Grain Dispenser

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MCEN 5045: Design for Manufacturability

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Revision Table

Rev.	Description	Date
1	Initial Release	12/2/2024

Executive Summary

This report presents an in-depth analysis and redesign of a grain dispenser, encompassing diagrams, design-for-assembly analysis, and economic evaluation of both an existing product and the proposed redesign. The study highlights the limitations of current market offerings, which are characterized by simple, cheaply made designs that fail to deliver the premium experience expected of a luxury kitchen appliance. These dispensers often lack features to prevent clogging, protect grain from contamination, and provide consistent, reliable performance.

The redesigned grain dispenser addresses these shortcomings with several key improvements. New features, such as an auger system to prevent clogging and a silicone gasket to seal the grain from moisture and contaminants, elevate the functionality and user experience. While the redesign increases the number of components from 9 to 19, thoughtful design choices, such as incorporating snap-fit connections, minimize the impact on assembly complexity. Additionally, the inclusion of electronics and vibrational motors enhances performance and reliability.

The cost of the redesigned dispenser will rise due to the additional components and improved materials, but this increase is justified by the substantial gains in functionality, durability, and consumer satisfaction. The redesigned product provides a significantly enhanced experience, aligning with the expectations of a premium kitchen appliance.

A complete drawing packet of the redesigned grain dispenser, detailing all components and subsystems, is included in Appendix A for further reference.

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Design Problem and Objectives

Grain is a cornerstone of daily nutrition for billions of people worldwide, serving as a dietary staple across diverse cultures and regions. Despite its global significance, the devices used for storing and dispensing grain often fail to meet the practical and emotional needs of consumers. Many households rely on manual measurement techniques, such as scooping grain directly from large sacks, which can be inefficient, messy, and prone to inaccuracies. While grain dispensers have the potential to improve convenience and functionality, they are often perceived as luxury items rather than essentials. To justify their place in the modern kitchen, these devices must not only perform their core functions—accurately dispensing consistent portions of grain—but also deliver a satisfying user experience that evokes a sense of value and reliability. Unfortunately, many current offerings in the market fall short, being cumbersome to operate and failing to meet consumer expectations for precision and ease of use. This underscores a pressing need for a redesigned grain dispenser that balances practicality, efficiency, and an enjoyable user experience.

The current grain dispensers available on popular retail platforms, such as Amazon, exhibit significant design flaws that undermine their functionality and user experience. A common example is shown below in figure 1, characterized by a white plastic body atop a separate dark gray base with a singular button for dispensing. This disjointed construction creates instability; a minor sideways force can easily tip the dispenser, leading to spillage of the stored grain. Additionally, the lid fails to form a proper seal with the body, leaving the grain susceptible to spilling and exposing it to potential contamination or moisture ingress. Beyond structural issues, the dispensing mechanism frequently jams due to the compacted grain. This flaw forces users to disassemble the dispenser entirely to clear blockages—an inconvenient and time-consuming process. In many cases, users abandon the dispensing function altogether, resorting to manually scooping grain from the top of the device. Such workarounds negate the very purpose of owning a grain dispenser and highlight the shortcomings in the current market offerings. These deficiencies underscore the need for a well-engineered solution that prioritizes stability, sealing, and reliable dispensing.

Figure 1: A typical grain dispenser found on popular retail platforms

The current market for grain dispensers is characterized by products that are poorly designed, prone to malfunction, and fail to deliver a satisfying user experience. This presents a clear opportunity for innovation: a thoughtfully designed grain dispenser that addresses these deficiencies could significantly enhance the daily lives of grain consumers worldwide. By prioritizing durability, functionality, and aesthetic appeal, a superior grain dispenser can fill this gap in the market.

An ideal solution would be to incorporate a robust sealing mechanism to prevent spillage, preserve freshness, and protect the grain from contaminants such as moisture, dust, or pests. Additionally, the dispenser should feature a self-unclogging mechanism to ensure consistent and reliable operation, eliminating the frustration caused by jamming. Beyond functionality, the design must evoke a sense of luxury, with sleek aesthetics and user-friendly features that make it a pleasure to use. By meeting these needs, a new grain dispenser can transcend its utilitarian purpose, becoming an indispensable and desirable device in modern kitchens.

Project Schedule

The project was completed over a six-week period, following a structured and collaborative approach to ensure success. Tasks were distributed equitably among team members, allowing each person to focus on areas aligned with their strengths and expertise. The Gantt chart below outlines all tasks required for the project, detailing when each was undertaken and identifying the team member responsible. Regular team meetings were held after each lecture to review progress, address challenges, and assign upcoming tasks, ensuring effective communication and coordination throughout the project timeline. The process began with a detailed analysis of a widely available grain dispenser design to identify its strengths and shortcomings. From this foundation, the team developed a redesigned product aimed at significantly enhancing user satisfaction. This systematic approach allowed the team to refine the product while maintaining focus on key objectives within the allotted timeframe.

Table 1: Gantt chart of the project schedule

Project: Rice Dispenser	Team Members				Date													
	Evan	Jacob	Luke	Rick	16-Oct	21-Oct	23-Oct	28-Oct	30-Oct	4-Nov	6-Nov	11-Nov	13-Nov	18-Nov	20-Nov	25-Nov	27-Nov	2-Dec
Project Proposal	X	X	X	X														
Diagrams	X	X																
Part Modeling		X	X	X														
Part Drawings		X	X	X														
Full Assembly Model				X														
DFA Analysis				X														
Economic Analysis			X															
Material Selection Analysis				X														
Design Changes	X	X	X	X														
Redesign Analysis: DFA				X														
Redesign Analysis: Economic			X															
Redesign Analysis: Assembly Model				X														
Final Report	X	X	X	X														
Final Report Presentation			X	X														

Diagrams

Black Box

The black box diagram helps to illustrate the critical inputs and outputs of the system separately from the internal subsystems that allow them to operate. The revised grain dispenser has three main inputs, and five outputs. Once this analysis is completed, a glass box diagram will be created to define the subsystems necessary to achieve the desired system outputs.

Figure 2: Black Box Diagram

Glass Box

The glass box diagram provides a clear representation of the system's functional flow by illustrating the inputs, processes, and outputs of the grain dispenser. The system receives three primary inputs: grain, which serves as the material to be dispensed; DC power, which powers the internal components; and user input in the form of a button press that initiates the dispensing process.

Once the button is pressed, the DC power activates an auger and a vibration motor. The auger facilitates the precise and consistent dispensing of grain, while the vibration motor ensures smooth flow by preventing clogs or blockages within the system. These components work together seamlessly to convert the inputs into the desired output. The outputs of the system include the primary result—the dispensed grain—as well as secondary outputs such as vibration, sound, and heat generated by the motors during operation. This diagram encapsulates the functional relationships within the system, highlighting how inputs are transformed into useful and unavoidable byproducts.

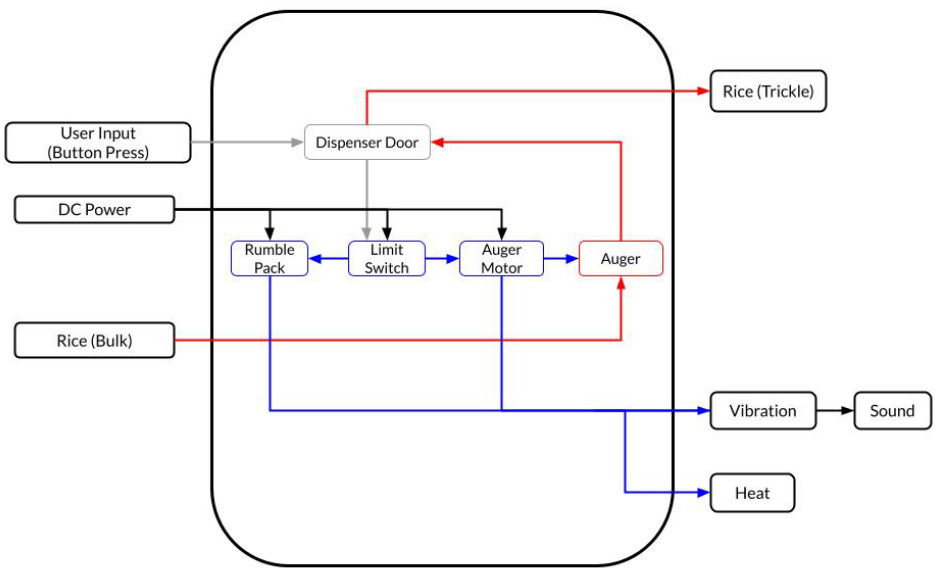


Figure 3: Glass Box Diagram

Fishbone

The fishbone diagram outlines the key subsystems and components of the grain dispenser, providing a detailed view of its functionality. The four primary subsystems are the agitators, which ensure smooth and even grain flow; the dispenser door, which controls the precise release of grain; the electronics, including the power supply, sensors, and controls; and the enclosure, which houses and protects all internal components. These subsystems are integrated into the main housing, designated as Part 101, which serves as the structural core of the device. The diagram emphasizes how these subsystems work together seamlessly to create a reliable and user-friendly product.

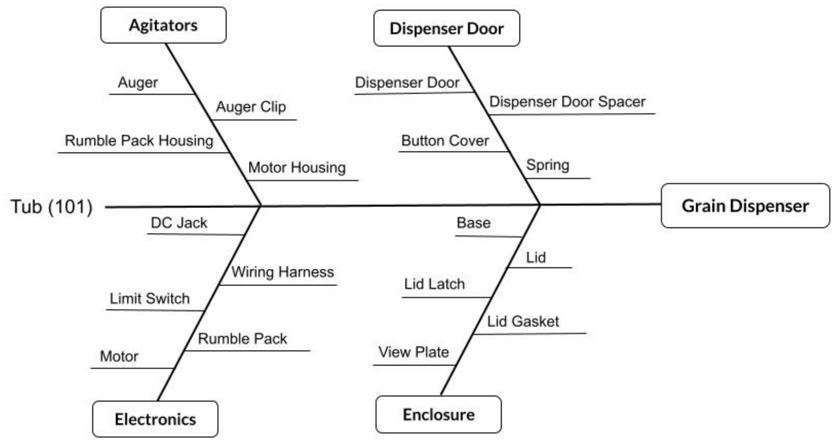


Figure 4: Fishbone Diagram

Patent Search

A comprehensive patent search was conducted to identify any existing intellectual property related to countertop granular product dispensers, especially those that agitate the stored material. The search resulted in a plethora of expired patents mixed with a few recent innovations in granular product dispensers intended for self-serve applications in restaurants.

Patent: US D 7,703,639 B2

This patent is on a granular product dispenser consisting of a sealed receptacle with a neck on the lower end, and a user-driven impeller used to dispense the product. The patent specifies that the impeller is flexible, so that it can conform to the shape of the neck and provide a seal for freshness. The patent was published on February 9, 2006, and expired on September 10, 2023. This design is commonly used to dispense moderate to large granular dry foods, such as cereal or pasta. Prior to the patent's expiration, this design was used primarily in wall-mounted commercial settings, but the expiration of this patent has led to a plethora of smaller-scale products intended for home use.

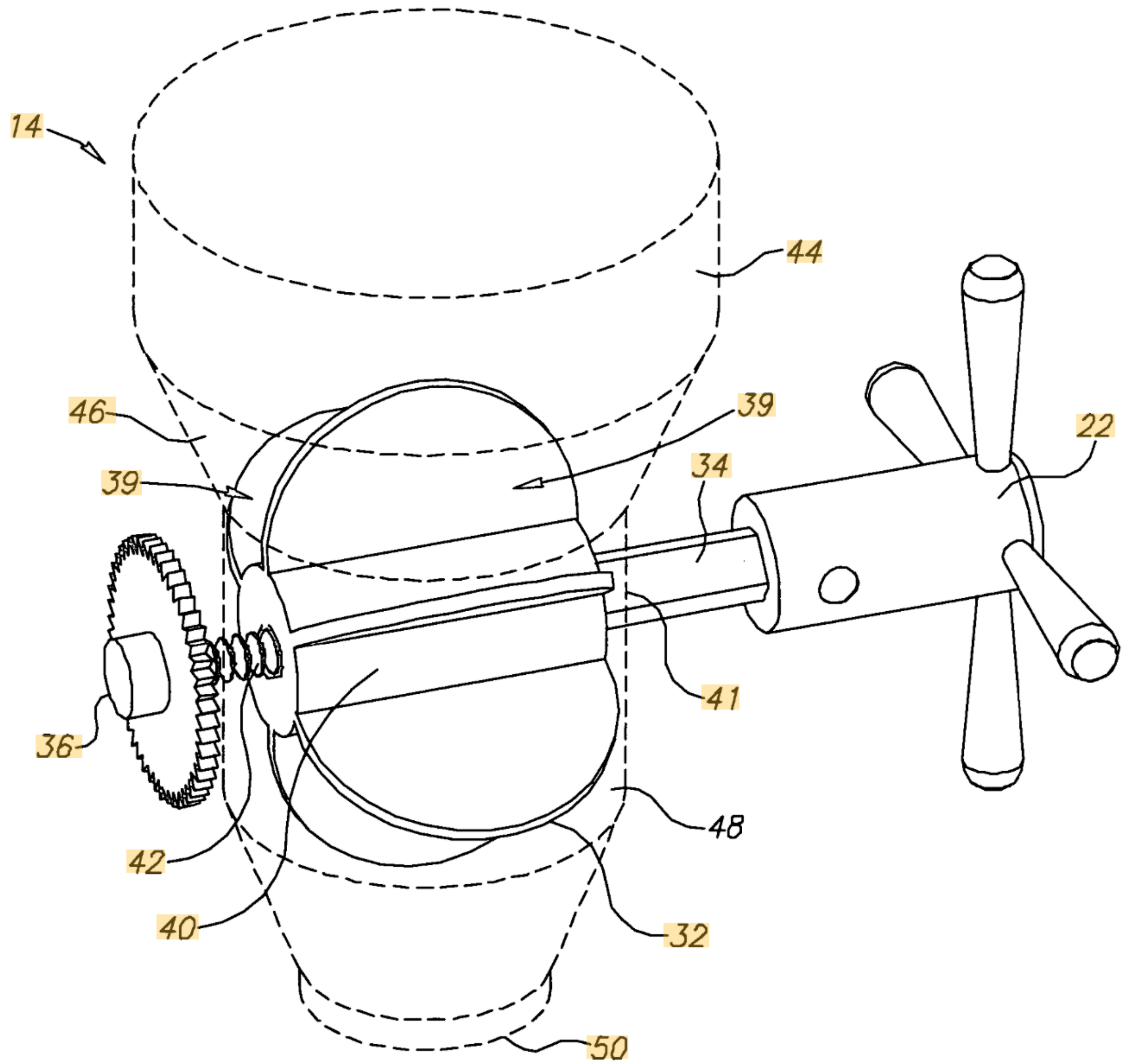


Figure 5: Patent US D 7,703,639

Figure 6: Countertop Example of Patent US D 7,703,639

Patent: US D 9,400,200 B2

This design patent is for a lever-actuated dry product dispenser with interchangeable portion control bins. The patent outlines a design in which a granular product is fed into an interchangeable bin contained by a rotating component that indexes it from the receiving to dispensing position. The patent also includes mention of a ratcheting handle system that prevents interference between the handle and the area under the dispenser. This patent was filed by Server Products on March 26, 2014, and is set to expire on May 23, 2032. Server Products markets this product as a dry food and candy dispenser for use in ice-cream shops, with an MSRP of around ~800 USD (as of 2024).

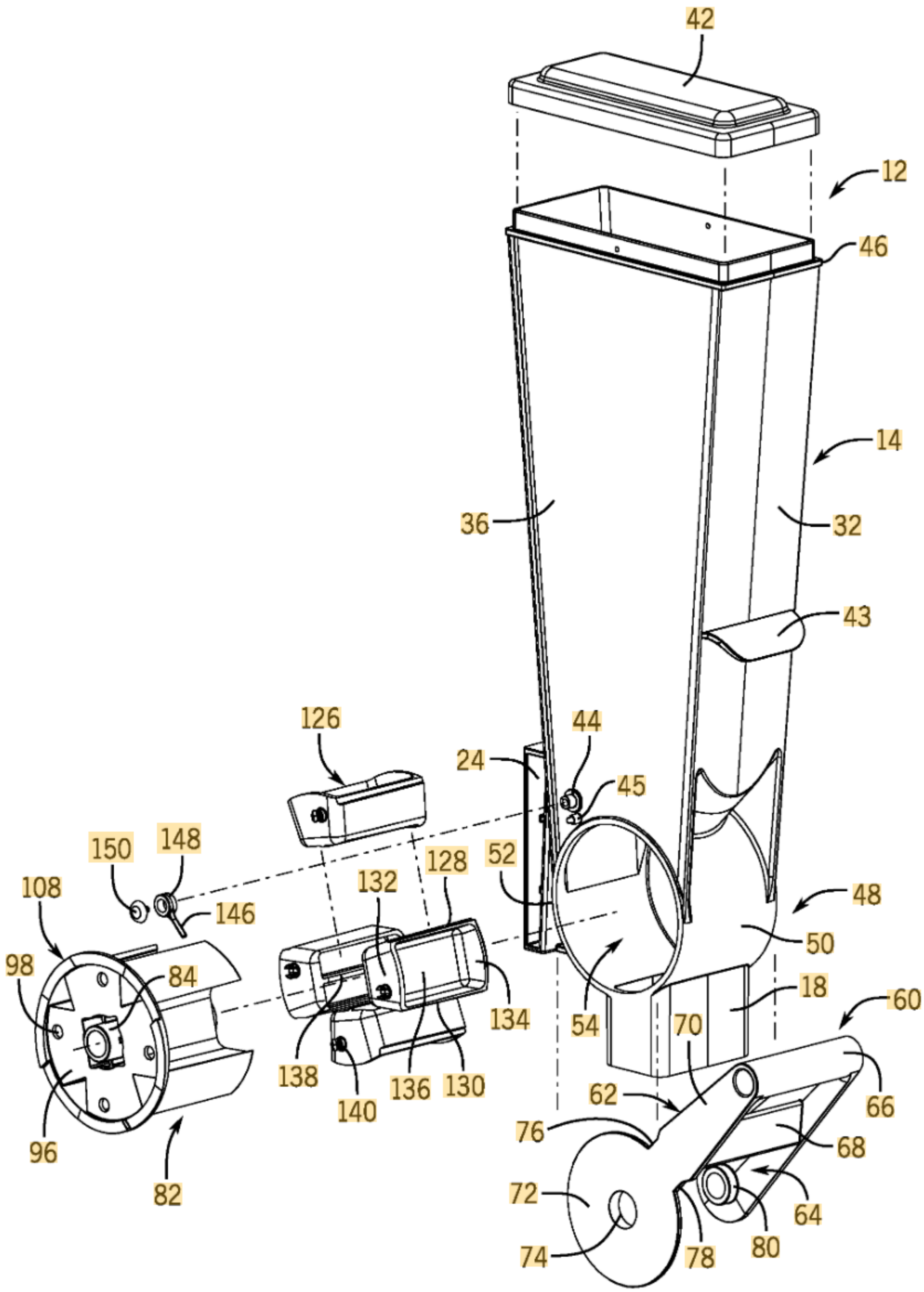


Figure 7: Patent US D 9,400,200 B2

Patent: US D 9,903,746 B2

This design patent is for an internal agitation bar to be used in conjunction with a lever-actuated, portioned granular product dispenser. This is one of the only products on the market that features a method of agitation for the stored good, and it was patented by Server Products on August 24, 2018. The patent is set to expire on May 26, 2036, and has yet to be implemented in a commercially available product.

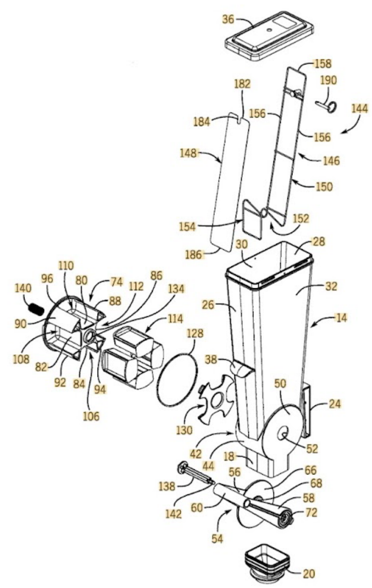


Figure 8: Patent US D 9,903,746 B2

No active patents were found for continuous dispensers, suggesting that these devices are not currently protected by enforceable patents. Additionally, many of the products in this segment of the market utilize similar basic designs, indicating that if patents for such designs once existed, they have likely expired and entered the public domain, making them generic and no longer enforceable.

The proposed grain dispenser redesign incorporates significant innovations that distinguish it from the existing products on the market. These differences, including advanced features such as an automated self-unclogging mechanism, enhanced safety systems, and improved material selection, ensure that our product is unique and original. Based on the findings of the patent search, there are no concerns regarding potential infringement, giving a clear pathway to bringing the design to market without legal barriers.

Initial Design

The initial design, as shown in Figure 9, was created to be representative of the button-actuated, continuous grain dispensers available on the market. This presents an opportunity to gain insight into the approximate cost of these products through our own economic analysis, providing a baseline cost that can be compared to the redesigned dispenser. Taking this approach allows for direct comparison between the redesigned product's unit cost and that of competitive offerings, as assumptions will be consistent across both analyses. This design also provides a solid starting point for the following redesign, as the extremely heavy emphasis on low component cost seen in this design will help to maintain low overall cost when additional features are added.

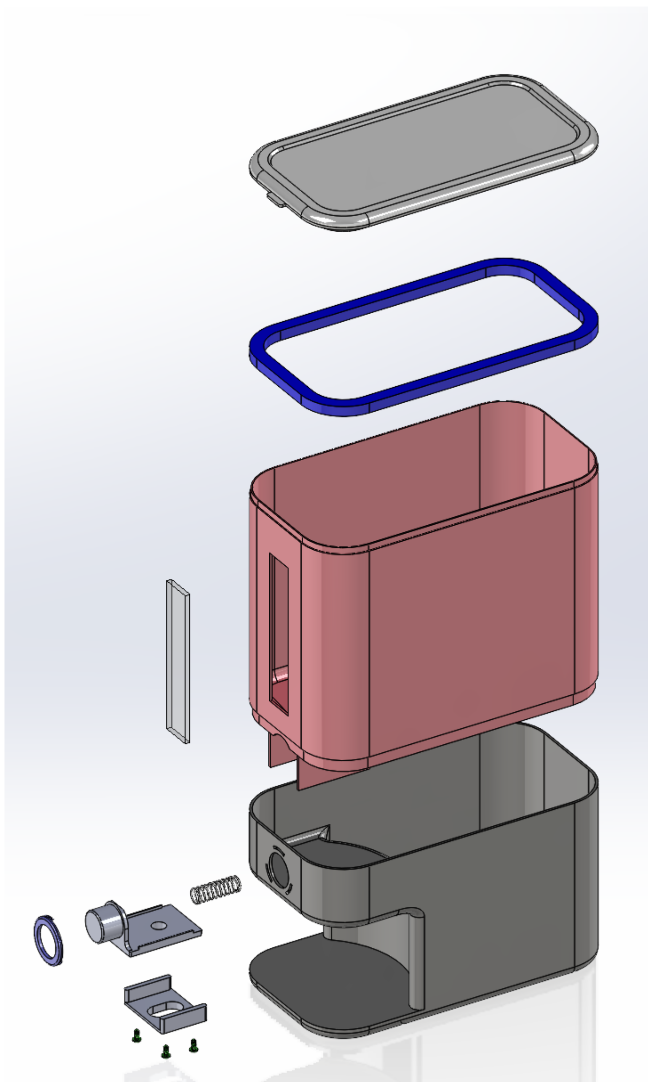


Figure 9: Exploded view of initial assembly

BOM - Initial

The initial design of the grain dispenser reflects a basic, widely available model commonly sold on retail websites. It consists of a straightforward structure with nine main components, including a tub for storing grain, a lid to cover and protect the contents, and a button mechanism that moves a door to release the grain. A bill of materials for the initial grain dispenser can be seen below in table 1. The assembly is minimalistic, relying on four identical screws for securing parts, while the remaining components are joined using tolerance fits to simplify manufacturing and assembly. The structural components, such as the tub and lid, are made from ABS plastic, chosen for its durability and resistance to wear. The retaining spring and screw are constructed from steel, providing the necessary strength for moving parts and ensuring the dispenser's longevity. This design heavily prioritizes simplicity and cost-effectiveness while maintaining functional reliability. The bill of materials highlights the economical use of materials and the streamlined approach to assembly, characteristic of mass-market designs.

