that the maximum impact force on a single blade would not exceed 224 lbf (1000 N). This value was considered to be a conservative estimate of the maximum load that would be experienced by an individual blade. Other forces that would be experienced by the blade during operation were considered to be relatively minor compared to the impact load and thus were not factored into the stress analysis.

To simulate the impact force, a uniformly distributed line pressure load was applied to the 7.5” blade edge, yielding a load of 29.9 lbf/in. The angle at which the load was applied greatly affected the maximum stress in the blade. To determine the worst case loading scenario, multiple iterations of the analysis were performed to determine the angle, relative to global axis, which produced the maximum stress. The blade loading condition and a graph of the maximum blade stress as a function of loading angle is shown below.

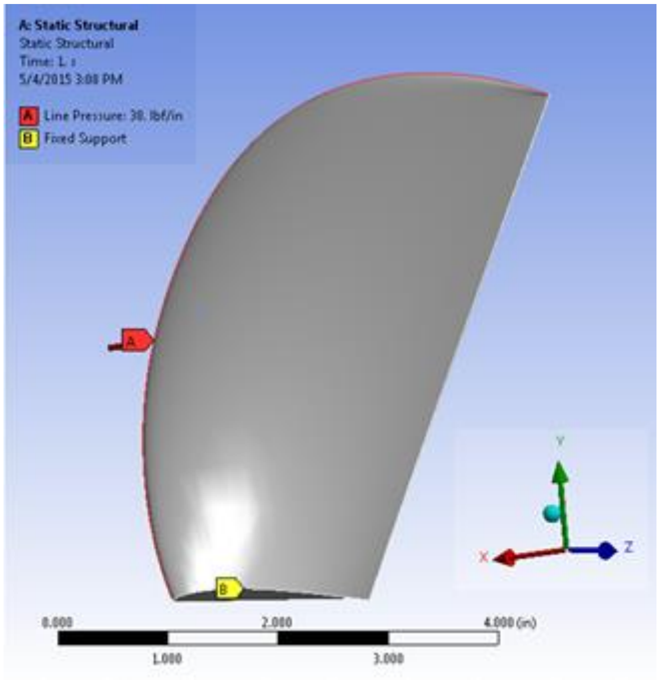
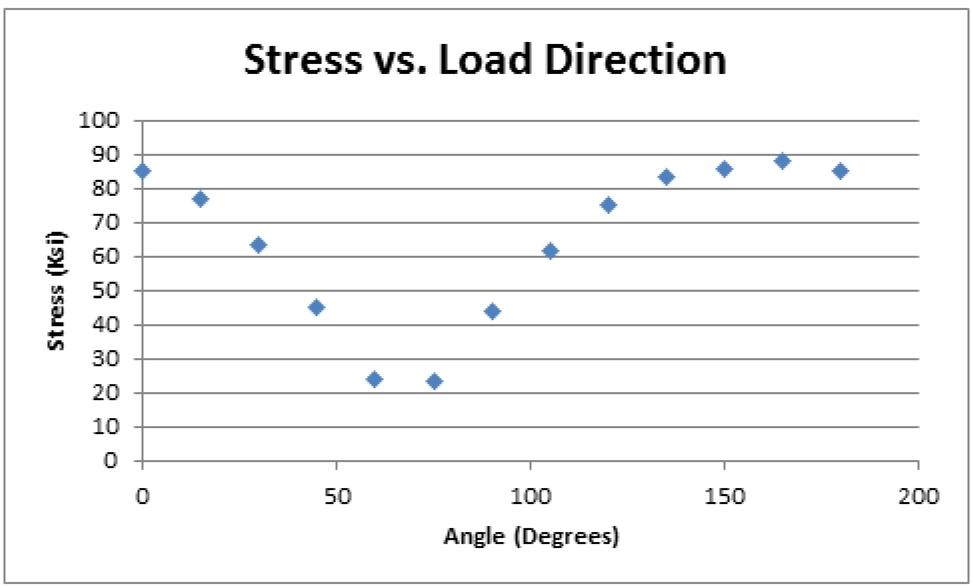


Fig. 19: Structural Analysis of Propeller Blade

Table 10: Stress vs. Load Direction



The blade thickness was determined using the 29.9 lbf/in impact load at the worst case scenario angle. A thickness of 0.35" produced a maximum stress of 19.9 Ksi. The yield strength of aluminum 6061-T6 is 40 Ksi, which provides a factor of safety of 2. A safety factor of 2 was considered acceptable due to the relatively severe impact load conditions applied to the blade. However, since the propeller is such a crucial component in the success of the entire boat, the blade thickness was increased to 0.4" to provide additional structural support.

