Spring 2016

Flag Raising Device

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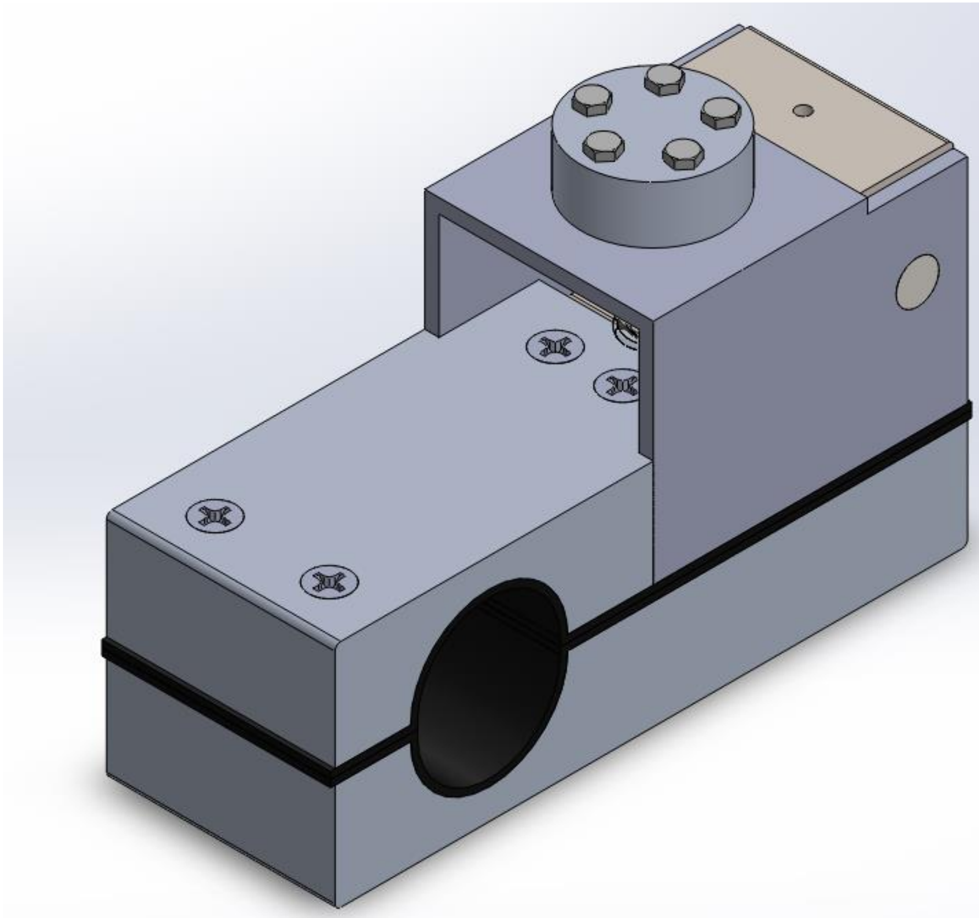

Flag Raising Device for Water Sports

JOSH QUINTERO

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Introduction

Motivation

The motivation for this project stems from a lifetime of boating with father Richard Jones. One problem that many people encounter, including Richard, was when towing someone behind a boat, is the difficulty with handling the warning flag. This flag is used to show other surrounding boats that someone has fallen into the water behind their boat. This warns other boats to stay far away from that area to keep safe from running over the swimmer. Although, when holding the flag in the boat, it can be hard to see at times. The boat driver, or other people standing in the boat, can sometimes get in the way from other boats surrounding to see the flag. This device will essentially put the flag on top of the boat tower, which will make the flag a lot easier to see. This brings much more security and safety for all the different kinds of water sports.

Acknowledgements

I would like to acknowledge the many teachers and staff within the Mechanical Engineering Technology program at Central Washington University. They fostered a comfortable learning program that made it easy to understand concepts and motivation to learn. I would also like to thank Richard Jones for not only lending his boat and equipment to help test for this project, but for also helping with the idea of the project.

Function Statement

This device will have the ability to attach to any boating tower that is used to tow a skier, wakeboarder, tube, or any other type of water sport. The device will automatically raise a flag when the tension in the towrope is released once the person who is being towed falls into the water. It must use the increase in tension to lower a flag, and use the decrease in tension to raise a flag to warn other surrounding boats when a swimmer has fallen into the water. It is important that this device will not damage the tower in any way and should be easily attached and detached to each boating tower it is designed for.

Requirements

The requirements for this device will be…

- The device must be able to withstand tension from 100lbs to 300lbs.
- The device must fit the size of Richard Jones' boat tower diameter of 2.5 inches.
- The device should fit within a volume of 1ft x 5in x 8 inches.
- A towing rope should easily attach to the device's eye ring with a simple boating knot. This is further explained in the description.
- All government and industry safety standards must be met.
- The flag stand is required to operate up to 8 hours a day, 3 days a week, with a design life of 20 years.
- This device should operate at temperatures ranging from 0 to 130°F.
- This device will cost less than $800.00.
- Someone in the boat can manually raise the flag.
- The flag-raising device should weigh no more than 30 pounds.

- Able to withstand the environments of fresh and salt water.

Engineering Merit

The engineering merit regarding this new device has come from some calculations to find out what will make this device successful. The first part is to figure out what kind of requirements this device needs to be successful. The requirements include the statements in the previous section. After carefully examining these requirements, some analysis was done to approve these requirements. This analysis was done with simple calculations. The calculations found for this device can be seen in Appendix A. After finding the analysis for the device, some design parameters were set. There will be some requirements such as the size needed for the device to hold properly. Another important requirement to think about when designing this device is that it will not weigh too much. There should be no excess weight on top of the tower that will put extra amounts of stress on the tower. It is then important to find the right material that will effectively follow this requirement. This device should also not damage the tower in any way. A padding or other type of material that will not scratch the tower is very important to many boat owners. Once the size is found, that is appropriate for the requirements and the calculations are figured out, the right material can then be selected.

Scope of Effort

The scope of effort for this device will see it as an attachment to a ski and wakeboard boat tower. This device will fit the tower on Richard Jones' boat. This tower has a diameter of 2.5 inches and is made of polished aluminum. Another important factor to think about is that this device will not scratch or break the tower it attaches to. It needs to attach and detach easily and in a quick manner.

Success Criteria

The device will attach to the ski boating tower, which will attach to a towing rope and will raise a warning flag when the person being towed falls into the water. This device will also be able to raise a flag if someone in the boat feels it is a safety hazard and needs to be raised without the towing rope.

The professors who are grading this project need to see how and why this device is successful. This can and will be done by video. Once the device has been completed, it will be taken out on Richard Jones' boat with the creator of this project and at least two other people. While one person volunteers to ski and wakeboard, Josh Quintero will take video of the device. This video will show the person being towed water skiing and wakeboarding to make sure this device works properly for many different scenarios.

Once the video is done and the device is seen to have worked properly, the video will be edited to a professional type of video that will be suitable to show to the professors. This video will show the device being put together, the device being attached to the tower, the device being used properly in different scenarios, and the device being taken off the tower and dissembled correctly. This video needs to be done correctly so it can convince the professors that this device is successful. Since the device needs to be used on a boat on some body of water, the professors will not be able to actually see the device work. Therefore, this video is very important.

Testing

The testing for this device will include:

- Time to install and uninstall on the tower
- Weight of the device
- Test to see if the device can raise and lower a flag given the right amount of tension
- The angle at which the flag rotates down at the correct amounts of tension

Design and Analysis

Approach: Proposed Solution

When it came to thinking about the tension constraints for the device, some easy calculations were formulated as you can find in Appendix A on Green Sheet 1. Even though the tension found in the rope was only 363 N, it can be considered that the values of tension will raise and lower by a good amount. Obviously, there will be people with varying masses that will be towed with this device, which will raise the amount of tension in the rope. In addition, there are different ways to play in the water with different types of skis and wakeboards that will generate higher and lower amounts of friction in the water. These higher amounts of friction will also generate higher amounts of friction.

Some situations to think about when designing the device is the many different values of tension that will occur while a skier or wakeboarder is being towed. One big situation to think about is the difference in tension on the rope and device between a wakeboarder and a skier. A wakeboard has a much larger surface than a ski. Therefore, the wakeboard will put a higher value of tension on the rope and device than someone who is skiing. This can also be said with an inflatable tube. There are many different shapes and sizes of water sporting tubes. Many of these tubes have different functions such as rolling, jumping, flying, etc. The values of tension will vary greatly with these different functions as well.

Other situations can happen while someone is being towed by the boat. There are many people who like to jump and do tricks with a wakeboard as high as 10 feet in the air. Other examples can be found when a tube is being pulled sharply around a corner, or when a slalom skier cuts fast and sharp across the wake. The tension will not stay the same throughout all of these situations. These calculations can also be found in Appendix A in Green Sheet 2, 3 and 4. Another situation to think about is when the person being towed lets go of the rope, or the person(s) falls off or out of a tube. There will still be some tension in the rope from the rope dragging the handle in the water or dragging the tube in the water. It is important that the device will still hold the flag in the air while some tension is being pulled on the rope and the device. This is the reason why in the requirements, the range of tension being used varies from 100N to 2400N.

Another design property that is important with this device is that it will be able to handle different environments. This device will likely be used in fresh and salt water. Therefore, it is important to find the right material so that this device will not corrode. Stainless steel can be chosen for its properties that will not allow it to corrode easily. The device will likely only be put on when it is needed. Once the device is not needed anymore, it will be taken off, cleaned, and put away properly. Still it is very important to choose the right material. While using stainless steel for its strength and non-corrosive properties, it is also important to think about the weight of the device. It is important to keep the device as light as possible. Extra amounts of weight on top of the tower can lead to a bigger amount of stress then it is designed to handle. Therefore, for the parts that are actually wrapping around the tower, the material will be aluminum. A certain type of aluminum that also has non-corrosive properties was the ideal choice since it will still likely in contact with fresh and salt water.

The next part of the design was figuring out how to attach a rope to this device. Most towing ropes already come with an enclosed loop on the end of the rope. This makes it difficult to design something easy to attach. Regularly when towing someone behind a boat a boating ski eye is used. A picture of this can be seen in Picture 1 in the following section. Most boaters already know how to use this ski eye so attaching one to the device was decided. This could be simply added to anything with the right size of diameter holes needed to slide the ski eye through. The rope is hooked onto the ski eye with a very simple hook that will be explained later.

The hook on the device needs to have a specific thickness so it can hold the tension without failing. Calculations below can be found below in Appendix A on Green Sheet 5 to support a certain thickness of the eye needed. The calculations found were very small. It is presumed that a stainless steel boating eye could not be made with such a small dimension. Either the material can be changed to accommodate, or using any thickness available of stainless steel should work. It was found that most stainless steel boating eyes were 3/8” to ½” in diameter. Based on the calculations below, this thickness of a boating eye will hold up very well.

Since the flag needs to be raised and lowered with a simple change in tension, it was decided that a part would rotate about a pin. This would allow the flag to be raised vertically in the air when the least amount of tension is being forced on it and allow the flag to rotate to a horizontal position when the right amount of tension is acted on the device. While in the horizontal position, the flag would be rendered down which means someone is being towed behind the boat. When the flag rotates up in the vertical position, this would mean there is a fallen swimmer in the water from the boat. This part would need to also attach the boating ski eye as described before. Therefore it would need to be wide enough to attach the two prongs on the back of the ski eye.

This device needed some type of housing for the rope attachment to rotate about a pin. It would also need to be hollow so that the rope attachment could fit inside and also rotate inside the housing. It was hard to find the right material for this since it also needs to be strong. It was finally decided to use stainless steel square tubing. Although expensive, the right size was found and chosen. Since the housing would be the main part of the device, the other parts would have to be attached to it. The bottom and top parts of the device that attach to the tower would be bolted to the housing. The rope attachment would be attached to the housing by a pin that would still allow it the rotate. As for the spring, it would be put through a hole on top of the housing. Then a cap, which would also be bolted to the housing, would hold the spring in place. The bottom of the spring will rest on the top part of the top tower attachment.

The big challenge was figuring out how to dictate the amount of forces that will allow a flag to be raised and lowered. It was decided that a spring would be used. This spring will be inserted into the device's housing where the back side of the rope attachment will swing up and make contact with the spring. This spring will dictate the flags raising and lowering between the forces of 100 N to 2400 N. Since the spring will experience such a high amount of force at some points when being used, the spring will have to be larger than the amount of space already provided in the housing. These calculations can be seen in Appendix A on Green Sheets 9 through 12. Therefore, a hole will need to be made at the top of the housing so the top of the spring can extend out. The spring cannot be just left with a hole or it would fly away when the device is first used. Some type of cap will need to be made to keep the spring from releasing from the device. This cap will have some type of indent so the spring can sit inside the cap without moving.

An added property to this device that needs to be designed is to manually have the flag raise with a simple switch or pull of a lever by someone in the boat. Sometimes a boat can be stopped in the middle of the water so the passengers and the driver can swim, jump in the water, bathe, etc. Although there is no one being towed behind the boat, there is still swimmers in the water sometimes even without a life jacket. This is a very important situation where other boats need to know if there are swimmers in the area. Another example of needing the raise the flag without someone being towed is if a sharp corner is taken, or massive waves cause someone from inside the boat to fall out. It can take too long for someone to find a flag hidden in the boats undercarriages before another boat realizes too late there is a swimmer that has fallen out of a boat. It would be very important for another passenger inside the boat to raise the flag immediately. Along with raising the flag with a simple switch or lever, the device should also be able to lower manually without the use of a towing rope. Once all swimmers are back inside the boat safely, it would then be necessary to lower the flag so boats around know it is safe.

An important factor with designing this device is that it can be attached and detached as the boat owner pleases. Most boat owners like to keep their boats very clean and tidy. When the boat is not being used to tow a skier, wakeboarder, etc., the device will be able to detach quickly so that the boat owner can put the device away for further use. This will allow the device and the tower to not sustain any type of damage further damage if both can be cleaned and properly stored away.

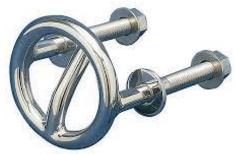
One of the most important factors of this device will be that it does not do any damage to the boat tower. Richard Jones is a stickler when it comes to his toys. He likes to keep them neat and tidy. This device needs to accommodate that. An easy solution would be to install some type of protective filming or foam in between the device and the tower. This material needs to also be corrosive resistant for the environment it will be used in. It should be a material that will keep clean and can be cleaned easily if it ever happened to get dirty.

Description

The proposed solution should be a lightweight attachment to the tower designed for. This device will bolt to itself around the tower. The boating tower this device is being designed for comes in a diameter of 2.5 inches. The cut of the hole needs to accommodate this design so that the device will have a snug fit and the device will not rotate with the tension reacting to it.

A very important factor when designing this device is whether or not it is easy to manufacture. The design of this device is not to be too complicated so it needs a master machinist to produce. A somewhat simple design that can allow an amateur machinist to produce is the best way to design this device.

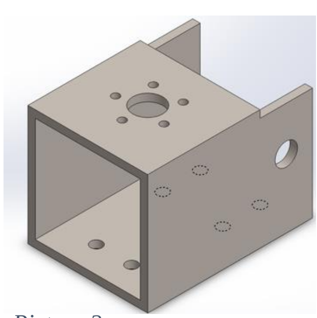
In the water sports industry, the usual “hook” for the towing rope is called a skiing eye. An example can be seen from the picture provided. The towing rope is connected by taking the loop of your rope, slipping it under the ski hook on the inside pointing up, then slipping the loop over thing sticking up. The rope should pull from under the tow hook. This same hook will be used in the device. It is an easy to use hook that has been an effective hook in the water sports industry for a long time. It is also cheap and easy to purchase at a decent cost at anywhere from $20 to $40. This skiing eye will attach to the rope attachment part of the device. It will be bolted into the rope attachment piece.



Picture 1

This eye will be attached to the rope when being towed. It is also important to think about possibly detaching the eye from the rope attachment part of the device when it is not in use. When the device is in use, it should be attached to the rope attachment piece. The rope attachment can be seen in Appendix B in Drawing 4. The bolts on the end of the ski eye will slide right through the two holes on the front of the rope attachment and can be secured from two nuts on the backside of the rope attachment.

Once the ski eye is attached to the rope attachment, these two parts can be added to the housing seen in Appendix B on Drawing 3. The rope attachment will be added to the housing by lining up the through hole from the rope attachment, to the two holes on the side of the housing. These parts will be held together by a pin that can also be seen in Appendix B on Drawing 6. This pin will need to stay stationary within the housing, but needs to allow the rope attachment to rotate. This rotation is the main function of the device that allows the flag to raise and lower. When the front part of the rope attachment rotates down from the tension from the rope, that backside of the rope attachment will rotate up. This backside of the rope attachment will contact a spring that will dictate the amount of force needed to rotate the rope attachment back and forth. This spring will sit inside the housing freely when there is no tension acting on the device. The spring then compresses upwards towards the top of the housing once the rope attachment rotates forward.



Picture 2

The housing will be attached to the top tower attachment. This part can be seen in Appendix B on Drawing 5. This top attachment will be bolted to the back of the housing. These holes can be seen in either drawing in Appendix B. This attachment of the housing and the top tower attachment will stay stationary with each other. There should be no movement. It is important that this top tower attachment will have the right dimension to sit on top of the tower. The design of the top tower attachment will have a slightly larger diameter than the tower itself. This is because a thin layer of foam will also be attached to both side of the device that will keep it from damaging the tower. A drawing of this foam can be found in Appendix B in Drawing 2. This thin layer was designed to be the exact size of the tower so that when installed, it will keep a snug fit on the tower. This material is also an important choice so that it will allow no slipping on the tower. Keeping the device stationary is important for its function.

The previously stated parts have all been a part of the top of the device. The bottom part of the device is all in one part. This piece, called the bottom tower attachment, will bolt to the housing and the top tower attachment. This part can be seen in Appendix B in Drawing 1. This bottom piece of the device will also have a thin layer of foam added to it so that it can protect the bottom side of the tower. The same shape and size of the foam attachment from the top part will be used on the bottom part as well. No other design was need for the bottom foam part. Again, the foam design can be seen in Appendix B on Drawing 2.

The material for this device also needs to be a light weight, but very strong as well. For the bottom and top part of the attachment, the material will be aluminum. This will ensure that the whole device can stay as light as possible. These parts can also be aluminum because they will not have as much force on them. This part simply needs to wrap itself around the tower to be successful.

The other parts of the device need to be stronger. Since this is the case, stainless steel was chosen as their material. Stainless steel was chosen because of the many forces each part of the device will face. The calculations for the forces can be found in Appendix A. The amount of stress the parts will face are also calculated in Appendix A. Once the calculations on the stress and strain of the parts was done, it was determined that a stronger material should be used. Stainless steel is a good choice because it is strong, but is also good for its material properties against corrosion. This device will be working in an environment where there is constantly water being thrown on it. For the device to work properly, it is very important that it will not fail due to corrosion. It is expected that the device to work for 20 years.

Benchmark

Since there has not been another device found that acts quite like this one, the benchmark for the device being built should provide a new benchmark. The device should surpass what regularly happens during water skiing activities. To be more specific, the benchmark for this device should be that no person should have to hold up a flag with their own power when a water skier falls into the water. The benchmark is that a flag will automatically raise when the tension is released in the towing rope. This device will provide a new benchmark that has never been seen before in the world of water sports.

Performance Predictions

This device will raise a flag when the tension in the towing rope is less than 100 N and will lower the flag when more than 100 N of tension is in the towing rope. This device will also fit on to a boating tower with the diameter of 2.5 inches. This device will be able to perform with tension forces of up to 2400 N. This device also needs to be manually activated if someone in the boat feels the need to raise the flag at any point. Most of the time skiing and wakeboarding activities are done in high temperature weather. Therefore this device will work in temperatures ranging from 70º F to 130º F. This device will also attach and detach with ease. The device will detach into five different pieces that will be easily and safely stored inside of the boat's storage capabilities. The flag raising device will also not corrode from salt or fresh water usage, and be cleaned easily after usage when detached.

Description of Analysis

All aspects of the device will be analyzed to ensure proper strength, while also maintaining a weight that will over strain and not damage the boating tower. The first part in analyzing this device would be to figure out the amount of tension a regular person will put on a towing rope when being towed being a ski boat. The mass for an average person was found to be 70 kg. The calculations for this analysis can be found in appendix A on Green Sheet 1. It was found that the tension force put on a towing rope by a regular size person is 363 N.

Amount of Tension a Regular Person Will Put on a Towing Rope:

$$F_N = mg\cos(\theta)$$

Frictional Force Between Skis and the Water:

$$F_f = F_N * \mu k$$

Gravitational Force on the Rope:

$$F_G = mg\sin\ (\theta)$$

Combined Tension on the Rope:

$$T = F_G * F_f$$

It is also important to determine the amount of force this tension will put on the device in the x and y direction. Since with most water sports, the person being towed will likely move back and forth behind the boat. However, the angles at which a person being towed behind the boat are not always the same. The most a person will rotate by is usually 45˚. The resulting forces in the x and y direction will be found then.

