Tidal Power Generation: Infrastructure

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Abstract

The ever growing concern over our current energy dependency has been a topic of interest in today's society. With clean and efficient energy being the top priority, the world is looking toward new technologies to fulfill our energy needs. Tidal power is one form of energy that has caught attention as of late. Tidal energy is both a clean and renewable source of power that has great potential. It also has the unique ability of being completely predictable, unlike solar or wind energy.

We have made it our mission to establish and develop a testing platform for tidal power generation at the University of New Hampshire. We will focus on the systems mechanical infrastructure while another group is tasked with the operation of the electrical package.

Introduction

Background of Tidal Power

Seventy percent of the Earth is covered with water. Oceans move in correspondence to the Earth's location in space, due to gravitational forces from the sun and the moon. This cycle of the water is called tides. Tides have two tidal cycles daily, causing both high tide and low tide in a single day. A huge amount of energy is used to create these currents. Using a method of capturing some of the energy in a high current area could create a great amount of renewable energy.

Tidal energy is a completely clean and renewable source of energy. It addresses the issues of both energy shortage and climate change. Unlike some of the other renewable sources of energy, it is very predictable because tidal cycles can be predicted centuries in advance and it does not depend on weather patterns.

Tidal power has been around for many years; however, it is still relatively unknown to the greater population. The first method of creating power from the tides was to dam the water at high tide, and controllably release it through a waterwheel. Though this only created a little bit of power, it provided a basis for the world's best known power plant: The La Rance Tidal Barrage located in Brittany France. It has been operating for twenty years with no mechanical breakdown.[1]

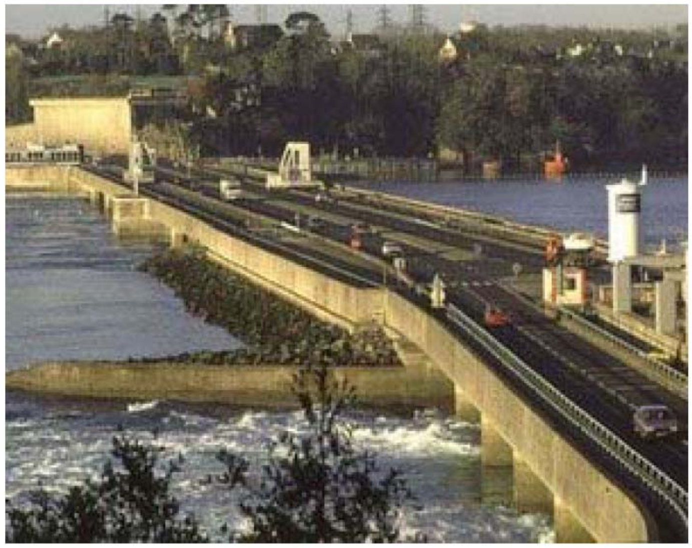


Figure 1: La Rance Tidal Barrage, Brittany France[1]

Figure 1 shows the overall dam and its obvious advantages; however, its main disadvantage is the effect the dam has on the river's ecosystem. As a result, scientists have recently turned to the idea of using the kinetic energy in the current to create the tidal power. This also allows for using both tidal cycles as opposed to just the outgoing tidal cycle. It is also more ecosystems friendly and doesn't have the negative effect of a blocked estuary.[1]

Synopsis of Last Year

The 2008-2009 academic year is the second year the University of New Hampshire has been researching Tidal Energy. Mechanical and Electrical Engineering undergraduate seniors started up the Tidal Energy Generation Project at the start of the 2007-2008 academic year. They performed all the preliminary research about tides and tidal power. From the information they found stated in the background above, they knew they wanted to use the kinetic energy of the moving tides to create their electricity, and using preexisting wind turbine theory and technology, were able to conclude that a turbine would be most beneficial.

The basic preliminary design of last year was to use a Gorlov Helical Turbine, which they were able to have donated, to create enough energy to power a couple light bulbs. The Gorlov Turbine was to be mounted to a cage, which was mounted on a platform supported by pontoons. The design can be seen in Figure 2.

[1] Pictures and Information received from: Tidal Power Generation in the Piscataqua River, University of New Hampshire, TECH 797 Ocean Projects 2007-2008.

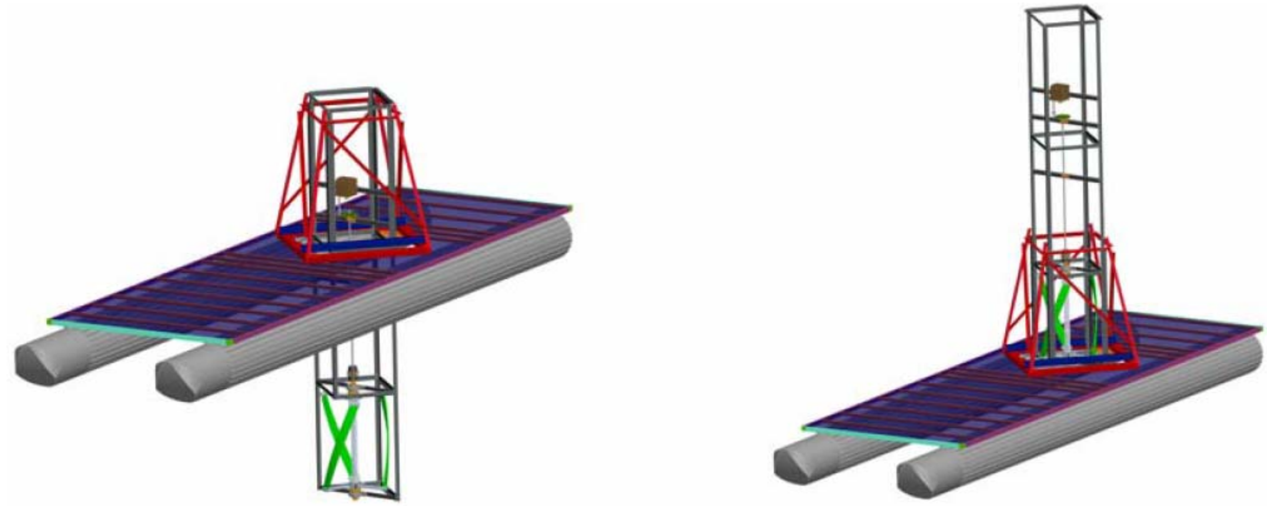


Figure 2: Gorlov Helical Turbine Design[1]

