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Frugal Clay Press for Nicaragua: Design of a Human-Powered Clay Brick Press for Rural Application

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ENTITLED

FRUGAL CLAY PRESS FOR NICARAGUA
Design of a Human-Powered Clay Brick Press for Rural Application

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By

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SENIOR DESIGN PROJECT REPORT

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ABSTRACT

This team was connected to a brick-making social entrepreneurship in Ciudad Darío, Nicaragua. Travel to Nicaragua in March of 2018 determined that the entrepreneurship wanted a manual brick press to increase the mechanical properties of bricks while decreasing the time needed for the bricks to dry before being baked. Fabrication of a semi-functional beta prototype was completed in May of 2018. Prototype operational tests showed that one cycle of brick compression and retrieval took roughly 3.5 minutes to produce a single double-sized brick. Water absorptivity tests determined that compressed bricks of red art clay experienced a percent absorptivity of 20.5%, with non-compressed bricks formed in Nicaragua having an absorptivity of 35.0%. Finally, the ultimate compressive strength of bricks produced using the prototype averaged to 1,640 psi, as compared to 822 psi of the Nicaraguan brick. Insufficient data was collected to confirm the safety and effectiveness of the design. Several mechanical errors in clay compression and subsystem interferences merit further redesign. Recommendations for design iterations are included for future design teams to finalize and deploy the device.

Keywords: mechanical, compress, press, brick, compound, lever, frugal

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Introduction

Project Motivation

A widely used building material in rural communities around the world is locally harvested clay. For example, the country of Nicaragua has a natural abundance of soil that, when mixed with water, sand and sawdust, forms a highly dense and malleable type of clay that is used in building bricks, roof tiles, and floor tiles in rural homes and buildings. The current clay brick and tile making methods in Central America and other developing countries, while allowing for mass production with cheap equipment, are often imprecise, cause long lead times in the forming processes, and require the equipment to be replaced often.

Figure 1: Clay worker in Ciudad Darío retrieving bricks from clay oven.

Because of this, tiles and bricks are not formed to a level where one can sufficiently ensure uniform and adequate mechanical properties for robust roofing or walls. The implementation of a clay brick making device would enable house builders to more easily and reliably form quality clay bricks for walls to use in construction of new homes and public facilities in rural communities of Nicaragua.

Field and Literature Review

This senior design team has researched and analyzed academic journals, textbooks and companies in the clay building materials industry and civil engineering standards that have proven to be useful in terms of defining some possible design constraints, understanding material properties and physical behavior of clay, and understanding how to design with frugality in design.

ASTM Experimentation Standards

In order to attain accurate and reliable results for testing procedures, it is important that a consistent set of universal metrics be used. For this purpose, the American Section of the International Association for Testing Materials has imposed a set of standards for how various tests should be performed [1]. These metrics are important because they provide us insight on the quality of the bricks and their resistance to certain failure modes. However, these metrics are only valuable and legitimate in that they are universally consistent. For the purposes of this project, it is imperative that these standards be followed such that the experiments conducted will be reliably accurate to verify the quality of compression achieved by the Frugal Clay Press design. ASTM Experimentation Standards guided the experimental design of the water absorptivity tests and compressive strength tests used in the prototype validation phase.

Water Absorption Test on Bricks

One important metric for testing the quality of bricks is their water absorption factor. In an article by Gopal Mishra, 2017, the significance of this metric, details on the testing process, and benchmarks for ideal results are elaborated [2]. According to Mishra, a brick with a water absorption of less than 7% when performing a cold absorption test is ideal, as it provides better resistance against damage by freezing. However, it is also noted that the brick should not exceed 20% water absorption. These methods are incredibly important to ensure that the Frugal Clay Press meets industry standards, as well as the standards of this team.

Optimum Moisture Content for Soil Compaction

One critical factor in the compression of clay and soil is the optimum moisture content for compaction. Moisture content refers to the percentage of total mass or weight of water in a given amount of clay. The optimum water content of a soil is the water content that will result in the maximum dry density of the clay after a given amount of compression. In other words, it is the moisture content that will allow for the most compression. If the clay has too small of a moisture content when being compressed, then the soil will resist compaction due to particulate friction and shear. This lack in lubrication will result in the clay not packing closely, leaving voids in the mass. However, if too much moisture is present, then the moisture will occupy space that would otherwise be taken up by particulate. Since water is fairly incompressible, this will result in voids upon evaporation, resulting in a low dry density as well.

The optimum moisture content varies from clay to clay. As a result, tests must be run to determine what that optimum moisture content is. Articles written by Neenu Arjun (2017) and I. H. Hamdani (1983) outline the significance of the optimum moisture content and provide methods for its determination in various clays [3][4]. While it is unlikely that a third world community will be able to operate at the optimum moisture content, it is still important to know. This is because the dimensions of the compression chamber being designed will be affected by the maximum expected compression. These same tests will also provide for a range of possible compression distances in terms of dry density.

Effect of Container Wall Friction on the Consolidation of Clay Specimen

A necessary factor in the design of a compression system is the frictional resistance and consolidation of clay in the compression chamber. A report by Owais Mir (2015) determined that increasing the diameter of the extrusion tube increased the aspect ratio, or the ratio of diameter to height of the chamber, and that different chamber materials had different friction coefficients for contact with clay [5]. An aspect ratio of 3 was determined to be most effective in the reduction of internal stress in the clay during compression, which would allow for more adequate consolidation of the clay. Even smaller aspect ratios were also found to reduce total stress in the clay by up to 50%. This suggests that a hand powered compression device should have a chamber aspect ratio of less than or equal to 3 to allow the user to compress the clay with the least clay resistance and physical effort expended during operation. It was also determined that the material chosen to be in contact with the clay had a much stronger influence than the aspect ratio of the compression chamber in ensuring low friction in compression. This was a crucial consideration in the design, as the device that was to be produced must be human powered and should therefore offer minimal resistance in clay compression while producing the most consistent mechanical advantage throughout the compression process.

Dealing with Non-Negotiables for Frugal Design

In this article (Lecompte et. al 2015), the authors discuss how to find the perfect middle ground between affordability and performance by analyzing the case studies of five frugal products in India [6]. Three general strategies for finding this middle ground are identified: design by aggregation, design by extension, and design by focalization. These three strategies are based of the key ideas of essential value, additional value, and cost. Each strategy weighs these components differently, providing the users with a qualitative and quantitative decision-making system. The article concludes that, in most cases, design by focalization drastically reduces the overall cost of the project by isolating the most essential value.

Additionally, the article discusses how to identify the "non-trade-offs", or aspects of the design that are considered non-negotiable to the design of the product. Overall, these ideas are essential in the design phase of the project and give crucial considerations on how to iterate upon the conceptual clay brick press design while emphasizing its frugality. The next design aspect to consider is the material properties of the clay that will be used in the brick making process, as materials that would be more effective in interacting with clay from the target community may not be affordable and could compromise the frugality of the design.

Design of Machine Elements

Information on mechanical advantage through power screws was used from this textbook to do a rough calculation on the force output that would be produced by a manual operator for a single lead screw extrusion design. Figure 4 in Appendix E shows a calculation for the force exerted on clay in an extrusion chamber using Equation 5.11 in Spotts, M.F,. et. al. (2004) assuming ACME threads and a force application of 50 lbs-f on a 3ft lever arm [7]. An important note is that this calculation is assuming that the power screw that is being operated is exerting "T_{raise}", or that the applied torque is being used to drive the lead screw vertically. It is assumed here that the force that the lead screw applies is transmissible translationally as well. This calculation was done to determine a compaction force that would be applied to the clay that would be pushed through a lead screw extrusion system, and estimate the force being applied by a clay tile making machine used for benchmarking purposes, YFHT.

Product Design and Development

This textbook has been used extensively in forming qualitative as well as quantitative questions to direct towards potential buyers and users of the device as well as sponsors of this design team (Ulrich, K.T & Eppinger, S.D, 2016) [8]. Members of the Engineers Without Borders club at Santa Clara University, Dr. Tonya Nilsson at Santa Clara University, and Alan Baez-Morales with the Frugal Innovation Hub at Santa Clara University were selected to be interviewed.

Manufacturing Engineering and Technology

The textbook used in Santa Clara's materials and manufacturing course provided useful information in understanding the most common form of clay extrusion known as direct extrusion [9]. Direct extrusion systems force raw material known as the billet through the die-mandrel to produce the desired shape. Indirect extrusion is another possible extrusion mechanism to produce clay bricks, and differs from direct extrusion in that the die is forced through the billet, as opposed to the billet being forced through a stationary die. It is also important to note that the necessary extrusion force is entirely dependent on the strength of the billet material and the friction between the material of the extrusion chambers and the billet. Extrusion of clay generally falls under the category of cold extrusion, meaning that extrusion of material happens at temperatures comparable to room temperature. While cold extrusion may produce heat through the process, the temperatures stay low compared to hot extrusion. Cold extrusion would have been the method of production if an extrusion system was designed.

Fireclay

FireClay is a sustainable clay tile making company based in San Francisco, CA [3]. The team made contact with a company representative named Neil Gotchman to gain information regarding industrial clay tile making standards and machinery. Most of the questions asked did not receive adequate answers as many responses were withheld as proprietary information. The most applicable information related to this project was that the company used industrial grade extruders to produce clay tiles at a rate of 25 squares per hour. Additionally, their website notes that southern California clay, dust from gravel production, recyclable glass, and post-industrial waste from FireClay's production facilities are used to make their tiles conform to standardized values for the absorptivity of water from the International Code Council, which are not made public.

MCA Roof Tile Inc.

MCA Roof Tile is a leading producer of clay roofing tiles in the United States located in Corona, CA [8]. The team contacted a sales representative at their general customer service phone number. From this conversation, the team learned that this company uses industrial extrusion machines to produce tiles made of a mixture of three materials: yellow shale, asphalt, and red clay. The clay tiles are of production standard of 15 weight percent absorptivity of water and made by their machines through cold extrusion at a rate of 100 tiles per minute. The representative did not know the exact specifications or material composition of their machine, nor did they know when extrusion dies were replaced. The information from this company aided the team in assessing industry standards, setting an upper limit of productivity achievable by the teams designs.

Project Objective & Team Goals

In November 29th, 2017, the Frugal Innovation Hub connected the Frugal Clay Press design team to Ladrería y Bloquera San Pedro: a social entrepreneurship in Ciudad Darío, Nicaragua. This small community of around fifteen to twenty workers fabricate and sell clay bricks and tiles to the main town of Matagalpa province. As it stands, the community is only able on average to produce about 9,000 bricks a month, or about 400 bricks per day. Connections made with the organization through Mr. Allan Baez-Morales of the Frugal Innovation Hub made it possible to partner with the community in Dario in December of 2017. Conversations with Mr. Gutierrez, owner of the social entrepreneurship, determined that they did not have the need for a clay tile production mechanism and wanted a device that solely focused on the production of bricks. Following partnership with Ladrería y Bloquera San Pedro, the design project objective was changed from the production of a clay tile extruder to the design of a manually operated clay brick press, and the Frugal Clay Press for Nicaragua project was officially established.

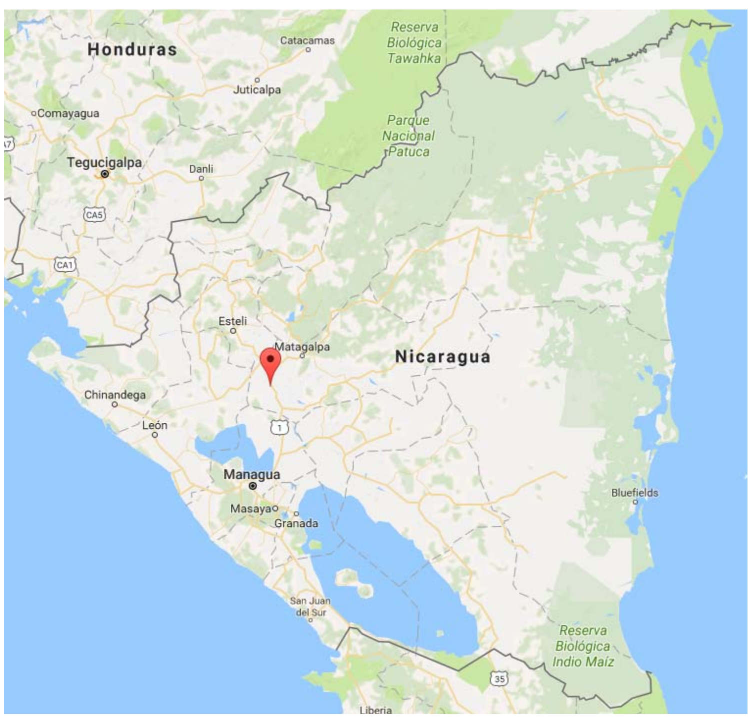


Figure 2: Province of Matagalpa, Nicaragua, where the partner organization Ladreria y Bloquera San Pedro is located. Map courtesy of Google maps.

The Frugal Clay Press design team desired to produce and test a fully functional prototype of the hand-powered clay brick compression device for Ladrería y Bloquera San Pedro by the Senior Design Conference on May 10th, 2018. The design was expected to successfully facilitate, expedite, and ease the process of forming and cutting clay bricks, only using building materials that may be cheaply and easily accessed by the target community. Components of the Frugal Clay Press for Nicaragua were to be designed from simple geometric shapes to allow the pieces to be easily machined, and were to be designed to be quickly bolted or welded together for easy assembly by the target community. Moreover, the design must be appropriately designed for easy operation, training, and maintenance by clay workers. Finally, a main goal of this design team was to travel to the target community in March of 2018 to conduct on-site clay research and in-depth voice-of-customer assessments, and to return once more in July of 2018 for final implementation in Ciudad Darío. The extent of fulfillment of these project goals is discussed throughout this thesis.

Systems Level Chapter

Customer Needs Assessment

Initial conversations with the owner of Ladrería y Bloquera San Pedro in the fall of 2017 as well as travel to Nicaragua in March of 2018 determined several explicit customer needs regarding the design of the Frugal Clay Press for Nicaragua. Teleconferences with Mr. Rolando Gutierrez from September 2017 to early March of 2018 were useful in understanding the current methods of brick production used in the community. A more detailed table enumerating the customer needs defined through Voice of Customer assessment is available in Appendix B.

The clay workers of the community are trained to mix clay and form bricks entirely by hand through a labor-intensive process that takes roughly four to six hours. Workers form clay mounds roughly two to four feet tall using a mixture of three Nicaraguan soils that are brought into the brick fields from local quarries. Mr. Gutierrez called the mixing a largely "empirical" process, where workers add sand and sawdust to the mounds until it "looks right." The workers are also trained to add two different types of dirt found in the brick field if the clay does not compact well, or to add sand when the clay is too compact or sticky for the molds. Finally, a hose is left to run atop a clay pile until the clay is wet enough to be scooped up by the workers and placed into wooden clay molds for forming. Because the amount of water added as not specific and uniform, it was difficult to determine the properties of the clay with any certainty.

One of the customer's largest hopes for the Frugal Clay Press was that it would reduce the amount of time needed to dry each brick before baking. Their clay mixing process relies on a significant amount of water because the clay has to be able to be easily transmitted into a wooden mold and be cohesive enough to retain its shape after removal of the wooden mold. While this allows the workers to make four bricks in just under one minute, the bricks that are formed are unable to be moved from where they were formed on the ground as the wetness of the clay makes it easy for the brick to fall apart when picked up or touched by the workers.

Additionally, wetter clay requires each brick to spend three days at a minimum on the ground to dry before being moved to a clay brick stack, or *macho*, for four more days before being placed into the clay brick oven for baking. Use of the Frugal Clay Press was expected to reduce the amount of time needed for the bricks to dry through Clay Compression. Clay workers operating the clay press would be using much less water in the mixing of clay. The result would be that the press would not only compress mixed clay into the shape of the brick they need, but it would also allow the workers to pick up and move newly formed bricks without them deforming during movement. This would assist the community in more quickly clearing up space in their bricklaying fields because clay workers are stacking the *machos* around the fields faster than the community is able to bake and sell bricks.

Figure 3: The clay brick stacks, or *machos*, created by the clay workers in Nicaragua to dry several clay bricks for six days in the brick fields.

Another need specified from the customer and the employees of the social entrepreneurship was that the press be a device that contributes to the team-oriented nature of their work. Travel to Nicaragua in March of 2018 allowed for members of the design team to speak with both Mr. Gutierrez and some of his employees regarding their concerns of the Frugal Clay Press design. A fear among the workers was that if the press was to be more efficient than they were at their work, Mr. Gutierrez would have reason to reduce the amount of work available to the workers, who were all men from ages 17 to 50 that did not have other work outside of brick making with the social entrepreneurship. This is addressed in the design itself, as two to three people are required to efficiently compress and retrieve clay bricks from the device. Speaking with Mr. Gutierrez determined, however, that increased brick throughput through the use of the Frugal Clay Press could actually increase the amount of work available at the brick fields. As more clay bricks are being made and dried, their clay oven may be operated much more frequently. The increased need for workers to be mixing clay, forming bricks, and operating the oven is anticipated to provide more employment opportunities for clay workers in Ciudad Darío.

System Level Requirements

Through teleconferences with the owner of Ladrería y Bloquera San Pedro, Mr. Rolando Gutierrez, and in-person interviews with his employees, a set of Product Design Specifications (PDS) were formed. These specifications served as system level requirements that were aimed to be achieved by the Frugal Clay Press prototype after its completion in June of 2018. The wooden mold currently used by the community to form clay bricks is defined as a datum for comparison to the goals of this design team for the Frugal Clay Press prototype. A more detailed PDS table is included in Appendix C.

<u>Throughput of Bricks</u>

Currently, clay workers are able to produce four bricks at a time using the wooden mold. The process of filling the mold with clay, forming the brick into shape, and taking out the mold takes roughly one minute. The target range for the Frugal Clay Press was to output two bricks in a single minute, from the beginning of filling the clay chamber to the extraction of the clay brick from said chamber. While this would reduce the amount of bricks produced per minute, it would hopefully compress the bricks thoroughly enough to reduce the amount of drying time needed by a significant amount.

Drying Time of Bricks

Newly formed bricks from the community in Nicaragua currently require six to nine days of drying on the ground before they are baked in their clay oven. This is because the clay that is used is overly saturated with water, which helps the workers more easily mix and form the clay into desired shapes. The target range for the Frugal Clay Press design was to reduce the amount of drying time to two to four days through clay compression.

Life of Assembly

The wooden molds used by the clay workers in Nicaragua last them about three months. This is because the wetness of the clay makes it possible for the wood to rot and deform over time. As the clay workers fill the molds and scrape clay off of the tops, the wood begins to dip because of repeated friction with the clay and the hands of the workers. To address this, the target range of life for the Frugal Clay Press was designed to be up to four years, as a majority of the device would be made of hot rolled steel.

Benchmarking Results

Pre-existing Products

Extensive market research yielded a variety of different concrete and clay brick making machines. It was first discovered that a large number of the clay brick making devices were industrial grade, pressurized extruders with cutting mechanisms. Because these products required a vast amount of electrical power input and were quite costly with prices ranging in the tens of thousands of dollars, the team decided to focus their analysis on mechanically powered machines that were priced at $3,000 and under. With modification, these general design concepts could be implemented in or improved on the Frugal Clay Press design concept.

Table 1: Summary of existing manual clay brick making devices.

Existing Product	Manufacturer	Price	Processing rate [pcs/hr]	Weight [lbs]	Dimensions of Product [ft]	Force Application [lbf]
YFHT [Appendix A]	Ying Feng Group	$1,999-2,999	125	660	3.94 x 4.27 x 3.94	4,500
YLF1-40 [Appendix A]	Ying Feng Group	$1,000	120	475	1.64 x 1.31 x 3.28	18,000-22,500
Stabilized Soil Brick Press [Appendix A]	Makiga Engineering	$1,000	56	286	1.75 x 2.25 x 3	22,800

The first two products are from the China Zhengzhou Ying Feng Group Ltd. YFHT is a large manual clay tile press and YLF1-40 is a moderately sized clay brick press with a simple lever. The brick press developed by Makiga Engineering is a smaller but similar product to the YLF1-40. The YFHT has a high production capacity but it is heavy enough to be difficult to transport to the target community and expensive enough to easily exceed the target community's budget. By using locally sourced materials, this team determined that it should be possible to make a smaller, more economical version of the press. Also, by using principle of mechanical advantage, it should be possible to condense the size and weight of the device into something that is manageable for clay workers in the target community to move if needed.

The YLF1-40 is more appropriate for the target community's uses compared to its larger counterpart, the YFHT. The YLF1-40 has relatively high production rate and is much cheaper, lighter and smaller than the YFHT. That being said, for something similar to be deployed in the target community, it would have to be manufactured from locally sourced materials. Furthermore, this current model is still a bit too heavy to be regularly transported between various locations and too complex to service with rudimentary knowledge of machines. This model could also be improved by adding multiple lever arms and more clay brick molds to produce more bricks at once. Finally, the Makiga Engineering stabilized soil brick press faces similar barriers to its slightly larger competitor. While this device is lighter and therefore more transportable, it has a slow cycle time and is equally as mechanically complex. If this lighter version could be reproduced cheaply with local materials, several devices for brick production could be used in parallel to make up for the production rate deficiency.

A significant factor to discuss among these devices is their ability to apply force to the clay. The YLF1-40 and the Makiga brick press are both capable of applying about the same amount of force to their bricks, which is rated at about 22,000 lbf. However, for the YFHT, no force application data was provided. As a result, basic calculations were done to estimate the force output assuming a 2 in ACME lead screw and a 3 ft wide force application wheel with the user inputting 50 lbs on each handle, the calculations for which can be found in Figure 4 in Appendix F. Out of the given machines, the YFHT has a very comparable force output to what the Frugal Clay Press is designed to achieve. The YLF1-40 and the Makiga brick press, on the other hand, have a far greater force output compared to the Frugal Clay Press, which is designed for a 3,200 lbf standard output and 9,600 lbf maximum output. However, it is worth noting that this is not a reflection of inherent design effectiveness, but rather the needs of the community in Nicaragua and the scope of the project. Changing the length of the input and output lever arms would allow for greater force application while retaining the same amount of compression, but at the cost of ease of use and frugality. An increased mechanical advantage would require a larger distance of force application. However, the intended users of this machine would likely find this amount of motion to be overly-cumbersome. Additionally, if the machine were capable of applying higher loads, then it would need to be designed to withstand the internal stress caused by this loading. This would not only require more expensive and robust parts, but would also prohibit the use of certain frugal design methods.

Layout of System-Level Design with Main Subsystems

Figure 4 is a simplified flow diagram for the operation of the Frugal Clay Press. The flow diagram begins with the input of clay and details the interactions between the subsystems, and concludes where the prototype outputs a double-sized clay brick ready to be cut and dried for later processes. The five main subsystems of the Frugal Clay Press include the Compression Chamber to contain the clay for compression; the Lever Arm, which requires input force from the operator and amplifies it to achieve appropriate compressive force; the Compression Plate, which uniformly delivers this compressive force to the clay in the Compression Chamber; the Clay Retrieval system, which allows the operator to return the Compression Chamber to loading position and to eject the clay bricks after compression; and the Base Fixture, which holds all of these subsystems together. The total duration of the brick making process from user input to clay brick retrieval is expected to take forty five seconds to a minute per cycle. The number of operators necessary to operate the device is expected to be two to three people. A single person would handle compressing the clay while one or two people would handle retrieving the compressed brick and refilling the Compression Chamber with a fresh amount of clay. A detailed discussion of the subsystem roles and designs is included in the Subsystem Chapters of this thesis.

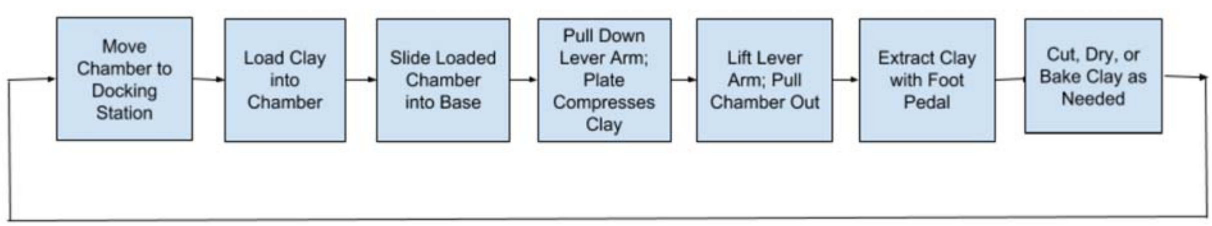


Figure 4: System level design and subsystem block diagram.

User Scenario

The Frugal Clay Press device is designed to be most effectively operated by three operators: one operator of the Lever Arm subsystem, and two operators for loading and retrieving the clay Compression Chamber. While this may be the case, it is also designed to still achieve its main functionalities if there is only one operator present.

1) First, a user docks the Compression Chamber on the edge of the support rails of the Base Fixture subsystem. From here, clay can easily be loaded into the chamber either by hand or with the aid of a shovel.

Figure 5: Step 1 of the user scenario.

2) Next, the user handling the Compression Chamber slides the Compression Chamber into the main body of the Base Fixture until it hits the wooden guard on the other side. In this position, the wood guard attached the Clay Retrieval side of the Base Fixture and the wood guard attached to the Compression Chamber should line up and be completely flush.

Figure 6: Step 2 of the user scenario.

3) Once the Compression Chamber is in the proper location, the user operating the lever holds up the lever while the other removes the Lever Arm support block.

Figure 7: Step 3 of the user scenario.

4) The user handling the Compression Chamber steps out of the way while the user handling the Lever Arm uses the three tier Lever Arm handle to compress the clay to full depth using their body weight.

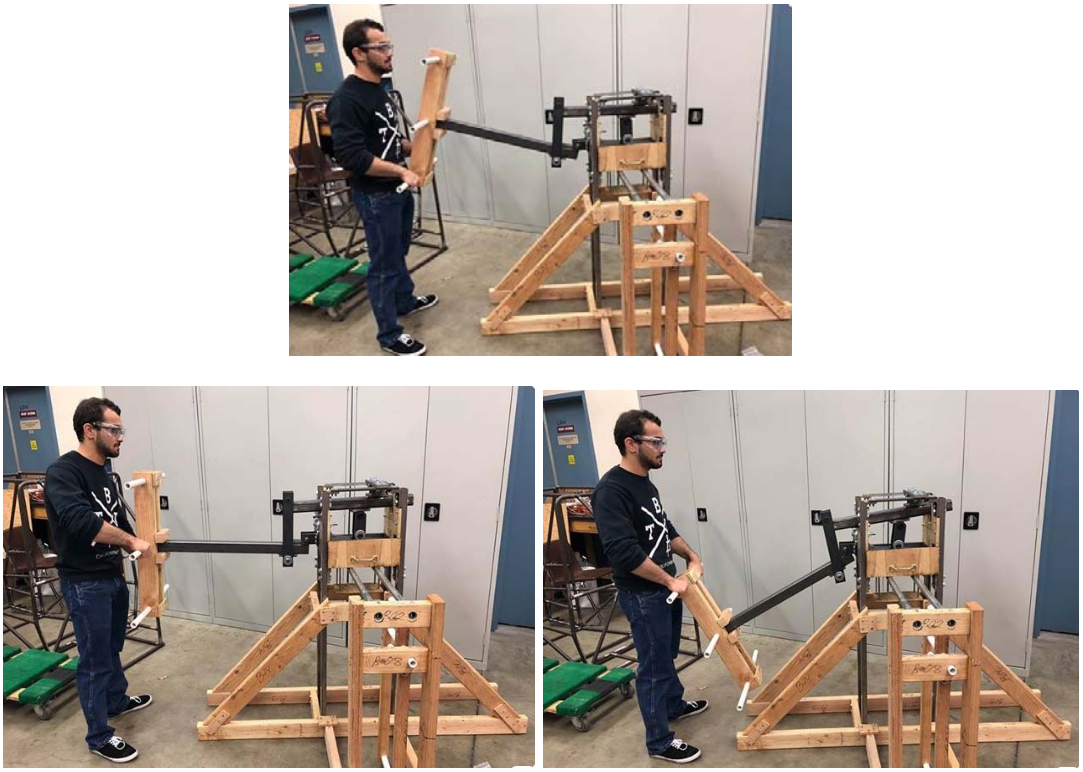


Figure 8: Step 4 of user scenario. Note that the user "climbs the ladder" when applying force on the input lever to consistently achieve maximum mechanical advantage throughout the stroke.

5) Once the clay has been compressed, the Lever Arm is raised back up to the upright position. The support block is reinserted to its position in the Base Fixture, and the user handling the Compression Chamber slides the chamber out into the retrieval area.

Figure 9: Step 5 of the user scenario

6) Finally, the clay is raised out of the Compression Chamber using a foot pedal mechanism to eject the newly compressed clay bricks. After the compressed clay is taken away, the foot can be taken off of the food pedal to allow for more clay to be loaded into the chamber for another cycle.

Figure 10: Step 6 of the user scenario.

Functional Analysis

Functional Decomposition

The primary function of this design is to amplify the user input force by a factor of 45 times through mechanical leverage to compress clay in a Compression Chamber. Conservative calculations estimate the input force to be in the realm of 70 lb-f, or around 310 N. This should result in an output force on the clay of roughly 3,200 lb-f, or 14.2 kN. A single user is estimated to be able to apply their full body weight if needed. In the worst case, the design should be able to accommodate the input force from two operators. As such, the device is designed to give the user the optimal mechanical advantage needed to produce clay bricks. The essential subfunctions include a cycle time of no more than one minute per brick, an efficient extraction method that is both ergonomic for operator and causes minimal deformation of the compressed brick, and a force application mechanism that requires no more than 3,200 pounds of force to compress the clay a distance of approximately ¾ of an inch, producing bricks of a consistent thickness of 2 ½ inches. To be a freestanding device, the base of the brick maker must be able to sustain the loads needed to form the clay bricks. All the components must have a lifespan of at least three years with a serviceability/cleaning period of three months.

Inputs, Outputs & Constraints Summary

The Frugal Clay Press has one primary input and output: newly mixed, amorphous clay, and properly dimensioned, well-pressed clay bricks respectively. The device should be able to consistently take approximately 8 kg of clay and produce a brick of length, width, and height dimensions of 12" x 10" x 2 ½". This forms two bricks at a time that can be cleanly cut in two with the dimensions of 12" x 5" x 2 ½". The chamber is built to filled with clay completely so that clay is level and flat with the top of walls of Compression Chamber. This method of filling helps ensure the output of uniformly sized bricks. The input clay must also be well within the range of plasticity to be readily formable but still hold its shape after processing. To be formable, this means the clay must have an acceptable moisture content. A moisture content upwards of 30% would render the clay oversaturated and compression of the clay useless. A moisture content of less than 15%, however, carries the risk of making bricks too dry and unable to be properly consolidated through compression. To facilitate the process, the bricks must be formed directly to the acceptable size prior to drying. Taking into account communities that may not have access to well balanced diet and healthy lifestyle, it is also important to minimize the amount of input force needed to produce the clay bricks.

Key System Level Issues, System Options, Trade-offs, & Rationale for Choices

Key System Level Issues

A key system level issue that was avoided was over-exceeding the allotted budget for prototype materials costs, which would have resulted in a product that would be out of reach financially for the community in Ciudad Darío. Additionally, the system level design had to have been be simple enough to be able to be manufactured with tools, materials and techniques readily available in the market countries. This necessitated that this design would be made mostly out of low grade steel and wood, which are not only much easier to acquire for building and replacing important design components, but can be machined in nearly any machine shop. Moreover, the use of steel and wood in the design allowed the design to be both frugal and still an effective human powered clay brick press that could apply a reasonable amount of force to achieve clay compression.

In addition to choosing frugal and strong materials suitable for the brick press, it was necessary for the design to be resistant to moisture, heat, and precipitation. As the majority of the design is intended to be made of metal and will most likely be situated outside in a tropical environment, the device has the potential of experiencing rusting, wear, creep, fatigue, and lubrication issues. The design must also allow for bricks to be easily removed from the compression system and brick mold as it is retrieved from the compression mechanism. A system level issue that was seen by judges in the Conceptual Design Review presentation on Monday, December 4th 2017 was that the unrestrained range of motion of the Lever Arm and the open nature of the Compression Plate and Compression Chamber interface created several dangerous pinch points for users and observers. It was also pointed out that the Lever Arm has the potential of falling on operators or surrounding people if it is not secured during brick retrieval, cleaning of the device, or other times when the press is not being used to compress clay.

In addition, the Frugal Clay Press design must be reasonably sized and easy to use. Using a compound lever to apply force necessitates that the input lever arm, at its highest point in its range of motion, can easily be reached by an average brick worker in the target community.

Because of this, it has been determined that the peak height of the input lever should be no higher than 5’7” above ground to allow the full range of motion of the Lever Arm to be accessible by a person of a height between 5’2” and 5’8”. Furthermore, the goal for the design was to allow for a single operator to be able to operate the compression of clay without physically overexerting themselves in operating the press. This required that the design simultaneously satisfy adequate levels of force application to the clay as well require a user input force of less than roughly 70 lbs-f (310 N) However, because clay has vastly different properties depending on its type and location, this input force may vary considerably in achieving acceptable levels of compression depending on the specific mixture being used any given day of operation. With that in mind, the Lever Arm subsystem had to be designed so that, if needed, two people would be able to pull on the lever without failing any of the design components, allowing a force of 140 lbs-f (620 N) to be input into the device through the Lever Arm subsystem. Despite this, the Frugal Clay Press is rated for an input force of 210 lbs-f (930 N) in its worst case loading scenario. Therefore, if the device were operated by two individuals larger than the average clay worker in Nicaragua, it may not withstand the input force being applied to compress the clay.

System Options

The two main system options considered were a clay extrusion system with a cutter and a clay brick press. The extruder would take an amorphous mass of clay and, using a die and mandrel, would press the clay through the process of cold extrusion it into a large sheet of the desired brick thickness that could be cut to the desired brick dimensions. The brick press on the other hand would take a smaller amount of clay that would be compressed to the exact brick dimensions as it is being molded. Both systems only form the brick to the proper pre-drying size and are not responsible for the drying process of brick making.

Trade-offs

The extruder would produce a larger number of bricks in a given period of time, however, it would be harder to control the quality of clay produced as it would be hard to feed a manual device with consistent input power. There is also a strong possibility that clay would get stuck in the die and mandrel of the extruder, thus causing problems for the operators, slowing the cycle time, increasing the frequency at which the machine would need to be cleaned, and potentially decreasing the quality of the bricks produced from the machine. Finally, extrusion is best done with an easily controlled electrical power input to produce quality bricks. Implementing electrical power, however, would compromise the appropriateness and frugality of the brick maker design. A clay press would take more time and cycles to create the same number of bricks than the extruder because it would operate without the use of electrical power. Because the press would be forming the bricks to the exact desired dimensions, the press would have higher consistency between different batches of bricks and thus tighter quality control over the product.

Rationale for current choice

The quality of the bricks produced from the newly proposed machine is of critical importance to the members of the target community. Therefore, the brick press concept has been chosen because of the reliability of the bricks coming from a press rather than the questionable quality of clay brick slabs that would be extruded and cut to size. Both methods would be superior to the current process, but the press would be much cheaper, more energy efficient, and involve technology that is much more appropriate for the target community. To compensate for the slower throughput, extra emphasis will be put on molding cycle time and formed clay retrieval methods.

Team and Project Management

Project Challenges & Constraints

<u>Time Constraints</u>

An overarching issue that limited the development, refinement, and experimental validation of the Frugal Clay Press for Nicaragua prototype was time constraints in design, fabrication, travel, and testing. First, a target community was not found by the team until the team was connected by the Frugal Innovation Hub at Santa Clara University to Ladrería y Bloquera San Pedro in November, or the tenth week of the Fall 2017 MECH 194 course. Because of this, a significant amount of time was spent developing the early design as a clay tile extruder. Later research and interviews with the customer in Nicaragua narrowed the design to be a double-brick hand-powered compression device, which was pursued further in the winter academic quarter from January to March of 2018.

Because further design work had to be completed and verified with finite element analysis (FEA), hand calculations, and interviews with the target community throughout the MECH 195 design course, fabrication and iterative design on the prototype was very limited. Iteration during this period focused mostly on finalizing subsystems in Solidworks and FEA for the purposes of purchasing necessary material and fabricating design components in the SCU machine shop. As a close-to-final design revision was not yet prepared by the team at the end of the Winter 2018 academic quarter, prototyping progress was limited to the completion of crucial pieces of the Compression Chamber, Base Fixture, and Compression Plate. Moreover, time taken to work with clay in the civil engineering laboratories and plan for travel to Nicaragua took precedence in the fabrication schedule, negating the possibility of having a testable prototype at the end of March 2018.

Materials Selection

As a design team in partnership with the Frugal Innovation Hub, the Frugal Clay Press for Nicaragua team was challenged to produce a design that emphasized both frugality and appropriateness. Frugality was understood by this team to mean the production of a clay press that was much cheaper than other clay presses that already existed on the market (Appendix A). Using the average prices of these devices as a metric for cost, it was determined that the cost of materials and manufacturing for the Frugal Clay Press prototype be no more than $1,000, with materials costs to be less than $800.

Design for appropriateness also necessitated that the device be easily powered in the community in Nicaragua. This changed the design from a clay extrusion device, which would have required a sizeable amount of electric power, to a purely human powered clay compression device for bricks. Moreover, the design was to only be composed of components and materials that were locally and cheaply accessible by members of the target community in Nicaragua. This was to ensure that the Frugal Clay Press design could be fabricated upon travel to Ciudad Darío, Nicaragua, as a main goal of the design team was to limit the amount of imported materials for the community. As a result, the final Frugal Clay Press prototype was composed solely of zinc fasteners, pine wood, hot rolled steel, and PVC pipes.

Design for Manufacturability & Resilience

Another challenge for the Frugal Clay Press for Nicaragua design project was to ensure that the design would be manufacturable with the tools and materials found in Ciudad Darío, Nicaragua. All design components were designed to be manufactured by a trained machinist solely with the use of milling machines, lathes, hand drills, band saws, miter saws, and belt sanders without the use of CNC machines. Components were also designed with simple geometries to allow machinists to fabricate core components of the design without computer aided machining. Moreover, all subsystems were designed to be fastened together using coarse-threaded machine screws, bolts, and fasteners. This was to ensure that if there were no welders present in the target community, machinists could easily machine design components and assemble the prototype solely with access to hand tools such as wrenches, hammers, allen keys, and screwdrivers.

The prototype was also designed for extended life and easy repair if design components experienced significant wear or failure. Because each component of the design was not manufactured using processes or materials unavailable in Nicaragua, this made it possible for design components to be easily replaced. This feature of the design would effectively extend the expected life of the device in the community, and would enable the customer to maintain the device without reliance on imported parts from the United States.

Soils Engineering

The most significant challenge faced in the design of the Frugal Clay Press for Nicaragua was learning how to apply principles of soils engineering in civil engineering to mechanical design.

As discussed in the articles written by Neenu Arjun (2017) and I. H. Hamdani (1983), the design for a clay press necessitated research on the mechanical properties of clay soils. What was found was that these properties were dependent on a large number of factors, including but not limited to grain size, type of clay, and composition of the soil mixture. Of these factors, the weight percent of water of the mixture was most critical in determining the compressive strength of the clay bricks that would be produced by the prototype. This necessitated that the design of the press not only included extensive stress analysis for each component and subsystem, but that an extensive amount of clay compression tests were conducted on clay mixtures of varying weight percent water and composition in order to determine the most appropriate stroke length of compression for the design.

Travel

A main goal of this design team, which also led to serious time constraints in the design process, was to travel to Nicaragua in the spring and summer of 2018. Travel was a necessity and a challenge for this team because there was no way to accurately model Nicaraguan soil for prototype testing in California. Up until March 2018, clay testing and design work was completed using a similar industry clay press, the Makiga Engineering Stabilizer Block Press, with a conservative guess of the type of clay present in Nicaragua. Soils analysis and experiments using clay found in Santa Clara, California would not have been enough to produce a robust design for the community of Ciudad Darío.

After completion of the exploratory trip to Nicaragua in March 2018, civil unrest in the country of Nicaragua began to surface. In May of 2018, the US Department of State changed the advisory level for travel to Nicaragua from a level 1 to a level 2, as significant threats were posed to locals and visitors alike by protesters and Nicaraguan law enforcement. Because of Santa Clara University's Global Engagement Office bylaws, return to Nicaragua was ruled impermissible. This necessitated that design work be refocused from producing a prototype for shipping and deployment to Nicaragua to completing the prototype for demonstration at the

Senior Design Conference and laying the groundwork for the Frugal Clay Press for Nicaragua project to continue as a legacy project with Santa Clara University.

Budget

A budget was used by this design team to ensure that all estimated costs and expenses relevant to the design of the Frugal Clay Press for Nicaragua design project were properly reported and justifiable with respect to the nature of the project for the purposes of seeking additional funding. Prototype costs and project expenses cataloged for the purposes of maintaining this budget are included in Tables 12 and 13 in the Costing Analysis section. A more in-depth list of prototype materials is included in the Parts List in Appendix 11.

Table 2: Total project budget revised April 2nd, 2018.

Category	**Description**	**Money Spent**
Prototype Costs	Compression Chamber	$200.00
	Compression Plate	$100.00
	Base Fixture	$150.00
	Lever Arm	$150.00
	Clay Retrieval	$40.00
	Bolts and Fasteners	$100.00
Travel Expenses	Spring Break Flights	$2,000.00
	Spring Break Lodging	$200.00
	Spring Break Food & Transportation	$1,000.00
	Summer Flights	$4,000.00
	Summer Lodging	$400.00
	Summer Food &	$4,000.00

	Transportation	
Anticipated Prototype Materials Costs		$740.00
Total Anticipated Costs		$12,340.00
Total Funds		$7,014.28
Necessary Fundraising		$5,325.72

Funding

Several sources of funding were earned by the Frugal Clay Press design team for the purposes of prototype fabrication and travel to Nicaragua. First, $1,800 was given by the SCU School of Engineering as primary funding for prototype materials costs and fabrication expenses. From September 2017 to June 2018, this source of funding was used to order stock materials and fasteners as well as commission welders for the welding of the Lever Arm assembly.

Table 3: Sources of funding for the Frugal Clay Press for Nicaragua design project.

Source	**Requested**	**Granted**
SCU SOE Funding	$ 2,000.00	$ 1,800.00
Xilinx Grant	$ 6,000.00	$ 3,300.00
Dean's Funding	$ 2,000.00	$ 1,914.28
TOTAL	$ 10,000.00	**$ 7,014.28**

Another $1,914.28 was provided by the Dean of Engineering at Santa Clara University to fund the team's exploratory trip to Nicaragua. This was to supplement the $3,300 awarded to the team from the Xilinx grant, which is given to senior design teams that would use the grant to expand the scope of the design project through travel. Because travel in March 2018 was limited to two members and a return trip to Nicaragua was deemed impermissible for the summer of 2018, travel expenses were limited to the $1914.28 total in flight expenses to and from Nicaragua in the exploratory trip.

To allow for the return trip to Nicaragua in July of 2018, an additional $5,200 was estimated to be earned through fundraising and researching additional funds. A GoFundMe page at the beginning of May 2018 was started to raise funds for the purposes of travel for the Frugal Clay Press design team. An application for the Santa Clara University 2018 Engineering Ethics Prize was submitted in April of 2018 to earn an additional $1,000. Finally, petitions were made to the Department of Mechanical Engineering at SCU to supplement whatever remaining funds would be necessary if a summer return trip was to take place in July of 2018.

Timeline

The timeline of this senior design project in its entirety is displayed in the Gantt chart used to document team milestones in Appendix I.

ME 194 (September 17, 2017- December 8, 2017)

Connection was made with the Frugal Innovation Hub in Week 1 of the design process to begin the search for a target community. Partnership with Ladrería y Bloquera San Pedro in Ciudad Darío, Nicaragua, however, was not accomplished until early December of 2018. This was particularly troublesome as many of the design reports assigned during this period required in-depth interviews, customer needs analysis, and further communication with a client that the team simply could not produce. This necessitated that design consolidation and testing of clay found local to Santa Clara was to proceed without knowledge of customer needs or the properties of the clay from a target community.

ME 195 (January 8, 2018- March 23, 2018)

Further design work for the Frugal Clay Press for Nicaragua was accomplished during this period, and prototype fabrication was begun. Extensive FEA in Abaqus was completed in this period to confirm the safety and feasibility of design changes. After being verified in Abaqus, a majority of the clay Compression Chamber and Compression Plate subsystems components were fabricated in the Santa Clara University machine shop.

Exploratory Trip to Nicaragua (March 22, 2018-March 26, 2018)

Both Milan Copic and Rafael Guerrero were able to travel with Mr. Allan Baez-Morales to Ciudad Darío, Nicaragua in March of 2018. During this trip, detailed observation of the community's clay making and brick baking processes were conducted. Additionally, a thorough voice of customer assessment regarding the conceptual design of the Frugal Clay Press was conducted through interviews with the owner of the social entrepreneurship and a handful of his employees.

ME 196 Design Finalization & Prototype Fabrication (April 2, 2018-May 9, 2018)

The bulk of prototype fabrication was completed in this period. Through FEA in Abaqus and trial and error in the machine shop, previously scrapped pieces were repurposed as design components such as the Lever Arm connection beams and the output fulcrum support plates. A standing prototype was achieved on May 9th, 2018 in preparation for the Senior Design Conference.

Senior Design Conference Presentation (May 10, 2018)

On May 10th, 2018, the Frugal Clay Press for Nicaragua prototype was presented at the 48th annual Santa Clara University Senior Design Conference. Overall, remarks of the design and the design process were positive, with clear advice to the design team to confirm the safety and effectiveness of the design through further testing.

Design Validation & Completion of Senior Thesis (May 10, 2018-June 6, 2018)

Prototype operation tests, clay water absorptivity tests, and clay brick compressive strength tests were conducted during this period to validate the Frugal Clay Press for Nicaragua prototype and design. The results of testing were collected and prepared for the completion of the team's senior thesis prior to graduation in June of 2018.

Design Process & Approach

Frugality and Manufacturability

The primary approach in the design for a manual clay press for clay workers in Nicaragua was to design with frugality in mind. Frugality, in the context of the design project, was ensuring that the product would be composed only of cheaply and locally accessible building materials. First, the use of cheap building materials meant that while the prototype materials that were chosen weren't of poor quality, they were affordable for the target community. Use of hot rolled steel, zinc fasteners, and pine wood for the prototype ensured that the clay press could withstand three times its anticipated stresses while limiting prototype materials costs to under $1,000. The accessibility of these materials by members of the target community in Nicaragua was also considered of utmost importance in the design of the Frugal Clay Press. Special care was taken to ensure that all building materials and fasteners could be purchased locally in Nicaragua without the need for importing parts. This was important to ensure that if parts were damaged, fatigued, or otherwise unusable, the clay working community could easily purchase and replace these parts for the press.

The manufacturability of the Frugal Clay Press design was also an important factor in the design process. All design components fabricated in the machine shop were designed using simple geometric shapes. This allowed for all machined parts to have been completed solely through the use of band saws, miter saws, milling machines, drill presses, hand drills, and hammers, which were confirmed to have been available local to Ciudad Darío during the team's exploratory trip in March of 2018. A design for manufacturability enables the Frugal Clay Press design to be easily fabricated and assembled in rural communities around the world that have trained local machinists.

User Centricity and Ease of Use

User centricity in design was considered important to enable the Frugal Clay Press to be easily used by members of the target community in Nicaragua. The current clay mixing and brick forming methods used by the community require workers to spend a significant amount of time squatting and bending their backs daily. Over time, work in this range of motion could cause a significant amount of health issues for the men that are employed by the social entrepreneurship. To address this, the Frugal Clay Press for Nicaragua was designed to allow all clay compression and brick retrieval work to be completed while standing. The Clay Retrieval subsystem of the design allows the operator to fill the clay into the Compression Chamber, load the chamber, and retrieve the brick all roughly three feet above the ground. The ergonomic ladder handle at the end of the output lever for the Lever Arm subsystem makes it possible for the operator to be able to consistently apply the maximum amount of force on the clay in the Compression Chamber throughout the entire stroke length. Altogether, these design features are intended to allow for clay brick forming processes to be completed by the clay workers without placing their bodies under exhaustive stress throughout the work day.

Increased Quality and Throughput of Bricks

The design of a clay compression device for brick making was mainly to improve the mechanical properties of the community's bricks while also increasing the rate of production and sale of bricks. Without clay compression, bricks are made with clay saturated with water, which is put into wooden molds and left to dry in the shape of a brick. Because the clay is saturated, voids inside of the clay are filled with water and air and weaken the strength of the bricks when dried. Oversaturated bricks also take much longer to dry, as the community has to wait six to nine days after molding a brick before baking it. With the Frugal Clay Press, it could be possible for less water to be used as compression enables drier clay to be able to be consolidated enough to retain its shape without crumbling. The compression of clay allows for more clay to be used per brick, which should increase the density of the bricks and their mechanical properties. Finally, the use of less water in clay mixing because of the Frugal Clay Press could allow the lead time between drying of the bricks and baking to be drastically reduced and increase the community's overall throughput of bricks.

Risks & Mitigations

Hazards in Manufacturing

Potential hazards in manufacturing, assembly, and operation are present in this design because a majority of the design components must be machined through the use of band saws, miter saws, milling machines, drill presses, hand drills, and hammers. This requires machining and assembly of each subsystems to be conducted by trained machinists with proper safety procedures and equipment.

Operational Hazards

In the operation of the press, there are potential trapping, pinching, and rotation hazards. In the Compression Chamber, Compression Plate, and Base Fixture interaction, there are multiple points inside the Base Fixture where user extremities could get caught and damaged in operation. This is mitigated by the addition of wooden guards that surround all openings to the base legs of the Base Fixture, which keep users' body parts away from clay compression at all times. The Lever Arm is also prone to falling on inattentive operators or surrounding people if left unattended to. The addition of a wooden stop to the lever arm, which sits between the output lever and the hard stop pieces, allows for the operator to place a stop on the output lever of the Lever Arm subsystem to prevent it from falling when not in use. A wooden guard on the front of the Compression Chamber also makes it possible for operators to retrieve the chamber from the Base Fixture with minimal risks of having extremities caught between the steel walls of the Compression Chamber and the base legs.

Travel to Nicaragua

A large safety concern for this project was the team's travel to Nicaragua in March 2018 and possible travel to Nicaragua in July 2018. Risk of illness, theft, and assault were all listed as common warnings to possible visitors to Nicaragua upon the team's first visit. While the first trip was safe and successful, civil unrest and violence erupted in Nicaragua shortly after the March 2018 trip. Because of this, the US Department of State issued a travel advisory on May 4th, 2018 of level 3, indicating that travel to Nicaragua in July 2018 would not be as safe. Since March

2018, and at the time of this publication, the travel advisory level remains at level 3. Because of this, a return trip to Nicaragua for the deployment of the prototype in July 2018 was deemed impermissible by Santa Clara University.

Team Management Approaches & Issue Resolution

The Frugal Clay Press for Nicaragua design team was composed of four undergraduate mechanical engineers. The designated team leader, Rafael Guerrero, served three primary functions. First, he was the point person in communication with the design team and ensured that information was correctly delivered from and received by the team. Secondly, he was responsible for the organization, planning, and execution of team meetings. Thirdly, he was the designated individual for planning team objectives for the week and delegation of team assignments as needed.

Although a single team leader was designated for management and communication purposes, the design team functioned with each member having equal responsibility and overall contribution to the design assignments and development. Work on the Advanced Design course deliverables, design research, and external meetings was distributed on a weekly basis. Work was distributed evenly with equal accountability by the team to accomplish tasks on time and with quality consistent with the team's expectations of professionalism. Work was also shifted as needed to accommodate a member's unexpected schedule conflicts, work overload, personal emergencies, and mental health/self care associated difficulties. Contribution, opinions, and critique were made open and expected by all team members to be communicated in a professional and respectful manner in all team activity and collaboration. Team meetings were approximately 1 to 2 hours weekly on Sundays, with additional meetings for assignments, testing, and other team activities scheduled if needed throughout the week. Direct, specific feedback from member to member was held privately as necessary. However, if personal issues became a team issue, the team gathered as a whole and addressed the member and their actions specifically.

Finally, each team member was equally responsible for contributing to and agreeing upon the final design that was prototyped from January to May of 2018. All members of this design team agreed to assume equal authorship, as well as equal responsibility for the successes and failures of the design throughout the design and fabrication process. Changes made to existing design concepts and documents, especially those changes made by a specific member, were not altered or deleted by any team member without permission of each member of the team. Additionally, all design concepts, calculations, documents, and any other work specifically related to the clay brick press design were reviewed by each member of the team prior to any team submissions and components manufacturing.

Subsystem Chapters

Subsystem Roles & Requirements

In this chapter, the design of a Frugal Clay Press is broken down into the individual subsystems authored by this design team. The Frugal Clay Press design is composed of five subsystems: the Base Fixture, the Lever Arm, the Compression Plate, the Compression Chamber, and the Clay Retrieval rail with base support. The options and tradeoffs of competing subsystem designs as well as the intricacies of the prevailing design for each subsystem are touched upon. Novel approaches and solutions to persistent problems are discussed.

Subsystem Function and Potential Options with Trade-offs

Base Fixture

The Base Fixture forms the backbone of the entire design. The Base Fixture houses the Compression Chamber during use and is permanently connected to other three subsystems. The base supports the Compression Chamber from the bottom during compression and transfers that force down to the ground. When compression is complete, the Base Fixture keeps the retrieval rail steady to allow for an operator to pull the Compression Chamber away from the Base Fixture, take out the brick, and reload the Compression Chamber with more clay. For frugality, the base legs are to be made out of hollow steel while the rest of its supporting structures are made out of wood.

The four options for an optimal Base Fixture include a double sided support truss fixture with a hard stop to ensure uniform compression of the clay with each cycle, a single sided truss with a hard stop, as well as both of these options without a hard stop (Appendix D). The single sided truss support idea did not take hold after the first several iterations as it became apparent that the double truss structure was needed to keep the base steady and stable in the direction of force application during compression. There was more debate over the implementation of the hard stop into the design because of the tradeoff of the benefits that hardstop offered versus the difficulty of its design. Difficulties with said hard stop stemmed from placing it precisely upon the Base Fixture to allow for uniform compression while also creating a robust enough piece to handle the input forces that would have been applied to the clay. However, due to the non-uniform nature of clay mixtures and the high priority of creating uniform bricks on the customer needs assessment, it was determined that moving forward with the double-sided truss supporting structure for the Base Fixture with a hard stop would best serve the customer's needs without compromising safety.

Lever Arm

The Lever Arm subsystem is the means by which the machine operator applies force to compress the input clay into bricks. Therefore, maximizing the force multiplication factor is important minimizing the amount of input force needed from the operator in order to produce sufficiently compressed bricks. The Lever Arm is connected directly to the Base Fixture at the compression fulcrum and the Compression Plate, hinging at the fulcrum to deliver force to the clay through the Compression Plate.

The five potential Lever Arm subsystems were either variants of simple or compound levers. The options for the simple levers include a pair of 2" x 4" wood beams reinforced with sheet metal, a single long solid metal bar, and a single long hollow metal bar. The choices for the compound fulcrum include solid and hollow versions of a two bar system with an input bar and a shorter output bar connected by a pair of thin metal flat bar strips (Appendix D). The wooden simple lever option was quickly cast out as it became apparent that it could not produce the range of forces necessary to compress the clay. While both the simple and compound levers could be designed to produce an optimal force multiplier, it was generally found that the range of motion of compound lever was much more manageable than that of simple lever, with the compound lever only needing a few feet to operate while the simple lever needed about the entire height of the operator to function. Additionally, the compound lever system was determined to be much safer as it incorporates more fulcrums affixed to the Base Fixture to support the weight of the subsystem. Finally, a difficult design decision was in choosing between making the compound lever out of solid or hollow members. While the solid member compound Lever Arm would have had reliable strength and durability, the hollow member version would be considerably cheaper. As frugality was one of the chief goals in this design, the hollow member compound Lever Arm was chosen to be implemented, keeping in mind additions may be needed in order to reinforce the Lever Arm subsystem.

Compression Chamber

The Compression Chamber houses the clay that is compressed and formed into bricks, and is responsible for handling pressures associated with the lateral expansion of the clay during compression. Of the subsystems in the Frugal Clay Press design, the Compression Chamber is the most crucial because it both houses the clay during compression and is also where the brick is extracted in the clay retrieval phase of operation.

The differing subsystem design options included a chamber that has the capacity for one brick, a chamber with the capacity for one larger brick that can be easily cut into two bricks of the desired size with an exterior device, and a chamber that could form separate two bricks with use of a partition (Appendix D). All options involved the design of a five sided rectangular prism with an open top to allow the Compression Plate to drop down and compress the clay within the Compression Chamber. The partitioned chamber was put aside rather early on in the design process as it was found that fabrication of such a chamber would be very difficult with the tools available to the design team and their customers. Furthermore, the Compression Plate would also have to have been partitioned into sections as well as to accommodate the chamber design, making that subsystem harder to design and fabricate as well. While containing the same level of simplicity as the single brick chamber, it was ultimately decided that the conjoined two brick chamber would improve the throughput of the device so that it could provide a reasonable match to the wooden mold used currently in the target community to produce bricks.

Compression Plate

The Compression Plate is the dynamic element in the Compression Chamber/Plate interface that actively compresses the clay to the desired thickness. Designs for the Compression Plate focused on implementing a guiding mechanism to ensure an easy and vertical range of motion. The variant designs for the compression lid include a simple flat metal plate, a simple flat metal plate with wooden blocks on the top as guides, a simple flat metal plate with small steel angles on the top, a partitioned metal plate to accommodate a partitioned chamber, and a plate system using a thinner metal plate attached to the underside of a moderately sized wooden plate (Appendix D). The partitioned plate was discarded when it became apparent that the partitioned chamber would not be implemented. The wood and thinner metal plate combination also was discarded as an option because prolonged exposure to moisture and stresses from fasteners involved with keeping the two plates together could contribute to the deterioration of the wood. The non-guided steel plate option also was discarded as it would have the potential to rotate mid-stroke and deliver uneven compression to the clay. Because of these issues, the design for a metal plate with the steel angle guides was chosen over wooden block guides as the prevailing design.

Clay Retrieval

The main function of the Clay Retrieval subsystem is to allow for travel of the Compression Chamber between the loading/retrieval position and the compression position inside the Base Fixture directly beneath the Compression Plate. By having the loading/retrieval position stationed safely away from the Base Fixture, the distance between retrieval and reloading processes and the Lever Arm allows for more people to be responsible for different parts of the machine while also adding lateral supports to the system as a whole. Additionally, to keep pace with the current forming process in place, ease in removing the compressed brick from the mold is an important design specification of the Clay Retrieval subsystem. It was decided early on that the Compression Chamber should slide along dual rails for stability and easy maneuverability. Furthermore, while the Clay Retrieval system was designed so it did not have to support the stresses of the Compression Chamber during compression, it was designed with appropriate materials to ensure that the rails could easily support the chamber when it is at full clay capacity.

The Clay Retrieval subsystem had several competitive ideas that had to be narrowed down. Concepts for a rail design to invert the chamber to let gravity ejecting the clay brick from the Compression Chamber and an elevating base ejection mechanism were considered. The most competitive designs included a single rail, removing the chamber and inverting the chamber manually, a singular rail with a wooden square A-frame for support with an inverting chamber with a small table to catch the clay, a singular rail with a wooden triangle frame with an inverting chamber and catching table, and a pair of rails with a wooden square A-frame and foot-driven ejection mechanism. Completely taking the heavy clay filled chamber off of the rail and manually rotating it upside down to remove the brick was found to be not only time consuming, but also sub-optimal ergonomically for operators. As such the idea was dismissed. Furthermore, through extensive testing at Santa Clara University's Civil Engineering lab, inverting the chamber to expel the clay in general was dismissed as a feasible concept because the Compression Chamber was designed to be approximately 60 lbs. In the end, the manual foot pedal ejection design was determined to be the most efficient and feasible way to quickly retrieve the compressed clay brick from the Compression Chamber.

Subsystem Structural Analysis

Below are what are considered to be the most important analyses for each subsystem. For a more in-depth analysis of all subsystems and parts, see Appendix H. All components were tested under loading conditions equal to the product of the expected load multiplied by the factor of safety conceived by an expected worst case scenario. A factor of safety of 3.0 was chosen for all calculations and stress modeling in Abaqus.

Base Fixture

As the Base Fixture is the backbone of the entire design, it was vital to ensure that none of the parts experienced failure under its loading conditions. Considering its importance, as well as the fact that it has the most pieces out of any subsystem, more effort went into analyzing this subsystem than any of the others. One of the most critical parts of this subsystem was the junction between the legs, Compression Chamber supports, and hard stop. The figure below, shows a solidworks FEA simulation of this junction, showing that it is able to withstand the maximum potential loads.

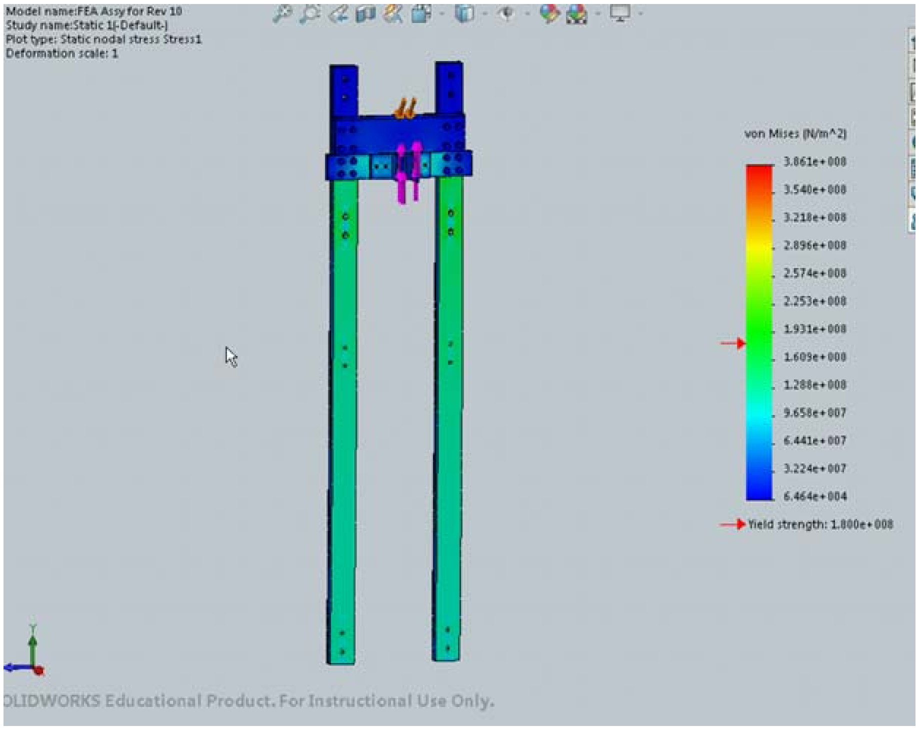


Figure 11: Results of SolidWorks FEA simulation, demonstrating that the designed system is capable of withstanding its potential loading.

Unfortunately, sometimes FEA analysis confirmed that failure under the expected loads with a factor of safety of 3.0 would occur, with no obvious correction available. One example of this is the B02 components, which are the angle brackets responsible for securing the top of the Base Fixture to the body. Even after making the simulation for the component as realistic as possible, as demonstrated in Figure 12 below, and attempting various iterations based on the materials held in stock during fabrication, there were still some cases in which the component would fail.

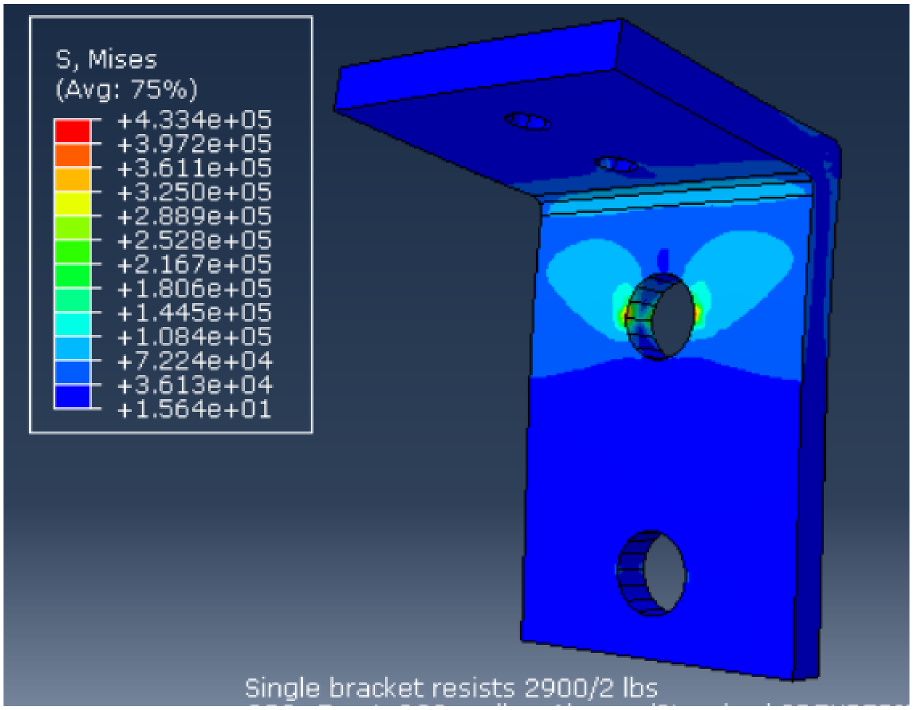


Figure 12: Iterated version of B02 with more realistic geometry that still fails by an order of magnitude.

For this piece, the temporary solution was to stack two L-brackets on top of one another. However, this will still result in failure in some cases. As a result, if this device were to be implemented, a more permanent solution would need to be implemented.

Lever Arm

Upon initially designing the lever arms, it was discovered that, even if a Lever Arm was capable of withstanding the bending force caused by usage, it would still fail due to contact stress, as shown in the figure below.

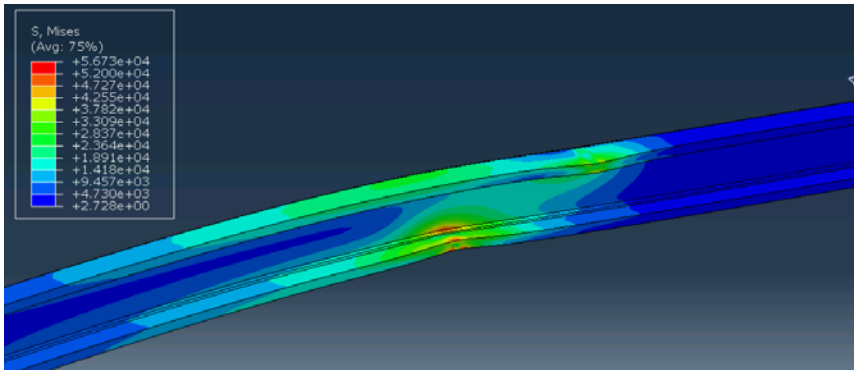


Figure 13: Initial design of L04, the input lever arm, which fails due to contact stress.

For these pieces, it was impractical to solve this problem by increasing the thickness of the tube, as it became very expensive and likely unavailable to the community in Ciudad Dario. As a result, the member was reinforced with additional steel to prevent failure at the contact points. As shown in Figure 14, this new iteration was capable of withstanding all expected loads.

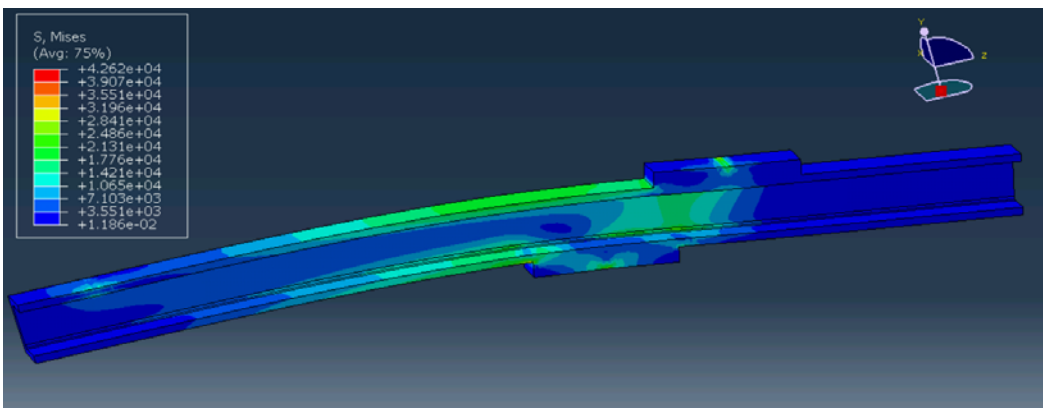


Figure 14: Result of FEA analysis on L04, showing that it survives its expected loading even at the contact points.

Compression Chamber

For the Compression Chamber, not only was it important that the chamber not fail, but that it not deform. It was assumed that stress would be perfectly distributed across all three dimensions, which is likely more severe than what is actually experienced. The Compression Chamber was designed to be screwed together because at this point in the design process it was unclear if the community had any type of welding ability. As a result, the chamber had a minimum thickness required by this design feature. Figures 15 and 16 show the results from testing these minimum thicknesses, showing that they not only do not fail, but that all potential deflection of the components is negligible.

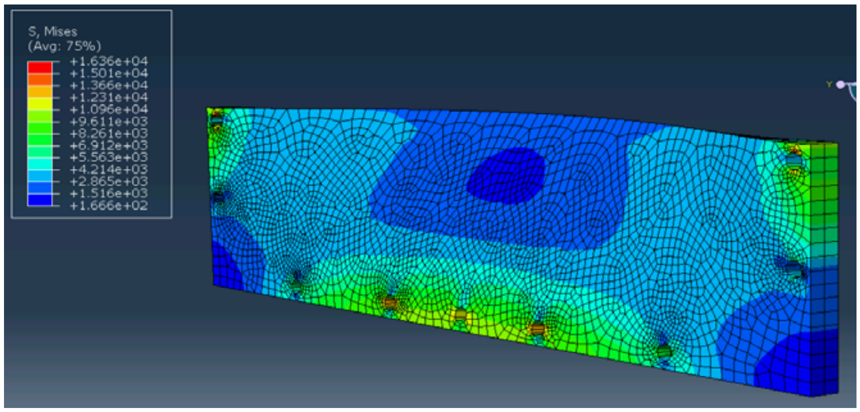


Figure 15: Stress analysis results of part C04, the side wall of the Compression Chamber.

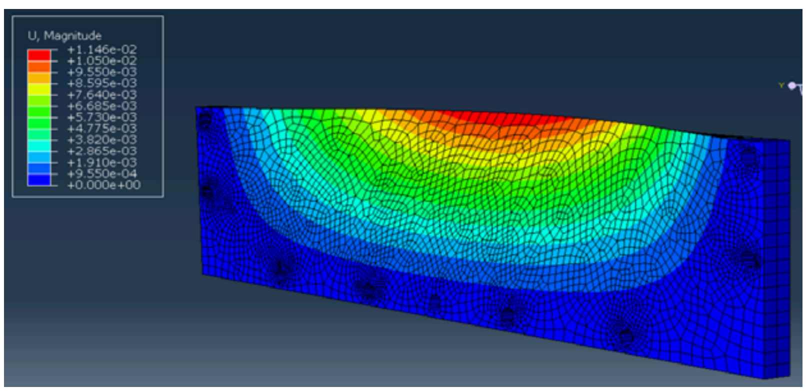


Figure 16: Displacement analysis results of part C04, the side wall of the Compression Chamber.

Compression Plate

Similarly to the Compression Chamber, the Compression Plate subsystem needed to be designed such that there was no deflection under given loads. Additionally, it was essential that the members that connected the plate to the Lever Arm would not buckle under the applied force, which was ensured through MatLab simulations. The primary point of concern, however, was the joints of the Compression Plate, as they were taking the highest loads out of any joints of the whole assembly. The calculations for the structural integrity for the bolts that make up these joints may be found in Table 2 Appendix E.

Clay Retrieval

The Clay Retrieval subsystem was a very basic subsystem with very little calculations needed. However, it was important to know with what material the rail systems could be safely constructed. In Appendix E, calculations were done to ensure that the rails could be made out of cheap PVC tubing if necessary. While the results showed it was possible, prototype operations testing determined that steel tubes would be a better decision.

Current Design Description & Novel Approaches to Problems

Base Fixture

Figure 17 below shows the fully developed double-sided support truss Base Fixture with the hard stop. This iteration includes several 2” x 4” wood pieces to span and connect the lateral length of the legs, a wooden piece to lock in one side of the rails for the Clay Retrieval subsystem, ½” thick metal blocks that support the Compression Chamber during compression, and wood paneling that reveals just enough of the upper structure to allow for proper integration with the other subsystems.

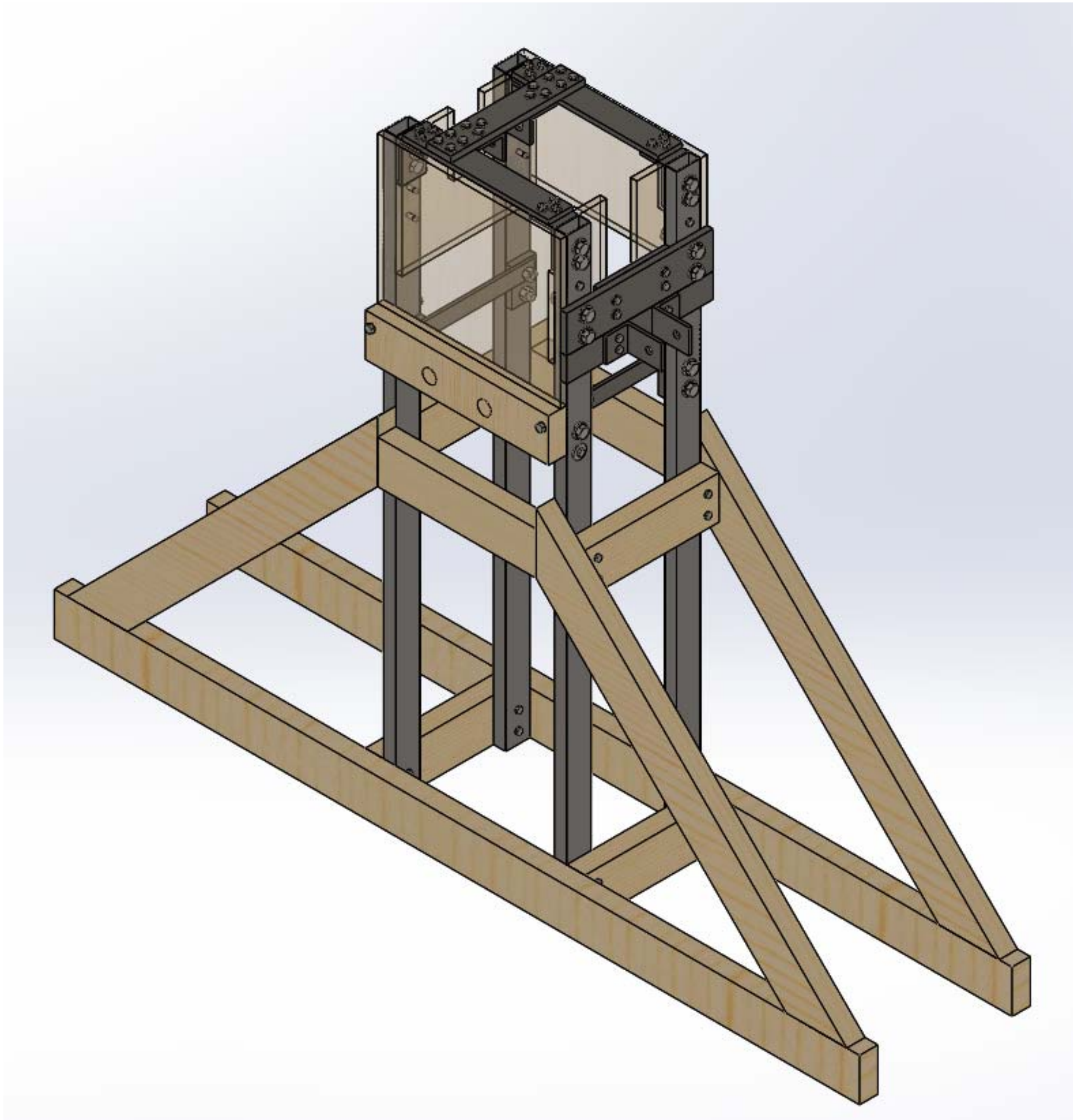
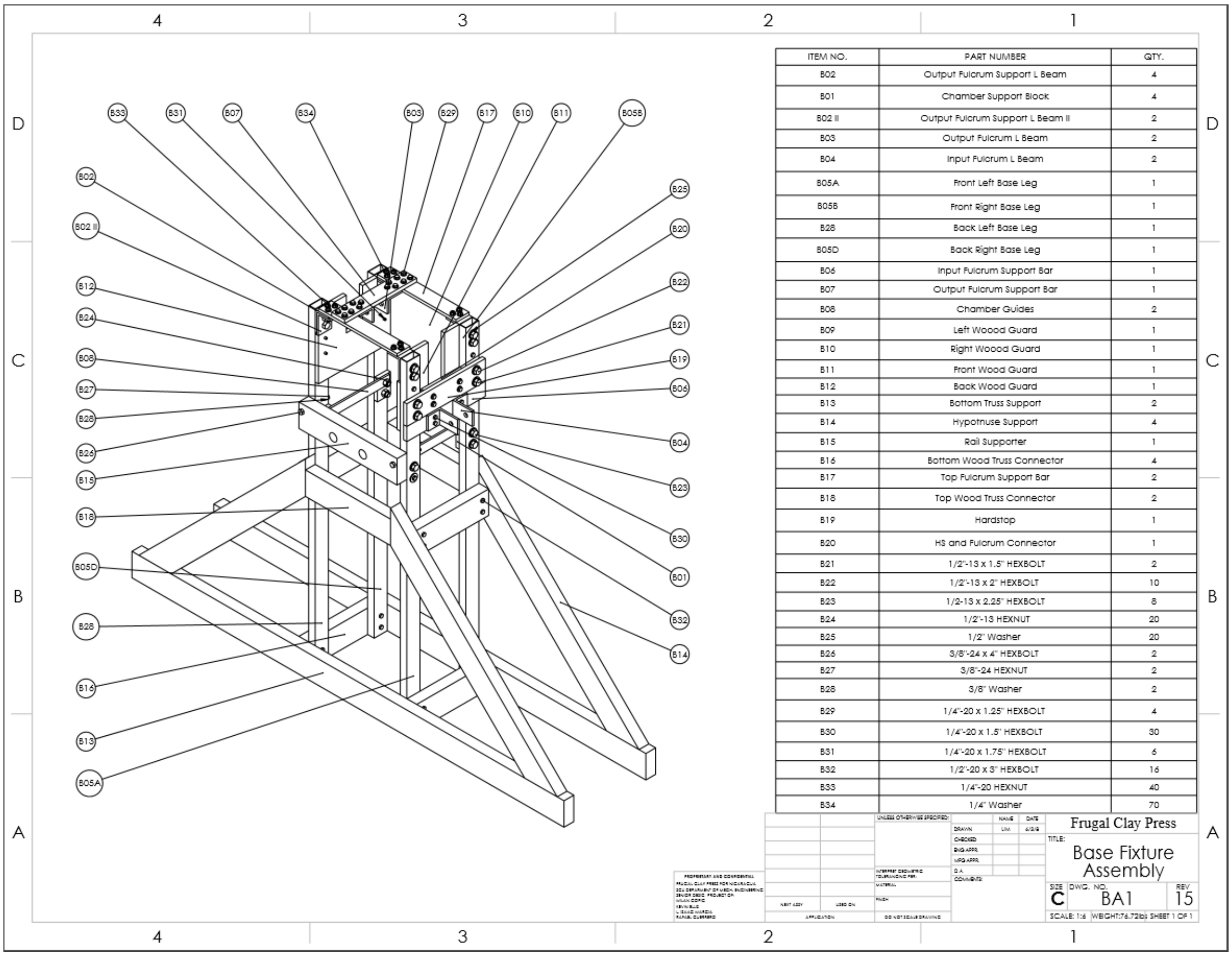


Figure 17: 3D model of the Base Fixture subsystem. Authored by L. Isaac Marcia.

Because of the relative simplicity of the design, there are only a few novel solutions thought of by this design team. One of the most notable of solutions was the attachment of the wood paneling to the Base Fixture through the use of adhesives. However, after a quick discussion with the machine shop manager, it was found this was not a feasible option as the wood-metal interface would be less than ideal in allowing the adhesive to set correctly. The other most notable solution included fastening the wood pieces together with nails. But as assembly began, the team noticed that the wood pieces were allowed to freely rotate about the nails, making the support structures less sturdy than initially anticipated. As such, nails were eventually replaced with wood screws to mitigate the issue. In the end, while most of the other subsystems around it changed greatly, the general design for the Base Fixture has remained relatively constant for the last several design iterations. The schematic in Figure 18 below outlines all the fabricated parts and fasteners used to bring this subsystem together.



ITEM NO.	PART NUMBER	QTY.
B02	Output Fulcrum Support L Beam	4
B01	Chamber Support Block	4
B02 II	Output Fulcrum Support L Beam II	2
B03	Output Fulcrum L Beam	2
B04	Input Fulcrum L Beam	2
B05A	Front Left Base Leg	1
B05B	Front Right Base Leg	1
B28	Back Left Base Leg	1
B05D	Back Right Base Leg	1
B06	Input Fulcrum Support Bar	1
B07	Output Fulcrum Support Bar	1
B08	Chamber Guides	2
B09	Left Woood Guard	1
B10	Right Woood Guard	1
B11	Front Wood Guard	1
B12	Back Wood Guard	1
B13	Bottom Truss Support	2
B14	Hypotnuse Support	4
B15	Rail Supporter	1
B16	Bottom Wood Truss Connector	4
B17	Top Fulcrum Support Bar	2
B18	Top Wood Truss Connector	2
B19	Hardstop	1
B20	HS and Fulcrum Connector	1
B21	1/2"-13 x 1.5" HEXBOLT	2
B22	1/2"-13 x 2" HEXBOLT	10
B23	1/2-13 x 2.25" HEXBOLT	8
B24	1/2"-13 HEXNUT	20
B25	1/2" Washer	20
B26	3/8"-24 x 4" HEXBOLT	2
B27	3/8"-24 HEXNUT	2
B28	3/8" Washer	2
B29	1/4"-20 x 1.25" HEXBOLT	4
B30	1/4"-20 x 1.5" HEXBOLT	30
B31	1/4"-20 x 1.75" HEXBOLT	6
B32	1/2"-20 x 3" HEXBOLT	16
B33	1/4"-20 HEXNUT	40
B34	1/4" Washer	70

Figure 18: Base Fixture subsystem mechanical drawing. Authored by L. Marcia.

Lever Arm

Even after settling on the the hollow member compound lever design, the details of the Lever Arm gradually changed with every iteration. The most important and lasting developments included having to redesign due to potential failure of the hollow members and poor ergonomics for Lever Arm operator. After intensive finite element analysis, it became clear that the hollow members would not survive the stresses applied to them during compression and would yield over time. As a result, ½" metal support plates were added to the necessary areas to reinforce the Lever Arm to prevent plastic deformation. The original Lever Arm handle simply went through the input lever with a single handle. However, because the operators were to apply upwards of 70 lbs-f over a range of 3 feet, it was determined that a better handle should be created to accommodate the operators so that they are more willing to work with the machine over the course of an 8 hour work day. The three tiered handle, optimized so the operator only has to apply force over approximately 1 foot of distance at a time, was the result.

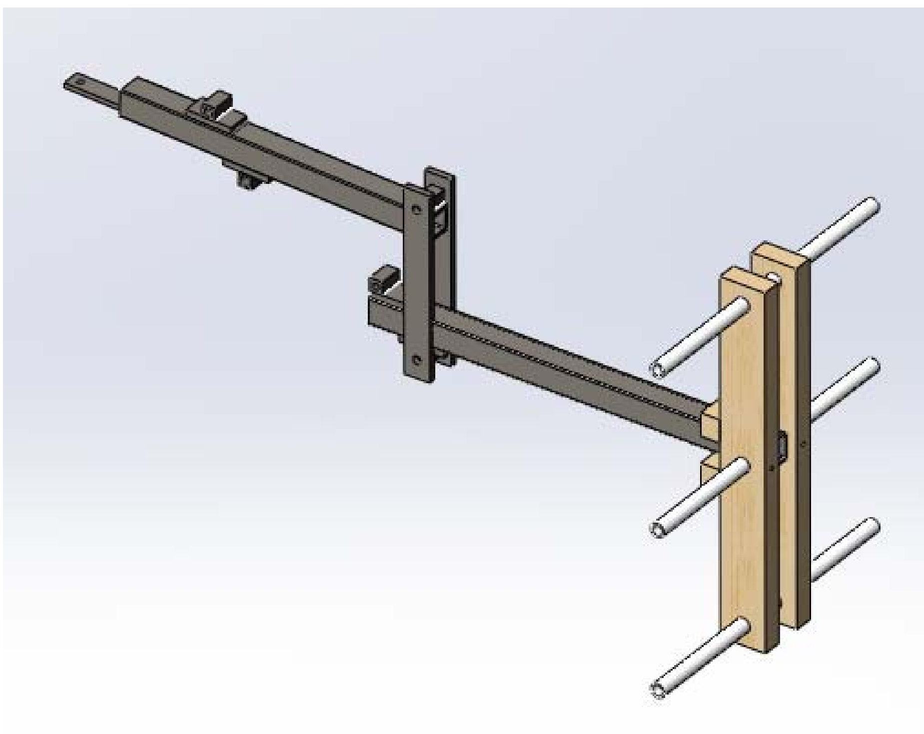


Figure 19: 3D model of the Lever Arm subsystem. Authored by K. Ellis.

One issue that persisted for quite a while was figuring out how to securely connect the hollow input and output lever arm bars to their respective fulcrums. This problem became prominent after it was discovered in Abaqus that connecting through the bars would lead to failure of both levers. The use of routing clamps and journals bearings were both considerations at the beginning, however, it was determined that the rountain clamps could not sustain the forces experienced by the lever arm. Similarly, the journal bearings would be much too expensive, driving up the cost of the product by nearly $100 for these connections alone. The team eventually decided to weld makeshift connection collars machined from steel square stock to the support plates on the hollow members to connect to the fulcrums on the Base Fixture.

The team also initially struggled in how to solve the ergonomic Lever Arm issue. The first competitive solution involved implementing simple handle in the input member along with an additional, raised handle to aid with compression as the operator entered the suboptimal range of motion for force application. This idea was abandoned after the three tiered handle produced the same result to a stronger effect. Figure 20 details the components in the most recent revision of the Lever Arm.

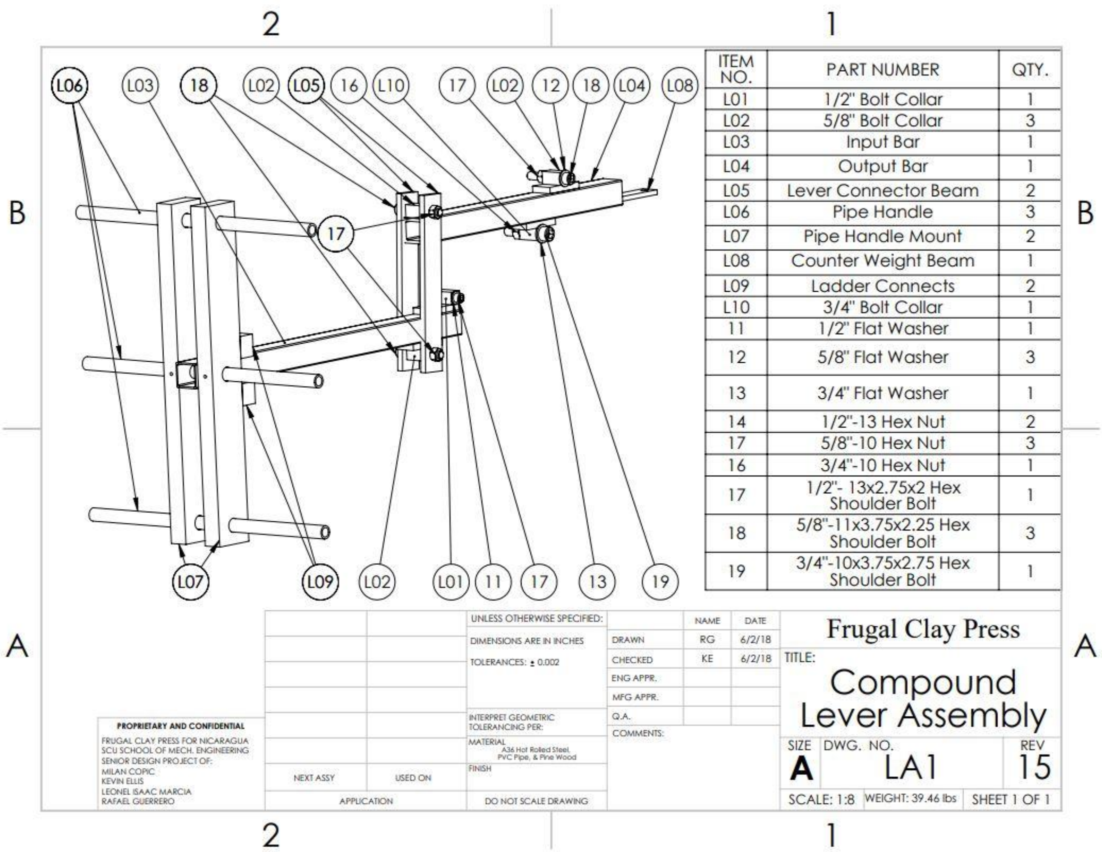


Figure 20: Lever Arm subsystem mechanical drawing and parts list. Authored by R. Guerrero.

Compression Chamber

The overall design for the Compression Chamber stayed relatively constant through the different iterations with notable exceptions in its interactions with other subsystems. The first of these changes based on system interactions was reorienting which side had the handle on it. This came about because the chamber needed to be reoriented in the Base Fixture to match up with Compression Plate. The second major change came with accommodating the Clay Retrieval design. To work with the foot pedal ejection idea, a wooden plate placed on the outside of the bottom of the chamber connected to an elevating acrylic sheet via standoffs so that force applied to the outside plate could be transferred to the elevation of clay bricks inside the chamber.

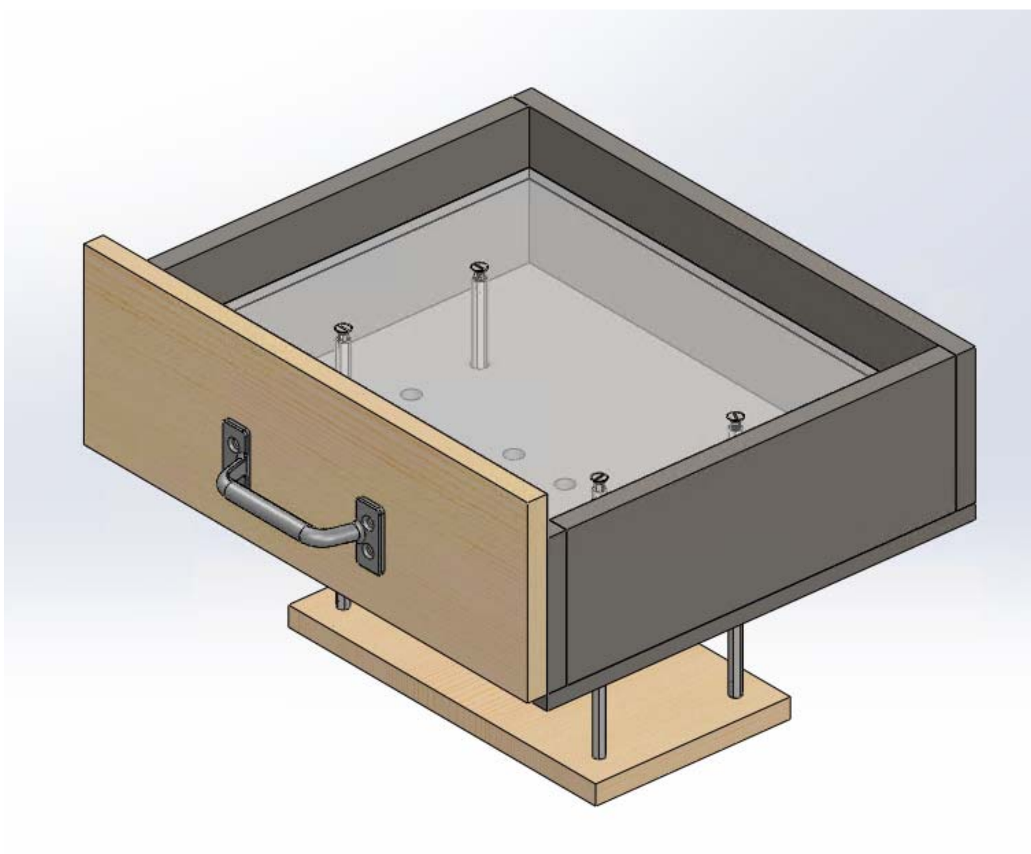


Figure 21. 3D model of the Compression Chamber subsystem. Authored by L. Isaac Marcia.

A couple novel solutions come to mind when discussing the development of the current Compression Chamber. The elevating sheet was going to be made out of sheet metal for its higher strength properties, however, it was found that sheet metal would not be able to adequately and uniformly support the clay upon ejection from the mold. Second, there were several competing ideas to cut the bricks as they were ejected from the chamber. The most feasible of these options was the implementation of an easily adjustable cable saw to slice the brick in half as is was lifted out of the chamber, using the force from the ejection plate to brick through the saw. Unfortunately, this concept and the current ejection method in place could not be reconciled in the subsystem interactions in the time given in the senior design project. That being said, this design team believes it could work in a future iteration. A detailed list of the components in this subsystem can be found in Figure 22 below.

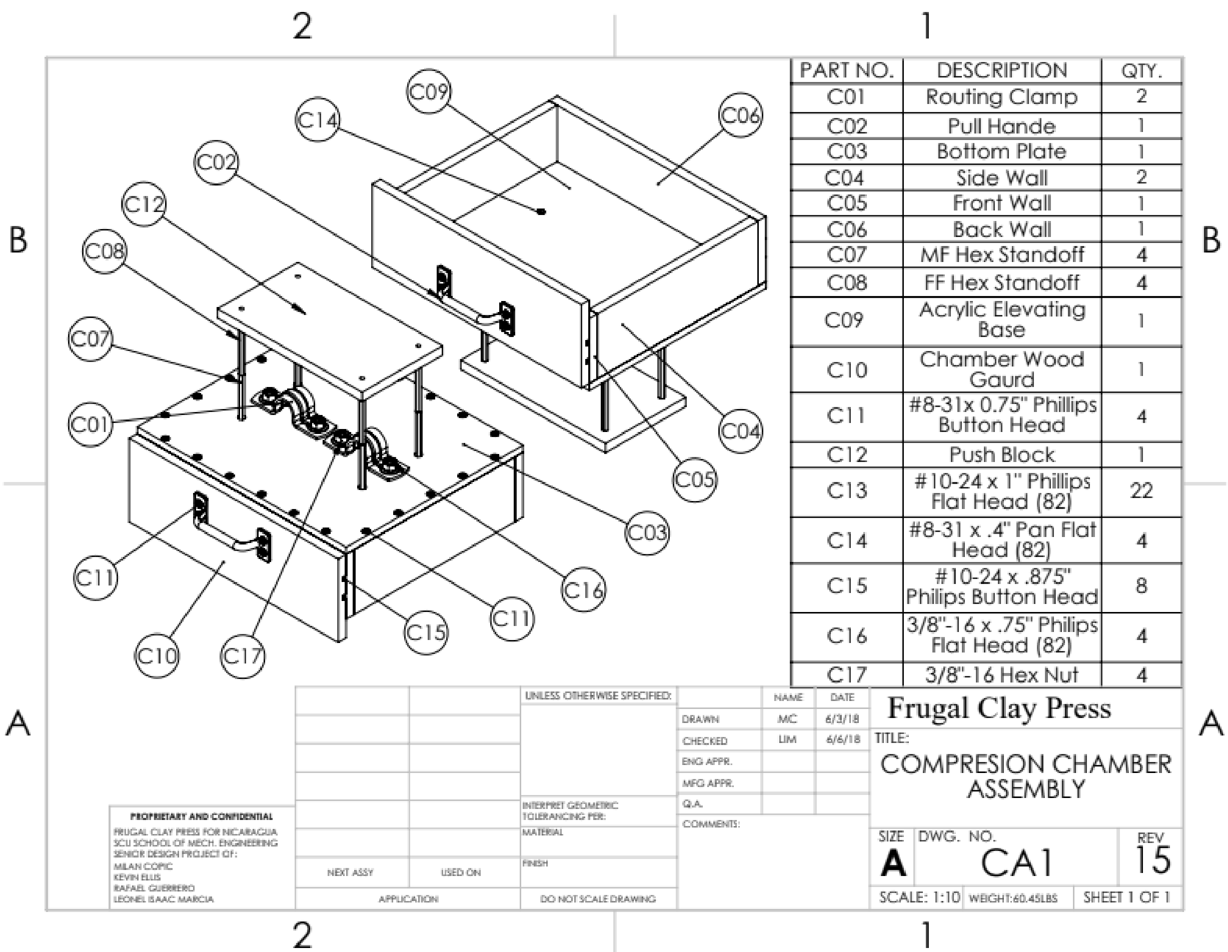


Figure 22: Compression Chamber subsystem mechanical drawing and parts list. Authored by M. Copic

Compression Plate

The Compression Plate has remained true to the initial design idea that was solidified following the subsystem scoring phase. The specifics of this design include a ¾" bolt to act as a fastenable pivot that can survive the stresses associated with compression and the implementation of a pair of steel angles along with 2" spacer to appropriate space the distance between the Compression Plate connecting beams that connect to the Lever Arm. Four steel angles are attached to each corner of the top of the Compression Plate to aid with the guidance of the plate down into the Compression Chamber. Steel angles were only used at the corners as opposed to spanning the whole length of the side to expedite manufacturing.

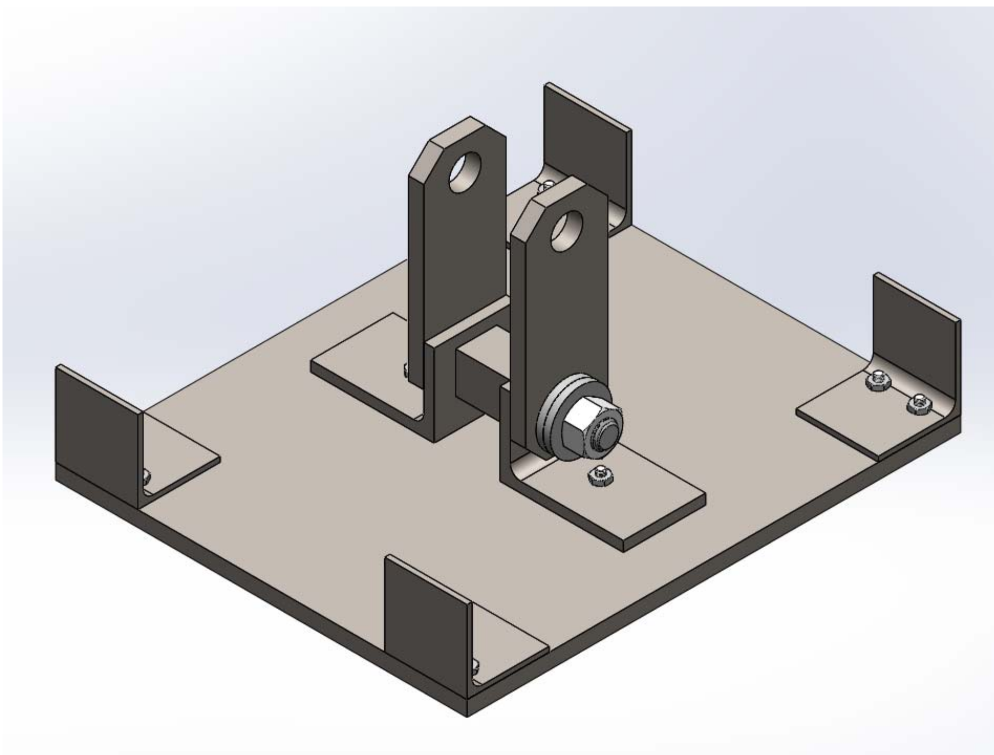
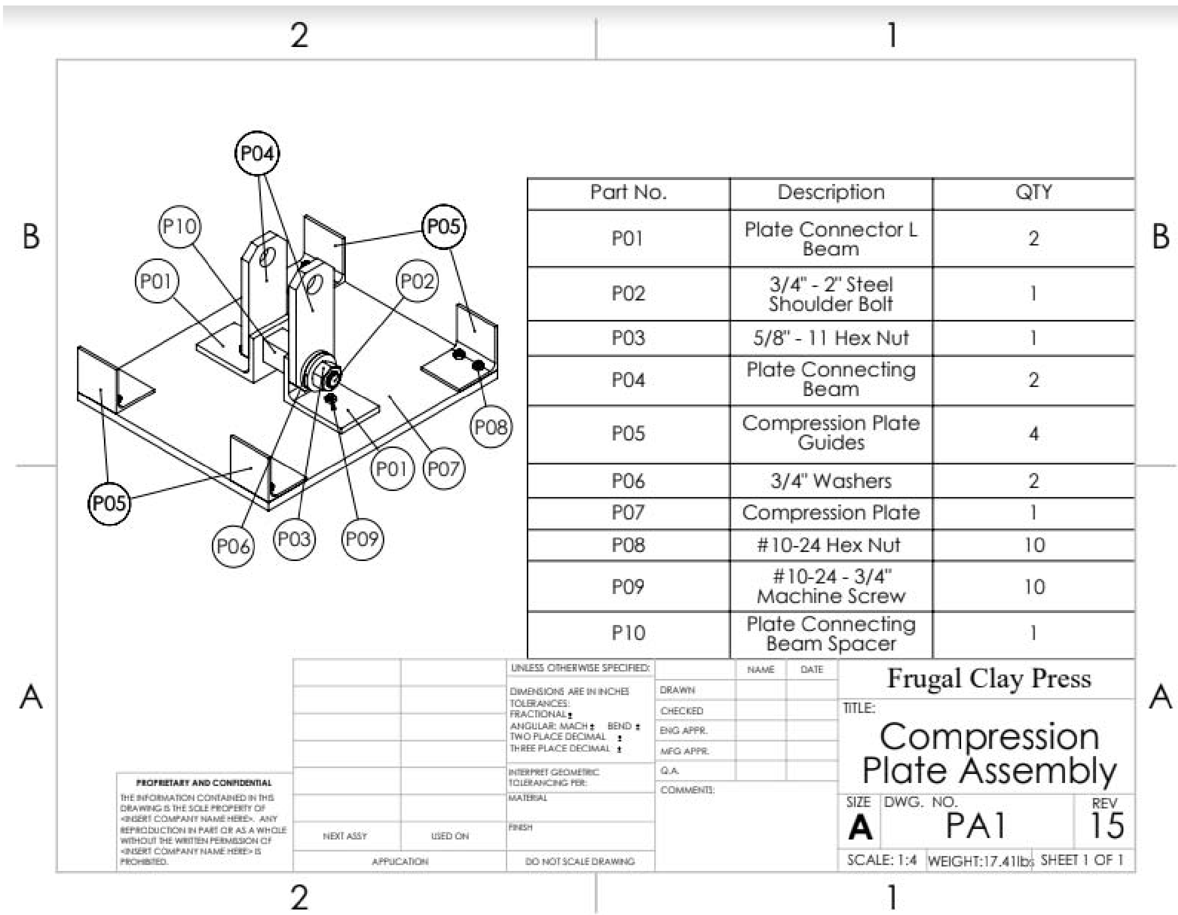


Figure 23: 3D model of the Compression Plate subsystem. Authored by L. Isaac Marcia.

A couple unused solutions for this subsystem include a sheet metal scoring plate attached to the bottom of the Compression Plate to make the brick easy to cut after compression and making the Compression Plate-Lever Arm connection ridgid instead of dynamic. The scoring plate was abandoned as there was no simple way in manufacturing to create the ridge necessary to score the clay using sheet metal. Similarly, the rigid connection was discarded in favor of the dynamic option. This was because it was significantly more difficult to attach to the hollow output member of the Lever Arm, and that some flexibility in the connection was needed as it traveled along a short angular path rather than a entirely vertical one. Figure 24 points out all the relevant pieces in this subassembly.



Part No.	Description	QTY
P01	Plate Connector L Beam	2
P02	3/4" - 2" Steel Shoulder Bolt	1
P03	5/8" - 11 Hex Nut	1
P04	Plate Connecting Beam	2
P05	Compression Plate Guides	4
P06	3/4" Washers	2
P07	Compression Plate	1
P08	#10-24 Hex Nut	10
P09	#10-24 - 3/4" Machine Screw	10
P10	Plate Connecting Beam Spacer	1

Figure 24: Compression lid subsystem mechanical drawing and parts list. Authored by L. Isaac Marcia.

Clay Retrieval

This subsystem was difficult to integrate into the entire assembly because of the need for tighter tolerances in the steel parts of other systems. The initial design of this subsystem did not have the wood supports that ran between the square A-frame legs and between the A-frame and the Base

Fixture, but were in fact later additions that were made after initial prototype testing. After such additions, the final result included a subsystem made almost entirely out of wood, with the exceptions of the PVC ejection pedal system and the galvanized steel retrieval rails. The retrieval rails are designed to be greased with lubricant to minimize the frictional contact between the Compression Chamber and the rails. The ejection mechanism is a simple class 1 lever with wood pieces extending a PVC rung down to foot level to allow for force input to come from the operators feet rather than their hands. The wood 2” x 4” sections are connected with wood screws while the pipes are pinned in place with ¼” machine screws.

