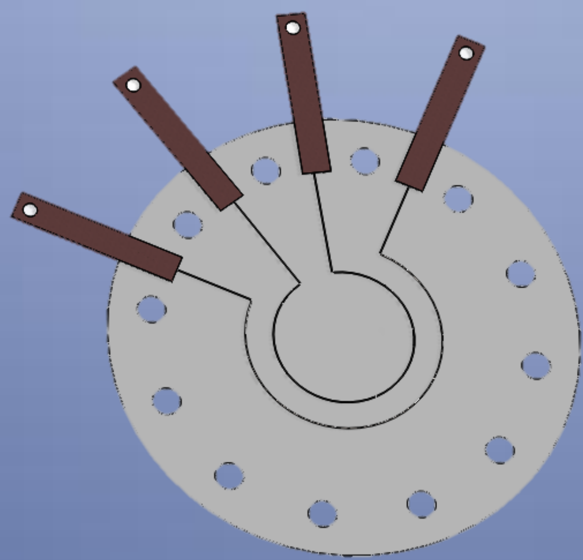


Bird Ingestion Test Separation Membrane

Final Design Report

Sponsoring Companies:	WestCaRD/GE Aviation
Project Advisor:	Kathryn Atamanchuk
Prepared for:	Dr. Paul Labossiere
Prepared by:	Team 21 - MACH 21

Matthew Bailes

Evan Foster

Matthew Tecson

Xin Yu

Due: December 1, 2014

Executive Summary

MACH 21 was tasked with designing a procedure and accompanying tooling to manufacture Mylar bird ingestion test separation membranes. The membranes are used to seal the chamber of an air cannon used in bird ingestion testing of GE Aviation aircraft engines at the WestCaRD Testing and Research Development Center. Currently, the membranes are being ordered from USA and suffer from inconsistency in manufacturing and large lead times. The membranes consist of two layers of Mylar film with heating wires and appropriate copper connections in between. The overall manufacturing process consists of four processes spread over three mechanical implements. The four processes are Mylar cutting, Mylar hole punching, wire processing and final assembly. The Mylar cutting machine consists of a linearly sliding utility blade to cut the Mylar to length, and a different utility blade that revolves on a circular track with a clamp to hold down the Mylar. The hole punching machine consists of a manually operated punch and die system with a rotating disk assembly to locate the holes. The wire processing and overall assembly process tooling were integrated into a single machine to save time in operation and space in storage. The wire bending and assembly plate consists of molds and a track along which a guide slides in order to deform the wire to the correct shape. The plate also includes a jig used to align the Mylar and wire assembly during assembly. The entire manufacturing system fits on a 6 x 3 foot table and a membrane can be manufactured in under 15 minutes. In the first year, the new manufacturing process is estimated to save approximately $50 and weeks of lead time over the previous system of purchasing the membranes. In the second year and years after, the manufacturing process is estimated to save upwards of $2500 per year. The cost to manufacture the tooling will be approximately $2700.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

The General Electric Testing and Research Development Centre (GE TRDC), shown in Figure 1 is a testing facility located at the Winnipeg James Armstrong Richardson International Airport. The site is owned by GE where West Canitest R&D Inc. (WestCARD) is a non-profit organization that facilitates research. Facility is operated by StandardAero and at the GE TRDC, prototype GE Aviation jet engines are tested to ensure they comply with government and industry safety regulations and guidelines.

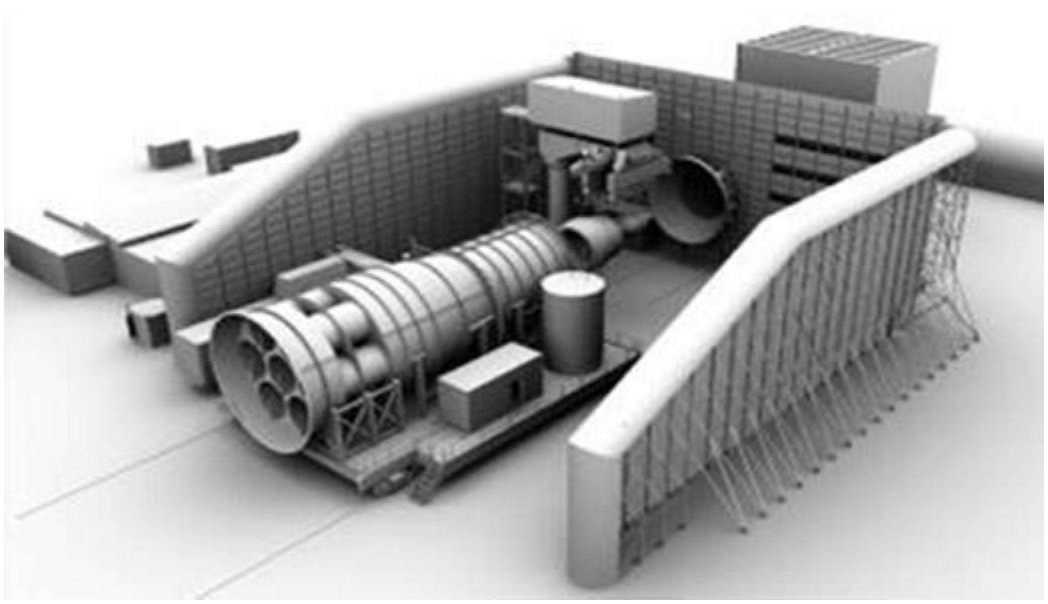


Figure 1 – Conceptual Design of GE Aviation TRDC [1]

Some of the tests performed at the facility include engine icing, ice crystal buildup and bird ingestion. The bird ingestion tests are performed by firing up to four bird carcasses out of an air pressure powered cannon into a running engine inside a wind tunnel. Once the birds are loaded into the chamber, there is a two layer Mylar separation membrane placed between the bird and the air tank. The membrane seals the tank from the chamber and barrel while the air tank is being pressurized. An electronic firing system causes the disk to burst, releasing the air pressure and accelerating the bird down the barrel and out into the jet engine.

The separation membrane itself is two layers of thin Mylar cut into circular disks which fit into a pipe flange in the chamber of the cannon. There are stainless steel wires running between the layers of Mylar which are attached to the electronic firing system. The Mylar discs and wires are fastened together with double sided adhesive tape. Reusable gaskets are then attached to either side of the membrane to help seal the chamber to air leaks. Figure 2 illustrates the general shape of a membrane and location of the wires.

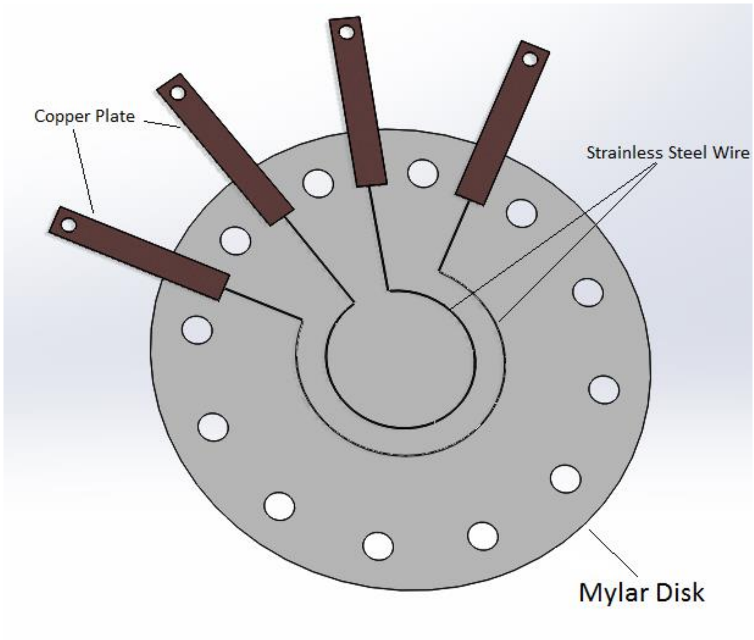


Figure 2 – Mylar Membrane

Presently, the Mylar membranes, which are procured from an American supplier, must be modified before use due to incorrect and inconsistent manufacturing. Without proper tooling, the membranes are being modified by hand at the TRDC, wasting valuable time and resulting in inconsistent wire placement and poor repeatability. There is also a lengthy order process and a very large lead time, resulting in delays in engine testing.

1.1 Project Objective

The objective of this project is to create a tool or a group of tools with an accompanying procedure to manufacture the Mylar membranes for bird ingestion test separation at the GE TRDC. Our design is expected to consistently and correctly manufacture the Mylar membranes in-house, which will greatly reduce the company's current lead time while giving WestCaRD/GE a higher return on investment. This will also reduce the administrative burden over the current process and will be easy to operate.

1.2 Customer Needs

To understand how we will solve the company's problem, we first identified the customer needs. After our team had a tour at GE’s facility and speaking with their Product Manager and engineers we have learned their needs. TABLE I highlights the customer needs with their corresponding impact on the overall design, using a rubric system out of 5 where 1 is lowest impact and 5 is the most impact. The impacts were decided internally as a group while considering client’s input on the matter. GE’s biggest concern was with the assembly not being consistent, therefore, anything in regards to that was scored with highest importance.

TABLE I – CUSTOMER NEEDS

#	Need	Impact
1	allows stock Mylar to be fed from a roll	3
2	creates uniform wire shape and location	5
3	provides a secure wire-lead connection	5
4	creates consistent Mylar disk shape	5
5	are simple for straightforward usage	2
6	produces up to 10 membranes in a working day of 8 hours	3
7	allows for return of investment within 1-2 years	4
8	fits within the GE TRDC	3
9	can be repaired on site	1
10	works exclusively with human operators (manual)	2
11	allows the product to perform in temperatures as low as -30° C	3

Once our team established the customer needs we considered the needs corresponding metric. The metrics are dependent variables which are solutions to the specific needs. The units are how the metric will be measured. To avoid redundancy, the metrics and units will be highlighted in the next section: Target Specifications

With the customer needs and metrics for measuring them established, our team better understood what our customer needs were with metrics on how we would solve each need. By creating a rubric of impact we could see the main needs that drove our design, which we effectively focused on the most important needs so the end product was the most to the customer's satisfaction. The main needs being as following: Create uniform wire shape and location, provides a secure wire-lead connection, and create consistent Mylar disk shape.

1.3 Target Specifications

Now that our team has established a metric for our customer needs, we needed to determine ideal and marginal acceptable target values that our design needed to abide by. Using the values known, we knew what our design required to be considered an acceptable product. Our target specifications were based on customer needs and metrics which are highlighted in TABLE II. It was important for our team to design within the metrics despite the minimal information provided for the first half of the project time. Due to a lot of specifications undetermined, we modified the target specification as information was provided.

TABLE II – TARGET SPECIFICATIONS

Metric #	Need #	Metric	Impact	Units	Value
1	1	Mylar sheet thickness	3	inch	0.013
2	2	Radius of wire	5	inch	6.75 and 7.5
3	2	Location of wire	5	inch	Inside ø7.90 gasket
4	3	Voltage test	5	Volts	N/A
5	4	Mylar shape	5	list	Per drawing
6	5	Time to learn process	2	minutes	<60
7	5, 6	Time to complete process	2, 3	minutes	<48
8	7	Unit manufacture cost	4	CDN$	TBD
9	8	Dimension of the tooling	3	inch	30 x 30 max base
10	9	Tools required for maintenance	1	List	Subj
11	10	Requires human input, not fully automated	2	Subj.	Man hours required
12	11	Temperature test	3	Celsius	-30 to 35

1.4 Constraints & Limitations

Now that the target specifications have been established, our team considered the constraints and limitations that would affect our design. The following list provides the constraints and limitations that our group has identified.

- Our manufacturing and tooling must produce membranes at GE TRDC
- Our manufacturing and tooling must abide by the Manitoba Workplace Safety and Health Regulation, M.R. 217/2006
- The project must be complete by the due date of December 1,2014
- The cost of implementing our design must be below the price of the current process

Other than having the manufacturing process at GE TRDC, these constraints have been determined internally as a team. The client has left these details mostly open-ended, mainly due to GE not having full details on the current manufacturing process of the off-site manufacturer.

2.0 Concept Generation

2.1 Individual Process

In order to efficiently create an effective manufacturing process our team decided to divide the work load by each team member designing one step of the manufacturing process. These processes include Mylar cutting, Mylar hole punching, wire bending/assembly and overall assembly. Once all designs were complete, a meeting was held to integrate as much process together to diminish the amount of machines and space needed. Details on each individual process can be found in Appendix A, which includes the steps of going from initial design to final design.

2.2 Integration Process

To produce the most space and time efficient design, integration of the individual manufacturing process was conducted. This way, less machines and space were needed. As a team, we reviewed each individual design and tried to find the best way to integrate each process together, with the goal of being able to produce one sole design that can manufacture all process.

Due to the complex designs of the Mylar cutting and hole punching processes, these two process were left as standalone processes. The wire bending and final assembly were simpler processes and due to their minimal individual parts were integrated together.

Therefore our final design has three total machines; one for Mylar cutting, one for hole punching and one for wire bending/assembly and burst disk assembly which will be shown in detail in the next section. Since our team was unable to design a single machine that could facilitate all processes in one, our focus was to make each machine as compact and easy to store as possible.

3.0 Details of Final Design

3.1 Intro

In this section the final design details are given which includes the three main processes; Mylar cutting, hole punching, and wire bending/assembly. The details are given in a concise format to show how the customer's needs were met. For a more descriptive explanation of the operation or cost analysis, the reader will be directed to the corresponding Appendix.

3.2 Mylar Cutting

3.2.1 Overview

This Mylar cutting machine can accommodate Mylar fed from a roll with a maximum width of 19 inches. The cutting machine is set up as shown in Figure 3, containing four main parts: cutting track (1), material clamp (2), cutting base (3) and cutting knife (4). A more detailed description of how this process works can be found in the operation manual, Appendix C. Instructions on how to assemble the Mylar cutting machine can be found in Appendix B and information of the part numbers are found in Appendix A.

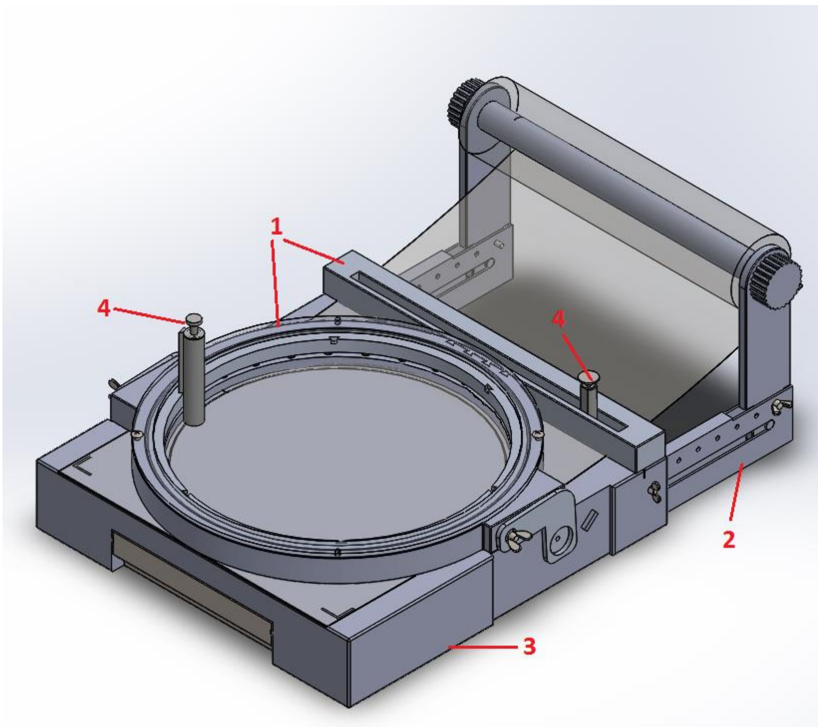


Figure 3 - Mylar Cutting Machine Overview

The total cost of the Mylar cutting machine is $1209.56 including materials and manufacturing. For a detailed cost distribution, see Appendix D. The engineering drawings for the components of the Mylar cutting machine can be found in Appendix E.

3.2.2 Consistent Dimension

A requirement of this project is to produce Mylar disks with a consistent circular dimension. A cutting track is used in order to achieve this goal. Two knives are designed specifically for this cutting machine. One knife is fixed on the inner ring of the circular cutting track with a quadratic key, revolving along the track and cutting Mylar sheets into disks of proper diameter. The other knife is fixed on the horizontal cutting track and used to cut off waste material.

In order to improve the machine performance, we designed a spherical ring groove on the bottom of the inner ring of the circular cutting track. The inner ring can then sit on top of the 30 ball bearings as shown in Figure 4. Each of these 30 balls has a designated spot on the outer ring. The outer ring is fixed on the cutting base, so the balls can only roll in their own spot. Therefore, the knife fixed on the inner rotational ring will always cut the material along same path.

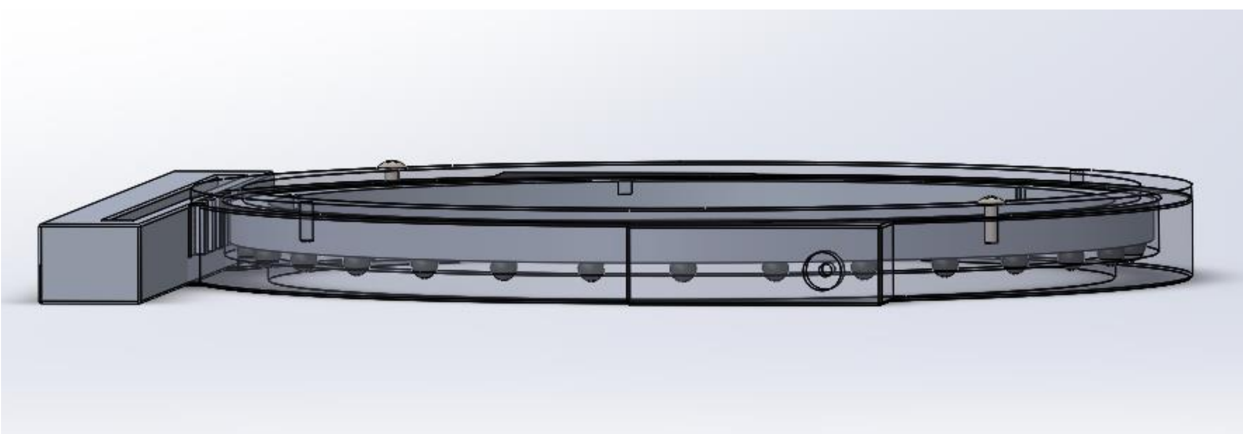


Figure 4 - Inter-Structure of Cutting Track

The horizontal track is fixed to the circular track outer ring by four quadratic keys and top plate as shown as Figure 5. The use of the horizontal track effectively reduces material waste.

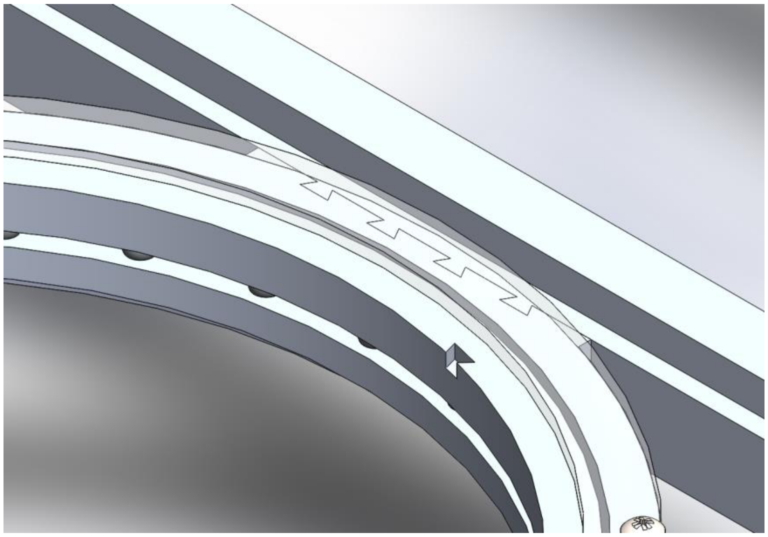


Figure 5 - Quadrangle Key Connection of Horizontal and Circular Tracks

In order to prevent the material from slipping, we used a rubber ring on the base and extruded a small portion above the base surface, as shown in Figure 6. The blue circle is the rubber ring applied to the cutting base. When the Mylar sheet contacts the rubber ring directly and is pressed by the cutting track, friction between the Mylar and rubber will prevent Mylar from sliding and improve dimensional consistency.

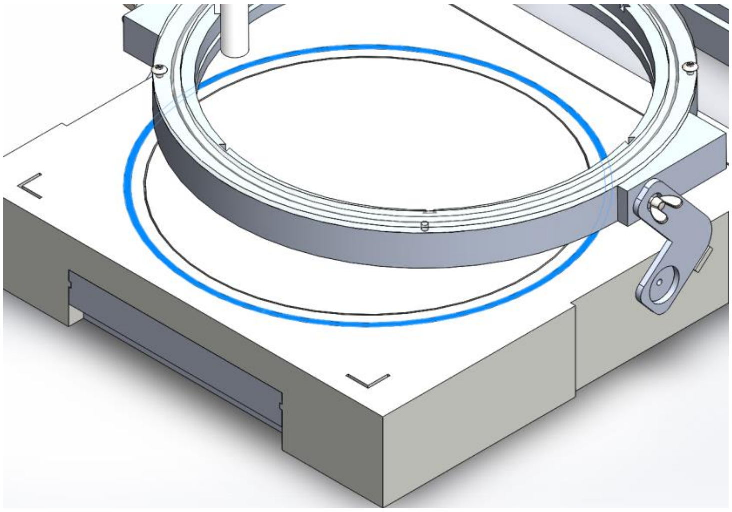


Figure 6 - Rubber Ring Is Plugged into Cutting Base

3.2.3 Ease of Use

The outer ring of the circular track is connected to the cutting base by two rotational levers. The operator can lift the cutting track up by holding the edge of the circular track's outer ring and pulling gently. Two levers rotate synchronously up to about 45ºand stop. The operator then pulls out material that is between the cutting base and the cutting track until the edge of Mylar sheet covers two small corner grooves on the base, as shown in Figure 7.

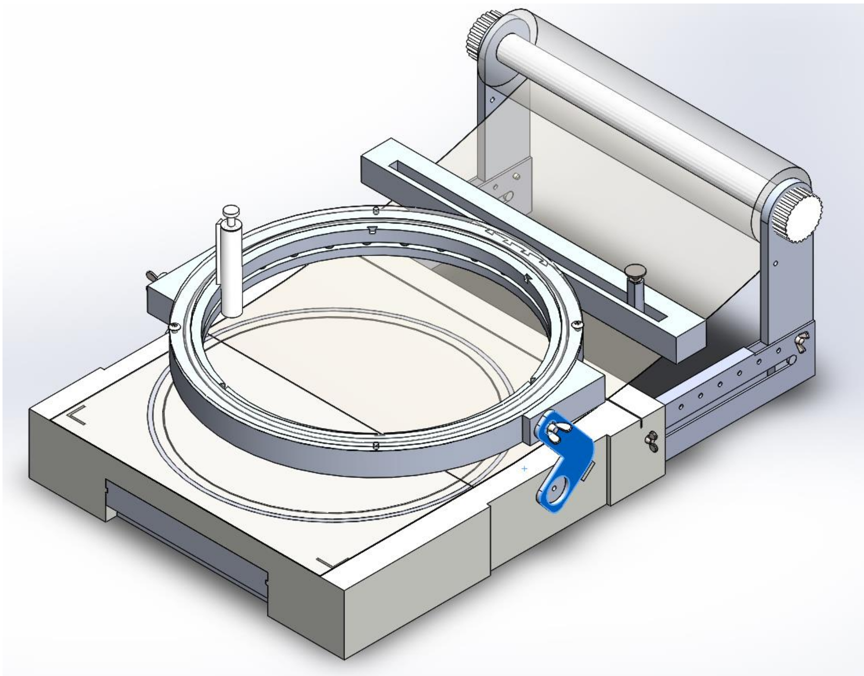


Figure 7 - Cutting Track Lifts Up and Set Mylar Sheet To Right Location

The operator then pulls down the cutting track, activates the push button on each knife in order to engage the blade, then Mylar is cut along the track. For safety considerations, the knife blade will not extend out of the shell until the push button is pressed. The operator can also adjust the amount of Mylar that is fed into the cutting machine using the rotating knob.

3.2.4 Material and Storage Configuration:

The machine parts are made of materials including 6061-T6 aluminum alloy, ABS plastic and stainless steels. Details of materials for each component can be found in Appendix D.

Since this machine will be in storage the majority of the time, it was designed with a storage configuration in order to save space in the facility. The Material roll can collapse and slide into the cutting base by sliding the lifting beams and retracting the beams into the base as shown in Figure 8.

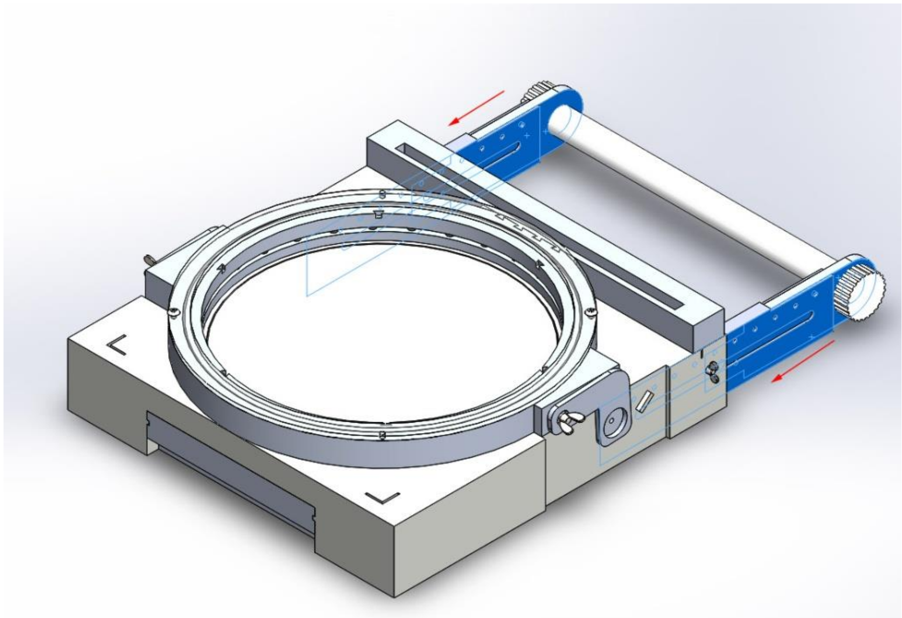


Figure 8 - Shrinking Material Holder Beams into Cutting Base

The cutting machine in storage configuration is shown in Figure 9. Small parts including the knives and pins can also be stored in the cutting base.

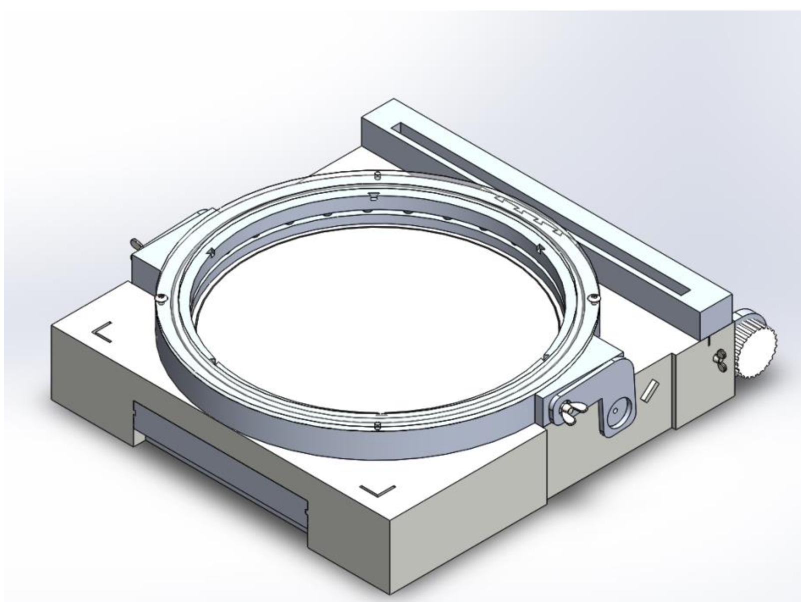


Figure 9 - Cutting Machine in Storage Configuration

3.3 Hole Punching

3.3.1 Overview

The main considerations of the design of the hole punch machine were ease of use, consistency of product, manufacturability. Secondary considerations included ease of assembly and storage capability. The general concept of the punch is a hand operated punch and die system. Human input uses the mechanical advantage of a lever arm to provide the force necessary to drive the punch through the Mylar in order to create clean bolt holes, one at a time. The Mylar materials sits sandwiched between two disks with pressure applied by threaded fasteners. The disk assembly provides protection and support for the Mylar and also locates the Mylar to the punch and die so the holes are in the right spot. Figure 10 displays the hole punch design. A more detailed description of how this process works can be found in the operation manual, Appendix C. Instructions on how to assemble the hole punch machine can be found in Appendix B and information of the part numbers are found in Appendix A.

The total cost of this machine is $1263.53 including materials and manufacturing. For a detailed cost distribution, see Appendix D. The engineering drawings for the components of the hole punch machine can be found in Appendix E.

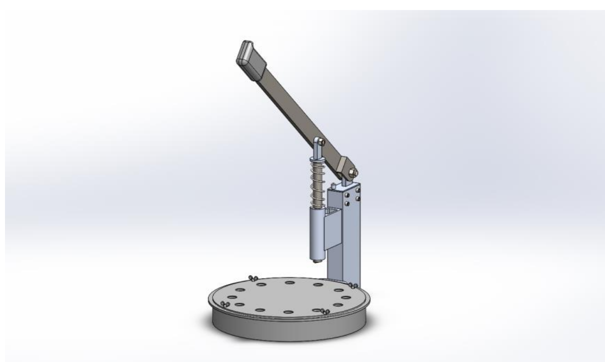


Figure 10 – Hole Punch Machine

3.3.2 Disk Assembly

The disk assembly, as previously mentioned, provides support and protection for the Mylar. In addition, the disk assembly ensures holes are punched in the right place by locating the Mylar to both the base and die. Both disks are round ¼ inch thick 6061-T6 aluminum plates. There is a small recess in the lower disk for the Mylar material to sit in and an equally sized extrusion in the upper disk to hold the Mylar in place. There are 12 holes around the disks which locate the holes to be in the Mylar. In addition, there are 4 threaded holes around the outer diameter of the disks to allow threaded wing bolts to hold the assembly together and there is a ½ inch lip on the lower disk to allow easier manipulation during operation.

3.3.3 Base Assembly

The base is a machined 6061-T6 aluminum billet which supports and aligns the die and upright. There are also cut-outs for the slug drawer, a slot for the base ring and a hole for alignment of the wing screws in the disk assembly. The 2.5 inch through-hole in which the die sits features a shoulder for the die to sit such that the top surface of the die sits 0.125 inch above the top surface of the base. The slug drawer is a removable container which catches the Mylar slugs from the punching process.

3.3.4 Upright Assembly

The upright is a 13 inch long piece of rectangle 6061-T6 aluminum tubing. There are holes drilled on every side through which threaded fasteners securely attach the upright to the base, neck and top pivot. For the neck and base screws, the opposite side features significantly larger holes through which the fasteners can be passed to facilitate easier assembly. The neck holds the punch assembly with a RC4 close running clearance fit to allow precise yet freely running movement of the punch. The primary function of the top pivot is to provide an axis of rotation for the lever arm. The pivot slip-fits into the upright and is secured with eight socket cap screws, four on each side. The top pivot also features a lever stop point, an extrusion on the top face of the pivot to stop the lever arm and punch from traveling too far.

3.3.5 Lever Arm

The lever arm is a 30 inch length of 1018 steel bar. One end is rounded off and has a welded on L-shaped flange. The bar is secured to the top pivot with a shoulder bolt and nut. The lever arm also has a ½ inch wide slot which connects the punch to the lever arm. The slot is cut at 17.5 degrees relative to the long axis of the bar to allow nearly vertical force to be transmitted from the arm to the punch assembly at the point where the punch contacts the Mylar. This also greatly reduces the horizontal forces applied to the punch assembly and neck during the rest of the stroke of the lever arm over a slot parallel to the long axis of the bar. The optional lever arm handle is injection moulded ABS which friction fits over the end of the handle. In order to cut costs, the lever arm handle can be replaced by dipping the lever arm in rubber.

3.3.6 Punch Assembly

The punch pivot connects the punch to the lever arm with a shoulder bolt and nut to allow for easy rotation. The punch pivot has a threaded rod bottom which threads into the punch, and a shoulder on which the punch spring sits. The punch spring sits around the punch between the punch pivot and the neck. The punch spring assists in keeping the lever arm in the upright position during disk rotations in regular operation.

3.3.7 Punch

The punch is a 12 inch length of 4140 chromoly steel. The punch face has 15 degree bevels in each direction from the center in the Y-Z plane. The elliptical side profile of the bevel in the X-Y plane is then hollowed out to create a two-pronged beveled punch face. The two sharp prongs were chosen to facilitate quick puncturing of the Mylar to prevent the Mylar from stretching resulting in a poorly cut hole. This punch face will also reduce the force required to penetrate the Mylar. Above the punch face, the punch has a 2.69 degree back taper for 2 inches behind the punch face to prevent the material from dragging on the sides after the punch after it penetrates the Mylar. The top of the punch has a two inch deep ½-20 threaded hole to attach the punch to the punch pivot.

3.3.8 Die

The die is a 2 inch long 2.5 inch diameter machined piece of 4140 chromoly steel. The center hole of the die has a 1.2 mil clearance on either side of the punch and a 50 mil bevel on the top edge. After ½ an inch of depth, the center hole opens up to a larger diameter so the slug can fall freely into the slug drawer. On the outside of the die there is a ¼ inch shoulder ¾ inch from the top of the die which sits on the corresponding shoulder in the base.

3.3.9 Storage Considerations

The hole punch machine breaks down simply for storage. Depending on the amount of storage space, one or more steps are required to reduce the overall size. The simplest step is to remove the base ring from the assembly and store the remainder of the machine flat on its side. If further size reduction is required, parts can be removed in the opposite order of the assembly manual found in Appendix B.

3.4 Wire Bending/Burst Disk Assembly

3.4.1 Overview

The wire bending/burst disk assembly process was designed specifically to satisfy the customer need of having uniform wire shape and location as seen in Table I. With a maximum level of impact on the final design at 5, it was critical this process was designed to operate effectively.

The design process consists of 4 main components; inner and outer wire molds, the work plate, the peg guide, and the assembly pegs. The assembly of these 4 components is displayed in Figure 11.

Human input is applied to the peg guide, guiding it along the outer and inner track for the outer and inner wire, respectively. When forming the inner wire, the outer mold is removed, allowing the peg moving along the inner track to press the wire against the inner mold. The outer wire is formed similarly however an outer mold is placed around the inner mold to form the outer wire shape. To assemble the Mylar membrane, the molds and peg guide are removed and the assembly pegs are used to locate the proper wire and Mylar positions. A more detailed description of how this process works can be found in the Appendix C. Instructions on how to assemble the wire bending/burst disk assembly machine can be found in Appendix B and information of the part numbers are found in Appendix A.

The total cost of this machine is $238.00 including materials and manufacturing. For a detailed cost distribution, see Appendix D. The engineering drawings for the components of the wire bending/burst disk assembly process can be found in Appendix E.

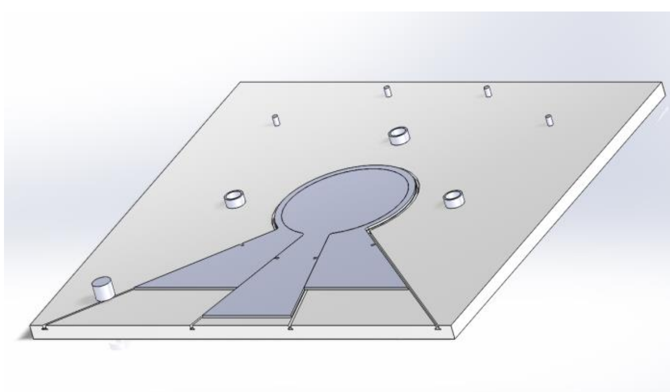


Figure 11 – Wire Bending and Assembly Table

3.4.2 Assembly plate

This component is a 25inX25inX0.81in plate made from ABS plastic with an imprint in the shape of the inner wire mold and seven holes for the assembly pegs. The main feature of the work plate is the T-channel. Two T-channels are cut through the material allowing the peg guide to slide along both the inner and outer wire paths, pressing the wire against the molds. A zoomed in image of the T-channel is displayed in Figure 12.

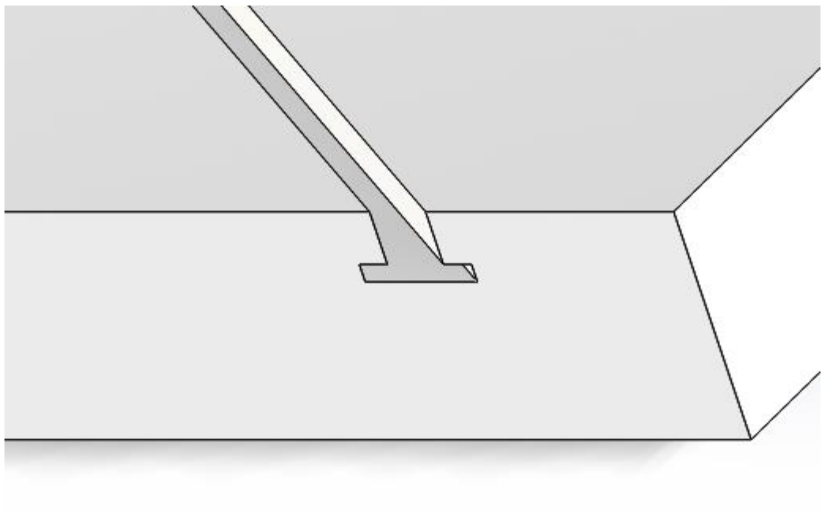


Figure 12 – T-channel

3.4.3 Guide

The guide consists of two sub-components; the outer peg cover and the inner peg. The inner peg is made out of 6061-T6 aluminum and is sized in order to travel along the T-channel with a uniform distance from the mold, equivalent to the diameter of the wire. The outer peg cover is made from ABS plastic and clasped by the operator allowing the inner peg to rotate along the wire as it runs through the channel.

3.4.4 Inner and Outer Wire Molds

These two separate pieces are both made from ABS plastic. The inner wire mold fits into the imprint in the work plate for when forming the inner wire. The outer wire mold is sized to fit perfectly around the inner mold when the outer wire is formed. Since the inner mold fits in an imprint in the work plate, it is 0.25-in thick while the outer mold, in order to be flush with inner mold is slightly thinner at 0.13-in. These molds are displayed in Figure 13. This component also includes a notch on both molds. These notches are used to mark where the copper lead starts in order to produce symmetrical wire formation.

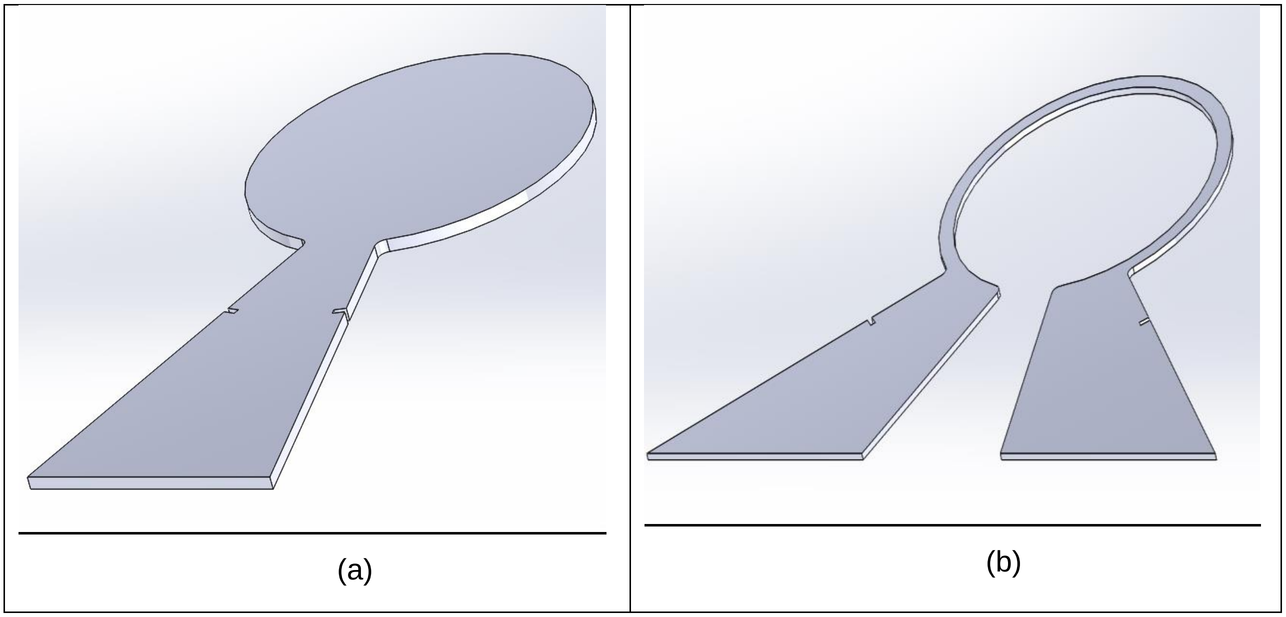


Figure 13 – (a) Inner Wire Mold (b) Outer Wire Mold

3.4.5 Assembly Pegs

The assembly pegs are separate pieces from the work plate made from ABS plastic. There are 4 small pegs used for the 0.28-in diameter holes made to hold the copper in place and 3 other 1-in diameter hollow pegs used to hold the Mylar in the correct position. These parts can be viewed in Figure 11.

Using this engineered work plate the inner and outer wires are consistently formed using a T-channel track along an inner and outer mold. Using the assembly pegs the location of these wires are placed directly in the center of the membrane, inside of the outer gasket.

3.5 Validation

Given the nature of this project was more focused on the design of the manufacturing process rather than numerical analysis our team chose to validate each process through analogous methods.

Using the sample test membranes supplied by the client, a single piece of Mylar was cut using a standard pair of scissors to see if any difficulties occurred. The scissors cut through the Mylar without difficulty. A push blade was then tested since it has a closer resemblance to the blade used in our design. The blade cut through the 0.013-in thick

Mylar smoothly. This verifies the process utilizing a clamp and a cutting base described in section 3.2 will function as designed.