The propeller will be constructed out of a 3 x 13 x 13 inch solid block of 6061-T6 aluminum using the college's five axis CNC milling machine. The CAESES CAD model of the propeller was exported into Solidworks where the block of material housing the propeller was modeled and where the hub edges were rounded for increased hydrodynamics. The file was then transferred over to the college's machinist who programmed the CNC machine using the model. The propeller was first machined out of a solid block of Butterboard to ensure the programming was correct and to allow for changes to be made before the final propeller was constructed out of aluminum. Fig. 20 shows the butterboard prototype during the machining process.

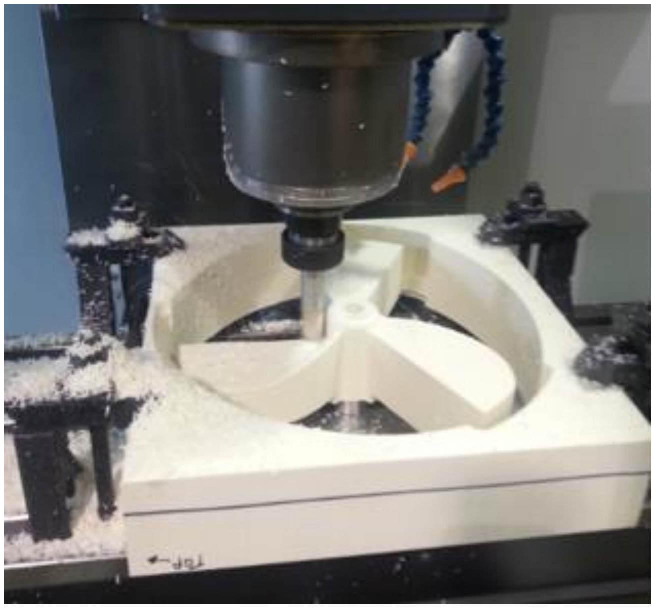


Fig. 20: Butter board Prototype during CNC Mill Machining

The butterboard prototype was completed and after inspection it was apparent that no major changes needed to be made. The propeller was carefully filed out of the butterboard housing and sanded on the tips in order to achieve a smooth surface. The final propeller is shown in Fig. 21 below.

Fig. 21: Final Product of Surface Piercing Propeller (2015)

