2018

MAGSEAL Edge Breaking Safety Device

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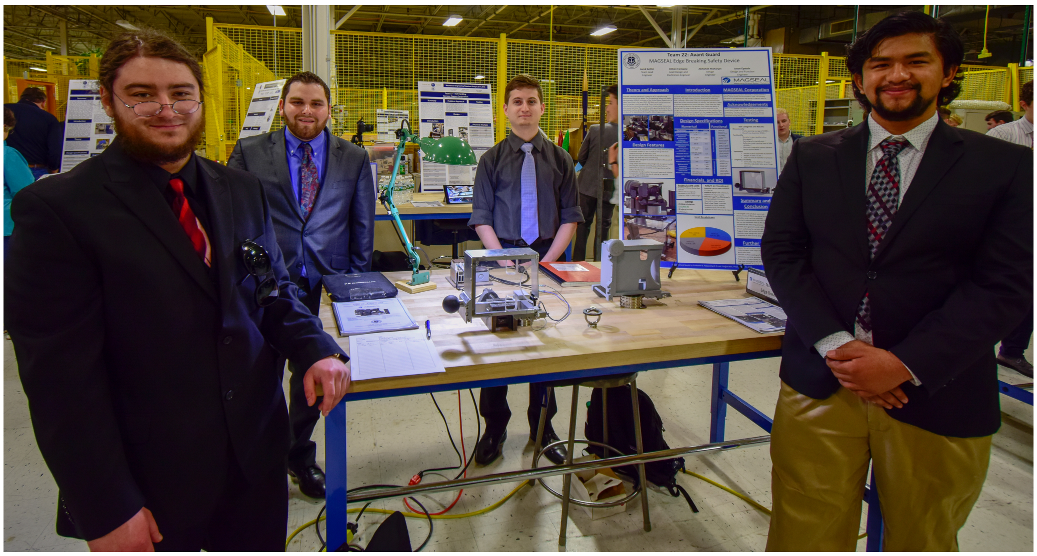
Team 22: Avant Guard

MAGSEAL Edge Breaking Safety Device

MAGSEAL
Maximizing Critical System Reliability



Team Members:

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UNIVERSITY OF RHODE ISLAND
HOPE
1892

MCE 401/402: Senior Capstone Design
Department of Mechanical, Industrial and Systems Engineering
Design Report
2017-2018

Abstract

Team 22 was approached by the Magnetic Seal Corporation to solve a problem: develop simple electro-mechanical safety guarding for an edge-breaking and chamfering lathe. To accomplish this, the current situation was thoroughly researched, the machine inspected by the team, and a preliminary patent search conducted to survey the current body of knowledge for machine guarding. Through lessons learned from this literature search, including mounting methods, shape considerations, and a means to electrically link the guard engagement to machine operation, 120 concepts were generated by the team and classified into four groups. A Quality Function Deployment comparison was performed and in addition to sponsor feedback, a preliminary design for the guard was modeled, drawn, and prototyped.

This design uses a steel frame to hold interchangeable polycarbonate panes with three contoured holes cut therein. One hole is provided for the operator to break the outside diameter of a part, another hole expressly for the inside diameter, and a relief by which a grinding wheel can approach and apply a chamfer feature into the part at variable angles. The holes are arranged and sized so that an operator cannot fit both edge-breaking stone and finger at once, and were a slip to occur, the hand would naturally move either against the frame wherein the pane would prevent contact, or away from the machine entirely. Aluminum sheathing is used to fully enclose the operation and prevent egress of debris or dust into the operator area. A two pin support approach was theorized, but not prototyped, for attachment of the guard to the machine.

Through inspection of this prototype and simulation within a faithful 3-D replica of the edge-breaking machine, this design was verified to fulfill MAGSEAL's requirements. The use of the safety guard will not increase cycle time and hypothesized to not be an inconvenience to the operator. Additional work will be carried out to fit the device to the lathe, incorporate electrical integration into the power system, and adapt the guard to the full range of processed parts.

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List of Acronyms, Nomenclature

220xx	Refers to Part Number for Team 22 Machine Guard	
AC	Alternating Current	
AISI	Amrican Iron and Steel Institute	
Al.	Aluminum	
ANSI	American National Standards Institute	
ASME	American Society of Mechanical Engineers	
ASTM	Formerly American Society for Testing and Materials, Currently ASTM International	
BOM	Bill of Materials	
CNC	Computer Numeric Control (Machining)	
DC	Direct Current	
FOS	Factor of Safety	
ID	Inside Diameter	
KIP	Kilo pound-force	
MAGSEAL	Magnetic Seal Corporation (Warren, RI)	
MSAG	MAGSEAL - Team 22 - Avant Guard, refers to Drawing Numbers	
OD	Outside Diameter	
OSHA	Occupational Safety and Health Administration	
QFD	Quality Function Deployment	
SHCS	Socket Head Cap Screw	
σ_s	Shear Yield Stress	MPa
σ_y	Tensile Yield Stress	MPa
σ_{ult}	Ultimate Tensile Stress	MPa
A_t	Tensile Stress Area	in^2
D, d	Diameter	in
E	Young's Modulus, Elastic Modulus	MPa
F, P	Force, Load	lbf
k	Stiffness	KIP/in
N	Factor of Safety	
S_p	Proof Strength	MPa

1 Introduction

Improper machine guarding is a hazard to all in manufacturing environments across the world and the globe. The Occupational Safety and Health Administration (OSHA), a division of the United States Department of Labor is responsible for insuring workers in manufacturing environments across the United States. In 2015 4,836 fatal work injuries occurred in the US, and out of those 4,836, 353 occurred in manufacturing environments and factories [9]. Many of these occurred due to improper machine guarding. OSHA recognizes these injuries as preventable, as had a guard been in place they would have been defined as a "near-miss" instead of an accident. During routine audits of manufacturing plants across the US OSHA insures the safety of the workers.

OSHA recommends multiple ways to mitigate the dangers in manufacturing environments [4]. Figure 1 shows the different types of controls that can be used for problem mitigation.

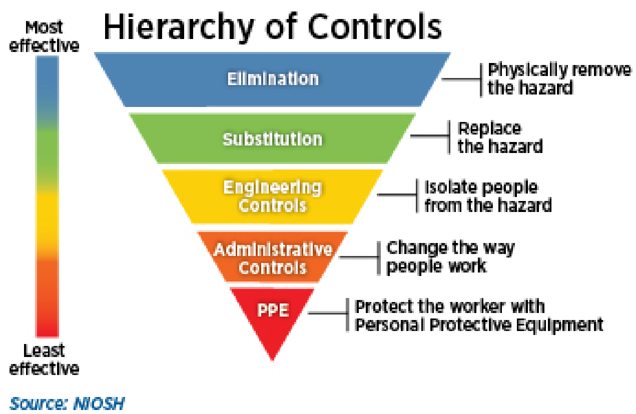


Figure 1: Different Types of Controls OSHA Recommends to Mitigate Problems (courtesy of OSHA.gov [4])

MAGSEAL pitched the idea of using an engineering control. In an engineering control the operator of the machine is removed from a hazard usually through the use of a guard. There are benefits of engineering controls over elimination especially when it comes to cost. In many scenarios eliminating the hazard through automating the process takes time and is generally expensive, therefore an engineering control tends to be the most economical.

1.1 About the Sponsor: MAGSEAL Corporation

MAGSEAL was founded in 1954 by George E. Colby and Robert L. Stevenson. The two founders patented the first magnetically energized rotary seal (patent number: 2843403). The original brochure for its magnetic shaft seals is shown in figure 2.

To this day the company is still owned by the Colby family. The company specializes in the development and testing of magnetic seals for aerospace and high precision applications. The company is based out of and has its manufacturing plant in Warren, Rhode Island.

Figure 2: MAGSEAL Brochure (courtesy of MAGSEAL [5])

1.2 Current Situation

When the team first visited the manufacturing plant in Warren, Rhode Island, the machine was seen in its current state (shown below in figure 3).

Figure 3: Deburring and Chamfering Machine at its Current State

As seen in the image, the machine has no safety guard, thus there exists potential for operator injury from the machine. About six months prior to the team's visit to the facility an injury had occurred while an operator was using the machine for production. This further increased the need for a safety solution for the machine.

This machine was custom built for MAGSEAL back in the 1970s to allow for them to easily process parts and break the sharp edges. It is one of two machines like it, both are owned by the MAGSEAL Corporation, and are located in Warren, Rhode Island. While both machines perform the same process the two are slightly different, notably in the orientation of the dust removal vaccuum. Shown below is a diagram of the machine (figure: 4)

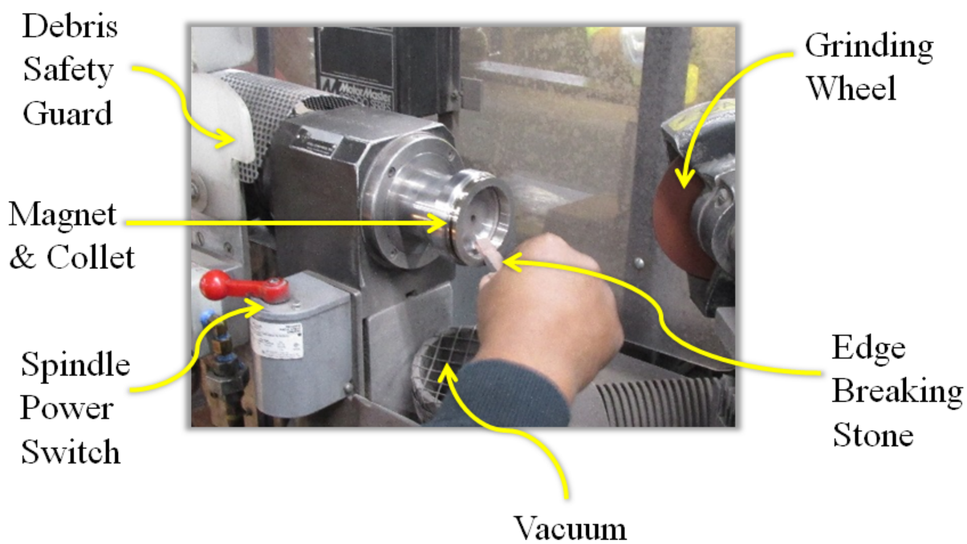


Figure 4: Diagram of the Edge Breaking and Chamfering Machine (Image courtesy of MAGSEAL [5])

1.3 Problem Definition

Deburring is a process that has been around for ages. When metal is traditionally cut there is always a small amount of material left that forms on the edge making it very sharp, this amount of small sharp metal is called a burr. Obviously companies can't ship out their various metal products with hazardous areas throughout, thus the process of deburring was created.

There are various ways to deburr parts. One process consists of spinning either the part or the deburring device at a certain speed and applying the device to the burr or vice versa. The reason this process must be done by hand is because only a very small amount of material needs to be removed and removing too much, depending on the tolerances, could render the part useless. Though deburring is a necessary part of production to ensure customer safety, there is currently nothing ensuring operator safety during this process. In fact, the act process of deburring by hand is extremely dangerous since, before deburred, the metal is sharp and moving at high speed with only an abrasive stone separating the operator finger with the sharp metal.

The need for precision and delicacy makes it hard to refine the old-school technique of deburring by hand and make it safer, however, this is exactly what the company MAGSEAL has asked us to create.

Shown below (figure: 5)is a diagram of a MAGSEAL seal prior to the deburring operation. As seen in the diagram the seal contains a total of four sharp edges (the ID on the front and back, and the OD on the front and back).

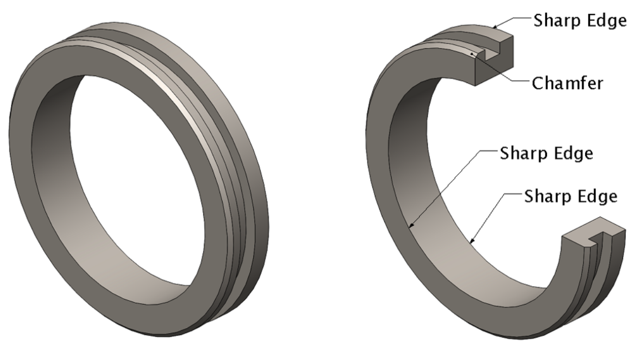


Figure 5: Diagram of Seal Sharp Edges

All of the sharp edges must be broken before the seal can move forward in the manufacturing process.

1.3.1 Original Problem Definition

A safety concern with deburring seal magnets, metallic rings held in a collet lathe spun at approx. 300 rpm. If the OD is broken before the ID, risk of hand injury occurs if the operator's hand slips and grazes sharp edge of the ID. A computer generated model of this hazard is shown in the figure below (figure: 6)

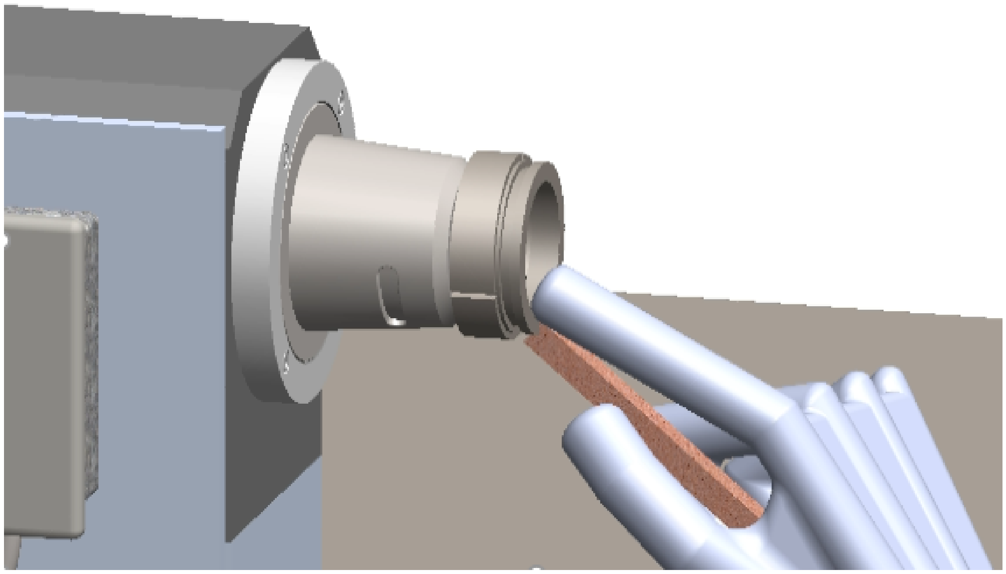


Figure 6: Computer Generated Model of Hazard (courtesy of [5])

The corners are broken with aluminum oxide abrasive files held in the gloved hand, automation of the process not possible. The machine is activated by drum switch in easy reach of operator, collet is pneumatically opened and closed by separate switch close to the same. Operator uses one hand to control the machine, edge-breaking process performed with the other hand. Feet are free and available for possible supplementary control.

- A device that forces the inside diameter before the outside diameter, in the event of operator slippage the inside diameter is not sharp thus the operator does not sustain an injury.
- Cannot add to the process cycle time.
- Cannot diminish the intimate sense of feel between operator and the file/ part. This is how the operator performs inspection of the part
- Cannot diminish the intimate sense of feel between operator and the file/ part.
- Must consider human factors such as operator fatigue, ability to process information, and simultaneous use of multiple appendages.
- Must accommodate parts as large as 5.00 inches in diameter and as small as 0.50 inches in diameter, various thicknesses up to one inch.
- Cannot hinder the automated chamfer-grinding process at angles from 30 to 60 degrees on the far side of part. This operation shall not be changed.

The table on the following page details some of the safety related (OSHA Machine Guarding Assessment [10]). On the table the S stands for satisfactory, while I means either the item needs improvement, is unsatisfactory, or non existent. The problem definition above will fix the deficiencies listed above.

Machine Guarding Assessment (Pre-Guarding)

Machine Nominclature: Magnet Deburring and Chamfering Machine	**Principle Use:** Breaking sharp edge on ID, and OD of cast magnets, then applying a 45° chamfer to both.	**Machine Manufacture Date:** 1970's
Machine Location: MagSeal Corporation, Warren Rhode Island		**Date of Assessment:** 10/1/2017

Initial Considerations

1. Can an individual be caught in, on or between two objects?	Yes
2. Can an individual be struck by an object?	Yes
3. Can an individual strike against a hazard object?	Yes
4. What physical hazards such as heat, cold, line pressurese, electrical, chemical and other hazards exist?	None
5. Identify: The point of operation, nip points, shear points, and other mechanical	Spinning Collet

Methods of Machine Safeguarding

Indicate: S: Satisfactory I:Needs Improvement/Non Existant (Unsatisfactory) R: Needs Repair

Guards

☑	Fixed Guards	☐ -S ☑ -I ☐ -R
☐	Interlocked Guards	☐ -S ☐ -I ☐ -R
☐	Adjustable Guards	☐ -S ☐ -I ☑ -R
☐	Self Adjusting Guards	☐ -S ☐ -I ☐ -R

Devices

☐	Photoelectric Sensing	☐ -S ☐ -I ☐ -R
☐	Radio Frequency Sensing	☐ -S ☐ -I ☐ -R
☐	Electromech. Sensing	☐ -S ☐ -I ☐ -R
☐	Pullback System	☐ -S ☐ -I ☐ -R
☐	Restraint System	☐ -S ☐ -I ☐ -R
☐	Pressure Sens. Body Bar	☐ -S ☐ -I ☐ -R
☐	Safety Tripod	☐ -S ☐ -I ☐ -R
☐	Safety Tripwire Cable	☐ -S ☐ -I ☐ -R
☐	Two-Hand Control	☐ -S ☐ -I ☐ -R
☐	Two-Hnd Trip Control	☐ -S ☑ -I ☐ -R
☐	Interlocked Gate	☐ -S ☑ -I ☐ -R
☐	Other Gate	☐ -S ☑ -I ☐ -R
☐	Presence-Sensing Mats	☐ -S ☑ -I ☐ -R

Feeding and Ejection Methods

☐	Automatic Feed	☐ -S ☐ -I ☐ -R
☐	Semi-Automatic Feed	☐ -S ☐ -I ☐ -R
☐	Automatic Ejection	☐ -S ☐ -I ☐ -R
☐	Semi-Automatic Ejection	☐ -S ☐ -I ☐ -R
☐	Robotic	☐ -S ☐ -I ☐ -R
☑	Manual Feed	☑ -S ☐ -I ☐ -R
☑	Manual Ejection	☑ -S ☐ -I ☐ -R

Miscellaneous Aids

☐	Audible Warnings	☐ -S ☐ -I ☐ -R
☐	Warning Lights	☐ -S ☐ -I ☐ -R
☐	Color Coding	☐ -S ☐ -I ☐ -R
☐	Hand Feeding Tools	☐ -S ☐ -I ☐ -R
☐	Awareness Barriers	☐ -S ☐ -I ☐ -R
☐	Holding Fixtures	☐ -S ☐ -I ☐ -R
☐	Protective Shielding	☐ -S ☐ -I ☐ -R
☐	Guard Rails	☐ -S ☐ -I ☐ -R
☐	Mechanical Barriers	☐ -S ☐ -I ☐ -R
☐	Appropriate Signage	☐ -S ☐ -I ☐ -R

Locations/Distancing

☑	Control Station Position	☑ -S ☐ -I ☐ -R
☐	Enclosure Fences	☐ -S ☐ -I ☐ -R
☐	Enclosure Walls	☐ -S ☐ -I ☐ -R
☑	Hazard Accessibility	☐ -S ☑ -I ☐ -R
☑	Hazard Positioning Ok	☐ -S ☑ -I ☐ -R
☑	Machine Positioning	☑ -S ☐ -I ☐ -R
☐	Reach Safe Distance	☐ -S ☐ -I ☐ -R

Other Methods

Remarks, Concerning Existing Safeguarding Conditions

No safeguards in place, operator fully exposed, hands are at risk of injury, no protection from flying chips

Table 1: Pre-Guarding Safety Assessment

1.3.2 Near-Miss Causes Problem Definition Change

The day before the team's second visit to MAGSEAL on November 16th, there was a safety incident that had a drastic impact on the machine guarding project. During normal deburring operations, the grinding wheel that puts a 45 deg (denoted in figure 3) failed sending shards of high velocity ceramic through the factory.

While no member of the MAGSEAL manufacturing team was injured during the incident, our sponsor decided that the operator, and those in the surrounding area needed to be protected during the entire operation. This included having the guard down during both the burr removal operation and the chamfering operation. In addition this would require putting a spring loaded guard on the chamfering grinder. This guard would protect the operator in the event of the failure of this chamfering wheel, along with protecting the back side of the hand of the operator from accidentally slipping and coming in contact with the chamfering wheel.

1.3.3 Changes and Updates to Problem Definition

On the team's second visit to MAGSEAL the team was informed that the project definition needed to be updated to reflect the incident described above. Requirement one was drastically changed to enhance operator safety.

Instead of forcing the inside diameter to have its sharp edge broken before the outside diameter, the device now needed to fully enclose the guard for the entire operation. Thus some new requirements became...

- The device must physically isolate the operator's hand from the sharp edge hazard, and fully encapsulate the part during the entire operation. The operator must be able to perform the process with the guard down at all times. In addition the chamfering operation that occurs after the sharp edge breaking procedure must also occur with the guard in the down position.
- The device must shut off the lathe power when disengaged.
- The device must be manually actuated by the hand which typically holds the edge breaking stone, to prevent this hand from entering the exposed hazard zone.

All other requirements were left the same.

1.4 Purpose, Scope and Objectives

The purpose of Team 22's project is to design a machine guard to protect the operator using the custom built deburring and chamfering machine, ensuring safe operation. The guard will be retrofitted onto a single machine but must also be flexible enough to be implemented on a second machine if MAGSEAL decides to do so.

The project will update the current machine to meet OSHA safety standards for machine guarding All custom designed components are required to meet all OSHA safety standards (these standards are discussed more in detail in section 12.2). This will be accomplished by designing an electromechanical guard. This guard must isolate the operator from the sharp edge hazards presented by the magnet without being able to be ignored by the operator. It must cost under $2,000 per unit, run on the available power or air supplied to the factory, and guard the entire range of parts expected to be produced and their collets. These considerations will be discussed more in detail in Section 6.

2 Project Planning and Project Management

2.1 Overview of Project Planning

Project planning and assigning responsibility for certain tasks and parts of a project is critical to the success of the project.

Before beginning the project Team 22 decided team roles of who would be responsible for what. The roles of each team member are shown in table 2.

Table 2: Team Members and Titles

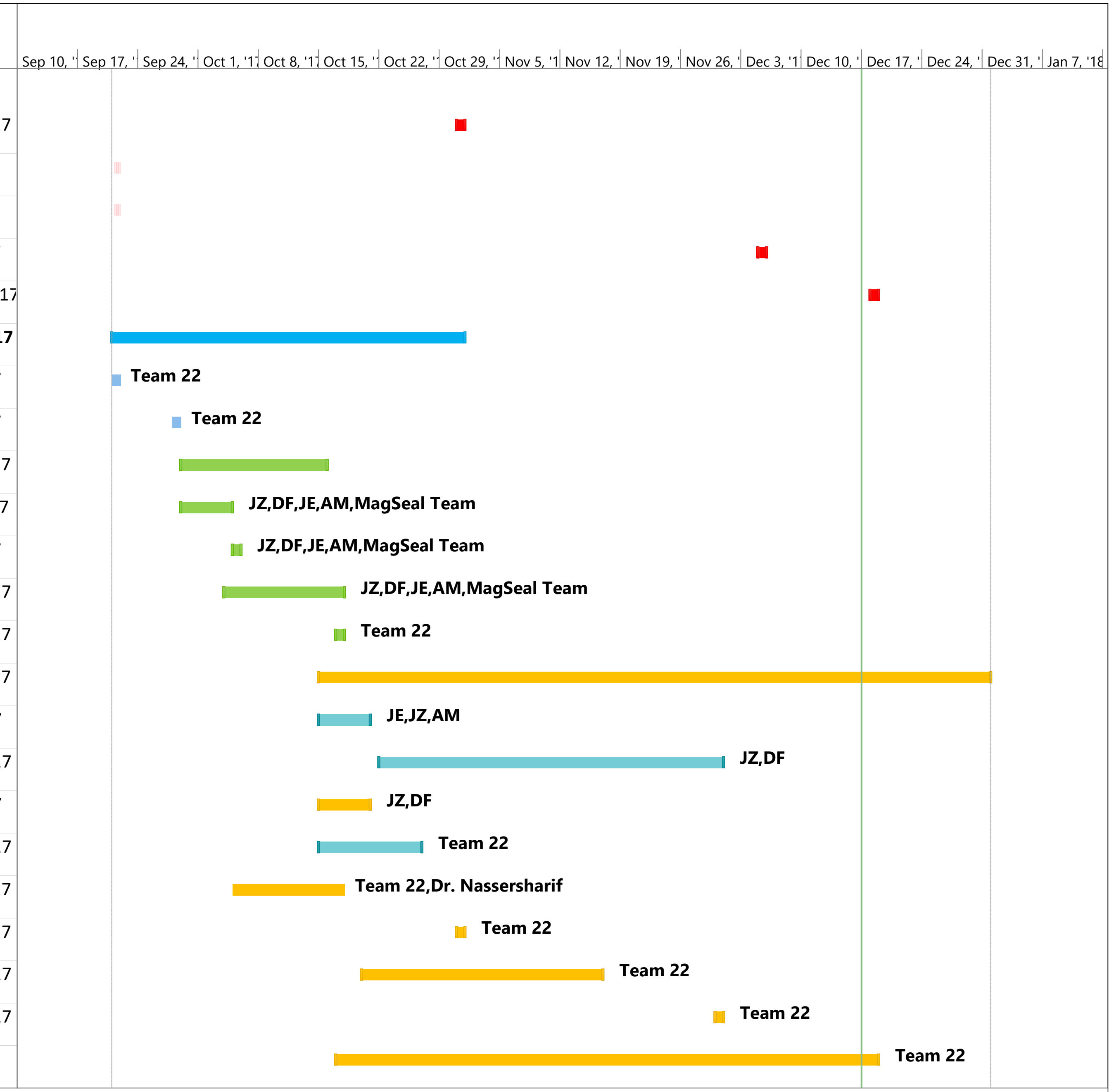
Name	**Title**	**Initials**
Jason Epstein	Design and Function Engineer	JE
Dillon Fontaine	Lead Design and Electronics Engineer	DF
Abhishek Maharjan	Design and Function Engineer	AM
Jared Zeitlin	Team Lead Engineer	JZ

2.2 Fall Semester

2.2.1 Fall Semester Gantt Chart

A Gantt Chart (shown in figure 7), a tool commonly used in project planning was created using Microsoft Project part of Microsoft Office 2016. The chart details all of the project tasks, deadlines, assigned team member and more. On the left side of figure 7 are details on the specific task relating to the project, while on the right side a bar denotes the dates and deadlines. The team members that were assigned to each task are shown to the right of the bar (this is is detailed in table 2). The chart made for easy organization of the project.

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Large Reports and Meetings Due Dates**			
2			CDR Presentation	1 day	Tue 10/31	Tue 10/31/17
3			Review Meeting 1	1 day		
4			Review Meeting 2	1 day		
5			Proof of Concept Presentation	1 day	Tue 12/5/	Tue 12/5/17
6			Semester Report	1 day	Mon 12/1	Mon 12/18/17
7			**Phase I Project Introduction**	**29 days**	**Thu 9/21/17**	**Tue 10/31/17**
8			Group Introduction	1 day	Thu 9/21/	Thu 9/21/17
9			MagSeal Visit	1 day	Thu 9/28/	Thu 9/28/17
10			**Phase II Preliminary Research and Development**	12 days	Fri 9/29/17	Sun 10/15/17
11			Define Problem, Understand Project Constraints	4 days	Fri 9/29/17	Wed 10/4/17
12			Review Problem and Design Constraints	1 day	Thu 10/5/17	Thu 10/5/17
13			120 Preliminary Design Concepts (30 Per Team Member)	10 days	Wed 10/4/17	Tue 10/17/17
14			Preliminary Design Concept Review	1 day	Tue 10/17/17	Tue 10/17/17
15			**Phase III Initial Revision(s) Design**	57 days	Sun 10/15/17	Sun 12/31/17
16			Preliminary CAD/CAM Development	6 days	Sun 10/15/17	Fri 10/20/17
17			Design Electronic Control Circuit	30 days	Sun 10/22/17	Thu 11/30/17
18			Preliminary 2D Drawing Development	6 days	Sun 10/15/17	Fri 10/20/17
19			Complete and Review CDR Presentatioon	10 days	Sun 10/15/17	Thu 10/26/17
20			Review Meeting 1	9 days	Thu 10/5/17	Tue 10/17/17
21			CDR Presentation	1 day	Tue 10/31/17	Tue 10/31/17
22			Review/Update CAD/CAM and Drawings for Prototyping	20 days	Fri 10/20/17	Thu 11/16/17
23			Complete Proof of Concept Presentation and Review	1 day	Thu 11/30/17	Thu 11/30/17
24			Final Report Compilation and Review	45 days	Tue 10/17/17	Mon 12/18/17



Project: MagSeal Safety Guardin
Date: Sun 12/17/17

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

Page 1

Figure 7: Gantt Chart Fall Semester

Using the project plan the team was able to stay on, and complete the tasks by the deadlines required. The team met every week to discuss project progress and the status of the tasks at hand, as well as to update the Gantt Chart.

2.2.2 Fall Semester Overview

The semester began when all capstone students attended lectures in which all twenty-five sponsors made presentations describing each project. Students then had to apply to five different projects which is how groups were chosen. This ensured that members of each project had a genuine interest in what they would be working on for the year. Members of Team 22, for example, all have previous machining experience that is crucial to understanding and finding a solution to this problem.

Upon choosing the groups the members of Team 22 decided on the team name of Avant Guard, a play on the term Avant Garde, meaning radical or unorthodox. Team members then met to discuss where each felt the direction the project should go. This was denoted as phase one on the Gantt Chart (all green bars signify phase one). This phase of the project included research into safety guarding standards including but not limited to, OSHA standards, and ASME standards related (these standards are discussed more in detail in 12).

The team then went to meet the MAGSEAL team in Warren, Rhode Island to observe the process to help fully understand the task at hand. The team toured the facility and gained knowledge about both the manufacturing processes used to produce the magnets as well as the magnetic seals themselves.

The team began to do a patent search to gain knowledge on safety guarding mechanisms that were already in use. The team found numerous patents that discussed, and demonstrated how a machine similar to the one that MAGSEAL was using could be implemented. The patents reviewed during the patent search gave valuable insight on potential solutions to the problem. This would help the team generate ideas and concepts that could potentially be implemented. (The patent search is discussed more in detail in section:4)

Design specifications were then decided upon. This included specifications on functional requirements, market identification, physical and dimensional constraints, and financial requirements. These design specifications would help evaluate potential solutions once concepts were generated by the team members.

Upon completion of the design specification documentation on October 5, 2017, the team began to generate concepts. Each team member was responsible for generating thirty different design concepts, giving the team one hundred and twenty possible design concepts to work with. This process analyzed all aspects of the machine and all parts of the project. Designs were created for numerous different parts and would assist in solving the problems and accomplishing all goals of the project. These ideas would later be analyzed to determine both the positive and negative benefits of each design.

The team then met to discuss the design concepts that were generated. Five unique possible design concepts were generated from the original one hundred and twenty. These five concepts combined the ideas from many of the different generated concepts and would undergo further study and analysis.

The team then began to work on the quality function deployment analysis (QFD). This would analyze which of the five concepts best met the criteria of the design specifications (section 6)

On October 10, 2017 the team met with Dr. Nassersharif for feedback and guidance on the project. Dr. Nassersharif shared his opinions on the project plan and gave some insight into what to expect for the critical design review (CDR). The team then prepared the CDR presentation, keeping in mind the suggestions given by Dr. Nassersharif.

The team then gave its CDR presentation to the class, and following the presentation received feedback on the design and utilized concepts. The CDR was considered a critical milestone in the project as it gave the team insight into what other engineers thought about the project and the solutions presented. Using the feedback the team implemented some of the suggestions made to further improve the design.

In mid-November the team went to visit the MAGSEAL team again in Warren, Rhode Island. At this meeting MAGSEAL informed the team of new developments on the project. These developments would have an impact on the design and is discussed in section 6. These updates were due to an incident that had occurred at the plant a day before the team visited. This change would enhance the safety features of the guard.

Team 22 then went back to work redesigning the components to meet the new problem definition and design specifications. The team took the updated design specifications and developed a computer automated design (CAD) using SolidWorks. The team worked rigorously up to the Thanksgiving break on the model in order to prepare it for 3D printing immediately after the break. The CAD model would allow for the team to have a bill of materials, as well as renderings ready for the presentation.

While continuously working on the guard the team prepared for its proof of concept presentation (POC). The team did more research into OSHA standards relating to both the electrical and mechanical components of the guard. In addition the team conducted materials research to gain a better understanding on the best material to produce certain parts with. The team did more work to fully grasp the financial aspects of the project and the possible potential to retrofit a second machine with the same system.

Concurrently occurring during presentations was the development of a prototype of the system. This involved building a prototype of the guard for the presentation. On Friday December 1, the team attempted to print all the pieces of the prototype model. The print was set to run for 62 hours and produce all pieces (see acknowledgement:22.2). The printer had an issue and failed causing the team not to have the prototype ready for the POC. The team then re-printed all the pieces later in the week to have a 3D printed mock-up of the design.

The team gave its POC on December 5th to the other engineering students in the capstone class. Just as with the CDR the team received feedback from the other engineers in the class. These changes were taken into consideration for future modifications.

Upon the conclusion of the POC, the last thing to be completed before the end of the semester was the final design report, along with organizing all digital files and references, and adding print-outs to the design binder.

The team remained on schedule for the entire semester despite the two setbacks of the design change, and the failed 3D print.

2.3 Spring Semester

2.3.1 Spring Semester Gantt Chart

ID	Task Name	Duration	Start	Finish
1	**Phase IV Prototype Build**	**16**	**Wed 1/24/18**	**Wed 2/14/18**
2	Orientation Spring	1 day	Wed 1/24/18	Wed 1/24/18
3	Team Meeting:	1 day	Wed 1/24/18	Wed 1/24/18
4	Completion of 3D	7 days	Fri 1/26/18	Mon 2/5/18
5	Meeting: Dr. Nassersharif	1 day	Fri 2/2/18	Fri 2/2/18
6	Prototype Assembly	1 day	Wed 2/7/18	Wed 2/7/18
7	MagSeal Visit 3:	1 day	Wed 2/14/18	Wed 2/14/18
8	Team Meeting 2	16 days	Fri 2/16/18	Fri 3/9/18
9	**Phase V Redesign to**	**26**	**Wed 2/14/18**	**Wed 3/21/18**
10	CAD Updates	13 days	Wed 2/14/18	Fri 3/2/18
11	Drawing Final Revisions	17 days	Tue 2/27/18	Wed 3/21/18
12	**Phase VI Guard**	**13**	**Wed 3/21/18**	**Fri 4/6/18**
13	Spring Break	7 days	Sun 3/11/18	Sun 3/18/18
14	Machining	11 days	Wed 3/21/18	Wed 4/4/18
15	Welding and Assembly	3 days	Wed 4/4/18	Fri 4/6/18
16	**Phase VII Testing**	**11 days**	**Fri 4/6/18**	**Fri 4/20/18**
17	Test 1 - 4	6 days	Fri 3/30/18	Fri 4/6/18
18	Test 5 - 9	1 day	Fri 4/6/18	Fri 4/6/18
19	Test 10 - 14	5 days	Mon 4/9/18	Fri 4/13/18
20	Test 15 - 17	1 day	Fri 4/6/18	Fri 4/6/18
21	Test Presentation	1 day	Wed 4/11/18	Wed 4/11/18
22	Brochure Work	10 days	Wed 4/11/18	Tue 4/24/18
23	Poster Work	10 days	Wed 4/11/18	Tue 4/24/18
24	Design Showcase Final	1 day	Wed 4/25/18	Wed 4/25/18
25	**Phase VIII Semester**	**5 days**	**Tue 5/1/18**	**Mon 5/7/18**
26	Dr. Nassersharif Team	1 day	Wed 4/25/18	Wed 4/25/18
27	Design Showcase	1 day	Fri 4/27/18	Fri 4/27/18
28	MagSeal Visit 5: Testing	1 day	Wed 5/2/18	Wed 5/2/18
29	Final Report Writing	8 days	Thu 4/26/18	Mon 5/7/18
30	Final Report Due	1 day	Mon 5/7/18	Mon 5/7/18
31	Final Magseal Visit and	1 day	Fri 5/11/18	Fri 5/11/18

Figure 8: Gantt Chart Spring Semester

2.3.2 Spring Semester Overview

The spring semester began after team 22 returned from winter break in mid January of 2018. The team had its fair share of work ahead of it as prior to leaving on break MAGSEAL updated the problem definition (see section 1.3.2).

Upon returning to the University of Rhode Island Schneider Electric facility, Team 22 held a meeting. In this meeting the team reorganized and prepared for the semester ahead. The team put together a plan on how, and which team member/asset would be responsible for what during the spring semester. Again using Microsoft Project, Team 22 created a project plan for the semester. This would insure that all deadlines, delivery dates and assignments would be completed on schedule and all targets would be met. The resulting project plan is shown in the Gantt chart on the previous page.

After reconvening and getting organized for the upcoming semester, team 22 then immediately got to work to update the CAD models and drawings in preparation of prototyping any additional parts that would be needed. The team understood early on that the prototype would be key when it came to ensuring that all project requirements were met, along with allowing for the team do multiple activities including but not limiting to testing, and procurement of parts.

On Friday February 7, the team met with Dr. Nassersharif for a third time for additional feedback and guidance relating to the updated problem definition, CAD work along with other logistical details. The team welcomed the feedback given by Dr. Nassersharif and was given the green light to go proceed with manufacturing the additional pieces required for the prototype.

The team prepared all files for 3D printing, planning to print the additional components on Monday, February 12, 2018. The team ran all of the parts through Materialise Magics STL repair software prior to printing then performed the necessary splicing. Upon verification of all details the team set the printer to run all parts at once just as it had done for the prior parts. After 46 hours of printing all parts necessary to complete the prototype were finished.

Concurrently occurring during the printing the team updated the bill of materials to include all the additional parts required for the construction of the project. The team then decided to procure all of the hardware needed for the project. This was done to allow for the prototype to be fully assembled and be functional allowing for testing to occur. On Friday February 16, the team placed its first of four order forms with Dr. Nassersharif. This order form included all hardware needed for the assembling of the guard and was sourced through McMaster-Carr.

Also occurring at this time members Team 22 also focused on developing a comprehensive test matrix for the safety guarding device. This matrix would eventually aid the team in developing a plan to perform all testing. This document would later be critical to the team when it came to testing.

Upon receiving parts from McMaster-Carr, the team worked together to assemble the prototype. The team then setup a meeting with representatives from MAGSEAL to visit and test the guard. In addition the test matrix was finalized in preparation of a visit to the MAGSEAL facility.

During this time the team prepared to manufacture the guard out of metallic components. The team sat down with all the drawings and put together the list of necessary off the shelf materials needed to machine the guard. After compiling all the necessary pieces into a capstone order form the team completed the order by sending it to Dr. Nassersharif.

In early March the team went to Warren, Rhode Island to visit MAGSEAL. During this visit the team had planned to fit the prototype to the machine, and begin the testing phase of the project though mother nature had other plans. Due to a violent Nor'easter, the power at the MAGSEAL facility went out preventing the team from performing the testing that they had planned. Although the team was not able to complete all objectives of the visit, it got extremely positive feedback from the MAGSEAL team and the machine operators.

During conversations with MAGSEAL, team 22 realized that some design modifications would be needed in order to meet all design specifications. A main concern was the position of the knob on the guard. The team made two realizations: the first was that if it was not in a comfortable position the operator would go to whatever length needed not to use the guard, and the second and more important realization was that the current location put the operators hand severely close to other hazards. Team 22 agreed with MAGSEAL and updated the CAD along with mechanical drawings to reflect the necessary changes.

It was also during this meeting that MAGSEAL offered to assist the team in the machining of the polycarbonate guarding panes. The team needed MAGSEAL's CNC vertical milling machine as the pane was to complex to complete through available machining methods at the Universtiy of Rhode Island machine shop.

A few days after the team visited MAGSEAL all the necessary components arrived needed to begin the fabrication of parts for the final revision of the guard. The team planned to begin all necessary machining operations upon return from spring break.

The team began the machining of the guard parts the week of March 19th. Beginning with the steel frame each piece was carefully marked, rough cut then milled to the specifications listed in the teams mechanical drawings. After almost 30 hours of machining and assembly, the guard was ready to begin the testing phase of the project.

Testing began just after machining when all parts were verified to meet the specifications listed on the mechanical drawings. These dimensions were inspected in accordance with the team's test matrix (shown in section: 14). Numerous dimensions were verified using calipers, visual inspection and the coordinate measuring machine.

The team then put the final details on its test report plan. This plan outlined all of the testing to be performed on the guard and is discussed more in detail in the testing section (section: 14). With all necessary work complete regarding the test plan the team could then go about performing all testing and building a test presentation.

The team gave its testing presentation on April 4th. Upon giving the presentation team 22 looked ahead to work that would need to be done before the end of the semester. This included developing a poster, brochure, and other project deliverables necessary to complete the project.

In mid-April, the team traveled again to the MAGSEAL facility in Warren, Rhode Island to perform the installation of the guarding mechanism. It was during this visit that the team would begin the testing the functionality of the guard. The testing performed at the facility would mainly focus on ergonomics, functionality and the durability of the guard. These tests would ensure that team 22 met all requirements of the project as well as ensure the sustainability of the guard over long periods of time.

At the end of April team 22 partook in the Capstone Design Showcase. It was here that the team showed off its efforts throughout the semester to the public and other teams. The team had over thirty people from the engineering community visit its booth and give praise to the project. Some believed that there were additional applications for the guard.

At the beginning of May the team prepared to wrap up the report. It met one final time with Dr. Nassersharif to ensure that it would meet all requirements of the project. In addition the team reviewed results of testing. The team finalized all documentation needed to write its final report.

The first week of May was a bitter sweet moment for team 22 as the project would begin to draw to a close. It began writing its final report for a submission date of May 7, 2018.

The entire duration of the project taught the members many valuable skills in the field of design engineering including but not limited to...

- Developing problem definitions
- Project Planning to meet deadlines and perform necessary tasks
- Revision and document control
- Researching potential existing off the shelf solutions
- Performing financial analysis and returns on investments
- Performing competitive analysis along with design specifications
- Creating CAD models and drawings for production parts
- Perform real world engineering analysis pertaining to standards
- Develop test plans and reports
- Take CAD designs through the manufacturing process
- Work in a professional environment and manner

These lessons learned over the 2017-2018 academic year throughout the duration of this project will assist the engineers of team 22 throughout their entire careers.

2.4 Document Organization

The team realized early on that having all documents organized would be vital to the project going forward. This was found to be especially vital when it came to CAD models as well as drawings. To insure organization of CAD drawings and files a part numbering system, and a drawing number system was instituted. All parts were assigned a 220XX, and all drawings were given a MSAG-00XX number. (all part, and document numbers are shown in section 11.1)

These were programmed into SolidWorks using the custom properties and custom sheet format feature to allow for files to be easily revised and saved.

2.5 Revision Control

As with all engineering projects document and revision control are extremely important. Team 22 realized that being able to go back to old designs and drawings would be critical. To allow for this the team instituted a basic revision system. All revisions that were made prior to the manufacturing of the guard had a PRE.XX number, while all of those that occurred after the machining of the guard had a revision number starting with an A. When a part was ready for manufacturing it was assigned the revision number of A.01. Every time a revision to a part was made it was saved with a name containing that revision. This allowed for the team to easily return to previous revisions.

Team member logbooks to keep notes proved vital to the project. The notes of each design in engineering logbooks allowed Team 22 to easily keep track of design modifications and clearly see the path of development of the product.

Through the use of document and revision control team 22 was able to stay organized throughout the entire project.

3 Financial and Cost Analysis

3.1 Funding and Budget

MAGSEAL provided the team with financial support for the development of the machine guard. The budget for the fabrication, production and installation of the guarding solution was set at $2000.00. MAGSEAL also expressed that safety is above all the most important aspect to the project, as adding a guard to the machine would cause a substantial decrease in risk of injury to the operator, and could potentially in the future remove the potential expense of workman's compensation due to injury to an operator, or in the event of fatal injury possible litigation against the corporation.

3.2 Development Costs

3.2.1 Human Resources Allocation and Labor Costs

Over the course of the 2017-2018 academic year, members of Team 22 spent many hours working on the project and developing the guard. These tasks including everything from CAD development, financial, engineering and competitive analysis, visits to MAGSEAL's facility in Warren Rhode Island, presentations and reports. Table 18 (in the appendix) was used to generate the chart shown below. This chart details how many hours each team member spent on different tasks and components of the project. This data was compiled from Team 22's weekly progress reports.

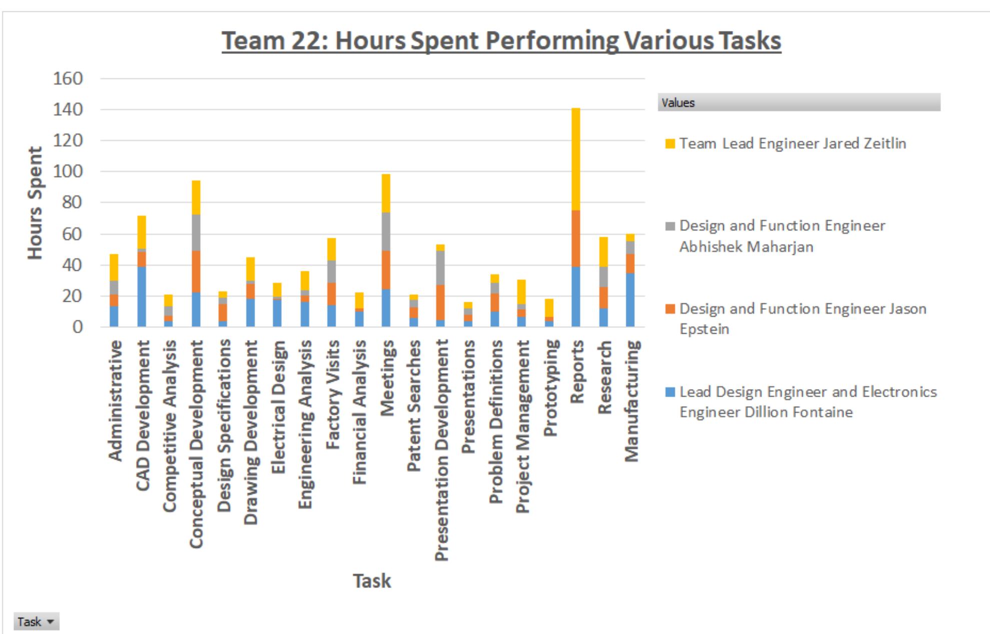


Figure 9: Team 22 Human Resource Allocation (see Table 18)

Team 22 also received helpful advice from members of the MAGSEAL Team, along with Dr. Nassersharif. These consultants provided the team with vital insight and knowledge on the project. The figure below shows data taken from a pivot table of the breakdown of the various tasks done by these consultants (Figure 10).

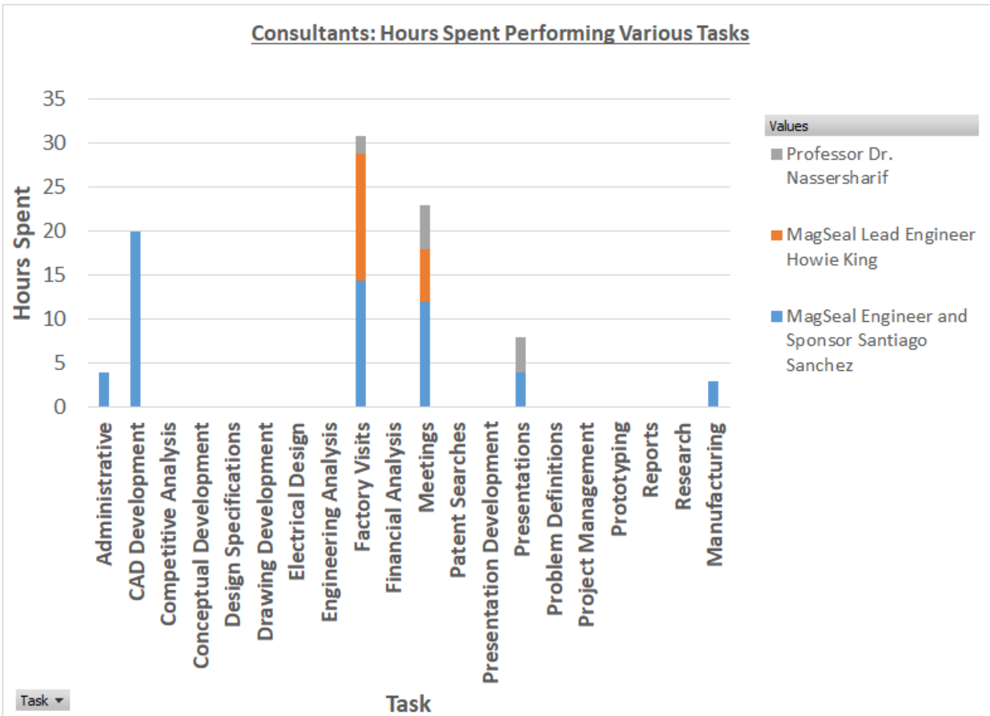


Figure 10: Team 22 Human Resource Allocation (see Table 19)

The team spent a total of 1035.1 hours working on the project throughout the academic year. A break down of how this time was spent is shown in the pie chart below (Figure 11).

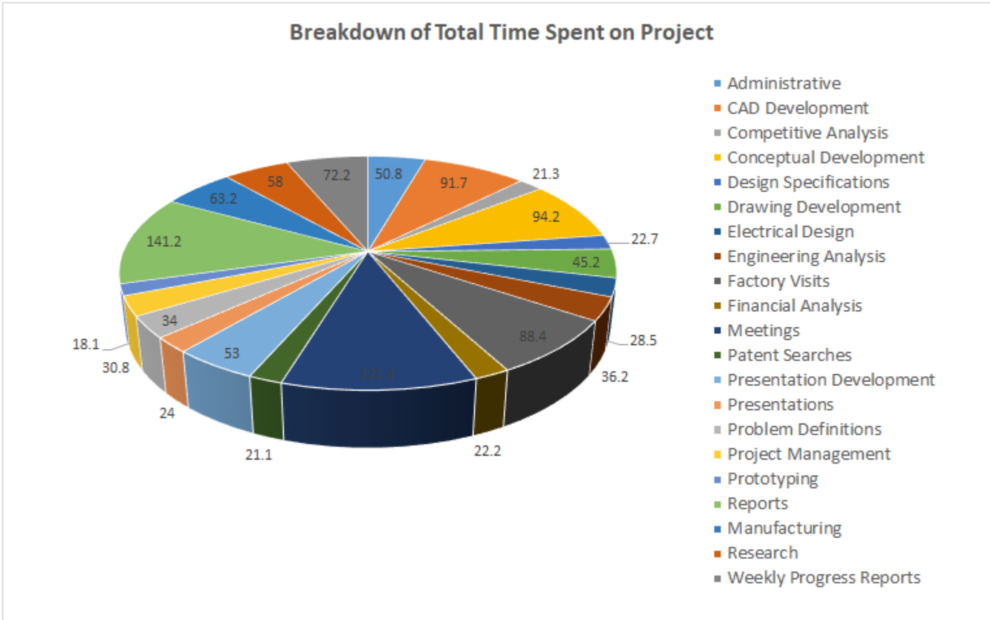


Figure 11: Team 22 Breakdown of How Time was Spent Throughout the Fall Semester

Upon knowing the hours labor costs can then be calculated. A cost for the time for an hour of each team member was calculated using the average entry level salary of a safety engineer. According to Glassdoor (Glassdoor [11]), the average starting salary for an entry level engineer is approximately $\$75,732$ a year. To find the hourly rate, the team then used the US government Office of Project Management to figure out how many hours the average safety engineer works a year. (US Government Office of Project Management [[12]]).This was found to be 2,087 hours annually. This factors in vacation and sick days as well as holidays. Knowing these two values a per hour rate was calculated to be $36.41.

The rate for the consultants to Team 22 was then researched. The team decided to use a rate of $80.00 per hour of consulting time (Consultant Journal [13])

The table (see below left 3) breaks down the labor cost for each individual member of Team 22 while the table on the right (table: 4) shows the consultant labor costs.

Engineer	Hourly Cost	Total Cost
Dillion Fontaine	$36.41	$11,174.23
Jason Epstein		$8,884.04
Abhishek Maharjan		$5,858.37
Jared Zeitlin		$10,748.23
	Totals	$36,664.87

Table 3: Team 22 Labor Costs

Consultant	Hourly Cost	Total Cost
Santiago Sanchez	$80.00	$4,080.00
Howie Kind		$1,680.00
Dr. Nassersharif		$600.00
	Totals	$6,360.00

Table 4: Consultant Labor Costs

Adding up the total labor costs for both the members of Team 22 as well as the consultants, labor for the project for the entire project cost $\$57,367.99$.

A break down of the total labor costs is shown in the pie chart below (figure 12).

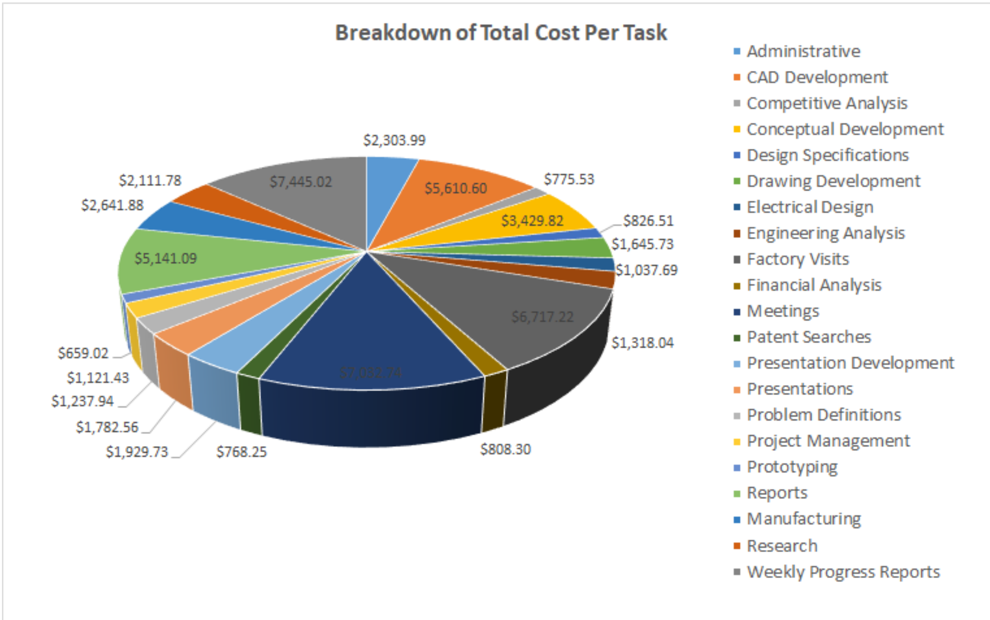


Figure 12: Cost Per Task Break Down

3.2.2 Prototype Cost

A cost analysis was performed on the 3D printed prototype. Due to complications during printing, the prototype needed to be reprinted twice. Due to this approximately 872.1 grams of filament (this is equivalent to 287.793 meters of filament) (Consumables For 3D Printers By 3D Printers [6]) was used The material used for the prototype was PolyMax PolyMaker Grey. This filament costs $49.99 per kilogram spool of filament (PolyMaker [14]). This made the total cost of material be $85.78. The rate for the machine was set to be $1.65 an hour (Kruno Knezic [15]). All costs associated with the production of the 3D printed prototyped model are shown below in table 5.