Forces on Device in x and y Direction:

$$F_x\ @\ \theta = F_T\sin(\theta)$$

$$F_y\ @\ \theta = F_T\cos(\theta)$$

The analysis done for the forces in the x and y direction were set for three different angles. The three angles analyzed were 15˚, 30˚, and 45˚.
Since there are different amounts of forces that act in two different directions, there will be some moments acting on the device. These moments were also analyzed for the three different angles as the calculations before. These calculations can be found in Appendix A on Green Sheet 3.

Reacting Moments on the Device:

$$\circlearrowleft +\Sigma M_A = 0: T_x\left(L_y\right) + M_A = 0$$

These calculations can be found in Appendix A on Green Sheet 4.

It was decided that a boat eye would be used to hold the towing rope. A boating eye is regularly used when towing a skier or wakeboarder behind a boat. It should then be determined the size of the boating eye. The right diameter needs to be used so that the eye will not fail under the amount of tension that will occur from the towing rope. These calculations can also be found in appendix A on Green Sheet 5. Since the diameter found was extremely small, any size of skiing eye would be allowed to be used. This part will be purchased and the available sizes of a boating eye are either 3/8 inch to 1/2 inch.

Allowable Area Undergoing Stress from Tension:

$$A = \frac{F_N}{\sigma_N}$$

The next set of analysis done is the centripetal force that the rope will undergo when the skier or wakeboarder cuts from side to side behind the boat. The skier will move in a circular motion behind the boat. The centripetal force, or tension, in the rope will keep the skier from skiing away from the boat. This centripetal force is important because it leads to the amount of force the device will ultimately experience. This calculation was done with two different values of speed. Speed varies greatly between the many different kinds of water sports. While some require the skier to reach speeds of 26.8 m/s, others only require the skier or wakeboarder to reach speeds of 6.9 m/s. These calculations can be found in Appendix A on Green Sheet 2.

Centripetal Force:

$$F_C = \frac{mv^2}{r}$$

Some force that may act along with the centripetal force is the resulting forces acting on the device from the skier moving back and forth behind the boat. Most skiers and wakeboarders like to skim across the water behind the boat. This results in different tension forces acting on the device in different directions instead of just straight behind the boat. The calculations for forces acting in different directions can be found in Appendix A on Green Sheet 3. These forces in different direction will lead to moments being created on the device. These moment calculations can be found in Appendix A on Green Sheet 4.

The next set of analysis was done for the pin on the device. This pin will experience most of the loads translated from the rope. While the pin will endure the loads from the previous calculations, it will also experience direct shear and stress. These calculations can be found in Appendix A on Green Sheets 6, 7, and 8. Therefore this pin is very important for the device. It will need to endure all of these loads without failing or the device will not work. It is an important job for a part to hold one part of the device while also allowing another part of the device to rotate about it.

Stress in Pin:

$$\sigma = \frac{F}{A}$$

The next part of analysis should be the type of spring that will be needed to input into this device. This spring is very important because it is the main and only part that dictates when the flag will be raised and lowered. This spring will need to endure forces from the rope attachment of up to 2400 N. This spring will also need to lower the flag when the forces are between 100 N to 2400 N but will allow the rope attachment to rotate back up when the forces are below 100 N. The spring analysis can be found in Appendix A on Green Sheets 9 through 12. The first part of the spring analysis started with the amount of working space available for a spring to fit inside the housing. From there a k value could be found. This k value is the spring rate.

Spring Rate:

$$k = \frac{\Delta F}{\Delta L}$$

The change in force is the difference between the force at operating length and the force at installed length. The force at operating length is the maximum force the spring sees in normal operation. The maximum force that will be exerted on the spring is 2400 N that can be seen in Appendix A on Green Sheet 2. The force at installed length is the value of force that varies between itself and the maximum force. This was found to be 100 N that can also be seen in Appendix A on Green Sheet 1.

The next part of analysis done on the spring was the full design of the spring. There was a bunch of equations and calculations done that can be seen in Appendix A on Green Sheets 9 through 12. Such calculations were:

Spring Index:

$C = D_m / D_w$

This spring index is the mean diameter of the spring to the wire diameter. This value is recommended to be greater than 5, with typical values ranging from 5 to 12. The next value to be calculated was the Wahl Factor, K, which is related to the spring index.

Wahl Factor:

K = $\frac{4C-1}{4C-4} + \frac{0.615}{C}$

The C in this equation is the spring index value. The Wahl Factor is the term that accounts for the curvature of the wire and the direct shear stress. The next part is to figure out the shear stress in the spring.

Shear Stress in a Spring:

$$\tau = \frac{8KF_0D_m}{\pi D_w^3}$$

The shear stress for any applied force, F, can be computed. This is seen in Appendix A. The man reason for computing the stress is the concern for when the spring is compressed to solid length under the influence of the maximum force.

Scope of Testing and Evaluation

It is important to know the kind of testing that will need to be done on this device. Obviously the needed requirements to test this device is a boat, some body of water, a person willing to ski, wakeboard, a rope, and some willing people to help with this testing. The equipment will be provided by Richard Jones in the form of a boat, tower, tow rope, and a wakeboard or ski. Another person willing to ski, the body of water and the time will be set at a later time when all parties are available for the testing.

Such different testing methods can be different tests with a slalom ski, double ski, wakeboard, and a tube. Testing for all of these scenarios will need to be done on this device. When being tested for all of these scenarios, it will need to be determined if the flag raising device is effective in all of the situations. The many different tensions that will occur between all of these scenarios needs to comply with the device. These tension forces will vary greatly between the different types of water sports tested for.

Analysis

Approach:

The first part of analysis done for this device was determining the amount of tension a regular size person puts on a towing rope when water skiing. This analysis can be found in Appendix A on Green Sheet 1. The regular amount of tension on a tow rope was found to be 363 N to 1000 N. Once this was found, it was then time to start designing the device. The design of the device did not come easily and many ideas were rejected. The hard part of the design was how this device would dictate the flag by the tension. After much thought and some research, a spring was chosen to dictate the raising and lowering of the flag. A spring can allow the device to lower at a certain value of force and will also allow the device to raise the flag when the value is below a certain design.

Design:

The design of this device is very important. It will dictate how the part reacts to the problem that is trying to be solved. Therefore, the design of each and every part will first start with different calculations. These calculations come from the different scenarios that happen during water skiing activities.

A very important design property with this device is that it will be able to handle different environments. This device will likely be used in fresh and salt water. Stainless steel can be chosen for its properties that will not allow it to corrode easily. The device will likely only be put on when it is needed. Once the device is not needed anymore, it will be taken off, cleaned, and put away properly. Still it is very important to choose the right material.

It is important to keep the device as light as possible. Extra amounts of weight on top of the tower can lead to a bigger amount of stress then it is designed to handle. Therefore for the parts that are actually wrapping around the tower, the material will be aluminum. A certain type of aluminum that also has non-corrosive properties was the ideal choice since it will still likely in contact with fresh and salt water.

The next part of the design was figuring out how to attach a rope to this device. Regularly when towing someone behind a boat a boating ski eye is used and will also be used for this device. This could be simply added to anything with the right size of diameter holes needed to slide the ski eye through. The rope is hooked onto the ski eye with a very simple hook.

Since the flag needs to be raised and lowered with a simple change in tension, it was decided that a part would rotate about a pin. While in the horizontal position, the flag would be rendered down which means someone is being towed behind the boat. When the flag rotates up in the vertical position, this would mean there is a fallen swimmer in the water from the boat. This part would need to also attach the boating ski eye as described before. Therefore it would need to be wide enough to attach the two prongs on the back of the ski eye. This makes the rope attachment part have to be at least 3.500" long. This ensures that it is wide enough for the ski eye to attach to it and also to withstand the forces that the bolts will put on the attachment.

This device needed some type of housing for the rope attachment to rotate about a pin. It would also need to be hollow so that the rope attachment could fit inside and also rotate inside the housing. It was finally decided to use stainless steel square tubing. It was the easiest stock material that could be found. A block of material would have been too hard to produce. The square tubing makes it easier to.

Since the housing would be the main part of the device, the other parts would have to be attached to it. The bottom and top parts of the device that attach to the tower will be bolted to the housing and the rope attachment would be attached to the housing. This will be attached by a pin that would still allow the rope attachment to rotate. As for the spring, it would be put through a hole on top of the housing with a cap, which would also be bolted to the housing. This would hold the spring in place.

It was decided that a spring would be used to dictate the amount of forces that will allow a flag to be raised and lowered. This spring will be inserted into the device's housing where the back side of the rope attachment will swing up and make contact with the spring. This spring will dictate the flags raising and lowering between the forces of 100 N to 2400 N. Since the spring will experience such a high amount of force at some points when being used, the spring will have to be larger than the amount of space already provided in the housing. These calculations can be seen in Appendix A on Green Sheets 9 through 12

An important factor with designing this device is that it can be attached and detached as the boat owner pleases. Most boat owners like to keep their boats very clean and tidy. When the boat is not being used to tow a skier, wakeboarder, etc., the device will be able to detach quickly so that the boat owner can put the device away for further use. This will allow the device and the tower to not sustain any type of damage further damage if both can be cleaned and properly stored away.

One of the most important factors of this device will be that it does not do any damage to the boat tower. Richard Jones is a stickler when it comes to his toys. He likes to keep them neat and tidy. This device needs to accommodate that. An easy solution would be to install some type of protective filming or foam in between the device and the tower. This material needs to also be corrosive resistant for the environment it will be used in. It should be a material that will keep clean and can be cleaned easily if it ever happened to get dirty.

Calculated Parameters:

Below will be the calculated constraints for each part of the device.

1. Rope Tension Analysis: The most important part of this project was determining the type of tension a rope undergoes under regular circumstances when towing a skier behind a boat. This was found to be about 363 N. The person skiing or wakeboarding does not always stay just behind the boat however. Most of the time the person being towed likes to sway back and forth in a circular motion behind the boat. A centripetal force needed to be calculated to keep the person being towed behind the boat. Once the person being towed starts to go back and forth, moments are created on the pin as well. These moments will put different stresses on the pin. Once this was found, the design of the device could be found.
2. Pin Analysis: An adequate pin was need to be found that would not fail under the force circumstances that it will encounter. The full calculated analysis can be found in Appendix A for the pin analysis. The first part of the analysis was to find the amount of force that would be put on the pin while disregarding the size of the pin. From the previous rope tension analysis, the force that would be acting on the rope would be 360 N to 1000 N. From this data, I could make a free body diagram of what the pin would undergo. This again can be seen in Appendix A. The forces in the x direction and the forces in the y direction were found using simple sum of the forces equations. A moment equation was not formulated because the pin will be rotated on by the rope attachment. Once the forces were found for the pin, the stress was next. The stress needed to be found to better understand the amount of loading this pin will undergo. It is important that this pin does not fail so that the rope will not fall into the water and the skier can continue to ski. A size of the pin was thought to be around 0.75 inches in diameter. It was thought to be a reasonable size for a pin. Once the pin stress was found, a type of material could be found next. Most of the materials were

found to properly exceed the amount of stress the pin in this device would encounter. The next step will be to find what kinds of materials are used best as a pin.

Device Assembly:

This device will assemble in seven different parts: the housing, the bottom attachment, the pin, the spring, the spring cap, the top attachment, and the rope attachment. The device will first be assembled by attaching the housing to the top attachment. This part can be set on the tower while the bottom attachment to the housing will be wrapped around the bottom part of the wakeboard tower and screwed into the top housing part. The next part of the assembly will be inserting the pin through the rope attachment and the housing so that the rope attachment can rotate but will stay intact with the housing. The spring can then be inserted into its housing spot. Once these steps have been done, the device will be completely assembled.

Tolerances:

There are some very important tolerances that will allow this device to function properly. One big tolerance that needs to be accounted for is the pin. This pin needs to be able to stay in the housing without moving or sliding out, but also allow the rope attachment to rotate. This tolerance will be set at $\pm$ 0.005 in. Other parts of the device will not be as important for the size and the tolerance that will be set for the other parts will be $\pm$ 0.010 in.

Device Shape

This device needs to be able to fit on many different shapes and sizes of boating towers. The boating tower industry is big with many different companies making towers. Therefore, each company will add their own touch on their respective tower.

This device will need to think of a shape that will attach to different shapes and sizes of a boating tower. Most towers are built in a circular shape. However, other towers will come in more of a square shape or an oval shape. Finding an appropriate shape to attach to these shapes of towers is needed. The device may have to attach to just the top of a tower depending on it a similar size can be found for different shapes of towers.

Device Assembly, Attachments

This device should be easy to assemble. It will be bought in thirteen different pieces with four of these “pieces” assembled as bolts, nuts and screws. The device will only need a few bolts and screws that will attach the main parts of the device. Then to attach the device on the tower, it will wrap around and can be bolted to itself that will tighten to each individual tower. The ski eye will be purchased and will not need any manufacturing done on it for it to be applied to the assembly. The piece will simply be attached as purchased.

On the inside that attaches this device to each tower will be a type of foam or other material that will allow each tower to not be scratched by the device. The type of foam that will be used is Conformable Water-Resistant Vinyl Foam. These vinyl foam sheets and strips are so conformable that once they are compressed they will not fully spring back. This foam offers excellent resistance to water, sunlight, and oxidation. This foam has closed-cell construction, which restricts water, air, and gases from being absorbed. This material also has an adhesive backing that will allow it to stick to the device at the right placement. People like to keep their boats shiny and scratch free so making the device soft on the inside should be done.

Technical Risk Analysis

With this type of device, there is a fair amount of risk. Being towed behind a boat is a risky activity that can and has led to many minor and serious injuries in the past. It is important to design this device to be as safe as possible with these activities.

First off, the weight of the device can be a risk since it will be attached to the top of a boating tower. It is important that this device will stay as light as possible so that it will not allow the tower to collapse on the passengers inside the boat. It is also important that this device stay sturdy on top of the boat even with the immense amount of pulling the rope and person being towed will put on the device. There needs to be no risk at all most importantly to the passengers inside the boat and also to the person being towed.

Many boat owners are very anal with how nice their boat looks. These people hate to see scratches and dents on any part of their very expensive toy. Therefore, it is important that this device will not scratch the tower or any other part of the boat. Boating equipment is very expensive. Boating towers especially are not cheap. So keeping the integrity of the tower and the boat it attaches to is a very important factor.

The cost is also a very important factor for this device. As previously stated, most equipment included in the boating industry is very expensive. Each new toy accompanying a boat can add hundreds to thousands of dollars. This device should remain at a cheaper price so that it can be easily available to any and all boat owners that like to play.

The most important factor however is the safety of the person being towed behind the boat. When going at high speeds in a boat, the water becomes less and less forgiving and more and more dangerous to the people playing in it. Many people have died by not being careful with these types of activities. This device must be able to withstand the calculated forces that normal people, or even the heaviest people put on a boating tower and boat.

Methods and Construction

Construction

The complete construction of this project was done in the machine shop in Hogue Hall provided by the MET staff. The material was purchased from McMasterCarr.com. The material was then sent to the school where the creator picked it up. Each part needed to be machined to some degree in the machine shop. The construction of this project was taken in a very careful manner. It was very important too. Some

of the material came late so the construction was pushed back farther than originally planned.

All of the construction for the project was done in the machine shop in Hogue Hall provided by the MET staff. The rope attachment, bottom and top tower attachments, housing, and spring cap were constructed on a manual milling machine. These were all simple jobs that included milling to the right lengths, machining the step for the rope attachment or boring out the right size hole for the top and bottom tower attachments. The spring cap was completed on a lathe. This inly needed a simple hole to be drilled through it. The spring was cut with a saw.

After each part was machined in the machine shop, various bolts, nuts and screws put it together. Some of the parts did not end up with the best dimensions because of some error from the creator. However, the assembly still came together successfully.

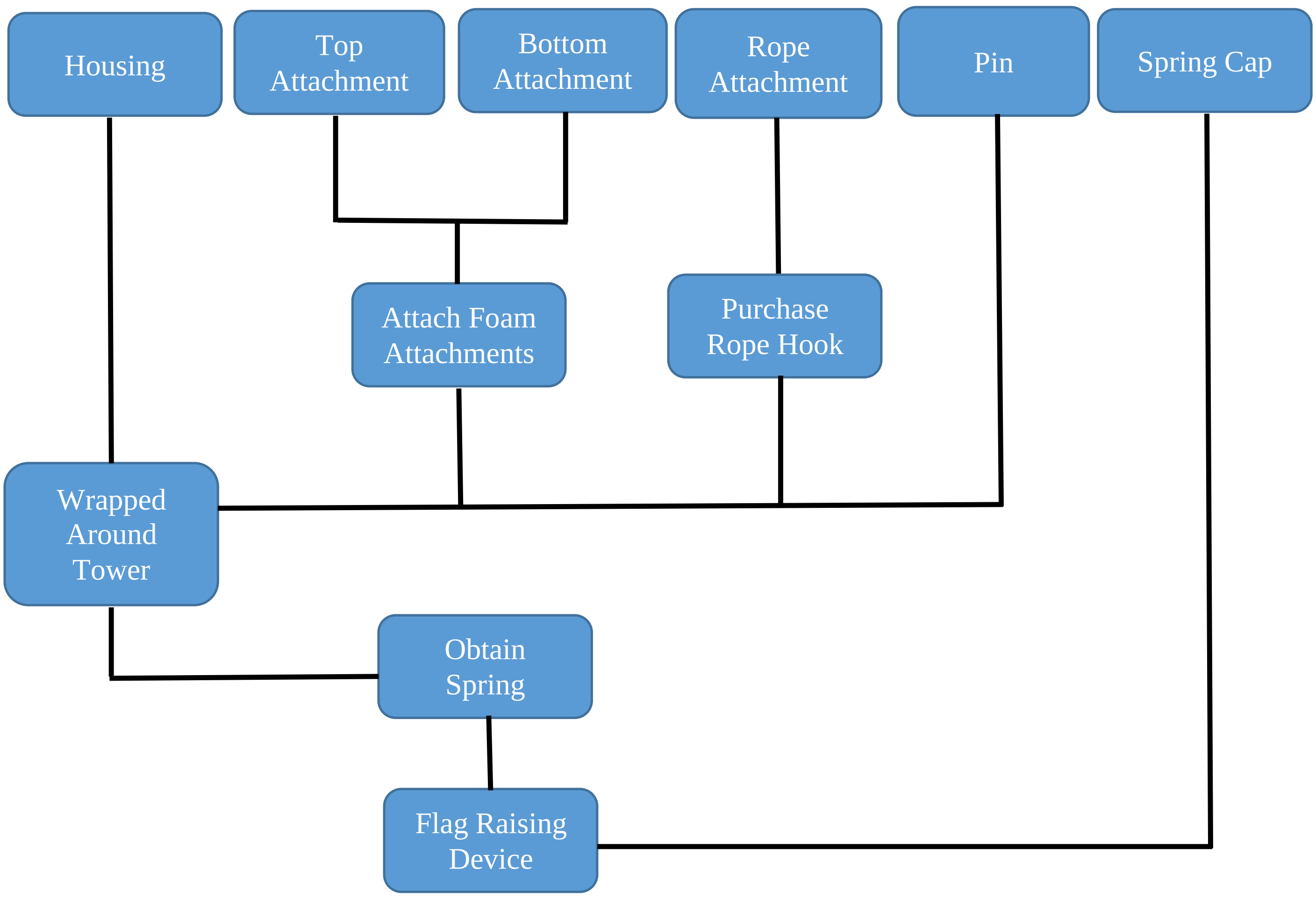
Description

Each part of the project was done in the machine shop in Hogue Hall provided by the MET staff. Each part was done in a different manner. Although most of it was done on the same machine.

This project was done with a few different kinds of material. Aluminum was the material chosen for the top and bottom tower attachments. The housing was made out of stainless steel and the rope attachment was made out of alloy steel. Different materials were chosen to try and keep the device as light as possible. Though the parts that were chosen stainless or alloy steel needed to be as strong as possible instead of light.

Drawing Tree

The following drawing tree will show how this device will be assembled into the final project. This device will not take very many steps to complete. First, the housing pattern will be created. Next, the rope attachment pattern is created. After these first two steps, they can both be machined while the rope hook can also be acquired. Once these steps have been done, the flag raising device will be completed.



