Spring 2018

Slab Tipper

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Portable Slab Tipper

By

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Abstract:

Stone countertops are very heavy and fragile. When installing a finished countertop, up to six workers are required to lift the stone onto the countertop, risking their safety and possibly breaking the stone. The safety of both the workers and the stone are very important, so there needs to be a better way. NSI Solutions came up with an idea for a mechanism to aid in the insulation process while limiting the number of workers required, and keeping the workers safer while adequately supporting the stone to prevent it from breaking. Designing methods and calculations were done to ensure the mechanism can support the stone while limiting the size and weight of the mechanism. During the construction process several changes were made to the design of the mechanism to make it easier to construct, limit cost, and increase the strength of the Slab Tipper. During the testing process, the mechanism will be evaluated and changes will be made to improve the Slab Tipper and ensure that it will work in the field. In the end the Mechanism will consist of two separate stands that can be stored in the installation truck when not in use. Then the stands can be set up next to the cabinets that the countertop will be installed on.

Key Words: support, strength, safety

Introduction

Description:

When installing a finished slab of granite, it is crucial that the slab is supported properly. Granit is so heavy that it can break under its own weight. This could lead to loss of thousands of dollars in materials, it could damage the cupboards, or injure workers. By designing a mechanism for installing the finished counter tops, the risk of injury or loss of revenue can be greatly reduced. The mechanism will also limit the amount of workers required for a large install, reducing the labor costs for some installations.

Motivation:

A company by the name NSI Solutions has requested an insulation mechanism after their partner company broke a large slab of granite during an installation over the summer. Luckily no one was injured and they were able to fix the counter top after several additional hours of work on the counter top. This may not be true for every instant in the future.

Function Statement:

The mechanism must be able to adequately support a finished slab of stone and transport it to the countertop

Requirements:

- Must be able to be carried by one person
  - Weigh less than 50lbs
- Must be able to support a finished countertop with a maximum weight of 1500lb
  - Stone must not flex more than .25" (number provided by NSI Solutions)
- Must be able to be operated by 2-3 person(s)
- Must protect the floors and cabinets
  - Properly disperse the weight of 1500lbs through its feet to prevent from breaking tile or wood floors (exert less than 250lb at any given point)
- Must cost less than $1000
- Must be able to be used on all counter heights
  - Height adjustable form 30" – 42"
- Must be able to be used in a 42" aisle (36" is ideal)
- Stand must be able to be setup close to cabinet
  - Pivot point 10"-12" from cabinet

Success Criteria

Success of the Slab Tipper will be judged based on its ability of demonstrating a working prototype for testing and evaluation. The Slab Tipper will be considered a success if it can successfully transport a completed stone countertop to the top of a cabinet without breaking, damaging the floor/cabinet, and reducing the amount of workers required for installation by at least one.

Design & Analysis

Installation of stone countertops requires several workers to transport the stone to the top of the counter and the stone can break under its own weight. The slap tipper is a mechanism that limits the amount of workers required to do an installation, while adequately supporting the stone reducing the risk of the stone breaking. In appendix A.1 there is a sketch showing the distribution of the mass of the stone in the upright position, for a free standing mechanism with four legs and feet, where the stone will be prepped for installation. In the upright positing the stone will be exerting a 600lb force downwards on the stand, where the pivot point will have to counteract that with a 600lb force upward to have Fy=0. Looking at the requirement that the stand must distribute the weight of the stone to prevent a tile floor from breaking. Appendix A.2 shows the first RADD calculations with free body diagrams breaking down the forces in the stand. With a SF of 2.0 each foot of the stand exerts a force of 375lb onto the floor. The tiles are rated for 250lb of force at one point according to ASTM C648. To avoid breaking or damaging the tile a foot was designed to distribute the force onto the tile into a larger area. With the foot designs the ceramic tile should only experience 29.84 psi at any given point of the foot. The drawing for the foot can be found in Appendix B.1.

After consulting with the owners of NSI Solutions, the four leg design was scraped and a three legged design was introduced. Still taking into account that the stand has to adequately distribute the weight of the stone to prevent from damaging the floor a second RADD was calculated. In Appendix A.3 shows the new 3 legged design and the force distribution that goes along with the new design. The final force was found to be a 500lb vertical point force being exerted on the floor. Taking the 250lb point breaking force, provided by ASTM C648, it is found that any foot with a surface area will distribute the force enough to prevent the floor from breaking. Taking the findings in Appendix A.3, a ladder style foot was designed to allow for the foot to pivot on an axis to help prevent high spots. It was also decided that the surface that comes into contact with the floor will be covered in a soft rubber to reduce the chance of scratching the floor as well as adding another method to prevent high pressure points. The Ladder style foot design can be found in Appendix B.6, with a base of 5”x2”. Appendix A.17 shows that the ladder foot has a surface area of 10in^2 and with a force of 500lb on every foot, each foot will exert a pressure on the floor of 50psi.

The Slab Tipper must be able to support a slab of granite up to 1500lb without breaking the stone. Looking at the requirements the stone must not deflect more than 0.25 inches. Taking into this requirement several methods were designed, to support the center of the stone. The original design can be seen in Appendix B.3 and Appendix B.15. This method of supporting the middle of the stone used 1" diameter steel pipe that is easily purchased in a local hardware store and one or two notched beams that lock onto the pipe and can be slid into place to support the center of the stone. The issue with this design is that the maximum deflection was found to be 5.5 inches, which is significantly over the requirement, calculations for this method is in Appendix A.10.

After consulting with the owner of NSI Solutions, the design to support the middle of the stone was simplified into a rectangular tube on edge, this will provide an increased moment of inertia limiting the deflection in the middle of the stone. The new design can be seen in Appendix B.12 and the calculations can be found in Appendices A.11-13. In A.11 calculations for a 2"x1" tube made of aluminum (aluminum was chooses to try and limit the weight of the full mechanism) with a thickness of .125 inches has a deflection of 0.868inches when loaded with a 1500lb slab, this is still over the requirement. It was decided that since the middle supports won't always be used, it isn't important that they be made of aluminum to reduce weight. Revision 3 uses the same dimensions as the aluminum square tube but in steel. The calculations for this is in A.12, when loaded with a 1500lb slab the middle of the stone will deflect 0.289 inches, this is just slightly over the requirement. In Revision 4, the final revision, a 2"x1" steel tube is still being used but the thickness was changed to 3/16 of an inch. When loaded up with a 1500lb slab Revision 4 of the middle support deflects 0.2166 inches in the center. This is under the requirement for deflection and is decided that the middle support will be 2"x1"-3/16" Steel Tube. The calculations for Revision 4 can be found in Appendix A.13.

During the construction process there was a few concerns raised. One being the amount the Pivot Plate would deflect under a max load of 1500 lbs. Shown in the calculations in appendix A.21, the deflection of the Plate was calculated to be 0.154 in using 1.5in x 1.5in x 3/16in square tubing. This was expectable being less than the requirement of 0.25in or less. The second concern raised was the shear force in the bolts holding the mounded bushings to the pivot plate. The original .25in bolts were found to be perfectly fine for this application, the shear force in the 1/4in bolt was calculated to be 6754.54lb /in^2. This is well below the allowable shear force of a grade 8 1/4in bolt of 91ksi, the calculations for the shear force can be seen in appendix A.20. but it was decided to go with Grade 8 5/16in diameter bolts as a safety precaution as well as visual appeal, to appear stronger.

Methods & Construction

The main goal of this project is to make a working prototype of a slab tipper mechanism that could be developed and changed at a later date to fit extra needs and requirements to be placed on the market to sell. The main focus is the tipping mechanism needing to adequately support the stone without breaking and being able to distribute the weight evenly to prevent from damaging the floor. Building the mechanism will require a combination of specially machined parts specifically for this mechanism as well as some premade parts purchased from sellers like

McMaster-Carr and Everett Steel. Though the preferred material for the selling model would be aluminum, to limit cost of the mechanism, ease construction methods, and access of material, the prototype will be mainly constructed of steel. The reason the prototype will be made of steel is because the prototype will only be used for proof of concept of the mechanism, also steel is easily accessible and reasonably cheap for this application. It also comes in a wide variety of thicknesses and shapes to meet the needs of the mechanism. Having steel being the main material for the mechanism, it allows parts to be welded without special equipment that would be required if the stand was constructed of aluminum. Steel is also a good option for the prototype, because one of the harder requirements for this mechanism, is that it needs to support a stone slab up to 1500lb. Stone is very brittle and needs to be supported adequately with minimal deflection to reduce the chance of the stone cracking or breaking. Steel provides a high strength that aids in the ability to support the stone with a simple design. This mechanism is being used as a proof of concept, being displayed at a granite tooling show at the end of the 2017-2018 school year. Where the potential marketability of the stand will be assessed and the current design can be modified to solve other problems in the future.

One of the bigger issues that was ran into during the manufacturing process what figuring out how to cut the angled notches in the outer portions of the back legs, as seen in appendix B.20 and B.21. It was decided to use an angle grinder to cut the notches. This was the best way to go about things due to the fact the legs were going to be welded on to the outer vertical post, any imperfections in the cuts could be filled in during the welding process. During the process of welding the legs to the vertical post, the heat from welding deformed the vertical post, making it difficult or impossible for the inner post to slide up and down. The inner post had to be sanded down with a sanding disk as well as a notch milled along the length of the post to make room for the weld bead on the inside of the outer post. One of the changes made to the design of the stand was to add a collar to weld the fine adjustment in to allow for easy disassemble, or the ability to change to a different fine adjustment threaded rod and nut. The majority of the stand was cut and welded together with the rest being pinned together. Another change that had to be made was using a bigger mounted bushing with a taller center height. The original mounted bushing had a center height that was too small and caused the Pivot Plate and the Pivot mount to run into each other and impeded the way the mechanism worked. The new mounted bearings had bigger holes that were spread father apart this was fixed by drilling one of the original holes for the other mounted bushing bigger then drilling an addition hole for the new bushing. The third old hole was then filled in weld and ground flat.

Testing Methods

The slab Tipper has several requirements that could be tested. One of the biggest requirements is that the stand cannot damage the floor when it is under load. Flooring tile is rated to withstand 250lb of force unsupported without breaking.

Test1:
In appendix A.3 there is an analysis sheet calculating the psi of each foot over a given area. Testing to make sure that the slab tipper matches these numbers is very simple. By placing each

foot of the stand on an individual scale and loading the stand, the downward force that will be exerted on the floor can be assessed.

Test 2:
To ensure that the stand distributes the weight enough to prevent damaging a tile floor, several test floors can be constructed using different types of floor tile, both installed properly and improperly (using the right amount of grout and a separate test floor that doesn't use the right amount of grout). Then the stands can be placed on the test floors and be loaded up with a full stone slab, observing the floor for cracks of breaks.

Another requirement that NSI Solutions has brought importance is the capability of the stand being used in a 42" aisle.

Test 3:
The mechanism must be able to be used in an aisle 36"-42". To test its capability in fulfilling this requirement a replica setup can be made using a table and a wall. Placing the table 36"-42" way from the wall, then setting up and loading the stands with a stone, a test can be done to see if the mechanism can transport the stone onto the counter top.

These methods are just some of the ways the mechanism can be tested. Other methods of testing that take place will be added to the report when they take place. NSI Solutions will also have some other testing method ideas that can take place during the time set aside for additional testing.

After the construction process it was clear that the biggest question about the slab tipper is if it is stable enough to hold a slab of stone and transport it onto a counter top. With this in mind the testing plan was changed from a weight distribution test, to a full on mock installation to test the overall functionality of the Slab Tipper as well as its stability and its ability to support a counter top. All of the testing took place in Mukilteo Washington at NSI Solution.

Test 1:
The Stand were set up for a mock install using a shipping crate as a counter, as seen in Appendix G.2. A forklift was used to pick up a slab of stone and set it on the stands. As predicted after construction, the stability of the stands was apparent to be an issue with the functionality of the mechanism. When loaded with a slab of stone of about 400lbs, the stand would pivot of the front foot and would fall over if the load was fully on the stand. Due to safety precautions the first testing process was stopped. After the first test it was decided that the base needs to be increased in size to make it more stable.

With the first test finished it was clear the center of gravity of the mechanism and stone was too far forward for the size of base that the slab tipper had. The changes that were made to the stand was welding a plate to the base of the stand to increase the area, as well as shortening the tipping surface to move the center of gravity back.

Test 2:
After the modifications were made to the stands, the second test could be done. This test was just like the first, to see the setup go to appendix G.3. With the same process a forklift was used to pick up a slab of white quartz that was about 483lbs. This particular stone was selected for the increased strength of the manmade product as well as its consistent density of about 20lbs/ft^2. When loaded the stands remained stable and the Slab Tipper was able to transport the stone onto the counter top by both 1 and 2 men. This was a big improvement from the first test. With the success with the smaller stone and larger white quartz slab was then loaded onto the slab tipper. The Larger stone was approximately 950lbs. The Slab Tipper remained stable and a single person was able to tip the stone controllably onto the counter top.

All of the testing was overseen by a profession in the Granit industry with over 10 years of experience. After the mock install test the stand were weighed and had a final weight of approximately 100lbs per stand, twice the required limit. The force required to keep the stone horizontal was gathered using a scale. Using the findings a force graph was able to made to show the force required to transport the stone to the counter top both with and without the Slab Tipper. To see the data gathered and the force chart see appendix G.1.

Budget/Schedule

NSI Solutions have provided a total budget of $1000, this is the money that they have set aside for this project alone. Additional money may be requested and provided upon approval by NSI Solutions. Current the budget consists of parts and material costs that will be ordered for the manufacturing stage of the project. Also is included in the budget is a personal labor cost $1.25/hour. The total cost of labor depends on the total time it takes in the design, manufacturing, and testing processes. The current budget breakdown chart is located in Appendix D.1, in the figure it shows the cost of materials to be $729.81, the Material cost table is located in Appendix C.1. D.1 also shows the current Total cost of $98.75 and the predicted final cost of $958.87. The predicted cost is under the $1000 budget but methods to reduce the cost of the project should be evaluated, to help prevent going over the budget.

The Slab tipper project was started approximately 30 days late due to complications and availability one certain products necessary to start the construction process. This pushed everything back, the construction process was behind the majority of the winter quarter only catching up and getting on track during the final two weeks of the quarter. One of the reasons why it took so long for the project to get caught up was due to the lack of machine shop and welding shop time. With these setbacks it was still possible to get the project finished on time along with additional improvements to the mechanism. The original projected total time was 183.25 hours with the current time spent on the project of 119.25 hrs. This leave approximately 60hrs for the testing process.

The original projected cost for the materials for the Slab Tipper was approximately $729.81. This was under the $1000 budget, but during the construction process some changes were made to the design of the mechanism as well as material choices changed. After the Tippers were fully construction the material costs came out to be $390.85. This is almost a 50% cost cut from the original projected cost, and falls well below the budget limit of $1000. This leave room for additional purchases during the testing process to aid in testing as well as making changes as needed.

During the Testing portion of the project some issues came to light and modifications had to be made, this caused additional purchases of material. The modifications were required to be made to make the mechanism functional. After all of the modifications were made to make the mechanism work the final cost of materials was $460.69, this is well under the $1000 budget and the predicted cost of the project.

Discussion

During the design process of this project, the slab tipper has under gone several revisions throughout the entirety of the fall quarter. The original design ideas consisted of both a free standing 4 legged stand and a stand that required that it be mounted to the cabinet prior to the installation of the stone counter top. The design that required to be mounted to the cabinet was quickly scrapped by NSI Solutions. The four legged design was later changed to a lighter more compact 3 legged design, where most of the design process took place. You can see the three legged design in Appendix B.7. Another idea that was scrapped pretty early in the design process was the use of a linear speed limiter. NSI Solutions decided that there wasn't a big enough need for the limiter to justify adding it to the design, Appendix B.5 shows the design that incorporated the linear speed limiter. The company that requested the Slab Tipper also requested a simplified design of the stand, which aided in revision 2 of the fine adjustment mount. The original Fine Adjustment Mount is located in Appendix B.10 and revision 2 of the mount is located in Appendix B.11. One of the bigger design changed that greatly reduced the potential cost of this project was getting rid of a third stand to support the middle of the stone. Although the third stand would have been a more rigid method in supporting the center of the stone. A beam design that ran between two stands was chosen to support the center of the stone. This greatly reduced the total weight of the mechanism as well reducing the storage size and cost of the project. The Beam design also went under a couple revisions the first is shown in Appendix B.15, this design didn't support the center of the stone enough and had a high risk of the stone breaking at the midpoint. After a couple more revisions in the calculations located in Appendices A.10-13, The final design for the middle support is two 2"x1"x8'-3/16" Steel Tube that run the distance between two stands. This design can be seen Appendix B.12.

Conclusion

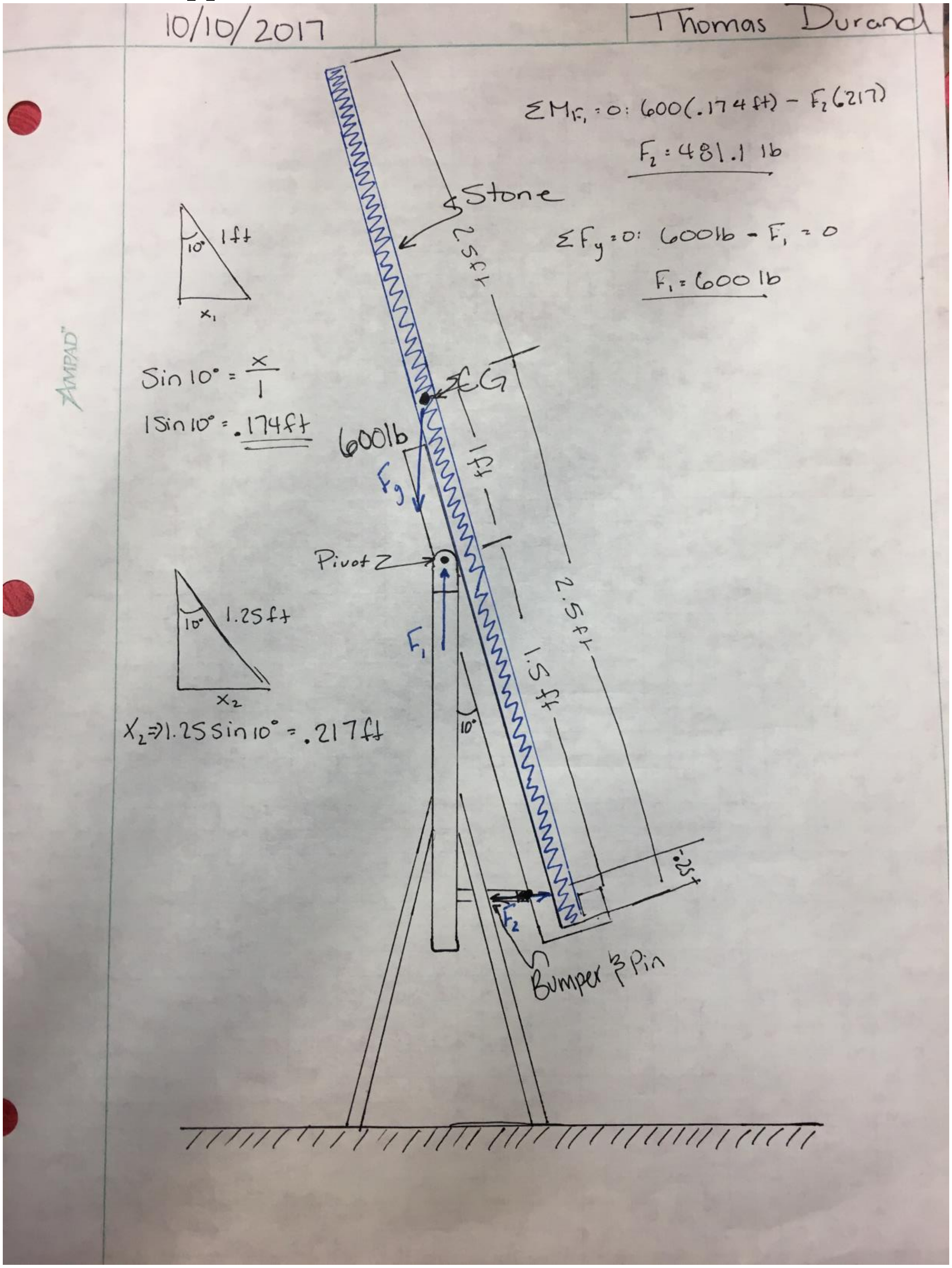
Success of this project relies on several major requirements, the ability to support a stone slab with a weight of 1500lb, protecting the floor by distributing the weight of the stone enough to prevent damaging the floor, and limiting the amount of workers required for a big installation. Calculations for these requirements can be found in Appendix A. A.13 shows the calculations of the final design for supporting the center of the stone. These calculations show that the stone will have minimal deflection when in the horizontal position limiting the potential of breaking the stone during installation. A.3 and A.18 shows the forces broken down along the components of the stand showing the force that each leg exerts on the floor then being dispersed across the surface area of the foot to limit the chance of the mechanism damaging the floor. Normally 5-6 workers are required for a big installation, but since the stand is supporting a majority of the stone slab, it is predicted that 2-3 workers may be required for the same install using the Slab Tipper mechanism. This can't be directly calculated using green sheets but Appendix A as a whole shows a significant amount of proof that this is possible. Assessment of this requirement will be evaluated upon completion of the manufacturing and testing stages.

After the construction process the two stands are complete and ready for the testing process. The stand came together as planned along with changes made after the design process. The stand is on the heavy side and could possibly be over the weight requirement. This is a minor issue due to the fact that the pivot plate and the stand can be separated from each other allowing for it to be moved with ease. The stand allows for installation at all required counter heights and room for variation.

The main requirement of the project was the mechanisms ability to transport a slab of stone to the counter top, this was proven to be met by the testing that was done. Along with this requirement was other such as be able to be operated by 2-3 people, weigh less than 50lbs, protect a tile or wood floor (exert less than 200lbs at any given point onto the floor), able to be used in a 42" isle, counter tops range from 30 to 42 inches, and cost less than $1000. All of the requirements were met except of the weight requirement. The mock install test was able to prove most of these to be met, the tipping surface was shortened to work in a 36" isle, 1 person was able to tilt a 963lb stone. The requirement of protecting the floor was not tested, but the calculations for three feet was done before testing and was predicted to be successful, so after the plate was welded to the feet it was decided that this requirement was met, as the plate was dimensioned to always be over at least one supporting beam in the floor. The weight requirement was not met, and it was about double the 50lb requirement, but this was decided to be the lease important of the requirements, as it is only a proof of concept for the company. If this was to be a product adopted by NSI Solutions the final product would be made of aluminum. Even with this in mind the tipping portion of the mechanism is easily separated from the stand portion, the base with plate weighs approximately 55lbs and the tipping portion about 40lbs, this makes the weight considerably easier to handle. After the whole testing portion was completed with modifications the project was deemed a success. All primary requirements were met, and the owners of NSI Solutions are satisfied with the Mechanism, it shows plenty of room for improving, and a promising future as having potential to become a marketable product.

Appendices

Appendix A.1 – Force Distribution on Stand



Appendix A.2 – RADD Weight Distribution 4 Legs

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RADD

Requirment: When supporting a full finished piece of stone the stand must not damage the floors. Tiles have a breaking strength of 250 lb, no tile should ever experience 250lb x force.

ASTM C648-04

Outrigger Pad

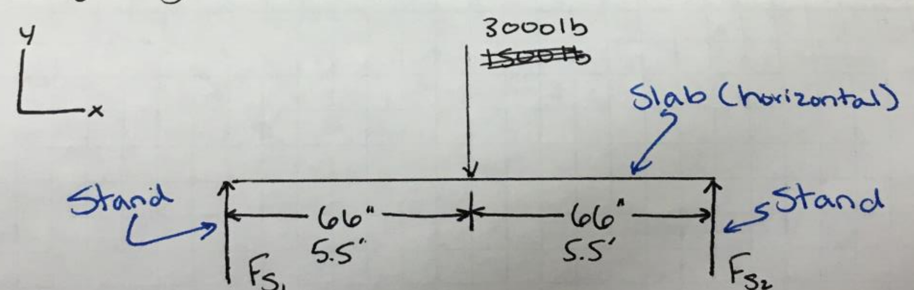
Analysis:

Avg max stone weight = ~~1200lb~~ 1500lb

SF = 2.0

Avg weight × S.F. ⟹ 1500lb × 2.0 = 3000lb

FBD.



$\Sigma M_{F_{S_1}} = 0 : 3000(\text{5.5}') - F_{S_2}(11') \Rightarrow \frac{F_{S_2}(11)}{11} = \frac{3000(5.5)}{11}$

$F_{S_2} = 1500\ \text{lb} \leftarrow$

$\Sigma F_y = 0 : 3000 - 1500 - F_{S_1} = 0 \Rightarrow F_{S_1} = 3000 - 1500$

$F_{S_1} = 1500\text{lb} \leftarrow$

$F_{S_1} = F_{S_2}$

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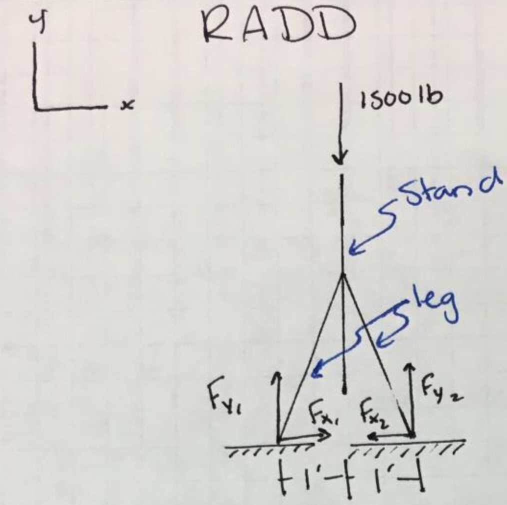
RADD

FBD$_2$



$F_{x_1} = -F_{x_2} \Rightarrow 0$

$F_{y_1} = F_{y_2}$

$\Sigma F_y = 0: \quad 1500\,lb - 2F_{y_1} = 0 \implies 2F_{y_1} = 1500\,lb$

$F_{y_1} = \underline{750\,lb} \leftarrow$

$F_{y_2} = \underline{750\,lb} \leftarrow$

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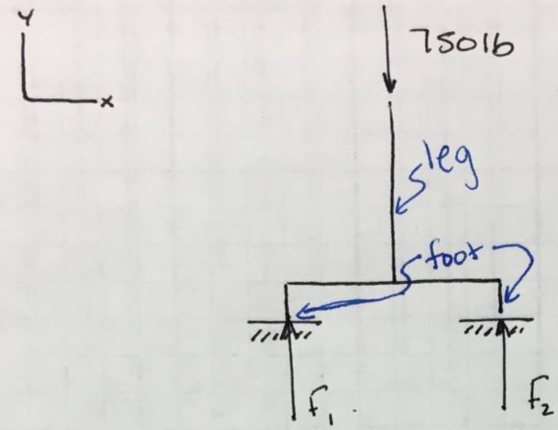
FBD$_3$



$F_1 = F_2$

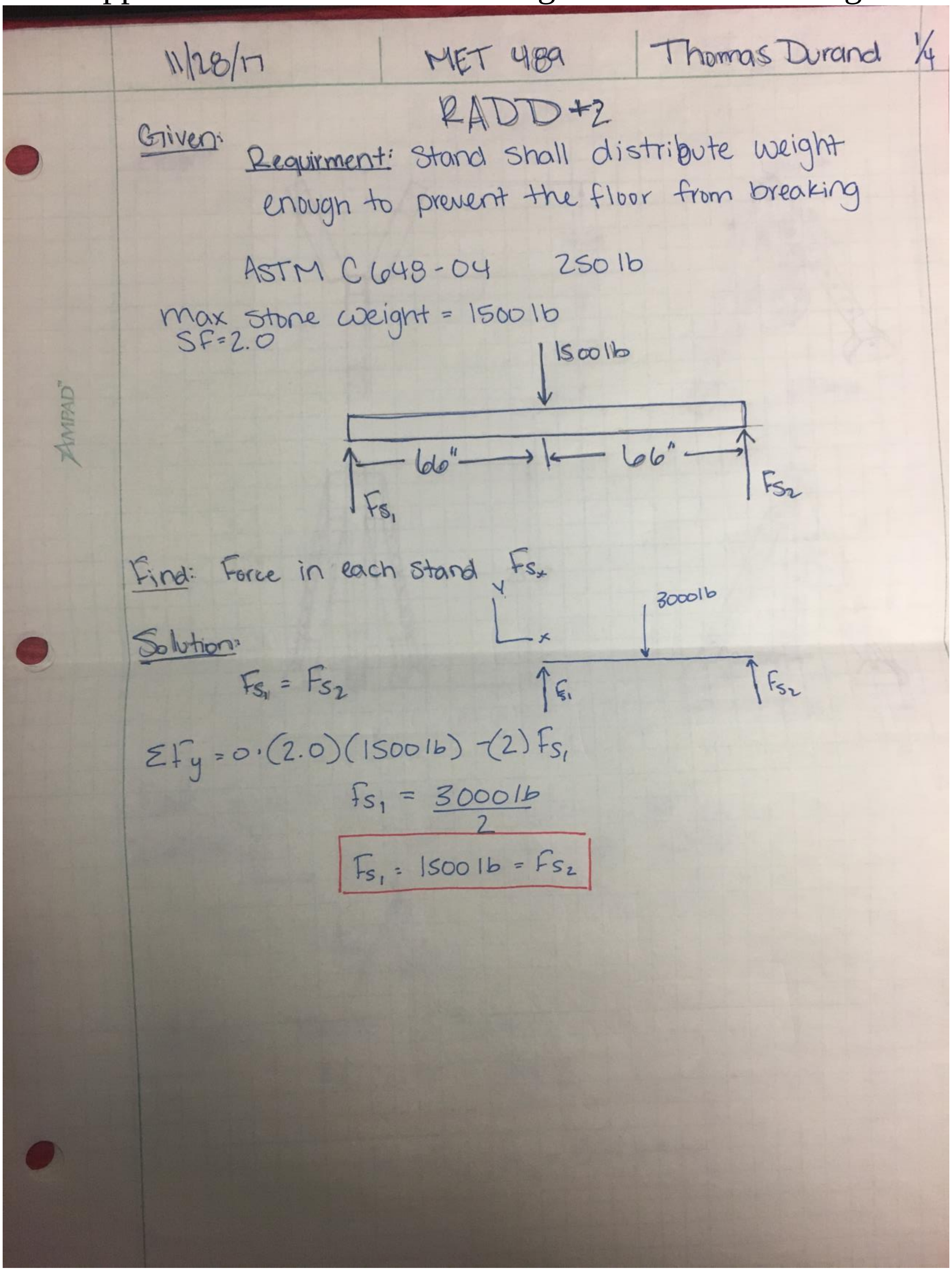
$\Sigma F_y = 0$: $750lb - 2F_1 = 0 \Rightarrow 2F_1 = 750lb$

$F_1 = \underline{375\ lb}$ ⟵

$F_2\ \underline{375lb}$ ⟵

375lb is the Force that each leg will be pressing down on the floor.