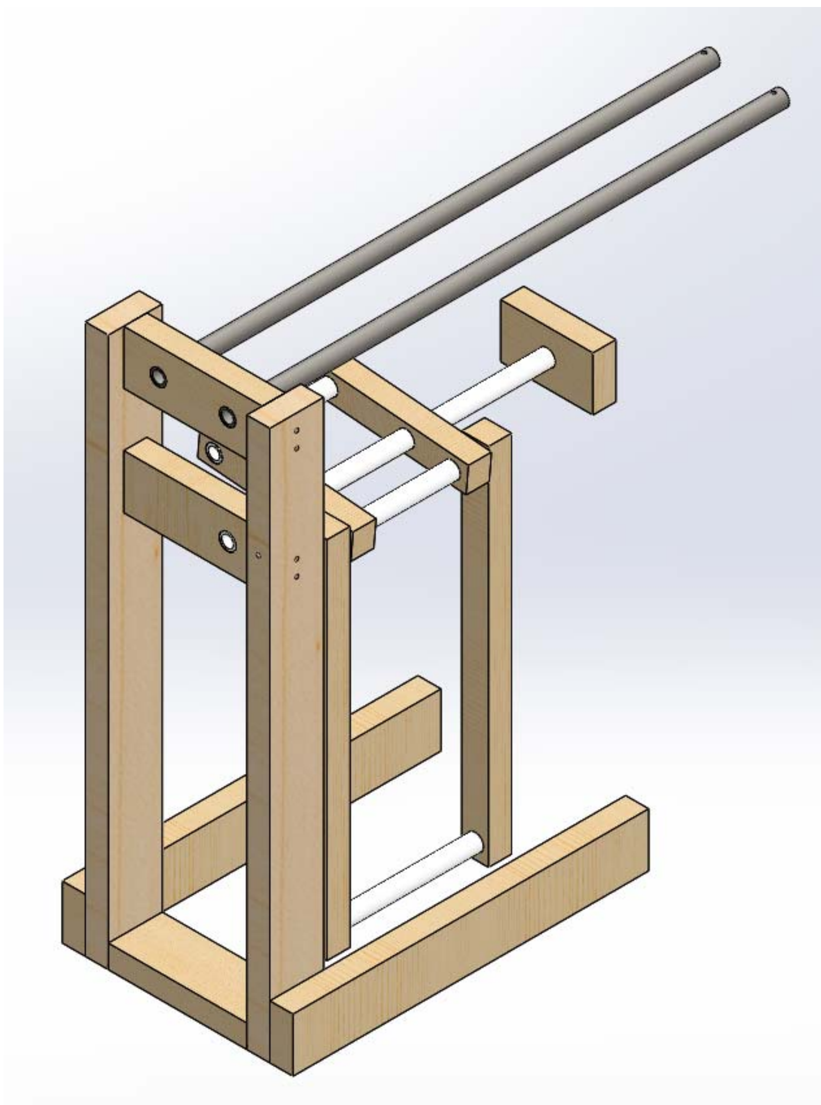
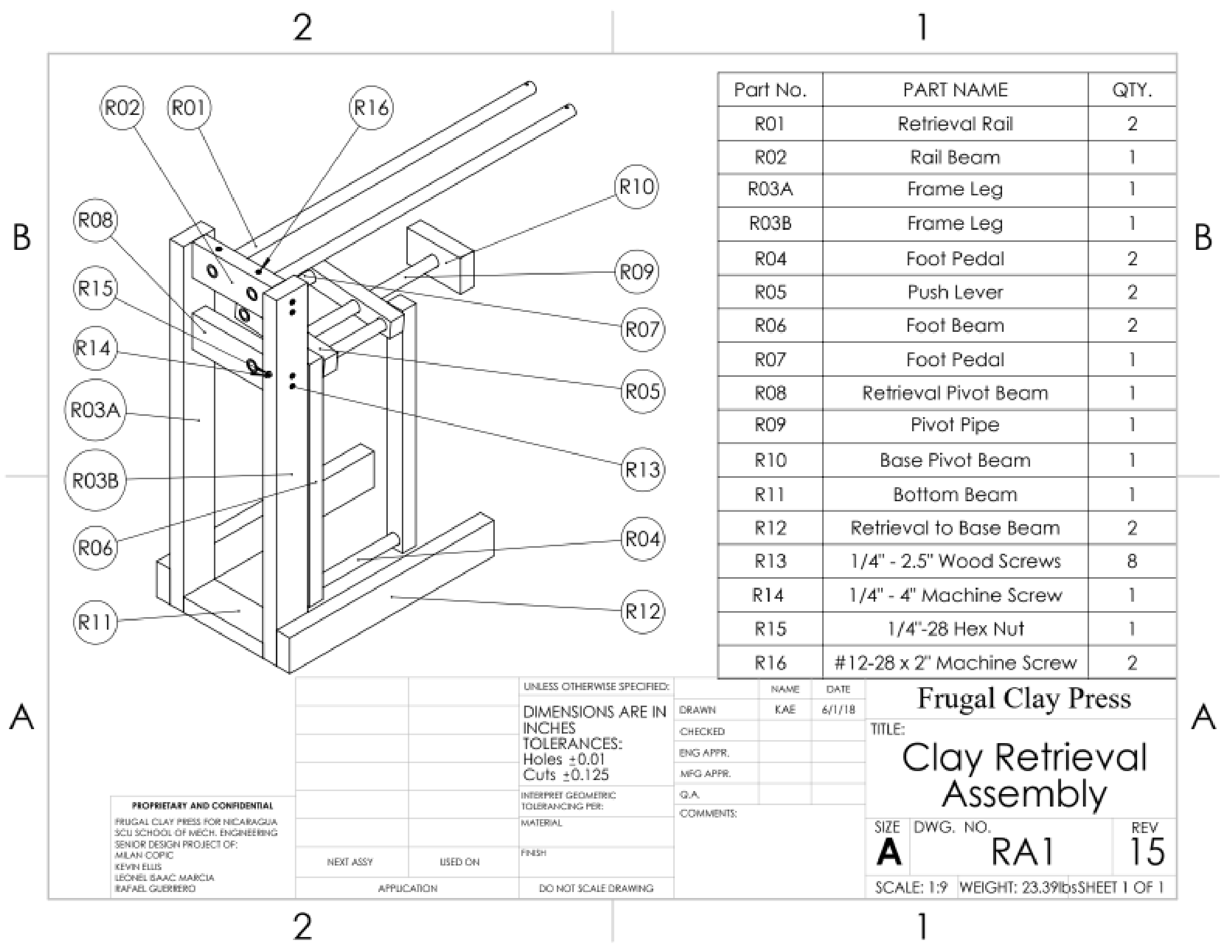


Figure 25: 3D model of Clay Retrieval rail subsystem. Authored by L. Isaac Marcia.

There were numerous novel solutions to the many problems encountered with this subsystem during design process. One of the most relevant to the current design was using solid rigid PVC cylinders as the retrieval rails. This solution was a main contender for use in the beta prototype as it was thought it would drastically reduce the sliding friction between the Compression Chamber and retrieval rail. However, it was discovered that the solid PVC would cost just as much as galvanized steel tubes but would experience wear much quicker than the steel and bended under the weight of the Compression Chamber. Another novel solution was using a galvanized steel nipple for the prototype retrieval rails. This particular solution involved embedding caps for the steel nipple into the wood pieces for the pipes to screw into, securing the rails translationally. This idea was cast aside in favor of pins, as it is possible that as the wood deteriorates, the cap could become loose and potentially fall out.



Part No.	PART NAME	QTY.
R01	Retrieval Rail	2
R02	Rail Beam	1
R03A	Frame Leg	1
R03B	Frame Leg	1
R04	Foot Pedal	2
R05	Push Lever	2
R06	Foot Beam	2
R07	Foot Pedal	1
R08	Retrieval Pivot Beam	1
R09	Pivot Pipe	1
R10	Base Pivot Beam	1
R11	Bottom Beam	1
R12	Retrieval to Base Beam	2
R13	1/4" - 2.5" Wood Screws	8
R14	1/4" - 4" Machine Screw	1
R15	1/4"-28 Hex Nut	1
R16	#12-28 x 2" Machine Screw	2

Figure 26: Clay Retrieval subsystem mechanical drawing and parts list. Authored by K. Ellis.

Prototyping Results

The beta prototype was successful in meeting nearly all of the team's expectations in functionality and tolerancing. That being said, several issues occurred during the manufacturing of the prototype. A recurring issue was the need to design for clearance holes. Holes had to be redrilled because initial assembly showed that there was often too tight a fit between steel pieces. Additionally, the base legs of the Base Fixture and the wood pieces of the Base Fixture and Clay Retrieval subsystems were fabricated using hand tools. This caused interactions with steel pieces to often be difficult because they were machined with much tighter tolerances. These issues were caught relatively early on in the metal fabricating process with only a few pieces having dimensions significantly deviate from nominal dimensions. However, these mistakes were caught inconveniently late into the overall project timeline and the team had to work with these deviantly dimensioned pieces for sake of time and cost. To address this, newly machined pieces were redimensioned according to machining errors on previously machined parts. This was done mostly to meet the preset fabrication schedule established at the beginning of January 2018 and limit prototype materials costs.

One example of manufacturing without focus on proper tolerancing and precision is the fabrication of hollow metal legs of the Base Fixture. Because the legs were thin and many holes holes needed to be drilled in order to allow for mating to many other components, a drill press was recommended to be used to drill the necessary holes. Holes were marked on the legs by using a tape measure and sharpie to roughly dimension where the holes were located. Because of this imprecise manufacturing method, the placement of the holes were inconsistent between the individual base legs. This was a problem because the holes were supposed to be line up horizontally to allow for proper mating with metal components that span the legs. To mitigate the imprecision of the base legs, the holes on the metal connecting components were drilled slightly larger to make for a looser clearance fit, making assembly easier.

Altogether, while the team was ultimately able to successfully mate most of the assembly, the prototype fell short in a couple key areas. First, the Compression Chamber could not easily slide in and out of the Base Fixture. Because the chamber supports were slightly misaligned, the Compression Chamber had to be manually reoriented each time it entered and exited the Base Fixture. Second, the Compression Plate/Compression Chamber interface did not interact as smoothly as anticipated. The Compression Plate at times entered the chamber at a skewed angle and at others got stuck against the wood guards, not even entering the Compression Chamber. Third, the combined truss supports of the Base Fixture and Clay Retrieval was not enough to sufficiently stabilize the system in the lateral direction, making the system slightly unsafe during testing. Finally, and most importantly, the Lever Arm range of motion did not sufficiently compress the clay into solid bricks and succeeded in only compressing the air cavities out of the input clay. These issues together determined that the prototype could not yet be successfully deployed to the target community as its functional capabilities were not up to the team's standards. However, the team believes that by recreating the current Frugal Clay Press design with greater attention to detail during the manufacturing process along with design improvements made to the Lever Arm and Base Fixture subsystems, the system could be fully deployable within a few additional iterations.

System Integration

This chapter takes closer look at the designed interactions that are necessary for this device to function properly. Some important interactions are: the ability for the Compression Chamber to slide on the rails of the Clay Retrieval subsystem, the ability of the Compression Plate to move through the Base Fixture and the Compression Chamber, and the ability for the clay to be extruded from the Compression Chamber with the foot pedal system. The conclusions of how well the subsystems actually integrated with each other are explained in the end of the Testing, Results & Design Validation chapter. A SolidWorks CAD model of the fully integrated Frugal Clay Press is depicted in Figure 27.

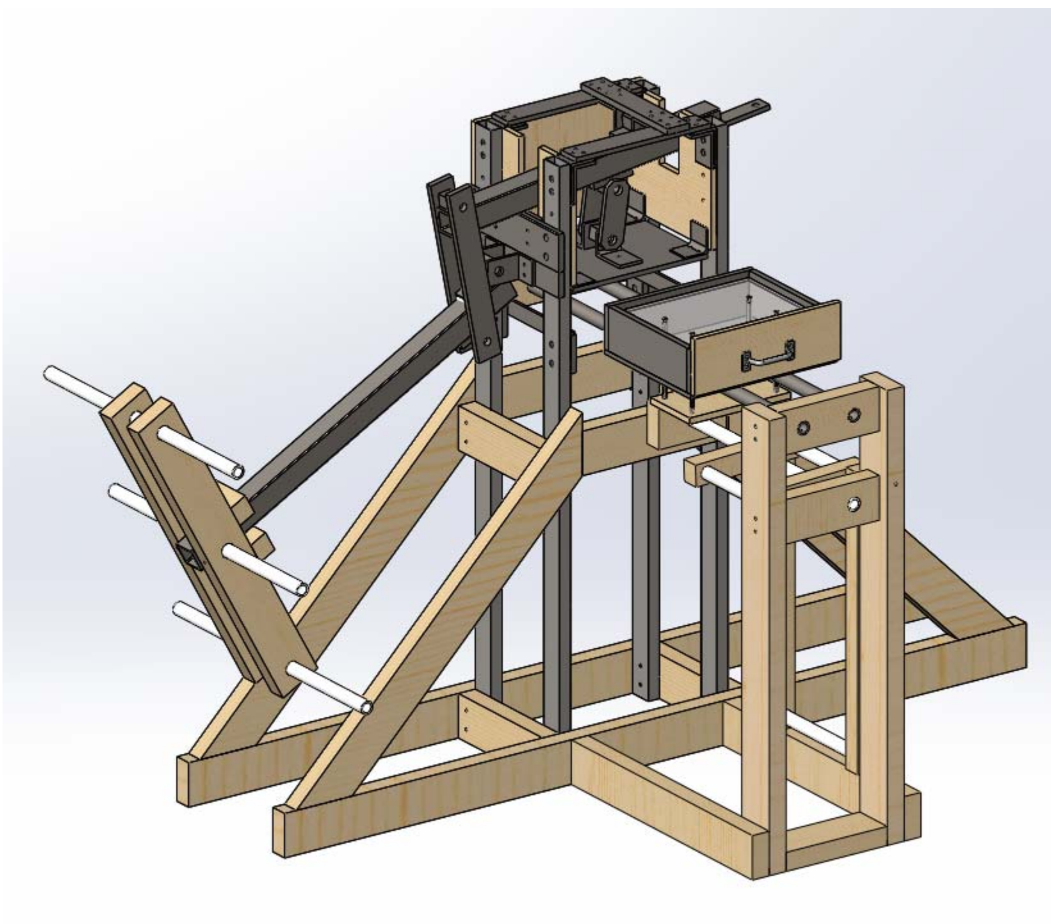


Figure 27: Solidworks model of the Frugal Clay Press prototype completed on May 9th, 2018 for the Senior Design Conference.

Clay Retrieval & Base Fixture Interaction

There are three points of interaction between the Clay Retrieval subsystem and the Base Fixture. Two steel pipes are pinned to the R02 and the B15. The main purpose of the steel pipes is to hold the Compression Chamber during clay retrieval and loading of the clay chamber. The R10 wood block is screwed on the the B18 beam, and the PVC pipe that it supports holds the foot pedal lever system. These interactions are depicted in Figure 28.

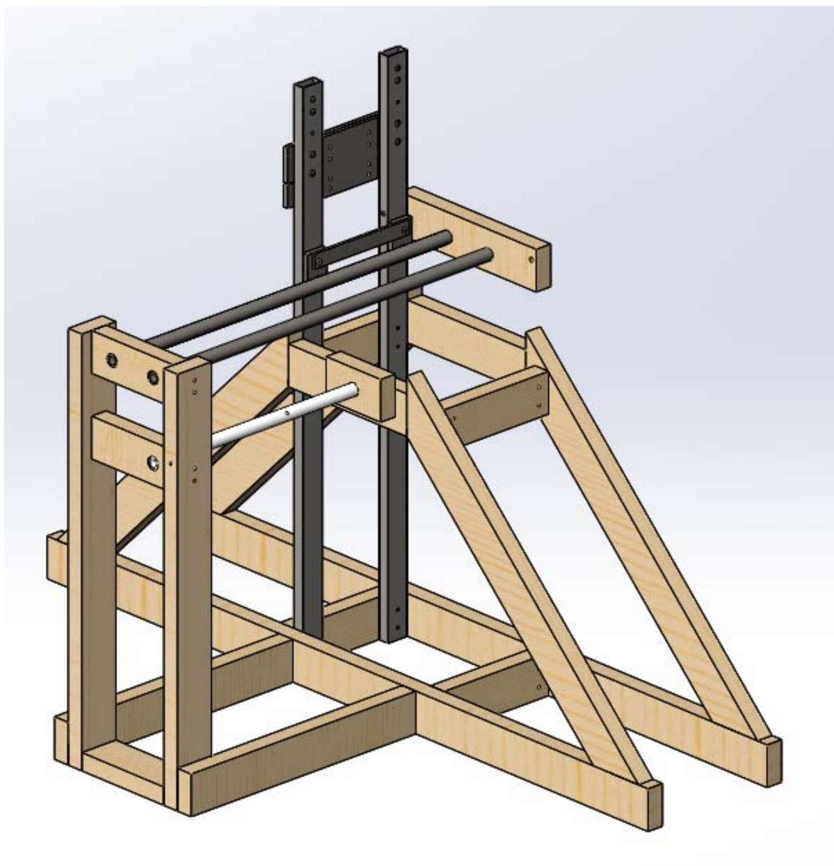


Figure 28: Solidworks model of the Clay Retrieval and Base Fixture interaction.

Clay Retrieval & Compression Chamber

One of the important interactions of the overall design, which is depicted in Figure 29, is the need for the Compression Chamber to slide along the retrieval rails, R01, so that the Chamber can be loaded and unloaded. The chamber is fixed to the rails via the routing clamps, C01. In order for a brick to be extracted from the chamber, the foot pedal in the Clay Retrieval system

(R04 - R10) has to push up on the push block, C17, that is attached to the elevating base via standoffs in the Compression Chamber. A model of this specific design interaction is depicted in Figures 30 & 31.

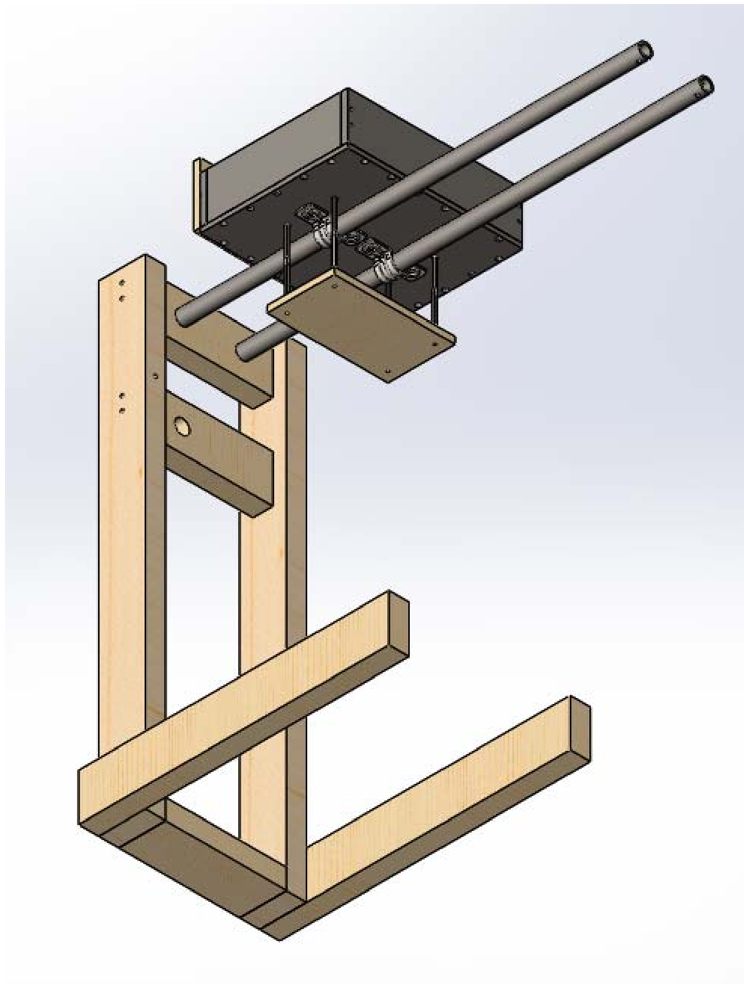


Figure 29: Interaction of the bottom of the Compression Chamber and the retrieval rails.

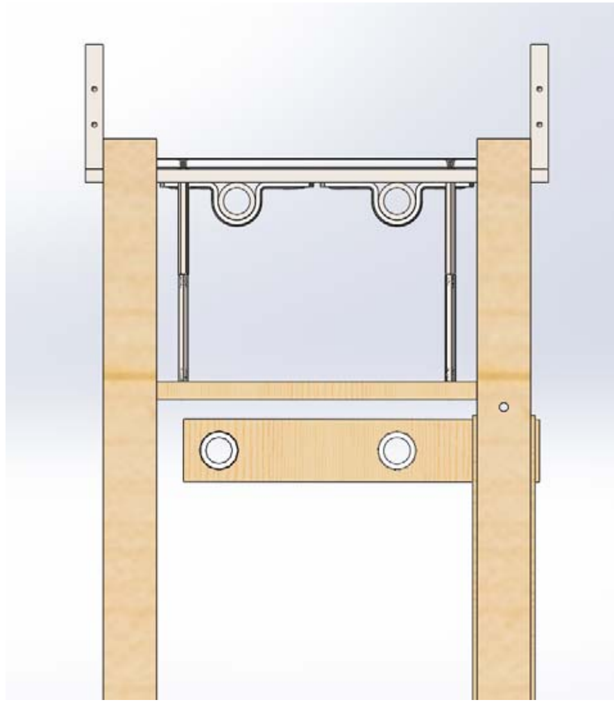


Figure 30: Solidworks section view of the foot pedal and the movable base in neutral position.

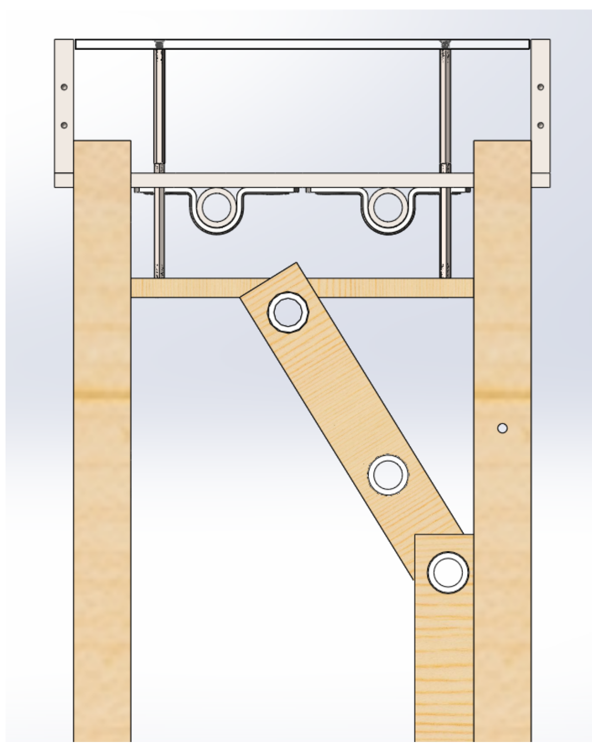


Figure 31: Solidworks section view of the foot pedal and the movable base in extended position.

Compression Chamber and Compression Plate

During each compression cycle there is an interaction between the Compression Plate and Compression Chamber subsystems. When the Compression Chamber is stationary in the Base Fixture and the Lever Arm is moved, the Compression Plate, P07, slides inside the Compression Chamber between the the chamber walls, C04-C06. The plate is undersized compared to the chamber opening to ensure fluid motion during use. The Compression Chamber guides, P05, also interact with the chamber side walls, P04, to ensure that the plate is maintained parallel to the plane of the bottom plate. These interactions can be seen in Figure 32.

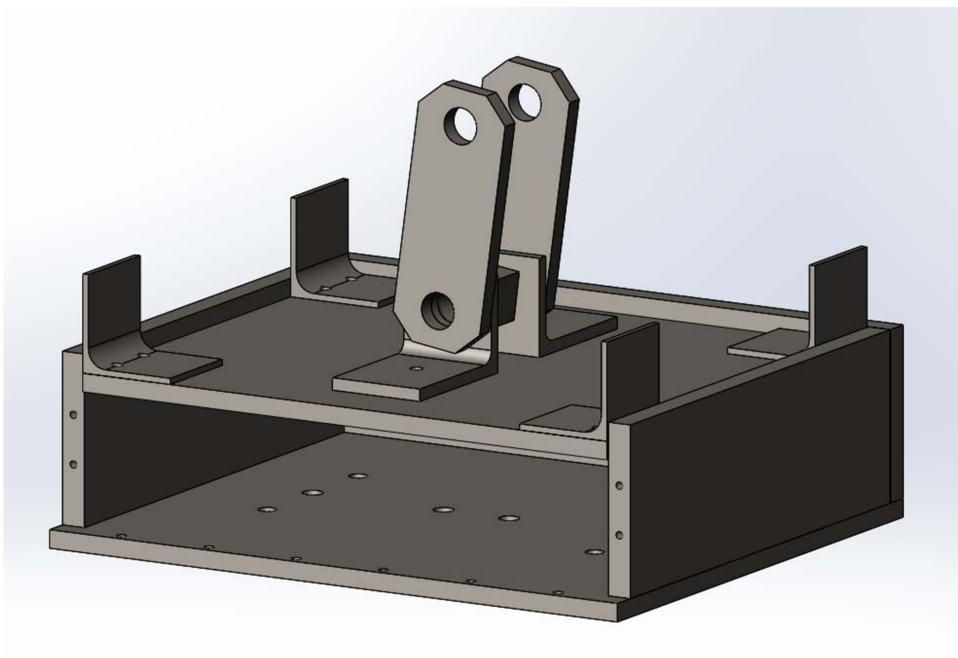


Figure 32: Solidworks section view of Compression Plate at full compression depth in the chamber.

Compression Chamber & Base Fixture

The purpose of the various interactions between the Compression Chamber and the Base Fixture are to improve ease of use and arrange the subsystems so that compression is consistent. Since the Compression Chamber needs to be oriented at a certain height within the base, the bottom plate of the chamber, C03, is held up by the Compression Chamber support blocks, B01. The bottom plate also rests on chamber guides, B21, so that the chamber stays level as it is slide into the Base Fixture. The chamber is to be slid into the back until the chamber back wall, C06, is in contact with the rail supporter wood beam, B15. These interaction are depicted in Figure 33.

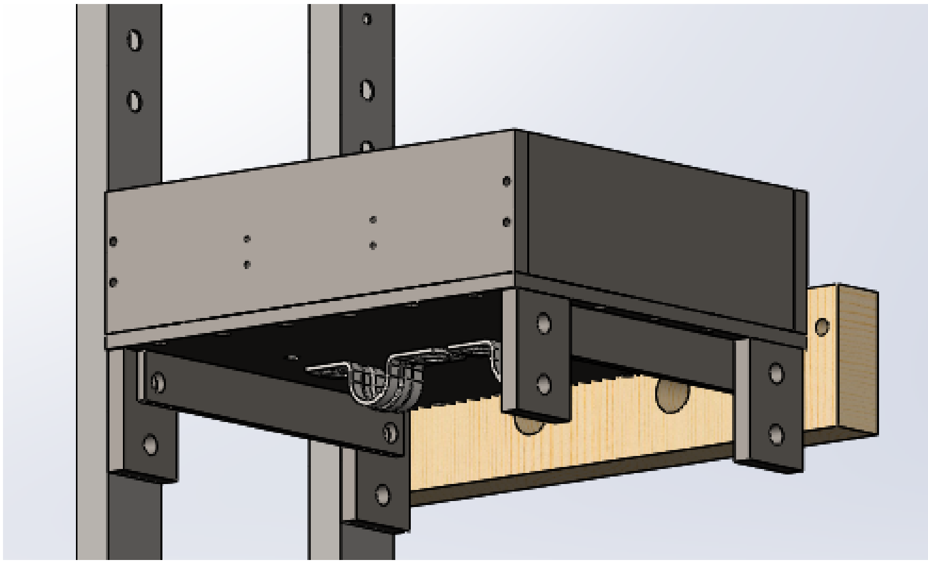


Figure 33: Interaction between the Compression Chamber and the chamber supports of the Base Fixture.

Compression Plate & Base Fixture

The interactions between the Compression Plate and the Base Fixture are meant to keep the Compression Plate horizontal during the compression cycle, as depicted in Figures 34 & 35. The Compression Plate guides, P04, slide against the front and back wood panels, B11 & B12.

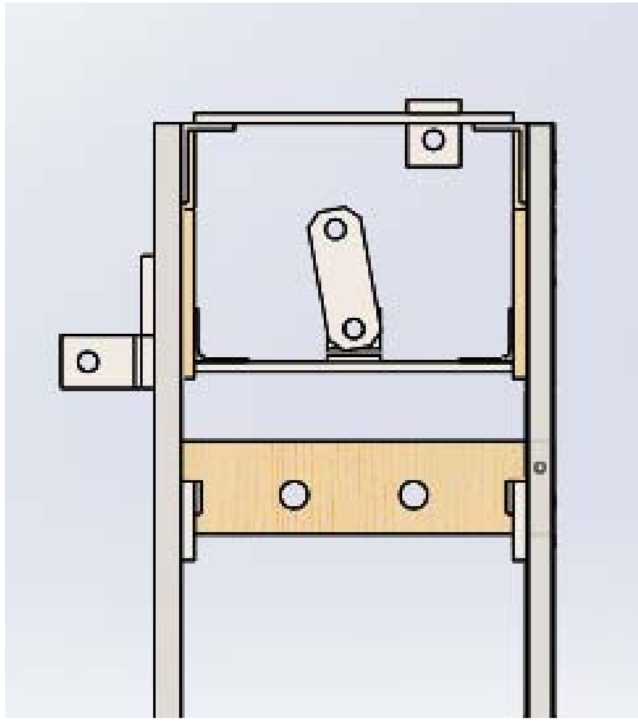


Figure 34: Location of the Compression Plate in relation to the base when plate is removed from the chamber.

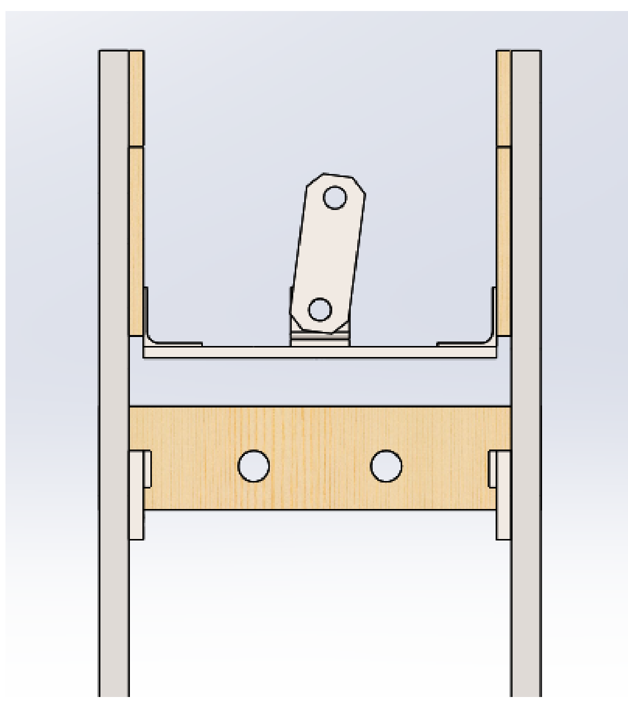


Figure 35: Location of the Compression Plate in relation to the base at full compression.

Lever Arm & Compression Plate

The interactions between the Lever Arm and the Compression Plate allow the Compression Plate to exert a magnified input force on the clay in the Compression Chamber. The motion of the plate with reference to the stroke length of the Lever Arm is depicted Figures 36 & 37. The compression plate connecting beam, P04, is bolted to the ¾" bolt collar on the output lever, L04, with a ¾" shoulder bolt.

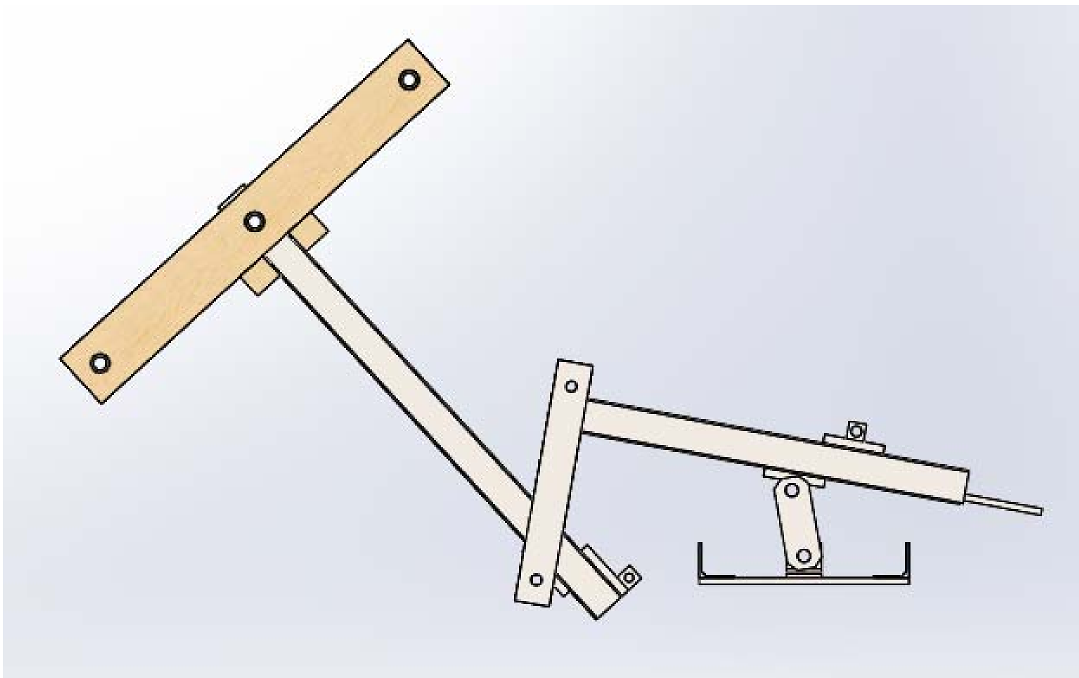


Figure 36: Position of the plate and lever at the top of the stroke.

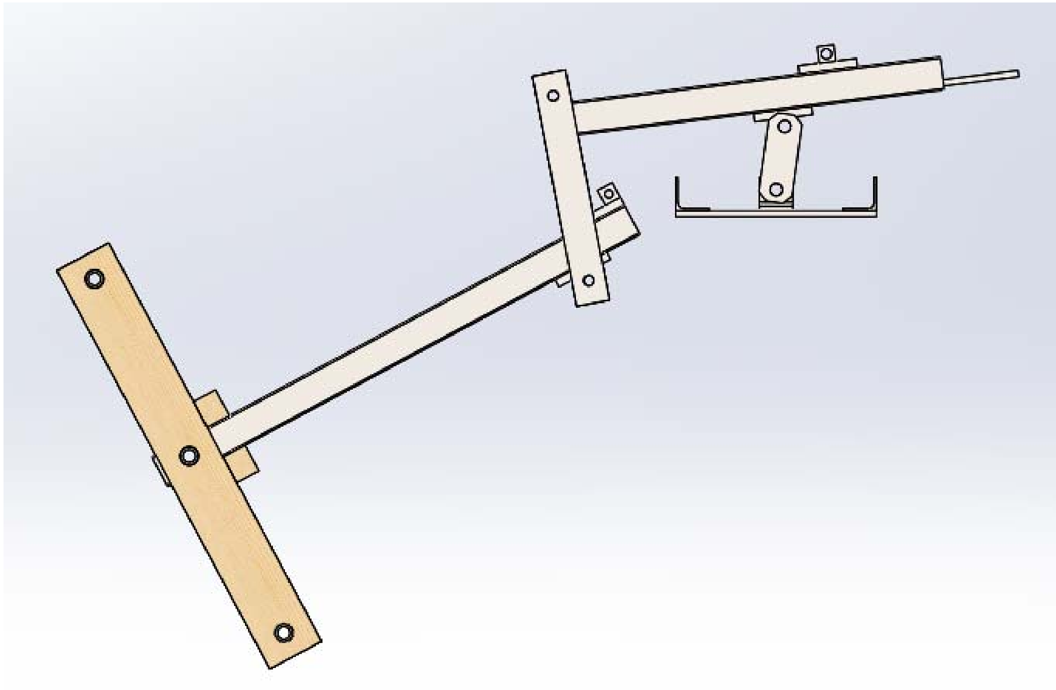


Figure 37: Position of the plate and the lever at the bottom of the stroke.

Lever Arm & Base Fixture

The main interactions between the Base Fixture and the Lever Arm are at key pivot points called the input and output fulcrums, which are needed to magnify the input force to the designed force output. The interactions also allow the stroke length to be fixed and consistent. As depicted in Figures 38 & 39, the output lever is suspended between the ½" bolt collar, L03, and the input fulcrum L beam, B04, and the ¾" bolt collar , L04, and the output fulcrum L beam. The stroke length is also determined by the interaction between the hard stop, B19, and the input lever, L03. A close up of this interaction is depicted in Figure 40.

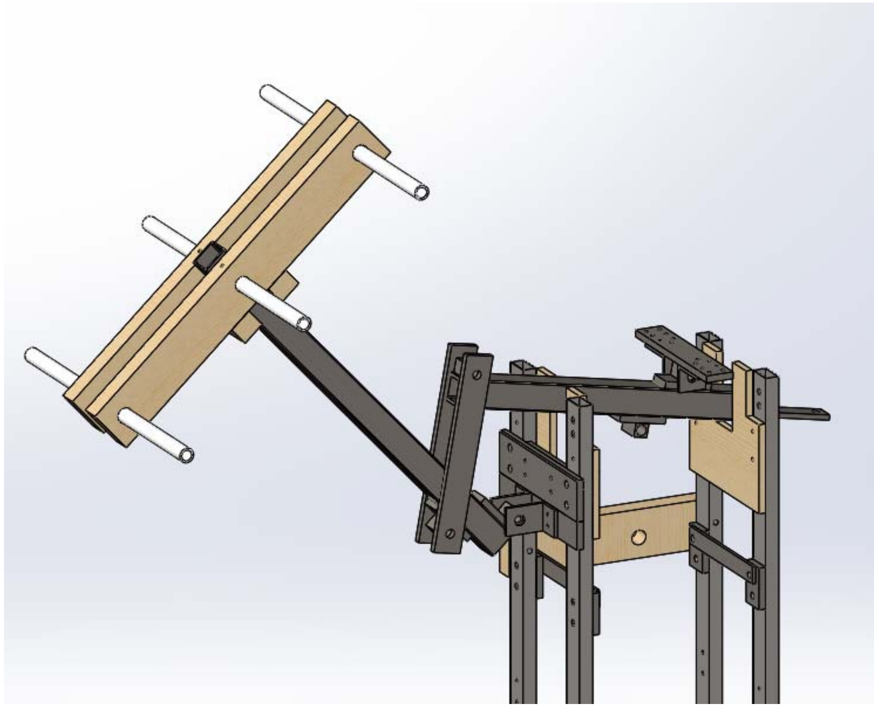


Figure 38: Position of the lever arms relative to the Base Fixture at top of stroke.

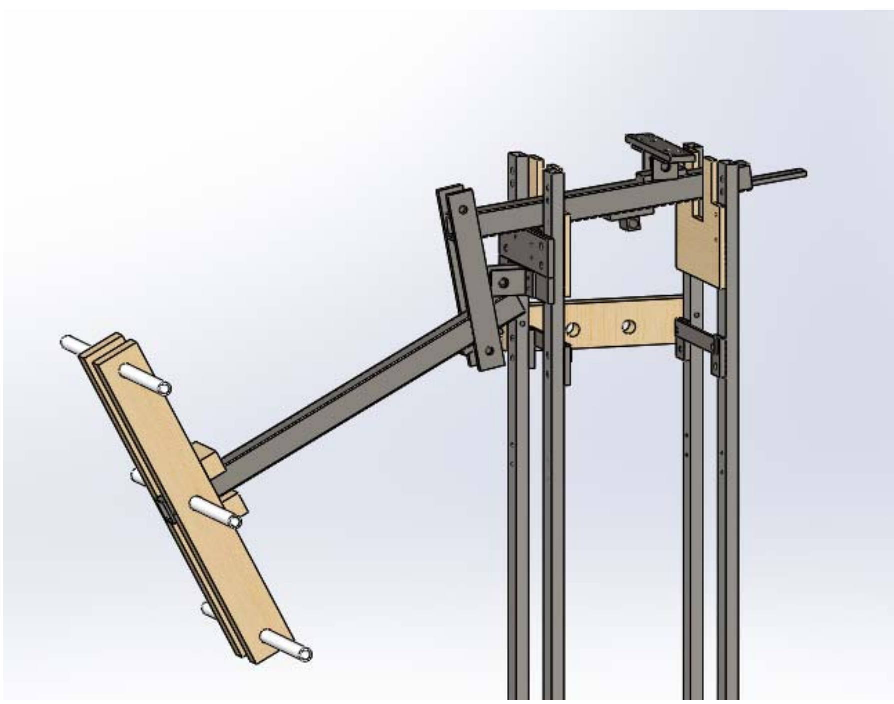


Figure 39: Position of the lever arms relative to the Base Fixture at bottom of stroke.

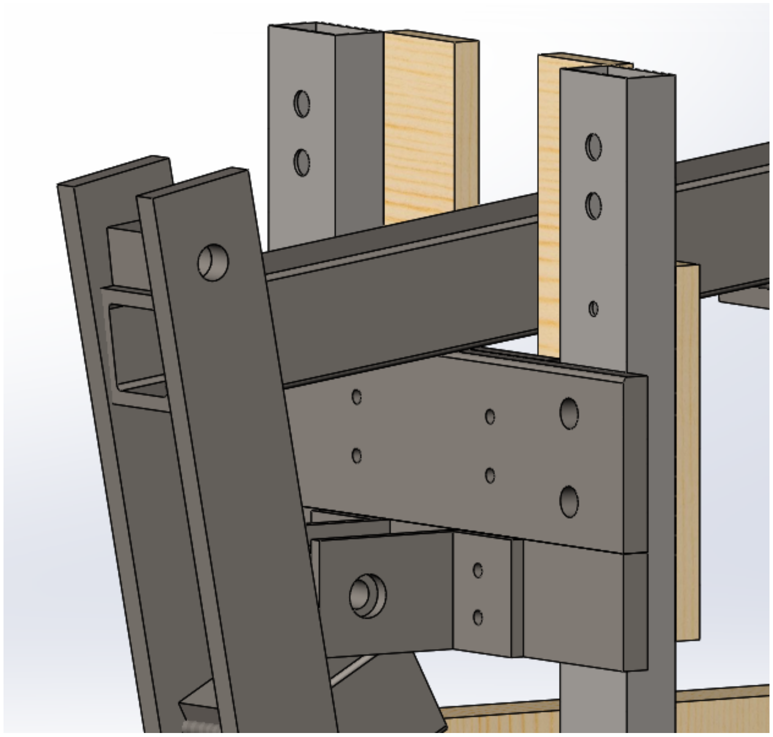


Figure 40: Input lever contacting the hard stop at the end of the stroke.

Testing, Results & Design Validation

Efforts to validate the Frugal Clay Press design through clay testing and prototype operation are discussed in this chapter. Data collection and analysis is included to evaluate the Frugal Clay Press prototype specifications and compare them to the product design specifications enumerated previously.

Experimental Protocol

In order to determine whether the Frugal Clay Press addressed the predefined customer needs in the product design specifications (PDS, Appendix C) , a set of goals and metrics for prototype specifications were compiled to form the experimental protocol in Table 4.

Table 4: Experimental Protocol; lists the desired tests needed to compare the prototype to the customer needs.

Evaluation	Location/Time	Equipment	Accuracy	Trials	Expected Outcome	Formulae or Assumptions	Man-Hours
Weight of Device	MECH Machine Shop	Large scale	1.0 lbs	4	170 lbs	No clay in device; device is balanced	1(1)= 1
Force Output	CENG Concrete Laboratory	Strain gauge, sandbag, large scale,	20 lbs-f	4	3,200 lbs-f	Uniform pressure on clay.	2(4)= 8
Force Input	CENG Concrete Laboratory	Burlap sack, sand, large scale, scooper	1.0 lbs	4	66 lbs-f	Point mass at end of lever arm; applies consistent force through compression	2(4)= 8
Brick Density	CENG Soils Laboratory	Medium scale, rulers	$3.3\text{x}10^{-3}$ sl/ft^3	8	$1.0\text{x}10^{-3}$ sl/ft^3	Clay brick is consistent throughout; uniform density	1(2)= 2
Compressed Clay Weight Percent Water	CENG Soils Laboratory;	Medium scale, clay kiln, ruler	5.0%	8	15-20%	Clay brick is consistent with; uniform density; voids not filled with air	4(4)= 16
Compressive Strength of Final Brick	CENG Concrete Laboratory	Concrete Compressive Machine	0.5 kpsi	8	3 kpsi	Clay brick is consistent with; uniform density; voids not filled with air	3(4)= 12

Rate of Production	CENG Concrete Laboratory	Clay Press; Redart Clay; Stopwatch	5.0 seconds	4	2 bricks/45 seconds	Subsystem interfaces are smooth; clay is consistent throughout;	2(4)= 8
Baked Brick Water Absorption	CENG Soils Laboratory	Water; bricks; containers; medium scale	0.5 grams	1	5 - 35%	24 hours is enough time for brick to be submerged in water	2(1) =2

Experimental Procedures

The following general safety guidelines were followed during the testing of the Frugal Clay Press prototype:

- Proper personal protective gear should be worn during operation i.e closed toed shoes, pants the cover the legs and safety glasses. No loose articles of clothing, long hair, or jewelry should be exposed.
- A wood block is to be placed between the hard stop and the output lever to ensure the lever is fixed in place when not in use; an individual will have their hands on the lever at all times.
- All individuals will keep their hands away from moving parts while they are in motion.
- All actions will be announced such that everyone involved in the compression process is aware.
- All individuals involved will be generally mindful of their surroundings, and will not be distracted by phones, conversations, etc.
- When compressing, the team member doing the compression will not apply their full body weight onto the lever.

Clay Mixing

Clay was prepared and mixed in the SCU Department of Civil Engineering Soils Laboratory and was then compressed using the Makiga block press and the Frugal Clay Press prototype. To determine the range of clay compressibility to be expected in Nicaragua, mixtures of the clay at a 20 weight percent water (wt% water) clay mixture and a 25 wt% water clay mixture were compressed using the Makiga block press. To test absorptivity, three different clay composition mixtures were compressed using the Makiga machine. To test the compressive strength, one clay mixture was compressed with this prototype. After consulting with Dr. Sukhmander Singh, the SCU faculty soils expert, it was determined the clay to be used to model the Nicaraguan clay was a subcategory of earthenware clay called redart clay. Overall, two 50 lb bags of redart clay were purchased from Planet Clay, a local clay shop. Dirt, sand and sawdust were incorporated into the clay mixtures and were provided from the stockpiles of the Civil Laboratory. Various tupperware bins, scales, and hand shovels were used to mix the materials together.

Procedure of clay mixing used for general compressibility of redart clay:

Two batches of clay were made to determine compressibility of clay, one with 20 wt% water and one with 25 wt% water. Two batches 2.5 kg of pure redart clay were weighed and put into two tupperware containers. Then 500 g of water was added and mixed with a hand shovel to one batch, and

625 g of water was mixed into the other batch. From here the clay mixtures were loaded and compressed with the Makiga brick press.

Procedure of clay mixing used for ideal brick composition tests:

Using multiple Tupperware containers, scales and hand shovels, three batches of clay are mixed to eventually test the absorptivity of the composition. The soil composition of each of the three batches are detailed in Table 5 . The batches are 20 wt% water and have a dry a cumulative dry mass of 4 kg.

Table 5: Soil composition of the clay batches made for absorption tests.

	Batch 1		**Batch 2**		**Batch 3**	
Material	**Percentage [%]**	**Mass [g]**	**Percentage [%]**	**Mass [g]**	**Percentage [%]**	**Mass [g]**
Clay	65	2600	80	3200	95	3800
Dirt	15	600	15	600	0	0
Sawdust	5	200	5	200	5	200
Sand	15	600	0	0	0	0

Procedure of mixing clay used for testing prototype:

Using multiple Tupperware containers, scales and hand shovels, two batches of clay were mixed to eventually test the compressive strength and prototype compressed bricks. The soil composition of the batches are detailed in Table 6 . Both batches are 20 wt% water and had a dry a cumulative dry mass of 4 kg.

Table 6: Soil composition of the clay batches made for compressive strength tests.

Material	Percentage [%]	Mass [g]
Clay	89	3560
Sand	10	400
Sawdust	1	40
Water	20	800

Makiga Block Press Tests

The Makiga stabilized soil block press was used for clay consolidation tests, and is depicted in Figure 41. The specifications of this model are given in the Benchmarking section of the report. Due to the depth of the chamber being 7.75” deep when the elevating base is at its bottom position, a secondary base was needed to be inserted into the chamber so that less clay could be used while still giving the machine a 3” compression distance. A wood beam with dimensions of 3.5” x 5.5” x 11” was cut and inserted into the chamber so that there was effectively a new, raised chamber bottom. The new height depth of the chamber is 4.25” and the range of motion of the base was still 3”. WD-40 was sprayed onto the internal surfaces of the compression chamber. After lubricant was applied, add sawdust to the bottom of the chamber, the clay mixture was loaded. After the lid was closed on the compression chamber, the lever arm was moved onto the metal pivot on top of the chamber lid. A secondary team member was needed to put their weight side on the machine on the opposite of Lever Arm movement so that the device did not tip during application. Once the lever was place, the rungs on the side of the lever were pulled down until full user body weight was applied. After the clay had been compressed and the lever could no longer descend, the lever was turned towards the opposite direction until the Lever Arm locks in bottom position, with the chamber base at top position. In this orientation, the lever was pulled down until the chamber base elevated the brick from the chamber for retrieval.

Figure 41: Picture of the makiga stabilized soil block press. The base of the chamber is completely elevated

Prototype Operation Tests

A single cycle of operation was measured from when the clay is initially loaded into the Compression Chamber to when the compressed clay is extruded from the chamber after Lever Arm application. The objective of the prototype operation tests were to observe the interactions between the subsystems, test the performance of the subsystems, and create prototype compressed clay bricks.

The compression cycle began with the Clay Compression chamber inside the Base Fixture, with the lever locked in the upwards position. From there, the Compression Chamber was slid out from position 1 to position 2 as shown in Figures 42 and 43 respectively.

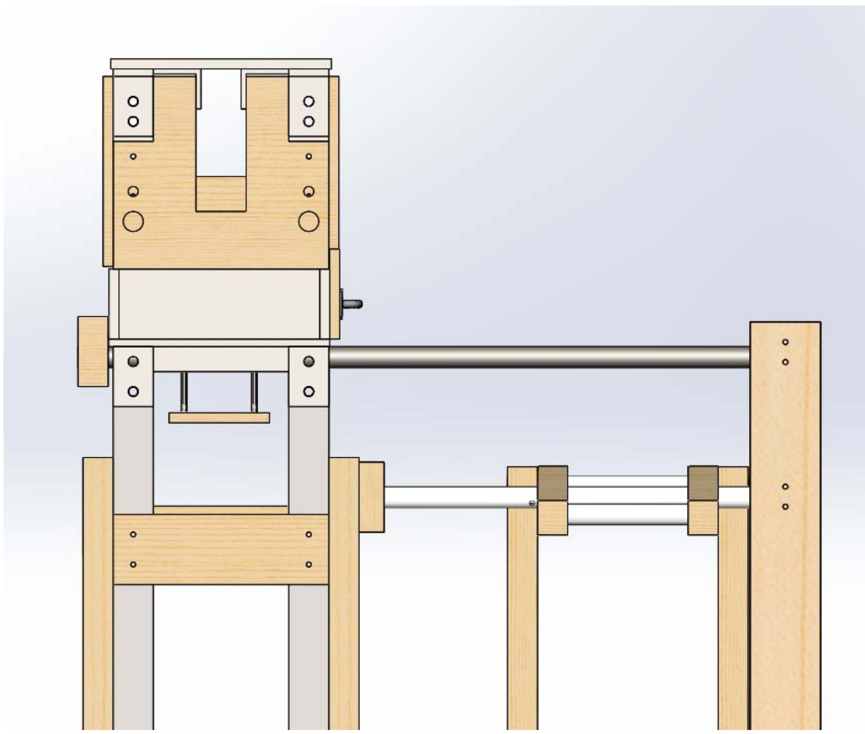


Figure 42: Compression Chamber loaded into position 1.

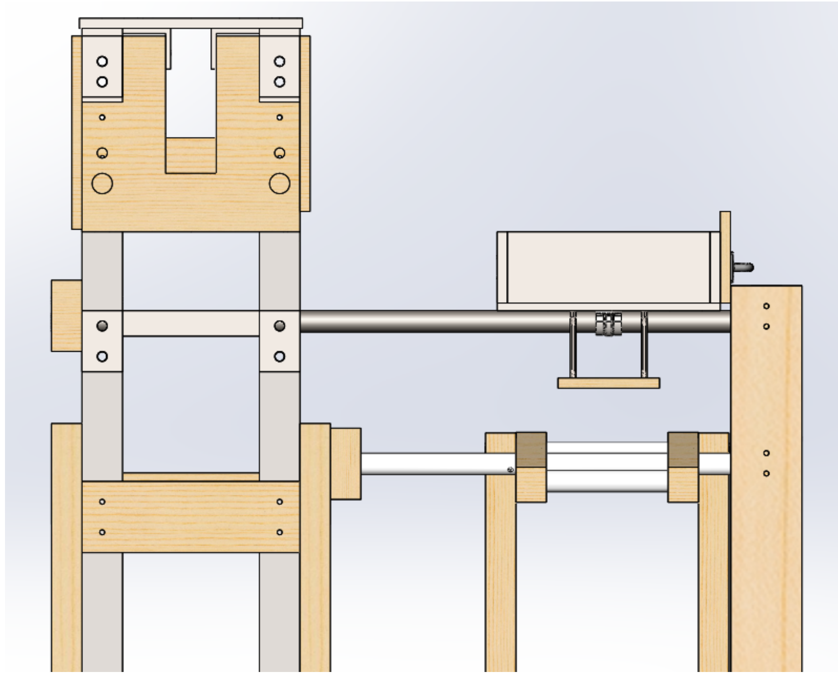


Figure 43: Compression Chamber loaded into position 2.

In this position, the Compression Chamber was loaded to the brim with clay. Once loaded, the operator moved the Compression Chamber along the retrieval rails from position 2 back to position 1. Once in position 1, the safety block that is supporting the lever in the upwards position was removed (Figure 44), and another operator in charge of the Lever Arm slowly compressed the clay until it reached the hard stop (depicted in Figure 45), or until it could no longer be compressed by reasonable force (see safety guideline 5). People not involved in the compression of the bricks were kept about five feet away from the device at all times during use.

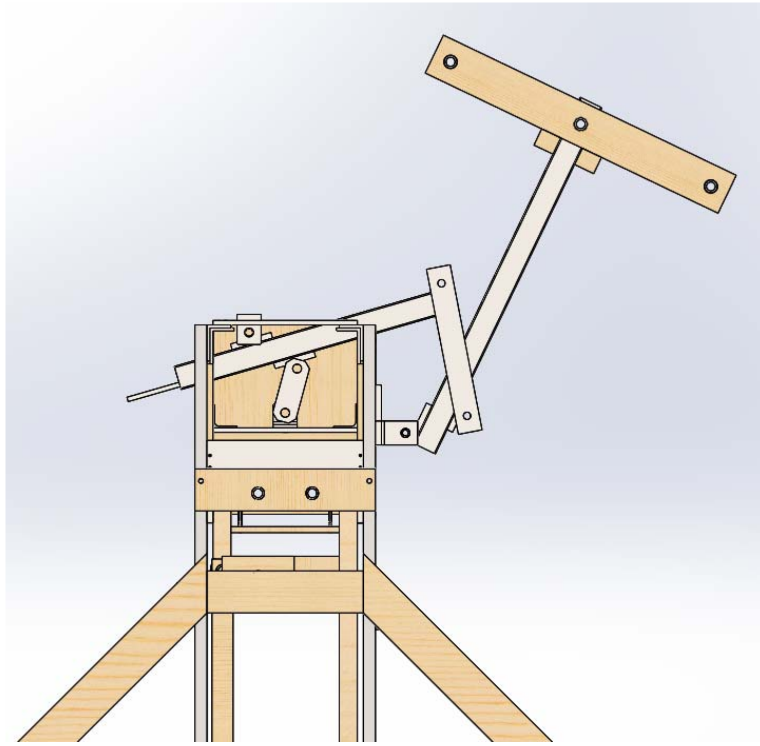


Figure 44: Lever arm at full lift height.

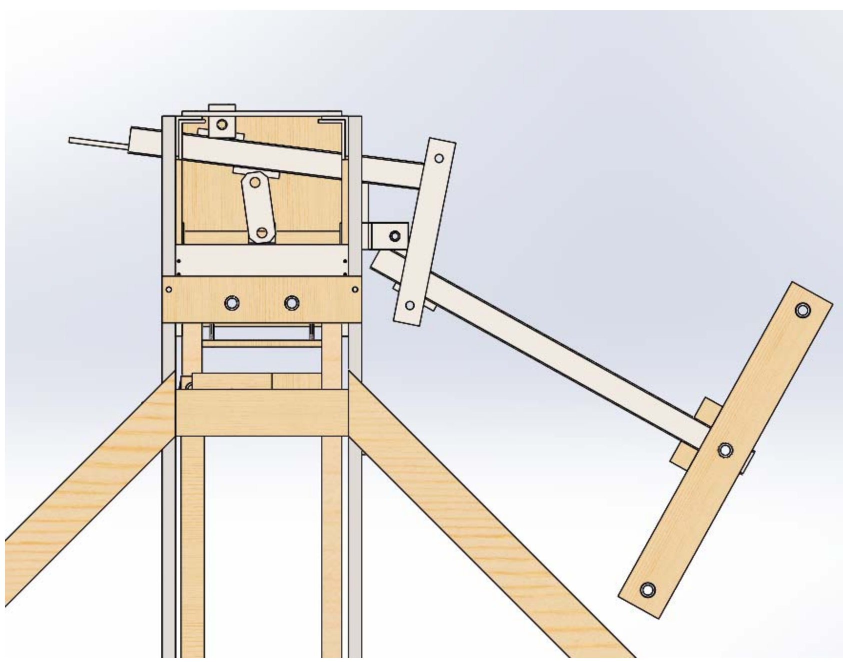


Figure 45: Lever arm once full compression has been achieved.

Once the clay had been compressed, the input lever was lifted to the upwards position (Figure 44) and the safety block was re-inserted between the input and output levers to hold them in place. The Compression Chamber was slid out from position 1 to position 2. In this position, the wooden plate attached to the elevating base of the Compression Chamber to lift up the brick was actuated by the foot pedal of the Clay Retrieval subsystem, which is depicted by Figure 46 & 47. A second operator pushed the extracted brick onto a tray that was being held by a third individual for final brick retrieval.

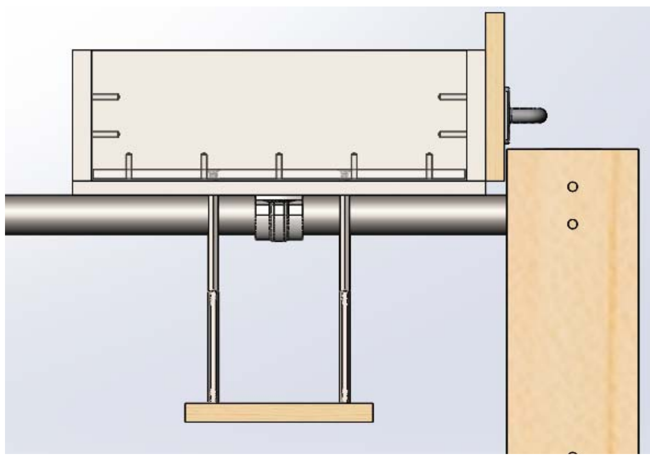


Figure 46: Section view of elevating base before clay extrusion.

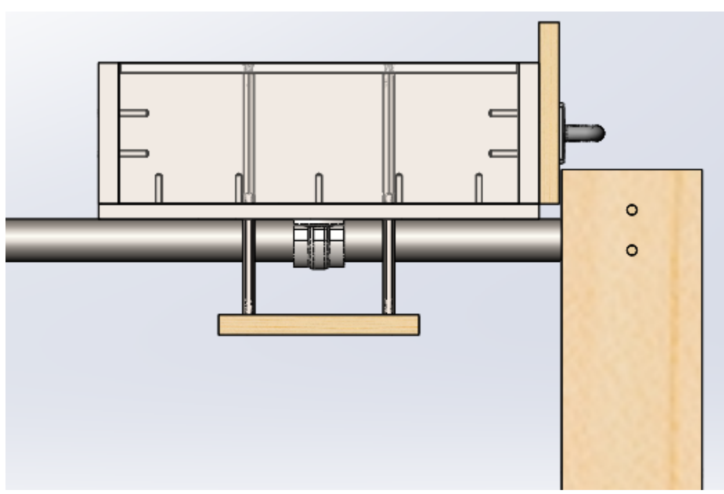


Figure 47:Section view of elevating base after clay extrusion.

Water Absorption Tests

The objective of the water absorption test was to determine the amount of water that is absorbed by a baked brick after 24 hours of being submerged in water. This experiment was conducted using five different bricks: a store-bought red clay brick, the brick brought back from Nicaragua, a brick made with pure clay, a brick made with redart clay, sand, and sawdust (referred to as CSS in Table 9), a brick made with clay, sand, sawdust and dirt (referred to as Dirt in Table 9); the later three bricks were made with the Makiga Stabilized Soil Block Press. The exact composition of these bricks can be found in Table 5.

A brick sample of rough length, width, and height dimensions 3" x 3"x2.5" was broken off each brick. Then, the dry weight of the brick pieces was measured with a medium scale of mass limit 4 kg. The brick pieces were completely submerged in a container filled with water. The brick pieces were left to sit in the water bath for 24 hours. Afterwards, the samples were taken out of the bath and the wet weight of the brick pieces was measured. From there, the percent mass change from the dry weight was calculated.

Density Measurement Tests

The densities of various bricks were determined by dividing the measured mass by the measured volume. To measure the mass of the brick, the fully baked sample was weighed on a scale. To measure the volume, the sample was either measured with a ruler or submerged in water to observe displacement.

Baked Brick Compressive Strength Tests

The purpose of the compressive strength tests on baked bricks was to determine the ultimate compressive strength of bricks produced by the Frugal Clay Press prototype. A single brick of dimensions 5" wide, 12" long, and 2.5" tall was brought back from the clay brick fields of Ladrería y Bloquera San Pedro in Ciudad Darío, Nicaragua to Santa Clara University. A manual brick cutter was used to cut the brick into three roughly equal parts of dimensions 5 in wide, 2.75 in long, and 2.5 in tall. Using the Frugal Clay Press prototype, a single double-sized brick composed primarily of redart clay mixed with sand and sawdust (properties in Table 5) was compressed into shape and extracted from the Compression Chamber. The double-sized brick was cut into smaller samples (dimensions in Table 11) and the samples were baked in a kiln at cone 04, or 1,940°F for 48 hours. Two red clay bricks (dimensions in Table 11) were purchased at a local Home Depot in Santa Clara.

All samples were primed for compressive strength tests using standards defined by ASTM for clay brick compression tests. The samples were placed onto a metal cooking sheet on top of a layer of activated Plaster of Paris, and left for about half an hour to allow the plaster to set. When the plaster had dried, the samples were removed, flipped upside down, and a second surface of the plaster was applied. Excess plaster was removed from each sample, and the samples were brought to the Civil Engineering Soils Laboratory for compressive strength testing.

A Tinius-Olsen compressive strength testing machine was calibrated to allow its maximum load capacity of 400,000 lbs-f to be reached. Each brick sample was placed on a plastered side as close to the center of the compression jaw as possible. The jaws were raised until the top jaw rested on the top of the sample and the machine was zeroed. An average load rate of 250 lbs/min was implemented in testing the bricks produced by the prototype, while an average load rate of 250 lbs/min and 2000 lbs/min were used to test the Nicaraguan brick samples and the two store bought bricks respectively. All samples were loaded at these rates until sufficient cracks began to form in the sample, or if the sample crumbled at the edges. When this occurred, the sample was understood to have reached failure, at which point the machine reported a negative load rate. The testing machine was then stopped and the brick sample was removed to allow for the next sample to be tested. Data on the dimensions of the brick sample, the load at failure, and the load rate were collected for each sample.

Results of Testing

Clay Compressibility Testing

After two batches of clay with differing weight percent water (wt% water) were mixed, one batch was inserted into the Makiga compression chamber; the height of the clay relative to the wood base before and after compression was recorded. After the bricks were compressed they were cut and lifted to observe whether or not the clay maintained a square shape. Knowing the clay height change and that the total mass of the clay in each batch (2.5 kg) the volume and density changes were calculated and are displayed in Table 7. When the 25 wt% water compressed brick was lifted from the wood block, it plastically deformed and bent under its own weight. The 20 wt% water compressed brick did not. The total height change for both bricks was about ⅝ of an inch.

Table 7: Quantitative and qualitative results of the the clay compressibility tests.

Weight Percent Water [%]	20%	25%
Initial Height [in]	2.125	2.250
Final Height [in]	1.500	1.625
Width [in]	5.512	
Length [in]	11.42	
Volume Decrease [%]	-0.294	-0.278
Density Increase [%}	7.138	7.138
Maintains Shape?	Yes	No
Cuttable?	Yes	Yes

Prototype Testing

On May 21st, 2018, two different prototype operation tests were conducted using the Frugal Clay Press Prototype. Table 8 details the main numerical findings in time trials of operating the prototype from the beginning of clay loading to the removal of the double-sized brick from the compression chamber. Despite this, mostly empirical results can be reported, as several issues with the prototype and the clay used were discovered throughout the conducted trials.

Table 8: Brick compression and rate of production tests using the Frugal Clay Press prototype.

Trial	Bricks Produced [bricks]	Time Per Cycle [s]	Accuracy [± s]	Outcome	Compression Achieved [in]	Accuracy [in]
1	2	210	1.0	2 bricks/3.5 min	0.75	0.1
2	2	198	1.0	2 bricks/3.3 min	0.75	0.1

Subsystem Interactions

Several mechanical errors in the subsystem interactions of the prototype were discovered in the time trials that merit future design iteration. Significant time delays were recorded in each time trial because of the Compression Chamber interaction with both the retrieval rail of the Clay Retrieval subsystem and the base legs of the Base Fixture. Because the Compression Chamber was designed to slide along the retrieval rails along a single clamps on either rail, the Compression Chamber was prone to rotating along the rail so that the chamber would often have to be reoriented to slide directly into the Base Fixture. Time was also taken to reposition the chamber to register against the back wood guard of the Base Fixture to ensure that the Compression Plate would enter the chamber without coming into contact with the corners of the chamber walls. The Clay Retrieval subsystem was designed to have a foot pedal that would push up on an adjoining plate to the Compression Chamber, however, tolerancing issues led to the foot pedal being removed from the assembly for testing. Finally, the Compression Plate subsystem would not always descend parallel to the bottom of the Compression Chamber. Despite having L-brackets at the top of the plate to keep the plate level throughout compression, tolerancing issues made it possible for the plate to tilt and catch against the side of the Base Fixture during its descent. This would occasionally result in uneven clay compression, or require the operator to manually reorient the Compression Chamber and Compression Plate to ensure level compression of the clay.

Clay Compression

Clay compression in the Compression Chamber and the formation of a compact double brick were achieved in both trials, however, not to a degree or efficiency that were competitive with the current brick molding practices using a wooden mold in Nicaragua. What was apparent in both trials was that although the Compression Plate was able to descend into the chamber successfully, it could sometimes tilt upon coming into contact with the clay or upon being lifted out of the chamber. This would result in the double-sized brick being compressed deeper on one edge and not enough on the other if the plate did not compress parallel to the base of the Compression Chamber.

Figure 48: Compressed brick after removal from the Compression Chamber.

What was also notable in clay compression tests was the quality of the bricks that were produced using the prototype. As seen in Figure 48, the bricks produced from the device were compressed to be consolidated enough for removal from the Compression Chamber. However, because a much lower weight percent of water was used in mixing the clay, these bricks look much less smooth on the surface and can crumble if moved too roughly or quickly. This is most likely because the clay at the tested moisture content could be compressed more. Cracks in the bricks from movement would eventually propagate and lead to whole chunks of the double brick during movement from the chamber. This necessitated the use of a dustpan and plastic bin lid to scoop the brick from the elevating base of the Compression Chamber onto the plastic lid to move the brick with minimal deformations.

Brick Retrieval & Cutting

Finally, operation testing of the Frugal Clay Press prototype determined that compressed bricks could be successfully elevated from the bottom of the Compression Chamber for removal. Upon raising the elevating base by hand, the clay brick was able to retain its shape even as the elevating base was outside of the chamber. This process was cumbersome, however, as the elevating base still experienced some friction with the chamber walls on its ascent. When the brick was moved too roughly or elevated at an angle so that the edges came into contact with the wall, some clay would start to crumble off of the edges.

Removal and cutting of the bricks, however, presented notable issues. First, the bricks were difficult to remove from the acrylic elevating base by hand as intended in the design. This required the brick to be prodded with a dustpan or sheet of sheet metal for removal. The bricks that were produced were also visibly prone to crumbling and breaking if moved too quickly or roughly during removal. While bricks were able to largely retain their shape if moved carefully, more than one person was required to complete brick retrieval. Furthermore, cutting of the brick was determined to be possible if done so slowly and carefully. This was accomplished in both trials using a piece of sheet metal of about 1/16 of an inch thick.

Figure 49: Double-sized brick halves after removal from Compression Chamber and being cut with sheet metal.

(a) (b)

Figure 50: Inner (a) and outer (b) faces of compressed bricks after removal and cutting. Note the presence of a round dome shaped mark at the corner of the brick in (b). This is because of the clay being compressed into the countersunk holes in the Compression Plate.

When the sheet metal descended upon the clay slowly and with a firm but careful amount of pressure, the brick was able to be cleanly in two. As seen in Figure 49 and Figure 50, the inner and outer faces of the brick are made relatively smooth by the sheet metal cutter and chamber wall respectively when a sheet metal cutter is used to cut the double-sized brick. The right half of the brick in Figure 50, however, did see crumbling at an edge after cutting. This was because the cutter was dragged back and forth to try to further separate the brick halves, which caused the sheet metal to have friction against the inside face of the brick and crumble the brick half.

Water Absorption Tests

It was found the the brick with the highest resistivity to water was the store-bought brick at 8.837% absorbed. The exact composition of the labs mixed bricks can be found in Table 9. The brick with the lowest resistivity to water was the clay, sand, sawdust, dirt brick (labeled as Dirt in Table 9). Out of the compressed brick, the mostly clay mixture had the highest resistivity to water. Generally the compressed brick outperformed or matched the quality of the hand-formed brick from Nicaragua, as it generally was able to absorb less water.

Table 9: Percent weight gain of the bricks from water absorption for 5 different bricks.

Brick	Before (g)	After (g)	% Absorbed
Bought	109.4	119.1	8.837
Mostly Clay	193.4	233.0	20.49
CSS	238.3	316.3	32.76
Nicaragua	166.2	224.3	35.00
Dirt	48.81	66.36	35.96

Density

Table 10 shows the mass, volume, and corresponding densities for various measured bricks. These samples include a brick created with the Frugal Clay Press, a brick purchased from Home Depot as a standard, and a brick brought back from Nicaragua.

Table 10: Density data for various brick samples.

Brick Type	Mass of Sample [g]	Volume of Sample [cm^3]	Density [g/cm^3]	Density [lb/ft^3]
Created	323.7	250	2.0	125.1
Purchased	501.1	150	2.2	134.8
Nicaragua	2360.6	2360	1.0	62.6

Compressive Strength Tests

Compressive strength tests determined that, in general, an uncompressed brick from the target community in Nicaragua failed at much lower stresses than bricks purchased at Home Depot and bricks compressed by the Frugal Clay Press prototype. Brick samples from the brick produced by the clay press prototype were largely able to withstand stresses up to 1,500 psi, with the sole exception being the third brick sample. Both samples from the Nicaraguan brick experienced failure much sooner, with the maximum stress experienced by the brick sample being 907 psi. The brick samples that experienced the highest stresses prior to failure were the store bought bricks, which both exceeded stresses of 100,000 psi under the Tinius-Olsen compressive strength testing machine.

Table 11: Compressive strength test results for brick samples produced by the Frugal Clay Press prototype (denoted FCP), purchased from Home Depot (denoted Store), and from a brick produced in Nicaragua by Ladrería y Bloquera San Pedro (denoted NCG).

Sample	Length [in]	Width [in]	Height [in]	Failure Load [lbs-f]	Failure Stress [psi]	Load Rate [lbs-f/s]
FCP 1	4.25	2.75	2.50	17800	1520	250
FCP 2	5.00	3.00	2.50	26600	1770	250
FCP 3	6.50	4.50	2.50	22700	776	250

FCP 4	5.50	2.50	2.25	34500	2510	250
Store 1	7.50	3.50	2.75	312000	11900	2500
Store 2	7.50	3.50	2.75	276000	10500	2500
NCG 1	5.00	2.75	2.50	12470	907	250
NCG 2	5.00	2.75	2.50	10135	737	250

Significance of Results

Clay Compressibility Testing

The were several objectives of the clay compressibility test. First of these was to determine the amount of compression that a clay sample can experience, and secondly, to observe which moisture content (wt% water) clay mixture would best be able to be cut and maintain shape after compression. The purpose of varying the wt% water of each batch was to observe what the wettest clay that could be compressed and still maintain its shape. This was necessary to know because each brick needed to dry enough so that the bricks could be easily removed from the chamber. Additionally, the use of drier clay in brick formation would allow the community to use less water in their processes, which has both positive environmental and economic impacts. The other advantage of drier bricks is that the time needed for brick to air dry is significantly reduced, which reduces the overall time required for bricks to be formed, baked, and prepared for sale. After this test was completed, it was determined that the maximum wt% water for all other clay mixtures used for prototype testing would be 20 wt% water.

From dimensional analysis before and after compression of the clay it was found that the maximum compressibility of the clay was found to be about 70% of its initial volume. From this result the height of the Compression Chamber walls were determined knowing that the final height of the compressed bricks is 2.5”. It was assumed that since the clay used to make the bricks in Nicaragua are composed of a much wetter mixture of local clays and other soils that the extent of compression would realistically be lower. Therefore this prototype was designed to compress clay to 77% of its original volume with beginning and ending height of 3.25” and 2.5” respectively, which corresponded to ¾” compressive distance achieved by the Lever Arm and Compression Plate subsystems in conjunction.

Prototype Operation Testing

Prototype operation tests determined that the prototype did not successfully achieve adequate compression of the bricks nor did it achieve a production rate comparable with that of the current clay brick forming methods of Ladrería y Bloqueria San Pedro. One of the main causes of this was the clay used in testing. Use of a clay mixture of 20% moisture content (weight percent water) produced bricks that were much drier than the clay used for bricks in Nicaragua, which require a moisture content upwards of 35-45%. While drier clay can be compressed much more adequately than clay with a higher moisture content, it is also more prone to deformation from crumbling. A side-by-side comparison of the bricks formed in Nicaragua and those formed with the prototype show that although the bricks formed by the wooden mold were too wet to be moved without breaking, their surfaces are smoother (Figure 51 (a) and (b)). This is significant because while the Nicaraguan bricks require much more time to dry, their surface finishes are much more aesthetically appealing, which is an important factor for customers of the social entrepreneurship.

Because the Compression Chamber of the Frugal Clay Press Design is only able to compress bricks about ¾ of an inch, the design must be modified to be able to compress bricks further. Even with 8000 grams of mixed clay used in the chamber, both timed trials showed that more than ¾ of an inch of compression could be achieved by the prototype. The bricks that were produced in the operation trials were compressed, but not enough to ensure that the bricks would not crumble upon removal or cutting. More thorough compression could be achieved either by increasing the height of the Compression Chamber walls, or by changing the position of the hard stop of the Base Fixture to increase the stroke length of the Lever Arm.

(a) (b)

Figures 51: Surface textures of a dried Nicaraguan brick (a) and a dried compressed brick from the Frugal Clay Press prototype (b).

The most significant empirical result of testing was that tolerancing of the prototype in fabrication negatively impacted the performance of the device in operation trials. Both time trials conducted required more than three minutes per cycle of operation, as compared to the 45 seconds that is taken to form four bricks at a time by the clay workers using the wooden mold. This was largely because many of the subsystem interactions of the Frugal Clay Press design were too tight, and assumed purely linear motion of each component. In actual practice, elements such as the Compression Plate and Compression Chamber were prone to rotation, as the tolerances between those elements and other subsystem components were too loose to ensure that linear motion can be achieved every cycle. Conversely, tolerances between the Compression Plate, Compression Chamber, and Base Fixture were found to be too tight. This required the user to have to consistently reposition the Compression Chamber when loading the chamber into the Base Fixture to prevent the chamber walls from catching on the base legs upon entry. Similarly, the chamber had to be reoriented by hand to ensure that the Compression Plate would descend directly into the chamber without rotation or tilting from contact with the chamber walls. Additionally, tolerancing issues affected clay compression. Compression plate stabilizers did not keep flush with the chamber guards on the Base Fixture or with the chamber walls during descent into the Compression Chamber. This led to uneven clay compression in the first trial where one side of the double brick was compressed deeper than the opposite side.

Water Absorption Testing

The water absorption test was done to prove two important points: to determine whether or nor compressed bricks do in fact resist water absorption more than the handmade Nicaraguan brick, and to determine which brick composition was the most resistant to water absorption. From these water absorption tests it was generally found that the redart bricks compressed with the Makiga Stabilized Soil Block Press absorbed less or as much water as the handmade brick. This suggests that the hypothesis that compressed bricks correspond with increased physical properties and overall increase is quality is correct. Out of the three bricks compressed, the mostly clay brick absorbed 12-15% less than the clay bricks composed with sand, sawdust, and/or dirt. The store bought red clay brick absorbed about 11% less than the mostly redart clay brick. The store bought brick was also the most dense, and had much smaller pores on the surface compared to the other bricks. The implications from these results are that a brick with high percentages of clay, absorb less water. Although the store bought brick is made from a different type of clay, it acts as a baseline of the possible absorptivity that a clay brick can have. Should this prototype be deployed in Nicaragua, wit would be suggested to use less dirt and/or sand in the brick mixture. Although absorptivity tests with the Makiga machine compressed bricks were conducted, there was no data collected with the compressed brick from the clay press prototype; therefore it is not possible to conclude how this prototype compares to standard store-bought bricks or Makiga compressed bricks. In future iterations of the this project, the absorptivity of prototype compressed bricks and Makiga compressed bricks should decrease either by optimizing the brick composition and/or improving the prototype compression.

Compressive Strength Testing

From compressive strength test results, it was determined that clay compression with the Frugal Clay Press prototype was indeed able to increase the mechanical properties of bricks. All four samples of the brick produced by the prototype were able to withstand loads larger than both samples from the Nicaraguan bricks. The industrial clay brick purchased at Home Depot, however, experienced stresses a factor of ten greater than the two other type of bricks. Despite the spread of the failure stresses in each of the samples, the results seem to provide supporting evidence to prove the effectiveness of clay compression in increasing the strength of bricks. This is especially significant, as these results were achieved with brick samples produced by the Frugal Clay Press Prototype. More compressive strength tests are necessary to conclude upon the actual extent of improvement in mechanical properties the Frugal Clay Press would provide for the community in Nicaragua with statistical significance. These tests could be conducted, however, because of time constraints following the Senior Design Conference and prior to the deadline for this senior thesis. Because of this, conclusions on the overall effectiveness of the Frugal Clay Press prototype in clay compression cannot be made with significant confidence.

Several sources of error in these tests must be acknowledged. First, the brick samples in these experiments did not have perfectly flat capped surfaces. The Plaster of Paris was applied to both surfaces using a cooking sheet, rather than a sized bath for each brick to ensure a flat layer would solidify on the bricks. This resulted in some brick samples having a ramped surface, which offset the compression plate used in the compressive strength testing machine. The uneven surfaces on some of the brick samples, namely samples FCP 1 and FCP 3, could have contributed to local failure that resulted in failure under a smaller load. The brick samples also varied in dimensions. Because of this, each sample did not experience the same pressure under the compressive strength machine at failure. The most significant source of error, however, is that the clay mixture used to form a brick with the Frugal Clay Press prototype and the store bought brick is significantly different than the mixture used in Nicaragua. This is because the community uses a mixture of local soils, sawdust, and sand that are not available in the United States. Moreover, their mixing process is done entirely empirically, which made it impossible to replicate the specific amounts of each material and water used in their mixture. Because of this, an earthenware clay known as redart clay was used as the best estimate for the clay found in Nicaragua, and was used to conduct all clay compression tests at Santa Clara University.

Future Iterations

Problems encountered with the current prototype as well as suggested solutions to those problems are discussed in this section. However, it is important to note that these are merely suggested solutions, and that there may be much more efficient solutions that are not included. It is important that any team taking on this project be able to look at the system as a whole with a fresh viewpoint, and not be restricted by the tunnel vision that long-term, in-depth work on the device will inevitably produce. Moreover, it is important to keep in mind that these solutions are a result of firsthand experience with the prototype, and that the validity of any of any of these solutions must still be discussed and considered in greater detail.

General

It was discovered that the community was capable of performing welding procedures well after many parts of the project had already been designed or manufactured. While the current design of the press is held together with fasteners to facilitate ease of assembly, disassembly, and shipping, there are some components that should be welded to better secure components together and provide additional structural stability to the design. Some examples of helpful weldments may include member B02 to B05 on the Base Fixture to increase stability, P01 to P07 on the Compression Plate to eliminate the need to use fasteners on the underside of the plate that may leave indents on the bricks, and welding the entirety of the Compression Chamber together to eliminate the need for fasteners. Depending on how the prototype would be shipped, it was potentially not as necessary as previously believed to use fasteners on every individual piece, and instead weld groups of parts of certain subsystems together. Nonetheless, it was important that the design implemented fasteners in case welding was unavailable in the target community. This decision was made to doubly ensure that the device could be entirely replicated with the community's hardware resources, which were confirmed during the exploratory trip to Nicaragua in March of 2018.

Another obstacle that the machine as a whole faces is that it will be exposed to conditions that make it susceptible to erosion, such as rain, dirt, and humid conditions. To remedy this, it may be valuable add a surface finish to the metal pieces to make them resistant to rusting. Ideally, this surface finish would also prevent the metal from getting overly-hot, as the machine will likely be in direct sunlight for long periods of time. Additionally, it would be ideal to replace many of the wooden pieces of the device with pieces more resistant to environmental wear, such as acrylic, metal, or pvc. This design change would be important for the wooden guards on the Base Fixture in particular.

Finally, there are some pieces that are not up to the standards of the factor of safety of the machine as a whole. For example, member B02, the detail drawing for which can be found in Appendix L, does not hold up to the factor of safety of the machine as is. A detailed structural analysis on all parts can be found in Appendix H.

Base Fixture

One of the most significant problems encountered with the Base Fixture of the prototype is that it is difficult to slide the Compression Chamber in and out of it. Firstly, the Compression Chamber can wiggle from side to side, but will not enter the Base Fixture unless it is oriented correctly. To fix this, one may make the rail and routing clamp system more precise, slightly spread apart the legs of the Base Fixture, add guiding components to the legs to keep the Compression Chamber straight once it enters the Base Fixture, machine chamfers on to the corners of Compression Chamber to guide the chamber into the correct orientation, or a combination of all of the above. Another reason the Compression Chamber is difficult to slide in and out is that it is not at exactly the correct height for the Compression Chamber supports (B01), and the Compression Chamber supports are not all at the same height as one another. This has several possible solutions. Firstly, welding the Compression Chamber supports to the Base Fixture legs as opposed to fastening them with bolts may result in better accuracy of placement.

Additionally, adding chamfers to the corners of the B01 components may help realign the Compression Chamber if it is too low. Alternatively, one may raise the height of the rails of the Clay Retrieval subsystem such that there is a slight gap in between the B01 pieces and the Compression Chamber. With this method, the Compression Chamber will not run into the supports, but the wood holding up the rails will deflect under pressure, allowing the B01 pieces to take the load during actual compression. Finally, one may consider adding a rail that spans from one B01 piece to the other on the same side, such as piece B21 in revision 15 of the solidworks model, or replace both the B01 pieces and B21 with one long L-bracket. Another opportunity for improvement in the Base Fixture is that, although it has trussing to ensure that the device does not tip forward when being used, lacks effective trussing to prevent side-tipping. As a result, it is important that the Base Fixture be modified such that it is stable in all directions.

Lever Arm

Although the Frugal Clay Press is most efficient when operated by multiple people, it ideally can be operated by only one. To accomplish this, it is necessary that the Lever Arm be able to support itself at its most upright point to allow for one person to use the lever, let go of it, and then retrieve the bricks from the side. The idea initially pursued by the team was to add a counterweight to the opposite end of the Lever Arm, such that in operation, the Lever Arm is effectively weightless to the user with a slight inclination to move to the top. This would not only make the input lever useable by a single individual, but reduce strain on the user, which would be especially important if being used by smaller or weaker individuals, such as young girls. The calculations for what counterweight would be required in conjunction with a simple, self-contained pulley system can be found in Appendix E, Figure 5. However, upon constructing the prototype, it was discovered that the lever was significantly easier to manage than expected to the point where it is debatable whether or not it is worth constructing. In the current prototype, the Lever Arm subsystem is sometimes propped up by placing a wooden block in between the input lever fulcrum and the output fulcrum. However, this is not considered up to the safety standards of the project. As a result, another idea would be to design a simple latch that would latch the input and output levers together at the highest point of the stroke.

Compression Chamber

Through welding, the need for fasteners may be eliminated. This is significant because the addition of fasteners in the chamber was the cause of an enormous amount of manufacturing time and relies on tight tolerances, introducing the possibility that the fasteners may not properly align. Additionally, the addition of fasteners necessitated that the walls of the Compression Chamber be a minimum thickness such that they could be properly drilled and tapped from the side in machining. However, this minimum thickness was much thicker than required for structural integrity to be achieved. As a result, if the Compression Chamber were welded, its cost and weight could be reduced.

When using the prototype, it was observed that the clay provided very little resistance, even up until the hard stop of the machine was reached. This indicates that the clay could be compressed much more than the ¾ inches that had been accounted for. The compressive distance of ¾ inches was initially chosen, even though it was estimated that the clay could potentially be compressed about 1.1 inches given perfectly ideal conditions. However, considering that the clay in Nicaragua is still largely unknown in composition and behavior, it was decided that being conservative in the calculation for the compressive distance was better such that the hard stop would always be reached by the Lever Arm subsystem and a brick of the proper height could consistently be achieved. However, upon using this prototype, it became apparent that not achieving enough compression to make a high quality brick may also be a concern. To address this issue, it would potentially be wise to make the walls higher than they are now to ensure that there is room for proper compression to be achieved. Then, when the device is implemented, the thickness of the clay elevator plate, C09, and the placement of the hard stop may be modified such that the appropriate amount of compression can be achieved while still resulting in the proper thickness defined by the customer in Nicaragua.

One final obstacle observed in the use of the Compression Chamber is that, regardless of the close tolerances, debris will find its way under the clay elevator, C09. To design against this, a possibility is to introduce trenches, gaps, or ridges of some sort onto the face of the bottom plate of the Compression Chamber, B03, for the debris to settle in without interfering with the rest of the system. This type of system would also require a easy and method to clean the bottom of the Compression Chamber.

Compression Plate

Arguably the most significant problem with the current prototype is the inability of the compression plate guiding system to work properly. This system was designed to ensure that the compression plate, P07, was always horizontal and uniformly applied force using the compression plate angle brackets, P05. These guides were meant to interact with the wooden guards to eliminate any rotation that may occur. However, if this critical system is to properly work, it is likely necessary that these angle brackets must be made to be significantly taller. Additionally, the descent of the compression plate may be made smoother if the plate stabilizers are interacting with a material that is smoother and has a better surface consistency than wood. These plate stabilizers should also be fastened to the compression plate, P07, more securely, as they were prone to wiggling or being moved during the compression cycle.

Clay Retrieval

An important consideration for the potential implementation of the prototype is that the brick produced is currently twice the width of that used by the community in Nicaragua. There are several solutions to this problem. The first solution would be to implement a cutting mechanism attached to the Clay Retrieval subsystem. Ideally the brick would be elevated out of the Compression Chamber, and then cut in half by a thin metal object or wire on a hinge that is permanently attached to the Clay Retrieval subsystem such that the cut would not be subject to human error, similar to the machine in Figure 4 of Appendix A. A second possible design solution would be to switch from a two brick chamber to a single brick chamber. This option has value as no cutting mechanism be required, and that the individual brick would receive more pressure because the same force would now be applied to a smaller area. The drawback to this option would be that it reduces throughput. One final option would be to add a thin metal piece inside the chamber itself, as seen in the figure below showing a possible attachment to the YLF1-40 device. This option seems very promising, but it is unknown if this same principle would succeed of the thin sheet increases in distance. Additionally, a method for attaching this thin sheet would need to be developed.

Figure 52: Removable thin metal piece of the YLF1-40 machine that allows two individual bricks to be made instead of one larger brick by allowing the brick to be cut and separated as it is being compressed. [13]

Upon attempting to use the prototype, it became immediately apparent that the foot pedal system of the Clay Retrieval would not work as is. This is because C07 and C08 would become improperly angled and the clearance holes for them were improperly manufactured, making them difficult to move. Multiple solutions were presented for this challenge. One solution would be to create a plate or slab with slots that would be placed at the end of the rails such that when the Compression Chamber has been pulled all the way to the outwards position, the C07 or C08 standoffs used for clay elevation would slide into the slots. Ideally, these slots, along with the holes on plate C03, could provide two-point stabilization that would minimize the wiggling that makes clay elevation difficult. Another practical solution would be do be rid of the foot lever system entirely and simply add handles to plank C12. This would require less materials, a less complex mechanism, and be fairly reliable. However, it would also require that there be a way to lock the clay elevator, C09 in the elevated position such that the clay could be retrieved once the user releases the handles.

Conclusions on System Integration & Design Validation

Overall, prototype tests following the completion of the Frugal Clay Press for Nicaragua prototype to confirm the safety and effectiveness of the design did not produce sufficient numerical data to make conclusions with statistical significance. Tolerancing issues and limitations to clay compression because of the design were found in conducting two separate timed trials for the prototype from the beginning of clay loading to the removal of the brick from the Compression Chamber. While testing did bring to light issues in the design to be addressed in future design iterations, there was not enough remaining time in the academic year to further refine the prototype to conduct better operation tests. Clay compression using the Frugal Clay Press prototype, however, determined that the drier clay used for operation tests was capable of being consolidated through compression. Both timed trials using the prototype showed that the double-sized brick could be elevated out of the Compression Chamber and, if moved carefully, could be removed from the chamber without experiencing significant deformation. This is a significant achievement of the device, as the wooden molds used in Nicaragua cannot be used to move clay bricks from where they are formed on the ground. While the bricks produced in both operation tests did experience crumbling and were not able to fully retain their shape, they were still much more resistant to deformation upon being moved than those of the Nicaraguan bricks, as witnessed during the team's exploratory trip to Nicaragua.

Costing Analysis

Tables 12 and 13 detail the total project expenses and total cost of materials used in the fabrication of the Frugal Clay Press prototype. While the previously included Budget section displayed conservative estimates for these costs, the following tables detail how funds were actually allotted from September of 2018 to June of 2018.

At the end of June of 2018, a total of $796.47 was spent in prototype materials costs and production. In comparison to the industry presses discussed in the Benchmarking Results section, the press is less than $1,000 USD. This gives the design the potential of being accessible to a wider range of communities worldwide, and especially for the customer and target community for this project in Ciudad Darío, Nicaragua. It is worth noting, however, that the amount spent on prototype materials exceeded the budgeted amount of $740. This is largely because of underestimated prices for fasteners and the need to repurchase steel for prototype components when stock steel was scrapped in machining errors. Despite this, prototype materials costs only exceeded the budgeted amount by $50 and about $5,723 dollars remained in team funds at the end of the project. The remaining funds were meant to support the travel of the entire design team to Nicaragua in July of 2018 to implement the prototype. Civil unrest throughout the nation shortly after the March 2018 trip, however, made it impermissible for Santa Clara University students to travel there since April 2018.

Total Project Expenses

Table 12: Total project expenses from January 2018 to May 2018.

PROJECT EXPENSES			
Category	**Retailer**	**Description**	**Money Spent**
Prototype Costs	McMaster	Elevating Base	$29.43
	Metals Depot	Initial Compression Plate	$63.74

	Online Metals	Initial Compression Chamber Walls	$85.26
	Home Depot	Base Fixture Trusses	$25.14
	Online Metals	New CC Walls	$64.33
	Metals Depot	CC Bottom	$54.30
	Online Metals	Base Legs	$68.00
	Bolt Depot	Fasteners	$69.22
	McMaster Carr	Standoffs	$22.54
	Lowe's	Plywood, fasteners	$59.84
	Home Depot	PVC, fasteners	$9.47
	McMaster Carr	Standoffs and Bushing	$51.34
	Home Depot	Fasteners, washers	$12.60
	McMaster Carr	Hex Flat Head Screw	$11.34
	Home Depot	Fasteners	$19.52
Travel Expenses	Hostal Dona Mina	Nicaragua Lodging	$223.69
	Metals Depot	Lever Arm and L Beam Purchase	$81.24
	San Jose Travel Clinic	Typhoid Shot	$116.00
	San Jose Travel Clinic	Typhoid Shot	$116.00
	United Airlines	Baggage	$107.50
Total Spent			$1,290.50
Total Funds			$7,014.28
Funds Available			$5,723.78

Cost of Materials

Table 13: Frugal Clay Press for Nicaragua final prototype materials costs.

PROTOTYPE COSTS		
Subsystem	**Description**	**Money Spent**
Base Fixture	Base Legs	$68.00
	Input Fulcrum Support, Hard Stop, Lever Connecting Beam, and Chamber Support Blocks	$85.26
	Wooden Truss Supports	$25.14
Compression Chamber	Chamber Walls	$64.33
	Elevating Base	$29.43
	M/F Standoffs & Bushings	$51.34
	F/F Standoffs	$22.54
	Bottom Plate	$54.30
Compression Plate	Compression Plate	$63.74
Lever Arm	Lever Arm & L Beam Purchase	$81.24
	Lever Arm Welding	$40.00
Retrieval Rail	Steel Rails & Rail Wood Trusses	$29.16
General	Bolts, Fasteners, PVC, & Plywood	$181.99
	TOTAL COST OF MATERIALS	$796.47

Recent and Relevant Patent Research

Key Design Dates

Invention of Frugal Clay Press Design & Partnership with Frugal Innovation Hub (11/13/17)

Revision 10 & The Fall Quarter Conceptual Design Review (12/5/17)

Revision 13 & Beginning of Prototype Fabrication (1/29/18)

Revision 14 & Completion of the Frugal Clay Press for Nicaragua Beta Prototype (5/9/18)

Revision 15 & Publication of the Senior Design Thesis (6/14/18)

Establishment of the Frugal Clay Press for Nicaragua Legacy Project (6/16/18)

Main Competing Technologies

The main competing technologies of the Frugal Clay Press design include pre-existing industrial presses, manual presses that may currently be used in communities similar to Ciudad Darío. Currently, the clay brick workers of Ladrería y Bloquera San Pedro use a small wooden brick frame composed simply of wood and nails. This device allows them to form a lot of bricks very quickly while the frame itself is cheap and easy to reproduce. However, to work, wetter clay is needed to fill the molds meaning it takes the bricks longer to dry. Furthermore, because no compression occurs, the maximum strength of the bricks are limited. Figure 53 below shows an example of said wooden frame.

Figure 53: Wooden mold currently used to form bricks without compression in Ciudad Darío, Nicaragua.

Appropriate industrial machines that exist come largely from the YingFeng Co. based out of Shandong, China. Figure 54 shows YLF1-40, one of their more popular machines. For a minimum of $1,000 USD, one can get a compact machine with a small clay storage/funnel bin, bottom up compression chamber, and a cam compression system with a long simple lever. The machine is simple to use and produces two solid bricks at a time, but is relatively expensive for a small company in a developing country as well as heavy and cumbersome to move.

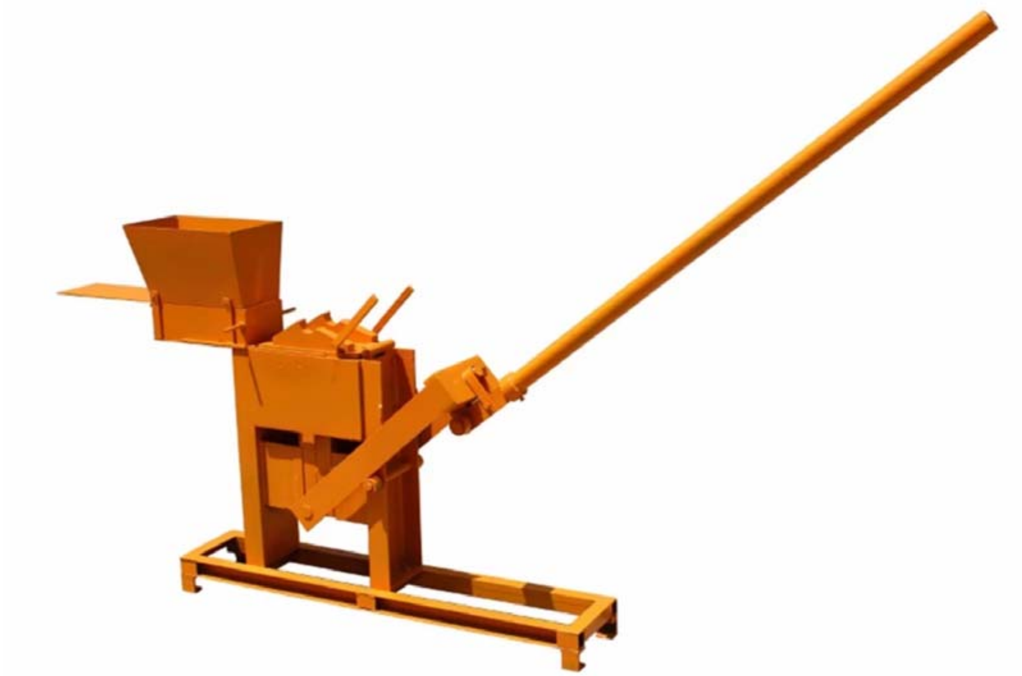


Figure 54: YLF1-40: One industry competitor for manual clay brick compression (Appendix A).

Advantages Over Existing Clay Press Designs

Unlike existing devices, the Frugal Clay Press for Nicaragua is composed solely of cheap and locally accessible building materials. The device relies on the use of hot rolled A36 Steel, pine wood 2x4 beams, and zinc plated fasteners and bolts, which are largely available in *ferreterias*, or hardware stores, in Nicaragua. This allows for the press to not only be cheaply assembled, but also allows for the design components to be cheaply replaced upon failure or extensive wear.

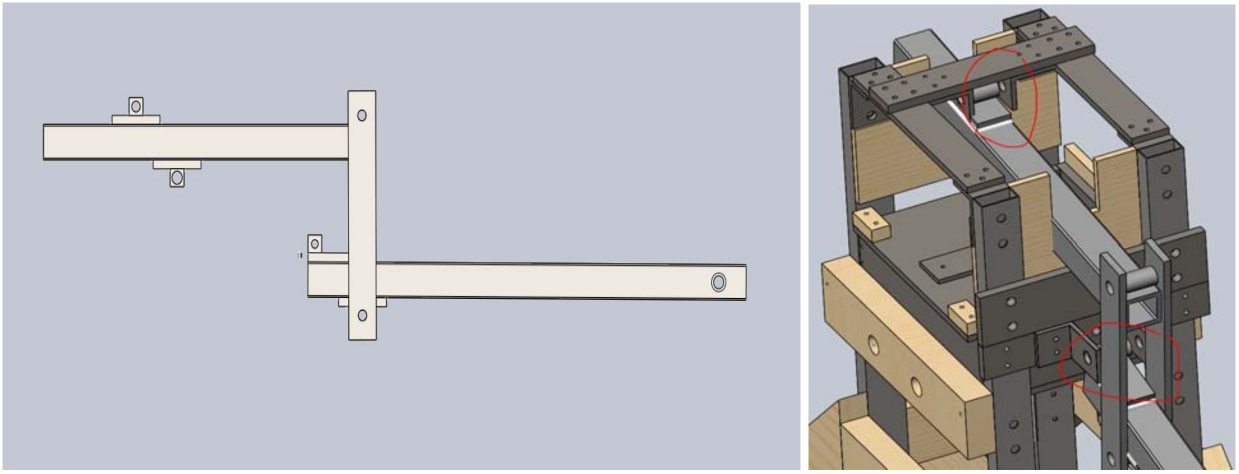
Components of the Frugal Clay Press are designed with geometric simplicity, allowing for all parts of the design to be fabricated from stock A36 steel and wood using a milling machine, drill press, band saws, and hand drills. The design also relies on simple welding operations to mate some key features. These parts, however, are designed to not require anything more than simple edge welds, which can be accomplished quickly and cheaply by local welders. If welders are not available to the community, a majority of the device can still be assembled using standardized english unit fasteners. A streamlined design for manufacturability and easy assembly distinguishes the Frugal Clay Press Design from the more expensive and geometrically complex devices found on the market that are inappropriate for application in rural communities in developing countries.

Finally, the Frugal Clay Press is noticeably cheaper than clay presses found in industry and in patent searches. Because industry presses often rely on complex welds to mate parts that often have to be pre-fabricated and assembled before deployment, these presses are often too expensive for rural communities such as Ciudad Darío, Nicaragua. Prices for these presses, as detailed in the Benchmarking section of the report, are commonly upwards of $1,000 USD. Cheap materials, easily manufacturability and assembly, and minimal reliance on welding allows for the Frugal Clay Press device to remain under $1,000 USD, with materials costs estimated to be just under $800 USD. This presents a significant advantage to existing devices, as the Frugal Clay Press is designed to be more affordable and maintainable by owners in rural communities.

Unique Design Features

Compound Lever Design

While most other manual compression machines have a long simple lever, this design employs a compound lever arm to accomplish comparable levels of compression to machines that feature a simple lever and cam force application system. By utilizing a compound lever, the overall range of motion the operator has to travel in order to compress the clay into bricks is greatly reduced, making the machine more ergonomic and better for long term use. Figure 55 shows the general concept as well as how the lever connects to the machine as a whole.



(a) (b)

Figure 55: (a) A normal view of the compound lever. (b) The compound Lever Arm implemented into the overall conceptual system with staggered fulcrums circled in red.

Ergonomic Handle

Further improving upon the ergonomic benefits of the compound lever, this machine also utilizes a three tiered ergonomic handle that allows the operator to apply force in a more optimal range of motion (from low torso to just beneath the hips, moving through approximately one foot of input lever arm motion before switching handles). In this optimal range, an operator can apply force by leaning their body weight over the handle rather having to use their muscles to apply force. By using this lever with three handle inputs, operators can use the device for longer with less strain on their bodies.

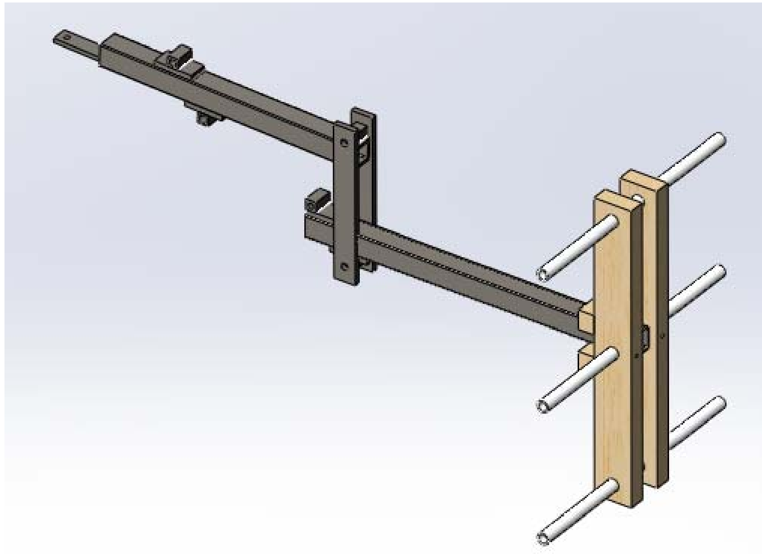
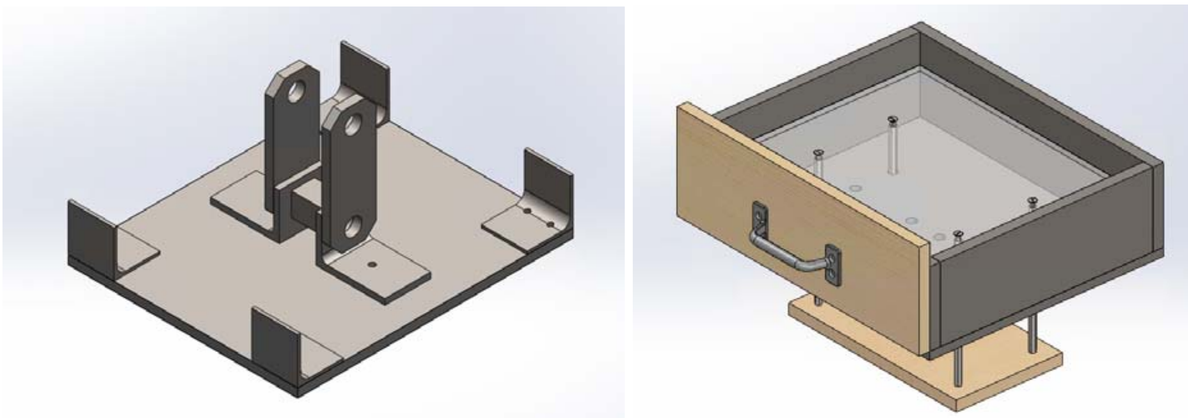


Figure 56: Model showing compound lever with ergonomic three tiered handle.

Compression Plate / Compression Chamber Subsystem Interface

The Compression Plate / Compression Chamber subsystem interface draws its uniqueness not from compression of amorphous clay into solid bricks, but from its method of top down compression instead of bottom up compression. This means pressure is applied to the top of the clay as opposed as to the bottom. Most other competitive machines on the market favor compression from the bottom to work in conjunction with their cam-driven compression. Figure 57 illustrates the subsystems in which the clay is stored and compressed.

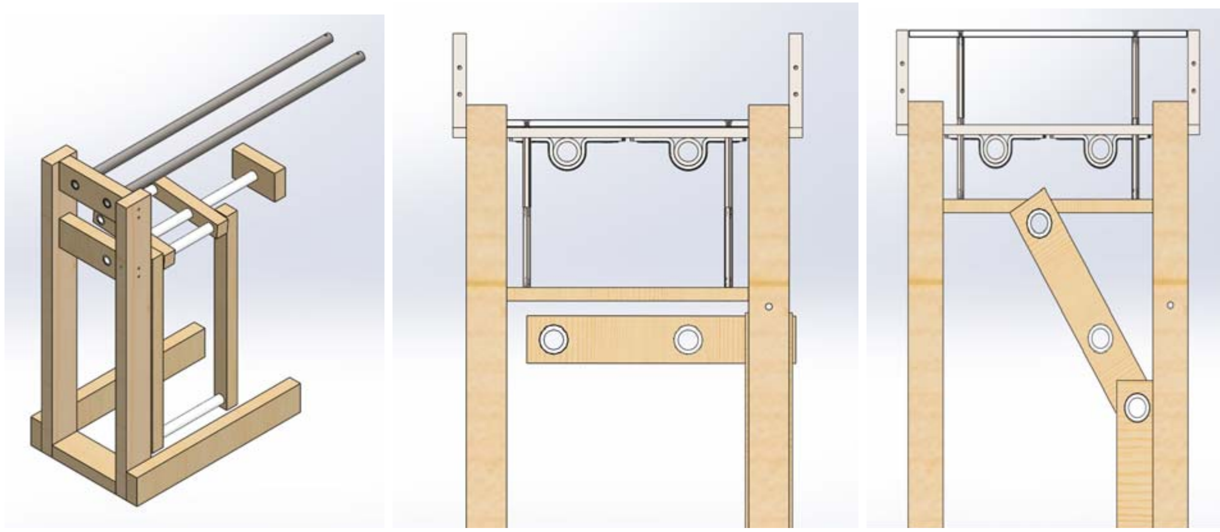


(a) (b)

Figure 57: (a) Compression Plate subsystem applies pressure to clay from above. (b) Compression Chamber subsystem stores and supports the clay from underneath during compression and uses the elevating base to aid in the extraction of clay during retrieval.