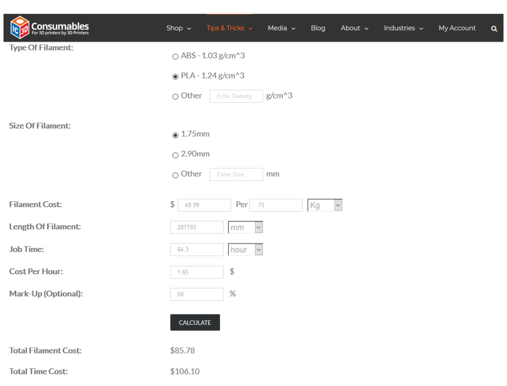


Figure 13: 3D Printing Cost Calculator (Consumables For 3D Printers By 3D Printers [6])

Expense	Total Cost
PolyMax Grey PLA Filament	$171.56
Total Machine Time Cost	$212.20
Loctite Super Glue	$4.19
Totals	$387.95

Table 5: 3D Printing Costs

3.2.3 Initial Build Cost

The team needed to deliver to MAGSEAL a fully functional guard by the end of the Spring 2018 semester.

To meet this project requirement and install the safety device on the first machine the team needed to perform the necessary sourcing to acquire hardware, raw materials that could be used in the milling operation, electrical components, and tools. All components were purchased through either The Mc-Master Carr Corporation or through Digi-Key.

To purchase the necessary parts the team filed order forms with the Mechanical Engineering Department of the University of Rhode Island. Table 20 located in the appendix shows all the parts procured by the team throughout the entire course of the project.

Shown below is a summary of the total costs needed to procure different costs center's of the project.

Cost Breakdown of Order Forms	
Category	**Cost**
Raw Materials	$262.74
Hardware	$146.07
Tools	$58.59
Electrical	$221.30
Total	$688.70

Table 6: Overview of Types of Parts Ordered to Complete Project

3.2.4 Other Overhead Costs

The cost for engineering software must also be factored in when looking at the costs of the project. The costs for the software used by the team is shown in the table below.

Software	Cost Per License	Licenses Needed	Total Cost
SolidWorks 2017	$3,995.00	2	$7,990.00
SolidWorks Simulation	$4,570.00	1	$4,570.00
Microsoft Office 365	$33.00	4	$132.00
Microsoft Project 2016	$539.00	2	$1,078.00
Microsoft Visio 2016	$299.99	1	$299.99
MultiSim 13	$3,024.00	1	$3,024.00
		Total Software Costs	$17,093.99

Table 7: Software costs for project developments

3.3 Mass Production Cost

A mass-production analysis was performed which accounted for the cost of machining and assembly of every part in the machine guard. Extensive machining experience, both in industry and out, enabled the group to estimate machining operations and their times. Data for the unit cost of labor was calculated using the mean hourly rate for the type of labor specified. Rates were based on 2016 data from the US Bureau of Labor and Statistics for machinists [22], welders [23], and general fabricators or assemblers [24]. The cost breakdown follows below.

[1]SolidWorks 2017 License Cost (Cati [16])

[2]SolidWorks Simulation 2017 License Cost (Cati [17])

[3]Microsoft Office 365 License Cost **this is per month for four months for four group members (Microsoft [18])

[4]Microsoft Project 2017 License Cost (Amazon [19])

[5]Mutisim 13 License Cost (National Instruments [20])

[6]Microsoft Visio 2016 (Microsoft [21])

Table 8: Mass-machining Cost Breakdown 1 of 2

Part Number:	Operation:	Man-minutes / Operation-Unit:	Cost per man-minute:	Total Cost / Operation-Unit:	Total Cost / Part:
MSAG22-0001	Rough Cutting	5	$ 0.346	$ 1.73	$ 10.38
	Squaring, edge finishing	10	$ 0.346	$ 3.46	
	Countouring, beveling	10	$ 0.346	$ 3.46	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0002	Rough Shearing	5	$ 0.346	$ 1.73	$ 19.03
	Edge radiusing	10	$ 0.346	$ 3.46	
	Corner releiving, contouring	20	$ 0.346	$ 6.92	
	Hole series	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0003	Rough cutting	5	$ 0.346	$ 1.73	$ 22.49
	Finish Milling	20	$ 0.346	$ 6.92	
	Side Beveling	20	$ 0.346	$ 6.92	
	Hole series	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0004	Rough cutting	5	$ 0.346	$ 1.73	$ 22.49
	Finish Milling	20	$ 0.346	$ 6.92	
	Side Beveling	20	$ 0.346	$ 6.92	
	Hole series	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0005	Rough cutting	5	$ 0.346	$ 1.73	$ 22.49
	Finish Milling	20	$ 0.346	$ 6.92	
	Side Beveling	20	$ 0.346	$ 6.92	
	Hole series	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0006	Rough Cutting	5	$ 0.346	$ 1.73	$ 25.95
	Finish Milling	20	$ 0.346	$ 6.92	
	Chamfering	15	$ 0.346	$ 5.19	
	Hole series	15	$ 0.346	$ 5.19	
	Hole Coring, Finish Reaming	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0007	Rough Cutting	5	$ 0.346	$ 1.73	$ 27.68
	Finish Milling	20	$ 0.346	$ 6.92	
	Chamfering, Radiusing	25	$ 0.346	$ 8.65	
	Hole series	15	$ 0.346	$ 5.19	
	Slotting	10	$ 0.346	$ 3.46	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0008	Rough Cutting	5	$ 0.346	$ 1.73	$ 25.95
	Finish Milling	20	$ 0.346	$ 6.92	
	Chamfering	15	$ 0.346	$ 5.19	
	Hole series	15	$ 0.346	$ 5.19	
	Hole Coring, Finish Reaming	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	

Table 9: Mass-machining Cost Breakdown 2 of 2

MSAG22-0014	Rough Shearing	5	$ 0.346	$ 1.73	$ 8.65
	Contouring	10	$ 0.346	$ 3.46	
	Drilling	5	$ 0.346	$ 1.73	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0015	Rough Shearing	5	$ 0.346	$ 1.73	$ 16.31
	Countouring	15	$ 0.346	$ 5.19	
	Drilling	15	$ 0.346	$ 5.19	
	Bending, Fitting	10	$ 0.247	$ 2.47	
	Corner releiving, radiusing	5	$ 0.346	$ 1.73	
MSAG22-0016	Rough Cutting	5	$ 0.346	$ 1.73	$ 20.76
	Finish Milling	10	$ 0.346	$ 3.46	
	Slotting	20	$ 0.346	$ 6.92	
	Drilling & Tapping	20	$ 0.346	$ 6.92	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0019	Rouch Cutting	5	$ 0.346	$ 1.73	$ 3.46
	Finish Turning	5	$ 0.346	$ 1.73	
MSAG22-0023	Rough Cutting	5	$ 0.346	$ 1.73	$ 17.30
	Finish Milling	10	$ 0.346	$ 3.46	
	Slotting	10	$ 0.346	$ 3.46	
	Chamfering	10	$ 0.346	$ 3.46	
	Hole Series	10	$ 0.346	$ 3.46	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0024	Rough Cutting	5	$ 0.346	$ 1.73	$ 10.38
	Finish Milling	10	$ 0.346	$ 3.46	
	Slotting	5	$ 0.346	$ 1.73	
	Hole Series	5	$ 0.346	$ 1.73	
	Final edge break	5	$ 0.346	$ 1.73	
MSAG22-0025	Rough Cutting	5	$ 0.346	$ 1.73	$ 15.57
	Finish Milling	10	$ 0.346	$ 3.46	
	Slotting	10	$ 0.346	$ 3.46	
	Hole Series	15	$ 0.346	$ 5.19	
	Final edge break	5	$ 0.346	$ 1.73	
FINAL ASSEMBLY	Alignment	5	$ 0.247	$ 1.24	$ 13.37
	Welding	15	$ 0.315	$ 4.73	
	Weld Grinding	10	$ 0.247	$ 2.47	
	Fastening	10	$ 0.247	$ 2.47	
	Inspection	10	$ 0.247	$ 2.47	
				Grand Total Cost / Unit:	**$ 282.26**

As can be seen from this table, the total per-unit cost for mass production is approximately \$282.26. This does not take into account the typical 25% markup associated with most industrial machine shops, nor does it include additional costs for painting and other finishing requirements. These are as yet undecided and thus not within the scope of this analysis. This breakdown also assumes that each operation requires only one operator at a time, which, in the group's experience, is reasonable for most light machining and fabrication operations.

In summary, team 22 spent approximately \$75,375.92 to develo and produce the final product.

The two pie charts shown below break down the cost centers that make up these total costs. The chart used to make the pie charts is table 21 in the appendix.

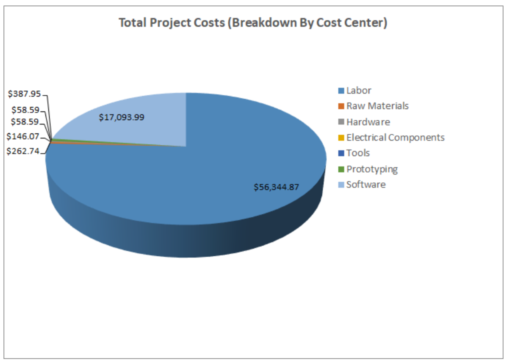


Figure 14: Total Cost Breakdown (in Dollars)

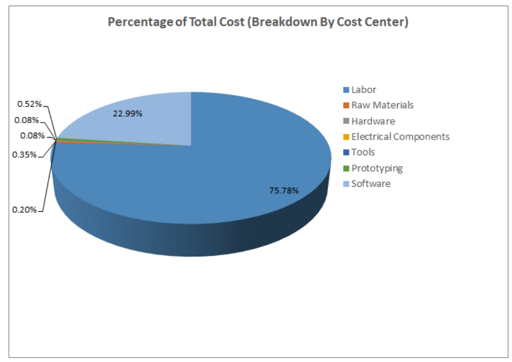


Figure 15: Total Cost Breakdown (Percentages)

3.4 Return on Investment

Risk assessment and reduction plays a large role when performing a return on investment (ROI) study on machine safety programs. Machine safety guarding projects are typically comprised of risk analysis, risk mitigation measures, and training on work procedures that advance the safety of the task being performed by the operator.

Risk assessment must be done to analyze the potential benefits of retrofitting the machine and calculating the ROI on adding a safety guard. During the deburring operation the operator places his hands extremely close to a sharp part that is rotating at a high rate of speed. If the part are to slip off the collet, or the operator were to slip with the stone while performing the operation there is a chance of serious injury.

When looking at mitigating risks the following questions must be asked to help determine whether the machine will produce an ROI (Rockwell Automation [25])...

1. If we buy or modify this machine, or the process what are the existing risks and what new risks are created?

   In the case of guarding the de-burring and chamfering machine, the potential added risks could be ergonomic. The potential ergonomic issues could arise due to the placement of the guard, and the action the operator has to take to lower the guard to the position required to perform the operation.

2. How do we mitigate these risks?

   In Team 22's case these ergonomic risks are rather simple to mitigate. There are a few possible ways...

   (a) Move the handle that is used to move the guard into place to a position that gives the operator the most comfort while performing the operation.

   (b) Institute a device that is automated that allows for the operator to move the guard in place via an electrical relay, or a mechanical device.

3. Could safety/risks compromise or reduce the operational efficiency gained by the new equipment or process? If so what corrective actions are appropriate?

   The cycle time added to this process by the guard is deemed negligible. This is due to the guard only needing to be cycled twice during the operation to de-burr a single magnet (at the beginning and at the end of the operation for each side of the magnet). As the operator is forced to turn the power off to the machine by throwing a switch when flipping the part, adding the guard does not add time to the process.

4. Are the existing safeguards applied in a way that provides an appropriate level of risk reduction while optimizing production efficiency?

   There are currently no safeguards in place to protect the operator from injury. Therefore the operator is at risk of serious injury.

5. If purchasing a new piece of equipment is the safety system consistent with the existing equipment within the facility?

   As the machine used during the operation is unique as there is only one of them in existence, a somewhat custom solution is needed to make the operation safe to the operator. Team 22 will follow OSHA standards, and the guidance of MAGSEAL to insure that the guarding solution either meets or exceeds the specifications detailed.

Many times machine safety programs are instituted as a result of an injury on a piece of equipment versus instituting safety equipment to begin with. This is done to eliminate any further injuries that could potentially occur due to improper machine guarding.

One way to look at the ROI on any safety related project is to look at the costs that occur due to injury. These costs include, workers compensation claims, the increase in insurance premiums, and in the most severe cases potential litigation against a corporation due to permanent injury. While these costs are hard to estimate before an injury occurs, they add up quick and can be well in excess of the cost of installing a safety device.

To examine this further MAGSEAL Corporation could analyze the claim frequency due to injuries that occurred using this machine. One such injury has occurred during the last six months of operating the machine. While team 22 does not know the extent of the costs incurred by MAGSEAL due to this injury to the operator (due to confidentiality on medical expenses) the team could assume that had the guard been on the machine it would have immediate return on investment had that injury been prevented.

Another angle that an ROI can be done on this safety guarding device is looking at the potential manufacturing time lost due to operator injury. As the machine has one main operator, an injury to MAGSEAL would cause financial loss as they would have to halt the process until the operator recovered from injury. Everyday that there is injury there is money instantly lost. Therefore any device that prevents operator injury pays for itself at the first "near miss" (OSHA defines this as an incident which occurs that an injury was prevented due to the safety guarding device).

We can add this in to the cost of the injury discussed before. The operator was out for a month of time. During that month MAGSEAL was without an operator to perform the process. Since MAGSEAL uses the machine on a large percentage of its magnets, the conclusion can be made that there was a loss incurred since magnetic seals could not be fully assembled during this time.

In summary while the safety guarding device will have a return on investment, it is extremely difficult to calculate an exact dollar amount or after what time period it will pay for itself. This time period as discussed earlier will depend on whether a "near-miss" incident occurs. Upon the first "near-miss" and injury prevented due to the guard, there will be an immediate return on investment.

3.5 Financial Summary

In summary, with the initial budget for the project being $2000.00, team 22 saved approximately $1300.00 (this accounts strictly for the cost of the guard and does not take into account labor and other costs). Team 22's ability to bring the project in on time and under budget can be attributed to numerous factors including but not limited to...

- Shopping for the best price when procuring parts
- Doing all machining in house
- Using as many off the shelf parts as possible
- Avoiding the use of custom fixturing and tooling

This shows that the team is capable of producing an effective product under budget without compromising safety and reliability.

4 Literature and Patent Searches

An exhaustive patent search was conducted before concept generation to establish a familiarity with existing designs as it applies to machine guarding and operator safety. Using these patents allowed the team to gain a better understanding of design approaches that have worked in the past, which ultimately reduced frustration in the conceptualization process and resulted in overall better concepts to be brought forward. Excerpts from three of the most relevant patents follow, the rationale behind their designs being key in guiding the team's own design process.

4.1 Patent No. US6390741B1 [1]

Title: Safety Guard Assembly
Original Assignee: Ben E. Jaeger
Issue Date: July 12, 2000

Abstract:
A safety guard assembly is adapted to be conveniently moved into position between a work area and an operator station. The safety guard is characterized by a unitary transparent polymer having a planar portion and ribs that impart to the planar portion rigidity against longitudinal bending and transverse flexing. Brackets are attached to opposite sides of the guard and an associated handle and one end of an associated universal support arm are connected to each bracket. The opposite end of each universal support arm is mounted remote from the work area. The handles and universal support arms enable the guard to be quickly and conveniently moved by an operator between positions adjacent to and remote from the work area. When moved between the work area and operator station, the guard restricts, from passage to the work station, chips, broken tools, coolant, etc. as might be ejected from the work area and that could otherwise strike and injure the operator, but otherwise permits the operator to clearly view the work area there through.

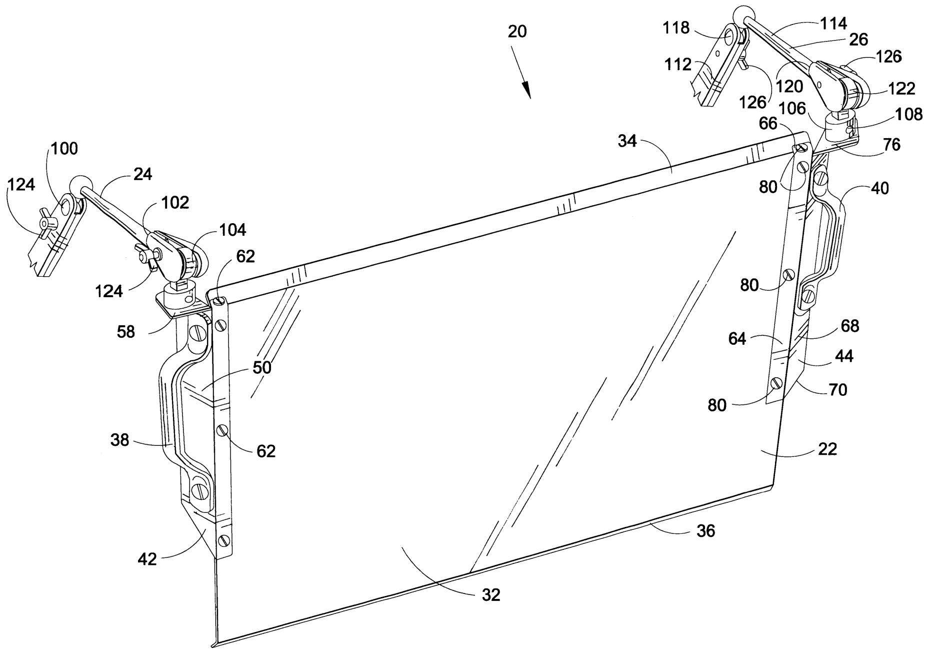


Figure 16: Representative Image for Patent No. US6390741B1 [1]

This first patent illustrates how a manipulatable screen can be used to guard a workspace. As it applies to the current problem, the screen could be limit din its motion to positions just covering and immeidately outside of the hazard area. The screen shape would obviously be changed to a shape which forces the ID to be broken first, perhaps covering the top half of the part, indicating to the operator that the inside has yet to be broken.

With this in mind, there must be a method provided that does not allow the guard to be ignored, perhaps an electrical solution which prevents the machine from being switched on when the guard is in the open position. Additionally, the articulation provided by this design is of special interest to the team because of the challenge of fitting a guard into the cramped space that surrounds the edge breaking machine. The variation in collet sizes and depths from the spindle also dictate the ability to adjust the guard, which the universal joints used in this patent provide.

Elements in this patent that are featured in the team's final design include the transparency of the pane so that the operator can still observe the work, as well as the use of a frame with handles for manipulation of the guard and support of the pane. The general philosophy of the guard protector against chips and debris is also preserved as a secondary function of the team's guard.

4.2 Patent No. US4114473A [2]

Title: Guard for Belt Pulley
Original Assignee: Henry M. Pollak
Issue Date: December 1, 1976

Abstract:
A guard is provided for installation within an endless belt extending around a pair of pulleys for preventing danger associated with the nip between the belt and pulleys without interfering with freedom of access to the belt.

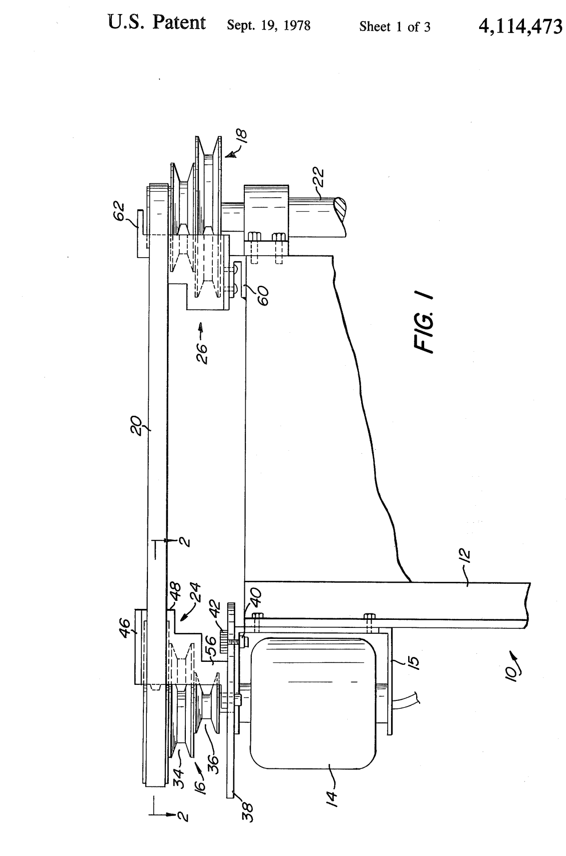


Figure 17: Representative Image for Patent No. US4114473A [2]

This design, though intended to guard the nip points on a belt assembly, has practical value to the problem at hand, mainly in that a half-round guard is used to cover certain elements of a rotating member. The general shape of the guard is very similar to early ideas presented to the team during the first plant visit. Concerning the problem at hand, a lip could be extended from the edge of this guard to cover to the center line of the lathe axis. In this way, the ID would be force to be broken, as the approach to any point of the OD would be denied by the guard being in position.

In a similar manner to the first patent, a system would need to be devised to prevent the machine from being powered on when the guard is out of position, though there is an added complication in that the edge breaking machine must be energized to allow for breaking of the OD, which thus dictates the use of logic to discern between a state when the guard is opened with the machine having already been energized and a state where it wa snot previously energized.

Though few elements from this design present themselves in the final concept, they appear numerously in the team's early concepts, with several variations of a design with mechanical and shape similarly to this one were featured in the QFD analysis. Indeed, the front runner in the QFD bore a striking resemblance to the shape of this design, though its function was novelly different.

4.3 Patent No. US5992276A [3]

Title: Safety Guard for Lathe
Original Assignee: David R. Sullivan
Issue Date: April 9, 1998

Abstract:
A safety apparatus for use in connection with motor driven machine tools such as engine lathes of the character used to dress the brake shoe and brake pad engaging surface of automobile brake drums and rotors. The safety apparatus can be quickly and easily attached to conventional brake drum/disc dressing lathes without the necessity of substantially modifying the lathes, does not interfere with the normal machining processes and yet fully protects the operator from accidentally contacting the rotating work pieces during the dressing operation. The apparatus includes novel safety switch mechanisms which positively prevent energization of a motor of the lathe using the factory installed "on-off" switch of the machine so long as the safety guard is in a raised position. Accordingly, required work piece set-up operations can be accomplished only through use of a specially wired foot switch which permits controlled, intermittent energization of the lathe motor by the operator.

U.S. Patent Nov. 30, 1999 Sheet 1 of 7 **5,992,276**

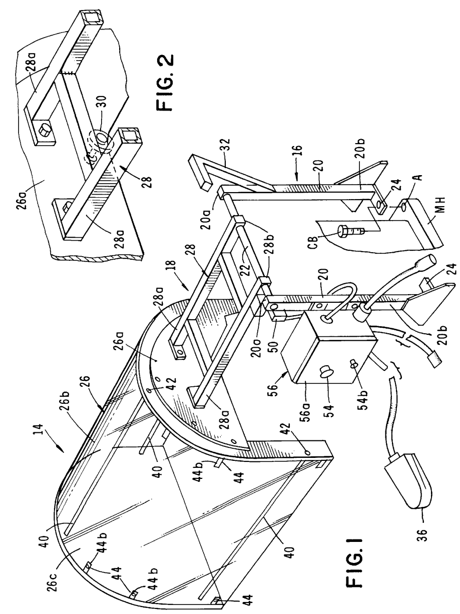


Figure 18: Representative Image for Patent No. US5992276A [3]

The third patent presented in this report has perhaps the most value to the team's problem. The device pictured is a transparent screen intended to guard the hazard area introduced by the use of a lathe for special application. In this respect, the philosophy of the two designs is identical, though the approach illustrated by this one is overall simpler than that necessitated by the team's problem. This design is concerned primarily with complete operator isolation, wherein the operator has no need to be intimately involved with the machining operation. To adapt this approach to the current situation, as the team has done, required several breaks in the enclosure for the introduction of the edge breaking stone and to allow relief for the chamfer grinding wheel.

The final guard presented by the team features a number of similarities to this design, especially with regards to the electrical wiring and safety mechanism incorporated therein. Although this feature did not translate into the final design, a foot pedal as described in the patent was considered for actuation of the guard, wherein the guard would be moved out of position only as long as the pedal was depressed. However, the mechanism by which the lathe is prevented from energizing when the guard is disengaged is a feature directly included in the final design, whereby a switch would be actuated by the opening of the guard, thus alerting an electrical system to disconnect power from the lathe motor.

5 Evaluation of the Competition

From the 120 concepts generated, it was then the group's task to choose three or four top choices for comparison via quality function deployment (QFD). Because all of Dillon's concepts concerned a device which functions as a stone holder / finger guard, the highest rated variation of this, a hybrid of ideas found in concepts 16, 24, and 30, was used as a representative of the type. From the remaining concepts, three other categories were created, a pivoting guard actuated electrically or by air, a translating guard actuated electrically or by air, and a pivoting guard manipulated entirely by hand. From these four, the team compared how well each design met the project criteria. The graphical analysis used to perform this can be found in Section 7.

As a result of this analysis, the pivoting actuated guard, originally powered by air pressure, was chosen as the base concept. However, as a result of changes to the problem definition from sponsor input, this design was modified to exclude actuation of any kind and possess a simplified electronic component. The final design aligns very well with the manually activated pivoting guard as described in the QFD, whose merits can be plainly seen therein.

6 Design Specifications

6.1 Original Design Specifications

The original design specification includes requirements divided into a number of different sections. This is a living document, updated by the team from time to time in accordance with new input from the sponsors and an evolving understanding of the problem definition.

Product Identification Following is a listing of baseline information for the identification of the team's project among others of the type.

- Product name: Electro-mechanical Deburring Safety Guard
- Permanent installation to edge-breaking machine
- For use in shop environment, 12-hour maximum up-time per day, maximum of 6 days per week

Market Identification Following is information relating to the target market for this device.

- MAGSEAL Corp., specific to their deburring machines, 5C collet lathe with up to 5.00 inch diameter step chuck
- Maximum of two units in foreseeable future

Key Project Deadlines Some key deadlines are shown below.

- End-of-Project no later than May 1, 2018 (tentative)
- Critical Design Review: Tue October 31, 2017
- Proof of Concept: Tue December 5, 2017
- End-of-semester Report: Mon December 18, 2017

Functional Requirements Following are a listing of functional requirements for this device.

- Must prevent the OD from being deburred before the ID
- Cannot be ignored by the operator / integral to the process
- Cannot increase routing time
- Provides a physical barrier to the sharp rotating OD when approached from the top
- Cannot disturb intimate contact between operator/deburring stone/part

- Cannot limit operator range of motion to where he cannot produce a radius from ID to face and OD to face

Physical Description / Constraints Following are the physical constraints for the guard.

- Must accommodate parts up to 5.00 inch in diameter, 0.50 inch thick
- Must be contained on far side of operator when disengaged
- Must envelope the upper half of center of parts down to 0.50 inches in diameter when engaged
- Must clear an automated grinding process which occurs on the far side of the part OD when disengaged (unhindered horizontal traverse at centerline by a 5.00 inch diameter grinding wheel)
- Must allow part to be removed from machine with minimum of 0.25 inch clearance all around when disengaged
- Must accommodate deburring stones up to 0.50 x 0.50 inches, 6.00 inches long
- Actuating mechanism must be powered by either 120V, single phase power or shop air at pressures down to 120psi
- Must be able to operate in the presence of abrasive dust

Financial Requirements Following are items related to the budget and other financial considerations.

- Maximum cost of $2,000.00 per unit
- Cost of maintenance not to exceed $50.00 per year
- Cannot incur any per-product costs (due to slower cycling)

Life Cycle Targets Following are items related to the product life cycle, including end of life requirements.

- Useful life no less than the lifetime of the base machine
- Shelf life is indefinite
- Requires maintenance no more frequent than twice per year, no less than once per year
- Reliability of five years for critical relays / switches and actuator seals
- End-of-life strategy: worn out components to be recycled as e-waste or scrapped

Numerical Constraints Numerical constraints are as follows and are self-explanatory.

Table 10: Numerical Project Requirements

Parameter:	Value / Limits:	Units:
Minimum Accepted Part Envelope:	Ø 0.50 x Ø 0.313 x 0.25	Inch
Maximum Accepted Part Envelope:	Ø 5.00 x Ø 4.50 x 0.50	Inch
Grinding Wheel Nominal Diameter	Ø 5.00	Inch
Minimum All-around Part Clearance when Disengaged	0.25	Inch
Maximum Deburring Stone Envelope	0.50 x 0.50 x 6.00	Inch
Available Power	120-240, single phase	Volt
Minimum Shop Air Pressure	120	psi
Maximum Per-unit Cost	2,000	Dollars
Maintenance Cost	50	Dollars / Year
Maintenance Frequency	1-2	Cycles / Year
Useful Life	≥ 5	Years
Shelf Life	∞	Years
Critical Part Reliability (Average Life)	5 (for relays and actuator seals)	Years

6.2 Updated Design Specifications

After the second plant visit, when the team learned that the problem definition had changed, the design specification was revisited and modified to reflect these new criteria. Life cycle targets and all numerical constraints were left untouched, as was the budget. Primarily, changes were in the nature of physical and functional requirements, wherin the following changes notably took place and are emphasized in bold.

New Functional Requirements

- **Must enclose the entire deburring and chamfering process**
- Cannot be ignored by the operator / integral to the process
- Cannot increase routing time
- Provides a physical barrier to **all hazard zones**
- Cannot disturb intimate contact between operator/deburring stone/part
- Cannot limit operator range of motion to where he cannot produce a radius from ID to face and OD to face

New Physical Description / Constraints

- Must accommodate parts up to 5.00 inch in diameter, 0.50 inch thick
- Must be contained on far side of operator when disengaged
- Must envelope **the entirety of each part except for windows designed to allow edge-breaking access.**

- Must clear an automated grinding process which occurs on the far side of the part OD when disengaged (unhindered horizontal traverse at center-line by a 5.00 inch diameter grinding wheel)
- Must allow part to be removed from machine with minimum of 0.25 inch clearance all around when disengaged
- Must accommodate deburring stones up to 0.50 x 0.50 inches, 6.00 inches long
- Actuating mechanism **must be manually operated.**
- Must be able to operate in the presence of abrasive dust

These changes significantly shifted the focus of the team from the original electrical aspect, deemed to be the most involved and complex, to designing a full enclosure that only allowed specific access points for the deburring stone. For the remainder of the semester, refining this design has had he full attention of the team.

7 Quality Function Deployment

7.1 Quality Function Deployment Overview

The quality function development(QFD) was used in the process of determining the most effective shield that would maximize safety and decrease human error in the workshop.

To do this first four five concepts out of the one hundred and twenty were chosen. Thse were the ones that best define certain criteria,such as; the type of shield, the means in which it is moves and whether it requires external input like actuation and power. These concepts were then compare to the un-shielded deburring process.
In the comparison of ideas the company requirements “Quality demand”, and the function requirements “Quality Requirements”, were taken into consideration and analyzed.
The customer requirements are as follows:

- Prevents finger contact to sharp edge.
- Cannot be ignored by operator.
- Does not increase cycle time.
- Clearance for part removal and reversal.
- Clearance for chamfer grinding operation.
- Operator sense of touch unhindered.
- Part must remain visible when guarded.
- Must run on supplied power or air pressure.
- Must accommodate stones up to 0.5 inch by 0.5 inch.

- Maintenance costs no more than 50 dollars per year.

The variable design parameters to achieve these goals are as follows:

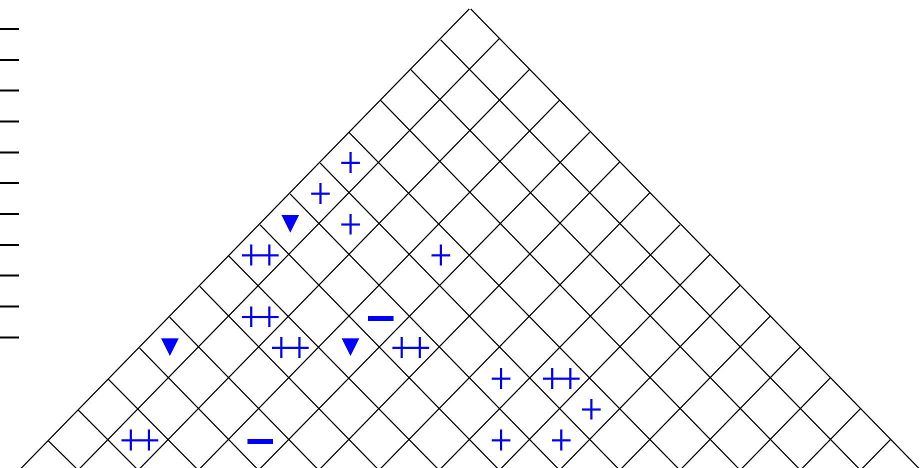
- Weight in hand
- Key Part Reliability
- Maintenance Frequency
- Guard Area
- Actuation Velocity
- Time to assemble per operation
- Dust Resistance
- Guard Rigidity / Failure Strength
- Force needed to actuate
- Type of drive mechanism
- Guard Material

The two requirements were first compared to each other to determine the magnitude of importance as well as the relationship of the criteria s. The relation ship can be seen in the QFD figure. Finally the concepts were then judged based on these requirement, the correlation of which can be seen on the plot of the QFD.

The QFD was a great help in determining of first main design for the concept design presentation. It helped lessen the time needed to analyze each concept by first making sure that the requirements given could be fulfilled by the ideas. After which we were able to zoom in on our main concepts by matching the qualities of each of the concepts with the points given and then compare those concepts left with each other. As such the four concepts left were able to summarize the abilities or function of the main categories of the rest of the concepts. Following the comparison of the four concepts with the original unguarded deburring method, the determine that the best shield design at the moment was the semi-actuated pneumatic shield.The shield was able to protect the user by coercing him/her into deburring the inner seal diameter as first required. Then by pressing a button or flipping a switch swing the shield up, allowing the user to work on the outer seal diameter as well as flip the seal to work on the other side.

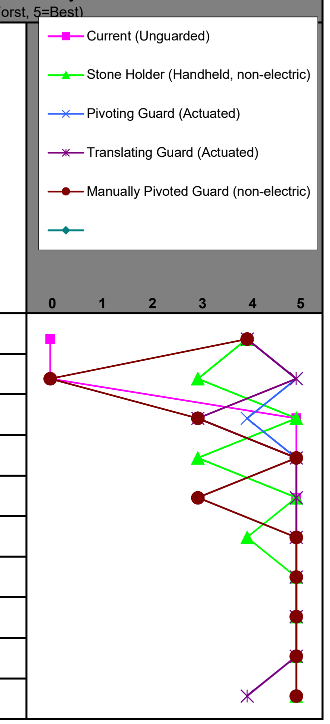
7.2 QFD Chart

Title: Electro-mechanical Deburring Safety Guard
Author: Dillon Fontaine, Jared Zeitlin, Jason Epstein, Abe Maharjan
Date: 10/17/2017
Notes: Team 22 - Capstone Design I - Fall 2017
For Magnetic Seal Corp.



Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼ (blue)	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 Weight in hand	2 Key Part Reliability	3 Maintenance Frequency	4 Guard Area	5 Actuation Velocity	6 Time to assemble per operation	7 Dust Resistance	8 Guard Rigidity / Failure Strength	9 Force needed to actuate	10 Type of drive mechanism	11 Guard Material	12	13	14	15	Current (Unguarded)	Stone Holder (Handheld, non-electric)	Pivoting Guard (Actuated)	Translating Guard (Actuated)	Manually Pivoted Guard (non-electric)
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▼	x	▲	x	▲	▲	▼	x	x					Competitive Analysis (0=Worst, 5=Best)				
1	9	12.2	5.0	Prevents finger contact to sharp edge	Θ			Θ				O			O					0	4	4	4	4
2	9	12.2	5.0	Cannot be ignored by operator	Θ					O			O							0	3	5	5	0
3	9	12.2	5.0	Does not increase cycle time			▲		Θ	▲	▲			Θ						5	5	4	3	3
4	9	12.2	5.0	Clearance for part removal / reversal				Θ												5	3	5	5	5
5	9	12.2	5.0	Clearance for chamfer grinding operation				Θ												5	5	5	5	3
6	9	12.2	5.0	Operator sense of touch unhindered				▲				Θ								5	4	5	5	5
7	9	9.8	4.0	Part must remain visible when guarded											Θ					5	5	5	5	5
8	9	7.3	3.0	Must run on supplied power / air pressure	O				O				Θ	Θ						5	5	5	5	5
9	1	7.3	3.0	Must accommodate stones up to 0.5" x 0.5"										▲						5	5	5	5	5
10	9	2.4	1.0	Maintenance costs no more than $50/year		Θ	Θ				Θ									5	5	4	4	5
				Target or Limit Value	< 1lbf	5 years	1-2 times/year	10" diameter circle	>15 in/s	1 hour (permanent installation), 1 minute (handheld)	100%	>30 Mpa	<25 lbf	N/A	N/A									
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	7	7	2	5	4	4	3	8	5	3									
				Max Relationship Value in Column	9	9	9	9	9	3	9	9	9	9	9									
				Weight / Importance	241.5	22.0	34.1	341.5	131.7	48.8	34.1	146.3	102.4	182.9	124.4									
				Relative Weight	17.1	1.6	2.4	24.2	9.3	3.5	2.4	10.4	7.3	13.0	8.8									



Powered by QFD Online (http://www.QFDOnline.com)

8 Conceptual Design

8.1 List of Concepts Generated

As part of the design process, once the problem was formally defined and existing literature relating to the topic thoroughly researched, concepts were then generated by each member of the group. Each member was responsible for 30 unique ideas, which were developed semi-independently from the other members. From this total of 120 concepts, similar ideas were combined and the most feasible ones systematically analyzed until 3-4 of the best were refined and prepared for a quality function deployment (QFD) analysis.

8.2 Dillon Fontaine's Concepts

The following concepts were created by Dillon and concern mainly a device for holding the edge-breaking stone. This device has a guard incorporated into its hilt that prevents finger contact with the rotating part. An overview drawing is given below, with many of the following items changing only facets of this base design.

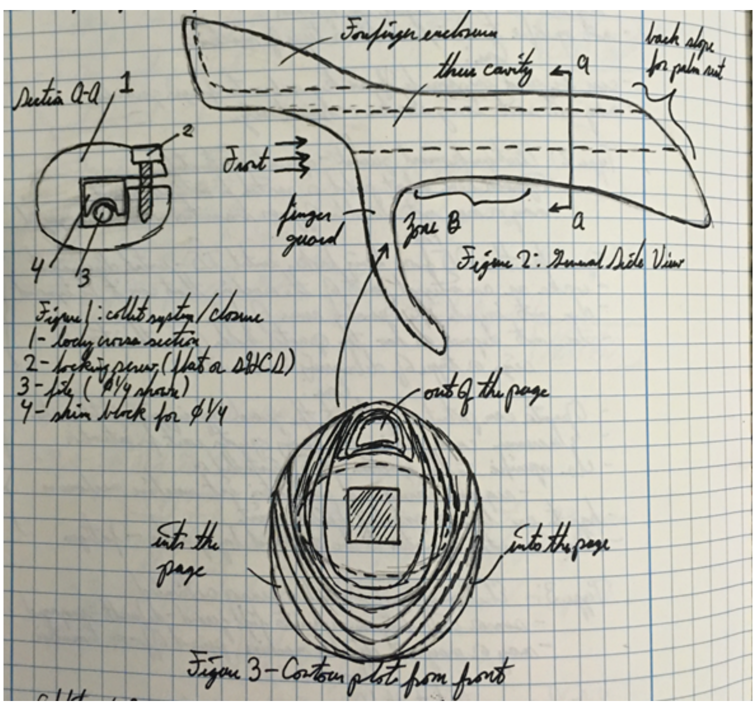


Figure 19: The Base Design for Stone Holding Derivatives

1. This is the basic design for a guard which is essentially a holder for the deburring stone. This design gives the operator a more comfortable grip, reducing fatigue and potentially decreasing cycle time and leading him to want to use the device rather than

avoid it. Figure 2 shows a plan view, with forefinger enclosure and stone cavity called out in phantom lines. The operator's forefinger is shielded by the enclosure at top, while the remaining fingers are protected by the finger guard shown from the front in Figure 3. This figure is a depth contour plot which shows how the finger guard slopes back from the forefinger enclosure. Figure 1 shows how the file would be held in a 1/2" x 1/2" cavity, with plastic interface blocks shimming different size stones, always pressed against the top spine of the tool. The cavity is split and tightened with three socket head cap screws (SHCS). The drawings are approximately actual size. Ideally the operator would have multiple units set up for him at the beginning of his shift and not need to adjust the unit at any time, rather picking up a new one when the stone becomes worn. All permutations hereafter are based off of this design and incorporate no other changes unless otherwise specified.

2. Decrease the forefinger enclosure tip to finger guard dimensions from the current two inches to one inch. Having this dimension longer increases support behind the stone, but limits the amount length of stone presented for ID work. Decreasing by half allows for a reasonable amount of rigidity but gives an extra inch before the stone becomes worn away and needs to be replaced.

3. Add finger grooves to the underside (Zone B, Figure 2). These will provide more comfort and a surer grip when used a particular way, potentially increasing productivity, but finger grooves in general force the operator to hold the tool in only this position, which the operator might tire of after a time.

4. Give a knurled texture to the same zone (Zone B, Figure 2). A texture may potentially come off as abrasive after long periods of handling, but if the peaks are rounded over, this is less likely. A texture also increases grip, not necessarily comfort, but also does not force a specific hand position.

5. Change the shape of the finger guard area, currently an approximate three inch circle when seen from the front to an ellipse with vertical axis of four inches, horizontal axis of 3.5 inches. This provides more of a barrier to the fingers and is safer, but may be less wieldy for the operator.

6. Eliminate the finger guard slope/radius so that it is vertical in Figure 2. This gives more room for large fingers and would eliminate undercut were the unit to be injection molded. This design could be molded with a standard two half mold and the cavity broached afterwards or molded by a removable third part.

7. Increase the Forefinger enclosure width from the as-shown 7/8 inch to at least 1.25 inches. This will accommodate larger fingers but will decrease the amount of clearance when the stone is close to worn away, but this is insignificant compared to the added flexibility afforded to the operator.

8. Make the forefinger enclosure and finger guard coincide, i.e. no overhang on the top portion. This creates a unit with much smaller profile and uses less material and is easier to manufacturer in quantities, but may hinder operator comfort by prohibiting his finger to be fully extended without severely altering his grip.

9. Limit the number of clamping screws to one from three. This may have an adverse effect on rigidity of the stone/holder interface but will make stone replacement or adjustment twice as fast.

10. Use thumb screws with knurled heads to clamp the stone. These will protrude out of the holder much more than SHCS but will make the unit adjustable without tools.

11. Use flat head machine screws to clamp the stone. These can be fully recessed into the holder and are adjustable with any flat head screwdriver. The operator will not be disturbed by any unnatural protrusions in the side of the unit.

12. Redesign the unit to be assembled from two halves. This allows the unit, cavity and all, to be molded with a two-part mold, while potentially sacrificing rigidity by splitting vertically into two pieces. The halves would likely be screwed together from the side.

13. Change the shim block (Item 4, Figure 1) material to aluminum so that the blocks may be easily machined in a mill and also last longer in wear than plastic.

14. Change the horizontal width of the finger guard to at least four inches to prevent any possibility of the operator's fingers from coming around the guard. This will reduce clearance slightly on tight ID's.

15. Increase the minimum wall thickness to at least 3/8 inches. This occurs between the forefinger enclosure and the stone cavity and is currently a quarter of an inch. Adding another half to this thickness may make the unit slightly less ergonomic for operators with small hands, but more than makes up for it with increased strength and rigidity.

16. Increase cavity size to 5/8" x 5/8" to accommodate larger stones. This again increases the overall size of the unit but affords much more versatility in the size and shapes of stones it can handle, notably for 1/2" triangular files which previously would have required two interface blocks.

17. Incorporate a pressure sensor and wire to the machine that prevents the machine from turning on unless the stone is being held. This adds complexity and a potential failure point to the design but prevents the operator from ignoring the holder and using a free stone.

18. The accompanying figure shows a screw drive which uses a keyed shaft at the end of a finger knob to advance a screw against the back of the stone, allowing easy adjustment of a worn area. The stone is either held to the screw in an adapter or there is a similar screw clamp to lock the stone after adjustment.

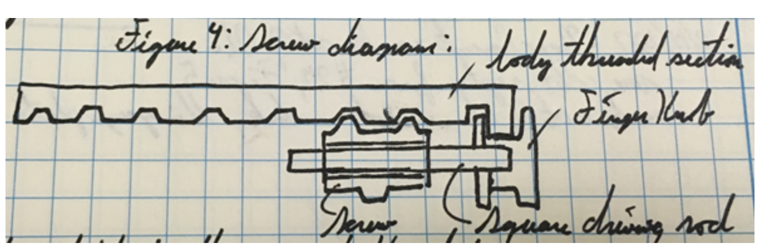


Figure 20: Keyed Screw-Plunger for tool-less Stone Adjustment

19. Incorporate a holder for the screw wrench in the basic design. If socket cap screws are used, a cavity for a spare Allen wrench is provided so that one is always on hand.

20. Change material from a 3-D printable or mold-able thermoplastic to a thermoset that is cast in a rubber mold. This allows replacements to be made in-house easily instead of ordering new units and is otherwise easier to manufacture in small quantities.

21. From Number 18, invert the design so that the driving rod becomes the internally threaded member which encloses the stone. The stone is held integral to the screw. This design gives an adjustment range that is the entire length of the stone rather than Number 18, which is limited by the driving rod bottoming out against the stone.

22. From Number 18, decrease the adjustment range and combine the screw and thumb knob into one part. The knob protrudes out the back of the device a small amount and advances with the stone. For a round stone, this allows easy rotation to present a fresh side.

23. From the base design, use steel threaded inserts for the clamp screws. This requires a slightly larger wall thickness to support it, but allows for smaller screws and nearly eliminates the risk of stripping the plastic.

24. Use a split collet type approach for holding the stone, which requires tapered threads to be cut into the body of the unit and a mating threaded ring, as shown int he accompanying figure. This forces the body to be round instead of ovoid, and requires a special thread-form for plastic.

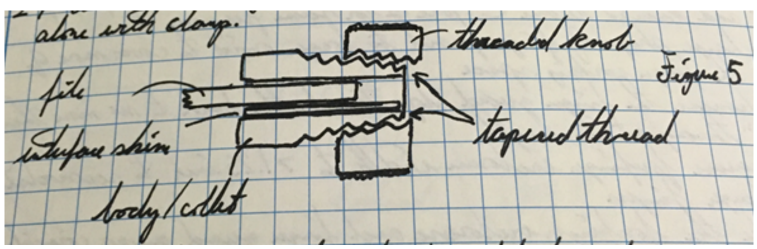


Figure 21: Tapered-Thread Split Collet for Stone Retention

25. Redesign to be machined from aluminum. This requires at least three parts that are then welded together, but the parts have simple features and make manufacture in small quantities much more streamlined and doable by any shop that can weld aluminum.

26. From Numbers 24 and 12, incorporate the split collet into each half of the unit. The threads can then be molded instead of cut while achieving the same effect. When snug, the threaded lock ring also increases the rigidity of the unit.

27. From Number 25, use steel to better resist the abrasion of the file slipping into the unit. This results in a more rigid and longer lasting product but is heavier, slightly harder to machine but easier to weld, and may have a more violent response if it contacts the part.

28. Use a hardwood such as oak as the base material, maintaining the screw inserts as in Number 23. This is easier to work with, lighter, but still strong and rigid. This method cannot be scaled for large quantities as injection molding can.

29. From Number 24, move the collet to the very front of the unit, forward of the forefinger enclosure. This would move it out of the operator's hand zone and maximize rigidity by clamping the stone closest to the point of contact.

30. From Number 29, use a standard taper pipe thread instead of a special form optimized for plastic. While this slightly increases chances of stripping, it makes the threads simple to cut with taper pipe die and the lock ring easy to make with standardly available taps.

8.3 Jared Zeitlin's Concepts

The following concepts were generated by Jared and mainly focus on a moving wall to protect the operator and those in the vicinity from injury. The moving wall prevents the operator from coming in contact with the machine thus reducing injury. The thirty concepts generated by Jared are shown below.

1. The concept shown below in figure (22), is a simple barrier that would align to the OD of the largest magnetic seal that goes through the operation. If the operator were to slip during the operation then the device would prevent them from coming in contact with the sharp edge. The drawbacks to this design is it is not as effective for the smaller magnets that need to be de-burred. In addition it does not protect other factory workers passing by from potential extracted chips.

   With the actuator located above the guard there is vertical translation. The benefit of this is there is more room to work with in the vertical plane. This is important as space is limited.

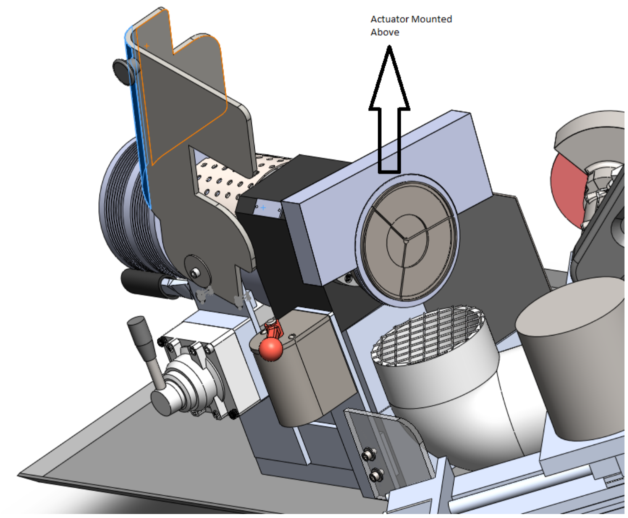


Figure 22: Guard that prevents the OD from being deburred before ID

2. The concept shown below (figure 23) is similar to that shown in figure (22). This guard has the same functionality of the first concept but rather has a cover. The advantages that this concept has over the first is that it offers some protection from chips that could potentially go flying. In addition it is more universal between different size magnets. As in concept one the device prevents the operator from coming in contact with the sharp edge of the outside diameter.

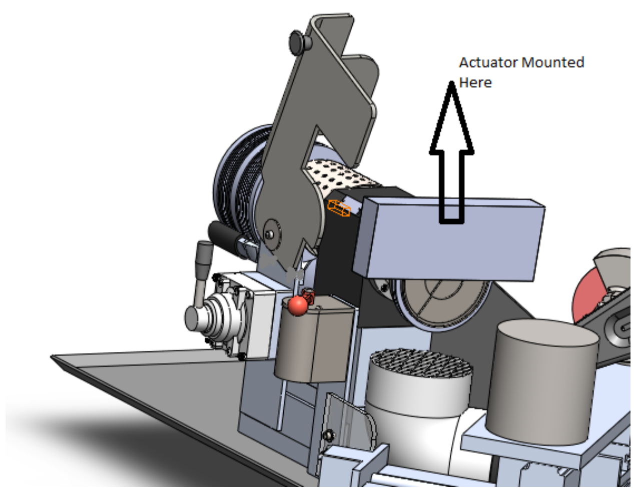


Figure 23: Guard that Mates with the OD and prevents the OD from being deburred first

3. This concept is similar to that of concepts one and two. In this concept the actuator translates along the horizontal axis as in concepts one and two the actuator translates along the vertical axis. There are pros and cons to this design. The pro is that we can

increase actuation speed by protracting and retracting the guard at an angle. The con of this is there is not a lot of room behind the machine, and the operator occupies the front of the machine.

4. The concept shown in 24 uses an actuator and a track rail system. When the foot pedal is pressed the guard either protracts or retracts along a rail to a fixed end stop. This is one way in which the path of retraction can be fully defined to avoid any interference with other parts of the machine.

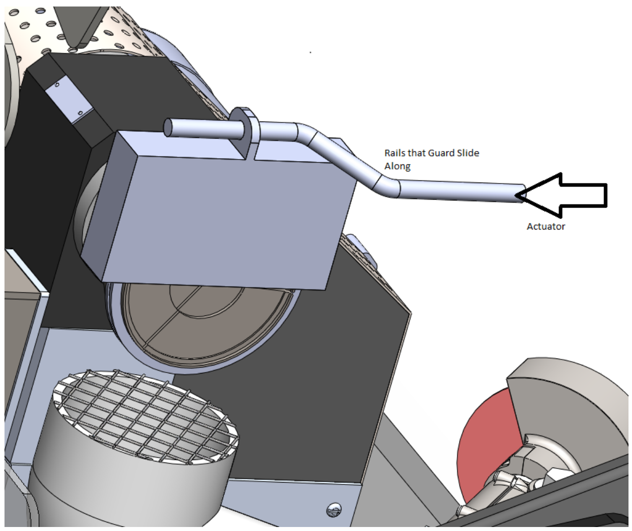


Figure 24: Guard that slides along a rail

5. The concept shown in figure 25 is a guard on a small DC motor that rotates about the midpoint of the collet. Like the other concepts guard is controlled via a foot pedal. There are some issues with this design when it comes to loading the part. The operator does not have full access to the part making loading difficult. This is detrimental as the operator must flip the part half way through the process to do break the edge on the back side of the part.