The gray tubes represent the pontoons. The blue platform the 2007-2008 tidal energy team designed and constructed. The red structure, which is known to the team members as the derrick, was pre-existing from a senior project quite a few years back, and was not being used anymore. This was used to the team's advantage to support the cage so that the system has more stability. The derrick will be bolted to the platform. The frame, also known as the cage, shown in gray, is what supports the turbine and the pulley system including the electrical components. The electrical components are high enough up that they are about eye level, completely above the water, when the turbine is fully submerged under water. The pulley system set-up can be seen in Figure 3. The brown box shown is where the alternator is located.[2]

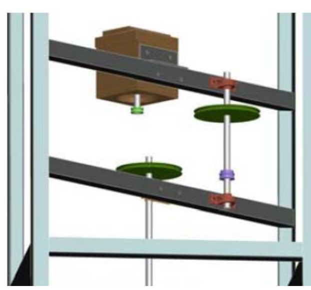


Figure 3: Two Step V-belt Pulley System

The chosen turbine has some flaws, which are important to note. The turbine, aluminum, has been mounted using steel bolts, which will eventually corrode due to seawater. This will make service and disassembly very difficult. Also important to discuss, is the fact that the helical turbine that the 2007-2008 team had assembled to the fabricated frame was a half-size turbine. This means that if the turbine were to be cut, and laid flat, for explaining purposes, the rotors would not completely overlap. This is modeled in Figure 4. In a full size, the blades would overlap, and the 2008-2009 team predicted that this will result in some energy loss.

[1] Picture received from: Tidal Power Generation in the Piscataqua River, University of New Hampshire, TECH 797 Ocean Projects 2007-2008.

[2] See appendix for details on how to get more information on the electrical components and the alternator.

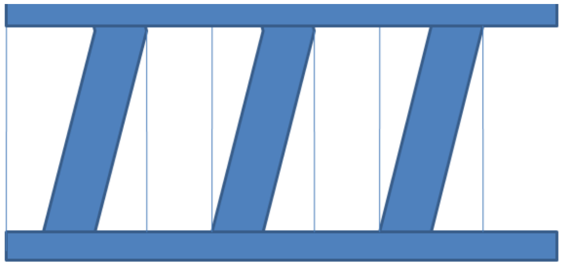


Figure 4: Half Helical Turbine Losses

Last year's team also determined a site location. The site location that they chose was between Dover and Newington, NH, under the Old General Sullivan Bridge, in the Piscataqua River. This spot not only has one of the highest current velocities in North America[2], but measurements were taken to provide evidence that there will be plenty of clearance between the river floor and the turbine.

Figure 5: Geographical Location of Proposed System Placement

Figure 5 shows a geographical location, and Figure 6 shows the river depths under the bridge. Last year's team was able to see these papers to help them with their research. Since this decision was made, NHDOT has approved UNH and the team to temporarily moor the turbine under the bridge.

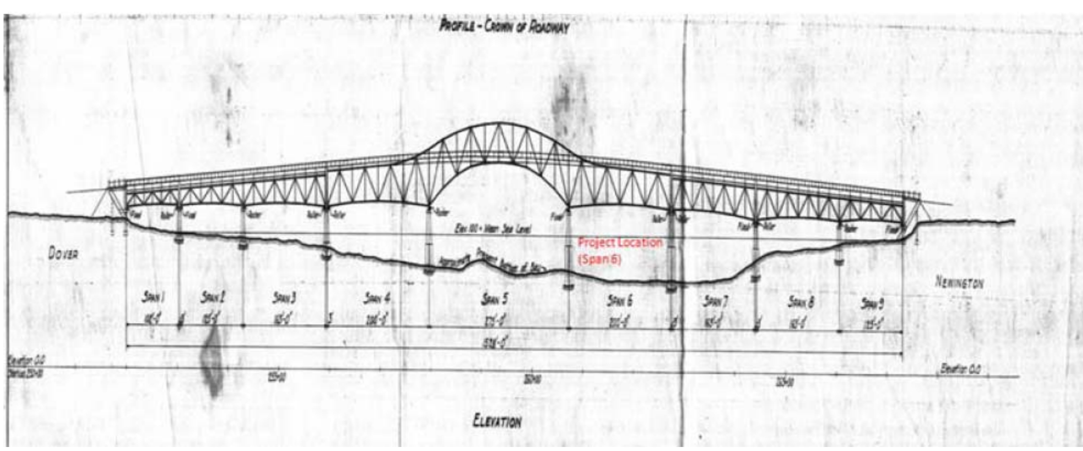


Figure 6: Project Location Within Bridge Structure

[2] http://tidesandcurrents.noaa.gov/faq4.html#70 (Nobles Point is in Portsmouth NH)

The last thing accomplished by the 2007-2008 tidal energy team was the initial fabrication of their design. After completion of the design, their goal was to fabricate and test their product. They had most of the fabrication complete when the school year came to a close. They completed fabrication of the cage, the derrick they already had to their disposal, as stated above, and they completed fabrication of the pontoon platform.

The 2008-2009 Tidal Energy Generation team came into the project with a lot that had been completed, but with a lot left to accomplish.

Goals

The major goal stated for this project was to moor the turbine platform to the General Sullivan Bridge and collect data reflecting the plausibility of the turbine's use as an alternative energy source. A number of intermediate goals were determined in order to facilitate the progress of the project. The completion of each of these goals was considered significant steps in the progression to the ultimate goal.

Intermediate Goals

- Design and construct apparatus to mount the derrick to the platform
- Design and construct cage guiding apparatus to aid in hoisting
- Design and construct a cage hoisting mechanism
- Mount cage and derrick to the platform
- Design and construct a support mechanism for cage the in the lowered position
- Perform tow test

Approach

The first three intermediate goals were instated simultaneously and were determined to be urgent. To design for these issues quickly and effectively, the team divided into groups of two and spent two days brainstorming ideas. Afterwards, the whole group collaborated, discussing the various ideas and discussed a most effective solution to each of the design challenges. Individuals then created scale drawings, material lists, and began determining the method of construction. After a specific plan was determined for each of the first three goals, the designs were presented to the faculty for further analysis and approval. Once approved construction of the mounting apparatus and cage guiding system were simultaneously initiated. Construction of the hoisting mechanism was initiated at a later point.

One major checkpoint in the construction of the project was the complete assembly of the cage, derrick, and platform. This task required a significant amount of planning, foresight, and communication. A number of detailed meetings were called to determine the best method of transportation and assembly. At this point, the group collectively made two major decisions; 1) the cage and derrick should be assembled in the high bay, then transported to the pier and 2) the heights of the platform, cage, and crane required that the derrick must be mounted on the platform at low tide. The University Grounds and Roads department was contacted to provide a truck and trailer for transportation. Majority of the student infrastructure and performance teams were present along with a good number of faculty and staff. David Shay and other key individuals from the university pier were contacted for permission to use the jib crane located on the pier and for assembly recommendations.

