Self-Leveling Stow-Away Pool Table: Manufacturing Manual

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Abstract

The Self-Leveling Stow-Away Pool Table was designed to be a user friendly device that could be easily operated by a novice user through reading the operating instructions. It consists of a network of components which work together to achieve the desired goal. That goal is to allow the pool table to have a traditional look and feel while still being able to stow-away and self-level at the push of a button. Assembly of the product is not required from the user. The stow-away process is quick and easy; it can be done by a single user with help from the operation instructions. Likewise for the self-leveling feature, the user control interface makes the self-leveling process simple and intuitive. If any malfunctions occur with the system, the troubleshooting process consists of determining the source of the malfunction. The three main sources of malfunction commonly are the linear actuators, the pins on the cart and the inclinometer. To avoid these malfunctions, regular maintenance of the system is highly recommended. This includes lubricating the moving parts, cleaning the entire system, and ensuring all bolts are secured. Replacement of most parts on the table only requires removing a few bolts. Parts such as the bumpers, the slate, and extra nuts or bolts can be easily sourced and quickly replaced. This product was designed for long term reliability, however proper upkeep and maintenance is still required to keep running at top standards.

Acknowledgments

Finances:

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Advice:

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The students of this 2014 Senior Design class have also been helpful in their feedback about the project and the presentations.

1. Introduction

The Self-Leveling Stow-Away Pool Table is the first of its kind. It has the full look, feel and functionality of a traditional, tournament regulation pool table plus the added benefit of stowing away, taking up less than 2 feet by 9 feet of floor space. This may be accomplished by a single user with a few simple steps placing the table in its stow-away position and rolling the table to the side. The table is also equipped with a self-leveling system which allows to the user to move the table to a new location and, with the push of a button, have the table adjust its playing surface to a level position to play pool.

Due to the size and complexity of this system, safely lifting, rotating and moving this pool table with only one person requires extensive mechanical assistance. Although this system was designed with safety as a top priority, dangerous situations can still occur if the system isn't operated properly. The user having no experience operating a system such as this should pay careful attention to the detailed instructions provided. The instructions detail everything that needs to be known about the system so that the user can operate the system in a safe and smart manner. Troubleshooting advice and routine maintenance instructions to maximize the life of the pool table and keep all features fully functioning.

2. Design for Manufacturing

The Self-Leveling Stow-Away Pool Table is comprised of 4 major types of assemblies: the frame, rail assemblies, leg assemblies, and cart assemblies. In addition to these assemblies, the pool table also requires a clothed slate, wood aesthetics and a mechatronics system. The assembly process itself will be briefly described below, covering the various assemblies and how each portion comes together to manufacture the entire system as a whole.

2.1 Frame (~5 Hours)

The frame was one of the most important components of the table. It needed to be capable of supporting and securing the 300 lb. slate in both the playing and stow-away positions. The frame itself was constructed out of reinforced steel which required manufacturing on the bandsaw and some welding. Since the frame is the backbone component, it was necessary to manufacture it first.

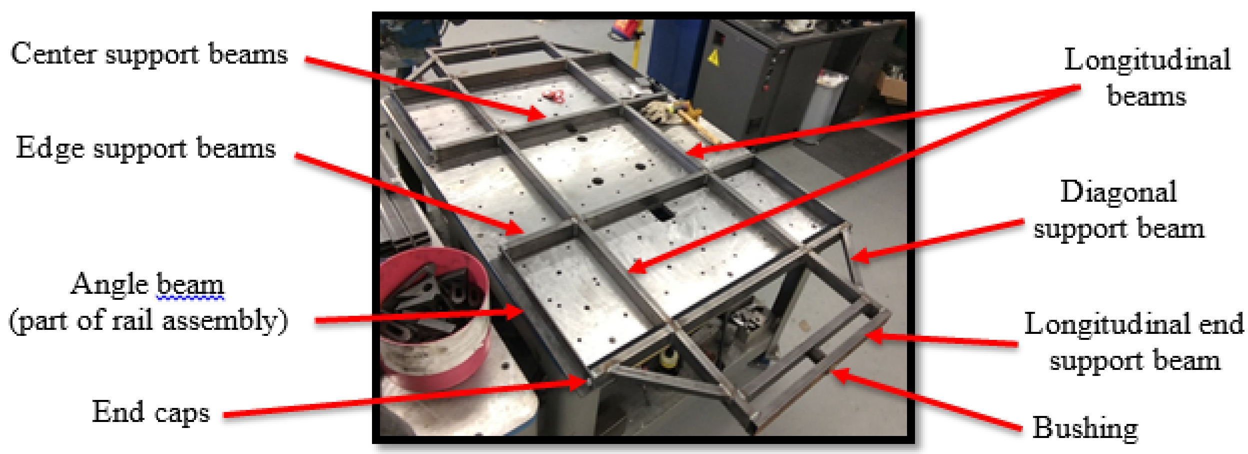


Figure 1. Steel Frame

2.1.1 Step 1: Cutting on the Bandsaw

After obtaining the steel tubing, cut the beams using a bandsaw for the frame's skeleton to size referring to the table and engineering drawing in Appendix A-1. The skeleton is comprised of the components pointed out in Figure 1 above, except for the angle beam, which is part of the rail assemblies.

2.1.2 Step 2: Drilling

Using a hole saw attached to the mill, holes were drilled into two of the center support beams and both of the longitudinal end support beams. The purpose of creating these holes is solely for mounting the bushings to the frame for which the pins of the carts will be inserted.

2.1.3 Step 3: Water Jet

After cutting the beams for the frame's skeleton, the end caps for connecting the rail assemblies to the frame need to be manufactured. The easiest and quickest way for creating these parts is by obtaining a ¼" sheet of steel and cutting them out using a water jet. The drawings for the end caps can be found in Appendix A-2.

2.1.4 Step 4: Welding

The final process to completing the pool table's frame is by welding all the components together. It is key to begin by welding the beams together in reference to the engineering drawing in Appendix A-1 to create the frame skeleton. It is also very important to weld the nut (in alignment with the end cap's hole) onto the inside of the end cap before welding it to the skeleton. Once the bushings are welded into position the frame is complete.

2.2 Rail Assembly (~10 Hours)

The rail assembly attaches directly to the pool table frame by means of an angle beam, end cap and nuts/bolts. It was designed to be easily removed for installing/repairing the slate or slate's table cloth by simply removing just a few bolts. The rail assembly is also designed to provide safe support to the slate when in the stow-away position. The manufacturing of the rail assembly is more complex than the frame assembly and requires about twice as much time to build.

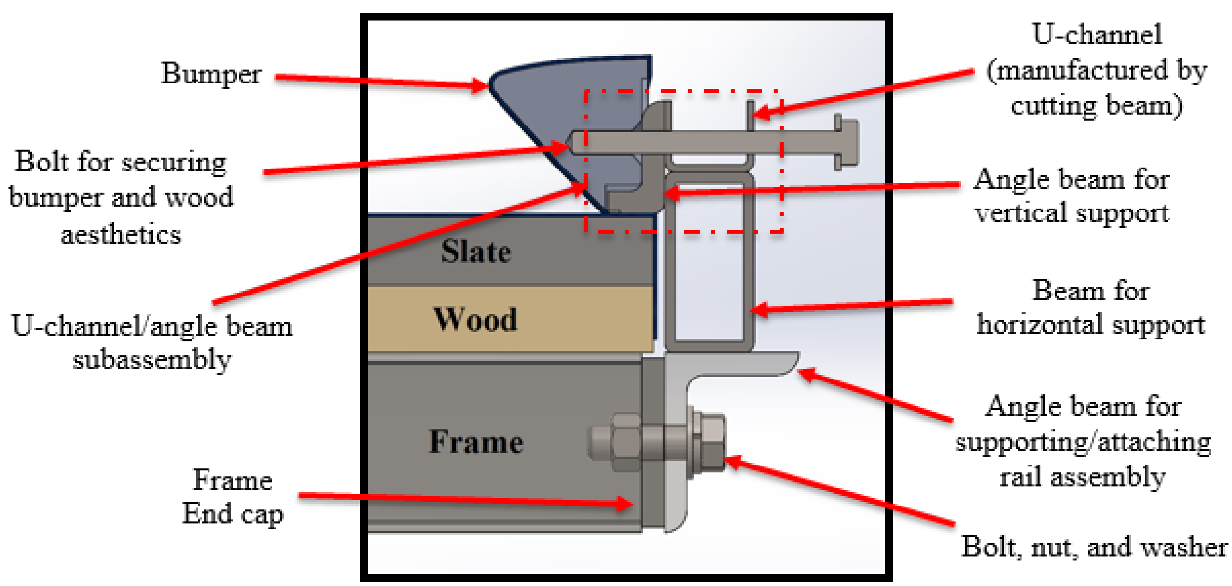


Figure 2. Rail Assembly Section

2.2.1 Step 1: Cutting on the Bandsaw

The rail assembly is mainly comprised of steel beams welded together, so the first step is to obtain the long beams and cut them into the different sections of various sizes, according to the drawings pertaining to the rail assembly. The components being cut on the bandsaw include both types of angle beams and both steel tubing beams. The u-channel is manufactured from one of the beams being cut in this step, but it doesn't become a u-channel until a later process.