Appendix G: Surface Drive

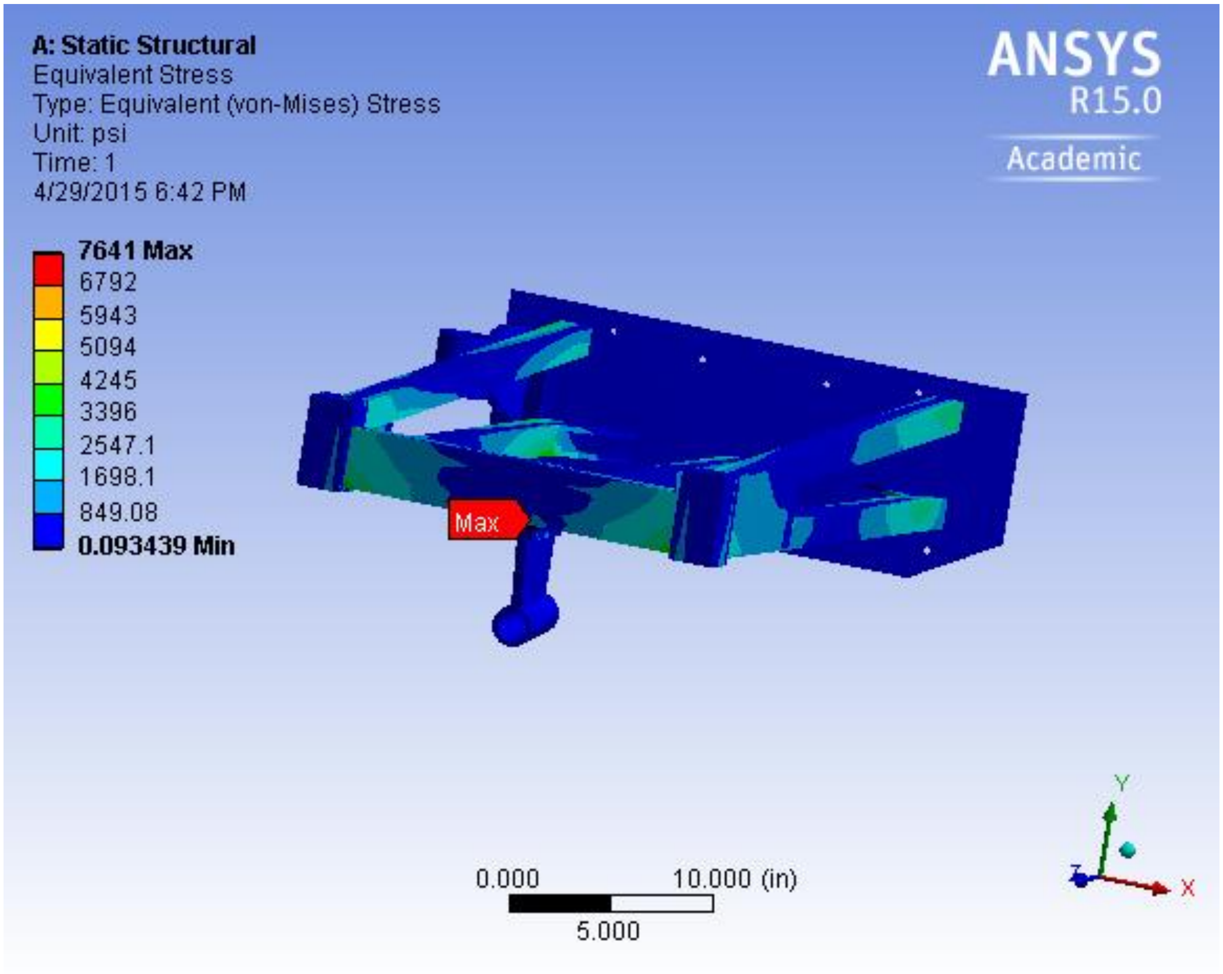


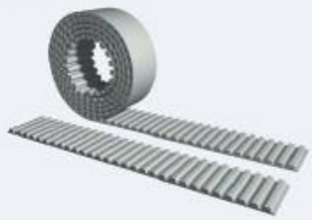
Fig. 22: Structural Analysis of Surface Drive Design

Appendix H: Drive Train

POLYURETHANE TIMING BELTS

TIMING BELT VERSIONS – CODES

Open Ended
– Code "M" –

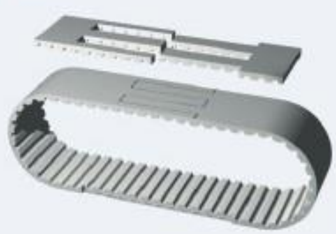


BRECO M timing belts are manufactured as open ended belts with bifilar, parallel tension members. The most common application is linear drives, in which rotary motor motion is translated into linear movement.

- High speed, up to 80 m/s
- High spring rate
- Any length available
- Various polyurethane materials available

Applications: Linear Drives

Spliced and Welded Endless
– Code "V" –



BRECO V timing belts are spliced and welded endless from open ended roll stock. The timing belt ends are joined together in a heat welding process. Virtually any length is possible and can be determined in one tooth increments. One half of the tension members transmit load in the weld area. Preferred for conveying belts, profiled belts, covered belts and general purpose applications.

- Can be profiled and machined
- Any length available
- Many facings are offered
- Various polyurethane materials available

Applications: Conveying

Truly Endless BRECOFLEX
– Code "BFX" –

BRECOFLEX BFX versions are manufactured as truly endless timing belts resulting in timing belts with no interruptions or joints. Two bifilar tension members are helically wound throughout the timing belt for superior strength and true tracking. All tension members carry full load throughout the entire timing belt length.

- High speed, up to 80 m/s
- High strength, up to 200 kW (275 hp)
- Wide range of standard sizes
- Long lengths available (up to 22 meters)

Applications: Power Transmission

BRECOflex CO., L.L.C. Toll Free: 1-888-463-1400 • Fax: 732-542-6725 • Website: www.brecoflex.com
12

POLYURETHANE TIMING BELTS

TOOTH PROFILES

T-Series

page 20 - 29

Standard timing belt for conveying and moderate power transmission applications

- Manufactured to DIN 7721
- Flexible for back bending applications
- Used for profiled belts with metric profile spacing
- Wide range of pitch sizes (2.0 mm to 20.0 mm)
- Wide range of belt widths (up to 150 mm)
- Bifilar tension member design for true tracking

AT-Series

page 30 - 37

High strength timing belt for power transmission and high accuracy positioning applications

- High strength tension members (up to twice as strong as standard T-Series and Imperial pitch belts)
- Increased tension member spring rate for better repeatability and reduced settling time
- High tooth shear strength (up to 45% higher than standard T-Series and Imperial pitch belts)
- Reduced backlash (zero backlash pulleys available for highest accuracy)
- Bifilar tension member design for true tracking

REDFLEX GEN III-Series

page 38 - 41

Highest strength timing belt available utilizing advanced materials for demanding power transmission applications

- More densely wound bifilar tension members for true tracking, up to 40% more tensile strength than AT-Series
- Increased tension member spring rate for better repeatability and reduced settling time
- High performance polyurethane for up to 60% higher tooth shear strength and improved service life
- Temperature range up to 100°C
- Used with standard AT-Series pulleys
- Available in AT3, AT5, AT10 and ATP10

