

High Accessibility Cabinet Insert

By

Matthew Leal



Table of Contents

High Accessibility Kitchen Cabinet Insert	1
Matthew Leal	1
Introduction.....	4
Motivation:.....	4
Function Statements.....	4
Design Requirements	4
Success Criteria.....	4
Scope.....	5
Benchmark	5
Project Success.....	6
Design and Analyses	7
Approach: Proposed Solution	7
Design Description.....	7
Performance Predictions	10
Description of Analyses	10
Analyses	12
Device: Parts, Shapes, and Conformation.....	15
Device Assembly	16
Methods and Construction	16
Solution Method.....	16
Construction.....	16
Renderings	18
Operation.....	18
Post Manufacturing Discussion, issues, and successes.....	18
Testing Method	20
Scope of Testing	21
Test Documentation and Deliverables	21
Budget/Schedule/Project Management	21
Managerial Approach.....	21
Cost and Budget.....	22
Schedule.....	22
Discussion	22
Project Progression	22

Successes.....	23
Learning through design iteration, and the future of this project	23
Conclusion	24
Acknowledgments.....	25
References	25
Appendices.....	26
Appendix A.....	26
Description.....	35
Assumptions.....	36
Model Information	36
Material Properties.....	37
Loads and Fixtures	38
Mesh information.....	39
Mesh information - Details	39
Study Results	41
Conclusion	44
Appendix C:.....	98
Appendix D:.....	100
Appendix E:	102
Appendix J:	105
Matthew Leal	105
Professional Profile.....	105
Accomplishments.....	105
Projects.....	105
Experience.....	106
Education	106
References	106
Public Profiles	106
Appendix X.....	107

Introduction

Motivation:

Watching grandparents and parents get older, it is clear that the struggle of day-to-day activities generally increases. One of the most recurring issues the older generation go through at least once a day is their inability to reach dishes, glassware, and other things on the topmost shelves in her kitchen. Not only is it difficult for them to use things such as stepstools, it also becomes increasingly dangerous, as with age, a fall from any height could be catastrophic.

With this scenario in mind, the need for an easily handled cabinet insert is extremely high. This insert will consist of two shelves that will unfold towards the user, and downward, significantly lowering the height at which the top shelf items are located.

This project also has the potential to help those with disabilities, such as those in wheelchairs, and overall lesser locomotive capability.

Function Statements

- This device must bring the contents of a high kitchen shelf to a lower level.

Design Requirements

This device must be able to do the following:

- Must hold a nominal weight of 15#, and a max weight of 30#
- Must lower highest shelf between to bottom of cabinet space.
- Must fit into a “standard” 27” x 16” x 11” cabinet space
- Entire unit must weigh less than 30# without load
- Must have a safety factor at least 1.5 on strengths of linkage arms
- Must assist user needed force to raise nominal load by at least 50%

Success Criteria

In order to consider this project a success, the device must successfully fit into a “standard” 27” x 16” x 11” cabinet. It also must completely lower the highest shelf to a comfortable height, which in this case, is to a level below the lowest shelf on the cabinet. It also must be easy to

operate, and assist the user in raising the nominal load by 50%. The forces necessary to move the assembly must comply with the forces predicted in the User Force Analysis (Appendix 9-11) up to within 10%.

Scope

For this project, the “cabinet” itself will be replicated with a wooden box built to the same specifications of the “standard” cabinet space in order to simulate the environment the insert would experience in the real world. Most of the parts, such as the physical shelf baskets themselves will be specc’d and purchased according to manufacturer specs on weight limits. All fasteners will also be specc’d and purchased according to manufacturer specs on strength limits, and also on what will be appropriate for the loads involved.

Also excluded in the “specs” of this assignment are the practicality of the shelf holding dishes. There will only a guard rod keeping the dishes from falling out, when in reality, there would be more of an aesthetically pleasing way of keeping the dishes in during transportation.

Benchmark

There are a few similar concepts on the market today that accomplish the same task. Most of these are electrically powered, and some use hydraulics to transport the load at hand. However, one cabinet insert that is only user powered is for sale on [kitchensource.com](http://www.kitchensource.com), and uses a similar “linkage” system to transport the load to the user. While there is not a lot of information on the way this product operates besides a short .gif on their website, I intended to mimic the descent pattern this device uses, as can be seen on this website.

<http://www.kitchensource.com/cabinet-organizers/rv-shelvingsystem.html>

Most of these are those that comply with the ADA for those with disabilities, so there will be quite a large variance between projects. The links below are a few benchmarks with similar design ideas to those that will be used in this project, along with an example in figure 1.

<http://www.barrierfree.org/accessible-kitchen/verti-adjustable-shelving>

<http://www.barrierfree.org/accessible-kitchen/approach-adjustable-cabinet/approach-adjustable-cabinet>

<http://www.eastersealstech.com/2014/06/04/accessiblekitchendesign/>

This benchmark does use a “gas-assist” technology, which seems to be referring to the gas spring seen in some of their photos.



Figure 1: ADA Benchmark.

Most of these benchmarks are electrically powered, which will be avoided for this project. However, overall design choices used for load bearing capabilities will be useful in the design choices for this project, along with the use of a gas spring.

Project Success

In order to quantify this project, a few crucial boxes must be checked off. One being the overall design function to “lower” the highest shelf to the same height of the lowest shelf. As the shelf is 27” tall, and the top shelf is 8.3” below that, the top shelf must completely lower at least 18.7” to achieve this. While numbers such as max load and overall design weight are slightly fuzzy, this is absolutely essential. It is also crucial that this project remain an “insert” so as to be able to fit into existing cabinets. The design must be completely powerless, and only use the users force inputs to move the shelves with the assistance of the gas spring. Success will come from a completely power-free design.

Design and Analyses

Approach: Proposed Solution

There are many ways to approach an issue like this. In order to lower the shelf insert to a comfortable height proposed in the function statements, the insert will use a user powered force, applied at a handle beneath the bottom shelf, to “pull” the shelf out of the cabinet, and downwards simultaneously. As can be seen in Appendix B-7, the user force will be transmitted through linkages between the shelf insert and its attaching face, along with the assistance of the gas spring.

Design Description

Due to the complex geometry involved in the multiple positions of the linkage arm and the shelf itself, the overall model was designed in Solidworks to be able to get the rough geometric relations in order. This was also crucial to ensure that the insert fit in the envelope of the cabinet. This generic model can be seen in figure 2.

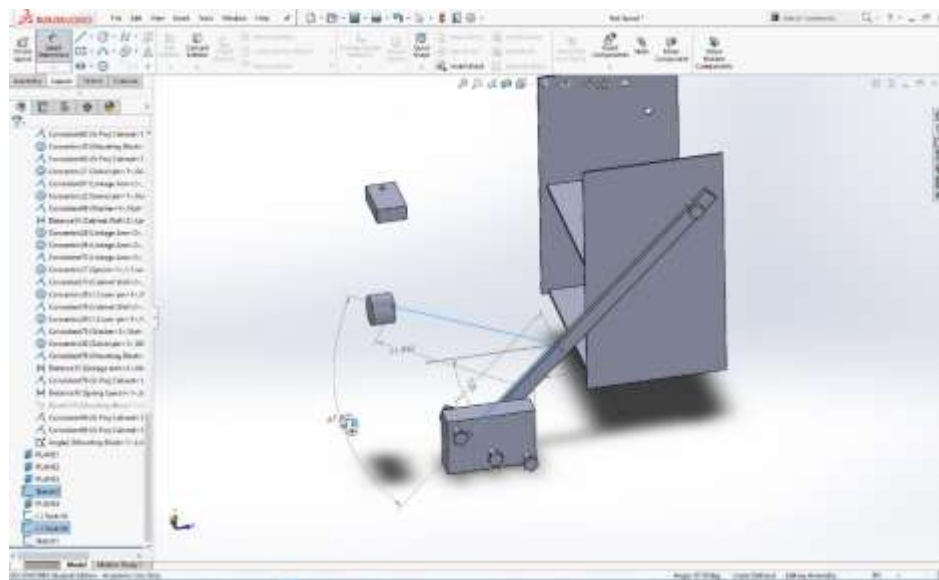


Figure 2: Geometric Solidworks Planning Example

This insert will be bolted onto the side wall of the existing cabinet (Appendix B-1) through a mount block. The shelving insert itself will consist of two shelves, each spaced 8 1/3" inches apart.

Using statics and strengths calculations to determine cross-sectional area and material selection, the 23" linkage arm will be bolted onto the shelves on one end, and the mount plate on the other (Appendix B-2). The attachment methods for the linkages to the body **MUST** allow for free rotation so the device motion can take place uninhibited. The device will be mounted to the body of the cabinet using "mounting plates", which will be attached to the sides of the cabinet walls.

In order control the descent speed of the shelf insert as it lowers into position, a gas spring will be specified and attached to the linkage arm, which will allow for it to assist the user in bringing a shelf into the upright position. This will work very similarly to how many gas springs are applied into the automotive industry, which is to apply a constant force through the duration of the stroke opening on the gas spring. This will be crucial in calculating the forces involved as the linkage arm swings. However, unlike the average "trunk-holding" gas spring, the gas spring used in this device will be a traction gas spring. Traction gas springs work the opposite way a normal gas spring does, as the natural force tends to want the spring to close, or pull-in (Figure 3).



Figure 3: Forces in a Traction Gas Spring

The device is stopped by a "stop" peg, or in this case, a bolt, and will use a "slide" to keep the gas spring from pulling up an empty shelf at an unwanted time. Both the stop and the slide will be mounted to the mounting plate will be on the mounting plate (Figure 4).

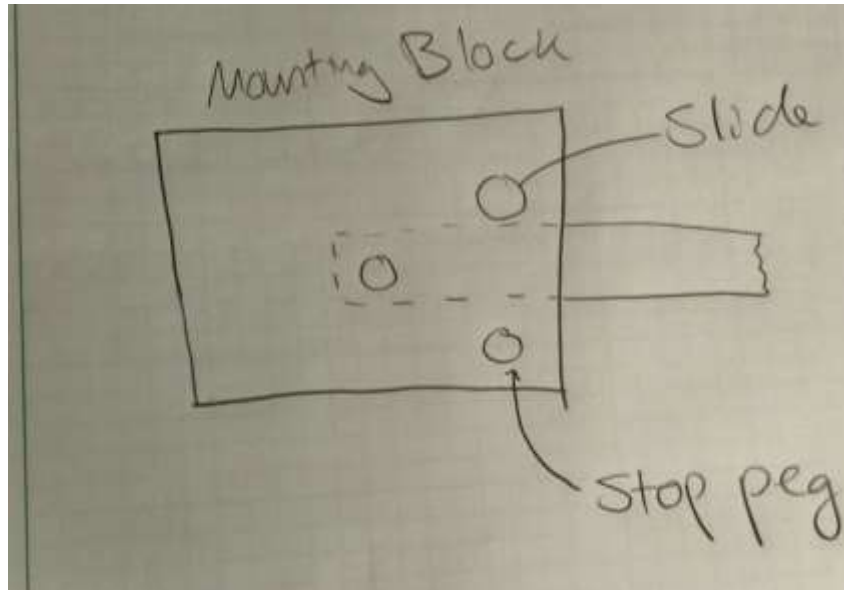


Figure 4: Basic Layout of Mount Block Assembly

The slide, which is a clevis pin in this case, allows the user to freely slide the pin back and forth, whilst being held in place by the cotter pin.

The mount plate, or mount box, acts as more of a spacer between the cabinet wall and the shelf insert. It also helps compensate for the forces acting on the forces caused by the shelf weight. This space is necessary to allow enough space for the spring to hang directly over the linkage arm. As the spring will be in the realm of 1" OD, it made sense for the mount plate to be slightly over 1" thick. The width and height of the mount plate were determined through geometric decision making so that the pin "stop", and the swivel pin, would have sufficient space. Due to this, the height and width of the mount plate are 6" x 3"

The mount plate will have two bolts going through it, bolting the mount plate to the cabinet wall, along with a swivel pin, and the slide. The bottom bolt, acting as a stop for the linkage arm, the "middle pin" acting as a swivel, in which the linkage arm will rotate about, and the top bolt helping hold the load that the entire system puts on the mount plate. (Figure 3).

The shelf insert itself consists of two "shelf walls", which are to be made from 1/8" 6061 aluminum sheet metal, as per the strengths calculations seen in Appendix A-16-18, will be screwed onto the shelf walls with two #4 machine screws (two to each wall, on each shelf side, eight total). After considering the strength equations applied in Appendix A-14-15, it would make sense to also make this shelf, then, out of the same thickness and alloy. However, as the shelf needs to be thick enough to accommodate #4 sized machine screws, a thickness of 1/4" was chosen.

Performance Predictions

The analyses provided in Appendix A 9-13 prove that the gas spring will assist the user in pushing the shelf up, and even dampen it on the way down.

The force the user must use to operate the system can be seen in Appendix A 31-33. These predicted forces will be within +/- 10% of the actual forces that will be used upon testing of this device (if estimated force is 100#, the actual force will be in the range of 90#-110#). This will indicate a successful analysis, and will signify the correct choice in gas spring.

Another very simple test that can determine whether or not the correct material and geometry were used for the loads involved. One can measure any sort of deflection in the load bearing linkage arms when at full load. If there is any deflection, then the load has breached the yield of the material, which is a failure in terms of this load bearing application.

Description of Analyses

In order for this project to achieve success, there are a few analytical aspects that must be solved early on. They can be broken down as such:

- Statics and Strengths on the linkage arms to determine linkage material and dimension
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Shear and moment diagrams.
 - Axial Stress
 - (6) $\sigma = Force/Area$
 - Shear Stress
 - (5) $\tau = V/A$
 - Bending Stress
 - (4) $\sigma = Mc/I$
 - Torsional Stress (non-circular cross section)
 - (7) $\tau = T/Q$
- Statics and Strengths on “mounting block” to determine material and dimensions
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Shear and moment diagrams.
 - Axial Stress

- (6) $\sigma = \text{Force/Area}$
 - Shear Stress
 - (5) $\tau = V/A$
 - Bending Stress
 - (4) $\sigma = Mc/I$
 - Torsional Stress (non-circular cross section)
 - (7) $\tau = T/Q$
- Statics and Strengths on fasteners to determine and spec necessary fastener sizes
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Shear and moment diagrams.
 - Shear Stress
 - (5) $\tau = V/A$
 - Bending Stress
 - (4) $\sigma = Mc/I$
- Statics and Strengths on “Slide”
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Shear and moment diagrams.
 - Shear Stress
 - (5) $\tau = V/A$
 - Bending Stress
 - (4) $\sigma = Mc/I$
- Statics and Strengths on Insert
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Shear and moment diagrams.
 - Axial Stress
 - (6) $\sigma = \text{Force/Area}$
 - Shear Stress
 - (5) $\tau = V/A$
 - Bending Stress
 - (4) $\sigma = Mc/I$
 - Torsional Stress (non-circular cross section)
 - (7) $\tau = T/Q$
- Determine necessary min/max force spring must exert on the system to allow for descent, but also to help the user push the shelf up.

- This uses equation 1 to sum moments about the linkage arm pin. This will show the force the user must exert on the system to overwhelm the natural moment caused without the stop bolt.
 - Summate forces in X & Y, along with moment (Equations 1,2,3)
 - (1) $\sum M = 0$
 - (2) $\sum F(y) = 0$
 - (3) $\sum F(x) = 0$
 - Spring force < Weight (in terms of moment about swivel point) (Appendix A 4-8)
- User force analysis
 - Determine how much force user must use to push up various loadings of the shelf
 - (1) $\sum M = 0$

Analyses

Gas Spring Speccking

Upon summing forces with the max load in Appendix A 4-8, it was determined that the spring force must always be less than 226lbs to allow for rotation. The next step to speccking a spring was inputting the various forces of each model, and choosing the one that was high enough to help dampen the descent/raise the shelf, but also not low enough to barely make a dent on the systems descent speed. As can be seen in Appendix A 9, a rough estimate of the users force of 5lbs was chosen as a target force for the user to have to generate to pull the device down. In order to achieve that, a spring force of 43 lbs was needed. However, upon searching for traction gas springs, the only available model was a 30lbf gas spring. A second analysis, using the 30lbf gas spring was completed to find the new user forces that would be necessary to pull down and push up a shelf at full load. In Appendix A 10, using the new 30lbf, the user will only have to generate 3.48lbf to initiate the descent of the shelf, and will require around a 20lbf push to initiate the gas spring at full load. However, due to the angle at which the gas spring acts on the link arm, this user force quickly decreases as the load moves up, to a low of 2.85lbf, well below the 50% threshold, as seen in Appendix A-11 and A-12.

User Force Analysis

A unique user force analysis was created in order to model how much force the user would have to put onto the system in order to close it, based on a specific load on the system (Appendix A 31-33). This user force was modeled by finding the moment the user would have to put on the system set the moment to zero. Once the user generated a force larger than said force, the system would begin to accelerate upwards. And, as the angle of the gas spring is at its most perpendicular to the linkage arm when the shelf is in its extended position, it will provide the greatest assist to the user. At the nominal weight of around 15lbs, the user will only have to generate 3.6lbf to trigger the ascent of the system. This is a huge success, as it cuts the users force input by 5x (Appendix A-32). While speccking out the gas spring for this purpose, and poor communication from the manufacturer, there is some doubt that the gas spring will mount to the back of the cabinet so as the “angle” in which the spring force acts on the link arm is exactly the

same angle used in these calculations. There are discrepancies with the way the fasteners will fit, the angle at which they will rotate, etc. These are things that will be cleared up upon the assembly. The exact angle can be more accurately measured once the assembly is fully put together. At that point, the calculations will be done with a more exact angle, which will tighten up the accuracy of this analysis.

Linkage Arms

With the spring force now clearly identified, it was possible to summate forces, and do statics and strengths equations for the linkage arms in both the extended and retracted positions. These two positions were chosen, as the retracted position will put the most axial stress on the system, and the fully extended will put the most bending stress on the linkage arm, as the weight of the shelf is fully perpendicular to the linkage arm. The max stress seen through analysis of both positions was seen as the bending moment (4) in the open position, and the torsional stress caused by the shelf. Combined stresses in this link arm showed this stress, being 19438 psi, was the driving factor in the material choice (Appendix A-27). Originally, there was a plan to use 4140 steel for this application, but upon sourcing material, it was clear 1018 was the cheaper, more readily available alternative with very similar mechanical properties. 1018 steel was chosen for its very high yield strength. This will ensure there is absolutely no yield in this device, which is essential, as a critical failure of the use of this device could cause injury.

Mount

According to the Solidworks analysis posted in Appendix A, with the stresses put on the mounting block (Appendix A-8), the mounting block accrues a max stress that still allows for a safety factor of around 70 on the block. This Solidworks analysis can be backed up with the forces found through hand calculation in Appendix A 1-3

Shelf & Shelf Walls

In the initial design for this project, shelves were planned to be built from aluminum sheet and plate. As the design called for a 60lb max load, proper strengths analysis of the material was performed in good practice. However, since many wooden shelves serve the same purpose of holding a small number of dishes, and at a fraction of the cost of aluminum, it made a lot more sense from an economic standpoint to manufacture shelves out of wood. Below, the results of the analysis for the aluminum shelves can be seen, which is proof of good engineering practice for a loading scenario such as this.

To find the proper materials needed to withstand the loadings of the system, statics and strengths equations were applied to the shelf geometry in order to optimize material choices (Appendix A 14-18). The max stress (4) in the shelves, under max load, was found to be 2.7 ksi (Appendix A 15). This led to the choice of 6061 Aluminum to be used for this shelf's material, as it is around 10x under the max yield of this alloy. The max stress (5) in the shelf walls, under max load, was found to be 2.7 ksi, so the same material choice was made. The same logic applied here as to the

link arm and the mount, where only having to source one material type (6061 for both the shelves and shelf walls) was the easier choice.

Slide

The statics and strength calculations for an empty shelf pushing against the slide were completed in Appendix A 28-29. The optimal cross-sectional area was decided on after finding a max bending stress (4) that was well under a material's yield. Originally, a turned down piece of aluminum was going to be used for this slide. However, a much easier solution would be to use a clevis pin. A zinc plated low carbon steel clevis pin was chosen for ease of purchase and cost. The analysis in Appendix A page 29 show that the stresses acting on this pin will create a stress that is less than half the yield for the material. This is more than acceptable for this application.

Fasteners

The analysis of the fasteners for this project were incredibly important, as a large amount of force will be put on both the stop bolt and the swivel bolt. In the fully extended position, there will be close to 400 lbs of force on both of these bolts (Appendix A-20). To accommodate, strengths calculations were used on both bolts in order to find the minimum acceptable diameter necessary to handle these forces. As grade 8 bolts were to be provided for this project free of charge, it was a natural material choice to use for these calculations. After applying strengths calculations to this material based on the forces in Appendix A-20, and an assumed safety factor of three, it was found that the minimum diameter necessary to accommodate these forces was 0.05". However, in order to have a bolt that stuck into the mount block (threaded portion) and to have a bolt with a machine finished shoulder long enough to allow the link arm to swivel about, a 1/2" diameter 2" long grade 8 bolt was chosen, as nominal sizes would not allow a small diameter with the proper shoulder lengths. Reapplying strengths calculations to the bolt with a 1/2" diameter showed a very small 2ksi, which proves this diameter is overkill, but necessary (Appendix A-36).

The analysis of the "stop bolt" proved that a larger diameter was necessary to accommodate the large moment the 400lb force placed on the bolt. After applying strengths calculations, and assuming a safety factor of 3, a minimum diameter of 0.59" was found to be required for this application (Appendix A-37). A 5/8" diameter bolt was chosen for this application, leading to a safety factor of 3.5 for the loads in play here.

This setup caused a moment that must be resisted by the mount block. If not, the mount block would naturally tip over clockwise. To prevent this, a design decision was made to add another bolt that is there to provide stability and resist said moment using its tensile strength. The magnitude of the moment, and the ratio both the stop bolt and this bolt resist said moment, can be found in Appendix A-39,40. In order to resist this moment, a minimum diameter for this bolt was found to be 0.0935". However, in order to find a standard bolt that is long enough for the application here, a 1/4" diameter grade 8 bolt was chosen, causing a rather large safety factor of 21.5 (Appendix A-41).

With the new found axial force on the stop bolt after the previous analysis, a mohrs circle analysis was placed on the stop bolt, as it now contained shear and normal stresses (Appendix A-42). Even with the new found axial loading, there will still be a safety factor of 3.46 on this bolt.

Force analysis was necessary in order to find the minimum diameter of the machine screws necessary to screw the shelf onto the shelf walls (a weld was possible, but if this were to be a consumer product, it'd have to come in a small package, and be assembled in this way). At this point, the decision was made to have a screw with at least 1/4" of length to be able to go all the way through the shelf wall, and into the shelf a decent amount. While a very small minimum diameter was found to be necessary, a much larger diameter screw will be used, as otherwise, it would be very difficult to drill and tap a hole smaller than a #4 hole (Appendix A-34). Because of this, a #4-40 screw will be used to mount the shelves to the shelf wall.

A word on steel alloy choice

The analyses in this report were made with 4140 steel in mind; an arbitrarily chosen grade of steel to predict the safety values (N) that the stresses placed on both the linkage arm and mount block. However, upon sourcing materials for these parts, it was clear that 1080 cold rolled steel was much cheaper, and much easier to source more specific stock that would meet the requirements for this project. The yield strength of 4140 is 60,200 PSI, and the yield strength of 1080 cold rolled is around 70,000 PSI. Since these two yield strengths are so similar, and in fact, the new material choice has a higher yield strength, it is the clear decision that this last minute material switch would be more than appropriate for these two parts (AISI 1018 Steel, Cold Drawn).

A word on aluminum alloy choice

The analyses in this report were made with 3003 aluminum in mind, which also was arbitrarily chosen grade of Aluminum which allowed the ball-parking of safety values (N) for the stresses placed on the shelves and shelf walls. However, upon sourcing materials for this project, it was clear that 6061 was both cheaper and more readily available for the intended use in this device. The two yield strengths for 3003 and 6061 are different, as 3003 has around an 18ksi yield, and 6061 has a much higher yield of around 40ksi according to Matweb. This last minute decision to switch to 6061 has simply doubled the safety factors involved in the design of the shelves and shelf walls. As this might call for a redesign, the 1/4" thickness of the shelf was chosen for fastener mounting purposes, so going for a smaller cross-sectional area would not be an easy possibility. In the future, however, there is a likelihood the 1/8" shelf walls could be reduced in cross-sectional area due to this jump in yield strength, and most likely, a thinner sheet of aluminum could be used.

