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Automation of Loin Puller Feeder Process

MECH 4860 Final Report

Sponsoring Company
HyLife Foods

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Executive Summary

Hylife has recently increased production and seeks to automate one of their existing processes. The process focuses on identifying, separating, orienting, and transferring hog middles from a main conveyor to two side conveyors. The middle is the section between the front and back legs of a hog and consists of the loin and belly. The current process is done manually by two workers. The manual work is strenuous on the workers, non-valued added, and inconsistencies can cause production halts and other issues. This report details a proposed automated solution that will relocate the current employees and save approximately $200,000 [CAD] annually.

The proposed design uses a vision system to distinguish left from right middles and determines their orientation as they travel down the main conveyor. The proposed design then uses an automated mechanical arm to orient and transfer the middles to each side conveyor. From there, the autonomous vertical sequencing gates ensure the middles are released at the same time to eliminate inconsistencies which halt production. The automated feeder design is situated on a motorized linear track that moves the entire design out of the way when manual work is desired. To adhere to CFIA safety standards and HyLife's internal food safety plan, the team implemented washdown protected actuators and food-safe materials, such as stainless steel 304 and 316 as well as UHMW PE. The design can adapt to different feed rates ranging from 300 to 600 [hogs/hour], and can also accommodate production growth in the foreseeable future.

The estimated total cost of the automated feeder is $256,110 [CAD], resulting in an estimated payback period of 1.3 [years]. Even though the payback period is higher than the ideal value of one year, it is below the upper specification limit of 1.5 [years]. Additionally, the team performed a preliminary stress and displacement analysis, using SolidWorks FEA. The results verify that all components of the final proposed design have a minimum factor of safety of 2.0.

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Glossary of Terms

The team summarised the terms and acronyms that are commonly used throughout the report below along with their meaning. These terms will aid in understanding the details of the final design.

BOM:	Acronym for 'Bill of Material', which is a complete list of every part required to build the product.
Cut floor:	The production area where the hog gets cut into different pieces.
CFIA:	Canada Food Inspection Agency enforces government policy on food safety.
End Effector:	Term used to describe the handling device at the end of a mechanical or robotic arm.
HACCP:	Hazard Analysis Critical Control Points, HACCP is a food safety plan that food processors must document and adhere to.
IP69K:	Ingress Protection Marking meaning that the part is dust tight and can withstand close-up, high pressure and high temperature spray downs.
Middle:	Refers the middle portion of a hog carcass which contains the backbone, ribs, loin, and belly.
Pareto Diagram:	A visual chart which displays a bar chart and a line graph in descending order to highlight more important factors contributing to a topic.
Vertically Integrated:	A vertically integrated company indicates that such company also owns the company's supply chain. In this case, HyLife also raises the hogs.

1. Introduction

This report will cover the final design of the automated feeder system which transfers hog middles from the main conveyor to the secondary side conveyors for loin pulling.

The report starts by covering the current process and its associated challenges. Then, the objectives, customer needs, and target specifications identified are outlined and discussed. Following, the design of each component is detailed and specific features which satisfy the customer needs are identified and explained. Furthermore, a detailed description on the theory of operation of the design is discussed. The theory of operation includes how each component of the design function together as well as how the automated feeder is designed to operate.

Following the theory of operation, the preliminary manufacturing drawing system used to convey the full design intent is introduced. Then, the preliminary cost and return on investment analyses of the complete automated feeder design is outlined. Lastly, the report concludes with future recommendations to the client to resolve design limitations and add future improvements.

2. Project Definition/Description

This section of the report outlines the project details such as the background, problem statement, and objectives. Next, the customer needs along with the target specifications that were identified by the client will be listed and discussed. This section will conclude with the design expectations used to formulate the final design.

2.1. Project Background

HyLife is a vertical integrated pork processing company based in La Broquerie Manitoba. HyLife was founded by the three Vielfaure brothers in 1994 with a goal to create the most efficient system for vertically integrated pork processing [1]. In 2008, HyLife purchased the Spring Hill Farms pork processing plant in Neepawa Manitoba to become a complete "Farm-to-Fork food processing company" [2].

The process of interest for this project takes place on the cut floor where carcasses enter from the cooler after being there over night. Carcasses, which are hung from their hind feet, are split into left and right halves then placed onto a conveyor. The hams and shoulders of each half are then removed using two bandsaws. Afterward, only the middles remain, which consist of the loin and belly, as shown in Figure 1.

Figure 1. Primal pork cuts [3]

The area of focus of the project occurs after the shoulders are removed and the two middle halves remain on the main conveyor. To separate the loin from the belly, the individual sides must be sorted and transferred into the correct loin puller. The loin puller requires that the left and right middles be oriented such that the shoulders face forward and the backbone face outward. In addition, both middles must be loaded simultaneously, otherwise sequencing issues will occur downstream. Figure 2 shows a visual representation of the orientation and transfer process. Once the loins are removed from the bellies, each part is sent to their respective lines for further processing.

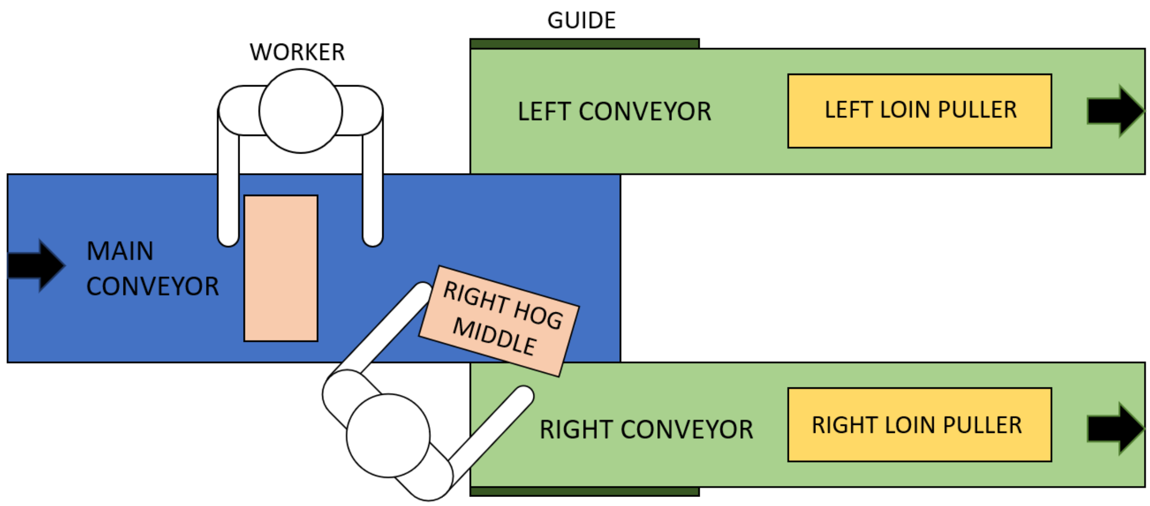


Figure 2. Current left and right middle transfer process [4]

2.2. Problem Statement and purpose

There are a few issues with the current process: the middles weight between 15-20 [kg] and a new set of middles comes every 6 seconds. The nature of the processes is repetitive and strenuous on the workers and creates risk of repetitive strain injuries. Another issue with the current process is that it is a non-value-added activity. Employing two employees full time on each shift costs HyLife roughly $200,000/year. The third issue with the current process is the inconsistent release of each middle to their respective loin puller. When the middles are not released simultaneously, they pile on top of each other further into the process. The pilled middles then trip a sensor that stops the upstream conveyors and the entire process, thus halting production. The final issue is if middles are released in the wrong orientation, or the backbones are too far away from the guide, there is a risk of jamming or even breaking the loin puller.

2.3. Objectives

The objective of this project is to automate the process of orienting, transferring and sequencing the middles. In comparison with the current manual process, automation presents the opportunity to have more consistent and concise placement of the middles on the loin puller conveyors. The automation of the process will also remove the random error inherent in processes involving human judgment. Another benefit of automating the process is that it will enable workers to work on other value-added processes in the plant.

2.4. Customer Needs

To build on the project objectives, customer needs were identified with the client. A total of 22 needs were created, each of which can be categorized into 4 categories – 'Heath, safety, and sanitation', 'operational', 'deliverables', and 'additional related needs'. In addition to identifying the needs, HyLife rated each need with a level of importance ranging from 1 to 10 (1 being very low, and 10 being very high). The needs, along with a brief description, are summarized in TABLE I through TABLE IV.

TABLE I
HEALTH, SAFETY, AND SANITATION NEEDS

Need No.	Importance Rating	Description
1.1	10	The product adheres to food industry's health and safety standards
1.2	10	The product adheres to sanitation and cleaning regulations/guidelines
1.3	10	The product retains its integrity with the daily sanitation and cleaning process
1.4	10	The product leaves notable gaps and drainage holes for cleaning and sanitation
1.5	7	The product is easy to disassemble and reassemble when cleaning and/or doing maintenance

From the above table, the health, safety, and sanitation needs are critical to the success of the project, and therefore must be considered thoroughly.

TABLE II
OPERATIONAL NEEDS

Need No.	Importance Rating	Description
2.1	10	The product can identify left and right middles pieces of the hog
2.2	10	The product can operate and adjust to different conveyor speeds, corresponding to any feed rate between 300 hogs/hour and 600 hogs/hour
2.3	10	The product properly orients the middle pieces onto the individual breaks
2.4	10	The product is fully automated with integrated logic
2.5	10	The product simultaneously loads left and right middle pieces
2.6	10	The product needs to make hog middle's backbone face outward and touch the guide on each break (left and right)

The operational needs listed above must be achieved to ensure the current production process at HyLife is maintained. If any of the above needs are not met, the project will be considered a failure.

TABLE III
NEEDS REQUIRED TO SATISFY PROJECT DELIVERABLES

Need No.	Importance Rating	Description
3.1	8	Customer deliverable 'Preliminary Stress Analysis' is completed
3.2	8	Customer deliverable 'Preliminary Cost Estimate' is completed
3.3	8	Customer deliverable 'Preliminary Return on Investment Analysis' is completed
3.4	8	Customer deliverable '3D CAD model' is completed
3.5	8	Customer deliverable '2D updated floor plan' is completed
3.6	8	Customer deliverable 'Preliminary Manufacturing Drawings' is completed
3.7	8	Customer deliverable 'Theory of Operation' is completed
3.8	8	Customer deliverable 'Design Limitation' is completed

It is important to note that the deliverables required are all preliminary. This means that the deliverables submitted are not completed by professional engineers and that the proper due-diligence must be taken to ensure accuracy and safety.

TABLE IV
ADDITIONAL RELATED NEEDS

Need No.	Importance Rating	Description
4.1	10	The product allows manual work as an option
4.2	5	The product stays within budget
4.3	1	The product identifies any abscesses in the hog (manual or automated)

The other needs, apart from 4.1, are of lower importance in comparison with the other needs. Although still relevant, the lower needs will have a reduced impact on the overall success of the project.

2.5. Target Specifications

To achieve the needs outlined earlier, specifications consisting of metrics and values were formulated. Specifications help quantify different aspects of the project and ultimately help set goals and/or guidelines. A total of 51 specifications were identified with HyLife and then categorized by whether they were quantified specifications or subjective specifications. The subjective specifications, shown in TABLE V, are either achieved or not and have a 'yes' or 'no' criteria. The quantified specifications, shown in TABLE VI, have a metric with a value and units.

TABLE V
SUBJECTIVE SPECIFICATIONS

Spec. No.	Description	Target Spec.
1.1	The product adheres to Hazard Analysis Critical Control Point Plan (HACCP Plan)	Yes
1.2	The product adheres to Safe Food for Canadians Regulations	Yes
1.3	The product adheres to HyLife's Workplace Health and Safety Rules	Yes
1.4	Meet sanitation and cleaning regulations/guidelines	Yes
1.5	Occurrence of condensation on the surfaces of the proposed product is considered and dealt with	Yes
1.6	The designed conveyor speed can vary between its allowable maximum and minimum speed	Yes
1.7	Incorporation of Emergency Stop Button	Yes
1.8	The product is fully automated with the implementation of logic	Yes
1.9	Preliminary maintenance schedule for key components or parts are provided	Yes
1.10	Preliminary numerical analysis results meet safety requirements	Yes
1.11	Preliminary cost analysis performed and demonstrated	Yes
1.12	Cost comparison between the proposed product and the existing process is performed and demonstrated	Yes
1.13	Preliminary CAD models are complete	Yes
1.14	CAD models illustrate proposed product design	Yes
1.15	CAD models are viewable and editable in Autodesk Inventor	Yes
1.16	Preliminary technical engineering drawings are available for all components designed	Yes
1.17	Preliminary manufacturing drawings are detailed with no missing dimensions or features	Yes
1.18	Detailed descriptions on how the proposed product works	Yes
1.19	Process flowcharts are provided for the proposed product	Yes
1.20	Design limitations are identified	Yes
1.21	Design limitations are reviewed and confirmed by the customer	Yes
1.22	Proposed product meets all requirements regarding constraints and limitations	Yes
1.23	The product stops running or can be manually operated when Left or/and Right break/conveyor is/are down	Yes
1.24	The product stops running or can be manually operated when Manual work is desired	Yes
1.25	Imperial unit system is used for fabricated components, metric unit system is used for purchased parts and fasteners.	Yes
1.26	Enough machine clearance to accommodate manual work	Yes
1.27	The product can identify and compensate hog middles with 15%-20% variation in size and weight	Yes
1.28	No foreign material markings on hog middles	Yes
1.29	Incorporation of Lock Out Tag Out in the proposed product design	Yes
1.30	Adhere to IP69K Ingress protection safety standards for contact surfaces and crucial components	Yes
1.31	Be able to withstand 180˚F cleaning water (As stated in IP69K rating)	Yes
1.32	Gaps are designed and integrated in the product to meet sanitation regulations	Yes
1.33	Drainage holes are designed and integrated in the product	Yes
1.34	Backbone is oriented to face outward and touch guide on left and right breaks	Yes
1.35	The product can rotate a hog middle from 0° to 360° until it reaches the proper orientation	Yes

The subjective specifications address a wide range of needs including the project deliverables, specific sanitation and health and safety requirements, and specific features HyLife would like to see on the final product, to name a few.

TABLE VI
QUANTIFIABLE SPECIFICATIONS

Spec. No.	Description	Unit	Value	
2.1	Time required to identify a left or right hog middle, excluding the time waiting to be loaded	sec	≤ 1	
2.2	Time required to identify and load a left and right hog middle before the next batch comes in from the main conveyor	sec	≤ 6.6	
2.3	Time offset of loading the right and left middle on their corresponding conveyors	sec	≤ 0.5	
2.4	Successful rate in identifying left or right hog middle	%	100	
2.5	Maximum and minimum processing capacities of the product, respectively	hogs/hr	600	300
2.6	Maximum and minimum speed of the main/incoming conveyor, respectively	ft/min	65	30
2.7	Speed for the loin puller conveyor	ft/min	60	
2.8	Temperature variation that the proposed product design can withstand and retain its integrity	˚F	13 - 180	
2.9	The frequency that one worker needs to check on the product in production	visits/hr	≤ 1	
2.10	Factor of safety used in design	N/A	2.0	
2.11	Expected life based on stress/fatigue analysis	years	10	
2.12	Estimated total cost of the product	CAD	200K	
2.13	Payback period required	months	18	
2.14	Time required to disassemble the product	min.	≤ 9	
2.15	Time required to reassemble the product	min.	≤ 9	
2.16	Dimensions of designated areas for manual work	ft^2	6 (3x2)	

2.6. Design Expectations

Before the design process started, HyLife provided design expectations that they would like to see met in addition to satisfying the needs. These expectations will aid the design process because they add insight and details for certain aspects of the design.

First, the physical components of the design as well as the operational logic of the product, is expected to be simple. The incorporated simplicity will ultimately lead to a better functioning design that can be better understood and maintained.

In relation to simplicity, HyLife expects all removeable parts of the product to be able to be removed without tools. Features such as guards and covers are expected to be removed and held in position by methods that do not require tools. This was requested because it saves the cleaning/sanitation and maintenance workers valuable time when performing their work. The expectation also ensures that the workers do not have to carry around tools with them throughout the production floor, which could add additional contamination risks.

When designing the product, HyLife expects certain materials to be used. Specifically, HyLife requests that materials that are already common on the production floor be used because they are confident in the quality and know the existing materials do not contaminate or damage the hogs in any way. HyLife requests that all structural and non-replaceable components of the product be made of 316 or 304 stainless steel. All replaceable components should be made from existing plastics such as UHMW, Nylon, Teflon, and/or HDPE.

The final expectation is that when the hog middles are moved from the main conveyor to their corresponding left or right side conveyors, the middles remain on the conveyors and are not lifted in any manner. Keeping the middles on the conveyors will avoid any possible damage to the middles when lifting them as well as eliminate any risk of having the middles fall and becoming contaminated or hurting other workers.

3. Final Design

Knowing the nature of the problem and the expectations of the design, this section outlines the full design of the automated feeder. The section starts with a general overview of the design and its main components then references important features and accessories that satisfy the client’s needs. Finally, the section concludes with a detailed description of each component of the full design.

3.1. Product Overview

The automated hog middle feeder makes the process of transferring and rotating hog middles more efficient and consistent in comparison with manual operation. The feeder consists of six main components: the identification system (green), the base (blue), the main arm (pink), the horizontal arm (yellow), the end effectors (purple), and the vertical sequencing gates (orange), see Figure 3. Each component has a specific purpose in the overall process and will be elaborated on further in the document.

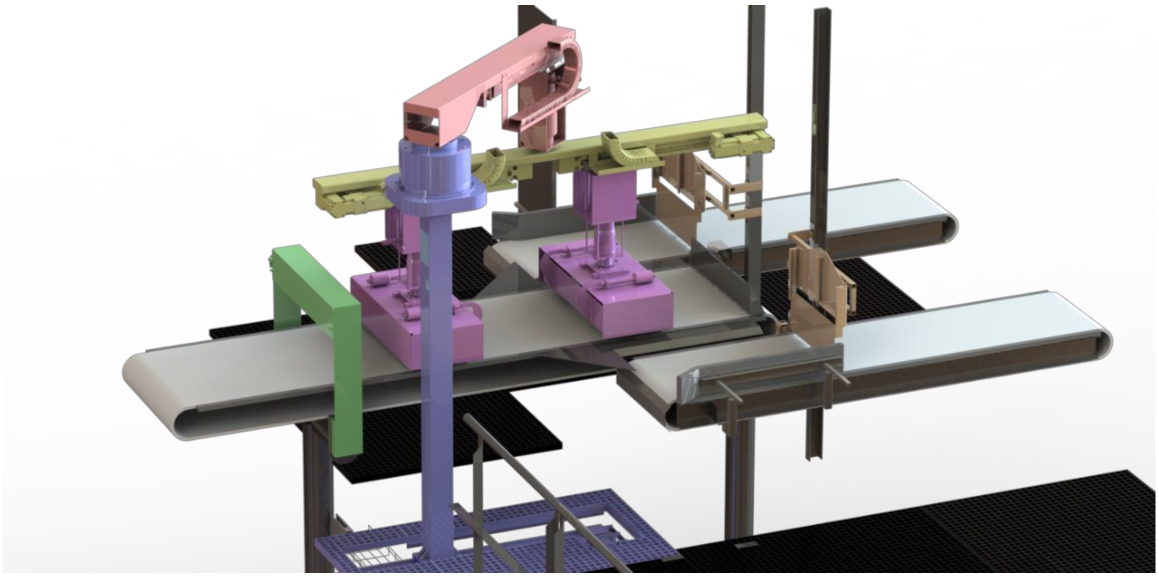


Figure 3. Isometric view of main feeder components

The purpose of the product is to autonomously identify, transfer, and rotate hog middles from a main conveyor onto two separate side conveyors. The feeder meets (CFIA) standards and is designed for easy and quick sanitation and cleaning. The following section will discuss relevant features and accessories of the feeder.

3.2. Product Features and Accessories

Several features of the automated feeder that should be noted include the incorporation of Lock Out Tag Out, an Emergency Stop button, the capability to adjust to any feed rate, electrical wire and air hose tracks, a removable box, IP69K rated actuation devices, and food safe surfaces where meat contact occurs.

Lock-Out Tag-Out is a safety procedure that ensures safety when maintaining or repairing the automated feeder. When the feeder is locked out, all power to the machine and its components is cut off at the source (electrically and pneumatically) and the switch is locked to ensure it cannot be turned back on until it is safe to do so. To lock-out the automated feeder, the device should first be in its *'manual'* mode and then the main power switch should be turned off. Once the switch is turned off, a physical lock should be placed on the switch so that it physically cannot be turned back on, see Figure 4. Only authorized personnel can lock-out or tag-out the device and should inform others when doing so.

[redacted]

Figure 4 Lock out tag out switch [5]

Another safety feature of the automated feeder is the Emergency Stop. If the device is in *'automated'* mode, the device will operate without operator input. Therefore, there will be no additional emergency stop button incorporated. But, the feeder will be connected to the existing emergency stop buttons on the main break. This will ensure that if an emergency button is pressed anywhere on the production floor, the automated feeder will stop anywhere during the process and hold its position. The feeder will continue its automated operation once the emergency stop button has been turned off and production resumes.

The automated feeder can adapt to any feed rate of the main conveyor. The adjustable operation time of the feeder is achieved by using the existing feed rate of the main conveyor. From the feed rate, the necessary motions of the feeder are divided and filled into the allotted time between sets of hog middles. More details on this motion process are discussed in section 0.

The feeder transfers the hog middles using various linear and rotary methods, which are powered either electrically, or pneumatically. Therefore, there are numerous electrical wires and air hoses throughout the feeder. The wires and hoses are kept organized and can move freely with the device by using tracks, see Figure 5. These tracks encase the wires and hoses and allow them to move with the components they are powering. In total, there are three wire tracks: one for the main arm and two for the horizontal arm.

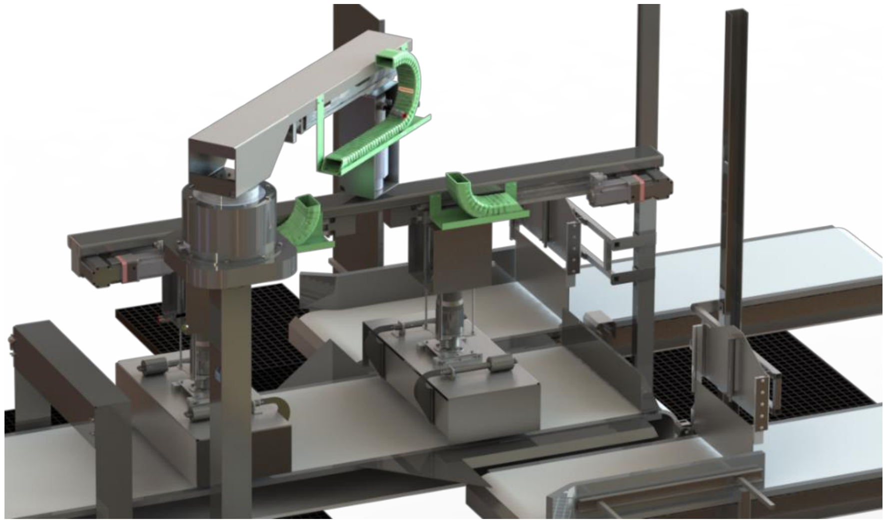


Figure 5. Location of cable tracks on main arm and horizontal arm

In addition to the tracks, wire and hose clips are fastened throughout the automated feeder to keep them organized and to avoid damaging the wires and hoses.

The box of the end effector can be separated from the housing by removing two pins and sliding the box out of the UHWM grooves, see Figure 6. This was designed so that the cleaning crew can manipulate and wash inside the box when sanitizing. More details on the end effector design are outlined in section 0.

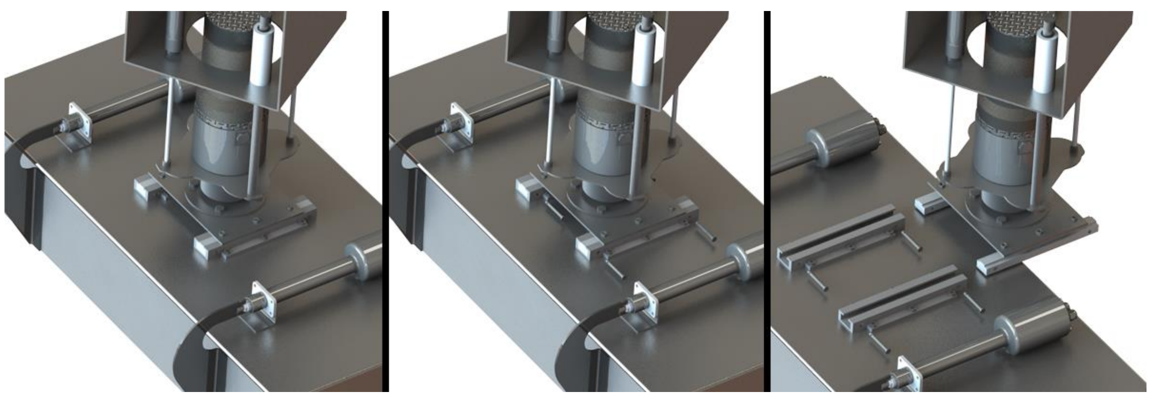


Figure 6. Steps to remove box from end effector for cleaning

To meet CFIA standards, devices and surfaces were made with IP69K rated actuators, and food-safe materials. The components of the automated feeder that contact the meat include the end effectors and the vertical sequencing plates. These components of the feeder are designed to be wash down safe at high pressures and can withstand hot chemical water used in the sanitation processes. The other components of the feeder are washdown safe, but not to the same level as the previously discussed components. However, the lower rated components are covered with polymer bags to protect them from the sanitation and cleaning process.

3.3. Detailed Component Design

Throughout this section, the details of each of the main components of the design are covered. The following section starts with the identification system, then moves through the arm assembly and concludes with the vertical sequencing gates. Any detailed information about the purchased components not discussed in the following section can be found in Appendix C – Purchased Part Specifications.

3.3.1. Identification Station

The identification system is stationed ahead of the remaining automated feeder components as shown previously in Figure 3. The identification station includes a vision camera, a linear track, and a housing structure, see Figure 7. However, HyLife and a third party will be responsible for the logistics and more advance PLC logic to integrate the vision system after the team hands off the preliminary design to HyLife.

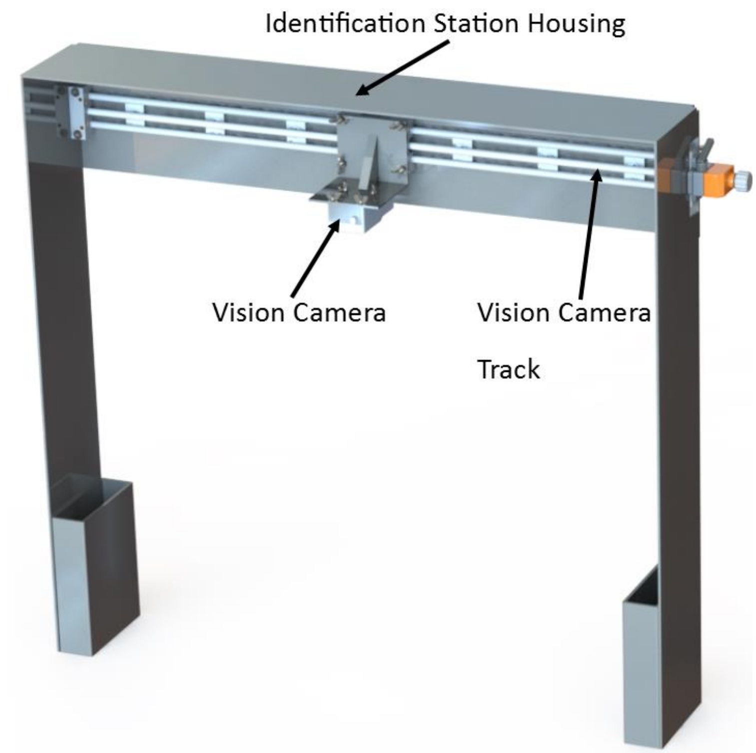


Figure 7. An illustration of the identification station

The team designed the housing structure for the camera and track so that the vision camera faces downward and is above the middles. The position allows the camera to remain stationary while the middles pass underneath on the main conveyor. The housing structure is comprised of several sheet metal parts that are welded together, and the entire housing is welded to the existing structure underneath the main conveyor.

The track is mounted on the back wall of the housing structure, using four M8 socket head screws with wing nuts. The camera is fastened to the linear track using an L-shaped mounting bracket. The camera can move linearly along the track by turning the knob on the end of the track, which is located on the outside of the support structure for easy access. The position of the camera on the track can be locked by using the included lead screw lock. Figure 8 shows the mentioned features of the vision camera's linear track.

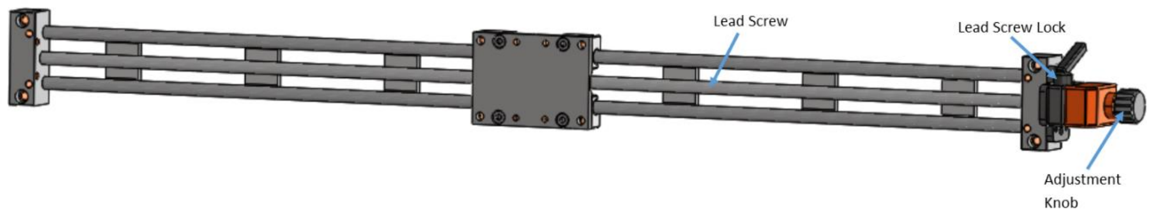


Figure 8. Key components of the vision camera's linear track

The camera identifies left and right hog middles and determines the orientation of each middle. The vision system identifies left from right by cross referencing each hog middle with numerous photos that have been input into the vision database. The left and right hog middles are mirrored in appearance and the vision system uses this characteristic to determine left from right. Each middle can be recognized using two features: the backbone and the visible ribs, shown in Figure 9.

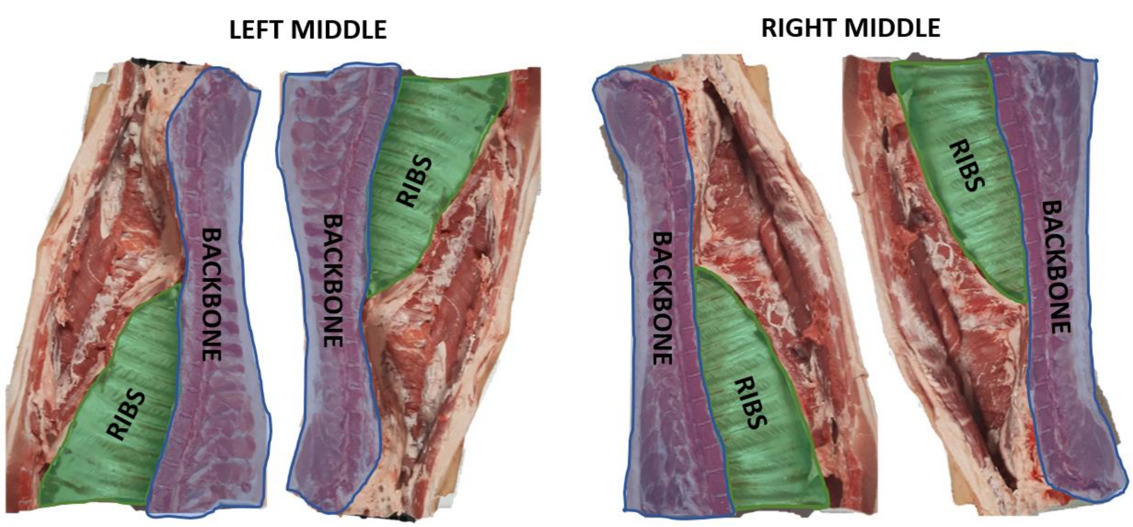


Figure 9. The backbone and the ribs on two typical middles

As shown in Figure 9, the areas are quite distinguishable because the bones are easily visible. Regardless of the hog middle's orientation, the shape that the backbone and exposed ribs make is different when comparing the left and right sides.

The orientation of each hog middle will be identified so that the end effectors can orient the boxes correctly to transfer both middles. More details on the end effectors will be discussed in section 0.

The orientation of each middle will be measured by determining the outer contour of the backbone in contrast with the white conveyor surface. From this contour, the system will create a straight line along the outside of the backbone, shown in Figure 10. The reference line created from the backbone profile will be used to identify the rotational position (θ_i) of the middle. Perpendicular to the reference line, two lines will project and lie tangent to the ham and shoulder boundary lines. These perpendicular lines will help identify the center of the middle and distance to the center (D_i) so that the end effector can position the box correctly.

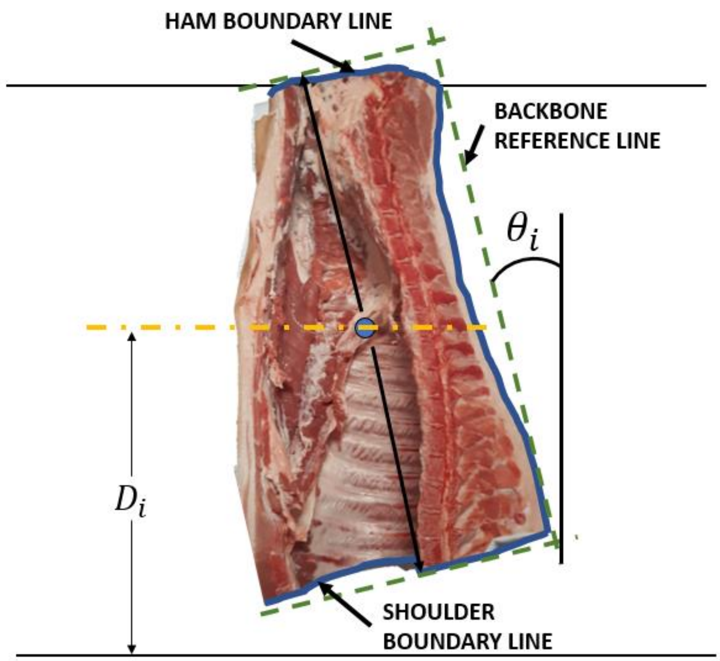


Figure 10. An illustration of the dentification schematic

3.3.2. End Effectors

There are two end effectors, each attached to a carriage from the horizontal arm. Each end effector consists of a 3-walled box with no base, an adjustable wall, two linear electric actuators, an inline gearhead, an electric servo motor, and two pneumatic cylinders. The design of the end effectors is compact, yet simple, adheres to IP69K standards, and allows accurate positioning of the hog middles, see Figure 11.

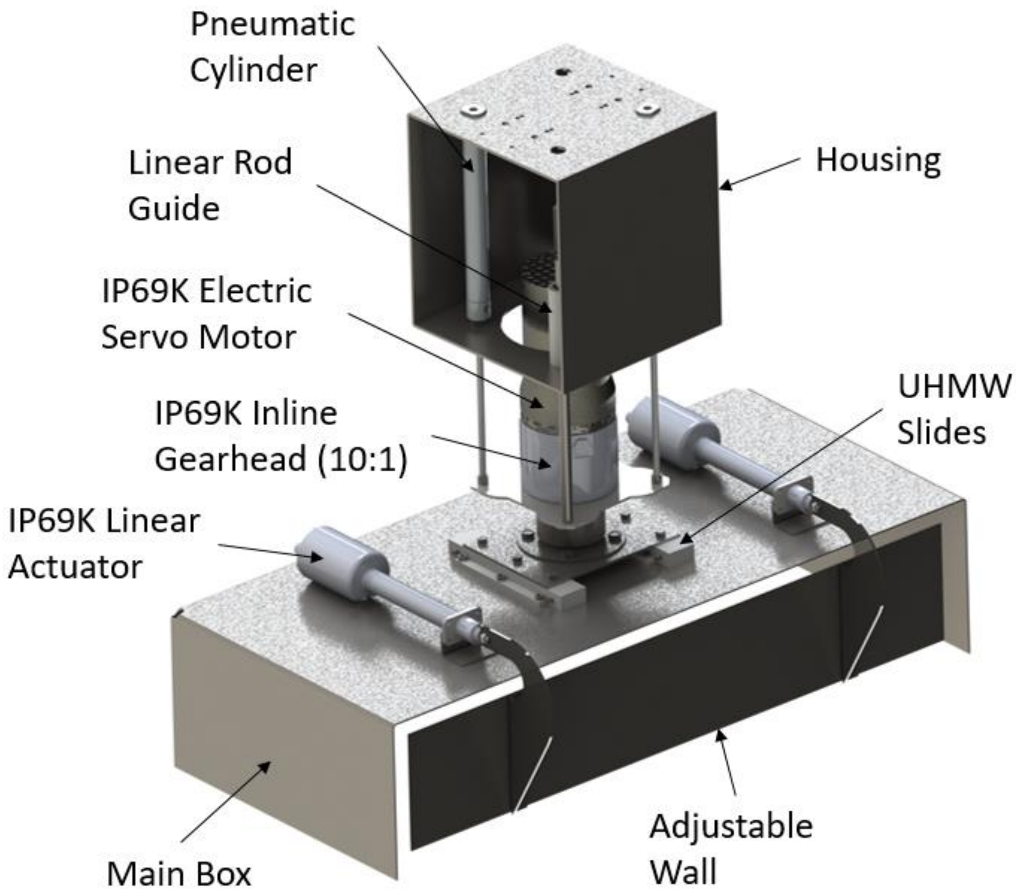


Figure 11. Assembled end effector

The hog middles vary in size and therefore the end effectors are designed to account for size variation. The middles currently average 41cm x 78cm, and the box was sized to be 87cm long to allow clearance and potential for larger hogs in the future. The width of the box is adjustable between 38cm and 48cm. The adjustable range allows for hog size variation and accommodates middles coming from hogs that are split incorrectly, thus resulting in larger than standard middles. The boxes width is adjusted using two linear actuators that move an adjustable wall as seen in Figure 12.

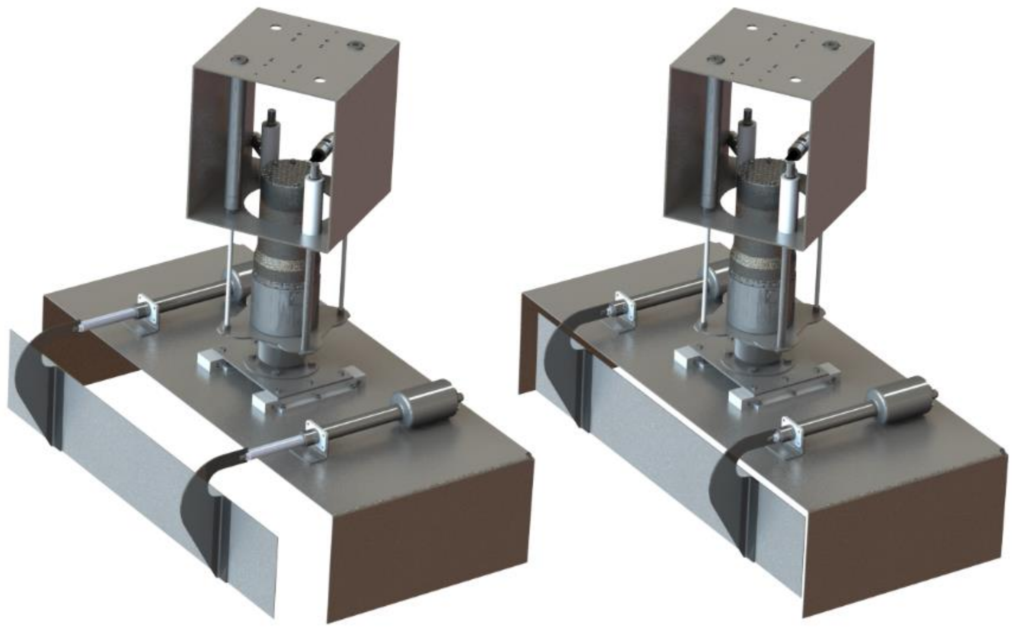


Figure 12. Open and closed adjustable wall

Each actuator is powered with a Nema size 17 stepper motor and the position and speed of the actuator is controlled by varying the input voltage. Additionally, each actuator can extend and retract up to 18in/s and supply up to 40lbf of clamping force. The actuators also have an incorporated encoder to accurately track the position of the actuator rod as it moves. This feedback will be used to continually control the position of the adjustable wall. The box and wall are both made of 316 stainless steel and have internal corners removed based on CFIA standards.

The box is attached to a housing which holds an electric servo motor and an inline 10:1 reduction gearhead. The servo motor has full 360˚ rotational mobility and is accurate when rotating in either direction, as seen in Figure 13.

Figure 13. Rotating box in two positions

Like all the other servo motors, the MPS-330P-MJ52DA servo motor used to rotate the box has an incorporated magnetic brake and accurate encoder. The brake ensures the rotational position of each box is maintained when all other components of the feeder are in motion. The encoder tracks the rotational speed and acceleration of the motor and is used to provide feedback to the controller.

The inline gearhead is connected to the boxes through a bearing keyway and a bolt. The gearhead selected has an internally threaded shaft and is rated for a 1755N axial load, which is more than enough for this application. The threaded shaft is bolted to the plate between the box splitting guides and the gearhead, as seen in Figure 14. The torque from the motor is transferred using a key. A housing is attached to the gearhead and containing a bearing to take up the radial loads experienced during operation. The bearing is secured between a shoulder and a retaining ring and has a seal to prevent ingress of water during sanitation, which satisfies HACCP standards.

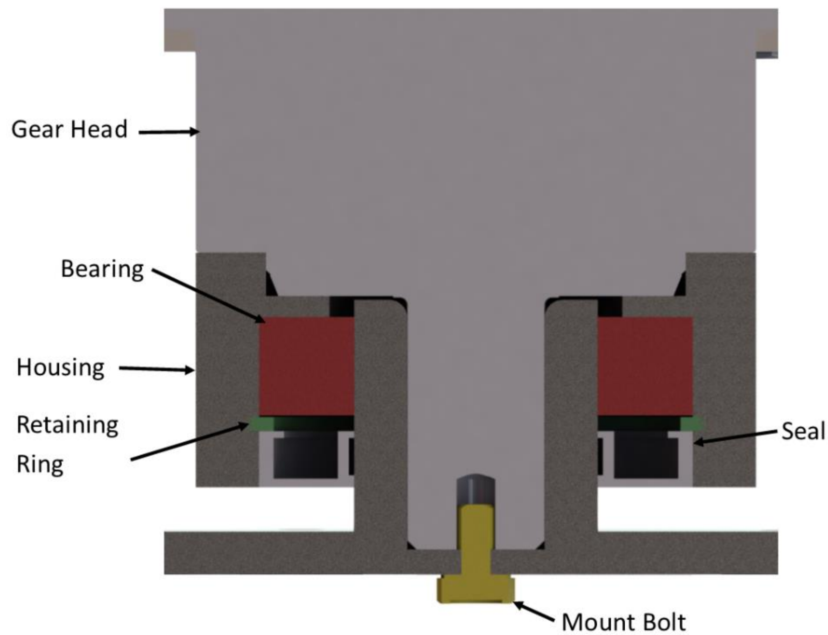


Figure 14. Gear head to box attachment

In addition to rotating the hog middles, each end effector can also engage and disengage the middles by dropping down, or lifting, respectively. This is achieved using two bidirectional pneumatic cylinders which are attached to a mounting plate. Both cylinders extend and retract the housing containing the servo motor and gearhead as well as the box itself, as seen in Figure 15.

Figure 15. Retracted and extended boxes

3.3.3. Horizontal Arm

The horizontal arm consists of a long rectangular support beam, two linear tracks, two 90˚ gearheads, and two electric servo motors, see Figure 16. The purpose of the horizontal arm is to extend and retract both end effectors from the main conveyor to the side conveyors.

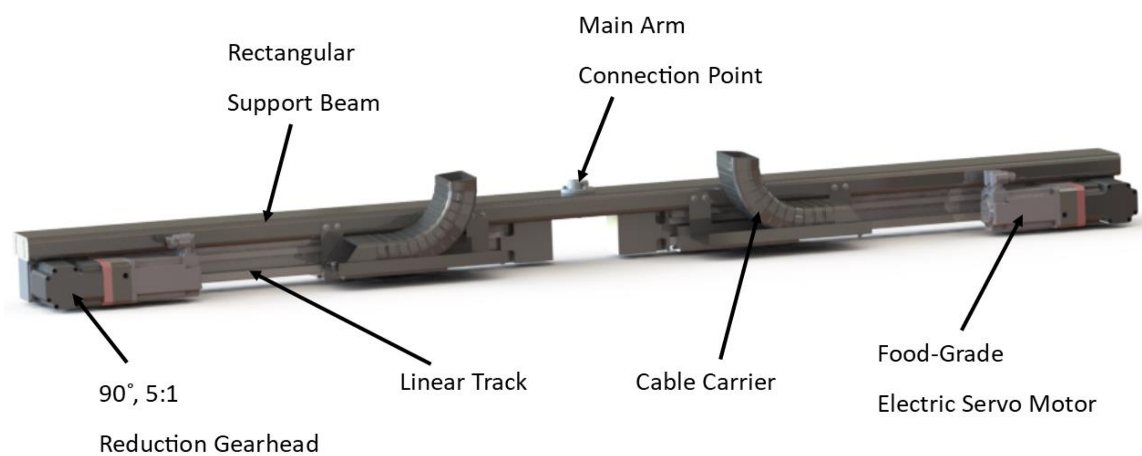


Figure 16. Rendered Horizontal Arm

Both linear tracks are mounted underneath the support beam equidistant from the center such that the gearhead and servo motors are mounted on the ends of the support beam. Both linear tracks are positioned such that the narrowest position of each carriage allows for a 6 [in] gap between the end effectors and the widest position allows the edge of the end effectors to rest against the guides of the side conveyors, see Figure 17. Based on the two positions mentioned, each carriage can travel 635 [mm].

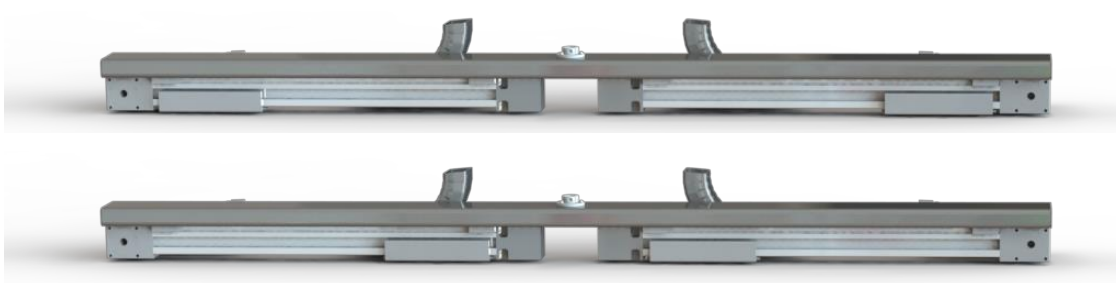


Figure 17. Narrow and wide positions of carriages

Each linear carriage is belt driven by an electric servo motor (MPF-B330P-MJ74BA) coupled with a 90˚, 5:1 reduction gearhead. The 90˚ gearheads were chosen to reduce the input RPM and increase out output torque while keeping the total length of the horizontal arm to a minimum. The linear tracks, gearheads, and servo motors on the horizontal arm are not IP69K rated, but are wash-down protected. To ensure the devices do not get damaged during cleaning, they are covered with a polymer bag. Like the other electric servo motors, the (MPF-B330P-MJ74BA) motor includes a magnetic brake and accurate encoder. The feedback from each encoder is used to control the position of the carriages on the linear tracks. The linear velocity of each carriage will be changed by varying the input voltage to the servo motors.

3.3.4. Main Arm

The main arm protrudes outward over the main conveyor from the rotary table as shown in Figure 18. The purpose of the main arm is to extend, retract, and rotate the horizontal arm which connects to the end effectors. The main arm consists of a support structure, a linear track, two electric servo motors, and two inline gear heads.

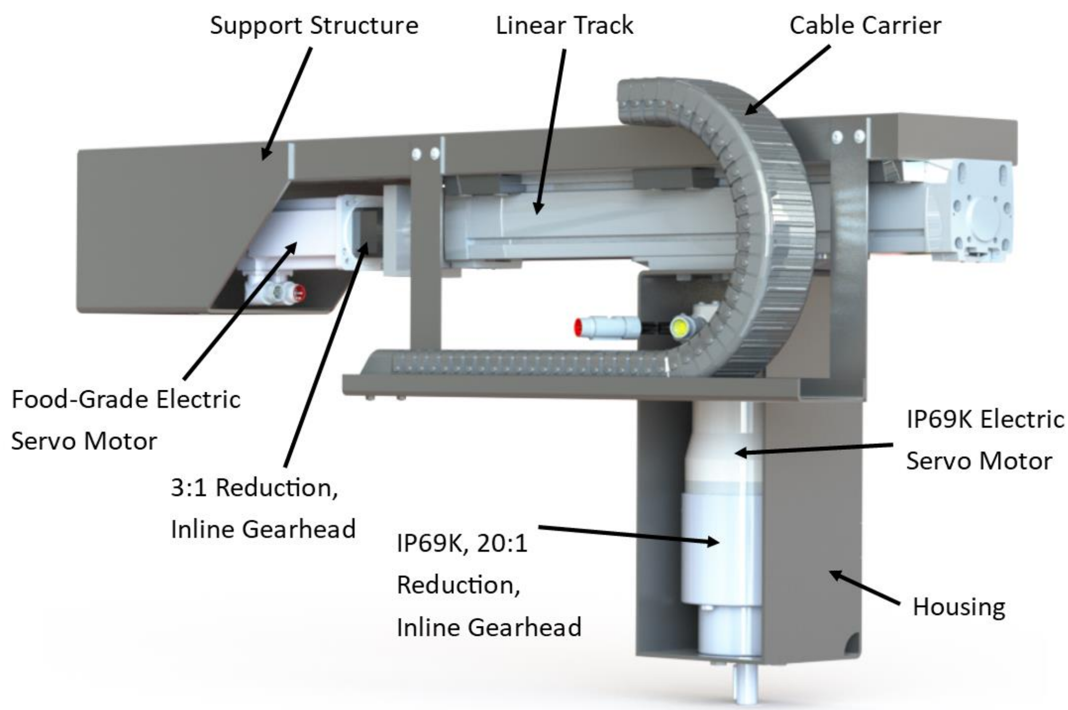


Figure 18. Full main arm assembly including linear track and rotary actuator

The linear track is mounted on the underside of the protruding rectangular tubing and allows linear motion of the horizontal beam and end effectors. The chosen linear track can withstand large moments that are exerted when the feeder moves dynamically. The carriage of the track can travel 400mm, which is the required range based on the motion of the system. The carriage is screw driven from an electric servo motor (MPF-A330P-MJ52DA) which has a 3:1 inline gearhead (XTA-070-003-3) coupled to it. The gearhead reduces the input RPM from the servo motor and increases the output torque to the linear track to ensure the operational requirements are met. The linear track, inline gearhead, and servo motor are coupled together using Thomson *RediMount* flanges that are specifically designed and chosen to fit the specific models chosen.

All drive components are not IP69K rated but are wash-down safe. To ensure their protection when cleaning, the linear track, gearhead, and electric servo motor are covered with a polymer bag.

The servo motor is equipped with a magnetic brake to ensure linear positions are held while other components of the feeder move. The servo motor also has a built-in encoder which accurately measures angular position, velocity and acceleration. The feedback from the encoder is used to compare the actual outputs to the variable inputs of the system. The electric motor will change the velocity and acceleration of the carriage by varying the input voltage to the motor.

Attached to the carriage of the linear track is a housing which holds an electric servo motor (MPS-A4540F-MJ54DA) and a 20:1 reduction, inline gearhead (AQT120-020). Both the electric motor and the inline gearhead are IP69K rated and therefore are fully protected. The output shaft of the inline gearhead attaches to the center of the horizontal arm and rotates the horizontal arm and end effectors based on the desired motion of the system, see Figure 19.

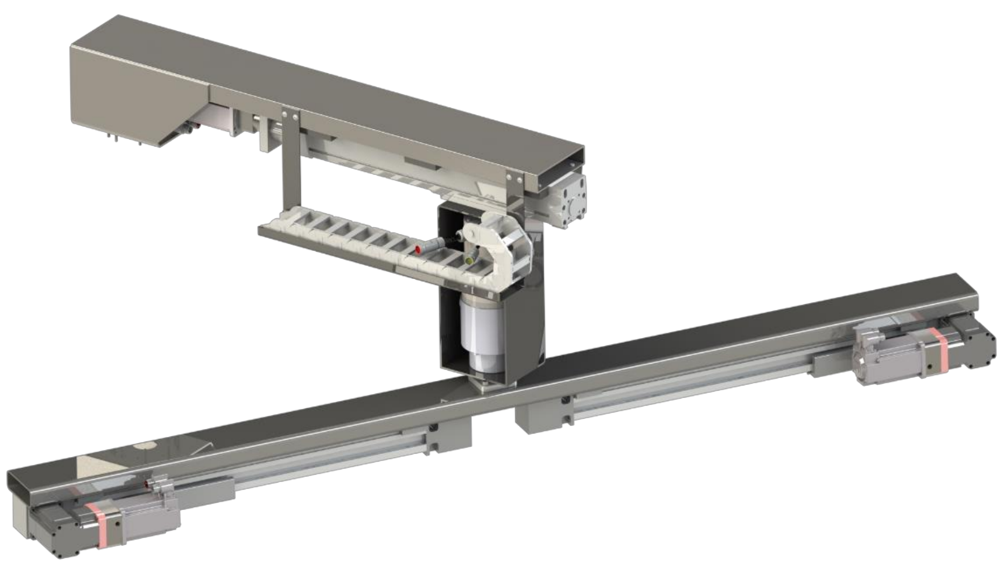
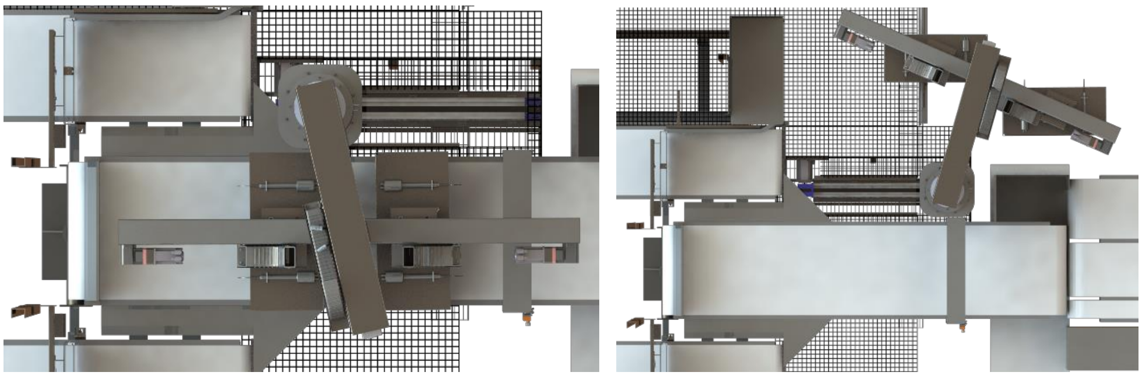


Figure 19. Rotary actuator attached to center of horizontal arm assembly

The servo motor and inline gearhead used to rotate the horizontal arm have the same features as the other two models used to drive the linear track. This includes the magnetic brake and accurate encoder.

3.3.5. Base Structure

As mentioned previously in section 3.2, the automated feeder has two different modes: the *'manual'* mode and the *'automated'* mode, shown in Figure 20. The *'manual'* mode is used when manual labour is desired over the automated feeder. In *'manual'* mode, the feeder will be powered off and moved away from its *'automated'* location to allow space for the workers. The *'automated'* mode is when the feeder is at its work location and functions autonomously.



(a) (b)

Figure 20. a) The illustration of the feeder when it is at the '*automated'* mode
b) The illustration of the feeder when it is at the '*manual'* mode

The feeder moves 1.016 meters (40 inches) between the pre-set positions of each mode using an electrically driven linear track, which is mounted below the food grade floor grating on the elevated work station. The main support beam of the feeder is connected to the carriage of the base linear track and supports the main arm, horizontal arm, and both end effectors, shown in Figure 21.

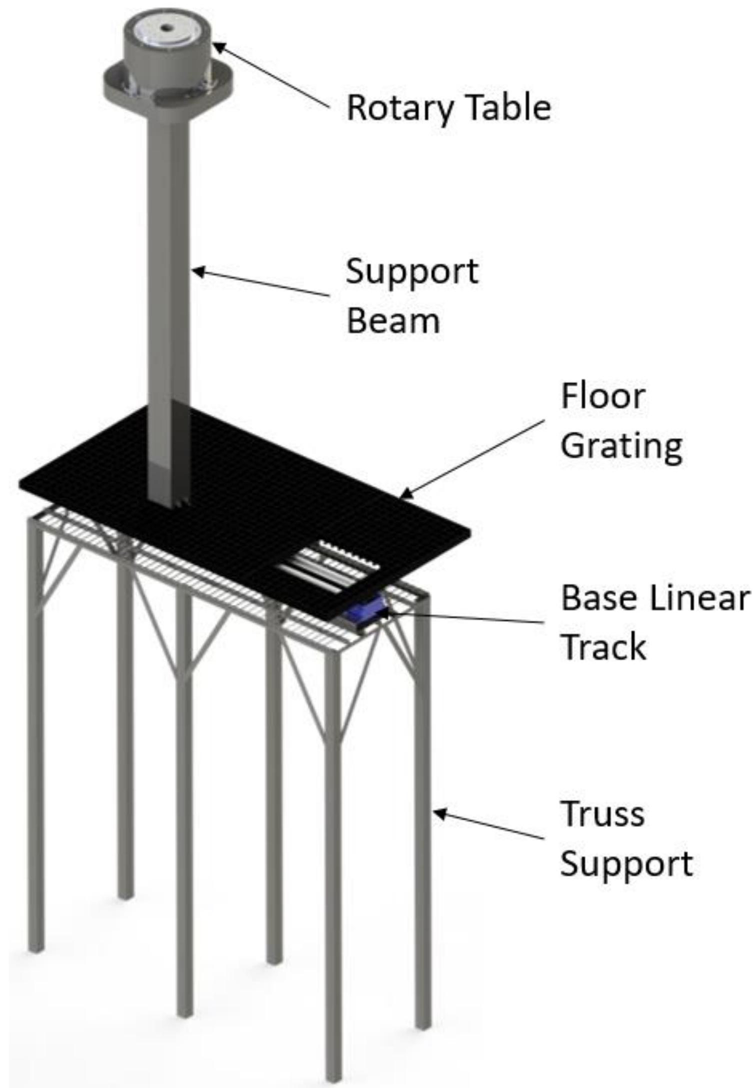


Figure 21. An illustration of the base structure

An electric servo motor (MPF-A430P-SJ74BA) is mounted to the linear track and can turn at a maximum speed of 270 RPM. The motor drives the carriage which is guided along tracks using a fully enclosed belt-drive system.

The position of the carriage along the linear track is maintained by a magnetic brake incorporated into the electric motor. Before moving positions, the food grade floor grating should be removed to allow the support beam to travel freely. Then, the electric servo motor will slowly accelerate the carriage, maintain a constant speed for a duration of time, then decelerate to a stop at the new position. Figure 22 shows the velocity profile of the arm base track carriage.

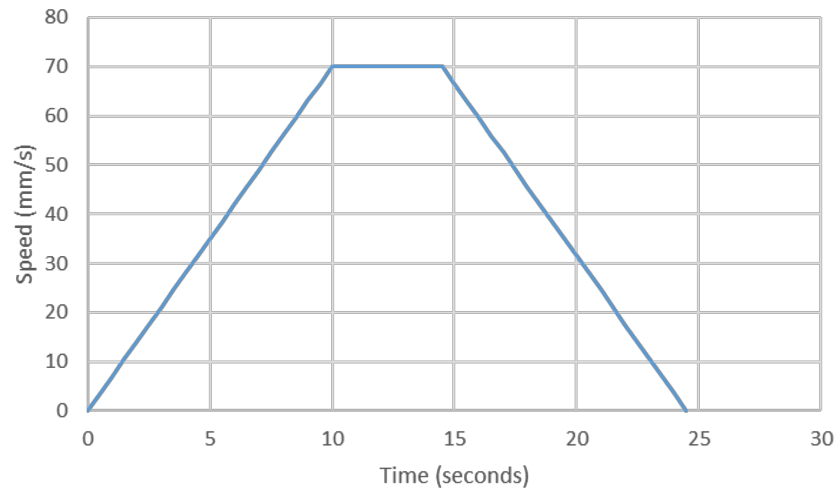


Figure 22. Velocity profile of the base track carriage

Varying the input voltage to the servo motor will achieve the various velocities required for the carriage to move along the track. Figure 23 shows the distance that the track carriage has travelled with respect to the time.

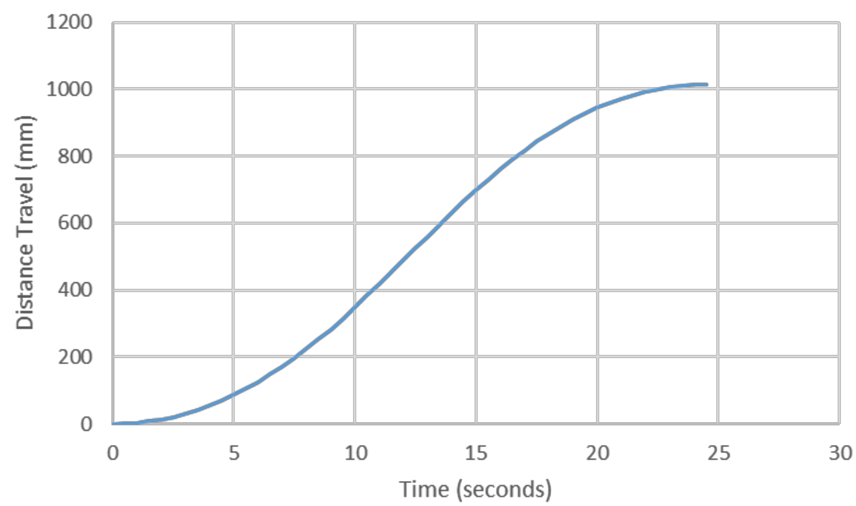


Figure 23. Displacement profile of the base track carriage

At the top of the support beam, an electrically powered rotary table is mounted to a container, as shown in Figure 21. The rotary table (ADR360-A215), rotates the main arm of the feeder along with the attached horizontal arm and end effectors. The rotary table is capable of 360˚ rotation and is accurate in both rotational directions.

3.3.6. Vertical Sequencing Gates

The two vertical sequencing gates are positioned above each side conveyor close to the end of the guide bars. The vertical gates, as seen in Figure 24, are mounted to existing C-beams using a rigid support structure.

Figure 24. Position and mounting of vertical sequencing gates

The purpose of the vertical sequencing gates is to hold the hog middles and then release them down each side conveyor at the same time. The middles are released when the gate lifts and the conveyor transports the middles underneath the gate. The main components of each of the two vertical gates include the mounting structure, a bidirectional pneumatic cylinder, a gate, and a photoelectric sensor, see Figure 25.

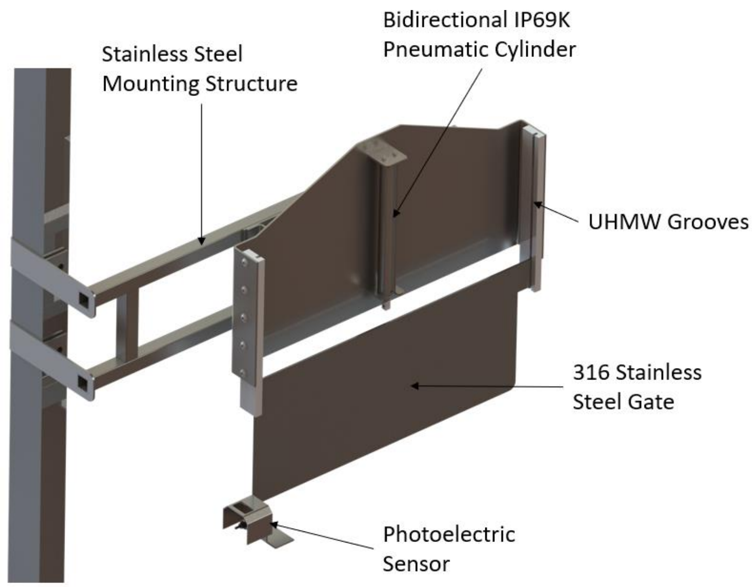


Figure 25. Components of a vertical sequencing gate

The existing guard rails are adjustable along the width of the conveyor and therefore the gate assembly is as well. The gate assembly can be incrementally moved and pinned to a new location on the horizontal guide, see Figure 24. Pins were used for easy removal for repositioning and cleaning purposes.

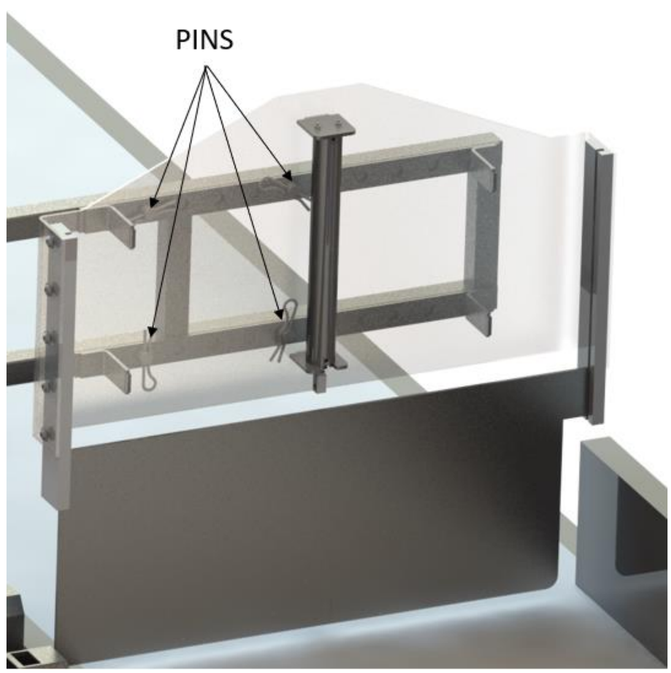


Figure 26. Location of removable pins for horizontal positioning and cleaning

The IP69K pneumatic cylinder is fastened to the back plate of the support structure and the rod of the cylinder is attached to the base of the gate. Each cylinder is rated to 250 [psi], which is more than enough to lift each gate. The gate can be easily removed for more rigorous cleaning and sanitation if necessary. Additionally, the gate slides up and down within UHMW grooves which allow for extra support and near-frictionless guidance. In the *'up'* position, the cylinder is retracted and holds the gate 9.5 [in] above the surface of the side conveyor. A typical hog middle is approximately 6 [in] tall, but additional clearance was added to account for size variations of the middles. In the *'down'* position, a 0.5 [in] clearance above the conveyor exists and the gate is lowered by extending the pneumatic cylinder. In total, the gate travels a total stroke of 9 [in], see Figure 27.