ATN-Series

page 42 - 44

Most advanced profile timing belt system utilizing molded belt cavities and specially designed inserts allowing profiles to be mechanically fastened

- Quick and easy profile change (variable profile pitch)
- Various profile materials can be utilized
- No belt disassembly necessary to change profiles
- Connecting kit available for field assembly
- ATN components available in nylon, brass, stainless steel
- Alternative to chain with the advantages of a timing belt

AT-SERIES

AT10

STEEL Tension Member — standard
KEVLAR® Tension Member — optional

TRULY ENDLESS - BFX

Pulleys page 168

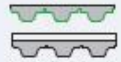
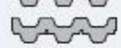
Widths: Standard Belt Widths in mm (in between widths available):
10 12 16 20 25 32 50 75 100 150

Pitch/Length Version	Number of Teeth
AT10 / 400 BFX	40
AT10 / 500 BFX	50
AT10 / 530 BFX	53
AT10 / 560 BFX	56
AT10 / 580 SFX	58
AT10 / 600 SFX	60
AT10 / 610 BFX	61
AT10 / 630 BFX	63
AT10 / 660 BFX	66
AT10 / 700 BFX	70
AT10 / 720 BFX	72
AT10 / 730 SFX	73
AT10 / 780 BFX	78
AT10 / 800 BFX	80
AT10 / 810 BFX	81
AT10 / 840 BFX	84
AT10 / 850 BFX	85
AT10 / 880 BFX	88
AT10 / 890 BFX	89
AT10 / 920 BFX	92
AT10 / 960 BFX	96
AT10 / 970 BFX	97
AT10 / 980 BFX	98
AT10 / 1000 SFX	100
AT10 / 1010 BFX	101
AT10 / 1050 SFX	105

Pitch/Length Version	Number of Teeth
AT10 / 1060 BFX	106
AT10 / 1100 BFX	110
AT10 / 1150 BFX	115
AT10 / 1200 BFX	120
AT10 / 1210 BFX	121
AT10 / 1240 BFX	124
AT10 / 1250 BFX	125
AT10 / 1280 BFX	128
AT10 / 1300 BFX	130
AT10 / 1320 BFX	132
AT10 / 1350 BFX	135
AT10 / 1360 BFX	136
AT10 / 1400 BFX	140
AT10 / 1420 BFX	142
AT10 / 1480 BFX	148
AT10 / 1500 BFX	150
AT10 / 1530 BFX	153
AT10 / 1600 BFX	160
AT10 / 1700 BFX	170
AT10 / 1720 BFX	172
AT10 / 1800 BFX	180
AT10 / 1860 BFX	186
AT10 / 1900 BFX	190
AT10 / 1940 BFX	194
AT10 / 2000 BFX	200
AT10 / 2120 BFX	212

Pitch/Length Version	Number of Teeth
AT10 / 2240 BFX	224
AT10 / 2360 BFX	236
AT10 / 2500 BFX	250
AT10 / 2650 BFX	265
AT10 / 2800 BFX	280
AT10 / 3000 BFX	300
AT10 / 3150 BFX	315
AT10 / 3350 BFX	335
AT10 / 3550 BFX	355
AT10 / 3750 BFX	375
AT10 / 4000 BFX	400
AT10 / 4250 BFX	425
AT10 / 4500 BFX	450
AT10 / 4750 BFX	475
AT10 / 5000 BFX	500
AT10 / 5300 BFX	530
AT10 / 5600 BFX	560
AT10 / 6000 BFX	600
AT10 / 6300 BFX	630
AT10 / 6700 BFX	670
AT10 / 7100 BFX	710
AT10 / 7500 BFX	750
AT10 / 8000 BFX	800
AT10 / 9000 BFX	900

Available Options (page 149):

- **PAZ** 
- **T-Cover** 
- **DL** 
- **DR** 

Further lengths up to 20,000 mm available.
Length of timing belt can be increased in increments of one tooth from minimum length of 720 mm.

Ordering example: BRECOFLEX Timing Belt 50 AT10 / 2360 BFX

Belt Width — 50
Pitch — AT10
Length — 2360
Truly Endless Length Code BFX — BFX

STOCK PULLEYS

The BRECO*flex* CO., L.L.C. pulley stocking program includes the pulley configurations listed below. Stock pulley material is aluminum with zinc plated steel flanges. Select the standard pilot bore or incorporate custom modifications, some of which are listed at the bottom and shown on the opposite page. Modified stock pulleys, in small quantities, are usually delivered in one week.