The hole punching process was tested using a 3-hole punch device with no complications punching up to two Mylar sheets at one time. With the mechanical advantage a lever provides utilized in our design (section 3.3), and appropriate clearance between the die and punch, this process is validated.

The safety wire used in the Mylar assembly was tested by wrapping it around a cylindrical object and examined how easily it lost the formed shape. The wire remained relatively unchanged when removed from the surface. With the use of a peg guide applying a uniform force along the wire (section 3.3) against the inner and outer molds, the wire will remain consistent when assembling the membrane.

3.6 Cost Analysis

3.6.1 Current Manufacturer Cost

The client purchases a single Mylar assembly for $64.20. Given the clients requirement of 40-50 assemblies a year, this comes to a total of $3231.00/year assuming they purchase the maximum of 50.

3.6.2 New Design Cost

A breakdown of the costs for the mechanism used in each process is given in TABLE III. A detailed cost breakdown for each mechanism can be found in Appendix D.

TABLE III – MACHINERY COST BREAKDOWN [2] [3]

Mechanism	**Cost ($)**
Mylar cutting	1209.56
Hole puncher	1263.53
Wire bending/assembly	238.00
Total	**2711.09**

The 6” width copper sheets come in lengths of 100ft and cost $86.46 each [4].

64ft of safety wire costs $11.95 where the inner wire is 36” and the outer wire is 32” [5].

The 18" Mylar roll comes in lengths of 150" and $16.20 for each roll [6].

The cost of the materials per assembly based on these values is given in TABLE IV.

TABLE IV – COST OF MATERIALS PER ASSEMBLY [2] [3] [4] [5] [6] [7]

Material	Cost/assembly ($)
Copper	4.22
Wire	1.06
Mylar	4.05
Total	**9.33**

Therefore the total cost of purchasing the material for 50 assemblies is $466.50.

Using the assumption that the client can manufacture the Mylar membranes on downtime and the amount of time to produce them is roughly equivalent to how long it takes to reconfigure the assemblies made from the current manufacturer, labor costs are neglected in this cost analysis.

TABLE V shows the total cost of implementing the proposed design and producing 50 Mylar membranes in one year.

TABLE V – COST OF DESIGN

	Cost ($)
Material	466.5
Machinery	2711.09
Total	**3177.59**

Given that the current process costs $3231.00 to produce 50 assemblies in a year, implementing the new design will save $53.41 in the time span of one year.

4.0 Conclusion

The objective of this project was to design a tool or group of tools with an accompanying procedure to manufacture the Mylar membranes for bird ingestion test separation at the GE TRDC. Our design is expected to consistently and correctly manufacture the Mylar membranes in-house, which will greatly reduce the company's current lead time while giving WestCaRD/GE a higher return on investment.

To meet these requirements while satisfying the customer's needs stated in TABLE I, our team split the manufacturing process into three major components; Mylar cutting, hole punching, and wire bending/assembly. The Mylar cutting machine is able to feed Mylar off a spool in which it is then cut into a square. This machine uses a clamp device and a knife that runs along a track to ensure the Mylar sheet is cut to the proper diameter consistently. The Mylar then moves to the hole punch where it is inserted between two discs and punched using a punch and die design. This punch design easily punches through the Mylar with the use of a mechanical lever. The wire bending and assembly table were integrated to save space and time during the process. This mechanism utilizes a guide through a T-channel that runs along inner and outer molds to form the inner and outer wires, respectively. The assembly concludes the process, which uses the assembly pegs inserted into the worktable and locates the proper position of the final Mylar membrane assembly.

With the recommended amount of production of 50 Mylar membranes a year as stated by our client, the total cost of implementing our design and manufacturing 50 Mylar membranes in one year is $3177.59. With the unit price from the current manufacturer of $64.62 for an assembled Mylar membrane, 50 membranes would cost a total of $3231.00 Therefore, implementing the new design provides a payback period within one year and saves $53.41 for the first year.

5.0 References

[1] Standard Aero "*ge_testing_img2*," in *GE RDTC Tags* [Online}. Available: http://standardaero.com/AboutUs/MediaCenter/Newsletters/govt_1_1/article_ge_testing.aspx (Accessed: Sept 24, 2014)

[2] Plastic News *"Current Resin Pricing"* [Online]: Available: http://www.plasticsnews.com/resin/commodity-thermoplastics/current-pricing (Accessed: Nov 27, 2014)

[3] Vincent Metals *"Daily Aluminum Prices"* [Online]. Available: http://www.vincentmetals.com/Daily_Aluminum_Prices.html (Accessed: Nov 27, 2014)

[4] Amazon "*110 copper sheet"* [Online]. Available:

[5] Amazon "*SS. Lockwire"* [Online]. Available: http://www.amazon.com/S-S-Lockwire-Canister-0-032-Dia/dp/B005VR49D6 (Accessed: Nov. 27, 2014)

[6] Plotter Paper Direct "*Papersource"* [Online]. Available: http://www.plotterpaperdirect.com/products/8-18-x-150-rolls-20-plotter-paper-2-core-1 (Accessed: Nov. 27, 2014)

[7] Fastenal "*Products*" [Online]. Available: https://www.fastenal.com/web/products (Accessed: Nov 27, 2014)

Appendix A Details on Individual Process

A.1. Intro

This Appendix contains the details of each individual process which includes: Mylar cutting, hole punch, wire bending/assembly and Burst Disk Assembly.

A.2. Mylar Cutting

In this section we will give the details of the Mylar cutting machine which is shown in Figure 14. The machine contains four main parts: cutting track (1), Mylar roll holder (2), cutting base (3), and knives (4). The Mylar cutting machine is a one man machine designed Mylar rolls up to a maximum width of 19 inches.

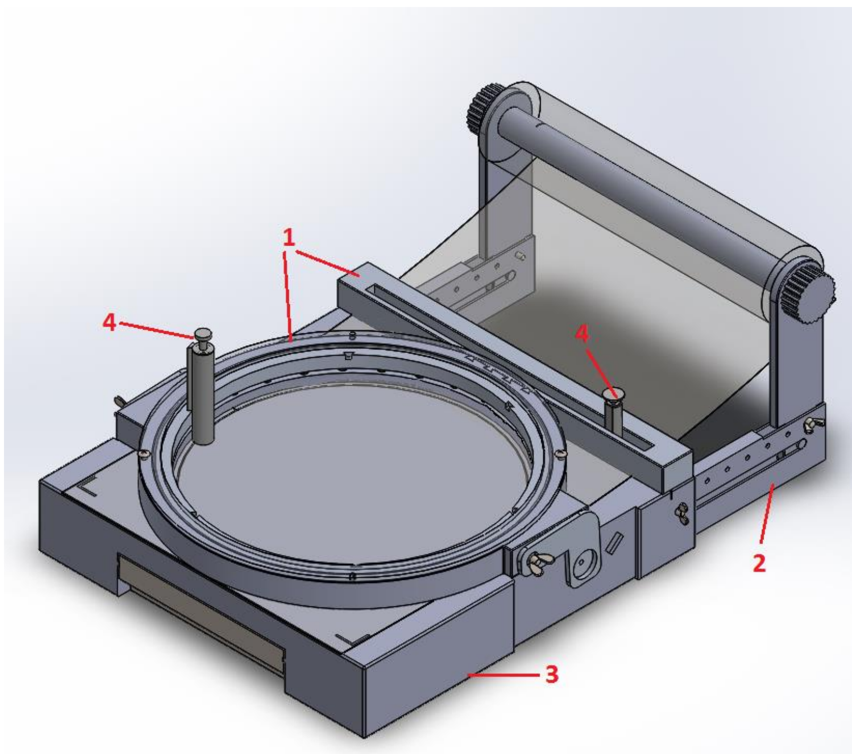


Figure 14 - Mylar Cutting Tool Overview

A.2.1 Cutting Track

The cutting track is composed of six individual parts and are listed in TABLE VI. The part numbers are also included. Each part in shown in an exploded view in Figure 15.

TABLE VI – CUTTING TRACK PARTS LIST

Parts Name	Quantity	Part Number
Truss Head Screw	2	A01
Circular Track Top	1	A02
Circular Track Inner Ring	1	A03
Rolling Ball	30	A04
Circular Track Outer Ring	1	A05
Horizontal Track	1	A06

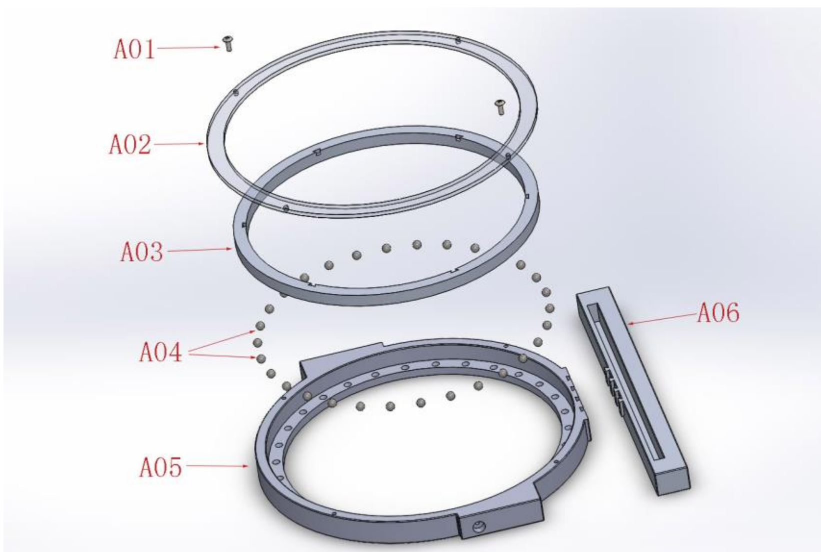


Figure 15 – Exploded View of Cutting Track

A.2.2 Mylar Roll Holder

The Mylar roll holder is composed of five individual parts and are listed in TABLE VII. The part numbers are also included. Each part in shown in an exploded view in Figure 16.

TABLE VII – MYLAR ROLL HOLDER PARTS LIST

Parts Name	Quantity	Part Number
Rod	1	A07
Rod Cap	2	A08
Rod Lifting Beam	2	A09
Pin Wing (0.25*0.75”)	2	A10
Adjusting Beam	2	A11

Figure 16 – Exploded View of Mylar Roll Holder

A.2.3 Cutting Base

The cutting base is composed of seven individual parts and are listed in TABLE VIII. The part numbers are also included. Each part in shown in an exploded view in Figure 17.

TABLE VIII – CUTTING BASE PARTS LIST

Parts Name	Quantity	Part Number
Left Lever	1	A12
Drawer	1	A13
Wing Pin (Type B, 0.25-3.00)	2	A14
Right Lever	1	A15
Wing Shoulder Screw Cap (Type B, 0.25-1.25)	2	A16
Cutting Base	1	A17
Rubber Ring	1	A18

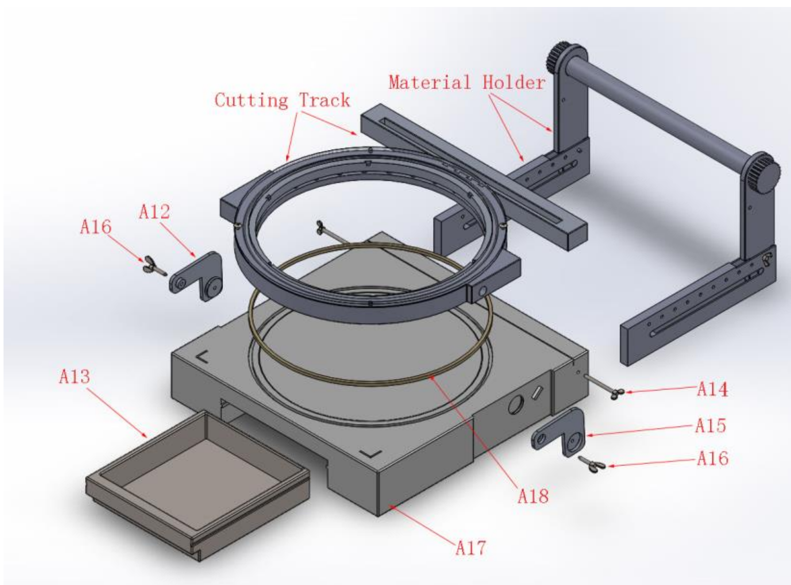


Figure 17 – Exploded View of Cutting Base

A.2.4 Cutting Pens

The cutting pens are composed of seven individual parts each and are listed in TABLE IX. The part numbers are also included. Each part in shown in an exploded view in Figure 18.

TABLE IX – CUTTING PENS PARTS LIST

Parts Name	Quantity	Part Number
Button A	1	A19
Fastener A	1	A20
Inner Stick A	1	A21
Spring A	1	A22
Shell A	1	A23
Blade A	1	A24
Screw (CR-THMS 0.112-48)	2	A25
Button B	1	A26
Fastener B	1	A27
Inner Stick B	1	A28
Spring B	1	A29
Shell B	1	A30
Blade B	1	A31

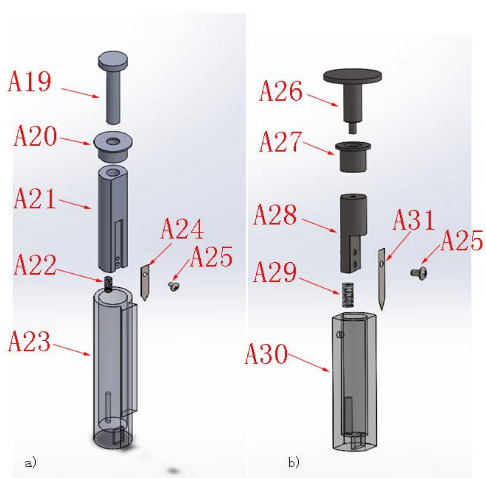


Figure 18 – Exploded View of Cutting Pens A and B

A.3. Hole Punch Machine

In this section we will give the details of the hole punch machine shown in Figure 19. The machine contains five main parts: disk assembly (1), upright assembly (2), base assembly (3), lever arm assembly (4), and punch assembly (5).

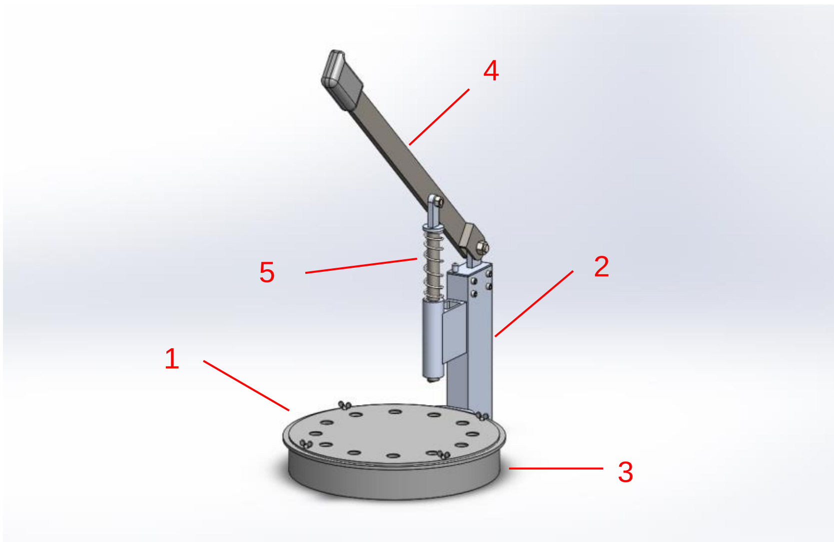


Figure 19 – Hole Punch Machine Overview

A.3.1 Disk Assembly

The Disk Assembly consists of three individual parts and are listed in TABLE X. The part numbers are also included. Each part in shown in an exploded view in Figure 20.

TABLE X – DISK ASSEMBLY PARTS LIST

Parts Name	Quantity	Part Number
Wing Screw	4	B02
Lower Disk	1	B21
Upper Disk	1	B22

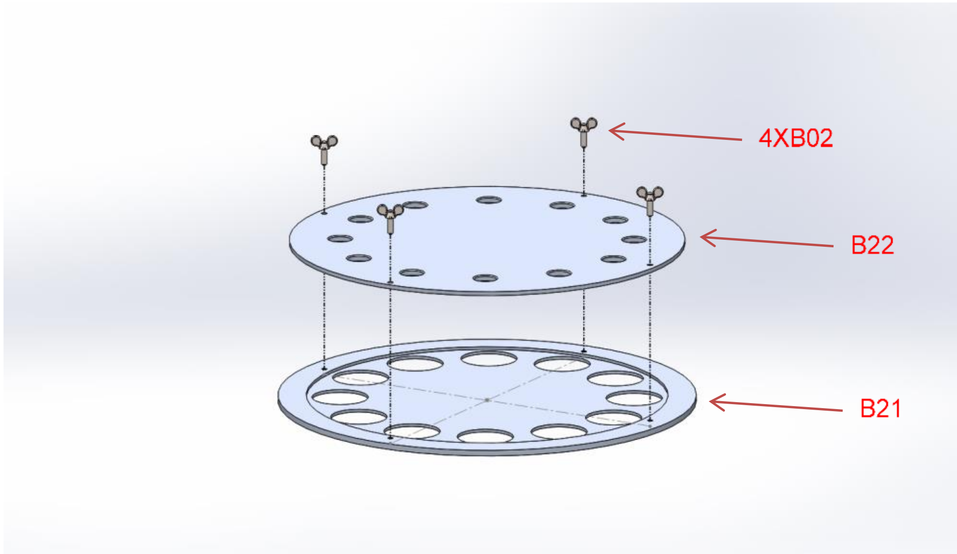


Figure 20 – Exploded View of Hole Punch Machine

A.3.2 Upright Assembly

The Upright Assembly consists of six individual parts and are listed in TABLE XI. The part numbers are also included. Each part in shown in an exploded view in Figure 21.

TABLE XI – UPRIGHT ASSEMBLY PARTS LIST

Parts Name	Quantity	Part Number
Hex Cap Screw	8	B01
Hex Cap Screw	2	B03
Hex Cap Screw	2	B04
Upright	1	B09
Neck	1	B10
Top Pivot	1	B11

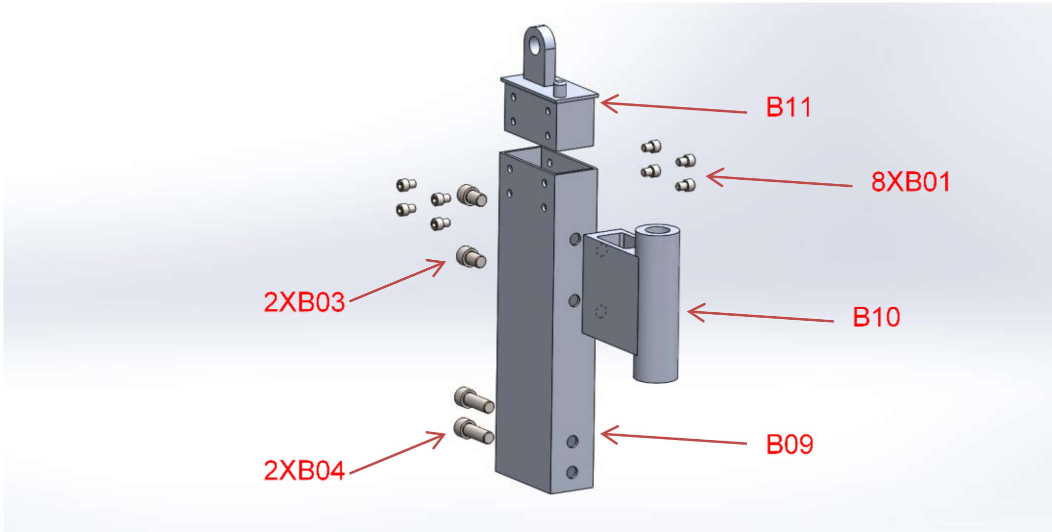


Figure 21 – Exploded View of Upright Assembly

A.3.3 Base Assembly

The Base Assembly consists of three individual parts and are listed in TABLE XII. The part numbers are also included. Each part in shown in an exploded view in Figure 22.

TABLE XII – BASE ASSEMBLY PARTS LIST

Parts Name	Quantity	Part Number
Die Base	1	B12
Die	1	B19
Drawer	1	B20

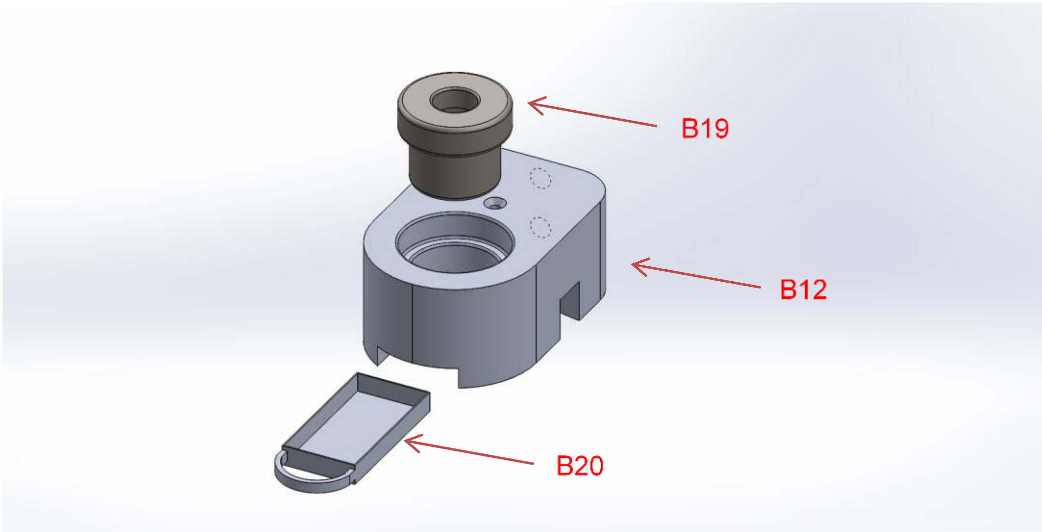


Figure 22 – Exploded View of Base Assembly

A.3.4 Lever Arm Assembly

The Lever Arm Assembly consists of four individual parts and are listed in TABLE XIII. The part numbers are also included. Each part in shown in an exploded view in Figure 23.

TABLE XIII – LEVER ARM ASSEMBLY PARTS LIST

Parts Name	Quantity	Part Number
Shoulder Bolt	1	B05
Lock Nut	1	B07
Lever Arm	1	B14
Lever Arm Handle	1	B15

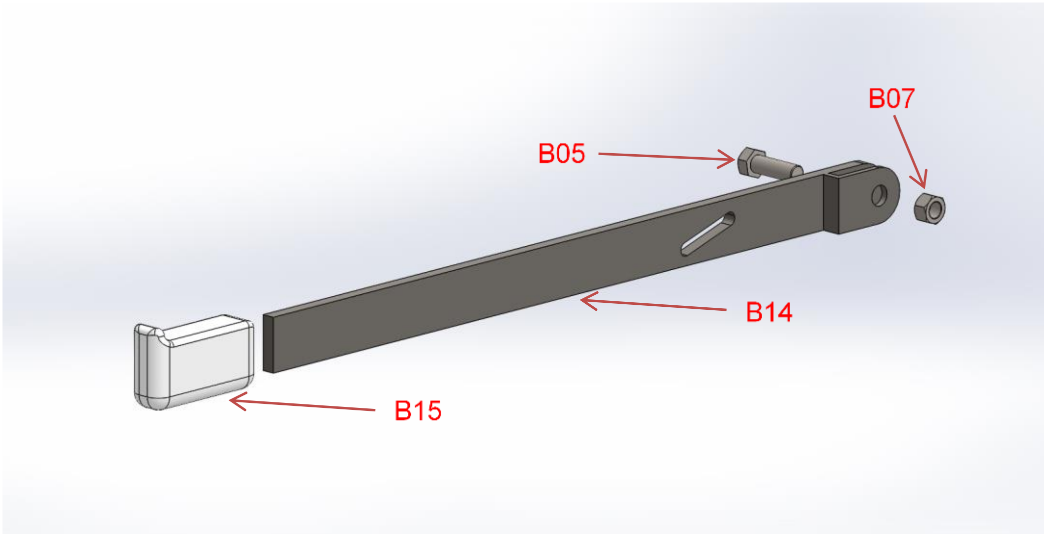


Figure 23 – Exploded View of Lever Arm Assembly

A.3.5 Punch Assembly

The Punch Assembly consists of four individual parts and are listed in TABLE XIV. The part numbers are also included. Each part in shown in an exploded view in Figure 24.

TABLE XIV – PUNCH ASSEMBLY PARTS LIST

Parts Name	Quantity	Part Number
Shoulder Bolt	1	B06
Lock Nut	1	B08
Punch	1	B16
Punch Pivot	1	B17
Punch Spring	1	B18

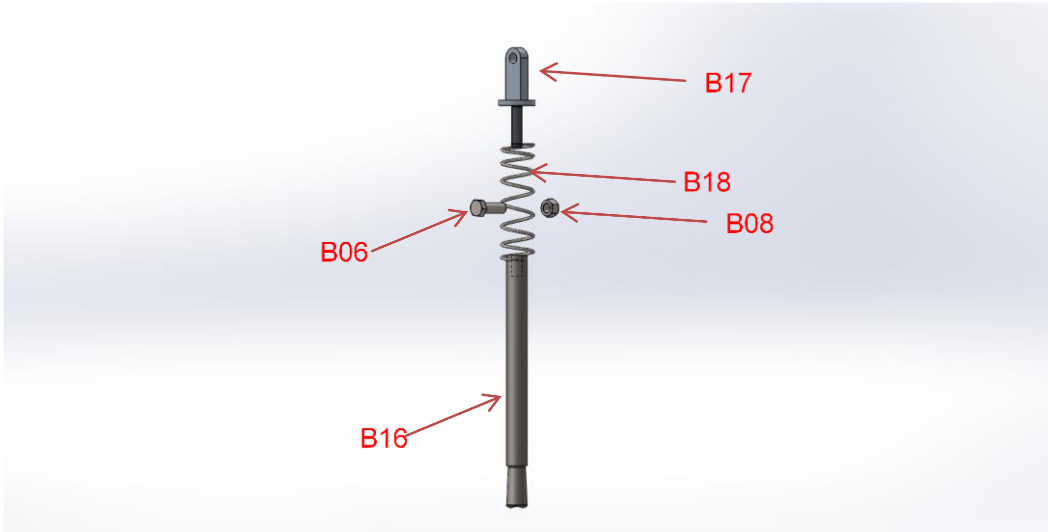


Figure 24 – Exploded View of Punch Assembly

A.4. Wire Bending/Assembly

This section will give details on the Wire Bending/ Assembly Machine from the initial design to end design before integration.

A.4.1 Initial Design

Our main goal for the wire-bending component of the manufacturing process was to design a process in which produces a consistent shape corresponding to the engineering drawing provided by the client. Our initial design concept generated from the concept design phase was the use of plate including rigid grooves with dimensions of the inner and outer wire diameters. A preliminary model for this design is shown in Figure 25. The preliminary model has different layers where the inner wire is formed using the bottom layer and the outer wire with the ledge directly above it.

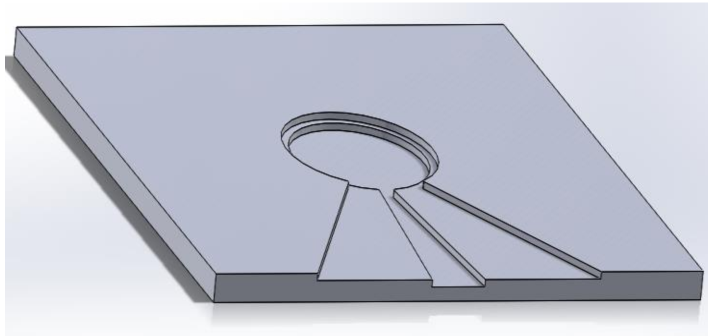


Figure 25 – Preliminary Wire Bending Model

In order to ensure consistency in the wire, a peg was used in the process to press the wire against the outer edge of the groove. This method provides pressure along the whole length of wire and therefore having a more consistent form, whereas free handing the wire along the mold would produce more uncertainty not having steady pressure. Figure 26 is the model highlighting the plane in which the peg would slide in order to form the outer wire.

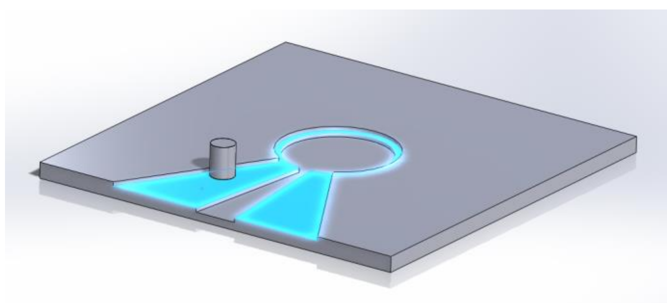


Figure 26 – Outer Wire Forming Plane

The process using the model shown in Figure 25 consists of starting with a precut piece of wire measured to the proper length. The wire is then placed into the bottom layer for the inner wire or second layer for the outer wire. The wire is pressed against the groove to get a general form and have the length of wire in the same plane. Holding down the wire at the straight end, the other hand is used to guide the peg along the outer edge and base to form a consistent wire formation.

A.4.2 Final Design Process

With the preliminary model for the wire bending process, our team looked to implement an additional feature to make the process less operator reliant. In order to do so we looked into a way for the peg to a have a fixed motion around the edge of the wire allowing the operator to act as the guide and the machine itself to apply the force perpendicular to the guided motion. In order to implement this feature, a T-channel was considered as shown in Figure 27.

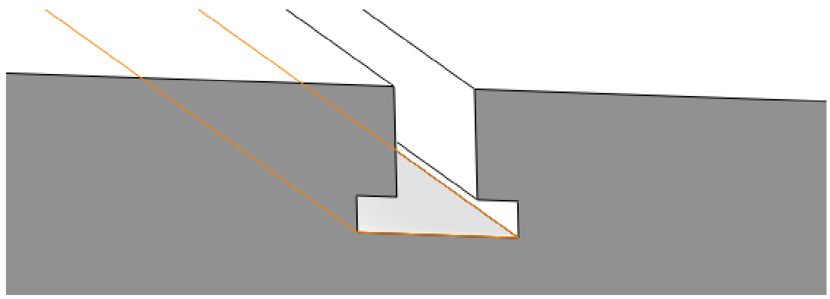


Figure 27 – T-Channel

With a T-channel cut through the plate, the peg would be able to slide in from the end of the plate and follow the fixed path. To add the T-channel track the model in Figure 25 must be modified. This modification was necessary in order to have a track for both the inner and outer wires. With the current model the track could only be applied to the inner wire, applying to the outer wire would interfere with the inner groove and was therefore not possible. To solve this problem the grooves cut into the plate were reversed and cut so the shape of the wire juts out of the plate as shown in Figure 28.

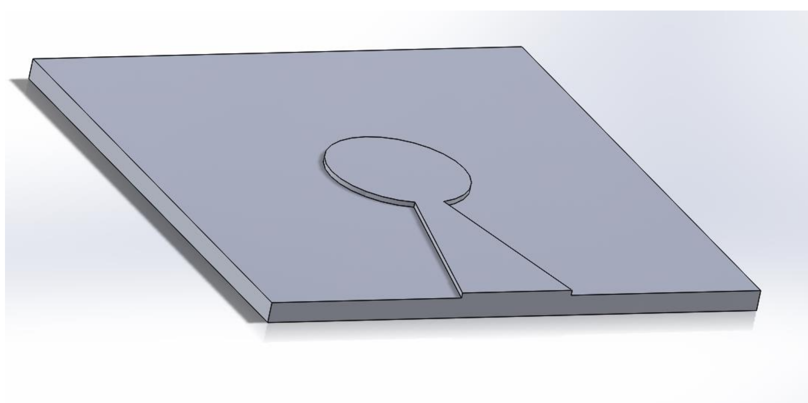


Figure 28 – Positive Mold

As seen in Figure 28, only the inner wire outline is protruding from the plate. This is done in order to have a guiding track for the inner wire then have a separate piece that is placed over the inner hole and form the shape for the outer wire. This outer shaped component is shown in Figure 29.

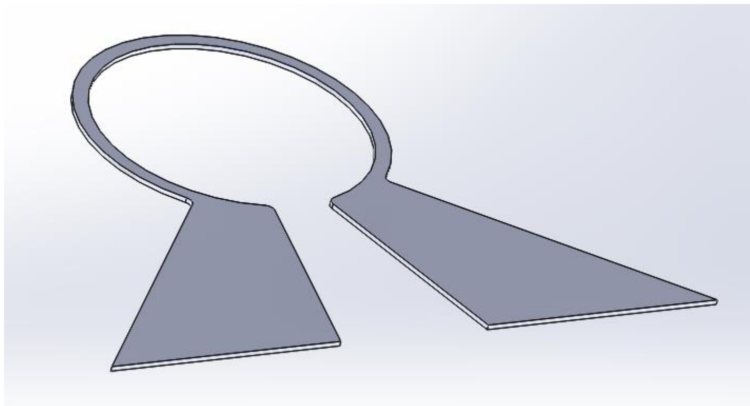


Figure 29 – Outer Wire Form

The final model including the guided track and separate component is shown in Figure 30.

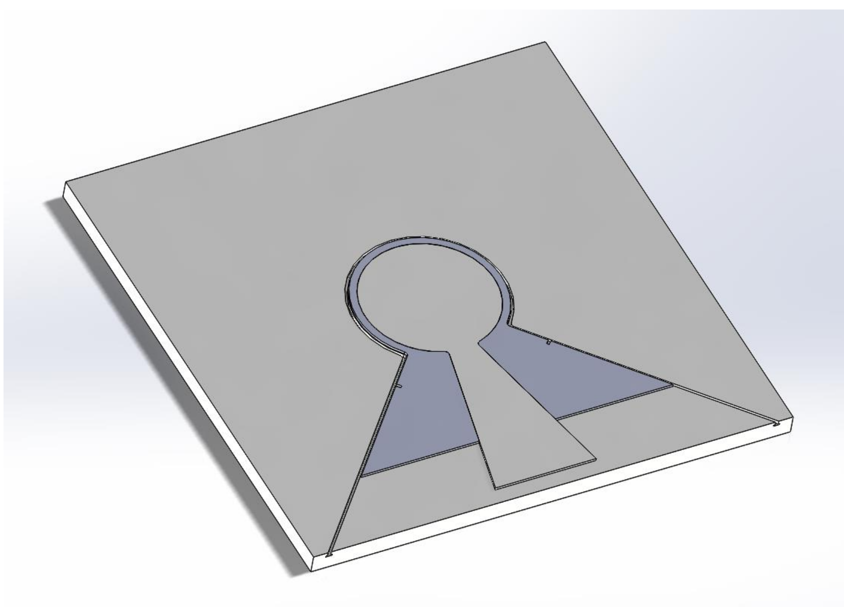


Figure 30 – Final Bending Model with Outside Track

The guide that would go along the track is shown in Figure 31. The peg is sized in order to travel along the track with a uniform distance from the mold equivalent to the diameter of the wire of 0.032 inches. A hollow cover is placed over the peg allowing the peg to roll along the wire.

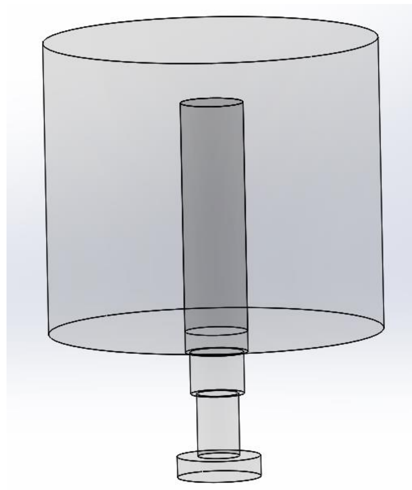


Figure 31 – Peg Guide

A.5. Burst Disk Assembly

This section will give details on the Wire Burst Disk Assembly from the initial design to end design before integration.

A.5.1 Initial Design

Initial design for the Burst Disk Assembly was to have a flat plate with two supports on the sides that would rest against the outside of the Mylar disk to keep in place as shown in Figure 32. The problem with this design was how to support the wires and keep them in the correct location.

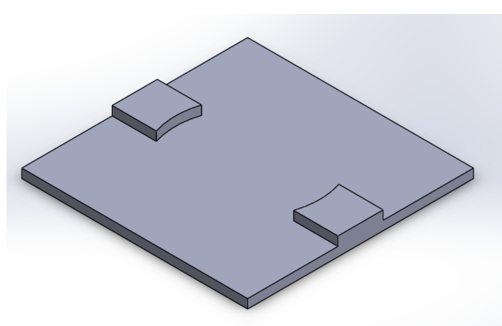


Figure 32 – Initial Assembly Table Design

A.5.2 Final Design

After review with the team a new design was suggested. The Mylar and copper leads have holes, which will be used to support and locate these parts of the assembly with pegs. There would be 4 pegs that would support the Mylar disks and another 4 for the copper leads as shown in Figure 33.

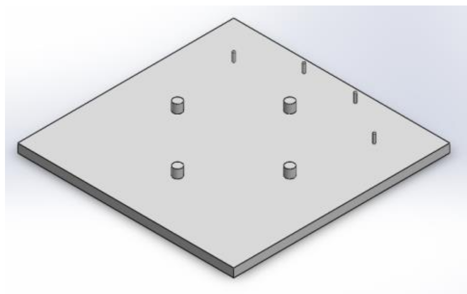


Figure 33 – Final Burst Disk Design

A.6. Integration of Wire Bending and Burst Disk Assembly

Since the plate for the final assembly was symmetrical, there was room to both bend the wire and conduct the final assembly.

A.6.1 Initial Integration Design

Initial integration design would have one end of the plate with the pegs for assembly, while the other end would have the inner wire mold with the separate component to fit and form the outer wire as shown in Figure 30. Due to the one peg from the assembly design being in the way of the inner mold from the bending design, it was removed and the integrated design having a total of three pegs holding the Mylar disk in place. The three pegs were also hollowed out to save on material as the pegs do not need to be very strong as they will not be carrying any loads as shown in Figure 34.

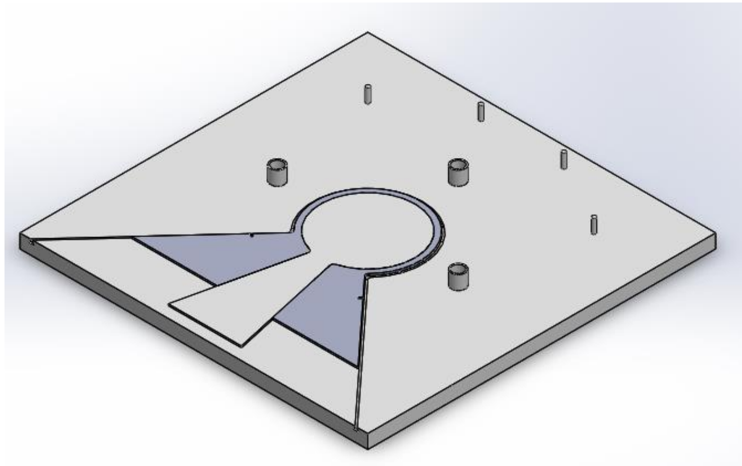


Figure 34 –Initial Wire Bend Assembly Design

A.6.2 Second Integration Design

To incorporate the wire bending process to the assembly table with minimal interference we wanted the assembly process to be done on a flush surface. In order to do so, the inner wire mold is made into a separate component similarly to the outer wire form. These pieces are shown in Figure 35.

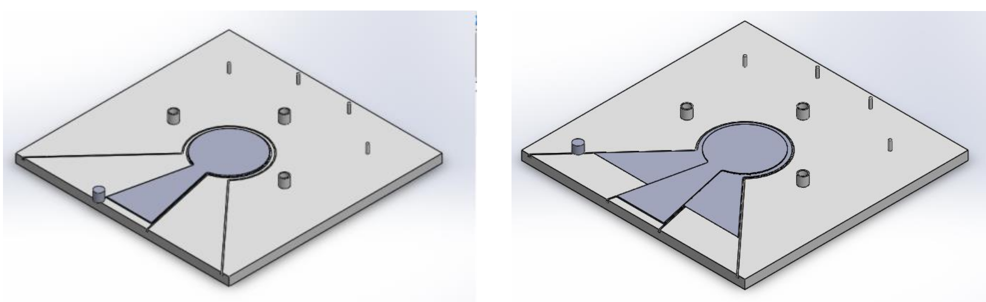


Figure 35 –Inner and outer wire forms.

Adding this change to the model allows for these pieces to be completely removed from the table when assembly is performed. When the first cut piece of Mylar is applied the assembly table, it will create a flat surface without having to rest on a jutted out section. The plate in this configuration is shown in Figure 36.

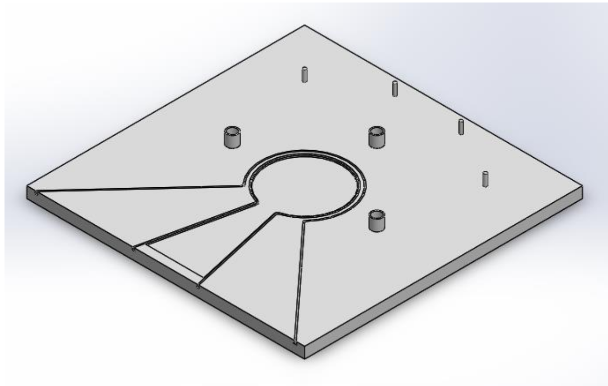


Figure 36 – Plate assembly configuration

A.6.3 Final Design

While the second integration design from Section A.6.2 was well suited to be the final design, having the pegs as part of the plate caused difficulty in storage. Therefore a final design was created, which looks exactly like the second integration design but with removable pegs. Holes were created where the pegs would go and threads added to the bottom of the pegs.

A.6.3.1 Overview of Wire Bending/Burst Disk Machine

The Wire Bending/Burst Disk Machine consists of six individual parts and are listed in TABLE XV. The part numbers are also included. Each part in shown in an exploded view in Figure 37.