Figure 27. Up and down positions of the gates

The middles are released simultaneously using the photoelectric sensors and the gates. The gates will lift simultaneously once both middles are present and pressed against the gates. The gates lift when both the photoelectric sensors have been tripped. Each sensor is mounted in front of the respective gate, to the side of the conveyor, and faces outward. The sensors are positioned this way because they are diffuse reflective photoelectric sensors. This means that the sensors project a red laser across the conveyor and measure the reflected beam, see Figure 28.

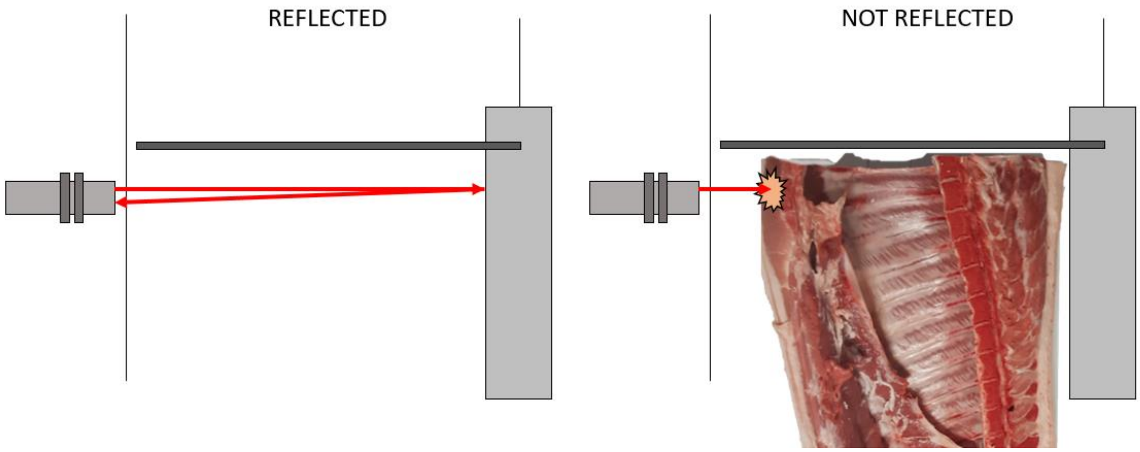


Figure 28. Reflected and non-reflected laser from photoelectric sensor

If there is no middles present, the projected laser will reflect off the UHMW guide and back to the receiver. If a middle is present, the laser will not reflect off the meat and the sensor signal will change.

4. Theory of Operation

This section will cover the theory of operation of the proposed design, which includes how each component contributes to the movement and positioning of the middles.

4.1. Motion Study

The feeder is designed to identify, engage, rotate, transfer, and release the middles in a short time period. The cyclic process is achieved through several specific steps which are shown in Figure 29. More details on each step are summarized in the following.

Figure 29. Position cycle of main arm, horizontal arm, and end effectors

Each process begins by identifying the left and right middles and determining their orientation (θ_i) and position (D_i). This preliminary step is detailed earlier in section 3.3.1. With the information gathered from the vision camera, the main arm and horizontal arm will adjust both end effectors to be in the 'Ready' position. The 'Ready' position, as seen in Figure 30, has the main arm perpendicular to the main conveyor, the horizonal arm parallel with the main conveyor, the horizontal linear tracks at their narrowest position, and the end effectors aligned and oriented to match the hog middles.

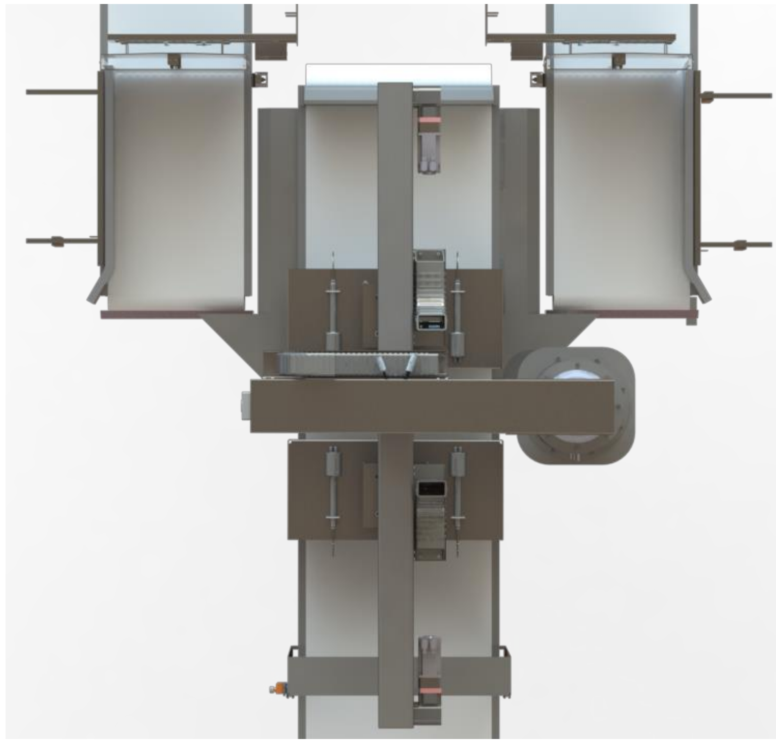


Figure 30. ‘Ready’ position of automated feeder

When the middles pass under the boxes, the boxes will drop and cover the boxes using the pneumatic cylinders of the end effectors. The described step is called ‘Drop’.

The following ‘Step 0’ rotates the boxes from their initial orientation (θ_i) to their final position (θ_f) so the backbones are facing outward. ‘Step 0’ is divided into three smaller steps, which include ‘Step 0a’, ‘Pause’, and ‘Step 0b’, see Figure 31.

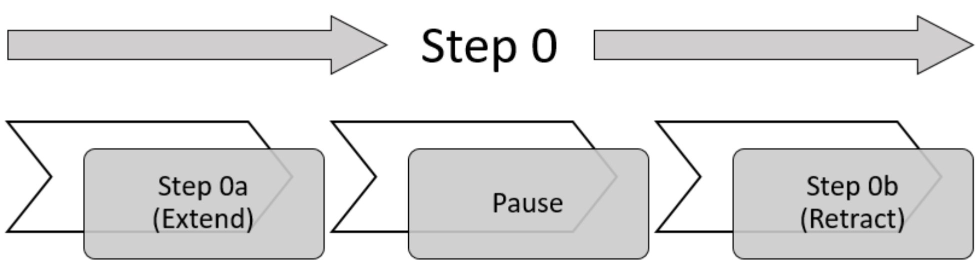


Figure 31. ‘Step 0’ breakdown structure

Initially, the boxes are too close together and would collide if they rotated. Therefore, each horizontal track will extend their respective end effector outward a distance of 300[mm] (‘Step 0a’). This distance is enough to allow the boxes to rotate freely without colliding with each other. Once the horizontal tracks move the required 300[mm] outward, they will remain at that position for a short time ('Pause'). Then, the horizontal track will retract back 300[mm] to have both boxes in their narrowest position ('Step 0b'). During the full duration of 'Step 0', the boxes will continually rotate from the initial orientation (θ_i) to the final orientation (θ_f). Also, the linear actuators will gently compress the adjustable wall against the side of the middles. Adjusting the wall ensures the middles cannot move in the box while they are being transferred. A visual breakdown of Step 0 is shown in Figure 32.

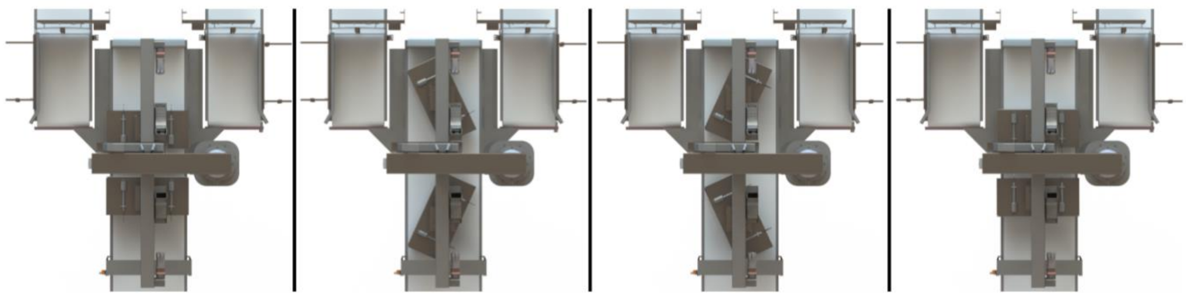


Figure 32. Iterative steps showing breakdown of 'Step 0'

Regardless of the initial orientation of the middles, the maximum possible rotational angle for each end effector to complete is 180˚. This is because the end effector will prioritize rotating the least amount. The following logic is used to determine rotational distance and direction, see TABLE VII. Throughout the remainder of the process, the boxes will not rotate until Step 3.

TABLE VII
ROTATION DISTANCE AND DIRECTION LOGIC FOR 'STEP 0'

Input		**Output**
$\mathbf{0° < \boldsymbol{\theta_i} < 180°}$	$0° \geq \theta_i \geq 180°$	Rotate:
1	0	CW $180° - \theta_i$
0	1	CCW $180° - \theta_i$

Next, ‘Step 1’ will transfer and rotate both end effectors down and to the end of the main conveyor, while keeping them centered on the width of the main conveyor. The final position will have the end effectors at the end of the main conveyor and positioned such that the backbones of each middles are facing outward. This is done by rotating the main arm, extending the main linear track, and rotating the horizontal arm, see Figure 33

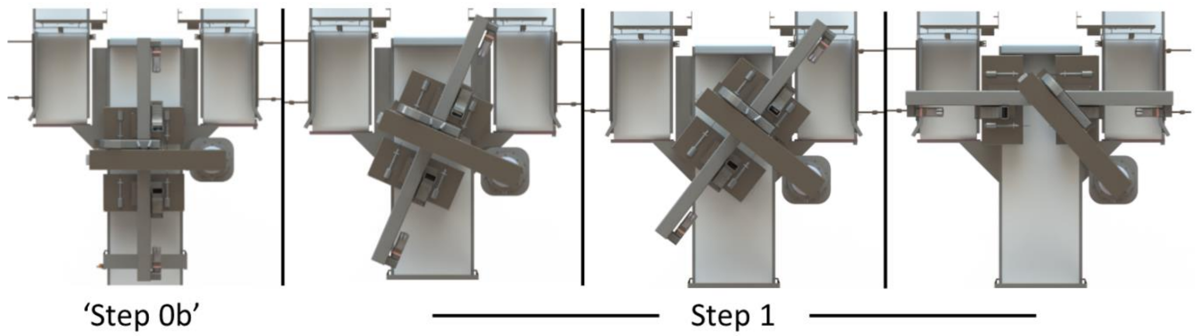


Figure 33. Iterative steps showing breakdown of Step 1

‘Step 1’ is a discrete process and does not change. Therefore, there is no logic to the process. During the entire duration of ‘Step 1’, the main arm will rotate CW 47˚, the horizontal arm will rotate CW 43˚, and the main linear track will extend D_1 distance from its initial position (D_i). The distance D_1 is determined as follows.

$$D_1 = Stroke\ Length - D_2 - D_i$$

$$D_1 = 400[mm] - 60[mm] - D_i$$

$$D_1 = 340[mm] - D_i$$

These specific distances and angles are based on the position of the device in *‘automated’* mode relative to the main conveyor and side conveyors.

Then, ‘Step 2’ will extend both end effectors outward from the end of the main conveyor to the side conveyors and finish positioning the end effectors. ‘Step 2’ is broken down into two separate steps called ‘Pause’ and ‘Step 2a’, see Figure 34.

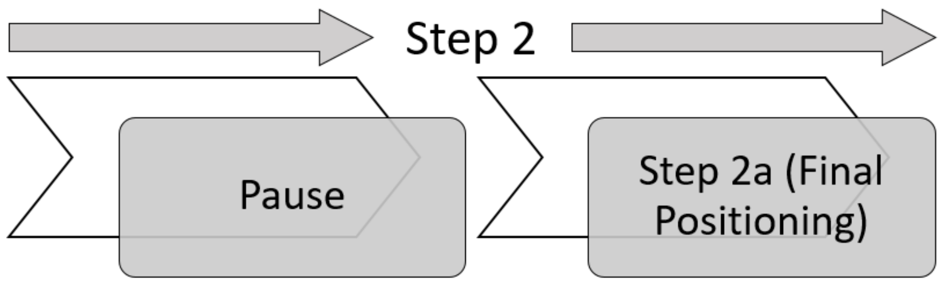


Figure 34. 'Step 2' breakdown structure

‘Step 2’ is a discrete motion process that does not change. Therefore, there is no logic for the process. Specifically, ‘Step 2a’ includes the motion where the main arm rotates CW 2˚, the horizontal arm rotates CCW 2˚, and the main linear track extends 60[mm]. Throughout the entire ‘Step 2’ process, the end effectors are moved outward 635[mm] on the horizontal tracks. The ‘Pause’ portion ensures the boxes are passed the stop wall at the end of the main conveyor before the boxes are moved to their final position. The final position has the backbone of each middle facing outward and touching the guard rail on each side conveyor. The entire motion process of ‘Step 2’ is shown iteratively in Figure 35

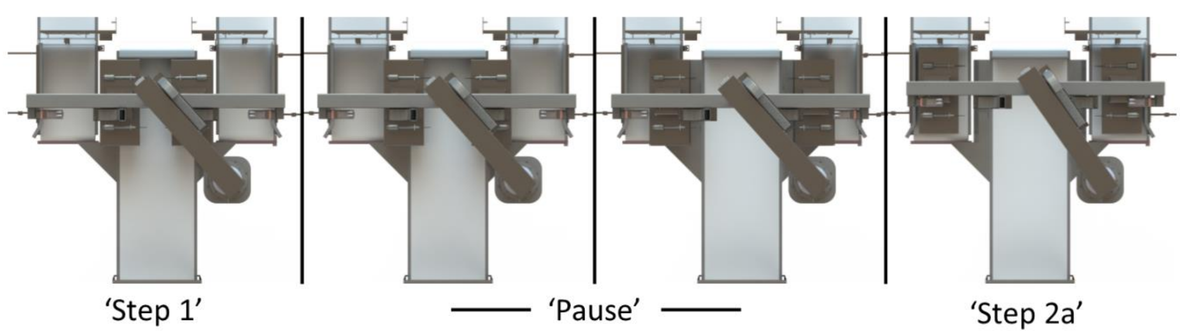


Figure 35. Iterative steps showing breakdown of ‘Step2’

Once the boxes are in the correct position, the ‘Lift’ step will widen the adjustable wall and lift the box using the pneumatic cylinders on each end effector. The linear actuators will widen the adjustable wall by completely extending the rod. This process is discrete and does not incorporate logic.

The final process, 'Step 3' returns the main arm, horizontal arm, and end effectors to the 'Ready' position. This is done by rotating the main arm, rotating the horizontal arm, retracting the main linear track, retracting both horizontal linear tracks, and rotating the boxes. The process of doing all these motions is divided into two steps including 'Pause' and 'Step 3a', see Figure 36.

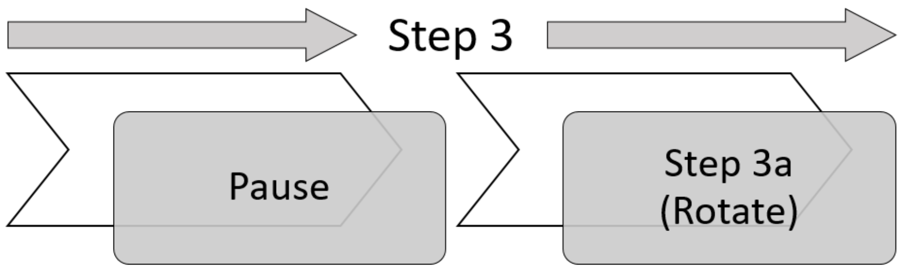


Figure 36. 'Step 3' breakdown structure

Throughout the entire duration of 'Step 3', the main conveyor will rotate CCW 49°, the main linear track will retract, the horizontal beam will rotate CCW 41°, the horizontal linear tracks will retract 635[mm], and the linear actuators will extend completely. The motion process of 'Step 3' is shown iteratively in Figure 37.

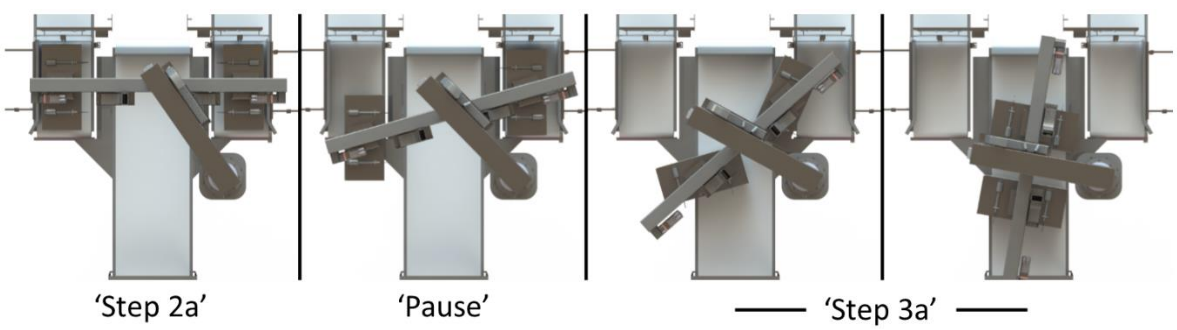


Figure 37. Iterative steps showing breakdown of 'Step 3'

'Step 3a' includes the rotation of the boxes from their final position (θ_f) to the 'Ready' position of the next set of middles. The 'Pause' step ensures that the boxes do not begin to rotate until they have been moved from the side conveyors. This ensures the boxes do not collide with the vertical sequencing gates or UHMW guide bars.

The boxes will rotate, and the main linear track will retract based on the orientation and position of the next set of middles. The following logic is used to determine the ‘Ready’ angle and position, see TABLE VIII.

TABLE VIII
LOGIC FOR END EFFECTOR AND MAIN LINEAR TRACK RETURN CONTROL

Input		Output	
$\mathbf{0° < \boldsymbol{\theta}_{\boldsymbol{i}} < 180°}$	$0° \geq \theta_i \geq 180°$	Rotate:	Retract:
1	0	CCW $180° - \theta_i$	400[mm] - D_i
0	1	CW $180° - \theta_i$	400[mm] - D_i

After ‘Step 3’ is complete, the entire process restarts and continues operating in a cyclic fashion. The following section will detail the timing and position controls designed to follow the motions described.

4.2. Timing and Position Controls

As mentioned previously, the feeder can adjust to varying feed rates based on the main conveyor speed. Therefore, the cycle time is not constant. To account for this, the steps to complete the entire process are allotted percentages of the total time required to complete one full cycle. However, several steps in the full process have a fixed time including: 'Drop', 'Pause' in Step 0, 'Lift', and 'Buffer'. The timing of each step for one full cycle is illustrated in Figure 38.

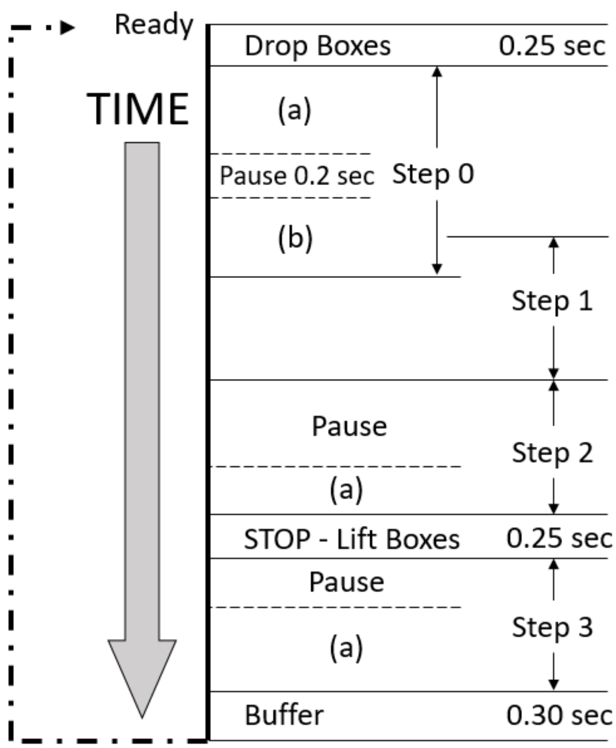


Figure 38. Chronological steps required to complete one full cycle

'Step 1' starts half-way through 'Step 0b' to save time. When half-way through 'Step 0b', both end effectors are 3/4 finished their rotation to the final orientation (θ_f) and are 150[mm] from returning to their narrowest position.

'Step 2a' begins at time 2/3 of 'Step 2'. The delay ensures that the end effectors travel 2/3 the distance (423[mm]) and do not collide with the back stop of the main conveyor.

‘Step 3a’ starts at time 1/4 of ‘Step 3’. The small delay before ‘Step 3a’ begins ensures that the boxes do not rotate and collide with any parts of the existing structure until they are clear to do so.

The total cycle time is calculated based on the main conveyor feed rate. The maximum feed rate is 600 hogs/hr, which results in a cycle time of 6.0 seconds. The available time to complete the cycle is determined by subtracting the constant times from the total cycle time.

$$t_a = t_{tot} - t_{drop} - t_{lift} - t_{buff}$$

The constant times shown are approximations. From the available time (t_a), ‘Step 0’, ‘Step 1’, ‘Step 2’, and ‘Step 3’ are divided out of 100%. The available time was divided to minimize the experienced torque and bending moments of various components of the feeder. The allotted percentages and corresponding times are summarized in TABLE IX.

TABLE IX
ALLOTTED TIMES FOR EACH STEP FOR COMMON FEED RATES

	Feed Rate	**600 Hogs/hr**	**540 Hogs/hr**	**300 Hogs/hr**
	Total Time [sec]	6.00	6.67	12.00
	Available Time [sec]	5.20	5.87	11.20
Step No.	**Allotted Percentage [%]**	**Allotted Time [sec]**		
0	33.50	1.74	1.97	3.75
0a	N/A	0.77	0.89	1.78
0b	N/A	0.77	0.89	1.78
1	21.91	1.14	1.29	2.45
2	26.00	1.35	1.53	2.91
2a	N/A	0.45	0.51	0.97
3	26.00	1.35	1.53	2.91
3a	N/A	1.01	1.15	2.18
	Total of Main Steps [sec]	5.20	5.86	11.14
	Difference [sec]	0.00	0.01	0.06

The calculations done to determine the torque, bending moments, and other dynamic loads are detailed in Appendix A – Stress Analysis. To minimize the experienced torque and bending moments on the drive components of the system, the input rotational acceleration was minimized. The acceleration was minimized by extending the acceleration period as much as possible. The longest possible time for acceleration and deceleration is half the time required to complete the motion. The general velocity versus time plot for all the drive components is shown in Figure 39.

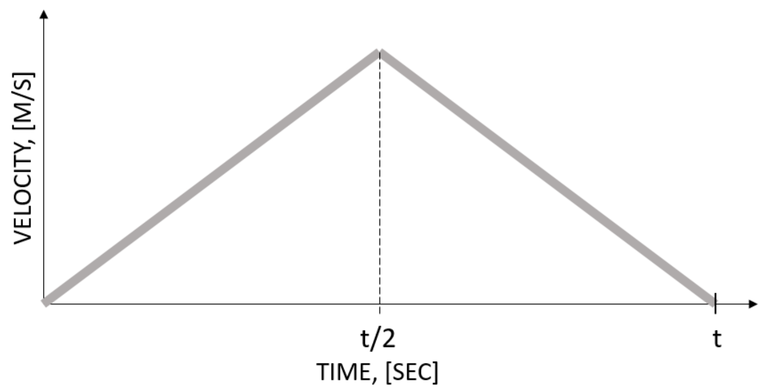


Figure 39. General velocity vs time plot for drive components

Based on the velocity characteristics shown, motion graphs were created to precisely display inputs to each drive component. Specifically, the main arm linear track, the horizontal arm linear tracks, the horizontal rotary motor, the end effector rotary motor, and the base rotary table are shown. The motion graphs of each component are summarized in the following, see Figure 40 to Figure 44. The angular or linear acceleration, velocity, and position of every component is included in each motion graph.

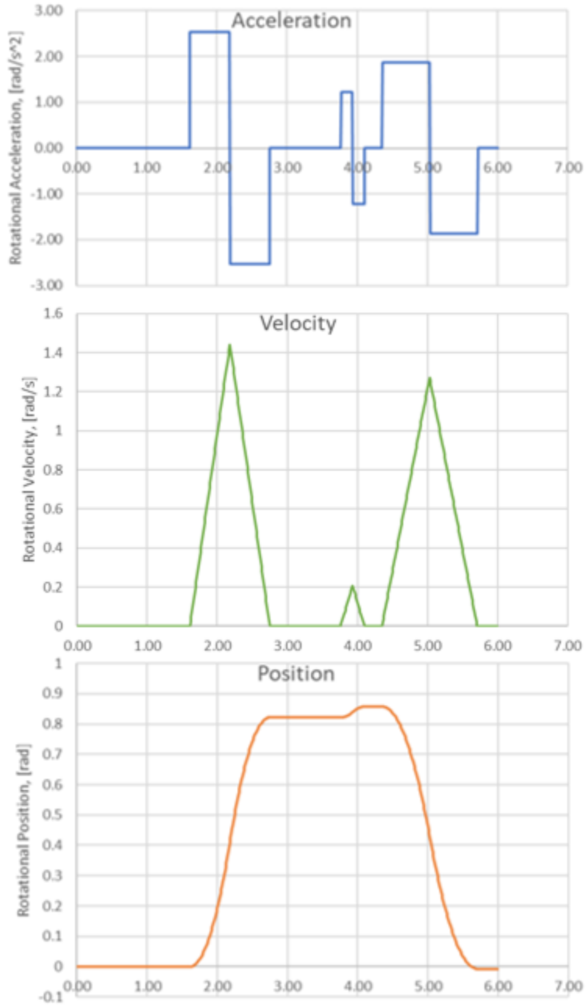


Figure 40. Motion graph of base rotary table

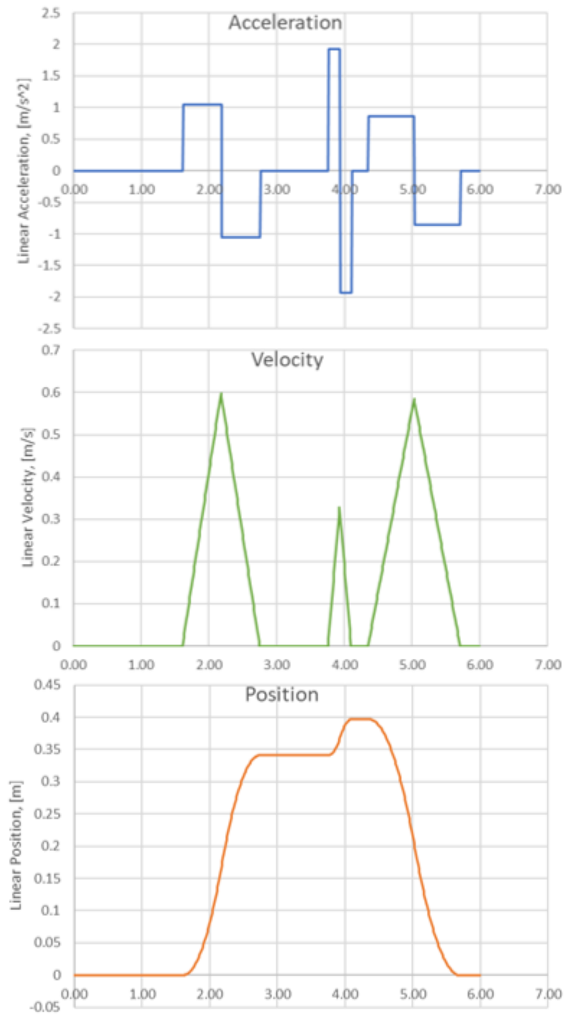


Figure 41. Motion graph of main arm linear track

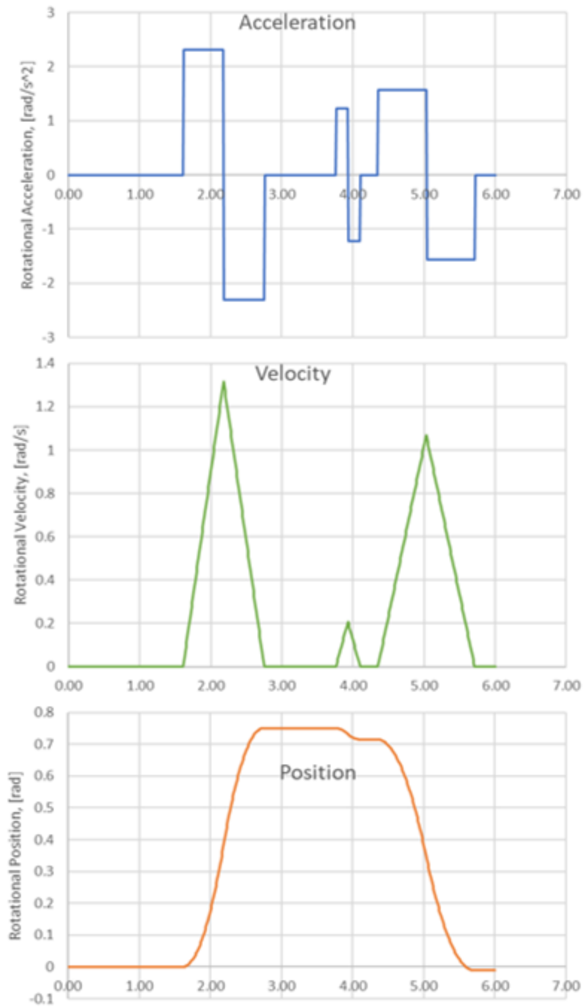


Figure 42. Motion graph of horizontal rotary motor

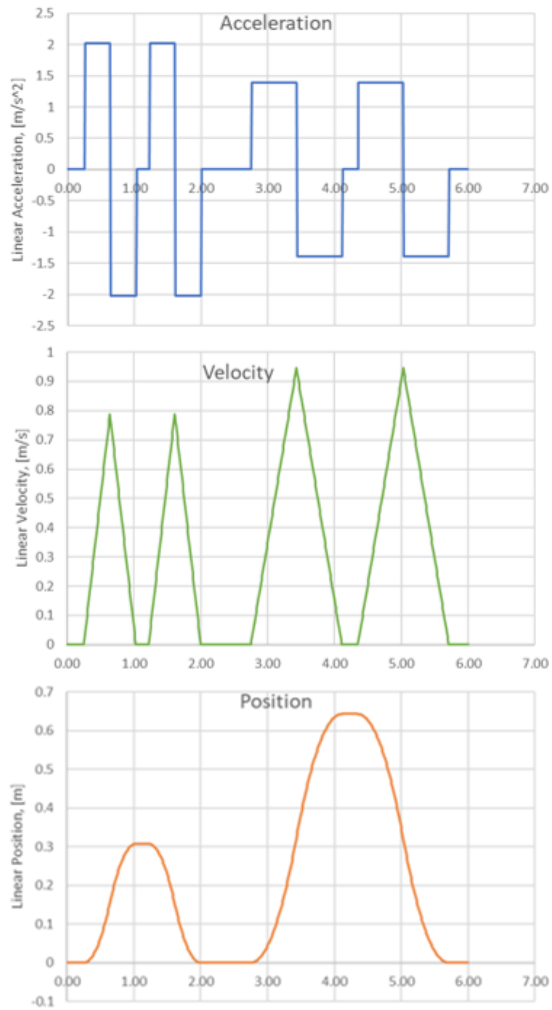


Figure 43. Motion graph of horizontal linear tracks

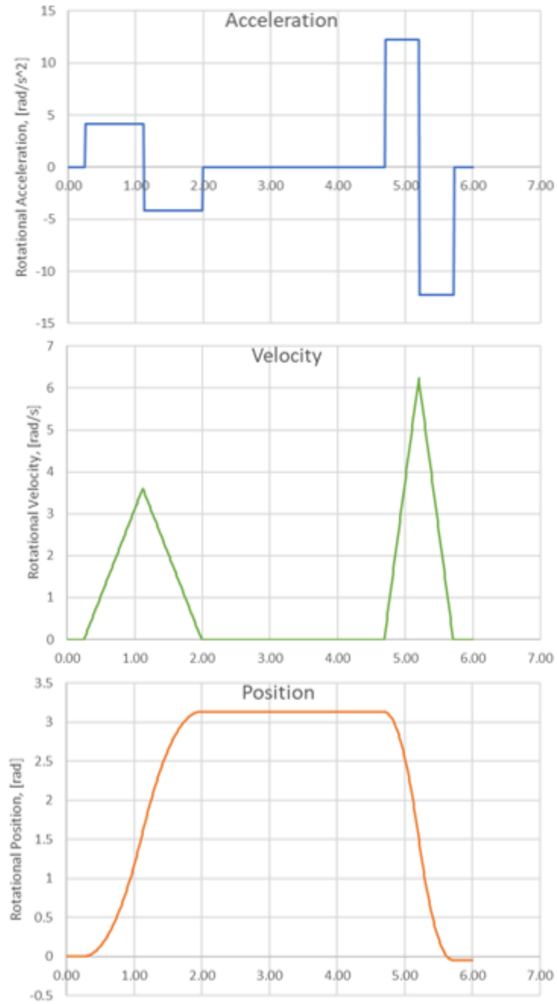


Figure 44. Motion graph of end effector rotary motor

The precise position of each drive component, the overall motions of the system, and the variable timing system was explained. The following section outlines the entire BOM for the automated feeder and displays several different drawings that are used to convey the complete preliminary design.

5. Preliminary Manufacturing Drawings and BOM

The team used SOLIDWORKS Education Edition 2018 SP3.0 to make the preliminary manufacturing drawings for all custom parts in the automated feeder design. This section contains a brief description of the drawing template that the team used as well as the three main types of drawings, which are the assemblies, the weldments, and the parts. The entire drawing package for the feeder design can be found in Appendix D – Preliminary Manufacturing Drawings.

Figure 45 shows a typical manufacturing drawing template that the team used. The brief descriptions of key information from the template are as follows:

- General Tolerance Block: This note adds a general tolerance constraint on all features' dimensions identified in the drawing.
- Material: Displays the material that the part is made of.
- Finish: Displays the desired surface finish of the part.
- Size: Displays the standard size of the drawing paper.
- First Issued: Indicates the date when the drawing was first completed.
- Drawn By: Indicates the author of the drawing with their initials.
- Checked By: Indicates the checker of the drawing with their initials.
- Used With: Provides a brief description of the assembly that the part is in.
- Description: Provides a brief description of the part, assembly, or weldment.
- Next Assembly: Displays the part number of the assembly that the part is in.
- Scale: Displays the ratio of the current size shown to its actual size.
- Weight: Provides the total weight of the part, assembly, or weldment.
- Part Number: Provides the part number of the part shown on the drawing.

A 200-level number indicates a purchased part. A 500-level number indicates a fabricated part. A 700-level number indicates an assembly. An 800-level number indicates a weldment. Additionally, the first three letters indicate which design system that the part, assembly, or weldment belongs to. ARM stands for the arm, which contains the main arm, the arm base, and the arm base support. EDF stands for the end effector, which contains the horizontal arm and the end effector. IDS stands for the identification station.

VPS stands for the two vertical gates, which contains the structure itself and the sensors used to detect the presence of the middles.

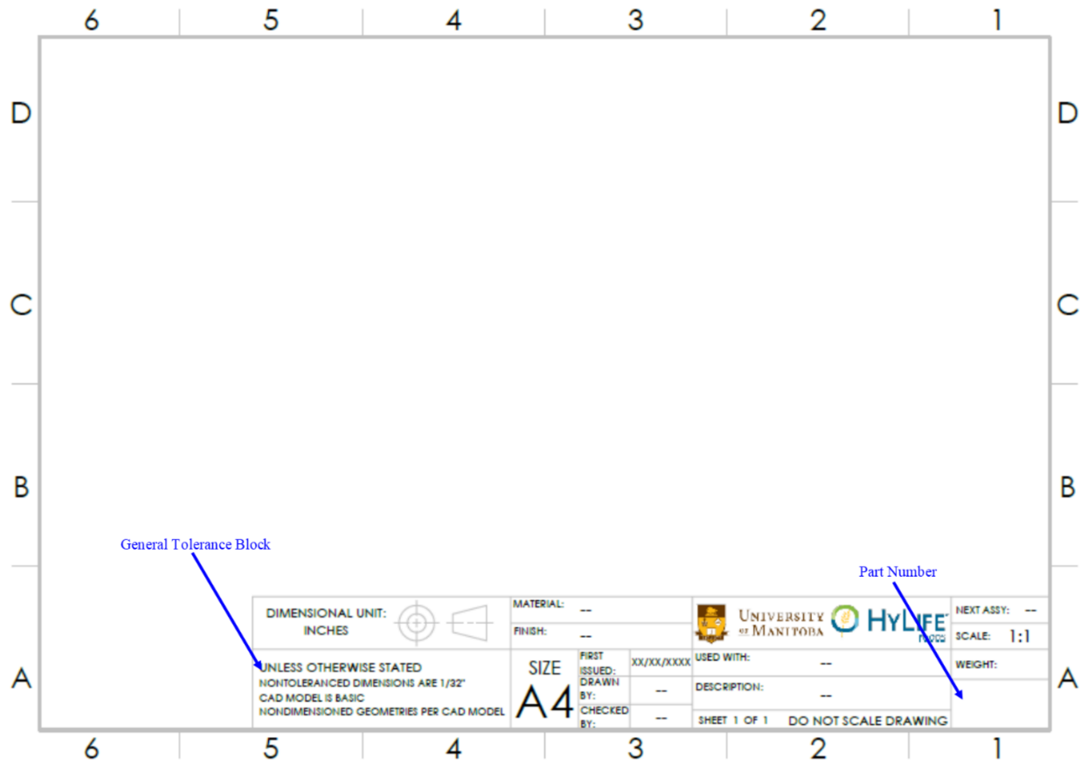


Figure 45. Preliminary manufacturing drawing template

Figure 46 shows the main arm assembly manufacturing drawing. As this is a top-level assembly, an exploded view also shows the necessary parts required to assemble the main arm as well as identifies their part numbers and names. The brief descriptions of key information from the assembly drawing are as follows:

- BOM: Contains all the parts in the assembly shown in the manufacturing drawing. A BOM commonly contains the item number, the part number, a brief description of each part, and the quantity needed for each part.
- Balloon: A balloon contains a predetermined number that matches the item number provided in BOM. Balloons can help the drawing interpolator to easily cross-reference between BOM and the parts shown in the exploded view.

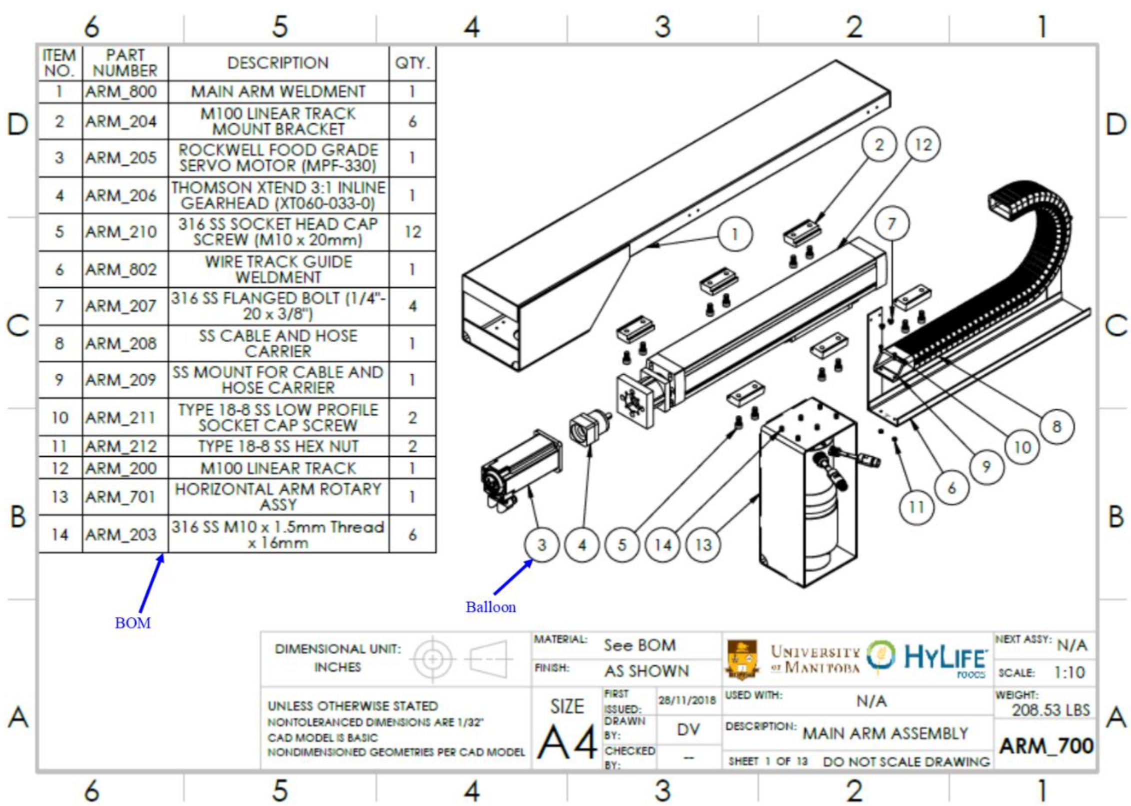


Figure 46. A typical preliminary manufacturing drawing for an assembly

Figure 47 shows the housing weldment for the main arm assembly. The drawing has an 800-level number because it is a welded part. Like an assembly drawing, a weldment drawing also contains a BOM to provide a list of parts that should be welded together. The brief descriptions of key information from the weldment drawing are as follows:

- Weldment Callout: Indicates the type and size of the weld.
- Weldment Notes: Additional notes left by the designer to clarify or emphasis certain callouts or features.
- Caterpillar: Type of annotation to show the weld preview based on the weldment callout.

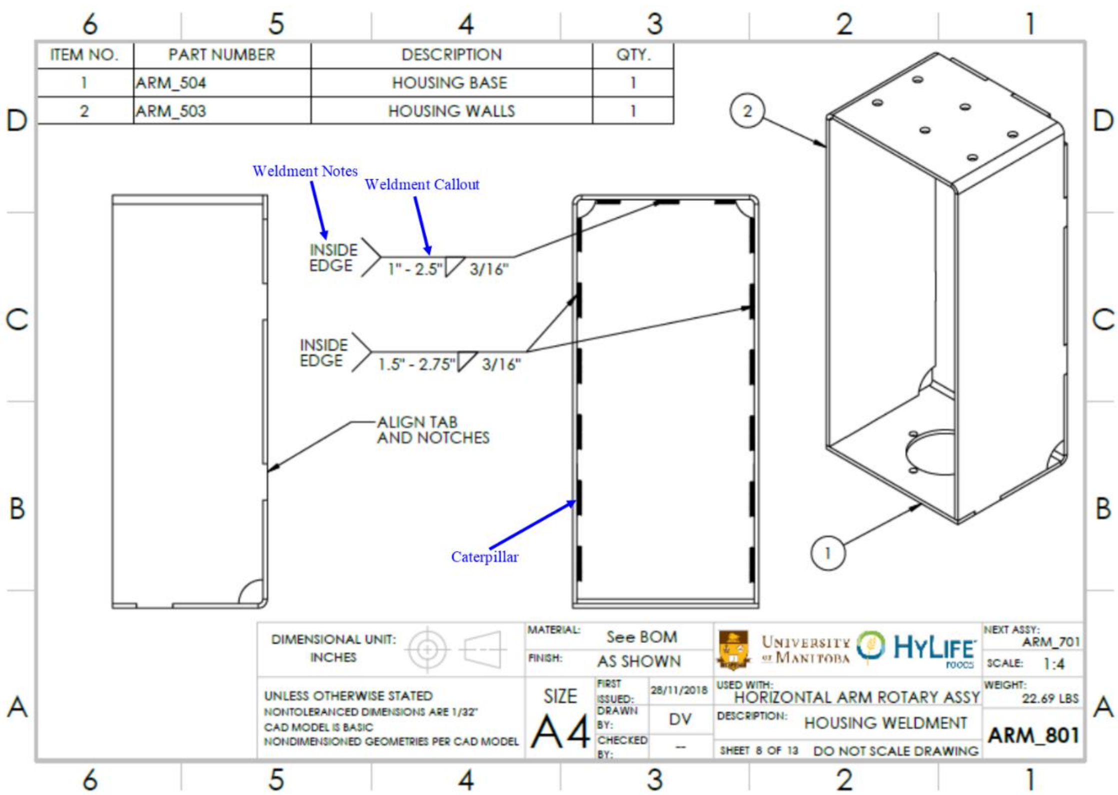


Figure 47. A typical manufacturing drawing for a weldment

Figure 48 shows the part drawing for the base piece of the housing weldment shown earlier. The key information from the part drawing is as follows:

- Bend Table: Indicates steps required to bend a flat part to get the desired finished part.
- Final Product: Provides a preview of the final product. In most cases, an isometric view is provided for reference.

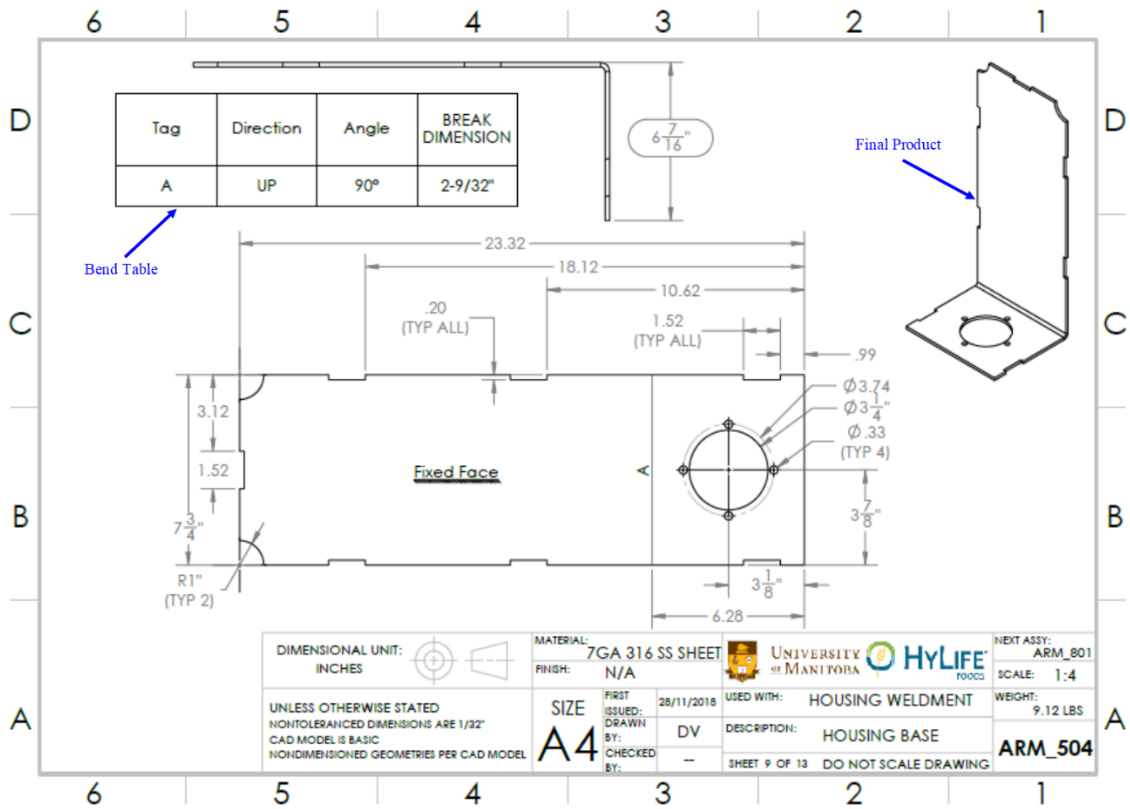


Figure 48. A typical manufacturing drawing for a part

TABLE X shows the complete bill of materials, BOM, of the automated feeder design.

TABLE X
COMPLETE BILL OF MATERIALS

Part Number	Part Description	Qty
r13_2a_01496_1a000_1_0_02	Arm base track carriage ROBOT 130 SP	1
ARM-524-R00-KF	Rotary Table Mount Shell	1
ARM-523-R00-KF	Rotary Table Mount Top	1
91287A303_18-8 STAINLESS STEEL HEX HEAD CAP SCREW	M8 x 1.25mm 22mm long	8
ARM-525-R00-KF	Rotary Table Mount Bottom	1
ARM-526-R01-KF	Main arm to rotary table Spacer	1
91287A154_18-8 STAINLESS STEEL HEX HEAD CAP SCREW	M8 x 1.25mm 30mm long	8
91292A135_TYPE 18-8 SS SOCKET HEAD CAP SCREW	M4 x 0.7mm x 30mm long	4
ARM-202-R00-KF	Rotary Table ADR360-A215-S/P-J/K-3.0-AB-7500-64X-P40	1
ARM-508-R00-KF	Arm base gusset top	8
ARM-511-R00-KF	Arm base track carriage mounting plate	1
ARM-510-R01-KF	Arm base vertical support column	1
ARM-509-R02-KF	Arm base rotary table mount platform	1
ARM-507-R00-KF	ARM BASE GUSSET BOTTOM	4
r13_2a_01496_1a000_1_0_01	ARM BASE TRACK ROBOT 130 SP	1
ARM-203-R00-KF	ARM BASE TRACK MOTOR ALLEN BRADLY MPF-A430P-SJ74BA	1
ARM-200-R00-KF	ARM BASE TRACK MOUNT 1001061 FIXING BRACKET	10
91292A152_TYPE 18-8 SS SOCKET HEAD CAP SCREW	M8 X 1.25MM 40MM LONG	10
ARM-527-R00-KF	REMOVABLE FIBERGLASS BAR GRATING A	1
ARM-528-R00-KF	REMOVABLE FIBERGLASS BAR GRATING B	1
ARM-529-R00-KF	REMOVABLE FIBERGLASS BAR GRATING C	1
ARM-530-R00-KF	REMOVABLE FIBERGLASS BAR GRATING D	1
ARM-519-R01-KF	ARM BASE TRACK TO METAL BAR GRATING SPACER	1
ARM-531-R00-KF	ARM BASE TRACK TO METAL BAR GRATING SPACER CAP	2
ARM-520-R00-KF	ARM BASE TRACK MOTOR MOUNT WITH DIRECT CUTOUT	1
ARM-521-R00-KF	ARM BASE TRACK MOTOR MOUNT BOTTOM PLATE	1
ARM-522-R00-KF	ARM BASE TRACK MOTOR MOUNT REAR VERTICAL SUPPORT	1
ARM-512-R01-KF	ARM BASE SUPPORT PLATFORM SUPPORTING LEG	6
ARM-513-R00-KF	ARM BASE SUPPORT PLATFORM METAL BAR GRATING ENCLOSURE L BRACKET LONG SIDE	2

Part Number	Part Description	Qty
ARM-514-R00-KF	ARM BASE SUPPORT PLATFORM METAL BAR GRATING ENCLOSURE L BRACKET SHORT SIDE	2
ARM-515-R00-KF	ARM BASE SUPPORT PLATFORM METAL BAR GRATING MIDDLE SUPPORT PLATING	2
ARM-516-R00-KF	ARM BASE SUPPORT PLATFORM SUPPORTING LEG TRUSS CONNECTOR	12
ARM-517-R00-KF	ARM BASE SUPPORT PLATFORM END SUPPORTING LEG CAP	4
ARM-518-R00-KF	ARM BASE SUPPORT PLATFORM MIDDLE SUPPORTING LEG CAP	2
Extended platform	7075T89 FIBERGLASS BAR GRATING FOOD GRADE	1
Removable grating A	7075T89 FIBERGLASS BAR GRATING FOOD GRADE	1
Removable grating B	7075T89 FIBERGLASS BAR GRATING FOOD GRADE	1
Metal Grating Vertical Plates	METAL DEPOT METAL BAR GRATING G43161. VERTICAL PLATES	7
Metal Grating Rods	METAL DEPOT METAL BAR GRATING G43161. TRANSVERSE RODS	46
IDS-500-R02-KF	IDENTIFICATION STATION HOUSING SHELL	1
IDS-504-R00-KF	IDENTIFICATION STATION HOUSING MOUNTING BOX	2
IDS-200-R00-KF	VS XF205M03I10EP BAUMER VISION CAMERA	1
IDS-501-R02-KF	IDENTIFICATION STATION HOUSING BACK PLATE	1
IDS-502-R01-KF	VISION CAMERA	1
IDS-503-R01-KF	IDENTIFICATION STATION CAMERA MOUNTING GUSSET	1
IDS-201-R00-KF	SLW-ESA180-1040-750-HK-PA-HR IDENTIFICATION STATION CAMERA TRACK	1
93805A256_18-8 STAINLESS STEEL THREADED ROD	M4 X 0.7MM 16MM LONG	4
94543A340_316 SS WING NUTS	M4 X 0.7MM	4
94545A230_18-8 SS WING NUTS	M6 X 1	4
93805A325_18-8 STAINLESS STEEL THREADED ROD	M6 X 1MM 35MM LONG	4
91292A151_TYPE 18-8 SS SOCKET HEAD CAP SCREW	M8 X 1.25MM 35MM LONG	4
94545A235_18-8 SS WING NUTS	M8 X 1.25MM	4
ARM-501-DV	BASE MOUNT PLATE	1
ARM-500-DV	MAIN ARM SUPPORT BEAM	1
ARM-502-DV	BASE BACK PLATE	1
ARM-507-DV	MAIN ARM BEAM CAP	2
ARM-201-DV	ROCKWELL IP69K (MPS-A4540F) SERVO MOTOR	1
ARM-202-DV	THOMSON AQUATRUE (AQT120) 20:1 INLINE GEARHEAD	1
ARM-203-DV	316 SS M10X1.5MM THREAD X 16MM (93635A412)	10
ARM-504-DV	HOUSING BASE	1

Part Number	Part Description	Qty
ARM-503-DV	HOUSING WALLS	1
ARM 505-DV	WIRE TRACK GUIDE	1
ARM-506-DV	WIRE TRACK MOUNT BRACKET	2
ARM-204-DV	M100 LINEAR TRACK MOUNT BRACKET	6
ARM-205-DV	ROCKWELL FOOD GRADE (MPF-B330P) SERVO MOTOR	1
ARM-206-DV	THOMSON XTEND (XTA-070) 3:1 INLINE GEARHEAD	1
ARM-210-DV	316 SS SOCKET HEAD CAP SCREW (M10X20MM) (92290A516)	12
ARM-208-DV	DURA-GUARD ENCLOSED CABLE AND HOSE CARRIER (3FT) (5608K74)	1
ARM-209-DV	BRACKETS WITH DIAGONAL FLANGE FOR HOSE CARRIER (5608K521)	1
ARM-211-DV	TYPE 18-8 LOW PROFILE SOCKET CAP SCREW (PART NO.)	2
ARM-212-DV	TYPE 18-8 SS HEX NUT (PART NO.)	2
ARM-200-DV	THOMSON M100 SCREW DRIVE LINEAR TRACK WITH REDIMOUNT FLANGE	1
VPS-200-DV	316 SS 1/4"-20 X 3/8" FLANGED HEAD SCREW (90909A526)	24
VPS-503-DV	RIGHT UHMW GROOVE	2
VPS-504-DV	LEFT UHMW GROOVE	2
VPS-502-DV	BACKPLATE	2
VPS-507-DV	BACK SUPPORT MOUNT BRACKET	8
VPS-506-DV	ADJUSTABLE PIN SUPPORT	4
VPS-511-DV	TOP CYLINDER MOUNT	2
VPS-514-DV	BOTTOM CYLINDER MOUNT	2
VPS-500-DV	SEQUENCING GATE	2
VPS-501-DV	ROD MOUNT TAB	4
VPS-508-DV	C-BEAM MOUNT	4
VPS-505-DV	SUPPORT SQUARE TUBING (1X1X16GA)	4
VPS-509-DV	C-BEAM MOUNT TAB	4
VPS-510-DV	SUPPORT BRACE	6
VPS-201-DV	SS 1/2" CLEVIS PIN WITH REUSABLE COTTER PIN (92401A706)	8
VPS-202-DV	BIMBA 9" STROKE IP69K BIDIRECTIONAL PNEUMATIC CYLINDER (SSFO-029-8W)	2
VPS-203-DV	BIMBA 9/16" BORE ROD PIVOT (RP-1/2)	2
VPS-204-DV	316 SS M3X0.5MM THREADED ROD (94185A578)	4
VPS-205-DV	316 SS M3X0.5MM HEX NUT (94150A325)	8
VPS-206-DV	18-8 TYPE SS 3/16" LOCKING PIN WITH RING (90170A205)	2
EDF-201-CM	DANIER F17080DN PNEUMATIC CYLINDER	4
EDF-546-CM	UHMW BUSHINGS	4
EDF-211-CM	BW-005625 WIPER SEAL	4

Part Number	Part Description	Qty
EDF-507-CM	MOUNTING PLATE	2
EDF-504-CM	MOUNTING BRACKET PART 2	2
EDF-545-CM	BUSING MOUNT	4
EDF-548-CM	CYLINDER MOUNT	2
EDF-503-CM	BOX MOUNT PLATE	2
Flat Head M6x1.0x25	FLAT HEAD M6X1.0X25	12
EDF-526-CM	QUICK DETACH GUIDES MALE SIDE	4
AQT080-005-MMR-612	10:1 GEAR HEAD	2
MPS-B330-J52DA	ALLEN BRADLEY SERVO MOTOR	2
EDF-542-CM	BEARING CASE/HOUSING	2
EDF-202-CM	35X62X8 SKF SEAL	2
EDF-532-CM	INTERNALLY KEYED SHAFT	2
EDF-533-CM	TORQUE TRANSFER PLATE	2
EDF-534-CM	MOTOR FACE MOUNT	2
EDF-521-CM	VERTICAL GUIDE ROD	4
EDF-547-CM	PNEUMATIC ROD MOUNT	4
EDF-525-CM	FEMALE BOX SPLIT MOUNTS	4
EDF-207-CM	ERD SS2 ACTUATOR IP69K NEMA STEPPER 100MM STROKE	4
EDF-500-CM	MEAT BOX	2
EDF-511-CM	ACTUATOR MOUNTS	4
EDF-549-CM	MOUNTING STUDS	24
EDF-501-CM	ADJUSTABLE PLATE	2
EDF-511-CM	ACTUATOR TO ADJUSTABLE PLATE MOUNT	4
EDF-502-CM	CLOSING PLATE MOUNTS	4
EDF-508-CM	QUICK DISCONNECT PINS	4
R-Clips	0.25" R-CLIPS	4
M8 Nuts		8
M6 Nuts		36
M8x1.25x12		8
M6x1.0x25		24
M6x1.0x10		12
EDF-551-DL	RECTANGULAR TUBING 5X2X0.25	1
9624T240	_FLANGED SHAFT COLLAR WITH MOUNTING HOLES 25 MM DIAMETER 303 SS	1
91292A135	18-8 STAINLESS STEEL SOCKET HEAD SCREW, M6 X 1 MM THREAD, 16 MM LONG	3
91292A156	18-8 STAINLESS STEEL SOCKET HEAD SCREW, M8 X 1.25 MM THREAD, 55 MM LONG	1
EDF-753-DL	THOMSON WH80 LINEAR ACTUATOR BELT DRIVEN, WHEEL GUIDE (WH08ZSXXXX-00635-01185VN0000S1)	2
EDF-751-DL	ALLEN BRADLEY MOTOR (MPF-B330P-MJ74BA)	2

Part Number	Part Description	Qty
EDF-757-DL	GEARBOX REDUCTION 5:1 [DTR90-005-0 (RM090-39)]	2
5608K531	CABLE TRACK DURA-GUARD ENCLOSED CABLE AND HOSE CARRIER (1.5" OD, 5.5" BEND RADIUS,1 FT)	2
5608K35	DURA-GUARD ENCLOSED CABLE AND HOSE CARRIER DIAGONAL FLANGE MOUNT (1.5" OD, 5.5" BEND RADIUS,1 FT)	2
90909A526	316 STAINLESS STEEL FLANGED BUTTON HEAD SCREW, 1/4"-20 THREAD, 3/8" LONG	8
92185A581	SUPER-CORROSION-RESISTANT 316 STAINLESS STEEL SOCKET HEAD SCREW, 5/16"-18 THREAD SIZE, 3/4" LONG	4
92673A119	18-8 STAINLESS STEEL HEX NUT, 5/16"-18 THREAD SIZE, ASTM F594	4
EDF-552-KF	TUBE CAPS	2
EDF-574-DL	CABLE TRACK MOUNT	1
EDF-523-DL	CABLE TRACK MOUNT	1
EDF-540-DL	TUBE INTERNAL SUPPORT	4

6. Preliminary Cost and Return on Investment Analysis

The cost and return on investment (ROI) analysis section covers the estimated total cost of the final proposed design. From the total cost, a return on investment analysis is conducted to estimate the time required to payback the input cost.

6.1. Cost Analysis

The following contains the cost break-down for only the top-level systems. Further break-down costs for each system can be found in Appendix B – Preliminary Cost Analysis. It should be noted that the team obtained the quotes for the systems shown in the month of November 2018, and the prices are subject to change after January 2019. The currency exchange rate, 1 USD to 1.3 CAD, is based on the data published on November 26, 2018. TABLE XI shows the cost break-down of the team's proposed design.

TABLE XI
COST BREAK-DOWN

System	Cost (CAD)
Arm Base	$36,393
Main Arm	$21,222
Horizontal Arm	$20,517
End Effector	$25,060
Identification Station	$9,757
2-Vertical Plates	$1,286
Integration	$125,000
Fabrication	$16,875
Total	**$256,110**

The total cost shown above do not include the following:

- Shipping
- Taxes
- Import Fees
- Opportunity Cost: Production Stop for Installation and Testing
- Fasteners
- Utility Costs
- Additional Sanitation and Maintenance Resources used

Figure 49 shows the Pareto diagram of the cost break-down. Aside from ‘Integration’ being the most expensive system to implement, the ‘Arm Base’ is the highest among the main components of the feeder.

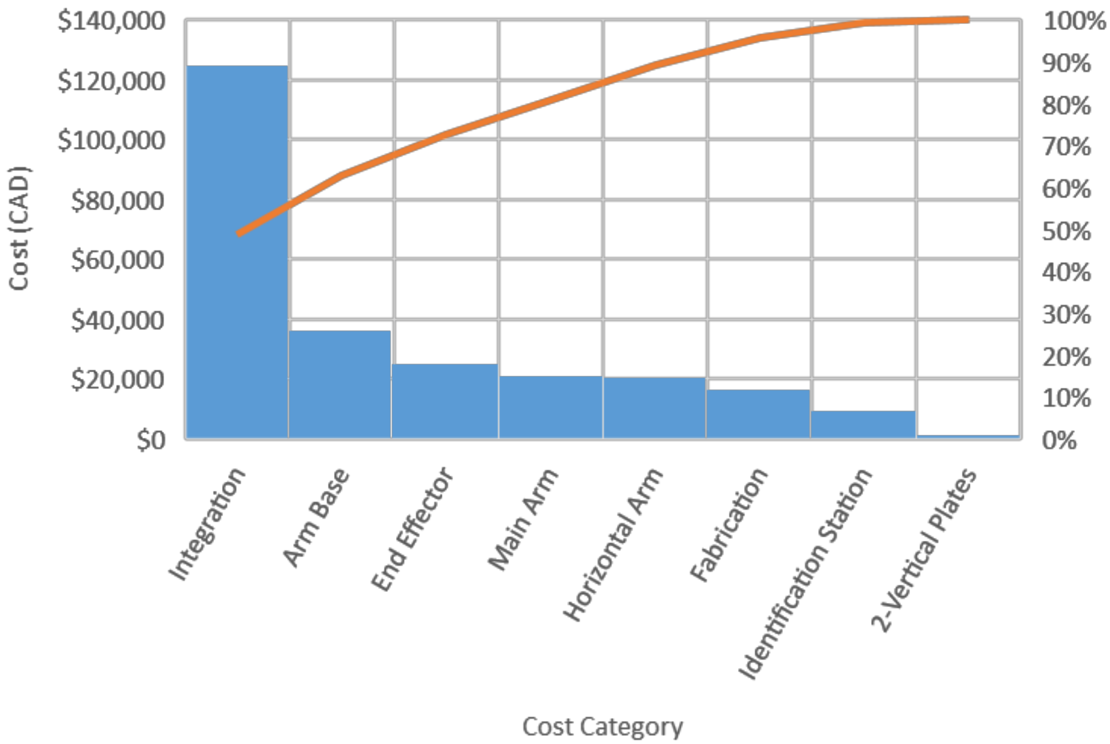


Figure 49. Pareto diagram of the top-level cost break-down

6.2. Return on Investment Analysis

In the return on investment analysis, the team used the approximation of $200,000 CAD yearly cost for the manual labor and a total cost of $256,110 CAD to implement the final proposed design.

Figure 50 shows the cost comparison between the automated feeder and the existing manual labor. Based on the graph, the break-even point is **1.3 years** with a return on investment rate of **78%** per year. The 78% ROI rate indicates each year HyLife would have 78% of their capital investment back from choosing the automated feeder over the current manual process.

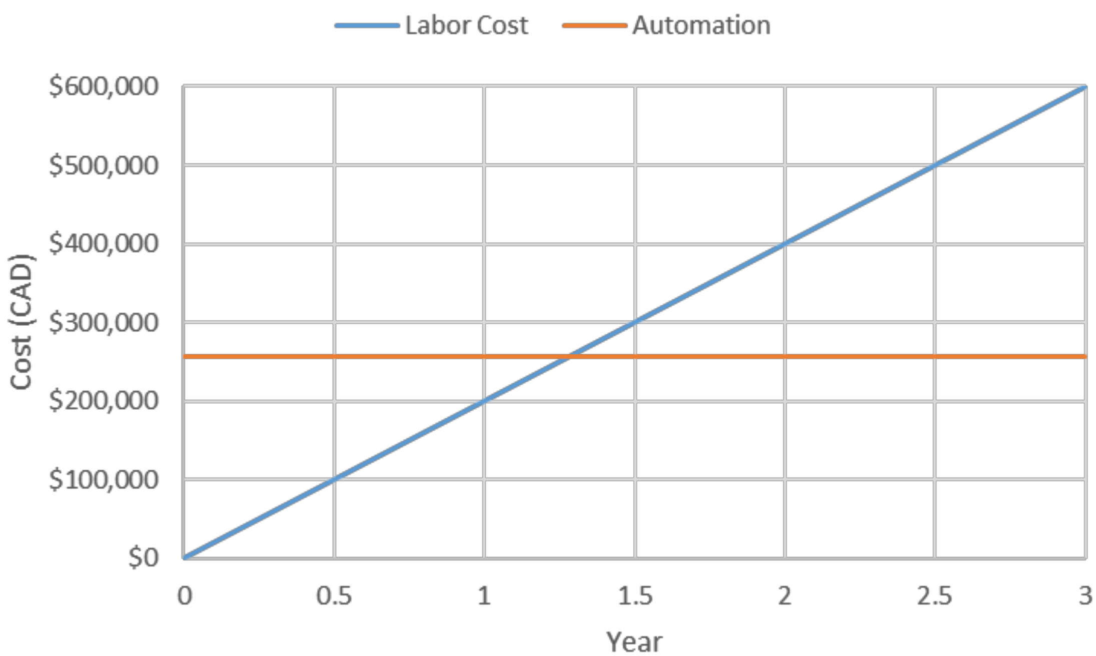


Figure 50. Automation and manual work cost comparison

The determined return on investment is within the maximum allowable return on investment period of 1.5 years. Therefore, the proposed design is within budget.

