

*April 23rd, 2015*

# MakaPad Sealing Optimization

Final Report

TEAM 7 ME 450 WINTER 2015

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Sponsors: Professors Elijah Kannatey Asibu, Chinedum Okwudire, & Moses Musaazi

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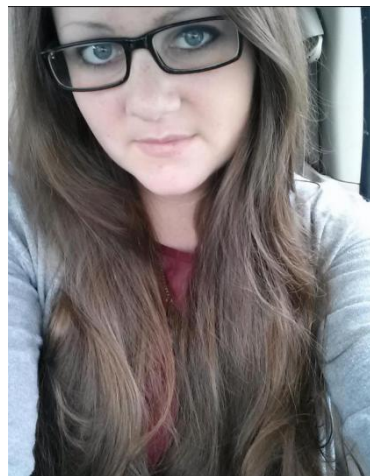
## AUTHORS



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## **EXECUTIVE SUMMARY**

Our project, MakaPad sealing optimization, had one main deliverable that we had to accomplish, which was generating a solution that could completely seal all four sides of the product in an efficient manner. When approaching our final design chosen concept we created a detailed engineering design of the prototype. Included in this report are some rough draft engineering drawings for the main components of the prototype generated in CAD.

Our design was generated using concepts from the previous two semester's designs as well as our own intuition. The design intends to seal Makapads by pressing a heating element from the bottom of our design onto the top surface, which will hold the outer material of our pad as well as the interior materials. Once the pads are properly placed in the depression area of the heat seal area on the base plate, a lever is pulled to lower the top surface, which is heated, onto the bottom in order to create enough heat for the seal.

Our current prototype is done in the manufacturing stages, besides for a few parts that need fine-tuning. We have validated our design drivers and performed the appropriate tests. A quantitative test to see how many pads could be loaded/unloaded in one minute on our mechanism to determine if we could reach the goal of 6 pads per minute were performed. A force test was conducted on the handlebar to ensure that the force required to press our mechanism down was less than 50 newtons. And finally, we will assessed several makapads after sealing them to ensure that a complete seal was met and there are no defects in our product.

Several changes were made to our design over the course of the project. We added two linkage bars from to our design which connect to the top plate, as we felt having a four bar linkage only complicated the design and made moving the top plate much harder than it needs to be. This is a very big change to our whole design, as the feedback from design review 3 and 4 helped us realize that we should simplify our design to make things easier on ourselves. In a very general sense, our product only needs to be able to move upwards and downwards in an efficient manner, and this is why we made these changes to our design.

Our current design incorporates the most up to date information, and we are comfortable with the information we have presented. The machine was presented at the Winter 2015 Design Expo at the University of Michigan Engineering North Campus. Curt Kemerer will be delivering the prototype in person to Uganda to introduce the new heat seal concept to the workers.

## BACKGROUND

A common problem for women in third-world countries is access to affordable female sanitary pads. Without access to affordable sanitary pads young girls often skip school during their menstrual cycles. Due to skipping school, the girls get behind in their studies and can often lead to dropping out of school all together. Or, in some cases, girls will find other ways to hide the menstrual cycle by using dirty rags or leaves, but these actions are often unsafe and unsanitary. Underprivileged girls can miss 10 to 20 percent of their school days, and they fall behind in the studies which leads to a high dropout rate [1]. However, “research shows that investments in female education can yield a “growth premium” in GDP trends and that narrowing the gender gap in employment can boost per capita income.” [2]. This suggests that more effort should be put towards keeping girls in school and providing them with cheaper female sanitary pad alternatives. Studies have shown that increasing sustainable access to basic sanitation and the full and productive employment for all, especially women who are otherwise only afforded minimal opportunities, are able to sustain a better quality of well being. [3].

MakaPad is a wonderful product designed by Dr. Moses Musaazi, a senior lecturer in the Department of Electrical and Computer engineering at CEDAT (College of Engineering, Design, Art and Technology) and founded the company Technology for Tomorrow (T4T) [4]. MakaPad provides disposable female sanitary products for underprivileged women in third-world countries. MakaPad is an acronym for “Menstruation, Administration, Knowledge, and Affordability” [5]. The company is based in Uganda and provides hundreds of local labor jobs for women. Currently, MakaPad is the only company to produce affordable female sanitary pads. Over 5 million pads are produced per year by MakaPad and the product is used mostly by local low income women and refugees [6]. The MakaPad is a 95% biodegradable pad made of local Ugandan materials and made by local Ugandan workers. A pack of ten MakaPads costs about 53 cents [7].

There are no direct competitors when it comes to low cost sanitary pads in Uganda. There are very few companies around the world attempting to create low cost pads for underdeveloped communities. In India, Arunachalam Muruganantham, an entrepreneur in the sanitary pad industry, noticed less than 12% of women there use sanitary pads and instead use dirty rags which can often lead to infections and illness [8]. However, in Uganda, and compared to the rest of the world, Dr. Musaazi’s MakaPad product is unique and yet a necessity. However, there is a company called AFRIPads that is a Ugandan based company. AFRIPads makes washable cloth sanitary pads that last for up to one year and saves cost of using disposable pads [9]. However, this is a slightly different type of product because it is reusable and therefore is a competitor, but not a direct competitor. Mr. Muruganantham designed a machine and material to create low cost disposable female sanitary pads in India [8]. Of course, there are the hundreds of female sanitary pads that are in high commercial production that are more expensive brands such as, Kotex, Always, Playtex...etc. These companies are not currently in direct competition with Dr. Musaazi’s company, but they could be in the future. He plans to expand his market to compete globally and not just Uganda and refugees [10].

## **PROBLEM DESCRIPTION**

MakaPad, the brand name for a class of locally-made sanitary pads, was developed by Prof. Moses Musaaazi at Makerere University in Uganda. The raw material is papyrus, which is mixed with recycled paper at one stage of the production cycle. A MakaPad is made using a manual labor production process [10]. First, papyrus is collected, peeled and cut into small pieces. Papyrus was chosen to be used in the absorbent layers of a MakaPad due to its high absorbency [11]. Using local raw materials significantly reduces the cost, making it more than 50% cheaper than the imported variety. The material used is more than 95% biodegradable and free of chemicals. Even though the current manufacturing method has elements of mass production, with individual stations requiring specific skills, there are several elements of the production system that need further analysis to enable system scalability, productivity, and reliability. The focus of this project will be to design and manufacture a prototype machine for sealing the pads, and will build off initial prototypes developed during previous semesters.

## **LITERATURE REVIEW**

The current problem with MakaPad manufacturing is that the sealing process is inefficient and creates a less than ideal seal quality. Currently in Uganda, MakaPad workers use conventional heat sealers, and seal one edge at a time. The workers are required to turn the pad 4 times in order to complete the seal [12]. Furthermore, the MakaPad can only be made in linear dimensions, as the current heat sealer is straight edged. This causes a problem with comfort and the variety of sizes that are available to women [13]. A solution to this problem would be a sealer that can seal all four sides at once, or cut the MakaPads themselves during the sealing process. Some constraints that are caused by this problem are that the sealing devices must be operated by someone at all times, and that the income that workers make is directly dependent on the output rate of their production. This causes an issue because workers are forced to work as fast as possible, and put less care into the quality of their product. We are also constrained by output waste from our operating process, and a limitation on the amount of power available to our sealing device. [10].

## **BENCHMARKS**

There are several types of sealing devices that are currently on the market that approach this problem in a variety of ways. These solutions all have their upsides, whether it be cost, output rate, power, and manufacturing process. Based on the extensive research we have conducted, we focused on output rate as the primary focus of our product. We will go into further detail regarding the different types of sealing processes and production setups.

### **Sealing Techniques**

Sealing sanitary pads is a problem that is mostly commercially solved with heat-sealing. These designs, formed through a similar process as what is currently used in Uganda, are used because of the relative ease of use, and the cost of the product [14]. Though heat sealing restricts the size and dimensions of the product, its the most simple and logical approach in the working environment in Uganda. Heat sealing does not work for all sanitary pad materials. For example, a

past invention uses hydrophobic fibers in one of its layers [15]. However, we have decided to focus our research on Heat Sealing methods due to its success and current use at the factory.

### Joule Heating

Joule heating devices that are used for sealing pads are also commercially available. As shown in the image below, this device provides a current through the heating element to create a high enough temperature to seal the product in a short amount of time. The heat melts the fabric layers together, and all four sides are sealed at once [16]. This invention has downsides, as there is a power limitation in the current work environment of 300 Watts, and cost limitations of importing several devices needed for production. Included is a diagram of the Joule Heating patent in Figure 1 below.

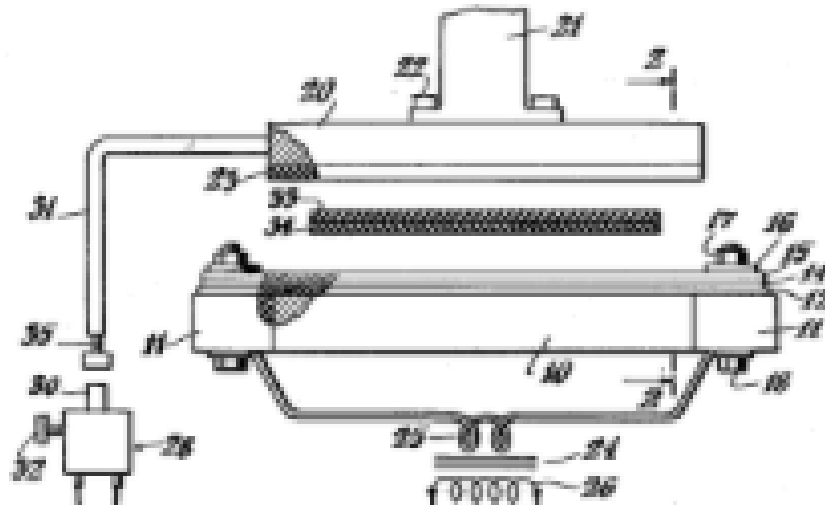


Figure 1: Diagram of US Patent 2574094 A, Joule Heating Patent

### Production Setups

Due to the overwhelming demand for sanitary pads across the globe, several inventions and patents regarding large-scale production have been implemented in the workplace. These devices vastly increase the output rate of these pads and provide unique approaches to alleviating this issue.

### Small Scale Production

Inventions and patents regarding small-scale production of sanitary pads have started to grow in the market. The device shown below, created by Arunachalam Muruganatham, is a machine that enables small-scale production of sanitary pads [8]. The design shown uses a spindle to hold the outermost layer of the sanitary pads while placing the interior materials under the heat seal (see Figure 2). The design uses heat-sealing to press the four sides of the sanitary pad down, and allows for adjustable lengths based on design specifications. Though this device can only seal one side of the pad at a time, it allows for more variability if necessary [17].



Figure 2: Mr. Muruganatham and his low cost sanitary pad production design [8].

### Large Scale Production

There are also full-scale industry machines that produce sanitary pads at an extremely high rate. These machines are much more complex and often are 100% automated, such as the product shown in Figure 3, below.



Figure 3: Diagram of Large Scale Production Sanitary Pad Machine DC-SN-500

This device, created by DingCheng Machinery Co. (Women Sanitary Napkin Machine DC-SN-500), creates a similar layer of absorbent material between the covering sheets, and creates a seal with a crimp pattern, which is rolled on with a roller [18]. The downside to this device is the immense size it occupies, and the large amount of power that is necessary to operate (100kW). It would also be difficult to export such a product to Uganda and train the Ugandan women to use a machine when simpler handheld devices are readily available

### USER REQUIREMENTS

We interviewed our sponsors Professors Elijah Kannatey Asibu and Chinedum Okwudire. We are still awaiting word and a meeting time from Dr. Moses Musaazi. In Table 1, page 7, we collected the appropriate customer user requirements. Our main concerns will be prioritizing a complete sealing process but at the same time maintain or increase the production rate. Complete sealing is the main issue as MakaPad would like to see no variation in the completed pads. There have been complaints of leakages in the past which would be due to the workers difference in applied force when it comes to using the straight-line heat sealers. Depending on how hard and how long a worker presses the sealer determines how well the seal will be. So with our future designs we hope to incorporate sealing that is complete and consistent.

Table 1: User Requirements and Specifications for MakaPad Sealing project

User Requirements	Priority	Specification	Rationale	Source
Complete Sealing	High	Consistent 100% sealing of layers	Products must be sealed to prevent leaks/contamination	[10]
Increase Production Rate	High	$\geq 6$ pads/min	Increase production to expand product market	[10]
Minimize Power Consumption	High	$< 300W$	Minimal power available at the solar powered facility and homes	[10]
Increase Sides Sealed per Stroke	High	$\geq 2$ sides sealed per stroke	Increase worker production and decrease worker fatigue	[M]
Durability	Med	$\geq 1$ year of operation	Capable of producing $> 1200$ pads a day for over a year	[M]
Ease of Operation	Med	$< 50$ N downward force application	Suitable for working age young women to use	[19,20]
Safety Concerns	Med	$> 10$ mm clearance	Provide protection from burns, cuts, and pinch points	[19,20]
Single Operator	Med	1 Operator	Must be capable of operation by one worker from home	[M]
Minimize Cost	Low	$< \$400$	$\$400$ budget imposed by class, minimize cost for business	Class Budget
Minimize Size	Low	$< 0.75$ cubic meter	Must fit comfortably in workstation or home	[M]

## ENGINEERING SPECIFICATIONS

Referring Table [1] above, the user requirements and their corresponding engineering specifications along with the source describe into further detail the importance of several requirements given to us by our sponsor. We labeled some requirements and specifications as high priority as they are the most important to meet the requirements of the project and satisfy the customer. The other categories of user requirement were divided between low and medium priority. We consulted our sponsor as well as our professor in order to properly rate our user requirements in importance.

### High Priority Requirements

At high priority we stated complete sealing would be the most important component in our design. The biggest complaints from the customers of the MakaPad are leakages, so we would like to improve the process so that there is 100% complete sealing of the pads and that our machine will allow us to do this consistently. Which leads into our next priority of optimizing production time and increasing the production rate of the products because our machine will be designed to make the manufacturing more efficient. Currently, the sealing station rate is approximately 4 pads per minute. Our goal is to improve this rate by outputting greater than 7



pads per minute. These values were deduced from referencing the previous ME 450 semester 2 teams report [19, 20]. In addition we determined that the machine should not only be quick but be easy to use. As MakaPad supports local women employees that do local hands on manufacturing work. The aim is to make the machine as easy to use as possible with force and weight concerns and therefore you should not need more than 50N of manual force to use the machine and therefore allow for successful repetition and a consistent product.

### **Medium and Low Priority Requirements**

The medium and low priority requirements are important but will not be the main focus when designing the machine. However, they are all valid and the attempt will be to meet all requirements. A power limitation of 300 Watts was strictly given to us per unit, as the maximum allowable power is extremely sensitive in the Ugandan workplace. Also, in Uganda there are limited electricity sources for the plant and they use solar panels to power their factories, which can sometimes be an unreliable power source. Safety concerns are always of priority, we want to keep the workers safe. Therefore we stated that there should be a 10mm clearance if necessary when applying to future designs and also to add barriers for pinch points to avoid injuries. Mostly we want to avoid pinch injuries and burns. Durability is also a medium priority, as this machine needs to be able to be used all year round several times a day. Production output is heavily reliant on durability, as the current rate of 5 million pads a year needs to be met or exceeded. We aim for our product to last at least 2 years, as this timeframe justifies implementing an entirely new product in the workplace. The lower priority requirements and engineering specifications are for minimizing cost, space, and operators. The cost of the design is limited by the ME 450 class budget of \$400, however we will aim to minimize these costs to make it more affordable to build and have multiple machines at the Ugandan factories. Minimizing the space allows for ease of use for the workers in small workstations at the factories. Therefore we have stated the design be within the dimensions of 1 square meter. Finally limiting the number of workers needed to use the machine is best to maintain an efficient production line. The engineering specification for this user requirement was to limit the workers needed per machine to be 1 to 2 people.

## **CONCEPT GENERATION**

This section describes lists the concepts that each team member identified as their best design and highlights some of the key features of each design. Each section goes into detail regarding unique features to each design.

### **Single Feed Concepts**

The Interchangeable Parts Vertical Press, Press Down & Alignment, and Versatile Manual Hand Held Concepts were all designed as single feed concepts. During concept selection these designs were considered the strongest competitors to choose from. There were additional concepts generated that can be found in Appendix A, that also considered a continuous feeding approach.

### **Interchangeable Parts Vertical Press Concept**

This concept was inspired by the previous team's press design, and sought to improve upon it while adding in additional functions. The basic operation of this design consists of the user

placing the first layer of seal material over the alignment markings, then the pad layers within the markings, and finally the second layer of seal material over the pads. With a quick visual check to make sure pads are correctly aligned, the worker could manually push the heating unit down the 4 guide bars, press the unit against the base for a set amount of time, and allow the unit to automatically spring back up to the starting position, as shown in Figure 4. The user would then remove the sealed pad and continue on to the next one.

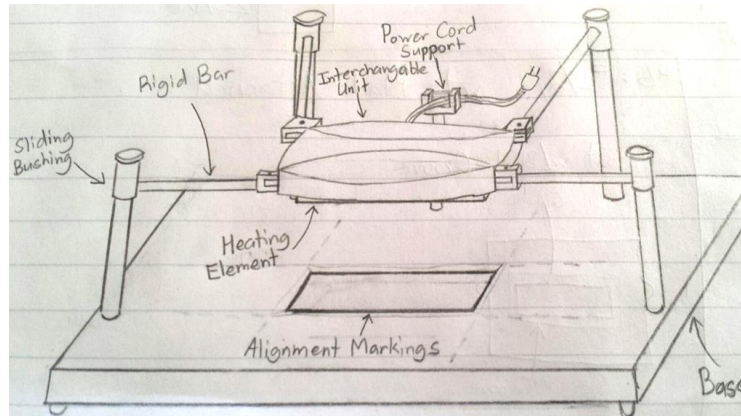


Figure 4: Diagram of Interchangeable Parts Vertical Press Concept

One of the main shortcomings of the previous design was the difficulty and excessive time required to align the pads. To address this area of concern, this design started by shifting the front two of the four support bars apart. This wider opening would allow a worker much more room to interact with the vicinity in which the layers and pads are organized without having to work around the support bars. The heating element was removed from the base of the unit to allow space for a new, easier alignment method. In the space where the pad would eventually be sealed, a very bright outline of the pad shape capable of being seen through the seal layers was placed. This new method would allow the worker to easily place the sealing components and visually confirm that they were in the correct location. In addition, this new design changed from sealing two pads at a time to sealing just one. Ideally, the time saved from having to position two pads at once would make the process much simpler and faster for the worker to carry out.

By reducing the number of pads being sealed from two to one, a variety of other design aspects would be improved. Because only one set of heating elements would now be used, the power requirement of the unit would be significantly reduced or more efficiently applied compared to the previous design. In addition, the current setup is very complex and cluttered, and reducing to one pad would make design, assembly, and organization much easier for the team and worker to deal with.

A key feature of this design is the interchangeable heating unit that could be swapped in and out by installing it into the four rigid bar attachments as shown in the drawing. This would be accompanied by an additional alignment outline that could be installed in place of the default rectangular markings. This would allow easy implementation of various heating units designed for various pad shapes that need to be sealed, such as the proposed winged design that will eventually be produced in greater quantities. This also allows the base components and heating

units to be separate entities, meaning that any potential replacements or repairs would not need to involve disabling the entire machine.

### **Press Down and Alignment Concept**

This design incorporates many elements from the semester 2 design. It has a push down mechanism in a square design. However, the heating elements were placed to the top to increase safety and maneuverability when aligning the layers of the pads. Also, the base of the machine has a depression indented into the base material, possibly of metal or hard foam. This depression rectangular hole is to help align the pad layers. Also, lines would be on the base as well extending past the size of the pad to allow for better alignment. The press down mechanism was just four vertical bars with bearings. The panel that pushes down contains the heating elements and control mechanism. A handle bar would be incorporated into the design to help push up and down. Also, this is a design that could be changed by replacing the depression portion of the base to a different shape and by using a different top press down panel to incorporate versatility.

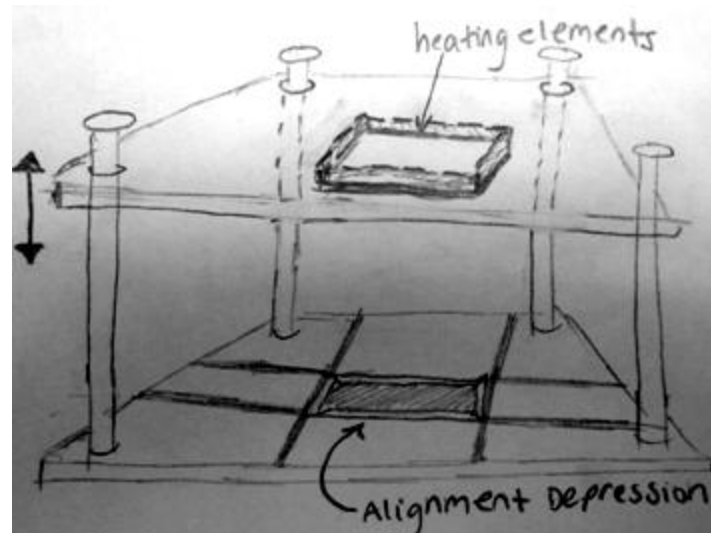


Figure 5: Diagram of Press down & Alignment Concept

This concept was also considered a “Reverse Panini press” because the semester 2 design was nicknamed the “Panini Press”. This concept is very similar from a vertical press down feature. However, the main differences are the heating elements were moved to the top panel, which then presses down onto the pad layers to seal. This increases safety of the worker by not having to lay pads down upon hot wires. This design is lacking an appropriate handle to easily move the top panel up and down. However it is a sturdy design that would likely produce consistent seals. There is a considerable weight reduction of the design as excess components are reduced. The main feature of this design is the depressed pad alignment area in the base of the design.

### **Versatile Manual Hand Held Concept**

This design, considered the “Extended Hair Straightener”, puts a new spin on the current product used in Uganda, however the key difference being the product is a handheld device and much smaller than what is currently used. This product works by loading the interior and exterior materials inside of the Straightener and then clamping down on the device once a high enough

temperature is reached, and then released once the product is finished. This product focuses on maintaining simplicity within the product, as this simple design is still very effective.

The main benefits of this concept are that a user can bring the product home with them and work on making pads on their own time, something that could potentially be extremely important for Ugandan women looking to earn as much money per MakaPad as possible. Furthermore, as shown in Figure 6 below, the Straightener has four sides that are heated at once, thus allowing for all four sides to be sealed in one stroke, a key design driver which we had to address. We were told by our sponsor to ensure that at least two sides of the MakaPad were sealed for every stroke, and this design accomplishes that.

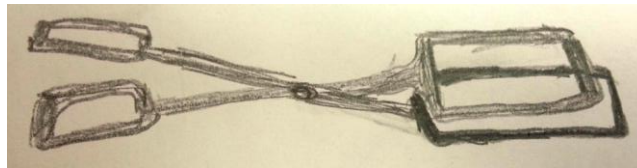


Figure 6: The overall view of the machine, which illustrates where the material will be held and the grip which is used to clamp down on the device.

The potential disadvantages of this design are that repeatability for each product may be slightly different, as the user has to manually load and hold the materials inside of the Straightener for every seal. This brings in human error, as a worker could very easily hold the MakaPad differently every time they load it into the device for sealing. Furthermore, since the user has to squeeze on the handle in order to close the device, error in pressure distribution between squeezes could cause different seals on the Makapads. This could be an issue, as someone who holds the device down for a short amount of time may not complete the seal and someone who holds the device down for too long could burn the material together and melt it.

## CONCEPT SELECTION

In order to compare our design concepts and ultimately select a final design, a Pugh chart was developed with a weighted scoring system (Table 2, Page 12). To create the chart, the user requirements and engineering specifications were translated into scoring metrics that would be used to evaluate the designs. The metrics were weighted on a scale from 1-4, where the highest priority metrics were assigned a 4 and the lowest priority were assigned a 1. Each metric was then evaluated on a scale from 1-5, with 5 being the best score and 1 the worst. After evaluating each metric for each concept, the scores were multiplied by their corresponding weight and summed to determine which design was the best.

The highest rated metrics corresponded to the highest priority user requirements: complete sealing, minimize power, operation time, and number of steps required to complete a seal. These focus on the actual performance of the machine and deal with measurable metrics rather than more subjective user requirements. The ability to achieve a consistent 100% seal over each pad is imperative for the success of any design. An important distinction was made between the two different parts of the process that account for operation time, seal time and alignment time. This is reflected in the chart where both time to align layers and time to seal are listed as metrics. Although their individual weights are 3 and 2 respectively, combined they account for a weight

of 5, which is indicative of the overall importance of operational speed in our design selection. Power minimization is paramount to success, as any prototype must be capable of operation at or under 300 W. Additionally, the number of steps required to complete a seal is important to the time and quality performance of the prototype. The top score in this metric could be received by designs capable of completing a seal in a single step.