TABLE XV – WIRE BENDING/BURST DISK MACHINE PARTS LIST

Parts Name	Quantity	Part Number
Small Pegs	4	C01
Hollow Pegs	3	C02
Assembly Plate	1	C03
Inside Mold	1	C04
Outside Mold	1	C05
Guide	1	C06

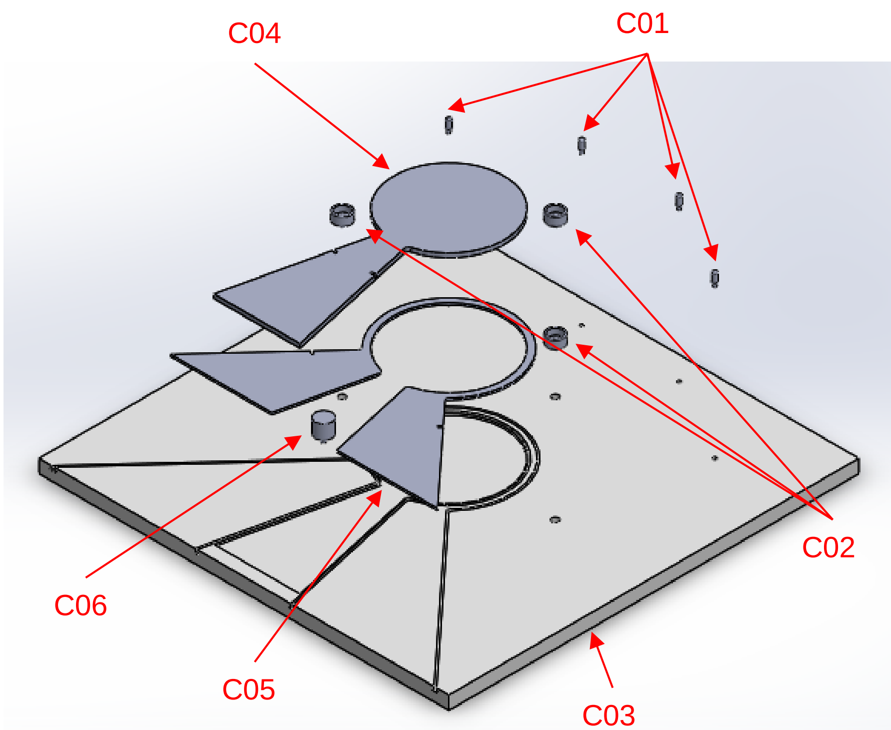


Figure 37 – Exploded View of Wire Bending/Burst Disk Machine

Appendix B Assembly Manual

B.1. Intro

This Appendix contains the assembly manual for each manufacturing process which includes the Mylar cutting machine, hole punch machine, and the wire bending/burst disk assembly machine. It also includes the process for assembling the copper leads to the wires.

B.2. Mylar Cutting Machine

This section provides the steps necessary for assembling the Mylar cutting machine.

B.2.1 Assembly of Cutting Track

1) Place 30x A04 Rolling Ball into the spherical grooved holes on A05 Circular Track Outer Ring.
2) Place A03 Circular Track Inner Ring onto A05 to secure the 30x A04 in place.
3) Connect A06 Horizontal Track to A05 using the quadrangle slots as shown in Figure 38. Then place A02 Circular Track Top over A03 and secure with 2x A01 Truss Head Screw.

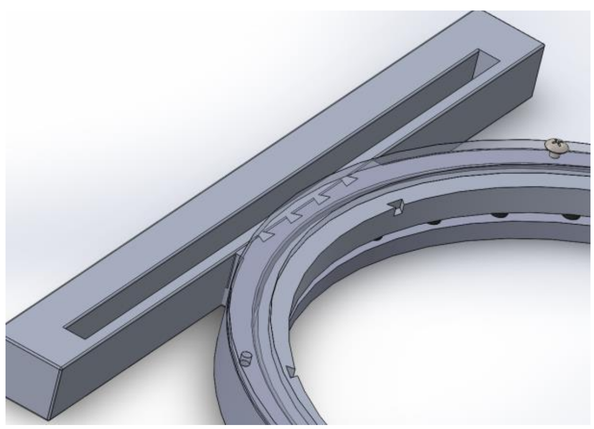


Figure 38 – Cutting Track Assembly

B.2.2 Assembly of Mylar Roll Holder

1) Place A09 perpendicular into the A11 Adjustment Beam. Ensure the peg on A09 sits inside the slot in A11. Secure A09 in place with an A10 Wing Pin.
2) Repeat step 1 for the other A09 and A11.
3) Place 2x A09 (one of each) on both ends of A07 Rod.

4) Secure them together with 2x A08 Rod Cap. Ensure the six semi cylindrical keys in A07 and A08 match together as shown in Figure 39.

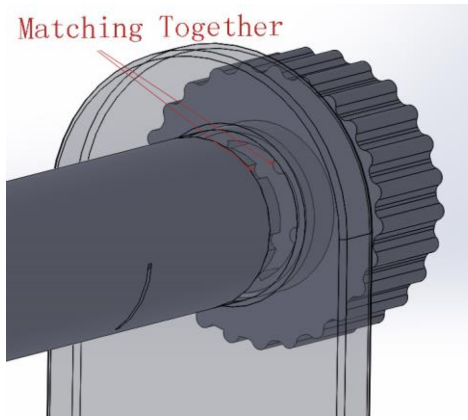


Figure 39 – Matching Semi Cylindrical Keys

5) This 90° configuration is considered the ready to use configuration. For storage configuration follow the next step.
6) Remove both A10 and position both A09 horizontally. Push both A09 along both A11 slots all the way as shown in Figure 40.

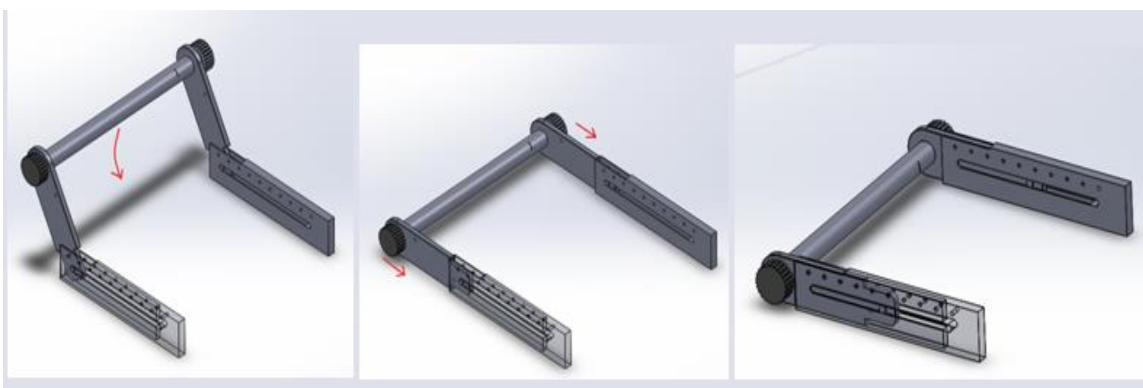


Figure 40 – Storage Configuration

B.2.3 Assembly of Cutting Knife A and B

1) Place A22 Spring A into the small extruded stick inside A23 Shell A.
2) Place A24 Blade A in A21 Inner stick A and secure with A25 Screw.
3) Insert A21 into A23 until it is through the hole at the bottom of A23.

4) Place A20 Fastener A into A21.
5) Insert A19 Button A into A21.
6) Place A29 Spring B into the small extruded stick inside A30 Shell B.
7) Place A31 Blade B in A28 Inner stick B and secure with A25 Screw.
8) Insert A28 into A30 until it is through the hole at the bottom of A30.
9) Place A27 Fastener B into A28.
10) Insert A26 Button A into A28.

B.2.4 Assembly of Mylar Cutting Machine

1) Ensure the Cutting Track (in ready to use configuration), Mylar Roll Holder and Knife A and B have been assembled per Sections B.2.1, B.2.2 and B.2.3.
2) Place A18 Rubber Ring into the circular groove in A17 Cutting Base.
3) Place the Cutting Track over top A18 and press gently down. Ensure the edge of A06 lines up with the long slot in A17.
4) Insert A12 Left lever into the left side of A17 and Cutting Track as shown in. Ensure bulge “a” connects with the Cutting Track and bulge “b” with A17. Secure bulge “a” with A16 Wing Shoulder Screw Cap.

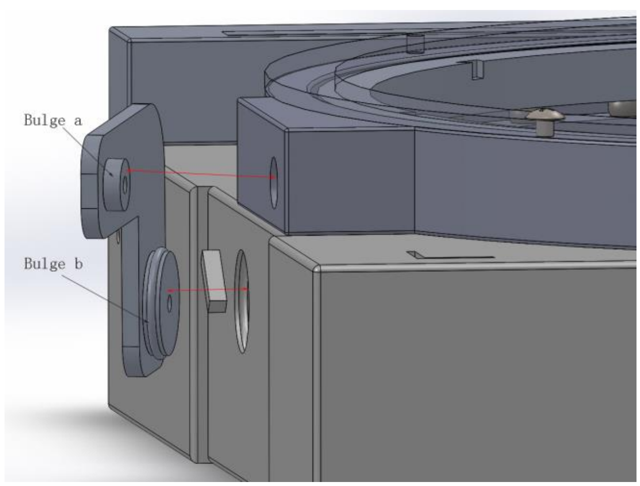


Figure 41 – Assembling Left Lever

5) Repeat Step 4 for A15 Right lever into the right side of A17 and Cutting Track.

6) Slide A11 Adjusting Beam into A17 until desired length is achieved. Secure in place using 2x A14 Wing Pin, one on each side of A17 as shown in Figure 42.

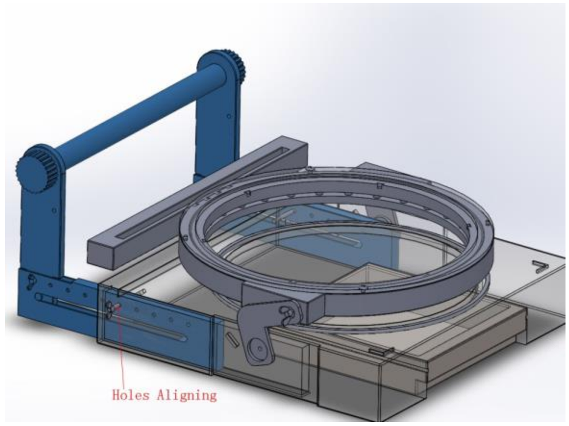


Figure 42 – Assembling Adjusting Beam

7) Place Cutting Knife A into any of the four grooves on A03 Circular Track Inner Race. Place Cutting Knife B into the indent on A06 Horizontal Track with the small hole on A30 Shell B facing A07 Rod as shown in Figure 43.

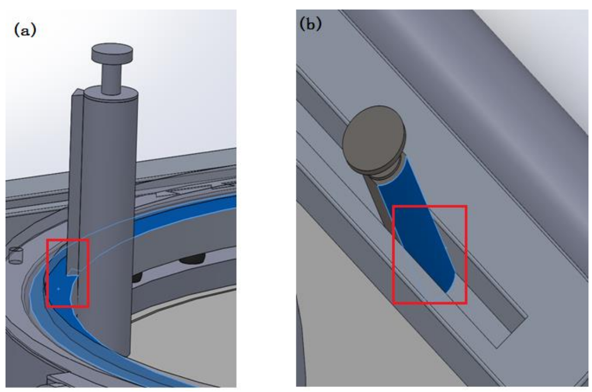


Figure 43 – Cutting Knife A and B to Cutting Machine

8) To place into configuration mode, perform Step 6 from Section B.2.2 then remove 2x A14 to push A11 all the way in A17. Re-insert both A14.

9) The Mylar Cutting Machine assembly is complete and shown in Figure 44 and ready for use or storage.

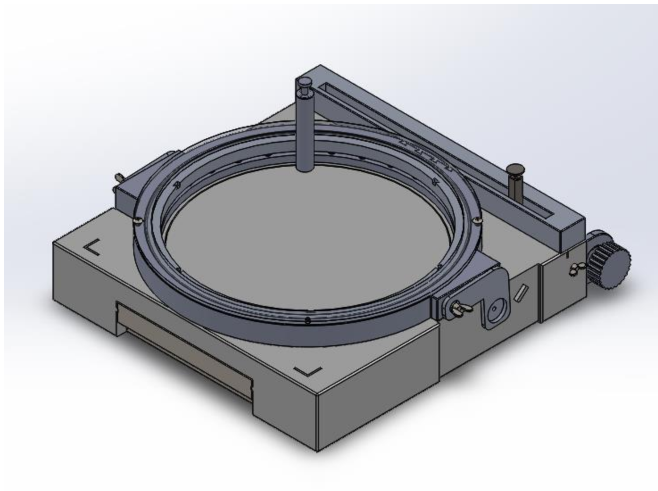


Figure 44 – Fully Assembled Mylar Cutting Machine

B.3. Hole Punch Machine

This section provides the steps necessary for the assembling the hole punch machine

1) Place B10 Neck to B09 Upright as shown in Figure 45. Secure using 2x B03 Hex Cap Screws

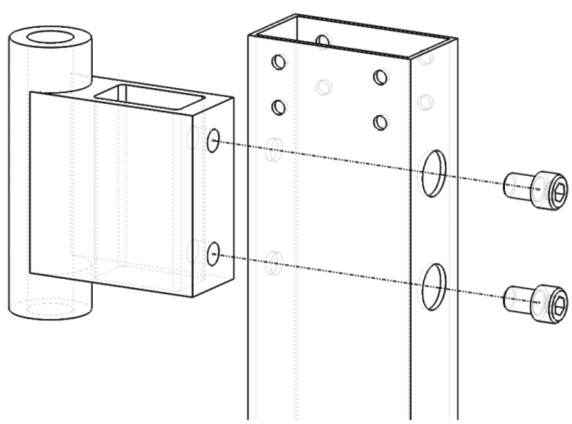


Figure 45 – Neck to Upright

2) Place B11 Top Pivot to B09 as shown in Figure 46. Secure using 8x B03.

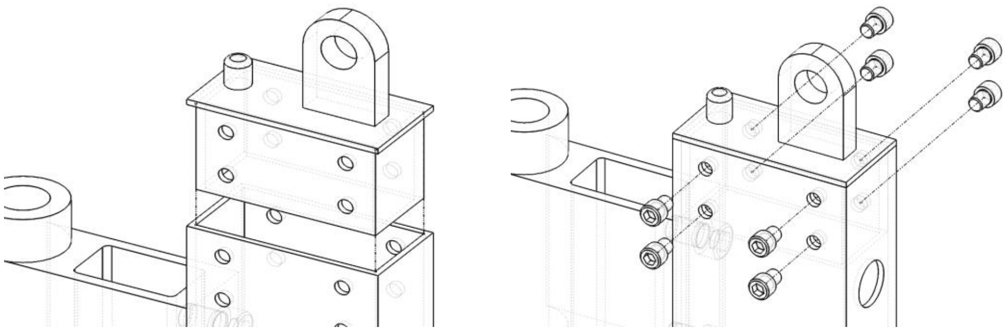


Figure 46 – Top Pivot to Upright

3) Place B12 Die Base to B09 as shown in Figure 47. Secure using 2x B04 Hex Cap Screws.

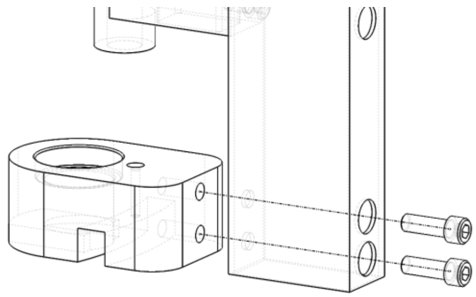


Figure 47 – Die Base to Upright

4) Place B12 Die Base into the corresponding slot on B13 Base Ring as shown in Figure 48.

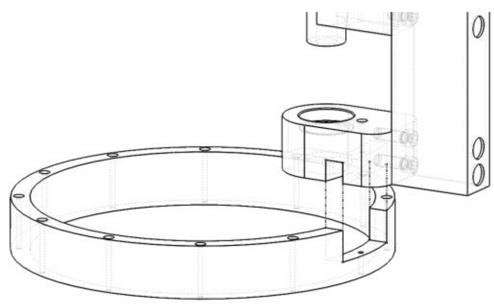


Figure 48 – Die Base to Base Ring

5) Press fit B15 Lever Arm Handle onto B14 Lever Arm as shown in Figure 49.

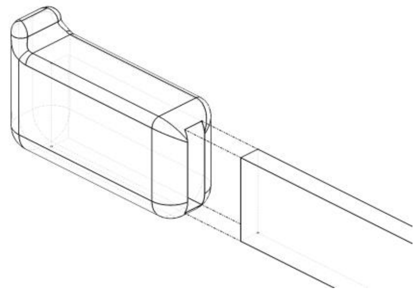


Figure 49 – Lever Arm Handle to Lever Arm

6) Thread B17 Punch Pivot into corresponding hole on B16 Punch as shown in Figure 50. Ensure to conduct this step carefully to not damage punching head.

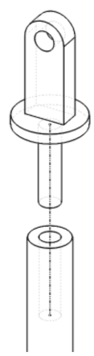


Figure 50 – Punch Pivot to Punch

7) Slide B18 Punch Spring over B16 Punch as shown in Figure 51.

Figure 51 – Punch Spring to Punch

8) Slide B16 into B10 as shown in Figure 52. Ensure to conduct this step carefully to not damage punching head.

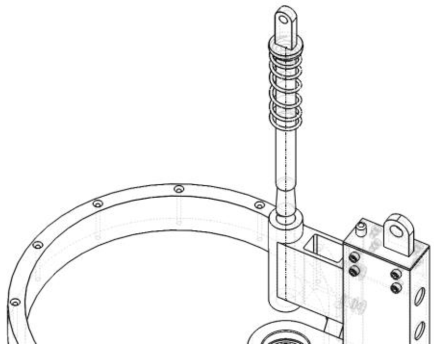


Figure 52 – Punch Assembly to Upright Assembly

9) Connect end of B14 into the top of B11 as shown in Figure 53. Secure using B05 Hex bolt and B07 Hex Nut. Ensure not to over tighten, the lever arm should be able to rotate freely.

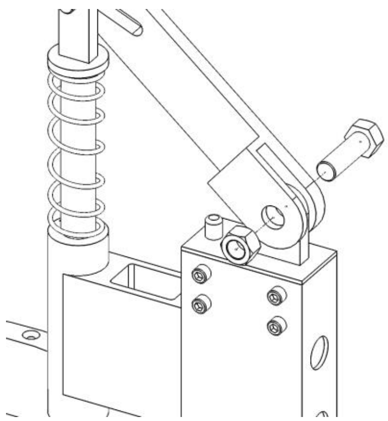


Figure 53 – Lever to Upright

10) Connect the middle of B14 to B17 as shown in Figure 54. Secure through the center slot using B06 Hex Bolt and B08 Hex Nut. Ensure not to over tighten, B06 should be able to rotate freely.

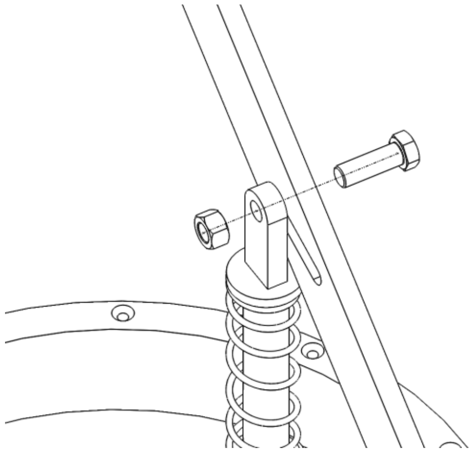


Figure 54 – Level to Punch Assembly

11) Place B19 Die into the corresponding hole on B12 as shown in Figure 55. Ensure to conduct this step carefully to not damage B19.

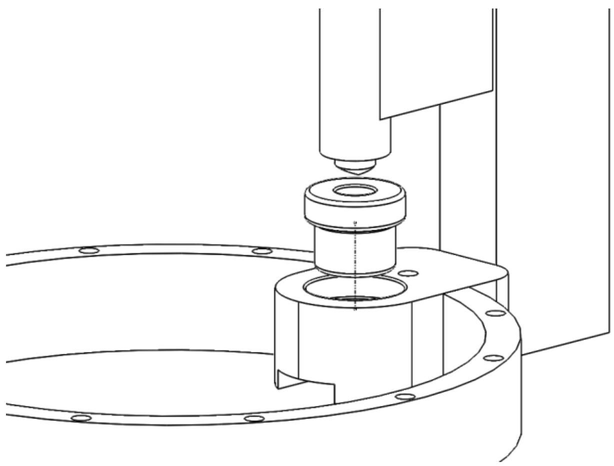


Figure 55 – Die to Die Base

12) Slide B20 Drawer into corresponding slot on B12 as shown in Figure 56.

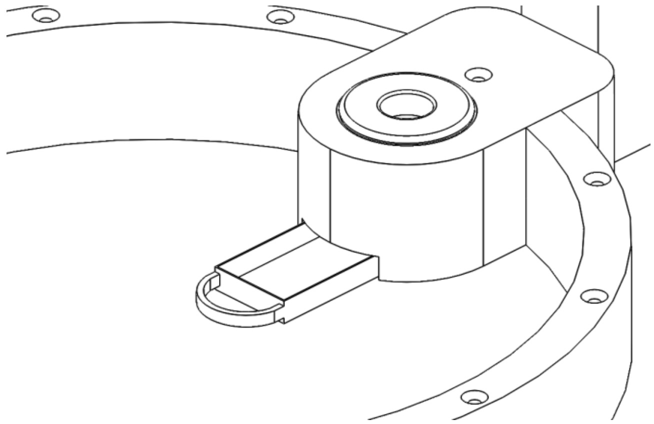


Figure 56 – Drawer to Die Base

13) Assembly of the Punch Machine is complete and shown in Figure 57 and ready for use.

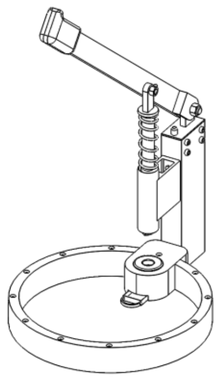


Figure 57 – Completed Punch Machine Assembly

B.4. Wire Bending/Burst Disk Assembly Machine

This section provides the steps necessary for assembling the Wire Bending/Burst Disk Assembly Machine

B.4.1 Assembly for Inner Wire Bending

1) Place C04 Inner Mold onto C03 Assembly Plate as shown in Figure 58.

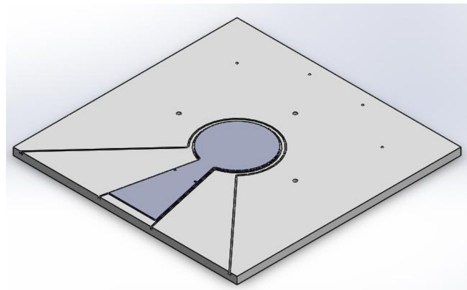


Figure 58 – Inner Mold to Assembly Plate

2) Place C06 Guide into the inner track of C03 as shown in Figure 59. Guide can be placed on the left or the right side of the mold, operator preference.

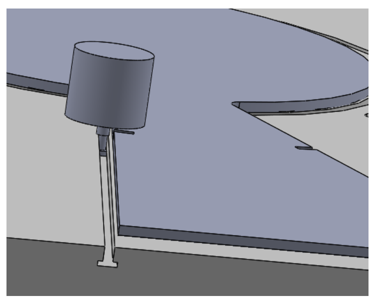


Figure 59 – Guide to Assembly Plate

3) The assembly is complete and ready to bend the inner wire

B.4.2 Assembly for Outer Wire Bending

1) Place C04 and C05 Outer Mold onto C03 as shown in Figure 60.

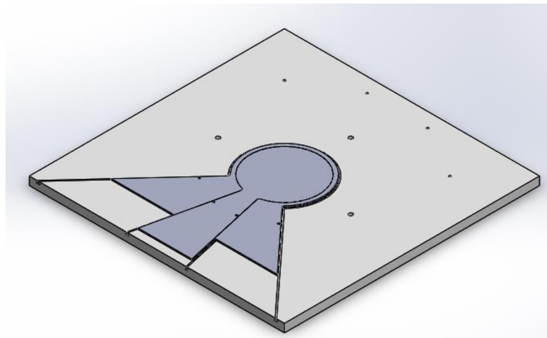


Figure 60 – Outer Mold Assembly Plate

2) Place C06 into the inner track of C03 as shown in Figure 61. Guide can be placed on the left or the right side of the mold, operator preference.

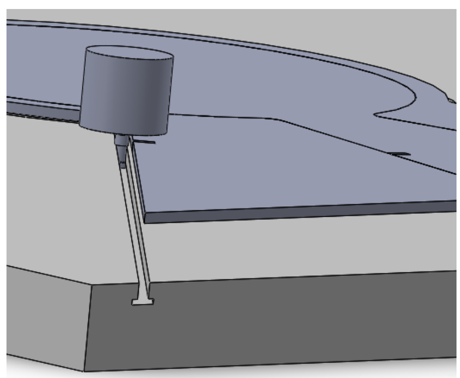


Figure 61 – Guide to Assembly Plate

3) The assembly is complete and ready to bend the outer wire

B.4.3 Assembly for Burst Disk Assembly

1) Screw in 4x C01 Small Pegs into the small holes in C03 as shown in Figure 62.

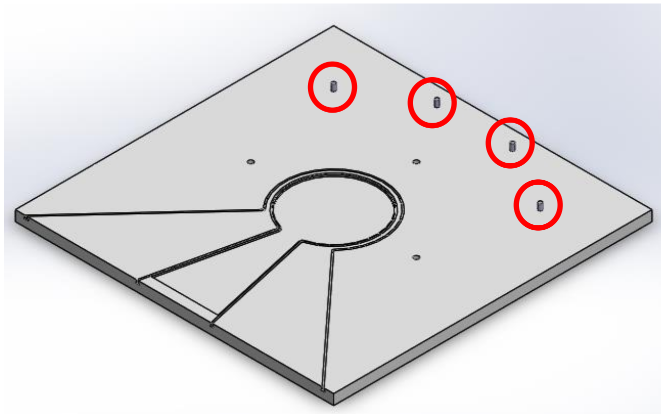


Figure 62 – Small Pegs to Assembly Plate

2) Screw in 3x C02 Hollow Pegs into the larger holes in C03 as shown in Figure 63.

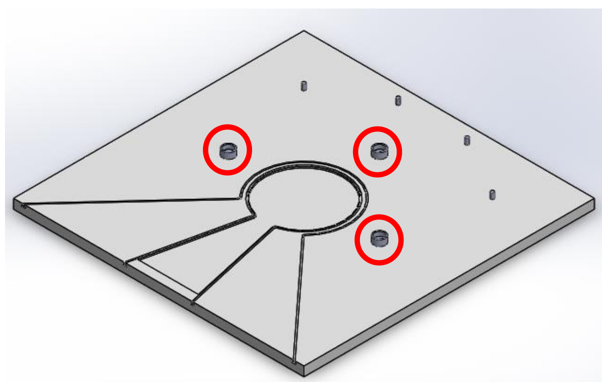


Figure 63 – Hollow Pegs to Assembly Plate

3) Assembly is complete and ready for Burst Disk Assembly.

B.5. Assembly of Copper Lead to Wire

This section provides the steps necessary for assembling the copper leads to the ends of the wires.

1) Drill a 0.28125” hole in the Copper Lead in the location shown in Figure 64.

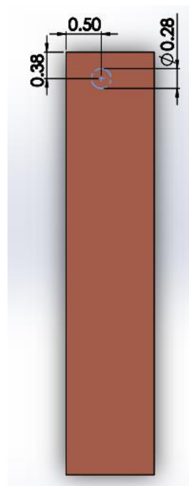


Figure 64 – Hole in Copper Lead

2) Mark a line across the Copper Lead 0.25” from the edge as shown in Figure 65. Note that there are two configurations one for each end of the wire.

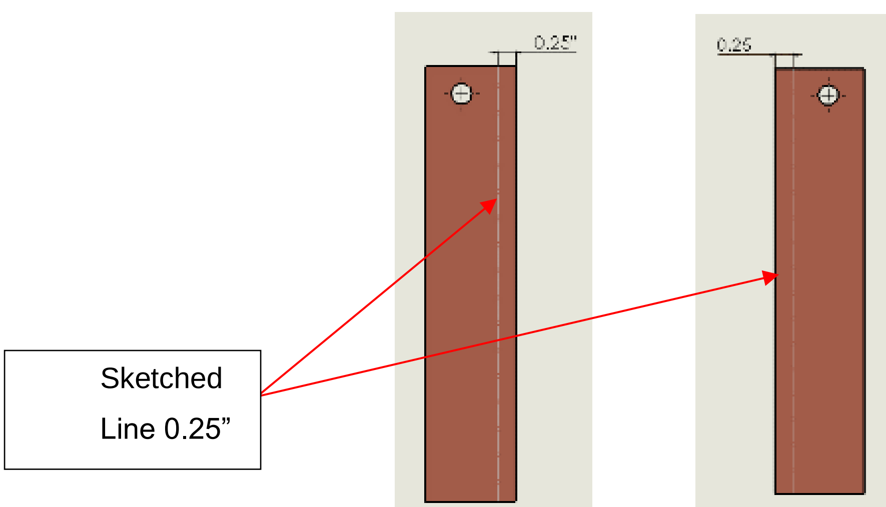
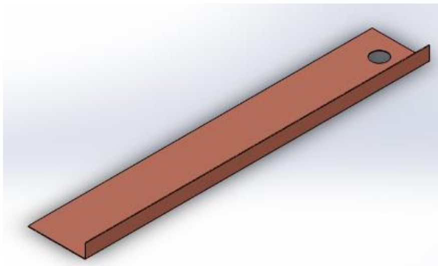


Figure 65 – Sketch Line Copper Lead

3) Clamp the Copper Lead on the work table and bend the edge 90° along the sketched line as shown in Figure 66.



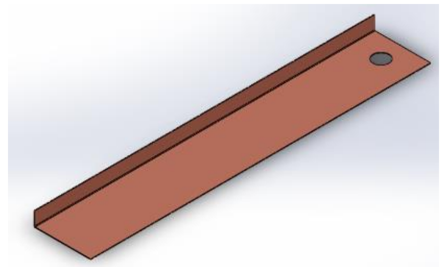


Figure 66 – 90° Bend Copper Lead

4) Bend each end of the Safety Wire 0.125” from the end in a hook shape as shown in Figure 67.

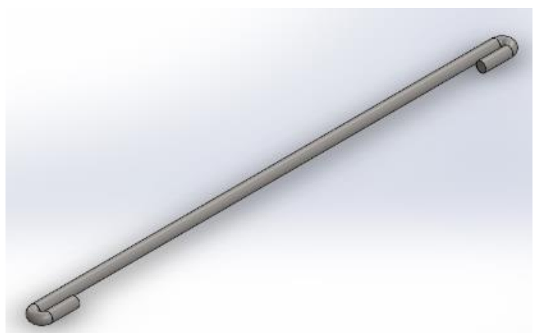


Figure 67 – Hook Bend in Wire

5) Place the Safety Wire on the Copper Lead as shown in Figure 68. Ensure that the end of the Safety Wire hooks around the end of the Copper Lead.

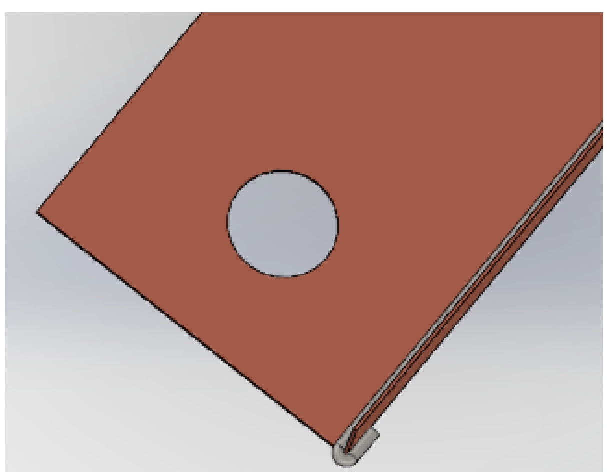


Figure 68 – Wire on Copper Wire

6) Repeat Step 4 on the other end of the Safety Wire and ensure to use the opposite configuration of Copper Lead.
7) Bend the edge of the Copper Lead using pliers until the edge of the Copper is firmly pressed against the rest Copper as shown in Figure 69.

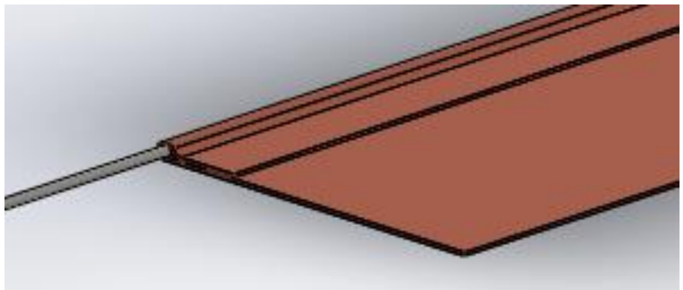


Figure 69 – Copper Lead Bent over Wire

8) Repeat Step 6 for the other Copper Lead
9) Solder each end of the Safety Wire as required to keep connection between the Safety Wire and Copper Lead.
10) Inner Wire Assembly and Outer Wire Assembly have been completed and ready for bending.

Appendix C Operation Manual

C.1. Intro

This Appendix contains the operation manual for each manufacturing process which includes the Mylar cutting machine, hole punch, and the wire bending/ Burst Disk Assembly plate.

C.2. Mylar Cutting Machine

This section provides the steps necessary for operating the Mylar cutting machine.

1) The Cutting Machine will be in storage in the configuration shown in Figure 70.

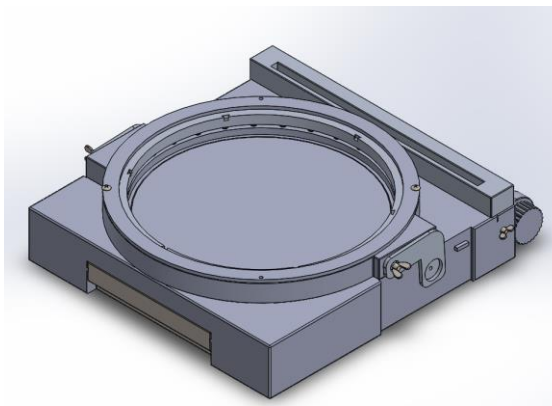


Figure 70 – Cutting Machine Storage Configuration

2) Pull out 2x A10 and A14 Pins from the sides of the Cutting Machine. Then slowly pull out A07 Rod to the desired length in the direction shown in Figure 71. Then position both A09 Rod Lifting Beams from horizontal to vertical position (90° degrees).

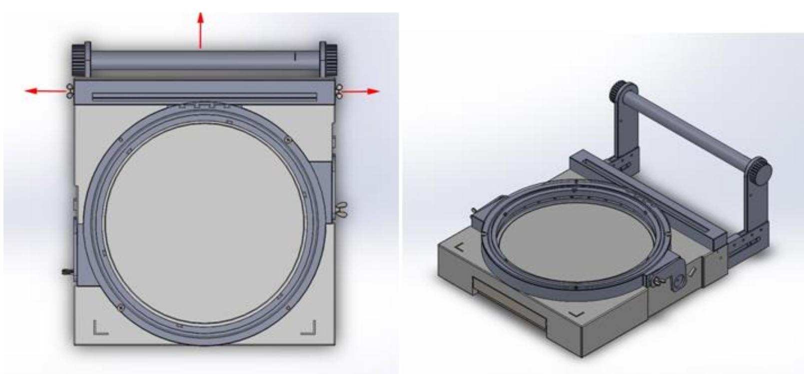


Figure 71 – Top View for Direction

3) Once the beam length has been set as needed, re-insert all A10 and A14 back into their holes on each side of the cutting base as shown in Figure 72

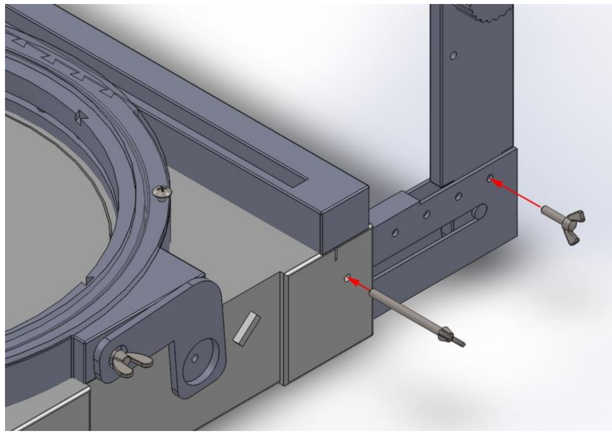


Figure 72 – Beam Length Extended

4) Remove one of the A08 rod cap and insert the Mylar roll as shown in Figure 73. Re-insert A08 to secure the Mylar roll in place.

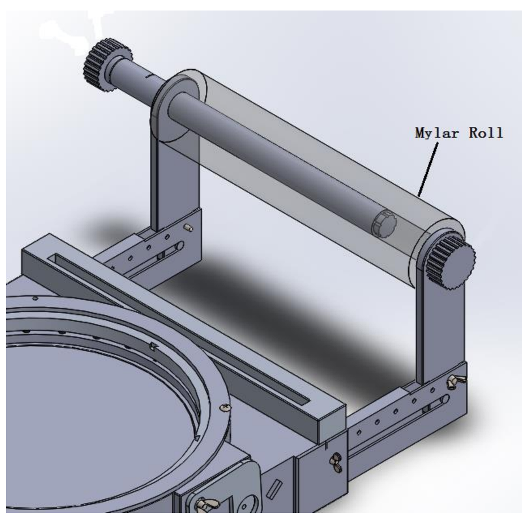


Figure 73 – Mylar Roll Placed in Machine

5) Place Cutting Knife A into any of the quadrangle grooves on A03 Circular Track Inner Ring. Then place Cutting Knife B in the horizontal groove as shown in Figure 74. Make sure the surface on Knife B with the small hole is facing towards the material holder.

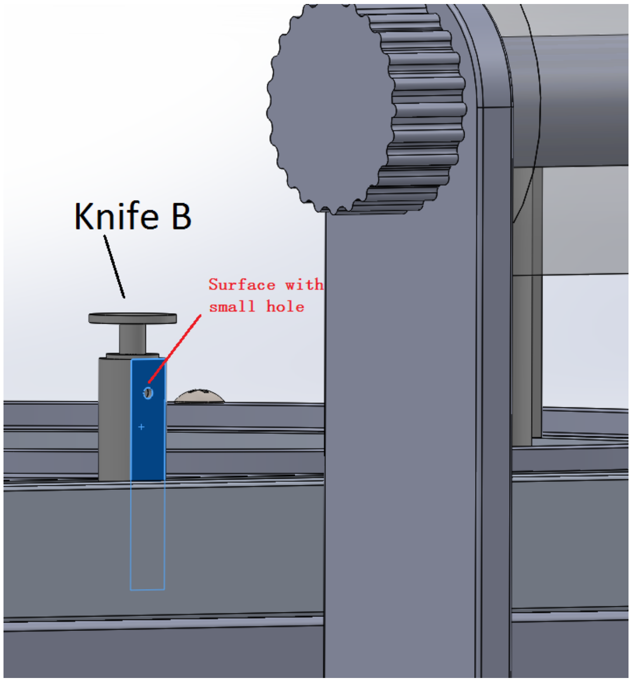


Figure 74 – Knife Assembly

6) Lift the two levers on either side of the machine and pull Mylar sheet between the base and pressing template as shown in Figure 75.

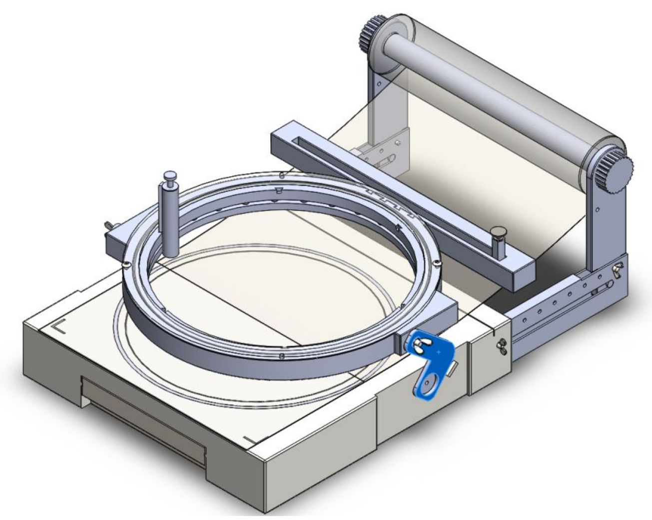


Figure 75 – Rolling Mylar onto Machine

7) Once the Mylar sheet covers the angle grooves on each edge of the machine, lower the Cutting Track down as shown in Figure 76. The machine is now ready to cut the Mylar sheet.

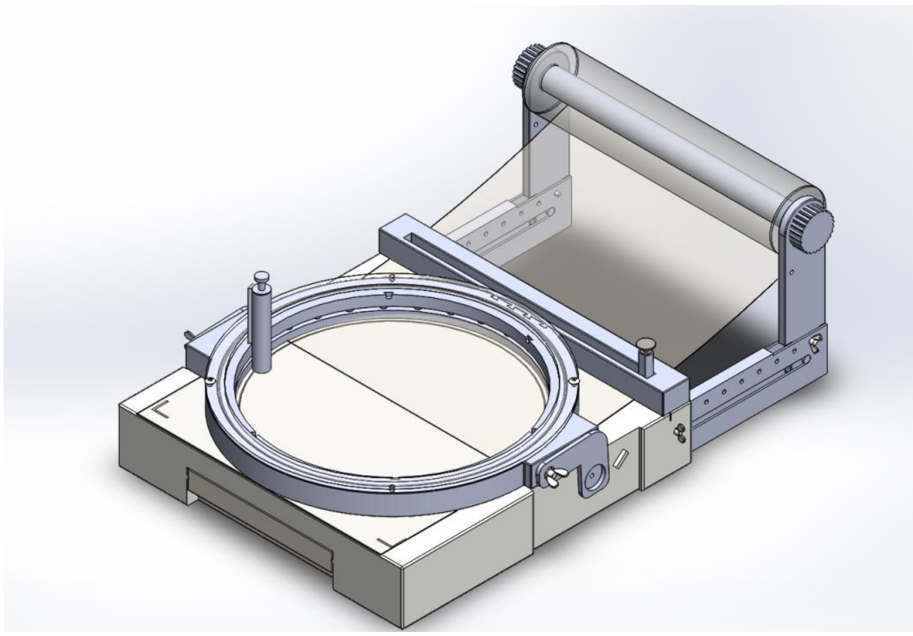


Figure 76 – Lowering Cutting Track

8) Press and hold button on top of Cutting Knife B to cut Mylar horizontally. Then press and button on top of Knife A to cut Mylar circularly. Release the button when cutting is complete. Note that releasing the button will cause the blade to spring back and will no longer be in use.
9) Lift up the two levers and collect the cut Mylar Disk and the waste material.
10) Cutting is complete and ready for storage configuration
11) Lift down the levers, take out all A10 and A14 and take out Mylar roll.
12) Place support beams back to horizontal position and push back all the way and secure with the A14.
13) Place both Cutting Pens A and B, and A10 in drawers for next use.

