

BOAT PROPULSION IMPACT RELIEF SYSTEM

A Baccalaureate thesis submitted to the
School of Dynamic Systems
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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April 30th 2015

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ABSTRACT

When an outboard or stern drive with hydraulic power trim strikes a submerged log at even moderate speeds, the trim cylinder rod(s) tries to extend and is immediately placed under tension, tremendous pressures are almost instantly developed in the rod side of the trim cylinder as the cylinder rod tries to extend. Without some means of relieving these pressures and allowing the drive to swing back, up, and over the log, either the boat would be stopped in an instant (ejecting everybody), some drive components would fail allowing the drive to partially or fully break loose, the transom of the boat would be partially or fully ripped off, or some combination of disastrous alternatives.

The damage caused from contact with foreign object debris to personal watercraft has been a problem for a long time in the maritime industry. This causes an increase in insurance premiums for boaters who utilize waters that are littered with debris. Property damage from striking a submerged object can range anywhere from minimal damage to expensive litigious wrongful death law suits.

The need for a hydraulically driven energy dissipation system is needed.

PROBLEM DEFINITION AND RESEARCH

PROBLEM DEFINITION

Boating on any body of water poses a high risk of damage to the hydraulic trim/propulsion unit of a watercraft from striking debris that is submerged just under the surface or objects floating on the surface. The saying on the water is not "IF" but "WHEN" you strike debris with your hydraulic trim unit. Damage from this type of contact can range from moderate, to your boat sinking. I personally have been a victim of striking a submerged tree on the Ohio River. It caused transom damage due to the forces of my boats propulsion unit contacting the debris at 20 MPH. The lower unit sits deeper in the water than the hull of the boat and is therefore exposed to the hazards of the water with zero protection. See figure 1 below.

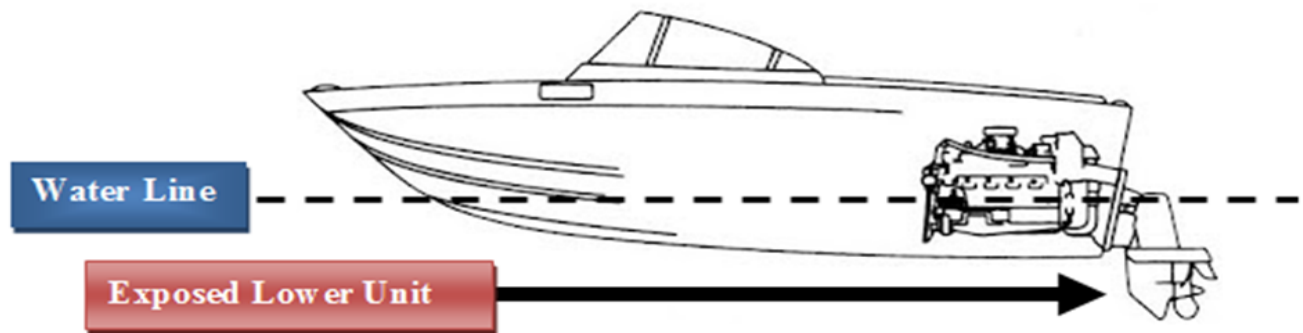


Figure 1 – Illustration of Outdrive and Hull

BACKGROUND

The hazards to a boaters property are a constant worry and an often incursion especially when spring time rains wash debris into waters ways from smaller tributaries. Rivers with a dam system are also major contributors to debris fields containing waterlogged trees which lurk a foot below the surface. Local sheriffs and DNR officers all over the country have tried to increase the level of alertness of boaters to these hazards by posting articles in local papers and posting signs at boat launches with locations of existing debris hazards. (1) The American Boating Association and the US Coast Guard have teamed up to give boaters tips and classes on signs of debris in the water because of the amount of bodily and property damage they cause. (2) Not to mention the cost to the taxpayer for water rescue operations. In Maryland, three boats sank on the inner harbor, all within 1 month, from striking their lower units on a recently installed dredge pipe which was not marked by the contracting company performing the work. (3) The hazards to a boat can be natural and man made.

All watercraft have trim/propulsion assemblies that pitch up and down hydraulically via two hydraulic cylinders. Most watercraft can only move about 30 degrees from full down to full trim up while operating in the water. The trim unit can also extent full upwards past the 30 degree mark for when you are pulling your boat on a trailer. You do not want the trim unit to sit as high as possible when towing. The trim angle can be adjusted while underway to

make changes to the boats handling and ride characteristics as water conditions change. These units are able to pitch up and down at an angle in order to change the boats plane angle by adjusting the angle that the propeller is sitting at in the water. Click on the link provided for a short video that will demonstrate the Hydraulic trim movement.

<http://www.youtube.com/watch?v=sY7aZiz01HI> (4)

Please see table 1 for a detailed explanation of possible trim angles and their resulting actions to the boats.




	<p>Trimming In (Down)</p> <ul style="list-style-type: none"> • Lowers the bow • Results in quicker planing, especially with a heavy load • Improves ride in choppy water • Increases steering torque or pull to the right
	<p>Neutral Trimming</p> <ul style="list-style-type: none"> • Lowers the bow • Normally results in greater efficiency. (Note that the propeller shaft, which connects the propeller to the drive shaft, is parallel to the surface of the water.)
	<p>Trimming Out (Up)</p> <ul style="list-style-type: none"> • Lifts the bow • Increases top speed • Increases clearance in shallow waters • Increases steering torque or pull to the left • In excess, causes the boat to bounce

TABLE 1 - THE THREE POSITIONS OF TRIM AND RESULTS ARE AS FOLLOWS:

RESEARCH

Below are just a few of the examples of damage that can occur when you strike debris at a high speed. Figure 2, seen below, illustrates a cracked skeg/gear housing to the propeller driven portion of the lower unit. (5) Figure 3 shows the damage to a transom from absorbing the impact of a land strike while the driver was backing the boat into the water. (6)



Figure 2 – Cracked skeg/Gear Housing to propeller

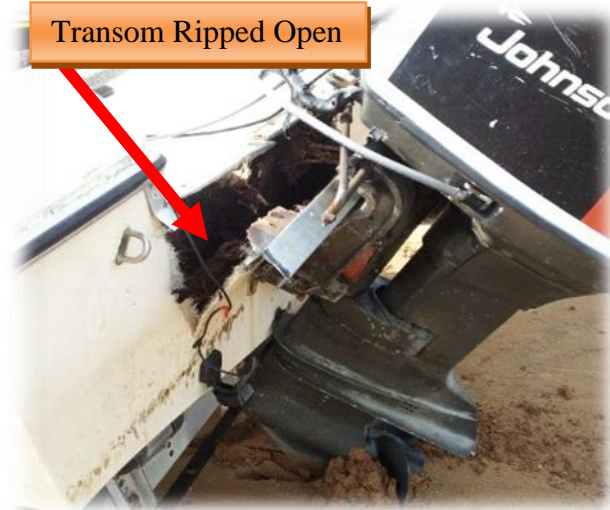


Figure 3 – Transom torn from boat

While boating in a lake at a depth of 47 ft., a boater struck rocks that jutted right out of the lake bed floor and were hidden just below the surface. (7) The resulting damage was a cracked open gear case housing as is illustrated in Figure 4. Another boater experienced the all too familiar damage resulting from contact with a rock or large dense debris at a very high speed seen in figure 5. (8) Typically just the lower unit will sustain catastrophic damage but in this case the operator lost his propeller as well.



Figure 4- Damage from impacting rocks in a lake.



Figure 5 – Gear case and propeller damage

A bass boat fisherman was heading to the opposite side of the lake at around 45 MPH when he struck something beneath the surface of the water and lost all forward propulsion. When he pulled up the engine to take a look at the propeller, his entire lower unit was totally sheared off. (9) See figure 6 for the carnage.



Figure 6- Total gear housing loss from impact

TECHNOLOGY AND EXISTING PRODUCTS

I did an extensive amount of research into existing products that are currently available and I found this product for example which would perform a protection function for the lower unit from striking debris. The product I found was a stainless steel skag cover that simply mounts to the bottom of your lower unit and protects it from scraping rocks or slight protection from very low speed impacts. (10) Even if you were to hit a large dense object at high speeds, this product would not protect your transom or lower unit from shearing off due to the stresses being absorbed directly into the cast housing. See Figure 7 for skag detail.



Figure 7- iboats skag cover

I was able to identify another product that will help to save the transom but this product only works while the boat is resting on a trailer. It is a rigid link that extends from the back of the trailer and allows that lower unit to rest on the link and relieves stresses from your transom. (11) This product may work but it does not do anything for your boat when it comes to striking debris in the water. See figure 8 below, for an illustration of the manner in which the rigid link supports the lower unit while in tow and reduces transom stress.



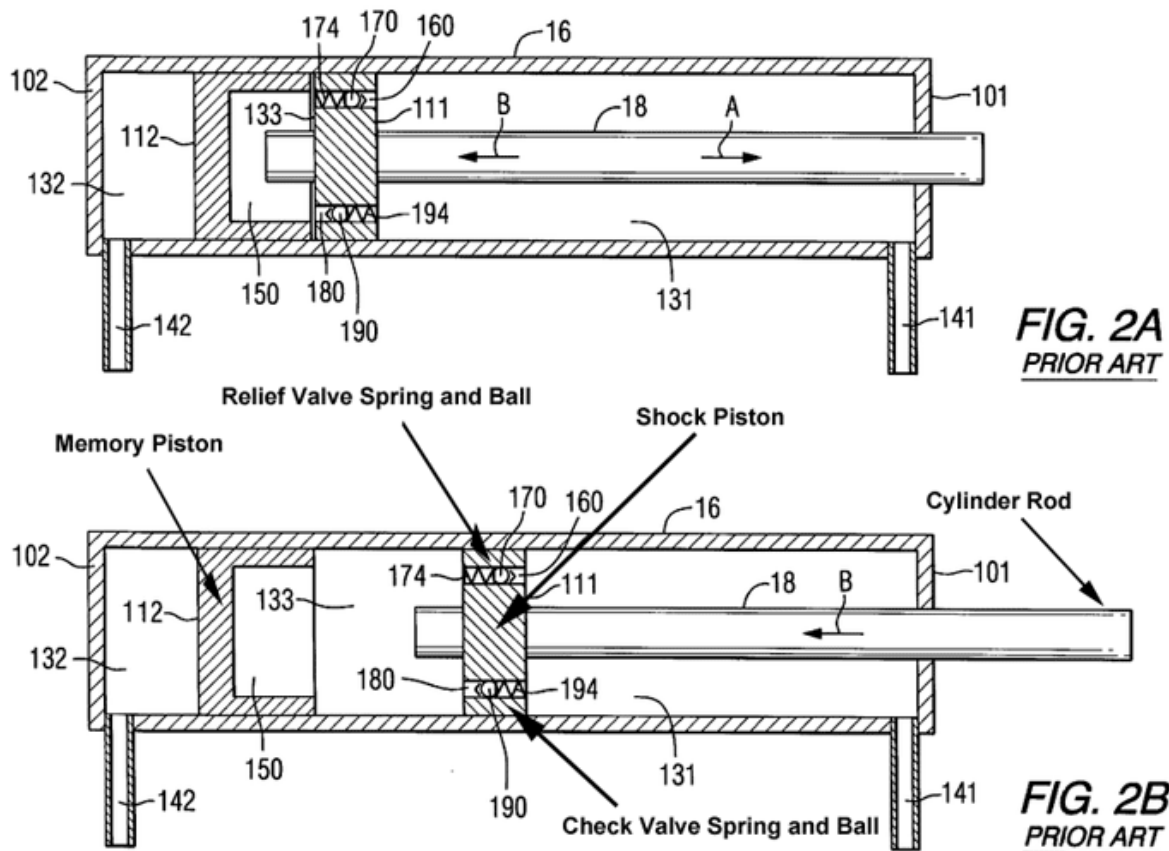
Figure 8- Trailer mounted Rigid Link supporting lower unit and reducing transom stress

Companies offer DIY kits which act to re-inforce the strength of your transom in the event of a log strike but it would not help with the damage that would be inflicted on the lower unit by the debris. It also violates one of the customer features of no drilling into the hull of the boat. Below is an illustration of the product which reinforces the transom through the engine mounts and drilling into the hull. (12) It also requires the installer to remove the engine, which is very complex for the average do it yourself boat owner. This also violates one of the customer features which is that it would be easy to use and install. See figure 9 for image of installed product.



Figure 9 – Transom reinforcements utilizing engine mounts.