After the successful assembly of the derrick to the platform, the hoisting mechanism was installed. As with all designs in the project, precautions were taken to insure the success of the hoisting mechanism; however, a weak link in the system was overlooked leading to a structural failure in the system. After considering a number of modifications, a slightly different hoisting system was successfully implemented.

The concern of a large drag force acting on the turbine when in its lowered position had been lightly discussed at this point. To air on the side of caution, the group began brainstorming ideas for a support system to disperse the overturning moment caused by the large drag force. A solution was quickly devised and implemented.

Little physical preparation was required for the tow test, though a good deal of foresight and caution was planned. The major success of the tow test for the infrastructure group was the proven stability of the parts and the structure as a whole.

The completion of all the intermediate goals allowed for a confident attempt at the ultimate goal of mooring the platform to the General Sullivan Bridge. Again, a good deal of communication was required to allocate resources and people for the bridge test. The platform was transported and successfully moored to the bridge for a number of hours before safely returning back to the UNH pier.

Design and Build

Cage

The cage was designed and fabricated by last year's Tidal Energy team to house the 1.5m Gorlov turbine for testing and bridge deployment. The cage was fabricated using 4 – 2.5" x 2.5" angle steel approximately 19' in length to form the 4 corners of the cage. Looking at the cage in elevation, the steel angle where then braced horizontally at the top, bottom and at 2 equal distances in between to prevent buckling of the columns.

Figure 7: Top Area of Cage

The cage was also braced diagonally on alternating sides by 2.5" x 2.5" steel angle to give lateral support to the cage. In plan the steel angles were also cross braced by 2" x 2" steel tubing which would also act as mounting locations for the alternator, pulley system, turbine shaft and turbine. The cage was not square in plan and its cross sectional dimensions varied along the entire 19' length of the cage. Its dimensions were 38" x 42" at its largest cross section.

The only modification made to the cage was the horizontal bracing at the top of the cage. When the steel angle was placed to be welded at the top of the cage, the flanges on all four sides were facing outwards. That means that the cross sectional dimensions at the top of the cage were 5" larger on each side, being approximately 43" x 47" in plan. The opening in the top of the derrick was 46" x 46", and the cage could not fit in the derrick. The solution was to cut off the entire top of the cage right below where the braces were welded and re-weld new braces with the flanges facing inwards, prohibiting any problems between the cage and the derrick.

The cage weighed approximately 1700 lbs, including the 1.5m turbine housed inside.

Derrick

The derrick was part of several previous years' Ocean Engineering projects and was laying around the Jere Chase Building waiting to be used for another project. It was originally two separate pieces; a base and a frame structure. The base was 6' long by 6' wide and was constructed of 4" x 4" hollow steel tubing. The frame was approximately 6' x 6' at its base and 46" x 46" at its top opening, constructed of 2" x 2" steel angle coming up at angles from the bottom to the top. It was braced horizontally and diagonally by 2" x 2" steel angle and was essentially a space frame with truss members to provide lateral stability to the structure.

Figure 8: Original Derrick

The cage, being 38" x 42" at its largest cross section, fit well inside the 46" x 46" top opening of the derrick. Since the derrick tapered from a 46" x 46" square opening to a 60" x 60" opening at the base, there needed to be guide rails welded the vertical length of the derrick. The guide rails prevented the cage from rocking around inside the derrick, transferred load from the cage to the platform, and assisted during raising and lowering of the cage. The cross section varied by 1" + at some locations on the cage, so it was decided to use 3" x 3" steel angle as the guide rails. Having 3" x 3" guide rails provided enough tolerance so that the cage would not come out of the guide rails, but also allowed room for the varying cross section to move up and down freely in the vertical direction without being bound up at any point in the guide rails.


Figure 9: Guide Rail Mounting and Figure 10: Complete Derrick Changes

Deck Support

The third challenge facing the Infrastructure team was designing a system to adequately mount the derrick and cage assembly to the deck of the platform. Although the previous design team had determined a mounting configuration, the specific structural components had yet to be designed.

From the previous year's numbers, a conservative load analysis showed that the mounting assembly would have to transmit approximately 2000lbs of vertical force and approximately 1000lbs of horizontal shear force to the deck of the platform. This presented a particular challenge due to the fact that the platform's deck was not designed to resist point loads. Despite being quite stiff, it was noted that the extruded aluminum channel supporting the deck would likely catastrophically fail if the shape deformed under load. Furthermore, the aggressive deployment schedule being pursued by the project group demanded an efficient, easy to assemble design.

During design meetings, two different options were proposed. The first involved a positive anchoring system that would receive the derrick assembly via bolted connection brackets. These brackets would be mounted on beams that would bear the full reaction load across the deck and down to the pontoons. This configuration would require more materials and fabrication time but would assume that the deck had no load bearing capacity and would carry a low risk of failure. This option is shown in Appendix C. The second proposed option involved setting the derrick directly on the platform's deck and relying on the derrick's tubular base frame to distribute the load over several deck braces. The derrick would be held in place by timber beams placed over the derrick base frame and bolted to a similar set of timber beams placed under the deck. The entire mounting assembly would be clamed to the deck via threaded rod run through the deck and timbers. This configuration is shown in Appendix B.

Figure 11: Deck Support

Although the latter option was simpler in concept, the lack of positive load transfer and the need to assemble the entire clamping system on site caused the first option to be preferred. While more complex, it was noted that the entire frame could be assembled in the shop and attached to the platform prior to mounting the derrick. Ultimately, only eight single bolted connections would need to be made while the derrick was hanging free on the pier's jib crane, greatly lowering the risk involved with this operation.

The preliminary design was made assuming S6x17.5 steel beams that were thought to be available from the OE Department. However, just prior to fabrication, it was discovered that these beams were being used as spreaders for heavy hoisting operations in the lab. The design was later revised to incorporate 4" aluminum I-beams that became available. While not nearly as strong as the steel beams, it was determined by basic beam analysis that two of these aluminum beams would adequately bear the expected loads. The final frame design is shown completed in Figure 12.

Figure 12: Working On the Platform

General Assembly

The Infrastructure team spent the majority of the first two months of the project finishing fabrication of the cage, derrick, and mounting frame assembly. Aside from fabrication of new components, the turbine shaft bearings needed to be drilled and mounted permanently to the cage, and several cage lattice members needed to be moved to accommodate design changes.