Device: Parts, Shapes, and Conformation

This device consists of

- 1x shelf

- 1x housing
- 1x linkage arm
- 1x gas spring
- 1x mount plate
- 1x ¼" x 3 1/2" grade 8 bolt (mount block support bolt)
- 1x ½" x 2" Grade 8 bolt (swivel bolt)
- 1x 3/8" shoulder bolt (shelf swivel bolt)
- 8x washer and nut combos

All geometry can be seen in of fit and parts can be seen in Appendix B 8-17.

Device Assembly

This device consists of the parts listed above. All parts will be secured to one another with the fasteners listed within the appendix. The spring will be mounted to the back of the cabinet, and the other side will be mounted to a hole drilled into the linkage arm

Methods and Construction

Solution Method

This project was designed and analyzed for success at CWU, using the resources available in the MET department. All parts will be manufactured per drawings, which can be seen in Appendix B.

Construction

In order to achieve the design for this device, the linkage arm, mounting block, shelves, shelf walls, and shelf rods, will all be machined out of raw stock. All of the machining required for this project is all possible in thanks to the machine shop located in Hogue Tech. The gas spring will not be manufactured, and will be purchased through a third party manufacturer.

The insert environment itself will be manufactured in the woodshop using scrap wood, as the design of that environment is not within the engineering scope of this project.

All of the fasteners, washers, nuts, spacers, and e-clips will be provided as a donation from Fastenal.

The “mounting block assembly” will consist of two bolts, one swivel pin, three washers, three nuts, and one spacer (bushing) to provide the correct spacing between the block and the linkage

arm. The slide will then be inserted into the machined hole in the mounting block, and will be secured in with a pin inside the insert environment. This assembly will then be bolted into the design environment, as seen in Appendix B 1-2.

To attach the gas spring to the device, two threaded holes will be machined into the linkage arm, as per Appendix B-8, and into the back board of the environment, as both ends of the gas spring have A3 threaded fittings.

The shelf will be screwed to the shelf walls with 1/8" machine screws, and will then be fitted to the linkage arm via a swivel pin. The linkage arm will then be fastened to the swivel pin going through the mounting block as can be seen in Figure 5.

According to Appendix E, device construction should take around 120 hours. This is due to the large amount of machining necessary to construct the various parts in this system. Also, the construction of the wood environment in a separate wood shop in which I will need to work around times will contribute a lot to that amount of time.

The final construction will resemble figure 5.



Figure 5: Constructed Device.

Renderings

Current renderings for all parts can be found in Appendix B 8-17. The parts will consist of the following:

- Mounting block assembly
 - Mounting block
 - Swivel bolt (1/2" x 2" Grade 8)
 - One 1/4" bolt
 - One 5/8" bolt
 - Three washers
 - One spacer
 - Two nuts
 - Slide
- Linkage arm assembly
 - Two washers
 - Swivel bolt (Shoulder Bolt)
 - Two Nuts
 - One spacer
 - Gas spring fastened to hole (Appendix B-32)
- Shelves
- Housing

Operation

The device will begin in its “closed” state, meaning the linkage arm will be perpendicular to the bottom of the cabinet environment, and the shelf will be fully inside the environment. To begin the descent, the user will pull down on the handle on the bottom shelf. This will begin the gas spring-damped descent of the shelf. Once the shelf is stopped by the stop pin/ bolt, the descent is complete, and the device is in its “opened” state. At this point, the user will push the slide into place, effectively locking the device. Once the user is done loading/unloading the device, the slide can be removed, and the gas-assisted shelf can be pushed back upwards into the closed state.

Post Manufacturing Discussion, issues, and successes.

Overall, the manufacturing for this project was estimated to be around 23 hours, and ended up being around 38 hours, nearly double the original estimate. This was due to the excessively long amount of time dedicated to machining the mount block correctly.

Mount Block – During the machining operations seen on the mount block, the threaded hole was threaded in the wrong direction through the mount block, after all four holes had already been machined. Below, the hole layout for the mount block can be seen in Figure 15.

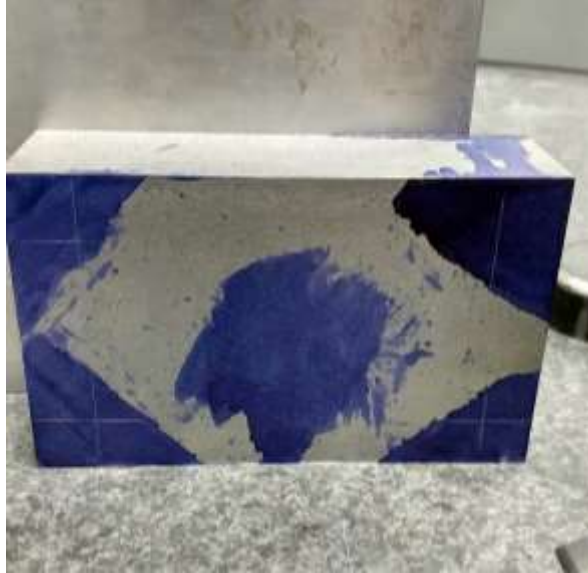


Figure 15: Mount Block hole layout

To machine the stock for the mount block down to the correct thickness, a lot of material had to be taken off. By hand, this would have taken many hours of painstaking precision and effort. Instead, a CNC Mill program was written to perform the necessary face milling. A copy of the written program can be seen in Appendix X. This program was run many times, each time with the Z height offset changed to cut to the correct depth. By running this program 10 times, it took the correct amount of material off the part. Figure 16 shows the mount block during the CNC milling operation.



Figure 16: CNC Mill Op

Shelves and Housing – The manufacturing of the shelves was quick and painless, using wood glue and a nail gun to fasten the wood together. This was much cheaper and faster than the original plan to manufacture the shelves from aluminum. Figure 17 shows the stock wood used to create both the shelves and the housing.



Figure 17: Housing and Shelf stock

Future Improvements – There are many improvements that can be made to the manufacturing process to improve efficiency and make the entire process more lean. For example, a CNC program could be written to face mill the stock down to size for the mount block, and then drill the holes. This would not be a time-consuming program to write, and would save hours on the manual drill press.

Purchasing the correct stock would also save an immense amount of manufacturing time, as if the correct stock with the correct thickness were to be purchased, an entire manufacturing step could be skipped.

Testing Method

As per the user force analysis described in the Introduction, the force the user needs to begin the shelf descent must be cut in half. This will be a little tricky to measure, but can be done simply with a scale (spring scale), which will be placed between the user force (users hand) and the shelf bottom. When the user pushes up on the scale, it can be read as soon as the shelf starts moving, indicating the force placed on the shelf for it to begin descending. This force must also come within 10% of the predicted force needed to raise the device to be able to be considered a success (Appendix A 31-33).

Scope of Testing

Testing the success of this project will be very straightforward. Test one will consist of a simple “max load” test. In this test, the device will be loaded to its maximum load, and if it can be successfully operated with no material or overall failure, it can be considered a success.

Test two will test whether or not the “slider” holds down the empty shelf efficiently.

Test three will test the behavior of the gas spring, and to see if the right spring was chosen for this application. This will be done by measuring the amount of force the user must “push” on the shelf with a full load, and see if it is less than if there were no spring there at all.

Once the force requirements from the user are taken, they will be cross-examined either through calculating the required force if the spring weren’t there, or physically taking the spring out, and testing the force required without the spring assistance.

Test Documentation and Deliverables

The push force required from the user on a full load will be recorded, as will subsequent forces at loadings of empty, in increments up to max load.

Load	Force required
Empty (0#)	
5#	
10#	
20#	
30#	

Budget/Schedule/Project Management

Managerial Approach

Assuming all R&D is complete, and only the manufacturing is required, every part will be manufactured in the order that makes sense. This means that parts that join together (i.e. pins through holes, etc) will be manufactured around the same time to ensure fit, so the manufacturer will not have to go back later, re-set up machines, and fix the issues. This means if a pin is meant

to go through a hole, the pin will have already had to be made, so that while the hole is being manufactured, an active “on-site test” will be done to ensure fit. If there are any issues, the manufacturer will be able to fix the issue with the current machine set up.

Cost and Budget

A parts list can be seen in Appendix C, which details description. Sources and costs can be seen in Appendix D. Some parts will be donated by various companies. For example, Fastenal will be providing all fasteners, nuts, and washers that will be needed for this project. These will be completely free of cost.

The cost of this project will be supported by the designer completely, aside from those pieces being donated, or any material which may be found to be in excess in the MET department.

Labor costs are estimated to be minimum wage in WA (\$9.47/hr), and with labor being estimated at 120 hours, total labor costs will be \$1136.4.

The total cost of this project is estimate to be around \$1400 (with labor), and around \$150 without.

Schedule

The current schedule for design, build, and testing, can be seen in Appendix E. The total predicted time for project completion is around 287 total hours.

Discussion

Project Progression

Throughout the development of this project, the main design changed many times. Upon careful inspection of the benchmark for this design, the first design consisted of two “link arms”, with one on each side of the shelf unit. However, this would’ve required two gas springs in order for no torsional stresses to build in the link arms due to the gas spring force. Looking through prices of gas springs, the design goal turned into being able to create the device with only one link arm, and in turn, only one gas spring. This, however, turned into a very large struggle, as having only one link arm caused a large amount of torsional force to build on the link arm and the mounting block. While it was difficult to account for the complex combined loading caused by this one-

armed setup, it cut the costs greatly by only needing one link arm, one mount plate, and one gas spring. The complex loading, however, has led to some very complex stresses that come into play when the device is fully extended. This caused the need to go to FEA for the mount block.

Another issue that has slowed the progress of the project is the seemingly incorrect spec'ing of the gas spring involved in lowering and raising the device. At first, an 80lb spring was spec'd when it seemed reasonable for the user to have to generate close to 15lbs of force to open and close the shelf. Upon testing the device, and the force required to lower the lever arm, it was clear that this theoretical force was much too high for this application. Because of that, a new way of analyzing user input force was used (INPUT CITATION), and thus, a new, much lower gas spring was used. If the correct analysis was used the first time, the project would have been overall cheaper, as multiple springs would not have been necessary to purchase.

Successes

Overall, there were many successful ideas that came out of the many iterations this project went through. At first, the idea was to use an extension spring to dampen the descent speed of the shelf, along with helping the user push a full load up. This led to countless frustration, as for one, an extension spring would be utterly aesthetically displeasing. The main problem with this idea, however, was the need to track the amount of "pull force" the spring would be exerting on the system as it was extending, as the force of a physical spring is defined by the length of its extension. This made spec'ing a spring for this nearly impossible. The "eureka" moment for this problem came when observing a car trunk being held open by a gas spring.

Further research into gas springs led to the choice of a traction gas spring, which has a constant pull-in force, which solved the problem caused by having a physical spring with a constantly changing force. This allowed for a constant force acting on the link arm, which also allowed for all strength calculations for said link arm to be completed with accuracy.

Another huge issue that came to mind halfway through the project came from the simple fact that that gas spring pull-in force would always be acting on the link arm. Due to this force, the arm would be pulled up when the shelf was empty (as the load on the shelf usually overpowered this force). After weeks of redesign ideas, the simplest solution became key. Simply, put a sliding stop over the link bar when in its lowered position to prevent any unwanted travel when empty.

At first, the stop bolt, the clevis pin slide, and the swivel bolt were originally planned to be turned down pieces of metal. However, upon fastener research, the decision was made to replace these machined parts with fasteners. This eliminated the need for any machining, and provided a very cheap alternative.

Learning through design iteration, and the future of this project

Towards the end of this project design timeline, there were many design choices made that, in the future, would most likely be revised. The biggest one being the choice of using only one link arm to support the shelf. The torsion caused by this setup was a nightmare to model, and ended

up putting stresses on the system that simply could've been avoided had there been two link arms. In an attempt to save money in material, the design was made less efficient than it could have been.

If this device were actually to go into production, a dual link-arm system would be implemented that would greatly reduce the necessary thickness of the mount block, and most likely, the link arm. While it would require more material, and two gas springs, it would simply be much more efficient, and might even save cabinet space, despite the logic that only one link arm system would take up less space than two.

A different way of mounting the block to the cabinet would also be required in a commercial production, as the user most likely would not like to see two giant bolt heads sticking out of their cabinet.

The shelf design itself would also most likely be changed to be more aesthetically pleasing, and the shelves would have a lip implemented on them so shelf contents would not fall out of the shelf. However, the shelf aesthetic design was not necessarily in the scope of this project; only the necessary material choices to handle the stresses placed on them.

The overall gas spring/rotational analysis was difficult, as the angles that the load and spring forces act on the rotational motion of the link arm are constantly changing throughout the movement path of the arm. This was a tough thing to balance, as a spring that might be great for helping the user push a load up might be too strong, and prevent the user from pulling the shelf down, or even become dangerous as the strong spring force could rip the shelf upwards if not properly locked down, resulting in injury. Per the ASME Engineering Ethics standards, safety is above all, the top priority. Due to this, the effectiveness of the gas spring in raising the load was hindered to ensure that if the user did slip and release an empty shelf from the lowered position, it would not snap up quickly and injure the user.

Conclusion

At the end of Fall quarter 2016, all research, design, and analysis, are complete for the High Accessibility Kitchen Cabinet Insert. It was crucial to complete all stress analysis accurately to ensure that no part would yield at any point during the operation of this device, as any failure with high weight loads could result in injury to the user. By completing accurate analysis, the correct material and material sizes were chosen with a high level of confidence. While the original critical design requirement of reducing the force the user must exert on the system by 50% at a nominal weight, it appears, according to predictive analysis, this force was reduced by much more than 50% around the optimal weight. This is a tremendous success, but will only be considered true success upon the accuracy of the predicted performance vs. the actual performance. The user force, being the predicted performance value, must be within 10% of the actual user force measured during the testing of this design. If these values do lie within this range, then the project can be measured as a complete success.

Acknowledgments

This project would not have been possible were it not for the resources and guidance available for reference at CWU. A special thanks to professors Pringle, Johnson, and Bramble for design and analysis help, and the constant feedback necessary for success throughout fall quarter. Matt Burvee was also key in helping guide this project, especially in regards to the use and function of traction gas springs. The feasibility of machining the parts involved in this project were guided by both Burvee and Bramble, leading to many design decisions being changed in regards to machinability.

All fastener research and design would not be possible without Steve Leal, regional manager at Fastenal, who provided guidance in special types of fasteners that would be critical in the function of this device. Fastenal also provided all fasteners and fastener accessories free of charge for this project.

References

Works Cited

"AISI 1018 Steel, Cold Drawn." *AISI 1018 Steel, Cold Drawn*. N.p., n.d. Web. 23 Nov. 2016.

"ASM Material Data Sheet." *ASM Material Data Sheet*. N.p., n.d. Web. 23 Nov. 2016.

AZoM, Written By. "AISI 1018 Mild/Low Carbon Steel." *AZoM.com*. N.p., 13 July 2013. Web. 23 Nov. 2016.

AZoM, Written By. "AISI 1018 Mild/Low Carbon Steel." *AZoM.com*. N.p., 13 July 2013. Web. 23 Nov. 2016.

AZoM, Written By. "AISI 4140 Alloy Steel (UNS G41400)." *AZoM.com*. N.p., 11 July 2013. Web. 23 Nov. 2016.

AZoM, Written By. "Aluminum / Aluminium 3003 Alloy (UNS A93003)." *AZoM.com*. N.p., 11 June 2013. Web. 23 Nov. 2016.

"Gas Springs." *Gecea RSS*. N.p., n.d. Web. 23 Nov. 2016.

@MetalSupermrkts. "7 Things to Consider When Choosing an Aluminum Grade | Metal Supermarkets." *Metal Supermarkets - Steel, Aluminum, Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze, Copper*. N.p., 09 May 2016. Web. 23 Nov. 2016.

@MetalSupermrkts. "What Aluminum Grade Should I Use? | Metal Supermarkets." *Metal Supermarkets - Steel, Aluminum, Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze, Copper*. N.p., 09 May 2016. Web. 23 Nov. 2016.

"Rev-A-Shelf "Premiere." *Www.kitchensource.com*. N.p., n.d. Web. 23 Nov. 2016.

"Section Modulus Equations and Calculators Common Shapes." *Engineers Edge - Reference Data for Engineers*. N.p., 05 Mar. 2013. Web. 23 Nov. 2016.

Springs, Industrial Gas. "Calculating Gas Spring Sizes - Industrial Gas Springs." *Calculating Gas Spring Sizes / Industrial Gas Springs*. N.p., n.d. Web. 23 Nov. 2016.

Springs, Industrial Gas. "Damped Gas Spring - Industrial Gas Springs." *Damped Gas Spring / Industrial Gas Springs*. N.p., n.d. Web. 23 Nov. 2016.

2, Page 1 Of, 2016 Date: November 16, Rev-03, and Strip.bo.hki. *Product Standard Socket Head Shoulder Screws, Knurled Head, Black Oxide* (n.d.): n. pag. Web.

Appendices

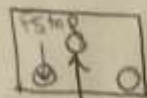
Appendix A

Mount Block analysis

Given: Highest σ occurs in mt Block when Link arm is extended (high Bolt forces)

- Bolts cause a torsional shear stress on mt Block from front

M_y F M_x resists moment caused by Bolt

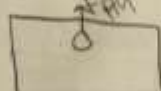
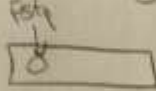


Back Bolt will be mounting Block to cabinet using its tensile strength

F_{pin}

- Break each hole down individually, so this analysis will look like

Side



Front

M_y

F

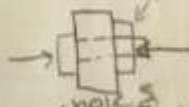
hole 1

M_x

F_{pin}

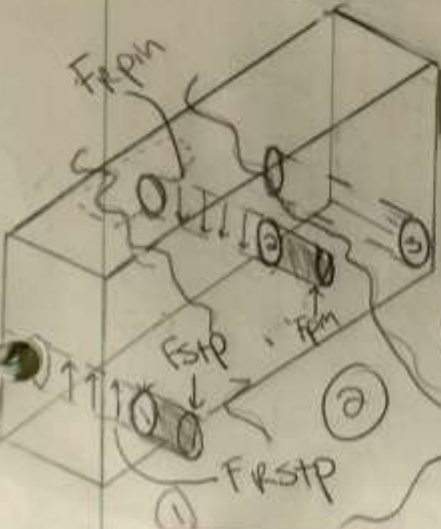
hole 2

(into page, 2)



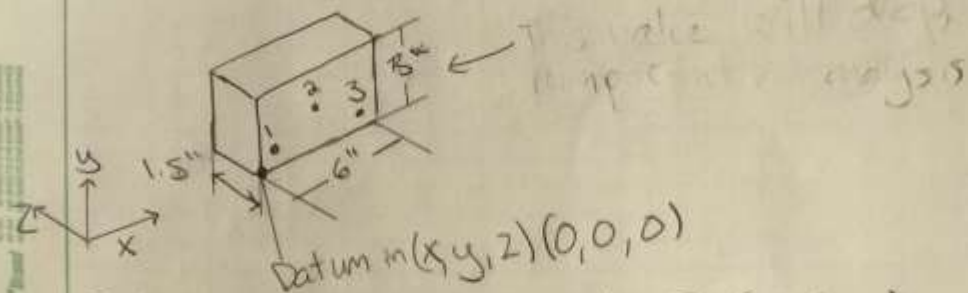
(this force prevents mt Block from tipping due to T caused by Bolt forces)

Analysis Broken Down into 3 parts



A-2

* Once stresses in sections 1, 2, & 3 are found, take to FEA in SW & compare values



① $(\frac{5}{8}, \frac{5}{8}, 0)$ ② $(3, 1.5, 0)$ ③ $(3, \frac{5}{8}, 0)$

①

Bolt in hole 1 has 396 lb of force

Find) Moment Block must use to resist Fpm (396 lb)



$$\sum M = 0$$

$$396(1.5) - M_R = 0$$

$$M_R = 594 \text{ lb}\cdot\text{in}$$

Matt Leal

A-3

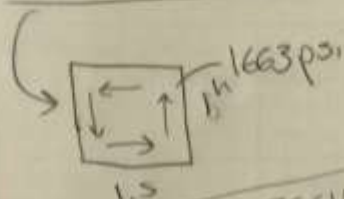
Given) $M_p = T = 297 \text{ lb}\cdot\text{in}$

Find) τ_{shear} acting on block

Soln

$$\tau_{\text{shear}} = \frac{T}{Q} = \frac{297 \text{ lb}\cdot\text{in}}{\frac{bh^2}{3} = 1.8(h/6) \cdot 51.8(1/1.5)} = \frac{\text{say}}{1.8(h/6) \cdot 51.8(1/1.5)}$$

$$\tau_{\text{shear}} = 1663 \text{ psi}$$



1.5h

b

while full height of Block is

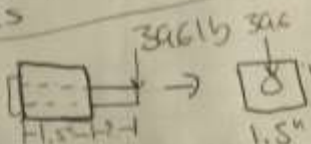
3h



The shear force of the bolt is more accurately modeled by two x-act areas

the height here is ≈ 1

Given)



Find) τ_{xy}

Soln

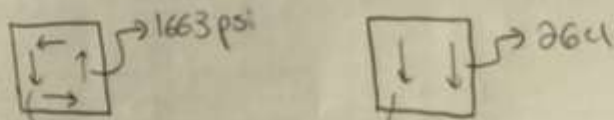
$$V = 396 \text{ lb}$$

$$\tau_{xy} = \frac{V}{A} = \frac{396}{(1 \times 1.5)} = 264 \text{ psi}$$

A-4

Given) $\tau_{xy} = 1663 \text{ psi}$ $\tau_{xy} = 264 \text{ psi}$

Find) τ_{max}



Soln

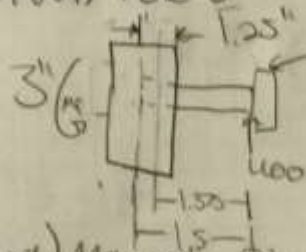
add the shear

$$\tau_{max} = \tau_{xy}, \tau_{xy} = 1663 + 264 \text{ psi} = \boxed{1927 \text{ psi}}$$

Matt Lal

A-5

Given) hole 2



Bolt doesn't go all the way through block

Find) Moment Block must resist 400 lb force

Soln

$$\sum M = 0$$

$$-400(1.5) + M_R = 0$$

$$M_R = 600 \text{ lb}\cdot\text{in}$$

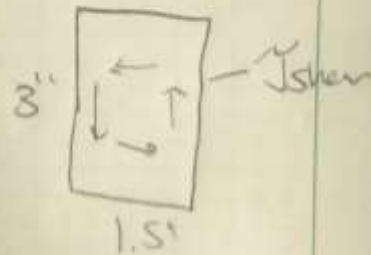
Given) $M_R = T = 600 \text{ lb}\cdot\text{in}$

Find) τ_{shear} acting on Block

Soln

$$\tau_{\text{shear}} = \frac{T}{A} = \frac{600 \text{ lb}\cdot\text{in}}{\frac{bh^2}{3}} = \frac{600}{\frac{3(1.8)(\frac{3}{4})^2}{3(1.8)(\frac{3}{4})}} = \frac{600}{3(1.8)(\frac{3}{4})}$$

$$\tau_{\text{shear}} = 293.333 \text{ psi}$$



Matt Leal	A-6
----------------	-----


Given) $\begin{array}{c} 400\text{ lb} \\ \downarrow \\ \square \\ 1\text{ s} \end{array}$


Find) τ_{xy}

Soln

⑤ $\tau_{xy} = \frac{V}{A} = \frac{400}{(5 \times 5)} = \boxed{80 \text{ psi}}$

Given) $\tau_{100} = 203 \text{ psi}$ $\tau_{xy} = 80 \text{ psi}$





Find) τ_{max}

Soln

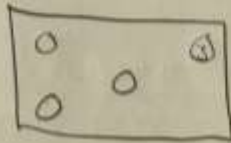
$\tau_{max} = 203 + 80 = \boxed{382 \text{ psi}}$

Matt Leal

A-7

So, These stresses on the Block are much less than the Syst. However, I want to make sure as this is complex loading and analysis, go to SW to analyze.