Retrieval Rail and Foot Pedal System

In most other designs on the market, clay retrieval and compression happens within the same small space with exceptions being big machines that compress large amounts of clay (see Appendix A). This particular retrieval rail system design physically separates these two processes by having a docking position at one end of the retrieval rail for loading unformed clay loading and removing compressed bricks from the Compression Chamber and a position set up for clay compression on the other. Also, when the clay bricks are ready to be removed from the chamber in the docking position, the bricks are ejected using a foot pedal to elevate the clay out of the chamber. Physically separating the locations where clay is retrieved and where the clay is compressed allows for multiple people to work different sections of the prototype at once. This compliments the community's current processes, which employ multiple clay workers in brick forming at a time. Overall, this can potentially can assist the social entrepreneurship in extending employment opportunities in the community.



(a) (b) (c)

Figure 58: (a) Isometric view of retrieval rail concept with foot pedal. (b) Section view of Compression Chamber in docking position with foot pedal in neutral position. (c) Section view of Compression Chamber in docking position with foot pedal in upright, extended position.

Commercialization Possibilities

As an open source design, the Frugal Clay Press for Nicaragua will not be commercialized for profit by the Frugal Clay Press team. Instead, the design will be made as a legacy project with original authorship explicitly credited to Milan Copic, Kevin Ellis, Rafael Delfin Guerrero, and L. Isaac Marcia. The design will be able to be replicated or modified by machinists, clay workers, other engineering design teams, or any individual that would benefit from the products produced by the clay compression device without legal measures being taken against them from the Frugal Clay Press team or Santa Clara University. Moreover, persons that have replicated or modified the Frugal Clay Press design for their own use will only be able to legally claim profits that are gained from the sale of the products produced by the press. This excludes claiming original authorship of the Frugal Clay Press design, as attempts to forge or otherwise falsely produce documentation that patents the Frugal Clay Press for Nicaragua design will be seen as grounds to take legal action by the Frugal Clay Press team and Santa Clara University.

Relevant Patent Classifications Summary

The Frugal Clay Press for Nicaragua design has been found to have the following relevant patent classifications: B28C, "PREPARING CLAY; PRODUCING MIXTURES CONTAINING CLAY OR CEMENTITIOUS MATERIAL, e.g. PLASTER" and B30B, "PRESSES IN GENERAL." While not having many official patent classifications, there are many different searchable terms that aided in the search of existing patents. "Clay", "compression", and "press" were the most important searchable terms that would be associated with this device, as the Frugal Clay Press for Nicaragua is a device intended for the compression of clay. "Brick", "lever", and "compound" were also useful in searching pre-existing patents as the device uses a compound lever system to compress clay into bricks. Finally, "manual" and "frugal" also helped locate designs similar to this one, as the device is entirely manually operated and is composed solely of cheap and locally accessible building materials for implementation in rural communities worldwide.

Prior Art Review & Distinction of Conceptual Design

Four of the most similar pre-existing patents have been collected and compared to the Frugal Clay Press in the subsections below. Full reproductions of said patents can be found in Appendix G.

Patent FR2545411A1: "Manual Press for Moulding Clay Bricks"

This French design for a manual clay press was published in 1983 by Francois De Silvestri. The design features a compound lever arm design that allows for clay compression into a mold. Compression in this system is bottom up, as the design has a movable lower plate actuated by the stroke of the lever [14].

The design has nine claims, of which claims 1 and 7 are most relevant. In claim 1, the inventor describes how the design is able to achieve compression through manual operation of a lever, which drives a movable bottom plate connected to the lever by two linkages. This plate slides from the bottom toward the top of the clay compression mold while inside the mold. Claim 7 states that this is achieved through the use of tension springs attached to webs in the frame of the press.

The Frugal Clay Press for Nicaragua design varies from this design in a few distinct ways. The movable bottom plate of the Frugal Clay Press design is not meant for compression, but rather to allow for easy retrieval of clay bricks from the Compression Chamber after compression. The Frugal Clay Press design also relies on the use of a two lever system, which allows for a force amplification of 45. De Silvestri's design uses a three-arm lever system that is attached to a movable bottom plate by two linkages, and a frame that provides additional advantage through two tension springs. The Frugal Clay Press design does not rely on these components, and instead achieves top down compression through the descent of a Compression Plate subsystem into a moveable Compression Chamber. The Frugal Clay Press design is further distinguished by its ergonomic three-tiered handle, which allows for the user to obtain maximum mechanical advantage throughout the entirety of the stroke length. With a single handle for the lever in De Silvestri's design, the user may have to vary the angle of force application because of the angle of the lever with respect to the base. The ergonomic handle of the Frugal Clay Press allows the user to adjust their grip on the Lever Arm subsystem to enable as close to a perpendicular force application on the lever as possible throughout the entire stroke.

Patent FR2519581A1: "Hand-Operated Brick Press"

This manual clay press featuring a two bar lever arm and a vertical cam compressing system was authored in 1982 by French inventor Daniel Turquin. This design compresses the clay into bricks top down and expels the clay from the mold from the bottom up. Although the device can hold up to four clay bricks at once, it only compresses two bricks at a time [15].

This design contains seven claims with claims 1 and 3 being the most relevant. The first claim elucidates that the simple two-levered compression system utilizes a helical cam to deliver enough force to compress the amorphous clay into a clay brick. Claim 3 states that the compression molds for the clay rotate about one of the legs as a central axis, parallel to the compression direction, for easy and accessible loading and unloading of the clay bricks. The molds rotate a half-turn about its axis to facilitate the compression process.

The Frugal Clay Press for Nicaragua compound lever and clay retrieval designs vary significantly from this design. Even though clay retrieval and compression can be operated simultaneously with two operators, this design still centralizes the area of clay retrieval around one of the legs of the device. Additionally, using rotation instead of translation to remove the clay bricks from the compressive position further differentiates the design from the Frugal Clay Press. While this design heavily relies on the use of a helical cam applying pressure vertically on the clay, the compound lever concept uses a two stage simple lever to apply compressive force nearly vertically. The ergonomics of the lever handles also differ. The Frugal Clay Press features a compound lever that uses a three tiered handle attached to the singular input lever arm to keep application site of input force over the optimal range of motion, while this patented design simply uses two separate lever arms to complete the full range of motion for compression.

Patent US1945399A: "Apparatus For Pressing Clay Products"

This particular manual clay press design was authored in 1932. The design features a complex gear mechanism and brake and ratchet mechanism used to control the extrusion of clay into a die. The mechanism presses clay through a cylinder towards a clay cutter, which then extrudes the shape onto a table to prevent deformation of the clay product [16].

There are nine claims associated with this design, of which claims 2 and 9 are most relevant to this review. Claim 2 elaborates on the functionality of the press, in which a clay product is produced by extruding clay out from a compression cylinder onto a table. The mechanism works through the operation of a rotating crank, which drives a set of gears at the top of the compression cylinder to drive a hammer that pushes clay through a die. In claim 9, the inventor states that extruded shapes are then cut at the bottom of the cylinder, as a ratchet controlled braking system ensures that the supporting table catches the extruded shape.

There are several fundamental differences between this design and that of the Frugal Clay Press for Nicaragua. Firstly, this press extrudes clay shapes by driving clay through a die and mandrel. The Frugal Clay Press design only compresses clay into the shape of a brick inside the Compression Chamber subassembly. Bricks are only “extruded” through elevation of the base plate of the Compression Chamber. The Frugal Clay Press relies on mechanical advantage for brick compression through the use of a compound lever system, whereas this design uses a rotating crank to drive a gear system to provide mechanical advantage for extrusion. Finally, the Frugal Clay Press does not need to rely on a supporting table or braking system to stop the falling of clay products. Instead bricks are retrieved from the Compression Chamber through the elevating base, which is also actuated by a lever system.

Patent US145358A “Improvement in Brick Making”

Another clay press patented in 1873 was reviewed in initial patent research. This device compresses rectangular bricks through the means of a compound lever, a mold that slides horizontally into the main housing of the device with the use of a handle, and a bottom up, lever-based clay retrieval system [17].

Being an older US patent, the exact number of claims are not enumerated. However, a couple of key design features are relevant in comparing this older device to the Frugal Clay Press design proposed in this report. First, this device uses a compound lever guided by a rack and pinion gear set that vertically compresses clay into bricks in a single stroke. Secondly, retrieval of clay bricks happens by sliding the compressed clay molds away from the compression position and expelling the bricks from the bottom up.

There exist several striking similarities with the Frugal Clay Press for Nicaragua, specifically with regards to the Lever Arm subsystem and Clay Retrieval subsystem. Even though the design for Nicaragua has a more ergonomic handle, both devices achieve compression of clay into bricks with a single stroke of a compound lever, with the only difference being the implementation of a rack and pinion in the older design. Moreover, the sliding, bottom up clay retrieval is quite close to the design presented in this patent. There is only a slight difference in how force is applied to eject the clay from the chamber. The most apparent difference between the two devices is that the Frugal Clay Press for Nicaragua is designed with safety being one its highest priorities, as seen with this covering of the Compression Chamber/Compression Plate interface. This older patented design appears to be more concerned with efficiency, as noted by their dual chambers for simultaneous loading/unloading and compression without external covers on either system.

Patentability Conclusions

The Frugal Clay Press for Nicaragua design contains several design components and system integrations that are potentially unique enough for patentability. This includes all the unique areas touched on in this patent report: the ergonomic compound lever, the enclosed compression position, and the horizontally sliding Clay Retrieval system. Firstly, the compound arm lever system is largely absent from recent patents and current competitors. Furthermore, the compression processes itself is different from most modern incarnations of an affordable clay brick press in that compression happens from the top down rather than the bottom up. Similarly, the Clay Retrieval design is different than most of the recent patents presented and other devices on the market because ejection of the clay bricks happens away from the compression position, which allows for quick loading and unloading of clay. Even though patent US145358A utilizes a compound lever, top down compression, and a horizontally living retrieval system, the Frugal Clay Press design's emphasis on quality ergonomics and safety are unique improvements on a system level to the manual clay press concepts reviewed in this patent report. Ultimately, while certain components may be similar to other patents or industrial competitors, the device as a whole is unique enough to file for a patent.

Engineering Standards & Realistic Design Constraints

Economic Constraints

It is estimated that 42.5% of the population of Nicaragua live below the poverty line, with 75.8% of the population living on less than $2 USD a day [12]. Existing manual clay brick press devices, however, are priced upwards of $1,000 USD (Table 1). The ability of residents of Ciudad Dario, Nicaragua to afford components of the Frugal Clay Press design limited the type of materials that were used in the design to materials that were relatively cheap and locally accessible to the community. Design components were designed or selected to ensure that the least amount of building materials and fasteners would have to be imported into Nicaragua, allowing the bulk of the assembly to be built using parts made or purchased in Nicaragua.

Sustainability Constraints

A larger issue of sustainability comes with the clay mixing and brick baking processes of the community. On a daily basis, clay workers in the community prime piles of clay for mixing by running a water hose over the pile for hours at a time. Not only does this make clay bricks take up to nine days of drying before baking, it also causes the community to use a large amount of freshwater in their operation. Clay compression, however, would allow the community to make stronger bricks with the use of much less water, as drier clay can be consolidated much more thoroughly with compression. Because of this, it became an important expectation of the community upon travelling to Nicaragua in March of 2018 for the press to be able to reduce the amount of water needed to form clay bricks because the customer wanted to reduce the time needed for clay bricks to dry before they are placed in the oven for baking.

Figure 59: Pile of Nicaraguan clay soils mixture, with hose running on top.

While this is an issue that is outside the scope of the project itself, another main concern was that the community in Nicaragua used a substantial amount of firewood to operate their clay brick baking ovens. Each batch of bricks baked in their large clay oven required the oven flame to be stoked for ten hours straight. While the owner of Ladrería y Bloquera San Pedro remarked that the wood that was used was an invasive species of tree in the area, it was not clear what other fuel sources they would rely on once their current supply of firewood was used up. It was also clear that the process of baking each batch of bricks produced strong black smoke for nearly two and a half days straight. This smoke production, if unchecked, could contribute to poorer air quality for the larger community of Ciudad Darío.

Figure 60: Clay brick oven and firewood used for baking dried bricks.

Manufacturability Constraints

Another concern for the clay press design was the ease of manufacturability of the device's subsystems and components. The Mechanical Engineering Machine Shop at Santa Clara University possessed multiple high-precision milling machines, lathes as well as vertical band saws and drill presses. While it was possible to machine all components of the design at Santa Clara University to a precision of ± 0.00005 of an inch, the community does not have the same access to computer-aided heavy fabrication machinery. This required tolerances in the design to be to a smaller degree of precision, as to allow the design to be made successfully regardless of the presence of computer aided machinery.

Ethical Constraints

With the design of a Frugal Clay Press for a community in Nicaragua, significant weight was placed in ensuring that design was responsive to the rights of the customer to communicate their needs, wants, and concerns regarding the performance of the design solution. The press was not only to be a capstone design project, but to be an actual product that would be implemented by Ladrería y Bloquera San Pedro and its clay employees. With this in mind, efforts were made before and during the exploratory trip to Nicaragua to contact the owner of the social entrepreneurship and gather feedback on the conceptual design of the Frugal Clay Press. This Voice of Customer assessment determined that their main expectation of the device was that compression would enable for bricks to be dried more quickly, so that more space can be freed up in the brick making fields for the formation of more bricks.

Another ethical consideration in the design of the Frugal Clay Press was with regard to design for the common good. Because the design was for a specific customer, the owner of the social entrepreneurship, it was necessary to understand the effects on the community beyond benefitting this enterprise. Travel to Ciudad Darío in March of 2018 determined that while the press would most directly benefit the social entrepreneurship, their increased productivity because of the press would actually require them to take on more workers. Many residents of Ciudad Darío are not able to find work locally and have to make a long and often dangerous trip to the larger city of Managua for work. Opening up the social entrepreneurship to the possibility of expanding employment opportunities would reinvigorate the local economy and engage more people in local paid labor than before.

Social Constraints

A concern that was communicated to this design team from clay workers employed by the social entrepreneurship in Nicaragua was that the device would render their employment obsolete. Currently, the harvesting of clay, formation of bricks in the wooden molds, and drying of the bricks requires multiple people working in conjunction. While it may not be the same for communities elsewhere, there are fifteen to twenty workers of Ladrería y Bloquera San Pedro that are employed daily to mix clay and form bricks. Workers were concerned that implementation of the clay press, if successful, would effectively reduce the amount of people the owner of the social entrepreneurship would need to hire. Despite the reassurance that this was not going to be the case and that the press would actually increase the amount of work available, the design was made to be operated by two to three workers at a time. This collaborative aspect of operating the Frugal Clay Press would make it possible for the community to still engage the same amount of workers in clay brick formation. Moreover, clay compression would allow for bricks to dry much more quickly than before, which could increase the rate at which bricks are baked. More clay workers would be needed to mix clay and form bricks to meet the increased throughput of clay in the community, thus making it possible for the Frugal Clay Press to have the potential to expand employment opportunities with Ladrería y Bloquera San Pedro.

Summary & Conclusions

Design Purpose & Potential

Over the course of the senior design process, the Frugal Clay Press team has aimed to create a device for a defined customer in Nicaragua. This manual clay compression device was to be capable of outputting high-quality building materials while emphasizing design principles of frugality and appropriate technology. Design choices were made to make the device less expensive than existing clay press devices, and so that it may be constructed exclusively with resources obtainable in the community without compromising functionality. While the design has the potential for being adapted for implementation in different environments around the world, the Frugal Clay Press design was refined to serve a brick-making coalition called Ladrería y Bloquera San Pedro in Ciudad Darío, Nicaragua.

Through several Voice of Customer assessment interviews, the design team determined that implementation of the Frugal Clay Press is capable of producing great benefits for the social entrepreneurship and the community of Ciudad Darío at large. Firstly, clay compression allows for bricks to be made denser and have increased mechanical properties. This works best for clay mixtures that are not oversaturated with water, as wetter clays tend to be more incompressible than drier clay. As clay workers in the community can only successfully mold clay bricks using wet, oversaturated clay with their current methods, the introduction of the Frugal Clay Press could allow clay workers to use less water in their clay mixture while ensuring that bricks will consistently be compressed to the desired shape and dimensions. This is significant because water usage is currently their largest expense, and exhausts the supply of freshwater available in the community. Finally, the clay press design is expected to significantly reduce the time a brick needs to dry before baking. This will not only increase the number of bricks they are able to make per day, but also expand opportunities for local, paid labor to the people of Ciudad Darío.

Prototype Construction & Validation

The Frugal Clay Press design prototyping phase took place from January 2018 to May 2018. Individual component designs were completed before the completion of the entire design to maintain the desired fabrication schedule. Extensive FEA in Abaqus was conducted before each individual piece was machined. All components of the Frugal Clay Press design were made of either hot rolled steel or wood, and were fastened together with zinc plated fasteners or welded. All machining operations were accomplished through the use of band saws, miter saws, milling machines, drill presses, hand drills, and hammers. A standing prototype was assembled for presentation and testing by May 9th, 2018.

Three main experiments were conducted to validate the effectiveness and safety of the Frugal Clay Press design. Prototype operation tests were conducted as time trials for one cycle of brick production. These time trials recorded the cycle from the beginning of loading the clay Compression Chamber to the final extraction of the brick in the Clay Retrieval subsystem. Samples of a clay brick brought back from Nicaragua were compared to samples of bricks formed by the Frugal Clay Press prototype through water absorptivity tests. Brick samples were left in buckets of water to determine if the compressed clay bricks were able to more effectively reject water absorption. Compressive strength tests conforming to ASTM standards for brick strength testing were also conducted on samples from bricks formed by the Frugal Clay Press prototype, samples from the brick brought back from Nicaragua, and on store-bought clay bricks to determine the ultimate strength in compression of each brick.

Through these separate tests, the Frugal Clay Press prototype was determined to not be prepared for final deployment to Nicaragua. Even though brick absorptivity tests and compressive strength tests determined that bricks produced by the Frugal Clay Press prototype were more water resistant and stronger than the brick sample brought back from Nicaragua, prototype operation tests demonstrated significant inconveniences and issues in mechanical interactions between subsystems. These issues made operation of the prototype inconsistent and increased the amount of time necessary to form two bricks. Moreover, clay compression achieved by the Frugal Clay

Press prototype was not sufficient enough to allow compressed bricks to retain their shape after extraction.

Final Remarks on the Frugal Clay Press Prototype

Through prototype validation, brick absorptivity tests and compressive strength tests determined that bricks produced by the Frugal Clay Press prototype were more water resistant and stronger than the brick sample brought back from Nicaragua. Despite this, tests conducted on bricks formed by the prototype were not of the quantity nor consistency necessary to conclude on the effectiveness of the press in improving brick mechanical properties. Moreover, operation tests confirmed that many key interactions between subsystems had issues because of machining tolerances that caused many inconsistencies, delays, and user inconveniences in use. Finally, the depth of compression of clay achieved by the design was not sufficient enough to achieve adequate compression of the clay. This resulted in bricks formed by the prototype to require delicate movement to retain their shape upon extraction from the clay Compression Chamber. This is significant because an expectation of the customer in Nicaragua was that newly compressed bricks would not have to dry on the floor for a few days before they could be stacked to dry further in clay *machos*. In light of these dilemmas, it is clear that future iterations upon this prototype are necessary before it can be deployed.

Project Legacy

While the device was capable of basic clay compression, it did not achieve a majority of the product design specifications enumerated by the customer at the beginning of the design process (Appendix C). However, it is worth noting that The Frugal Clay Press was capable of generating bricks that were stronger than the brick brought back from the community in Nicaragua. The Frugal Clay Press design team worked in collaboration with Mr. Rolando Gutierrez and the clay workers of Ladrería y Bloquera San Pedro in Nicaragua to make the design best appropriate for their needs, wants, and concerns for the clay brick forming processes. It is the honest wish of this team that despite the need for further revisions on the Frugal Clay Press design, the customer will be able to receive and implement the device. Because of this, this design team has taken steps to establish the Frugal Clay Press for Nicaragua project as a Santa Clara University legacy project. These are previous senior design projects at SCU that are continued by faculty so that they may be adopted and finished by a new group of dedicated seniors. Continuation of the design project through another design team may make it possible for the community to receive a much more safe, effective, and robust version of the design in the future.

Significant Takeaways & Reflections on the Frugal Clay Press Design Project

Several design considerations that were discovered through the design process must be discussed in evaluating this team's efforts in the design of the Frugal Clay Press for Nicaragua. Firstly, knowledge of soils engineering was necessary for a more effective design in this project. As a result, it would be ideal if the next team to take on this project was composed of civil and mechanical engineering students. Second, effort must be made of the design team to understand the community of Ciudad Darío and their resources. Design for appropriateness in this project relied on close communication with Mr. Gutierrez throughout the design and prototyping phases as to ensure that this custom press design would uniformly compress bricks to their defined dimensions and still involve multiple clay workers in the brick forming processes. Third, it is important that SolidWorks be utilized to its fullest in this project. Various problems were encountered in detailed design that were only discovered in dimensional analysis of the CAD models. These modeling issues included fasteners interference with critical components, component interferences because of tight tolerances, and discrepancies between the travel and behavior of several design mechanisms and systems in the modeling software and the actual prototype.

Successes of this design team in the progression of the Frugal Clay Press for Nicaragua design project must also be acknowledged. This design team was the first to partner with the social entrepreneurship, Ladrería y Bloquera San Pedro. Because of this, a future design team will have a predetermined customer that they may begin the senior design project with, making it much easier for the future team to design for appropriateness for the target community. Out of all thirteen design teams in the graduating class of 2018, the Frugal Clay Press for Nicaragua team was the only team to travel to their target community. Participant observation and in-person Voice of Customer assessment interviews, which were made possible through partnership with the Frugal Innovation Hub, significantly impacted the Frugal Clay Press design and distinguished this project from other design projects in the Department of Mechanical Engineering. Finally, the Frugal Clay Press for Nicaragua project required not only mechanical engineering analysis and design skills, but also civil engineering knowledge of soils engineering. Despite this, the project was advanced by the work of four mechanical engineers, who in addition to applying mechanical design skill to the Frugal Clay Press design conducted research and experimentation in the field of civil engineering. Progress of this initial Frugal Clay Press for Nicaragua design team during the 2017-2018 academic year at Santa Clara University effectively laid the groundwork for a future mechanical and civil engineering interdisciplinary team to solve a tangible engineering problem in a real community in the world.

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APPENDICES

APPENDIX A: Existing Products

Summary:

Over the course of researching pre-existing competitive clay press designs, it became clear that the current market for manual clay presses were dominated by countries in the developing world, with China and various African nations being the forerunners. Specifications of size, weight, throughput, going market price, etc. for a few of the most popular products the team found are available below.

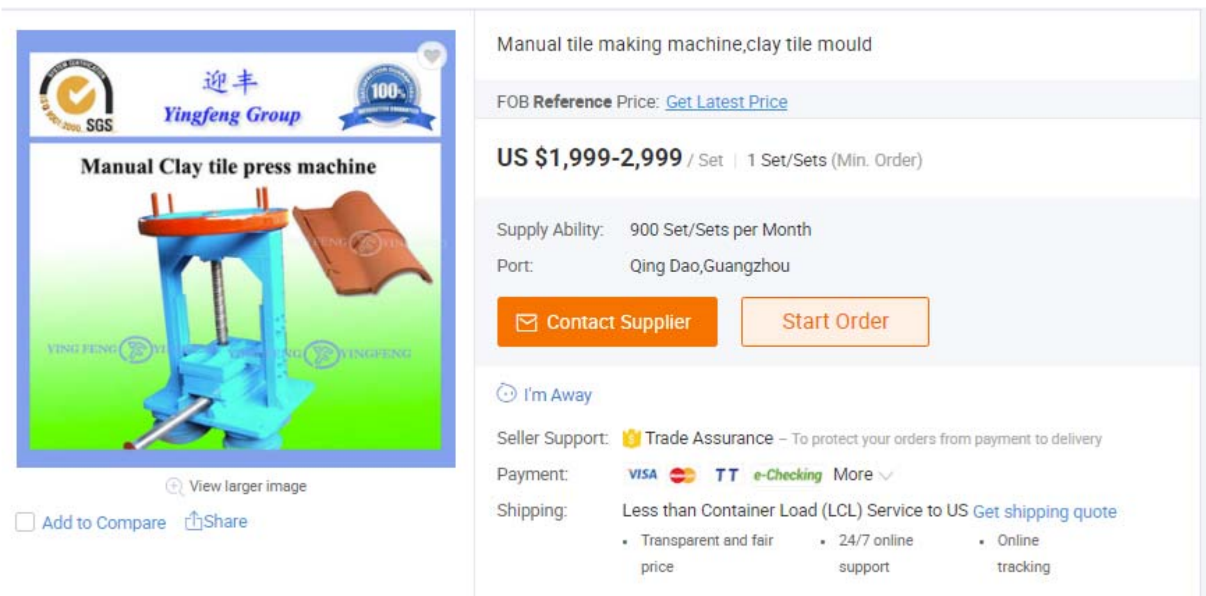
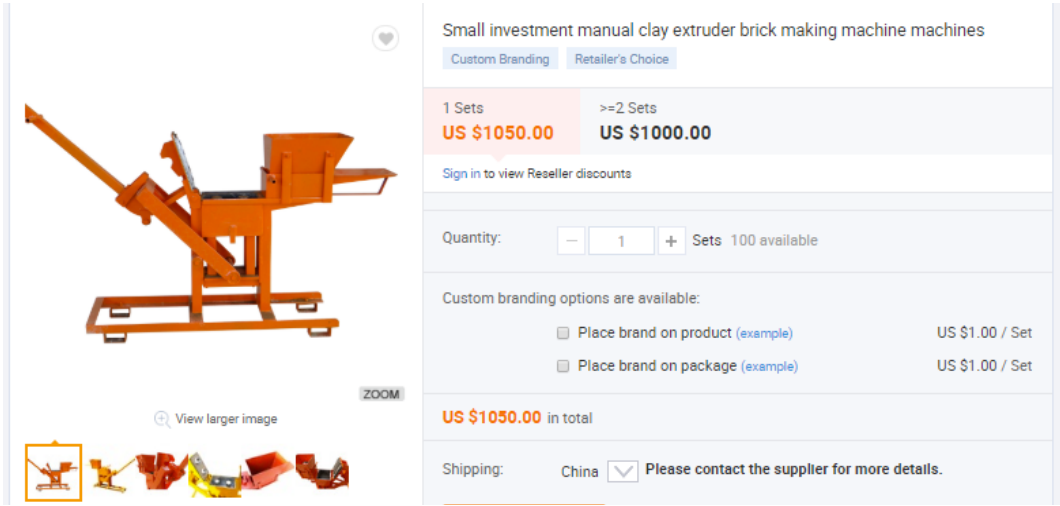


Figure 1: Ying Feng Group’s manual, screw driven clay tile press, YFHT.



Machine Description

Brief introduction.

1. Totally manual, suitable to where there is difficult to use electricity.
2. Manual clay extruder brick making machine uses free soil and water as raw materials, so you need to spend little money and earn your invest back real soon.
3. The mould uses precise wire cutting technology to reduce error and carburizing heat treatment technology to prolong its service life.
4. High pressure, quick brick forming, brick produced are of high strength, smooth surface and even density.
5. Capable of making all kinds of interlocking brick, simply by changing the moulds.

Host machine main technology parameter			
Dimension	600x400x800mm	Weight	130Kg
Shaping cycle	20~35s	Pressure	16Mpa
Host machine power	Hand press	Mixer model	JQ350
Capacity	960Pcs/8 hours	Maximum block size	Standard size
Pieces/Mould	1	Voltage	no need

Figure 2: Ying Feng Group's manual clay brick press, YLF1-40.

Stabilized Soil Block Press Technical Data

Typical Compression force	80-100 kN
Weight	130 Kg
Typical daily production with 4 workers	**400-500 blocks**

Technical Specifications of Stabilized Soil Blocks

Weight	5 Kg
Size	**290mm x 140mm x 115mm**
Number of Blocks per bag of cement	**100-150 blocks**
Recommended wet curing period	7 days
Minimum dry compressive strength	2.5 N/mm^2
Maximum wet compressive strength	1.5 N/mm^2
Maximum water absorption (after 28 days)	15%
Blocks are ready for use after	14 days

Cement to Soil ratio will vary according to soil type and should be determined by testing the soil for shrinkage. This can be done quickly & easily using a special shrinkage box supplied with the Block Press. Please note that heavily clay soils, where shrinkage exceeds 40mm, the soil may require further stabilization with sand.

Shrinkage	Less than 12mm	12 – 23mm	24 – 39mm
Cement to Soil Ratio	1:18	1:16	1:14
Approximate no of blocks	150	120	100

Figure 3: Makiga Engineering stabilized soil clay brick press.

Figure 4: Brick extruder machine fabricated by IPRC -Kigali.

APPENDIX B: Customer Needs Table

Summary:

The customer needs matrix, Table 1, is based on interviews of the defined project customer, Ladrería y Bloquera San Pedro and analysis of the specifications of existing products. The purpose of this table is to understand all the need of the customer and then categorize those needs in groups and by order of importance.

Table 1: List of customer needs for the clay brick press. Primary customer needs are bolded. Level of importance of the need are denoted by the number of * symbols. Latent needs are denoted by a ! symbol.

**	**Machine produces quality Bricks**	**	**Machine is reliable**
*	Bricks last a long time	!	Joints and Junctions withstand static forces
	Bricks have even consistency	**!	Brick forming components do not deform
	Bricks need to withstand local weather conditions		Metal from is resistant to water and weather
*	Bricks are durable and do not break easily		Machine requires little maintenance
	Wires cut cleanly through clay slab at angles	**	Machine can withstand many cycles and has a long lifespan
**	Machine applies a constant force	!	The machine is safe to use
	Clay needs to be extruded from chamber evenly		
		***	**Machine is frugal**
**	**Machine is easy to use**		Materials used are as inexpensive as possible

**	1-2 average people of target community can apply enough force	!	Material needed are accessible to the community/general location
**	Compression Plate should easily slide into Compression Chamber	!	Machine needs to be affordable to target community
*	Machine makes bricks within 5 simple steps		Machine must be human-powered
	Handles need to be ergonomic		
	The correct way to use the machine is the easiest way to use the machine	***	**The machine is an appropriate technology**
!	Use of the machine is relatively intuitive.		Machine can be assembled at or near target community
	Clay can be directly loaded into compression chamber	!	The machine can be understood by the members of the community
	Machine is shippable	*	The machine could potentially be repaired by the members of the community
**	**Many bricks need to be made quickly**		
	Compression chamber slides easily		
	Machine produces two bricks at the same time		

APPENDIX C: Product Design Specifications

Summary:

After understanding the customer needs, various parameters of their methods were tabulated. Once their methods were understood, target ranges for an eventual were ideated and were compared to current methods to clearly define the advantages and disadvantages of creating a fugal clay press. These comparisons are detailed in Table 1.

Table 1: Product Design Specifications. Updated December 5, 20 2017.

Parameters	**Unit**	**Datum**	**Target Range**
Drying Time	Days	6 - 9	2 - 4
Throughput	Bricks/Minute	4	2
Manufacturing Cost	USD	5	500
Maximum Compressive Force of Device on Clay	lbs-f	N/A	4,000
Number of Operators	People	1-2	1-2
Weight of Device	lbs	2	200
Percent Volume Compression	%	0	20-30
Life of Assembly	Months	3	48
Brick Composition	Type	Natural Clay, Dirt, Sand Sawdust	Model: Earthenware Clay, Sand Sawdust
Target Market	Type	N/A	Brick Makers in Third World

			Countries
Minimum Human Force Input for Compression	lbs-f	N/A	75
Power Source	Type	Manual (By Hand/Feet)	Manual (Compound Lever Force Multiplication)
Dimension of Brick	in (l,w,h)	12x5x2.5	12x5x2.5
Reloading/Forming Time	Minutes	0.5	1
Brick Density	lb/ft^3	62	125
Compression/Forming Time	Minutes	N/A	5

APPENDIX D: Subsystem Selection Matrices

Summary:

Updated frequently to adequately compare new potential design changes with past ideas, the current selection matrices feature at least five weighting criteria in addition to the perceived cost and time to manufacture each idea. Each subsystem had at least three competitive options to work with while undergoing the scoring process. In some cases the prevailing solution barely won out over other competitive options.

Table 1: Base Fixture Weighting

Project:	**Frugal Clay Press**	
System:	**Base Fixture**	
Date:	**16-Mar-18**	
	Criterion	FACTOR
1	Safety	25
2	Compactness	3
3	Replaceability/Repairabi	12
4	Simplicity	10
5	Durability	15
Cost		25
Time		10
SUM		**100**
Target		**100**

Table 2: Base Fixture Concept Scoring

CRITERIA	FACTOR	YLF1-40 Lever Arm		Double Sided Base Guards w/ Hard Stop		Double Sides Base w/o Hard Stop		Single Side Base w/ Hard Stop		Single Side Base w/o Hard Stop	
Time – Design	5	3		2		3		3		4	
Time – Build	5	3		2		2		3		3	
Time – Test	4	4		3		3		3		3	
Time weighting	10		7.333333		5.17		5.83		6.50		7.17
Cost – Prototype	$ 200.00	$ 200.00		$ 175.00		$ 160.00		$ 165.00		$ 150.00	
Cost – Production	$ 200.00	$ 200.00		$ 125.00		$ 110.00		$ 115.00		$ 100.00	
Cost weighting	25		25		18.75		16.88		17.50		15.63
Safety	20	3	60	5	100	4	80	3	60	1	20
Compactness	15	3	45	2	30	2	30	4	60	4	60
Replaceability/Repairability	10	3	30	3	30	4	40	3	30	4	40
Simplicity	5	3	15	1	5	3	15	2	10	3	15
Durability	15	3	45	5	75	4	60	5	75	3	45
	TOTAL		195.0		248.4		234.6		243.3		189.5
	RANK										
	% MAX		78.5%		100.0%		94.4%		98.0%		76.3%

Table 3: Lever Arm Weighting

Project:	**Frugal Clay Press**	
System:	**Lever Arm**	
Date:	**16-Mar-18**	
	Criterion	FACTOR
1	Mechanical Advantage	25
2	Compactness	20
3	Replaceability/Repairabi	10
4	Simplicity	5
5	Durability	15
Cost		15
Time		10
SUM		**100**
Target		**100**

Table 4: Lever Arm Concept Scoring

CRITERIA	FACTOR	YLF1-40 Lever Arm		2 Beam Wooden Lever		Solid Metal Simple Lever		Hollow Metal Simple Lever		Hollow Metal Compound Lever		Solid Metal Compound Lever	
Time – Design	5	5		4		5		4		2		3	
Time – Build	5	2		4		4		4		2		2	
Time – Test	5	5		3		4		4		4		4	
Time weighting	10		8		7.33		8.67		8.00		5.33		6.00
Cost – Prototype	$ 200.00	$ 200.00		$ 45.00		$ 120.00		$ 80.00		$ 100.00		$ 150.00	
Cost – Production	$ 200.00	$ 200.00		$ 30.00		$ 100.00		$ 60.00		$ 80.00		$ 130.00	
Cost weighting	15		15		2.81		8.25		5.25		6.75		10.50
Mechanical Advantage	25	3	75	3	75	3	75	3	75	5	125	5	125
Compactness	20	3	60	3	60	3	60	3	60	5	100	5	100
Replaceability/Repairability	10	3	30	5	50	3	30	3	30	2	20	2	20
Simplicity	5	3	15	5	25	4	20	3	15	2	10	2	10
Durability	15	3	45	2	30	5	75	5	75	4	60	4	60
	TOTAL		225.0		252.9		266.1		264.8		325.9		321.5
	RANK												
	% MAX		69.0%		77.6%		81.6%		81.2%		100.0%		98.6%

Table 5: Compression Chamber Weighting

Project:	**Frugal Clay Press**	
System:	**Compression Chamber**	
Date:	**16-Mar-18**	
	Criterion	FACTOR
1	Robustness	30
2	Compactness	5
3	Replaceability/Repairabi	5
4	Simplicity	15
5	Durability	25
Cost		10
Time		10
SUM		**100**
Target		**100**

Table 6: Compression Chamber Concept Scoring

CRITERIA	FACTOR	YLF1-40 Lever Arm		One Brick Chamber		Combined Two Brick Chamber		Partitioned Chamber	
Time – Design	5	3		5		5		3	
Time – Build	5	5		3		3		2	
Time – Test	5	5		4		4		3	
Time weighting	10		8.666666		8.00		8.00		5.33
Cost – Prototype	$ 200.00	$200.00		$ 75.00		$90.00		$ 120.00	
Cost – Production	$ 200.00	$200.00		$ 50.00		$75.00		$ 100.00	
Cost weighting	25		25		7.81		10.31		13.75
Robustness	30	3	90	3	90	4	120	3	90
Compactness	5	3	15	3	15	3	15	3	15
Replaceability/Repairability	5	3	15	3	15	3	15	3	15
Simplicity	5	3	15	3	15	3	15	1	5
Durability	25	3	75	3	75	3	75	3	75
	TOTAL		210.0		227.9		255.4		214.6
	RANK								
	% MAX		82.2%		89.2%		100.0%		84.0%

Table 7: Compression Plate Weighting

Project:	**Frugal Clay Press**	
System:	**Compression Plate**	
Date:	**5-Nov-17**	
	Criterion	FACTOR
1	Replaceability/Repairability	5
2	Simplicity	15
3	Safety	10
4	Guiding Potential	25
5	Durability/Robustness	15
Time		15
Cost		15
SUM		**100**
Target		**100**

Table 8: Compression Plate Concept Scoring

CRITERIA	FACTOR	YLF1 40 - Bottom up Compression lid		Basic Single Metal Plate		Metal Lid w/ Wood Guides		Metal Lid w/ Steel Angle Guides		Wood Lid with metal bottom - two parts		Partitioned Lid	
Time – Design	3	3		5		5		4		4		3	
Time – Build	3	3		5		5		4		4		3	
Time – Test	4	4		4		4		4		4		4	
Time weighting	15		15		21.67		21.67		18.33		18.33		15.00
Cost – Prototype	$ 200.00	$200.00		$ 40.00		$50.00		$65.00		$40.00		$80.00	
Cost – Production	$ 200.00	$200.00		$ 40.00		$45.00		$50.00		$30.00		$65.00	
Cost weighting	15		15		3.00		3.56		4.31		2.63		5.44
Replaceability/Repairability	5	3	15	4	20	4	20	3	15	2	10	1	5
Simplicity	15	3	45	5	75	5	75	4	60	2	30	1	15
Safety	10	3	30	3	30	4	40	4	40	3	30	4	40
Guiding Potential	25	3	75	2	50	3	75	4	100	4	100	4	100
Durability/Robustness	15	3	45	4	60	3	45	4	60	3	45	4	60
	TOTAL		210.0		240.3		259.8		282.4		224.0		229.6
	RANK												
	% MAX		74.4%		85.1%		92.0%		100.0%		79.3%		81.3%

Table 9: Clay Retrieval Weighting

Project:	**Frugal Clay Press**	
System:	**Clay Retrieval**	
Date:	**16-Mar-18**	
	Criterion	FACTOR
1	Ease of Access	20
2	Cycle Time	20
3	Mold Durability	10
4	Easy ejection of clay	15
5	Bricks solid enough to be lifted	15
Time		10
Cost		10
SUM		**100**
Target		**100**

Table 10: Clay Retrieval Concept Scoring

	TARGET or	DESIGN IDEAS									
CRITERIA	FACTOR	YLF1 40 Popup Brick		Base and rail support slider - A frame w/ foot ejction		Base and rail support slider - wood A frame w/ rotating chamber		Base and rail support slider - triangle frame w/ rotating chamber		Total drawer pull out	
Time – Design	2	2		2		2		3		5	
Time – Build	2	2		4		3		4		5	
Time – Test	4	4		4		3		3		4	
Time weighting	10		10		13.33		10.83		14.17		20.00
Cost – Prototype	$ 200.00	$200.00		$ 70.00		$60.00		$40.00		$10.00	
Cost – Production	$ 200.00	$200.00		$ 50.00		$40.00		$20.00		$ -	
Cost weighting	10		10		3.00		2.50		1.50		0.25
Tiles Easily Come Out of Mold	15	3	45	5	75	2	30	2	30	1	15
Mold Durability	10	3	30	4	40	3	30	3	30	2	20
Ease of Access	20	3	60	4	80	4	80	4	80	3	60
Cycle Time	20	3	60	4	80	4	80	4	80	2	40
Bricks solid enough to be lifted	15	3	45	3	45	3	45	3	45	3	45
	TOTAL		240.0		323.7		271.7		269.3		179.8
	RANK										
	% MAX		74.2%		100.0%		83.9%		83.2%		55.5%

APPENDIX E: Calculations

Summary:

Various calculations were needed in order to verify that the prototype design did not fail within the defined factor of safety, met the desired product specifications, and had a significant impact on the target community

Mechanical Leverage Calculations

Due to the complex nature of the compound lever system designed, the device does not output a consistent mechanical advantage for the entirety of the stroke. Instead, the dynamically changing angles of the interacting components cause a variation in the mechanical advantage achieved. Figure 1 shows a graph of the mechanical advantage as a function of the vertical angle of the input lever. To obtain these numbers, the Solidworks model was used, and the compression lid was set to various distances inside the Compression Chamber. The distance was considered to be zero when the bottom of the Compression Plate, P07, was flush with the top of the Compression Chamber subsystem. Once the distance was set, the interaction angles between the vertical axis, the input lever arm, the connecting beam, the output lever arm, and member P04. Using net moment calculations, the force applied to member P04 was for each individual distance. Figure 2 shows example calculations that were used to create Figure 1. However, for convenience, the calculations were then calculated in excel as a function of the various angles observed.

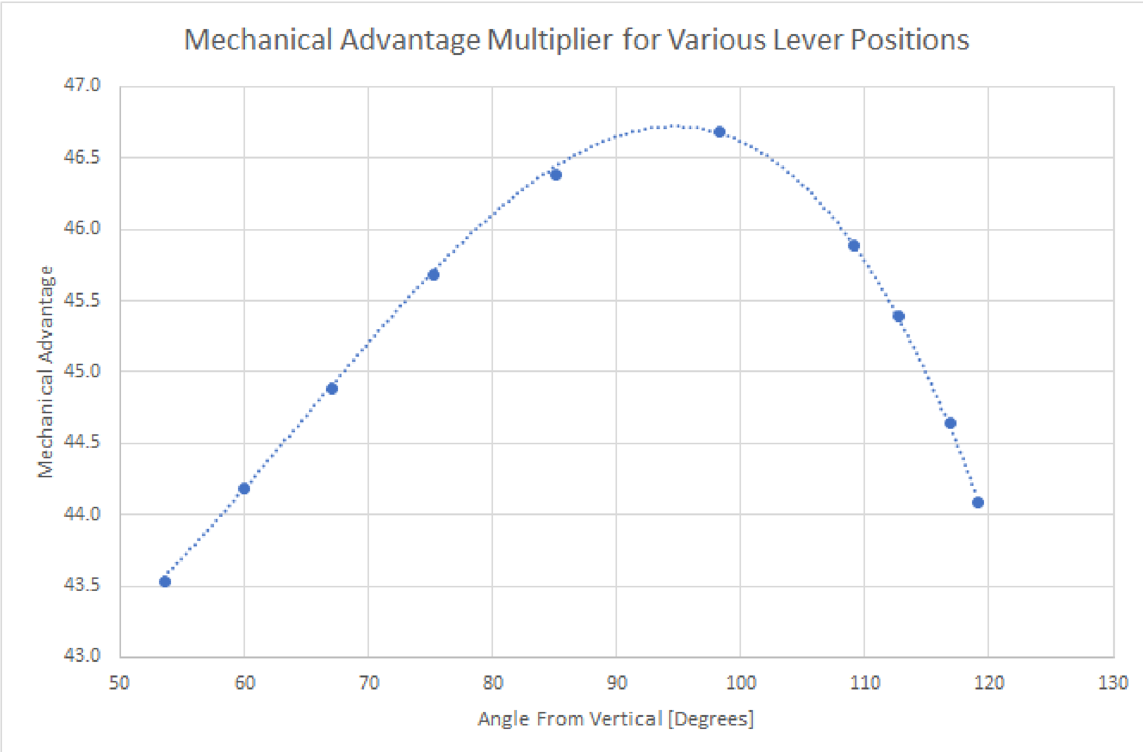


Figure 1: Graph of the mechanical leverage applied versus the angle of the input lever with reference to an upward facing vertical axis

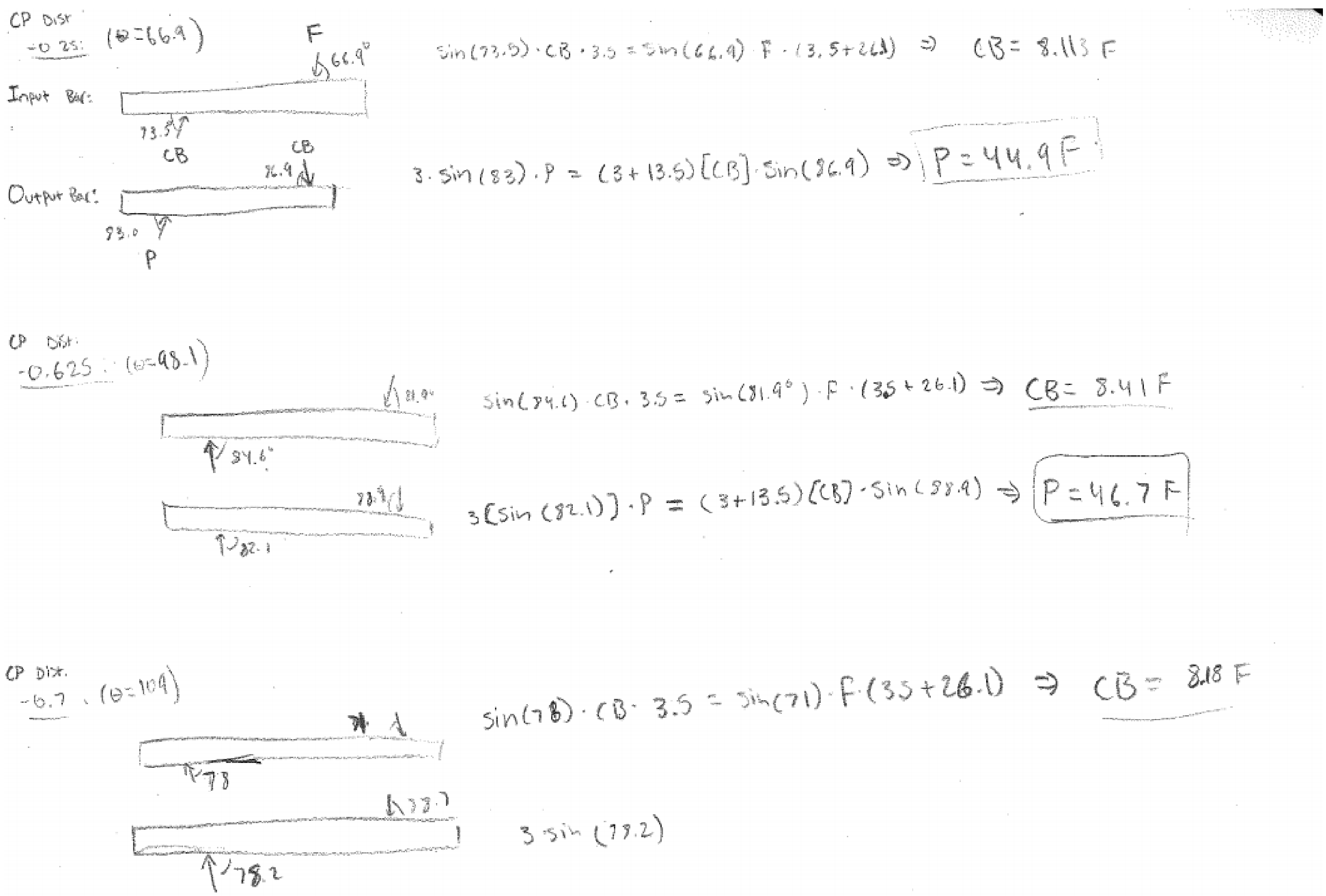


Figure 2: Sample calculations for force output at various Compression Plate locations within the Compression Chamber.

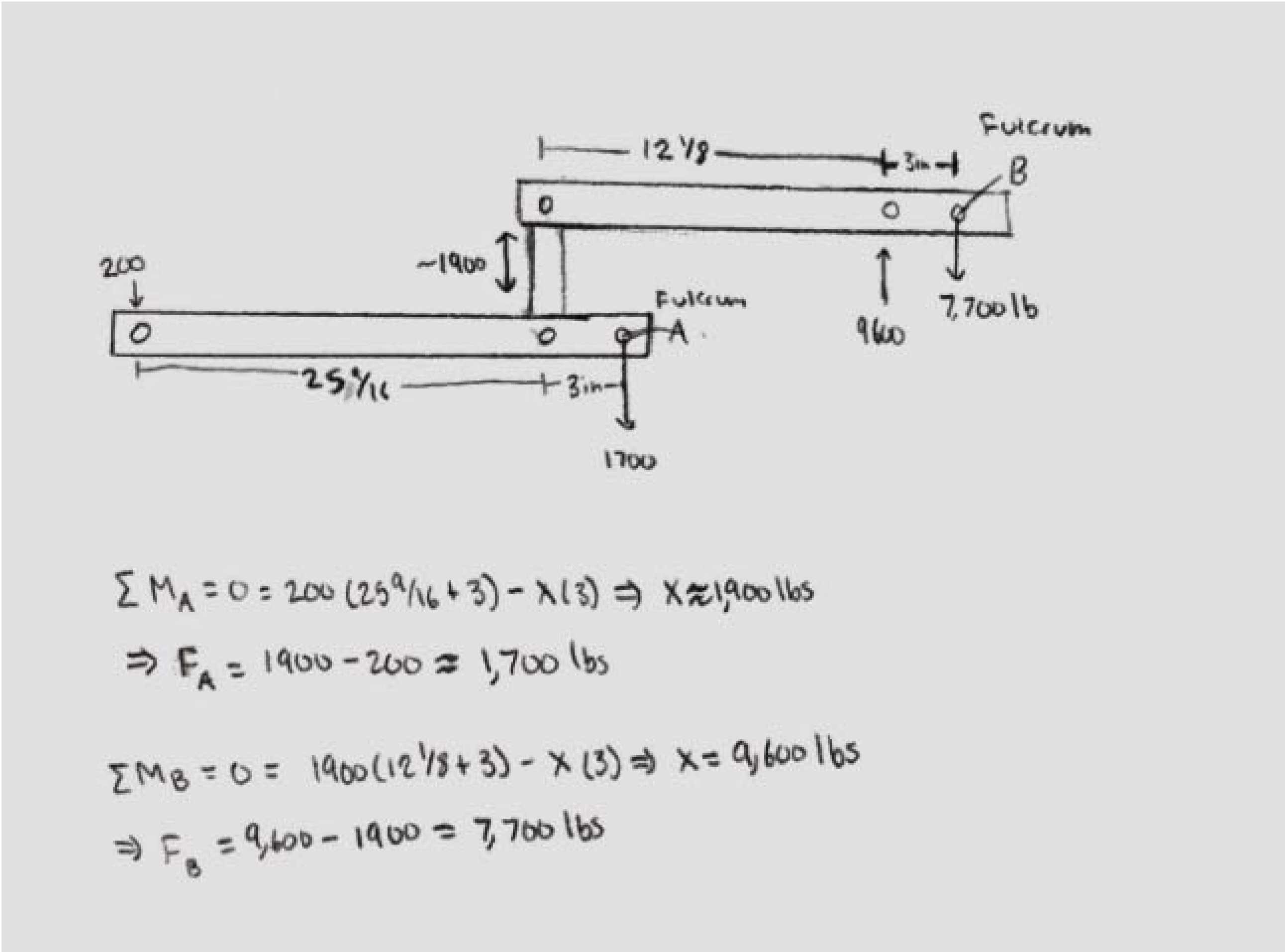


Figure 3: Example of net moment calculations when bars are perfectly horizontal, with resulting internal and external stresses.

Impact Report Calculations

The impact of this press prototype on the target community and customer is predicted in three categories: water usage reduction, drying/baking time, and employment.

<u>Water Usage Reduction</u>

Estimated Moisture Content used: 35%

Nicaraguan Clay brick mass: 4000 g

Nicaraguan Clay brick water used: 1,400 g

Gallons used: 0.369841 gallons

Liters used: 1.4 L

Per 1,000 bricks: 1,400 L or 369.80 gallons

Frugal Clay Press

Estimated Moisture Content used: 15%

Clay brick mass: 4000 g

Clay brick water used: 600 g

Gallons used: 0.158503 gal

Liters used: 0.6 L

Per 1,000 bricks: 600 L or 158.503

Reduction of water usage by:

Table 1: Estimated moisture content calculated for a nicaragua formed brick versus a prototype compressed brick

	Mass of Brick Materials [g]	Estimated Water Weight Percent [%]	Water Usage Per Brick [L]
Nicaraguan Clay	4000	35	1400
Clay for Frugal Clay Press	4000	15	600
		Reduction of Water Usage [%]	57

Drying/Baking Time

As is:

Time needed to dry before machos: 2 days

Time to dry in machos: 4 days

Time to bake: 3 days:

Total time: 9 days per batch

With Press:

Time needed to dry before machos: 1 day

Time to dry in machos: 2 days

Time to bake: 3 days

Total time: 6 days

Reduction of Lead Time per batch:

$$\frac{6-9}{9}x100 = 33.3\%$$

Employment

As is:

Current amount of employees: 20 (ish)

Start time: 5:30 AM

End time: 1:30 PM

Total working hours: 8 hrs

Total person hours/day: 20(8)= 160 hours

With Press:

Same amount of employees: 20

Start time: 5:30 AM

End time: 4:00 PM

Total working hours: 10.5 hrs

Total person hours/day: 20(10.5)= 210 hours

Increase of person hours to productivity

$$\frac{210-160}{160}x100 = 31.25\%$$

Bolt and Screw Calculations

Due to the constraint of shippability this press is designed to become assemblable using common fasteners. Since nearly all the pieces interact with some fastener and/or experience some type of force loading it is crucial that the fasteners that hold together this device are able to withstand the these forces. The results from these calculations were compared to the bolt material properties in Appendix F.

Table 2: Sample shear calculation for the shoulder bolts at each interaction of the Lever Arm subsystem. The shear stress is calculated using force over effective area of shear planes.

	Bolt Diameter (in)	Net Force (lbs)	No. of Shear Planes	Shear Stress (psi)
Bolt 1 (In. Bar/ Connection Beam)	0.625	1900	2	3097
Bolt 2 (In. Bar/ In. fulcrum)	0.5	1700	2	4329
Bolt 3 (Connection Beam/ Out. Bar)	0.625	1900	2	3097
Bolt 4 (Out. Bar/ Comp. Plate)	0.75	9600	2	10865
Bolt 5 (Out. Bar/ Out Fulcrum)	0.625	7700	2	12549

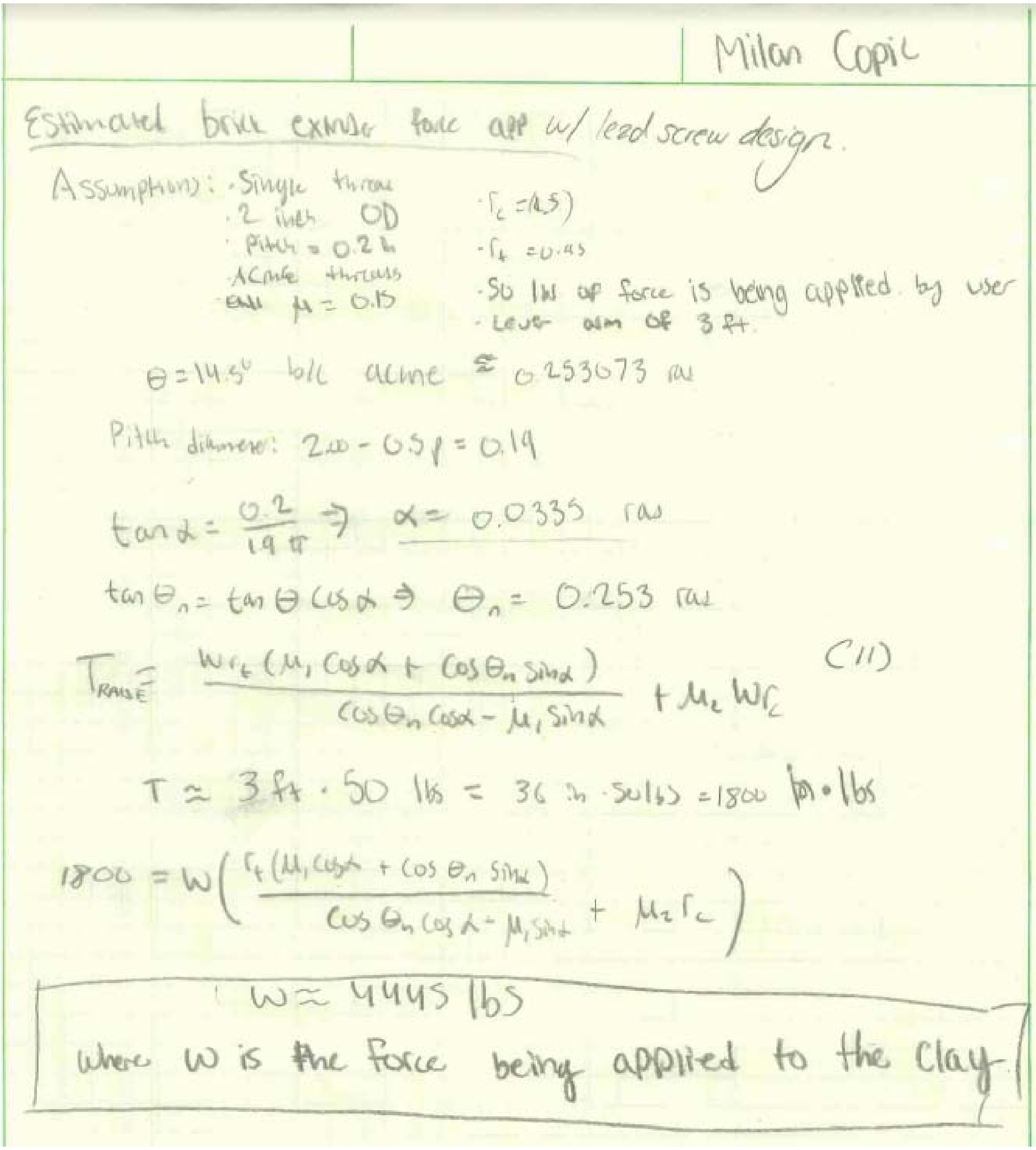
PVC Calculations

The max bending stress and deflection were calculated for the cases of a full and an empty Compression Chamber. These were calculated to see if PVC pipes would not only survive, but also deflect minimally under this loading. It was assumed the retrieval rails were simply supported and the weight of the chamber acted as a point load.

Table 3: Sample bending calculation for PVC

Net Force (lbs)	Outer Diameter (in)	Wall Thickness (in)	Bending Length (in)	Moment (lbs-in)	Bending Stress (psi)	Bending Stress (MPa)	Deflection (in)
80.0	1.050	0.113	18.000	1440	8166	56.30	0.51
60.00	1.050	0.113	18.00	1080.0	6124	42.23	0.38

Miscellaneous


Milan Copic

Estimated brick extruder force app w/ lead screw design.

Assumptions: · Single thread
· 2 inch OD
· Pitch = 0.2 in
· Acme threads
· $\mu = 0.15$
· $r_c = 0.5$
· $r_t = 0.45$
· 50 lbs of force is being applied by user
· Lever arm of 3 ft

$\theta = 14.5°$ b/c acme ≈ 0.253073 rad

Pitch diameter: $2 in - 0.5p = 0.19$

$\tan\alpha = \frac{0.2}{19\pi} \Rightarrow \alpha = 0.0335$ rad

$\tan\theta_n = \tan\theta\cos\alpha \Rightarrow \theta_n = 0.253$ rad

$$T_{RAISE} = \frac{W r_t(\mu_1\cos\alpha + \cos\theta_n\sin\alpha)}{\cos\theta_n\cos\alpha - \mu_1\sin\alpha} + \mu_2 W r_c \quad (11)$$

$T \simeq 3\text{ ft} \cdot 50\text{ lbs} = 36\text{ in} \cdot 50\text{ lbs} = 1800\text{ in} \cdot \text{lbs}$

$$1800 = W\left(\frac{r_t(\mu_1\cos\alpha + \cos\theta_n\sin\alpha)}{\cos\theta_n\cos\alpha - \mu_1\sin\alpha} + \mu_2 r_c\right)$$

$W \simeq 4445$ lbs

where W is the force being applied to the clay.

Figure 4: Lead screw extrusion or compression hand calculations.

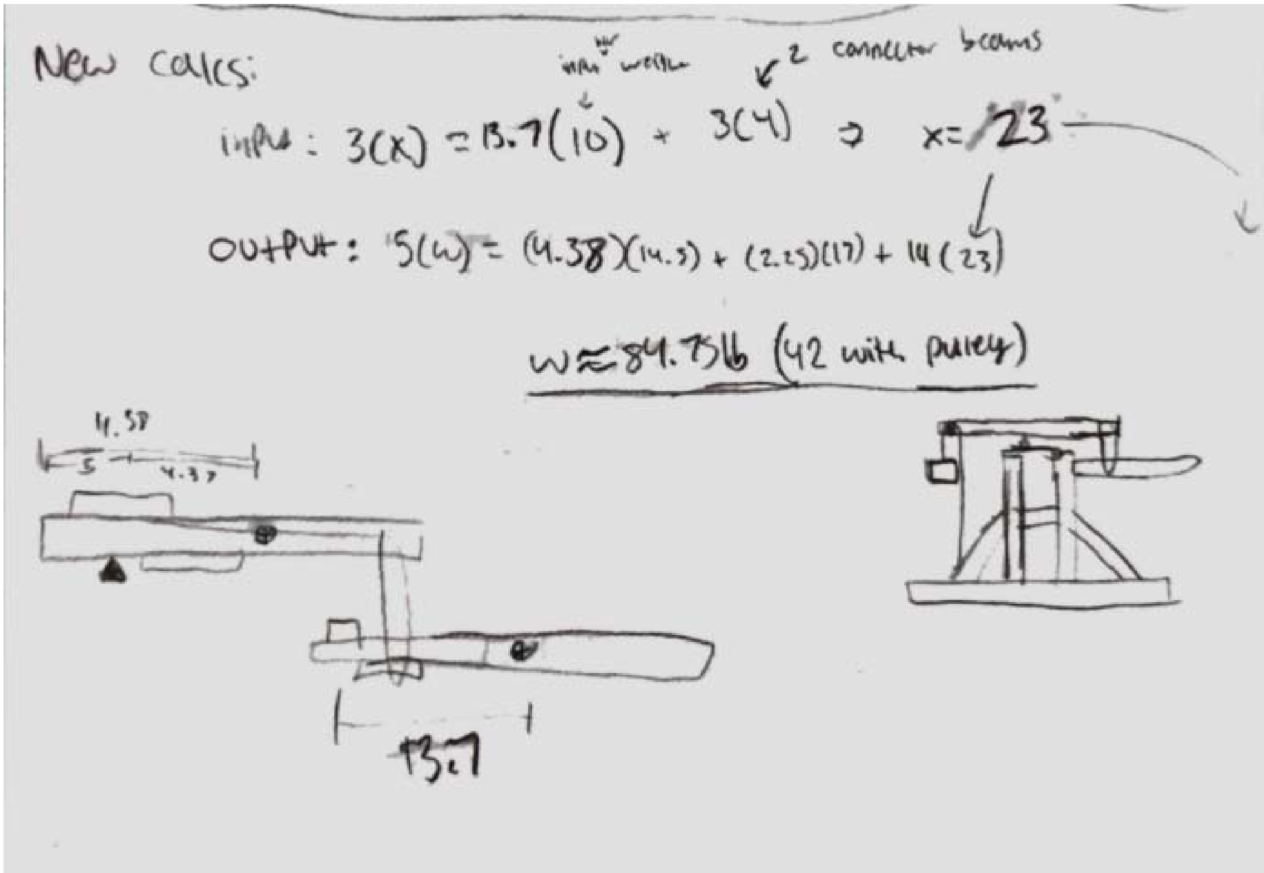


Figure 5: Calculation for the necessary Lever Arm counterweight using weights and centers of gravity obtained via solidworks.

APPENDIX F: Manufacturer Information

Summary:

Understanding the material properties were essential in choosing the appropriate materials and fasteners in constructing the beta prototype. As such, charts and tables related to the material properties for plastic tubing (novel solution) and standard bolt grades are replicated below.

Bolt Material Properties

The table below was referenced often by the team in making prudent decisions in choosing appropriate fasteners for almost all the connections between components. The team generally chose to use fasteners with larger diameters than those with a higher grade in ensuring the fasteners used would survive the shear loads put upon them [18] [19].

SINGLE SHEAR CALCULATIONS, MIN. LBS

NOMINAL BOLT DIAMETER	BODY SHEAR AREA, SQ IN	GR 2	A307A & B	GR 5 / A325	GR 8 / A490
1/4"	0.04908	2,179.2	1,766.9	3,533.8	4,417.2
5/16"	0.07669	3,405.0	2,760.8	5,521.7	6,902.1
3/8"	0.11044	4,903.5	3,975.8	7,951.7	9,939.6
7/16"	0.15033	6,674.7	5,411.9	10,823.8	13,529.7
1/2"	0.19634	8,717.5	7,068.2	14,136.5	17,670.6
9/16"	0.24850	11,033.4	8,946.0	17,892.0	22,365.0
5/8"	0.30679	13,621.5	11,044.4	22,088.9	27,611.1
3/4"	0.44178	19,615.0	15,904.1	31,808.2	39,760.2
7/8"	0.60132	21,647.5	21,647.5	43,295.0	54,118.8
1"	0.78539	28,274.0	28,274.0	56,548.1	70,685.1
1 1/8"	0.99401	35,784.4	35,784.4	62,622.6	89,460.9
1 1/4"	1.22718	44,178.5	44,178.5	77,312.3	110,446.2

DEFINITIONS:

> Ultimate Tensile Strength, UTS - PSI - Lbs/Square Inch
> Ultimate Shear Strength, USS - PSI USS = .6 X UTS
> Body Shear Area, BSA - Square Inches
> Single Shear Strength, SSS - Lbs SSS = USS X BSA

Figure 1: Shear strength chart of commercial bolts of various grades in single shear

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Bolt Grade Markings and Strength Chart

US Bolts

Head Marking	Grade and Material	Nominal Size Range (inches)	Mechanical Properties: Proof Load (psi)	Mechanical Properties: Min. Yield Strength (psi)	Mechanical Properties: Min. Tensile Strength (psi)
No Markings	**Grade 2** Low or medium carbon steel	1/4" thru 3/4"	55,000	57,000	74,000
		Over 3/4" thru 1-1/2"	33,000	36,000	60,000
3 Radial Lines	**Grade 5** Medium carbon steel, quenched and tempered	1/4" thru 1"	85,000	92,000	120,000
		Over 1" thru 1-1/2"	74,000	81,000	105,000
6 Radial Lines	**Grade 8** Medium carbon alloy steel, quenched and tempered	1/4" thru 1-1/2"	120,000	130,000	150,000
A325	**Grade A325** Carbon or Alloy Steel with or without Boron	1/2" thru 1-1/2"	85,000	92,000	120,000
Stainless markings vary. Most stainless is non-magnetic	**18-8 Stainless** Steel alloy with 17-19% Chromium and 8-13% Nickel	All Sizes thru 1"		20,000 Min. 65,000 Typical	65,000 Min. 100,000 – 150,000 Typical

Figure 2: Bolt grade specifications from BoltDepot.com

PVC Material Properties

Below is a select list of the bending strength ranges of some of the stronger common plastics. While plastics are generally considered weak in bending, the bending strength of Rigid PVC seemed a good fit for the team's need of creating a pair of cheap and easy to fabricate retrieval rails [20].

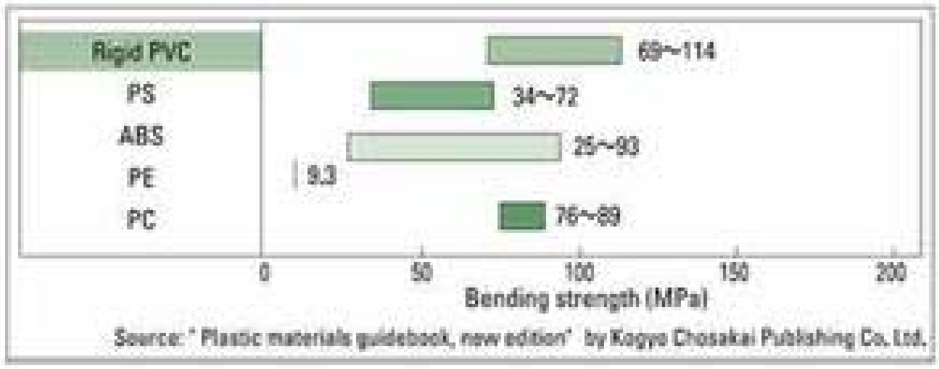

Figure 3: Bending strength chart for various types of plastic tubing.

APPENDIX G: Important Patent Copies

Summary:

While the patentability of the Frugal Clay Press was not a real concern to the team as this was never a for-profit project, exploring the USPTO and IPO archives for pre-existing patents was still insightful in that it gave the team an idea of which systems were universal and what type of interactions and components could be considered unique and patented. Full length copies of the patents discovered in their native language are reproduced in the subsections below.

Patent FR2545411A1

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(71) Demandeur(s) : *DE SILVESTRI François.* — FR.

(72) Inventeur(s) : François De Silvestri.

(73) Titulaire(s) :

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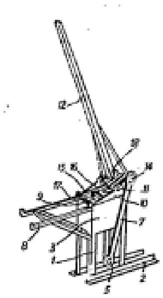
(54) **Presse manuelle pour le moulage de briques en terre.**

(57) Presse manuelle pour le moulage de briques en terre. Un moule 3 à axe vertical a un plateau inférieur mobile réuni par des bielles extérieures 7 à un levier 12 qui est pivotant autour d'un axe 11 supporté d'un cadre 15 pouvant coulisser sur des glissières 8 afin de dégager totalement l'ouverture supérieure du moule 3, ce cadre 15 portant par l'intermédiaire de ressorts de suspension 17 un plateau supérieur 9 qui est poussé à l'intérieur du moule 3 en fin de course de compression du levier 12 grâce à une surface de poussée 18 prévue sur ce dernier à l'opposé de l'axe 14 d'articulation des bielles 7.



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L'invention a pour objet une presse à fonctionnement manuel qui sert à fabriquer à partir de terre par compression dans un moule des briques utilisables pour la construction de maisons.

On doit comprendre le mot terre avec le sens le plus général ; il s'agit en fait d'argile ou de composition à base d'argile, ou de mélanges convenables de terres diverses qui peuvent contenir aussi des grains de sable et auxquels on peut encore ajouter du ciment en proportion faible en général. Il est entendu que l'invention convient pour le moulage par compression de toutes matières moulables pouvant constituer des briques.

Il existe déjà des presses à main que l'on emploie pour fabriquer des briques en terre, principalement dans les pays en voie de développement où le climat est relativement sec, comme de nombreux pays d'Afrique.

La presse de l'invention se distingue des presses connues parce qu'elle permet de démouler la brique réalisée par la même ouverture que celle qui sert à remplir le moule. En outre, la presse de l'invention permet aussi, selon un perfectionnement supplémentaire, de comprimer la terre dans une première direction puis de la comprimer ensuite dans une seconde direction opposée à la première, ce qui confère aux briques une grande compacité et une meilleure résistance à l'écrasement.

Une presse manuelle pour le moulage de briques à partir de terre comprend un bâti, un moule fixé à ce bâti avec son axe placé verticalement et ayant une ouverture supérieure et une ouverture inférieure ; un plateau inférieur servant de fond à ce moule, un plateau supérieur, un levier articulé par rapport au moule et relié à un plateau pour le déplacer à l'intérieur du moule. Selon l'invention, le plateau supérieur est déplaçable en sens transversal par rapport à l'ouverture supérieure du moule qu'il peut dégager totalement ou obturer totalement ; le levier est articulé autour d'un axe déplaçable avec le plateau supérieur et il est relié au plateau inférieur par deux bielles opposées extérieures au moule, ce plateau inférieur étant monté à l'intérieur du moule pour pouvoir y coulisser parallèlement à lui-même sous l'action des bielles.

De préférence, le plateau supérieur est déplaçable le long de glissières soutenues par le bâti au niveau de l'ouverture supérieure du moule.

Selon un premier aspect de l'invention, le levier est articulé directement sur la face supérieure du plateau supérieur.

Selon un second aspect de l'invention, comportant un perfectionnement supplémentaire, un cadre est monté déplaçable le long des glissières, le levier est articulé autour d'un axe supporté par ce cadre, le plateau supérieur est suspendu au cadre par un organe élastique et il est dimensionné pour pouvoir pénétrer dans le moule et y coulisser parallèlement à lui-même; en outre, deux surfaces de poussée correspondantes sont prévues sur le levier et sur la face supérieure du plateau supérieur. Ces surfaces de poussée viennent en contact quand le levier est sur le point d'arriver à la fin de sa course dans le sens de la compression.

Dans l'un et l'autre cas, l'extrémité inférieure de chaque bielle est attelée à un axe transversal guidé en coulissement en sens vertical par le bâti en dessous du moule et le plateau inférieur est relié à cet axe transversal. Grâce à cet axe transversal guidé, le levier peut servir à déplacer le plateau inférieur dans l'une et l'autre position du plateau supérieur.

On donnera maintenant, sans intention limitative et sans exclure aucune variante, une description de deux exemples de réalisation. On se reportera aux dessins annexés dans lesquels :

- la figure 1 est une vue de côté d'une presse à main conforme au premier aspect de l'invention, le plateau supérieur étant à sa position de dégagement et le moule étant ouvert par son ouverture supérieure ,

- la figure 2 est une vue analogue à la figure 1 montrant le plateau supérieur à sa position d'obturation du moule ,

- la figure 3 montre la même presse à la fin de l'opération de compression ,

- la figure 4 montre la même presse à la fin de l'opération de démoulage par l'ouverture supérieure du moule ,

- la figure 5 est une vue en perspective de dessus d'une presse à main conforme au second aspect de l'invention, le plateau supérieur étant à sa position de dégagement et le moule étant ouvert par son ouverture supérieure ,

- la figure 6 est une vue en perspective de dessus de la presse de la figure 5, du côté opposé à celui de cette figure, montrant le plateau supérieur à sa position de compression peu avant son fonctionnement sous l'action du levier.

La presse représentée sur les figures 1 à 4 est réalisée selon un premier aspect de l'invention. Elle comprend un bâti 1 avec une base 2 suffisante pour l'ancrer au sol ou pour lui donner par lestage une stabilité convenable. Ce bâti 1 porte un moule 3 à axe vertical, à ouverture supérieure et à ouverture inférieure. Dans ce moule 3 est monté un plateau inférieur horizontal 4 déplaçable parallèlement à lui-même en sens vertical à l'intérieur du moule dont il constitue le fond. A cet effet, il est réuni par un organe de liaison approprié non représenté à un axe transversal 5. Ce dernier est tenu et guidé en coulissement dans deux glissières verticales 6 qui sont pendantes en dessous du moule 3 à l'intérieur du bâti 1.

Sur deux côtés opposés du bâti 1 et du moule 3 deux bielles 7 sont articulées par une première extrémité respectivement sur les extrémités opposées de l'axe transversal 5.

Deux glissières horizontales 8 sont soutenues par le bâti 1 sensiblement au niveau du sommet du moule 3, en dehors de ce dernier, entre les plans parallèles dans lesquels se trouvent les bielles 7. Sur ces glissières 8 est monté coulissant un plateau supérieur 9 qui peut occuper une position de dégagement comme le montre la figure 1 dans laquelle il dégage totalement l'ouverture supérieure du moule 3. En coulissant, ce plateau supérieur 9 peut venir occuper une position de fermeture, comme le montre la figure 2, dans laquelle il obture l'ouverture supérieure du moule 3.

La face supérieure du plateau supérieur 9 porte une chape 10 qui soutient un axe 11 autour duquel est articulée une extrémité d'un levier 12. Ce dernier a une courte extension 13 à 90° qui est traversée par un axe 14 sur lequel sont articulées les bielles 7 par leur seconde extrémité.

La presse étant à la position visible sur la figure 1, avec le levier 12 dressé de sorte que le plateau inférieur 4 occupe une position basse, l'ouverture supérieure étant dégagée par le plateau supérieur 9 mis à sa position de dégagement, on peut remplir le moule 3, ensuite on le ferme en faisant coulisser le plateau supérieur 9 (figure 2). Le levier 12 est alors abaissé jusqu'à une position horizontale (figure 3). Pendant ce mouvement les bielles 7 font monter le plateau inférieur 4 qui comprime la matière contre le plateau supérieur 9. L'axe transversal 5 coulisse dans les glissières verticales 6 mais il n'a qu'une faible course qui correspond juste à la compression de la matière qui remplit le moule. Quand cette opération de compression est terminée, on fait coulisser le plateau supérieur 9 à sa position de dégagement, ce qui ouvre le moule 3. A ce moment, on peut abaisser encore davantage le levier 12 (figure 4); ceci fait coulisser l'axe transversal 5 dans les glissières verticales 6 et monter le plateau inférieur 4 qui pousse par l'ouverture supérieure la brique moulée B. Le démoulage se fait donc par la même ouverture que celle du remplissage.

Selon le second aspect de l'invention illustré par les figures 5 et 6, la presse a les mêmes caractéristiques générales que l'on vient de décrire en référence aux figures 1 à 4. Pour cette raison, on a utilisé les mêmes références pour désigner les pièces qui ont les mêmes fonctions. L'exemple des figures 5 et 6 comprend un perfectionnement supplémentaire qui est le suivant.

La chape 10 qui porte l'axe 11 du levier 12 est supportée par un cadre 15 et non directement par le plateau supérieur 9. Ce dernier est suspendu à l'intérieur du cadre 15 à l'aide d'un organe élastique. Par exemple, symétriquement à l'axe 11, le cadre 15 a deux traverses 16 qui servent chacune à fixer à l'aide d'une vis de réglage une extrémité d'un ressort de traction 17 à l'extrémité opposée duquel est suspendu le plateau supérieur 9. Celui-ci a des dimensions qui lui permettent de s'engager à l'intérieur du moule 3 en coulissant parallèlement à lui-même, contre la force de rappel des ressorts 17, quand le cadre 15 est mis à la position d'obturation au-dessus du moule 3. En fait l'obturation est réalisée par le plateau supérieur 9 lui-même.

A sa face inférieure tournée vers le plateau supérieur 9 vers la fin de l'opération de compression, le levier 12 est pourvu d'une surface de poussée 18 à laquelle correspond sur la face supérieure du plateau supérieur 9 une surface de poussée analogue (non visible sur les figures). Cette face du levier 12 est à l'opposé de celle où se trouve l'extension 13.

Le fonctionnement de la presse ainsi perfectionnée est identique à ce qui a été expliqué plus haut avec la différence que lorsque le levier 12 se rapproche de sa position horizontale et que les bielles 7 ont pratiquement terminé la phase de compression par le soulèvement du plateau inférieur 4, la surface de poussée 18 du levier 12 rencontre la surface de poussée correspondante du plateau supérieur 9. Ce dernier est donc forcé à l'intérieur du moule 3 pendant que les ressorts 17 s'allongent. Le plateau supérieur 9 n'a pas besoin d'une course importante. Il comprime par le haut la matière qui a déjà été comprimée par le bas avec une course plus longue.

Sur une presse conforme au second aspect de l'invention, on a évalué d'après les forces mises en oeuvre et les bras de levier que le plateau inférieur 4 réalise une compression avec une poussée vers le haut de 7 tonnes en direction du plateau supérieur qui obture alors le moule 3 et que le plateau supérieur 9 réalise ensuite une compression complémentaire avec une poussée vers le bas de 14 tonnes en direction du plateau inférieur qui est alors retenu en position pratiquement immobile par les bielles 7, le levier 12 ne se déplaçant que très peu par rapport à l'horizontale.

Les briques réalisées ont donc une excellente compacité.

Le démoulage s'effectue ensuite comme expliqué plus haut, en commençant par le dégagement de l'ouverture supérieure du moule, ce qui s'obtient par le coulissement du cadre 15 (et du plateau supérieur 9 qui y est suspendu) le long des glissières horizontales 8 sur lesquelles repose ce cadre 15.

REVENDICATIONS

1. Presse manuelle pour le moulage de briques à partir de terre comprenant un bâti (1), un moule (3) supporté par ce bâti avec une ouverture supérieure et une ouverture inférieure, un plateau inférieur (4) servant de fond au moule, un plateau supérieur (9), un levier (12) articulé par rapport au moule autour d'un axe (11) et relié à un des plateaux pour le déplacer à l'intérieur du moule, caractérisée en ce que le plateau supérieur (9) est déplaçable en sens transversal par rapport à l'ouverture supérieure du moule entre une position de dégagement et une position d'obturation de cette ouverture, l'axe (11) d'articulation du levier (12) est déplaçable avec le plateau supérieur (9) et ce levier (12) est relié au plateau inférieur (4) par deux bielles (7) extérieures au moule (3), ce plateau inférieur (4) étant monté coulissant parallèlement à lui-même à l'intérieur du moule.

2. Presse selon la revendication 1 caractérisée en ce que le plateau supérieur (9) est monté coulissant le long de glissières (8) supportées par le bâti (1) au niveau de l'ouverture supérieure du moule (3).

3. Presse selon la revendication 1 caractérisée en ce que l'axe (11) du levier (12) est supporté par une chape (10) fixée au plateau supérieur (9).

4. Presse selon la revendication 1 caractérisée en ce que le plateau inférieur (4) est réuni à un axe transversal (5) monté coulissant dans des glissières verticales (6) et les bielles (7) sont articulées sur les deux extrémités opposées de cet axe transversal (5) sur deux côtés opposés du moule (3).

5. Presse selon la revendication 1 caractérisée en ce que le levier (12) a une courte extension (13) à 90° qui porte un axe (14) autour duquel sont articulées respectivement les bielles (7).

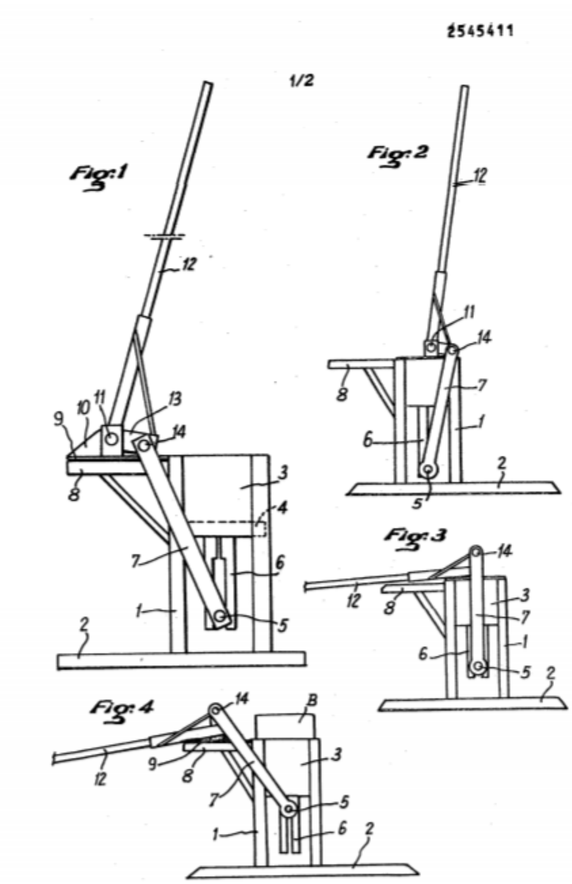
6. Presse selon la revendication 1 caractérisée en ce que l'axe (11) du levier (12) est supporté par un

cadre (15) déplaçable en sens transversal le long de glissières (8) par rapport à l'ouverture supérieure du moule, le plateau supérieur (9) est dimensionné pour pénétrer dans l'ouverture supérieure du moule (3) et il est suspendu à ce cadre (15) à l'aide d'un organe élastique, le levier (12) possède sur sa face tournée en fin de course de compression vers ce plateau supérieur (9) une surface de poussée (18) à laquelle correspond une surface de poussée analogue sur ledit plateau supérieur (9), de sorte que le levier (12) est apte dans la dernière partie de sa course de compression à faire coulisser ce plateau supérieur (9) dans le moule (3) contre l'action de rappel de l'organe élastique.

7. Presse selon la revendication 6 caractérisée en ce que le cadre (15) comprend deux traverses (16) disposées de part et d'autre de la position de l'axe (11) du levier (12), un ressort de traction (17) est accroché à chacune de ces traverses (16) et le plateau supérieur (9) est suspendu à ces ressorts (17).

8. Presse selon la revendication 7 caractérisée en ce que chaque ressort (17) est accroché à sa traverse (16) par l'intermédiaire d'une vis de réglage.

9. Presse selon la revendication 6 caractérisée en ce que le levier (12) a une courte extension (13) à 90° qui porte un axe (14) autour duquel sont articulées respectivement les bielles (7) et la surface de poussée (18) est située à l'opposé sur le levier (12) de cette extension (13).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1/2
Fig:1
Fig:2
Fig:3
Fig:4
1 2 3 4 5 6 7 8 9 10 11 12 13 14
B

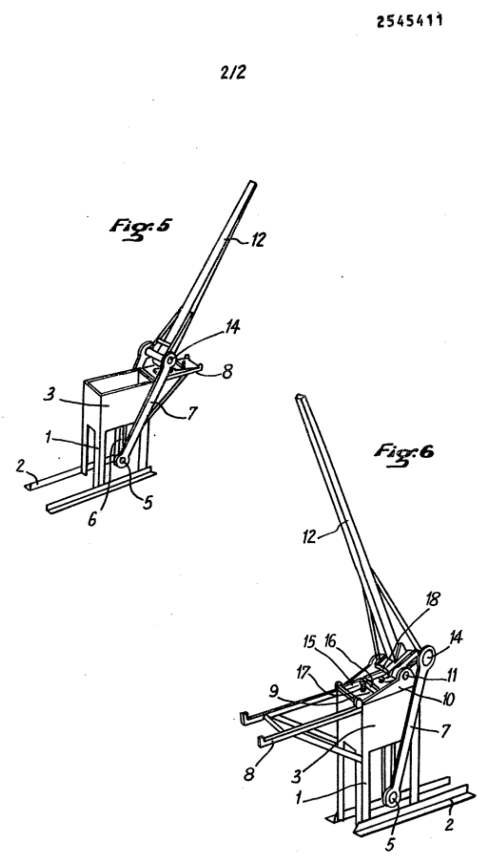
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Fig:5
Fig:6
1 2 3 5 6 7 8 9 10 11 12 14 15 16 17 18

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DEMANDE DE BREVET D'INVENTION

(21) **N° 82 00408**

(54) Presse à démultiplication à came.

(51) Classification internationale (Int. CL [3]). B 30 B 1/26; B 28 B 3/02, 7/10, 7/22; B 30 B 11/10.

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D Vente des fascicules à l'IMPRIMERIE NATIONALE, 27, rue de la Convention — 75732 PARIS *CEDEX 15*

La présente invention a pour objet une presse, manuelle ou mécanique, dont la démultiplication contrôlée est réalisée au moyen d'une came. L'invention s'applique notamment, mais non exclusivement, au compactage des briques en terre crue, utilisé depuis fort longtemps dans certaines régions pour la construction de bâtiments. La terre peut comporter un pourcentage plus ou moins important d'argile. On peut aussi, mais ce n'est pas indispensable, y ajouter un stabilisant, par exemple du ciment.

L'invention s'applique avantageusement aux presses de petites capacités, notamment les presses manuelles, pour chantier, utilisables in situ, mais elle s'applique également aux presses mécaniques, utilisables dans une unité de production, comme cela ressortira de la description ci-après.

Les presses manuelles existantes fonctionnent avec un système de démultiplication variable non contrôlé, qui nécessite un effort final important, et un retour du bras de levier à sa position initiale qui représente un temps mort. Le système de démoulage lui aussi a besoin d'une opération de retour qui ne peut se réaliser que lorsque la brique est dégagée.

La présente invention qui a pour objet une presse comportant une table de pression fixe et un piston de pressage mobile et un système rotatif d'entraînement avec un arbre commandé en rotation par un organe moteur, est remarquable notamment en ce que l'arbre porte une came coopérant avec un palpeur solidaire du piston de pressage, le profil de la came comportant un premier trajet du genre hélice ou spirale produisant un accroissement sensible du rayon sur un tour, les deux extrémités de ce premier trajet étant reliées par un second trajet s'étendant sensiblement sur une partie d'un rayon, le palpeur étant sollicité élastiquement vers la came.

Avantageusement, la presse comporte un moule ayant au moins deux empreintes, le moule étant mobile de façon qu'une empreinte puisse venir sur la table de pression en dessous du piston de pressage mobile, tandis qu'une autre empreinte vient se placer en dehors de la table, en dessous d'un piston de démoulage, monté pour effectuer un déplacement parallèle au piston de pressage, et entraîné par ledit piston de pressage simultanément dans un mouvement dans le même sens.

Cette presse permet d'éviter tous les temps morts, à la compression comme au démoulage, ceci grâce à son système rotatif de démultiplication contrôlée à came. Le retour du piston de presse et du piston de démoulage se fait instantanément et simultanément, une fois le travail de compactage et d'éjection accomplis. La table de réception, située sous le poste de démoulage, évacue la brique dessous le moule en basculant sous le poids de celle-ci. Les moules peuvent effectuer une rotation sitôt les pistons remontés, pour passer à l'opération suivante.

Le système rotatif de démultiplication à came offre l'avantage de pouvoir être calculé en fonction de la réaction à la compression du matériau à compacter, en vue d'obtenir un couple d'entraînement régulier. Une démultiplication contrôlée, comme celle-ci, permet d'éviter un effort final important en répartissant le travail sur tout le développement de l'opération, donc, soit de moins fatiguer l'opérateur, soit de pouvoir y associer un moteur de faible puissance par rapport à la pression obtenue.

D'autres caractéristiques de l'invention apparaîtront au cours de la description qui va suivre, donnée à titre d'exemple non limitatif en regard des dessins ci-joints, et qui fera bien comprendre comment l'invention peut être réalisée.

Les dessins montrent :

figure 1, une vue en perspective simplifiée d'une presse selon l'invention, et

figure 2, une vue en plan d'un profil de came.

La presse de la figure 1 comporte un socle 1, deux montants verticaux 2, 2' en haut desquels sont fixés des paliers 3, 3' portant l'arbre 4 sur lequel sont calés une came 5 et un croisillon d'entraînement 6. Contre la came 5 est appliqué un galet palpeur 8 monté en rotation à l'extrémité supérieure d'une barre 9, dont l'extrémité inférieure est fixée à un piston de pressage 10. Un guidage approprié, non représenté pour clarifier la figure, est prévu pour la barre 9. Cette barre 9 est rappelée vers le haut par un ressort 11, fixé par une console 12 à la barre 9 et par une console 13 au montant 2'. Le ressort maintient le galet 8 contre la came 5 et rappelle la barre, avec le piston de pressage, quand l'opération de compactage est terminée. Un profil de came 5 est représenté en plan sur la figure 2. Il comprend un premier trajet 15 s'étendant du point A au point B, correspondant à la descente du piston et au compactage. Un des buts recherché est d'avoir un couple d'entraînement régulier pour une augmentation rapide de l'effort de compression. Dans ce but, sur le premier trajet du profil le rayon de la came croît d'abord rapidement sur le début de ce premier trajet, puis croît moins rapidement sur la fin du premier trajet de façon à obtenir un déplacement du palpeur plus faible à la fin du trajet pour une même rotation angulaire de l'arbre d'entraînement, pour exercer une pression plus forte.

A titre d'exemple avec un rayon OA de 8 cm et un rayon OB de 18 cm, on obtient un déplacement de 10 cm, ce qui permet d'avoir une pression de 30 tonnes pour un couple résistant de 100 kg.m ce qui est relativement facile à exercer avec des bras de levier d'une longueur d'environ 1,5 m. Le trajet de retour 16 emprunte une partie d'un rayon OB de la came qui peut présenter au voisinage du point A une concavité assurant une position de repos, et une mise en pression rapide au début du mouvement de rotation à partir du point A.

Une table de compression fixe 18 est placée sous le piston 10. Un moule 19 comportant par exemple quatre alvéoles ou empreintes est monté à rotation autour du montant 2', pour tourner dans le sens de la flèche F_1 sur la table de compression 18. Après chaque compactage sous le piston 10, on fait tourner le moule au moyen des poignées 20, sous l'emplacement occupé après rotation d'un quart de tour dans le sens de la flèche F_1, par l'empreinte qui a été compactée, la table de compression est échancrée, et il y a au même niveau une table de réception 22 supportée par deux pieds télescopiques 23, 24, légèrement inclinés vers l'extérieur (côté opposé à la manivelle) maintenus allongés par des ressorts. On peut prévoir un ressort de rappel 25 joignant les extrémités opposées des deux pieds. La combinaison des trois ressorts avec l'inclinaison des pieds font que la table bascule sous le poids de la brique, jusqu'à se dégager dessous le moule, et revient à sa place initiale dès que la brique est enlevée. Pour accélérer et assurer dans tous les cas le dégagement de la brique compactée, il est prévu un piston de démoulage 27 dont l'entraînement peut être assuré par un levier 28, articulé en un point fixe, sur la barre 9 et sur la tige d'entraînement du piston 27.

Le fonctionnement de la presse apparait clairement de la description précédente. De la terre, ou un autre matériau équivalent est introduit dans une empreinte du moule dégagée (l'empreinte 29 sur la figure 1) pendant une opération de pressage. Le moule 19 est tourné d'un quart de tour, l'empreinte 29 se place sous le piston 10. On fait effectuer une rotation à l'arbre 4 et à la came 5, dans le sens de la flèche F_2 ce qui comprime la terre sous le piston 10, pendant que l'on remplit de terre l'empreinte suivante. Puis on tourne à nouveau le moule d'un quart de tour et l'on fait à nouveau tourner la came d'un tour, ce qui comprime une deuxième brique pendant que la première est éjectée, et pendant que l'on remplit de terre l'empreinte suivante, et ainsi de suite.

Dans ces conditions, cette presse permet à deux opérateurs peu expérimentés d'obtenir un débit d'environ cent briquesà l'heure, et plus avec un troisième. A titre indicatif le rendement en utilisation manuelle peut être le suivant :

- Compactage et démoulage simultanés : 5 à 10 secondes suivant opérateur
- Temps de maintien en pression (facultatif) : 2 secondes
- Contrôle remplissage et rotation table : 5 secondes
- Temps total pour la fabrication d'une brique :
  . mini : 10 secondes
  . maxi : 17 secondes

La pression de compactage est déterminée par la quantité de terre introduite dans le moule. Ceci explique l'importance de l'opération de contrôle. Un surplus de terre peut bloquer le cycle de compactage. Un manque de terre diminue de fait la pression exercée. La démultiplication croissante permet l'avance rapide du piston au départ du mouvement, et évite tout risque de détérioration du compactage en cas de mauvais positionnement des moules.

Le retour automatique des pistons et de la table de réception de la brique démoulée, par ressort de rappel, évite tout temps mort et manipulations inutiles.

La rapidité de l'enchaînement n'est ainsi limitée que par les facteurs humains.

La presse présentée est adaptée au compactage de la terre crue, sèche ou plastique pour la production de briques de construction à bonne résistance mécanique.

Le système rotatif à démultiplication contrôlée à came, peut être utilisé pour tout dispositif de pressage manuel ou mécanique ayant des exigences de coût et de rapidité.

La presse de l'invention est de technicité simple, de conception rustique et de réalisation robuste. Elle offre une grande puissance de compactage et un rendement élevé pour un investissement faible. On conçoit aisément que l'entraînement peut être mécanique : dans ce cas les opérateurs assurent le remplissage des moules et l'évacuation des briques. Une trémie peut être prévue pour faciliter le remplissage, et l'évacuation peut être automatisée simplement. La presse peut ainsi être utilisée dans une unité fixe de grande capacité pour une production locale, ou encore dans des unités mobiles associées à un malaxeur, actionné par un moteur du véhicule porteur.

Il va de soi que le mode de réalisation décrit n'est qu'un exemple et qu'il serait possible de le modifier notamment par substitution d'équivalents techniques, sans sortir pour cela du cadre de l'invention.

REVENDICATIONS :

1.- Presse comportant une table de pression fixe (18) et un piston de pressage mobile (10) et un système rotatif d'entraînement avec un arbre (4) commandé en rotation par un organe moteur (6), caractérisée en ce que l'arbre (4) porte une came (5) coopérant avec un palpeur (8) solidaire du piston de pressage, le profil de la came comportant un premier trajet (15) du genre hélice ou spirale produisant un accroissement sensible du rayon sur un tour, les deux extrémités de ce premier trajet étant reliées par un second trajet (16) s'étendant sensiblement sur une partie d'un rayon, le palpeur étant sollicité élastiquement vers la came.

2.- Presse selon la revendication 1, caractérisée en ce qu'elle comporte un moule (19) ayant au moins deux empreintes, le moule étant mobile de façon qu'une empreinte puisse venir sur la table de pression en dessous du piston de pressage mobile (10), tandis qu'une autre empreinte vient se placer en dehors de la table, en dessous d'un piston de démoulage (27), monté pour effectuer un déplacement parallèle au piston de pressage, et entraîné par ledit piston de pressage simultanément dans un mouvement dans le même sens.

3.- Presse selon la revendication 2, caractérisée en ce que le moule (19) est mobile en rotation autour d'un axe parallèle à la direction de déplacement du piston de pressage (10).

4.- Presse selon une des revendications 2 ou 3, caractérisée en ce que le second piston (27) est lié au premier par un levier (28).

5.- Presse selon une des revendications 2 à 4, caractérisée en ce qu'elle comporte en dessous du piston de démoulage un support (22) soutenu élastiquement, et monté de façon à basculer lors d'un déplacement en sens contraire du soutien élastique(23, 24, 25).

6.- Presse selon une des revendications précédentes, caractérisée en ce qu'une barre (9) est prévue entre le palpeur (8) et le piston de pressage (10).

7.- Presse selon une des revendications précédentes, caractérisée en ce que sur le premier trajet (15) du profil le rayon de la came croît d'abord rapidement sur le début de ce premier trajet, puis croît moins rapidement sur la fin du premier trajet de façon à obtenir un déplacement du palpeur plus faible à la fin du trajet pour une même rotation angulaire de l'arbre d'entraînement, pour exercer une pression plus forte.

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Fig:1

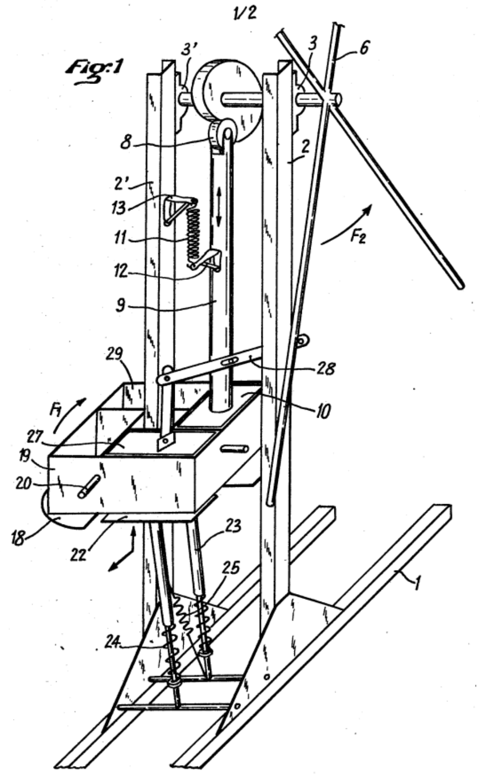

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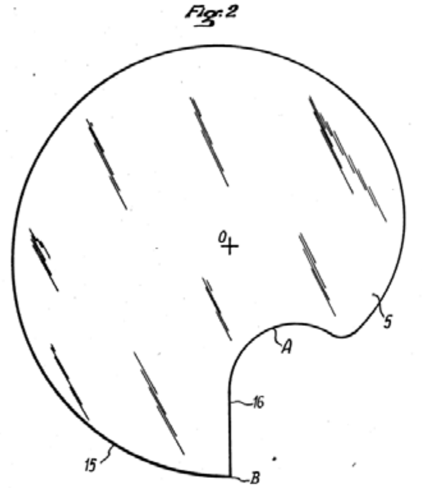
Fig:2



Patent US1945399A

Jan. 30, 1934. A. E. GUSKEA ET AL 1,945,399

APPARATUS FOR PRESSING CLAY PRODUCTS

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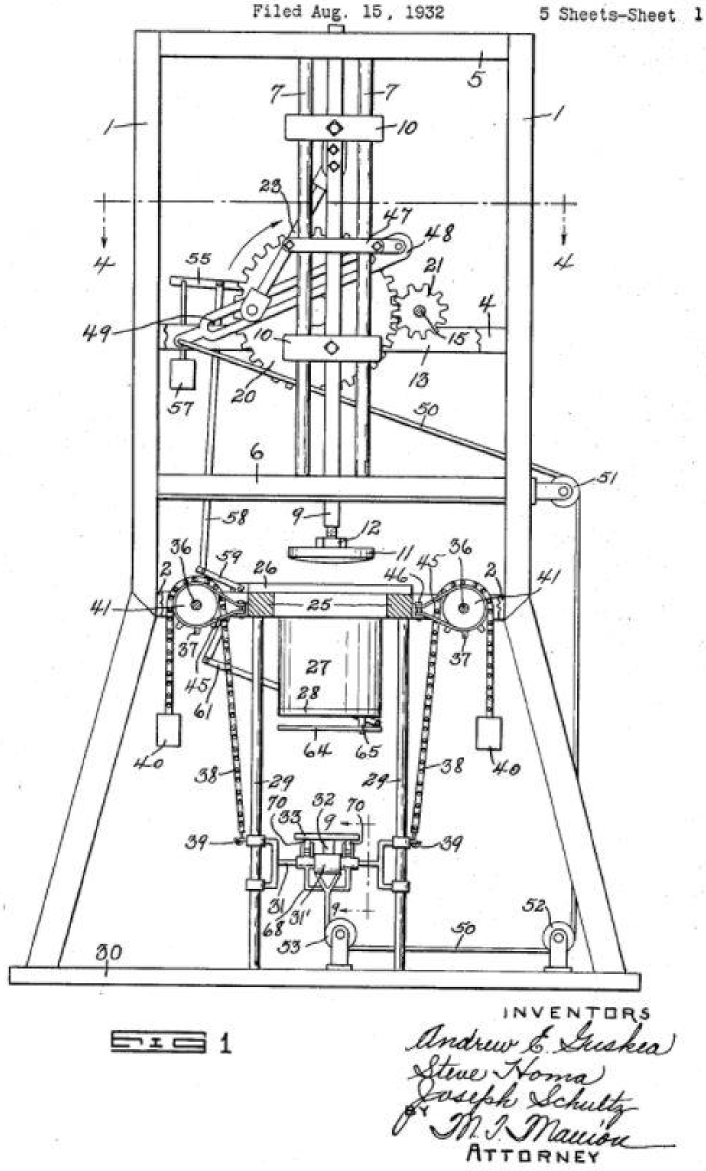

Jan. 30, 1934. A. E. GUSKEA ET AL 1,945,399

APPARATUS FOR PRESSING CLAY PRODUCTS

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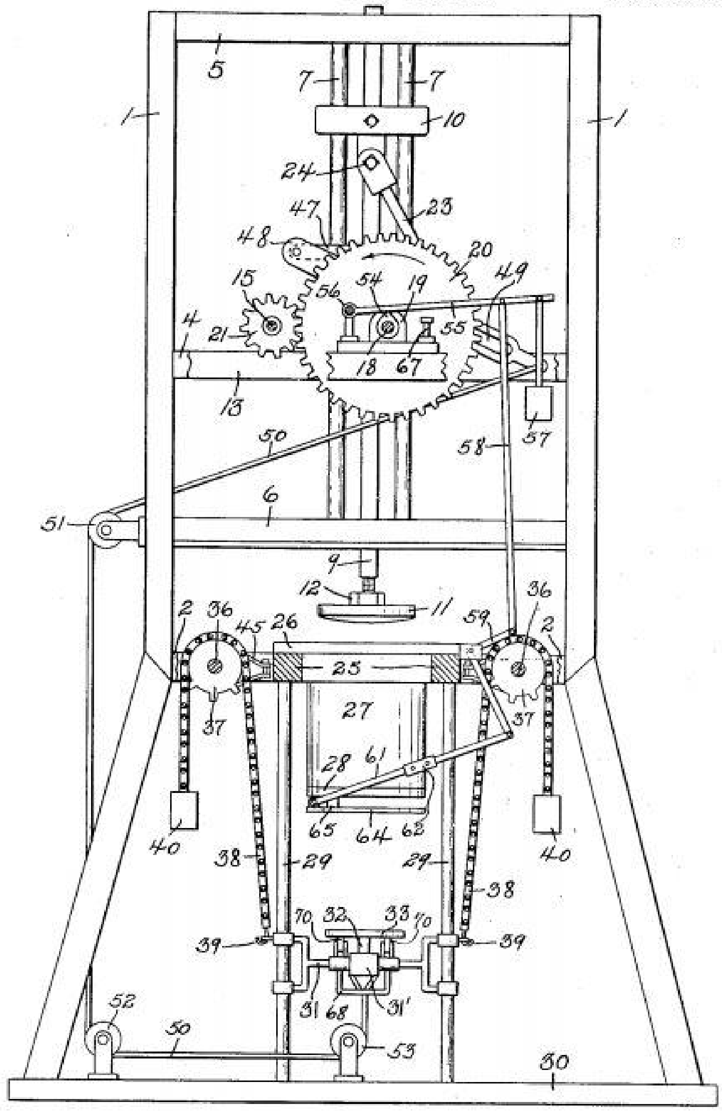

FIG 2

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Filed Aug. 15, 1932 5 Sheets-Sheet 3

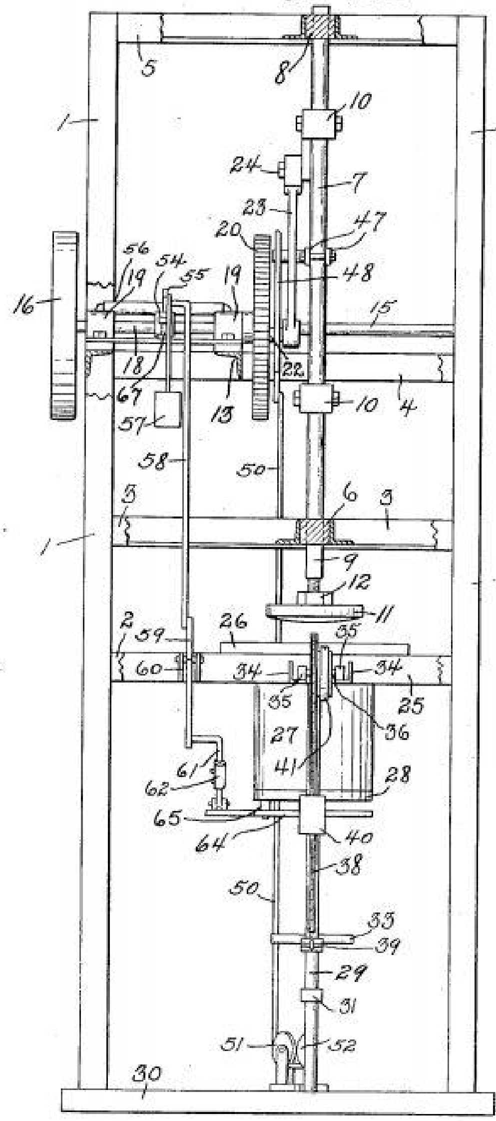

FIG 3

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APPARATUS FOR PRESSING CLAY PRODUCTS

Filed Aug. 15, 1932 5 Sheets-Sheet 4

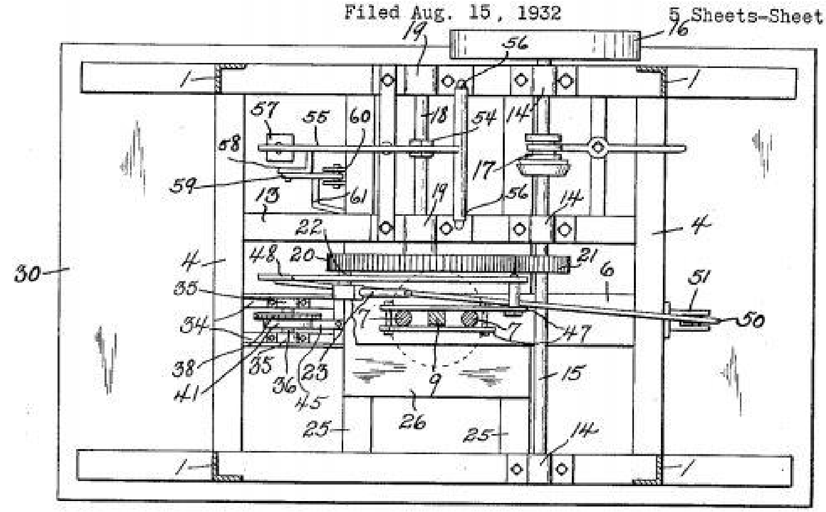

FIG 4

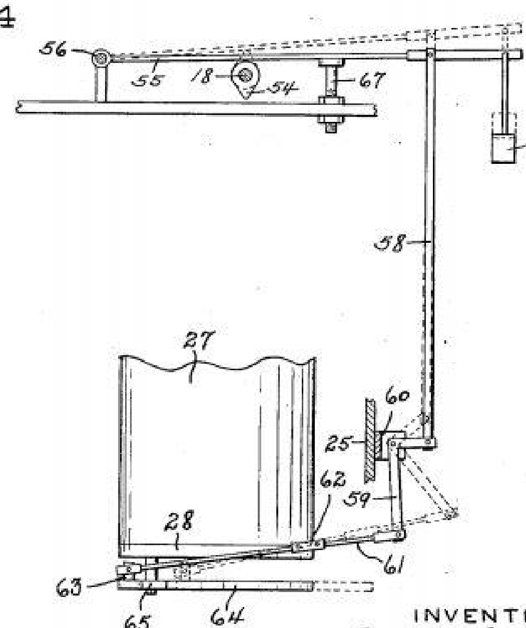

FIG 5

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APPARATUS FOR PRESSING CLAY PRODUCTS

Filed Aug. 15, 1932 5 Sheets-Sheet 5

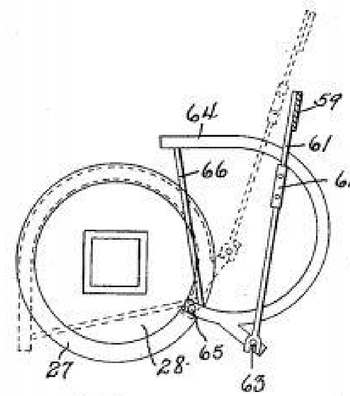

FIG 6

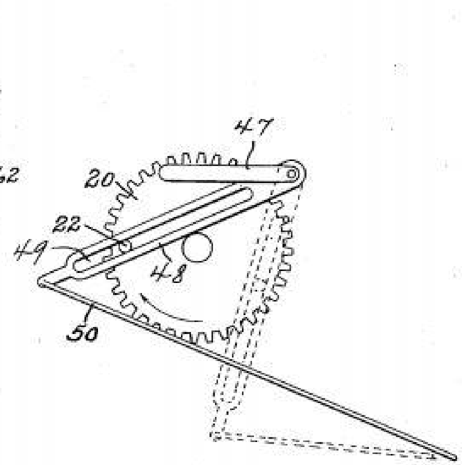

FIG 7

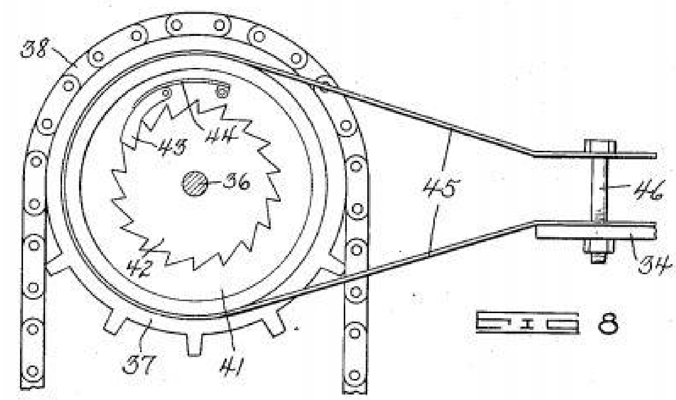

FIG 8

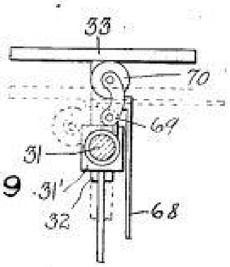

FIG 9

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Patented Jan. 30, 1934 **1,945,399**

UNITED STATES PATENT OFFICE

1,945,399

APPARATUS FOR PRESSING CLAY PRODUCTS

Andrew E. Guskea, Steve Homa, and Joseph Schultz, Toronto, Ohio

Application August 15, 1932. Serial No. 628,784

9 Claims. (Cl. 25—30)

This invention relates broadly to apparatus for manufacturing clay products, and it has for its object to provide a press for simplifying the manufacture of such clay products as sewer pipe, flue liners, conduit for electric cables, and the like.