Much time was spent designing a guide system to allow the cage to ride smoothly within the derrick. Several elaborate schemes were developed, however the final design involved a simple set of guide rails fabricated from L2.5x2.5x.025 steel angle with a one-inch clearance for the cage.

Fabrication was accomplished in the Ocean Engineering shop using shop tools and tools purchased for this project. A gantry with a single one ton and a single half ton chain hoist was used to handle the cage, derrick, and mounting frame and to manipulate large components. The extensive drilling of structural steel components proved to be a particular challenge. Initially holes were hand drilled using standard multi-application drill bits. However, extremely poor drilling performance and excessive bit wear prompted a switch to more expensive cobalt steel bits. While drilling performance and bit life improved, it was found that positional accuracy was difficult to maintain due to excessive bit walking. The use of a magnetic base drill and proper lubrication further improved drilling quality, however the small sizes of the steel members used proved to provide insufficient attractive surface for the drill's magnetic base, which is intended for use on large structural members. However, with sufficient care and time, the improved tools and methods greatly accelerated the pace of fabrication.

Figure 13: Mag Drill

Once the mounting frame was assembled, the derrick base frame was placed on the frame and the connection angles were matched drilled to the frame I-beams and to the derrick frame its self. However, the mounting frame appears to have not been squared properly prior to the drilling leading to alignment problems during erection.

With fabrication complete, the team was tasked with assembling the cage and derrick and transporting them together, along with the mounting frame, to the pier for erection onto the platform. The shop forklift was used along with the gantry and assistance of Grounds and Roads to horizontally slide the cage into the derrick on the shop floor. The completed assembly, now weighting over 2500lbs, was the loaded onto a university trailer and hauled to the pier.

At the pier, the mounting frame was attached to the deck of the platform with twenty-four three eights bolts installed through the aluminum deck braces. Installing these bolts under the deck proved to be a challenge due to the extremely confined space above the pontoons. Ultimately these bolts were installed with long handled tools, some improvised on site. While mounting the frame, the frame was held to square with the deck, which ultimately proved to put the frame out of alignment with respect to the derrick. This, however, was due to a layout error during frame fabrication.

Figure 14: Lowering Cage and Derrick Onto Platform

After the mounting frame was secured to the platform, the platform was towed to end of the UNH pier and moored to the floating dock section below the pier's three ton jib crane. The cage and derrick, now assembled, were hoisted horizontally off the pier and set on the lower floating dock section. However, it was discovered that the range of the jib crane was insufficient to allow the cage to be hoisted vertical while allowing the crane block to hang vertically. The cage was then repositioned in a manner that allowed the cage to be raised with minimal eccentricity with respect to the hoist. After reviewing the hoisting procedure with the erection crew, the cage was carefully raised to a vertical position without difficulty. At this point, it was discovered that the crane height was insufficient to hoist the derrick high enough to clear the mounting frame brackets at the time's tidal elevation. After waiting several hours, the tide had receded enough to allow the assembly operation to continue. Once the derrick was landed on the frame, the bracket alignment issue was discovered. To remedy the problem, the bracket with the least apparent error was bolted to the derrick, and the remaining brackets were re-positioned allowing the final connections to be made and the crane released.

With the major components assembled, the platform was towed its mooring position on the beach to allow the cage hoisting winches to be installed. Several subsequent days were used to complete this operation. In the process, the hoist system was redesigned due to failure of a pulley mounting location on the mounting frame, shown in Figure 15.

Figure 15: Eye Bolt Failure

The pulley had been used to change the cable direction by nearly one hundred and eighty degrees, thereby applying nearly four thousand pounds on the pulley mounting bolt. In lieu of buying new hardware, the winch positions were moved from their original position on the mounting frame beams to a built-up position on the platform deck, thus eliminating the need for the failed pulleys. After a load-test, the platform was ready for testing.

Winches

Due to the complexity of the design, the cage was limited in the space available for lifting and lowering. Having taken the idea of a trailer, where you can lower and raise the boat and lock it in position in either direction, the design was modified so the cage and be held at any height. These limitations made the lifting winch a more complex design compared to the standard that can be bought at a local boating store. Since the cage is very heavy and going to be lifting in a vertical fashion compared to the typical horizontal the system had to be set up so the winch was pulling in a horizontal mode while the cage was able to go vertical. Another main factor that the winch had to be able to handle was the direct load it would be carrying for a longer period of time. The winch had to have a capacity that would allow a safe working load with a factor of safety. Having the turbine cage weighing it at roughly 1700 pounds, it was decided that a min of 2500 lb capacity was needed. This factor of safety would be in place so the person involved in the raising and lowering would not have to worry about the winch failing. Another factor that was made sure of was that the winch had two modes of movement. Having the ability to gear up or down to higher or lower ratios allows for whoever is to be lifting the cage, to be able to do it easily. Because of the orientation of the whole derrick and cage the system required two winches to be used. Because two were required the overall load was reduced for each winch. Though this was true, the design that was chosen required that each winch be able to hold the whole system by itself for safety reasons. The winch that was finally chosen to tackle the task was made by Fulton Marine. It was a two speed, dual direction with stop. The winch had a capacity of 3200 lb and was zinc plated. It had the ability to carry up to 175 feet of wire rope at 7/32”, of which we chose to use 1/4” cable which allotted us over 100 feet of cable which was plenty adequate. The winch can be seen in Figure 16 and 17.

Figure 16: Fulton Marine Winch and Figure 17: Winch Mount

As can be seen here in Figure 16, each winch had a long handle at ten inches which created a clearance issue. The winch was relocated and lifted on blocks to solve this issue. The lifted location can be seen in Figure 17.

Lift System

The original design was to have each winch on the deck of the boat, but the design was modified to not have the cables running along the deck for the safety of the workers on the platform while afloat. The second design can be seen here in Figure 18. This new design allowed for the cables to be out of the way and each "lifter" out of the line of fire in case the cable was to rupture.

Figure 18: Lift Layout

This design was then modified after mechanical failure in a steel piece. This failure can be seen here in Figure 19. This failure was due to the overestimate made in the strength of the metal at the bend point in the eyebolt. Since the eyebolt was not a fully welded loop, the eye opened up as can be seen here in Figure 19 and the pulley was released from its fixed end and the lift system failed.