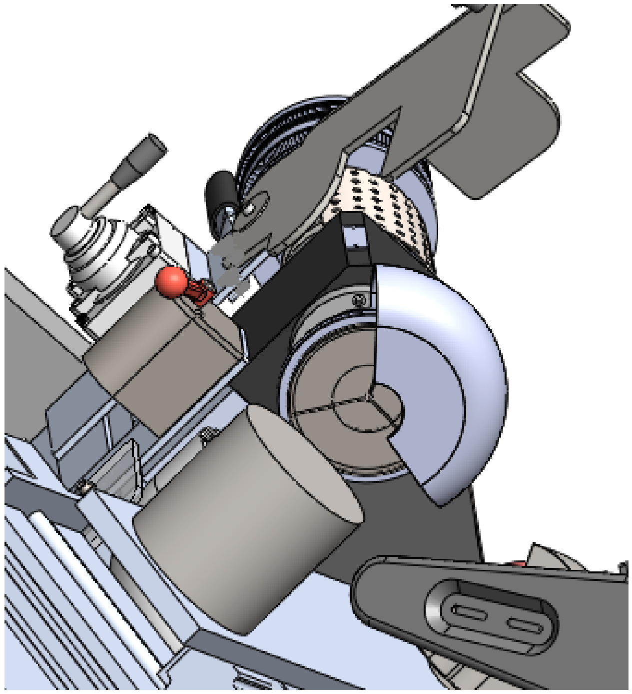


Figure 25: Rotating Guard

6. The concept shown in 26 is a manually operated guard. Before the operation the operator would pull the guard forward. Using a feedback sensor the guard would send a signal to a PID control unit. Unless the guard was down then the machine would not activate. While this concept is rather simple in terms of design work it has the potential to add routing time thus causing an increase in labor costs for the operation.

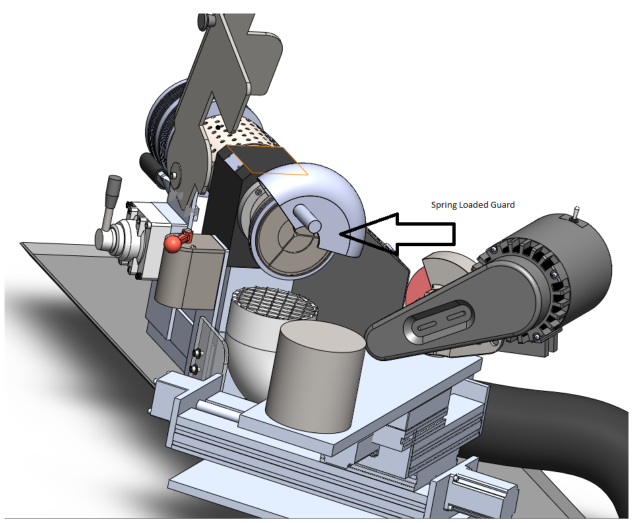


Figure 26: Manually operated guard

7. This concept adds a level of automation to the one above. This concept adds a loaded spring. The guard remains manually operated but springs forward unless it is being

held back. The spring would require some sort of electronic tensioning system to allow the operator to release the tension in the spring to break the sharp edge. A with concept six there is an issue with loading in the next part to have its edge broken.

8. This concept adds an electronic component to the previous one. This electrical component would pass an infinitely small current across the guard. When the guard is lowered it would close an electrical circuit. The circuit would interface with the power switch of the deburring machine. Unless the circuit was closed the machine would not turn on. In turn this would force the operator to use the safety device.

9. This concept builds on the previous concepts. This concept involves a system similar to the infrared system in a garage door opener. An infrared sensor would be placed on the machine and one would be placed on the guard. The master guard would be on the machine. If the infrared beam between the two sensors was broken a relay would be instantly tripped killing the power to the machine thus forcing the operator to use the guard along with preventing the operator from being injured.

10. This concept is similar previous concepts. This concept uses a spring loaded pin (located near the front of the guard) and a force feed back sensor located on the machine). For the machine to be turned on the spring loaded pin would need to be in contact with the force feedback sensor in order for the machine to be turned on.

11. This concept (shown in figure 27) is similar to the one shown in figure 24. This concept fixes the guard at a pivot point on the bottom right. One end of the cable is attached to an eye hook device on the top, and the other is attached to a servo motor. When the tension is released in the cable, it will cause the guard to go down. The motor will be controlled with either a switch or a foot pedal.

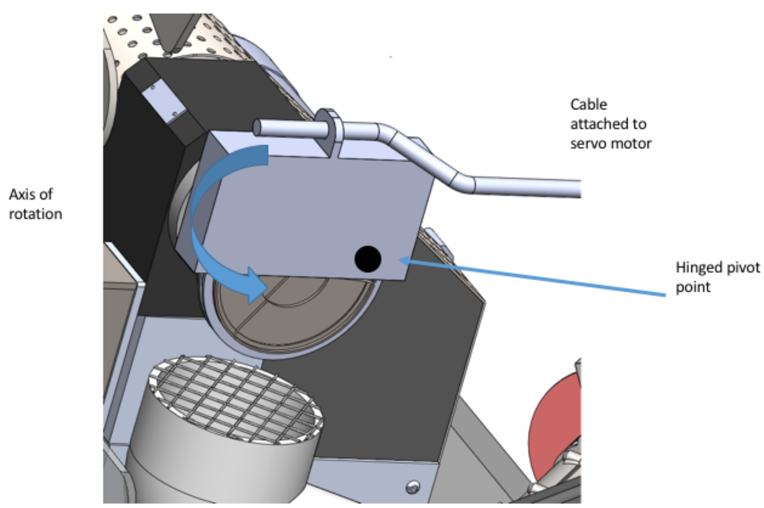


Figure 27: Cable Attached to Servo Motor

12. This concept takes advantage of the chip guard already in place on the machine. This guard would be attached to the chip guard and when the operator moves the chip

guard to the down position the machine guard comes down with it. The flaw of this is that the operator does not necessary

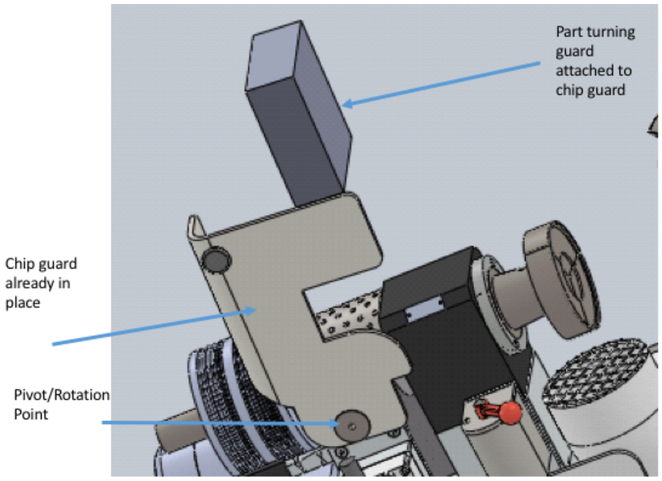


Figure 28: Guard attached to chip guard

13. Concept thirteen builds off concept twelve by adding a small stepper motor to the pivot point. This motor would be wired into the power switch and would cause the chip guard to rotate 90 degrees. This would occur simultaneously as the machine powers on.

    This concept uses a motor and a dowel pin connected to a guard. The motor is activated by a foot pedal or push button switch and comes down on the part when activated.

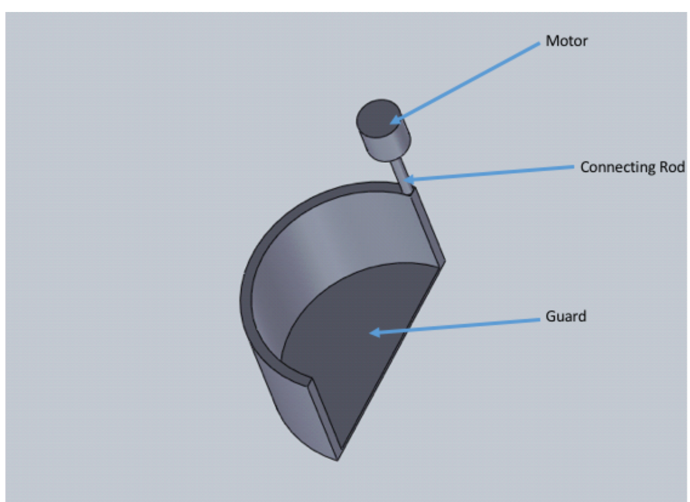


Figure 29: Motor operated guard on a connecting rod

14. This concept is a glove box type device. The operator is forced to put his hands through a glove box to perform the operation. There are some down sides to a glove

box for this process. The main issue is it inhibits the ability to inspect the part using the current inspection methods.

15. This concept uses a guard mounted to the motor housing. The stone is placed on the chamfered piece as shown in the diagram the guard and the piece that the stone sit in a slot. This allows for the piece to be easily removable for loading and unloading of parts.

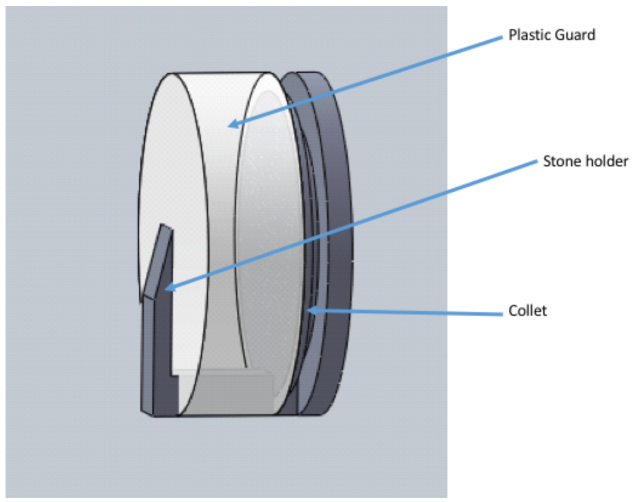


Figure 30: Guard Mounted on Motor Housing

16. This concept is a pair of gloves that are made of a rubberized material that still allows for the operator to use his tactile sense. The glove would protect the operator in the event he were to slip while deburring the part. The down side to the gloves is that they are removable and have no way to ensure the operator is using them.

17. his concept is similar to a previous one. It is a set of arms that are hung from a cable or apparatus that the operator slides his hands into. These arms hold the stone and prevent the operator from coming in contact with the part.

18. This concept is a design change to the concepts that use a linear actuator. Instead of a linear actuator they use a rotary actuator. The reason for this design is a rotary actuator tends to be more compact then a linear actuator. As space is limited a rotary actuator may be more ergonomic.

19. This concept is a concept that uses a cage type guard similar to the guard shown in concept five. A cage guard has pros and cons. The pro of the cage guard is that the operator has more ergonomic flexibility but in turn does not protect passerbys.

20. This concept replaces the track in a previous concept with a ball screw. The ball screw has a stepper motor on it. A ball nut is fastened to the guard. Using the ball screw when activated the guard translates back and forth.

21. This concept adds onto the previous one by adding a ball screw to the slot. Using this ball screw attached to a stepper motor the piece will translate back and forth. With a

sensor that can detect where the ball nut is in its cycle the machine will not power on.

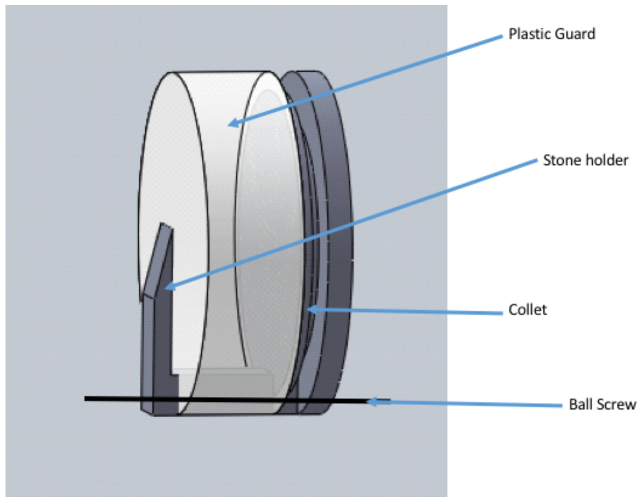


Figure 31: Stone holding guard that translates on a ballscrew

This concept uses an off the shelf lathe guard from McMaster Carr and adds a front shield to it. A new bolting interface is mated to the lathe machine block shown below.

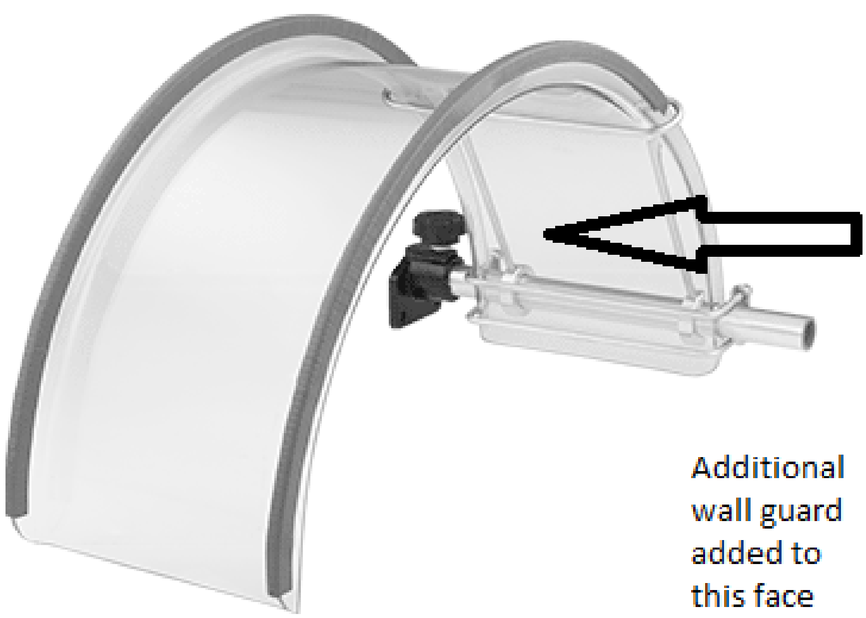


Figure 32: Modified off the shelf lathe guard (Image Courtesy of McMaster Carr Part Number 6157A45 [7])

The following concepts are for different mounting options for the guard. These concepts are different methods for mounting the guard to the deburring machine.

22. This concept is a method for mounting the guard to the machine and a way to fasten it. Using longer fasteners the entire mechanism fastens to this part. The big pro on using an off the shelf part is the cost as off the shelf parts tend to cost less then custom designed parts.

23. This concept is a second possible method of mounting the guarding device to the machine. This utilizes the space behind the machine along with two screws already fastened to a right angled beam.

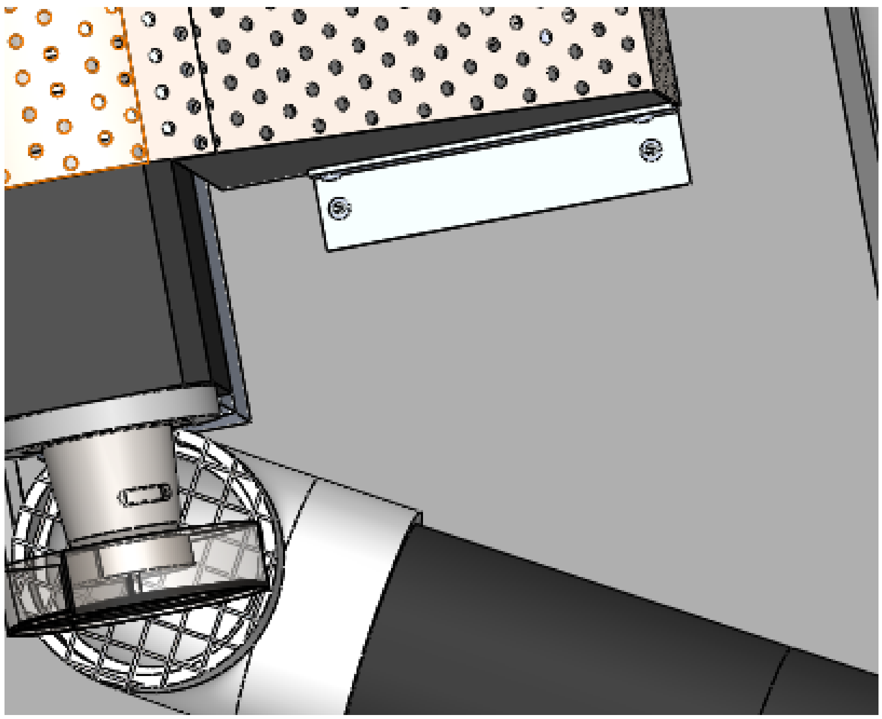


Figure 33: L Bracket Mounting Scheme

24. This concept is another possible method of mounting the guarding device to the machine. This devices again utilizes longer fasteners and mounts it to the top of the machine block. It uses two fastening points already being used.

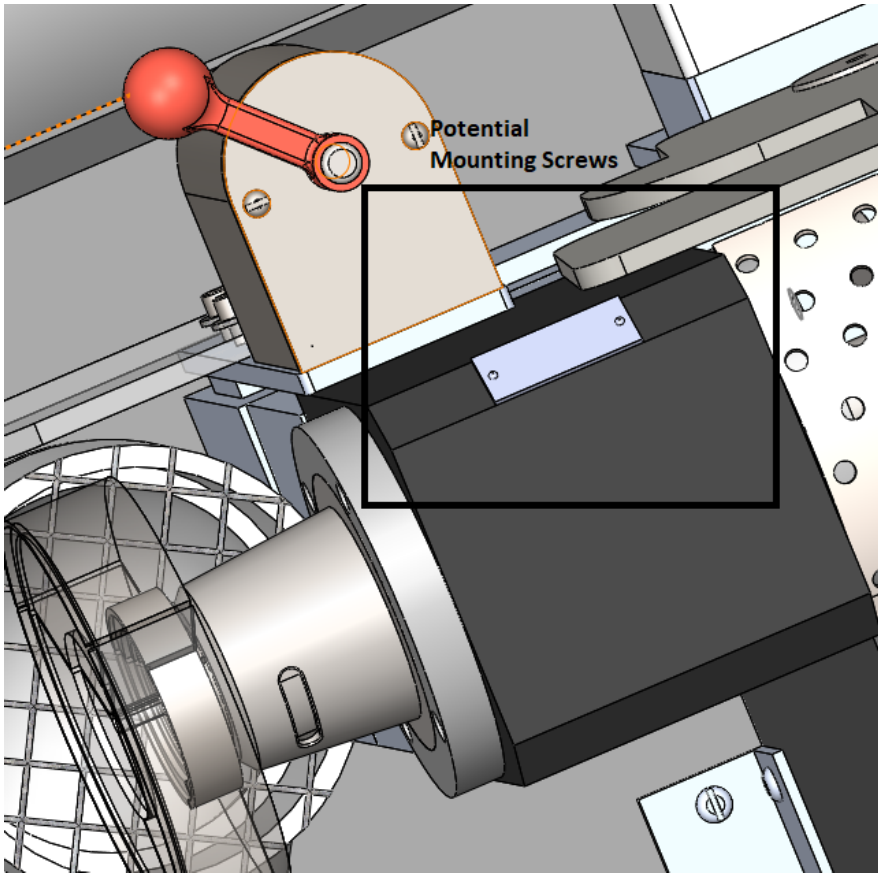


Figure 34: Potential fastening location

The following design concepts are for a second guard for the chamfering grinding wheel .The grinding wheel and the machine that spins the part have the same power supply thus the grinding wheel is constantly on.

25. This design concept protects the operator from the chamfer grinding wheel by using a spring loaded guard similar to those found on mitre and tile saws. The guard springs up when it gets close to the part and then adds the chamfer.

26. This design concept adds a proximity sensor to the grinding wheel. if the proximity sensor senses the operator getting to close to the grinding wheel it powers off the machine.

27. This concept for guarding the grinding wheel is software related. If the software were reprogrammed based on the switch that causes the grinding wheel to translate then the risk of the operator having the back of his hand lacerated during the operation will be removed. The wheel would be turned on by the switch that activates the translation of the wheel.

28. This concept is for a electronic control circuit for the guard. The circuit will consist of a counter made of D-flip flops. When the counter reaches values of 1 and 3 the guard will protract. When the counter reaches values of 2 or 4 it will retract. The operator

will use either a single pushbutton or a single SPDT switch to control the guard. In addition a sensor of some sort will also be an input. When this sensor is triggered it will immediately power down the machine. This control switch will interface with the power switch of the machine. A conceptual diagram is shown below. A circuit of some sort will be required for any guard involving a motor or actuator.

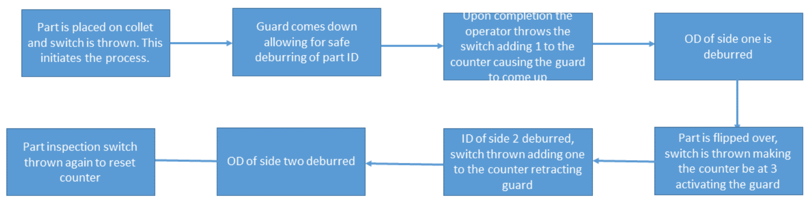


Figure 35: Circuit flow concept

8.4 Jason Epstein's Concepts

The next 30 design concepts were created by Jason with influence from various sources. These concepts are a mix of stationary or dynamic walls and several other innovative guarding methods. We were told to keep an open mind with this assignment so some of the designs may seem a bit extravagant, yet all are plausible solutions. Some are slight variations of each other but these small changes in design do play crucial roles in the effectiveness of the device.

1. This solution would consist of a mechanically controlled wall above the collet. When the part is inserted the wall could be activated using a foot pedal and would cover the top half of the collet. This ensures that the inner diameter is deburred first since it is the most probable for injury. Once the inner diameter is deburred the wall can be activated to move so the outer diameter can be deburred.

2. This solution would be similar to the first except instead of up and down this wall will rotate on a pivot. The type of actuation of a wall can play a huge role in the function of the device. A rough drawing is shown below.

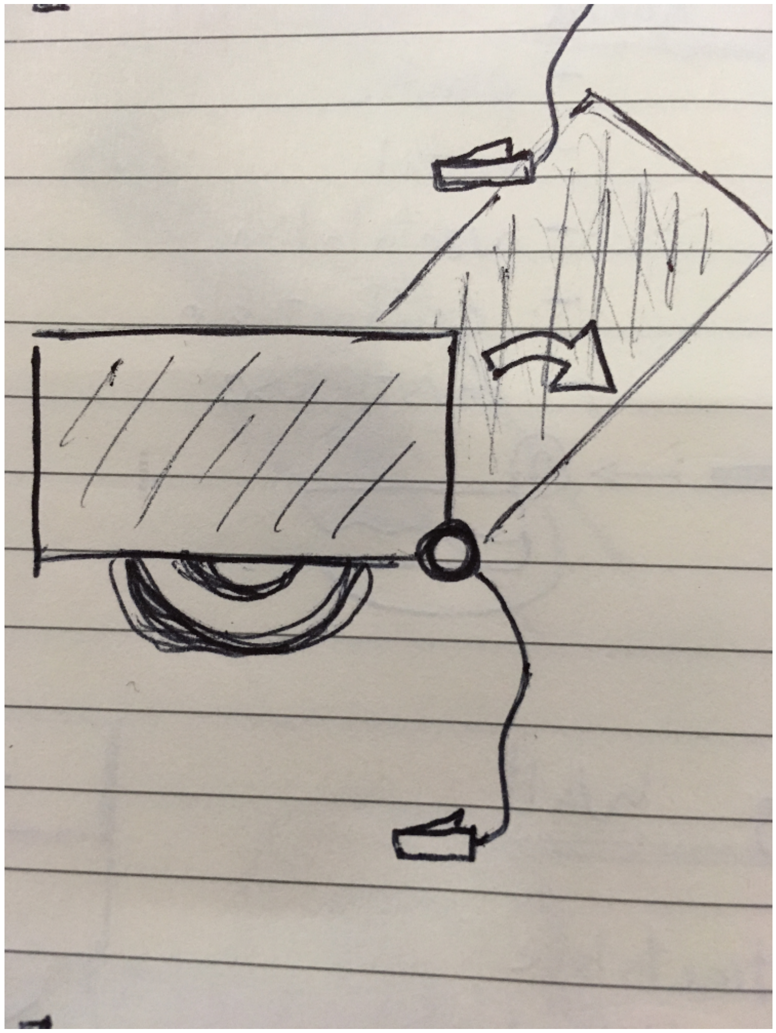


Figure 36: Pivoting Guard

3. This solution is a wall that comes in from the side on a track of sorts and has a slit below the centerline in it to allow deburring for a range of size seals. The slit would have to be big enough for the deburring stone to fit through but not big enough for a human finger to prevent injury. It would also be nice if this guard was transparent so the operator could see where the part was. A picture depicting this design is shown below.

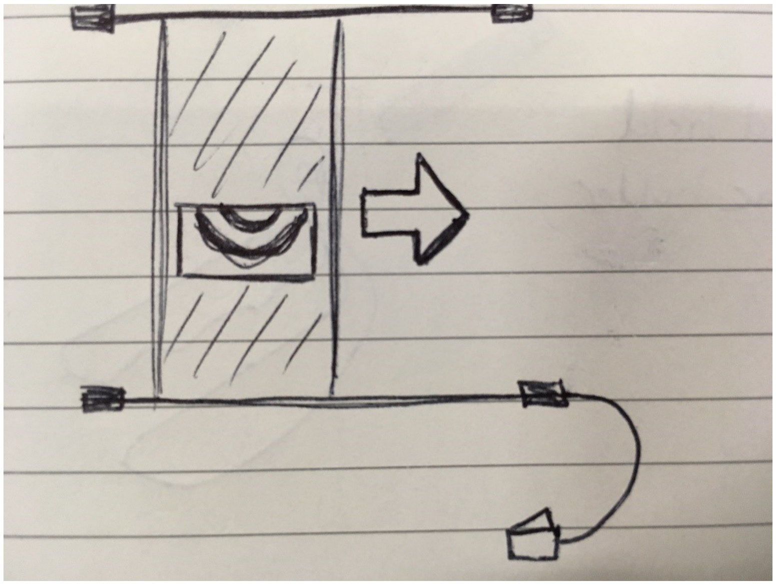


Figure 37: Guard with slit

4. This design is similar to previous one except this would be a wall that actuates on the Y axis with a vertical slit for deburring. The full coverage of the part provides maximum safety for the operator. The slit method works well because it can be used for a range of size seals. As with the previous design, the slit must be small enough to prevent operator injury.

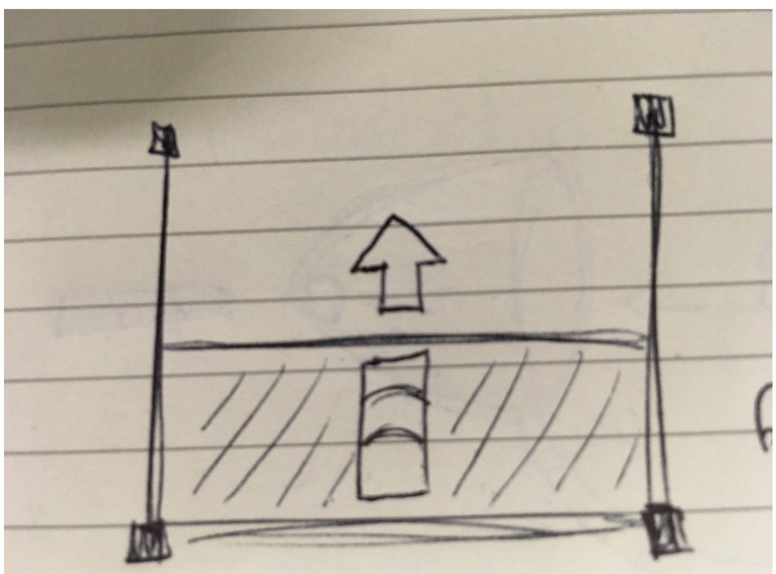


Figure 38: Guard with Slit V2

5. This design is the same as idea 4 except the wall will come from the bottom instead of on top. It would depend on the work area for which is more convenient.

6. Another actuating wall that covered the entire collet except the wall is made of a strong mesh like a gate. This would allow deburring due to the holes but it would block a hand from touching the burrs. The mesh size would have to be small enough to block out fingers but big enough to allow the stone through. This design would provide great ventilation and visibility to the part. The mesh could even be made of a strong cloth, although metal would be more stable and have a better resistance to daily use. Steel would probably have the highest life expectancy in this environment.

7. Although considered personal protective equipment a hand-held stone holder with finger guard would be the most convenient solution. Most operators would be happy to use this type of equipment if it exist. It doesn't interfere with the operator's sense of touch and takes virtually no extra time. When the stone becomes too used the operator has to put it down and pick up a new one regardless. With this device the operator simply takes out the old and inserts the new. There is no need for any external power source or electrical components. The only flaw in this solution is that there is no guarantee that it is used. If some measure was taken to ensure use this solution would be extremely effective.

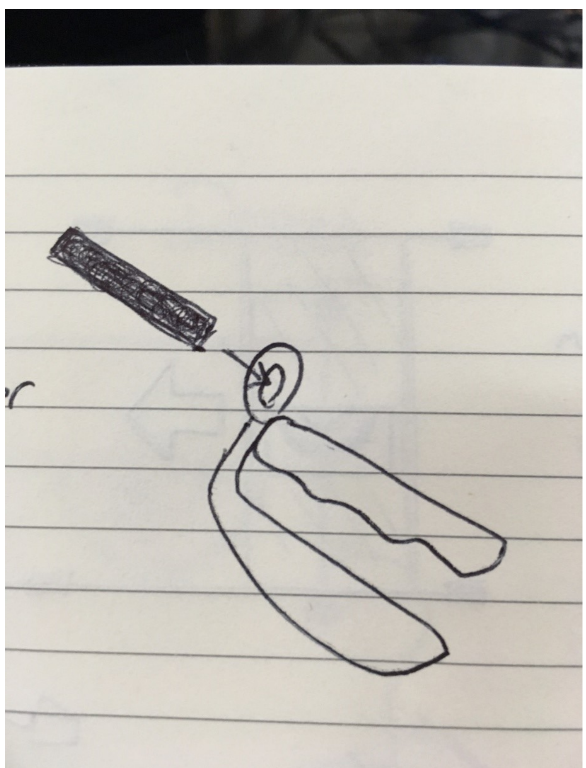


Figure 39: Hand-held stone holder

8. This is another form of stone holder except it would surround the entire hand with a hole for the stone and be attached to the machine using a sort of flexible cord. The cord would hold the guard in free space while the operator isn't using it. This may be more convenient than having to put something down like in the previous design. A

rough sketch is shown below

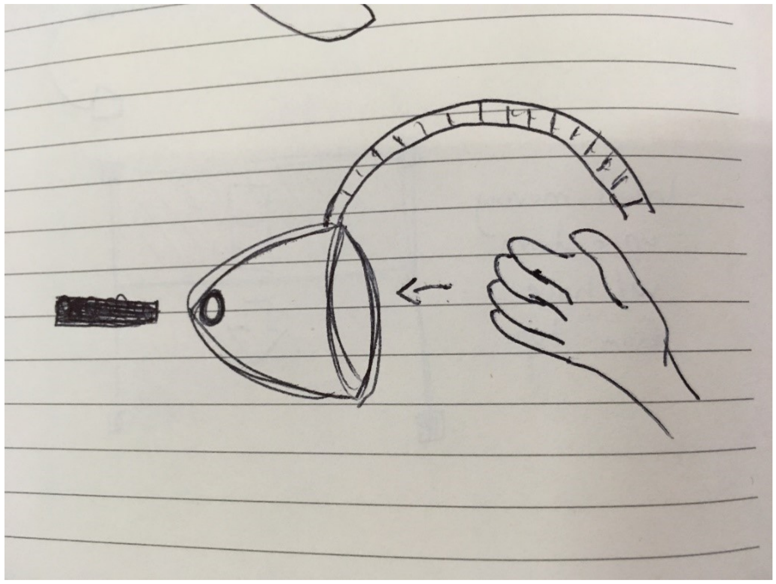


Figure 40: Hand guard

9. This next guard is similar to design 8 except more ergonomic. This modification would improve ventilation for the operators hand. The top half being exposed does not increase harm to the operator since the stone is generally applied in the downward position. The inside would also contain a soft material and allow the stone to be held with ease . Any amount of comfortability would be greatly appreciated by the operator since they will be using the device just about every day.

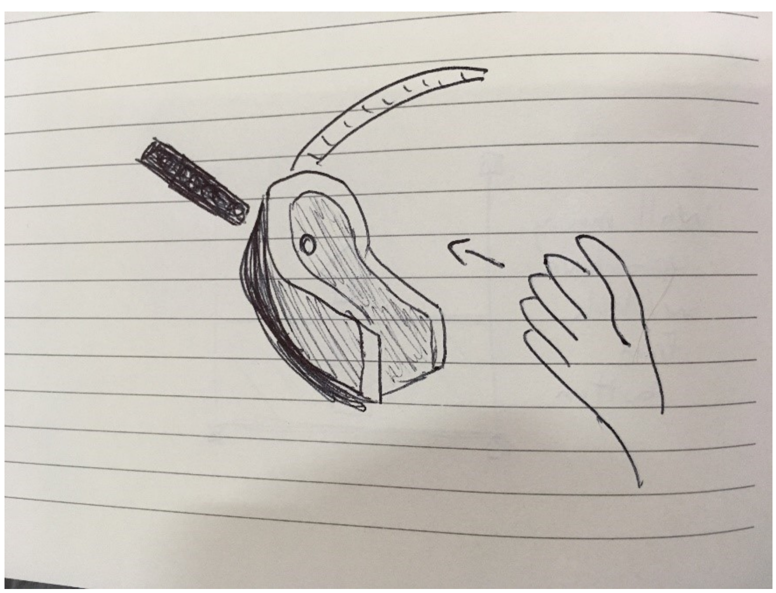


Figure 41: Hand guard V2

10. Another variation of Design 8 above would be if instead of a cord that allows the tool to “float” it would be retractable. It would be the same type of guard attached to an elastic rod that goes back to its original position. This allows the user to grab it, use it, then let it go and have it automatically move out of the way to flip the part or do the grinding operation. This would save a good amount of time in moving the guard back and forth.
11. A spring powered guard attached to the lathe. It would have enough room to slide the part in and would be a wall with a thin slit through the middle. The wall would sit at an inch out from the collet and on springs so you can push it up to the part to deburr it but it would shoot back out after. However this guard would have to allow for the grinder to perform the chamfer while attached to the lathe directly.
12. This solution would qualify as personal protective gear but it would be a firm guard that can attach to the operator’s wrist. This would block the underside of the operator’s fingers from touching sharp edges while leaving the hand free to operate equipment.
13. A spring powered guard that the operator can swing down and lock into place. After deburring the guard can be disengaged and swing up and out of the way. It would have to lock and unlock quickly similar to a seat belt fastener.
14. Similar to design 9 but it would be a circular plate with a hole in the middle and be attached to a retracting holding system, like the one used in an architect style retracting lamp. This is different from the ones that required insertion of the hand because it would take more time to insert a hand into something than just move it into place .
15. Measures would have to be taken to ensure the use of the previous safety device. Since a lot of the time things can be neglected if they slow down a process of if the process can be complete without them these safety measures would have to be wired with the machine to ensure use. This could be accomplished if the machine didn’t turn on if the safety device wasn’t being used. This would have to be overridden for when the grinder comes in since the part must be spinning during the chamfer.
16. A rather eccentric idea could be a type of mini airbag. Air bags deploy in cars once the car is hit with a significant enough force. This idea would consist of an adjustable sensor that goes through the inside of the part which would be where a stray finger could be sliced. If a finger slips through it would activate a small airbag in the center of the piece that would push the finger out and block the entire inside diameter. It would then deflate so the part could be removed. This idea will only work if the sensor is accurate enough and the airbag deploying speed is extremely fast.

The next couple of designs all deal with the grinder that comes in after the edge breaking is done to apply a chamfer. The grinder wheel is always spinning and very close to the back of the operator’s hand. This can be dangerous and we were asked to throw in a safety solution for this issue if we have time.

17. My first design for this safety guard is just a stationary wall blocking the wheel from the direction of the operator's hand, obviously the wall could not interfere with the chamfering process. Since the grinder only extends to touch the edge of a part and move a quarter inch back and forth I think that a stationary wall could be designed to simply block the users hand from touching the grinding wheel and be moved out of the way during the chamfer.

18. Another form of safety guard for the grinding wheel is another actuating wall. This would be between the hand and the wheel and would retract when the wheel is activated to start the chamfer.

19. A design similar to 14 can also be used to "float" a wall in between the hand and the wheel but it would have to be physically moved in and out of the way, which would ultimately add cycle time. Also it could be mistakenly left out of the way which could lead to injury. An electrically controlled one would be better.

20. An improvement of the previous design could be a guard that can be made to be linked with the program that controls the wheel. The operator manually activates the program for the wheel to come in and move back and forth to ensure the chamfer is applied. I'm sure a line of code can be added to activate an actuator attached to a wall before moving the wheel.

21. Below is a general rail system that will be used for some of the designs of a solution to this problem. It would have panels that can be retracted similar to a garage door.

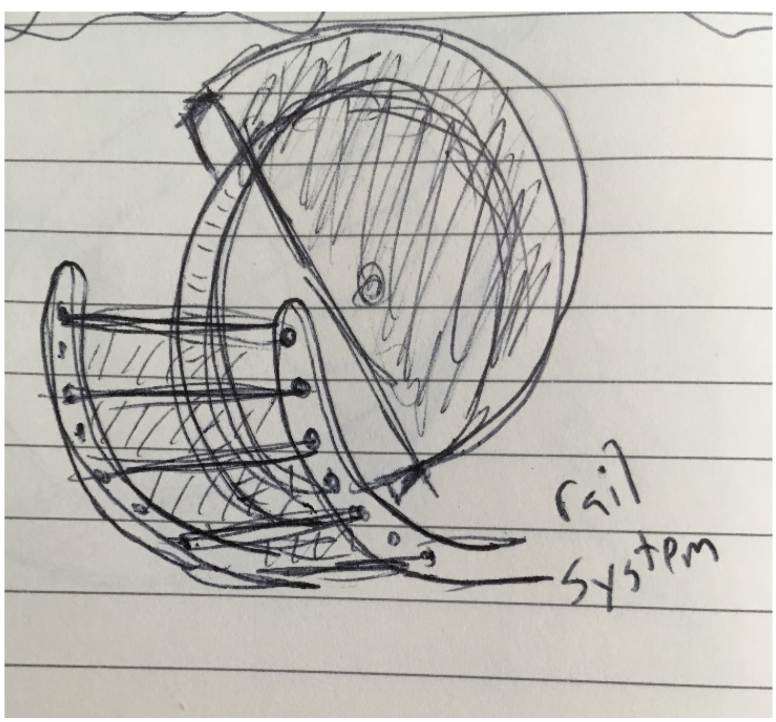


Figure 42: Rail System

22. In combination with the rail system, this design features a pulley so that when the grinder extends to execute the chamfer it simultaneously retracts the guard. The wheel doesn't come out very far so there would have to be a pulley system to amplify the rate at which the guard retracts.

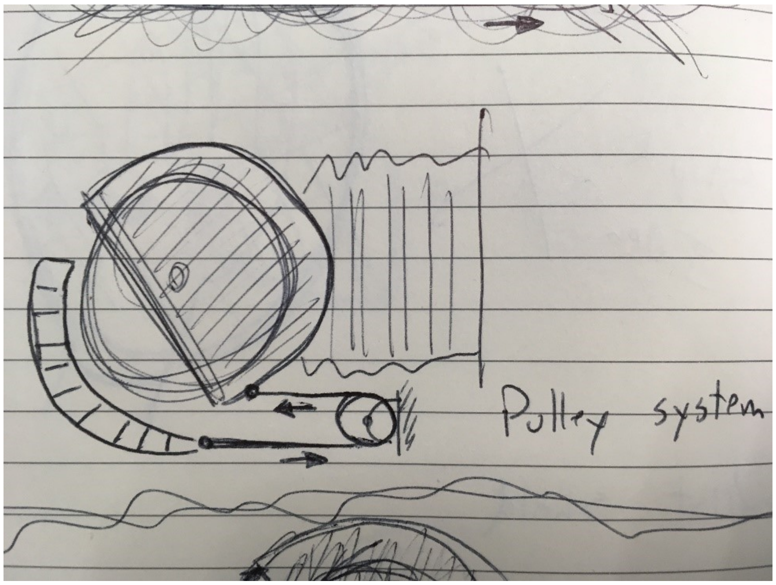


Figure 43: Pulley System

23. This is a similar design except instead of a pulley the guard is driven by a gear. Since motion applied in one direction to a gear causes motion in the opposite direction on the opposite side, this design seemed feasible. There would, however, have to be a long line of teeth on this design, making it slightly impractical.

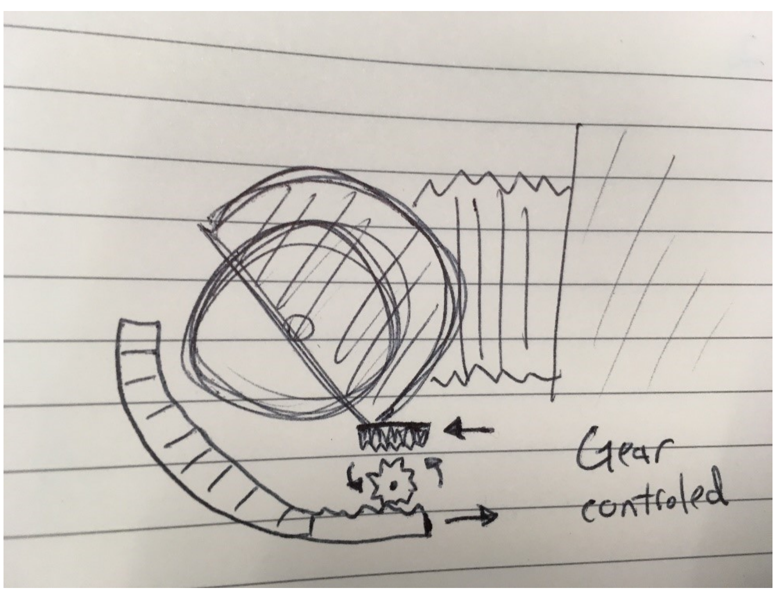


Figure 44: Gear System

24. While designs 21 and 22 make sense, they ensure that the rate the wheel extends and the rate the guard retracts are directly proportional. The guard may have to retract quicker than the speed at which the wheel comes out to avoid interference. This may result in a system of pulleys or gears that account for the distance and speed extended/ retracted.

25. Another design for this guard would be the same rail system except it would come from the top. There would be wheels above the grinder so that as the grinder extended the guard can stack above it, then fall back down when the grinder retracts.

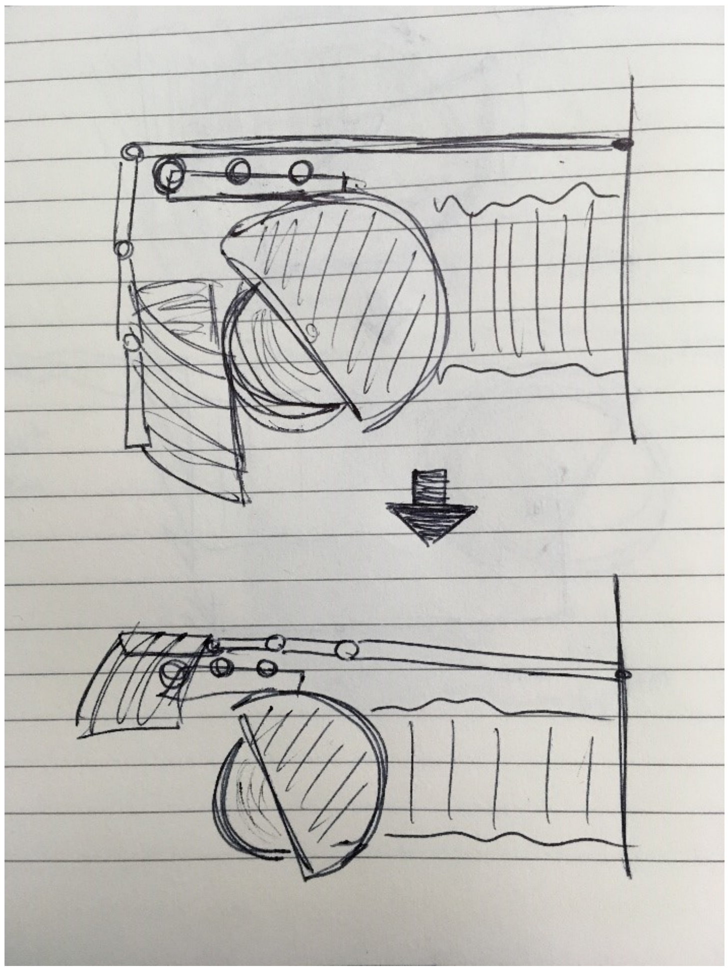


Figure 45: Grinder Guard

26. This design is very similar to design 25 except more precise and clean looking. It fully covers the entire wheel instead of just blocking off the area. It requires no electricity and preforms the task required incredibly well. This design was reconsidered and improved on because it is likely the most plausible for the safety guard of the grinding wheel. A drawing is shown below of the system described with a straight forward view of the guard.

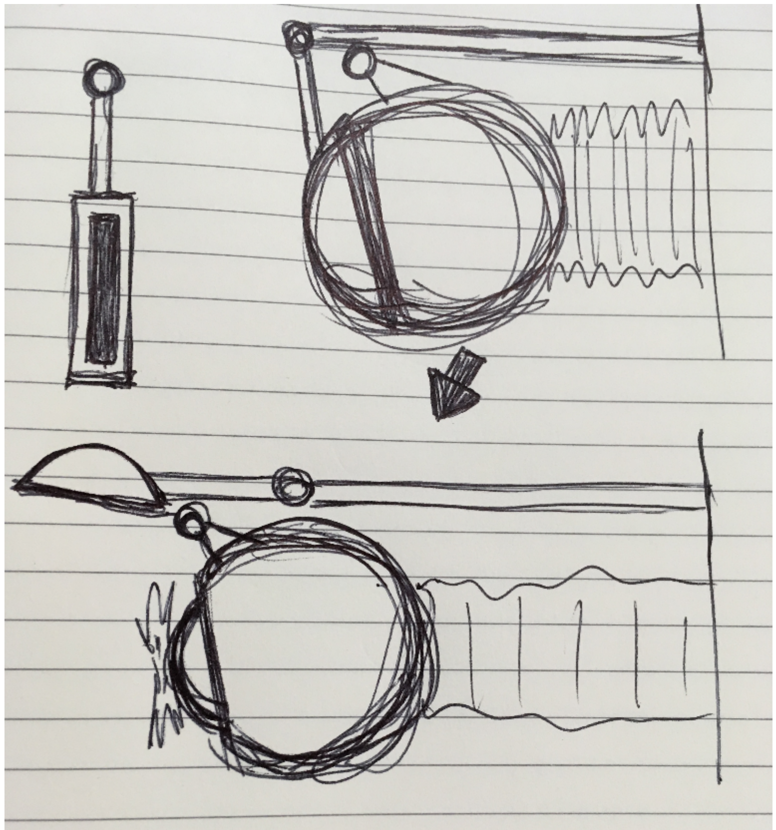


Figure 46: Grinder Guard V2

27. This design would not include the rail system. This design would be two bars coming from both sides of the grinding wheel. They are spring loaded and attached to wall panels that are connected to the wall. When the wheel comes out the bars are pulled backwards, exposing the wheel. When the wheel retracts the springs kick in and push the bars back up to cover the wheel.

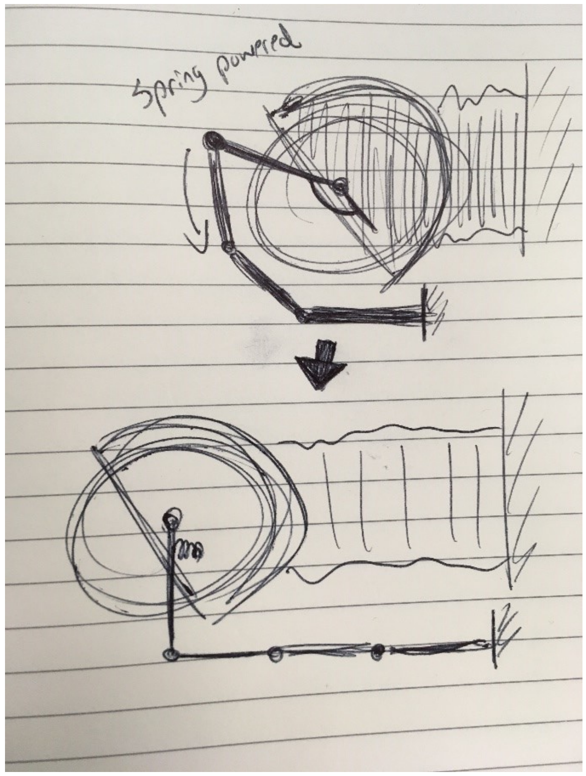


Figure 47: Spring System Grinder Guard

28. The same design as 26 except from the top instead of bottom. This might provide more protection and would go with gravity instead of going against gravity.
29. This is a combination of the fully encased wheel and the string with pulley. The cover would be hinged and spring powered so it would return to its position when the grinder retracts. I can also see this design really working well in its actual application.
30. This solution is a combination of design 26 and the pulley. I think that it is much more feasible that the guard comes out to the top instead of bottom. I also like the pulley system because it can be installed on a pivot for when the grinder does it quarter inch back-and- forth. This would also be spring powered but it is always good to not be fighting gravity at rest. I think that this idea would be easily installed and work very well.

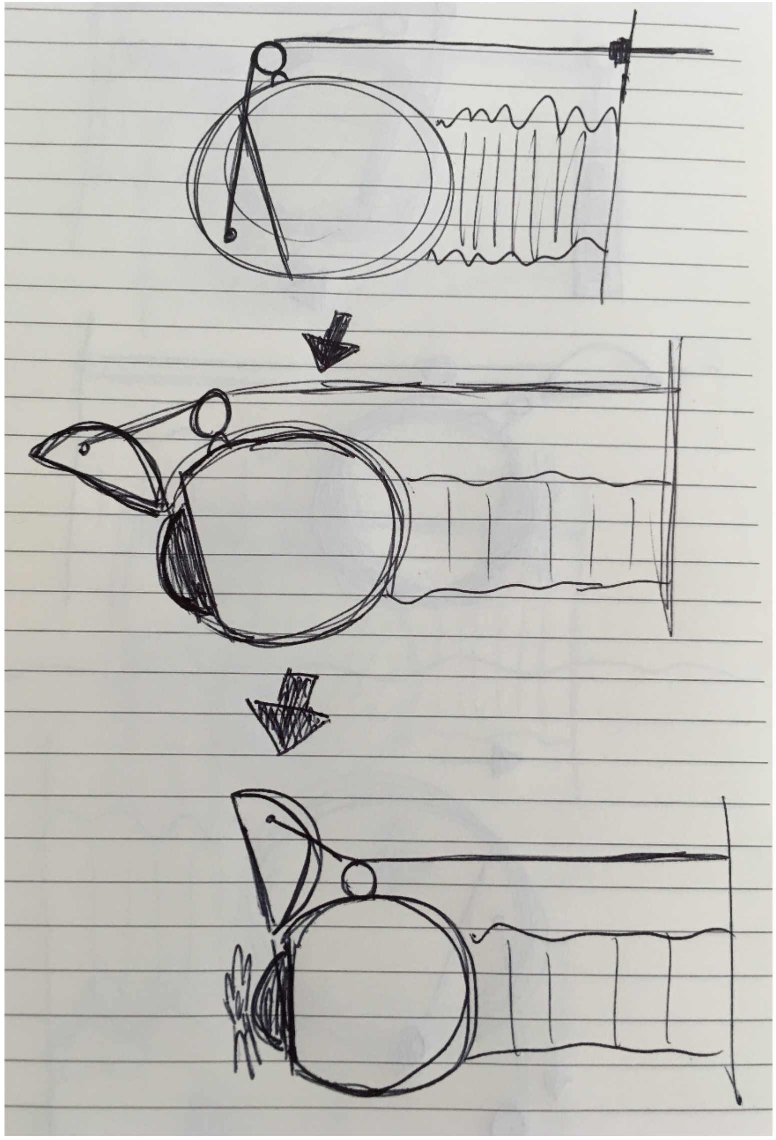


Figure 48: Pulley System Grinder Guard

8.5 Abhishek Maharjan's Concepts

The following concepts were generated by Abhishek Maharjan. They consist of eight ideas, some are similar yet all are unique.

- Type I. A crane/robotic arm type mechanism with a shielded hand rest that will protect the hand from slipping, so that there is no question on harming the fingers. This mechanism will be fixed to the table, such that the employee will have no option but to use the device. The deburring stone will be held in the hand and be rested on the hand shield. The mechanism will be connected to the hand by a metal bracelet that will allow the employee to securely attach his hand to the mechanism. This type of concept is shown below in figure: 49.

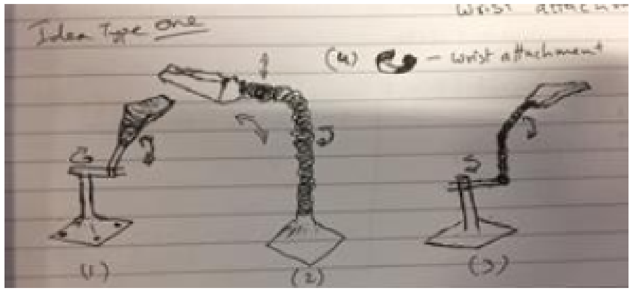


Figure 49: Type One Concept: Robotic Crane or Arm

- Type II: A hand held safety device that will allow an employee to hold a stick of deburring stone while protecting the employee in the deburring process. A pressure switch will be placed on the handle with out with the machine will not run, even when the main switch is turned on. This type of concept is shown below in figure: 50.

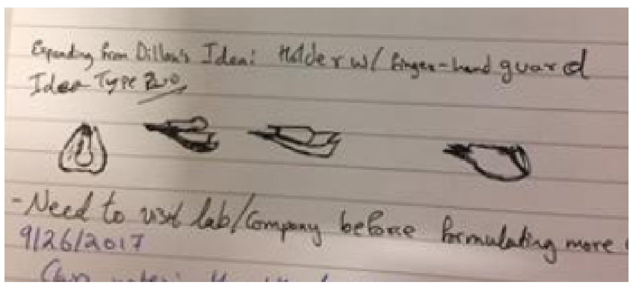


Figure 50: Type Two Concept: Hand Held Safety Device

- Type III: A semi-automatic guard directly connected to the machine, it will have a moving shield/ cover with inner diameter greater than the largest seal and inner thickness greater than the largest than the largest seal. This type of concept is shown below in figure: 51.