Parts List

Part For	Type/Material	Part/Item Number	Stock Bought	Price	Quantity	Total
Ski Eye (Overton's)	Stainless Steel	11898		$30.00	1	$34.99
Housing	Super-Corrosion Resistant 316 Stainless Steel	2937K29	4ft x 4ft x ¼ square tubing: ½ ft. length	$62.25	1	$62.25
Pin	Very High-Strength 15-5 PH Stainless Steel Rod,		¾" Dia: ½ ft.	$16.01	1	$16.01
Rope Attachment	4140 Multipurpose Alloy Steel	6552K555	4" x 4" x ½ ft.	$82.14	1	$82.14
Bottom and Top Attachment	Hard High-Strength 7075 Aluminum	9055K33	4" x 2" x 1 ft.	$162.25	2	$324.50
Foam Attachment	Conformable Water-Resistant Vinyl Foam	86025K72	Adhesive Back, 1/8" Thick, 36" x 54" Sheet	$19.88	1	$19.88
Front Tower Attachment Screws	Zinc-Plated Alloy Steel Socket Head Cap	90128A367	3/8"-24 Thread, 1-1/4" Length1	$5.68	1	$5.68
Spring	Cut to Length Rectangular Wire Die Spring	9625K13	1" Hole, ½" Rod, .219" Wire	$51.85	1	$51.85
Spring Cap Hex Nuts	Cadmium Yellow-Chromate Plated Steel	95036A012	Grade 9, 1/4"-20 Thread Size, 7/16" Wide,17/64" High	$11.46	1	$11.46
Spring Cap Bolts	Type 316 Stainless Steel Hex Head Cap Screw	92186A547	3/8"-24 Thread, 1-1/4" Length	$5.68	1	$5.68
Back Tower Attachment Screws	Zinc-Plated Steel Flat Head Phillips	90273A636	3/8"-16 Thread, 3" Length	$5.42	1	$5.42
Spring Cap	High-Strength 2024 Aluminum	9034K72	Rod, 2-1/2" Diameter, 1" Long	$12.05	1	$12.05
Ball Mill (MSCdirect)	Uncoated, 5 Inch Overall Length	01760784	1-1/4 Inch Shank Diameter, Spiral Flute	$106.93	1	$106.93
					Total	$738.84

Table 1

Manufacturing Issues

There were a few issues when trying to manufacture the device. For one, some of the material came in different sizes than advertised from McMasterCarr. The spring cap came in a longer length than what was ordered. Therefore, the length had to be turned down to the length that was planned for.

Another issue was dealing with the stainless steel housing. Stainless steel turned out to be a very hard material to work with in the machine shop. This is because the material hardens with heat. Therefore, when trying to drill into the material, it seemed to harden each time a little bit was taken off. Some help was needed from Matt Burvee to help explain how to correctly and effectively drill through the material. Milling this material for the length also was not an easy task because of the same reason. Since the material was also hollow tubing, the machining process was very loud and had to be taken slowly.

One issue found for the top and bottom attachments was figuring out how to correctly cut the hole needed for these parts. An original plan was to buy a ball mill that was big enough to cut these holes. However, a big enough ball mill was not found at a decent enough price. Therefore the plan had to change. Ted Bramble helped figure out a new idea by bolting together the top and bottom attachments and putting them both in a vice on a manual milling machine. A boring bar was then used to bore out the right size hole for the two attachments at the same time. This ended up being very effective because then the holes would line up with each other when put together.

One final issue came when trying to put the assembly together. The top attachment was not sitting inside the housing quite right. This is because the inside of the housing was rounded instead of having sharp corners like originally planned. The material just came like this. Therefore, a file was taken to the edges of the top attachment that would sit in the housing. These edges were ground down until the top attachment sat flat in the housing.

Discussion of Assembly

After figuring out the manufacturing issues, the assembly was able to come together correctly. Each part came together into one final assembly with no sub-assemblies. There was really no issue when putting the parts together into the assembly. Everything fit as it was supposed to.

The first and most important part of the assembly started with the top and bottom tower attachments. This is the most important part because it is where and how this device will attach to the tower of the boat. The holes needed to be the right size so that it would fit around the tower, but also not be too big so that it moves too much. On the inside of the top and bottom tower attachments was a very important piece of foam. This foam will allow the device to not scratch the tower of the boat. This is important because boat owners like to keep their things nice and shiny. If the device were to damage the towers then it would end up not being bought by consumers. This foam would also keep the device from moving too much.

The next part of the assembly is the housing. This housing will be attached in between the two tower attachments. The housing is where all of the rest of the device will be located. It is where the spring, pin, rope attachment, and spring cap will hold itself together. Since this piece was so important, stainless steel was chosen for its strength and resistance to corroding. The housing also has a piece of foam at the bottom of it to keep from scratching the rest of the device.

After attaching the top and bottom attachment with the housing, the spring can then be inserted through the top hole of the housing. The spring will sit on the top of the top attachment inside the housing. The spring will then be capped by the spring cap at the top of the housing. The spring cap will be held by five bolts through the cap and housing and will be held at the bottom of the bolts with nuts on each bolt

Then the rope attachment can be attached to the assembly. The pin is slid through the housing, through the hole in the rope attachment, and through to the other side of the housing. This pin the what the rope attachment piece will rotate about to raise and lower the flag. The pin is a press fit into the housing while it is a clearance fit for the rope attachment. The pin needs to stay in the housing and not slide back and forth. Therefore, it needs to be tight. Since the rope attachment will rotate back and forth, it needs to be a clearance fit.

Finally, the last part of the assembly is attaching the hook to the rope attachment piece. There are two holes in the rope attachment where the rope hook will fit through. Then two nuts will keep the rope hook from leaving the rope attachment. The towing rope will attach to the towing hook which rotates the rope attachment down to react with the spring inside the housing.

Testing Method

Introduction

The base of the testing will be to find out if the device works or not. The device will be attached to Rich Jones boat tower, attached to a towing rope, and a wakeboarder will be towed. The testing procedure should start with the scenario that will likely produce the most tension on the rope and the device. The believed scenario that will produce the most tension will be towing someone on a wakeboard. This is because the wakeboard has a bigger surface than a ski. It is believed to produce more tension than a tube because the boat generally goes slower in the water so there is more drag from the wakeboard in the water.

Method/Approach

Testing procedures for testing the flag raising device:

1. Assemble top, bottom attachments and housing onto boat tower
2. Insert spring, spring cap, and bolts to top of housing
3. Insert rope attachment and pin into housing
4. Attach towing hook to rope attachment
5. Attach towing rope to towing hook
6. Throw out rope into the water
7. Start the boat; wakeboarder geared up and ready to go in water
8. Start the boat will a little bit of tension
9. Raise the wakeboarder out of the water
10. Examine device to see if it is working correctly or there is any deformation issues
11. Have wakeboarder fall and see if flag raises correctly
12. Repeat process 10 times and record data to see if runs correctly each time

Schedule

The schedule for this project is summarized in the two figures in Appendix E. These figures break down the many steps done for this project broken up into six different major sections. The first figure shows the name of each task, the date it was planned to start, the amount of days planned to complete the task, the actual start date, the actual amount of days taken to complete, and the percentage of the task that is done. The second figure shows the figure as before with an added chart. This added chart is a Gantt chart. This shows the same data in a chart form.

These six different sections contain smaller and more detailed actions that were done for the project. The chart shows what the task is, the date of the task, and the duration that it took to complete that task. The duration is put into days. Each task has been set to last for a certain number of days. The total number of days that this project will take is 196 days. This seems like a long time for just one project. However, some of these tasks can be done simultaneously. Such as getting the many parts of the proposal done can mostly be done concurrently.

This project will cover the whole school year starting in September and will finish in June. The project is split into three different parts. The first part of the project is the design and analysis phase. This phase starts with an idea, continues with analysis and some design, and ends with a proposal and a design ready to be made. The second phase of the project is actually making the part. This includes obtaining the materials and parts for the device, machining the parts that are needed to be machined, and completely assembling the device for testing. The third phase of the project is when the testing starts. The device will be tested for its proper use. During and after the testing is done, a final report will be created for the whole project.

There are also three major milestones that are set by the MET 495 schedule. These are the main milestones for this whole project. The first milestone is the approval of the project on October 5, 2015. The next milestone is the completed project that is due on March 12, 2016. The completed project is to be completed by June 7, 2016.

Cost and Budget

This project depended on the creator of this project, Josh Quintero. There was no sponsor for this project and any all costs will be handled from the designer and creator of the project. All the decisions on parts came on the discretion of Josh Quintero and whether or not he has enough money to buy the needed parts.

The original budget for this project was set at $800.00. The true amount needed was $738.84 for the skiing eye part and the stock material needed to machine. This projected budget was formed from an estimate of all the needed parts and material.

The only part needed to purchase would be the skiing eye. This part is found to be about $35. Most of the parts of this device will need to be machined. As the creator does not want to be short by any means on the raw material, a greater amount then needed will be bought for each part that is to be machined. This will ensure that all of the stock material needed to machine the parts is available. The most expensive material to buy is the stainless steel parts. This includes the pin and the rope attachment parts. The stainless steel is more expensive than the aluminum parts.

Most of the parts will be purchased from www.mcmaster.com. This website will provide the rest of the needed stock to machine the parts needed for the device. The prices and the size needed for each part are in Table 1 in Appendix C. There is another table that lists the part number for each piece that will be bought from www.mcmaster.com

A ball mill needed to be purchased to complete the tower hole on the top and bottom attachments. This part was purchased from www.mscdirect.com. The skiing eye was also purchased from a different site than mcmaster.com at www.overtons.com. This can be seen in Appendix C on table 1. The parts that are purchased from a site other than McMaster-Carr will be in parenthesis in the name of the part.

Discussion

The project ended up being a success. There are parts of the device that did not meet the requirements set out for the project in the beginning. Although the exact effectiveness of the device does not complete all of the design requirements, it can still be seen as an effective device and project. When attached to the tower of the boat it was designed for, it was seen that the main idea of the device worked. The flag rotated down and fit on top of the tower. There are aspects of the device that obviously need to be fixed or changed if this were to become an actual project.

If this project or device were to become an effective product to be bought on the market, there are a few things that need to be changed. The first and most important change to this device is that it needs to cut down on the weight. The device is too heavy to sit on top of the tower. When modeled in SolidWorks, it was shown to weigh only 23 pounds. However, when it was manufactured, the device actually ended up weighing over 47 pounds. Some of the other requirements of the device also need to be met as some of them were not.

Conclusion

This device has been considered, analyzed, and designed that will satisfy all of the function requirements that are described in the opening part of the proposal. This device has been made to the likes of Richard Jones and his boating tower. It will function properly to his liking and the way he wants it to be used.

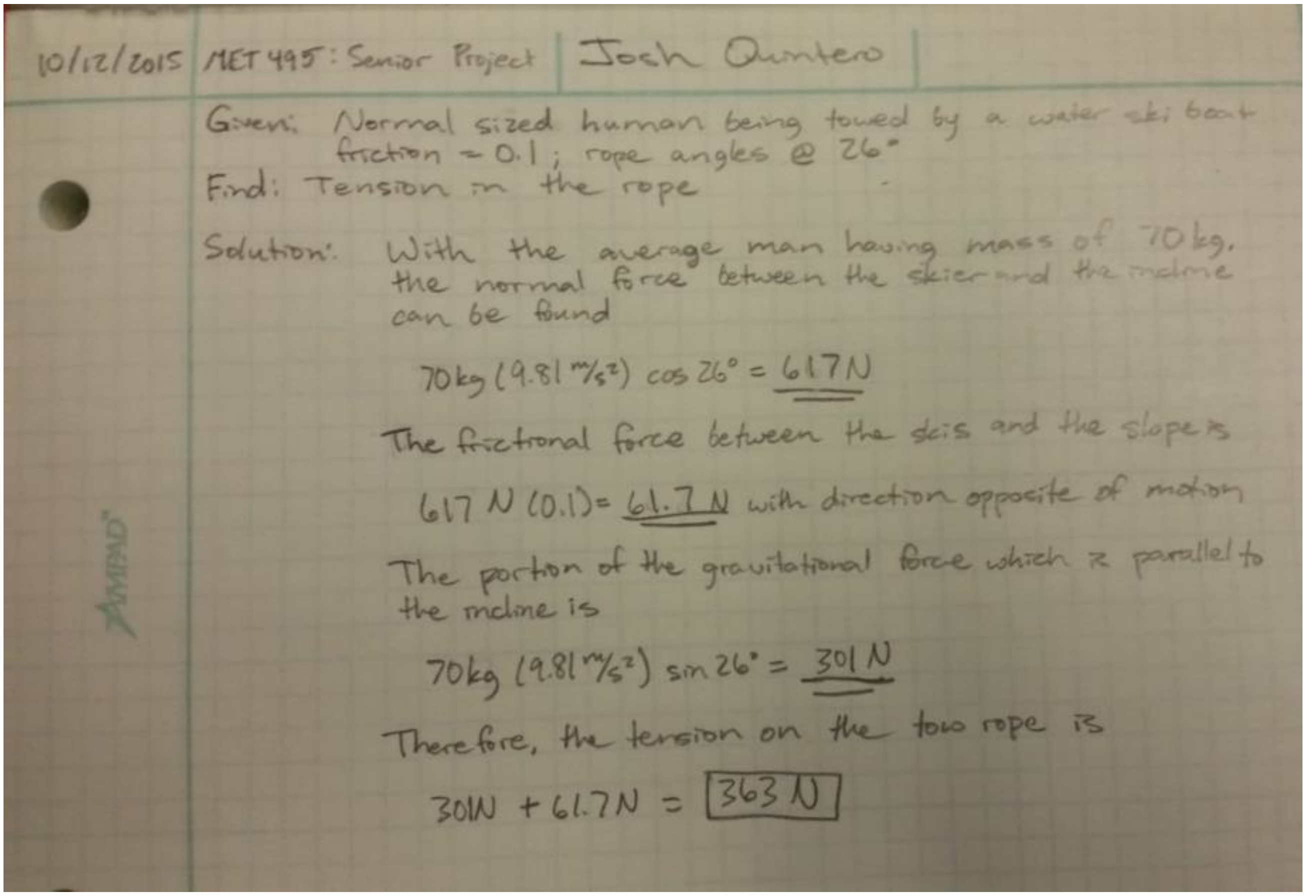
As previously stated, the budget for this project will come solely from Josh Quintero, the designer and producer. Although the project seems to be very expensive to create, it is not too expensive to get the project done. With the two jobs Josh Quintero has, he is able to pay for it all. If there were ever a need to purchase some more material that may be out of the price range, then Richard Jones, the father of Josh Quintero, would gladly help with that.

This project will also need the help from a few other people that need to be acknowledged. The MET staff at Central Washington University will lend themselves and their equipment so that this project will become successful. Their time and knowledge will be required and desired to get through the difficulties. The staff will lend their equipment such as the machine shop as well. It would be extremely hard to get this project done if it were not for the MET staff to allow the project to be produced in the machine shop.

The most interesting part about this device will be the spring. It will be fascinating to see this spring able to dictate the fluctuating forces for the most important part of this device. The most important part of the device is obviously the function of raising and lowering a flag.

This project will be successful when it properly raises a warning flag after a skier falls down into the water. It also needs to lower the flag when a person begins to ski or wakeboard to be successful. This success comes from many hours of analyzing the many different forces that result from water skiing and wakeboarding.

Appendix A: Green Sheet Analysis



10/12/2015 | MET 495: Senior Project | Josh Quintero

Given: Normal sized human being towed by a water ski boat
friction = 0.1 ; rope angles @ 26°

Find: Tension in the rope

Solution: With the average man having mass of 70 kg, the normal force between the skier and the incline can be found

$$70\,kg\,(9.81\,m/s^2)\cos 26° = 617\,N$$

The frictional force between the skis and the slope is

$$617\,N\,(0.1) = 61.7\,N$$ with direction opposite of motion

The portion of the gravitational force which is parallel to the incline is

$$70\,kg\,(9.81\,m/s^2)\sin 26° = 301\,N$$

Therefore, the tension on the tow rope is

$$301\,N + 61.7\,N = \boxed{363\,N}$$

Green Sheet 1

Given: mass of regular size person = 70 kg
velocity ranges from 15 mph to 60 mph
length of tow rope = 70 feet

Find: Centripetal force in rope to rotate

Solution:

$$\frac{15\ \text{mile}}{\text{hr}} = \frac{1.609\ \text{km}}{1\ \text{mile}} = 24.1\ \text{km/h}$$

$$\frac{60\ \text{mile}}{\text{hr}} = \frac{1.609\ \text{km}}{1\ \text{mile}} = 96.5\ \text{km/h}$$

$$70\ \text{feet} = \frac{0.3048\ \text{meter}}{1\ \text{foot}} = 21.3\ \text{m}$$

$$\frac{24.1\ \text{km}}{\text{hr}} \times \left(\frac{1\ \text{hr}}{3600\ \text{s}}\right) \times \left(\frac{1000\ \text{m}}{1\ \text{km}}\right) = 6.69\ \text{m/s}$$

$$\frac{96.5\ \text{km}}{\text{hr}} \times \left(\frac{1}{3600\ \text{s}}\right) \times \left(\frac{1000\ \text{m}}{1\ \text{km}}\right) = 26.8\ \text{m/s}$$

$$T = \frac{mv^2}{r} = \frac{(70\ \text{kg})(6.69\ \text{m/s})^2}{21.3\ \text{m}}$$

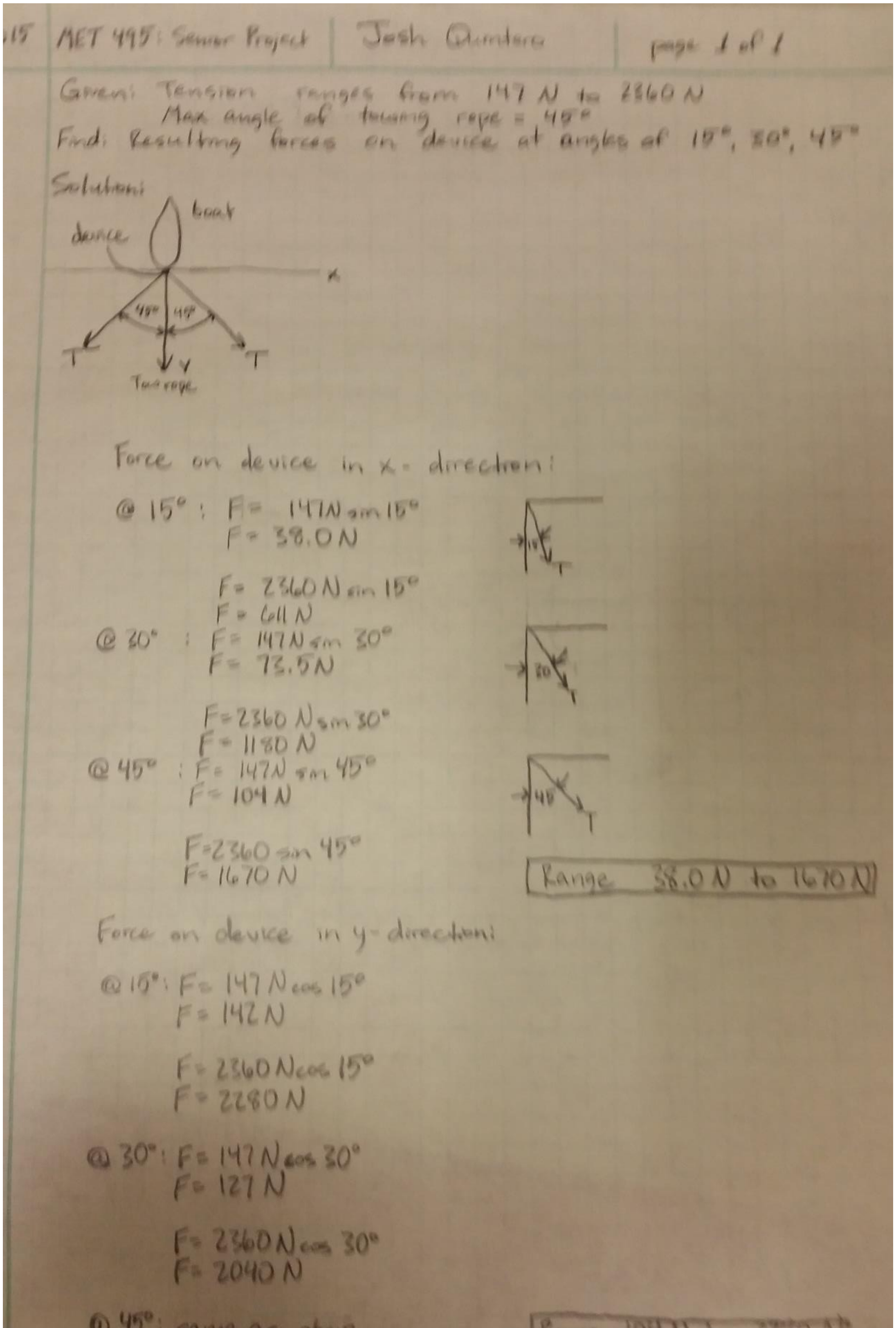
$$\boxed{T = 147\ \text{N}}$$

$$T = \frac{mv^2}{r} = \frac{(70\ \text{kg})(26.8\ \text{m/s})^2}{21.3\ \text{m}}$$

$$\boxed{T = 2360\ \text{N}}$$

These calculations can be described as when the skiier or wakeboarder is moving back and forth behind the boat in a circular motion. It is concluded that the string will undergo tensions from 147 N to 2360 N.