Table 2: Pugh Chart Concept Selection weighted scoring system

Design Criteria	Weight	Continuous Feed: Semester 1	Panini Press: Semester 2	Press Down Alignment	Interchange Parts	Hair Straightener	Combo Concept
100% Seal	4	3	4	5	5	5	5
Time to Align Layers	3	2	2	4	4	2	4
Time to Seal	2	3	4	4	4	4	4
Minimize Power	4	2	3	4	4	3	4
# of Steps to Complete	4	4	5	5	5	5	5
Durability	3	4	4	3	3	3	4
Ease of Use	3	2	4	3	3	2	5
Operators Required	3	5	5	5	5	5	5
Minimize Force Required	3	2	4	3	3	4	4
Safety Risks	3	4	5	4	4	3	5
Minimize Cost	2	3	2	3	3	4	3
Minimize Space/Size	2	2	4	3	4	5	4
Consistency/Repeatability	2	3	4	3	3	2	5
# Pads Sealed per Operation	2	5	2	1	1	1	1
Manufacturability	2	4	3	3	3	3	3
Design Simplicity	1	4	3	3	3	4	3
Customizability	1	1	1	4	5	1	3
Maintenance	1	3	3	3	3	5	3
Total		141	165	166	169	157	186

The medium rated metrics (with a weight of 3) correlated to the medium ranked priority user requirements. These metrics include durability, ease of use, operators required, safety risks, and minimize force required. Because thousands of pads are produced daily, it is important that the design would be durable and able to withstand repeated use and abuse over a significant portion of time. The ease of use and minimize force required metrics both derived from the ease of operation user requirement. This is to distinguish between grading the designs both on the engineering specification of minimizing force and how easy the machine is to use. Ideally, the design would be easy to understand and have a very quick learning curve so that the workers in Uganda would be quick to learn the process and open to its implementation. The safety risks metric was graded by evaluating both the inherent safety risks of each design (i.e. burn, cut, or pinch points) and the ability of each to design to safely protect against these risks.

The lowest rated metrics (weights of 1 or 2) consisted of the lowest priority user requirements in addition to some facets of the design that were more important to the team's ability to create the prototype. These metrics include minimize cost, minimize space/size, consistency/repeatability, manufacturability, design simplicity, customizability, number of pads sealed per operation, and maintenance. Consistency and repeatability are important so that the final design can achieve a consistent and reliable seal quality, and considers how sturdy the concept is in addition to how much user variability is allowed. Manufacturability and design simplicity go hand in hand in addressing how feasible each design would be for the team to machine and assemble. These metrics were evaluated based on design aspects such as number of components, moving

elements, electrical components, materials, organization, manufacturing processes required, and many others. Customizability was included as a way to evaluate a concept's ability for potential adaptation to other seal shapes, alignment methods, and heating characteristics. Finally, the number of pads sealed per operation was included to reward designs that increased pad throughput and strived for near continuous feed.

After an initial evaluation of every concept generated, the team eliminated designs that were obviously infeasible or incapable of meeting the more important user requirements. Each team member selected what they believed to be their best concept, and the team as a whole generated a concept that utilized the best individual aspects of each design being considered. These four concepts and the benchmark designs from the previous two semesters were analyzed with the Pugh chart scoring method, and resulted in the team's combined concept receiving the highest score. By breaking down the scoring, it is evident that by selecting the best aspects of other concepts, this concept had no glaring weaknesses that the others possessed. The combined design scored a 4 or 5 in all of the high and medium weighted metrics while also receiving the highest score of all designs in the ease of use and consistency/repeatability categories. Overall, the well roundedness of the combined design led to its selection as the best design moving forward.

### Initial Concept Selection

The final design selected was the "Combo Concept", seen in Figure 7. This was a team generated idea that incorporated some of the best features from multiple individual concepts.

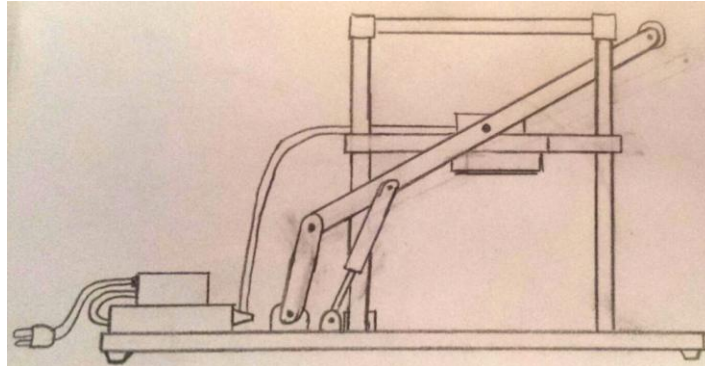


Figure 7: Diagram of final design selection "Combo Concept" from a side view

It features a four bar linkage system, including 2 gas struts to balance and support the ease of movement of the handle. The handle has been designed to not interfere with the moving heating panel that can be pressed down. When pressed down the heating elements attached to the bottom side of the moving panel will press down upon a base. On the base is a pad alignment location marked with red lines and a depression to set the pad layers. This alignment area, see in Figure 8, was included to increase speed of alignment and increase proper alignment of the pad layers when the heat press is pressed down to seal.



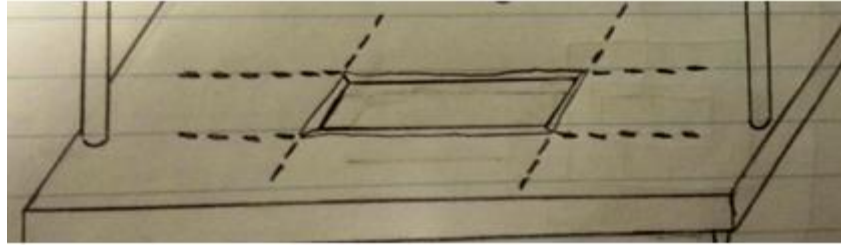


Figure 8: Diagram of final design selection “Combo Concept” from an above view of the base alignment depression area

The heating elements will be controlled with a power supply, timer, and switch; these electronics will be attached to the base on the backside of the design. The front shafts are spaced apart approximately 18 inches to allow for more room for the workers to reach into the machine to lay down the pad layers.

Placing the heating elements on the top moving panel instead of the base allows for safer and quicker access to the pad alignment area, therefore preventing worker burn injuries but increase production rate. In addition, by selecting a single load design this decreases the overall power needs of the system, and decreases the unit weight. Decreasing the power usage is essential to managing the effectiveness of the heat seal. Being concerned with only one pad heating at a time reduces complexity and our 300W power limit will be more attainable.

We found this design scored highest in the Pugh Chart concept selection stage and adequately meets the user requirements the best. We also conducted a sensitivity analysis by changing the weighted values of Pugh chart. The final concept selection came to be the same before and after the sensitivity analysis. The most important aspects of the chosen concept are that it decreases alignment time, seals all four sides of the pad with one stroke, and minimizes power usage.

## **KEY DESIGN DRIVERS AND CHALLENGES**

Current Design drivers started with needing to meet the user requirements and engineering specifications. We needed to choose a design that met a low power requirement, consistent 100% sealing of more than 1 side of the pad at a time, and easy to use at a fast rate. When it came to choosing our final design we looked at the method of heating. Pressing or rolling were the two most common heating design ideas. Rolling seemed optimal for continuous feed systems and pressing was more applicable to single feed. Our team decided that a pressing mechanism would suit our requirements best.

Also, we needed to decide what type of loading we wanted our machine to do. Would we use single, double, or continuous feed? The previous projects focused on continuous and double feed, but our team aims to tackle a single feed wanting to cut out the complexity of the design. Single loading will hopefully be easier to load and align the layers of the pad. Concerning the base, it will likely be made of metal, a thick foam, or rubber. There will be a small depth depression in the base the size of a MakaPad to allow for easier alignment of the layers. Also included will be lines stretching across the base for all four sides of the rectangular base depression to aid in placement of layers.

Our supporting structure needed to incorporate how to support the heating mechanism and the pressing mechanism. The suitable designs that came forward were various types of rods and vertical support beams with bearings, hydraulics, or springs. The design needs to be easy to press down with small amount of force to prevent fatigue in the workers. Therefore our approach will be to use a handle that can press down a panel onto a base to heat seal. This will be controlled by four bars; two hinge bars and two hydraulic cylinder bars. This is similar to the semester 2 design. Our aim is to make the opening wider for easier access to the alignment area on the base of the mechanism.

Heating elements are a great concern when it comes to the project. They need to be well controlled to not over or under heat. In the future some electrical work will need to be carefully evaluated to select and correct a timing mechanism. Past semester teams found this to be the most difficult and expensive portion of the project. If the heating elements are not selected properly the sealing of the layers could be too hot and burn holes in the layers or not burn enough and will eventually leak. Designing a mechanism to load only pad at a time will hopefully decrease complexity but also power. Utilizing Nichrome wires for heating seems the best option. More research will go into the specific type of wires. We aim to use a continuous Nichrome metal ribbon wire to reduce complexity and weight, but increase seal consistency. When considering power limitations on a single load one pad at a time method, this will be more feasible. The power to heat multiple heating elements may be difficult; therefore a single load heating mechanism will hopefully be easier to fall under the 300W power limitations. In addition we will look into incorporating a power supply for the design. We plan to incorporate a switch mechanism for the design. The switch will help control the timing mechanism of the heating elements. Controlling the heating for 2-3 seconds seems optimal to not under or over heat the pad. This eliminates the variability that would come with worker differences in length of pressing the heat elements.

Future challenges for the team seem to circle around the heating elements. Further research will be going into selecting and purchasing an appropriate product. In addition the electronics that monitor and control the heating elements may be difficult to customize and accurately find the correct power and time for the heating wire.

## **ENGINEERING ANALYSIS AND DESIGN DRIVERS**

When observing and analyzing the sealing process for the MakaPad, the main systems that contain the design drivers are the sealing completion, minimizing overall cost, and increasing the production rate. For these design drivers, we performed engineering analysis in order to analyze whether our design will work under the working conditions efficiently and effectively. The sections below detail this analysis.

### **Completed Seal**

After conducting the necessary research and consulting with our sponsors, Dr. Musaaazi and Dr. Asibu, we determined that having a 100% complete seal was the highest priority for our product. In order to create the seal, we have decided to use resistive wires, which will, when activated, melt the composite materials together. These wires will remain stationary on our design. We plan on using wires that are made by nichrome, which is a material that is widely used in heat-sealing



machines [21]. This material is ideal for our product because it has a high resistivity, and a low heating capacity, something that is crucial for a product like ours.

We used the CES EduPack in order to find an appropriate value for the thermal expansion coefficient, a key variable when determining the usability of this material. The thermal expansion coefficient for nichrome is approximately  $\alpha = 1.28 \times 10^{-5} \pm 0.125 \times 10^{-5} \text{ } ^\circ\text{C}^{-1}$ . We consulted with the previous ME 450 team that worked on this project last semester and found a reasonable value for the melting temperature for the outermost material as  $175 \text{ } ^\circ\text{C}$ . Also, we are able to assume that the wires will remain at room temperature in the Ugandan workplace as  $27 \text{ } ^\circ\text{C}$  [22]. Using this information, we calculated the thermal strain, shown in Eq. 1 below, as approximately:

$$\varepsilon_T = (1.28 \times 10^{-5} \pm 0.125 \times 10^{-5} \text{ } ^\circ\text{C}^{-1}) \times (175 \text{ } ^\circ\text{C} - 27^\circ\text{C}) = 0.189\% \pm 0.021\% \text{ (Eq. 1)}$$

Calculating the thermal strain allows us to account for the thermal expansion that will take place during the heating process, as well as potentially from the welding process if we chose to take this path. By welding the nichrome wires together, we would be able to create our own continuous circuit without stretching our budget past our limitations. A potential problem that we foresee during the welding process is the wires expanding past their limitations and causing permanent deformation. This would render the wires useless, and thus we plan on testing the ability of welding nichrome wires through several trials before we implement it in our final design.

We experimentally, as well as through consultation from both previous teams, were able to find the expansion in the nichrome wires, to ensure our model would be a feasible design. We were also recommended to use a wired circuit for our design that was already connected and wired, because the previous team found wiring themselves to be extremely difficult and challenging. In our system, a wire that is 75 mm in length, with a width of 2.5mm and a thickness of 150  $\mu\text{m}$ , under tension, would look fairly similar to the circuit shown in Figure 10 (pg. 17).

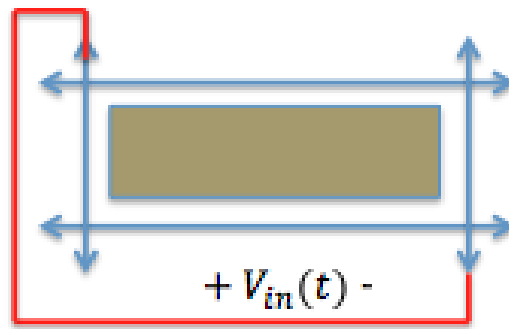


Figure 10: An illustration showing our current wiring setup for our design, with red representing the wiring and blue representing the heating elements.

In this design, each wire would be individually placed over the other wires, essentially creating a forced circuit. Since the wires would be touching, the circuit would be complete and fully functional. Excess heating at the four corners, where the wires overlap, is a potential problem,

however we plan on implementing a timing mechanism which will allow the user to remove the top plate once the seal is achieved.

Due to budget constraints, as well as practicality issues, we were unable to order a continuous fed nichrome wire. Thus, we plan to move forward with the individually circuited system, as shown in Figure 10.

This setup will allow us to seal one MakaPad at a time, and avoid any unnecessarily complex arrangements. Furthermore, in order to better understand how the temperature at all points of the wire fluctuates, we approximated the wire temperature at Voltage increments from 0 to 12 Volts, held for approximately 2 seconds. We felt as though this time interval would be an appropriate amount of time to simulate the heat press time while pushed down. With this setup, there is a slight variation in temperature at different points in the wiring, but with a circuited model, we feel comfortable that the temperature in the wiring will safely reach the 175 °C minimum needed to complete a seal.

### **Minimizing Cost**

Since our product is being used in an environment where natural products are mostly used, having a reasonable budget is extremely important and necessary for our design. Cost is an important design driver for almost any product, however especially for ours due to these circumstances. Since our product will be able to achieve a complete seal, as shown in the previous sections, as well as increase the production rate, we are comfortable with the tradeoff associated with implementing a new product vs. the cost of implementation. Though there is a cost associated with producing and implementing a new product, the increase in production will minimize this issue as well as potentially make a profit for the workers.

After our team member Carlea Hazzard visited the workplace in Uganda, we became more confident in this approach, as she brought us back feedback from the workers, who seemed comfortable with dealing with these applications. Though they seemed somewhat apprehensive with learning a new machine that dealt with several automated parts at once, after demonstrating how our mechanism would work, their opinions were altered.

We also began recycling old materials from the previous ME 450 teams to ensure that our individual cost of our product did not exceed the \$400 limitations placed upon us. We were able to re use four shafts from the previous team as well as leftover nichrome wires for our own testing. This was extremely helpful and beneficial as we were able to get a better understanding of the material properties of nichrome before final design testing and implementation. Due to the overwhelming cost of ordering a full circuited wire, this method was the most ideal.

### **Production Output Rate**

One of our biggest specified goals with our project was to increase the current production rate by approximately 50-100%. To accomplish this, we need our prototype to produce at least 6 pads a minute to safely reach this goal. The steps that are involved in the full sealing process are placing the interior and exterior materials together, placing them onto our prototype, pressing down to create the seal, and then finally removing the product once it is finished. This does not take into account the cutting process, however we are primarily concerned with just increasing the sealing production output rate.

In order to simulate the cooling/heating of the wires, which is the primary issue regarding the speed at which the MakaPad's can be loaded and unloaded onto the mechanism; we created a simulation using COSMOL Multiphysics. We did this in order to find the temperatures associated with input voltages that are given into our system. The wire that we used in our simulation was a nichrome wire, and the material that we chose as the base material was teflon. We chose to use teflon due its high electrical resistivity as well as from a recommendation from the previous ME 450 Team. Teflon will be able to withstand temperatures much higher than what we anticipate facing. On top of this teflon surface, the material, which we used to simulate the outer sealing material was a thermoplastic film, which we felt was an acceptable representation of what we will be using with our prototype. This material was chosen to be polyethylene, because of its current use in the market in heat-sealing devices. Figure 11 below gives an image of what our simulation looked like in COSMOL Multiphysics.

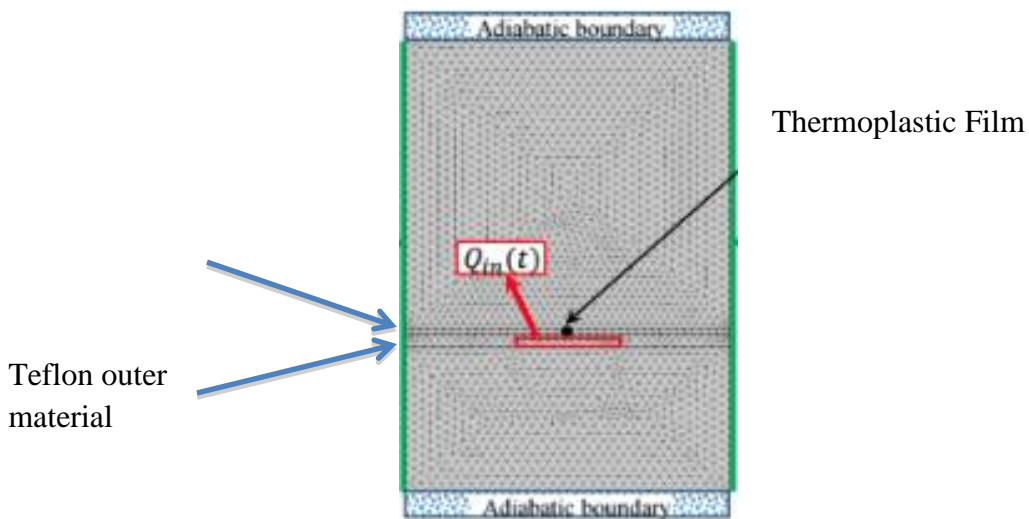


Figure 11: An image of the cross section from COSMOL Multiphysics, where the green represents the sidewalls, and  $Q_{in}$  represents the temperature of the outside material.

The temperature that we measured to determine appropriate conditions was measured from the red block,  $Q_{in}(t)$ , in Figure 11.

After identifying the necessary characteristics to all of the material in our simulation, we decided to find the time it would take to go from the ambient temperature of  $27^{\circ}\text{C}$  to the temperature needed to create the seal,  $175^{\circ}\text{C}$ . The equation that represents the surface heat flux in order to find this value is:

$$Q_{fc} = h(T_a - T_b) \quad (\text{Eq. 1})$$

where  $h$  is the heat transfer coefficient for free convection,  $T_a$  is the ambient temperature, and  $T_b$  is the temperature at the outer side of the wall. It was crucial that we found the surface heat flux because it gives us an understanding of the rate of energy transfer that will take place through our surface. We used  $h = 5 \text{ W}/\text{m}^2\text{K}$ , which we found as a reasonable value. After representing the necessary variables and assigning proper conditions, we used simulations of voltage pulses of

27 Volts, for application times of 1.7 seconds. We took note of the output temperatures during this time, for a full cycle of approximately 10 seconds. Taking note the time when the temperature reaches over 175 °C, and when the temperature cools below dangerous levels for humans to touch. After conducting this simulation, we can safely say that we will be able to reach our goal of at least 6 pads a minute. This is a reasonable expectation because in a 10 second cycle, the sealing temperature is reached, as well as the safe temperature where a human being can feel safe putting their hands in between the system. 10 seconds is a fairly safe expectation as well, and we believe that a higher rate than this will be possible without neglecting safety for the workers.

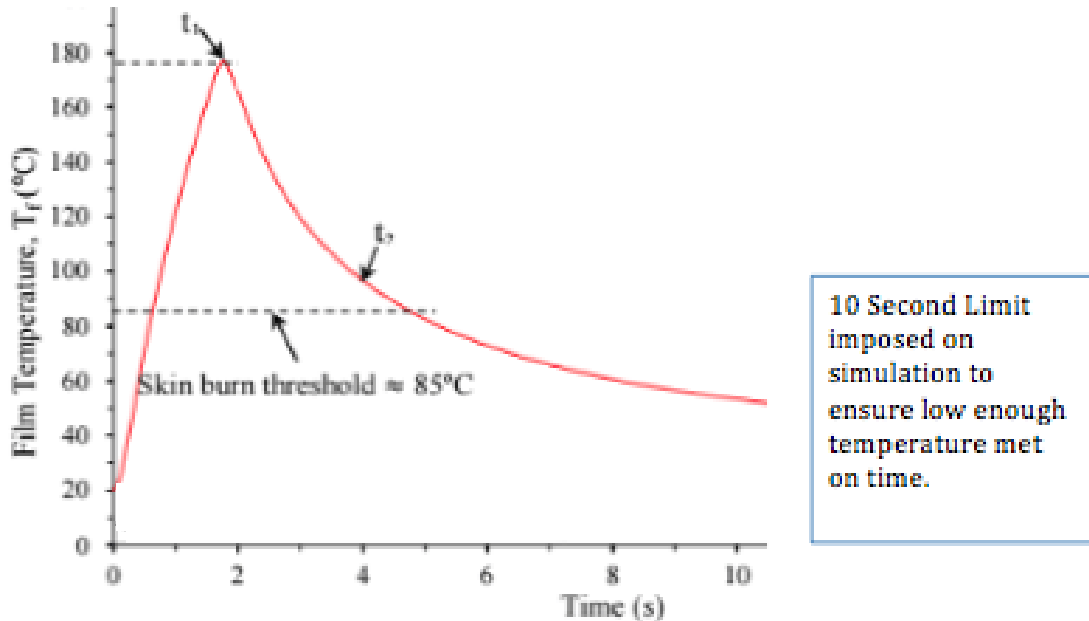


Figure 12: A representation of the temperature variation that will occur over a 10 second period of time from a voltage impulse, similar to what will happen in the working conditions.

As can be seen by this graphic simulation, the melting temperature can be reached in an extremely fast amount of time, (approximately 2.3 seconds), and then the temperature slowly decreases to an acceptable temperature where the worker can safely adjust anything on the prototype. A safe temperature of 85 °C was determined from the International Organization for Standardization [23].

Conducting this analysis allows us to be comfortable with operating on our mechanism at the rate that's needed to achieve our goal of increasing the production rate. Solely based on engineering analysis, we are comfortable with claiming that increasing the production rate by 50% will be met due to this. Though we have not practiced physically loading and unloading the Makapads on our design, once familiarized with this process we will be able to achieve this goal.

### Failure Modes and Effect Analysis

In order to determine potential risks that may be involved with our design, we performed failure modes and effect analysis on our system. We have attached the full table with our analysis in Appendix B. The four main systems that we have decided to analyze are the sealing plate, the support structures, the linkage system/handle, and the wiring assembly. We went into further

detail about the functions of each system in relation to our entire product, as well as potential means of failure that could occur for each system. We also identified and assigned numerical values for the level of safety or lack of safety for each system. In order to do so, we analyzed the impact of failure for each system in relation to the whole mechanism.

In order to generate appropriate values for the risk associated with our mechanism, we assigned numerical values to each part on a 1-10 scale, with 1 being not severe and 10 being the most severe situation. Table 3 below details the breakdown that we used in order to determine what numbers we assigned to each situation.

Table 3: Ranking scale that we used to rate the severity of potential failure modes

<b>Product/Category</b>	<b>Severity on Effect/Product</b>	<b>Rank</b>
<b>Safety Regulations Not Met/Severe Injury Risk</b>	Potential failure affects can occur without warning	10
	Potential failure affects can occur with warning	9
<b>Primary Function Loss</b>	Primary function is lost	8
	Primary function stops working properly	7
<b>Secondary Function Loss</b>	Secondary function is lost	6
	Secondary function stops working properly	5
<b>Functionality Annoyance</b>	Few workers annoyed by product malfunction	4
	Some workers annoyed by product malfunction	3
	Many workers annoyed by product malfunction	2
<b>No Issues</b>	No effects	1

After assigning these values, we made another table that ranked the probability of occurrence for each failure mode. This was important because some issues could be forecasted to occur more frequently than others, and creates a more reliable scale when calculating the R.P.N. Our scale was from 1 to 10, with 1 being highly unlikely to occur and 10 being extremely likely to occur. Table 4 below illustrates the key that we used to determine these occurrences.

Table 4: Grading scale to determine likelihood of failure occurring

<b>Probability of Occurrence</b>	
1	Very unlikely
2 to 4	Small chance at failure
5 to 6	Moderate chance at failure
7 to 8	High chance at failure
9 to 10	Almost certain chance at failure

Finally, we created a table to determine the likelihood that we would be able to detect failure if it took place. Our scale again was from a 1-10 scale, with 1 being extremely likely to determine failure and 10 being almost impossibly likely to determine failure. Table 5 (pg. 21) illustrates these values.

Table 5: Ranking scale used to measure possibility of detecting failure modes

<b>Failure Detection Probability</b>	
<b>1</b>	<b>Almost certain</b>
<b>2</b>	<b>Very high chance</b>
<b>3 to 4</b>	<b>Moderate chance; few customers notice defect</b>
<b>5 to 6</b>	<b>Moderate chance; customers notice defect</b>
<b>7 to 8</b>	<b>Low chance; customers will most likely notice defect first</b>
<b>9 to 10</b>	<b>Almost no chance user detects prior to customer</b>

After assigning these respective values to each table, we multiplied all three numbers together for each potential failure to create a Risk Priority Number. RPN's with fairly low numbers are risk's that we are acceptable and less concerned with, and risks that are greater than 90 are risks that we are more concerned with.