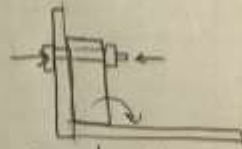
Design Philosophy



hole 3 will be added to the Block as a factor of safety, just to cover the blocks natural tendency to flip this way



due to loading. It will be placed in this pos to help prevent the block flipping



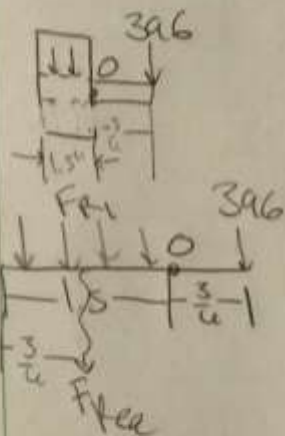
- The tensile strength will ensure the block won't flip.
- The hole & Bolt will match hole / Or ease of machining & bolt sourcing
- will alleviate tensile force on Bolt in hole (since theres already a large shear force on it)

Matt Leal

$T_1 \frac{16}{in} = A-8$

Given) $F_{sp} = 396 \text{ lb}$

Find reaction force F_R in mt Block hole 1



$$\sum M_0 = 0$$

$$396(3/4) = F_R(3/4)$$

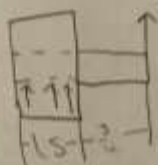
$$F_{Re} = 396 \text{ lb}$$

$$F_R = \frac{396 \text{ lb}}{1.5 \text{ in}} = 264 \frac{\text{lb}}{\text{in}}$$

Use in SW analysis

Given) $F_{pm} = 400 \text{ lb}$

Find) reaction F in mt Block hole 2



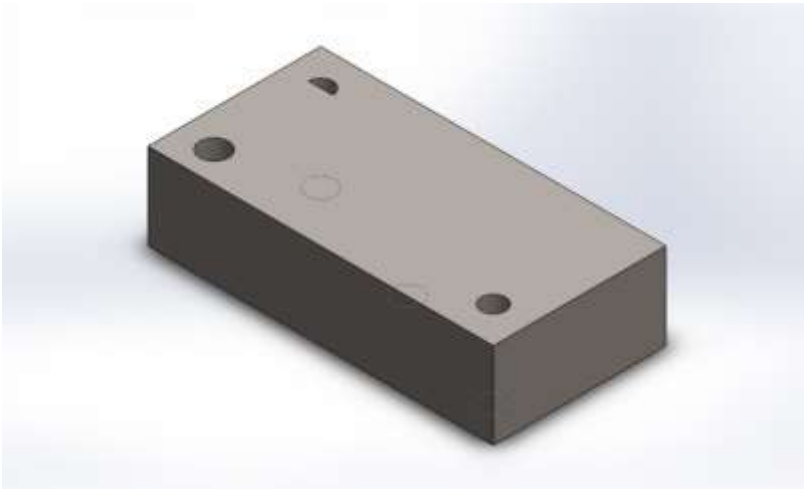
$$\sum M_0 = 0$$

$$400(3/4) = F_R(3/4)$$

$$F_{Re} = 400 \text{ lb}$$

$$F_R = \frac{400 \text{ lb}}{1.5 \text{ in}} = 267 \frac{\text{lb}}{\text{in}}$$

Use in SW analysis



Simulation of Mounting Block

Date: Saturday, November 12, 2016
Designer: Solidworks
Study name: SimulationXpress Study
Analysis type: Static

Table of Contents

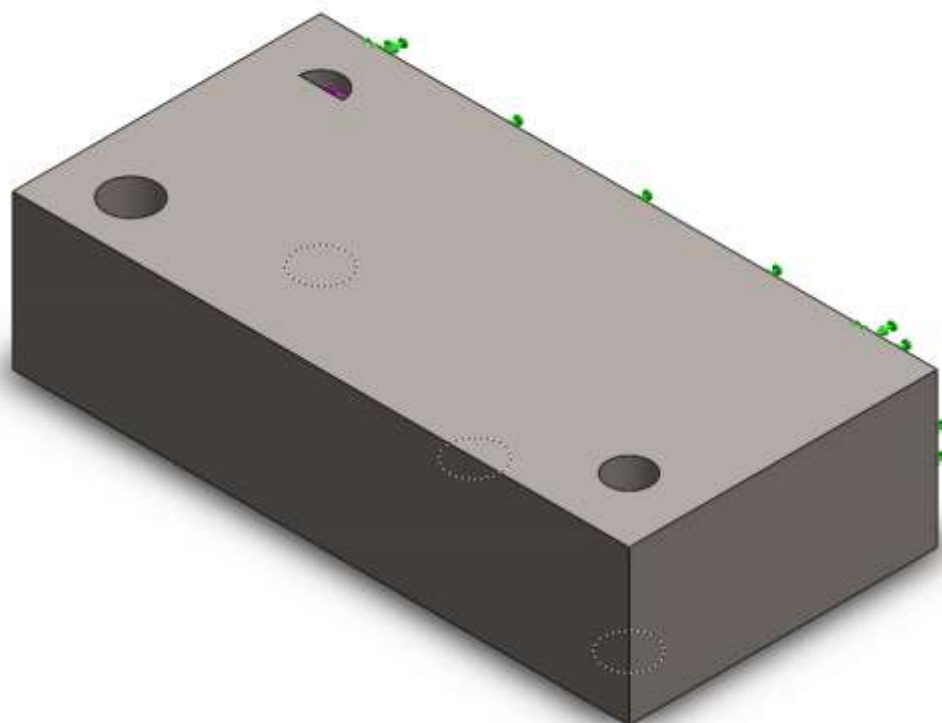
35

Description

No Data


Assumptions

Model Information

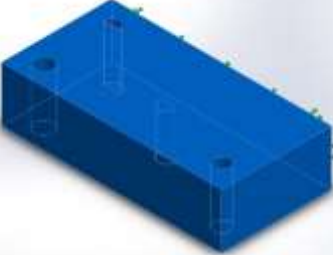


Model name: Mounting Block
Current Configuration: Default

Solid Bodies



Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude3 	Solid Body	Mass:3.38327 kg Volume:0.00043099 m ³ Density:7850 kg/m ³ Weight:33.156 N	K:\Sr Project\Mounting Block.SLDPR Nov 12 18:42:56 2016

Material Properties

Model Reference	Properties	Components
	<p>Name: AISI 4130 Steel, annealed at 865C</p> <p>Model type: Linear Elastic Isotropic</p> <p>Default failure criterion: Unknown</p> <p>Yield strength: 4.6e+008 N/m^2</p> <p>Tensile strength: 5.6e+008 N/m^2</p>	<p>SolidBody 1(Boss-Extrude3)(Mounting Block)</p>

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 1 face(s) Type: Fixed Geometry

Load name	Load Image	Load Details
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 396 lbf
Force-2		Entities: 1 face(s) Type: Apply normal force Value: 400 lbf

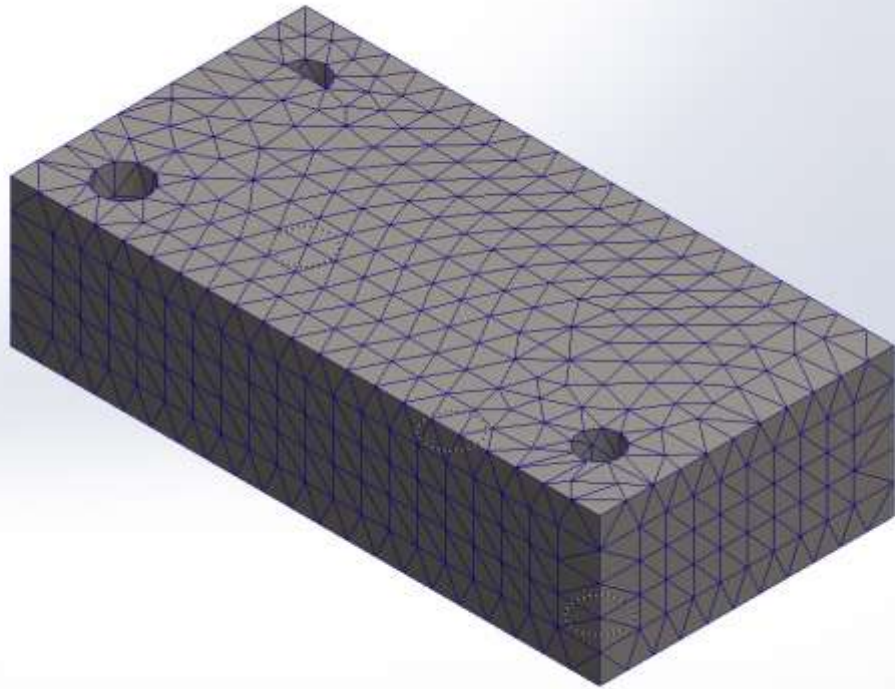
Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.297464 in
Tolerance	0.0148732 in
Mesh Quality	High

Mesh information - Details

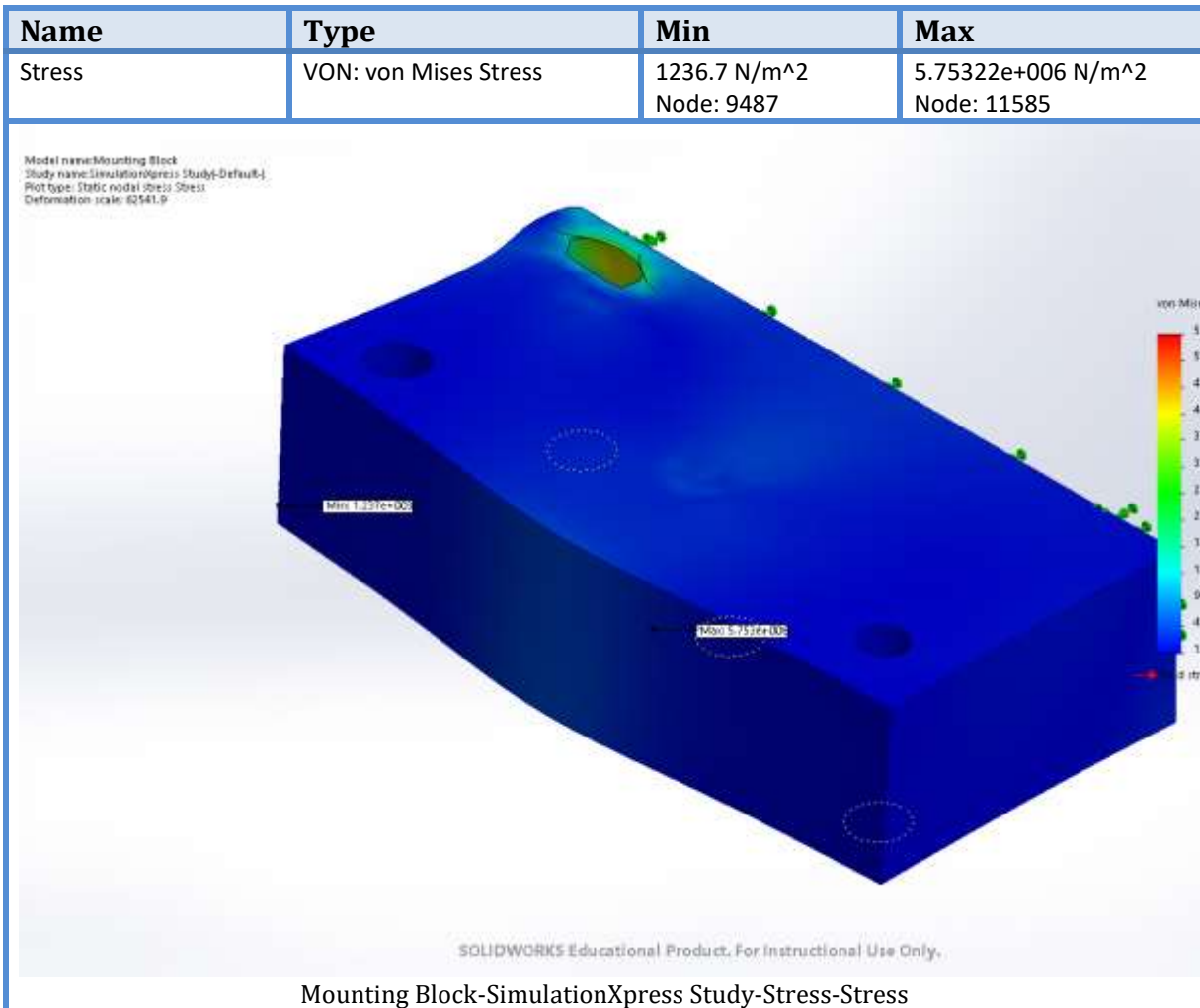
Total Nodes	11638
Total Elements	7446
Maximum Aspect Ratio	4.6582
% of elements with Aspect Ratio < 3	99.5
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh:mm:ss):	00:00:01
Computer name:	MATT-HP

Model name: Mounting Block
Study name: SimulationXpress (Study-Default)
Mesh type: Solid Mesh

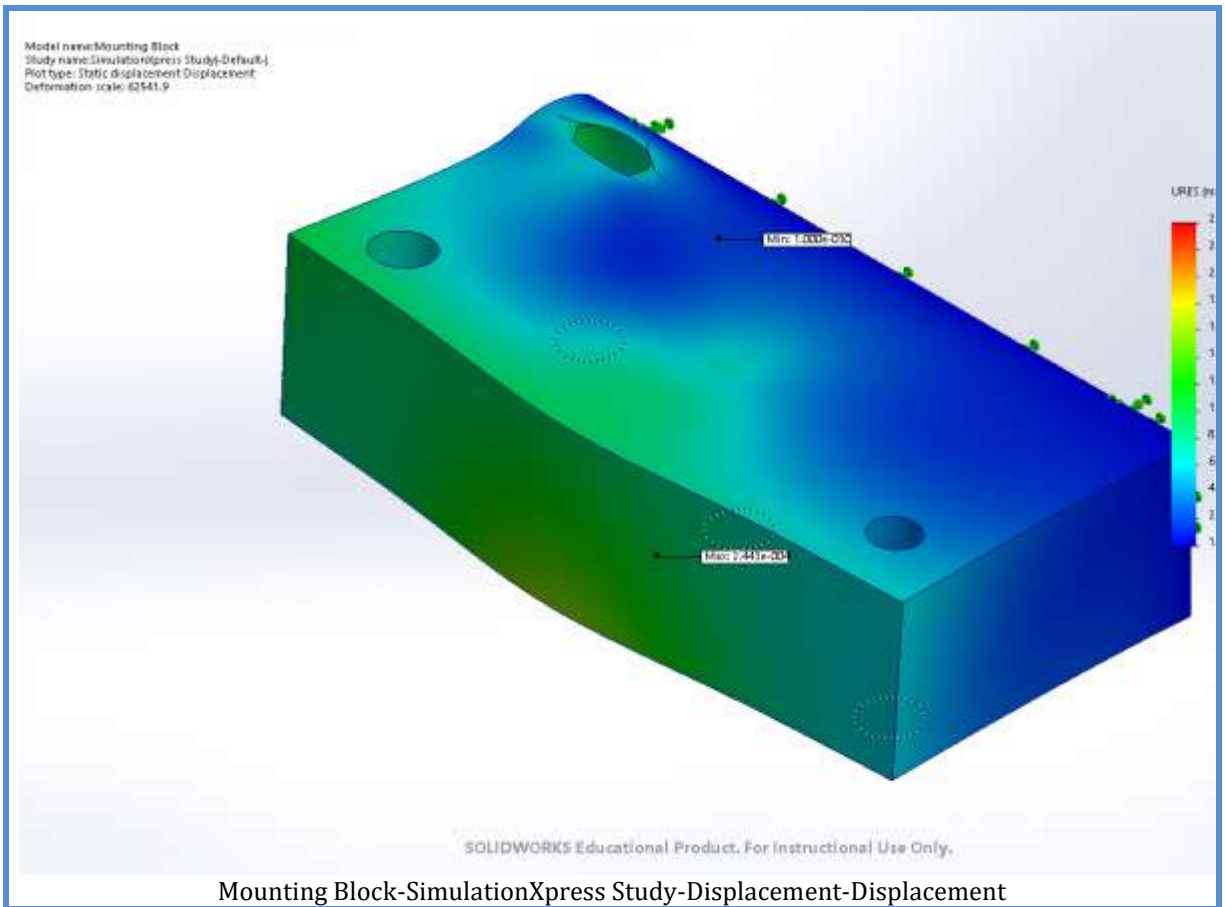


SOLIDWORKS Educational Product. For Instructional Use Only.

Study Results

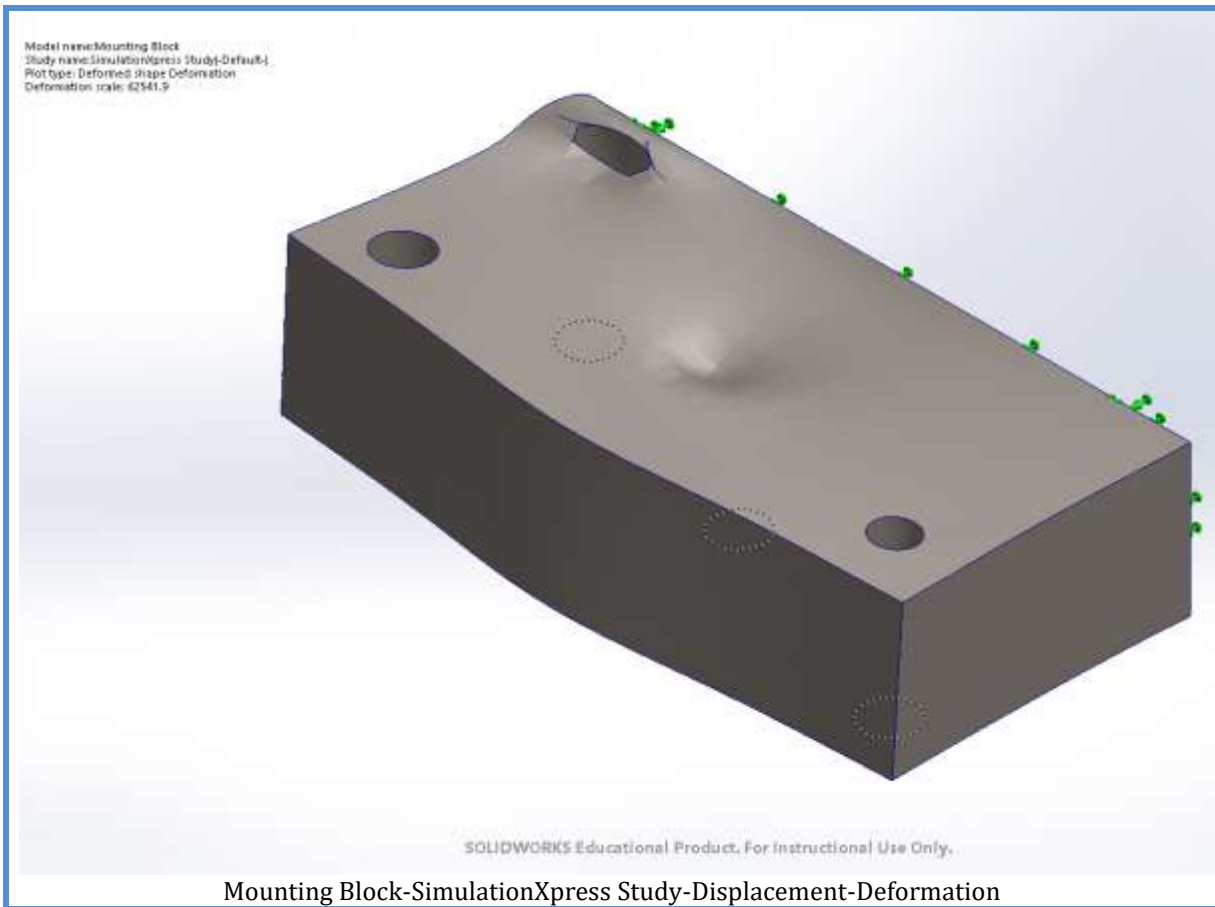


Name	Type	Min	Max
Displacement	URES: Resultant Displacement	0 mm Node: 115	0.000244339 mm Node: 11573

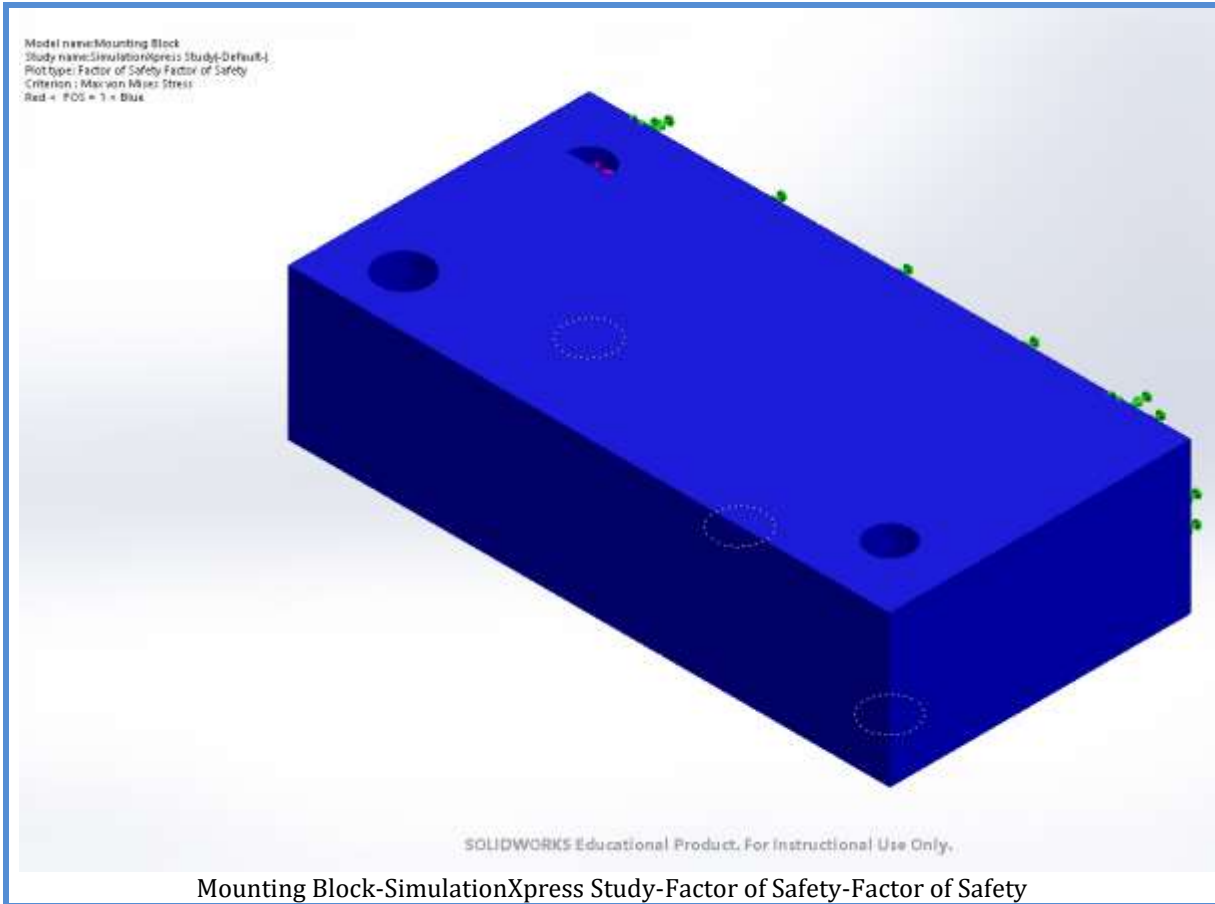


Mounting Block-SimulationXpress Study-Displacement-Displacement

Name	Type
Deformation	Deformed shape



Name	Type	Min	Max
Factor of Safety	Max von Mises Stress	79.9552 Node: 11585	371959 Node: 9487



Conclusion

The minimum FoS that occurs during the maximum loading of this block is 79.