The best product I have found on the market today is one produced by Mercury Outboard Marine engines that is currently in use on their outboard motors only. I cannot find its use on sterndrive driven watercraft which is the most popular style of boat propulsion to date. This type of system employed by Mercury Marine Engines is patented technology and utilizes small relief valves installed inside of the piston inside the hydraulic cylinder that allow high pressure spikes to be relived. This is a feasible way of accomplishing the energy dissipation of a log strike but it would require a customer to purchase updated cylinders from the manufacturer which can be quite expensive. (13) (14) See figure 10 below.



Basic Trim Cylinder Log Strike System
Shown As Prior Art In Brunswick Corporation U.S. Patent 6,176,170

Figure 10 – Image from US Patent 6,176,170 illustrating relief valve and fluid flow

INTERVIEWS

Don Hedrick is a boating enthusiast and professional Maritime Captain with over 40 years' experience at the helm of personal watercraft up to 36' in length. I spoke with Don about my problem statement and he agreed that a system which could prevent or at minimum, limit the damage from hitting submerged debris would be a huge plus for boaters with outdrives. Don said that this device it should have the ability to be installed by the average boat owner with standard tooling. No cutting or modification of the hull would be allowed. Don said he would also like a way to perform a functional check on it periodically to ensure maximum protection. I talked with other boaters that Don introduced me to and they all agreed with his

earlier stated points. The boaters I talked with said that if the system works they would be comfortable spending \$450 per unit. (15)

I spoke with Ed Alf and his certified Boat Technician about the problem statement to get their perspective. They both said that they have performed several repairs to boats that have been struck by floating debris. Ed was actually interested in selling a product we developed at his shop for interested boaters. The mechanic told me that it would be a good design to include another component that when a strike is sensed it immediately cuts off the engine to help reduce damage to the spinning propeller. Both techs recommended no hull modification and that it be easy to test and maintain. (16)

I sent an email to Lawrence Hansen and inquired about this problem with his insurance company. He said that they do pay out a lot of money to repair boats that have struck submerged debris and was interested to know more about what I planned to do. I told him that everything was in preliminary stages at this point. He did tell me that if I was able to design a system which limited damage or eliminated it that his group would offer a discount to the owners. The insurance group would need to look over the details of the product and see the demonstration of it operating. He said that it would need to be installed by a certified boat mechanic for the discount to be given. They would also determine if the operational check was sufficient and it would need to be a low maintenance item. Minimal parts design. (17)

CUSTOMER NEEDS

During my interviews with industry experts and the end users whom would ultimately interact with the product, I was able to identify several customer needs that would make the product much more desirable. (15) One of the main things that I was told in my interview and research when talking with potential customers was that they wanted the device or system to be easily installed. It should be able to be completed by the average do it yourself boat owner. In order to meet this demand I will have to keep parts contained in one single unit so that they only have to focus on installing one part that makes up the entire system.

Another major customer feature was that no one wanted to cut into their boats hull for any reason. (16) I will have to make sure all components that make up this system will interact with the boat from inside the hull. The interviews also produced evidence that the customers wanted this system to be easy to work on, maintain or simply be a low maintenance item.

Customers also wanted a way to perform functional check on their safety system either yearly or after a major impact to ensure its operation is still correct. I can think of a few ways to do this but it will depend on which way the design goes once I get into Senior Design II. I could use a pressure pump with a pressure gauge to test a hydraulic release valve where you could witness a pressure drop once you hit a pressure high enough to activate the release valve. I could also use a pressure switch that has indicator lights on it to indicate that an over pressure situation has been sensed and the valve opened properly.

I spoke with an insurance agent that said if I could prove my system would work and function in the manner in which I described, his insurance group would offer any boaters using it a discount. However they would need to be installed by certified technicians in order to gain the discount. (17)

PRODUCT FEATURES & OBJECTIVES

Based on the survey, the product objectives are the list of features that are taken into consideration. The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met.

1.) No Hull Modification (35%)

- a. System will interact with propeller from inside boat.
- b. Utilize existing fluid lines for pressure sensing.
- c. Use through hull sonar system for FWD looking electronic warning

Every customer I talked with stressed that modifying their hull was off the table. When you make a hole in the boat that is below the waterline, you increase the risk of leakage and hull degradation. That kind of damage can ruin a boat and even cause it to sink. Instead of drilling holes in the hull or transom, I will develop any system to interact with the lower unit from existing fluid lines that run through factory made provisions. I have thought of a few ways to achieve this for example one method would be using inline pressure switches on the trim up and down hydraulic lines. Another way of achieving this goal would be to use a through-hull sonar sensor that could detect a large dense object and would alert the boater to FOD by lighting up an LED installed on the dash. The system sensing the dense object would also immediately shut down the engine to avoid propeller damage.

2.) Ease of Maintenance (15%)

- a. System should be accessible enough to perform inspection
- b. Uses standard tooling
- c. Use material capable of resisting corrosion in a humid environment
- d. System override capability

When talking with the experts and operators of boats I also found that many of them wanted were very adamant about it being easy to maintain. I came up with a few ways to help aid the customer in getting any easy maintainable item with many characteristics. First I would be sure that the device would use standard tooling to install and would also mount to the boat in an easily accessible area. I want to make it from a material that resists corrosion since it will be installed in an area where water sometimes collects in the bottom of the boat. Another option which was mentioned was to have a system override of the device in case it fails and needs to be disabled in order to regain normal operation. This would be as simple as a shutoff valve before the pressure release valves. In an instance where a relief valve sticks open you could throw the shutoff and regain control of the boat.

3.) Cost 15%

- a. Be less than \$450.00
- b. Use readily available standard parts and materials.

Clearly the cost is always an issue and I have looked at purchasing standard material and parts that are readily available and cheaper than machining custom parts. I have looked into maritime quality relief valves to use in this application but I have plans to do testing with

cheaper ones to see if they are affected by the environment of humidity and heat from the engine.

4.) Ease of Installation (DIY boat owner can complete) 15%

- a. Uses standard tooling
- b. Compactness for installation in tight quarters
- c. System should be secured to boat transom or engine cavity floor

Retro fitting a boat with a new device can be cumbersome especially since the engine compartments are very tight and surrounded with wires, fluid lines and engine drive components. I want to make the device as small as possible which would eliminate the need for several different installation locations. I want the device to be installed in one area and will be secured using screws that will go into the transom. Care must be taken to ensure that the length of the screws will not penetrate the transom fiberglass. I could leave this step up to the owner to verify they are short enough.

5.) Ability to perform functional check 10%

- a. Provide test apparatus for verification of correct system operation

Each boat owner and technician I spoke with wanted a way to verify that the system was functioning properly after sitting for a long time. If I use pressure relief valves I could sell a separate kit which would tap into the fluid lines and supply pressure against the pressure valves. Attached to the apparatus would be a pressure gauge to witness the pressure build to a pre-determined valve and then drop off when the pressure exceeds the capability of the relief valve. For an electronic version I could use pressure sensors and a small self-check system device which has LED indicator lights. It would still require the pressure pump to induce the impact condition on the system.

6.) Safety 5%

- a. Allow function which cuts off engine when impact is sensed.

I do think that including this part of the system into the design will be beneficial to the boater and the robustness of the device to provide maximum protection to your boat. I plan on using a pressure sensor which will transmit a signal to an ignition interrupter device that would stop the propeller from spinning. This would stop the propeller from spinning and possibly saving it from damage as it passes the large object causing the over pressure condition.

7.) Ease of use 5%

- a. System will work autonomously of operator input

My device will work totally without any input from the operator of the boat. This way the boater can enjoy his time instead of constantly searching for possible sign of floating debris. It will work even if the power is off and you are pulling the boat out of the launch area and forget to bring the trim unit to the full up or tow position. This is another occurrence where boaters often damage their propulsion unit. If they bring their boat onto the trailer but forget to raise the lower unit before driving away, it will scrape up the concrete ramp as they pull the boat from the water.

DESIGN

DESIGN ALTERNATIVES AND SELECTION

The first design concept that I came up with was to have breakaway shear pins that attached the hydraulic actuators to the drive unit. In the event that a log strike occurred, the pins would be engineered in a manner that they would breakaway at a specific amount of stress, allowing the drive to freely swing upwards. This would save the transom of the boat from being damaged and maintain the integrity of the hull allowing your boat to stay afloat. See Figure 11 below.

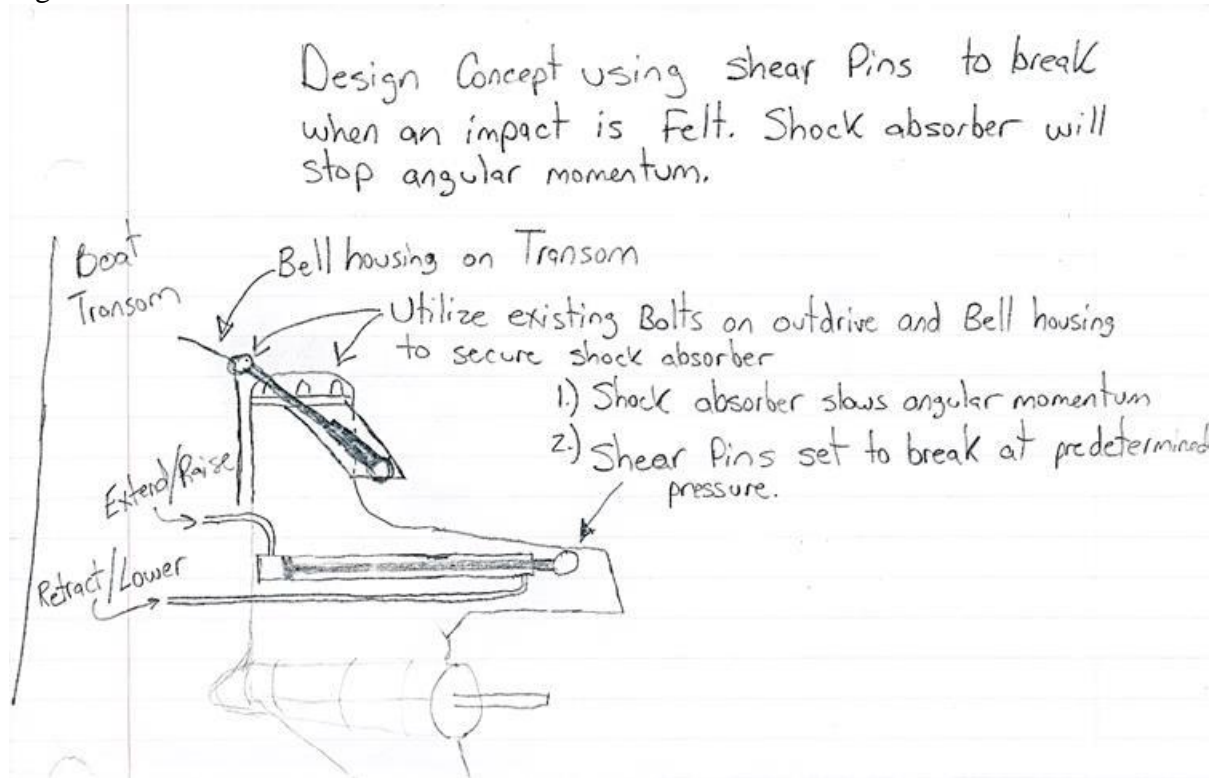


Figure 11- Design Concept 1 using shear pins

After Breakaway, a shock absorber mounted between the bell housing and upper part of the lower unit, would slow the angular momentum of the drive so that it does not contact its travel limits and break off. Currently, the biggest problem with striking objects below the water is the lower unit flipping into the boat and killing passengers.

The downside of this design concept is that after an impact you would not be able to operate the boat unless you carried extra pins and a small set of tools. The boater would also have to get into the water to lift up the drive and reconnect it to the trim cylinders while installing the new pins. It would require you to carry a small set of tools and parts. However, unfavorable weather conditions could inhibit human contact with water.

The shear pin idea would be very cheap and easy to install but the brackets and shock absorber needed to slow the angular momentum of the drive would add high cost due to it

operating in a corrosive environment. The shock would have to be manufactured custom as nothing is currently available for use in that environment and it would add maintenance for the operator. The shock absorber would also add other issues like drag, unwanted water spray behind the boat when towing skiers and it could present an unpleasant appearance that some boaters might not like.

Another design concept was to allow the energy created from the impact to be dissipated through a series of hydraulic relief valves installed in line with the existing fluid lines, which would allow the drive to swing up in the event of an impact. Use of a shock absorber would be utilized to dampen the angular momentum of the drive before hitting its travel limits and breaking off. This design would involve brackets that would fasten onto existing bolts which would support the shock absorber from the bell housing to the upper part of the lower unit. See figure 12 below.