In order to fix the issues associated with high RPN numbers, we proposed a variety of solutions that could alleviate these issues. In order to make sure there is a great enough clearance with the sealing plate, we proposed to install a stopper system that will regulate the motion of the plate. In order to ensure our mechanism will function under the maximum allowable force, we proposed/implemented a large enough lever arm which reduces the total amount of force needed to pull down the plate. To ensure the mechanism will operate smoothly, we proposed to use bearing and oil the joints regularly to lessen the friction between parts. These full results are shown in Appendix B, Table 1.

Overall, our mechanism does not foresee any major issues with performance and static issues. The main issue that we are concerned with is safety for the Ugandan workers. This was a major concern during our Engineering Analysis as well, as we ensured a low enough temperature was met to not burn a workers hand during the sealing process. We ensured that the wires in our

heating system will be guarded properly, and not left on for extended periods of time with the timer, and this will be a preventative measure for the works. A timer system, which turns on/off the voltage impulse, will be implemented in our design, and this will alleviate any issues with our wire overheating and a worker getting badly burned operating the machine.

## FINAL DESIGN

After conducting the engineering analysis, assessing the design drivers, and constructing the mockup, we developed a preliminary prototype design using SolidWorks CAD modeling. This model, shown in Figure 13 below, was presented at Design Review 3. After gathering feedback from teams and instructors during the review and additional feedback from Carlea's Uganda trip, we assessed our model and made many changes to the design that we believed would improve the prototype. This section will detail the final model and some of its key features in addition to the challenges that our team anticipates as the final design progresses.

### Previous Design Iterations

The model of the design iteration #2 for Design Review #4 is shown above in its entirety in Figure 13. While some of the electrical components are approximations for design purposes, all of the major mechanical and positioning aspects have been designed. The key features of the design can be broken down into three general categories: alignment/assembly method, force application, and heating element. This design was attempted at manufacturing however once assembled the design did not function as well as we hoped. We ran into binding issues in the linear sleeve bearings and the force to overcome the gas struts proved to be too much to press down without the mechanical advantage of the linkage-handle system. These concerns and difficulties with the design once built led the team to retrofit the design and edit features of it to improve the overall motion. This led to a third and current design iteration that was presented at the Design Review #5.

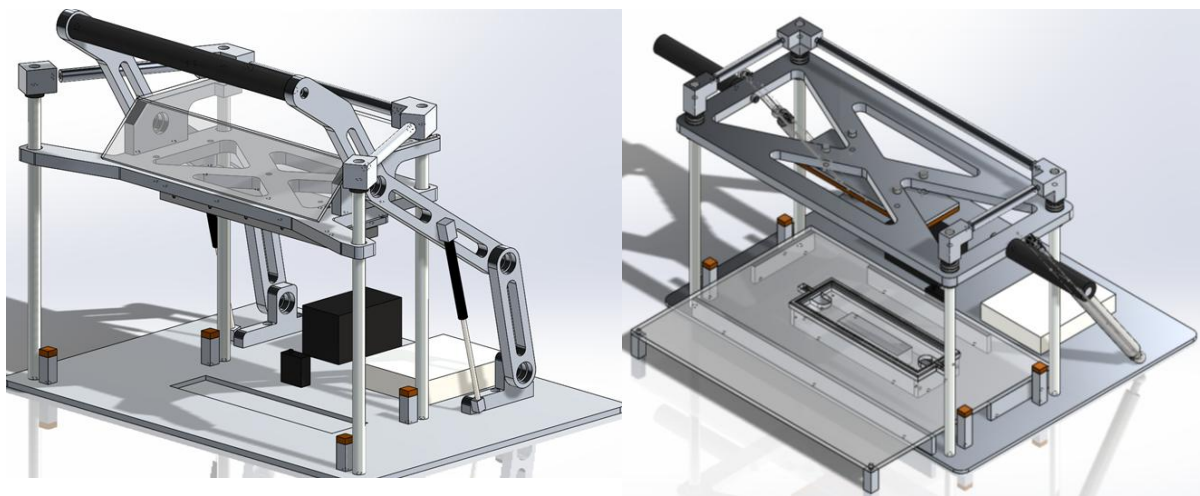


Figure 13: Initial prototype design presented at Design Review 3 (left) and design iteration #2 presented at Design Review 4 (right).



## Final Design

The current design that has a manufacturing model is pictured below in Figure 14. This design has some design changes that can be viewed in further detail in Appendix F, where there is a compiled list of engineering change notices. The current design features an alignment method, force application apparatus with a linkage-handles system, and an electronic heating element portion of the design. Major changes in the design between DR4 and DR5 consisted of switching the handle bars from the side to moving to a linkage system with handle bars placed in the front which the user can push down. In addition there were small dimension changes that had to be made to a few components due to application of rubber and Velcro to make the design more accessible and user friendly. Adjustable support bars going across the top of the design were manufactured but unable to finish due to the unavailability of a left handed tap for a ¼-28 hole in order to ensure the bars be adjustable. Fortunately, the university machine shop recently acquired the tool and this will be finished and applied in the final design for the Design Expo.

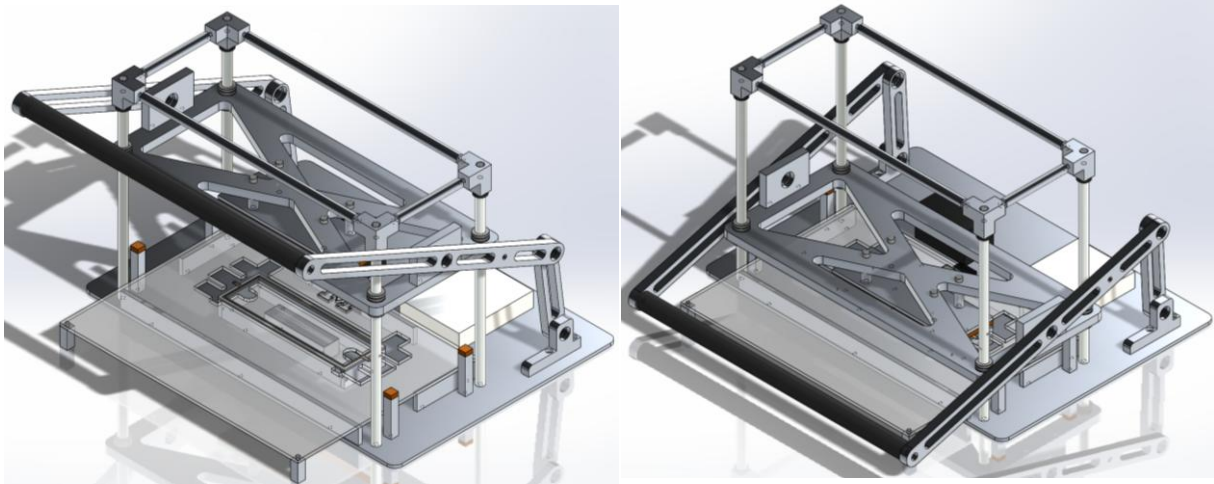


Figure 14: Model shows the prototype in its fully raised starting position (left) and fully compressed sealing position (right). Labeled are the [1] assembly plate, [2] force application apparatus, and [3] heating element.

The alignment method was designed to be very simple, user friendly, and efficient, and this is reflected in the design, as seen in Figure 15. There is a raised assembly plate made of acrylic that surrounds the heating element and is almost flush with the heating element. The purpose of this plate is to allow the user to assemble the layers to be sealed in front of the machine. Once the layers are ready, they can be easily slid into place inside of the heating element. There is a slightly lowered support plate inside of the heating element, so that when the pad slides into place the user can quickly visually and physically confirm it is in the right place. These acrylic plates will be simply attached by velcro to their supporting components, allowing for easy access to the components below for maintenance and anything else if necessary.



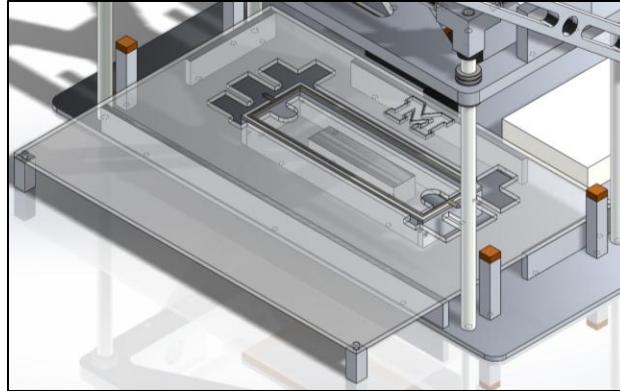


Figure 15: Alignment/assembly method and heating element

The force application apparatus is shown in Figure 16. Four vertical chrome plated shafts are connected to the base plate and press plate, which is capable of sliding up and down the shafts within its boundaries (hard stops at top and bottom). The sliding mechanism is a linear sleeve bearing on each shaft, which allows for low friction and low maintenance sliding. A short handle attached to linkages that are attached at the side center of the press plate covered with a rubber grip is attached to the center on either side of the press plate in order to greatly reduce manufacturing while still minimizing any torque that the system might produce. The gas struts, attached on either side to the base and the linkages near the handle, are important in allowing the user to maintain location of the press plate when they are not applying force so that it does not slip and create safety issues. By applying vertical forces to the handle, the user can press the unit down, seal the pad, and restore it to its initial position to begin sealing the next pad.

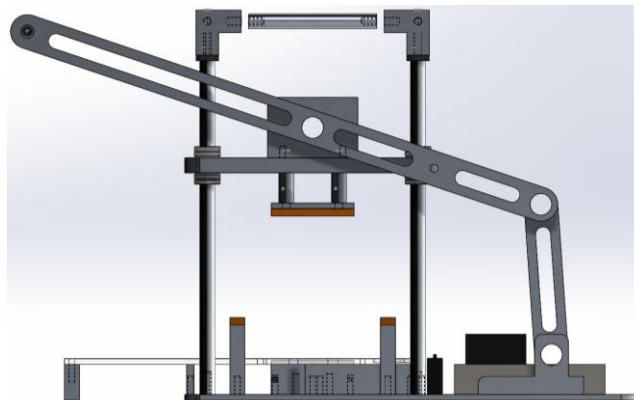


Figure 16: Force application apparatus

The heating element, in Figure 15, consists of a number of components installed underneath the assembly plate on the base of the unit. The four straight Nichrome wires are covered by a protective layer of Teflon cloth, which is then secured to rectangular aluminum support. The decision was made to install the heating element on the bottom of the plate as a result of multiple factors, including ease of manufacturing, ease of maintenance, fewer moving components, and user input from the workers in Uganda. The Teflon cloth layer effectively holds the wires in place and prevents the plastic layers being sealed from melting and sticking to the wires. In addition, there is a sensor at the bottom of the plate that will be activated when the system is in its fully compressed position. The sensor activates the heating element for the specified amount

of time, allowing for consistent, quality sealing. If in the future it is desired to expand capabilities to include different pad shapes (i.e. wing shaped pad) that must be sealed, then one can simply develop a new nichrome wire shape and install the new components to the machine base plate. A new assembly plate could then simply be laser cut to fit the new pad shape. This allows for quick and easy replacement and customizability without manufacturing an entirely new machine.

### **Current Manufactured Prototype**

As stated previously, the manufacturing of the DR5 model design was educational and enlightening. The current design manufactured can be seen in pictures of Figure 17 below. The majority of the parts were manufacturing the machine shop using a mill, lathe, drill press, saw, water jet, and laser cutter.

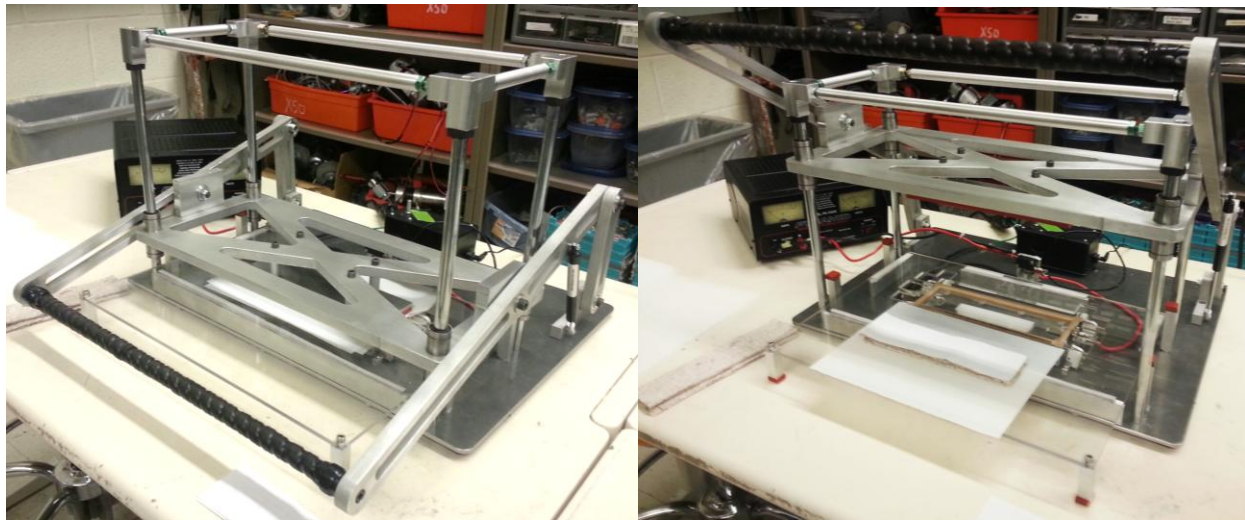


Figure 17: Photos of the prototype with the assembly plate in the pressed down position (left) and the upright position (right)

## **VALIDATION**

In order to verify that our machine met the necessary user requirements, we set up tests to ensure that these design drivers were met. The three tests that we conducted to validate our user requirements were an alignment time test, and a force/operation test, and a sealing completeness test. The following sections detail the testing that we conducted and the results of our analysis.

### **Alignment Time**

In order to ensure that the end result of increasing production was met, we knew it was crucial that the pads could be loaded onto our machine in an adequate amount of time. To reach our goal of increasing production from around four pads a minute to six pads a minute, we would need to load at the very minimum one pad every ten seconds. We conducted a time study to ensure that this goal could easily be met. In order to test the amount of time needed to load the pads on to our machine, we had all three team members perform the loading/unloading phase, and then extrapolate the time to a minute to find the time needed. The alignment test included lining up all the layers of the Makapad, placing the Makapad onto the sealing station, and removing the pad

from the sealing station. Our teams time to align the Makapad was approximately 11 seconds. From this time, we calculated that our alignment time for one minute would be 5.45 pads per minute. This is an improvement from the method used today, however based on this approximation we do not meet our goal of six pads a minute. However, due to us not being as experienced with aligning the pads in our hands prior to placing them in our mechanism, we think with more practice that we will meet our goal of six pads a minute. We plan on re-testing the alignment time in the upcoming days until we meet our goal.

### **Force/Operation Test**

In order to determine the required force needed to press down our mechanism, we plan on using force gauges to determine the downward force, in newtons. The maximum force that we were allowed was 50 newtons, a reasonable force approximation for women in Uganda to be able to apply. We conducted a test and found that it only required 1.33kg to pull the handle down, which corresponds to less than 15 newtons.

### **Completed Seal**

Having our product create MakaPad's with a 100% complete seal is the most important specification that we needed to meet. Having unsealed sides could lead to leaking when being used, as well as uneven sides that would cause discomfort for the user.

In order to validate whether our machine creates pads that are completely sealed, we sealed ten pads of our own, and determining qualitatively if they are properly sealed or not. We assessed each one individually, taking note of the quality of seal on all four sides including the corners. Adjustments based on the effectiveness of the seal will be made using our timing mechanism, which determines how long the voltage is applied through our system. If we are not satisfied with our results, we will make changes to the heating time and make iterations until we are satisfied with our results.

The completed seal effectiveness was approximately 95% sealed for the pads. This is due to overheating in the corners of the pads where the wires overlap creating a 'hot spot' along the wires. Extra Teflon tape was applied to the corners to prevent the overheating however we found results to be inconsistent. Unfortunately, we were not able to achieve the 100% complete seal for all our tested heat sealed pads.

### **FUTURE RECOMMENDATIONS**

Currently a power supply from the University of Michigan Mechatronics Lab has been utilized for the powering and control of the heating elements. However, a smaller more appropriate power supply has been purchased to be placed on the base plate of the machine. A power supply was purchased to send along with the prototype to Uganda to allow for live testing. In addition, if multiple machines were to be manufactured we would suggest using a single loop nichrome band heating wire element. Using a continuous heat band would eliminate any inconsistent or overheated areas when sealing.

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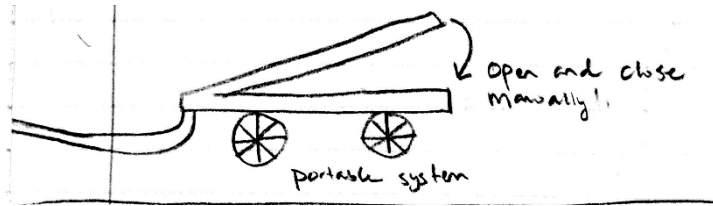
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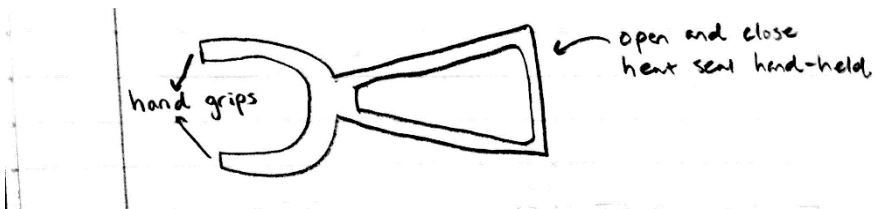
## APPENDIX A: ADDITIONAL CONCEPTS

1.



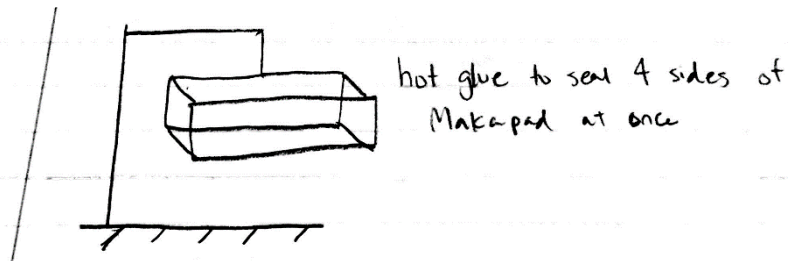
This design is fairly similar to the current product used in Uganda, however the main difference being wheels attached to the bottom of the mechanism to allow for easier maneuverability during the sealing process to turn the product around.

2.



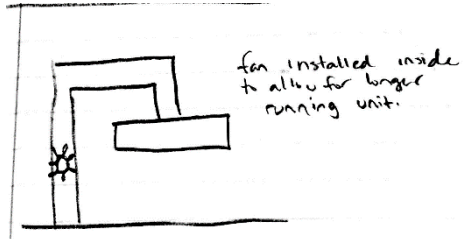
This device uses a handheld grip in order to have a device that can be used as a modified hair straightener to seal the MakaPad.

3.



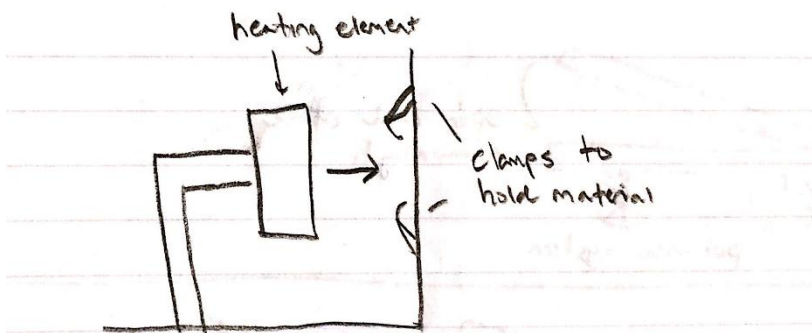
This device uses a four sided hot glue seal to press down on the MakaPad in order to seal it in one stroke.

4.



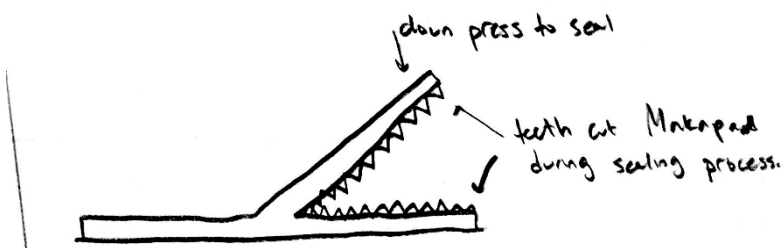
This device has an installed fan inside of the mechanism, which allows for longer continuous running due to the fan keeping the entire system cooled.

5.



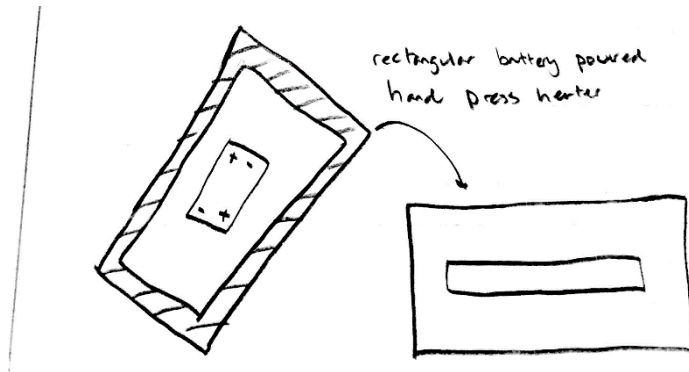
This device horizontally presses the MakaPad in order to seal it, and holds the MakaPad material on grips, which are attached to a vertical plate next to the product.

6.



This device combines both the sealing and the cutting process into one, thus taking one step out of the entire system. The clamp is pressed down and heat seals while the teeth cut the material.

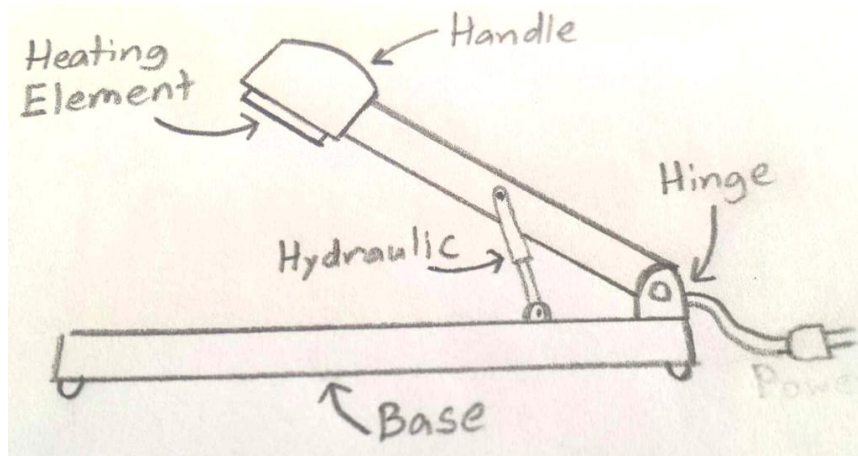
7.



rectangular battery powered  
hand press heater

This device looks similar to a handheld board eraser, as it is battery powered and the user manually presses the piece onto the material in order to seal it.

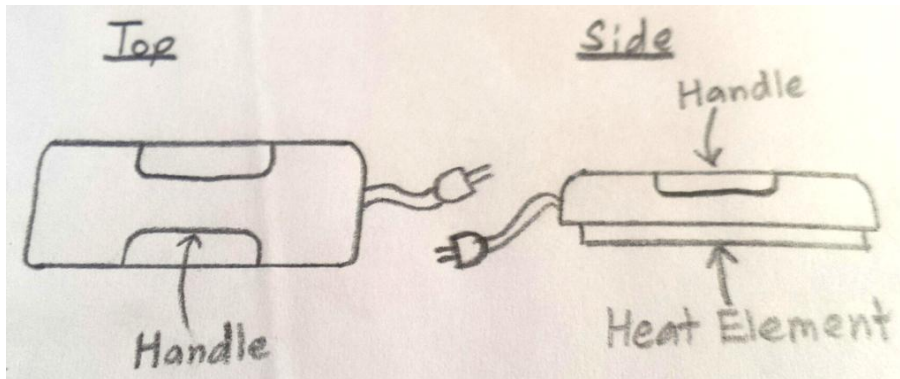
8.



*Single Pad Hinged Press:* A heating element capable of sealing an entire pad at once is attached to the end of a hinged bar, allowing the user to push the unit down and seal a pad aligned using markings on the base. Hydraulics/springs would automatically lift the unit back up.