Matt Leal

SE project

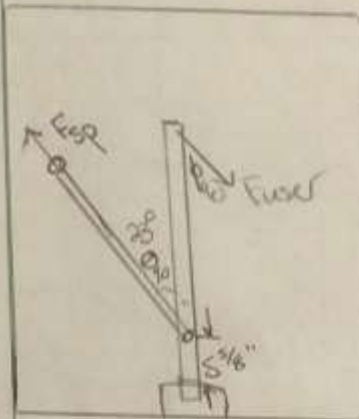
Gas spring re-analysis (post-assembly) Values measured directly

Given) $\theta_{90} = 23^\circ$

$L_{arm} = 23"$

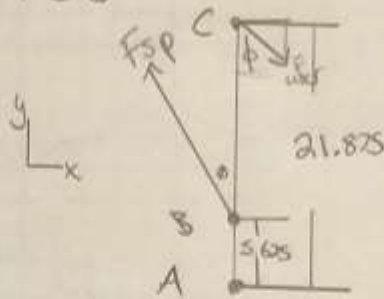
$\phi_{90} = 60^\circ$

$F_{user} \approx 51bs?$ (pulling down from upright)



Find) F_{sp} (estimate $\approx 20lbs?$)
to initiate movement

FBD



soln

$\sum M_A = 0$

$$-51bs (\sin 60) (21.875) + F_{sp} (\sin 23) (5.625) = 0$$

$F_{sp} = 43lbs$ (half of current model design)

Matt Leal Sr proj
 Given) at a certain point, w/ normal load, I want shelf w/ contents to fall by itself (user doesn't keep pulling all the way down)
 • at 25° from vert, or 65° from henz, shelf should fall on its own

• w_{shelf (full)} → wt I will shoot for,
 so it'll fall with & w/o loading on shelf!
 • w_{empty} ≈ 15 lbs
 • w_{full} ≈ 15 lbs + 20 lbs = 35 lbs
 • so, w_{des} = 25 lbs!

Find) Esp so at 65° , w_{des} overpowers ^{spring} moment & descends itself

FBD

$\sum M_A = 0$
 $-(25 \text{ lbs})(\sin 25^\circ)(21.875) + F_{sp}(\sin 30^\circ)(5.625) = 0$
 $F_{sp} = 87.1 \text{ lbs}$

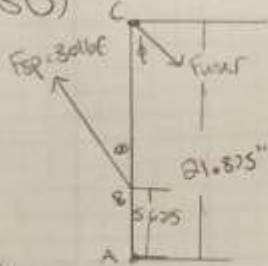
use lowest Fsp in cases (should still fall!)
 (From Bansbach, choose 30 lb weight!) (only avail)

Math lead

A-10

Given 30 lbf, Fig on A-9,

Find) F_{BC} (pull down), $\theta = 23^\circ$, $\phi = 60^\circ$
FBD)



soln

$$\sum M_A = 0$$

$$-F_{BC}(\sin 60)(21.875) + 30 \text{ lbf}(\sin 23)(5.625) = 0$$

$$F_{BC} = \boxed{3.48 \text{ lb}}$$

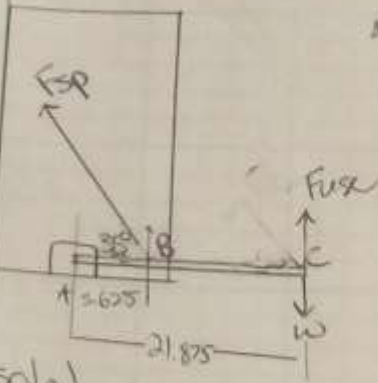
A-11

Matt Uall

A-11

Given $F_{sp} = 30 \text{ lbf}$, $W_{\text{shelf}} = 2.5 \text{ lbs}$ (Design load) (see A-a)
Find) F_{user} (to generate lift)

* Measurements taken directly



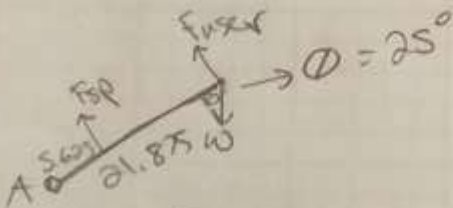
soln)

$$\sum M_A = 0$$

$$2.5 \text{ lb} (21.875) - F_{\text{user}} (21.875) - 30 \text{ lbf} (5.625) = 0$$

$$F_{\text{user}} = 20 \text{ lb} \leftarrow \text{Max user force}$$

when F_{sp} is \perp to arm



$$\sum M_A = 0$$

$$-30 \text{ lbf} (5.625) - F_{\text{user}} (21.875) + (2.5) \sin 25^\circ (21.875)$$

$$F_{\text{user}} = 2.85 \text{ lb}$$

Insert analysis A-14 Matt Leal



Given - mat'l props (Al 3003, $S_y = 21 \text{ ksi}$)

- $\frac{1}{4}$ " thickness (to accommodate fastener)
- Density = 0.099 lb/in^3

$\bullet W = (60 \text{ lbs} / 2) + W_{\text{wall}}$
 \downarrow
 estimates, since dimensions are known

$\bullet W = (30 \text{ lbs}) + (1.4 \text{ lb}) = 31.4 \text{ lb}$ (dist load)

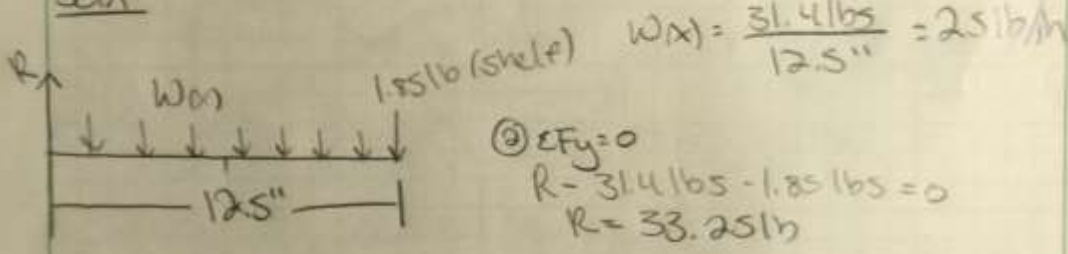
\bullet Shelf dimensions = $4" \times 12.5" \times \frac{1}{4}"$

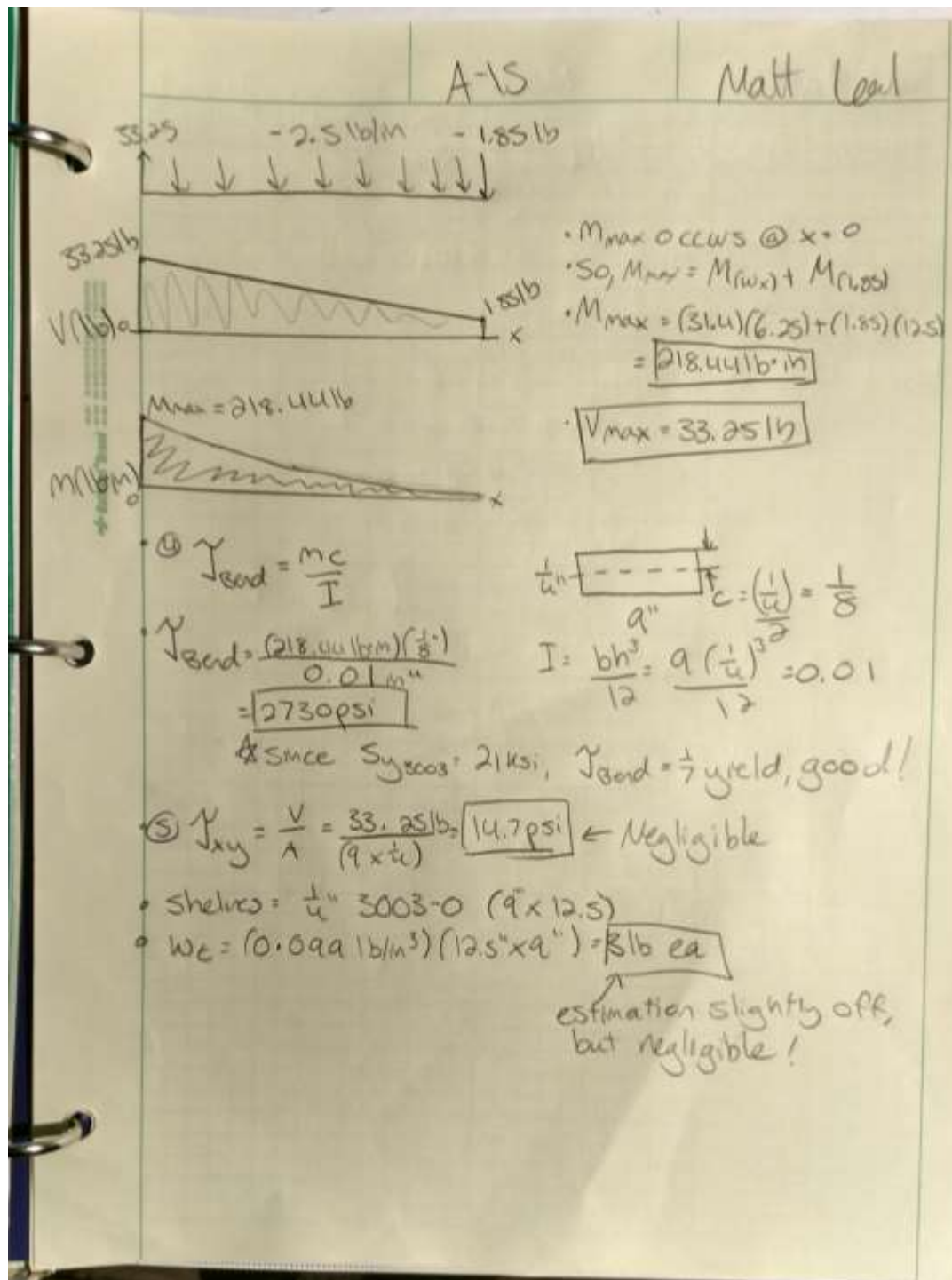
\bullet Assume  This wall bears no load
 So treat it like  shelf

Find T_{end} & T_{xy}

\bullet can current model withstand T_{max} ?

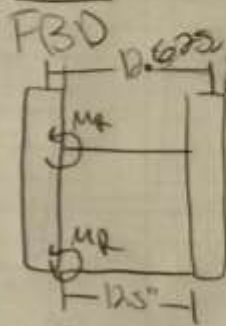
soln





A-16

Matt Leal

Insert analysis (shelf wall)Given) $t_{\text{wall}} = \frac{1}{8}"$, $W_{\text{wall}} = 1.85 \text{ lb}$, $W_{\text{shelf}} = 3 \text{ lbs}$ Find) Torsion caused by weight of shelf
(can current design withstand?)Soln

Assume 2 shelves, each causes its own moment on shelf wall

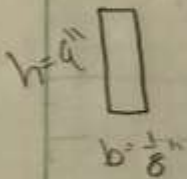
Both moments equal (assume same loading)

 $M_{\text{max}} = 218.44 \text{ lb}$ (see previous page) M_{max} caused by the loading of the shelf, is resisted by M_R ① $\Sigma M = 0$

$$M_{\text{max}} - M_R = 0$$

$$M_R = 218.44 \text{ lb}\cdot\text{in}$$

According to Matt,



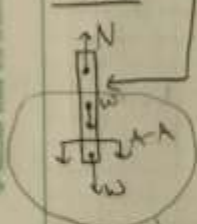
$$\textcircled{7} \quad J = \frac{T}{Q} \rightarrow M_R = \frac{218.44 \text{ lb}\cdot\text{in}}{\frac{(\frac{1}{8}) (4)^3}{3 \cdot 1.8 (\frac{1}{8})}}$$

$$J = \frac{218.44}{\frac{10.125}{132.6}} = \boxed{2860 \text{ psi}}$$

A-17

Matt Lord

Insert analysis (shelf wall)

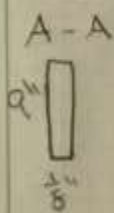
Given) $W_{load} = 30 \text{ lb}$, $W_{shelf} = 5 \text{ lb}$, $W_{wall} = 1.85 \text{ lb}$ $W_{wall} = (16.67' \times 9" \times 8")$ Find) σ_{axial} from W_{load} on shelf wallSolveFBD• σ_{max} occurs here ($\frac{P}{A}$) P is highest

$$W = W_{load} + W_{shelf} + W_{wall} \\ = 30 + 5 + 1.85 = 34.85 \text{ lb}$$

$$\textcircled{2} \sum F_y = 0$$

$$N = 2w = 2(34.85) = 69.7 \text{ lb}$$

$$\textcircled{3} \sigma_{axial} = \frac{P}{A}$$

• In region labeled σ_{max} , $P = N = 69.7 \text{ lb}$ 

$$\textcircled{6} \sigma = \frac{P}{A} = \frac{69.7 \text{ lb}}{(9" \times \frac{1}{8}")} = \boxed{62 \text{ psi}}$$

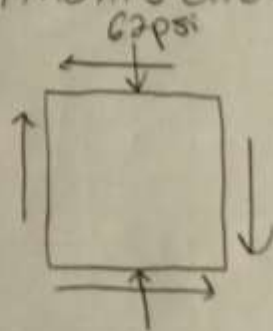
Now, Mohr's circle!

A-18

Matt Lent

Insert analysis (shelf wall)

- With the combo of normal & shear pressure, Mohr's circle necessary to find σ_{max}
- Given) $\tau = 2860 \text{ psi}$, $\sigma = 62 \text{ psi}$
- Find) Mohr's circle (or, use equations)



$$\begin{aligned}\sigma_x &= 0 \\ \sigma_y &= -62 \text{ psi} \\ \tau &= 2860\end{aligned}$$

Solve

(4-1)

Max principal σ

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2}$$

$$= \frac{62}{2} + \sqrt{\left(\frac{-62}{2}\right)^2 + 2860^2} = \boxed{2891 \text{ psi}}$$

- Max shear stress

$$\begin{aligned}(4-4) \quad \tau_{max} &= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{62}{2}\right)^2 + (2860)^2} \\ &= \boxed{2860.17 \text{ psi}}\end{aligned}$$

So, $\sigma_{max} = 2891 \text{ psi}$, this is more than
a 7x Fos w/ $S_{y \text{ Alum}} = 21 \text{ ksi}$

A-1a

Matt Lent

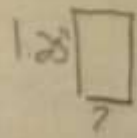
Linkage arm analysis

Given) $F_{sp} = 80 \text{ lb}$, $W = 60 \text{ lb (max)}$

Find) X-sec area for link arm

Assume

must at least be 1.25" wide (for fasteners...)



(So, find optimal? w/ loads involved!)

Needs

M_{max} (when shelf fully extended)

- causes largest moment, ergo, largest stress

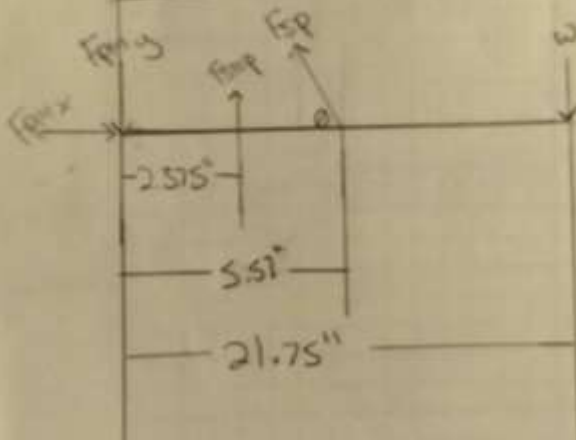
σ_{axial}

- when shelf closed



So, sum forces

$\theta = 55^\circ$ (per SW)



(measuring forces 5/8" from each edge [fastener holes] of 25" OG Length)

A-20

Matt Leal

Sum Forces!

$$\textcircled{1} \sum M_{F_{\text{stop}}} = 0$$

$$(60 \text{ lbs})(21.75") - 80 (\sin 53)(5.57) + F_{\text{pmg}}(2.375") = 0$$

$$F_{\text{pmg}} = 400 \text{ (new)}$$

$$\textcircled{2} \sum F_y = 0$$

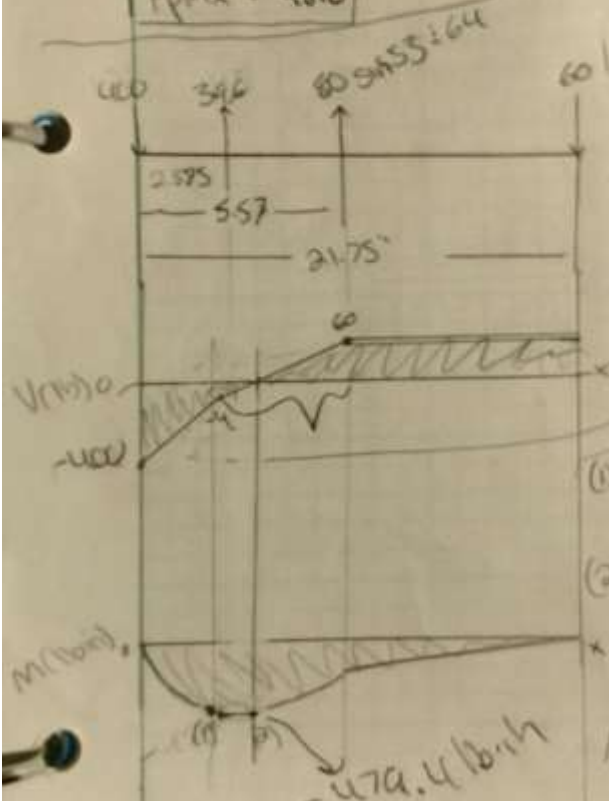
$$-400 \text{ lb} + F_{\text{stop}} + 80 \text{ lb}(\sin 53) - 60 \text{ lb} = 0$$

$$F_{\text{stop}} = 346 \text{ lb}$$

$$\textcircled{3} \sum F_x = 0$$

$$F_{\text{pmx}} - (80)(\cos 53) = 0$$

$$F_{\text{pmx}} = 481 \text{ lb}$$



where $V(x)$ crosses x-axis, that point!

$$V(x) = \frac{64}{5.105}x - 4$$

$$0 = \frac{64}{5.105}x - 4 \rightarrow x = 0.2(21.75) = 2.575"$$

$$N_{\text{max}} = -400 \text{ lb}$$

$$(1) = \left(\frac{346}{21.75} \right) x^2 - 400x \text{ at } 2.575$$

$$= -479.4$$

$$(2) = \left(\frac{64}{5.105} \right) (x^2) - 4x \text{ at } (0.109)$$

$$= -0.399$$

$$M_{\text{max}} = (1) + (2) = -479.4 - 0.399$$

$$= -479.4 \text{ lb-in}$$

A-21

Matt Cent

Link arm analysis

Calc stress

④ $\sigma_{\text{bend}} = \frac{M c}{I}$ → using 4140 steel, $S_y = 214 \text{ ksi}$
 I want to be max @ $\frac{1}{3} S_y$
 so $\sigma_{\text{bend (allow)}} = \frac{214,000}{3} = 71,333 \text{ psi}$

Solve for I (ergo, b·h)

$$h = 1.25 \text{ in} \quad c = \frac{h}{2} = 0.625 \text{ in}$$

$$73,000 = \frac{(472 \text{ lb} \cdot \text{in}) (0.625)}{I}$$

$$I = 0.004$$

$$I = \frac{bh^3}{12} \quad (h = 1.25)$$

$$\frac{12I}{h^3} = b = \frac{12(0.004)}{(1.25)^3} = 0.025 \text{ in} \text{ so, } b, \text{ or thickness}$$

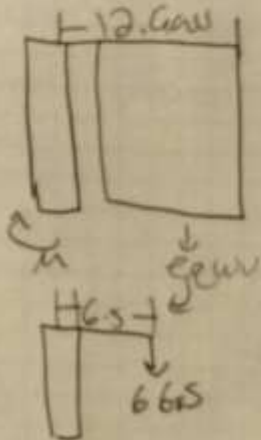
must be at least 0.025" to stay around 73ksi.
 try $\frac{1}{4}$ "

$$\sigma = \frac{(472 \text{ lb} \cdot \text{in}) (0.625)}{\frac{(\frac{1}{4}) (1.25)^3}{12}} = 73,577 \text{ psi}$$

good!

A22

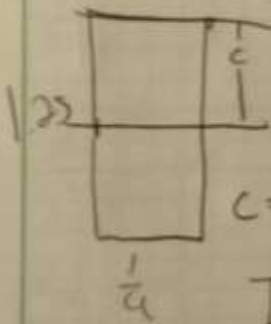
Matt Lem

Check Find Oserd for upright posⁿ

$$W_{\text{shelf}} = 6.5 \text{ lbs} + 60 \text{ lb load} = 66.5$$

$$\text{moment} = 66.5 (6.5) = 432 \text{ in. lb}$$

$$\sigma = \frac{Mc}{I} = \frac{432 (0.625)}{0.04} = 6.7 \text{ ksi} < \frac{S_y}{3}$$



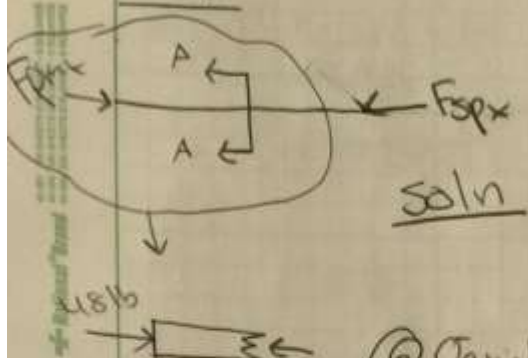
$$c = \frac{1.25}{2} = 0.625 \text{ in}$$

$$I = \frac{bh^3}{12} = 0.04$$

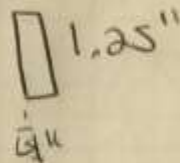
good!