2.2.2 Step 2: Manufacture U-channel/angle beam subassembly

Using a jig, weld the small angle beam (used for vertical support) and the steel tubing (that ends up becoming the u-channel later on) sections together. After the welding, take the subassembly to the mill and use an end mill to drill a hole in the subassembly for the bolts that will secure the bumper and wood aesthetics to the rail assembly. Once the hole is drilled, use the end mill to cut off the top portion of the angle beam and steel tubing to create the U-channel. It is important to drill the hole first to preserve the structure of the steel tubing.

2.2.3 Step 3: Drilling

Drill the holes for the bolts that secure the entire rail assembly to the frame of the table using an end mill. The locations of the holes are found on the engineering drawings in the Appendix A.

2.2.4 Step 4: Welding

The final step to completing the rail assembly, other than bolting the components together, is by welding the large angle beam, horizontal support beam, and the u-channel/angle beam subassembly together in accordance with the drawings. Once this welding is done, all of the metal beams will be permanently attached to each other and the bumpers can be bolted on, and then the entire assembly can be mounted onto the frame.

2.3 Leg Assembly (~8 Hours)

The leg assembly provides as a frame for the linear actuators with which we will raise and lower the table. The assembly attaches to the frame with hinges, allowing for the legs to fold when stowing away the pool table. A visual breakdown for the leg assembly can be seen in Figure 3 below. There are four leg assemblies total.

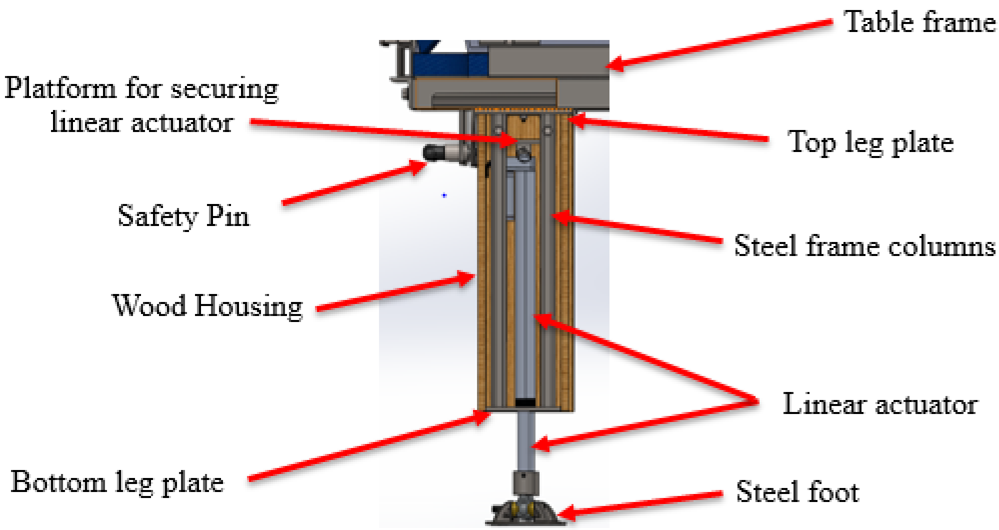


Figure 3. Leg Assembly Cross Section

2.3.1 Step 1: Cutting on the Bandsaw

The first step is to begin cutting the steel tubing into the correct sizes to create the columned frame that houses the linear actuator.

2.3.2 Step 2: Water Jet

Using the water jet, cut out the top and bottom leg plates as well as the platform for supporting the linear actuator within the leg assembly frame. Make sure to tab the small pieces so that they don't drop inside the Omax Waterjet.

2.3.3 Step 3: Drilling

Drill the holes in the columns that will hold the platform in place. An F drill bit is recommended, but it may be increased if proper fitment is not achieve. Deburr the entry and exit path of the holes created by the bits.

2.3.4 Step 4: Welding

The platform must be tacked together using the actuator as a fitment reference. After removing the actuator, apply the welds at the necessary heat level and keep it separated from the electronics until cool to the touch. The columns should be welded so that the top plate maintains a flat contact with the frame in its vertical position. Brass bushings may now be press fitted to the bottom plate after the welds have cooled and no more deformation is expected.

2.4 Cart Assembly (~4 Hours)

The cart assemblies are designed and manufactured to support the total weight of the pool table and is necessary for the stow ability of the table. There are two cart assemblies (one for each end of the table) and are each on wheels for the sake of movability. The cart assembly is simple and is broken down into components in Figure 4.

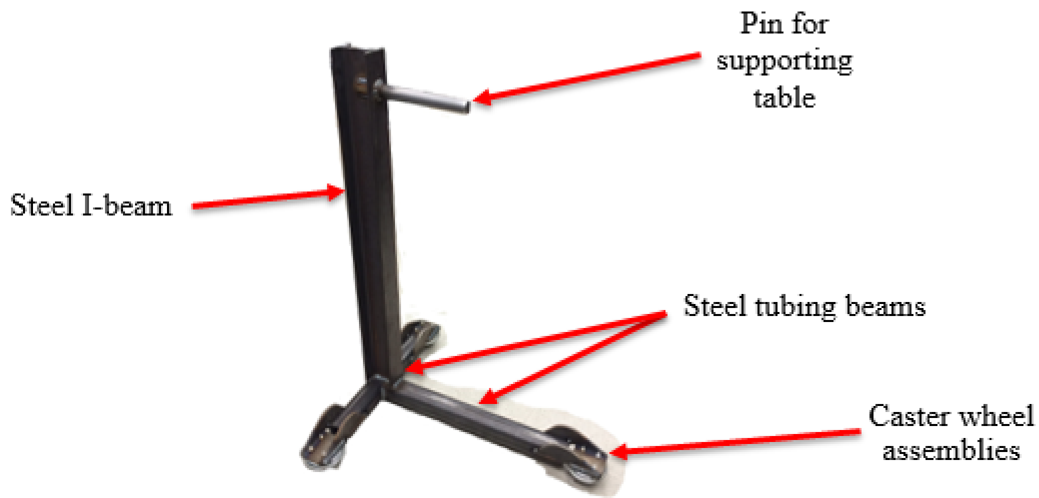


Figure 4. Cart Assembly

2.4.1 Step 1: Cutting on the Band-saw

The first step is to begin cutting the steel tubing, steel I-beam, and supporting pin to the correct lengths (sizes) using a bandsaw.

2.4.2 Step 2: Water Jet

Using the water jet, cut out the six platforms and braces that will hold the casters to the cart.

2.4.3 Step 3: Drilling

The I-Beam must be securely clamped on the mill by an experienced operator. The hole to be made will be 1.625 in. deep, and 1 in. in diameter, so proper precautions must be taken so that the specific energy of the steel does not overpower the mill creating a dangerous situation to bystanders.

2.4.4 Step 4: Welding

The final step to completing the carts is to weld the components together. Starting with the steel tubing that makes up the base and moving up to the I-beam, clamp the pieces so as to minimize deflection due to weld shrinkage pull. Insert the pin in the hole made in step 3 and tack it on the bottom face. Depending on which way the weld pulled, adjust the order in which you weld the pin to the I-beam. Experience shows that it is best to start at the base and make corrections with a mallet. Once sufficient weld surface has been created, finish the pin assembly by welding the ring that will press against the table in the stowing mode. The casters can now be welded to the platforms and the rest of the assembly, maintaining the straightness of pin in relation to the floor. Minor corrections may be made by twisting the I-beam along its long axis, where it has the least strength. A small but firm twisting motion should plastically deform the I-beam just enough to straighten the pin.

2.5 Mechatronics System

The mechatronics system is what integrates the computer programming, electronics, and pool table into a self-leveling system.

2.6 Wood Aesthetics

The woodwork for the table is outsourced for the sake of providing the customer with a high quality pool table appearance. The purpose of the wood aesthetics is to cover up all the steel and make the table look and feel like a standard, elegant pool table.