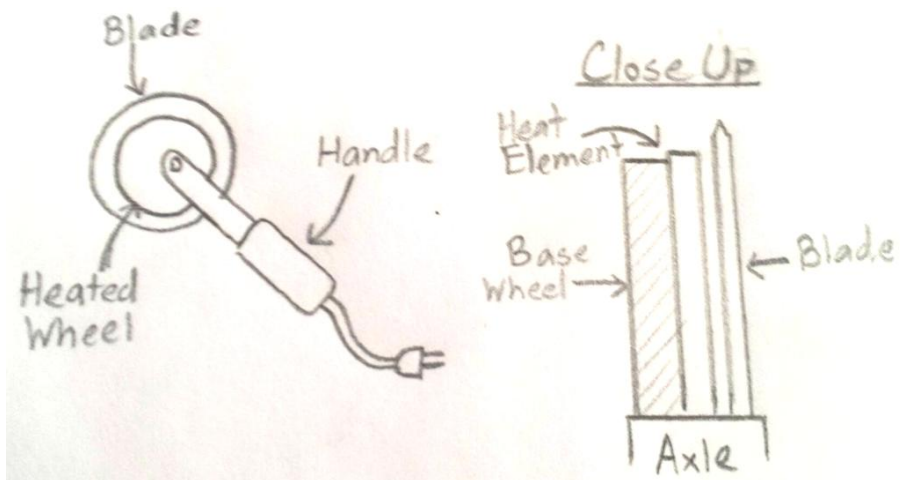


9.



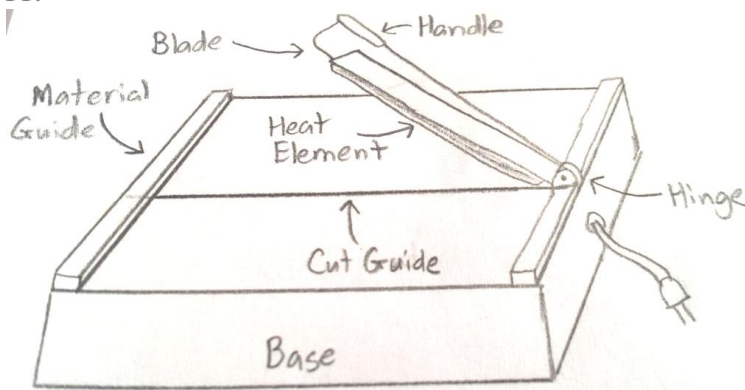
*Handheld Heat Press*: A single handheld unit with a protective handle on top and the heating element on the bottom. The user would place unit over pads for sealing and press down.

10.



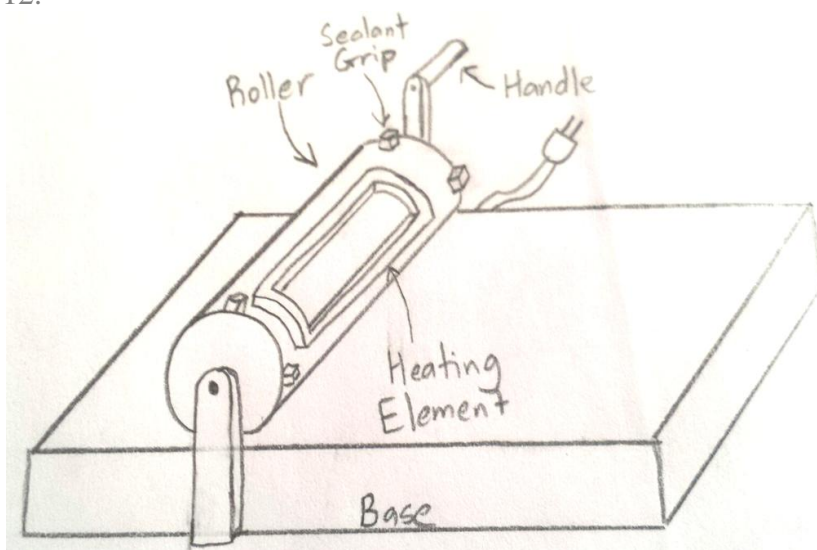
*Heated "Pizza Cutter"*: A handheld design based on a pizza cutter, the user would be able to heat the sides around the pads while simultaneously cutting the excess material.

11.



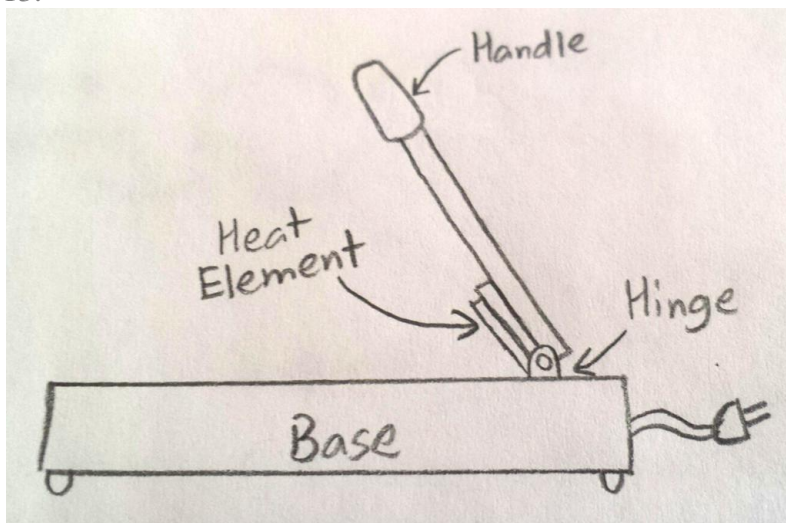
*Heated Bar with Blade*: Similar to the current heating bar being used in Uganda only with a blade attached to simultaneously cut through the center of the sealed area to increase production by eliminating the separate cutting stage.

12.



*Continuous Roller:* A wheel with multiple heating elements on it would be manually cranked, gripping the seal material and pulling it and the prearranged pads through to be completely sealed.

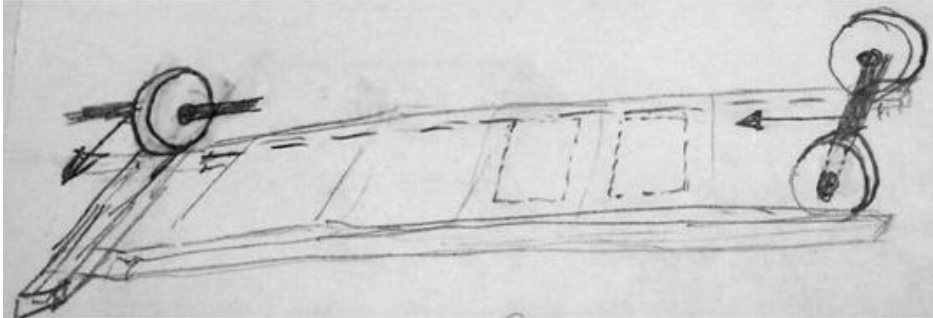
13.



*3 Sided Overlap Press:* This concept would require only one layer of seal material by folding the excess over a pad and sealing the other 3 sides. This would eliminate the need to seal the 4<sup>th</sup> side and will be a more secure.

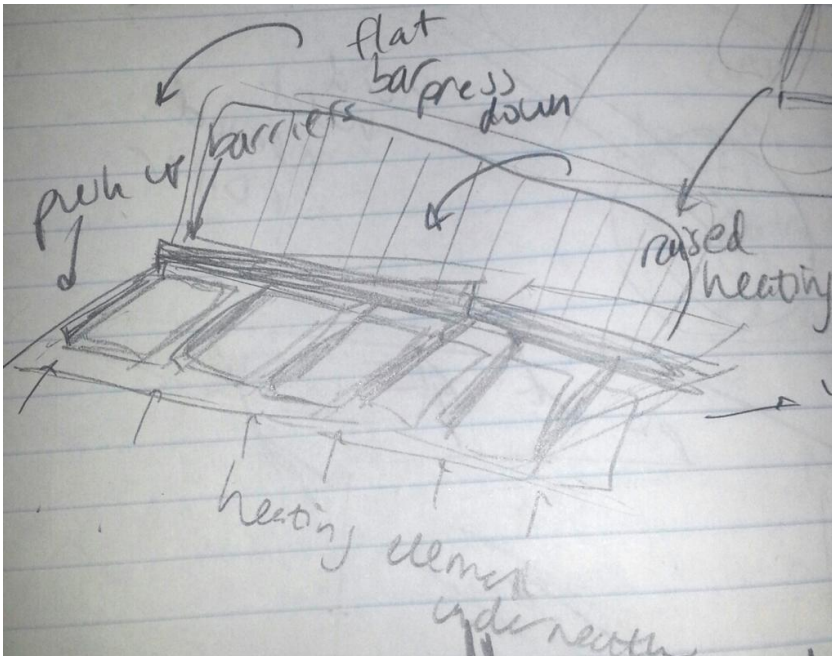
14.

### Rolling Mechanism Concepts



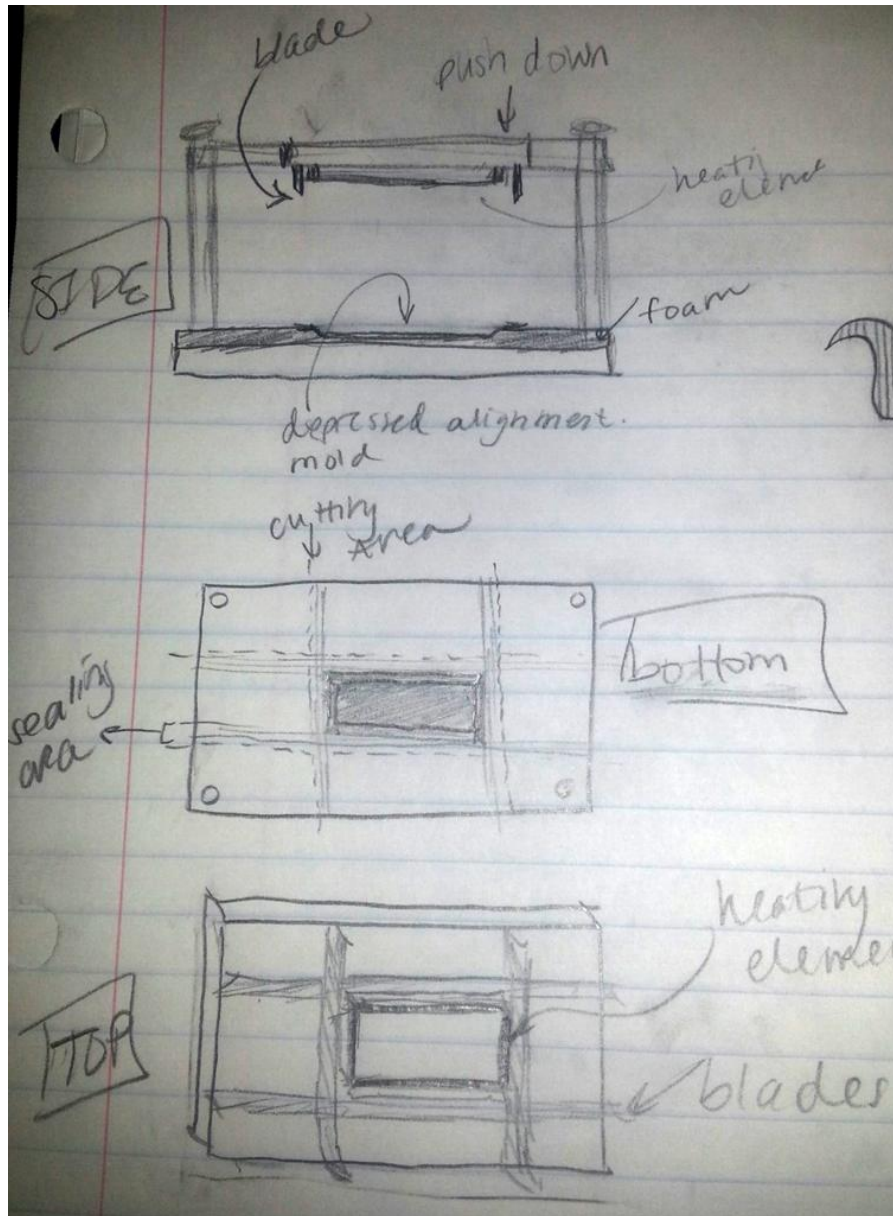
“Continuous Roller Rails”: This design was for a **continuous feed**. Once the layers had been put together you would pull the aligned layer roll through the mechanism for about 6 to 12 pads depending on how large the design needed to be. The long rail rollers would heat seal as the roller pressed down and the rails were long heating elements below. There would be a roller on both long edges that would seal about 12 pads on the long ends. Then, the rest of the feeding material would be pulled through and a third wheel would roll on a rail so that we could heat seal between each individual pad on the roll and therefore get all sides of the pad sealed.

15.



A multi press heat sealer clamp with heating elements on the bottom. Has a hinge mechanism for the heating clamp that presses down on the pad edges.

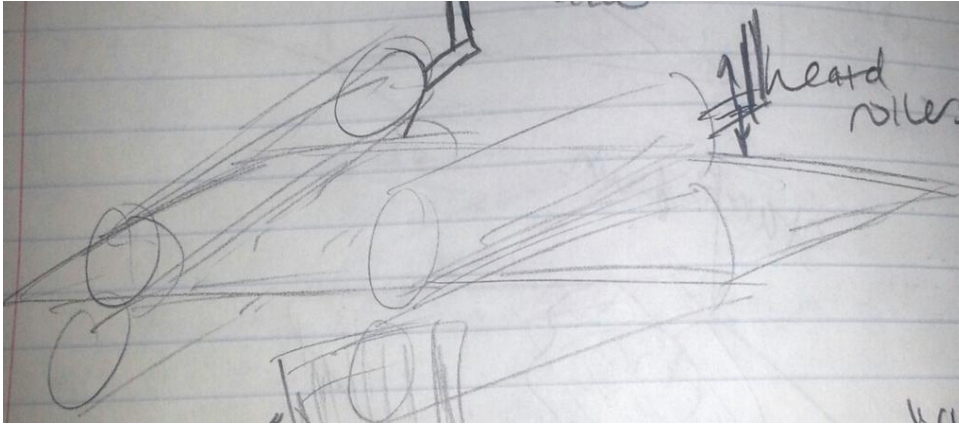
16.



This design incorporates sealing and a cutting mechanism. It follows the similar press down method of other designs. A panel with heating elements on top is pressed down on top of pad layers. The pads are placed on the bottom panel in the alignment area which are located by lines and a depression. Then there are blades that are on the top panel that cut the edges of the pad when pressed down.



17.



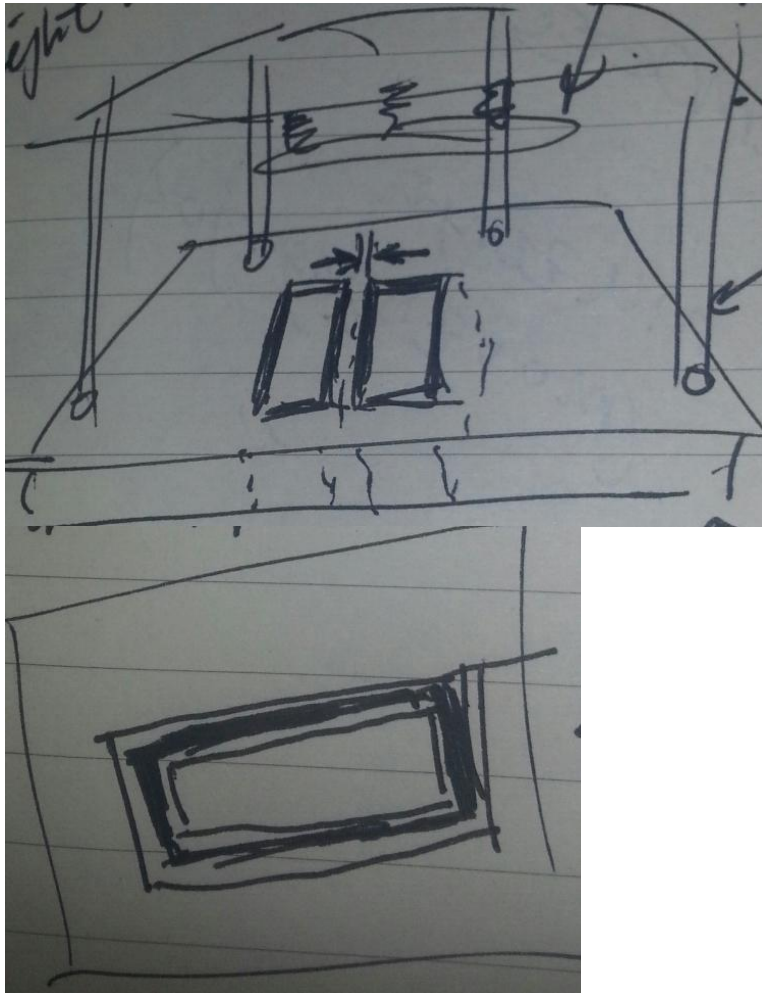
This design is for a continuous pad feeding design, so that the layers of the pads are continuous rolls of materials fed into the machine. The machine has heated rollers so that when the material is fed through, the rollers heat up and seal the pad layer.

18.



This design is for a single pad at a time. This incorporates a press down mechanism with the heating mechanism on top. The press down panel is attached to a rotating mechanism that lifts up and down when pressing the heating elements to the pad layers on base.

19.



This design incorporates a press down mechanism with a spring loaded press down panel with heating elements on the bottom base layer. This can do two pads a time for each press. The bottom panel with the heating elements also includes an alignment depression zone for the pad layers to be placed. Also the surrounding area of the panel around the base is brought up to the same level as the heating element height to allow for ease of pad layer alignment and sliding.

## APPENDIX B: FMEA ANALYSIS

Table 1: FMEA analysis and ranking of potential failure mode

Item and Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Control(s)	Detec	R.P.N	Recommended Action(s)	Responsibility & Target Completion Date
<b>Sealing Plate</b>										
Clearance of less than 10 mm when shut	Clearance greater than designated value	Risk of Injury during operation	9	Clamp stops do not properly protect from injury	4	Place a stopper to hold sealing plate	3	108	Install the stopper system to have a motion that does not allow for concern of injury	C. Hazzard: 3/10/15
Operate Comfortably & Smoothly	Too much friction in between parts	Motion will not be ideal	7	Sticking between joints that are moving	5	Use bearings/oil joints regularly	4	140	N/A	
Less than 50N Operating force	User cannot press mechanism down with more than 50 N	User will not be able to operate properly	8	Bad design for lever arm	4	Force analysis to test force needed	3	96	N/A	
<b>Support Structures</b>										
Support provided for Sealing Plate	Structure fails under stress/deforms	Sealing plate cannot open/close properly	6	Material yields /folds under immense stress	4	Select appropriate materials to handle conditions	2	48	N/A	
<b>Linkage System/Handle</b>										
User can operate machine properly	System too large for user to maneuver	User cannot operate the machine	5	Bad Design	2	Size limitations for parts/overall design	2	20	N/A	
Sealing plate moves up/down	Linkage doesn't allow for ea	Difficult for user to operate	3	Linkage not formed correctly	3	Bearing Installation/AD AMs analysis	3	27	N/A	
<b>Wiring Assembly</b>										
Power consumption minimized	Power consumption of 300 W exceeded	Machine won't operate in Uganda	8	Too much current passed through wires	3	Testing to see power needed to seal with Nichrome	3	72	N/A	
User safety	Wire guarding is not properly done	Heating elements too hot for user to touch	7	Guarding not installed properly	6	N/A	2	84	N/A	
All 4 sides sealed completely	All sides do not seal at the same time/not seal effectively	Complete seal doesn't occur	9	Wires not installed properly	5	Analyzed heating of all 4 sides of wire	1	45	N/A	
All 4 sides sealed completely	Heated wires stay on for too long	Extra material is burned,	8	Improper material properties used	7	Testing to see heating times on wires	1	56	Add wire guarding	M. Kalaria: 3/10/15

## APPENDIX C: MANUFACTURING PLANS

Part: Arm Long

Date: 2/27/15

Material: 6061 Aluminum 1/2" Thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Waterjet outer profile and slots	Waterjet			
2	Place part into vise on mill	Mill	Vise		
3	Insert drill chuck and edge finder, locate X/Y datum	Mill	Vise	Drill chuck, edge finder	900
4	Centerdrill the two 0.72" diameter holes in the aluminum plate	Mill	Vise	Center drill, drill chuck	1600
5	Centerdrill the 0.27" diameter hole	Mill	Vise	Center drill, drill chuck	1600
6	Drill the two 0.72" diameter holes through the aluminum plate.	Mill	Vise	Drill chuck, 23/32 drill bit	1500
7	Drill the two holes to 0.8750" diameter down 0.25" into the link.	Mill	Vise	Drill chuck, 7/8 drill bit	1500
8	Drill the 0.107" diameter hole through the aluminum plate	Mill	Vise	Drill chuck, H drill bit	1500
9	Remove part from vise, flip over and reinsert in vise	Mill	Vise		
10	Find x and y datum lines using the edge finder	Mill	Vise	Drill chuck, edge finder	900
11	Centerdrill the 0.266" diameter hole.	Mill	Vise	Center drill, drill chuck	1600
12	Drill the 0.266" diameter hole through the plate	Mill	Vise	Drill chuck, H drill bit	1500
13	Drill the 0.266" diameter hole to 0.438" diameter down 0.25" to counterbore it for a 1/4 SHCS.	Mill	Vise	Drill chuck, 1/4 SHCS counterboring tool	900
14	Tap 0.107" diameter hole with #6-32 tap		Vise	#6-32 tap	
15	Deburr holes and edges			Deburrer	



Part: Arm Short

Date: 2/27/15

Material: 6061 Aluminum 1/2" Thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Waterjet outer profile and slot	Waterjet			
2	Place part into vise on mill	Mill	Vise		
3	Insert drill chuck and edge finder, locate X/Y datum	Mill	Vise	Drill chuck, edge finder	900
4	Centerdrill the two 0.72" diameter holes in the aluminum plate	Mill	Vise	Center drill, drill chuck	1600
5	Drill the two 0.72" diameter holes through the aluminum plate.	Mill	Vise	Drill chuck, 23/32 drill bit	1500
6	Drill the two holes to 0.8750" diameter down 0.25" into the link.	Mill	Vise	Drill chuck, 7/8 drill bit	1500
7	Deburr holes and edges			Deburrer	

Part: Arm Mount Left/Right

Date: 2/27/15

Material: 6061 Aluminum 1/2" Thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Waterjet outer profile	Waterjet			
2	Place part into vise on mill	Mill	Vise		
3	Insert drill chuck and edge finder, locate X/Y datum	Mill	Vise	Drill chuck, edge finder	900
4	Centerdrill the 0.72" diameter hole in the aluminum plate.	Mill	Vise	Center drill, drill chuck	1600
5	Drill the 0.72" diameter hole through the plate	Mill	Vise	Drill chuck, 23/32 drill bit	1500
6	Drill the hole to 0.8750" diameter down 0.25" through the plate	Mill	Vise	Drill chuck, 7/8 drill bit	1500
7	Remove part from vise and flip. Reinsert the part in the vise.	Mill	Vise		
8	Insert edge finder and find x and y datum lines.	Mill	Vise	Drill chuck, edge finder	900
9	Centerdrill the 0.20" diameter holes.	Mill	Vise	Center drill, drill chuck	1600
10	Drill the 0.20" diameter holes through the plate.	Mill	Vise	Drill chuck, #8 drill bit	1500
11	Drill the 0.20" diameter holes to 0.375" diameter holes down 0.19" for a counterbore for 10-24 SHCS.	Mill	Vise	Drill chuck, 38 drill bit	1500
12	Deburr holes and edges			Deburrer	

Part: Assembly Plate front Support

Date: 2/27/15

Material: 6061 Aluminum ¼” thick, 1” width

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 16” long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	¾” 2-flute endmill, collet, file.	840
3	Measure to correct 8” length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15” (10-24 tapped hole) 3 holes	Mill	Vise	Drill chuck, center drill	1600
6	Drill the (3) holes .75” into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise				
8	Right hand tap the hole .5” into part		vise	10-24 tap, oil	
9	Deburr & file		vise	Deburring tool, file	

Part: Assembly Plate Side Support

Date: 2/27/15

Material: 6061 Aluminum 1/4" thick, 1" width

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 4" long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	3/4" 2-flute endmill, collet, file.	840
3	Measure to correct 8" length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15" (10-24 tapped hole) two holes	Mill	Vise	Drill chuck, center drill	1600
6	Drill the (2) hole .75" into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise				
8	Right hand tap the hole .5" into part		vise	10-24 tap, oil	
9	Deburr & file		vise	Deburring tool, file	
10	Repeat steps 1-9 to make 2 parts				

Part: Assembly Plate Back Support

Date: 2/27/15

Material: 6061 Aluminum ¼” thick, 1” width

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 8” long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	¾” 2-flute endmill, collet, file.	840
3	Measure to correct 8” length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15” (10-24 tapped hole) two holes	Mill	Vise	Drill chuck, center drill	1600
6	Drill the (2) hole .75” into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise				
8	Right hand tap the hole .5” into part		vise	10-24 tap, oil	
9	Deburr & file		vise	Deburring tool, file	