Table 2: Original Grain Dispenser BOM

Bill of Material				
Product: Original Grain Dispenser				Date:11/26/24
Assembly: 200				
Item #	**Part #**	**Qty**	**Name**	**Material**
1	101	1	Tub	ABS
2	102	1	Lid	ABS
3	103	1	Lid Retainer	ABS
4	104	1	Base	ABS
5	105	1	Button Cover	ABS
6	106	1	Dispenser door	ABS
7	107	1	Dispenser door Bracket	ABS
8	108	4	Retaining screw	Steel
9	109	1	Spring	Piano Wire
10	110	1	View plate	PC

DFA Analysis - Initial

When evaluating this product there were several design characteristics that were noted, some of which hindered the assembly of the product and others that aided in its assembly. The original product is simple to assemble with most components utilizing friction fits or geometry to stay connected. In addition to these simple connection points there are 4 screws used to hold the dispenser door bracket to the tub. These screws are not easy to access and require the entire assembly to be flipped upside down to access them, increasing the complexity to assemble and otherwise simple product. However, while the simplicity of most of the interfaces allows for quick assembly they also allow for quick disassembly even when it is not desired. The loose fit of most of the geometric and friction connections means the assembly is prone to falling apart when in use and does not make for a sturdy product.

Looking at the DFA analysis, there are a few operations and components that lead to inefficiencies in the assembly of the unit. The theoretical minimum design is simple even though the actual part is not much more complex. Despite the relative simplicity of the design, it still scores poorly in handling, insertion and secondary operations largely due to the screws mentioned earlier. Removal of the screws and redesigning of the mating components would go a long way to increasing the ease of assembly.

Table 3: Original Grain Dispenser DFA Analysis

DFA Analysis Worksheet

Assembly Name: Original Rice Dispenser

Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing	
Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium /High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around
101	Tub	1	9	1	0	LOW	1	0	0
102	Lid	1	1	0	0	LOW	0	0	0
103	Lid Retainer	1	2	0	0	LOW	0	0	0
104	Base	1	2	1	0	LOW	1	0	0
105	Button Cover	1	1	0	0	LOW	0	0	0
106	Dispenser door	1	3	1	0	LOW	1	0	0
107	Dispenser door Bracket	1	7	1	0	LOW	1	0	1
108	Retaining screw	4	1	0	0	LOW	2	0	0
109	Spring	4	2	0	0	LOW	2	0	0
110	View plate	1	1	0	0	LOW	0	0	1
	Totals	16	29	4	0	0	8	0	2
	Design for Assembly Metrics	**21.54065923**		**25.00%**	**←Theor. Effy. Pract. Effy.→**		**50.00%**	**0.5**	
	Targets			**60.00%**			**80.00%**	**0**	

DFA Analysis Worksheet

Assembly Name: Original Rice Dispenser **Team:** Evan, Jacob, Luke, Rick **Date:** 11/30/2024

Part		Handling			Insertion				Secondary Operations				
Part Number	Part Name	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
101	Tub	0	0	0	0	0	0	0	0	0	0	0	0
102	Lid	0	0	0	0	0	0	0	0	0	0	0	0
103	Lid Retainer	0	0	0	0	0	0	0	0	0	0	0	0
104	Base	0	0	0	0	0	0	0	0	0	0	0	0
105	Button Cover	0	0	0	0	0	0	0	0	0	0	0	0
106	Dispenser door	0	0	0	0	0	0	0	0	0	0	0	0
107	Dispenser door Bracket	0	0	0	0	0	0	0	0	0	0	0	0
108	Retaining screw	0	0	4	4	2	0	0	4	4	0	0	0
109	Spring	1	0	0	0	0	0	0	0	0	0	0	0
110	View plate	0	0	0	0	1	0	0	0	0	0	0	0
	Totals	1	0	4	4	3	0	0	4	4	0	0	0
	Design for Assembly Metrics	**1.25**			**1.75**				**2**				
	Targets	**0.25**			**0.25**				**0.5**				

Economic Analysis - Initial

For the original grain dispenser, the unit cost for each part was found using economic analysis. In the original design there are 10 unique parts, with 2 of them being COTS parts. For the COTS parts, their unit cost was calculated by researching and making assumptions via McMaster-Carr.

To have multiple total cost figures to compare, order of magnitude analysis was also performed. Magnitude estimates only consider the material cost and the weight of the part; this makes the estimate very crude but usually can get into the ballpark of a good estimate. The total cost of all parts, excluding COTS parts, was $22.49 in the order of magnitude analysis and $15.09 in the economic analysis.

For the original design, the total grain dispenser cost is $16.54, which is comparable to similar products on the market that normally cost around $30 - $40. This indicates about a 55% margin for this product.

The main economic analysis for total unit cost of each part is made up from five different equations that are used to estimate the full cost of the grain dispenser. This analysis also requires a few assumptions to work properly. The assumptions and the equation are explained below.

Economic Analysis Equation:

Unit Cost: $C_U = C_M + C_L + C_T + C_E + C_{OH}$ (1)

Material Cost: $C_M = \frac{mc_m}{1-f}$ (2)

$m = weight\ of\ material\ (lb)$

$c_m = cost\ of\ material\ (\frac{\$}{lb})$

$f = fraction\ of\ material\ that\ ends\ up\ as\ scrap$

Labor Cost: $C_L = \frac{c_w}{n'}$ (3)

$c_w = hourly\ cost\ of\ wages\ and\ benefits\ (\frac{\$}{hr})$

$n' = production\ rate\ (\frac{units}{hr})$

Tooling Cost: $C_T = \frac{c_t k}{n}$ (4)

$c_t = cost\ of\ making\ tooling\ (\$)$

$n = entire\ production\ run\ (\#\ of\ parts)$

$k = tooling\ wear\ factor\ (k = \frac{n}{lifespan\ of\ tooling})$

Equipment Cost: $C_E = \left(\frac{1}{n'}\right)\left(\frac{c_e}{Lt_{wo}}\right)q$ (5)

$c_e = cost\ of\ capital\ equipment\ (\$)$

$n' = production\ rate\ (\frac{units}{hour})$

$L = load\ factor, fractional\ time\ equipment\ is\ productive$

$t_{wo} = capital\ write\ off\ time\ (yr)$

$q = fraction\ of\ equipment\ sharing\ between\ products$

Overhead Cost: $C_{OH} = \frac{c_{OH}}{n'}$ (6)

$c_{OH} = overhead\ hourly\ rate\ (\frac{\$}{hr})$

$n' = production\ rate$

Economic Analysis Assumptions:

1. Of one specific grain dispenser, 1,000 are sold per month according to amazon analytics.
2. Accounting for sales from other sites/brands/stores, an assumption of 240,000 units are sold yearly.
3. $1 million in capital costs divided by # of parts.
4. COTS part cost estimates come from McMaster Carr.
5. Labor Rate comes from the average rate of a machinist in the USA.
6. 1 operator/machine.
7. Each part has 1 machine, and works 2 shifts, for 50 weeks a year = 4000 work hours per year.
8. Production rate 60 = 240,000 dispensers per year / 4000 hours per year.
9. ABS processes are done via injection molding.

Initial Design Economic Analysis:

Table 4: Initial design economic analysis

Part Number	101	102	103	104	105	106	107	108	109	110
Part Name	Tub	Lid	Lid Retainer	Base	Button Cover	Dispenser Door	Dispenser Door Bracket	Retaining Screws	Spring	View Plate
Cost Element	**ABS**	**ABS**	**ABS**	**ABS**	**ABS**	**ABS**	**ABS**	**COTS**	**COTS**	**PC**
Material Cost, c_m ($/lb)	$ 0.72	$ 0.72	$ 0.72	$ 0.72	$ 0.72	$ 0.72	$ 0.72			$ 1.45
Fraction of Process that is Scrap, *f*	0.05	0.05	0.05	0.05	0.05	0.05	0.05			0.05
Mass of Part, *m* (lb)	1.46	0.21	0.07	1.52	0.01	0.05	0.03			0.06
C_m Unit Cost of Material	**$ 1.1065**	**$ 0.1592**	**$ 0.0531**	**$ 1.1520**	**$ 0.0076**	**$ 0.0379**	**$ 0.0227**			**$ 0.0916**
Labor Cost, c_w ($/hr)	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00			$ 26.00
Production Rate, *n* ' (units/hr)	60	60	60	60	60	60	60			60
C_L Unit Cost of Labor	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**			**$ 0.4333**
Tooling Cost, c_t ($/set)	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00			$ 20,000.00
Total Production Run, *n* (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000			1,000,000
Tooling Life, n_t (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000			1,000,000
Sets of Tooling Required, *k*	1	1	1	1	1	1	1			1
C_T Unit Cost of Tooling	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**			**$ 0.0200**
Capital Cost, c_e ($)	$125,000.00	$125,000.00	$125,000.00	$125,000.00	$125,000.00	$ 125,000.00	$ 125,000.00			$125,000.00
Captial Write-Off Time, t_{wo} (yrs)	5	5	5	5	5	5	5			5
Load Fraction, *L* (fraction)	1	1	1	1	1	1	1			1
Load Sharing Fraction, *q*	1	1	1	1	1	1	1			1
C_E Unit Cost of Capital Equipment	**$ 0.1042**	**$ 0.1042**	**$ 0.1042**	**$ 0.1042**	**$ 0.1042**	**$ 0.1042**	**$ 0.1042**			**$ 0.1042**
Factory Overhead, c_{OH} ($/hr)	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00			$ 60.00
Production Rate, *n* ' (units/hr)	60	60	60	60	60	60	60			60
C_{OH} Unit Cost of Factory Overhead	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**			**$ 1.0000**
Total Unit Cost = $C_M + C_L + C_T + C_E + C_{OH}$	**$ 2.6640**	**$ 1.7167**	**$ 1.6106**	**$ 2.7095**	**$ 1.5651**	**$ 1.5954**	**$ 1.5802**	**$ 0.1600**	**$1.2900**	**$ 1.6491**
Cost of Various Part via CustomPartNet										
Total Product Cost = Sum of Total Unit Costs	**$ 16.5405**									
Order of Magnitude Calculation:	**$ 22.4910**									
Material Cost:	$ 1.0512	$ 0.1512	$ 0.0504	$ 1.0944	$ 0.0072	$ 0.0360	$ 0.0216	$ -	$ -	$ 0.0870
MFG Cost:	$ 3.1536	$ 0.4536	$ 0.1512	$ 3.2832	$ 0.0216	$ 0.1080	$ 0.0648	$ -	$ -	$ 0.2610
Price:	$ 9.4608	$ 1.3608	$ 0.4536	$ 9.8496	$ 0.0648	$ 0.3240	$ 0.1944	$ -	$ -	$ 0.7830

Redesign

The grain dispenser redesign has the primary goal of improving in four major areas: providing more consistent granular flow, providing an airtight enclosure, increasing holding power between interfacing components, and increasing DFA metrics. Secondarily, the redesigned dispenser should retain a reasonable level of part simplicity, and a reasonably low overall cost. Because of the scope of this redesign, it was split into two distinct parts.

First, an adaptive redesign was done to our initial assembly, introducing two new features: a sealing lid, and an electric auger/vibration system to provide consistent agitation. At this stage, these components were designed to have minimal interference with existing parts and were primarily secured using screws or other fasteners. While DFM was considered in the process of designing these parts, DFA was not prioritized. This approach allowed the team to work on these subsystems in parallel without the use of a PDM software. While outside of the scope of this project, this design would also be a great template for a functional prototype that could be added to an existing dispenser with little modification.

After the adaptive redesign was completed, the assembly underwent a second redesign process to prioritize DFA, resulting in the final assembly seen in Figure 10. This provided an opportunity for the initial design's issues with unwanted disassembly to be addressed whilst removing unnecessary fasteners and reducing component count. Logistically, the split between these redesigns also provided time for material analysis to be concluded so that snap fit components could be properly designed.

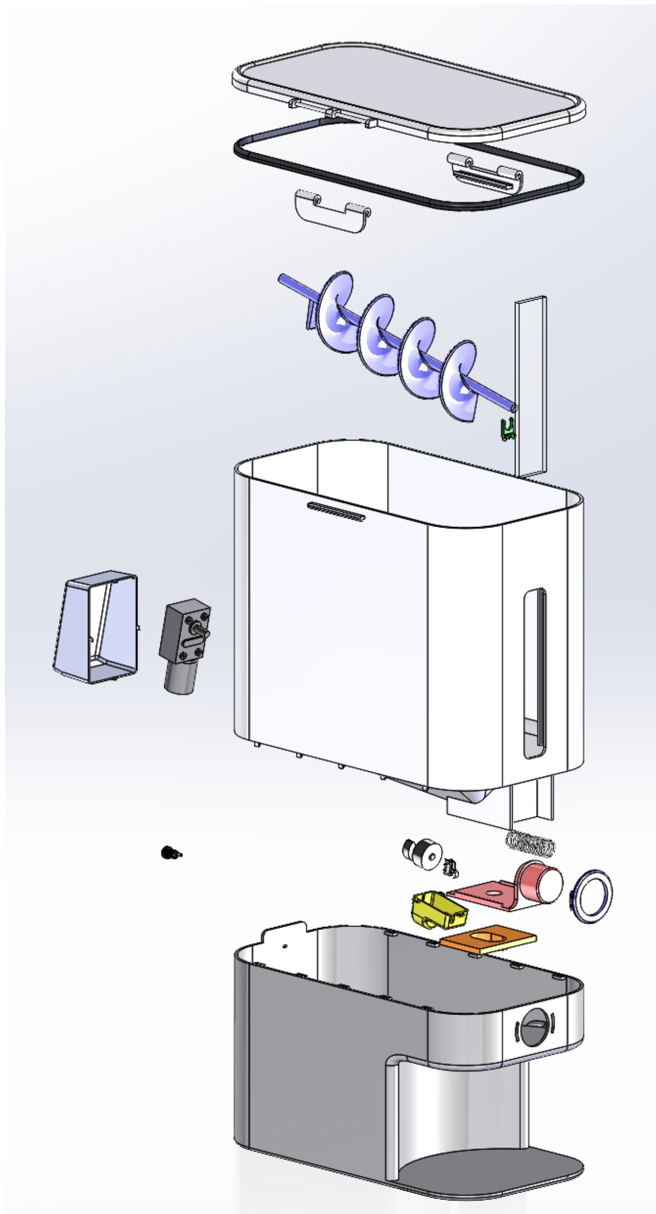
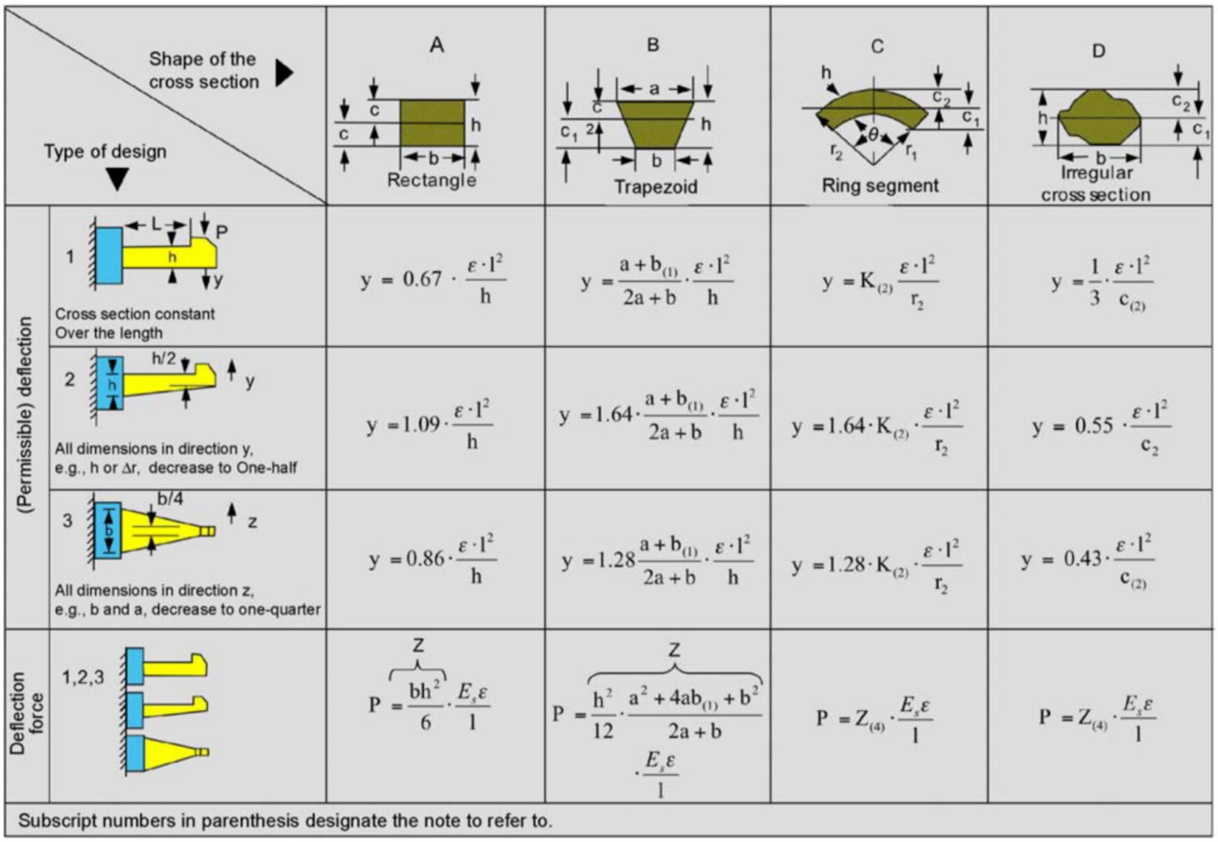


Figure 10: Exploded view of final assembly

Snap Fit Design

All the cantilever snap fit features present in the grain dispenser design have a rectangular cross section and constant cross section over the length. The maximum permissible deflection for this situation can be defined by equation 7, as seen in cell A1 of Figure 11.



Type of design / Shape of the cross section		A Rectangle	B Trapezoid	C Ring segment	D Irregular cross section
(Permissible) deflection	1 Cross section constant Over the length	$y = 0.67 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = \frac{1}{3} \cdot \frac{\varepsilon \cdot l^2}{c_{(2)}}$
	2 All dimensions in direction y, e.g., h or Δr, decrease to One-half	$y = 1.09 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.64 \cdot \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.64 \cdot K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = 0.55 \cdot \frac{\varepsilon \cdot l^2}{c_2}$
	3 All dimensions in direction z, e.g., b and a, decrease to one-quarter	$y = 0.86 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.28 \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.28 \cdot K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = 0.43 \cdot \frac{\varepsilon \cdot l^2}{c_{(2)}}$
Deflection force	1,2,3	$P = \overbrace{\frac{bh^2}{6}}^{Z} \cdot \frac{E_s \varepsilon}{l}$	$P = \overbrace{\frac{h^2}{12} \cdot \frac{a^2 + 4ab_{(1)} + b^2}{2a+b}}^{Z} \cdot \frac{E_s \varepsilon}{l}$	$P = Z_{(4)} \cdot \frac{E_s \varepsilon}{l}$	$P = Z_{(4)} \cdot \frac{E_s \varepsilon}{l}$

Subscript numbers in parenthesis designate the note to refer to.

Figure 11: Deflection of various snap fit features

$$y = 0.67 * \frac{\varepsilon * l^2}{h} \qquad (7)$$

y = Permissible deflection (mm)

ε = Permissible strain

l = Length of feature (mm)

h = Feature thickness (mm)

In this case, the permissible strain for ABS can be defined as 0.025 for short term strain applications, and 0.015 for frequent separation.

To determine the geometry for our snap fit features, we defined the feature thickness and length first, which allowed for the permissible deflection to be solved for and used to create the geometry for the feature. Because the product is not intended to be disassembled, all internal snap fit features present in the design will be permanent and will have a 90-degree angle on the inner side of the feature. For the lid latch snap fit features, a returning angle of inclination was used, to facilitate easy opening by the user.

For the design of the snap feature on the lid, shown in Figure 12, the calculations for allowed deflection, deflection force, and mating force are as follows.

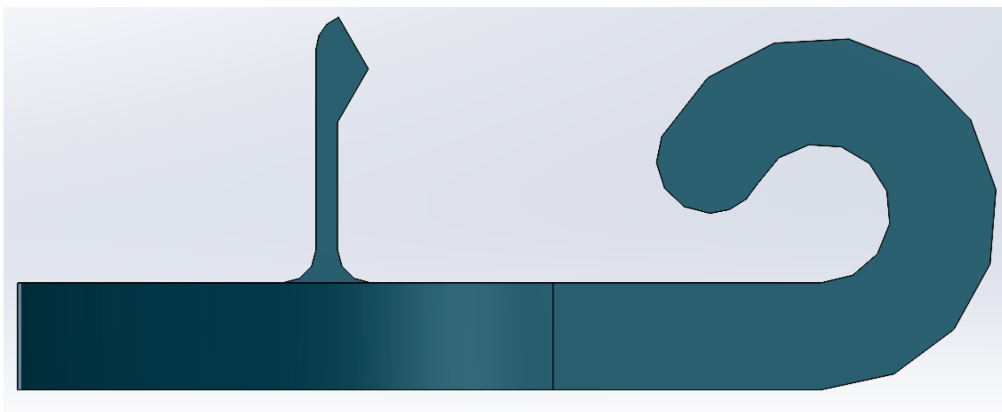


Figure 12: Side profile of the lid snap fit.

Permissible deflection:

ε = 0.015

l = 5.08 mm (0.2 in)

h = Feature thickness 0.508 mm (0.02 in)

This results in a maximum allowed deflection of 0.510 mm (0.02 in).

The deflection and mating force can be found using the following equations. Since the design of the snap fit for this component has identical angles on each side, the angle of inclination will be identical in both directions.

Deflection force:

$$P = \frac{bh^2}{6} * \frac{E_S \varepsilon}{l} \qquad (8)$$

Es = 1600 N/mm^2

b =63.5 mm

h =0.508 mm

l =5.08 mm

This results in a deflection force of 12.90 N (2.90 lbf)

Mating force:

$$W = P * \frac{\mu + \tan(\alpha)}{1 - \mu * \tan(\alpha)} \quad (9)$$

μ = 0.69 for ABS-ABS connections

α = 30 degrees

This results in a mating force of 26.54 N (5.96 lbf).

BOM - Redesign

The redesign of the grain dispenser incorporates additional components to enhance both functionality and user experience, resulting in a more complex assembly than the initial design. These new features include an electronic system, an auger mechanism for consistent grain flow, and a vibrational motor to prevent clogs and ensure smooth dispensing. The bill of materials for the redesigned grain dispenser can be found below in table 5. The inclusion of these components addresses the limitations of the original design and adds significant value to the product.