Green Sheet 2



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Given: Tension ranges from 147 N to 2360 N
Max angle of towing rope = 45°
Find: Resulting forces on device at angles of 15°, 30°, 45°

Solution:

Force on device in x-direction:

@ 15° : F = 147 N sin 15°
F = 38.0 N

F = 2360 N sin 15°
F = 611 N

@ 30° : F = 147 N sin 30°
F = 73.5 N

F = 2360 N sin 30°
F = 1180 N

@ 45° : F = 147 N sin 45°
F = 104 N

F = 2360 sin 45°
F = 1670 N

Range 38.0 N to 1670 N

Force on device in y-direction:

@ 15°: F = 147 N cos 15°
F = 142 N

F = 2360 N cos 15°
F = 2280 N

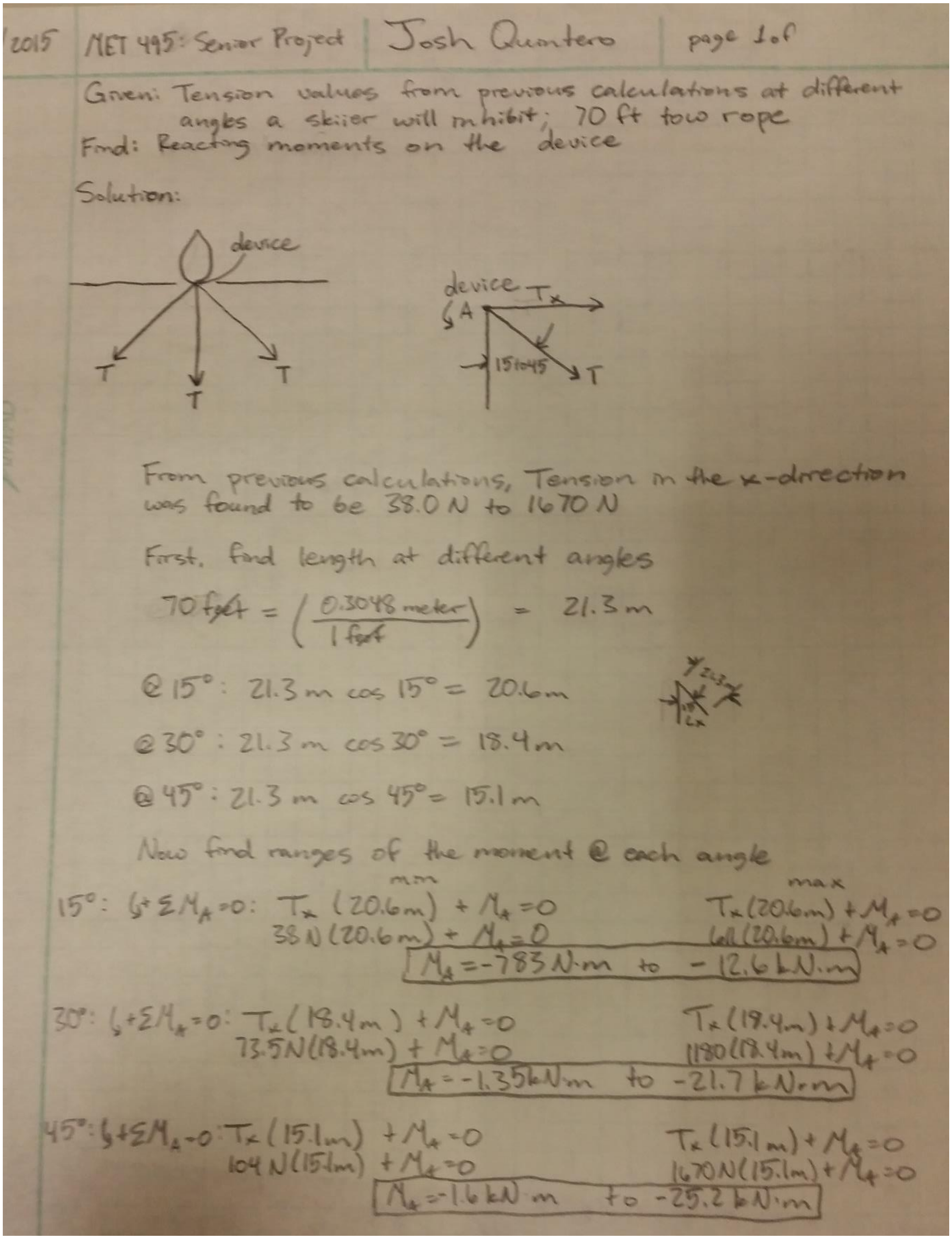
@ 30°: F = 147 N cos 30°
F = 127 N

F = 2360 N cos 30°
F = 2040 N

@ 45°: same as above

Range 104 N to 2280 N

Green Sheet 3



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Given: Tension values from previous calculations at different angles a skiier will inhibit; 70 ft tow rope

Find: Reacting moments on the device

Solution:

From previous calculations, Tension in the x-direction was found to be 38.0 N to 1670 N

First, find length at different angles

$$70 \text{ feet} = \left(\frac{0.3048 \text{ meter}}{1 \text{ foot}}\right) = 21.3 \text{ m}$$

@ 15°: 21.3 m cos 15° = 20.6 m

@ 30°: 21.3 m cos 30° = 18.4 m

@ 45°: 21.3 m cos 45° = 15.1 m

Now find ranges of the moment @ each angle

15°: $\circlearrowleft + \Sigma M_A = 0$:

- min: $T_x (20.6 \text{m}) + M_A = 0$; $38 \text{ N} (20.6 \text{m}) + M_A = 0$
- max: $T_x (20.6 \text{m}) + M_A = 0$; $611 (20.6 \text{m}) + M_A = 0$

$M_A = -783 \text{ N·m}$ to -12.6 kN·m

30°: $\circlearrowleft + \Sigma M_A = 0$:

- $T_x (18.4 \text{m}) + M_A = 0$; $73.5 \text{N} (18.4 \text{m}) + M_A = 0$
- $T_x (18.4 \text{m}) + M_A = 0$; $1180 (18.4 \text{m}) + M_A = 0$

$M_A = -1.35 \text{ kN·m}$ to -21.7 kN·m

45°: $\circlearrowleft + \Sigma M_A = 0$:

- $T_x (15.1 \text{m}) + M_A = 0$; $104 \text{ N} (15.1 \text{m}) + M_A = 0$
- $T_x (15.1 \text{m}) + M_A = 0$; $1670 \text{N} (15.1 \text{m}) + M_A = 0$

$M_A = -1.6 \text{ kN·m}$ to -25.2 kN·m

Green Sheet 4

5 MET 495A: Senior Project | Josh Quintero

Given: Previous calculations of tension on towing rope
Find: minimum allowable area of ski eye to hold tension
Solution:

From the previous calculation, it was found the normal or average tension in the rope from a skier to be 363 N. We can use this to determine the minimum allowable area of the boating ski eye.

Tensile force can be described by the equation

$\sigma = F_n/A$ where σ = normal stress, F_n = normal component force, A = area

solving for A changes the equation to

$A = F_n/\sigma$

For σ, I will use the value of steel. I will use steel because most of the ski eyes I found on the internet are made from steel.

For steel, the tensile strength can be found as

$\sigma_{steel} = 793\ MPa$
from Machine Elements in Mechanical Design on page 730

so $A = \dfrac{363\ N}{793(10^6)\ Pa}$

$A = 457\ nm^2$

This area is very small. So we can calculate for the force being at the highest end of the device needs.

$A = \dfrac{1000\ N}{793(10^6)\ Pa}$

$= 1.26\ \mu m^2$

The radius of the hook can be found from the equation $A = \pi r^2$

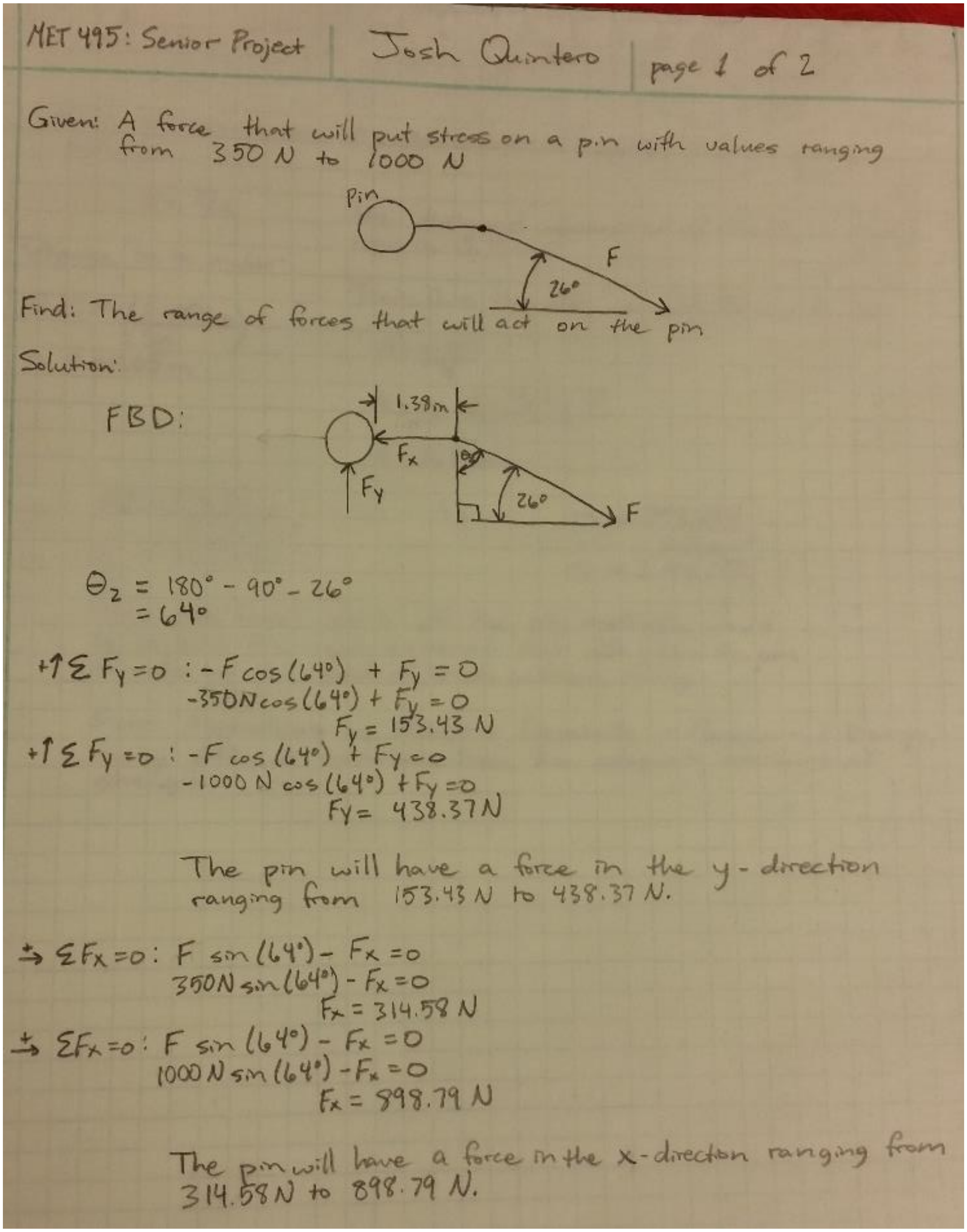
$r^2 = A/\pi$

$r = \sqrt{A/\pi}$

$r = \sqrt{\dfrac{457 nm^2}{\pi}}$ to $r = \sqrt{\dfrac{1.26 \mu m^2}{\pi}}$

$r = 38.7\ \mu m$ $= 634\ \mu m$

Green Sheet 5



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Given: A force that will put stress on a pin with values ranging from 350 N to 1000 N

Pin

F

26°

Find: The range of forces that will act on the pin

Solution:

FBD:

1.38m

F_x

F_y

26°

F

$$\theta_2 = 180° - 90° - 26° = 64°$$

$$+\uparrow \Sigma F_y = 0 : -F\cos(64°) + F_y = 0$$
$$-350N\cos(64°) + F_y = 0$$
$$F_y = 153.43\ N$$

$$+\uparrow \Sigma F_y = 0 : -F\cos(64°) + F_y = 0$$
$$-1000\ N\cos(64°) + F_y = 0$$
$$F_y = 438.37 N$$

The pin will have a force in the y-direction ranging from 153.43 N to 438.37 N.

$$\xrightarrow{+} \Sigma F_x = 0 : F\sin(64°) - F_x = 0$$
$$350N\sin(64°) - F_x = 0$$
$$F_x = 314.58\ N$$

$$\xrightarrow{+} \Sigma F_x = 0 : F\sin(64°) - F_x = 0$$
$$1000\ N\sin(64°) - F_x = 0$$
$$F_x = 898.79\ N$$

The pin will have a force in the x-direction ranging from 314.58 N to 898.79 N.

Green Sheet 6

Now to calculate the amount of stress the pin will undergo.

$\sigma = F/A$

the designed diameter of the pin right now is 0.75in.

Change in to meter

$0.75in \left(\frac{0.0254m}{1in}\right)$

$= 0.01905m$

There fore the area can be found to be:

$A = \frac{\pi D^2}{4}$

$A = \frac{\pi (0.01905m)^2}{4}$

$A = 363 \mu m$

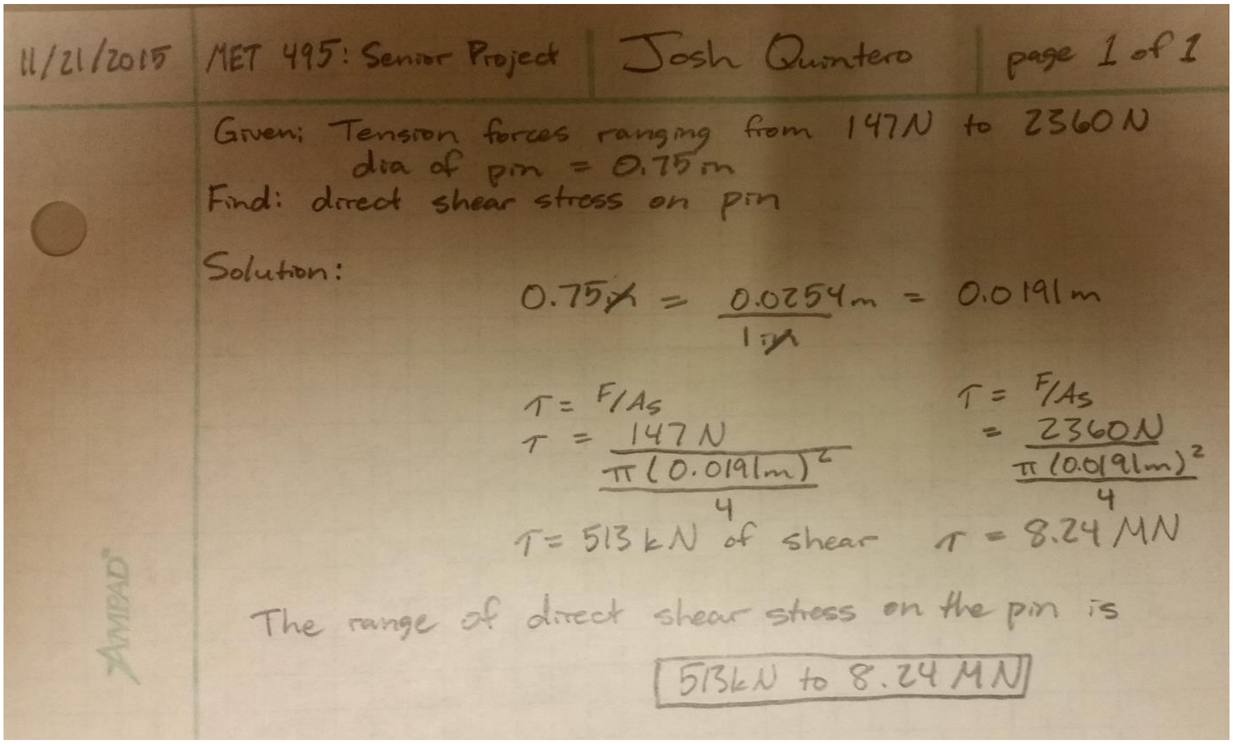
$\sigma_x = \frac{314.58N}{363 \mu m^2}$ to $\sigma_x = \frac{898.79N}{363 \mu m^2}$

$\sigma_x = 867 kPa$ to $\sigma_x = 2.48 MPa$

Now the final part of the pin analysis would be to find the right material that will allow the pin to undergo this kind of stress without failing.

From Appendices in Machine Elements in Mechanical Design, many different materials have the adequate amount of strength.

Green Sheet 7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Given: Tension forces ranging from 147N to 2360N
dia of pin = 0.75 in

Find: direct shear stress on pin

Solution:

$$0.75\,in = \frac{0.0254\,m}{1\,in} = 0.0191\,m$$

$$\tau = F/A_s \qquad \tau = F/A_s$$

$$\tau = \frac{147\,N}{\frac{\pi(0.0191\,m)^2}{4}} \qquad = \frac{2360\,N}{\frac{\pi(0.0191\,m)^2}{4}}$$

τ = 513 kN of shear $\quad \tau$ = 8.24 MN

The range of direct shear stress on the pin is

513kN to 8.24 MN

Green Sheet 8

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Given:
Max force = 54 lb
Min force = 23 lb
$L_i = 3.250$ in
$L_o = 0.750$ in

Find: k & L_f

Solution:

Spring Rate

$k = \Delta F / \Delta L$ eq. 18-1 pg. 600

$$k = \frac{(54\text{ lb} - 23\text{ lb})}{(3.250\text{ in} - 0.750\text{ in})}$$

$$\boxed{k = 206.8\ \text{lb/in}}$$

Free Length of Spring

$k = \frac{F_o}{L_f - L_o}$ eq. 18-16 pg. 600

$$(L_f - L_o)k = F_o$$

$$L_f - L_o = F_o / k$$

$$L_f = F_o / k + L_o$$

$$L_f = \frac{54\text{ lb}}{206.8\text{ lb/in}} + 0.750\text{ in}$$

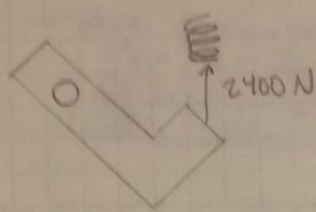
$$\boxed{L_f = 3.36\text{ in}}$$

Green Sheet 9

Given: Upward force from rope attachment to spring is 2400 N; D_m = 2.0in; ASTM 231; k = 206.8 lb/in

Find: Required spring analysis to choose correct spring

Solution:



The force will be translated to U.S. units to work with the dimensions of the device.

$$2400\,N \times \frac{0.225\,lb}{1\,N} = 540\,lb = F_o$$

Use trial wire from Table 18-2 pg. 598 : Motts

U.S. steel wire gage no. 0 @ 0.3065 in = D_w

Spring Index

$C = D_m/D_w$ pg. 600

$$C = \frac{2.0in}{0.3065in}$$

$C = 6.53$

Wahl Factor

$K = (4C-1)/(4C-4) + 0.615/C$ pg. 605

$$K = \frac{4(6.53)-1}{4(6.53)-4} + \frac{0.615}{6.53}$$

$K = 1.23$

Shear Stress in Spring

$$\tau_o = \frac{8KF_oD_m}{\pi D_w^3} \quad \text{eq. 18-4 pg. 604}$$

$$\tau_o = \frac{8(1.23)(540lb)(2.00in)}{\pi(.3065in)^3}$$

τ_o = 117500 psi < 139000 psi from fig. 18-11 pg. 603

Number of Coils

$$N_a = \frac{GD_w}{8kC^3}$$

$$N_a = \frac{(11200000psi)(0.3065in)}{8(206.8\,lb/in)(6.53)^3}$$

N_a = 7.45 coils

Solid Length

$L_s = D_w(N_a+2)$

L_s = 0.3065in (7.45+2)

L_s = 2.90 in

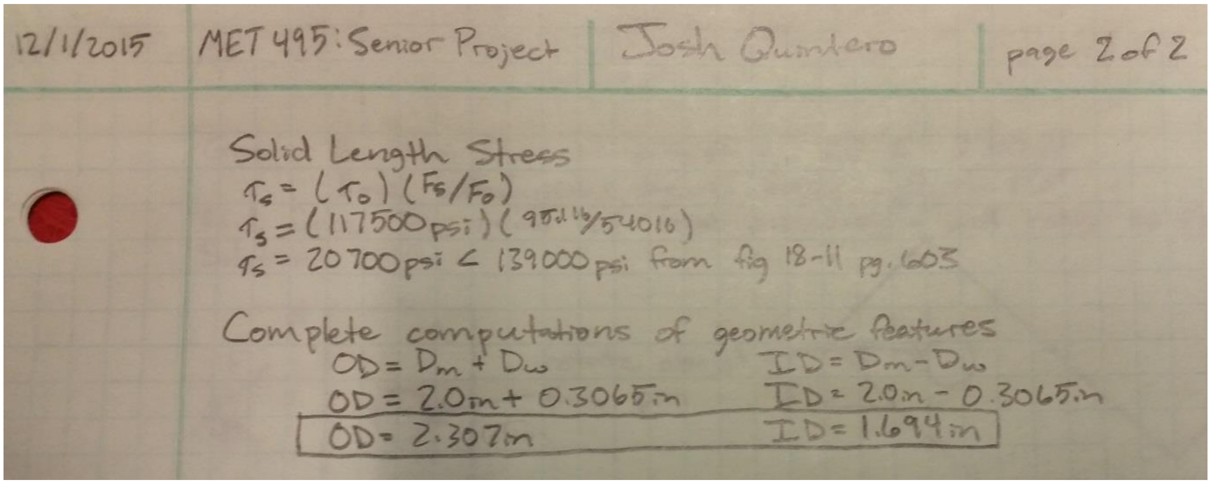
Force at Solid Length

$F_s = k(L_f - L_s)$

F_s = (206.8 lb/in)(3.36in − 2.90in)