Part: Assembly Plate Front Legs

Date: 2/27/15

Material: 6061 Aluminum 1/2" thick x 1/2" square stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 1.19" long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	3/4" 2-flute endmill, collet, file.	840
3	Measure to correct 1.19" length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15" (10-24 tapped hole) hole	Mill	Vise	Drill chuck, center drill	1600
6	Drill the hole .75" into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise				
8	Right hand tap the hole .5" into part		vise	10-24 tap, oil	
9	Deburr & file		vise	Deburring tool, file	
10	Repeat steps 1-9 to make total of 2 parts				

Part: Assembly Plate

Date: 2/27/15

Material: Acrylic 3/16'' thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Upload file and prepare laser cutter	Laser Cutter		Laser cutter	
2	Laser cut outside profile, clearance holes and heating area cutout	Laser Cutter		Laser cutter	
3	Remove paper backing				



Part: Base Plate

Date: 2/27/15

Material: 6061 Aluminum 3/16" Thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Waterjet outer profile	Waterjet			
2	Place part into vise on mill	Mill	Vise		
3	Insert drill chuck and edge finder, locate X/Y datum	Mill	Vise	Drill chuck, edge finder	900
4	Centerdrill all holes	Mill	Vise	Center drill, drill chuck	1500
5	Drill the four 0.257" diameter holes through the aluminum plate.	Mill	Vise	Drill chuck, #7 drill bit	1600
6	Drill the twenty-seven 0.201" diameter holes through the aluminum plate	Mill	Vise	Drill chuck, F drill bit	1600
7	Deburr holes and edges			Deburrer	

Part: Handle Bar

Date: 2/27/15

Material: 6061 Aluminum 1/2" Round Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut stock to desired length	Bandsaw			
2	Insert part into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	
3	Center drill and drill hole 1.00" into part	Lathe	1/2" Collet	Center drill, #7 drill bit	
4	Remove part from spindle chuck and clean hole			Deburrer	3000
5	Reinsert other end into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	
6	Center drill and drill hole 1.00" into part	Lathe	1/2" Collet	Center drill, #7 drill bit	3000
7	Tap holes down 0.75" into part	Lathe	1/2" Collet	1/4-20 UNC tap, handle	
8	File edges			File	

Part: Hard Stop

Date: 2/27/15

Material: 6061 Aluminum 1/2" Square Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut stock to size (2.3")	Bandsaw			
2	Place part into vise on drill press	Drill Press	Vise		
3	Center drill hole in center of small face	Drill Press	Vise	Drill chuck, center drill	900
4	Drill the 0.201" hole 0.8" into part	Drill Press	Vise	Drill chuck, #7 Drill Bit	1600
5	Tap holes down 0.75" into part			1/4-20 UNC tap, handle	
6	File and deburr			File, deburrer	

Part: Heat Element Long Support

Date: 2/27/15

Material: 6061 Aluminum ¼” thick, 1” width

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 8” long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	¾” 2-flute endmill, collet, file.	840
3	Measure to correct 8” length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15” (10-24 tapped hole) two holes	Mill	Vise	Drill chuck, center drill	1600
6	Drill the (2) hole .75” into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise and mount thick side up	Mill	Vise		
8	Center drill the four 5/32” clearance holes	Mill	Vise	Drill chuck, center drill	1600
9	Drill the four 5/32” holes through the piece	Mill	Vise	Drill chuck, 5/32 drill bit	1500
8	Right hand tap the 10-24 holes 0.5” into part		Vise	10-24 tap, oil	
9	Deburr & file		Vise	Deburring tool, file	

Part: Heat Element Short Support

Date: 2/27/15

Material: 6061 Aluminum ¼” thick, 1” width

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 2.75” long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	¾” 2-flute endmill, collet, file.	840
3	Measure to correct 8” length with caliper.	Mill	Vise	Caliper	
4	Fill part on long edge. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
5	Center drill the .15” (10-24 tapped hole) two holes	Mill	Vise	Drill chuck, center drill	1600
6	Drill the (2) hole .75” into the part	Mill	Vise	Drill chuck, #25 drill bit.	1500
7	Remove part from vise and mount thick side up	Mill	Vise		
8	Center drill the two 5/32” clearance holes	Mill	Vise	Drill chuck, center drill	1600
9	Drill the two 5/32” holes through the piece	Mill	Vise	Drill chuck, 5/32 drill bit	1500
8	Right hand tap the 10-24 holes 0.5” into part		Vise	10-24 tap, oil	
9	Deburr & file		Vise	Deburring tool, file	

Part: Long/Short Support Rod

Date: 2/27/15

Material: 6061 Aluminum 1/2" Round Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Map aluminum round stock to size			Square gauge, surface plate	
2	Mount part on lathe spindle chuck	Lathe	1/2" Collet		
3	Install tool post with cutting bit and insert part	Lathe	1/2" Collet	Tool post, turning bit	
4	Turn the material to proper diameter and angle	Lathe	1/2" Collet	Tool post, turning bit	3000
5	Face end of material	Lathe	1/2" Collet	Tool post, parting bit	3000
6	Remove part from spindle chuck, clean the edge, map the stock to designed length			Deburring tool, surface plate, height gauge	
7	Insert part into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	3000
8	Center drill and drill down 0.61" into the part	Lathe	1/2" Collet	Centerdrill bit, #3 drill bit	3000
9	Remove part from spindle chuck and clean hole			Deburring tool	
10	Reinsert other end into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	
11	Center drill and drill hole 0.61" into part	Lathe	1/2" Collet	Centerdrill bit, #3 drill bit	
12	Left hand tap hole down 0.50" into part	Lathe	1/2" Collet	1/4-28 UNF LHT tap, handle	
13	Right hand tap the other hole down 0.50" into the part	Lathe	1/2" Collet	1/4-28 UNF RHT tap, handle	
14	File and deburr			Deburring tool, file	

Part: Pad Plate

Date: 2/27/15

Material: Acrylic 3/16'' thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Upload file and prepare laser cutter	Laser Cutter		Laser cutter	
2	Laser cut outside profile	Laser Cutter		Laser cutter	
3	Remove paper backing				

Part: Pad Plate Support

Date: 2/27/15

Material: 6061 Aluminum 1" Square Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to 4" long	Band saw	Vise		
2	Mount in vice. Face off the cut edge using end mill. Remove part and file edge.	Mill	Vise	$\frac{3}{4}$ " 2-flute endmill, collet, file.	840
3	Measure to correct 4" length with caliper.	Mill	Vise	Caliper	
4	Mount in vice. Face off side to achieve 0.75" height. Remove part and file edge.	Mill	Vise	$\frac{3}{4}$ " 2-flute endmill, collet, file.	840
5	Insert drill chuck. Find x & y datum lines.	Mill	Vise	Drill chuck. Edge finder	900
6	Center drill the .15" (10-24 tapped hole) two holes	Mill	Vise	Drill chuck, center drill	1600
7	Drill the two holes .75" into the part with #25 drill bit	Mill	Vise	Drill chuck, #25 drill bit.	1500
8	Right hand tap the 10-24 holes 0.5" into part		Vise	10-24 tap, oil	
9	Deburr & file		Vise	Deburring tool, file	



Part: Press Plate

Date: 2/27/15

Material: 6061 Aluminum 1/2" thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut outside profile, inner cutouts and clearance holes.	Waterjet			
2	Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
3	Center drill the four shaft holes.	Mill	Vise	Drill chuck, center drill	1600
4	Drill the four holes in steps of .375", .75", and 55/64"	Mill	Vise	Drill chuck, .375" drill bit, .75" drill bit, 55/64" drill bit	1500
5	Ream holes using 0.8745" reamer	Mill	Vise	Collet, 7/8" undersized reamer	100
6	Deburr & file		vise	Deburring tool, file	

Part: Press Plate Mini

Date: 2/27/15

Material: 6061 Aluminum 3/16" thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to size using	Band saw	Vise		
2	Mount in vice. Face off the cut edges using end mill. Remove part and file edge.	Mill	Vise	3/4" 2-flute endmill, collet, file.	840
3	Flat side. Mount in vice. Insert drill chuck. Find x & y datum lines. Use edge finder	Mill	Vise	Drill chuck. Edge finder	900
4	Center drill the 4 holes	Mill	Vise	Drill chuck, center drill	1600
5	Drill the 4 holes through the part	Mill	Vise	Drill chuck, #7 drill bit.	1500
6	Remove part from vice				
7	Tap holes for 1/4-20 tap		Vise	1/4-20 UNC tap, handle	
6	Deburr & file		vise	Deburring tool, file	

Part: Press Plate Spacer

Date: 2/27/15

Material: 6061 Aluminum 1/2" Round Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Map aluminum round stock to size			Square gauge, surface plate	
2	Mount part on lathe spindle chuck	Lathe	1/2" Collet		
3	Install tool post with cutting bit and insert part	Lathe	1/2" Collet	Tool post, turning bit	
5	Face end of material	Lathe	1/2" Collet	Tool post, turning bit	1000
8	Center drill and drill down 1.25" into the part	Lathe	1/2" Collet	Centerdrill bit, size H drill bit	1000
9	Cut piece to 1" length using 1/8" parting tool	Lathe	1/2" Collet	Tool post, parting bit	800
14	File and deburr			Deburring tool, file	

Part: Press Support

Date: 2/27/15

Material: 6061 Aluminum 1/2" thick

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut outside profile.	Waterjet			
2	Mount in vise. Insert drill chuck. Find x & y datum lines	Mill	Vise	Drill chuck. Edge finder	900
3	Center drill the two .15" holes in bottom of piece.	Mill	Vise	Drill chuck, center drill	1600
4	Drill the two .15" holes 0.74" into piece	Mill	Vise	Drill chuck, #26 drill bit	1500
5	Remove part and insert part flat side up in vise. Find x & y datum lines	Mill	Vise	Drill chuck. Edge finder	900
6	Center drill 0.72" hole	Mill	Vise	Drill chuck, center drill	1600
7	Drill 0.72" hole completely through	Mill	Vise	Drill chuck, 23/32" drill bit	1500
8	Drill 0.875" hole down 0.25" into part for counterbore	Mill	Vise	Drill chuck, 7/8" drill bit	1400
9	Deburr & file		vise	Deburring tool, file	

Part: Shaft

Date: 2/27/15

Material: Chrome Plated Steel 1/2" Round Stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Map the stock to designed length		1/2" Collet	surface plate, height gauge	
2	Insert part into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	
3	Center drill and drill hole 1.00" into part	Lathe	1/2" Collet	Centerdrill bit, #7 drill bit	3000
4	Remove part from spindle chuck and clean hole	Lathe		Deburring tool	
5	Reinsert other end into lathe chuck and face end	Lathe	1/2" Collet	Tool post, parting bit	
6	Center drill and drill hole 1.00" into part	Lathe	1/2" Collet	Centerdrill bit, #7 drill bit	3000
7	Tap holes down 0.75" into part	Lathe	1/2" Collet	1/4-20 UNC tap, handle	
8	File and deburr			Deburring tool, file	

Part: Shaft Cap

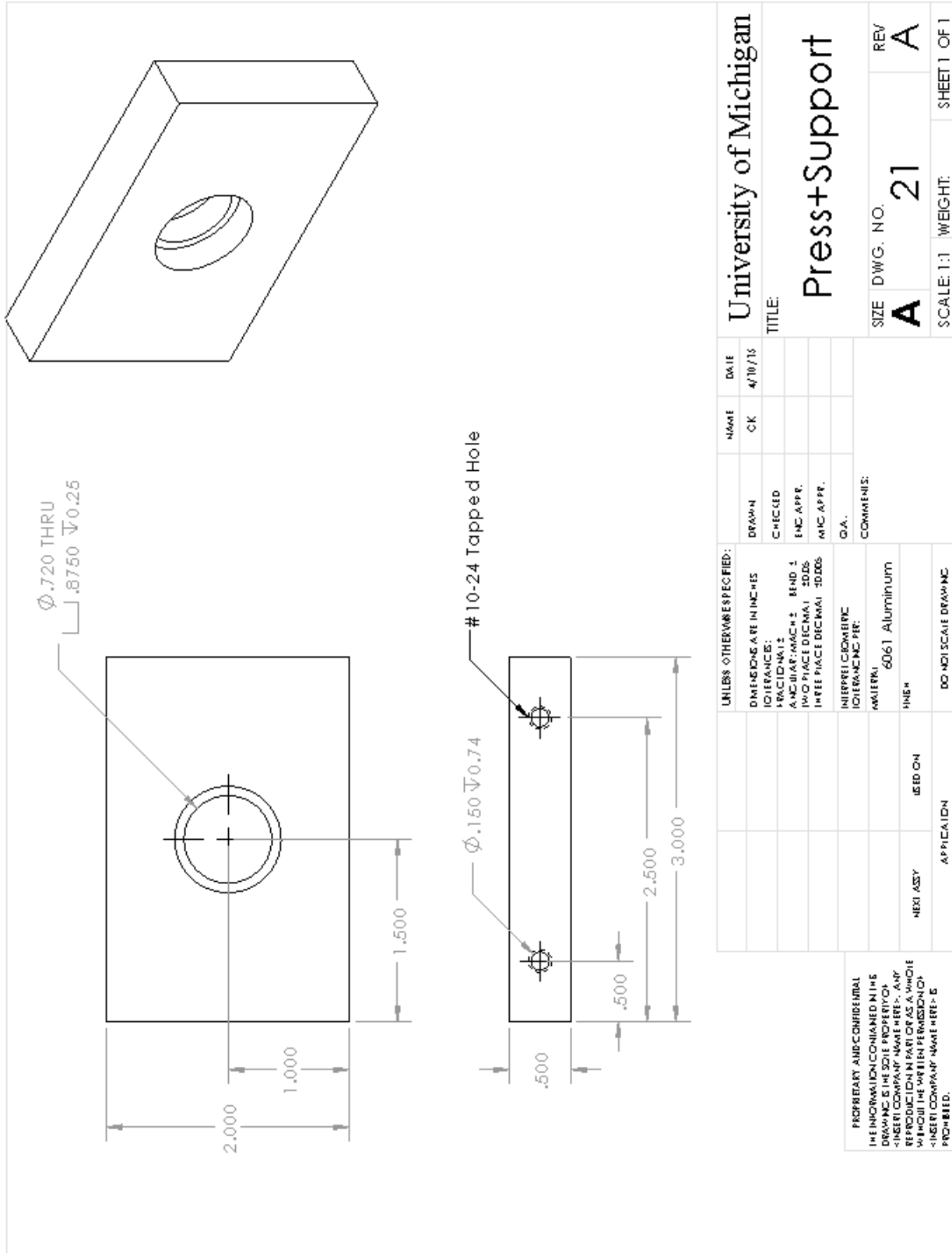
Date: 2/27/15

Material: 6061 Aluminum 2'' square stock

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed (RPM)
1	Cut piece to size	bandsaw	vises		
2	Mount in vice. Face off one edge using end mill. Remove part and file edge	mill	vises	3/4'' inch 2-flute endmill, collet, file	840
3	Replace part and remove material. Cut to size. Measure with caliper.	mill	vises	3/4'' inch 2-flute endmill, collet, caliper	840
4	Insert drill chuck. Find x & y datum lines. Use edge finder.	mill	vises	Drill chuck. Edge finder	900
5	Center drill the 0.266'' diameter hole	mill	vises	Center drill, drill chuck.	1600
6	Drill the hole through the piece.	mill	vises	Drill chuck, H drill bit	1500
7	Counter bore the hole down .25'' into the piece	mill	vises	Drill chuck, 7/16 drill bit	1500
8	Remove part from vice & flip over. Reinsert into vice.	mill	vises		
9	Insert drill chuck. Find x & y datum lines. Use edge finder	mill	vises	Drill chuck. Edge finder.	900
10	Center drill the .5'' dia. Hole.	mill	vises	Drill chuck, center drill	1500
11	Drill hole down .75'' into part.	mill	vises	Drill chuck, 31/64 drill bit	1600
12	Ream the hole.	mill	vises	Drill chuck, 1/2'' reamer	100
13	Remove part from vice and flip over. Reinsert to vice.	mill	vises		
14	Insert drill chuck. Find x & y datum lines. Use edge finder.	mill	vises	Drill chuck, edge finder	900
15	Center drill the .213'' diameter hole	mill	vises	Drill chuck, center drill	1600
16	Drill the hole down 0.714'' into the plate	mill	vises	Drill chuck, 3 drill bit	1500
17	Left hand tap the hole down .5'' into the part	mill	vises	1/4-28 UNF LHT tap, oil	
18	Remove part from vice and flip over. Reinsert into vice	mill	vises		
19	Insert drill chuck. Find x and y datum lines. Use edge finder.	mill	v vises	Drill chuck. Edge finder	900

20	Center drill the .213" dia. Hole	mill	visе	Drill chuck, center drill	1600
21	Drill the hole down .714" into plate	mill	visе	Drill chuck, 3 drill bit	1500
22	Right hand tap the hole down .5" in to the part	mill	visе	1/4-28 UNF RHT tap, oil	
23	Deburr the holes and file edges	mill	visе	Deburrer, file	
24	Repeat steps to create a total of 4 parts.	mill	visе		

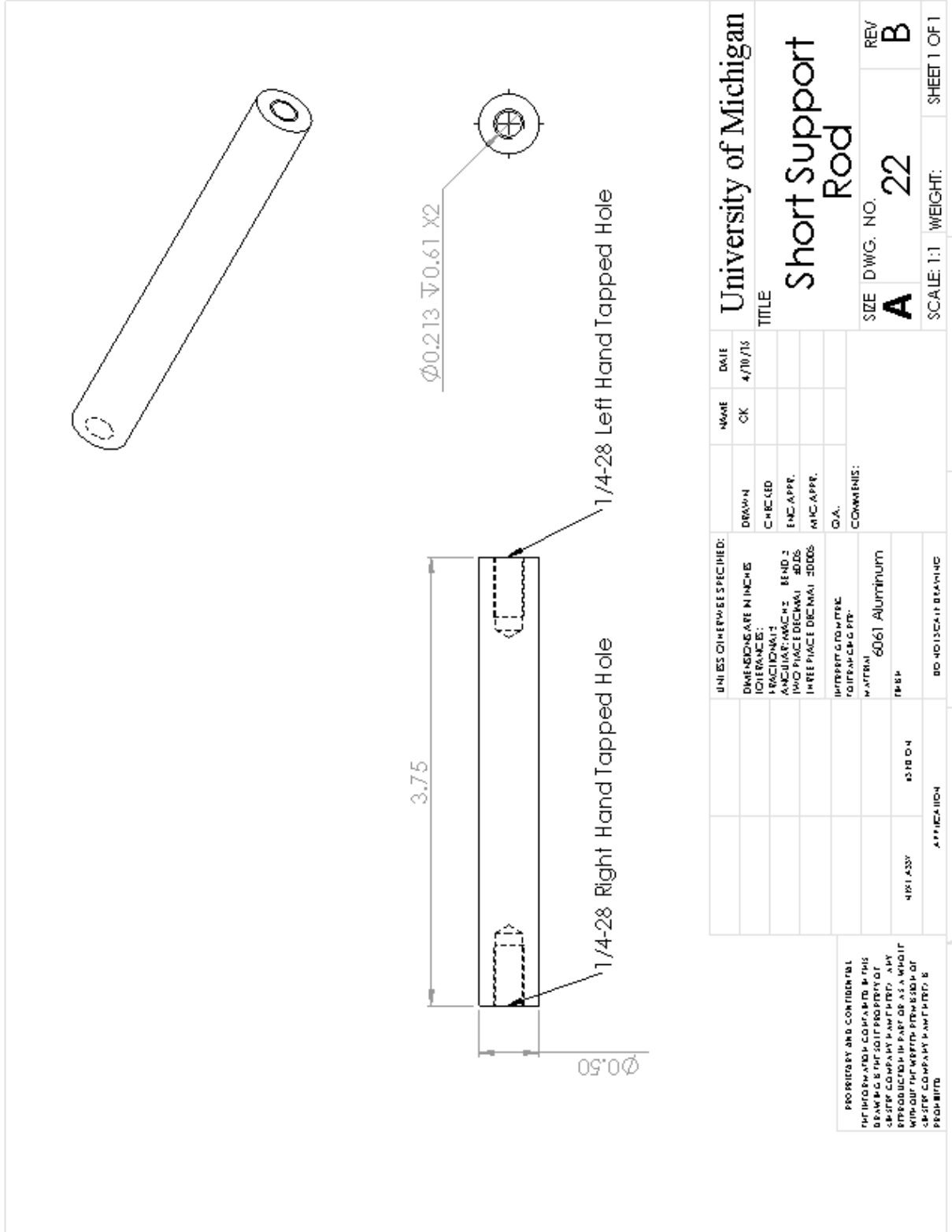
Appendix D: Engineering Drawings



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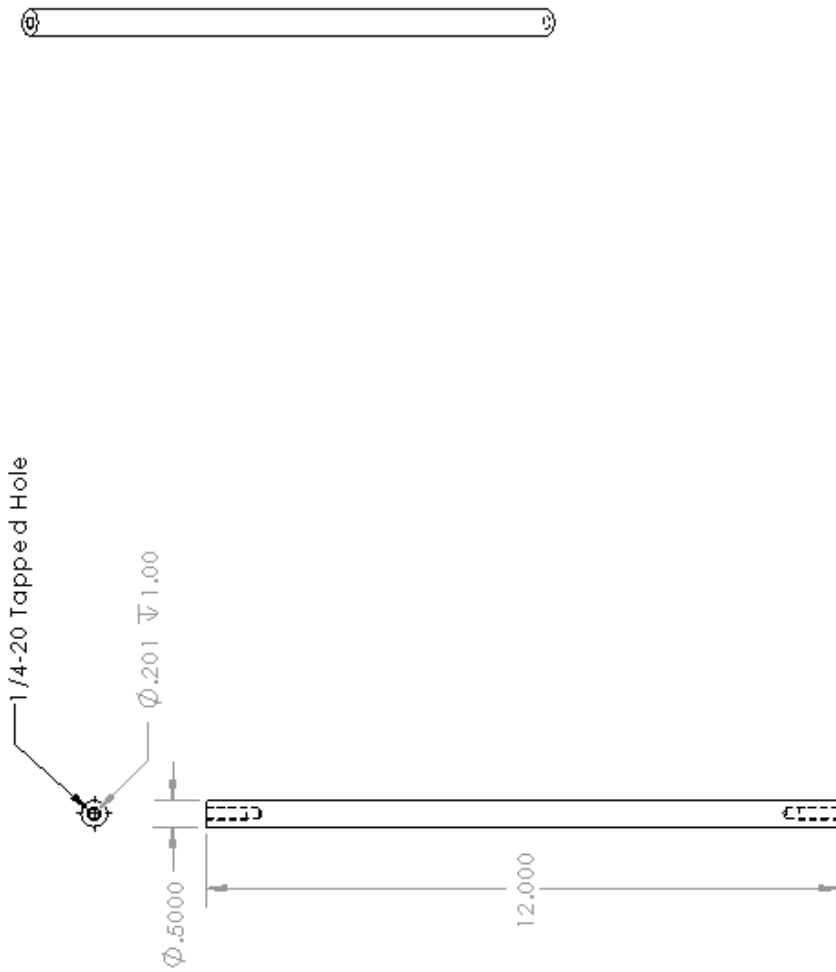
UNLESS OTHERWISE SPECIFIED:		DRAWN		NAME		DATE		University of Michigan	
DIMENSIONS ARE IN INCHES		CHECKED		CK		4/10/15		TITLE:	
TOLERANCES:		END APPR.						Press+Support	
FRACTIONS: 1/16		MTC APPR.						SIZE DWG. NO.	
DECIMALS: .0005		G.A.						A 21	
ANGLES: 30, 45, 60, 90, 120, 150, 225, 300, 315		COMMENTS:						SCALE: 1:1 WEIGHT:	
SURFACE FINISH: 32 RMS		MATERIAL: 6061 Aluminum						SHEET 1 OF 1	
HOLE POSITION: 100% PER		NEXT ASSY							
HOLE SIZE: 100% PER		USED ON							
HOLE TYPE: 100% PER		APPLICATION							
HOLE LOCATION: 100% PER		4							
HOLE DIA: 100% PER		5							
HOLE LENGTH: 100% PER		3							
HOLE TAP: 100% PER		2							
HOLE THREAD: 100% PER		1							





UNIVERSITY OF MICHIGAN		NAME	DATE	TITLE	
University of Michigan		CK	4/30/15	Short Support Rod	
DRAWN		CHECKED		SIZE	DWG. NO.
ENCH. APPR.		ENCH. APPR.		A	22
MTC APPR.		MTC APPR.		SCALE: 1:1	WEIGHT:
Q.A.		Q.A.		REV	
COMMENTS:		A			
MATERIAL		6061 ALUMINUM			
PART NO.		4318 0-4			
APPLICATION		3			
5		1			
6		2			
7		3			
8		4			
9		5			
10		6			
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12		8			
13		9			
14		10			
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100		96			

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University of Michigan  
**Shaft**