A-23

Matt Leal

Linkage arm analysisGiven) $\tau_{\text{Bend}} = 7357 \text{ psi}$, $F_{\text{pinx}} = 481 \text{ lb}$ Find) σ_{axial} in linkage armFBD

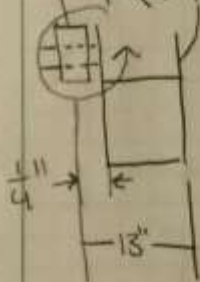
A - A

Soln

$$\textcircled{6} \sigma_{\text{axial}} = \frac{F}{A} = \frac{481 \text{ lb}}{(\frac{1}{4}) (1.25)} = \boxed{153 \text{ psi}}$$

Given) $W_{\text{load}} = 30 \text{ lbs}$, $W_{\text{shelf}} = 3 \text{ lbs}$, $W_{\text{wall}} = 1.85 \text{ lbs}$ Find) M_R , $\tau_{\text{torsional}}$ (extended position)

Arm M_R insert M_R is the reaction to the moment caused by the weight of the insert and its load.



$$\textcircled{1} \sum M = 0$$

$$M_{\text{load}} - M_R = 0, M_{\text{load}} = M_R$$

Front

A-24

Matt Lail

Linkage arm analysis

FBD

wall WM wall

$$W_M = \frac{W_{load} + W_{shelf}}{L}$$

$$W_M = \frac{60 \text{ lbs} + 6 \text{ lbs}}{12.5''} = 5.3 \frac{\text{lb}}{\text{in}}$$

*Find equiv force

for $W_M \rightarrow F_w$

$$F_w = 66 \text{ lb} @ \frac{1}{2} \text{ distance of } W_M, \text{ or } \frac{1}{2}(12.5'') = 6.25''$$

So

$$\sum M = 0$$

$$(1.85 \text{ lb})(2'') + 66 \text{ lb}(6.5'') + 1.85(15'')$$

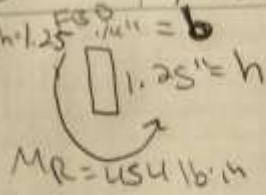
$$- M_R = 0$$

$$M_R = 454 \text{ lb} \cdot \text{in}$$

A-25

Matt Law

Given) $M_R = T = 454 \text{ lb}\cdot\text{in}$, $b = \frac{1}{4} \text{ in}$, $h = 1.25 \text{ in}$
 Find) $\tau_{\text{torsional}}$
 Soln



$$(7) \quad \tau_{\text{max}} = \frac{T}{Q} = \frac{454 \text{ lb}\cdot\text{in}}{3 + 1.8 \left(\frac{h}{b} \right)}$$

$$\tau_{\text{tors}} = \frac{454 \text{ lb}\cdot\text{in}}{\frac{(\frac{1}{4}) (1.25)^2}{3 + 1.8 \left(\frac{1.25}{\frac{1}{4}} \right)}} = \frac{454}{0.390625} = 13,947 \text{ psi}$$

Given) $V_{\text{max}} = -400 \text{ lb}$, $A = \frac{1}{4} \text{ in} \times 1.25 \text{ in} = 0.3125 \text{ in}^2$

Find) τ_{xy}

Soln

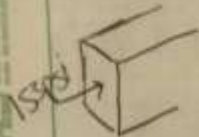
$$(8) \quad \tau_{xy} = \frac{V_{\text{max}}}{A} = \frac{400 \text{ lb}}{0.3125 \text{ in}^2} = 1280 \text{ psi}$$

A-26

Malt Lar

Given: $\sigma_{axial} = 153 \text{ psi}$ $\sigma_{bend} = 7357 \text{ psi}$ $\tau_{torsional} = 13,947 \text{ psi}$ $\tau_{xy} = 1280 \text{ psi}$ Find: σ_{max} & τ_{max}

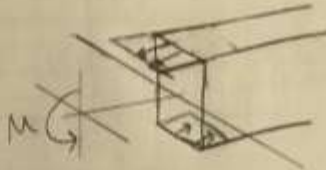
FBD (similar to p615 Hibbler)



$$\sigma = \frac{P}{A} = 153 \text{ psi}$$



$$\tau_{tor} = \frac{T}{Q} = 13,947 \text{ psi}$$



$$\tau = \frac{V}{A} = 1280 \text{ psi}$$

$$\sigma_{bend} = \frac{mc}{I} = 7357 \text{ psi}$$

$$\sigma_{max} = \sigma + \sigma_{bend} \text{ (Bottom portion of cross-section)} \\ = 153 \text{ psi} + 7357 \text{ psi} = \boxed{7510 \text{ psi}}$$

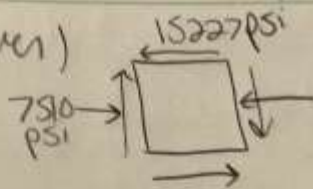
$$\tau_{max} = \tau + \tau_{torsional} = 1280 \text{ psi} + 13,947 \text{ psi} \\ = \boxed{15,227 \text{ psi}}$$

Here, τ & τ_{tor} are in same direction, so add!

A-27

Matt Leal

Given)



$$\sigma_x = 7810$$

$$\sigma_y = 0$$

$$\tau_{xy} = 15227$$

Find) Max principal stress & shear stress

Soln

$$(4-1) \sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_1 = \frac{7810}{2} + \sqrt{\left(\frac{7810}{2}\right)^2 + (15227)^2} = \boxed{19438 \text{ psi}}$$

$$(4-4) = \sqrt{\left(\frac{\sigma_x + \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{7810}{2}\right)^2 + (15227)^2} = \boxed{15683 \text{ psi}}$$

So, the max stress this Bar will undergo is a tensile 19438 psi (compression)

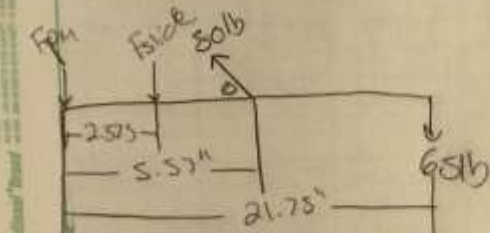
This is less than $\frac{1}{3} S_{y \text{ sat}}$ (at 21400)

So, there is a FOS of 3.24 on this Bar in its extended pos

Slide Bolt analysis A-28 Matt Law
 Given) 80 lb Gas spring pulls on 65 lb shelf (empty shelf)
 Find) Bolt to use for slide that holds Link
 arm in "down" position

FBD

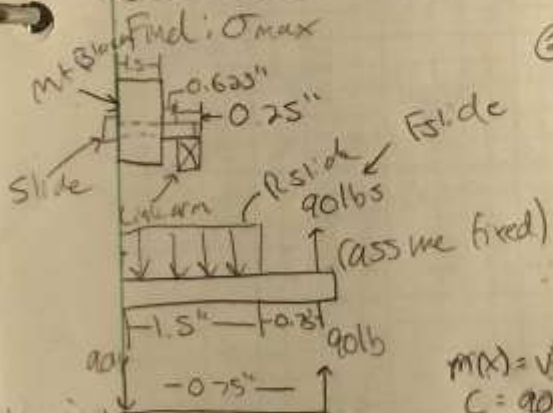
$$\theta = 53^\circ$$



$$\textcircled{1} \sum M_{pm} = 0$$

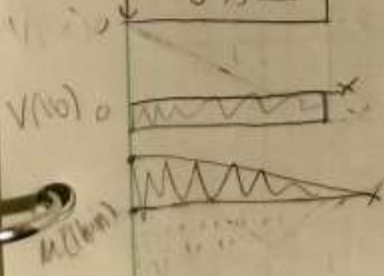
$$65lb(21.75") - (80lb)(5.57)(\sin 53) + F_{slide}(2.375") = 0$$

$$F_{slide} = 90 lb$$



$$\textcircled{2} \sum F_y = 0$$

$$90lb - R_{slide} = 0, R_{slide} = 90lb$$



$$m(x) = v(x) = -90' = -90x + c$$

$$c = 90 \cdot 2.25 = 202.5$$

$$m(x) = -90x - 202.5$$

$$M_{max} \text{ occurs when } x = 0,$$

$$M(0) = -90(0) - 202.5$$

$$M_{max} = -202.5 lb \cdot in$$

A2A Matt Lal

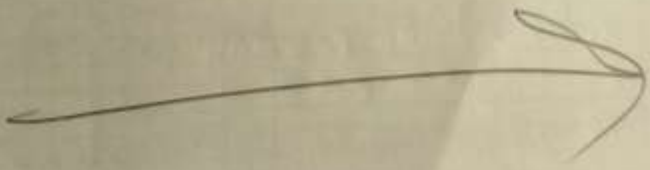
Given) $V_{max} = 90 \text{ lbs}$ $M_{max} = 202.5 \text{ lb}\cdot\text{in}$
 Find) σ_{max}

⑤ $\tau_{max} = \frac{F}{A}$
 * I have a supply of clevis pins on hand, try
 $\frac{1}{4}" \times 2.5"$ S&W pin (18-8 SS)
 $\hookrightarrow EL = \frac{F \cdot EL}{A}$

\downarrow
 18-8 SS $\rightarrow S_y = 65 \text{ ksi}$ (per Fastenal Tech ref)
 So, shoot for $\sigma_{max} = \frac{1}{3} S_y = \frac{65 \text{ ksi}}{3} = 22 \text{ ksi}$

\downarrow
 ⑤ $\tau = \frac{F}{A} = \frac{90 \text{ lb}}{\pi (\frac{1}{8})^2} = 1.8 \text{ ksi} \checkmark \checkmark \checkmark$

⑥ $\sigma_{bend} = \frac{M \cdot c}{I} \rightarrow c = r = \frac{1}{8}"$
 $\hookrightarrow I_{circ} = \frac{1}{4} \pi r^4 = \frac{1}{4} \pi (\frac{1}{8})^4 = 0.0002$
 $= \frac{202.5 \text{ lb}\cdot\text{in} (\frac{1}{8})"}{0.0002} = 126 \text{ ksi}$
 Clevis pin too high try $\frac{1}{2}"$



A-30

Math Lear

Given) $V_{max} = 90 \text{ lbs}$, $M_{max} = 202.5 \text{ lbs in}$ Find) σ_{max} Assum $\frac{1}{2}'' \times 2\frac{3}{4}''$ SSL clevis pin, $\sigma_{max} < 22 \text{ ksi}$

$$\gamma = \frac{90}{\pi(\frac{1}{2})^2} = 458 \text{ psi} \checkmark$$

$$\sigma_{max} = \frac{m c}{I} = \frac{r}{\frac{1}{4}} = \frac{202.5(\frac{1}{4})}{0.003} = 17 \text{ ksi}$$

very good

* Since I'm already drilling a $\frac{3}{8}''$ hole in block, try $\frac{3}{8}''$ dia pin (easier mfg setup!)

* $\frac{3}{8}'' \times 2\frac{3}{4}''$ SSL

$$\gamma = \frac{90}{\pi(\frac{3}{8})^2} = 815 \text{ psi}$$

$$\sigma = \frac{m c}{I} = \frac{202.5(\frac{3}{8})}{0.001} = 38 \text{ ksi}$$

NO \nearrow $38 \text{ ksi} > 22 \text{ ksi (allow)}$

SO, pick $\frac{1}{2}'' \times 2\frac{3}{4}''$ SSL clevis pin from
Fastenal part 0156956

Out of stock, use zinc plated A191 low carbon
Stl, $S_y = 40 \text{ ksi}$, still less than $\frac{1}{2} S_y$,

SO part # 0156724
& cotter # 45285

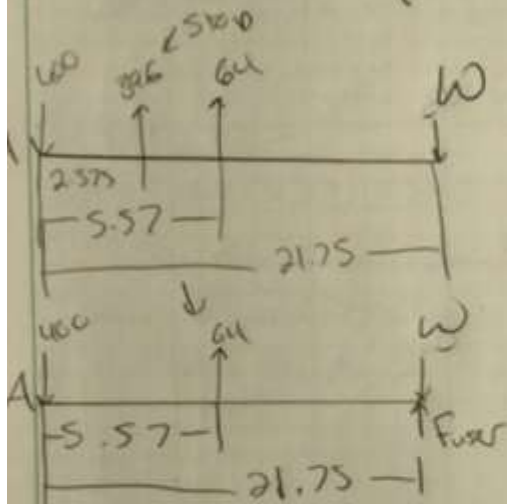
A-31

Math Level

User Force Analysis

rationale

w/ current setup, find force user will have to place on sys to start ascent of shelf
 essentially, set $T_{stop} = 0$, and Break $Mpm = 0$



$$\Sigma M_A = (64)(5.57) + (64)(21.75) = 1946.8 \text{ lb}\cdot\text{in}$$

so user must generate 946.8 lb·in across 21.75 in

$$\frac{946.8}{21.75 \text{ in}} = 43 \text{ lb! This is a lot, but is based}$$

on real loading of 60 lb w/ SF of 1.5...

so try w/ 40 lb

$$\Sigma M_A = 64(5.57) + (40)(21.75) = 513 \text{ lb}\cdot\text{in}$$

$$\frac{513 \text{ lb}\cdot\text{in}}{21.75 \text{ in}} = 23 \text{ lb force... great! almost halved!}$$

A-32

Matt Lew

User force analysis

① 20 lb...

$$\Sigma MA = -(64)(5.57) + (20)(21.75) = 78.52 \text{ lb}\cdot\text{in}$$

$$\frac{78.52 \text{ lb}\cdot\text{in}}{21.75 \text{ in}} = \underline{\underline{3.61 \text{ lb}}} \quad \text{WOOO!}$$

② 10 lb

$$\Sigma MA = -(64)(5.57) + 210.75 = -138.48$$

- , so anything around 10 lbs / less, user will have to hold shelf as it self raises (after removing slide lock)

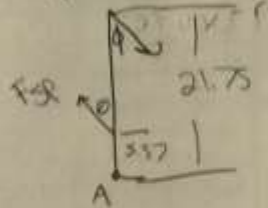
A-33

Matt Leal

User force analysis

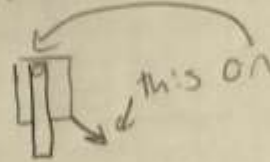
Force user must use to pull down empty Shelf

$$F_{SP} = 80 \text{ lb}$$



$$\theta = 31^\circ$$

ϕ = us estimate of force Vector from



$$\sum M_A = 0$$

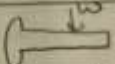
$$-(80 \text{ lb}) \sin 31(5.57) + (F) \sin 48(21.75) = 0$$

$$F = 15 \text{ lbs}$$

Not Bad!


A-34 Matt Leal

Shelf screw analysis

Given 

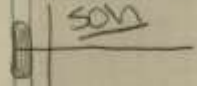
2 shelves carry load & self

$$w = w_{\text{shelf}} + \frac{1}{2} w_{\text{wall}} + \frac{1}{2} w_{\text{load}} = .3 + (1.85/2) + (69/2) = 34 \text{ lbs}$$

But, plan on 2 screws per shelf side 

So $w_{\text{true}} = \frac{w}{2} = 17 \text{ lbs}$

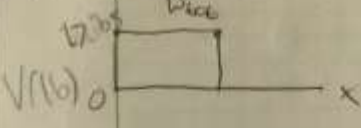
use 1/4" long machine screws, Dia = 0.086 (#2-56) since I have these
 zinc finish stl, called carbon stl...
 general $S_y = 53 \text{ ksi}$ (Assume low carbon...)

Will the screws work? 


$w(x) = 34 \text{ lbs} / (1/8 \text{ in}) = 272 \text{ lb/in}$

$\frac{1}{8}$ " shelf wall, so $L = \frac{1}{4} - \frac{1}{8} = \frac{1}{8}$, assume \therefore

② $\sum F_y = 0$, $N = w_{\text{true}} = 17 \text{ lbs}$



$V_{\text{max}} = 17 \text{ lbs}$
 $V_{\text{end}} = 0$
 $M(x) = V(x) \cdot x = 17x$
 $M_{\text{max}} \text{ occurs @ } x = 0$
 So $M_{\text{intert}} = M_{\text{max}} = 17 \text{ lbs} \cdot (\frac{1}{8}) = 2.125 \text{ lb-in}$



So, Biggest stress will be \uparrow shear not bend

So, ③ $\tau_{\text{shear}} = \frac{F}{A} = \frac{17 \text{ lbs}}{\pi (0.043)^2} = 3 \text{ ksi}$, well below S_y , so

good!

older 8x#2-56x1/4" machine screws
 Fastenal # 70596

Matt Leal

Analysis

A-35

Given: Force on pivot Bolt $F = 400 \text{ lb}$

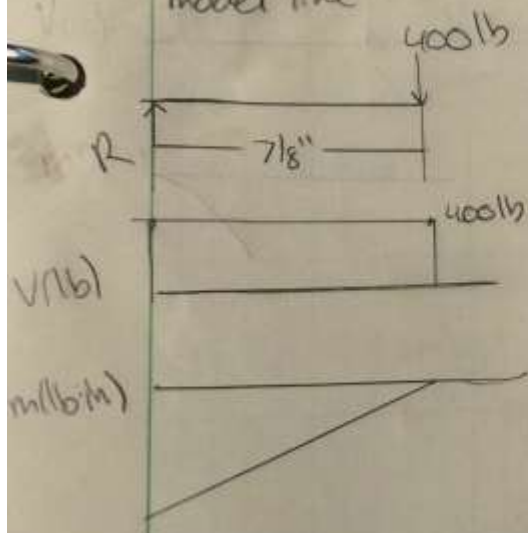
- Bolt Length must be 2" long and have at least 1" thread (since hole will be drilled & tapped slightly over 1" into block)

Find: stress on bolt

- min bolt Dia (assume Grade 8 strength)



Since this area is basically "fixed support" in the block model like



$$\sum F_y = 0$$

$$R = 400 \text{ lb}$$

$$V_{\max} = 400 \text{ lb}$$

$$m = 400 \text{ lb} (7/8") = 350 \text{ lb} \cdot \text{in}$$

Failure mode will most likely be Shear

$$\tau_d = \frac{V}{A} \Rightarrow \text{Area}$$

Matt Leal

Analysis

A-3c

Try $N=3$

$$\text{So, } \sigma_d = \frac{S_y \text{ Bolt}}{3} = \frac{136 \text{ ksi}}{3} \approx 45.3 \text{ ksi}$$

$$\text{So, } A_{mn} = \frac{400 \text{ lb}}{43000 \text{ psi}} = 0.009 \text{ in}^2$$

$$A_{CNC} = \pi r^2$$

$$\sqrt{\frac{A}{\pi}} = r_{mn} = \sqrt{\frac{0.009}{\pi}} = 0.05 \text{ in}$$

While a $\frac{1}{8}$ " Bolt would work here, I need a thread length of 1", and according to a fastenal fastener expert, only way I could get that is with a $1\frac{1}{2}$ " Dia 2" Long Bolt. So, due to availability, I will use a $\frac{1}{8}$ " Dia 2" Long grade 8 Bolt.

Given:

Find: γ_{actual}

Soln

According to failure theory $\text{Shear yield} = \frac{1}{2} S_y$

$$\text{So, } \sigma_d \text{ actually} = \frac{45.3 \text{ ksi}}{2} = 22.65 \text{ ksi}$$

$$\gamma_a = \frac{V}{A} = \frac{400 \text{ lb}}{\pi (\frac{1}{8})^2} = 2 \text{ ksi, which is } 10\times \text{ less than } \tau_{sy}.$$

Overkill, but necessary for the application

Math Calc	Analysis	A-37
<p>Given) $F_{stop} = 396 \text{ lb}$ Find) Amm for stop bolt <u>Soln</u></p> <p>portion in mt block reacts to F_{stop}, so, model as if it's a fixed support</p> <p> $R = 396 \text{ lb}$ $V_{max} = 396 \text{ lbs}$ $m = 396 (2.25) = 891 \text{ lb-in}$ Failure mode: σ_{Bend} </p>	<p> $\epsilon F_y = 0$ $R = 396 \text{ lb}$ </p>	<p>A-37</p>
<p>① $\sigma_B = \frac{mc}{I}$ or $\frac{m}{S}$</p> <p>$S = \frac{m}{\sigma_d}$</p> <p>Trying $N=3$, $\sigma_d = \frac{S_y}{N} = \frac{S_y}{3} = \frac{130 \text{ ksi}}{3} = 43.3 \text{ ksi}$</p> <p>so, $S = \frac{891}{43000} = 0.02$</p> <p>$S = \frac{\pi d^3}{32} = 0.02 \Rightarrow d = 0.54 \text{ in}$</p>	<p>Assume grade 5 Bolt</p>	

Matt Leal

Analysis

A-38

For $N=3$, $d_{min}=0.5a"$. It would be nice to use a $1/8"$ Dia (for machining, it's easier to machine the same dia hole as others, less c/o time)
So, Lets try to Find N when $d=1/2"$

Given) $m=8a1lb/m$, $d=1/2"$

Find) N, σ_B

Soln

$$\sigma_B \cdot \frac{m}{S} = \frac{8a1}{\frac{\pi (1/2)^3}{32}} = 72,605 \text{ psi}$$

$$N = \frac{S_y}{\sigma_B} \cdot \frac{130,000}{72,605} = 1.79 \text{ Bad!}$$

So, go back to using a $d > 0.5a"$
try $5/8"$ dia

Given) $d=5/8"$, $m=8a1lb/m$, $S_y=130ksi$

Find) N

Soln

$$\sigma = \frac{m}{S} = \frac{8a1}{\frac{\pi (5/8)^3}{32}} = 37,173 \text{ psi}$$

$$N = \frac{S_y}{\sigma} = \frac{130,000 \text{ psi}}{37,173 \text{ psi}} \rightarrow 3.5 \text{ good!}$$

So, need $d=5/8"$ $L_{min}=3\frac{3}{8}"$, grade 8

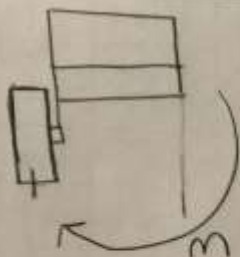
Use Fastenal 015318

$5/8" \times 3\frac{3}{8}"$ grade 8 cap screw

Matt Leal

Analysis

A-39

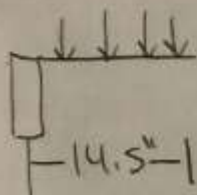


Given: w assembly + Load = 701bs

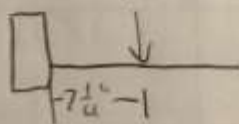
- The setup causes a moment that must be resisted at the block. Otherwise, the block will naturally "fall" clockwise. While the stop bolt will prevent this, a design decision was made to add another bolt that only is there to provide stability & help resist the natural moment from the assembly weight with its tensile strength.