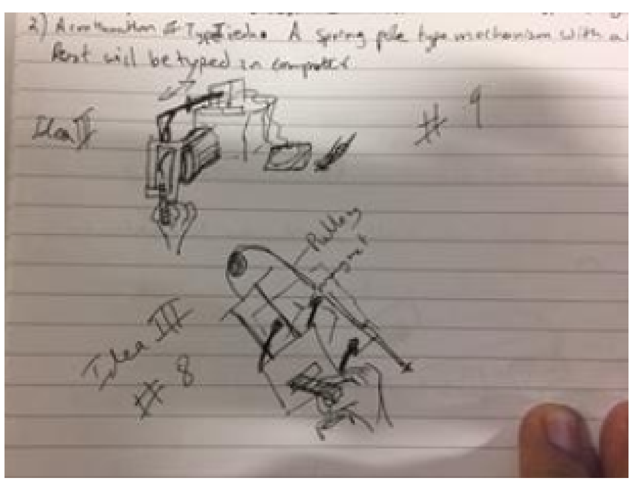


Figure 51: Type Two Concept: Hand Held Safety Device

- Type IV: A glove type PPE, will be made of different materials that are rip resistant.This type of concept is shown below in figure: 51.

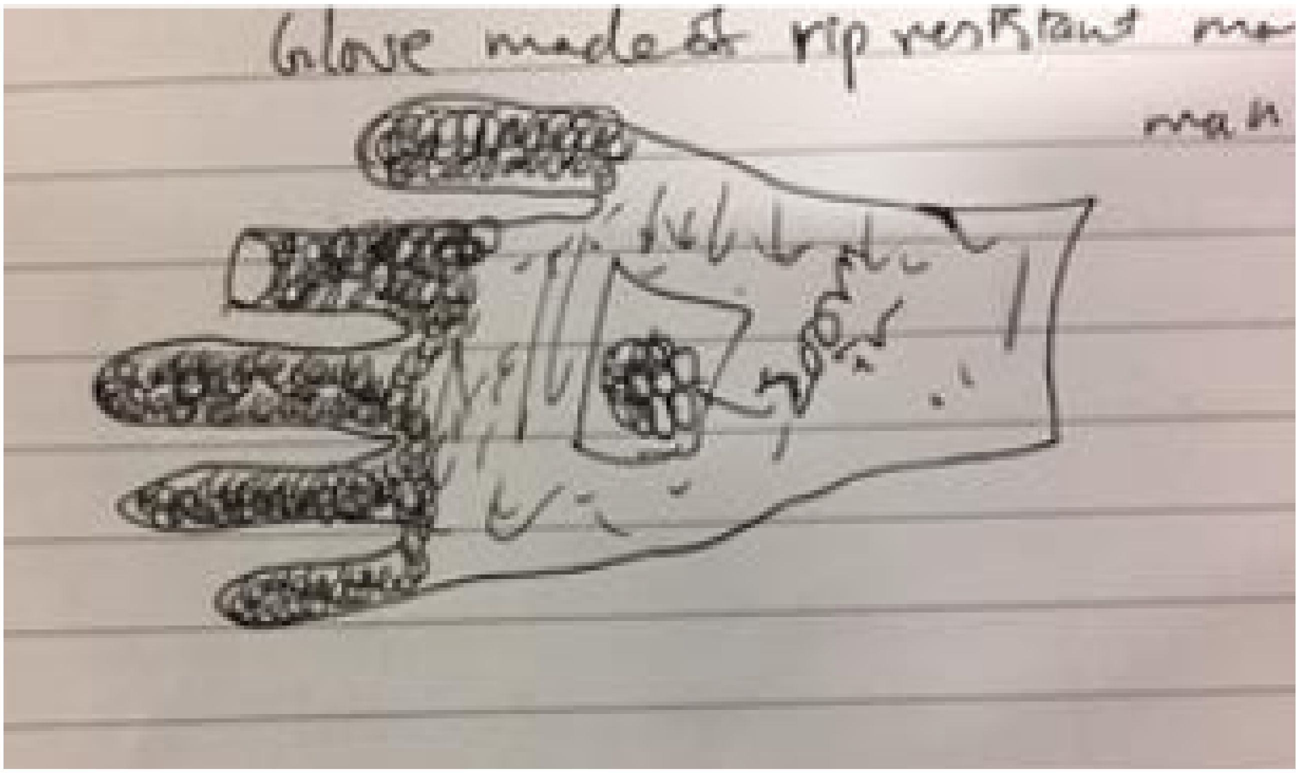


Figure 52: Type Four Concept: Glove Type PPE

- Type V: Fully automatic shield system that runs on coded program.
- Type VI: Manual switch shield (two input system), this system will be made in such a way that when at rest it will sat at rest so that there will be no instance of the shield accidentally coming back.
- Type X: improvement to the stone and the way it's held
- Type X2: lasers

1. Type I idea: A standing rotating arm mechanism, consisting of 2 arms that move and a shield that connects to the hand by a snapping mechanism on the hand shield.
2. Type I idea: A standing spring type rod with a hand shield that reacts to the amount of force placed on the shield. Works in such manner that the shield is in motion with the hand.
3. Type I idea: A mix of idea 1 and 2. A standing mechanism where a rod is connected to the table, on the top of the standing a turning rod/lever is connected horizontally, on the end of the 2nd rod/lever, a bending springy rod is connected to the hand shield with the mechanics of Type 1 idea.

4. Type II idea: A simple hand held shield that protects the bottom of the hand allowing for easy inspection of the shield. It will have a cavity in the handle where the deburring stone will be placed.

5. Type II idea: a long cone like hand held device that is half a foot long, a stone will be attached to the device with a clamp that will securely hold the stone. The device's length and lightness will allow the employee to easily switch between inspection and deburring.

6. Type II idea: a mini umbrella type shield that holds the stone in the rod on middle, the umbrella is clear so that it doesn't block view of the seal. Works with the general type 2 features.

7. Type III idea: a moving shield that opens when a button on the shield is pushed. This mechanism will force the employee to do the ID before the OD. When the employee is no longer doing the OD, the shield will come down. This happens due to a sensor sensing the position of an object before the seal, when there is nothing there it will release the shield. The shield will swing open above the seal and is perpendicular to the table.

8. Type III idea: a square shield hanging of a pulley, the shield will have four rods, one at each corner. Those rods will have small electromagnets, that turns on when the pulley is turned on, allowing for movement of the shield when the seal needs to be switched. The shield will have a wide horizontal hole to allow for deburring.

9. Type III idea: a rectangular shield with a long vertical hole the size of the largest stone. It will keep the employee from slipping by limiting the regions where slipping occurs. When the seal needs to be removed, a button can be pushed that will extend the shield forwards, so that the employee can go remove the seal.

10. Type III idea: a semi-automatic shield that is connected to the machine and moves diagonally away from the machine when a foot pedal is pressed. The shield will be clear so that the view of the seal is not blocked. As long as the foot pedal is not being pressed the employee will not be able to switch the seal around.

11. Type X idea.: the stone is the most important part of the deburring the process, as such preventing it from breaking is also very important. To protect the integrity of the deburring stone, it will be placed in a rectangular ruler type stick with a slot. This stick will have grips so that fingers do not slip. It will be deigned such that for each type of stone, there will be a type of stick. It will be covered more on one side than the other so the deburring can be done with the uncovered side.

12. Type IV idea: a "chain-mail" glove. Made of durable links 3mm in diameter woven in a configuration that strengthens the gloves maneuverability and be rip resistible. It will have partial exposure at the index finger to allow for inspection.

13. Type IV idea: a "padded" glove. Made with Kevlar and with thin metal plated in-between two layers for added protection. This will add more comfort to the employee with the same amount of access as the previous idea.

14. Type IV idea: a "scaled" glove, a leather glove with metal plates place in scale like manner(curved) in a force dispersing way that will prevent the wearer from injury.

15. Type V idea: a fully automated shielding system in which the employee would de-burr, switch and replace the seal in a sequential manner. The employee would need to de-burr the ID in the given time after which the shield would move out of the way horizontally, then the employee would do the OD, after which he would switch the flip the seal and the shield would come back. The shield will be a clear shape with a hole in the middle that has a diameter slightly larger than the ID.

16. Type V idea: an automatic shield that relies on a senor and timer to shield the OD. First, the shield will be a crescent moon shape with a 30-degree tilt on a conveyor belt system. It will stay shielding the OD for a certain time after which a light will go on, on the shield indicating that it can be moved. Then the user would move the hand towards the OD, and the shield would move back allowing the user to work on the OD. Once the OD is done and the sensors present reads nothing is covering the OD, an orange light will turn on indicating that the user should switch the seal and that the shield will fall in a given time.

17. Type VI idea: A shield attached to a bent arm at 45-degrees that can be moved back by manually pulling on the arm. The arm will be connected to the machine via a hinge, which will allow for the movement of the shield during the de-burring process. The employee will pull back on the arm at the joint allowing the employee to work with the seal.

18. Type VI idea: a rectangular shield with a vertical rectangular hole. It will be connected to a long horizontal tract that will allow the shield to be moved by hand. This tract is then connected to the machine by two rods on the ends of the tract. The height of the shield and tract is such that the removal and switching of the shield is very easy.

19. Type VI idea: Instead of pulling a manual shield system that moves out of the way by pushing on a lever. The shield will move in an arch when the end of the lever is pushed. This will be much quicker than any actuated design as it will rely on hand power.

20. Type X idea: a long stick holder. This will be a simple stone holding device that will accommodate any type of stone, like the previous stick idea it will expose more on one side than the other will. This will protect the user by giving him a solid object in his hand that is a distant away from the edge if the seal.

21. Type I idea: An arm that hangs on top of the machine and comes above the rotating seal. On the end of the arm sling will be present. The user's wrist will go on the sling and when he needs to de-burr the seal he will push down on the elastic sling. As the sling will limit the movement of the user, he or she will not slip.

22. Type II idea: a fast frequency hand held vibrating de-burring tool. In the form of a gun, when its trigger is pulled will cause its tip to vibrate at a high frequency causing the de-burring process to quicken. This tool will be similar to a vibrating tooth brush,

furthermore there will be a distance from the hand and the seal, such that in the event of slipping there will be no injury to the user.

23. Type II idea: a magnetic rod. This rod will be able to securely hold any type of stone and due to its magnetism, will not allow the user to be exposed to the seal when the machine is running.

24. Type II idea: a clear plastic umbrella type guard that can hold any type of stone and is able to fold its hood/top at different angles. This will be due to hooks or locks in the rod of the umbrella that will connect to the umbrella spine. This umbrellas hood/top will be made of foldable but clear plastic to allow for easy in folding. The folding will allow different sized seals to be worked on without any hindrance.

25. Type I idea: A single rod made up of many connected rods, with the top most piece having a sidepiece connecting to it that is able to rotate. The top side piece also contains the de-burring stone attached to it. The device is hollow inside; each smaller rod is connected to the one above and below it in horizontal locks, with the final two pieces connected in a vertical lock. The final two pieces are special as the last rod contains an inner rod inside it that when a button is pushed will release it. How this device works is that first the pieces move horizontally so it is under the seal, then the ID is done by rotating the sidepiece. Then a button will be pushed on the second piece, which will release the vertical rod allowing the user to reach and de-burr the OD.

26. Type X2 idea: a system that relies on lasers to sense the position of the hand at each point of the de-burring process. Such that, when there is a slip, the algorithm that the laser will rely on will sense the change and stop the machine. The algorithm of the laser will be different for each user and the processor that utilizes it, will be directly connected to the machine to control its motion.

    Technicalities of the devices:

27. Semi-automatic devices will rely on a pneumatic valve to control the movement of the device. A lever with a hinge will be connected one shield to the arm connecting to the shield and one end to the actuating cylinder, such that the movement of the actuator will move the shield.

28. Instead of pulling back a standard manual switch shield with the hand, it will be connected to a side lever controlled by the foot. When the foot is pressed on the floor pedal it will pull on the lever and until released. This will make moving the shield easier than when pulling on the shield by hand.

29. The movement of the arms of any safety device will be fairly quick to make sure that there is no damage to the device, certain points of impact will have rubber stoppers on them. This way the rubber stoppers can absorb the force of impact. This is very crucial for Type III, Type V and Type VI ideas where, there are instances where the device will move quickly.

30. The environment of the lab is a very dirty place, as such any device made needs to have items that protect its integrity for its given life span. Any hinged device will

have flexible accordion covers on the joints. Any actuators will be in a sealed tight box, allowing only the arm to be exposed. Any electrical device will need to be kept in a temperature isolated box that is also easily opened for maintenance, in turn any exposed wires will need to be insulated and out of the way.

9 Design For X

9.1 Safety

The main focus and objective of this project is safety. The guard is being created solely to ensure that no harm can come to the operator during this abrasive process. To guarantee the maximum level of protection for the operator the entire hazardous area is being blocked off with minimum holes to allow for the edge breaking to take place. The hazardous area is blocked from the front as well as both sides just in case the lathe malfunctions in any way and launches the seal out. The guard is securely held in the engaged position due to the precision manufacturing of the handle support bracket to allow it to rest comfortably yet firmly on the support pin. This prevents the operator from accidentally disengaging the guard because it will be too tight and would take a noticeable amount of force to accomplish. Additionally, there is a switch which controls a solid state relay mounted to the side of the pivot beam. This relay interrupts power to the lathe motor, meaning that when the guard is disengaged, the lathe cannot be powered on, meaning that the guard cannot be ignored as the operation cannot take place without its use. Additionally, to prevent the pane from being removed from the guard, there is provision to use security hex bolts, which have a stud that prevents them from being loosened by ordinary wrenches. These are not furnished with the guard, however, being an inconvenience during set-up. They could be used though, if it is found that unauthorized pane removal becomes a problem.

9.2 Ergonomics

One ergonomic modification occurred with the location of the handle. It was initially placed on the top corner of the guard closest to the operator and extruding out the front of the guard. At this location, the operator would use his right hand to manipulate the guard into the open position, and in so doing present that arm dangerously close to the chamfer grinding wheel. To minimize reach and with operator feedback after presentation of the 3D printed prototype, this handle location was changed to be on the lower left side, integrating the two left-side brackets into one larger bracket. This new part was also made out of aluminum to reduce weight and the impact it would have on the center of mass and balance of the guard as a whole.

The change in handle location drastically decreases the distance the operator must reach from his body to open the guard. It also allows the use of the left hand, which has its waiting position near the new handle location where it also actuates the pneumatic collet closer. In this way, the right hand will not have to put the deburring stone down but is allowed to hold it throughout the entirety of the cycle. The hazard to he right hand is eliminated, and there is no trade off for the left as there is a constant minimum distance between the left hand and grinding wheel throughout actuation. The guard also physically isolates the left hand from the grinding wheel by nature of its left sheathing and frame, and also because the new handle location is farther back from the front of the device in the machine direction.

9.3 Durability

The device was designed with regards to durability in a working environment wherein certain stresses would be applied. It was theorized that the operator may rest the tool on the guard pane, and so the device uses two point supports with a reinforced steel main beam and hardened steel support pin. The modified support pin bracket distributes the weight of the guard over more area of the support pin and also at a location closer to the mounting bracket, thus reducing the bending moment felt on the pin. This arrangement maximizes rigidity against downward forces, while the extended support pin bracket also helps to increase rigidity in the machine direction. Lateral rigidity is increased by the same token, by the longer support pin bracket distributing lateral forces over the support pin, reducing lateral bending stresses and applying the center of any lateral load much closer to the mounting bracket than what had previously been established.

With regards to wear, the aluminum bearings are included to separate the steel surfaces of the pivot beam and hinge bracket. By sandwiching this softer material between these polished surfaces, the aluminum will burnish over time, creating a naturally wear resistant surface. The washers are also easily replaced in the event of excessive wear, but this should not have to be done more than once within the lifetime of the machine it is attached to. By account of the infinite adjustability of the take up nut, any looseness in the joint can be eliminated by simply tightening the nut. Replacement only needs to occur when the washers have completely worn away, which is theorized to happen only after decades of service.

The susceptibility of the take up nut to vibration is mitigated by two key features. Firstly, the lock nut is of the nylon variety, purposely designed to conform to the threads of the pivot beam and not loosen under vibration. Secondly, if this is not enough to prevent loosening, there is an extra length of shank left purposefully for the addition of a jam nut, which provides as much friction on the threads as they can physically withstand, thus ensuring vibration resistance.

9.4 Manufacturability

The device was manufactured from primarily custom-fabricated components taking advantage of off-the-shelf components wherever possible. To keep machining time to a minimum, standard sizes and prismatic shapes were used extensively, allowing purchasing of ground stock wherein minimal machining was required to bring parts to the correct shape and size.

Considerations were made to avoid the use of non-standard cutters wherever possible, so that only two cutters needed to be purchased. Features such as slot widths, counter-bores, threaded holes and corner radii were chosen to allow the use use of standard sized tools.

The fabrication process took 27 hours to complete over a period of one week, conducted by members of the team. A general procedure for machined components consisted of general rough-cutting, machining to size, putting in secondary features such as slots and bosses, hole drilling and tapping, and finally a thorough edge break. Most components being prismatic in nature, milling was the primary mode of machining, though some turning was utilized specifically for the adjustment buffer. Welding and free-hand grinding was used to shape the frame post-machining.

10 Project Specific Details and Analysis

10.1 Market Analysis

There is a vast market for safety devices across not only the United States but the world. Keeping workers safe while they perform their jobs affects all corporations large and small.

While the market for safety devices is large, the market for the specific guard that team 22 designed is small. The guarding solution is considered a one off as there are only two machines that exist like it in the world.

The market for the device only consists of team 22's sponsor MAGSEAL as it is specifically designed for their machine and to fit the needs of their process.

10.2 Demand Forecasting

Demand forecasting for safety devices for a machine that was custom built for a company and a specific purpose can sometimes be difficult. Team 22's design is custom designed to fit the process and the machine that MAGSEAL uses.

Team 22 does see the potential to make slight modifications to the design to retrofit the second machine that MAGSEAL uses. While this machine is not exactly the same as the one the guard is being specifically designed for, with slight modifications to the frame, mounting brackets and hinge, this is possible.

Manual lathe type devices are extremely difficult to guard. Thus they tend to require a custom guarding solution in order to make them meet OSHA Standards. The reason for this is due to the guard tending to get in the way of the sensitivity of the operation/process that the lathe is performing.

With this in mind Team 22 sees the concept of the designed guard being applied to other lathes if the pane were modified to meet the process that the specific lathe is performing.

In summary while the team designed the guard to meet the demand for the two machines that are currently in use by MAGSEAL, it does not mean that the principles and concepts of the guard can not be applied to other machines and operations. Since most forms of deburring lack any form of safety measure this idea, after various modifications, could be widely popular in the machining industry.

10.3 Cost Versus Price

Team 22 did some research on what some of the possible costs would potentially be if the machine was not guarded. In addition to the potential of injury to the operator, the potential loss of time due to injury, and the cost of compensation of workers due to injury and potential for legal prosecution the cost of an OSHA violation must also be examined.

To get a better understanding of the potential costs of an OSHA violation, Team 22 spoke with Tim LaLonde, a Senior Safety Specialist and Engineer for Tiffany & Co. Tim, focuses on improving safety within manufacturing environments along with helping insure that Tiffany's large manufacturing meet all OSHA standards in the event of an audit. Tim shared some of the costs of the estimated costs associated with an OSHA violation (see table 11)

Potential 2016 Maximum Penalties		
Violation Type	Current Maximum Penalty	2016 Maximum Penalty
Other then Serious Violations	$7,000	$12,600
Serious Violation	$7,000	$12,600
Willful Violation	$70,000	$126,000
Repeat Violation	$70,000	$126,000

Table 11: Estimated OSHA Violations Costs (source: OSHA Education Center [8])

Upon examining the table shown above, that even the least serious violation, which OSHA defines as an "Other Then Serious Violation", carries a penalty of $12,600 dollars.

According to Tim, a machine that is not guarded properly (any machine that does not have a guard that meets OSHA standard 1910.212 (for more information on this see section 12.2)) carries a maximum fine around $12,600.

Team 22 then compared this price of not having the proper machine guarding to the cost of the guard (having a budget of $2000 dollars). With this in mind the cost of not having the machine properly guarded is approximately $10,600 dollars. This is potentially a huge cost savings for MAGSEAL when comparing it to the minimal $2000 for the guard.

[6]OSHA Costs per Injury (OSHA Education Center [8])
[7]Special Thanks to Tim LoLonde see acknowledgements, 22.2

11 Detailed Product Design

11.1 Bill of Materials

11.1.1 Overview

To organize all parts needed for the project team 22 developed a comprehensive bill of materials (BOM). A BOM was created for both the custom parts along with the off the shelf components. The team created separate BOMs for the mechanical (table 12) and the electrical components (14). These are discussed and shown in the respective sections below.

11.1.2 Mechanical Components

11.1.2.1 Custom Mechanical Components

The Bill of Materials of the mechanical components is featured below. As can be seen from this, there are a total of 11 individual custom parts, not including standard hardware. Each of these is only represented in the assembly once, except for the retainers, which are represented twice. Only two materials are used in this construction, an aluminum alloy, namely 6061-T6 for its easy availability and prolific use in industry, as well as its strength. The frame and related brackets are made from mild steel, typically AISI-1018 or -1020 again for its easy availability, ease of machining, and higher strength than aluminum alloys. A detailed discussion on each part follows the BOM.

Table 12: Bill of Materials Custom Mechanical Components

ITEM NUMBER	DRAWING NUMBER	PART NUMBER	PART NAME	QTY.
1	MSAG22-0001	22001	GUARD PANE, LARGE COLLET	1
2	MSAG22-0002	22002	LEFT SHEATHING	1
3	MSAG22-0003	22003	FRAME TOP	1
4	MSAG22-0004	22004	FRAME LEFT	1
5	MSAG22-0005	22005	FRAME BOTTOM	1
6	MSAG22-0007	22007	LEFT PIN SUPPORT BRACKET	1
7	MSAG22-0008	22008	HINGE JOINT BRACKET	1
8	MSAG22-0014	22014	PANE RETAINER	1
9	MSAG22-0015	22015	TOP SHEATHING	1
10	MSAG22-0016	22016	PIVOT BEAM	1
11	MSAG22-0023	22023	MOUNT BRACKET	1
12	MSAG22-0024	22024	BEAM CAMP	1
13	MSAG22-0025	22025	CLAMP BACKER	1
14	MSAG22-0028	22028	ADJUSTMENT BUFFER	1

11.1.2.2 Off the Shelf Mechanical Components

Team 22 as discussed, decided to use as many off the shelf components in the guard as possible. Many of these components are the various pieces of hardware necessary for the assembly of the guard.

Each off the shelf component was given a part number in the numbering system as well. This was done for organizational purposes. In addition a drawing was made of these components as well. This allowed for them to be included in the CAD models and have extensive dimensional documentation of the parts.

All off the shelf parts were sourced from McMaster-Carr. A bill of materials of the off the shelf components is shown below. (table 13)

Table 13: Bill of Materials Off the Shelf Mechanical Components

ITEM Number	DRAWING NUMBER	TEAM 22 PART NUMBER	ITEM DESCRIPTION	VENDOR	VENDOR PART NUMBER	QTY.
15	MSAG22-0009	22009	KNOB HANGLE	MCMASTER-CARR	60975K86	1
16	MSAG22-0010	22010	0.25-28 SHCS X 0.375	MCMASTER-CARR	92196A315	8
17	MSAG22-0011	22011	10-32 FLAT HEAD X 0.375	MCMASTER-CARR	92210A301	5
18	MSAG22-0012	22012	10-24 SHCS X 0.625	MCMASTER-CARR	92196A244	6
19	MSAG22-0017	22017	10-24 X 0.1875 SET SCREW	MCMASTER-CARR	92311A237	1
20	MSAG22-0018	22018	0.375 FLAT WASHERS	MCMASTER-CARR	93286A045	2
21	MSAG22-0019	22019	PIVOT PIN	MCMASTER-CARR	97042A324	1
22	MSAG22-0020	22020	10-24 SHCS X 0.25	MCMASTER-CARR	92196A309	1
23	MSAG22-0021	22021	3/16 DOWEL PIN	MCMASTER-CARR	90145A512	1
24	MSAG22-0022	22022	0.375-16 LOCKNUT	MCMASTER-CARR	90101A243	1
25	MSAG22-0026	22026	SUPPORT PIN	MCMASTER-CARR	90145A605	1
26	MSAG22-0027	22027	ADJUSTMENT KNOB	MCMASTER-CARR	5993K75	1
27	MSAG22-0029	22029	.25-20 SHCS X 1.00	MCMASTER-CARR	92196A542	2
28	MSAG22-0030	22030	10-24 SHCS X .875	MCMASTER-CARR	92196A246	3
29	MSAG22-0031	22031	0.375 X 0.5 UNTHREADED SPACER	MCMASTER-CARR	92320A726	1
30	MSAG22-0032	22032	.1875-16 X 1.50 FLAT HEAD	MCMASTER-CARR	92210A628	1

11.1.3 Electrical Components

All the electrical components utilized in the guard were off the shelf components. Team 22 used either McMaster-Carr or DigiKey to procure all of the electrical components. Team 22 decided to use the supplier part numbers for the electrical components as many were complex. In addition no drawings were made of the electrical components. Shown below is a bill of materials of the electrical components used. (table: 14)

Table 14: Bill of Materials Electrical Components

ITEM NUMBER	PART NUMBER	PART NAME	QTY.
1	8085T15	Subminiature Washdown Snap-Acting Switch, Lever Actuator, 5A Switching Current	1
2	72035K511	UL Class CC Time-Delay Midget Fuse for Motors, 1A	1
3	4234K2	Inline Holder for UL Class CC Midget Fuse	1
4	4234K3	Rubber Cover for Inline Holder for Midget Fuse	1
5	1041N11	Screw Terminal Block with See-Through Cover & 4 Enclosed Side-Mount Circuits	1
6	71425K23	Heat-Shrink Spade Terminals for 16-14 Wire Gauge and Number 6 Screw	1
7	7934K13	Reducing Crimp-on Butt Splices, Heat-Shrink, for 16-14 to 22-18 Wire Gauge	1
8	8248K16	Harsh Environment Cable, Three 16-Gauge Wires x 10 FEET	1
9	7870T31	Black 16 Gauge Appliance Cable x 10 FEET	1
10	9096T11	Premium Straight-Blade Connector, Three-Blade Straight Plug, Grounded, NEMA 5-15, Black	1
11	Z169-ND	RELAY SSR SPST-NO 10A@240VDC	1
12	Z924-ND	HEAT SINK TRACK MNT FOR G3NA SER	1
13	7852K11	Heat-Shrink Wrap 1.2" ID Before Shrinking, 8" Long	1
14	72035K518	UL Class CC Time-Delay Midget Fuse for Motors, 10A	1

11.2 Computer Automated Design Mock-up and Detailed Part Discussion

Following is a photo-realistic rendering constructed inside Solidworks. Placeholders for mounting and support pins are visible, though these have not been finalized by the team and are only used to illustrate the function of the device. The assembled frame is used to hold the pane, which has three cut-outs. The top is used for access to the OD and is large enough to only allow a reasonable range of motion for the deburring stone. The hole is designed to disallow the stone and a finger from entering the hazard zone at the same time. The bottom hole is provided for access to the ID and has increased clearance between it and the center line for the stone to pass through. Lastly, a side relief is featured to allow the chamfer grinding wheel to make its approach.

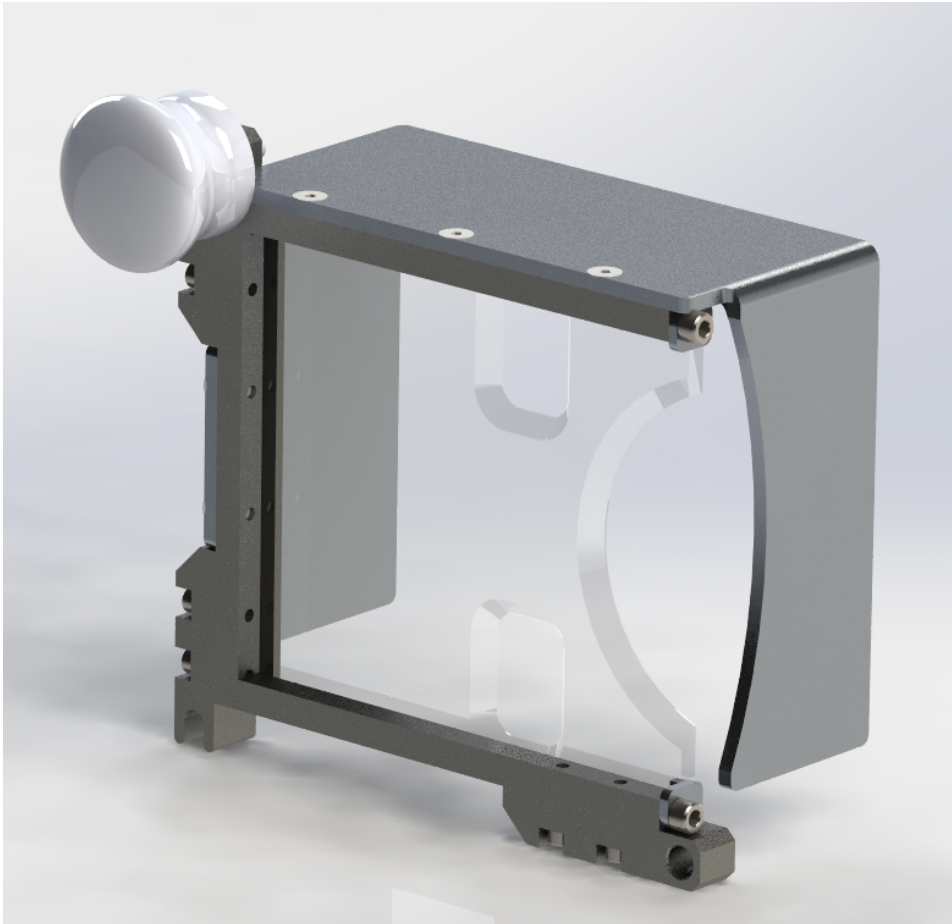


Figure 53: Perspective Rendering of the Complete Assembly

In normal use, the presence of the pane would force the operator to hold the stone slightly farther away from the guard and thus in a position where even if the stone slips, the finger will strike the pane and not the part. This pane is retained by the frame on one side, top, and bottom by channels milled for this purpose, and is allowed to egress on the operator's far side. The panes are inter-changeable, with different hole locations provided for different part size ranges throughout the entire requested range.

22001 - Guard Pane - Large Collet The guard pane is made from Lexan 9034, a commonly available grade of commercial polycarbonate. This particular pane is designed for the largest range of magnets produced by MAGSEAL held in a 5-inch collet. The location of tool entry ports is arranged to provide OD access at the top as well as ID access at the bottom.at which points the edge breaking stone moves typically from horizontal to vertically down. A side relief is featured on the right side of the pane to allow the chamfer grinding wheel to approach the part. This clearance is kept close to prevent exposing the sharp edge to the operator.

The pane is a machined piece of Lexan sheet already to stated thickness within the specified tolerances. The piece is made square and to size, then contoured by hand or CNC. A pronounced 45 degree bevel is added to these contours to allow the stone more vertical clearance without further exposing the magnet.

22002 - Left Sheathing The left sheathing is a simple piece of 6061-T6 Al. sheet, 1/8" thick designed to enclose the left side of the guard, deflecting any debris that would have been ejected out of the machine. Ideally, the part would be stamped in a mass production setting, but is easily sheared and then machined to shape. Corner reliefs are featured on all inside corners to prevent the outside corners of the neighboring brackets from interfering with the sheathing fitment. Holes are then drilled and countersunk to provide maximum grip area to the #10 machine screws that hold it in place.

22003 - Frame Top The top member of the frame acts retains the pane from vertical upwards motion in a milled channel expressly for this purpose. Starting from 0.75" square barstock, the member is rough cut to length and then machined to final length. The slot is then milled parallel to the long axis. Next, the part is oriented to drill and tap the pane retainer threaded hole, followed by mounting thru-holes for the top sheathing. lastly, a 45 degree miter is added to the opposite end to mate with the frame side. A final edge breaking, as with all parts, completes the member.

22004 - Frame Left The left side of the frame is constructed of the same material with identical starting dimensions as the top member. The process is also similar, with the same considerations for length and squareness. A channel for the pane is milled, holes for the left sheathing and brackets are drilled and tapped, and finally miters are put onto both ends for alignment.

22005 - Frame Bottom The bottom frame member is constructed in very similar fashion to the top, with an additional milling operation being performed on the pane side of the channel. Material is cleared out of this zone, leaving a back wall tot he channel only at points immediately bordering the ends of the part. This is done to allow the pane to theoretically touch the magnet if desired without interference from the guard. This feature was especially requested by MAGSEAL.

22007 - Left Pin Support Bracket This bracket is designed to interface with a 0.313" diameter support pin. A slot with full radius oriented in the machine direction interfaces with this support pin to carry the weight of the left side of the device, as well as prevent lateral motion and downward force due to operator contact. The screw holes has been replaced with a full bust-out slot counterbore to eliminate a zero thickness edge along the front of the bracket. The bracket is the full length of the sheathing to distribute the weight over the most surface area, as well as to minimize the bending moment exerted on the support pin by bringing the line of action closer to the mount bracket.

22008 - Hinge Joint Bracket The hinge joint is nearly identical to the handle brakcet except that holes and counterbores occur on the opposite side, the orientation is flipped, and it is only as deep in the machine direction as the frame member it is mounted to. The hole used here is a close clearance for 0.375" partially threaded stud. A cap washer will fully constrain the axis of rotation of the guard. Protruding on the opposite side of this bracket is a boss for a 3/16" dowel pin which doubles as a stop preventing rotation of the guard past the vertical and allowing it to rest at this position and to activate a switch which will cause the lathe motor to energize or stop whether the guard is down or up, respectively.

22009 - Knob Handle This handle is a subassembly composed of three off-the-shelf components: a rubber threaded machine knob, an unthreaded spacer, and a flat head screw. The screw is countersunk into the left pin support bracket, where it lies flush on the inside surface. The screw protrudes out to the operator side of the device, where the knob is attached to its end to provide a usable handle. the unthreaded spacer is included to offset the knob from the bracket surface, ensuring grip.

22014 - Pane Retainer The pane retainer acts as bearing plate distributing the holding force of the retainer screw onto the pane, keeping it firmly locked in its cavity. This part is of the same material as the sheathing, being either a stamping in a mass-production setting or can be cut out of plate stock for prototyping. A hole is drilled near one corner to allow for the retainer screw, with a radius on the corner being concentric to the same, allowing the retainer to pivot for easy pane replacement. The other corners feature radius' and corner breaks so as not to catch on the pane or frame during operation, as is the general practice.

22015 - Top Sheathing The top sheathing is made out of the same aluminum sheet as the left sheathing, and would again be stamped if made en masse. The operations are similar albeit more complicated, with special contouring being made to relieve the chamfer grinding wheel when installed. The sheathing is bent so that this one part encloses both the top and right side. the grinding wheel relief is designed so that this constant relief will be suitable for all sizes of parts to be turned on the machine.

22016 - Pivot Beam The pivot beam is manufactured from a rectangular block of steel, one inch tall and 3/4" wide. A slot of width 1/2" and depth 1/4" is cut into one side, creating a prismatic shape that can be easily clamped by both halves of the beam clamp. A hole is made in the forward end of the beam for the partially threaded pivot pin. Directly underneath is a threaded hole for a stop screw, which by way of the pivot pin, prevents rotation past the vertical. There is also provision on the side for mounting of the guard switch, which requires two #2-56 threaded holes.

22023 - Mounting Bracket The mount bracket is a block of aluminum with a large slot cut on its right side to allow the passage of the pivot beam. Around this slot are three counterbored holes for #10-24 screws. These screws affix both halves of the clamping mechanism, rigidly attaching these components. A hole is provided on the far left end for the support pin, left undersized to allow for a press fit. For added security, there is a shallow set screw hole directly above. Immediately below is a large chamfer so that the bracket will not intrude into the path of the existing motor drum switch.

22024 - Beam Clamp The beam clamp is the outwad half of the clamping mechanism designed to hold the pivot beam at an adjustable machine direction extension. The part is made from a 2" square extrusion of aluminum, with slots milled to match the cross-section of the pivot beam, also allowing some clearance. In the middle is a threaded hole for the adjustment knob to engage with, and immediately above and below are clearance holes for screws holding the two clamp halves together, thus forming a rigid clamp unit. Where the threaded hole would meet the pivot beam, a counterbore is provided for a buffer to distribute the clamping force over a larger area and to prevent marring the pivot beam surface. Lastly, holes are drilled and tapped to allow mating with the mount bracket and rigid attachment thereof.

22025 - Clamp Backer The clamp backer is the second half of the clamping unit, made of the same material and in the same general shape. With a broad slot to encompass the remainder of the pivot beam shape, there are threaded holes for the mating screws that were drilled and counterbored in the beam clamp. There is also material cleared out from the reverse side where the backer would interfere with the lathe bearing housing. Lastly, there is a single threaded hole for attachment to the mount bracket, so that there is a combined three point attachment of the clamp unit to said bracket.

22028 - Adjustment Buffer This buffer is a simple piece of turned 1/2" aluminum rodstock, with material shaved from its diameter so that it may freely fit into a 0.500" counterbore. It is approximately 0.10" in thickness, squared and polished on both faces so that the full face surface may be brought to bear on the pivot beam. Its primary role is to distribute the adjustment screw force over a wider area and by way of a softer material to prevent marring of the beam.

11.3 Hardware

As with any assembly, hardware plays a critical role. Avant guard is no exception. The guarding assembly requires forty one pieces of hardware to fully assemble.

Team 22 chose to use 18-8 stainless steel hardware. This decision was made for many reasons. The main reason being 18-8 (similar to that of 316L) has great corrosion resistance properties. The team felt that while corrosion resistance was not going to play that much of a factor in the machined parts, as it did not matter if they showed some signs of corrosion, it would for the hardware. The team did not want the fastener heads or threads to strip due to corrosion.

The reason is if they did it would be extremely difficult if not impossible to remove them and replace parts if necessary. If this were to occur it would prevent MAGSEAL in the future from making any changes to the guarding assembly.

11.4 Mechanical Drawings

Mechanical drawings are provided for reference in the Appendix. A custom sheet format was created by the group for consistency and professionalism, as well as a simple numbering system to link parts to drawings in concise fashion. Industry standard dimensioning schemes were used throughout, gleaned from extensive experience reading and creating industry-level technical drawings. Geometric tolerancing (GDT) was used when necessary according to ASME Y-14.5-2009, a standard for GDT. Standardized hole and weld call-outs are utilized where applicable. Please refer to the Appendix for the complete set of drawings (See Appendix 22.1)

12 Engineering Analysis

12.1 Pane Analysis

With the pane that protects the operator from both flying chips and more vitally from potentially serious injury, it being fail proof is critical to the entire project. Due to this an in-depth engineering analysis was done on both the pane and the parts that retain it in place. Numerous failure cases are discussed in detail below. The analysis was done using the equations using equations in Shigley's Mechanical Engineering Design (Budynas and Nisbett [26])

12.1.1 Case 1: Shear Causing Failure of the Retainer

The retainer was the first part of the design that underwent analysis. This was done to insure that the retainer that prevents the guard from slipping past a point (as shown below in figure 54) has a high enough factor of safety that forces in typical operation would not cause the retainers to shear.

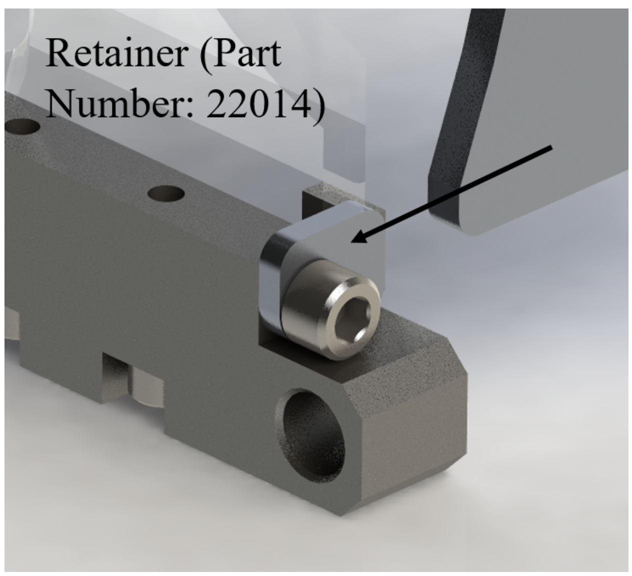


Figure 54: Diagram of Pane Retainer and Case 1: Shear Causing Failure on the Retainer

To calculate forces that would be required to shear the retainer, the shear area (A_s) had to be determined. This was found using equation 1.

$$A_s = 0.50in * 0.125in = 0.0625in^2 \tag{1}$$

With the retainer being made from the material 6061-T6 Aluminum, the yield stress (σ_y) is approximately equal to $35ksi$. (Hibbeler [27]). With this being the yield stress, the shear stress (σ_s) for this material is equal to $17ksi$ (Hibbeler [[27]])

It was decided that since the parts could not fail, regardless of the condition during normal operation, or during conditions resulting from failure of the collet system, such as loss of grip, a factor of safety (N) should be 2. The force per retainer for this factor of safety was then solved for using equation 2.

$$N = 2 = \frac{NF}{A_s} = \sigma_s \tag{2}$$

The force required to cause failure was found to be $531.3lb_f$ per retainer. This value is well above any conditions that would be seen in operation of the guard. Team 22 decided that due to this value being so high the area of the retainers was acceptable.

12.1.2 Case 2: Screw and Joint Separation

Another failure situation occurs when the screw separates from the joint. This occurs when the retainer has taken all the potential force that it can possibly take thus the entire load is transfered to the screw. Table 15 shows the values for the fastener that is used to hold in the retainer to the frame (this is shown in 55)

Bolt Characteristic	Value
A_t	$0.0364in^2$
S	$33ksi$
E	$10,000ksi$
D_{shank}	$0.375in$
D_{thread}	$0.25in$

Table 15: Characteristics of a $\frac{1}{4} - 28$ UNF Socket Head Cap Screw

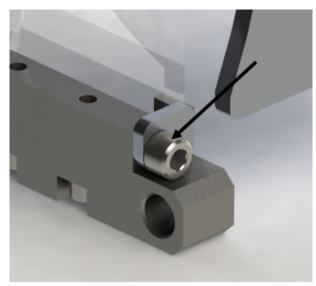


Figure 55: Separation of the fastener from the joing due to applied force

Just as with the retainer the factor of safety for the joint (N_j) for the fastener was set to be two. The equation used to solve for this factor of safety is shown below [3] (Budynas and Nisbett [26]).

$$N_j = 2 = \frac{F_i}{p(1 - C)} \tag{3}$$

Where the pre-load of the fastener (F_i) is equal to:

$$F_i = 0.75F_p = 0.75A_tS_p \tag{4}$$

For this equation, A_t represents the area of the threads, while S_p

And where the fraction of the load carried by the bolt (C) is equal to:

$$C = \frac{k_b}{k_b + k_m} \tag{5}$$

Where k_b represents the bolt stiffness factor and k_m represents the member stiffness factor.

To solve for k_b the following equation was used:

$$kb \approx k_t = \frac{A_t E}{l_t} \tag{6}$$

l_t represents the length of the thread. This value was found using the following equation.

$$l_t = h + \frac{d}{2} \tag{7}$$

Using this equation the bolt stiffness factor for the fasteners utilized in this location was found to be 4222 KIP/in. To find the stiffness of the member (the retainer is considered the member) the following equation was used:

$$k_m = \frac{0.5744\pi E d}{ln(\frac{(1.155t+D-d)(D+d)}{(1.155t+D+d)(D-d)})} \tag{8}$$

Using this equation the member stiffness was found to be 8056 KIP/in.

12.1.3 Case 3: Failure of Pane Bearing on Retainers

In addition to causing a shearing stress on the retainer, a lateral force creates a compressive bearing stress on the pane itself, localized to the area in contact with the retainer, as visible in Figure 54. The dimensions of this area consist of the full pane width of 0.25" extending the distance the retainer is in contact with the pane, or 0.50". Thus,

$$A_b = 0.25\text{"} * 0.50\text{"} = 0.125\text{in}^2 \tag{9}$$

where A_b is the bearing area. For Lexan 9034, the pane material, σ_{ult}, or the ultimate tensile strength, is approximately equal to σ_y, or the yield strength of 9.0ksi [28]. Thus the following equation can be written governing the maximum lateral force that can be applied to the pane before localized failure at the bearing points occurs, using an FOS $N = 2$.

$$\frac{NF}{A_b} = \sigma_{ult} \Rightarrow F = 562.5\text{lbf (per retainer)} \tag{10}$$

From this equation and solution, it can be seen that the system will fail from a lateral load first at the retainer, as this component has the least allowable force. This is desirable as the retainer is an easily replaced, cheaply manufactured component, whereas the pane and frame are much more complex and expensive to manufacture.

12.2 OSHA Requirements

Compliance with OSHA standards proved to be critical to Team 22 throughout the machine guarding project.

While OSHA does not have any specific standards for lathes, they do have standards to cover general machine guarding. All components of the machine guard had to be compliant with OSHA Standard 1910.212 (OSHA 1910.212 [10]). Sections of the standard that the guard must apply with are discussed in detail below. The entire standard can be seen in appendix B 22.2.

12.2.1 1910.212(a)(1) Compliance

The standard states in section 1910.212(a)(1), "Types of guarding. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by the point of operation, ingoing nip points, rotating parts, flying chips, and sparks. Examples of guarding methods are barrier guards, two-hand tripping devices, electronic safety devices, etc." (OSHA 1910.212 [10])

Team 22 meets this standard through its current design. The design protects both the operator and those in the surrounding vicinity of the machine, from both chips and sparks flying to the potential of the magnet becoming a projectile. As stated in the standard, the guard could be considered a barrier guard with an electronic safety device.

12.2.2 1910.212(a)(2) Compliance

This section of the standard states "General; requirements for machine guards. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard" (OSHA 1910.212 [10])

The design detailed in this report complies with this section of the standard. The guard is permanently fixed to the machine and cannot be removed.

12.2.3 1910.212(a)(3) Compliance

This section of the standard has multiple parts. This section discusses the operation of the guard at the point of guarding. The subsections that make up this section are discussed below.

12.2.3.1 1910.212(a)(3)(i)

This subsection states "Point of operation is the area on the machine where the work is actually performed upon the material being processed" (OSHA 1910.212 [10])

Team 22's guard shields the operator at the point at which the de-burring and chamfering operation occur. Team 22's guard goes one step further than this section requires. The entire operation is performed while the guard is in the down position.

12.2.3.2 1910.212(a)(3)(ii)

This subsection states, "The point of operation of machines whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefor, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle." (OSHA 1910.212 [10])

The guard designed protects the operator from being lacerated by the part which can occur at the beginning of the operation when there is a sharp edge on the part. The pane (part number 22001 and shown in drawing 72) art during the operation and restricts the operator from having any body parts within the danger zone.

12.2.3.3 1910.212(a)(3)(iii)

This subsection states "Special hand tools for placing and removing material shall be such as to permit easy handling of the material without the operator placing the hand in the danger zone. Such tools shall not be in lieu of of other guarding by this section, but can only be used to supplement protection provided." (OSHA 1910.212 [[10]])

The guard allows for the operator to use the required stone hand tool through a hole in the guard. This is shown below in figure 56.

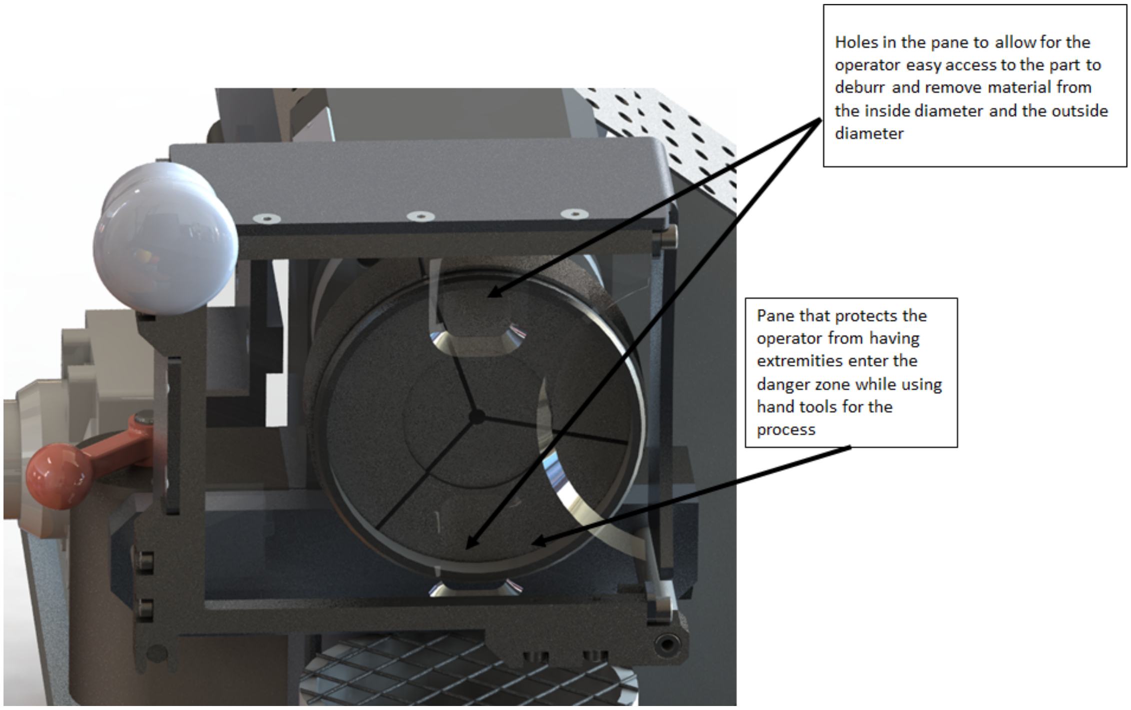


Figure 56: Diagram of ability of operator to use hand-tools to remove material from the magnet

As seen in the image the pane allows for the full use of the required hand tools for removing materials. The pane prevents the operator from placing his hand in the danger zone.

12.2.4 Summary on Compliance with OSHA Standard 1910.212

To summarize, Team 22's design meets or exceeds all criteria defined by OSHA standard 1910.212.

12.3 Corrosion Resistance

While the guard is being placed in a somewhat harsh environment (being a machine shop), Team 22 determined through discussions with the engineers at the MAGSEAL corporation not to worry about corrosion on any custom made parts. Team 22 did decide though that it was to its advantage to use stainless steel hardware as any potential corrosion to the hardware would make any modifications to the guard down the line extremely difficult.

To summarize, corrosion of the guard assembly was not a factor in the design.

13 Build and Manufacturing

13.1 Proof of Concept/Prototype

An additive manufactured full-scale prototype of the complete guard assembly was created, faithful to all drawings presented in the Appendix. Due to the inability of the frame material to be properly tapped for screws or welded, in place of actual fasteners, glue was used to hold the frame together. An image of the prototype follows.

Figure 57: Front Perspective View of Prototype

13.2 General Remarks

As can be seen from the figure, all parts fit and function as intended. The pane fits into the frame smoothly and snugly, with no play or wobble. The grinding wheel relief in both the pane and sheathing leaves a generous amount of clearance for the chamfering wheel when approaching at either a 30 or 45 degree angle.

13.3 Verification of Function

When viewed in Solidworks using the provided faithful 3-D replica of the edge breaking machine, the function of the guard becomes fully realized. Using a true-to-life model of the largest magnet size, designed to fit into a supplied 5-inch step chuck, the guard allows full clearance for the grinding wheel when set to any angle in the stated range. Special attention is given to troublesome points of contact on the grinding wheel housing and support base, but clearance is maintained even at these points of closest approach.

The ability of the guard to rotate without contact with the collet or part was also verified. Of particular design concern was the extent to which material was cleared from the pane retention slot on the bottom frame member, and the extent to which this affected the rigidity of the pane when seated. Using the 3-D printed prototype, it was noted by the team that even with material substantially weaker in flexure than the specified steel and polycarbonate, the pane was seated firmly in the frame with no tendency to bow or buckle. It was noted that the friction of the pane in its slot actually worked to increase the overall frame rigidity by acting as a secondary member, thus allowing stress flow in a closed loop and drastically increasing stiffness.

When viewed in the context of the complete Solidworks machine assembly, the guard was able to rotate about the axis of the hinge bracket without a single part coming in contact with either collet or part. the position of this axis was set to a point that allowed ample clearance at the top of the guard for maneuvering of the edge breaking stone at the top of the work, and enough clearance at the bottom to allow the operator to view the entire thickness of the part for inspection. Under these conditions, the guard is allowed to move in the machine direction until it would theoretically lie coplanar with the part and still not interfere. The frame is relieved at all points transcribing the collet area so that ample clearance is maintained even at the closest approach, in the event the guard flexes on its supports.

The depth of the guard sheathing was verified in Solidworks to both never interfere with the machine controls at any point during its rotation and to enclose even the thickest collet / part combination. Using a model for the smallest available collet, which also protrudes the least from the spindle nose in the machine direction, a worst case scenario for depth clearance was set up and tested. The result of this test is that no point of the guard ever encroaches on the plane of the machine control switch in any case whatsoever. Using models for the largest collet and adding to this the maximum part thickness, it was also verified that the depth of sheathing would never in any case leave the collet or part exposed from any direction in front or on the operator's side of the machine (i.e., any point where the operator would be positioned during normal operation). Thus the spatial validity of the guard was confirmed.

13.4 Meeting the Design Specifications

As evident in Section 6, for the guard to fulfill the solve the problem as defined, it must meet all relevant specifications. With regards to function, as described in Subsection 6.2 enumerating the current requirements of the device, the design meets these at all points except for those acknowledged for further work in following semester. Notably, the device does fully enclose the entire process as described above, guards all hazard zones as described above, and does not disturb operator grip with his tool or range of motion thereof. When the electronic control aspect of the design is introduced next semester, the guard should not increase cycle time as the time for the operator to disengage the guard is less than the time the lathe spindle takes to wind down, and the motion required to do so replaces the activation of the machine switch. Additionally, the function of the guard as a motor power disconnect when disengaged ensures the operator cannot ignore the device, as proper use of the guard is required to allow the edge breaking machine to function at all.

With regards to physical constraints, as already specified, the guard allows the maximum part envelope to be contained without interference. Additionally, with the position of the pivot and support pins, the guard is contained entirely on the operator's far side when in the disengaged position. This position also guarantees part clearance for removal, another specification. Windows are provided for deburring stone access as specified, the height and width of these windows being at least twice the maximum stone envelope, ensuring both access and range of motion while still ensuring safety by disallowing the tool and finger room to enter the hazard zone at once. The actuation method is manual as indicated by the prototype's use of a handle for manipulation, and the simple pivot operation, particularly when using gasket bearings on the pivot bar, is practically impervious to dust and gives excellent service life.