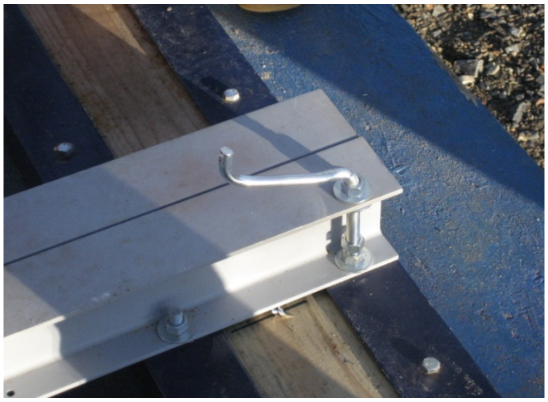


Figure 19: Failure In Eyebolt

After this failure the lift design went back to the original idea to allow for a point less system. This system allowed the cable to travel straight up the and down the derrick and then along the deck surface to the winch which was placed over two deck supports roughly 4-6’ from the support frame. This new design can be seen in Figure 20. The new design not only proved to be functional but worked flawlessly in the field.

Figure 20: Lift System

Cables Stays

For extra support to the platform and cage, stays were added. Similar to the idea behind a sailboat mast, the cables were designed to add support for the forces that the structure didn’t account for. These stays were made adjustable to accommodate for any extra variation in the height. Since the turbine was to be tested at a non specified height, the stays had to accommodate the differences. The stays are made of the same wire that was used in the lift system. This cable has a working load of over 1400 lbs which made them perfect for this job. The reason the stays were added were to give extra front to back support and to give redundancy to the support/lift system. Each side perpendicular to the platform has two cables attached at the base.

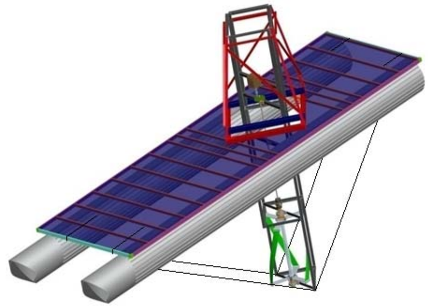


Figure 21: Platform With Cable Stays

From each corner one cable runs to the bow of the platform and the other to the stern. The cable then runs through a metal pipe bend which stops the cable from kinking around the corners of the platform and from moving laterally. The cable then runs up to a splice where the cable turns into braided rope. The rope allowed for more bending and more adjustments to be made. Due to the stiffness of the wire rope, it does not allow for tight bends or “knots.” Because the design needed to be able to be tied off, the use of marine horn cleats were used. The horn cleats require the rope to bend at steep angles which would kink the wire and not allow for a quality knot to be made. So because of this the rope was spliced into the wire cable. This was done using bowlines, a nautical knot used for various purposes, which allowed for easy removal if needed since the knot can be broken even after have a large load applied. This can be seen here in Figure 22.

Figure 22: Cable Stay Knot

Testing

First Tow Test: Galen J

The first tow test was a basic tow test out and back. This test was to prove the system not only worked but was stable enough during a towing situation. Due to the fact the system was never tested in previous years there was no way of knowing how it all would react. There were many skepticisms and thoughts on how the platform would move through the water, but it was unclear on how well the system would move. Because of this uncertainty the first test was done in a vigilant manor. The main goal of the first test was to prove the system could work. This was to be done by accelerating the system through the water at a constant pace. The speed at which the turbine was going to start rotating was unknown. From Lucid Energy Technologies, who donated the turbine, we knew the system wouldn't start until at least 2 meters per second.

When the team arrived at the pier the day of the tow they were awakened by a dilemma. The platform over the weekend was pushed up the beach and turned sideways. This created a major issue for the team as they had no way other than waiting for the tide to return. This bad situation can be seen in Figure 23. After many attempts of trying to pull the platform off the beach with mechanical power, the team dug small trenches to allow the water to go under the platform when it got high enough. The team had decided prior to the water reaching the platform to spin it. Due to the orientation and the water level for the day, the boat wasn't going to be in the water enough to move. So the team all gathered on one end, lifting the stern rotated the platform to perpendicular of the beach. This was then followed by the Galen J being attached to the platform and the team pushing while the boat pulled. The final outcome was a perfect solution to the issue which was a floating platform. Once the platform was in the water the test was allowed to commence.

Figure 23: Beached Pontoon Boat

Because of the uncertainty of the platforms handling under tow a 60 foot long tow bridal configuration was used. This bridal was extra long in case the platform had undergone damage during the storm due to rocks on the beach which had gone unnoticed as well as in case an incident occurred where the platform was to flip or sink, the bridal wouldn't pull the Galen J down. The Galen J can be seen in Figure 24.

Figure 24: Galen J

It is a twenty foot small hard chine working boat owned by the University of New Hampshire for their marine programs. The platform was connected to the bridal by a five foot "V" which fed into a sixty foot line. This line then went into another "V" which was connected to the Galen J's stern. Once the platform and boat were attached the moving test was started. With the help of the small rib craft and the captain and deck hands of the Meriel B the platform was kept going straight. The platform was towed at variable speeds, starting at an idle and slowly increasing to 4 knots. The turbine started to spin at 3 knots. This was a knot slower than it was expected to which caused a setback to the project. Once the platform and boat made it through the channel and to the other side, they turned around with the help of the rib and headed back to the pier. The boat ran into an issue coming back with the current, because the platform was not in as much control as the group would have liked due to the current controlling the platform. The current was initiating the platform to be pulled at an awkward angle causing the Galen J to tilt over and have a heel to it. The tow was then stopped and the rib helped straighten out the platform. The cage was then lifted up and the platform was then towed into the harbor. Following the out and back the platform was returned to the beach side by side of the Galen J. Having the platform directly next to the boat gave the driver more control and allowed the Galen J to handle the platform right up to the beach where group members were awaiting its arrival.

The first tow test in terms of the goals that were set out prior to the event not only achieved success but exceeded the expectations. With the first tow test done the team not only proved the platform could be towed, but proved that data could be collected. This was a huge step for the performance group. The team was able to gain valuable information about the turbine for instance the starting speed of rotation. The test also proved to the Ocean Engineering Lab and Meriel B employees that the platform could be towed at variable speeds which would allow the team to do a second tow test with the Meriel B.

Second Tow Test: Meriel B

The second tow test took place on January 29, 2009. After the initial tow test to see if the platform was stable in the current, the second tow test was more about getting useful data from the turbine itself before a bridge test could be considered. Instead of using a bridal and being towed behind a vessel as in the first tow test, it was decided that the platform be tied to the side of the Meriel B and towed up and down the Piscataqua River that way. This allowed for more control of the platform, as well as ease of communication and the moving of team members and testing equipment between the Meriel B and the platform. The platform was towed up and down the Piscataqua three times, each at variable speeds. As far as data collection, every time the platform was towed the speed of the current, the speed at which the current began to move the turbine, and the rpm of the turbine shaft were all measured.