The electronic components are off-the-shelf items made from a variety of materials, ensuring reliability and ease of replacement if needed. The auger system, crucial for dispensing grain accurately and efficiently, is fabricated from ABS plastic due to its strength and durability. A silicone gasket has been added to the lid, providing a secure seal to protect the grain from contamination and moisture, improving freshness and hygiene. Additionally, the dispensing door and its supporting bracket are made from food-grade high-density polyethylene (HDPE), a material known for its safety, durability, and resistance to wear. The revised bill of materials reflects these enhancements, balancing improved performance with durable and food-safe materials to meet both functional and safety requirements.

Table 5: Redesigned Grain Dispenser BOM

Bill of Material					
Product: Redesigned Grain Dispenser					Date:11/26/24
Assembly: 200					
Item #	**Part #**	**Qty**	**Name**	**Material**	**Make/Buy**
1	101	1	Tub	ABS	Make
2	102	1	Auger	ABS	Make
3	103	1	Auger Clip	ABS	Make
4	104	1	Servo Cover	ABS	Make
5	105	1	Rumble housing	ABS	Make
6	106	1	Rumble pack	Various	Buy
7	107	1	Motor	Various	Buy
8	108	1	DC Panel Connector	Various	Buy
9	109	1	Limit Switch	Various	Buy
10	110	1	Lid	ABS	Make
11	111	2	Lid Latch	ABS	Make
12	112	1	Lid Gasket	TPR	Make
13	113	1	Base	ABS	Make
14	114	1	Button Cover	ABS	Make
15	115	1	Dispenser door	HDPE	Make
16	116	1	Dispenser door Bracket	HDPE	Make
17	117	1	View plate	PC	Make
18	118	1	Spring	Piano Wire	Buy
19	119	1	Wiring Harness	Various	Make

DFA Analysis - Redesign

The focus on DFA of the redesign was to eliminate fasteners and difficult to assemble components. The primary way of doing this was to redesign the dispenser door bracket, the lone component requiring 4 screws to fasten it to the upper assembly. On the original design this component required the entire assembly to be flipped upside down so 4 difficult to access screws could be fastened. In the redesign, this component and the space it occupies was reconfigured to eliminate the need for screws but also allow the component to be installed in the same orientation as the other components before and after it. Additionally, snap fittings were added to most of the components, replacing the friction and geometrical connections of the original design, this allows for a more secure assembly without adding additional complexity or steps to the assembly process.

The results of this design change can be seen in the DFA analysis as there are dramatic improvements in the handling, insertion and secondary operations scores with Error proofing being the only one not to hit the targeted score. There are still some components that remain as potential inefficiencies in the assembly process. The inclusion of a spring used to cycle the dispenser door in both designs adds a component easily tangled with other like components and requires the assembler to hold it in place as the door is installed. The volume view door was unchanged and is completely symmetric but is required to be installed in a specific orientation. Lastly, the DC connector is a panel mount style which requires a backing nut to be screwed onto the inside. These are all minor inefficiencies but lead to a significant hit to the targeted score due to the relatively simple theoretical design.

Table 6: Redesigned Grain Dispenser DFA analysis

DFA Analysis Worksheet									
Assembly Name:	Redesigned Rice Dispenser								
Part		**DFA Complexity**		**Functional Analysis / Redesign Opportunity**				**Error Proofing**	
Part Number	**Part Name**	**Number of Parts (Np)**	**Number of Interfaces (Ni)**	**Theoretical Minimum Part**	**Part Can Be Standardized (if not already standard)**	**Cost (Low/Medium/High)**	**Practical Minimum Part**	**Assemble Wrong Part/ Omit Part**	**Assemble Part Wrong Way Around**
101	Tub	1	8	1	0	LOW	1	0	0
102	Auger	1	2	0	0	LOW	0	0	0
103	Auger Clip	1	2	0	0	LOW	0	0	0
104	Servo Cover	1	2	0	0	LOW	0	0	0
105	Rumble housing	1	2	0	0	LOW	0	0	0
106	Rumble pack	1	1	0	0	LOW	0	0	0
107	Motor	1	2	0	0	MEDIUM	0	0	0
108	DC Panel Connector	1	1	0	0	LOW	0	0	0
109	Limit Switch	1	2	0	0	LOW	0	0	1
110	Lid	1	3	0	0	LOW	1	0	0
111	Lid Latch	2	2	0	0	LOW	0	0	0
112	Lid Gasket	1	2	0	0	LOW	0	0	0
113	Base	1	2	1	0	LOW	1	0	0
114	Button Cover	1	1	0	0	LOW	0	0	0
115	Dispenser door	1	2	1	0	LOW	1	0	0
116	Dispenser door Bracket	1	2	0	0	LOW	1	0	0
117	View plate	1	1	1	0	LOW	0	0	0
118	Spring	1	2	0	0	LOW	1	0	1
	Totals	19	39	4	0	0	6	0	2
	Design for Assembly Metrics	**27.22131518**		**21.05%**	**←Theor. Effy. Pract. Effy.→**		**31.58%**	**0.5**	
	Targets			**60.00%**			**80.00%**	**0**	

DFA Analysis Worksheet													
Assembly Name:	Redesigned Rice Dispenser	**Team:**	Evan, Jacob, Luke, Rick							**Date:**	11/30/2024		
Part		**Handling**			**Insertion**				**Secondary Operations**				
Part Number	**Part Name**	**Tangle, Nest, or Stick Together**	**Flexible, Fragile, Sharp or Slippery**	**Pliers, Tweezers, or Magnifying Glass Needed**	**Difficult to Align/ Locate**	**Holding Down Required**	**Resistance to Insertion**	**Obstructed Access/ Visibility**	**Re-orient Workpiece**	**Screw, Drill, Twist, Rivet, Bend, or Crimp**	**Weld, Solder, or Glue**	**Paint, Lube, Heat, Apply Liquid or Gas**	**Test, Measure or Adjust**
101	Tub	0	0	0	0	0	0	0	0	0	0	0	0
102	Auger	0	0	0	0	0	0	0	0	0	0	0	0
103	Auger Clip	0	0	0	0	0	0	0	0	0	0	0	0
104	Servo Cover	0	0	0	0	0	0	0	0	0	0	0	0
105	Rumble housing	0	0	0	0	0	0	0	0	0	0	0	0
106	Rumble pack	0	0	0	0	0	0	0	0	0	0	0	0
107	Motor	0	0	0	0	0	0	0	0	0	0	0	0
108	DC Panel Connector	0	0	0	0	0	0	0	1	1	0	0	0
109	Limit Switch	0	0	0	0	0	0	0	0	0	0	0	0
110	Lid	0	0	0	0	0	0	0	0	0	0	0	0
111	Lid Latch	0	0	0	0	0	0	0	0	0	0	0	0
112	Lid Gasket	0	0	0	0	0	0	0	0	0	0	0	0
113	Base	0	0	0	0	0	0	0	0	0	0	0	0
114	Button Cover	0	0	0	0	0	0	0	0	0	0	0	0
115	Dispenser door	0	0	0	0	0	0	0	0	0	0	0	0
116	Dispenser door Bracket	0	0	0	0	0	0	0	0	0	0	0	0
117	View plate	0	0	0	0	0	0	0	0	0	0	0	0
118	Spring	1	0	0	0	1	0	0	0	0	0	0	0
	Totals	1	0	0	0	1	0	0	1	1	0	0	0
	Design for Assembly Metrics	**0.25**			**0.25**				**0.5**				
	Targets	**0.25**			**0.25**				**0.5**				

Economic Analysis - Redesign

For the redesign of the grain dispenser, economic analysis was performed again to compare against the original design. After the various design changes the new total cost ended up being $33.30 which is almost double the original cost at $16.54.

Order of magnitude analysis was also performed on all but the COTS parts. The redesign order of magnitude cost was calculated as $21.26 while the original was $22.49, making the redesign $1.23 less expensive according to this analysis.

Since the redesign is double the cost of the original, the market cost will increase to keep margins reasonable for the producer. The new cost of the redesigned product with added functionality would range from $60 to $80. Even though there is a 50% increase in cost, the added functionality provides a more enjoyable user experience expected from quality kitchen appliances.

Table 7: Redesign economic analysis

Part Number	101	102	103	104	105	106	107	108	109	110
Part Name	Tub	Auger	Auger Clip	Servo Cover	Rumble Housing	Rumble Pack	Motor	DC Panel Connector	Limit Switch	Lid
Cost Element	**ABS**	**ABS**	**ABS**	**ABS**	**ABS**	**COTS**	**COTS**	**COTS**	**COTS**	**ABS**
Material Cost, c_m ($/lb)	$ 0.72	$ 0.72	$ 0.72	$ 0.72	$ 0.72					$ 0.72
Fraction of Process that is Scrap, *f*	0.05	0.05	0.05	0.05	0.05					0.05
Mass of Part, *m* (lb)	1.49	0.14	0.0006	0.041	0.009					0.2
C_m Unit Cost of Material	**$ 1.1293**	**$ 0.1061**	**$ 0.0005**	**$ 0.0311**	**$ 0.0068**					**$ 0.1516**
Labor Cost, c_w ($/hr)	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00					$ 26.00
Production Rate, *n* ' (units/hr)	60	60	60	60	60					60
C_L Unit Cost of Labor	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**					**$ 0.4333**
Tooling Cost, c_t ($/set)	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00					$ 20,000.00
Total Production Run, *n* (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000					1,000,000
Tooling Life, n_t (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000					1,000,000
Sets of Tooling Required, *k*	1	1	1	1	1					1
C_T Unit Cost of Tooling	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**					**$ 0.0200**
Capital Cost, c_e ($)	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00					$ 84,000.00
Captial Write-Off Time, t_{wo} (yrs)	5	5	5	5	5					5
Load Fraction, *L* (fraction)	1	1	1	1	1					1
Load Sharing Fraction, *q*	1	1	1	1	1					1
C_E Unit Cost of Capital Equipment	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**					**$ 0.0700**
Factory Overhead, c_{OH} ($/hr)	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00					$ 60.00
Production Rate, *n* ' (units/hr)	60	60	60	60	60					60
C_{OH} Unit Cost of Factory Overhead	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**					**$ 1.0000**
Total Unit Cost = $C_M + C_L + C_T + C_E + C_{OH}$	**$ 2.6526**	**$ 1.6294**	**$ 1.5238**	**$ 1.5544**	**$ 1.5302**	**$ 3.4500**	**$ 3.5900**	**$ 0.1000**	**$ 2.0000**	**$ 1.6749**
Cost of Various Part via CustomPartNet										
Total Product Cost = Sum of Total Unit Costs	**$ 33.3040**									
Order of Magnitude Calculation:	**$ 21.2629**									
Material Cost:	$ 1.07	$ 0.10	$ 0.00	$ 0.03	$ 0.01	$ -	$ -	$ -	$ -	$ 0.14
MFG Cost:	$ 3.22	$ 0.30	$ 0.00	$ 0.09	$ 0.02	$ -	$ -	$ -	$ -	$ 0.43
Price:	$ 9.66	$ 0.91	$ 0.00	$ 0.27	$ 0.06	$ -	$ -	$ -	$ -	$ 1.30

Part Number	111	112	113	114	115	116	117	118	119
Part Name	Lid Latch	Lid Gasket	Base	Button Cover	Dispenser Door	Dispenser Door Bracket	View Plate	Spring	Wiring Harness
Cost Element	**ABS**	**Silicon**	**ABS**	**ABS**	**ABS**	**HDPE**	**PC**	**COTS**	**COTS**
Material Cost, c_m ($/lb)	$ 0.72	$ 0.33	$ 0.72	$ 0.72	$ 0.72	$ 0.30	$ 1.45		
Fraction of Process that is Scrap, *f*	0.05	0.15	0.05	0.05	0.05	0.05	0.05		
Mass of Part, *m* (lb)	0.014	0.051	1.17	0.01	0.05	0.03	0.06		
C_m Unit Cost of Material	**$ 0.0106**	**$ 0.0198**	**$ 0.8867**	**$ 0.0076**	**$ 0.0379**	**$ 0.0095**	**$ 0.0916**		
Labor Cost, c_w ($/hr)	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00	$ 26.00		
Production Rate, *n '* (units/hr)	120	60	60	60	60	60	60		
C_L Unit Cost of Labor	**ABS**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**	**$ 0.4333**		
Tooling Cost, c_t ($/set)	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00		
Total Production Run, *n* (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000		
Tooling Life, n_t (units)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000		
Sets of Tooling Required, *k*	1	1	1	1	1	1	1		
C_T Unit Cost of Tooling	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**	**$ 0.0200**		
Capital Cost, c_e ($)	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00	$ 84,000.00		
Captial Write-Off Time, t_{wo} (yrs)	5	5	5	5	5	5	5		
Load Fraction, *L* (fraction)	1	1	1	1	1	1	1		
Load Sharing Fraction, *q*	1	1	1	1	1	1	1		
C_E Unit Cost of Capital Equipment	**$ 0.0350**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**	**$ 0.0700**		
Factory Overhead, c_{OH} ($/hr)	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00	$ 60.00		
Production Rate, *n '* (units/hr)	120	60	60	60	60	60	60		
C_{OH} Unit Cost of Factory Overhead	**$ 0.5000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**	**$ 1.0000**		
Total Unit Cost = $C_M + C_L + C_T + C_E + C_{OH}$	**$ 0.5656**	**$ 1.5431**	**$ 2.4101**	**$ 1.5309**	**$ 1.5612**	**$ 1.5328**	**$ 1.6149**	**$ 1.2900**	**$ 1.5500**
Cost of Various Part via CustomPartNet									
Total Product Cost = Sum of Total Unit Costs									
Order of Magnitude Calculation:									
Material Cost:	$ 0.01	$ 0.02	$ 0.84	$ 0.01	$ 0.04	$ 0.01	$ 0.09	$ -	$ -
MFG Cost:	$ 0.03	$ 0.05	$ 2.53	$ 0.02	$ 0.11	$ 0.03	$ 0.26	$ -	$ -
Price:	$ 0.09	$ 0.15	$ 7.58	$ 0.06	$ 0.32	$ 0.08	$ 0.78	$ -	$ -

Material and Manufacturing Analysis

When choosing materials there are several factors that need to be considered such as strength requirements, functionality, geometry and manufacturing processes available and cost to name a few. For this product there are several components that share most of these traits with one another so to streamline the material selection process the components have been split into 4 subcategories: Structure, Mechanisms, Miscellaneous, and COTS. Material and process selection for each of these categories was done with a simplified version for the COTS components done as we are not purchasing these components. The parts are broken into their categories as follows:

Structure

These are components that make up the main structure of the grain dispenser and typically do not move. Since there are no major loads applied to this product, and these are static components, only one material selection will be performed for all parts in this category. Making all these components from the same material will help to decrease costs as more material can be bulk ordered, and all machines can be calibrated to a specific material.

<u>Components</u>:

- 101 – Tub
- 103 – Auger Clip
- 105 – Rumble pack housing
- 110 - Lid
- 113 - Base
- 114 – Button Cover

<u>Key Characteristics</u>:

- Able to manufacture complex geometries cheap, fast, and on a large scale
- Food safe, easy to clean, and/or bacterial resistant
- Rigid enough to prevent deformation while handling with everyday use
- Moderate strength or better
- Moderate durability and impact resistance or better to prevent breaking if dropped from shoulder height
- Low Cost
- Smooth surface texture
- Non-porous

The main driver for selection of these parts will be low cost and high-volume materials as well as available manufacturing methods. Right away we can eliminate some materials as they do not meet one or multiple of the basic criteria set for these parts. These eliminated materials are:

- Natural materials
- Woods
- Ceramics
- Foams

Using 9 we can determine that all components in this category fall in the S/SS4-6 or the U7 complexity. This leaves only injection molding and milling as viable manufacturing process candidates. However, with production numbers expected to be in the 10,000-100,000+ we can eliminate milling as a cost-effective method as shown in Figure 11, leaving only injection molding as a viable process.

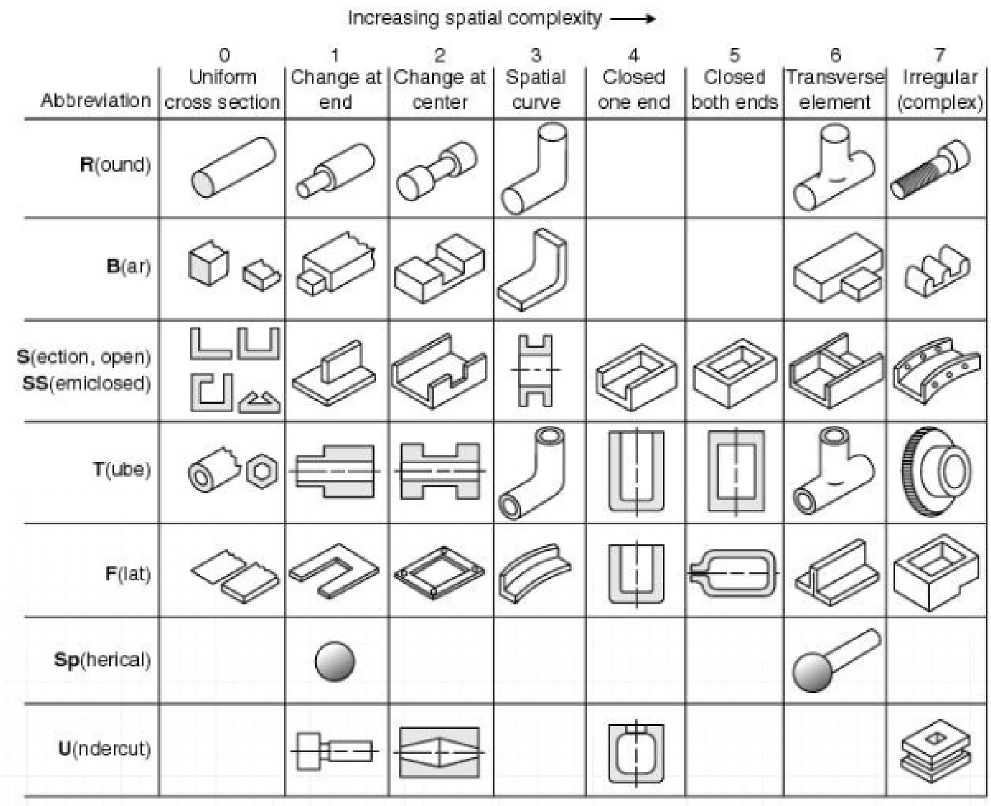


Figure 13: Part Complexity chart

Ability of Manufacturing Processes to Produce Shapes

Process	Capability for Producing Shapes
Casting processes	
Sand casting	Can make all shapes
Plaster casting	Can make all shapes
Investment casting	Can make all shapes
Permanent mold	Can make all shapes except T3, T5; F5; U2, U4, U7
Die casting	Same as permanent mold casting
Deformation processes	
Open-die forging	Best for R0 to R3; all B shapes; T1; F0; Sp6
Hot impression die forging	Best for all R, B, and S shapes; T1, T2; Sp
Hot extrusion	All 0 shapes
Cold forging/cold extrusion	Same as hot die forging or extrusion
Shape drawing	All 0 shapes
Shape rolling	All 0 shapes
Sheet-metal working processes	
Blanking	F0 to F2; T7
Bending	R3; B3; S0, S3, S7; T3; F3, F6,
Stretching	F4; S7
Deep drawing	T4; F4, F7
Spinning	T1, T2, T4, T6; F4, F5
Polymer processes	
Extrusion	All 0 shapes
Injection molding	Can make all shapes with proper coring
Compression molding	All shapes except T3, T5, T6, F5, U4
Sheet thermoforming	T4, F4, F7, S5
Powder metallurgy processes	
Cold press and sinter	All shapes except S3, T2, T3, T5, T6, F3, F5, all U shapes
Hot isostatic pressing	All shapes except T5 and F5
Powder injection molding	All shapes except T5, F5, U1, U4
PM forging	Same shape restrictions as cold press and sinter
Machining processes	
Lathe turning	R0, R1, R2, R7; T0, T1, T2; Sp1, Sp6; U1, U2
Drilling	T0, T6
Milling	All B, S, SS shapes; F0 to F4; F6, F7, U7
Grinding	Same as turning and milling
Honing, lapping	R0 to R2; B0 to B2; B7; T0 to T2, T4 to T7; F0 to F2; Sp

Figure 14: Part process availability based on part complexity

MATERIAL / QUANTITY	IRONS	STEEL (carbon)	STEEL (tool, alloy)	STAINLESS STEEL	COPPER & ALLOYS	ALUMINIUM & ALLOYS	MAGNESIUM & ALLOYS
VERY LOW 1 TO 100	[1.5][1.6] [1.7][4.M]	[1.5][1.7] [3.10][4.M] [5.1][5.5] [5.6]	[1.1][1.5][1.7] [3.10][4.M] [5.1][5.5] [5.6][5.7]	[1.6][1.7][3.7] [3.10][4.M] [5.1][5.5][5.6]	[1.5][1.7] [3.6][4.M] [5.1]	[1.5][1.7] [3.7][3.10] [4.M][5.5]	[1.6][1.7] [3.10][4.M] [5.1][5.5]
LOW 100 TO 1,000	[1.2][1.5] [1.6][1.7] [4.M] [5.3][5.4]	[1.2][1.6] [1.7][1.10] [4.M][5.1] [5.3][5.4][5.5]	[1.1][1.2][1.7] [4.M][5.1] [5.3][5.4] [5.5][5.6][5.7]	[1.2][1.7] [3.7][3.10] [4.M][5.3] [5.3][5.4][5.5]	[1.2][1.3][1.5] [1.7][1.8][3.3] [3.6][4.M][5.1] [5.3][5.4]	[1.2][1.5][1.7] [1.8][3.7][3.10] [4.M][5.3] [5.4][5.5]	[1.6][1.7] [1.8][3.10] [4.M][5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.2][1.3] [1.5][1.6] [1.7][3.11] [4.A][5.2]	[1.2][1.3][1.5] [1.7][3.1][3.3] [3.10][3.11] [4.A][5.2][5.3] [5.4][5.5]	[1.2][1.5][1.7] [3.1][3.4][3.11] [4.A][5.2][5.3] [5.4][5.5]	[1.2][1.5][1.7] [3.1][3.2][3.7] [3.10][3.11] [4.A][5.2][5.3] [5.4][6.0]	[1.2][1.3][1.5] [1.8][3.1][3.2] [3.10][3.11][4.A] [5.2][5.3][5.4]	[1.2][1.3][1.4] [1.5][3.1][3.3] [3.7][3.10][3.11] [4.A][5.3][5.4][5.5]	[1.3][1.5] [1.8][3.1] [3.3][3.4][3.10] [4.A][5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.2][1.3] [3.11][4.A]	[1.0][2.1][3.3] [3.4][3.5] [3.11][3.12] [4.A][5.2][5.5]	[3.1][3.4][3.5] [3.11][3.12] [4.A][5.2]	[1.0][3.1] [3.3][3.4] [3.5][3.11] [3.12][4.A]	[1.2][1.4][1.8] [3.1][3.3] [3.4][3.5][3.11] [3.12][4.A]	[1.2][1.3][1.4] [1.8][3.1][3.3] [3.4][3.5][3.11] [3.12][4.A][5.5]	[1.3][1.4] [3.1][3.3] [3.4][3.5] [3.12][4.A]
HIGH 100,000+	[1.2][1.3] [3.11][4.A]	[1.9][3.1] [3.2][3.3] [3.4][3.5] [3.12][4.A]	[4.A]	[1.9][3.2] [3.3][4.A]	[1.2][1.M][3.1] [3.2][3.3][3.4] [3.5][3.7][3.8] [3.11][3.12][4.A]	[1.2][1.3][1.4] [1.6][3.1][3.2] [3.3][3.4][3.5] [3.8][3.12][4.A]	[1.3][1.4] [3.1][3.3][3.4] [3.8][3.12][4.A]
ALL QUANTITIES	[1.1]	[1.1][1.5] [3.0][3.0] [3.0]	[1.6][3.6]	[1.1][1.6] [3.6][3.8][3.9]	[1.1][1.6] [3.6][3.8] [3.9][5.5]	[1.1][1.6] [3.4][3.5] [3.6]	[1.1][3.5] [3.6][3.8]