C.3. Hole Punch Machine

This section provides the steps necessary for operating the Hole Punch machine.

1) Place Mylar disk blank into depression in B21 Lower Disk.
2) Place B22 Upper Disk onto B21, lining up the four holes along the outside of the disks.
3) Secure B22 to B21 with 4x B02 Wing Screws as shown in Figure 77. Tighten hand screws only hand tight.

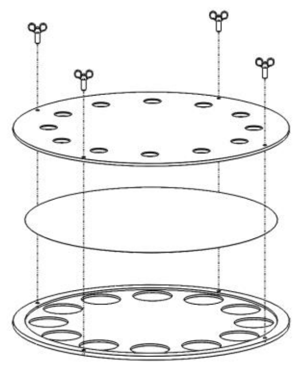


Figure 77 – Upper Disk to Lower Disk

4) Place Disk Assembly onto B12 Die Base and B13 Base Ring, allowing the extra length of the B02 to slide into the corresponding holes on B12 and/or B13 as shown in Figure 78. Ensure to conduct this step carefully to not damage B19 Die and the face of B16 Punch.

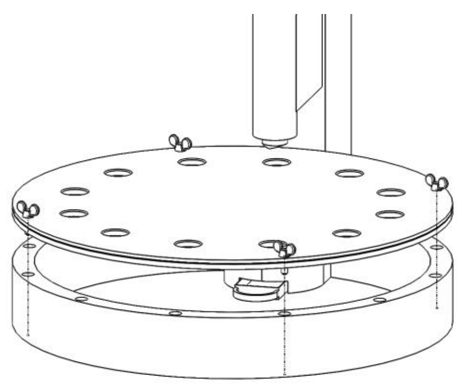


Figure 78 – Disk Assembly to Die Base and Base Ring

5) Firmly pull down on B15 Lever Arm Handle and apply steady pressure so that B16 completely penetrates Mylar blank and B14 Lever Arm contacts stop point on B11 Top Pivot as shown in Figure 79.

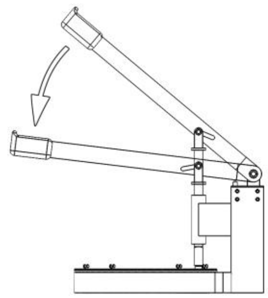


Figure 79 – Punching Hole in Mylar

6) Slow rotate B15 back to its original position as shown in Figure 80.

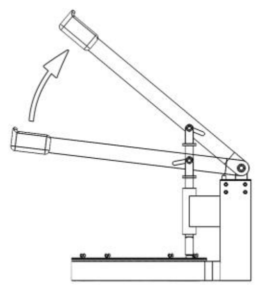


Figure 80 – Lever Arm to Original Position

7) Lift Disk Assembly and rotate 30° to the next set of holes on B12 and/or B13 as shown in Figure 81.

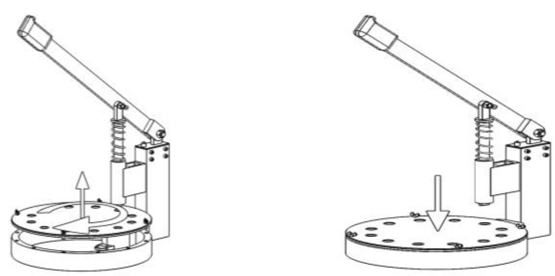


Figure 81 – Rotating for Next Set of Holes

8) Repeat steps 4 through 7 eleven more times to punch a total of 12 holes in the Mylar disk blank.
9) Remove Disk Assembly from Punch Machine and remove 4x B02 from the Disk Assembly as shown in Figure 82.

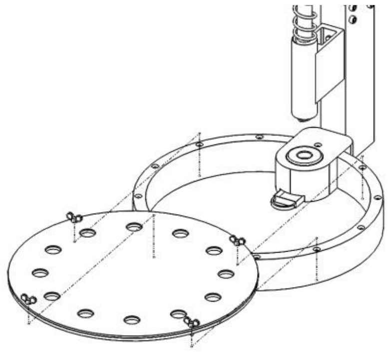


Figure 82 – Removing Disk Assembly

10) Remove B22 and remove Mylar Disk as shown in Figure 83. The Mylar disk blank is now ready for final assembly.

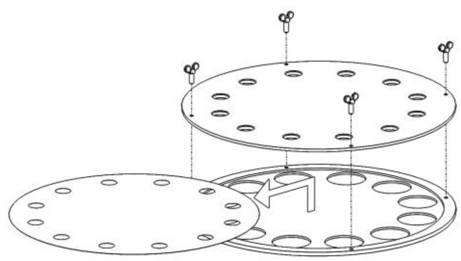


Figure 83 – Removing Mylar Disk

11) Slide out B20 Drawer and dispose of the extra pieces of Mylar as shown in Figure 84.

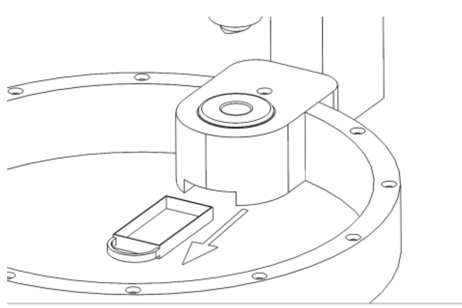


Figure 84 – Removing Extra Mylar Pieces

C.4. Wire Bending/Burst Disk Assembly Plate

This section provides the steps necessary for operating the Wire Bending/Burst Disk Assembly Machine

C.4.1. Operation for Inner Wire Bending

1) Ensure the Wire Bending/Burst Disk Assembly Machine has been assembled in the Inner Wire configuration per Section B.4.1.
2) Run C06 Guide through the inner track until positioned beside the slot in C04 as shown in Figure 85.

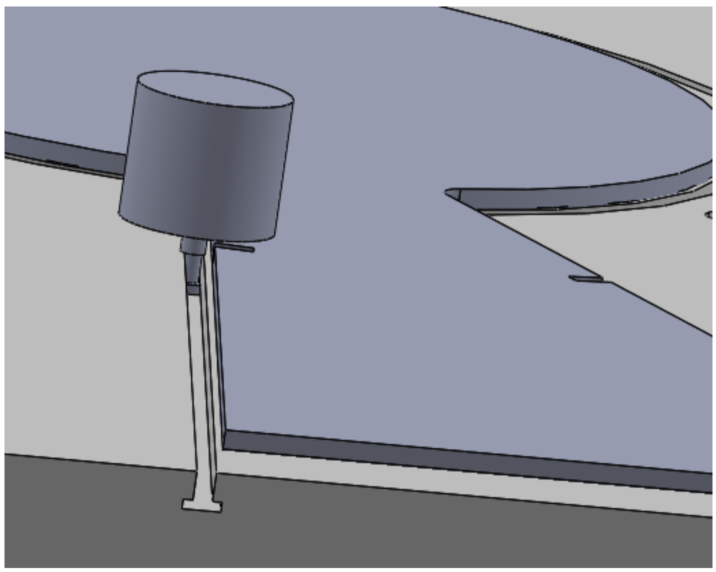


Figure 85 – Guide to Assembly Plate

3) Place the Inner Wire Assembly against C04. Secure the end of the copper lead that is on the side of C06 with tape.
4) Run C06 along the inner track until it reaches the Copper Lead on the other end.
5) Wire has been bent, shown in Figure 86, and ready for Burst Disk Assembly.

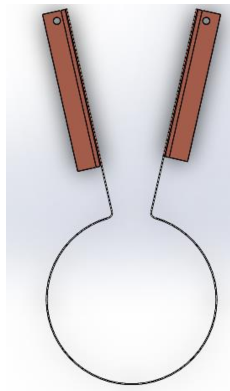


Figure 86 – Completed Inner Wire Assembly

5.1

5.2 Operation for Outer Wire Bending

1) Ensure the Wire Bending/Burst Disk Assembly Machine has been assembled in the Inner Wire configuration per Section B.4.2.
2) Run C06 Guide through the outer track until positioned beside the slot in C04 as shown in Figure 87.

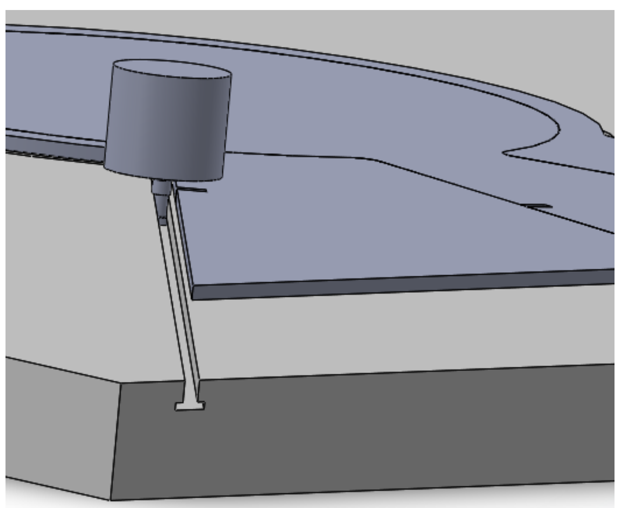


Figure 87 – Guide to Assembly Plate

3) Place the Outer Wire Assembly against C04. Secure the end of the copper lead that is on the side of C06 with tape.
4) Run C06 along the inner track until it reaches the Copper Lead on the other end.

5) Wire has been bent, shown in Figure 88, and ready for Burst Disk Assembly.

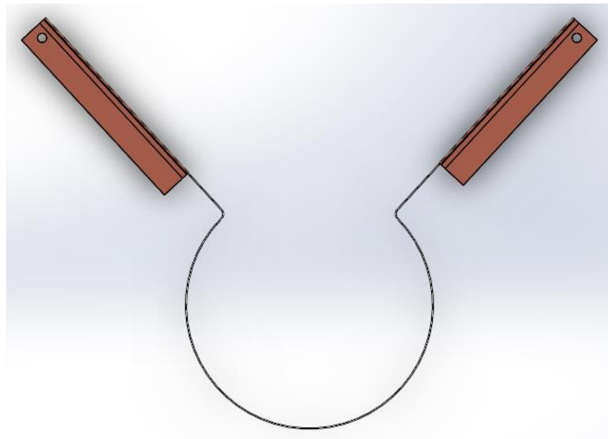


Figure 88 – Completed Outer Wire Assembly

C.4.2. Operation for Burst Disk Assembly

1) Ensure the Wire Bending/Burst Disk Assembly Machine has been assembled per Section B.4.3 and both Wire Assemblies have been bent to shape per Section C.4.1 and 5.2.
2) Place one Mylar Disk on C03 Assembly Plate as shown in Figure 89.

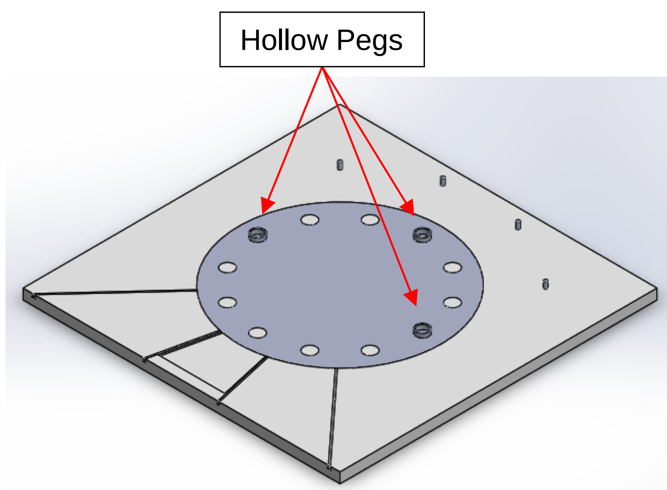


Figure 89 – Mylar Disk to Assembly Plate

3) Place Inner Wire Assembly on C03 as shown in Figure 90. Ensure the holes in the Copper Leads go through the 2x C01 Small Pegs and that the Safety Wire rests against the Mylar disk.

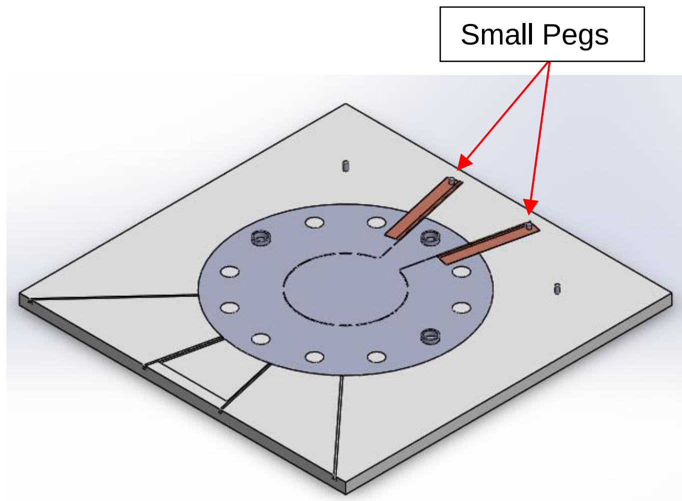


Figure 90 – Inner Wire Assembly to Assembly Plate

4) Repeat Step 3 for the Outer Wire Assembly as shown in Figure 91.

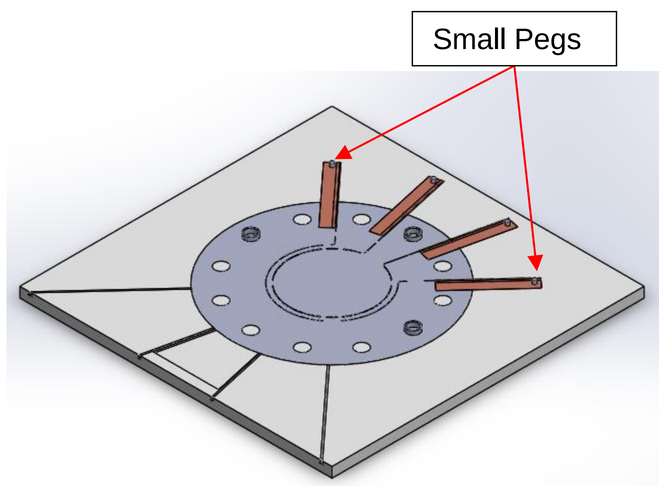


Figure 91 – Outer Wire Assembly to Assembly Plate

5) Place double sided tape on the Mylar disk as shown in Figure 92. Ensure no tape is applied on the Safety Wires.

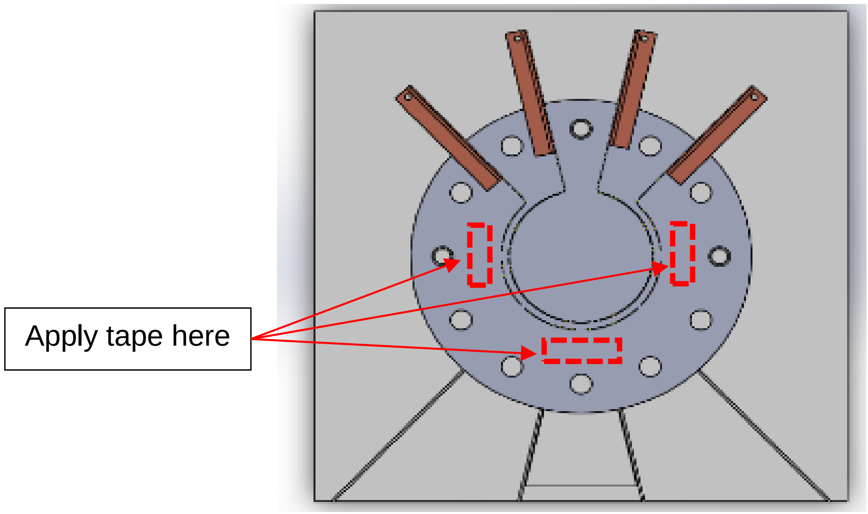


Figure 92 – Apply Tape to Mylar Disk

6) Place a second Mylar Disk on C03 as shown in Figure 93. Ensure the Mylar Disk goes through the 3x C02 Hollow Pegs and sits against the first Mylar Disk.

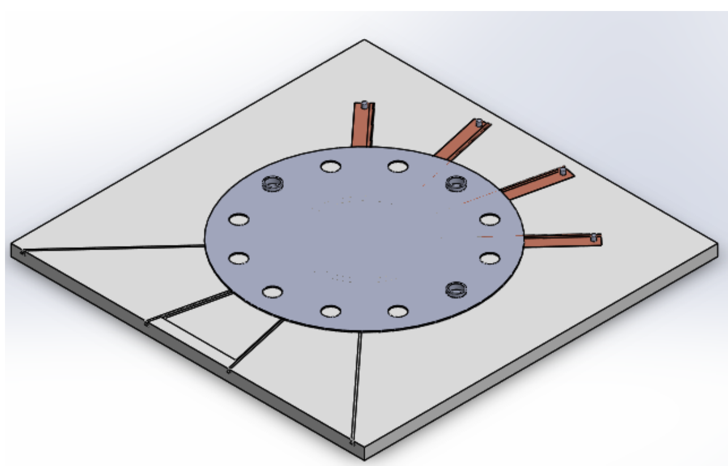


Figure 93 – Second Mylar Disk to Assembly Plate

7) Press down on the top Mylar Disk in the areas where the tape has been applied to secure the assembly together.
8) Remove the completed assembly from C03.

9) Burst Disk Assembly is complete and shown in Figure 94.

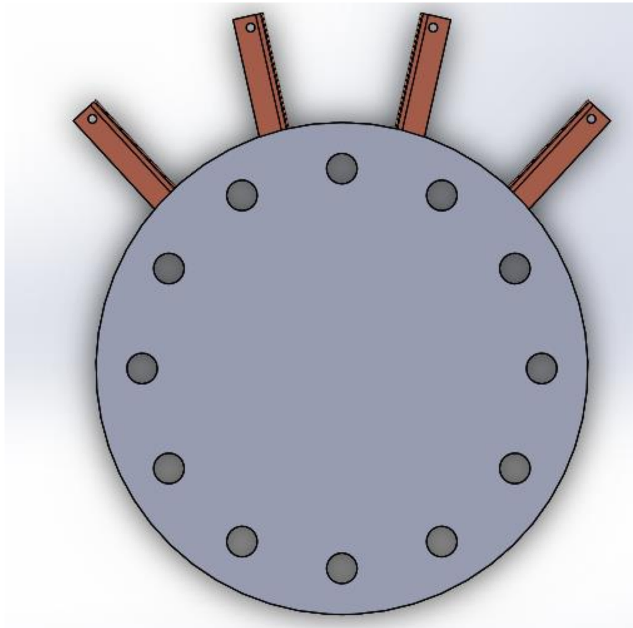


Figure 94 – Completed Burst Disk Assembly

Appendix D Details of Cost

D.1. Intro

This Appendix contains the details of the cost analysis for each manufacturing process which includes the Mylar cutting machine, hole punch, and the wire bending/ burst disk assembly machine. Our team assumed an hourly rate of $100/hour for manufacturing for all applicable parts.

Each manufacturing cost table in this section will include the following columns: Part Name, Quantity, Part Number, Unit Cost per individual part in $, Manufacturing Time in hours, and Total Cost in $. Each material cost table in this section will include the following columns: Material, Mass of material in lb, Cost/lb in $ and Total Cost in $.

D.2. Mylar Cutting Machine

This section will give the details of the cost for the Mylar Cutting Machine. TABLE XVI shows the breakdown of the manufacturing cost and TABLE XVII shows the breakdown of the material cost.

TABLE XVI – MYLAR CUTTING MACHINE MANUFACTURING COST

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
Truss Head Screw	2	A01	0.02176	0	0.04
Circular Track Top	1	A02	See TABLE XVII	0.25	25.00
Circular Track Inner Ring	1	A03	See TABLE XVII	1.0	100.00
Rolling Ball	30	A04	0.1577	0	4.73
Circular Track Outer Ring	1	A05	See TABLE XVII	0.5	50.00
Horizontal Track	1	A06	See TABLE XVII	0.25	25.00
Rod	1	A07	See TABLE XVII	0.25	25.00
Rod Cap	2	A08	See TABLE XVII	1.0	100.00
Rod Lifting Beam	2	A09	See TABLE	0.5	50.00

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
			XVII		
Pin Wing (0.25*0.75”)	2	A10	1.63	0	3.26
Adjusting Beam	2	A11	See TABLE XVII	1.0	100.00
Left Lever	1	A12	See TABLE XVII	0.5	50.00
Drawer	1	A13	See TABLE XVII	0.5	50.00
Wing Pin (Type B, 0.25-2.00)	2	A14	2.52	0	5.04
Right Lever	1	A15	See TABLE XVII	0.5	50.00
Wing Shoulder Screw Cap (Type B, 0.25-1.25)	2	A16	1.10273	0	2.20
Cutting Base	1	A17	See TABLE XVII	1.5	150.00
Rubber Ring	1	A18	See TABLE XVII	0.25	25.00
Button A	1	A19	See TABLE XVII	0.25	25.00
Fastener A	1	A20	See TABLE XVII	0.25	25.00
Inner Stick A	1	A21	See TABLE XVII	0.5	50.00
Spring A	1	A22	3.95	0	3.95
Shell A	1	A23	See TABLE XVII	0.25	25.00
Blade A	1	A24	3.99	0	3.99
Screw	2	A25	0.02176	0	0.04
Button B	1	A26	See TABLE XVII	0.25	25.00

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
Fastener B	1	A27	See TABLE XVII	0.25	25.00
Inner Stick B	1	A28	See TABLE XVII	0.25	25.00
Spring B	1	A29	3.95	0	3.95
Shell B	1	A30	See TABLE XVII	0.25	25.00
Blade B	1	A31	3.99	0	3.99
				Subtotal	1056.16

TABLE XVII – MYLAR CUTTING MACHINE MATERIAL COST

Material	Mass [lb]	Cost/lb [$]	Total [$}
ABS Plastic	2.31	1.33	3.07
6061-T6	165.2	0.91	150.33
		Subtotal	153.40

Therefore the total for the Mylar Cutting Machine is $1209.56.

D.3. Hole Punch Machine

This section will give the details of the cost for the Hole Punch Machine. TABLE XVIII shows the breakdown of the manufacturing cost and TABLE XIX shows the breakdown of the material cost.

TABLE XVIII – HOLE PUNCH MACHINE MANUFACTURING COST

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
Hex Cap Screw	8	B01	0.213	0	1.70
Wing Screw	4	B02	1.83	0	7.32
Hex Cap Screw	2	B03	0.5554	0	1.11

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
Hex Cap Screw	2	B04	1.43	0	2.86
Shoulder Bolt	1	B05	4.2	0	4.20
Shoulder Bolt	1	B06	2.62	0	2.62
Lock Nut	1	B07	0.305	0	0.31
Lock Nut	1	B08	0.1326	0	0.13
Upright	1	B09	See TABLE XIX	0.75	75.00
Neck	1	B10	See TABLE XIX	0.5	50.00
Top Pivot	1	B11	See TABLE XIX	0.5	50.00
Die Base	1	B12	See TABLE XIX	0.75	75.00
Base Ring	1	B13	See TABLE XIX	0.5	50.00
Lever Arm	1	B14	See TABLE XIX	0.5	50.00
Lever Arm Handle	1	B15	See TABLE XIX	0.5	50.00
Punch	1	B16	See TABLE XIX	1	100.00
Punch Pivot	1	B17	See TABLE XIX	1	100.00
Punch Spring	1	B18	16.49	0	16.49
Die	1	B19	See TABLE XIX	1.5	150.00
Drawer	1	B20	See TABLE XIX	0.5	50.00
Lower Disk	1	B21	See TABLE XIX	2	200.00
Upper Disk	1	B22	See TABLE XIX	2	200.00
				Subtotal	1236.74

TABLE XIX – HOLE PUNCH MACHINE MATERIAL COST

Material	Mass [lb]	Cost/lb [$]	Total [$}
ABS Plastic	4.67	1.33	6.21
6061-T6	17.32	0.91	15.76
1018 Steel	8.66	0.38	3.29
4140 Steel	4.03	0.38	1.53
		Subtotal	26.79

Therefore the total for the Hole Punch Machine is $1263.53.

D.4. Wire Bending/Burst Disk Assembly Machine

This section will give details of the cost for the Wire Bending/Burst Disk Assembly Machine. TABLE XX shows the breakdown of the manufacturing cost and

TABLE XXI shows the breakdown of the material cost.

TABLE XX – WIRE BENDING/BURST DISK MACHINE PARTS LIST

Parts Name	Quantity	Part Number	Unit Cost [$]	Manufacturing Time [Hours]	Total Cost [$]
Small Pegs	4	C01	See TABLE XXI	0.25	25.00
Hollow Pegs	3	C02	See TABLE XXI	0.25	25.00
Assembly Plate	1	C03	See TABLE XXI	0.67	67.00
Inside Mold	1	C04	See TABLE XXI	0.33	33.00
Outside Mold	1	C05	See TABLE XXI	0.33	33.00
Guide	1	C06	See TABLE XXI	0.5	50.00
				Subtotal	233.00

TABLE XXI – WIRE BENDING/BURST DISK ASSEMBLY MACHINE MATERIAL COST

Material	Mass [lb]	Cost/lb [$]	Total [$}
ABS Plastic	3.76	1.33	5.00
		Subtotal	5.00

Therefore the total for the Wire Bending/Burst Disk Assembly Machine is $238.00.

Appendix E Engineering Drawings

E.1. Intro

This Appendix contains the engineering drawings for each manufacturing process which includes the Mylar cutting machine, hole punch, and the wire bending/ burst disk assembly machine. Drawings include drawings for each individual part as well as sub-assembly drawings and full machine assembly drawings.

E.2. Mylar Cutting

Figure 95 is the manufacturing engineering drawing for the Cutting Machine.

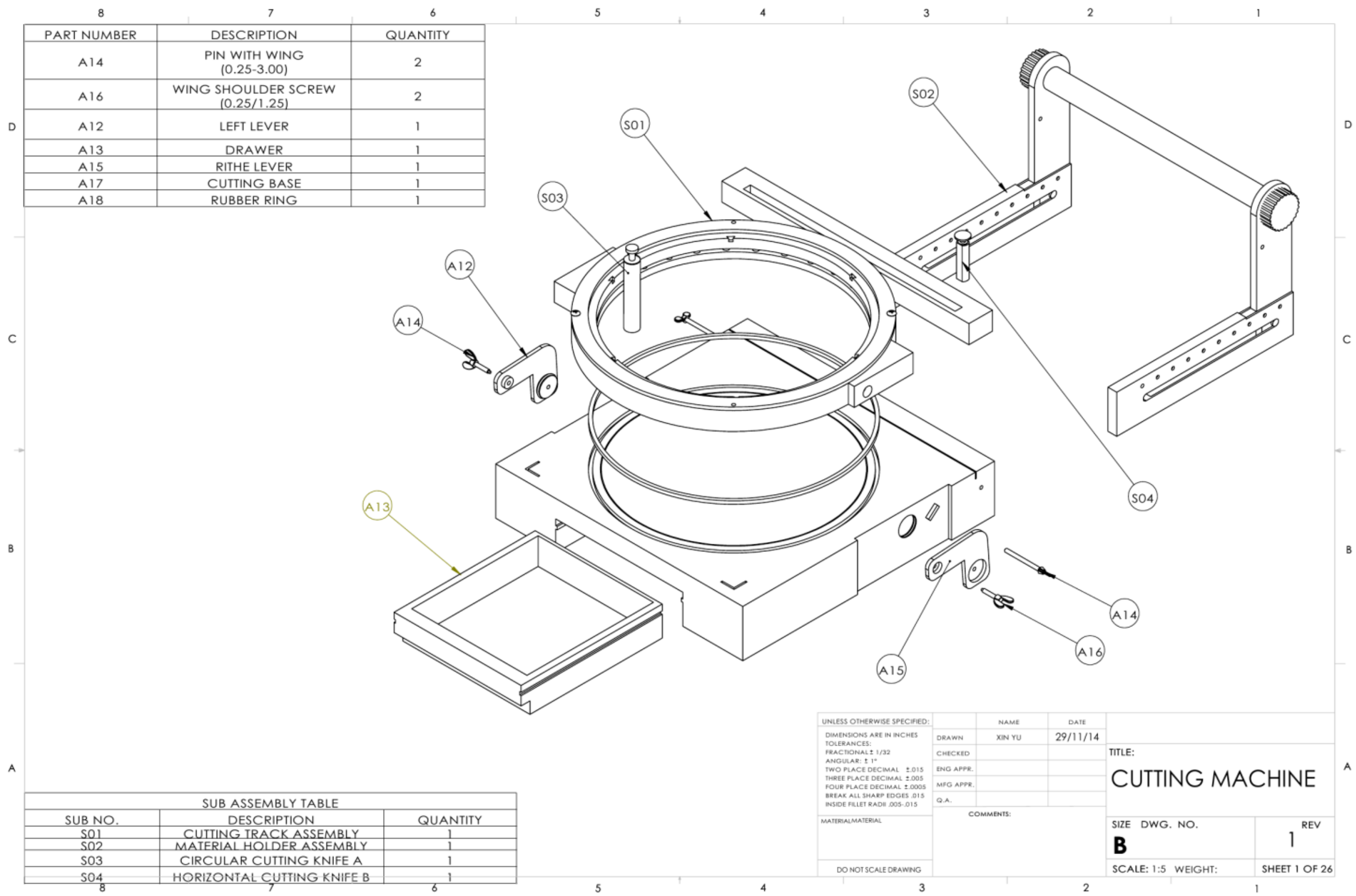


Figure 95 – Completed Burst Disk Assembly Drawing

Figure 96 is the manufacturing engineering drawing for the Cutting Machine.

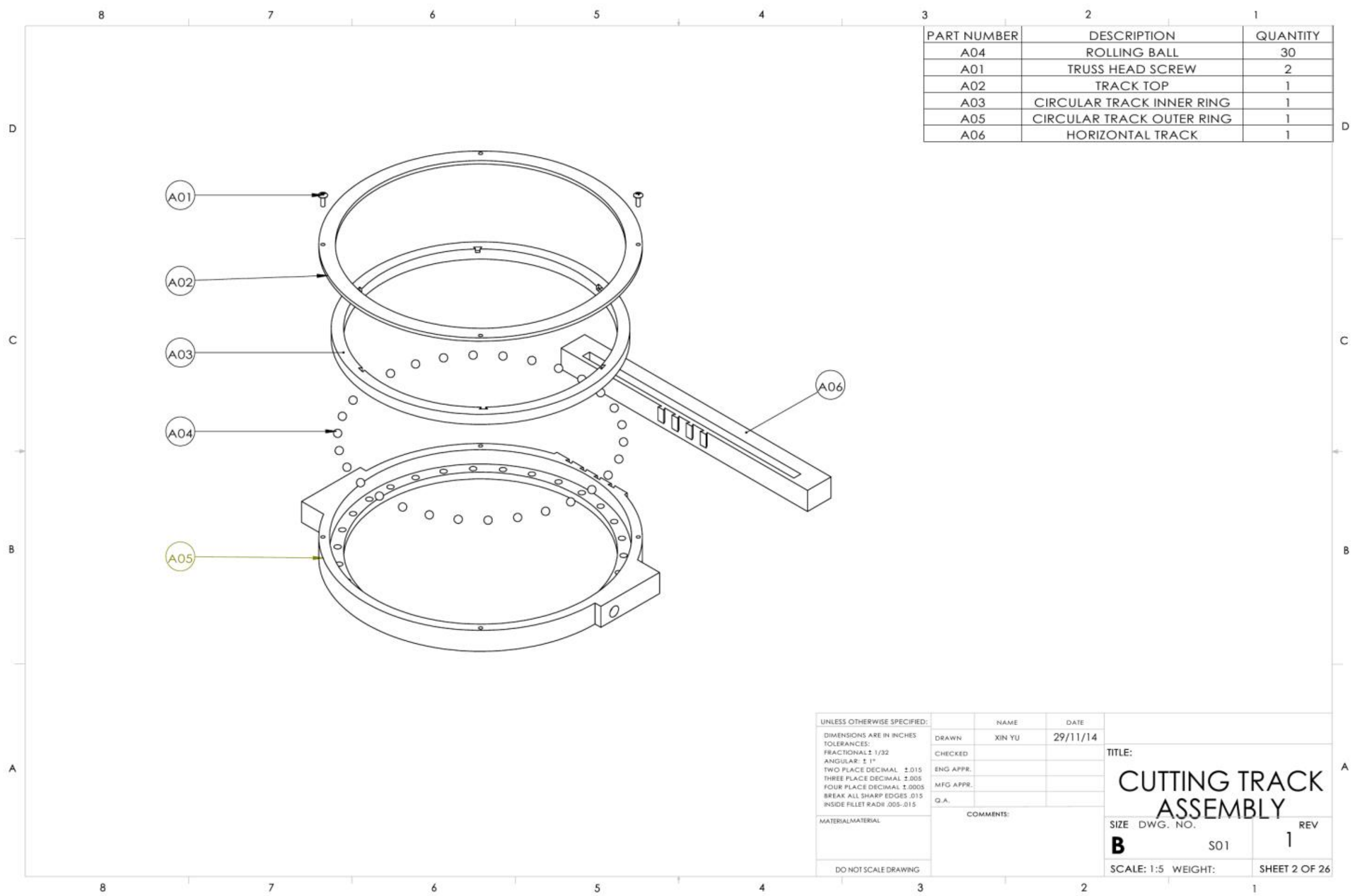


Figure 96 – Cutting Track Assembly Drawing

Figure 97 is the manufacturing engineering drawing for the Material Holder.

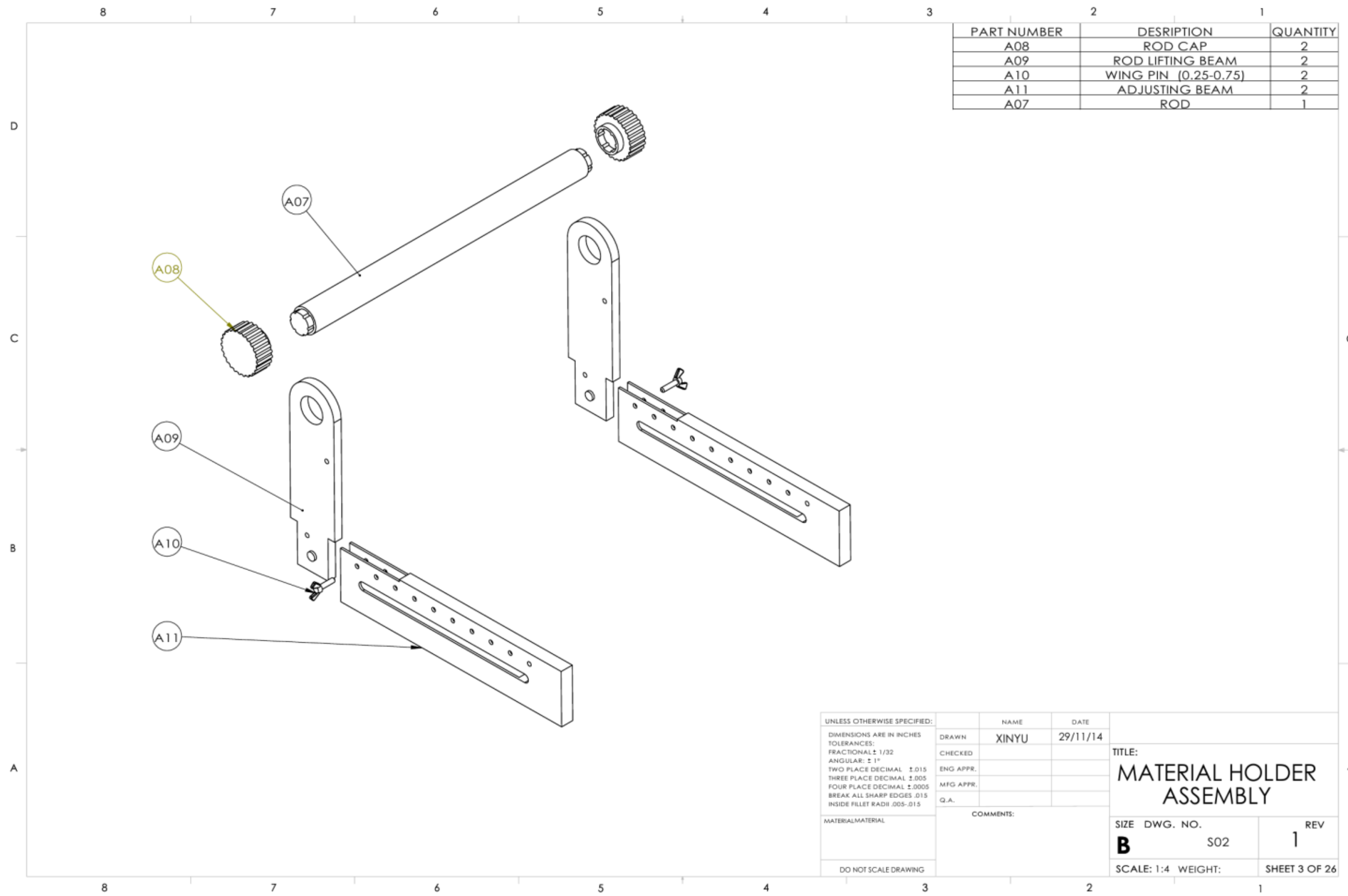


Figure 97 – Material Holder Drawing

Figure 98 is the manufacturing engineering drawing for both Cutting Knife A and B.