7. Future Recommendations

The team moved forward with the project to the best of their knowledge; however, there are aspects of the project that the team has not been able to verify or validate. This is due to the team's limitation on their technical knowledge and resources available in the time frame provided.

Therefore, the team, to their best knowledge, organized the following recommendations, which should be considered to ensure a safe and effective automated feeder solution for HyLife. Specifically, the team categorized the recommendations into five main aspects, which are the numerical analysis, the structural validation, the information inquiry, prototyping and testing, and additional considerations.

Numerical Analysis

The numerical analysis aspect focuses on performing the additional and rigorous numerical analysis on the structural components. The following shows these recommendations with a brief explanation.

- **Fasteners**: The team implemented a variety of fasteners in the design to hold structures in place. However, the team did not perform any analysis on the fasteners to ensure the loads exerted on them will not lead to failure. The team recommends HyLife validating the size, amount, and type of the fasteners implemented in the design are safe and effective.
- **Stress Analysis**: Even though the team validated the key design components with SolidWorks FEA, a commercial finite element analysis software; however, numerical software, such as ANSYS APDL, can be beneficial in providing more accurate solutions for additional optimization and validation.
- **Fatigue Analysis**: Even though the team considered all dynamic loading cases during operation, the team did not performance fatigue analysis on the moving structures that undergo cyclic loadings during operation. This process can ensure these structures will not fail prematurely, such as failing well under their yield stress, and establish a maintenance schedule based on the life obtained from the fatigue analysis.

- **Loads and Boundary Conditions**: Correct loading and boundary conditions are the foundation to have an accurate FEA analysis. The team applied the loading and boundary conditions to the best of their knowledge; however, the team believes that additional validations on the boundary and loading conditions can be beneficial to verify the stress and displacement.
- **Motor Life:** Even though the team selected the motor based on the published information from the vendor's catalogues, the team recommends having the motor specifications checked by a professional prior to purchase to avoid mis-interpolation of the motor specifications from the team's end.
- **Load Inertia**: The team approximated the component geometries to regular shapes, such as cylinders and cubes, in the load inertia calculations so that the team could move forward with the detailed design development. However, the team's approximation on the geometry can either over or under estimate the load inertia, which can lead to under or over size the motors or supporting structures. Therefore, the team recommends to numerically calculate the load inertia so that the structures and motors can be optimally selected or sized.
- **Motion Control** – **Motor**: The team selected the motors solely based on the torque and RPM requirements; therefore, the team recommends also validating the selected motors from the motion control aspect, such as the ratio between load and motor inertia as well as the effective torque of the motor. By doing such, the motor can effectively control the load to avoid vibration resonance during the operation.
- **Motion Control – Rotary Table**: The team designed a rather aggressive motion profile for the arm to ensure the design can operate at the feed rate of 600 hogs/hour. Specifically, when the first CW 47 degrees rotation is initiated, the largest torque occurred at the rotary table for 600 hogs/hour is 711.8 N·m. This torque is above the rated continuous torque specification of 377.9 N·m, which occurs at the feed rate of 454 hogs/hour, and well below the rated peak torque specification of 1133.8 N·m. Since the current configuration puts quite bit of pressure on the rotary table, the team

recommends achieving one or more of the following to reduce the workload of the rotary table and prolong its service life:

a. Reduce the load of inertia
b. Allocate additional time to complete the motion
c. Longer dwell time

Structure Validation

To implement the proposed design system, structural components need to be either integrated into or altering the existing system. Due to the team's limited knowledge on the aspect of structural engineering, the team recommends verifying the following prior to implementing the proposed design. The following shows these recommendations with a brief explanation.

- **Elevated Platform Support Leg**: To provide sufficient room for the propose design's arm base, the team needs to relocate the side support leg to the end. The team mentioned this change in the 2D layout deliverable for additional reference. However, this requires additional calculations and design of the structural components so that they can safely withstand the machinery on the elevated floor as well as the workers.

- **Cable Tray**: This is another change needs to be made to provide space for the proposed design system. The team recommends verifying the feasibility of rerouting the existing cable carrier tray to a lower position, which is under the metal bar gratings.

- **Concrete Fixture**: To effectively and safely mount the arm base support to the concrete floor, the team recommends having professional structural engineers to develop the details of how the structure will be mounted to the floor.

Information Inquiry

The information inquiry aspect contains further required communications with vendors to finalize parts and complete the proposed design. The following shows these recommendations with a brief explanation.

- **Motor – Main Arm Track**: The team sized the XTend Inline Gearhead from Thomson Linear (XTA-070) that couples the main arm linear track and the MPF-4540 servo motor. However, the RediMount flange is not a stock part. The team recommends communicating with a Thomson Linear representative about fabricating a custom-made RediMount flange or developing alternatives.

Prototyping and Testing

The prototyping and testing aspect contains the parts that require additional testing to ensure their proper functionality and meet the design intent. The following shows these recommendations with a brief explanation.

- **Pneumatic Systems**: The team recommends testing the designed pneumatic systems by using the existing pressure system on the production floor prior to implementation. This will ensure the correct sizing and calibration of the valves and other components.

- **Photoelectric Sensors**: The team recommends testing these Omron sensors to confirm the projected laser can reflect off UHMW surface. Specifically, the team selected these sensors to detect the presence of the hog middles at the two-vertical plate location.

- **Vision Camera**: The team recommends testing the vision camera to ensure proper feature recognition when it is operating under the cut floor environment. Specifically, the main concern from the team is the camera having a rated operation temperature at 5°C. However, Baumer does offer an industrial version of the vision camera that can withstand a harsher environment.

- **Safety Guard Wall**: The team needed to narrow the wall by 3 inches in the CAD model to provide a safe passage for the horizontal arm to rotate. However, the team only verified the dimensions based on the CAD model provided. Therefore, the team recommends verifying the space available for the horizontal arm to rotate at the end of the main conveyor and making according changes as necessary.

- **Abscess Table**: The team did not permanently mount the abscess tables to any structure. However, the team recommends testing the abscess table's stability based on current fixture configuration. If HyLife desires a more stable abscess table, the team recommends welding the abscess table to nearest wall/steel support to provide additional stability when the meat is transferred to the abscess table.

Additional Considerations

The additional considerations aspect contains further improvements to optimize the proposed design's functionality. The following shows these recommendations with a brief explanation.

- **Structural Deformation**: Even though the team designed all parts to have a maximum displacement of under 2 mm, the displacement accumulation can play a big role on the design's accuracy during operation, which is crucial for automation designs. Therefore, the team recommends verifying the accumulated displacement and increasing component's stiffness as necessary. This action can reduce displacement and increase its precision. For example, having a thicker wall for the arm base platform support legs can reduce the current maximum displacement of 1.9 mm, which can result in better performance but a heavier design.

8. Summary

This report covered the problems with the current process of transferring middles as well as the needs, specs, and deliverables required for this project. These include adhering to food industry health and safety standards to prevent contamination of the pork. There where many operational needs including that the design could identify left and right middles, adapt to various production speeds, simultaneously release the left and right middles, and orient the middles correctly with the backbone facing outward. There where also a few miscellaneous needs including the design allowing manual work and keeping the design within budget.

These needs where met through a variety of means. To meet food safety regulations, the materials used where limited to materials that could withstand the harsh cleaning environment as well as perform under the conditions on the cut floor. The materials used are primarily stainless steel 304 and 316, and UHMW PE. Actuators where chosen that met washdown standards appropriate for their desired operation. For the end effector, this meant that all motors and actuators meet IP69K standard for high pressure washdown and ingress protection. Other components will require bagging during sanitation as they cannot withstand the high-pressure washdown, these components however do not contact the meat and are therefore less of a concern for sanitation. Drainage holes were incorporated in the design to prevent pooling of water after sanitation. Pooling water can harbor and grow bacteria, which leads to contamination of the food products. Open sections and areas with notable gaps where used where possible as they have no surfaces that cannot be inspected for cleanliness. Where open sections could not be used, sections where capped on the ends to prevent and potential harborage of bacteria.

To meet Hylife's operational needs, a machine vision system was selected for use in identifying middles. The chosen vision system will allow flexibility in determining the orientation of the middles and allows for future features such as abscess identification. The vision system also distinguishes left and right middles. The feeder is designed to adapt to variable operation speeds based on production speeds ranging from 300-600 [hogs/hr]. To ensure the middles are sequenced consistently, a system of vertical gates has been designed that will release the middles at precisely the same time and eliminate issues downstream caused by poorly sequenced middles.

The design meets the additional needs through multiples methods and components. The design has been built on a track that can move the entire assembly out of the way to allow for manual work in 24 seconds. The complete proposed design cost was above the ideal budget of $200,000 for a 1-year payback, however, the cost did meet the marginal budget of $300,000 for a 1.5-year payback with a total estimated cost of $256,110. The final design stayed within budget by sourcing appropriate components and ensuring they did not have additional features that were not necessary.

9. References

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[7] T.12, "Automated Loin Puller Feeder: Project Definition Report," University of Manitoba, Winniepg, 2018.

Appendices

The following information adds more detail to specific areas of the report that are not necessary but are still relevant to the design process. Specifically, the stress analysis on all major components, the detailed data and specifications of purchased parts, all the preliminary manufacturing drawings, and the more details cost breakdown analysis are included in the Appendix.

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Appendix A – Stress Analysis

This section will cover the preliminary stress analysis that was done to size appropriate components. The preliminary dynamic loads were determined by hand and the finite element stress analysis was done using SOLIDWORKS Education Edition 2018 SP3.0. A factor of safety of 2 was used at the request of the client to ensure the design does not fail prematurely.

Structural material used in the design include: Stainless Steel 316, UHMW PE, and 304 Stainless Steel. The mechanical properties used in the preliminary calculations are summarized in TABLE AI.

TABLE AI
MECHANICAL PROPERTIES FOR MATERIALS USED

	Stainless Steel 304	**Stainless Steel 316**	**UHMW PE (HDPE)**
Elastic Modulus [N/m^2]	1.97×10^{11}	1.93×10^{11}	8.94×10^{8}
Poisson's Ratio	0.29	0.30	0.46
Tensile Strength [N/m^2]	505×10^{6}	515×10^{6}	39.9×10^{6}
Yield Strength [N/m^2]	215×10^{6}	205×10^{6}	24×10^{6}

Preliminary Load Determination

Before the various components of the design were subjected to FEA, the loading conditions were determined. The loading conditions are based on the motion steps of the automated feeder. Only single dynamic motions were considered when determining the loads.

Each step is allotted a specific time to complete the full required motion. The worst case occurs when the hog feed rate is 600 hogs/hour, which amounts to a 6 second cycle time. The bending moments and torques experienced are the highest at this feed rate because the input accelerations are the highest to keep up with the fast motion speeds.

There are five different components that receive different inputs based on the motion step. These components include the main arm linear track, the horizontal arm linear track, the base rotary table, the horizontal arm rotary motor, and the end effector rotary motor. All these components will be analyzed dynamically for each step of the motion process they are moving.

The end effectors move during two different steps of the motion process. The first motion is a 180 rotation in ‘Step 0’ and the second is another 180 during ‘Step 3a’. To determine the input torque to rotate the end effectors the required angle in the desired time, the rotational acceleration and moment of inertia first need to be determined. The moment of inertia was approximated to a rod of length L and mass *m* rotating about its center.

$$T = \alpha I \qquad \alpha = \frac{2\Delta\theta}{\Delta t^2} \qquad I = \frac{1}{12} mL^2$$

The angular acceleration, moment of inertia, and final torque results for each of the two steps are summarized in TABLE AII. For ‘Step 0’, the moment of inertia includes the weight of the middle while ‘Step 3a’ does not.

TABLE AII
SUMMARY OF LOADS EXPERIEINCED BY END EFFECTOR ROTARY MOTOR

Angle of Rotation, $\Delta\boldsymbol{\theta}$ $[\boldsymbol{rad}]$	**Change in time,** $\Delta\boldsymbol{t}$ $[\boldsymbol{sec}]$	**Rotational Acceleration,** $\boldsymbol{\alpha}$ $[\boldsymbol{rad/s^2}]$	**Moment of Inertia,** $\boldsymbol{I}$ $[\boldsymbol{kgm^2}]$	**Torque,** $\boldsymbol{T}$ $[\boldsymbol{Nm}]$
Step 0				
$\boldsymbol{\pi/2}$	0.985	3.25	1.786	5.81
Step 3a				
$\boldsymbol{\pi/2}$	0.574	9.60	0.70	6.70

The horizontal linear tracks move the end effectors during four different steps of the motion process. Specifically, the horizontal linear tracks move during ‘Step 0a’, ‘Step 0b’, ‘Step 2’, and ‘Step 3’. The motion during ‘Step0a’ and ‘Step 0b’ are the same and therefore only will be calculated once. During ‘Step0a’, the horizontal tracks extend 300 [mm]. For ‘Step 2’, the tracks extend 635 [mm], and for ‘Step 3’ the tracks retract 635 [mm].

To determine the bending moments acting on the carriage of the linear track, the linear acceleration and force need to be determined.

$$M = Fd \qquad\qquad F = ma \qquad\qquad a = \frac{2\Delta d}{\Delta t^2}$$

The distance used to determine the bending moment is the distance from the base of the carriage on the linear track to the center of gravity of the end effector. For ‘Step 0a’, and ‘Step 2’, the center of gravity is lower because the boxes are extended. During these two steps, the mass of the middle is also considered. During ‘Step 3’, however, the center of gravity is closer to the carriage because the boxes are retracted and not carrying a middle.

The linear acceleration, force, and bending moment results for each of the three steps are summarized in TABLE AIII.

TABLE AIII
SUMMARY OF LOADS EXPERIENCED BY HORIZONTAL ARM LINEAR TRACKS

Distance Travelled, Δd [m]	**Change in time, Δt [sec]**	**Linear Acceleration, a [m/s^2]**	**Force, F [N]**	**Bending Moment, M [Nm]**
Step 0a & Step 0b				
0.150	0.443	1.54	63.01	56.28
Step 2				
0.3175	0.765	1.09	44.66	48.39
Step 3				
0.3175	0.765	1.09	44.66	12.15

The horizontal rotary motor rotates the horizontal arm about its center. Throughout the entire motion process, the motor rotates the horizontal arm during three separate steps. Specifically, the motor rotates the horizontal arm during 'Step 1', 'Step 2a', and 'Step 3'. During 'Step 1', the motor rotates 43˚, during 'Step 2a', the motor rotates 2˚, and during 'Step 3', the motor rotates 41˚. The same rotary equations are used, however, when calculating the moment of inertia, the moment of inertia created from the end effectors were also considered.

$$T = \alpha I \qquad \alpha = \frac{2\Delta\theta}{\Delta t^2} \qquad I_1 = \frac{1}{12}mL^2 \qquad I_2 = mr^2$$

During 'Step 1' and 'Step 2a', the end effectors are at an approximate maximum distance of 300 [mm] from the center of rotation. During 'Step 3', the end effectors are approximately 635 [mm] from the center of rotation. Also, during 'Step 1' and 'Step 2a', the mass of the end effector as well as the mass of the middles are considered. However, during 'Step 3', only the mass of the end effectors is considered.

The rotational acceleration, moment of inertia, and torque for each step are summarized in TABLE AIV.

TABLE AIV
SUMMARY OF LOADS EXPERIENCED BY HORIZONTAL ARM ROTARY MOTOR

Angle of Rotation, $\Delta\theta$ [rad]	**Change in time, Δt [sec]**	**Rotational Acceleration, α [rad/s^2]**	**Moment of Inertia, I [kgm^2]**	**Torque, T [Nm]**
Step 1				
0.3752	0.645	1.82	$I_1 = 18.3$ $I_2 = 10.42$	52.27
Step 2a				
0.0175	0.191	0.96	$I_1 = 18.34$ $I_2 = 10.42$	27.62
Step 3				
.3578	0.765	1.23	$I_1 = 18.34$ $I_2 = 32.99$	63.16

The main arm linear track moves the horizontal arm and end effectors linearly during three different steps of the motion process. Specifically, the linear track moves during ‘Step 1’, ‘Step 2a’, and ‘Step 3’. The track extends 340 [mm] in ‘Step 1’, extends another 55 [mm] in ‘Step 2a’, and retracts 395 [mm] in ‘Step 3’. The bending moment calculated is comprised of two forces acting at two different distances. The first force is the mass of the horizontal arm being accelerated, and the second force is the mass of the end effectors and middles being accelerated. During ‘Step 3’, the mass of the middles is omitted because they are not moved during this step. The same equations used in determining the horizontal tracks acceleration, force, and bending moments are used to determine the main arm linear track values. The results are summarized in TABLE AV.

TABLE AV
SUMMARY OF LOADS EXPERIENCED BY MAIN ARM LINEAR TRACK

Distance Travelled, Δd $[m]$	Change in time, Δt $[sec]$	Linear Acceleration, a $[m/s^2]$	Force, F $[N]$	Bending Moment, M $[Nm]$
Step 1				
0.170	0.645	0.82	$F_1 = 41.05$ $F_2 = 67.35$	77.30
Step 2a				
0.028	0.192	1.51	$F_1 = 75.45$ $F_2 = 123.78$	112.66
Step 3				
0.198	0.765	0.68	$F_1 = 33.87$ $F_2 = 55.56$	26.03

The final component is the base rotary table, which rotates during ‘Step 1’, ‘Step 2a’, and ‘Step 3’. Specifically, the rotary table rotates 47˚ during ‘Step 1’, rotates 2˚ during ‘Step 2a’, and rotates 49˚ during ‘Step 3’. To determine the torque required to rotate the main arm, horizontal arm, and both end effectors, the moment of inertia was estimated to be a cantilever mass rotating at the end of a massless rod (I_2) as well as a rod of mass rotating about its end (I_3). The following equations were used.

$$T = \alpha I \qquad \alpha = \frac{2\Delta\theta}{\Delta t^2} \qquad I_2 = mr^2 \qquad I_3 = \frac{1}{3}mL^2$$

During all three steps that the rotary table is operational, both moment inertia equations are considered. However, during ‘Step 1’ and ‘Step 2a’, the mass in I_2 considers the mass of the horizontal arm, both end effectors, and both middles. During ‘Step 3’, the mass of the middles is not considered as they are not transferred during this step. The results of the rotational acceleration, moment of inertia, and torque are summarized in TABLE AVI.

TABLE AVI
SUMMARY OF LOADS EXPERIENCED BY BASE ROTARY TABLE

Angle of Rotation, $\Delta\theta$ [rad]	**Change in time, Δt [sec]**	**Rotational Acceleration, α [rad/s^2]**	**Moment of Inertia, I [kgm^2]**	**Torque, T [Nm]**
Step 1				
0.4102	0.645	1.99	$I_2 = 256.66$ $I_3 = 24.94$	559.20
Step 2a				
0.0175	0.191	0.96	$I_2 = 256.66$ $I_3 = 24.94$	270.38
Step 3				
0.4276	0.765	1.47	$I_2 = 203.99$ $I_3 = 24.94$	336.59

Vertical Sequencing Gates FEA

The results from the FEA simulation are summarized in TABLE AVII.

TABLE AVII
SUMMARY OF FEA RESULTS FOR VERTICAL SEQUENCING GATE COMPONENTS

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Gate	67N	3.89E+07	5.27	1.28	4 points Jacobian	5.08	60562

The vertical sequencing gates hold the meat in place, then release them simultaneously into their respective loin puller. The gate of the assembly experiences the force of the meat pushing on it as the conveyor continues to move. The pushing force was determined based on friction and the mass of the middles. The coefficient of friction between the meat and the polypropylene conveyor surface was estimated.

$$F_a = F_{fs} = \mu_s mg = 0.4(17\ kg)(9.81) = 67\ [N]$$

Both the left and right vertical sequencing gates experience the same loading, therefore only one will be simulated. The gate will only experience the pushing force when in the down position, so only this situation was simulated. The gate is guided from two UHMW grooves. The contact between the UHMW grooves and the gate was simulated by splitting a small portion on the edge of the gate and fixing it, see Figure A1.

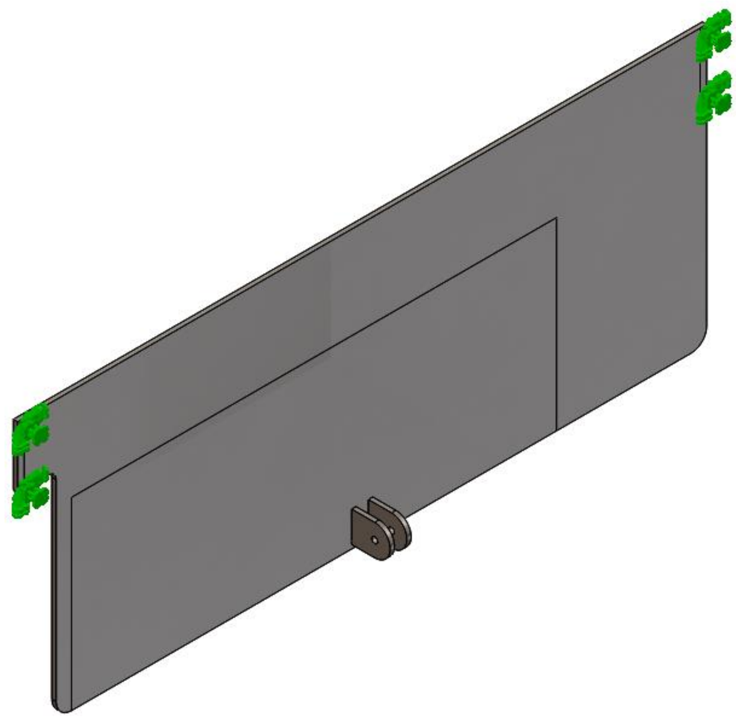

Figure A1. Fixed locations on gate simulating contact with UHMW grooves

The pushing force was applied to the large split area shown in Figure A2.

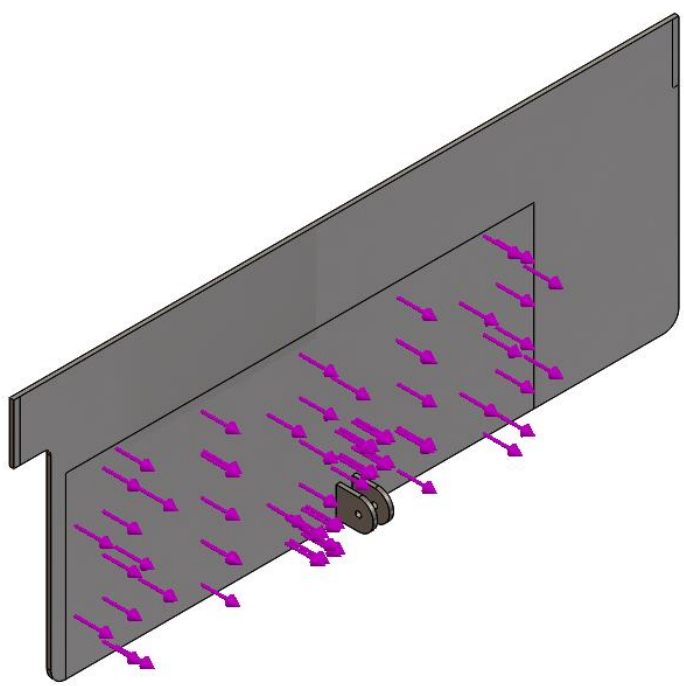

Figure A2. Applied force simulating pushing of meat on gate

The results of the simulation show that the maximum stress (38.89 MPa) occurs at the corner where the UHMW and gate contact, see Figure A3. This means that the entire gate has a minimum factor of safety of 5.27.

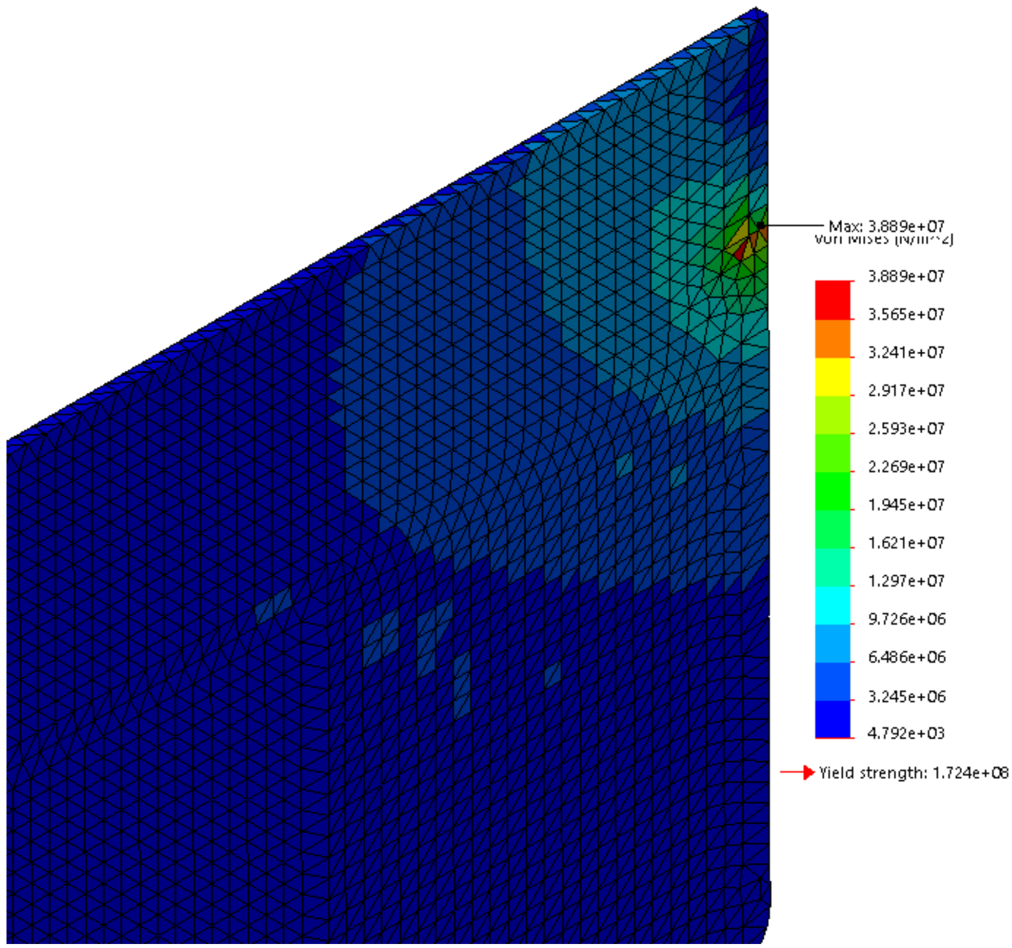

Figure A3. Location of stress concentration at contact location

The displacement of the gate is centralized around the area where the meat contacts the gate. The maximum deformation is 1.28 [mm] and occurs at the bottom of the gate and at the center of the applied force, see Figure A4.

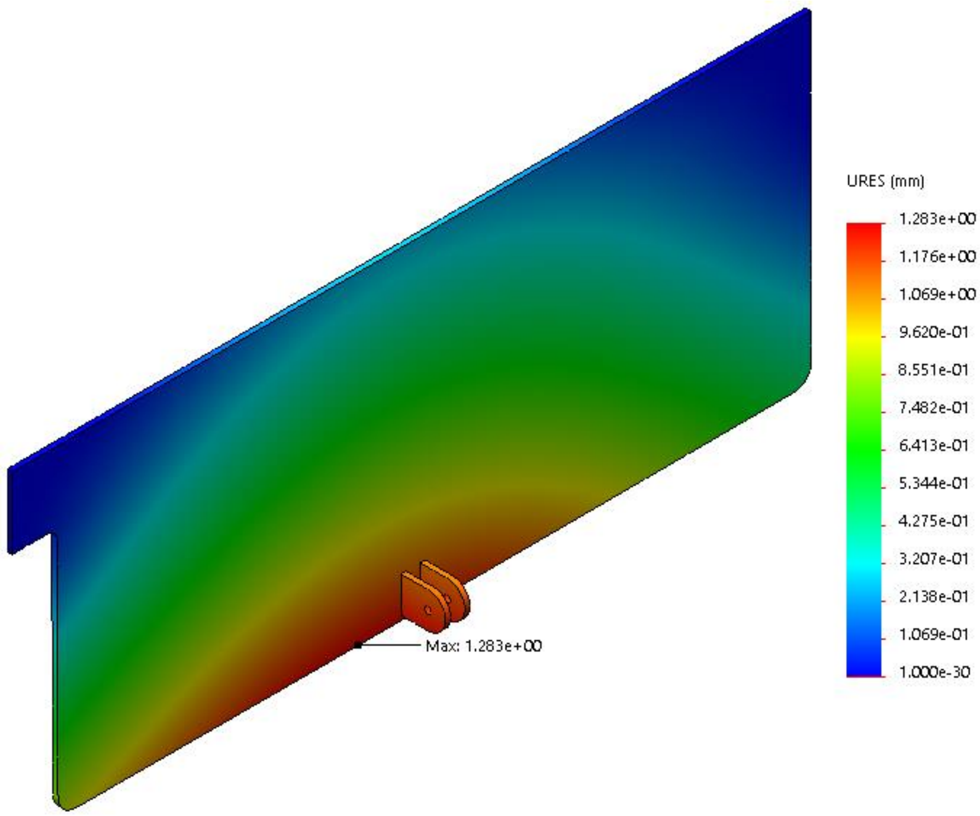

Figure A4. Displacement of gate when meat pushes against the gate

End Effector FEA

Stress was analyzed across the end effector for two of the motions, these are the initial turning 180° of the meat and the final return. These motions where analyzed over other motions because they all have the same type of motions, but the first motion has a greater lateral and rotational acceleration than all others except the final return motion. The final return motion has no meat in the box but has the greatest rotational acceleration, so it was also analyzed to ensure this would not create any issues. A summary of all parts and conditions analyzed can be seen in TABLE AVIII.

TABLE AVIII
SUMMARY OF FEA RESULTS FOR END EFFECTOR COMPONENTS

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Box	28N·m 30.8N	3.28E+07	4.70	3.14	4 points Jacobian	17.88	4451
UHMW	UHMW guide	14N·m 116N	1.70E+07	4.94	0.004	4 points Jacobian	5.82	20972
316 SS	Vertical Guides	28N·m 92N	4.57E+07	2.53	2.15	4 points Jacobian	9.26	13519
316 SS	Box	11N·m 134N	1.66E+07	9.80	1.69	4 points Jacobian	10.64	5224
UHMW	UHMW Guides	17N·m 116N	4.15E+06	4.09	0.002	4 points Jacobian	3.62	61203
316 SS	Vertical Guides	34N·m	3.96E+07	2.46	1.01	4 points Jacobian	9.26	13519

A sample calculation for the first step pushing and rotating, will first be presented to better understand the calculation of forces acting on the components. The torque acting on the box can be found by summing the torques due rotational acceleration and friction through the following equation.

$$Torque = \ddot{\theta} I_{xx} + Fd$$

The moment of inertia of the meat can be approximated to that of a uniformly distributed rectangle, the mass moment of the box is taken from SolidWorks as 1.058 [Nm^2].

$$I_{xxmeat} = \frac{1}{12}(Mass)(L^2 + W^2) = \frac{1}{12}(20)(0.78^2 + 0.41^2) = 1.28\ [Nm^2],$$

$$I_{xxtotal} = 2.338\ [Nm^2]$$

The torque due to friction can be found through the following equation.

$$Torque = \left(\frac{2}{3}\right)\left(\frac{0.78}{2}\right)(20 * 9.81) * 0.4 = 20.4\ [Nm]$$

$$Torque = 3.25 * 2.338 + 20.4Nm = 28\ [Nm]$$

The force of accelerating the meat laterally can be found through Newtons second law.

$$F = ma = 20 * 1.54 = 30.8\ [N]$$

The loads are applied as shown in Figure A5, the torques where applied as forces on the back wall and actuator mounts and the forces due to acceleration of the box where applied as body forces indicated by the red looping arrow on the top of the box. The box was fixed where the quick split guides will mount.

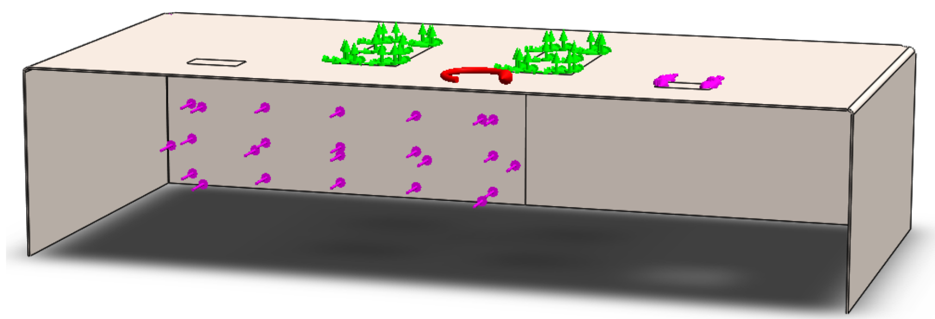

Figure A5. Forces Applied to Box Condition 1

The maximum stress was found to occur where the quick split guides are attached as the force must be taken up there the resulting stress plot can be seen in Figure A6.

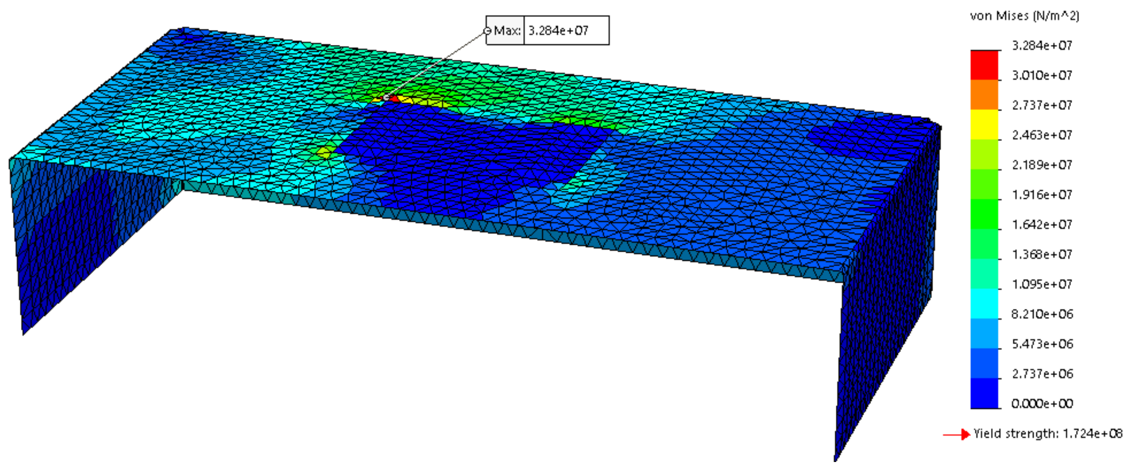

Figure A6. Stress on Box Condition 1

The maximum displacement was found to be 3.14 [mm] this occurred at the end of the box as seen in Figure A7. Displacements should be further validated in prototyping as there will be a piece of meat providing additional rigidity in the model that was not simulated.

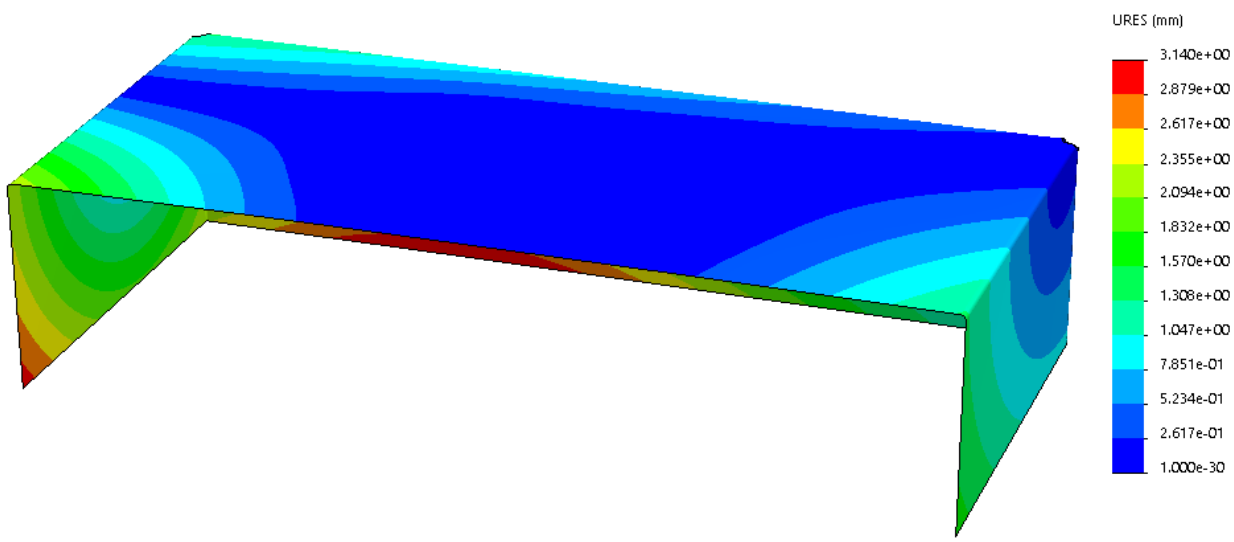

Figure A7. Displacements of Box Condition 1

The first condition simulated on the UHMW quick split guides was the initial movement. The stress was found to peak in the pin connecting the male and female sides as seen in Figure A8. This is due to the loads caused by friction going entirely through the pin due to the orientation.

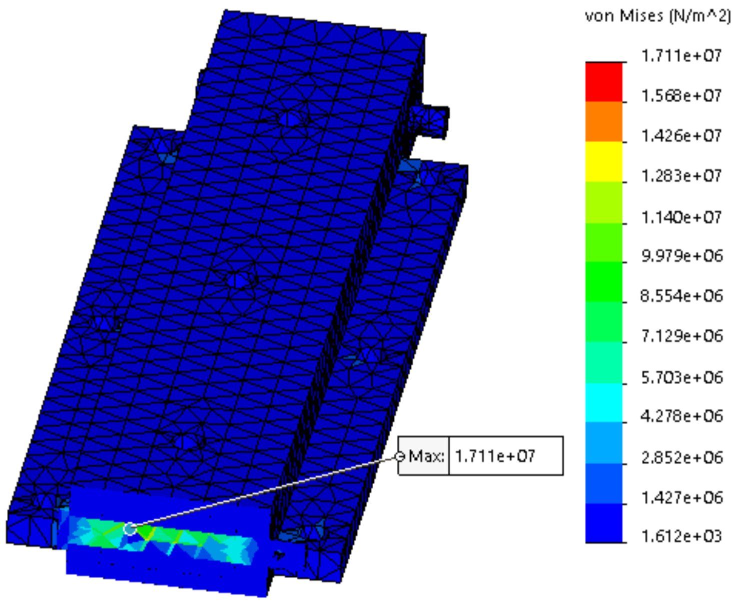

Figure A8. Stress in Quick Split Guides Condition 1

The displacements where found to be very small across the guides with a maximum of 4.3X10^{-2} [m] as seen in Figure A9.

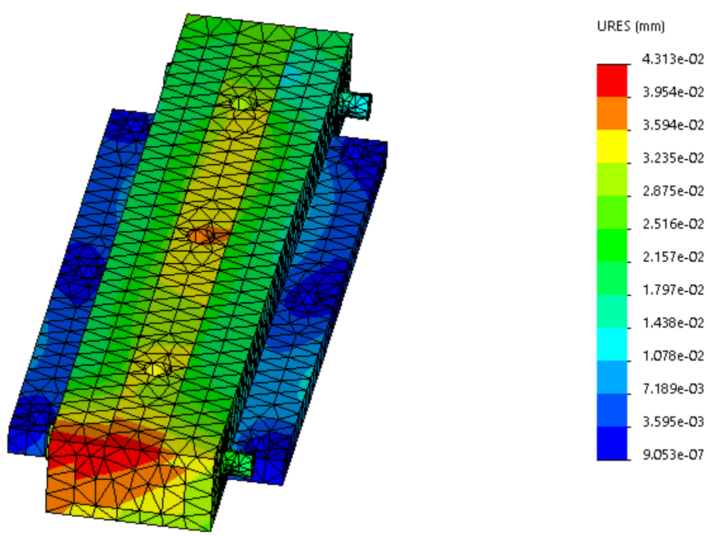

Figure A9. Quick Split Guides Displacements Condition 1

The stress for the vertical guides was found to peak at $4.568X10^{7}$ [Pa] for the first loading condition, this occurs on the inside of the mounting box around the inside cut out. The plot of the stresses can be seen in Figure A10.

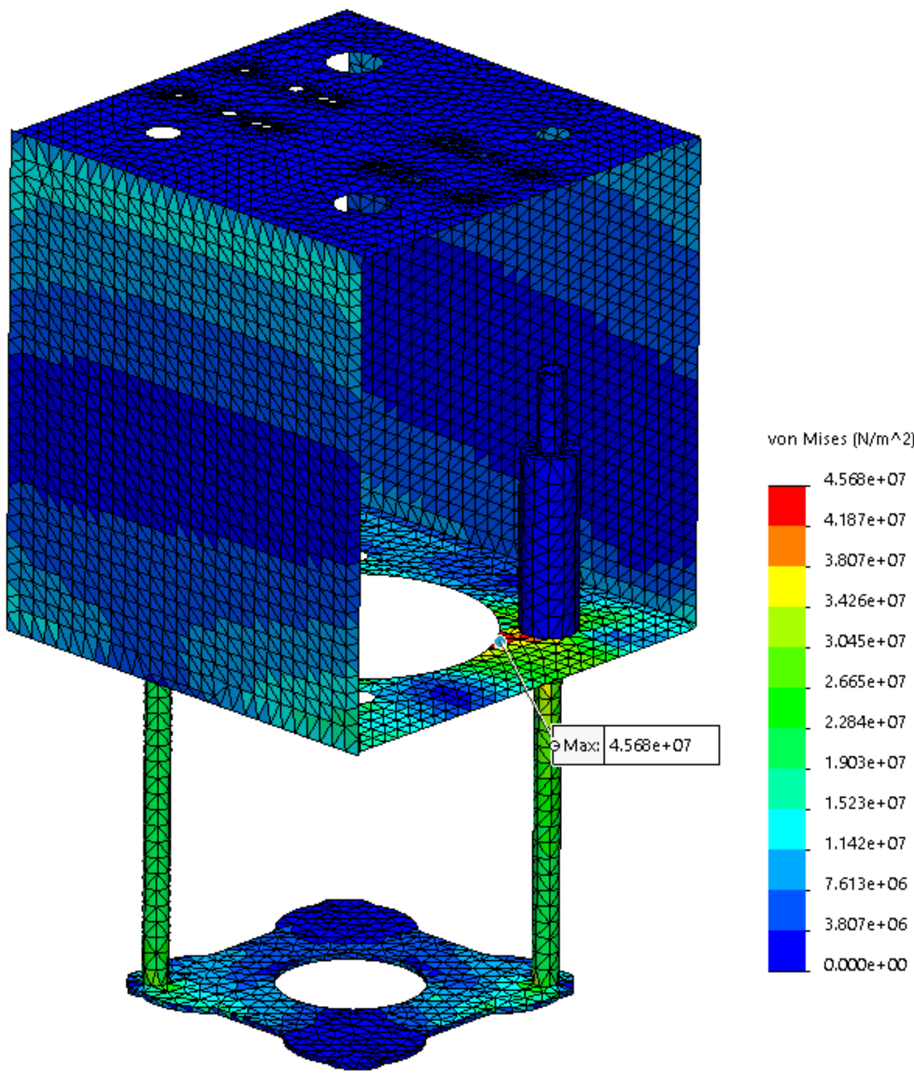

Figure A10. Stress in Vertical Guides Condition 1

The displacements where found to be relatively large for this part at 2.148 [mm], this occurs at the bottom of guides where the loads are applied as seen in Figure A11.

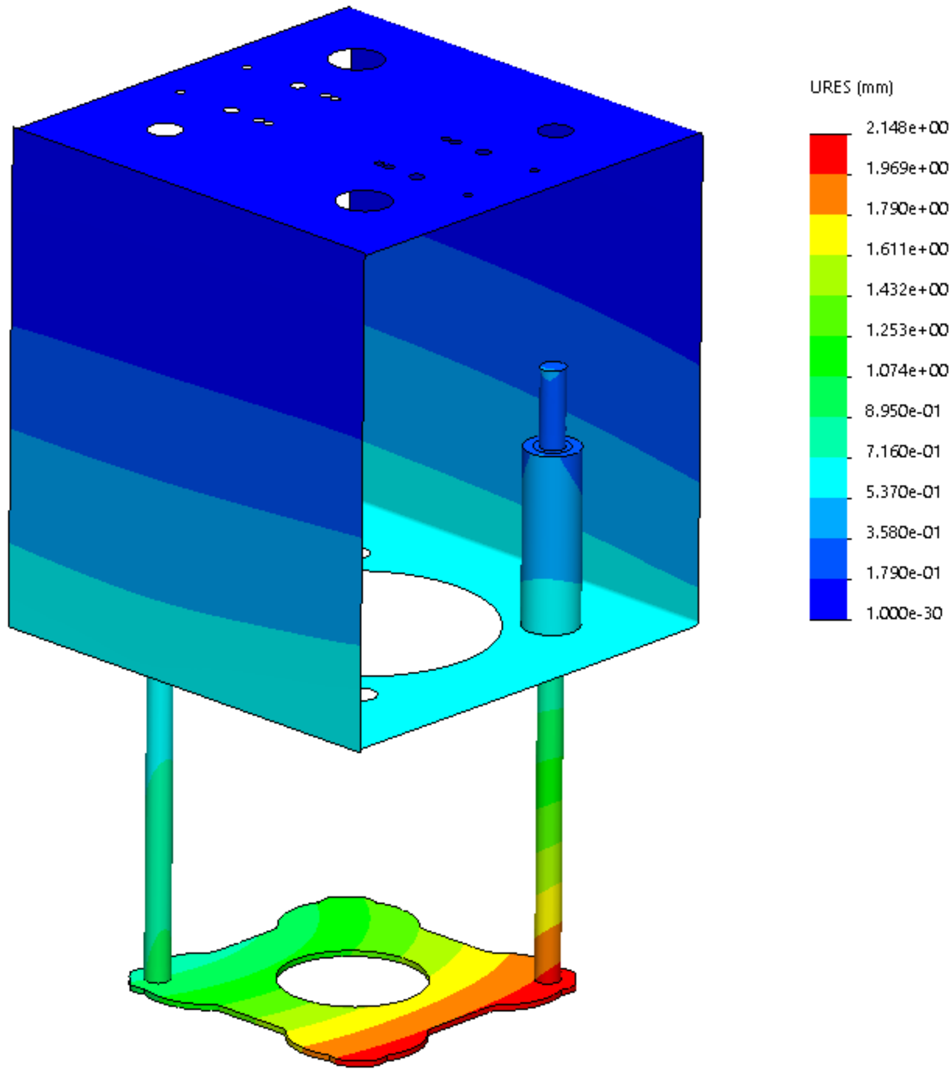

Figure A11. Displacement of Vertical Guides for Condition 1

The second loading condition is the return after placing the meat, this condition has very high rotational accelerations at 9.6 [rad/s^2], the same 3 components where analyzed under these conditions. The box was analyzed with the loads and fixtures shown in Figure A12. The loads due to the rotational acceleration of the movement are applied at the mounts and the body force due to rotational acceleration was in the same manner as condition 1.

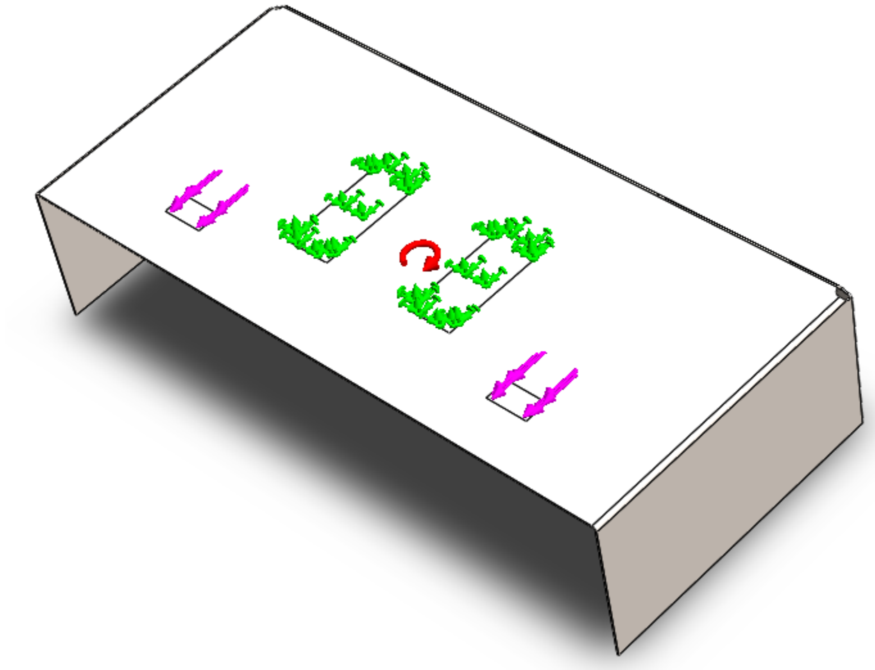

Figure A12. Box Loads and Fixtures Condition 2

The stresses where found to peak in the back corners of the box this is due to the forces from the rotational acceleration causing greater body forces at positions farther from the rotational axis and these points being subject to increasing distance from the axis as the rest of the box deforms. The peak stress was found to be $1.662X10^7$ [Pa] these results are plotting in Figure A13.

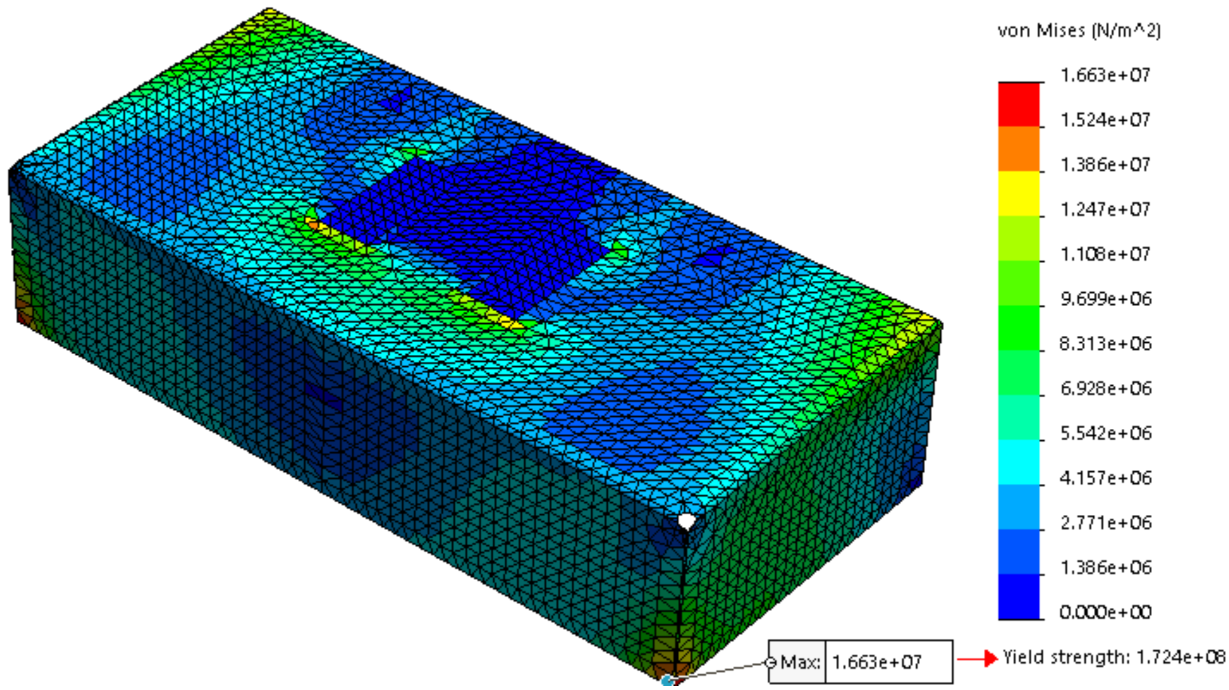

Figure A13. Box Stress Loading Condition 2

The displacements where found to be the greatest at the open face of the box where they where 1.686 [mm] as plotted in Figure A14.

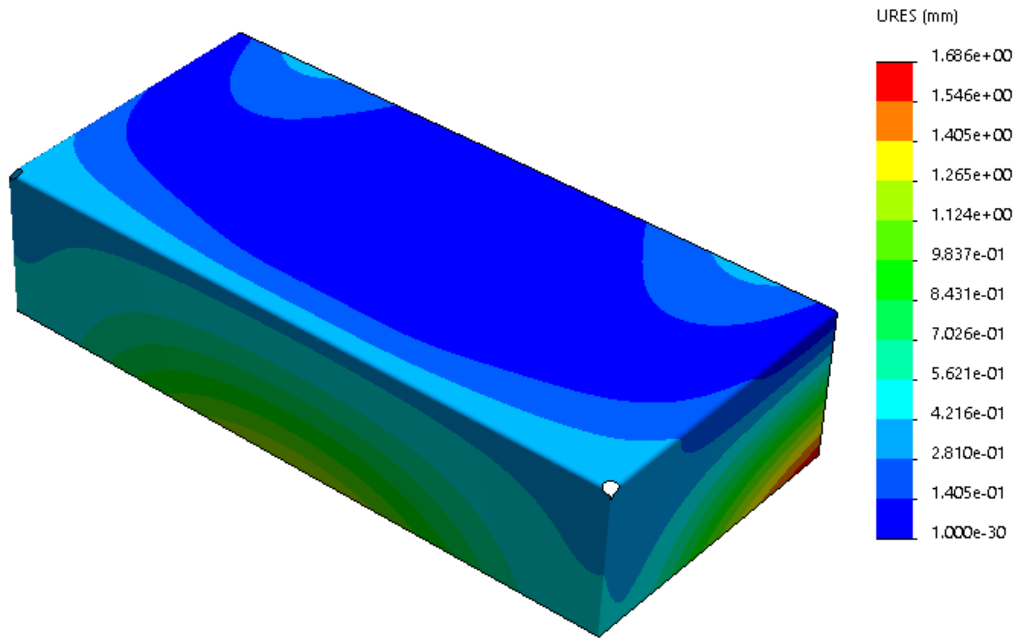

Figure A14. Box Displacement Loading Condition 2

The UHMW guides where found to have a peak stress of $4.148X10^6$ [Pa], this occurs are the bolt holes where the torque is transferred form the guides to the box. These results are plotted in Figure A15.

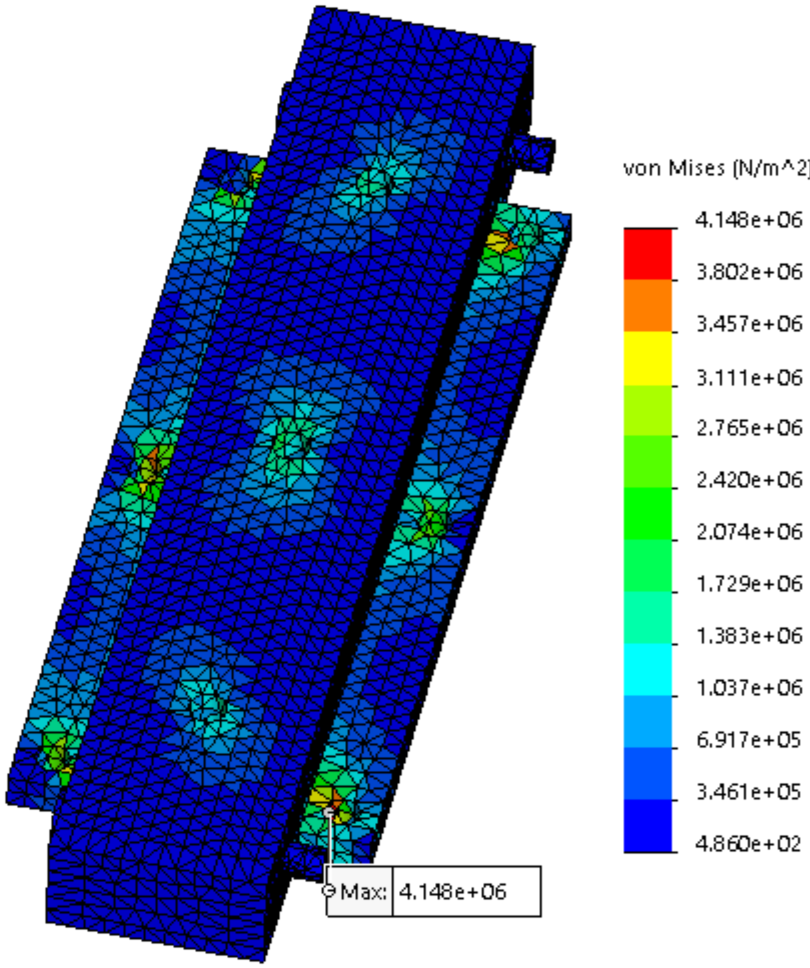

Figure A15. Quick Split Guides Condition 2 Stress

The displacements where found to be very small at 0.0028 [mm], these results are presented in Figure A16.

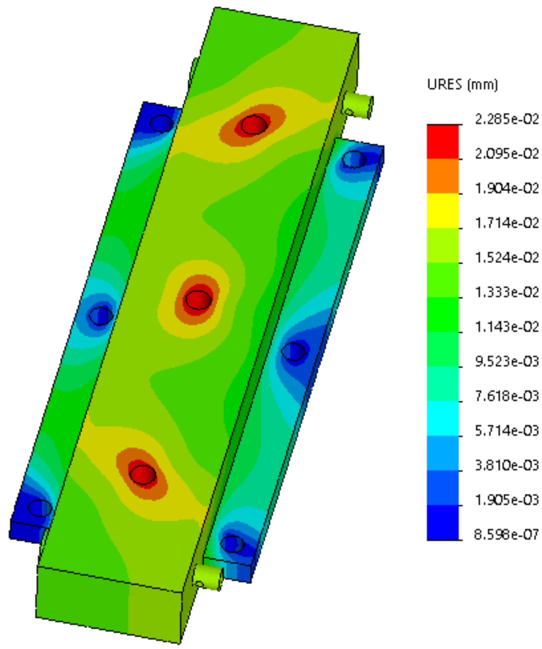

Figure A16. Displacements of Quick Split Guides Condition 2

The final end effector component analysis will be on the vertical guides the stresses where found to peak at $3.936X10^7$ [Pa] as seen in Figure A17 This occurs in the area that the vertical shaft meets the motor mounting plate, with this care should be taken to ensure weld fillets are made to the correct size in this area.

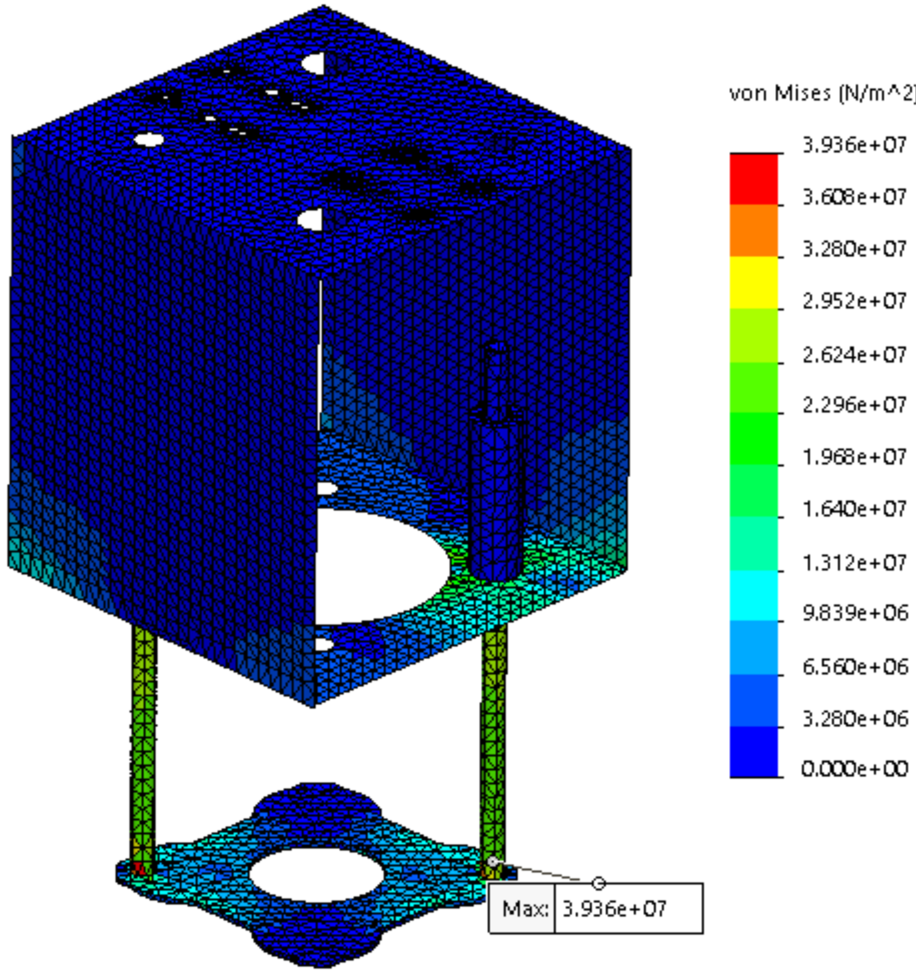

Figure A17. Vertical Guides Condition 2 Stress

The displacement of the vertical guides was found to peak at 1.005 [mm] for the second loading condition as seen in Figure A18.

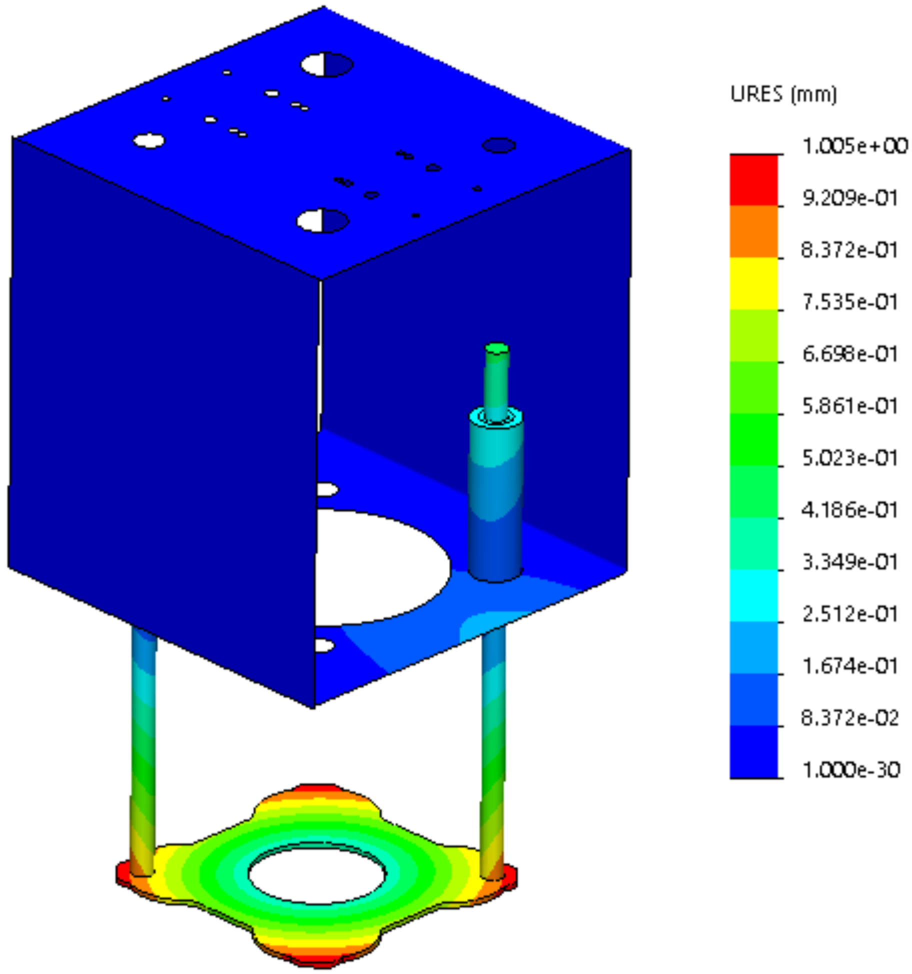

Figure A18. Vertical Guides Displacement Loading Condition 2

Horizontal Arm FEA

TABLE AIX shows the summary of the FEA results for the rectangular tubing with internal supports of the horizontal arm.

TABLE AIX
FEA RESULTS FOR HORIZONTAL ARM COMPONENTS

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Rectangular Tubing	54.8N·m 608N 269N	2.85E+07	5.96	1.599	4 points Jacobian	10	74901

The horizontal arm experiences dynamic and static loading in the horizontal arm tubing. The main arm experiences static loads that account for the weights of the linear actuators, and their associated motors, gearboxes, and mounts. This is simplified to be a uniform load from the bottom ends of the tube to almost to centre of the tube, where the distance between the loads are 152 [mm]. The static load of the end effector and hog middle will be represented as a uniform load the same length as the actuator carriage at the widest position, which is 130 [mm] from the end. The dynamic loading is also added from the preliminary load determination section into the FEA of the horizontal arm tube.

The loads applied to the horizontal arm are shown in Figure A19.

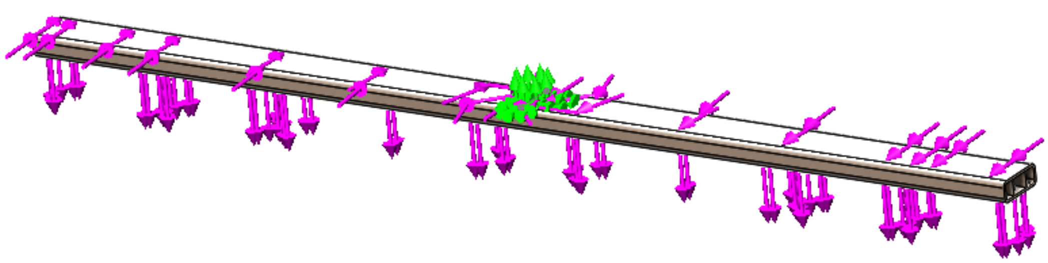

Figure A19. Applied loads on horizontal arm rectangular tubing

The maximum stress of 28.56 [MPa] is found to occur around the centre of the tube, where the circular mount would be fixed to.