MATERIAL / QUANTITY	ZINC & ALLOYS	TIN & ALLOYS	LEAD & ALLOYS	NICKEL & ALLOYS	TITANIUM & ALLOYS	THERMOPLASTICS	THERMOSETS	FR COMPOSITES	CERAMICS	REFRACTORY METALS	PRECIOUS METALS
VERY LOW 1 TO 100	[1.1][1.7] [3.10][4.M] [5.5]	[1.1][1.7] [3.10][4.M] [5.5]	[1.1][3.10] [4.M][5.5]	[1.5][1.7] [3.10][4.M] [5.1][5.5][5.6]	[1.1][1.6] [3.7][3.10] [4.M][5.1] [5.5][5.6][5.7]	[2.5] [2.7]	[2.5] [3.7]	[2.2] [2.6] [5.7]	[1.5] [5.1] [5.5] [5.6] [5.7]	[1.1] [5.7]	[5.5]
LOW 100 TO 1,000	[1.1][1.7] [1.8][3.10] [4.M][5.5]	[1.1][1.7] [1.8][3.10] [4.M][5.5]	[1.1][1.8] [3.10][4.M] [5.5]	[1.2][1.5][1.7] [3.10][4.M] [5.1][5.3] [5.4][5.5][5.6]	[1.1][1.6][3.7] [3.10][4.M][5.1] [5.3][5.4][5.5] [5.6][5.7]	[2.3] [2.5] [2.7]	[2.2] [2.3]	[2.2] [2.3] [2.6] [5.7]	[5.1] [5.3] [5.5] [5.6] [5.7]	[5.7]	[5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.3][1.8] [3.3][3.10] [4.A][5.5]	[1.3][1.5] [3.2][3.10]	[1.3][1.5] [3.3][3.10]	[1.2][1.3][1.5] [1.7][3.1][3.2] [3.11][4.A][5.1] [5.3][5.4][5.5] [3.10]	[3.1][3.7] [3.10][3.11] [4.A][5.2] [5.3][5.4][5.5]	[2.3] [2.5] [2.6] [2.7]	[2.2] [2.3] [2.4]	[2.1] [2.2] [2.3]	[5.2] [5.3] [5.4] [5.5]		[5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.3][1.4] [3.3][3.4] [3.5][3.12] [4.A]	[1.3][1.4] [3.3][3.4] [3.12]	[1.3][1.4] [3.3][3.4] [3.8][3.12] [4.A]	[3.1][3.3][3.5] [3.4][3.11] [3.12][4.A] [5.2][5.5]	[3.1][3.4] [3.11][3.12] [4.A][5.2][5.5]	[2.1] [2.3] [2.6] [2.7] [2.8]	[2.1] [2.3] [2.9]	[2.1] [2.3]	[3.11]	[3.12]	[3.5]
HIGH 100,000+	[1.4][3.2] [3.3][3.4] [3.5][4.A]	[1.4][3.3] [3.4][4.A]	[1.4][3.2] [3.3][3.4] [4.A]	[3.2][3.3] [4.A]	[4.A]	[2.1] [2.6] [2.8]	[2.1] [2.3] [2.4] [2.9]		[3.7] [3.11]		[3.5]
ALL QUANTITIES	[3.6][3.8] [3.9]		[3.5]	[1.1][1.6] [3.4][3.5] [3.8]	[3.8][3.9]				[5.5]	[1.5]	[1.6]

KEY TO MANUFACTURING PROCESS PRIMA SELECTION MATRIX:

CASTING PROCESSES
[1.1] SAND CASTING
[1.2] SHELL MOULDING
[1.3] GRAVITY DIE CASTING
[1.4] PRESSURE DIE CASTING
[1.5] CENTRIFUGAL CASTING
[1.6] INVESTMENT CASTING
[1.7] CERAMIC MOULD CASTING
[1.8] PLASTER MOULD CASTING
[1.9] SQUEEZE CASTING

PLASTIC & COMPOSITE PROCESSING
[2.1] INJECTION MOULDING
[2.2] REACTION INJECTION MOULDING
[2.3] COMPRESSION MOULDING
[2.4] TRANSFER MOULDING
[2.5] VACUUM MOULDING
[2.6] BLOW MOULDING
[2.7] ROTATIONAL MOULDING
[2.8] CONTACT MOULDING
[2.9] CONTINUOUS EXTRUSION (PLASTICS)

FORMING PROCESSES
[3.1] CLOSED DIE FORGING
[3.2] ROLLING
[3.3] DRAWING
[3.4] COLD FORMING
[3.5] COLD HEADING
[3.6] SWAGING
[3.7] SUPERPLASTIC FORMING
[3.8] SHEET-METAL SHEARING
[3.9] SHEET-METAL FORMING
[3.10] SPINNING
[3.11] POWDER METALLURGY
[3.12] CONTINUOUS EXTRUSION (METALS)

MACHINING PROCESSES
[4.A] AUTOMATIC MACHINING
[4.M] MANUAL MACHINING

(THE ABOVE HEADINGS COVER A BROAD RANGE OF MACHINING PROCESSES AND LEVELS OF CONTROL TECHNOLOGY. FOR MORE DETAIL, THE READER IS REFERRED TO THE INDIVIDUAL PROCESSES.)

NTM PROCESSES
[5.1] ELECTRICAL DISCHARGE MACHINING (EDM)
[5.2] ELECTROCHEMICAL MACHINING (ECM)
[5.3] ELECTRON BEAM MACHINING (EBM)
[5.4] LASER BEAM MACHINING (LBM)
[5.5] CHEMICAL MACHINING (CM)
[5.6] ULTRASONIC MACHINING (USM)
[5.7] ABRASIVE JET MACHINING (AJM)

Figure 15: Process availability per material and quantity

With this information in mind, we can start to narrow down the specific materials that will be used. Injection molding is done mainly with thermoplastics as outlined in Figure 12.

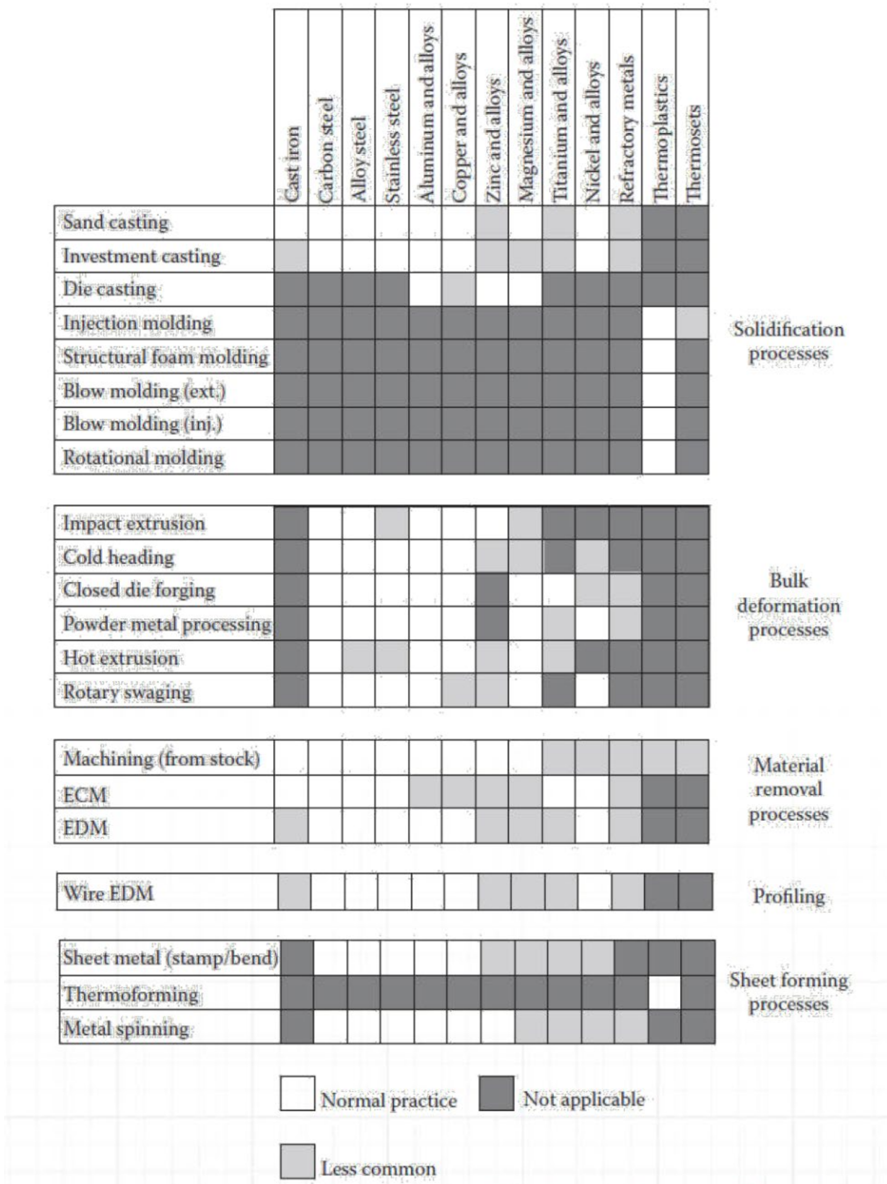


Figure 16: Process availability per material type

Using the Ashby chart in 13 we can further identify the best candidates from the materials. All these parts can be best described as plates or sheets, so our performance characteristic is governed by the equation below:

$$C = \frac{{\sigma_f}^{\frac{1}{2}}}{C_R \rho} \qquad (2)$$

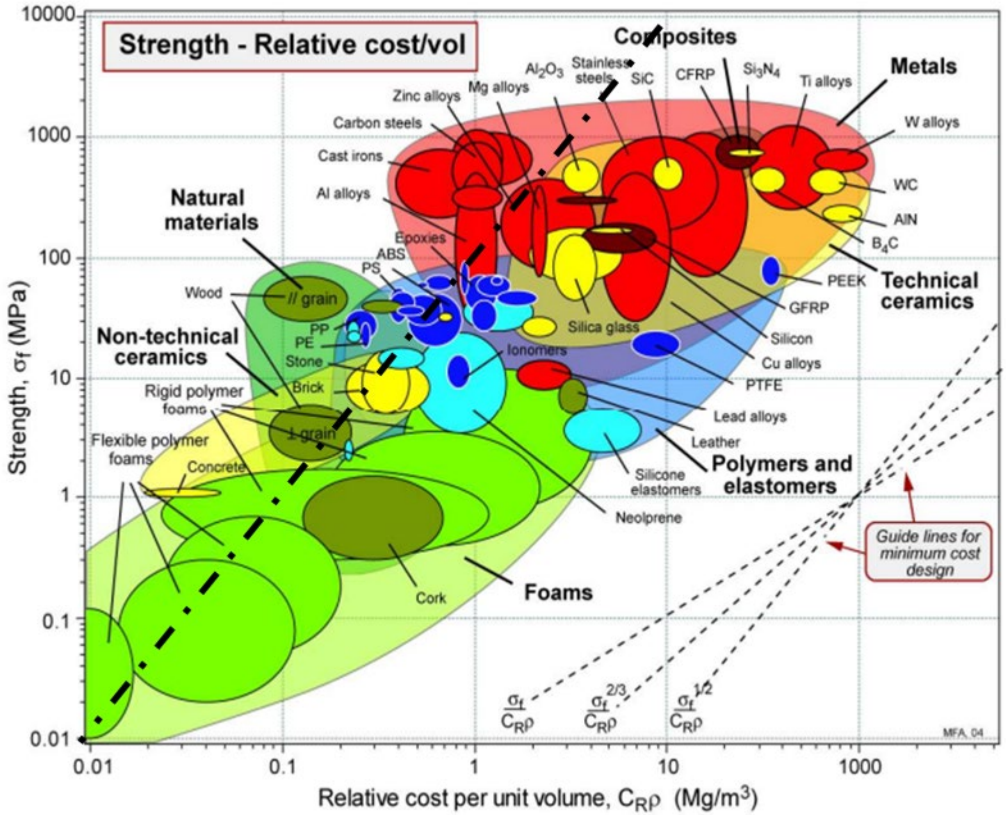


Figure 17: Ashby chart of material strength vs cost

Aiming for as minimal a cost as possible, we can follow the black dotted line to the best potential fits for these applications. ABS is a solid choice as it is a very common material used in injection molding, is relatively cheap, can come in almost any color and has decent impact resistance which will prevent the dispenser from breaking or being damaged in the event of a fall form countertop height.

Mechanisms

These are components that make up the moving parts of the grain dispenser. These are low force operations that are expected to be cycled hundreds or thousands of times across the lifespan of the product. Each component has unique functions that need to be accounted for when selecting materials.

<u>Components</u>:

- 102 – Auger
- 111 – Lid Latch
- 115 – Dispenser Door
- 116 – Dispenser Door Spacer

Key Characteristics:

- Auger: the auger will be constantly pushing the grain or other food material through the tub towards the dispenser door. Due to this the auger will need to be made of a relatively wear resistant material
- Lid Latch: needs to be rigid as its ability to hold its shape will determine how snuggly the lid stays sealed. Some deflection is fine and is even preferred but the material must hold its shape while under a moderate load
- Dispenser door and Dispenser door Spacer: both components will be making direct contact with each other as they slide past each other. A low friction surface and good wear resistance is vital to prevent component degradation and prevent shavings of the material from ending up in the user's food. This is a relatively low force operation so overall strength is not as critical.

Starting the same way with these components as we did with the structures group, we can quickly determine that injection molding is also the best manufacturing method for these components. Each of these components fall in the S/SS0-4 part complexity from Figure 9 meaning milling and injection molding are the best options available. However, for the same reasons as outlined before milling is not viable from a cost standpoint. ABS has good wear resistance and is rigid. Combine these factors with the advantages outlined in the structures section and it remains a good choice for the auger. While there are better options in terms of strength that can be used with the lid latch it is still best to go with ABS. The main reason being that the mating surface is located on the tub which is also made of ABS. Using the same material for both not only saves on cost but also ensures that neither side is made from a harder plastic that would lead to uneven wearing or marring of one of the interfaces. ABS is rigid enough to last the lifetime of the product and is often used in similar applications on storage cases and houseware.

The ideal material to use on components that need low friction contact points would be PTFE (Teflon). PTFE is expensive and difficult to injection mold due to its high viscosity when melted. An alternative low friction plastic would be high density Polyethylene (HDPE). HDPE is easy to injection mold, has similar strength characteristics to ABS and has a low coefficient of friction. While HDPE is less impact resistant than ABS, these components are largely internal and will be protected from impacts by the tub and base.

Miscellaneous

These are components that make up the remainder of the assembly and do not fit in a specific category

Components:

- 112 – Lid Gasket
- 117 – View Plate

Key Characteristics:

- Lid Gasket: The lid gasket will be used to seal the tub from the outside air. This component needs to be flexible and soft to conform to the interface between the lid and tub. This material will also provide the force that will keep the lid latches engaged so it will need some elasticity when compressed.
- View Plate: The volume view plate will be visible from the front of the assembly and need to be clear to see the volume levels of the food inside. It will also need to have the same impact resistance as the components in the structure category since it is an external component

These components are quite a bit different in shape and size than any other components. Both are relatively flat giving the lid gasket an F2 complexity and the view plate and F0 complexity from Figure 9. This allows almost all types of manufacturing to be considered for this application. However, several materials can be eliminated immediately since they do not meet the key criteria for these parts. Metals, foams and natural materials are not clear and will not work for the view plate while metals, natural materials (except for rubber), ceramics and most thermoplastics are not elastic and soft enough to be considered for the gasket. This leaves thermoplastics and glasses for the view plate and rubber, foam, and elastomers for the gasket. However, Figure 11 shows that many of these materials do not have cost effective processes to produce such high quantities of parts in these forms. Foam is a cheap material in the Ashby chart in Figure 13 but would be an expensive material to manufacture while thermoplastics are cheaper in material cost and manufacturing methods for the view plate. Plus, the lack of adequate impact resistance with cheaper glass options raises safety concerns when in contact with food items. Considering these factors the best choice for the viewing plate would be polycarbonate as it is cheap, clear, easy to injection mold, and has impact resistance like ABS. Acetal is another easily injection molded clear thermoplastic, but it lacks the impact resistance needed for this part. For the gasket there are several injection molding options such as silicon rubber, buna-n rubber, latex materials, or neoprene but the best option would be thermoplastic rubber (TPR) due to its cheap pgrain and ease of injection molding.

COTS

For the COTS product specific material selection is not available so material selection can only go so far as to make sure the materials used are food safe and compatible with the interfacing components. All of the COTS products are made of various common metals and plastics that are safe with all the materials selected above.

Professional, Ethical, and Safety Discussion

While a grain dispenser is a relatively simple kitchen gadget, addressing professional, ethical, and safety concerns is essential to ensure the product's reliability and trustworthiness. The foremost priority is the safety of the materials used. The dispenser must be constructed from certified food-safe materials to prevent harmful substances from leaching into the stored grain, safeguarding consumer health. Given the growing awareness of microplastics contamination in food, the design must take measures to avoid contributing to this global issue, ensuring the materials used are durable and resistant to degradation over time.

Incorporating an auger mechanism to prevent clogs introduces additional safety considerations. Without proper safeguards, the auger could pose a risk of injury to users who might inadvertently reach into the dispenser while it is in operation. To mitigate this risk, the design will include a sensor system that prevents the auger from operating unless the lid is securely in place. This safety feature ensures that users cannot access moving components during operation, effectively reducing the likelihood of accidents. Additionally, clear warning labels will be strategically placed to alert users to potential pinch points, further enhancing the product's safety profile. These measures collectively ensure that the grain dispenser is not only functional and efficient but also adheres to the highest standards of safety and ethical responsibility.

Conclusion

This report has focused on redesigning a grain dispenser to improve functionality, durability, and user satisfaction. The analysis began with an assessment of the design problem, highlighting the inadequacies of current market offerings. Through detailed diagrams, including black box and glass box models, the subsystems and functional flows of the dispenser were thoroughly mapped. A fishbone diagram further elucidated the relationship between key components, setting the stage for targeted improvements.

The initial design evaluation revealed deficiencies in material selection, assembly complexity, and user experience. The original bill of materials (BOM) and design-for-assembly (DFA) analysis provided a baseline for understanding cost-effectiveness and assembly challenges, such as the reliance on screws and unstable geometric connections. Economic analysis established the viability of the original design while underscoring opportunities for cost optimization.

Building on this foundation, the redesign introduced significant advancements. New features, such as an auger mechanism, silicone gasket, and vibrational motor, improved consistency, sealing, and clog prevention. Emphasis on DFA principles, including snap-fit connections, reduced assembly complexity and increased structural integrity. The redesign's economic analysis confirmed the cost-effectiveness of these enhancements, maintaining market competitiveness despite increased material and component complexity.

Material and manufacturing analysis ensured that food-safe, durable, and cost-effective materials were selected for the structure, mechanisms, and miscellaneous components. Injection molding emerged as the optimal manufacturing process, balancing precision, efficiency, and scalability. This approach streamlined production and supported the economic feasibility of the redesigned product.

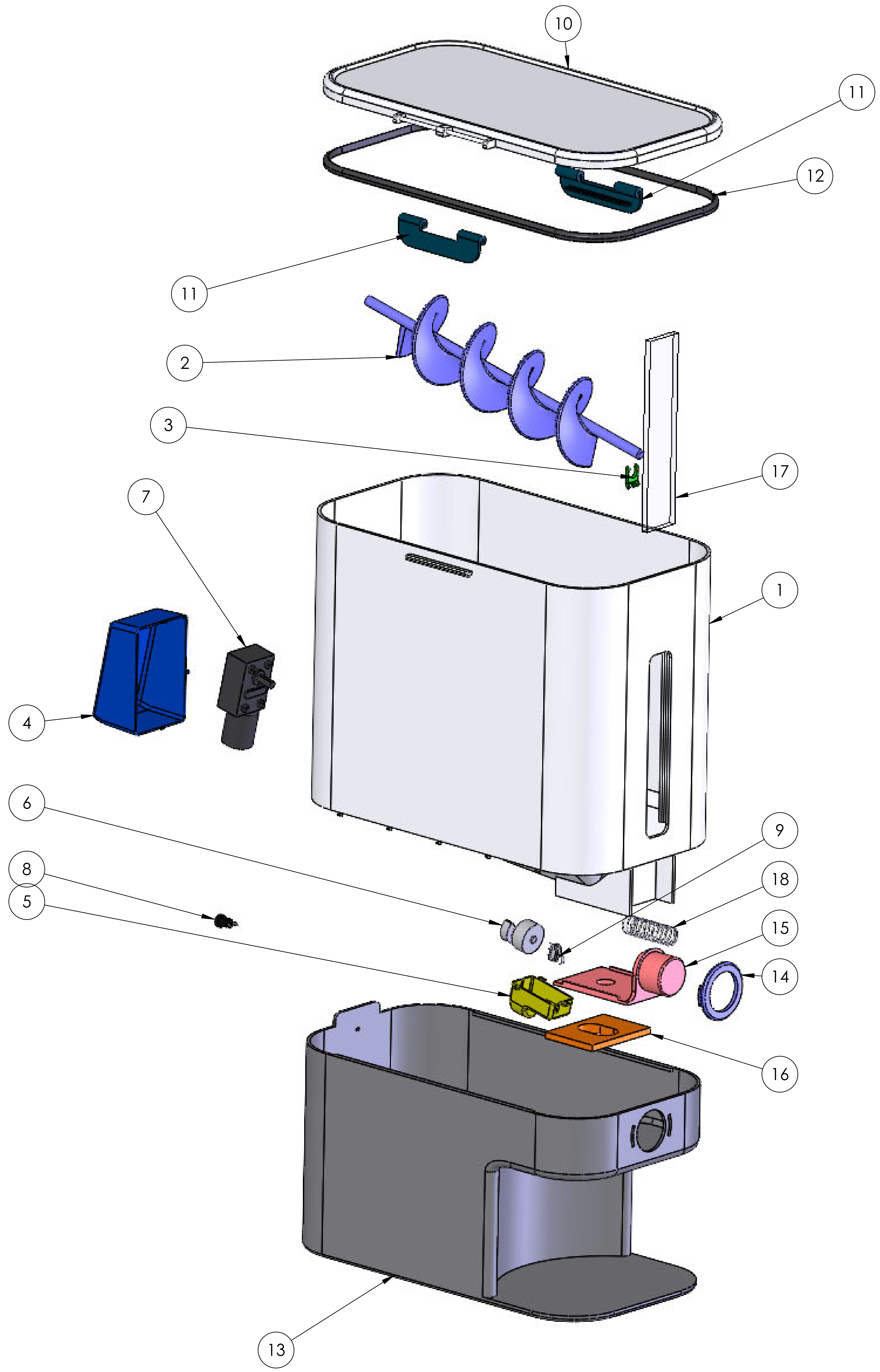
The project adhered to professional, ethical, and safety standards, incorporating features to prevent injury, safeguard food hygiene, and reduce environmental impact. Measures such as safety sensors, clear warning labels, and the use of durable, food-safe materials emphasized user trust and ethical responsibility.

The redesigned grain dispenser addresses the limitations of existing products by combining advanced functionality, improved user experience, and cost-efficiency. It represents a well-engineered solution aligned with the needs of modern consumers, offering a premium, reliable, and desirable addition to the kitchen.

Appendix A – Engineering Drawings

Appendix A contains the complete engineering drawings for the redesigned grain dispenser. This packet includes detailed drawings of all individual components and assemblies, providing comprehensive specifications. Each drawing includes the necessary dimensions, tolerances, and material details required for manufacturing, ensuring the design can be accurately and efficiently produced.

REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	101	TUB	1
2	102	AUGER	1
3	103	AUGER CLIP	1
4	104	MOTOR COVER	1
5	105	RUMBLE PACK HOUSING	1
6	106	RUMBLE PACK LARGE	1
7	107	MOTOR	1
8	108	DC PANEL CONNETOR	1
9	109	MCMASTER PN 7792N15	1
10	110	LID	1
11	111	LID LATCH	2
12	112	LID GASKET	1
13	113	BASE	1
14	114	BUTTON COVER	1
15	115	DISPENSER DOOR	1
16	116	DISPENSER DOOR SPACER	1
17	117	VOLUME VIEW PLATE	1
18	118	MCMASTER PN 9657K484	1
19	119	WIRING HARNESS	1

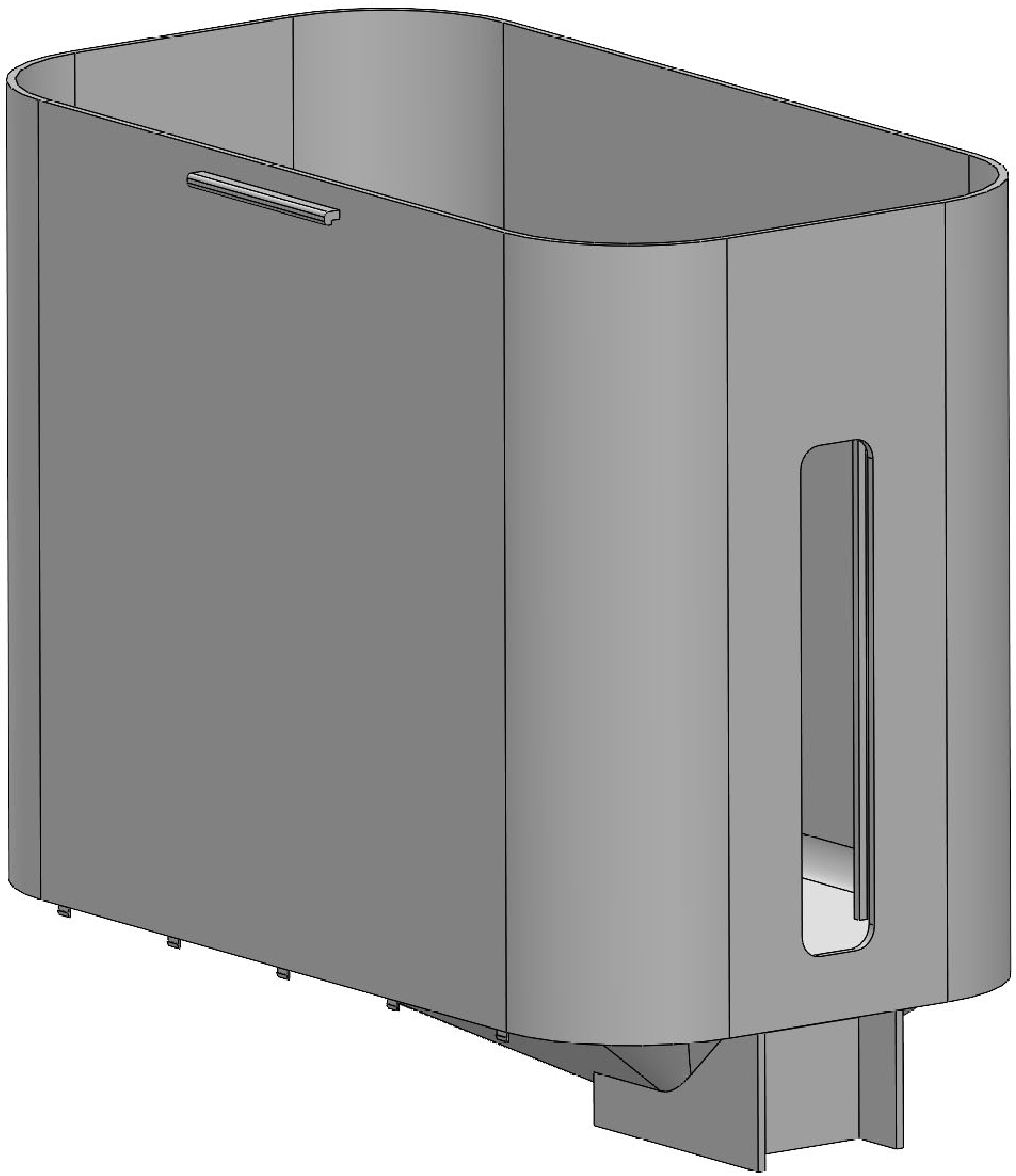
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427

DESCRIPTION
UPDATED DISPENSER

PN	REV	SHEET
200	A	1 of 1

REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/28/2024

NOTES:
1. ALL WALL THICKNESSES ARE .010 UNLESS OTHERWISE SPECIFIED
2. DRAFT ANGLES SHALL BE .5° UNLESS OTHERWISE SPECIFIED



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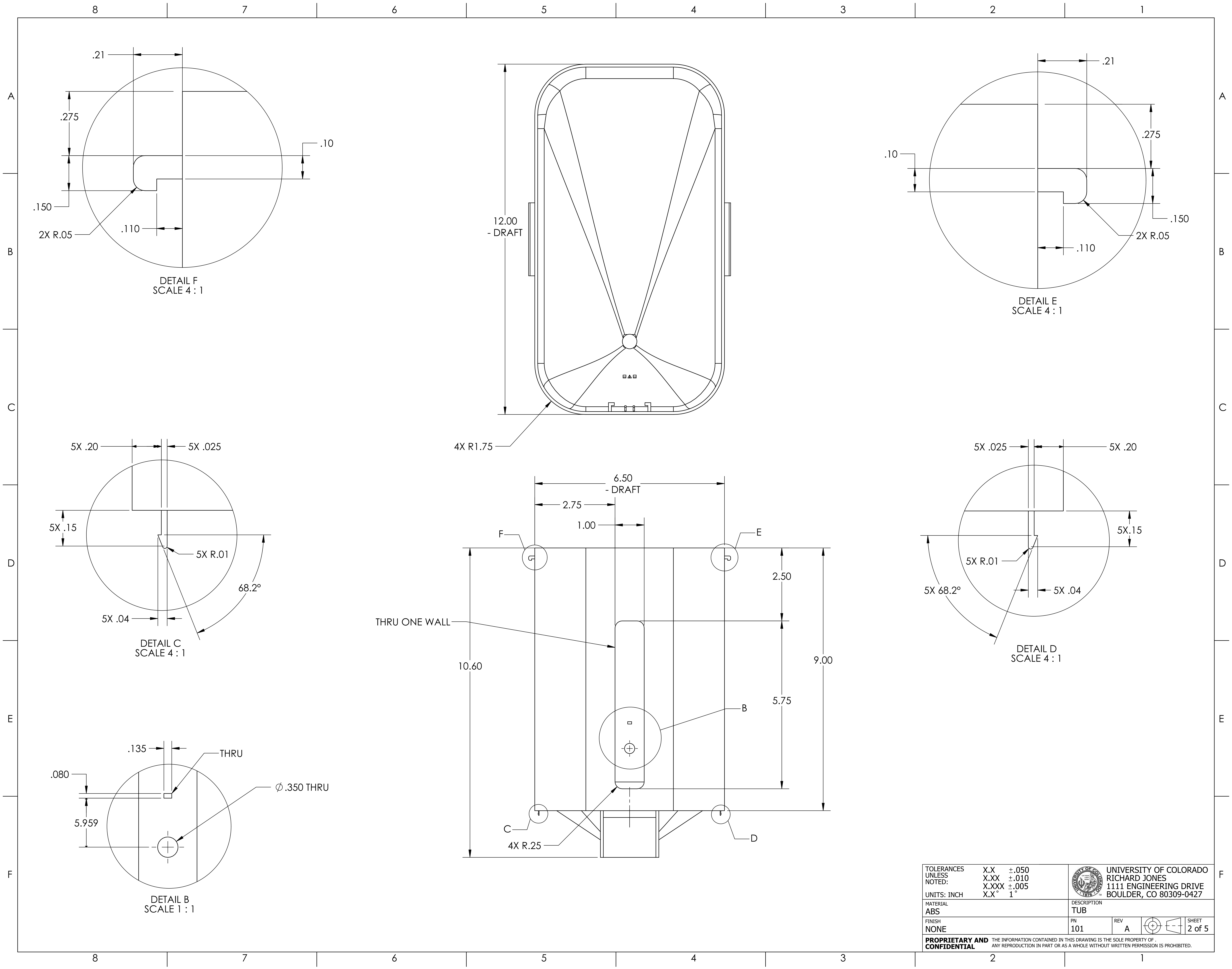

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10.60
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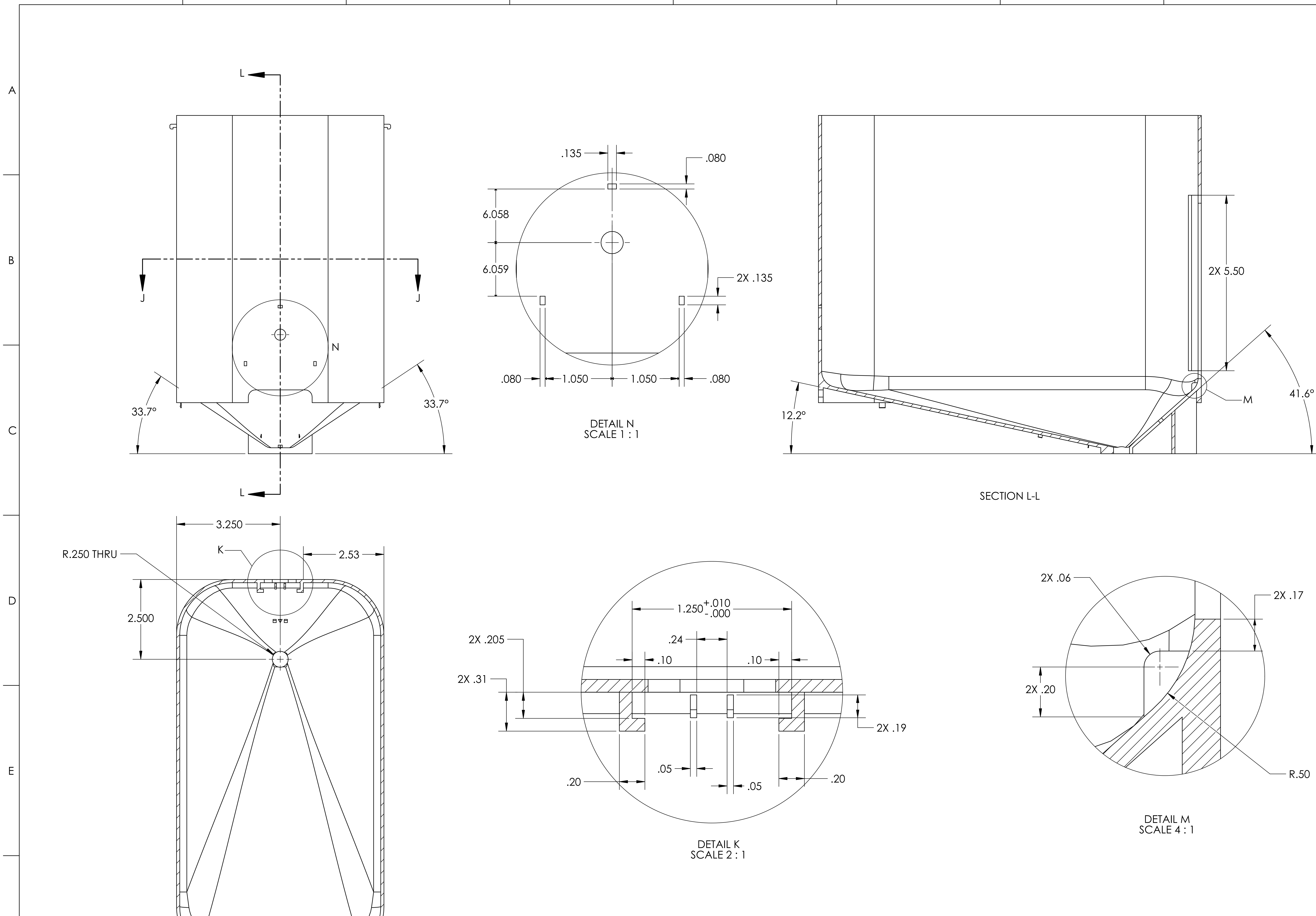
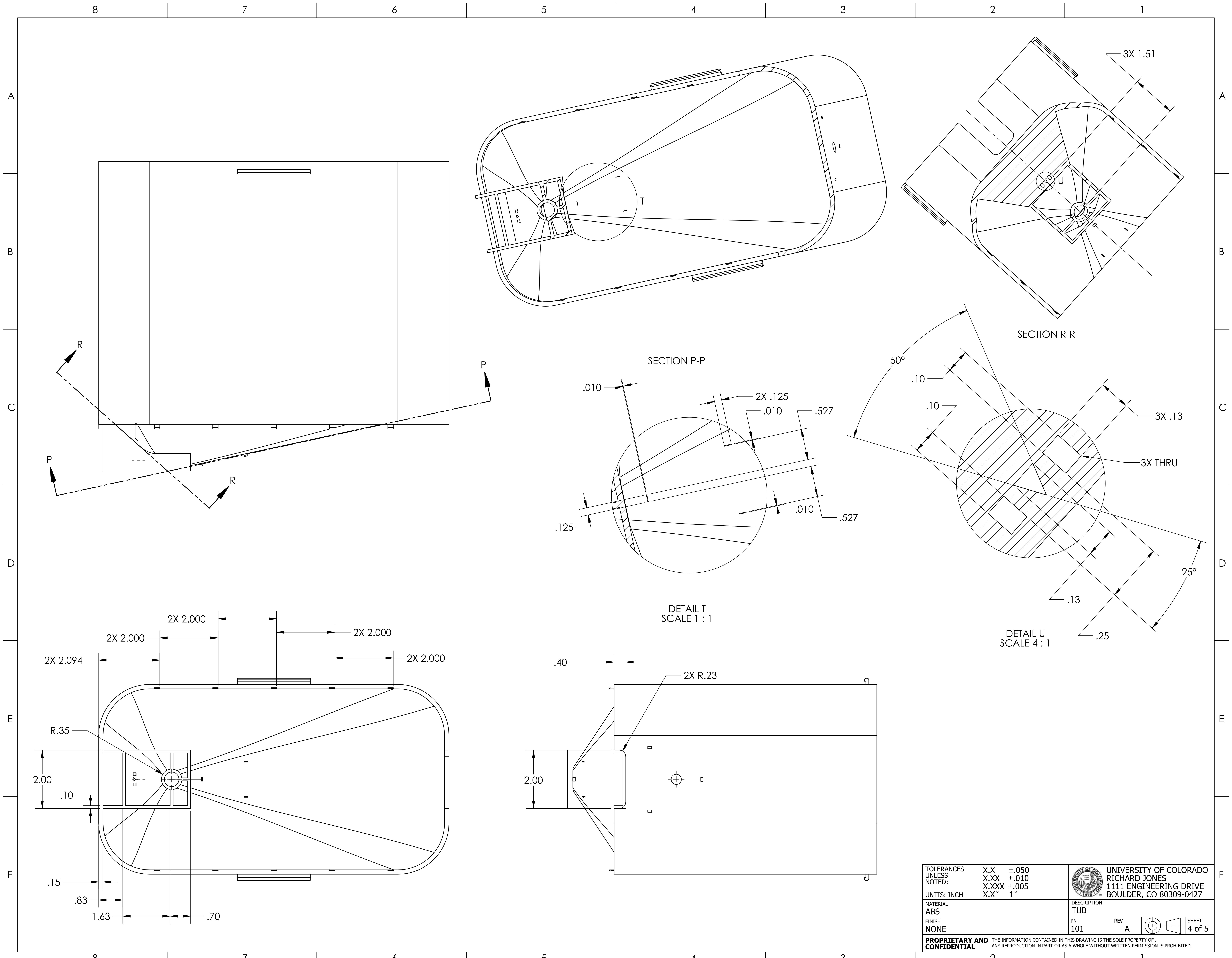


TOLERANCES UNLESS NOTED: UNITS: INCH	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL ABS		DESCRIPTION TUB	
FINISH NONE		PN 101	REV A	SHEET 3 of 5



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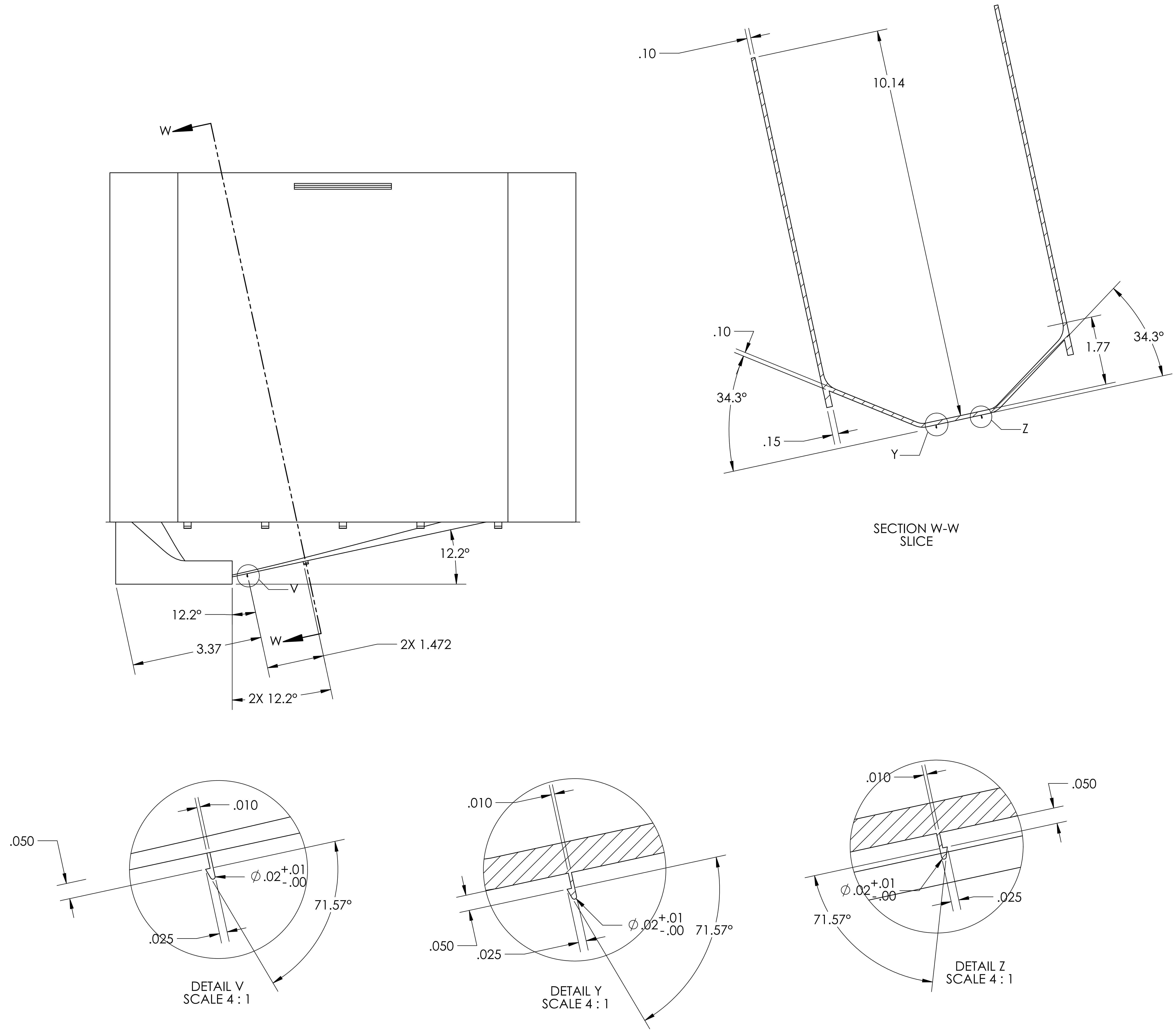
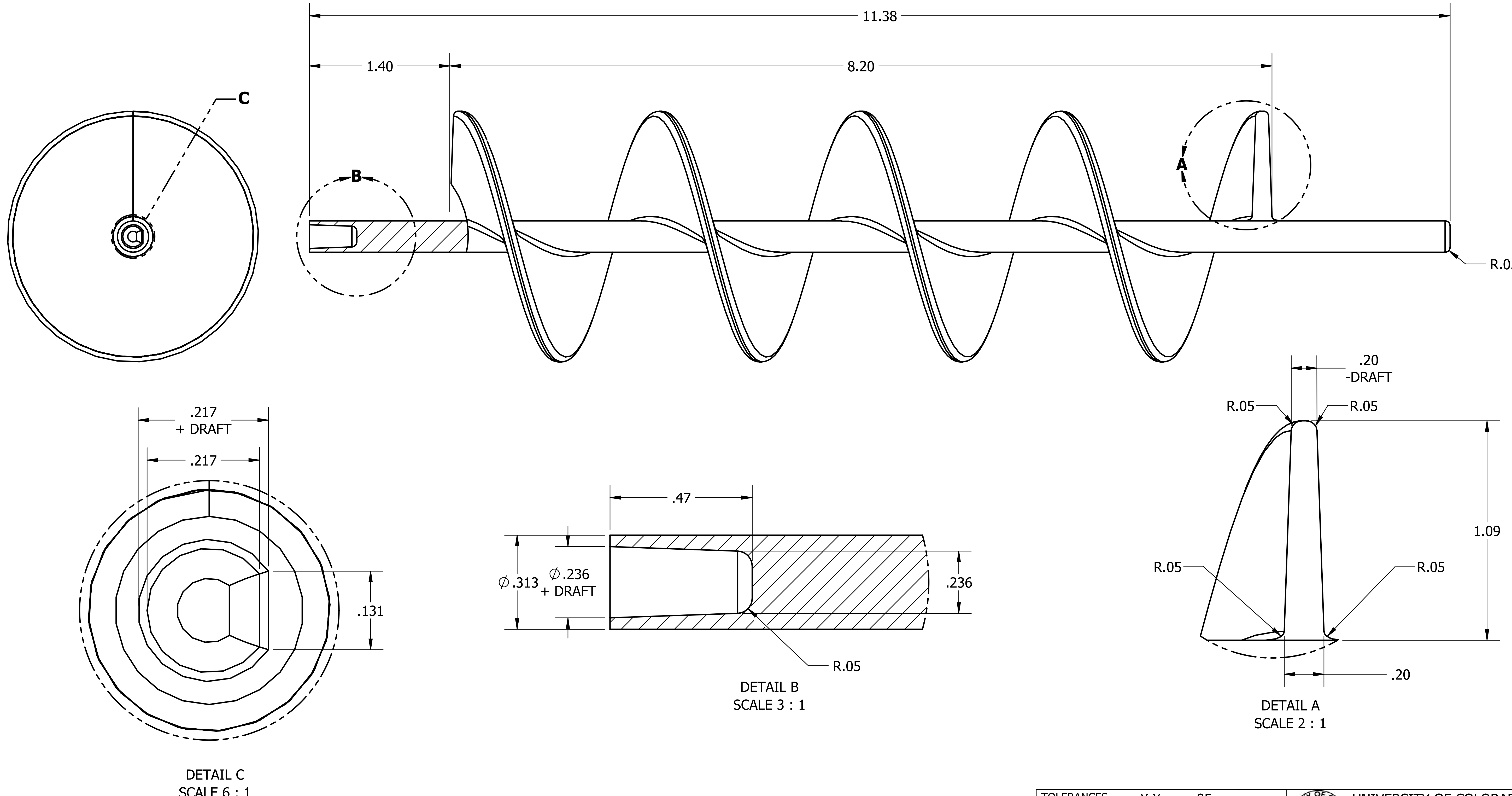