Appendix A.3 – RADD #2 Weight Distribution 3 Legs



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RADD #2

Given: **Requirment:** Stand shall distribute weight enough to prevent the floor from breaking

ASTM C648-04 250 lb

max stone weight = 1500 lb

SF = 2.0

Find: Force in each stand F_{S_x}

Solution:

$F_{S_1} = F_{S_2}$

$\Sigma F_y = 0 : (2.0)(1500\,lb) - (2) F_{S_1}$

$F_{S_1} = \frac{3000\,lb}{2}$

$F_{S_1} = 1500\,lb = F_{S_2}$

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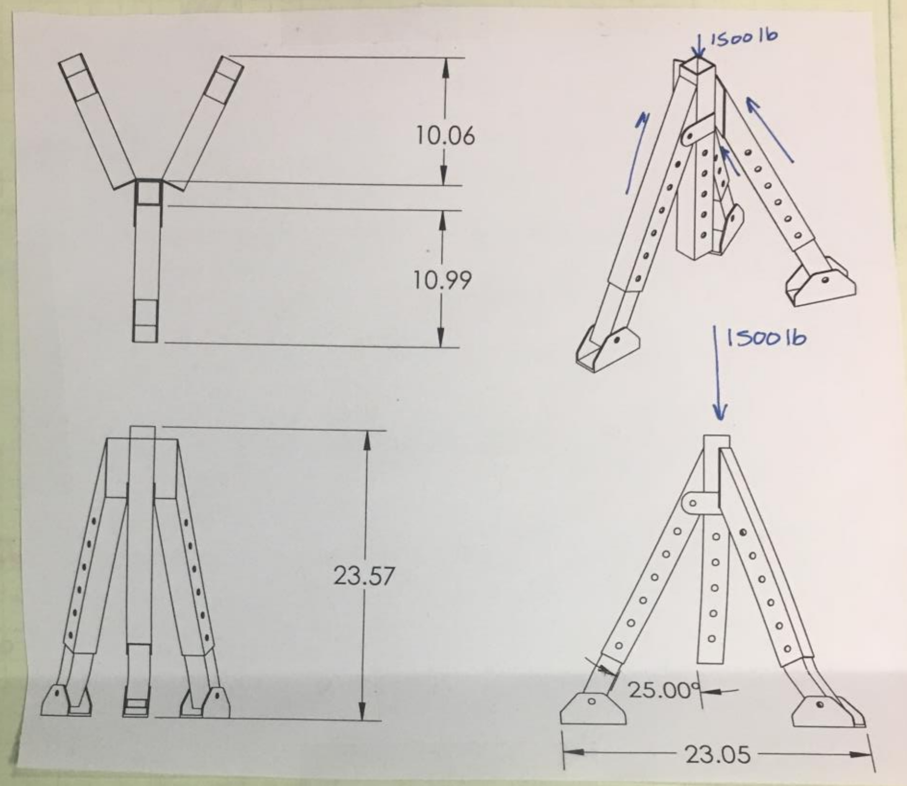
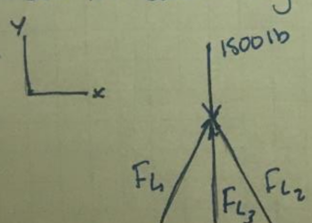
RADD #2

Given:



Find: Forces in each leg

Solution:



Assuming all legs are at exactly 25° from vertical

$F_{L_1} = F_{L_2} = F_{L_3}$

$\Sigma F_y = 0: \quad 1500\,lb - 3 F_{L_1} \cos 25° = 0$

$F_{L_1} \cos 25° = \frac{1500\,lb}{3} \qquad F_{L_1} = 551.69\,lb$

$F_{L_1} = F_{L_2} = F_{L_3} = 551.69\,lb$

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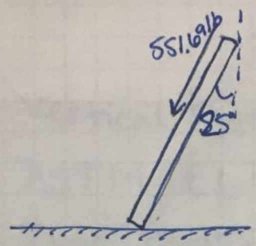
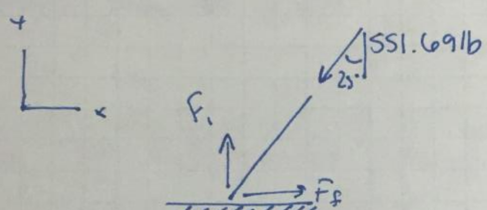
RADD #2

Given:



Find: Force exerted on Floor by one individual leg

Solution:



* Don't Need to solve for F_f (Force Friction)*

$\Sigma F_y = 0: \; 551 \cos 25° - F_1 = 0$

$F_1 = 500 \text{ lb}$

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RADD #2

Given: Vertical point Force = 500lb on Floor

ASTM C648-04

Floor breaks @ 250lb

~~SF~~ .

Find: minimum area of foot to ~~flood~~ not Break Tile ~~flr~~ floor

Solution:

Since the forces at hand are point forces as long as the weight is distributed over any area the tile should not Break.

Appendix A.4 – Buckling and Tube Size

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~~Calculate~~ Using Buckling forces to Calculate size of A36 Tubing needed

(Numbers for forces are from RADD #1)

Given: F = 1500 lb (with a S.F. = 2.0)

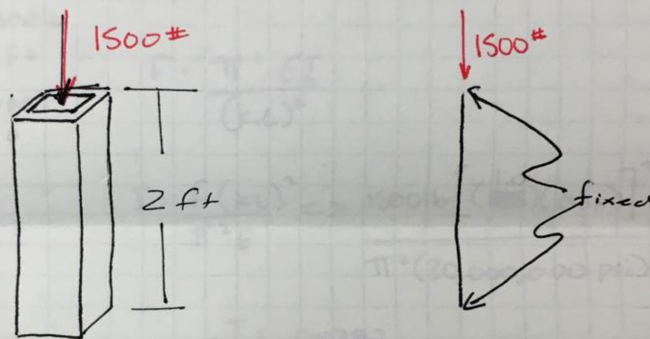
Material: A36 Hot Rolled Steel tubing

E = 30 MSI

2 fixed ends

Find: Crossectional Area of Tube needed

Solution:



K = .5

L: 2ft

E: 30 Msi

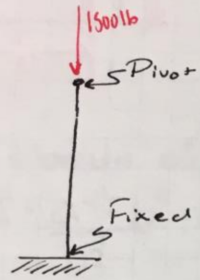
F = 1500 lb

I: Smallest Area mom. inertia

$$F = \frac{\pi^2 E I}{(kL)^2} \Rightarrow \frac{F(kL)^2}{\pi^2 E} = I$$

$$I = \frac{1500\,\text{lb}\left[(0.5)(24\,\text{in})\right]^2}{\pi^2 (30{,}000{,}000\,\text{psi})} = .0007295$$

Buckling with one Pivot and One fixed end.



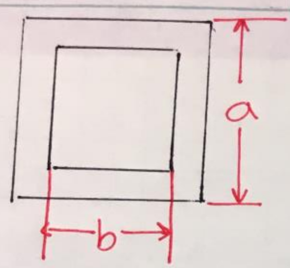
$F = 1500lb$
$L = 2ft$
$E = 30Msi$
$k = 1.0$

$$F = \frac{\pi^2 EI}{(kL)^2}$$

$$I = \frac{F(kL)^2}{\pi^2 E} \Rightarrow \frac{1500lb\left[(1.0)(24in)\right]^2}{\pi^2(30{,}000{,}000\ psi)}$$

$$I = .00292$$

10/31/17 | MET 489 | Thomas Durand



Finding Tube Size

Area Moment of Inertia Section Properties = I

$$I = \frac{a^4 - b^4}{12}$$

@ 2" × 2" - 1/8 thick Tubing

a = 2"
b = 1.75"

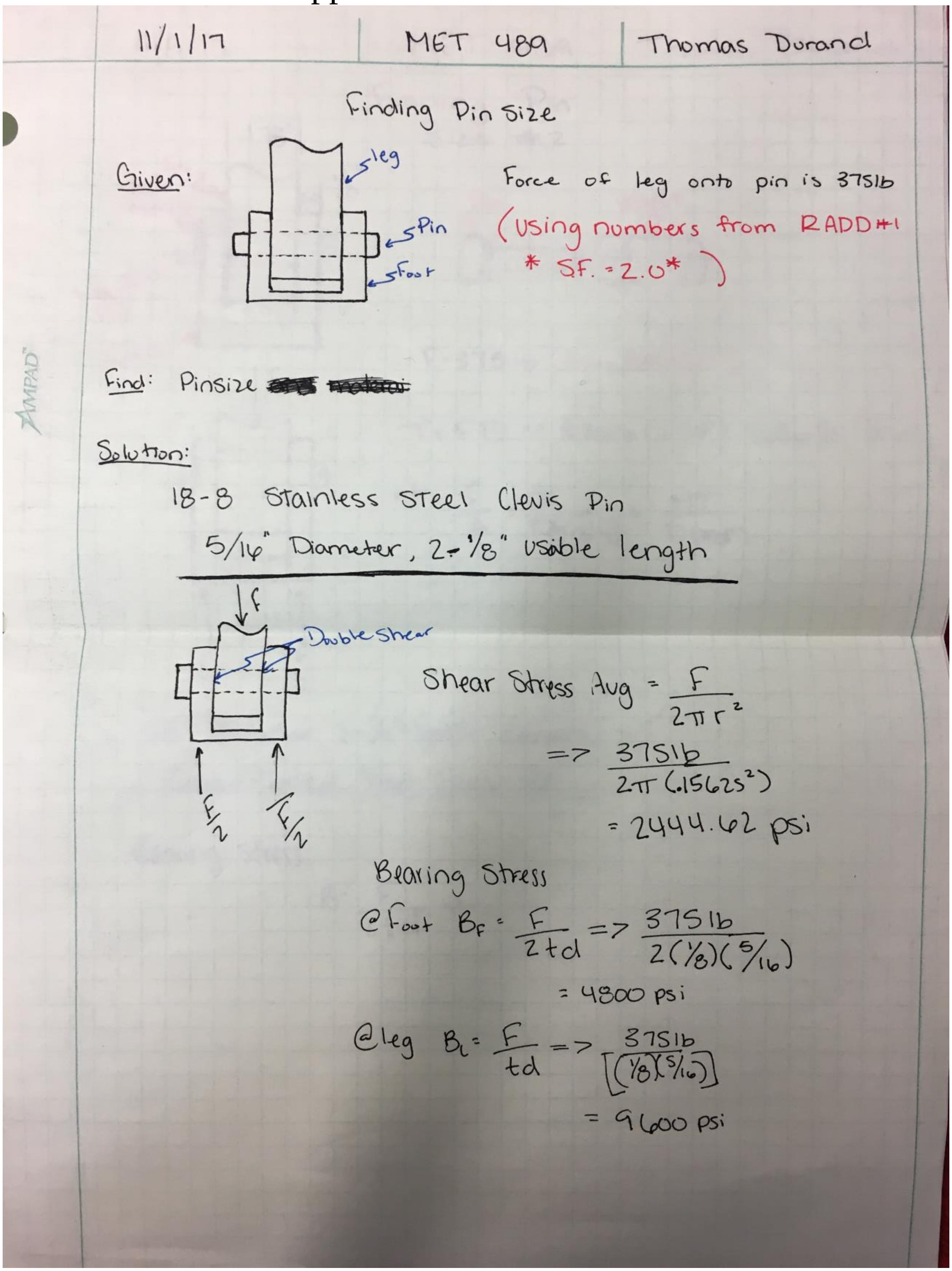
$$I = \frac{2^4 - 1.75^4}{12} = .5518$$

@ 1.75" × 1.75" - 1/8 thick Tubing

a = 1.75"
b = 1.5"

$$I = \frac{1.75^4 - 1.5^4}{12} = .3597$$

Appendix A.5 – Pin Shear



11/1/17 | MET 489 | Thomas Durand

Finding Pin Size

Given:

Force of leg onto pin is 375lb (Using numbers from RADD #1 * S.F. = 2.0*)

Find: Pinsize

Solution:

18-8 Stainless Steel Clevis Pin

5/16" Diameter, 2-1/8" usable length

Shear Stress Avg $= \frac{F}{2\pi r^2}$

$\Rightarrow \frac{375lb}{2\pi(.15625^2)}$

$= 2444.62$ psi

Bearing Stress

@Foot $B_F = \frac{F}{2td} \Rightarrow \frac{375lb}{2(1/8)(5/16)}$

$= 4800$ psi

@leg $B_L = \frac{F}{td} \Rightarrow \frac{375lb}{[(1/8)(5/16)]}$

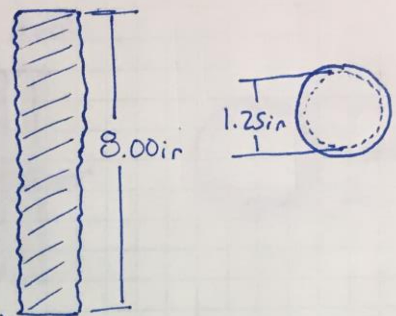
$= 9600$ psi

Appendix A.6 – Fine Adjustment Buckling Rev1

11/30/17 | Fine Adjustment Buckling | Thomas Durand 1/1

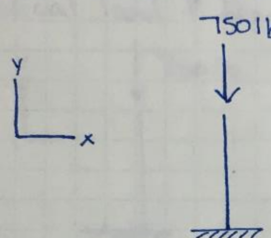
Given: Steel threaded Rod

$F = 750$ lb 1½"-6 Grade 8
$SF = 2.0$
Fixed One end
$L = 8.00"$
$K = 2.10$
$S_y = 130$ ksi
$E = 30$ Msi



Find:
Critical load & Allowable load

Solution:



$$A = \frac{\pi D^2}{4} \Rightarrow \frac{\pi (1.25)^2}{4} = 1.23\,in^2$$

$$I = \frac{\pi D^4}{64} \Rightarrow \frac{\pi (1.25)^4}{64} = 0.1198\,in^4$$

$$r = \sqrt{I/A} \Rightarrow \sqrt{\frac{0.1198\,in^4}{1.23\,in^2}} = 0.3125\,in$$

$$\text{Slenderness Ratio} = \frac{KL}{r} \Rightarrow \frac{(2.10)(8.00\,in)}{0.3125\,in} = 53.76$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} \Rightarrow \sqrt{\frac{2\pi^2(30\times10^6)}{(130\times10^3)}} = 67.49$$

53.76 < 67.49
Short Column

Johnson Formula

$$P_{cr} = A S_y\left[1 - \frac{S_y(KL/r)^2}{4\pi^2 E}\right] \Rightarrow (1.23in^2)(130\times10^3)\left[1 - \frac{(130\times10^3)\left(\frac{(2.10)(8.00in)}{0.3125in}\right)^2}{4\pi^2\,(30\times10^6)}\right]$$

$$= \boxed{109174.15\ lb}$$

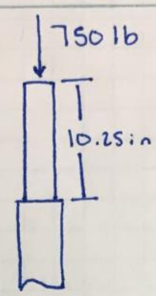
$$P_a = P_{cr}/SF \Rightarrow 109174.15lb/2.0 = \boxed{54587.07lb}$$

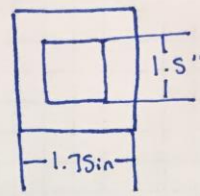
Appendix A.7 – Vertical Adjustment Buckling

11/30/17 | Tube buckling | Thomas Durand

Given:

$F = 750 lb$
$SF = 2.0$
Fixed one end
$L = 10.25 in$
A36 Steel tube
$k = 2.10$
$E = 30 Msi$
$S_y = 36 ksi$

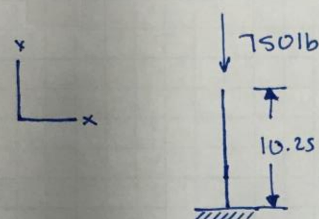




Find:

Critical load & Allowable load

Solution:



$$A = BH - bh \Rightarrow (1.75 \times 1.75) - (1.5 \times 1.5) = 0.8125 in^2$$

$$I = \frac{BH^3 - bh^3}{12} \Rightarrow \frac{(1.75)(1.75)^3 - (1.5)(1.5)^3}{12} = 0.3597 in^4$$

$$r = \sqrt{\frac{0.3597 in^4}{0.8125 in^2}} = 0.6654$$

$$\text{Slenderness Ratio} = \frac{\overset{k}{(2.10)}\overset{L}{(10.25)}}{0.6654} = 32.351$$

Column Constant = C_c

32.351 < 128.25 => Short Column

$$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} = \sqrt{\frac{2\pi^2 (30 \times 10^6)}{(36 \times 10^3)}} = 128.25$$

Johnson Formula

$$P_{cr} = A S_y \left[1 - \frac{S_y (kL/r)^2}{4\pi^2 E}\right] \Rightarrow \left[1 - \frac{(36\times10^3)\left[((2.10)(10.25))/(0.6654)\right]^2}{4\pi^2 (30 \times 10^6)}\right](0.8125 in^2) \times (36\times10^3)$$

$$= 2831.96 lb$$

$$P_A = P_{cr}/SF \Rightarrow 2831.96 lb / 2.0 = 1415.98 lb$$

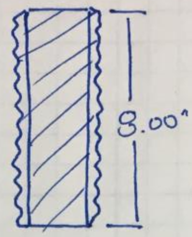
Appendix A.8 – Fine Adjustment Buckling Rev 2

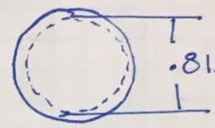
11/30/17 | 1"-8 Buckling | Thomas Durand | 1/1

Given:

1"-8 Grade 8 threaded Rod

$F = 750\,lb$
$SF = 2.0$
Fixed one end
$L = 8.00"$
$k = 2.10$
$S_y = 130\,ksi$
$E = 30\,Msi$

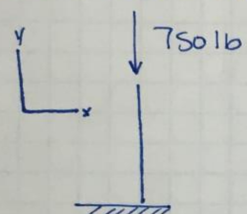




Find:

Critical load & Allowable load

Solution:



$$A = \frac{\pi D^2}{4} \Rightarrow \frac{\pi (0.813)^2}{4} = 0.519\,in^2$$

$$I = \frac{\pi D^4}{64} \Rightarrow \frac{\pi (0.813)^4}{64} = 0.0214$$

$$r = \sqrt{I/A} \Rightarrow \sqrt{\frac{0.0214\,in^4}{0.519\,in^2}} = 0.203$$

$$\text{Slenderness Ratio} = \frac{kL}{r} \Rightarrow \frac{(2.10)(8.00\,in)}{0.203} = 82.66$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} \Rightarrow \sqrt{\frac{2\pi^2 (30\times10^6)}{(130\times10^3)}} = 67.49$$

$82.66 > 67.49$ long Column

Euler Formula

$$P_{cr} = \frac{\pi^2 E A}{(kL/r)^2} \Rightarrow \frac{\pi^2 (30\times10^6)(0.519\,in^2)}{\left(\frac{2.10\times 8.00\,in}{0.203}\right)^2} = \boxed{22{,}497.51\,lb}$$

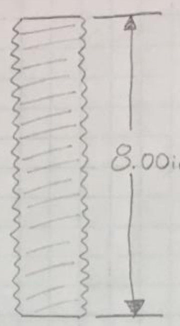
$$P_a = P_{cr}/SF \Rightarrow 22{,}497.15\,lb/2.0 = \boxed{11{,}248.76\,lb}$$

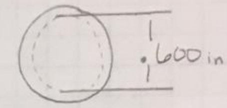
Appendix A.9 – Fine Adjustment Buckling Rev 3

12/1/17	3/4" - Buckling	Thomas Durand

Given: 3/4"-10 Grade 8 threaded Steel Rod

F - 750 lb
SF = 2.0
Fixed one end
L = 8.00 in
K = 2.10
S_y = 130 ksi
E = 30 MSi

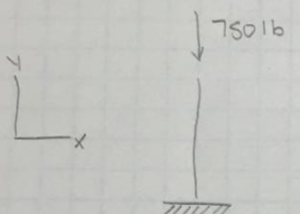




Find:

Critical load and Allowable load

Solution:



$$A = \frac{\pi D^2}{4} \Rightarrow \frac{\pi (.600)^2}{4} = .283 in^2$$

$$I = \frac{\pi D^4}{64} \Rightarrow \frac{\pi (.600)^4}{64} = .00636 in^4$$

$$r = \sqrt{\frac{I}{A}} \Rightarrow \sqrt{\frac{.00636 in^4}{.283 in^2}} = .15 in$$

$$\text{Slenderness Ratio} = \frac{KL}{r} \Rightarrow \frac{(2.10)(8.00)}{.15 in} = 112$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} \Rightarrow \sqrt{\frac{2\pi^2 (30 \times 10^6)}{(130 \times 10^3)}} = 67.49$$

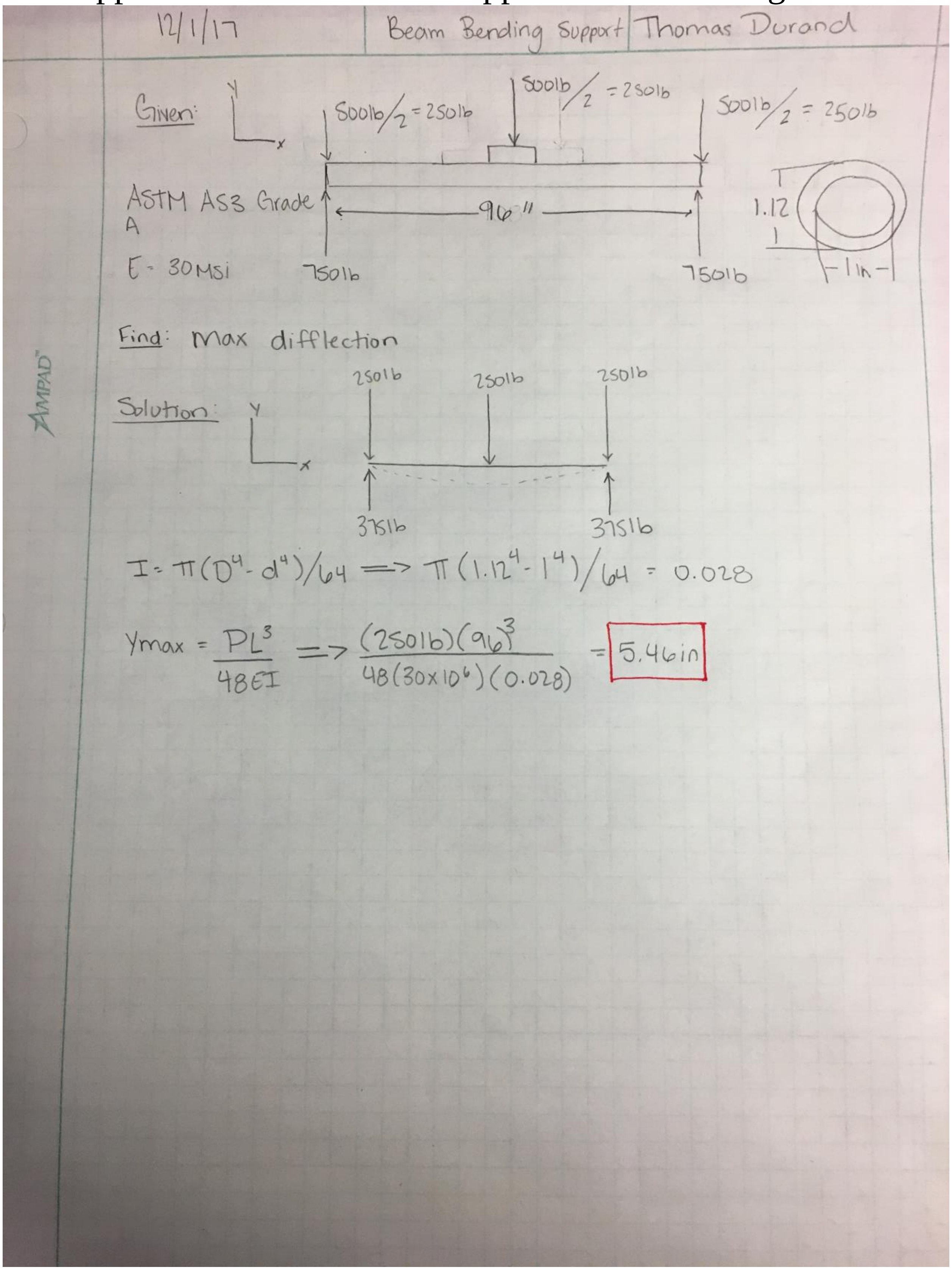
long Column

Euler Formula

$$P_{cr} = \frac{\pi^2 E A}{(KL/r)^2} \Rightarrow \frac{\pi^2 (30 \times 10^6)(.283 in^2)}{\left((2.10)(8.00)/.15\right)^2} = \boxed{6673.86 lb}$$

$$P_a = P_{cr}/SF \Rightarrow 6673.86/2.00 = \boxed{3336.93 lb}$$

Appendix A.10 – Middle Support Beam Bending Rev 1



12/1/17 | Beam Bending Support | Thomas Durand

Given:

500lb/2 = 250lb

500lb/2 = 250lb

500lb/2 = 250lb

ASTM A53 Grade A

E = 30Msi

96"

750lb

750lb

1.12

1in

Find: Max diffection

Solution:

250lb

250lb

250lb

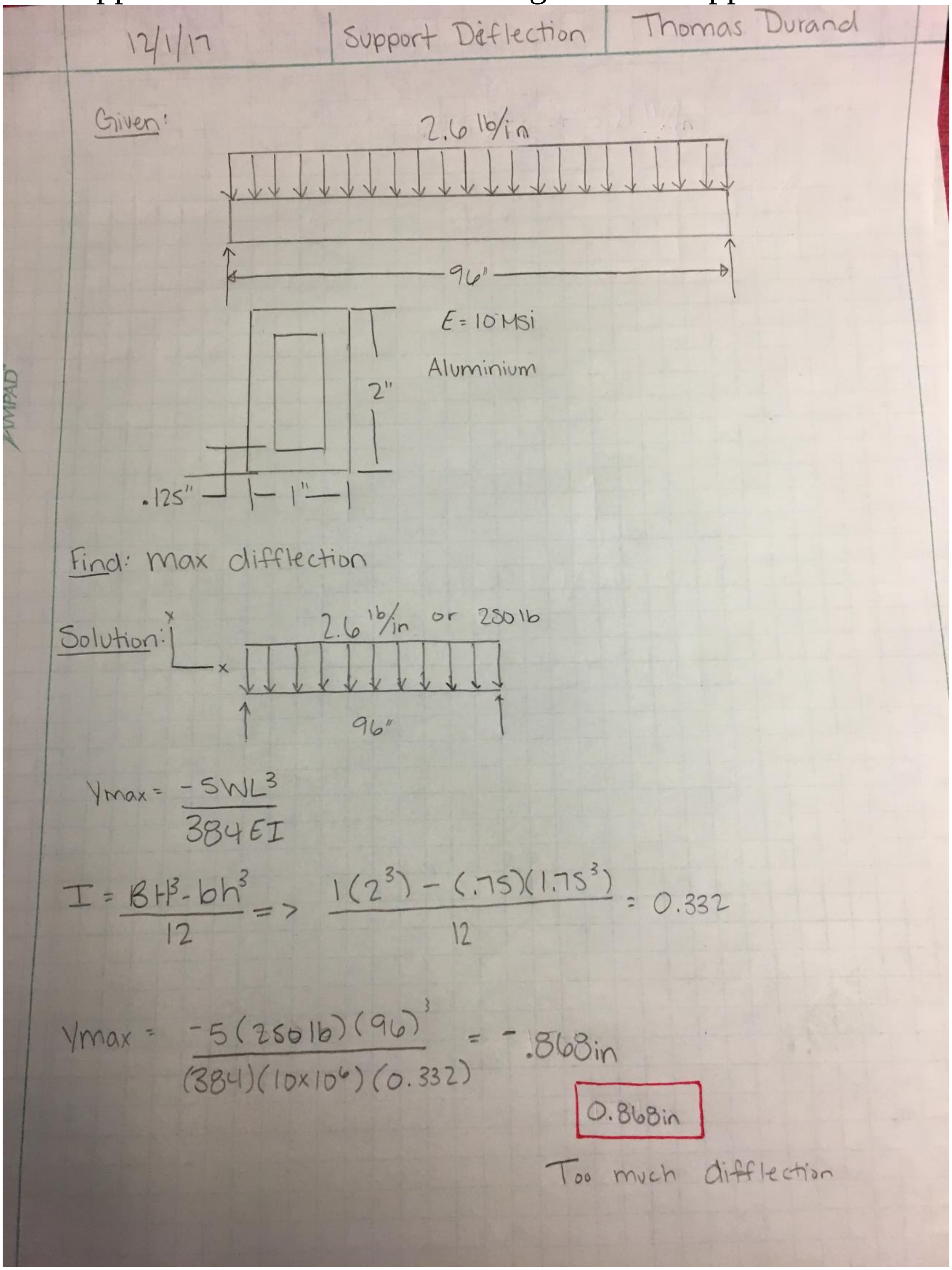
375lb

375lb

$I = \pi(D^4 - d^4)/64 \Rightarrow \pi(1.12^4 - 1^4)/64 = 0.028$

$Y_{max} = \frac{PL^3}{48EI} \Rightarrow \frac{(250lb)(96)^3}{48(30\times10^6)(0.028)} = 5.46in$

Appendix A.11 – Beam Bending Middle Support Rev 2


12/1/17 | Support Deflection | Thomas Durand

Given:

2.6 lb/in

96"

E = 10 MSi

Aluminium

2"

.125"

1"

Find: max diffletion

Solution:

2.6 lb/in or 250 lb

96"

$$Y_{max} = \frac{-5WL^3}{384EI}$$

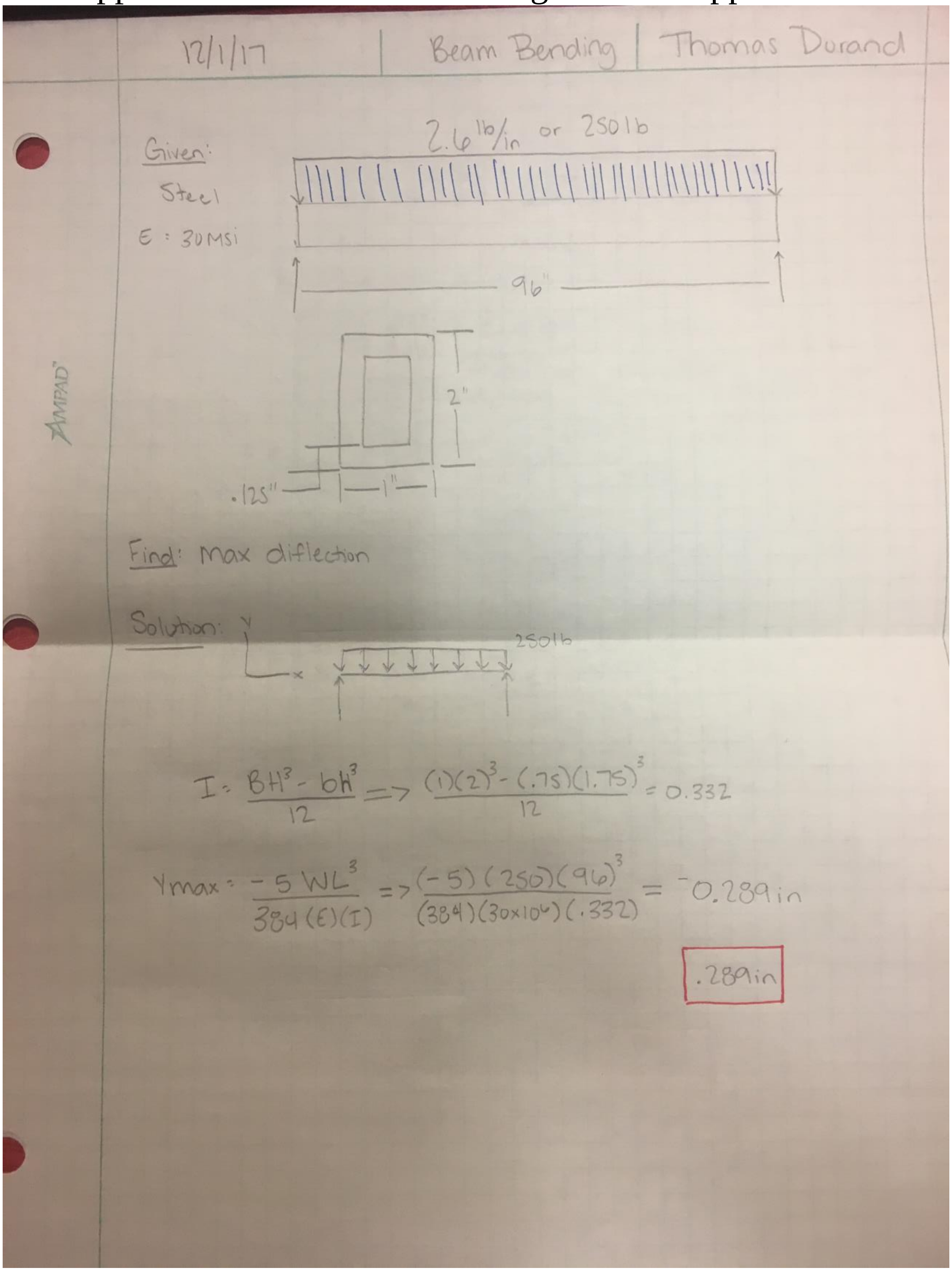
$$I = \frac{BH^3 - bh^3}{12} \Rightarrow \frac{1(2^3) - (.75)(1.75^3)}{12} = 0.332$$

$$Y_{max} = \frac{-5(250\,lb)(96)^3}{(384)(10 \times 10^6)(0.332)} = -.868\,in$$

0.868in

Too much diffletion

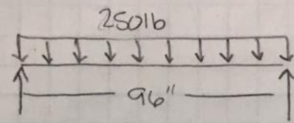
Appendix A.12 – Beam Bending Middle Support Rev 3



Appendix A.13 – Beam Bending Middle Support Rev 4

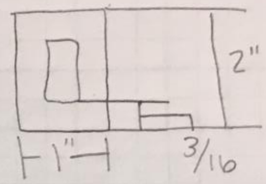
12/1/17 | Beam Bending | Thomas Durand

Given:



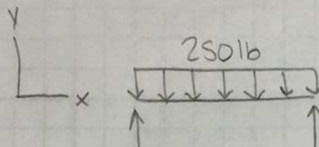
Steel

E=30Msi



Find: max deflection

Solution:

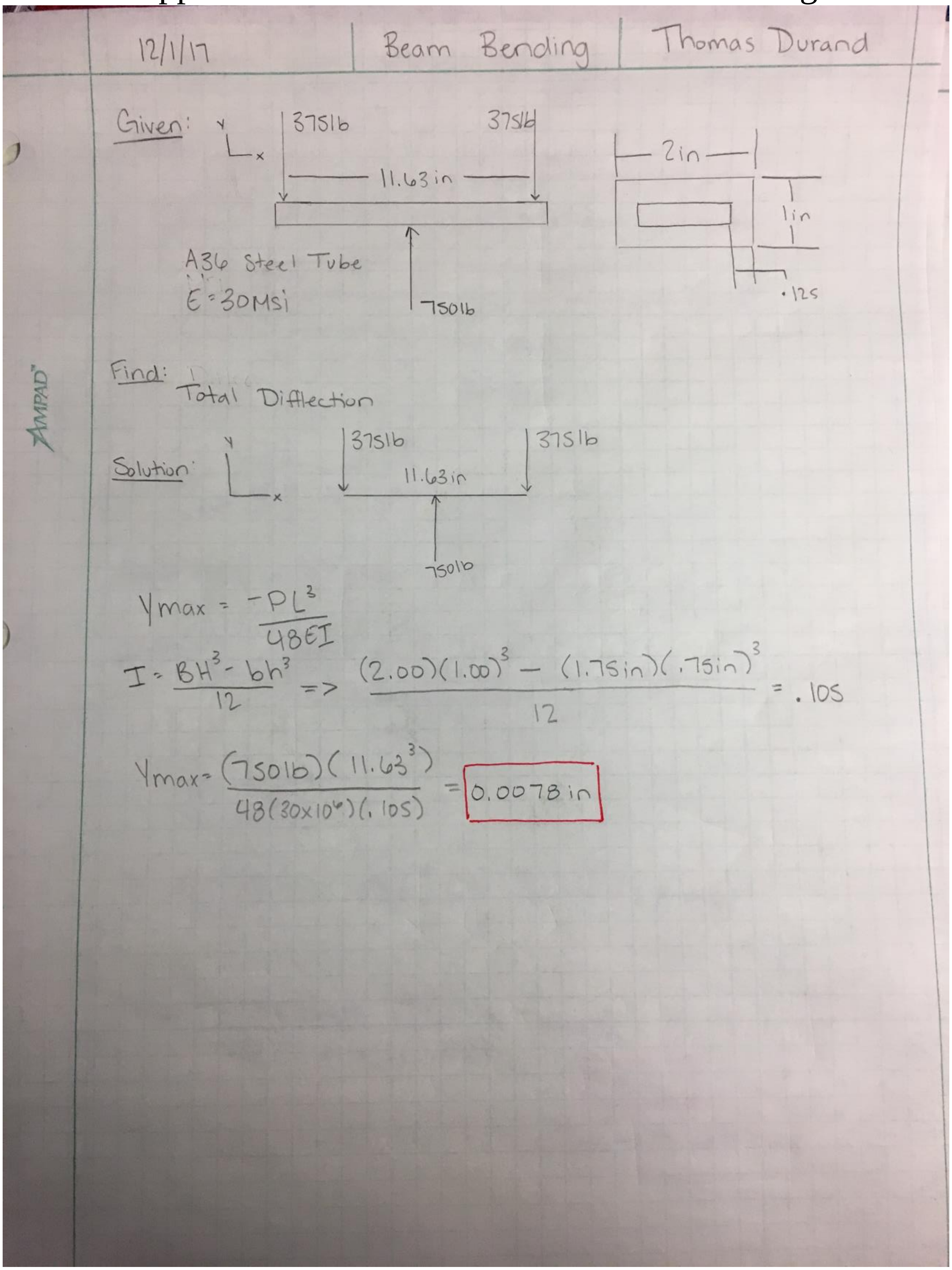


$$I = \frac{BH^3 - bh^3}{12} \Rightarrow \frac{(1)(2)^3 - (.625)(1.625)^3}{12} = 0.4432$$

$$Y_{max} = \frac{-5WL^3}{384EI} \Rightarrow \frac{(-5)(250)(96)^3}{384(30\times10^6)(0.4432)} = -0.2166$$

.2166 in

Appendix A.14 – Pivot Bracket Beam Bending



12/1/17 | Beam Bending | Thomas Durand

Given:

375lb 375lb

11.63in

2in

1in

.125

A36 Steel Tube

E=30Msi

750lb

Find:

Total Difflection

Solution:

375lb 375lb

11.63in

750lb

$$Y_{max} = \frac{-PL^3}{48EI}$$

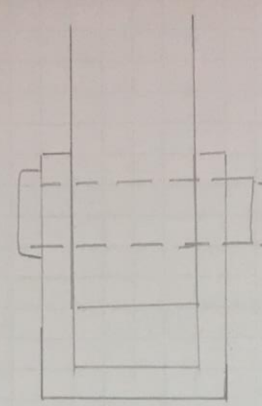
$$I = \frac{BH^3 - bh^3}{12} \Rightarrow \frac{(2.00)(1.00)^3 - (1.75in)(.75in)^3}{12} = .105$$

$$Y_{max} = \frac{(750lb)(11.63^3)}{48(30 \times 10^6)(.105)} = \boxed{0.0078 in}$$

Appendix A.15 – Foot Pin Shear Force

12/4/17	Foot Pin Shear	Thomas Durand

Given:



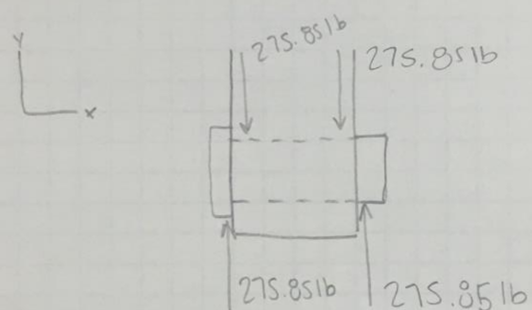
F = 551.69 lb

Double shear

½" A36 Clevis pin

Find: Shear in pins in foot

Solution:



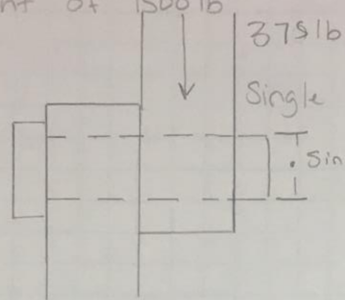
$$\tau = \frac{\left(\frac{F}{A}\right)}{2} \Rightarrow \frac{\left(\frac{551.69}{\frac{\pi(.5)^2}{4}}\right)}{2} = \boxed{1404.87\ \text{lb}}$$

Appendix A.16 – RADD #3 Pivot Pin Shear

12/4/17	Pin Shear 1	Thomas Durand

RADD #3

Given:
Requirmen - must be able to support a slab weight of 1500 lb



Find:
Shear Force in pin to Figure out pin material

Solution:

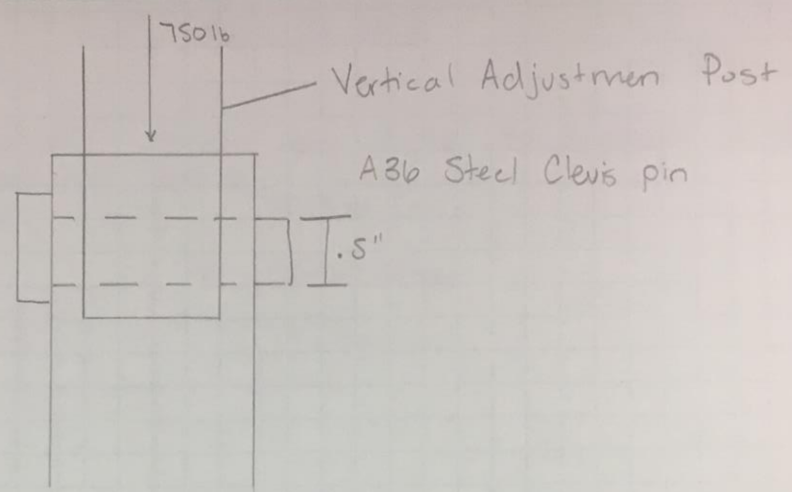
$$\tau = \frac{F}{A} = \frac{375\,lb}{\frac{\pi(.5)^2}{4}} = \boxed{1909.85\ Psi}$$

* Basic Mild A36 ½"-2" Clevis pin will work

Appendix A.17 – Vertical Adjustment Pin Shear

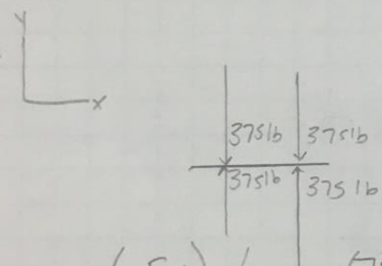
12/4/17	Double pin Shear	Thomas Durand

Given:



Find: Shear in pin to ensure ½" A36 Clevis pin will work

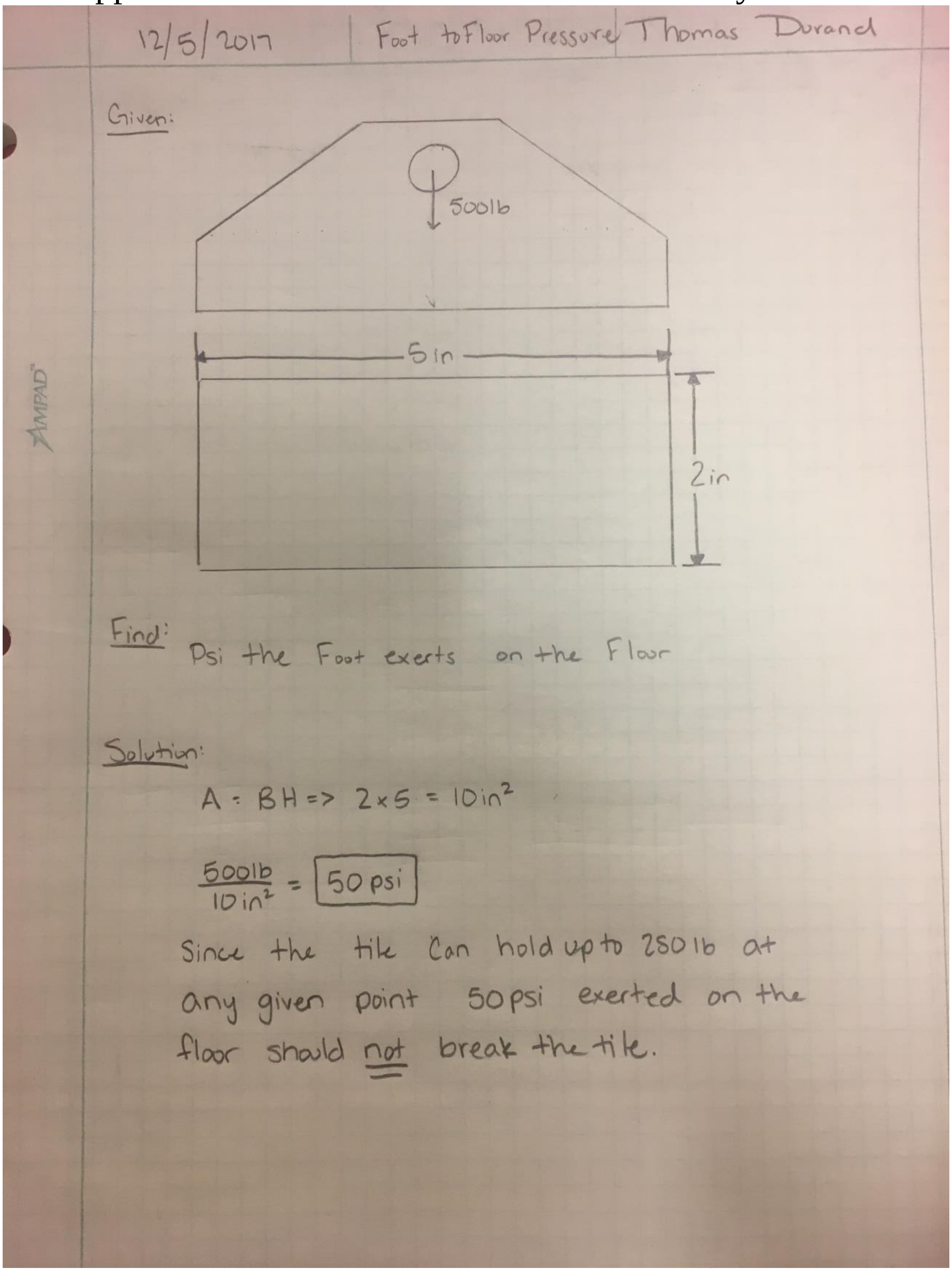
Solution:



$$\tau = \left(\frac{F}{A}\right)/2 \Rightarrow \left(\frac{750}{\frac{\pi(.5)^2}{4}}\right)/2 = \boxed{1909.85\,psi}$$

* ½" A36 Clevis pin will work

Appendix A.18 – Pressure Exerted on Floor by the Foot



12/5/2017 | Foot to Floor Pressure | Thomas Durand

Given:

500lb

5 in

2 in

Find: Psi the Foot exerts on the Floor

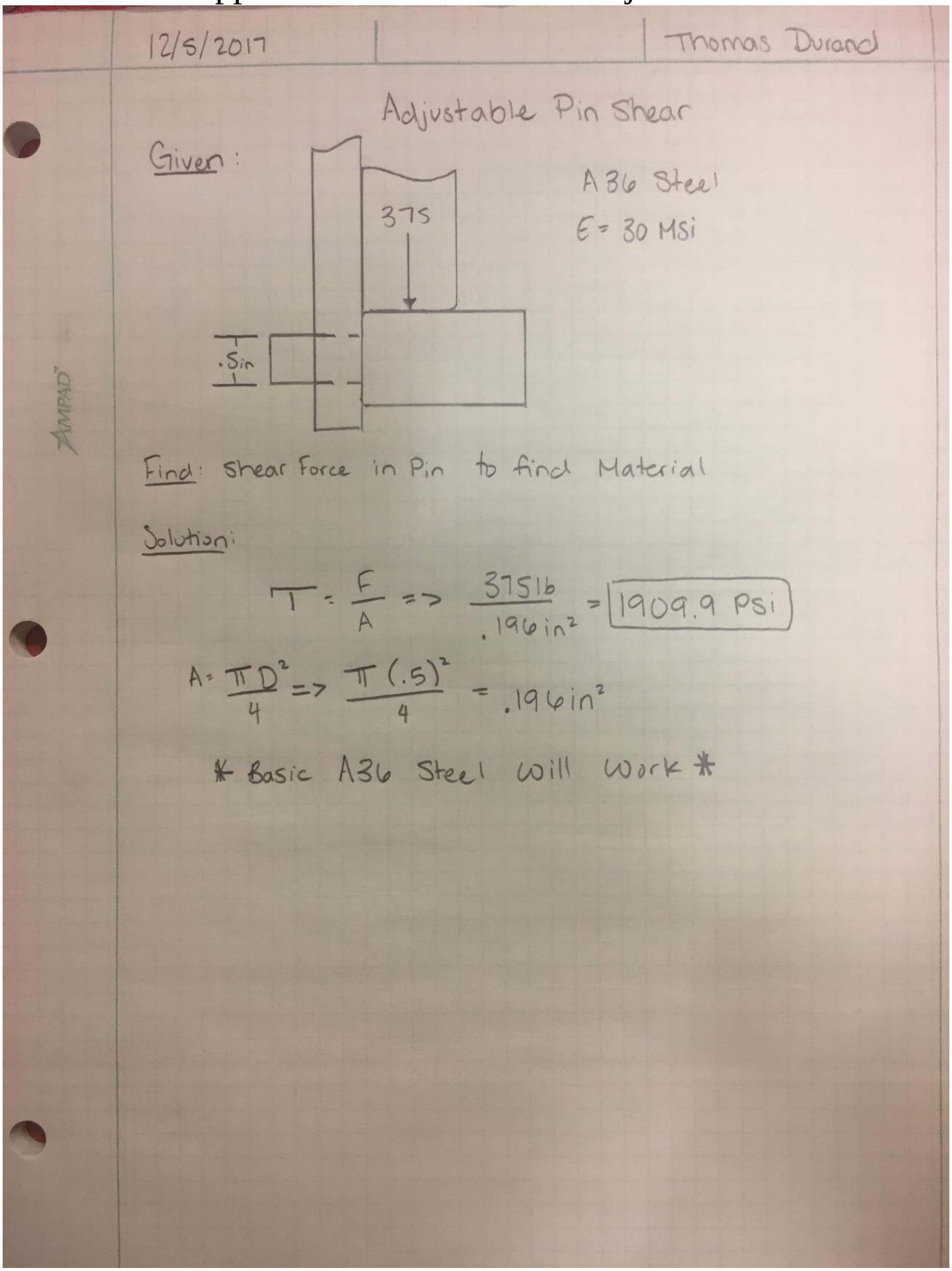
Solution:

$A = BH \Rightarrow 2 \times 5 = 10 in^2$

$\frac{500 lb}{10 in^2} = \boxed{50 psi}$

Since the tile can hold up to 250 lb at any given point 50 psi exerted on the floor should not break the tile.

Appendix A.19 – Shear of Adjuster Pin



12/5/2017 | Thomas Durand

Adjustable Pin Shear

Given:

A36 Steel

E = 30 MSi

Find: Shear Force in Pin to find Material

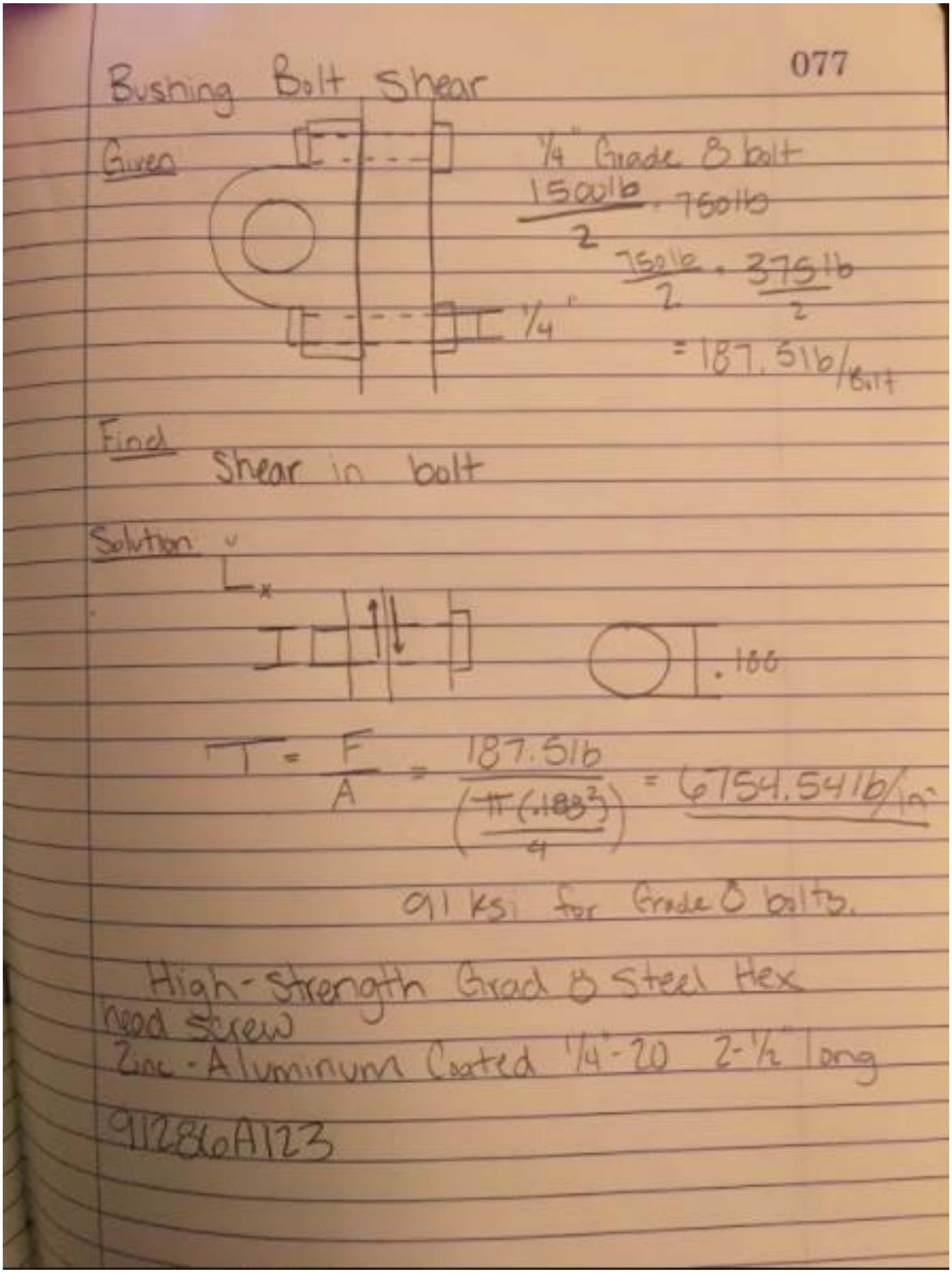
Solution:

$$\tau = \frac{F}{A} \Rightarrow \frac{375\,lb}{.196\,in^2} = \boxed{1909.9\ Psi}$$

$$A = \frac{\pi D^2}{4} \Rightarrow \frac{\pi(.5)^2}{4} = .196\,in^2$$

* Basic A36 Steel will work *

Appendix A.20 – Bolt Shear



077

Bushing Bolt Shear

Given

1/4" Grade 8 bolt

$\frac{1500lb}{2} = 750lb$

$\frac{750lb}{2} = \frac{375lb}{2}$

$= 187.5lb/Bolt$

1/4"

Find

Shear in bolt

Solution

.188

$$\tau = \frac{F}{A} = \frac{187.5lb}{\left(\frac{\pi(.188^2)}{4}\right)} = 6754.54lb/in^2$$

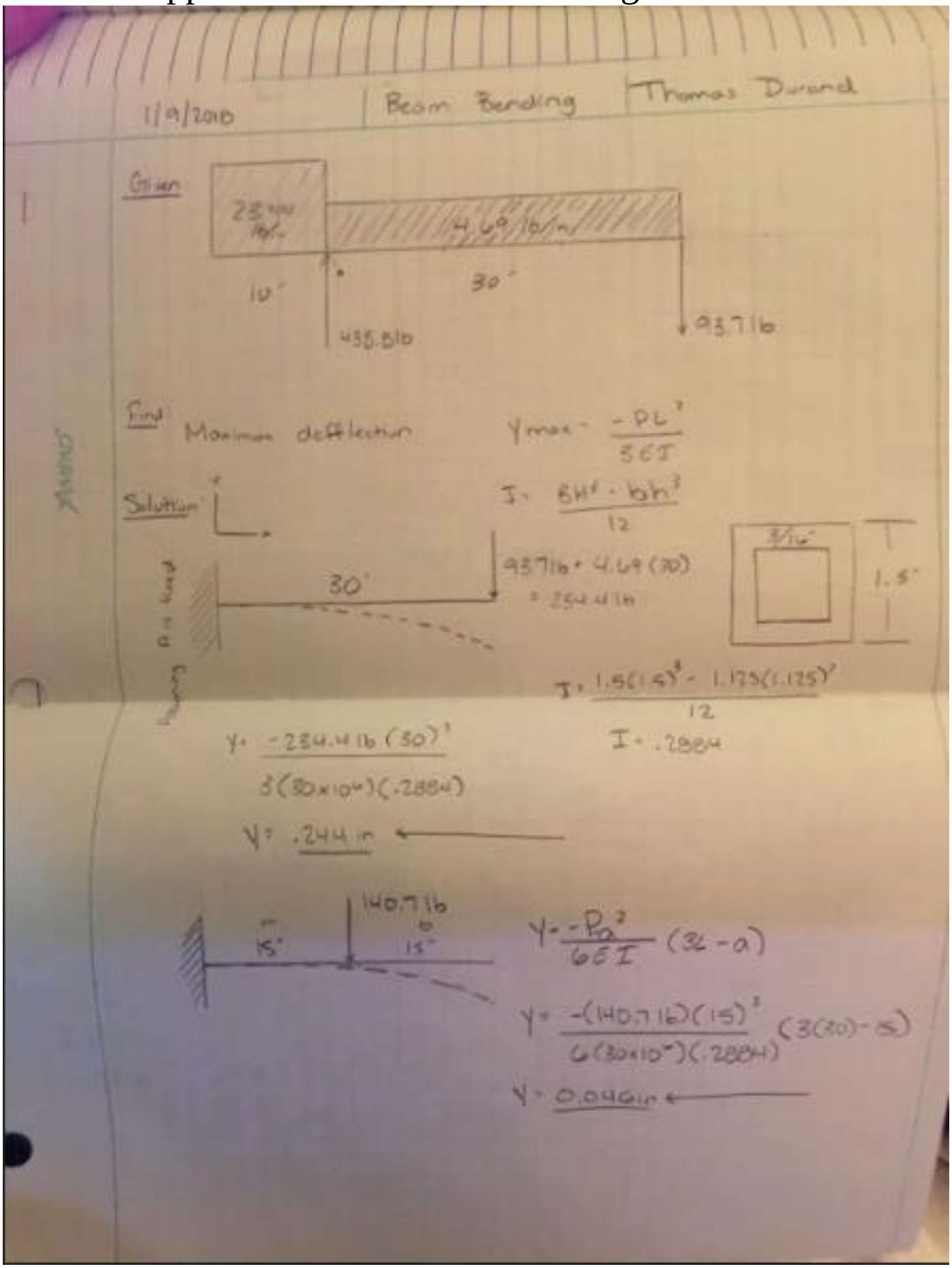
91 ksi for Grade 8 bolts.