Figure 25: Meriel B and Platform On the Piscataqua

The second tow test was a success. Nothing broke, even at towing/current speed upwards of 6 knots. The test also brought usable data for the performance team, as well as proof that a bridge test was definitely feasible.

Figure 26: Jim, Michele, and Tom in Survival Suits

Third Test: General Sullivan Bridge

After the successful completion of both tow tests it was time to test on location at the General Sullivan Bridge. This test included several steps that would pass great insight on the potential issues of a permanent testing location at the General Sullivan Bridge. The plan called for the use of the Meriel B to tow the platform, the Galen J for attaching a line around the base of the bridge for mooring, and a small grey rib for auxiliary support.

The Galen J launched from the UNH pier first to attach floating line to the base of the bridge. This crew included Jud DeCew, Tim Pickett, Ryan Despins, and Dave Shay. After the platform was prepped and secured, the Meriel B followed upriver at a slower pace. At this time the water was low with an outgoing tide, which allowed for easy passing under the Memorial Bridge. The height of the raised cage required the Sarah Long Bridge to be raised for passing. The rest of the trek upriver was uneventful.

Once the Meriel B arrived at the bridge, the Galen J was putting the finishing touches on the floating line mooring. Both vessels moved to the Great Bay side of the bridge, and the platform was prepped for testing. Slack water was fast approaching and the window for an easy hook up was on hand. The platform was passed on to the Galen J for fastening with the help of the small grey rib. The platform was attached to the floating line with relative ease.

At this point testing began. The Galen J was used for checking current speeds at different location under the bridge. The turbine would not start for quite some time due to current speeds slowly ramping up to maximum incoming current. It was noted that there was vibration in one of the lines. This could be attributed to uneven line length in the mooring attachment. There were also considerable ice chunks floating by since the testing was done in February. The platform appeared to have little or no difficulty with the ice striking the cage and most pieces bounced out immediately.

The turbine did not initially start until given a hard turn by those on the platform. The difficulty in starting was attributed to old bearing lubrication and cold weather. Once this first static friction was overcome the turbine had no trouble with keeping rotational speed. In fact, the turbine eventually stalled during testing and then self started.

Figure 27: Platform Under General Sullivan Bridge

After testing the platform for several hours under location, the mooring lines were cut and the platform was handed back to the Meriel B for towing. The trip back to the UNH pier was again uneventful except for a slight clearance scare at the Memorial Bridge.

Testing was a success from the infrastructure standpoint. There were no mechanical failures and the system performed relatively well. The only issue of note was the tough static starting of the turbine.

Rebuild

Both of the systems mentioned in this section are under construction as of the completion of this report. It is our goal to complete both of these and have the system tested again under the General Sullivan Bridge by the end of the semester.

Belt Drives and Clutch

The performance team decided that the turbine could generate the most amount of power by raising the gear ratio, because, currently, the gear ratio was set to power a set of light bulbs. The performance team said that a ratio of at least 100:1 would be sufficient. After research on pulleys and belts, it was determined that a 10:1 is extremely rare. It was decided that putting a three step pulley system would be the best idea. Although it causes more mechanical loss in the system, it was not be significant enough and it less expensive.

There were two main designs for the clutch system. The purpose of a clutch is to be able to disengage the mechanical system from the electrical system in case of an emergency, or for the use of further mechanical tests. The first design was using the alternator as a clutch, because the alternator is currently removed after every test. By attaching the alternator on a sliding angle beam, the alternator could move in the x-direction along the frame, which would loosen and tighten the belts.

The second design involved moving one of the entire shafts. This would tighten and loosen two belts, but would leave the alternator fixed in place as well as provide more space between the individual's hands and the spinning pulleys, which is more ideal. This system involved attaching the bearings to movable angle beams which in unison will move in the x-direction, loosening and tightening both belts.

It was decided that the second design would be more cost effective and safer, as well as faster to disable if need be. The second design is currently in process of being made; all parts have been ordered, and half of it is currently assembled. During the next few weeks the fabrication will be completed.

Cage Modifications

Upon recommendation from the Performance project, and in line with the next logical progression of the Infrastructure project, the decision was made after the bridge test to scale up the cage to handle the full sized nine foot turbine rotor. Several options were considered to modify the cage, but the least complex option was determined to be to cut off the lower section of the cage and to extend the cage with new angle sections. Of primary concern for this modification is the increase in moment induced in the frame due to the longer moment arm and higher applied forces. To address this concern, a 3-D matrix structural analysis package, Mastan2, was used to analyze the cage with the maximum expected load applied at the bearing points. The analysis showed the stress induced in the steel, which was conservatively assumed to be ASTM A36, was within the limits allowed by the AISC structural steel building code, however the factor of safety was low. It was decided that if the wire stays are elongated and pre-tensioned and used in conjunction with the extended cage section, that a sufficient factor of safety can be attained. Fabrication of the extended cage and full sized rotor has started, and it is hoped that they can be completed and tested during this semester.

Conclusions

The second year of working on this turbine continued that plan of completing a testing platform. This design is by no means final and its sole purpose is to get a turbine in the water and producing power. This second year of work completed major steps in having a fully functioning test platform.

This year, the team finished work on and assembled the cage, derrick, and pontoon platform. Several necessary auxiliary systems were also created, such as the lift system, the deck support, and the cable stays. All of this work was done at a rigorous schedule to allow time for testing in the later portion of the academic year.

This year had many firsts including testing of the complete system on the Piscataqua River. This was a crucial step in the development of the system and allowed for observations that were not predicted from the classroom. Valuable insight was gained from the stability of the system and potential limiting factors.

Overall, the team can record this year as a success. A completed system now allows for future students to modify and optimize performance on the platform. Having these major components finished and functional allows for more time to be spent on evaluating minor details in the system. It is the desire of the team for this project to be continued by future classes.

Future Work and Recommendations for Next Year

There is still plenty of work to be done in future years to create a well developed and fine tuned system. The work done by this year's team created key blocks that can now be built off.

First, the housing cage for the turbine needs to be streamlined. The initial design is structurally sound, but creates major turbulence in the water flow. All platform pieces that are submerged during testing can create addition force on the mooring system or worse, disrupt the flow to the turbine. Piping or an airfoil design should be considered for the turbine housing structure.