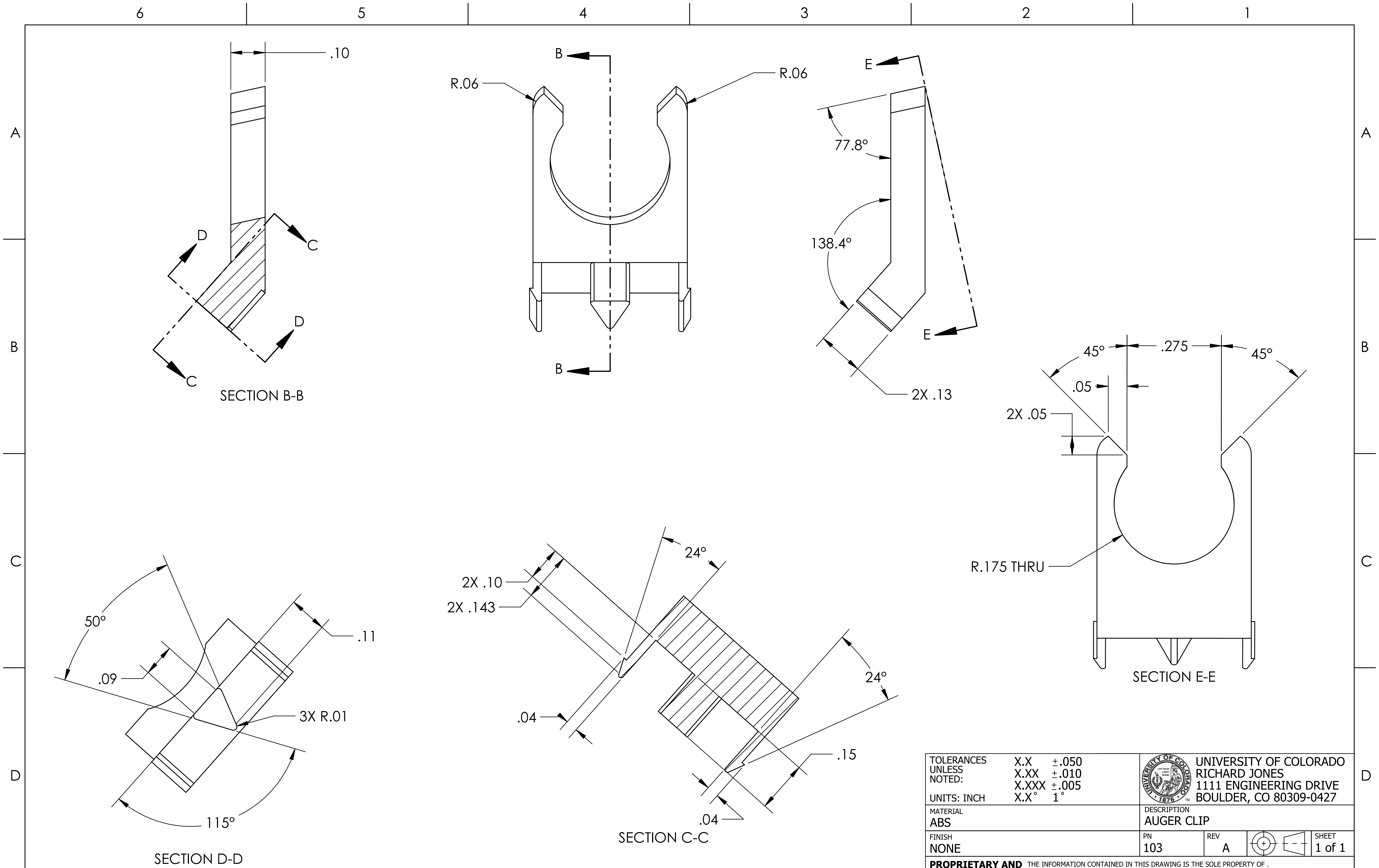
TOLERANCES UNLESS NOTED: X.X ±.050, X.XX ±.010, X.XXX ±.005, X.X° 1°; UNITS: INCH		UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL: ABS		DESCRIPTION: TUB	
FINISH: NONE	PN: 101	REV: A	SHEET: 5 of 5

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/26/2024



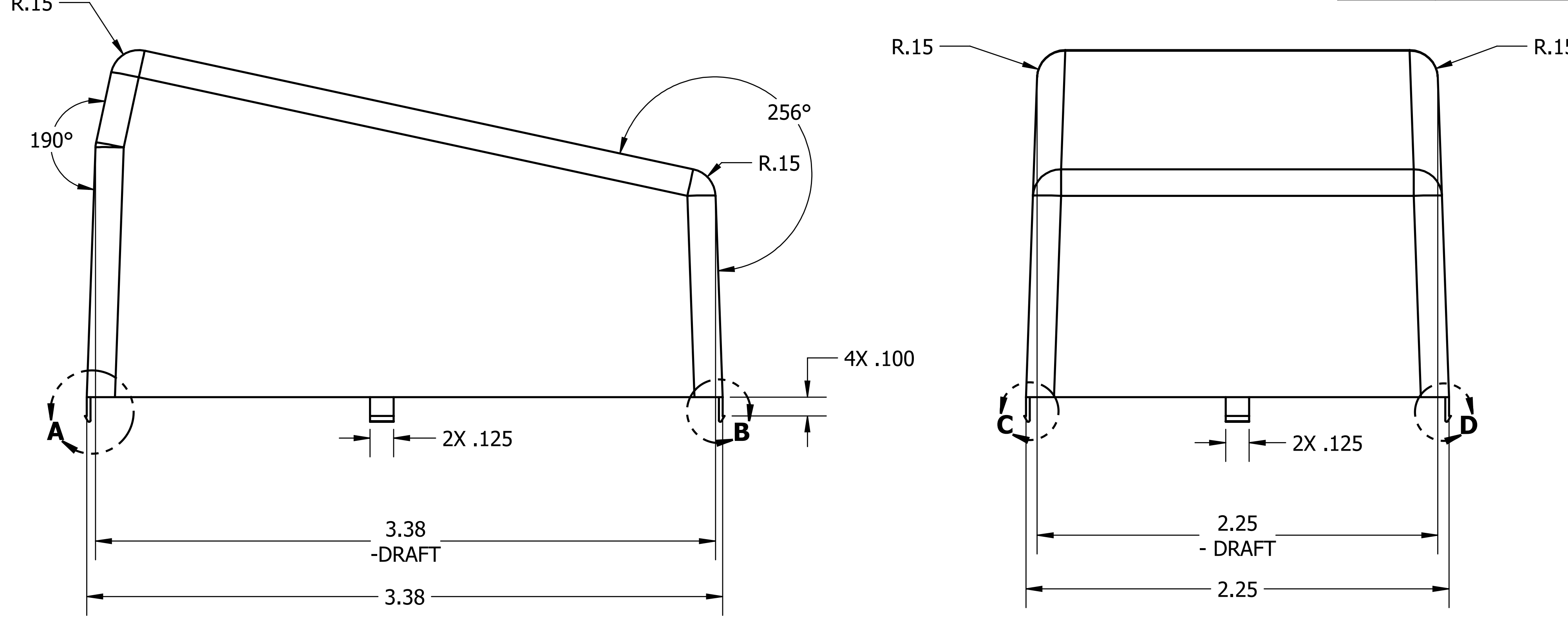
NOTES:
1. SCALE 1:1 UNLESS SPECIFIED OTHERWISE
2. ALL DRAFT 2 DEG UNLESS SPECIFIED OTHERWISE
3. DRAFT REMOVES MATERIAL.
4. HELIX COMPLETES 4 FULL REVOLUTIONS

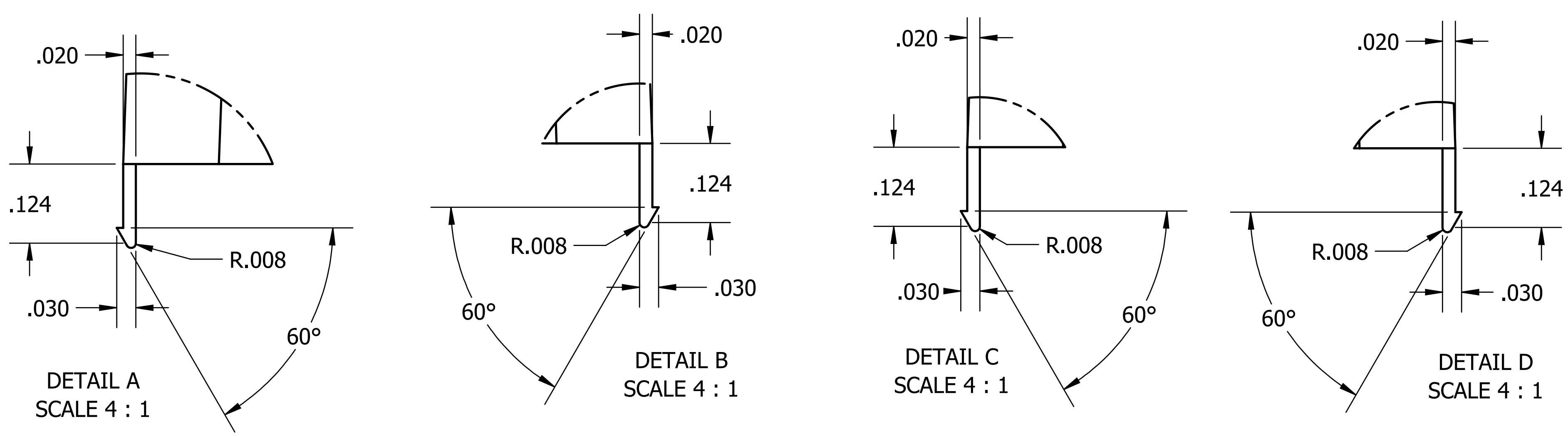
TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±.05 X.XX ± .01 X.XXX ± .005 X.X° 1°	UNIVERSITY OF COLORADO JACOB FOLEY 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL ABS		DESCRIPTION AUGER
FINISH NONE		PN 102 · REV A · SHEET 1 of 1



TOLERANCES UNLESS NOTED: X.X ±.050; X.XX ±.010; X.XXX ±.005; X.X° 1° UNITS: INCH	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427		
MATERIAL ABS	DESCRIPTION AUGER CLIP		
FINISH NONE	PN 103	REV A	SHEET 1 of 1

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/26/2024





NOTES:
1. WALL THICKNESS 0.50" UNLESS SPECIFIED OTHERWISE
2. DRAFT IS 2 DEG UNLESS SPECIFIED OTHERWISE
3. DRAFT REMOVES MATERIAL
4. SCALE IS 1.25:1 UNLESS SPECIFIED OTHERWISE

TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ± 0.05 X.XX ± 0.01 X.XXX ± 0.005 X.X° 1°	UNIVERSITY OF COLORADO JACOB FOLEY 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL ABS		DESCRIPTION MOTOR COVER
FINISH NONE		PN 104 · REV A · SHEET 1 of 1

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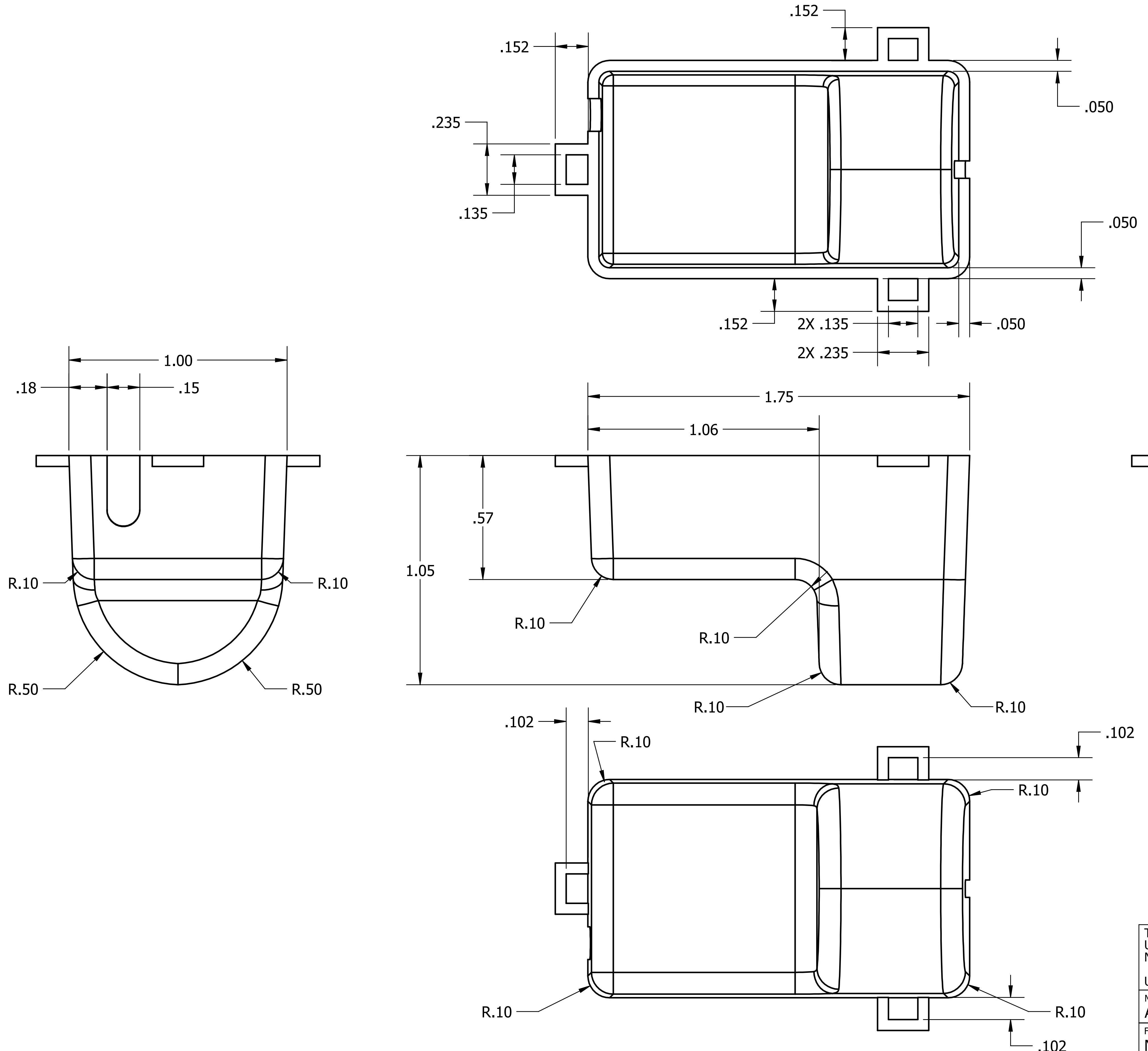
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/26/2024

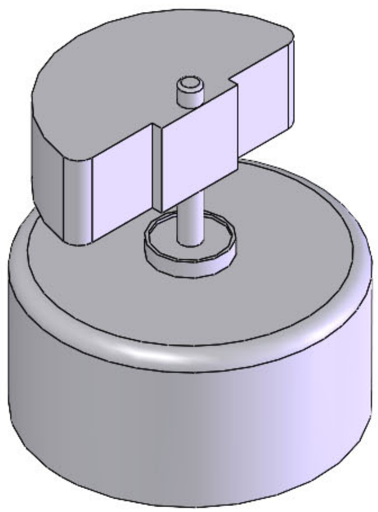


NOTES:
1. 2 DEG DRAFT UNLESS SPECIFIED OTHERWISE
2. DRAFT REMOVES MATERIAL
3. 0.050" WALL THICKNESS UNLESS SPECIFIED OTHERWISE
4. 0.10" FILLET UNLESS SPECIFIED OTHERWISE

TOLERANCES UNLESS NOTED: X.X ± 0.05, X.XX ± 0.01, X.XXX ± 0.005, X.X° 1°; UNITS: INCHES		UNIVERSITY OF COLORADO JACOB FOLEY 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL ABS		DESCRIPTION RUMBLE PACK HOUSING
FINISH NONE	PN 105	REV A · SHEET 1 of 1

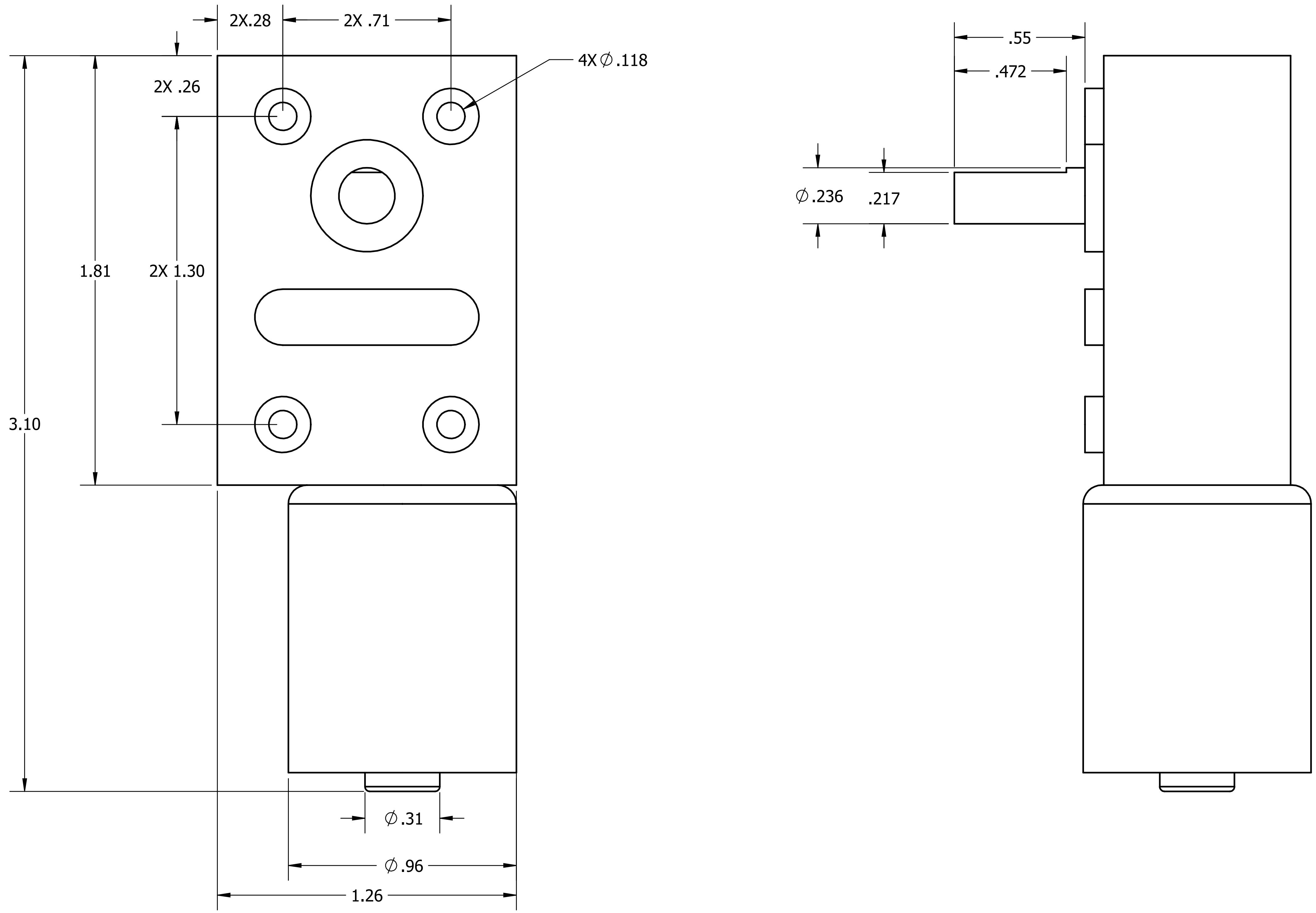
NOTES:
1. XBOX LARGE RUMBLE PACK

REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024



TOLERANCES UNLESS NOTED: X.X ±.050; X.XX ±.010; X.XXX ±.005; X.X° 1° UNITS: INCHES		UNIVERSITY OF COLORADO 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427			
MATERIAL STAINLESS STEEL		DESCRIPTION RUMBLE PACK LARGE			
FINISH NONE		PN 106	REV A		SHEET 1 of 1

REV.	DESCRIPTION	DATE
A	INIITIAL RELEASE	11/26/2024

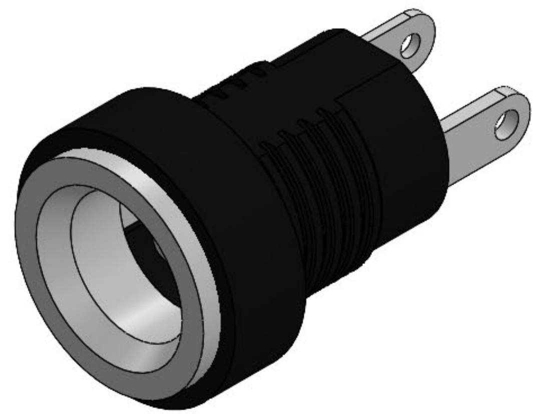


NOTES:
1. COTS PART, REFERENCE 107.STEP REV. A FOR FULL DIMENSIONS
2. SCALE IS 3:1 UNLESS STATED OTHERWISE.