With regards to budget, the mass-machining analysis in Subsection 3.3 shows a per unit cost of approximately $215.00 to construct, significantly below the prescribed budget of $2,000.00. Taking into account markups were a machine shop to produce the guard and reasonable estimations for the cost of the desired future electrical components, the cost of a functioning unit would still never approach the budget allowance.

In summary, the guard as designed by the team fully meets all currently relevant specifications, with the remainder to be addressed in the following semester, though it is worthy to note that these are minimal in nature.

13.5 Manufacturing the Final Product

13.5.1 Raw Materials

The raw materials used consisted of stock 6061T6 Aluminum, Low Carbon Steel, and Polycarbonate. Shown below is a list of the raw materials that were used. All of the raw materials were sourced through McMaster-Carr.

Number of Pieces	McMaster-Carr Part Number	Item Description	Team 22 Part Number
1	8975K224	6061 Aluminum, 5/8" Thick x 3" Wide, 1/2 Feet Long	22007
1	90145A605	18-8 Stainless Steel Dowel Pin, 5/16 Diameter, 5" Long	22026
1	8975K619	6061 Aluminum, 1/2" Thick x 1-3/4" WideX 1ft	22023
1	9517K564	Tight-Tolerance Low-Carbon Steel Bar, 3/4" Thick, 1" Wide x 1ft	22016
1	8975K941	6061 Aluminum, 7/8" Thick x 2" Wide X 1ft	22023, 22025
3	9517K481	Tight-Tolerance Low-Carbon Steel Bar, 3/8" Thick, 3/4" Wide x 1 Ft	22003, 22004, 22005
1	9517K542	Tight-Tolerance Low-Carbon Steel Bar, 5/8" Thick, 3/4" Wide	22008
1	89015K222	6061 Aluminum Sheet, 0.09" Thick, 4" x 24"	22015
1	60975K86	Comfort-Grip Plastic Ball Knob with 3/8"-16 Threaded Hole, 1-7/8" Head Diameter	22009
1	92196A542	18-8 Stainless Steel Socket Head Screw, 1/4"-20 Thread Size, 1" Long	22029
1	8975K577	6061 Aluminum, 1/8" Thick x 1/2" Wide x 1ft	22014

Table 16: Stock Raw Materials Used to Manufacture Parts

13.5.2 Aluminum and Steel Components

Machining of most metallic components was accomplished through milling, the shapes of most components being prismatic in nature. When possible, large diameter carbide end mills were utilized for maximum material removal rate and efficiency. Considerations especially for aluminum components include the following:

- Two-flute cutters were preferred due to additional chip clearance. In soft materials such as aluminum, excessively high cutting forces develop as chip size decreases, so it is actually much more efficient to take large cuts with heavy feeds per tooth.
- Spray coolant of the soluble oil variety was used extensively as aluminum is a "sticky" metal to cut, easily welding to the cutting edges of end mills and drills. A soluble oil was used to disperse heat through evaporative cooling and for its low viscosity, which allows the oil to flow more readily into the cut.
- Higher surface speeds were used with aluminum, which are allowable because of its relative softness and the heat resistance of carbide. Finishing cuts in particular utilized high surface speeds with low feeds per tooth to leave extremely smooth surfaces, a requirement on some parts for proper function.

Steel components were machined in similar ways, albeit with necessarily lower surface speeds, comparable but generally smaller feeds per tooth, and the use of a thicker cutting oil due to its lubricity, especially when drilling and tapping as was often done.

Several special tools were utilized for several of the parts. For the critical bevels on the frame members, controlled by a parallelism tolerance, a special chamfer cutter was purchased. Taking advantage of the inherent milling machine spindle-table alignment, this cutter was the most accurate method available to the team at the time to create these chamfers. A special size ball-end mill was also purchased to create the groove for the support pin in its bracket. This size was not stocked at the machine shop. The mill was also coated carbide, which gave us a finer finish on this critical surface.

13.5.3 Guard Pane Machining

The polycarbonate pane was machined by Santiago Sanchez at Magseal using a manual milling machine. The rectangular slots were milled with end mills and chamfered with a countersink. The large radiused bevel was created using a specially ground fly cutter set at the correct radius. Due to the limitations of manual milling, this process inevitably leaves clouded chamfered surfaces, with the only mitigation being machining under flood coolant, typically with a CNC machine to control feeds and speeds to those uniquely suited for milling plastics.

13.6 Electrical

A simple electrical relay control circuit was developed to link the energization of the lathe motor with the engagement of the guard. A schematic of this circuit is shown below.

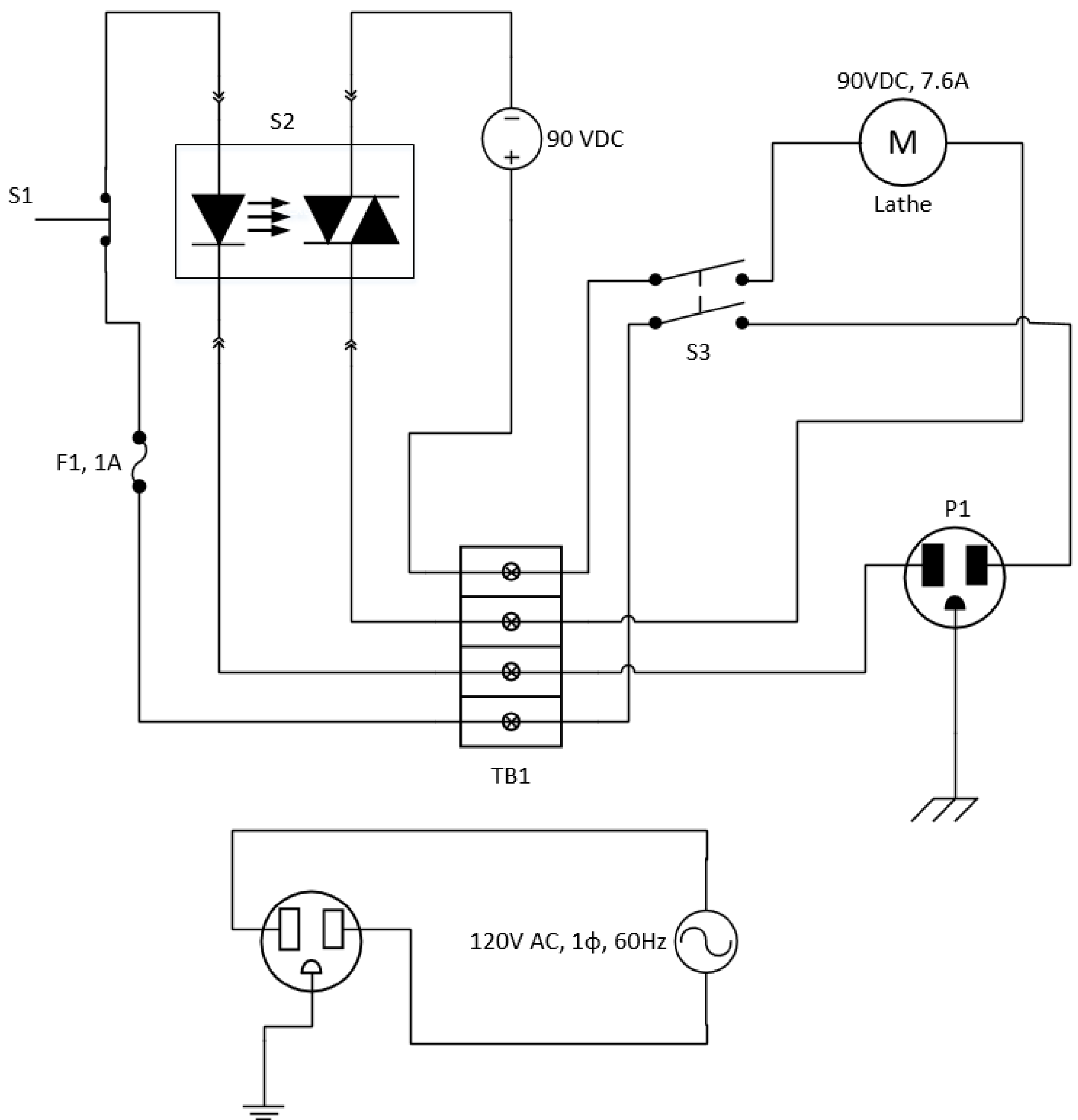


Figure 58: Schematic of Electric Control Circuit

The switch S1 is mounted to the pivot beam, utilizing the stop pin to actuate it. By connecting one of the hot legs of the AC control circuit to the switch, through an in-line fuse, and then to a control terminal of the relay, The energization of the relay was made to follow the engagement of the guard. When closed, the relay would allow the load current to flow in the relay. When open, the relay would open, interrupting the load current.

The control and load circuits were also wired to independent channels on the existing motor drum switch, so that by deactivating this switch, both the control and load circuits would be interrupted. This is allowable because at no point would the load need to be connected to the relay if the control circuit was interrupted, nor would the control circuit need to be connected if the load was interrupted elsewhere in the line. This allows the operator to shut down the entire electrical part of the machine with one switch, a desirable feature.

13.6.1 Assembly of Electrical Components

Electrical components were assembled according to all trade practices on the subject, including using grounded plugs. In the case of the control circuit, where the relay uses the voltage difference between hot legs and does not require grounding, the ground from the receptacle was connected to the machine chassis, a standard practice. All connections were housed in a terminal box so that accidental contact could not occur. All terminal connections were also made using crimped spade connectors, which make modifications and disassembly easy. The relay was mounted to a heat sink rated for continuous usage, and both the terminal box and relay were screwed to a polycarbonate mounting plate in such a manner as to promote proper air flow through the heat sink. The heat rise of the relay was compared to safe operating temperatures for the polycarbonate so that overheating is a non-issue. The panel is designed to be mounted out of the way, possibly underneath the machine, where air flow is generally unrestricted and it is out of the way of tampering.

13.7 Installation

The guard was mounted to the machine using socket head cap screws. A diagram of the bolt pattern and mounting configuration is shown below. The mounting utilized 3, 5/16 socket head cap screws.

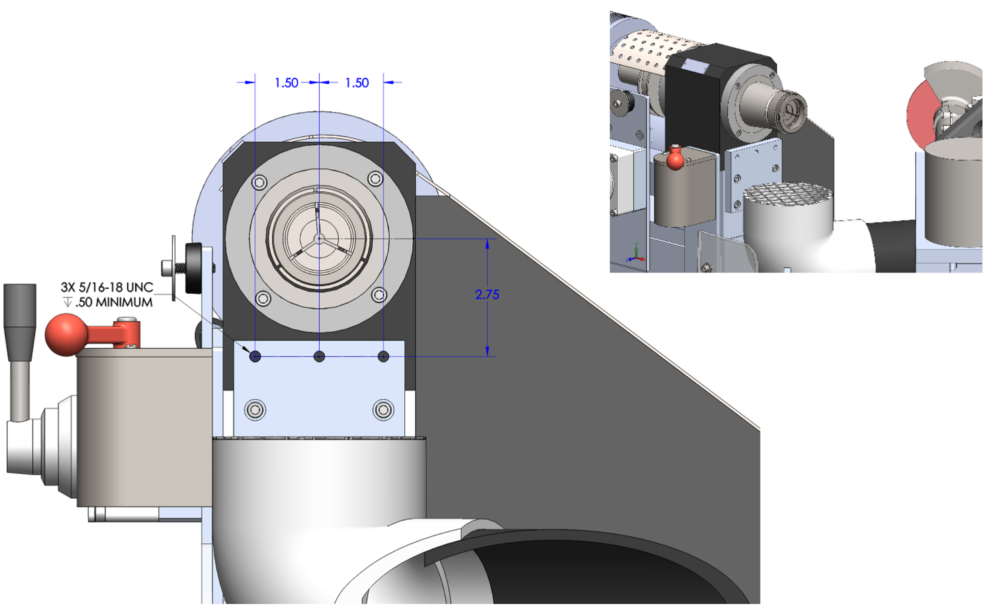


Figure 59: Mounting Bracket

Shown below are some images of the machine with the guard mounted.

The photos on the top show the guard mounted and it being in the engaged position. The two photos on the bottom show the guard in the disengaged position.

Figure 60: Guard Mounted to Deburring and Chamfering Machine

14 Testing

14.1 Testing Overview

Team 22's test plan consisted of various tests that were conducted to ensure the maximum efficiency, reliability and sustainability, as well as ensure that the product meets all OSHA Standards for machine guarding safety [10].

For the guard to be considered effective it had to fulfill all requirements specified in the problem definition1.3.2. The main objective of the device is to protect the operator from accidental injury while allowing the edge breaking and chamfering operation to be performed unhindered. These requirements are more deeply detailed in the design specifications6. The design specifications depict exact measurements and tolerances that are involved in this procedure that need to be kept in mind when designing the guard. The numerical requirement section encompasses all numerical values involved. They also contain a financial condition and targeted life cycle of the product specified by the company. A Quality Function Deployment diagram was created to list the physical requirements of the device and rate their importance7. Using this engineering tool the team decided which aspects needed more attention than others. A project plan was created to map out the work that has to be done over the period of the course to make sure the project is on schedule and keep the company informed.

While the idea of this project could be applied to several machining devices, this guard is designed to fit and function properly for this one specific machine and operation. The front panel is designed explicitly to allow the edge breaking process performed on MAGSEAL seals. In addition, the team designed additional parts to accommodate other aspects of the process, such as the vacuum tube that is mounted underneath the lathe to remove swarf created from the deburring and chamfer operations.

Through various tests, imperfections in the design were discovered and modifications were made accordingly. This device had to be comfortable and practical for the operator to use. These aspects were tested through installing the guard on the lathe and allowing the operator use it for an extended period of time. The operator then reflected on the functionality, and gave additional input on potential ideas to improve performance. As the guard will be used frequently the team had to consider long term effects it might undergo and prepare accordingly.

14.1.1 Test Staffing

The position of the guard will be electronically connected to the switch activating the lathe. When the guard is disengaged the lathe will not be allowed to activate. Once the guard is securely engaged the lathe will be able to receive power. This electro-mechanical engineering control was put into effect to guarantee the guard will be used and impossible to ignore. The team believes that this method of activating the lathe is reliable as well as efficient. The lathe must be stopped three separate times. Once to insert the part, once to flip the part over, then finally to remove the part. During each of these transitions the guard must be up because the operator must directly contact the part. At no point would the guard need to be disengaged while the lathe is running, thus the guard position controlling the operation of the lathe is highly effective and also second nature.

The guard handle is located in close proximity to the previously used drum switch, performs the same function at the same points in the operation, and is designed to be actuated by the same hand. Additionally, no other part of the process is changed by the installation of this guard. Thus, minimum training will be required to use this device.

14.1.2 Team Member Testing Responsibilities

The testing effort was lead by Team 22's Lead Engineer Jared Zeitlin. The specific tests were be performed by both team members and members of the MAGSEAL team.

Jared coordinated all efforts relating to setting up testing and assigning responsibilities to team members. He also ensured that all testing objectives are met and along with Jason Epstein, the team's Design and Function Engineer will prepare all deliverables at the conclusion of testing. Jared was responsible for ensuring the safety of all during the tests and had the final say whether or not a test should go ahead as scheduled. In addition he coordinated with any consultants, or technicians for any outside training on equipment that was required.

Team 22's Lead Design Engineer Dillon Fontaine will specified test requirements relating to the physical design of the device and ensuring structural integrity. Dillon oversaw all dimensional test items to ensure the tolerances of each part correspond to the parts design dimensions.

Team 22's Function Engineer Jason Epstein was responsible for ensuring that all testing relating to all the functional requirements were met. In addition Jason worked with Jared to ensure that all work relating to OSHA compliance is complete.

14.1.3 Environmental Requirements During Testing

14.1.3.1 General Environmental Needs

Team 22 did not require any specific environmental needs for testing requiring operator feedback or quantitative tests that occur on the shop floor.

14.1.3.2 Specific Environmental Requirements During Testing

Team 22 required the use of MAGSEALS clean inspection room for ensuring that all dimensions on the machined design meet the requirements specified on the mechanical drawings. Team 22 made use of MAGSEALS optical inspection equipment within its clean room.

The pane opacity tests also required use of the clean room.

Cleaning of the device for inspection of parts after being in service required a disposal method for the metal swarf produced by the operation as well as the solvents used to clean the device. Additionally, the polish used to test resurfacing of the pane requires its own disposal method and considerations for application and removal of excess polish. These materials may be volatile or flammable in nature, should be kept separate of each other when disposed, and must be disposed of in accordance to the company's legal obligations for hazardous or industrial waste.

14.1.4 Suspension Criteria and Resumption Requirements

Testing occurred as scheduled as there was no structural failure, the operator was never in danger, and no component of the guard came in contact with the machine with the exception of the guarding pane, which may made superficial contact without serious harm to the device or parts.

In the event that any of these did occur, testing would have been paused, an incident report filed detailing observations from all personnel present, and the team would have reconvene to determine the cause of the failure.

In the event of structural failure, corrective actions would have be taken and further simulations run outside of service to ensure that the new structure is capable of surviving. Had any unintended part contact resulted from the lack of rigidity, measures would have been brought to the redesign phase to strengthen the frame and testing restarted on the new iteration. Unintended part contact occurring as a result of extreme abuse or failure of the lathe itself was not considered a guard failure, and as a result no changes were made to the designn. Unintended part contact due to low clearances on unadjustable parts did not require attention. Unintended part contact due to low clearances on parts that were adjustable simply required adjustment at which point testing resumed as normal, assuming no damage has occurred to the guard.

Once changes have been made to resolve the issue, test data with dependencies on the changed components will be discarded and testing resumed until all components had been tested according to the test matrix, Section **??**.

14.2 Test Matrix

Team 22 then went ahead and designed a comprehensive test matrix. This matrix details each of the elements that team 22 tested and was part of the deliverables that was presented to MAGSEAL upon completion of the project.

The test matrix breaks down testing into four categories. They include, dimensionality (see section: 14.3.3), functionality (see section 14.3.4), durability (see section 14.4), and ergonomics (see section: 14.5.1). These are discussed more in detail in

Test Number:	Components Involved:	Feature Tested:	Instrument Used:	Repetitions:	Statistics to be Collected:	Tester:	Date:	Result:
Dimensionality:								
1	22003 FRAME TOP, 22005 FRAME BOTTOM	Linear outside distance between 22003 and 22005 at the far right ends when assembled	Calipers, CMM	5	Average, Std. Dev.			
2	22004 FRAME TOP, 22005 FRAME BOTTOM	Linear outside distance between 22003 and 22005 at the far left ends when assembled	Calipers, CMM	5	Average, Std. Dev.			
3	22023 MOUNT BRACKET, 22026 SUPPORT PIN	Vertical deflection of 22026 in the bracket under the application of 20lbs of downward force	Instron Tensile Machine	2	Average			
4	COMPLETE ASSEMBLY	Vertical deflection of 22016 assembled under application of 20lbs downward force to 22019	Instron Tensile Machine	2	Average			
Functionality:								
5	COMPLETE ASSEMBLY	Minimum distance between 22022 and largest collet when guard is brought through a complete cycle	Calipers, manual measurement	10	Average, Std. Dev.			
6	COMPLETE ASSEMBLY	Smallest clearance between part held in largest collet and 22001 to avoid contact when 20lbs is applied downwards onto the guard	Calipers, scale, manual measurement	5	Average, Std. Dev.			
7	COMPLETE ASSEMBLY	Smallest clearance between part held in largest collet and 22001 to avoid contact when 20lbs is applied onto the guard along the machine spindle axis	Calipers, scale, manual measurement	5	Average, Std. Dev.			
8	COMPLETE ASSEMBLY	Smallest clearance between chamfer grinding wheel and 22001 while grinding the smallest part held in large collet	Calipers, manual measurement	5	Average, Std. Dev.			
9	COMPLETE ASSEMBLY	Smallest clearance between chamfer grinding wheel housing and all frame components while grinding the smallest part held in large collet	Calipers, manual measurement	5	Average, Std. Dev.			
10	COMPLETE ASSEMBLY	Time for each part in a batch of ten parts	Stopwatch	2	Average, Min, Max, Std. Dev. of times with and without guard			
Durability:								
11	22019 PIVOT PIN, 22022 0.375-16 LOCKNUT	Is 22022 loose enough to move by hand?	None (observed, tested in service)	Once every 250 cycles for 1500 cycles	Pass/ Fail (One failed trial fails the entire test)			
12	COMPLETE ASSEMBLY	Deviation in clearance between 22001 and collet from the value measured immediately after set-up (creep in service)	Calipers, manual measurement	Once every 250 cycles for 1500 cycles, Initial value measured after set-up	Change with time			
13	22001 PANE FOR LARGE COLLET	Deviation in optical clarity of 22001 in service	Opacity meter	Once every 250 cycles for 1500 cycles, Initial value measured after set-up	Change with time			
14	22001 PANE FOR LARGE COLLET	Change in optical clarity after application of plastic polish	Opacity meter	Once every 250 cycles for 1500 cycles, before and after application of polish	Change with time			
Ergonomics:								
15	COMPLETE ASSEMBLY	Distance from operator's left hand rest position to position when guard is fully disengaged (operator reach)	Meter stick	10	Average, Std. Dev.			
16	COMPLETE ASSEMBLY	Can operator's finger enter through 22001 while holding the smallest honing stone, working through an entire cycle?	None (observed)	5	Pass/ Fail (One failed trial fails the entire test)			
17	COMPLETE ASSEMBLY	Can operator generate correct radii on parts held in largest collet?	None (observed)	10	Pass/ Fail (One failed trial fails the entire test)			

Figure 61: Test Matrix

14.3 Test Items

14.3.1 Test Plan Identifer

The test plan is not included within this report but shall be referenced throughout this section. The test plan can be found in Team 22's binder as well as on SAKAI.

The test plan document number is: **Test Plan Report - TP-MSAG22-A**.

14.3.2 Features Not Tested

Below is a list of features that Team 22 did not test for as they are not considered critical.

- All dimensions that are not explicitly called out in the above section are assumed to be inspected upon completion of the manufacturing process by the machinist. In addition parts that are found to be out of the tolerances specified are assumed to be rejected and the part is either reworked until it is.

- Corrosion resistance will not be tested for as it is not a critical factor for the function of the guard, but merely an aesthetic one. The customer does not require for the guard to be corrosion resistant, as it is not going to be in a harsh environment. The team does not anticipate for corrosion to be a factor during the lifespan of the product.
- Impact of an ejected collet. This is cost prohibitive. This type of failure is too variable, the debris can hit with widely varying forces, shapes, and angles of attack to the point where testing would not give useful results as a worst case scenario is impossible to estimate. Failure of this kind is outside the scope of this guard.

14.3.3 Dimensionality

Team 22's design had numerous tolerances and geometric dimensioning call outs that were critical to the operation, and success of the guard. With all manufactured parts tolerances must be accounted for as no parts can be manufactured to perfection. To call out dimensional tolerances, Team 22 used the rules of geometric dimensioning and tolerances outlined in ANSI Standard 14.5. A list of all critical tolerances and dimensional features that must undergo inspection is included in the dimensionality section of the test matrix (figure: 61, they are also listed below). The drawings with the specific callouts are shown in the appendix respectively.

Numerous methods were used to ensure dimensional accuracy of the critical tolerances listed above. The most right column on the test matrix details the instruments and or tools that were used to perform the necessary inspections. (see figure 61)

Although each individual piece was designed on SolidWorks to fit together perfectly, there was no guarantee that the parts will work together as smoothly once actually created. It is extremely important that every component is as secure as possible. Any small amount of movement within pieces that aren't dimensionally correct will be a huge weak spot once the guard is attached to a lathe that is constantly vibrating.

To minimize the amount of slack between pieces the team inspected all measurements of each part several times.

Measurements were taken using numerous different devices to insure dimensional accuracy. Vernier calipers and micrometers were used for every part to get the most accurate readings possible. For parts of the device that required more precision a coordinate-measuring machine (CMM) was utilized.

All test items fall into two categories. The first category is physical dimensions, while the second category is interactions with the operator.

The following list is the physical dimensions that were tested.

- Linear outside distance between 22003 and 22005 at the far right ends when assembled

- Linear outside distance between 22003 and 22005 at the far left ends when assembled
- Vertical deflection of 22026 in the bracket under the application of 20lbs of downward force
- Vertical deflection of 22016 assembled under application of 20lbs downward force to 22019
- Minimum distance between 22022 and largest collet when guard is brought through a complete cycle
- Smallest clearance between part held in largest collet and 22001 to avoid contact when 20lbs is applied downwards onto the guard
- Smallest clearance between part held in largest collet and 22001 to avoid contact when 20lbs is applied onto the guard along the machine spindle axis
- Smallest clearance between chamfer grinding wheel and 22001 while grinding the smallest part held in large collet
- Smallest clearance between chamfer grinding wheel housing and all frame components while grinding the smallest part held in large collet
- Deviation in clearance between 22001 and collet from the value measured immediately after set-up (creep in service)
- Deviation in optical clarity of 22001 in service
- Change in optical clarity after application of plastic polish
- Distance from operator's left hand rest position to position when guard is fully disengaged (operator reach)

14.3.3.1 Dimensionality Test Results

Upon completion of machining, the dimensions listed above were verified and found to be in compliance with the requirements.

14.3.4 Functionality

This guard will be permanently attached to the machine. In addition the guard contains electrical components that activate the machine. This engineering control solidifies that the lathe cannot be used without the guard, resulting in the guard experiencing heavy usage everyday. The goal of this project was not to make a device that gets in the way and does not infuriate the operator.

Using first-hand machining experience taken from some of the team members the guard was designed to be as comfortable and least troublesome as possible. If the comfort of the operator was not taken into consideration the process would surely be impeded by the device.

The guard has been designed to function quickly and effectively in this very swift machining process.

The requirements for the functionality aspects are detailed in the test matrix 61.

14.3.4.1 Reduction of Operator Risk

The chief function of this device is to reduce the risk of an operator injury while performing the deburring process. As such, special holes were made into the guard pane which are the only access points for the operator to contact the part. These holes have been sized to allow a full working range of motion but not so large to allow both a finger and the deburring stone to touch the rotating sharp part. Even with the smallest stones available, the limited opening was designed to cause the presence of the finger to hinder working range of motion, thus isolating the operator from the hazard. Principal testing was carried out to judge the effectiveness of this hole size as it tries to strike a balance between safety and range of motion. Using the results of these tests, the hole size, location, and contour may be adjusted to optimally protect the operator.

14.3.4.2 Impact on Process Time

As with all safety related devices, features must be incorporated that do not obstruct the current process and time. The design incorporates numerous features to ensure that the time to perform the process is not drastically increased. These features are present in both the electronics of the guard as well has the pane that protects the operator. To ensure that the guard does not increase the time it takes to operate the machine, the switch the operator has to toggle has been instituted into the guard. This has two important advantages. The first is that the operator must perform an operation in which the process time is already accounted for, and the second more important is that the operator must lower the guard in order for the machine to power on.

The pane also incorporates numerous design features to not increase process time. With the current configuration of the pane the operator will be able to perform all current functions with the guard in its engaged position. This removes the need for the guard to continuously be raised, and lowered to perform the operation.

14.3.4.3 Time Studies and Analysis

Team 22 needed to prove and ensure that the time to perform the operation does not significantly increase when the guard is used. Safety and increase in process time must be balanced that the benefits gained from the added safety do not decrease the productivity on the manufacturing floor.

Team 22 conducted process time studies using a stop watch. Before installing the guard on the machine, the team took a work order of 20 seals and recorded the time it took for the operator to perform the process for each seal. In addition the time to process the entire work order was also recorded. Data was collected using the form shown below (figure: 62)

TEST FORM - MSAG22-TF.0-(____)

Supervisor to Testing:	
Date:	
Location:	

Test ID#:	Revision #:	Trial #:	Time:	Cycle Number (if applicable):	Instrument Used (Type and Manufacturer):	Result / Statistics:	Comments / Operator Notes:

Figure 62: MSAG22-TF.00-(XXXX) Time Study Test Form

The same study was then be performed using a second work order of 20 of the exact same seals used for the time study before the guard was instituted. For this study team 22 installed the guard. The same form will be used to collect the data.

All data was then entered into Excel where a rigorous statistical analysis will be undertaken. Numerous values will be analyzed, then compared to determine whether or not the guard had a significant impact on the time it takes for the operator to perform the process. These values include but are not limited to...

1. Average time it takes to perform the process
2. Maximum/minimum time it takes to perform the process
3. Standard deviation in time from part to part and all parts together
4. Variance in time from part to part

Upon completion of the statistical analysis team 22 then needed to determine if the increase in process time was significant enough to cause a decrease in efficiency and productivity. An increase in time will then need to be translated into dollars lost over a period of a fiscal year. This value will then need to be compared to the cost of not instituting the machine guard.

Team 22 then analyzed the costs from the safety device not being instituted. These potential costs are detailed more in section 3

Numerous factors play into this. In the case of this machine time lost due to injury has a potential to heavily increase costs. This is due to the fact there there is a single operator that can perform the operation thus the machine is down when that operator is injured. The medical costs of the injury will also need to be evaluated when looking at the potential cost increase if the time of the process increases.

As with all safety devices, the time lost due to increases in process times was also be weighed versus the unethical decision to not guard the machine and risk operator safety. As operator safety is important, and the fact that MAGSEAL wants to retain its employees and keep them happy this will need to be heavily weighed should the process time be drastically increased.

14.3.4.4 Time Study Results

The time study was performed multiple times and in accordance with our test plan.

The results were as follows...

The average time it took to deburr a work order without the guard was 7 minutes and 20 seconds, while the average time to perform the operation with the guarding device in place was 7 minutes and 36 seconds. This is an increase of 3.5%.

The difference in the process time between having and not having the guard is 16 seconds. This time can be considered insignificant. In addition the return on investment (ROI) discussed in 3, must be taken into account. While the process time is slightly increased, thus the cost to perform the operation is increased, an injury resulting could cost alot more then this slight increase.

With all this in mind it is determined that the resulting increase in process time will not cause a substantial enough impact to not guard the machine to protect the operator.

14.4 Durability

14.4.1 Durability and Long-term Stability

The guard must show long term endurance, being used as a permanent attachment to the edge breaking machine. This is a critical customer requirement referred to throughout the design process, and so certain elements must be tested to ensure its durability and longevity.

14.4.2 Endurance of the Pane Material

Tests have been created for the pane, which is subject to large amounts of accelerated grinding dust and chips from the edge breaking operation. The longevity of the pane before its surfaces become too optically opaque for proper operation will be assessed and a model attempted to be quantified that relates this deterioration over time in order to implement a maintenance or replacement schedule. Additionally, a polish designed to fill scratches on the guard pane will be tested at several points to judge its effectiveness in restoring the pane's clarity.

The opacity of poly carbonate is close to a value of one. This means that the guard pane except in the areas in which a chamfer was applied during machining is virtually transparent. (figure: 63)

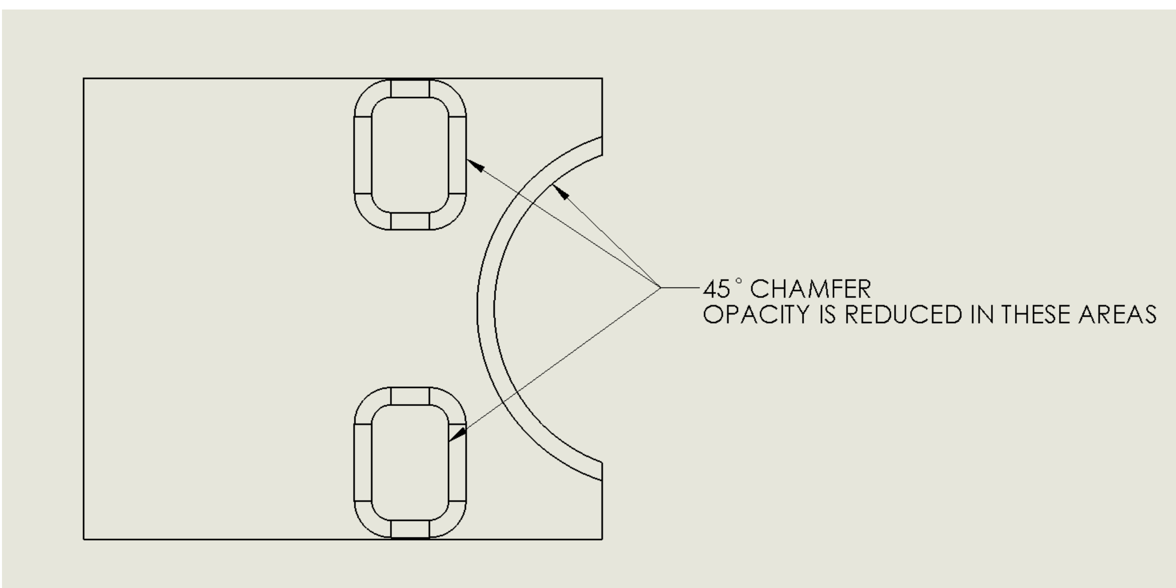


Figure 63: 45° Chamfer Locations Where Opacity is Decreased

Testing of the endurance of the pane due to chip damage was extremely difficult to test as the time period that was allowed for testing was too short to gain accurate results. Over the short test period the opacity of the guard was virtually unchanged. Shall the opacity change substantially over a long period of time the MAGSEAL Corporation can quickly change out the pane.

14.4.3 Vibration Resistance

Resistance to vibration during machine operations will be a factor in the sustainability, and the longevity of the guard. As the guard is being permanently installed on a lathe like machine that runs for the majority of an eight hour shift five days a week, the guard is somewhat susceptible to vibration. This lathe exerts a small amount of vibrational energy that, over longer periods of time, could have adverse effects on anything attached to it. This could act on various different parts of the guard, from the mounting bracket to the frame and everything in between. If any of the fasteners loosen, it will create a chain reaction of the parts they are holding together being able to wiggle around and loosen other parts that they come in contact with. Similarly, once a part loosens slightly it becomes more susceptible to loosening further upon encountering additional vibrations. In order to prevent the internal destruction of the guard, the team must plan for the entire device to be able to withstand vibration. The durability of the guard can be tested by attaching it to the lathe for a period of time and collecting data.

Sensor Kinetics Pro was used gain initial insight into the vibration of the machine. While the vibration of the machine is minimal, any vibration of parts overtime can cause fasteners and assembled parts to come loose, and weaken joints, as well as degrade the functionality of the device. Shown below is a graph of the acceleration data taken by sensor kinetics pro (figure: 64)

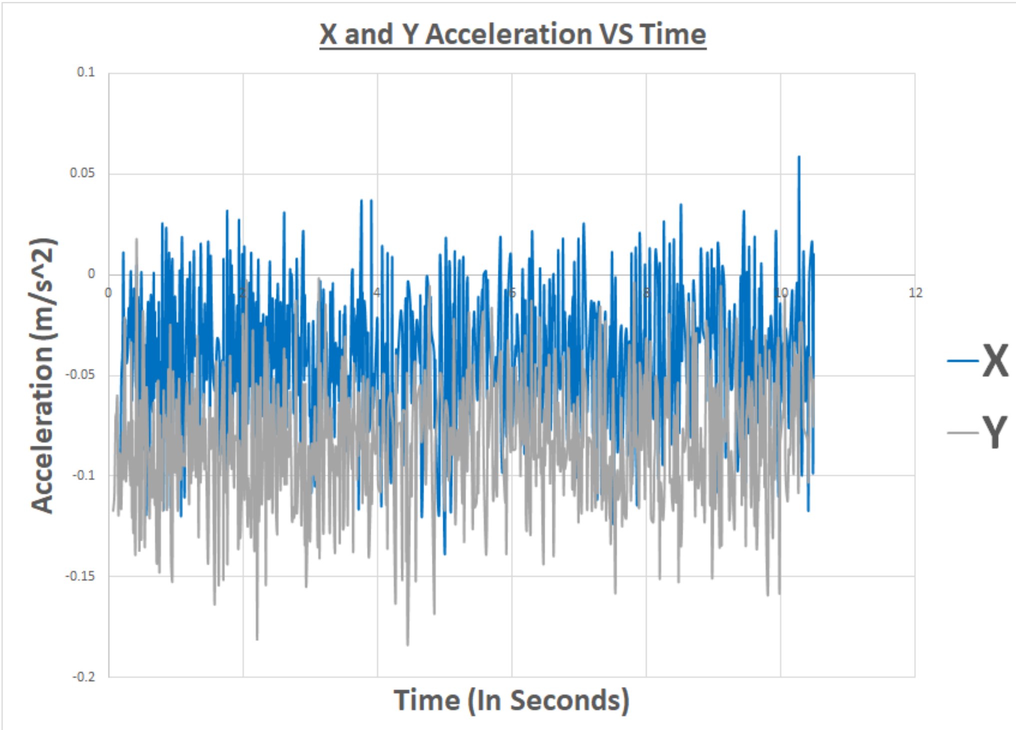


Figure 64: X and Y Acceleration Data VS Time

The graph above shows that the acceleration due to vibration is minimal and is within acceptable limits. For an extra level of retention, blue locktite will be added to all fasteners. This will ensure that vibration will be no factor and won't degrade the integrity of the guard.

The G-Force on the guard was also logged using sensor kinetics pro. Shown below is the G-Force due to vibration on the guard VS time.

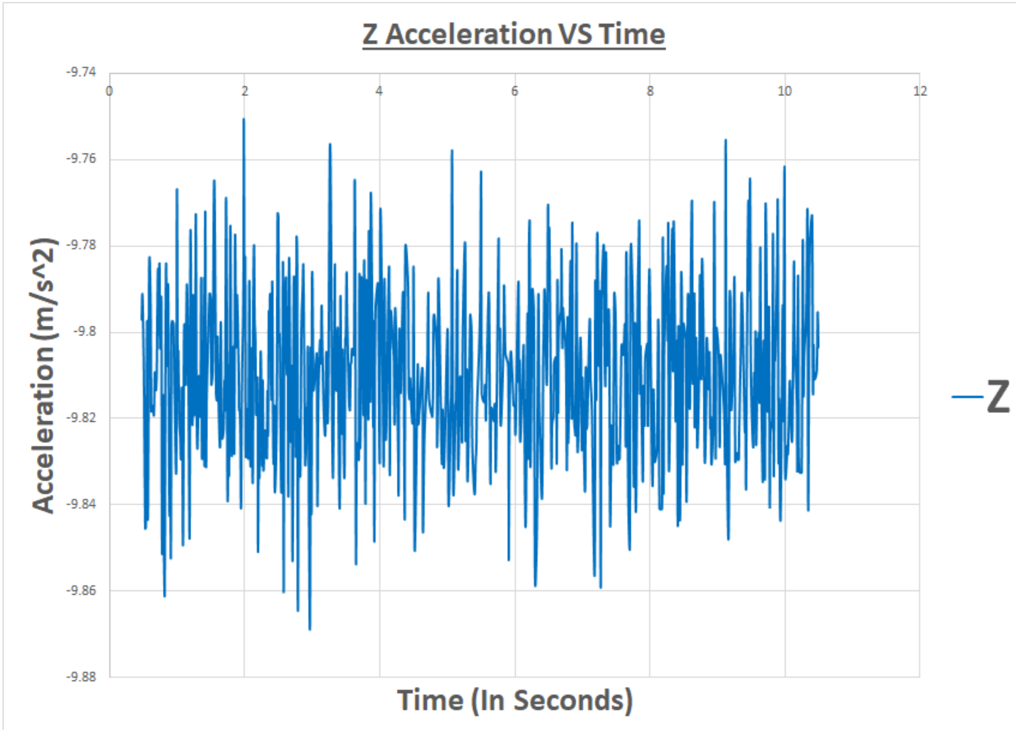


Figure 65: G-Force Due to Vibration VS Time

The graph shows that the additional force that is caused use to vibration in the Z direction is insignificant.

It can be concluded that vibration of the lathe will have little to no impact upon the operation of the guard.

14.5 Ergonomics

14.5.1 Ergonomic Testing Requirements

A major customer requirement for the guarding solution is for it to be ergonomic to the operator. Shall the guard not be an ergonomically viable solution the operator/the customer will remove the guard from the machine as it hinders their operation.

Testing must be done to ensure that the guard is ergonomic to operate. Some ergonomic factors that must be looked at are listed below.

- Point where the operator opens and closes the guard
  - What is the distance that the operator must reach to open and close the guard? Is the handle in an acceptable position to prevent potential ergonomic injuries?
  - Is the point at which the operator opens and closes the guard free and clear of any potential hazards or obstructions?

- Allow for full range of motion during the process, and not hinder operation
  - Does the guard hinder the operator from performing the operation as he would have before its institution?
  - Is the operator able to perform the required part inspection?
  - Does the operator retain the ability to perform all essential functions related to the process with the guard in the engaged position?

14.6 Ergonomic Test Results

The results of the ergonomic tests were extremely positive.

The location of the handle where the guard is actuated keeps the operator's extremities out of the danger zone as well as is in a location that prevents the operator from ergonomic injury. The distance that the operator needs to reach to activate the guard is approximately 10 inches. This is well within acceptable limits as the operator only needs to bend his elbow to activate the guard.

The guard allowed for the operator to perform the process with little to minimal changes to the current process utilized. The operator retained his full range of motion as well as allowed for him to perform the necessary inspection of the part using his tactile sense.

An unexpected positive test result did occur throughout the ergonomic testing. The guard aided the operator in the process of removing the sharp edge from the part. The 45 degree chamfered edge around the hole in the pane used for the operator to place the stone through allowed for the operator to put less stress on his hand. He was able to lean the stone on the chamfered edge. This is an unexpected ergonomic benefit of the guard. A diagram of this is shown below in figure 66.

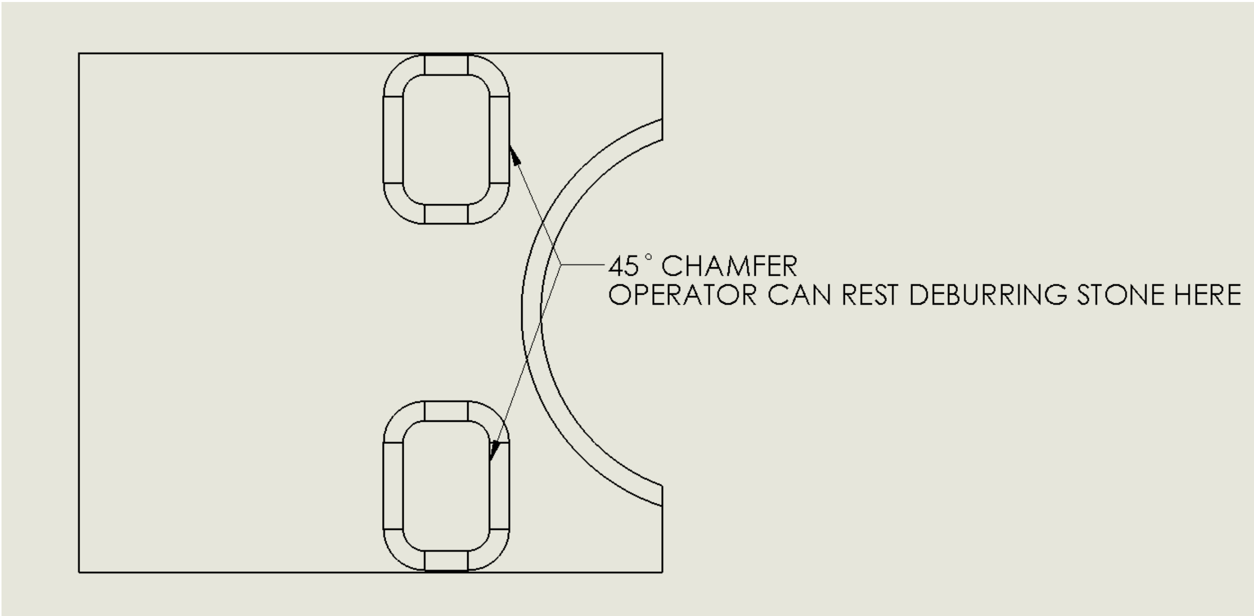


Figure 66: 45° Chamfer Operator Can Rest Stone On While Performing Process

Overall the guard proved to be an ergonomic success. Operator feedback in regard to ergonomics will be discussed more in section 14.7.

14.7 Operator Feedback

Operator feedback is critical whenever instituting a new piece of safety equipment into a process. If the operator does not approve of the device the chances of him attempting to override it are high. Therefore to ensure that the operator uses the device listening to his feedback was critical to the success of the project.

To get operator feedback the team sat down with both Doug the main operator, and Santiago Sanchez the engineer at MAGSEAL that advised the team on the project.

An initial thought was that the guard felt very solid and was easy to move. This can be attributed to the steel frame as well as the effort to make the parts of the guard being actuated as light as possible. This is extremely positive feedback about the design of the guard team 22 delivered in general.

While the operators like using the device and feel the solution will work in the long term, the initial feeling is that the motion of moving the guard into position is somewhat weird. This can be attributed to the change in the process. Both the operator and the MAGSEAL engineer believe that overtime this motion will become more natural.

One thing that the operator realized while conducting the testing was that he tended to reach to open his guard with his right hand as opposed to his left as the guard was designed for. The design intended for the operator to use his left hand intentionally as the action and position of the guard is closer to his left hand. Team 22 believes that as the guard is used in production the operator will get use to activating the guard using his left hand.

One complaint that the operator had was that the aluminum sheathing does not extend enough to collect the dust and other debris that result from the deburring process. The other flaw that arises from this is in the event of magnet failure there is the potential for pieces of the magnet to be ejected from the area below the guard potentially injuring the operator. This issue can be easily fixed in the future and is further discussed in section 20.5.

The last piece of operator feedback regards the screw that prevents the guard from rotating past 90°. This was not forseen by the team when the redesign was performed. This is necessary to allow for clearance when a job is set up for grinding. MAGSEAL plans to institute a simple fix to this by putting a removable stop pin instead of a screw.

Besides these few minor things that will need to be addressed, the operators were very happy with the guard.

15 Redesign

After meeting with Meagseal to do preliminary testing with the 3D printed assembly, the team utilized the feedback made by the company members, as well as the team's individual inputs, to redesign the guarding mechanism

The modifications increased it ergonomic quality, effectiveness, enhance safety and process efficiency.

15.1 Redesign Overview

The main goal of the redesign was to make improvements to the existing design, while making sure that the problem definition and the specifications set by the company were both satisfied. The design for the guard must protect the user's hand from harm while allowing the user to perform the deburring operation on the seals. The pane of the guard must accommodate different size seals from as large as five inch diameter to half an inch in diameter. Due to the delicate nature of the process the user's sense of touch must also be unhindered by the guard. In addition to this, the design must also allow for the grinding wheel to come in to preform a chamfer operation to the seals.

When creating a product the first design conceived is rarely the same as the final product. Products and devices must go through several stages of testing and experience redesign in order to improve on functionality. The initial design of the guard satisfied all the design specifications, however, once the prototype was brought to the company for preliminary testing some ergonomic issues came to light. If the testing did not occur it would have resulting in the finished product containing imperfections. Testing is performed in order to capture and reduce these imperfections and maximize functionality making the device as user-friendly as possible.

The group's initial design was built keeping in mind all of the mentioned specifications (see section 6). Shown below is the rendering of the initial design (figure **??**)

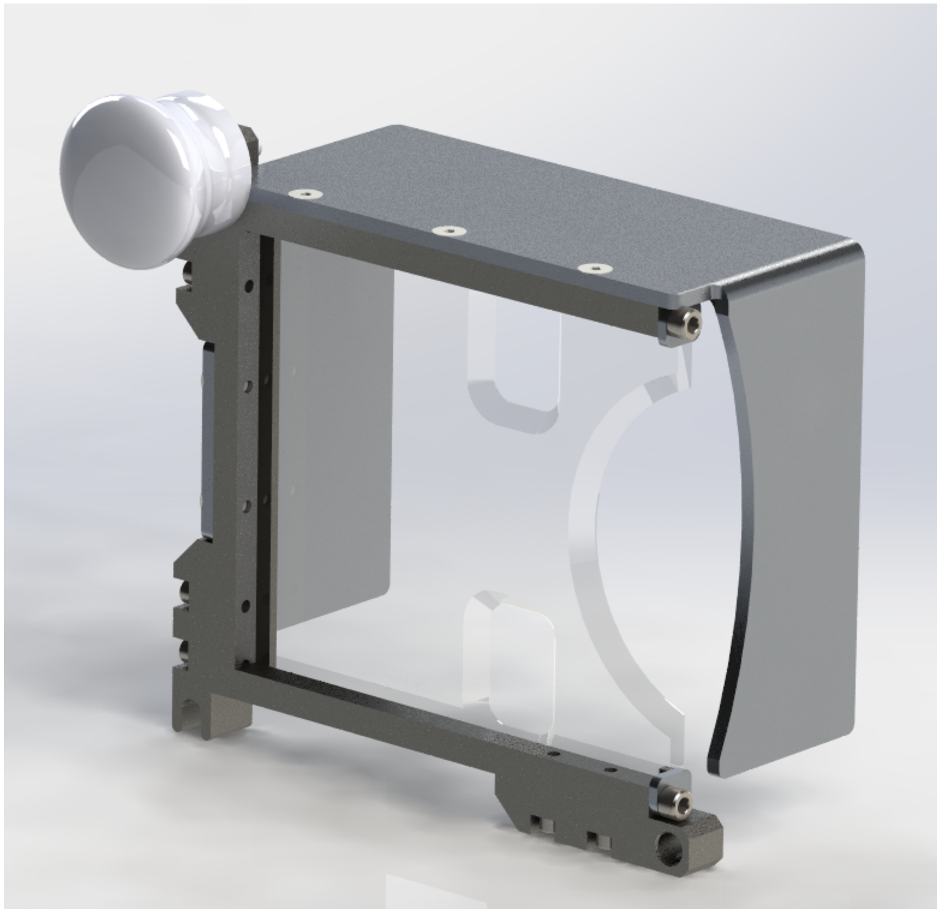


Figure 67: Rendering of the Original Design

The picture above (figure: 67) is a 3D rendering of the devices initial design.

The day the team went to MagSeal to conduct testing with the prototype there was a severe rainstorm. The weather resulted in the company experiencing a blackout while the team was on site. The main goal of that day was to assess the condition of the design and test its compatibility with the operator. Luckily the trip wasn't completely sabotaged by the blackout since the device could still be handled by the operator without the machine having power. The testing resulted in the operator and team agreeing that the operator's hand comes dangerously close to the grinding wheel when reaching for the knob to flip the guard to the engaged position. Once arriving back on campus the team discussed how to solve this issue.

15.2 Changes to the Initial Design

While the employees of the sponsoring company involved were overall pleased with the design there are always improvements that can be made. During the team's visit the operator along with several other employees were able to express concerns and ideas for improvement to the team.

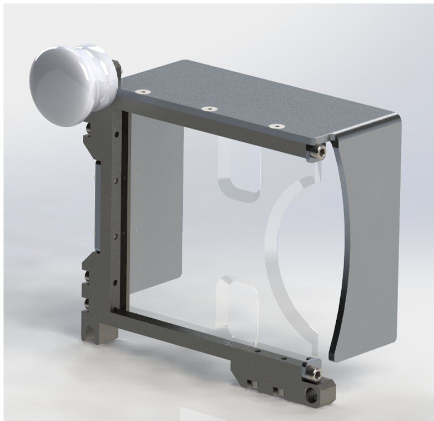
The first concern that was expressed to the team was to make a change to the location of the actuation knob. The knob was originally on the front face of the guard, specifically on the top left of the frame. It was placed there due to the internal strength of the frame. While this design looked good on paper, once the prototype was brought to the company and tested with the operator it was clear that the location of the knob put the operators hand dangerously close to the grinding wheel. It was also discussed that the initial location of the knob was just slightly out of reach of the operator making it uncomfortable to use and agreed upon that it could be made more ergonomic.

Another design issue discussed during this visit was the piviot point of the shield. The team's advisor brought to attention that the pivot point was not in the most efficient position and was too close to the deburring collet, which could potentially hinder the process when deburring larger seals. This issue was solved by increasing the length of the pivot bracket and moving the location of the pivot point slightly to the right. The pivot point is the only thing supporting the guard when it is in the disengaged position. Slight modification to this point changes how the weight of the guard is distributed on the joint.

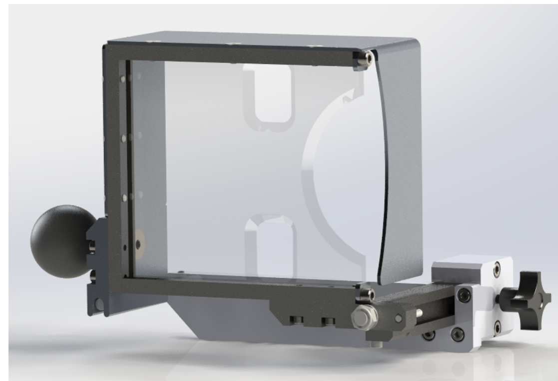
The final change in design from the initial model is the length of the support bracket. This modification incorporates the new location of the knob with a stress analysis. Lengthening this bracket more evenly distributes the stress from the weight of the guard onto the support pin. This results in the guard being more stable in the engaged position. It also looks better to have the bracket the same length as the walls of the guard and also prevents anything from entering the guard accidentally from that area.

15.3 Updated Handle Location

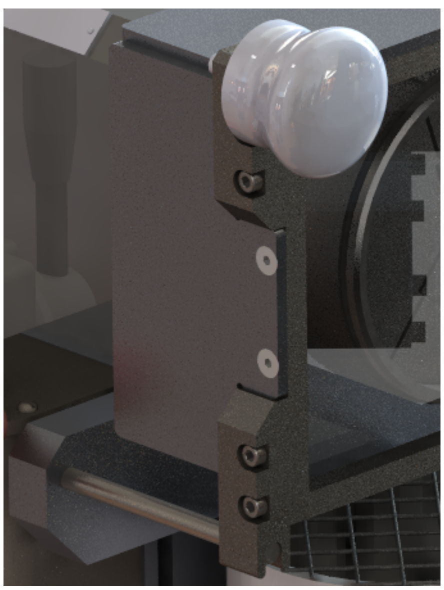
The team was able to view how the operator would actually interact with the guard during a testing visit. The most prominent issue deduced from the preliminary testing was the location of the knob. The team along with several employees, including the operator, discussed the relocation of this knob. The danger of the initial location was that the operator's hand would be required to get extremely close to the grinding wheel when the guard was in the upright position. The initial location of the handle also was a little too far away for the operator, resulting in a small inconvenience. Although this may sound trivial, the operators comfort is a priority of the team when designing this device and is taken very seriously. The team knew that the knob could be relocated, making the device more ergonomic, resulting in optimal comfort for the operator. The relocation of the knob resulted in the team discovering another component that could be improved. The support bracket was extended to more evenly distribute the weight of the guard onto the support pin, resulting in the guard being more securely supported in the engaged position. The increased stability of the guard is a major improvement in design as well as the suport pin hav



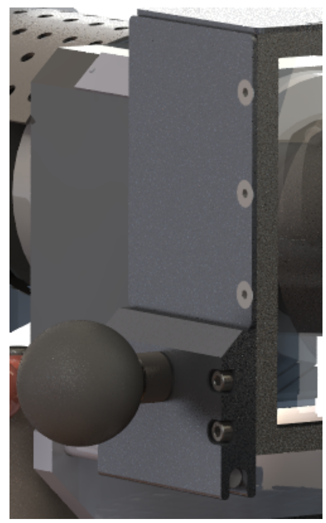
(a) Original Guarding Handle Location Overview



(b) Improved/Redesigned Handle Location Overview



(c) Original Guarding Handle Location Close Up



(d) Improved/Redesigned Handle Location Close Up

Figure 68: Original VS New Handle Location

15.4 Ergonomics

Overall the improvements made to the shield design increased the shield's ergonomics. Whether it was by moving the location of the pivot point or by changing the position of the shield handle. It was a welcomed plus that these changes also helped increase security to the user; the relocation of the handle decrease the risk of hand injury by slippage or the lack of attention. The shield pane already gave open access to the user while protecting the fingers from the sharpness of the seals. Having the ability to change the pane while matching the seals also increases the ergonomics of the shield design. In regards to improvement of the pane design, the team's advisor recommended a square opening to give better access to the grinding wheel.