Assume each bolt resists $\frac{1}{2}$ of this moment

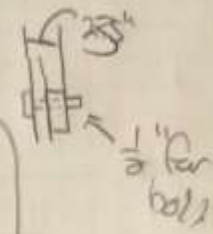
Find: Mass assembly, σ_{bol} , D_{min} Bolt, combined stress on stop bolt \hookrightarrow on bolt



equivalent lever arm 701bs



$$M_{\text{assembly}} = 701b(7.25") = 507.5167b$$

Matt Leal	Analysis	A-39
<p>① $\sigma_{\text{berd}} = \frac{M}{S}$ Assume $N=3$</p> <p>$\sigma_{\text{berd}} = \sigma_d = \frac{S_u}{N} = \frac{130 \text{ ksi}}{3} = 43 \text{ ksi}$</p> <p>$S = \frac{M}{\sigma_d} = \frac{253.75 \text{ lb}\cdot\text{in}}{43000} = 0.006$</p> <p>$S = \frac{\pi d^3}{32} \Rightarrow d_{\text{min}} = 0.39$</p> <p>So, use a grade 8 $d = \frac{1}{2}"$, $L_{\text{min}} = 3\frac{1}{2}"$</p> <p>Not available in 3", smallest is $\frac{1}{4}"$ dia..</p> <p>So, buy $\frac{1}{2}" - 20 \times 3\frac{1}{2}" \#1818$ Fastenal!</p>	<p>wrong</p> 	
<p>Given $d = \frac{1}{4}"$, $\sigma = 253.75 \text{ lb}\cdot\text{in}$</p> <p>Find σ_b, N</p> <p>① $\sigma_b = \frac{M}{S} = \frac{253.75}{\frac{\pi (\frac{1}{4})^3}{32}} = 20 \text{ ksi}$</p> <p>$N = \frac{S_u}{\sigma_b} = 6.3 \leftarrow \text{high, but only due to upsizing } D, \text{ so}$</p> <p>OK</p>		

Mat Lab

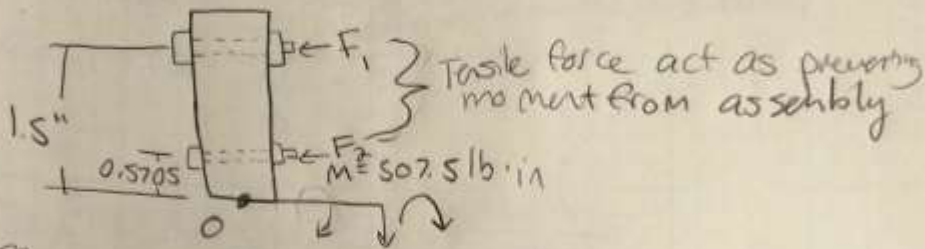
Analysis

A-40

Given $m = 507.5 \text{ lb} \cdot \text{in}$

Find Moment each bolt resists

Soln



$$\sum M = 0$$

$$507.5 \text{ lb} \cdot \text{in} - F_1(1.5) - F_2(0.5705) = 0$$

$$1.5 F_1 + 0.5705 F_2 = 507.5 \text{ lb} \cdot \text{in}$$

We know F_1 is 2.63x bigger than F_2 (Leet ann comparison, so

$$F_1 = 2.63 F_2$$

$$1.5(2.63) F_2 + 0.5705 F_2 = 507.5 \text{ lb} \cdot \text{in}$$

$$4.516 F_2 = 507.5 \text{ lb} \cdot \text{in}$$

$$F_2 = 112.3 \text{ lb}$$

$$1.5(F_1) + 0.5705(112.3) = 507.5 \text{ lb} \cdot \text{in}$$

$$F_1 = 295.6$$

Matt lead Analysis A-41

Given) $F_1 = 225.6 \text{ lb}$, $F_2 = 112.8 \text{ lb}$

Find) σ_{axial} on both bolts

* On 5th & 6th bolt, apply Mohr's circle to current stress on it

* d_{min} of bolt;

Soln

Since F on bolt 1 is only axial \rightarrow grade 8 bolt

$$\sigma_{\text{axial}} = \sigma_{\text{all}} = \frac{S_y}{N} = \frac{130 \text{ ksi}}{3} = 43.3 \text{ ksi}$$

$$\textcircled{2} \sigma_{\text{all}} = \frac{F}{A} \rightarrow A = \frac{F}{\sigma_{\text{all}}}, \frac{\pi d^2}{4} = \frac{225.6 \text{ lb}}{43000}$$

$$d_{\text{min}} = 0.0035 \text{ in}$$

So, For bolt 1, $d_{\text{min}} = 0.0035 \text{ in}$, $L_{\text{min}} = 3 \text{ in}$

Min Dia for 36" bolt @ Fastenal is $\frac{1}{4} \text{ in} = 20 \times 3 \text{ in}$

Given: $D = \frac{1}{4} \text{ in}$, $F = 225.6 \text{ lb}$

Find: σ_{axial} , N

$$\textcircled{3} \sigma_{\text{axial}} = \frac{F}{A} = \frac{225.6 \text{ lb}}{\frac{\pi (\frac{1}{4})^2}{4}} = \boxed{602 \text{ ksi}}$$

$$N = \frac{S_y}{\sigma_{\text{axial}}} = \frac{130 \text{ ksi}}{6.02 \text{ ksi}} = \boxed{21.5}$$

\uparrow
too high, but must happen due to standard bolt sizing

Math Lab

Analysis

A-42

Given) F_{axial} on stop bolt = 112.3 lb, $D = 5/8"$

Find) σ_{axial}

Mohr's circle to find σ_{max} in stop bolt

$$\sigma_{\text{axial}} = \frac{F}{A} = \frac{112.3 \text{ lb}}{\frac{\pi (5/8)^2}{4}} = 366 \text{ psi}$$

$$\sigma_{\text{bends}} = 37,137 \text{ psi}$$

$$\sigma_{\text{max}} = \sigma_{\text{axial}} + \sigma_{\text{bends}} = 37,137 + 366 = 37,503 \text{ psi}$$

$$\tau_{\text{xy}} = \frac{V_{\text{max}}}{A} = \frac{39.6 \text{ lb}}{\frac{\pi (5/8)^2}{4}} = 1290 \text{ psi}$$

Given) $\sigma_x = 37,503 \text{ psi}$, $\tau_{xy} = 1290 \text{ psi}$

Find) σ_{max} (Mohr's), N

Soln

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_1 = \frac{37,503}{2} + \sqrt{\left(\frac{37,503}{2}\right)^2 + 1290^2} = \boxed{37,547 \text{ psi}}$$

$$\tau_{\text{max}} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{37,503}{2}\right)^2 + 1290^2}$$

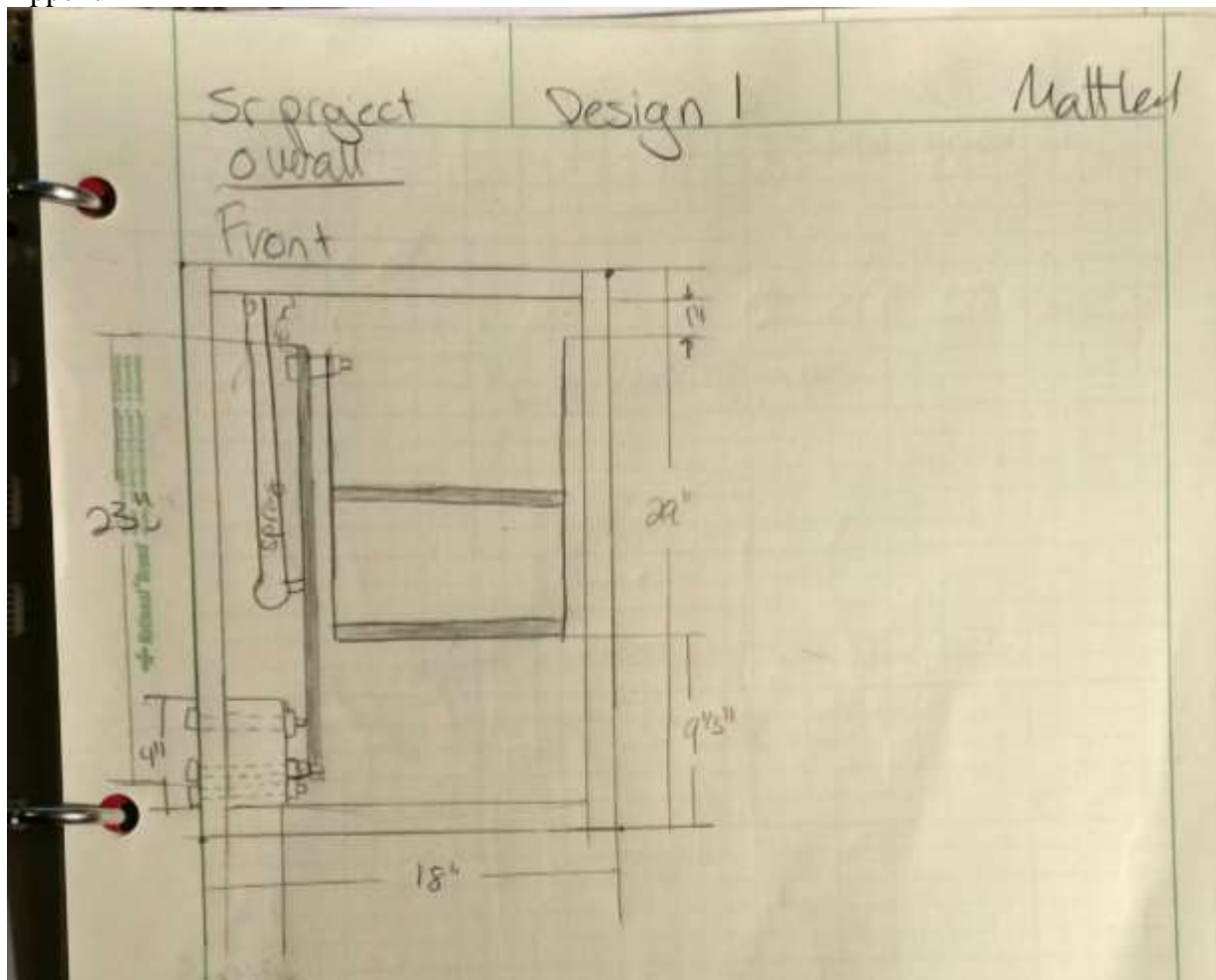
$$\tau_{\text{max}} = \boxed{18,795 \text{ psi}}$$

$$N_{\sigma} = \frac{S_y}{\sigma_1} = \frac{130,000}{37,547} = \boxed{3.46} \leftarrow \text{good!}$$

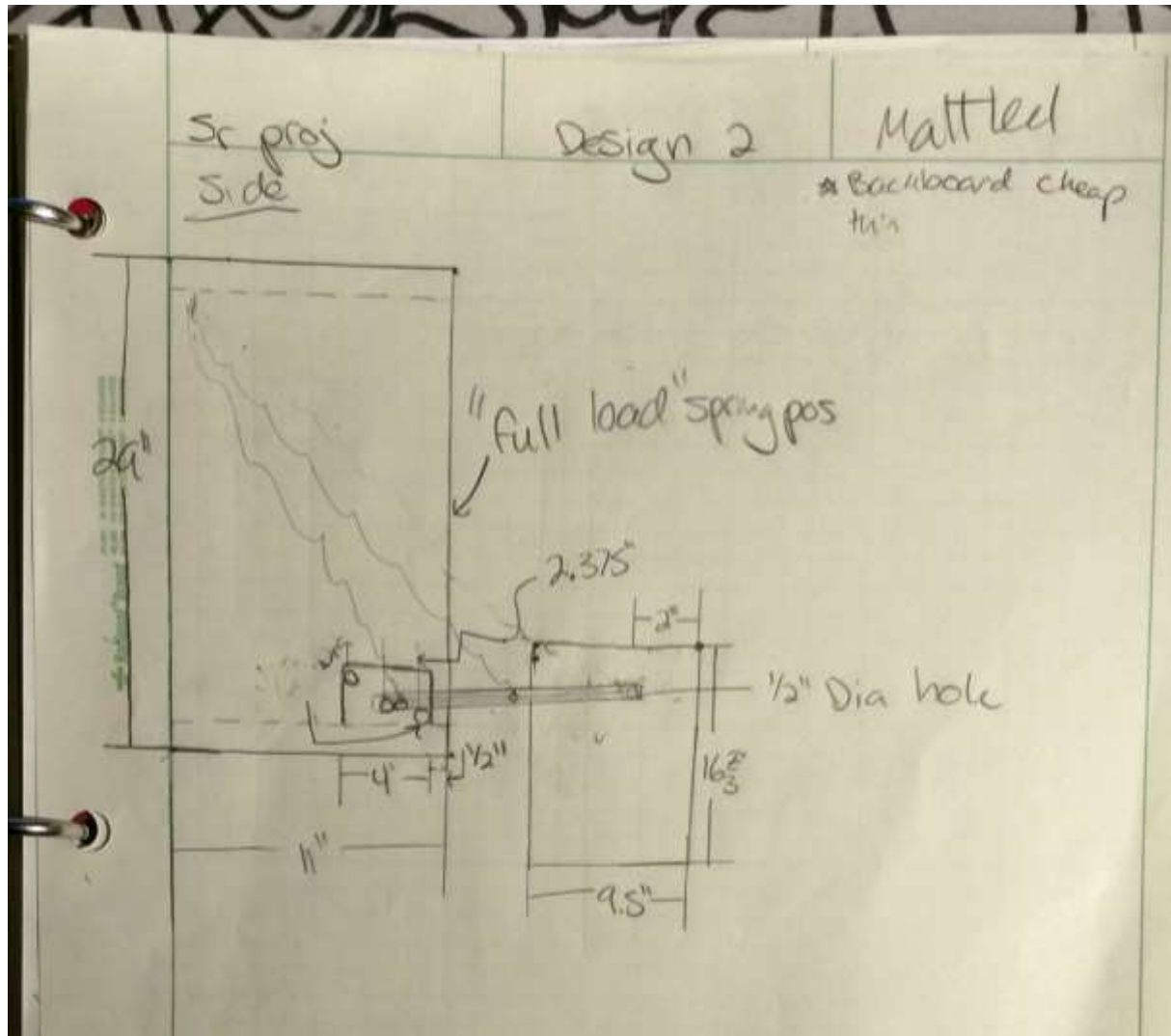
$$N_{\tau} = \frac{S_y}{\tau_{\text{max}}} = \frac{130,000 \text{ psi}}{18,795 \text{ psi}} = \boxed{6.9}$$