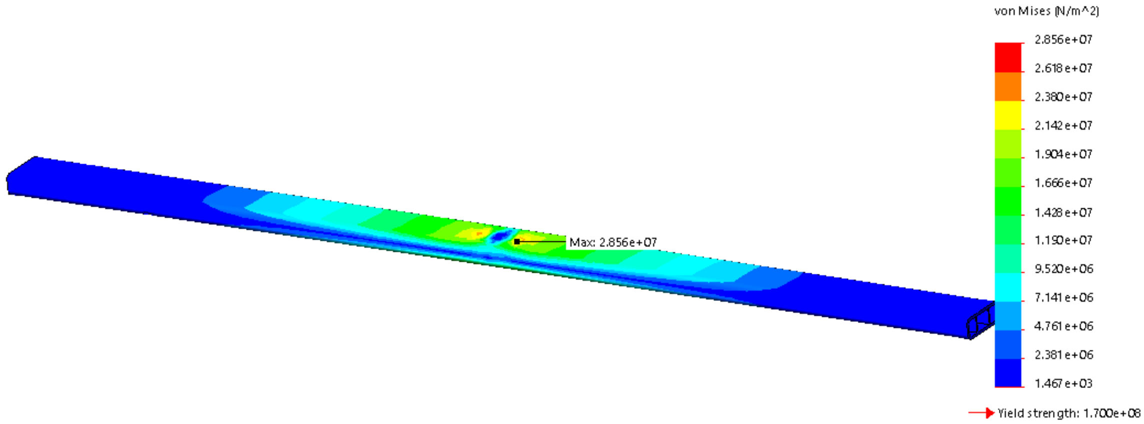

Figure A 20 Stress on the Horizontal Arm Tube

The maximum displacement was found to occur at the ends of the tube at a displacement of 1.599 [mm].

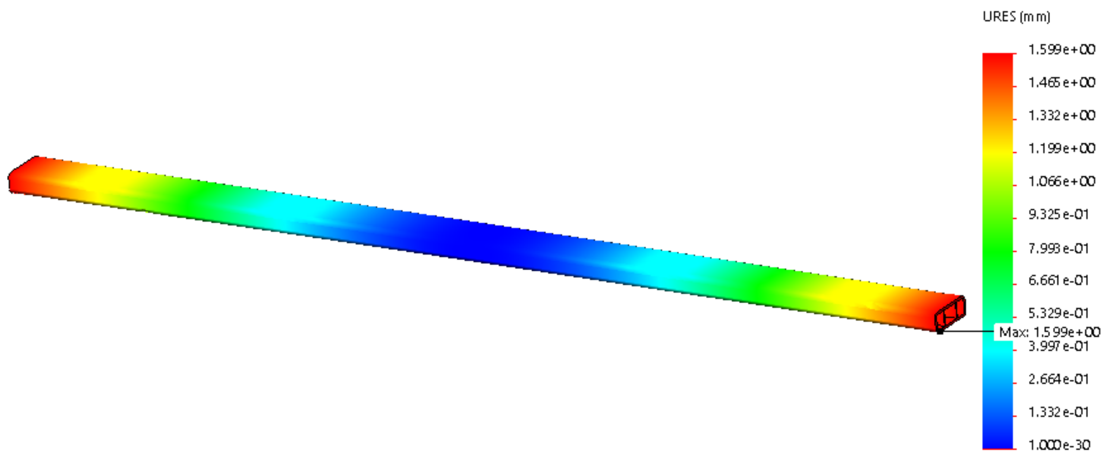

Figure A 21 Deformation of horizontal arm tube

Main Arm FEA

The FEA results are summarized in TABLE AX.

TABLE AX
SUMMARY OF FEA RESULTS FOR MAIN ARM COMPONENTS

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Main Arm Support	840N·m 170N 1780N 77N	9.64E+07	2.13	3.3	4 points Jacobian	13.34	71278
316 SS	Rotary Motor Housing	63 N·m 1780N	6.60E+07	3.1	0.33	4 points Jacobian	7.55	62888

There are two components of the main arm that experience dynamic and static loading: the main arm support, and the rotary motor housing. The details from the FEA analysis on each component are explained in the following. Only the worst loading scenario was simulated.

The main arm support experiences a cantilever load from the supported weight of the horizontal arm and both end effectors. In addition to the supported weight, the square tubing also supports the linear track, inline gearhead, and electric servo motor, which all have mass. The locations of each mass along the length of the rectangular beam are shown in Figure A22.

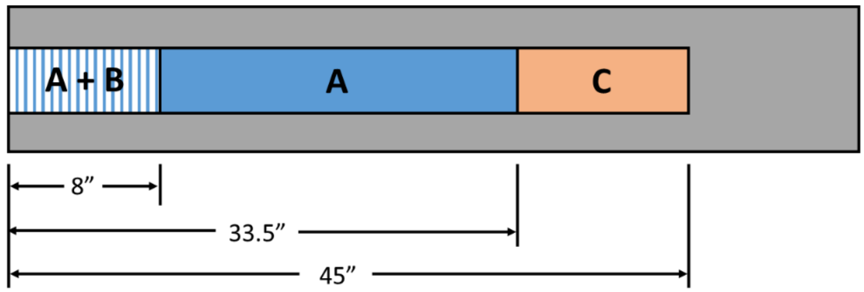

Figure A22. Static load locations on rectangular tubing of main arm support

Load A is the load from the weight of the linear track, Load B is the load from the weight of the horizontal arm and both end effectors, and Load C is the load from the weight of both the inline gearhead and electric servo motor. The magnitude of each load is 170 [N], 1780 [N], and 77 [N], respectively.

In addition to the static loading, the main arm also experiences torque when moving positions. The worst torque the main arm experiences is 840 [Nm]. To simulate the loading described, several portions of the main arm support were split to better replicate the areas where the loads are applied. The applied static loads and torque on the model are shown in Figure A23 and Figure A24 , respectively.

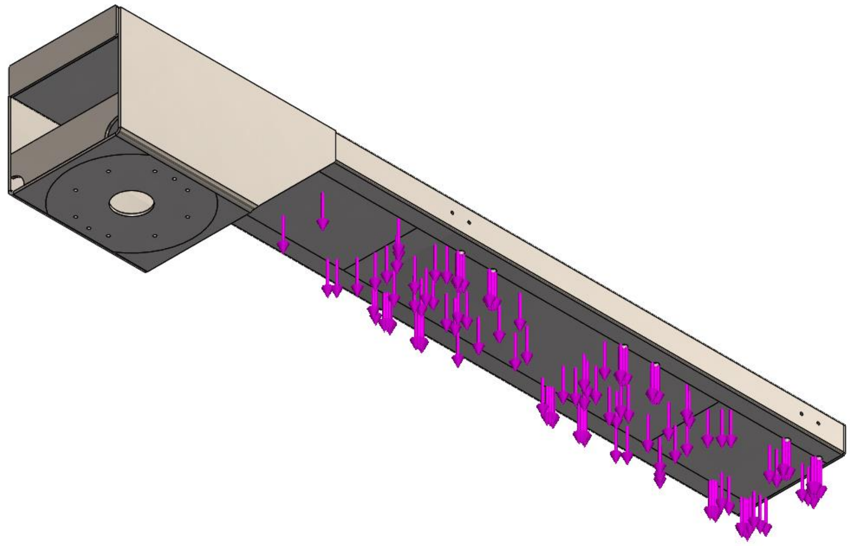

Figure A23. Applied static loading on main arm support

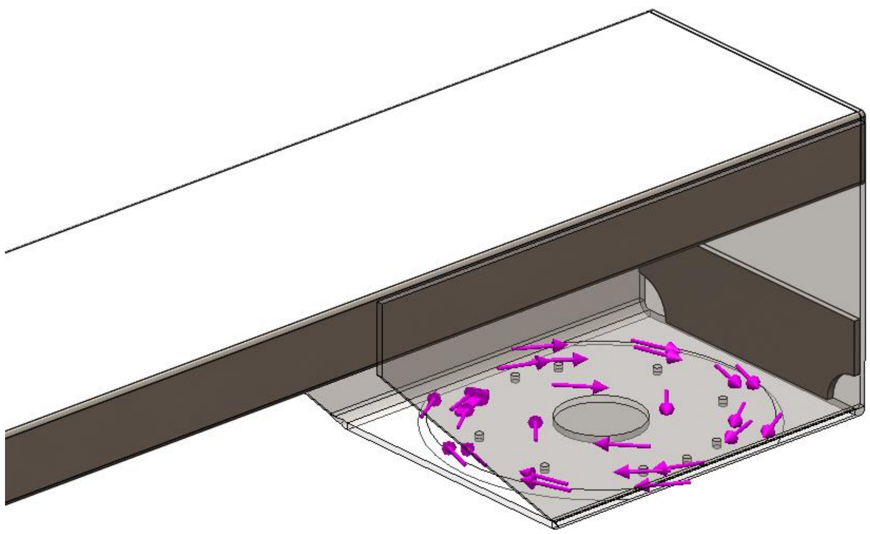

Figure A24. Applied dynamic torque on base of main arm support

The applied torque was applied to the top surface of the base plate. The main arm support was fixed on the bottom surface of the base plate as shown in Figure A25.

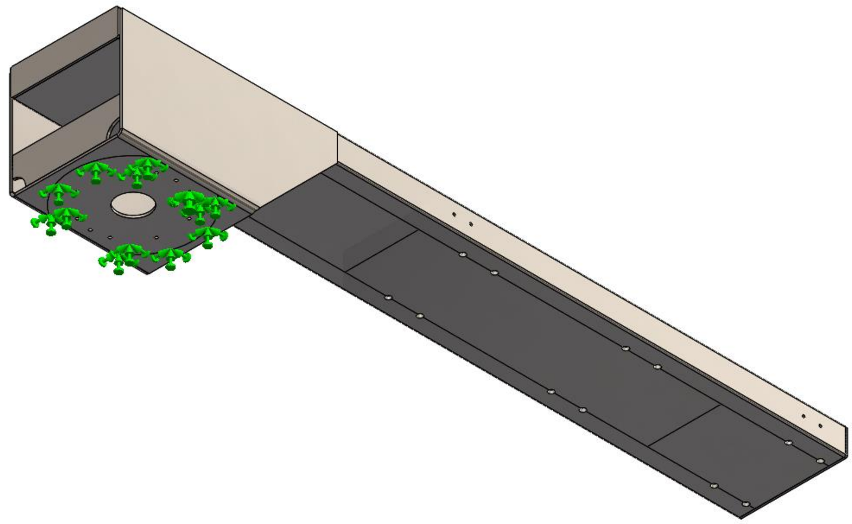

Figure A25. Fixed base location during FEA simulation

The results from the FEA simulation show a peak stress at the inside corner of the base plate, see Figure A26 and Figure A27. This stress concentration make sense because the corner has a small radius and experiences both the static load and applied torque.

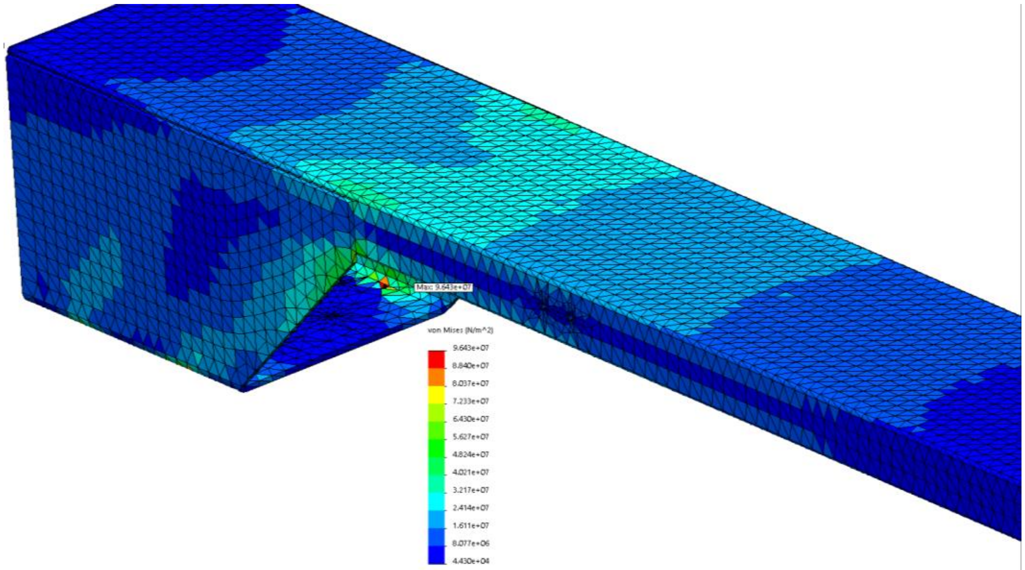

Figure A26. von Mises stress results for main arm support

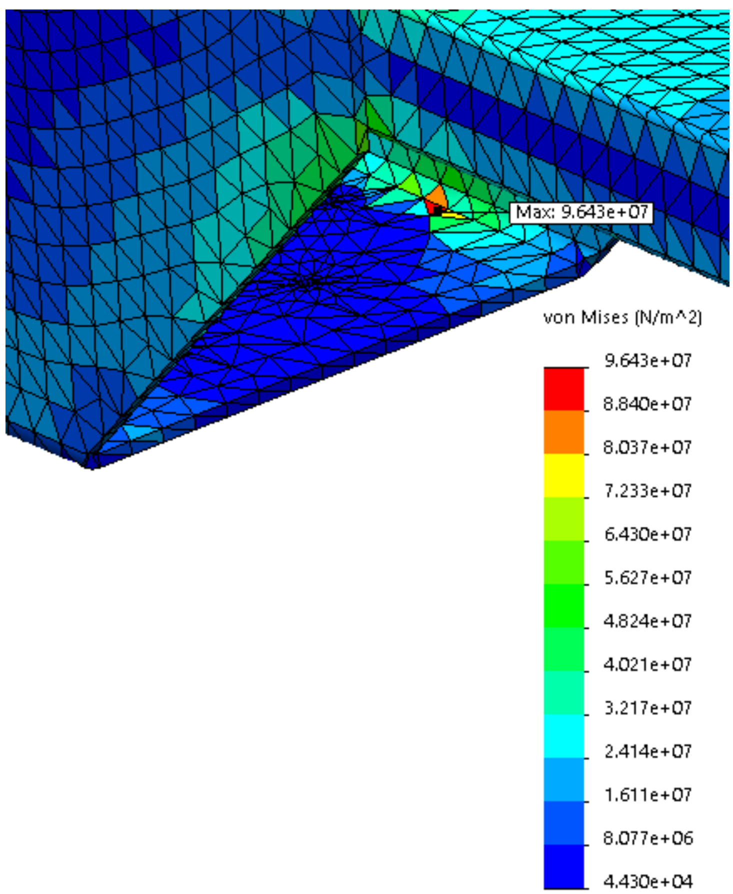

Figure A27. Close-up of inside corner showing stress concentration

The peak stress at the inside corner is 96.43 [MPa], which means the entire support has a minimum factor of safety of 2.13.

The deformation of the main arm is minimal, which is favorable. The end of the cantilever rectangular beam has the largest deformation of 3.296 [mm], see Figure A28 and Figure A29.

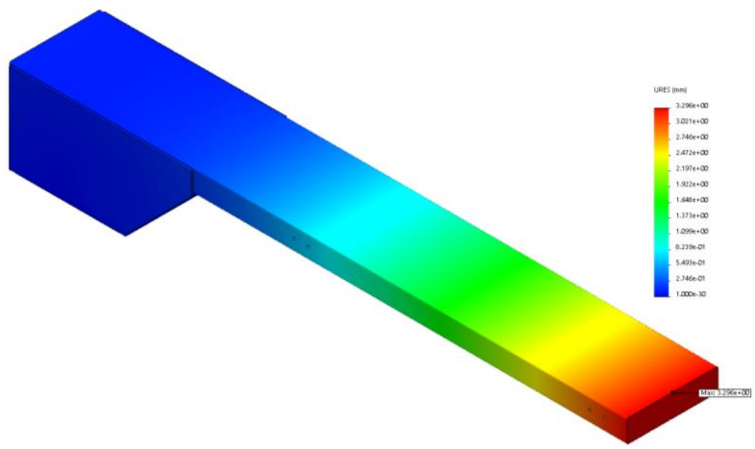

Figure A28. Deformation of main arm support

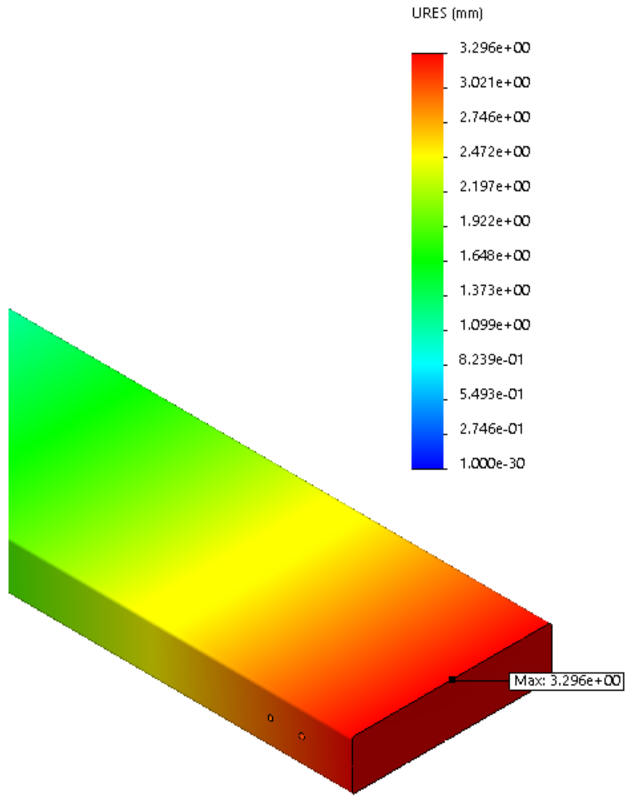

Figure A29. Close-up showing location of maximum deformation on main arm support

The second component that was analyzed is the rotary motor housing. This component will experience a torque when the horizontal arm and end effectors rotate. Only the largest torque was simulated. Additionally, the housing will support the weight of the horizontal arm and both end effectors.

The maximum torque the housing will experience is 63 [Nm]. The simulated torque and downward load was applied to a split surface on the bottom of the housing where the motor mounts to the housing, see Figure A30. The housing was fixed at the top as it would be to the main arm linear track carriage.

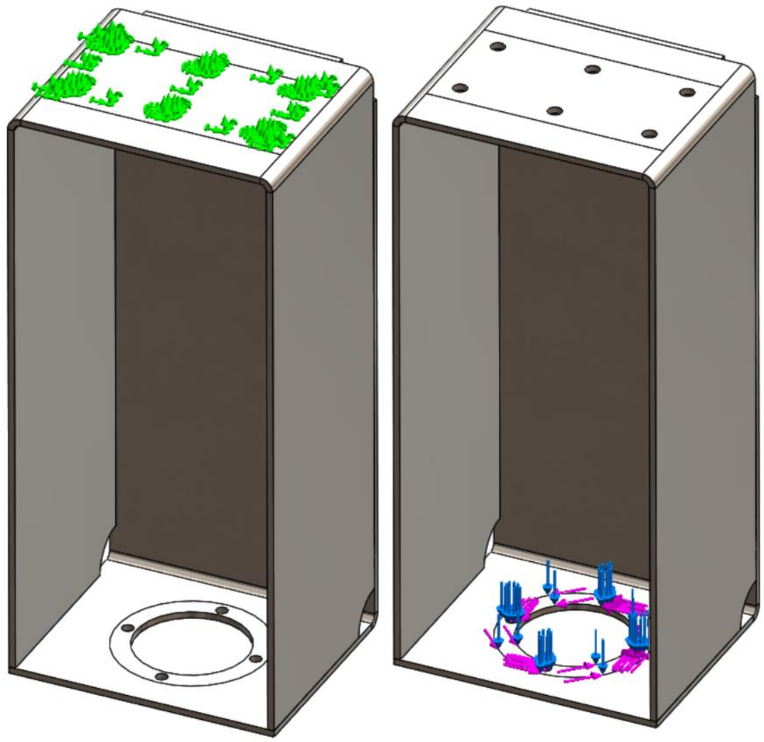

Figure A30. Fixture and applied loading locations on housing component

From the results, the maximum von Mises stress (65.96 MPa) occurs on the underside and edge of a screw hole, see Figure A31 and Figure A32. Again, this makes sense as tight corners and discontinuities are locations of stress concentration.

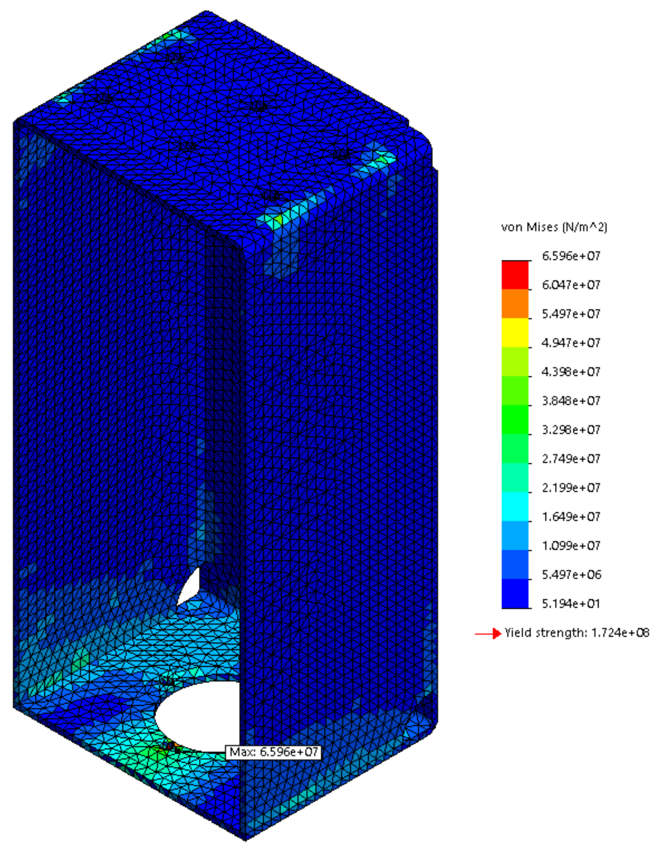

Figure A31. von Mises stress distribution for the housing component

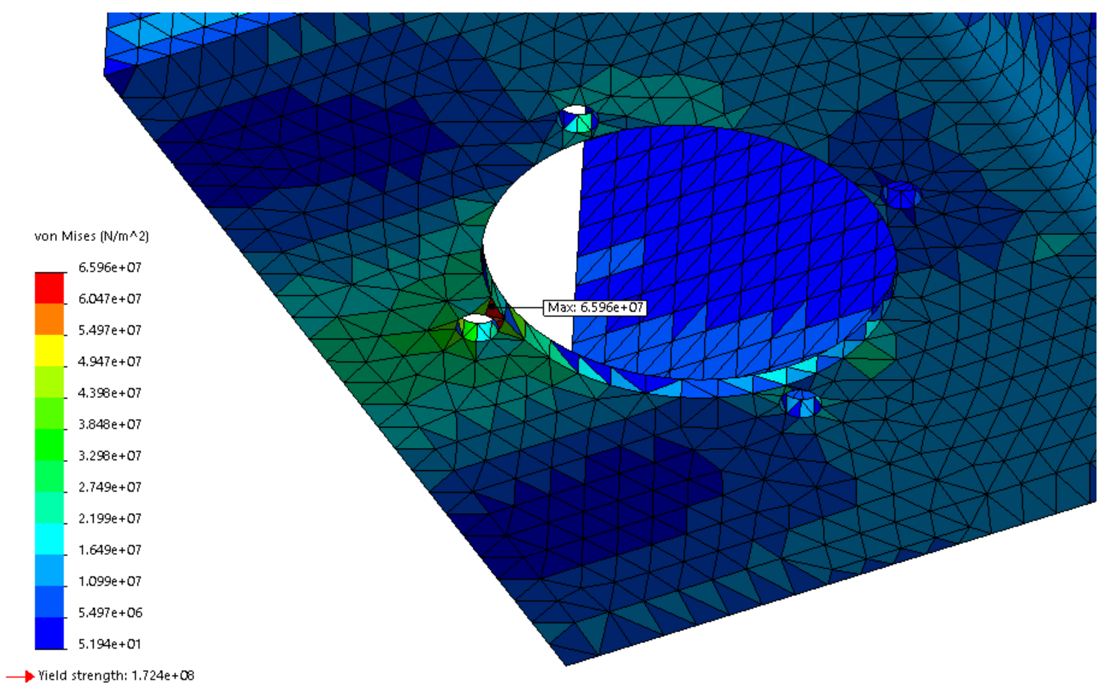

Figure A32. Close-up of stress concentration on edge of screw hole

The deformation of the housing is mainly concentrated at the bottom open end of the housing component, see Figure A33. The maximum deformation is 0.33 [mm] and occurs at the outside edge of the center circle.

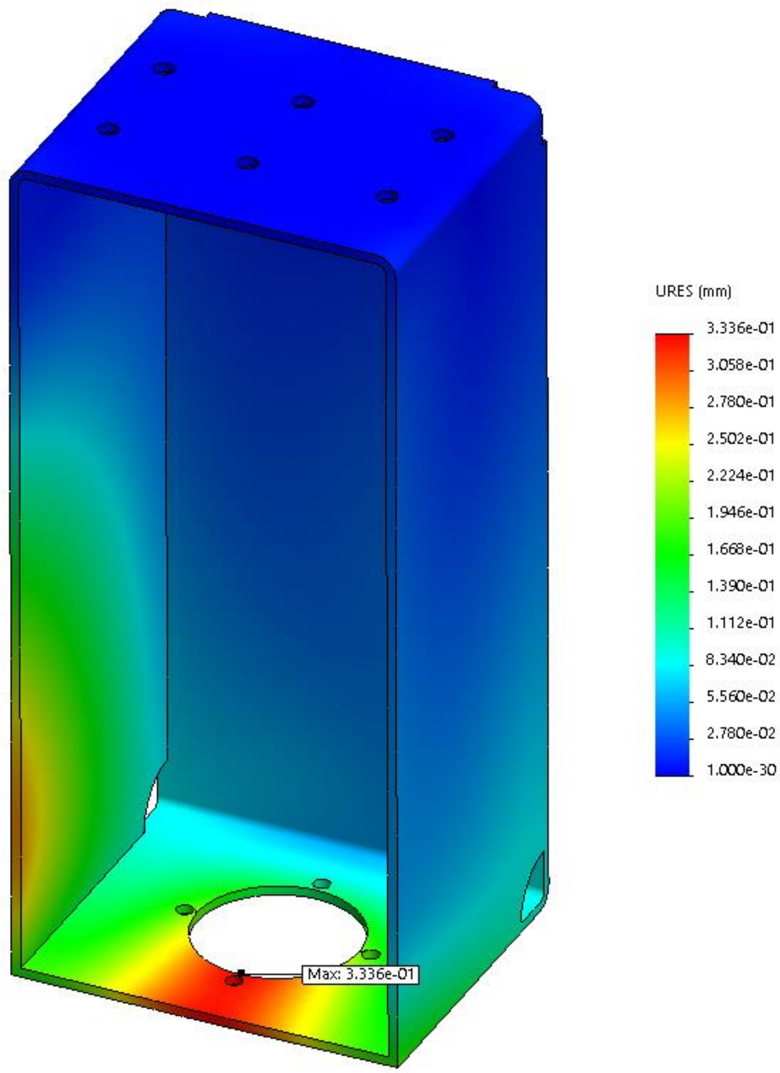

Figure A33. Displacement of the housing component after applied loading

Arm Base FEA

TABLE AXI shows the summary of FEA results for the arm base.

TABLE AXI
FEA RESULTS SUMMARY FOR THE ARM BASE

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
304 SS	Arm Base	840N·m 3150N·m 2156N	9.46E+07	2.2	0.62	4 points Jacobian	5.08	1152469
304 SS	Rotary Table Container	840N·m 3149N·m	4.00E+07	5.2	0.02	4 points Jacobian	3.81	163382
HDPE	Rotary Table to Main Arm Spacer	840N·m 3149N·m 2156N	7.99E+06	4.0	0.16	4 points Jacobian	2.54	532057
304 SS	Arm Base Track Spacer	840N·m 3149N·m 4900N	1.04E+07	19.9	0.06	4 points Jacobian	7.62	118697
304 SS	Simulated Arm Base Truss Support	840N·m 3149N·m 5880N	4.36E+07	4.7	1.91	4 points Jacobian	5.08	2488857

Figure A34 shows the diagram used to determine the loading conditions for the finite element analysis of the arm base.

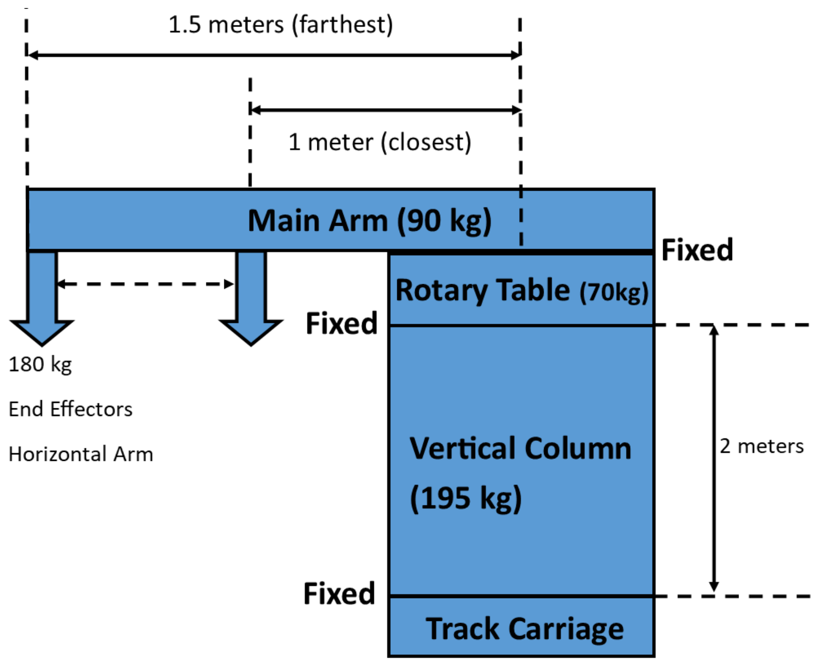

Figure A34. Estimated dimensions used to determine loading conditions

There are three major loads on each assembly structure of the arm base, and they are the load due to gravitational forces from the structures above, the rotation torque during the operation, and the torque generated due to the weight-offset. However, the weight-offset torque is approximately the same throughout the entire arm base, as the arm base is approximated as concentric throughout. The approximated rotation torque is transmitted throughout the entire arm base without any loss or increment.

It should be noted that the calculated the mass sum of the end effectors and the horizontal arm as well as the main arm is about 20 [kg] lower what are used in the loads calculations, shown in Figure A34. Also, the full extension of the main arm payload is about 0.3m shorter than what is shown in Figure A34. The team exaggerated these loading conditions to compensate for other possible underestimation, such as the rotation of the horizontal arm can add addition length to where the payload's location is and the missing electrical components, such as wires and control units, can add additional weight as well.

$$Weight\ Offset\ Torque$$

$$= (180\ kg\ \times 9.81\ \times 1.5\ m) + 90\ kg \times 9.81\ \times \left(\frac{1.5}{2} - \frac{0.36}{2}\right) m$$

$Rotation\ Torque = 840\ N \cdot m$

For example, the gravitational load on the spacer between the rotary table to the main arm is derived from the total mass on top of the spacer, which is 494.4 [kg]. The team rounded up the mass to 500 [kg], which is 4900 [N].

Figure A35 shows the loading conditions applied in SolidWorks on the spacer between the main arm and the rotary table.

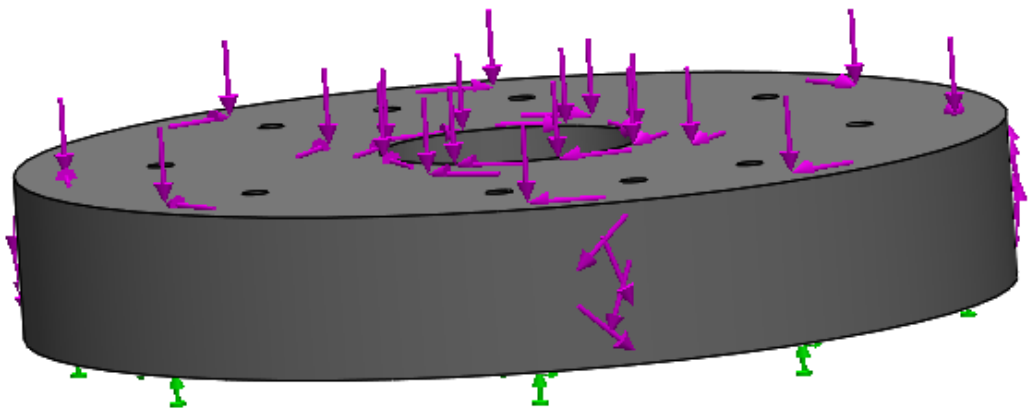

Figure A35. Loading conditions of the rotary table to the main arm spacer

Figure A36 shows the stress results of the spacer from SolidWorks FEA.

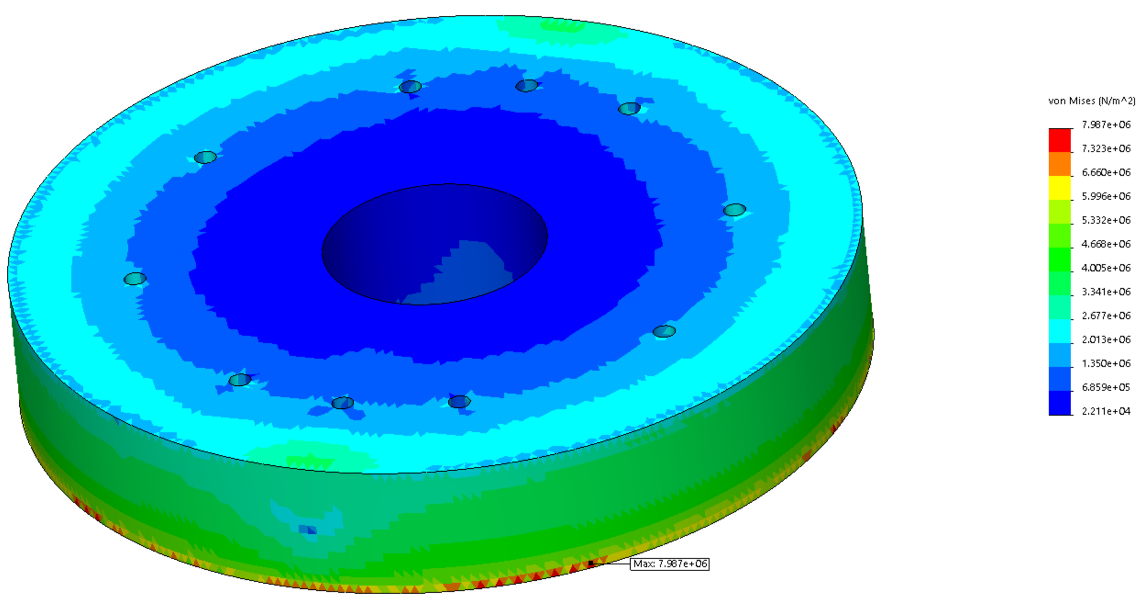

Figure A36. Stress results of the rotary table to the main arm spacer

Figure A37 the close-up view of the spacer where the maximum stress occurs.

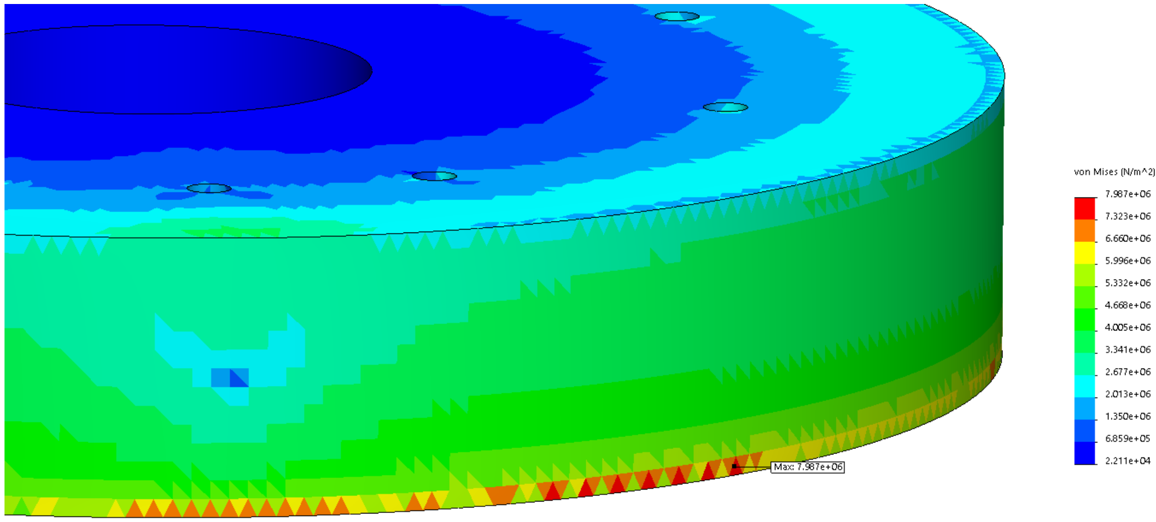

Figure A37. Close-up view of stress results for the rotary table to the main arm spacer

Figure A38 shows the displacement on the spacer between the main arm and the rotary table.

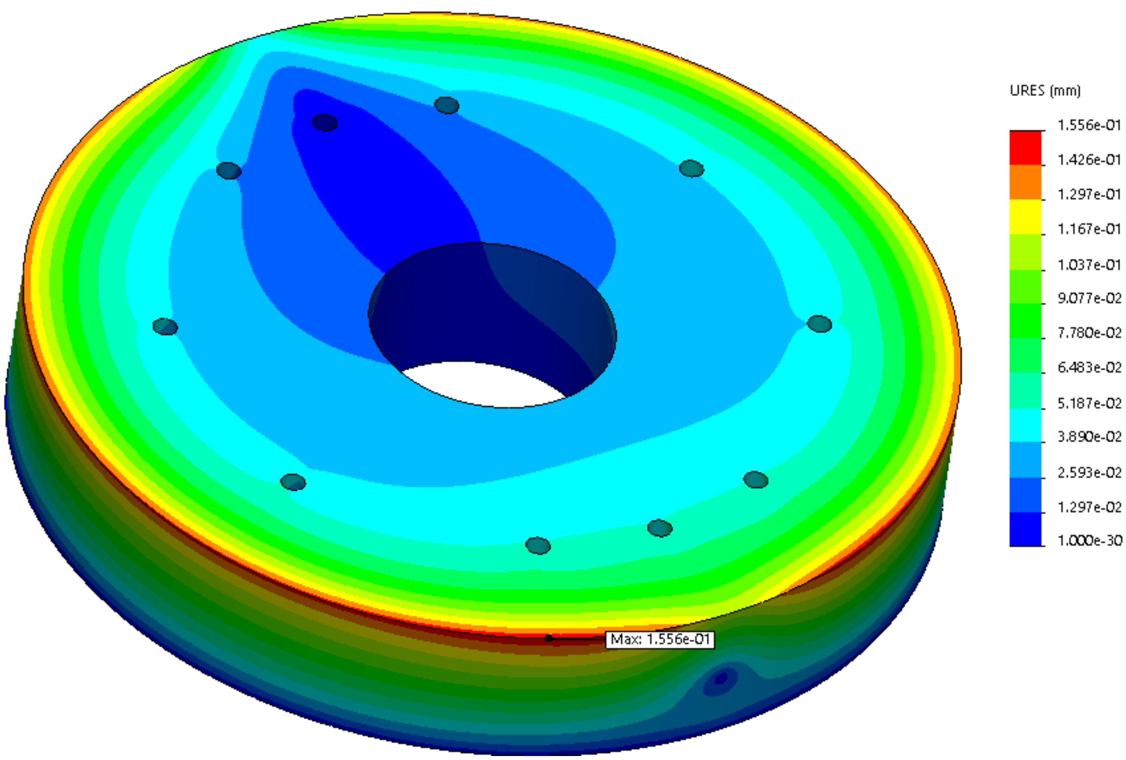

Figure A38. Displacement results of the rotary table to the main arm spacer

Figure A39 gives a detailed view of the maximum displacement location.

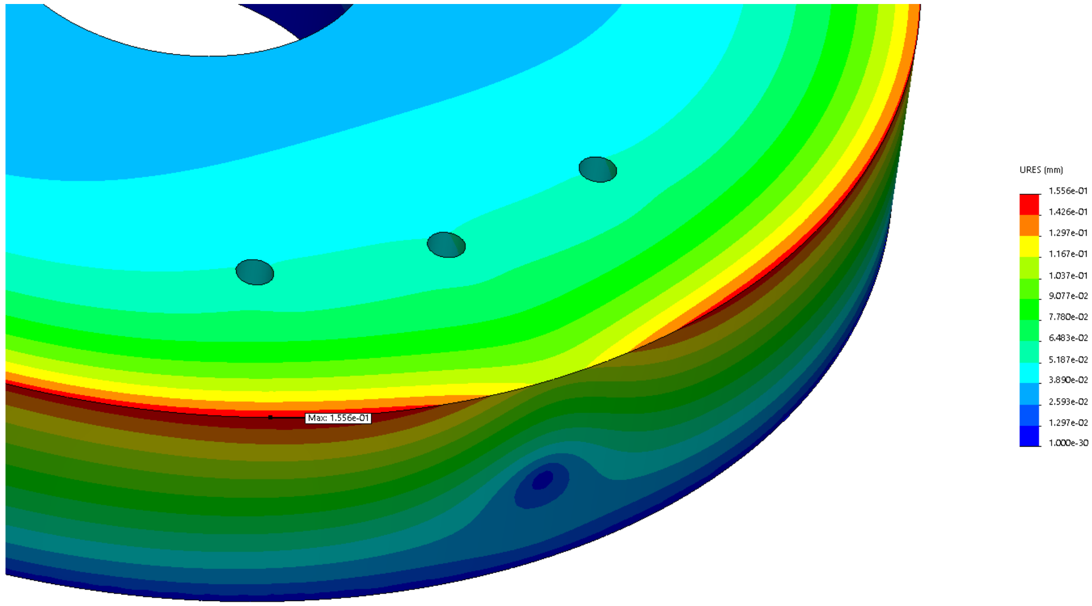

Figure A39. Close-up view of displacement results for the rotary table to the main arm spacer

Figure A40 shows the loading conditions applied in SolidWorks FEA.

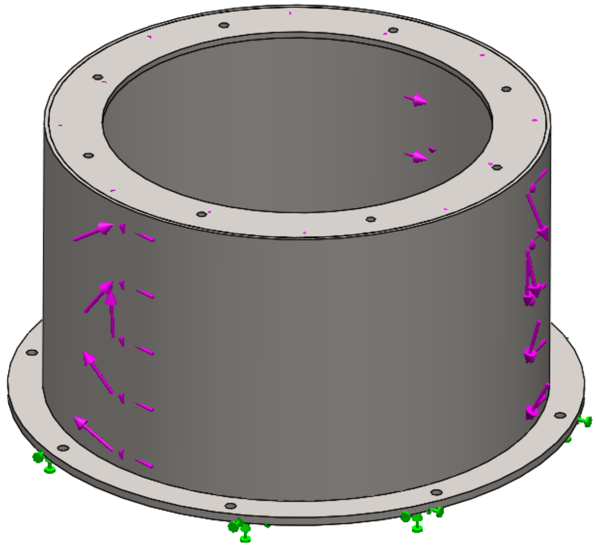

Figure A40. Loading conditions of the arm base rotary table container

Figure A41 shows the stress distribution of the rotary table container from SolidWorks FEA.

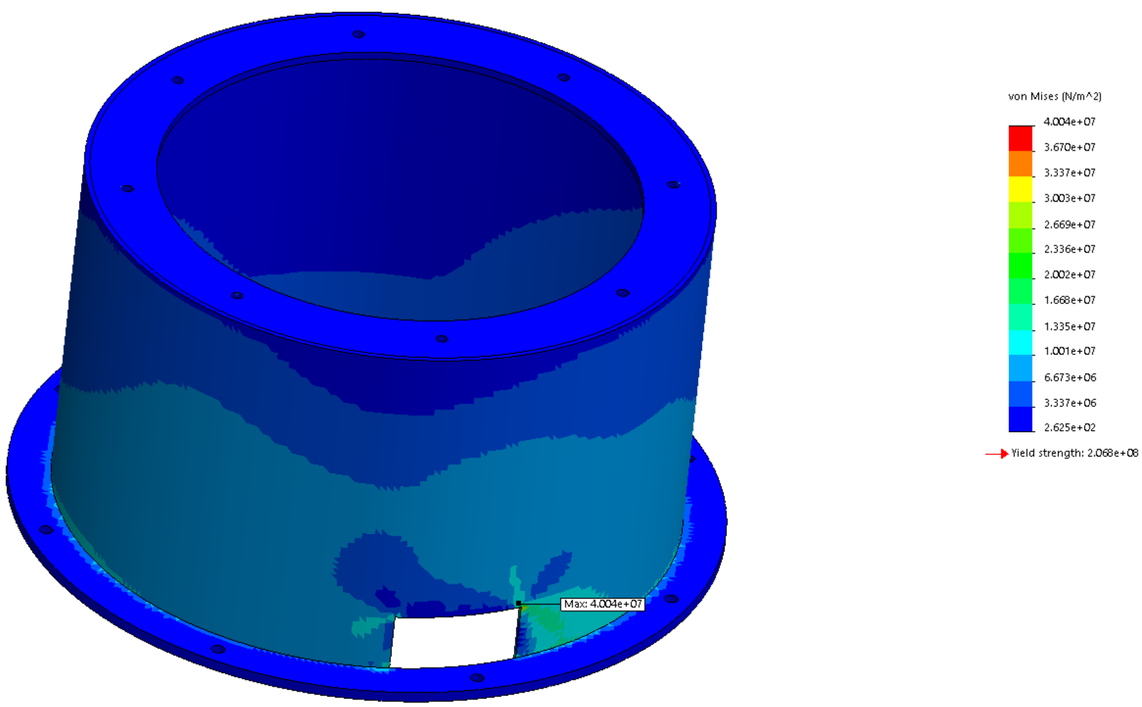

Figure A41. Stress results of the arm base rotary table container

Figure A42 shows the detailed view where the maximum stress occurs on the rotary table container. As the location is around a sharp edge, a filler can be added to reduce the stress concentration.

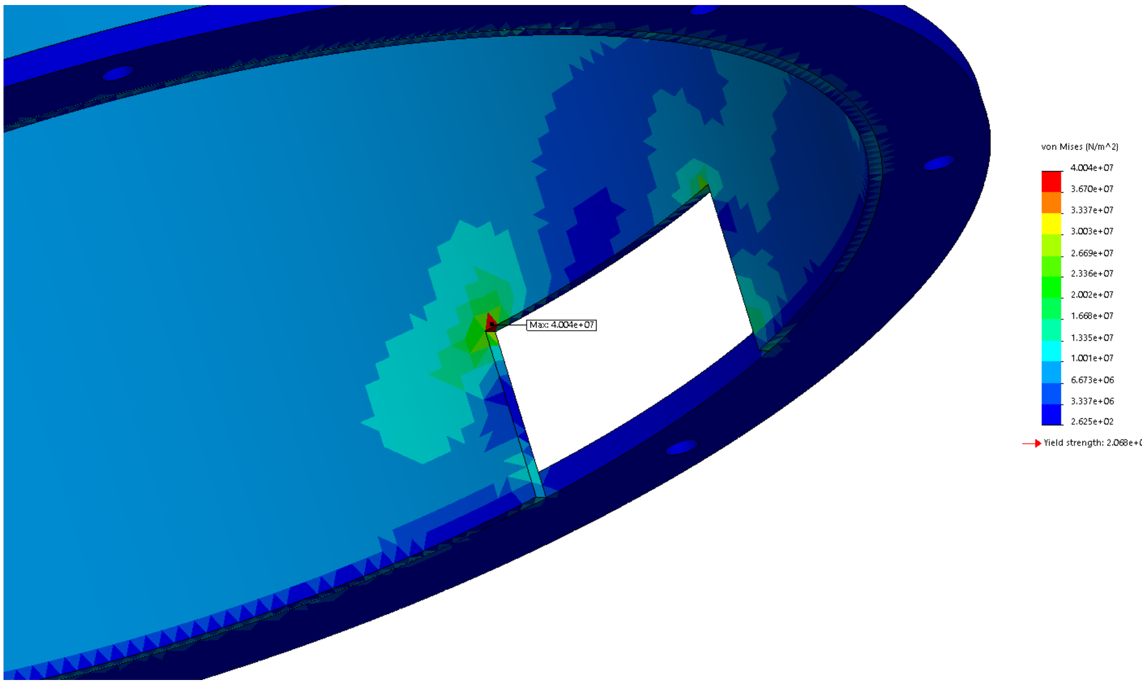

Figure A42. Close-up view of the stress results for the arm base rotary table container

Figure A43 shows the displacement distribution of the rotary table container.

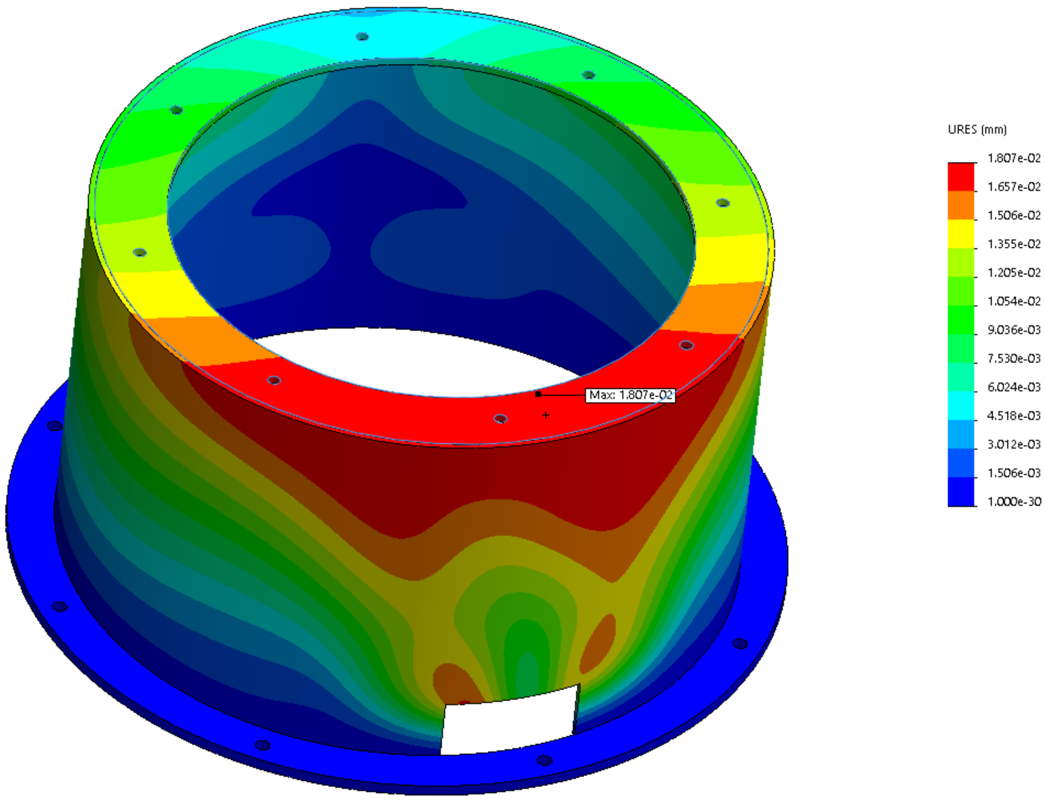

Figure A43. Displacement results of the arm base rotary table container

Figure A44 shows a more detailed view of the location where the maximum displacement occurs on the rotary table container.

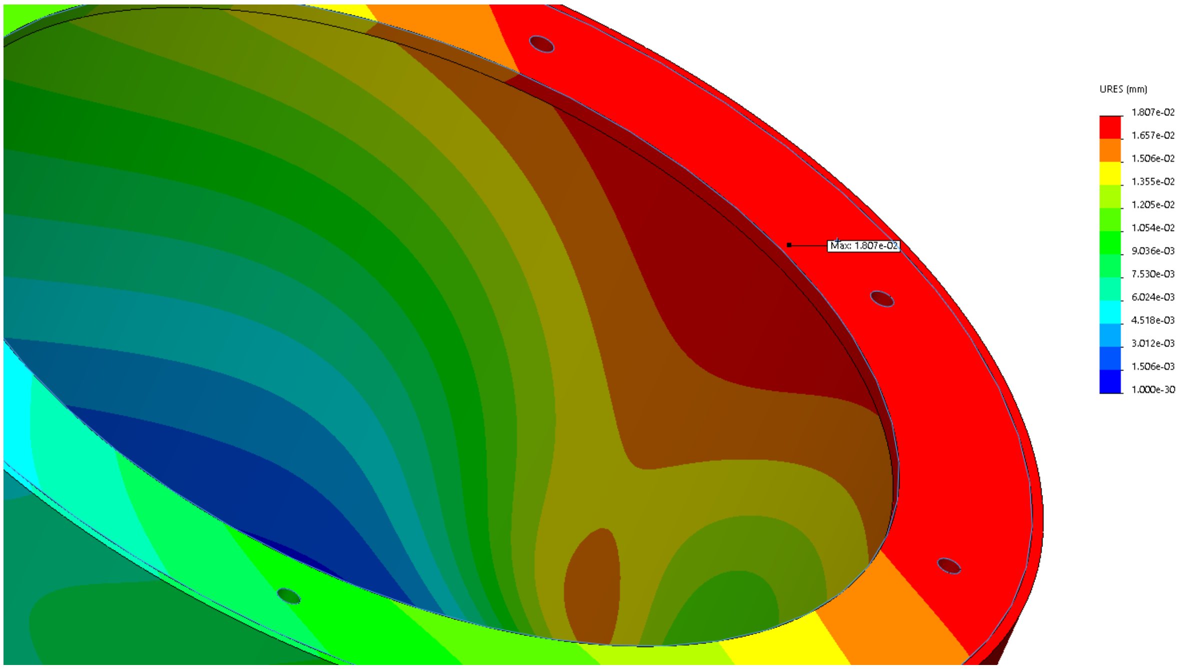

Figure A44. Close-up view of the displacement results for the arm base rotary table container

Figure A45 shows the FEA stress results from SolidWorks FEA of the arm base.

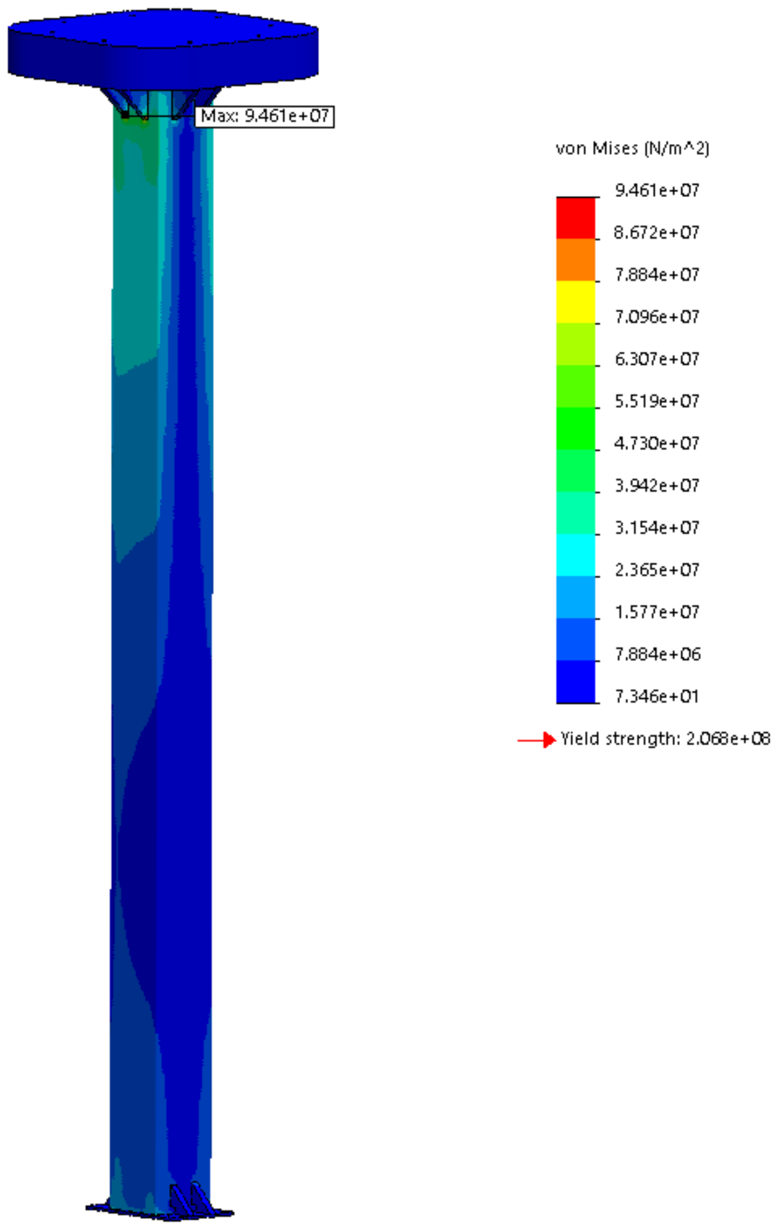

Figure A45. Stress results of the arm base

Figure A46 gives a detailed view of the maximum stress location on the arm base. As the location has a rather sharp transition, a fillet or more gentle transition can be added to reduce stress concentration.

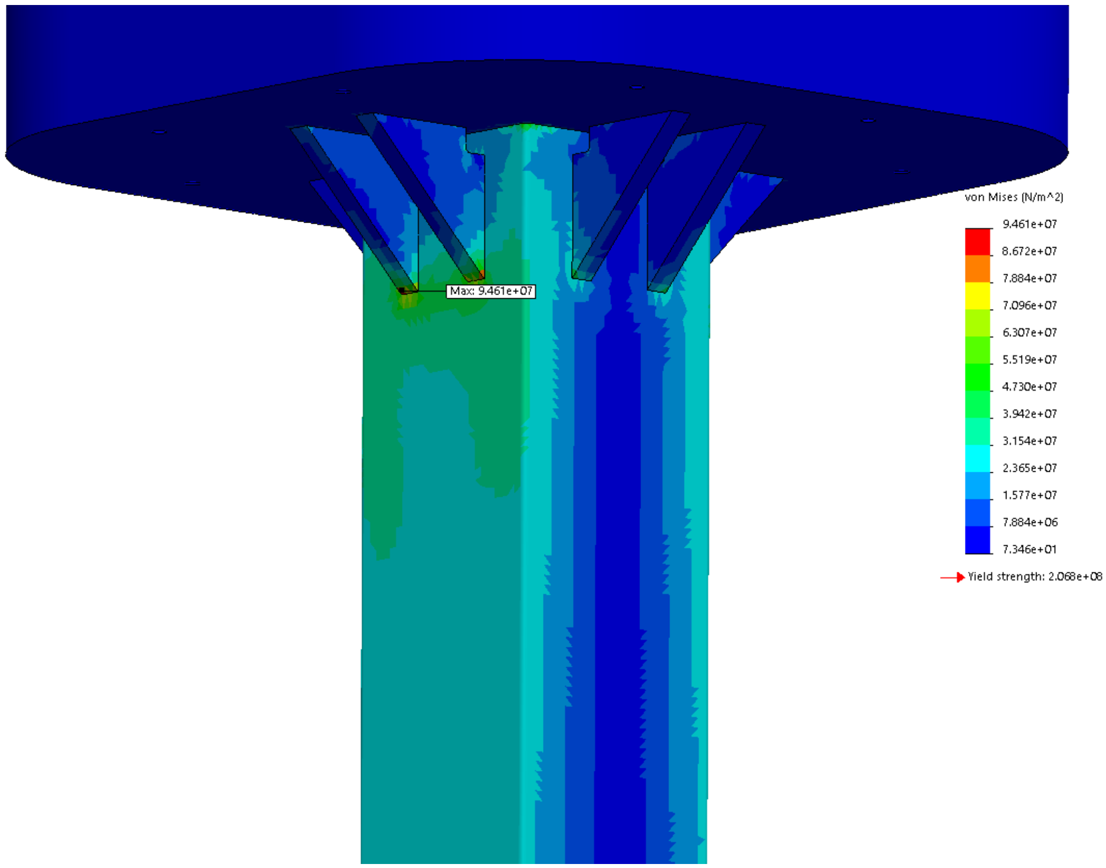

Figure A46. Close-up view of the stress results for the arm base

Figure A47 shows the displacement distribution of the arm base.

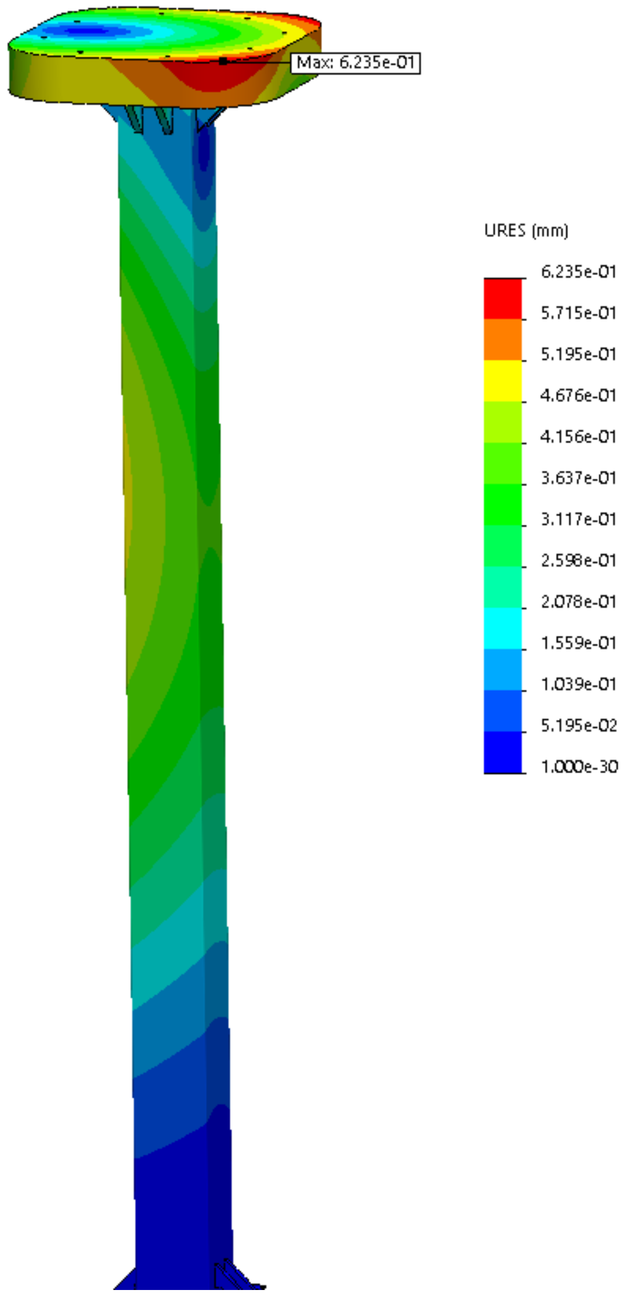

Figure A47. Displacement results of the arm base

Figure A48 shows a detailed view of the maximum displacement of the arm base.

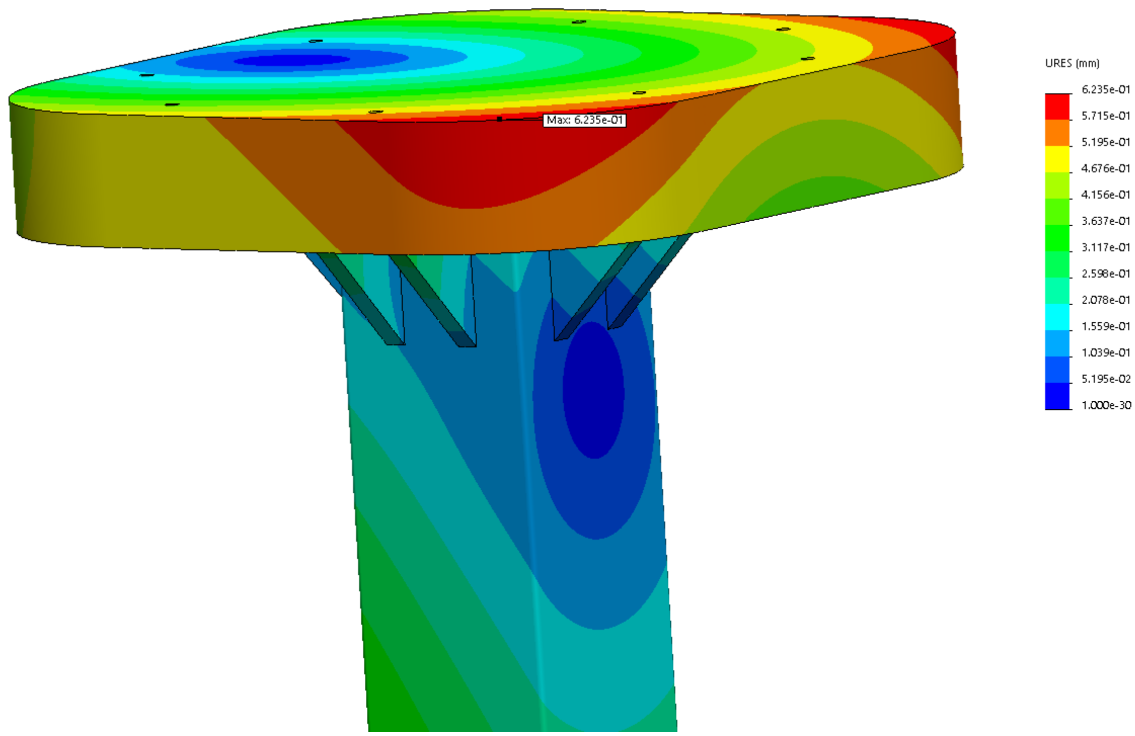

Figure A48. Close-up view of the displacement results for the arm base

Figure A49 shows the loading conditions of the spacer for the arm base track.