A further object of the invention is to provide a press of the character mentioned which is substantially automatic in its operation and which, therefore, is responsible for great economy in the production of clay products.

A further object of the invention is to provide a press for extruding therefrom such products as those above mentioned, the mechanism having associated therewith cutting means whereby such products are automatically cut into predetermined desired lengths.

A still further object of the invention is to provide a table for supporting the formed product as it is being extruded downward from the die of the press, such table being automatically supported by mechanical tension against the lower end of the formed product and receding downwardly away from the die with the thereby carried formed product in a manner and at a speed that the product (still in its plastic state) will not collapse, buckle or bend.

With these and other important objects in view, the invention resides in the features of construction, arrangement of parts, and combination of elements which will hereinafter be described, reference being had to the accompanying drawings, in which—

Figure 1 is a front elevation of the invention with a portion of the frame thereof shown in broken section;

Figure 2 is a rear elevation of the invention similar to Fig. 1;

Figure 3 is an end elevation of the same, portions of the frame being shown in broken section;

Figure 4 is a top sectional view, the section being taken on line 4—4, Fig. 1, a portion of the structure being shown in fragmentary section;

Figure 5 is a detail view of the cutter and its associated actuating mechanism;

Figure 6 is a bottom view of the cylinder and associated forming die illustrating the operation of the cutter;

Figure 7 is a detail view of the slotted lever and cable for actuating downward travel of the supporting table and cross-bar;

Figure 8 is a detail view of the brake and ratchet mechanism controlling the downward speed and operation of the supporting table; and—

Figure 9 is a sectional view, the section being taken on line 9—9, Fig. 1.

Referring to said drawings, the reference numeral 1 designates generally the upright corner members of a frame of a press, said corner members being positioned relative to a rectangular arrangement, said vertical corner members being supported in rigid position by means of horizontally disposed bracing members 2, 3, 4 and 5, respectively, the bracing members 3 being located only at the opposite ends of the frame.

A supporting bar 6 has each of its ends supported by the end bracing members 3, and, in turn, said bar 6 supports intermediate its ends a pair of spaced parallel vertically extending standards or guides 7, the upper ends of said guides being rigidly held in position by a bar 8 extending longitudinally of the frame adjacent the upper end thereof.

A vertically reciprocable plunger rod 9 is provided intermediate the parallel guides 7, the same being vertically slidable through bearing apertures (not shown) located in the bars 6 and 8. The plunger rod 9 has permanently attached thereto guide plates 10 whose opposite ends embrace the vertical guides 7 and are slidable thereon for affording true vertical reciprocal movements to the rod 9.

The lower end of the plunger rod 9 is provided with screw threads and is designed to have threaded thereon a die head 11, said head 11 being held in fixed position by means of a lock nut 12. Obviously, this arrangement permits limited vertical adjustment to be made of the die head 11 with respect to the die, which will hereinafter be fully explained.

A bearing supporting member 13, preferably made of angle iron, extends longitudinally of the frame of the press and has its opposite ends permanently attached to the two end bracing members 4, as clearly shown in Fig. 4.

Journaled in bearings 14 is a shaft 15 which carries on one of its ends a pulley wheel 16 and which is separated intermediate its ends, preferably between the bracing member 4 and the supporting member 13, for the introduction of appropriate clutch mechanism 17.

A short shaft 18 is journaled in bearings 19 and carries on its inner end a gear 20 which meshes with a pinion 21 carried by the shaft 15. Said gear 20 carries on its face a wrist pin 22 which has connected thereto the lower end of a connecting rod 23, the opposite, or upper, end of said connecting rod being connected to a trunnion 24 which is permanently attached to the plunger rod 9.

Spaced parallel bars 25 span the distance between the front and rear bracing members 2 and support intermediate their ends an apertured plate 26 from which depends a cylinder 27, in the lower end of which is located the usual bell or forming die 28.

As is manifest, rotation of the shaft 15 by means of appropriate power applied to the pulley wheel 16 imparts rotation to the gear 20 through the pinion 21. Rotation of the gear 20 imparts alternate vertical reciprocal movements to the plunger rod 9 and the thereby carried head 11 through the intermediacy of the connecting rod 23, as is well understood. Thus, clay in its plastic state introduced in a mass into the interior of the cylinder 27 will be extruded or expelled downward and outward from said cylinder and past the forming die 28 on the downward stroke of the head 11 to form the clay product.

As is well known in the art, considerable upward pressure must be applied to the lower end of the formed product as it is being expelled downwardly from the die in order to prevent collapse of the formed product and to keep the product from becoming bent or out of alinement. This is ordinarily accomplished by means of a vertically slidable table which is located directly underneath the cylinder 27 and which is designed to support the pressed product and to recede downwardly away from the cylinder at substantially the same speed at which the formed product is being expelled from said cylinder during the pressing operation, said table at all times being under sufficient upwardly applied pressure against the lower end of the product as it is being expelled to prevent collapse or bending of the formed clay product. To so operate the table and to apply the necessary pressure, we have designed a mechanical arrangement which is purely automatic and requires no manual attention, and which will now be described.

A pair of spaced parallel guide posts 29 have their upper ends permanently attached to the bars 25 and have their lower ends resting on the base 30 of the press. So disposed, as shown in Figs. 1 and 2, the cylinder 27 occupies a position between the two parallel guide posts 29. A cross bar 31 is disposed between the guide posts 29 and has each of its ends bifurcated and embracing the guide posts, thereby permitting the bar 31 to be vertically movable thereon. As shown in the drawings, particularly Fig. 9, the cross bar is made round in cross section, but the same has a portion 31' midway of its length of rectangular form in cross section. This rectangular portion is vertically apertured to removably receive therein a stem 32 upon the upper end of which is permanently attached the under side of the supporting table 33, the latter being of flat disk form.

As shown in Figs. 3 and 4, spaced bearing supports 34 are located between the end bracing members 2 and the plate 26, each pair of said supports carrying bearings 35 in which are journaled a shaft 36 carrying a sprocket wheel 37, the peripheral teeth of which engage or mesh with a length of sprocket chain 38. One end of each chain 38 is provided with a hook 39 which engages a loop or eye provided on the bifurcated end of the cross bar 31. The opposite end of each chain carries a counterweight 40 for a purpose to be hereinafter made clear.

A brake drum 41 is also carried by each of the shafts 36 adjacent the sprocket wheel 37, said drum 41 normally being freely rotatable on said shaft. Located internally of the peripheral flange of the brake drum and carried by the shaft 36 in fixed relation thereto is a ratchet 42 adapted for engagement with a pawl 43 pivotally connected to the internal side wall of the drum 41 and maintained in contact with the ratchet by means of the spring 44. A suitable brake band 45 embraces the brake drum 41 and the braking power or tension of said band is rendered adjustable by means of the bolt 46.

A lever support 47 composed of two plates which complementally embrace the guides 7 approximately midway of their heighth has pivotally connected thereto the upper end of a slotted lever 48. This lever, as is shown in detail in Fig. 7, is constructed so as to provide a longitudinally extending slot or guideway 49 intermediate its sides, and which slot or guideway has slidably received therein the wrist pin 22 of the gear 20, said slotted lever preferably occupying a position intermediate the face of the gear 20 and the connecting rod 23.

One end of a length of wire cable 50 is permanently fastened to the lower end of the slotted lever and said cable extends therefrom outwardly and downwardly of the press frame, being passed over a pulley 51 located at one end of the frame and then being passed inwardly about pulleys 52 and 53 which are located on the base of the press. From said pulley 53, which is located directly beneath the supporting table 33, the cable is extended upwardly and the end fastened to the cross bar 31. As will be noted, the cable 50 positively connects the cross bar 31 and the slotted lever 48.

With the plunger rod 9 and the thereby carried die head 11 in its fully raised position for the commencement of the downstroke of the latter elements, the slotted lever 48 occupies a position depending substantially vertical from its pivot. At this point, the table 33 occupies an elevated position abutting the die 28. Rotation of the gear 20 in the direction indicated by the arrows in Figs. 1 and 7 causes the wrist pin 22 to travel in the guideway toward the lower end of the lever thereby swinging the lower end of the lever upwardly in the arc of a circle during its travel, as is shown in Fig. 7. Such swinging movement imparted to the lever causes the cable 50 to be carried thereby, resulting in pulling the cross bar 31 and table 33 downwardly and away from the die. This action is synchronized with the downstroke of the die head through the cylinder so that the supporting table 33 is receding downwardly supporting the lower end of the product being formed.

The downward travel of the cross bar 31 carries with it the sprocket chains 38, rotating the sprocket wheels 37 and their shafts 36 in their travel. Rotation of the shafts 36 results in the thereby carried ratchets being rotated in like direction and thus engaging the pawls 43. Such engagement of the pawls directly connect the brake drums 41 with the rotation of the shafts and the drums are caused to likewise rotate. Such rotation, however, is resisted somewhat due to the pressure exerted by the brake bands 45 on the drums resulting in the cross bar being lowered against a certain amount of resistance.

Said brake mechanism is rendered particularly desirable in the event that the downward pressure exerted by the formed product should exceed the pulling pressure exerted by the cable, as when the cable is stretched somewhat to allow slack in its length. Additionally, the counterweights 40 carried by the chains add further resistance to the downward travel of the cross bar, all of which tend to afford sufficient upward pressure by the table 33 against the lower end of the product being formed to prevent collapse or sagging of the product.

At the limit of the downstroke of the die head 11, the formed product is automatically cut into a predetermined length by a cutting mechanism to be described later. However, on the upstroke of the plunger 9 and die head 11, the end of the slotted lever 48 to which is attached the end of the cable 50 is still being elevated due to the path of travel taken by the wrist pin 22 with respect to the guideway 49, as will be understood after a study of Fig. 7 of the drawings. Thus, it will be seen that the supporting table 33 and crossbar 31 continue their downward travel away from the die during both the downstroke and upstroke of the plunger. This permits the formed and severed product to be lowered sufficiently to permit its removal from the table 33.

At the approximate instant the upstroke of the plunger is completed and the gear 20 has rotated to a point where the downstroke of the plunger is about to commence, the wrist pin 22 has exerted its lifting force with respect to the lever 48 and has traveled in the guideway 49 to a point adjacent the upper, or pivoted, end of the slotted lever 48. At this point, the wrist pin 22 commences to travel downwardly in the arc of a circle and exerts a depressing force returning the slotted lever downwardly to the initial vertical depending position.

The return stroke of the slotted lever 48 to its depending position is accelerated inasmuch as the fulcrum of the leverage force exerted by the wrist pin on the slotted lever is considerably lessened due to the travel of the wrist pin in the guideway. It will be seen from an examination of Fig. 7 of the drawings that an elevating force is applied to the lever throughout approximately 270° of the rotation of the gear 20 and that the slotted lever is returned to its depending position during the remaining 90° of rotation. Thus, tension is instantaneously released on the cable and the same becomes slack, at which time the counterweights 40 are taken downward by gravity at considerable speed, lifting the table 33 and cross bar 31 upwardly by means of the chains 38 to a position underlying and abutting the forming die prior to the time the die head on its downstroke enters the cylinder for forming another product. The brake drums 41 are rendered inoperative, or stationary, during the upward travel of the table 33 and the simultaneous downward travel of the counterweights 40 due to the fact that the teeth of the ratchet 42 are not engaged by the pawl 33, but ride freely thereunder.

The construction and operation of the automatic cutting mechanism hereinbefore referred to is substantially as follows:

Keyed or fastened to the shaft 18, intermediate its ends, preferably between the bearings 19, is a cam 54 designed to act upon the under side of a lever 55, which has one end pivotally connected, as shown at 56, and the opposite end having suspended therefrom a counterweight 57. Adjacent the free end of said lever 55 is suspended in a ball and socket joint a connecting link or rod 58 which, in turn, acts upon a bell-crank 59. Said bell-crank is pivoted to a clevis-bearing 60. The end of the bell-crank opposite that attached to the connecting link 58 is connected to one end of a horizontal connecting rod 61 (shown adjustable as to length by means of a slip-coupling 62). The end of the horizontal connecting rod opposite the end attached to the bell-crank is bifurcated forming a clevis or yoke which pivotally engages a pin 63 formed integral with the bow-cutter 64, which latter is in turn pivotally connected to the underside of the cylinder 27, as shown at 65. Across the chord of the arc formed by this bow-cutter is fastened a cutting element 66, preferably of taut wire. A vertically adjustable set screw 67 is provided to limit the throw of the cutter.

Rotation of the shaft 18 causes similar rotation of the cam 54. The form or throw of said cam raises and depresses the lever 55 about its pivotal point, carrying vertically therewith the connecting rod 58 and bell-crank 59, in turn imparting a reciprocating horizontal motion to the rod 61. As is obvious, such movement imparts to the bow-cutter oscillatory motion about its pivotal point in such manner and to such an extent that the cutting element 66 is driven through the formed product, completely severing the latter. The above described cutting action is so timed or synchronized by proper location of the throw of said cam so as to cause the formed product to be severed at the instant of commencement of the upward stroke of the die head 11 and during downward movement of the supporting table 33. The counterweight 57 is provided solely for the purpose of assuring positive downward movement of said lever 55.

Mounted on the rectangular portion 31' of the cross bar 31 is a U-shaped table elevating lever 68, the vertical extending portions thereof being pivoted intermediate their ends to the rectangular portion 31' of the cross bar, as shown at 69, and each of said vertical members carries rollers 70 at their upper extremity. Said rollers, when the lever occupies a vertical position, are designed to support the table 33 elevated above the cross bar, and said table occupies such elevated position during normal operation of the press. However, in the event that some hard foreign substance should become mixed with the plastic clay and should inadvertently be introduced into the cylinder and which could not be expelled past the die, thereby clogging the latter, downward reciprocation of the die head 11 may be stopped, as by means of the clutch mechanism 17. The portion of the formed product already expelled downwardly from the die may be manually severed adjacent the die, following which the lower portion of said lever 68 is raised upwardly 90° in the arc of a circle, thereby moving said lever from a vertical position to a horizontal position, resulting in the table 33 being lowered by gravity sufficiently to permit removal of the severed portion of the product and providing ready access to the forming die for removal from the cylinder, after which the foreign substance may be readily removed. The operation herein described is illustrated in detail in Fig. 9 of the drawings.

It is thought that the operation of the press and the function of its various parts will readily be understood from the foregoing description and that, therefore, a further detailed description of the operation would add nothing of importance to a clear understanding of this invention. Further, while we have described the invention more or less in detail, it will be understood that we do not limit ourselves to details of construction and arrangement of parts except as may be required by a fair interpretation of the terms of the appended claims.

What is claimed is—

1. In a press of the character described, a cylinder having a forming die associated therewith, a crank rotatably mounted on said press, a die head carried by a plunger rod reciprocable in said cylinder and adapted to have reciprocable movements imparted thereto by means of said crank, a slotted lever having one end thereof pivoted to a stationary portion of the press, said crank being adapted to travel longitudinally in said slotted lever for raising and lowering the free end of said lever, a vertically movable supporting table located beneath said cylinder, and means connecting the free end of said slotted lever and said supporting table whereby upward movement of the free end of said slotted lever imparts a lowering movement to said table.

2. In a press of the character described, a cylinder having a forming die associated therewith, a crank rotatably mounted on said press, a die head carried by a plunger rod reciprocable in said cylinder and adapted to have reciprocal movements imparted thereto by means of said crank, a slotted lever having one end thereof pivoted to a stationary portion of the press, said crank being adapted to travel longitudinally in said slotted lever for raising and lowering the free end of said lever, a vertically movable supporting table located beneath said cylinder, means connecting the free end of said slotted lever and said supporting table whereby upward movement of the free end of said slotted lever imparts a lowering movement to said table, and means independent of said last mentioned means for imparting elevating movement to said table.

3. In a press of the character described, a cylinder having a forming die associated therewith, a crank rotatably mounted on said press, a die head carried by a plunger rod reciprocable in said cylinder and adapted to have reciprocal movements imparted thereto by means of said crank, a slotted lever having one end thereof pivoted to a stationary portion of the press, said crank being adapted to travel longitudinally in said slotted lever for raising and lowering the free end of said lever, a vertically movable supporting table located beneath said cylinder, means connecting the free end of said slotted lever and said supporting table whereby upward movement of the free end of said slotted lever imparts a lowering movement to said table, means independent of said last mentioned means for imparting elevating movement to said table, and cutting means synchronized with the rotation of said crank and adapted to function during a portion of the rotation of said crank.

4. In a press of the character described, a cylinder having a forming die associated therewith, a crank rotatably mounted on said press, a die head carried by a plunger rod reciprocable in said cylinder and adapted to have reciprocal movements imparted thereto by means of said crank, a slotted lever having one end thereof pivoted to a stationary portion of the press, said crank being adapted to travel longitudinally in said slotted lever for raising and lowering the free end of said lever, a vertically movable supporting table located beneath said cylinder, and means connecting the free end of said slotted lever and said supporting table whereby upward movement of the free end of said slotted lever imparts a lowering movement to said table, said lowering movement being accomplished against the retarding force exerted by applied braking energy.

5. In a press of the character described, the combination of a forming die and a reciprocable die head, a rotatable crank mounted on said press by means of which reciprocatory movements are imparted to said die head, slidable means located in line with said forming die for supporting the formed product as it is expelled from said die and adapted to recede away from said die, and means synchronized with the rotation of said crank for severing the formed product into a predetermined length during the travel from said die.

6. In a press for forming clay products, the combination of a forming die and a reciprocable die head, a rotatable crank carried by said press by means of which reciprocatory movements are imparted to said die head, vertically slidable means underlying said forming die for supporting the formed product following expulsion thereof from said die, means connecting said crank and said slidable means and synchronized with the stroke of the die head for effecting downward travel of said supporting means, and independent means for effecting upward return travel of said supporting means following removal of said product.

7. In a press for forming clay products, the combination of a forming die and a reciprocable die head, a rotatable crank carried by said press by means of which reciprocatory movements are imparted to said die head, vertically slidable means underlying said forming die and normally held in underlying abutting relation to said forming die by means of suspended counterweights attached thereto, and means connecting said crank and said slidable means and synchronized with the stroke of the die head for effecting downward travel of said supporting means at a predetermined speed against the resistance of said counterweights.

8. In apparatus for forming clay products, a frame, a reciprocable die head operable in a forming die, a rotatable shaft journaled in bearings on said frame and carrying a crank by means of which reciprocatory movements are imparted to said die head, vertically movable means underlying said forming die for supporting the formed product as it is expelled from the forming die, cutting means pivotally connected beneath said die adapted upon actuation to sever said product into a predetermined length, and means for actuating said cutting means consisting of a cam carried by said crank-carrying shaft and link and lever mechanism attached to said cutting means and said frame.

9. In a press for forming clay products, a forming die, a reciprocable die head, a rotatable crank mounted on said press by means of which reciprocatory movements are imparted to said die head, vertically movable means underlying said die for supporting the formed product as it is expelled from said die, means connected to said crank and said supporting means for effecting downward travel of said supporting means, and ratchet controlled braking means whereby downward travel of said supporting means is effected against automatically applied braking force and upward return movement is effected without such braking force.

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Patent US145358A

UNITED STATES PATENT OFFICE.

JAMES M. MITCHELL, OF DUNLAP, IOWA.

IMPROVEMENT IN BRICK-MACHINES.

Specification forming part of Letters Patent No. **145,358**, dated December 9, 1873; application filed April 4, 1873.

To all whom it may concern:

Be it known that I, J. M. MITCHELL, of Dunlap, in the county of Harrison and State of Iowa, have invented certain Improvements in Brick-Presses, of which the following is a specification:

My invention relates to a hand-press for molding brick, &c.; and consists in a novel combination of mechanism, in which a single movement of a hand-lever presses one brick, and delivers the previous one from its mold.

Figure 1 is a vertical section of my machine on the line *x x* of Fig. 2; Fig. 2, a top-plan view of the machine; Fig. 3, a vertical section on the line *y y* of Fig. 2, showing the manner in which the bricks are delivered from the mold.

In the drawing, A represents a strong rectangular frame, constructed at the middle with an upright portion, *d*, in which there is mounted a vertical plunger, B, as shown in Figs. 1 and 2. On the top of the frame A there are mounted two horizontally-sliding mold-frames, C, which may be moved to and fro, so as to come alternately under the plunger B. These molds are united by a link, *c*, and are moved by a hand-lever, D, which is pivoted to the frame and connected by a link, *d*, to one of the molds, as shown in Fig. 1. The plunger B is made with a rack, *e*, on one side, and is moved up and down by a pinion, *f*, formed on the end of a lever, F, which is pivoted in the top of the frame, as shown in Figs. 1 and 2. The lever F extends forward and has its end connected by a rod, *g*, to a hand-lever, G, which is pivoted to the front of the frame in convenient reach of the operator, so that by depressing the lever the plunger may be forced down into whichever mold may chance to be under it.

In order to admit of the ejectment of the brick from the molds, the latter are made with movable bottoms, *h*, which may be pushed up from below. In opposite ends of the frame there are mounted below the level of the molds two plungers, H, to push up the mold-bottoms. These plungers H are operated by levers, I, pivoted to the frame, the inner ends of the levers being passed through the respective plungers, while their outer ends are connected by the links *i* to a cross-bar, *k*, secured to the hand-lever G, as shown in Figs. 1, 2, and 3, so that when the said lever is depressed to force the compressing-plunger B down, it at the same time raises both delivering-plungers. The arrangement of parts is such that when either mold is under the pressing-plunger the other is over its corresponding delivery-plunger.

The machine is operated as follows: After a brick is pressed in one mold, the other mold is filled with clay, and then the molds moved by the lever D until the one containing clay is under the pressing-plunger B, and the one containing brick over its delivery-plunger. The hand-lever H, being then depressed, brings down the plunger B and compresses the clay in the one mold, and at the same time raises the delivery-plunger and ejects the brick from the other mold, the brick being immediately removed by an attendant. The lever is then raised so as to lift the pressing-plunger and lower the others, and the mold from which the brick was delivered filled with clay. The molds are then moved back to their first position, the hand-lever again operated, and so on repeatedly, the two molds being brought alternately under the pressing-plunger, and each mold brought alternately under said plunger and over the delivery-plunger.

It is obvious that, instead of using two single molds, two sets of molds may be employed, and also that the connection between the hand-lever G and the delivery-plungers may be made in other ways than that shown.

The press constructed on my plan is strong, cheap, and compact, and can be operated with ease and rapidity. It will be found of service for pressing not only brick, but other articles, as soap, &c.

Having thus described my invention, what I claim is—

1. In combination with the movable molds C, the plunger B, lever F, rod *g*, and hand-lever G, constructed and operating as described.

2. In combination with the hand-lever G and the pressing-plunger B, operated thereby, the sliding molds C and the delivering-plungers H, also operated by the hand-lever G, the parts being all constructed and arranged to operate substantially as shown.

JAMES M. MITCHELL.

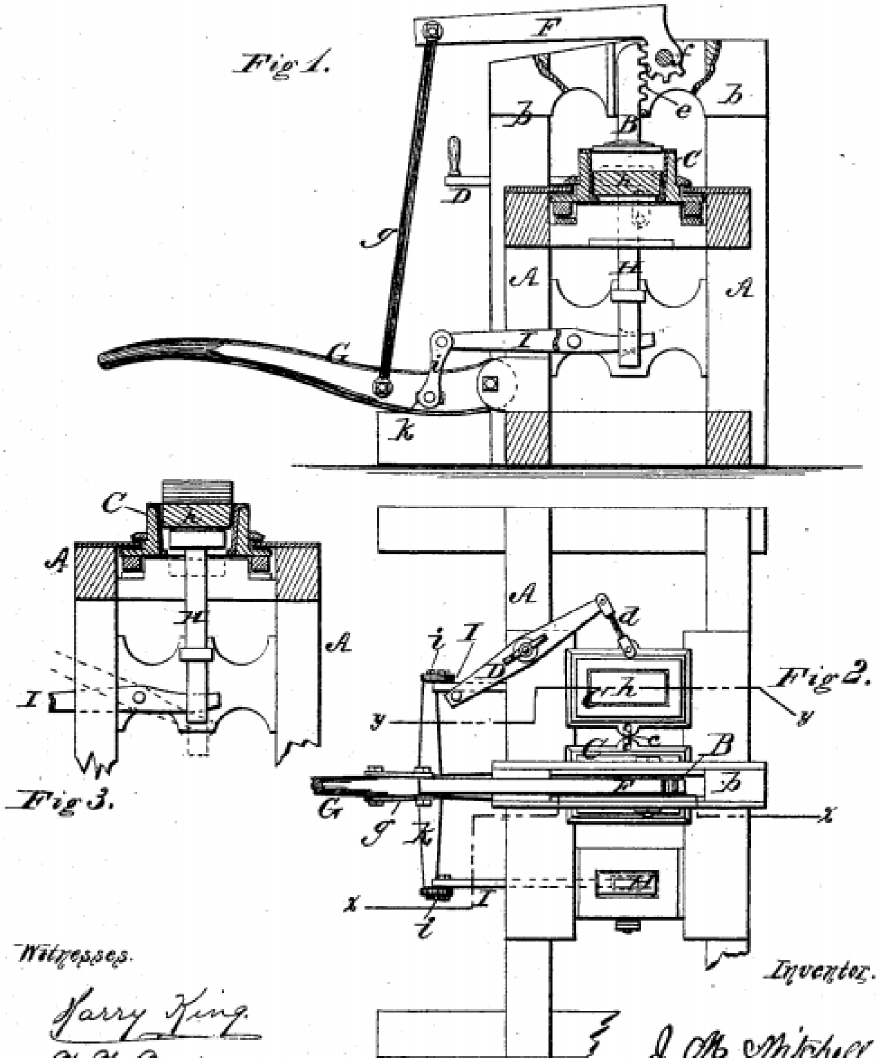
Witnesses:
S. J. PATTERSON,
H. L. BOND.

1000 w

J. M. MITCHELL.

Brick-Machines.

No. 145,358. Patented Dec. 9, 1873.



Witnesses.

Harry King.

W. W. Dodge.

Inventor.

J. M. Mitchell

By his attys

Dodge & Son

APPENDIX H: Stress Analysis of Components

Materials:

All components being analyzed, unless otherwise specified, are A36 Hot-Rolled steel. Components are to operate in a hot, humid working environment.

Table 1: A36 Hot-Rolled steel Material Properties

Material Property	Numeric Value
Modulus of Elasticity	29.0×10^6 psi
Poisson's Ratio	0.26
Tensile Yield Strength	3.63×10^4 psi
Compressive Yield Strength	2.20×10^4 psi
Ultimate Tensile Strength	$5.80 \times 10^4 \sim 7.98 \times 10^4$ psi

Simplifying Elements:

For all Finite Element Analysis, components were analyzed as three dimensional solid models, and were broke down into quadratic tet-shaped elements. Additionally, all loads were applied as a ramp function.

Compression Chamber Subsystem

Description:

The Compression Chamber subsystem consists of four ½ inch thick walls standing atop a ½ thick bottom plate, all fastened together with machine screws. The Compression Chamber is to be supported by L-brackets at each corner. This subsystem directly interacts with the Compression Plate subsystem.

Analysis/Sketch:

Major assumptions include that the walls are fastened to each other and to the bottom with negligible gaps in between, the Compression Plate is applying a force normal to the bottom of the Compression Chamber, and that a constant pressure is experienced on all walls and the bottom of the Compression Chamber. Applying a factor of safety of 3.00, the pressure experienced by the chamber is 80.0 psi.

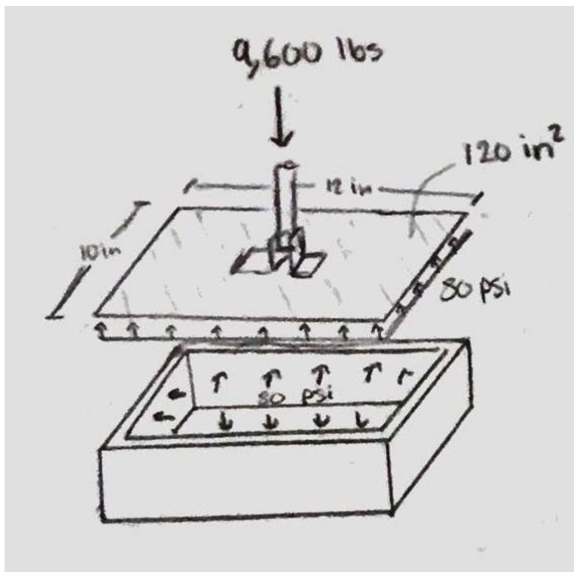


Figure 1: Sketch showing the distribution of pressure on the chamber walls and the Compression Plate in psi. Not to scale.

C03: Chamber Bottom

Boundary Conditions:

The bottom of the chamber was given small partitions at the corners to represent the contact area of the chamber supports. The part was given pinned boundary conditions at the very inside corner of that face, shown as a blue dot in Figure 2. On the other side, a uniform pressure of 80 psi was applied.

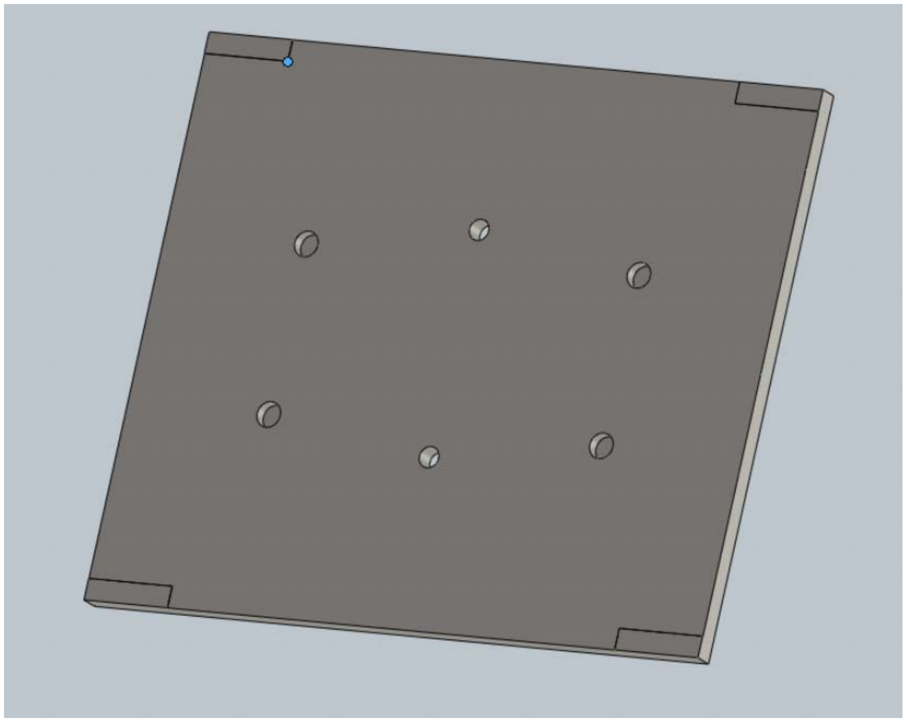


Figure 2: CAD model of “C03 - Chamber Bottom” using Solidworks.

Expectations: If this part were to fail, it would likely fail by bending at the center where the chamber bottom plate is not supported. Deformation from bending may also be an issue even if it does not fail, as bending in the metal can affect the shape of the brick prior to retrieval.

Results:

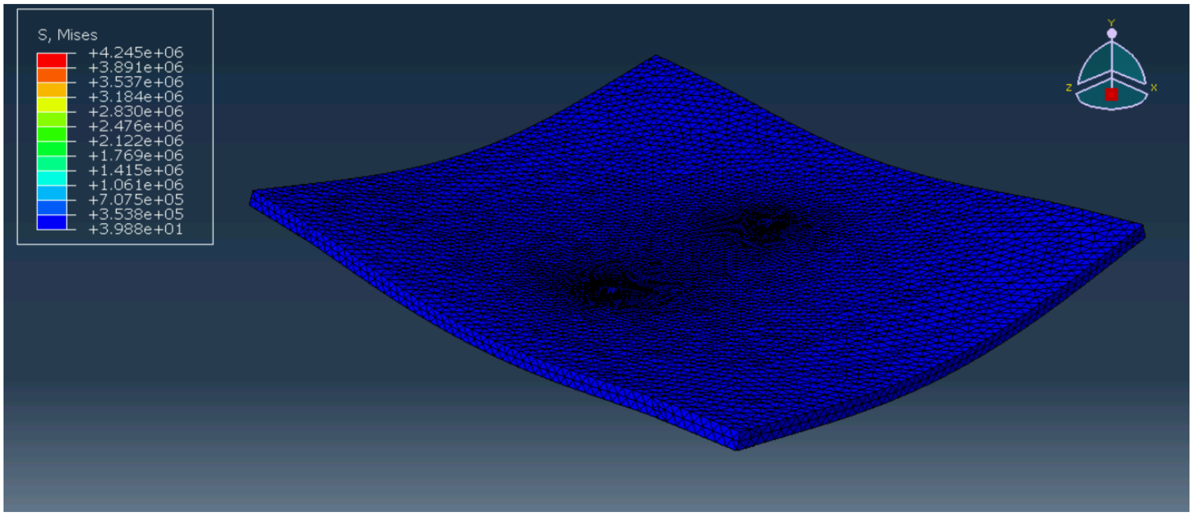


Figure 3: 3D model of the projected stresses experienced by C03 with predicted loading conditions using Abaqus.

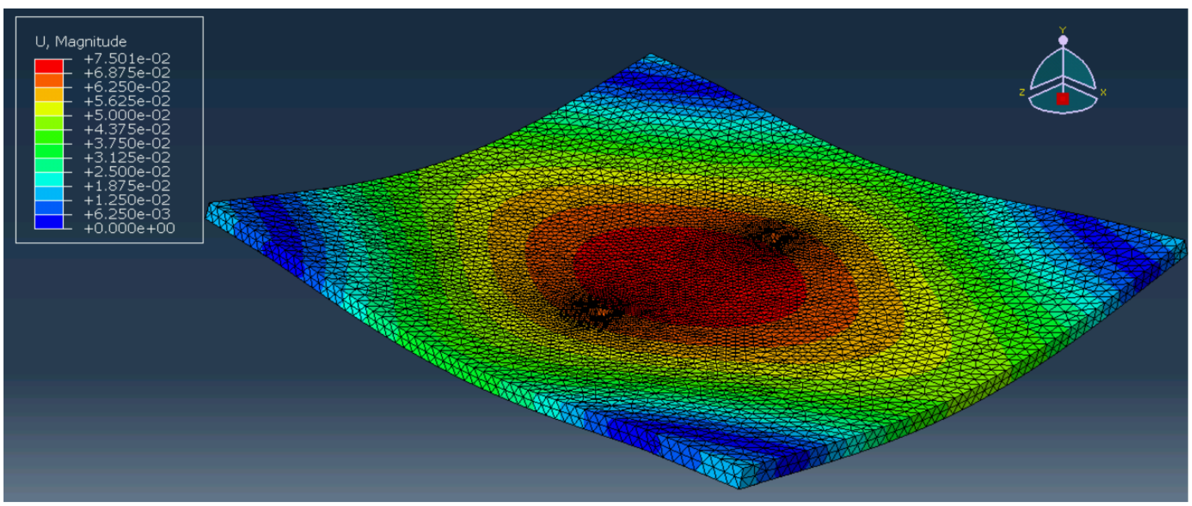


Figure 4: 3D model of the projected deformation experienced by C03 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

As demonstrated from Figures 3 and 4, most of internal stress within the part is well under the yield point of A36 steel. This is true even at the middle where deformation and failure due to bending was projected to be a significant issue. What is important to note, however, is that there are stress concentrations at the pinned areas of the part that under the given loading conditions are experiencing stresses above the yield point. While these points might suggest that the part would fail, I believe that it is simply the result of unrealistic boundary conditions. The part would actually be supported by the bottom face, which would greatly distribute the load applied to the bottom plate. Additionally, the stress concentration is likely due to the fact that there is actually a small extrusion on the part created in the Solidworks model used to distinguish between the bottom face and the simple partition. As a result, this likely magnified the stress concentration projected in Abaqus. Another test should be run in future FEA predictive modeling with the same boundary conditions, but instead using partitions created in Abaqus. FEA shows that the deformation experienced by C03 is negligible considering its purpose, meaning that this part is significantly robust with respect to the predicted loading situations.

C04: Side Wall

Boundary Conditions:

The left, right, and bottom faces of this rectangular part are modeled as fixed to represent the screws that were planned to be used to fasten the walls together. A uniform pressure of 80 psi was applied on the front face of C04.

For the small shear test, the top left portion of the wall was isolated to show the stress concentration on the upper-leftmost hole of the part. A cumulative surface traction of about 700 pounds-force was applied to the inside face of the hole of the isolated portion, and the right edge of C04 was made fixed in the small shear analysis.

Expectations:

In Figure 5, critical areas of projected failure of C04 are shown to be failure at the middle of the wall by bending, as well as at the stress concentrations at the holes, which indicate possible failure by shear or bending. Additionally, Figure 6 indicates a possibility of elastic deformation to occur at the top surface of C04 because of the loading situations and boundary conditions.

This is significant for further FEA using stricter boundary conditions, because deformation at this area of the part could lead to clay seeping out of the top during compression.

<u>Results</u>

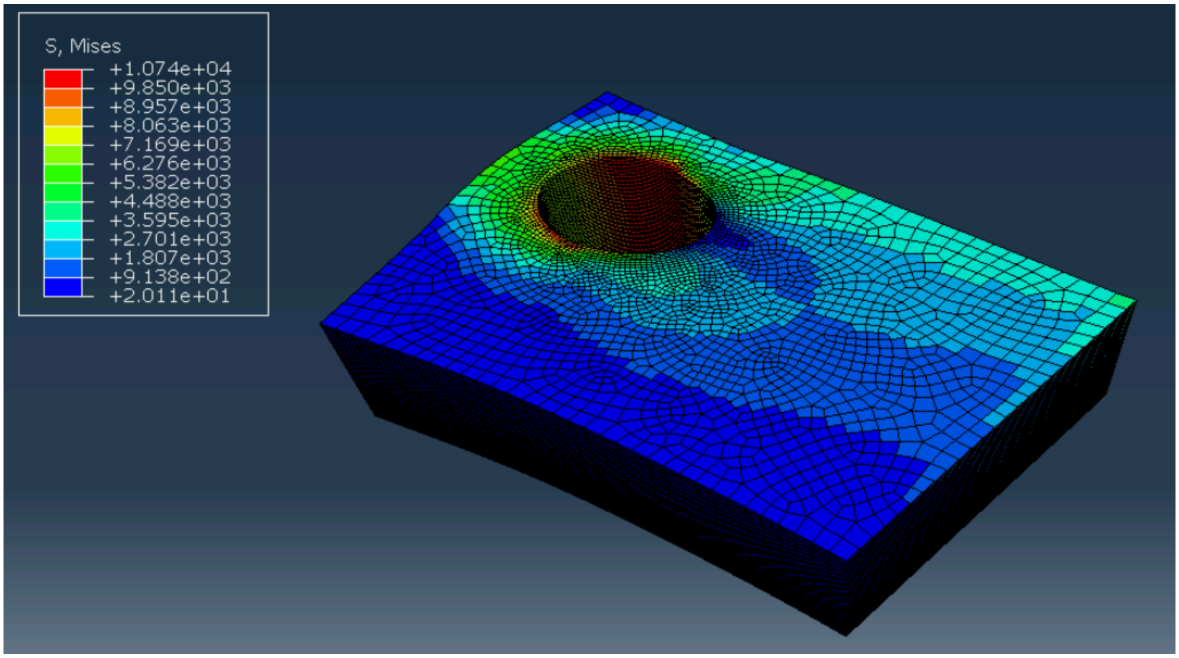


Figure 5: 3D model of the projected stresses experienced by C04 with predicted loading conditions using Abaqus.

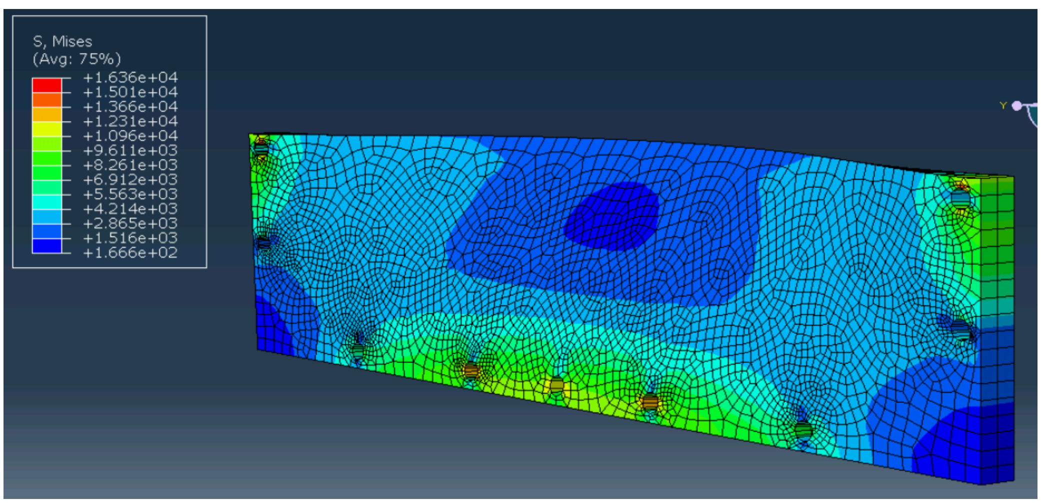


Figure 6: 3D model of the projected stresses experienced by C04 at the top left corner with predicted loading conditions using Abaqus.

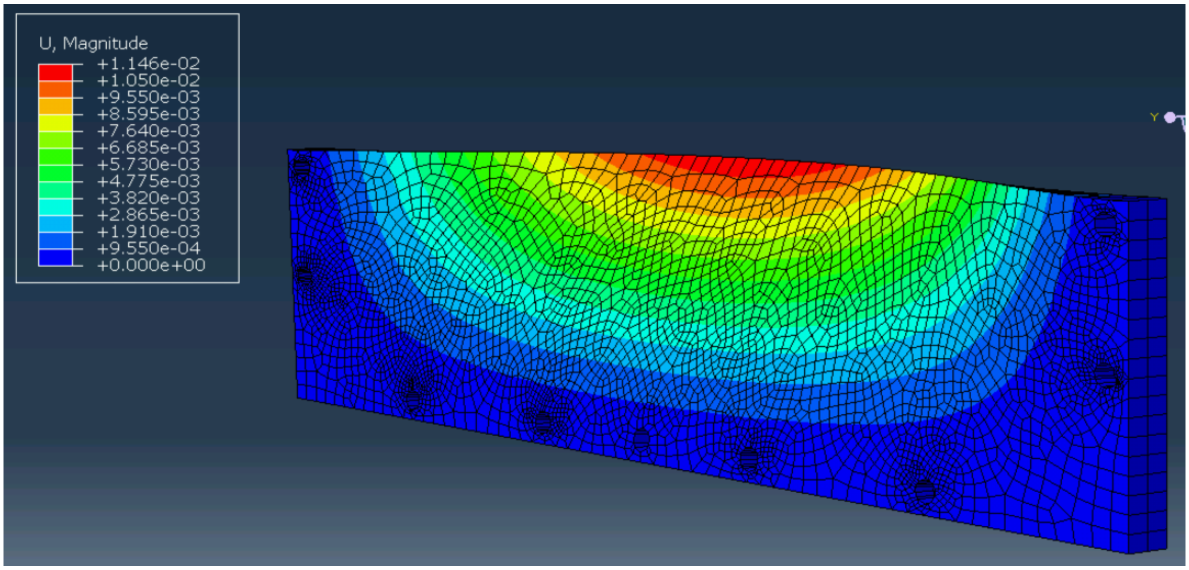


Figure 7: 3D model of the projected deformation experienced by C04 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

The maximum stress experienced by the part under the given loading conditions is located at the stress concentrations created by the holes, as seen in Figure 5. Given the predicted stresses acting on C04, FEA has indicated that the experienced stresses are below the yield stress of the part. This indicates that with a factor of safety of 3.00, the part should not experience neither deformation nor local yielding. Additionally, Figure 7 shows that the part will not fail as a result of shear created by the screws. As a result, this part is sufficiently robust. It is also clear that the maximum deformation experienced by the wall is of an order of magnitude of 1.00×10^{-2} inches, which is negligible considering the size of the Compression Chamber and the bricks that it will produce.

Compression Plate Subsystem

Description:

The Compression Plate subsystem transmits the force input from the Lever Arm subsystem into the clay being housed in the Compression Chamber. The Compression Plate is connected to the Lever Arm by a short connecting beam, which is attached to the Compression Plate by a pair of L-brackets. The Compression Plate is to have a block at each corner of the top side to help ensure that the Compression Plate is always parallel to the bottom of the Compression Chamber during compression.

Analysis/Sketch:

It is assumed that the Compression Plate will be applying force normal to the bottom of the Compression Chamber. Applying a factor of safety of 3.00, the pressure experienced by the plate is 80.0 psi as seen in Figure 1.

P07: Compression Plate

Boundary Conditions:

This part was fixed on two face partitions on the top of the plate that represent the areas of contact force between the top surface of the plate and the parts that connect it to the output lever. One of these partitioned faces is highlighted in Figure 8 below. Additionally, there was an 80 psi pressure applied to the bottom side of the part, which represents the outward force exerted by the deforming clay on the walls during compression.

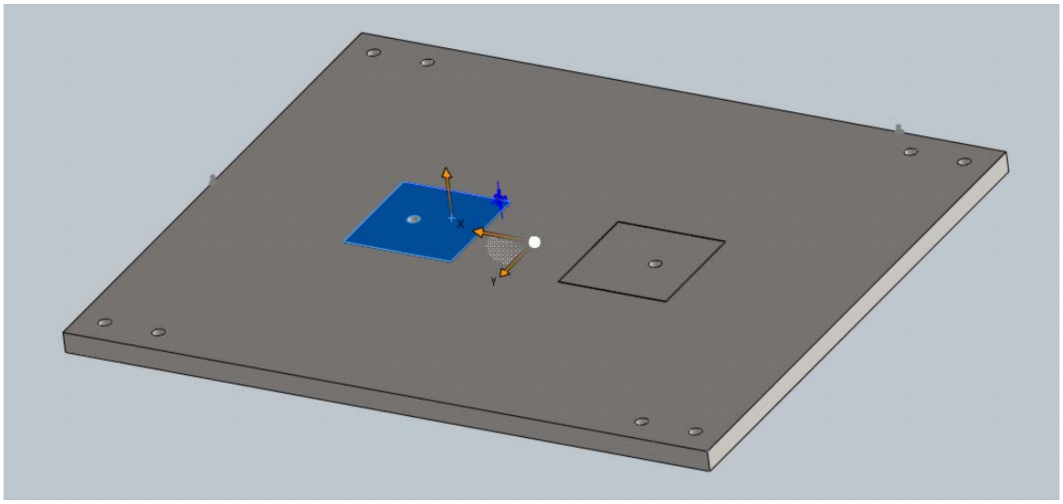


Figure 8: SolidWorks model of P07 - Compression Plate

Expectations:

Failure is predicted to occur towards the center of the part at the partitioned areas because of contact stress with other parts of the Compression Plate subsystem. Additionally, there might be excessive bending at the edges, which could deform the shape of the brick.

Results:

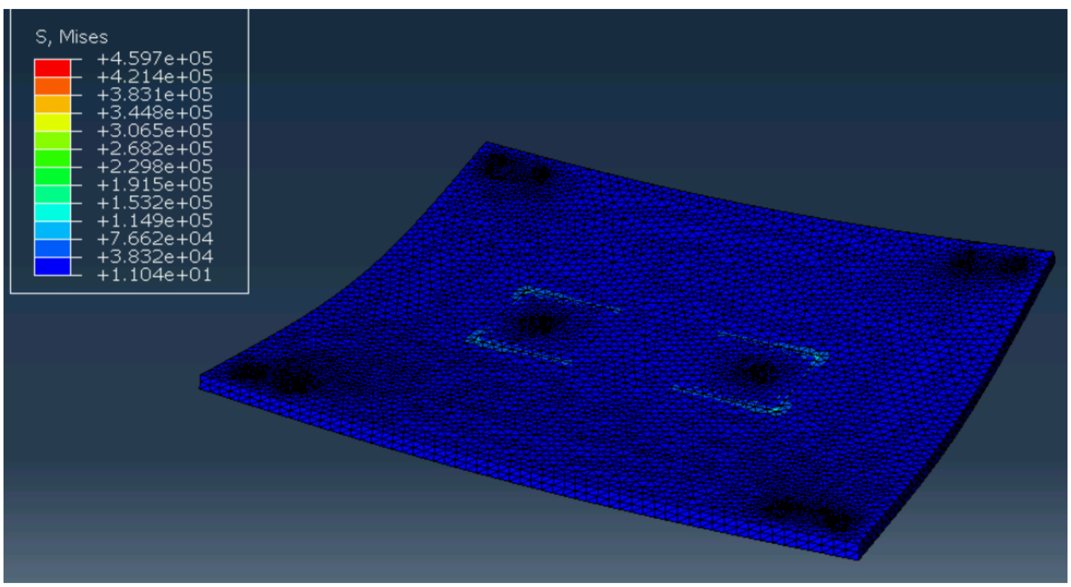


Figure 9: 3D model of the projected stresses experienced by P07 with predicted loading conditions using Abaqus.

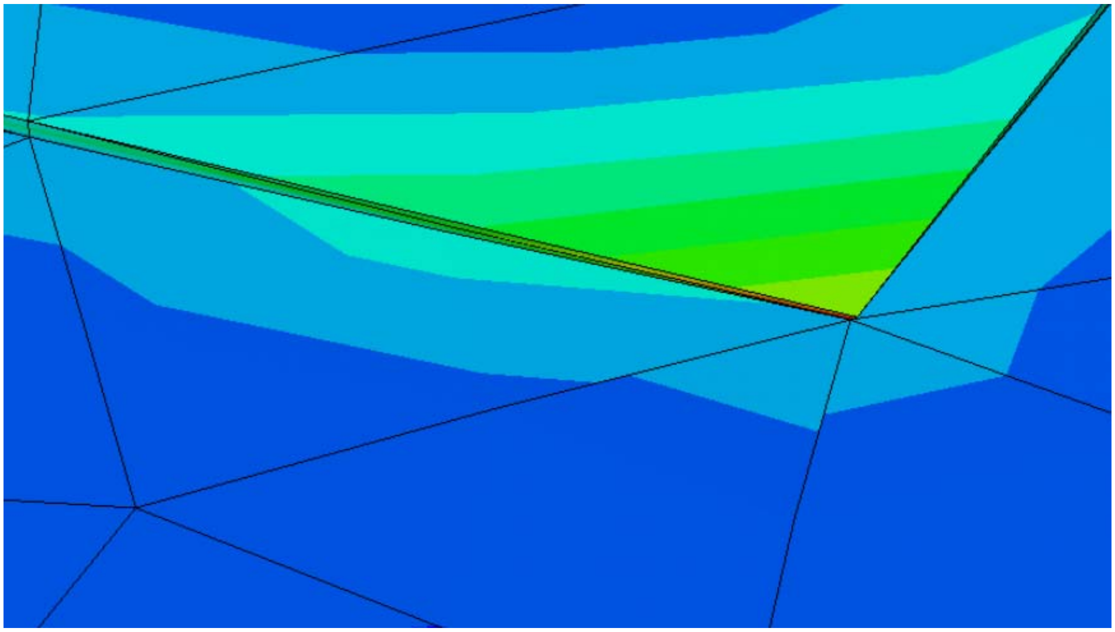


Figure 10: Enlarged image of the location on P07 where the stress concentration is happening.

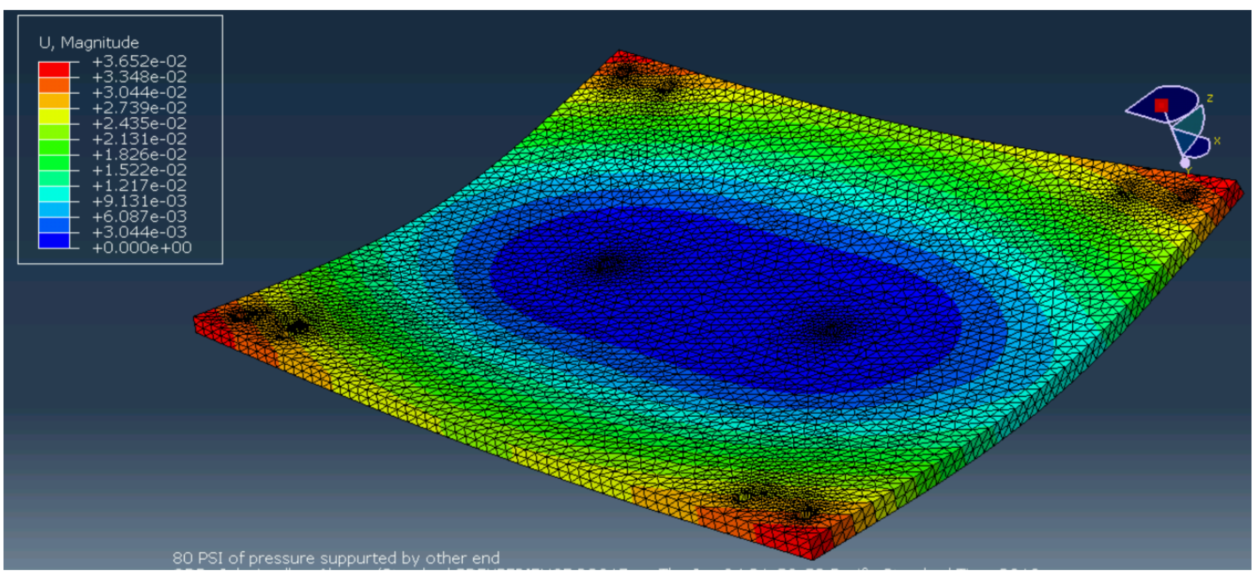


Figure 11: 3D model of the projected deformation experienced by P07 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Similar to part C03, the loading situations on the part indicate stresses that are largely under the yield stress of A36 steel. The Abaqus model in Figure 11 shows us that the maximum possible deformation experienced at the corners of the part due to contact stress is negligible. This is true for most of the part except for the pinned corners of the plate, which is likely due to the fact that the face partition was done using a small extrusion in Solidworks as opposed to a partition operation in Abaqus. Because of this, this test will likely have to be repeated using a simple partition made in Abaqus. If there is failure at these corners due to contact stress, one simple design solution would be to install a metal sheet or plate with the intention of distributing the load.

Base Fixture Subsystem

Description:

The Base Fixture subsystem connects and supports all active subsystems throughout clay compression, transmitting the forces experienced by the other subsystem to the ground. The subsystem consists of four metal rectangular hollow members and several connecting 2”x4” wood pieces of varying lengths. Several L-brackets connect supporting beams and connections to the other subsystems. Finally, a large rectangular “hard stop” for the Lever Arm is attached to the Base Fixture to prevent over-compression of the clay. Figure 12 below shows a brief sketch of how the supporting base legs interact with the other subsystems, and the shear flow that is expected to occur under the given loading situations.

Analysis:

Major assumptions regarding this subsystem are the following: that the gap between the hardstop and the input fulcrum support bar is negligible, the base legs are perpendicular to the ground and parallel to one another, all the base legs distribute applied loads equally, and that the Base Fixture is fixed against both translation and rotation while in use.

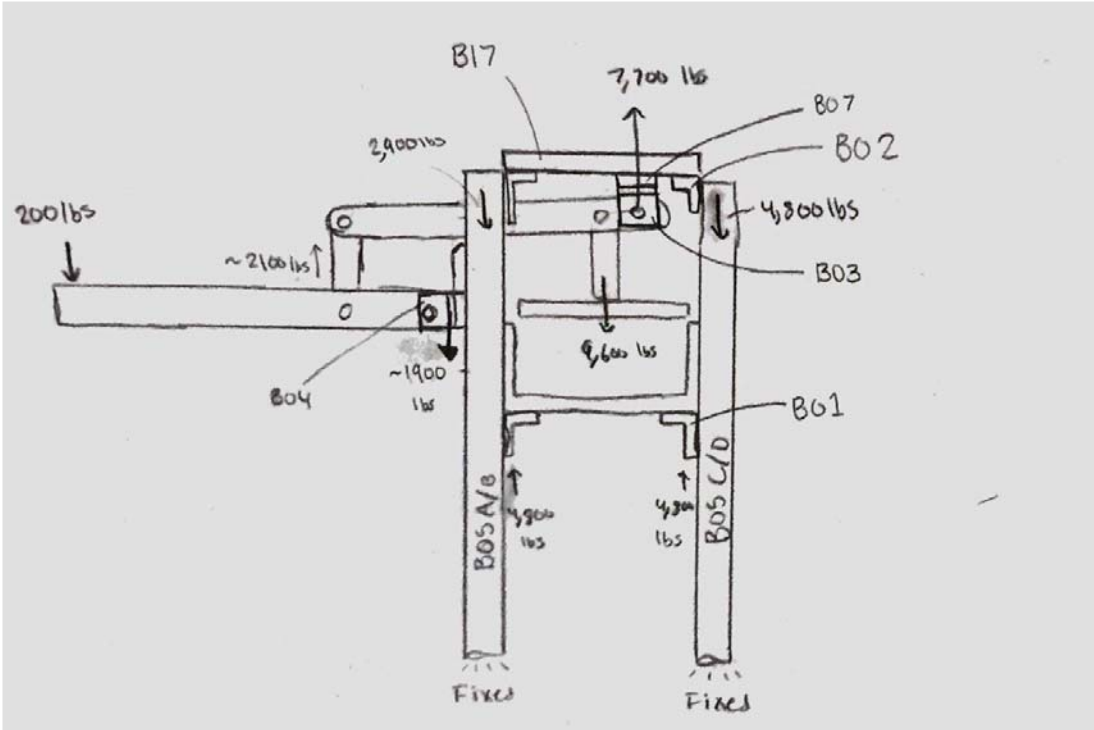


Figure 12: Labeled pieces in Base Fixture subsystem as well as the internal force transfer flow throughout, justifying the boundary conditions in the components analyzed. Not drawn to scale.

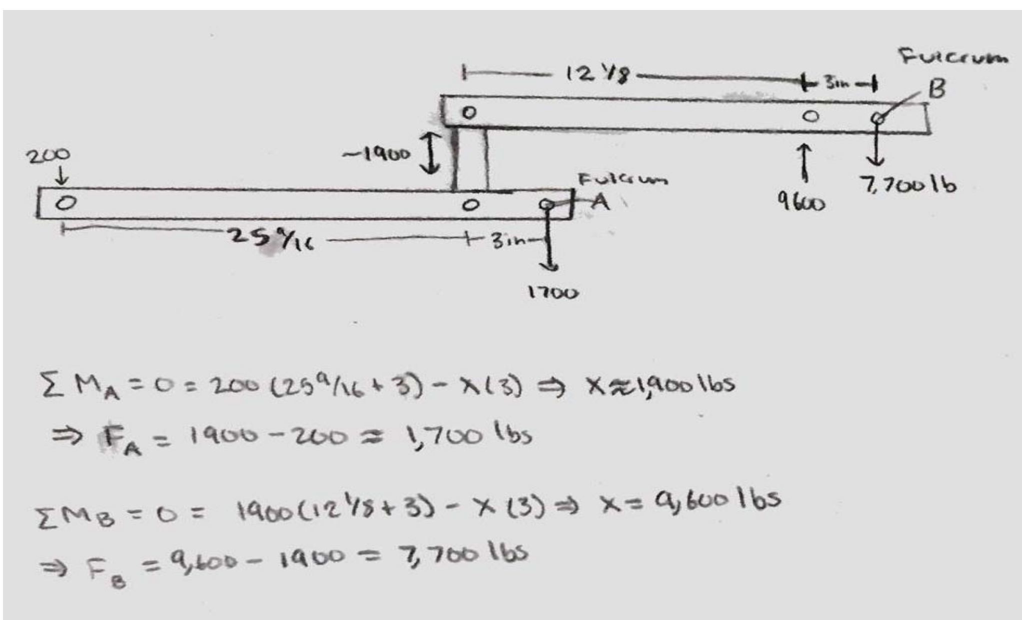


Figure 13: Compound lever and calculations in the scenario where the hard stop is not hit and full range of clay compression is not achieved. Not drawn to scale.

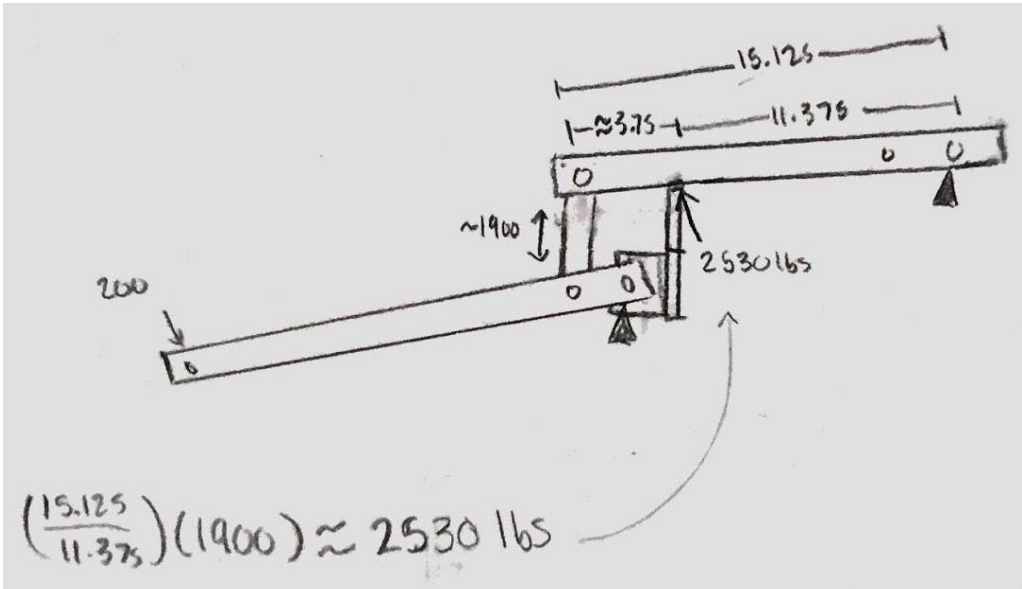


Figure 14: Compound lever and calculations in the scenario where the hard stop is hit and the full range of clay compression is achieved. Not drawn to scale.

B01: Compression Chamber Supporting L Bracket

Boundary Conditions:

For this piece, the inside faces of the horizontal pair of holes are pinned. This boundary condition represents bolts keeping the part in place, as representation of the connecting bolts in Abaqus or Solidworks was not attempted.

An exerted 600 psi pressure on the top plate is modeled to represent the predicted stresses that would occur in supporting the maximum predicted loads onto the Compression Chamber. In the case where a 200 lb force input is exerted on the input lever arm, a force of 9,600 lbs will be experienced by the Compression Chamber. This represents a worst case scenario, where forces are scaled up using a factor of safety of 3.00. Since there are four of these pieces supporting the Compression Chamber, and each piece is 4.00 in^2, this results in a 600 psi pressure.

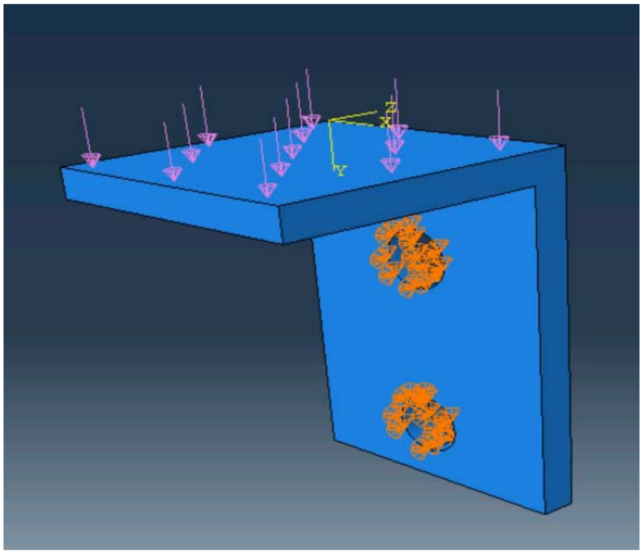


Figure 15: Boundary conditions modeled for B01 - Supporting L Bracket using Abaqus.

Expectations: The critical points on this part are expected to be the stress concentration at the 90 degree bend and the stress concentration at the holes.

Results:

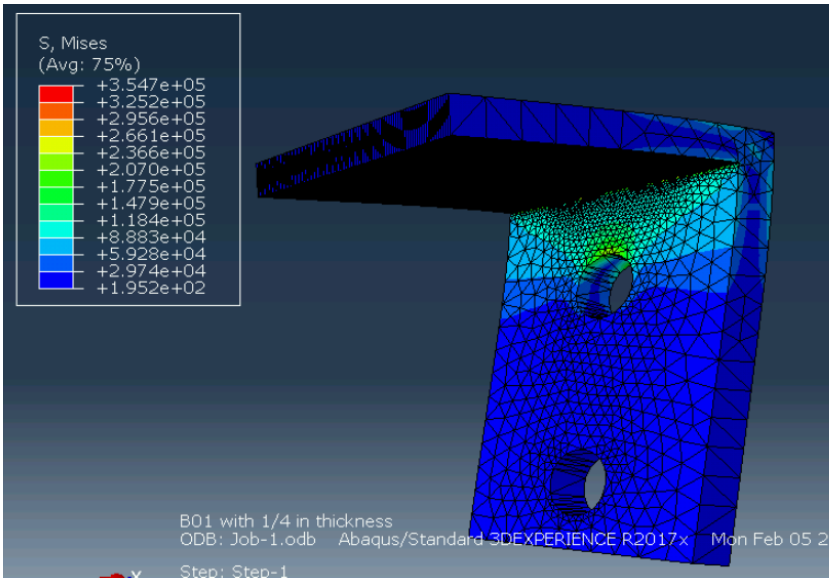


Figure 16: 3D model of the projected stresses experienced by B01 with predicted loading conditions using Abaqus.

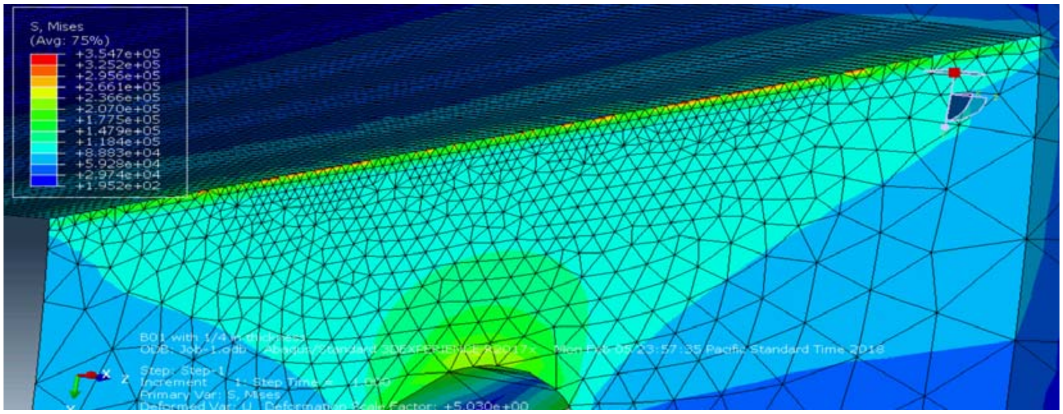


Figure: 17: Enlarged image of the projected stresses experienced at the inside corner of B01 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Unfortunately, this piece is predicted to experience yielding and significant deformation under the given loading situations. While the highest stress concentrations were at the predicted locations, the part also fails in between the holes and the bend. However, it is worth noting that the stress at the bend is likely exaggerated, as a perfect 90 degree bend is not a realistic part for us to purchase. However, this FEA simulation suggests that L-brackets are likely not the best choice for this component. As a result, the team has shifted to using a 0.5 inch metal sheet to support the Compression Chamber instead.

B02: Output Fulcrum Support L Beam (Initial)

Boundary Conditions:

For this piece, the faces on the inside of the horizontal pair of holes is fixed, which represents the bolts that would keep the part in place. Additionally, the faces on the inside of the vertical pair of holes experience a surface traction of 6.00×10^3 psi applied to them normal to the face of the L-bracket. This represents the fact that this part needs to withstand 2,400 lbs as shown in Figure 12, and the inside area of each hole is 0.20 in^2. As a result, this surface traction represents 2,400 lbs of upwards force being evenly distributed along the holes.

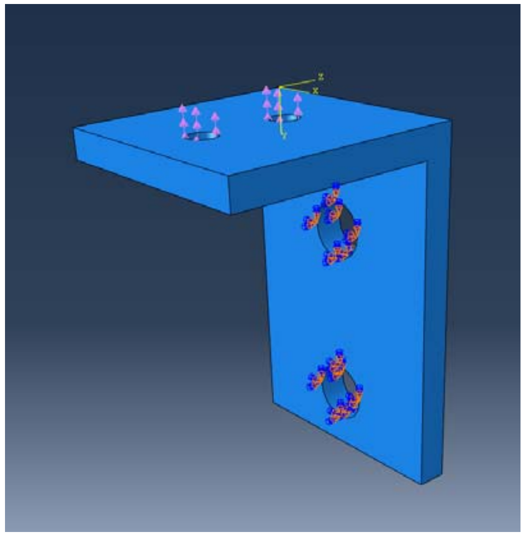


Figure 18: Boundary conditions modeled for B02 - Output Fulcrum Support L Beam.

Expectations:

Similar to B01, this part's critical points are at the bend and the holes. Failure is expected to occur due to bending or shear.

Results:

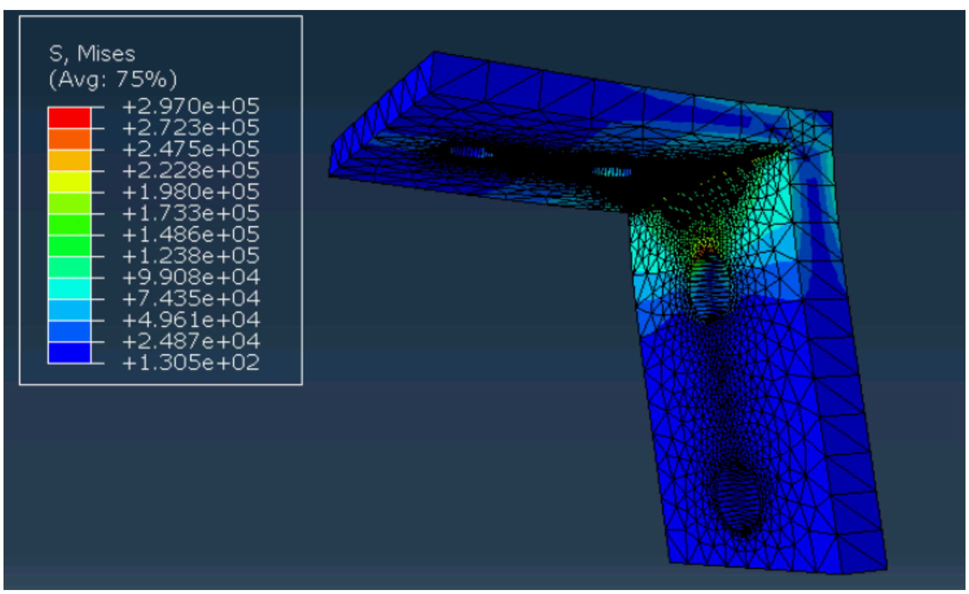


Figure 19: 3D model of the projected stresses experienced by B02 with predicted loading conditions using Abaqus.

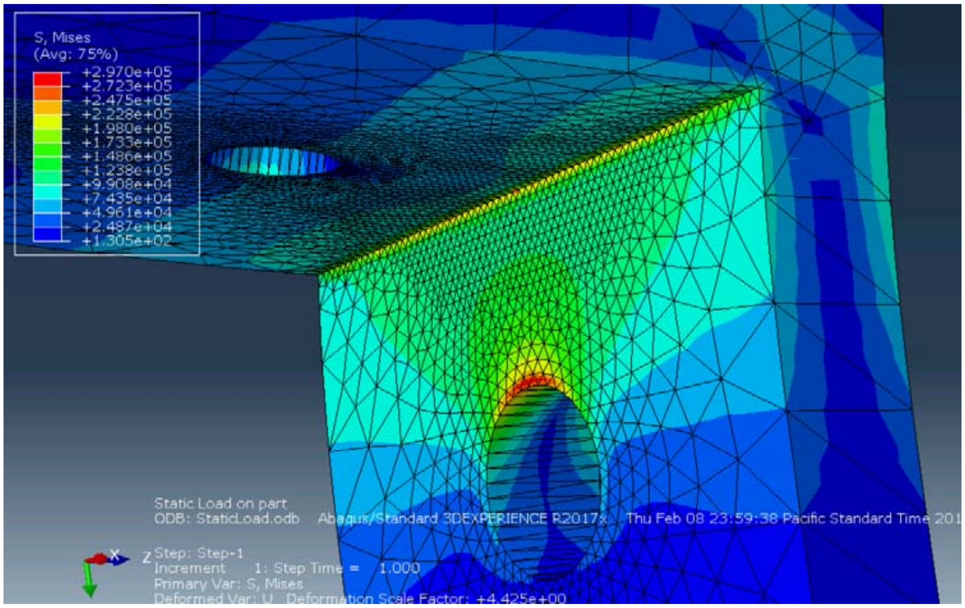


Figure 20: Enlarged image of the projected stresses experienced at the inside corner of B02 with predicted loading conditions using Abaqus.

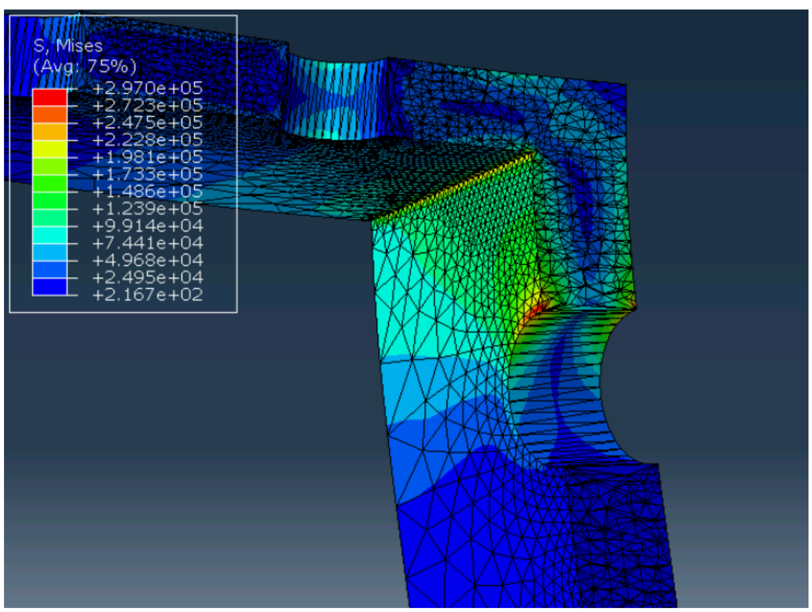


Figure 21: Cross-sectional view of the projected stresses experienced by B02 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Again, the L-bracket design fails at the predicted critical points, as well as the area in between the bend and the holes. With this piece, it is worth considering the fact that unrealistic boundary conditions may lead to exaggerated results. To remedy this, a small radius of curvature could be added to the inside of the angle. This would be a more realistic representation and will likely significantly reduce the stress concentration in that area. Additionally, even though the part is being pulled upwards, it is the top of the hole that is experiencing the stress concentration, which is not possible. A more realistic boundary condition at these points can be modeled by partitioning the inside face of the hole to a top and bottom region, and only fix the bottom region. This would more accurately represent the reactionary force created by a bolt. Considering all of these potential modifications, another updated FEA simulation should be run before it is concluded that this part fails and a redesign of the L-bracket support members.

B02 (Additional Iterations)

Adding Curvature to the Model and Improving Boundary Conditions

One of the issues with this model is that the sharp 90 degree angle of the bracket likely creates exaggerated stress concentrations. To combat this, a fillet of 0.1 inches was given to the part, which was an educated estimate as to the actual curvature of the part. Additionally, as shown in Figure 23 below, the hole was partitioned such that only the bottom face was fixed, with was meant to more accurately represent a bolt interacting with it.

Boundary Conditions:

As mentioned above, the bottom faces of the holes were fixed to better simulate a bolt interaction. As for the forces, they were applied using a surface traction on the holes in the same way as the first iteration. This time, however, the load was reduced to $3.625\text{x } 10^3$ psi to simulate the 1450 lbs-f load experienced by each L-bracket on the front legs (B05A/B).

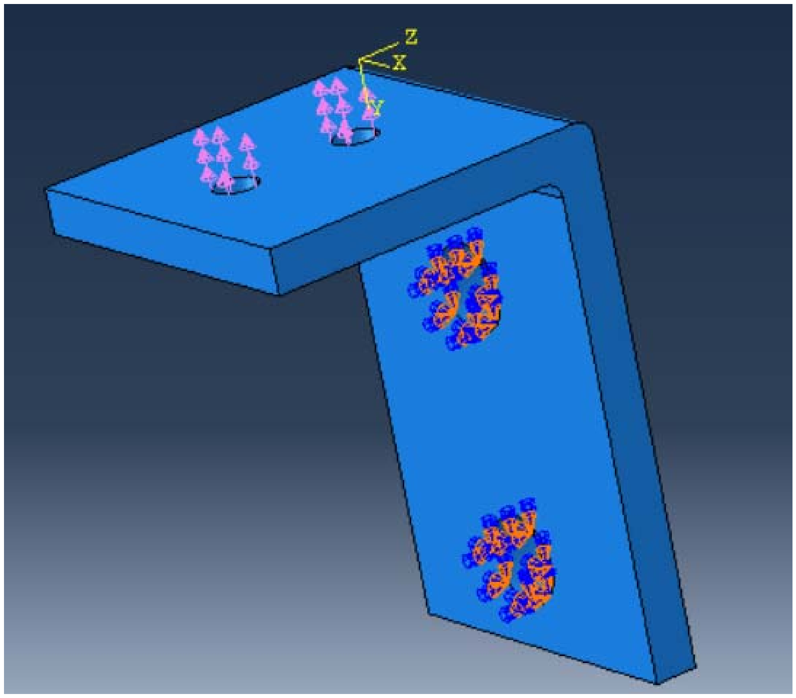


Figure 22: Boundary conditions modeled for the new iteration of B02.

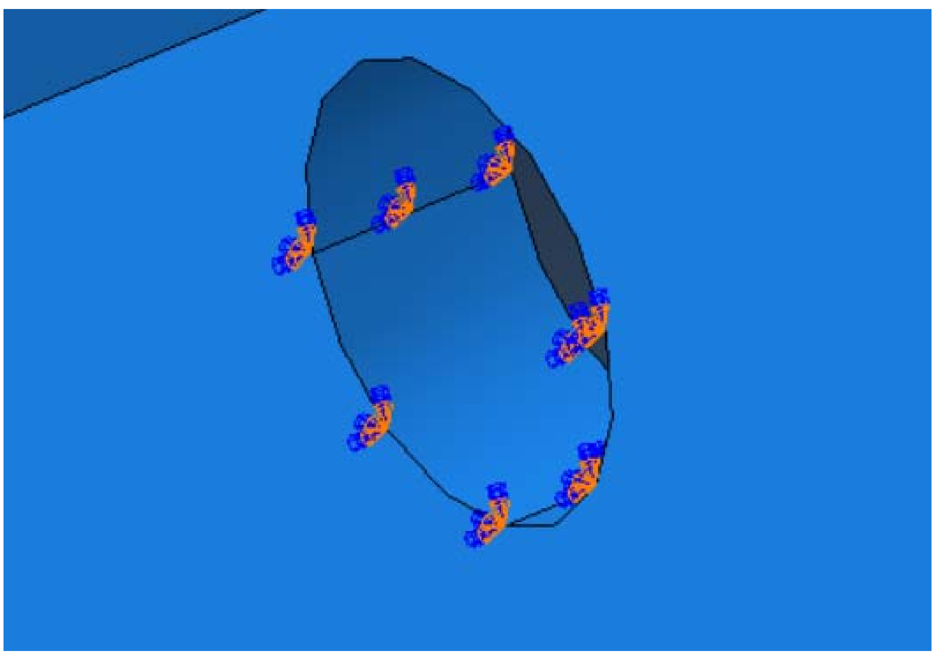


Figure 23: Close-up of boundary condition modeled for the new iteration of B02.

Results:

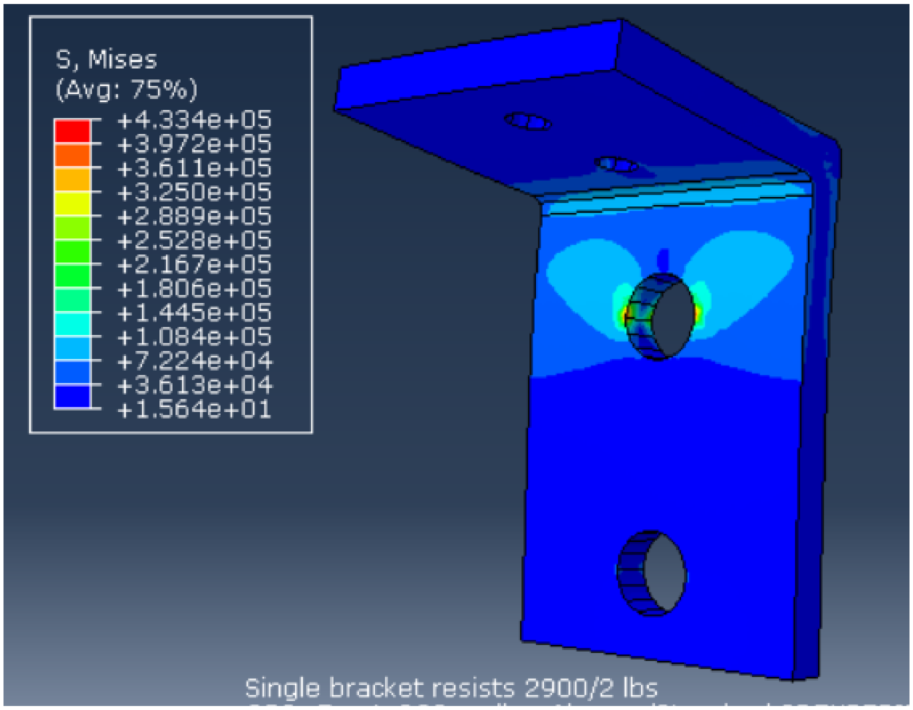


Figure 24: 3D model of the projected stresses experienced by iterated B02 with predicted loading conditions using Abaqus.

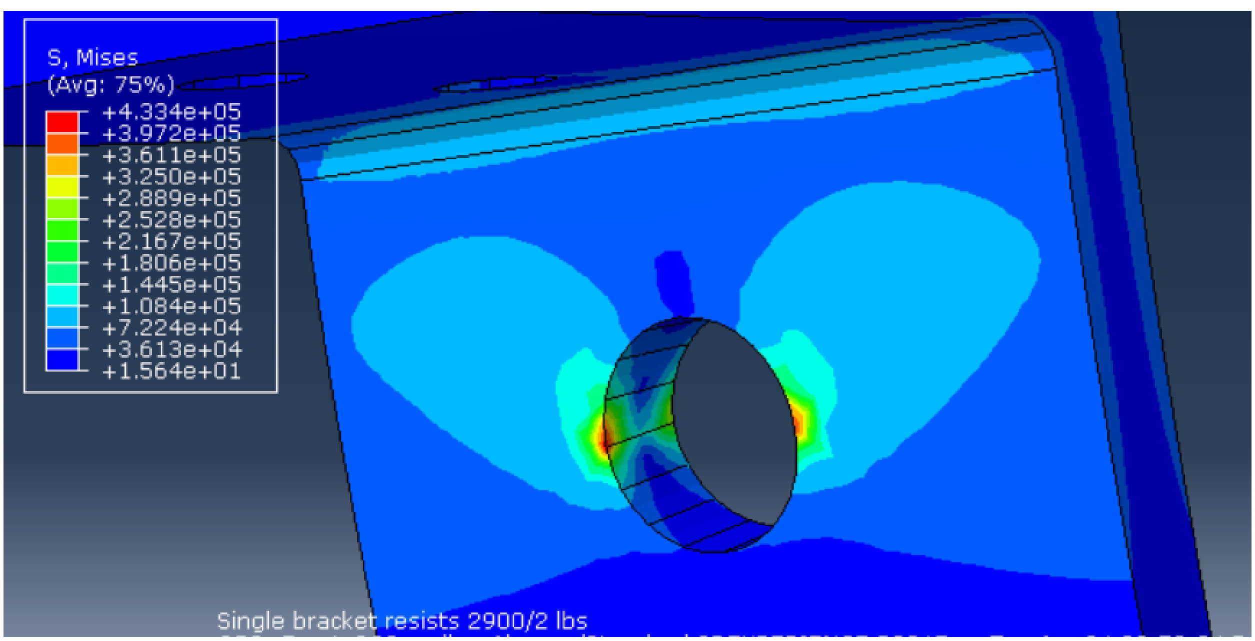


Figure 25: Close-up of highest stresses from Figure 24.

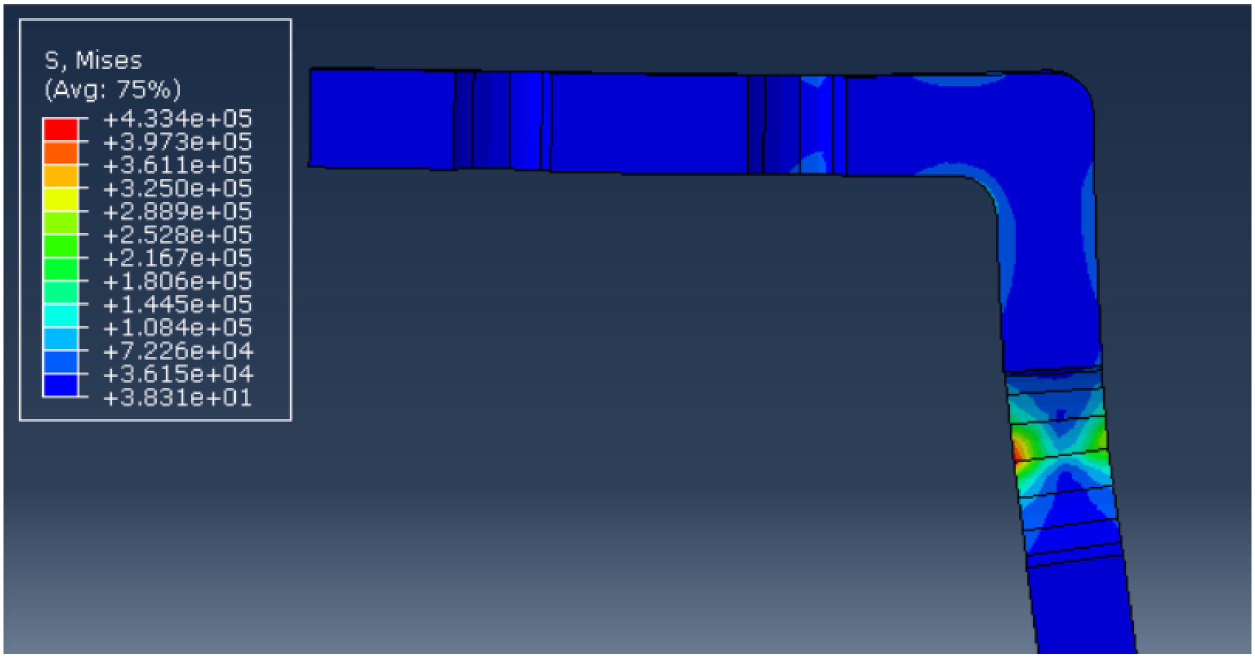


Figure 26: Cross-section of 3D model of the projected stresses experienced by iterated B02 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Unfortunately, even for the 1450 lbs-f scenario, the stresses were still more than the part could handle. As a result, all four B02 pieces can fail even with these revisions. As a result, it was necessary to update the part itself, as opposed to simply the CAD.

Stacking 2 L-Brackets on Top of One Another

One idea that was tested was stacking 2 L-brackets on top of one another to see if the two of them together would be able to withstand the load. This test was done in SolidWorks, since assemblies are much easier to do with this software.

Boundary Conditions:

To complete this simulation, the back of the outside L-bracket was given a fixed boundary condition. This was done such that the simulation could be run by SolidWorks. Next, the holes were given a distributed upwards load (something that can be done in SolidWorks, but not Abaqus) of 1450 lbs-f for one simulation and 2400 lbs-f for another simulation.

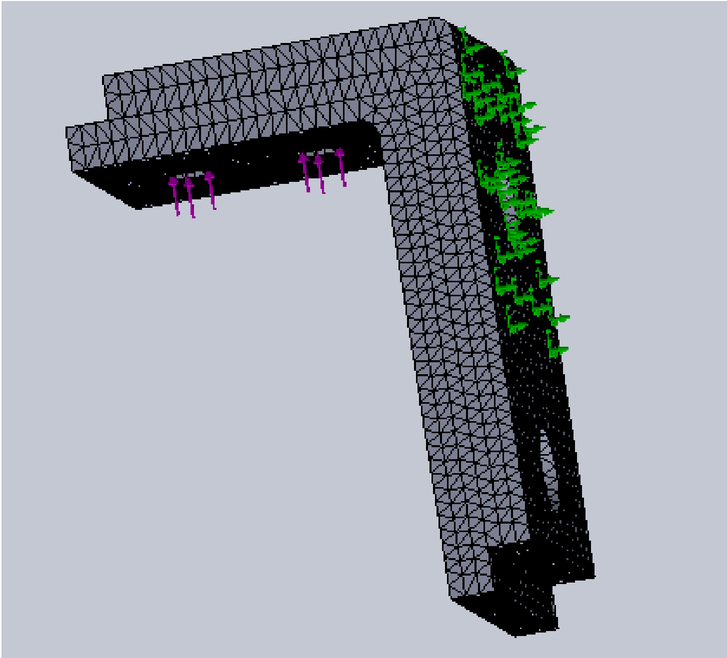


Figure 27: 3D model of the boundary conditions for the SolidWorks simulation for two B02 units stacked together.

Results:

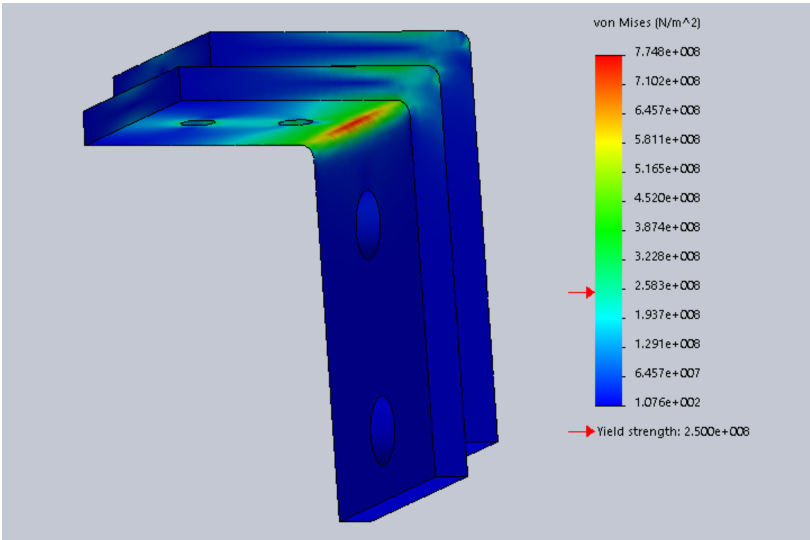


Figure 28: Results of the simulation from Figure 27 for a total applied load of 1450 lbs-f.

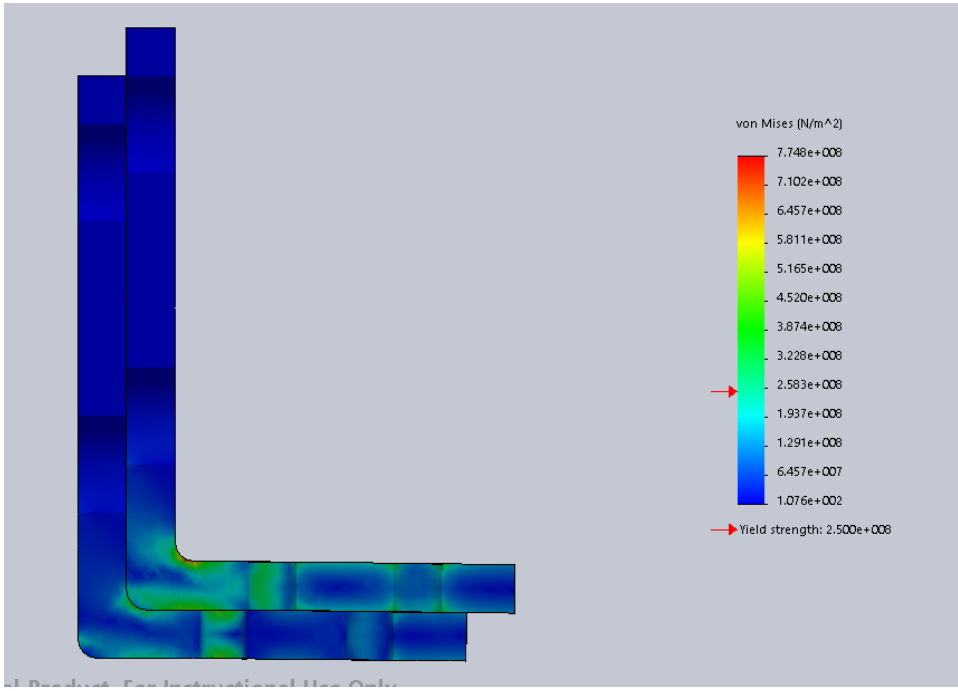


Figure 29: Cross-section of results of the simulation from Figure 27 for a total applied load of 1450 lbs-f.

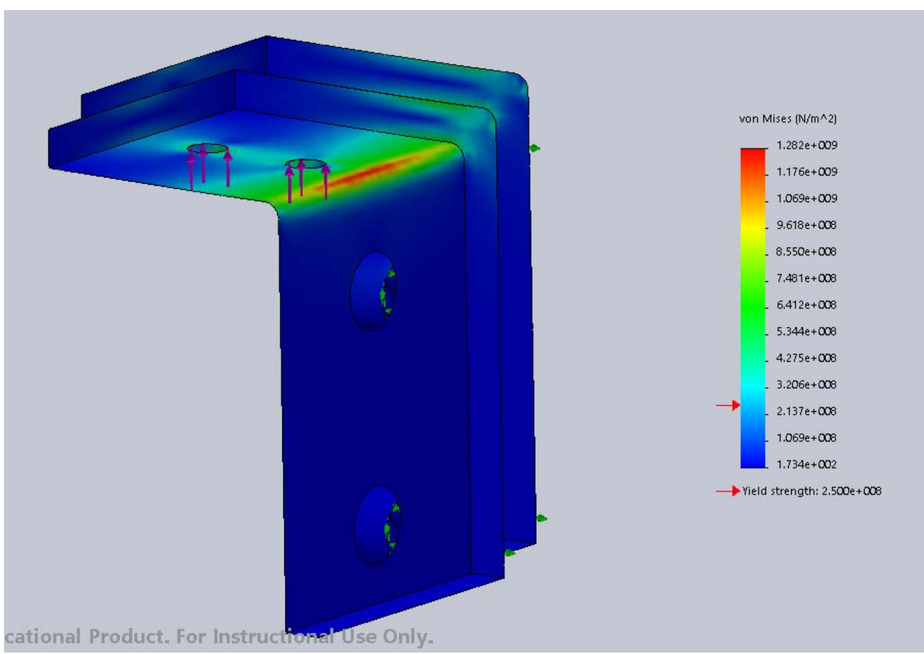


Figure 30: Results of simulation from Figure 27 for a total applied load of 2400 lbs-f.

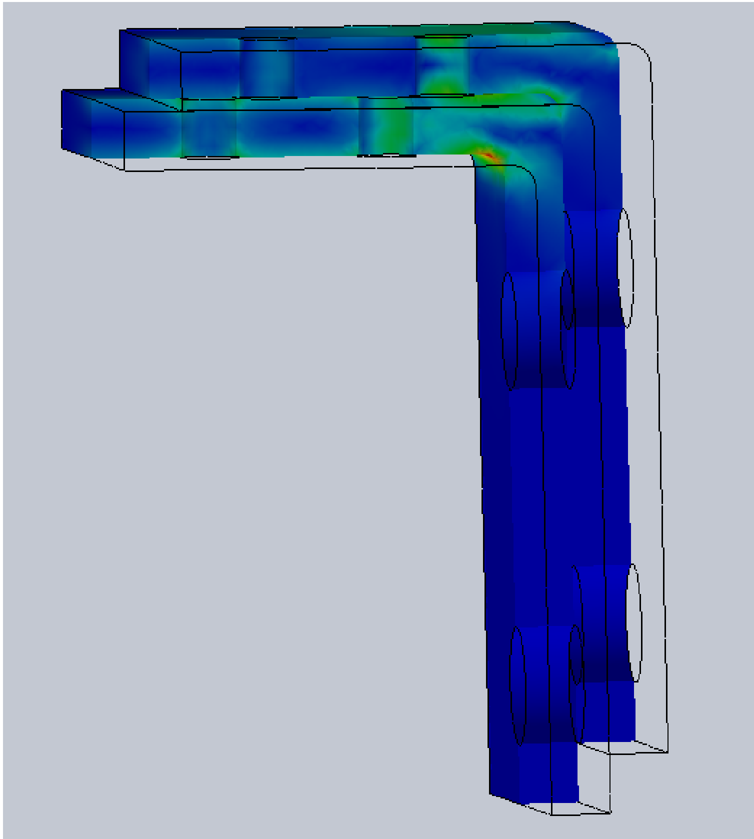


Figure 31: Cross-section of results of the simulation from Figure 27 for a total applied load of 2400 lbs-f

Interpretation and Discussion:

Unfortunately, it appears that stacking the parts on top of one-another did not achieve the desired result. In both cases, the parts still fail.

Welding 2 L-Brackets Together

One final idea that the team came up with was welding the 2 L-brackets together such that they essentially became one thick piece. Once again, this was tested for both the 1450 lbs-f and 2400 lbs-f scenarios.

Boundary Conditions:

The boundary conditions of this simulation were essentially the same as those of the second iteration of this same piece. The only difference was that the surface tractions were adjusted such that the same force was still achieved. For the 2400 lbs-f and 1450 lbs-f scenarios, this meant surface tractions of 3.056×10^3 psi and 1.846×10^3 psi respectively, as the new area over which the force was applied was 0.7854 square inches.

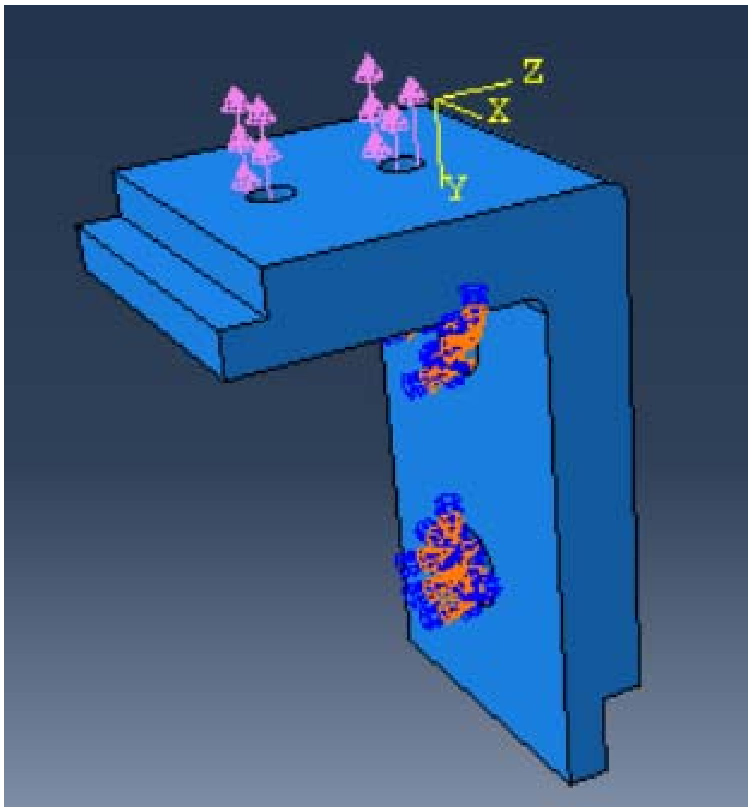


Figure 32: Boundary conditions modeled for the new iteration of B02.