F_s = 95.1 lb

Cont. next page



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Solid Length Stress

$\tau_s = (\tau_o)(F_s/F_o)$

$\tau_s = (117500\,psi)(9501\,lb/54016)$

$\tau_s = 20700\,psi < 139000\,psi$ from fig 18-11 pg. 603

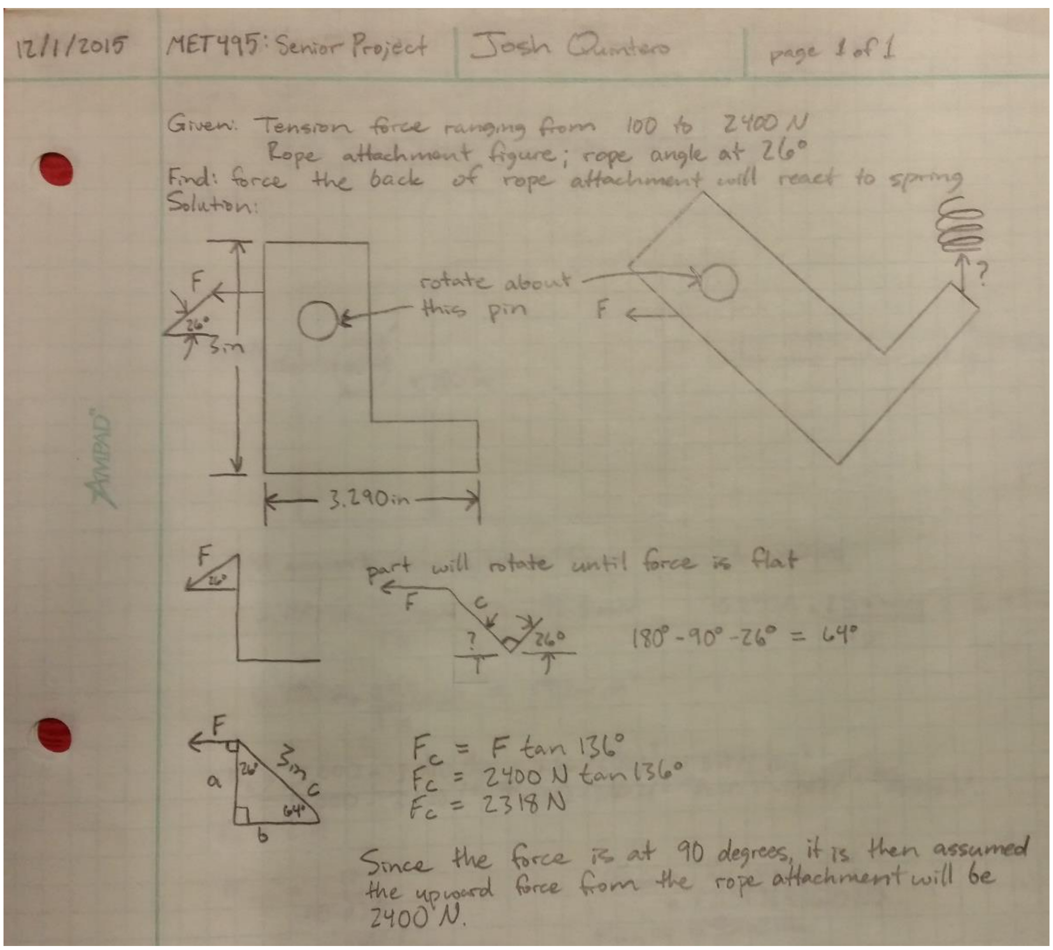
Complete computations of geometric features

$OD = D_m + D_w$ | $ID = D_m - D_w$

$OD = 2.0in + 0.3065in$ | $ID = 2.0in - 0.3065in$

$OD = 2.307in$ | $ID = 1.694in$

Green Sheet 11



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Given: Tension force ranging from 100 to 2400 N

Rope attachment figure; rope angle at 26°

Find: force the back of rope attachment will react to spring

Solution:

$F_c = F \tan 136°$

$F_c = 2400\,N \tan 136°$

$F_c = 2318\,N$

Since the force is at 90 degrees, it is then assumed the upward force from the rope attachment will be 2400 N.

Green Sheet 12

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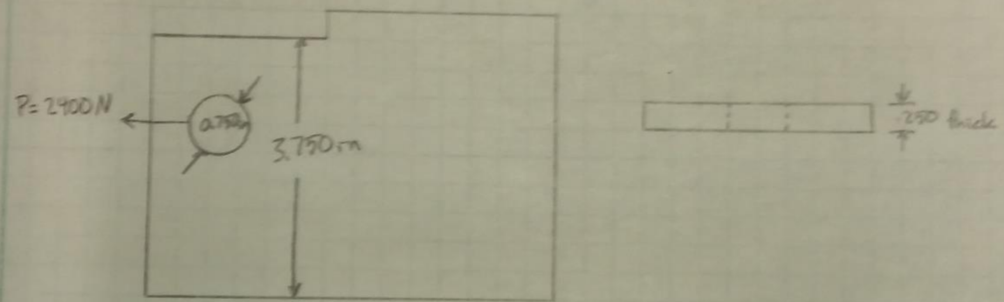
Given: Forces acting on pin

Find: stress and strain on holes of housing

Solution:



First convert measurements from inches to meters

$3.750\ in \times \frac{25.4\ mm}{1\ in} = 95.3\ mm$ $\quad 0.250\ in \times \frac{25.4\ mm}{1\ in} = 6.35\ mm$

$0.750\ in \times \frac{25.4\ mm}{1\ in} = 19.1\ mm$

$K_t = 3.000 - 3.140\ d/D + 3.667\,(d/D)^2 - 1.527\,(d/D)^3$

$= 3.000 - 3.140\,(0.750/3.750) + 3.667\,(0.750/3.750)^2 - 1.527\,(0.750/3.750)^3$