Pitch	teeth range (not all # of teeth available from	to	stock pulleys available for belt widths (mm)	Pitch	teeth range (not all # of teeth available from	to	stock pulleys available for belt widths (mm)
T2.5	10	60	6,10	XL	10	40	12.7, 25.4
T5	10	60	10, 16, 25	L	10	25	25.4, 50.8
T10	12	60	16, 25, 32, 50	H	14	40	25.4, 38.1, 50.8, 76.2
AT3	15	72	6, 10, 16	TK5 K6	25	48	50
AT5	15	72	10, 16, 25, 32	TK10 K13	20	48	50, 100
AT10	15	60	25, 32, 50	ATK10 K6	20	60	50, 100
ATN10	25	60	25, 50	ATK10 K13	20	60	50, 100
ATN12.7	20	32	25, 50, 75, 100	HK13	20	36	50.8, 101.6
ATL5	25	72	10, 16, 25, 32	BAT10	20	60	32, 50
ATL10	25	60	25, 32, 50				

All stock timing belt pulleys can be customized and modified to specific requirements. Complex machining and intricate details can be realized. These modifications can include but are not limited to the following:

- add/remove flanges
- finish bore
- remove or change hub
- cut key seat
- reduce pulley width
- counter bores
- set screws
- taper bores
- bolt holes
- snap ring grooves
- lightening holes
- self-tracking groove

Please provide your requirements to BRECO*flex* CO., L.L.C. Engineering Department.

The following are technical specifications for the LEM-200 D126 sprint motors

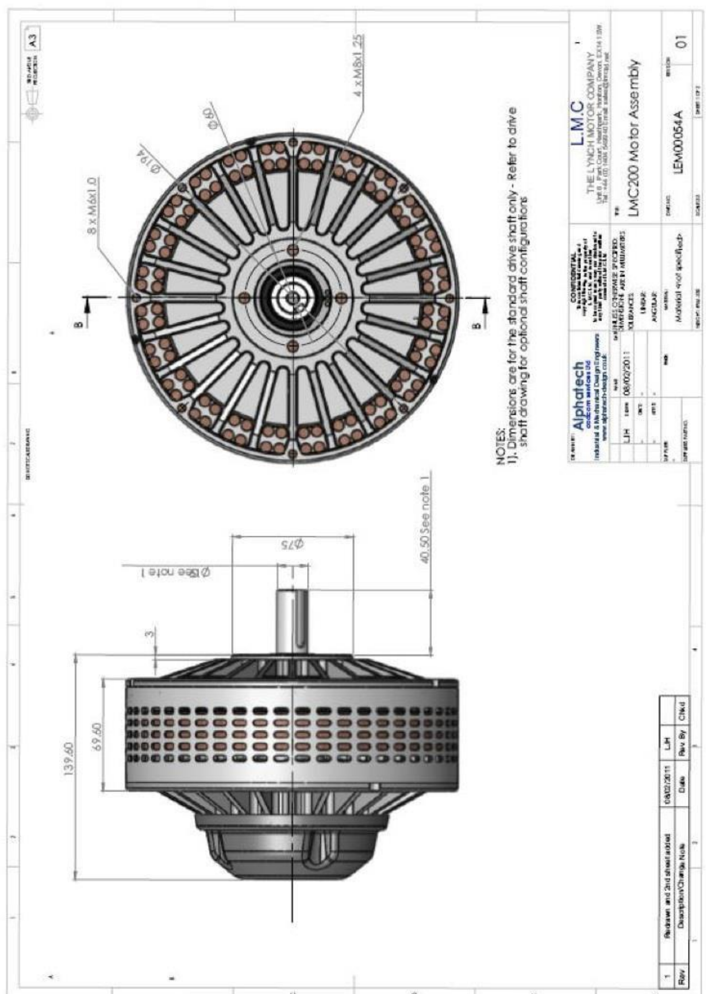
LMC
Generating Movement Efficiently

Motors

LEM-200

Technical Data:

Motor	No Load Current	Torque Constant	Speed Constant	Armature Resistance DC	Armature Inductance @ 15kHz	Armature Inertia	Peak Power	Peak Efficiency	Peak Current	Rated Power	Rated Speed	Rated Voltage	Rated Current	Rated Torque
	A	Nm/A	Rpm/V	mΩ	μH	Kgm^2	kW	%	A	kW	Rpm	V	A	Nm
95	6	0.113	81	21.5	22	0.0238	18	92	400	6	3888	48	175	19
126	10	0.0737	105	175	6	0.0234	7.59	83	400	5.06	2520	24	270	19.2
127	5	0.15	54	22.5	23	0.0236	16.08	89	400	8.55	2592	48	215	31.5
D95B	6	0.14	76	20.5	11	0.0238	28.50	92	400	15.00	6000	72	200	30.0
D126	5	0.0748	100	138	5	0.0234	11.14	81	400	6.91	3600	36	250	18.3
D127	4	0.17	50	17.5	13	0.0236	25.38	92	400	12.56	3600	72	200	33.3
D135	3.5	0.185	45	16.75	16	0.0236	29.04	93	400	14.39	3780	84	200	36.4
D135 RAG	7.36	0.207	42	16.95	16	0.0238	34.32	93	400	16.84	4032	96	200	39.9
D135 RAGS	7.45	0.21	40	16.95	16	0.0238	36.00	93	400	18.00	4400	110	200	42.0