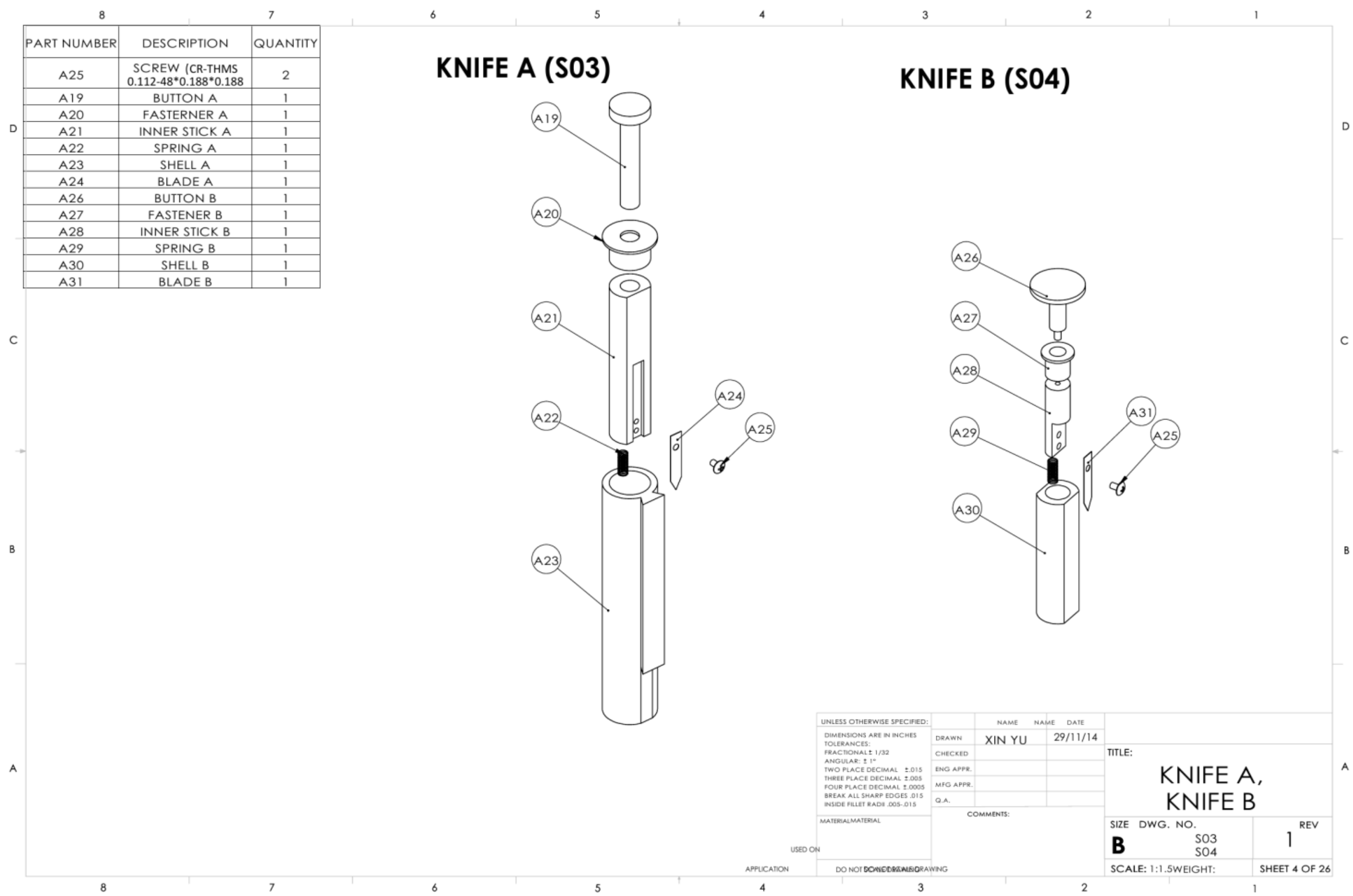


Figure 98 – Knife A and B Drawing

Figure 99 is the manufacturing engineering drawing for Track Top

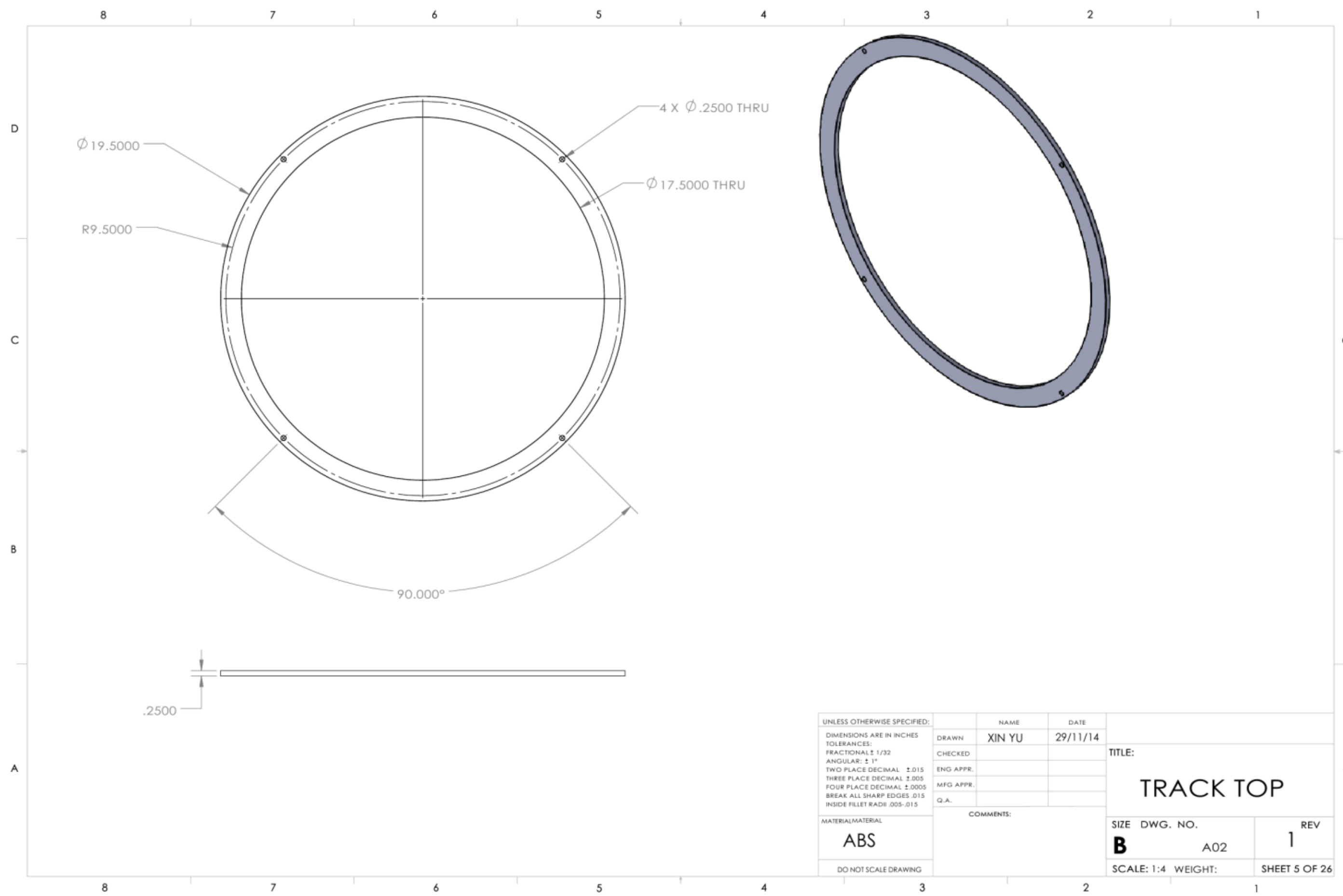


Figure 99 – Track Top Drawing

Figure 100 is the manufacturing engineering drawing for the Circular Track Inner Ring

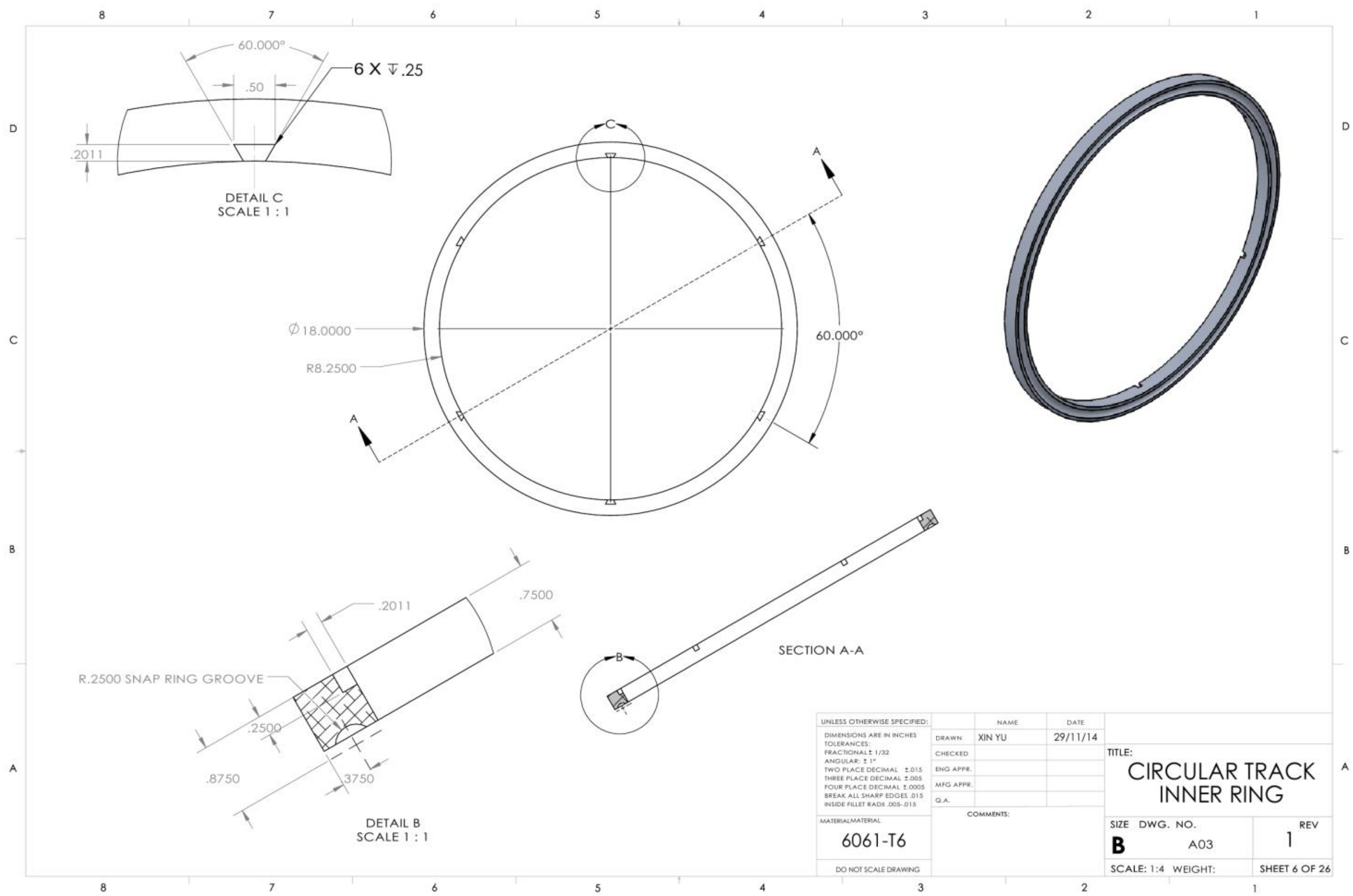


Figure 100 – Circular Track Inner Ring Drawing

Figure 101 is the manufacturing engineering drawing for the Circular Track Outer Ring.

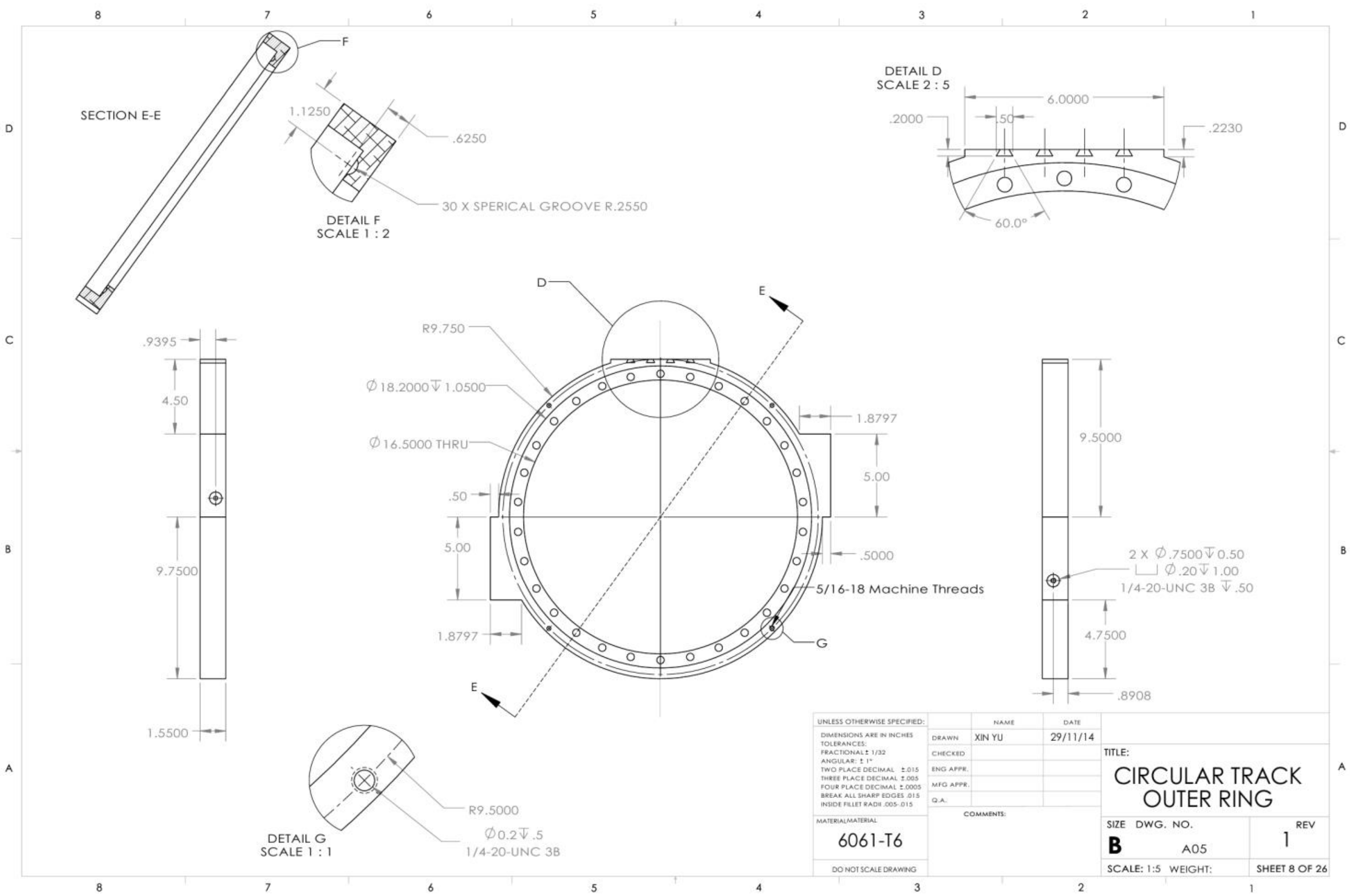


Figure 101 – Circular Track Outer Ring Drawing

Figure 102 is the manufacturing engineering drawing for the Horizontal Track.

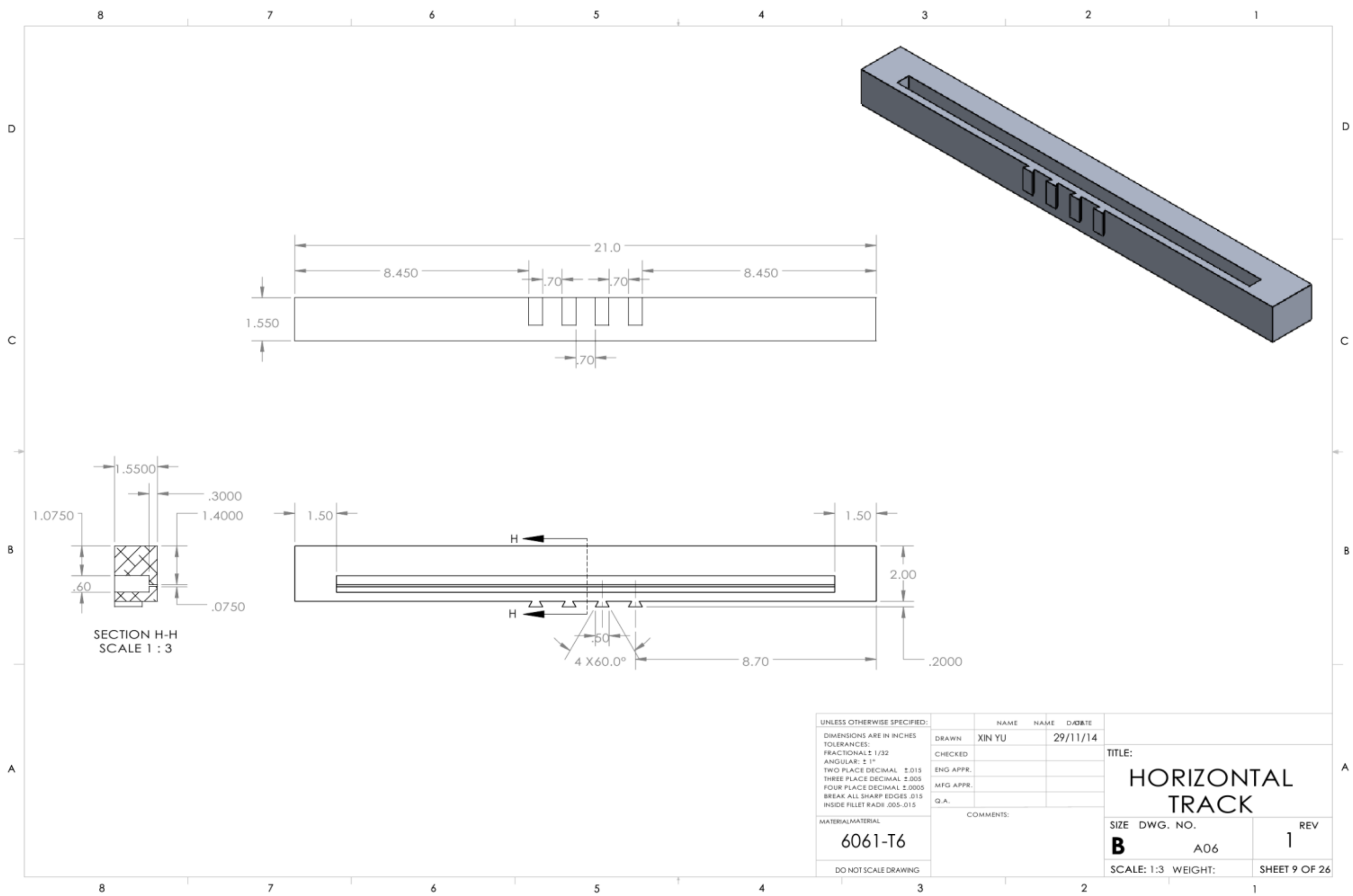


Figure 102 – Horizontal Track Drawing

Figure 103 is the manufacturing engineering drawing for the Rod.

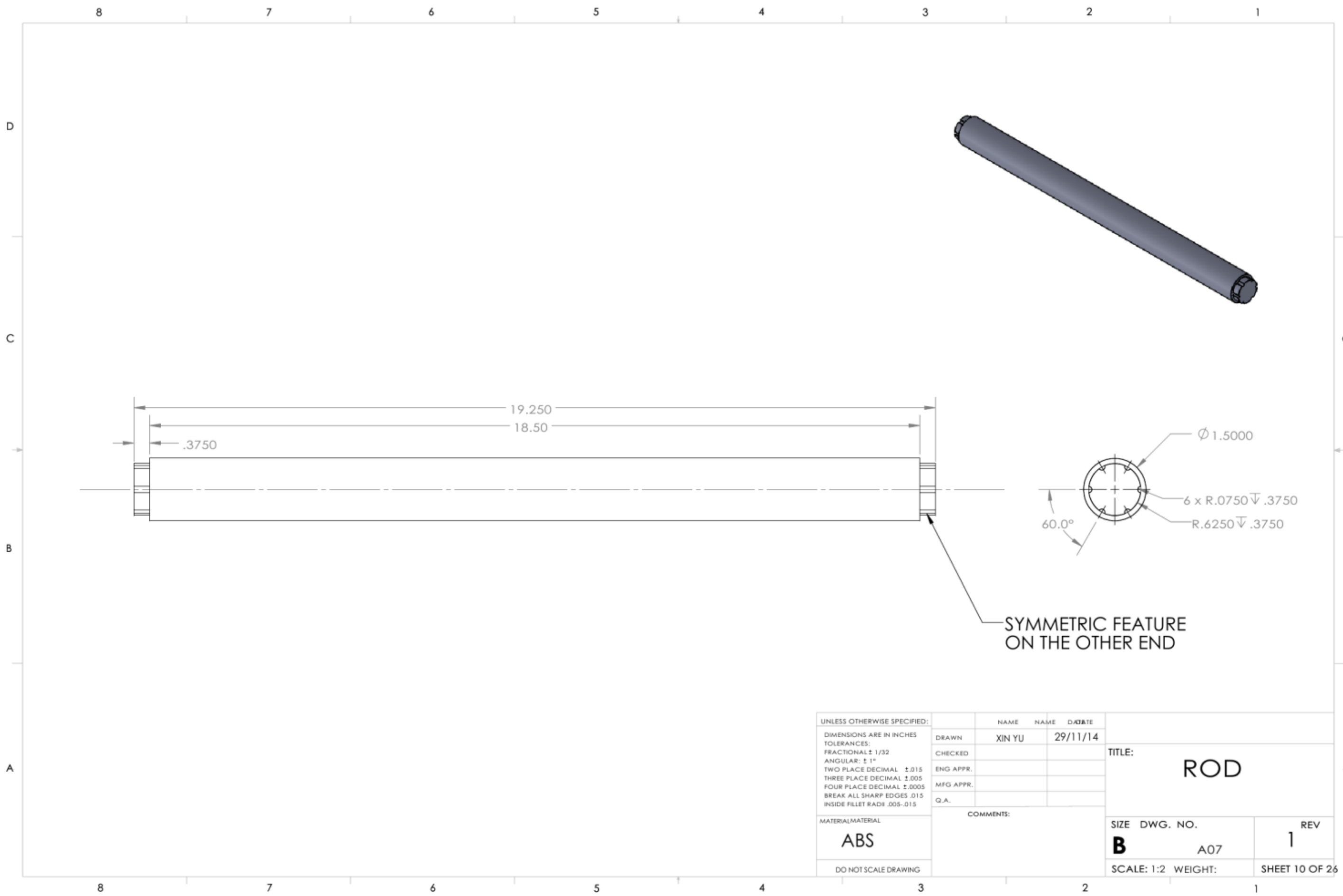


Figure 103 – Rod Drawing

Figure 104 is the manufacturing engineering drawing for the Rod Cap.

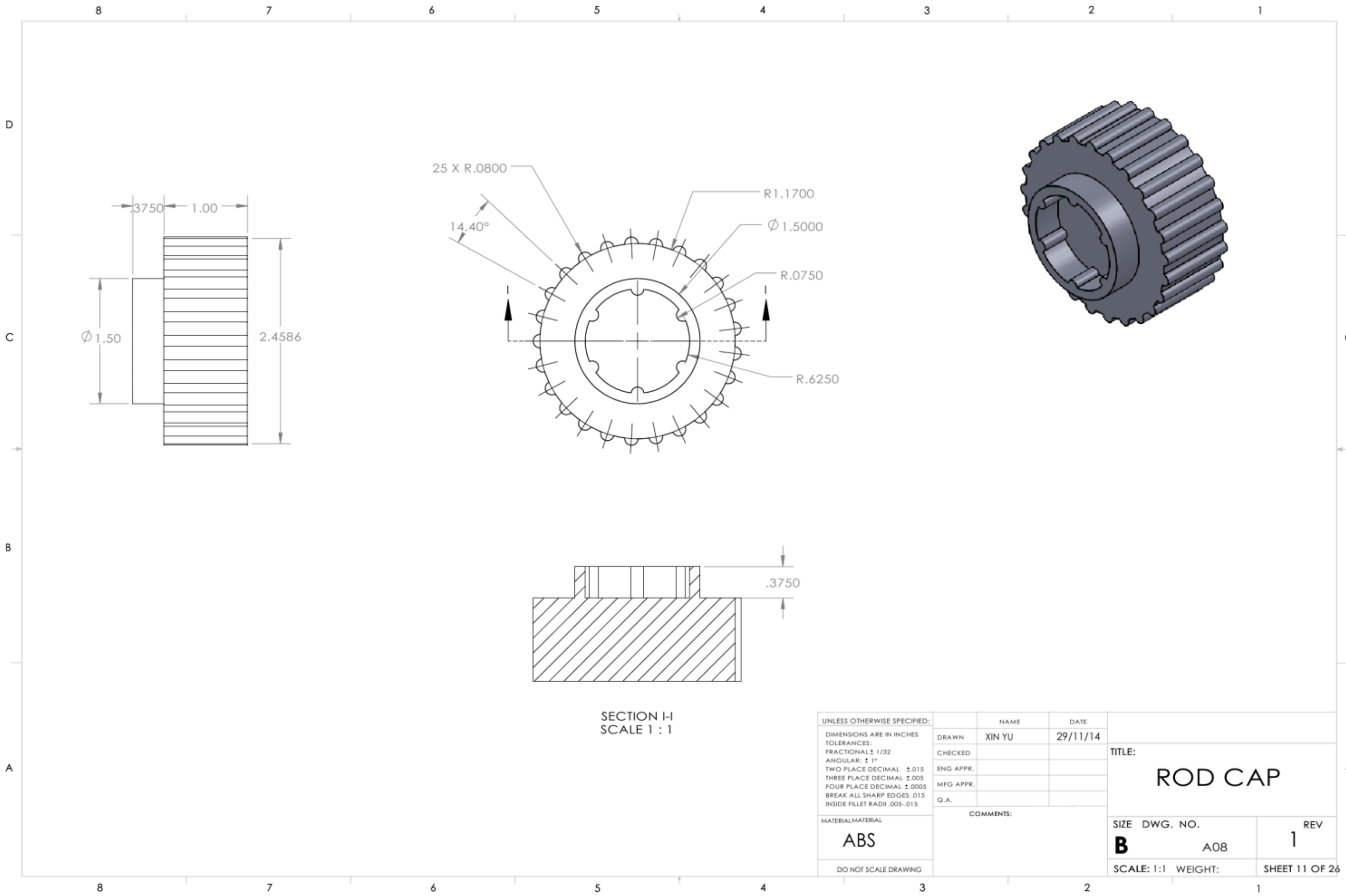


Figure 104 – Rod Cap Drawing

Figure 105is the manufacturing engineering drawing for the Rod Lifting Beam.

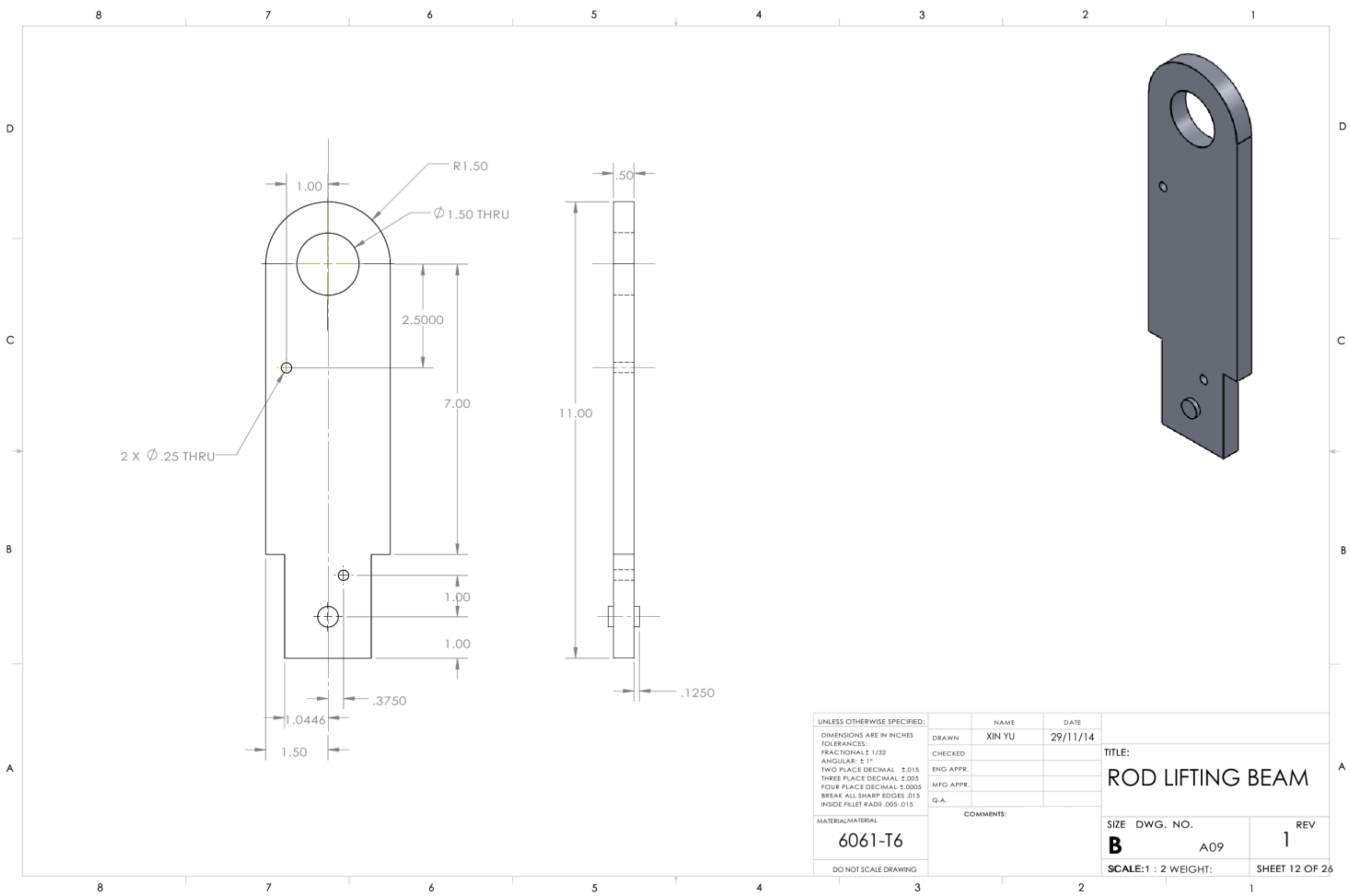


Figure 105 – Rod Lifting Beam Drawing

Figure 106 is the manufacturing engineering drawing for the Adjusting Beam.

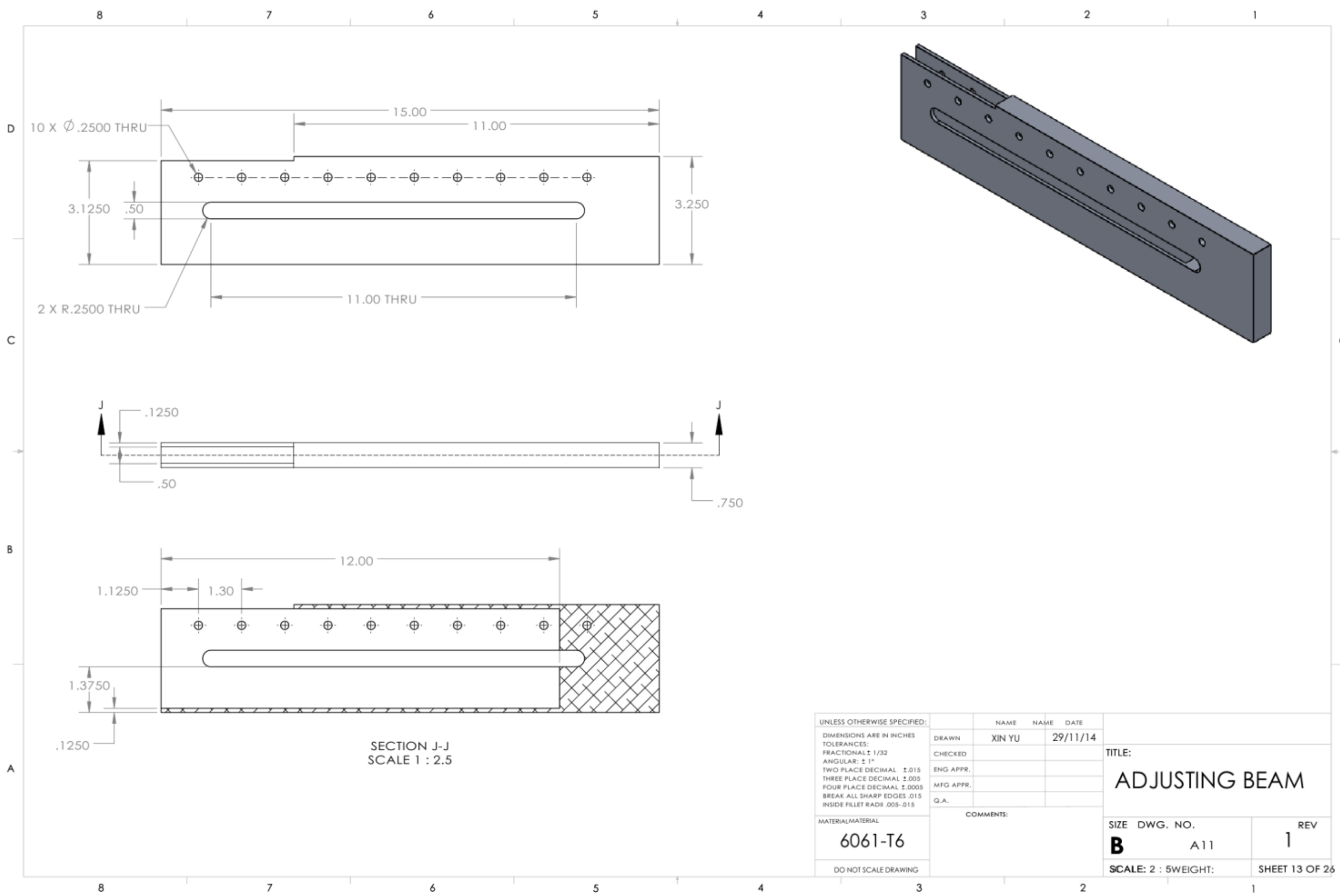


Figure 106 – Adjusting Beam Drawing

Figure 107 is the manufacturing engineering drawing for the Left Lever.

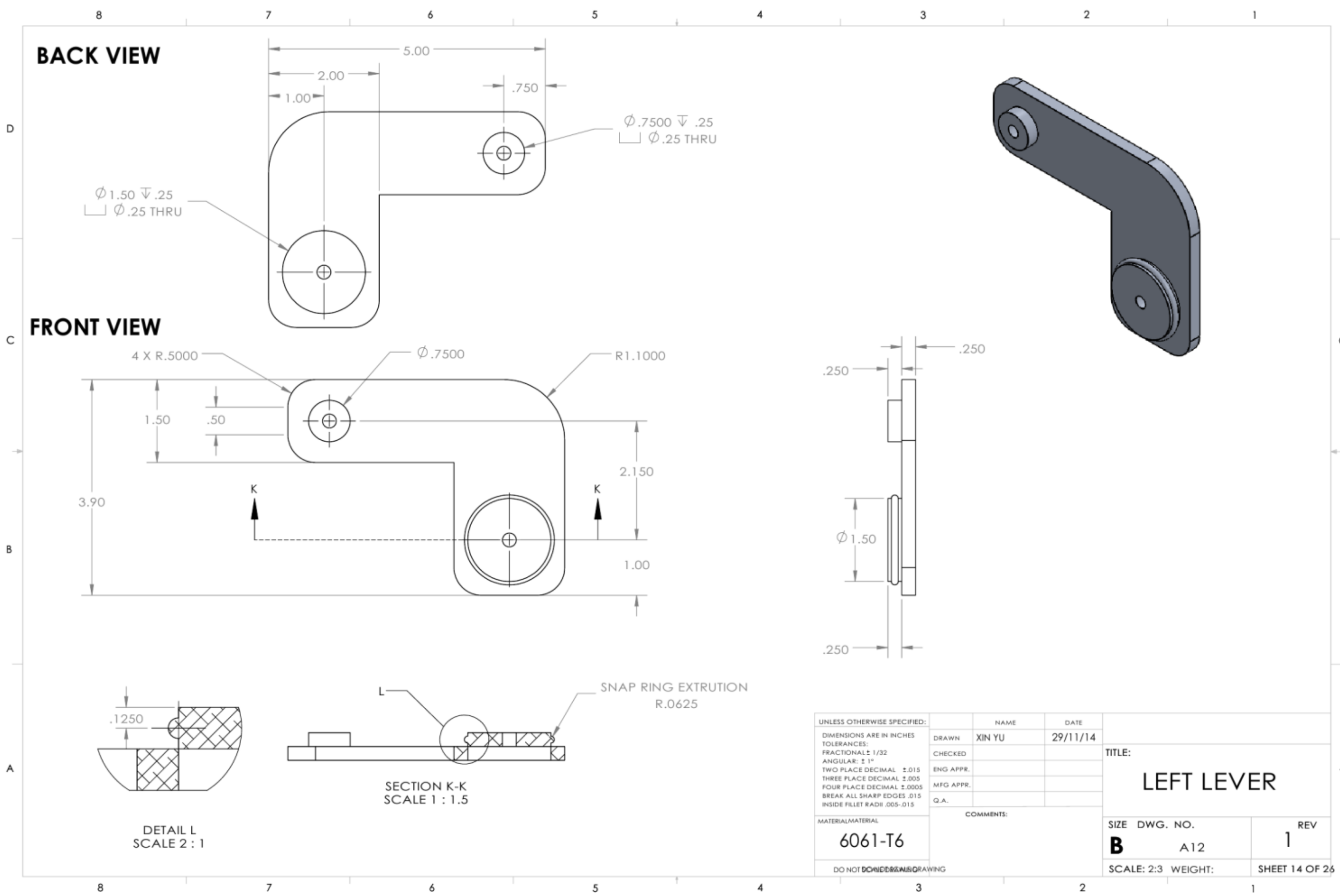


Figure 107 – Left Lever Drawing

Figure 108 is the manufacturing engineering drawing for the Drawer.

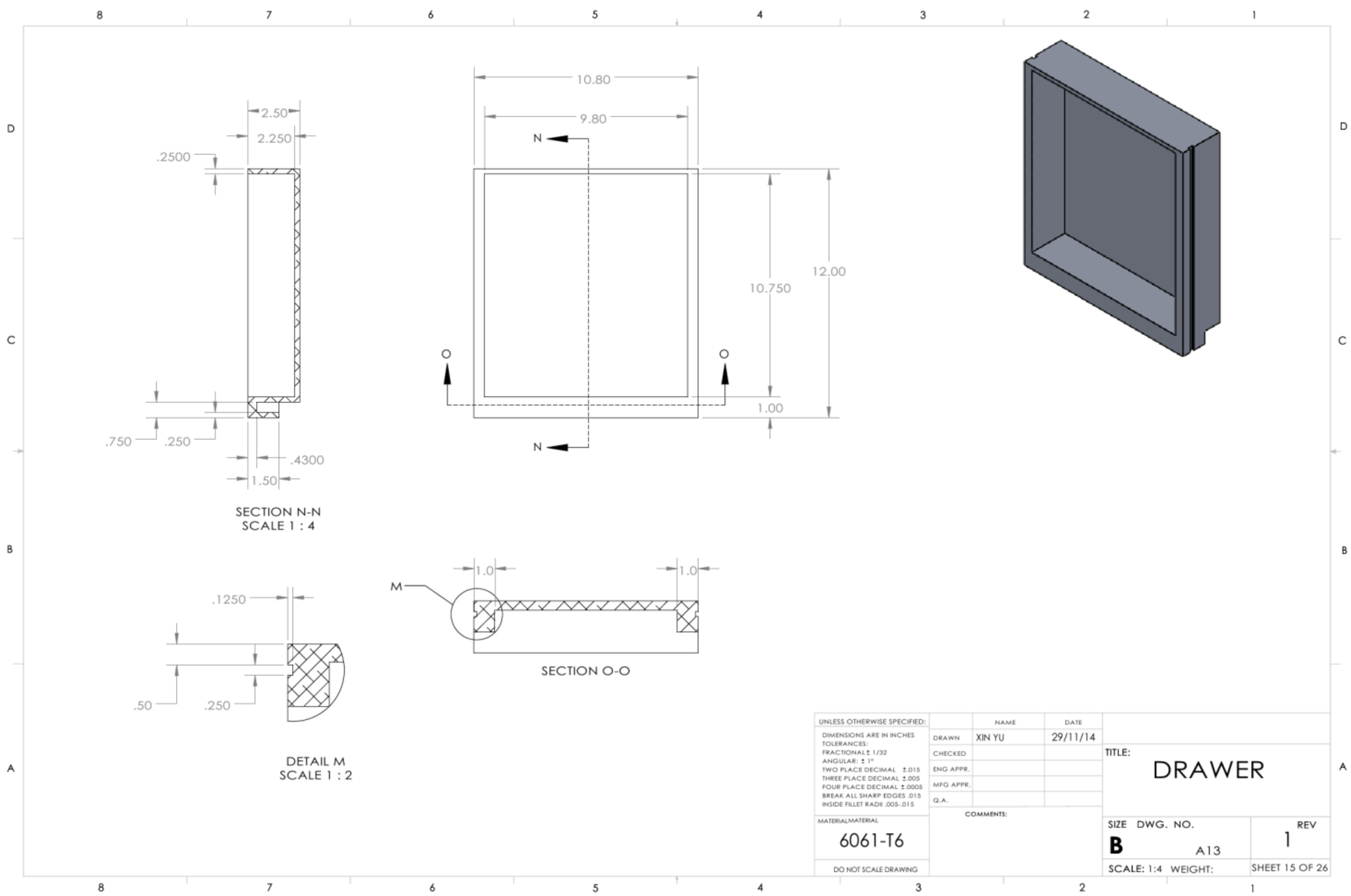


Figure 108 – Drawer Drawing

Figure 109 is the manufacturing engineering drawing for the Right Lever.

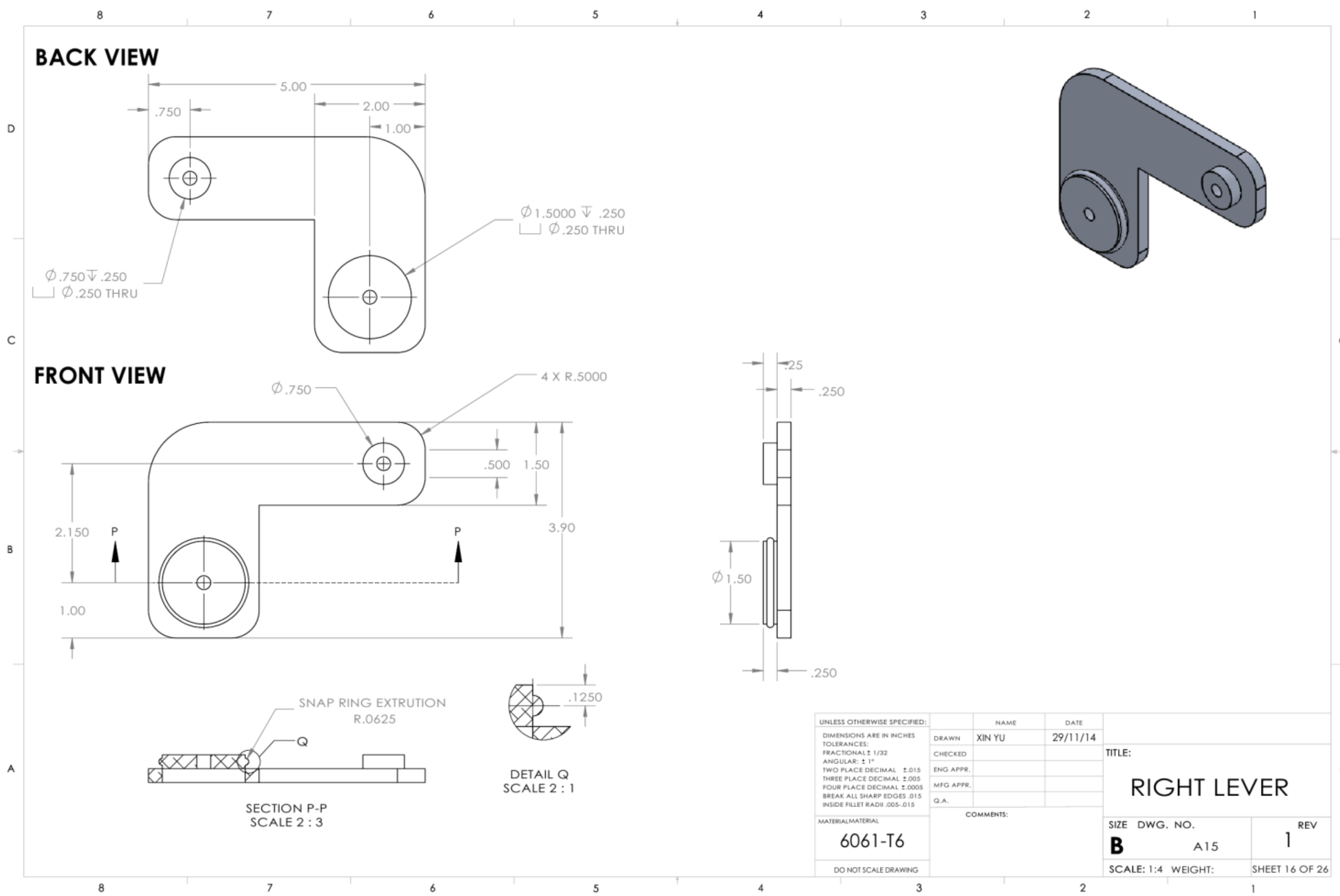


Figure 109 – Right Lever Drawing

Figure 110 is the manufacturing engineering drawing for the Cutting Base.