Results:

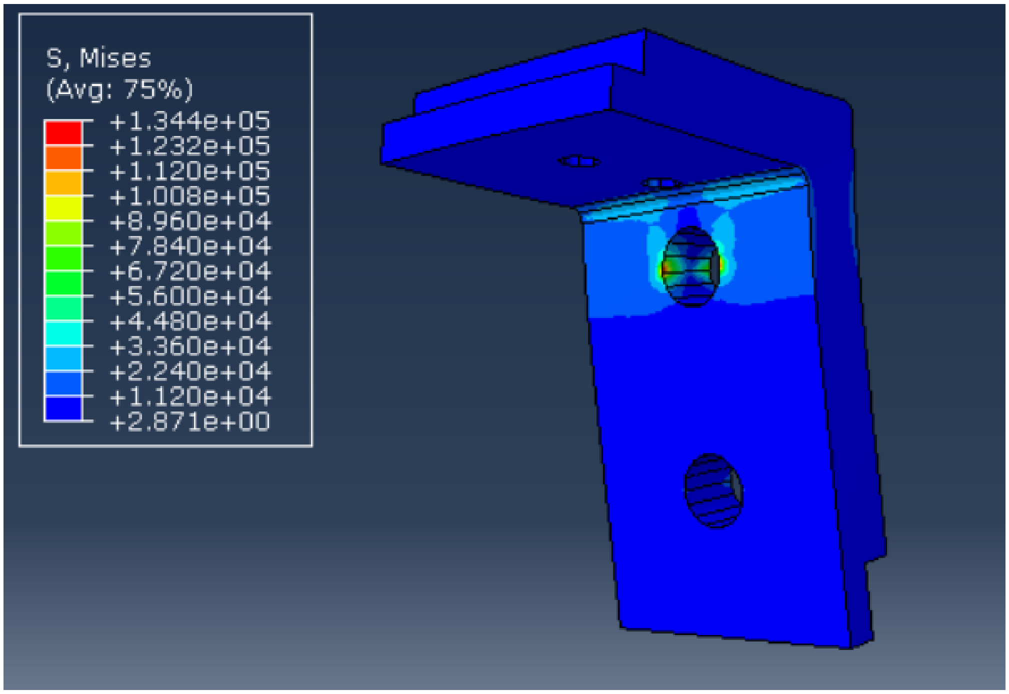


Figure 33: 3D model of the projected stresses experienced by iterated B02 with predicted loading conditions using Abaqus for total applied load of 1450 lbs-f.

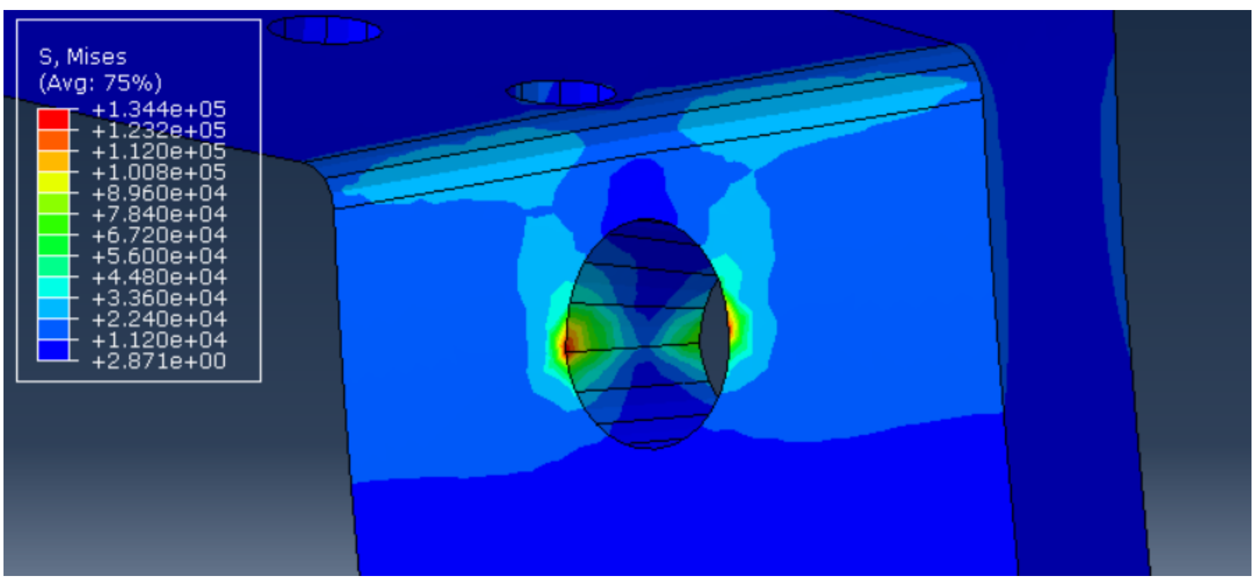


Figure 34: Close-up of stress concentrations of Figure 33.

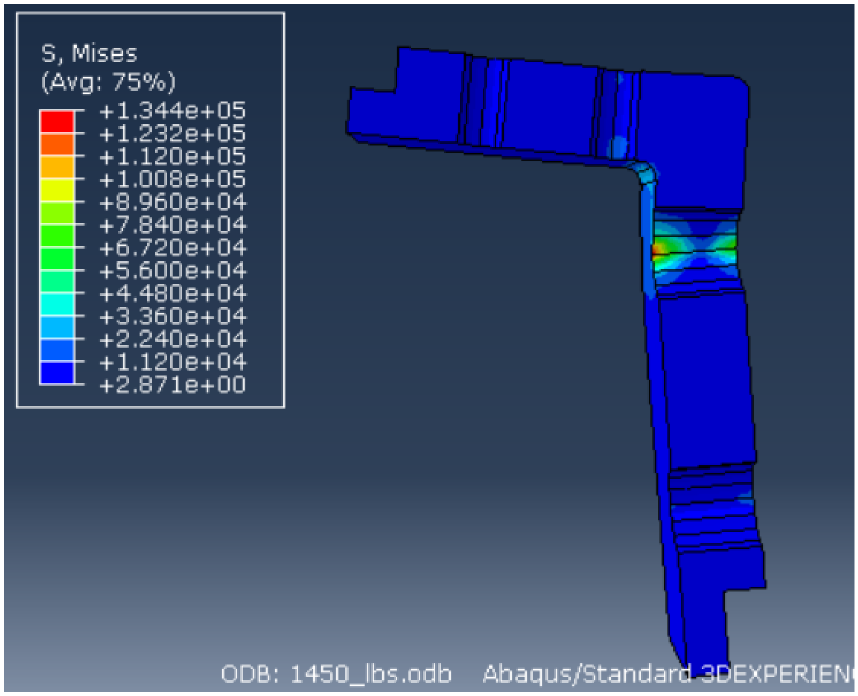


Figure 35: Cross-section of 3D model of the projected stresses experienced by iterated B02 with predicted loading conditions using Abaqus for total applied load of 1450 lbs-f.

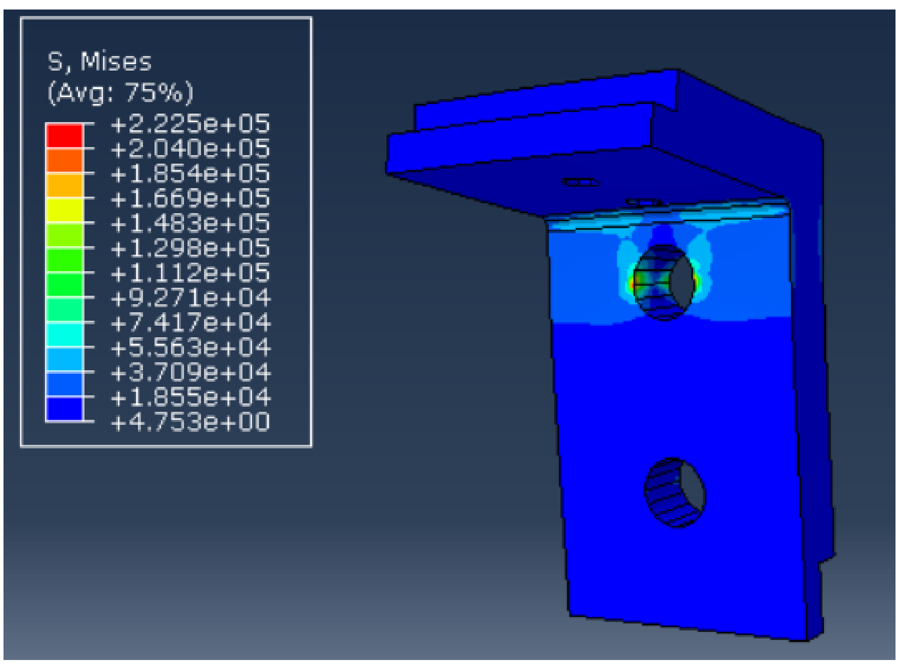


Figure 36: 3D model of the projected stresses experienced by iterated B02 with predicted loading conditions using Abaqus for total applied load of 2400 lbs-f.

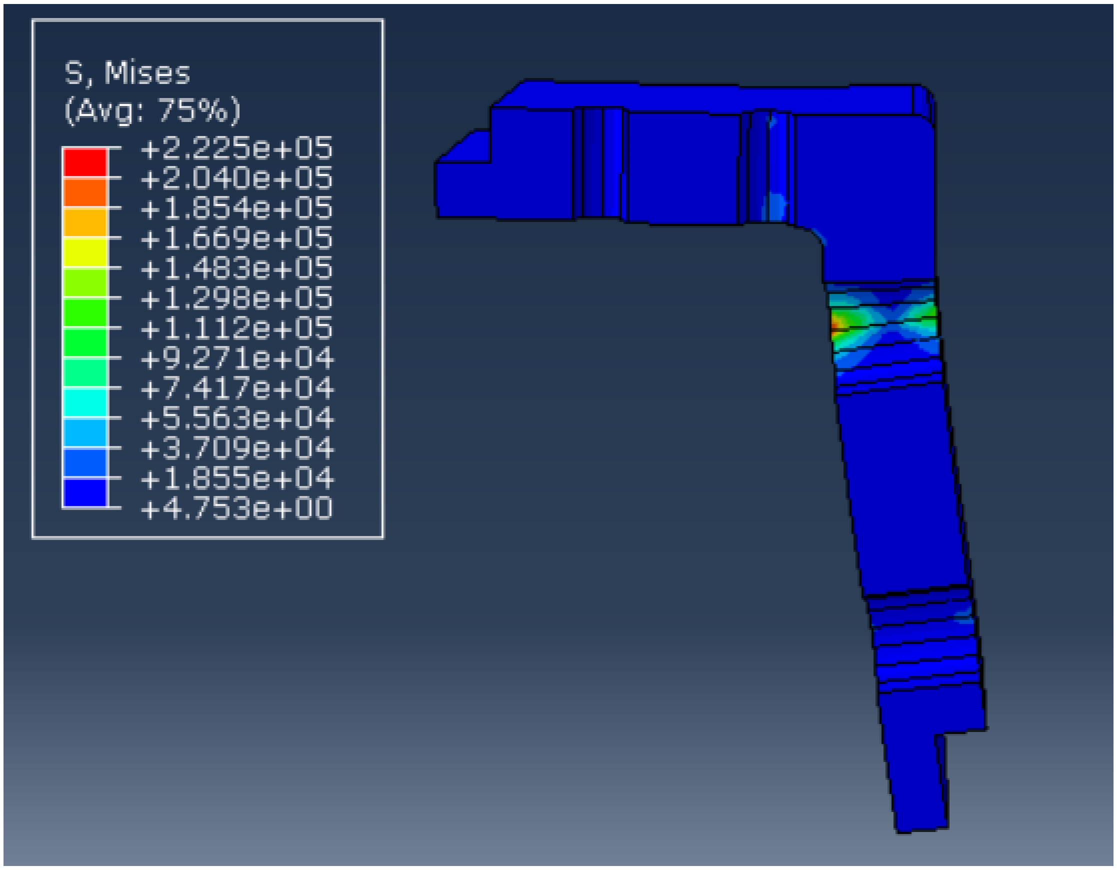


Figure 37: Cross-section of Figure 36.

Interpretation and Discussion:

For the 1450 lbs-f scenario, the part is safe everywhere except for the stress concentrations shown in Figure 34. To fix this, one may consider adding more bolt holes on the same horizontal plane to distribute the load. Alternatively, one could consider welding the part to the leg, as welding such a piece would likely not reduce the shipability of the leg. As for the 2400 lbs-f scenario, the inside curve of the bracket experiences a little too much stress. This could be remedied by welding a piece to the inside of the bracket to assist in resisting the bending. Other than that, it has the same issue as the 1450 lbs-f scenario.

B03: Output Fulcrum Supporter

Boundary Conditions:

As can be seen in Figure 38, one face of B03 is fixed in place, which represents the contact stress area that it has with the output fulcrum beam. The inside of the large hole in this figure is given a downwards tractionary force of 6.51×10^3 psi, which represents the force due to lever compression at an input of 200 lbs-f. This expected stress comes from the 7,700 lbs-f load shown in Figure 12 as it is distributed over 2 L-brackets, which is divided by the 0.59 in^2 area of the inside face of the hole.

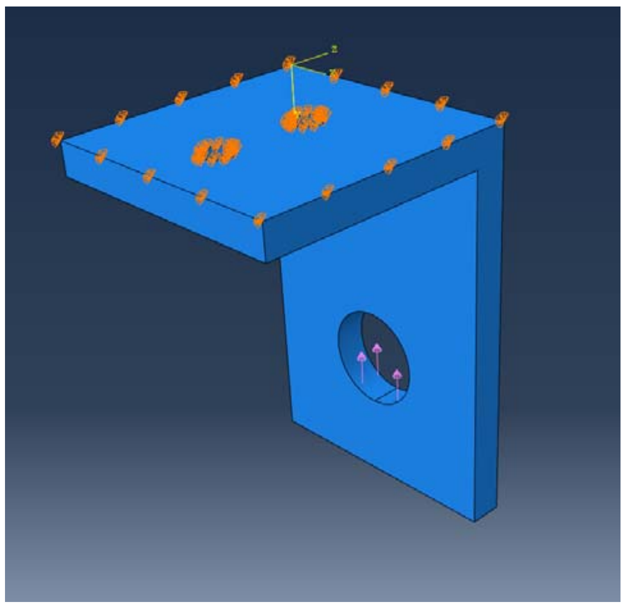


Figure 38: Boundary conditions modeled for B03 - Output Fulcrum supporter using Abaqus.

Expectations:

The critical region of this part is the area between the large hole and the fixed bottom through compressive stress. Failure is expected to occur at the large hole from bearing stress, and at the right angle of the part from bending.

Results:

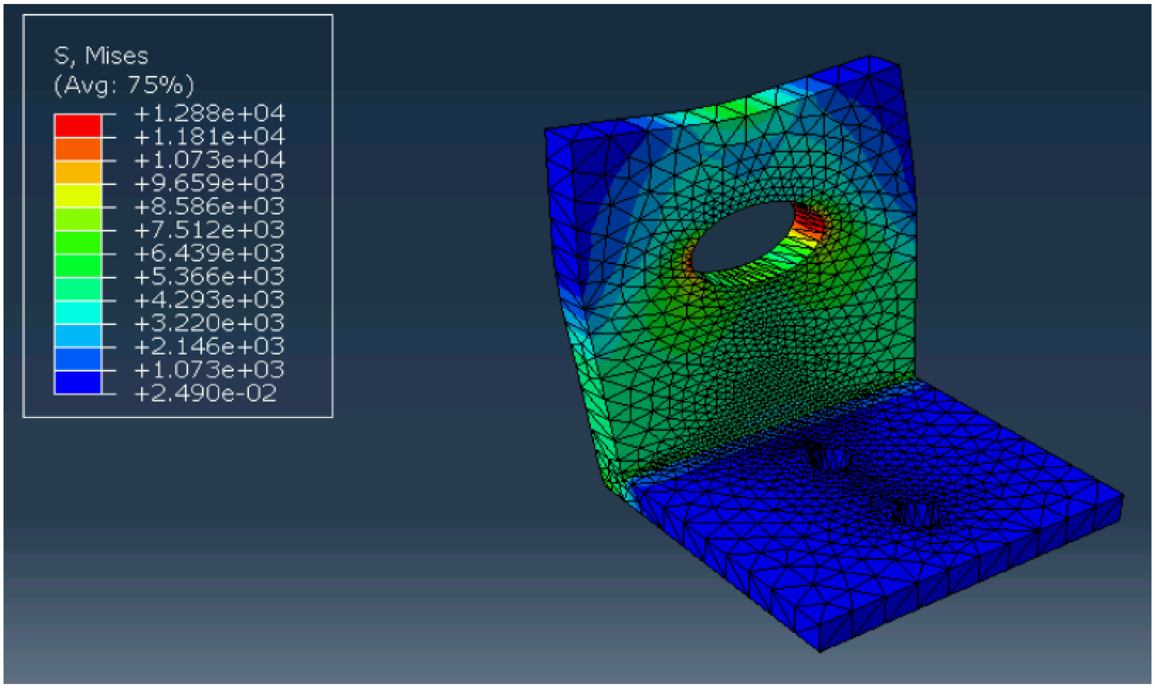


Figure 39: 3D model of the projected stresses experienced by B03 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

As all stresses experienced by the part are below the yield point of the material, this part is not expected to experience failure or significant deformation under the given loading conditions.

B04: Input Fulcrum L-Bracket

Boundary Conditions:

To simulate the loading on this piece, the part of the piece that will be in contact with part B06 - Input fulcrum support beam, was given a fixed boundary condition. On the top of the inside of the hole that the input lever will be interacting with, a surface traction of 3.226 x10^3 psi was applied in the x-direction, as shown below.

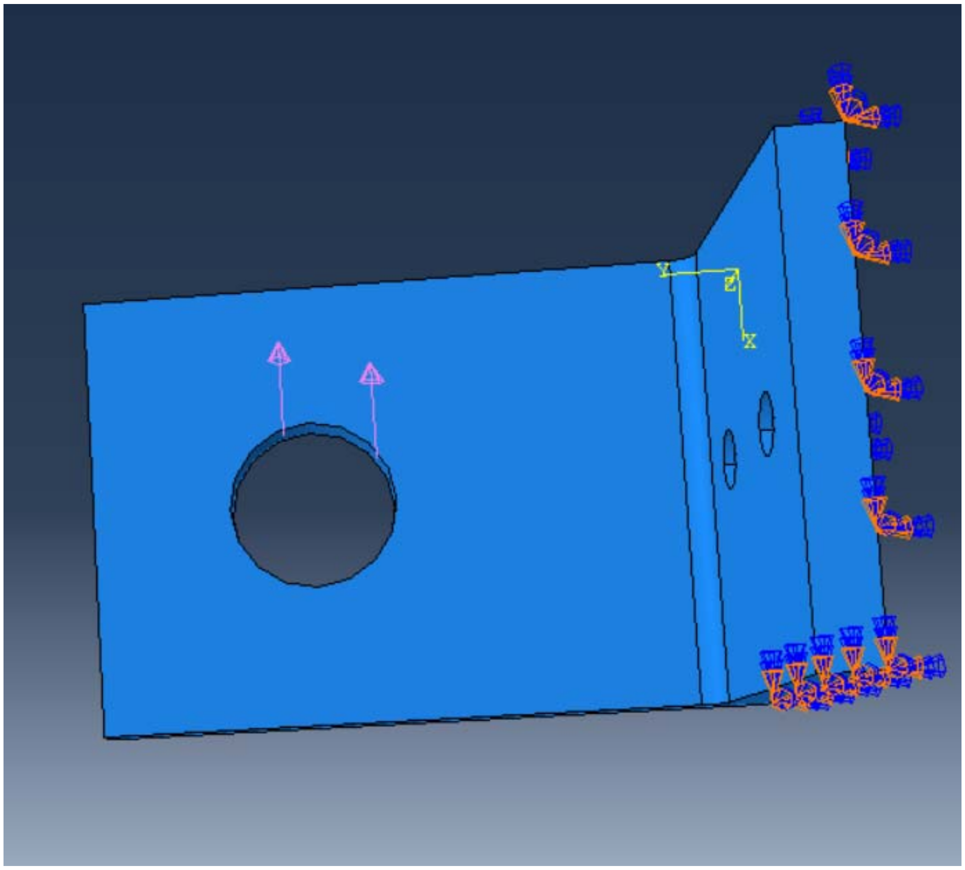


Figure 40: Boundary conditions modeled for part B04 using Abaqus.

Expectations:

This piece was also simulated as part of a SolidWorks assembly FEA, which suggested that the part would survive. However, as this part was important with a high perceived risk, it was determined that it should be simulated by itself in abaqus.

Results:

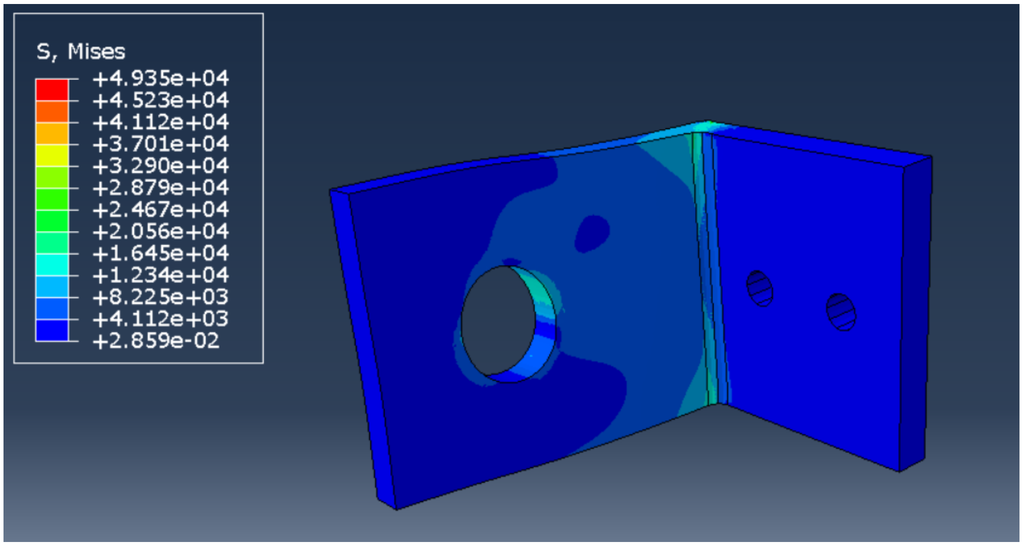


Figure 41: 3D model of the projected stresses experienced by B04 as a result of predicted loading conditions using Abaqus.

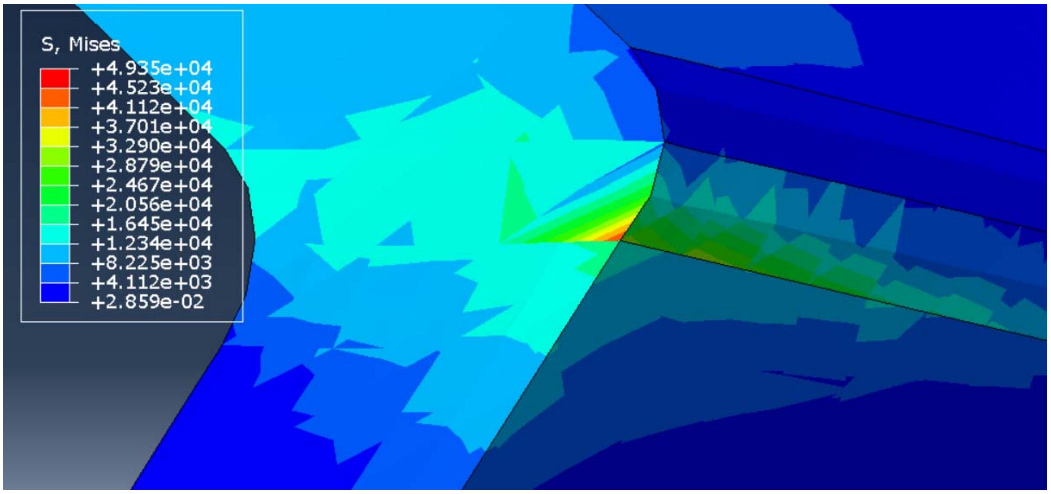


Figure 42: The results of Figure 41 with a focus on the back corner of the L-bracket.

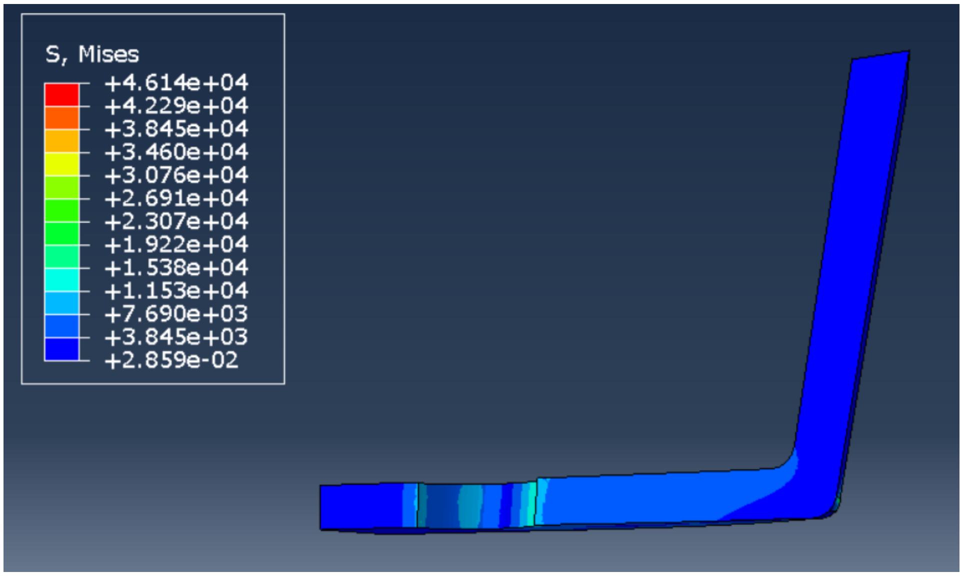


Figure 43: 3D model of the projected stresses of the cross section of part B04 as a result of predicted loading conditions using Abaqus.

Interpretation and Discussion:

According to the results, the only place on B04 that was shown to have a stress concentration high enough to cause failure is at the edge of the fixed boundary condition. However, this is simply a fictitious stress caused by the boundary conditions selected, and would not exist in the actual part.

B05A/B: Front Legs

Boundary Conditions:

No Hard Stop: In this situation, which is demonstrated by Figure 12, the legs will experience shear if the Compression Plate and Lever Arm subsystems are not able to achieve full compression of the clay. This also corresponds to the hard-stop not being reached by the Lever Arm subsystem. In this scenario, shown by Figure 44, the bottom of the leg is fixed.

The bottom pair of holes are experiencing a downwards traction of 2.67×10^5 psi, which is the result of the 9,600 lbs distributed among the four base legs as seen in Figure 12, where each leg is represented with two holes and 4.50×10^{-2} square inches per hole.

The middle pair of holes experience an upwards traction, which is the result of the 1,900 lbs shown in Figure 12 distributed over 2 legs, each leg with 2 holes and $2.56x10^{-1}$ in^2.

Finally, the top pair of holes shown in Figure 44 experience an upwards traction of $1.61x10^4$ psi applied to the inside face of the holes, which results from the 2,900 lbs force shown in Figure 12 distributed over 2 legs, each over 2 pairs of holes with an inside area of $4.50x10^{-2}$ in^2 each. For all loading scenarios, it was assumed that only the pair of holes on the front side of the piece would bear any of the loads.

Hard Stop: In this scenario, the Lever Arm has achieved the full range of compression of the clay and is hitting the hard-stop. The bottom of each leg was modeled as fixed. Because of the complex angles and interactions involved in this loading situation, this piece cannot be simulated by itself. Instead, it needs to be simulated as an assembly in Solidworks, which is shown in the results as Figure 49. This simulation included the two front legs (B05A/B), the two back legs (B06 & B04), the hard stop, and simulated bolts. The purple arrows pointing upwards on the assembly represent the force being applied to the inside of the holes of the two B04 pieces. Each hole experiences 850 lbs of force as a result of the 1,700 lb-f distributed load on both B04 pieces (Figure 13). The orange arrows represent the 2,530 lb force applied by the hard stop also shown in Figure 13.

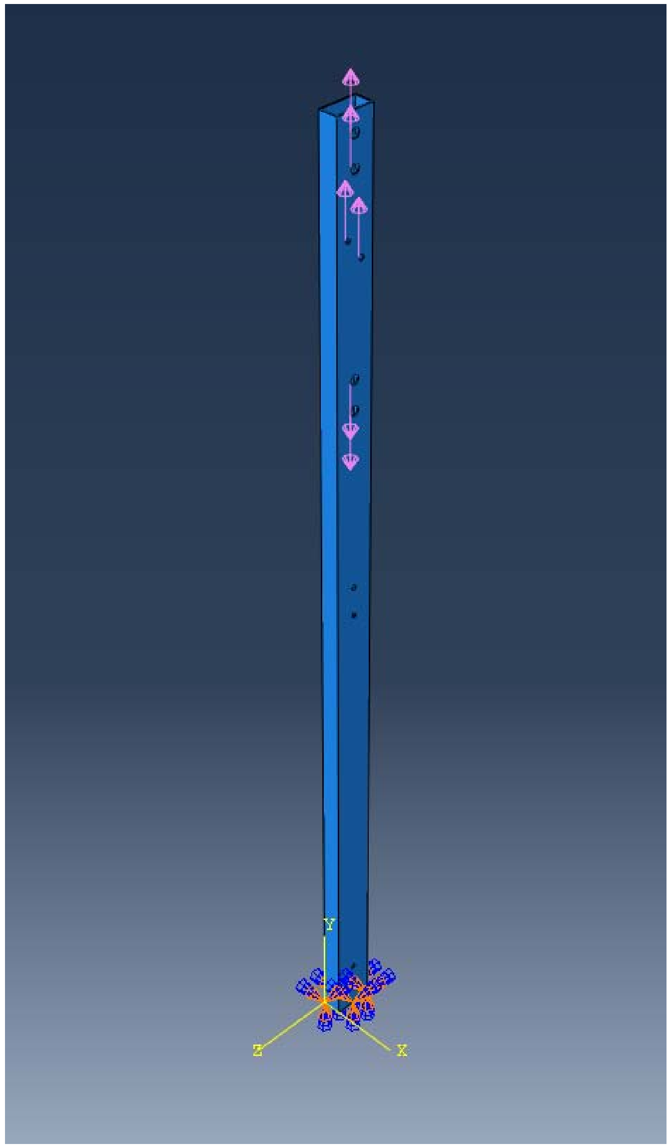


Figure 44: Boundary conditions modeled for “B05A/B - Front Legs”, upon the Lever Arm not being able to fully compress the clay to the “hard-stop” limit of the device.

Expectations:

In the loading situation where no hard-stop is present, B05A/B are most likely to fail as a result of the shear caused by the contact stress of the bolts at the various holes. This indicates that the most likely point of failure would be bending caused by the moments generated by the irregular force inputs, as well as the stress concentrations at the holes. Buckling of the base legs is also of concern to this design. Unlike the scenario where there is no hard-stop, each base leg is now experiencing compression as opposed to tension.

Results:

No Hard Stop:

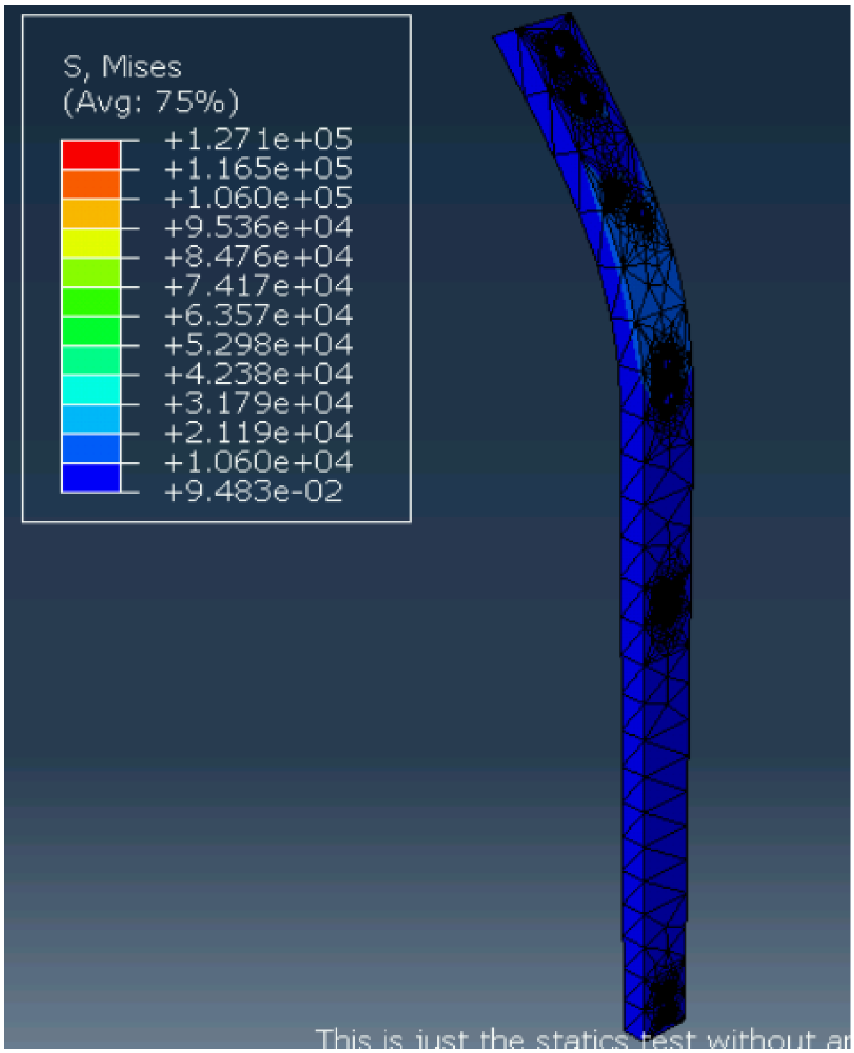


Figure 45: 3D model of the projected stresses experienced by B05A/B with predicted loading conditions using Abaqus.

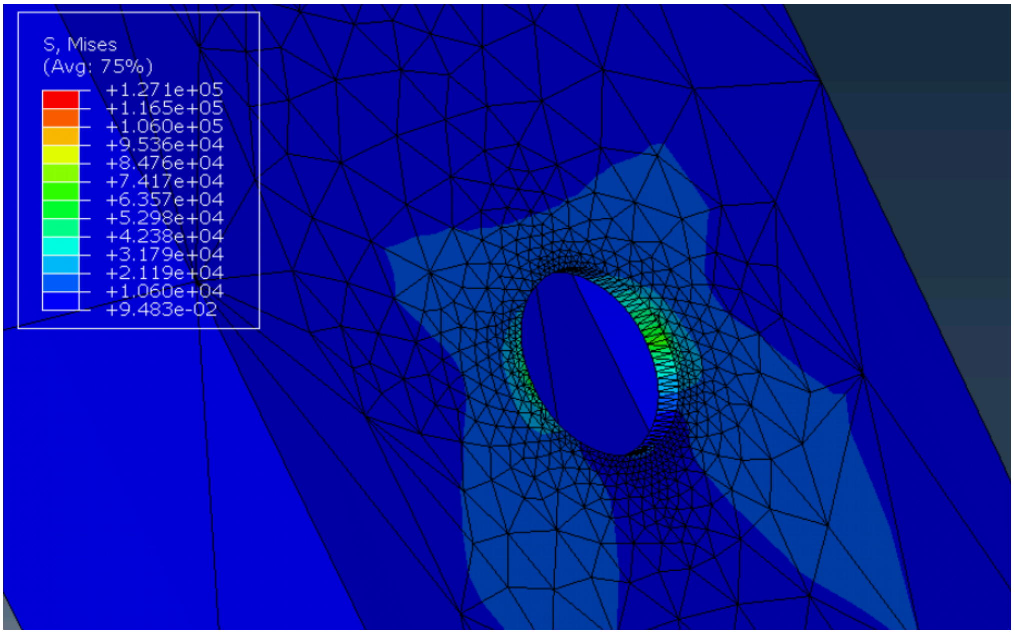


Figure 46: Enlarged image of the projected stresses experienced at the top hole of B05A/B with predicted loading conditions using Abaqus.

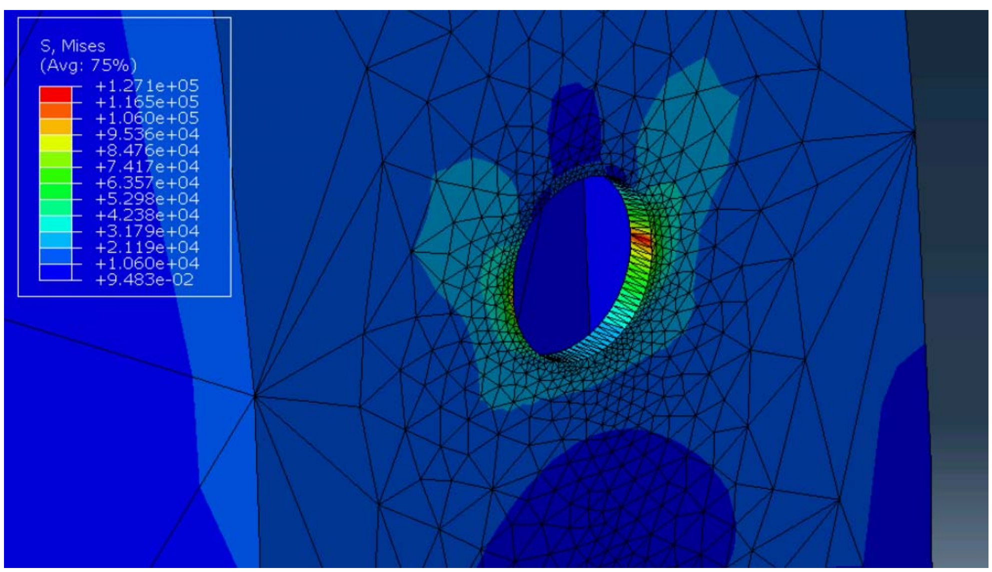


Figure 47: Enlarged image of the projected stresses experienced at the bottom hole of B05A/B with predicted loading conditions using Abaqus.

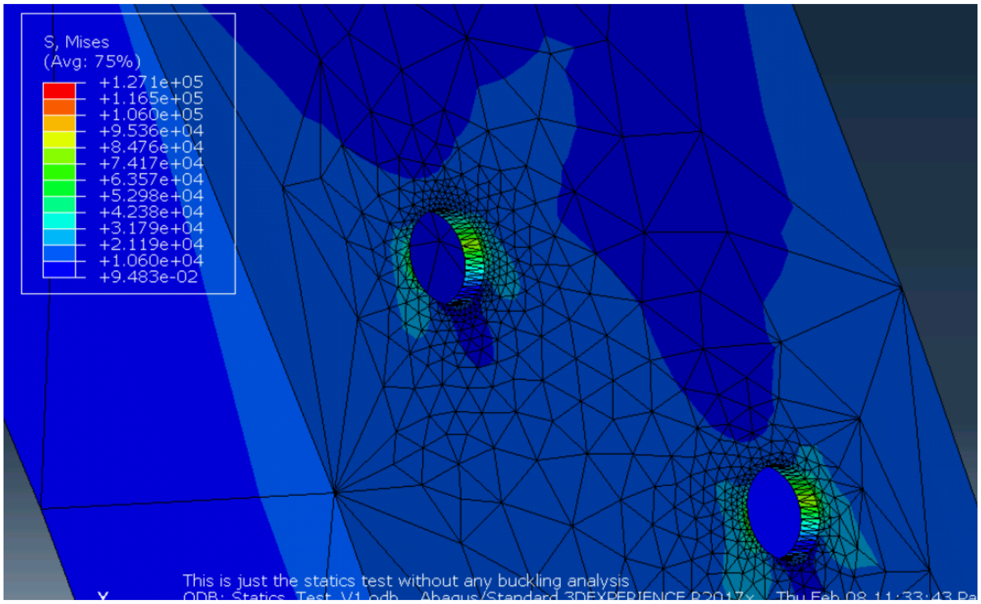


Figure 48: Enlarged image of the projected stresses experienced at the middle holes of B05A/B with predicted loading conditions using Abaqus.

Hard Stop:

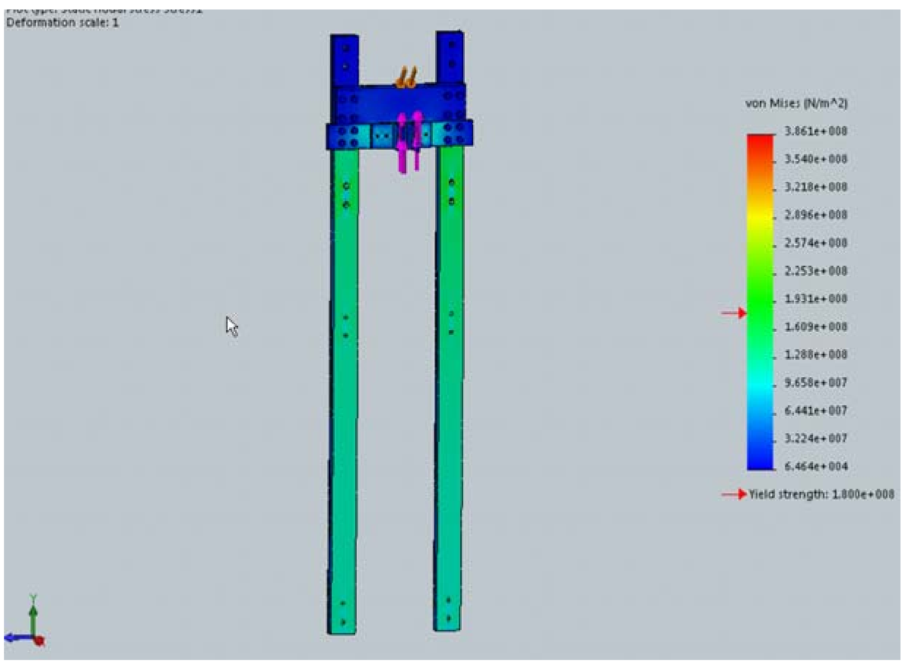


Figure 49: 3D model of the projected stresses experienced by the hard stop with predicted loading conditions using SolidWorks.

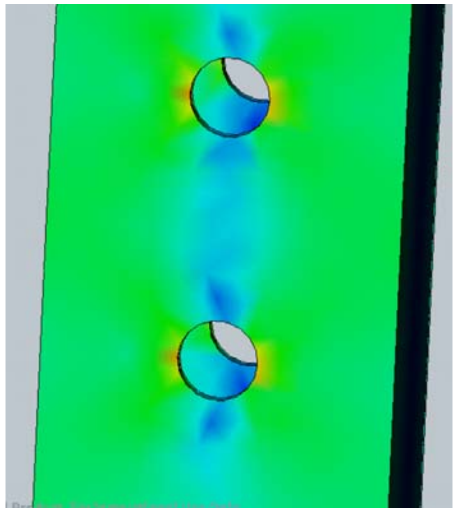


Figure 50: Enlarged image of the projected stresses at the holes beneath the fulcrum support experienced with predicted loading conditions using SolidWorks.

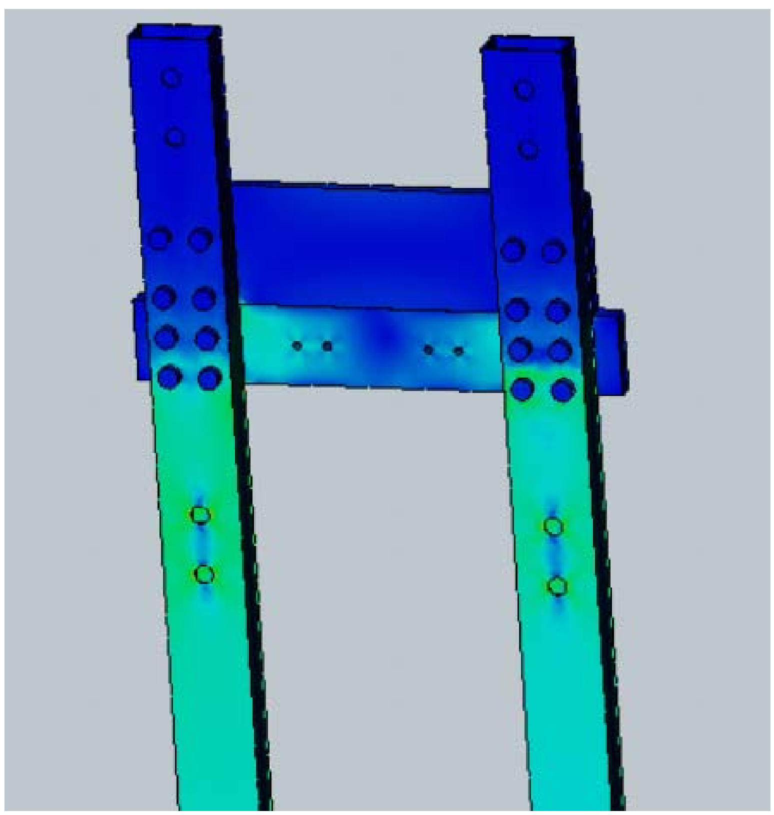


Figure 51: Enlarged image of the projected stresses experienced at the hard stop with predicted loading conditions using SolidWorks.

Interpretation and Discussion:

No Hard Stop: As can be seen from the FEA results, the front base legs B05 A/B would only fail at stress concentrations, experiencing nominal deformation. Considering that the boundary conditions are very conservative, and that the consequence of failure at these regions would be the slight deformation of the holes, it is likely that this piece will not experience yielding or significant deformation in this anticipated worst case scenario. Nonetheless, the possibility of adding more holes such that the stress can be distributed more evenly along the part will be considered.

Hard Stop: From Figure 49, it can be observed that the legs would experience stresses under the yield strength of the material, with the exception of the areas of largest stress concentration around the holes. After discussing the analysis with faculty of the Department of Mechanical Engineering at SCU, it was concluded that these concentrations are likely exaggerated, and that they are likely not a concern.

While this seems to indicate that this part is safe from failure, another concern was that of buckling of the legs from the applied loading conditions. To address this concern, a matlab code was created to find the critical buckling load for a variety of boundary conditions. Using this code, it was found that in the worst case, the critical buckling load is about $1.80x10^3$ lbs. It is clear, however, that from the fulcrum support towards the end of the base leg, the part is likely only experiencing about 200 lbs. The more realistic critical buckling load is likely smaller than this due to the additional moments introduced by the irregular loading situation. Considering that the critical load from the MatLab simulation is substantially more than what the part is actually predicted to experience, it was determined that the part is safe from failure and significant deformation under the given loading conditions. The MatLab code is shown in Figure 93.

B05C/D: Back Legs

Boundary Conditions:

In this simulation, only the holes on one side of the leg are modeled as taking all of the load. The bottom holes shown in Figure 52 have an downwards-facing surface traction applied to the inside face. This surface traction represents the shear experienced by the Base Fixture as it is supporting the Compression Chamber during compression. As shown from Figure 12, a force of 9,600 lbs is expected to be distributed to four legs, each of which use two holes with an internal surface area of $0.04.50\text{x}10^{-2}$ in^2 to support the load. This results in a traction of $2.67\text{x}10^3$ psi. The top holes are experiencing an equivalent traction in the opposite direction.

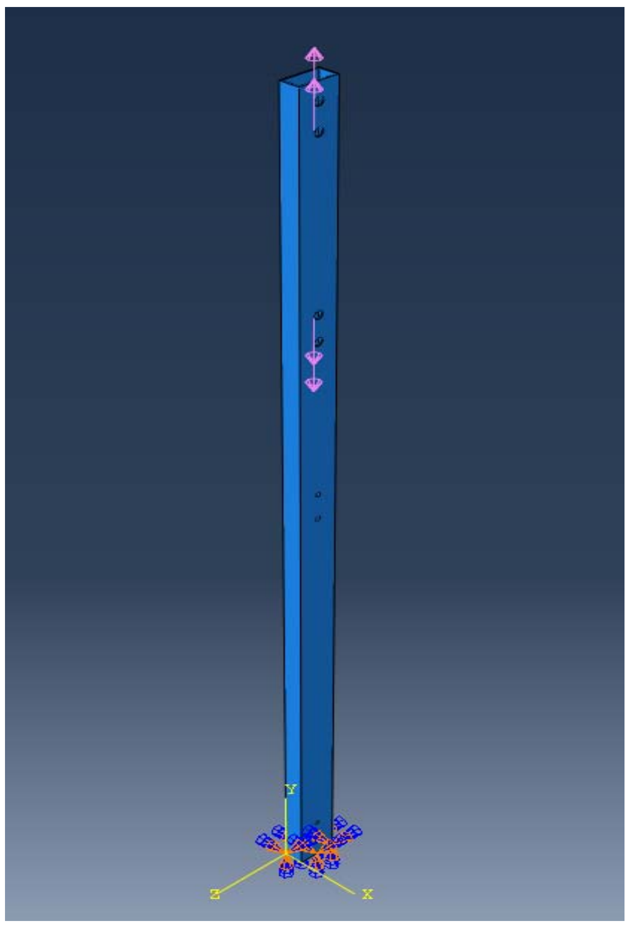


Figure 52: Boundary conditions modeled for B05C/D - Back Legs using Abaqus.

Expectations:

Similar to parts B05A/B, the primary mode of failure expected for this piece is from contact stress experienced at the holes.

Results:

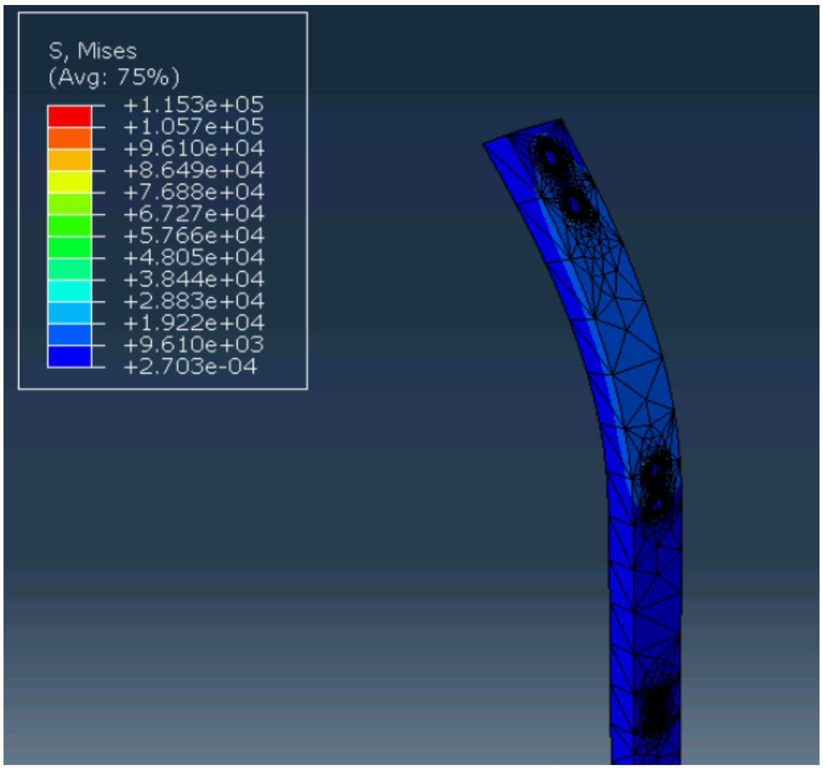


Figure 53: 3D model of the projected stresses experienced by B05C/D with predicted loading conditions using Abaqus.

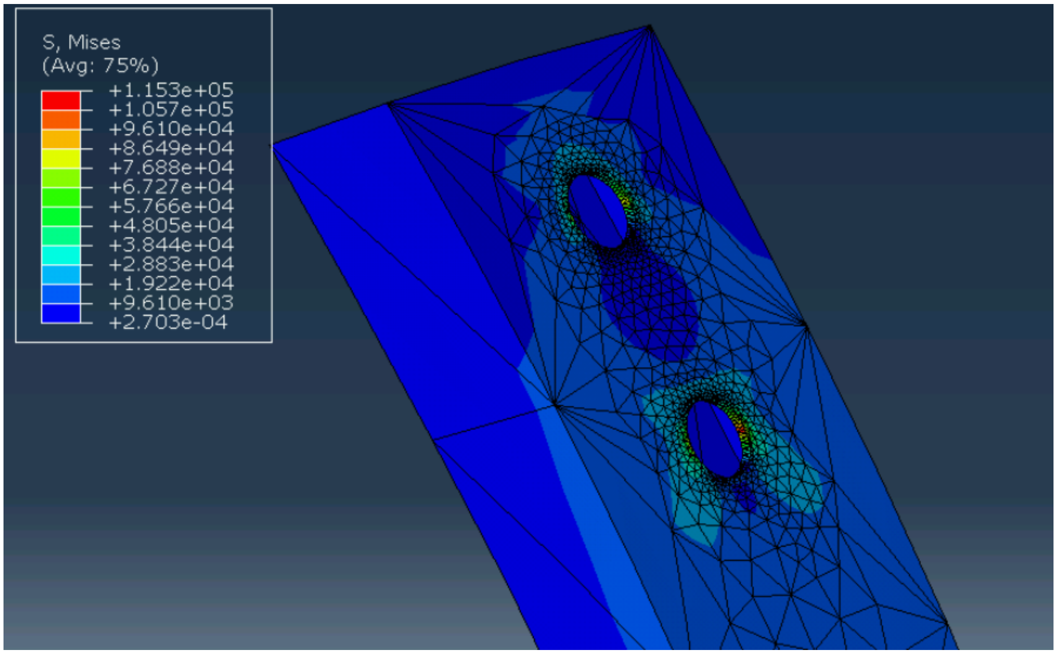


Figure 54: Enlarged image of the projected stresses experienced at the top holes with predicted loading conditions using Abaqus.

Interpretation and Discussion:

These results warrant the same reaction as those from part B05A/B. Although it does affirm that a hard stop is needed, considerations must also be made regarding the possibility of buckling in repeated clay compression.

B07: Output Fulcrum Support Bar (Initial)

Boundary Conditions:

In this simulation, the holes closest to the outside have been fixed in place as shown in the figure below. This represents the edge of the part being fixed by bolts. The holes closest to the inside have a surface traction of 8.19×10^3 psi applied to them, which represents the 7,700 lb force shown in Figure 12 being distributed over 2 different holes, each with an internal surface area of 0.47 in^2.

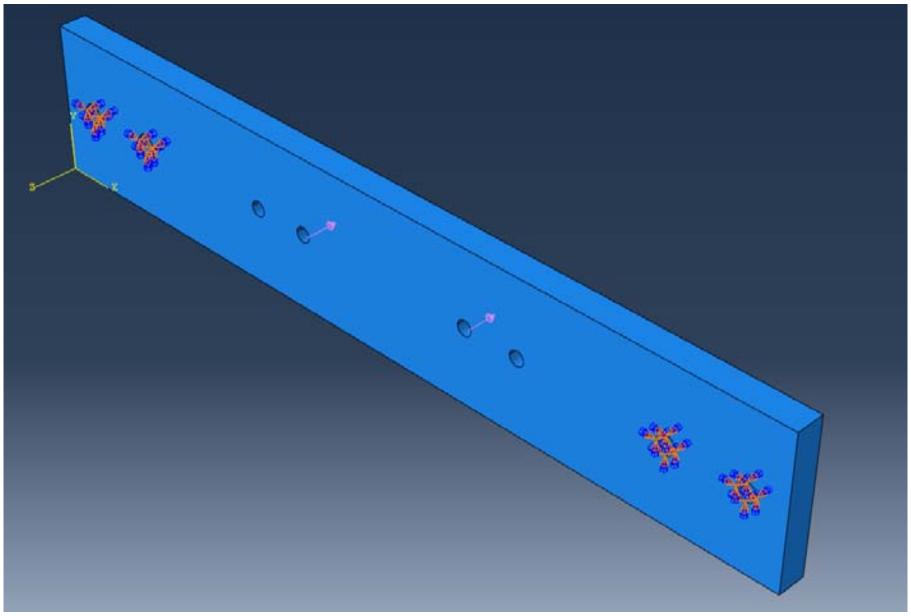


Figure 55: Boundary conditions modeled for B07- Output Fulcrum Support Bar using Abaqus.

Expectations:

Considering the slenderness of the part and the locations of force application, this part is most likely to fail due to bending or by the stress concentrations at the edges.

Results:

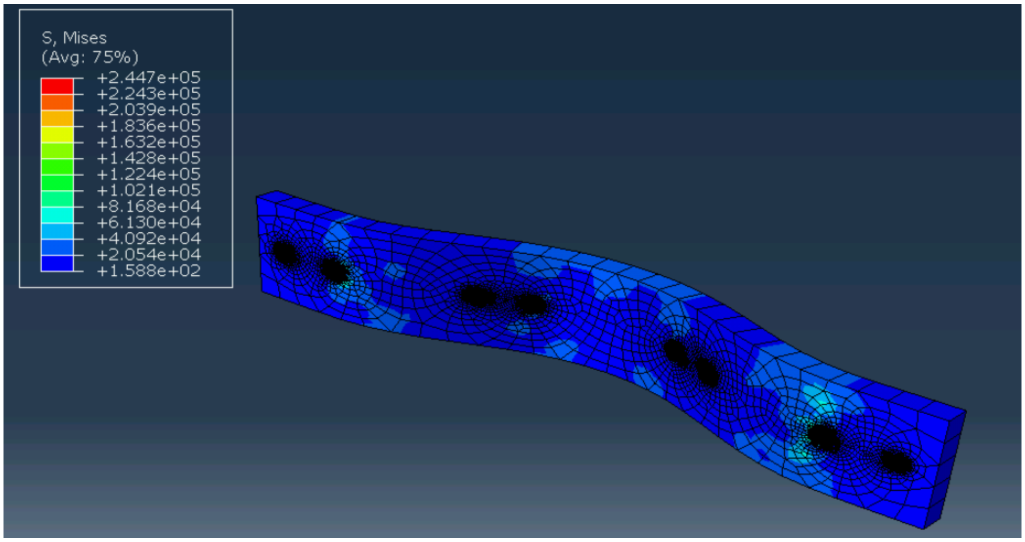


Figure 56: 3D model of the projected stresses experienced by B07 with predicted loading conditions using Abaqus.

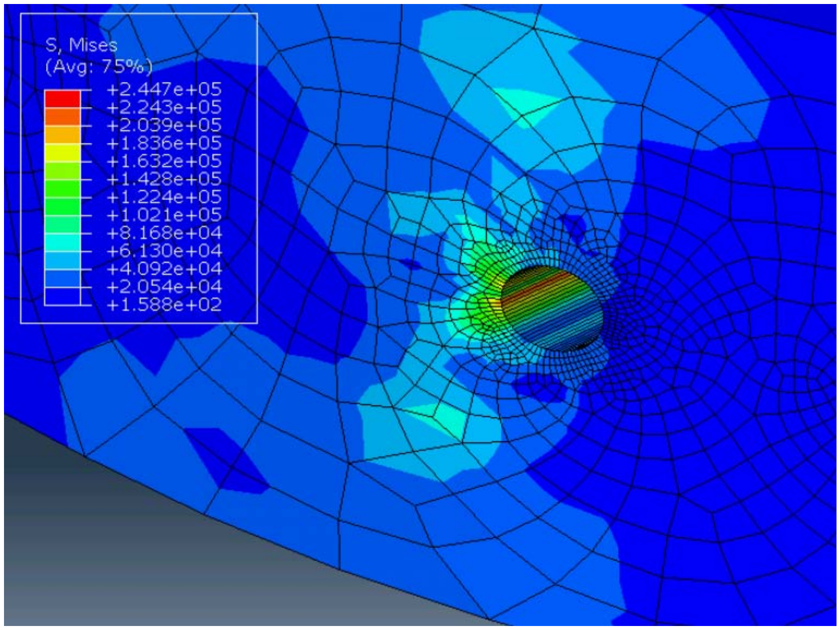


Figure 57: Enlarged image of the projected stresses experienced at the second hole from the right of B07 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

This projected failure is likely because of the boundary conditions that were used to simulate the loads on the part. Since it is the inside of the holes that the forces are being applied to, there are likely stress concentrations in this analysis that won't exist in the prototype because the loads would be distributed to the bolts and supporting L brackets. To better distribute this load, however, adding more bolts in the member should be considered, as well as move the placement of this piece in the overall assembly such that it is better supported by other members in the Base Fixture.

B07 (Additional Iteration)

Boundary Conditions:

The four holes closest to each edge are fixed, while the holes closes to the center of the piece have the same surface traction applied to them as the first iteration of B07.

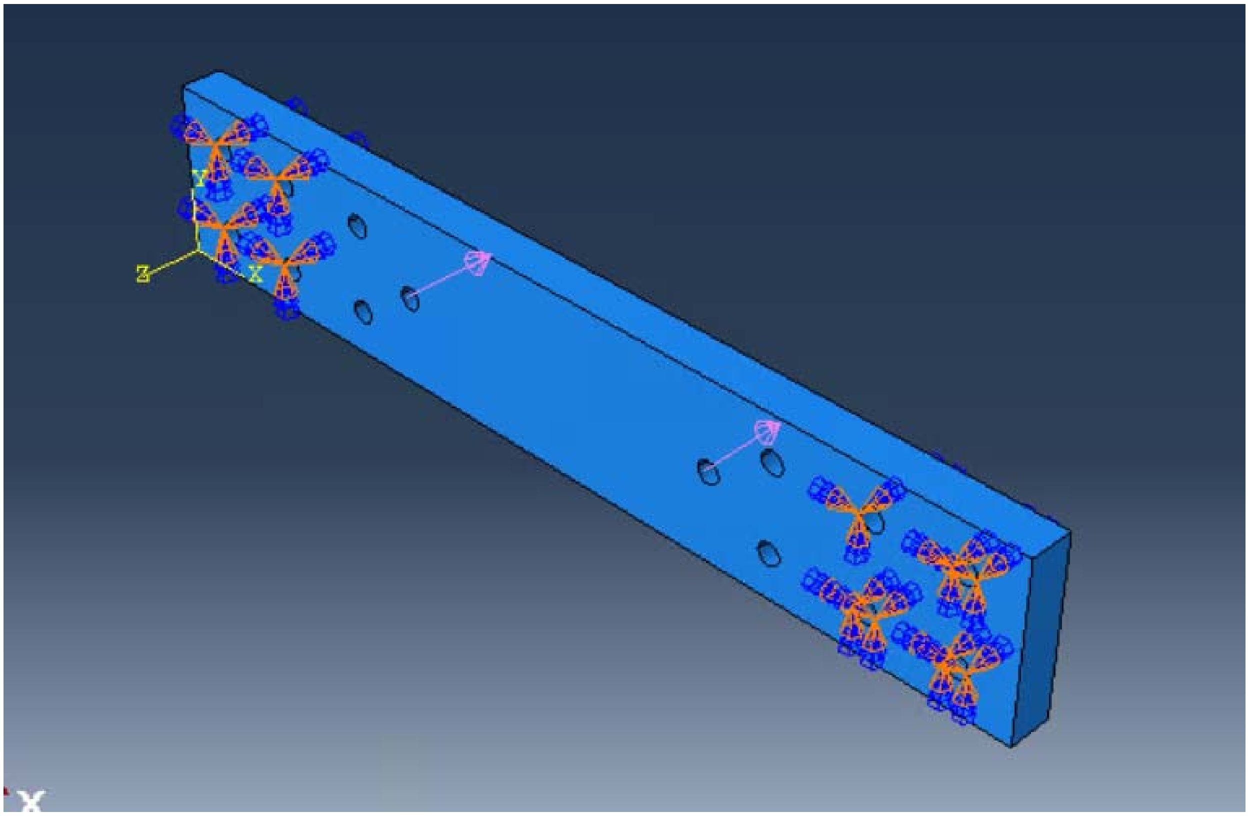


Figure 58: Boundary conditions modeled for the second iteration of B07- Output Fulcrum Support Bar using Abaqus.

Expectations:

The addition of more holes was expected to better distribute the load of the part and reduce the stress concentrations. However, the fact that material has been taken away to accommodate these new holes is of concern.

Results:

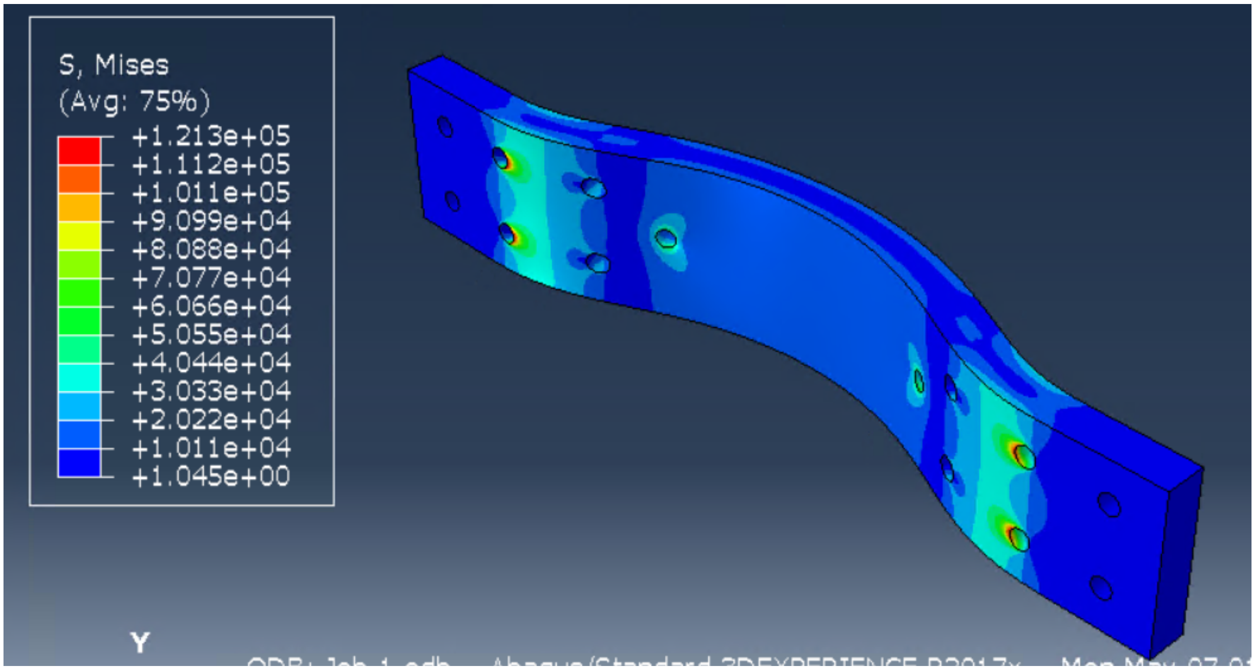


Figure 59: 3D model of the projected stresses experienced by the second iteration of B07 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Not only does the addition of more holes cut the expected stress concentration in half, but it better distributed loads throughout the part. While technically the simulation suggests that the part is still at risk of failure, this failure only occurs at the holes. After discussions with this team's project advisor, Dr. Tim Hight, it was determined that using a fixed boundary condition on the insides of the holes is likely to generate stress concentrations that are inaccurately high. As a result, it was determined that this part was safe.

B17: Top Fulcrum Support Bar

Boundary Conditions:

In this simulation, partitions on the surface of the part were created to represent the contact area of the nuts that are fixing this component in place (Figure 60). These partitions were given z-symmetry boundary conditions, such that the part could potentially slide along the xy-axis at these points but remaining fixed in the z-direction. This was done with the purpose of reducing the possible stress concentrations of the part. Additionally, the four holes on the inside of the part were given a traction force in the z-direction that represents the 7,700 lb force shown in Figure 12, which is distributed over two parts over a combined surface area of 1.18 in^2 between all four holes.

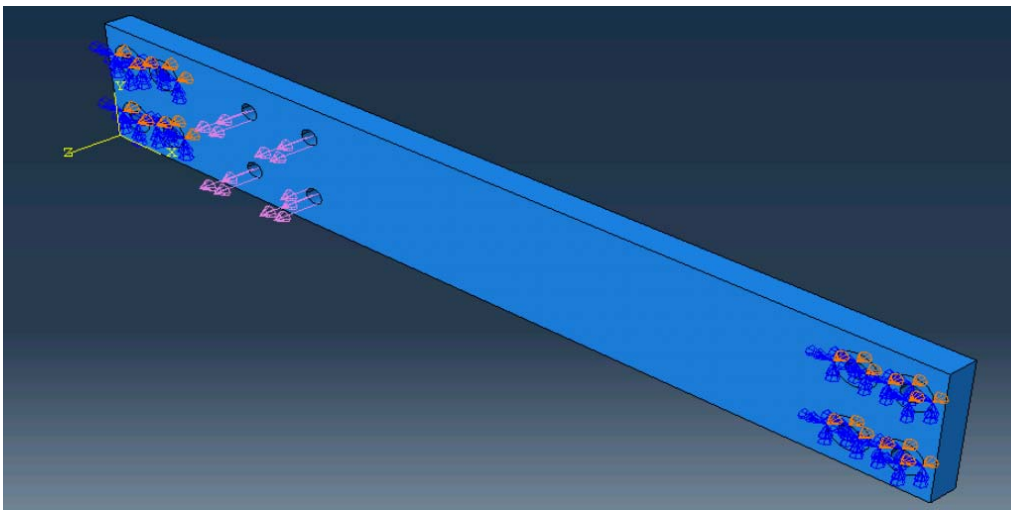


Figure 60: Boundary conditions modeled for B17- Top Fulcrum Support Bar using Abaqus.

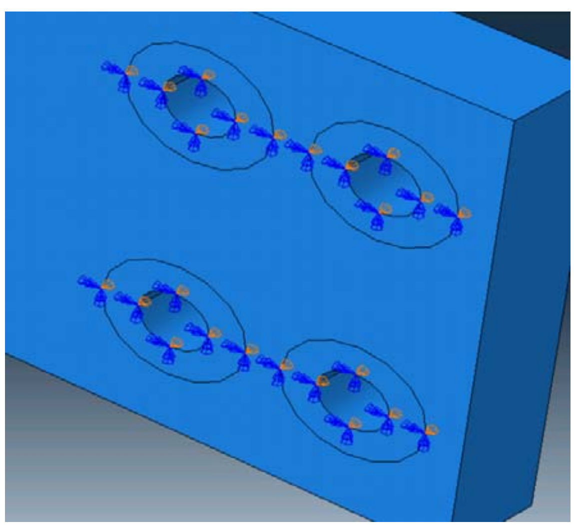


Figure 61: Enlarged image of the boundary conditions modeled at the right end of B17 using Abaqus.

Expectations:

The failure mode of this piece would likely be due to shear or bending stress at the area in between the fixed holes. Additionally, contact force next to the stationary holes may lead to failure at these areas of high stress concentration.

Results:

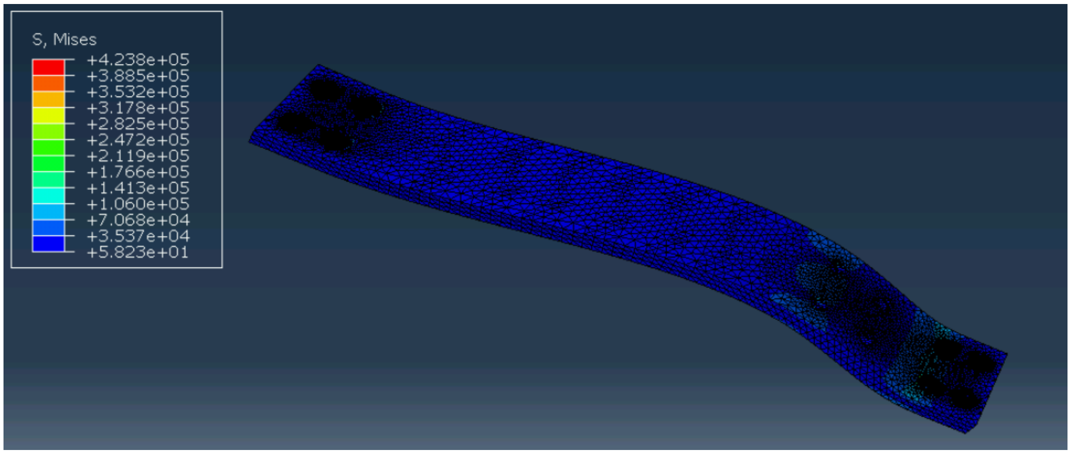


Figure 62: 3D model of the projected stresses experienced by B17 with predicted loading conditions using Abaqus.

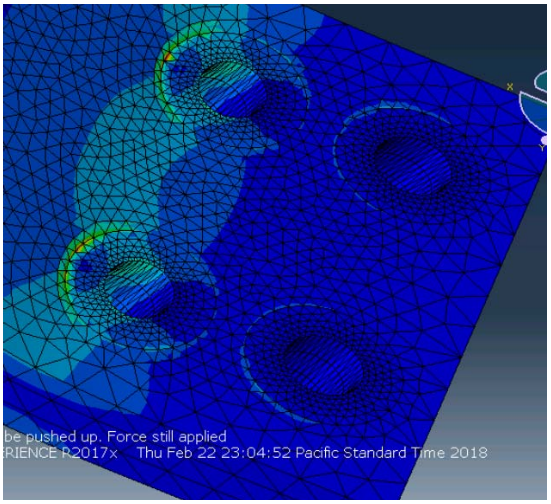


Figure 63: Enlarged image of the projected stresses experienced at the right end of B17 with predicted loading conditions using Abaqus.

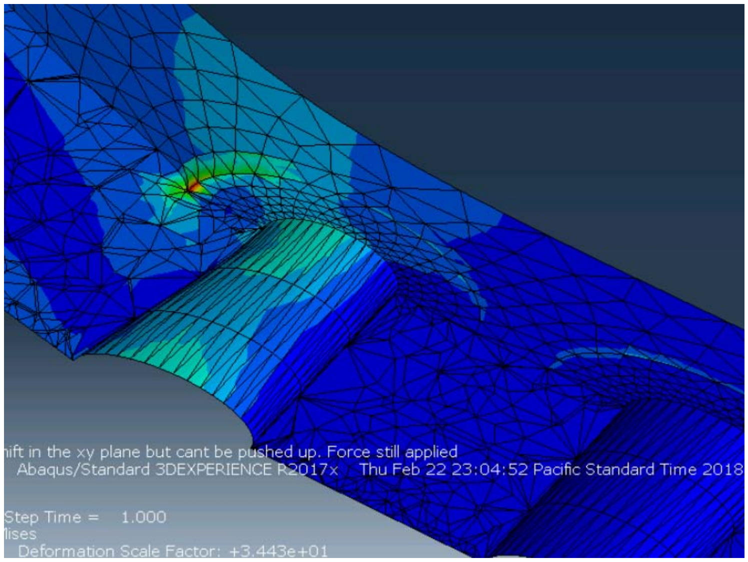


Figure 64: Cross sectional view of the projected stresses experienced at the right end of B17 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

From this simulation, the part fails at the critical points right around the fixed holes. While the part as a whole does not fail, the surface of it will. This surface failure will lead to cracking over time, and expedite fatigue failure of the member. However, it is worth noting that the very high stress concentrations at the edge of the fixed face partitions are likely fictitious due to the strict boundary conditions. As for the rest of the part, the stress experienced are bordering the expected yield strength of the part. If stresses at this part were to be designed against, a metal sheet or plate to the top of the part to distribute the stresses can be used to brace the part.

Lever Arm Subsystem

Description:

The Lever Arm subsystem is a compound lever system that consists of two individual levers of different lengths, each with their own fulcrums, connected by metal connecting beams. The input lever, located at the front of the Base Fixture, has a handle for users to grip apply force upon. The output lever, located on top of the Base Fixture, applies the force to the compression lid subsystem. Both lever arms are hollow beams of differing thicknesses. Figures 13 and 14 show sketches of the Lever Arm subsystem under various loading conditions with applied forces.

Analysis:

Major assumptions regarding this subsystem are the following: The fulcrums of both lever arms act as "pinned" boundary conditions for the sake of force flow diagrams, the user is applying a force perfectly downwards and with no uneven forces creating a moment unless explicitly stated, and the contact stress of fulcrums could be modeled by even pressure on an area of about 0.1 in thick and just under 2 in long.

L03: Input Beam (Initial)

Boundary Conditions;

For this component, a fixed boundary condition was added to one end of the beam, with various uniform pressures being applied to small areas that represent contact stresses. These uniform pressures add to a total force of 200 lbs-f at the area closest to the fixed end, 1900 lbs-f at the area in the middle, and 1700 lbs-f at the very end. These forces can be seen on Figure 65.

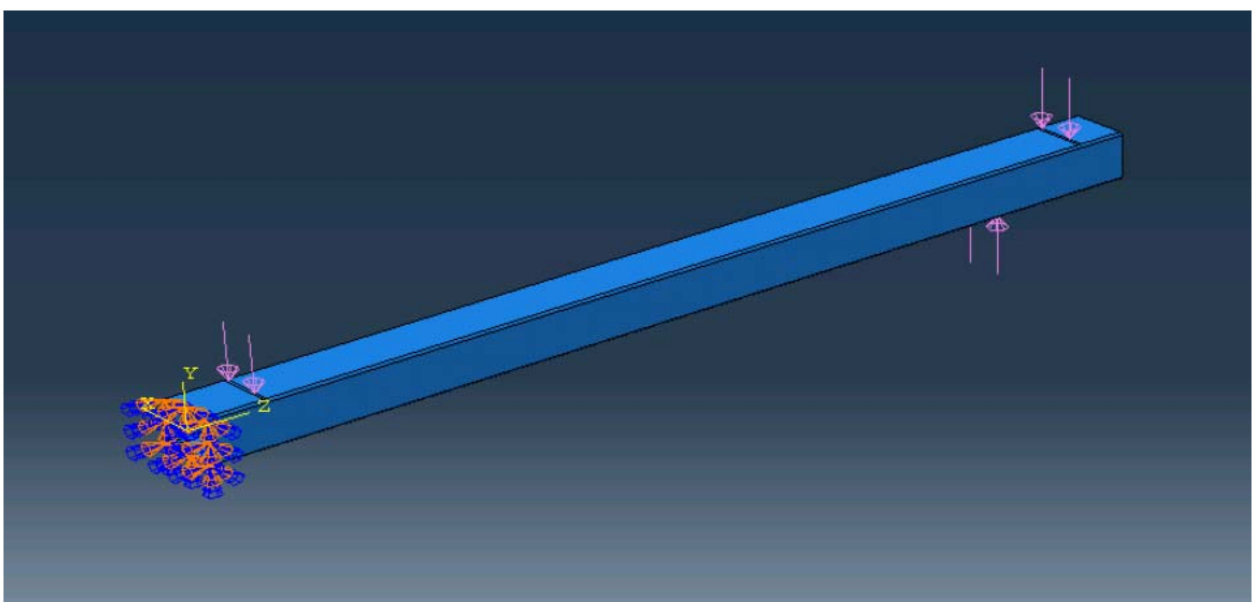


Figure 65: Boundary conditions modeled for L03 - Input Beam using Abaqus.

Expectations:

Upon first inspection, it would make sense that the piece be able to withstand the bending stress caused by the forces. If there were to be any issues, it would likely be with contact stress.

Results:

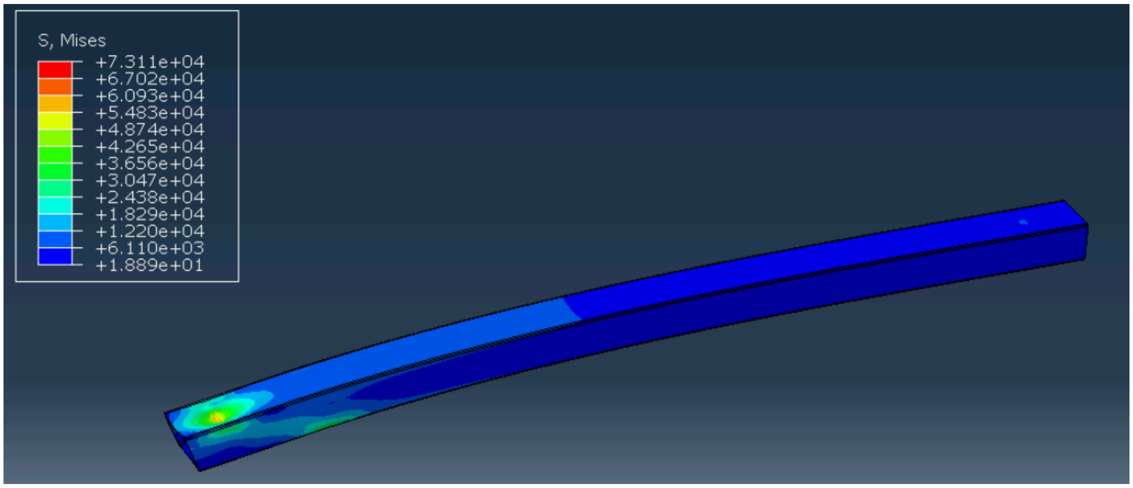


Figure 66: 3D model of the projected stresses experienced by L03 with predicted loading conditions using Abaqus.

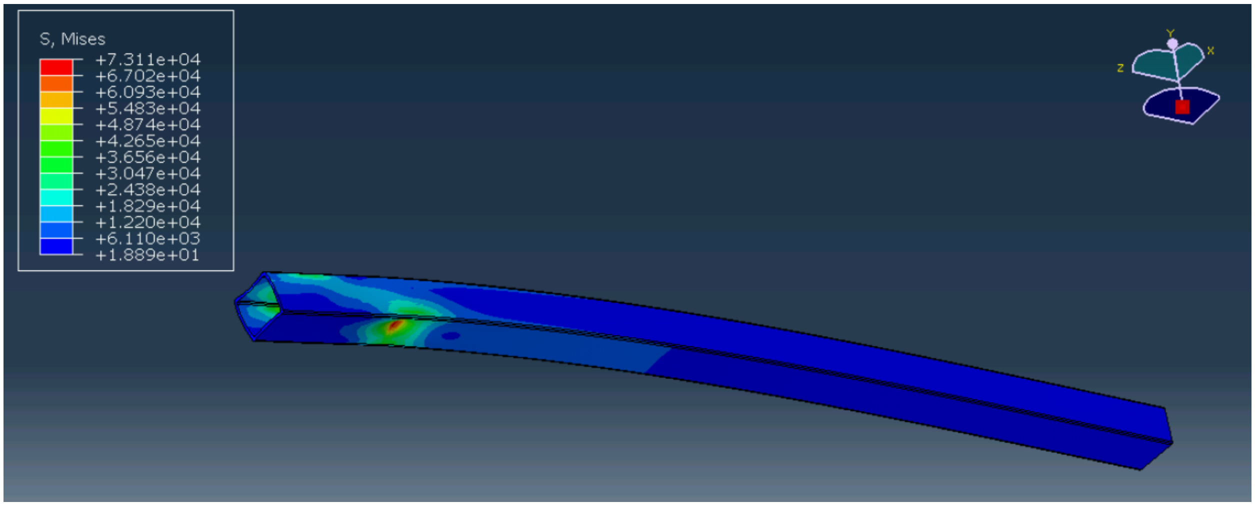


Figure 67: 3D model of the projected stresses experienced by B17 with predicted loading conditions using Abaqus.

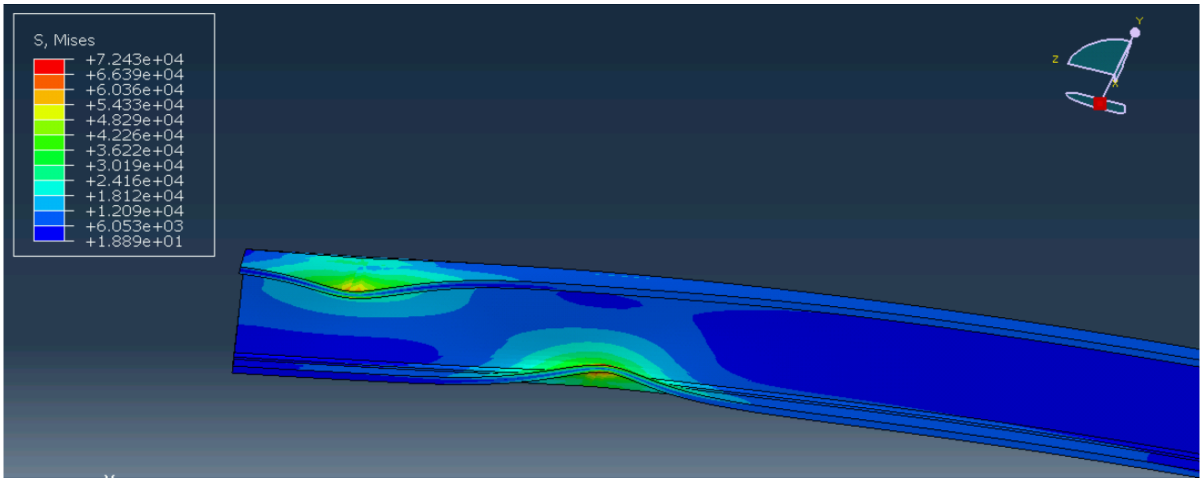


Figure 68: Close-up of the cross-section of the stresses shown in Figures 66 and 67.

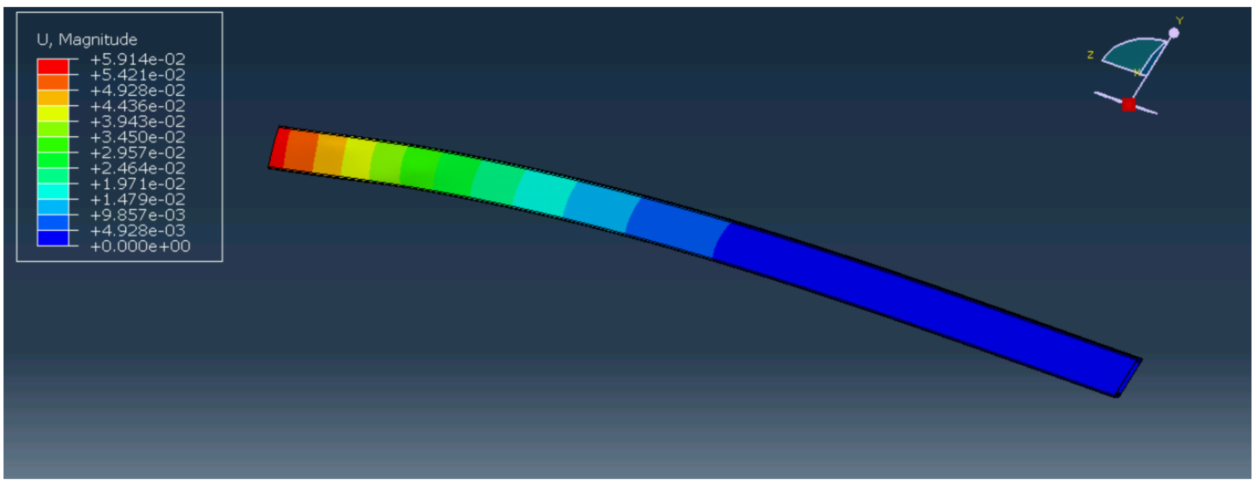


Figure 69: 3D model of the projected deformation experienced by L03 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

From the results above, it can be observed that the part fails due to contact stress, but not necessarily bending stress. As a result, it is likely possible to avoid buying a thicker beam if the component can simply be reinforced at the areas of contact stress along the part. Luckily, while the part does fail, it can be observed that devlection in the bar is negligible, with deflection reaching only up to 0.06 in at the maximum. It is worth noting, however, that this assumes elastic behavior beyond the point of yield stress.

L03: Input Beam (Additional Iteration)

Adding Reinforcement Plates to Areas of High Contact Stress

The implemented solution to the problems of the first iteration of L03 was to weld 0.5 in thick reinforcement plates made scrap steel to the areas of high stress concentration. The plates are 2 in wide and 3.5 in long.

Boundary Conditions:

The boundary conditions of this piece are the same as that of the original L03, as can be seen in Figure 70. However, this time, there is also a case to account for the moment generated by uneven force application, which is shown in Figure 71. All boundary conditions in this scenario are the same, except instead of a 200 lbs-f load, there is one 1500 lbs-f point load pointed downwards, and one 1300 lbf-f point load going upwards. This represents a net 200 lbs-f force aimed downwards, like normal, but with a 2600 in-lbf force moment generated at the end. This represents one 200 lb force being applied at the very far end of a 1 ft input bar.

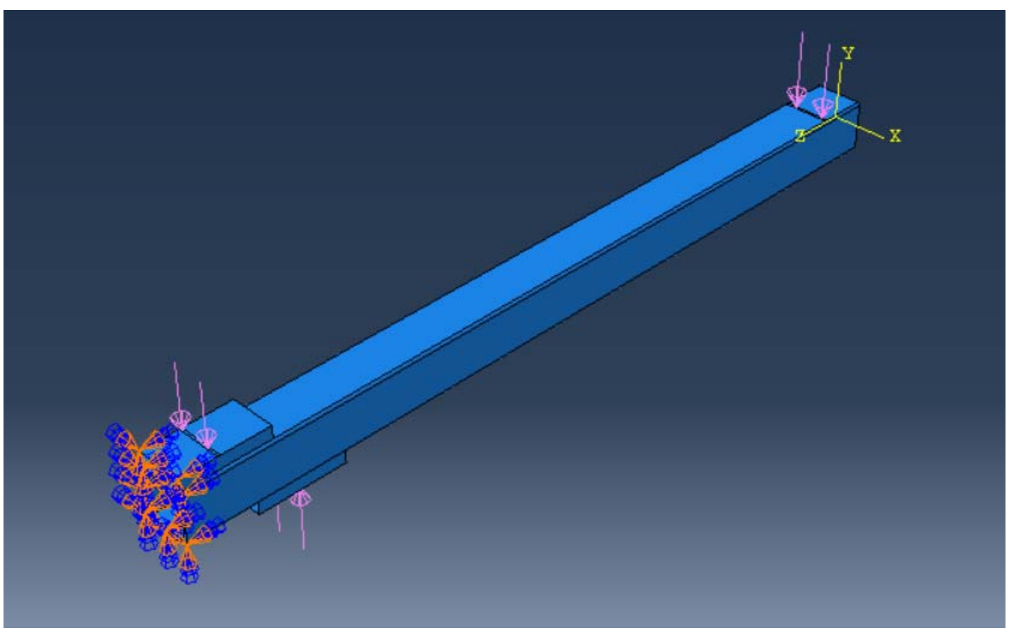


Figure 70: Boundary conditions modeled for updated L03 - Input Beam using Abaqus for the scenario of normal loading conditions.

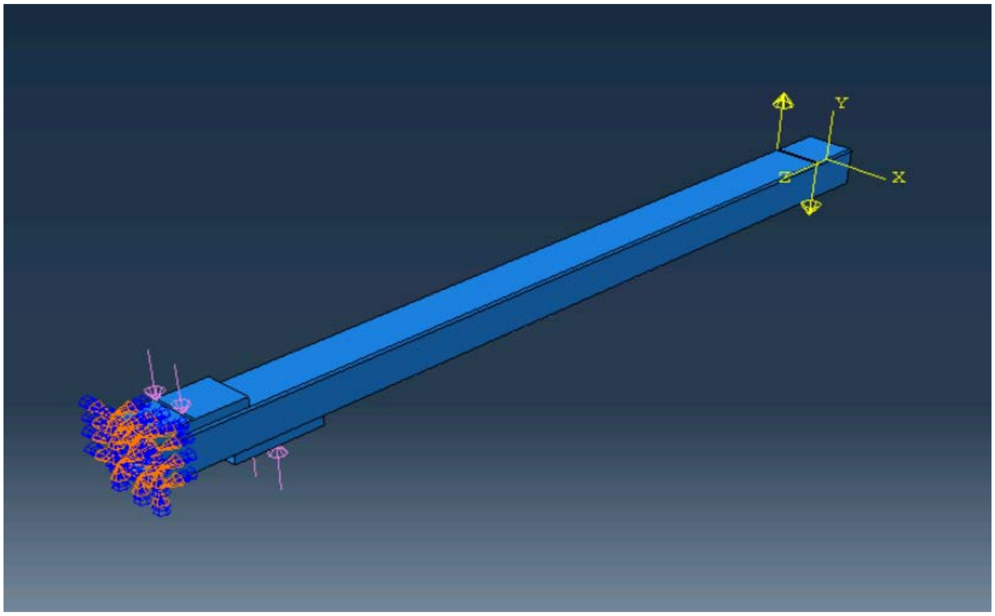


Figure 71: Boundary conditions modeled for updated L03 - Input Beam using Abaqus for the scenario of asymmetric forces that generate a moment.

Results:

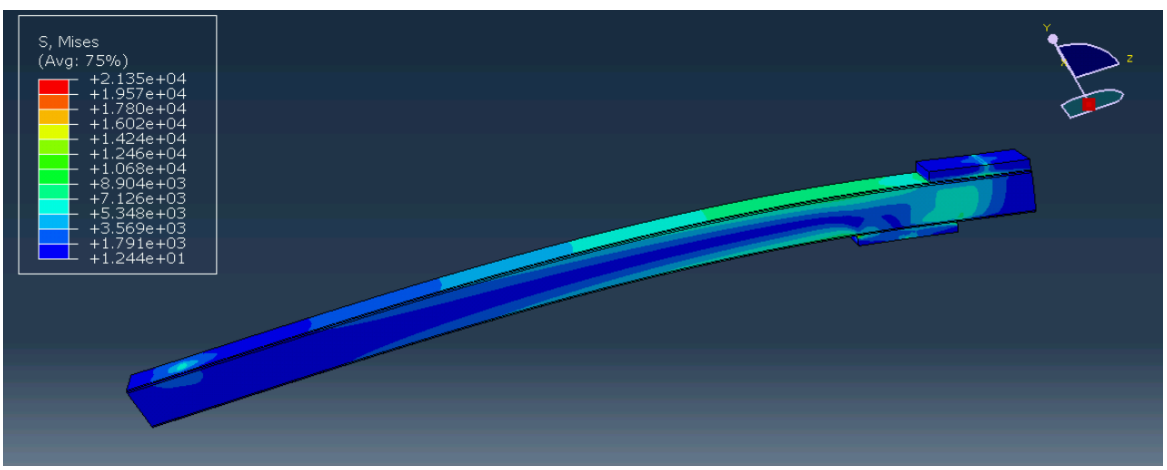


Figure 72: 3D model of the projected stresses experienced by L03 with the boundary conditions for the normal loading scenario.

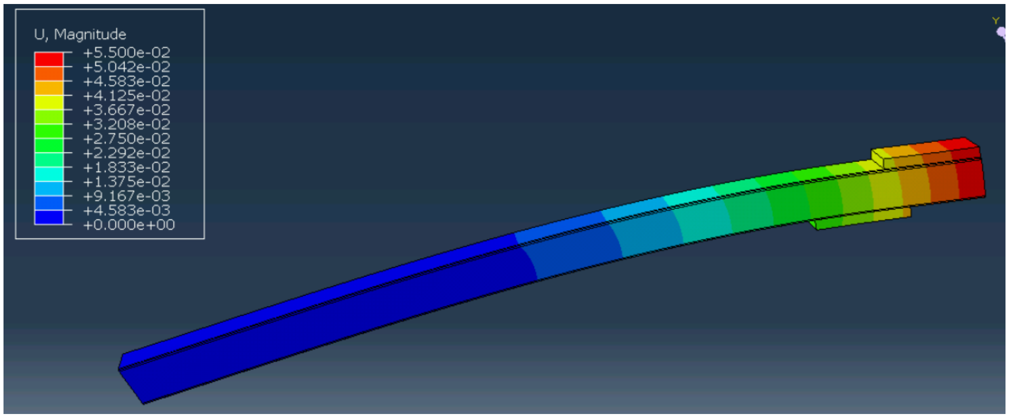


Figure 73: 3D model of the projected displacement experienced by L03 with the boundary conditions for the normal loading scenario.

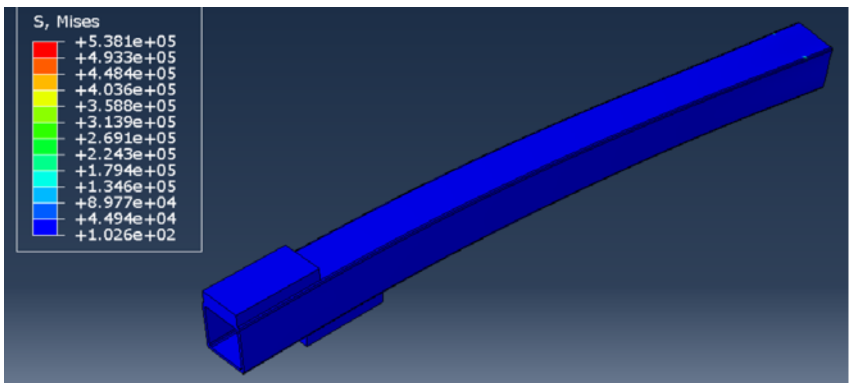


Figure 74: 3D model of the projected stresses experienced by L03 with the boundary conditions for asymmetric moment loading scenario.

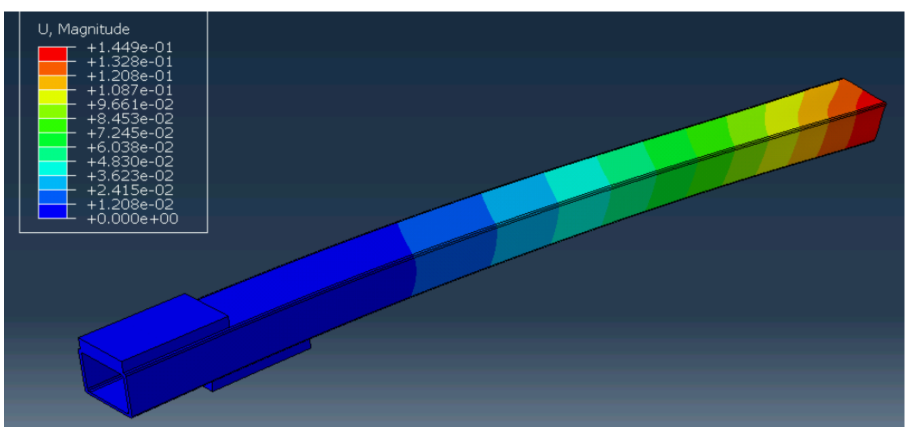


Figure 75: 3D model of the projecteddisplacement experienced by L03 with the boundary conditions for asymmetric moment loading scenario.

Interpretation and Discussion:

In the normal case, the reinforcement beams successfully reduce the stress concentrations, making the part viable. Additionally, deflection caused by the loading is negligible. As for the case in which there is a moment, both the stresses and the deflection are negligible.

L04: Output Beam (Initial)

Boundary Conditions:

At one end of the beam there is a fixed boundary condition. At the fulcrum point, closest to that boundary condition, there is a uniform load of 7,700 lbs-f. In the middle, where the output lever arm is applying force to the Compression Plate, there is a uniform load of 9,600 lbs-f. Finally, at the far end, there is a force of 1,900 lbs-f, which represents the force applied by the connecting beams.

Expectations:

Upon first inspection, it would make sense that the piece be able to withstand the bending stress caused by the forces. If there were to be any issues, it would likely be with contact stress.

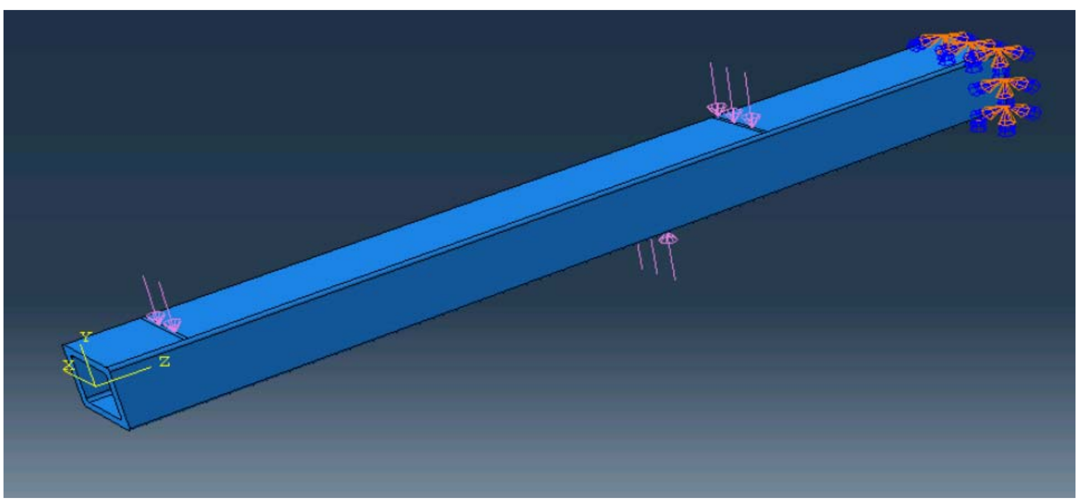


Figure 76: Boundary conditions modeled for L04 - Output Beam using Abaqus.

Results:

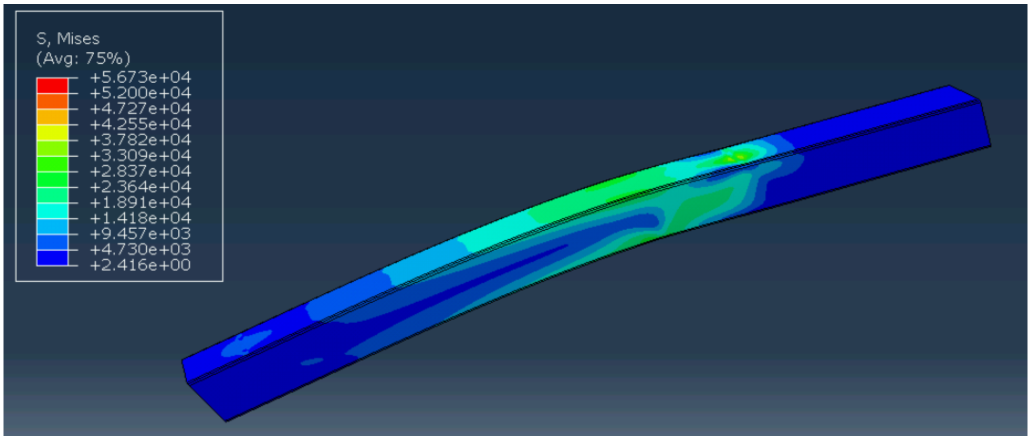


Figure 77: 3D model of the projected stresses experienced by L04 with predicted loading conditions using Abaqus.

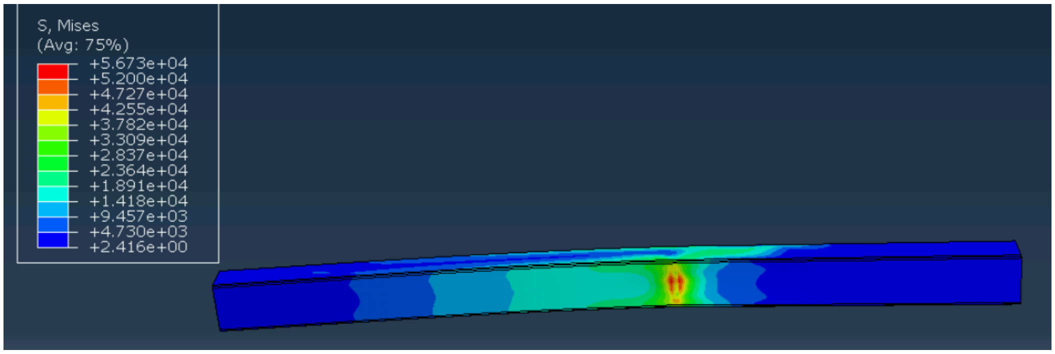


Figure 78: 3D model of the projected stresses experienced by L04 with predicted loading conditions using Abaqus.

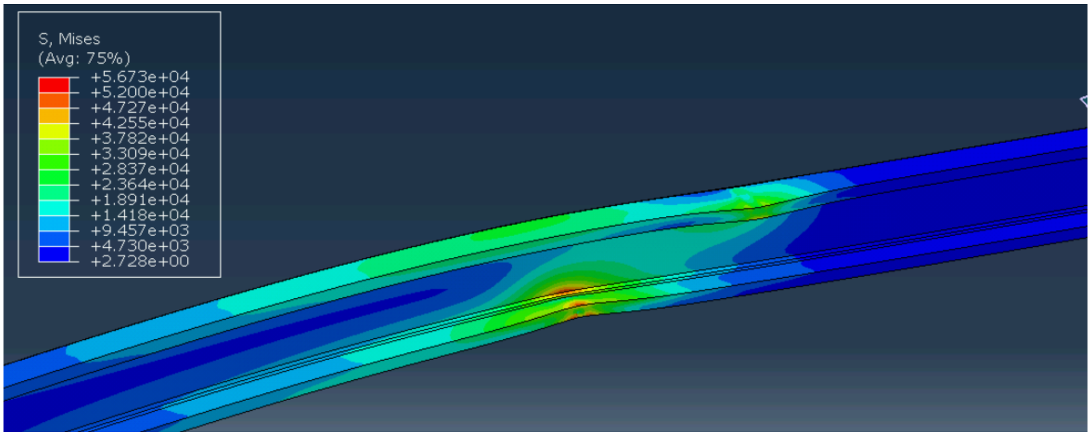


Figure 79: Cross-section of the model from Figures 77 and 78.

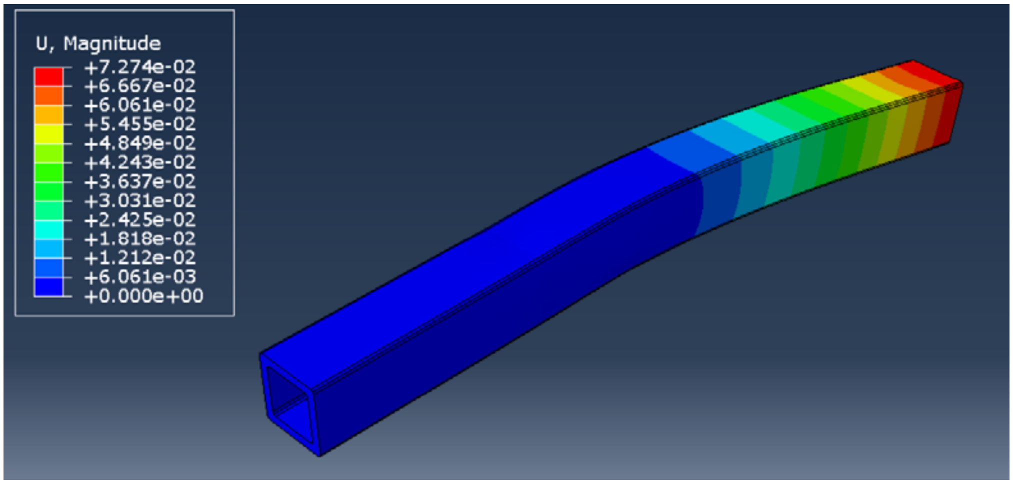


Figure 80: 3D model of the projected deformation experienced by L04 with predicted loading conditions using Abaqus.

Interpretation and Discussion:

Similar to the input lever arm, this lever arm only fails at the points at stress concentration, and has negligible deformation. The solution to this is to add reinforcement at these points.

L04: Output Beam (Additional Iterations)

Adding Reinforcement Plates to Areas of High Contact Stress

The implemented solution to the problems of the first iteration of L03 are to weld 0.5 in thick reinforcement plates made scrap steel to the areas of high stress concentration. The plates are 2 in wide and 3.5 in long.