TOLERANCES UNLESS NOTED: X.X ± 0.05, X.XX ± 0.01, X.XXX ± 0.005, X.X° 1° UNITS: INCHES	UNIVERSITY OF COLORADO JACOB FOLEY 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL ALUMINUM, STAINLESS STEEL	DESCRIPTION MOTOR & GEARBOX	
FINISH N/A	PN 107 REV A	SHEET 1 of 1

REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024

NOTES:
1. COTS DC PANEL CONNECTOR



TOLERANCES UNLESS NOTED: X.X ± X.XX ± X.XXX ± UNITS: X.X° °		UNIVERSITY OF COLORADO 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427			
MATERIAL N/A		DESCRIPTION DC PANEL CONNECTOR			
FINISH N/A		PN 108	REV A		SHEET 1 of 1

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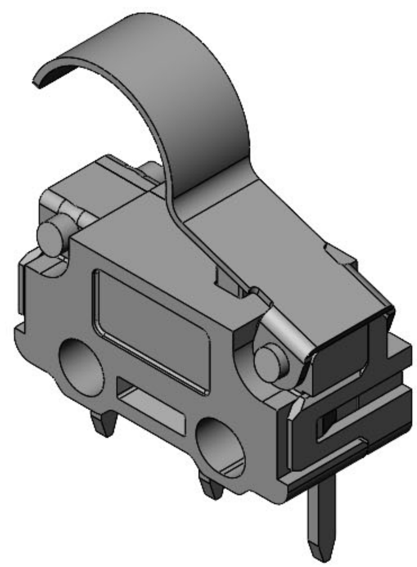
REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024

NOTES:
1. MCMASTER PN 7792N15



TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL N/A		DESCRIPTION Ultra-Miniature Snap-Acting Switches
FINISH N/A		PN 109 · REV A · SHEET 1 of 1

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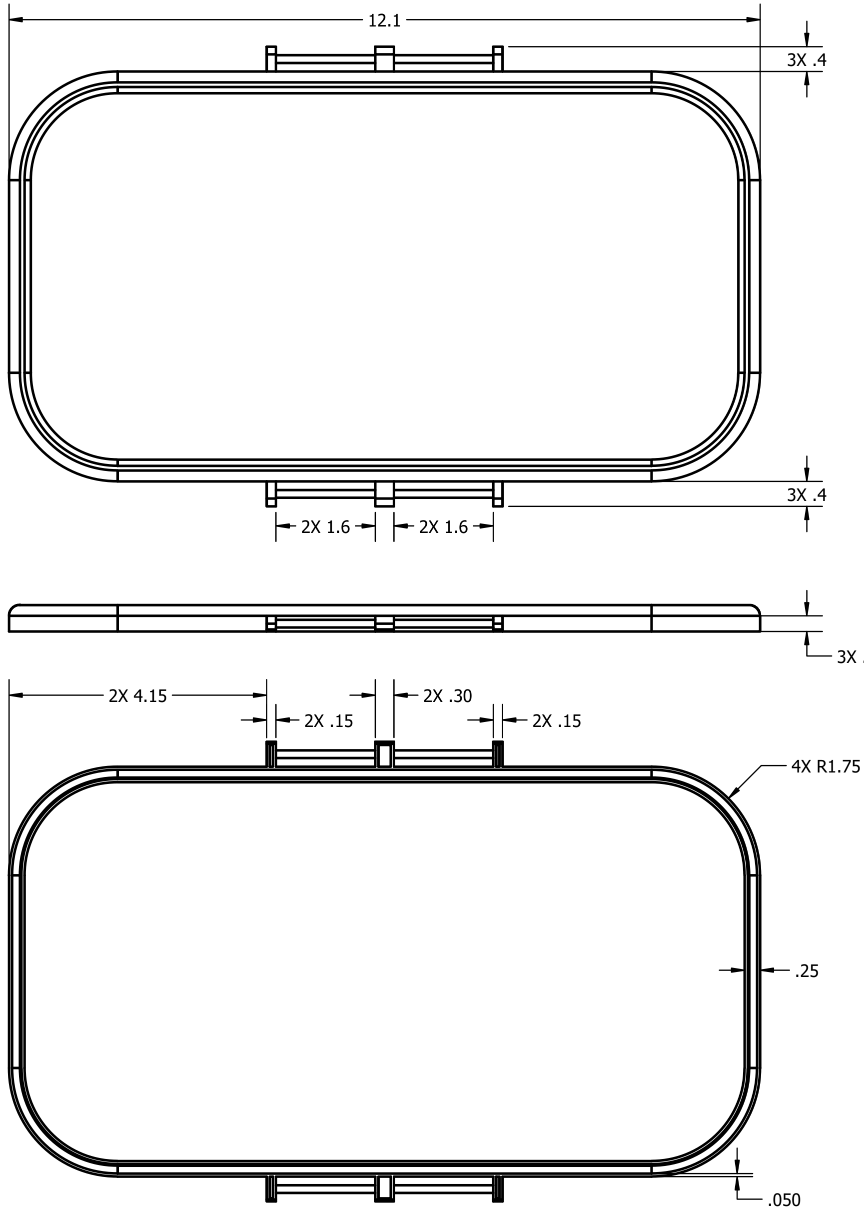
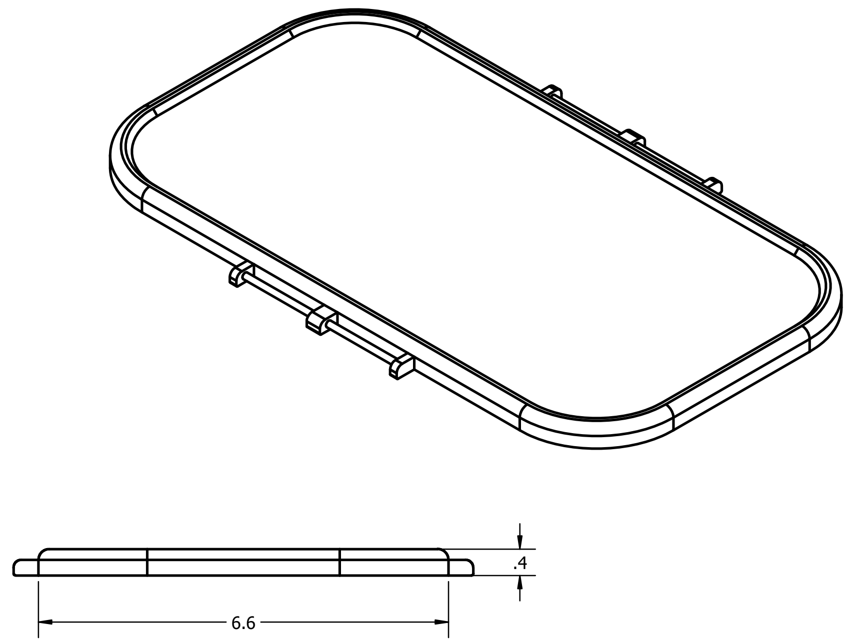
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/21/2024





NOTES:
1. UNLESS OTHERWISE MARKED, ALL MATERIAL THICKNESS IS 0.050"

TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±0.05 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5 °	UNIVERSITY OF COLORADO LUKE JENSEN 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL ABS		DESCRIPTION LID
FINISH NONE		PN 110 · REV A · SHEET 1 of 2

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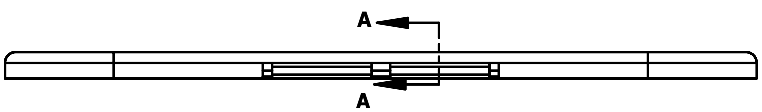
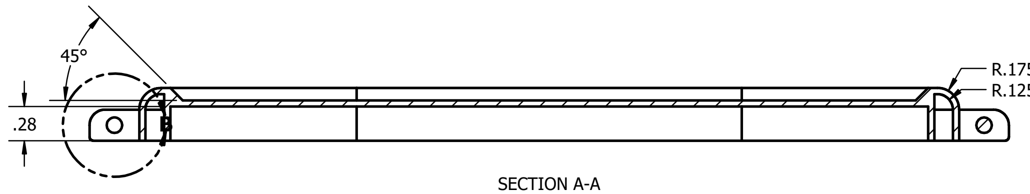
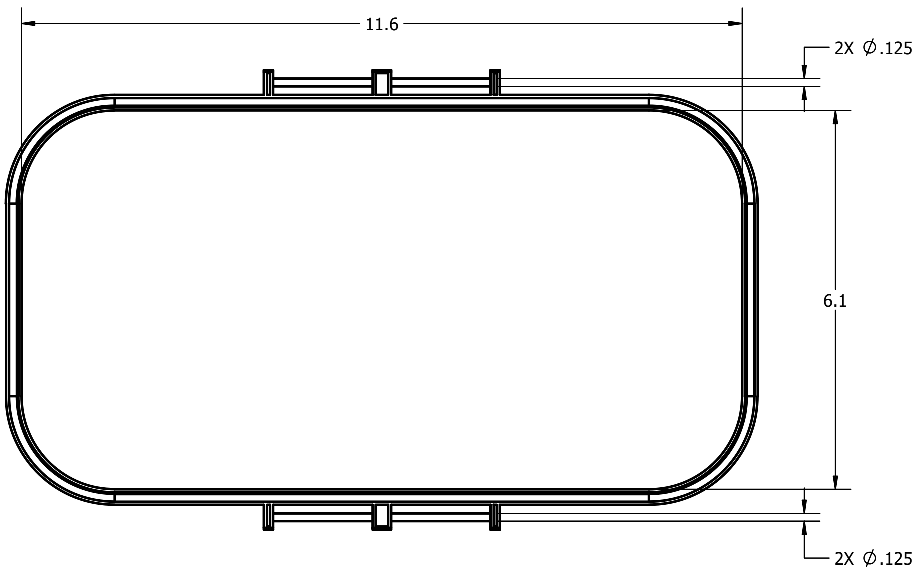
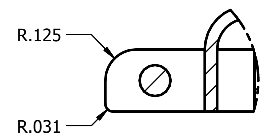
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/21/2024





SECTION A-A
SCALE 1 : 1



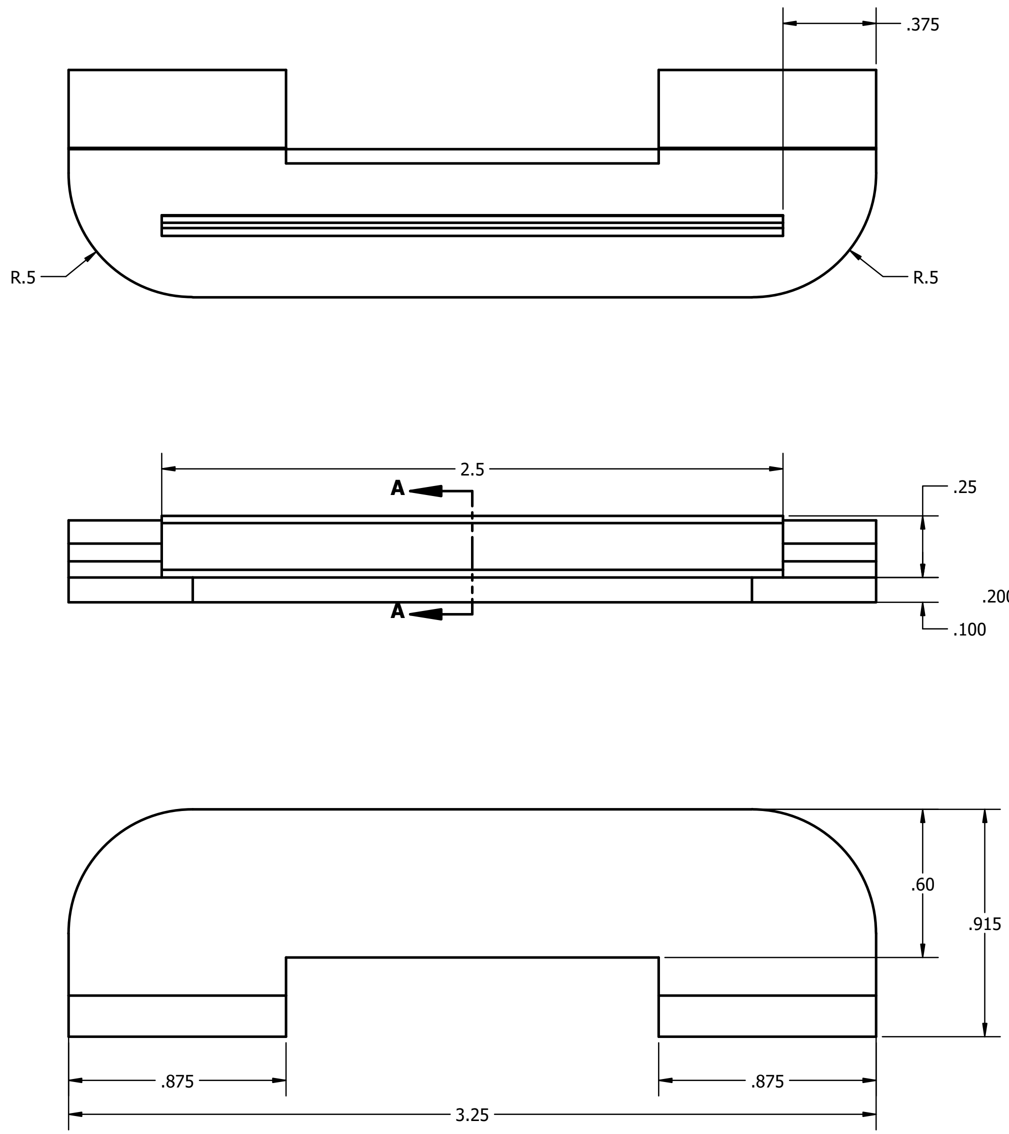


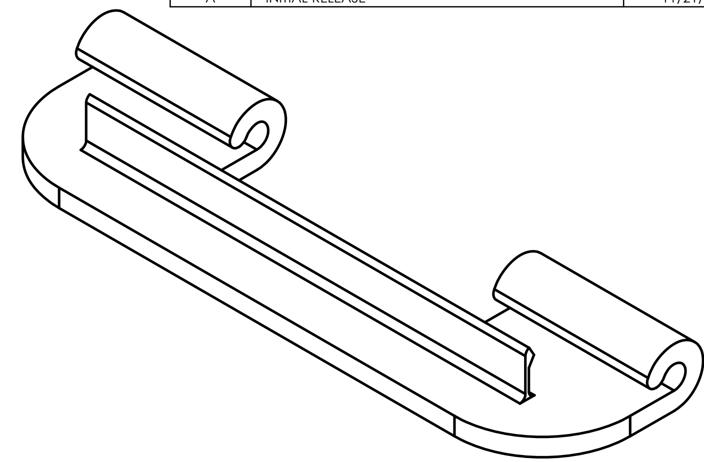
DETAIL B
SCALE 2 : 1

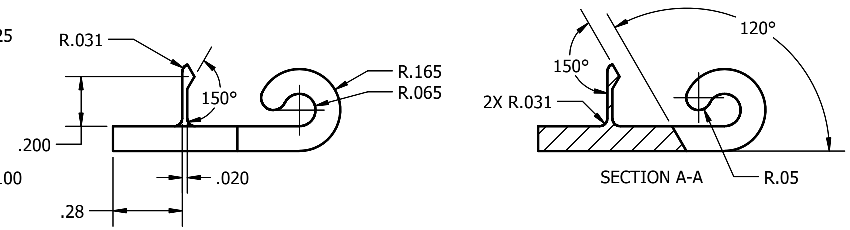
NOTES:
1. DIMENSIONS IN "DETAIL B" ARE THE SAME FOR THE 6X FEATURES 3X ON EACH SIDE

TOLERANCES UNLESS NOTED: X.X ±0.05; X.XX ±0.01; X.XXX ±0.005; X.X° 0.5 °; UNITS: INCHES	UNIVERSITY OF COLORADO LUKE JENSEN 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL: ABS	DESCRIPTION: LID	
FINISH: NONE	PN: 110 · REV: A	SHEET: 2 of 2

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/21/2024







TOLERANCES UNLESS NOTED:	X.X ±0.05 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5 °	UNIVERSITY OF COLORADO LUKE JENSEN 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCHES		
MATERIAL ABS		DESCRIPTION LID LATCH
FINISH NONE		PN 111 · REV A · SHEET 1 of 1

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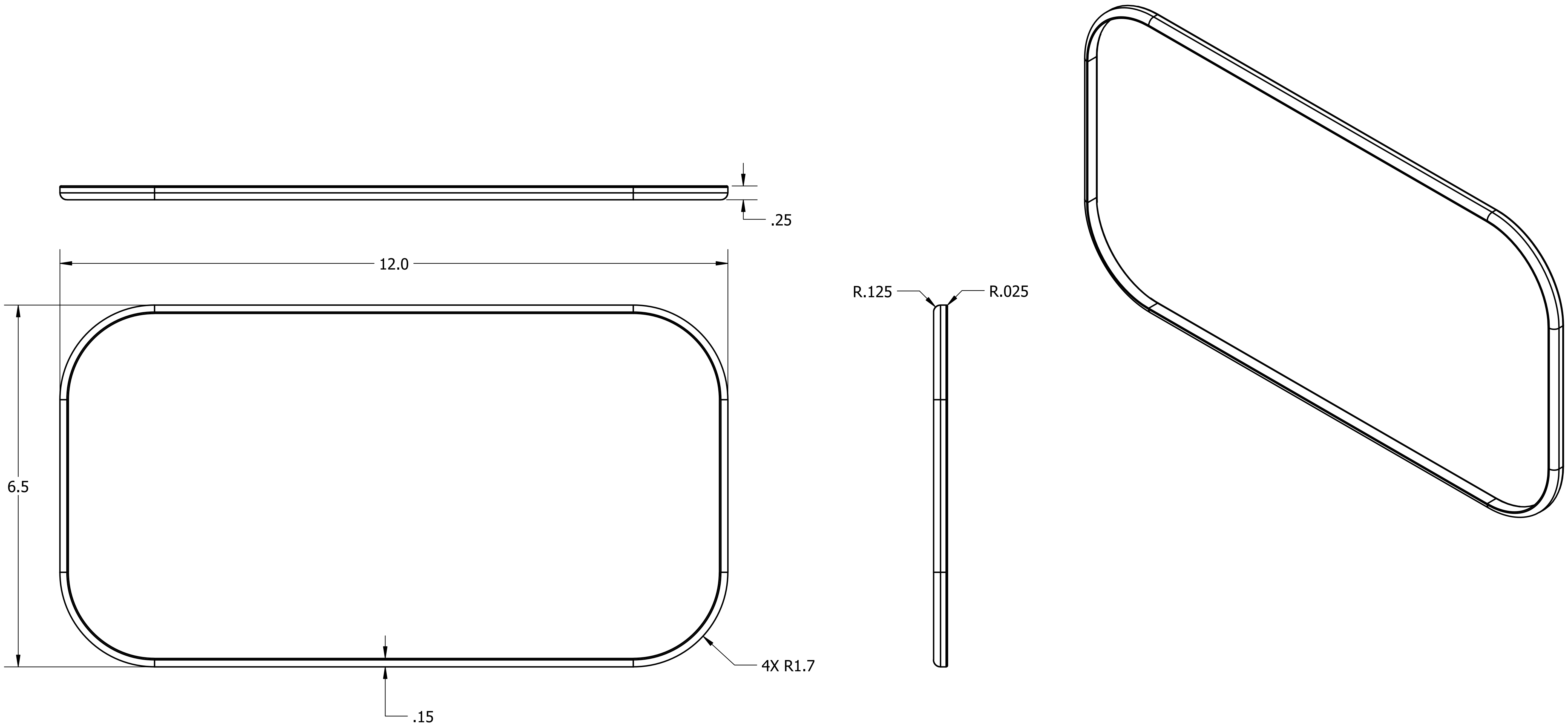
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	11/20/2024



TOLERANCES UNLESS NOTED:	X.X ±0.05 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5 °	UNIVERSITY OF COLORADO LUKE JENSEN 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
UNITS: INCHES			
MATERIAL TPR		DESCRIPTION LID GASKET	
FINISH NONE		PN 112	REV A
		SHEET 1 of 1	

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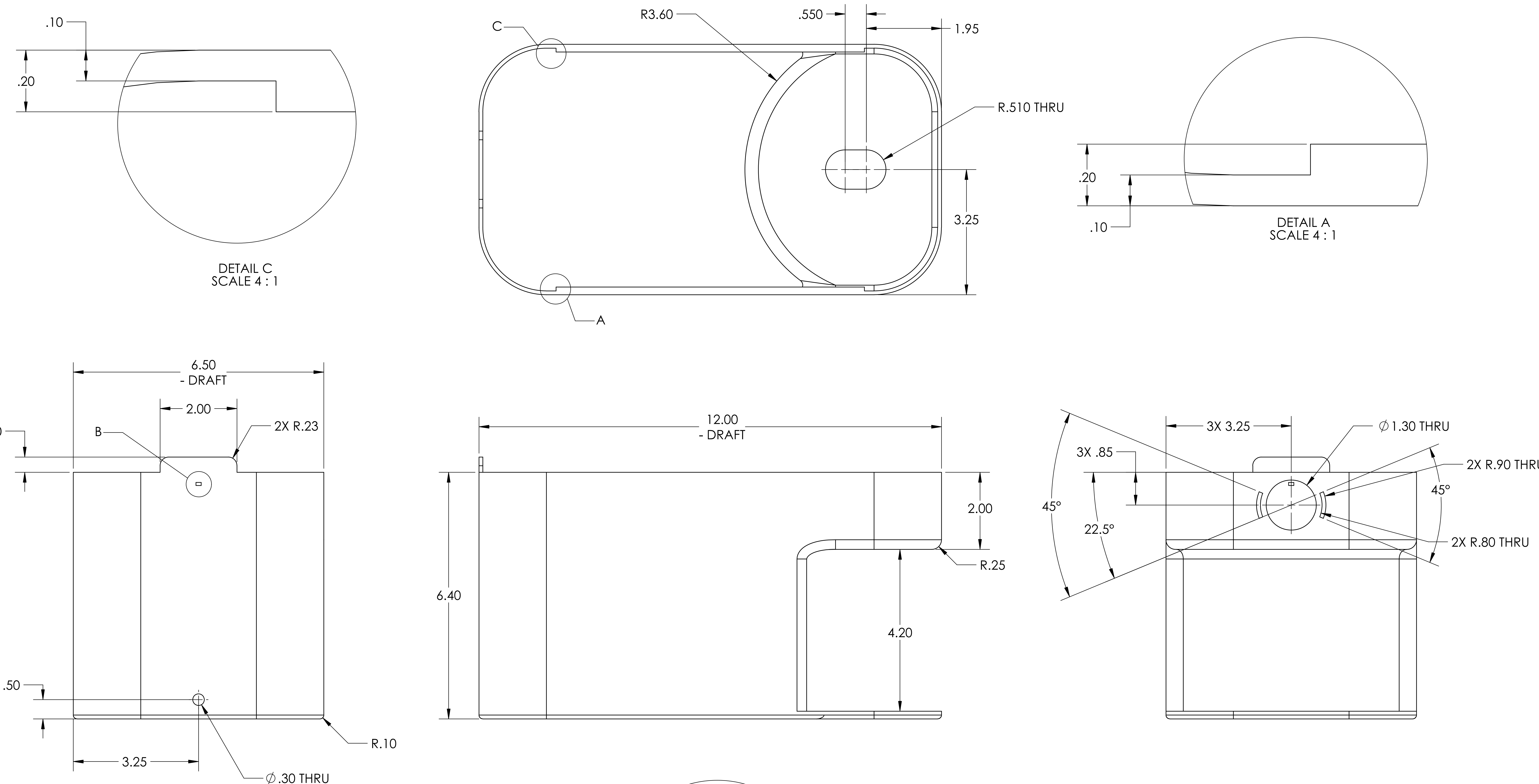
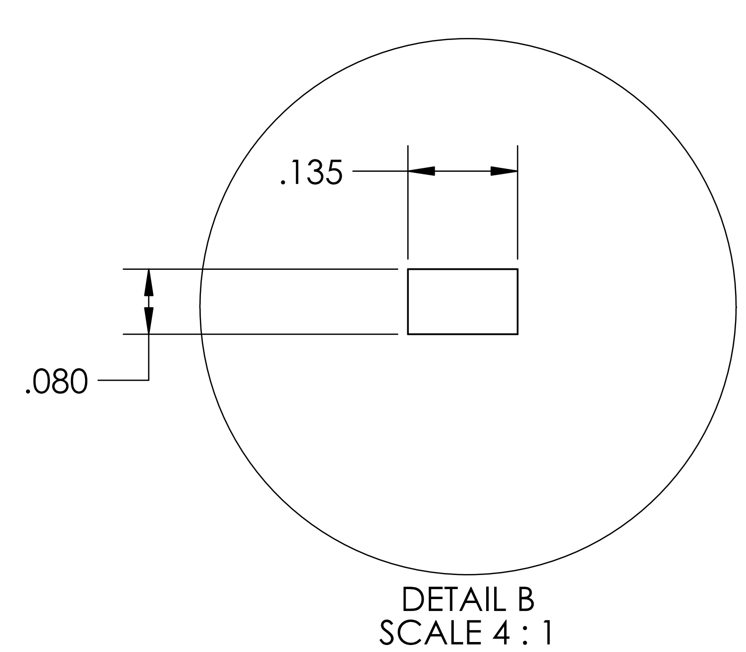
REV	DESCRIPTION	DATE
A	INITAL RELEASE	11/27/2024

NOTES:
1. ALL WALL THICKNESSES ARE .010 UNLESS OTHERWISE SPECIFIED
2. DRAFT ANGLES SHALL BE 1°





TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°		UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCH			
MATERIAL ABS		DESCRIPTION BASE	
FINISH NONE		PN 113	REV A / SHEET 1 of 2