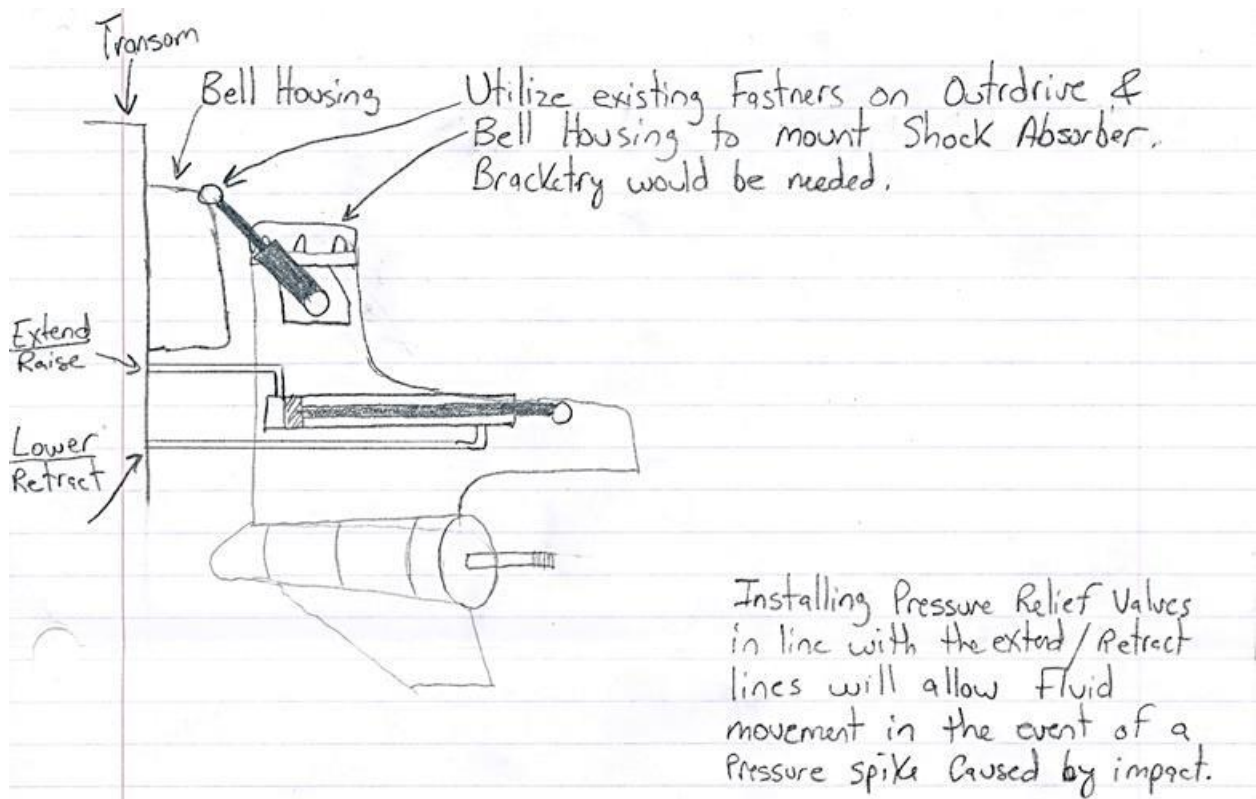


Figure 12- Design Concept 2 using relief valves and shock absorber

After calculating the worst case scenario impact forces, which were near one million foot-pounds, we knew that just a shock absorber alone would not absorb all of those forces. We needed something heavier like a spring. The hydraulic release valves would need to have extra tanks for supplying fluid to fill the non-rod side of the cylinders in the event of a log strike to keep air from entering the system. The downside of this damping method is that the shock is mounted outside of the boat. Some owners would not like the appearance, drag it

may cause or the spray it would kick up behind the boat as they travel. If you tow skiers behind your boat the spray would inhibit the view of anyone behind you making it an unsafe activity to partake in. Aside from aesthetics and safety, the shock would have to be manufactured from corrosion resistive materials at very close tolerances since it would be exposed to water. This would require a lot of extra maintenance and cost.

This image shows a hydraulic fluid line schematic of the initial design with respect to using relief valves and a shock absorber on the inside. I discovered that this method would not be possible due to the suction and return bypass lines would require the installer to have skill in drilling and adding fluid fittings to retro fit their existing reservoir. This violated a customer feature which stated that it must be able to be installed by any DIY boater with minimal tooling. The reservoir capacity would also need to be increased because after an impact all of the fluid would be removed from the reservoir and will introduce air into the system.

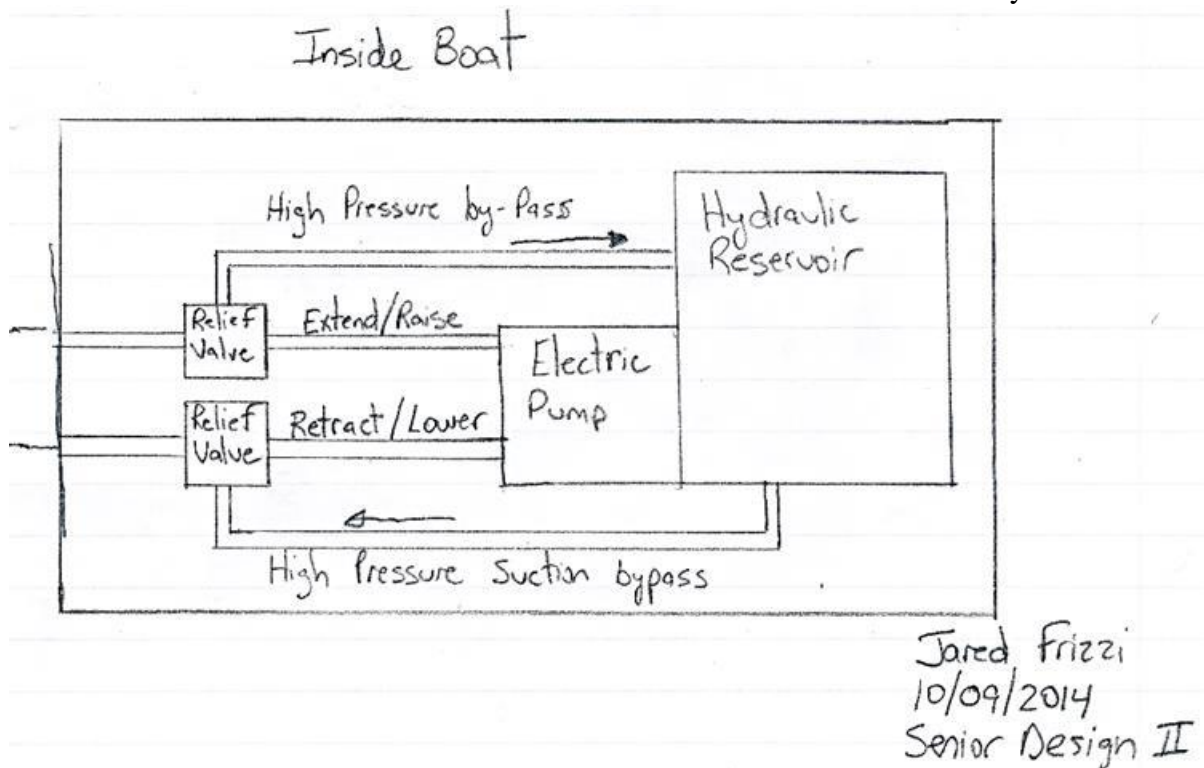


Figure 13 – Design Concept 3 Internal Relief Valves no Damper

The next design concept that was considered was to use a hydraulic dampening system that consisted of a piston/cylinder system with a spring which would dampen the flow of fluid rushing into it after a log strike. The damping system would be externally mounted onto the actuating cylinders. It would consist of a relief valve, a flow directional valve and the damping system. When a log strike occurs, a relief valve would open and port fluid directly into the damping cylinder which is mounted on the existing hydraulic actuator. This would allow the unit to swing up and over the object while damping the angular momentum to keep the drive from slamming into its travel stops. The damping cylinder system is designed to hold 15% more fluid than the total fluid capacity of both hydraulic drive actuators combined.

After the strike has past, the operator would reach down and open the fluid directional valve to allow the fluid trapped in the damping cylinder to return to the system. The compressed nature of the spring/piston assy inside the cylinder will force the fluid out and back into the boats hydraulic trim system. See Figure 14 below for illustration of this concept.

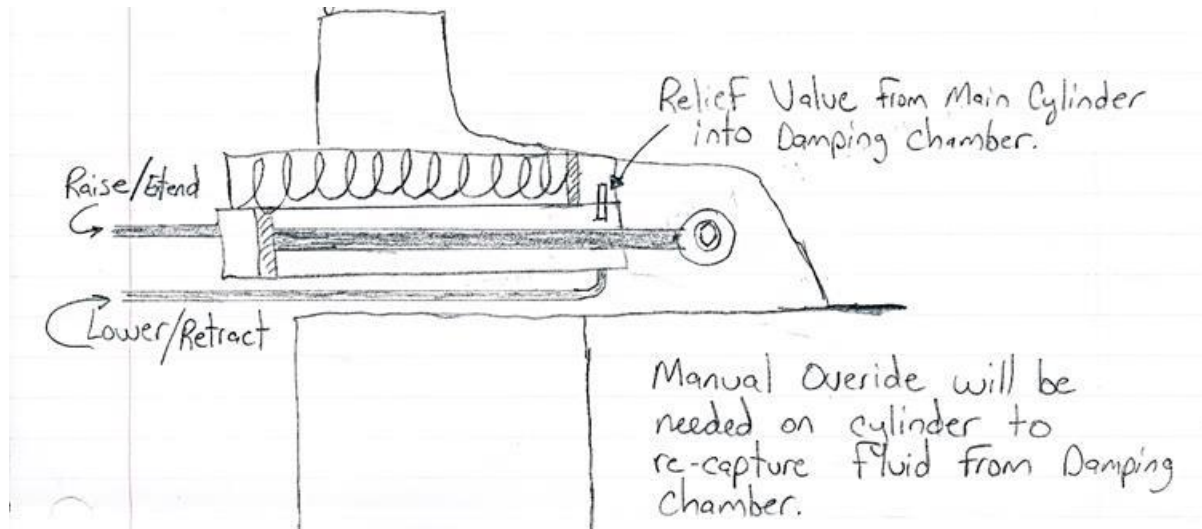


Figure 14- Design concept 4 Externally Mounted Internally Relieved Cylinder

After analyzing this design I realized it would require extra fluid tanks located in the extend and retract lines to maintain a constant supply of hydraulic fluid to keep from introducing air into the system. These reservoirs would have to be mounted on the inside of the boat inline with the extend and retract lines.

Another issue I saw with this design was the cost of the materials and added maintenance due to the damping system being mounted in a submerged marine environment. It also has the possibility to add drag and change steering capability. See the design concept illustrated below for explanation of fluid tanks.

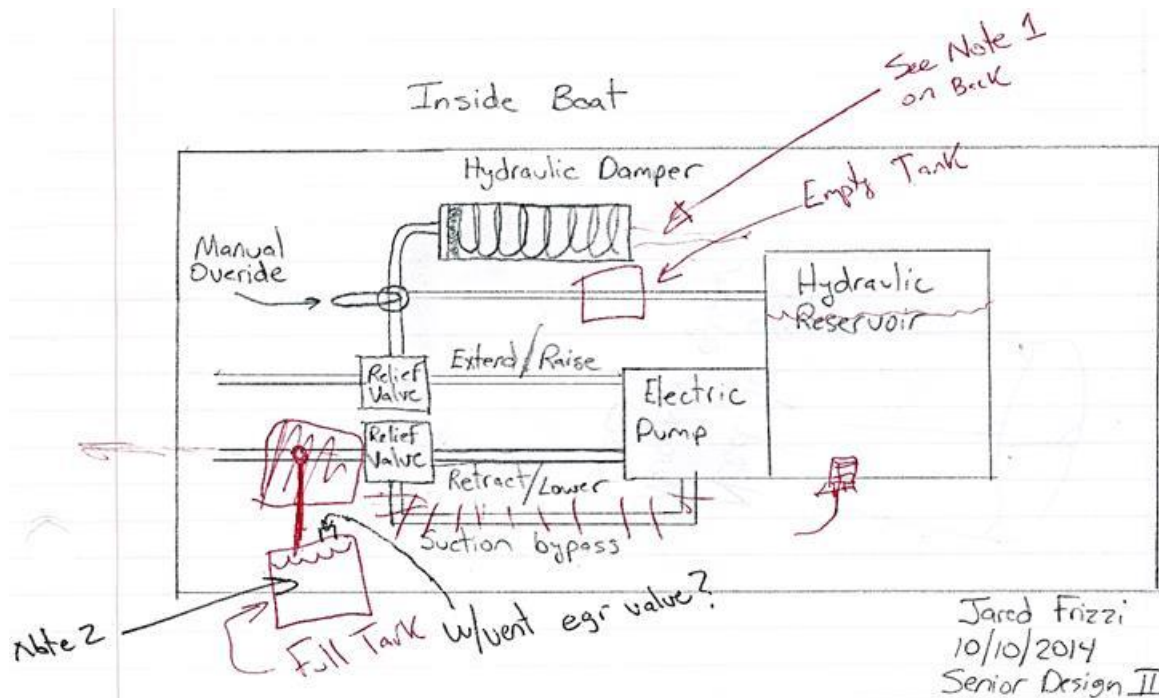


Figure 15- Design Concept 5 Utilizing Dampener and Overflow Reservoirs

The final concept that I decided on was a system to incorporate components and ideas from the last design concept but to move it inside of the boat which would be out of a submerged maritime environment. It will include a series of relief valves, piston/spring damper and extra fluid tanks to allow ample fluid available.