Boundary Conditions:

The boundary conditions for this piece is the same as that for the original. However, two simulations were done. In one simulation, the fixed boundary condition is at the end closest to the connecting beams of the Lever Arm subsystem, as shown in Figure 81. In the other simulation, it is on the end closest to the fulcrum, as shown in Figure 82. The purpose of having both of these boundary conditions was to ensure that the fixed boundary condition was not unintentionally providing the part with extra resistance to collapsing.

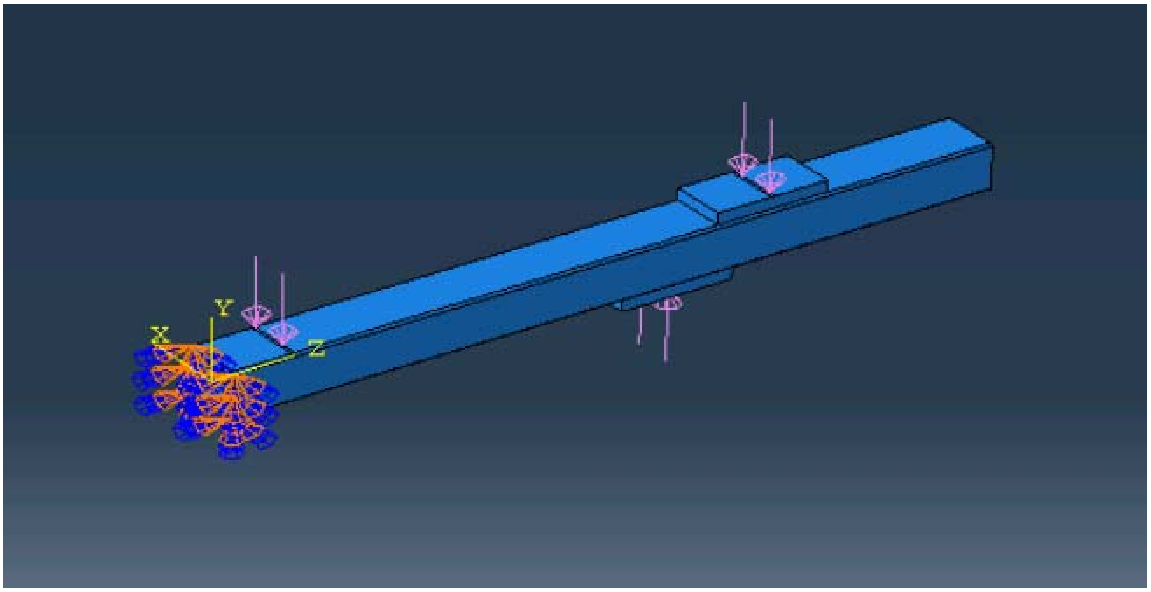


Figure 81: Boundary conditions modeled for updated L04 - Output Beam where the fixed boundary condition is closest to the end of the connecting beams, which apply the force of 1,900 lbs-f.

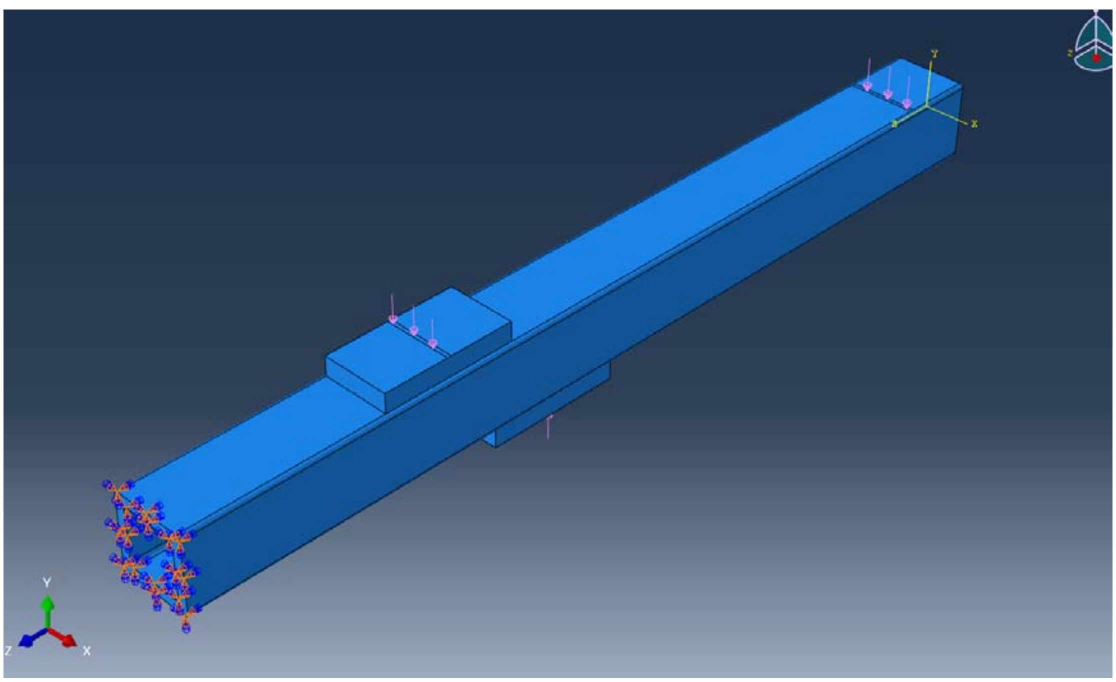


Figure 82: Boundary conditions modeled for updated L04 - Output Beam where the fixed boundary condition is closest to the end of the lever fulcrum, which applies the force of 7,700 lbs-f.

Results:

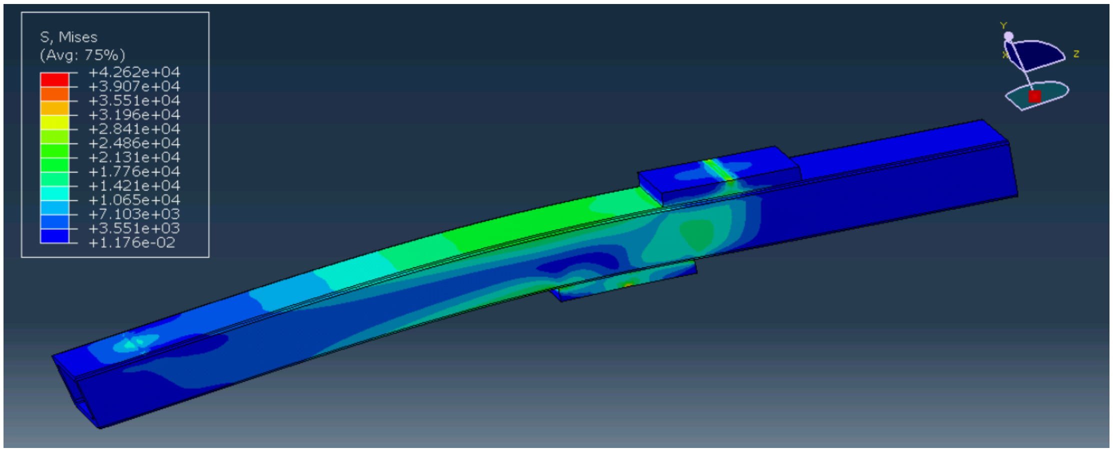


Figure 83: 3D model of the projected stresses experienced by the updated L04 with predicted loading conditions using Abaqus for the loading condition from Figure 81.

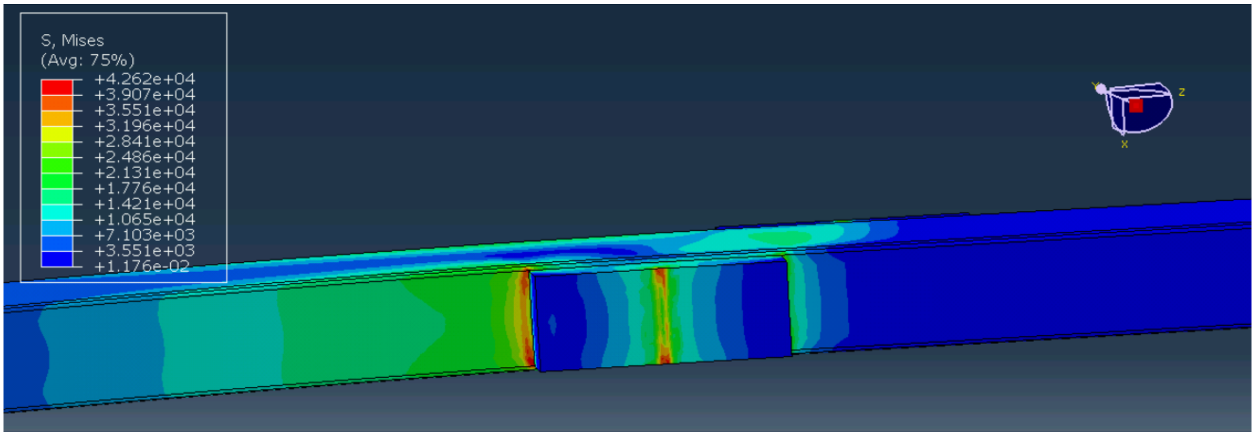


Figure 84: 3D model of the projected stresses experienced by the updated L04 with predicted loading conditions using Abaqus for the loading condition from Figure 81.

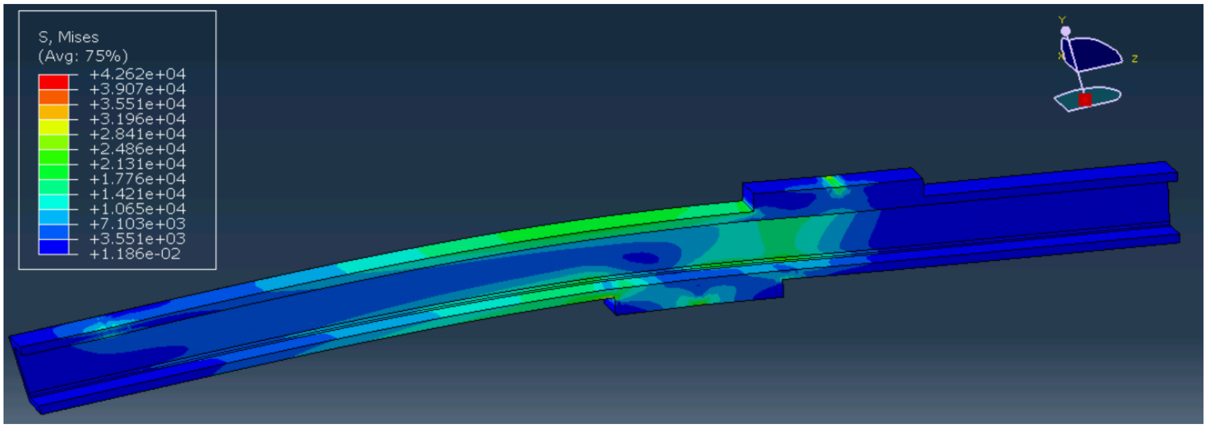


Figure 85: Cross section of the model from Figures 83 and 84.

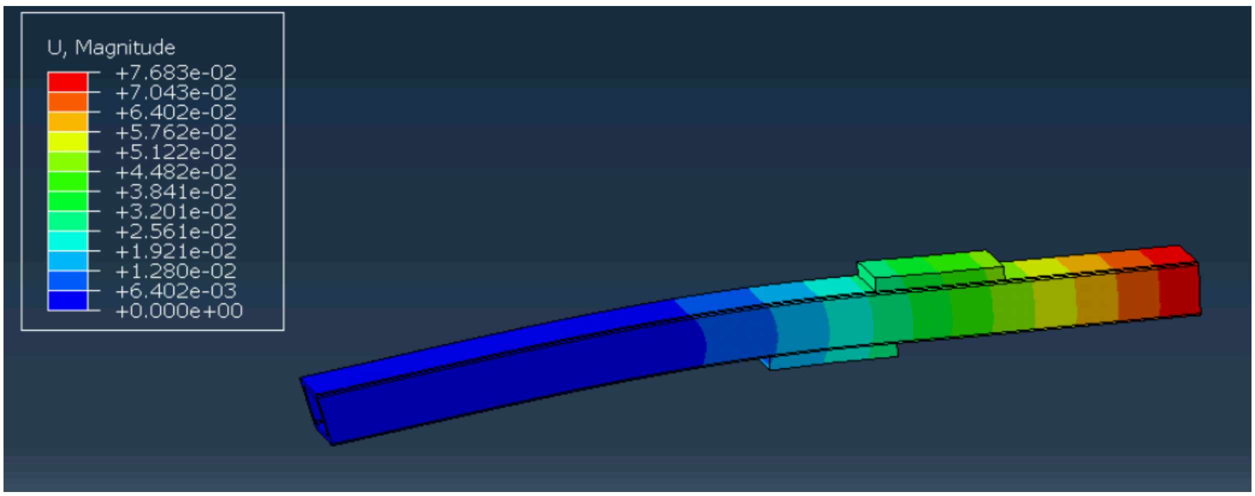


Figure 86: 3D model of the projected displacements experienced by the updated L04 with predicted loading conditions using Abaqus for the loading condition from Figure 81.

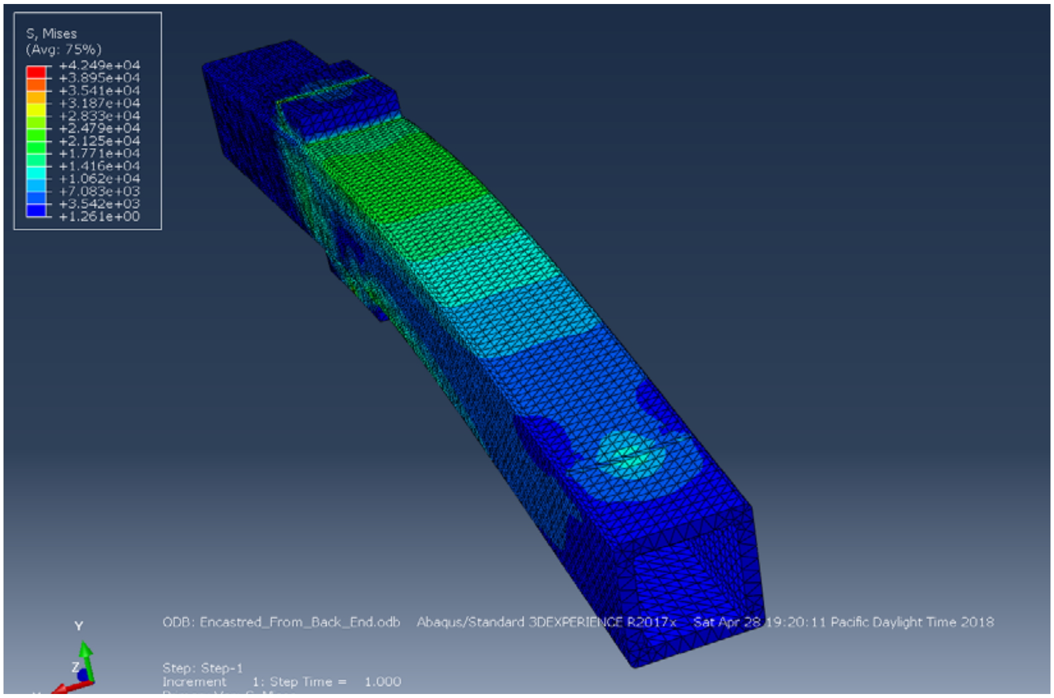


Figure 87: 3D model of the projected stresses experienced by the updated L04 with predicted loading conditions using Abaqus for the loading condition from Figure 82.

<u>Interpretation and Discussion:</u>

As a whole, the part seems to withstand the applied loads with the introduction of the reinforcement plate. The only locations at which the stress barely exceeds the yield stress of the metal is at the exact surface of the force application and the a corner where the reinforcement block and hollow member meet, both of which can be seen in Figure 84. However, the stress at the corner is likely fictitious as the part is modeled as a perfect 90 degree angle, when it would not be in actuality. Additionally, the point load at the stress concentration will likely have little to no impact on the part, as it will only cause mild deformation on a buffer piece that will not affect the part as a whole.

<u>L05: Lever Connecting Beam</u>

<u>Boundary Conditions:</u>

Each hole on L05 was divided into two sections. The section of each hole farthest from the center was given a surface traction of 3225.8 lbs-f per square inch, which pulls the piece apart.

This number comes from the combined 1,900 lbs-f load that the two L05 pieces would have to withstand distributed to 950 lbs-f to each, divided by 0.2945 square inches per area (for a thickness of 0.25). This surface traction changed depending on the thickness of the designed piece. This loading is shown in Figure 88.

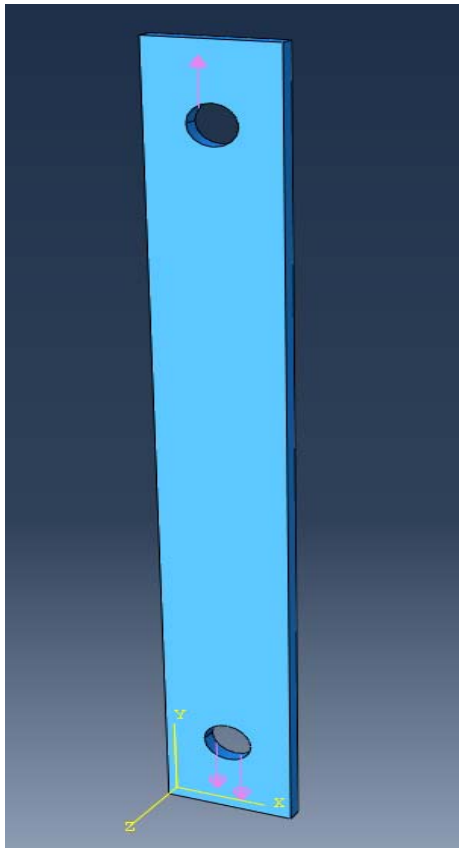


Figure 88: Boundary conditions modeled for L05 - Connecting Beam, where each surface traction is applying a force of 950 lbs-f.

Expectations/Results: :

This piece was iterated until it became as economically efficient as possible. The team started with dimensions that were believed to be close to just barely meeting predefined factors of safety, and then iterated until the piece was the smallest standard size that it could be while still withstanding its required loads:

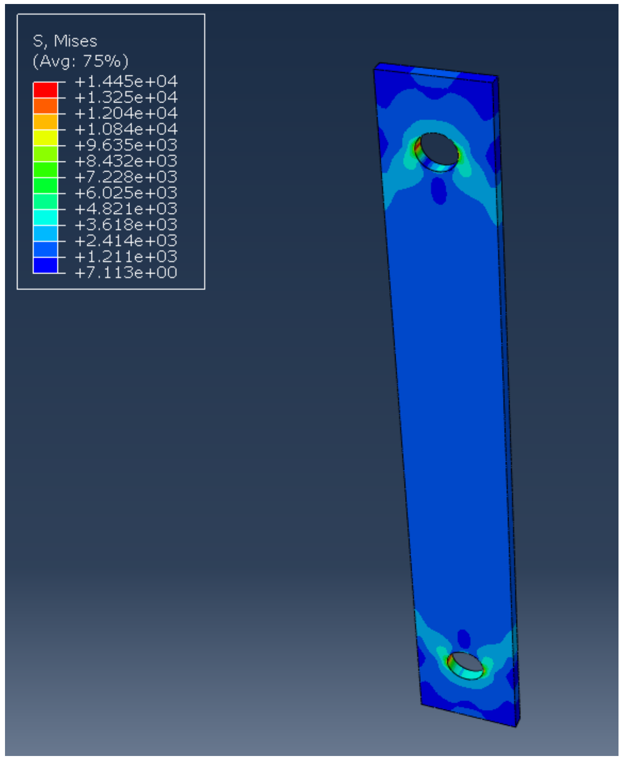


Figure 89: 3D model of the projected stresses experienced by the first L05, which is 15 inches long, 0.25 inches thick, and 2 inches wide. This piece was easily strong enough to survive, and was thus later iterated to be smaller to me more frugal.

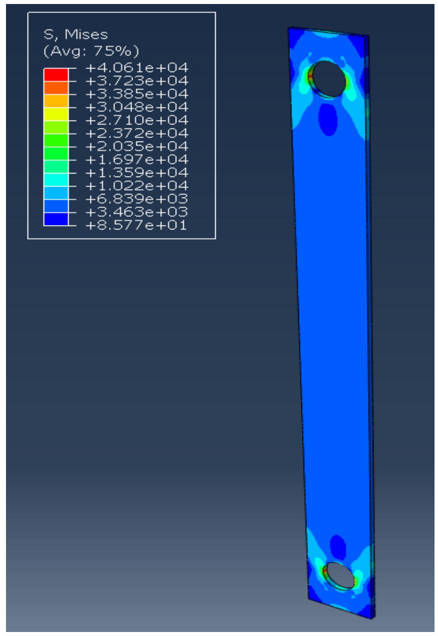


Figure 90: 3D model of the projected stresses experienced by a later iteration of L05. This piece was not up to the factor of safety.

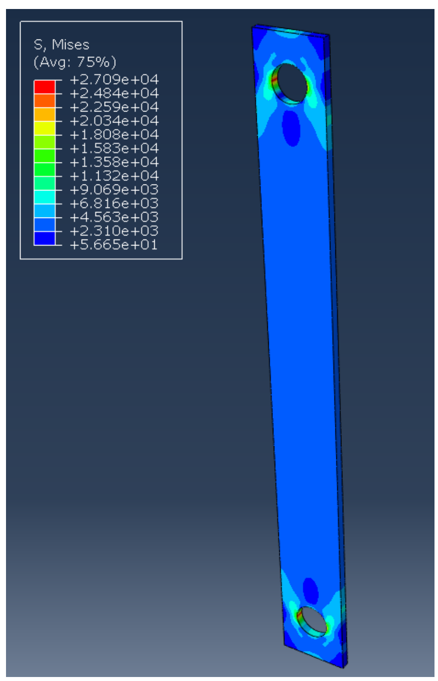


Figure 91: 3D model of the projected stresses experienced by a later iteration of L05. This piece could not be decreased in thickness or width without failing. As a result, it is considered economically efficient.

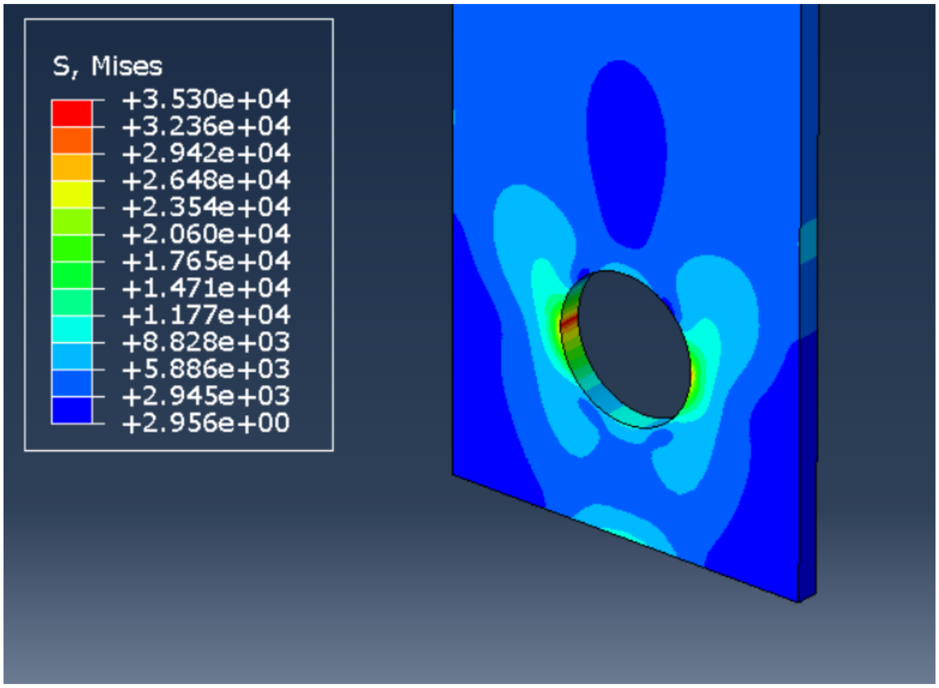


Figure 92: 3D model of the projected stresses experienced by a later iteration of L05, which is 14 inches long, 0.125 inches thick, and 2 inches wide. This piece could not be decreased in thickness or width without failing. As a result, it is considered economically efficient.

Interpretation and Discussion:

After many quick iterations, it was determined that the piece could have a length of 14 inches long while either having a cross sectional area of 1.88in x 1.5in or 1.25in x 2in. These are both standard sizes, and the width and thickness of both of these pieces cannot go down another standard size without becoming too weak. As a result, either of these dimensions work.

Buckling Calculations

K.A. Ellis Buckling Calcs

0.065in walls, 48in length member, Worst Case K

```
B=2;
H=1;
t=0.065;
b=B-2*t;
h=H-2*t;
Ix=(B*H^3)/12-(b*h^3)/12
Iy=(H*B^3)/12-(h*b^3)/12
E=29*10^6;
L=4*12;
K=2.1;
Pcr=(pi^2*E*Ix)/((K*L)^2)
```

```
Ix =

    0.0640


Iy =

    0.1926


Pcr =

  1.8042e+03
```

0.065in walls, 48in length member, Best Case K

```
K=0.5;
Pcr=(pi^2*E*Ix)/((K*L)^2)
```

```
Pcr =

  3.1827e+04
```

0.065in walls, 40in length member, Worst Case K

```
L=40;
K=2.1;
Pcr=(pi^2*E*Ix)/((K*L)^2)
```

```
Pcr =

  2.5981e+03
```

0.065in walls, 40in length member, Best Case K

```
K=0.5;
Pcr=(pi^2*E*Ix)/((K*L)^2)


Pcr =

   4.5831e+04
```

0.12in walls, 48in length member, Worst Case K

```
t=0.12;
L=4*12;
K=2.1;
Pcr=(pi^2*E*Ix)/((K*L)^2)


Pcr =

   1.8042e+03
```

0.12in walls, 48in length member, Best Case K

```
K=0.5;
Pcr=(pi^2*E*Ix)/((K*L)^2)


% The thickness of the walls of the Base Legs have no bearing on
 buckling (as what would be
% expected of a thin walled member), but will probably affect shear.


Pcr =

   3.1827e+04
```

Figure 93: The MatLab presenting the critical buckling loads for several test cases considering varying wall thicknesses and lengths of the base legs as well as differing boundary conditions representing the best and worst case scenarios.

Post Analysis

Problems Encountered

There were various problems encountered using Abaqus and solidworks FEA methods. The first problem was how to accurately apply certain boundary conditions or loads to specified regions in ways that resulted in a realistic simulation. Depending on how one tries to partition a face or where one chooses to apply the load, the results of the simulation can be very misleading. Additionally, at the very edge of the boundary conditions that one sets, you are likely to experience fictitious or exaggerated stresses due to how Abaqus operated.

Another problem lies in the fact that the student-license of solidworks does not allow for the use of more than a limited number of elements, meaning that the resolution for any given simulation can only be so high. Not only does this affect the accuracy of simulations for individual parts, but it makes it impossible to run an accurate assembly simulation for more than a few pieces at maximum. This is unfortunate, because an assembly would likely be more realistic in terms of complex force transferment. However, even when an assembly was used for FEA, such as in the case of B05A/B, the simulation itself took upwards of 30 min.

Conclusion

Over the course of this exercise, much has been learned about the FEA process. Not only has this design team learned how to better use the software, but the team also learned how to critically analyze the results taking into consideration the fundamental concepts of Finite Element Methods. Among the simulations completed, some resulted in parts being redesigned or replaced, some prompted changes to the system as a whole, and some brought up the need for follow-up analysis before any definite conclusions could be made. Continued use of FEA is needed on part modifications to ensure that each part is safe against failure and fatigue stress while still keeping prototype costs below $700. .

APPENDIX I: Gantt Chart

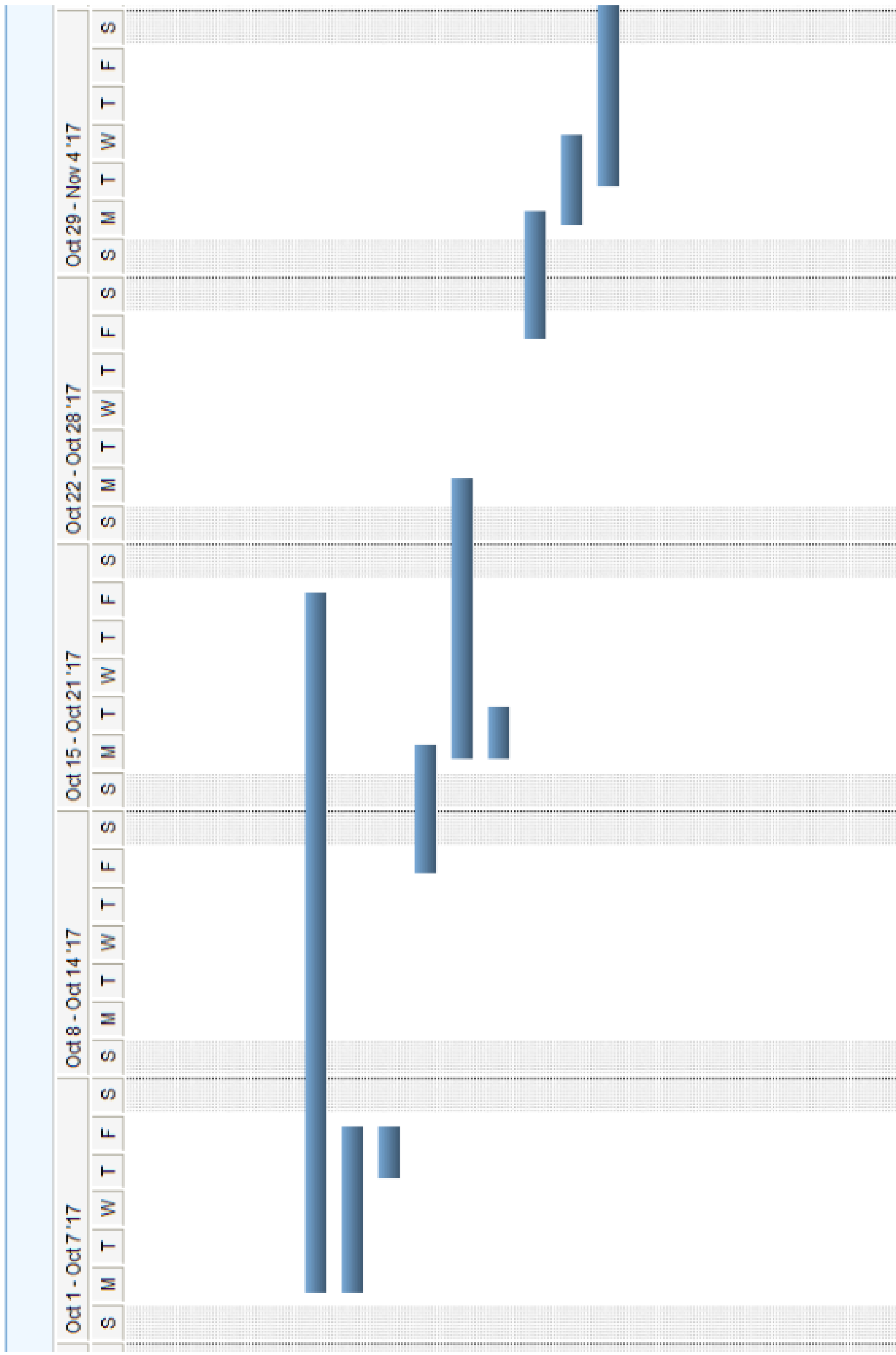
Summary:

Throughout the academic year schedules and gantt charts were created to guide and record progress of various tasks and milestones. The time dedicated to milestones and tasks and the milestones are listed per quarter.

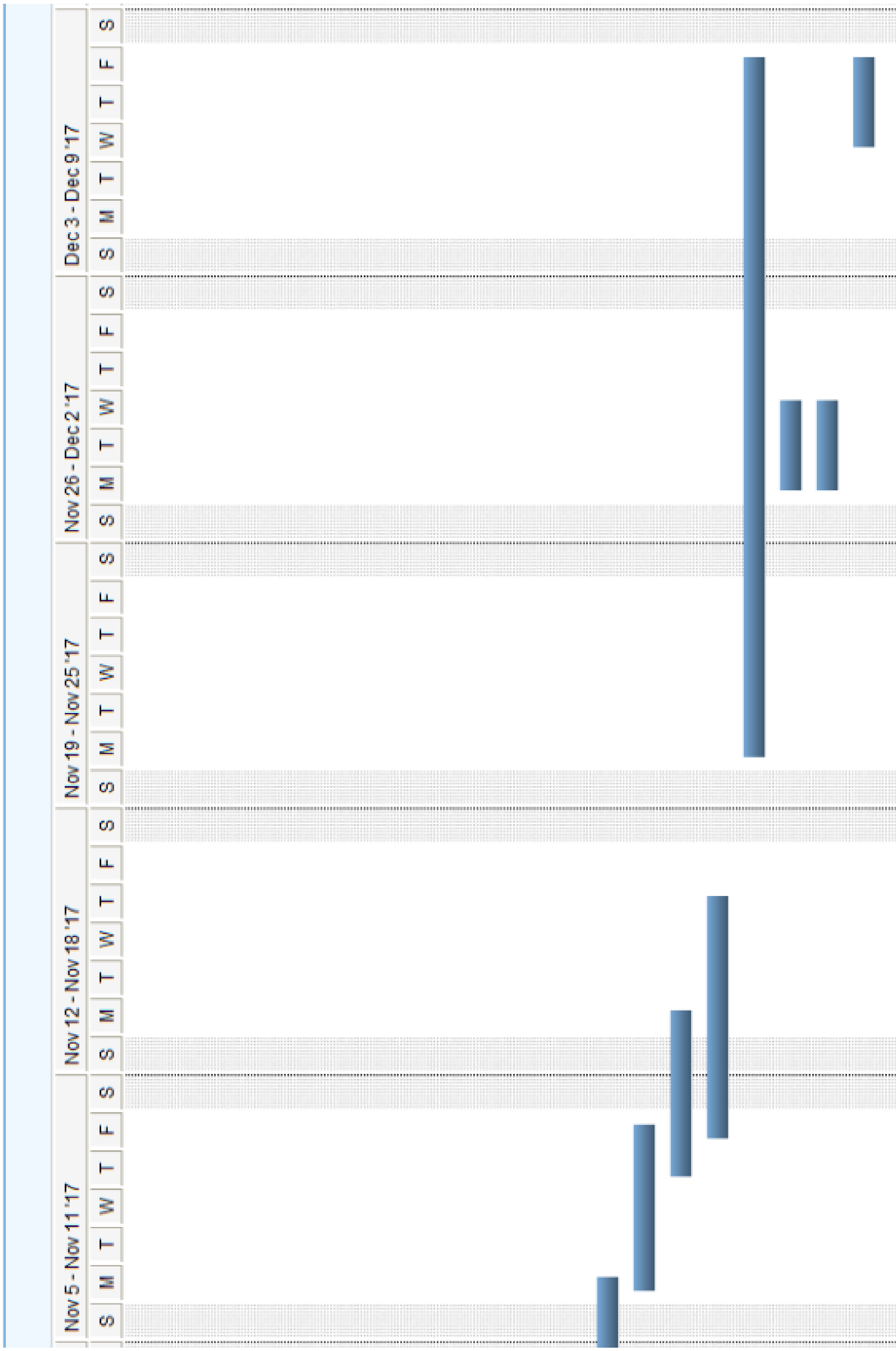
Fall Quarter Schedule

Project Name **Fall Gantt**

	Name	Duration	Start	Finish
1	Team Forming and Reflection	5days?	09/18/2017	09/22/2017
2	Possible Project Review	6days?	09/20/2017	09/27/2017
3	Project Proposal	3days?	09/25/2017	09/27/2017
4	Funding Research	5days?	09/25/2017	09/29/2017
5	Market Research	5days?	09/25/2017	09/29/2017
6	Customer/ Company Interviews	15days?	10/02/2017	10/20/2017
7	Preliminary Market Report	5days?	10/02/2017	10/06/2017
8	Preliminary Customer Needs Report	2days?	10/05/2017	10/06/2017
9	Product Design Specifications Presenta...	2days?	10/13/2017	10/16/2017
10	Final Customer Needs Report	6days?	10/16/2017	10/23/2017
11	Funding Proposal	2days?	10/16/2017	10/17/2017
12	Petroski Paper	2days?	10/27/2017	10/30/2017
13	Subsystem Sketches	3days?	10/30/2017	11/01/2017
14	Subsystem Matrices	5days?	10/31/2017	11/06/2017
15	Concept Consolidation	5days?	11/06/2017	11/10/2017
16	Concept Design Report Draft	3days?	11/09/2017	11/13/2017
17	Safety Review	5days?	11/10/2017	11/16/2017
18	Design Consolidation	15days?	11/20/2017	12/08/2017
19	CDR Presenation	3days?	11/27/2017	11/29/2017
20	Physical Mockup	3days?	11/27/2017	11/29/2017
21	Conceptual Design Review	3days?	12/06/2017	12/08/2017

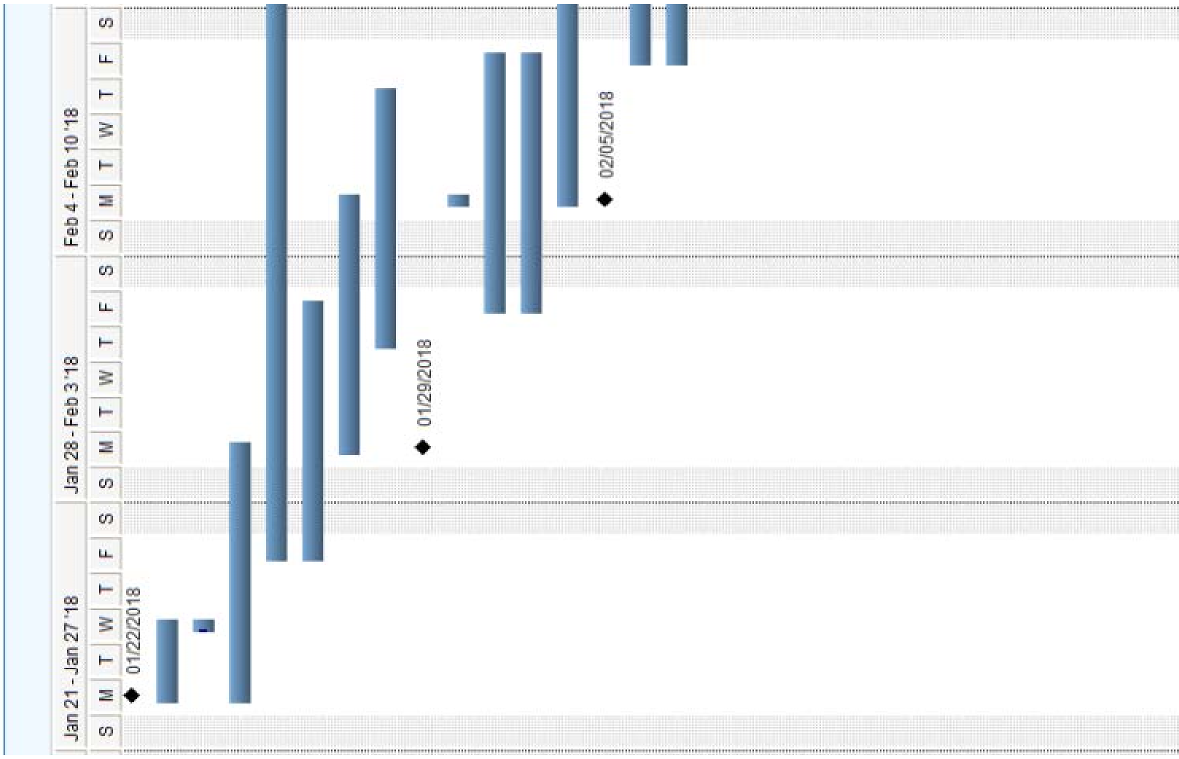


Oct 1 - Oct 7 '17
Oct 8 - Oct 14 '17
Oct 15 - Oct 21 '17
Oct 22 - Oct 28 '17
Oct 29 - Nov 4 '17
S M T W T F S



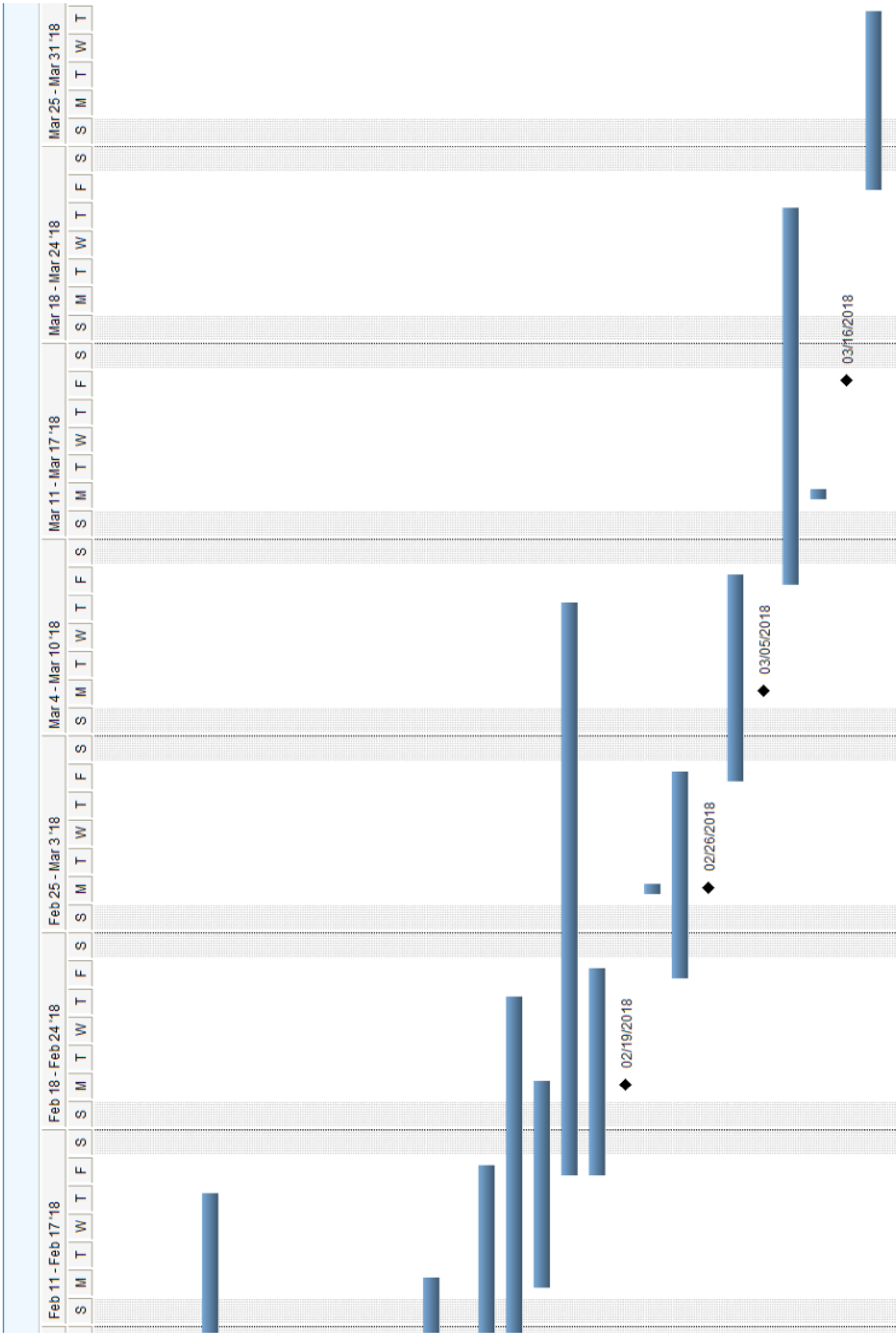
Nov 5 - Nov 11 '17
Nov 12 - Nov 18 '17
Nov 19 - Nov 25 '17
Nov 26 - Dec 2 '17
Dec 3 - Dec 9 '17

Winter Quarter Schedule



Project Name **Winter Gantt**

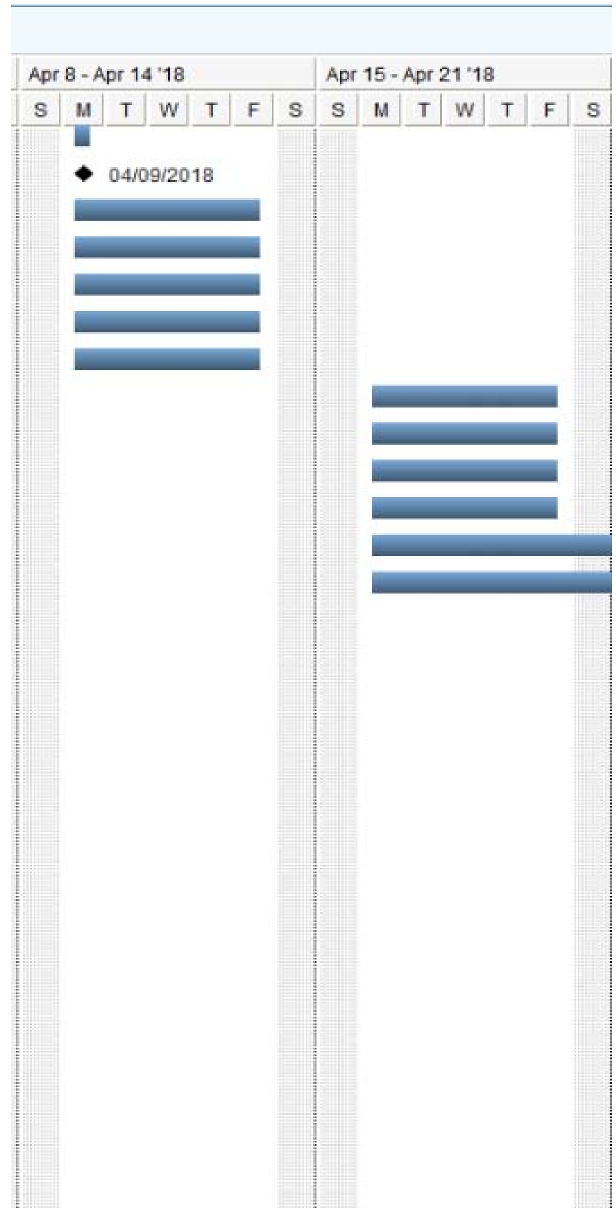
	Name	Duration	Start	Finish
1	Parts List	0day	01/22/2018	01/22/2018
2	Create Compression Chamber Sketc...	3days	01/22/2018	01/24/2018
3	Buy Compression Chamber Materials	1day	01/24/2018	01/24/2018
4	Comp. Cham. FEA and Calcs	6days	01/22/2018	01/29/2018
5	Assemble Comp. Cham. Subsystem	15days	01/26/2018	02/15/2018
6	Base Ficture FEA and Calcs	6days	01/26/2018	02/02/2018
7	Base Fixture Sketches	6days	01/29/2018	02/05/2018
8	Clay Tests	6days	02/01/2018	02/08/2018
9	Budget Update	0day	01/29/2018	01/29/2018
10	Buy Base Fixture Materials	1day	02/05/2018	02/05/2018
11	Compression Plate FEA and Calcs	6days	02/02/2018	02/09/2018
12	Retrieval Subsystem Sketches	6days	02/02/2018	02/09/2018
13	Compression Plate Subsystem Sketc...	6days	02/05/2018	02/12/2018
14	Oral Presentation/Drawings	0day	02/05/2018	02/05/2018
15	Lever Arm FEA and Calcs	6days	02/09/2018	02/16/2018
16	Compression Chamber Testing	10days	02/09/2018	02/22/2018
17	Lever Arm Sketches	6days	02/12/2018	02/19/2018
18	Assemble Base Subsystem	15days	02/16/2018	03/08/2018
19	Retrieval Subsystem FEA and Calcs	6days	02/16/2018	02/23/2018
20	Family Weekend Poster	0day	02/19/2018	02/19/2018
21	Buy Compression Plate Materials	1day	02/26/2018	02/26/2018
22	Finalize Subsystem Sketches	6days	02/23/2018	03/02/2018
23	Zen Paper	0day	02/26/2018	02/26/2018
24	Full Assembly Sketches	6days	03/02/2018	03/09/2018
25	Analysis Report	0day	03/05/2018	03/05/2018
26	Compression Plate Assembly	10days	03/09/2018	03/22/2018
27	Buy Lever Arm Material	1day	03/12/2018	03/12/2018
28	Formal Progress Report	0day	03/16/2018	03/16/2018
29	Trip to Nicaragua	5days	03/23/2018	03/29/2018

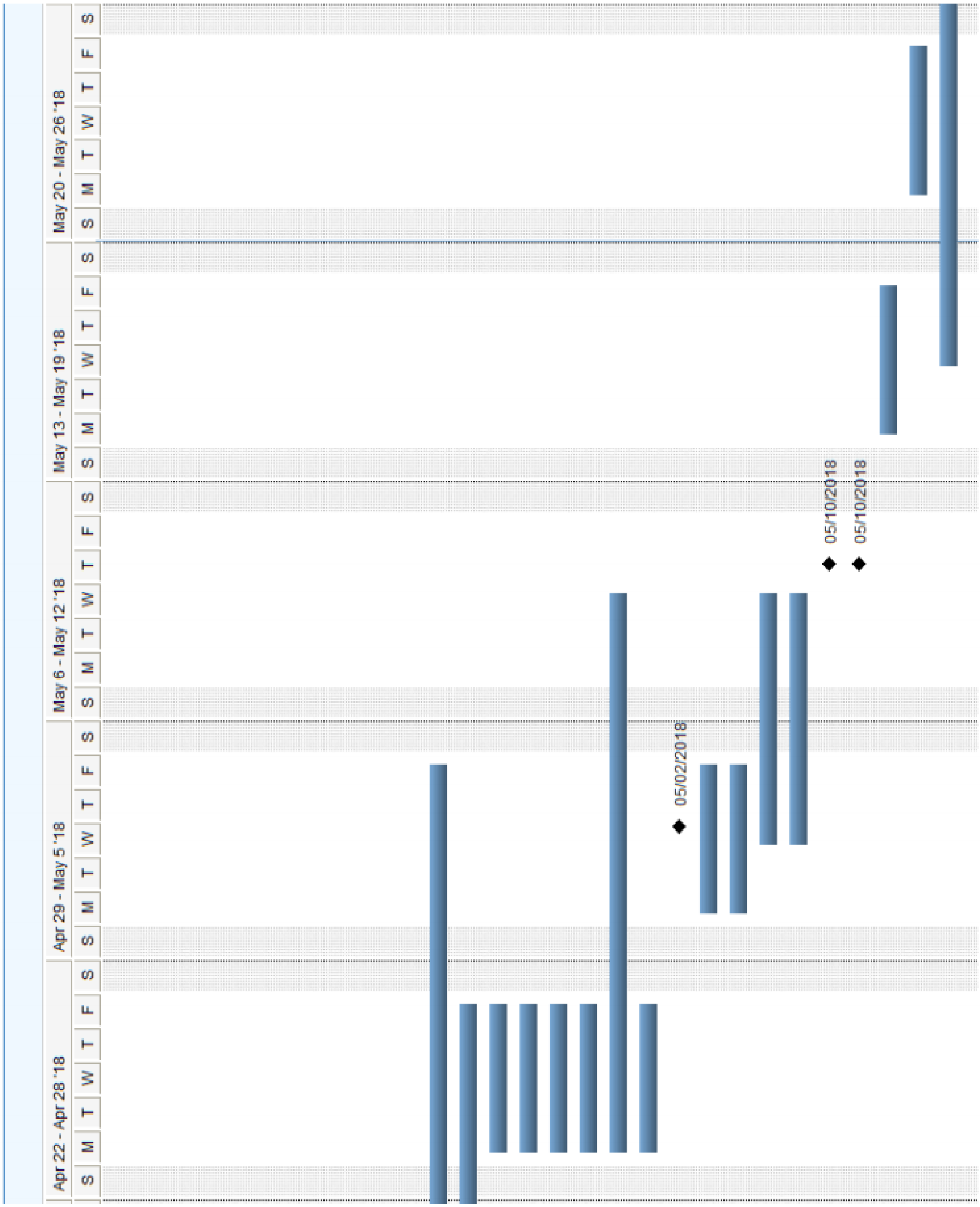

Feb 11 - Feb 17 '18
Feb 18 - Feb 24 '18
Feb 25 - Mar 3 '18
Mar 4 - Mar 10 '18
Mar 11 - Mar 17 '18
Mar 18 - Mar 24 '18
Mar 25 - Mar 31 '18
02/19/2018
02/26/2018
03/05/2018
03/16/2018

Spring Quarter Schedule.

Project Name **Spring Gantt**

	Name	Duration	Start	Finish
1	Buy Retrieval Subsystem Mat'l	1day?	04/09/2018	04/09/2018
2	Preview Day Presentation	0day	04/09/2018	04/09/2018
3	Ethics Prize Submission	5days?	04/09/2018	04/13/2018
4	Comp. Plate and Lever Arm Redesign Meeti...	5days?	04/09/2018	04/13/2018
5	Comp. Chamber /Base Fixture Fabrication	5days?	04/09/2018	04/13/2018
6	PDS Update	5days?	04/09/2018	04/13/2018
7	Base Fixture SW and FEA Validation	5days?	04/09/2018	04/13/2018
8	Fastener Research and Purchasing	5days?	04/16/2018	04/20/2018
9	Experimental Protocal	5days?	04/16/2018	04/20/2018
10	Lever Arm FEA Validation	5days?	04/16/2018	04/20/2018
11	Lever Arm Design Iteration Meetings	5days?	04/16/2018	04/20/2018
12	Base Fixture Fabrication	15days?	04/16/2018	05/04/2018
13	Clay Retrieval SW Redesign	10days?	04/16/2018	04/27/2018
14	Clay Retrieval Fabrication	5days?	04/23/2018	04/27/2018
15	Lever Arm Calculations	5days?	04/23/2018	04/27/2018
16	Lever Arm SW Design Iterations	5days?	04/23/2018	04/27/2018
17	Civil Lab Compression Tests	5days?	04/23/2018	04/27/2018
18	Remain Subsystem Fabrication/Integration	13days?	04/23/2018	05/09/2018
19	Impact Report	5days?	04/23/2018	04/27/2018
20	Impact Report Presentation	1day?	05/02/2018	05/02/2018
21	Base Fixture Iterations in Solid Works	5days?	04/30/2018	05/04/2018
22	Remaining Material Purchases	5days?	04/30/2018	05/04/2018
23	Clay Baking/ Clay Testing	6days?	05/02/2018	05/09/2018
24	Conference Presentation Prep	6days?	05/02/2018	05/09/2018
25	Senior Design Conference Presentation	0day	05/10/2018	05/10/2018
26	Xilinx Presentation	0day	05/10/2018	05/10/2018
27	Prototype Assembly Refinements	5days?	05/14/2018	05/18/2018
28	Prototype Testing	5days?	05/21/2018	05/25/2018
29	Thesis Writing	18days?	05/16/2018	06/08/2018




Apr 22 - Apr 28 '18
S M T W T F S
Apr 29 - May 5 '18
S M T W T F S
May 6 - May 12 '18
S M T W T F S
May 13 - May 19 '18
S M T W T F S
May 20 - May 26 '18
S M T W T F S
05/02/2018
05/10/2018
05/10/2018


May 27 - Jun 2 '18
S M T W T F S
Jun 3 - Jun 9 '18
S M T W T F S

APPENDIX J: Senior Design Conference Presentation Slides

Summary:

The 45th Annual Senior Design Conference took place May 10th, 2018. The Frugal Clay Press design team presented to an audience of friends, family, faculty, and practicing engineers in Benson Memorial Center. The presentation, as included below, focused on highlighting the frugality of the Frugal Clay Press for Nicaragua design and the anticipated potential the project had to benefit the community of Ciudad Darío.

Santa Clara University

SENIOR DESIGN CONFERENCE

Frugal Clay Press for Nicaragua

Milan Copic, Kevin Ellis, Rafael Guerrero and L. Isaac Marcia

Team Adviser: Dr. Timothy Hight

Frugal Innovation Hub — DEPARTMENT OF MECHANICAL ENGINEERING

Presentation Outline

FRUGAL CLAY PRESS FOR NICARAGUA — M. Copic, K. Ellis, R. Guerrero, L. I. Marcia

Project Purpose & Motivation

DEPARTMENT OF MECHANICAL ENGINEERING

Project Inspiration

- Project Inspiration from Dr. Tonya Nilsson (EWB Liaison)
  - Similar project with roof tiles in Rwanda

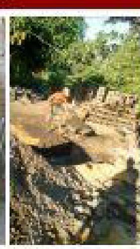
Clay Tile Extruder with Cutter

DEPARTMENT OF MECHANICAL ENGINEERING

"Engineering with a Mission"

Parameters of Frugality:

- Simple to Apply
- Not Energy Intensive (Human Powered)
- Uses Local Resources and Labor
- Easily Shippable

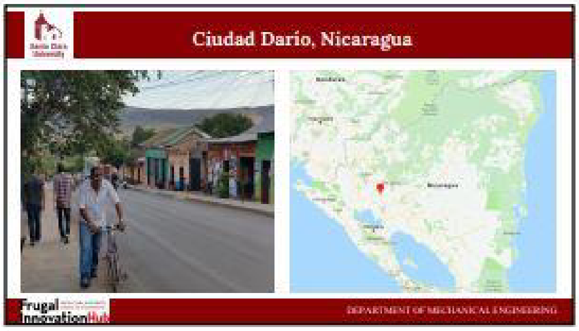


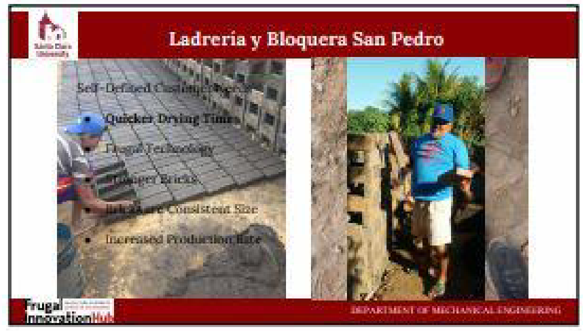
DEPARTMENT OF MECHANICAL ENGINEERING

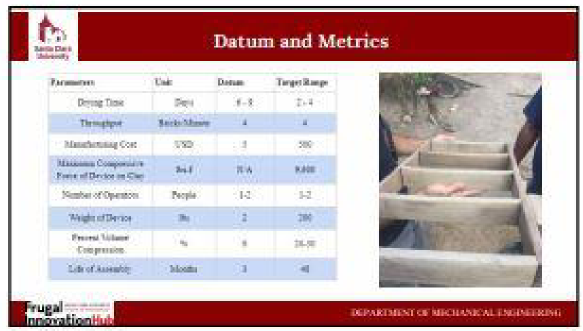
FRUGAL CLAY PRESS FOR NICARAGUA — M. Copic, K. Ellis, R. Guerrero, L. I. Marcia

Partnership with the Frugal Innovation Hub

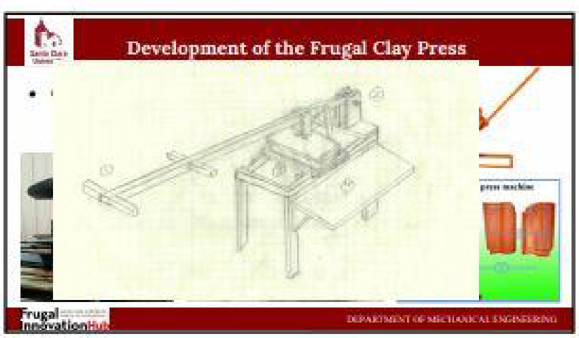
DEPARTMENT OF MECHANICAL ENGINEERING



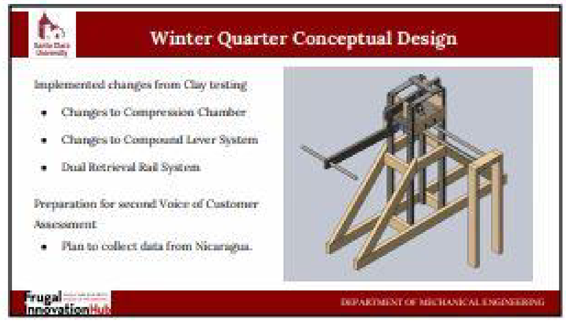


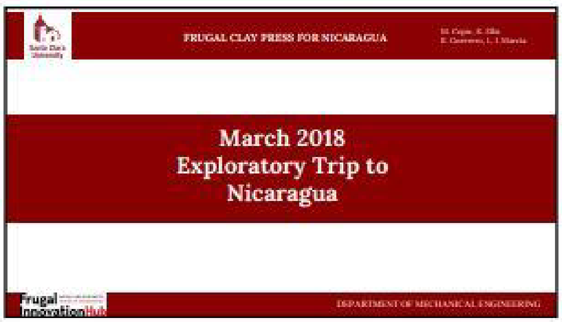


Parameters	Unit	Datum	Target Range
Drying Time	Days	6 - 8	2 - 4
Throughput	Bricks/Minute	4	4
Manufacturing Cost	USD	3	300
Maximum Compressive Force of Device on Clay	lbs-f	N/A	8,000
Number of Operators	People	1-2	1-2
Weight of Device	lbs	2	200
Percent Volume Compression	%	8	20-30
Life of Assembly	Months	3	48




Clay Testing & Prototype Validation
DEPARTMENT OF MECHANICAL ENGINEERING

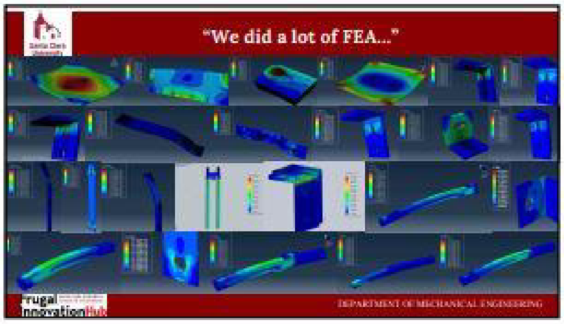

Winter Quarter Conceptual Design
Implemented changes from Clay testing
Changes to Compression Chamber
Changes to Compound Lever System
Dual Retrieval Rail System
Preparation for second Voice of Customer Assessment
Plan to collect data from Nicaragua.
DEPARTMENT OF MECHANICAL ENGINEERING

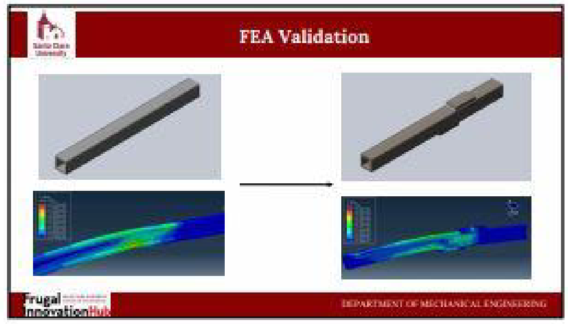

FRUGAL CLAY PRESS FOR NICARAGUA
March 2018
Exploratory Trip to
Nicaragua
DEPARTMENT OF MECHANICAL ENGINEERING

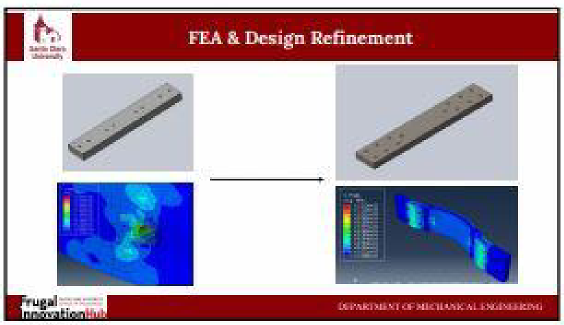

Purpose of Travel
Ascertain available local materials and machining capabilities
Engage in participant observation in current brick-making process
Test local clay
DEPARTMENT OF MECHANICAL ENGINEERING

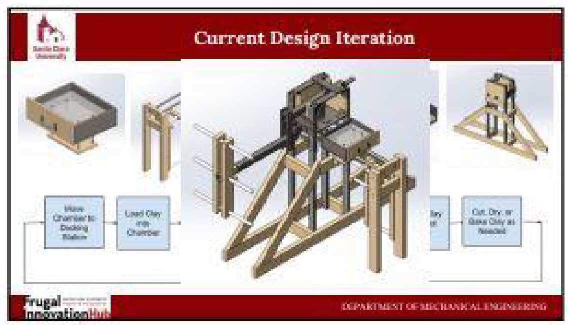

In-Person Voice of Customer Assessment
DEPARTMENT OF MECHANICAL ENGINEERING

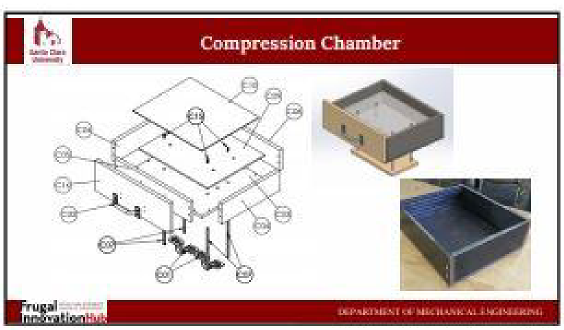

FRUGAL CLAY PRESS FOR NICARAGUA
Prototype Fabrication
&
Validation
DEPARTMENT OF MECHANICAL ENGINEERING

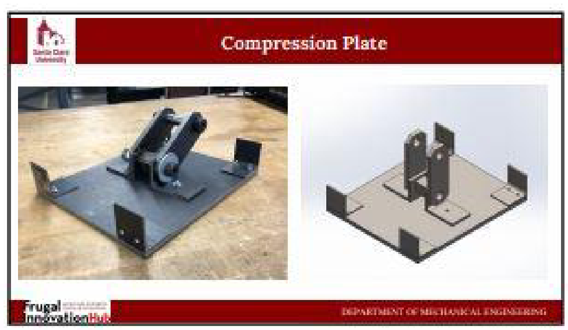

"We did a lot of FEA..."
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING

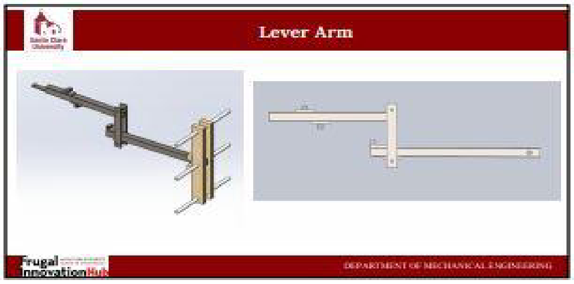

FEA Validation
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING

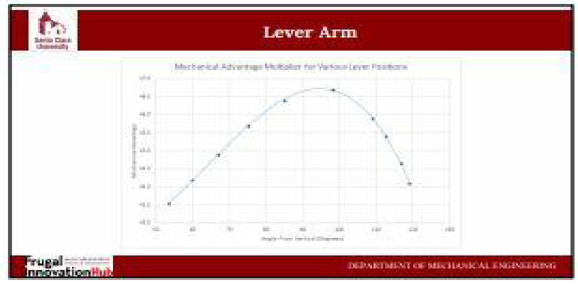

FEA & Design Refinement
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING

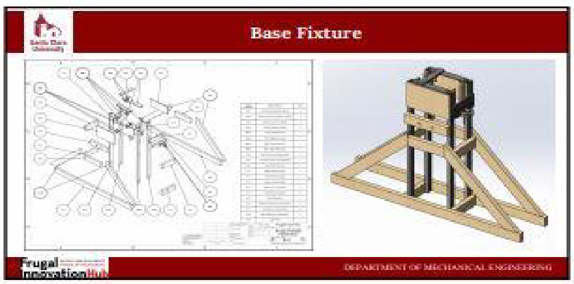

Current Design Iteration
Move Chamber to Docking Station
Load Clay into Chamber
Cut, Dry, or Bake Clay as Needed
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING

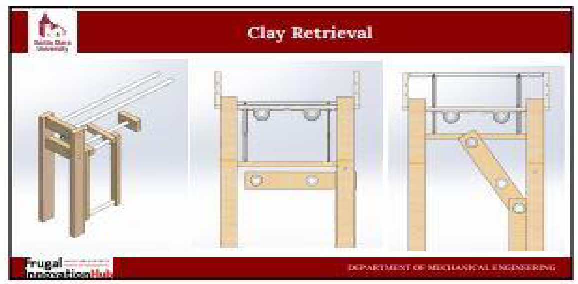

Compression Chamber
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Compression Plate
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Lever Arm
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Lever Arm
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Base Fixture
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Clay Retrieval
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Prototype Testing & Analysis
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


FRUGAL CLAY PRESS FOR NICARAGUA
Future Iteration
&
Project Impact
Frugal Innovation Hub
DEPARTMENT OF MECHANICAL ENGINEERING


Future Design Changes & Testing
Design Changes:
Auxiliary Cutting Mechanism
Surface Finish
Welded Chamber
Phase Out Wood
Locking Lever Arm
Improve Compression Plate Guiding
Ongoing Testing
Baked Brick Strength
Brick Absorptivity
Optimal Brick Composition
Measured Force Application
DEPARTMENT OF MECHANICAL ENGINEERING


Environmental & Societal Impact of Implementation
Water usage as largest expense
Increased workable hours per day
Nicaragua clay at 40 weight percent water
Increased employment opportunities with Ladería y Bloquera San Pedro
Reduce water usage to 4,100 gallons per month.
DEPARTMENT OF MECHANICAL ENGINEERING


Product Deployment & State of Nicaragua
Ideal Plan:
Build Device; Train Users
Setbacks:
US Travel Advisory
→ Level 3: Reconsider Travel
Secondary Plan:
Ship Device ~ $1,600 US
Send Detailed Instructions
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Design Legacy & Future Implementation
Legacy Project
Open Source Design
Possibly Used by and Continued with Engineers Without Borders
DEPARTMENT OF MECHANICAL ENGINEERING


Challenges
DEPARTMENT OF MECHANICAL ENGINEERING


Santa Clara University
Conclusion
Evolution of the Frugal Clay Press Design
Voice of Customer Assessment & Travel to Nicaragua
Prototype Realization & Validation
Projected Impact & Design Legacy of the Frugal Clay Press

APPENDIX K: Parts List

Summary:

The summation of all the bought parts, machined and/or fabricated parts, and standard fasteners used to build this prototype are enumerated in Table 1.

Table 1: Description of the part numbers, part names and quantities of those parts.

Subsystem	Part Number	Part Name	Quantity
Base Fixture	B01	Chamber Support Block	4
	B02	Output Fulcrum Support L Beam	4
	B02 II	Output Fulcrum Support L Beam II	2
	B03	Output Fulcrum L Beam	2
	B04	Input Fulcrum L Beam	2
	B05A	Front Left Base Leg	1
	B05B	Front Right Base Leg	1
	B05C	Back Left Base Leg	1
	B05D	Back Right Base Leg	1
	B06	Input Fulcrum Support Bar	1
	B07	Output Fulcrum Support Bar	1
	B08	Chamber Guides	2
	B09	Left Wood Guard	1
	B10	Right Wood Guard	1
	B11	Front Wood Guard	1
	B12	Back Wood Guard	1
	B13	Bottom Truss Support	2
	B14	Hypotenuse Support	4

	B15	Rail Supporter	1
	B16	Bottom Wood Truss Connector	4
	B17	Top Fulcrum Support Bar	2
	B18	Top Wood Truss Connector	2
	B19	Hardstop	1
	B20	Hardstop and Fulcrum Connector	1
	B21	1/2"-13 x 1.5" Hex Bolt	2
	B22	1/2"-13 x 2" Hex Bolt	10
	B23	1/2"-13 x 2.25" Hex Bolt	8
	B24	1/2"-13 Hex Nut	20
	B25	1/2" Flat Washer	20
	B26	3/8"-24 x 4" Hex Bolt	2
	B27	3/8"-24 Hex Nut	2
	B28	3/8" Flat Washer	2
	B29	1/4"-20 x 1.25" Hex Bolt	4
	B30	1/4"-20 x 1.5" Hex Bolt	30
	B31	1/4"-20 x 1.75" Hex Bolt	6
	B32	1/4"-20 x 3" Hex Bolt	16
	B33	1/4"-20 Hex Nut	40
	B34	1/4" Flat Washer	70
Compound Lever Arm	L01	1/2" Bolt Collar	1
	L02	5/8" Bolt Collar	3
	L03	Input Bar	1

	L04	Output Bar	1
	L05	Lever Connector Beam	2
	L06	Pipe Handle	3
	L07	Pipe Handle Mount	2
	L08	Counter Weight Beam	1
	L09	Ladder Connects	2
	L10	3/4" Bolt Collar	1
	L11	1/2" Flat Washer	1
	L12	5/8" Flat Washer	3
	L13	3/4" Flat Washer	1
	L14	3/8"-24 Hex Nut	1
	L15	1/2"-13 Hex Nut	3
	L16	5/8"-11 Hex Nut	1
	L17	1/2'-13 x 2" Hex Shoulder Bolt	1
	L18	5/8"-11 x 2" Hex Shoulder Bolt	3
	L19	3/4"-10 x 2" Hex Shoulder Bolt	1
Compression Chamber	C01	Routing Clamp	23
	C02	Pull Handle	1
	C03	Bottom Plate	1
	C04	Side Wall	2
	C05	Front Wall	1
	C06	Back Wall	1
	C07	MF Hex Standoff	4

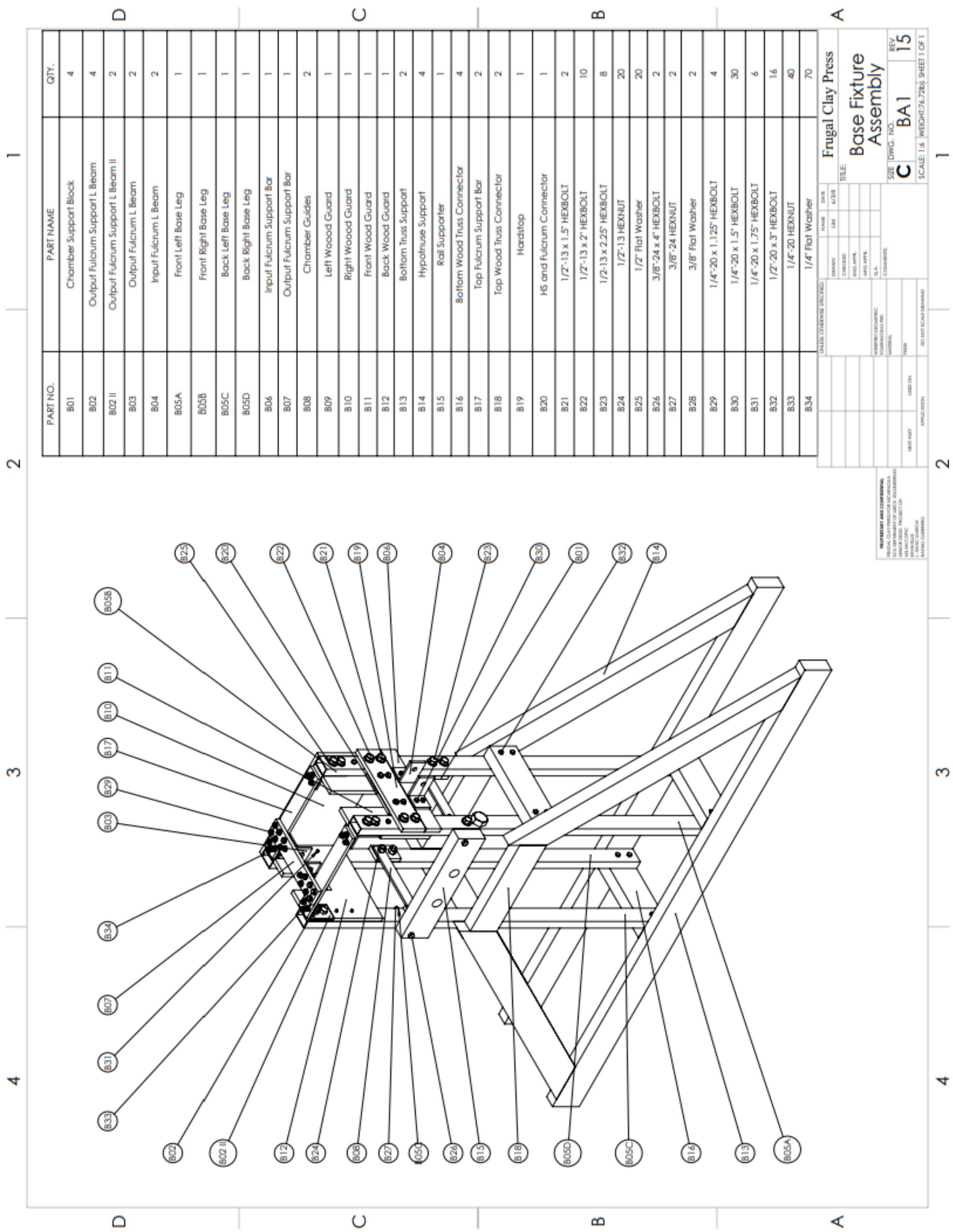
	C08	FF Hex Standoff	4
	C09	Acrylic Elevating Base	1
	C10	Chamber Wood Guard	1
	C11	#8-31 x 0.75" Phillips Button Head	4
	C12	Push Block	1
	C13	#10-24 x 1" Phillips Flat Head (82)	22
	C14	#8-31 x 0.4" Pan Flat Head (82)	4
	C15	#10-24 x 0.875" Phillips Button Head	8
	C16	3/8"-16 x 0.75" Phillips Flat Head (82)	4
	C17	3/8"-16 Hex Nut	4
Compression Plate	P01	Plate Connector L Beam	2
	P02	3/4" x 2" Steel Shoulder Bolt	1
	P03	5/8"-11 Hex Nut	1
	P04	Plate Connecting Beam	2
	P05	Compression Plate Guides	4
	P06	3/4" Flat Washer	2
	P07	Compression Plate	1
	P08	#10-24 Hex Nut	10
	P09	#10-24 x 0.75" Machine Screw	10
	P10	Plate Connecting Beam Spacer	1
Clay Retrieval	R01	Retrieval Rail	2
	R02	Rail Beam	1
	R03A	Left Frame Leg	1

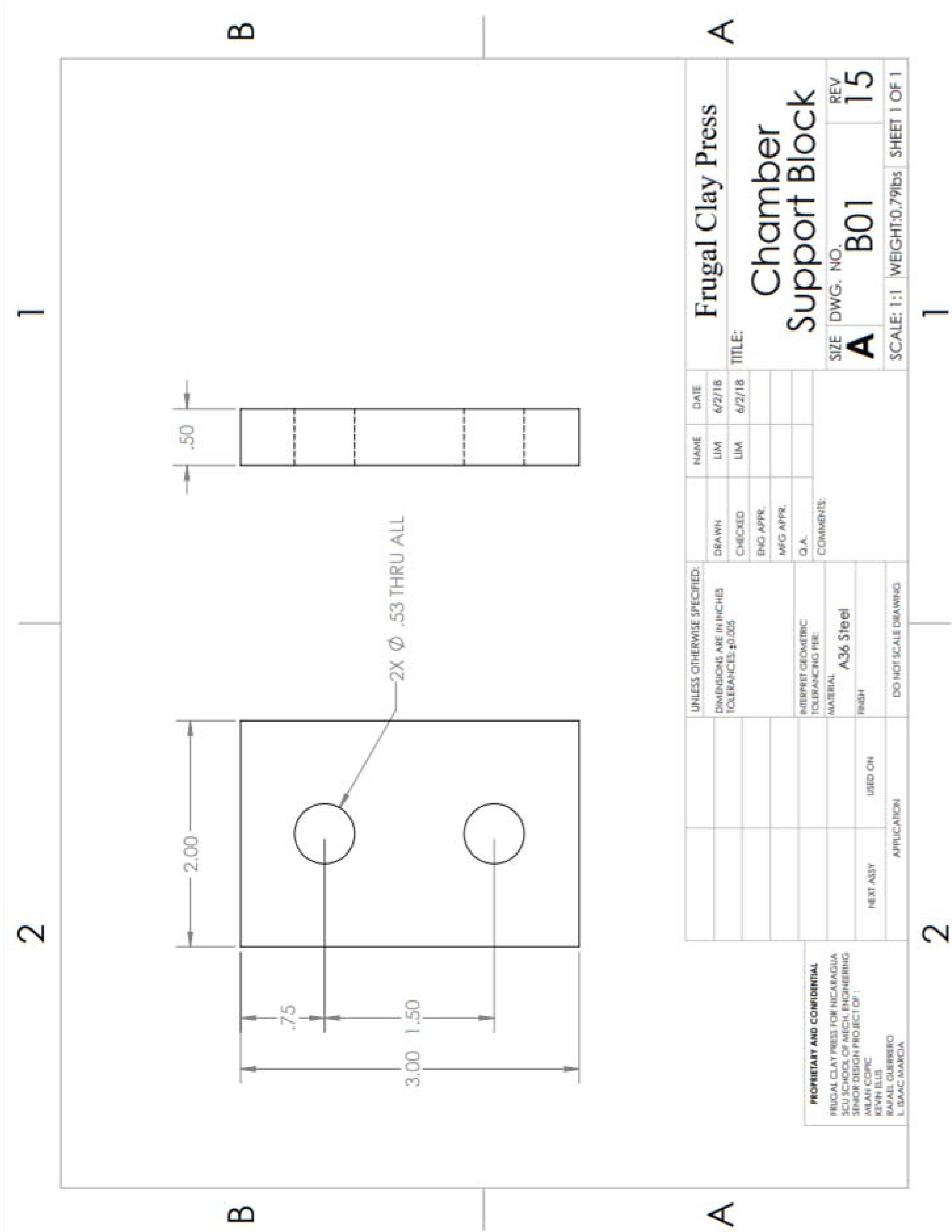
	R03B	Right Frame Leg	1
	R04	Push Pipe	1
	R05	Push Lever	2
	R06	Foot Beam	2
	R07	Foot Pedal	2
	R08	Retrieval Pivot Beam	1
	R09	Pivot Pipe	1
	R10	Base Pivot Beam	1
	R11	Bottom Beam	1
	R12	Retrieval to Base Beam	2
	R13	1/4" x 2.5" Wood Screw	8
	R14	1/4"-28 x 2.5" Hex Bolt	2
	R15	1/4"-28 x 4" Hex Bolt	1
	R16	1/4"-28 Hex Nut	3

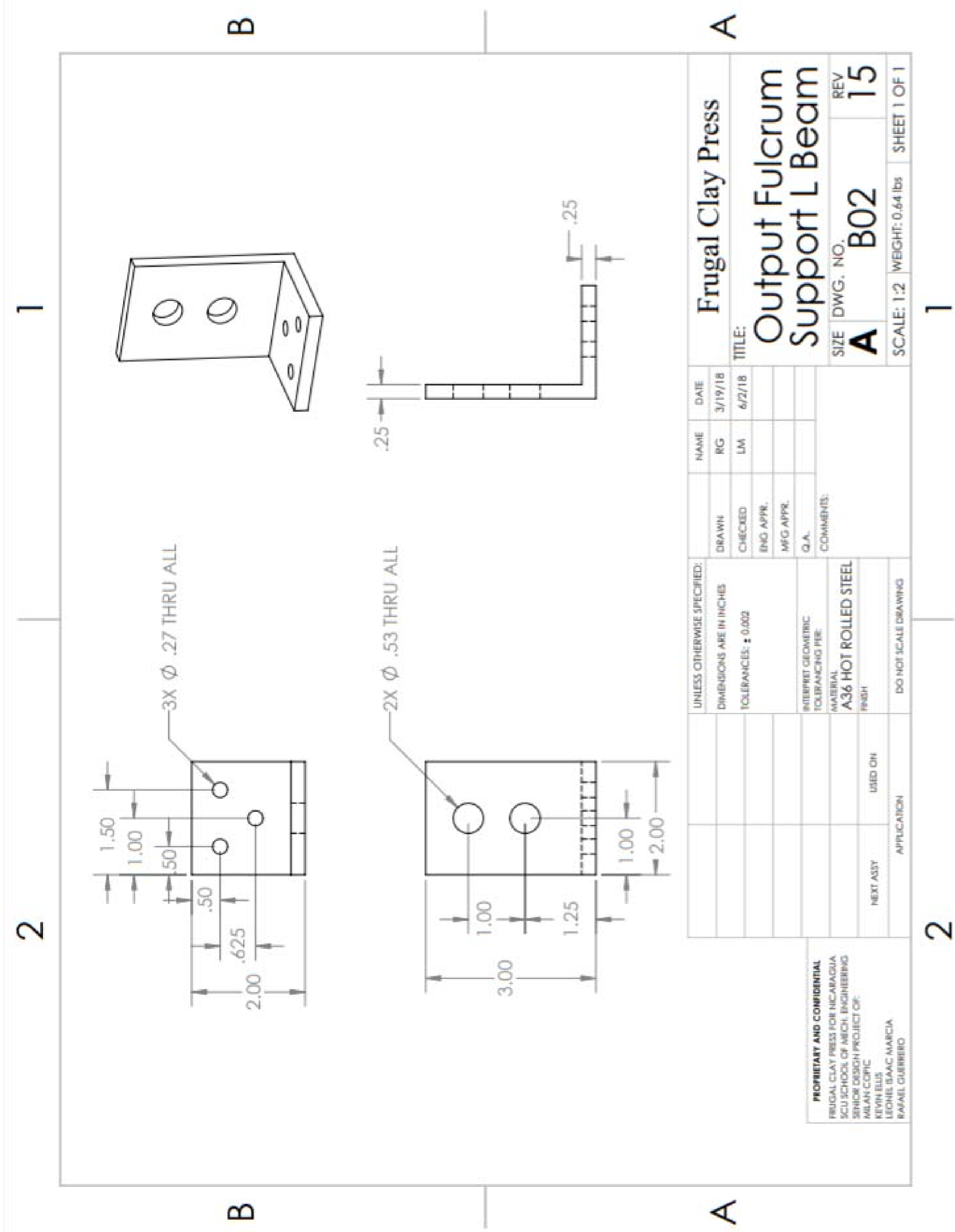
APPENDIX L: Detail and Assembly Drawings

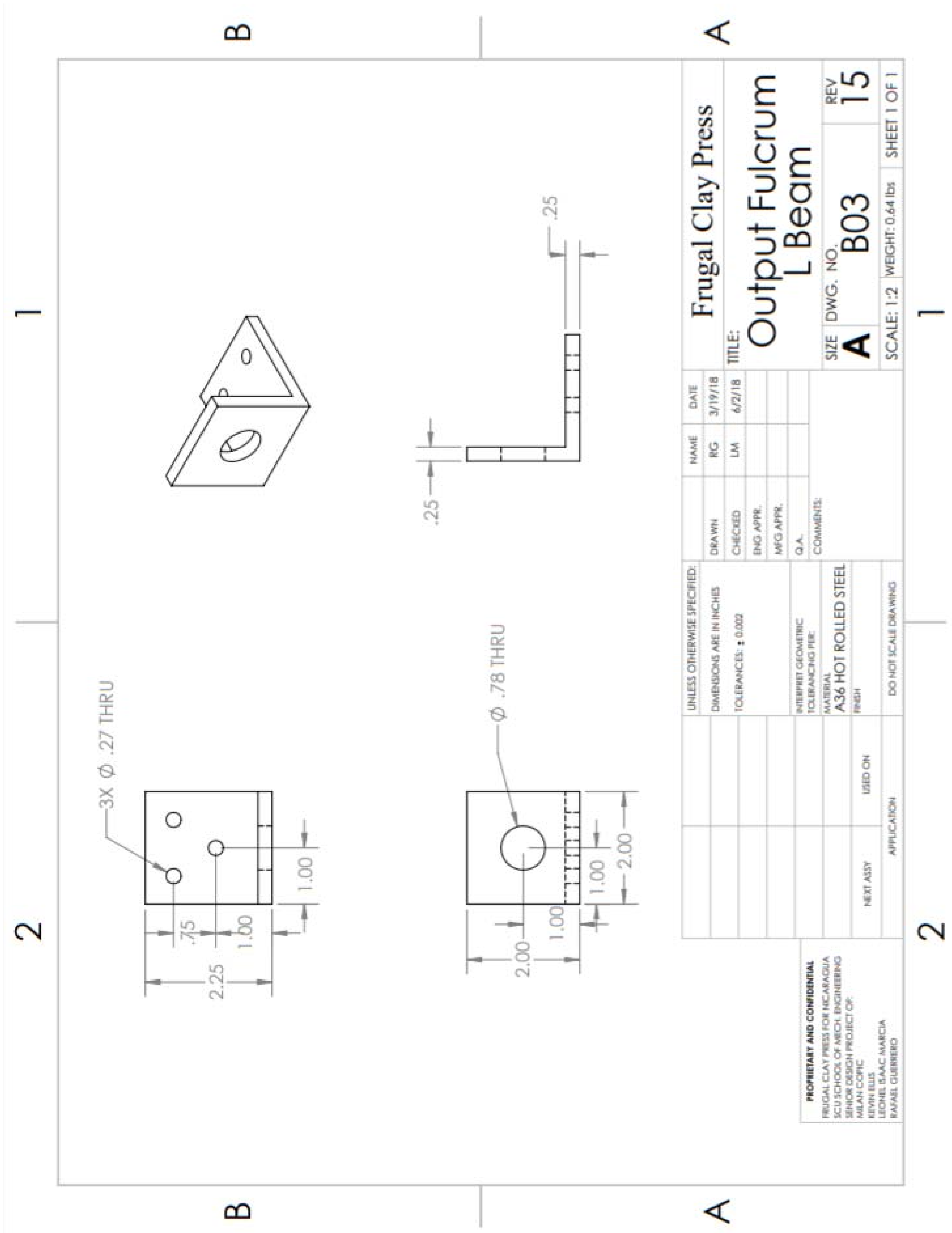
Summary:

The detail drawings for all the parts that were machined or manufactured in SCU's laboratories are presented. Overall there are 57 part drawings and 5 subsystem assembly drawings that were created.

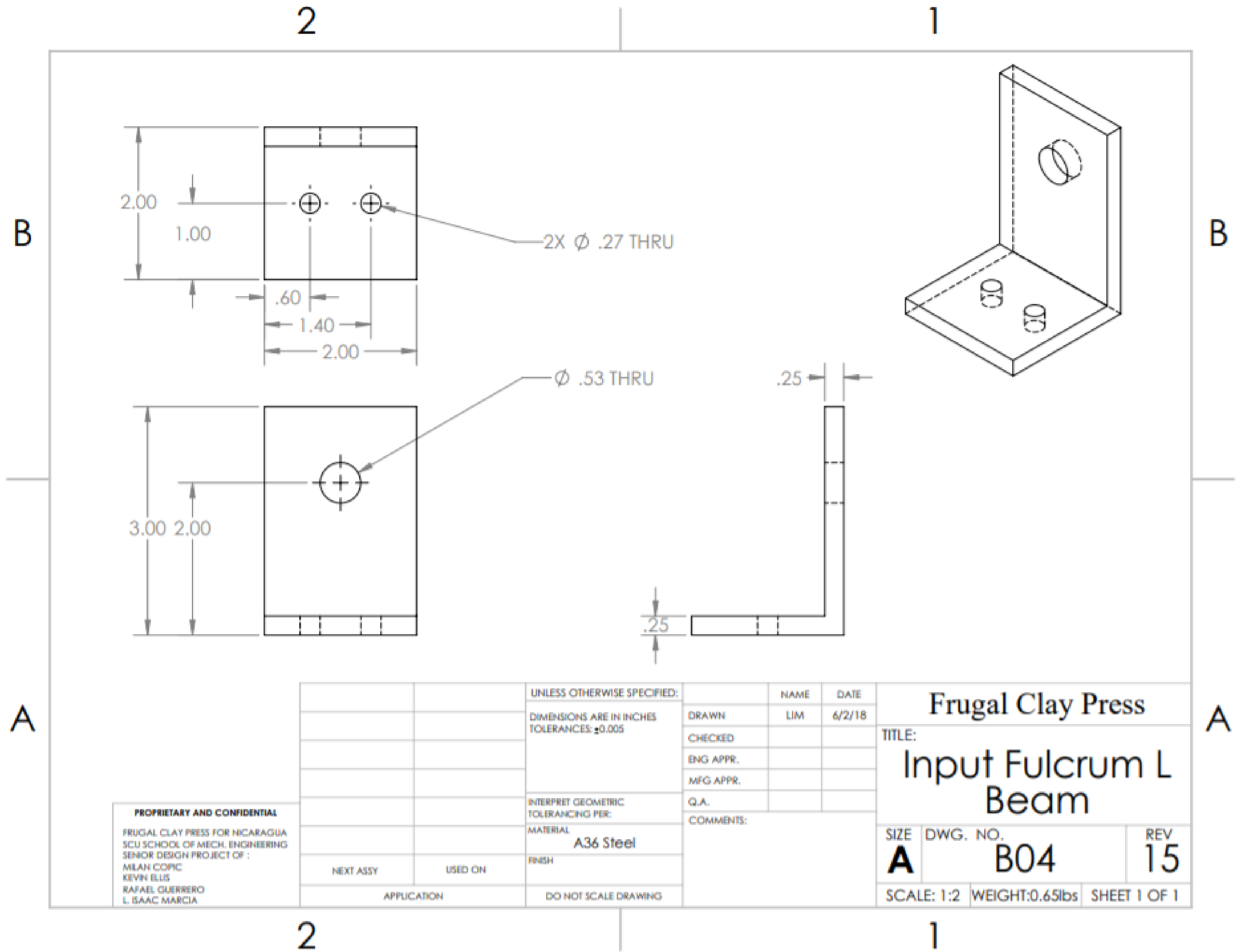



Frugal Clay Press
TITLE:
Chamber Support Block
SIZE A
DWG. NO. B01
REV 15
SCALE: 1:1
WEIGHT:0.79lbs
SHEET 1 OF 1
2X Ø .53 THRU ALL
.50
2.00
.75
1.50
3.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
LIM
6/2/18
CHECKED
LIM
6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF :
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
L. ISAAC MARCIA
A
B
1
2

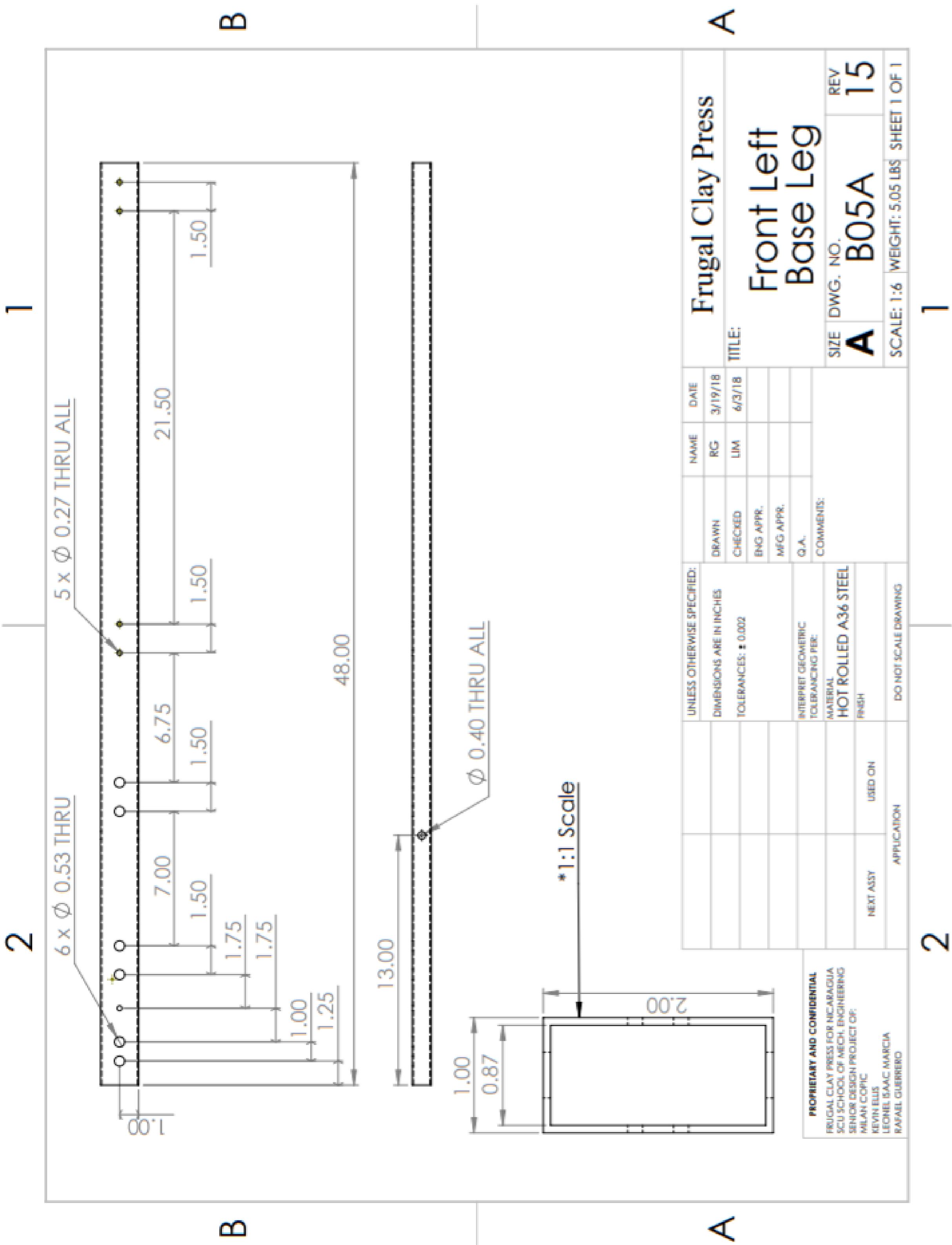

Frugal Clay Press
TITLE:
Output Fulcrum Support L Beam
SIZE A
DWG. NO. B02
REV 15
SCALE: 1:2
WEIGHT: 0.64 lbs
SHEET 1 OF 1
3X Ø .27 THRU ALL
2X Ø .53 THRU ALL
1.50
1.00
.50
.50
.625
2.00
1.00
1.25
3.00
1.00
2.00
.25
.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 3/19/18
CHECKED LM 6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2



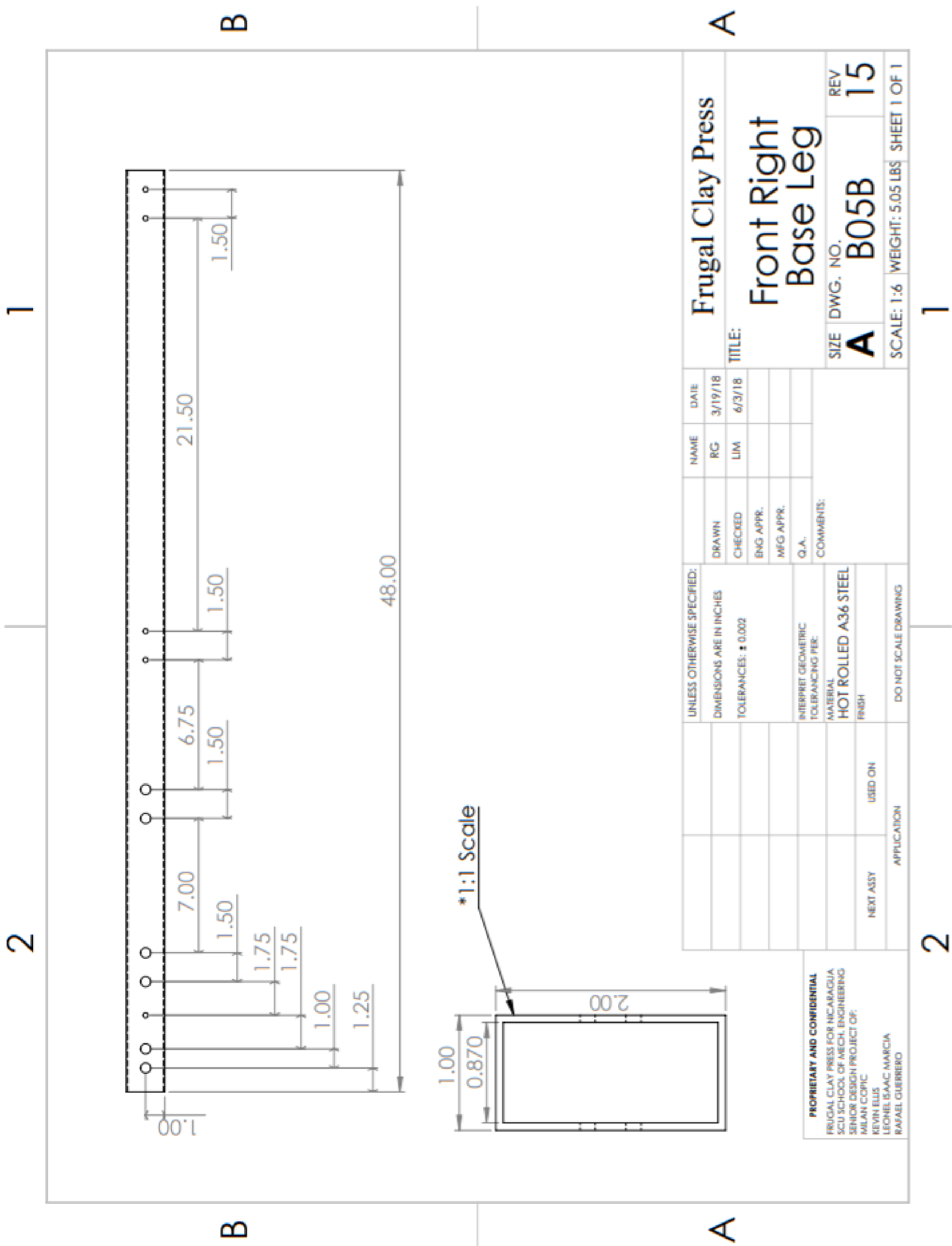
3X ⌀ .27 THRU
⌀ .78 THRU
.75
1.00
2.25
1.00
2.00
1.00
1.00
2.00
.25
.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LM
6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Output Fulcrum L Beam
SIZE
A
DWG. NO.
B03
REV
15
SCALE: 1:2
WEIGHT: 0.64 lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



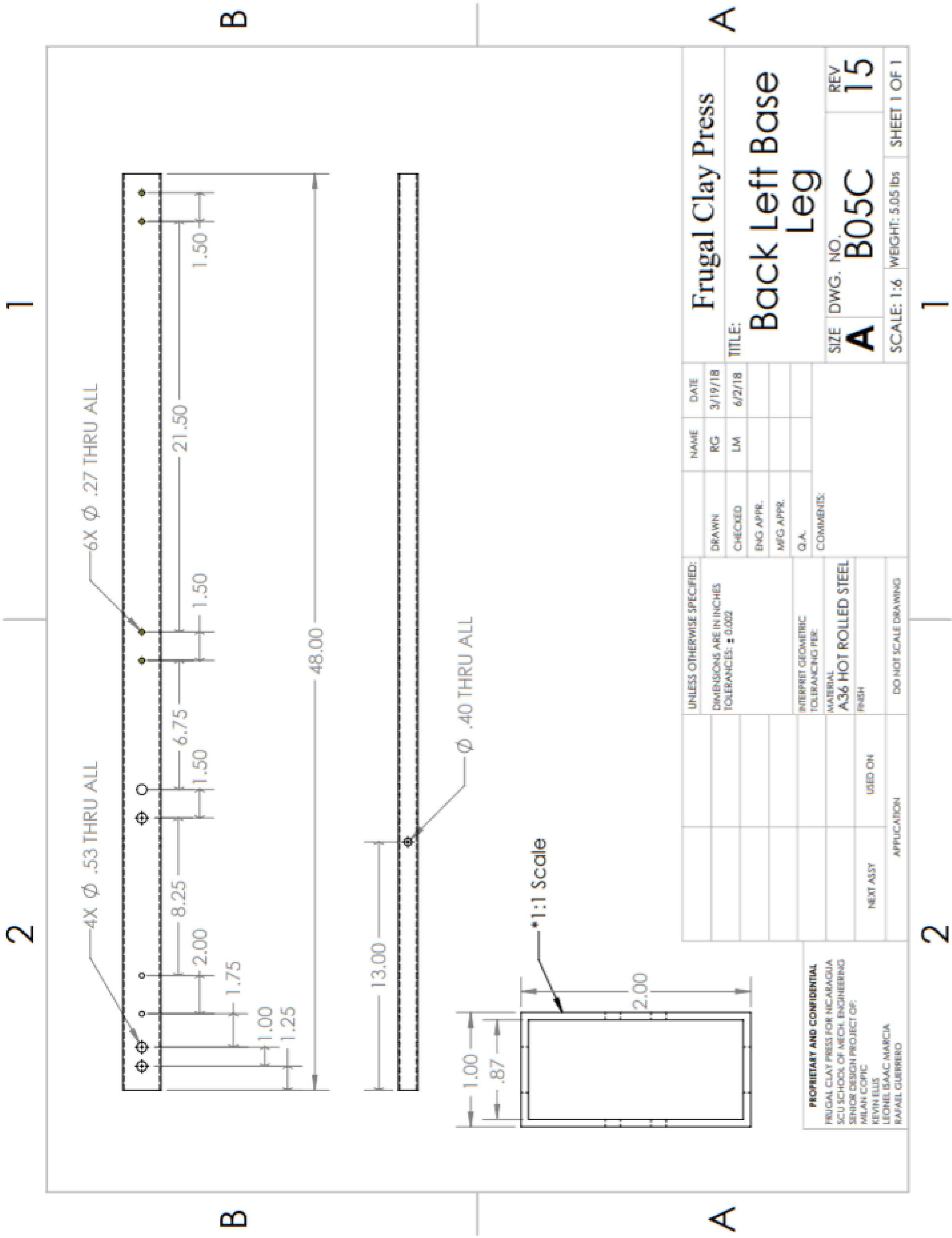
2X ⌀ .27 THRU
⌀ .53 THRU
2.00
1.00
.60
1.40
2.00
3.00
2.00
.25
.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
LIM
6/2/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Input Fulcrum L Beam
SIZE
A
DWG. NO.
B04
REV
15
SCALE: 1:2
WEIGHT:0.65lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF :
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
L. ISAAC MARCIA