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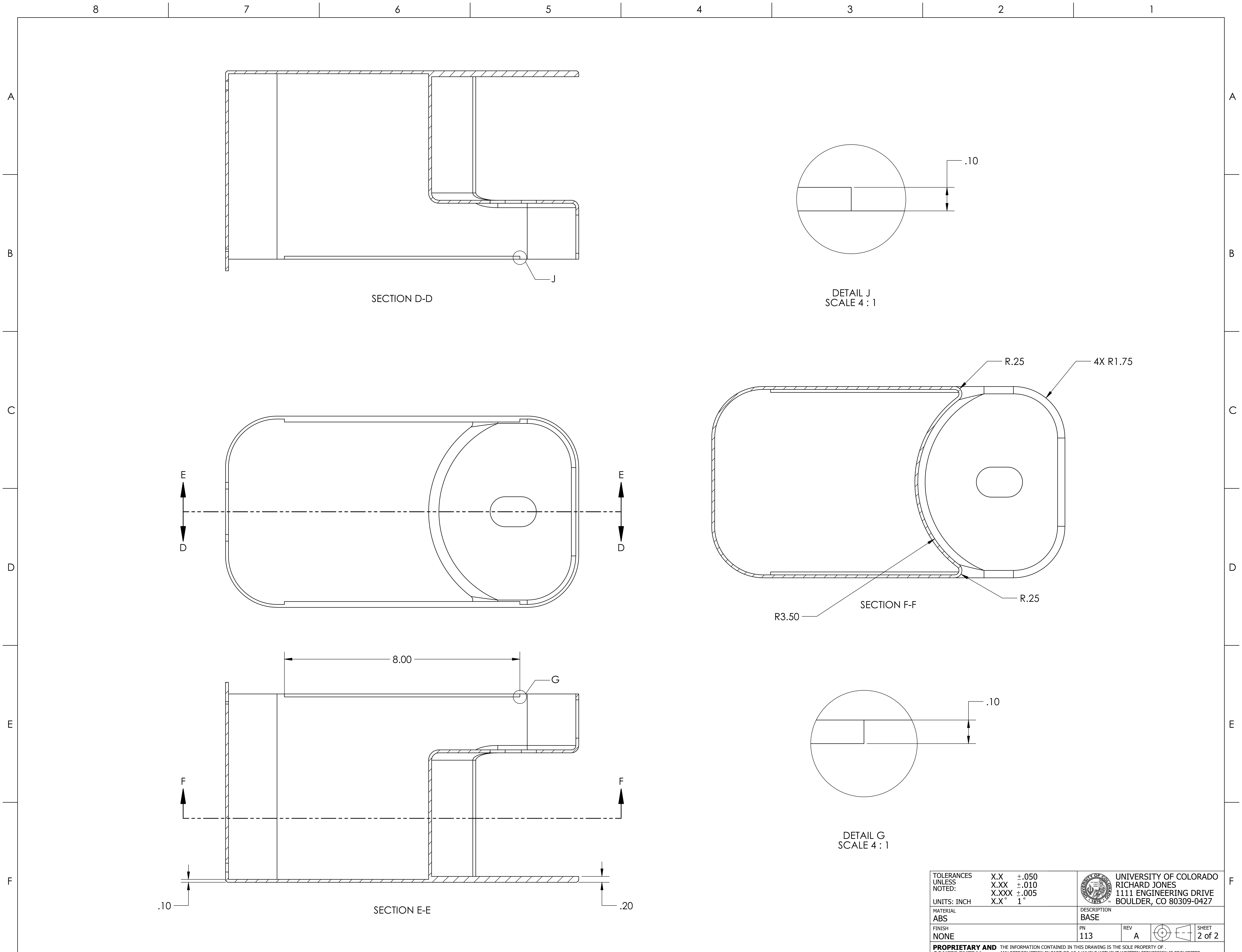
SECTION D-D
J
DETAIL J
SCALE 4 : 1
.10
R.25
4X R1.75
E
D
SECTION F-F
R3.50
R.25
8.00
G
F
DETAIL G
SCALE 4 : 1
.10
.20
SECTION E-E
TOLERANCES UNLESS NOTED:
X.X ±.050
X.XX ±.010
X.XXX ±.005
X.X° 1°
UNITS: INCH
UNIVERSITY OF COLORADO
RICHARD JONES
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
MATERIAL
ABS
DESCRIPTION
BASE
FINISH
NONE
PN
113
REV
A
SHEET
2 of 2
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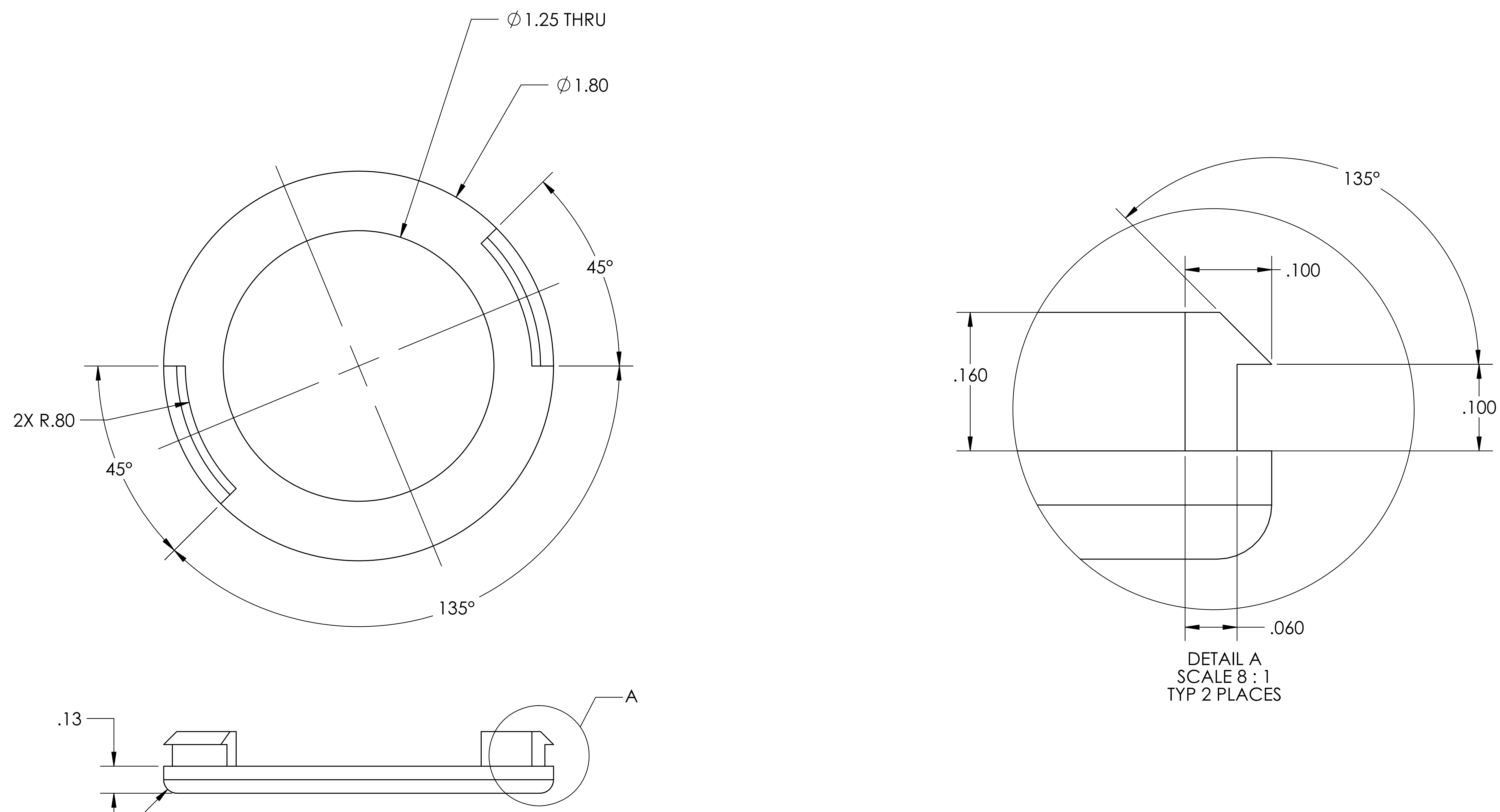
REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024



TOLERANCES UNLESS NOTED: X.X ±.050, X.XX ±.010, X.XXX ±.005, X.X° 1° UNITS: INCH	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL ABS	DESCRIPTION BUTTON COVER	
FINISH NONE	PN 114	REV A · SHEET 1 of 1

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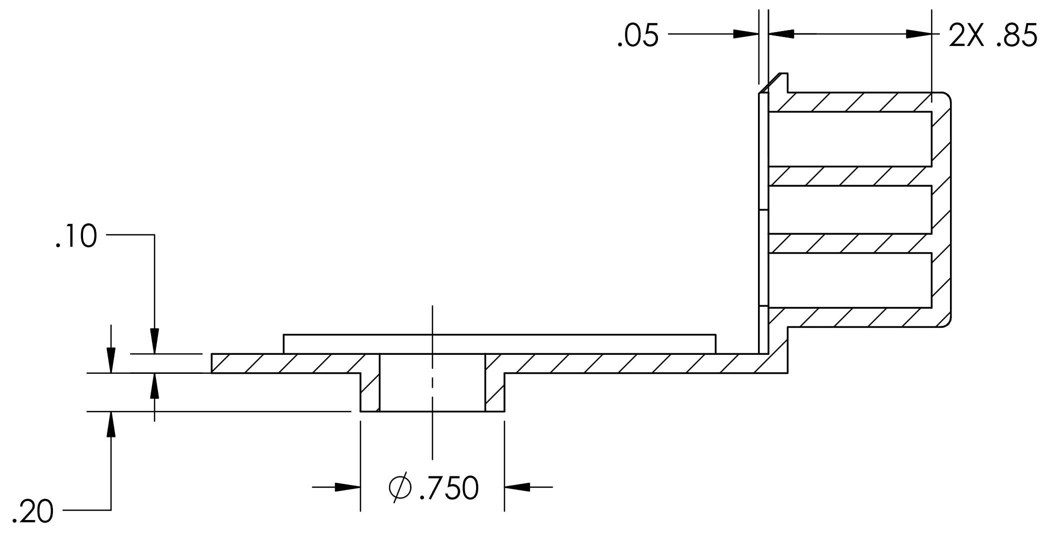
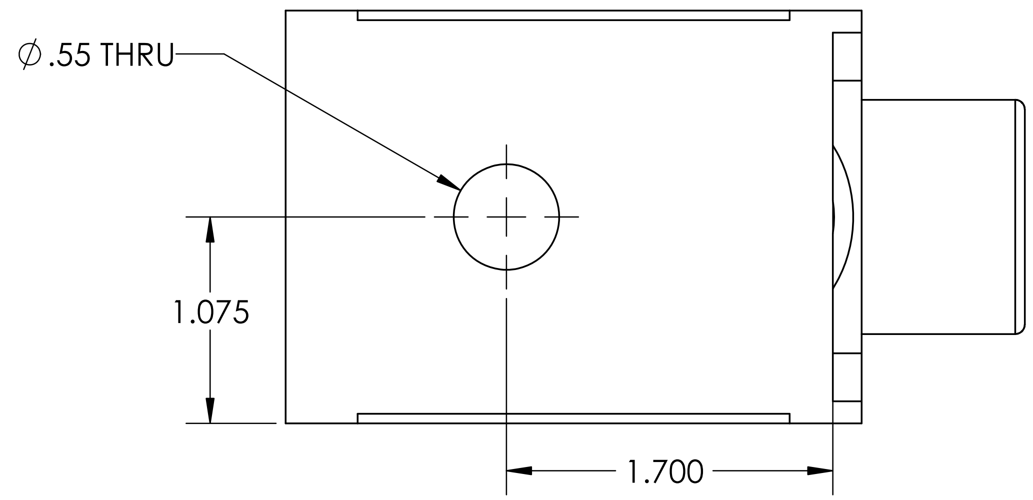
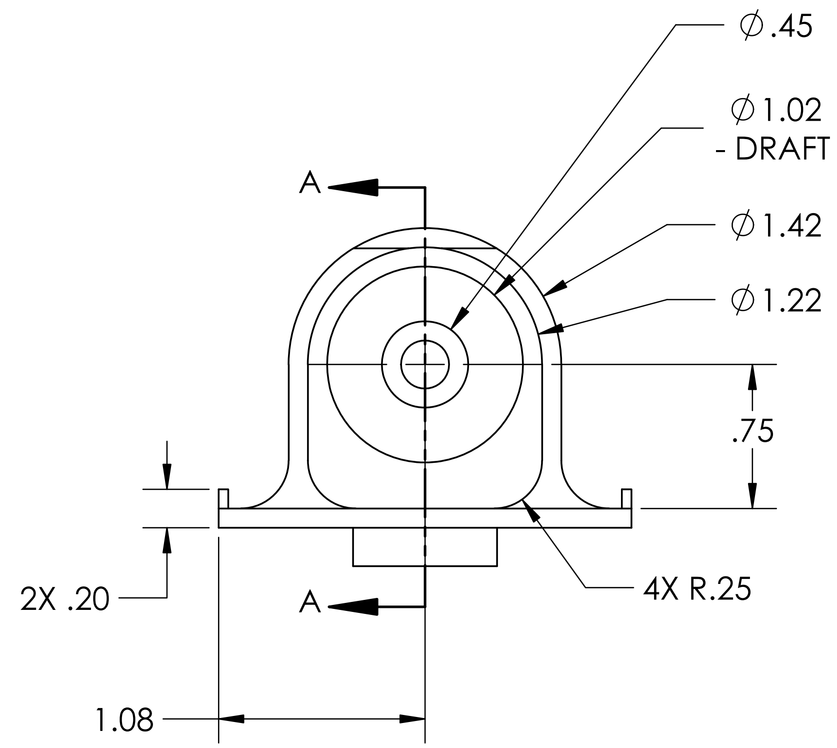
REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/21/2024

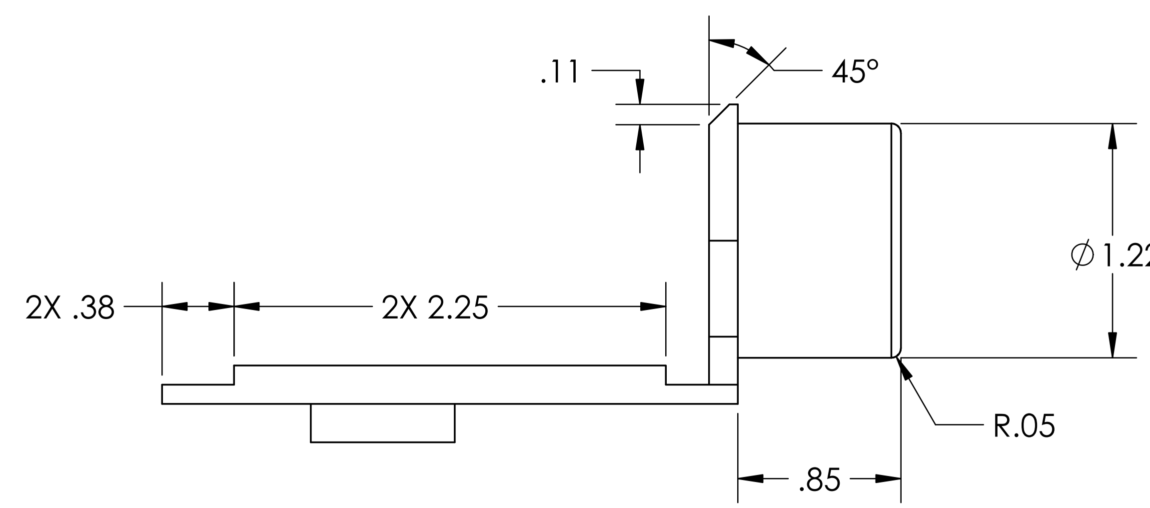
NOTES:
1. DRAFT ANGLES SHALL BE 1 ° UNLESS OTHERWISE SPECIFIED



SECTION A-A

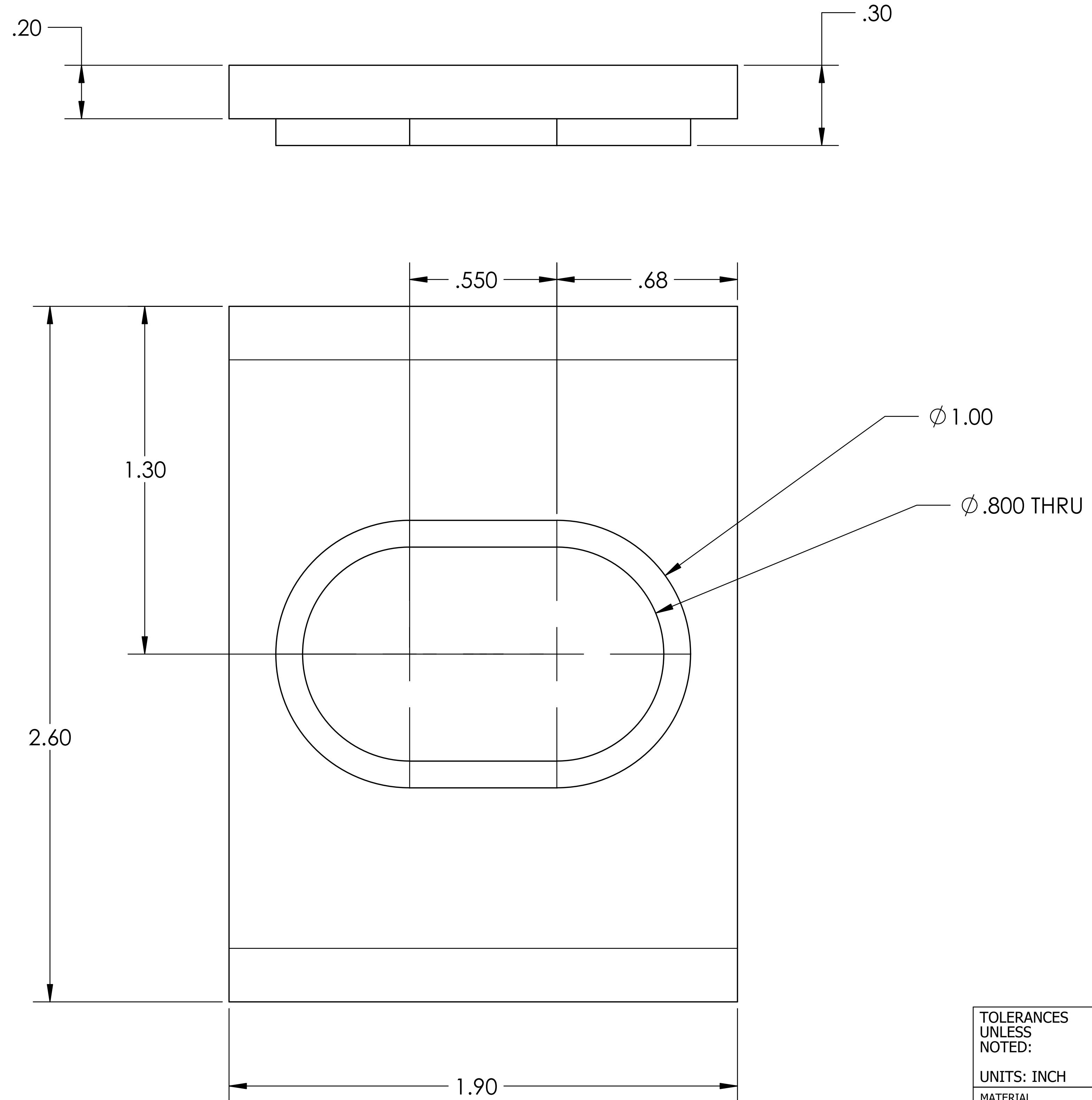






TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCH		
MATERIAL ABS		DESCRIPTION DISPENSER DOOR
FINISH NONE		PN 115 / REV A / SHEET 1 of 1

REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/18/2024



TOLERANCES UNLESS NOTED: X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1° UNITS: INCH		UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL HDPE		DESCRIPTION DESPENSER DOOR SPACER	
FINISH NONE	PN 116	REV A	SHEET 1 of 1

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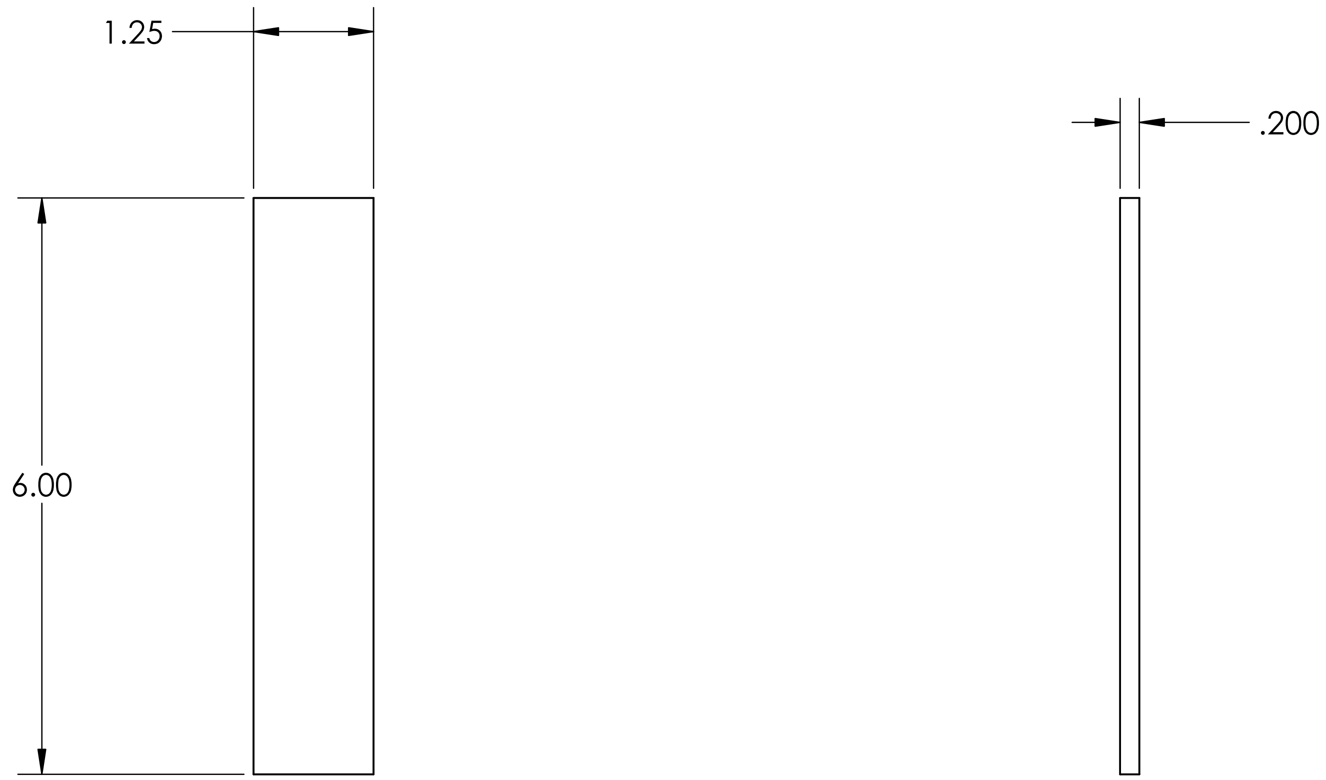

TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCH		
MATERIAL POLYCARBONATE - CLEAR		DESCRIPTION VOLUME VIEW PLATE
FINISH NONE		PN 117 / REV A / SHEET 1 of 1

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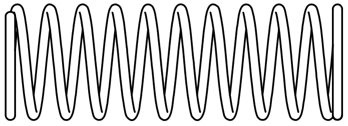
REV	DESCRIPTION	DATE
A	INITIAL RELEASE	11/29/2024

NOTES:
1. MCMASTER PN 9657K484



TOLERANCES UNLESS NOTED: X.X ±.050, X.XX ±.010, X.XXX ±.005, X.X° 1°; UNITS: INCHES		UNIVERSITY OF COLORADO RICHARD JONES 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427			
MATERIAL Music-Wire Steel		DESCRIPTION Compression Spring			
FINISH NONE		PN 118	REV A		SHEET 1 of 1