$$N_{\text{min}} = 3.46 = \text{good}$$

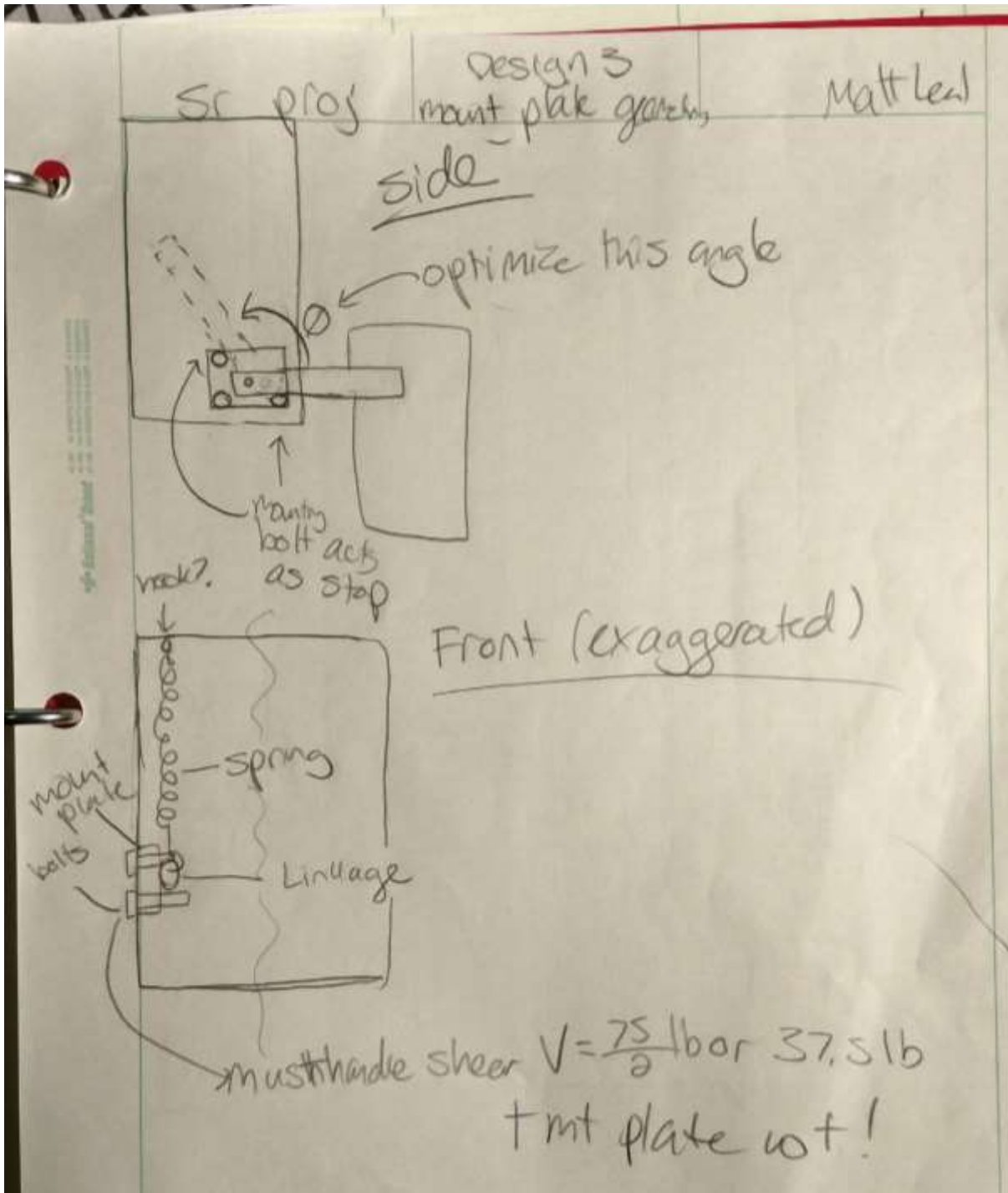
Appendix B



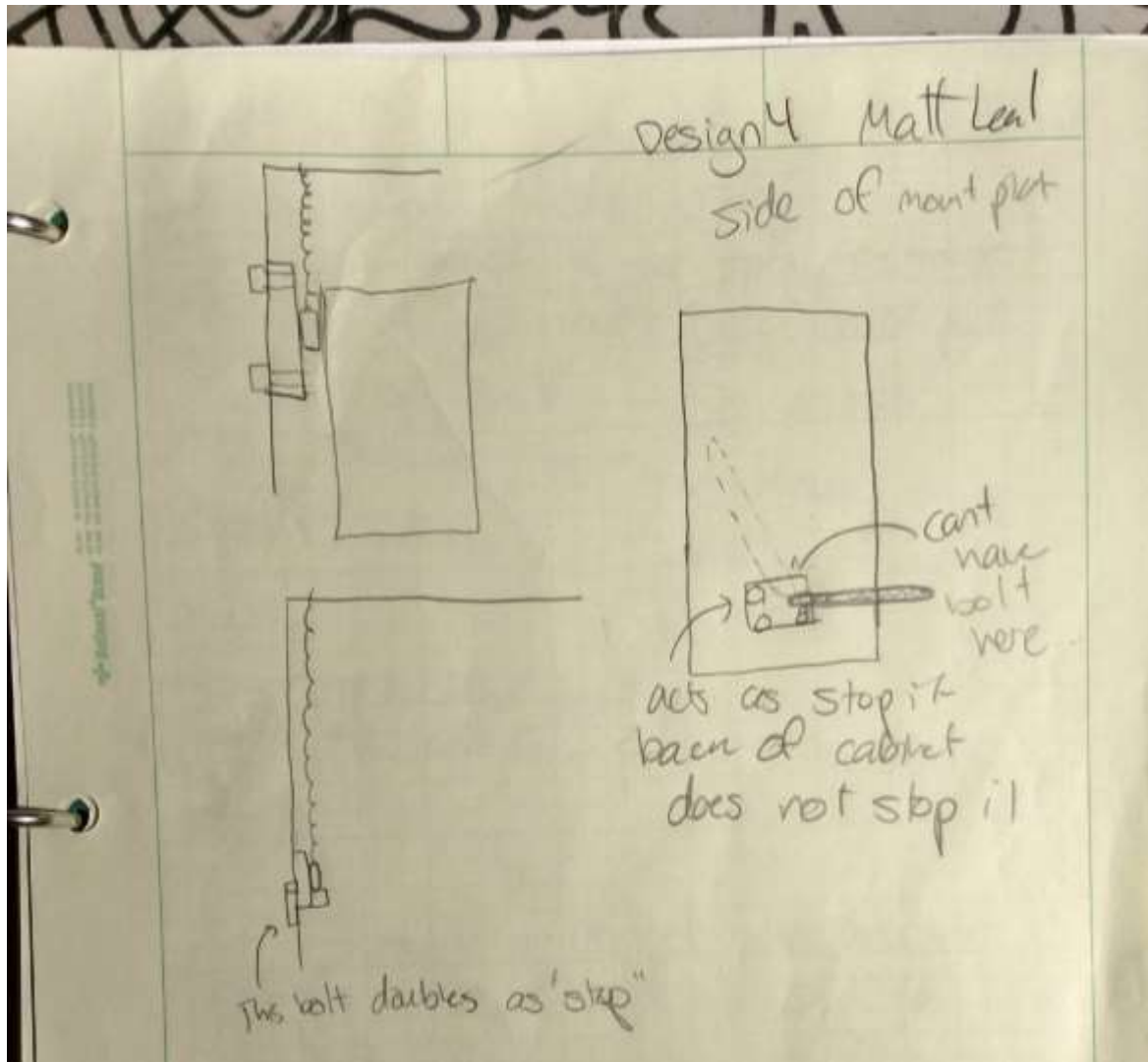
B-1



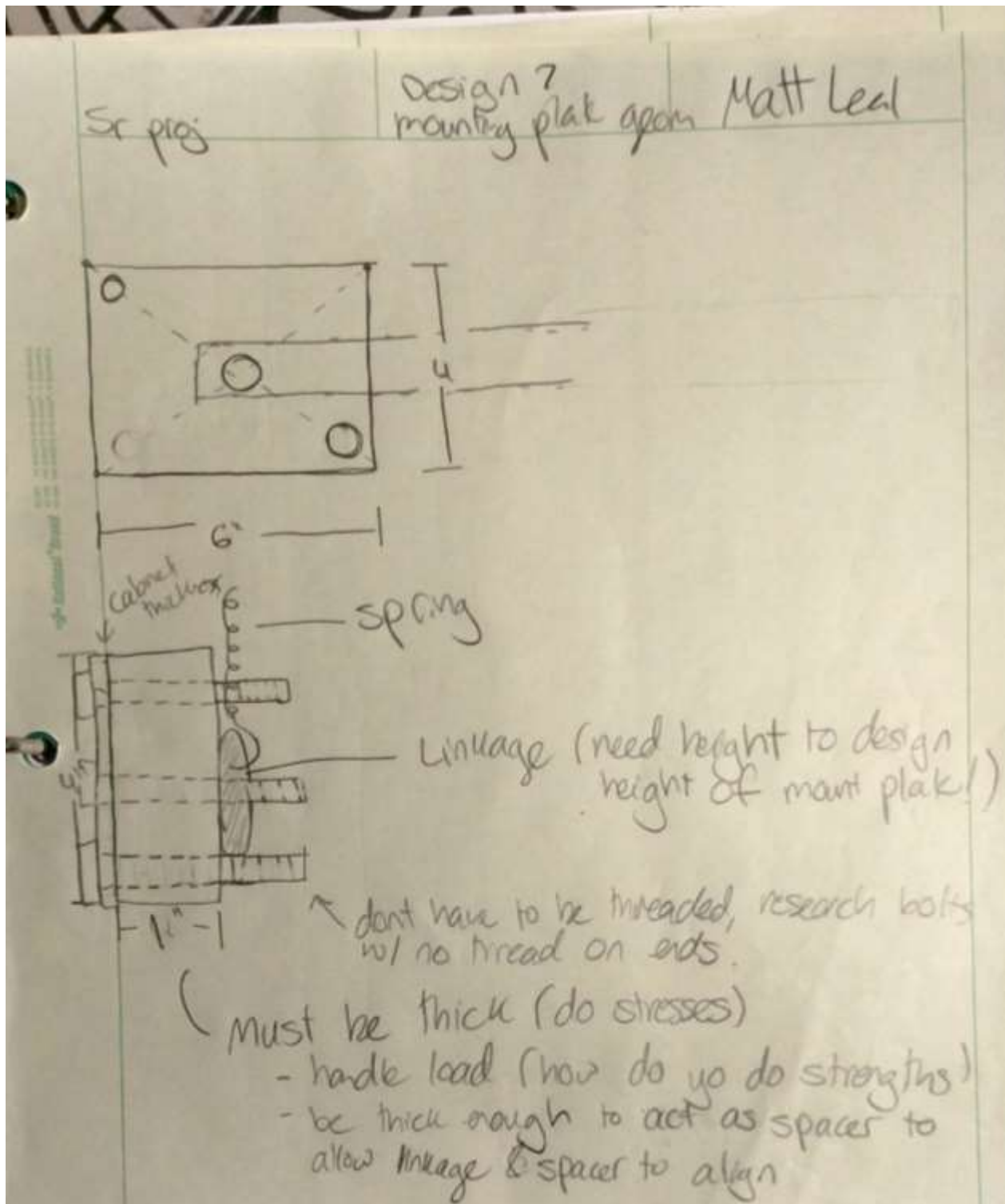
B-2

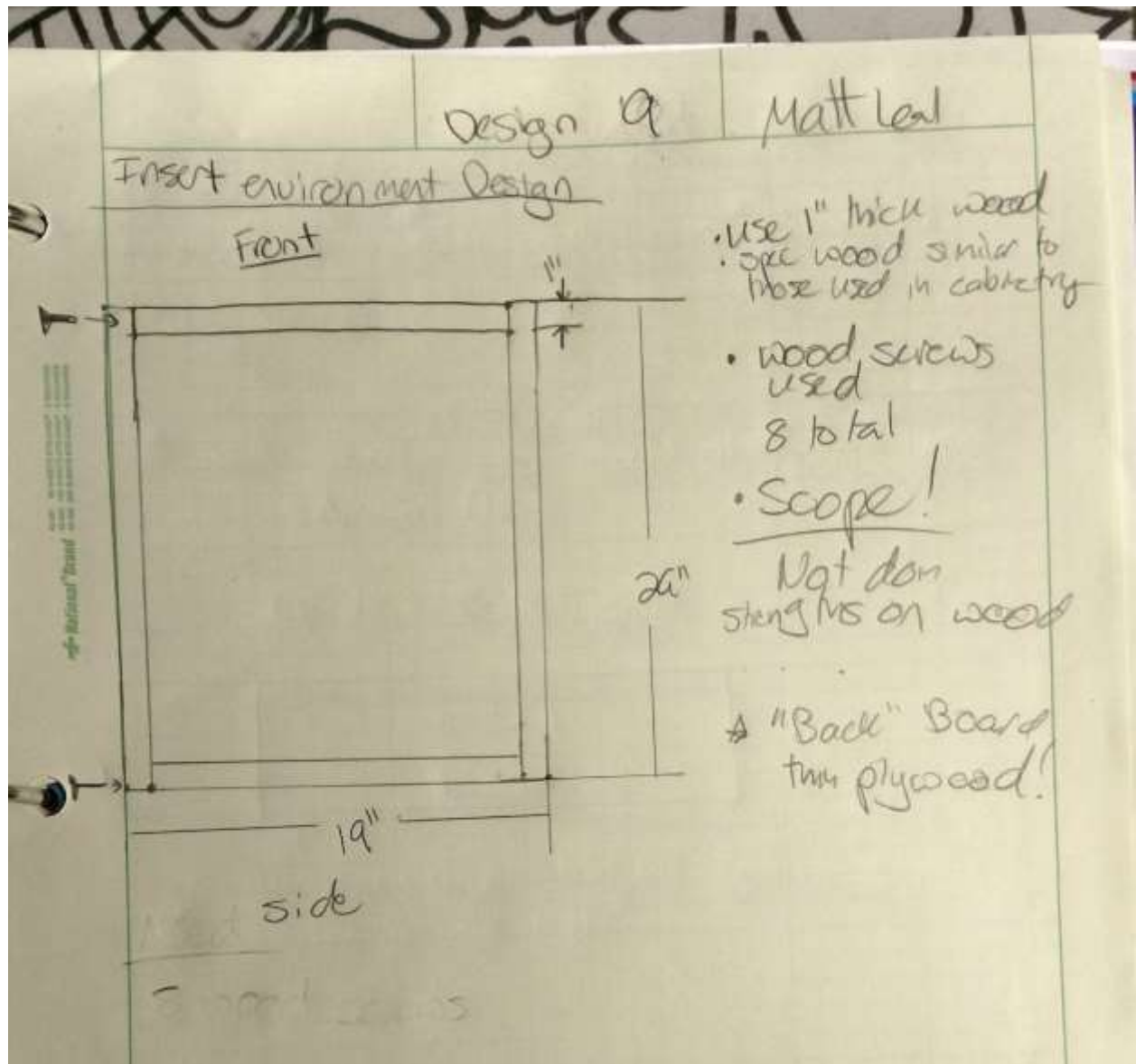


B-3



B-4

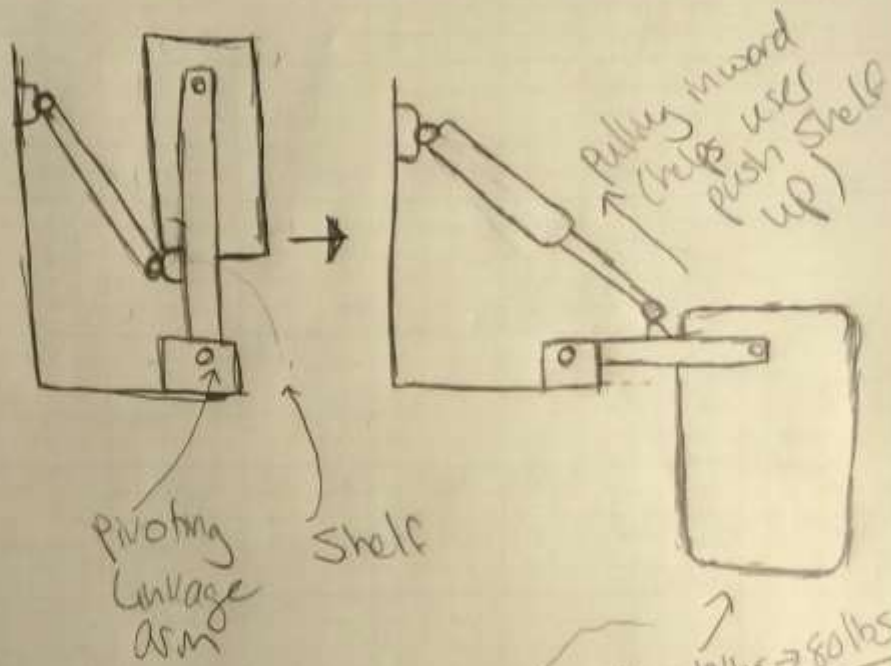




B-6

Sr proj Design 112 Matt Leal
Gas spring concept

Gas traction (pull-in force...)



Need

- k (For gas spring)
- Dimensions of standard gas spring
- ensure gas-traction is correct gas spring type

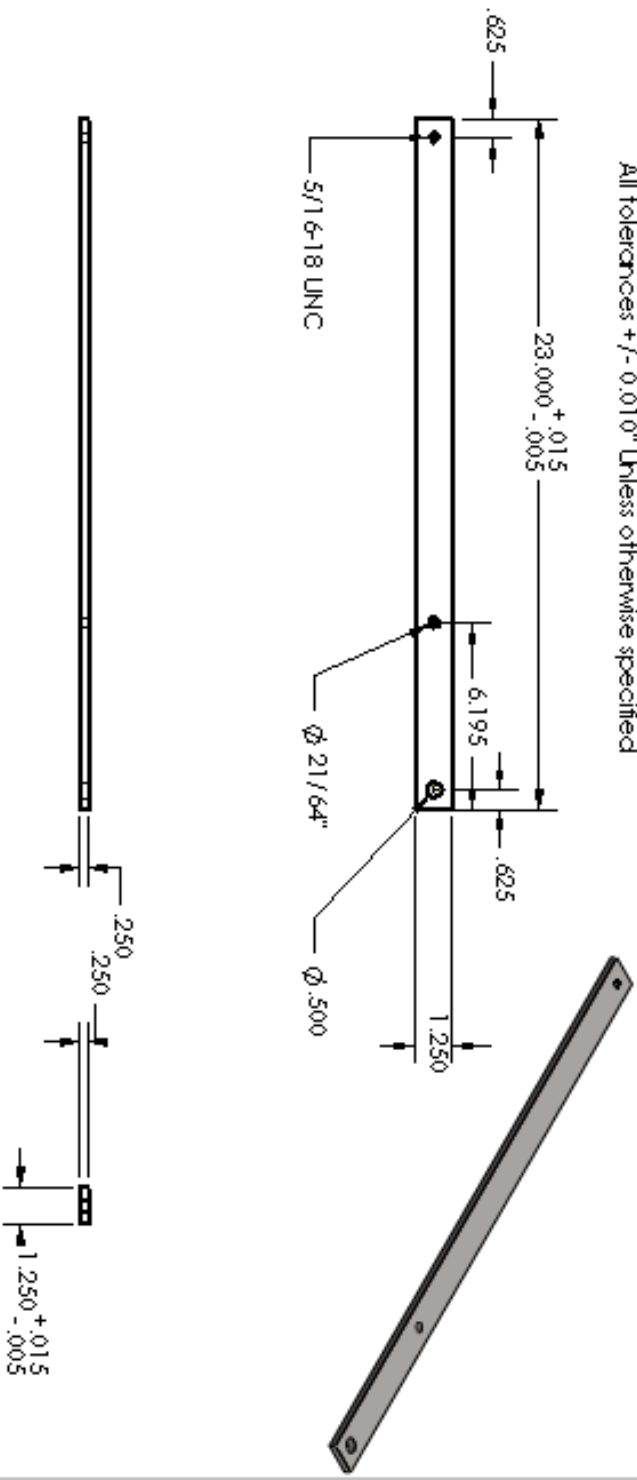
$W \approx 10 \text{ lbs} \rightarrow 80 \text{ lbs}$

(changes w/ dishes being loaded/unloaded)

2

1

All tolerances +/- 0.010" Unless otherwise specified

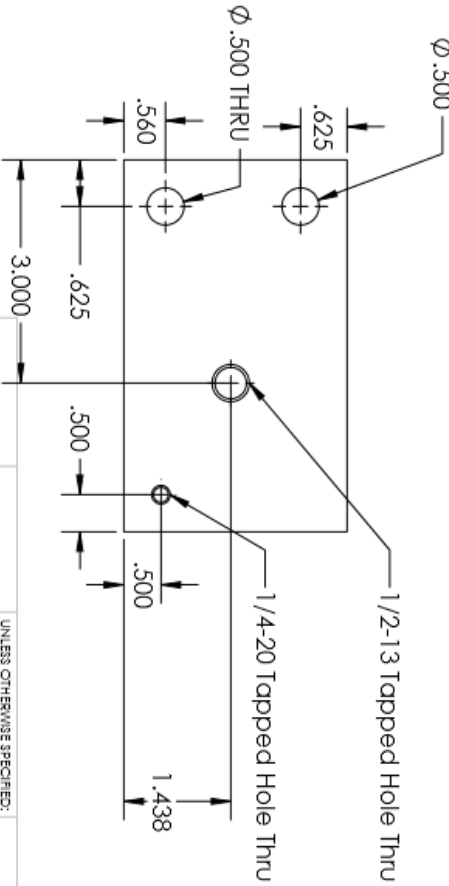
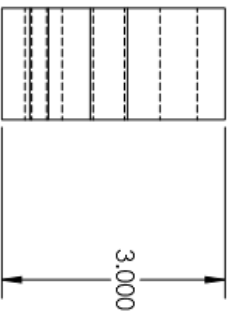
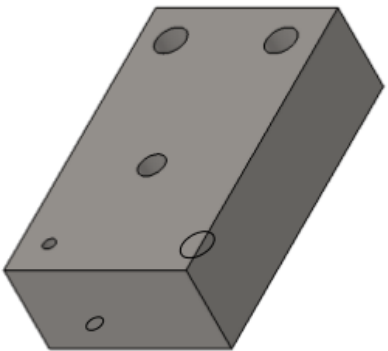
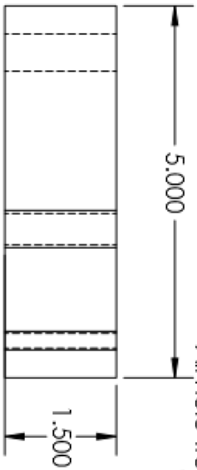


UNLESS OTHERWISE SPECIFIED:				DRAWN		DATE	
DIMENSIONS ARE IN INCHES				CHECKED			
FRACTIONS: 1/16, 1/8, 1/4, 1/2, 3/4, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000				CHECKED			
APPROVALS AND COMMENTS:				DATE			
BY: [Signature]				DATE			
TITLE:				DATE			
Linkage Arm				DATE			
SIZE: DWG. NO.				DATE			
A				DATE			
SCALE: 1:1 WEIGHT:				DATE			
SHEET 1 OF 1				DATE			

2

1

All tolerances +/- 0.010" unless otherwise noted.
All hole diameter tolerances +/- 0.005"
All hole true center location must be within +/- 0.005"



PROPERTY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY OF
SOUTHWEST ENGINEERING
REPRODUCTION IN PART OR AS A WHOLE
WITHOUT WRITTEN PERMISSION IS
PROHIBITED.

NOT FOR
USE ON
PRODUCT FOR
INSTRUCTIONAL USE ONLY

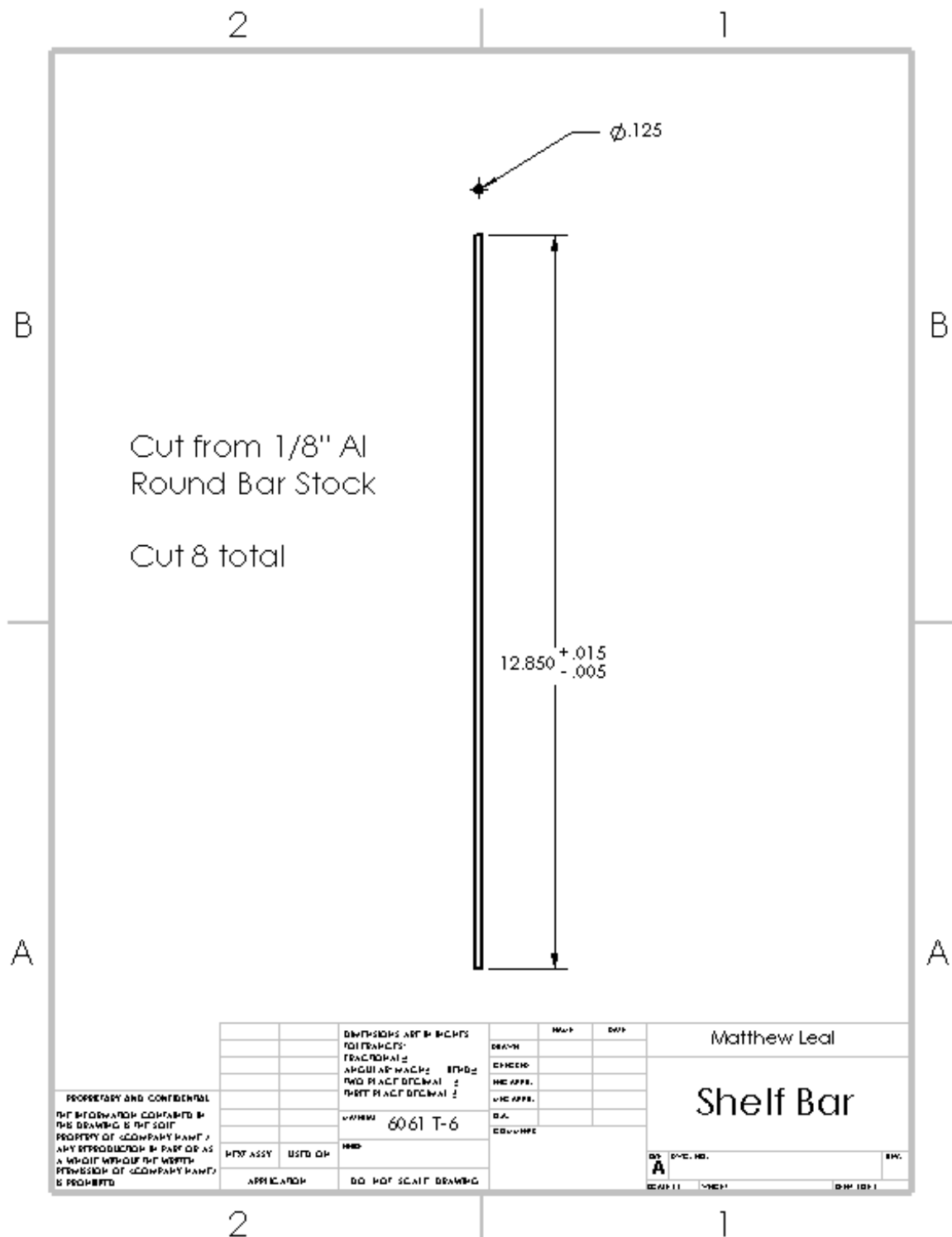
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL:
ANGULAR: MACH. ±
TWO PLACE DECIMAL:
THREE PLACE DECIMAL:
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL:
1018 Steel

FINISH
DO NOT SCALE DRAWING

TITLE:
Matthew Leel
Mount Block
SIZE DWG. NO. A
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

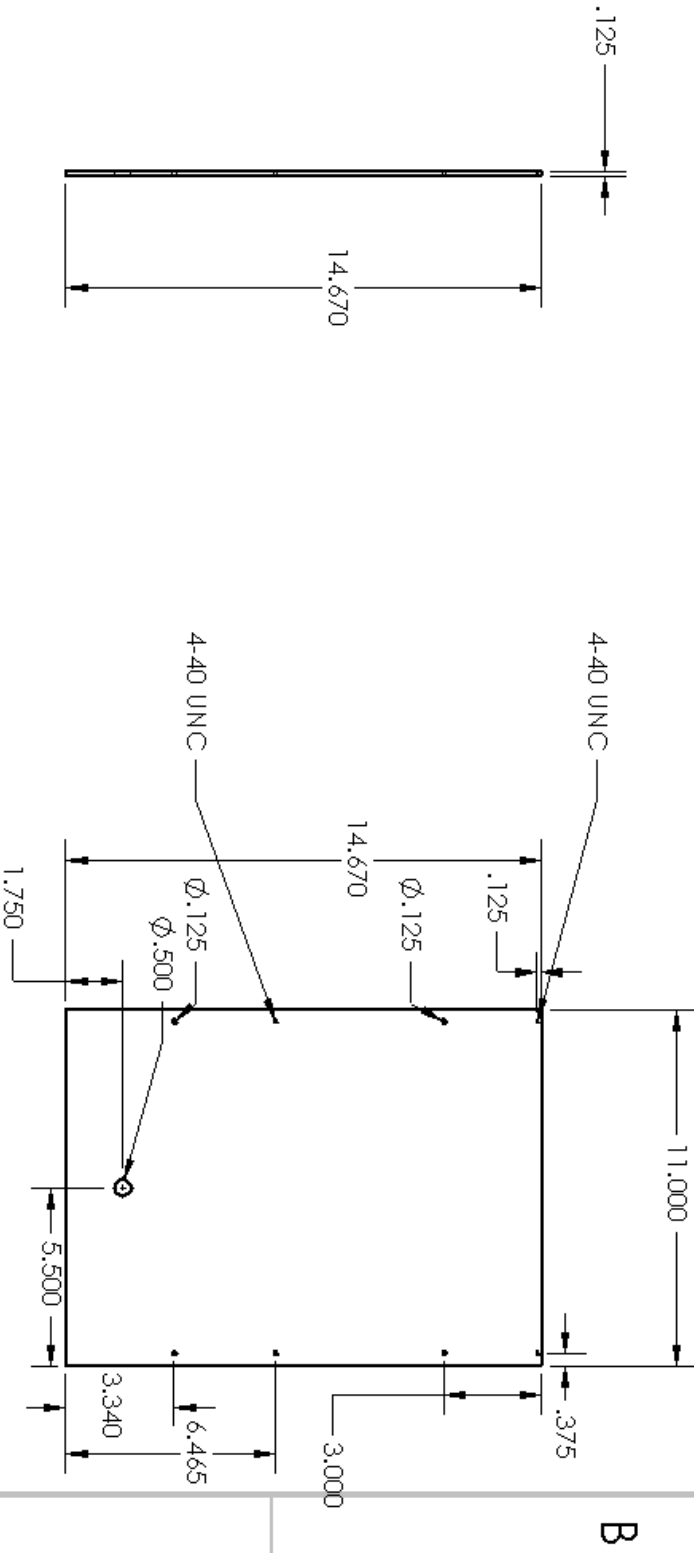
2

1



B-10 (OLD CONCEPT)

All holes thru-all
All tolerances +/- 0.010" Unless otherwise noted



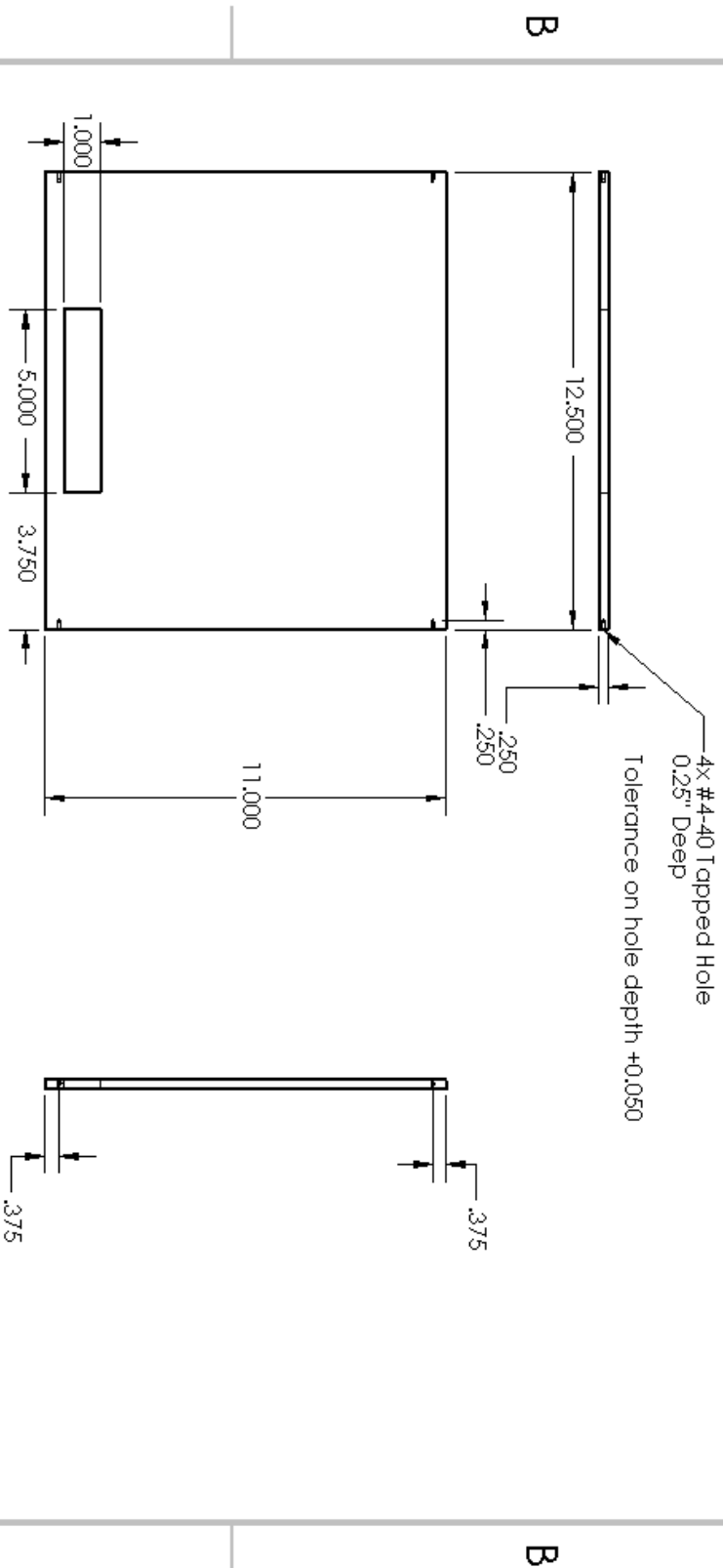
UNLESS OTHERWISE SPECIFIED:		DIMENSIONS ARE IN INCHES		TOLERANCES:		FRACTIONAL ±		ANGULAR: MACH ±		BEND ±		TWO PLACE DECIMAL ±		THREE PLACE DECIMAL ±	
DRAWN		NAME		DATE		CHECKED		ENG APPR.		MFG APPR.		Q. A.		COMMENTS:	
TITLE:		Matthew Leal		DATE		SIZE		DWG. NO.		REV		A			
Shelf Wall with hole															
MATERIAL		6061 Aluminum		FINISH		NEXT ASSY		USED ON							
PROPERTY AND CONFIDENTIAL															
THE INFORMATION CONTAINED IN THIS															
DRAWING IS THE SOLE PROPERTY OF															
ENTER COMPANY NAME HERE. ANY															
REPRODUCTION IN PART OR AS A WHOLE															
WITHOUT THE WRITTEN PERMISSION OF															

B-11 (OLD CONCEPT)



2

1



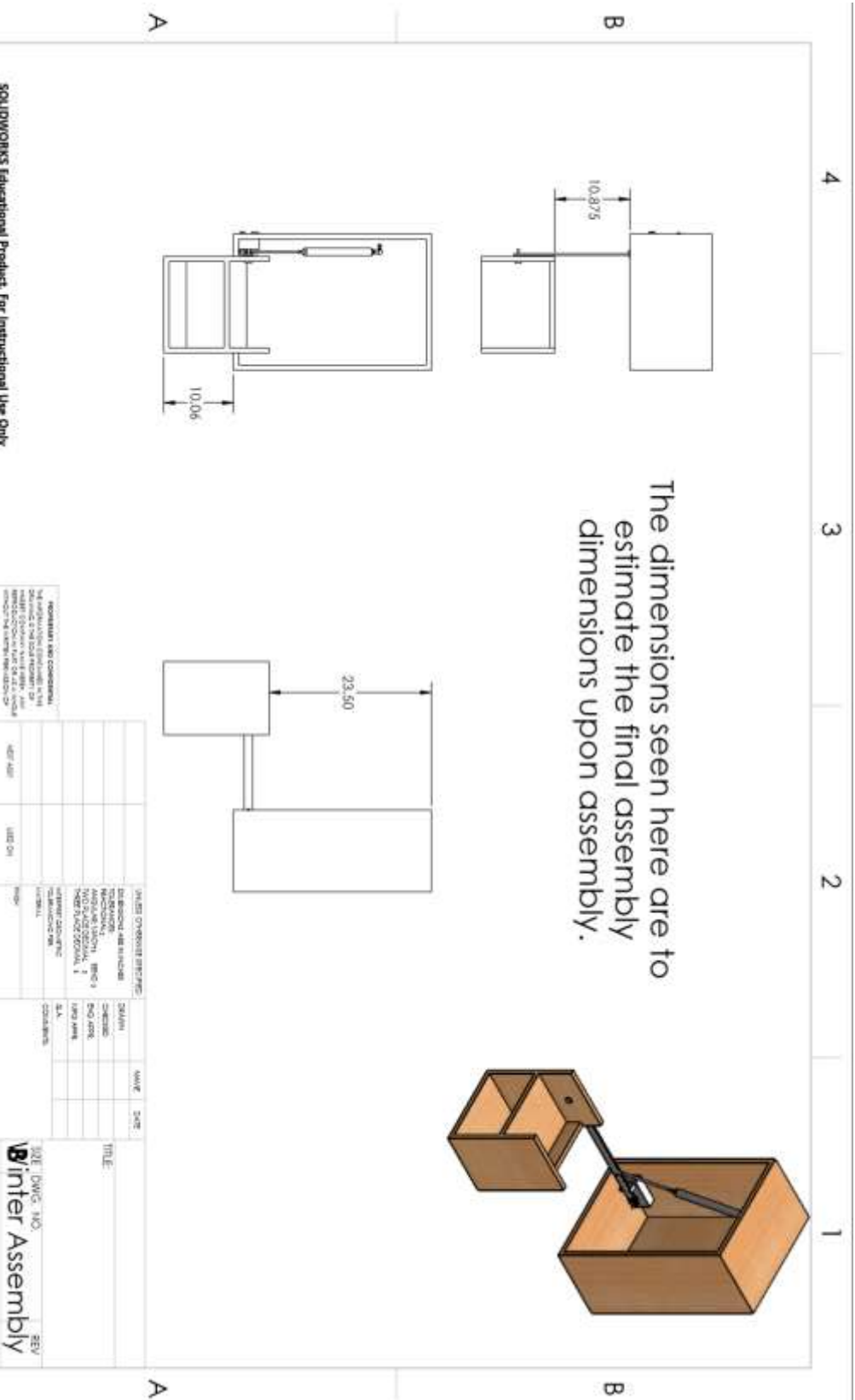
PROPERTY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY OF
INTERCOMPANY WARE, HEREIN. ANY
REPRODUCTION IN PART OR AS A WHOLE
WITHOUT THE WRITTEN PERMISSION OF
INTERCOMPANY WARE HEREIN IS
PROHIBITED.