2.7 Final Assembly (~2 Hours)

After cleaning up the primed hinges, align the leg assembly with the corners of the frame and place the hinge so that it does not create interference when the legs fold away. It is important to ensure that the clean prime-less side of the hinge is exposed for the mig welder to make good contact with the metal. Weld hinge to leg. Weld hinge to frame.

The lateral supports must be assembled such that the 3/8” bolts fit through the big angle irons and thread into the now hidden nuts inside the frame. With the lateral supports in place, and while holding the blinds (the top and side wooden pieces that wrap around the playing area) bolt on the appropriate bumpers through the wood and U-channels, noting the difference in end angles so that the six pieces are symmetric with the corner pockets. It is recommended that bolts are firmly tightened, but without causing the wooden part of the bumpers to flex more than what is necessary for them to straighten up.

At this point all major components should be rigidly attached to the frame, so that the mechatronic system can be secured to the bottom support of the slate. Ensure that the wires coming from the actuators do not get tangled up during operation by being loosely laid on the wood. Crown staples may be used to take up the slack when the wires hang lower than the skeleton. Once all the wiring has been soldered, use the wood screws to drill no more than ½ in. into the wood through the electronics' polycase.

Do a detailed walkthrough to make sure there are no sharp edges left on the skeleton. Check for loose bolts and missing washers. As a final check, engage the carts and retract the legs to perform a full stowing process as described in the operations manual. The system should rotate smoothly and with little effort if the proper balance was achieved. Small weights may be attached inside of the leg assemblies if the rotation requires more than 20 lb. of force at the proper hand location due to an imbalance.

Figure 5. Table Alignment with Carts Full Assembly

3. Design for Reliability

3.1 FEA Analysis

The product ultimately consists of two carts and one table, which are three independently movable parts. The system can be analyzed in two of its configurations: the stowed and the free-standing configurations.

When the carts are separated from the table (free-standing configuration), the weight of the table is held by its own legs. Initial tests showed that the weight bearing capabilities of the legs were sufficient, and correlate with the expected results, however, there is noticeable flex on the linear actuators' shafts when the table is set up higher than the usual 30 in. playing height. Although the operations manual advices users against lifting the table higher than that except to begin the stowing process, there is a possibility for the shaft to buckle under conditions of misuse. Additionally, the back and forth radial deflections of said aluminum shafts could theoretically create a long-term material failure due to fatigue (cyclic loading), but at the highest stress below aluminum's yield strength, its endurance limit is 10,000 cycles. If the table were to be moved once per day, it would take 27 years to surpass the aforementioned limit.

When the table and carts are joined together (stowed configuration), the weight of the table is supported by carts rather than the legs. The weakest part of the carts are the 1 in.-diameter steel pins. A finite element analysis (FEA) was performed using Dassault Systemes' Solidworks simulation package, where the wheels are assumed to be fixed, the entire assembly bonded, and the shaft loaded vertically with 300 lbf. As seen in Figure 6, the highest Von Mises stress is found near the pin-beam intersection on the top side, where the material is deformed in tension. It is important to note the deformation is scaled to 112 for visual purposes. Considering a mild steel yield strength of 36,000 psi and a maximum stress of 13,000 psi at the pin, we arrive at a factor of safety of 2.7. Lastly, we followed standard procedure for refining the mesh and found no significant variation in the results when increasing elements past the automatically generated size.

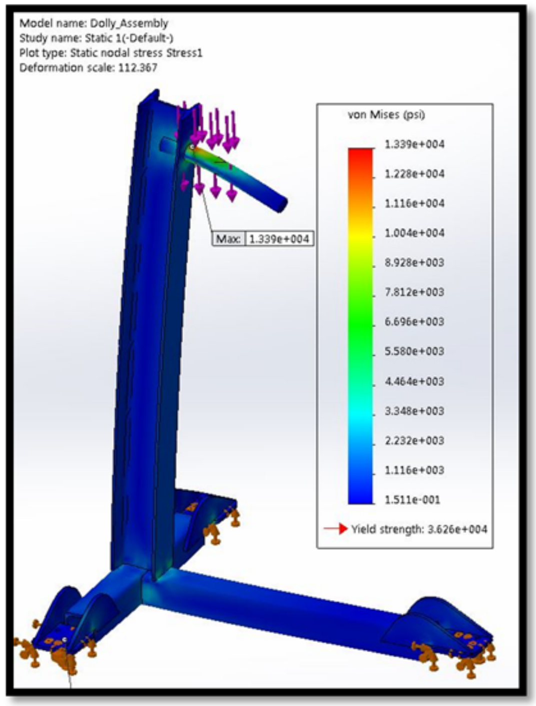


Figure 6. FEA Analysis on Cart

Following the manufacturer's caster wheel load rating of 264 lb., and making an even-distribution assumption, the three-caster setup of the carts provides a factor of safety of 2.6 under the same 300 lbf used in the FEA described above.

The steel skeleton is reinforced in key areas. Since the bushings are the point of contact between carts and table, the tubing that holds them is supported by the diagonal braces on the corners of the frame. Due to its abundant availability, we used 1 in. square tubing of 0.12 in. wall thickness. It was noted by faculty and staff that future iterations of this frame need not bracing of such thickness, since it can be seen with the naked eye that the structural support provided by the bracing is justified only under much larger loads. The recommendation was to source thinner tubing in order to save weight while still adding rigidity to the frame.

The carts and frame are connected by its pins and bushings respectively. It is well known that smooth operation of low speed rotating components can be achieved with bushings, as opposed to roller bearings, and that a brass-steel interaction decreases component wear over time. Considering that this product will not be used in a lab environment (with strict maintenance procedures), we selected oil impregnated bushings to keep the friction low without the need for the user to follow a lubrication schedule. Additionally, every time the carts are connected, the pressure between the components makes an imperceptible but sufficient amount of oil to seep out onto the pins, effectively adding a coat of it which acts as protection against rust.

There are questions regarding the longevity of corroded parts whenever components are made of carbon steel. To address that concern, paint is applied to all steel surfaces that are exposed to the elements. After some deliberation, it was decided that a powder coat method of painting–although more costly- was justified. The paint job was outsourced for this first prototype, but could be implemented as an in-house procedure when the production output is scaled to multiple units per month as a justified expense with quick return on investment.

3.2 FMEA Analysis

There were three important occasions when the team was faced with the possibility of the project or system failing. In order of severity: cart material failure, fabrication tolerances too small for the user’s comfort when performing maintenance, and poor fitment of wooden pieces. Following the advice from experienced fabricators Jeremy Phillips and Stephen Avery, appropriate steps were taken to reduce the risks associated with the problems described here. Using industry-standard Failure Mode Effect Analysis procedure, the situations is described in tabular format in Appendix B. As of the date of this report, all actions taken have resulted in much lower risk as expected.

4. Design for Economics

Due to their detailed craftsmanship, pool tables can be extremely expensive ranging upwards of $10,000. The price of a pool table mainly depends on the quality of material it is made of. The main differences between a high and low quality pool table is in the playing surface and the decorative wood. The playing surface of a high end pool table is made of quarried slate whereas a lower end table typically has a wooden playing surface. The advantage of using a slate as opposed to wood is that slate wont warp over time like wood. This is important because one of top priorities of the Self-Leveling Stow-Away Pool Table is keeping the playing surface level. For this reason, slate is used in the design of the table. The decorative wood on a pool table consists of the rails, cabinets and legs of the table. They are typically made of either solid or pressed wood. Solid wood gives the table more support and has more grain beauty compared to pressed wood. Another option is to use veneers of hardwood on top of pressed wood; this provides the look of solid wood but it doesn't have the support. The wood on the Self-Leveling Stow-Away Pool Table is only there for purely aesthetic reasons. Support is provided by a steel frame which the wood will conceal. For this reason, veneers are used on the design and only enough wood is needed to cover the outside of the table.

4.1 Competition Comparison

The cost to design and manufacture the Self-Leveling Stow-Away Pool Table is $2,900.60. This cost includes spare parts such as two extra linear actuators and an extra microcontroller. It also includes all added features that increase aesthetics such as the rails, cloth, pockets and sights. Figure 7 shows a breakdown of how the $5,000 budget was spent.