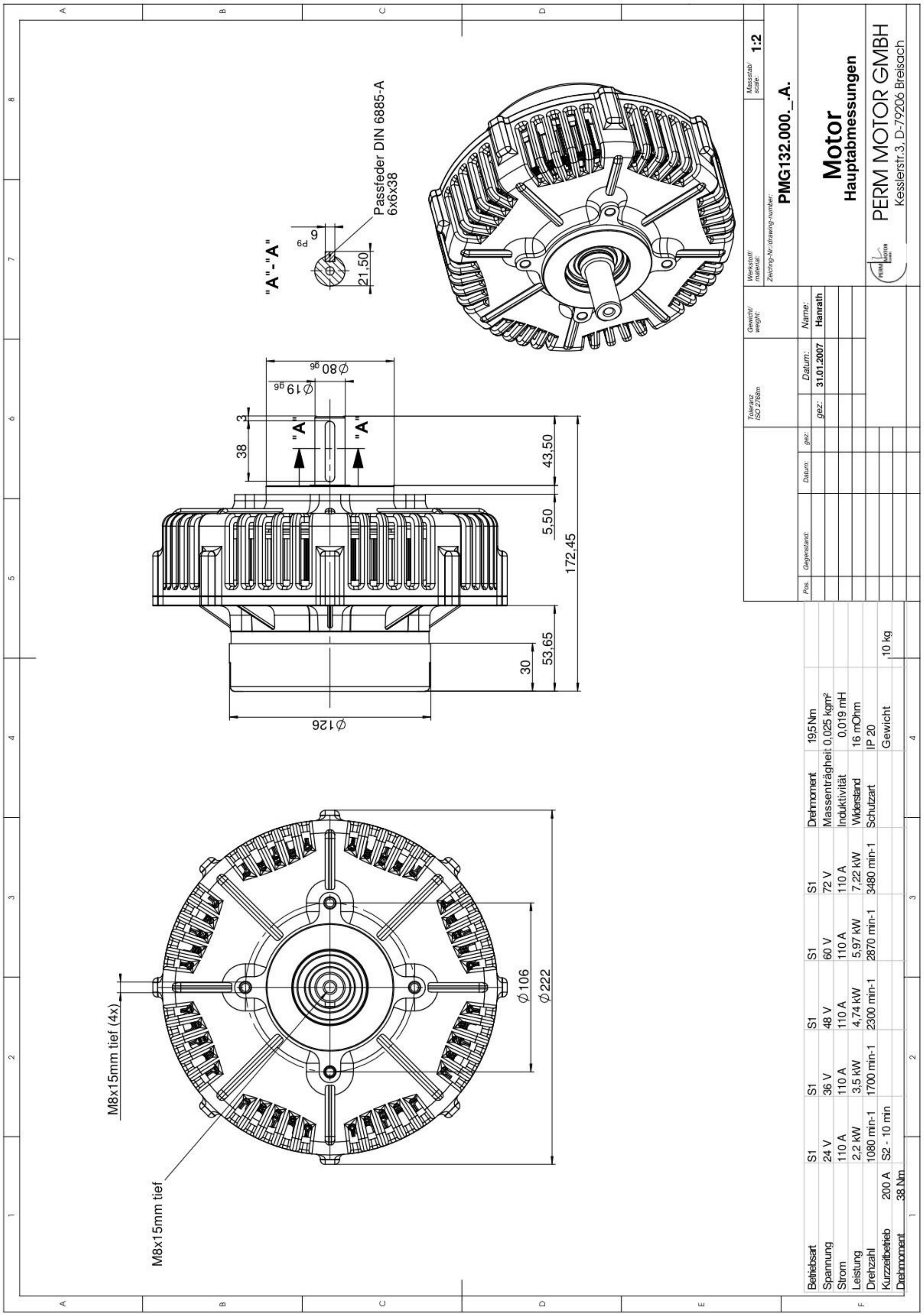
ISO 14001
ISO 9001

LMC Ltd
Generating Movement Efficiently

www.lmcltd.net sales@lmcltd.net
Unit 8 Park Court, Heathpark, Honiton, Devon, EX14 1SW.
Tel: +44 (0)1404 549940 Fax: +44 (0)1404 549546