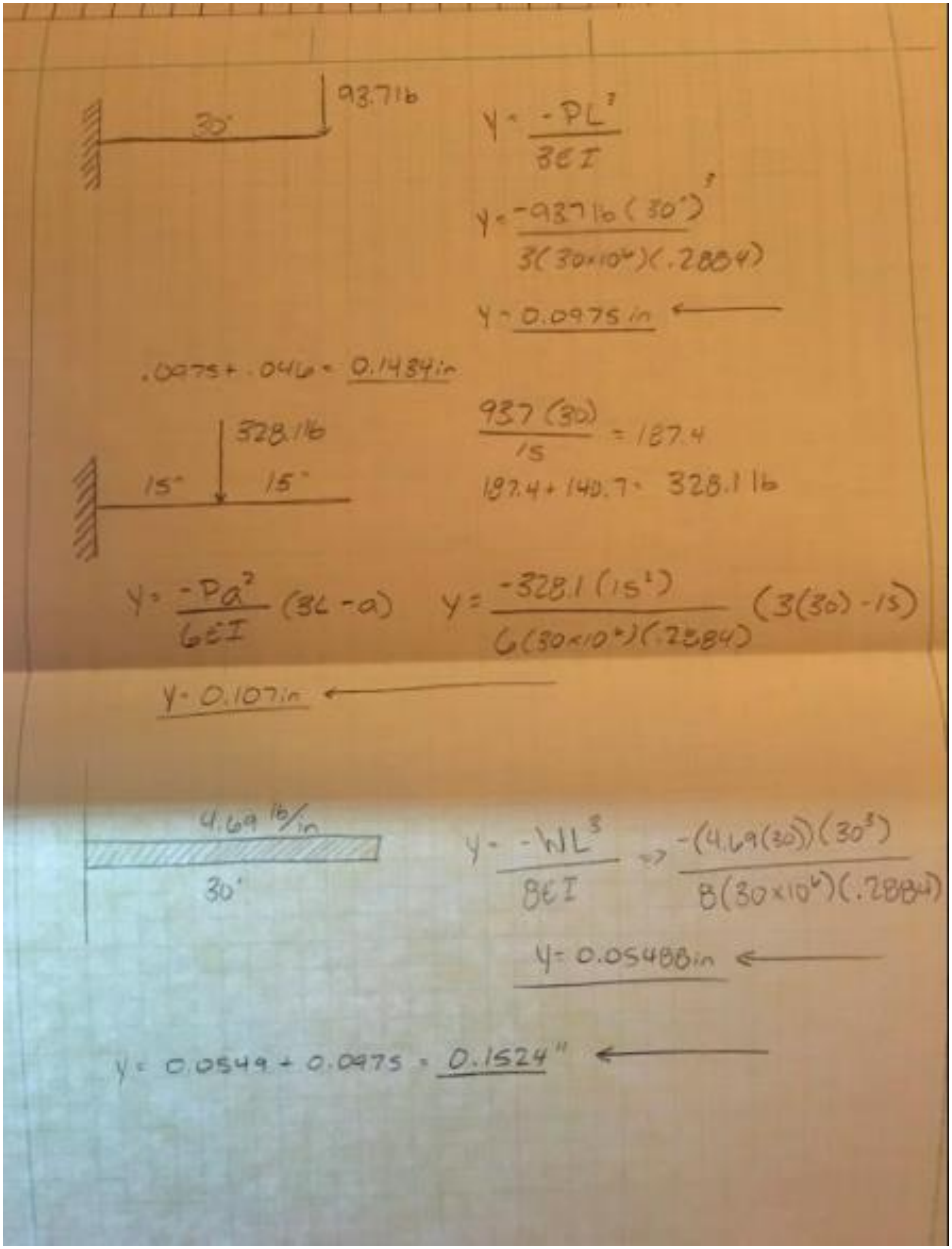
High-Strength Grade 8 Steel Hex head screw

Zinc-Aluminum Coated 1/4"-20 2-1/2" long

91286A123

Appendix A.21 – Beam Bending Pivot Plate





93.7 lb, 30"

$$y = \frac{-PL^3}{3EI}$$

$$y = \frac{-93.7\,lb\,(30")^3}{3(30\times10^6)(.2884)}$$

$y = 0.0975\,in$ ←

$.0975 + .046 = 0.1484\,in$

328.1 lb, 15", 15"

$$\frac{93.7\,(30)}{15} = 187.4$$

$187.4 + 140.7 = 328.1\,lb$

$$y = \frac{-Pa^2}{6EI}(3L - a) \qquad y = \frac{-328.1\,(15^2)}{6(30\times10^6)(.2884)}\,(3(30) - 15)$$

$y = 0.107\,in$ ←

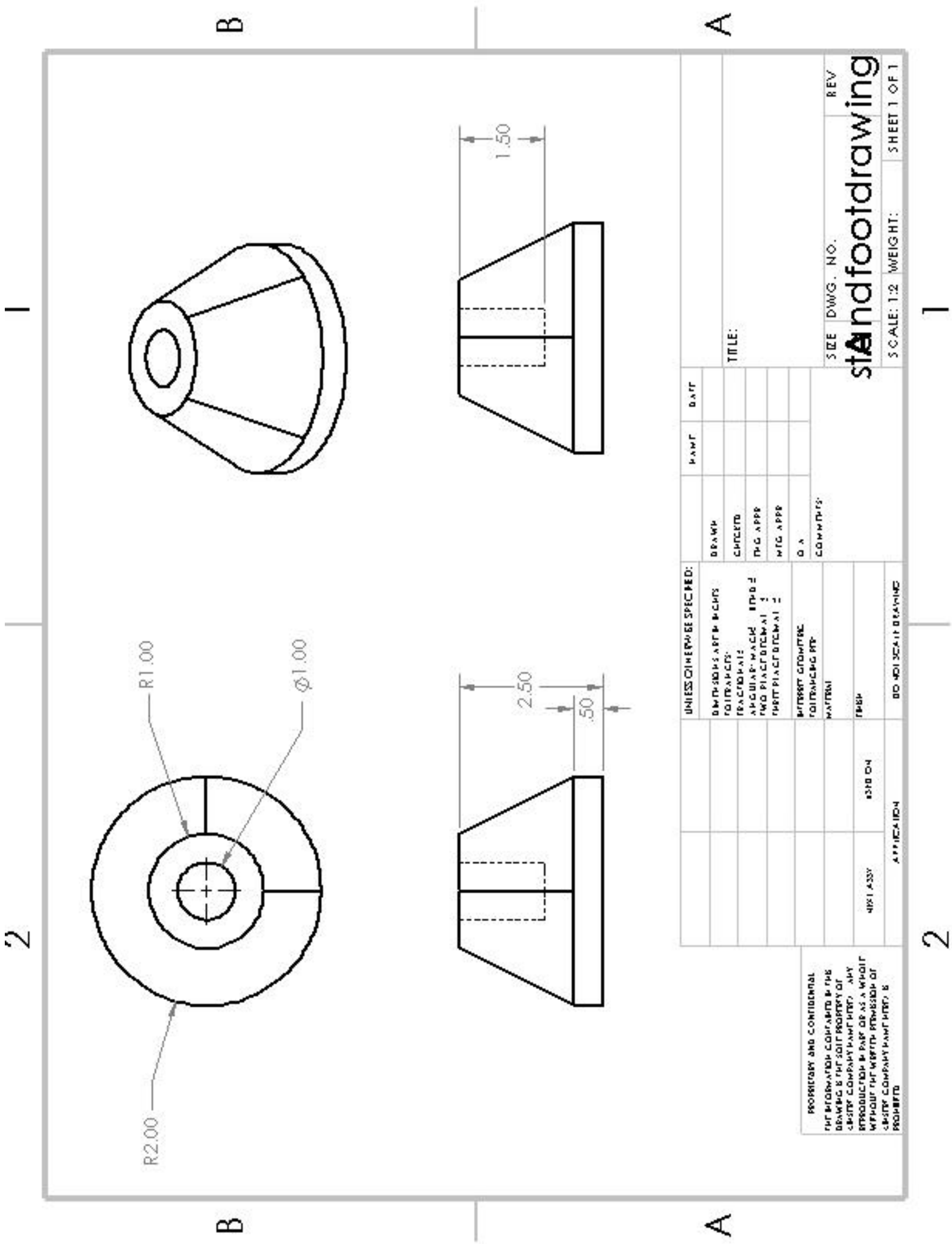
4.69 lb/in, 30"

$$y = \frac{-WL^3}{8EI} \Rightarrow \frac{-(4.69(30))(30^3)}{8(30\times10^6)(.2884)}$$

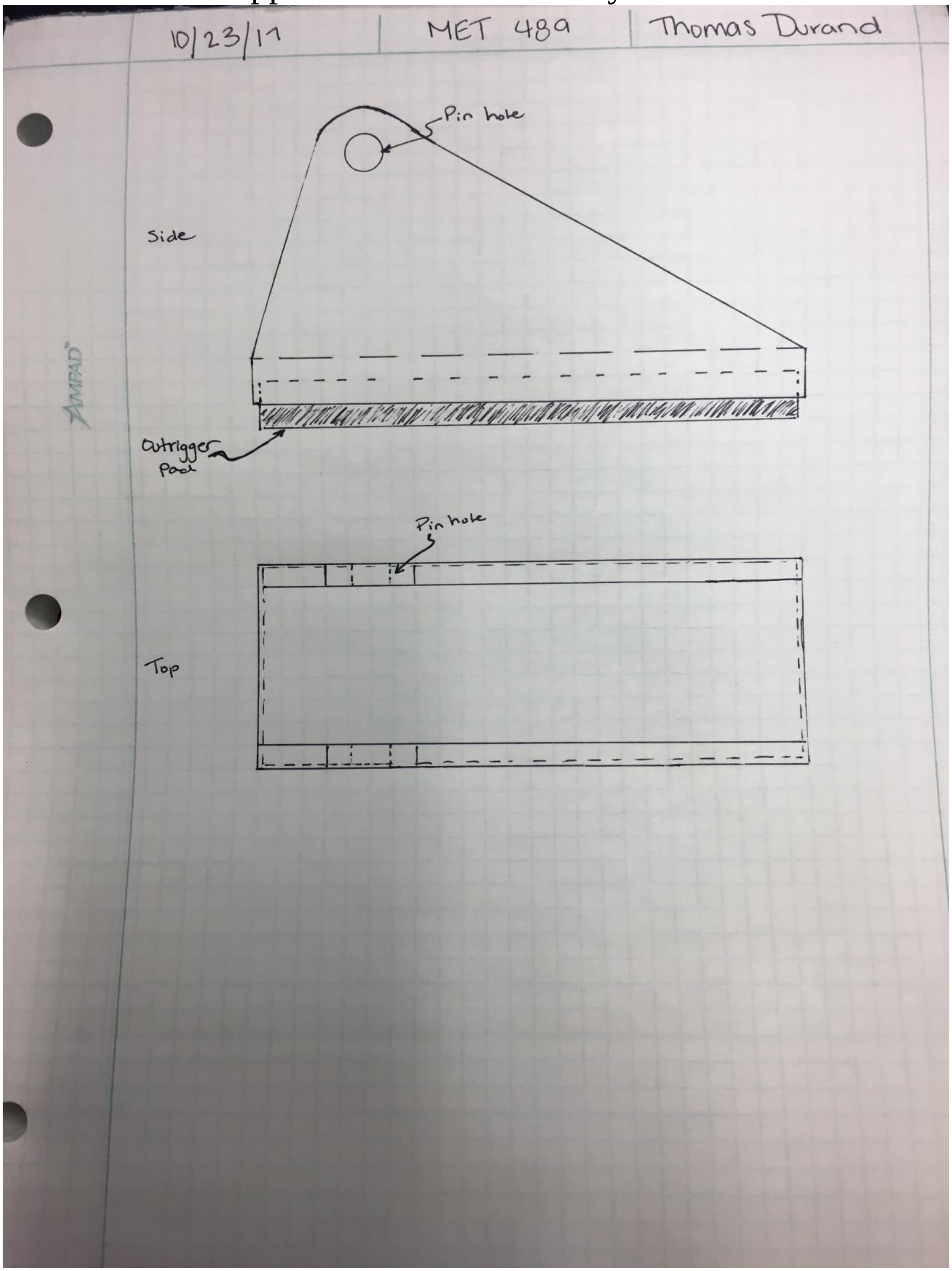
$y = 0.05488\,in$ ←

$y = 0.0549 + 0.0975 = 0.1524"$ ←

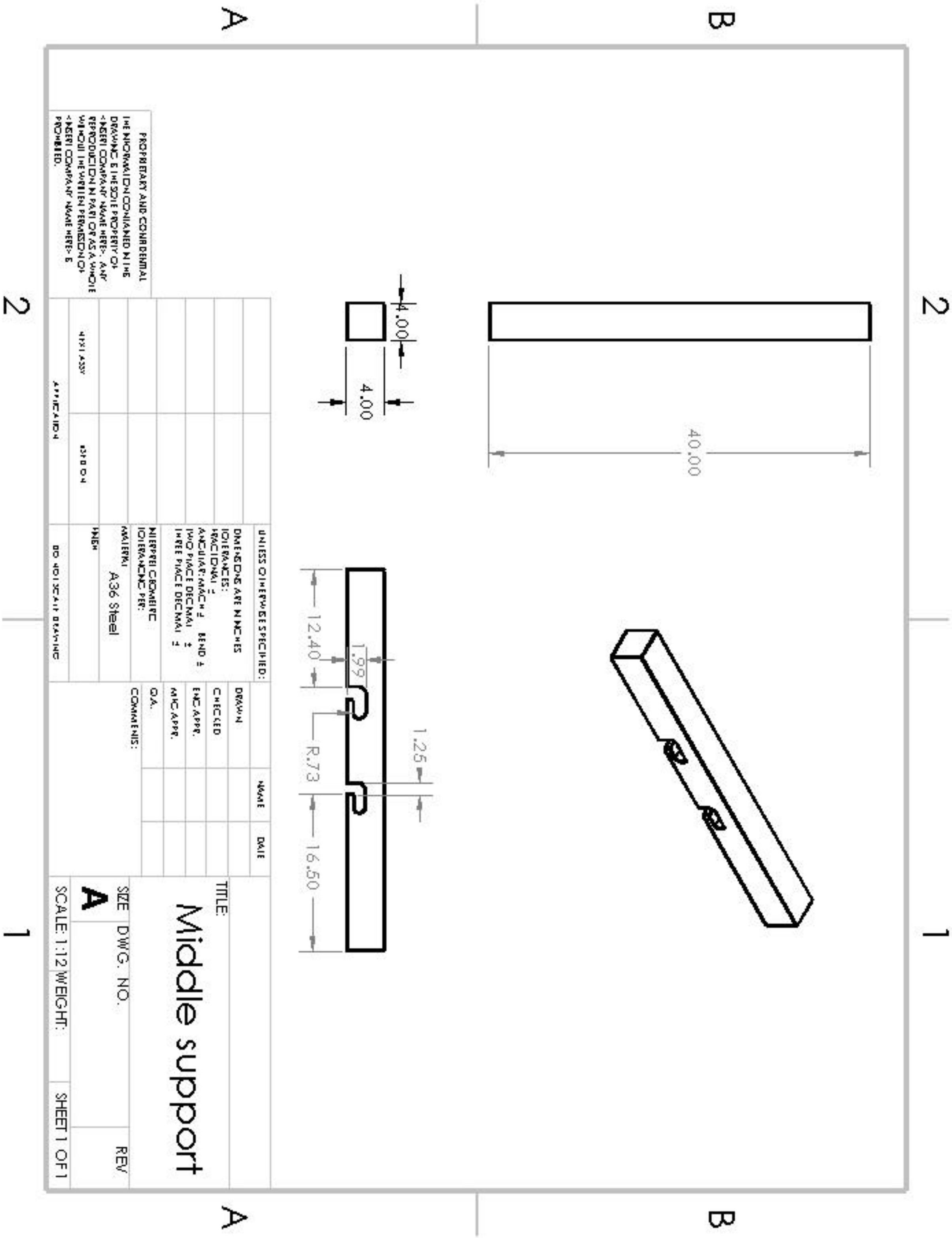
Appendix B.1 – stand foot Revision 1



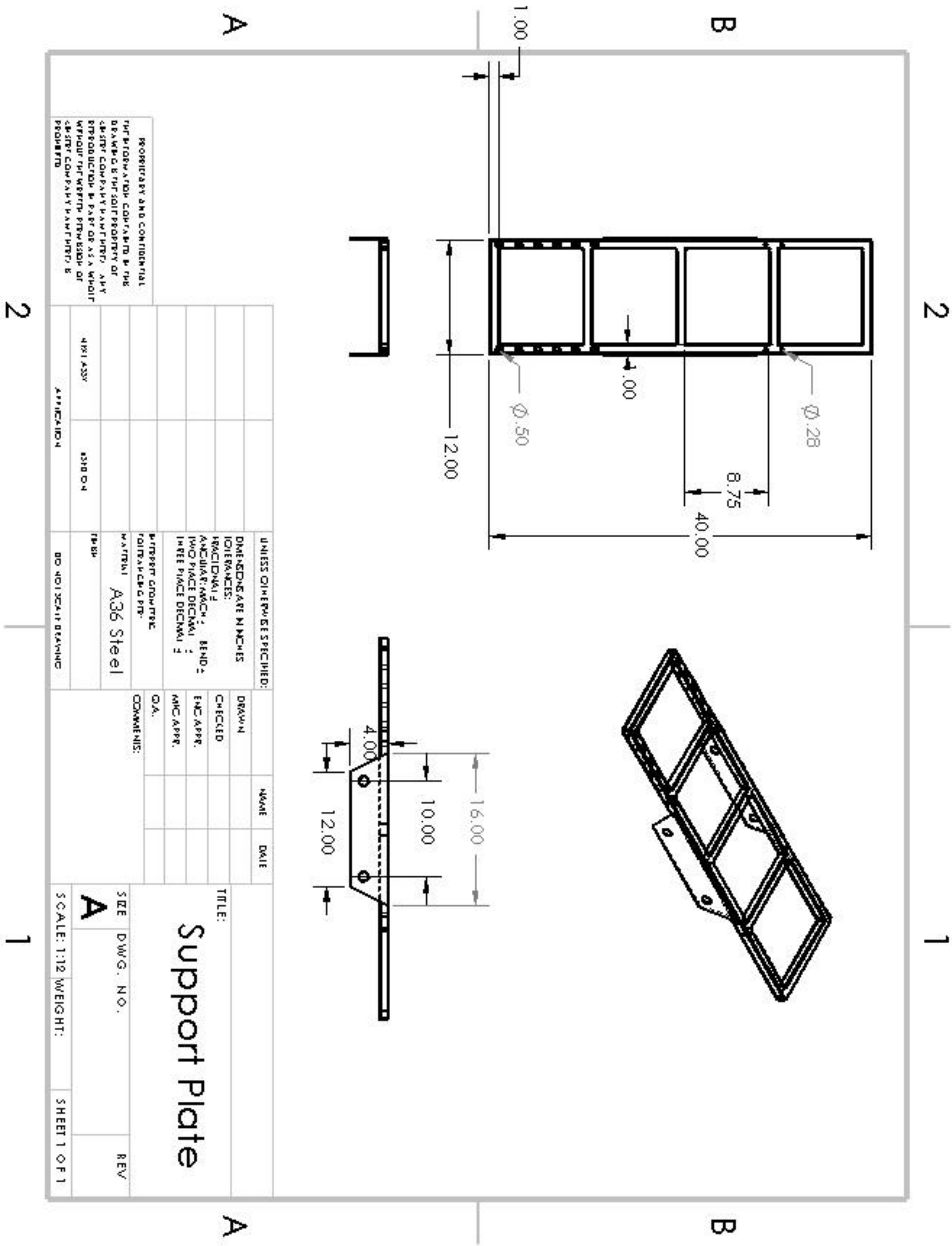
Appendix B.2 – Ladder Style Foot



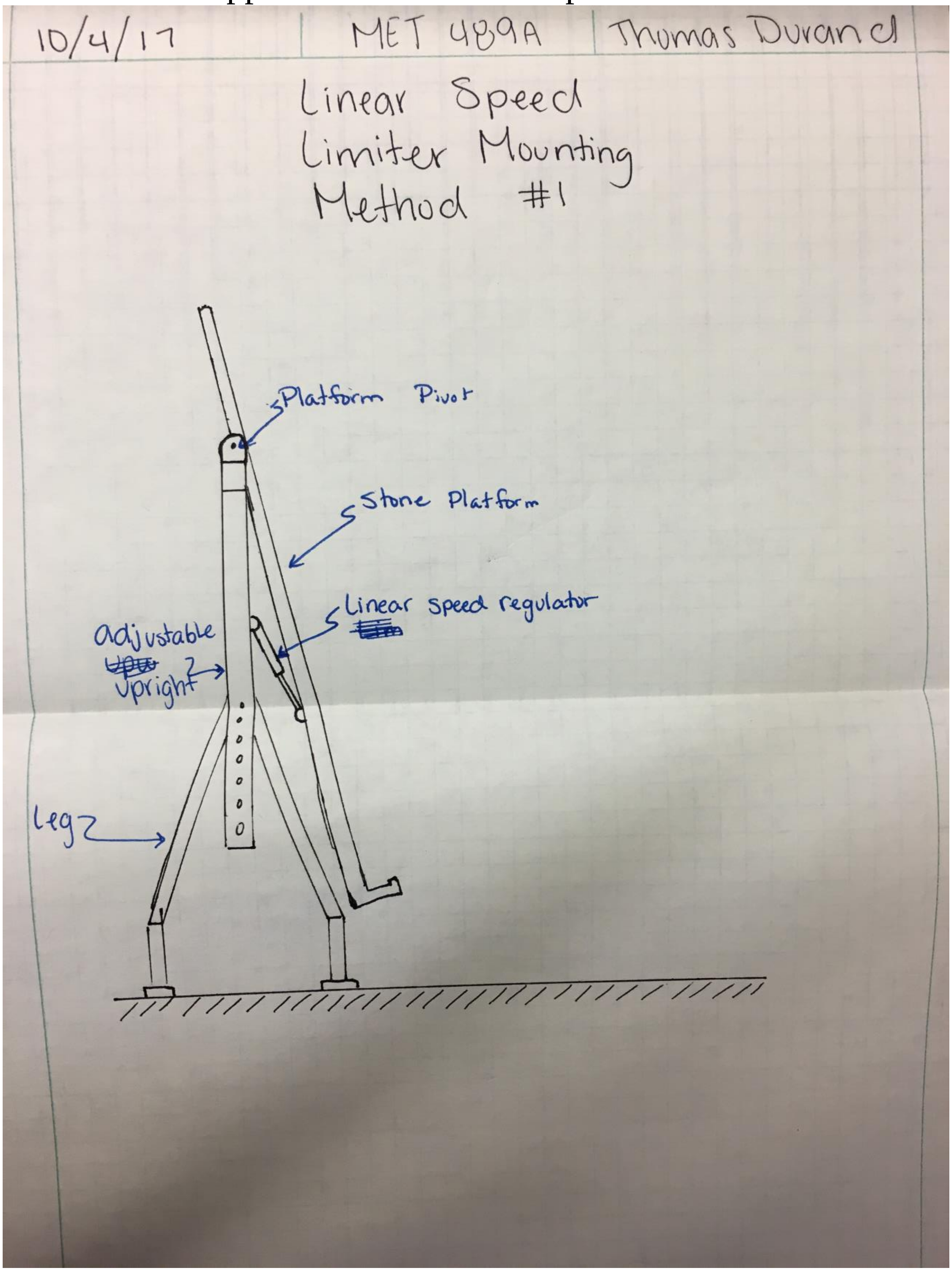
Appendix B.3 – Middle Support

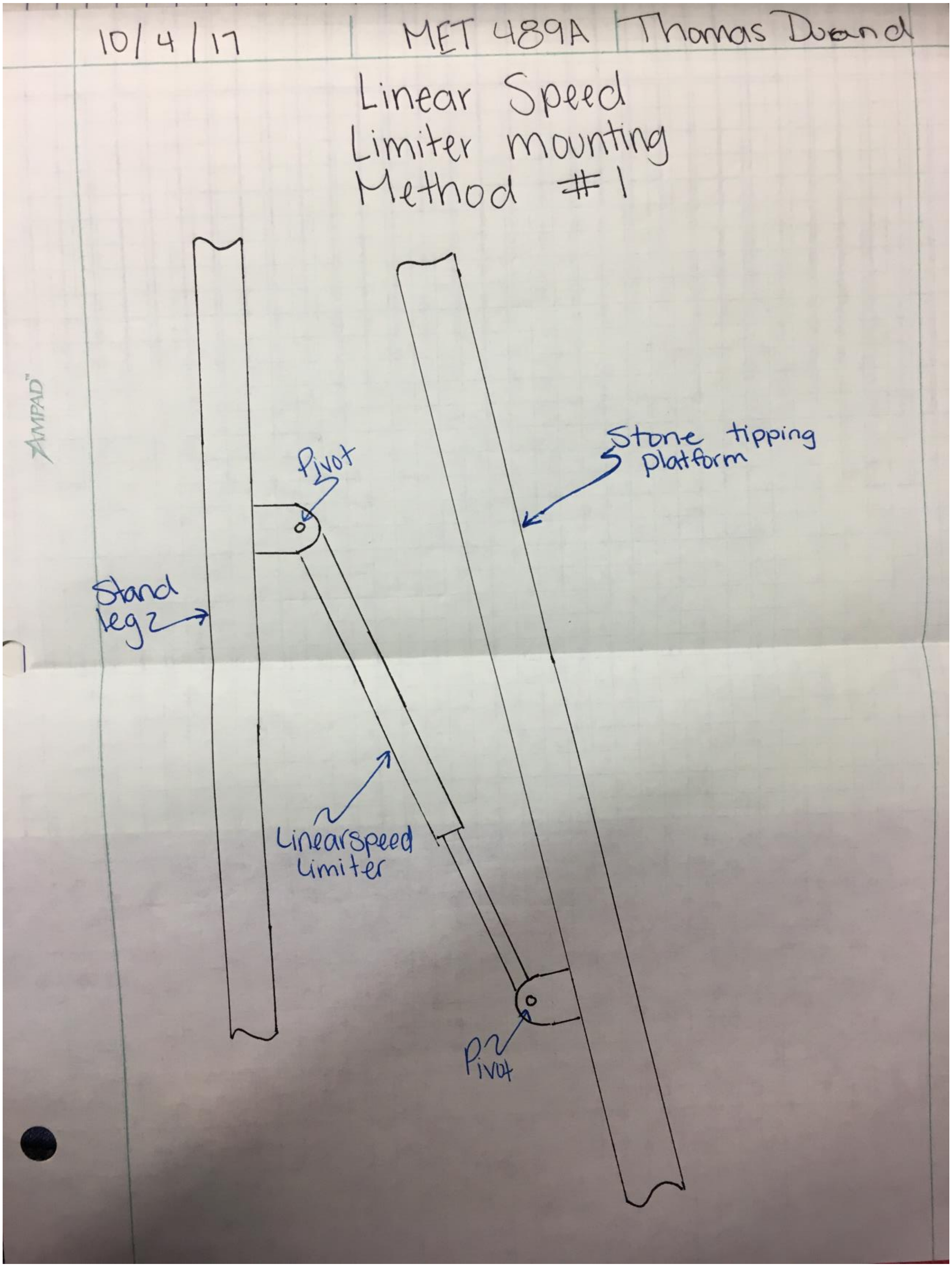


Appendix B.4 – Support Plate

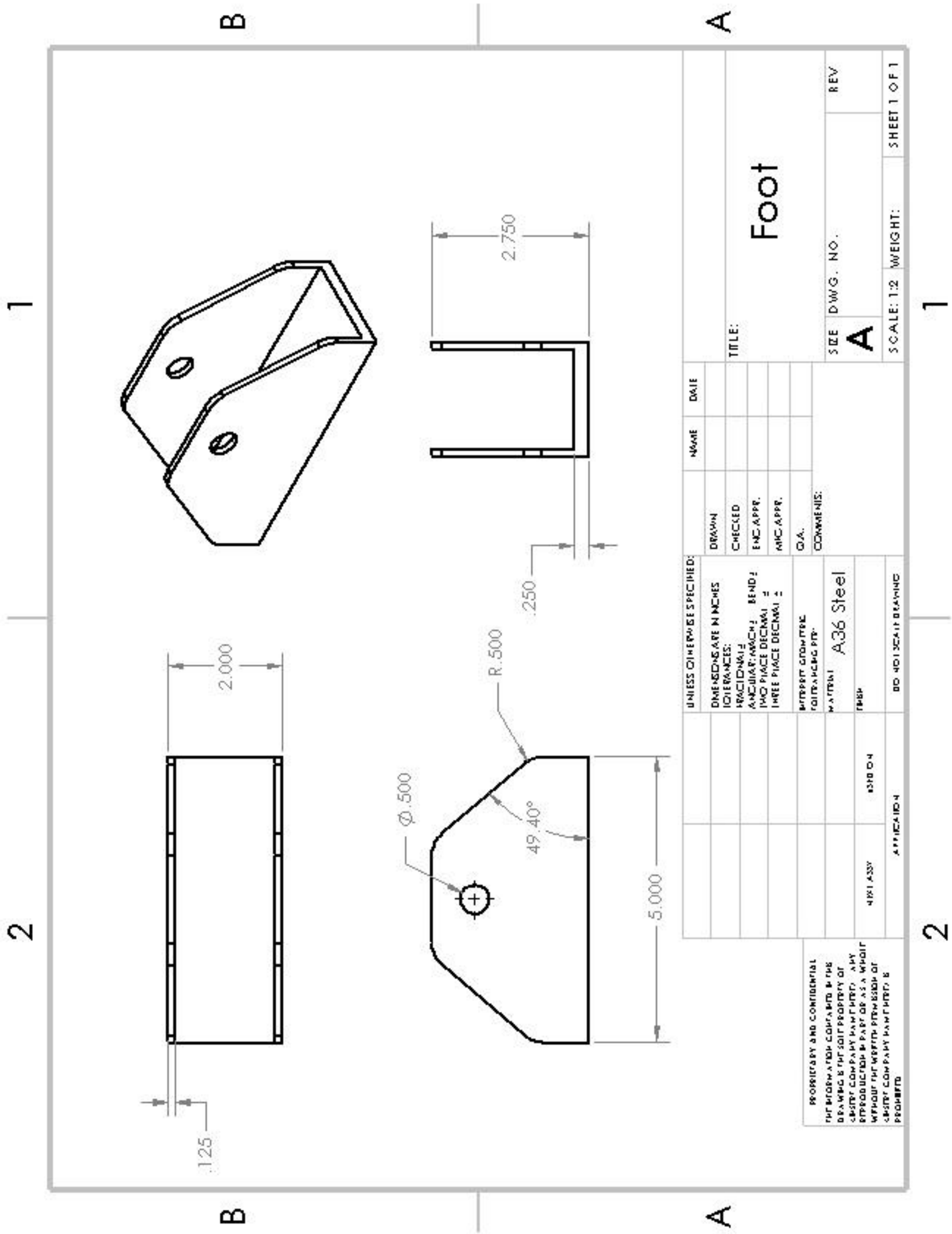


Appendix B.5 – Linear Speed Limiter

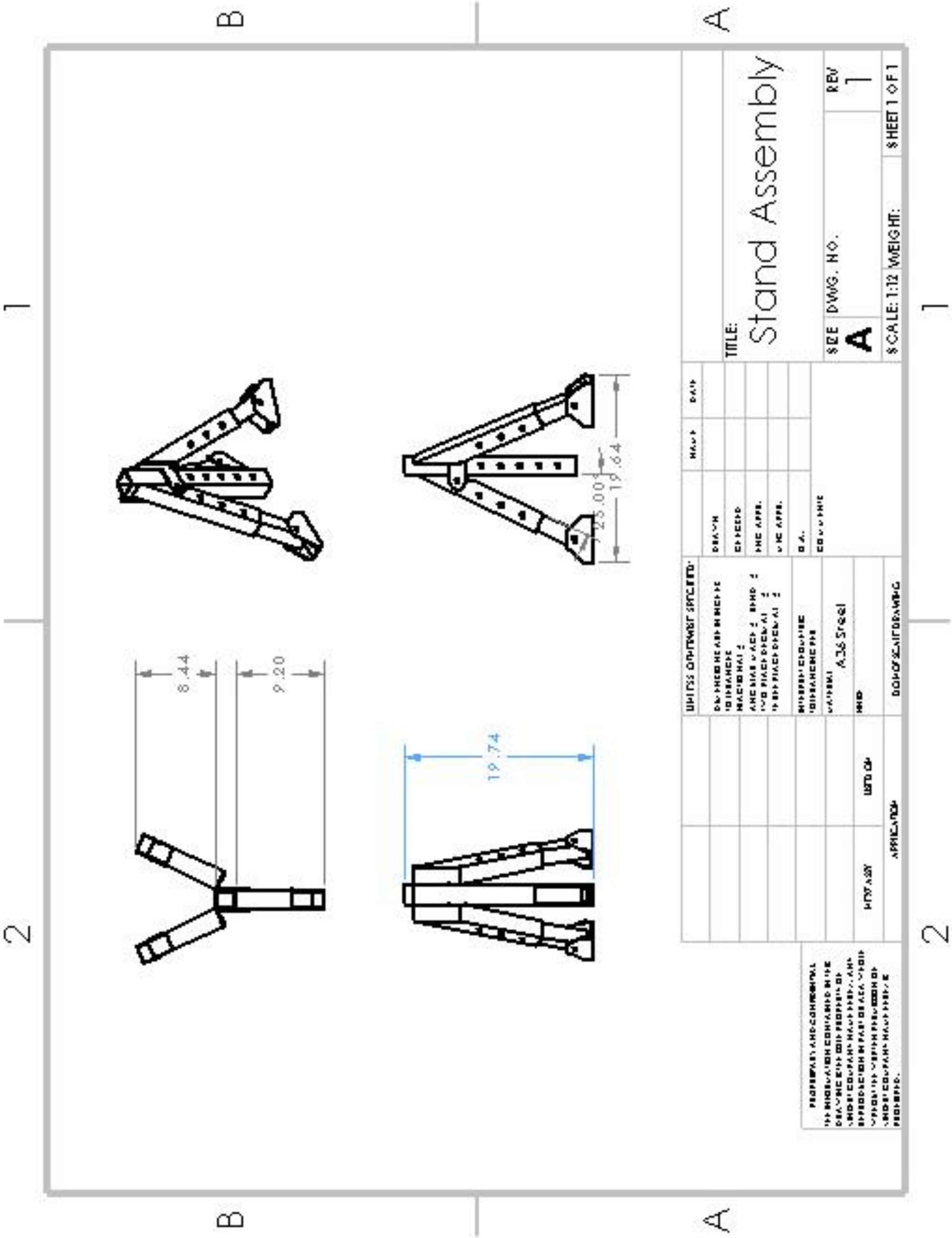



10/4/17
MET 489A
Thomas Durand
Linear Speed
Limiter mounting
Method #1
Stone tipping
platform
Pivot
Stand
leg 2
Linearspeed
Limiter
Pivot