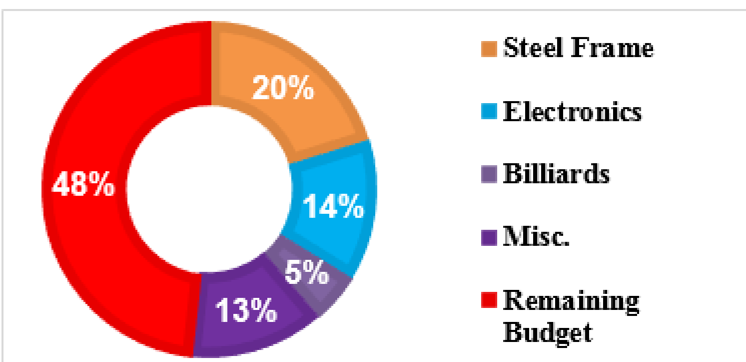


Figure 7. Breakdown of $5,000 dollar budget for designing and manufacturing

The majority of the budget was spent on the steel frame because providing support and maintaining safety is vital when operating such a heavy piece of equipment. The billiards section includes all of the components which contribute to actually providing a joyful playing experience for the user. This includes the bumpers, pockets, cloth and sights. With 48% of the budget still remaining, there is still plenty of potential to increase the overall value of the pool table while still keeping the cost of the table relatively low.

The two most popular manufacturers of pool tables are Brunswick and Olhausen. Both companies make a variety of different pool tables ranging from affordable tables to expensive high end tables. The prices of these tables can range from as $2,000 to $40,000. The top selling pool tables for Brunswick and Olhausen are the Camden and the Santa Ana, respectively. Figure #8 provides a comparison between the prices of these top selling tables and the Self-Leveling Stow-Away Pool Table.

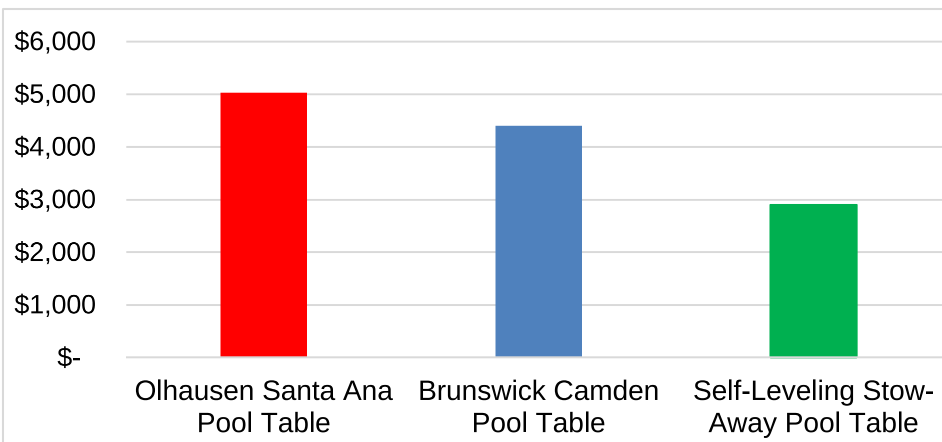


Figure 8. Table Price Comparison

The SLSA pool table is over $1,000 cheaper than Brunswick's tops seller and over $2,000 cheaper than Olhausen's. This, plus the added convenience of the SLSA pool table, makes for a very competitive product on the market.

4.2 Potential Buyers

The SLSA pool table's low cost isn't even the main factor that would allow it to be a top seller in the recreation market. The SLSA pool table's stow-away capability makes it a necessity for buyers who can't afford the large amount of permanent space that a traditional pool table would take up. A prime example of these buyers are commercial establishments such as sports bars and restaurants. Restaurants often have to sell their pool tables because they simply aren't worth taking up room that could otherwise seat more guests and makes the business more money. The SLSA pool table could allow for businesses to provide a pool table for patrons to use on slower nights or it could be easy stowed into a storage room on busy nights to provide for more room to house patrons.

The convenience of the SLSA pool table also extends into the household. Homes with pool tables usually have a room dedicated just for playing billiards because of the large amount of space needed to play. On special occasions, that room could provide valuable use if the pool table weren't there. For example, if a household is hosting a large dinner party, the room could be used to seat guests in if there isn't enough room in the main dining room. Also, some pool table owners may have their table in the garage. Understandably, a garage can provide much more use then as an area to play pool. The SLSA could solve all of these problems caused by a pool table taking up a large area of permanent space.

4.3 User Friendly Design

Innovative, non-traditional products can be intimidating to potential buyers because they are unfamiliar with it and aren't sure how easy it will be to use. This is why creating a user friendly design is important. The design should as simple as possible while still remaining effective to accomplishing the goals. The features of the SLSA pool table are ones that are new to the billiards industry and potential buyers. The design of the user friendly interface and the stow-away safety features will help the user comfortably become accustomed to this new idea.

The self-leveling feature of this design is as easy as its name suggests; with just the push of a button the self-leveling components of the table get to work and quickly level the table. The table will have many other features which are just as easy to use by simply navigating through the menu on an LCD screen with a simple three button control panel. This simplicity will prevent the user from feeling overwhelmed by too many buttons or confusing options to choose from.

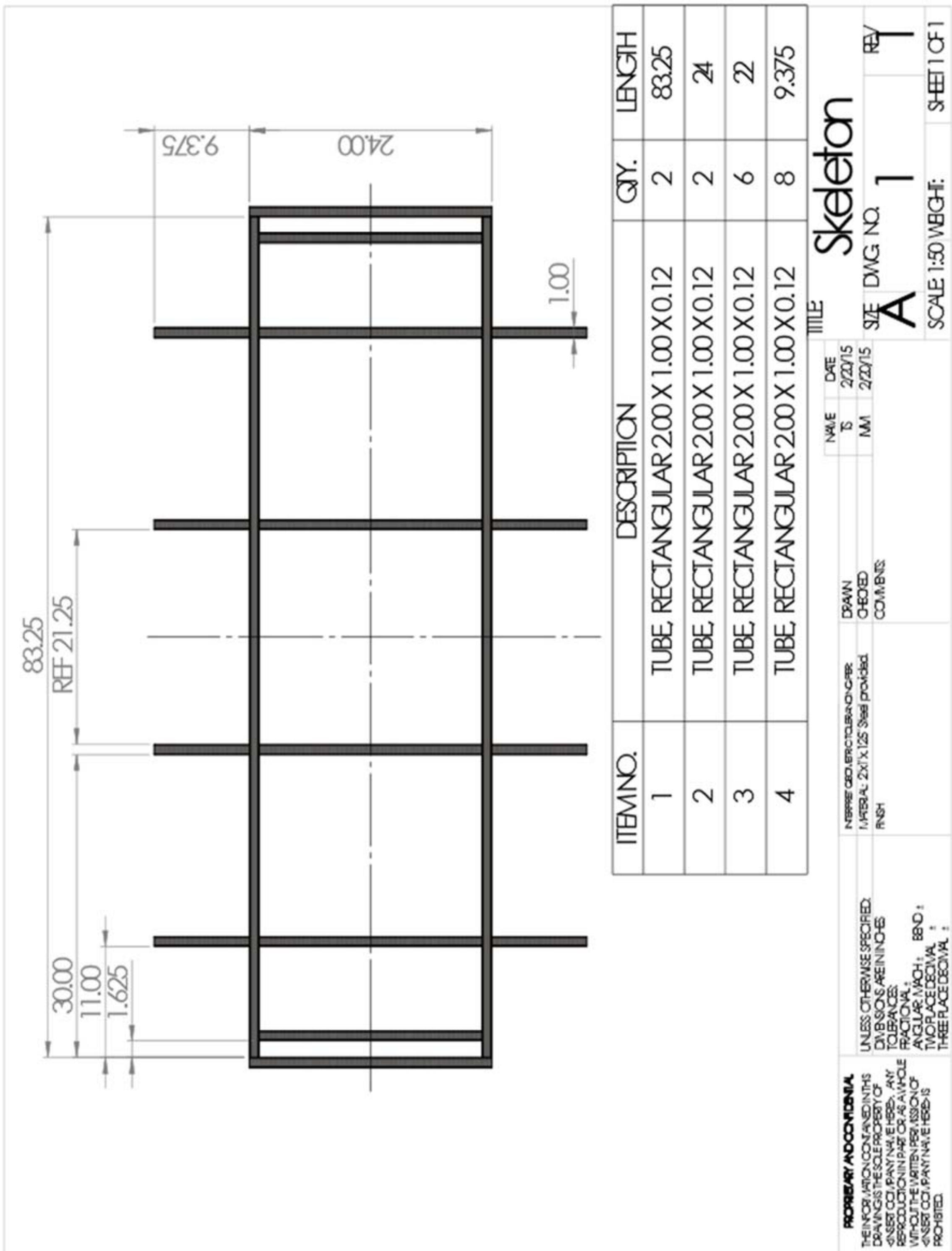
Lifting an 800lbs mechanism is definitely intimidating to the average person. The stow-away process may seem difficult to most people because of this. However, the user will quickly find out just how easy this process can be done with the SLSA pool table. By design, the axis of rotation of the pool table passes right through the center of gravity of the table. With no net moment on the table, rotating the table into the stow-away position can be easily accomplished by one person with very little effort. Locking pins have been equipped on the table to secure the table in place once it reaches the 90 degree of rotation into the stow-away position. This allows for the mechanism to be stable and for risk to be minimized by transporting the table. Four large caster wheels on each of the carts make moving the table just as easy as rotating it.