When a log strike occurs, the relief valves will open and fluid will be ported into the damper assy. The operator then needs to manually open the directional flow valve to allow the dampened fluid to return to the boats hydraulic system. The boater can then resume normal operations.

One of the differences in this final design is that it will incorporate a micro switch that is tripped when the pressure relief valve is opened. It will then remove a ground signal to an ignition interrupter which will stop the motor from revving. The reason this is important is because when a propeller operating at 3,000 RPM's loses the resistance of pushing against the water, will cause the engine to rev very high and could possibly damage your engine. See design concept illustrated below in figure 16 for the hydraulic fluid flow schematic.

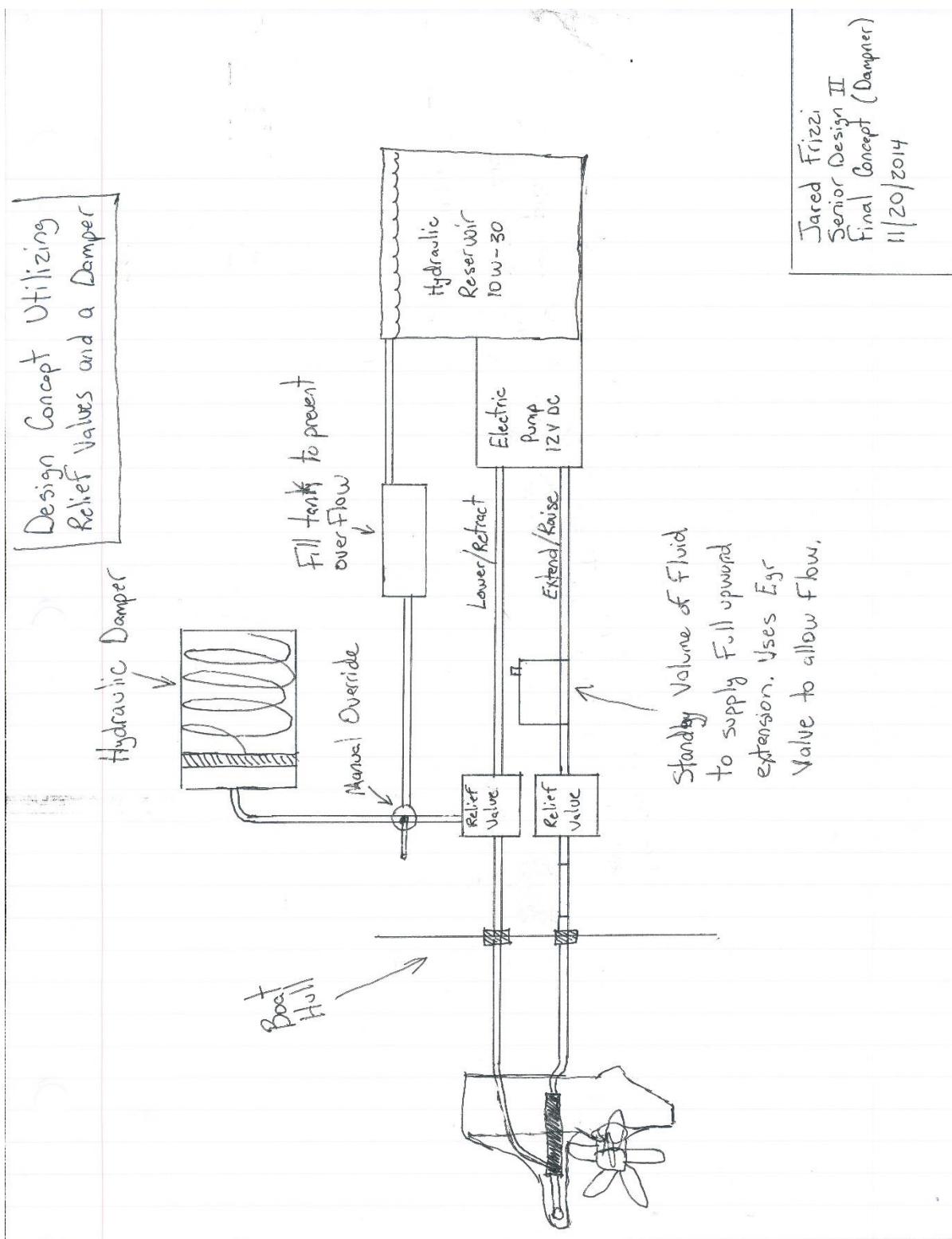


Figure 16- Final Design Concept

FINAL DESIGN SELECTION

A weighted rating method was used in order to select the design that fulfilled the most customer needs. Below is a table that shows the weight given to each characteristic. A grade was given to the specific design based on how it fulfilled that characteristic, these grades ranged from zero to five. The grade was then multiplied by the weight assigned to that characteristic and the sum of all of these for one design was the weighted total. Each weighted total for the design was then compared and the highest was selected as the design to base the solution off of.

	Candidate Method			
Property	Shear Pin Design	Relief Valve W Shock absorber	Hydraulic Dampner inline with fluid flow	Relief Valve / dampner system integrated into Hydraulic Cylinders
No Hull Modification 35%	5	5	5	5
Ease of Maintenance 15%	5	4	4	4
Cost 15%	5	4	3	2
Ease of Installation 15%	5	3	4	4
Ability to Perform Functional Check 10%	0	2	5	5
Safety 5%	0	2	5	5
Ease of Use 5%	5	5	5	5
Totals	425	395	440	425

Table 2 – Weighted Rating Method

PRODUCT

In this view we can see all of the components which make up the energy dissipation system. The fully developed product would reside inside of an aluminum enclosure but that was left off in this view in order to see the components involved in this design.

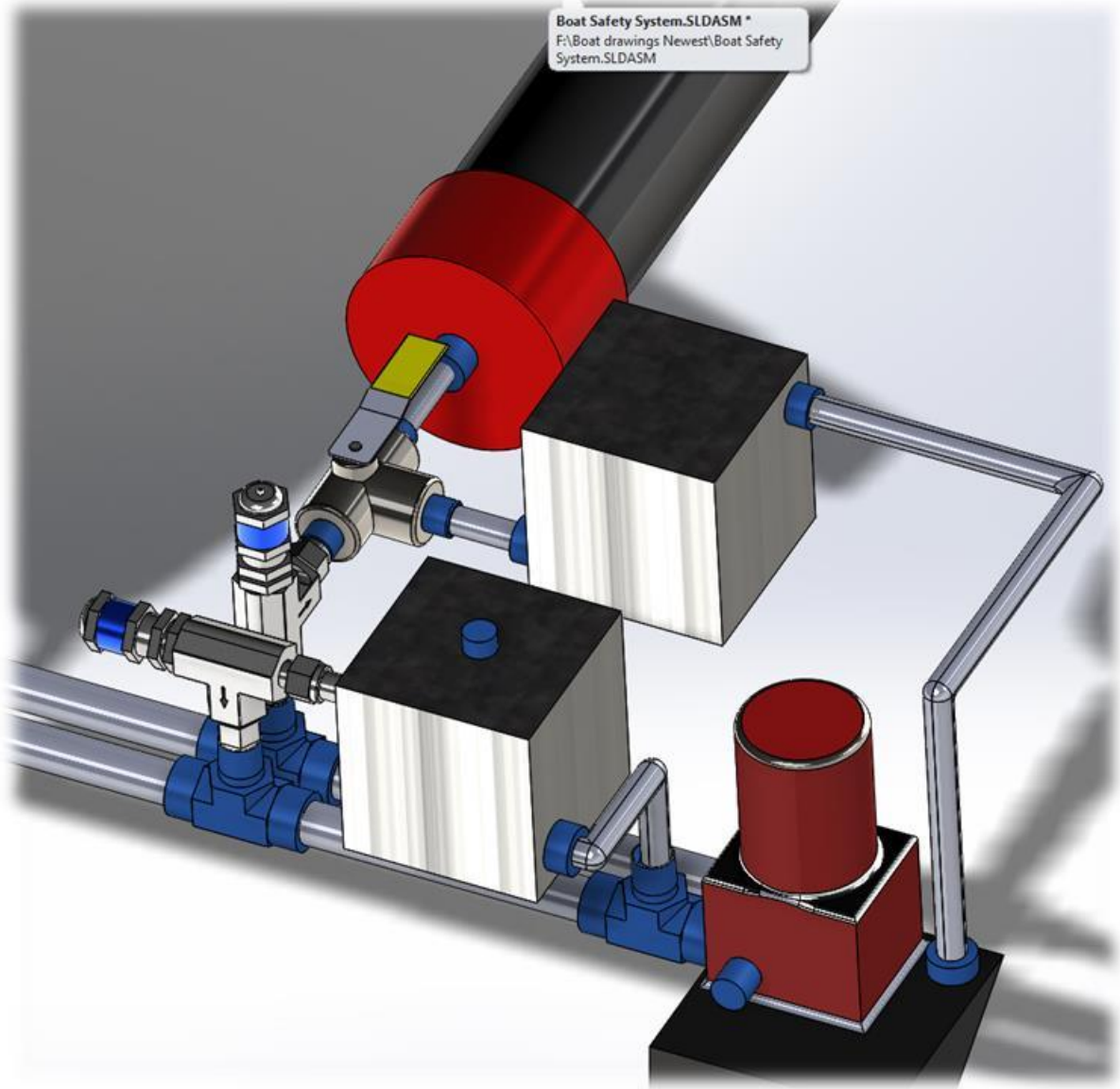


Figure 17 – 3D rendering showing complete system connected to boat hydraulic pump