SIZE DWG. NO. REV  
**A 24 A**

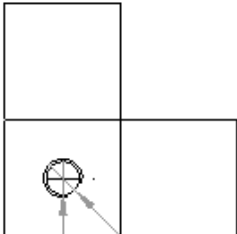
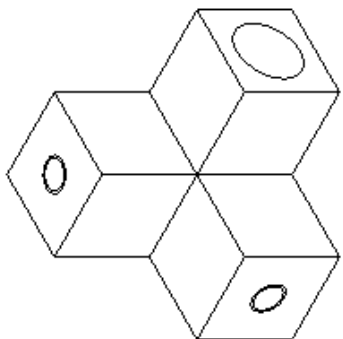
SCALE: 1:3 WEIGHT: SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/15
FRACTIONS:	DRAWN	
ANGLES: 1/4" MIN.	CHECKED	
FINISH: 125 RA	END APPR.	
THREADS: 1/8" MIN. DIA. 30 DIA.	ARC APPR.	
INTERPRETING:	G.A.	
TOLERANCES PER:	COMMENTS:	
AWLERN		
CHROME PLATED STEEL		
FMS		

DO NOT SCALE DRAWING

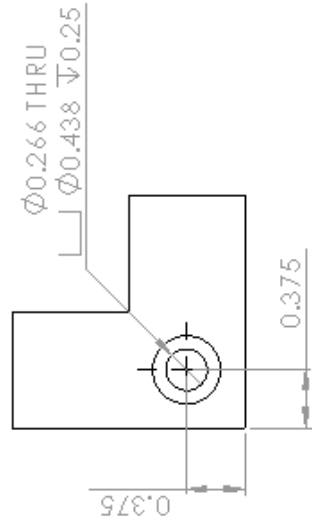
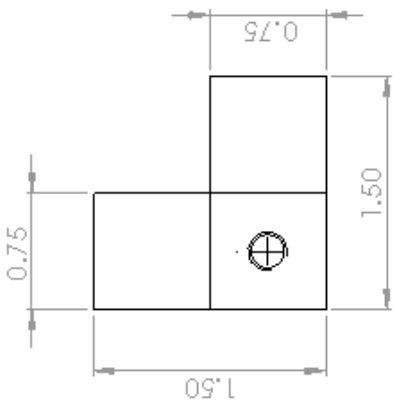
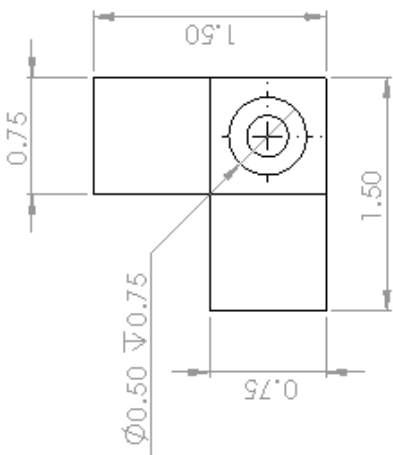
APPLICATION	USED ON

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$\varnothing 0.213 \sqrt{0.71} X2$

1/4-28 Tapped Hole X2



$\varnothing 0.266$  THRU  
 $\varnothing 0.438 \sqrt{0.25}$

University of Michigan  
Shaft Cap Large

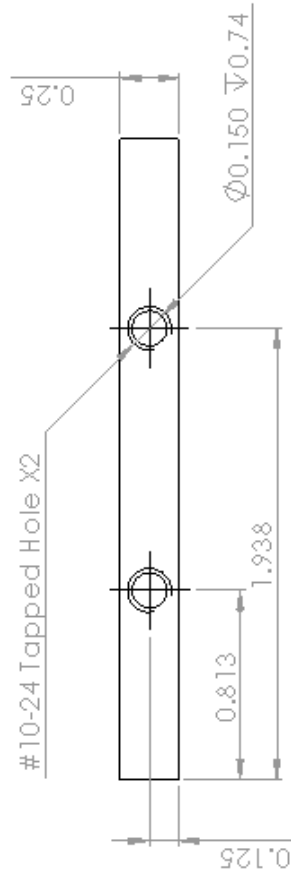
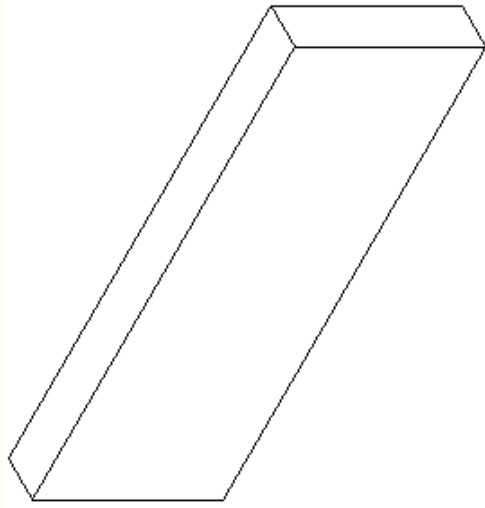
NAME	DATE
CK	4/10/13

UNLESS OTHERWISE SPECIFIED:	DRAWN	CHECKED	ENG. APPR.	MTC. APPR.	G.A.	COMMENTS:
DIMENSIONS ARE IN INCHES						
TOLERANCES:						
FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2						
DECIMALS: .005, .010, .015, .020, .030, .040, .050, .060, .070, .080, .090, .100						
ANGLES: 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180						
SPRINGS: UNLESS OTHERWISE SPECIFIED, SHOW UNSTRESSED LENGTH AND COIL FORM						
THREADS: UNLESS OTHERWISE SPECIFIED, SHOW UNSTRESSED LENGTH AND COIL FORM						
WELDING: UNLESS OTHERWISE SPECIFIED, SHOW UNSTRESSED LENGTH AND COIL FORM						
MATERIAL: 6061 Aluminum						
FINISH: UNLESS OTHERWISE SPECIFIED, SHOW UNSTRESSED LENGTH AND COIL FORM						

SIZE	DWG. NO.	REV
A	23	B

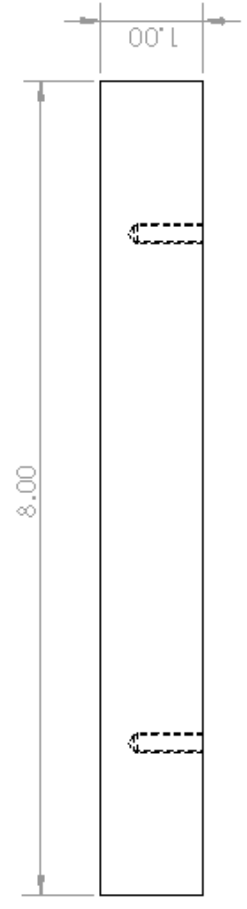
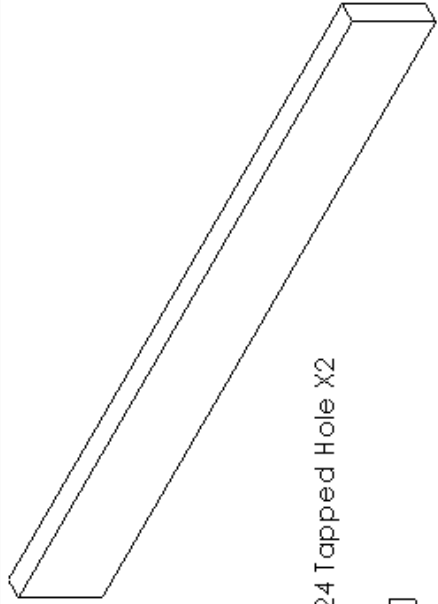
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1
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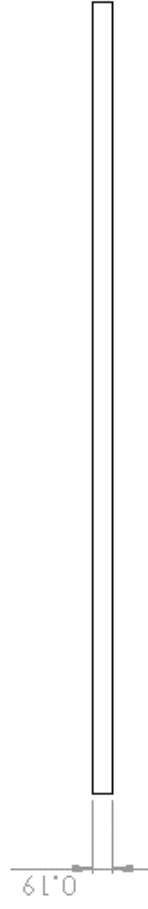
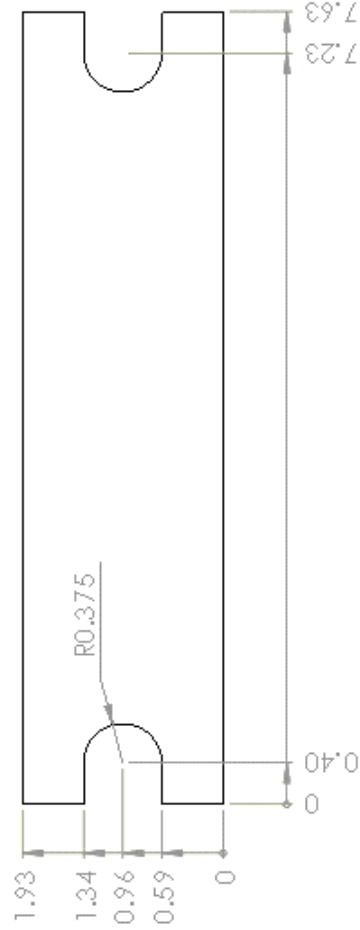
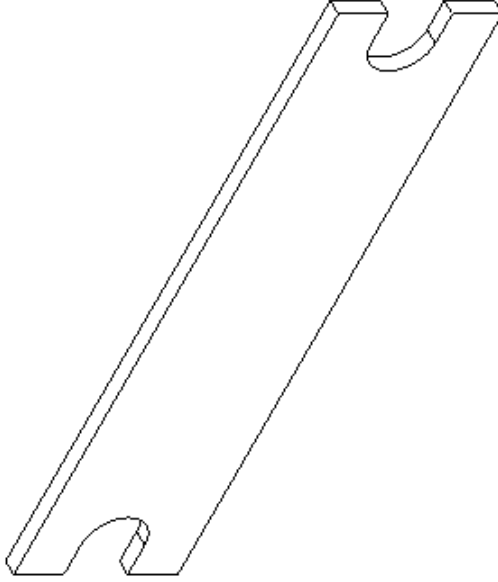
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	University of Michigan	
DIMENSIONS ARE IN INCHES	DRAWN	CK	4/10/18	Heat Element Short Support	
TOLERANCES:	CHECKED			SIZE	REV
FRACTIONS: 1/16, 1/8, 3/16, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1	ENC APPR.			A	14
DECIMALS: 0.0005, 0.001, 0.002, 0.005, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1	MFC APPR.			SCALE: 3:2	WEIGHT: SHEET 1 OF 1
ANGLES: MINIMUM 30 DEGREES	D.A.				
HOLE LOCATIONS: UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE TO CENTER UNLESS NOTED OTHERWISE	COMMENTS:				
MATERIAL: 6061 Aluminum					
FINISH:					
NEXT ASY	USED ON				
APPLICATION					
5	4	3	2	1	

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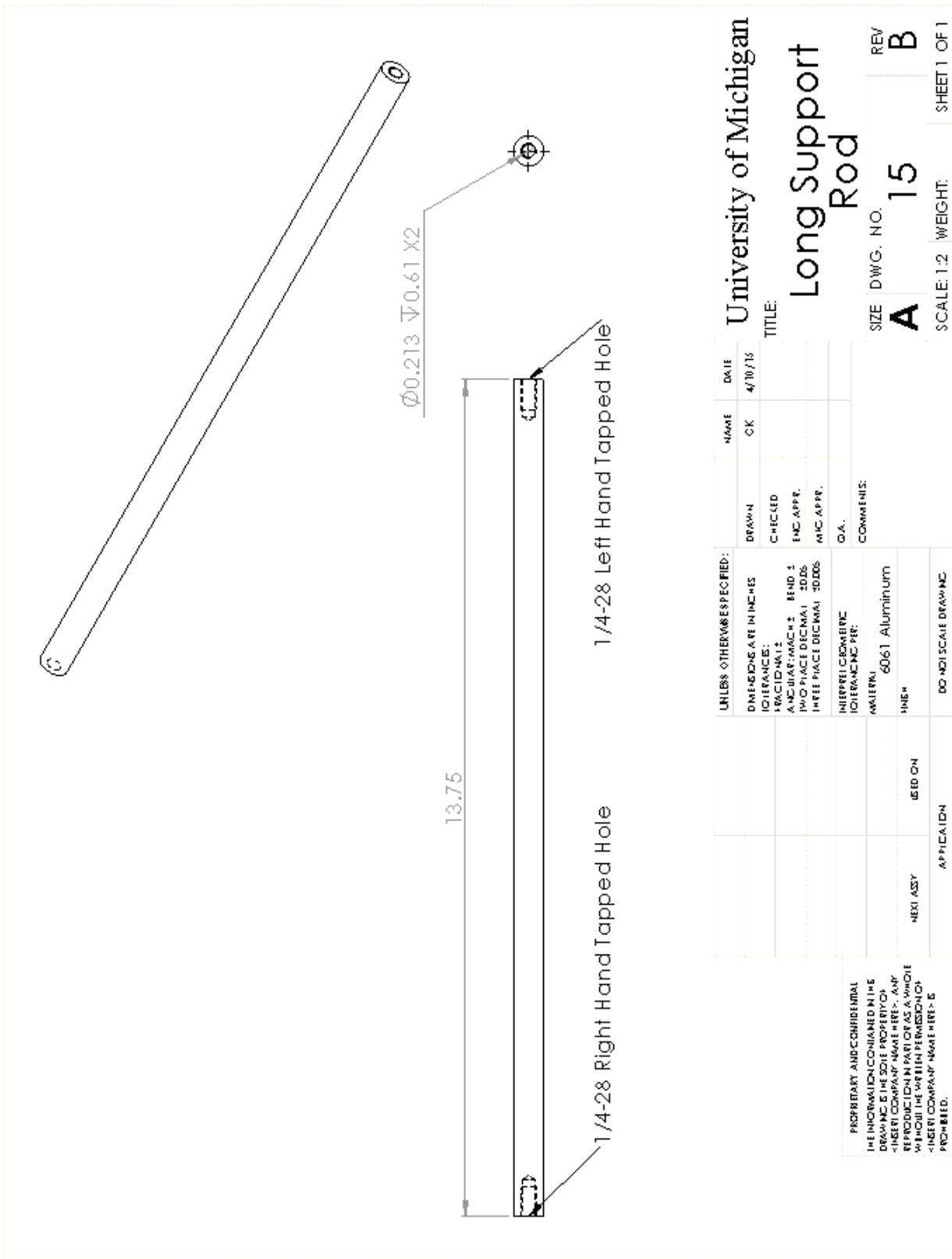
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	University of Michigan	
DIMENSIONS ARE IN INCHES	DRAWN	CK	4/10/75	TITLE: Heat Element Long Support	
TOLERANCES:	CHECKED			SIZE	REV
FRACTIONS	END APPR.			A	13
ANGULAR: MACH 2 BEND 1	MFG APPR.			SCALE: 2:3	WEIGHT: SHEET 1 OF 1
IN-O-FACE DECIMAL 2	D.A.				
THREE PLACE DECIMAL 2	COMMENTS:				
INTERFERENCE					
TOLERANCE PER:					
MATERIAL:					
6061 Aluminum					
FINISH:					
BEZEL ON					
APPLICATION					
5	4	3	2	1	

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UNLESS OTHERWISE SPECIFIED:		NAME	DATE	University of Michigan
DIMENSIONS ARE IN INCHES		CK	4/10/15	REV
TOLERANCES:		DRAWN		B
FRACTIONAL ±		CHECKED		
DECIMAL ±		ENG. APPR.		
THREE PLACE DECIMAL ±		MIC. APPR.		
THREE PLACE DECIMAL ±		Q.A.		
INTERFERENCES		COMMENTS:		
INTERFERENCE PER:		MATERIAL: Acrylic		
NEXT ASY		USED ON		
APPLICATION		DO NOT SCALE DRAWING		
5		4		3
0.19		2		1
1.93		SCALE: 2:3		WEIGHT:
1.34		SIZE		DWG. NO. 17
0.96		TITLE		Pad Plate
0.59		SHEET 1 OF 1		
0				
0.40				
0				
7.23				
7.63				
R0.375				

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University of Michigan

# Long Support Rod

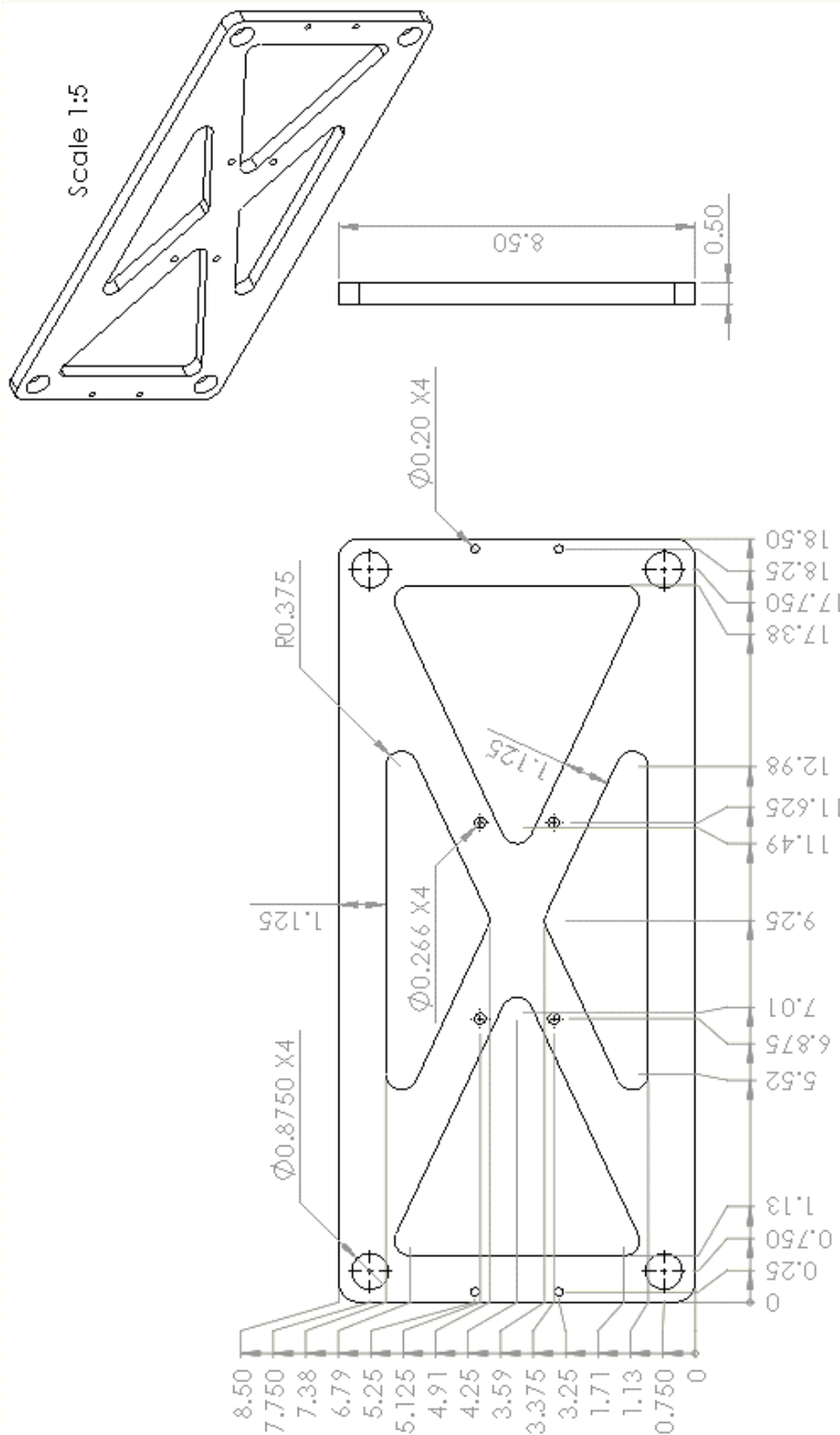
SIZE DWG. NO. REV

**A** 15 **B**

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/30/75
TOLERANCES:		
FRACTIONS: ±	CHECKED	
DECIMALS: ±	ENG APPR.	
ANGLES: ±	MTC APPR.	
THREE PLACE DECIMALS: ±0.005		
THREE PLACE DECIMALS: ±0.005		
INTERFERENCES:		
TOLERANCES PER:		
MATERIAL:		
6061 Aluminum		
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SEE ON		
APPLICATION		
DO NOT SCALE DRAWING		

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**University of Michigan**

**Press Plate**

SIZE: **A** DWG. NO.: **18** REV: **C**

SCALE: 2:7 WEIGHT: SHEET 1 OF 1

NAME	DATE	CK	4/10/16
DRAWN			
CHECKED			
ENG APPR.			
MFG APPR.			
G.A.			
COMMENTS:			
INTERPRETATION:			
AMERICAN			
6061 Aluminum			
P/N#			

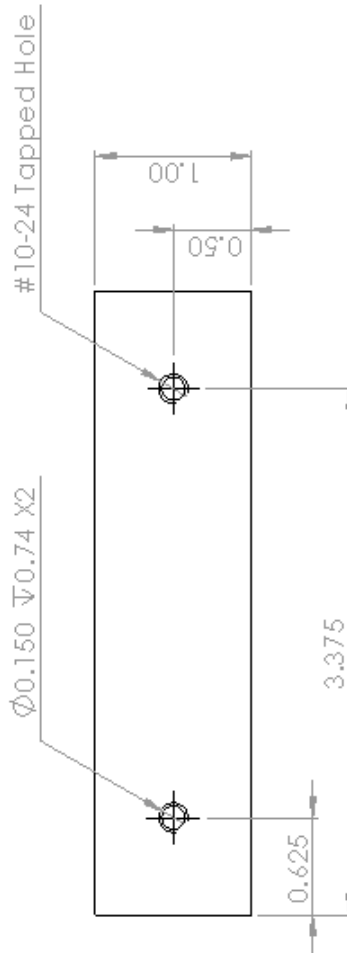
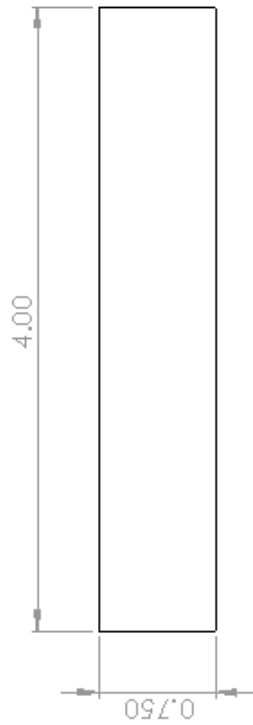
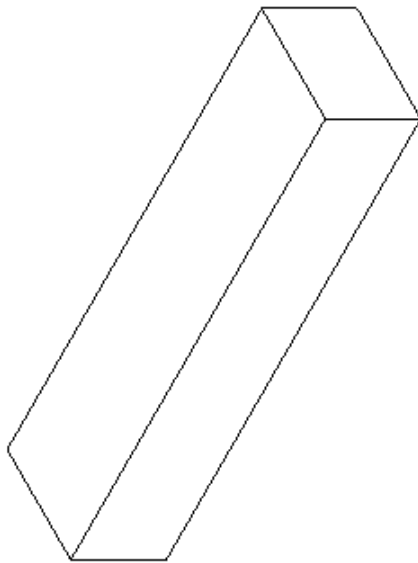
UNLESS OTHERWISE SPECIFIED:  
 DIMENSIONS ARE IN INCHES  
 DECIMALS ARE TO BE ROUNDED TO THE NEAREST THIRD OF A DECIMAL  
 HOLE DIA. TO HOLE DIA. UNLESS OTHERWISE SPECIFIED  
 UNLESS OTHERWISE SPECIFIED: 30006  
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APPLICATION	4	5
NEXT ASSY	USED ON	

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University of Michigan

TITLE: Pad Plate Support

SIZE DWG. NO. **A** 16 REV **B**

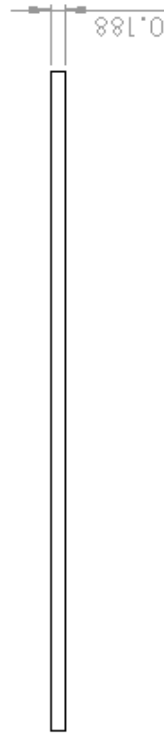
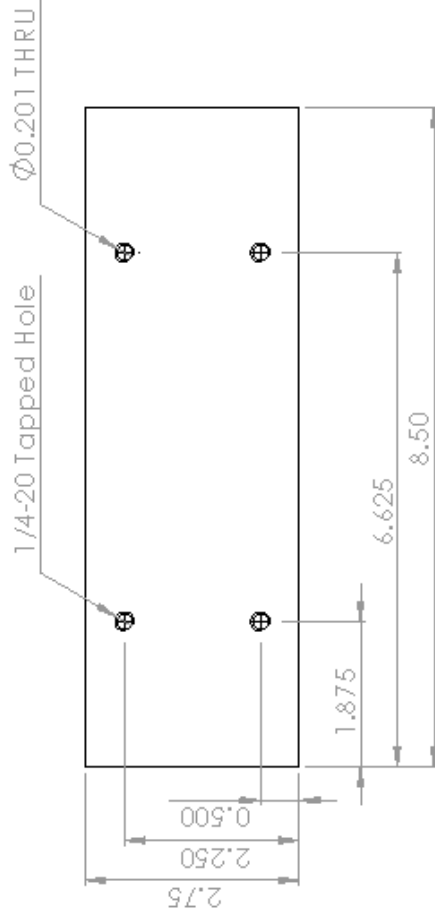
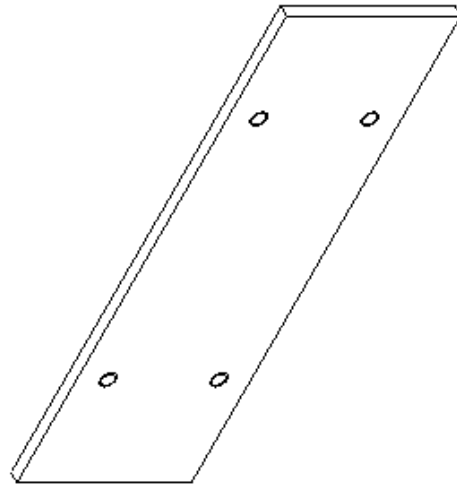
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UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/13
TOLERANCES:		
FRACTIONS: ±		
DECIMALS: ±		
ANGULAR: ±		
WELD FACE DECIMAL: ±		
FREE FACE DECIMAL: ±		
INTERPRET COMMERCIAL TOLERANCES PER:		
MATERIAL: 6061 Aluminum		
FINISH:		
NEXT ASY		
USED ON		
APPLICATION		
DO NOT SCALE DRAWING		