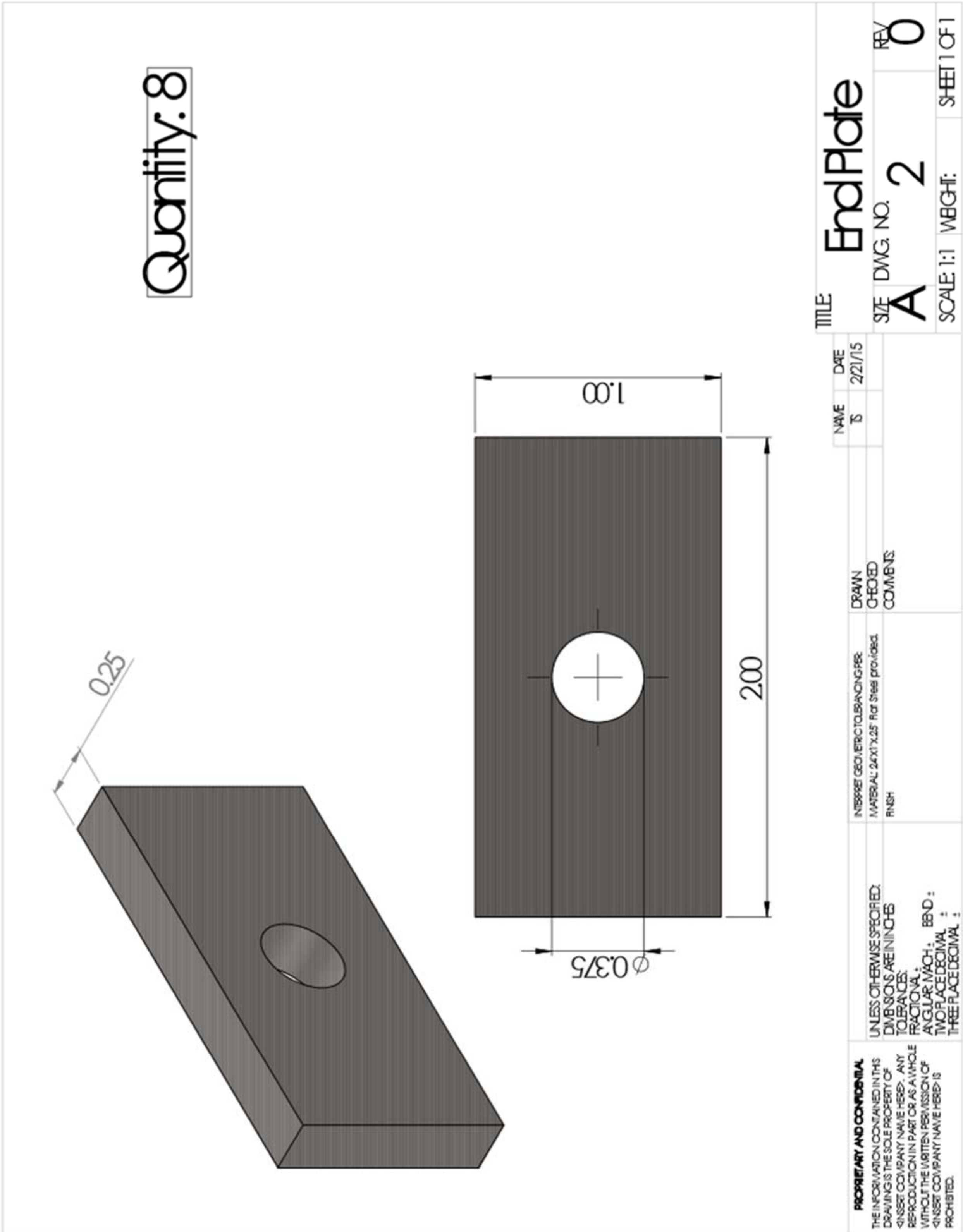
After a short demonstration on how to operate the features of the SLSA pool table, potential buyers can quickly see its ease of use. This will eliminate any doubt or timidity about this innovative product. In additional to its affordability and convenience, the ease of use of the SLSA makes for a very appealing product to a vast variety of customers.

References

[1] "Prime-Line 1/4-20 Carriage Bolts with Nuts-GD 52103 - The Home Depot." *The Home Depot*. Web. 29 Mar. 2015. <http://www.homedepot.com/p/Prime-Line-1-4-20-Carriage-Bolts-with-Nuts-GD-52103/202633663>.