$K_t = 2.51$

$\sigma_{nom} = \frac{P}{(D-d)t}$

$= \frac{2400\ N}{(.953 - .191)(.0635)}$

$\sigma_{nom} = 49600\ Pa$

$\sigma_{max} = K_t\ \sigma_{nom}$

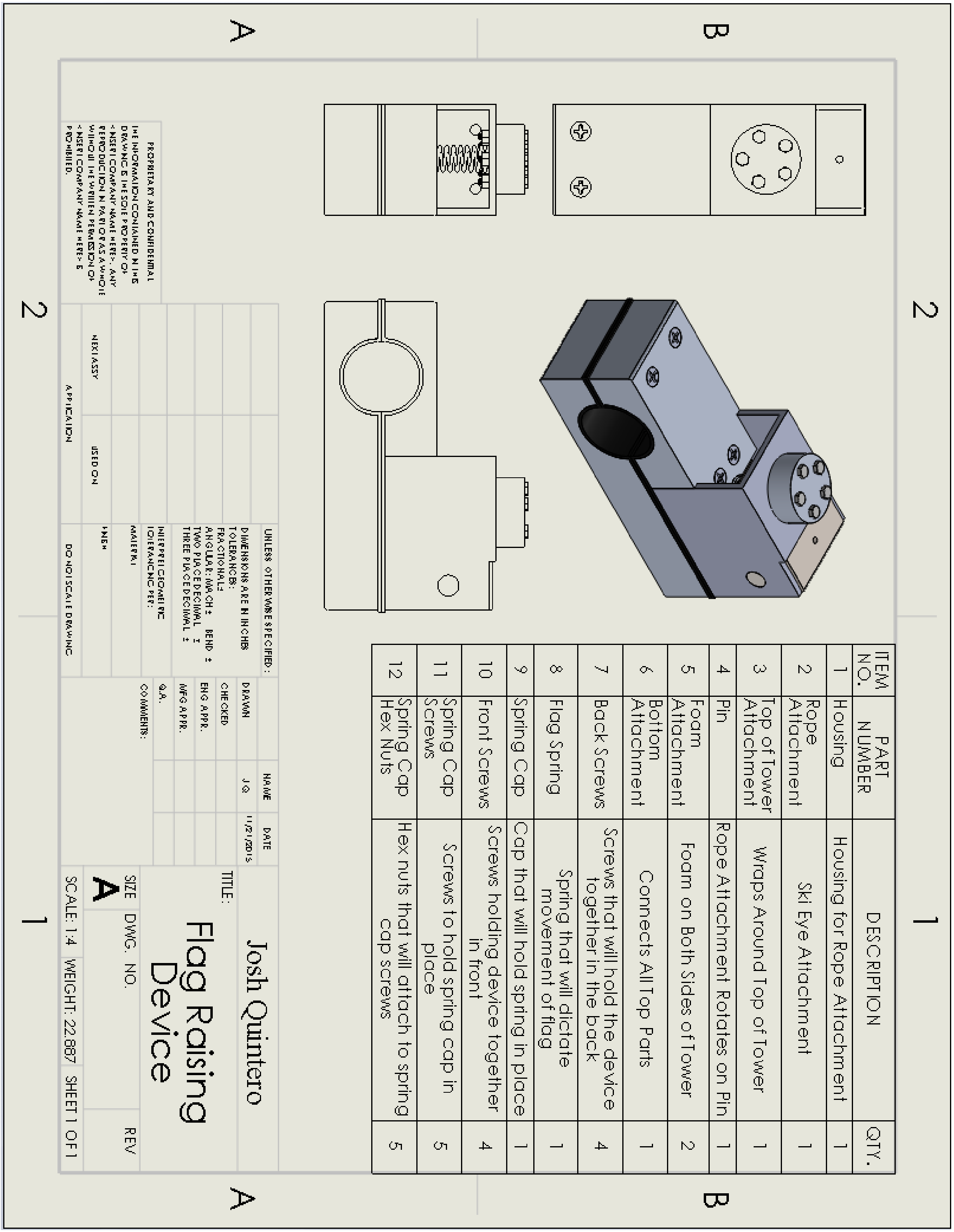
$= (2.51)(49600\ N)$

$\sigma_{max} = 125000\ Pa$

Green Sheet 13

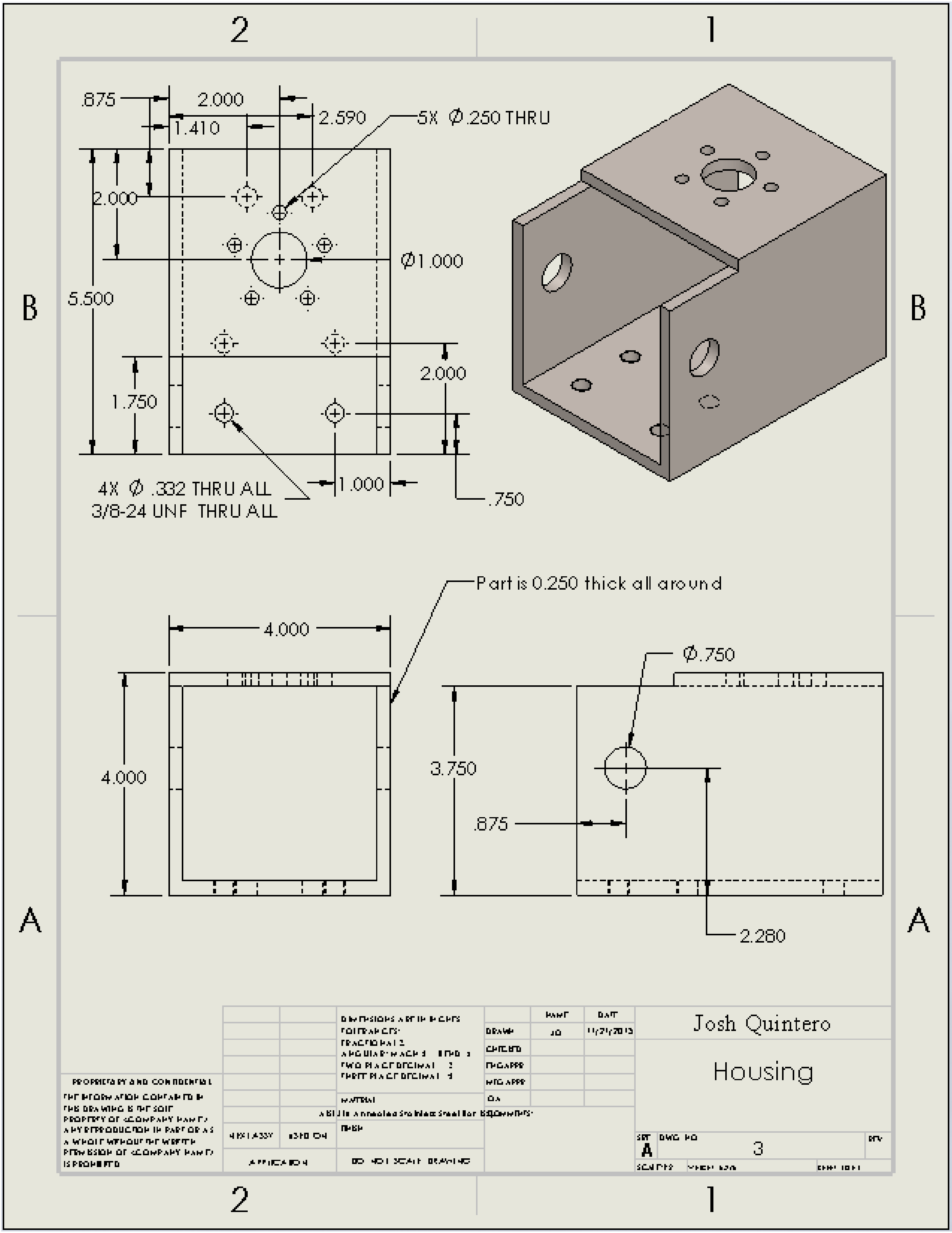
Appendix B: Drawings

Assembly Drawing



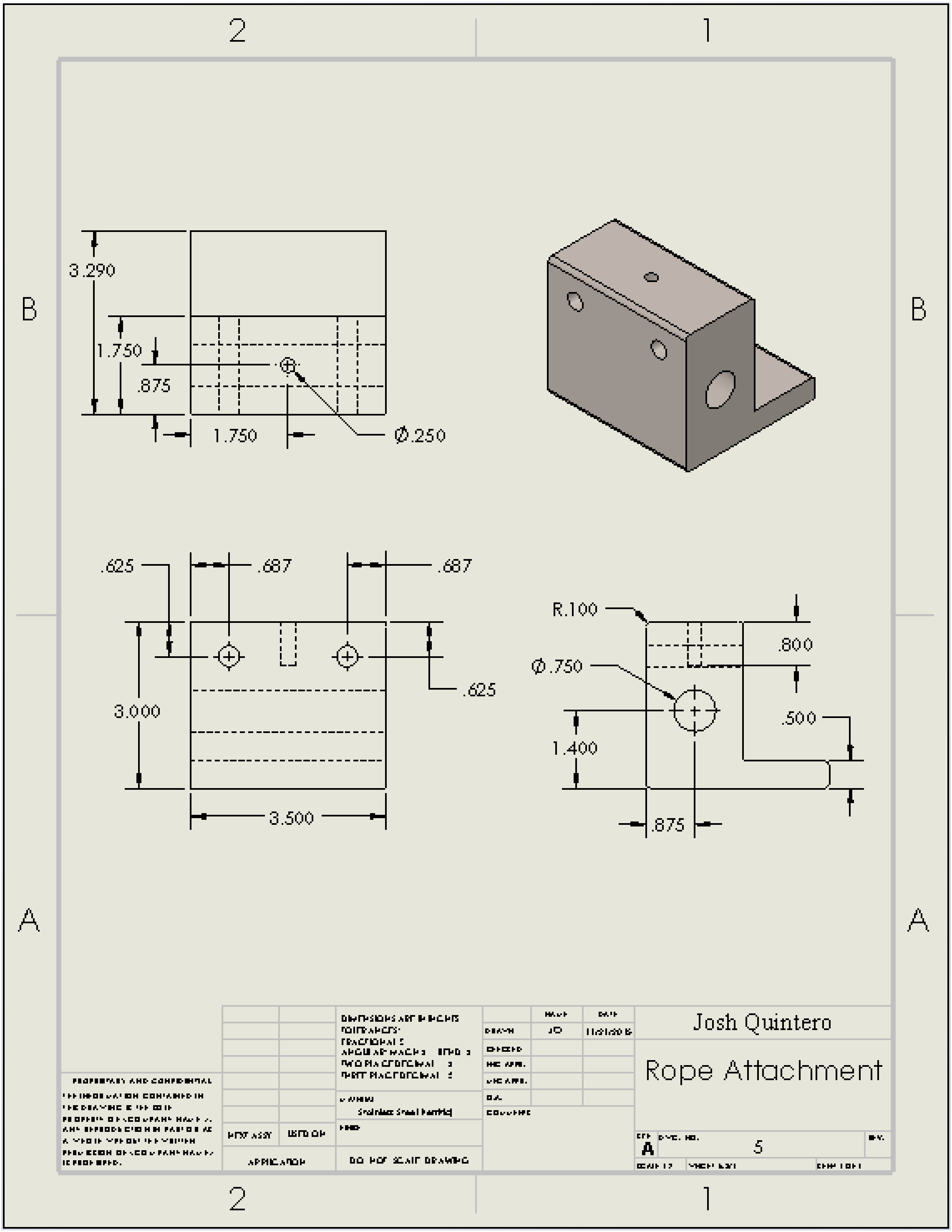
Drawing 1

Housing



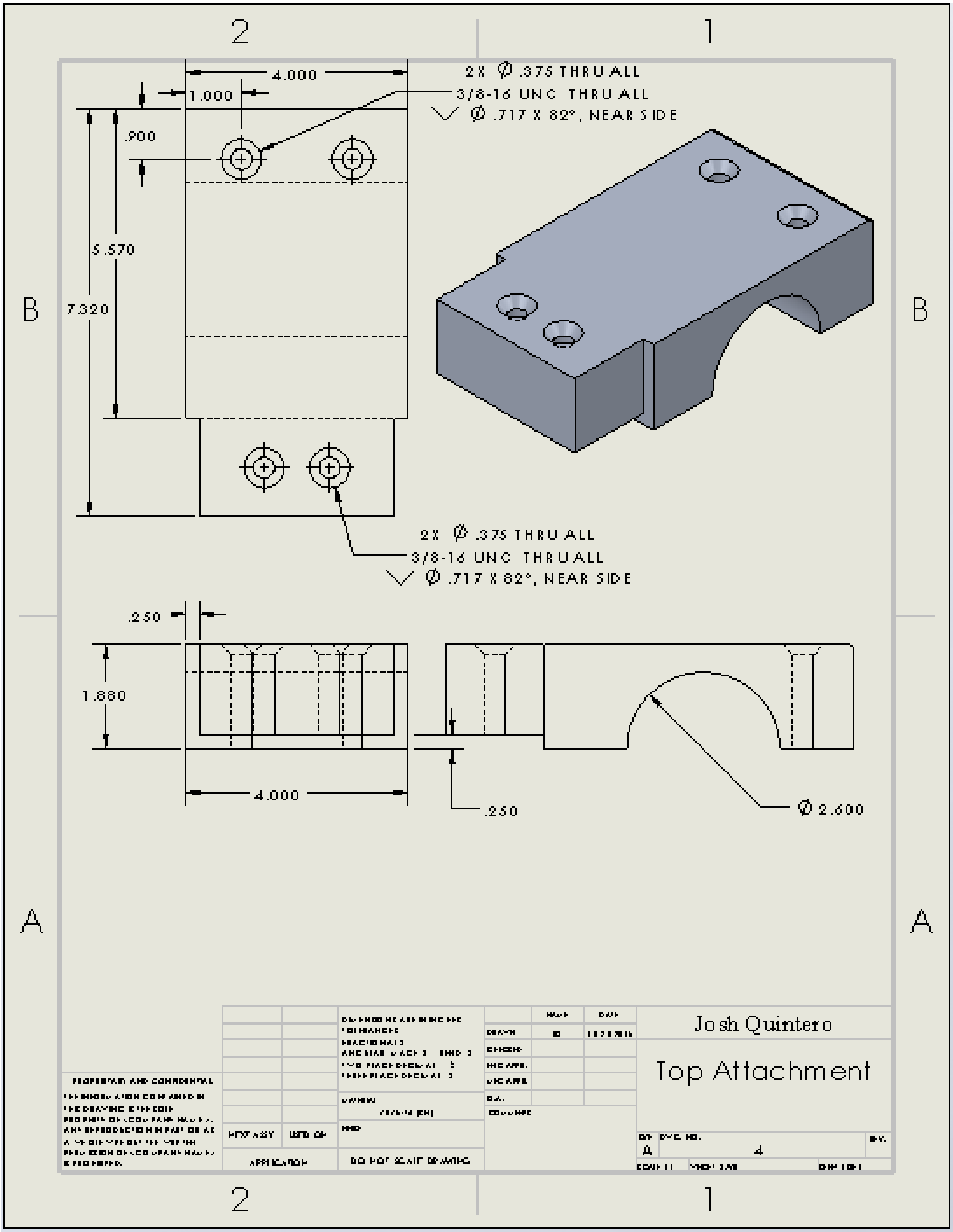
Drawing 2

Rope Attachment



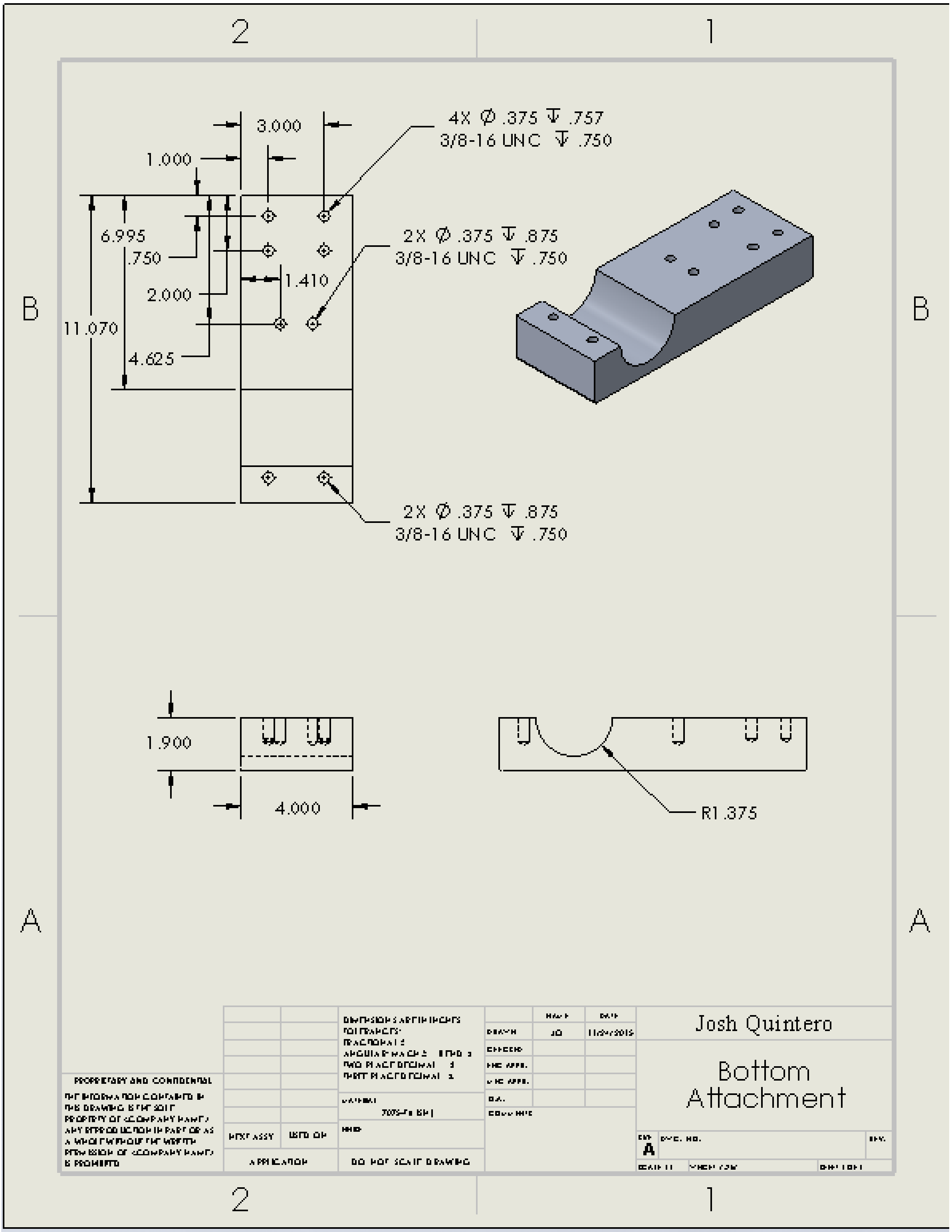
Drawing 3

Top Attachment



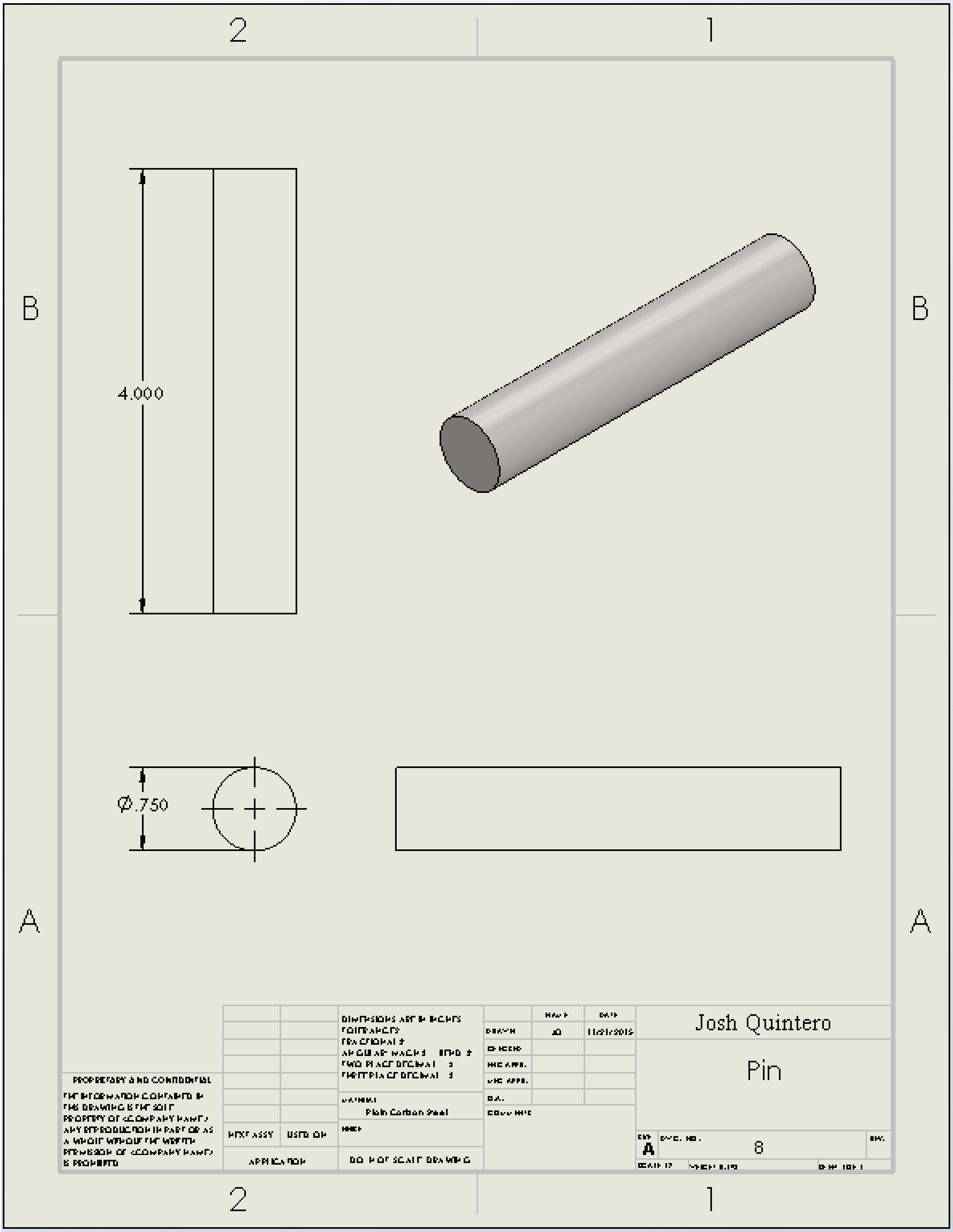
Drawing 4

Bottom Attachment



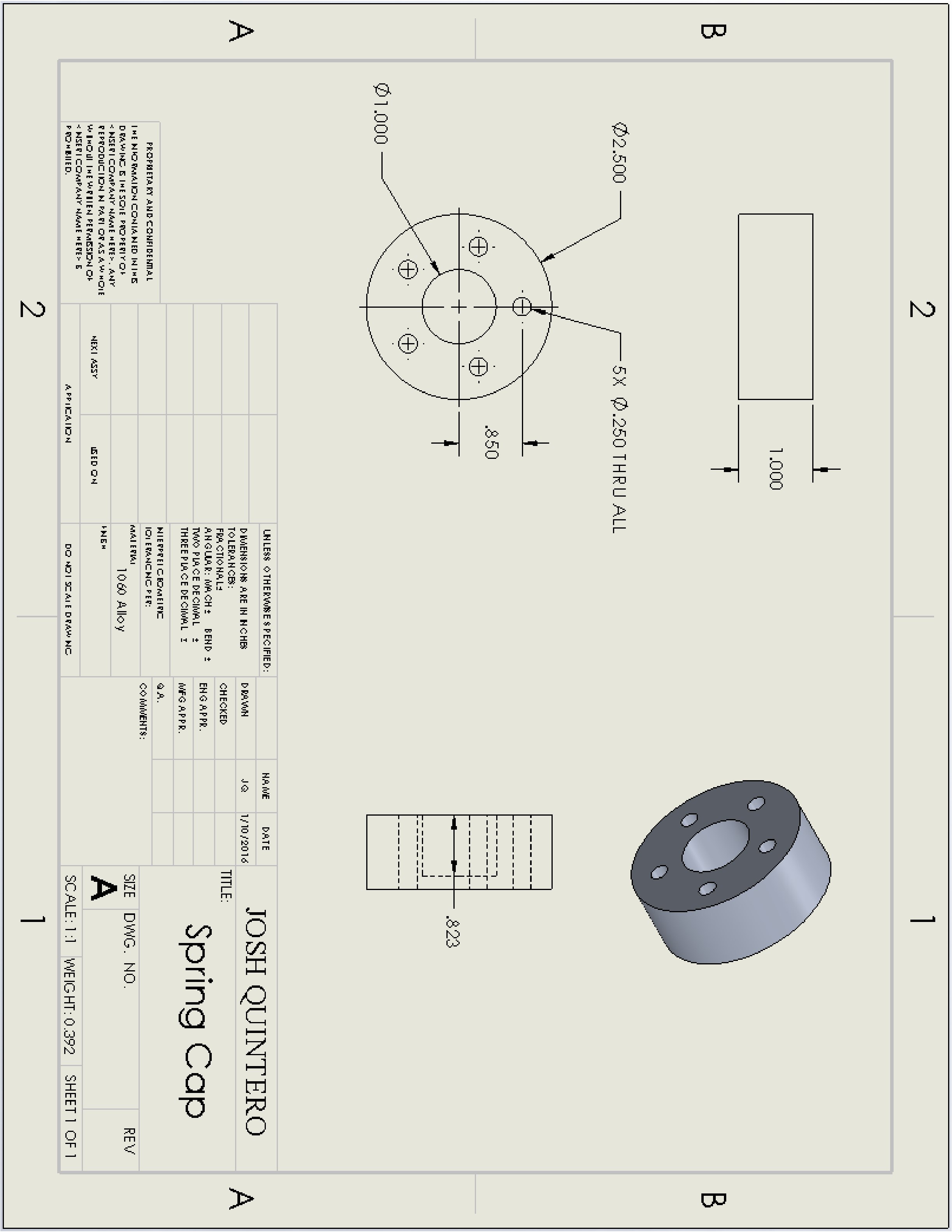
Drawing 5

Pin



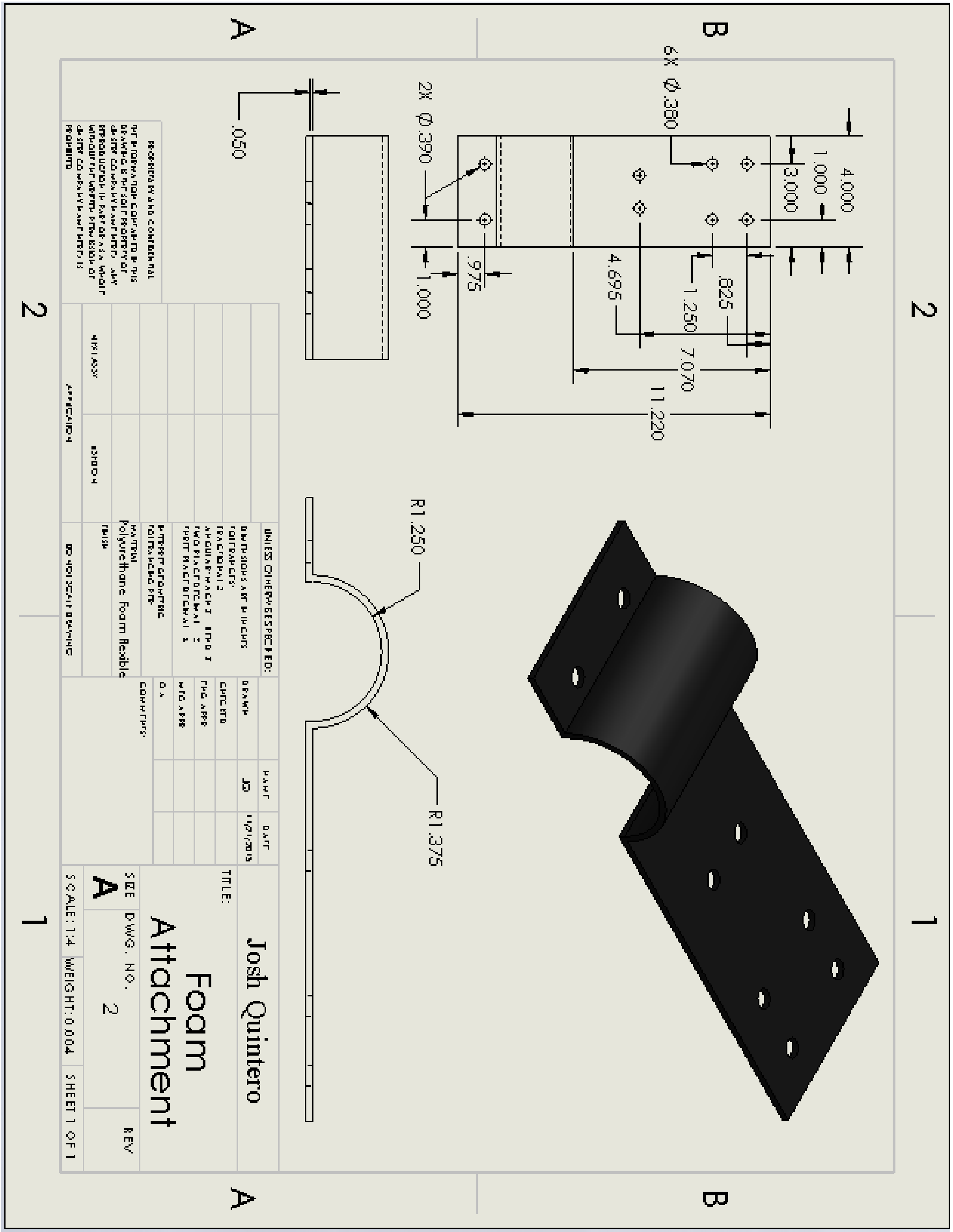
Drawing 6

Spring Cap



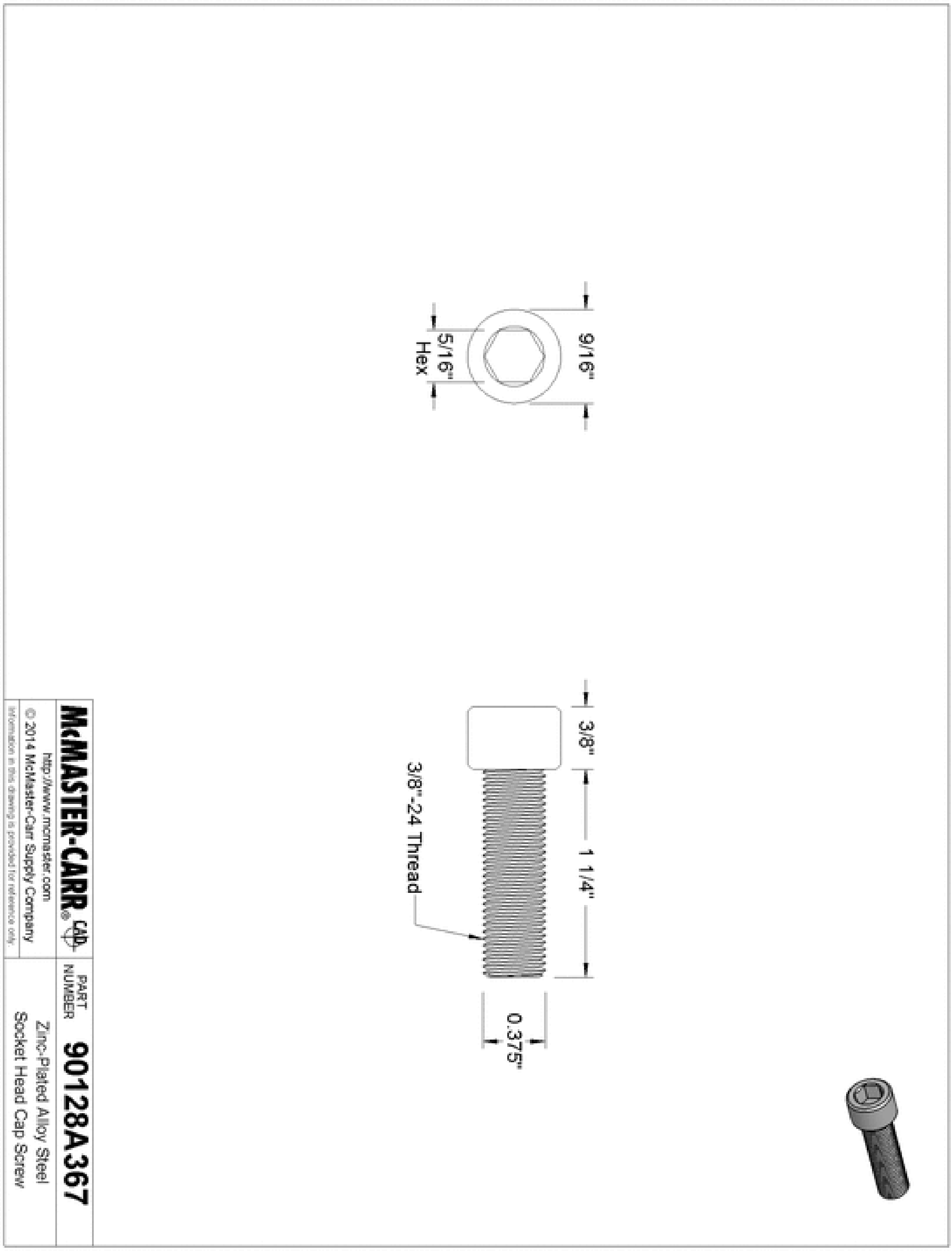
Drawing 7

Foam Attachment



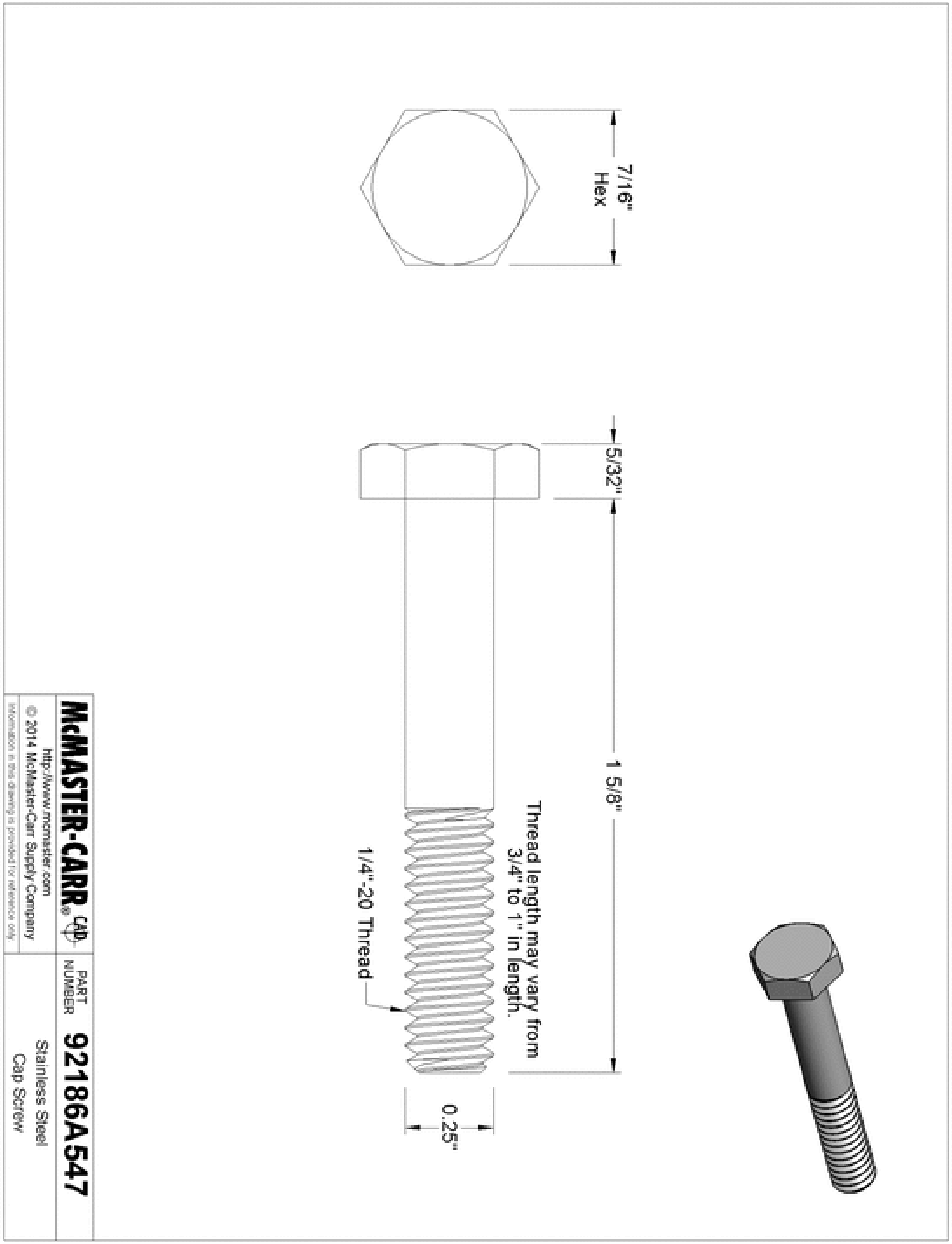
Drawing 8

Front Device Screws



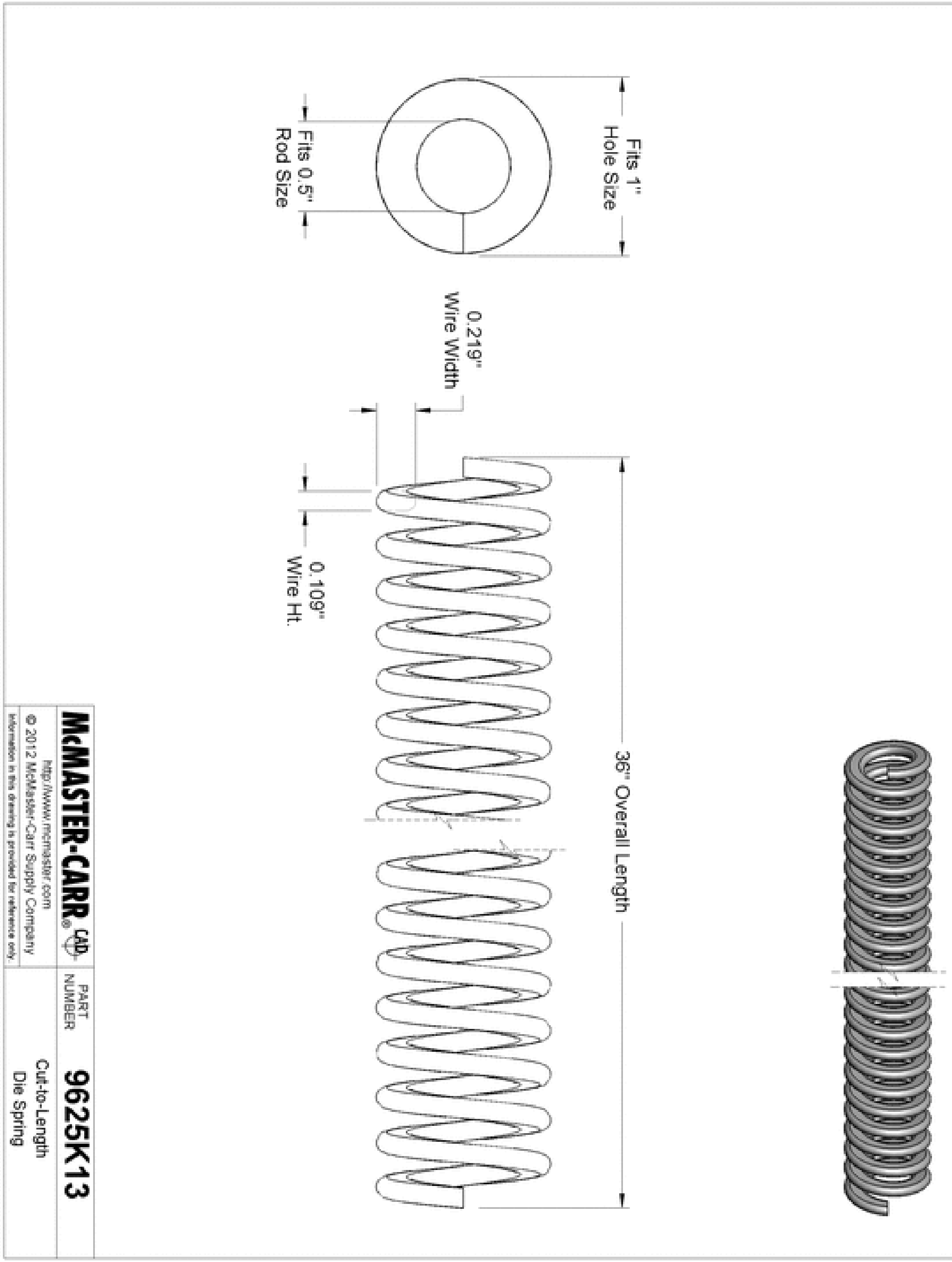
Drawing 9

Spring Cap Bolt



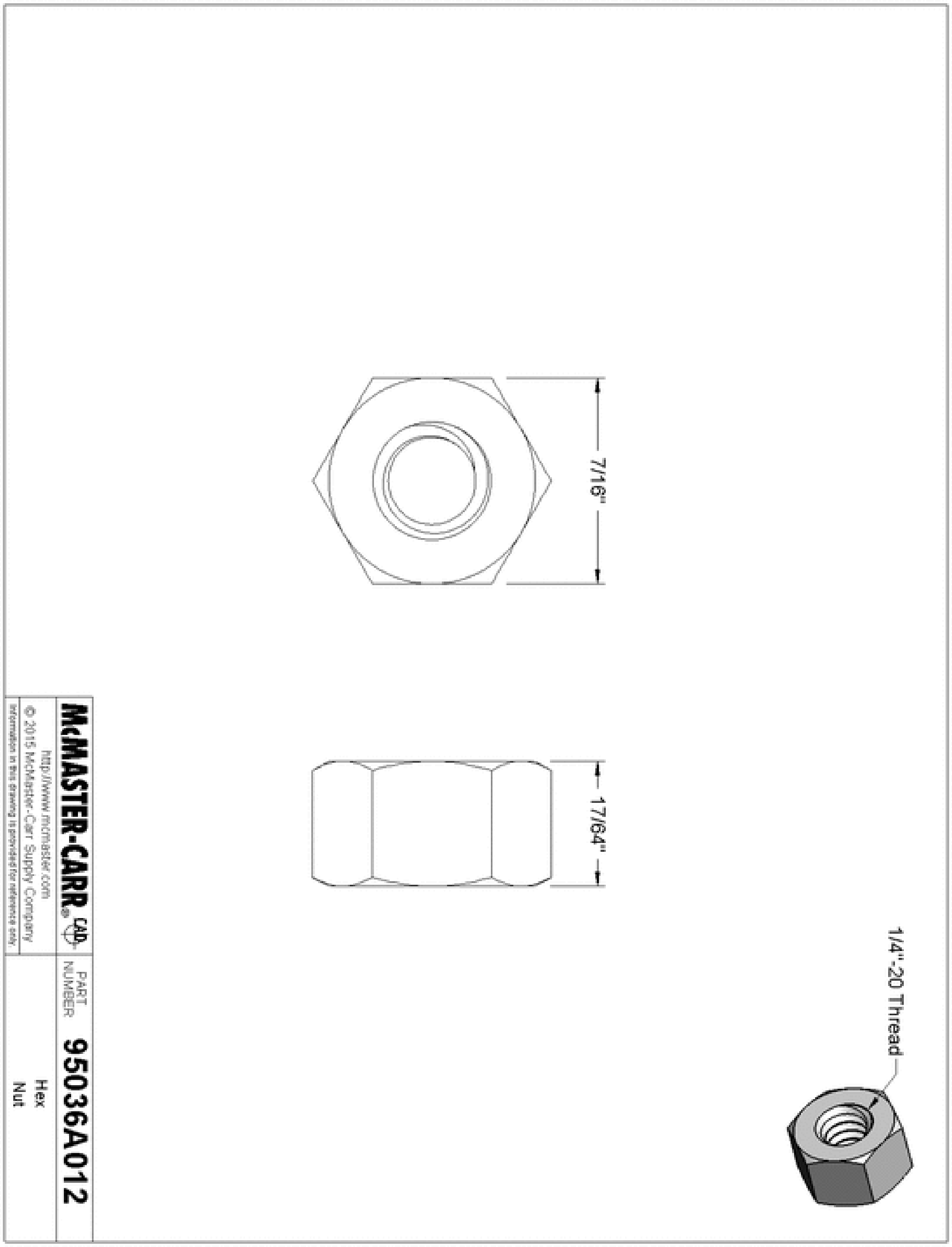
Drawing 10

Spring



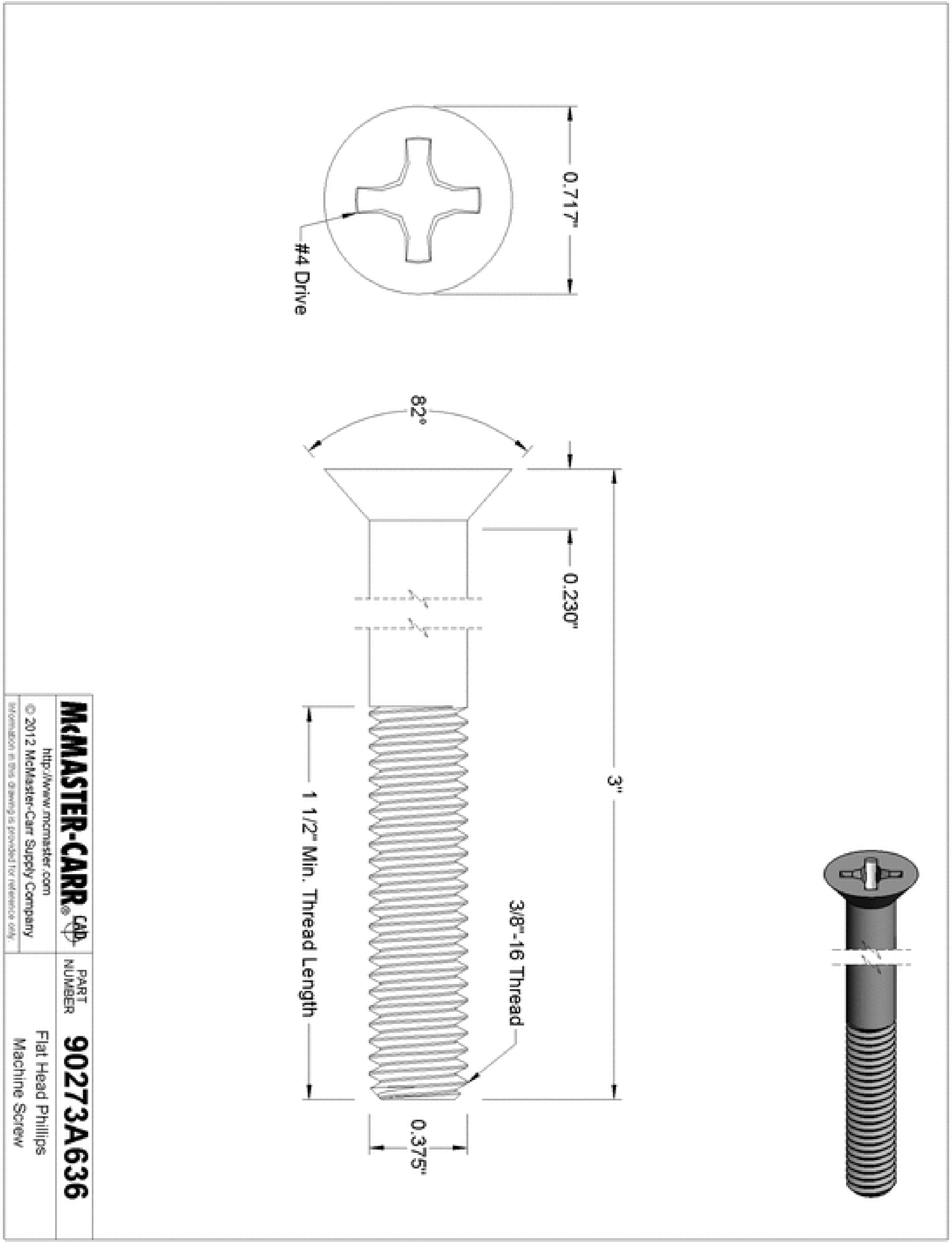
Drawing 11

Spring Cap Nut



Drawing 12

Back Device Screws



Drawing 13

Appendix C: Parts List

Flag Raising Device Parts List			
Item #	Quantity	Drawing Number	Part Name
1	1	2	Housing
2	1	3	Rope Attachment
3	1	4	Top Attachment
4	1	5	Bottom Attachment
5	1	6	Pin
6	1	7	Spring Cap
7	2	8	Foam Attachment
8	4	9	Front Device Screws
9	5	10	Spring Cap Screws
10	1	11	Spring
11	5	12	Spring Cap Nut
12	4	13	Back Device Screws
13	1		Ski Eye

Appendix D: Budget

Part For	Type/Material	Part/Item Number	Stock Bought	Price	Quantity	Total
Ski Eye (Overton's)	Stainless Steel	11898		$30.00	1	$34.99
Housing	Super-Corrosion Resistant 316 Stainless Steel	2937K29	4ft x 4ft x ¼ square tubing: ½ ft. length	$62.25	1	$62.25
Pin	Very High-Strength 15-5 PH Stainless Steel Rod,		¾" Dia: ½ ft.	$16.01	1	$16.01
Rope Attachment	4140 Multipurpose Alloy Steel	6552K555	4" x 4" x ½ ft.	$82.14	1	$82.14
Bottom and Top Attachment	Hard High-Strength 7075 Aluminum	9055K33	4" x 2" x 1 ft.	$162.25	2	$324.50