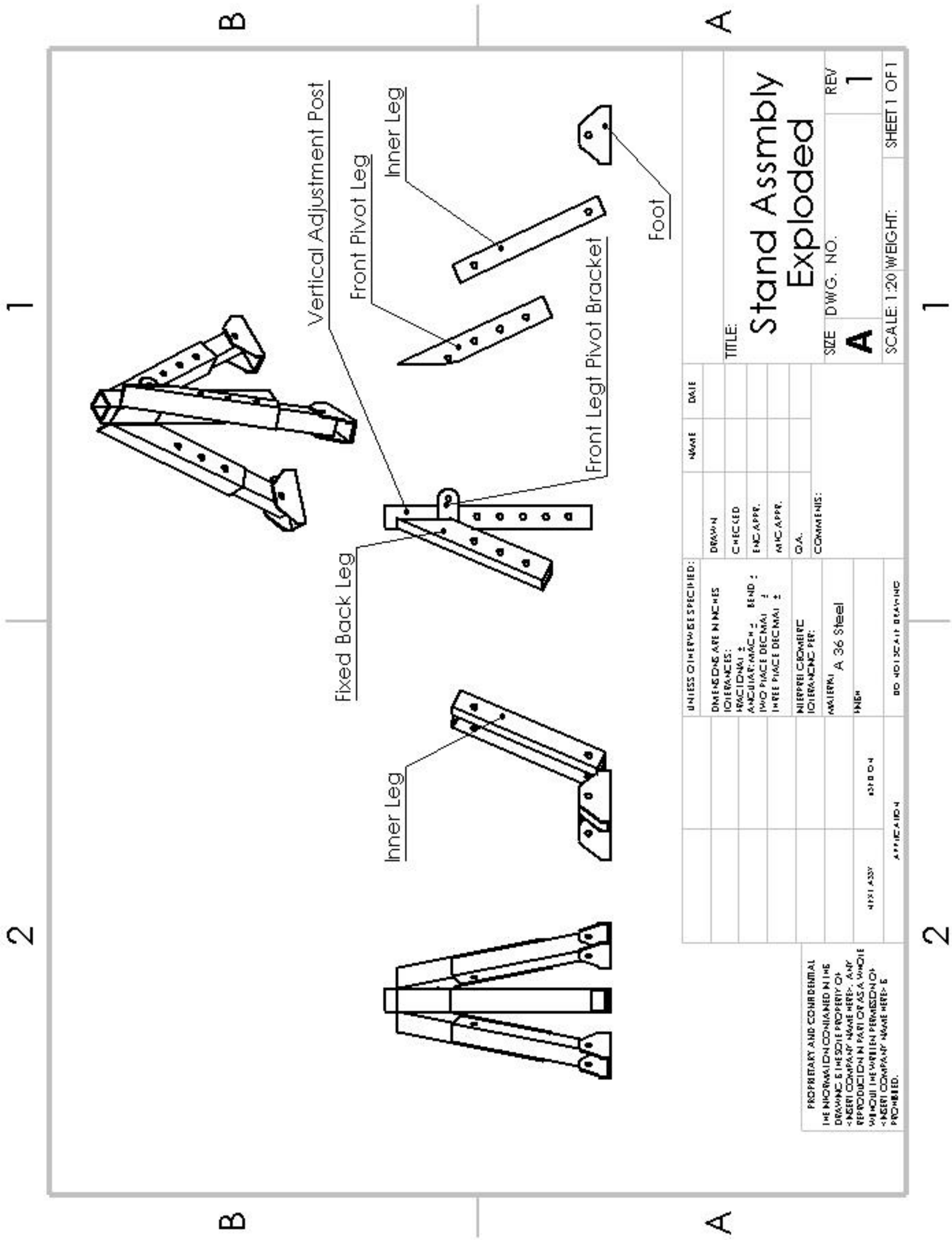
Appendix B.6 – Foot Design Rev 2



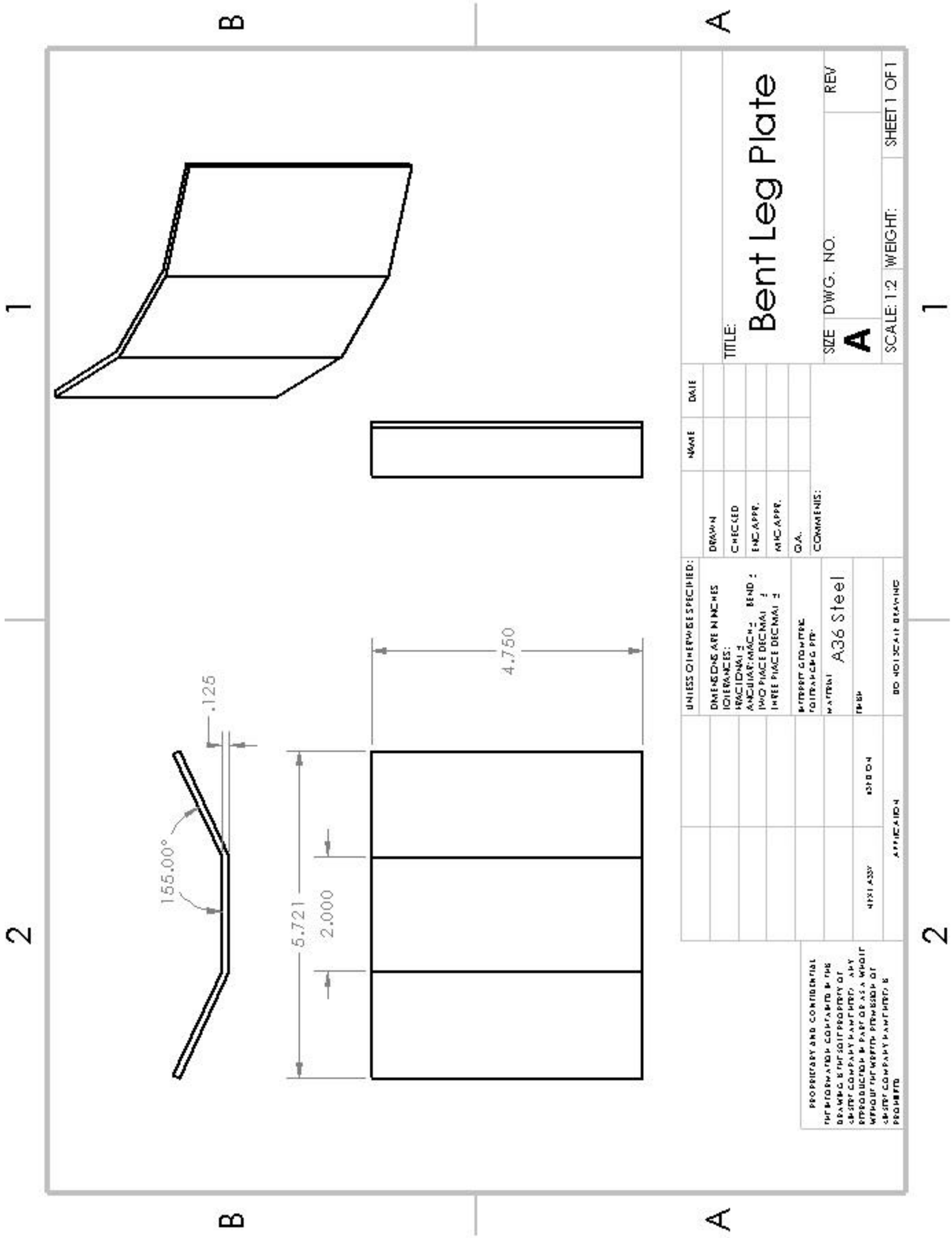
Appendix B.7 –Stand Assembly



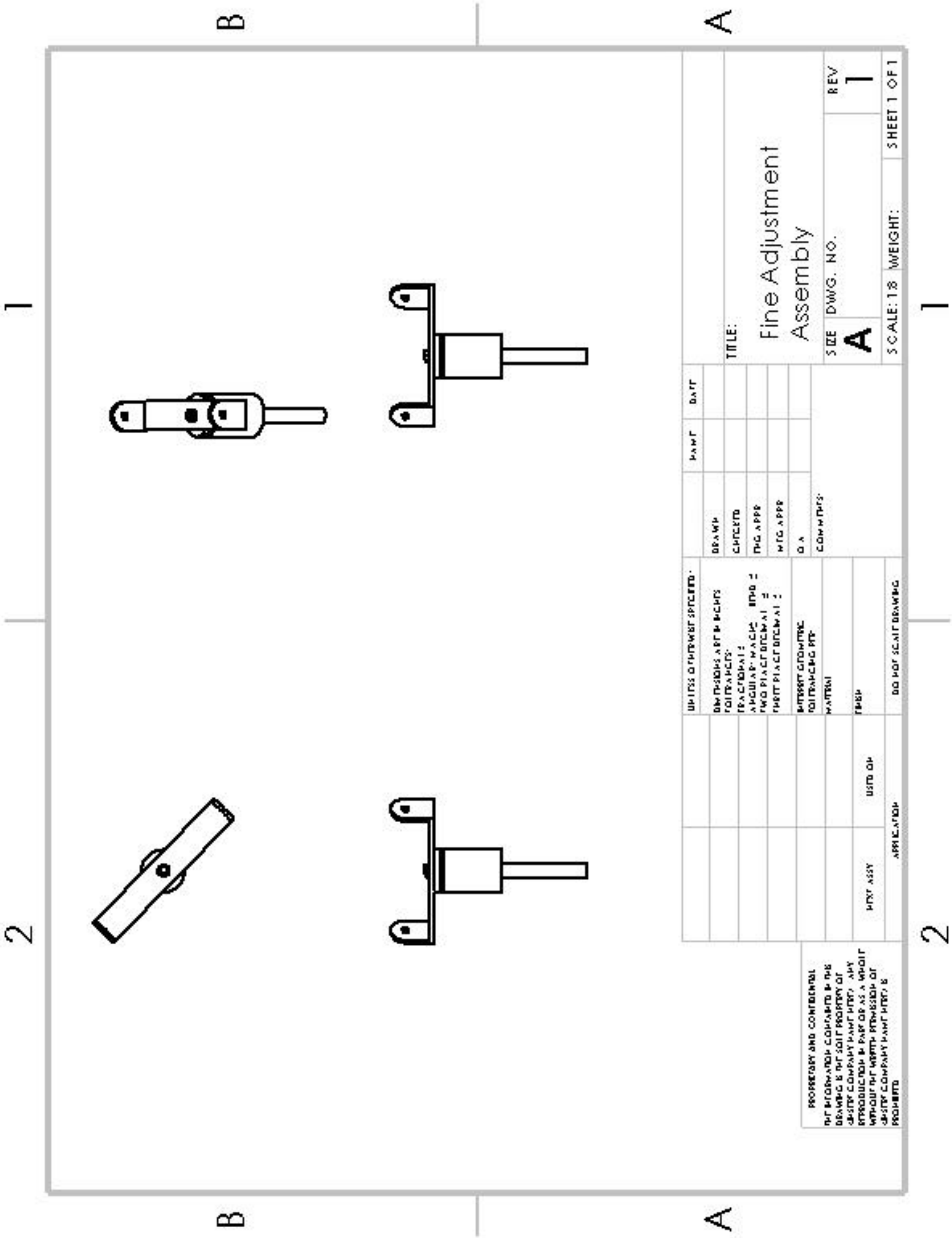
Appendix B.8 – Exploded Stand Assembly



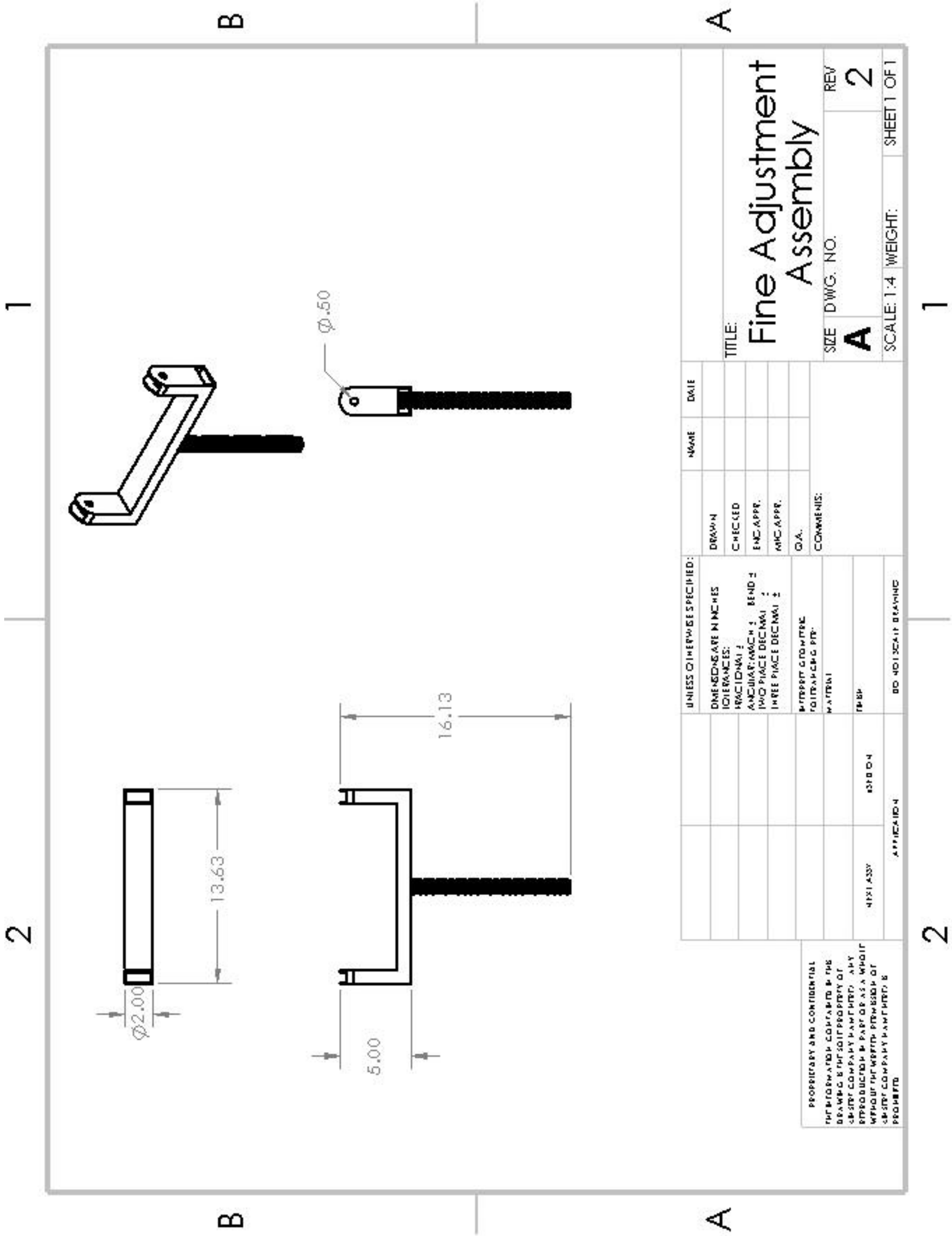
Appendix B.9 – Bent Leg Plate



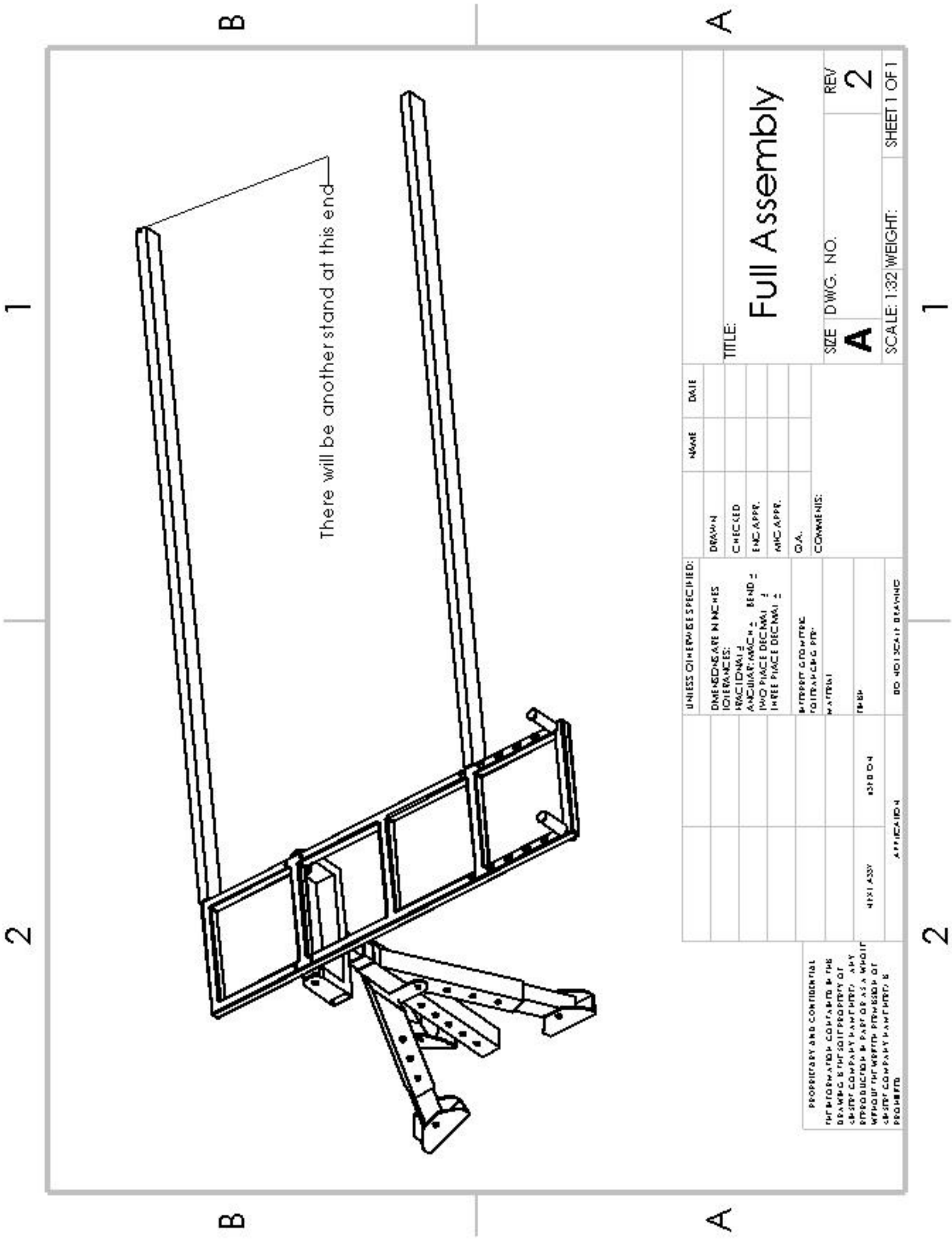
Appendix B.10 – Fine Adjustment Assembly Rev 1



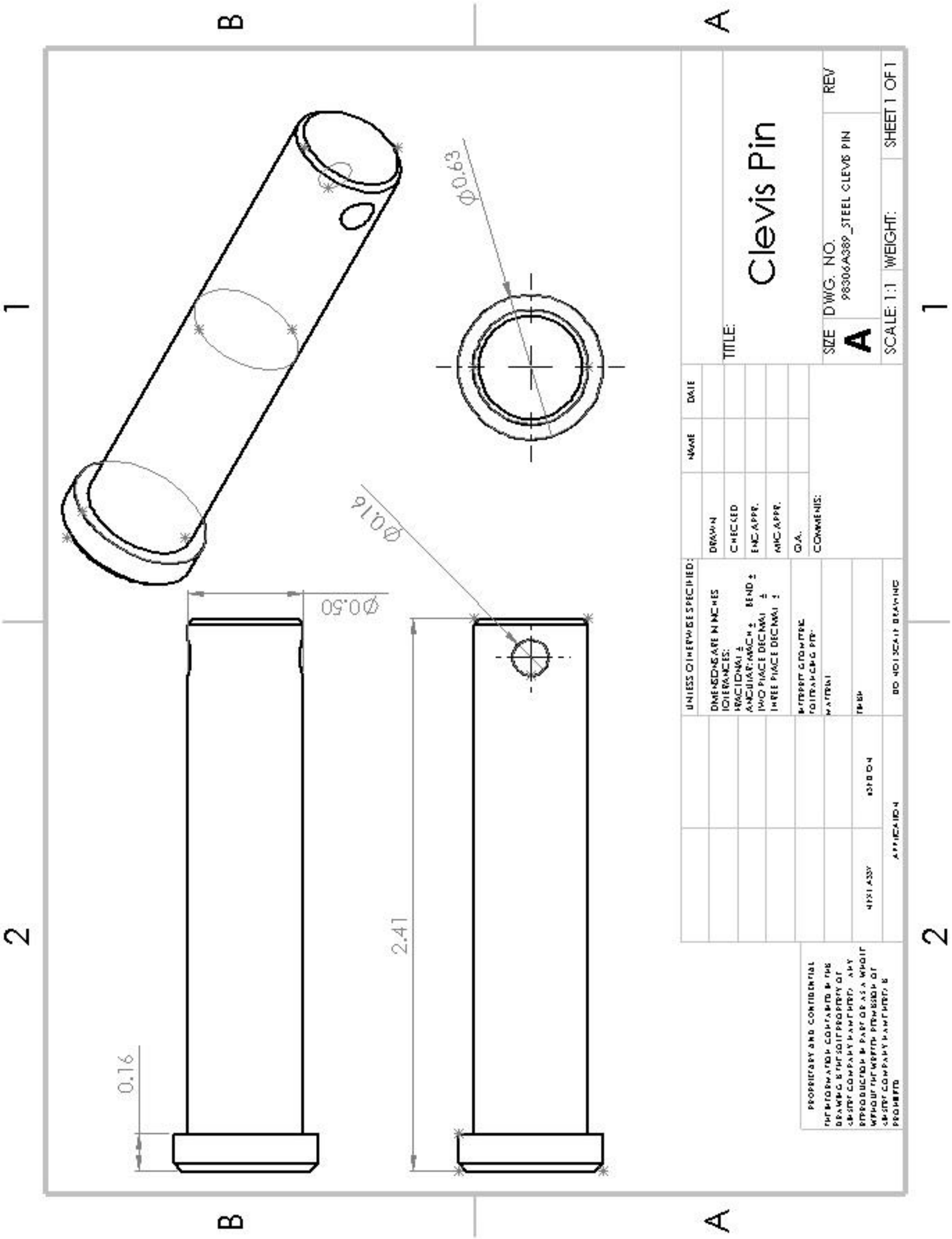
Appendix B.11 – Fine Adjustment Assembly Rev 2



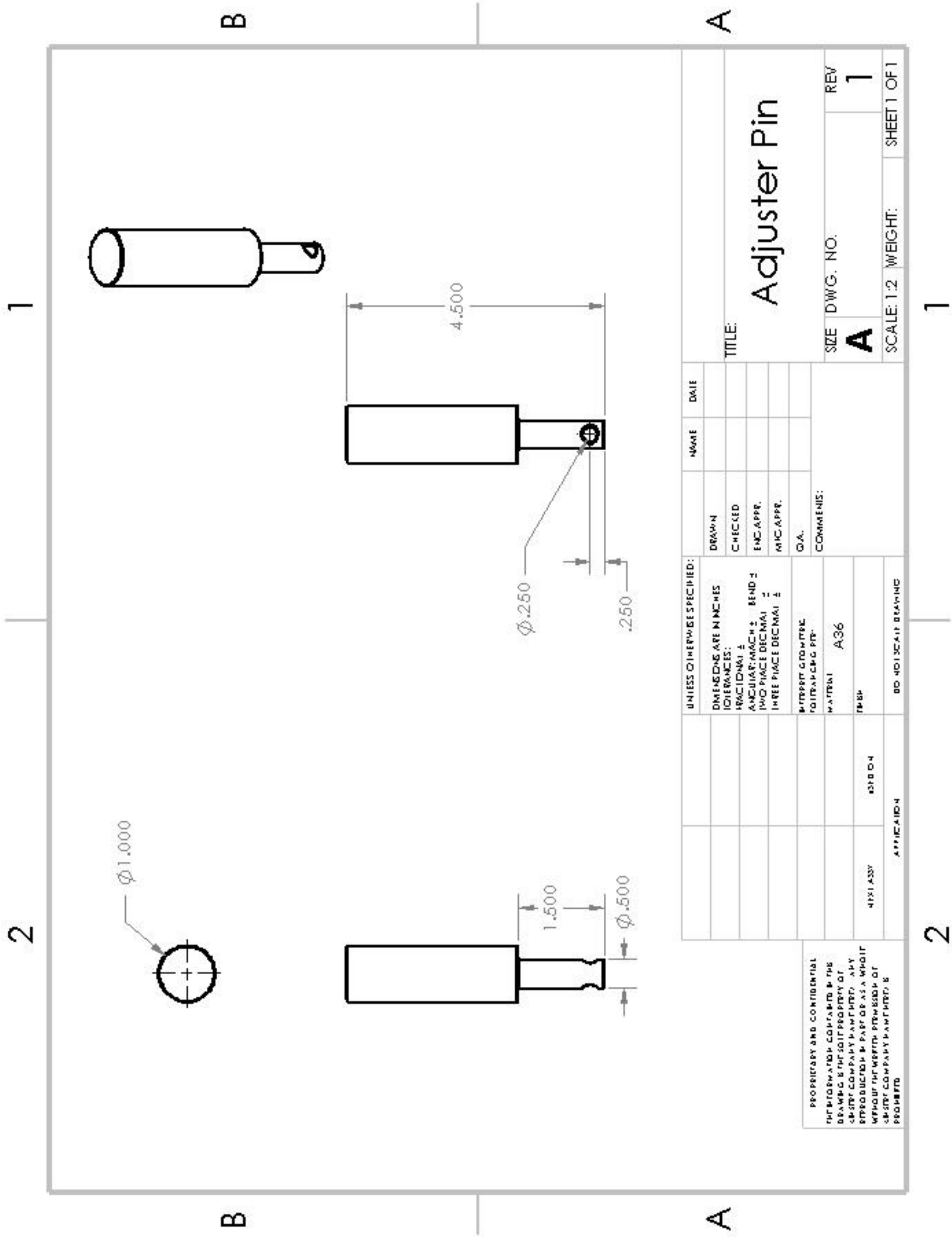
Appendix B.12 – Full Assembly Rev 2



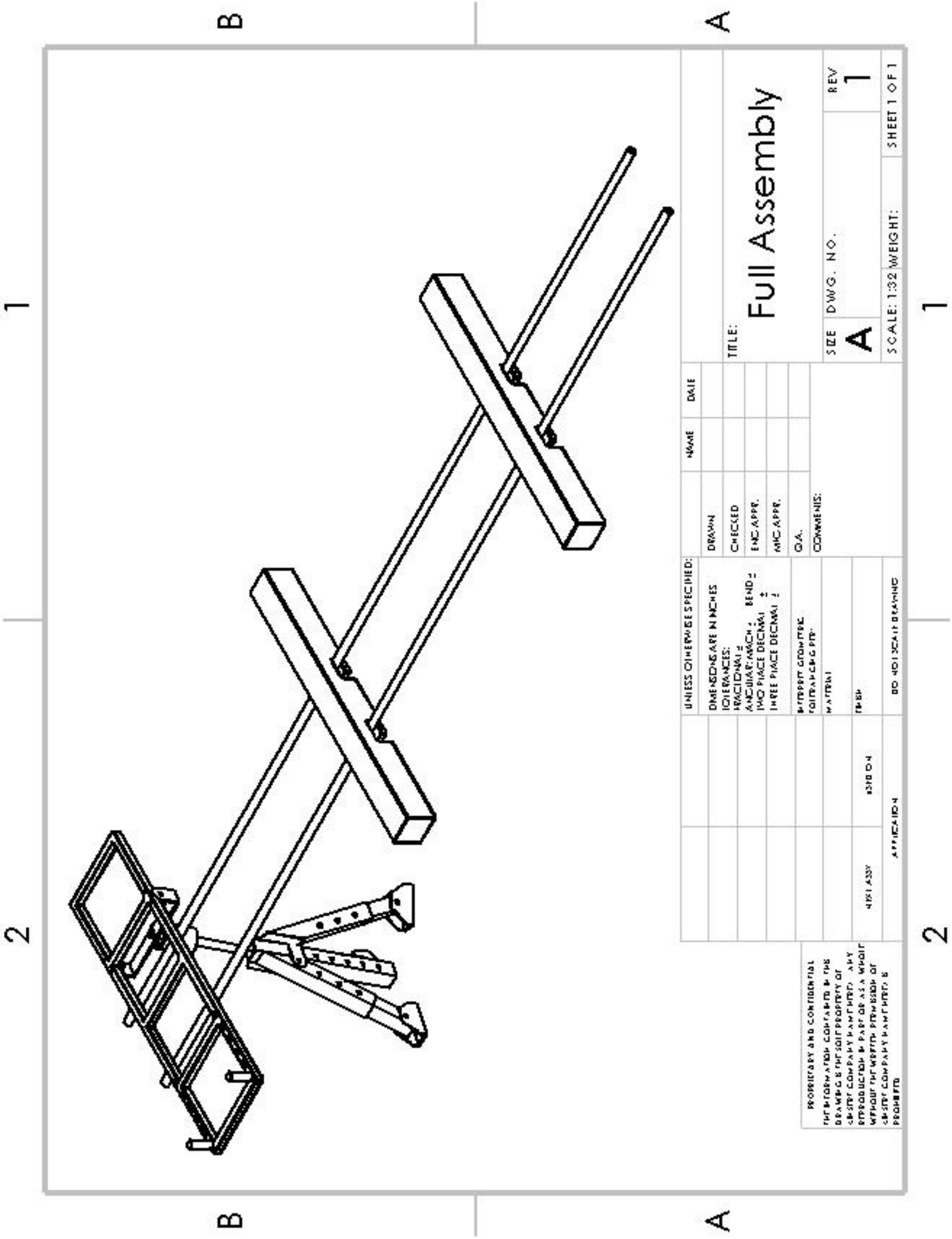
Appendix B.13 – McMaster Carr ½” – 2” Steel Clevis Pin