Appendix A: Engineering Drawings

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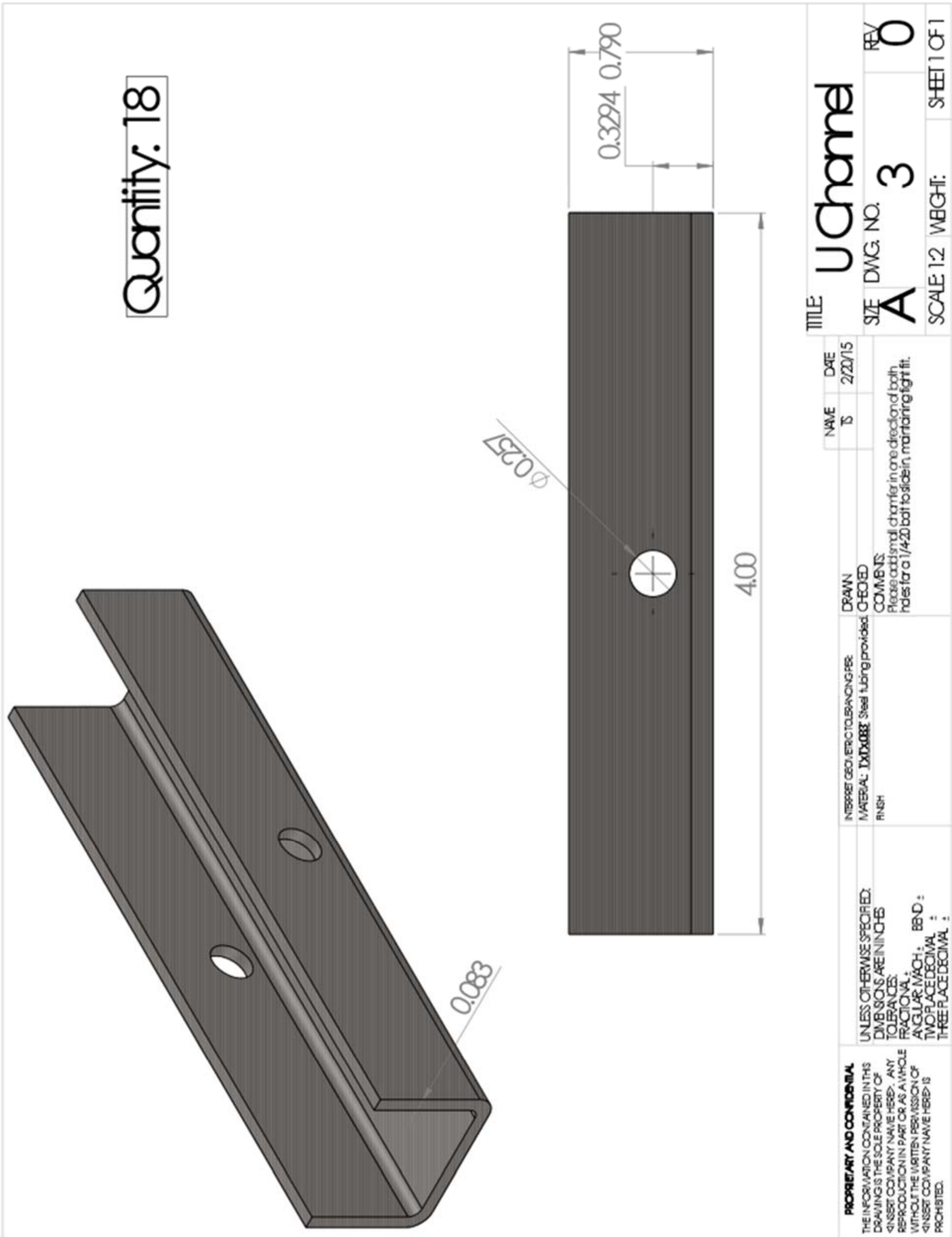
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UNLESS OTHERWISE SPECIFIED:
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PROPRIETARY AND CONFIDENTIAL
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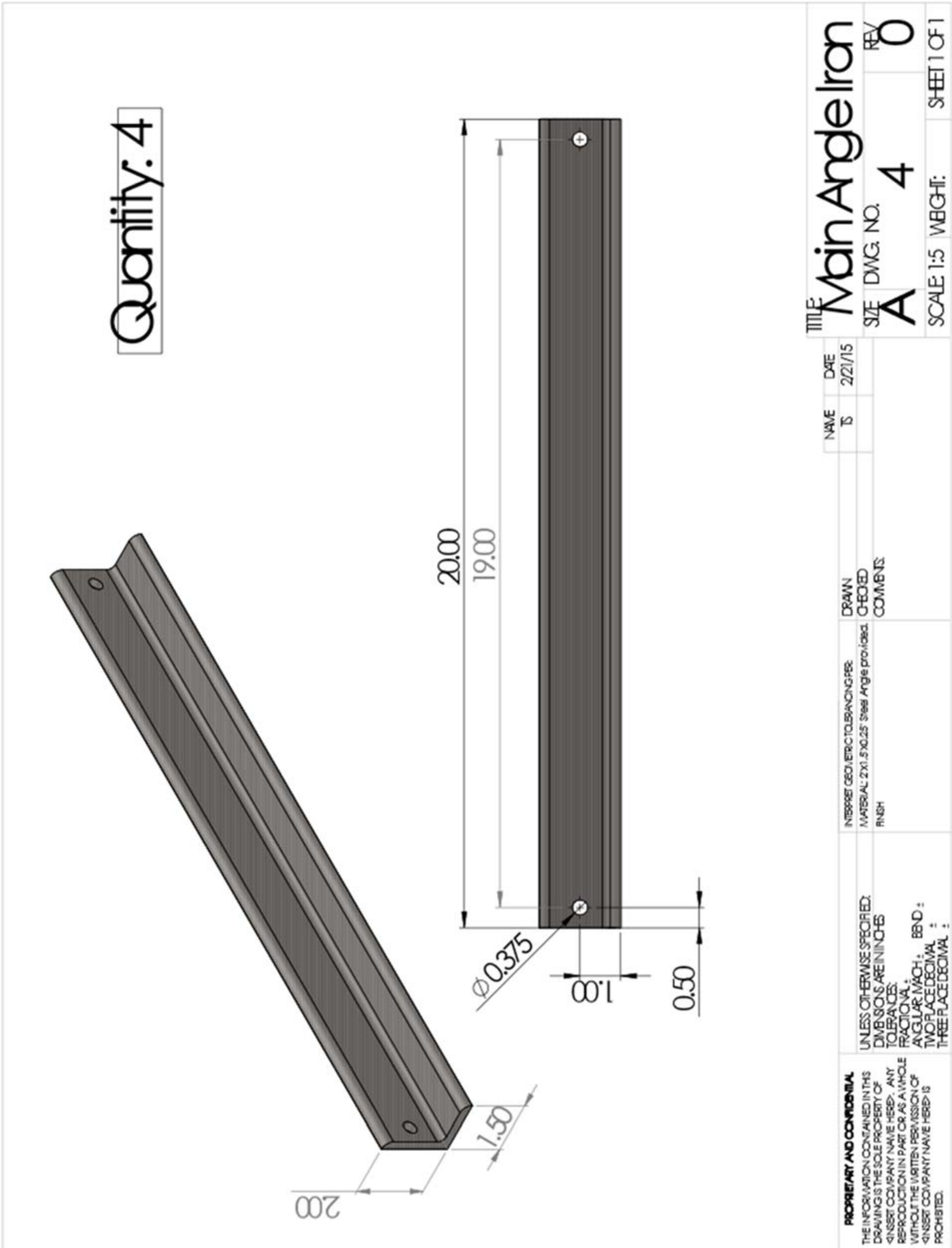