Foam Attachment	Conformable Water-Resistant Vinyl Foam	86025K72	Adhesive Back, 1/8" Th ick, 36" x 54" Sheet	$19.88	1	$19.88
Front Tower Attachment Screws	Zinc-Plated Alloy Steel Socket Head Cap	90128A367	3/8"-24 Thread, 1-1/4" Length1	$5.68	1	$5.68
Spring	Cut to Length Rectangular Wire Die Spring	9625K13	1" Hole, ½" Rod, .219" Wire	$51.85	1	$51.85
Spring Cap Hex Nuts	Cadmium Yellow-Chromate Plated Steel	95036A012	Grade 9, 1/4"-20 Thread Size, 7/16" Wide,17/64" High	$11.46	1	$11.46
Spring Cap Bolts	Type 316 Stainless Steel Hex Head Cap Screw	92186A547	3/8"-24 Thread, 1-1/4" Length	$5.68	1	$5.68
Back Tower Attachment Screws	Zinc-Plated Steel Flat Head Phillips	90273A636	3/8"-16 Thread, 3" Length	$5.42	1	$5.42
Spring Cap	High-Strength 2024 Aluminum	9034K72	Rod, 2-1/2" Diameter, 1" Long	$12.05	1	$12.05
Ball Mill (MSCdirect)	Uncoated, 5 Inch Overall Length	01760784	1-1/4 Inch Shank Diameter, Spiral Flute	$106.93	1	$106.93
					Total	$738.84

Table 1

Appendix E: Schedule/Gantt Chart

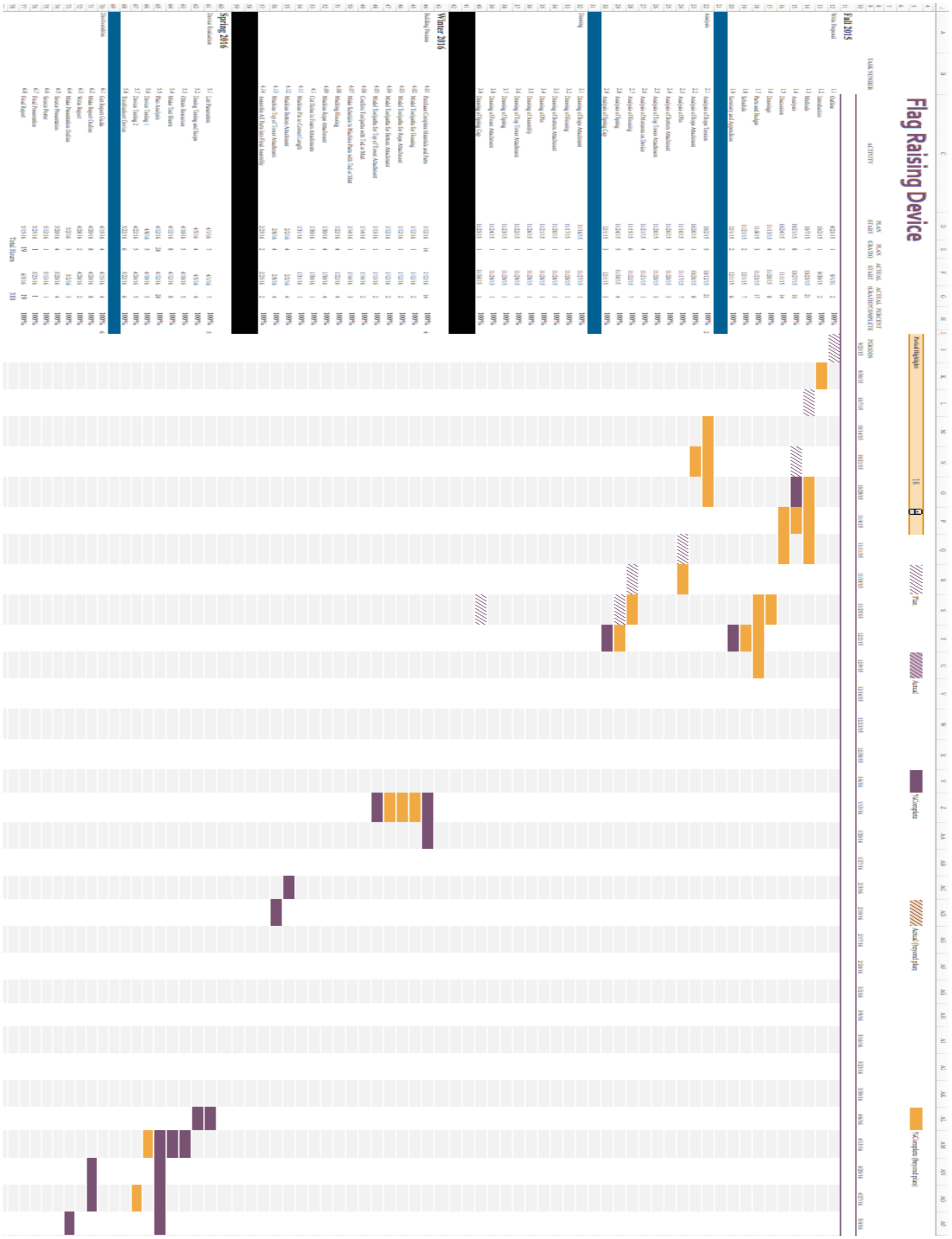


Figure 1

Appendix F: Expertise and Resources

- Analysis Equations
  - Machine Elements in Mechanical Design Fifth Edition By Robert L. Mott
- Educational Support
  - Dr. Johnson, Central Washington University Program Coordinator, Mechanical Engineering Technology
  - Professor Pringle, Central Washington University Professor, Mechanical Engineering Technology
  - Professor Beardsley, Central Washington University Professor, Mechanical Engineering Technology
- Manufacturing Support
  - Ted Bramble, Central Washington University Professor, Mechanical Engineering Technology
  - Matt Burvee, Central Washington University, Engineering Technician
  - Central Washington University Machine Shop provided machining tools and equipment to manufacture the designed parts for the project

Appendix G: Testing Report

Introduction:

The testing for the Flag Raising Device was broken up into two different tests. The first test was to test that the spring inside of the device worked for the tension requirement that was set in the proposal. The second testing was to test that the device fit on the boat tower that it was designed for.