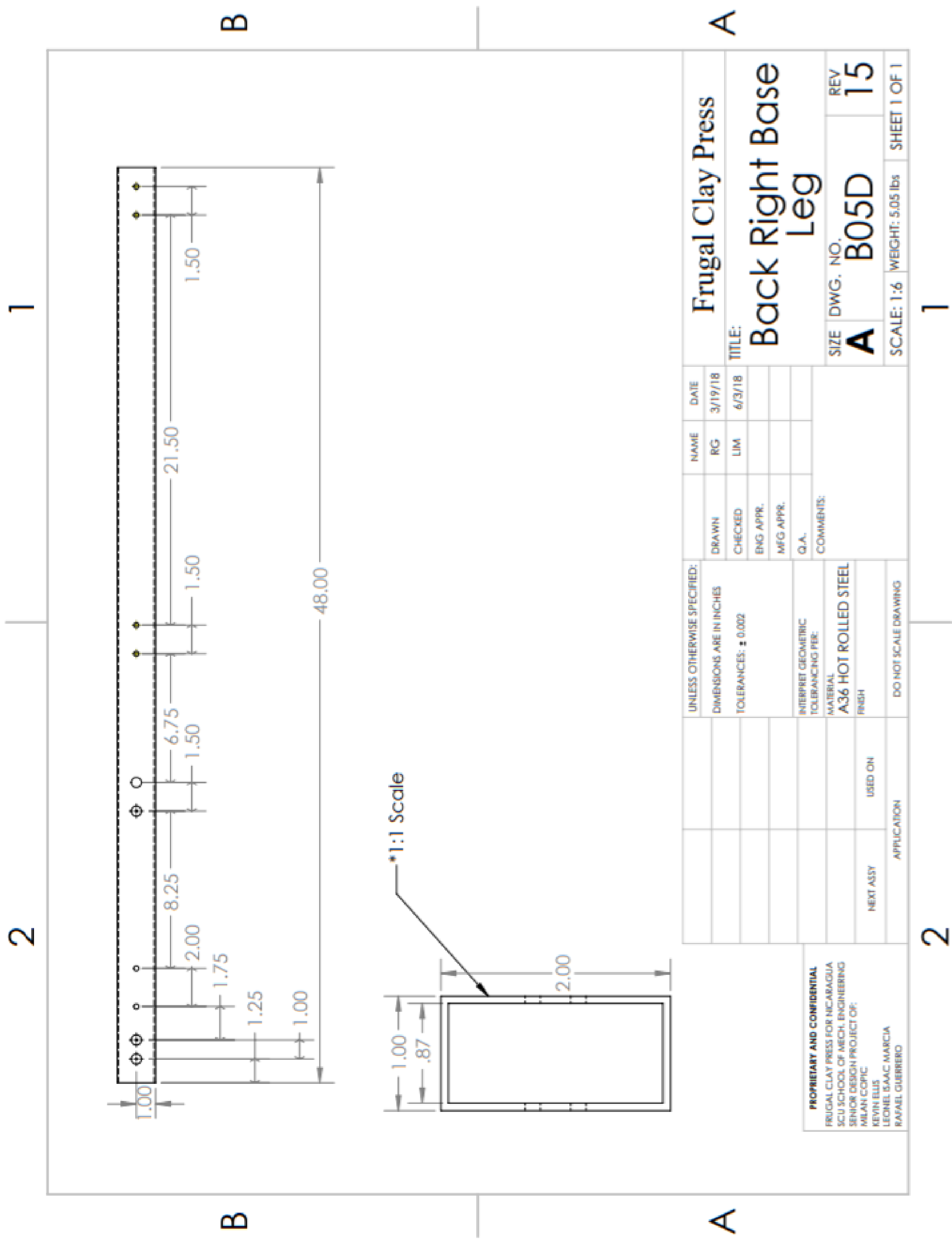


6 x Ø 0.53 THRU
5 x Ø 0.27 THRU ALL
Ø 0.40 THRU ALL
*1:1 Scale
48.00
21.50
7.00
6.75
1.50
1.75
1.00
1.25
13.00
2.00
0.87
Frugal Clay Press
TITLE:
Front Left Base Leg
SIZE A
DWG. NO. B05A
REV 15
SCALE: 1:6
WEIGHT: 5.05 LBS
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
HOT ROLLED A36 STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 3/19/18
CHECKED LIM 6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

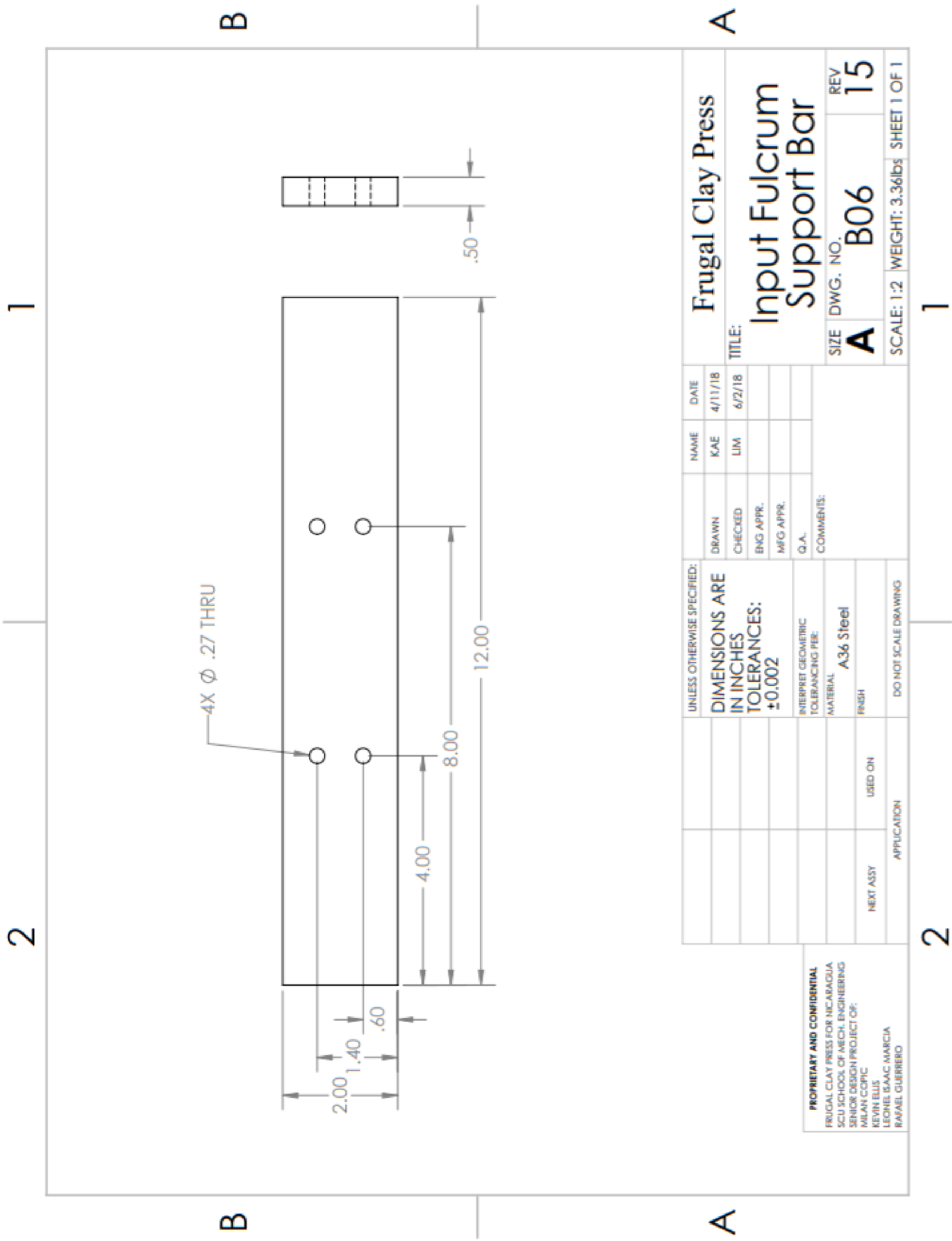


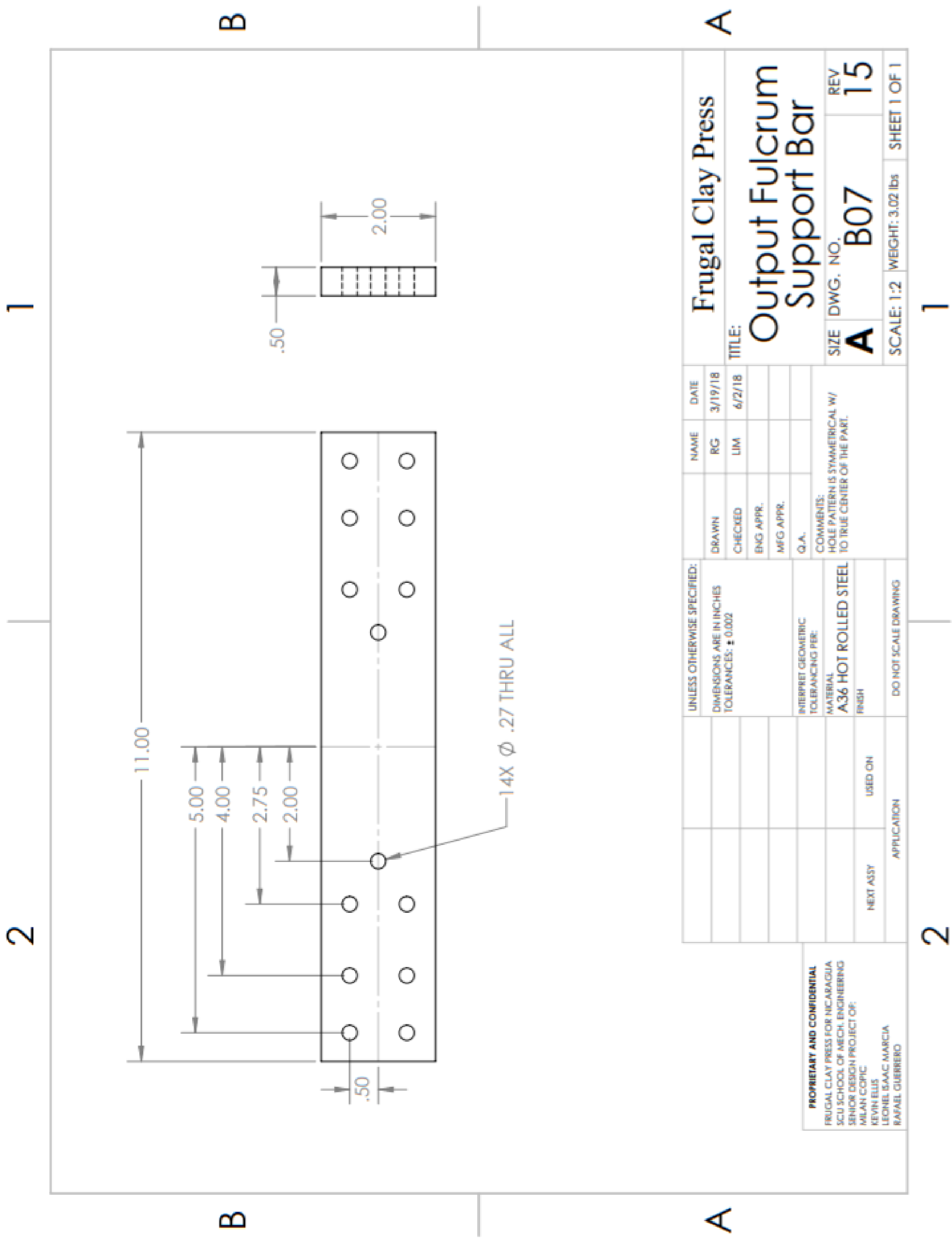
Frugal Clay Press
TITLE:
Front Right Base Leg
SIZE A
DWG. NO. B05B
REV 15
SCALE: 1:6
WEIGHT: 5.05 LBS
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
HOT ROLLED A36 STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
*1:1 Scale
48.00
21.50
6.75
7.00
1.50
1.75
1.00
1.25
2.00
0.870

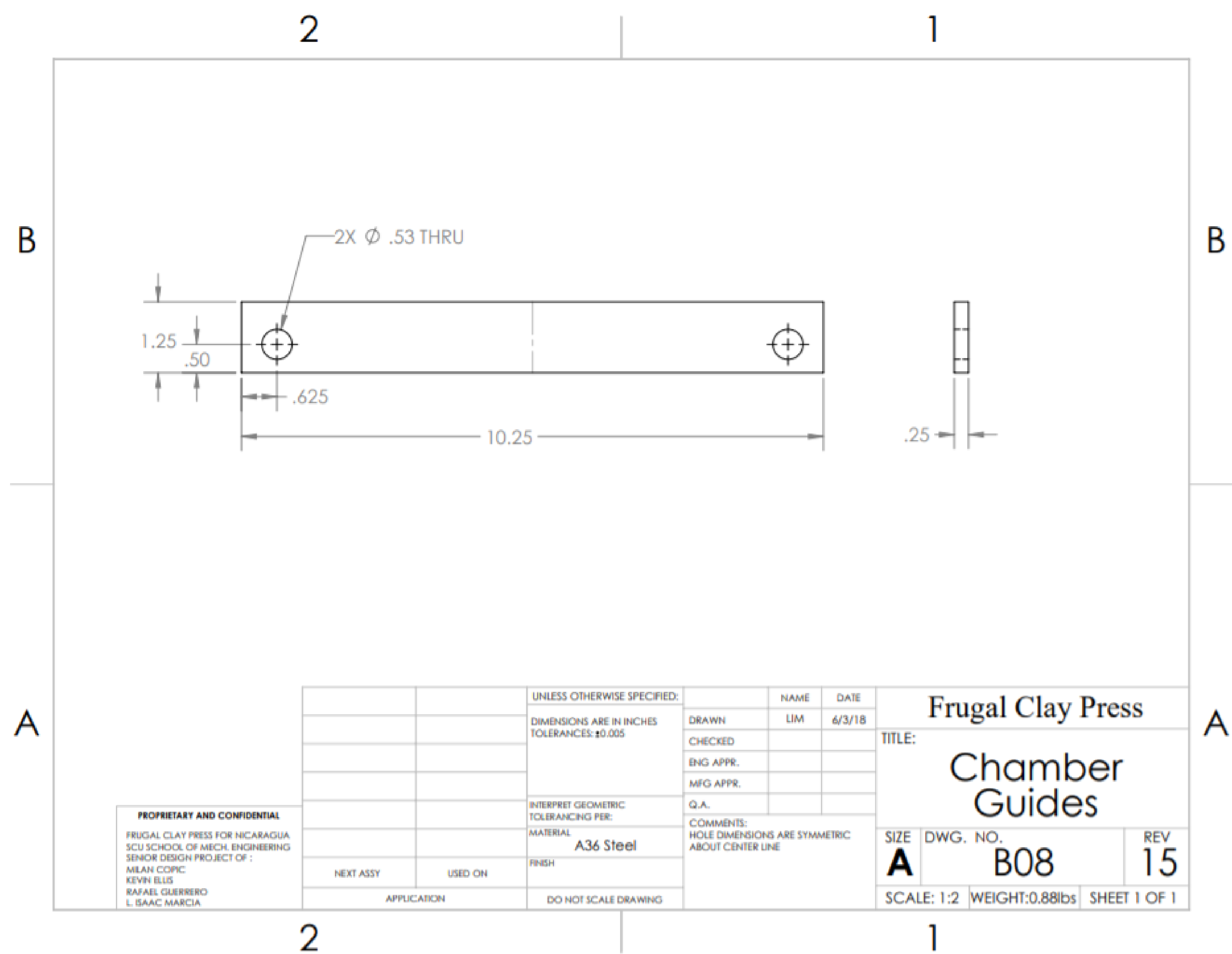

Frugal Clay Press
TITLE:
Back Left Base Leg
SIZE A
DWG. NO. B05C
REV 15
SCALE: 1:6
WEIGHT: 5.05 lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN RG 3/19/18
CHECKED LM 6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
4X Ø .53 THRU ALL
6X Ø .27 THRU ALL
Ø .40 THRU ALL
*1:1 Scale
48.00
21.50
8.25
6.75
2.00
1.75
1.50
1.25
1.00
13.00
.87
A
B
1
2

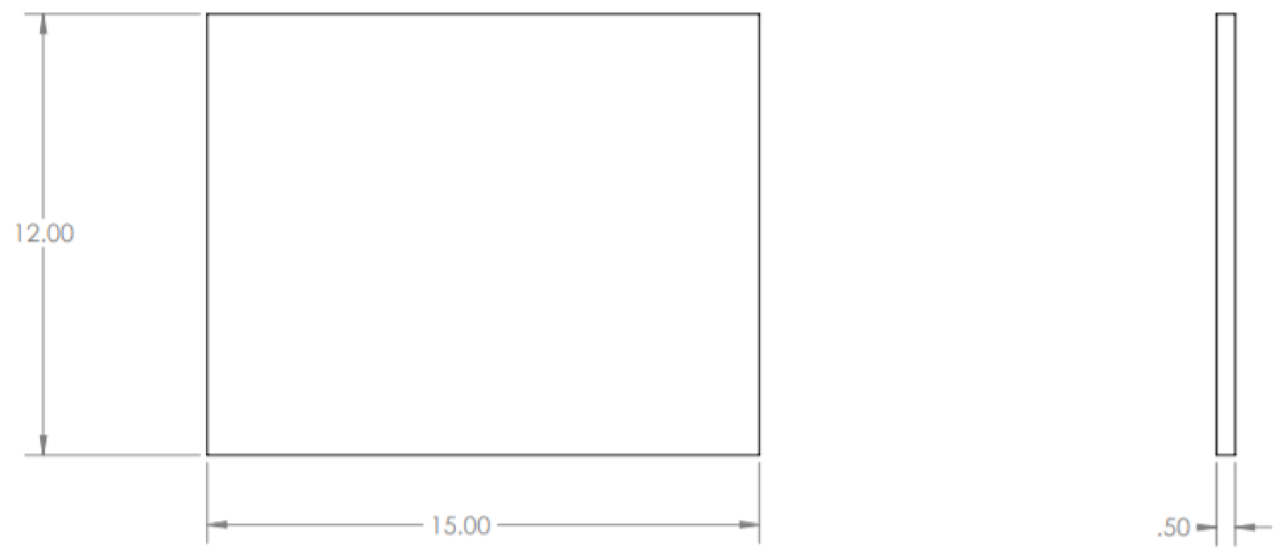


Frugal Clay Press
TITLE:
Back Right Base Leg
SIZE A
DWG. NO. B05D
REV 15
SCALE: 1:6
WEIGHT: 5.05 lbs
SHEET 1 OF 1
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
*1:1 Scale
48.00
21.50
1.50
1.50
6.75
1.50
8.25
2.00
1.75
1.25
1.00
1.00
2.00
1.00
.87


4X Ø .27 THRU
.50
12.00
8.00
4.00
2.00
1.40
.60
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
±0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Steel
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
4/11/18
CHECKED
LIM
6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Input Fulcrum Support Bar
SIZE
A
DWG. NO.
B06
REV
15
SCALE: 1:2
WEIGHT: 3.36lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO


11.00
5.00
4.00
2.75
2.00
.50
14X Ø .27 THRU ALL
.50
2.00
Frugal Clay Press
TITLE:
Output Fulcrum Support Bar
SIZE A
DWG. NO. B07
REV 15
SCALE: 1:2
WEIGHT: 3.02 lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 3/19/18
CHECKED LIM 6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
HOLE PATTERN IS SYMMETRICAL W/ TO TRUE CENTER OF THE PART.
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2


2X Ø .53 THRU
1.25
.50
.625
10.25
.25
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF :
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
L. ISAAC MARCIA
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
LIM
6/3/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
HOLE DIMENSIONS ARE SYMMETRIC ABOUT CENTER LINE
Frugal Clay Press
TITLE:
Chamber Guides
SIZE
A
DWG. NO.
B08
REV
15
SCALE: 1:2
WEIGHT:0.88lbs
SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	RG	3/19/18
CHECKED	LIM	6/2/18
ENG APPR.		
MFG APPR.		
Q.A.		

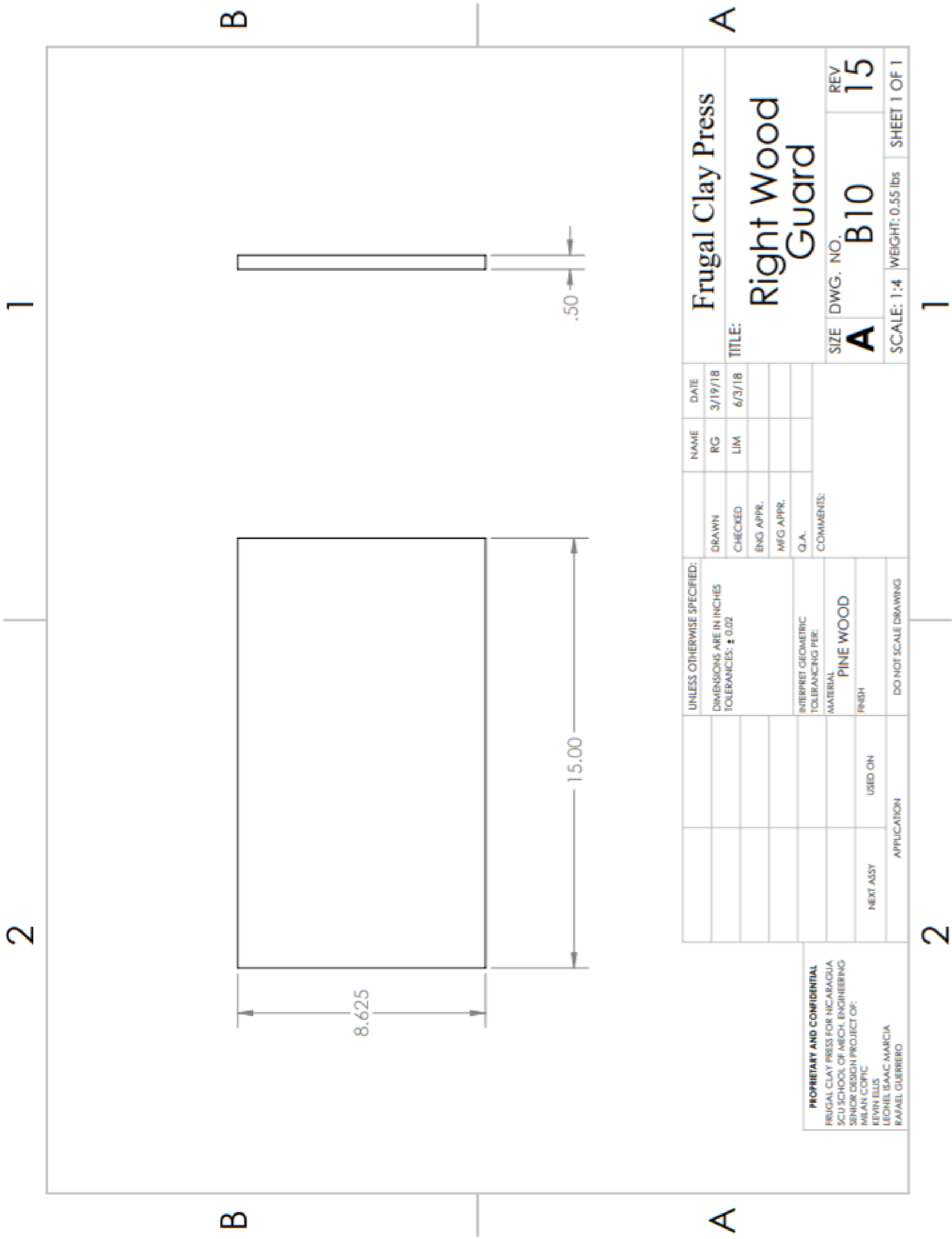
COMMENTS:

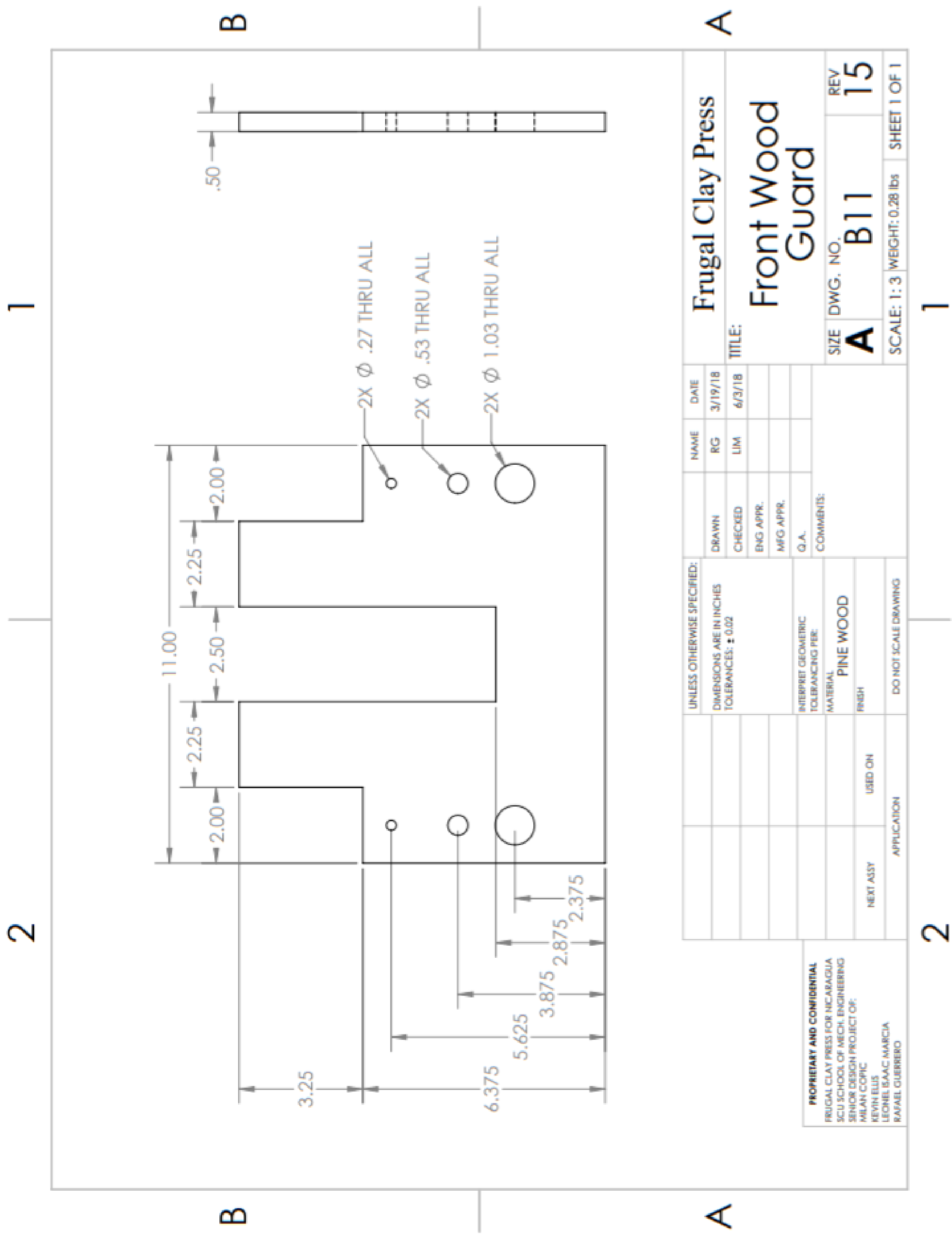
Frugal Clay Press

TITLE:
Left Wood Guard

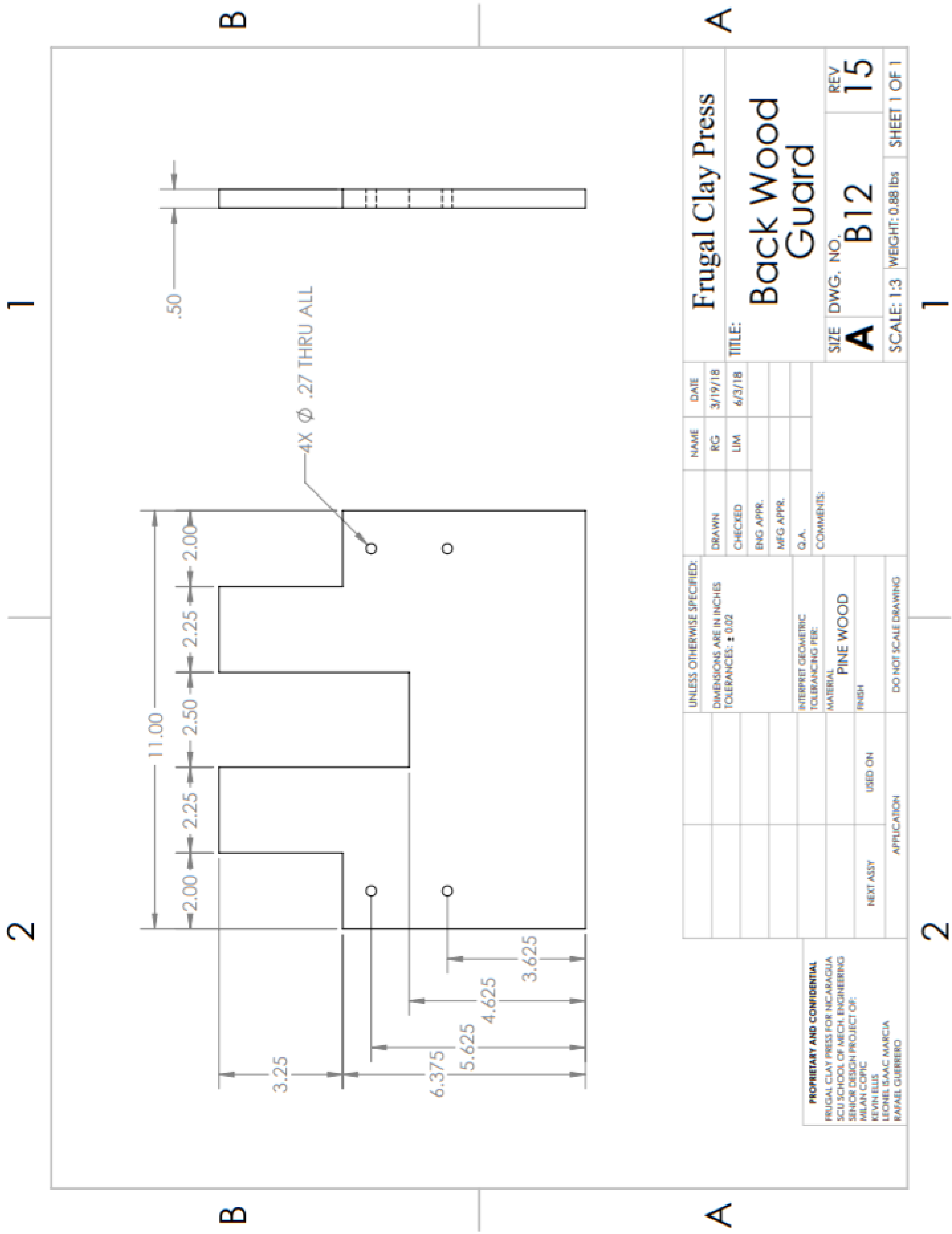
SIZE A | DWG. NO. B09 | REV 15

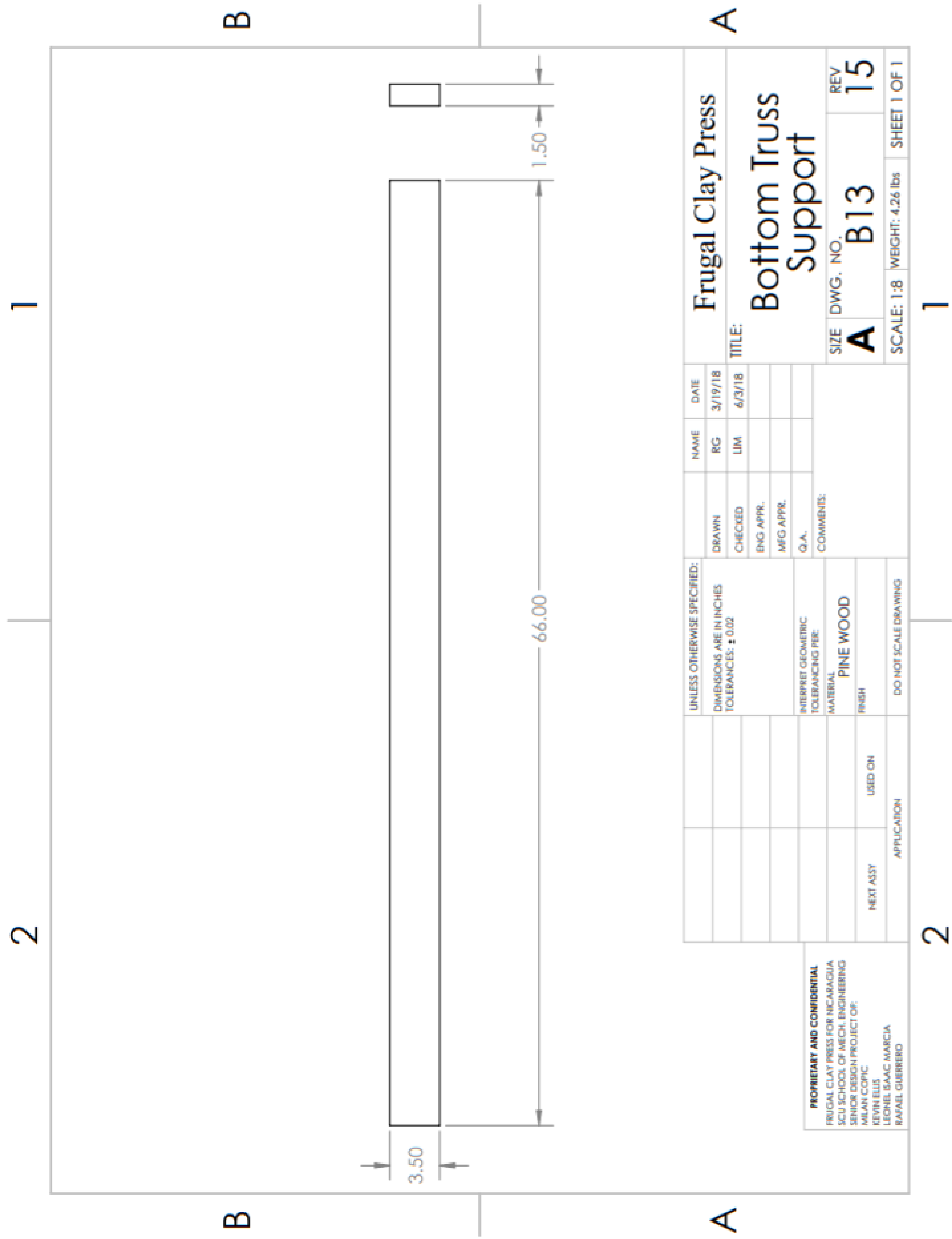
SCALE: 1:4 | WEIGHT: 0.88 lbs | SHEET 1 OF 1


Frugal Clay Press
TITLE:
Right Wood Guard
SIZE A
DWG. NO. B10
REV 15
SCALE: 1:4
WEIGHT: 0.55 lbs
SHEET 1 OF 1
DRAWN RG 3/19/18
CHECKED LIM 6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL PINE WOOD
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
15.00
8.625
.50

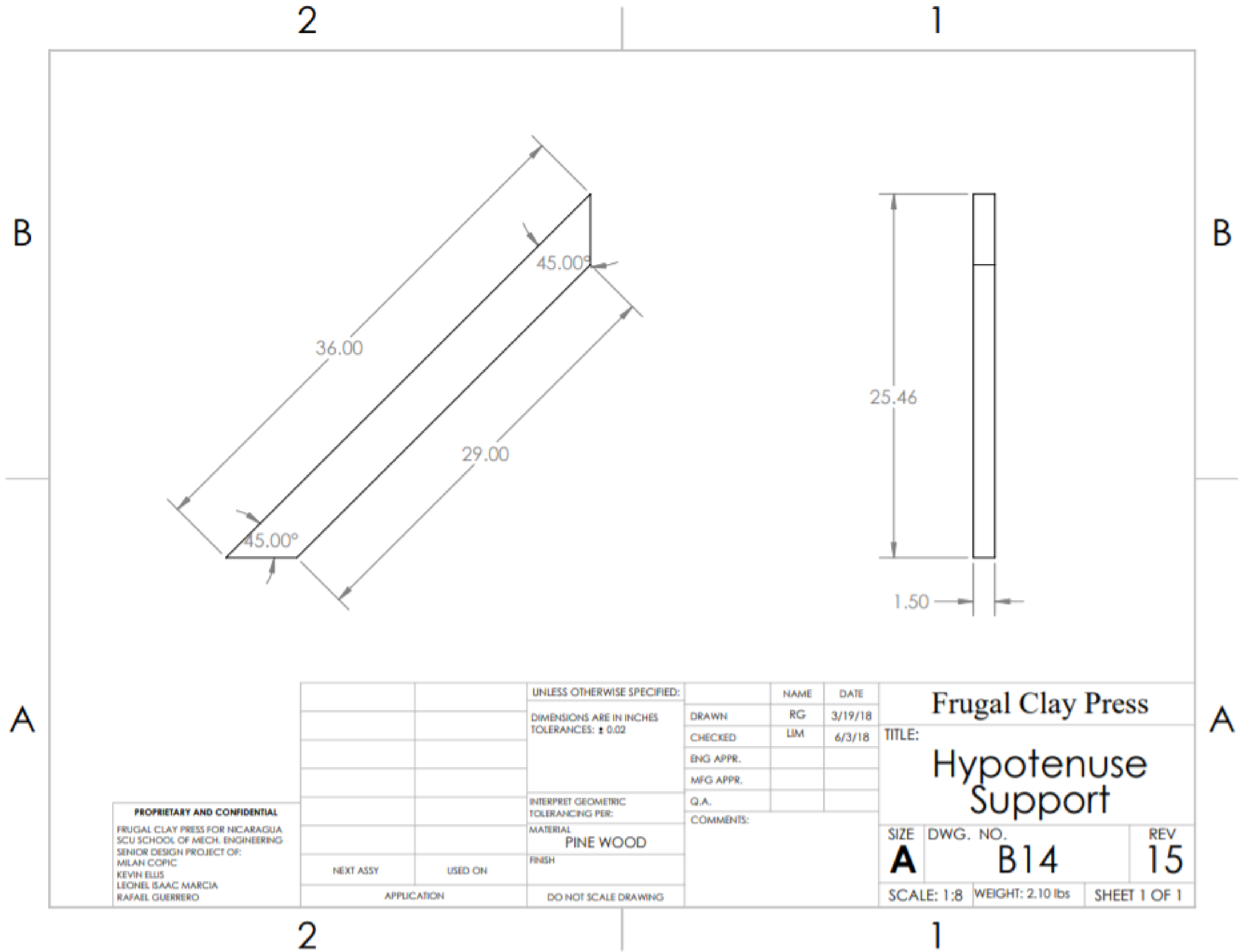


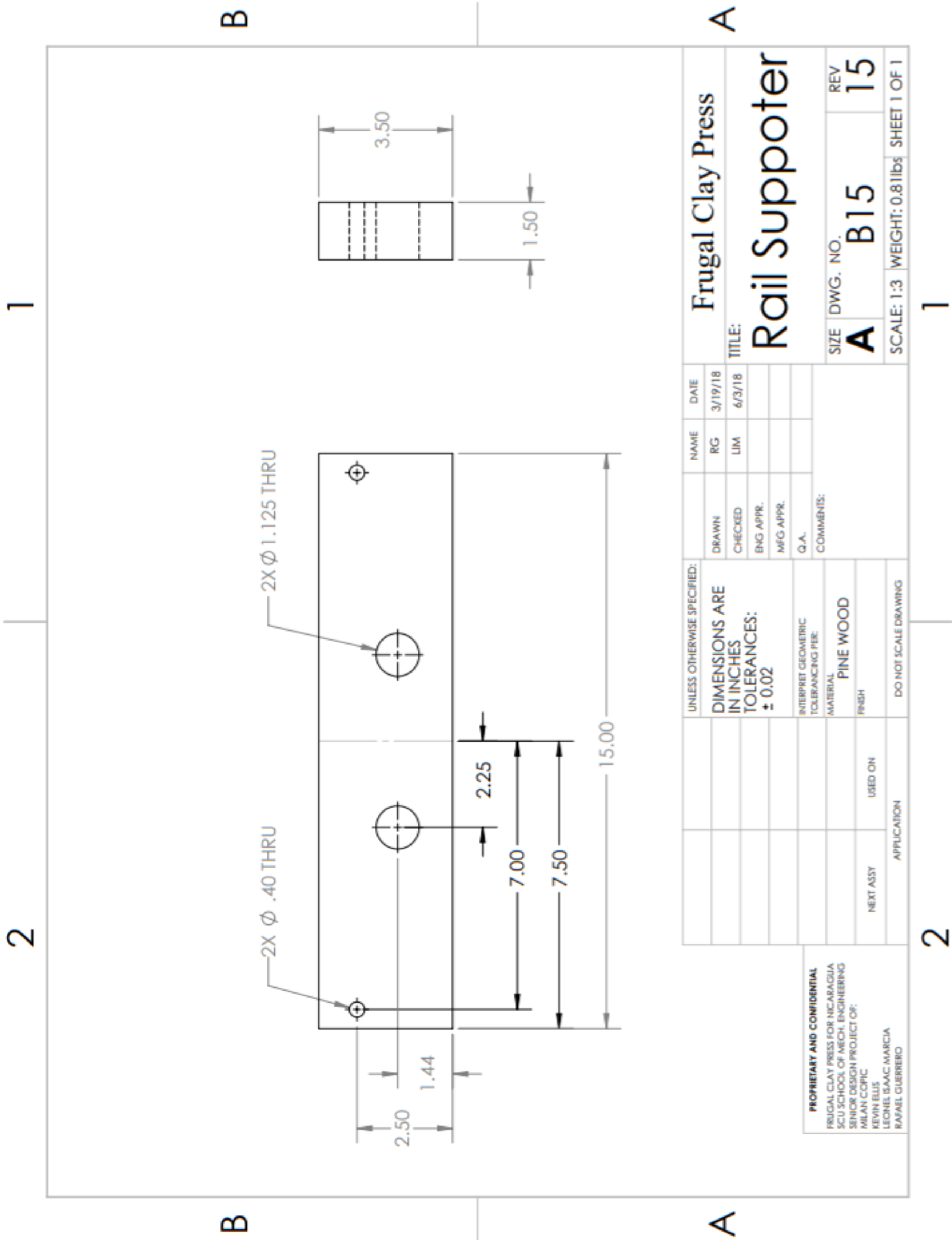
.50
2X ⌀ .27 THRU ALL
2X ⌀ .53 THRU ALL
2X ⌀ 1.03 THRU ALL
11.00
2.00
2.25
2.50
2.25
2.00
3.25
6.375
5.625
3.875
2.875
2.375
Frugal Clay Press
TITLE:
Front Wood Guard
SIZE A
DWG. NO. B11
REV 15
SCALE: 1:3
WEIGHT: 0.28 lbs
SHEET 1 OF 1
NAME
DATE
DRAWN RG 3/19/18
CHECKED LIM 6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2

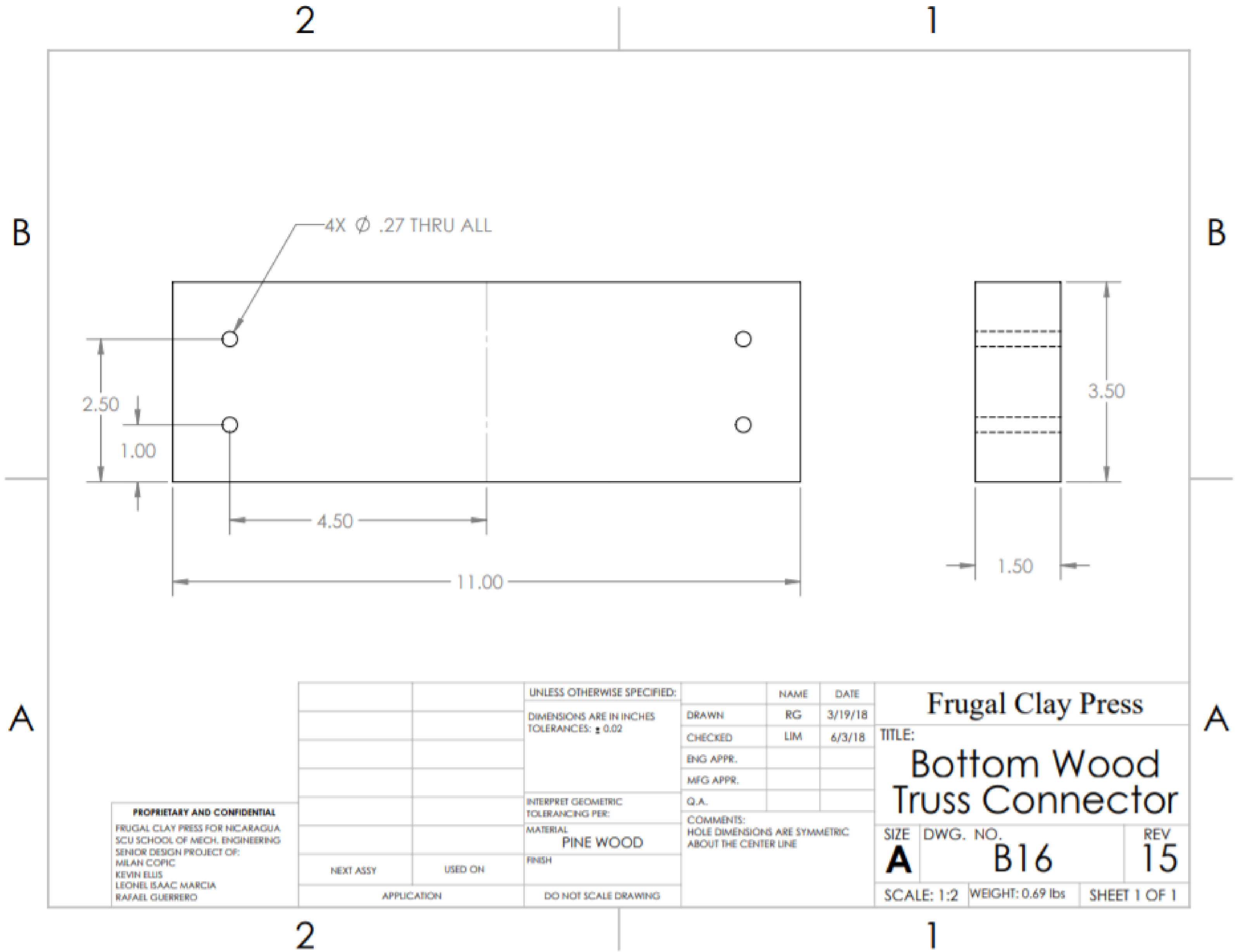

B
1
A
2
.50
4X ⌀ .27 THRU ALL
11.00
2.00
2.25
2.50
2.25
2.00
3.25
6.375
5.625
4.625
3.625
Frugal Clay Press
TITLE:
Back Wood Guard
SIZE
A
DWG. NO.
B12
REV
15
SCALE: 1:3
WEIGHT: 0.88 lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

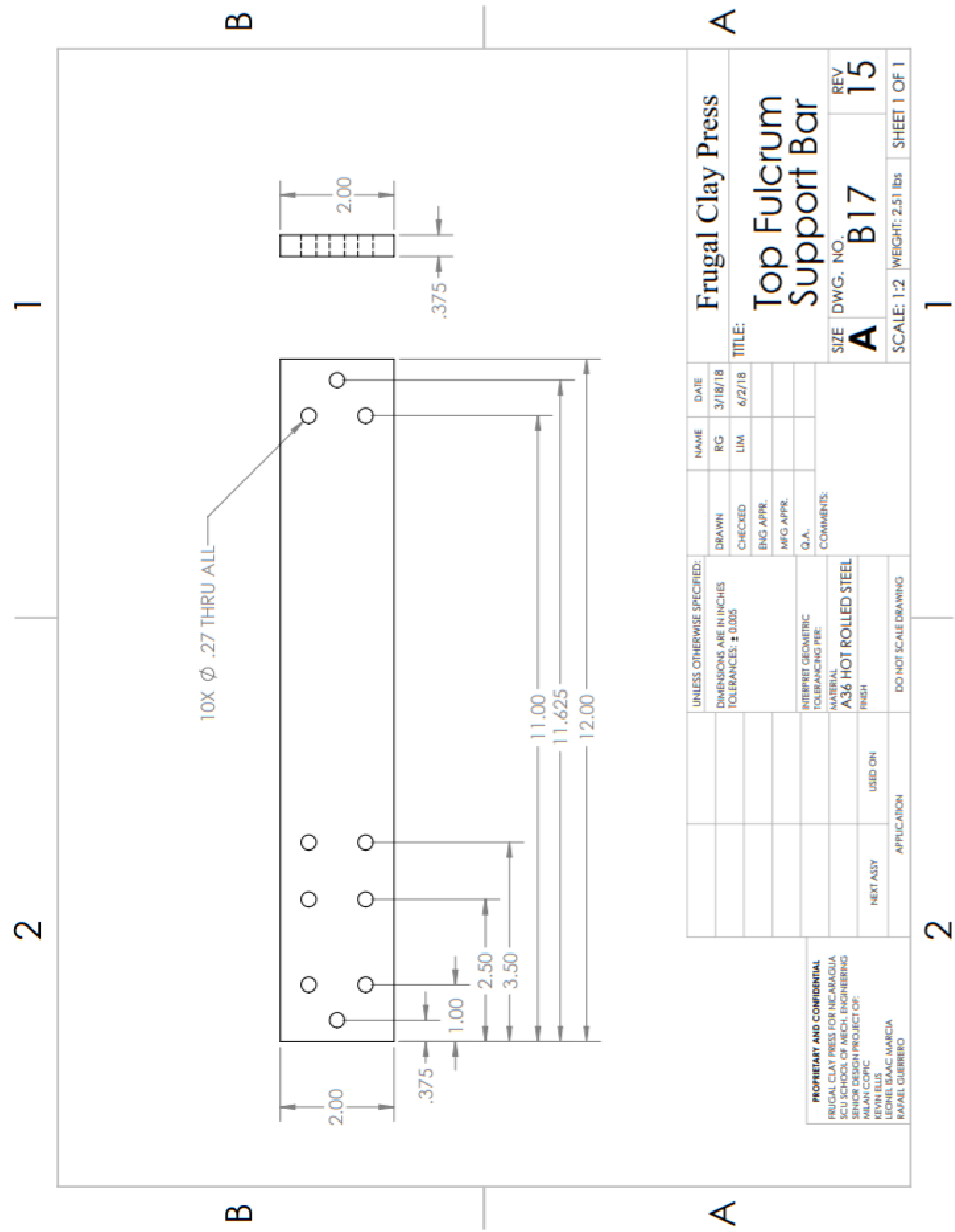


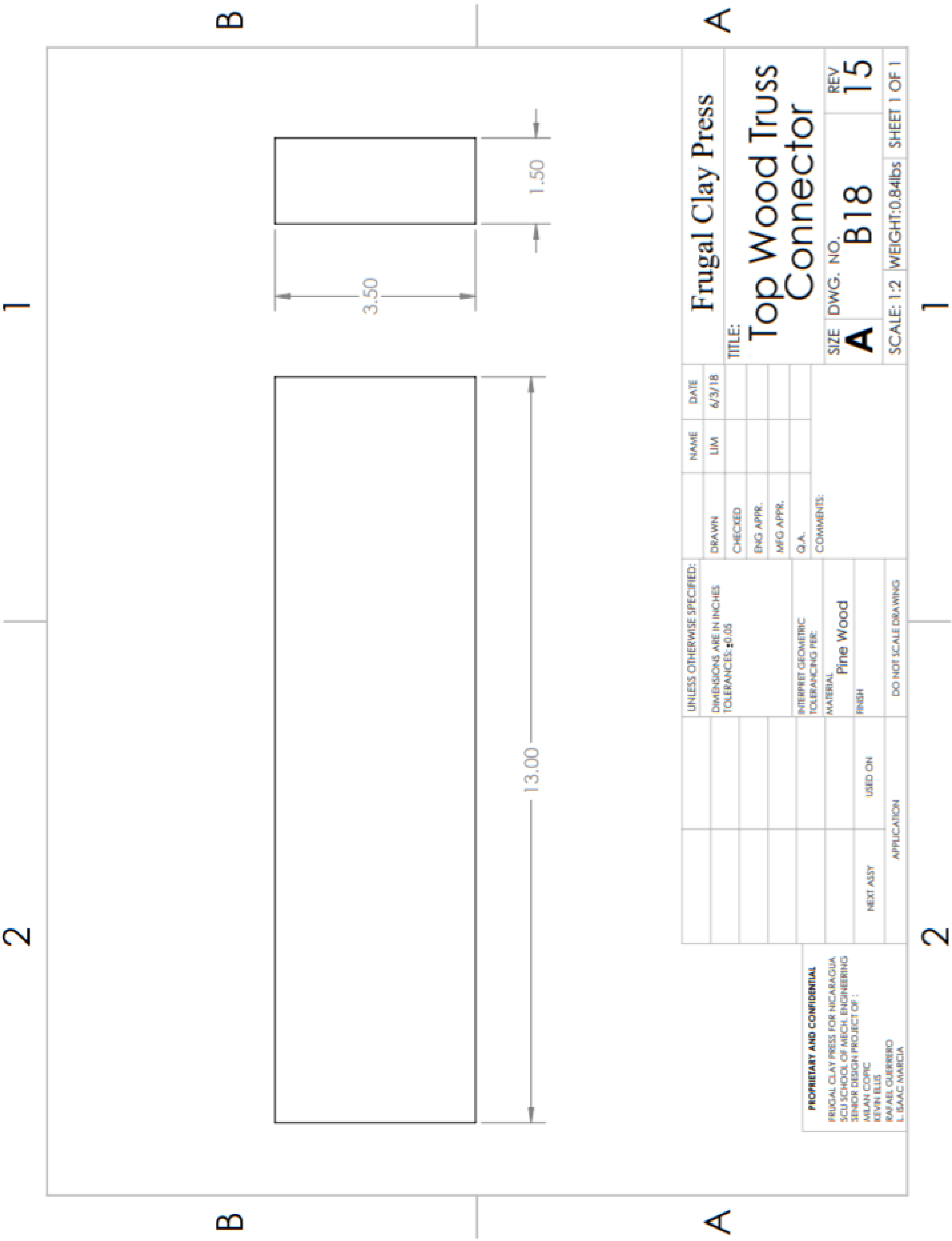
B
A
1
2
1.50
66.00
3.50
Frugal Clay Press
TITLE:
Bottom Truss Support
SIZE
A
DWG. NO.
B13
REV
15
SCALE: 1:8
WEIGHT: 4.26 lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO


2
1
B
A
36.00
29.00
45.00°
45.00°
25.46
1.50
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Hypotenuse Support
SIZE
A
DWG. NO.
B14
REV
15
SCALE: 1:8
WEIGHT: 2.10 lbs
SHEET 1 OF 1

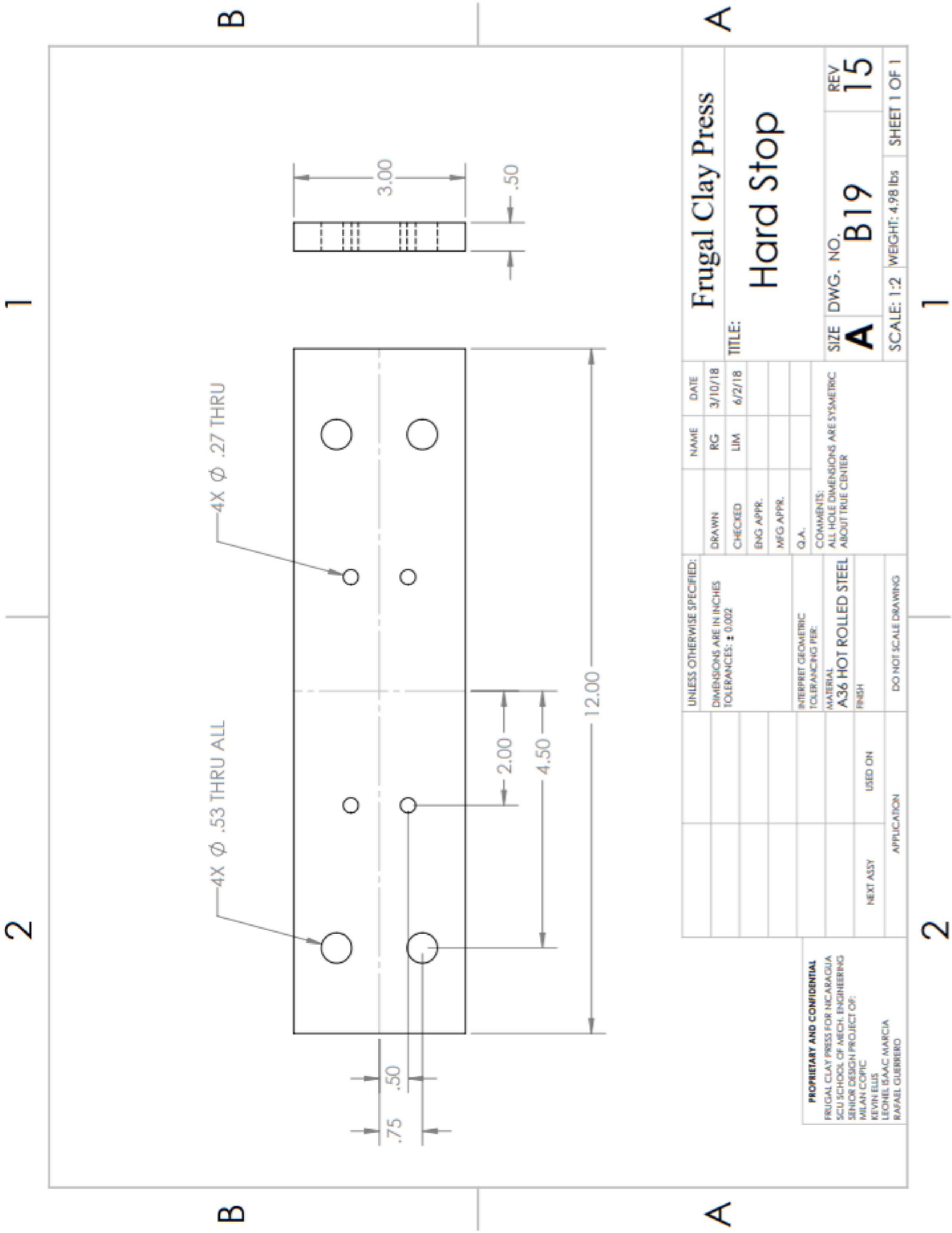

2X Ø .40 THRU
2X Ø 1.125 THRU
3.50
1.50
2.25
7.00
7.50
15.00
1.44
2.50
Frugal Clay Press
TITLE:
Rail Suppoter
SIZE
A
DWG. NO.
B15
REV
15
SCALE: 1:3
WEIGHT: 0.81lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO


4X Ø .27 THRU ALL
2.50
1.00
4.50
11.00
3.50
1.50
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
PINE WOOD
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
3/19/18
CHECKED
LIM
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
HOLE DIMENSIONS ARE SYMMETRIC
ABOUT THE CENTER LINE
Frugal Clay Press
TITLE:
Bottom Wood
Truss Connector
SIZE
A
DWG. NO.
B16
REV
15
SCALE: 1:2
WEIGHT: 0.69 lbs
SHEET 1 OF 1

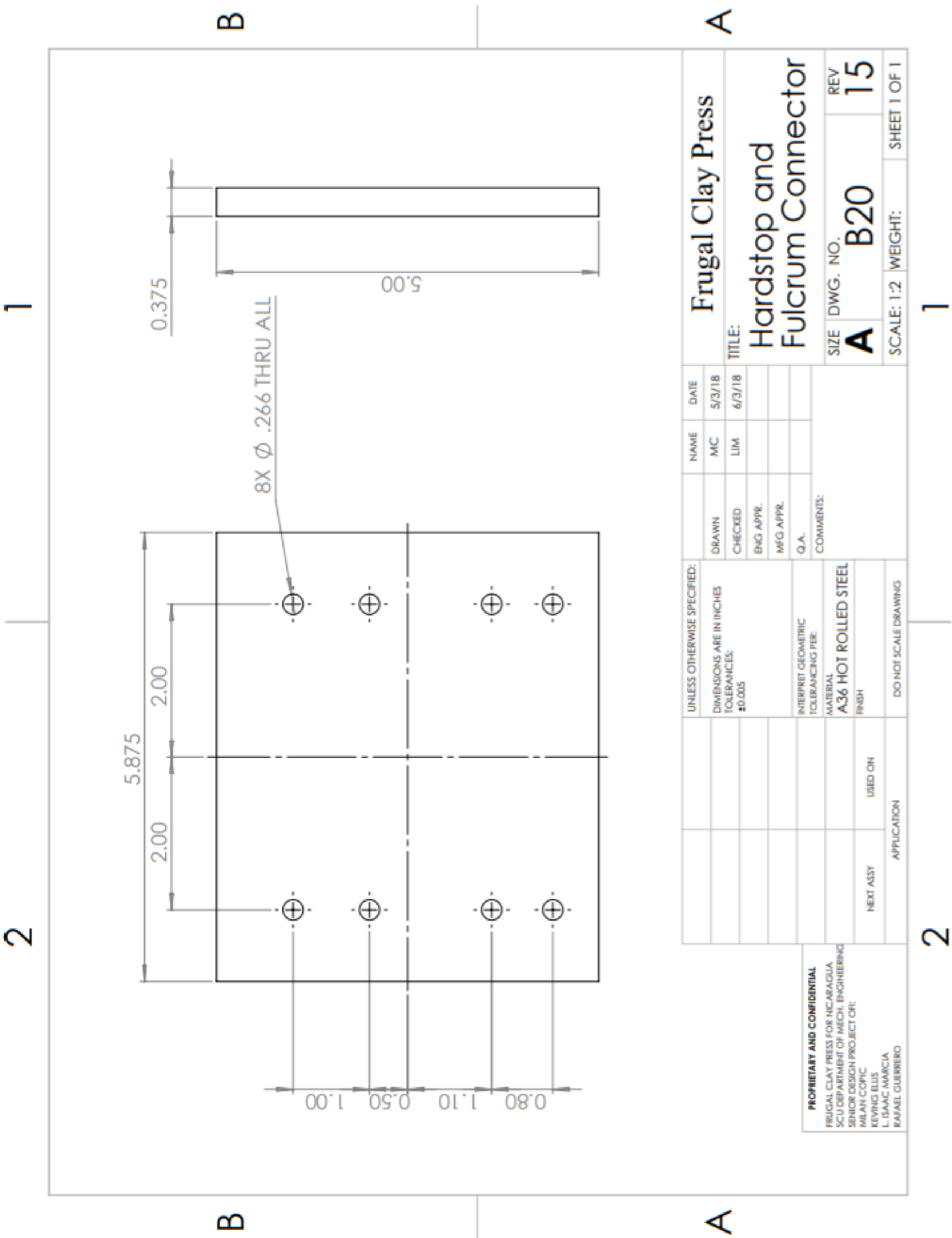

10X ⌀ .27 THRU ALL
2.00
.375
1.00
2.50
3.50
11.00
11.625
12.00
Frugal Clay Press
TITLE:
Top Fulcrum Support Bar
SIZE A
DWG. NO. B17
REV 15
SCALE: 1:2
WEIGHT: 2.51 lbs
SHEET 1 OF 1
NAME DATE
DRAWN RG 3/18/18
CHECKED LIM 6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



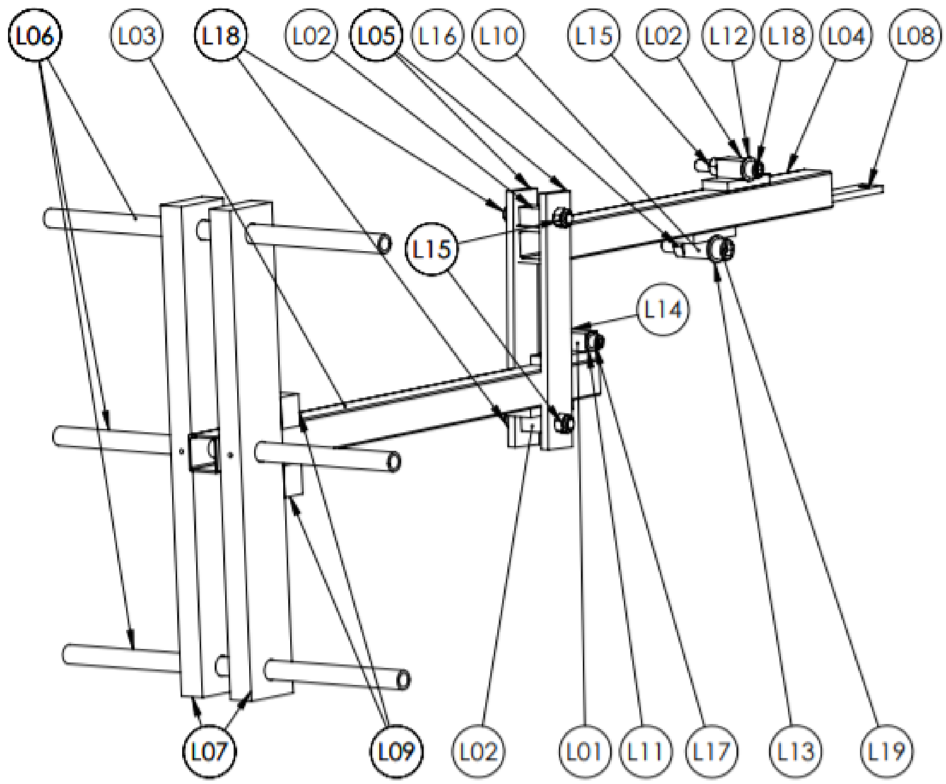
13.00
3.50
1.50
Frugal Clay Press
TITLE:
Top Wood Truss Connector
SIZE A
DWG. NO. B18
REV 15
SCALE: 1:2
WEIGHT:0.84lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ±0.05
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Pine Wood
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
LIM
6/3/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF :
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
L. ISAAC MARCIA



4X Ø .53 THRU ALL
4X Ø .27 THRU
3.00
.50
2.00
4.50
12.00
.50
.75
Frugal Clay Press
TITLE:
Hard Stop
SIZE
A
DWG. NO.
B19
REV
15
SCALE: 1:2
WEIGHT: 4.98 lbs
SHEET 1 OF 1
NAME
DATE
DRAWN
RG
3/10/18
CHECKED
LIM
6/2/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ALL HOLE DIMENSIONS ARE SYSMETRIC ABOUT TRUE CENTER
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



B
1
2
A
0.375
5.00
8X ⌀ .266 THRU ALL
5.875
2.00
2.00
1.00
0.50
1.10
0.80
Frugal Clay Press
TITLE:
Hardstop and Fulcrum Connector
SIZE A
DWG. NO. B20
REV 15
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NAME DATE
DRAWN MC 5/3/18
CHECKED LIM 6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU DEPARTMENT OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVING ELLIS
L. ISAAC MARCIA
RAFAEL GUERRERO



Part No.	PART NAME	QTY.
L01	1/2" Bolt Collar	1
L02	5/8" Bolt Collar	3
L03	Input Bar	1
L04	Output Bar	1
L05	Lever Connector Beam	2
L06	Pipe Handle	3
L07	Pipe Handle Mount	2
L08	Counter Weight Beam	1
L09	Ladder Connects	2
L10	3/4" Bolt Collar	1
L11	1/2" Flat Washer	1
L12	5/8" Flat Washer	3
L13	3/4" Flat Washer	1
L14	3/8"-24 Hex Nut	1
L15	1/2"-13 Hex Nut	3
L16	5/8"-11 Hex Nut	1
L17	1/2"-13 x 2" Hex Shoulder Bolt	1
L18	5/8"-11 x 2" Hex Shoulder Bolt	3
L19	3/4"-10 x 2" Hex Shoulder Bolt	1

PROPRIETARY AND CONFIDENTIAL

FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL A36 Hot Rolled Steel, PVC Pipe, & Pine Wood
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	RG	6/2/18
CHECKED	LIM	6/5/18
ENG APPR.		
MFG APPR.		
Q.A.		

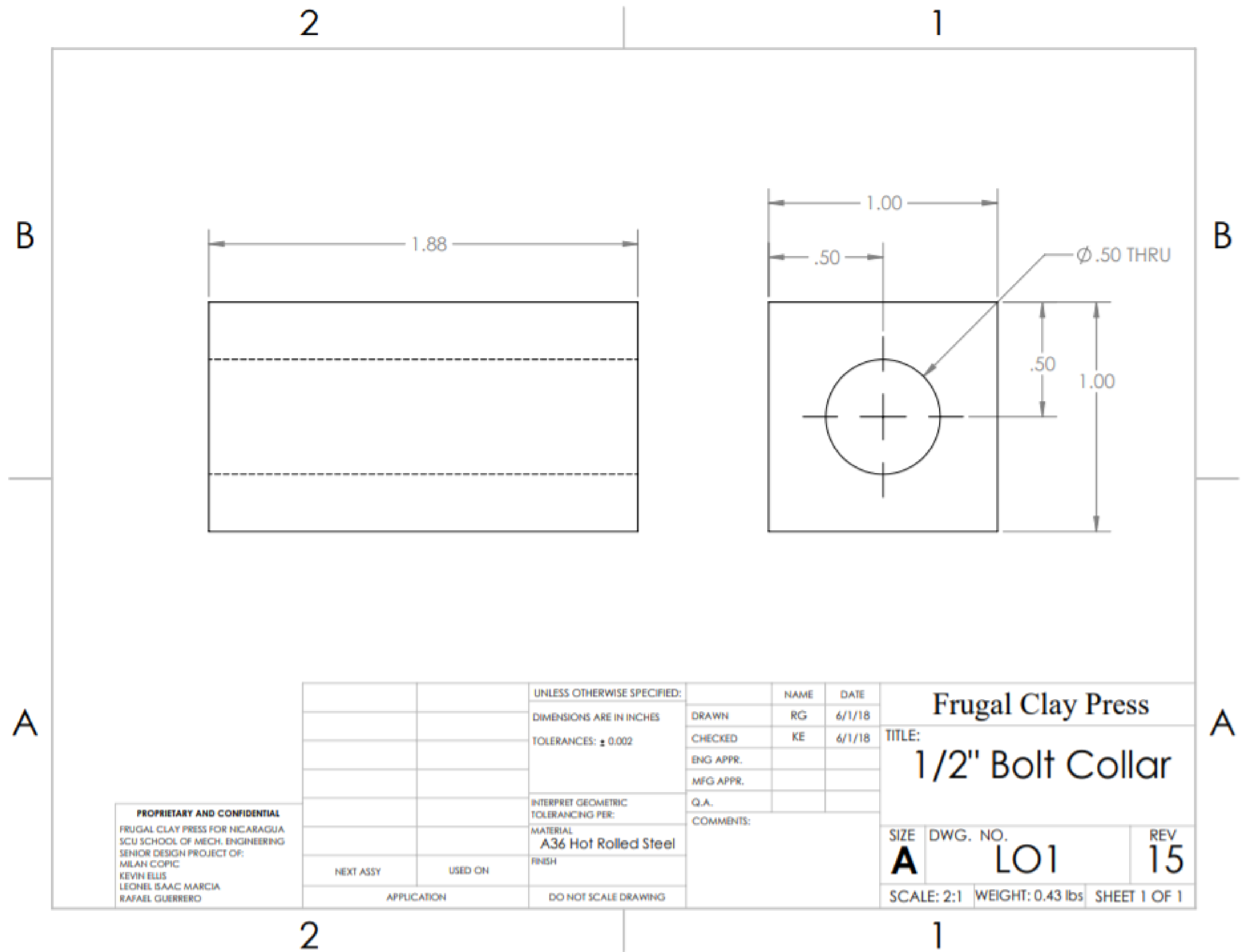
COMMENTS:

Frugal Clay Press

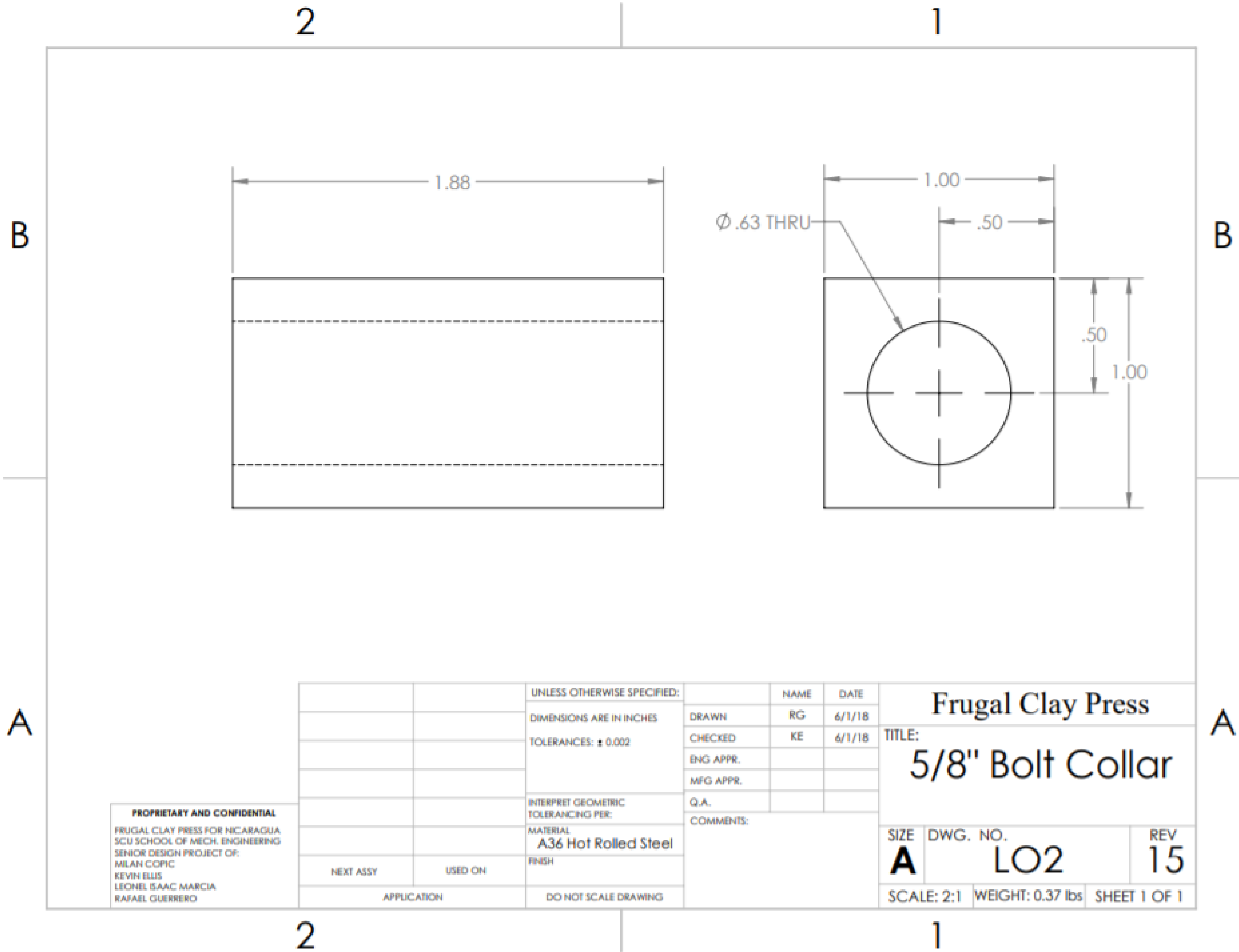
TITLE: **Compound Lever Assembly**

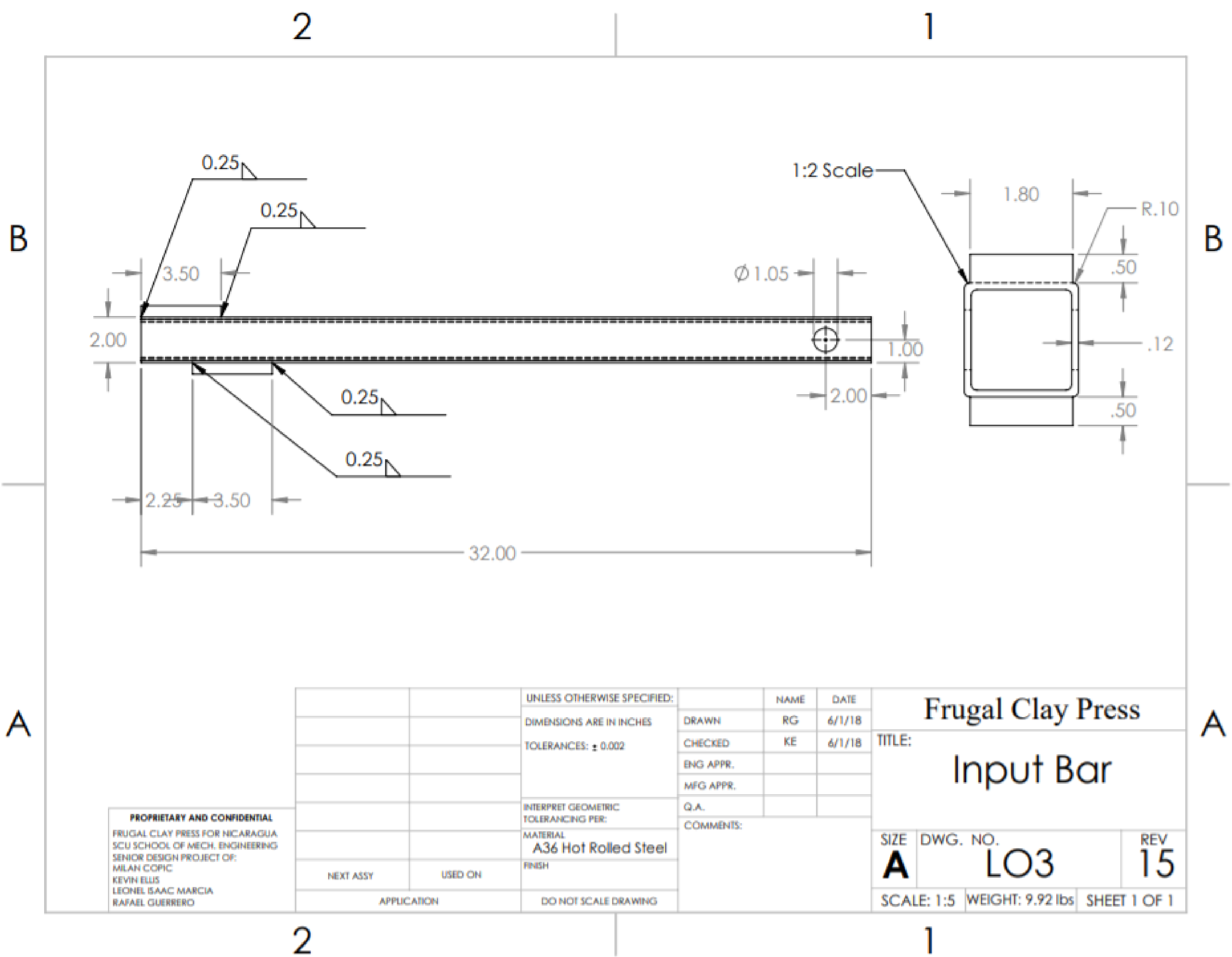
SIZE A | DWG. NO. LA1 | REV 15

SCALE: 1:8 | WEIGHT: 39.46 lbs | SHEET 1 OF 1

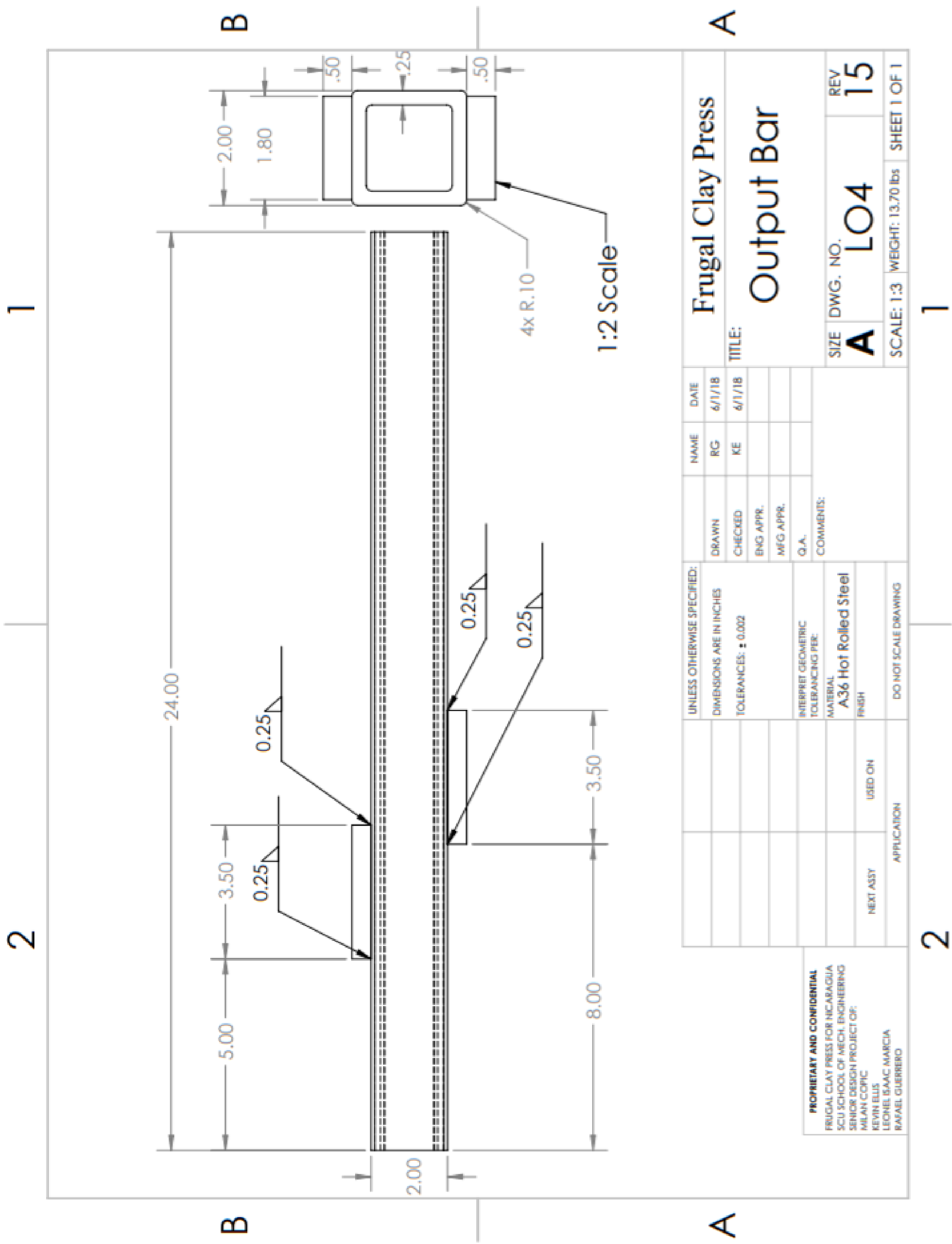


1.88
1.00
.50
Ø .50 THRU
.50
1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
1/2" Bolt Collar
SIZE A
DWG. NO. LO1
REV 15
SCALE: 2:1
WEIGHT: 0.43 lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

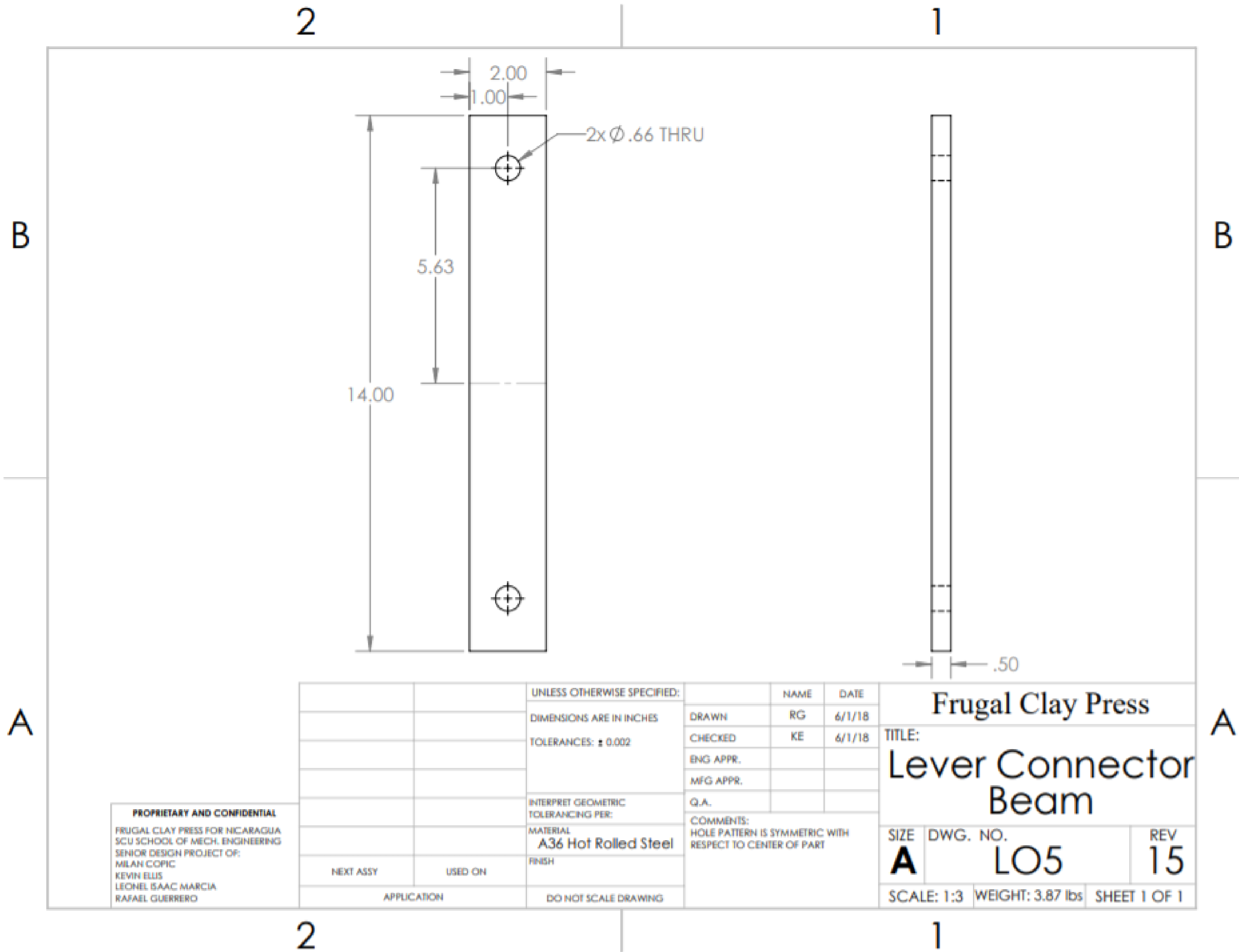

2
1
B
A
1.88
1.00
.50
Ø.63 THRU
.50
1.00
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
6/1/18
CHECKED
KE
6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
5/8" Bolt Collar
SIZE
A
DWG. NO.
LO2
REV
15
SCALE: 2:1
WEIGHT: 0.37 lbs
SHEET 1 OF 1



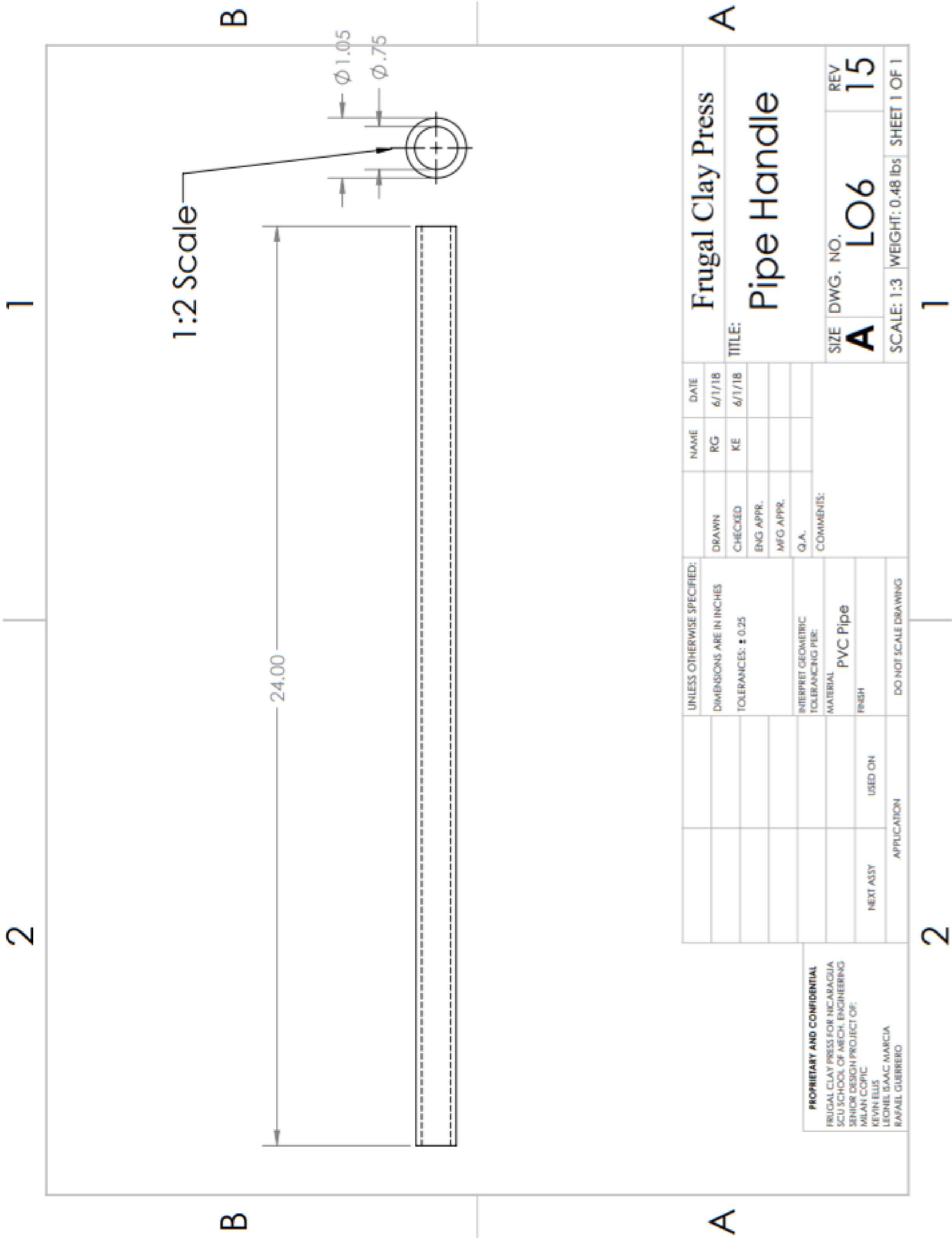
0.25
0.25
3.50
2.00
0.25
0.25
2.25
3.50
32.00
Ø1.05
1.00
2.00
1:2 Scale
1.80
R.10
.50
.12
.50
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Input Bar
SIZE A
DWG. NO. LO3
REV 15
SCALE: 1:5
WEIGHT: 9.92 lbs
SHEET 1 OF 1

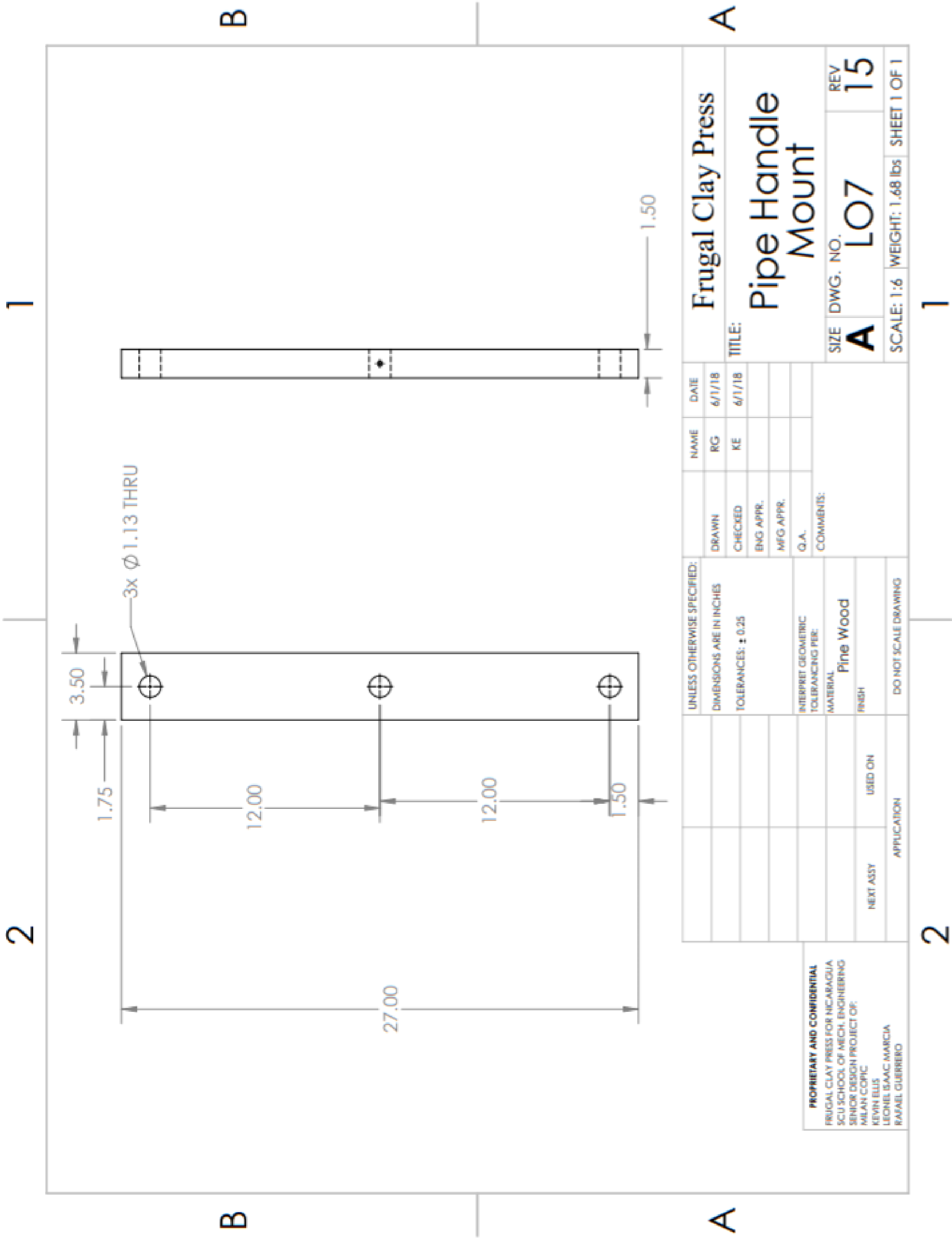


Frugal Clay Press
TITLE:
Output Bar
SIZE A
DWG. NO. LO4
REV 15
SCALE: 1:3
WEIGHT: 13.70 lbs
SHEET 1 OF 1
1:2 Scale
4x R.10
24.00
5.00
3.50
8.00
2.00
1.80
.50
.25
0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

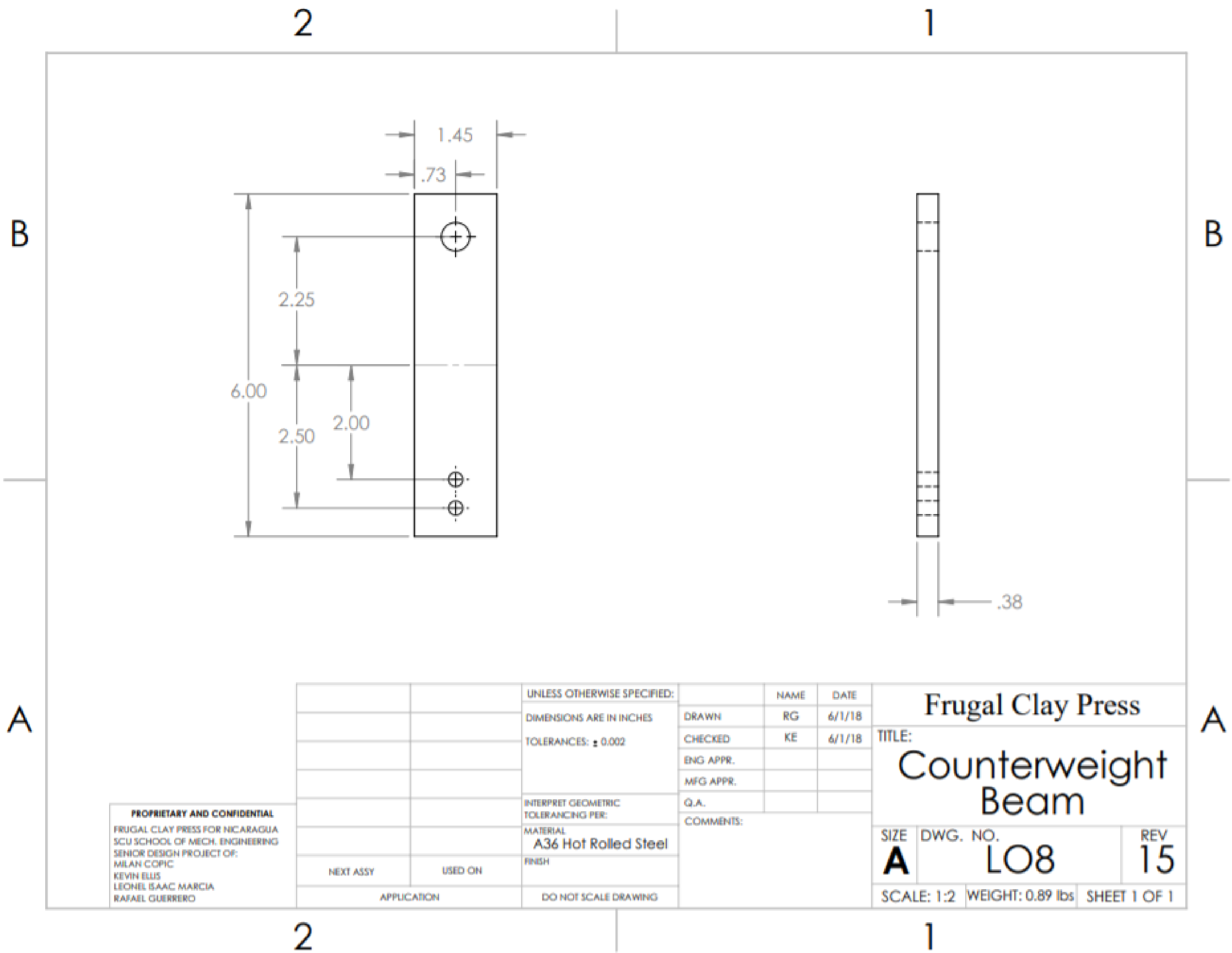


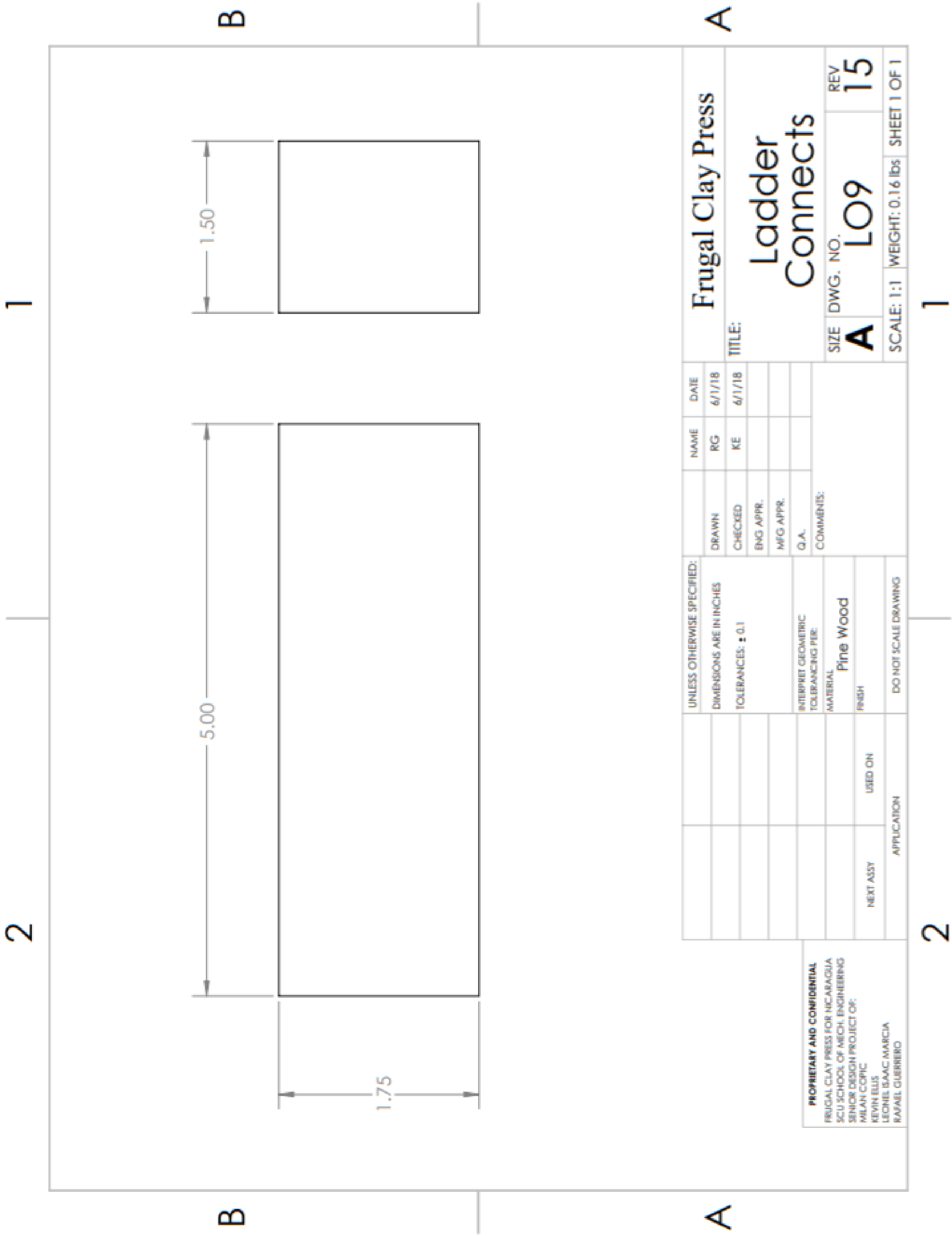
2.00
1.00
2x Ø .66 THRU
5.63
14.00
.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
HOLE PATTERN IS SYMMETRIC WITH RESPECT TO CENTER OF PART
Frugal Clay Press
TITLE:
Lever Connector Beam
SIZE A
DWG. NO. LO5
REV 15
SCALE: 1:3
WEIGHT: 3.87 lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO


1:2 Scale
Ø1.05
Ø.75
24.00
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.25
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC Pipe
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
6/1/18
CHECKED
KE
6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Pipe Handle
SIZE
A
DWG. NO.
LO6
REV
15
SCALE: 1:3
WEIGHT: 0.48 lbs
SHEET 1 OF 1

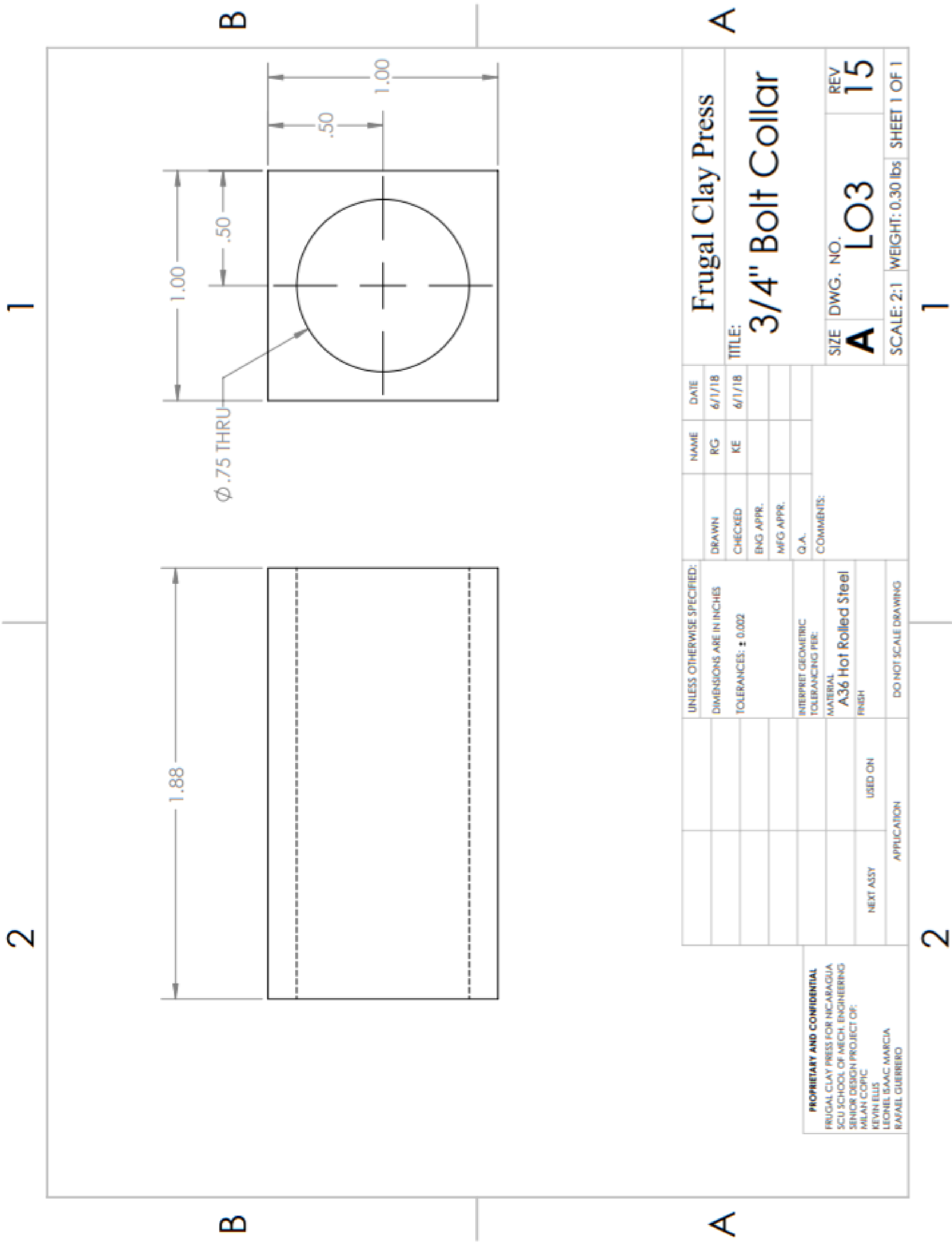


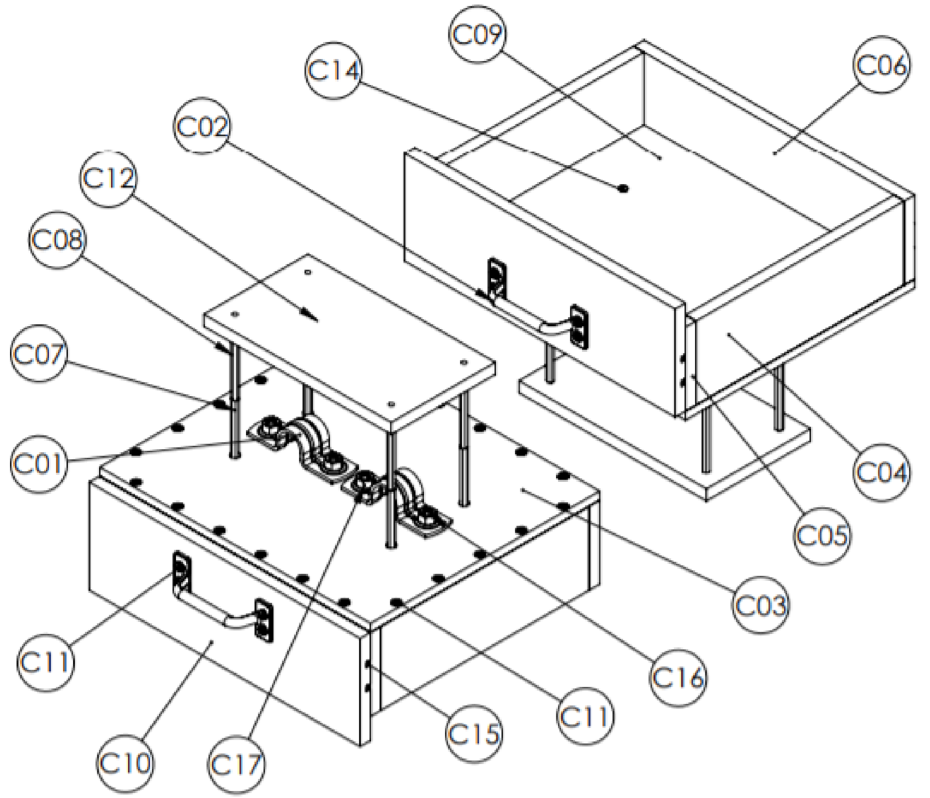
Frugal Clay Press
TITLE:
Pipe Handle Mount
SIZE A
DWG. NO. LO7
REV 15
SCALE: 1:6
WEIGHT: 1.68 lbs
SHEET 1 OF 1
3x Ø1.13 THRU
27.00
12.00
12.00
1.50
1.75
3.50
1.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.25
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Pine Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
6/1/18
CHECKED
KE
6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO