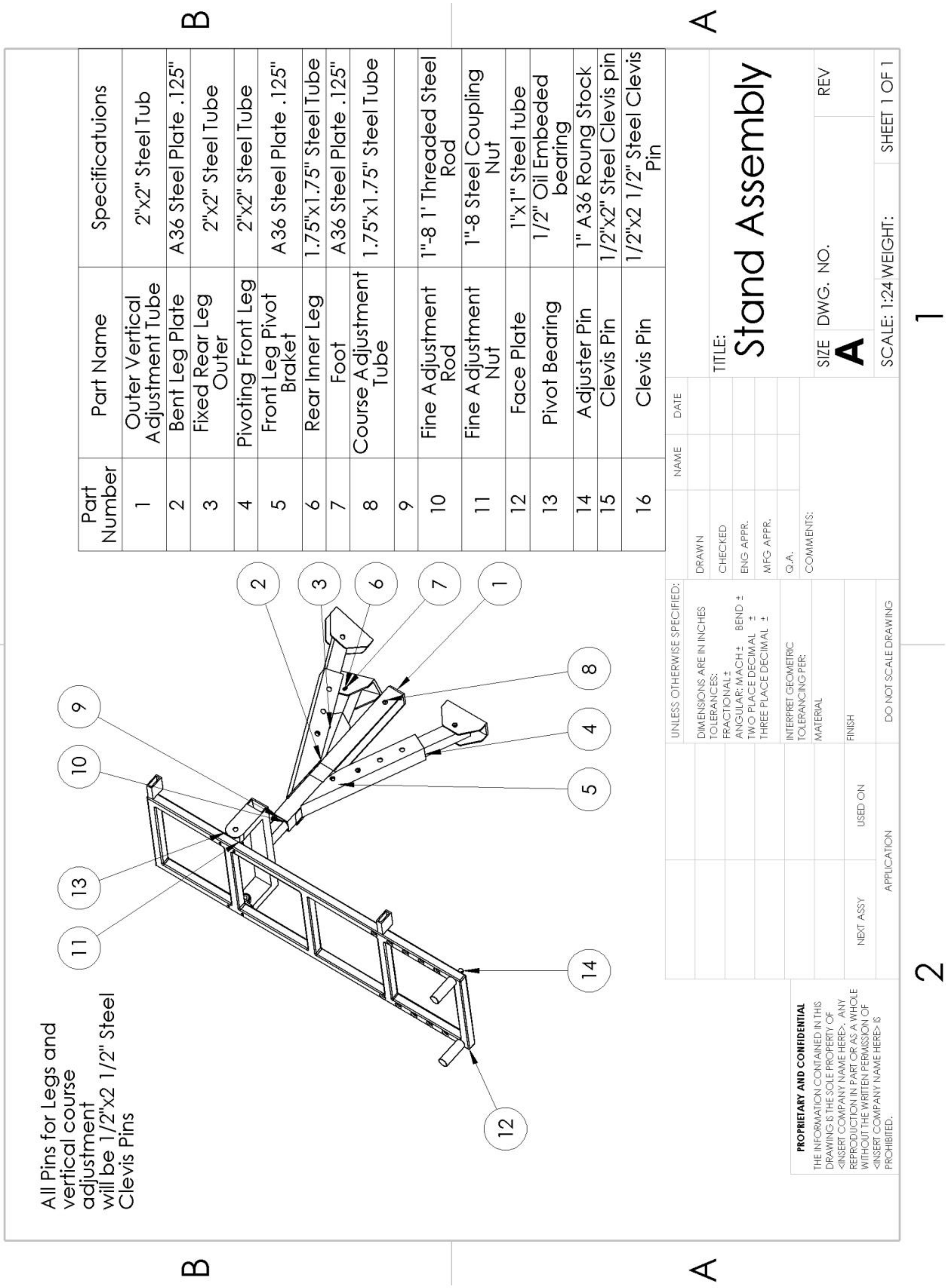
Appendix B.14 – Adjuster Pin



Appendix B.15 – Full Assembly Rev 1

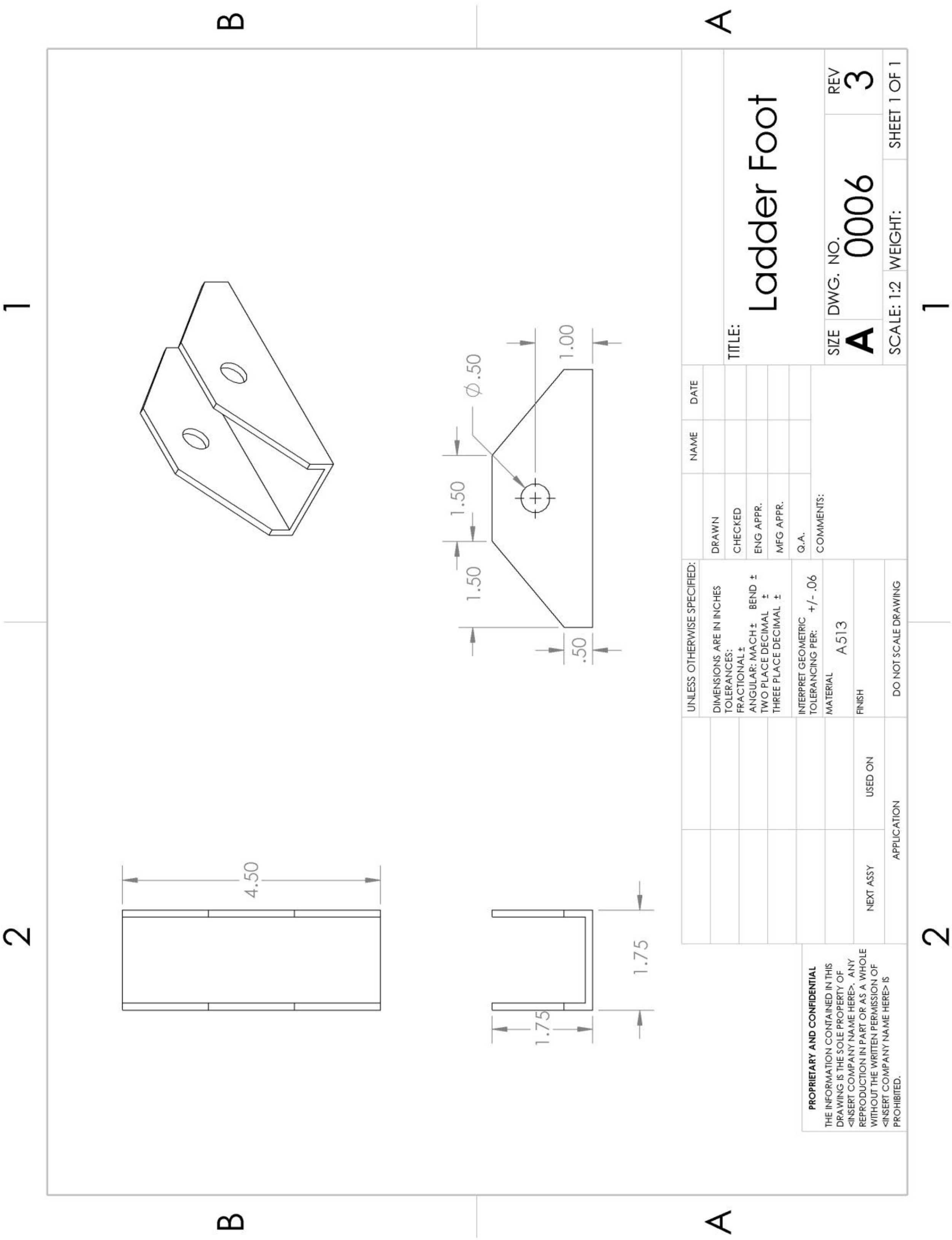


Appendix B.16 – Assembly Drawing

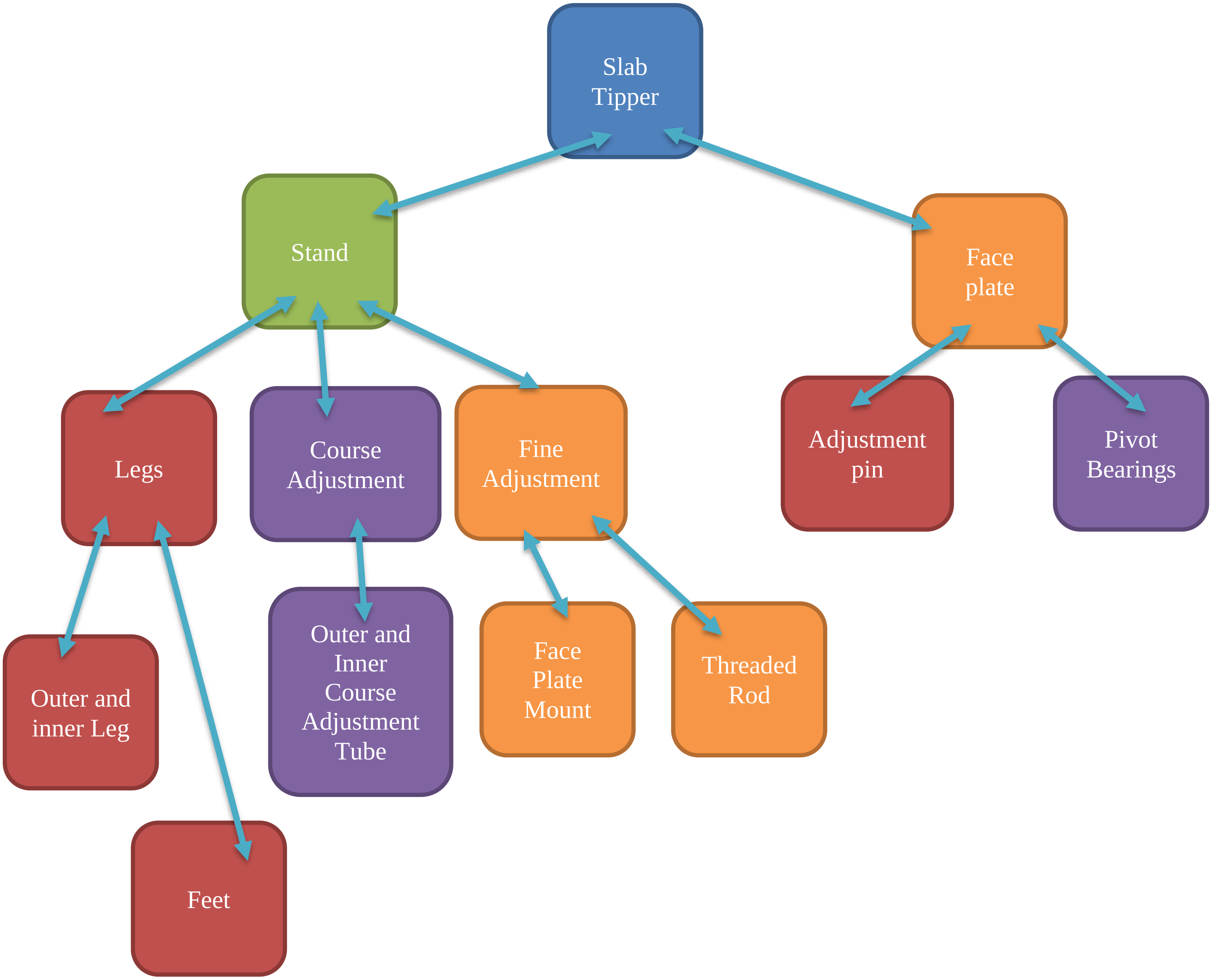


Part Number	Part Name	Specificatuions
1	Outer Vertical Adjustment Tube	2"x2" Steel Tub
2	Bent Leg Plate	A36 Steel Plate .125"
3	Fixed Rear Leg Outer	2"x2" Steel Tube
4	Pivoting Front Leg	2"x2" Steel Tube
5	Front Leg Pivot Braket	A36 Steel Plate .125"
6	Rear Inner Leg	1.75"x1.75" Steel Tube
7	Foot	A36 Steel Plate .125"
8	Course Adjustment Tube	1.75"x1.75" Steel Tube
9		
10	Fine Adjustment Rod	1"-8 1' Threaded Steel Rod
11	Fine Adjustment Nut	1"-8 Steel Coupling Nut
12	Face Plate	1"x1" Steel tube
13	Pivot Bearing	1/2" Oil Embeded bearing
14	Adjuster Pin	1" A36 Roung Stock
15	Clevis Pin	1/2"x2" Steel Clevis pin
16	Clevis Pin	1/2"x2 1/2" Steel Clevis Pin