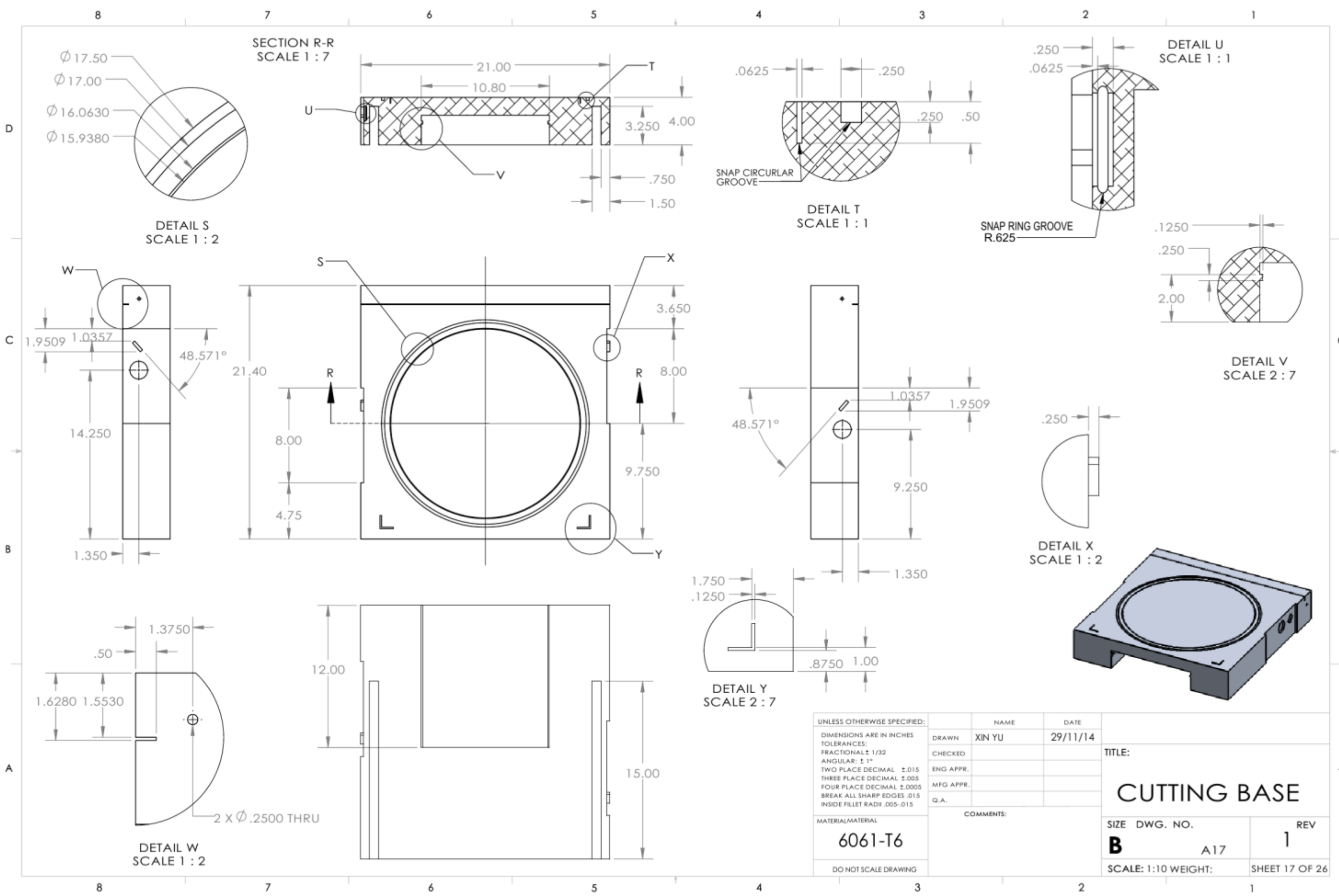


Figure 110 – Cutting Base Drawing

Figure 111 is the manufacturing engineering drawing for the Rubber Ring.

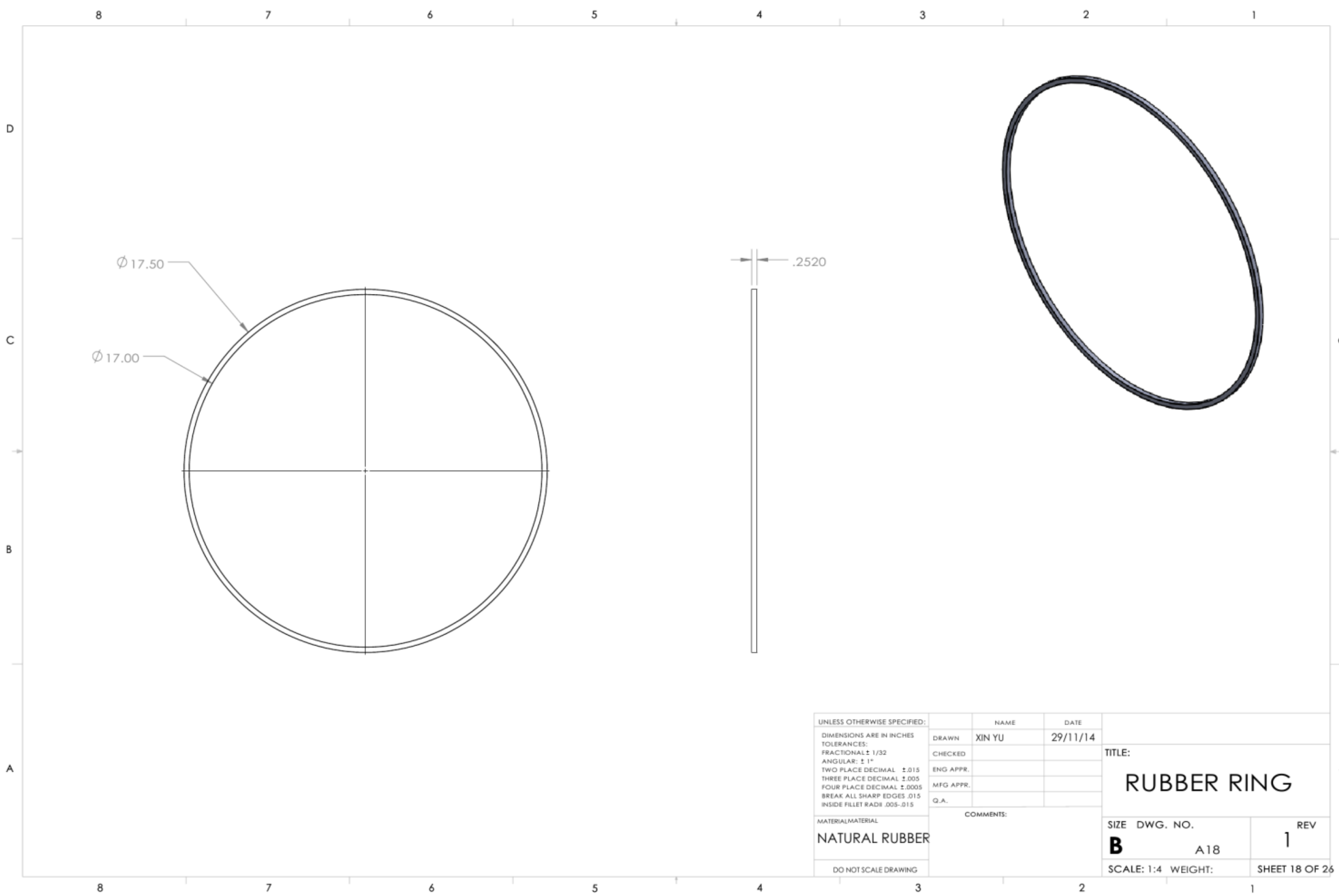


Figure 111 – Rubber Ring Drawing

Figure 112 is the manufacturing engineering drawing for both Button A and Fastener A.

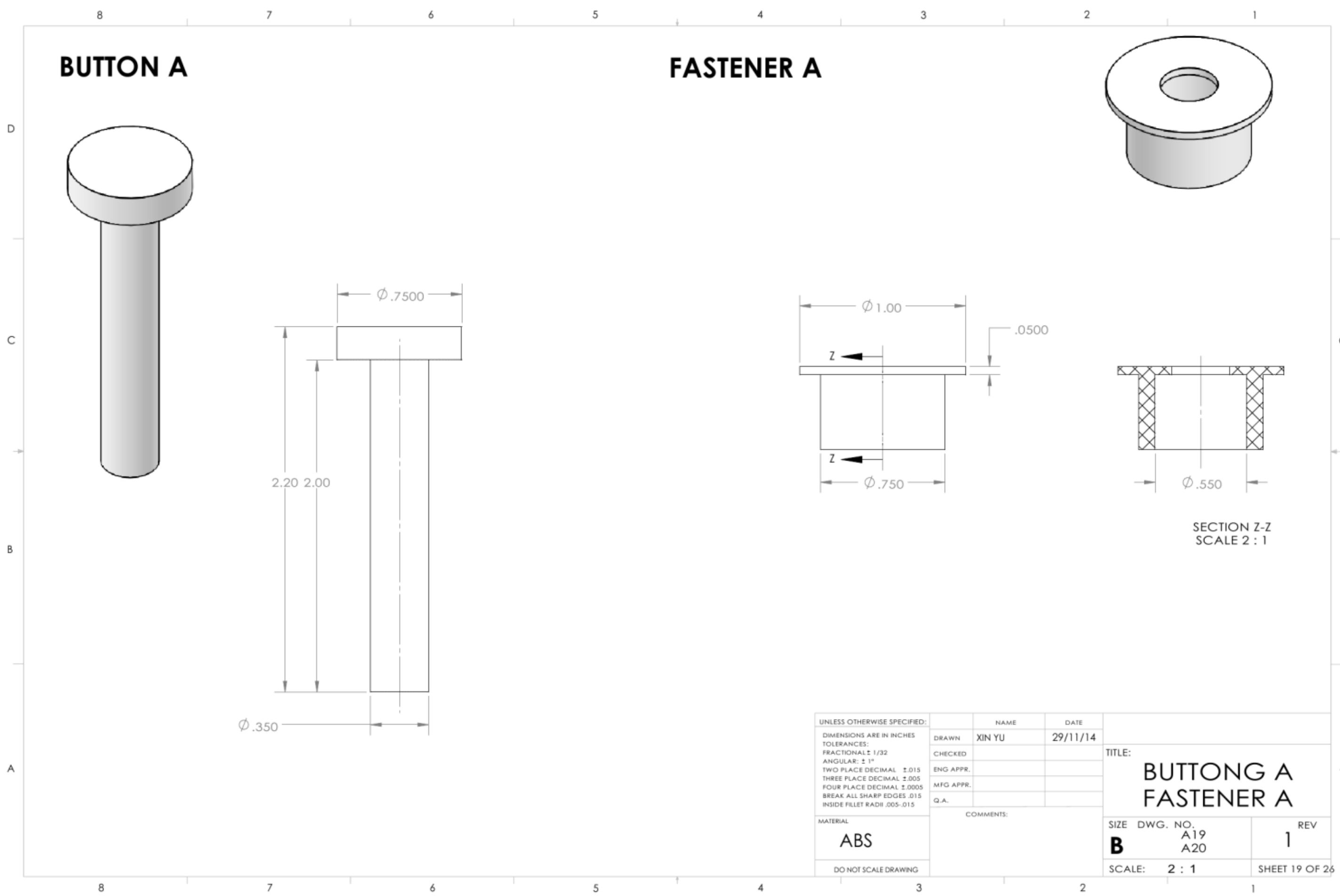


Figure 112 – Button A and Fastener A Drawing

Figure 113 is the manufacturing engineering drawing for the Inner Stick A.

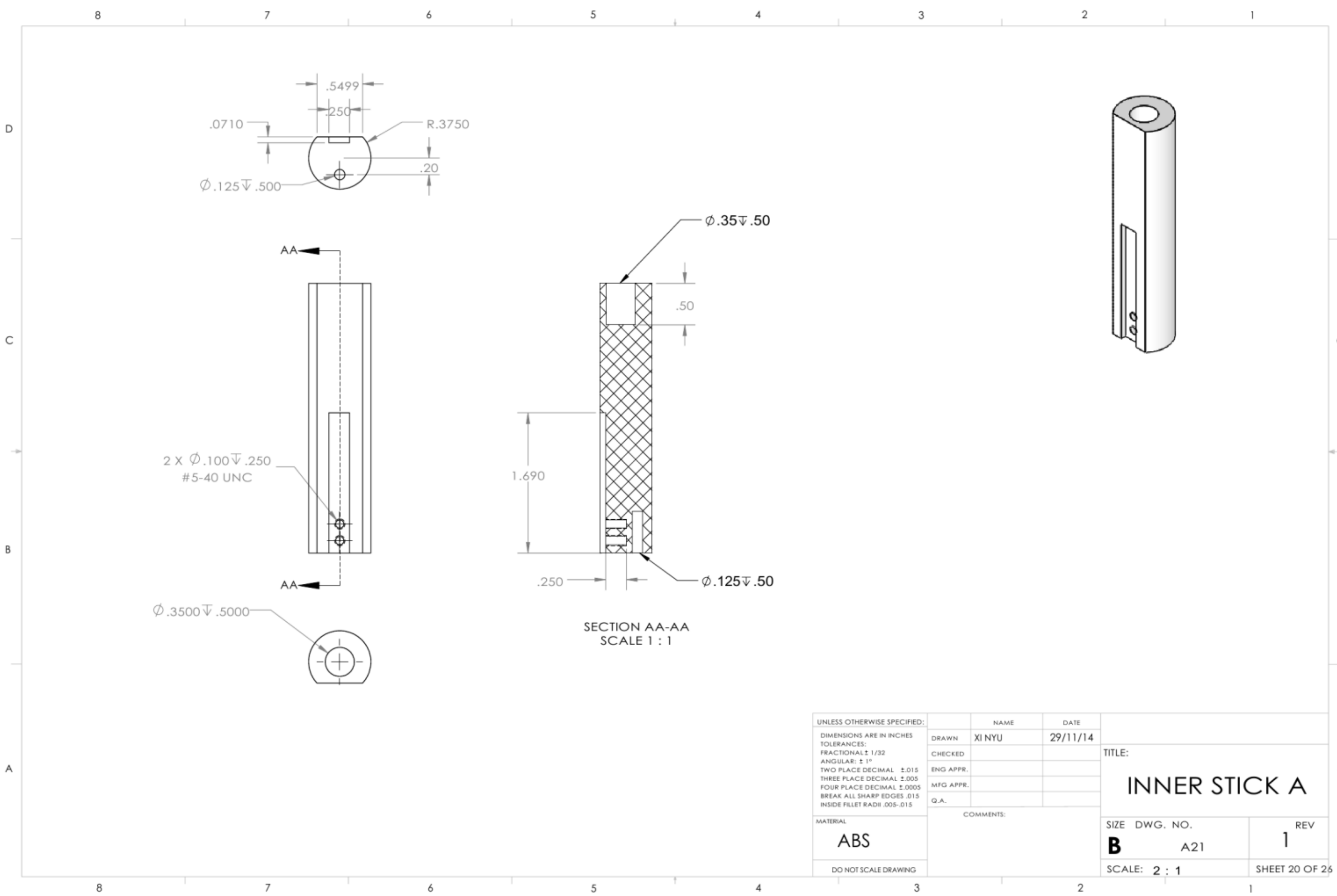


Figure 113 – Inner Stick A

Figure 114 is the manufacturing engineering drawing for the Shell A.

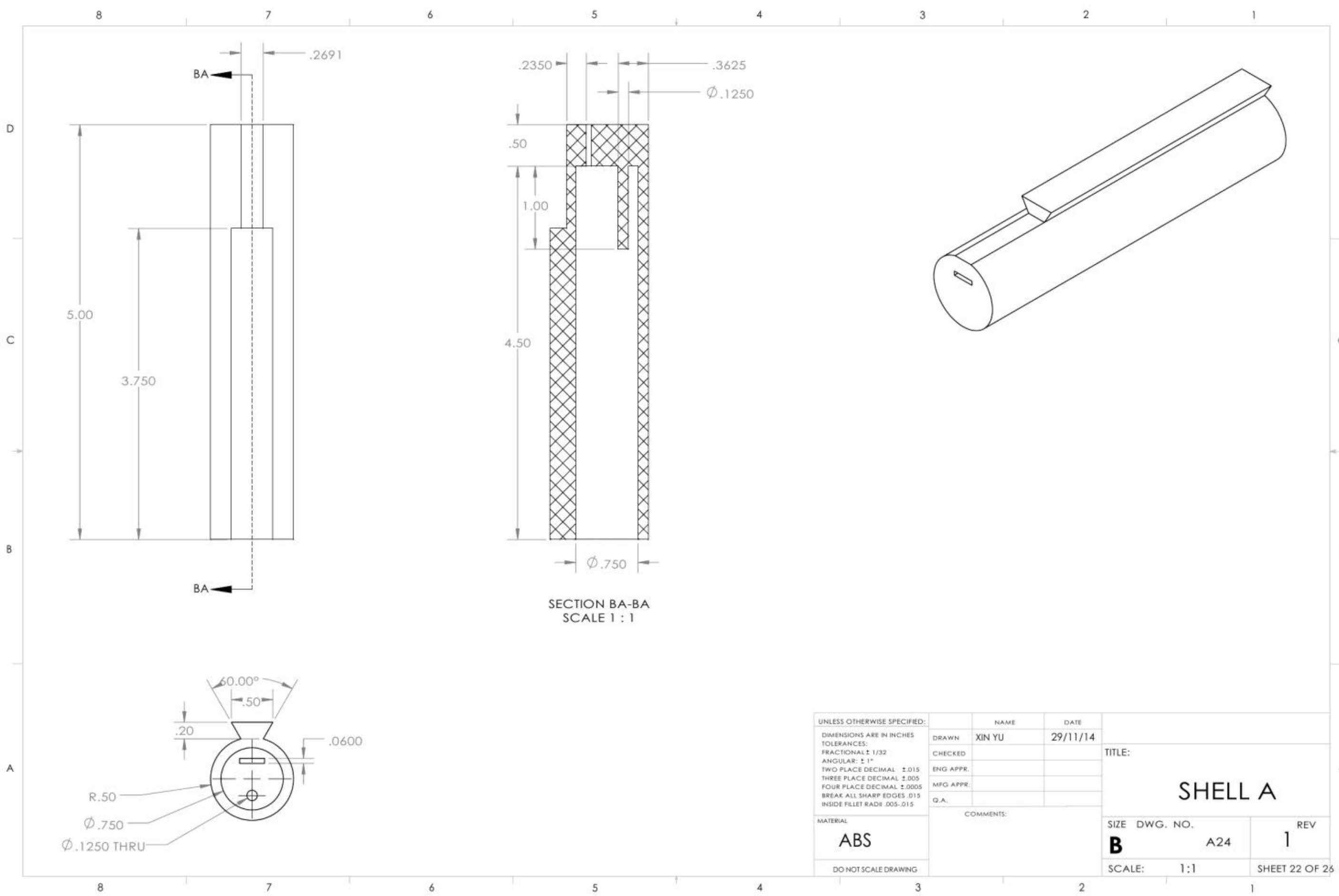


Figure 114 – Shell A Drawing

Figure 115 is the manufacturing engineering drawing for both the Button B and the Fastener B.

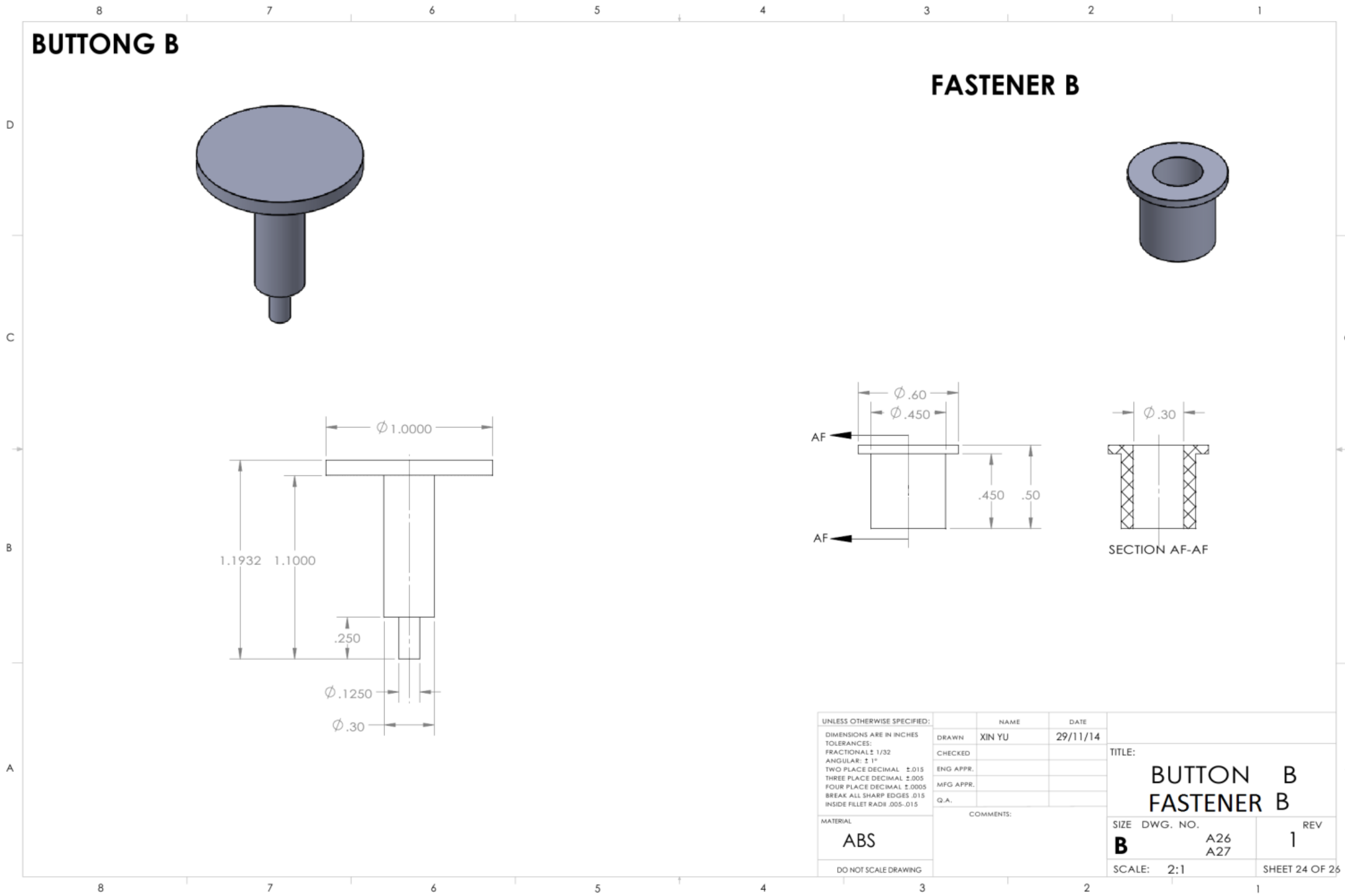


Figure 115 – Button B and Fastener B Drawing

Figure 116 is the manufacturing engineering drawing for the Inner Stick B.

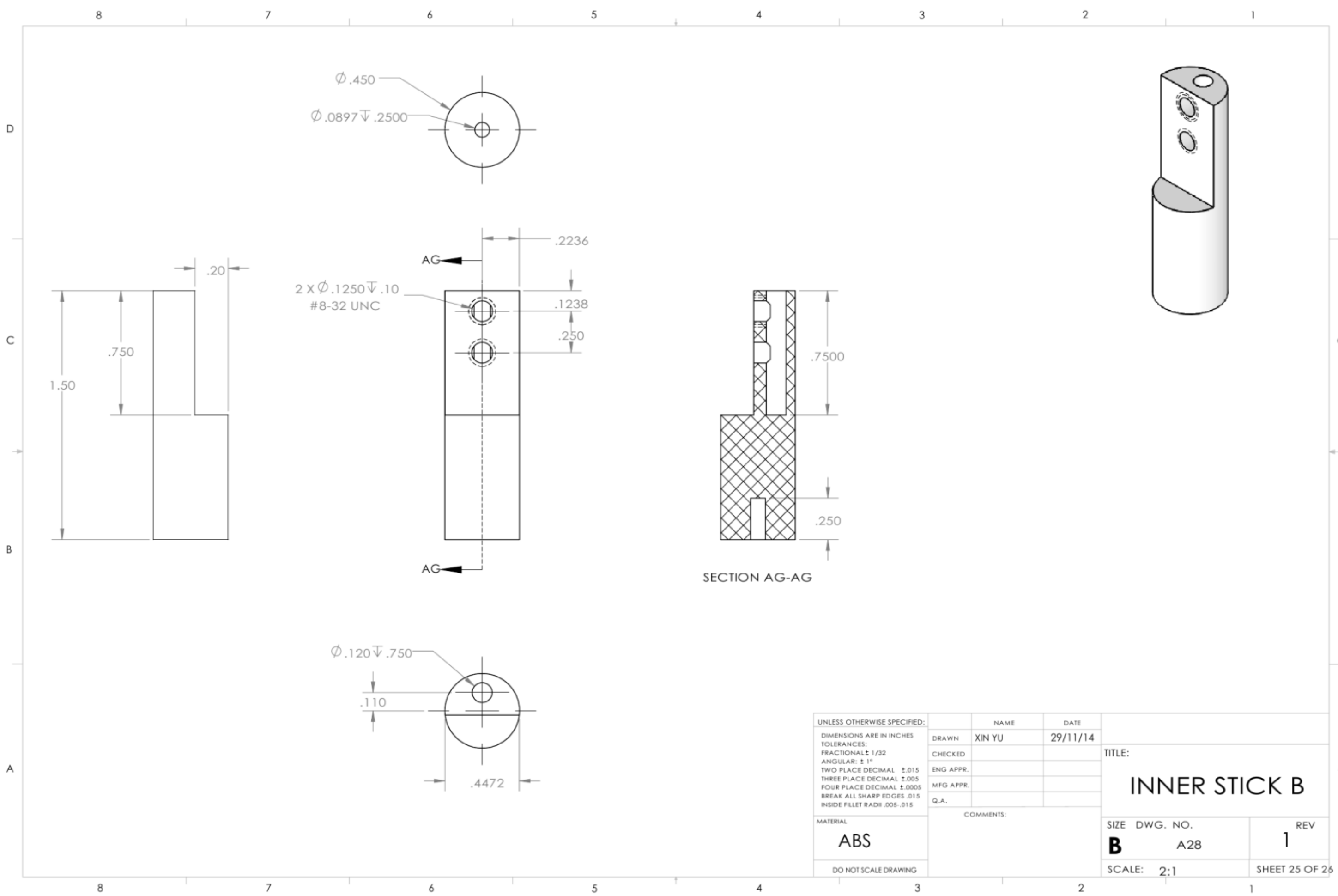


Figure 116 – Inner Stick B Drawing

Figure 117 is the manufacturing engineering drawing for Shell B.

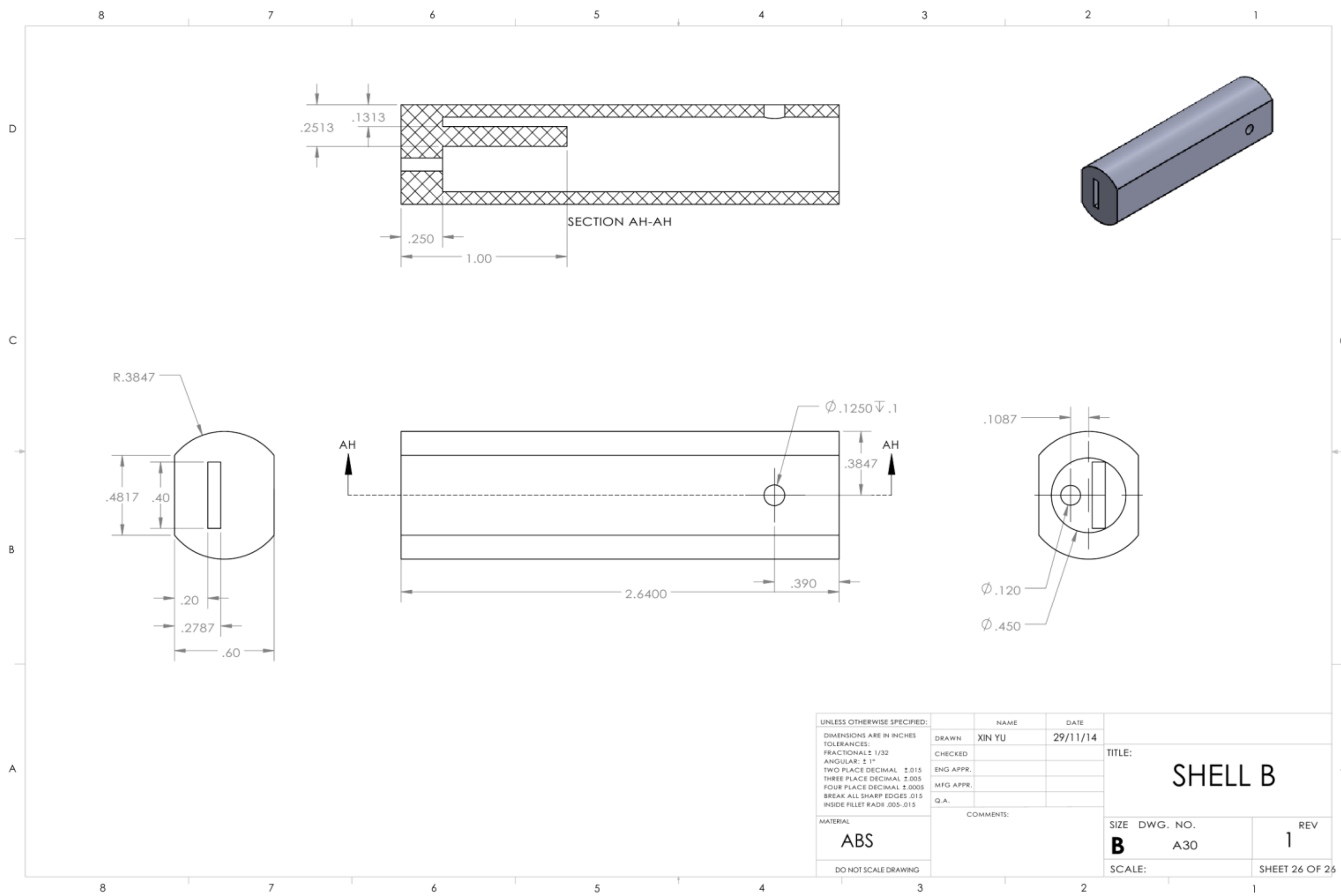


Figure 117 – Shell B Drawing

E.3. Hole Punch

Figure 118 is the manufacturing engineering drawing for the Hole Punch Machine.

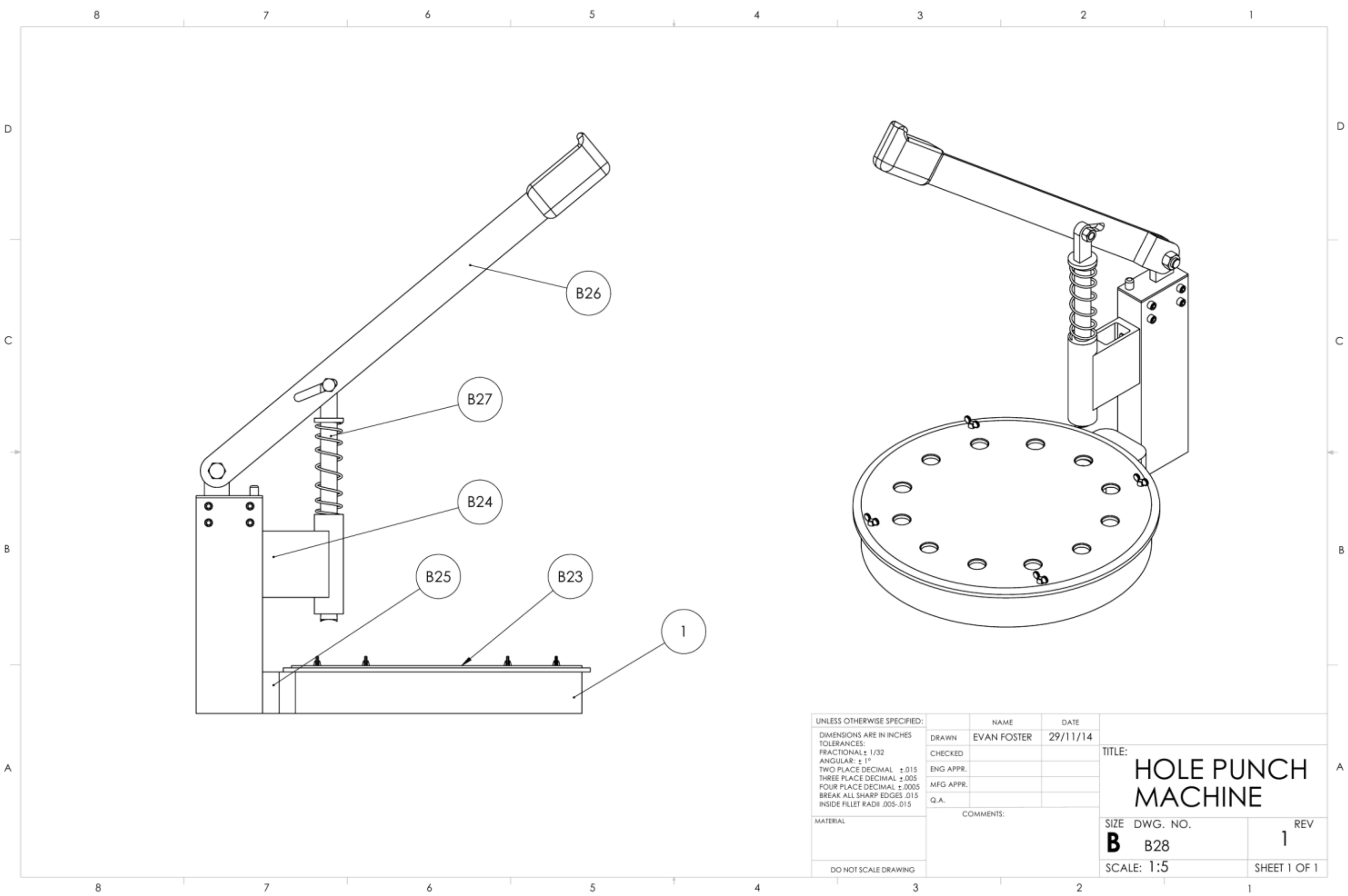


Figure 118 – Hole Punch Machine Drawing

Figure 119 is the manufacturing engineering drawing for the Disk Assembly.

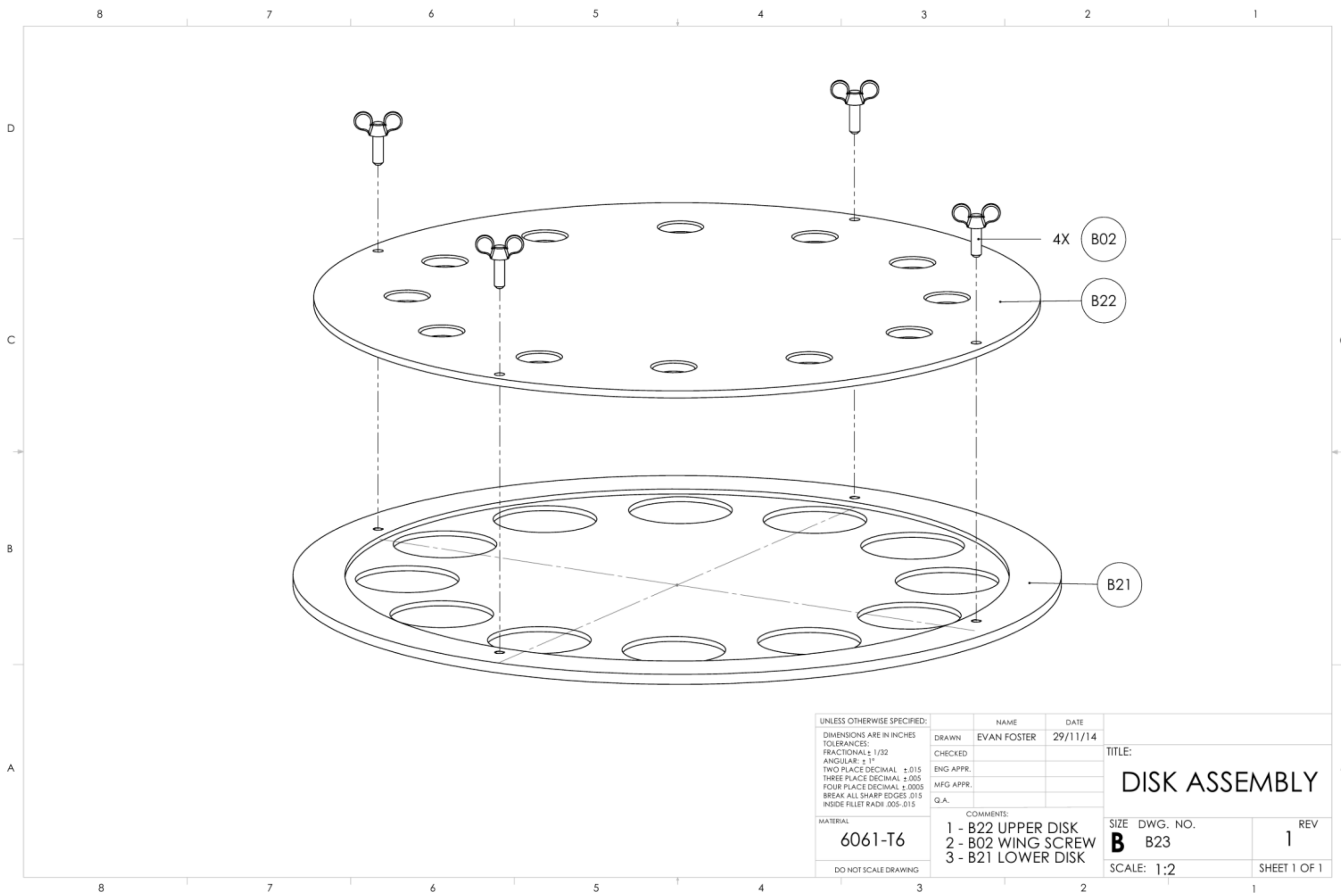


Figure 119 – Disk Assembly Drawing

Figure 120 is the manufacturing engineering drawing for the Upright Assembly.

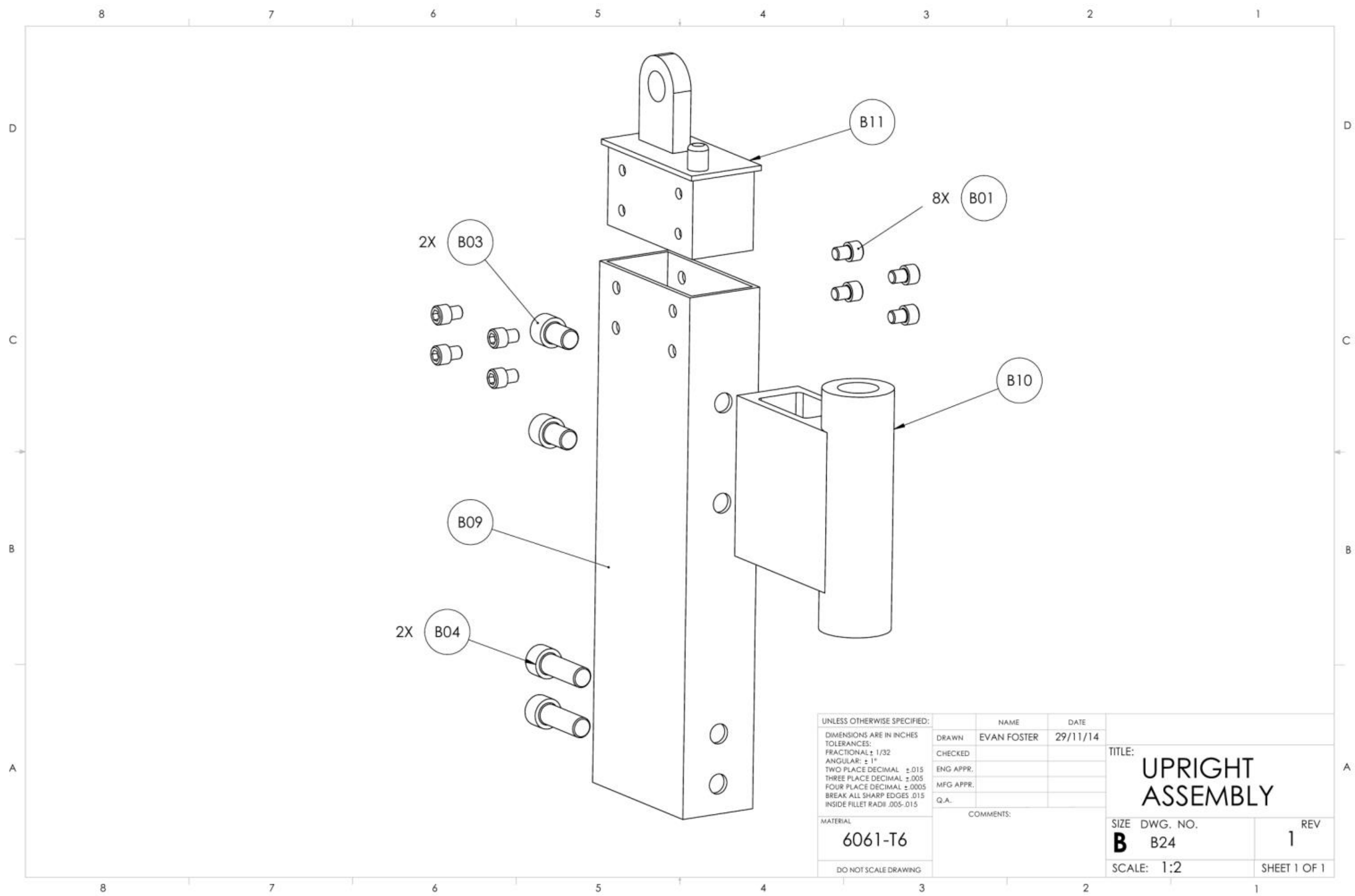


Figure 120 – Upright Assembly Drawing

Figure 121 is the manufacturing engineering drawing for the Base Assembly.