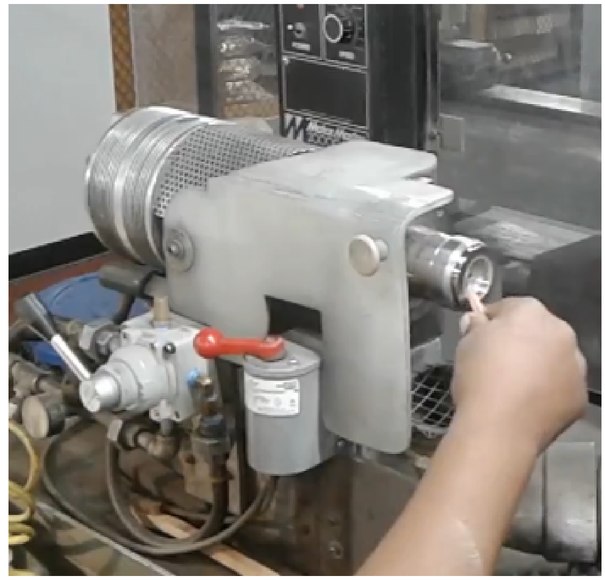
16 Operation

The creation of this device is focused heavily around the deburring operation. The operation has a specific natural flow to it and the device must not interfere or negatively influence that flow. The team believes that the device created will accomplish the goal of protecting the user without disturbing the flow of the process.

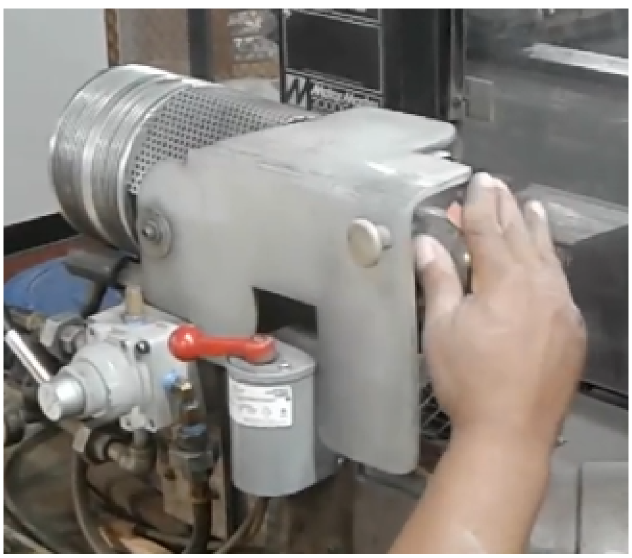
16.1 Deburring Process Overview

The main process this project is centered around is deburring. The act of grinding away excess sharp metal, called a burr, that is left on parts after most machining processes. This burr can be taken off using a deburring tool or some type of abrasive material such as a grinder or deburring stone. Each method has it's own benefits and drawbacks. When using a grinding wheel the burr is removed quickly however the operator must be careful not to take off too much material. Using a deburring tool the operator can peel away the burr very effectively but it takes more time and it is hard to get into corners. The process that this device revolves around is spinning the part in a lathe and applying an abrasive deburring stone to it, effectively removing the burr from the full 360 degree edge of the part. The dangerous aspect of this process is that the part is circular on the edge that requires deburring, which could easily result in the operator's hand slipping when applying the stone. The guard created prevents this by limiting the movement of the stone through only providing a small window in which the stone can be applied. Shown on the following page (figure 69 and 70) are the steps that are performed during the process. These were the steps taken before the institution of the guard.

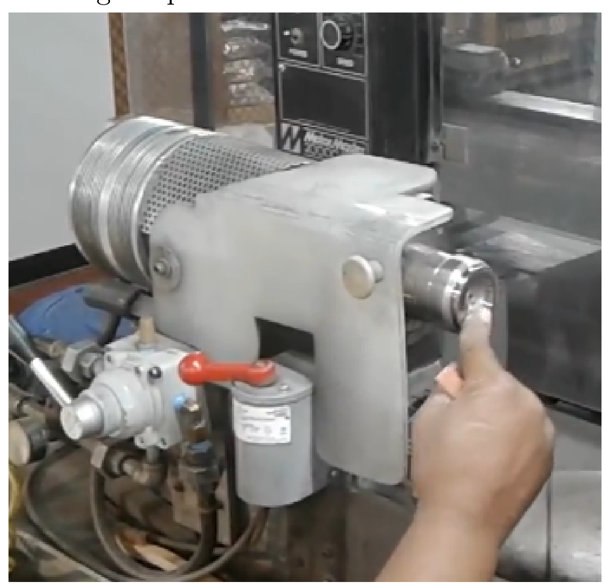
(a) **Step 1:**Place seal into collet and tighten collet to secure the seal, turn on machine



(b) **Step 2:**Apply abrasive stone to the exposed inner edge of part

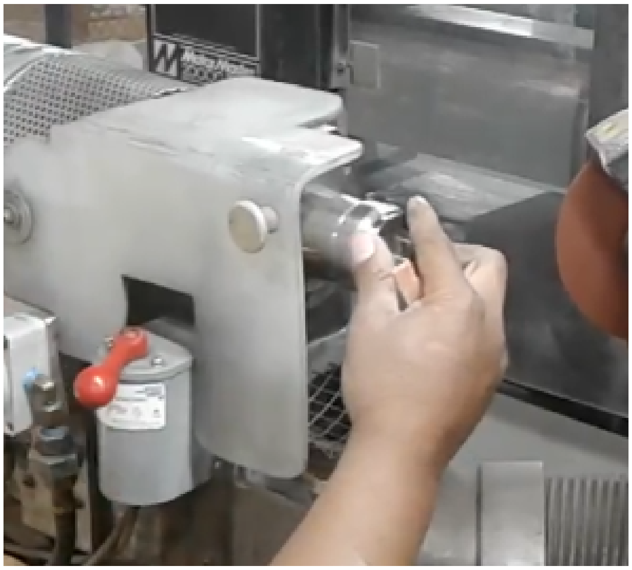


(c) **Step 3:**Apply abrasive stone to the exposed outer edge of part



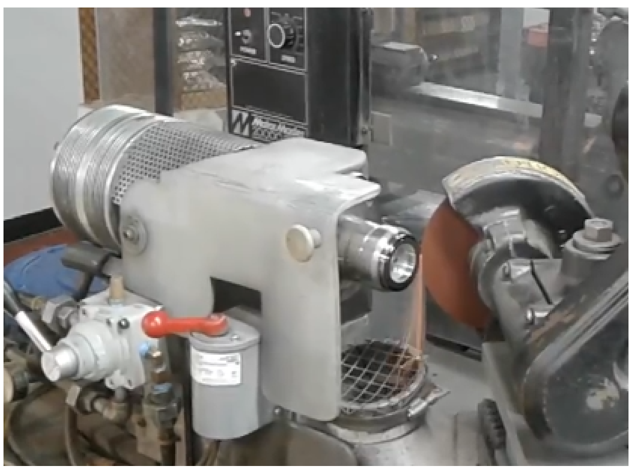
(d) **Step 4: Inspect the ID using tactile sense**

Figure 69: Magnetic Seal Deburring Process Steps 1-4

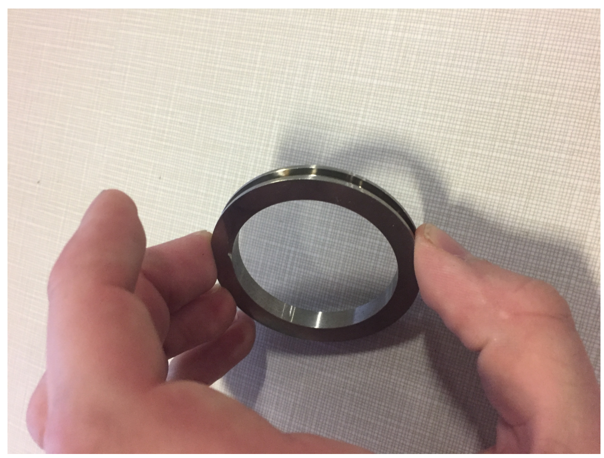


(a) **Step 5:**Inspect the OD using tactile sense, upon completion of inspection power off the machine

(b) **Step 6:**Flip the seal and perform steps 2-5 on the backside of the seal



(c) **Step 7:**Activate grinding wheel operation to apply a 45 degree chamfer to the outer edge of the part



(d) **Step 8:**Loosen collet, and retrieve completed part

Figure 70: Magnetic Seal Deburring Process Steps 5-8

16.2 Guard Setup Procedure

The process of setting up the guard is a fairly simple one. The operator would have just put in the correct size collet that fits the parts he is preparing to deburr. After doing so, the operator would insert the Pivot Beam (Part Number: 22016) into the adjustable fixture. This allows the operator to set the resting position of the guard right up against the collet to provide minimum distance that the operator must insert the stone. Once the guard is in place the operator can put in the correct frontal pane that allows access to the inner and outer diameter of the seals. That completes the setup and the guard is ready for use. The setup of this device takes a minimum amount of time, possibly a small amount longer than putting in the right size collet. The ergonomic setup optimizes the use of the device by not requiring a large thought process to accomplish. The team kept in mind that the guard will be much more pleasant to use the easier it is to operate and designed it accordingly.

16.3 Old Procedure VS New Procedure

The old procedure of simply deburring the part with no safety precautions definitely takes less time than preforming the process with a guard, however, it contains a much bigger risk. The process consists of inserting the seal, deburring the exposed sharp edges (inner and outer diameters), flipping the part, deburring the edges on that side, then the grinding wheel coming in to preform the chamfer operation. The operator repeats this same process hundreds of times a day and could become quite tired and fatigued. This much repetition could result in an even greater chance of injury. It is for this reason the company request an engineering safety measure be put into place.

The new procedure containing the use of the guard has clear benefits over the procedure without the guard. The setup of the guard described above takes a very minimal amount of time. This process consists of inserting the seal, putting down the guard, deburring the exposed edges, raising the guard up, flipping the part, putting down the guard, deburring the edges on that side, the chamfer operation must be applied while the guard is down, and finally lifting the guard and removing the seal. While this process does involve moving the guard up and down three times, this action takes no more time than securing the part in the collet or turning the machine on or off. In fact the feature of the position of the guard controlling the activation of the lathe slightly shortens the run time. Despite the ergonomic design of the guard and all efforts to minimize run time it is inevitable that overall the run time would be minorly increased. The company expects this condition and accepts the extended run time as a trade for the safety of the operator.

1. Place seal into collet and tighten collet to secure the seal
2. Move guard into engaged position thus activating the lathe
3. Apply abrasive stone to the exposed inner and outer edges of the part
4. Disengage guard causing the lathe to power down
5. Loosen collet to allow part to be flipped then re-tighten the collet

6. Move the guard back into engaged position to activate the lathe
7. Apply abrasive stone to the exposed inner and outer edges of the part
8. Activate the grinding wheel to put a 45 degree chamfer on the outer edge of the part
9. Disengage guard causing the lathe to power down
10. Loosen collet and remove seal

17 Maintenance

17.1 Maintenance Overview

Maintenance is extremely important when designing safety related devices. Team 22 took this heavily into consideration when designing the device. This ensures that the guard is extremely reliable and works when needed.

The device was designed to be virtually maintenance free with just two exceptions. The two exceptions are discussed below.

17.2 Lock-nut Inspection and Tightening

The lock-nut (as shown in figure 71 below) requires periodic inspection to ensure that it is tight enough. This lock-nut adjusts the amount of force required to raise and lower the guarding mechanism.

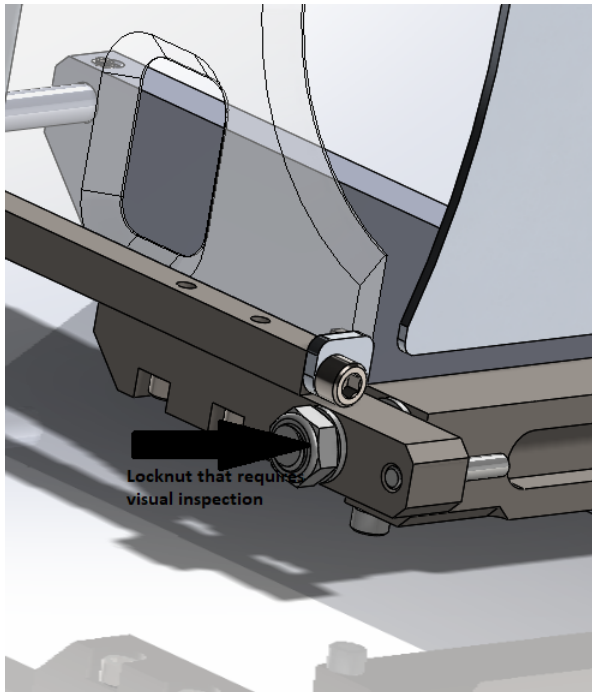


Figure 71: Lock-Nut that Requires Visual Inspection

The lock-nut contains a nylon insert. This insert should prevent it from loosening over time. Should it become lose the operator could use a wrench or a ratchet to tighten it.

17.3 Pane Maintenance

The second component that requires maintenance is the guarding pane. The pane overtime will get scratched due to chip and other debris.

The pane was designed to be easily changeable. This allows it to not only be replaced over time but allows the guard to be extremely versatile. It allows for the guard to be updated shall MAGSEAL add another size seal to its product line in the future.

18 Additional Considerations

18.1 Economic Impact

In total, as can be gleaned from cost analysis, the guard has a per-unit cost of approximately \$650.00 in materials and hardware, as well as approximately \$300.00 in estimated labor costs, for a total impact of less than one thousand dollars per unit.

This unit, per OSHA, represents a reasonable effort to provide effective guarding to the machine, thus mitigating liability for the company on the order of \$10,000. Devices of this type, which mitigate risk for far less than the risk could cost, could easily support a trend of investment by companies to guard their machines. This would in turn lead to an increase in the up-front cost of products produced on these machines as the cost of the machine itself is effectively increased. However, as companies become cognizant that their machines will effectively cost them less when risk is taken into account and accidents no longer cost as much, the overall price of products should eventually decrease. Because companies no longer have to budget as much towards risk of injury, relatively cheap devices of this nature could in fact lead to less expensive products int he long term. This type of trend is readily seen in reverse, in say the health-care industry, where skyrocketing prices seem to follow the cost of risk mitigation via providers paying exorbitant prices for business insurance. When the risk decreases, cost of insurance decreases, allowing for cheaper service and products while maintaining profit margins.

18.2 Environmental Impact

The device, being manufactured out of a majority of machined components, has a significant environmental impact. The machining processes used therein typically require various coolants and oils, mostly synthetic in origin, such as Cool-Mist spray and flood coolant which was used extensively. This product is a type of soluble oil which must be separated from its water base before disposal. The oil is very damaging to the environment if not disposed in this way, with water table contamination and possible plant death as the substance is marginally toxic. The same applies to the cutting oil used in tapping and some drilling of steels, which is a thicker synthetic.

These chemicals have impacts that extend into industry from their use in the shop, requiring a dedicated industry of manufacture, packaging, down to disposal and recycling of the packaging. The oils are contained in plastic containers, again synthetic materials that have a profound environmental impact from plastic reaction products. Even more damaging is the impact of improperly disposed plastic, which fills landfills, often making their way into waterways and eventually the open ocean. This argument can be extended to all manner of packaging for all hardware and raw materials, which because this device uses, it must create demand for such products to be made.

18.3 Societal Impact

This product represents a step taken by the management of a company to account for the safety of its laborers, thus fostering an environment of responsibility within the workplace. The argument can be made that when this kind of care and cognizance is shown in a work setting between people of differing social and economic classes, as general laborer and manager typically will be, this same compassionate attitude is fostered outside the workplace in general society. A worker will remember the steps taken by his superiors to protect his bodily safety, and will be more likely to show these same considerations if he ever finds himself in a managerial position. This sets up a positive cycle of reinforcement working towards promoting the general safety and respect of coworkers, which is vital to a productive company. This positive cycle is likely to carry over into other areas of a worker's life. He will remember the respect shown towards him, take pride in his work, which will encourage similar behavior from his contemporaries.

A worker will also demand this type of respect from a company that does not show it, encouraging the spread of respect and managerial accountability for worker safety wherever this type of relationship exists, not necessarily in an industrial setting. This spread of demanding respect will lead a proud workforce that takes pride in its work, from general laborer on up to management. This fosters the kind of environment where ideas are more likely to be heard, success be had by the general laborer, and advancement attainable by anyone in the workforce.

18.4 Political Impact

The device has a limited impact on politics thanks to its dependence on certain materials in its construction, such as steel and aluminum. At the time of this writing, there is political contention over tariffs for these two raw materials. Manufacturers of these type of devices that depend on these materials will naturally be of the position that tariffs that tend to raise the prices of these materials are to be avoided, as a price raise would only tend to decrease their profits and competitiveness.

Additionally, the types of companies which this class of device aims to serve, namely the manufacturing industry, is impacted by politics in several ways. Firstly, these companies also typically have dependence on the very same materials mentioned above. For example, even though MAGSEAL does not directly manufacture products out of steel, their testing devices use it, as do the manufacturing machines themselves, including fixtures. Their products do include materials derived from aluminum, however, and so there is an indirect dependence on the availability and cost of this metal on the price, and thus competitiveness of their products.

18.5 Ethical Considerations

This device represents an ethical responsibility of a company to care for the safety of its labor force and to take precautionary measures to ensure a task is as minimally dangerous as possible. This device is also an OSHA compliant guard, and so represents a legal responsibility of the company to mitigate their own risk in the safety of a laborer. As such, there are certain considerations that the installer of this guard must take in its installation which the design team has built into the device.

The device is designed to not be ignored via a switch which prevents the energization of the lathe motor unless the guard is engaged. The installer may provide an override switch for those certain times where operation of the lathe is required without the guard present. It is his responsibility that such a switch is not installed in a location where the operator can easily defeat the guard, thus diminishing its usefulness and putting him in jeopardy.

Additionally, this device makes no guarantees as to its ethical use in the environment it was designed for. There is no element of this device which protects any other part of the work environment besides the deburring and chamfer-grinding process. It does not distinguish between use of a proper working duration and overworking by the operator. It doe snot distinguish between a well qualified operator and an ill-equipped one. These are the sole responsibility of the company.

18.6 Health, Ergonomic, and Safety Considerations

This device, in its capacity as a safety guard, is entirely designed to protect the health and safety of the operator. As a shield from debris, it protects the operator from most types of flying matter, including accelerated dust, chips, and in the worst case, an ejected part. However, ejected collets, do their large mass, are not designed to be withstood by this device, though the high-impact polycarbonate pane is theorized to provide a strong measure of protection.

The device is designed to directly interact with its operator. As such, an anti-slip rubber handle has been provided that is the right size for gripping by the adult hand of either gender. The weight-in-hand of the device is kept under three pounds, well within guidelines on the subject for reducing operator fatigue. As a result of redesign, the handle position was changed to a position that minimized operator reach. at all points, the ergonomics of the device were a top priority.

18.7 Sustainability Considerations

The device, as a permanent fixture onto the lathe, has a minimum of consumable parts. However, the pane which is interchangeable, may need replacement from time to time. Because it is made of polycarbonate, it may be easily recycled, reducing its environmental impact and making the device naturally sustainable. Another potentially consumable part is the nylon locknut, wherein again, this part is also recyclable. lastly, in the case of extreme wear over a lifetime of service, certain wearing parts such as the aluminum washers may require replacement, though the timeline for this replacement is theorized to be after decades of service, and the amount of aluminum consumed by the wearing of these parts is negligible compared to the aluminum composing the rest of the device.

19 Conclusions

In conclusion, the design as represented by the final design satisfies all relevant design specifications, as enumerated above (section 6). Functionally, the guard was simulated to enclose both the largest and smallest collets and parts with no interference at any point during the travel of the guard into or out of engagement. The pane was shown to allow ample space for operator range of motion without exposing the hazard zone in a way where slippage of the stone from the work would lead to injury. The guard is manually actuated by a knob in a position that forces the operator to use the hand normally holding the edge-breaking stone, forcing pre-occupation of that hand during times when a potential rotating hazard will be exposed. With the addition of electrical integration this manual disengagement will lead to deenergization of the lathe motor, so that the spindle will come to a stop during this window of pre-occupation. This system also forces use of the guard, as the machine cannot be started with the device out of engagement. At no point is the working hand free to enter the hazard zone when the machine is under power, which is the ultimate aim of this project.

The guard design in its current form also satisfies all manner of financial and manufacturability constraints. As documented previously, the device can be realized if need be in a small manufacturing environment with no requirement for special tooling beyond that carried by the ordinary machine shop. The design was also shown to be scalable for mass production with a per-unit labor cost not exceeding $282.96 3 and simplicity of assembly being a top consideration. All parts are machined from commonly available materials in standard stock sizes with minimal machining required to reduce this size or make the part square. Holes drilled are typically through and always normal to the surface they begin on. Most tapped holes are held to thread tolerances achievable with standard ground taps and typically do not require bottoming. Fasteners used are standard sizes in standard lengths easily available from multiple vendors.

The guard design as it exists is an affordably constructed, functioning enclosure that positively protects the operator from a rotatng sharp hazard while not inhibiting the ability of the operation to be performed as usual. Minimal impact on the deburring process is expected to occur both in the complexity of operations to be performed or cycle time, and at all times the operator is physically isolated from any and all hazards.

20 Further Work

Though some inventions may have been around for a while and preform their roles seemingly perfectly, very few designs are ever actually perfect. Most devices can be slightly altered to improve convenience or comfort and even functionality. While the current design of this safety guard seems like it can preform the intended function very well, there are always modifications and aspects that can be improved on. Each member of Team 22 keeps the safety guard in mind in their everyday lives, constantly thinking of ways to upgrade and refine the device with influence from other electrical and mechanical assemblies.

Instruments such as a Quality Function Deployment chart have been created to aid in engineering design. This is a particularly helpful method in deciding between what features to include or not in the final design of a product. This type of analysis tool makes sure that no design with potential is crossed off the list too quickly. Some design ideas may seem like they will work well on paper but don't preform adequately when actually tested.

SolidWorks is an example of an extraordinary engineering design software in which any device/assembly be created and tested using finite element analysis within the program, simulating the effects of real life environments. The software can be used to show the user areas of high stress, which are exactly where fracture would occur, and adjustments can be implemented accordingly. Although a large amount of work has been put into making the device what it is today, there are still a couple of aspects that need to be taken care of.

20.1 Accommodation of Various Size Collets

Another issue that came to light during the design process is that MAGSEAL has a couple different size seals they produce. The seals vary from xx . Just about every lathe has the feature of interchangeable collets to accommodate various size parts. Consequently, larger seals require larger collets to hold them. The dimensional increase occurs only in the diameter of the collet and how far it sticks out from the spindle nose. These various size collets alter the area between the guard and the seal which, as previously explained, must abide by a very specific tolerance.

In order to get maximum efficiency out of the device the guard must be able to be adjusted horizontally to move closer and further away from the lathe. A solution to this problem would be mounting the guard on a plate with a slider underneath that attaches to a track. The track would allow movement of the guard to align perfectly with any size collet, similar to the track and carriage used to move a center drill back and forth on lathes. There would also be a way to lock the slider once the guard is in the optimal position. An extra safety measure would be wiring the the lathe so that it could not activate unless the slider is locked, as well as the guard being in the down position. These types of tracks used to slide and lock devices are fairly basic on most lathes used for machining.

20.2 Accommodation of Various Size Seals

After Team 22's second meeting with MAGSEAL the design mainly consisted of an actuating wall that blocks off the top half of the seal, as this was a suggestion of a solution. The sponsor, however, retracted the suggestion after experiencing an unexpected incident and expressed that it would be much safer to enclose the entire hazardous area instead of focusing on one specific injury. The sponsor suggested implementing various slits in the guard to allow access of the stone and grinding wheel. Variations of this kind of guard were previously considered by the team and can be seen in the list of design concepts. The slits must be big enough to allow the stone through as well as the seal to be seen clearly. The stone only being able to be applied to a small section of the seal prevents slippage, even if slippage were to occur the seal being nearly fully guarded would prevent any injury.

The main issue with the "wall with slit" design is that the area that needs to be deburred varies with different size seals. The guard pane, discussed in section 10.1 of the Engineering Analysis, is a removable barrier with slits to accommodate the various operations. The slits are strategically put into this barrier to ensure only a small amount of the seal is uncovered to allow the edge to be broken. The requirement for the placement of the slits in the wall is to be accurate enough to align with the top edge of the seal. It would be near impossible to make a single guard that works with all size seals, thus resulting in the removable panel design.

The guard will include various barriers with custom slits created specifically for each size seal. All barriers will leave space to allow the chamfer to be applied. Making this part of the guard variable is by far the most efficient way of solving this issue.

20.3 Potential Pane Redesign

One aspect of the guard that requires additional attention is the frontal pane. Only one pane was designed so far that works explicitly for a single size of seals. The initial idea was to make several different panes to accommodate each size seal. This would be a decent solution, however, it may add up to a good amount of time spent changing out the panes. For this reason the team searched for a better solution. The team desired a specific pane designed in order to make the guard universal for all size seals.

Perhaps the simplest solution to this would be a pane with a single vertical slot through the center of the lathe. The slot would only be wide enought to fit the deburring stone through. This would allow seals of any diameter to be deburred while still blocking the users hand from reaching the hazardous area. It would also still have material removed on the right side to allow the grinding wheel to preform the chamfer operation.

20.4 Manual Guard Override

In early May during one of the team's final visits to MAGSEAL, Santiago Sanchez expressed the potential need for a manual override to the safety circuit. The over ride would be placed in an area that would be difficult for the operator to access but would allow for ease of maintenance to the machine.

This solution will be implemented by MAGSEAL when they feel it is needed.

20.5 Changes to Sheathing

To address operator feedback regarding dust collection and further improvements, the top sheathing will need to be extended. This modification has multiple benefits: the first being that more debris that is a result of the deburring process will be contained thus the work area will be more cleanly, and the second is for additional operator protection in the event of a catastrophic magnet failure.

Should the magnet fail during the deburring process and the operators hand be located under/near the bottom of the guard when the magnet is ejected from the collet, he is in danger. To prevent this extending the steel sheathing would ensure that the operator is fully protected.

This is not an immediate issue and will be further addressed before the guard is fully instituted into operation.

20.6 Institution of Dust Collection Device

Another potential improvement that could be made is adding a square shaped funnel at the bottom of the guard that would attach to the vaccuum dust collection system.

This is not a safety improvement but more of an aesthetic/cleanliness improvement. This would catch more of the dust and chips that are a result of the deburring process and would keep less dust from becoming airborne and spreading through the shop causing dust build up on machines.

MAGSEAL and team 22 discussed the addition of such device at various points throughout the project and it was determined that if such a device were warranted it would be designed and instituted at a later date.

20.7 Application of Surface Coatings for Corrosion Resistance and Aesthetics

The application of surface coatings to the parts is another area that could be addressed if needed in the future. These coatings could include an anodize, powder coat or paint. The reason for these coatings would be if MAGSEAL suddenly felt extra corrosion resistance was need as well as it would provide slightly more protection to the parts from flying debris. The coatings would also enhance the aesthetics of the guard.

The team looked into the cost of applying these coatings and discussed it with MAGSEAL. It was determined that the application of surface coatings was not cost effective. MAGSEAL advised not to apply any coatings and said it would if it needed to later in the service life of the guard.

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22 Appendix

22.1 Mechanical Drawings and Schematics

The following mechanical drawings make up a complete part listing for components used in the prototype guard. Hardware is also included for reference.

PART NUMBER	PART NAME	DRAWING NUMBER
22001	GUARD PANE, LARGE COLLET	MSAG22-0001
22002	LEFT SHEATHING	MSAG22-0002
22003	FRAME TOP	MSAG22-0003
22004	FRAME LEFT	MSAG22-0004
22005	FRAME BOTTOM	MSAG22-0005
22007	LEFT PIN SUPPORT BRACKET	MSAG22-0007
22008	HINGE JOINT BRACKET	MSAG22-0008
22009	KNOB HANGLE	MSAG22-0009
22010	0.25-28 SHCS X 0.375	MSAG22-0010
22011	10-32 FLAT HEAD X 0.375	MSAG22-0011
22012	10-24 SHCS X 0.625	MSAG22-0012
22013	GUARD ASSEMBLY	MSAG22-0013
22014	PANE RETAINER	MSAG22-0014
22015	TOP SHEATHING	MSAG22-0015
22016	PIVOT BEAM	MSAG22-0016
22017	10-24 X 0.1875 SET SCREW	MSAG22-0017
22018	0.375 FLAT WASHERS	MSAG22-0018
22019	PIVOT PIN	MSAG22-0019
22020	10-24 SHCS X 0.25	MSAG22-0020
22021	3/16 DOWEL PIN	MSAG22-0021
22022	0.375-16 LOCKNUT	MSAG22-0022
22023	MOUNT BRACKET	MSAG22-0023
22025	BEAM CAMP	MSAG22-0024
22025	CLAMP BACKER	MSAG22-0025
22026	SUPPORT PIN	MSAG22-0026
22027	ADJUSTMENT KNOB	MSAG22-0027
22028	ADJUSTMENT BUFFER	MSAG22-0028
22029	.25-20 SHCS X 1.00	MSAG22-0029
22030	10-24 SHCS X .875	MSAG22-0030
22031	.375*0.5 UNTHREADED SPACE	MSAG22-0031
22032	.1875-16 X 1.50 FLAT HEAD	MSAG22-0032