Developing a full tidal cycle capable design is paramount to long scale testing. The current design allows for one direction of tide flow before having to be repositioned. This step is tricky because it could include a complete overhaul of the current pontoon platform. There also might be a way to develop a unique mooring system that allows for the current pontoons to be used.

Concerns have also been express about interactions with the local plant and animal life. Key among this is how to prevent anything from going into the fast spinning turbines. Issues with impeding flow will surface and unique screening ideas will have to be developed.

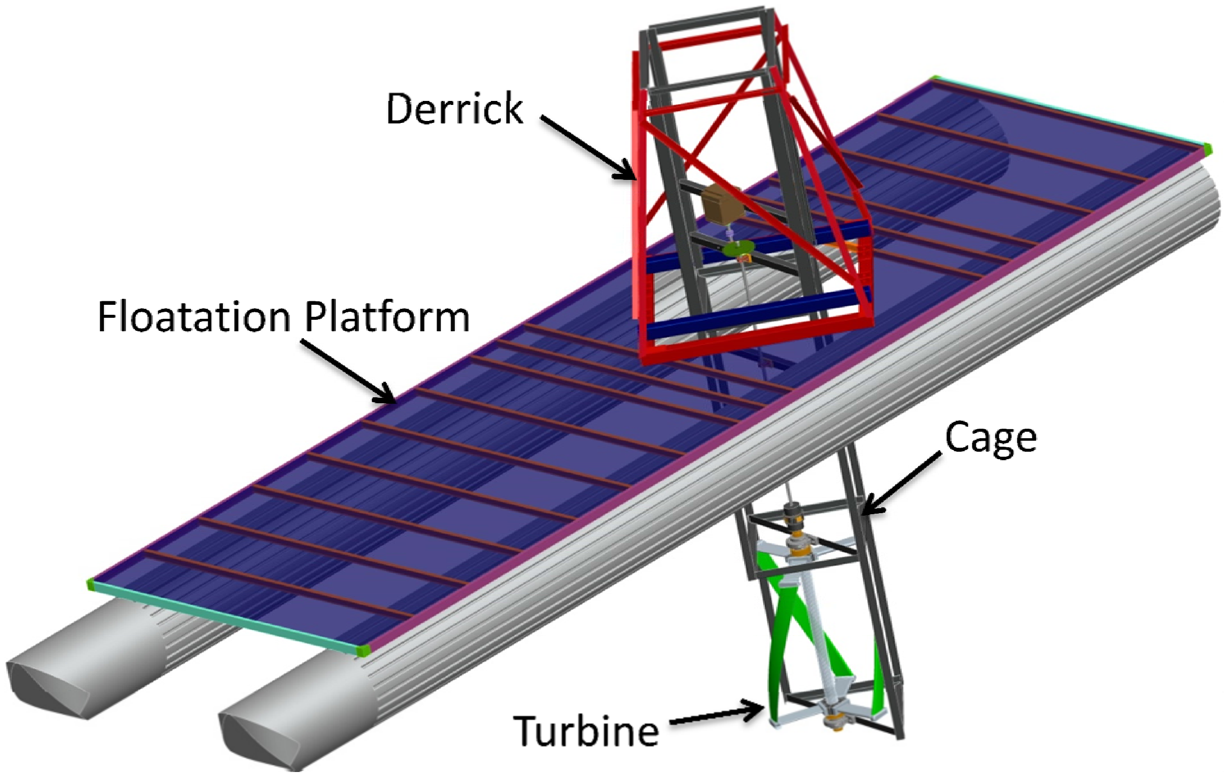
The belt drive system should be optimize to produce the desired RPM for the alternator. This will require extensive testing and possibly the purchase of a new alternator. This is another area of efficiency that needs to be improved to show the potential of a tidal turbine system.

The final step should be a permanent mooring site under the General Sullivan Bridge. Interaction between future groups and the DOT will be required. Upcoming work on the new twin bridge presents an opportune time for this section of the project. The new bridge could present better testing environments by creating a more direct current flow. Equipment used to create the new bridge might also be used in creating the permanent testing location.