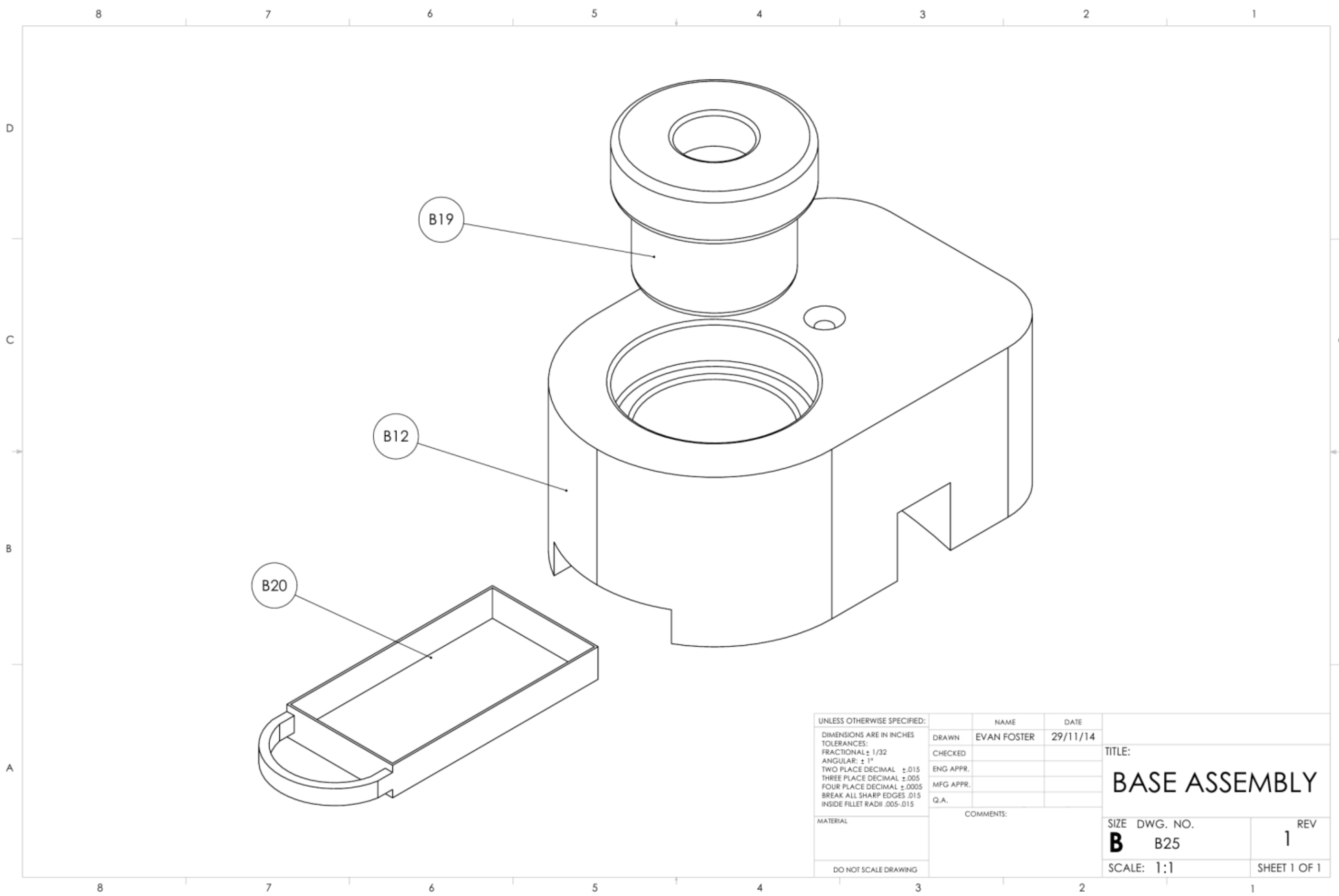


Figure 121 – Base Assembly Drawing

Figure 122 is the manufacturing engineering drawing for the Lever Arm Assembly.

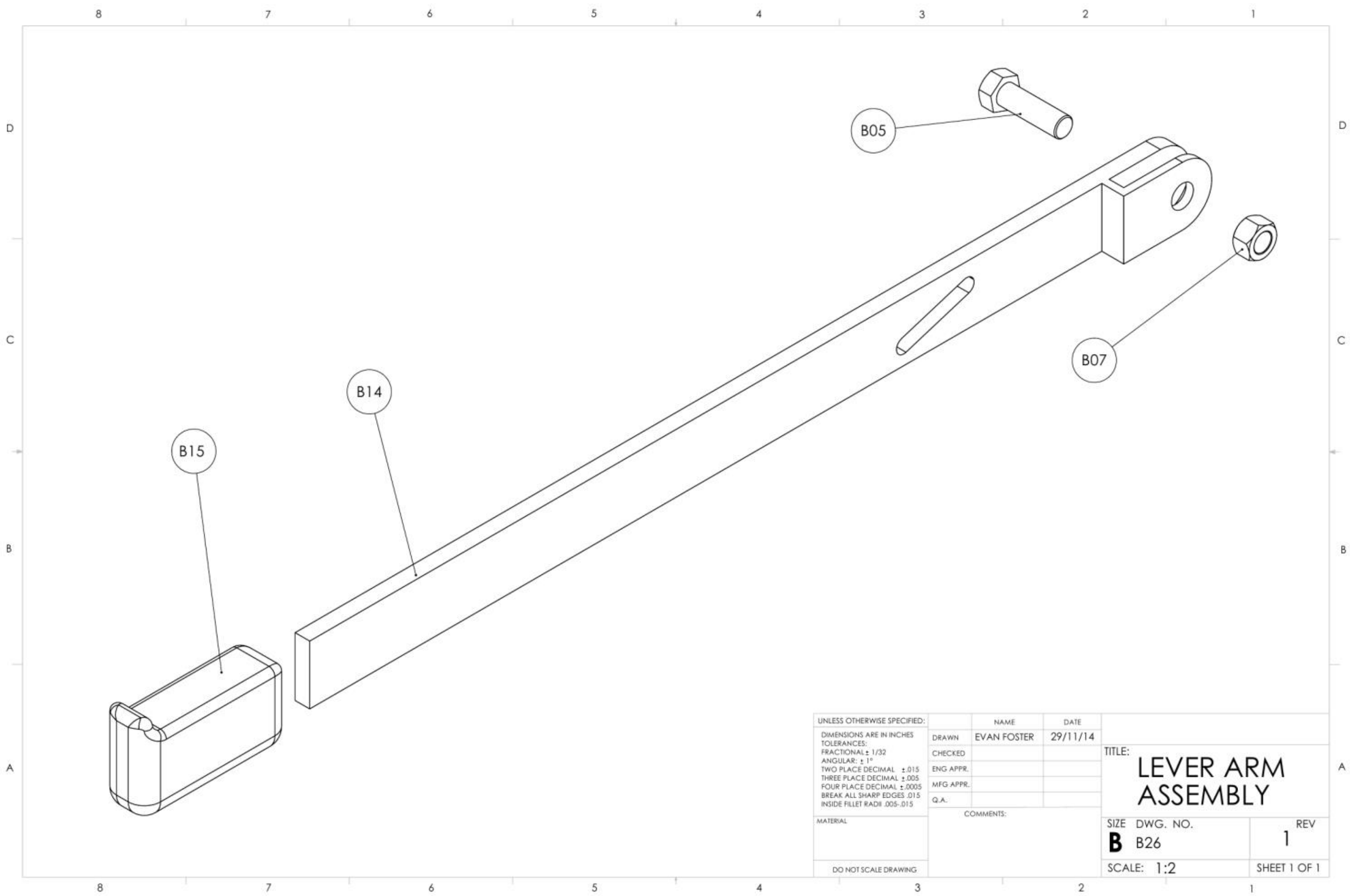


Figure 122 – Lever Arm Assembly Drawing

Figure 123 is the manufacturing engineering drawing for the Punch Assembly.

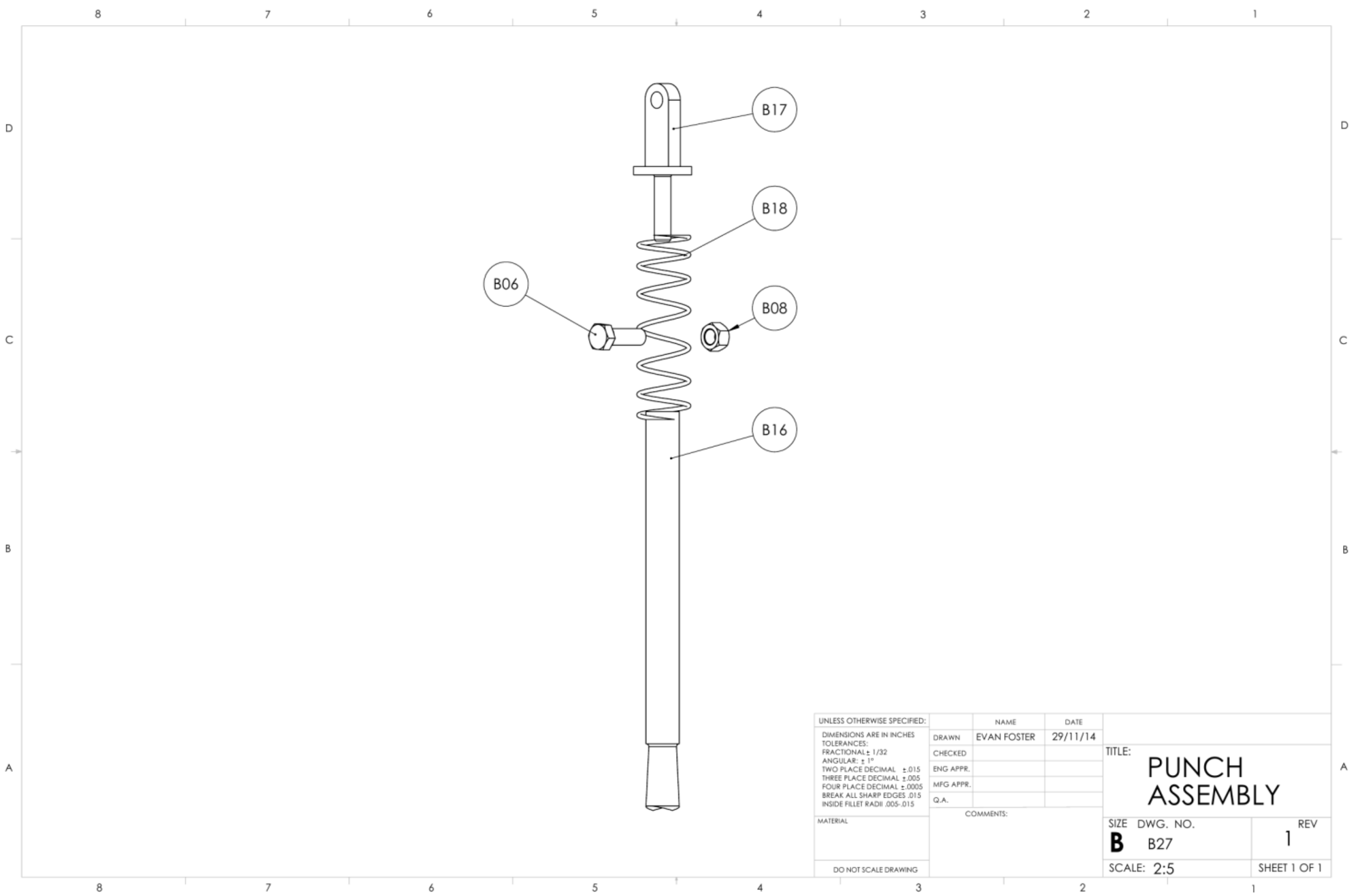


Figure 123 – Punch Assembly Drawing

Figure 124 is the manufacturing engineering drawing for the Upright.

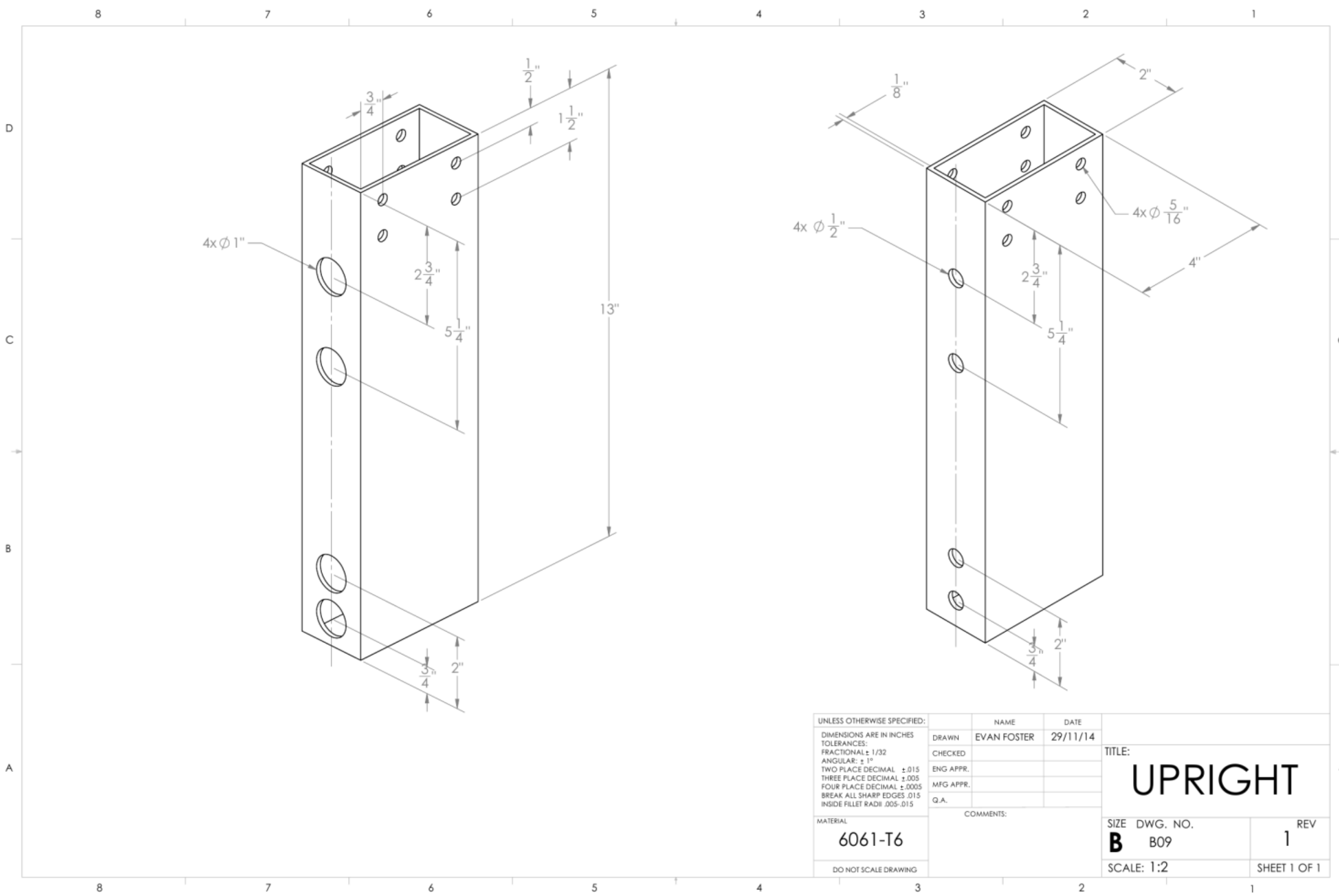


Figure 124 – Upright Drawing

Figure 125 is the manufacturing engineering drawing for the Neck.

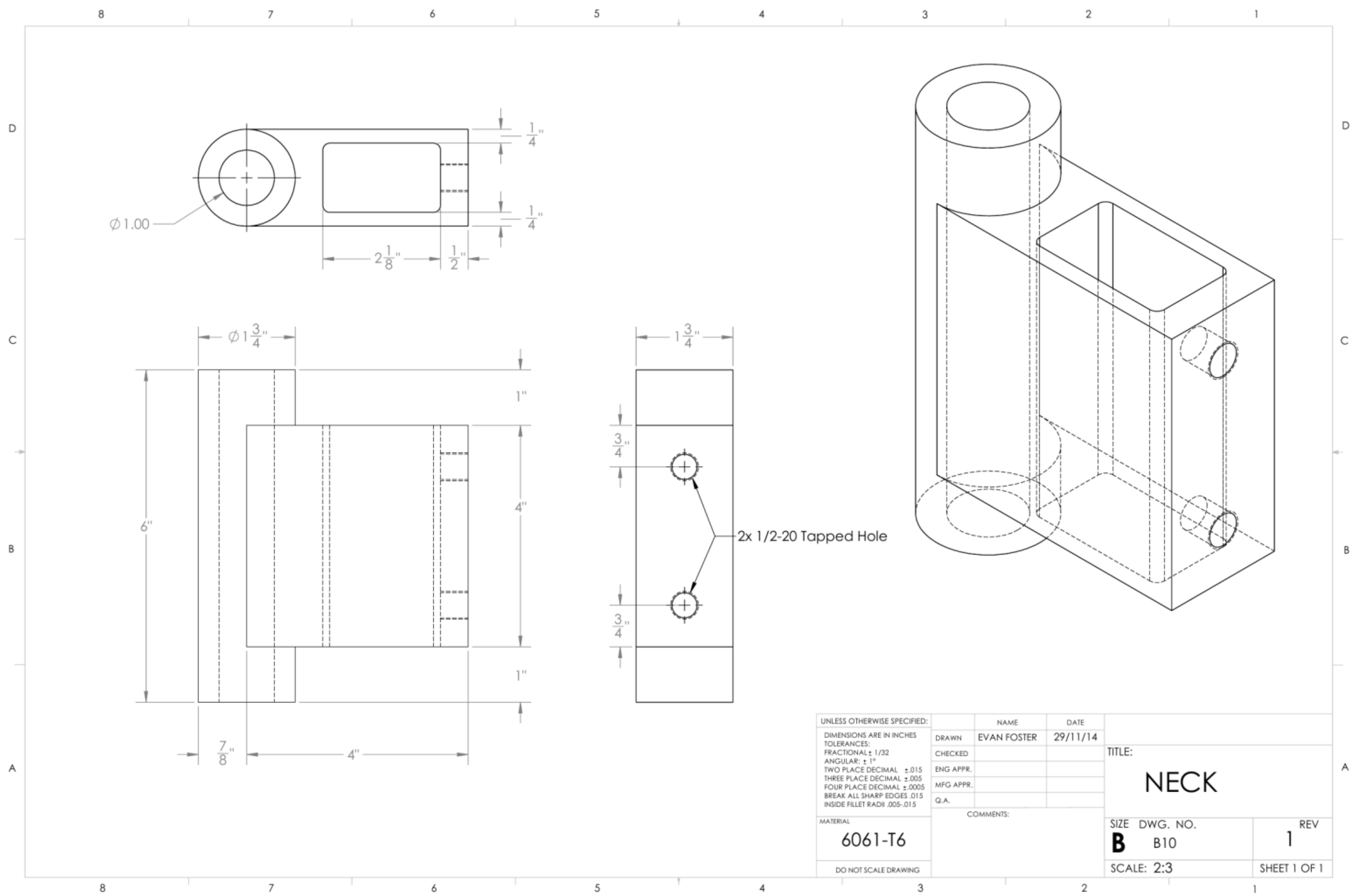


Figure 125 – Neck Drawing

Figure 126 is the manufacturing engineering drawing for the Top Pivot.

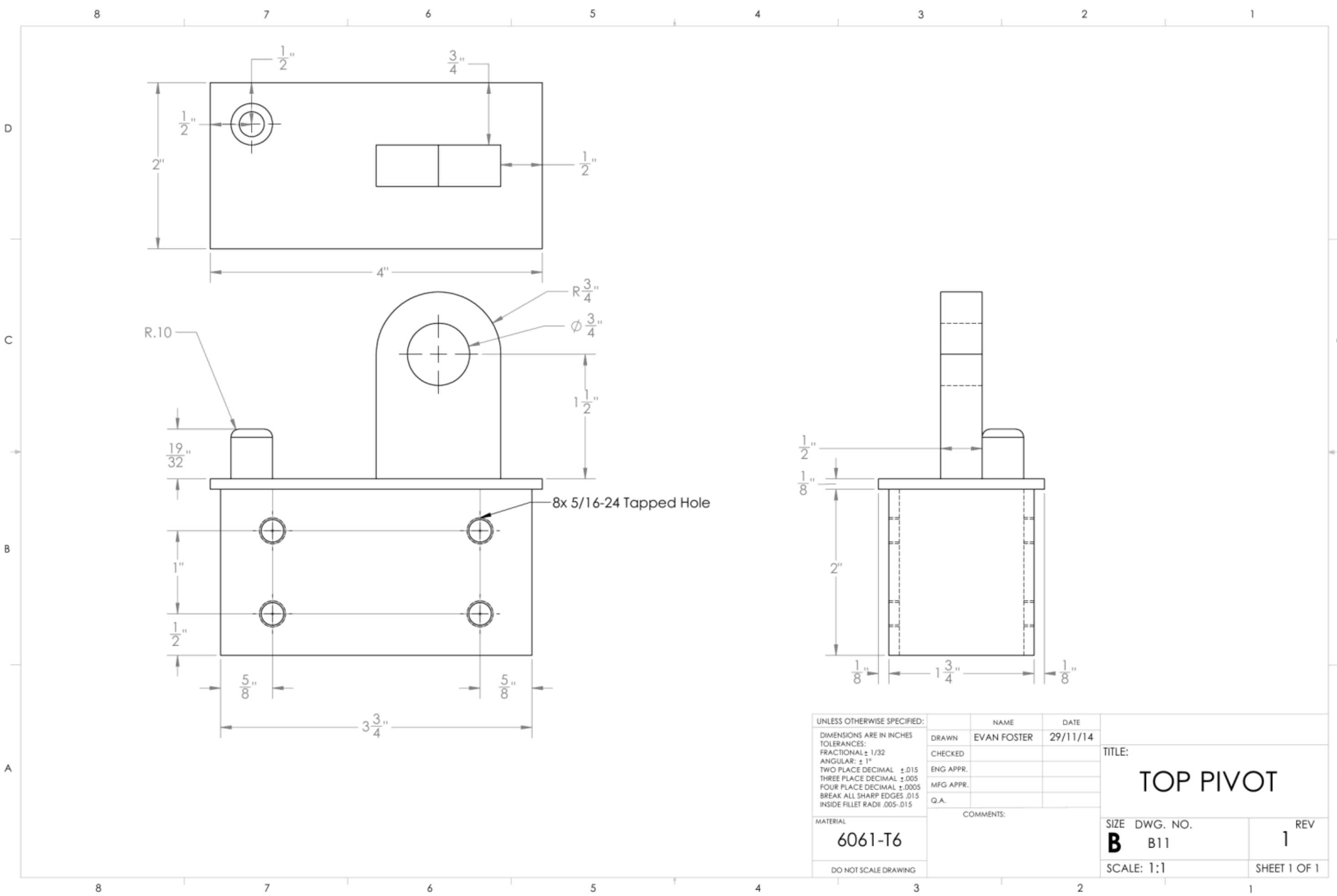


Figure 126 – Top Pivot Drawing

Figure 127 is the manufacturing engineering drawing for the Die Base.

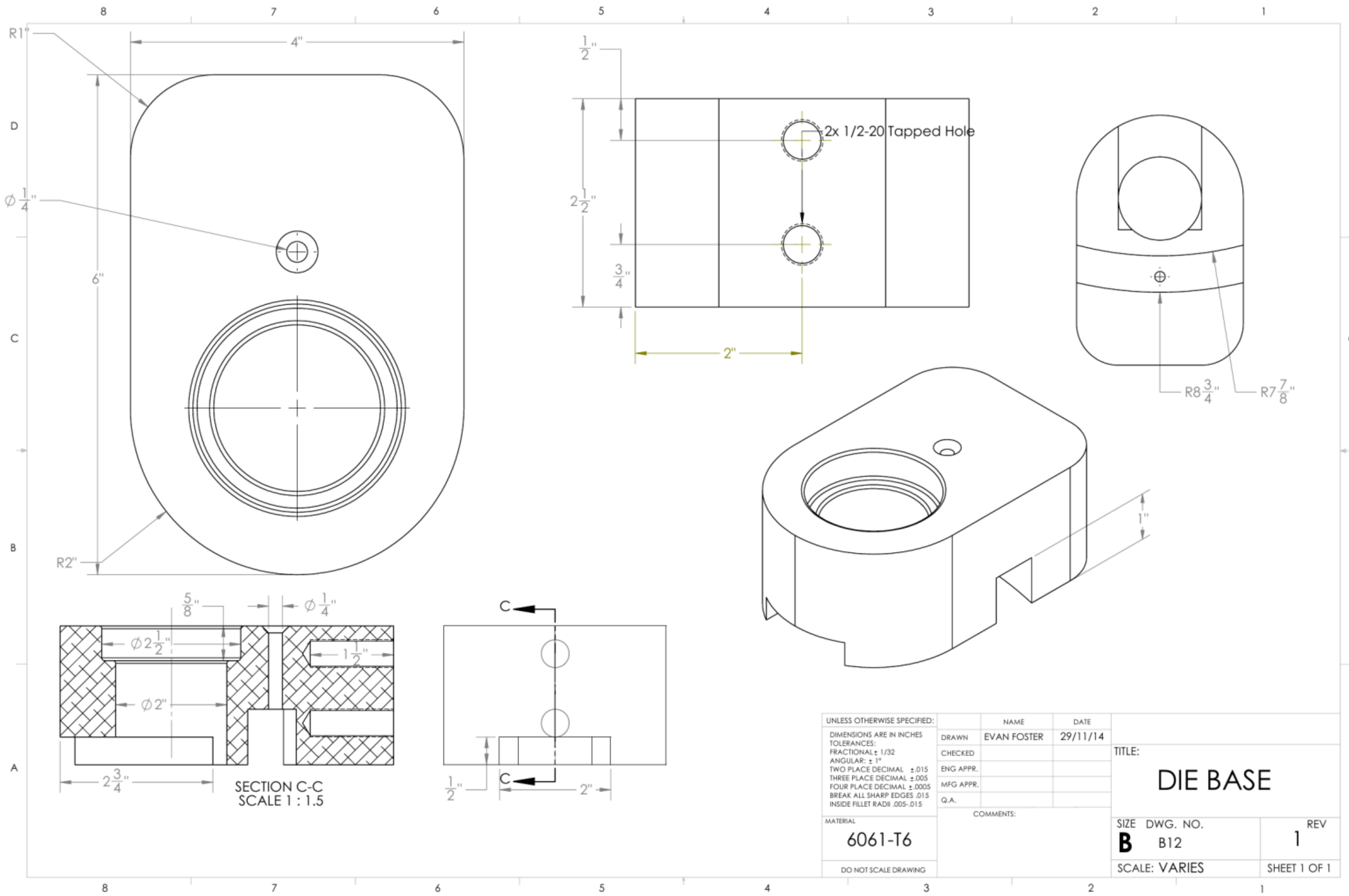


Figure 127 – Die Base Drawing

Figure 128 is the manufacturing engineering drawing for the Base Ring.

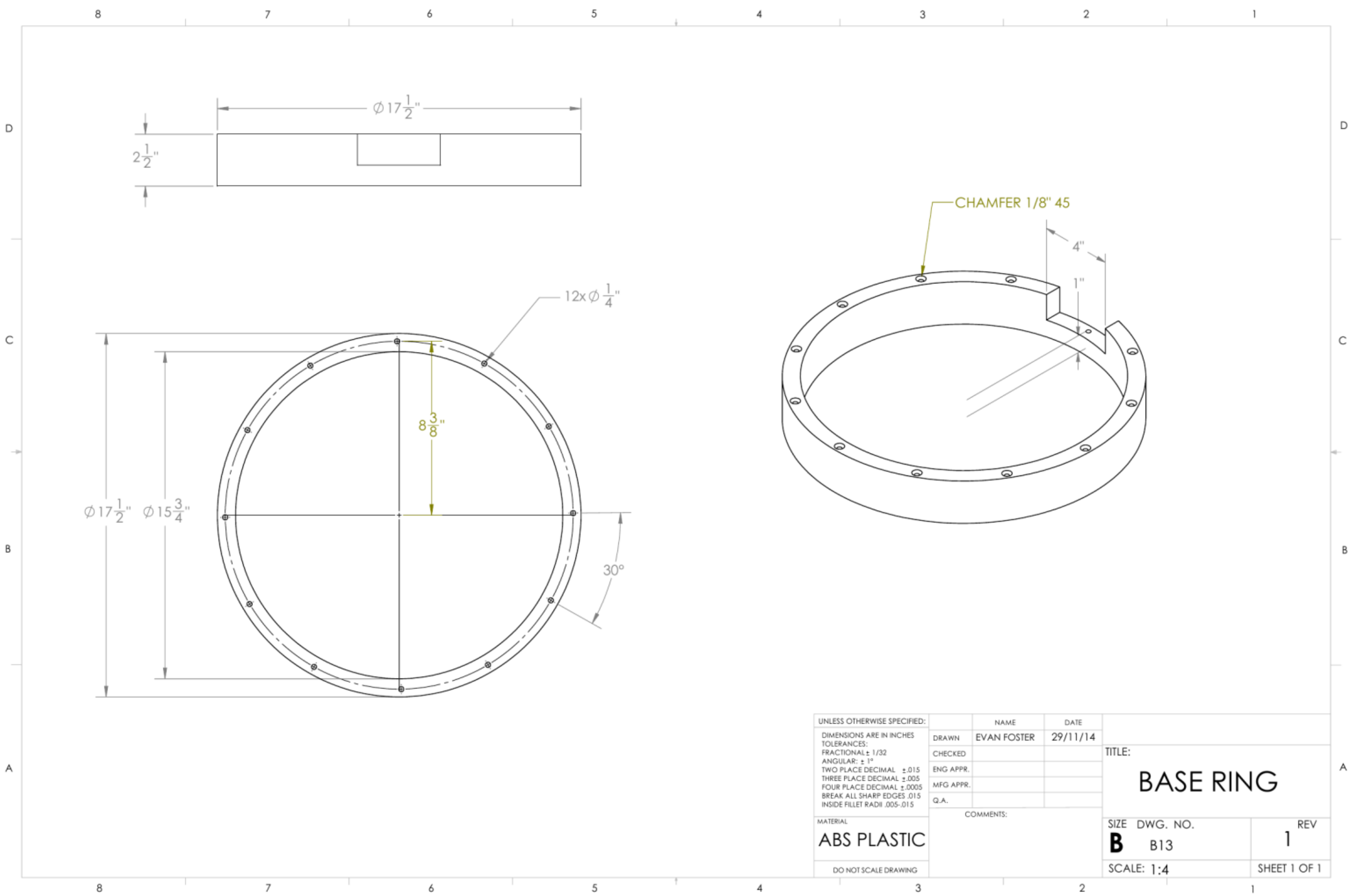


Figure 128 – Base Ring Drawing

Figure 129 is the manufacturing engineering drawing for the Lever Arm.

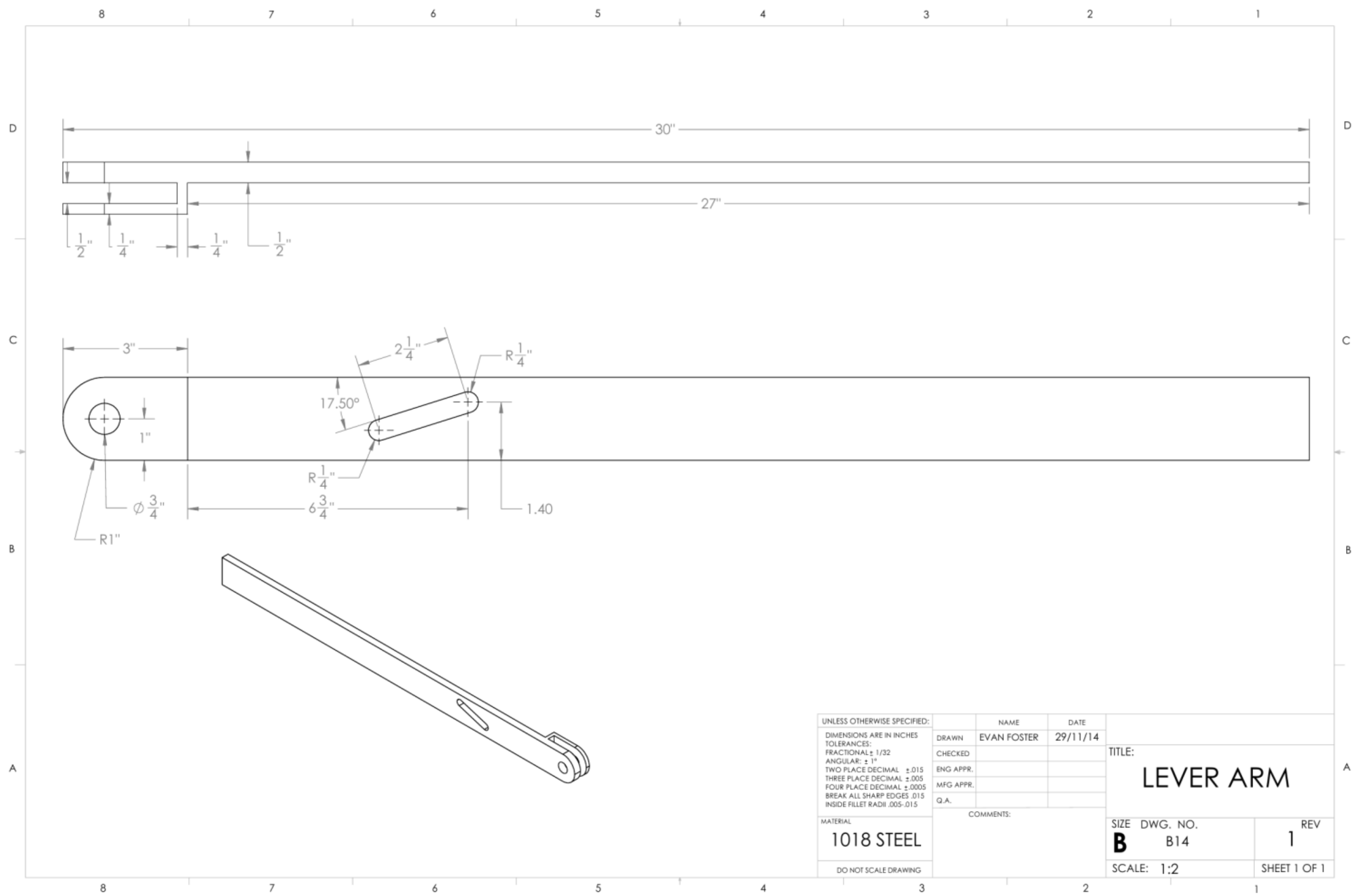


Figure 129 – Lever Arm Drawing

Figure 130 is the manufacturing engineering drawing for the Punch.

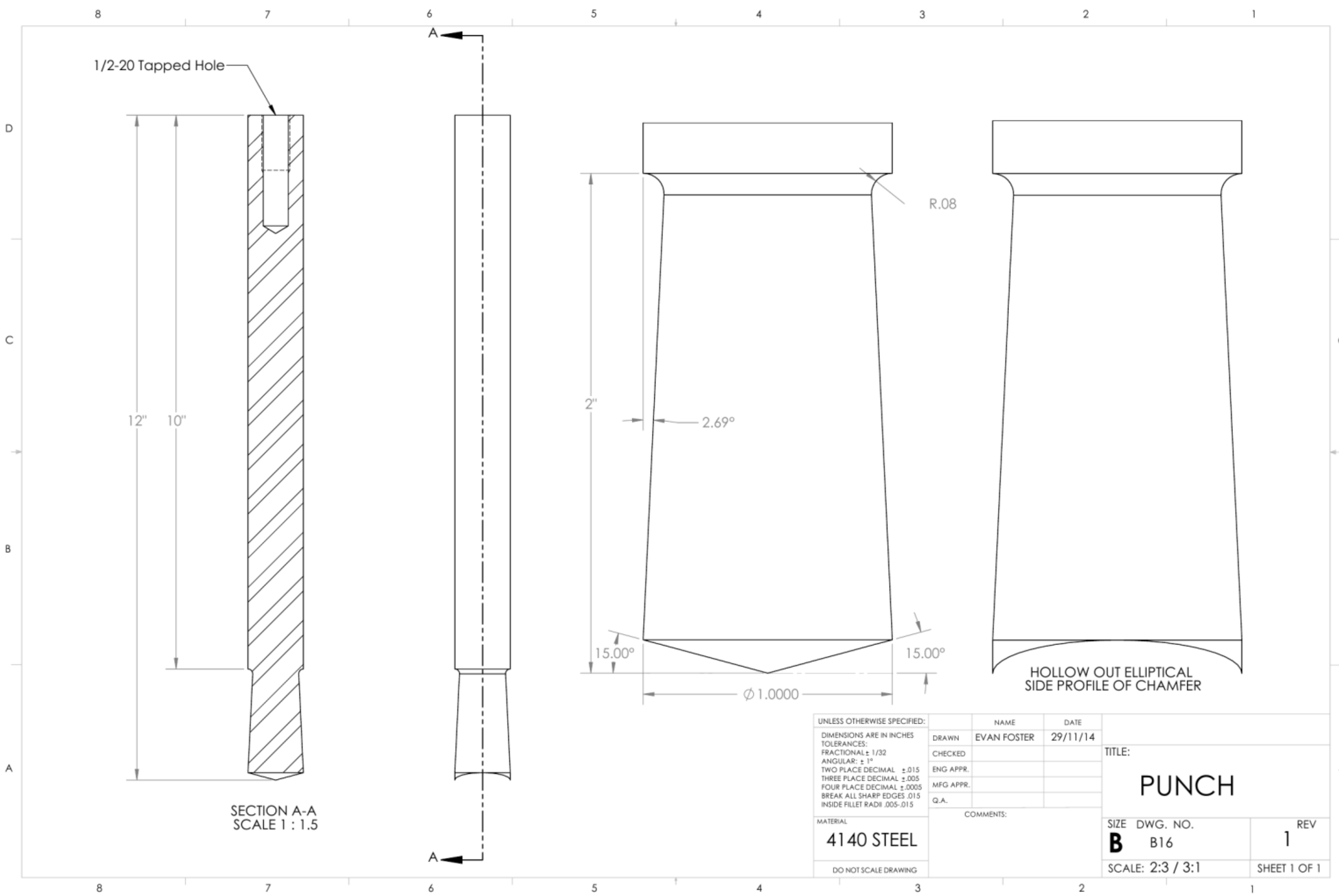


Figure 130 – Punch Drawing

Figure 131 is the manufacturing engineering drawing for the Punch Pivot.

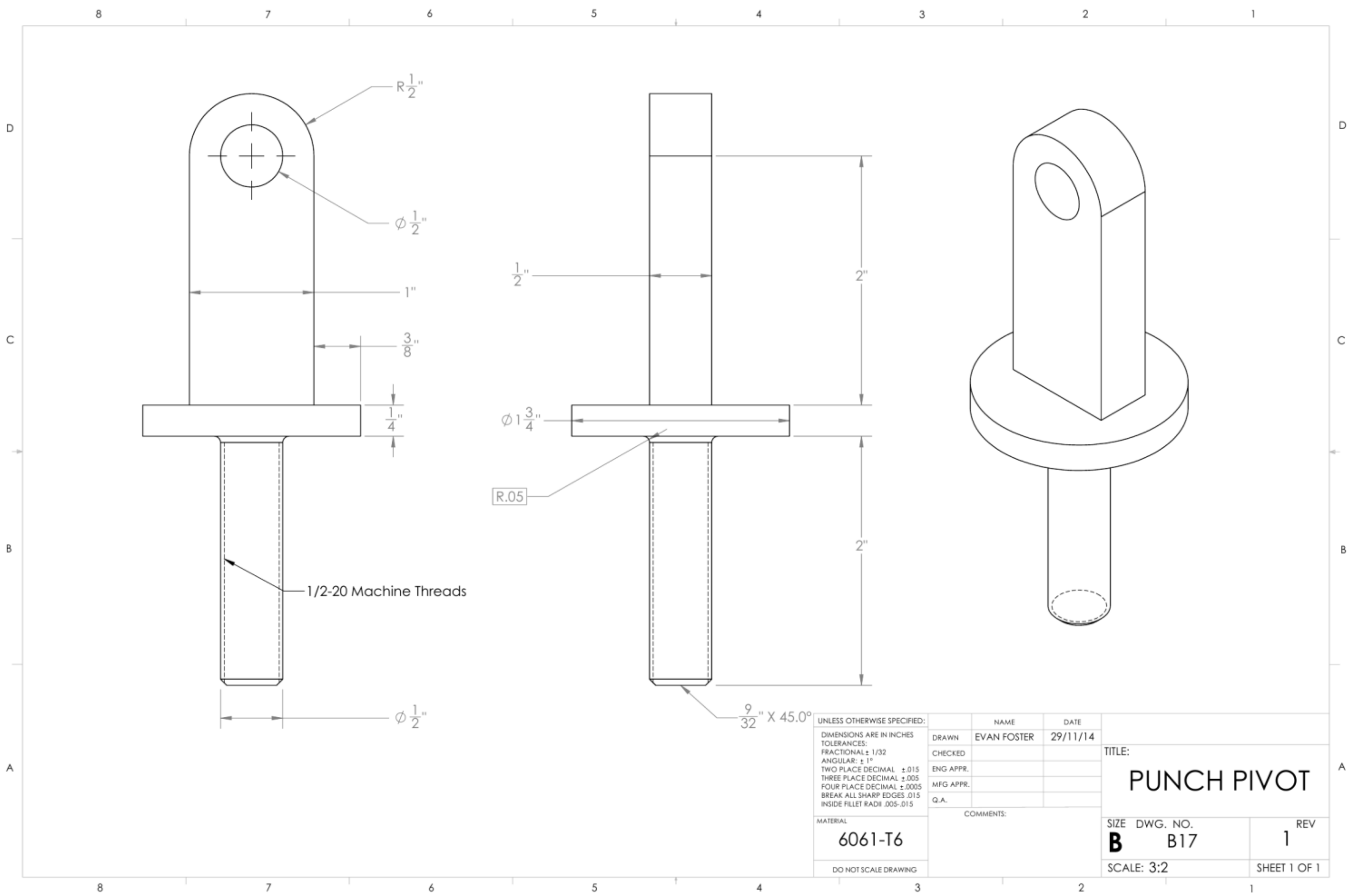


Figure 131 – Punch Pivot Drawing

Figure 132 is the manufacturing engineering drawing for the Die.