Table 17: Drawing and Part Numbers

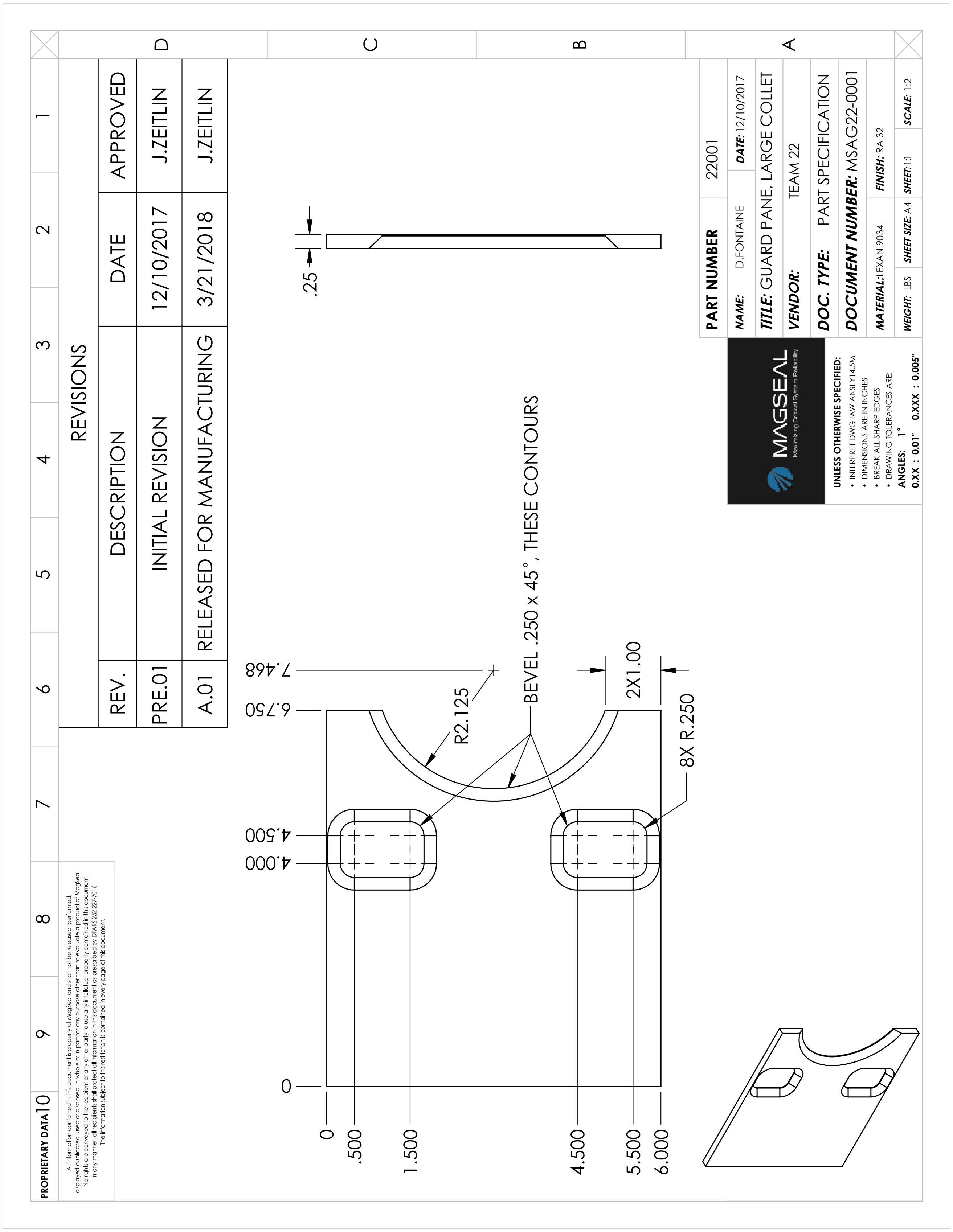

Figure 72: MSAG22-0001 Guard Pane Large Collet

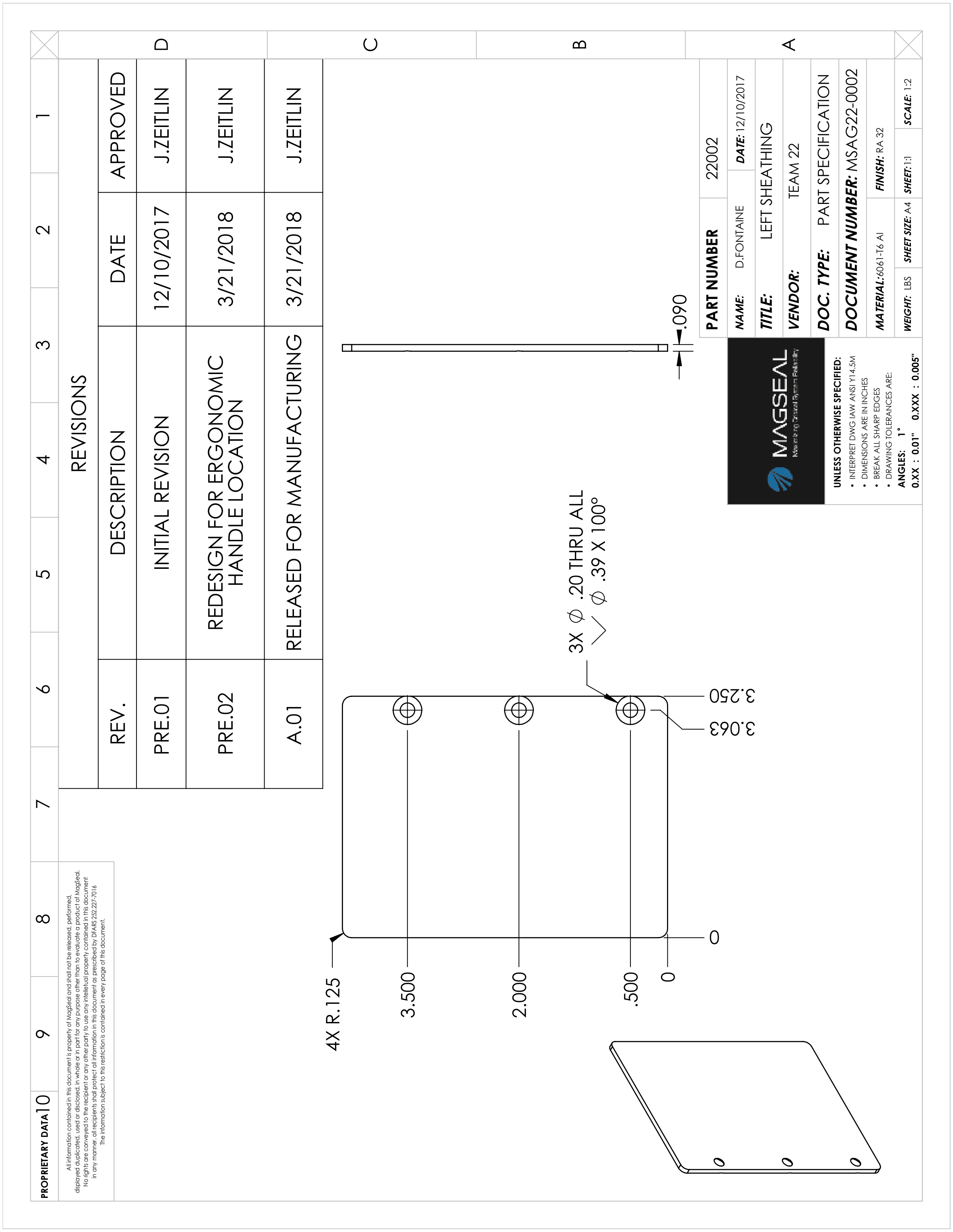

Figure 73: MSAG22-0002 Left Sheathing

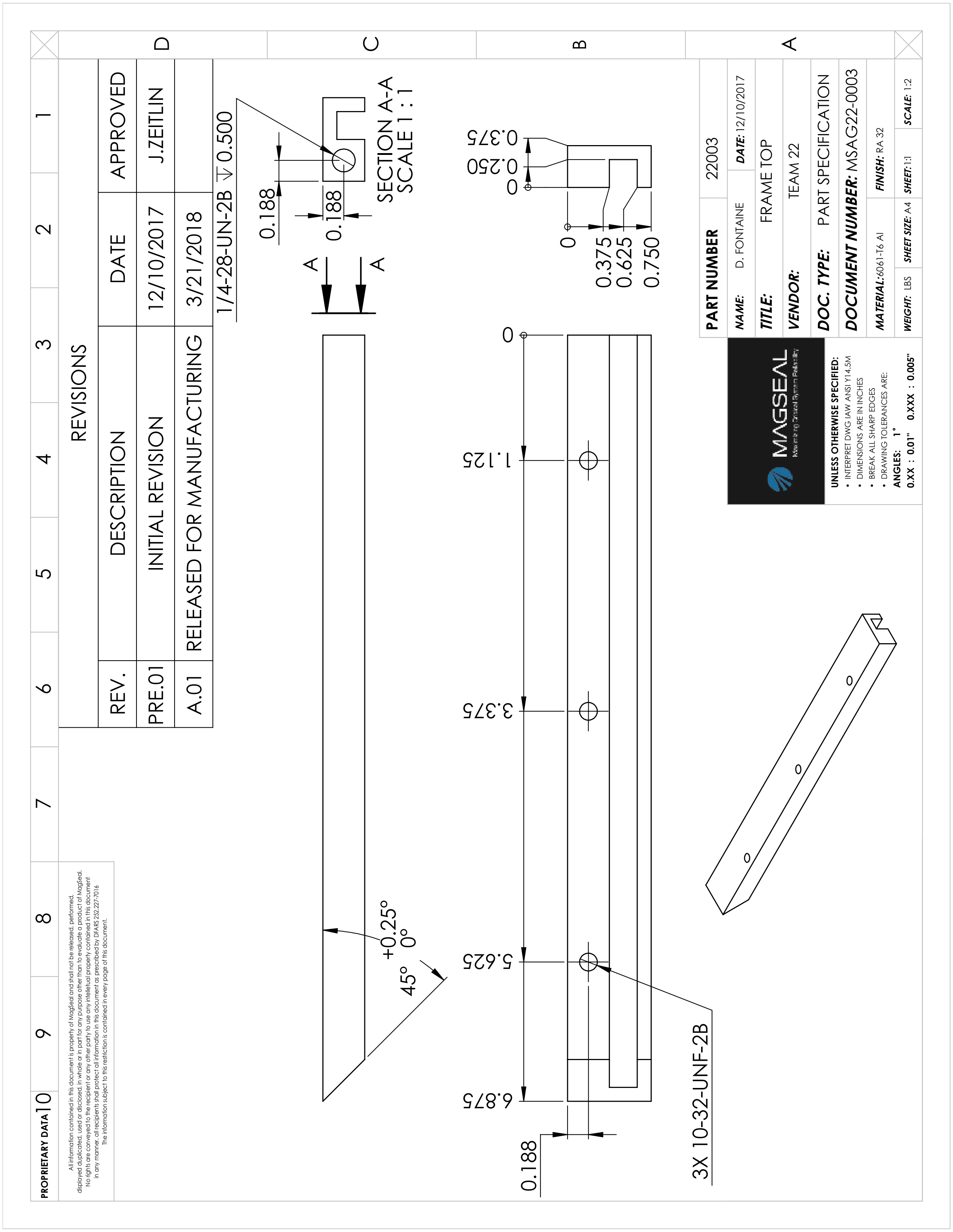

Figure 74: MSAG22-0003 Frame Top

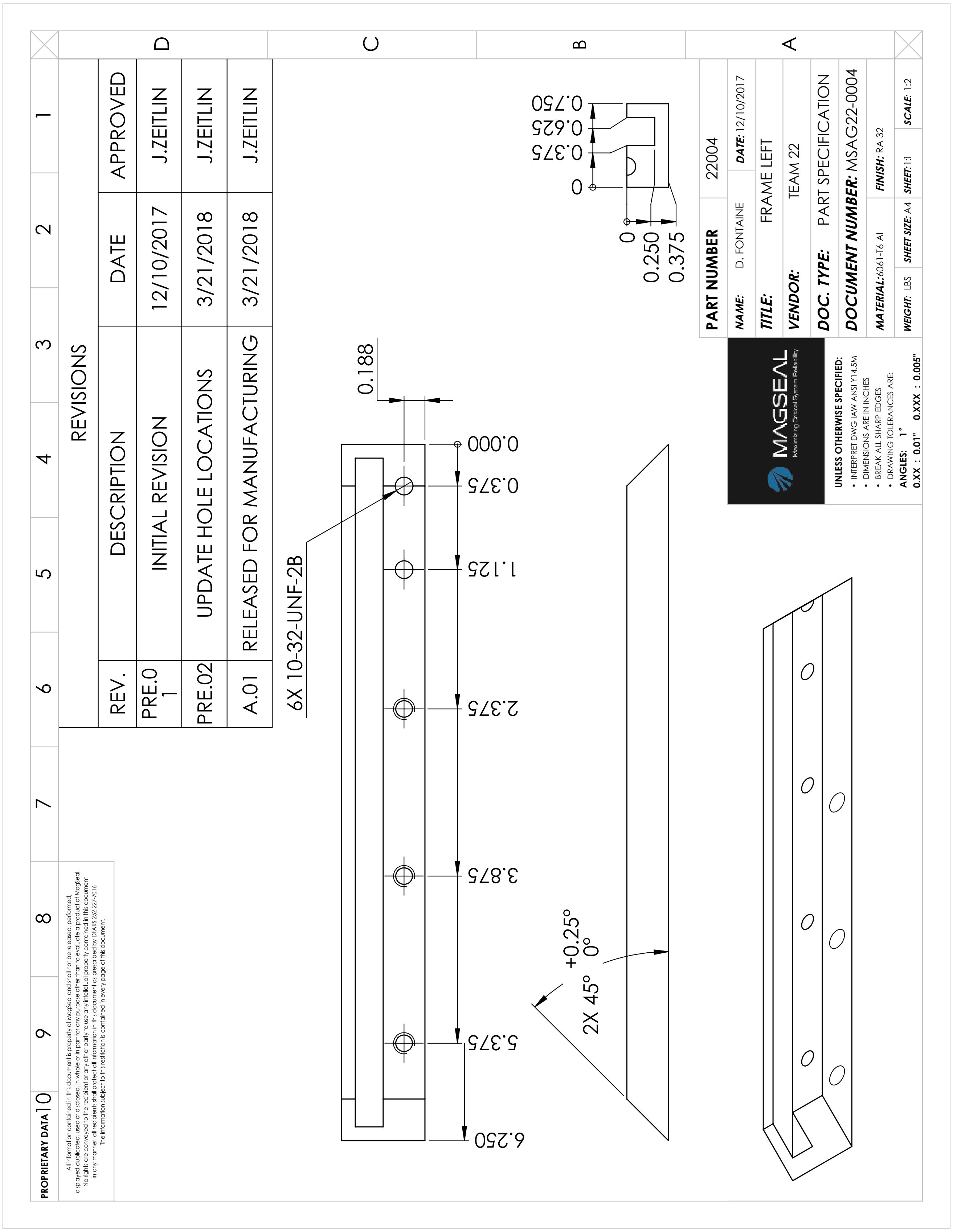

Figure 75: MSAG22-0004 Frame Left

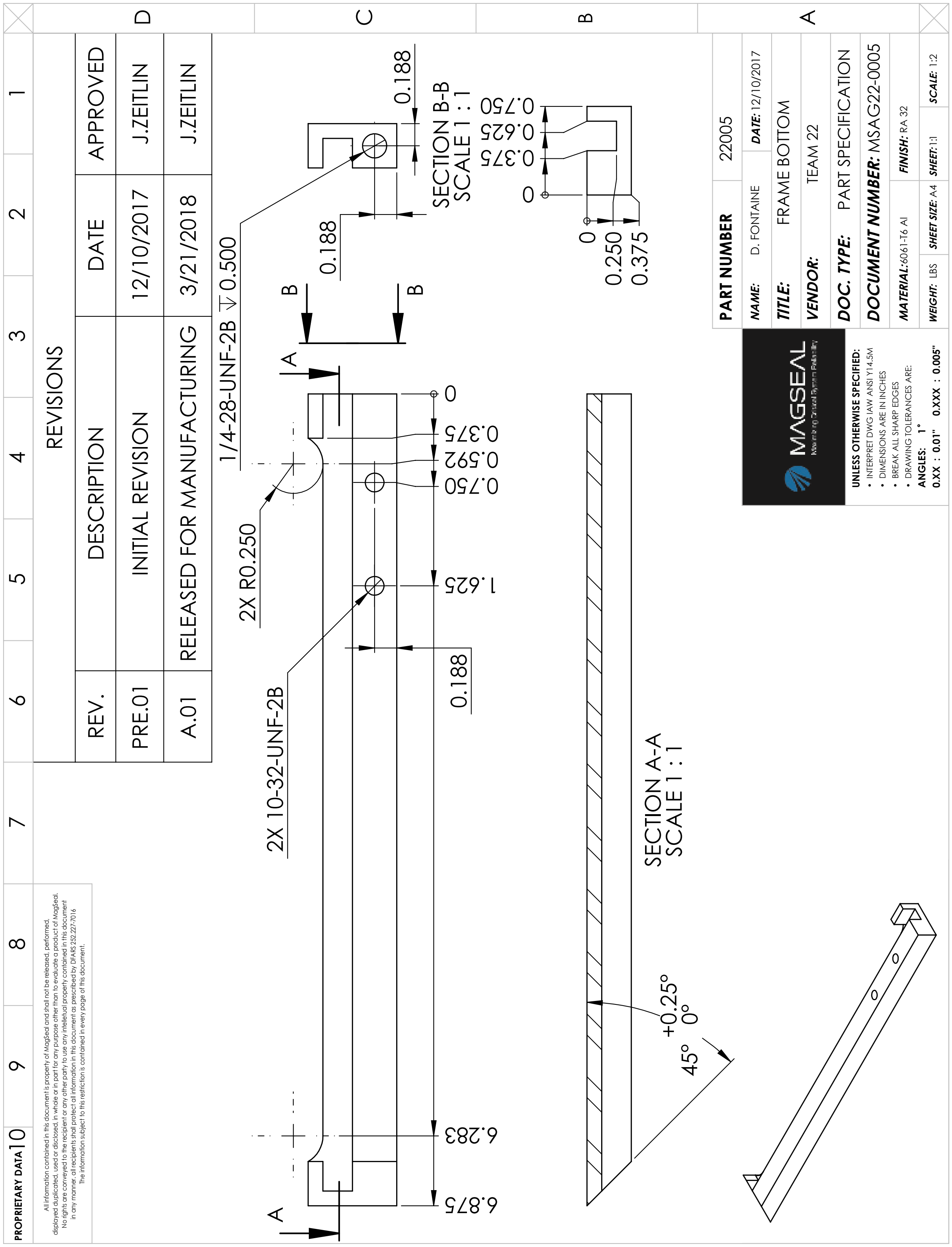

Figure 76: MSAG22-0005 Frame Bottom

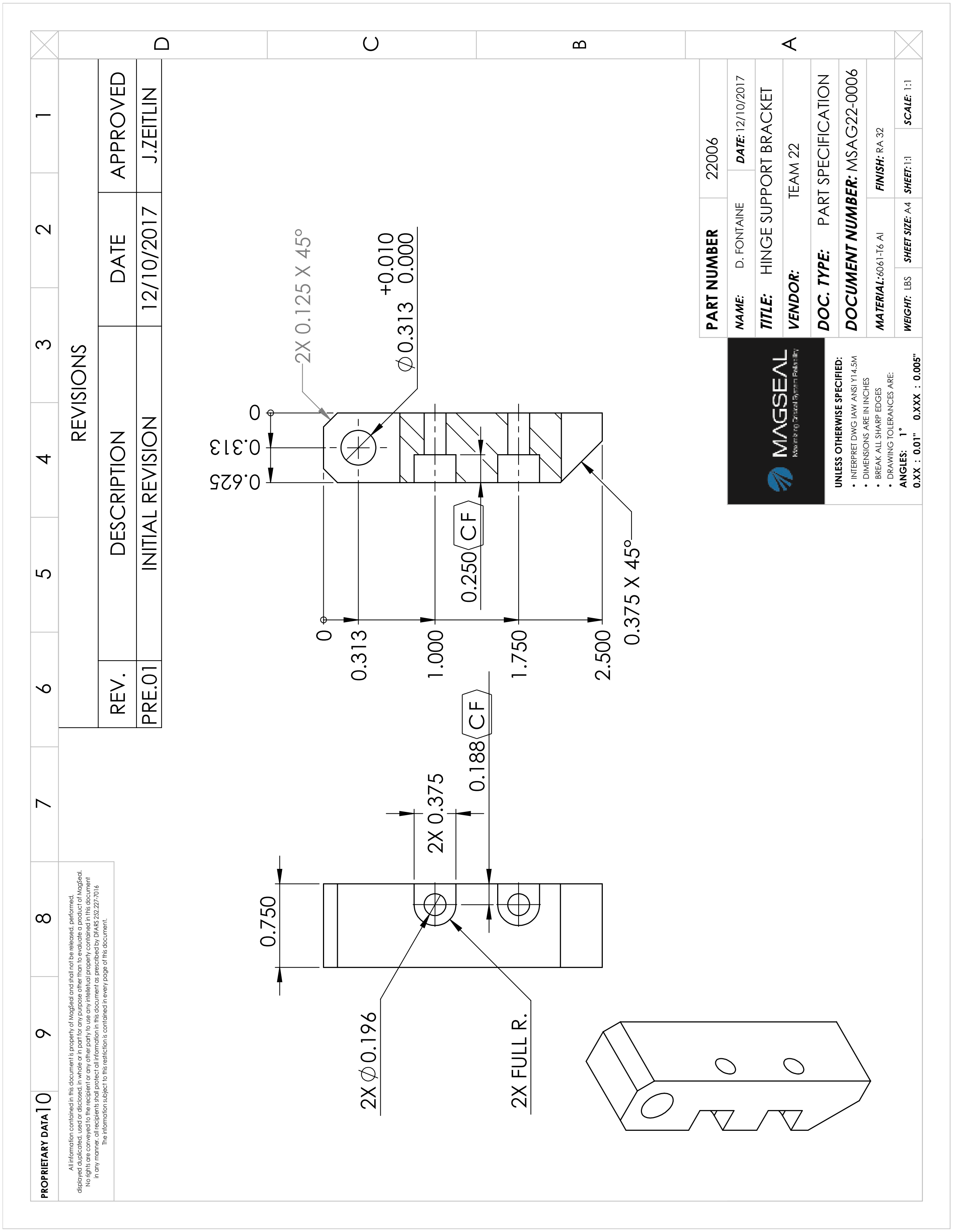

Figure 77: MSAG22-0006 Handle Support Bracket

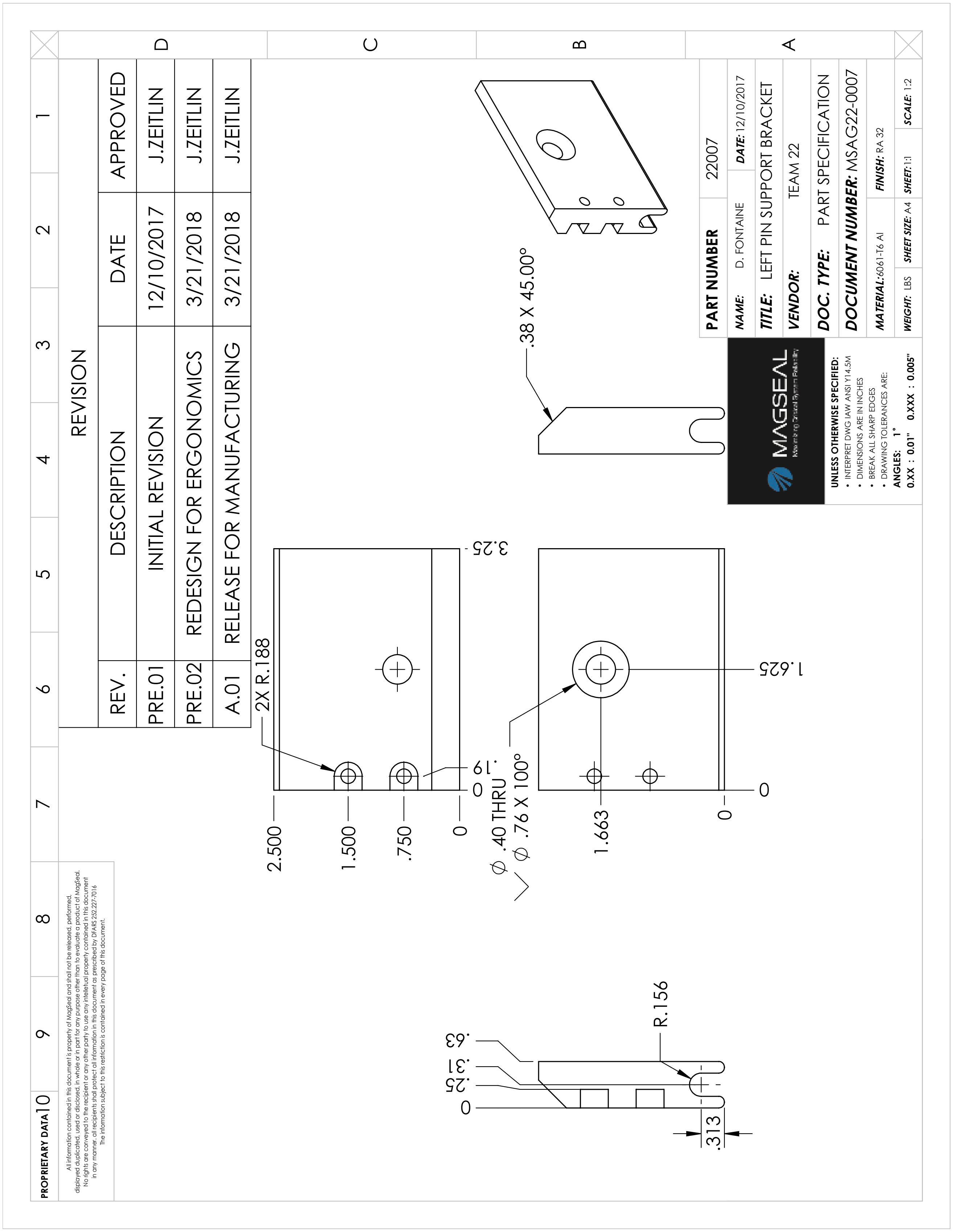

Figure 78: MSAG22-0007 Left Pin Support Bracket

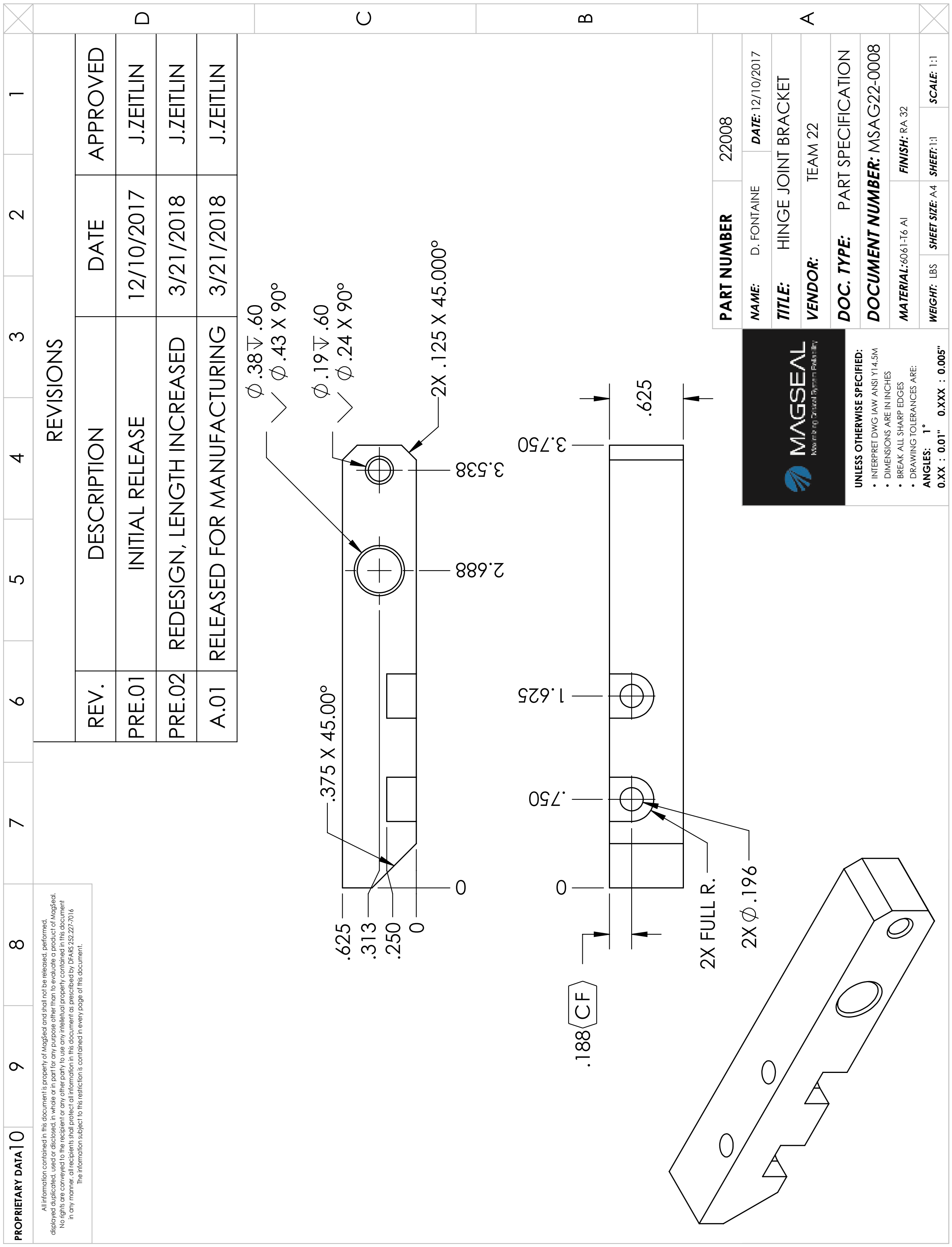

Figure 79: MSAG22-0008 Hinge Joint Support

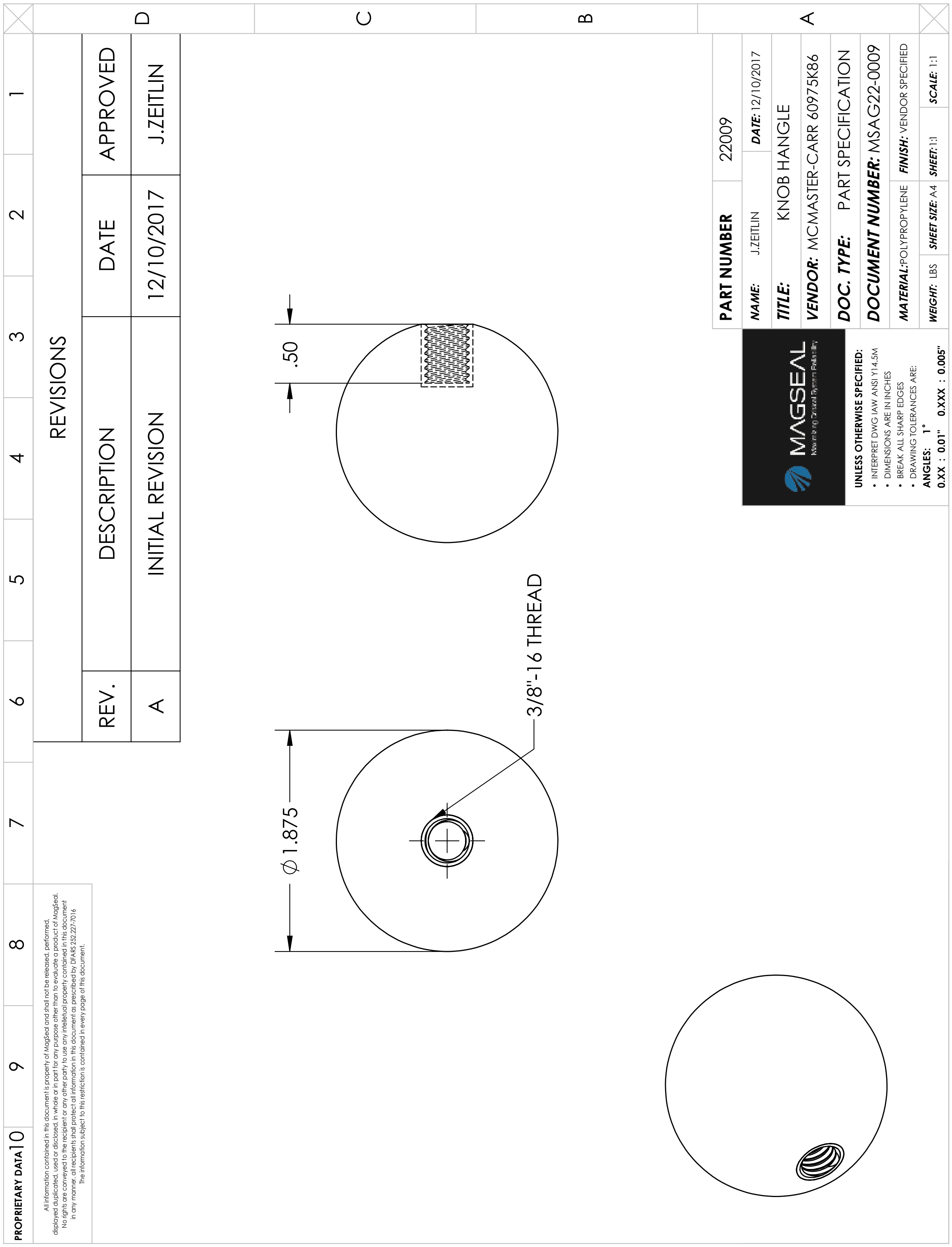

Figure 80: MSAG22-0009 Knob Handle McMaster McMaster

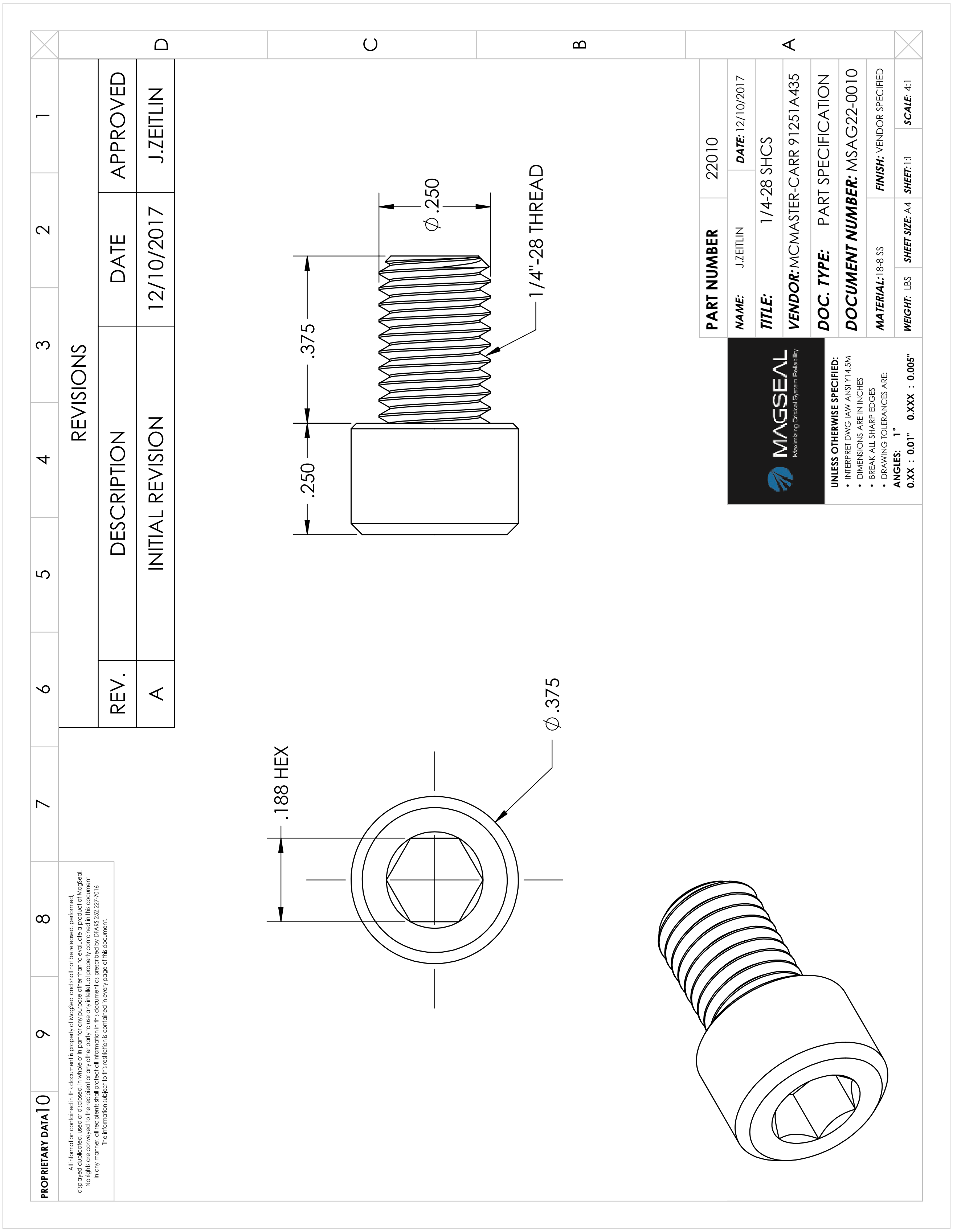

Figure 81: MSAG22-0010 1/4-28 SHCS McMaster

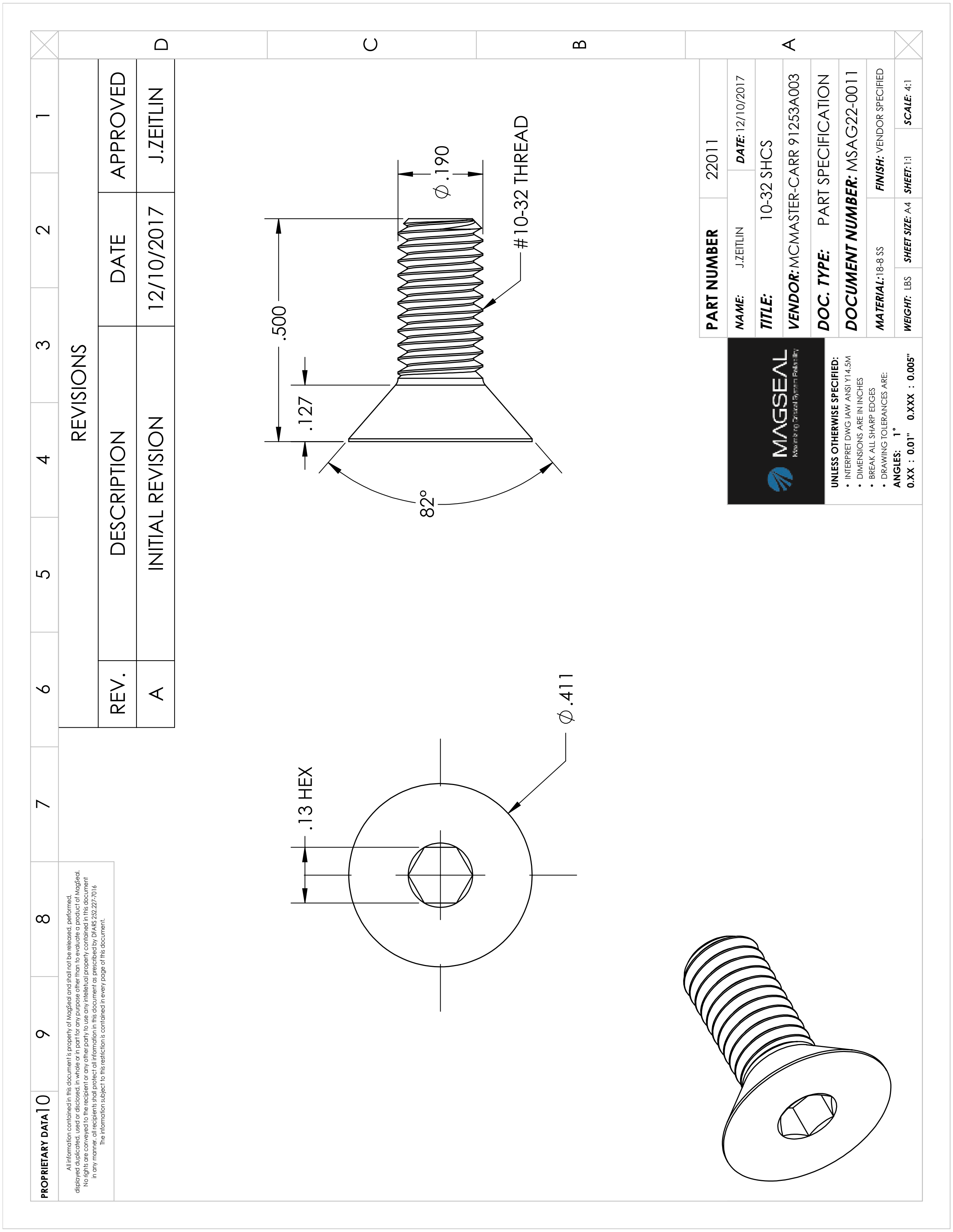

Figure 82: MSAG22-0011 10-32 Flat Head McMaster

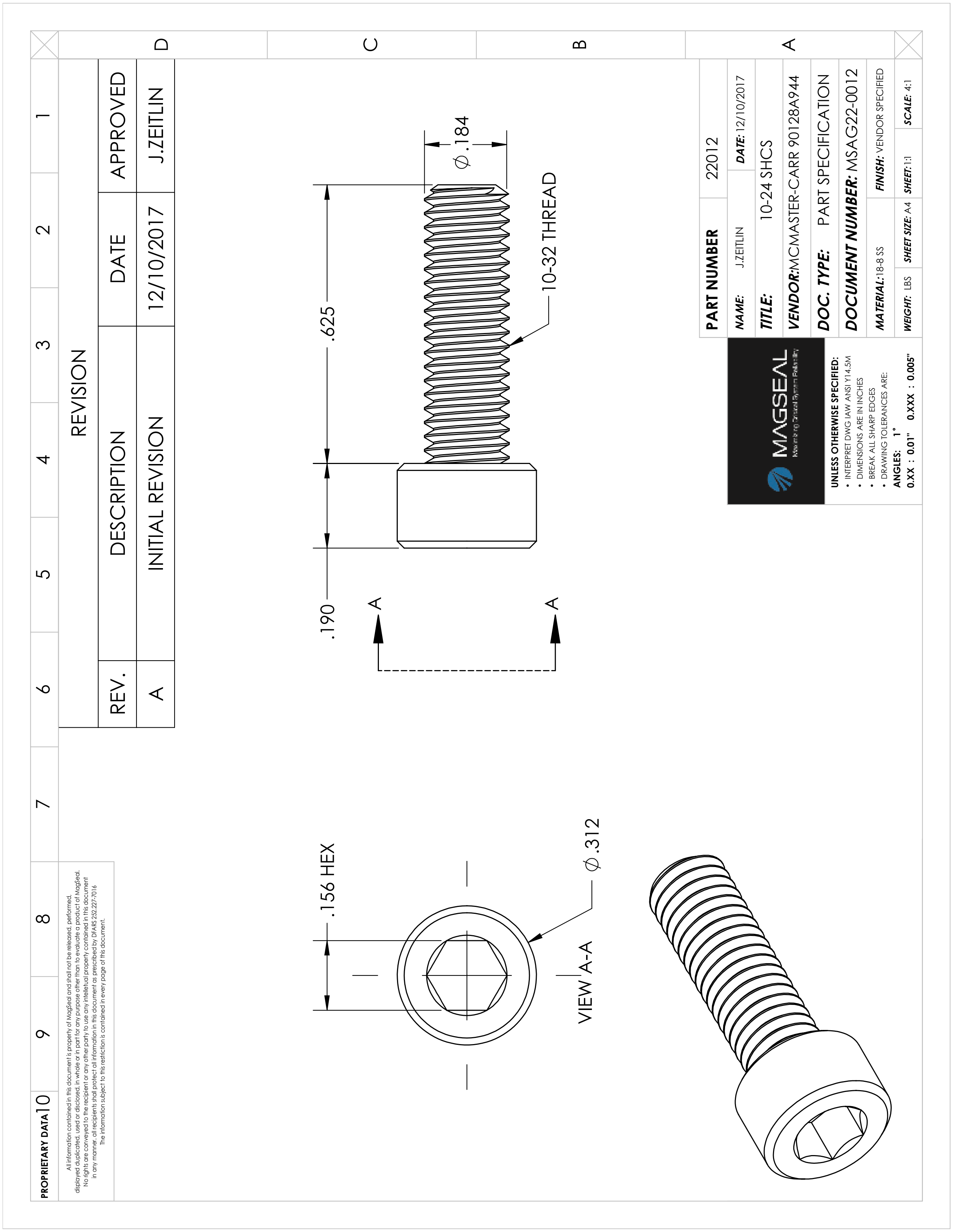

Figure 83: MSAG22-0012 10-24 SHCS McMaster

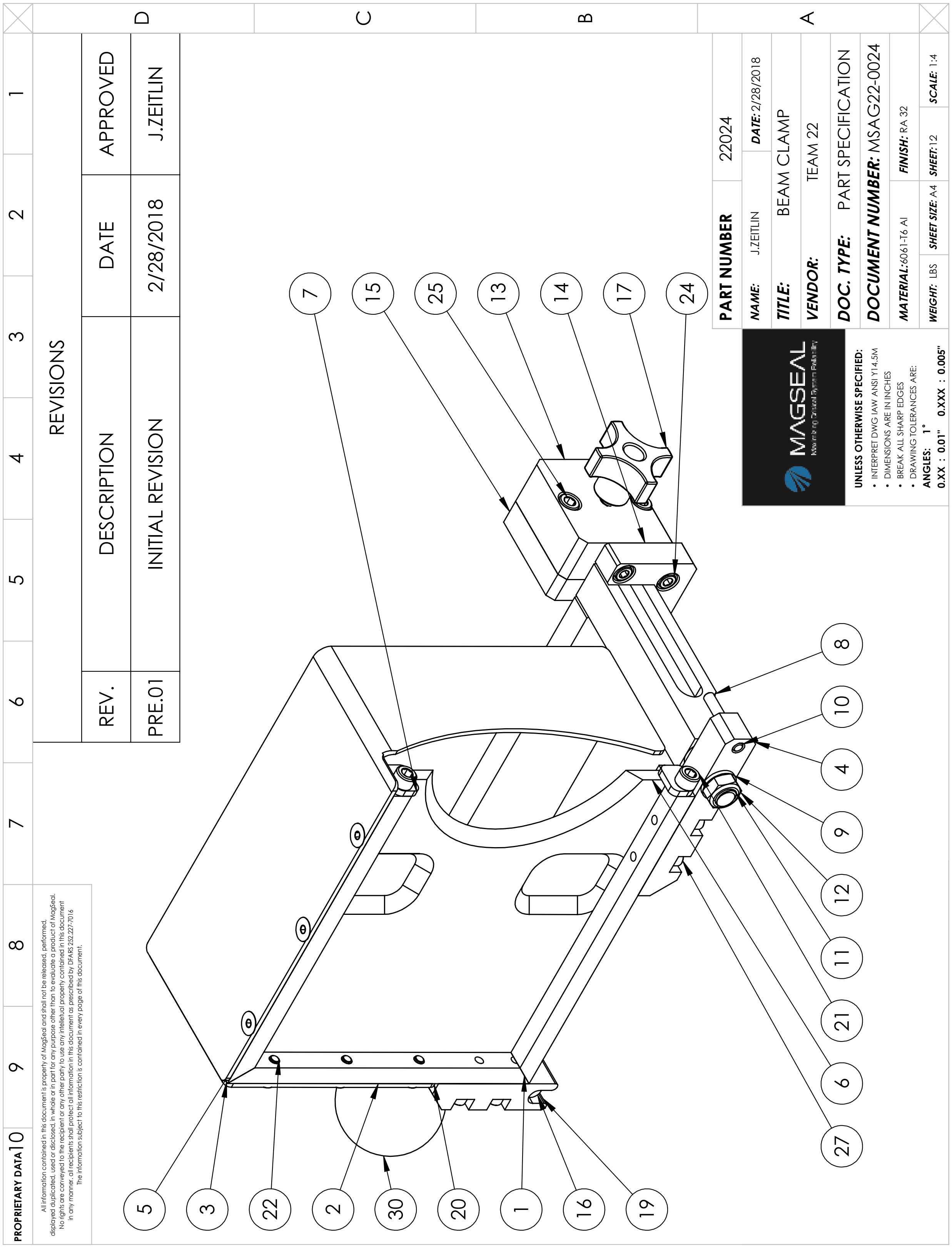

Figure 84: MSAG22-0013 Guard Assembly

Figure 85: MSAG22-0013 Guard Assembly Bill of Materials

ITEM NO.	PART NUMBER	QTY.
1	22005 FRAME BOTTOM	1
2	22004 FRAME LEFT	1
3	22003 FRAME TOP	1
4	22008 HINGE JOINT BRACKET	1
5	22015 TOP SHEATHING	1
6	22001 GUARD PANE, LARGE COLLET	1
7	22014 PANE RETAINER	2
8	22016 PIVOT BEAM	1
9	93286A045	2
10	90145A512	1
11	97042A324	1
12	90101A243	1
13	22024 BEAM CLAMP	1
14	22023 MOUNT BRACKET	1
15	22025 CLAMP BACKER	1
16	22026 SUPPORT PIN	1
17	5993K12	1
18	22028 ADJUSTMENT BUFFER	1
19	22007 LEFT PIN SUPPORT Rev Pre.02	1
20	22002 LEFT SHEATHING Rev Pre.02	1
21	91251A435	2
22	91253A003	6
23	92196A309	1
24	92196A246	3
25	92196A542	2
26	92311A237	1
27	90128A944	4
28	92320A726	1
29	92210A628	1
30	60975K86	1