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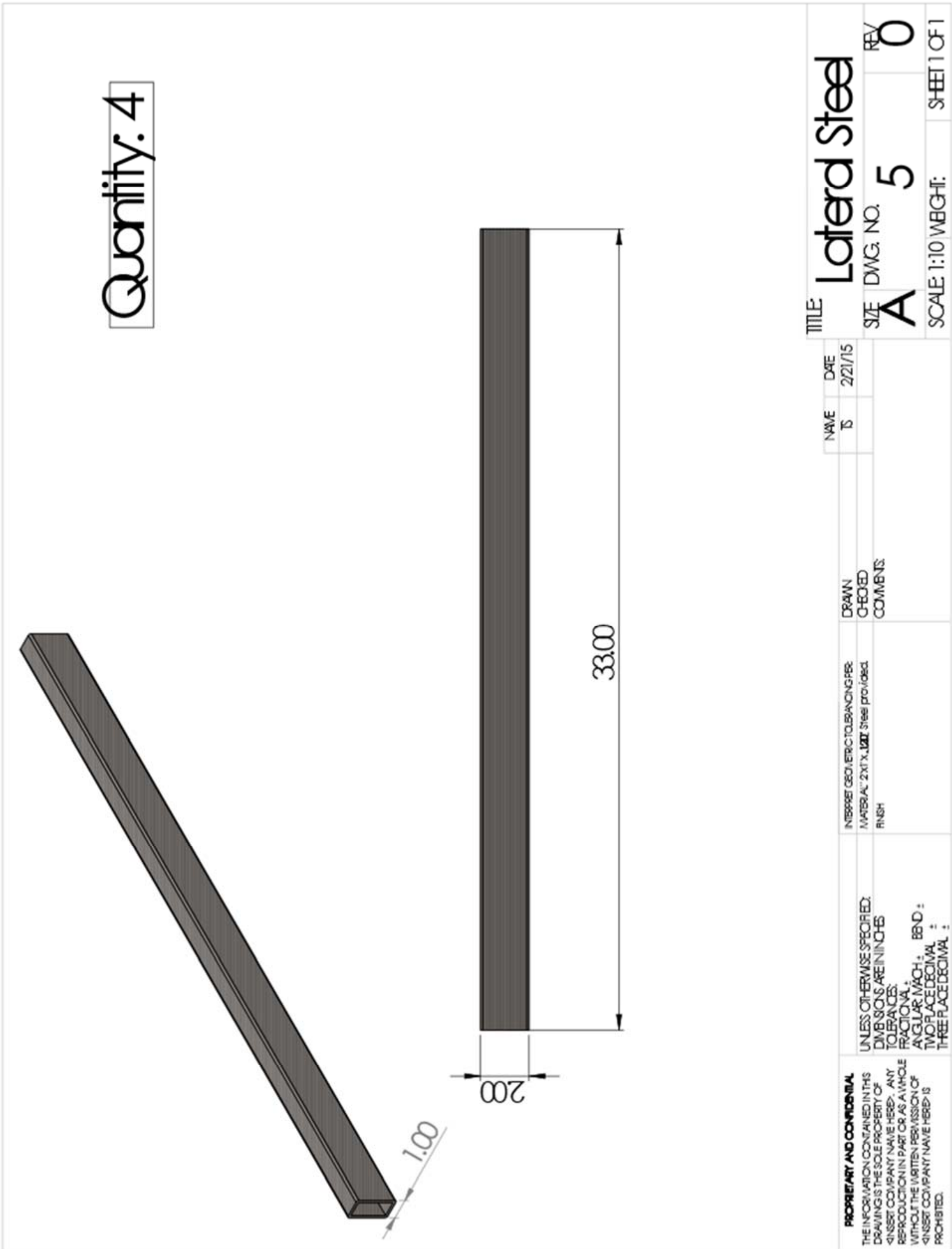
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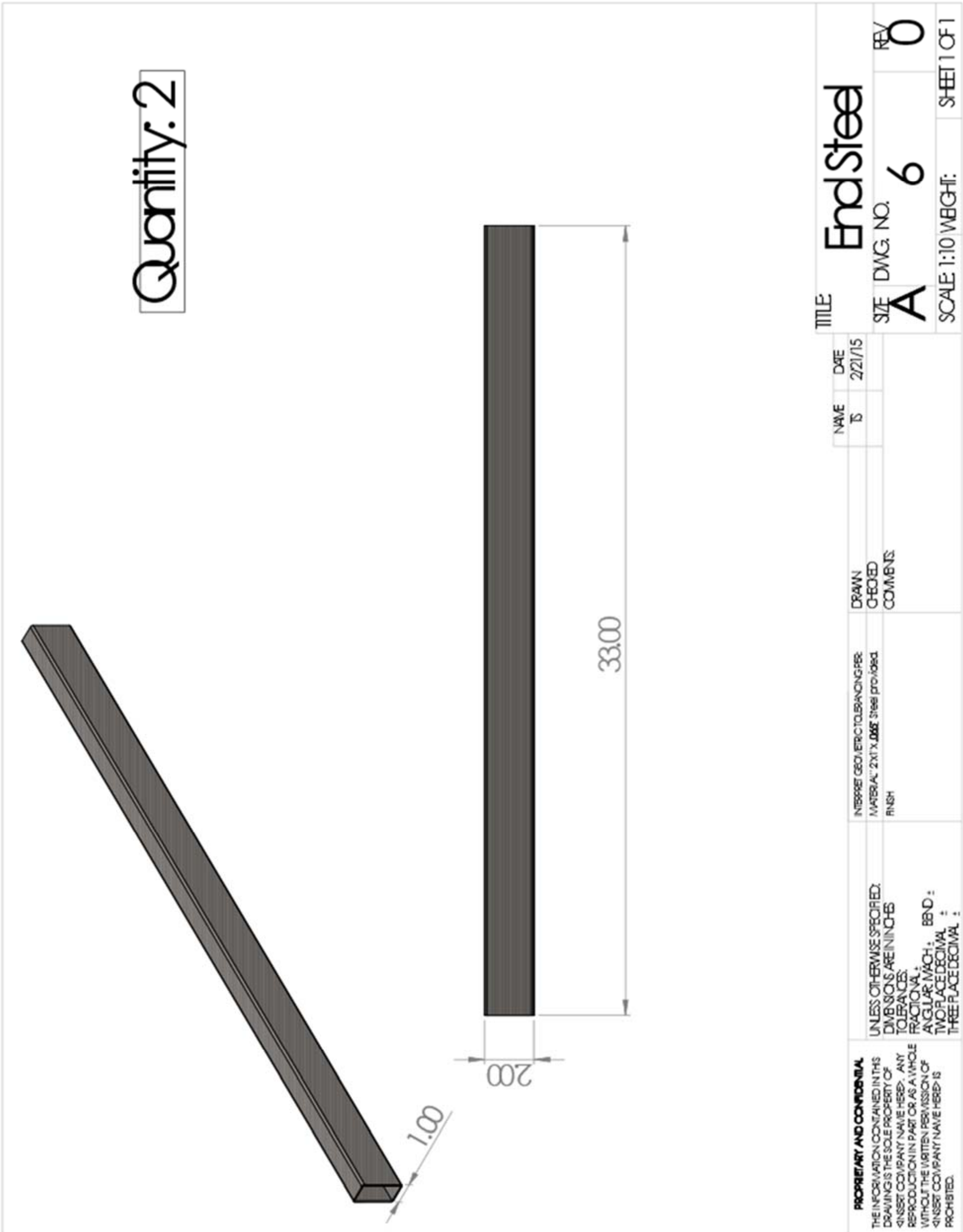
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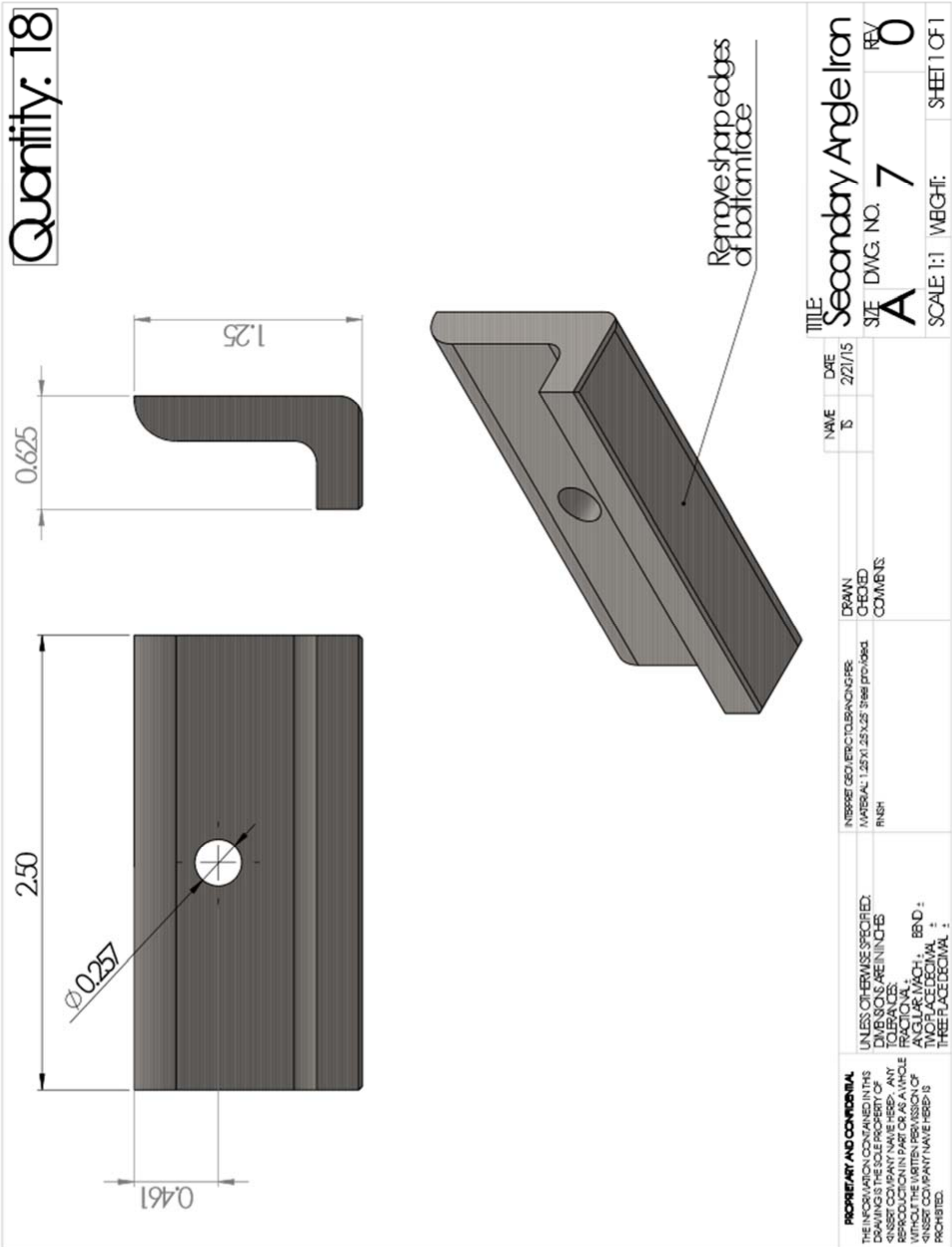
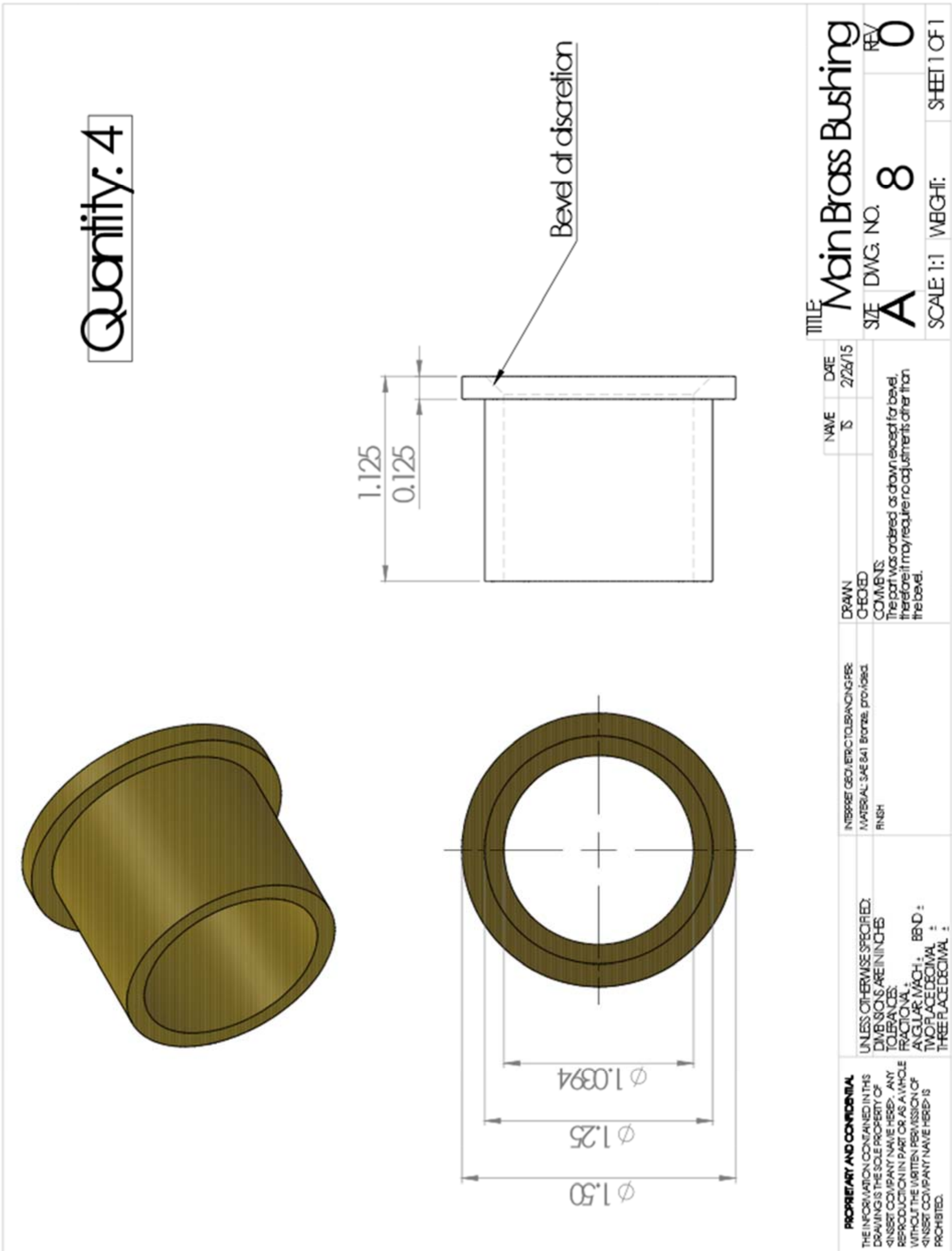
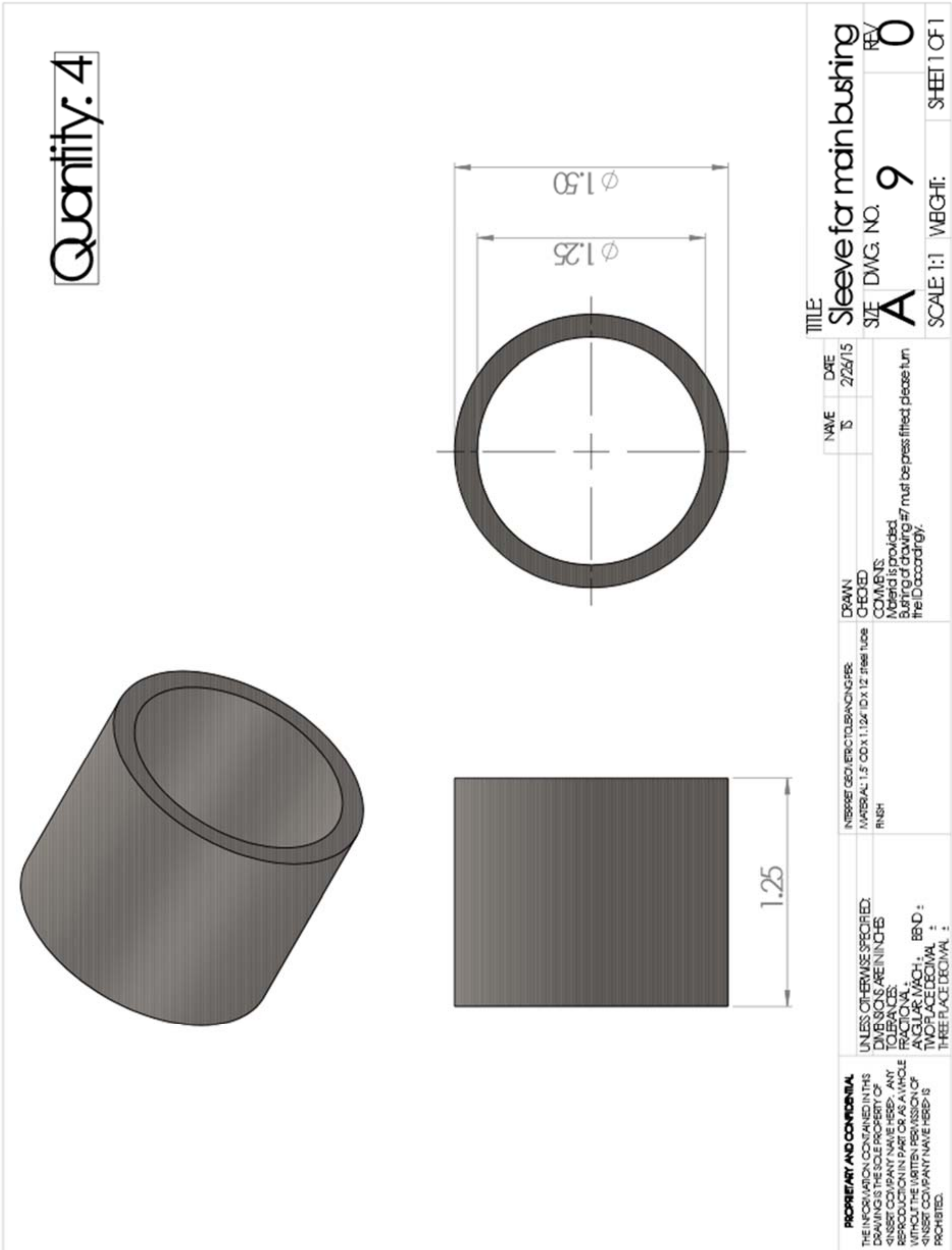
COMMENTS:
PROPRIETARY AND CONFIDENTIAL