UNLESS OTHERWISE SPECIFIED:		DRAWN		NAME		DATE	
DIMENSIONS ARE IN INCHES		CHECKED					
TOLERANCES:							
FRACTIONS: 1/16							
DECIMALS: 2							
HOLE PLACES DECIMAL 2							
HOLE PLACES DECIMAL 2							
INTERPRET GEOMETRIC							
TOLERANCING PER:							
MATERIAL							
6061 T6511							
FINISH							
NEXT ASSEMBLY							
APPLICATION							
DO NOT SCALE DRAWING							

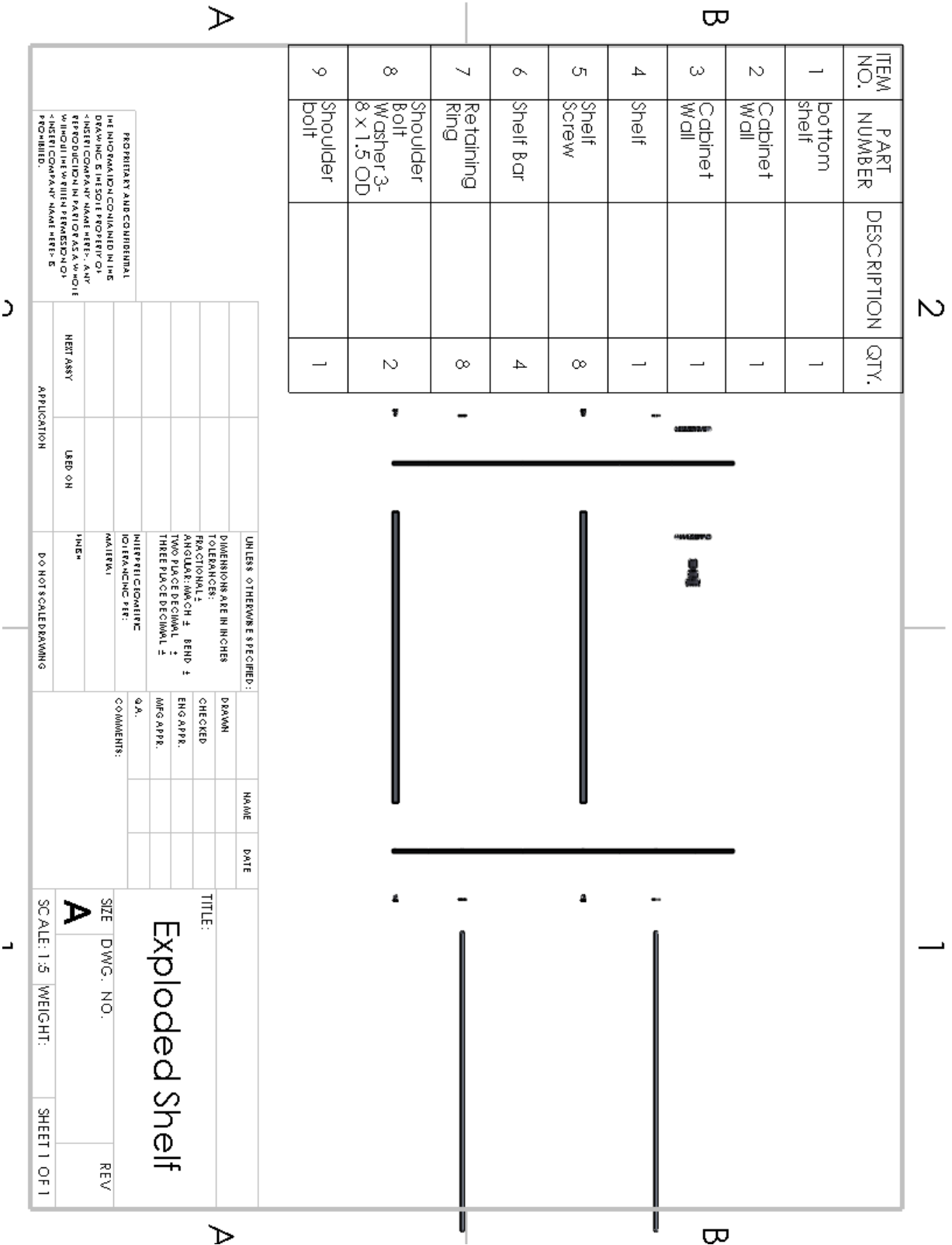
2

1

B-14 (OLD CONCEPT)



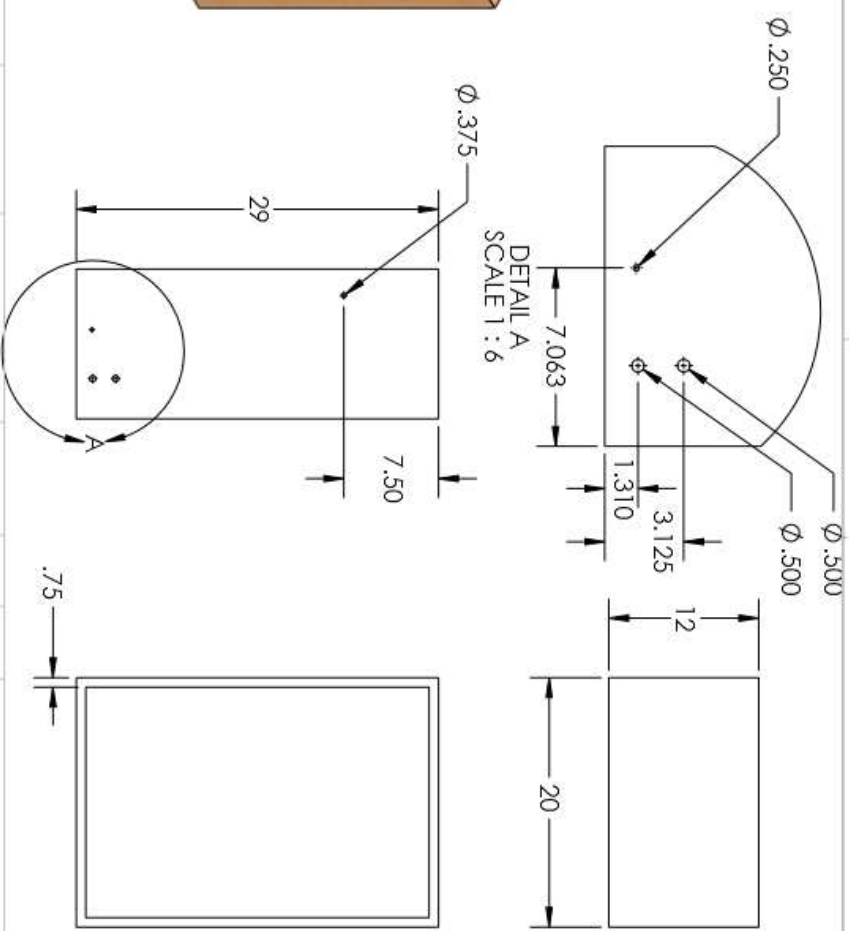
B-16



B-17 (OLD CONCEPT)

2

1



UNLESS OTHERWISE SPECIFIED:				DRAWN		NAME		DATE	
DIMENSIONS ARE IN INCHES				CHECKED					
TOLERANCES:				ENG APPR.					
FRACTIONAL: ±				I/FG APPR.					
ANGULAR: 1/40° ±									
TWO PLACE DECIMAL: ±0.010									
THREE PLACE DECIMAL: ±0.005									
INTERPRET GEOMETRIC TOLERANCING PER:				Q.A.					
MATERIAL:				COMMENTS:					
FINISH									
DO NOT SCALE DRAWING									

PROPERTY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT PERMISSION IN WRITING IS PROHIBITED.

NOT FOR USE ON

FOR Instructional Use Only

APPLICATION

SIZE DWG. NO.

Housing Actual

REV

SCALE: 1:12 WEIGHT:

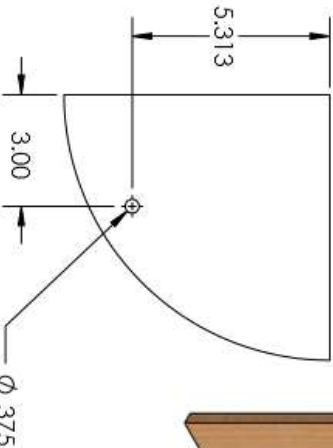
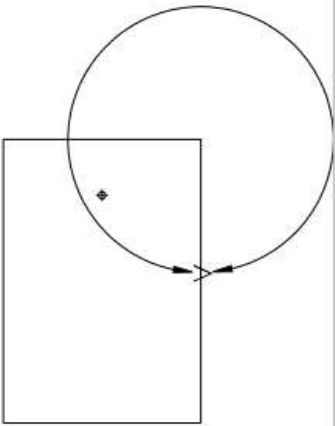
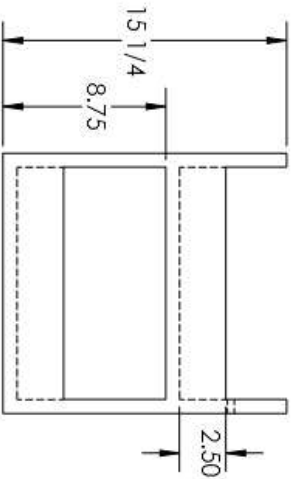
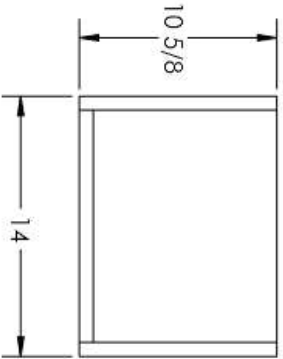
SHEET 1 OF 1

2

1

2

1



DETAIL A
SCALE 1 : 4

PROPERTY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY OF
SOLIMONSONS FOR EDUCATIONAL
PRODUCTS. ANY REPRODUCTION IN PART OR AS A WHOLE
WITHOUT WRITTEN PERMISSION IS
PROHIBITED.

UNLESS OTHERWISE SPECIFIED:		DRAWN		NAME		DATE	
DIMENSIONS ARE IN INCHES		CHECKED					
TOLERANCES:		ENG APPR.					
FRACTIONAL: 1/4		MFG APPR.					
ANGULAR: 1/4CH+/-							
BEND: 2							
TWO PLACE DECIMAL: ±.010							
THREE PLACE DECIMAL: ±.005							
INTERPRET GEOMETRIC							
TOLERANCING PER:							
MATERIAL:							
FINISH:							
APPLICATION:							

PROPERTY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY OF
SOLIMONSONS FOR EDUCATIONAL
PRODUCTS. ANY REPRODUCTION IN PART OR AS A WHOLE
WITHOUT WRITTEN PERMISSION IS
PROHIBITED.

DO NOT SCALE DRAWING

TITLE:		Matthew Leal	
SIZE:		DWG. NO.	
SCALE: 1:8		WEIGHT:	
SHEET 1 OF 1		REV	

Appendix C:

Item Desc	Supplier	Part #	Quantity
Gas Spring	Bansbach	A3A3Z-3-200-355-355N.	1
Shoulder Bolt	Fastenal	1126327	1
Grade 8 ½" x 2" Bolt	Fastenal	0115211	1
E-clips	Fastenal	0425226	8
Machine Screw	Fastenal	1128643	8
Al Rod	Metals Depot	R318	6ft
Clevis Pin	Fastenal	0156776	1
Cotter Pin	Fastenal	45288	1
1/8" Nylon Spacer	Fastenal	11107659	5
Grade 8 ¼"-20 x 3" Bolt	Fastenal	0115015	1

1/2" Stop Bolt	Fastenal	0115318	1
1/4" Washer	Fastenal	33857	1
1/4" Nut	Fastenal	36402	1
5/8" Washer	Fastenal	33819	1
5/8" Nut	Fastenal	36414	1
3/8" Jam Nut	Fastenal		1
3/8" Washer	Fastenal	11101274	2
1/2" Washer	Fastenal	33861	1
1018 for Arm	Speedy Metals	18f.25x1.25-24	24"
1018 for Mount Block	Speedy Metals	18f2x3-6"	6" (custom)
6061 round for Shelf Bars	Online Metals	NO PART #	6ft
6061 for Shelf Wall	Online Metals	NO PART #	1/8" x 24"x 36"
6061 for Shelves	Online Metals	NO PART #	1/4" x 12" x 36"

Appendix D:

Current Budget:

Item Desc	Supplier	Part #	Cost	Quantity
Clevis Pin	Fastenal	0156776	DONATION	1
Cotter Pin	Fastenal	45288	DONATION	1
Gas Spring	Bansbach	A3A3Z-3-200-355-355N.	\$18	1
Shoulder Bolt	Fastenal	1126327	DONATION	1
Grade 8 ½" x 2" Bolt	Fastenal	0115211	DONATION	1
E-clips	Fastenal	0425226	DONATION	8
Machine Screw	Fastenal	1128513	DONATION	8
Al Rod	Metals Depot	R318	\$3.70	6ft

1/8" Nylon Spacer	Fastenal	11107659	DONATION	5
Grade 8 1/4"-20 x 3" Bolt	Fastenal	0115015	DONATION	1
1/2" Stop Bolt	Fastenal	0115318	DONATION	1
1/4" Washer	Fastenal	33857	DONATION	1
1/4" Nut	Fastenal	36402	DONATION	1
5/8" Washer		33819	DONATION	1
5/8" Nut		36414	DONATION	1
3/8" Jam Nut			DONATION	1
3/8" Washer		11101274	DONATION	2
1/2" Washer		33861	DONATION	1
1018 for Arm	Speedy Metals	18f.25x1.25-24	\$6.07	24"
1018 for Mount Block	Speedy Metals	18f2x3-6"	\$24.72	6" (custom)

6061 round for Shelf Bars	Online Metals	NO PART #	\$1.21	6ft
6061 for Shelf Wall	Online Metals	NO PART #	\$46.57	1/8" x 24"x 36"
6061 for Shelves	Online Metals	NO PART #	\$38.25	1/4" x 12" x 36"
TOTAL			\$138.52	

Red text indicates stock that would be bought if the aluminum shelving concepts were going to be manufactured

Appendix E:

SCHEDULE FOR SENIOR
PROJECT

PROJECT TITLE: High Accessibilty Kitchen Cabinet Insert

Matthew Leal Senior Project Timeline

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1

Plan Duration Actual Start

% Complete

Actual (beyond plan)

% Complete (beyond plan)

1 period = 1 day, Beginning Jan 10 2017

Feb 1

ACTIVITY PLAN START PLAN DURATION ACTUAL START ACTUAL DURATION PERCENT COMPLETE

Source and order 1018 1 1 1 1 100%

Source and order fasteners 3 1 3 2 100%

Link arm setup sheet 6 1 6 1 100%

Machine link arm 13 4 13 4 100%

Mount block setup sheet 19 1 19 1 100%

Machine mount block 22 3 22 5 100%

Source and order shelf 25 1 28 1 100%

Use SW to model 30 2 31 1 100%

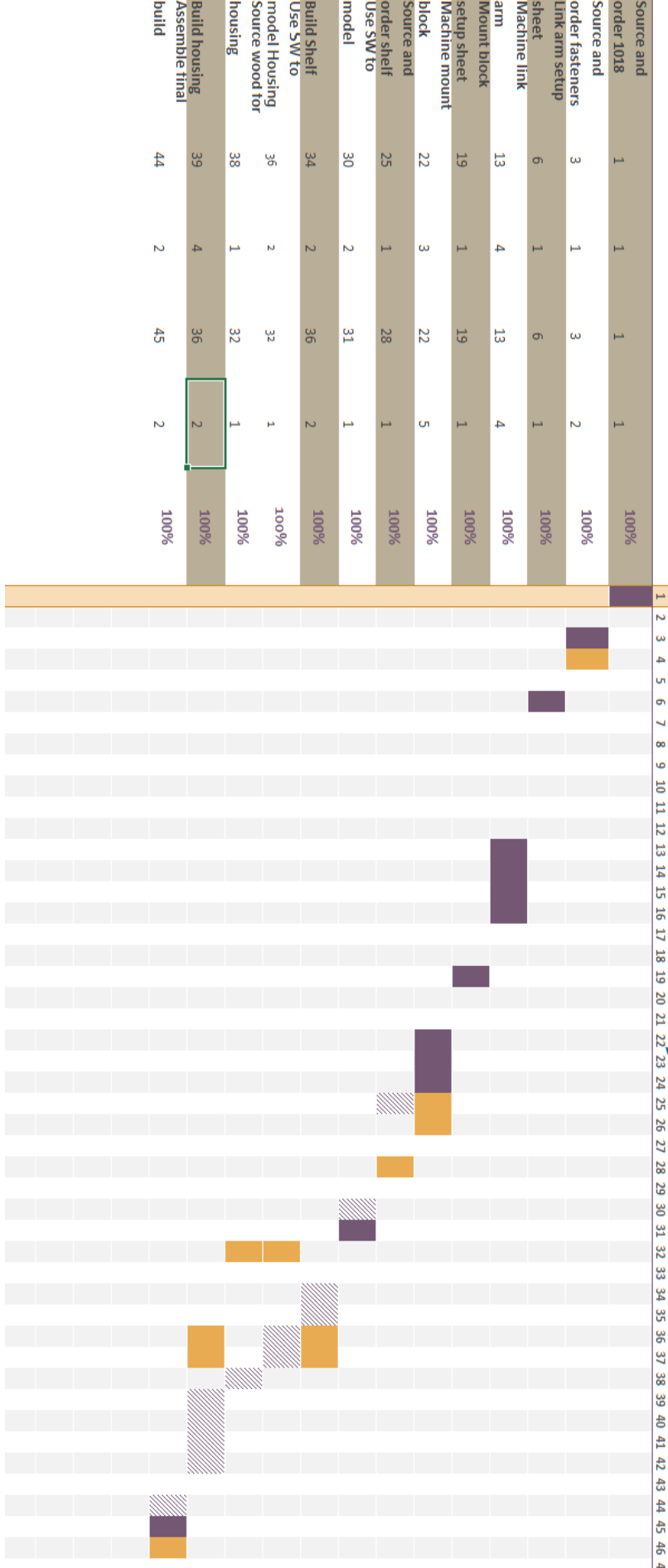
Build Shelf Use SW to model Housing Source wood for housing 34 2 36 2 100%

36 2 32 1 100%

38 1 32 1 100%

Build Housing Assemble final build 39 4 36 2 100%

44 2 45 2 100%



	A	B	C
1	TASK	Estimated Time (hr)	Actual Time (hr)
2			
3	Source and order 1018	1	1
4	Source and order fasteners	1	2
5	Link arm setup sheet	1	2
6	Machine link arm	3	4
7	Mount block setup sheet	1	2
8	Machine mount block	3	10
9	SW MODEL SHELF	1	2
10	Source and order shelf	1	1
11	Build Shelf	3	4
12	Use SW to model Housing	1	1
13	Source wood for housing	4	1
14	Build housing	2	5
15	Assemble final build	1	3
16	Total	23	38

Appendix J:

Matthew Leal

425-750-3674

6429 137th Pl SW Edmonds, WA 98026

msleal425@gmail.com

Professional Profile

- Skilled with Computers
 - Microsoft Office
- Skilled with AutoCAD and Solidworks
 - Certified Solidworks Associate
- Involved in lean manufacturing studies
- Actively designed products for machining
- Designed Programs for CNC mills and lathes
- Designed and cast parts in a foundry
- Professional speaking skills

Accomplishments

Academic

- Cumulative 3.4 GPA.
- Achieved Quarterly Honor Roll with the maximum load of classes (Winter 2014).
- Achieved Quarterly Honor Roll during every term involving MET classes.

Projects

- High Accessibility Kitchen Cabinet Insert (Senior Capstone Project at CWU).
 - Below, a working proposal for the project can be reached.

<https://drive.google.com/open?id=0B3zuPAotYpmLTkloemdvYnR5c3M>

Experience

Food Prep/ Dishwasher	John's Grill, Mukilteo, WA	08/12-09/13
Dishwasher	Sakuma Japanese Restaurant, Mukilteo, WA	06/14-09/14
Car Wash Attendant	Mr. Kleen Car Wash, Lynnwood, WA	06/15-09/15

Education

Graduate	Kamiak High School, Mukilteo, WA	06/13
In-Progress	Mechanical Engineering Technology Major at Central Washington University	Graduate date: 06/17

References

• John Alden	Owner of John's Grill/ Former Employer Johnsgrill@hotmail.com	425-347-1068
• Karen Hanreiter	Family Friend	425-652-9468
• Charles Pringle	CWU MET professor and advisor Charles.Pringle@cwu.edu	509-963-2437

Public Profiles

- LinkedIn
 - www.linkedin.com/in/Matthew-Leal

Appendix X

(CNC Mill Facing Program)

%

O0425

N1 (Rapid to cut position)

(3/4" Face Mill)

G90 M6T1 G43 H1

G54 G00 X-0.475 Y-2.625

M3 S750

/M8

Z1.000

Z0.100

Z-0.050

N2 (Cut Pass 1 .050)

G01 X5.275 F8

G00 Z.250

X-0.475 Y-1.875

N3 (Cut Pass 2 .050)

Z-0.050

G01 X5.275 F8

G00 Z.250

X-0.475 Y -1.125

N4 (Cut Pass 3 .050)

Z-0.050

G01 X5.275 F8

G00 Z.250

X-0.475 Y-0.375

N5 (Cut Pass 4 0.50)

Z-0.050

G01 X5.275 F8

G00 Z.250

Z1.00

G32 M9 M5

G91 G28 Y0

M30

%