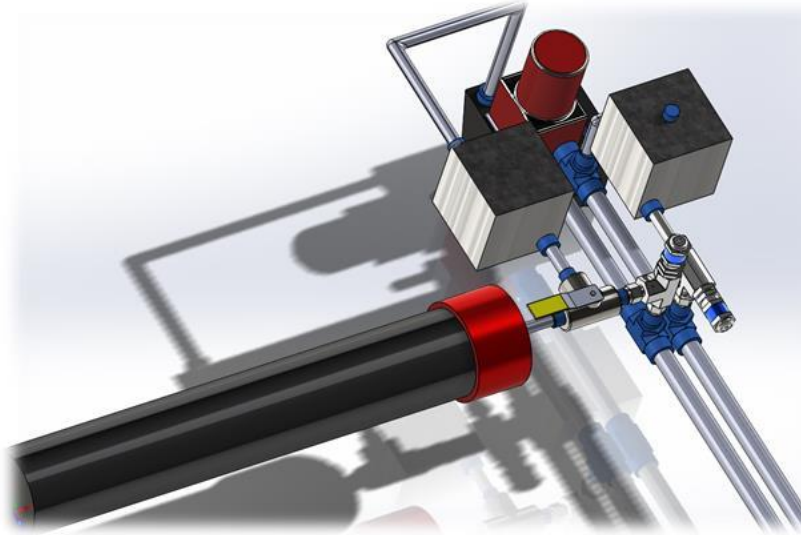


Figure 18 – 3D rendering of complete damping cylinder

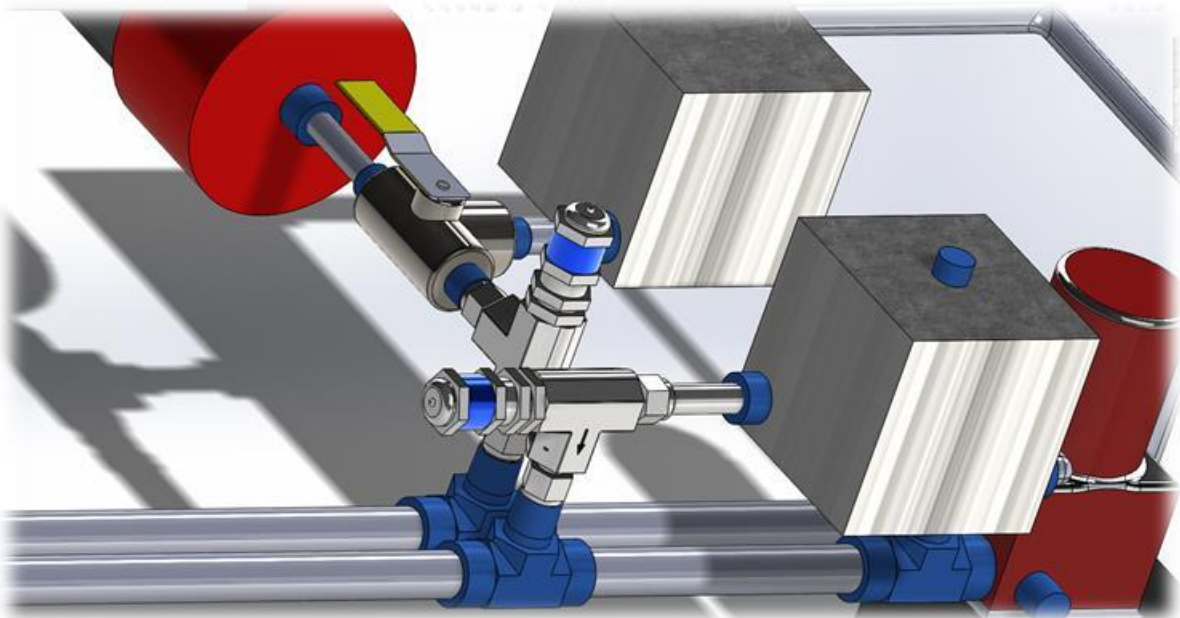


Figure 19 – Alternative view of 3D rendering of complete damping cylinder

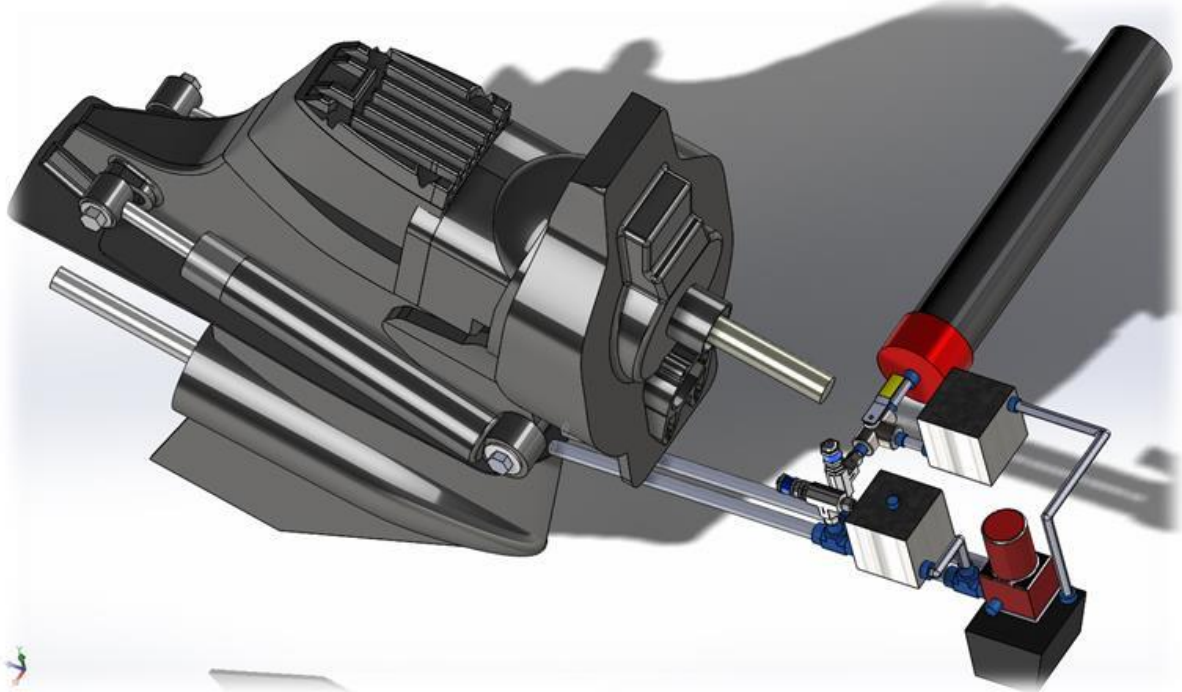


Figure 20 –3D model showing complete system connected to boat components

Final Design Product Overview

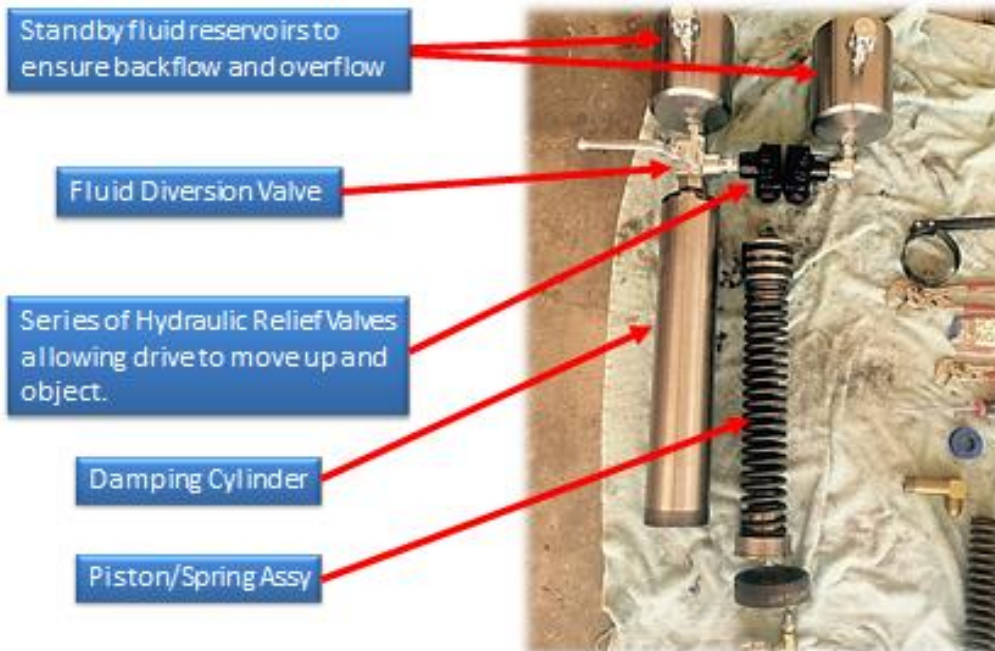


Figure 21 –Product Component Description

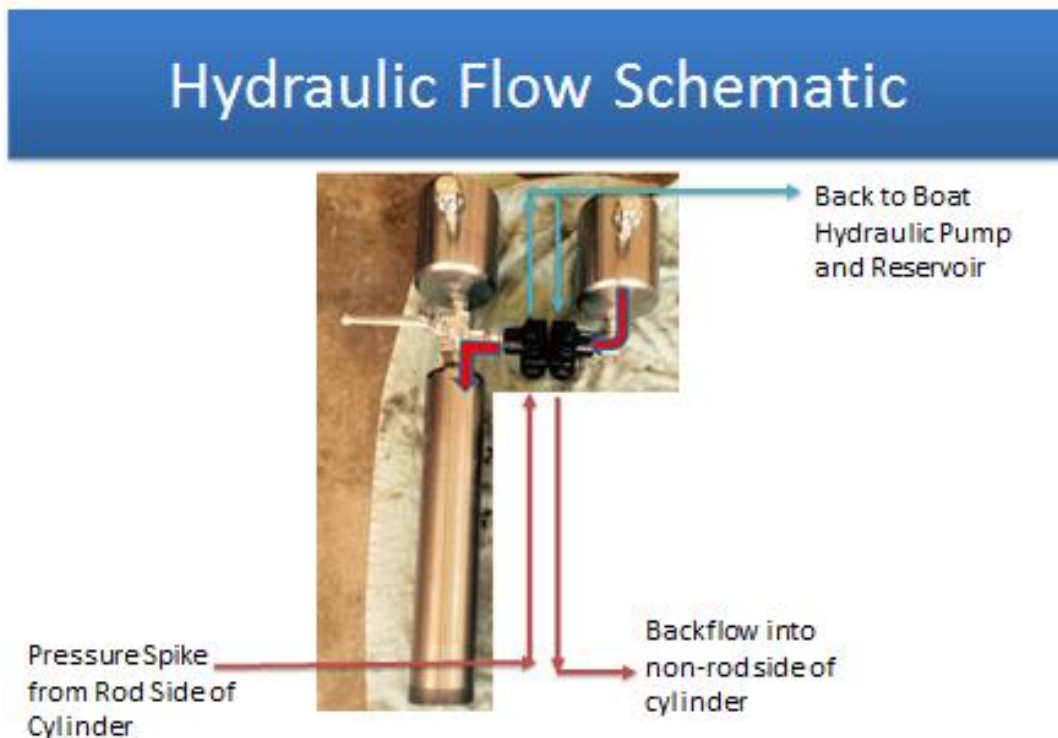


Figure 22 –Hydraulic Flow Schematic

LOADING CONDITIONS

The loading conditions that will exist on this product will occur within the damping cylinder where pressure spikes encountered from impacting debris will be absorbed by a piston/spring cylinder assy. There are no structural loading conditions to analyze on the overall system itself as it will rest within a metal enclosure and be secured to the floor of a boat in the utility bay.

The burst pressure for the cylinder was calculated using the yield strength of DOM 1026 on a 0.25" thick wall which was found to be at 10,000 PSI. Using a safety factor of 2 we downgraded the pressure rating of the damping cylinder to 5000 PSI.

DESIGN ANALYSIS

The entire operation of this system is based off of impulse and momentum calculations using a coefficient of restitution of 0.6 which represents wood. This product is designed to be in contact with debris for 0.01 seconds which is what the spring constants and speeds are based off of also.

First, a speed was chosen as a nominal value at which the system would operate and based off of local laws restricting speed and reported debris strike speeds, we chose 20 MPH. Based off of the speed we were able to calculate the amount of forces generated within the onboard hydraulic system during a debris strike. Utilizing this value, which is considered a

worst case scenario, the damping system was devised using burst pressures and spring constants surrounding the worst case scenario.

I chose to use DOM metal for the damping cylinder because of its high yield strength and readily available material because of its wide use in high pressure hydraulic applications. We calculated the amount of stroke needed to effectively absorb the total volume of fluid displaced in the event of a debris strike and settled on a 4" bore cylinder. With the 4" bore cylinder you would only need 2.54" of stroke to absorb an impact that fully displaced the total fluid volume from the power trim cylinders. Based on the 2.54" of stroke needed to absorb a worst case scenario impact, I chose a spring that would deflect a full 3" until it hit the solid height.

The pressure at which the pressure release valves open was chosen based off of a test I conducted on a 1989 Wellcraft boat with a Mercruiser Alpha one Outdrive. I installed pressure gauges in-line with the cylinders to monitor the highest pressure experienced from the cylinders while operating the boat at very high speeds and fast starts. During this test the highest pressure encountered was 28 PSI. This pressure was experienced with three total people in the boat and a full tank of gas. Based on this experimental data I have set the pressure relief valves to begin opening at 150 PSI. The sooner you open the relief valve, the quicker you can allow the boats outdrive to begin swinging up and over the object it is striking.

Spring constants were calculated for the force we set the relief valves to open at and a suitable spring was purchased that had a solid stack height of 3". Once the relief valves had opened and allowed the drive unit to swing up and over the object, the fluid would be ported into the damping cylinder. The spring/piston assy inside the damping cylinder would dampen the angular acceleration of the drive unit to retard its motion until the relief valves closed.

ASSEMBLY

The compactness of the unit is important since some boats have limited space in their utility/engine area. To keep the unit compact, components were coupled directly to each other using hydraulic bushings. This also eliminated the cost in manufacturing several complex lengths of hydraulic tubing which might include tight bend radiuses that not only increase the price but add to the build time.

All connections were made using O-rings and Teflon tape to seal the threads and prevent leaks or SAE connections were used with flare fittings. The piston and spring were inserted into the damping cylinder about half way and then the cylinder was filled with hydraulic fluid. Then the piston and spring were seated fully to push out any air which may have entered the system and the gland nut was tightly secured on the back of the cylinder to hold the spring tightly inside the damping cylinder.