Page 2 of 2

The following are technical specifications for the Perm PMG132 endurance motor



PERM MOTOR

Technical Specs
PMG 132

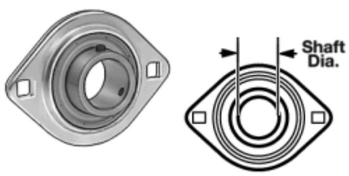
Voltage	24 V	36 V	48 V	60 V	72 V
Operation mode	S 1	S 1	S 1	S 1	S 1
Current	110 A	110 A	110 A	110 A	110 A
Power	2,5 kW	3,5 kW	4,74 kW	5,97 kW	7,22 kW
rpm	1080 min-1	1700 min-1	2300 min-1	2870 min-1	3480 min-1
torque	20 Nm				
inertia	0,025 kgm²				
inductance	0,019 mH				
resistance	16 mOhm				
protection	IP 20				
weight	11 kg				
Short time operation	200 A	S2 10 min			
peak torque	38 Nm				

The following are technical specifications for bearings selected for the design

Mounted Bearings

This product matches all of your selections.

CAD | Catalog Page | Bookmark

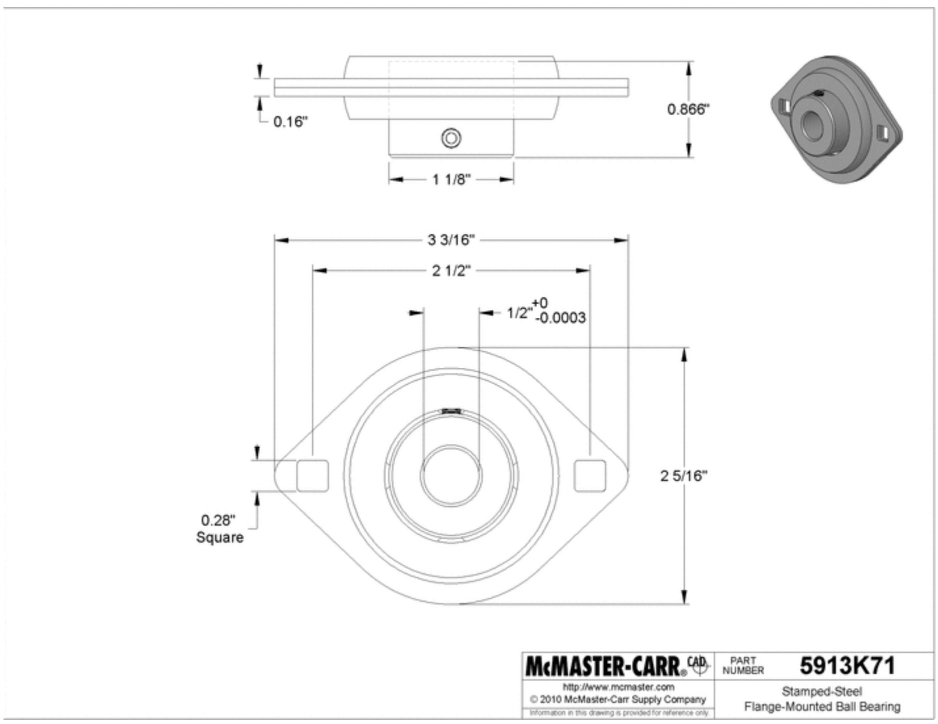


5913K71

Each ADD TO ORDER

In stock for $11.33

Mounting Style	Flange Mount
Flange Mount Type	Standard
Type	General Purpose
Bearing Style	Ball
For Shaft Diameter	1/2"
Dynamic Radial Load Capacity, lbs.	716
Maximum rpm	5,800
ABEC Precision Bearing Rating	ABEC-1
Housing Material	Steel
Steel Housing Material	Stamped Steel
Bearing Material	Steel
Temperature Range	-4° to +212° F
Bearing Construction	Double Sealed
Maximum Shaft Misalignment	3°
Secures/Attaches With	Double Set Screw
Note	Bearing insert is deep grooved to retain lubricant and block out dirt. Set screws included.



Appendix I: Solar Panel Technical Information

US

SCHOTT PERFORM™ POLY
Polycrystalline Solar Modules

SCHOTT PERFORM™ POLY 220/225/230/235/240

At a glance

- Industry leading warranty
- Narrow output tolerance
- Long-term reliability
- High resistance to mechanical loads
- Up-to-date features
- Environmentally friendly

SCHOTT Solar manufactures modules in Albuquerque, New Mexico, and other global production facilities.