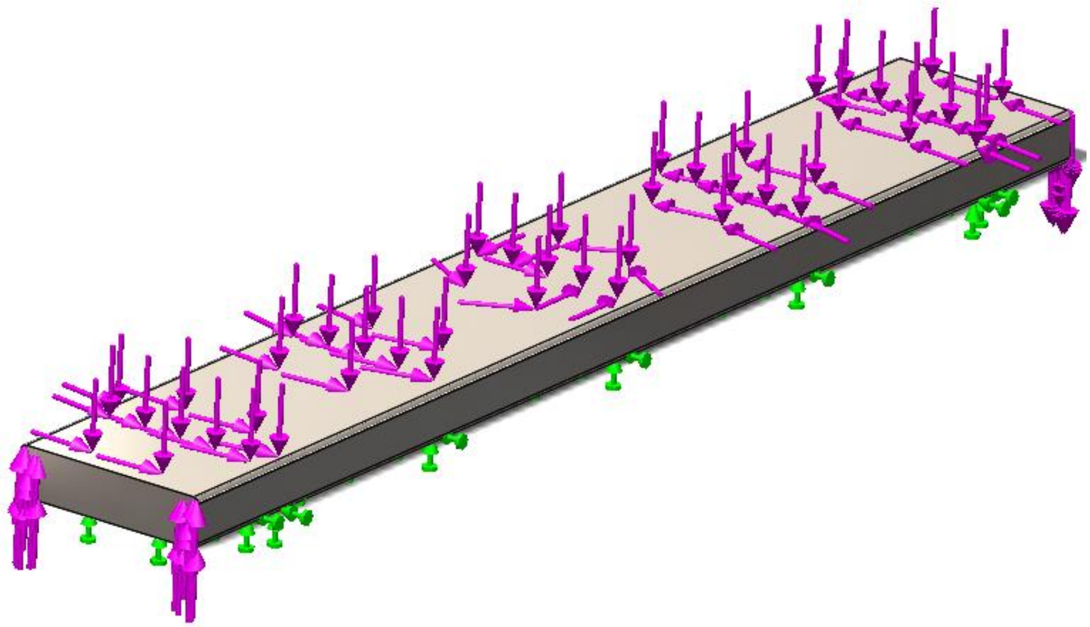

Figure A49. Loading conditions of the arm base track spacer

Figure A50 shows the FEA stress results obtained from SolidWorks FEA.

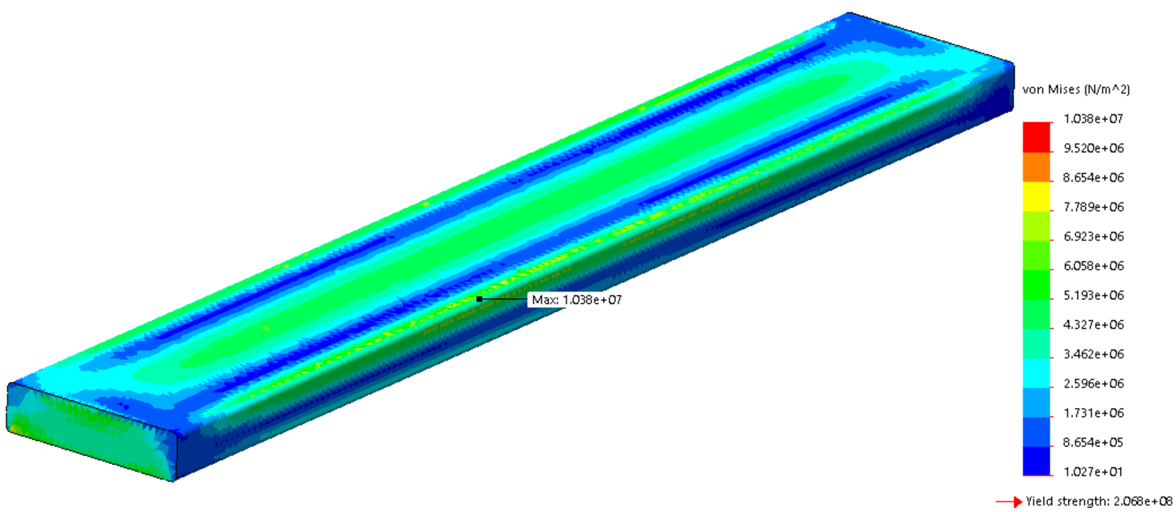

Figure A50. Stress results of the arm base track spacer

Figure A51 gives a detailed view of the maximum stress location, which is on the outer edge of the spacer. This type of high stress, from sharp transitions, can be reduced by adding a larger fillet if that is required.

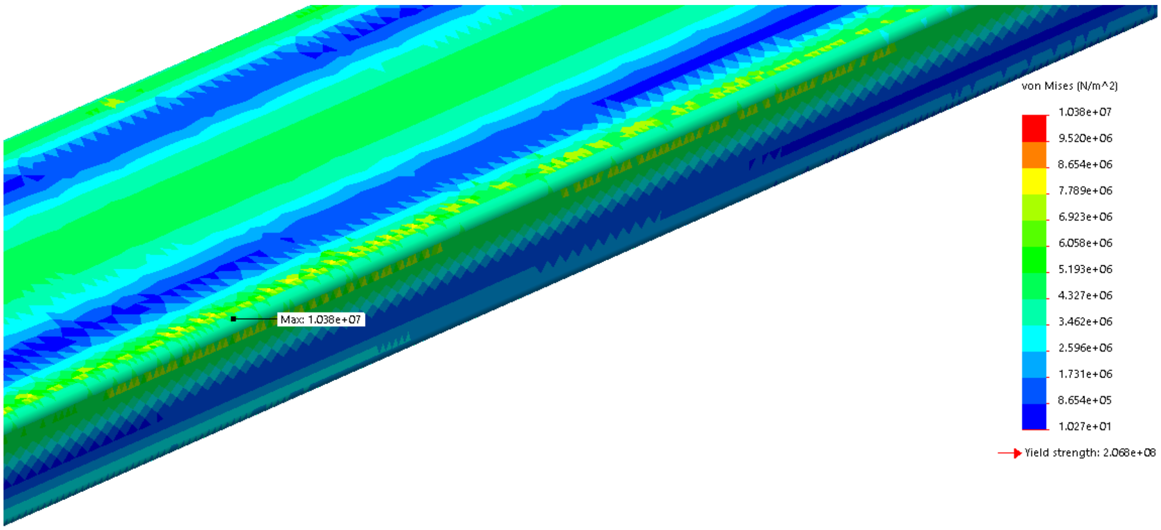

Figure A51. Close-up view of the stress results for the arm base track spacer

Figure A52 shows the displacement distribution of the arm base track spacer.

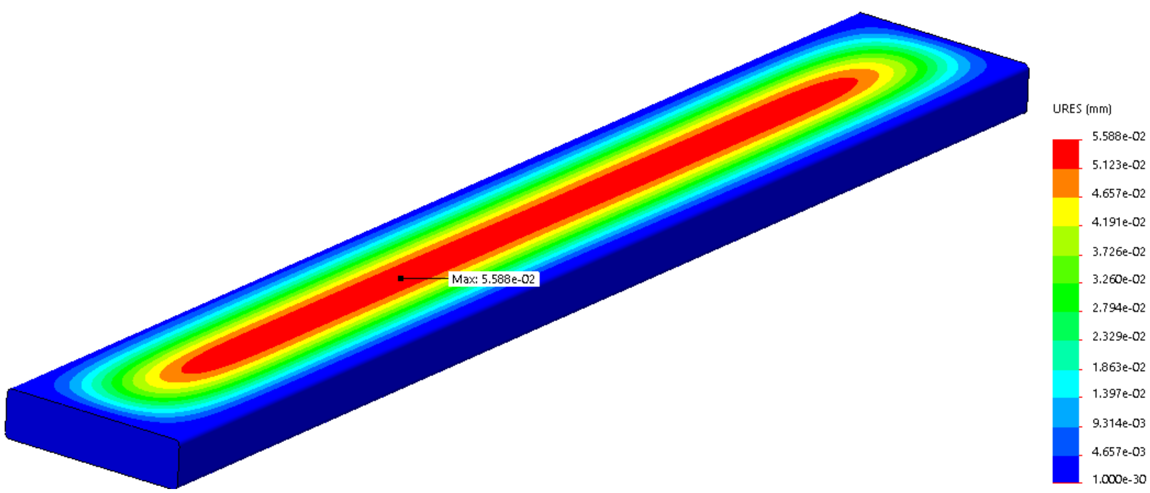

Figure A52. Displacement results of the arm base track spacer

Figure A53 shows the loading conditions of the arm base truss support. It should be noted that this is not the exact platform structure as shown in the detail design. Since the top of the truss support is a purchased part, which is the metal bar gratings, it is rather difficult to apply proper loads. Therefore, it is simplified to a rectangular block with the same thickness, 1 inch. This simulated model should yield very close results comparing to the exact structure.

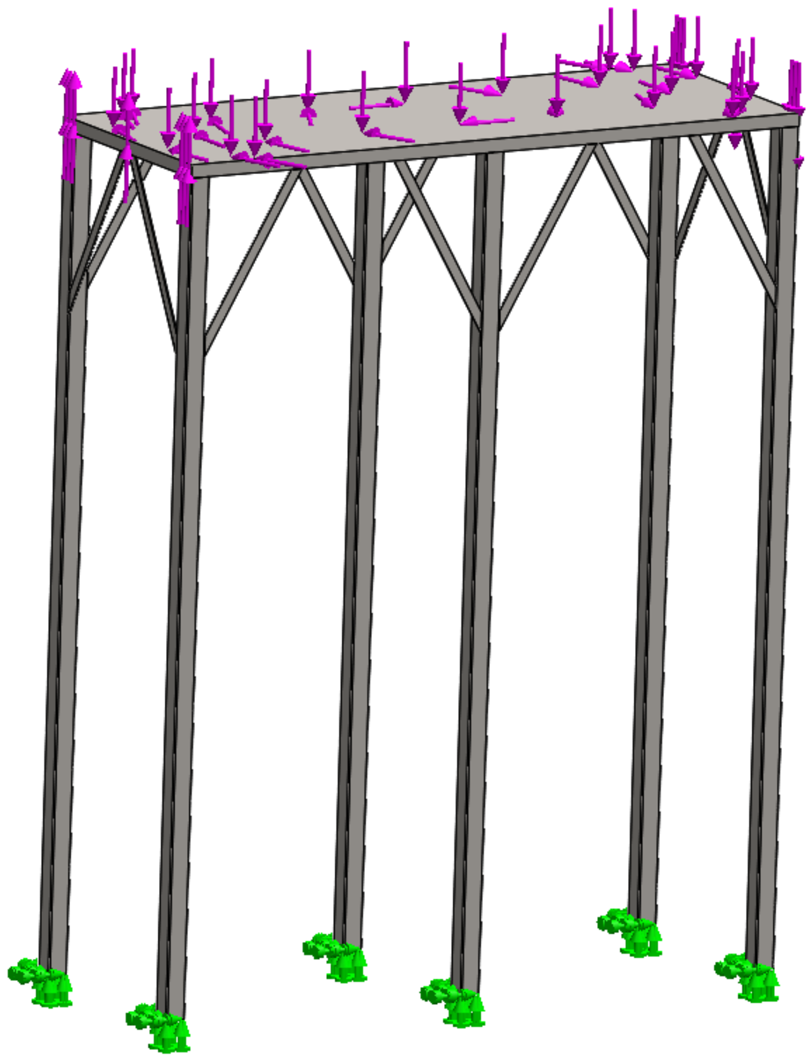

Figure A53. Loading conditions of the simulated arm base truss support

Figure A54 shows the stress distribution of the truss support structure from SolidWorks FEA.

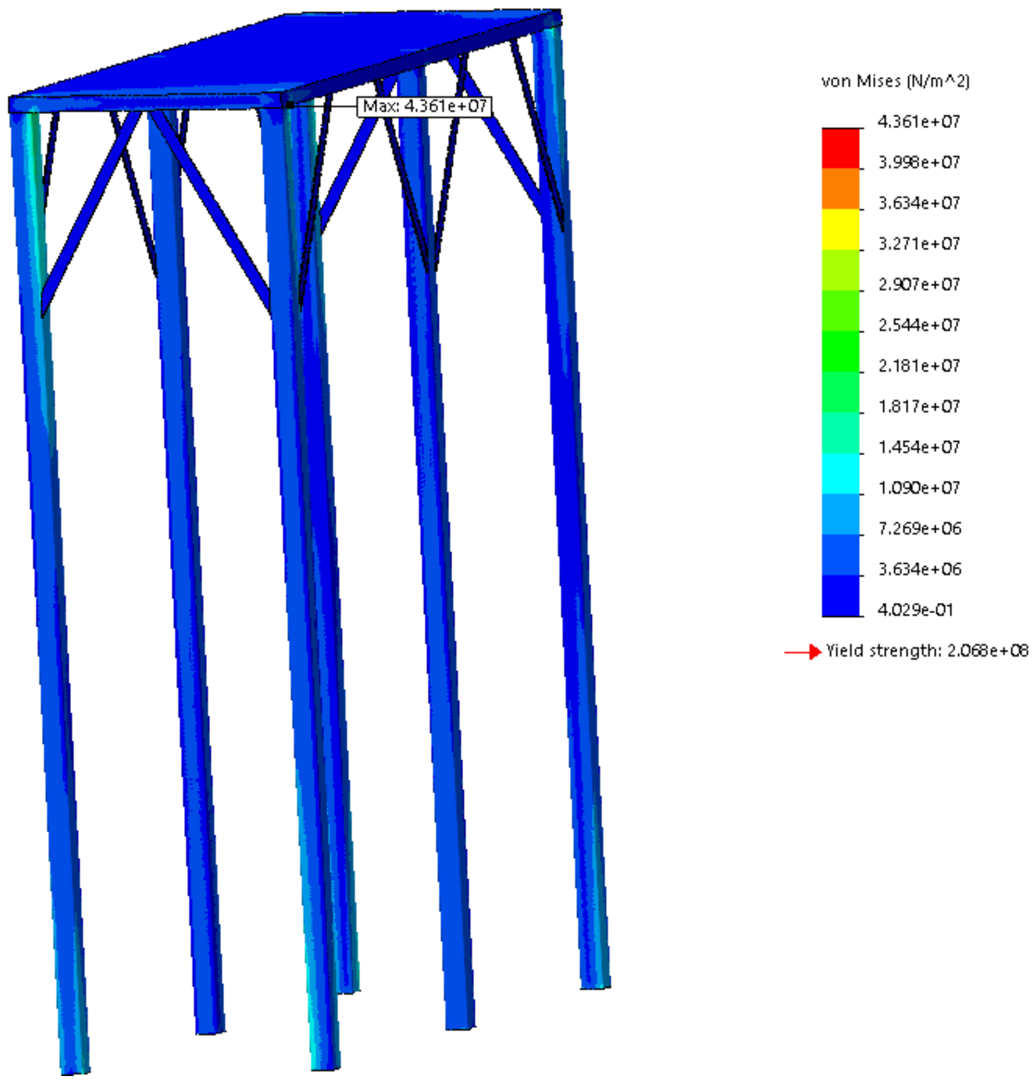

Figure A54. Stress results of the simulated arm base truss support

Figure A55 gives a detailed view of the maximum stress location of the arm base truss support structure.

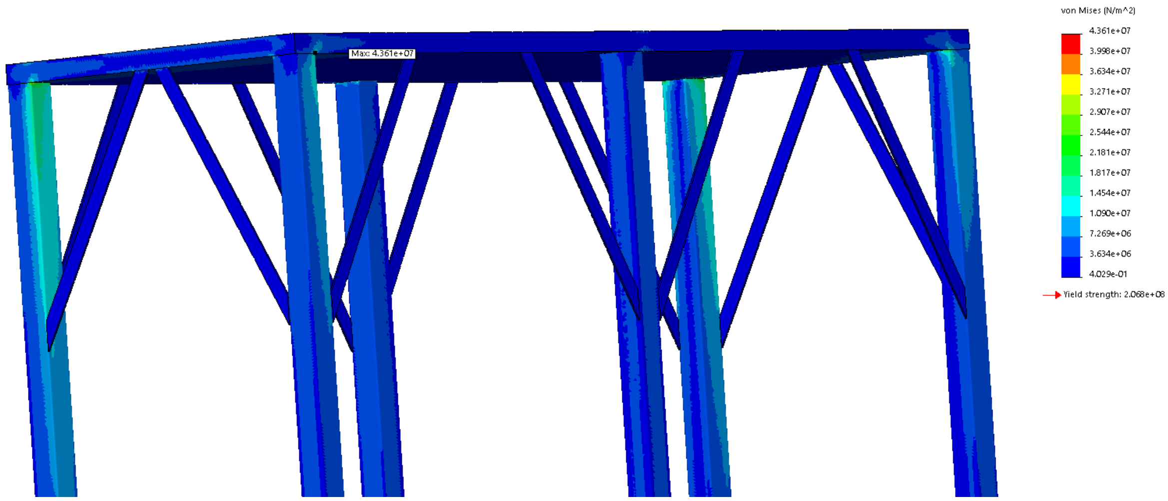

Figure A55. Close-up view of the stress results for the simulated arm base truss support

Figure A56 shows the displacement distribution of the arm base support structure.

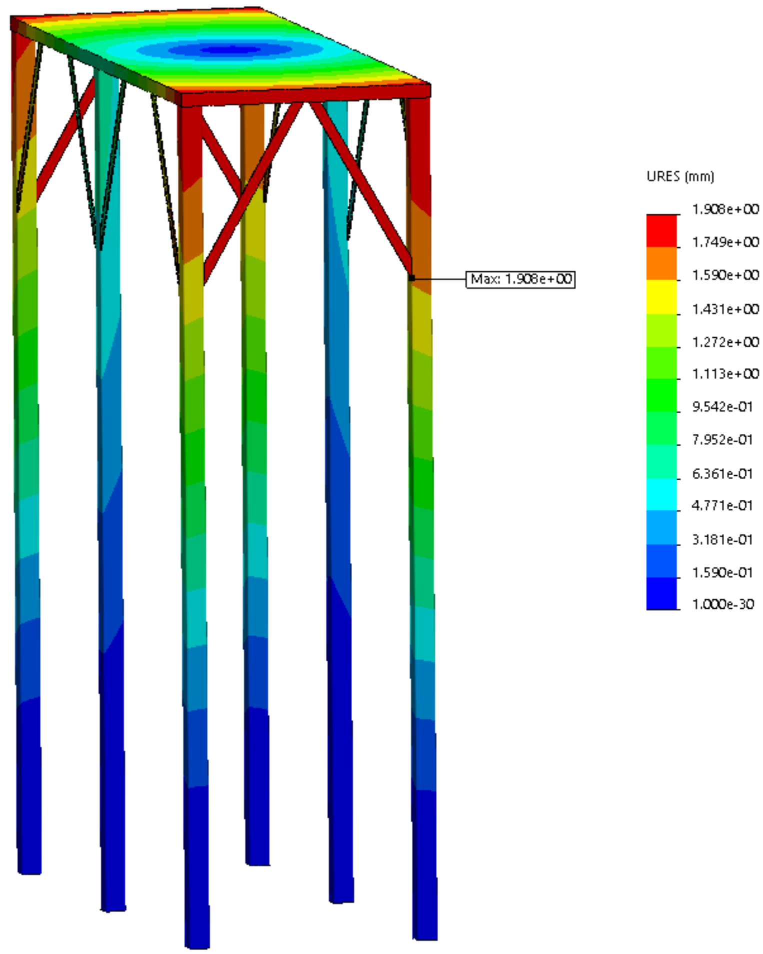

Figure A56. Displacement results of the simulated arm base truss support

Figure A57 shows the displacement distribution of the simulated arm base truss support structure.

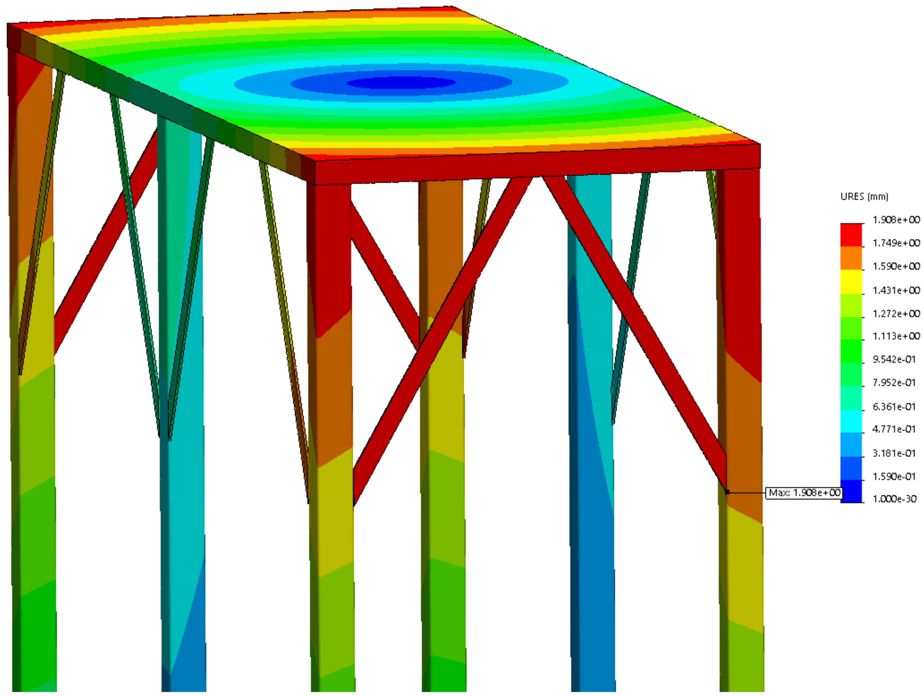

Figure A57. Close-up view of the displacement results for the simulated arm base truss support

Identification Station Housing FEA

TABLE AXII shows the summary of FEA results for the identification station housing.

TABLE AXII
FEA RESULTS SUMMARY FOR THE IDENTIFICATION STATION

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Identification Station Housing	69N	1.23E+06	139.8	0.01	4 points Jacobian	2.54	1307359

Figure A58 shows the stress distribution of the identification station housing from SolidWorks FEA. The loads exerted on the housing are from the camera, the linear lead screw track, and additional weights, such as fasteners. Specifically, the total load is estimated at 7 kg.

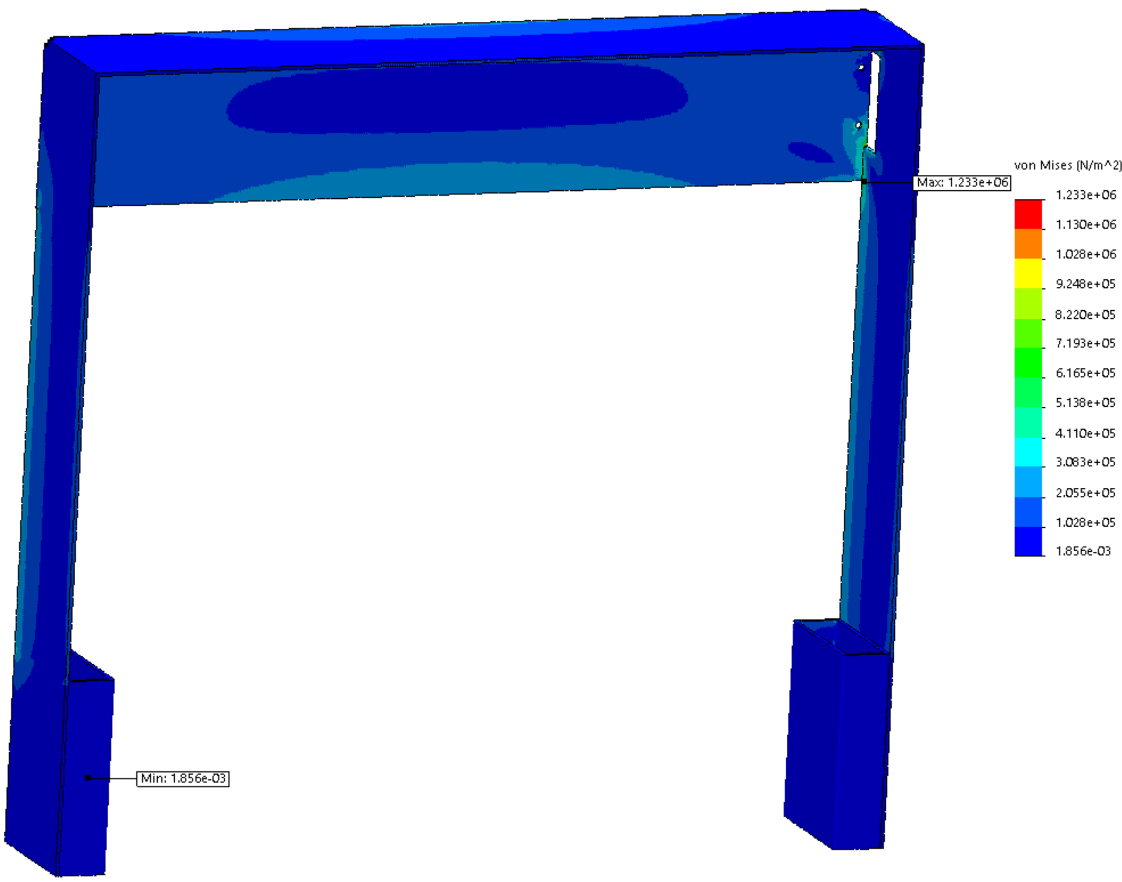

Figure A58. Stress results of the identification station housing

Figure A59 shows the displacement distribution of the identification station housing.

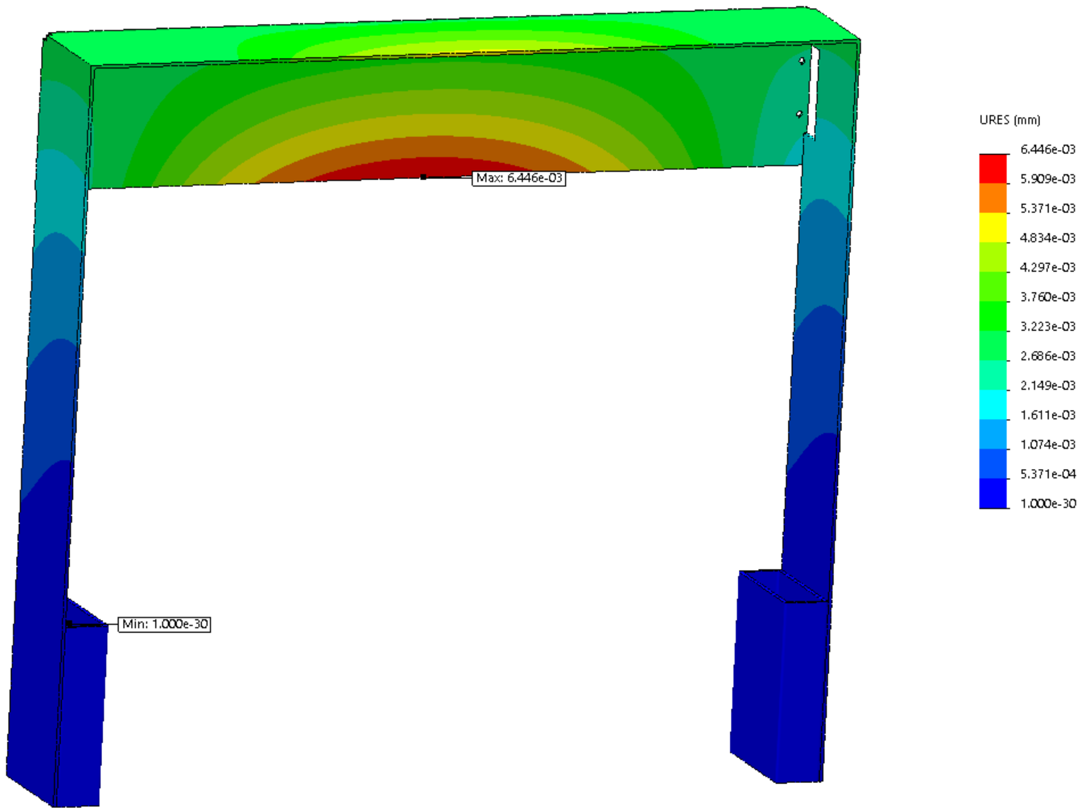

Figure A59. Displacement results of the identification station housing

Removable Fiberglass Bar Grating Supports FEA

TABLE AXIII shows the summary of FEA results for the removable fiberglass bar grating supports.

TABLE AXIII
FEA RESULTS SUMMARY FOR THE REMOVABLE FIBERGLASS BAR GRATING SUPPORTS

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
304 SS	Removable Grating Support A	3214.4N	1.90E+08	1.1	2.40	4 points Jacobian	4.06	54589
304 SS	Removable Grating Support B	3214.4N	1.15E+08	1.8	0.44	4 points Jacobian	3.08	61027
304 SS	Removable Grating Support C	3214.4N	9.08E+07	2.3	0.22	4 points Jacobian	2.70	59054
304 SS	Removable Grating Support D	3214.4N	1.55E+08	1.3	1.34	4 points Jacobian	3.69	57005

Figure A60 shows the loading conditions of the removable fiberglass bar grating support. The fixtures are preliminarily located at the ends. However, the fixture locations are subject to change as they can be welded to any adjacent frame at any location. Additionally, the assumption is that each support will be taken a load of 4 person with a weight of 180 lbs per person. The team exaggerated the loads to cover some possible extreme-loading conditions.

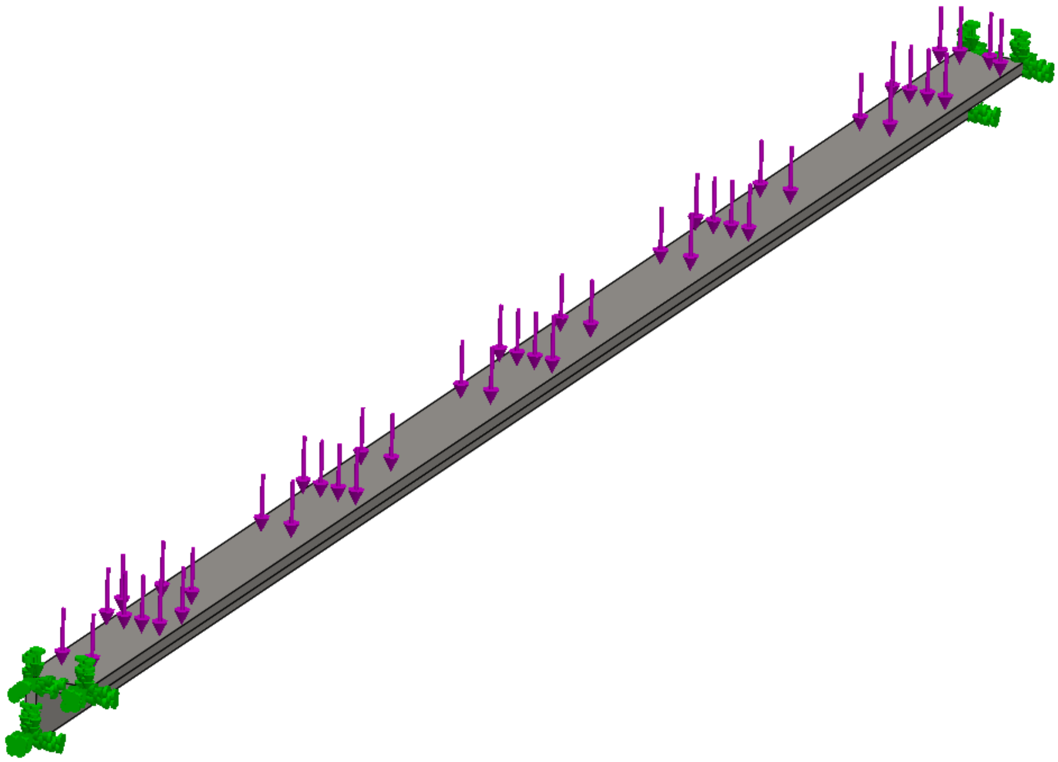

Figure A60. Loading conditions of the removable fiberglass bar grating support

Figure A61 shows the stress distribution of the removable fiberglass bar grating support A.

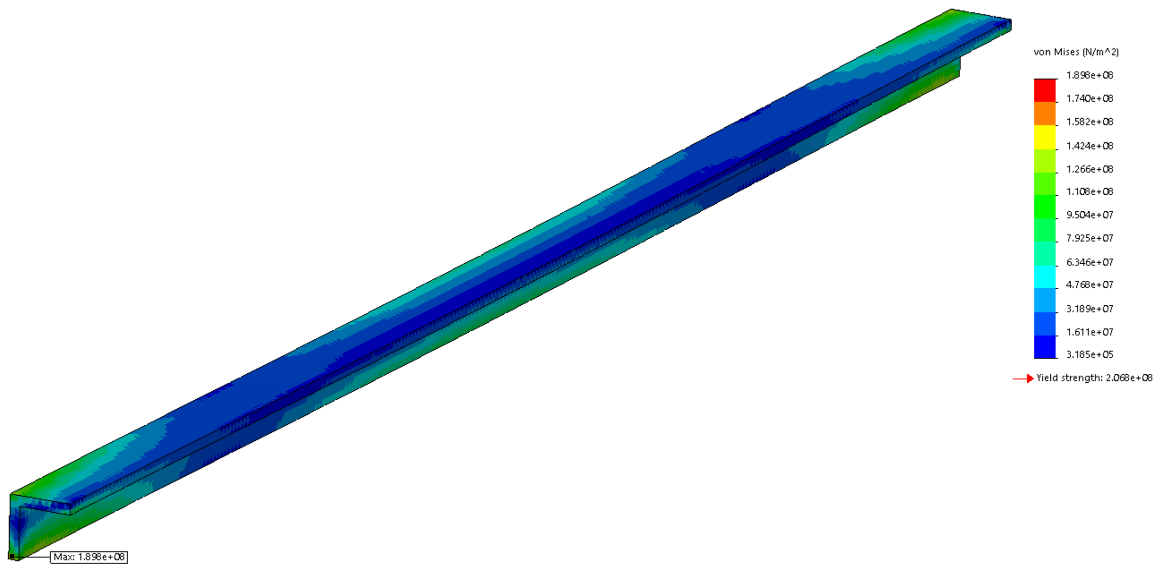

Figure A61. Stress results of the removable fiberglass bar grating support A

Figure A62 gives a detailed view of the maximum stress location on the removable fiberglass bar grating support A. Even though this only gives a safety factor of 1.1, this is from a rather extreme case of loads, and the maximum stress location is at a sharp edge, which can have stress concentration. This can be mitigated by the addition of a gentle fillet or a thicker wall.

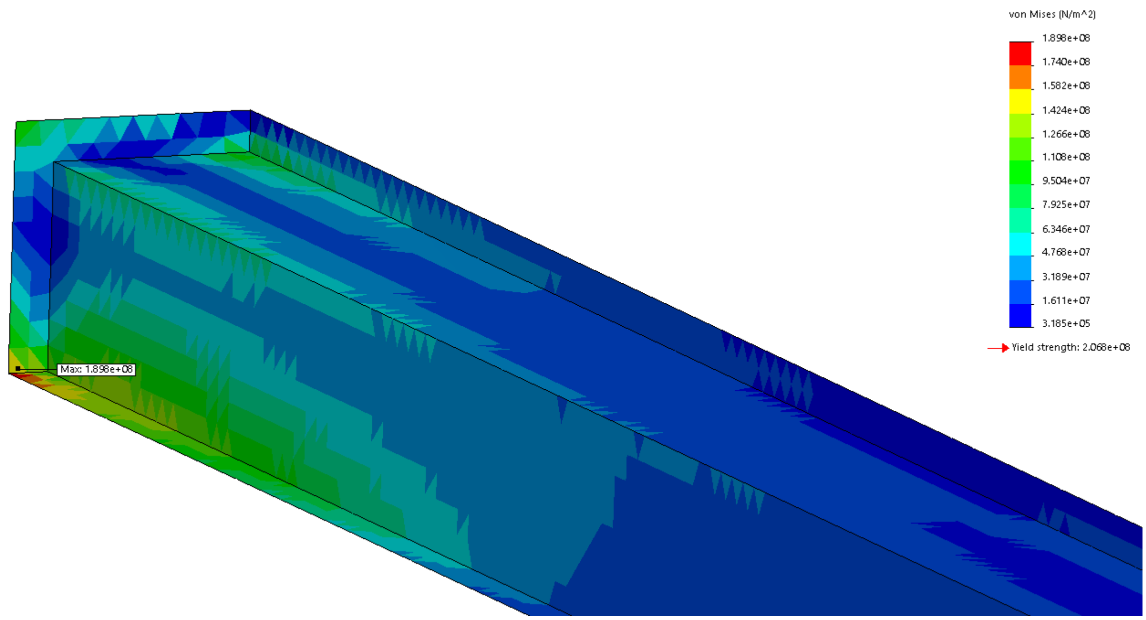

Figure A62. Close-up view of the stress results for the removable fiberglass bar grating support A

Figure A63 gives the displacement distribution of the removable fiberglass bar grating support A. At such extreme loading case, this bar only displaces about 2.4 [mm], which is acceptable.

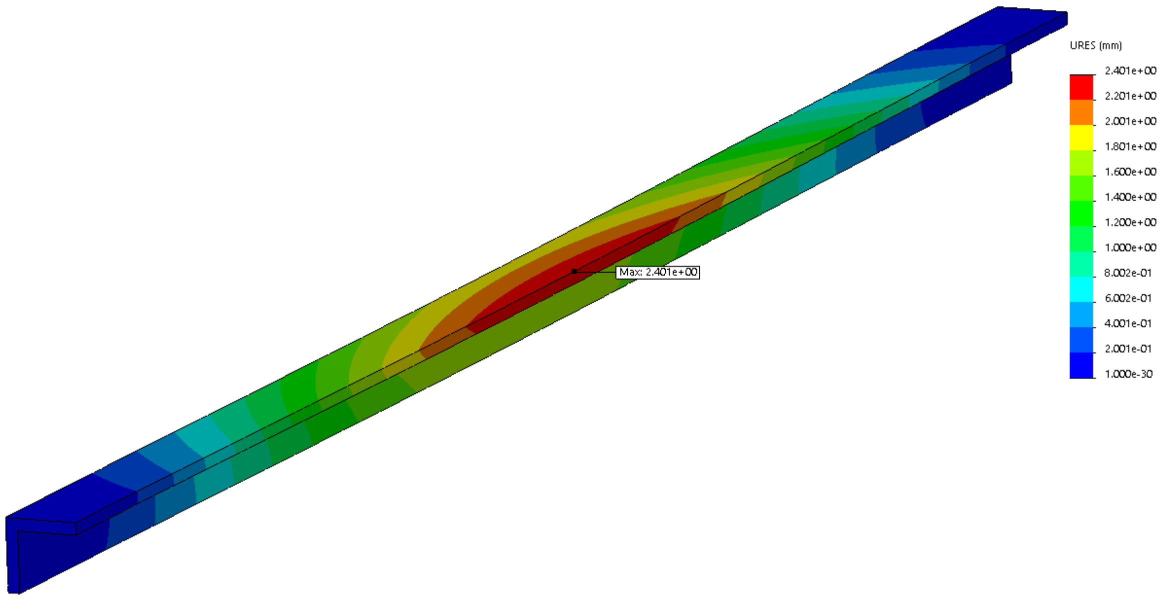

Figure A63. Displacement results of the removable fiberglass bar grating support A

Figure A64 gives a detailed view of the removable fiberglass bar grating support A's maximum displacement location.

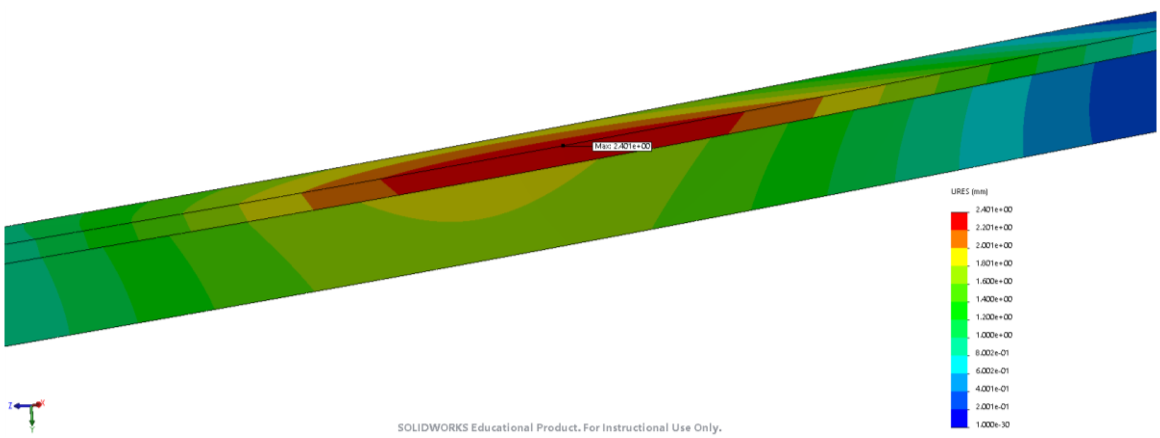

Figure A64. Close-up view of the displacement results for the removable fiberglass bar grating support A

Figure A65 shows the stress distribution of the removable fiberglass bar grating support B.

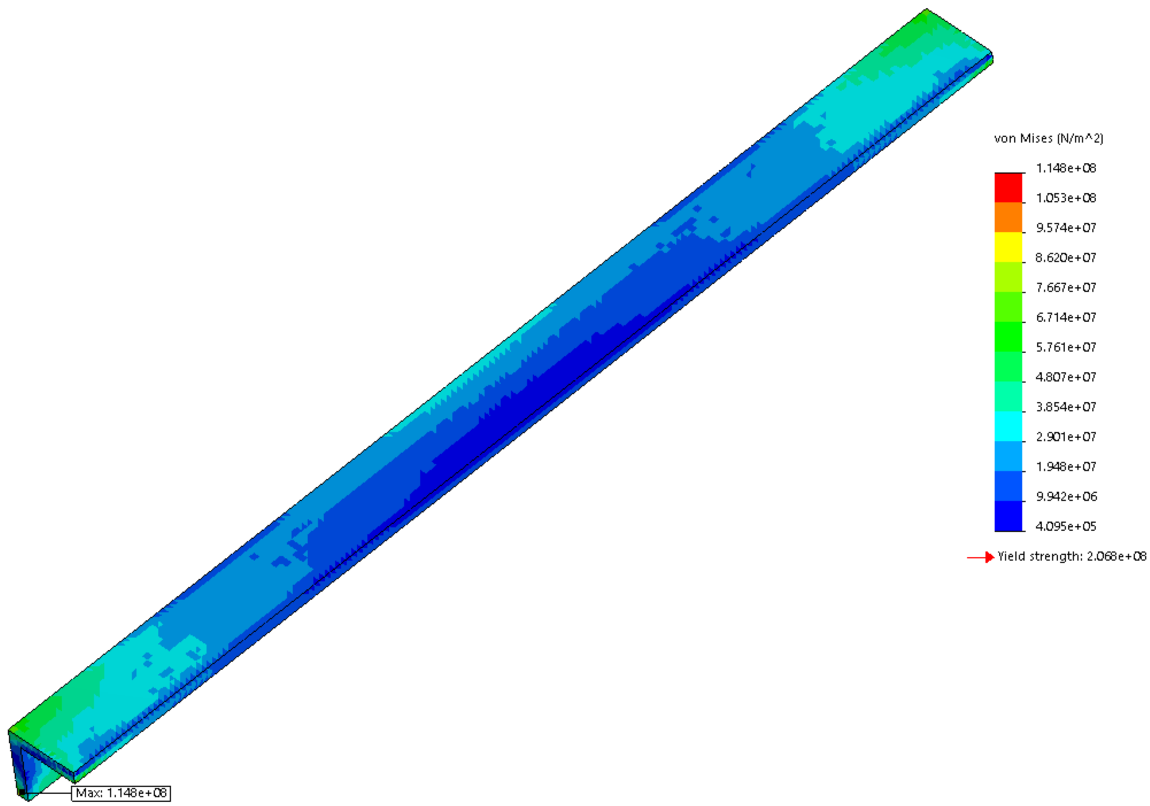

Figure A65. Stress results of the removable fiberglass bar grating support B

Figure A66 gives a detailed view of the maximum stress location on the removable fiberglass bar grating support B.

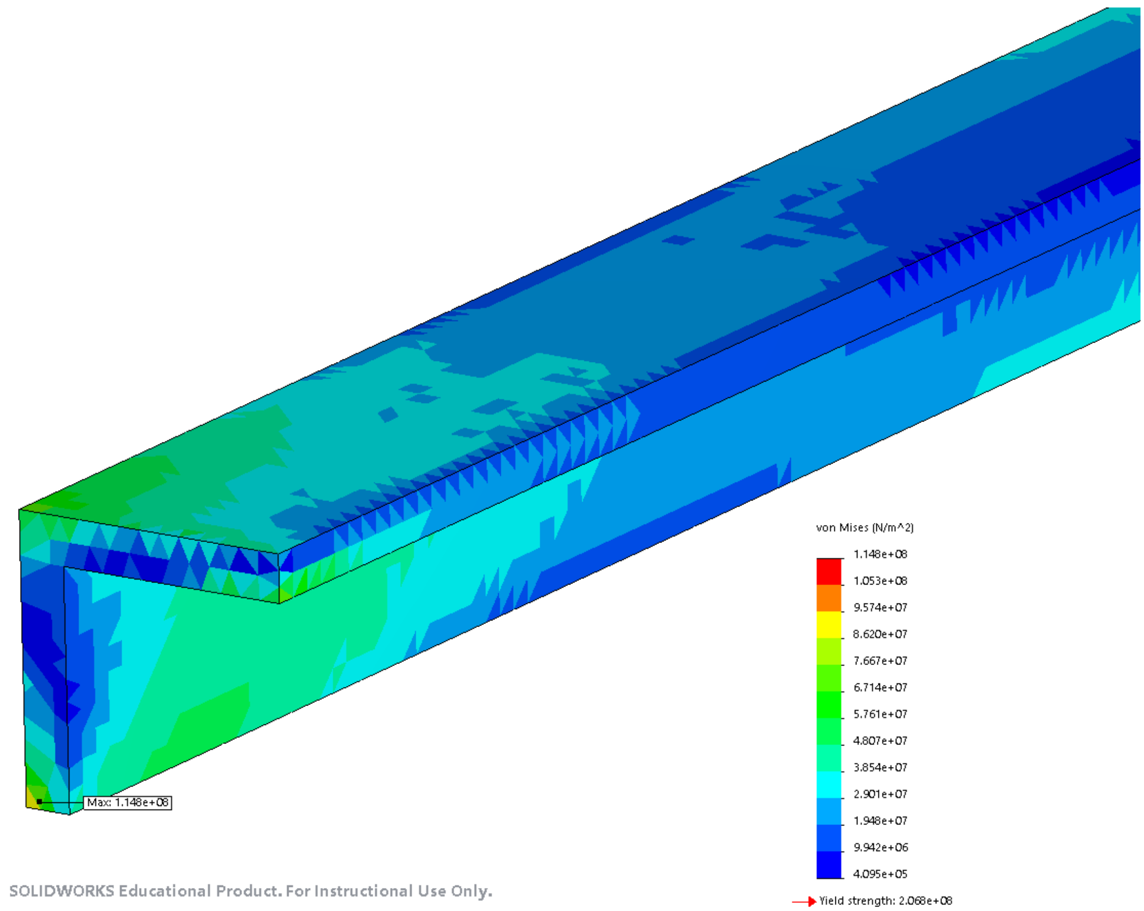

Figure A66. Close-up view of stress results for the removable fiberglass bar grating support B

Figure A67 shows the displacement distribution of the removable fiberglass bar grating support B.

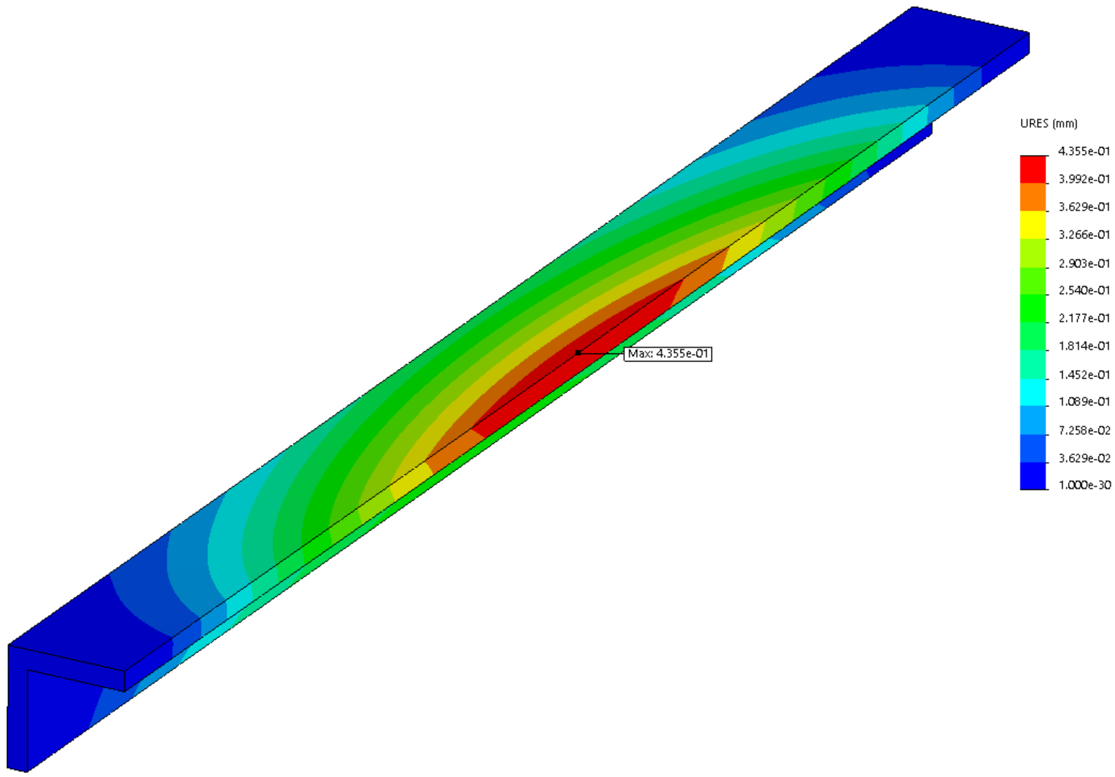

Figure A67. Displacement results of the removable fiberglass bar grating support B

Figure A68 shows the stress distribution of the removable fiberglass bar grating support C from SolidWorks FEA.

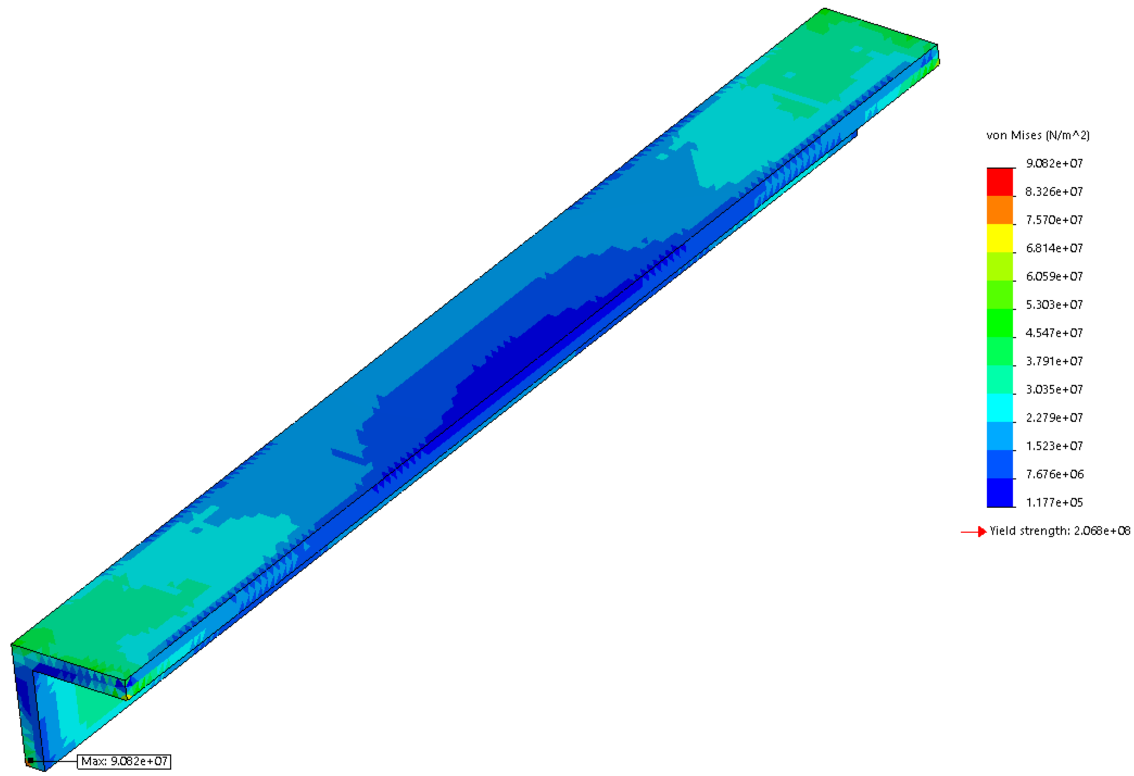

Figure A68. Stress results of the removable fiberglass bar grating support C

Figure A69 gives a detailed view of maximum stress location on the removable fiberglass bar grating support C.

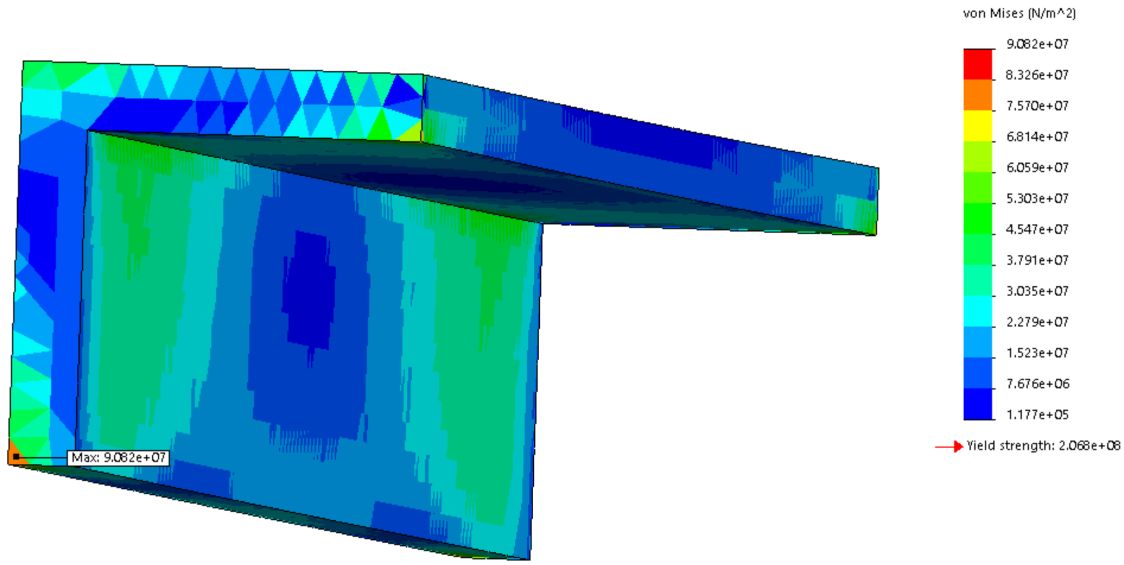

Figure A69. Close-up view of the stress results for the removable fiberglass bar grating support C

Figure A70 shows the displacement distribution of the removable fiberglass bar grating support C.

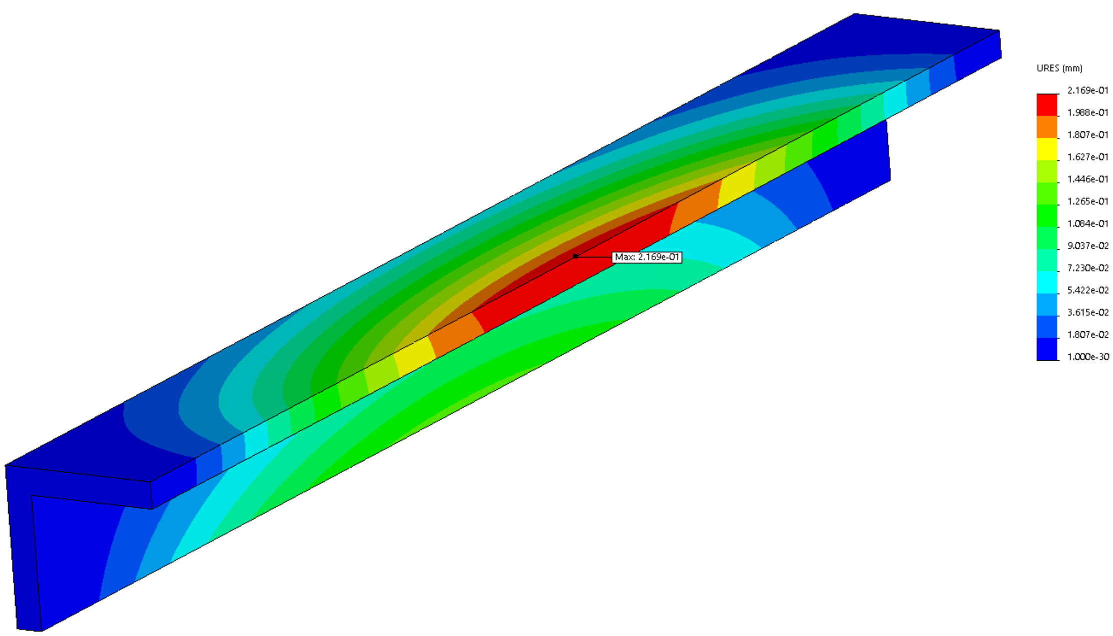

Figure A70. Displacement results of the removable fiberglass bar grating support C

Figure A71 shows the stress distribution of the removable fiberglass bar grating support D. The resulted safety factor is 1.3. However, this is simulating a rather extreme loading case.

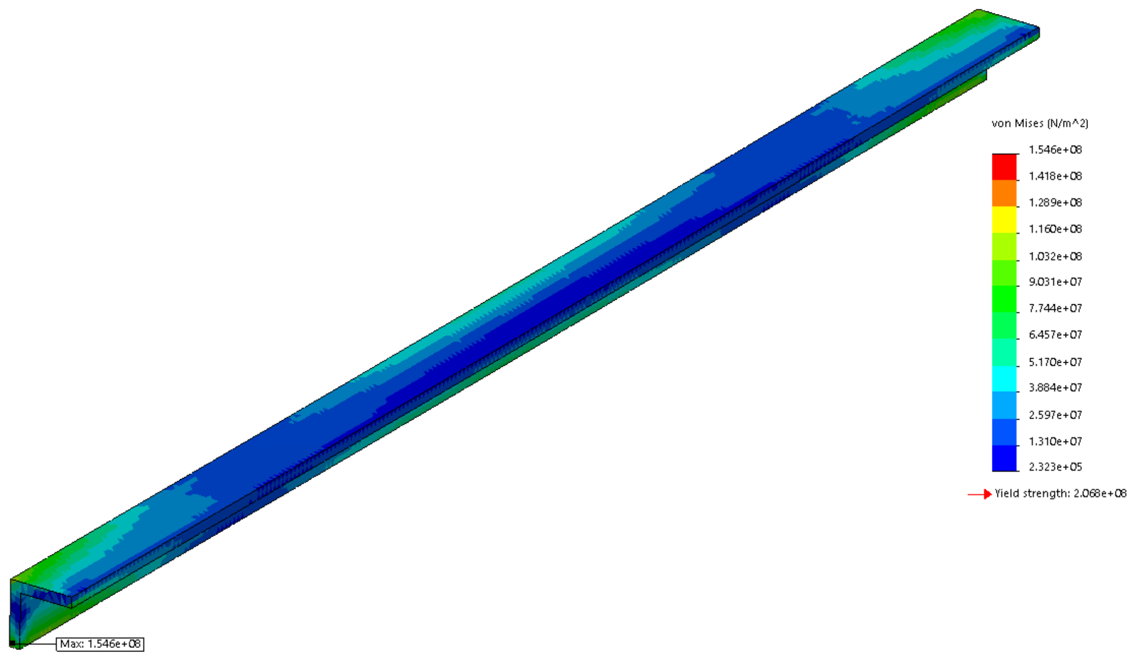

Figure A71. Stress results of the removable fiberglass bar grating support D

Figure A72 gives a detailed view of the maximum stress location. As the maximum stress occurs at a sharp edge, a fillet can mitigate the stress concentration at such location.

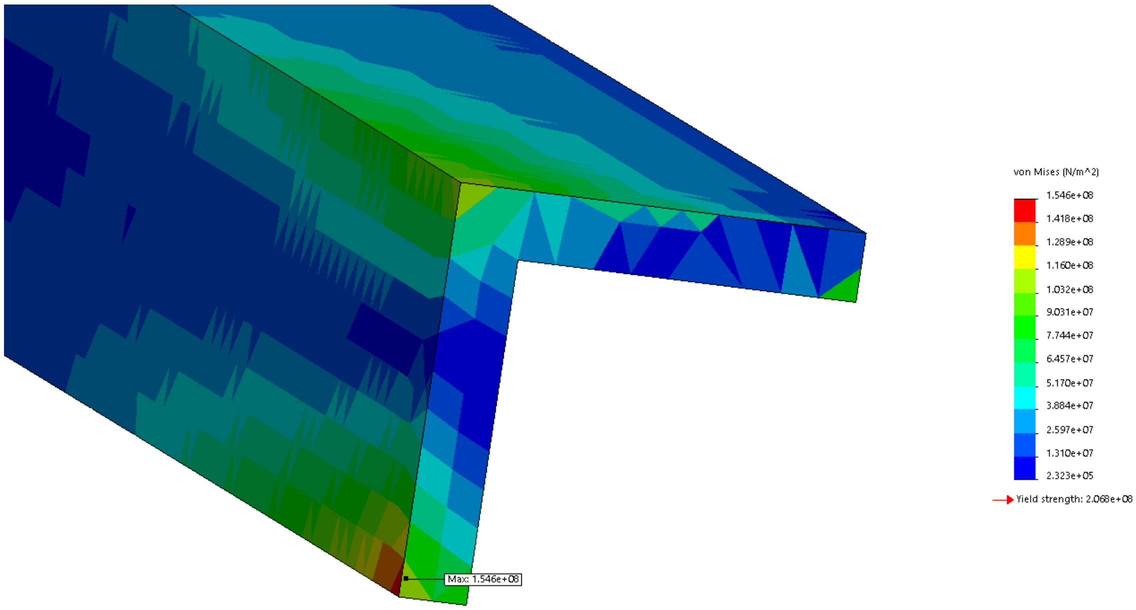

Figure A72. Close-up view of the stress results for the removable fiberglass bar grating support D

Figure A73 shows the displacement distribution of the removable fiberglass bar grating support D.

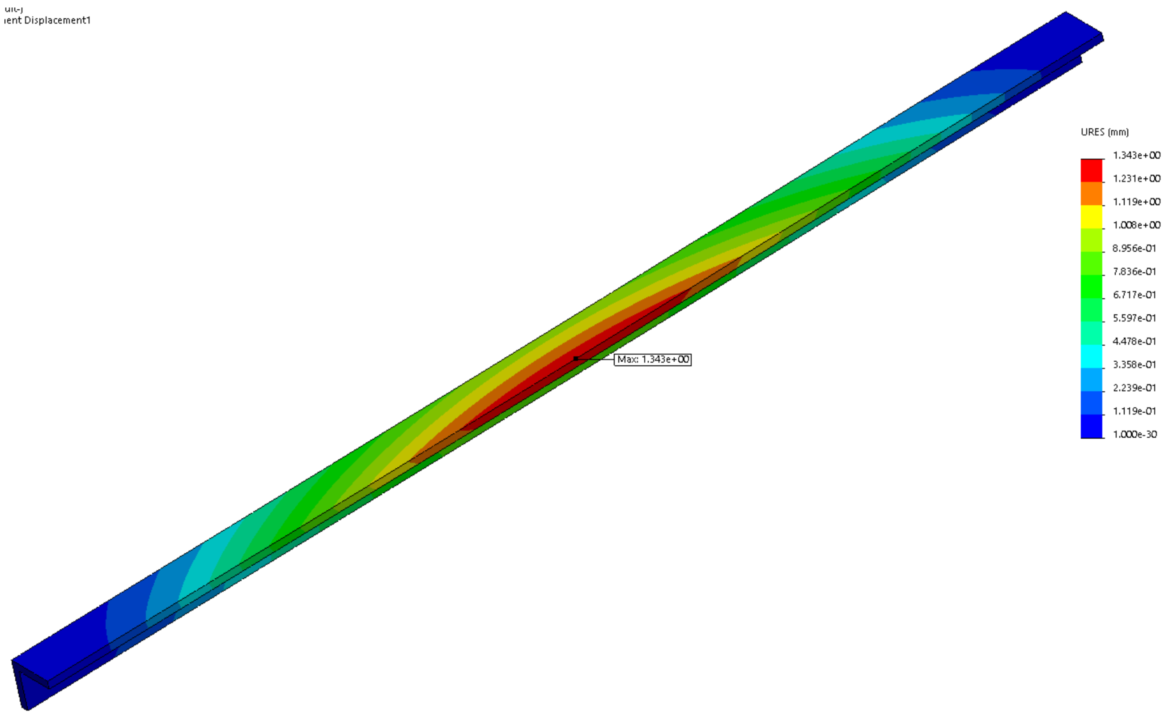

Figure A73. Displacement results of the removable fiberglass bar grating support D

Abscess Table Support Leg FEA

TABLE AXIV shows the summary of FEA results for the abscess table support leg.

TABLE AXIV
FEA RESULTS SUMMARY FOR THE ABSCESS TABLE SUPPORT LEG

Material	Component	Forces	Peak Stress (Pa)	Factor of Safety	Max Displacement (mm)	Elements		
						Type	Size (mm)	Qty
316 SS	Abscess Table Support Leg	230N	2.66E+06	64.7	0.01	4 points Jacobian	3.34	30472

Figure A74 shows the loading conditions of the abscess table's support leg. The loading condition is estimated at 3 middles with total mass of 31 [kg] each middle. The weight from the middles is evenly distributed to the 4 legs that are support the abscess table. Therefore, each leg is taking 230 [N] pressing force.

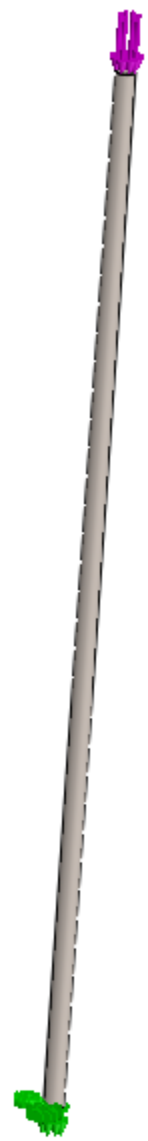

Figure A74. Loading conditions of the abscess table support leg

Figure A75 shows the stress distribution of the abscess table's support leg.