When assembling it is important to attach the common port of the three way valve to the damping cylinder so that when it is actuated the fluid will either go from the release valve to the damping cylinder or from the damping cylinder to the overflow tank.

The standby reservoir also needs to be filled with fluid after all connection are made by

pouring fluid in through the tank breather valve. This ensures that when an object is struck, there is a positive volume of fluid to be backfilled into the cylinders on the power trim.

COMPONENT SELECTION

The hydraulic relief valves were purchased from Prince Hydraulics due to their ability to flow 30 GPM and its adjustable relief range of 100 to 500 PSI. The GPM rating was important since we were working with an impact time in contact of 0.01 seconds. It needed to be able to flow fluid in the small amount of time. The three way valve was purchased from prince also because it was rated for 3000 PSI and also had a 30 GPM rating.

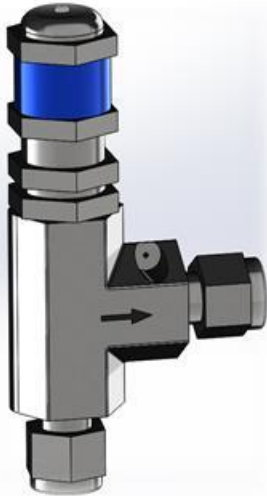


Figure 23- 3D rendering of release valve

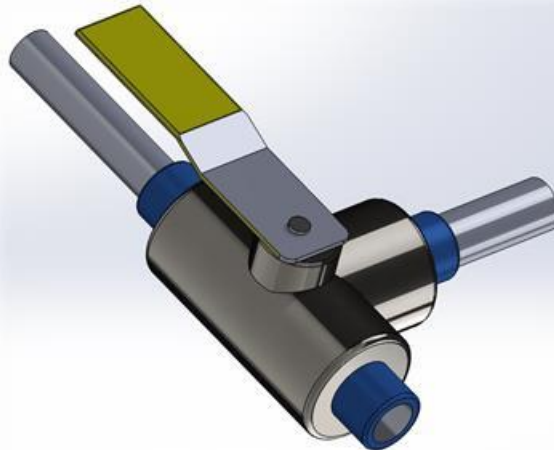


Figure 24 – 3D rendering of 3-way valve

The damping cylinder was made from 0.25” DOM steel because of its high yield strength when calculating the burst pressure under a worst case scenario.



Figure 25 – 3D rendering of complete damping cylinder

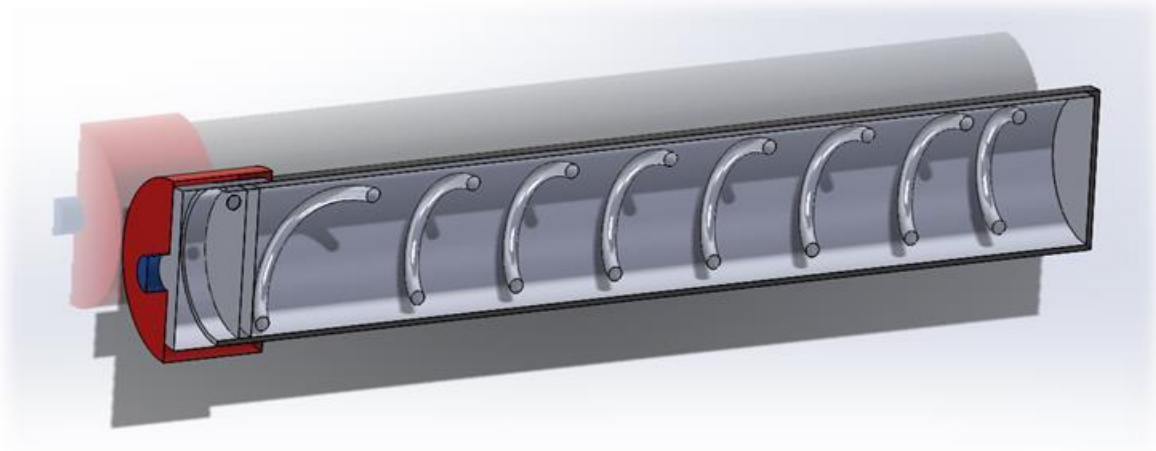


Figure 26 – 3D rendering of cutaway view showing damping cylinder, spring and piston

The fluid standby and overflow reservoirs will see no pressure differentials and did not require structural integrity in their design. I manufactured my fluid overflow boxes with scrap steel cylinders and welded end caps onto them. The overflow reservoir will deliver hydraulic fluid back to the boats main hydraulic pump via a flexible line. The boats onboard hydraulic reservoir caps are all the same size so I picked this nipple assy with matching thread size which screws directly onto the reservoir. The flexible overflow line from the overflow reservoir will be connected to this nipple.

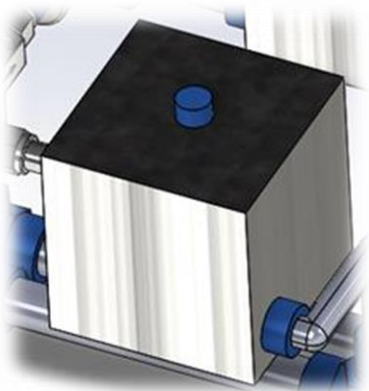


Figure 27 – 3D model of standby tank and overflow tank



Figure 28 – 3D model of modified reservoir cap

BILL OF MATERIAL

<u>Component</u>	<u>Description</u>	<u>Vendor</u>	<u>Budget Cost</u>	<u>Actual</u>
Hydraulic Release Valve	Relief valve	EATON	\$58.00	105.00
Mounting Assy	Plate or bracket	LBM	\$1.00	4.50
Bulk Flexible Hydraulic Hose	.025" I.D Tubing 20000 PSI	Discount Hydraulics	\$6.00	35.00
Pressure Switch contact	10,000 PSI	Mouser Electronics	\$1.48	27.50
Kill Switch Relay	Interrupts ignition circuit	West Marine	\$35.99	35.99
Machining Hours	1.5 Hours @ \$40.00/hr	LBM	\$60.00	60.00
AN-Fittings	Anodized Blue	Grainger	\$40.00	40.00
Selector Valve	Three way vlave	Grainger	\$15.00	6.00
EGR Valve	Vacuum release for	Grainger	\$8.00	4.00
Fluid Boxes	Standby reservoir	UC Metal Shop	\$0.00	0.00
Reservoir cap W nipple	Return to pump	3D print	\$0.00	0.00
Sheet of Aluminum	3' X 3'	AK Steel	\$0.00	0.00
Damping Cylinder	Raw Stock DOM Steel	Rumpke Hydraulics	\$95.00	\$0
Overflow Tanks	Raw Stock DOM Steel	Rumpke Hydraulics	\$ \$60	\$0
			TOTAL	
			\$330.47	\$317.49

Table 3- BOM

CALCULATIONS

All calculations were made based on a worst case scenario to examine the amount of force exerted on a boats power trim drive unit without a dampening system installed.

Volume in Damping Cylinder

One area of concern was if the log strike was forceful enough to cause the drive unit to swing through most of its travel, how would we ensure there was enough damping force available before the damping cylinder bottomed out? Taking the total volume of each hydraulic actuator on the drive unit and adding them would give us the total possible volume displacement in a worst case scenario. Ensuring that there was enough volume for an extra 10% of total fluid displacement in the damping cylinder was a simple fix for this problem. This is not represented in the calculations but is incorporated into the designs.

Impact forces

$$\mathbf{Mass}_{BOAT} = \frac{\mathbf{Weight}}{\mathbf{Gravity}} = \frac{2000 \text{ LB}}{32.2 \text{ Ft/Sec}^2} = 62 \text{ slug}$$

$$\mathbf{Speed} \left(\frac{\text{ft}}{\text{Sec}} \right) = \frac{20 \text{ Miles}}{\text{Hour}} * \frac{1 \text{ Hour}}{3600 \text{ Sec}} * \frac{5280 \text{ Ft}}{1 \text{ Mile}} = 29.3 \text{ ft/sec}$$

$$\mathbf{Impulse} = F_{AVERAGE} \Delta t = m \Delta v$$

$$\mathbf{Force}_{AVERAGE} = m * \frac{\Delta v}{\Delta t} = 62 \text{ slug} * \left[\frac{29.3 \left(\frac{\text{ft}}{\text{sec}} \right)}{\frac{1}{29.3} \text{ Sec}} \right] = 53,226 \text{ LB}$$

$$\mathbf{Velocity} = U + \mathbf{Acceleration} * \mathbf{time}$$

$$\left(\frac{35 \text{ ft}}{\text{sec}} \right) = \left(\frac{44 \text{ ft}}{\text{sec}} \right) + \mathbf{Acceleration} * (.03 \text{ Sec})$$

$$\mathbf{Acceleration} = \left[\frac{\left(-9 \frac{\text{ft}}{\text{sec}} \right)}{(.01 \text{ Sec})} \right] = -900 \frac{\text{ft}}{\text{Sec}^2}$$

$$\mathbf{Force} = \mathbf{Mass} * \mathbf{Acceleration} = \left[\frac{(2000 \text{ lb})}{\left(\frac{32.2 \text{ ft}}{\text{Sec}^2} \right)} \right] * \left(-900 \frac{\text{ft}}{\text{Sec}^2} \right) = 55,900 \text{ lb}$$

Damping Cylinder Max Pressure

Using a factor of safety of 2 against the 3,000 PSI relief valve pressure, the max pressure for this cylinder should be 10,000 PSI.

$$\text{Pressure}_{\text{Power Trim Cylinders}} = \frac{\text{Force}}{\text{Area}} = \frac{55900 \text{ LB}}{\pi * 0.5'^2} = 71,174 \text{ PSI}$$

$$\text{Max Stress } (\sigma_c) = \left[\frac{(\text{Pressure}) * (\text{Diameter})}{(2 * \text{Wall Thickness})} \right] = \left[\frac{\left(\frac{150 \text{ lb}}{\text{in}^2} * 4 \text{ in} \right)}{(2 * 0.25 \text{ in})} \right] = 1200 \text{ PSI}$$

$$\text{Burst PSI} = \frac{2 * (\text{Wall Thickness}) * (\text{Tensile Strength})}{\text{Outside Diameter}} =$$

$$\frac{[(2) * (0.25) * (85,000 \text{ PSI})] 1026 \text{ DOM}}{4 \text{ inches}} = 10,400 \text{ PSI}$$

Total Volume displaced From Rod Side of power trim Cylinder (Stored in overflow Tank)

$$\text{Volume} = \left[\pi * \left(\frac{1.750''}{2} \right)^2 * 10'' \right] - \left[\pi * \left(\frac{1.00''}{2} \right)^2 * 10'' \right] * 2 = 32 \text{ Cubic Inches}$$

Total Volume to be back filled into non rod side of cylinder (Stored in Standby Tank)

$$\text{Volume} = \left[\pi * \left(\frac{1.750''}{2} \right)^2 * 10'' \right] * 2 = 48 \text{ Cubic Inches}$$

Flow Rate of Relief Valve

$$\text{Flow Rate} = \frac{30 \text{ Gallons}}{\text{Min}} * \frac{1 \text{ Min}}{60 \text{ Sec}} * \frac{231 \text{ in}^3}{1 \text{ Gallon}} = 115.5 \left(\frac{\text{inch}^3}{\text{Sec}} \right)$$

Stroke length of piston from Volume displaced in a 4" bore cylinder from 32 in³

$$\text{Stroke} = \frac{\text{Volume}}{\pi * r^2} = \frac{32 \text{ in}^3}{\pi * 2 \text{ in}^2} = 2.54''$$

Working Fluid Line Pressures

All of the fluid lines currently installed on the boat are rated for 3,000 PSI and the fluid lines used in the design will be rated for this as well.

Damping Cylinder Spring Constant

$$\text{Force} = \text{Pressure} * \text{Area} = \left(\frac{55,900 \text{ lb}}{\text{in}^2} \right) * \pi * 2.5 \text{ in}^2 = 439,042 \text{ Lb}$$

$$\text{Spring Constant } (k) = \left[\frac{\text{Force}}{\text{Distance } X} \right] = \left[\frac{439,042 \text{ lb}}{20 \text{ in}} \right] = 21,952 \text{ lb/in}$$

FABRICATION

The manufacturing of the components for this project involved use of a lathe, drill press, commercial band saw and MIG welder.

The Damping cylinder was machined on a lathe to the diameter which we calculated. Use of a commercial band saw was used to cut the raw stock cylinder to length and then a vertical mill was used to remove material from each end which verified they were true. Next an end cap was welded to one side of the cylinder with a MIG welder on a rotating table and then utilizing the lathe I cleaned up the welds. Threads were manufactured on the opposite end of the damping cylinder for a gland nut which holds the spring/piston inside the damper.