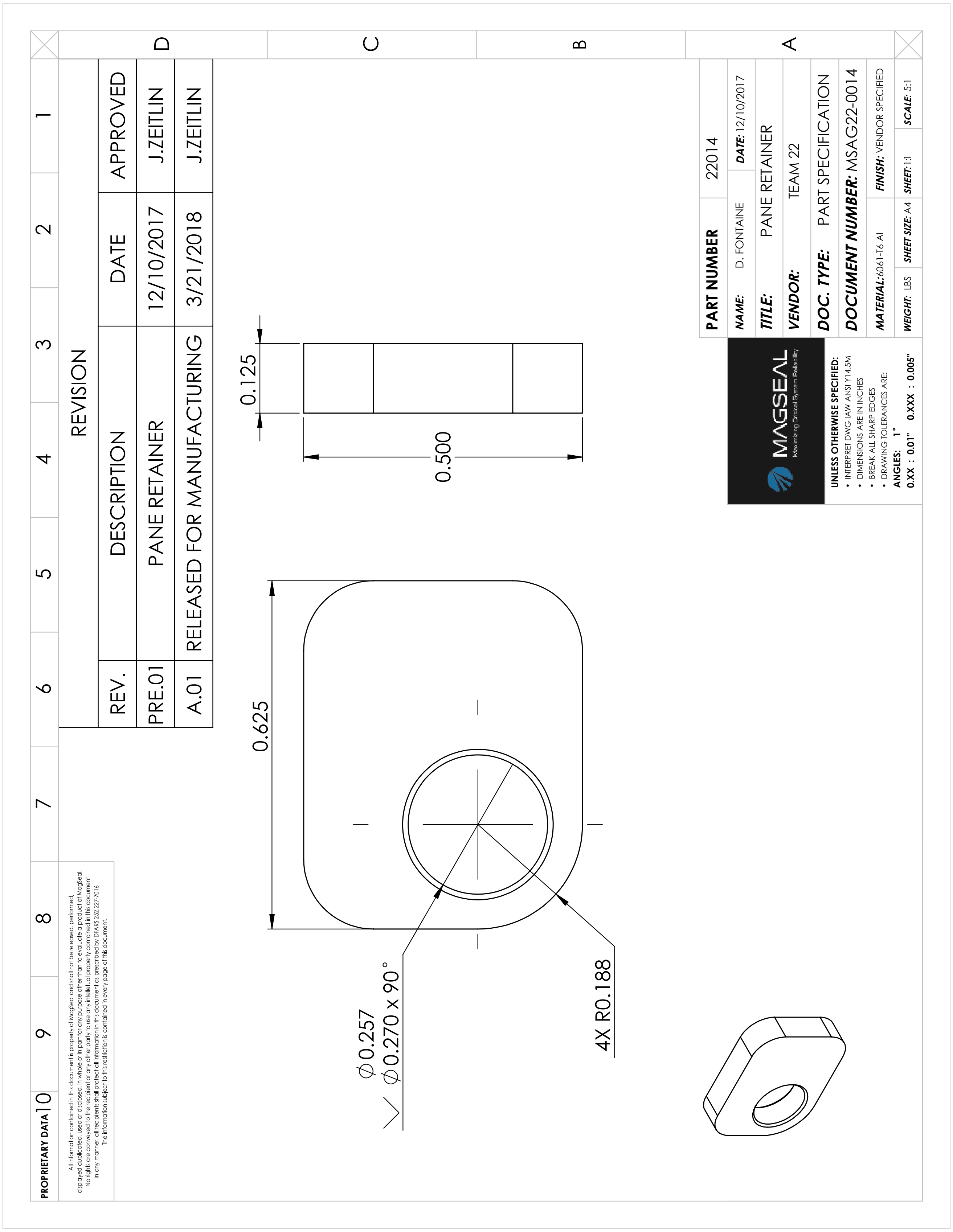

Figure 86: MSAG22-0014 Pane Retainer

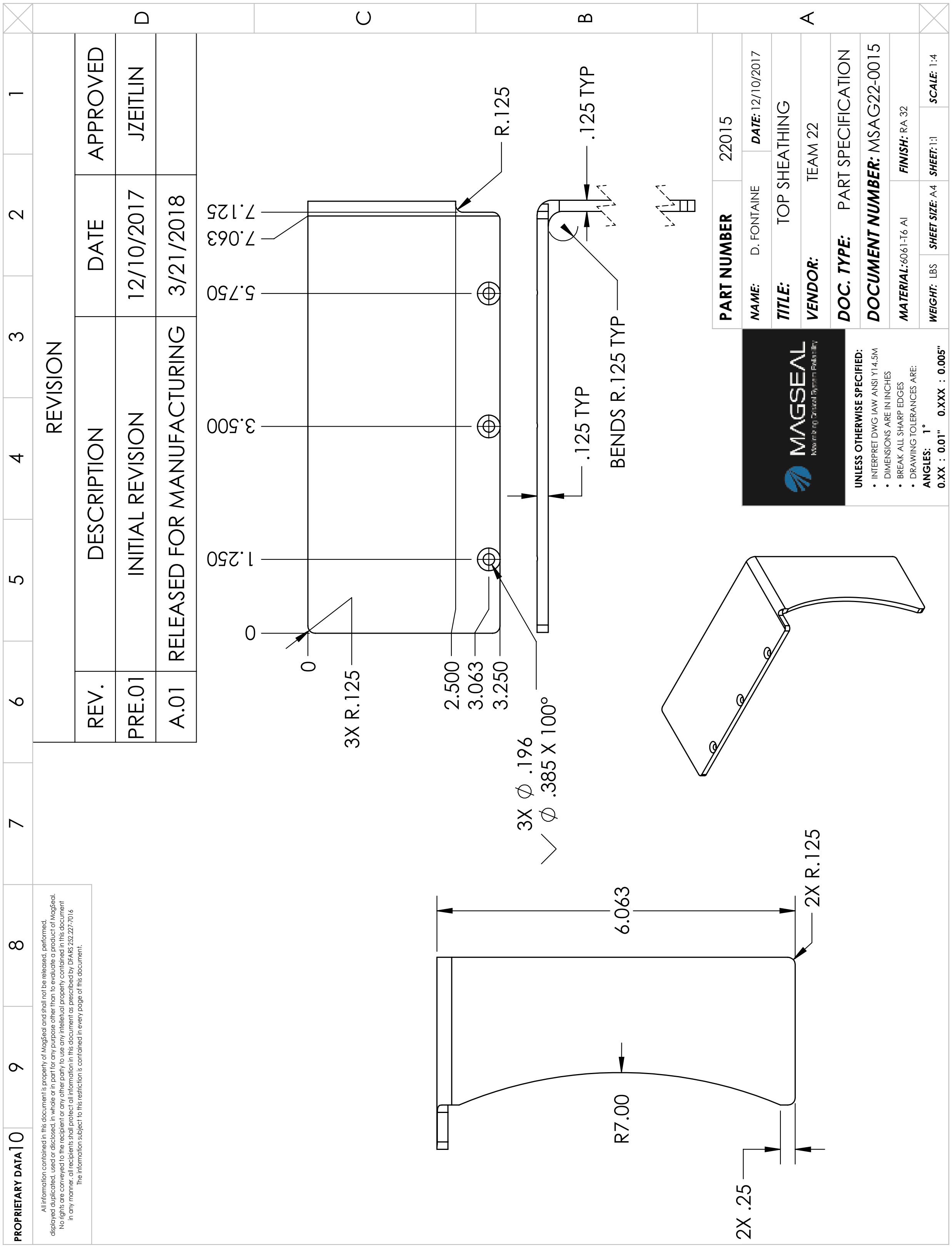

Figure 87: MSAG22-0015 Top Sheathing

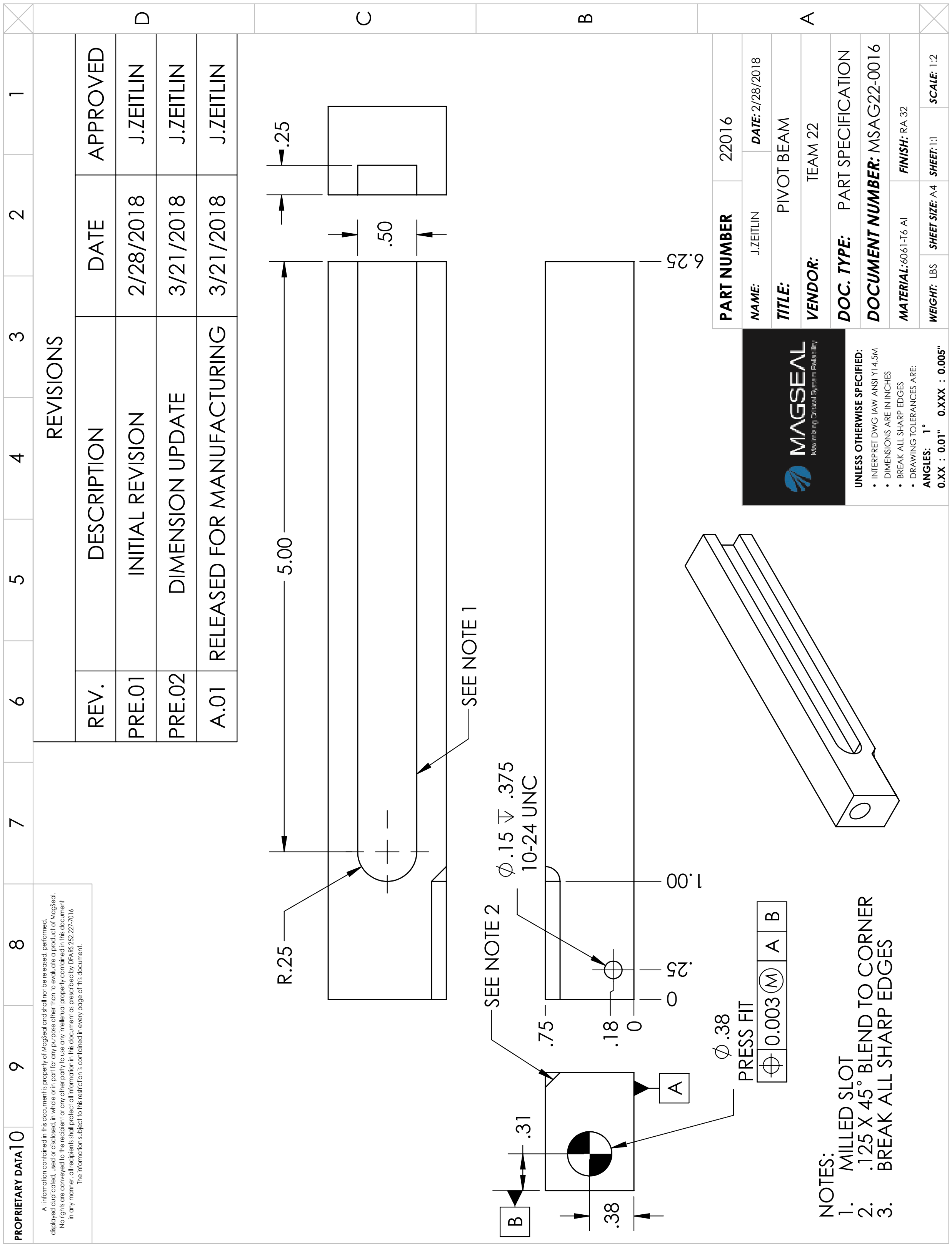

Figure 88: MSAG22-0016 Pivot Beam

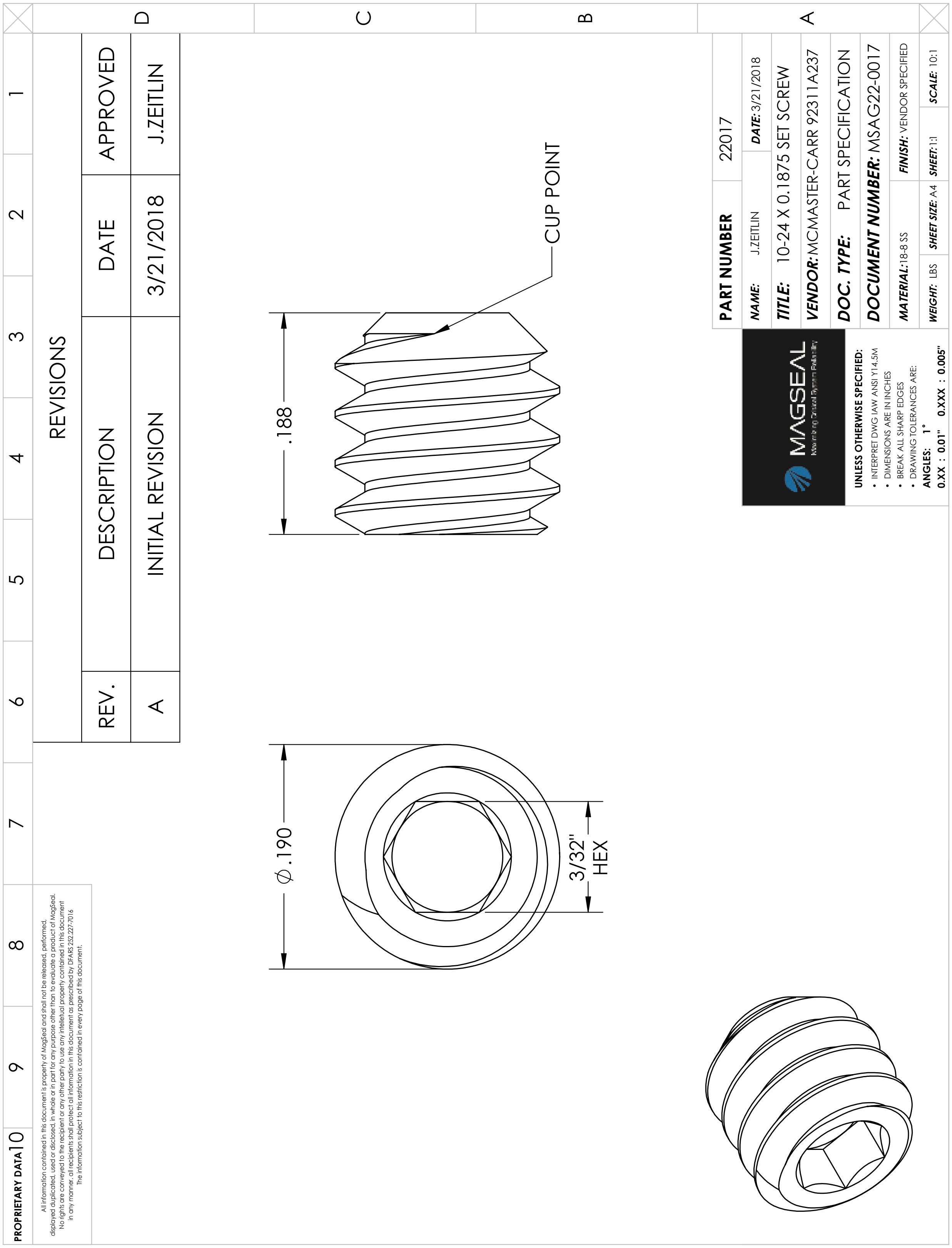

Figure 89: MSAG22-0017 10-24 X 0.1875 Set Screw

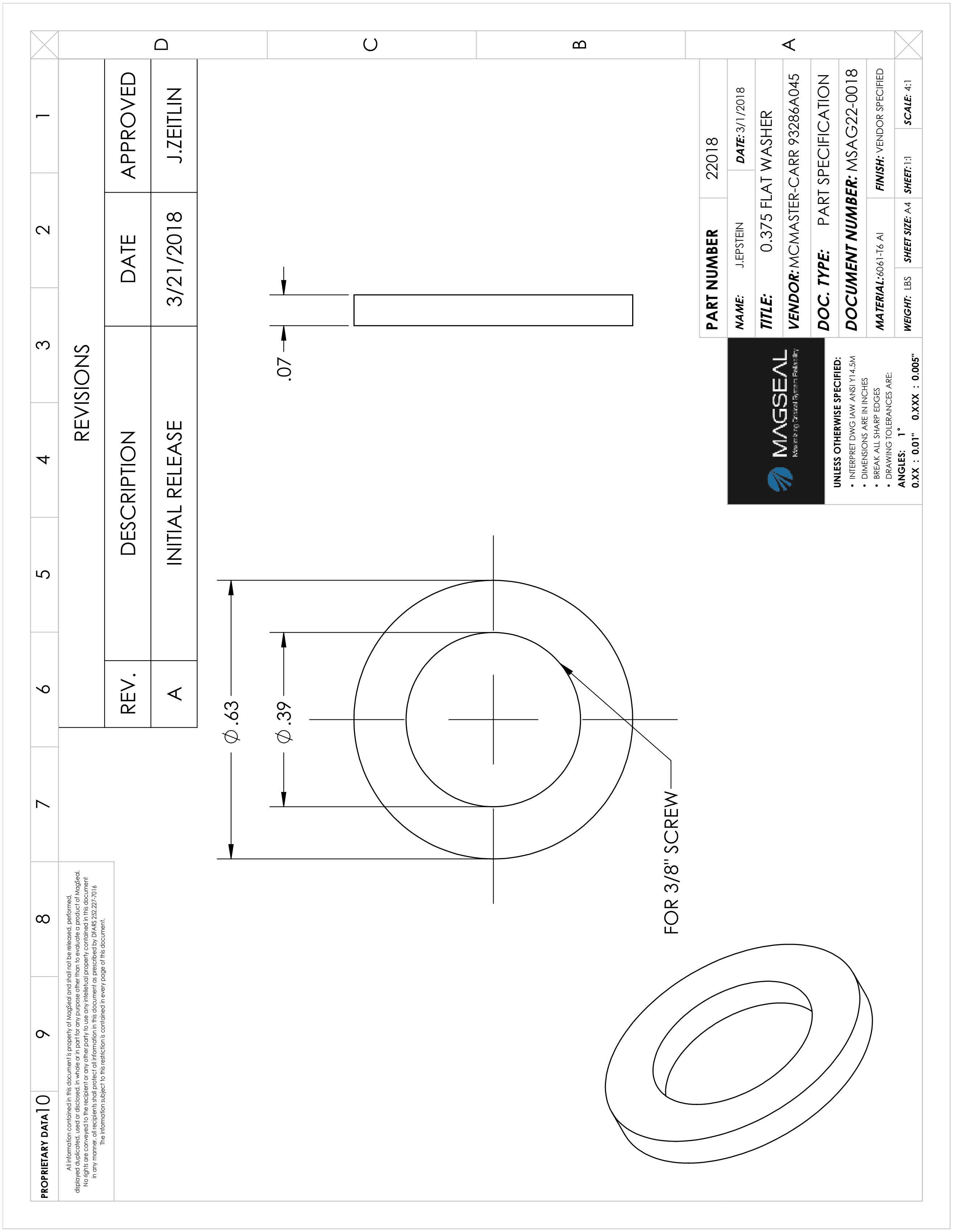

Figure 90: MSAG22-0018 0.375 Flat Washer

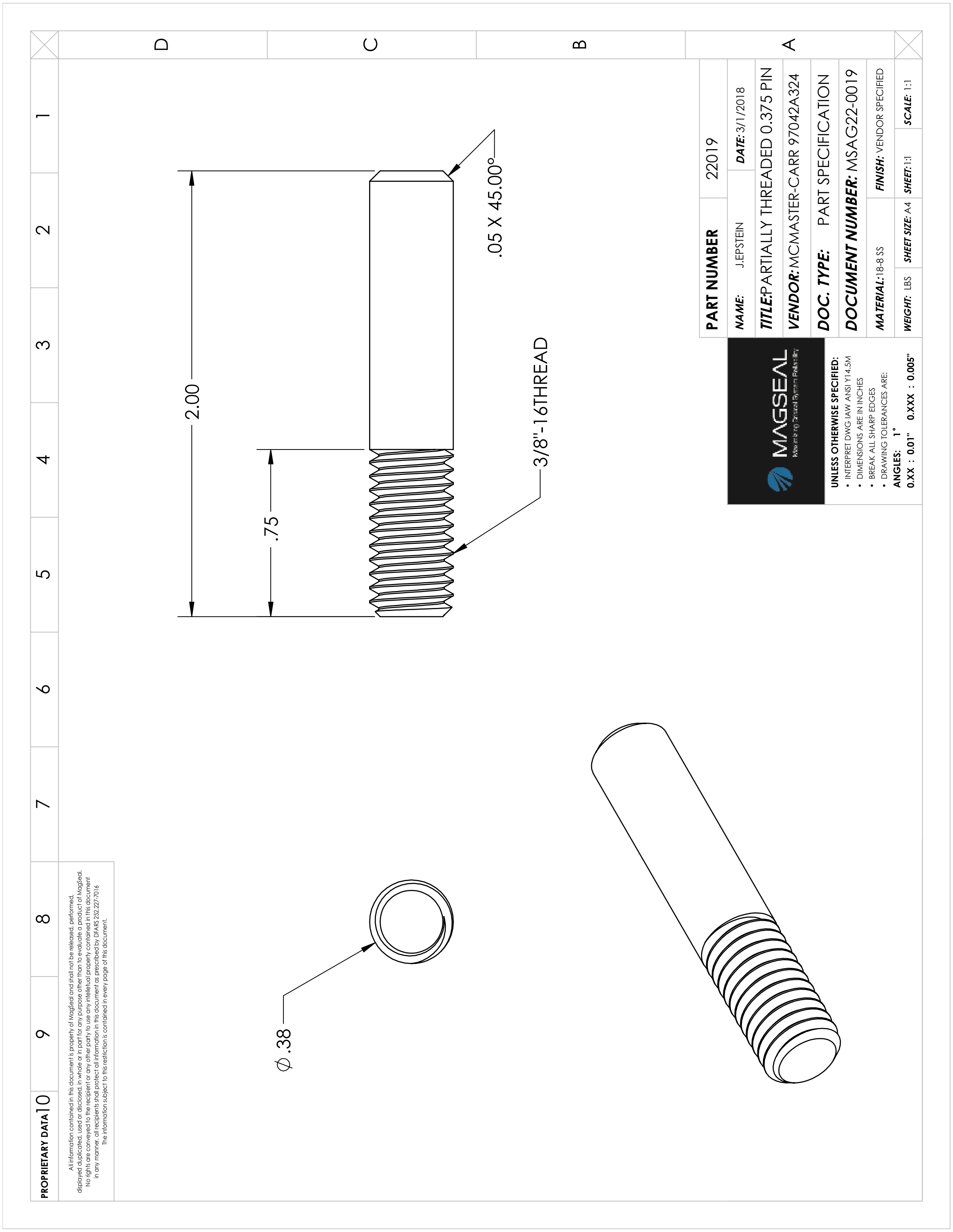

Figure 91: MSAG22-0019 Partially Threaded Pin

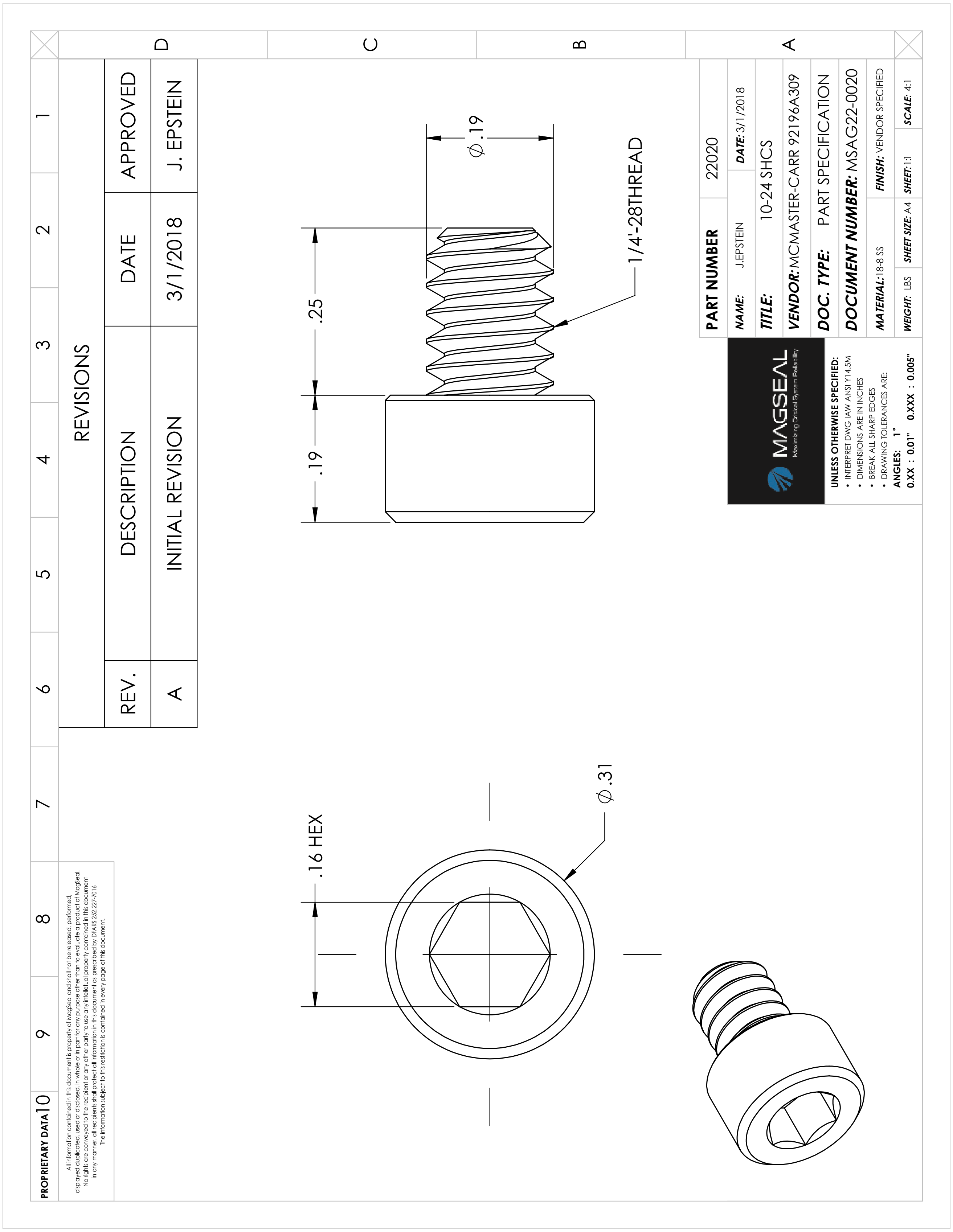

Figure 92: MSAG22-0020 10-24 SHCS X 0.25

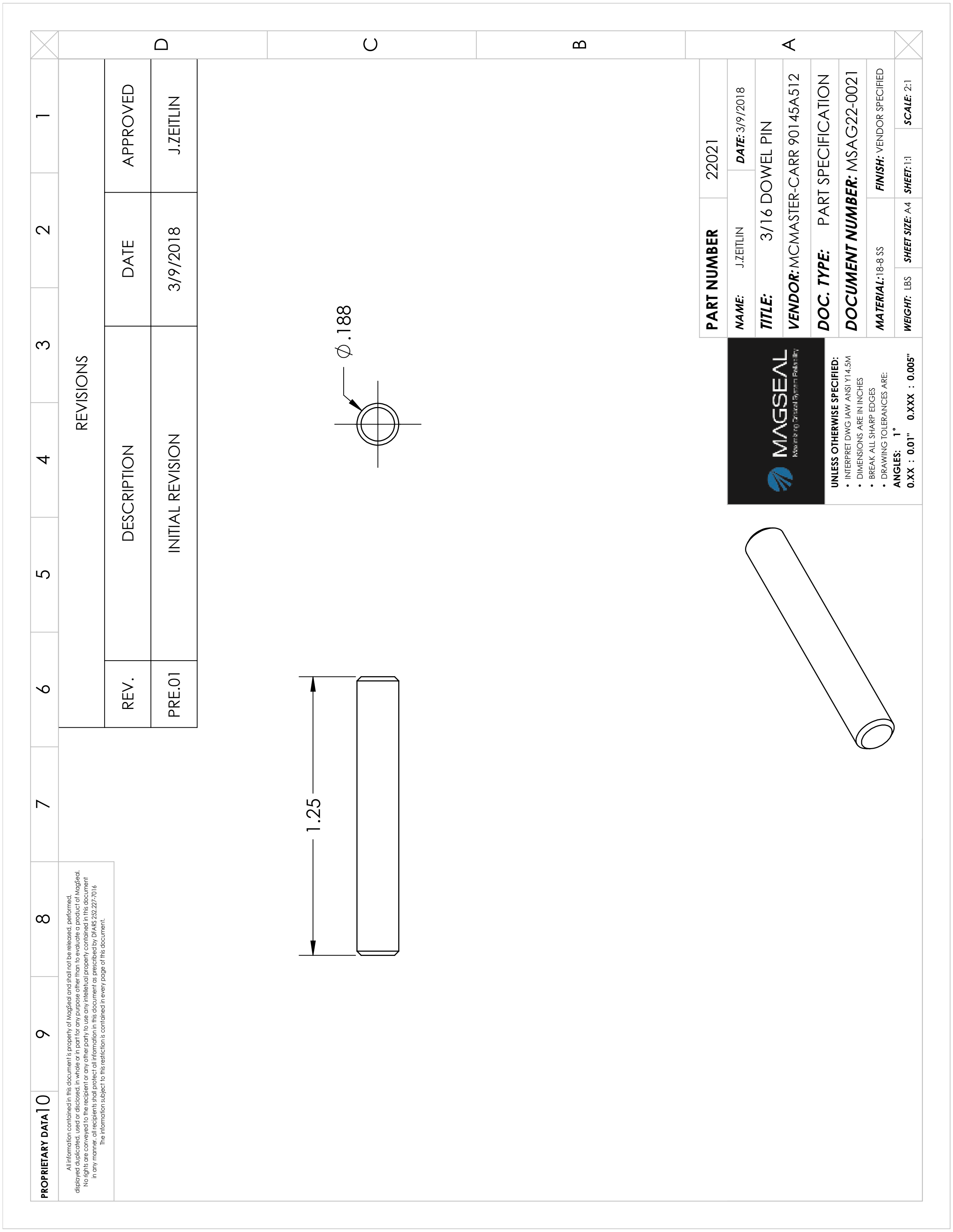

Figure 93: MSAG22-0021 0.1875 Dowel Pin

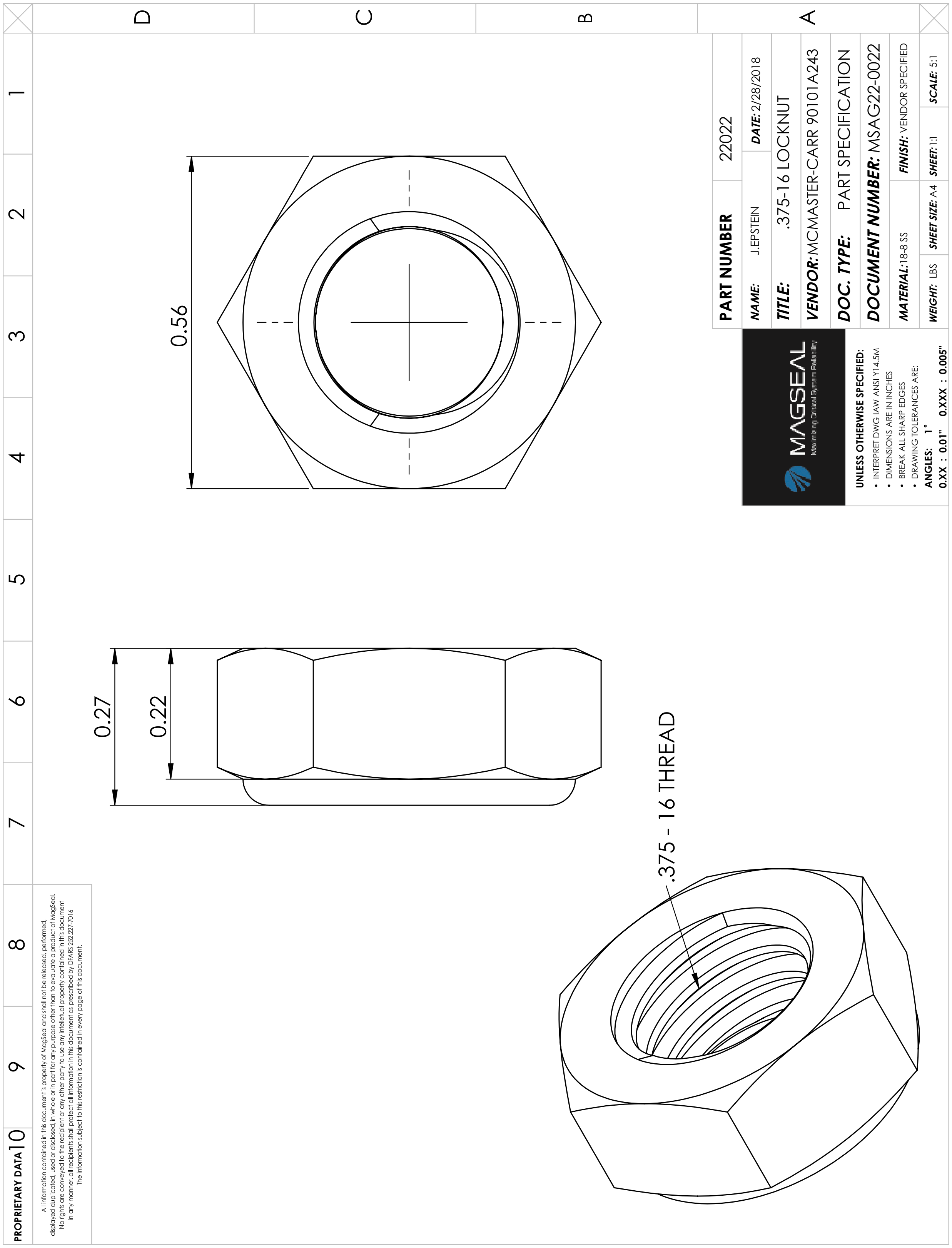

Figure 94: MSAG22-0022 0.375-16 Locknut

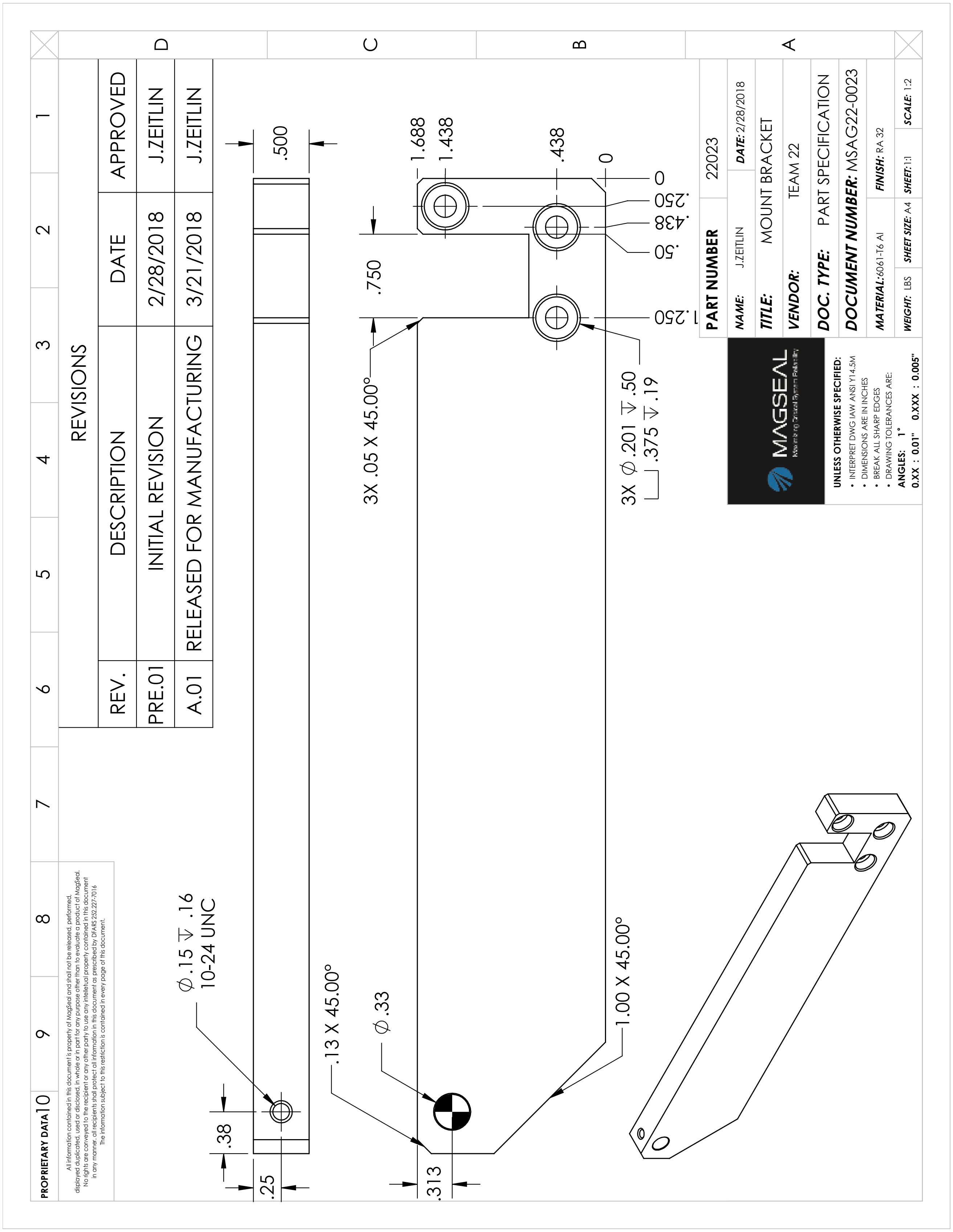

Figure 95: MSAG22-0023 Mounting Bracket

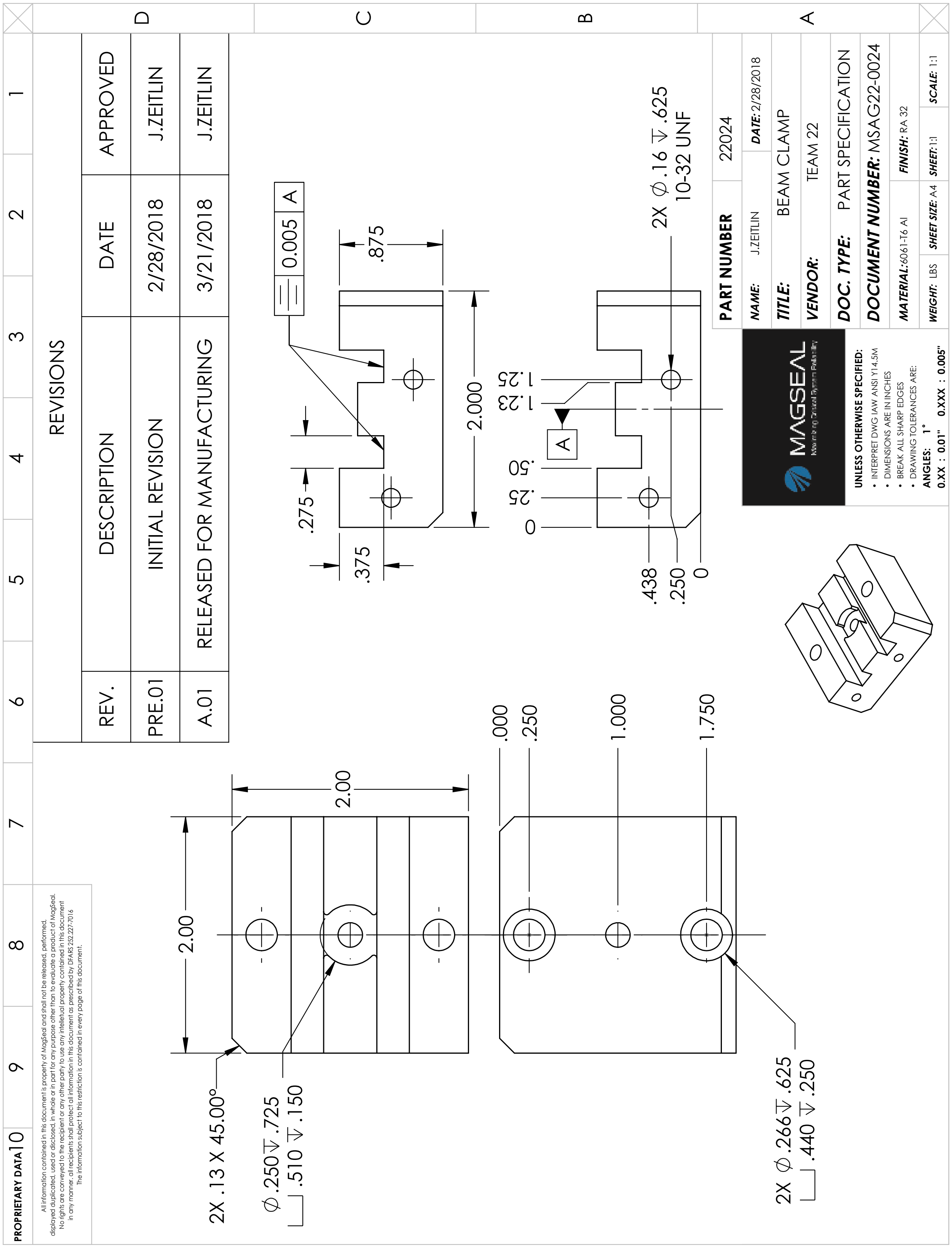

Figure 96: MSAG22-0024 Beam Clamp

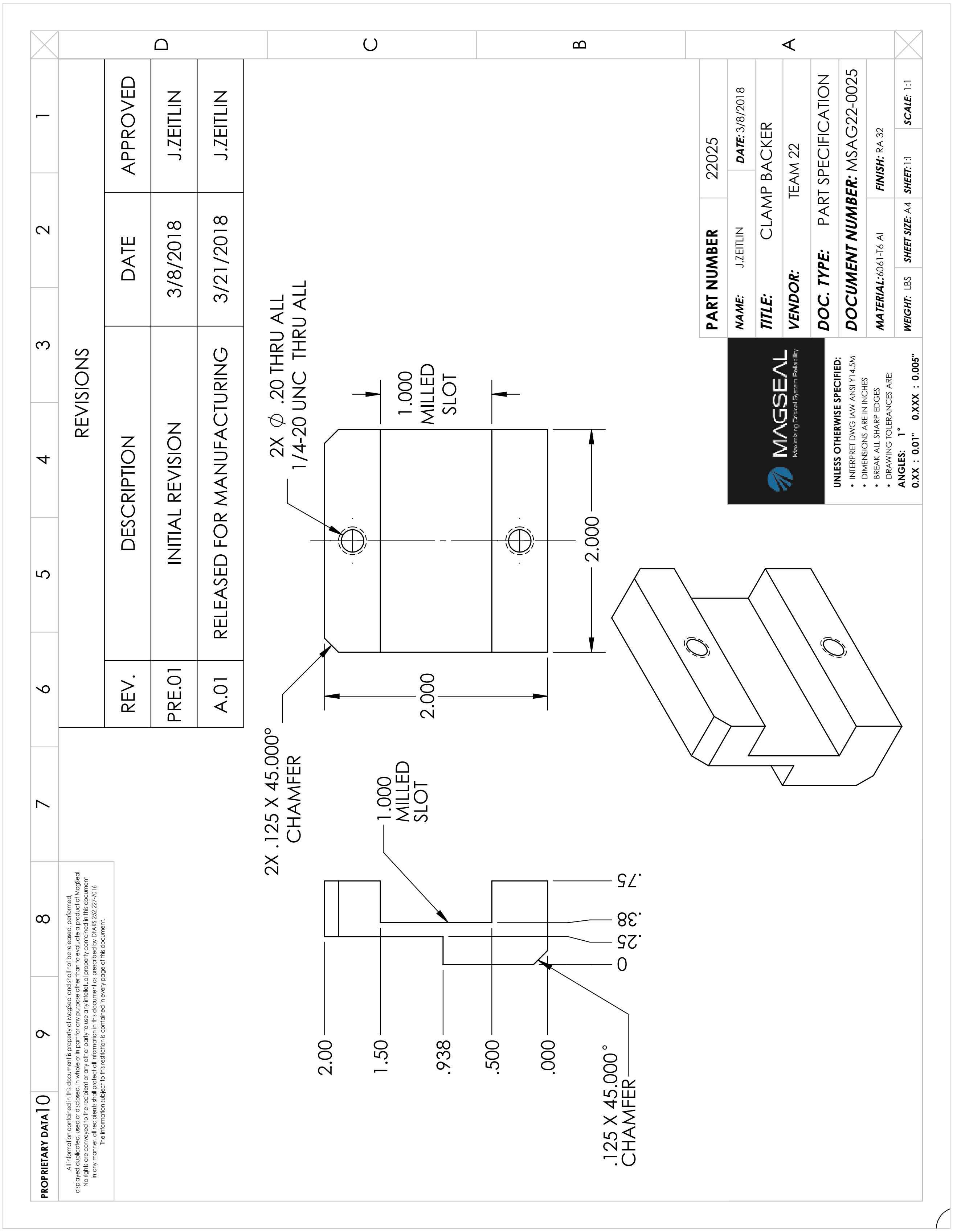

Figure 97: MSAG22-0025 Clamp Backer

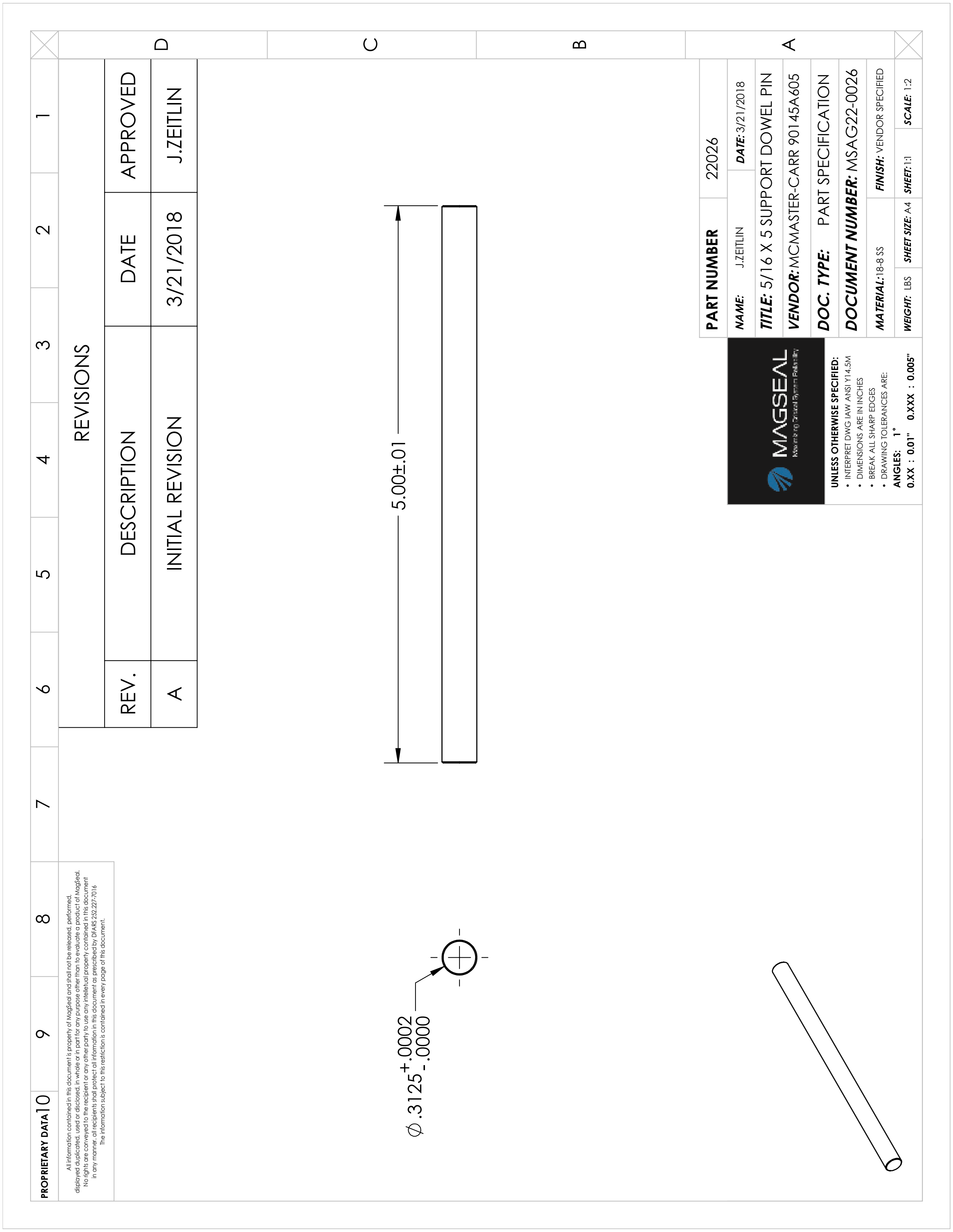

Figure 98: MSAG22-0026 5/16 X 5 Support Dowel Pin

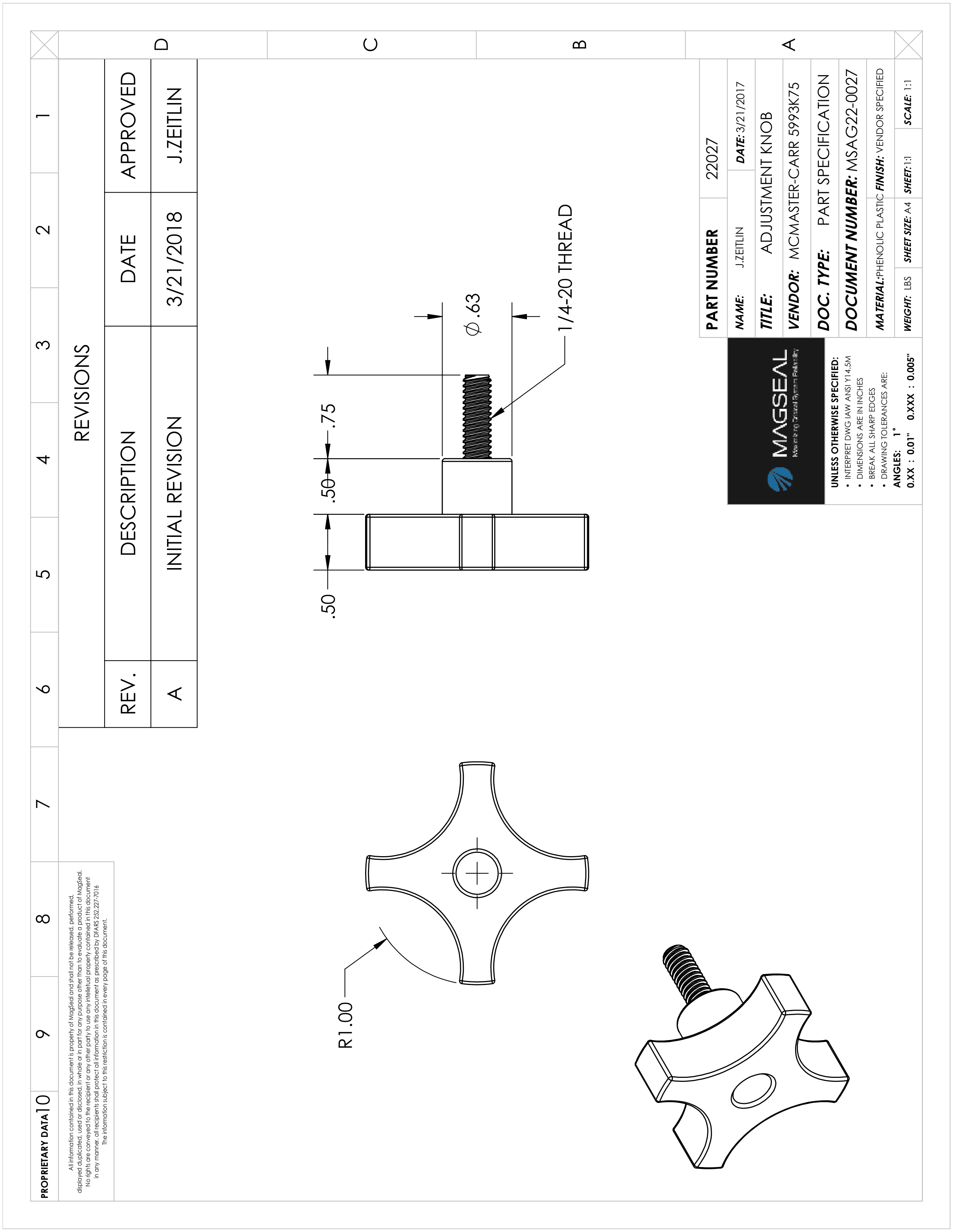

Figure 99: MSAG22-0027 Adjustment Knob

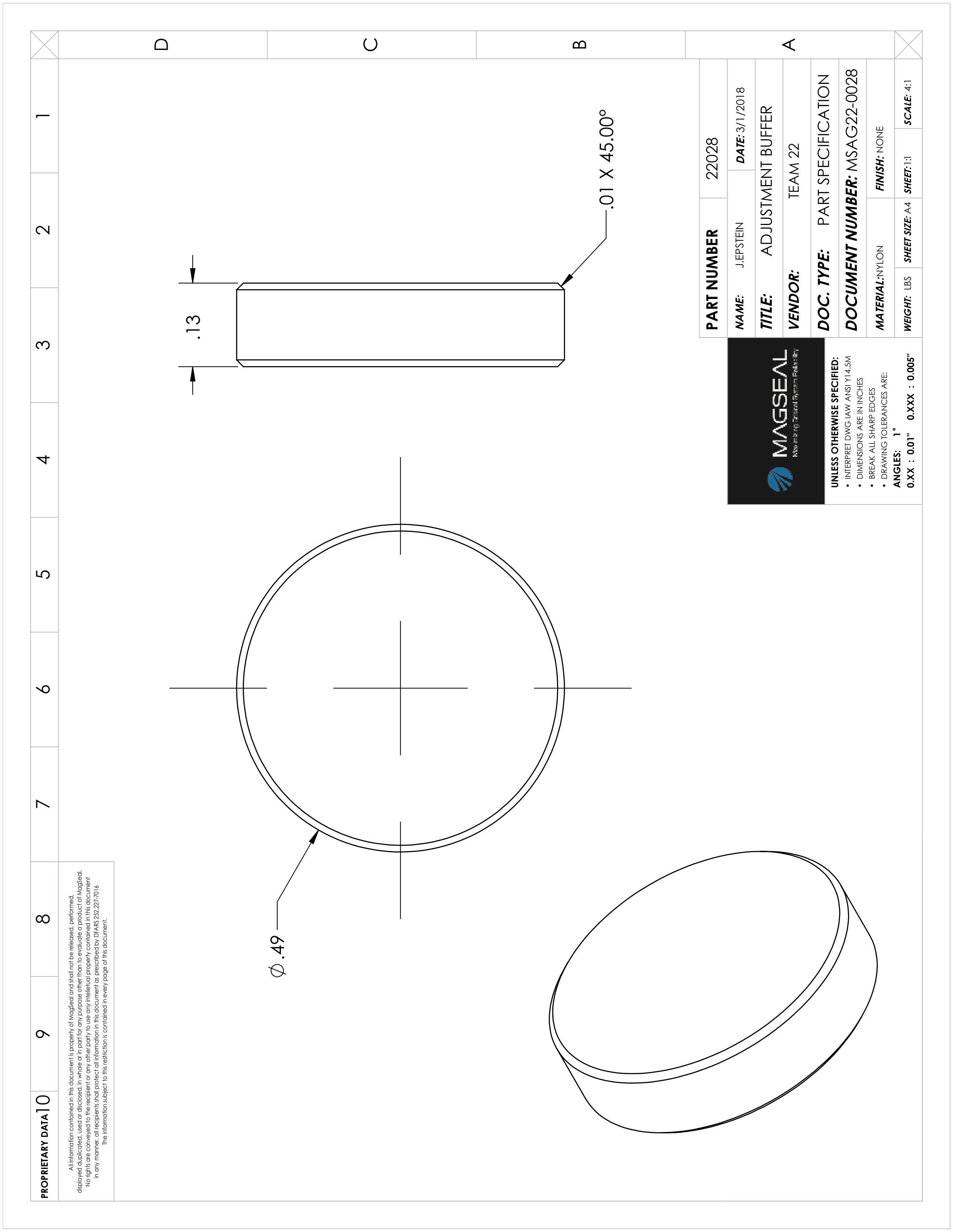

Figure 100: MSAG22-0028 Adjustment Buffer

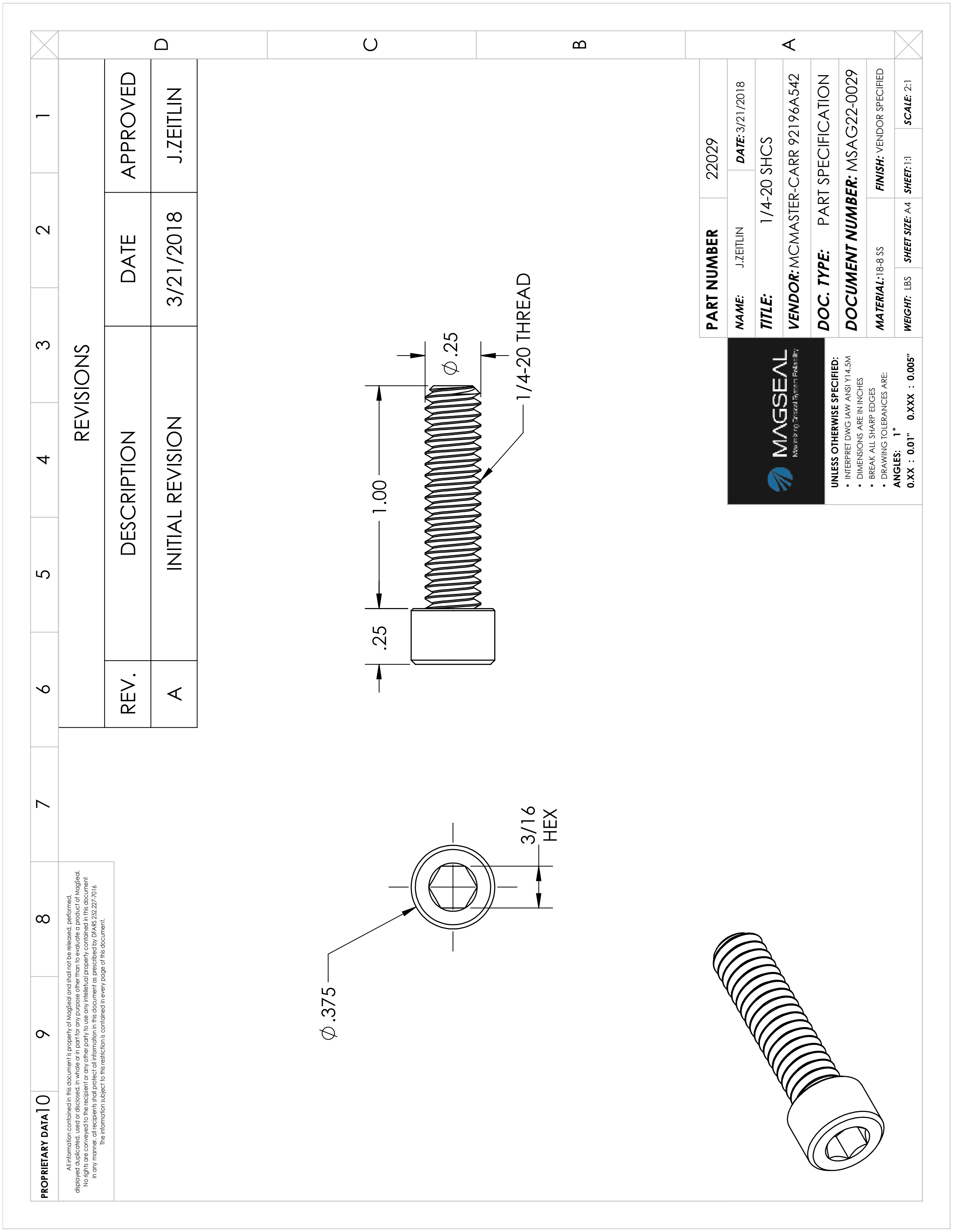

Figure 101: MSAG22-0029 1/4-20 X 1 SHCS

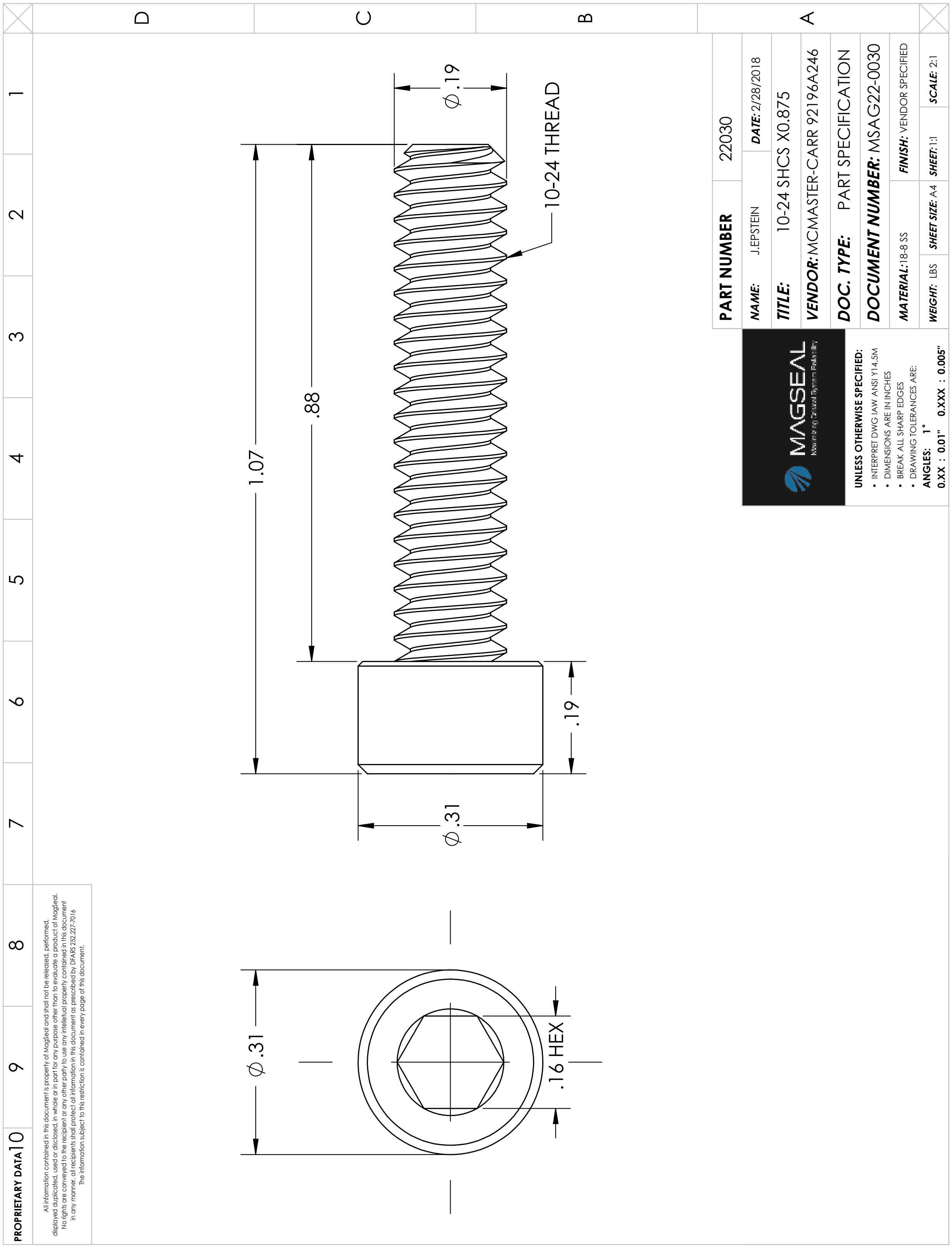

Figure 102: MSAG22-0030 10-24 X 0.875 SHCS

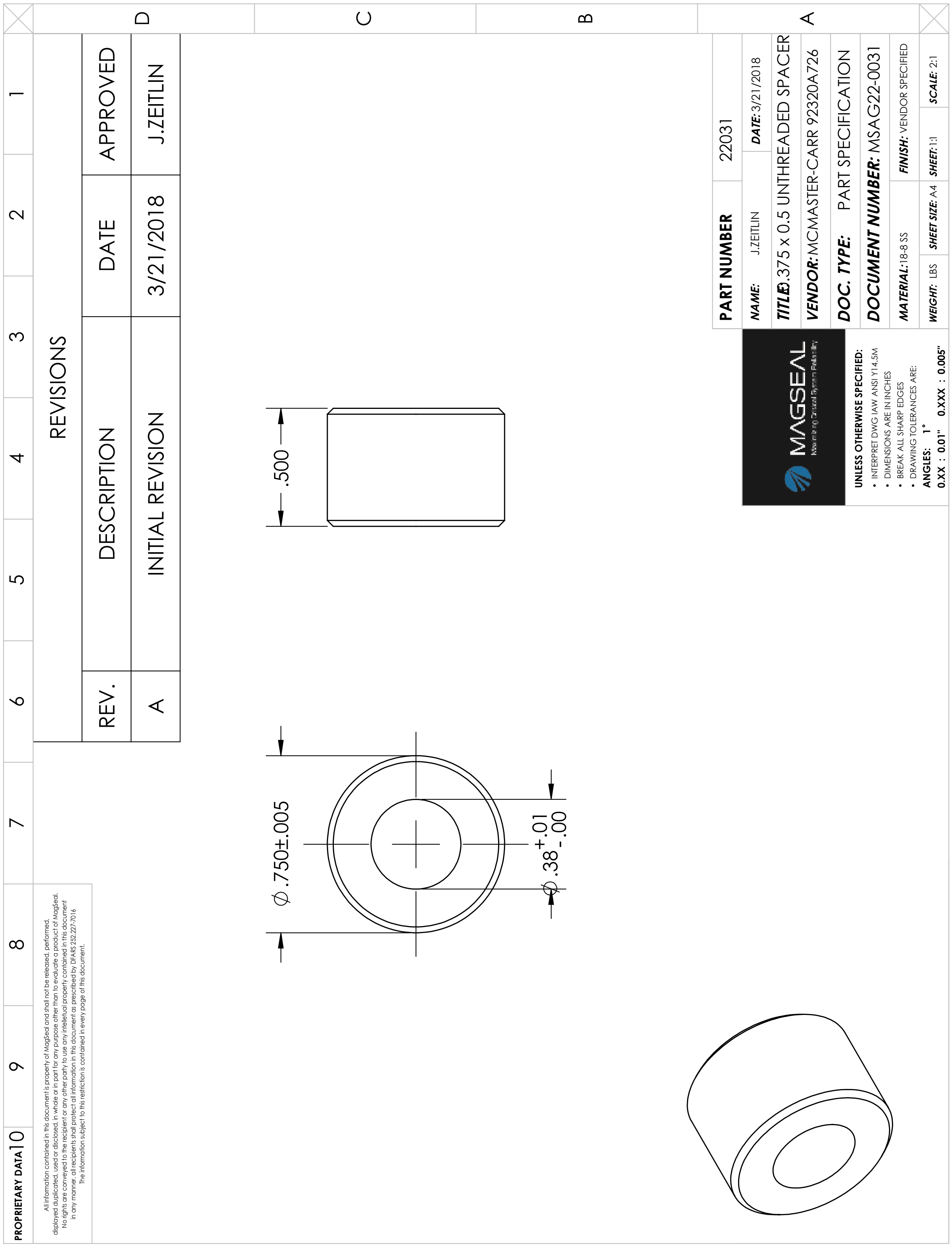

Figure 103: MSAG22-0031 0.375 X 0.5 Unthreaded Spacer

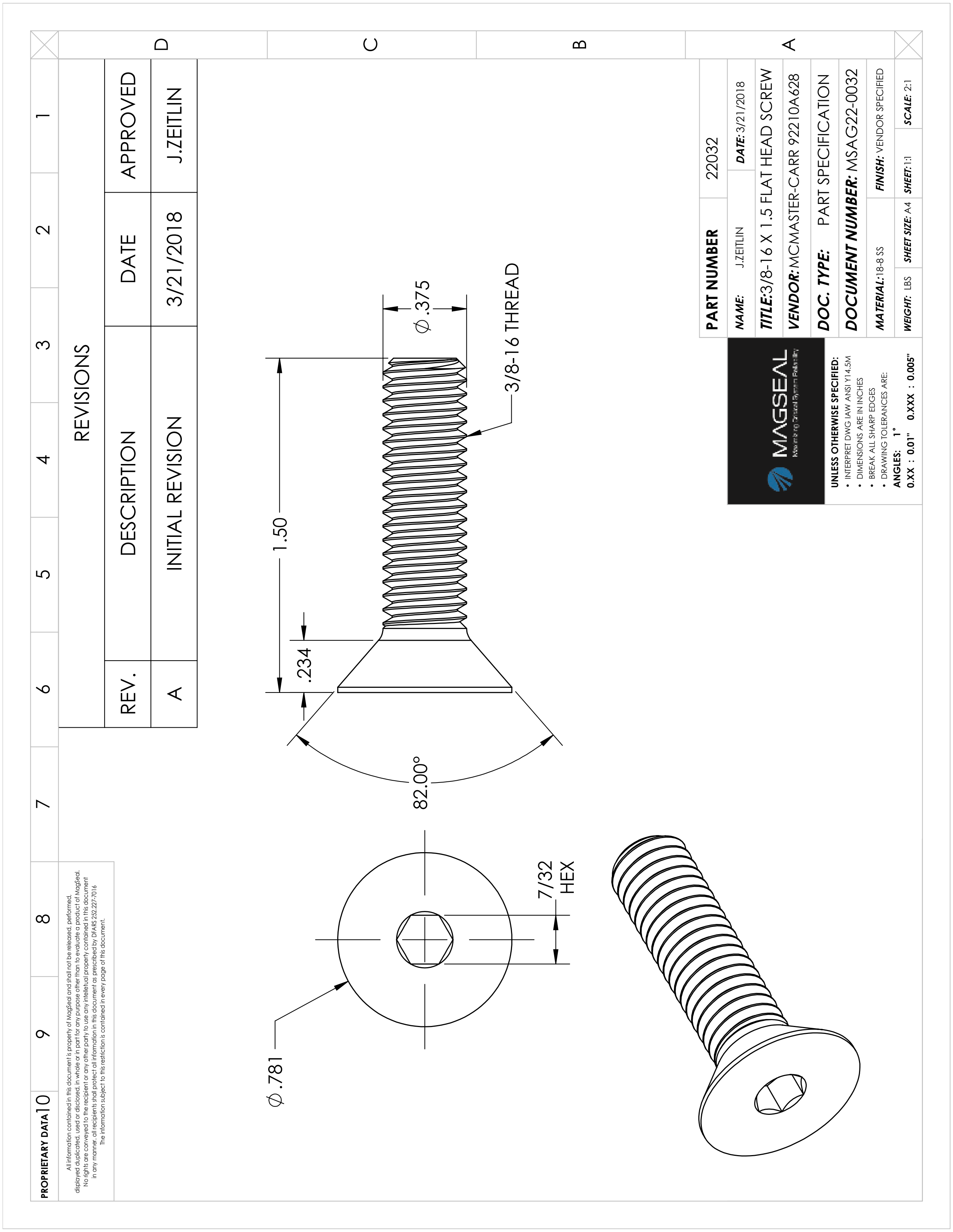

Figure 104: MSAG22-0032 0.1875-16 x 1.50 Flat Head Screw

22.2 Financial Analysis and Miscellaneous

Category	Hours Spent			
	Team 22 Members			
	Dillion Fontaine	Jason Epstein	Abhishek Maharjan	Jared Zeitlin
Administrative	13.2	7.6	9.4	16.6
CAD Development	38.6	9.7	2	21.4
Competitive Analysis	3.6	4	5.8	7.9
Conceptual Development	22.6	26.6	23.2	21.8
Design Specifications	3.6	10.9	4.4	3.8
Drawing Development	18.2	9.6	1.8	15.6
Electrical Design	17.3	1	1	9.2
Engineering Analysis	16.4	4.2	3.4	12.2
Factory Visits	14.4	14.4	14.4	14.4
Financial Analysis	9.8	2	0	10.4
Meetings	24.6	24.6	24.6	24.6
Patent Searches	5.6	7.1	4.6	3.8
Presentation Development	4.6	22.7	21.6	4.1
Presentations	4	4	4	4
Problem Definitions	9.8	12.1	6.6	5.5
Project Management	6.4	4.8	3.6	16
Prototyping	3.6	3	0	11.5
Reports	38.8	36	0	66.4
Manufacturing	35	12	8	5.2
Research	12.2	13.9	12.8	19.1
Weekly Progress Reports	4.6	13.8	9.7	1.7
Total Hours Spent	306.9	244	160.9	295.2

Table 18: Team 22 Human Resource Allocation

Category	Hours Spent		
	Outside Consultants		Faculty
	Santiago Sanchez	Howie King	Dr. Nassersharif
Administrative	2	0	0
CAD Development	10	0	0
Competitive Analysis	0	0	0
Conceptual Development	0	0	0
Design Specifications	0	0	0
Drawing Development	0	0	0
Electrical Design	0	0	0
Engineering Analysis	0	0	0
Factory Visits	7.2	7.2	0
Financial Analysis	0	0	0
Meetings	6	4	2
Patent Searches	0	0	0
Presentation Development	0	0	0
Presentations	2	0	2
Problem Definitions	0	0	0
Project Management	0	0	0
Prototyping	0	0	0
Reports	0	0	0
Research	0	0	0
Weekly Progress Reports	0	0	0
Total Hours Spent	27.2	11.2	4

Table 19: Outside Consultant Resource Allocation

Parts Ordered to Complete the Project				
Order Form	Part Number	Description	Total Cost	Category
1	92196A315	0.25-28 SHCS X 0.375	$9.95	Hardware
1	92210A301	10-32 FLAT HEAD X 0.375	$6.34	Hardware
1	92196A244	10-24 SHCS X 0.625	$10.34	Hardware
1	92196A246	10-24 SHCS X 0.875	$12.31	Hardware
1	92196A542	0.25-28 SHCS X 1.00	$12.89	Hardware
1	90145A512	3/16 DOWEL PINS 1.25	$10.07	Hardware
1	93286A045	3/8 ALUMINIUM WASHER	$2.50	Hardware
1	97042A324	3/8-16 PARTIALLY THREADED STUD	$11.26	Hardware
1	92196A309	10-24 SHCS X 0.25	$4.33	Hardware
1	90101A243	0.375-16 LOCKNUT	$6.23	Hardware
1	5993K75	High-Temperature, with 1/4"-20 Thread 1" Long Stud, 2" Wide Head	$4.54	Hardware
1	92311A237	10-24 SET SCREW X 0.1875	$4.82	Hardware
2	8975K224	6061 Aluminum, 5/8" Thick x 3" Wide, 1/2 Feet Long	$9.94	Raw Material
2	90145A605	18-8 Stainless Steel Dowel Pin, 5/16 Diameter, 5" Long	$6.00	Hardware
2	8975K619	6061 Aluminum, 1/2" Thick x 1-3/4" WideX 1ft	$7.37	Raw Material
2	9517K564	Tight-Tolerance Low-Carbon Steel Bar, 3/4" Thick, 1" Wide x 1ft	$23.76	Raw Material
2	8975K941	6061 Aluminum, 7/8" Thick x 2" Wide X 1ft	$17.04	Raw Material
2	9517K481	Tight-Tolerance Low-Carbon Steel Bar, 3/8" Thick, 3/4" Wide x 1 Ft	$45.27	Raw Material
2	9517K542	Tight-Tolerance Low-Carbon Steel Bar, 5/8" Thick, 3/4" Wide	$19.36	Raw Material
2	89015K222	6061 Aluminum Sheet, 0.09" Thick, 4" x 24"	$16.13	Raw Material
2	60975K86	Comfort-Grip Plastic Ball Knob with 3/8"-16 Threaded Hole, 1-7/8" Head	$4.69	Hardware
2	92320A726	Stainless Steel Unthreaded Spacer, 3/4" OD, 1/2" Long, for 3/8" Screw	$11.24	Hardware
2	92210A628	18-8 Stainless Steel Hex Drive Flat Head Screw, 3/8"-16 Thread Size, 1-	$6.45	Hardware
2	92196A542	18-8 Stainless Steel Socket Head Screw, 1/4"-20 Thread Size, 1" Long	$12.89	Hardware
2	8975K577	6061 Aluminum, 1/8" Thick x 1/2" Wide x 1ft	$0.99	Raw Material
3	29895A54	45 Degree Bevel Cutter, 1-1/2" Diameter	$130.49	Tools
3	8977A881	Ball-End, TiN Coated, 4 Flute, 5/16" Mill Diameter	$39.01	Tools
4	8085T15	iniature Washdown Snap-Acting Switch, Lever Actuator, 5A Switching Cu	$6.63	Electrical
4	72035K511	UL Class CC Time-Delay Midget Fuse for Motors, 1A	$14.72	Electrical
4	4234K2	Inline Holder for UL Class CC Midget Fuse	$21.00	Electrical
4	4234K3	Rubber Cover for Inline Holder for Midget Fuse	$3.06	Electrical
4	1041N11	w Terminal Block with See-Through Cover & 4 Enclosed Side-Mount Circ	$15.55	Electrical
4	71425K23	Heat-Shrink Spade Terminals for 16-14 Wire Gauge and Number 6 Screw	$5.75	Electrical
4	7934K13	educing Crimp-on Butt Splices, Heat-Shrink, for 16-14 to 22-18 Wire Gaug	$12.37	Electrical
4	8248K16	Harsh Environment Cable, Three 16-Gauge Wires x 10 FEET	$19.10	Electrical
4	7870T31	Black 16 Gauge Appliance Cable x 10 FEET	$11.36	Electrical
4	9096T11	Straight-Blade Connector, Three-Blade Straight Plug, Grounded, NEMA 5	$15.36	Electrical
5	Z169-ND	RELAY SSR SPST-NO 10A@240VDC	$61.88	Electrical
5	Z924-ND	HEAT SINK TRACK MNT FOR G3NA SER	$15.47	Electrical
6	92210A086	18-8 Stainless Steel Hex Drive Flat Head Screw	$4.37	Hardware
6	2636A116	General Purpose Tap for Through-Hole Threading, 2-56 Thread Size, wit	$11.56	Tools
6	7852K11	Heat-Shrink Wrap 1.2" ID Before Shrinking, 8" Long	$12.95	Electrical
6	72035K518	UL Class CC Time-Delay Midget Fuse for Motors, 10A	$14.72	Electrical
6	91292A117	18-8 Stainless Steel Socket Head Screw M4 x 0.7 mm Thread, 12 mm Long	$6.59	Hardware

Table 20: List of Parts and Costs Ordered to Complete Project

Total Costs (By Cost Center)		
Cost Center	**Total Cost**	**Percentage**
Labor	$56,344.87	75.78%
Raw Materials	$262.74	0.35%
Hardware	$146.07	0.20%
Electrical Components	$58.59	0.08%
Tools	$58.59	0.08%
Prototyping	$387.95	0.52%
Software	$17,093.99	22.99%
Total	$74,352.80	100.00%

Table 21: Total Costs Breakdown

rings from pierced discs or thick-walled, ring-shaped blanks between rolls which control wall thickness, ring diameter, height and contour.

(10) *Bolt-headers* mean the same as an upsetter or forging machine except that the diameter of stock fed into the machine is much smaller, i.e., commonly three-fourths inch or less.

(11) Rivet making machines mean the same as upsetters and boltheaders when producing rivets with stock diameter of 1-inch or more. Rivet making with less than 1-inch diameter is usually a cold forging operation, and therefore not included in this subpart.

(12) Upsetters (or forging machines, or headers) type of forging equipment, related to the mechanical press, in which the main forming energy is applied horizontally to the workpiece which is gripped and held by prior action of the dies.

(f) As used in § 1910.219, unless the context clearly requires otherwise, the following mechanical power-transmission guarding terms shall have the meaning prescribed in this paragraph.

(1) *Belts* include all power transmission belts, such as flat belts, round belts, V-belts, etc., unless otherwise specified.

(2) *Belt shifter* means a device for mechanically shifting belts from tight to loose pulleys or vice versa, or for shifting belts on cones of speed pulleys.

(3) *Belt pole* (sometimes called a *belt shipper* or *shipper pole*,) means a device used in shifting belts on and off fixed pulleys on line or countershaft where there are no loose pulleys.

(4) *Exposed to contact* means that the location of an object is such that a person is likely to come into contact with it and be injured.

(5) *Flywheels* include flywheels, balance wheels, and flywheel pulleys mounted and revolving on crankshaft of engine or other shafting.

(6) *Maintenance runway* means any permanent runway or platform used for oiling, maintenance, running adjustment, or repair work, but not for passageway.

(7) *Nip-point belt and pulley guard* means a device which encloses the pulley and is provided with rounded or rolled edge slots through which the belt passes.

(8) *Point of operation* means that point at which cutting, shaping, or forming is accomplished upon the stock and shall include such other points as may offer a hazard to the operator in inserting or manipulating the stock in the operation of the machine.

(9) *Prime movers* include steam, gas, oil, and air engines, motors, steam and hydraulic turbines, and other equipment used as a source of power.

(10) *Sheaves* mean grooved pulleys, and shall be so classified unless used as flywheels.

[39 FR 23502, June 27, 1974, as amended at 39 FR 41846, Dec. 3, 1974; 53 FR 8353, Mar. 14, 1988]

§ 1910.212 General requirements for all machines.

(a) *Machine guarding*—(1) *Types of guarding*. One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are—barrier guards, two-hand tripping devices, electronic safety devices, etc.

(2) *General requirements for machine guards*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.

(3) *Point of operation guarding*. (i) Point of operation is the area on a machine where work is actually performed upon the material being processed.

(ii) The point of operation of machines whose operation exposes an employee to injury, shall be guarded. The guarding device shall be in conformity with any appropriate standards therefor, or, in the absence of applicable specific standards, shall be so designed and constructed as to prevent the operator from having any part of his body in the danger zone during the operating cycle.

(iii) Special handtools for placing and removing material shall be such as to permit easy handling of material without the operator placing a hand in the danger zone. Such tools shall not be in lieu of other guarding required by this

Acknowledgements

Team 22 would like to thank Santiago Sanchez, and Howie King for their guidance and advisement throughout the project, along with putting in numerous hours to model the machine in SolidWorks to allow the team to conduct numerous studies and better visualize the problem.

Team 22 would like to thank Dan Stein, and Bill Walek of the Tiffany & Co. Process Engineering Team for assisting Jared with preparing STL files for 3D printing and allowing us to print the prototype on a large 3D printer at Tiffany & Co.'s facility in Cumberland Rhode Island.

Team 22 would like to thank Tim LaLonde for giving the team insight into analyzing the safety aspect of the project. Tim's information helped in analyzing the guard from an OSHA perspective as well as performing the product specific analysis.

Team 22 would like to thank Dr. Bahram Nassersharif for assisting team 22 for providing feedback along with consulting on various aspects of the project.