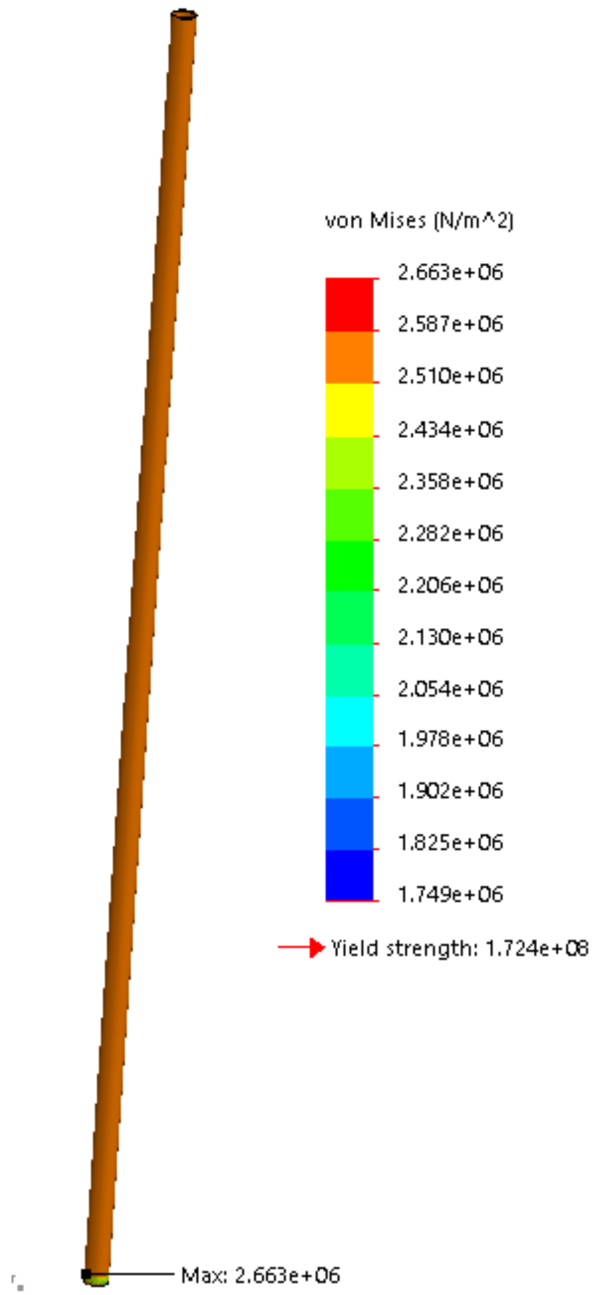

Figure A75. Stress results of the abscess table support leg

Figure A76 gives a detailed view of the maximum stress location on the abscess table's support leg.

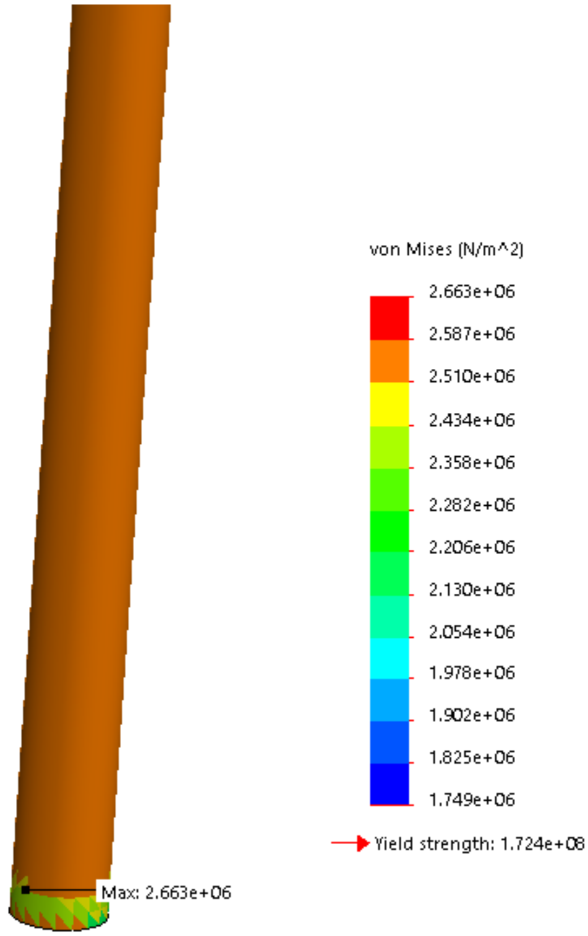

Figure A76. Close-up view of the stress results for the abscess table support leg

Figure A77 shows the displacement distribution of the abscess table's support leg.

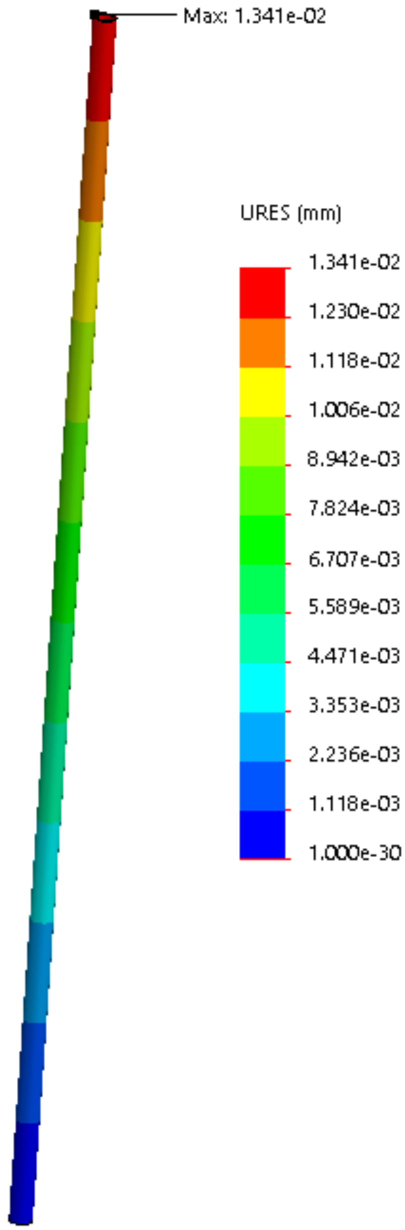

Figure A77. Displacement results of the abscess table support leg

Figure A78 gives a detailed view of the maximum displacement location on the abscess table's support leg.

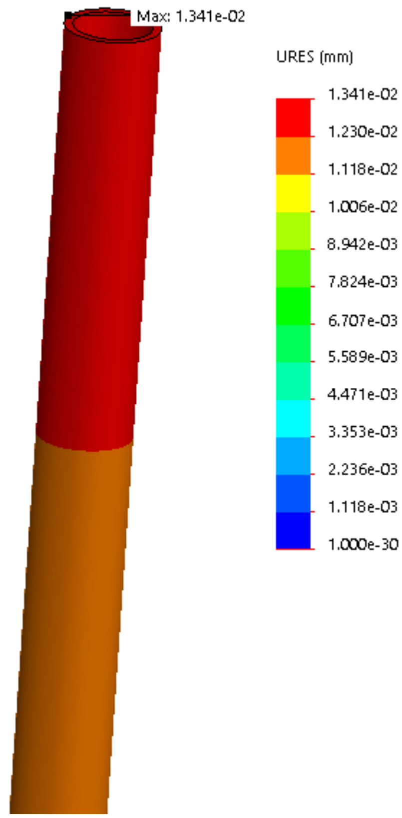

Figure A78. Close-up view of the displacement results for the abscess table support leg

Appendix B – Preliminary Cost Analysis

This section provides a rather detailed cost breakdown on the total cost of the automated feeder. These detailed costs are categorized by their respective sections, such as the arm base and the main arm.

TABLE BI shows the estimates, provided by HyLife, that the team used to conclude a total cost of the automated feeder.

TABLE BI
COST ESTIMATES MADE TO DETERMINE TOTAL COST

Category	Unit Price (CAD)
Stainless Steel	\$9 per pound
HDPE	\$0.8 per pound
Fabrication	\$75 per hour @ 200 hours minimum

TABLE BII shows the detailed cost breakdown of the arm base.

TABLE BII
ARM BASE DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Track Motor	MPF-A430P-SJ74BA	Allen Bradly	2897	1	2897
Track Part A	Y-R131CO15651AC	Ringball	8508	1	8508
Track Part B	Y-9EPLH084010H	Ringball	1730	1	1730
Track Mount Brackets	1001061 Fixing Bracket	Ringball	25	10	251
Rotary Table	ADR360-A215-S/P-J/K-3.0-AB-7500-64X-P40	Akribis	14366	1	14366
Metal Grating	G43161 (3ft x 6ft)	Metal Depot	1488	1	1488
Raw Metal Stock			9	794 lbs	7150
HDPE			0.79	5 lbs	4

TABLE BIII shows the detailed cost breakdown of the main arm.

TABLE BIII
MAIN ARM DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Track	MG10S25LXUF1-00400-00796XN000S1	Thomson Linear Motion Systems	4980	1	4980
Track Mount	D312-334	Thomson Linear Motion Systems	21	6	127
Track Motor Coupler	XTA070-003-0 (RM060-XXX)	Thomson Linear Motion Systems	2000	1	2000
Horizontal Arm Rotary Motor Gear Box	AQT120-020 (MMR-691 Motor Mount ID)	Thomson Linear Motion Systems	6298	1	6298
Horizontal Arm Rotary Motor	MPS-A4540F-MJ54DA	Allen Bradley	2668	1	2668
Linear Track Motor	MPF-A330P-MJ74BA	Allen Bradley	3821	1	3821
Cable Hose	5608K74	McMaster - CARR	177	1	177
Cable Hose Mounts	5608K521	McMaster - CARR	40	1	40
Raw Metal Stock			9	124 lbs	1112

TABLE BIV shows the detailed cost breakdown of the horizontal arm.

TABLE BIV
HORIZONTAL ARM DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Track Motor	MPF-B330P-MJ74BA	Allen Bradley	3763	2	7525
Linear Track	WH08ZSXXXX-00635-01185VN0000S1	Thomson Linear Motion Systems	3823	2	7645
Track Motor Gear Box	DTR90-005-0 (RM090-39)	Thomson Linear Motion Systems	2000	2	4000
Track Mount Clamps	890 190 02	Thomson Linear Motion Systems	20	8	160
Shaft Clamp Mount	9624T24	McMaster - CARR	9	71	637
Cable Hose	5608K76	McMaster - CARR	151	1	151
Cable Hose Mounts	5608K75	McMaster - CARR	159	2	318
Raw Metal Stock			80	1 lb	80

TABLE BV shows the detailed cost breakdown of the end effector.

TABLE BV
END EFFECTOR DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Box Rotation Motor	MPS-A330P-MJ52DA	Allen Bradley	4869	2	9739
10:1 Gear Box	AGT080-010-005-0-MMR	Thompson	2257	2	4514
Pneumatic	F17080DN	Automation Direct	120	2	240
Load taken Bearing	NTN 6007	Motion Canada	40	2	80
Bushing Seals	BW-005625	Kepco Seals	20	4	81
Seals	35X62X8 HMSA10 RG	Motion Canada	11	1	11
Retaining Ring	DHO-64	Huyett	1	1	1
Pneumatic on box's top	ERD10 SN02 SM150 LMI IP69K SS21 AMS1B1E1	Tolomatic	2360	4	9440
Raw Metal Stock			9	106 lbs	950
HDPE			0.79	5 lbs	4

TABLE BVI shows the detailed cost breakdown of the identification station.

TABLE BVI
IDENTIFICATION STATION DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Vision Camera	VS XF205M03I10EP	Baumer	7855	1	7855
Camera Track	SLW-ESA180-1040-750-HK-PA-HR	igus	1466	1	1466
Raw Metal Stock			9	48 lbs	436

TABLE BVII shows the detailed cost breakdown of the vertical sequencing gates.

TABLE BVII
VERTICAL SEQUENCING GATES DETAILED COSTS

Item	Part Number	Vendor	Unit Cost (CAD)	Quantity	Total Cost (CAD)
Pneumatics	SSFO-029-8W	Bimba	285	2	569
9/16" Rod Eye	RP-1/2	Bimba	18	2	36
Middle Presence Sensor	E3FB-DN12-2M	Omron	84	2	168
Raw Metal Stock			9	57 lbs	509
HDPE			0.79	5 lbs	4

Appendix C – Purchased Part Specifications

The following appendix includes all relevant purchased part catalogue pages and specification sheets. These documents add additional information for the implementation process as required.

The team divided them into five main categories based on the nature of their functions in the automated feeder design. These five categories are the actuators, the electronics, the motors, the motorized linear tracks, the manual linear tracks, and the structural parts. The content guide for Appendix C is shown in the following, which also provides the number of pages that one expected to see in each category.

Category	Number of Pages Contained
Actuators	57
Electronics	17
Motors	48
Motorized Linear Tracks	10
Manual Linear Tracks	4
Structural Parts	2

The category, **Actuators**, contains Bimba Pneumatic Cylinders [1], Tolomatic ERD Actuators [2], Nitra Penuatic Cylinder [3], and Akribis Rotary Table [4].

The category, **Electronics**, contains Omron Photoelectric Sensor [5] and Baumer Vision Camera [6].

The category, **Motors**, contains Planetary Gearheads [7] and Rockwell Motors [8].

The category, **Motorized Linear Tracks**, contains ROBOT 130P [9], Thomson Linear Tracks [10].

The category, **Manual Linear Tracks**, contains igus linear track for the vision camera [11].

The category, **Structural Parts**, contains the effector bearing [12] and the base support metal bar grating [13].

References – Appendix C

[1] Bimba, "Stainless Steel Flat-I," [Online]. Available: https://www.bimba.com/sites/default/files/Documents/ss-flat-catalog-1.pdf. [Accessed 5 December 2018].

[2] Tolomatic, "ERD-SS2 Stainless Steel Electric Actuators with Integrated Motor," Tolomatic, [Online]. Available: https://www.tolomatic.com/products/product-details/erd-ss2-stainless-steel-electric-actuators-with-protective-motor-enclosure/resources. [Accessed 5 December 2018].

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[10] Thomson, "Linear Motion Systems," [Online]. Available: https://www.thomsonlinear.com/downloads/lms/Linear_Motion_Systems_cten.pdf#page=112. [Accessed 5 December 2018].

[11] igus, "drylin® SLW - the compact - stainless steel version," [Online]. Available: https://www.igus.com/info/lead-screw-units-slw-the-compact. [Accessed 5 December 2018].

[12] NTN, "Ball and Roller Bearings," [Online]. Available: http://www.ntnamericas.com/en/website/documents/brochures-and-literature/catalogs/a-1000.pdf. [Accessed 5 December 2018].

[13] MetalsDepot, "Stainless Steel Bar Grating," [Online]. Available: https://www.metalsdepot.com/assets/files/Page_Editor_Files/stainlessbargratingloadtables.pdf. [Accessed 5 December 2018].

Appendix C

Appendix D – Preliminary Manufacturing Drawings

The following appendix includes the drawing package of the automated feeder design including the preliminary manufacturing drawings of all assemblies, sub-assemblies, weldments, and components. It should be noted that the drawing package only includes the fabricated parts.

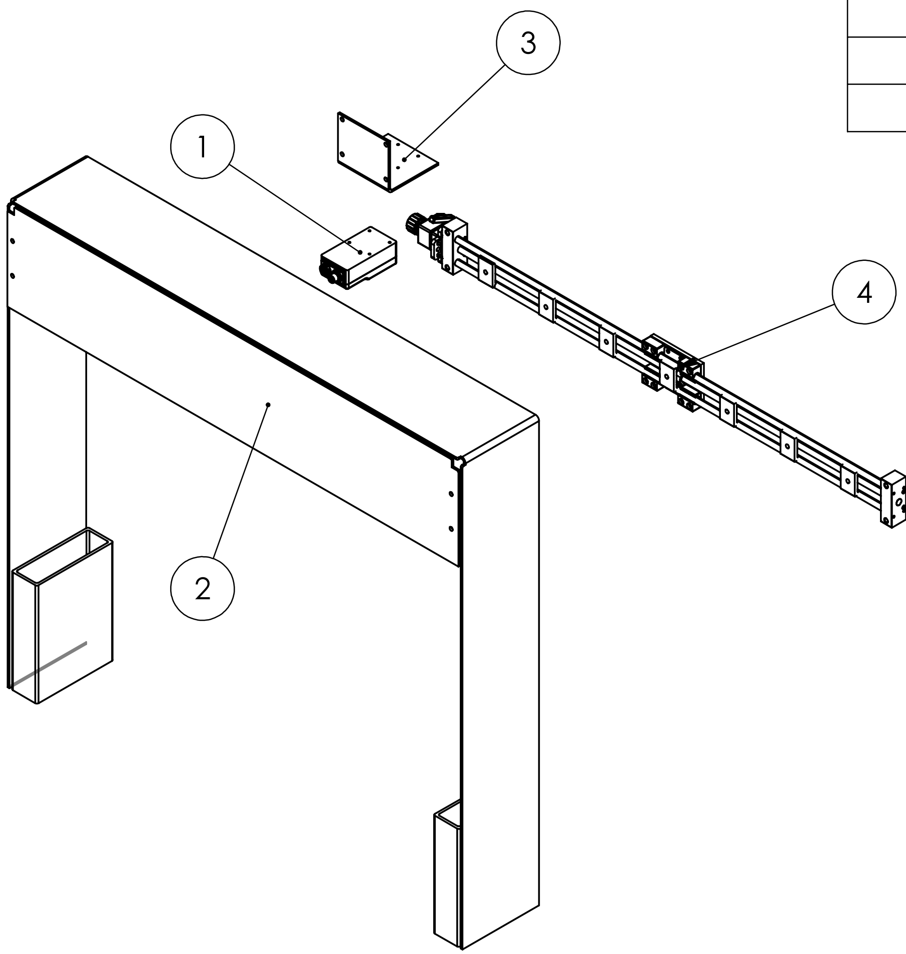
The team divided the drawings into seven systems based on their functions. These seven systems, in order, are the identification station, the vertical sequencing gates, the end effector, the horizontal arm, the main arm, the arm base, and the arm base support. The content guide for Appendix D is shown in the following, which also the number of pages that one expected to see in each system.

Automated Feeder Systems	Number of Pages Contained
Identification Station	8
Vertical Sequencing Gates	20
End Effector	31
Horizontal Arm	8
Main Arm	13
Arm Base	12
Arm Base Support	22

Preliminary Manufacturing Drawing Package
Identification Station

Appendix D

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	IDS-200-R00-KF	VISION CAMERA	1
2	IDS-800-R00-KF	IDENTIFICATION STATION HOUSING	1
3	IDS-801-R00-KF	VISION CAMERA MOUNT	1
4	IDS-201-R00-KF	CAMERA TRACK	1



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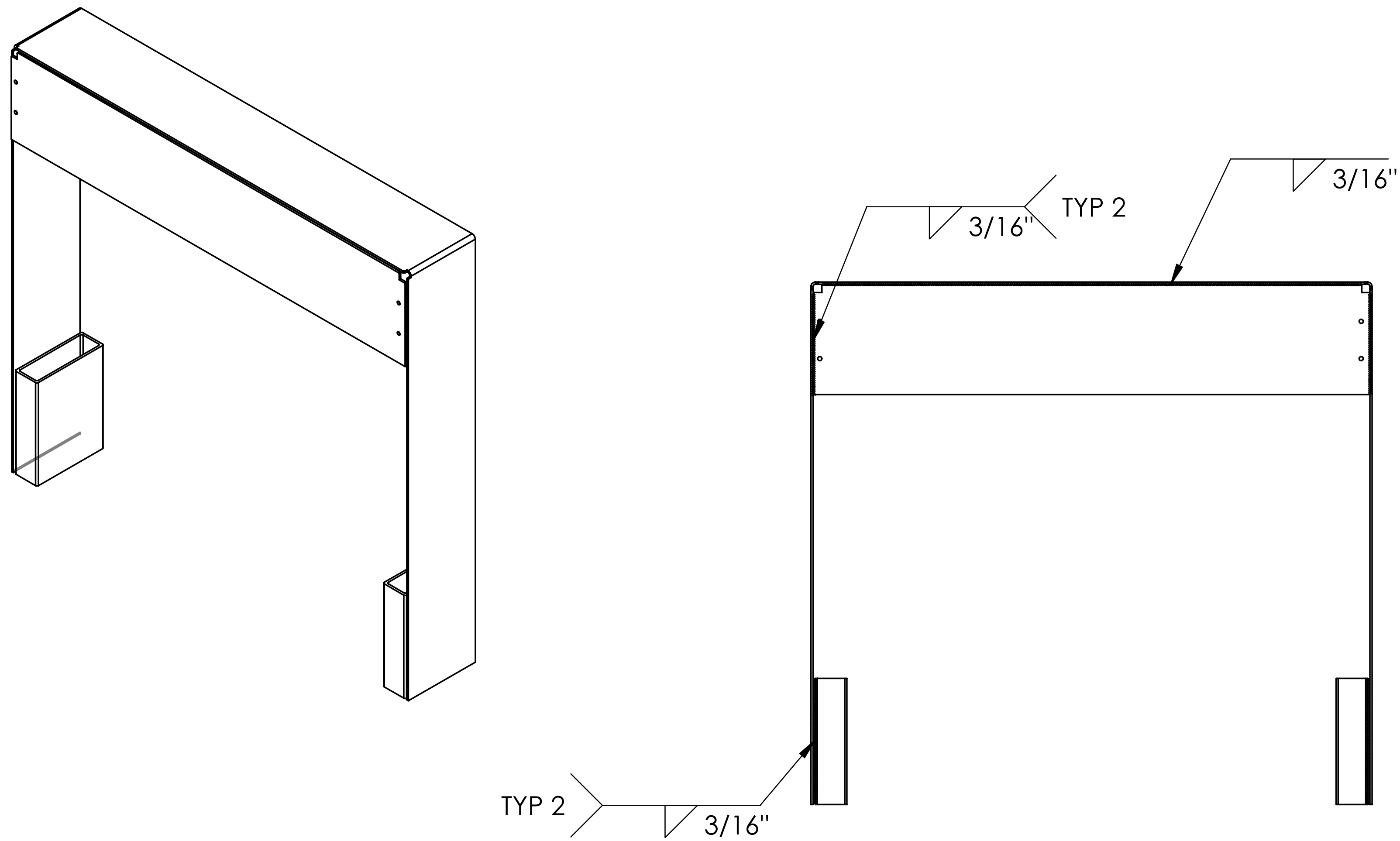
		DRAWN BY: K.F	DESCRIPTION: IDENTIFICATION STATION
		CHECKED BY: --	SHEET 1 OF 8 DO NOT SCALE DRAWING
			WEIGHT:
			IDS-700



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MATERIAL: SEE BOM
FINISH: AS SHOWN

SIZE A4

FIRST ISSUED:	11/28/2018
DRAWN BY:	K.F
CHECKED BY:	--

UNIVERSITY OF MANITOBA HYLIFE FOODS

USED WITH: IDENTIFICATION STATION

DESCRIPTION: IDENTIFICATION STATION HOUSING

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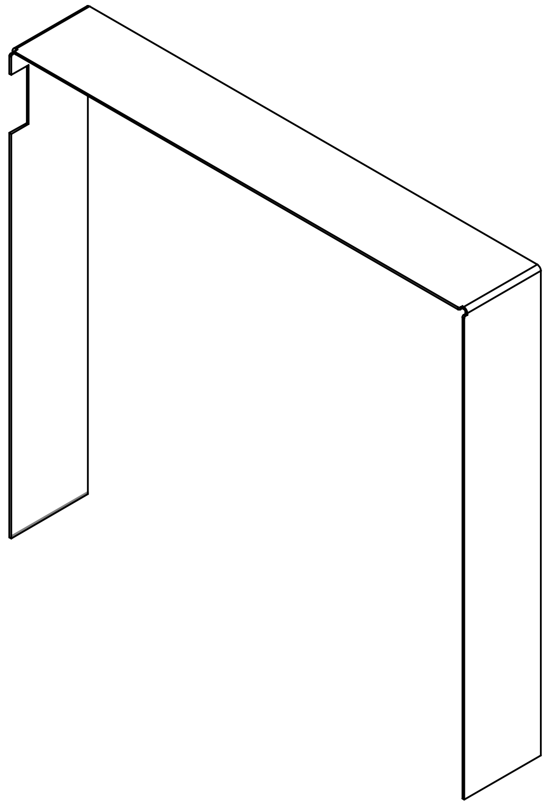
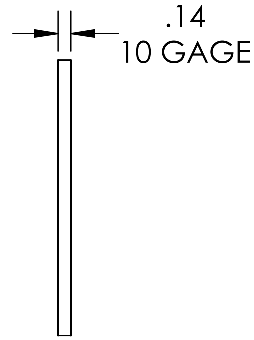
WEIGHT:

IDS-800





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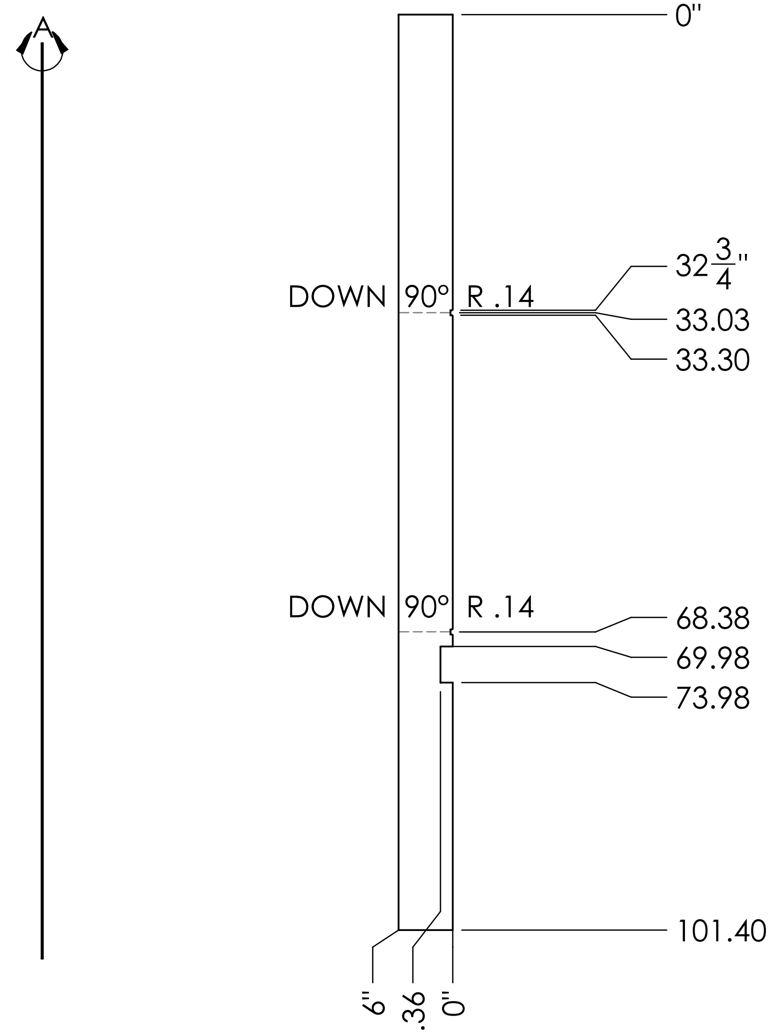

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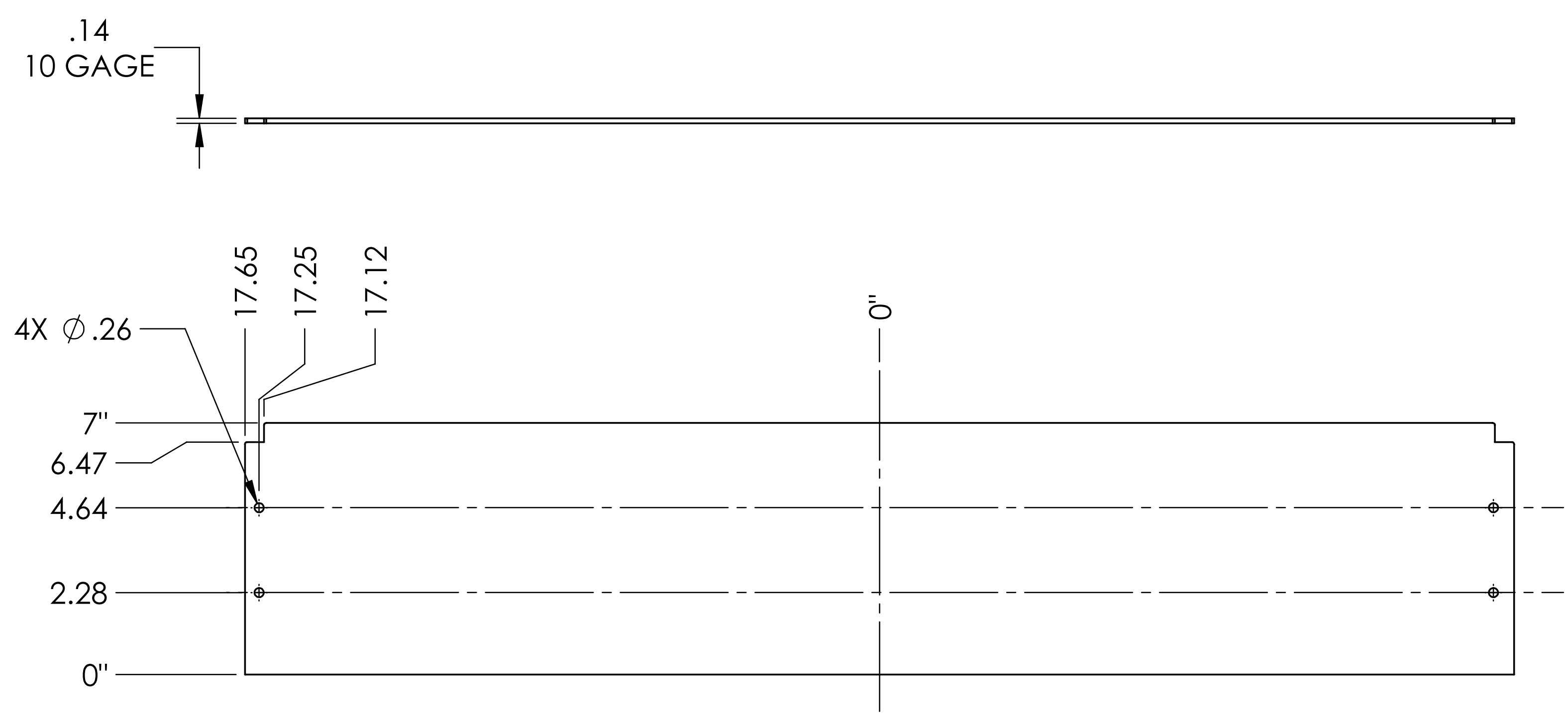

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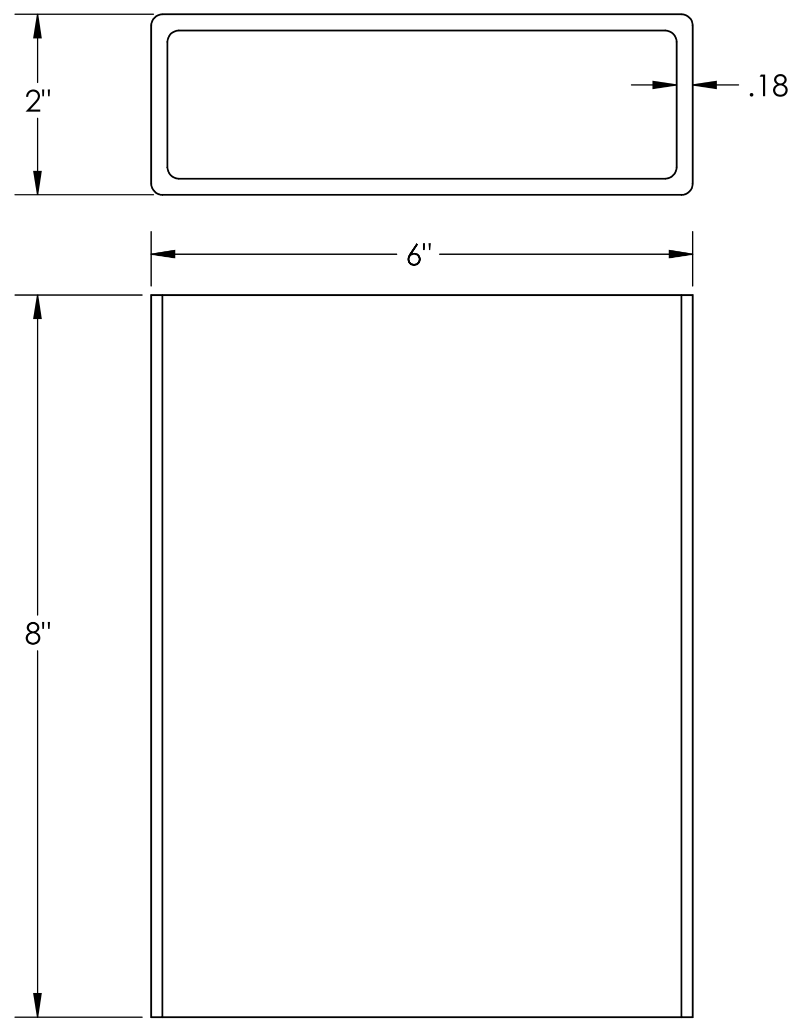

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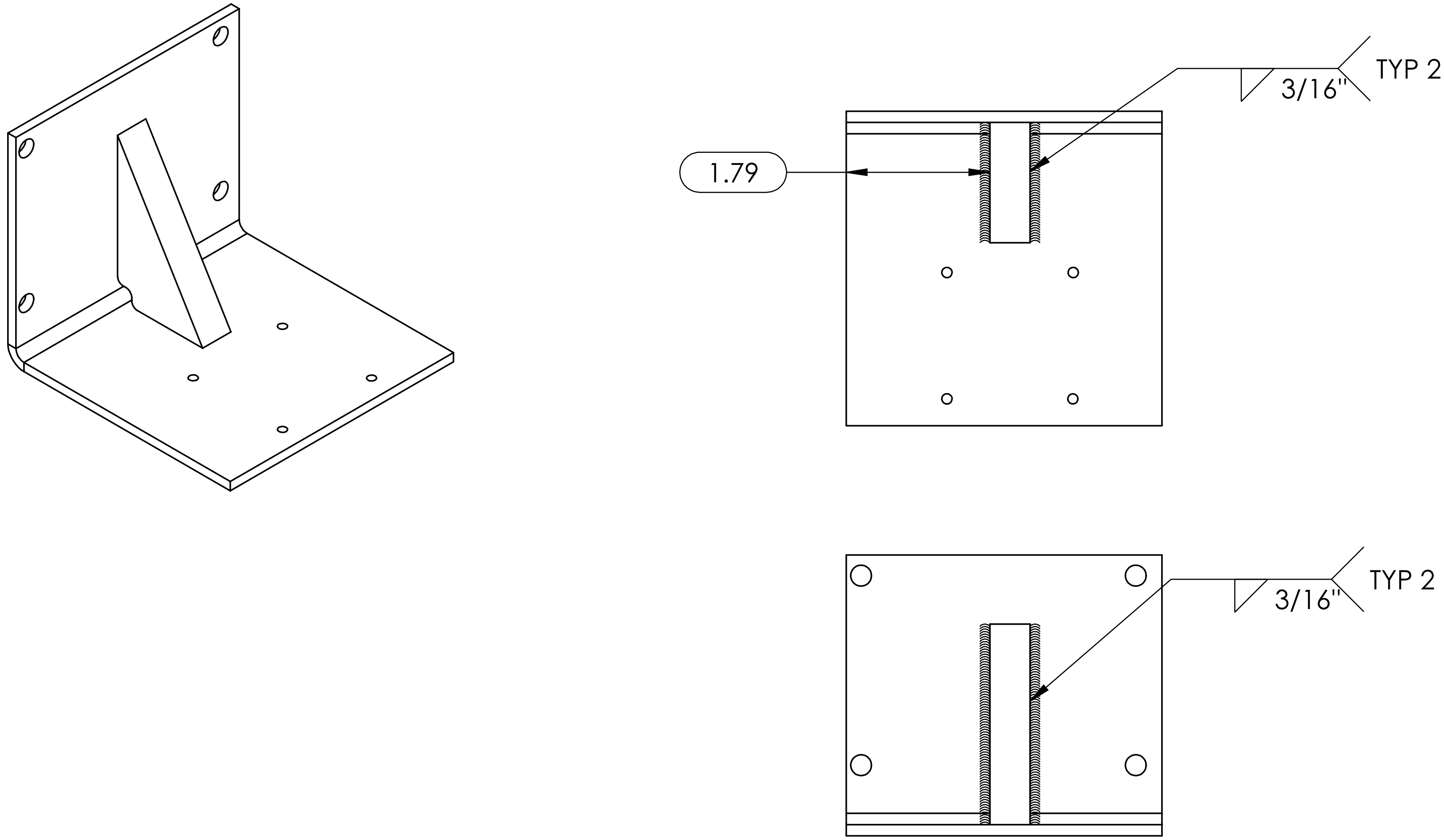

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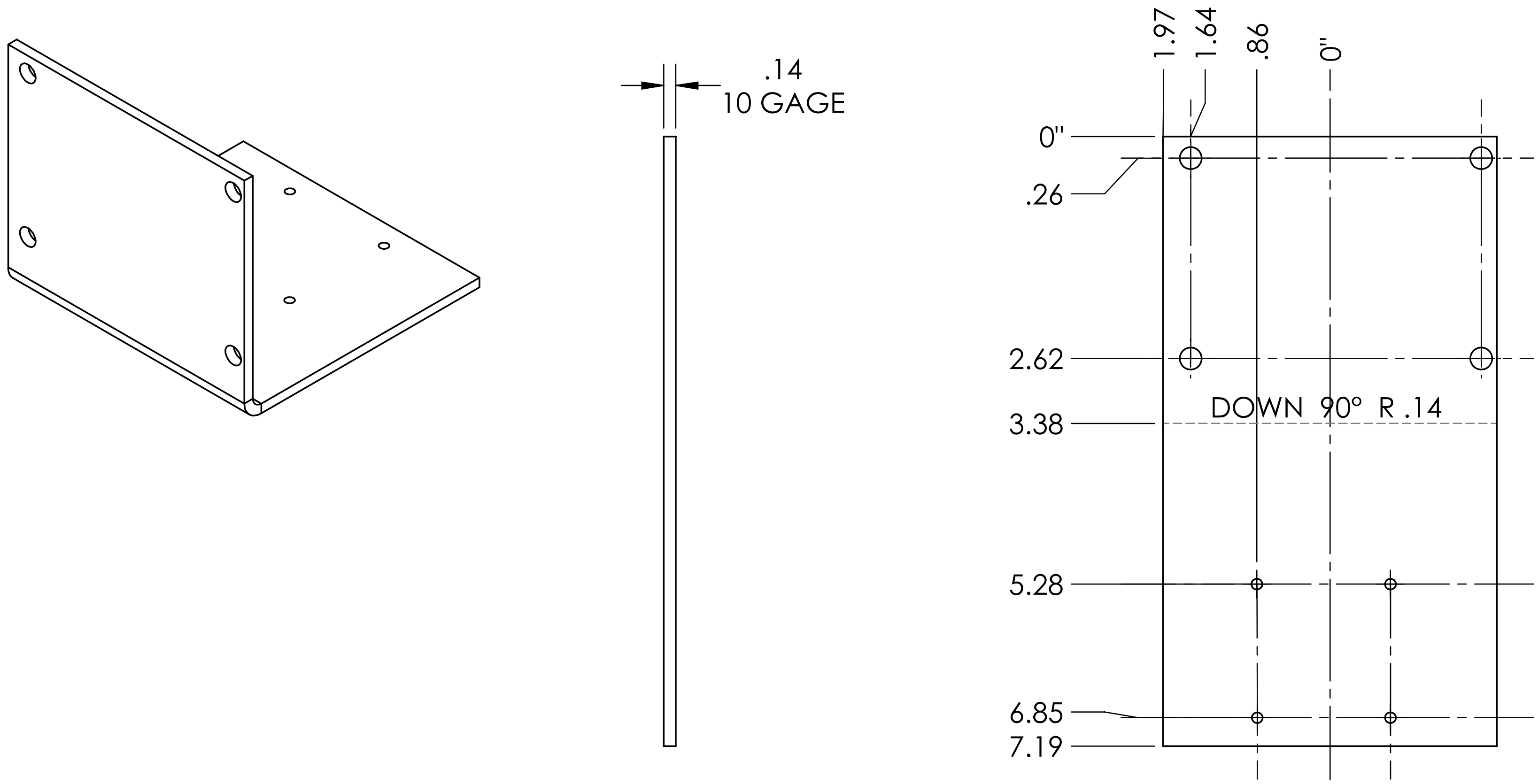

NOTE:
0.125 INCH SHEET METAL

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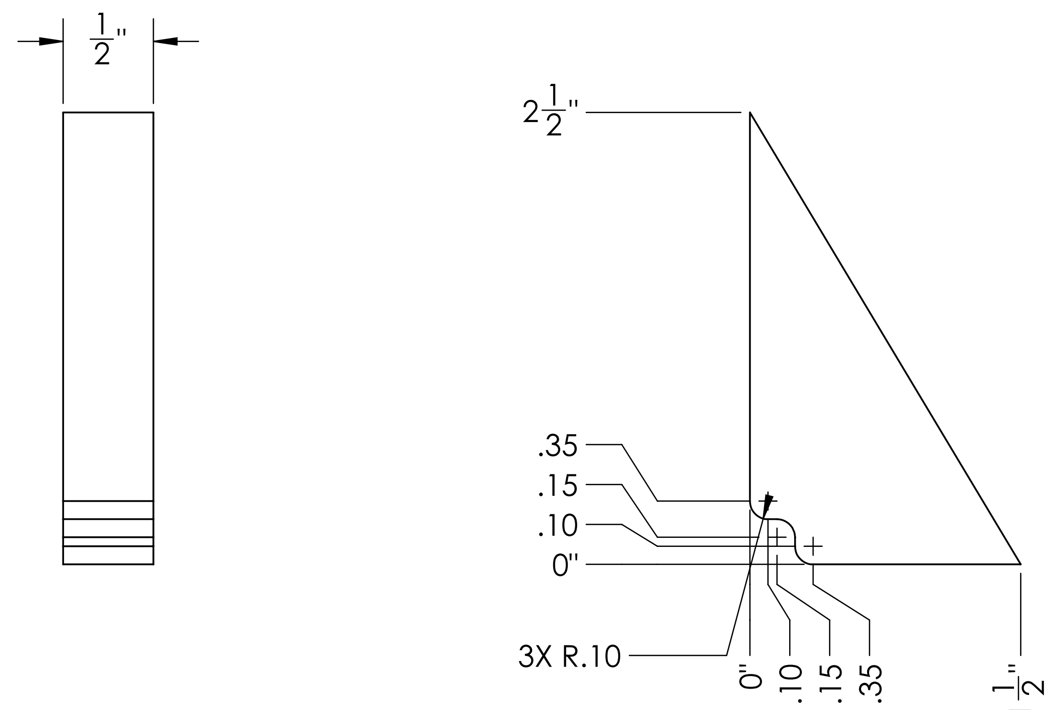

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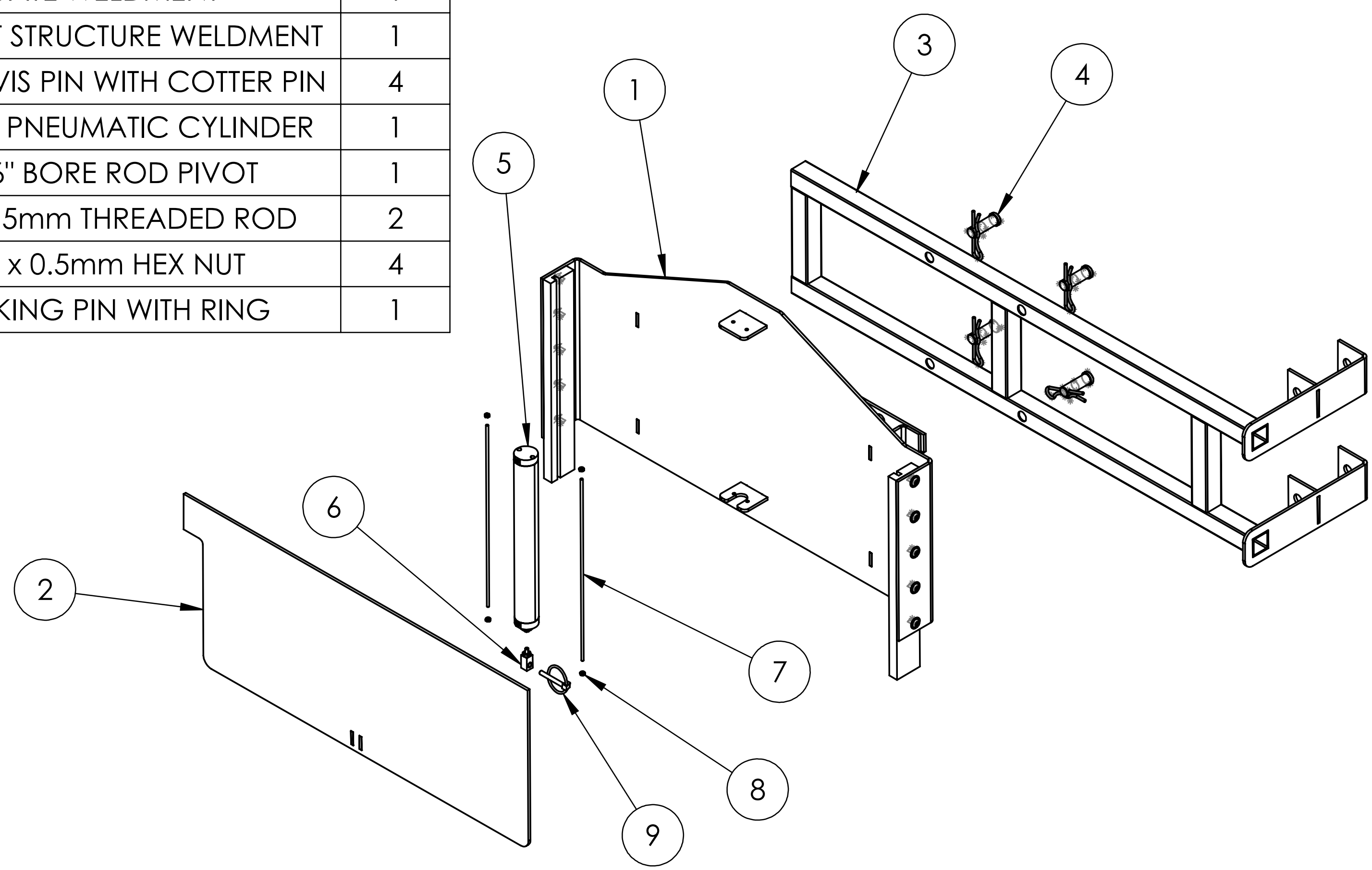
Preliminary Manufacturing Drawing Package
Vertical Sequencing Gates

Appendix D

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_701	BACKPLATE ASSEMBLY	1
2	VPS_801	GATE WELDMENT	1
3	VPS_804	SUPPORT STRUCTURE WELDMENT	1
4	VPS_201	1/2" CLEVIS PIN WITH COTTER PIN	4
5	VPS_202	IP69K SS PNEUMATIC CYLINDER	1
6	VPS_203	9/16" BORE ROD PIVOT	1
7	VPS_204	M3 x 0.5mm THREADED ROD	2
8	VPS_205	M3 x 0.5mm HEX NUT	4
9	VPS_206	LOCKING PIN WITH RING	1



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		CHECKED BY: --	SHEET 1 OF 20 DO NOT SCALE DRAWING	

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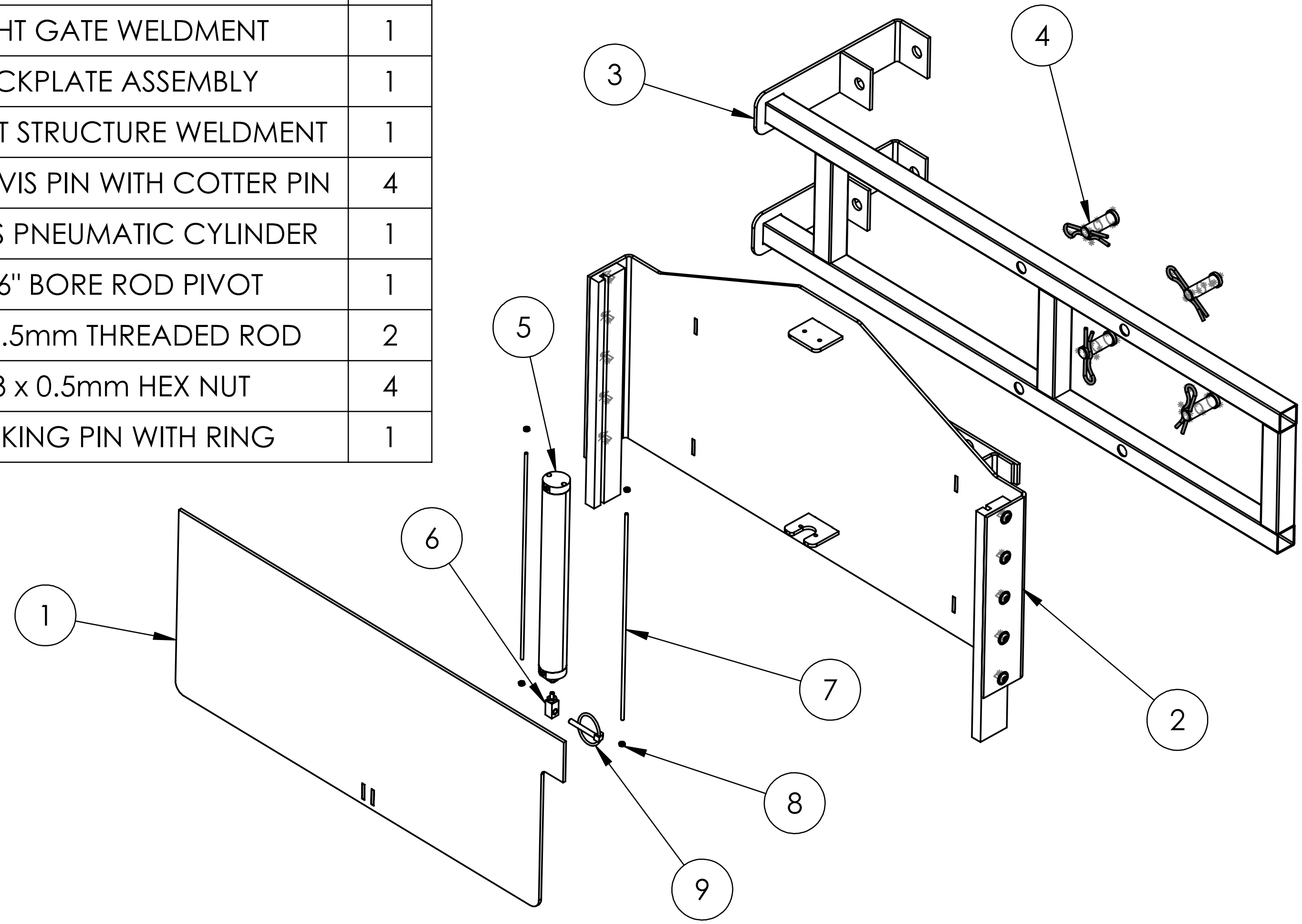
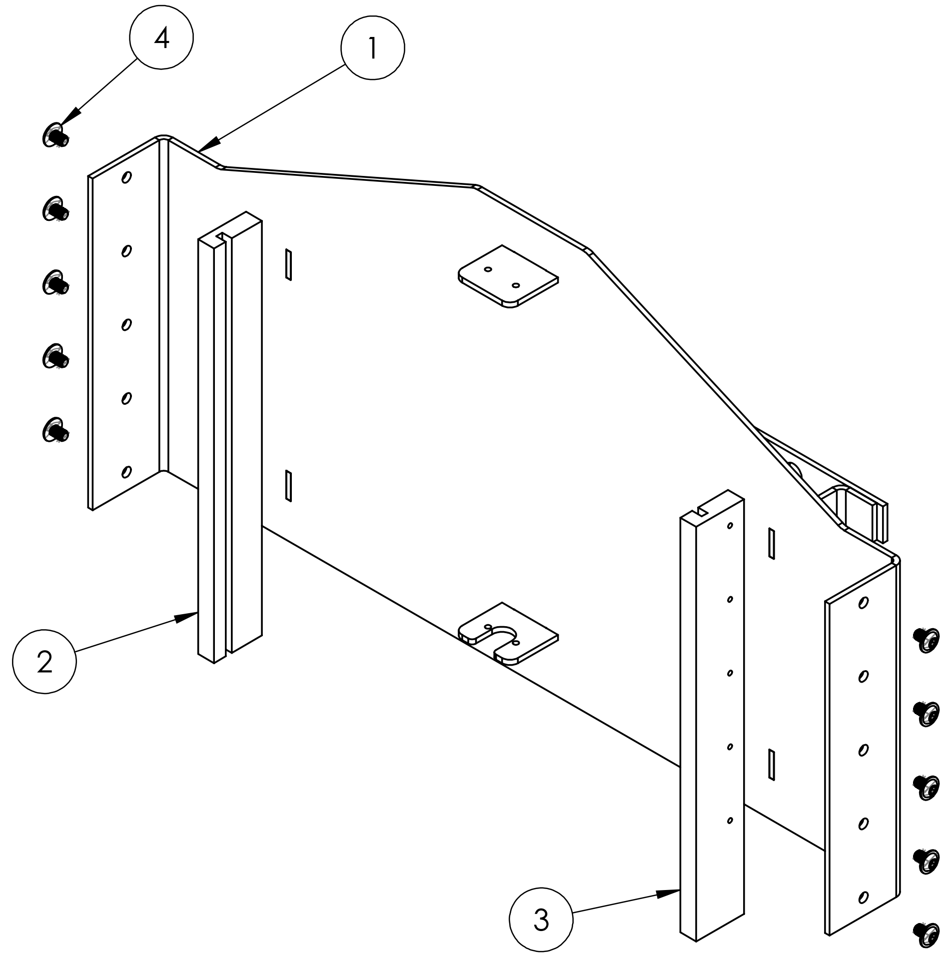
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_800	RIGHT GATE WELDMENT	1
2	VPS_701	BACKPLATE ASSEMBLY	1
3	VPS_804	SUPPORT STRUCTURE WELDMENT	1
4	VPS_201	1/2" CLEVIS PIN WITH COTTER PIN	4
5	VPS_202	IP69K SS PNEUMATIC CYLINDER	1
6	VPS_203	9/16" BORE ROD PIVOT	1
7	VPS_204	M3 x 0.5mm THREADED ROD	2
8	VPS_205	M3 x 0.5mm HEX NUT	4
9	VPS_206	LOCKING PIN WITH RING	1

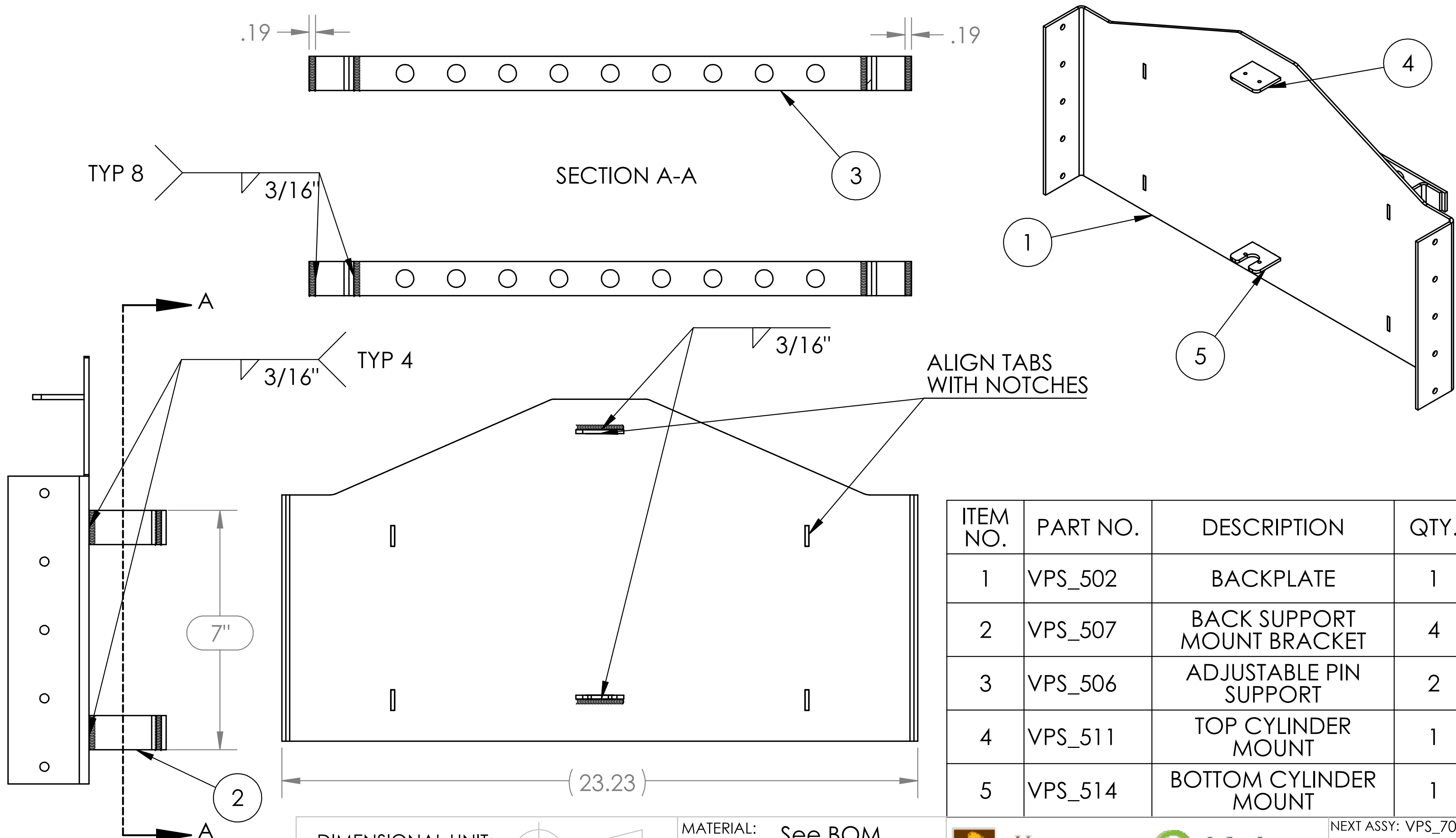


DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM FINISH: AS SHOWN	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: N/A SCALE: 1:8
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: N/A DESCRIPTION: RIGHT VERTICAL SEQUENCING GATE ASSY SHEET 2 OF 20 DO NOT SCALE DRAWING	WEIGHT: 29.85 LBS VPS_700

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_803	BACKPLATE WELDMENT	1
2	VPS_504	LEFT UHMW GROOVE	1
3	VPS_503	RIGHT UHMW GROOVE	1
4	VPS_200	1/4"-20 FLANGED SS BOLT	10



DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_702
	FINISH: AS SHOWN			SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: VERTICAL SEQUENCING GATE ASSY	WEIGHT: 14.24 LBS
		DRAWN BY: DV	DESCRIPTION: BACKPLATE ASSEMBLY	VPS_701
		CHECKED BY: --	SHEET 3 OF 20 DO NOT SCALE DRAWING	



ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	VPS_502	BACKPLATE	1
2	VPS_507	BACK SUPPORT MOUNT BRACKET	4
3	VPS_506	ADJUSTABLE PIN SUPPORT	2
4	VPS_511	TOP CYLINDER MOUNT	1
5	VPS_514	BOTTOM CYLINDER MOUNT	1

DIMENSIONAL UNIT: INCHES

MATERIAL: See BOM

FINISH: AS SHOWN

UNIVERSITY OF MANITOBA

HYLIFE FOODS

NEXT ASSY: VPS_702 VPS_700

SCALE: 1:4

UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

SIZE A4

FIRST ISSUED:	11/28/2018
DRAWN BY:	DV
CHECKED BY:	--

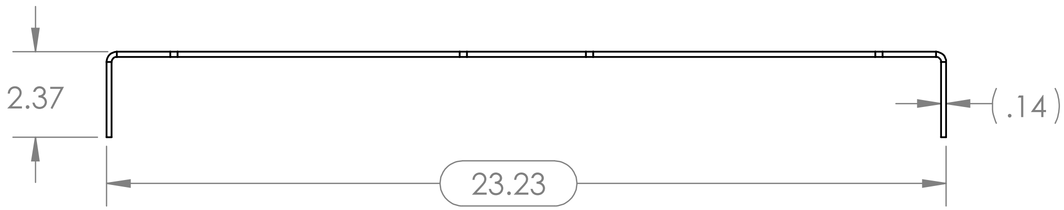
USED WITH: VERTICAL SEQUENCING GATE ASSY

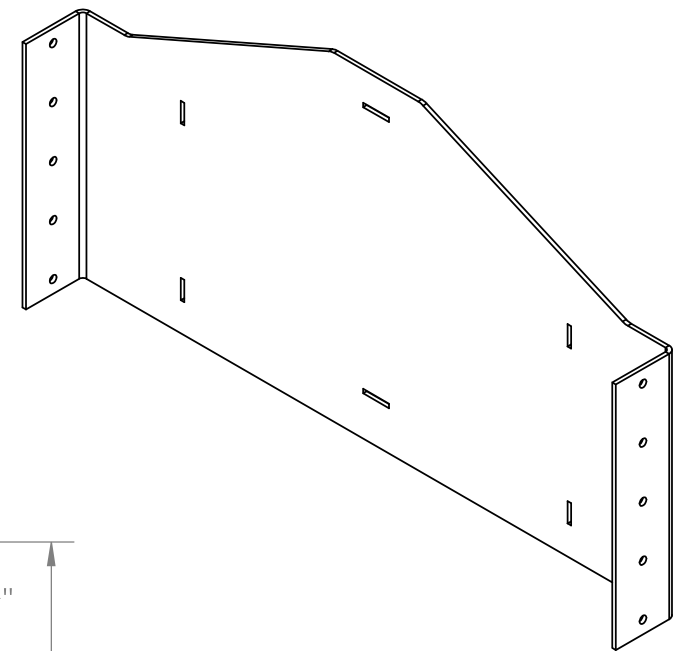
WEIGHT: 13.69 LBS

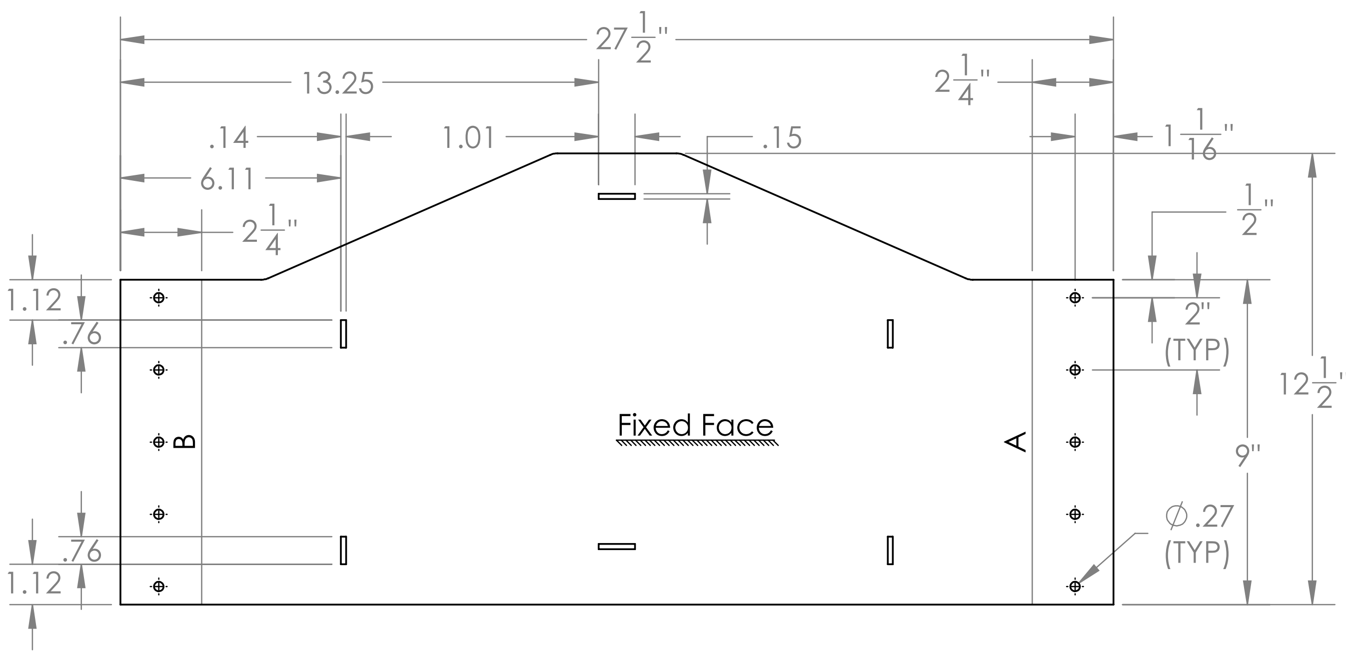
DESCRIPTION: BACKPLATE WELDMENT

VPS_803

SHEET 4 OF 20 DO NOT SCALE DRAWING







Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	0.14
B	UP	90°	0.14

DIMENSIONAL UNIT: INCHES

UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL: 10GA 316SS SHEET
FINISH: N/A