Requirements:

The requirements for this device will be…

- The device must be able to withstand tension from 100lb to 2400lb.
- The device must fit the size of Richard Jones' boat tower diameter of 2.5 inches.
- The device should fit within a volume of 1ft x 5in x 8 inches.
- A towing rope should easily attach to the device's eye ring with a simple boating knot.
- All government and industry safety standards must be met.
- Someone in the boat can manually raise the flag.
- The flag-raising device should weigh no more than 30 pounds.
- The flag needs to lower zero degrees or completely horizontal.

Parameters of Interest:

The most important factor is that the flag will lower when the tension in the towing rope meets 100 lb. This is the main part of the project. The second most important parameter is making sure that the device will actually fit on the tower. If the device cannot fit, then obviously the device will not work. The rest of the parameters of interest can be seen in the requirements for the the device.

Predicted Performance:

The prediction for these tests is simply that it will work. The analysis done for the device as well as the manufacturing done should allow the device to work as planned. It is believed that the flag will start to rotate down to horizontal when the tension in the towing rope reaches 100 pounds.

Data Acquisition:

The data that was taken for the first test was the amount of tension that it took for the flag to lower. This data was taken from a spring scale that was obtained from Professor Beardsley. The data was then recorded on a piece of paper for a certain amount of trials. The data was then put into a table in excel.

The data for the second test was the same as the first since the first test failed and a couple different aspects of the device were changed. The second test also included how far down the flag lowered. The same spring scale was used for this second test as well. The data was taken the same way. First reading it off of the spring scale and then recorded onto a piece of paper. Afterwards, the data was put into excel.

Schedule:

The schedule for the first test was on the weekend of 4/8/2016 to 4/10/2016. This can be seen in the Gantt chart as task number 5.6. The testing for this had to be done before the following week to report it to the rest of the senior class. The testing only took a couple hours on the first scheduled day of testing.

The second testing was done two weeks later on 4/22/2016 to 4/24/2016. This task can be seen on the Gantt chart as task number 5.7. This testing also had to be done before the following week to do a second report on the testing. The second testing took a little bit longer than the first. This is because of reasons that will be stated later in the report. This second testing actually took place on the second day of the scheduled testing and took close to six hours to test.

Method:

The method between the two tests differed in a couple different aspects but was essentially the same. The first test was very simple and was able to be done in Ellensburg. The second testing had a couple more features to be looked at. This test was actually taken back to Tumwater where the device could be attached to the boat tower and tested on top of the boat.

Resources:

For the first test, there was only a few resources needed to make the testing possible. First, obviously the device was needed for the testing. Another resource was a pole that is cemented into the garage of Josh Quintero. This pole is what the device was attached to. A spring scale obtained from Professor Beardsley was also needed. Rope was needed to tie on the device and another piece of rope was needed to tie on the other side of the spring scale. Another person was also needed to pull on the rope while the project designer, Josh Quintero, recorded the data. A piece of paper, pen, and a computer was needed to record the data of the test.

The second test needed quite a bit more resources. The plan was to take the device home to Tumwater to actually test the device on the boat it was designed for. The first and most important resource for the second testing was the boat and the tower. Some thick pieces of rubber were needed to attach the device to the tower that will be explained later. The spring scale was needed again. Also, a protractor was needed with this test to see about what angle the flag was rotating down to. Five different springs that where obtained from Professor Beardsley were needed to test. Since the spring purchased for the device was too stiff, these other springs were needed to test. Video was taken of this second test so a smart phone was used for these videos as well as taking various pictures. Rope was again needed but this time it was the actual rope that would be used in wakeboarding and water skiing situations. Next was a little two step stool that would allow someone to get on and attach the device to the tower. Three other people were also needed for the second testing. Their roles will be discussed later in the report. Other resources were paper, pen, and a computer for data.

Data Capture:

As stated before, the data first was taken on a piece of paper and pen. The first test was done to test and make sure the flag rotated down and at what amount of tension in the rope it started to rotate down. So in a table, I had trials one through 10. For each trial, I would write down the amount of tension it took to start the rotation of the flag.

As for the second test, it was the same. However, this time the device was tested for three different springs. The original spring was tested as well as two other springs that were obtained from Professor Beardsley. Three of the springs obtained from Professor Beardsley were too small to work in the device. The three springs were tested just like in the first test. Each spring was run through 10 trials with the amount of tension required to move the flag recorded on each trial for each spring. The second part of the testing for the second test was to see how far the flag actually rotated down. So for each of the 10 trials, the angle of the flag was also taken once the spring scale read 100 lb.

Once all of the data was recorded on paper, the data was taken inside and inputted into the computer. The data was put into an excel spreadsheet where it could be easily organized.

Test Procedure Overview:

The first test was simple that just tested one simple aspect of the device. It was connected to a post and pulled on by a rope and using a spring scale. The data was recorded based off of the amount of tension required to move the flag down.

The second test had some more parts to it. The device was taken home to Tumwater and tested on top of the boat it was designed for. The boat was taken out of the garage and the tower was raised on the boat. The device could then be attached to the tower. After it was attached, a piece of rope was tied to the hook on the device and on one side of the spring scale. Another rope was tied to the other side of the spring scale. While one person recorded data, pictures and video, two other people pulled on the rope.

After these tests were done, the data recorded on each sheet of paper was taken and input an excel spreadsheet on a computer.

Operational Limitations:

Some limitations were first set because of the timing of testing. Obviously it would have been nice to test the device out on the water and have it really tested fully for what it was designed for. However, with it still being early in the year, it wasn't possible to get the boat out and ready to put into the water. Therefore, the device could not be fully tested although with each test it was simulated to the best of its ability.

Precision and Accuracy Discussion:

The main part of the testing for both tests was the spring scale obtain from Professor Beardsley. The accuracy for the spring scale was not as good as needed. When pulling on the rope, it was hard to keep the tension at the right amount needed. As the other person or persons were pulling, the scale would jump from plus to minus 10 pounds as it was not easy to keep steady. So some of the data could be off from what it really is. The data was kind of an average of what it looked like on the scale as well as the angle.

One part of the second test that made it hard to be completely accurate was that the hole on the device was a little too big for the tower. Since the hole was too big, the device at first rotated down each time. Once some pieces of rubber were put in between the device and the hole it was able to be secured better for testing.

Data Storage/Data Presentation:

Data was first recorded on a piece of paper when doing the testing. Afterwards, the data was taken to a computer and input into an excel spreadsheet. The data will be presented into a simple table. There is no need for graphs or charts when showing the data.

Test Procedure:

The two tests will be split up and discussed in different sections:

Test 1:

The first test was done in Ellensburg on Friday April 8th, 2016. It was done at the house of Josh Quintero. The testing started at 3:00 p.m. in the garage. The following steps will detail how the testing was done:

1) Get help from one other person (Josh Quintero's roommate, Joe Nevin). Get him ready to help with the testing
2) Assemble the device
   a) Pin through housing
   b) Ski eye connected to rope attachment with screwing in nuts
   c) Spring inserted into housing
   d) Spring cap connected on top of housing including bolts and nuts
3) Bring device into the garage to prepare for the testing
4) Attach top and bottom attachments to pole in garage
5) Assemble the housing part (already partly assembled) to the rest of the device attached to the pole (insert and screw in screws in back, middle, and front of device)
6) Tie one piece of rope to the ski eye on the rope attachment
7) Attach top end of the spring scale to the first piece of rope
8) Tie another piece of rope to the bottom end of the spring scale
9) Make sure all bolts, nuts, screws are tightened down before starting the test
10) Set up table on a piece of paper for the testing (example will be shown later in the report)
11) Set up roommate on the rope that is attached to bottom end of spring scale

Now the actual testing can start

12) Have roommate pull until the flag starts to lower
13) As roommate pulls, watch until the flag starts to lower and record the amount of tension from the spring scale
14) Repeat steps 12 and 13 10 times and record the value of tension each time
15) Make sure data accurately represents the test
16) Detach the ropes, disassemble the device from the pole and thank the roommate for the help
17) Take the data inside and input the data on a computer into an excel spreadsheet

There was no risk or safety issues while dealing with the first test. Both participants still wore safety glasses just in case. The most important part was making sure all the bolts, screws, and nuts were secured. Once all of them were fixed, the device would not move besides the rope attachment that is supposed to move.

This first test was not a successful one. It was determined that the spring designed and purchased for was too stiff. Each trial showed that the flag did not move even with the roommate pulling as hard as he could. The device was designed to rotate the flag down at 100 pounds of tension. The spring scale would show over 200 pounds of tension and the flag was still not moving down. There were some good things about the device in that the rest of it was able to stay together even with all the tension pulling on the device. That was a big positive in knowing that the rest of the device stayed together.

Test 2:

The second test was done on Saturday April 23rd, 2016 in Tumwater, Washington at the home of Josh Quintero. This was the site where the boat and tower are. This boat and tower is what the device was designed exactly for. The second testing started at 4:00 p.m. outside the garage. The following steps detail how the second testing was done:

1) Create room to drag the boat on the trailer out of the garage (the boat is used sometimes as storage in that garage. Stuff all around and on top of the boat needed to be moved to get the boat out of the garage)
2) Get three other people that are ready to to help with the testing
3) Remove wheel ramps that do not allow the boat to roll out of the garage
4) With the help of two other people, slowly roll the boat out into the driveway of the house
5) When there is enough room, stop the boat and insert the wheel ramps to keep the boat from moving anymore
6) Get up into the boat and raise the tower from its stand
7) Insert the required bolts and nuts on each side of the tower to make it stand
8) Assemble the device
    a) Pin through housing
    b) Ski eye connected to rope attachment with screwing in nuts
    c) Spring inserted into housing
    d) Spring cap connected on top of housing including bolts and nuts
9) Obtain stool from the garage and set up inside the boat to reach the tower
10) Bring device parts and half assembly into the boat
11) Attach top and bottom attachments to the tower by inserted screws in the back and middle parts of the device
    a) Rubber pieces that are ¼" thick are inserted in between the tower and device so that the device fits securely on top of the tower
12) Bring the first part of the assembly from step 7 and attach it to the top and bottom attachments that are already attached to the tower
13) Tie one piece of rope to the ski eye part of the device
14) Attach the other end of the rope to the top end of the spring scale
15) Grab another rope that has a wakeboarding handle and attach it to the bottom end of the spring scale
16) Make sure all the nuts, bolts, and screws are attached and tightened down to be safe
17) Set up a piece of paper with a table that is able to take data on

Now the actual testing can start

18) Have one or two people grab the handle on the piece of rope that is attached to the bottom end of the spring scale
19) Have that person pull on the rope until the flag starts to rotate
20) Repeat this step for 10 trials
21) Insert another spring and repeat the same process 10 times again
22) Repeat this trial for all 5 springs and record the data for each
23) Reset the device with the original spring
24) With the nest part of the test, pull until the spring scale reads 100 pounds and record at what angle the flag rotates down to
25) Repeat for all of the springs at 10 trials each
26) After the testing is done, detach the device by unscrewing all of the bolts and nuts and take the assembly out of the boat
27) Take the pins out of the side of the tower and slowly take the tower down and rest it on the tower stand
28) Take the stool out and clean up the boat for any dirt that may have gotten on the tower or seats
29) Push the boat back into the garage and set the wheel ramps at the wheels so the boat will stay in place
30) Take the paper with the data and insert into a computer on an excel spreadsheet
31) Thank your people for the help with the testing

With the device being used on the tower, there was little concerns for safety. The device was attached successfully where it would not move at all. Even pulling on the device did little to concern the people doing the test with any safety concerns. Once all of the screws, bolts, and nuts were securely tightened, there was no need to be concerned with the device falling off.

The second test ended up being a very successful test. More springs were tested and a spring that was able to work for the right amount of tension was found. Also, another factor was tested too. The angle that the flag rotates down was recorded for each. This gives more data and another aspect of what is good or bad about the project. The best part of the second test was being able to actually test the project on the boat and tower it was designed for. It was also good to see the device work at the projected angle of 26 degrees that a towing rope will actually pull on the device.

However, the flag also did not lower down as far as the device should. The flag really only rotated to an angle of 23 degrees. The reason for this failure is because the rope attachment is too long in the back part of the piece. It needs to be shorter in the back end of the piece so that it can react with the spring inside the housing at a higher spot and push the spring up higher which allows the flag to rotate down farther. Another idea is that the rope can be connected up higher on the hook. During one of the tests, the rope was held at the top of the ski eye. It allowed the flag to rotate down another 10 to 15 degrees. This paired with a shorter back of the rope attachment piece can allow the flag to rotate down another 20 to 25 degrees. This still does not pass all the way down to 90 degrees but it is a start. A final idea to get the flag to rotate down farther is to have the ski hook connected higher to the rope attachment. It is connected towards the middle of the rope attachment piece. The holes drilled in the rope attachment could be higher.

Deliverables:

The following tables illustrate the data that was obtained from both tests:

Test 1:

Test	1	2	3	4	5	6	7	8	9	10
Tension	200+	200+	200+	200+	200+	200+	200+	200+	200+	200+

Again this was the first test that ultimately failed. As you can see in the table, the person pulled on the device with as much power as he could. As the spring scale continued to read over 200 pounds of tension, the flag in the device would not move. This first test was seen as a failure as it did not meet the criteria set for the device and just for the testing.

Test 2:

Spring 1

Test	1	2	3	4	5	6	7	8	9	10
Tension	105	107	103	100	100	103	105	100	110	100

The first spring is the spring that ultimately met the requirements for rotating the flag at 100 pounds. It was the most successful spring out of the rest of the ones tested.

Spring 2

Test	1	2	3	4	5	6	7	8	9	10
Tension	80	77	70	72	70	73	75	77	82	77

The second spring ended up being a little too weak as far as the requirement it was designed for. The spring allowed the flag to rotate lower than 80 and just about 80 pounds of tension. This spring was the second most successful out of the 5 springs tested for.

Spring 3

Test	1	2	3	4	5	6	7	8	9	10
Tension	0	0	0	0	0	0	0	0	0	0

Spring 4

Test	1	2	3	4	5	6	7	8	9	10
Tension	0	0	0	0	0	0	0	0	0	0

The next two springs ended up being too small inside of the device. The length was not long enough inside the device to actually work. Therefore, each trial was made zero.

Spring 5										
Test	1	2	3	4	5	6	7	8	9	10
Tension	200+	200+	200+	200+	200+	200+	200+	200+	200+	200+

The fifth spring was the original spring that was tested for. It was thought that maybe having it on the tower and the rope reacting on the spring like it was designed for would allow it to work. However, the flag would still not rotate down even when the tension would go over 200+ pounds.

Spring 1										
Test	1	2	3	4	5	6	7	8	9	10
Angle	25	27	22	22	23	22	25	22	27	25

This second table shows the angle at what the first spring rotated down the flag. Obviously this test does not satisfy the requirements for the device or the testing. It was required to rotate all the way horizontal or 90 degrees. The angle shows how far down the flag rotated from horizontal.

Spring 2										
Test	1	2	3	4	5	6	7	8	9	10
Angle	33	35	37	32	30	35	33	32	30	35

This table shows how far down the flag rotated down with the second spring. Since the spring was weaker and looser than the first, the flag was able to rotate down farther. There is no table for the 3rd, 4th, or 5th springs because they did not work with this device.

Conclusion:

The two tests came with two different results. While the first test was a complete failure, the second test came away with some good results. There was not much data to be recorded with the first test because it was not a success. The second test had some data that was successful. A spring that allowed the 100 pounds was required and used. However, there was still some more bad news with the second test. The flag was not able to rotate down far enough because of how the rope attachment is built. The back part of the rope attachment needs to be machined down to allow it push the spring up farther and the flag down farther to horizontal.

Appendix H: Testing Documentation

Table 1: Mass of Flag Raising Device

Mass of Flag Raising Device				
Mass Limit	Estimated Mass	Measured Mass	% Difference	% Over Limit
30 lbs	23 lbs			

Table 2: Spring Tension Testing 1

Test	1	2	3	4	5	6	7	8	9	10
Tension										

Table 3: Spring Tension Testing 2

Test	1	2	3	4	5	6	7	8	9	10
Spring 1										
Spring 2										
Spring 3										
Spring 4										
Spring 5										

Table 4: Angle Testing

Test	1	2	3	4	5	6	7	8	9	10
Spring 1										
Spring 2										
Spring 3										
Spring 4										
Spring 5										

Appendix I: Testing Data

Table 1: Mass of Flag Raising Device

Mass of Flag Raising Device				
Mass Limit	Estimated Mass	Measured Mass	% Difference	% Over Limit
30 lbs	23 lbs	47.3 lbs	51.4%	36.6%

The Flag Raising Device ended up weighing a lot more than expected. When modeled in SolidWorks, the device was measured to be 23 pounds exactly. For some reason the device ended up weighing 51.4% pounds more than expected. The materials assigned for each piece in the device in SolidWorks were exactly the same or almost exactly the same as the material bought for each piece.

Table 2: Spring Tension Testing 1

Test	1	2	3	4	5	6	7	8	9	10
Tension	200+	200+	200+	200+	200+	200+	200+	200+	200+	200+

The first test on the device was testing the amount of tension in the rope that the flag started to rotate down. The device was hooked up to a bar and pulled on with a spring scale to test to see what amount of tension the flag started to rotate down. The device was designed for the flag to rotate down at 100 pounds of tension. The first test showed that the flag did not rotate even after pulling over 200 pounds of tension in the rope. The reason for this is the spring bought for the device was too strong. Some calculations must have been wrong on the analysis for the spring.

Table 3: Spring Tension Testing 2

Test	1	2	3	4	5	6	7	8	9	10
Spring 1	105	107	103	100	100	103	105	100	110	100
Spring 2	80	77	70	72	70	73	75	77	82	77
Spring 3	0	0	0	0	0	0	0	0	0	0
Spring 4	0	0	0	0	0	0	0	0	0	0
Spring 5	200+	200+	200+	200+	200+	200+	200+	200+	200+	200+

The second spring tension testing was done at the home of Josh Quintero. It was attached to the boat tower the device was designed for. After the first test was a failure, four more springs were obtained from Professor Beardsley as well as the spring scale again. Since the spring designed for did not work, more springs were acquired to test. The original spring was also tested to see if the values of tension would change when pulled on at an angle rather than pulled straight. The first spring tested ended up showing values around what the device was tested for. A second spring showed values that were just under what the device was designed for. Two of the springs ended up being too small for the device and therefore rotated with barely any amount of tension in the rope. The original spring showed the same amount of tension showed in the original testing.

Table 4: Angle Testing

Test	1	2	3	4	5	6	7	8	9	10
Spring 1	25	27	22	22	23	22	25	22	27	25
Spring 2	33	35	37	32	30	35	33	32	30	35

This table shows the second part of test two. This test was to show the angle of the flag when 100 pounds of tension was reacted in the rope. The requirement for the flag was that it would rotate a full 90 degrees or horizontal. The weaker spring or spring two showed a higher angle of rotation compared to the first spring.

Appendix J: Resume

Joshua R. Quintero

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OBJECTIVE

An internship where I can utilize my proficiency and interests in mechanical engineering and will provide me with a foundation for my future career interests.

EDUCATION

Bachelor of Science in Mechanical Engineering Expected June 2016
Central Washington University, Ellensburg, WA
GPA: 3.0

Relevant Coursework
Three-Dimensional Modeling
Engineering Project Cost Analysis

SKILLS

Computer: Microsoft Word, Excel, Access, PowerPoint, SolidWorks, CAD
Certifications: First AID/CPR, Food Handler's Permit, MAST Permit

WORK EXPERIENCE

Event Server, SwiftWater Cellars, Cle Elum, WA March. 2014 - Present

- Event services for over 300 people
- Work with team of 8 to 12
- Set up, cater, and take down events

Intramural Sports Supervisor, CWU, Ellensburg, WA September 2013 - Present

- Work on teams of 2 to 6
- Supervise up to 100 participants with 6 employees
- Set up and take down after each game
- On the hiring committee for sports officials, new supervisors, Graduate Assistant
- Promoted from Intramural referee after two years
- Deal with parents, participants, coaches with many conflicts
- Manage and execute referee trainings with up to 30 referees

Intramural Sports Referee, CWU, Ellensburg WA October 2011 – September 2013

- Work with crew of 2 to 4 referees
- Referee many sports including basketball, softball, dodgeball, flag football
- Deal with conflicts within games and after
- Set up and take down after each game