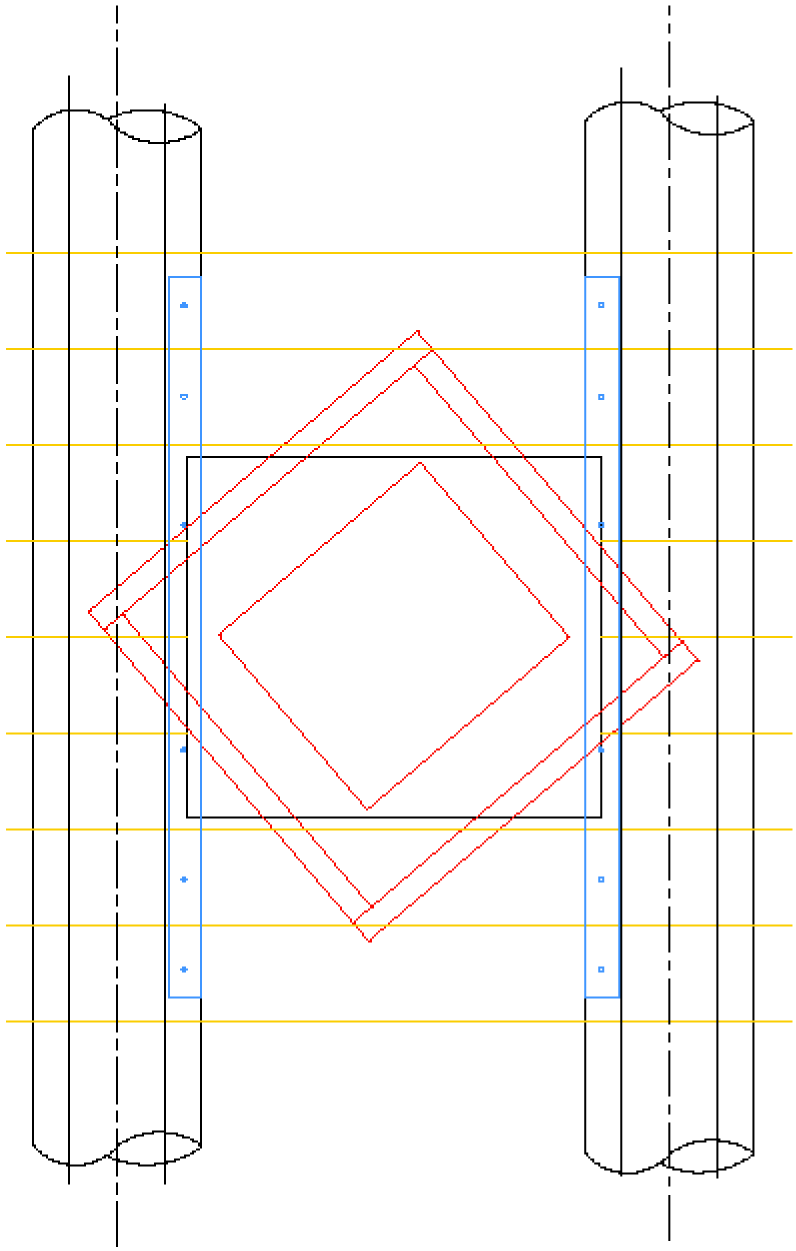
Appendices

Please note that the Synopsis of Last Year is a brief overview of what the 2007-2008 Tidal Energy team accomplished throughout the year, as well as a brief overview of their design. The electrical component was omitted because this paper talks solely about the infrastructure and testing that the team accomplished, and all electrical components of the 2008-2009 Tidal Energy team can be found in another document by Jacob Finch, Christopher Thompson and Kevin Phlanz. For a more detailed description of the design and electrical aspect, as well as design alternatives, please see the 2007-2008 Tidal Energy documentation: Tidal Power Generation in the Piscataqua River, University of New Hampshire, TECH 797 Ocean Projects 2007-2008.

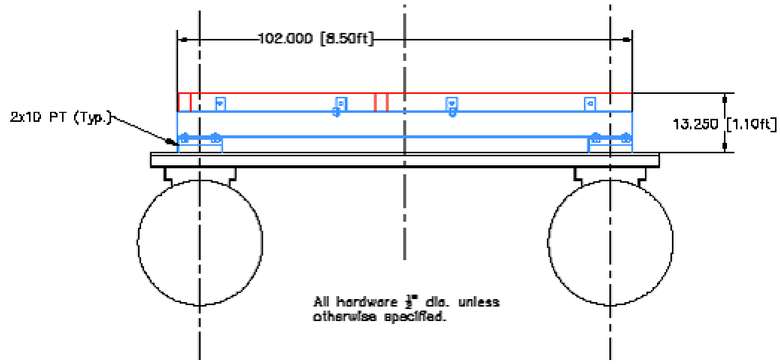
Appendix A: Definition of Parts

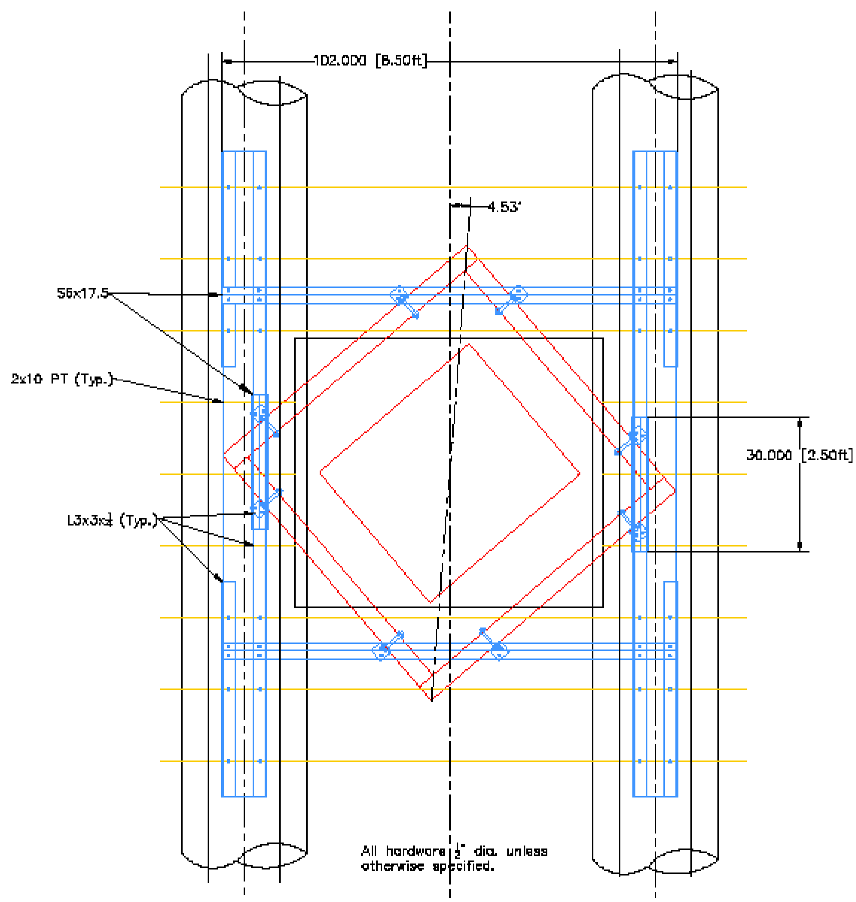


Appendix B: Alternative Derrick Mounting



Appendix C: Final Mounting Frame





Appendix D: Boat Reference

Small Grey Rib

Galen J

Meriel B

Appendix E: Expense Report

Date (YR_MM_DD)	Cost	Store	Description
08_10_21	$89.02	Home Depot	Materials and Tools
08_10_24	$171.80	Cohen Steel Supply	Materials
08_10_24	$32.25	Cohen Steel Supply	Tools
08_10_24	$43.29	Car Mileage	Miscellaneous
08_10_27	$937.78	Home Depot	Materials and Tools
08_10_28	$240.56	Northern Tool +Equipment	Winches
08_11_03	$274.00	fastener warehouse p-card	Decking
08_11_03	$41.14	Home Depot	Tools
08_11_04	$153.15	Home Depot	Materials and Tools
08_11_13	$36.94	Home Depot	Materials
08_11_22	$14.73	Ricci Lumber	Materials
08_12_02	$50.80	Fastener Warehouse	Materials
08_12_02	$23.96	Seacoast Ace Hardware	Materials
08_12_02	$29.24	Seacoast Ace Hardware	Materials
08_12_02	$33.98	Ricci Lumber	Tools
08_12_02	$86.87	Home Depot	Materials
09_04_01	$421.53	McMaster-Carr	Materials
09_04_01	$135.00	Novel Iron Works	Materials
09_04_01	$192.96	Damage Replacements	Tools

Starting Balance	Total Cost	Remaining Balance
$3,000	$3,009	$441
Additional Funding		
$450		

The remaining balance will be used by the end of the semester. There is ongoing work to launch a final test and several additions are being made to the system. For more information, please visit the Rebuild section of this report.