SIZE A4

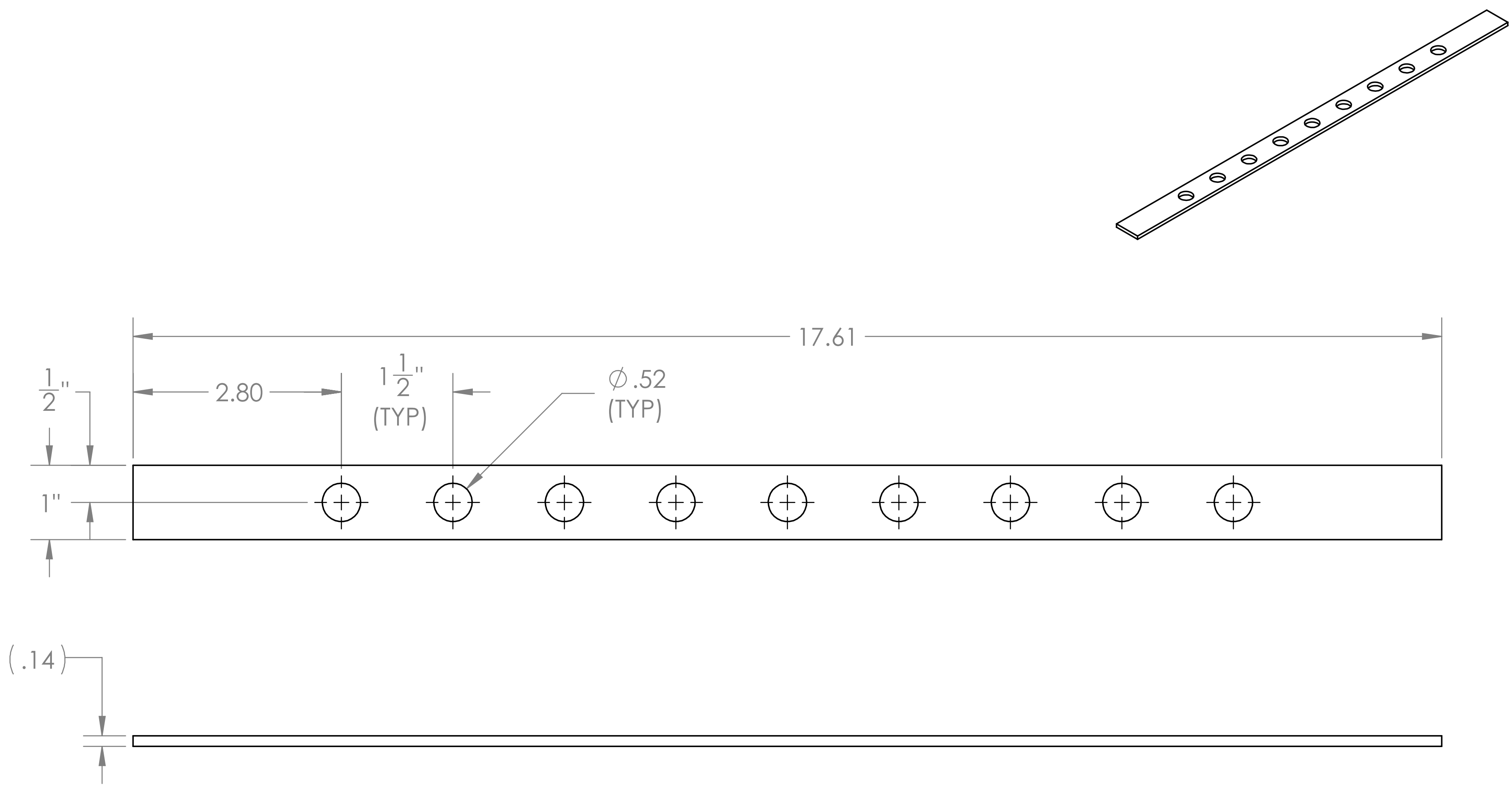
FIRST ISSUED: 11/28/2018
DRAWN BY: DV
CHECKED BY: --

UNIVERSITY OF MANITOBA
HYLIFE FOODS

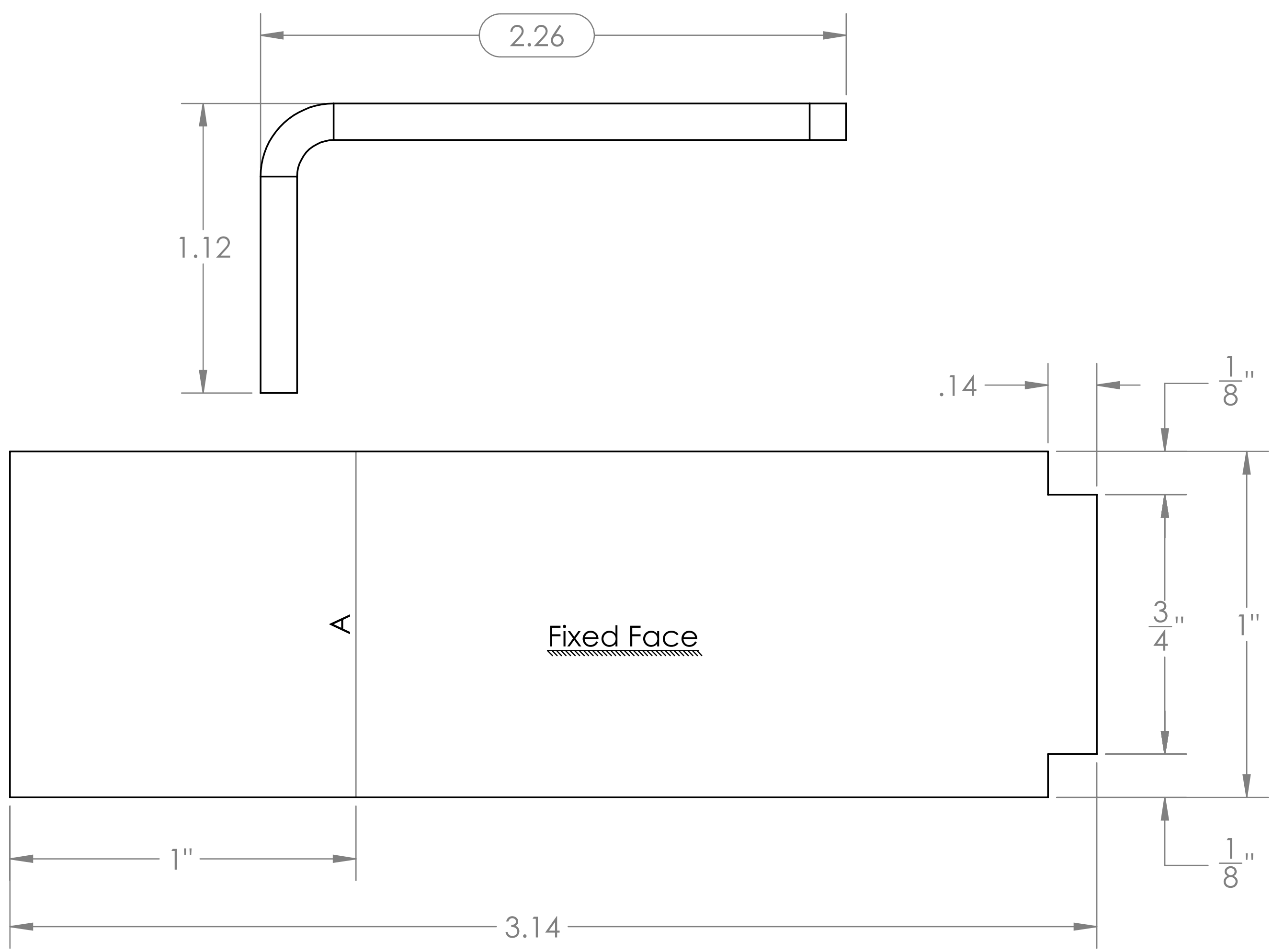
USED WITH: BACKPLATE WELDMENT
DESCRIPTION: BACKPLATE
SHEET 5 OF 20
DO NOT SCALE DRAWING

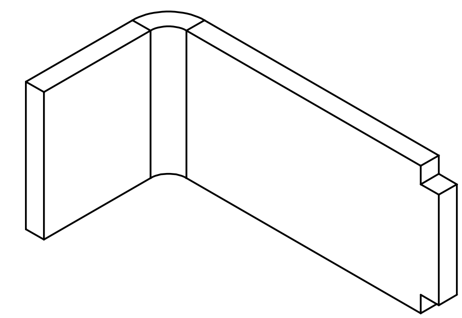
NEXT ASSY: VPS_803
SCALE: 1:4
WEIGHT: 11.67 LBS

VPS_502



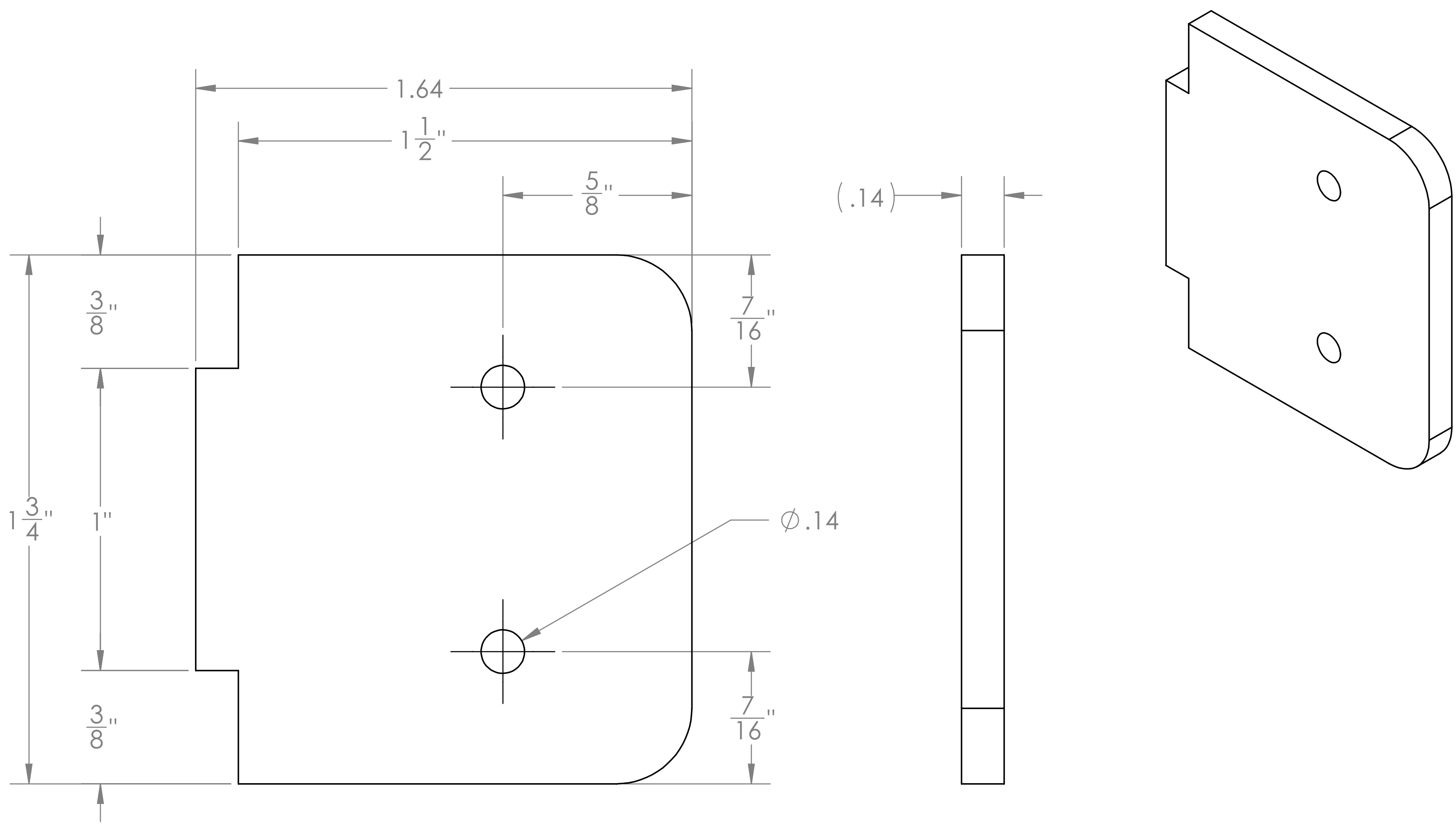
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_803
	FINISH: N/A			SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: BACKPLATE WELDMENT	WEIGHT: 0.64 LBS
		DRAWN BY: DV	DESCRIPTION: ADJUSTABLE PIN SUPPORT	VPS_506
		CHECKED BY: --	SHEET 6 OF 20 DO NOT SCALE DRAWING	



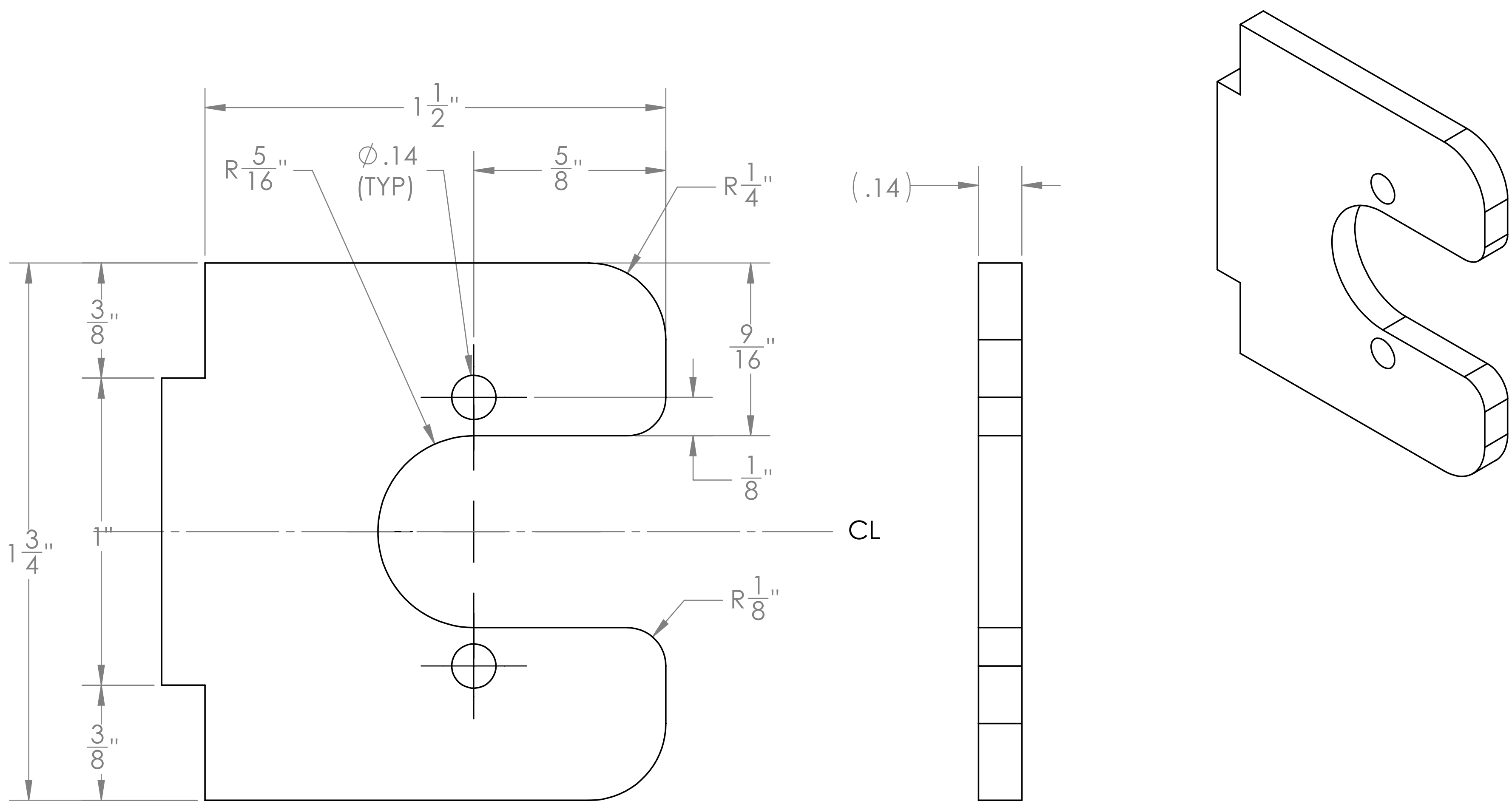


Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	1"

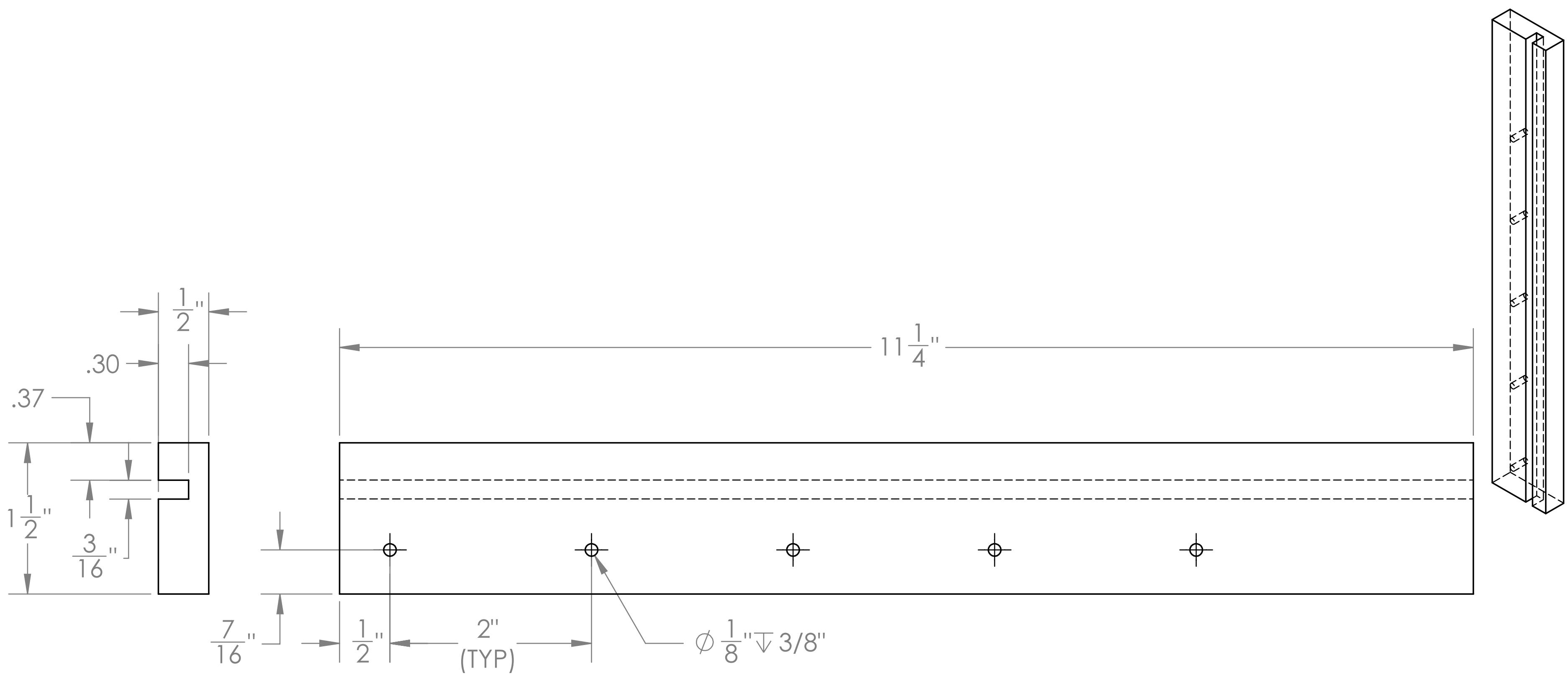
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_803
	FINISH: N/A		SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: BACKPLATE WELDMENT	WEIGHT: 0.13 LBS
	FIRST ISSUED: 11/28/2018	DESCRIPTION: BACK SUPPORT MOUNT BRACKET	VPS_507
	DRAWN BY: DV	SHEET 7 OF 20	DO NOT SCALE DRAWING
	CHECKED BY: --		



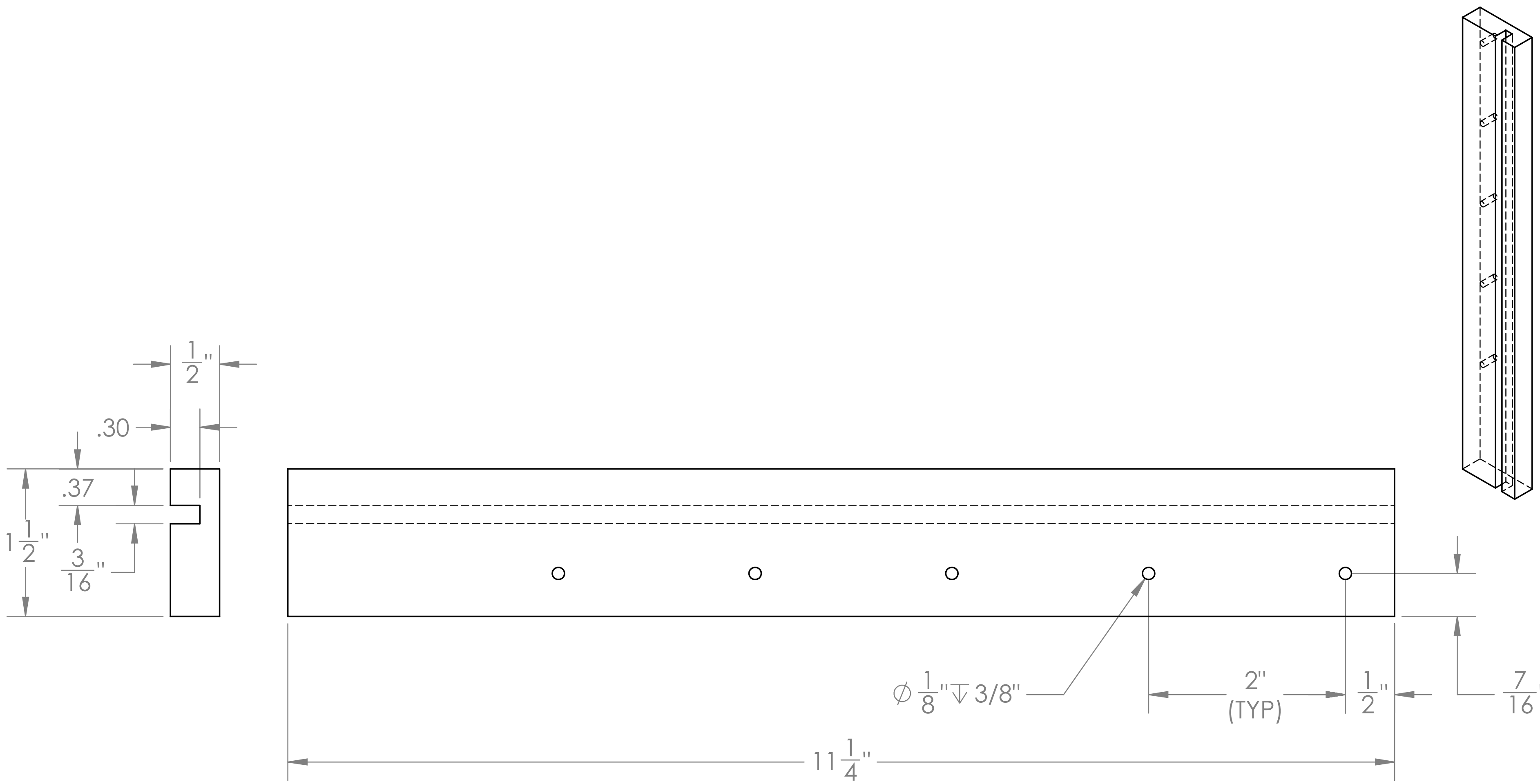
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_803
	FINISH: N/A		SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: BACKPLATE WELDMENT	WEIGHT: 0.13 LBS
	FIRST ISSUED: 11/28/2018	DESCRIPTION: TOP CYLINDER MOUNT	VPS_511
	DRAWN BY: DV	SHEET 8 OF 20	DO NOT SCALE DRAWING
	CHECKED BY: --		



DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_803
	FINISH: N/A			SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: BACKPLATE WELDMENT	WEIGHT: 0.10 LBS
		DRAWN BY: DV	DESCRIPTION: BOTTOM CYLINDER MOUNT	VPS_511
		CHECKED BY: --	SHEET 9 OF 20 DO NOT SCALE DRAWING	

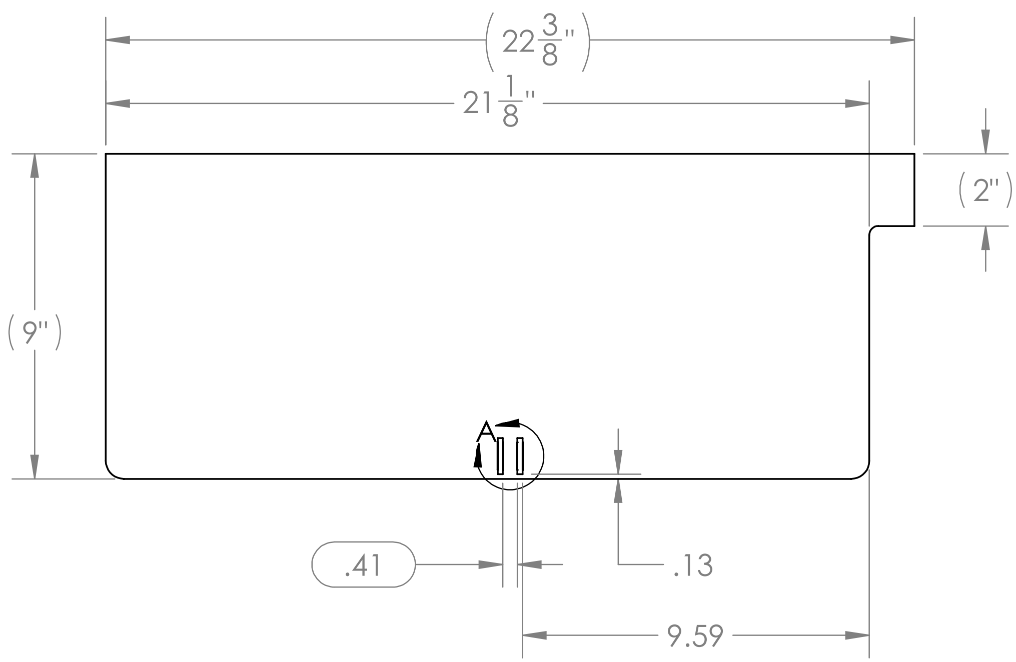


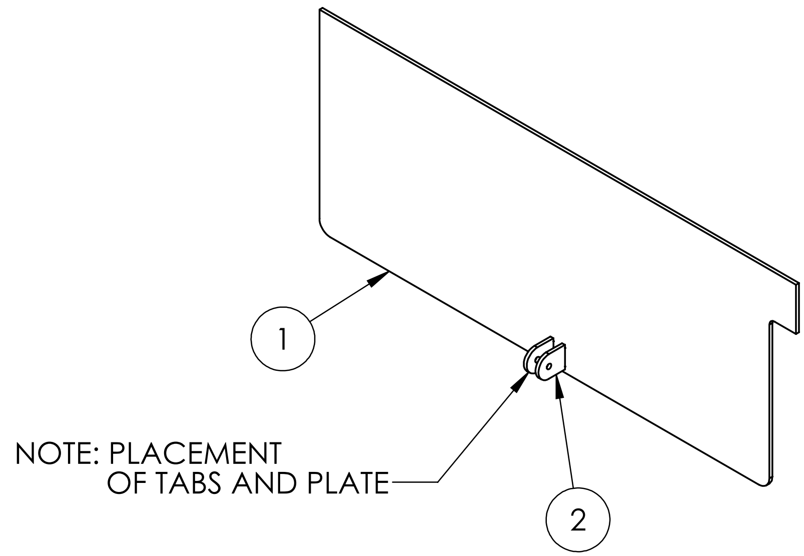
DIMENSIONAL UNIT: INCHES	MATERIAL: 1/2" UHMW		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: VPS_701
	FINISH: N/A				SCALE: 2:3
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: VERTICAL SEQUENCING GATE ASSY		WEIGHT: 0.27 LBS
		DRAWN BY: DV	DESCRIPTION: LEFT UHMW GROOVE		VPS_504
		CHECKED BY: --	SHEET 10OF 20	DO NOT SCALE DRAWING	

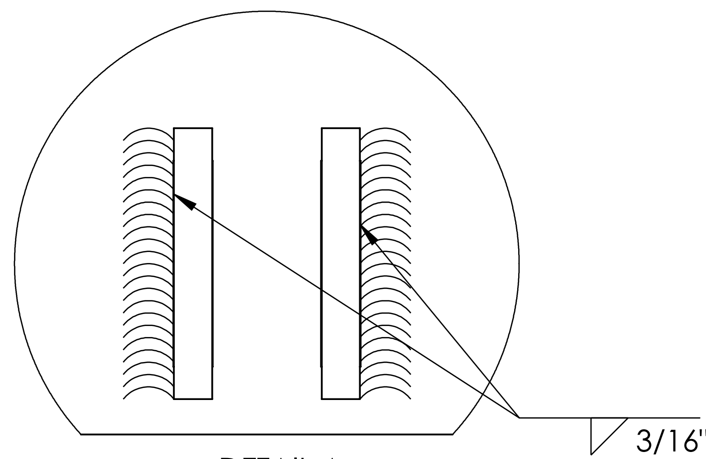


DIMENSIONAL UNIT: INCHES	MATERIAL: 1/2" UHMW FINISH: N/A	UNIVERSITY OF MANITOBA · HYLIFE FOODS	NEXT ASSY: VPS_701 SCALE: 2:3
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: VERTICAL SEQUENCING GATE ASSY DESCRIPTION: RIGHT UHMW GROOVE SHEET 11OF 20 DO NOT SCALE DRAWING	WEIGHT: 0.27 LBS **VPS_503**

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_500	SEQUENCING GATE	1
2	VPS_501	ROD MOUNT TAB	2



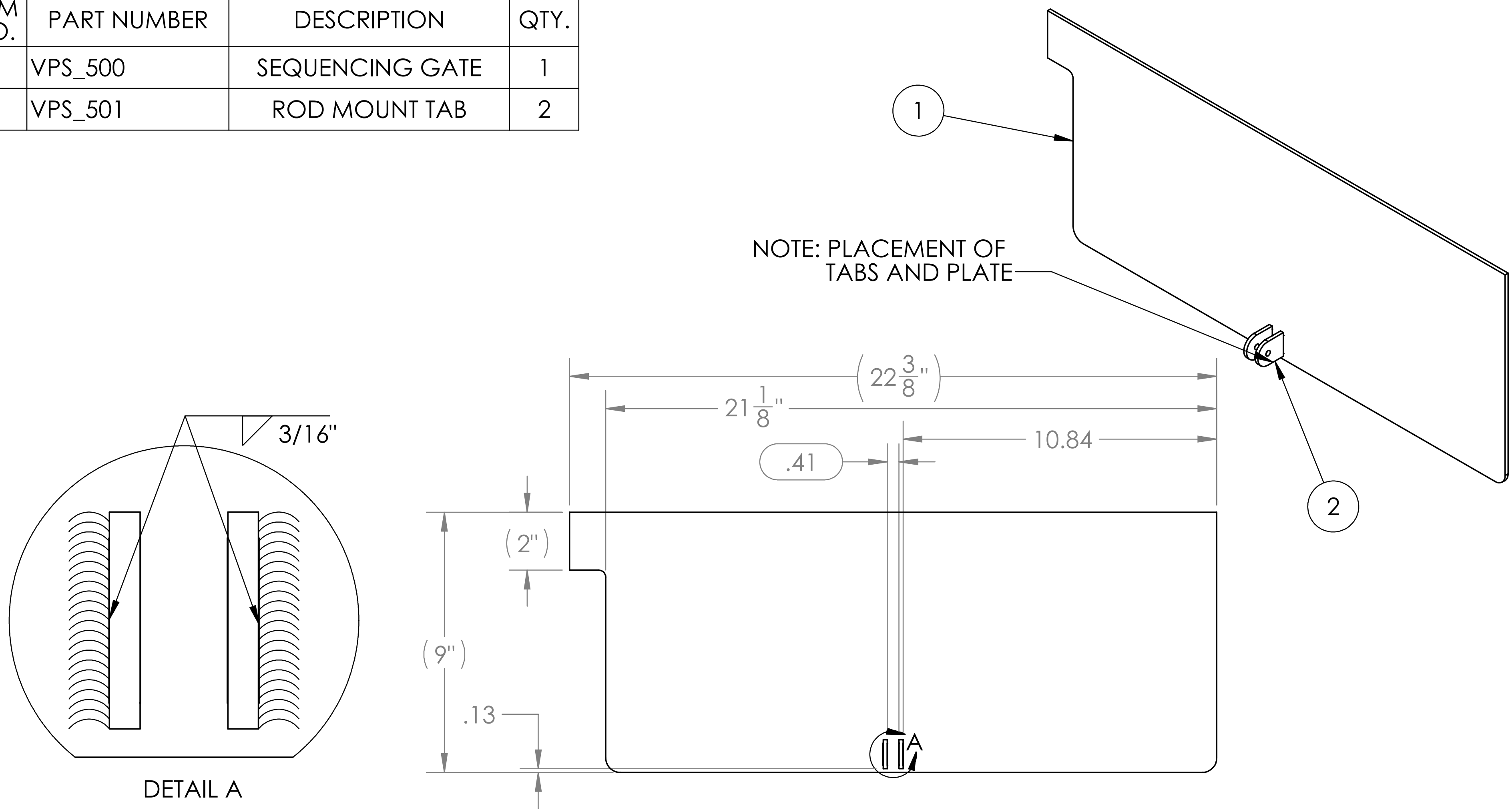




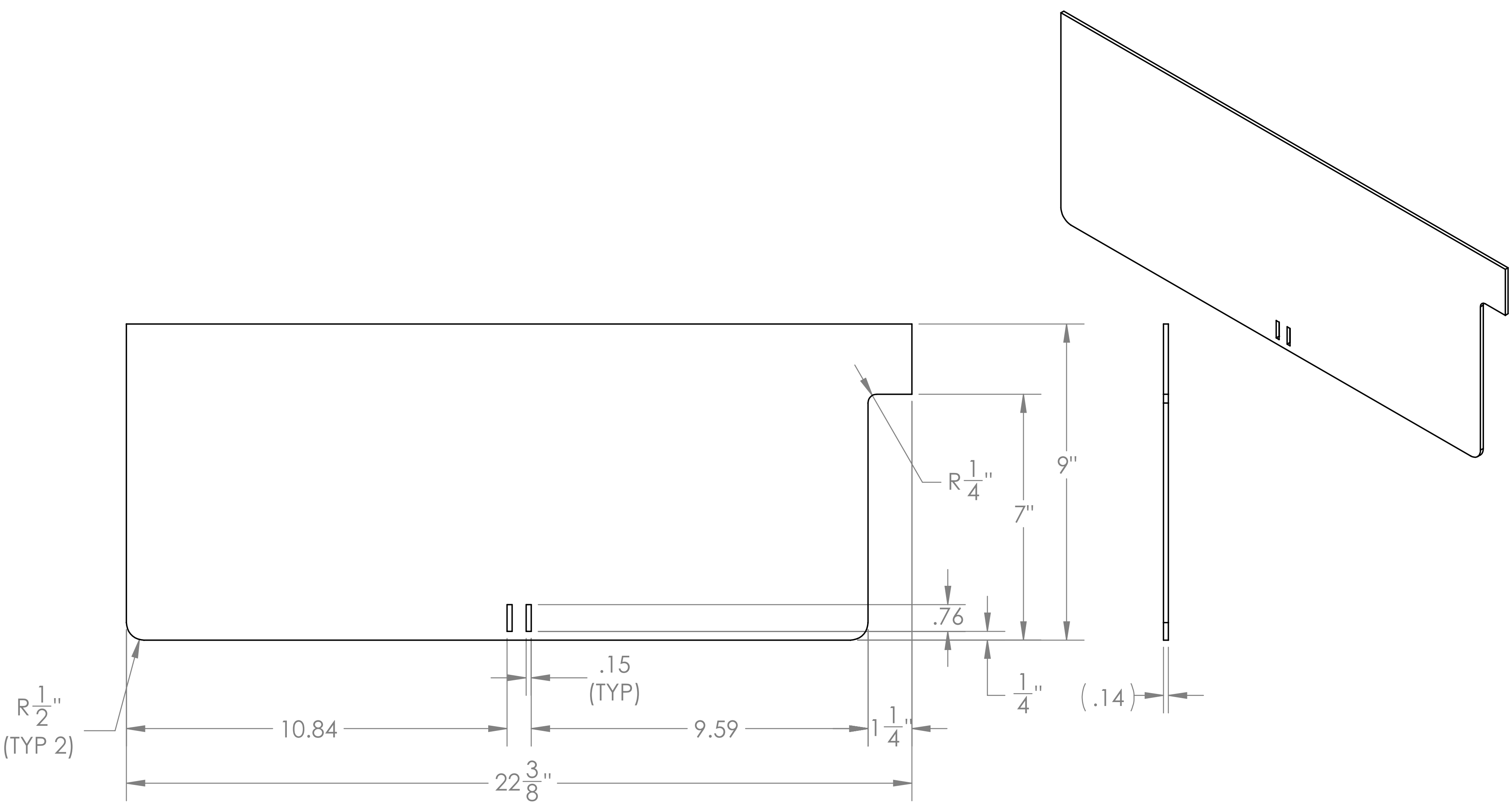
DETAIL A

DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_702
	FINISH: N/A			SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: LEFT VERTICAL GATE ASSY	WEIGHT: 7.94 LBS
		DRAWN BY: DV	DESCRIPTION: LEFT GATE WELDMENT	VPS_801
		CHECKED BY: --	SHEET 12OF 20 DO NOT SCALE DRAWING	

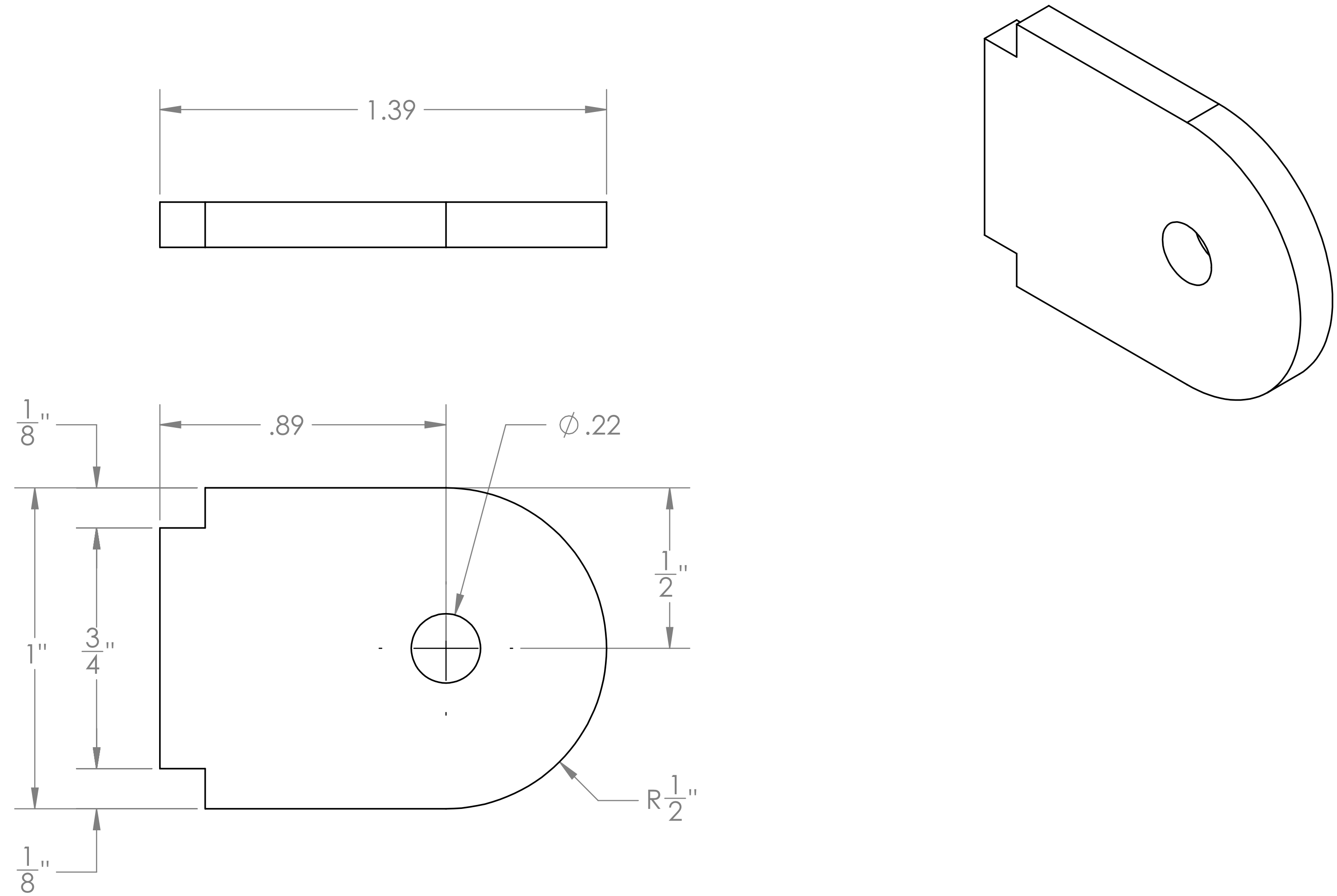
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_500	SEQUENCING GATE	1
2	VPS_501	ROD MOUNT TAB	2



DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_700
	FINISH: N/A		SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: RIGHT VERTICAL GATE ASSY	WEIGHT: 7.94 LBS
	FIRST ISSUED: 11/28/2018	DESCRIPTION: RIGHT GATE WELDMENT	VPS_800
	DRAWN BY: DV	SHEET 13OF 20 DO NOT SCALE DRAWING	
	CHECKED BY: --		

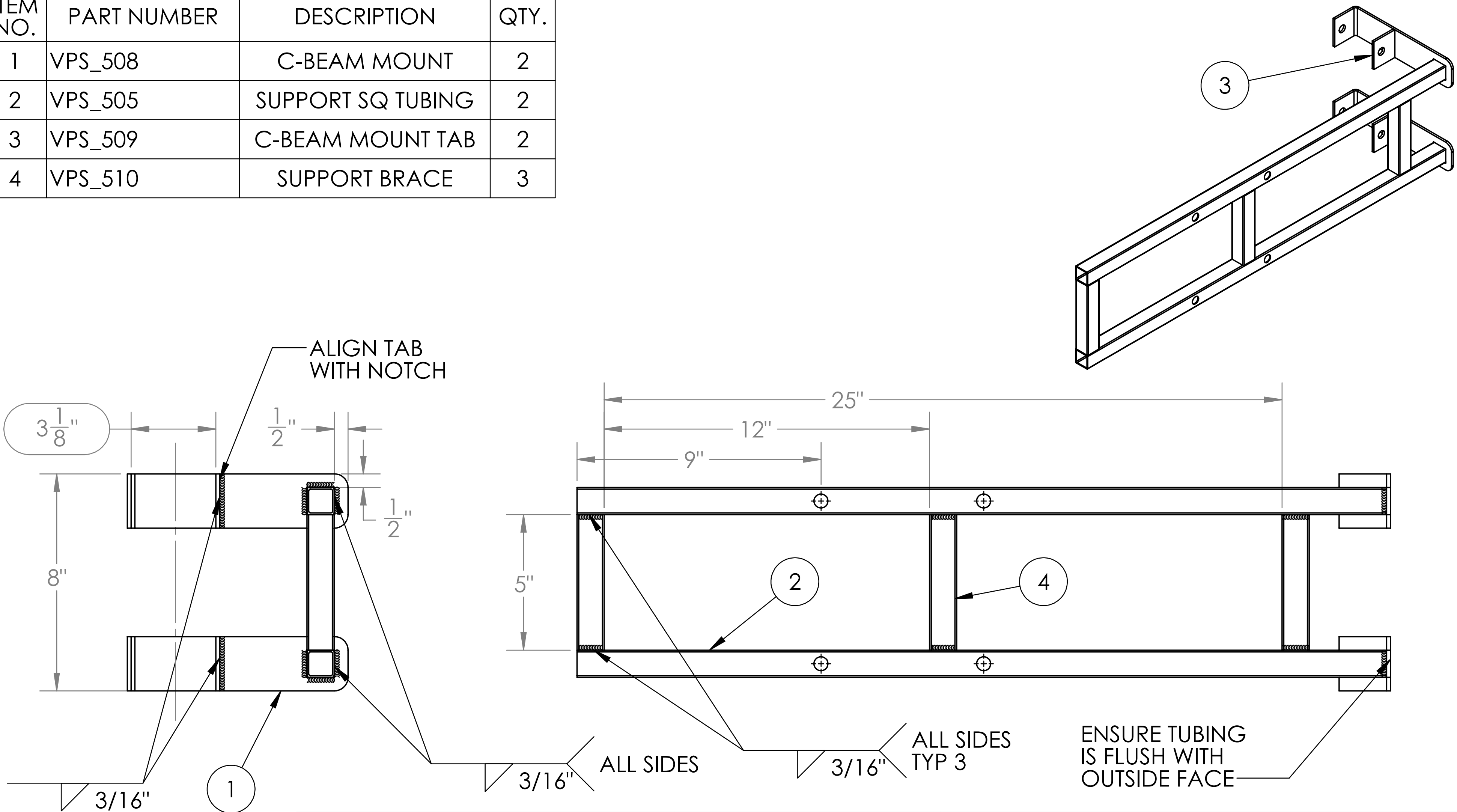


DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_800 VPS_801
	FINISH: POLISHED			SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: GATE WELDMENT	WEIGHT: 7.84 LBS
		DRAWN BY: DV	DESCRIPTION: SEQUENCING GATE	VPS_500
		CHECKED BY: --	SHEET 14OF 20 DO NOT SCALE DRAWING	

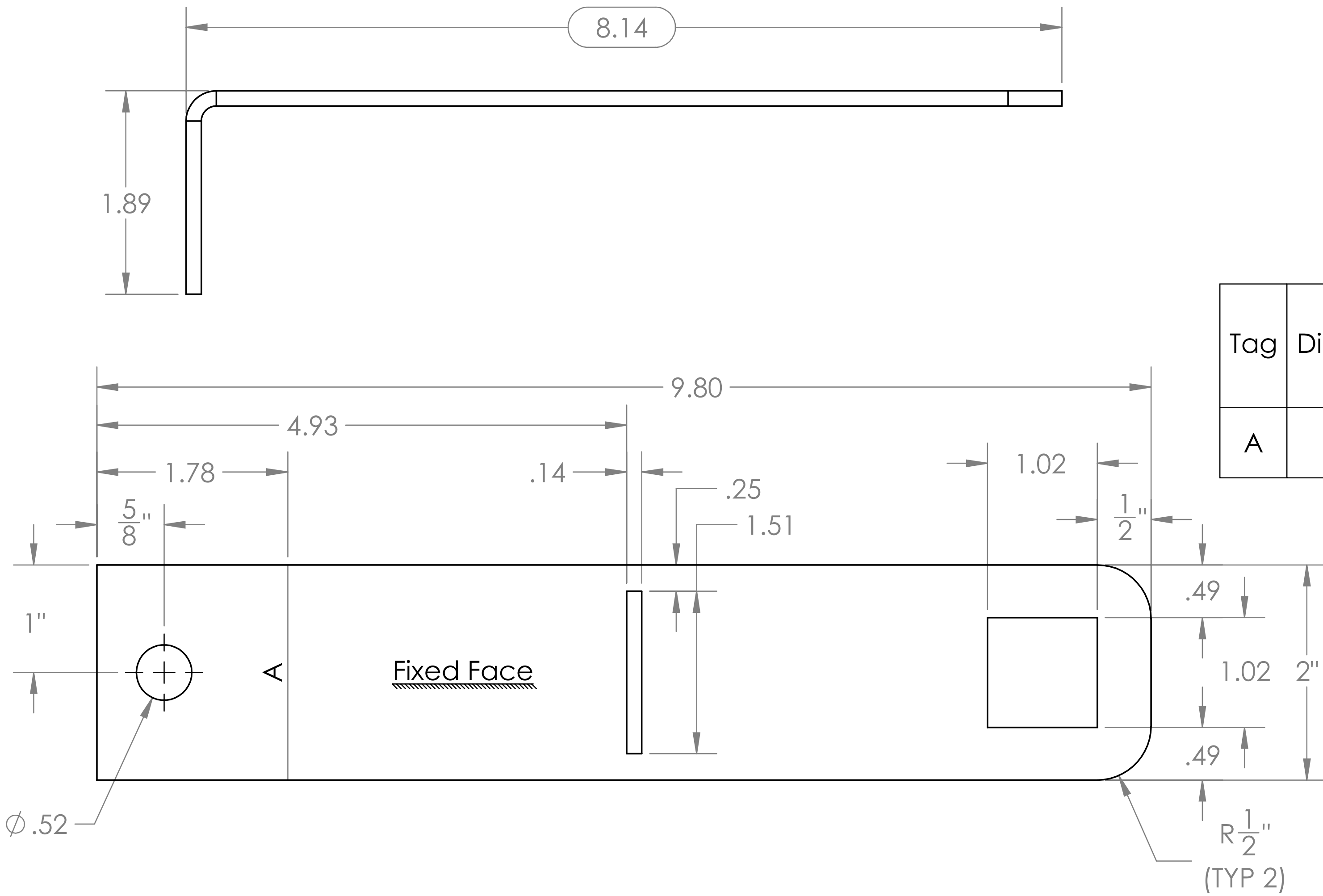


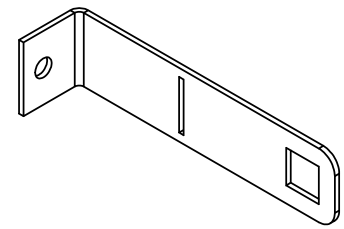
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_800 VPS_801
	FINISH: POLISHED				SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: GATE WELDMENT	WEIGHT: 0.05 LBS
		DRAWN BY:	DV	DESCRIPTION: ROD MOUNT TAB	VPS_501
		CHECKED BY:	--	SHEET 15OF 20 DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VPS_508	C-BEAM MOUNT	2
2	VPS_505	SUPPORT SQ TUBING	2
3	VPS_509	C-BEAM MOUNT TAB	2
4	VPS_510	SUPPORT BRACE	3



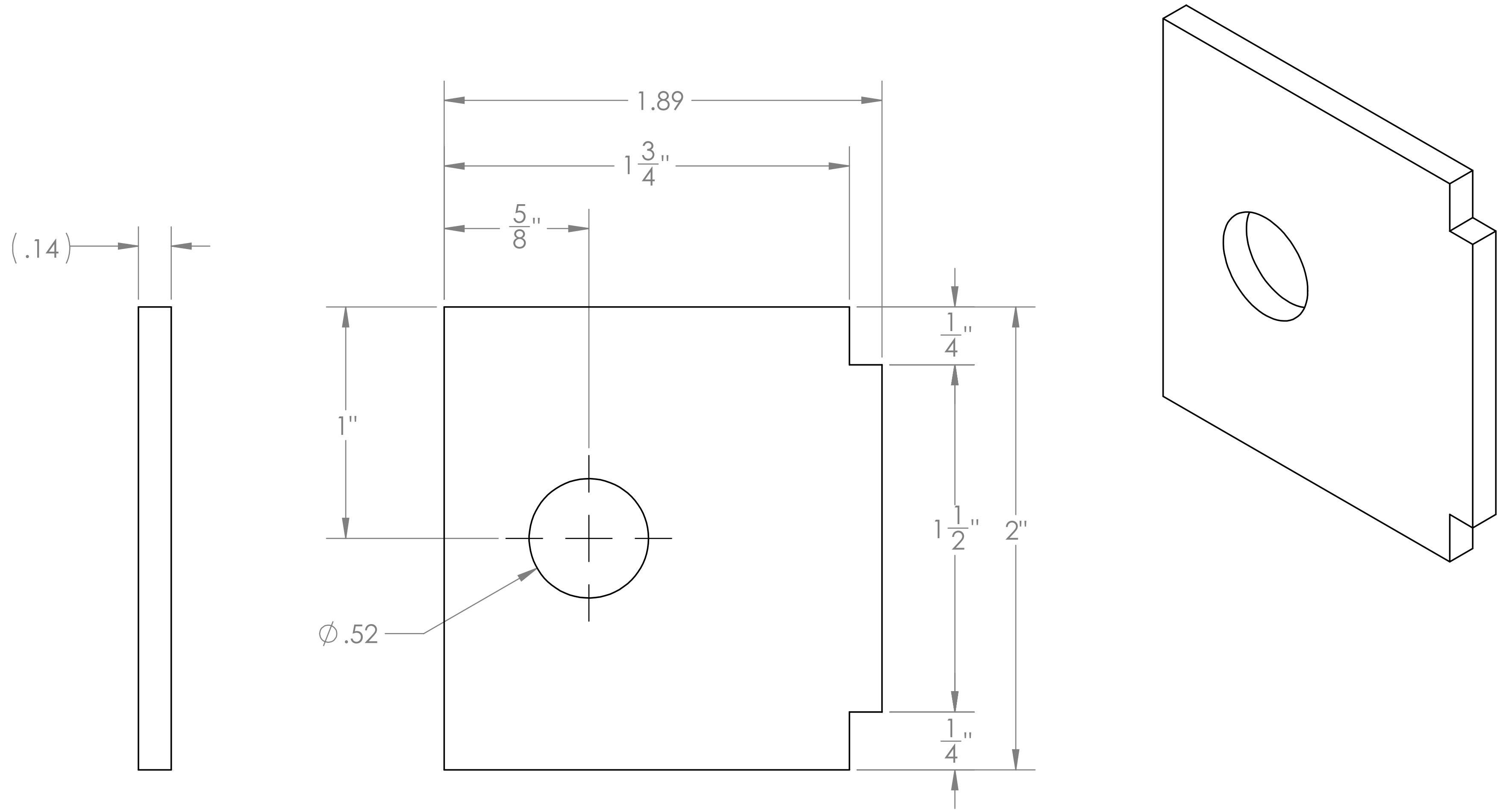
DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM		NEXT ASSY: VPS_700 VPR_702
	FINISH: AS SHOWN	UNIVERSITY OF MANITOBA / HYLIFE FOODS	SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: VERTICAL SEQUENCING GATE ASSY	WEIGHT: 0.27 LBS
		DRAWN BY: DV	DESCRIPTION: SUPPORT STRUCTURE WELDMENT	VPS_804
		CHECKED BY: --	SHEET 16OF 20 DO NOT SCALE DRAWING	



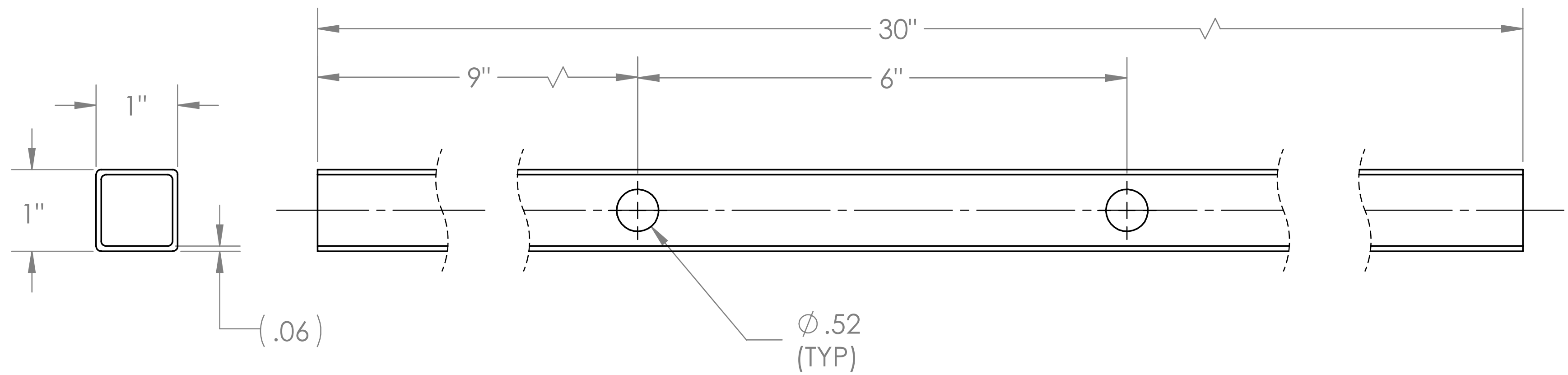


Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	1.78"

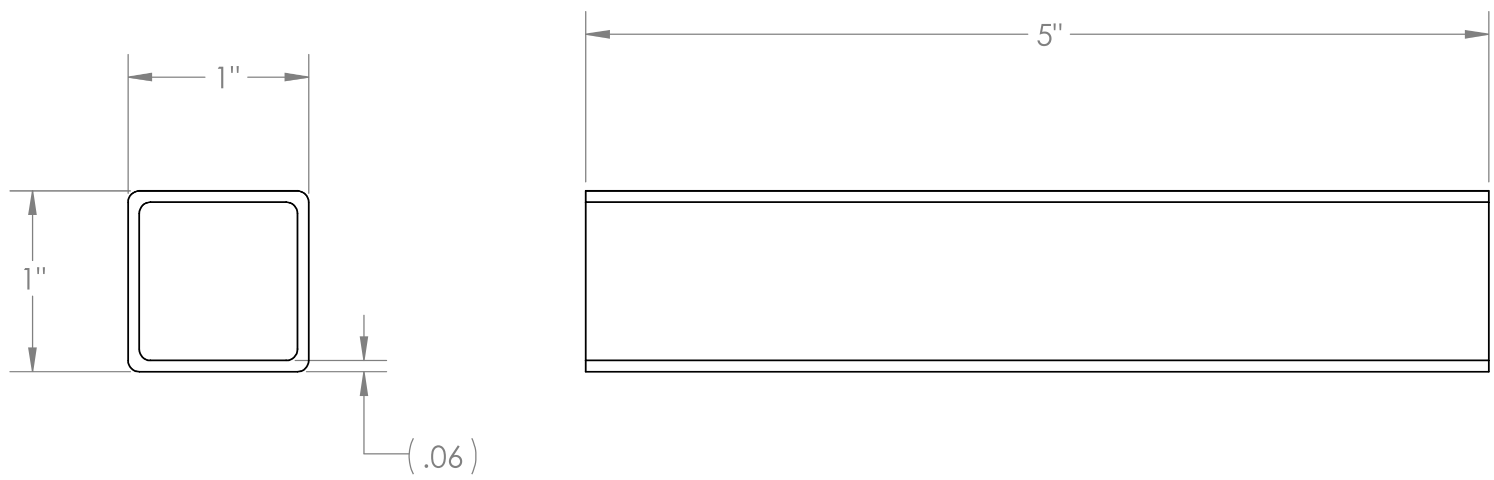
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: VPS_804
	FINISH: N/A			SCALE: 2:3
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: SUPPORT STRUCTURE WELDMENT	WEIGHT: 0.73 LBS
		DRAWN BY: DV	DESCRIPTION: C-BEAM MOUNT BRACKET	**VPS_508**
		CHECKED BY: --	SHEET 17OF 20 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_804
	FINISH: N/A		SCALE: 3:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 / FIRST ISSUED: 11/28/2018 / DRAWN BY: DV / CHECKED BY: --	USED WITH: SUPPORT STRUCTURE WELDMENT	WEIGHT: 0.14 LBS
		DESCRIPTION: C-BEAM MOUNT TAB	VPS_509
		SHEET 18OF 20 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL:	1" x 1" x 16GA 304SS SQ TUBING	UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: VPS_804
	FINISH:	N/A			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH:	SUPPORT STRUCTURE WELDMENT	WEIGHT: 2.00 LBS
		DRAWN BY: DV	DESCRIPTION:	SUPPORT SQ TUBING	VPS_505
		CHECKED BY: --	SHEET 19OF 20	DO NOT SCALE DRAWING	



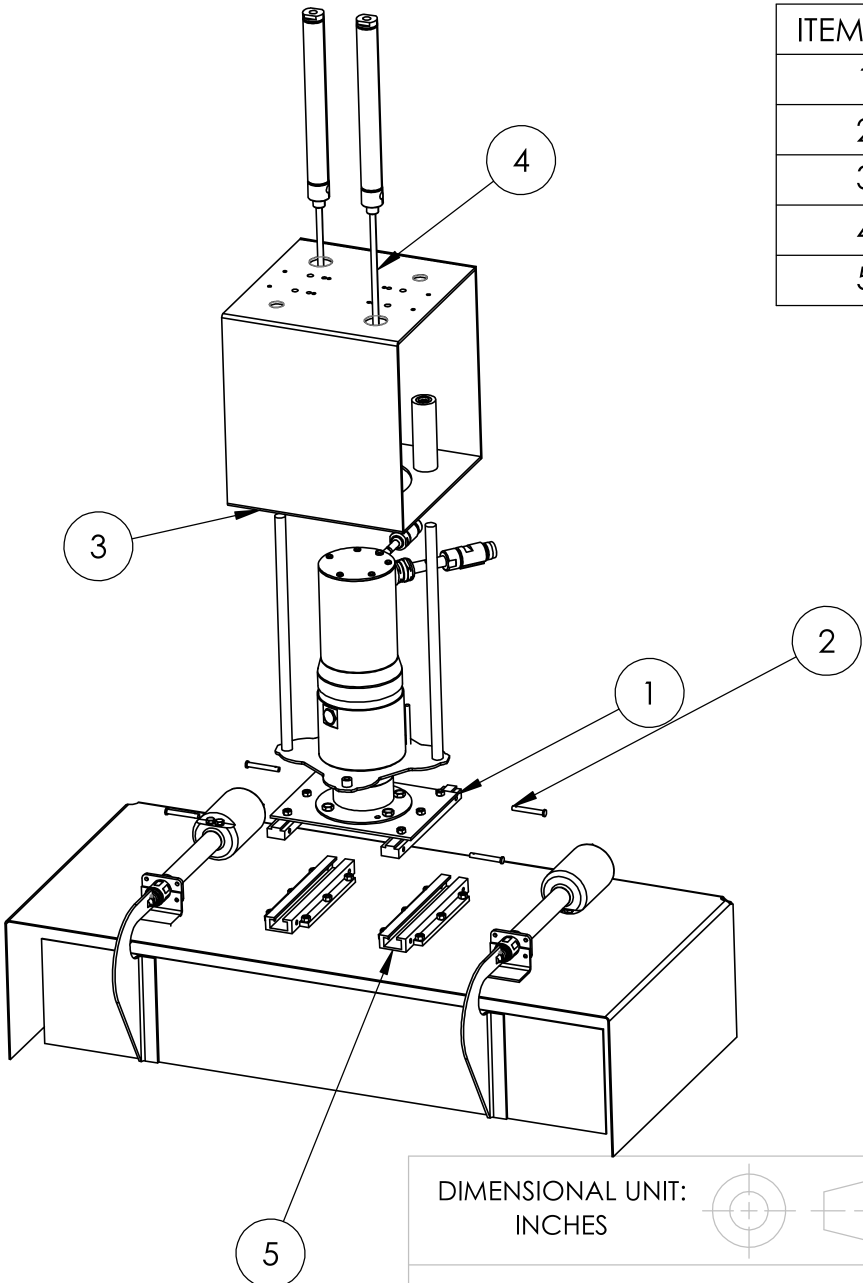
DIMENSIONAL UNIT: INCHES	MATERIAL: 1" x 1" x 16GA 304SS SQ TUBING		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: VPS_804
	FINISH: N/A			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: SUPPORT STRUCTURE WELDMENT	WEIGHT: 0.34 LBS
		DRAWN BY: DV	DESCRIPTION: SUPPORT BRACE	VPS_510
		CHECKED BY: --	SHEET 20OF 20 DO NOT SCALE DRAWING	

Preliminary Manufacturing Drawing Package

End Effector

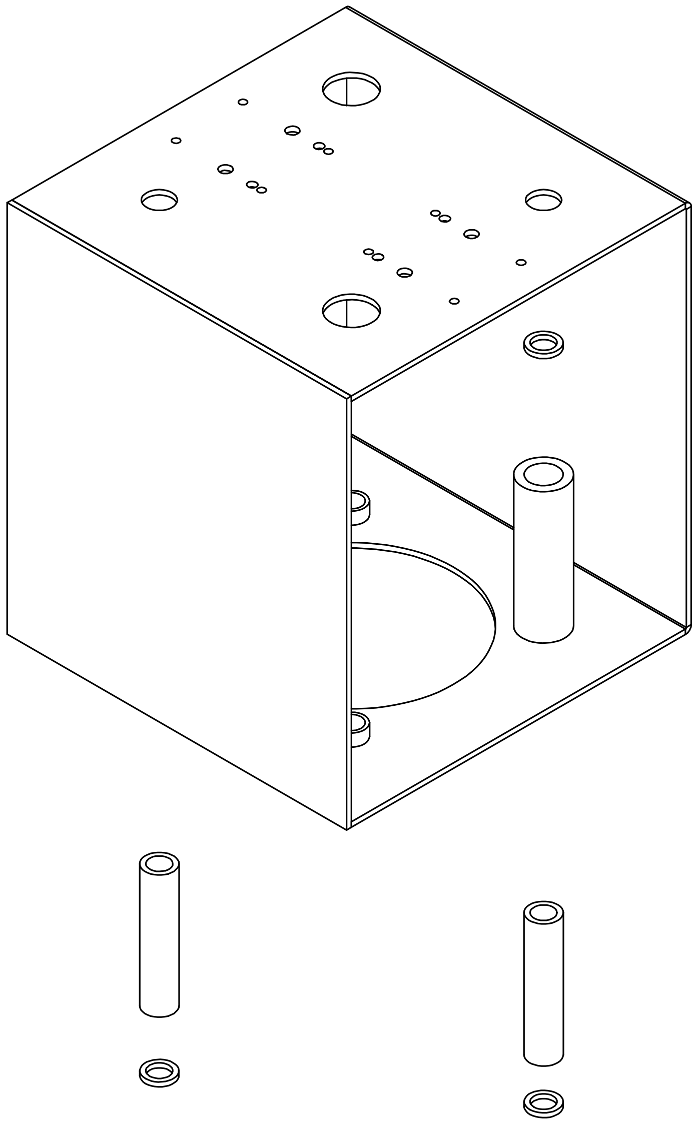
Appendix D

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-726-R00-CM	Motor to Box	1
2	EDF-508-R00-CM	Quick Detach Pins	4
3	EDF-702-R00-CM	Mounting Bracket	1
4	EDF-201-R00-Cm	Danier F17080DN	2
5	EDF-703-R00-CM	Box Assembly	1