Quantity: 18
2.50
Ø0.257
0.461
0.625
1.25
Remove sharp edges of bottom face
TITLE:
Secondary Angle Iron
SIZE
A
DWG. NO.
7
REV
0
SCALE 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
TS
2/21/15
DRAWN
CHECKED
COMMENTS:


Quantity: 4
Bevel at discretion
1.125
0.125
⌀ 1.0394
⌀ 1.25
⌀ 1.50
TITLE:
Main Brass Bushing
SIZE A
DWG. NO. 8
REV 0
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
2/26/15
DRAWN
CHECKED
COMMENTS:
The part was ordered as drawn except for bevel, therefore it may require no adjustments other than the bevel.
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL: SAE 841 Bronze, provided
FINISH
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
PROPRIETARY 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 THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.


Quantity: 4
⌀1.50
⌀1.25
1.25
TITLE:
Sleeve for main bushing
SIZE
A
DWG. NO.
9
REV
0
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
TS
2/26/15
CHECKED
COMMENTS:
Material is provided.
Bushing of drawing #7 must be press fitted please turn the ID accordingly.
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL: 1.5" OD x 1.124" ID x 12" steel tube
FINISH
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
PROPRIETARY AND CONFIDENTIAL
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Appendix B: FMEA Analysis

	Key Input	Failure Mode	Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Responsible party	Action taken	Date
A	Dolly	Pin welds breaking	Collapse of table. Injury to user.	10	Improper material and geometry	6	None	10	600	Increase pin size	Silva	Increase weld area by inserting pin into the i-beam	2/15/2015
A'	Dolly	Pin welds breaking	Collapse of table. Injury to user.	10	Improper material and geometry	1	Testing of every dolly before delivery of product	2	20	None	DNA	DNA	Current
B	Slate replacement	Not being able to fit a replacement slate as promised.	User tries to force fit and drops the slate.	5	High friction between angle irons and slate. Using uneven wood support.	2	CAD tolerances used to estimate fitment.	6	60	Make all angle irons removable	Manahan	As suggested.	1/20/2015
B'	Slate replacement	Not being able to fit a replacement slate as promised.	User tries to force fit and drops the slate.	5	High friction between frame and slate. Using uneven wood support.	1	CAD tolerances used to estimate fitment.	2	10	None	DNA	DNA	Current
C	Woodwork	Uneven surfaces and poor fitment	Cost due to time spent reworking. Additional risk of powertool injuries.	7	Imperfect frame fabrication. Improper tools.	8	None	5	280	Obtain better tools like a table saw, or outsource wood work.	McHugh	Woodwork will be outsourced	3/30/2015
C'	Woodwork	Uneven surfaces and poor fitment	Cost due to time spent reworking.	7	Imperfect frame fabrication. Poor quality control.	3	Each piece is checked against the specific table it's going on.	5	105	Specify quality checks in contract with supplier.	Silva	As suggested.	4/2/2015