1.45
.73
2.25
6.00
2.50
2.00
.38
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Counterweight Beam
SIZE A
DWG. NO. LO8
REV 15
SCALE: 1:2
WEIGHT: 0.89 lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



Frugal Clay Press
TITLE:
Ladder Connects
SIZE A
DWG. NO. LO9
REV 15
SCALE: 1:1
WEIGHT: 0.16 lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.1
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL Pine Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 6/1/18
CHECKED KE 6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
1.50
5.00
1.75


Frugal Clay Press
TITLE:
3/4" Bolt Collar
SIZE
A
DWG. NO.
LO3
REV
15
SCALE: 2:1
WEIGHT: 0.30 lbs
SHEET 1 OF 1
1.00
.50
1.00
.50
1.88
Ø.75 THRU
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Hot Rolled Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
6/1/18
CHECKED
KE
6/1/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2



PART NO.	DESCRIPTION	QTY.
C01	Routing Clamp	2
C02	Pull Hande	1
C03	Bottom Plate	1
C04	Side Wall	2
C05	Front Wall	1
C06	Back Wall	1
C07	MF Hex Standoff	4
C08	FF Hex Standoff	4
C09	Acrylic Elevating Base	1
C10	Chamber Wood Gaurd	1
C11	#8-31x 0.75" Phillips Button Head	4
C12	Push Block	1
C13	#10-24 x 1" Phillips Flat Head (82)	22
C14	#8-31 x .4" Pan Flat Head (82)	4
C15	#10-24 x .875" Philips Button Head	8
C16	3/8"-16 x .75" Philips Flat Head (82)	4
C17	3/8"-16 Hex Nut	4

	NAME	DATE
DRAWN	MC	6/3/18
CHECKED	LJM	6/6/18
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

UNLESS OTHERWISE SPECIFIED:

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY | USED ON

APPLICATION

PROPRIETARY AND CONFIDENTIAL

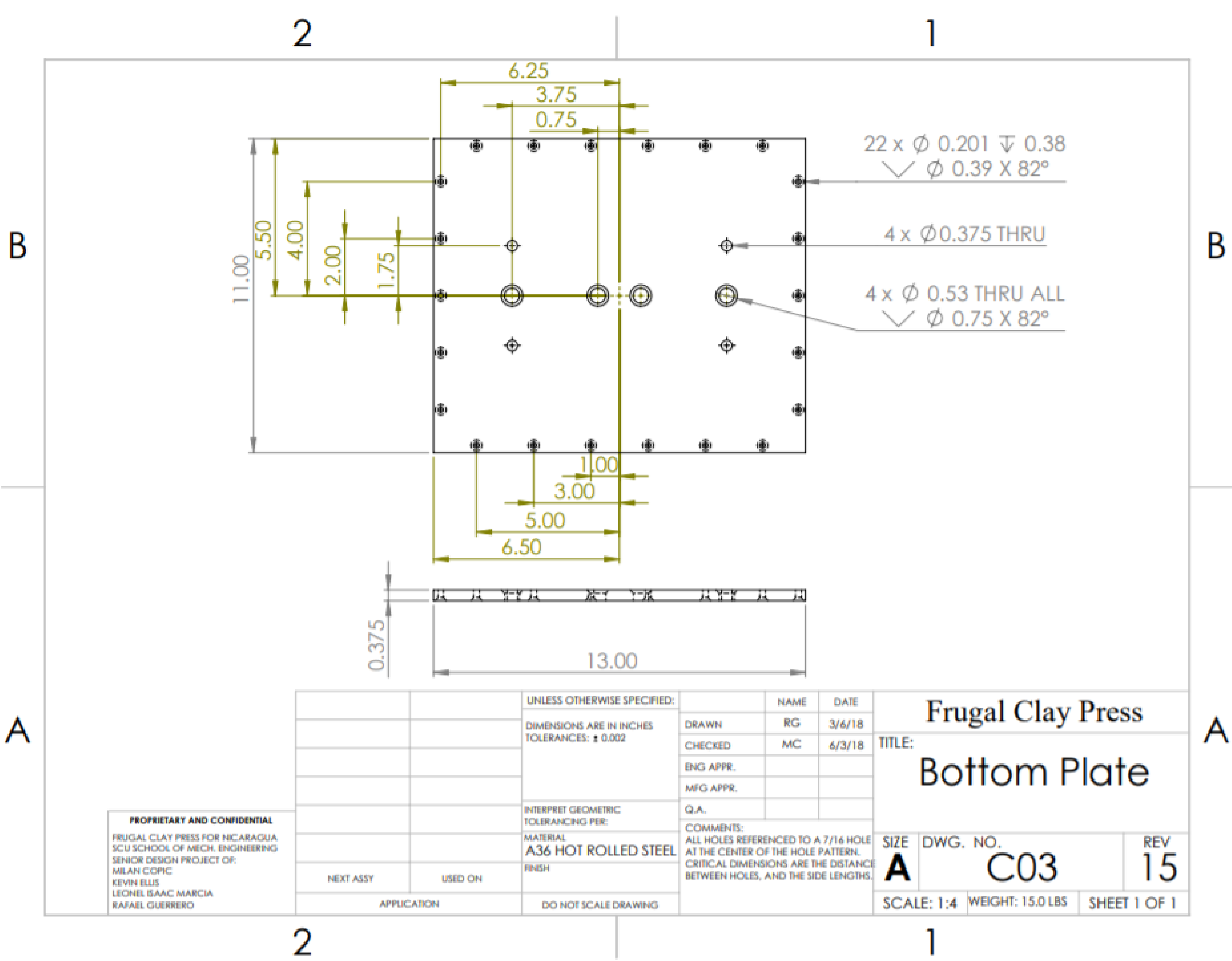
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
LEONEL ISAAC MARCIA

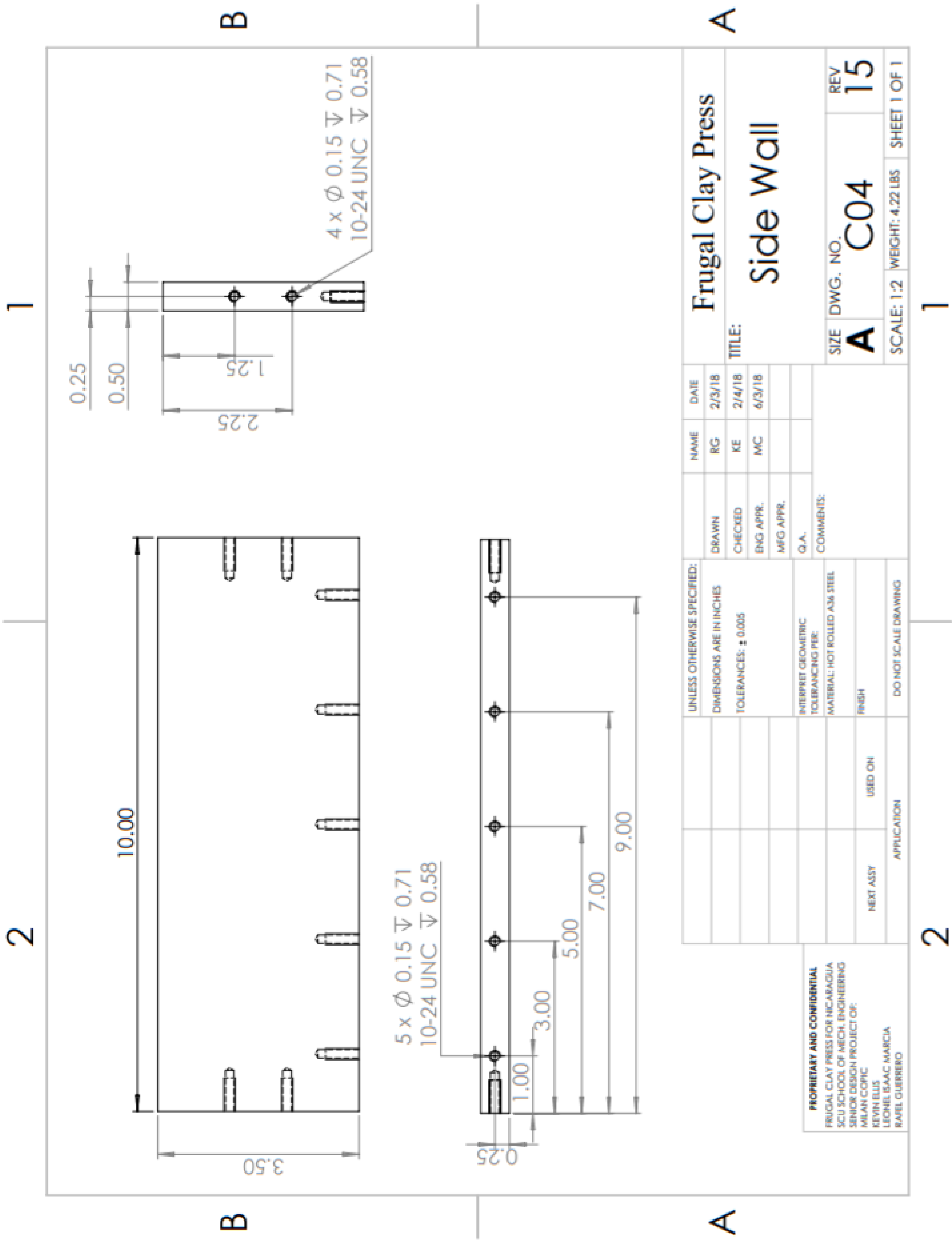
Frugal Clay Press

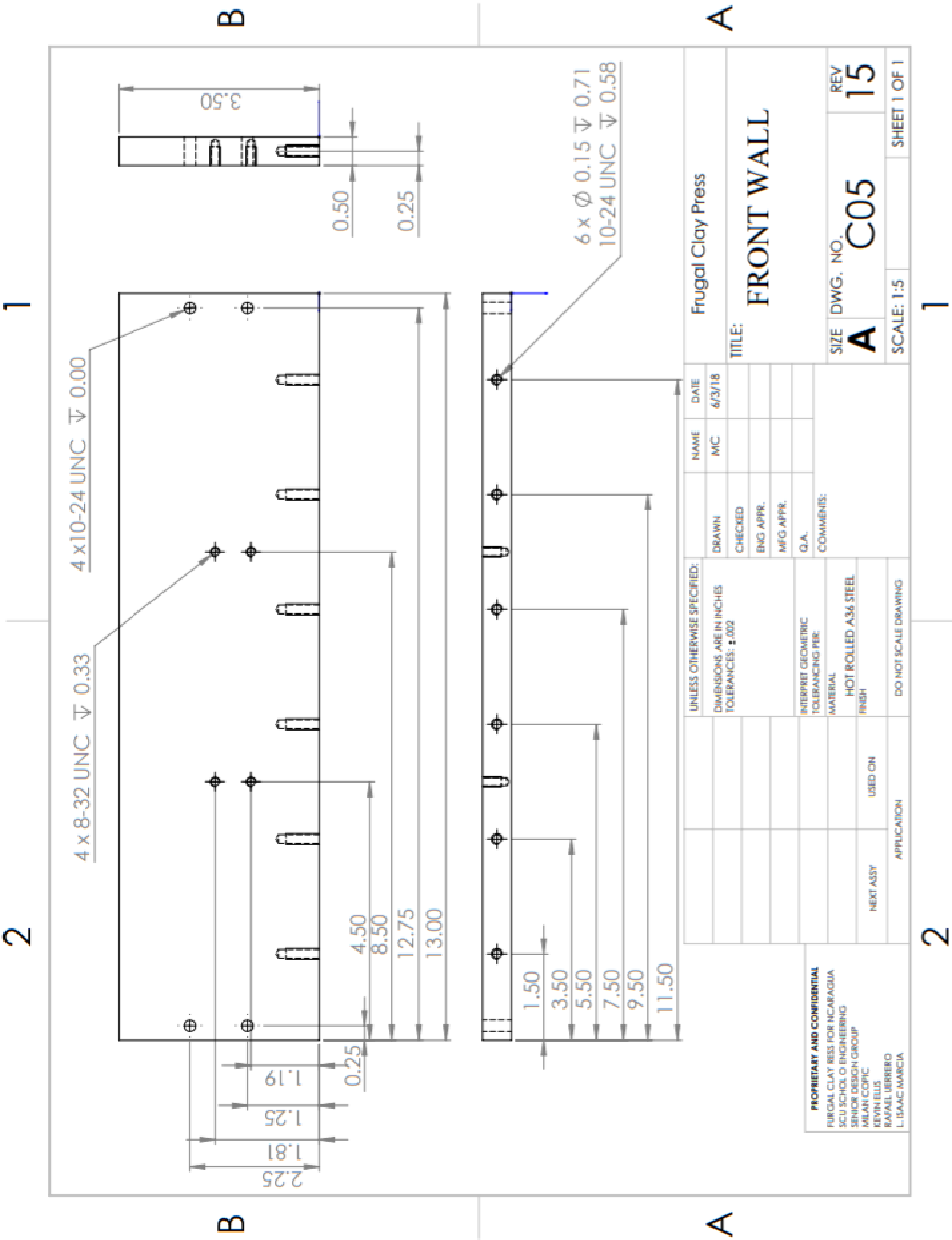
TITLE:
COMPRESION CHAMBER ASSEMBLY

SIZE A | DWG. NO. CA1 | REV 15

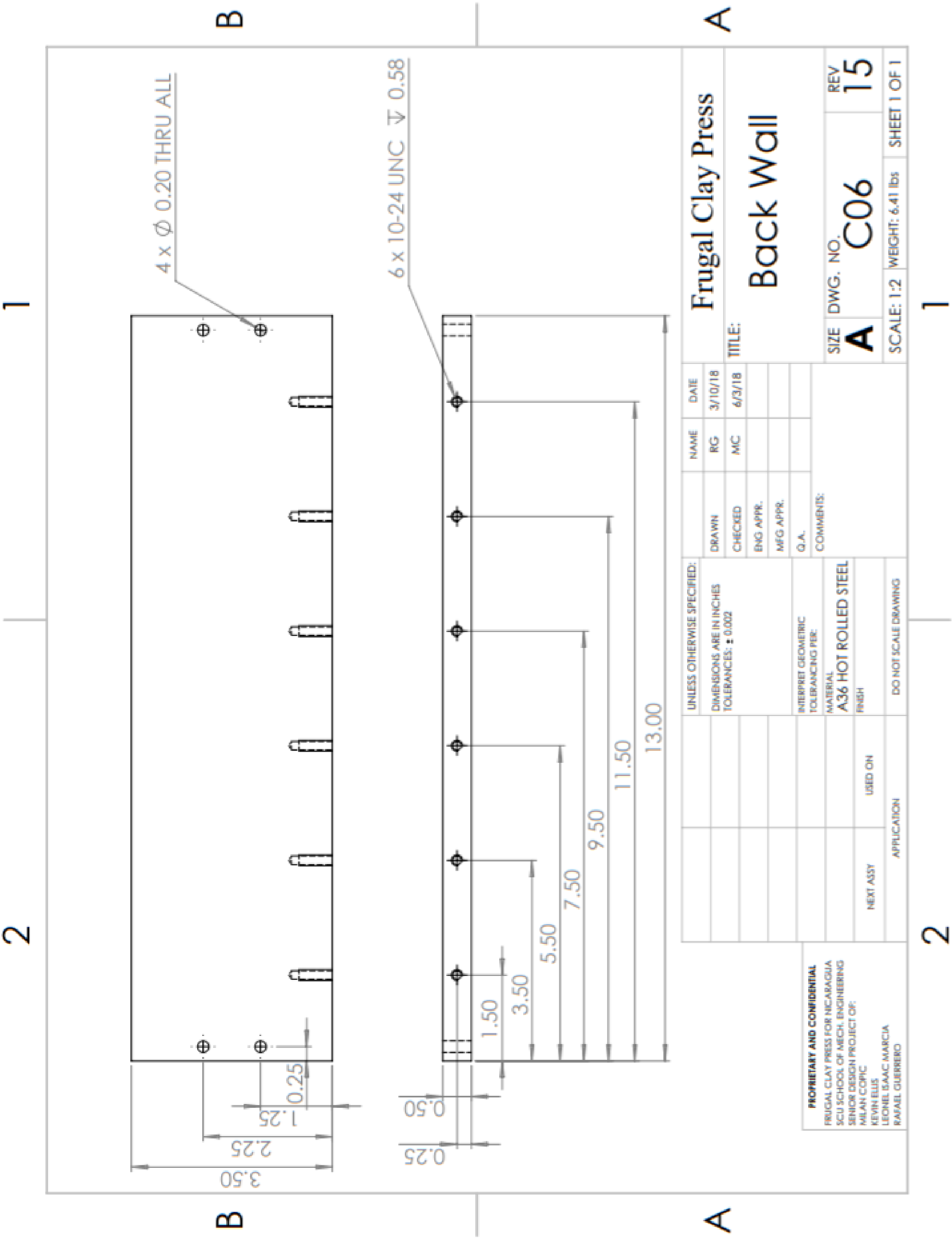
SCALE: 1:10 | WEIGHT:60.45LBS | SHEET 1 OF 1

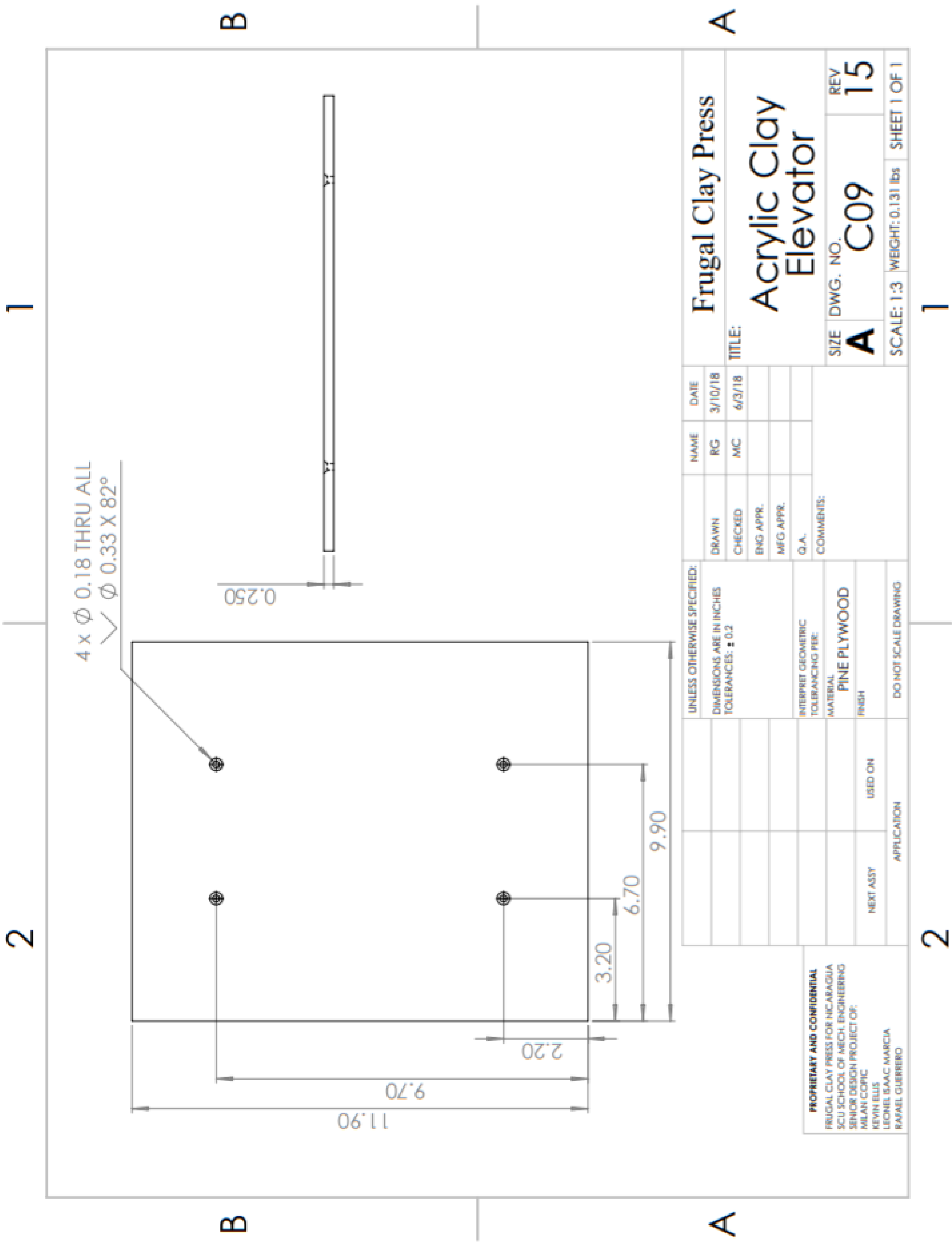

6.25
3.75
0.75
22 x Ø 0.201 ↧ 0.38
⌵ Ø 0.39 X 82°
4 x Ø0.375 THRU
4 x Ø 0.53 THRU ALL
⌵ Ø 0.75 X 82°
11.00
5.50
4.00
2.00
1.75
1.00
3.00
5.00
6.50
0.375
13.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
RG
3/6/18
CHECKED
MC
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
ALL HOLES REFERENCED TO A 7/16 HOLE AT THE CENTER OF THE HOLE PATTERN. CRITICAL DIMENSIONS ARE THE DISTANCE BETWEEN HOLES, AND THE SIDE LENGTHS.
Frugal Clay Press
TITLE:
Bottom Plate
SIZE
A
DWG. NO.
C03
REV
15
SCALE: 1:4
WEIGHT: 15.0 LBS
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2


Frugal Clay Press
TITLE:
Side Wall
SIZE
A
DWG. NO.
C04
REV
15
SCALE: 1:2
WEIGHT: 4.22 LBS
SHEET 1 OF 1
4 x Ø 0.15 ↧ 0.71
10-24 UNC ↧ 0.58
5 x Ø 0.15 ↧ 0.71
10-24 UNC ↧ 0.58
10.00
3.50
0.25
0.50
1.25
2.25
1.00
3.00
5.00
7.00
9.00
0.25
NAME
DATE
DRAWN
RG
2/3/18
CHECKED
KE
2/4/18
ENG APPR.
MC
6/3/18
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL: HOT ROLLED A36 STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFEL GUERRERO
A
B
1
2

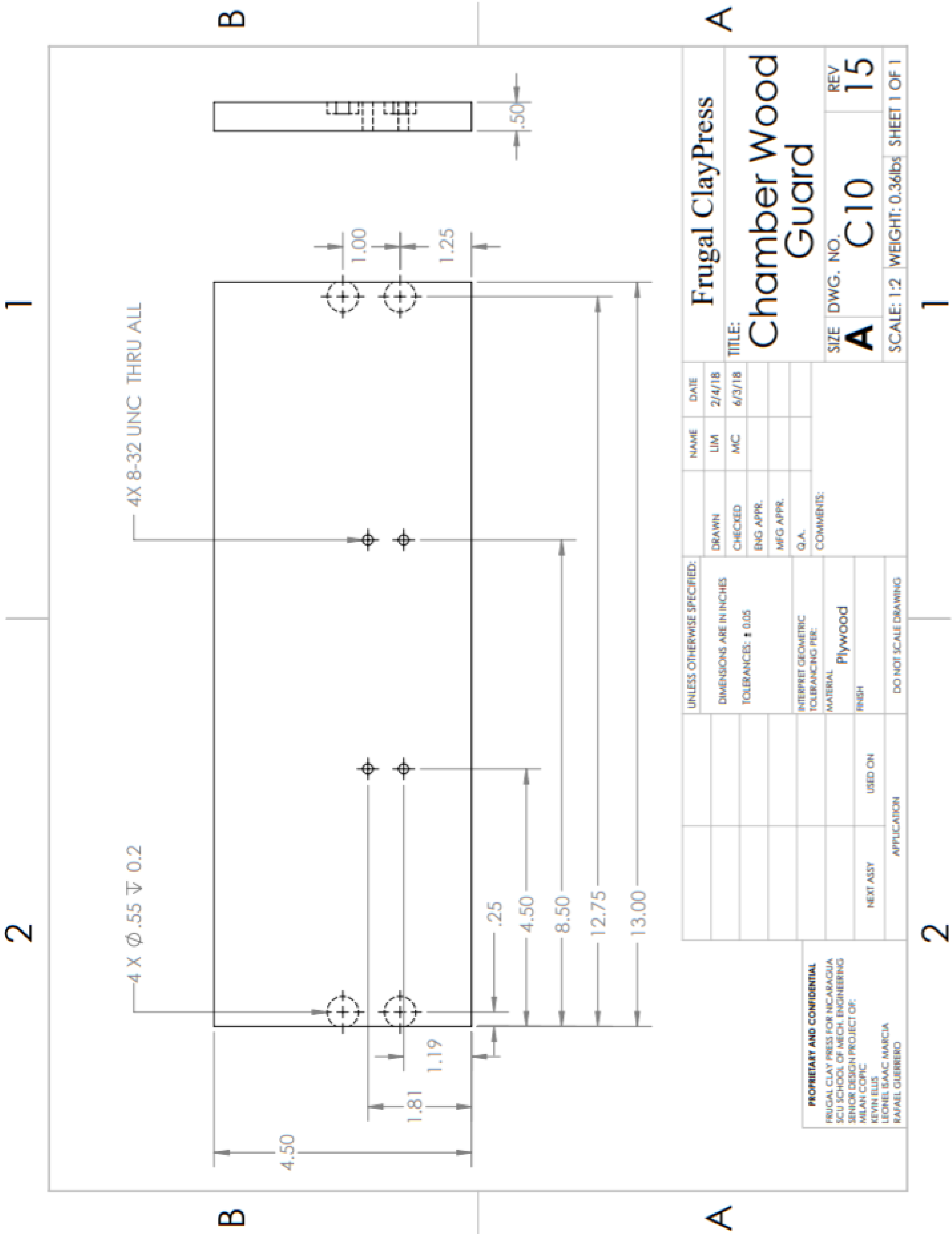


Frugal Clay Press
TITLE:
FRONT WALL
SIZE A
DWG. NO. C05
REV 15
SCALE: 1:5
SHEET 1 OF 1
4 x 10-24 UNC ⊽ 0.00
4 x 8-32 UNC ⊽ 0.33
6 x Ø 0.15 ⊽ 0.71
10-24 UNC ⊽ 0.58
3.50
0.50
0.25
4.50
8.50
12.75
13.00
1.50
3.50
5.50
7.50
9.50
11.50
1.19
1.25
1.81
2.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ±.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
HOT ROLLED A36 STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
MC
6/3/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
B
A
1
2

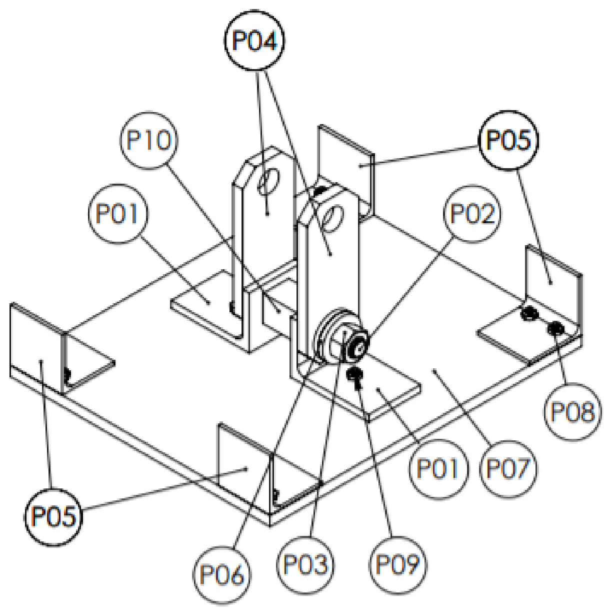

4 x Ø 0.20 THRU ALL
6 x 10-24 UNC ↧ 0.58
3.50
2.25
1.25
0.25
0.50
0.25
1.50
3.50
5.50
7.50
9.50
11.50
13.00
Frugal Clay Press
TITLE:
Back Wall
SIZE
A
DWG. NO.
C06
REV
15
SCALE: 1:2
WEIGHT: 6.41 lbs
SHEET 1 OF 1
NAME
DATE
DRAWN
RG
3/10/18
CHECKED
MC
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.002
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 HOT ROLLED STEEL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2



4 x Ø 0.18 THRU ALL
⌵ Ø 0.33 X 82°
0.250
11.90
9.70
2.20
3.20
6.70
9.90
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.2
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PINE PLYWOOD
FINISH
DO NOT SCALE DRAWING
NAME DATE
DRAWN RG 3/10/18
CHECKED MC 6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Acrylic Clay Elevator
SIZE A
DWG. NO. C09
REV 15
SCALE: 1:3
WEIGHT: 0.131 lbs
SHEET 1 OF 1



4X 8-32 UNC THRU ALL
4 X Ø.55 ↧ 0.2
.50
1.00
1.25
.25
4.50
8.50
12.75
13.00
1.19
1.81
4.50
Frugal ClayPress
TITLE:
Chamber Wood Guard
SIZE
A
DWG. NO.
C10
REV
15
SCALE: 1:2
WEIGHT: 0.36lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.05
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Plywood
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
LIM
2/4/18
CHECKED
MC
6/3/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



Part No.	Part Name	QTY
P01	Plate Connector L Beam	2
P02	3/4" - 2" Steel Shoulder Bolt	1
P03	5/8" - 11 Hex Nut	1
P04	Plate Connecting Beam	2
P05	Compression Plate Guides	4
P06	3/4" Washers	2
P07	Compression Plate	1
P08	#10-24 Hex Nut	10
P09	#10-24 - 3/4" Machine Screw	10
P10	Plate Connecting Beam Spacer	1

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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

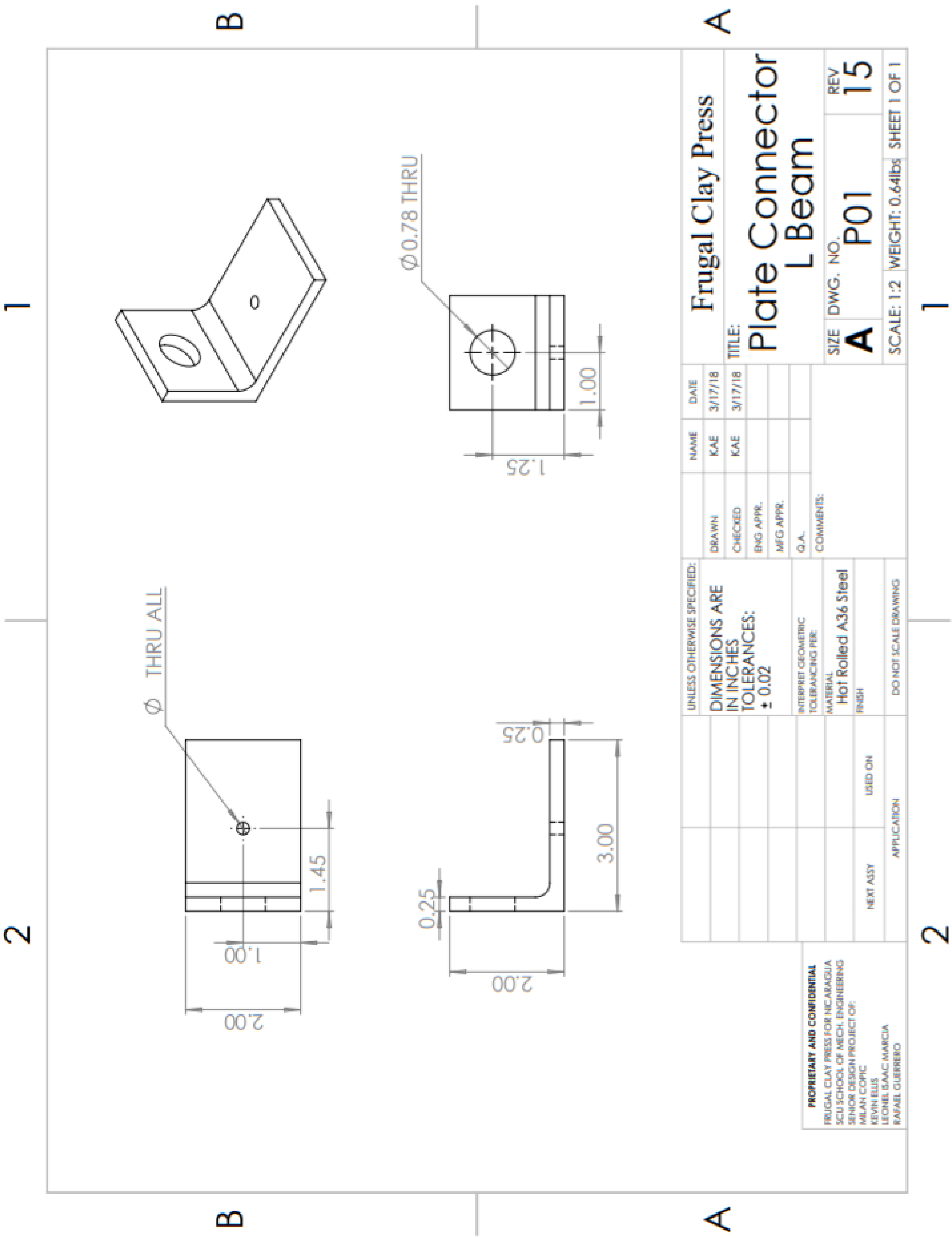
Frugal Clay Press

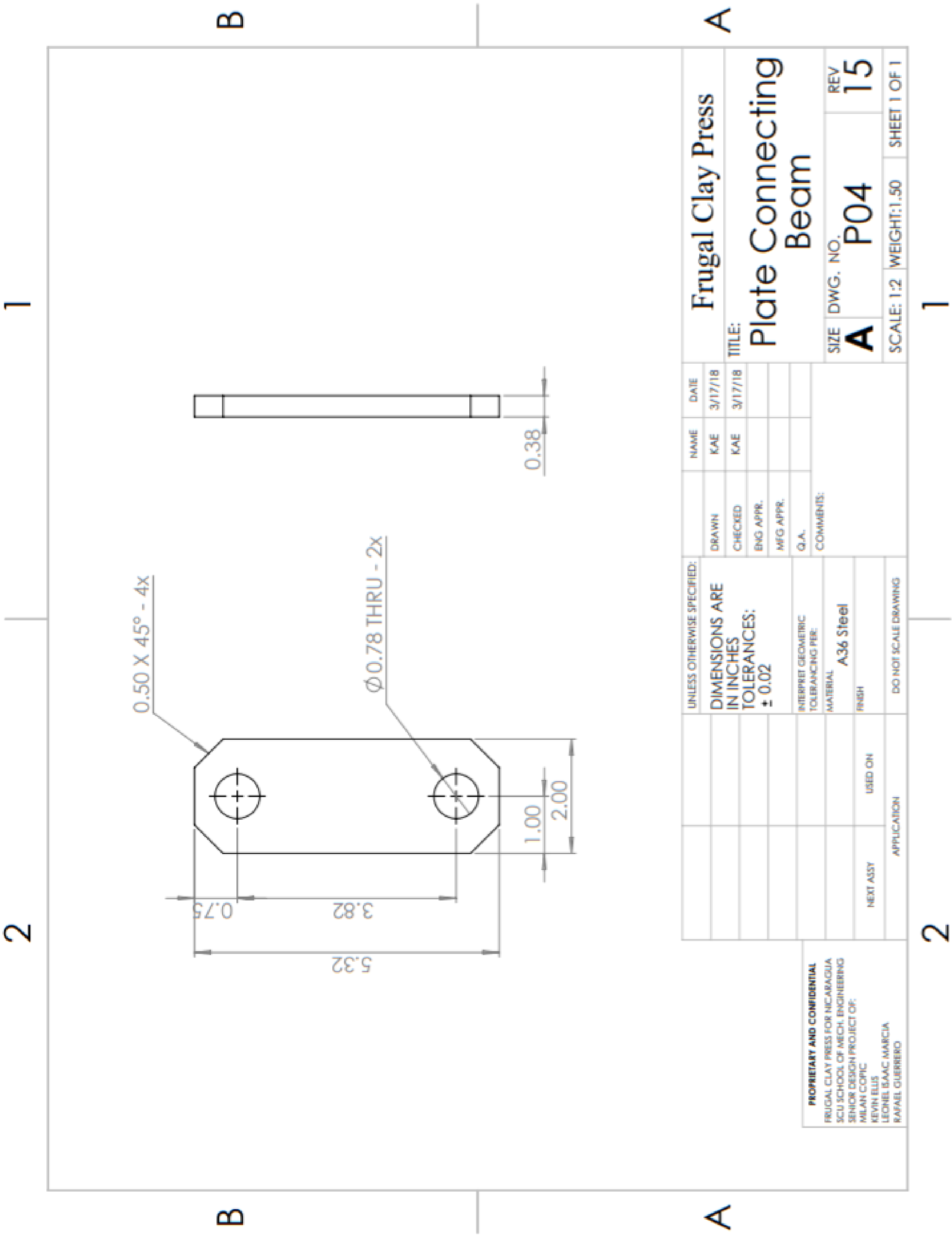
TITLE:

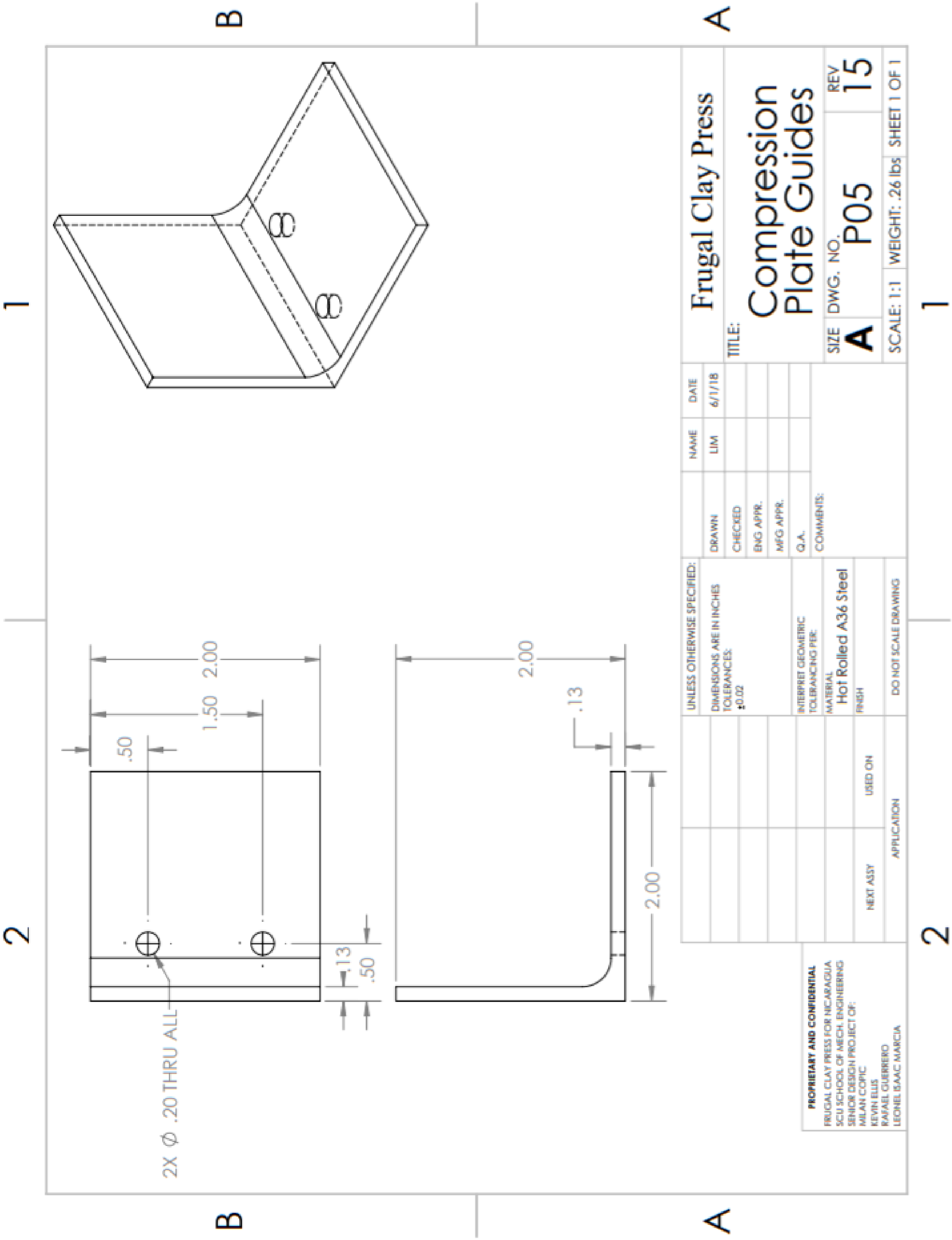
Compression Plate Assembly

SIZE A | DWG. NO. PA1 | REV 15

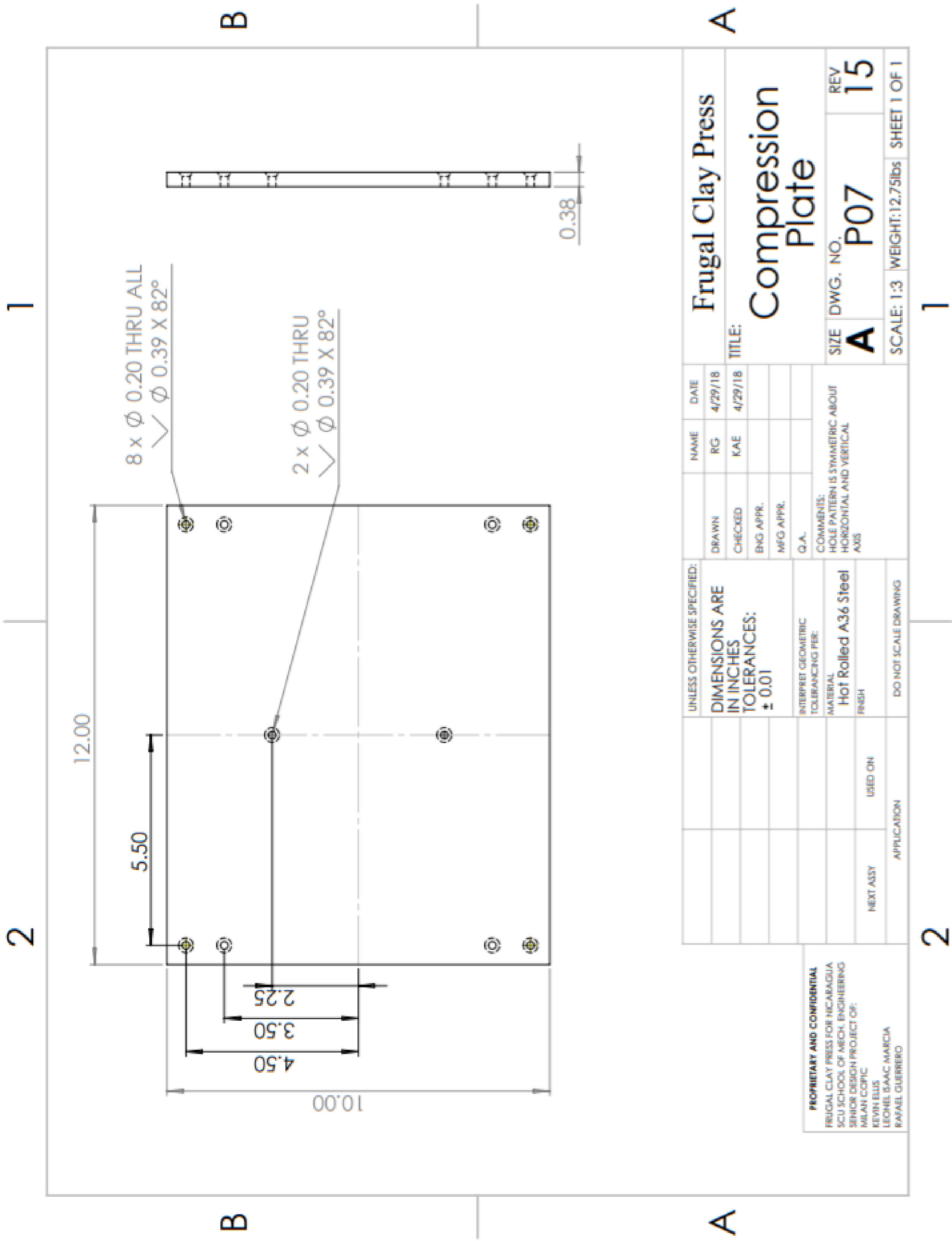
SCALE: 1:4 | WEIGHT:17.41lbs | SHEET 1 OF 1


Frugal Clay Press
TITLE:
Plate Connector L Beam
SIZE A
DWG. NO. P01
REV 15
SCALE: 1:2
WEIGHT: 0.64lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Hot Rolled A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
3/17/18
CHECKED
KAE
3/17/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
Ø THRU ALL
Ø 0.78 THRU
2.00
1.00
1.45
0.25
3.00
1.25
A
B
1
2

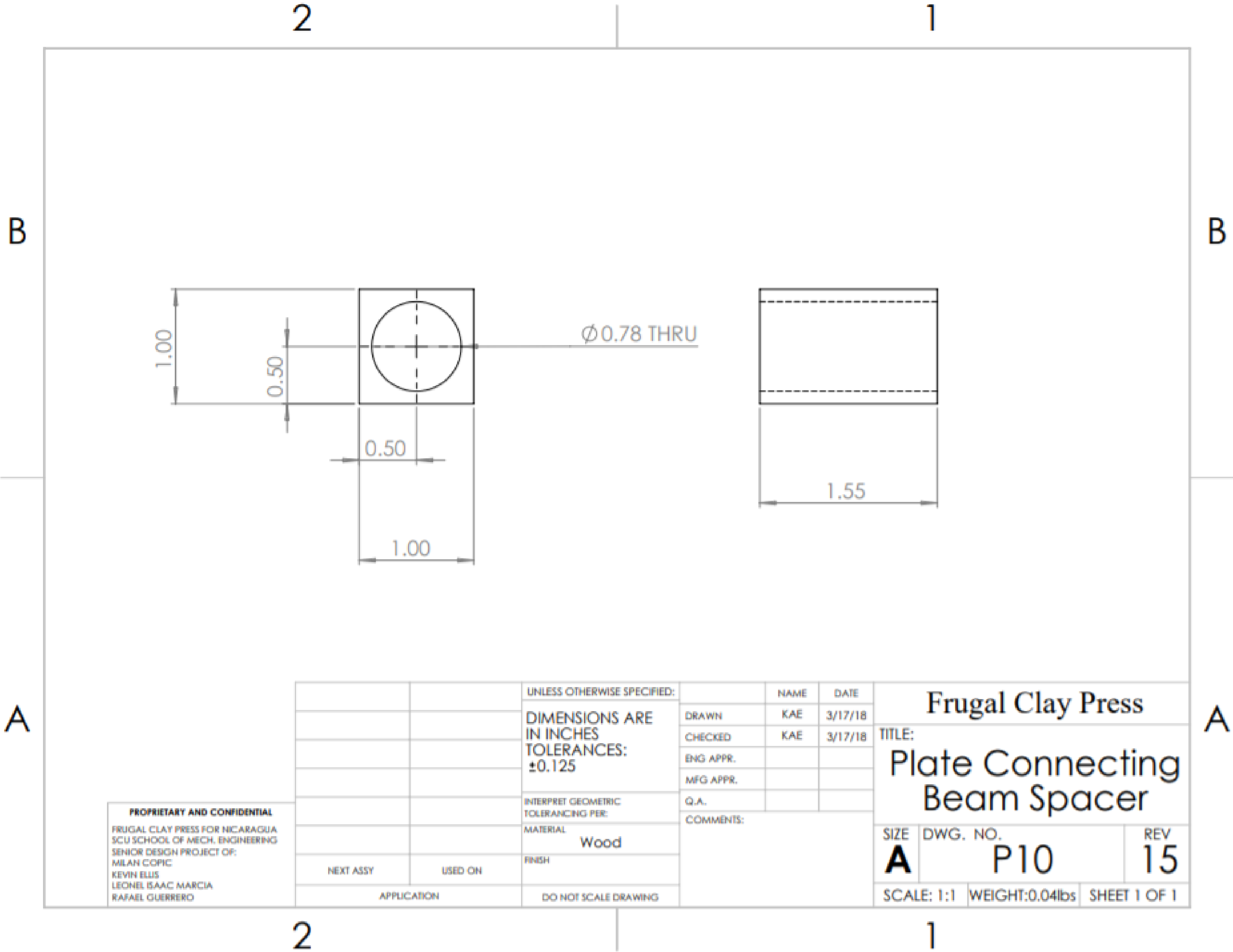

0.50 X 45° - 4x
Ø0.78 THRU - 2x
0.38
0.75
3.82
5.32
1.00
2.00
Frugal Clay Press
TITLE:
Plate Connecting Beam
SIZE
A
DWG. NO.
P04
REV
15
SCALE: 1:2
WEIGHT:1.50
SHEET 1 OF 1
NAME
DATE
DRAWN
KAE
3/17/18
CHECKED
KAE
3/17/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
± 0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2



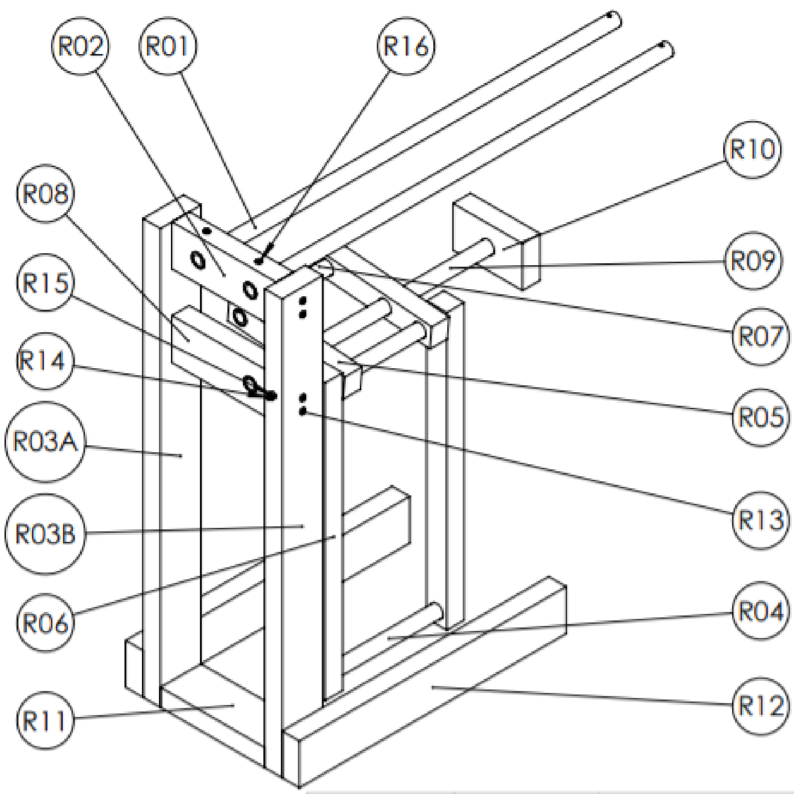
Frugal Clay Press
TITLE:
Compression Plate Guides
SIZE A
DWG. NO. P05
REV 15
SCALE: 1:1
WEIGHT: .26 lbs
SHEET 1 OF 1
NAME
DATE
DRAWN
LIM
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
±0.02
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Hot Rolled A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
RAFAEL GUERRERO
LEONEL ISAAC MARCIA
2X Ø .20 THRU ALL
.50
1.50
2.00
.13
.50
2.00
.13
2.00
A
B
1
2



Frugal Clay Press
TITLE:
Compression Plate
SIZE A
DWG. NO. P07
REV 15
SCALE: 1:3
WEIGHT: 12.75lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: ± 0.01
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL Hot Rolled A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN RG 4/29/18
CHECKED KAE 4/29/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS: HOLE PATTERN IS SYMMETRIC ABOUT HORIZONTAL AND VERTICAL AXIS
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
8 x Ø 0.20 THRU ALL
Ø 0.39 X 82°
2 x Ø 0.20 THRU
Ø 0.39 X 82°
12.00
5.50
2.25
3.50
4.50
10.00
0.38
A
B
1
2



Ø0.78 THRU
1.00
0.50
0.50
1.00
1.55
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES TOLERANCES: ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL Wood
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME DATE
DRAWN KAE 3/17/18
CHECKED KAE 3/17/18
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Plate Connecting Beam Spacer
SIZE A
DWG. NO. P10
REV 15
SCALE: 1:1
WEIGHT:0.04lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO



Part No.	PART NAME	QTY.
R01	Retrieval Rail	2
R02	Rail Beam	1
R03A	Frame Leg	1
R03B	Frame Leg	1
R04	Foot Pedal	2
R05	Push Lever	2
R06	Foot Beam	2
R07	Foot Pedal	1
R08	Retrieval Pivot Beam	1
R09	Pivot Pipe	1
R10	Base Pivot Beam	1
R11	Bottom Beam	1
R12	Retrieval to Base Beam	2
R13	1/4" - 2.5" Wood Screws	8
R14	1/4" - 4" Machine Screw	1
R15	1/4"-28 Hex Nut	1
R16	#12-28 x 2" Machine Screw	2

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FRUGAL CLAY PRESS FOR NICARAGUA
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LEONEL ISAAC MARCIA
RAFAEL GUERRERO

NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KAE	6/1/18
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

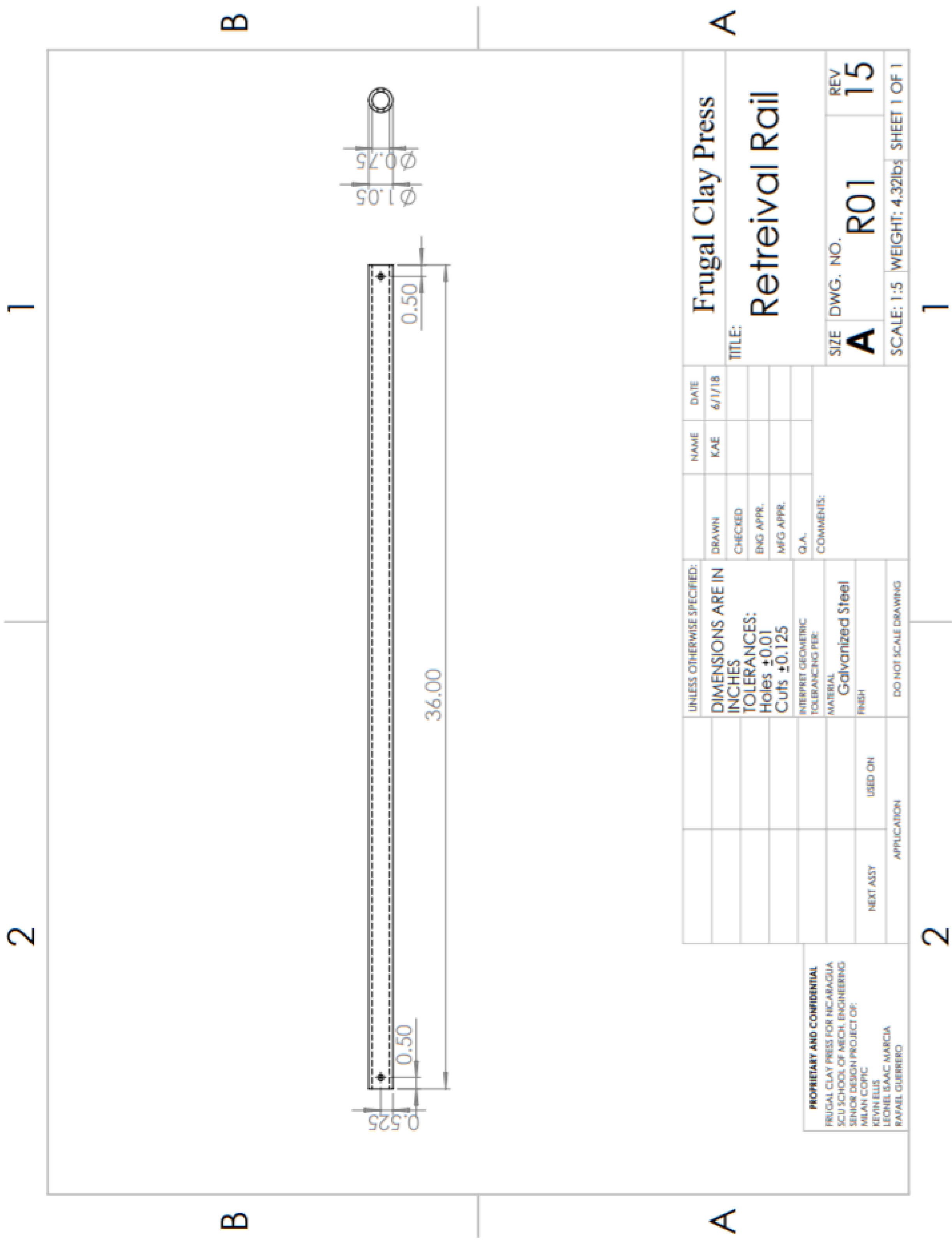
COMMENTS:

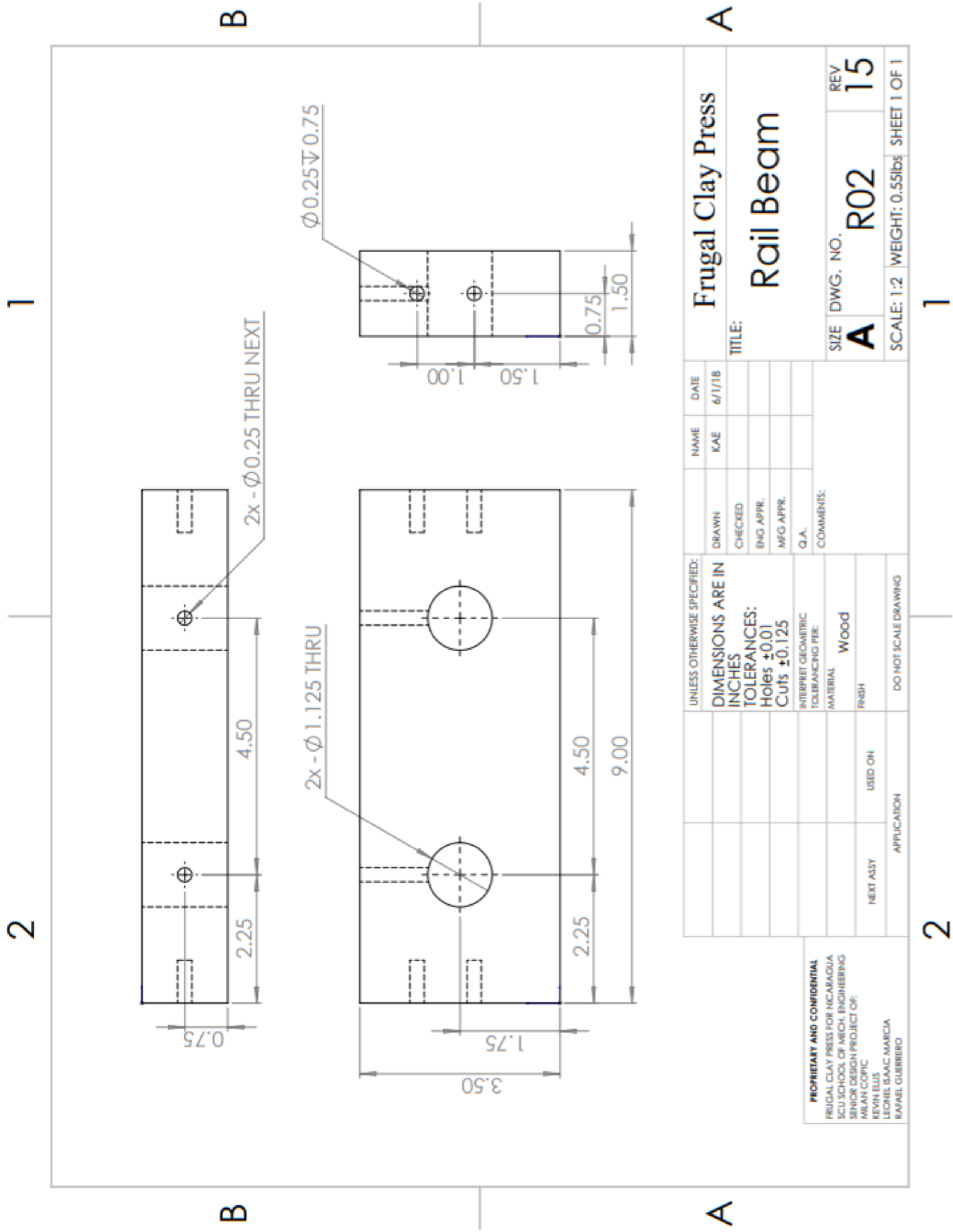
Frugal Clay Press

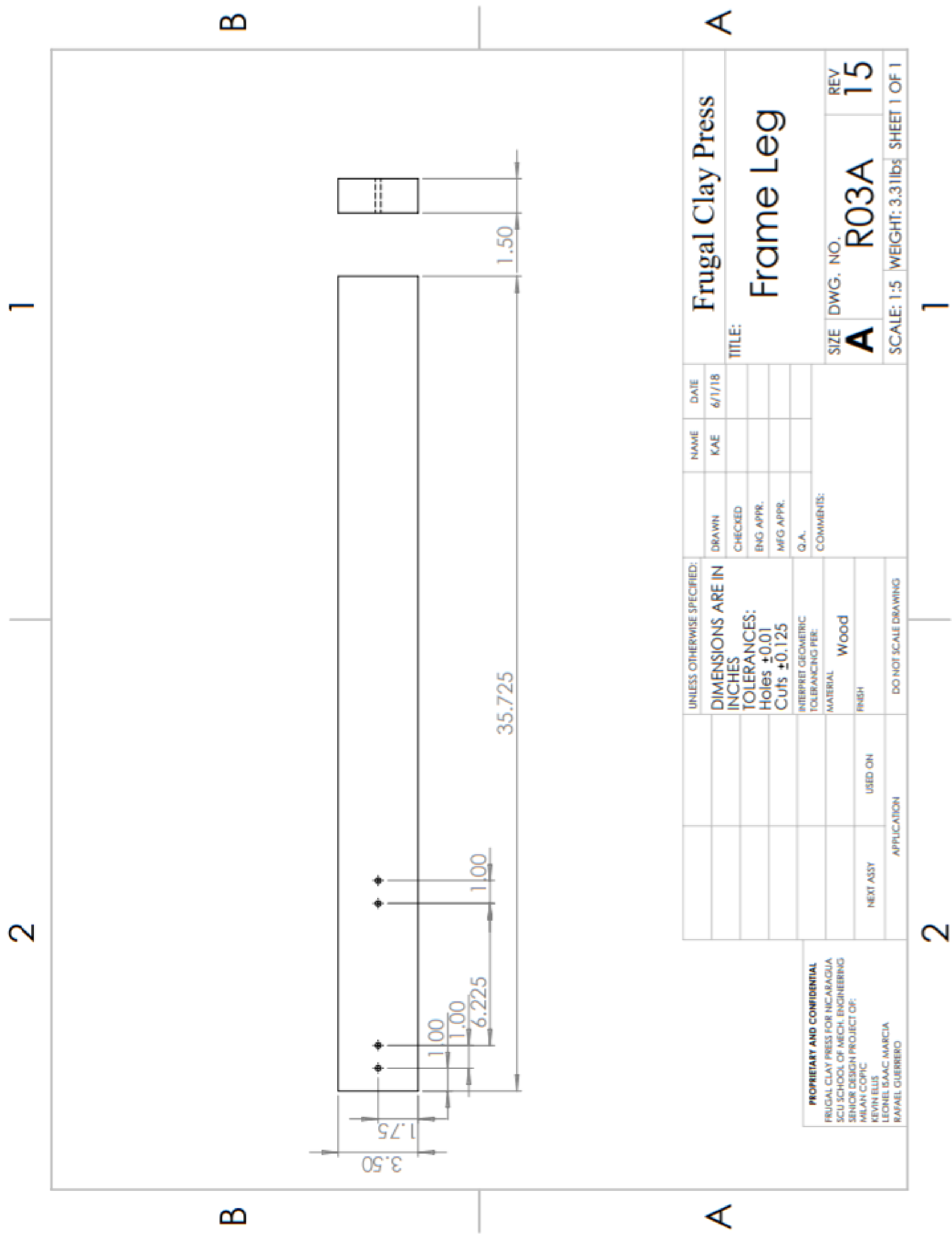
TITLE:
Clay Retrieval Assembly

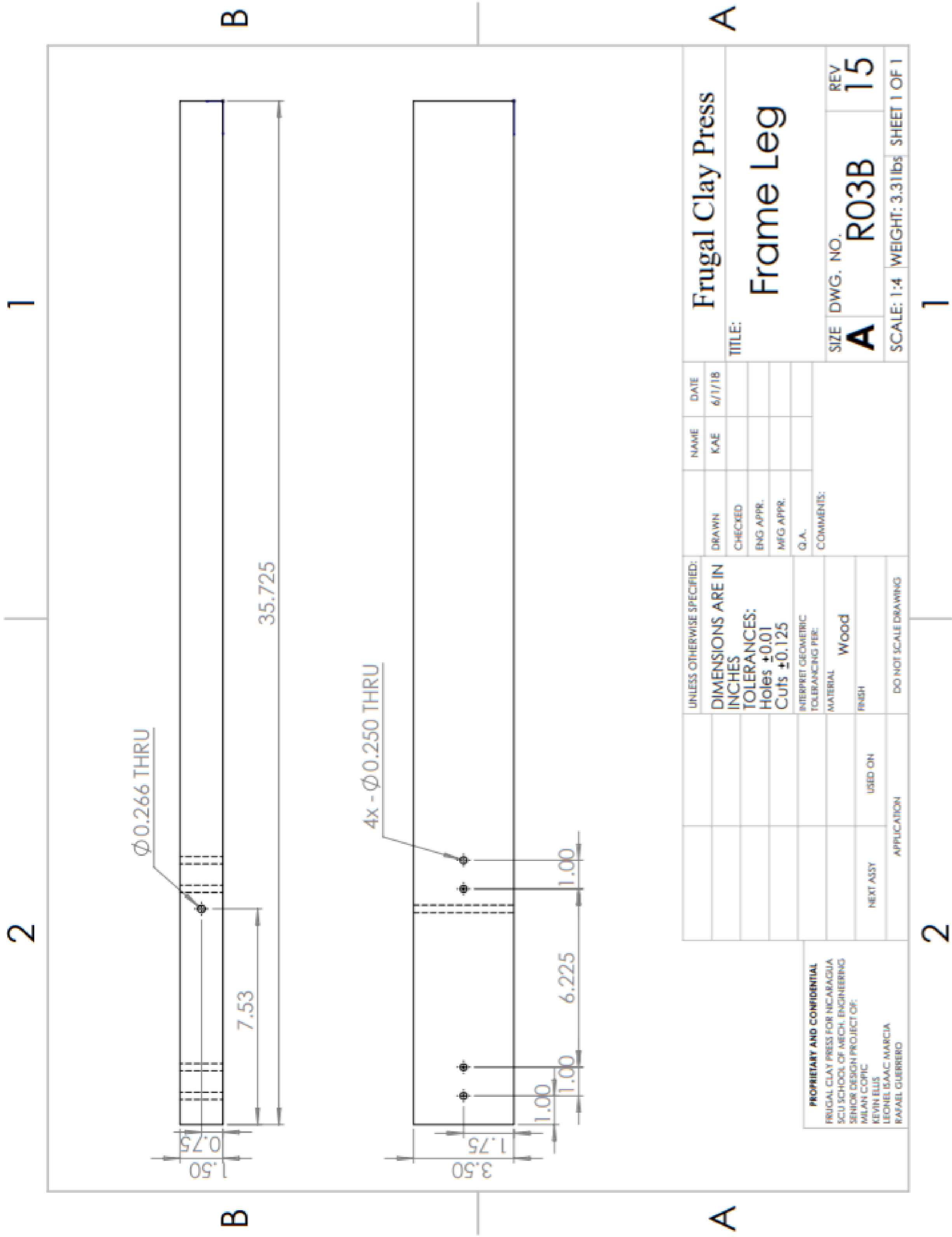
SIZE A | DWG. NO. RA1 | REV 15

SCALE: 1:9 | WEIGHT: 23.39lbs | SHEET 1 OF 1

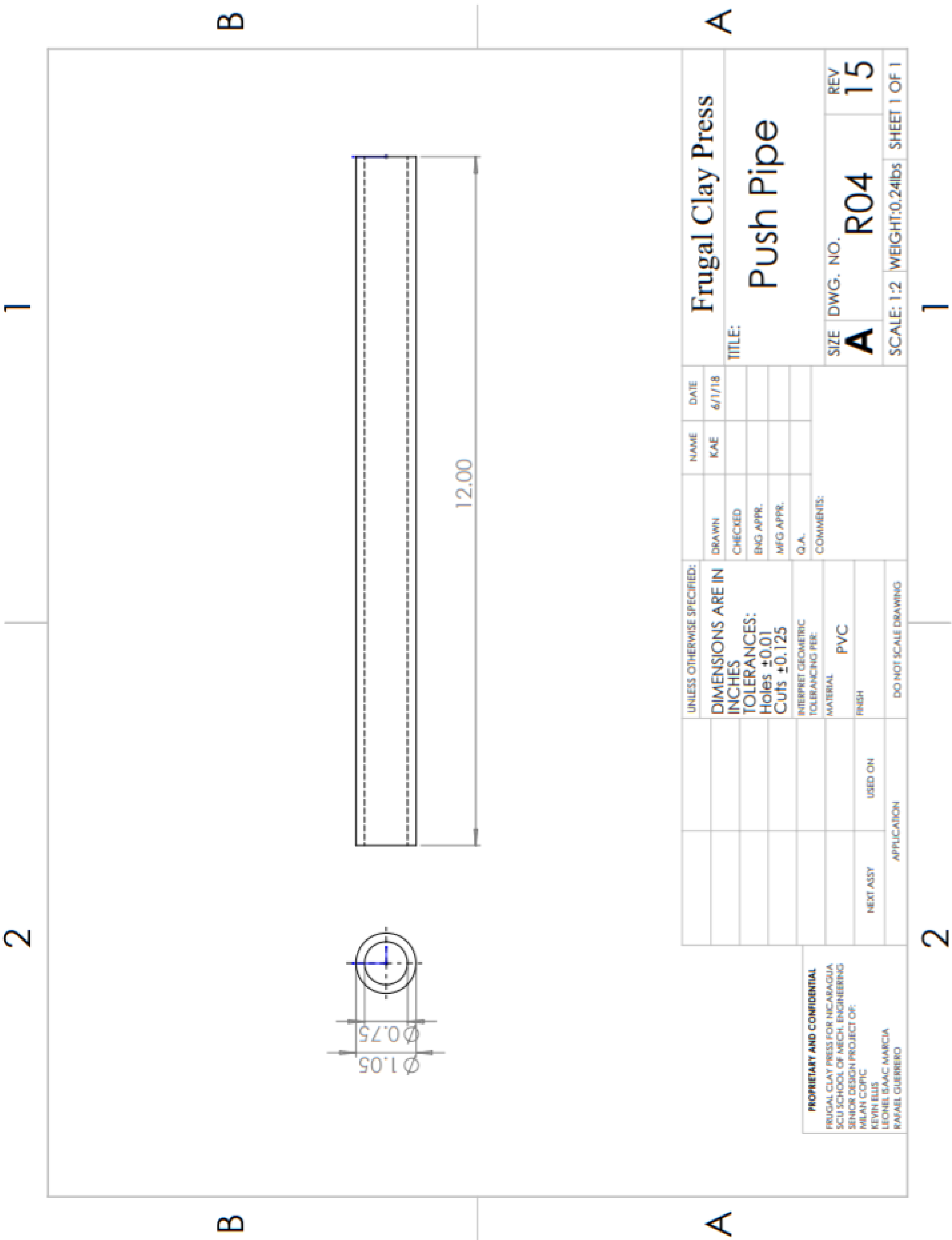

Frugal Clay Press
TITLE:
Retreival Rail
SIZE
A
DWG. NO.
R01
REV
15
SCALE: 1:5
WEIGHT: 4.32lbs
SHEET 1 OF 1
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Galvanized Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
36.00
0.50
0.50
0.525
Ø1.05
Ø0.75
A
B
1
2

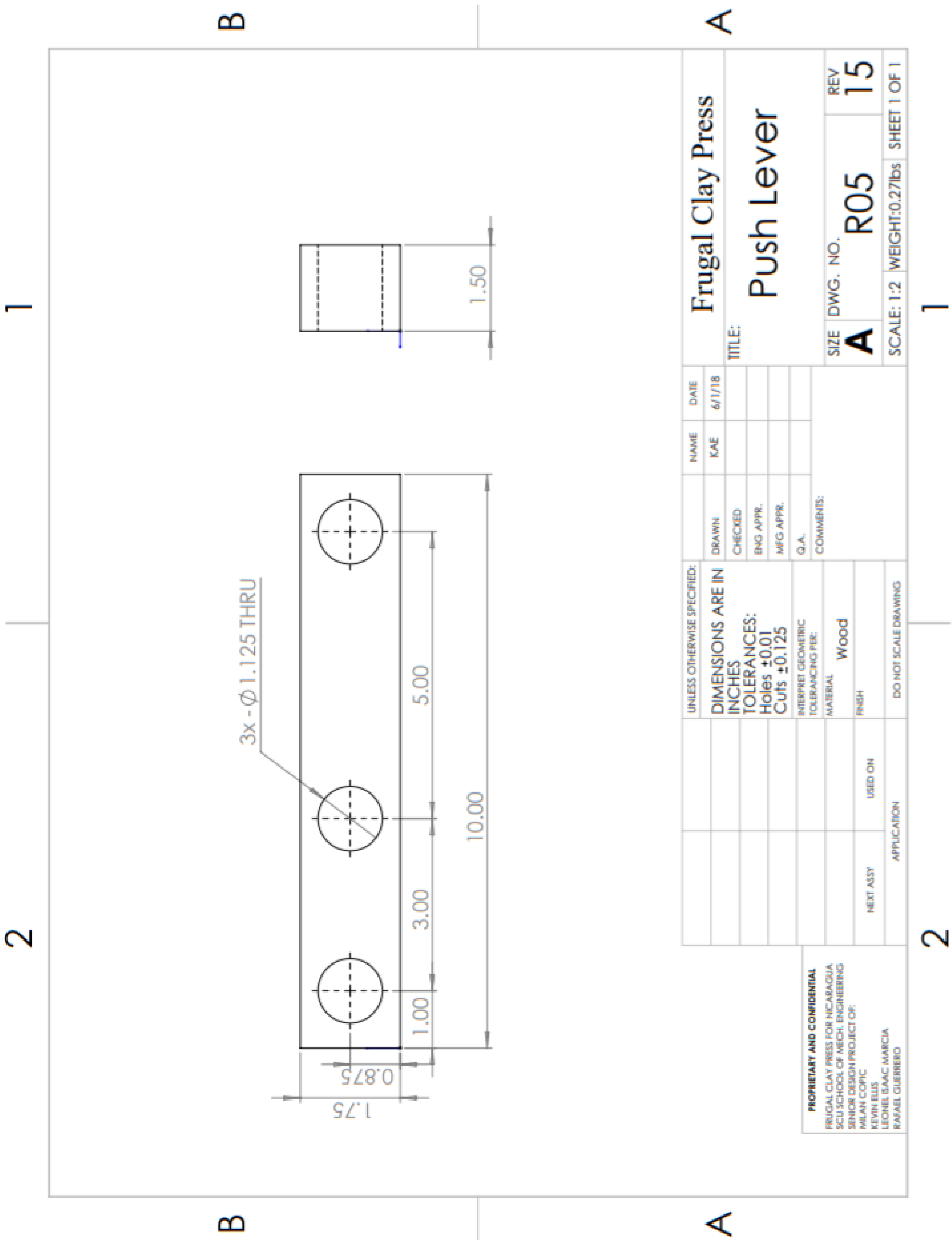

Frugal Clay Press
TITLE:
Rail Beam
SIZE A
DWG. NO. R02
REV 15
SCALE: 1:2
WEIGHT: 0.55lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
2x - Ø0.25 THRU NEXT
2x - Ø1.125 THRU
Ø0.25 ↧ 0.75
4.50
2.25
0.75
4.50
9.00
2.25
1.75
3.50
1.00
1.50
0.75
1.50
A
B
1
2


Frugal Clay Press
TITLE:
Frame Leg
SIZE A
DWG. NO. R03A
REV 15
SCALE: 1:5
WEIGHT: 3.31lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL Wood
FINISH
DO NOT SCALE DRAWING
DRAWN KAE 6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
35.725
1.50
1.00
1.00
1.00
6.225
1.75
3.50
A
B
1
2



Frugal Clay Press
TITLE:
Frame Leg
SIZE A
DWG. NO. R03B
REV 15
SCALE: 1:4
WEIGHT: 3.31lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
Ø0.266 THRU
4x - Ø0.250 THRU
35.725
7.53
6.225
1.00
1.00
1.00
0.75
1.50
1.75
3.50
A
B
1
2


Frugal Clay Press
TITLE:
Push Pipe
SIZE A
DWG. NO. R04
REV 15
SCALE: 1:2
WEIGHT:0.24lbs
SHEET 1 OF 1
12.00
Ø0.75
Ø1.05
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2


3x - Ø1.125 THRU
5.00
3.00
1.00
10.00
1.50
0.875
1.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Push Lever
SIZE
A
DWG. NO.
R05
REV
15
SCALE: 1:2
WEIGHT:0.27lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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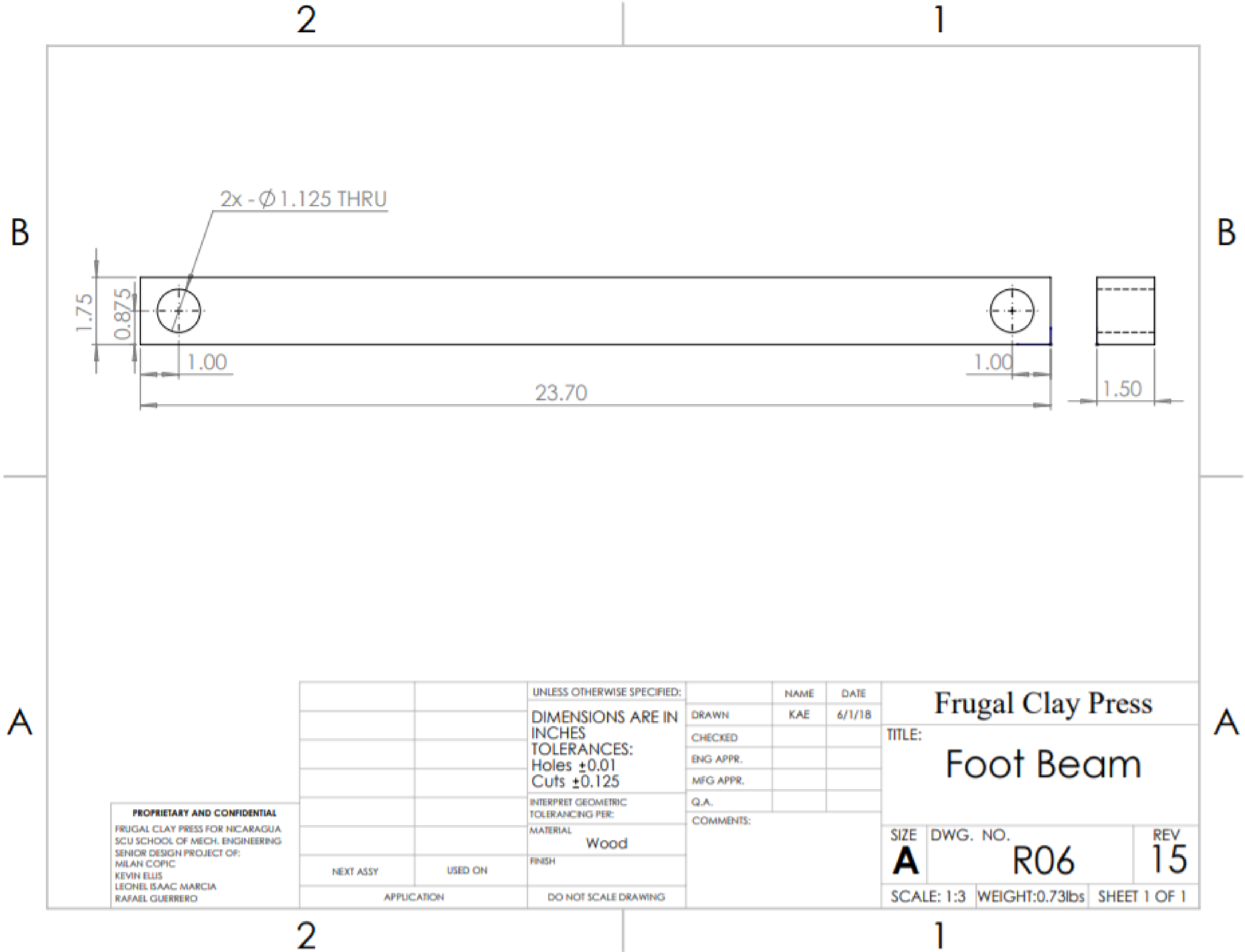
RAFAEL GUERRERO


2x - Ø1.125 THRU
1.75
0.875
1.00
1.00
23.70
1.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Foot Beam
SIZE
A
DWG. NO.
R06
REV
15
SCALE: 1:3
WEIGHT:0.73lbs
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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SCU SCHOOL OF MECH. ENGINEERING
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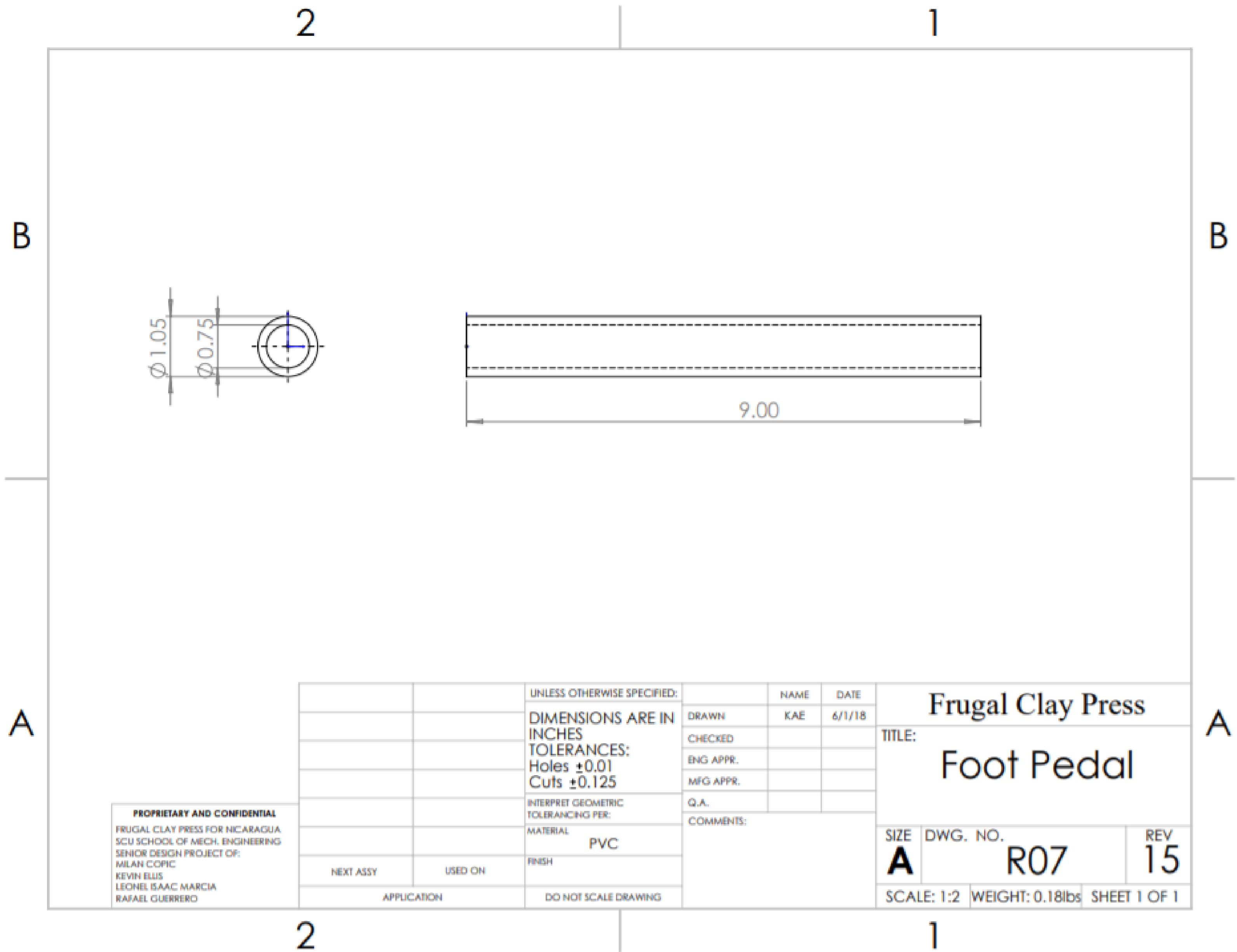
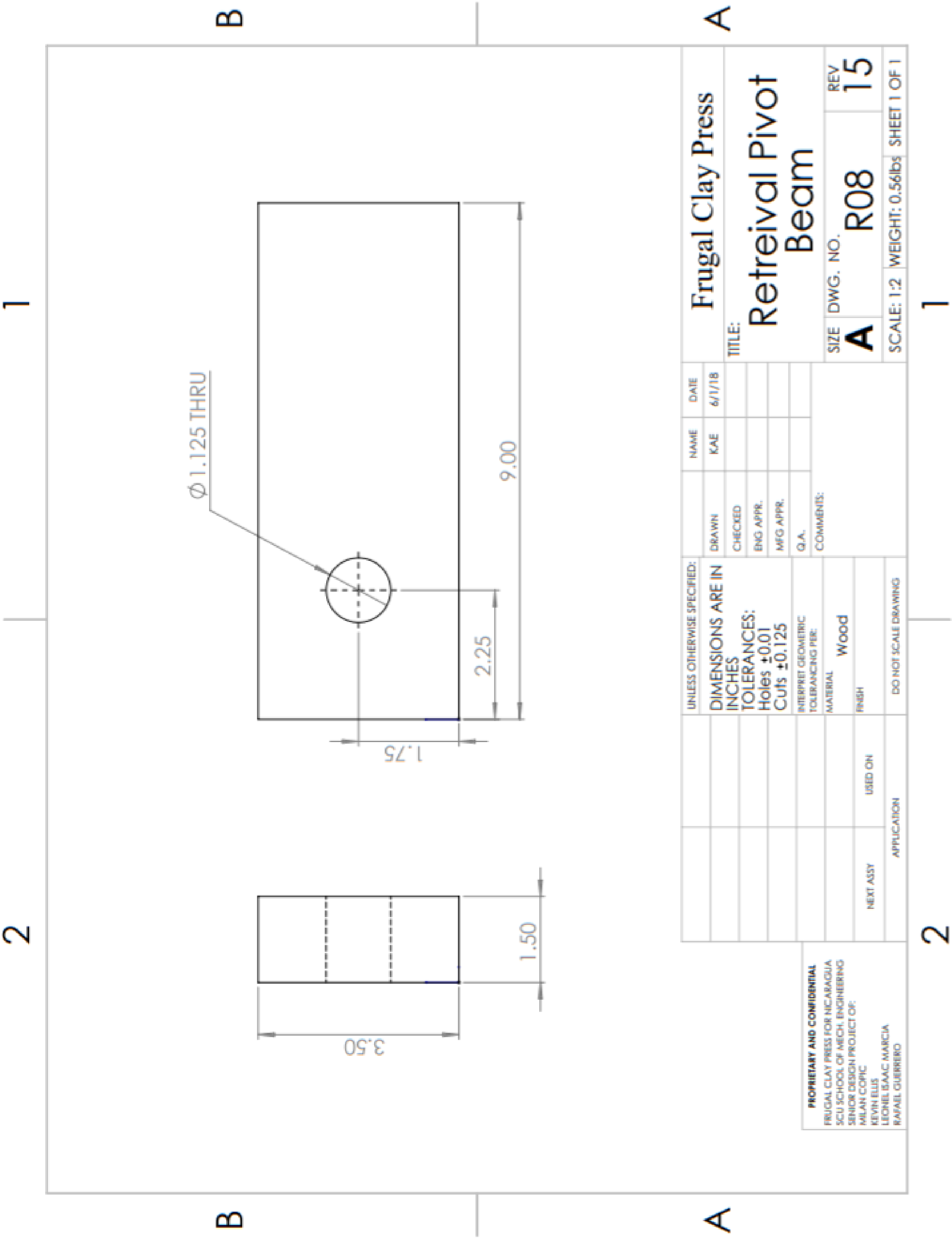
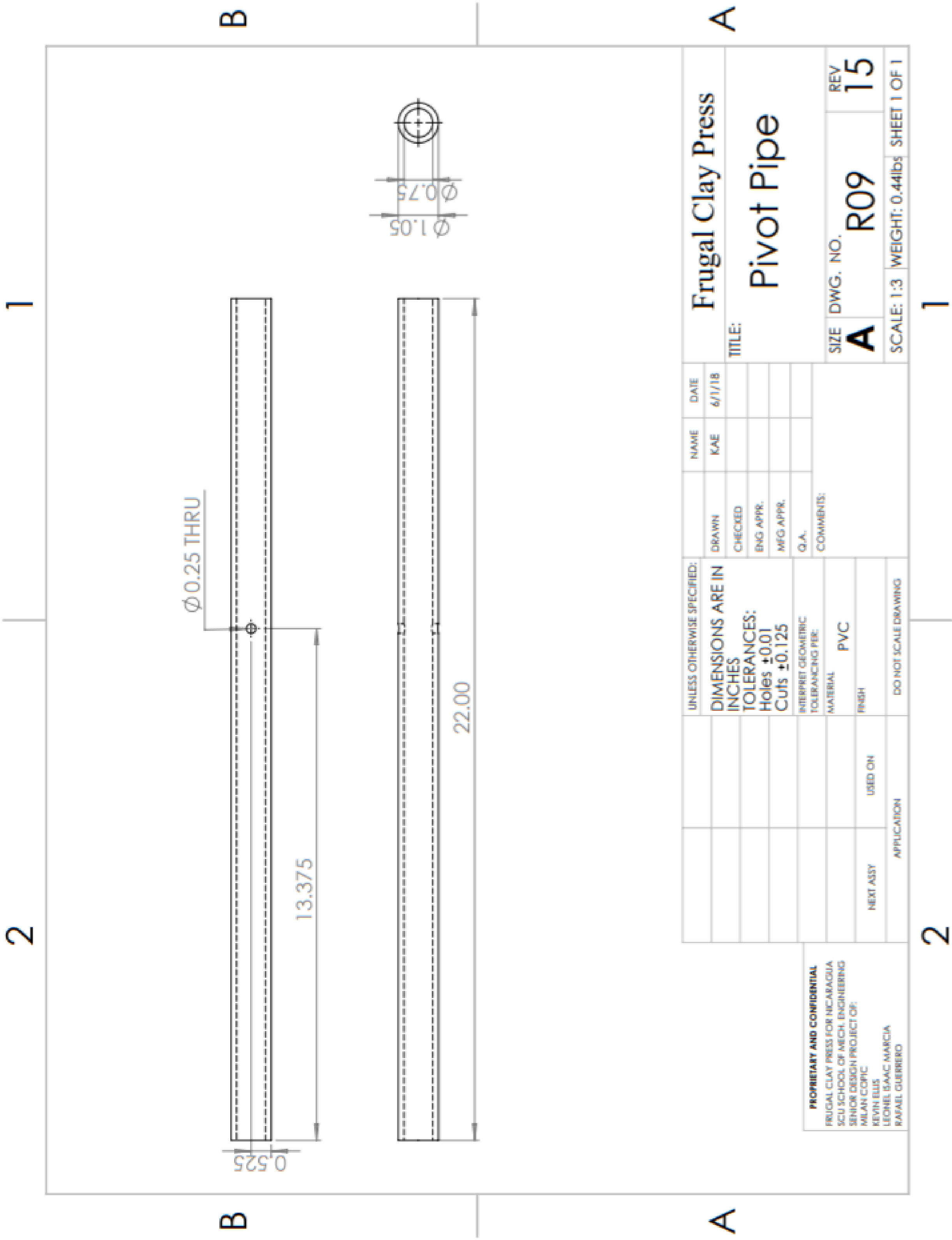
LEONEL ISAAC MARCIA
RAFAEL GUERRERO

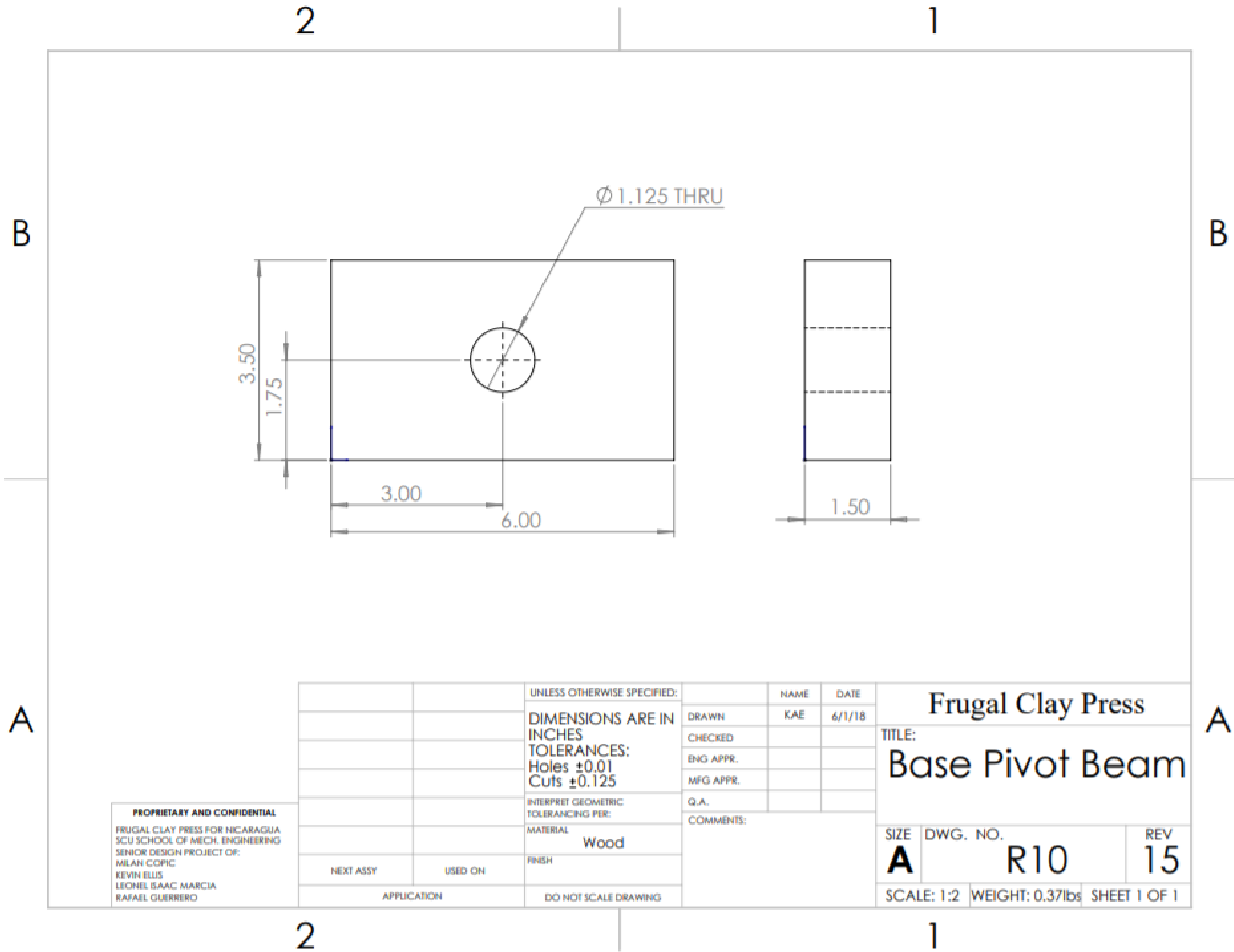


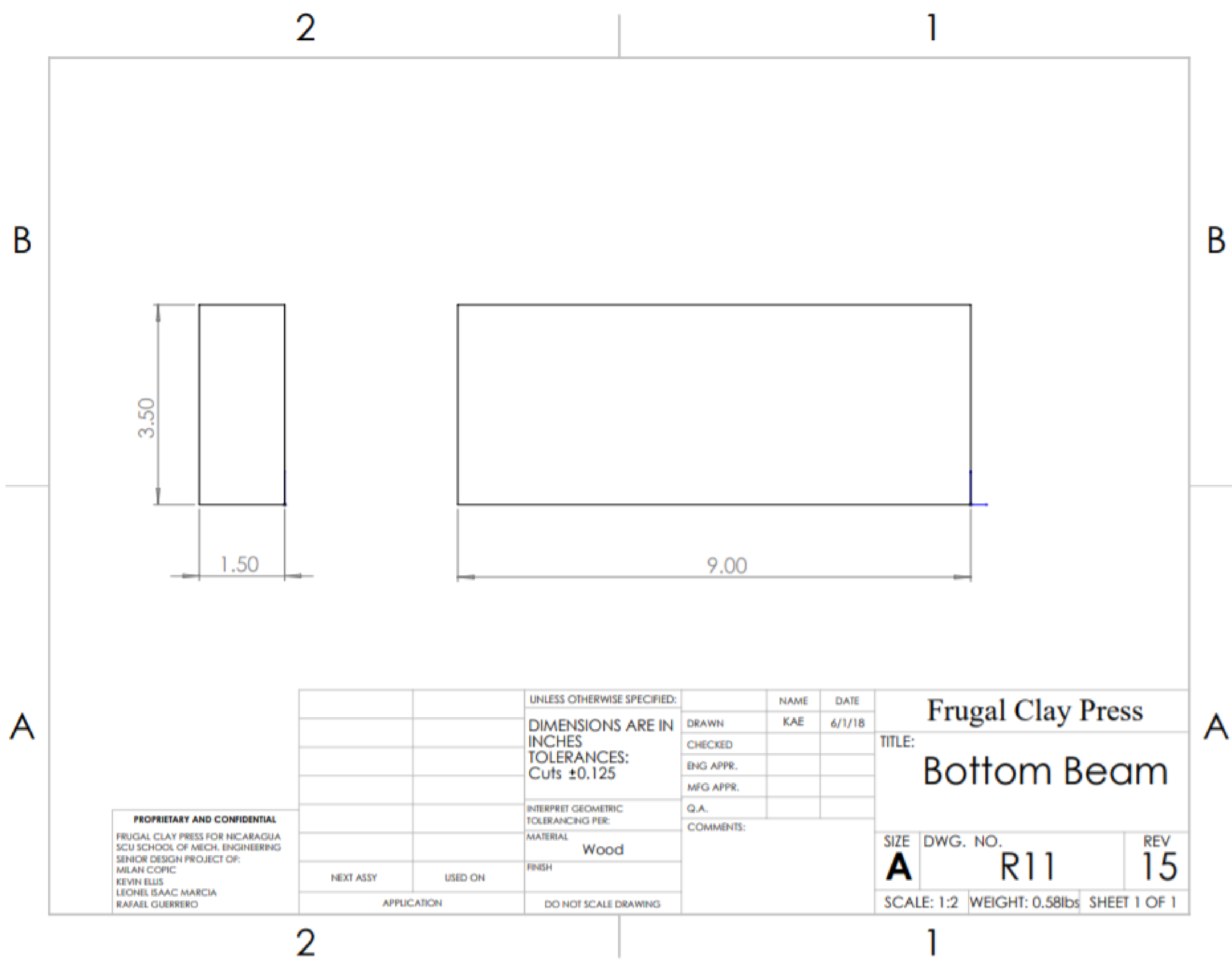
Ø1.05
Ø0.75
9.00
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Foot Pedal
SIZE
A
DWG. NO.
R07
REV
15
SCALE: 1:2
WEIGHT: 0.18lbs
SHEET 1 OF 1


Frugal Clay Press
TITLE:
Retreival Pivot Beam
SIZE A
DWG. NO. R08
REV 15
SCALE: 1:2
WEIGHT: 0.56lbs
SHEET 1 OF 1
Ø1.125 THRU
9.00
2.25
1.75
1.50
3.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
A
B
1
2

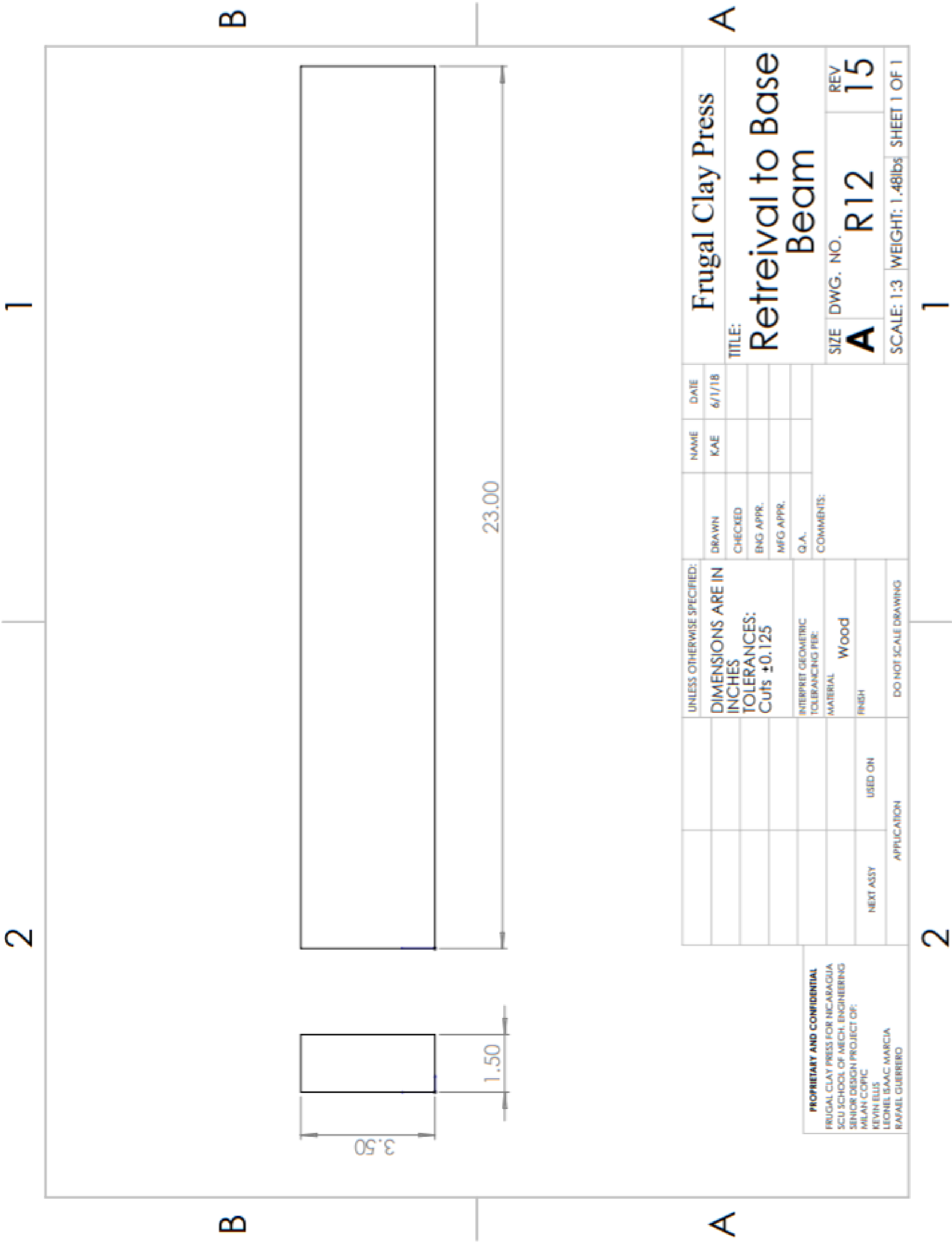


Frugal Clay Press
TITLE:
Pivot Pipe
SIZE A
DWG. NO. R09
REV 15
SCALE: 1:3
WEIGHT: 0.44lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
PVC
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
Ø0.25 THRU
13.375
22.00
0.525
Ø0.75
Ø1.05
A
B
1
2


2
1
B
A
Ø1.125 THRU
3.50
1.75
3.00
6.00
1.50
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Holes ±0.01
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Base Pivot Beam
SIZE
A
DWG. NO.
R10
REV
15
SCALE: 1:2
WEIGHT: 0.37lbs
SHEET 1 OF 1



2
1
B
A
3.50
1.50
9.00
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Frugal Clay Press
TITLE:
Bottom Beam
SIZE
A
DWG. NO.
R11
REV
15
SCALE: 1:2
WEIGHT: 0.58lbs
SHEET 1 OF 1


B
1
2
A
23.00
1.50
3.50
Frugal Clay Press
TITLE:
Retreival to Base Beam
SIZE
A
DWG. NO.
R12
REV
15
SCALE: 1:3
WEIGHT: 1.48lbs
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
Cuts ±0.125
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Wood
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KAE
6/1/18
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
FRUGAL CLAY PRESS FOR NICARAGUA
SCU SCHOOL OF MECH. ENGINEERING
SENIOR DESIGN PROJECT OF:
MILAN COPIC
KEVIN ELLIS
LEONEL ISAAC MARCIA
RAFAEL GUERRERO