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University of Michigan

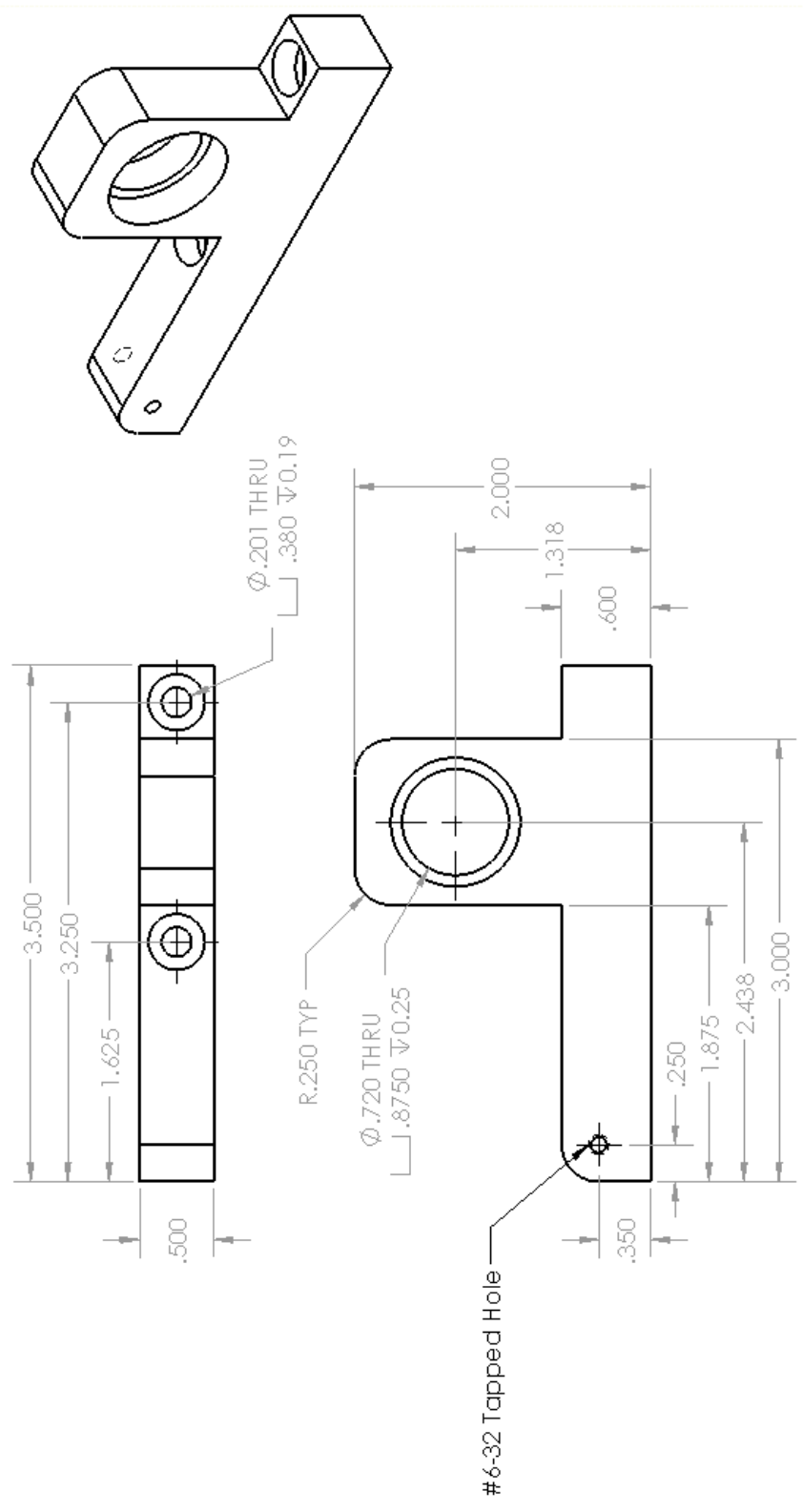
Press Plate Mini

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/30/15
TOLERANCES:	DRAWN	
FRACTIONAL ±	CHECKED	
DECIMAL ±	ENG APPR.	
ANGLE ±	MFG APPR.	
WELD ±	G.A.	
FREE PLACE DECIMAL ±	COMMENTS:	
THREE PLACE DECIMAL ±		
OTHERWISE AS SHOWN		

SIZE	DWG. NO.	REV
A	19	B
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

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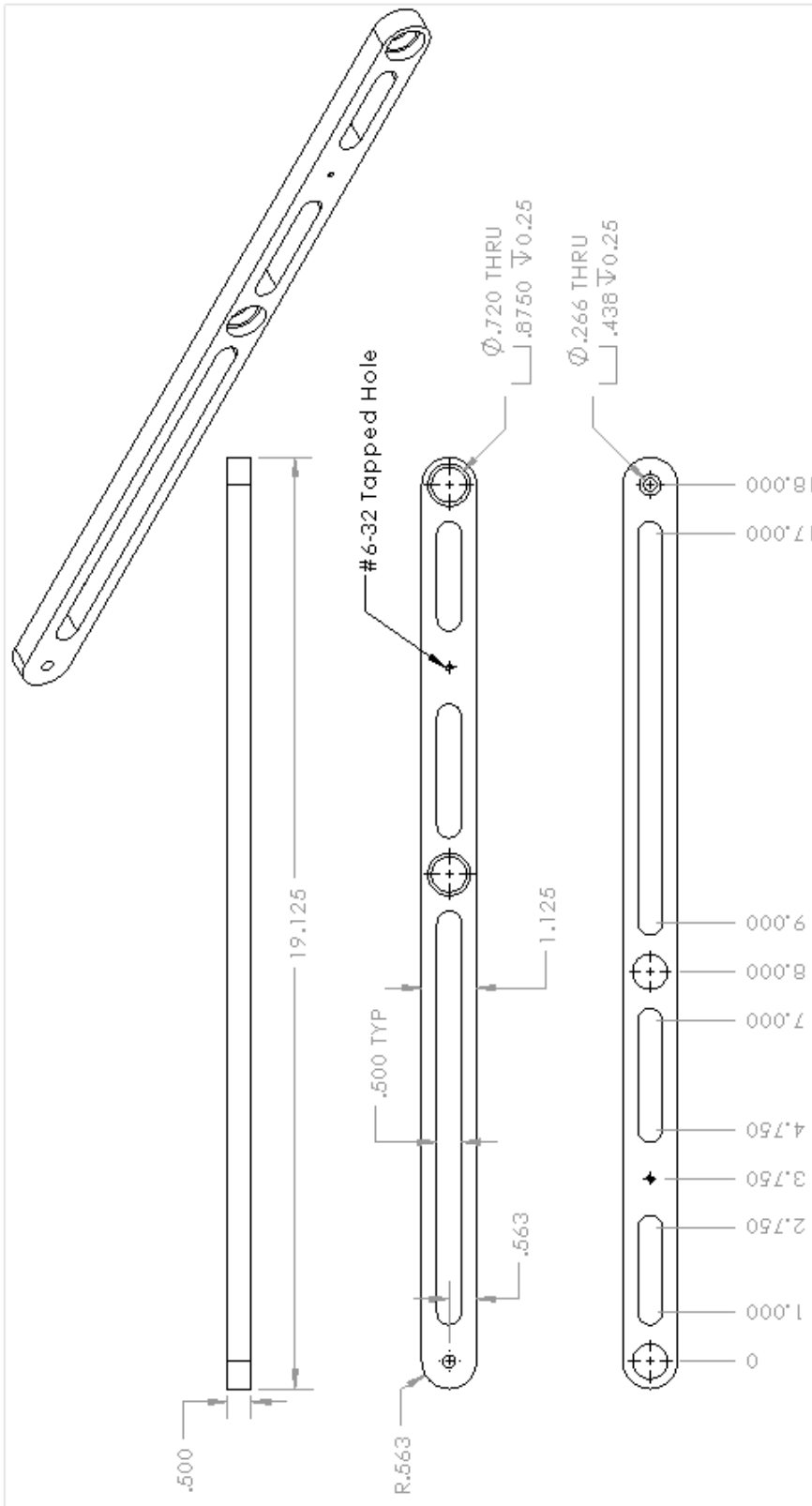
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APPLICATION	4
NEXT ASY	5
USED ON	



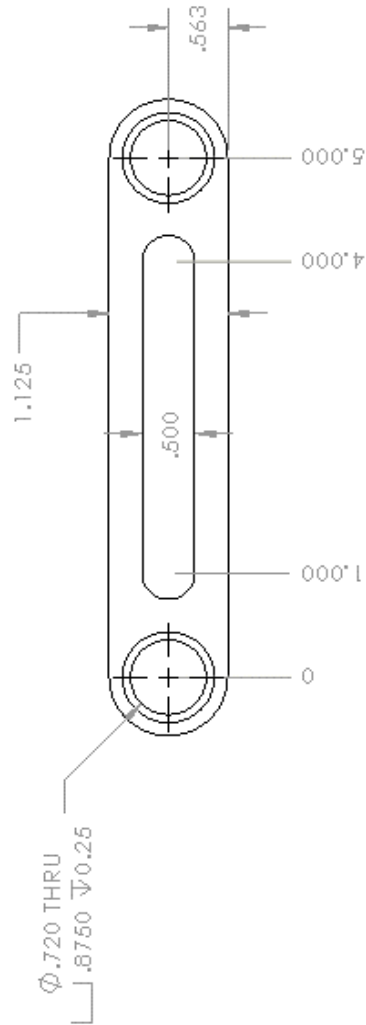
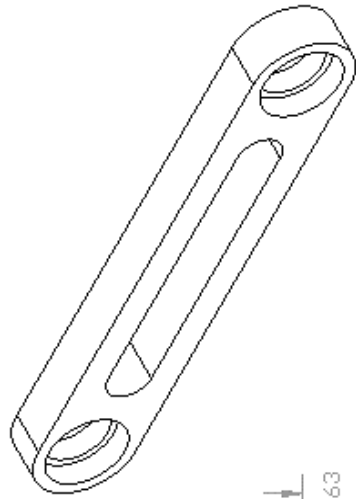
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/15	
TOLERANCES:	DRAWN		
FRACTIONALS	CHECKED		
ANGULARS: MAX ±	ENG APPR.		
TWO PLACE DECIMAL	MFG APPR.		
THREE PLACE DECIMAL ±0.005	Q.A.		
INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:		
MATERIAL	6061 Aluminum		
FINISH			
HEAT ASSY	USED ON		
APPLICATION	DO NOT SCALE DRAWING		

University of Michigan  
 TITLE: Arm+Mount+Left  
 SIZE DWG. NO. **A** 03 REV **B**  
 SCALE: 1:1 WEIGHT: SHEET 1 OF 1

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UNLESS OTHERWISE SPECIFIED:		NAME	DATE	University of Michigan	
DIMENSIONS ARE IN INCHES		COCK	4/30/15	TITLE: Arm Long	
TOLERANCES:		DRAWN		SIZE	DWG. NO.
FRACTIONAL		CHECKED		A	01
ANGULAR: MACH 2 BEND 1		ENG APPR.		SCALE: 1:3	WEIGHT:
WELD PLACE DECIMAL SDDS		MFG APPR.		REV	B
HOLE PLACE DECIMAL SDDS		D.A.		SHEET 1 OF 1	
INTERFEROMETRIC		COMMENTS:			
TOLERANCE PER:					
MATERIAL:					
6061 Aluminum					
FINISH:					
DO NOT SCALE DRAWING					
NEXT ASSY		USED ON			
APPLICATION					
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University of Michigan

TITLE:

Arm Short

SIZE DWG. NO. **A** 02

REV **B**

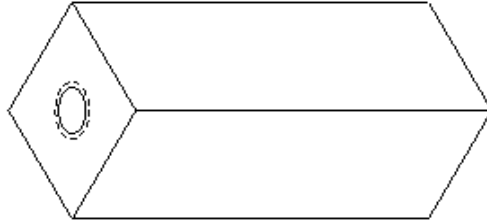
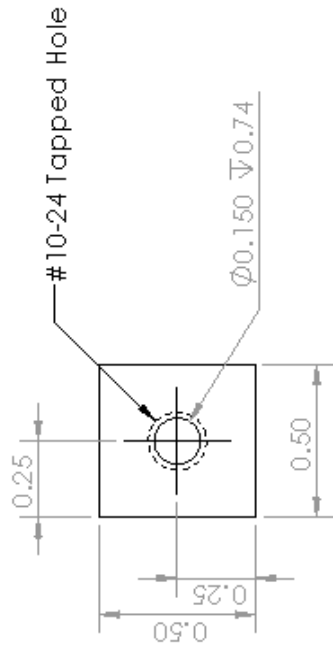
SCALE: 2:3 WEIGHT: SHEET 1 OF 1

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TOLERANCES:	CHECKED		
FRACTIONS: 1	END APP.		
DECIMALS: 2	END APP.		
THREE PLACE DECIMALS: 3	END APP.		
THREE PLACE DECIMALS: 3	END APP.		
INTERFERENCES:	G.A.		
INTERFERENCES:	COMMENTS:		
MATERIAL: 6061 Aluminum			
FINISH:			
DO NOT SCALE DRAWING			

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**University of Michigan**  
**Assembly Plate**  
**Front Legs**

TITLE: \_\_\_\_\_  
 SIZE: **A** DWG. NO. **05** REV **B**  
 SCALE: 2:1 WEIGHT: \_\_\_\_\_ SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:	NAME	DATE	DRAWN	CHECKED	ENG APPR.	MFG APPR.	D.A.	COMMENTS:
DIMENSIONS ARE IN INCHES	CK	4/10/15						
TOLERANCES:								
FRACTIONS: _____								
DECIMALS: _____								
ANGLES: _____								
UNLESS OTHERWISE SPECIFIED:								
MATERIAL:								
6061 Aluminum								
FINISH:								
DO NOT SCALE DRAWING								

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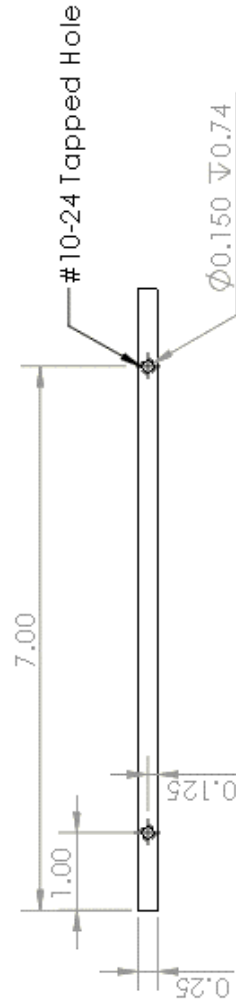
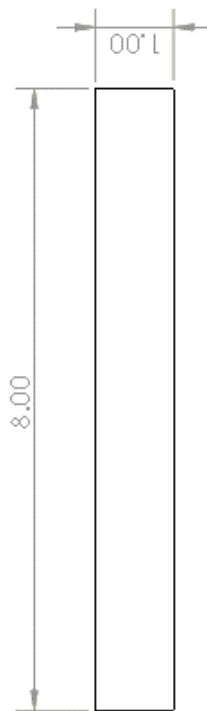
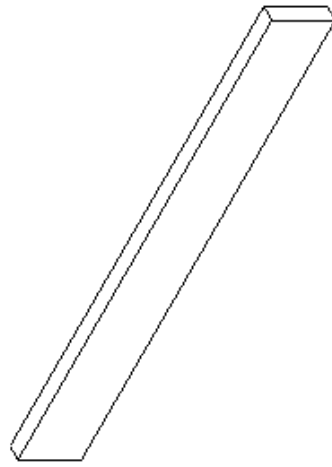
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3

2

1





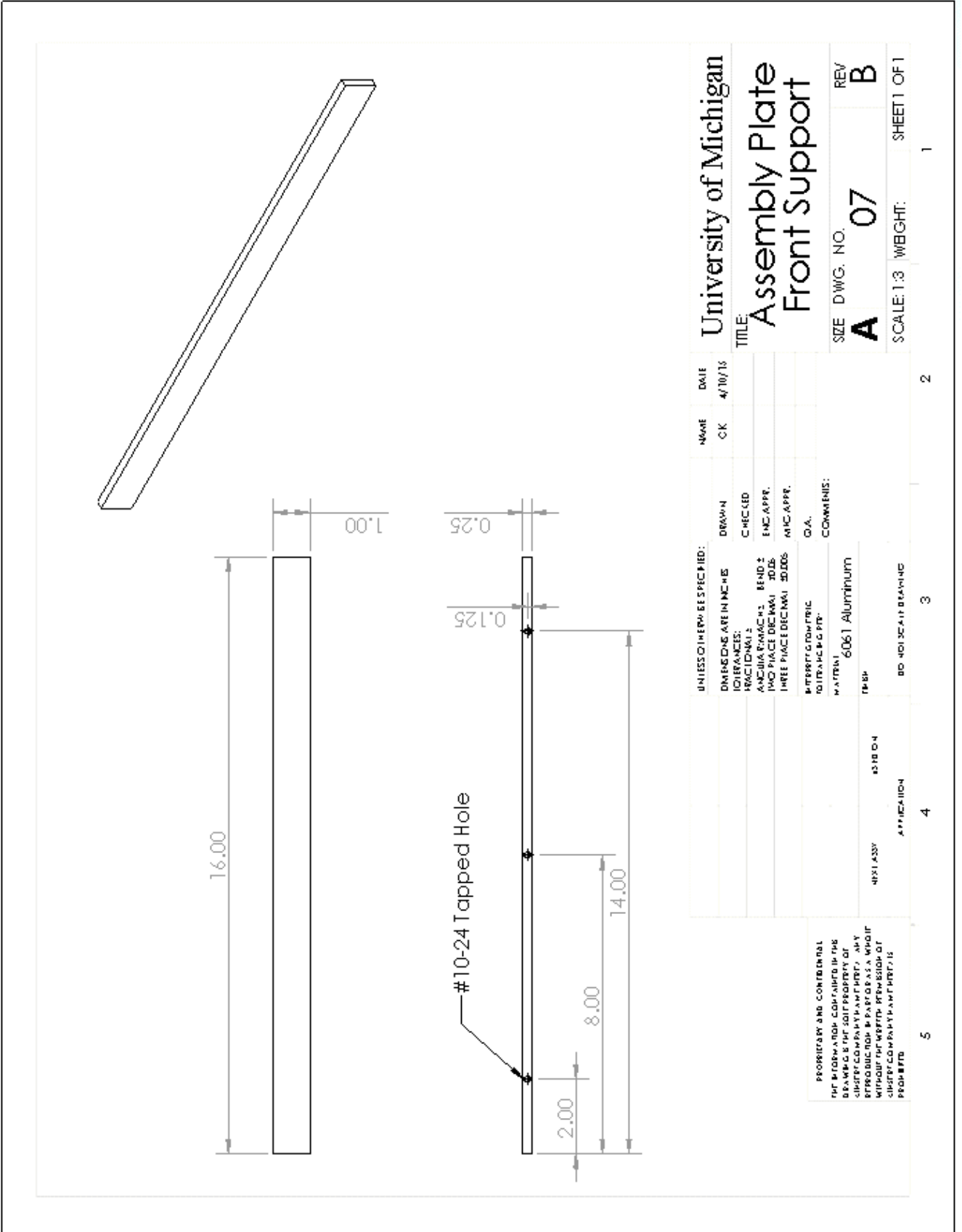
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University of Michigan  
 TITLE: Assembly Plate Back Support  
 SIZE: A  
 DWG. NO.: 06  
 REV: B  
 SCALE: 1:2  
 WEIGHT:  
 SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/15
TOLERANCES:		
FRACTIONS: 1/16, 1/8, 3/16, 1/2, 5/8, 3/4		
DECIMALS: .0005, .001, .002, .005, .010, .015, .030, .045, .090, .150		
ANGLES: MINIMUM .005		
SPRINGS: PER ASME Y14.3		
WELDING: PER ASME B4.2		
THREADS: PER ASME B1.1		
FINISHES: UNLESS OTHERWISE SPECIFIED		
INTERPRETATION PER:		
INTERPRETATION PER:		
MATERIAL: 6061 Aluminum		
FINISH:		
DO NOT SCALE DRAWING		

5	4	3	2	1
APPLICATION	USED ON	DO NOT SCALE DRAWING	SCALE: 1:2	WEIGHT:
APPROVED	DATE			

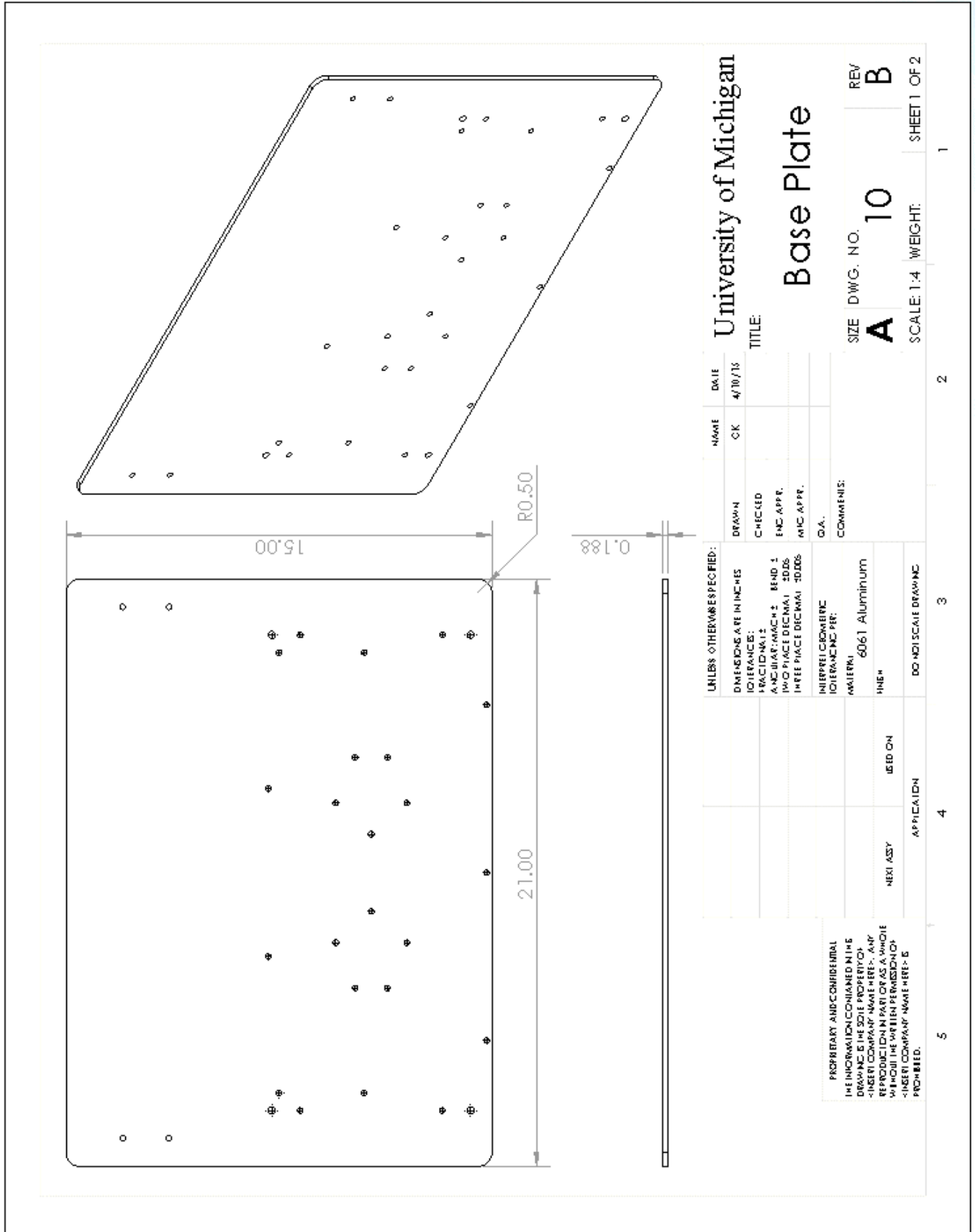




UNIVERSITY OF MICHIGAN  
**Assembly Plate  
 Front Support**  
 SIZE DWG. NO. **A 07** REV **B**  
 SCALE: 1:3 WEIGHT: SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/16
TOLERANCES:	DRAWN	
FRACTIONAL 1/16	CHECKED	
ANGULAR DIMENSIONS - BEND 2	ENC APPR.	
POD THREE DECIMAL 300S	MFG APPR.	
THREE PLACE DECIMAL 300S	MFG APPR.	
INTERFEROMETRIC	Q.A.	
QUALITY CONTROL	COMMENTS:	
MATERIAL	6061 Aluminum	
FINISH		
4021 ASSY	4021 B D N	
APPLICATION	BO 4015 CA 11 BEAMING	