The modules from Albuquerque:
- Qualify as a domestic end product under the Buy American Act (BAA)
- Qualify as a U.S.-made end product under the Trade Agreement Act (TAA)
- Qualify as a domestic manufactured product under the American Recovery & Reinvestment Act (ARRA)

SCHOTT Solar has been a leading global developer and manufacturer of solar products for over 52 years. Engineered in Germany, the high quality SCHOTT Solar PV modules are extremely durable and reliable as demonstrated in several important ways:

Industry leading warranty: SCHOTT Solar offers an industry leading linear power output warranty for 25 years in addition to five years warranty for any defects in materials or workmanship. This enhancement provides 6% more guaranteed power over the 25 year period compared to standard step-down warranties common in the industry.

Narrow output tolerance: SCHOTT PERFORM™ POLY modules are among the industry leaders in lower output tolerances. SCHOTT Solar sorts all modules to a positive tolerance (minus zero watts) which provides for a stable, high energy output you can feel secure in.

Long-term reliability: SCHOTT modules are environmentally tested to double the industry certification standards for thermal cycling and damp heat tests to ensure consistent and superior performance over the long term. In addition, SCHOTT has performance data from over 25 years of actual field testing that supports our high quality products.

High resistance to mechanical loads: SCHOTT Solar modules are tested to an extreme loading pressure of 5,400 Pa to ensure additional security for your investment.

Up-to-date features: SCHOTT Solar modules offer up-to-date electrical features such as double insulated PV cables for use with transformerless inverters and locking connectors.

Environmentally friendly: Due to our concern with job site waste and disposal costs, we bulk pack our modules in a manner that significantly reduces cardboard waste.

SCHOTT solar

Techn ica l Data

Electrical Data

Module type		SCHOrr PERFORM" POLY 220	SCHOrr PERFORM" POLY 225	SCHOrr PERFORM" POLY 230	SCHOrr PERFORM"POLY 235	SCHOrr PERFORM" POLY 240
Nominalpower [Wpf	Pm"	,220	,225	,230	>235	,240
Voltage at nominalpower M	VmW	29.7	29.8	30.0	30.2	30.4
Current at nominalpower [A]	Im"	7.41	7.55	7.66	7.78	7.90
Open-<:ircuit voltage M	Vu	36.5	36.7	36.9	37.1	37.3
Short<ircuit current [A]	I_	8.15	8.24	8.33	8.42	8.52

STC (1000 W/m' AM 1.5 cell temperature 25°C)
Power sorting tolerance (as measured by flasher) -0 Watts/ +4.99 Watts

Data at Normal Operating Cell Temperature (NOCT)

Nominalpower [Wp]	Pm"	158	161	165	169	172
Voltage at nominalpower M	Vmw	26.7	26.9	27.1	27.2	27.4
Open-circuit voltage M	Vu	33.3	33.5	33.7	33.9	34.1
Current at nominalpower [A]	Im"	6.53	6.60	6.67	6.75	6.83
Temperature [C]	Tnct	45.5	45.5	45.5	45.5	45

NOCT (800 W/m' AM 1.5 winds peed 1 m/s ambient temperature 20°C)

Data at Low Irradiation

At a low irradiation intensity of 200 W/m(AM 1.5 and cell temperature 25°C) 97% of the STC module efficiency (1000 W/m?) will be achieved.

Temperature Coefficients

Power [%/C]	-0.44
Open -circuit voltage [%/°C]	-0.32
Short circuit current [%/°C]	+0.04

Characteristic Data

Solar cells per module	60
Cell type	6" (156 mm x 156 mm) full square
Front panel	Low-iron solar glass
Frame material	Anodized aluminum
Connection	junction box with 3 bypass diodes PVWIRE 43.3" (1,100 mm) x 4 mm' TYCO Solarlok connectors

Dimensions and Weight

Dimensions	66.34" (1,685 mm) x 39.09" (993 mm) tolerance± 0.118" (3 mm)
Thickness	1.97 (50 mm) tolerance± 0.04" (1 mm)
Weight	Approx. 41.51bs. (18.8kg)

limits

System voltage [V_d	600
Maximum reverse current (A)*	15
Operating module temperature rCJ	-40 to 85
Maximum load (lbs/ft')	75
Fire classification	C

**No external current greater than V - shall be applied to the module*

Qualifications

The SCHOrr PERFORM" POLY 220/225/230/235/240 Watt modules are certified to and meet the requirements of UL 1703.

SCHOTT Solar reserves the rights to make specification changes without notice. For detailed product drawings and specifications, please contact SCHOTT Solar or an authorized reseller.
t Nominal value at STC conditions, ± 4% measurement tolerance

SCHOTT Solar PV, Inc.
U.S. Production Facility
5201 Hawking Drive, SE
Albuquerque, NM 87106
Toll free: 888-457-6527
Email: sales@us.schottsolar.com

SCHOTT
solar