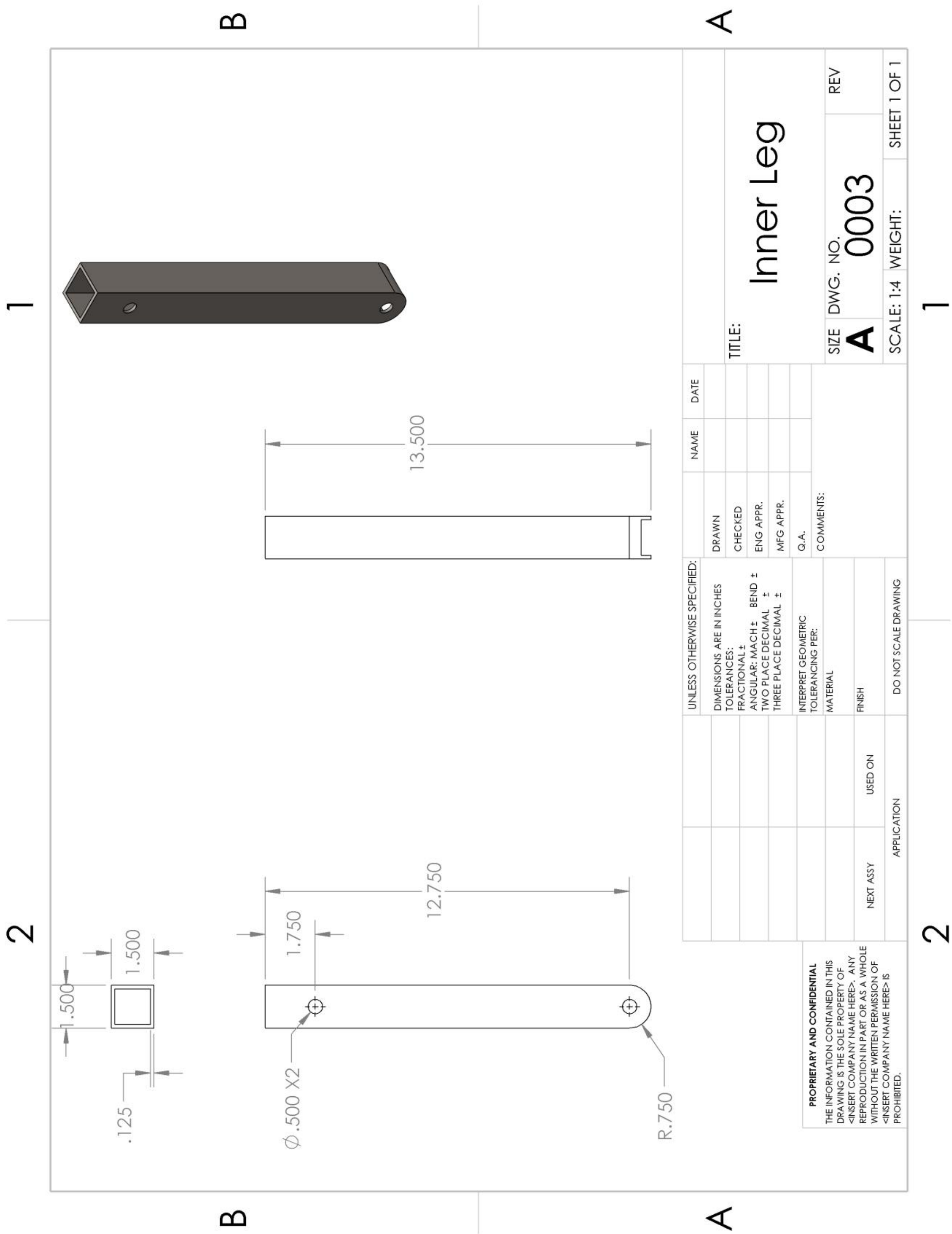
Appendix B.17 – Foot Design Rev 3



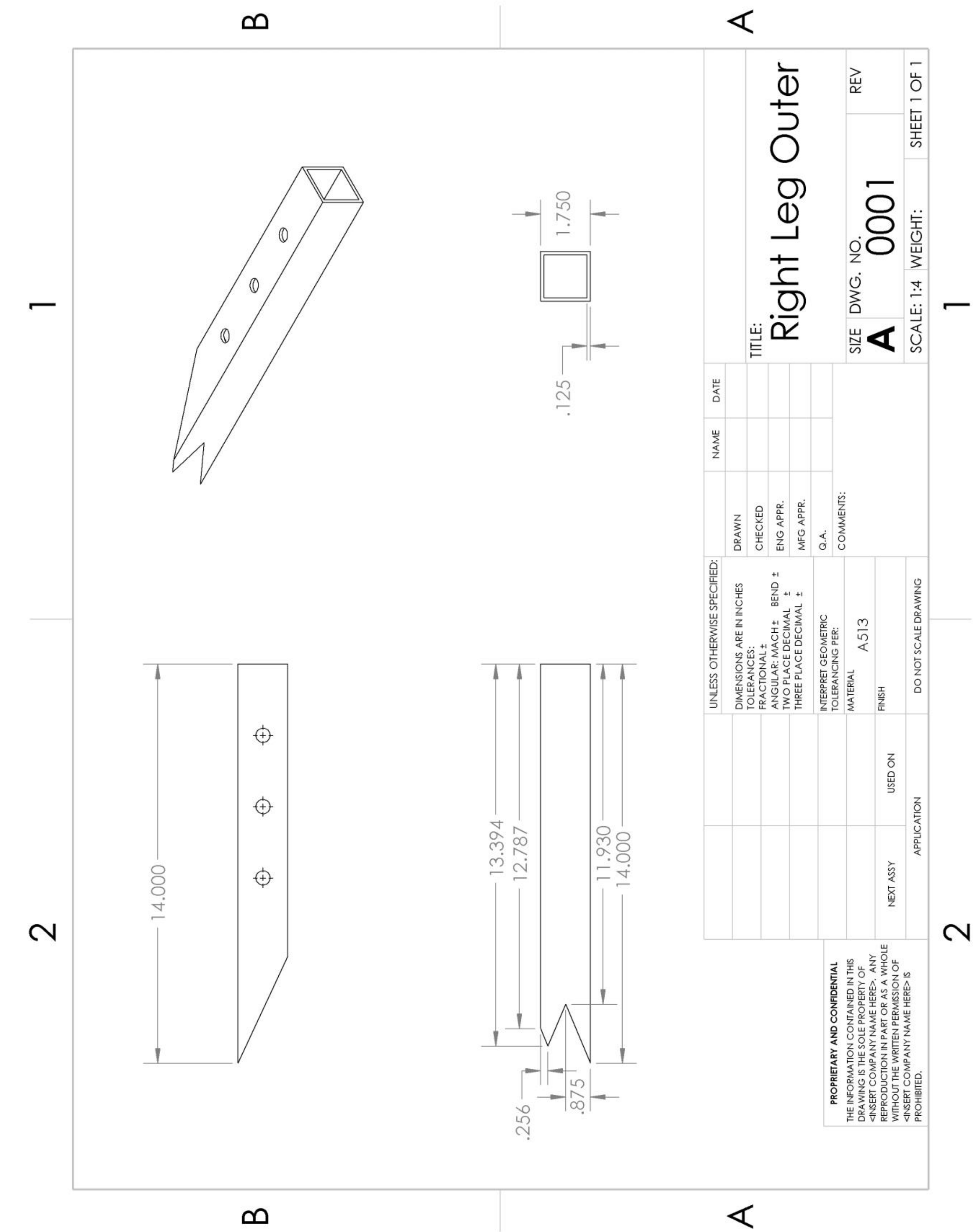
Appendix B.18 – Tree



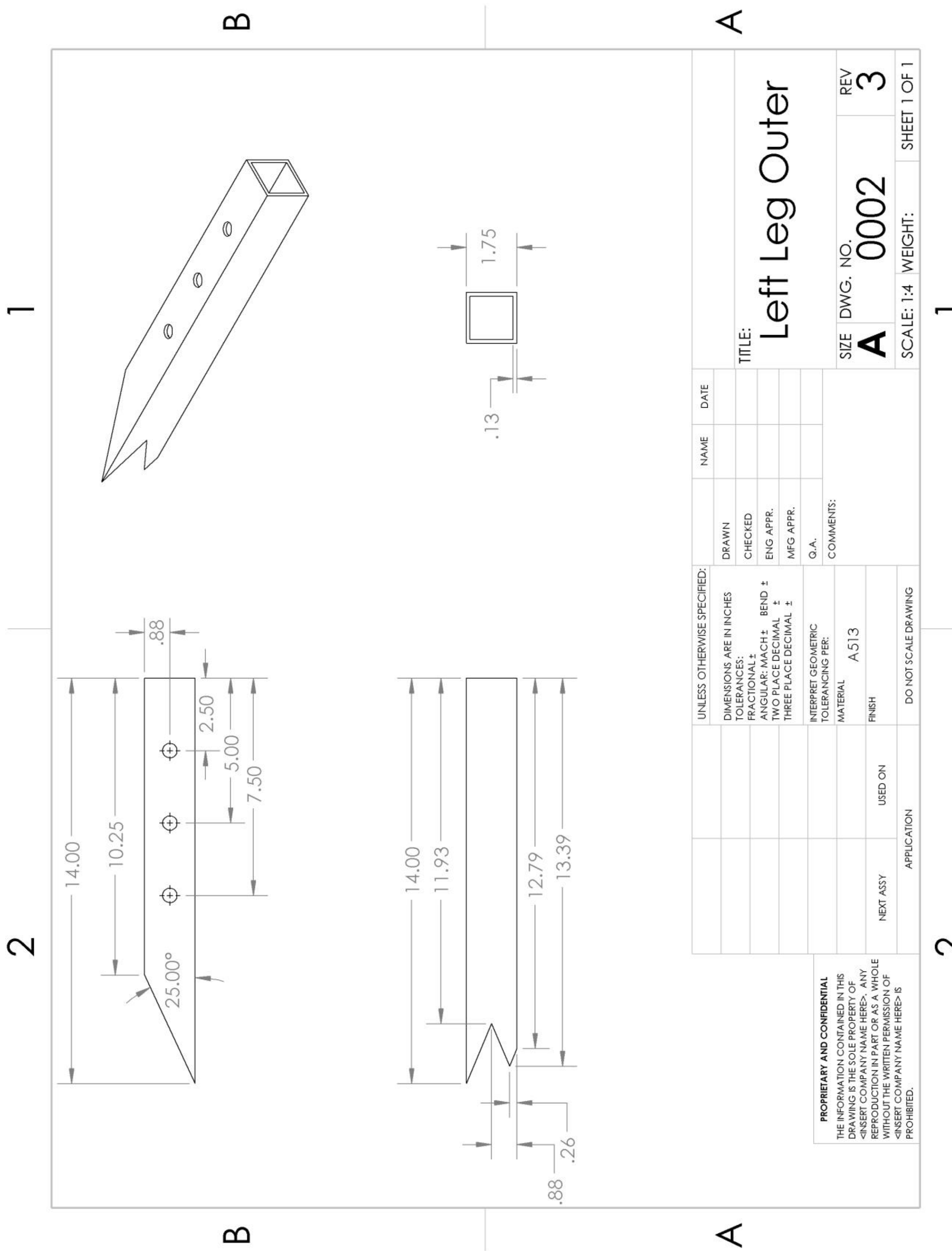
Appendix B.19 – Inner Leg



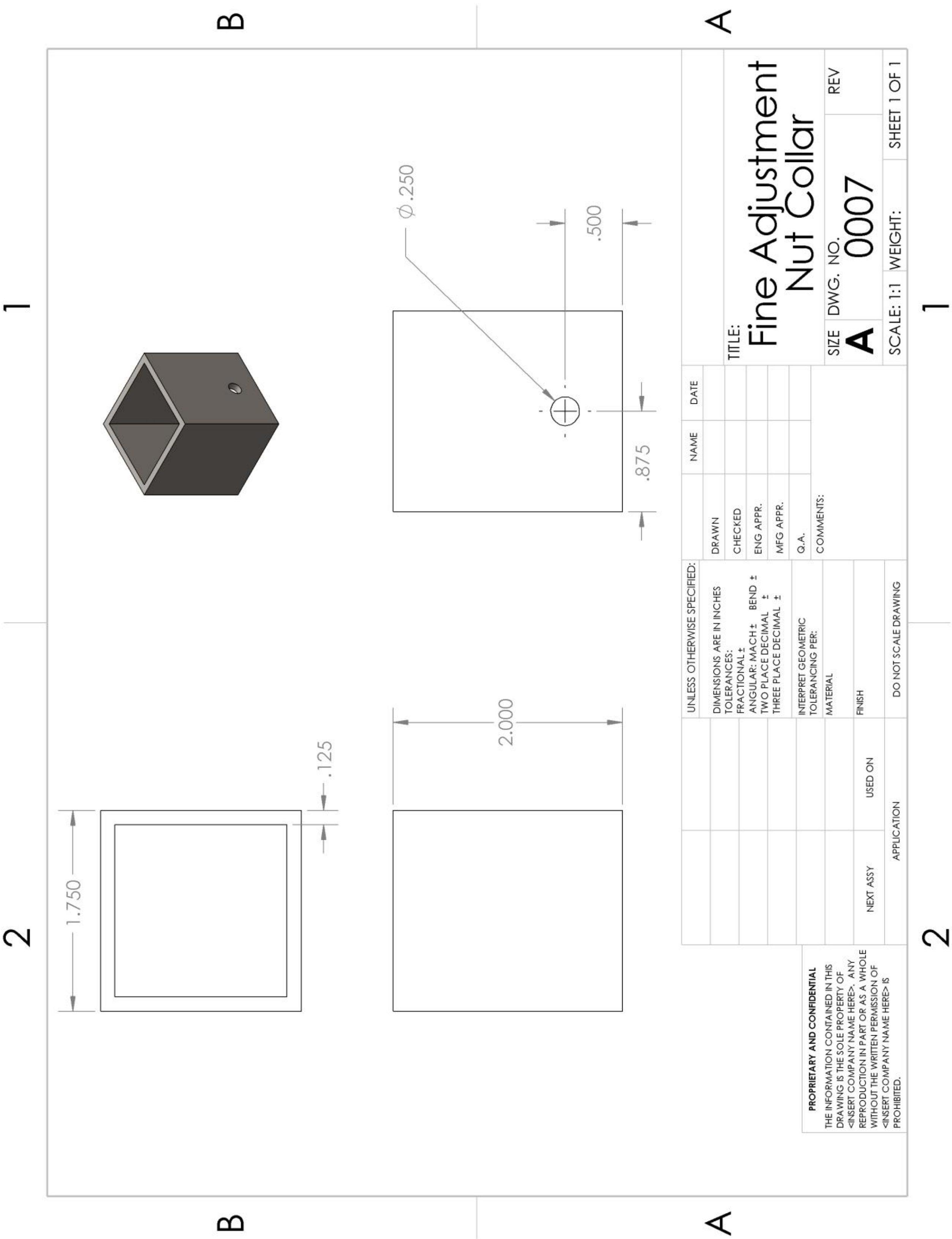
Appendix B.20 – Right Leg Outer REV 2



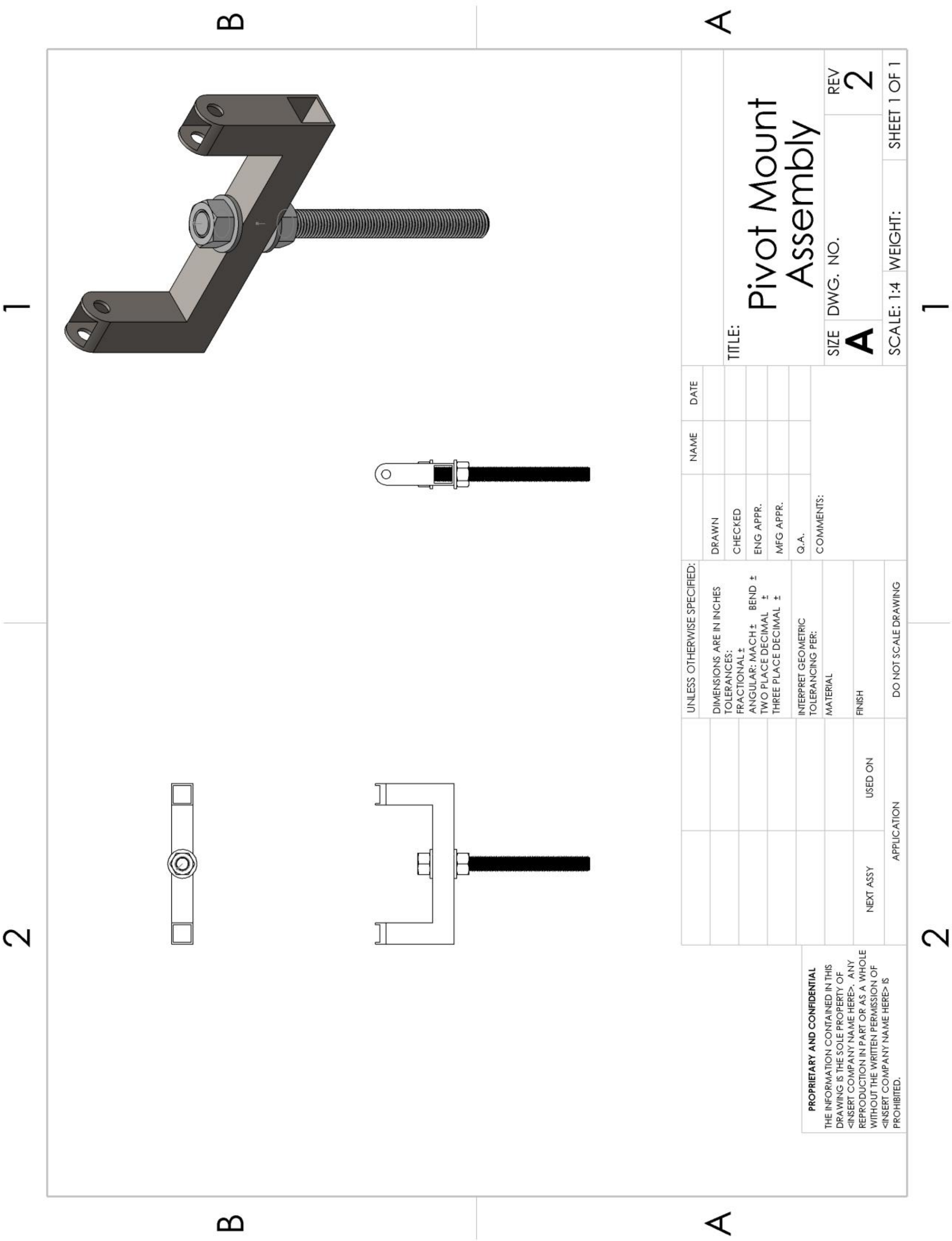
Appendix B.21 – Left Leg Outer



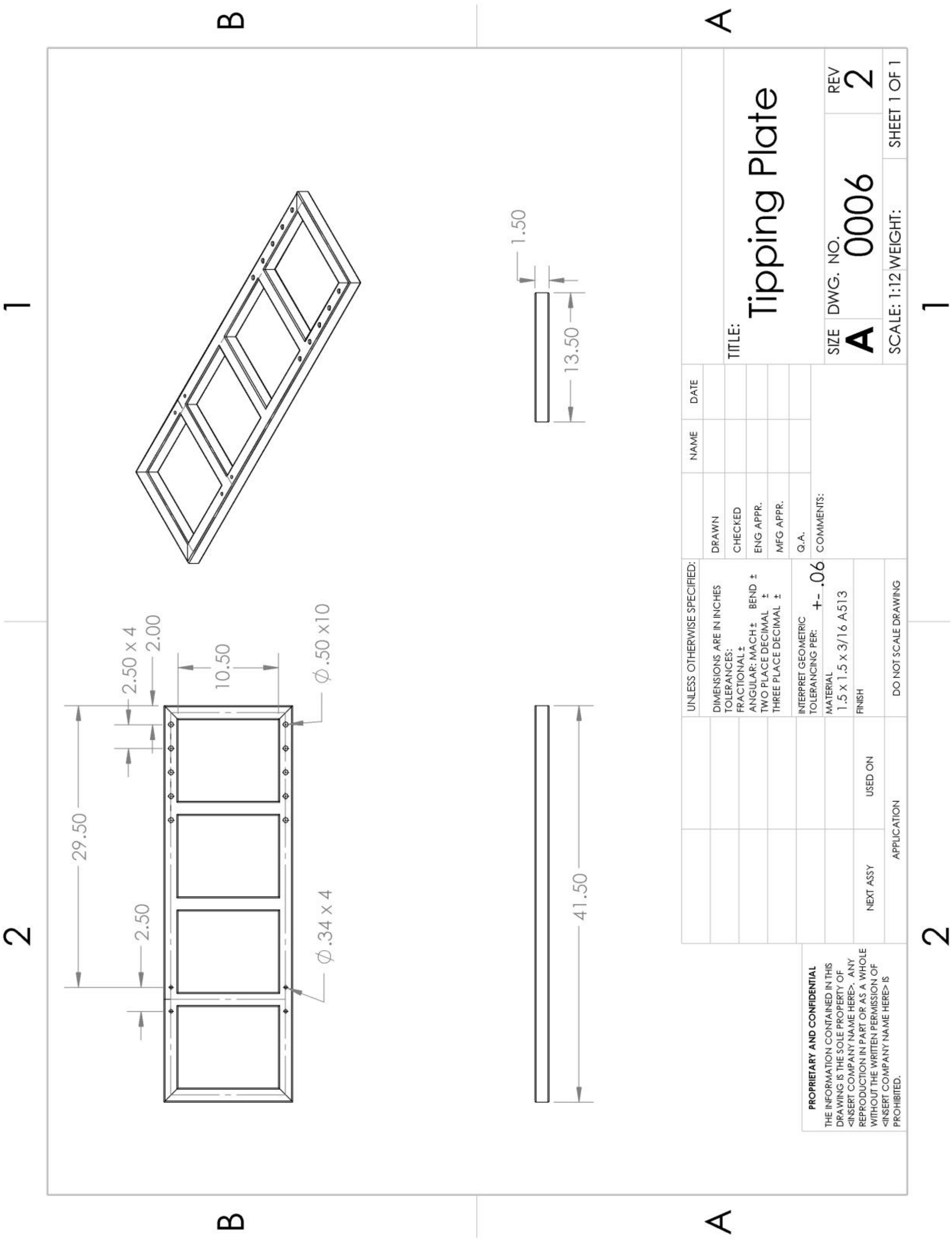
Appendix B.22 – Fine Adjustment Collar



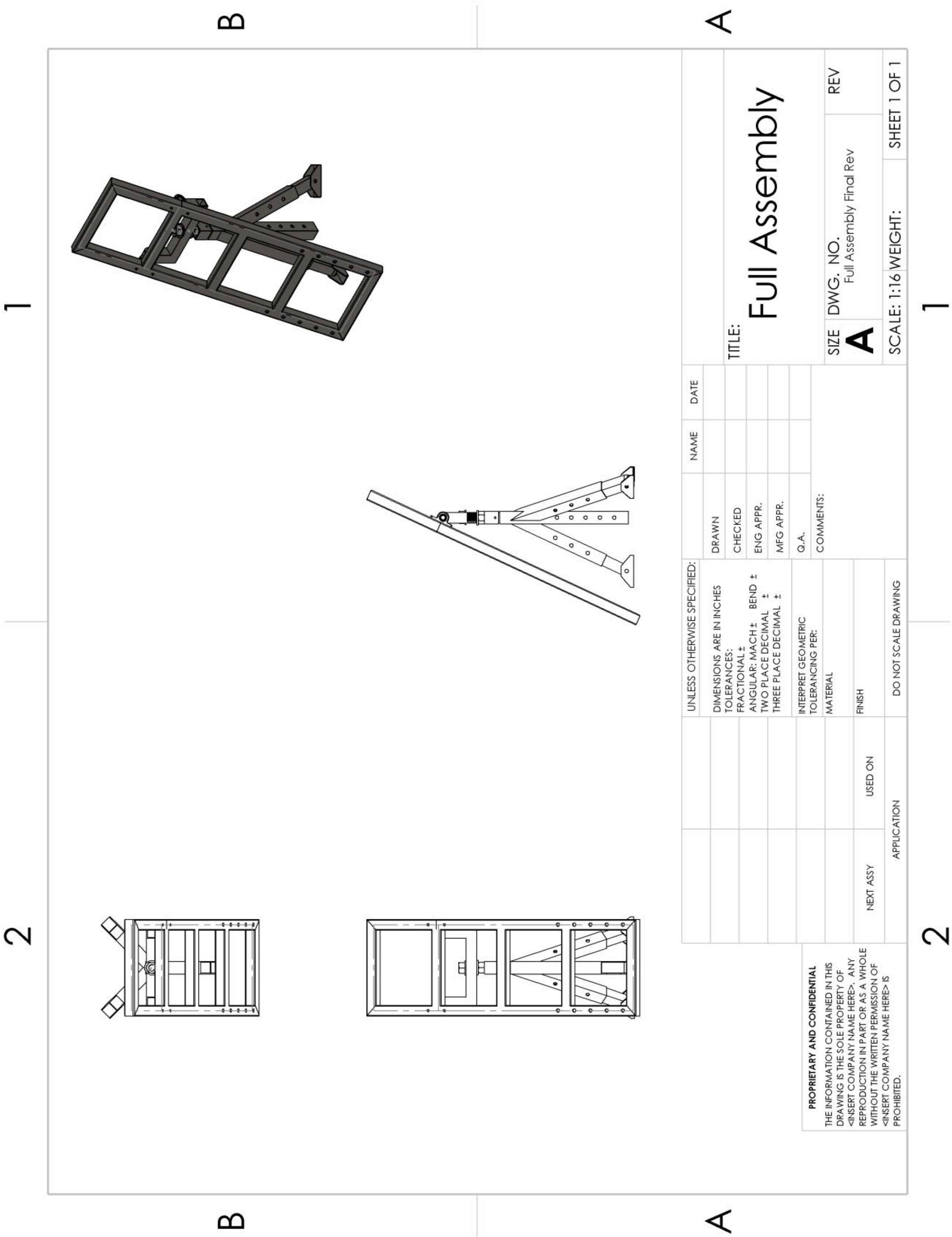
Appendix B.23 – Pivot Mount Assembly



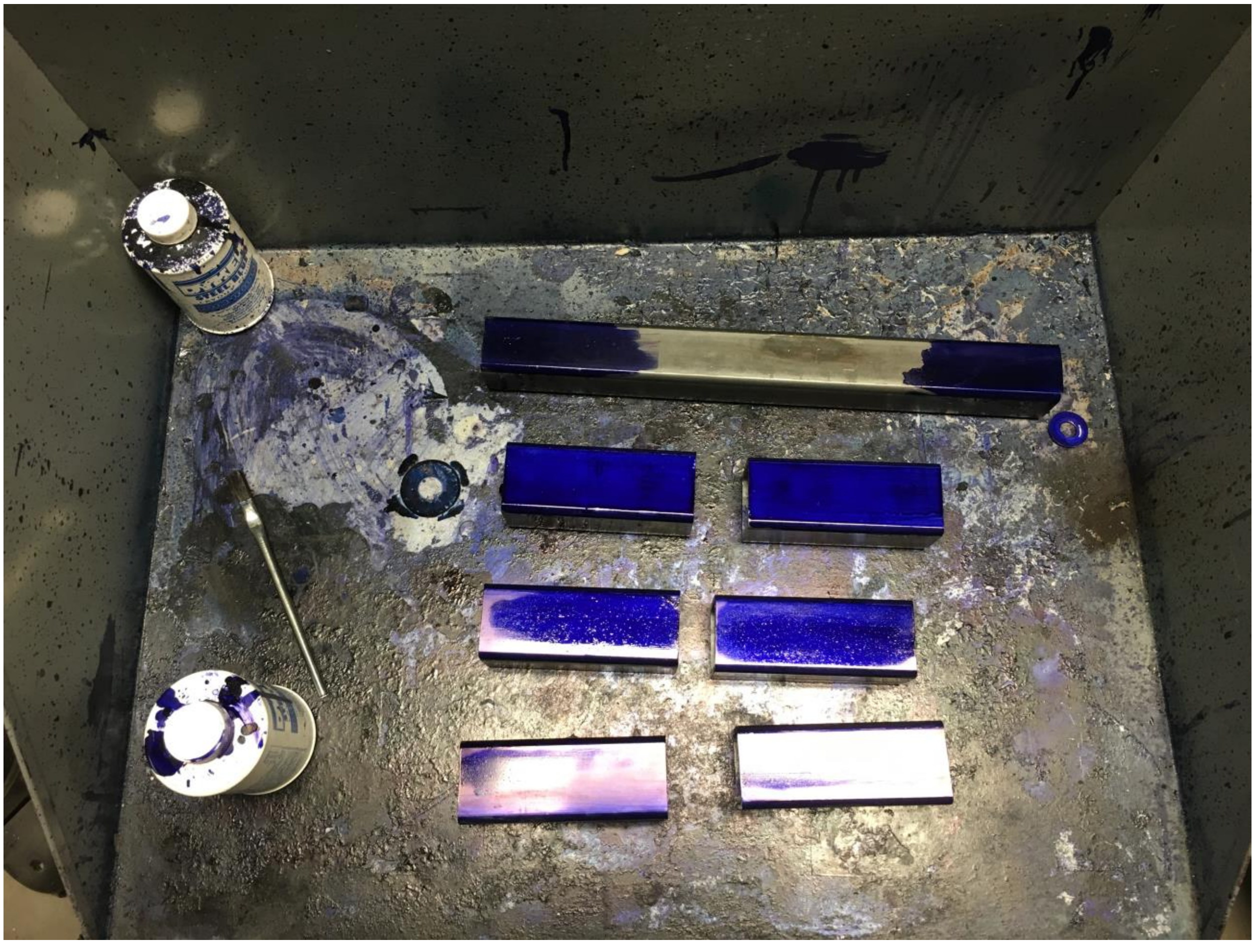
Appendix B.24 – Tipping Plate REV 2

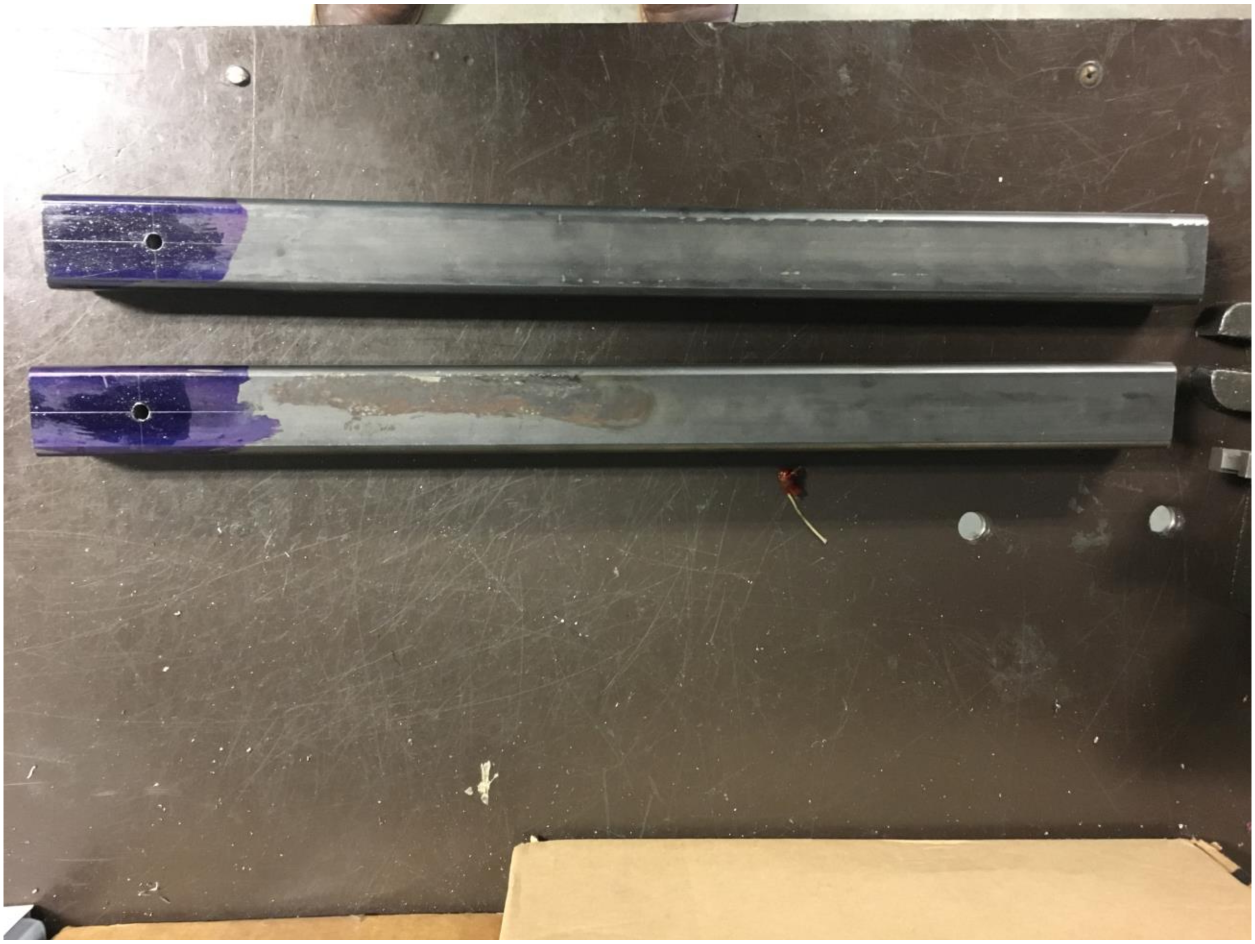


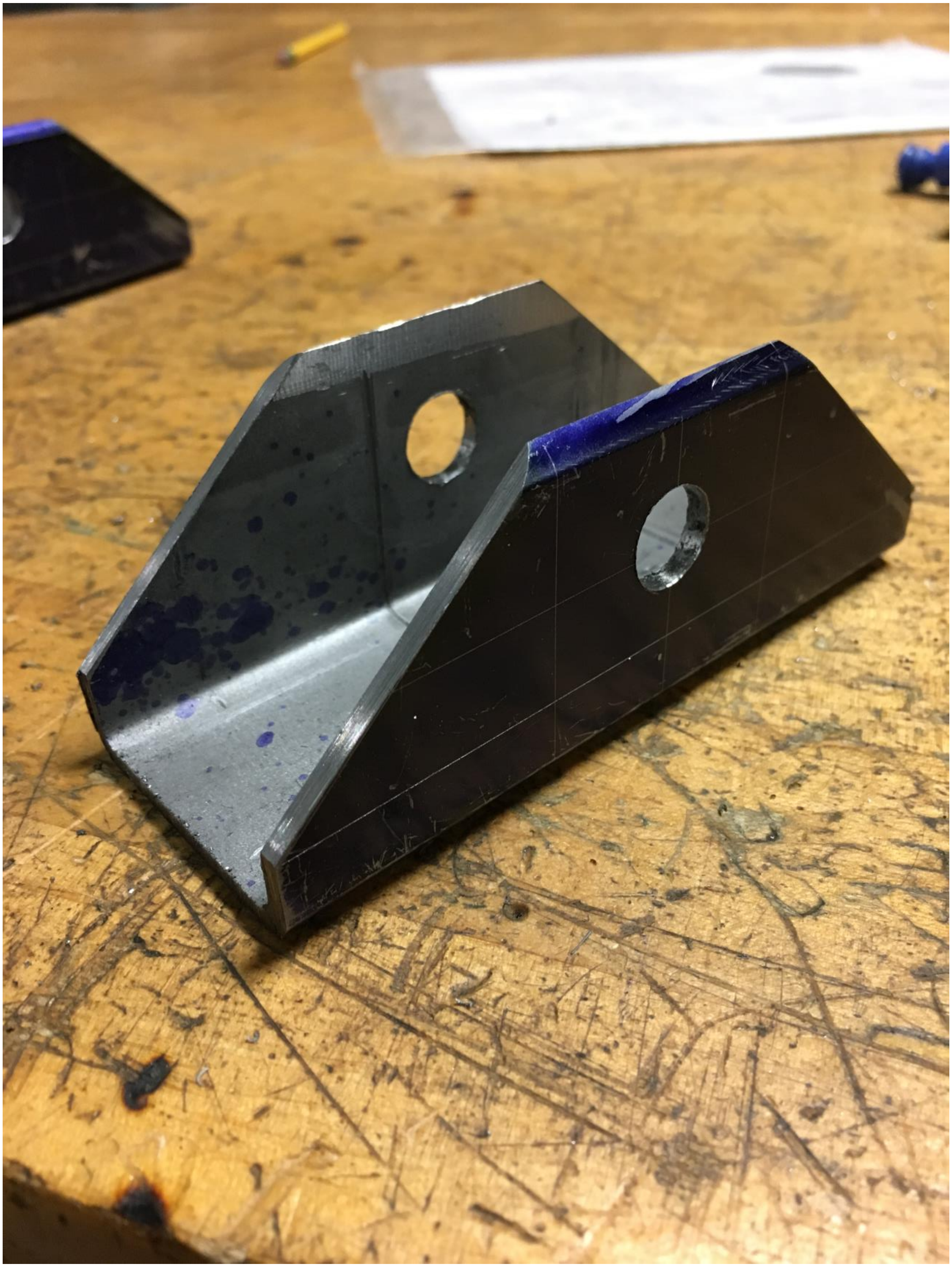
Appendix B.25 – Final Assembly

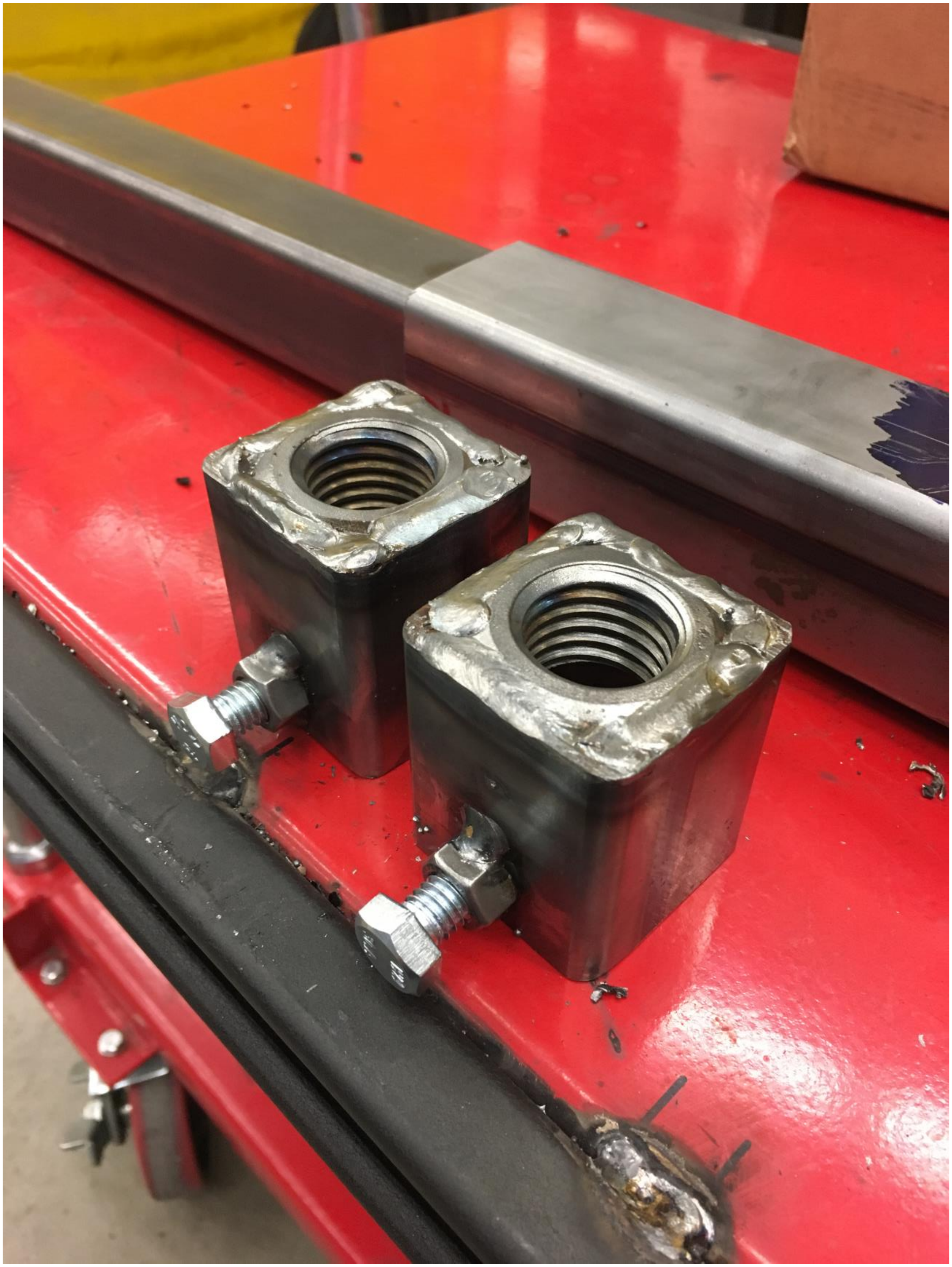


Appendix B.26 – Photos of Construction Process





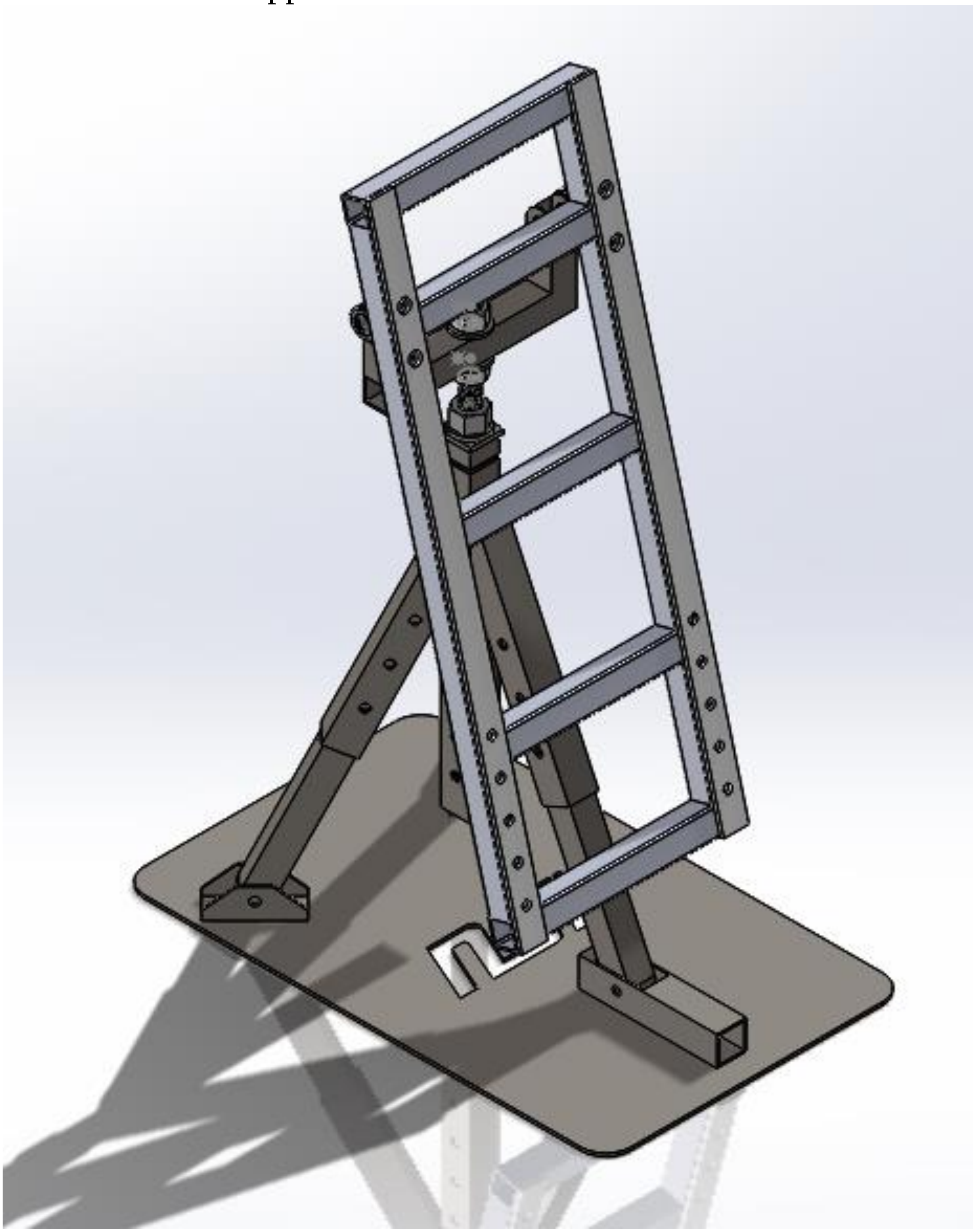





CAUTION


ULAS
ACME
SQUARE
THREADS

Appendix B.26 – Modifications



Appendix B.27 – Video

Construction:

https://www.youtube.com/watch?v=bJZ7zSVKmVM&feature=youtu.be

Testing:

https://www.youtube.com/watch?v=dxC4jQtkDOY

Appendix C.1 – Cost Sheet

Cost Of Material and Parts				
Material/Part	**Company**	**Price each ($)**	**Quantity**	**Total for Part ($)**
Fixed Bearing	McMaster Carr	11.11	4	44.44
1" - 8 Threaded Rod 1'	McMaster Carr	11.63	2	23.26
1/2"- 2" Steel Clevis Pin	McMaster Carr	8.99	4	35.96
1/2"-2 1/2" Steel Clevis Pin	McMaster Carr	10.59	14	148.26
1"-8 Threaded coupling nut	McMaster Carr	16.3	2	32.6
2"x2"x120"Steel Tube	Online Metals	63.6	1	63.6
1.75"x1.75"x 20' steel tube	Online Metals	153.72	1	153.72
.125" Steel Plate 36"x36"	Online Metals	77.57	1	77.57
1"x1"x280" Steel Tube	Online Metals	106.4	1	106.4
1" Steel Round Stock 2'	Online Metals	16.2	1	16.2
2"x1" HR Rectangulart Tube .125 5'	Online Metals	27.8	1	27.8
			Total Combined Price	729.81

Actual Cost Sheet							
Item	**Company**	**Price ($)**	**Part Number**	**Quantity**	**Cost ($)**	**Date Ordered**	**Date Received**
1/2" Oil-embeded Mounted Sleeve Bearing	McMaster Carr	$ 11.11	5912K4	4	$ 44.44	12/12/2017	12/13/2017
1" - 8 Threaded Rod 2'	McMaster Carr	$ 21.67	90322A222	1	$ 21.67	12/12/2017	12/13/2017
1/2"- 2" Zinc Plated Steel Clevis Pin (5 Pack)	McMaster Carr	$ 6.56	97245A718	1	$ 6.56	12/12/2017	12/13/2017
1/2"- 2 1/4" Zinc Plated Steel Clevis Pin (5 Pack)	McMaster Carr	$ 7.00	97245A721	3	$ 21.00	12/12/2017	12/13/2017
1"-8 Low-Strenght Steel Square Nut (5 Pack)	McMaster Carr	$ 8.71	90043A095	1	$ 8.71	12/12/2017	12/13/2017
1-3/4" X .120 Square Tube	Everett Steel	$ 46.00	ASTM A513	10'	$ 46.00	12/22/2017	12/22/2017
1-1/2" X .120 Square Tube	Everett Steel	$ 67.00	ASTM A513	20'	$ 67.00	12/22/2017	12/22/2017
16 GB Sandisk SD Card	Best Buy	$ 12.99		1	$ 12.99	12/26/2017	12/26/2017
1-1/2" X .188" Square Tube	Everett Steel	$ 78.17	ASTM A513	20'	$ 78.17	1/20/2018	1/22/2018
1-1/2" X .188" Square Tube	Everett Steel	$ 19.54	ASTM A513	5'	$ 19.54	1/20/2018	1/22/2018
1-3/4" X .120 Square Tube	Everett Steel	$ 17.81	ASTM A513	5'	$ 17.81	1/20/2018	1/22/2018
Zinc-Plated Steel Clevis Pin with Hairpin Cotter Pin, 1/2" Diameter, 3-1/4" Usable Length, Packs of 5	McMaster Carr	$ 8.21	97245A730	1	$ 8.21	2/28/2018	2/29/2018
Zinc-Plated Steel Clevis Pin with Hairpin Cotter Pin, 1/2" Diameter, 3-3/4" Usable Length, Packs of 5	McMaster Carr	$ 8.58	97245A733	1	$ 8.58	2/28/2018	2/29/2018
2' of 1/2" ID Vinyl Tube	Ace Hardware	$ 1.18	4027512	1	$ 1.18	3/5/2018	3/5/2018
Self tapping Crews 100 Count	Ace Hardware	$ 12.59	5034152	1	$ 12.59	3/5/2018	3/5/2018
3/16" Steel Plate 35x36"	Everett Steel	$ 63.66	Astm A36	1	$ 63.66	4/18/2018	4/18/2018