Figure 29 – Welding End Caps on Damping Cylinder



Figure 30 – Machining Damping Cylinder

Next using a drill press, I drilled the hole for the fluid flow into the damping cylinder and then I manually threaded it for a flare fitting where it would connect to the three way valve. The piston assy was donated by Rumpke hydraulics. I machined a spring stabilizer block that would fit in the middle of the spring which stabilized it so that when under compression it stayed secured in place.

The standby and overflow reservoirs were machined in the exact same manner as the damping cylinder was except end caps were welded onto both sides of the cylinder and holes were drilled on each side to allow for fluid flow in and out of the tanks. I also drilled and tapped holes in the tops of the tanks where the PCV valves would be installed. The holes were threaded manually by hand like in the damping cylinder.

TESTING

I tested two different prototypes of this system with failure on the first but success on the second. During testing of the first prototype, I hooked it up to my boat and found an object in the Ohio River to impact while observing the movement of the outdrive. I first impacted the log at 10 MPH with no movement from the out drive but then increased my speed to 20 MPH on the 2nd attempt. When I impacted the log on the 2nd attempt my systems standby reservoir exploded and ripped the tie straps securing it onto the back of the boat. I lost the entire project in the river and was unable to recover it. After much thought and discussion with my professor I have come to the conclusion that the failure was due to the three way valve being in the wrong position. Instead of porting the fluid pressure to the damping cylinder, it ported fluid to the standby reservoir which was not made to handle any pressure. While I was securing the system to my boat I moved the handle on the valve in order to fit it between the bars on the swim platform where it was to be secured. I forgot to move the handle back to the position where fluid would be directed into the damping cylinder and so when the release valves opened they dumped pressure into the overflow tank which couldn't handle the pressure and it exploded.

My recommendation was to find a spring loaded valve which was normally open in the damping cylinder position and in order to relieve the pressure to the overflow tank the operator would have to manually move the valve against the spring and then it would automatically return to the damping position. Not all was bad from this failure because after the confusion of the explosion we noticed that the outdrive did indeed move upwards halfway through its normal travel. So we proved that this system does work by relieving pressure through the existing hydraulic lines.

For my second prototype I built the same system again except I did not test it on a boat this time but on a hydraulic mule that was producing 5000 PSI. During the test we opened the valve at 1000 PSI and worked the pressure up to 3000 PSI and we could tell it was working because there was a drop in pressure just before the hydraulic relief valve after we turned the mule on. To determine how much the spring was compressing I took a wooden dowel rod and put it through the breather hole until it hit the back of the piston in the damping cylinder. We applied the pressure again and it was moving 2" out of the cylinder. We applied more pressure and around 4000 PSI the spring was totally depressed. We took it up to 5000 PSI and while the spring didn't move because it was already fully compressed the damping cylinder was able to hold the pressure.

PROJECT MANAGEMENT

BUDGET

I have sourced sheet aluminum, cylinder steel and labor hours from local machine shops. I fully expect the budget to change as my design matures and I encounter unexpected design changes and flaws. Please see the budget below in Table 4.

<u>Component</u>	<u>Description</u>	<u>Vendor</u>	<u>Budget Cost</u>	<u>Actual</u>
Hydraulic Release Valve	Relief valve	EATON	\$58.00	105.00
Mounting Assy	Plate or bracket	LBM	\$1.00	4.50
Bulk Flexible Hydraulic Hose	.025" I.D Tubing 20000 PSI	Discount Hydraulics	\$6.00	35.00
Pressure Switch contact	10,000 PSI	Mouser Electronics	\$1.48	27.50
Kill Switch Relay	Interrupts ignition circuit	West Marine	\$35.99	35.99
Machining Hours	1.5 Hours @ \$40.00/hr	LBM	\$60.00	60.00
AN-Fittings	Anodized Blue	Grainger	\$40.00	40.00
Selector Valve	Three way vlave	Grainger	\$15.00	6.00
EGR Valve	Vacuum release for	Grainger	\$8.00	4.00
Fluid Boxes	Standby reservoir	UC Metal Shop	\$0.00	0.00
Reservoir cap W nipple	Return to pump	3D print	\$0.00	0.00
Sheet of Aluminum	3' X 3'	AK Steel	\$0.00	0.00
Damping Cylinder	Raw Stock DOM Steel	Rumpke Hydraulics	\$95.00	\$0
Overflow Tanks	Raw Stock DOM Steel	Rumpke Hydraulics	\$ \$60	\$0
			TOTAL	
			\$330.47	\$317.49

Note: LBM = Lambert Brothers Machine Company

Table 4- Budget

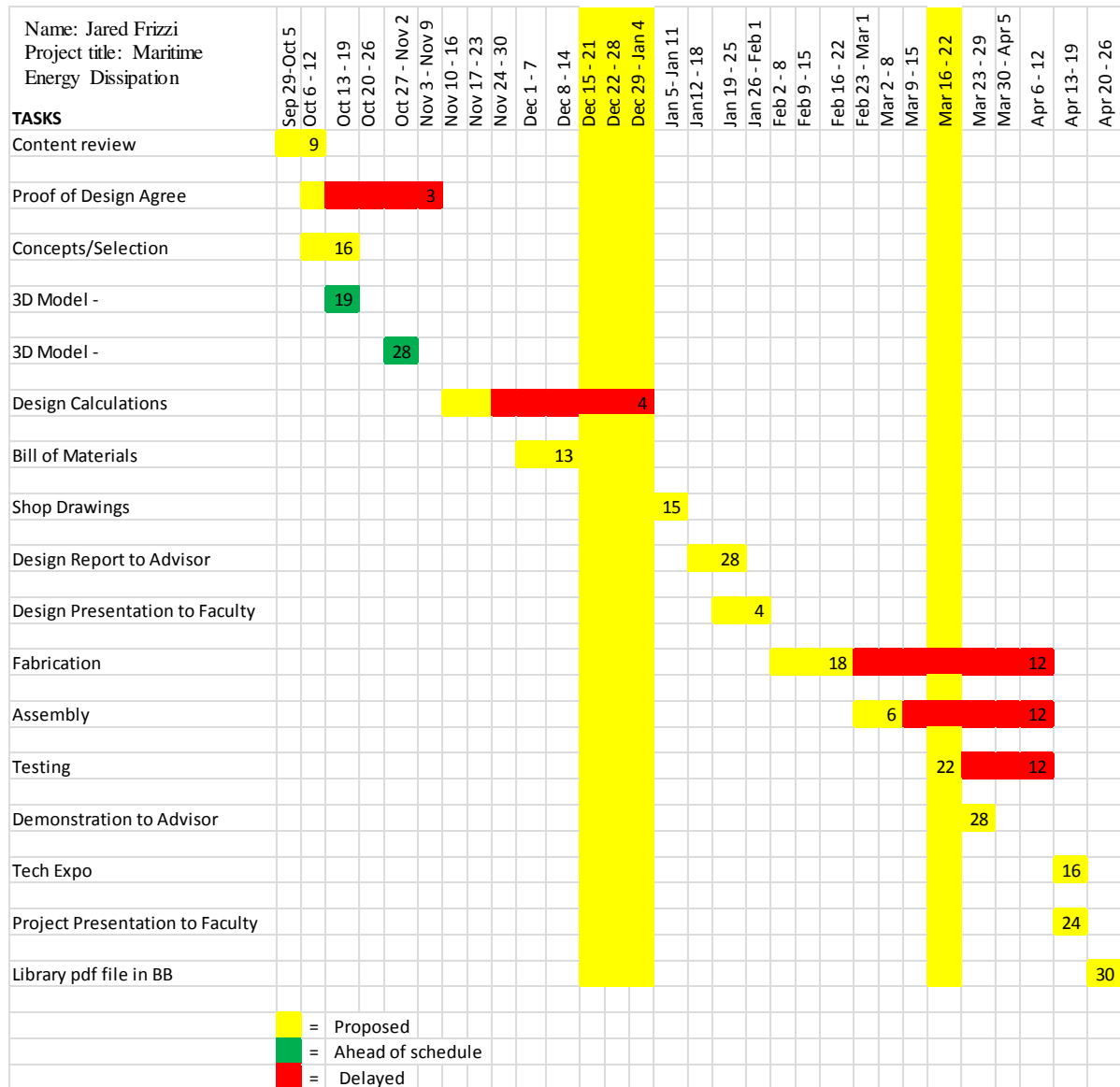
SCHEDULE

Figure 31 – Schedule

REFERENCES

1. Sheriff's Office warns boaters about floating debris on Flaming Gorge. *SweetwaterNOW*. [Online] 06 30, 2014. [Cited: 09 15, 2014.] <http://www.sweetwaternow.com/sheriffs-office-warns-boaters-floating-debris-flaming-gorge/>.
2. Guard, US Coast. Deadheads Can Get You if You Don't Watch Out. *American Boatign Association*. [Online] 05 26, 2011. [Cited: 10 01, 2014.] http://www.americanboating.org/safety_deadheads.asp.
3. Nery, Steve. Three boats hit dredge pipe in Chester, 1 sinks . *The Star Democrat*. [Online] 05 15, 2007. [Cited: 10 01, 2014.] http://www.stardem.com/news/article_cca55c9a-7fdb-5533-9f55-432abe9d6df7.html?mode=jqm.
4. *Tilt & Trim Down of Lower Unit Video*. Gavinswadel (Youtube).
5. Burn, J. Cracked Lower Unit from impact (Photos W damage). *iboats*. [Online] [Cited: 10 01, 2014.] <http://forums.iboats.com/forum/engine-repair-and-maintenance/yamaha-suzuki-outboards/342084-cracked-lower-unit-yamaha-90>.
6. gilligan2032. 1976 Cobia Tri Hull Transom Destroyed - HELP Pictures. *iboats forums*. [Online] 16 09, 2012. [Cited: 10 01, 2014.] <http://forums.iboats.com/forum/boat-repair-and-restoration/boat-restoration-building-and-hull-repair/593176-1976-cobia-tri-hull-transom-destroyed-help?t=578908>.
7. Loucks, Gary. Garys Outdoor Wanderings 2 Hit rocks in lake Photos. *Garys Outdoor Wanderings 2* . [Online] [Cited: 10 01, 2014.] <http://garysoutdoorwanderings2.blogspot.com/2012/02/henderson-island-shipwrecked.html>.
8. Service, Baker Marine. Baker Marine – Muskegon Boat Repair. *Jamesmaurer*. [Online] [Cited: 10 01, 2014.] <https://www.jamesmaurer.com/baker-marine-muskegon-boat-repair.asp>.
9. Davis, J. Lower Unit Ripped Off (Photos of Damage). *BassBoat Central*. [Online] [Cited: 10 01, 2014.] <http://www.bbcboards.net/mercury-motors/313320-lower-unit-ripped-off.html>.
10. iboats. Skeg Guards. *iboats.com*. [Online] [Cited: 08 25, 2014.] http://www.iboats.com/Megaware-SkegGuard-by-KeelGuard/dm/cart_id.767313715--session_id.249579511--view_id.716803.
11. Cabelas. Cabelas Frame Mount Transom Saver. *Cabelas Worlds Foremost Outfitter*. [Online] [Cited: 08 25, 2014.] <http://www.cabelas.com/product/Cabelas-Frame-Mount-Transom-Saver/737477.uts>.
12. Transom Reinforcement for Outboard conversion. *boatdesigns.net*. [Online] April 2007. [Cited: 08 25, 2014.] <http://www.boatdesign.net/forums/boat-design/transom-reinforcement-outboard-conversion-15706-2.html>.
13. Mark Ellens, Edward Max Leite, Graeme Michael Dempster, Jasenn Michael Howe. *Energy dissipation valves for hydraulic cylinders*. US20060083641 A1 USA, 04 20, 2006. Application.
14. Uppgard, et al. *Hydraulic actuator with shock absorbing capability* . 6,176,170 USA, March 3, 1999. Application.