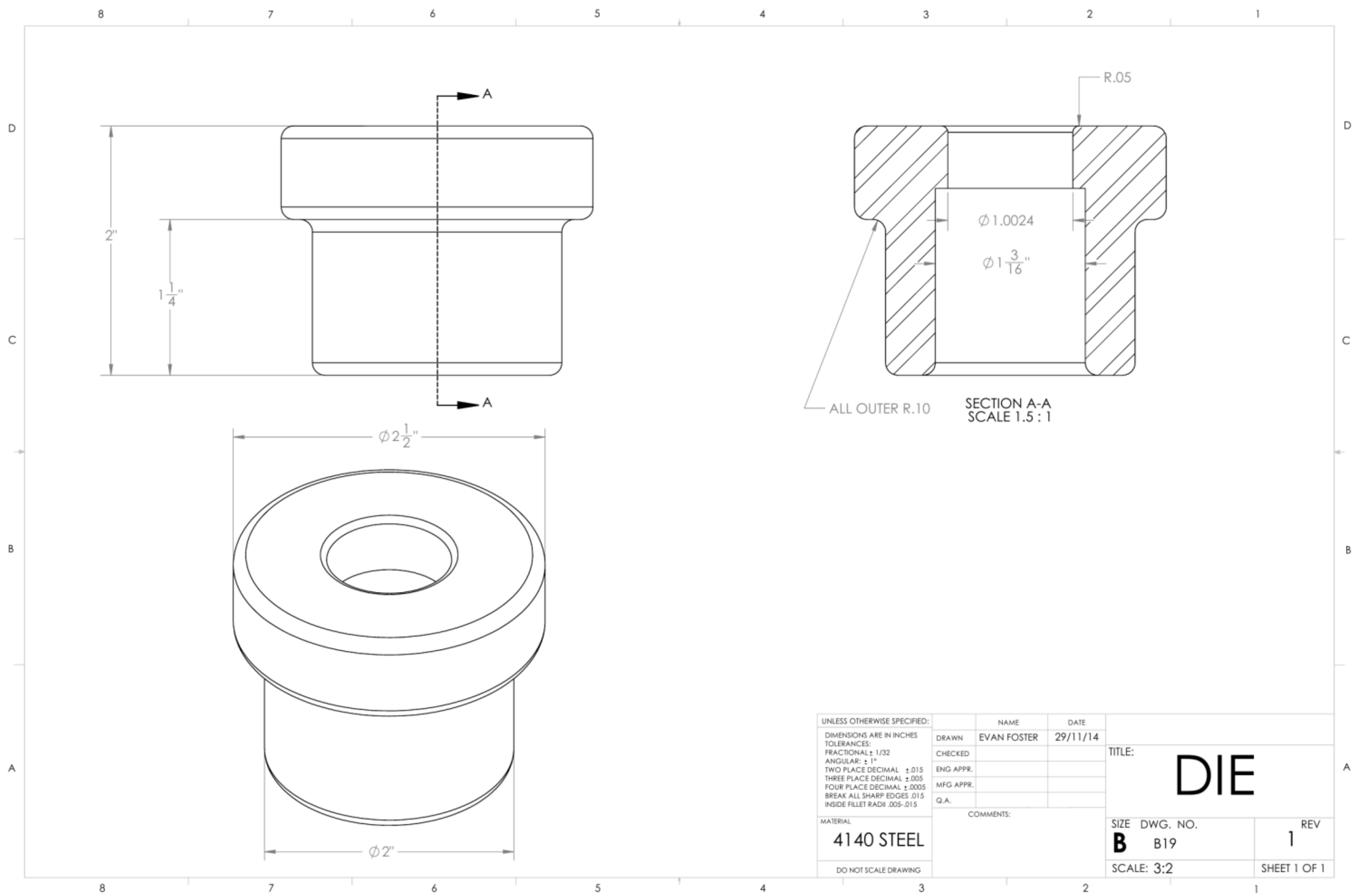


Figure 132 – Die Drawing

Figure 133 is the manufacturing engineering drawing for the Slug Drawer.

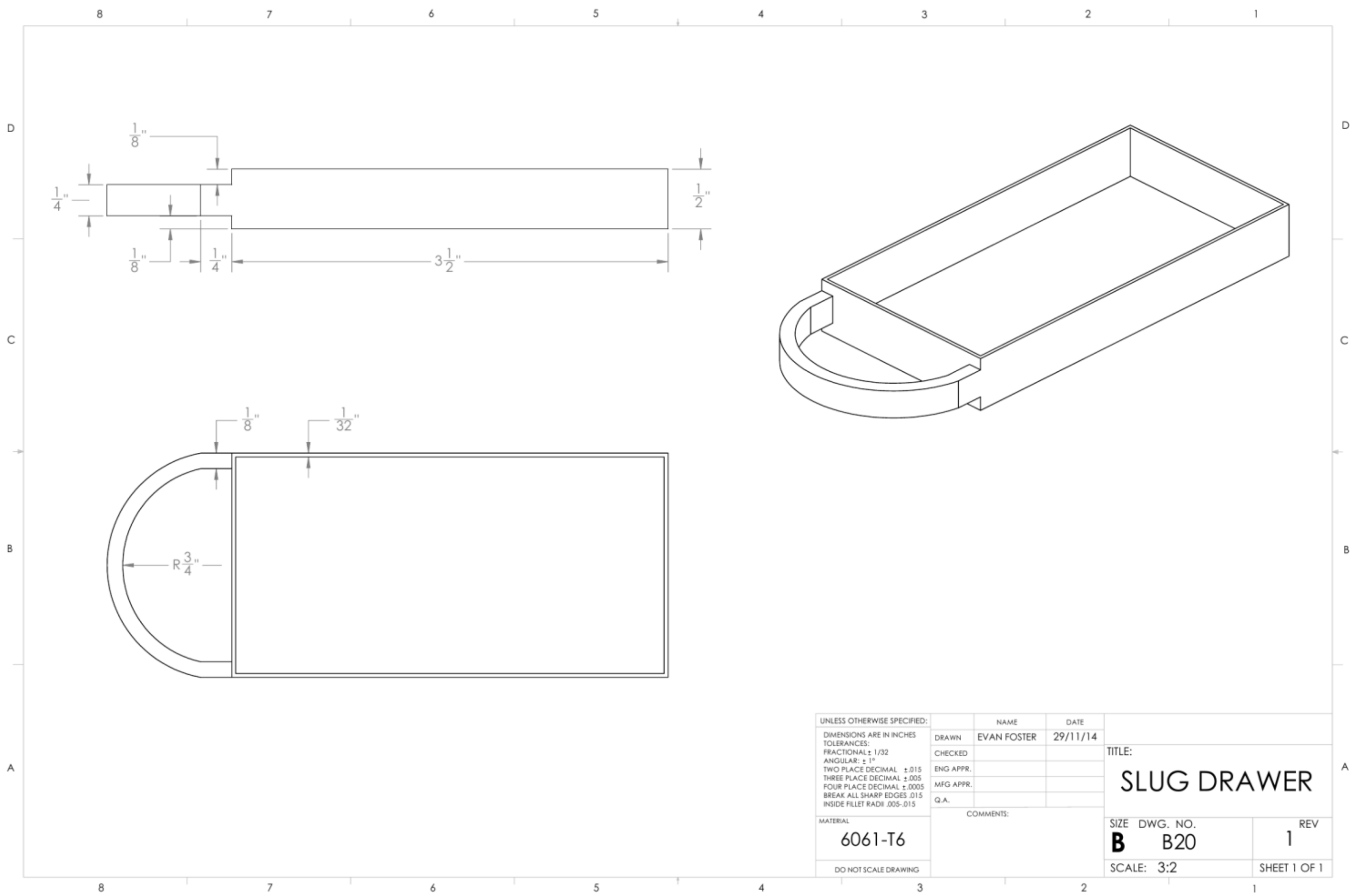


Figure 133 – Slug Drawer Drawing

Figure 134 is the manufacturing engineering drawing for the Lower Disk.

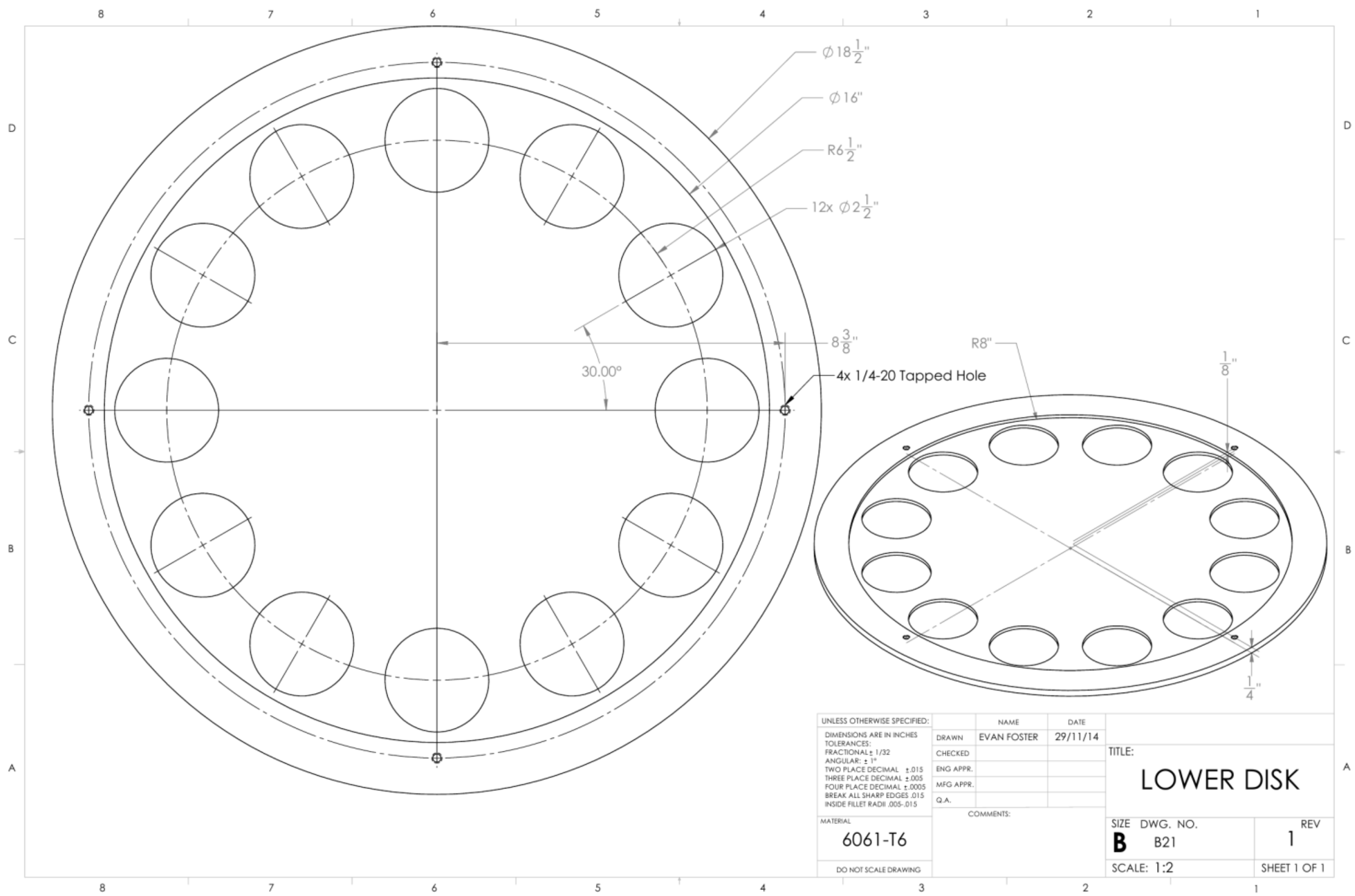


Figure 134 – Lower Disk Drawing

Figure 135 is the manufacturing engineering drawing for the Upper Disk.

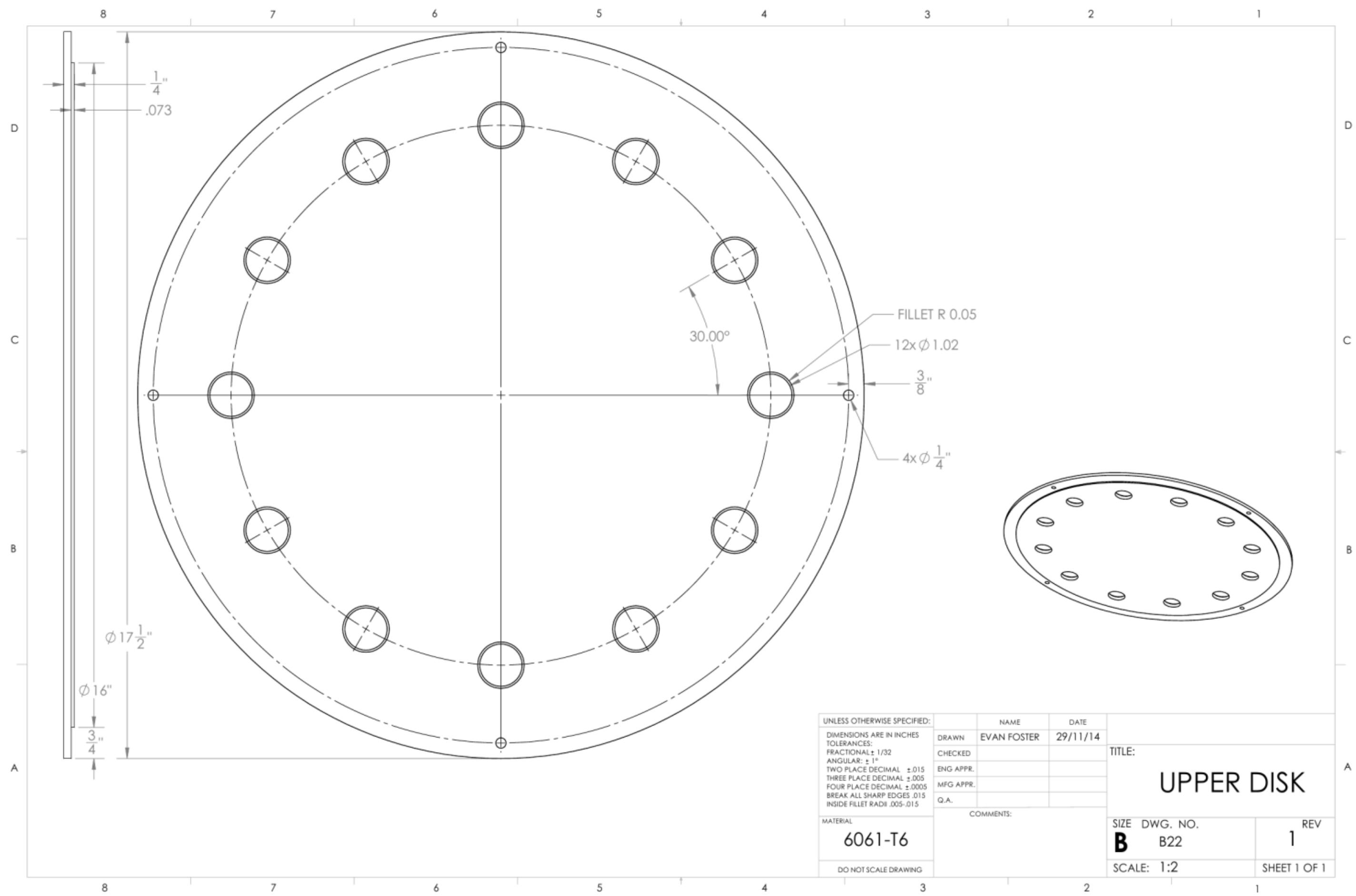


Figure 135 – Upper Disk Drawing

E.4. Wire Bending/Burst Disk Assembly

Figure 136 is the manufacturing engineering drawing for the Wire Bending/Burst Disk Assembly

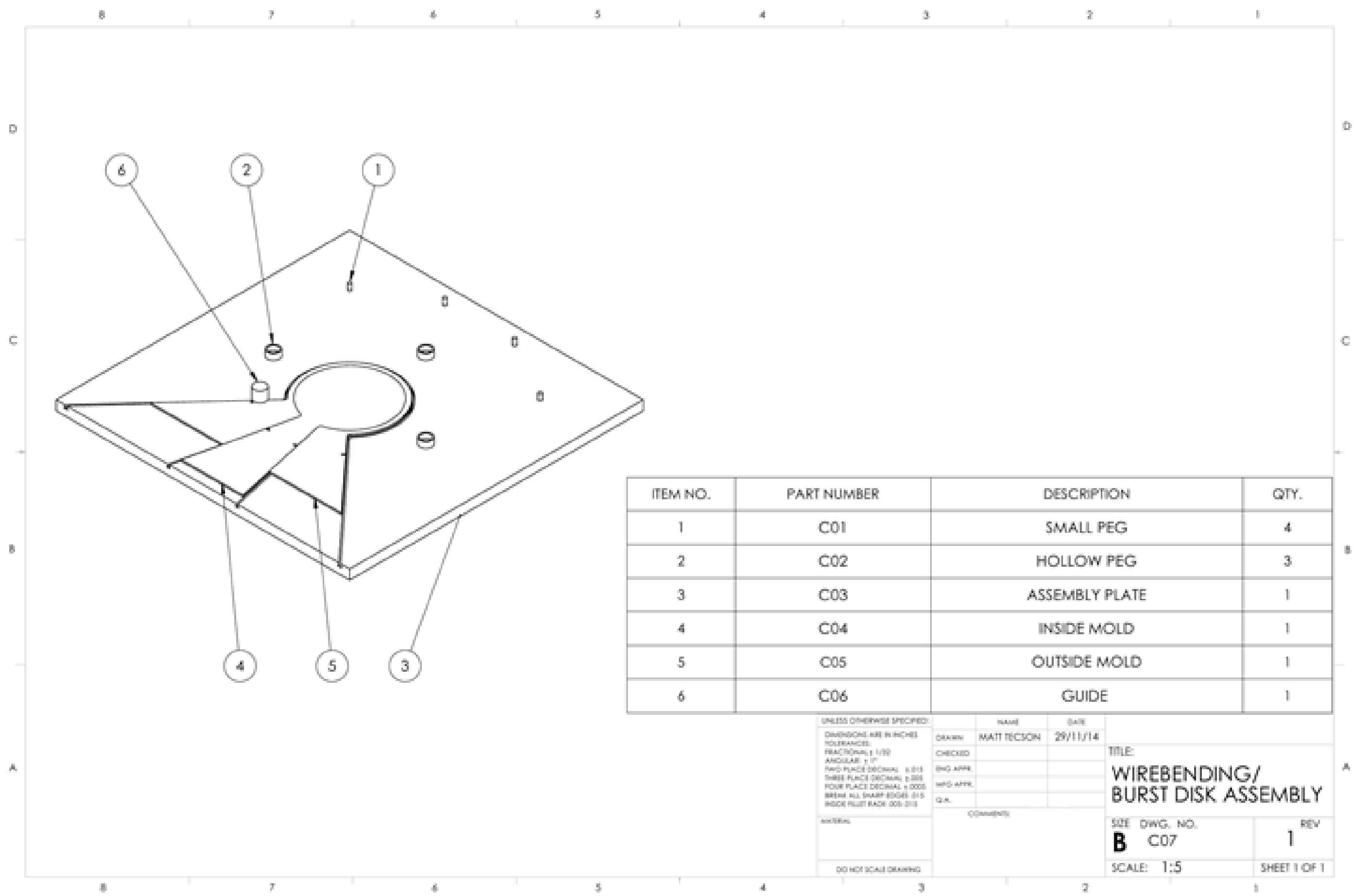


Figure 136 – Wire Bending/Burst Disk Assembly Drawing

Figure 137 is the manufacturing engineering drawing for the Small Peg.

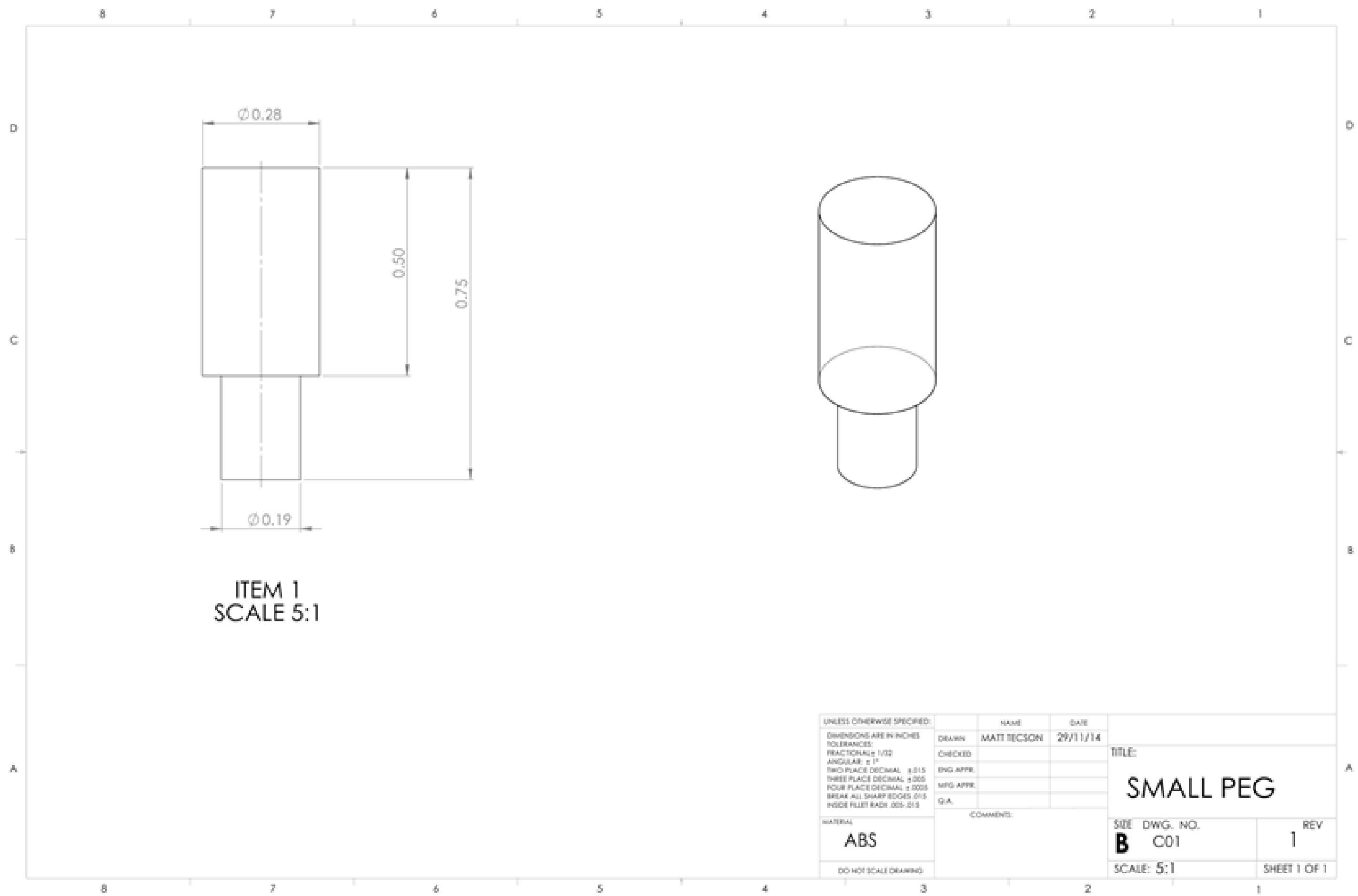


Figure 137 – Small Peg Drawing

Figure 138 is the manufacturing engineering drawing for the Hollow Peg.

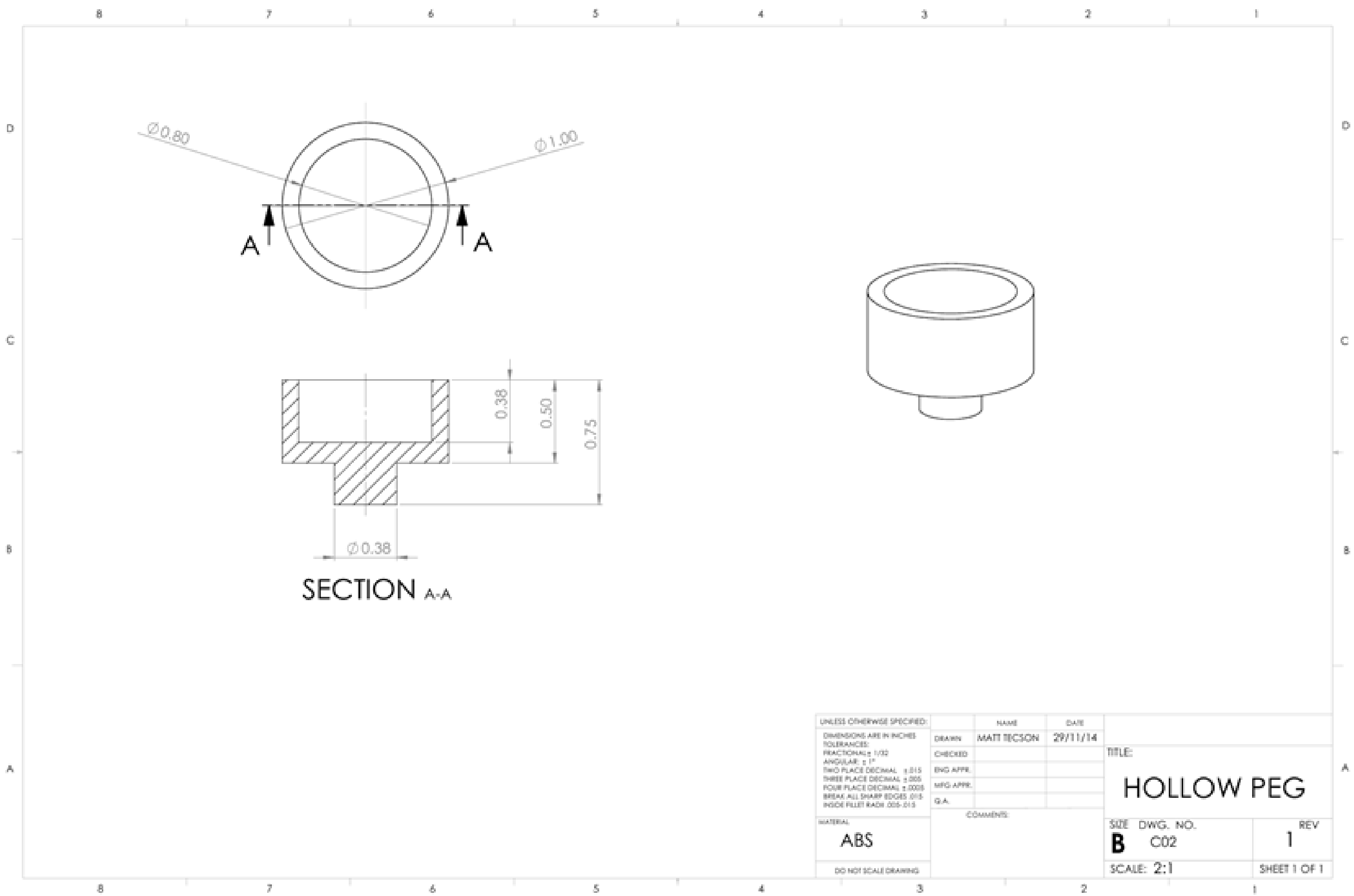


Figure 138 – Hollow Peg Drawing

Figure 139 is the manufacturing engineering drawing for the Assembly Plate.

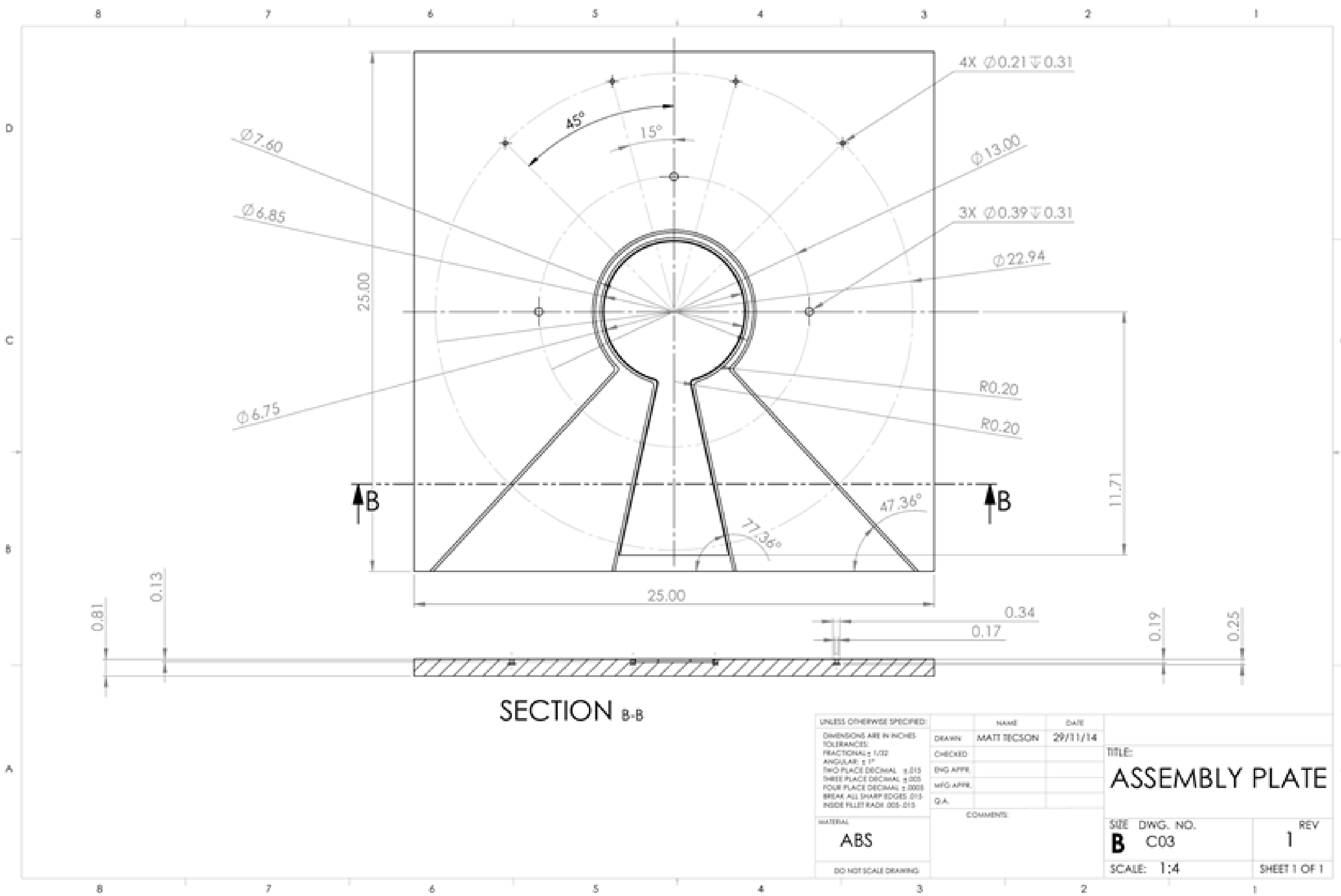


Figure 139 – Assembly Plate Drawing

Figure 140 is the manufacturing engineering drawing for the Inner Mold.

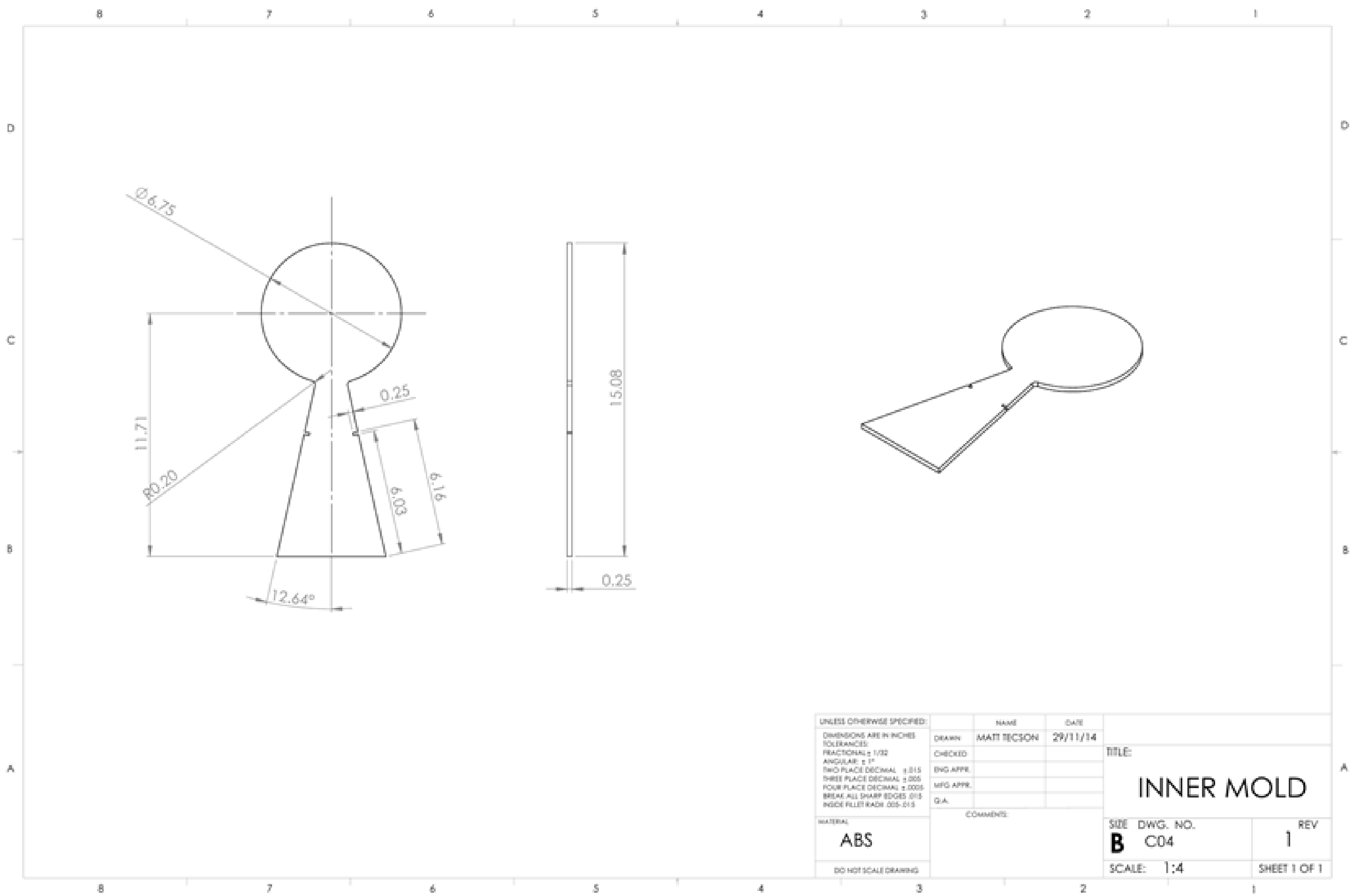


Figure 140 – Inner Mold Drawing

Figure 141 is the manufacturing engineering drawing for the Outer Mold.

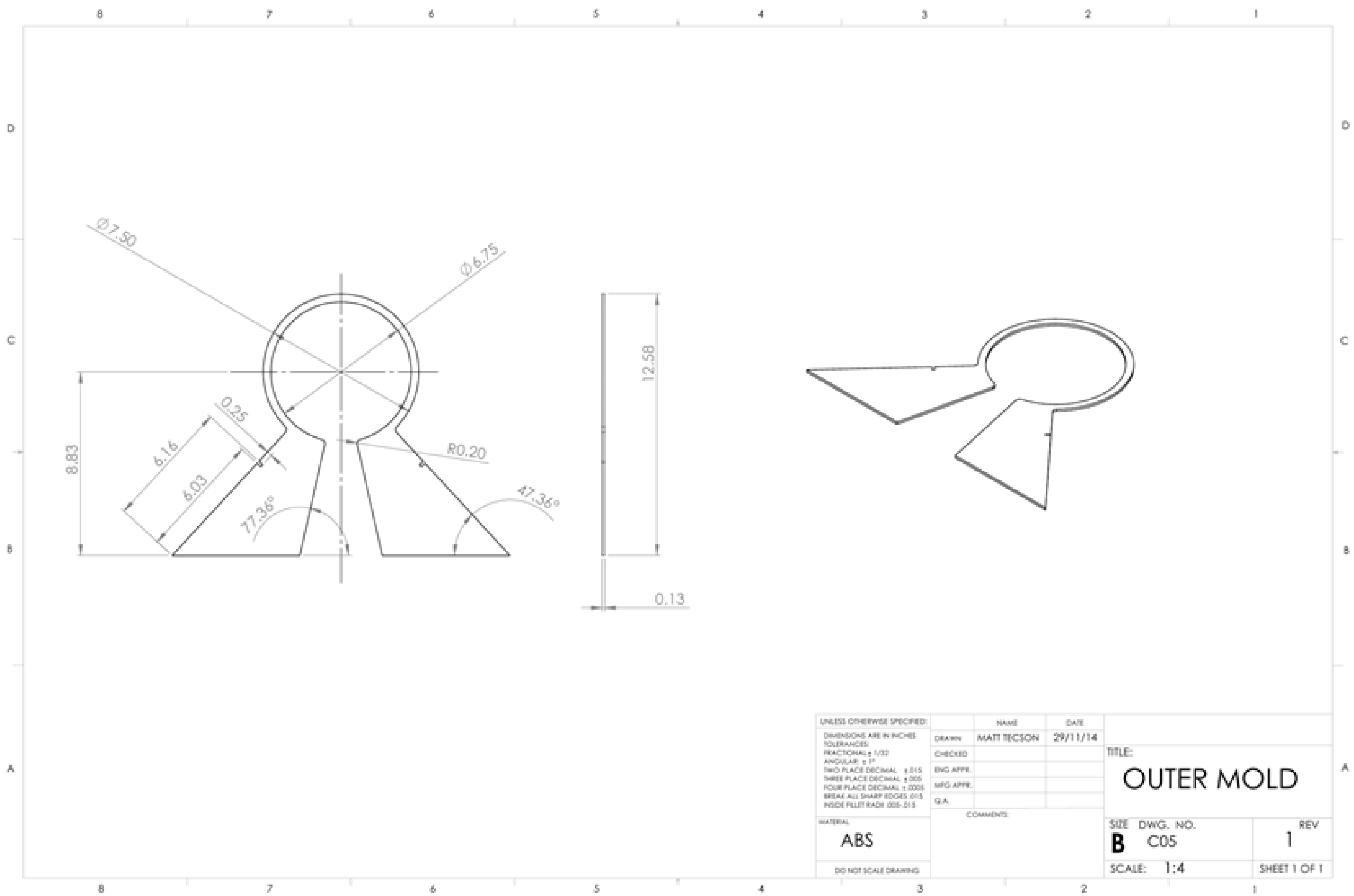


Figure 141 – Outer Mold Drawing

Figure 142 is the manufacturing engineering drawing for the Guide.

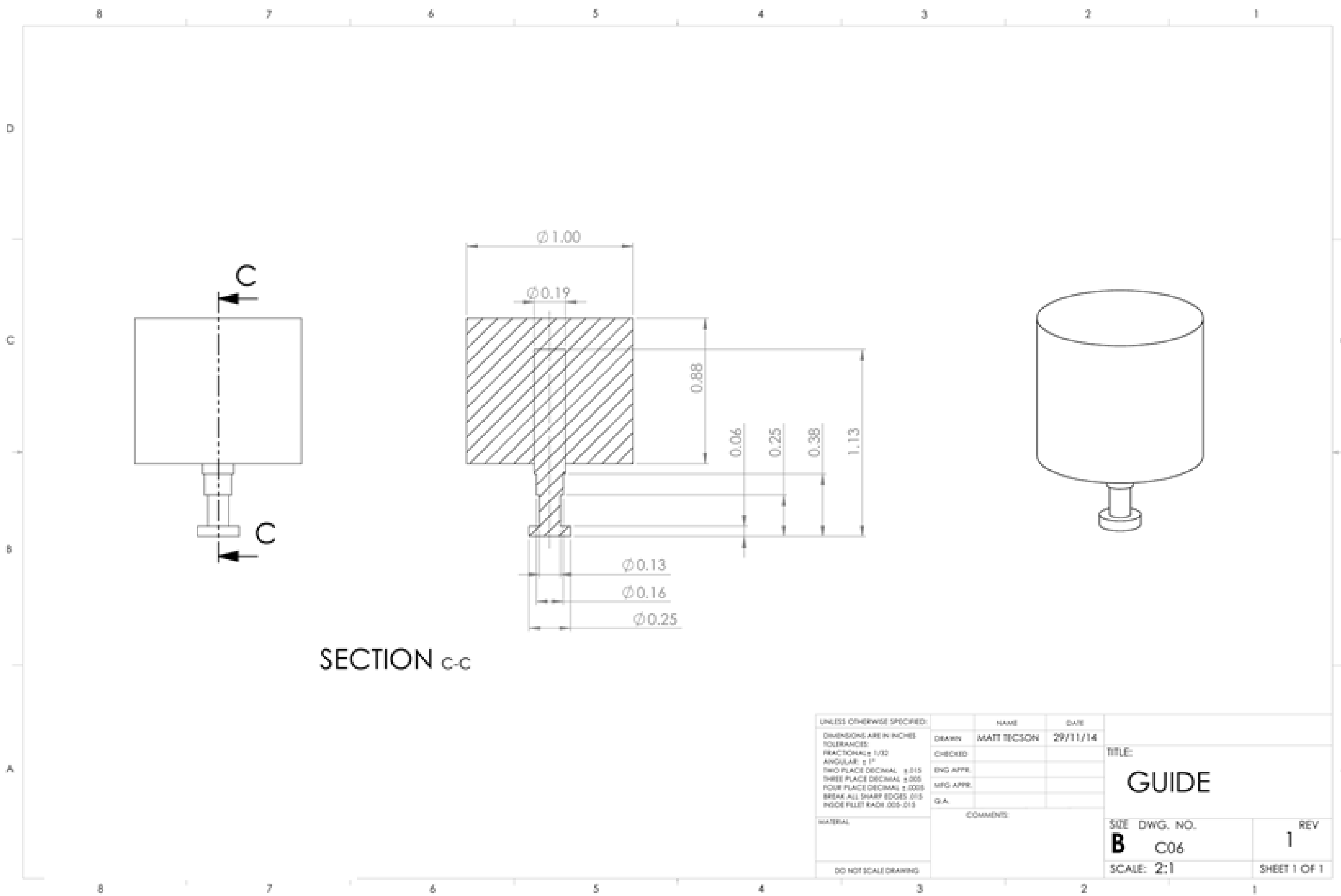


Figure 142 – Guide Drawing