First Order		12/12/2017
Total Before Shipping ($)	$	102.38
Shipping ($)	$	8.36
Final Total ($)	$	110.74
First Steel Order	No Shipping Cost (Picked Up)	
Total Before Tax ($)	$	113.00
Tax ($)	$	10.96
Final Total ($)	$	123.96
BestBuy	16 GB Sandisk SD Card	
Total Before Tax ($)	$	12.99
Tax ($)	$	1.19
Final Total ($)	$	14.18
Second Steel Order		1/20/2018
Total Before Tax ($)	$	115.52
Tax ($)	$	11.55
Final Total ($)	$	127.07

Second Order		
Total Before Shipping ($)	$	16.79
Shipping ($)	$	7.06
Final Total ($)	$	23.85
Ace Hardware		3/5/2018
Total Before Tax ($)	$	13.77
Tax ($)	$	1.13
Final Total ($)	$	14.90
Modification Purchases		4/18/2018
Total Before Tax ($)	$	63.66
Tax ($)	$	6.18
Final Total ($)	$	69.84

Overal Total Cost ($)	$ 460.69

Appendix D.1 – Budget

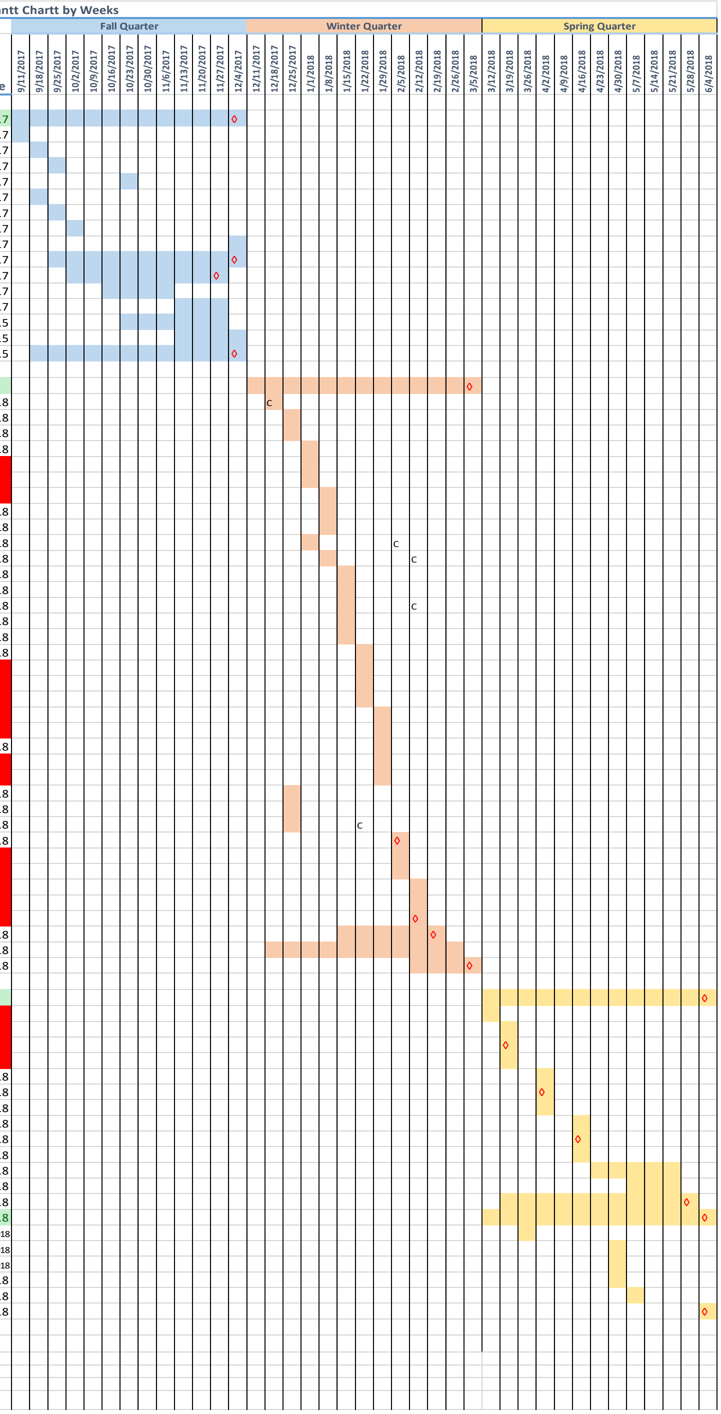
Budget					
Parts	Company	Cost Per ($)	Quantity	Total Cost ($)	
Fixed Bearing	McMaster Carr	11.11	4	44.44	
1" - 8 Threaded Rod 1'	McMaster Carr	11.63	2	23.26	
1/2"- 2" Steel Clevis Pin	McMaster Carr	8.99	4	35.96	
1/2"-2 1/2" Steel Clevis Pin	McMaster Carr	10.59	14	148.26	
1"-8 Threaded coupling nut	McMaster Carr	16.3	2	32.6	
2"x2"x120"Steel Tube	Online Metals	63.6	1	63.6	
1.75"x1.75"x 20' steel tube	Online Metals	153.72	1	153.72	
.125" Steel Plate 36"x36"	Online Metals	77.57	1	77.57	
1"x1"x280" Steel Tube	Online Metals	106.4	1	106.4	
1" Steel Round Stock 2'	Online Metals	16.2	1	16.2	
2"x1" HR Rectangulart Tube .125 5'	Online Metals	27.8	1	27.8	
			Total Combined Price	729.81	
Labor	Predicted time	Time So Far	Pay Per Hour	Predicted Final Cost	Current Cost
personal Labor	183.25	79	1.25	229.06	98.75
			Predicted Final Total Cost	958.87	
			Current Total cost	98.75	

Appendix E – Schedule Gantt chart

Below is a Gantt Chart breaking down the Slab Tipper project over the course of the year into Fall, Winter, and Spring Quarters. Fall Quarter consists of the design process of the project as well and the green sheet calculations and writing of the proposal. Winter Quarter consists of the Manufacturing stage of the project and Spring Quarter is the testing portion of the project. You can view each quarter in depth in the chart below breaking down each phase into fine detail. Milestones are identified by ◊.

To View Gantt Chart in Greater Detail zoom in using slider located in the bottom right corner of word.

Task Number	Task	Estimated Time(hr)	Actual Time (hr)	Completion Date
	Fall Quarter			
00001	Proposal	50	79	12/5/2017
00002	Intro	0.5	1	12/5/2017
00003	Design Analysis	2	2	12/5/2017
00004	Methods of Construction	2	1	12/5/2017
00005	Testing Methods	2	1	12/5/2017
00006	Schedual/ Project Management	5	6	12/5/2017
00007	Gantt Chart	3	4	12/5/2017
00008	Discussion	1	1	12/5/2017
00009	Conclusion	1	1	12/5/2017
00010	Green Sheets	10	15	12/5/2017
00011	3D Model	10	8	11/10/2017
00012	Revision 1 of 3D Models	3	2	11/30/2017
00013	Revision 2 of 3D Models	2	1	12/5/2017
00014	Drawings	5	4	11/28/2015
00015	Revise Drawings	2	2	12/5/2015
00016	Appendicies	20	30	12/5/2015
00017	**Winter Quarter**			
00018	Manufacturing	40		
00019	Order Material	3	2	3/1/2018
00020	Cut Material	2	4.5	2/20/2018
00021	Layout and Mark Tubing for stand	1	1	2/15/2018
00022	Drill holes in stand	2	5	2/1/2018
00023	Make jigs for stand assebly	5		
00024	Bend Leg Plate	1		
00025	Make Front Leg Pivot Brackets	2		
00026	Prep Material For Welding	1	1	2/29/18
00027	Weld Stand together	5	3	2/29/18
00028	Make course adjustment tube	3	2	2/2/2018
00029	Prep Fine Adjustment Material For Welding	1	0.25	2/29/2018
00030	Weld Fine adjustment nut to collar	0.25	0.25	2/20/2018
00031	Cut Bar for Pivot mount	0.25	0.5	2/17/2018
00032	Cut Tube for Face plate	1	2	2/7/2018
00033	Prep Face Plate Material For Welding	1	0.5	2/22/2018
00034	Weld Face Plate	3	2	2/23/2018
00035	Drill holes in Face plate	2	2	2/19/2018
00036	Cut Material For Pegs	1		
00037	Turn Pegs	2		
00038	Drill pin Holes in Pegs	0.5		
00039	Layout and Centerpuch Pivot parts	2		
00040	Drill, Tap, and assemble Pivots	2		
00041	Cut Fine Adjument Rod	0.25	0.25	2/14/2018
00042	Prep Fine Adjustment Rod and Pivot For Welding	0.5		
00043	Weld FineAdjustment rod to pivot	0.5		
00044	Cut Material For Feet	2	1	1/17/2018
00045	Layout Design For Feet	2	1	1/18/2018
00046	Make Feet	5	3	1/19/2018
00047	Assemble Stand	3	2	3/7/2018
00048	Cut Material for Center Support Brackets	0.5		
00049	Make Center Support Brackets	0.25		
00050	Prep Center Support Brackets For Welding	0.25		
00051	Weld Center Support Brackets to Face Plate	1		
00052	Make Center Supports	0.5		
00053	Make Modifications to Stand	8	4	2/16/2018
00054	Consult Company about Stand	2	1	3/9/2018
00055	Make Aditional Modifications to Stand	4	2	3/8/2018
00056	**Spring Quarter**			
00057	Start Testing	40		
00058	Make Replica floor Testing	5		
00059	Setup Floor Testing	1		
00060	Cunduct Floor Testing	3		
00061	Gather Data For Floor Testing	1		
00062	Setup Load Testing	1	0.5	5/4/2018
00063	Conduct Load Testing	2	2	5/4/2018
00064	Gather Loading Data	1	0.5	5/6/2018
00065	Setup Work Space Area Testing	2	0.25	5/4/2018
00066	Conduct Workspace Area Testing	1	0.25	5/4/2018
00067	Gather Work Space Testing Data	1	0.25	5/4/2018
00068	Additional testing methods	6	1	5/12/2018
00069	Compile All Data	4	3	5/14/2018
00070	Make Modifications to Stand	8	3	5/1/2018
00071	Report	10	4	5/31/2018
00072	Document Construction Processes	2	1	5/31/2018
00073	Document Testing Processes	2	1	5/31/2018
00074	Document Testing Results	1	1	5/31/2018
00075	Analyse/inturptret Test Results	1	1	5/31/2018
00076	Conclude Test Resutls	1	1	5/31/2018
00077	Write Report Conclusion	1	1	5/31/2018
	Predicted Completion Time (hr)	183.25		
	Actual Completion Time (hr)		136	
	Was removed from the Plan			



Appendix F - Acknowledgment

Project was provided and requested by NSI Solutions

Funded by NSI Solutions

Mentors for Advice

Don Durand – NSI Solutions
Dr. Johnson – CWU
Professor Pringle – CWU

Facilities Provided by

NSI Solutions
CWU Shop

Winter Quarter:

Thank you to Staff for monitoring the CWU Shop and Welding Shop open for the manufacturing process as well as providing help when needed. There was several parts during the manufacturing process that required the aid of another person and the CWU Shop Techs and Staff were there to provide the assistance. Thank you to Don Durand from NSI Solutions for providing funding for the project, advise and assisting in the ordering process.

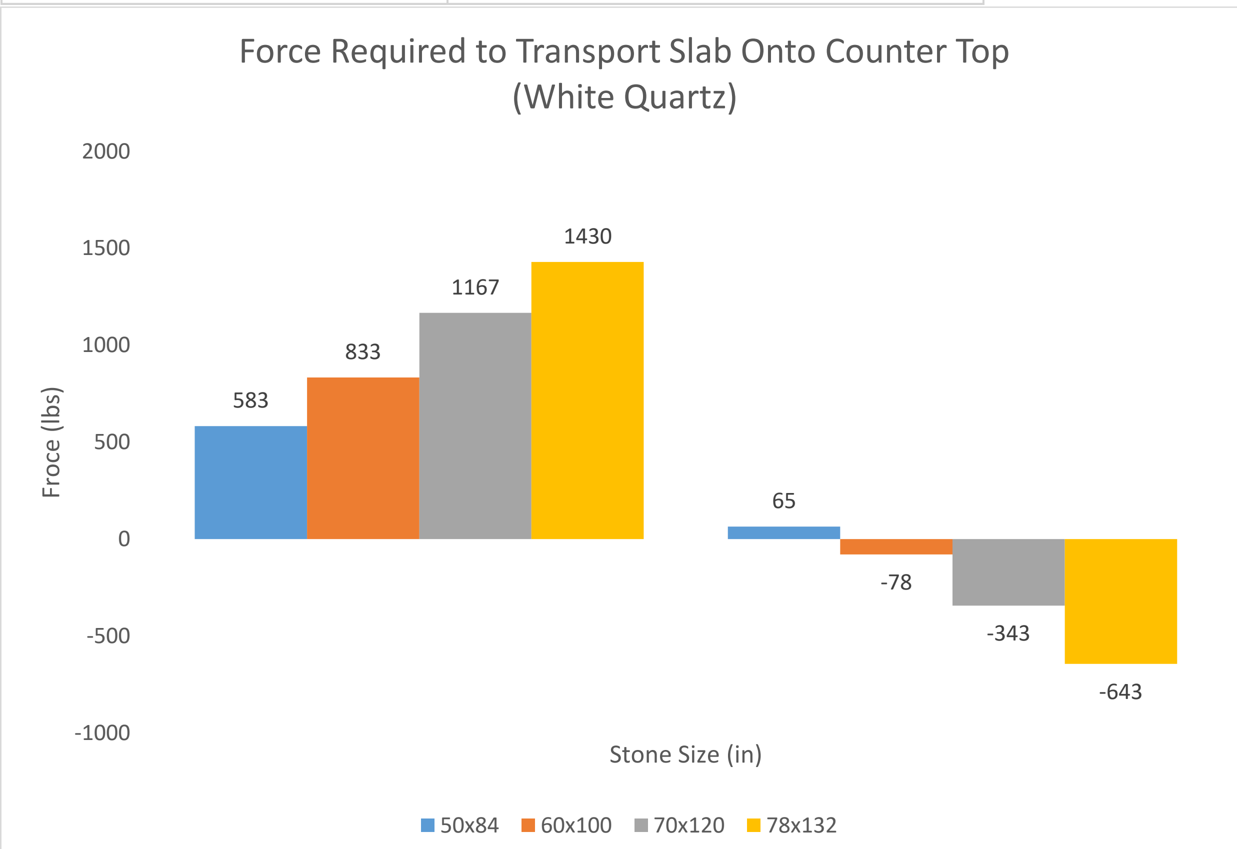
Appendix G.1 – Testing Data

Slabs				
	Length (ft)	Width (ft)	weight (lbs)	Type
Stone 1	4.17	7	583	White Quartz
Stone 2	5.5	8.75	963	White Quartz

Weight Test					
	Base weight (lbs)	Tipping surface (lbs)	total weight (lbs)	requirement weight (lbs)	percent over
Slab Tipper V2	53	40	93	50	186%
	106%	80%			

	Projected for 1500lbs	Actual for 963lbs
force to hold stone horizontal	90lbs	120lbs

Improvments to be made:	
1	make the stand shorter
2	lock in the upright and horzontal position
3	new pins
4	stop from spinning
5	rate control?



Appendix G.2 – Test 1 Setup

Appendix G.3 – Test 2 Setup

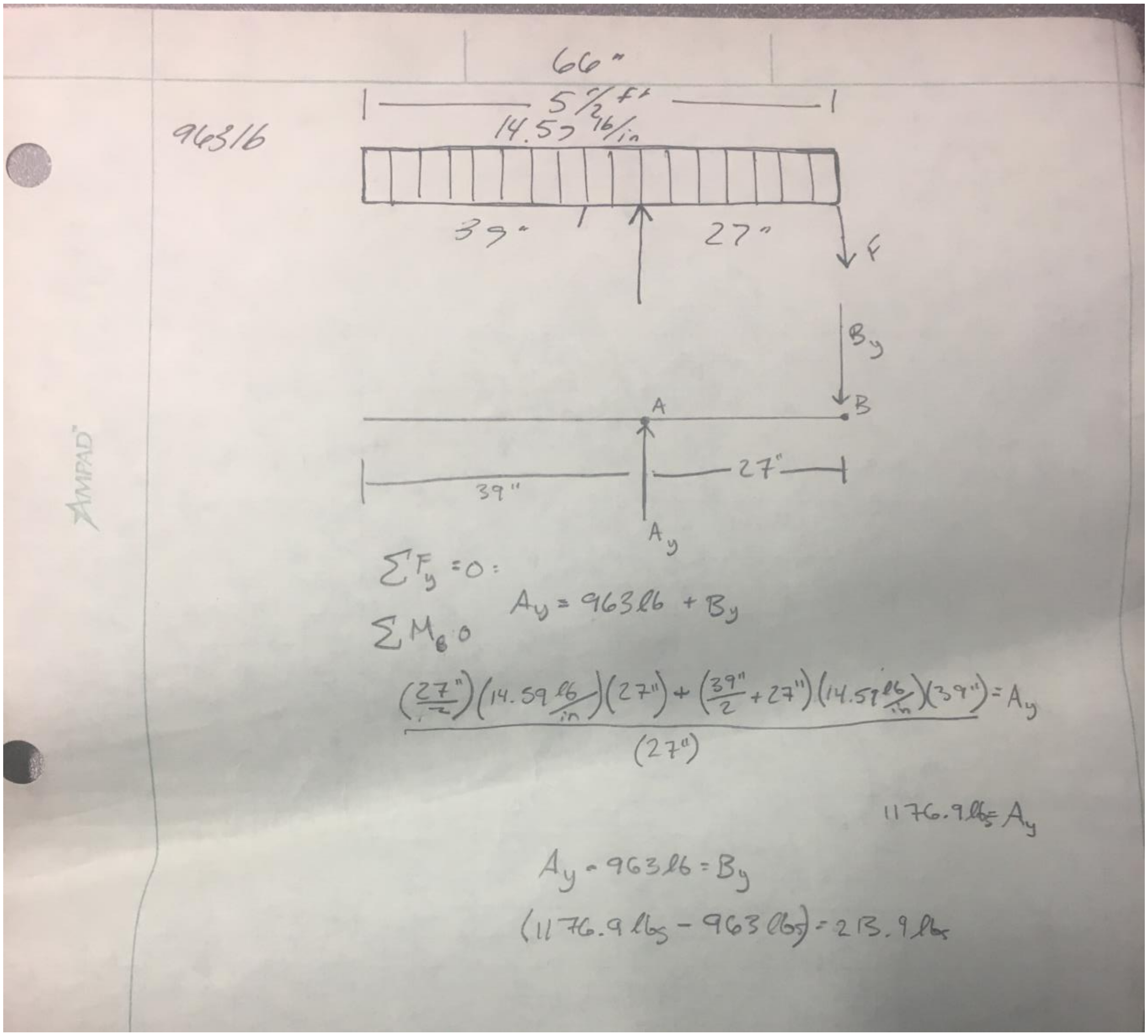
Appendix H – Data Evaluation

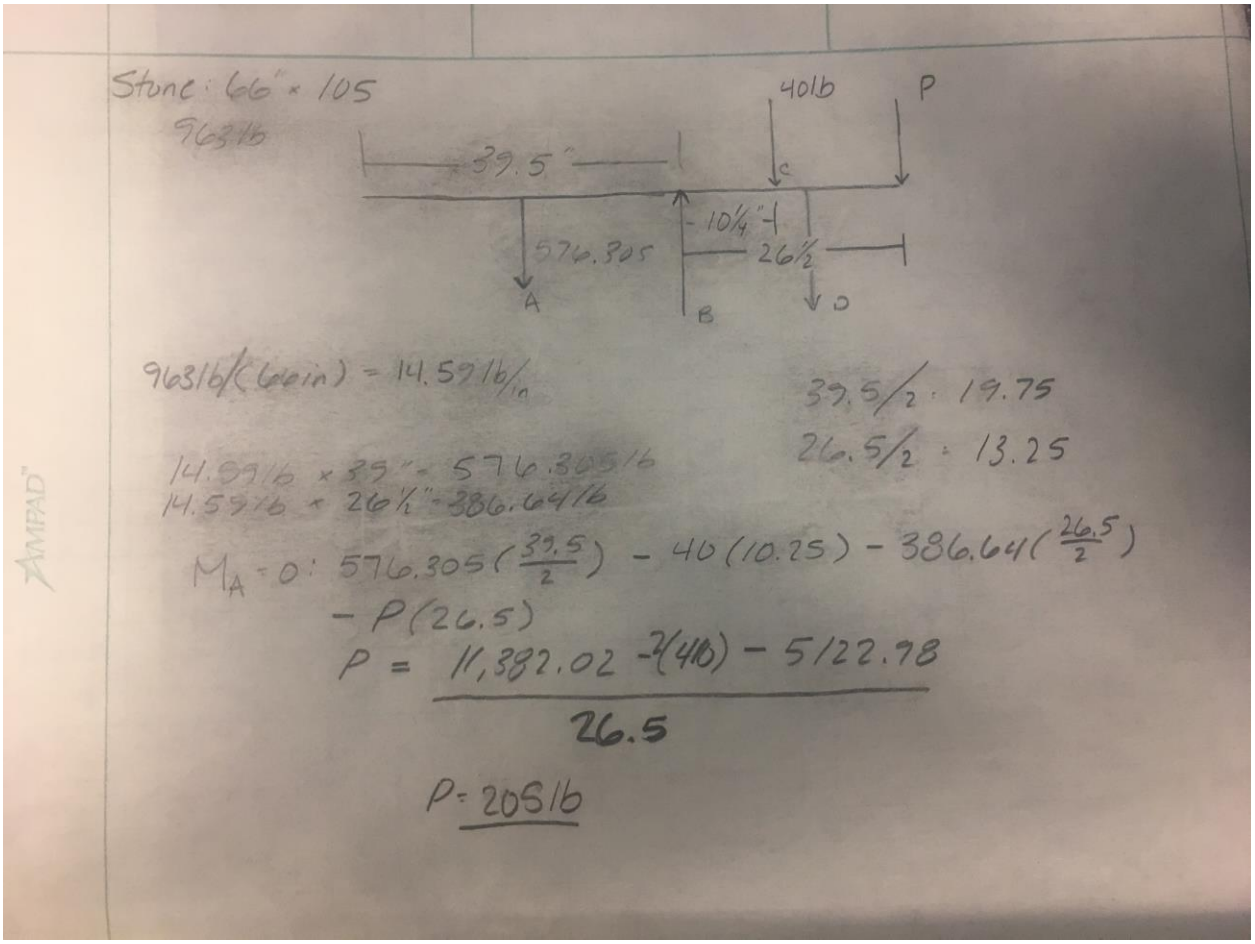
Stone Sizes						
Width (in)	Length (in)	weight (lbs)	Force required by workers (lbs)			
50	84	583	65			
60	100	833	-78			
70	120	1167	-343			
78	132	1430	-643			

lbs/in (width)
11.67
13.89
16.67
18.33

stone above pivot (in)	Weight above pivot (lbs)	weight below pivot (lbs)
23.5	274	309
33.5	465	368
43.5	725	442
51.5	944	486

stone above pivot (in)	Weight above pivot (lbs)	weight below pivot (lbs)
23.5	274	309
33.5	465	368
43.5	725	442
51.5	944	486


66"
5 1/2 ft
14.59 lb/in
963 lb
39"
27"
F
By
A
B
27"
39"
Ay
ΣFy = 0:
Ay = 963 lb + By
ΣMB = 0
((27"/2)(14.59 lb/in)(27") + (39"/2 + 27")(14.59 lb/in)(39")) / (27") = Ay
1176.9 lbs = Ay
Ay − 963 lb = By
(1176.9 lbs − 963 lbs) = 213.9 lbs


Stone: 66" × 105
963lb
39.5"
40lb
P
C
10¼"
576.305
26½
A
B
D
963lb/(66in) = 14.59lb/in
39.5/2 = 19.75
26.5/2 = 13.25
14.59lb × 39.5" = 576.305lb
14.59lb × 26½" = 386.64lb
MA = 0: 576.305(39.5/2) − 40(10.25) − 386.64(26.5/2)
− P(26.5)
P = 11,382.02 − 2(410) − 5122.98
26.5
P = 205lb

Appendix I - Slab Tipper Testing

Introduction:

The requirements that will be tested is the mechanisms ability to support a slab of stone and transport it to a counter top. The stone could be a wide variety of weights but it has a maximum weight of 1500lbs. The other things that are going to be tested is the weight of each stand, the force to keep the stone horizontal, and the functionality of the mechanism.

Requirements:

- Mechanism supports and transports a stone up to 1500lbs to a counter top
- Weighs under 50lbs
- can be used by 2-3 people

This testing report includes two testing procedures. For the first test the Slab Tipper was predicted to support the stone and transport it to the counter top, but be slightly unstable due to the three legged construction. It was also predicted to be slightly over the 50lb limit. For testing procedure two the Slab Tipper was predicted to be more stable while holding and transporting the stone, be easier to use, b ut be significantly over the weight limit.

Methods/Approach:

The testing will be held in Mukilteo at NSI Solutions shop. The owners and workers there will be at hand to help the testing the process. The stone will be provided by the partner company Natural Stone Interiors. The tools needed to conduct the tests are clamps, Fork Lift, Table, and a Scale. The ability to support the stone as well as functionality will be judge by works that have worked in the field for a significant amount of time. The weight will be gathered with an electronic package scale. Stone slabs will be transported and lowered on to the Slab tipper with fork lifts to begin the testing phase. They will then be fully supported by the Slab Tipper. Then a mock installation process will be done by tilting the stand till the stone touches the counter top, this test the stands ability to hold and transport the stone as well as the functionality and practicality of this mechanism. After the stone is horizontal and resting on the counter top a scale will be placed on the end not resting on the counter. The force will be applied in the downward direction till the stone is fully suspended, the scale will then read the force required by the worker to keep the stone at this horizontal position. All of the testing will be recorded via cell phone video/camera.

Testing Procedure:

Test 1

During the first test day the stands were set up next to a shipping crate at counter height. A stone slab was then picked to do the test. When the slab was lowered onto the stands using the fork lift, it was clear that the testing had to be stopped, the stands weren't stable enough to hold the stone. When under load the stands would pivot over the front foot and was very unstable. If the testing were to continue it would be putting the testers at risk of injury. Then a meeting was held to improvements that need to be made to the stand to increase the stands stability and functionality.

Test 2

Like test 1 the stands were set up next to a table for a mock installation. The difference between tests 1 and 2 was there was modifications made to the stand the biggest one being, a metal plate was welded to the feet to make one big base, making the base wider and longer, in turn making the stands more stable. The stands were first loaded up with a relatively small slab of 560lbs. With the improvements made to the stands it was able to support the stone without issues. Then two people tilted the stone onto the counter top to get the feel of how the weight transfers during the tilting motion. Then a single person tilted the stone into the horizontal position. Then the stone slab was slid onto the counter top to continue the mock install. It was clear that the stands could handle the weight so a larger stone of 960lbs was selected to another mock install. The same procedure took place, first two people tilted the stone, then one person. After the mock install was done a scale was placed on the end of the stone away from the table. A force was applied in the downward direction on the scale till the stone was fully suspended horizontally. The scale reading was then recorded, this is to figure out the force required by the user to counteract the tipping motion.

Deliverables:

After the two tests some conclusions could be drawn about the Slab Tipper. Although the maximum weight of stone was not used during the test, it is clear that the stands done have a problem with holding a stone of approximately 1000lbs. Further testing can be done to test the maximum weight of stone. One of the requirements is that the slab tipper could be used by 2-3 people. This requirement was put into place because the Tipper's job is to reduce the amount of workers needed to install, as well as making it safer and easier. The with the slab tipper 2-3 people requirement is definitely possible. It is clear that the Tipper makes it easier to get the stone onto the counter top, now the main limiter is getting the stone onto the stand. Testing made it clear that two people could easily tip the slab onto the counter for installation, but most likely two people couldn't lift the stone onto the tipper without help. This means you only need the number of workers required to lift the stone for the install, this means the number of workers could vary depending on the strength of the given workers. With the 980lb stone the force required to hold the stone horizontal was approximately 120lbs. This means if one worker could get the stone onto the tipper they could do the whole install themselves. The complete tipper weighs 93lbs per stand. This is almost twice the requirement. This is due to the modifications that were required to make the stands more stable.

Although the stands are overweight they split into two parts making them easier to transport. These stands are also being used as a proof of concept with the final version being made of aluminum. Over all the Slap Tipper is a success, it fulfills the main requirements and has the capability to be improved to make it a better project. Some of the improvements that could be made to the tippers are installing a locking mechanism to lock the stand in the upright and horizontal position, making the stands shorter and lighter, changing the pins that hold the weight of the stone to have a bigger lip, and preventing the tipping surfaces from spinning when horizontal.

Appendix J - Resume

Thomas Durand

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Marysville, WA 98270

Career Objective

A position as a Mechanical Engineer, that will allow me to use my problem solving and design skills I've gathered to assist in the design and fabrication of mechanical components.

Education Background

Bachelor of Science, Central Washington University, expected June 2018

Major: Mechanical Engineering Technology

GPA: 2.750

Work Experience

Fabrication, December 2016-Present

NSI Solutions, Lynnwood, Washington

Tool Assembly, August 2016-Present

NSI Solutions, Lynnwood, Washington

- Designing tables, tool displays, etc.
- Selecting appropriate materials for various projects
- Welding and building tables, displays and equipment for the shop

Lift Operator, 2017 Winter Season

Summit at Snoqualmie

- Performed routine lift inspections
- Excelled in customer service for all patrons of the Summit
- Operated a high-speed fixed-grip lift

Cashier, March 2015 – December 2017

Central Washington University Dining, Ellensburg Washington

- Cashier
- Help customers
- Stock shelves
- Moving stock with pallet jack

Skills

- *Computer Experience:* Excel, Word, PowerPoint, SolidWorks, Auto CAD, CNC manual programing
- *Machining:* Manual mill and lathe, CNC mill and lathe, Welding, numerous metal and woodworking machines and tools
- *CAD:* Currently in the process of acquiring my CSWP (Certified SolidWorks Professional)

Achievements

2013-2016 Central Washington University Baseball Team
2013 Native American Student of the Year
2013 Marysville Pilchuck High School Honor Society

References Available Upon Request