15. Hedrick, Don. *Commadore Four Seasons Yacht Club*. [interv.] Jared Frizzi. 08 25, 2014.
16. III, Ed Alf. *President of Sea Ray Cincinnati*. [interv.] Jared Frizzi. Cincinnati, 08 25, 2014.
17. Hansen, Lawrence. *Insurance Agent for Maritime Insurance Group*. Milwaukee, 08 2014.
18. EATON. EATON Hydraulic Pressure Control Valves. *EATON Hydraulic Pressure Control Valves*. [Online] EATON. [Cited: 07 21, 2014.] http://www.eaton.com/Eaton/ProductsServices/Hydraulics/Valves/Screw-InCartridgeValves/PCT_262533.
19. Costs, Grainger Aluminum. Aluminum Rod Stock. *Grainger*. [Online] Grainger. [Cited: 08 10, 2014.] <http://www.grainger.com/category/aluminum-rod-stock/aluminum/raw-materials/ecatalog/N-c0h>.
20. Maritime Relay Kill Switch. *West Marine*. [Online] [Cited: 09 24, 2014.] <http://www.westmarine.com/buy/bennett-marine--interrupter-relay-switch--193054>.
21. Honeywell/ Micro Switch Industrial Pressure Sensors. *Mouser Electronics*. [Online] [Cited: 09 24, 2014.] <http://www.mouser.com/Search/Refine.aspx?Ne=254016&N=1323038+10834220+4289186805>.
22. Modeling Boat Motor Log Strikes – A Senior Design Project. *Propeller Guard Information Center*. [Online] 2012. [Cited: 01 2015, 01.] <http://www.propellersafety.com/4883/research-projects/modeling-boat-motor-log-strikes-senior-design/#>.

APPENDIX A - RESEARCH

Interview with Maritime Captain: 08/25/14, Don Hedrick, Commodore of Four Seasons Yacht Club: 4609 Kellogg Ave, Cincinnati, OH 45226, PH: 513-615-3232

Don is a boating enthusiast and professional Maritime Captain with over 40 years' experience at the helm of personal watercraft up to 36' in length. Spoke with Don about my problem statement and he agreed that a system which could prevent or at minimum, limit the damage from hitting submerged debris would be a huge plus for boaters with outdrives. He invited others at the club over to our conversation and they also agreed it would be a great product and showed a lot of interest in it.

I picked up a few points of interest from some potential customers. They said that it should have the ability to be installed by the average boat owner with standard tooling. No cutting or modification of the hull would be allowed.

They said they would also like a way to perform a functional check on it periodically to ensure maximum protection.

The boaters I talked with said that if the system works they would be comfortable spending \$450 per unit. They also asked about regular MX.

Interview with Boat Dealership Owner Ed Alf III, 08/25/14, President of Sea Ray of Cincinnati: Sea Ray 4609A Kellogg Avenue Cincinnati, Ohio 45226 PH: 513-871-5555

I spoke with Ed and his certified Boat Technician about the problem statement to get their perspective. They both said that they have performed several repairs to boats that have been struck by floating debris. Ed was actually interested in selling a product we developed at his shop for interested boaters. The mechanic told me that it would be a good design to include another component that when a strike is sensed it immediately cuts off the engine to help reduce damage to the spinning propeller. Both techs recommended no hull modification and that it be easy to test and maintain.

Interview with Insurance Company, 08/01/14, Maritime Insurance Group Agent Lawrence Hansen 832 Niagara Avenue Sheboygan, WI 53081 PH: (920) 457-7781

I sent an email to Lawrence and inquired about this problem with his insurance company. He said that they do pay out a lot of money to repair boats that have struck submerged debris and was interested to know more about what I planned to do. I told him that everything was in preliminary stages at this point. He did tell me that if I was able to design a system which limited damage or eliminated it that his group would offer a discount to the owners. The insurance group would need to look over the details of the product and see the demonstration of it operating. He said that it would need to be installed by a certified boat mechanic for the discount to be given. They would also determine if the operational check was sufficient and it would need to be a low maintenance item. Minimal parts to make up the design.

MegaWare Skeg Guard

Keel Guard is a slip on cover that a user can install on the skag of their lower propulsion unit to protect it from damage. It can also install over an existing skag that has sustained damage to replace the loss of steering control from material loss.



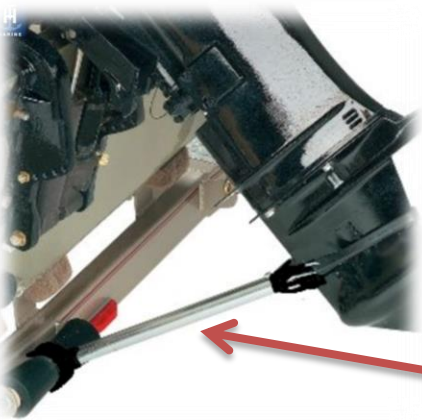
[Link 09/01/2014](#)

Megaware Skeg Guard by
Keel Guard

This Product requires drilling into the lower unit which increases the possibility of drilling into a sealed lubrication cavity. You could also drill into gears inside the housing. Possibility to introduce a ton of FOD. My product would stop this type of damage from happening at all and eliminate the need for it. Cost is \$90.00.

Cabela's Frame Mount Transom Saver

The Trasom saver is a rigid link that supports the weight of the lower unit as the boat is transported on a trailer. It only works when boat is loaded onto transport trailer.



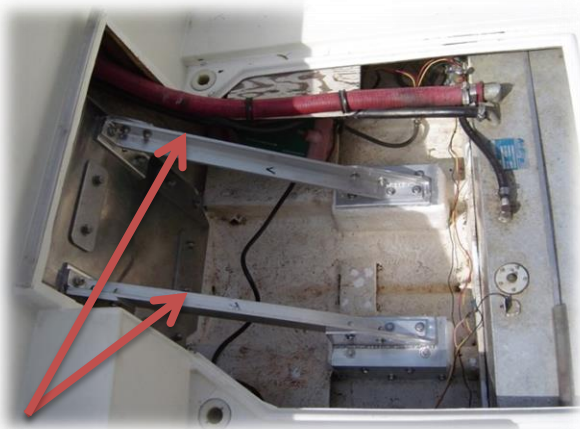
[Link 08/30/2014](#)

Cabela's Frame Mount
Transom Saver

This Product requires drilling into the boat trailer frame. Installation would be much simpler than my current idea but this product does not provide any protection when boat is operating on the water. Cost is \$56.00.

Boat Design Angle Bar Reinforcement

The product works to reinforce the transom by redirecting forces into the motor mounts in the hull. It uses a steel plate that mounts against the transom and accompanying angle brackets secure it to the floor.



[Link](#) 09/10/2014
boatdesign.net

This Product requires drilling into the boat hull in several places and requires the removal of the engine for installation. I do believe that this product can work well for its intended purposes but it adds weight to the back of the boat and it adds more items in the engine cavity. Working around the brackets would be difficult. It is also a custom build and cannot be purchased. Cost is \$400.00

APPENDIX B - PRODUCT OBJECTIVES

Product Objectives

Based on the survey, the product objectives are the list of features that are taken into consideration. The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met.

1.) No Hull Modification (35%)

- d. System will interact with propeller from inside boat.
- e. Utilize existing fluid lines for pressure sensing.
- f. Use through hull sonar system for FWD looking electronic warning

2.) Ease of Maintenance (15%)

- e. System should be accessible enough to perform inspection
- f. Uses standard tooling
- g. Use material capable of resisting corrosion in a humid environment
- h. System override capability

3.) Cost 15%

- c. Be less than \$450.00
- d. Use readily available standard parts and materials.

4.) Ease of Installation (DIY boat owner can complete) 15%

- d. Uses standard tooling
- e. Compactness for installation in tight quarters
- f. System should be secured to boat transom or engine cavity floor

5.) Ability to perform functional check 10%

- b. Provide test apparatus for verification of correct system operation
- c.

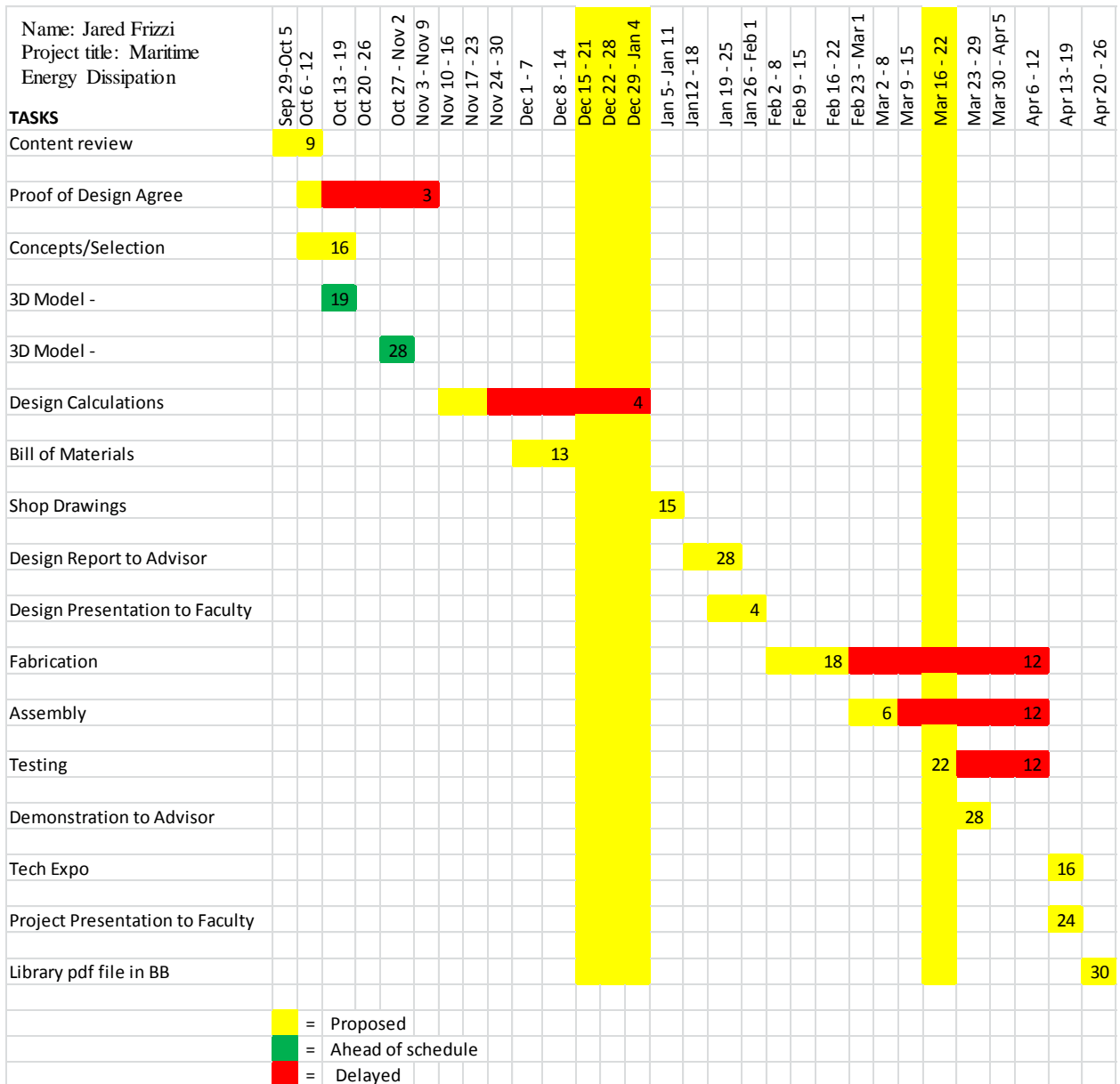
6.) Safety 5%

- b. Allow function which cuts off engine when impact is sensed.

7.) Ease of use 5%

- a. System will work autonomously of operator input

APPENDIX C - SCHEDULE



APPENDIX D - BUDGET

<u>Component</u>	<u>Description</u>	<u>Vendor</u>	<u>Budget Cost</u>	<u>Actual</u>
Hydraulic Release Valve	Relief valve	EATON	\$58.00	105.00
Mounting Assy	Plate or bracket	LBM	\$1.00	4.50
Bulk Flexible Hydraulic Hose	.025" I.D Tubing 20000 PSI	Discount Hydraulics	\$6.00	35.00
Pressure Switch contact	10,000 PSI	Mouser Electronics	\$1.48	27.50
Kill Switch Relay	Interrupts ignition circuit	West Marine	\$35.99	35.99
Machining Hours	1.5 Hours @ \$40.00/hr	LBM	\$60.00	60.00
AN-Fittings	Anodized Blue	Grainger	\$40.00	40.00
Selector Valve	Three way vlave	Grainger	\$15.00	6.00
EGR Valve	Vacuum release for	Grainger	\$8.00	4.00
Fluid Boxes	Standby reservoir	UC Metal Shop	\$0.00	0.00
Reservoir cap W nipple	Return to pump	3D print	\$0.00	0.00
Sheet of Aluminum	3' X 3'	AK Steel	\$0.00	0.00
Damping Cylinder	Raw Stock DOM Steel	Rumpke Hydraulics	\$95.00	\$0
Overflow Tanks	Raw Stock DOM Steel	Rumpke Hydraulics	\$ \$60	\$0
			TOTAL	
			\$330.47	\$317.49

Note:

LBM = Lambert Brothers Machine Company