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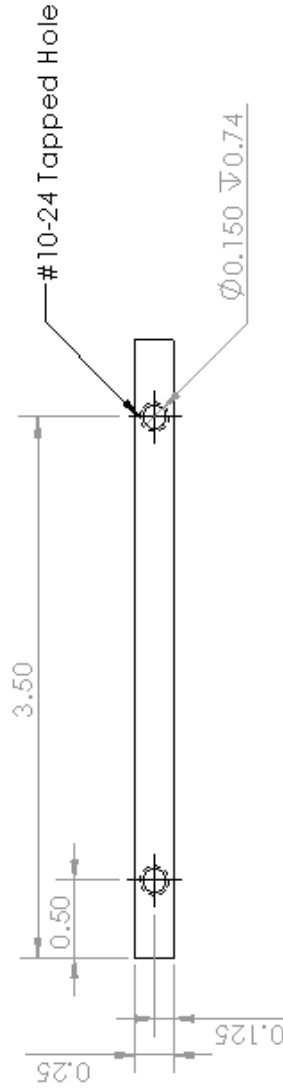
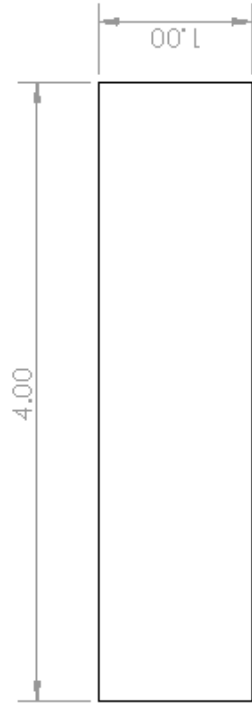
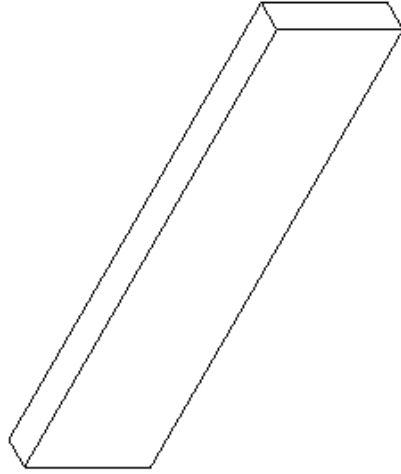
**University of Michigan**  
**Base Plate**  
 SIZE DWG. NO. REV  
**A** **10** **B**  
 SCALE: 1:4 WEIGHT: SHEET 1 OF 2

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES	CK	4/10/15
TOLERANCES:		
FRACTIONS: ±0.005		
DECIMALS: ±0.005		
ANGLES: ±0.005		
SPACES: ±0.005		
THREE PLACE DECIMAL: ±0.005		
INTERPRET DIMENSIONS TO NEAREST 0.005		
UNLESS OTHERWISE SPECIFIED:		
MATERIAL:		
6061 ALUMINUM		
FINISH:		
USED ON:		
APPLICATION:		

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DRAWN	CK	4/10/15
CHECKED		
ENG. APPR.		
MFG. APPR.		
G.A.		
COMMENTS:		

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DRAWN	CK	4/10/15
CHECKED		
ENG. APPR.		
MFG. APPR.		
G.A.		
COMMENTS:		

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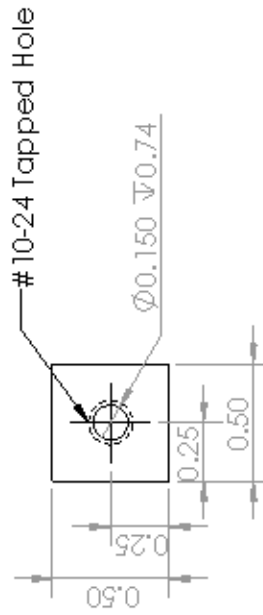
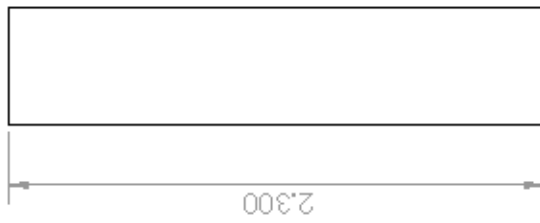


UNLESS OTHERWISE SPECIFIED:  
 DIMENSIONS ARE IN INCHES  
 DECIMALS  
 FRACTIONS  
 FINISHES  
 ALL DIMENSIONS 2 BEND 1  
 IN PLACE DECIMAL 30DS  
 THREE PLACE DECIMAL 30DS  
 UNLESS OTHERWISE SPECIFIED:  
 DIMENSIONS PER:  
 MATERIAL:  
 6061 Aluminum  
 FINISH:  
 NONE

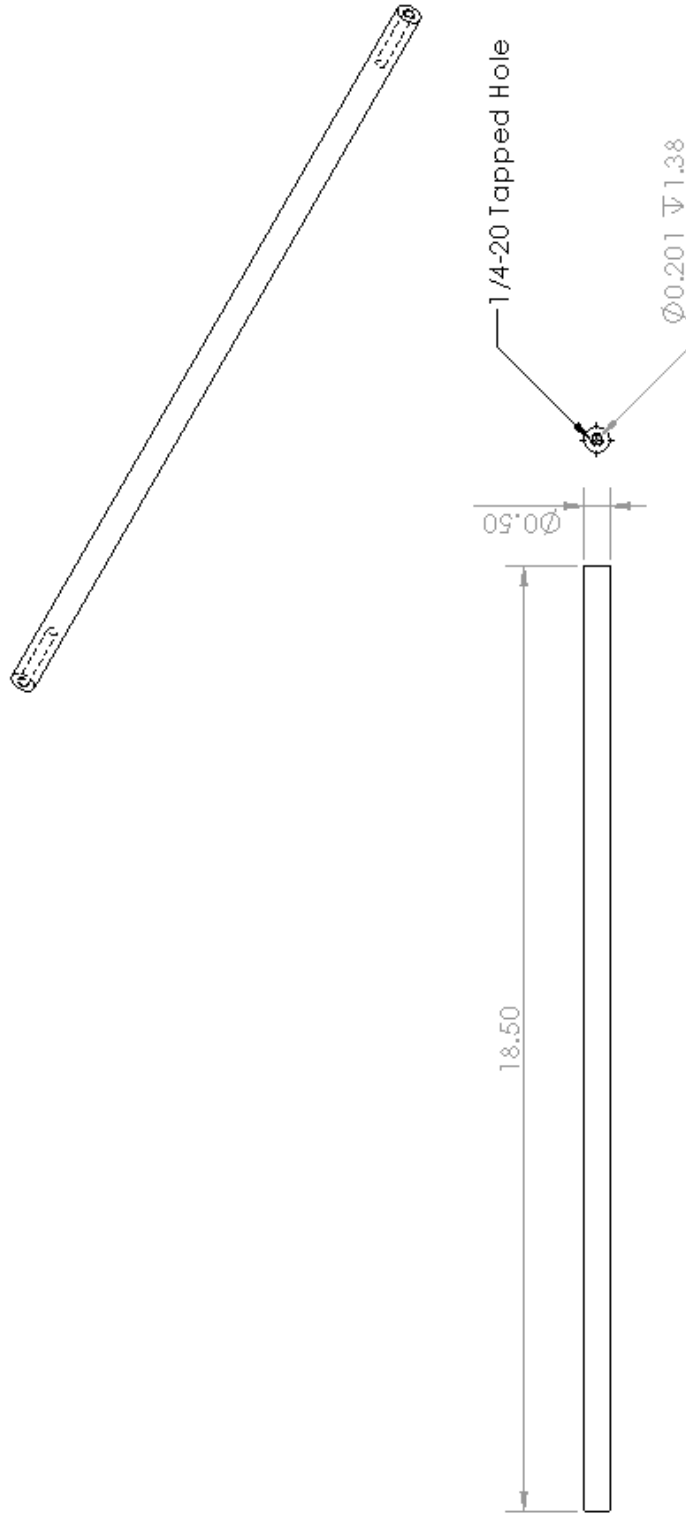
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UNLESS OTHERWISE SPECIFIED:	NAME	DATE	UNIVERSITY OF MICHIGAN
DRAWN	CK	4/10/15	Assembly Plate
CHECKED			Side Support
ENG APPR.			
MFG APPR.			
Q.A.			
COMMENTS:			
SIZE	DWG. NO.	REV	
A	08	B	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 1	

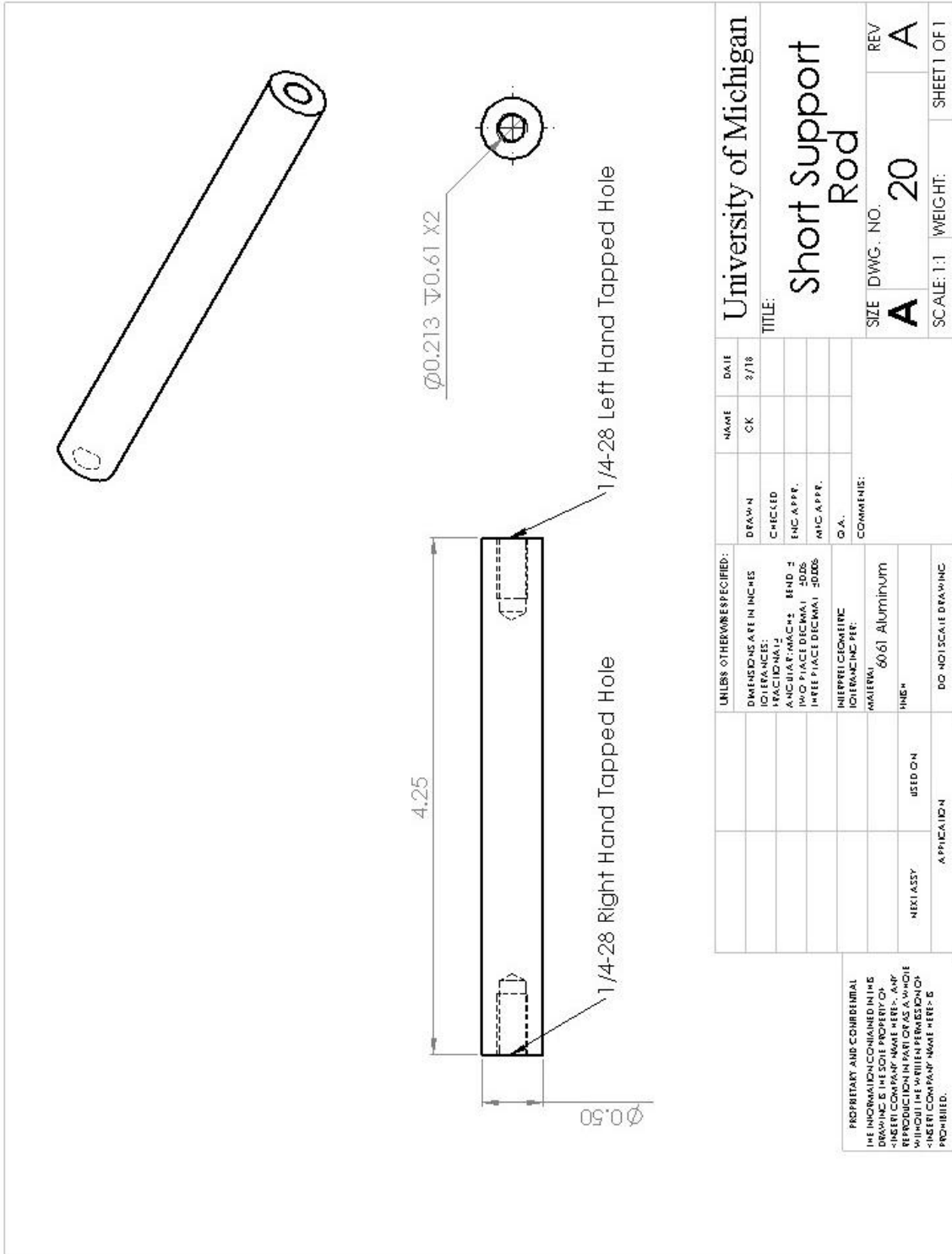
5 APPLICATION 4 3 2 1



UNLESS OTHERWISE SPECIFIED:		UNIVERSITY OF MICHIGAN	NAME	DATE
DIMENSIONS ARE IN INCHES	DRAWN	University of Michigan	CK	4/10/16
TOLERANCES:	CHECKED	TITLE		
ANGLES: ±0.1°	ENG APPR.	Hard Stop		
FINISHES: AS SUPPLIED	MFG APPR.	SIZE DWG. NO.		
THREADS: PER ANSI B1.13-2	QA	<b>A</b> 12		
WELDING: PER AWS A5.1	COMMENTS:	SCALE: 3:2		
PLATING: PER ASTM B680	6061 Aluminum	WEIGHT:		
PAINT: PER SSPC-PA 1	REVISION	SHEET 1 OF 1		
PROPERTIES AND CONFIDENTIALITY: PER MIL-STD-883C	APPROVALS			
PROPERTIES AND CONFIDENTIALITY: PER MIL-STD-883C				
PROPERTIES AND CONFIDENTIALITY: PER MIL-STD-883C				
PROPERTIES AND CONFIDENTIALITY: PER MIL-STD-883C				
PROPERTIES AND CONFIDENTIALITY: PER MIL-STD-883C				



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		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONS: ±0.005 DECIMALS: ±0.0005 HOLE PLACES DECIMAL: ±0.0005 THREE PLACE DECIMAL: ±0.0005 UNLESS OTHERWISE SPECIFIED: TOLERANCES PER: MATERIAL: 6061 Aluminum FINISH:	CK	4/10/15	Handle Bar
NEXT ASSY USED ON APPLICATION	DO NOT SCALE DRAWING	SIZE <b>A</b>	DWG. NO. <b>11</b>	REV <b>B</b>	SCALE: 1:3 WEIGHT: SHEET 1 OF 1
5	4	3	2	1	1





## APPENDIX E: BILL OF MATERIALS

Table E.1: List of materials that we purchased for our prototype during the semester.

Material #	Associated Parts	Material	Amount	Cost
1	Handle, Support Bars	½" Aluminum Round Stock	5'	
2	Base Plate, Mini Press Plate	3/16" Aluminum Sheet	3' x 1.5'	
3	Press Plate	½" Aluminum Sheet	2' x 3'	
4	Handle Grip	Mizuno Handle Grip	6'	
5	Power Supply	Mean Well SP-320-15 Power Supply	1 Unit	\$73.87
6	½" Linear Ball Bearings	McMaster-Carr Part #60595K433	4 Parts	\$134.00
7	Assembly Plate Supports, Heating Element Supports	1" x ¼" Aluminum Bar Stock	6'	
8	Assembly Plate, Pad Support Plate	3/16" Acrylic Sheet	2' x 2'	\$30.90
9	Fasteners	¾" Wide Velcro	3'	
10	½" Linear Sleeve Bearings	McMaster-Carr Part #9533T3	4 Parts	\$62.92

Total Cost: ~\$413.00

Note: The ½" linear sleeve bearings purchased were not actually used in the final prototype after their performance was deemed unacceptable and they were replaced by the linear ball bearings.

## APPENDIX F: Engineering Change Notices

The following list details all of the design changes that we made between Design Review 4 and Design Review 5 and the changes we anticipate making before the Design Expo.

1. Addition of linkage components into the design, including two arm mounts, two short links, two long links, and two mounts on the press plate.
2. Modification of handle to attach to long links and extend completely across front of machine.

3. Addition of holes to base plate for wire mounts, sensor mount, ground wire, power supply, and arm mounts.
4. Changing linear sleeve bearings to linear ball bearings.
5. Modify press plate spacer from 0.313" to 1.0" in length.
6. Changed hard stops from 1.4" to 2.25" in length.
7. Changed assembly plate legs from 1.188" to 1.5" in length.
8. Modify spacer between long link and press plate arm mount to improve handle performance.
9. Remake support bars with correctly tapped holes.
10. Add a fourth support bar to the front of the design.
11. Add any additional fasteners to secure electrical components and wires to the base plate.

## **APPENDIX G: Individual Statements**

### **Milan Kalaria**

#### **Ethical Design Statement**

Throughout our entire design process, the Code of Ethics for Mechanical Engineers has been applied to the design process. In order to address ethics, we took a very open approach to every step of our design, ensuring that we did not infringe on ideas and concepts that were not generated from our team. Ethics were extremely important in this process, as we made several design ideas, and compared these with a Pugh chart. This took out all bias that we may have for designs, and ensured that we picked the best design based on characteristics alone. We considered several aspects when selecting our final proposed design. We took into account a variety of different designs that were as abstract as possible, ranging from a handheld heat sealer all the way to a continuous feed heat sealer that operates with a much bigger space and area. We made sure to do this because this helped keep our options open and stay ethical when deciding on our final product. Keeping a narrow mind on potential designs can lead to an infringement on design ethics because you are bringing in bias to your design, which can lead to several issues in the long term. We also made sure to make changes whenever necessary, instead of looking past potential problems that we saw as we designed our mechanism. Though it was much harder to finish our design after we realized we needed to manufacture linkage bars, we proceeded to do so because we knew there was an inherent flaw with using just gas struts to move our top plate. Our engineering ethics made us analyze our mechanism and move past small issues in the short term to make sure our machine operates well in the long term. Several companies have gotten in trouble for hiding design flaws that may seem small, but end up causing devastating consequences once operated.

#### **Environmental Impact Statement**

I have considered the impact of our design on the environment throughout the entire design process. Our design used mostly recycled metal and very few newly ordered parts, which reduces the environmental impact of ordering unnecessary new materials. The environmental impact of our solution is only from the power outlet needed to run our design. Our design needs to use power to operate, and thus it was unavoidable to reduce this impact on the environment. If we had ordered our materials all from scratch, these materials would have had to be shipped to a local vendor, and then delivered via delivery truck to our place. This ecological footprint would have been much bigger than necessary, and we were happy to avoid this issue. Our product can also be completely recycled at the end life, as the parts we have can be melted down and re made into whatever the user feels necessary. Very few parts need to be thrown out completely, some being the Kevlar tape and the nichrome wires used to heat the makapds. Overall, our environmental impact of our design is very small, and the ecological footprint is almost negligible. I am extremely satisfied with the small environmental impact that our product has on the world.

## **Carlea Hazzard**

### **Ethical Design Statement**

The Code of Ethics for the American Society of Mechanical Engineers require engineers to use their knowledge and skill for the enhancement of human welfare, being honest and impartial, and striving to increase the competence and prestige of the engineering profession. As a student working with the MakaPad Sealing Optimization team our project has met these overlying criteria for engineering ethics. Our project is closely related to the welfare of humans as we have designed a machine that will be used to better the lives of women in underdeveloped countries by increasing production of the MakaPad at lower costs to reach more women and help the local Ugandan women that work for the Technology For Tomorrow company. We have done our best to design this machine to be safe for the worker and create a safe product. The materials selected were designed for sturdy repetitive use, but sharp corners were avoided for most areas of the design. We have been honest and impartial in our work. We report weekly to our sponsor with the honest progress and provide proof and documentation of the work through design review milestones. We have communicated with our sponsor with the process of the design and provided reasons for changes. We aimed to be impartial in this process; to please all parties affected by the MakaPad project, including the group members, professors, sponsors, MakaPad workers and consumers. By balancing the wants, needs, and specifications of multiple groups we have designed a machine that will meet the requirements for these people. For the final design we have included safety features such as hard stops, electrical grounds, rubber handles, filed or rounded edges, heat sensor timer, gas struts to hold up the press plate, and protected pinch points, There was plenty of debate on how to best protect the hands of the workers when around the heating elements and whether top or bottom would be better, Several factors went into this decision such as worker familiarity, ease of manufacturing, and design validation. There were concerns about the heating elements in both the top and bottom positions, but ultimately the bottom position was decided. Including a timer heat sensor will help aid the wires from overheating and the assembly plate should allow workers to align pads and slide into the alignment press area without prolonged touching near the heat elements. Overall our design was created with honest and good intentions to better the MakaPad heat sealing process.

### **Environmental Impact Statement**

Recently I have had the opportunity of attending a Life Cycle Assessment seminar with University of Michigan Mechanical Engineering Professor Steve Skerlos. Between DR5 and the Design Expo, I intend to perform a streamlined life cycle assessment concerning our prototype based upon the materials used and what type of emissions would be involved with this. This LCA will just been an estimate and the calculations will be found using the CES software. Our proposed machine we hope will increase the efficiency and production of the MakaPad. By using our design we hope they will use less or the same amount of energy that the factory currently uses but be able to produce more MakaPad at this same energy value. Unfortunately, due to the nature of the task at hand with heating elements, we were limited with what type of wires and materials we could use when it came to manufacturing. A suggestion for “fixing” the prototype would be to work the Makerere University in Uganda and partner with them to better understand what materials and manufacturing capabilities are available for the MakaPad heat seal machine.

Currently the design features a majority of aluminum, and while this is a sturdy material, there could have been other options to provide a sustainable approach. However, currently the heat sealer machines used at the factory are purchased from local vendors. So, our design offers the option of collaboration with the university to manufacture the heat sealer machines with their own resources. Finally, our prototype was created by re-using or repurposing multiple components and materials utilized in previous generations of the MakaPad heat sealing project. This eliminated not only cost but reduced the delivery emissions impact of several materials. Most of the metal was made from scrap metal from the university machine shop or purchased at the local Ann Arbor metal parts vendor, Alro Metals. Re-purposed and reused components of the design include the chrome-plated shafts, screws, PTFE protective heat element layer, support rod connection pieces, handle linkages, and the nichrome wire heating elements. Re-using the components and materials of previous projects for our prototype reduced our potential emissions and environmental impact.

**Curt Kemerer**

### **Ethical Design Statement**

Ethics have played a key role in the design process of our prototype. Because the MakaPad and its production counterparts are heavily influenced by human interaction, it is vital that we consider the Code of Ethics for Mechanical Engineers throughout the entire design process. As an example, the first fundamental canon of the ASME code of ethics states that “engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.” This has played a major role in the design of our prototype, because the safety and welfare of the people who will be using it have been the main priorities for our team. Our product involves multiple components that could potentially lead to burns, cuts, or pinch points, and as such we have designed our product to eliminate these dangers and protect the user as much as possible. Some of our other main user requirements are directly reflective of our goal to improve the welfare of the user, such as increasing production time, decreasing the number of steps required to seal each pad, and lowering the input force required. By increasing the production rate for the process, the workers will have more earning potential and therefore increase their quality of life. Minimizing the force required to operate the machine and decreasing the number of steps required to seal each pad increases the ergonomics of the process and reduces worker fatigue, improving the working conditions drastically and making their day to day lives much better.

An additional fundamental principle of the ASME code of ethics states that we must be honest and impartial in our dealings with clients and the public. Throughout the design process we have been in constant contact with our sponsors and advisors. We have always been truthful in our project updates, keeping our invested parties updated with accurate progress measurement. This has allowed us to keep on a track that is most beneficial for all involved parties. We have also been impartial throughout the design process by making decisions that consider all parties involved and attempt to meet our sponsors’ requirements as best as we can. Input from all others involved in this project, including sponsors, advisors, student colleagues, the workers themselves, and many others have been considered to make our project as beneficial and ethical as we could. While there are also many other applications of the code of ethics to our project,

overall I believe these examples show that we have made every effort to be ethical in the design of our MakaPad sealing prototype.

### **Environmental Impact Statement**

Sustainable design is something that is becoming increasingly important in today's society, and is something that we have addressed in our design. Perhaps most evident is our attempt to reduce the power that is required to operate our prototype. Electricity is not always reliable in Uganda, and the sealing step is the only step in the MakaPad cycle that requires electricity. As such, we have sought to reduce power consumption even below the 300 W requirement in an effort to reduce the power consumption and all negative associated impacts throughout the life of the product.

In the design and manufacturing of our prototype, the materials selection process has had much room for improvement. A majority of our design components are made of aluminum or other metals, which require a lot of energy input to make and then machine down to size. However, to reduce this impact we reused as many components as possible from previous teams and also acquired our aluminum either from the local metal scrap shop or the mechanical engineering machine shop here at the university. In fact, very few materials were ordered for the production of our prototype, eliminating the environmental costs of having to make and ship new materials. Our prototype was also designed to eliminate as much end of life impact as possible. Because there are multiple components yet very few that need maintenance or constant replacement, there will be little maintenance cost for the operation of our prototype. If anything does need to be replaced, it can be without having to scrap any other parts of the design. When the entire product does eventually reach the end of its life, it can be scrapped out and recycled so that most of its metal components can be reused. To "fix" or otherwise reduce the environmental impact of our design, I believe that the design can be simplified to remove some of the material required and that new materials can be researched that are more eco friendly than aluminum and steel.