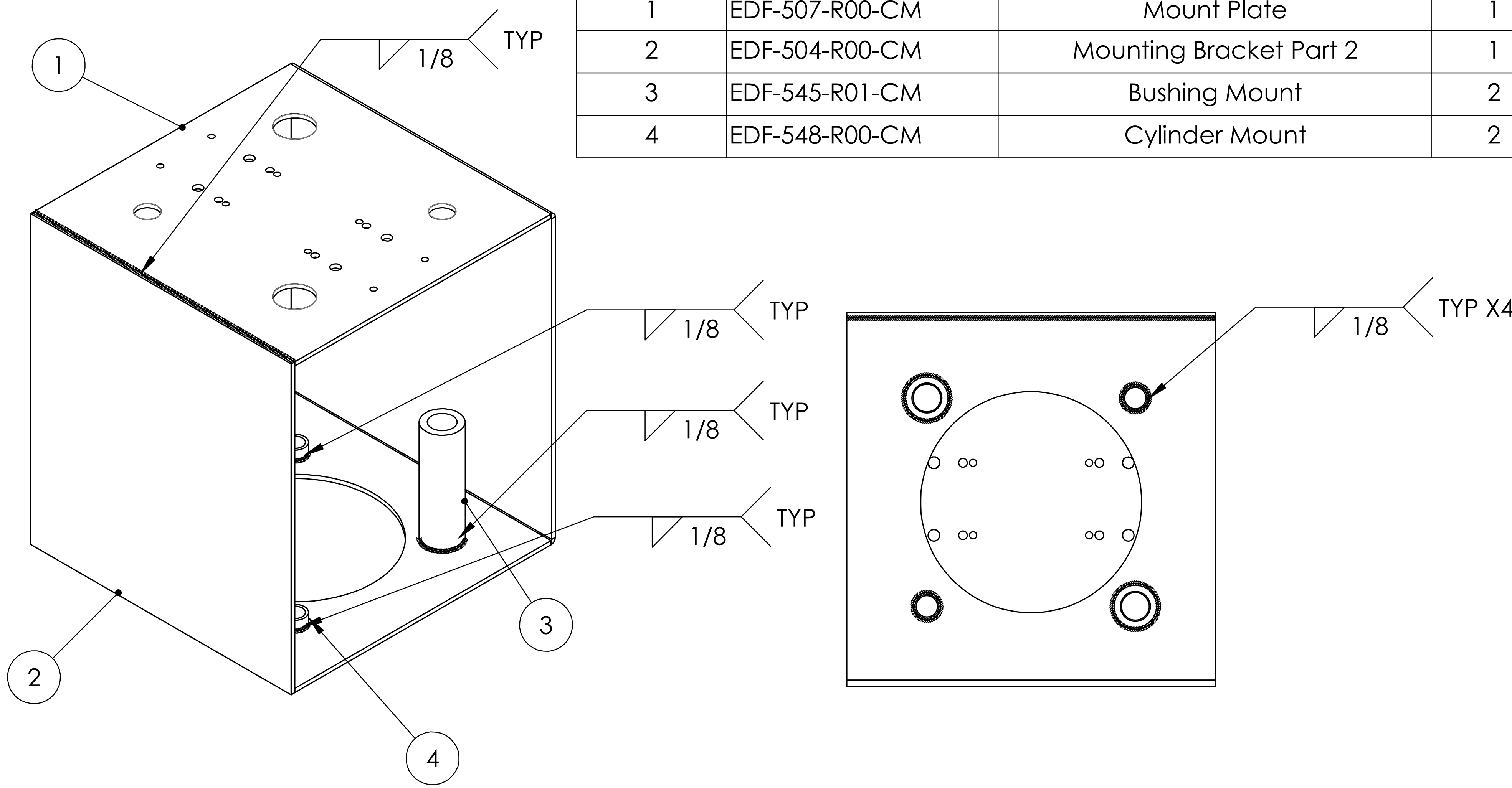
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM FINISH: AS SHOWN	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: -- SCALE: 1:10
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: CM CHECKED BY: --	USED WITH: N/A DESCRIPTION: GRIPPER ASSEMBLY SHEET 1 OF 31 DO NOT SCALE DRAWING	WEIGHT: 93.53LBS EFD_724

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-800-R00-CM	Mounting Bracket	1
2	EDF-546-R00-CM	UHMW Bushings	2
3	EDF-211-R01-CM	BW-005625 Wiper Seal	4



DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM	UNIVERSITY OF MANITOBA HYLIFE FOODS	NEXT ASSY:EDF_726
	FINISH: N/A		SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: GRIPPER BOX	WEIGHT: 18.32lbs
	FIRST ISSUED: 11/28/2018	DESCRIPTION: MOUNTING ASSMEBLY	EDF_702
	DRAWN BY: CM	SHEET 2 OF 31	DO NOT SCALE DRAWING
	CHECKED BY: --		

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-507-R00-CM	Mount Plate	1
2	EDF-504-R00-CM	Mounting Bracket Part 2	1
3	EDF-545-R01-CM	Bushing Mount	2
4	EDF-548-R00-CM	Cylinder Mount	2



DIMENSIONAL UNIT:
INCHES

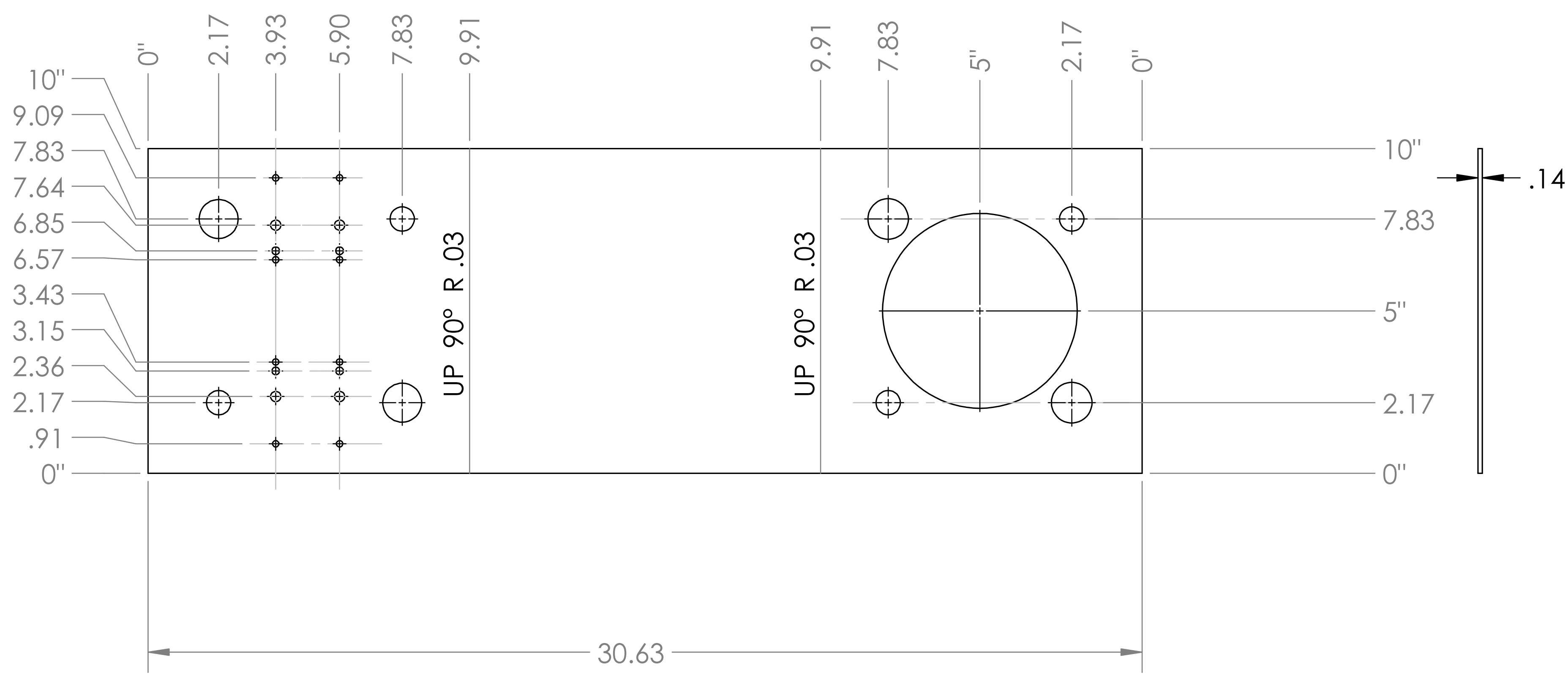
UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL:	316SS	FINISH:	N/A
SIZE A4	FIRST ISSUED: 28/11/2018	DRAWN BY: CM	CHECKED BY: --

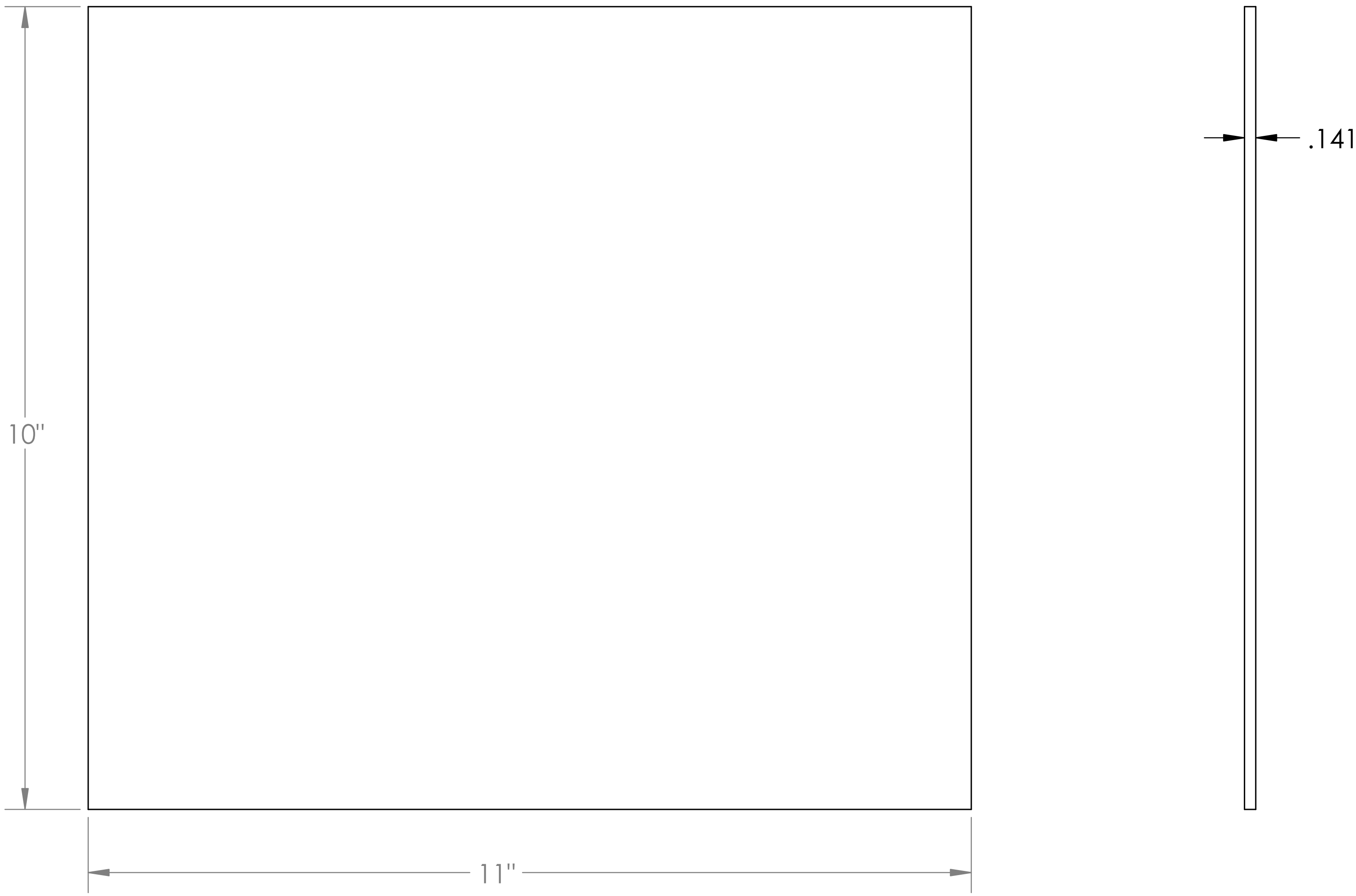
UNIVERSITY OF MANITOBA HYLIFE FOODS

USED WITH: MOUNTING BOX
DESCRIPTION: Mounting Box Weldments
SHEET 3 OF 31 DO NOT SCALE DRAWING

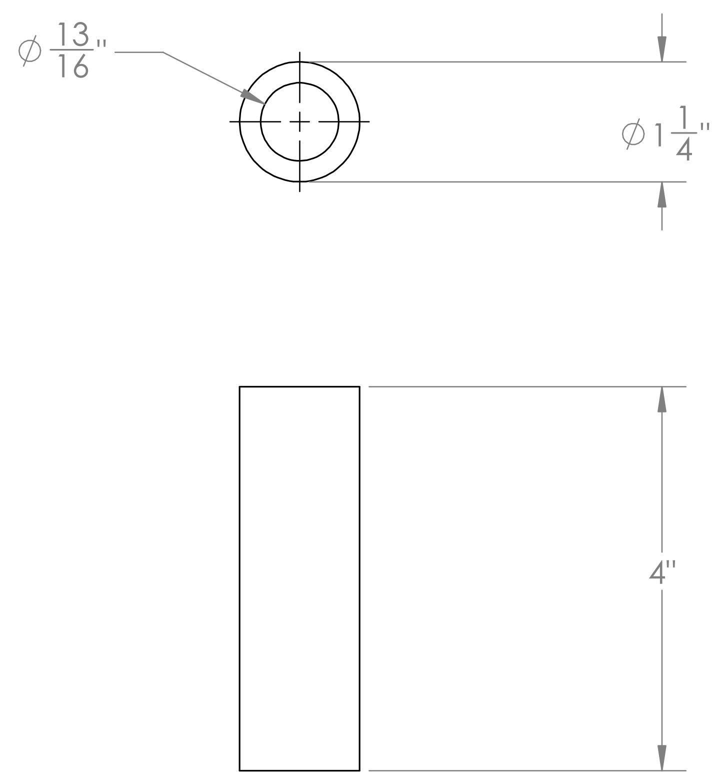
NEXT ASSY: EDF_702
SCALE: 1:1
WEIGHT: 17.12lbs
EDF_800



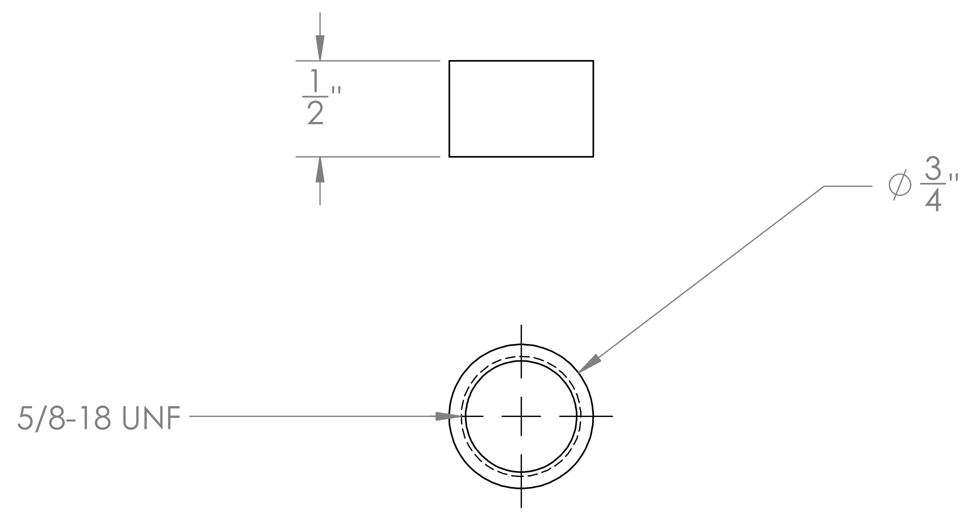
DIMENSIONAL UNIT: INCHES	MATERIAL: 10 GAUGE 316SS	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_800
	FINISH: AS PROCESSED		SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: MOUNTING ASSEMBLY	WEIGHT: 11.4LBS
	FIRST ISSUED: 27/11/2018	DESCRIPTION: MOUNTING BOX	EDF_507
	DRAWN BY: CM	SHEET 4 OF 31	DO NOT SCALE DRAWING
	CHECKED BY: --		



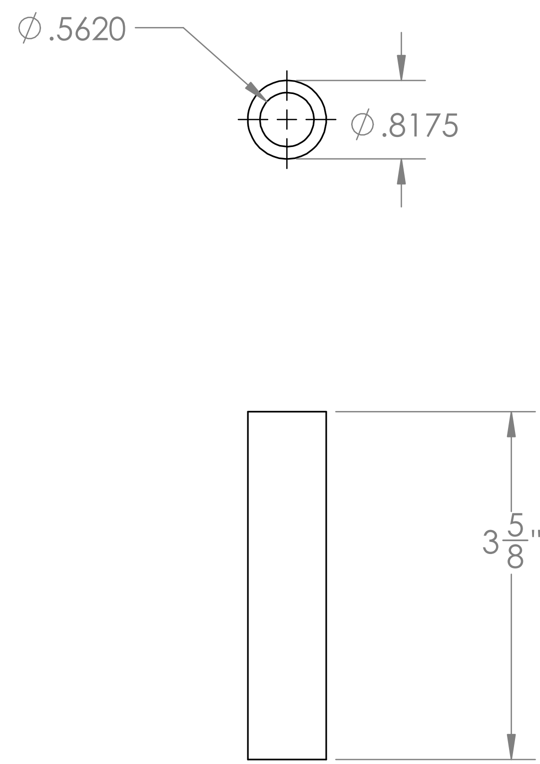
DIMENSIONAL UNIT: INCHES	MATERIAL: 10 GAGE 316SS		UNIVERSITY OF MANITOBA HYLIFE FOODS	NEXT ASSY:EDF_800
	FINISH: AS PROCESSED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: MOUNTING BOX ASSEMBLY	WEIGHT: 4.48LBS
		DRAWN BY: CM	DESCRIPTION: MOUNTING ASSEM PLATE	EDF_504
		CHECKED BY: --	SHEET 5 OF 31 DO NOT SCALE DRAWING	



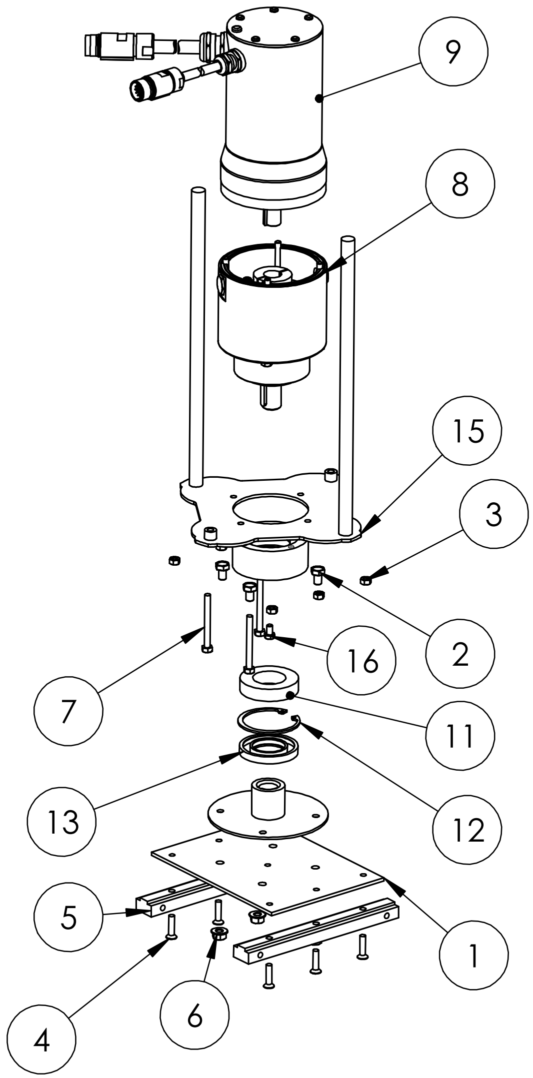
DIMENSIONAL UNIT: INCHES	MATERIAL:	316SS		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: EDF_800
	FINISH:	AS MACHINED				SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH:	MOUNTING BOX ASSEMBLY	WEIGHT: 0.289LBS
		DRAWN BY:	CM	DESCRIPTION:	BUSHING TUBES	EDF_545
		CHECKED BY:	--	SHEET 6 OF 31	DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_800
	FINISH: AS MACHINED				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH: MOUNTING BOX ASSSEMBLY	WEIGHT: 0.026LBS
		DRAWN BY:	CM	DESCRIPTION: CYLINDER NOSE MOUNTS	EDF_548
		CHECKED BY:	--	SHEET 7 OF 31 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: UHMW PE			NEXT ASSY:EDF_702
	FINISH: AS MACHINED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: MOUNTING ASSEMBLY	WEIGHT: 0.037LBS
		DRAWN BY: CM	DESCRIPTION: UHMW PE BUSHINGS	EDF_546
		CHECKED BY: --	SHEET 8 OF 31 DO NOT SCALE DRAWING	



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-503-R00-CM	Box Mount Plate	1
2	M8 x 1.25 x 12 --12WN	M8 x1.25-12 Bolt	4
3	M8 x 1.25 --N	M8 x 1.25 Nut	4
4	Flat Head M6 x 1.0 x 25	Flat Head M6 x 1 x 25	6
5	EDF-526-R00-CM	Quick deatch guides male side	2
6	M6 x 1	M6 Nut	6
7	M6 x 1.0 x 60	M6 x 1.0 x 60	4
8	AQT080-005-0-MMR-612	10:1 Gear Head	1
9	MPS-x330x-xJ52DA	MP-Series stainless-steel motors	1
10	EDF-542-R00-CM	Bearing Case	1
11	EDF-202-R00-CM	NTN 6007 Bearing	1
12	B27.1 - NA2-244	Retaining Ring	1
13	EDF-205-R00-CM	SKF 35x62x8 Seal	1
14	EDF-801-R00-CM	Torque Transfer Coupling	1
15	EDF-802-R00-CM	Vertical Guides Mount	1
16	M6 x 1.0 x 10	M6 x 1.0 x 10 Bolt	1

DIMENSIONAL UNIT: INCHES

UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL: SEE BOM
FINISH: N/A

SIZE A4

FIRST ISSUED: 11/28/2018
DRAWN BY: CM
CHECKED BY: --

UNIVERSITY OF MANITOBA — HYLIFE FOODS

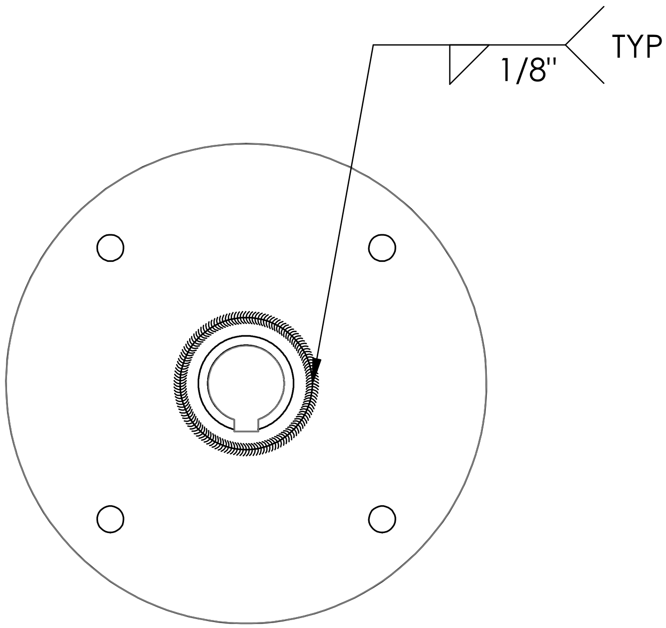
USED WITH: END EFFECTOR
DESCRIPTION: MOTOR MOUNTING

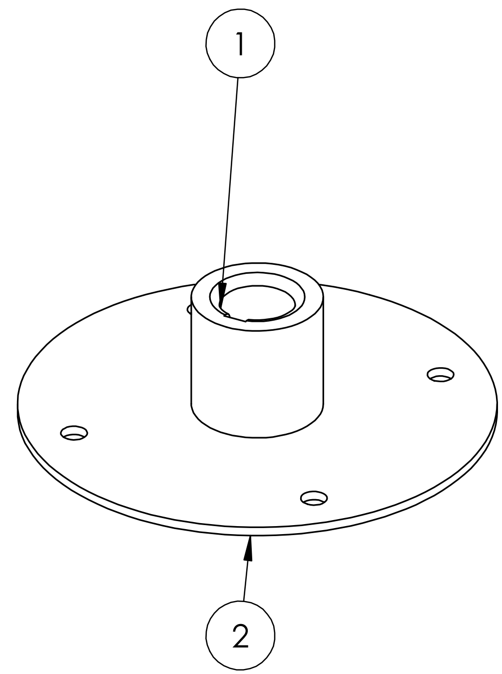
SHEET 9 OF 31 DO NOT SCALE DRAWING

NEXT ASSY:EDF_724
SCALE: 1:8
WEIGHT: 36.81LBS

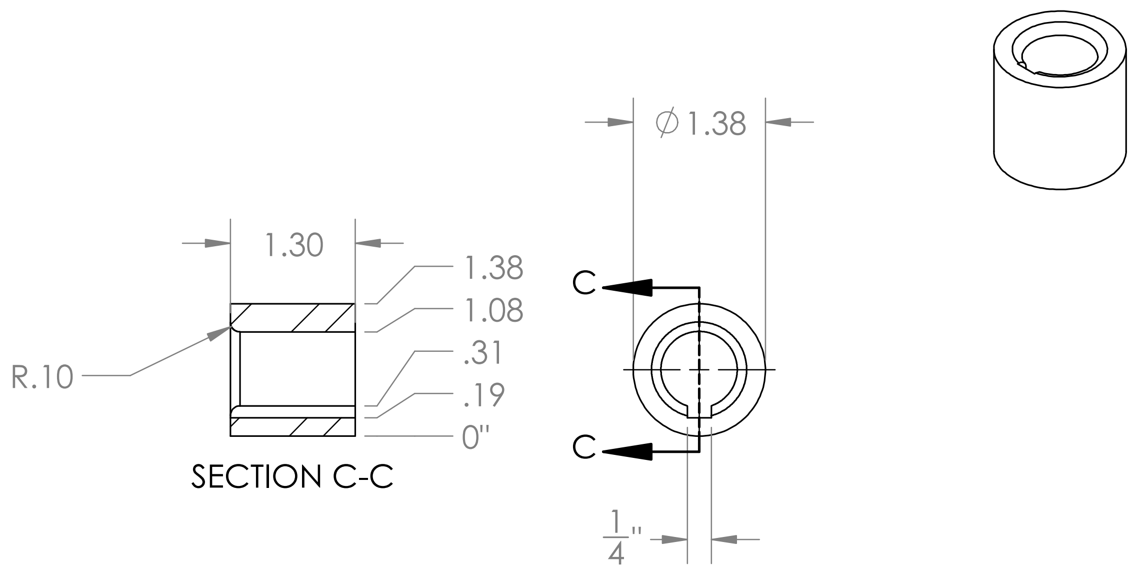
EDF_726

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-532-R01-CM	Internally Keyed Shaft	1
2	EDF-533-R01-CM	Torque Plate	1

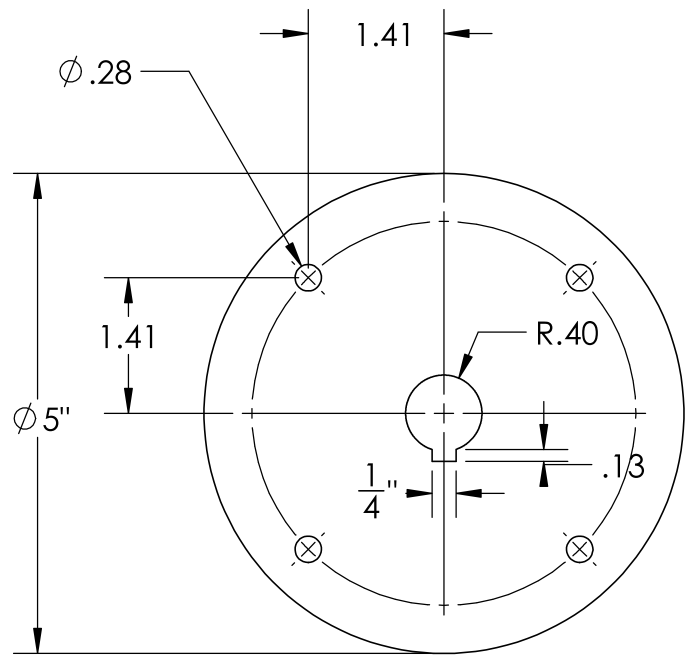




DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_726
	FINISH: N/A		SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: BOX MOUNT ASSEM	WEIGHT:3.15LBS
	FIRST ISSUED: 11/28/2018	DESCRIPTION: TORQUE COUPLING SHAFT	EDF_801
	DRAWN BY: CM		
	CHECKED BY: --	SHEET 10OF 31 DO NOT SCALE DRAWING	

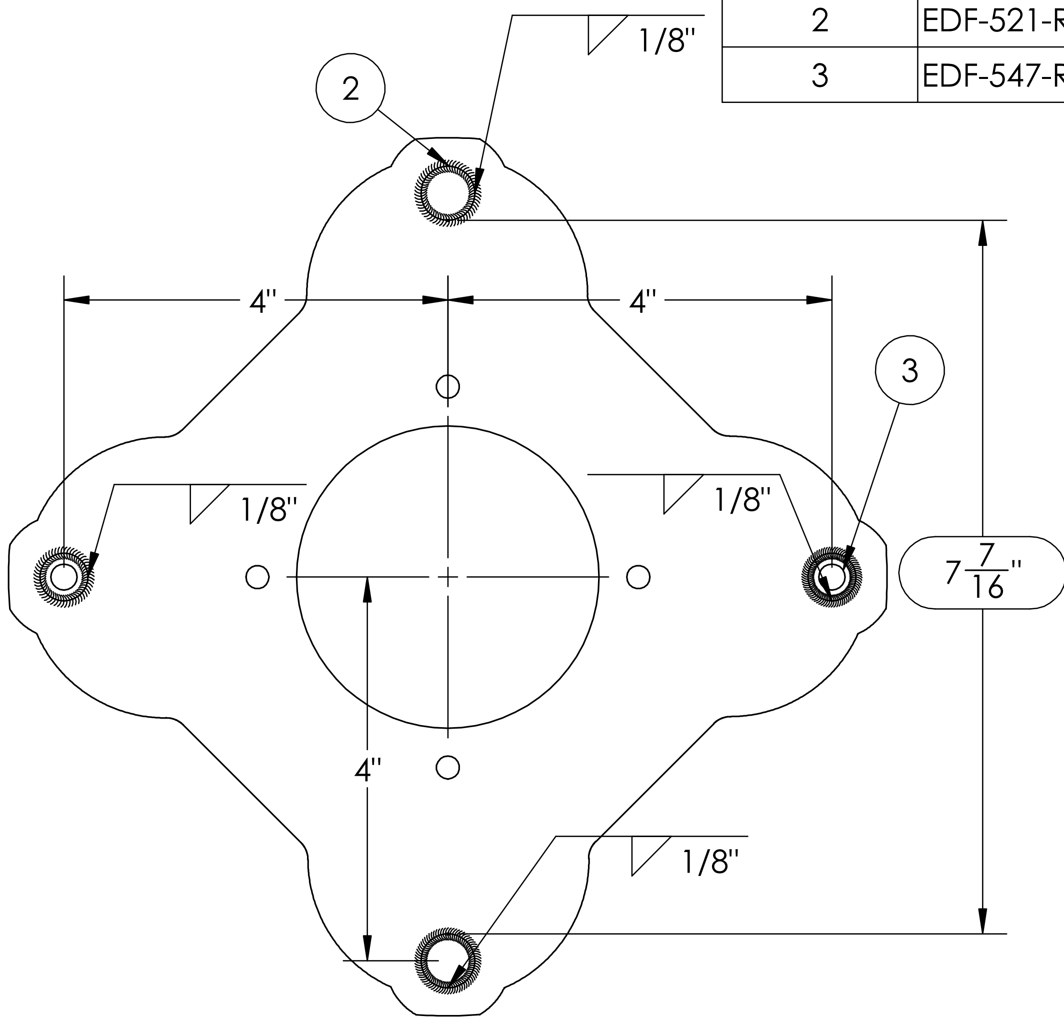


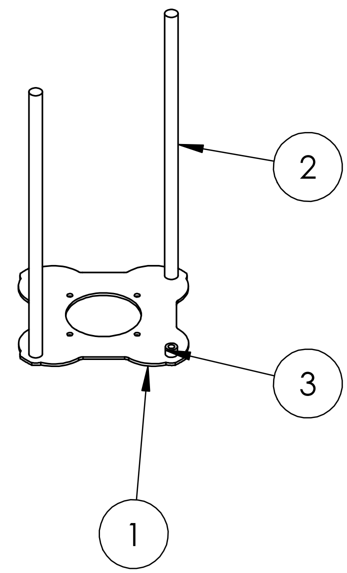
DIMENSIONAL UNIT: INCHES	MATERIAL: SS316		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_801
	FINISH: AS MACHINED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: TORQUE COUPLING SHAFT	WEIGHT: 0.36LBS
		DRAWN BY: CM	DESCRIPTION: INERNALLY KEYED SHAFT	EDF_532
		CHECKED BY: --	SHEET 11OF 31 DO NOT SCALE DRAWING	



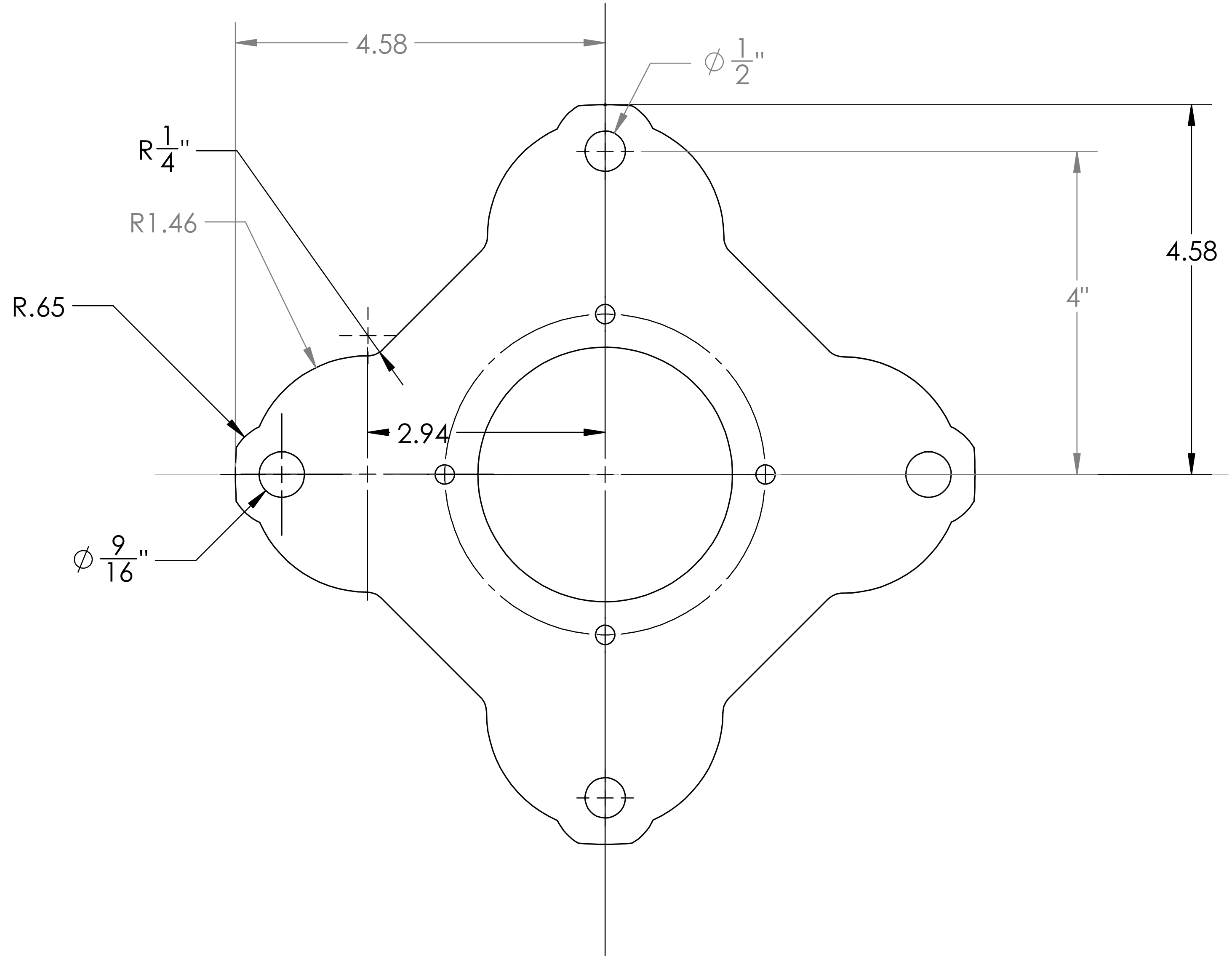
DIMENSIONAL UNIT: INCHES		MATERIAL: SS316		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_801
		FINISH: AS MACHINED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH: TOURQUE COUPLING ASSEMBLY	WEIGHT: 0.55LBS
		DRAWN BY:	CM	DESCRIPTION: MOUNTING PLATE	EDF_533
		CHECKED BY:	--	SHEET 12OF 31 DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-534-R01-CM	Motor Face Mount	1
2	EDF-521-R00-CM	Vertical Guide Rod	2
3	EDF-547-R00-CM	Pneumatic Rod Mount	2

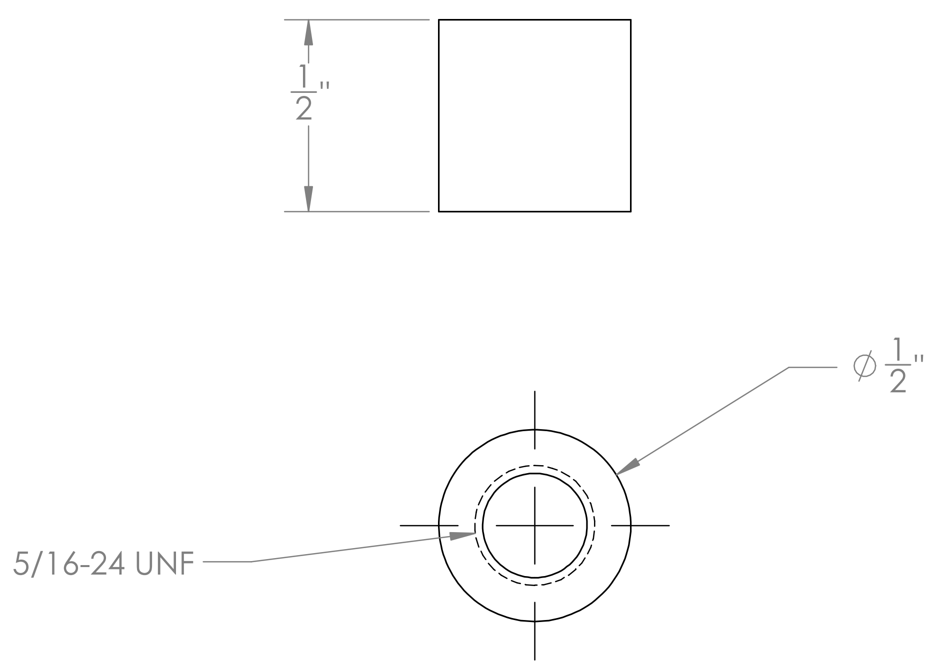




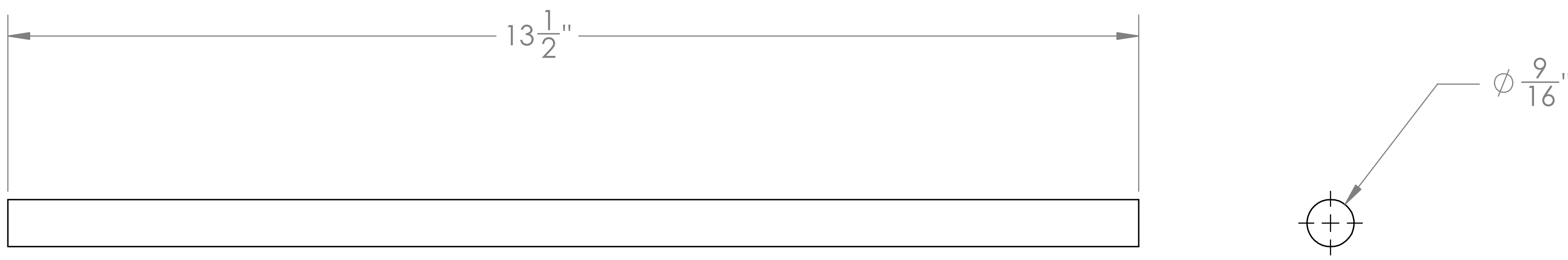
DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS	FINISH: N/A	UNIVERSITY OF MANITOBA · HYLIFE FOODS		NEXT ASSY:EDF_726
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: MOTOR MOUNTING		SCALE: 1:2
		DRAWN BY: CM	DESCRIPTION: VERTICAL GUIDE RODS MOUNTS		WEIGHT: 3.24LBS
		CHECKED BY: --	SHEET 13OF 31	DO NOT SCALE DRAWING	EDF_802



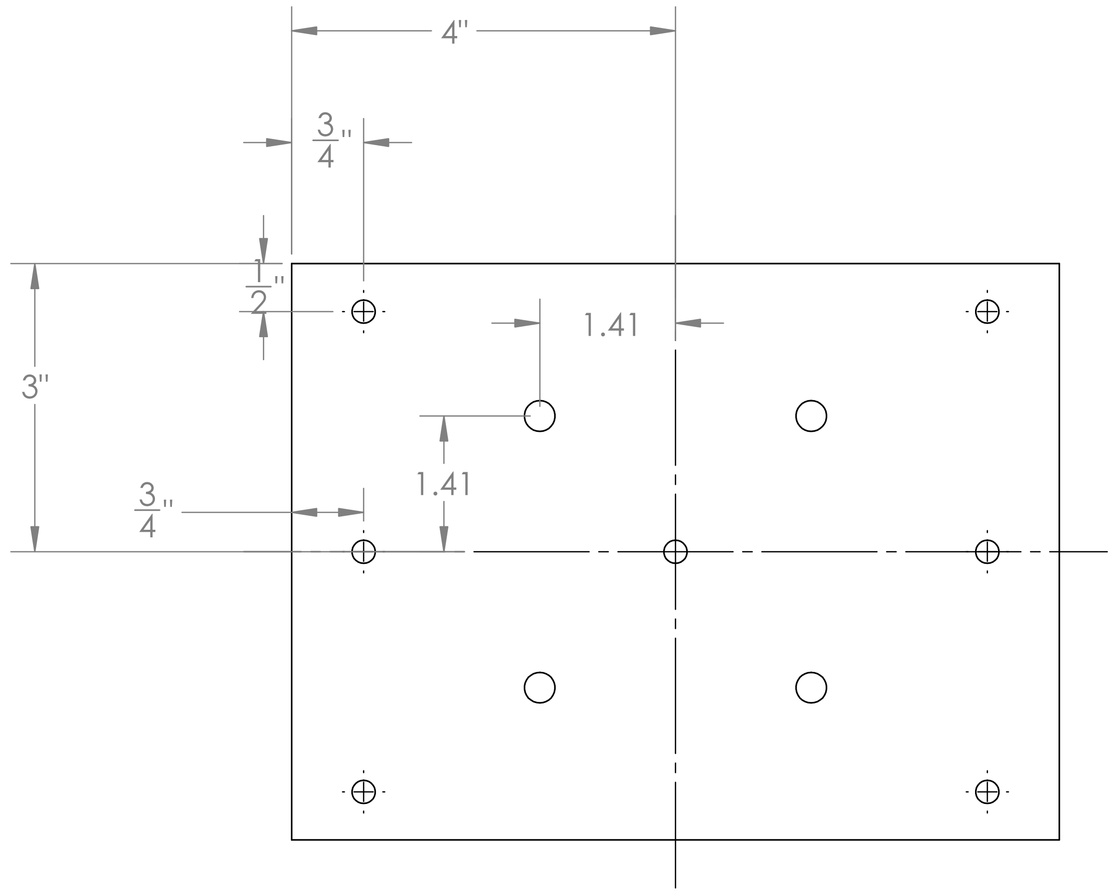
DIMENSIONAL UNIT: INCHES	MATERIAL: SS316	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_802
	FINISH: AS PROCESSED		SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 — FIRST ISSUED: 27/11/2018	USED WITH: VERTICAL GUIDE WELDMENT	WEIGHT: 1.28LBS
	DRAWN BY: CM	DESCRIPTION: MOTOR MOUNT PLATE	EDF_534
	CHECKED BY: --	SHEET 14OF 31 DO NOT SCALE DRAWING	



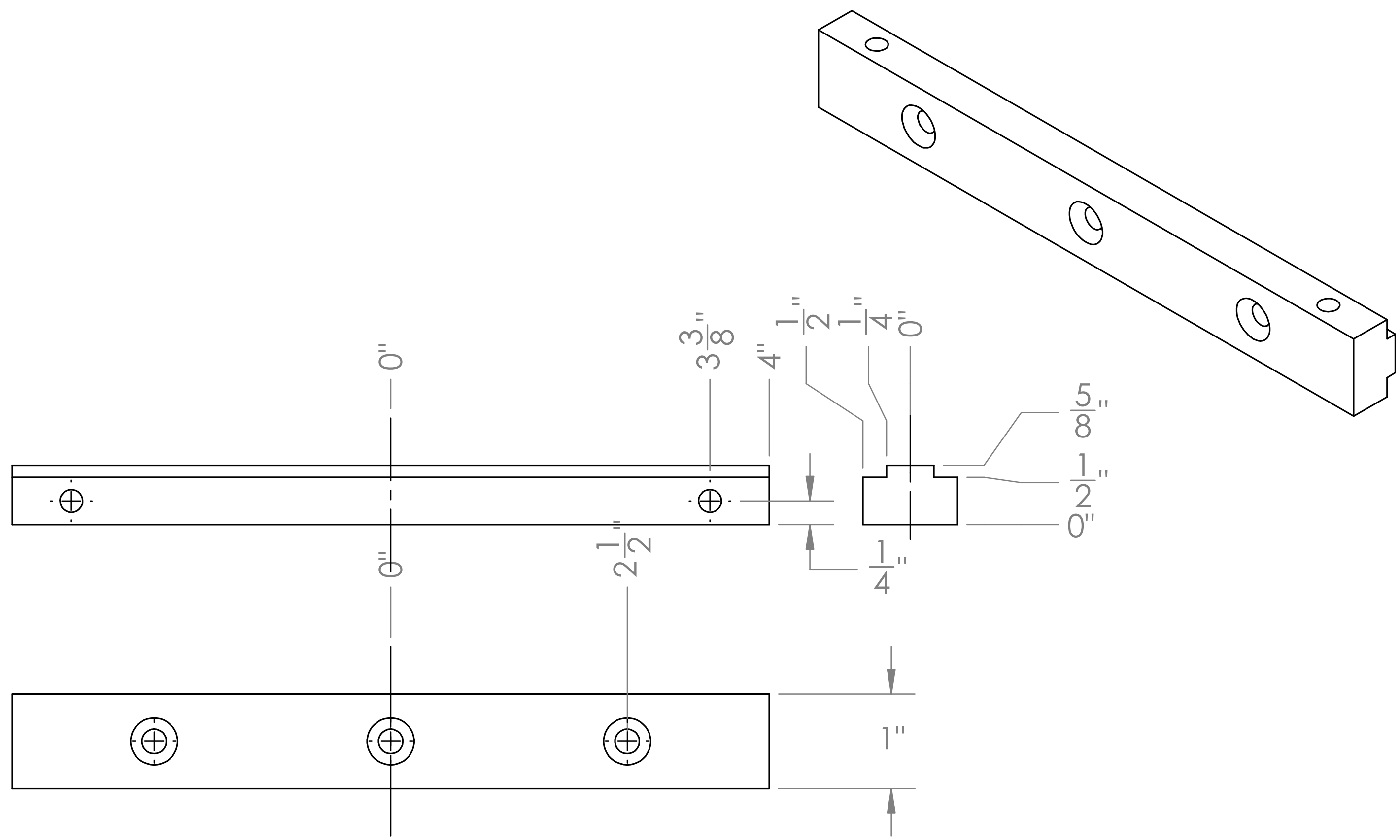
DIMENSIONAL UNIT: INCHES	MATERIAL: SS316	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_802
	FINISH: AS MACHINED		SCALE: 2:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 27/11/2018 DRAWN BY: CM CHECKED BY: --	USED WITH: MOTOR MOUNT ASSEMBLY DESCRIPTION: CYLINDER ROD MOUNT SHEET 15OF 31 DO NOT SCALE DRAWING	WEIGHT: 0.02LBS EDF_547



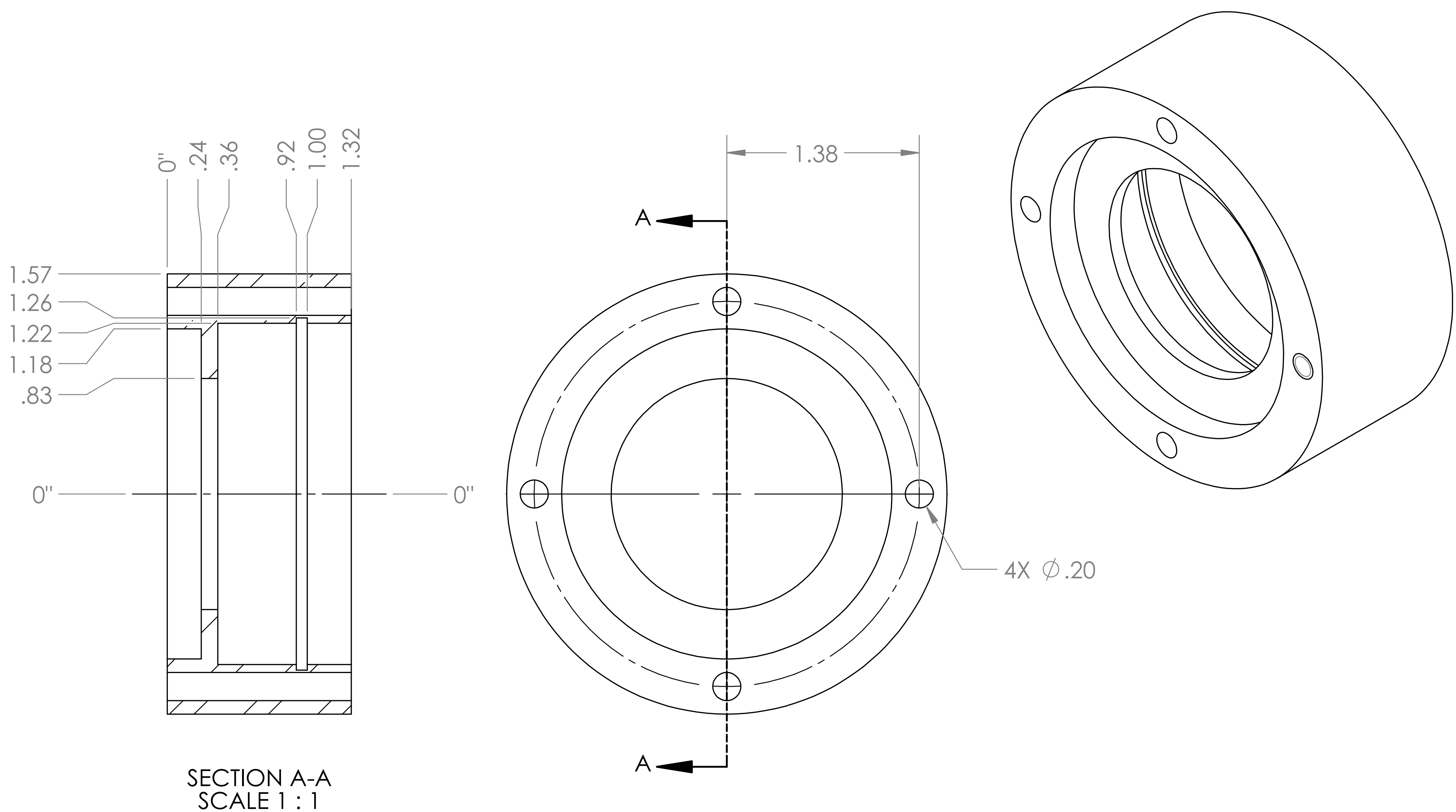
DIMENSIONAL UNIT: INCHES	MATERIAL: SS316		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_802
	FINISH: 32			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: MOTOR MOUNT ASSEMBLY	WEIGHT: 0.97LBS
		DRAWN BY: CM	DESCRIPTION: GUIDES TO RUN IN BUSHINGS	**EDF_521**
		CHECKED BY: --	SHEET 16OF 31 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: SS316			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_726
	FINISH: AS PROCESSED				SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH: MOTOR MOUNTING	WEIGHT: 1.93LBS
		DRAWN BY:	CM	DESCRIPTION:QUICK DETACH MOUNTING PLATE	EDF_503
		CHECKED BY:	--	SHEET 17OF 31 DO NOT SCALE DRAWING	

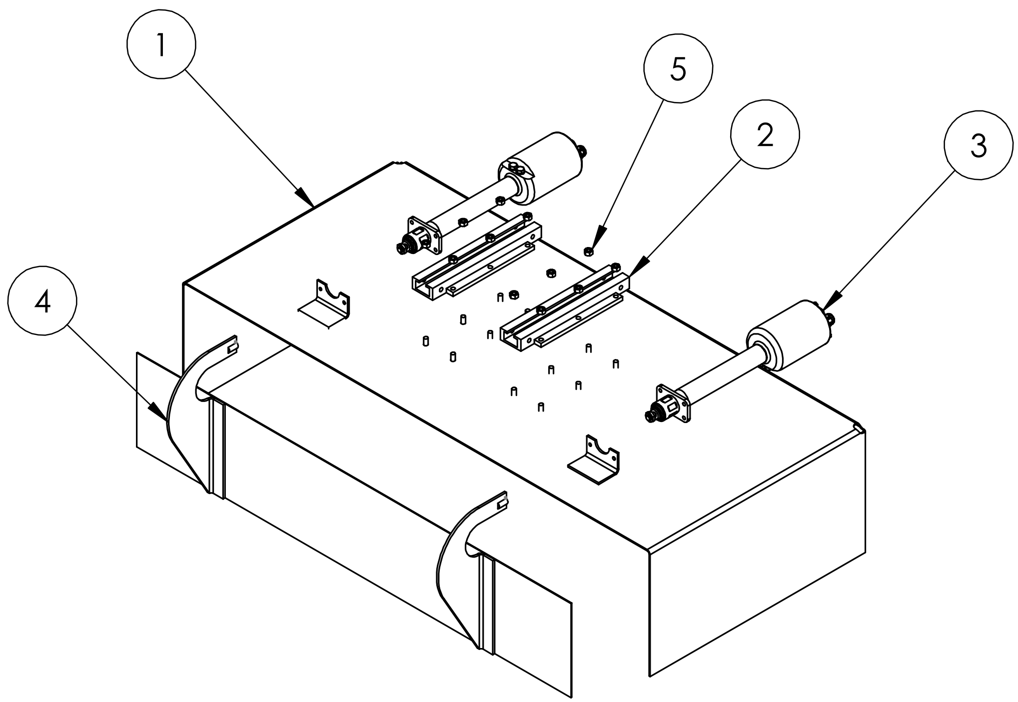


DIMENSIONAL UNIT: INCHES	MATERIAL: UHMW PE			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_726
	FINISH: As Machined				SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH: Box Assembly	WEIGHT: 0.16LBS
		DRAWN BY:	CM	DESCRIPTION: Mating Guides Male Side	EDF_526
		CHECKED BY:	--	SHEET 18OF 31 DO NOT SCALE DRAWING	



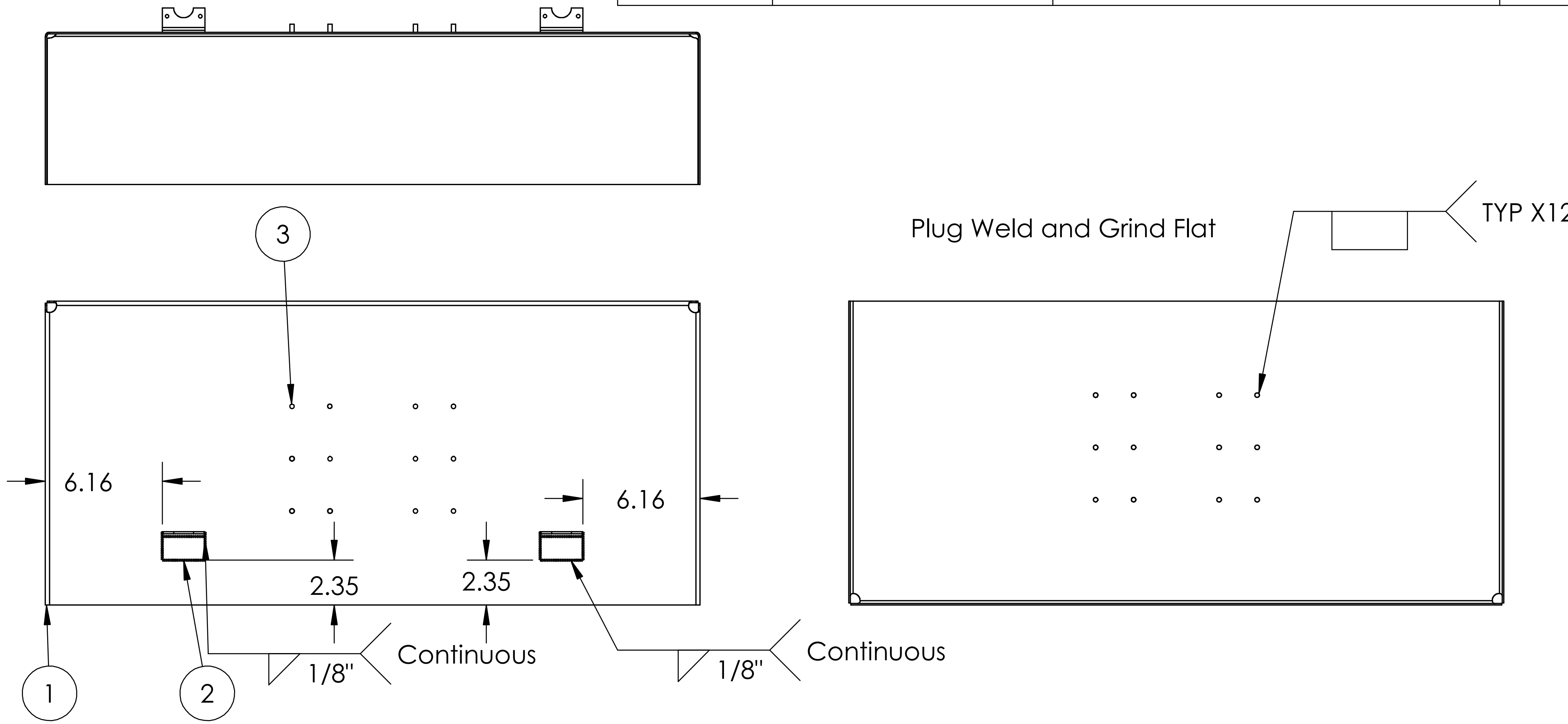
DIMENSIONAL UNIT: INCHES	MATERIAL:	SS316	UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: EDF_726
	FINISH:	AS MACHINED			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH:	MOTOR MOUNT	WEIGHT: 1.23LBS
		DRAWN BY: CM	DESCRIPTION:	BEARING MOUNT	
		CHECKED BY: --	SHEET 19OF 31	DO NOT SCALE DRAWING	EDF_504

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-803-R00-CM	Box with welded parts	1
2	EDF-525-R00-CM	Female Box Split Mounts	2
3	EDF-207-R00-CM	ERD SS2 Actuator	2
4	EDF-805-R00-CM	Meat Wall	1
5	B18.2.4.2M - Hex nut, Style 2, M6 x 1 --D-N		12

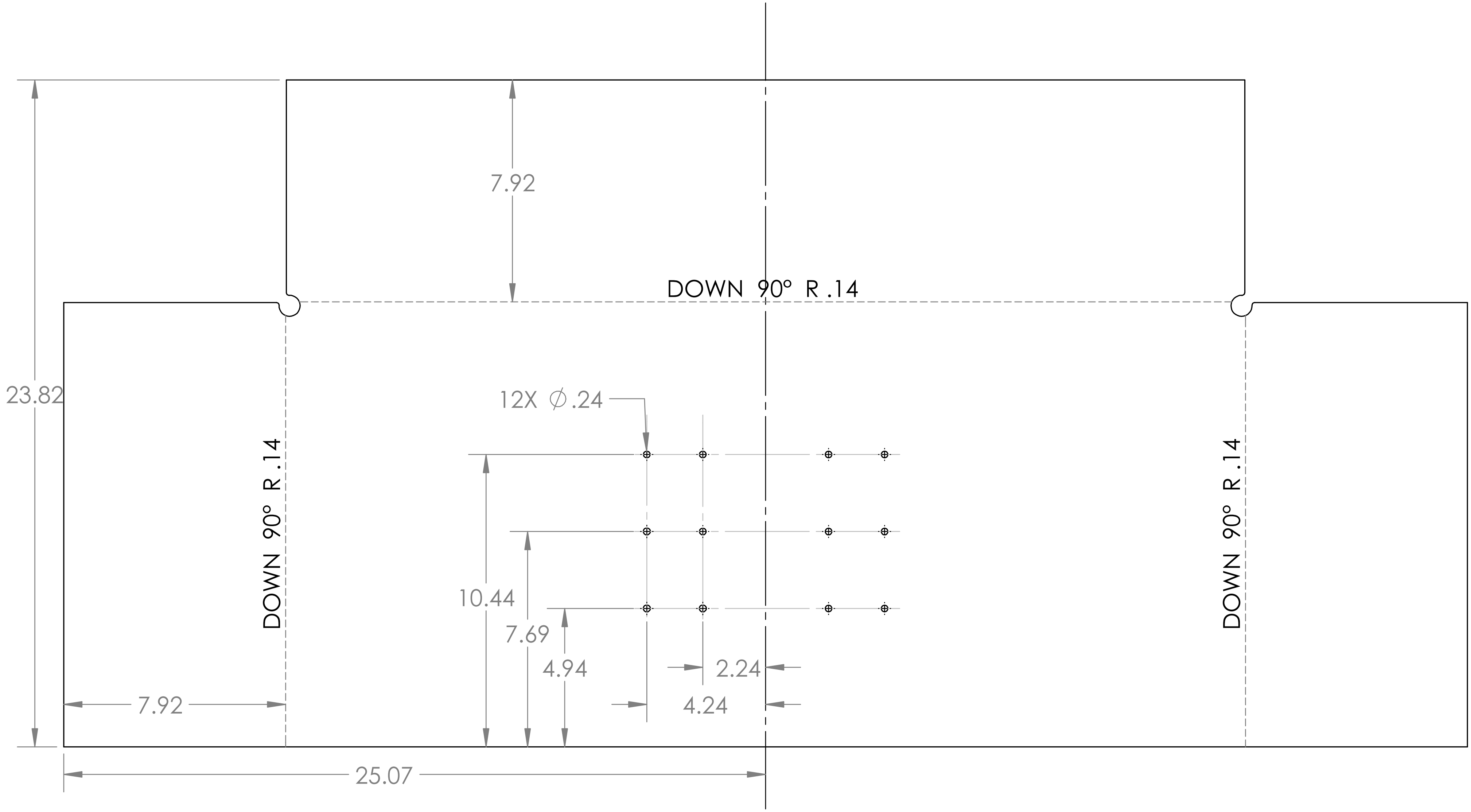


DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF_724
	FINISH: N/A			SCALE: 1:20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 28/11/2018	USED WITH: GRIPPER ASSEMBLY	WEIGHT: 38.77LBS
		DRAWN BY: CM	DESCRIPTION: BOX ASSEMBLY	EDF_703
		CHECKED BY: --	SHEET 20OF 31 DO NOT SCALE DRAWING	

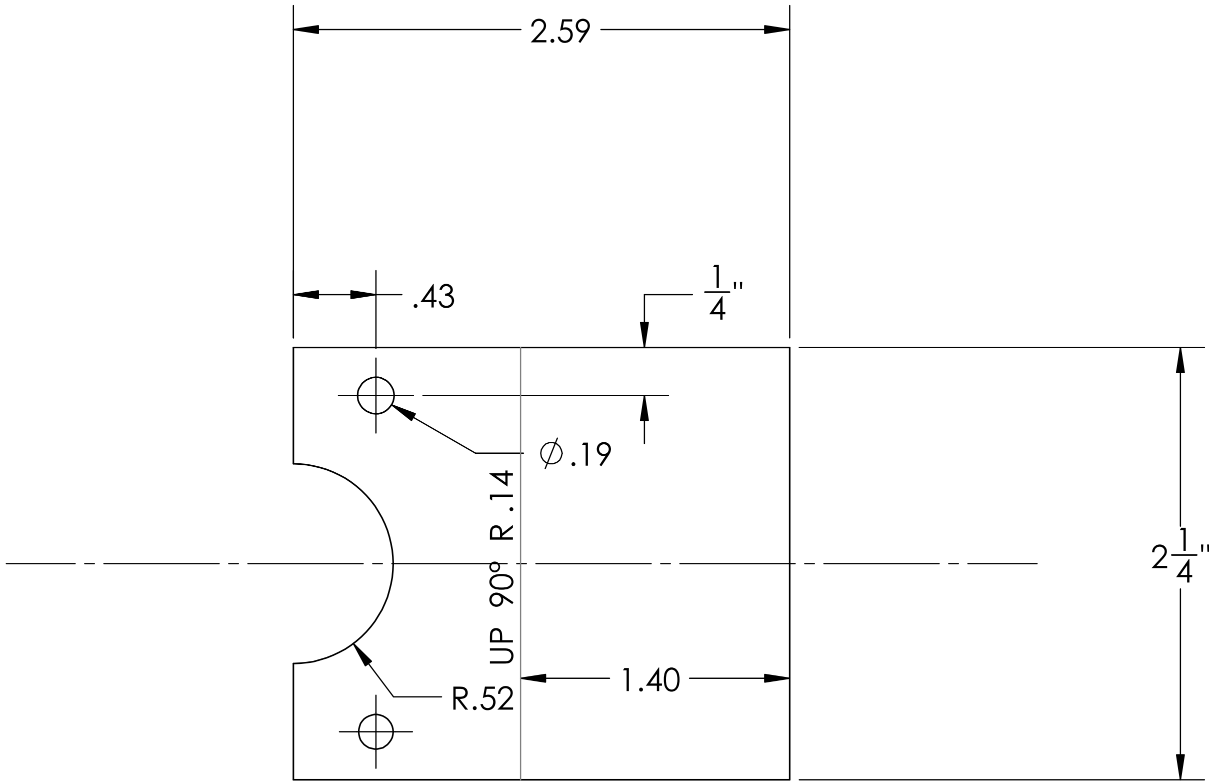
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-500-R01-CM	Meat Box	1
2	EDF-511-R00-CM	Actuator Mounts	2
3	EDF-549-R00-CM	Mounting Studs	12



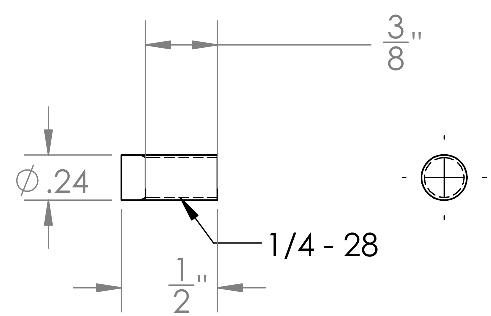
DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_703
	FINISH: 32			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 28/11/2018	USED WITH: BOX ASSEMBLY	WEIGHT: 24.45LBS
		DRAWN BY: CM	DESCRIPTION: BOX WELDMENT	EDF_803
		CHECKED BY: --	SHEET 21OF 31 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: SS316			NEXT ASSY:EDF_803
	FINISH: 125			SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: BOX WELDMENTS	WEIGHT: 24.03
		DRAWN BY: CM	DESCRIPTION: EDF-501-R00-CM01	EDF_500
		CHECKED BY: --	SHEET 22OF 31 DO NOT SCALE DRAWING	

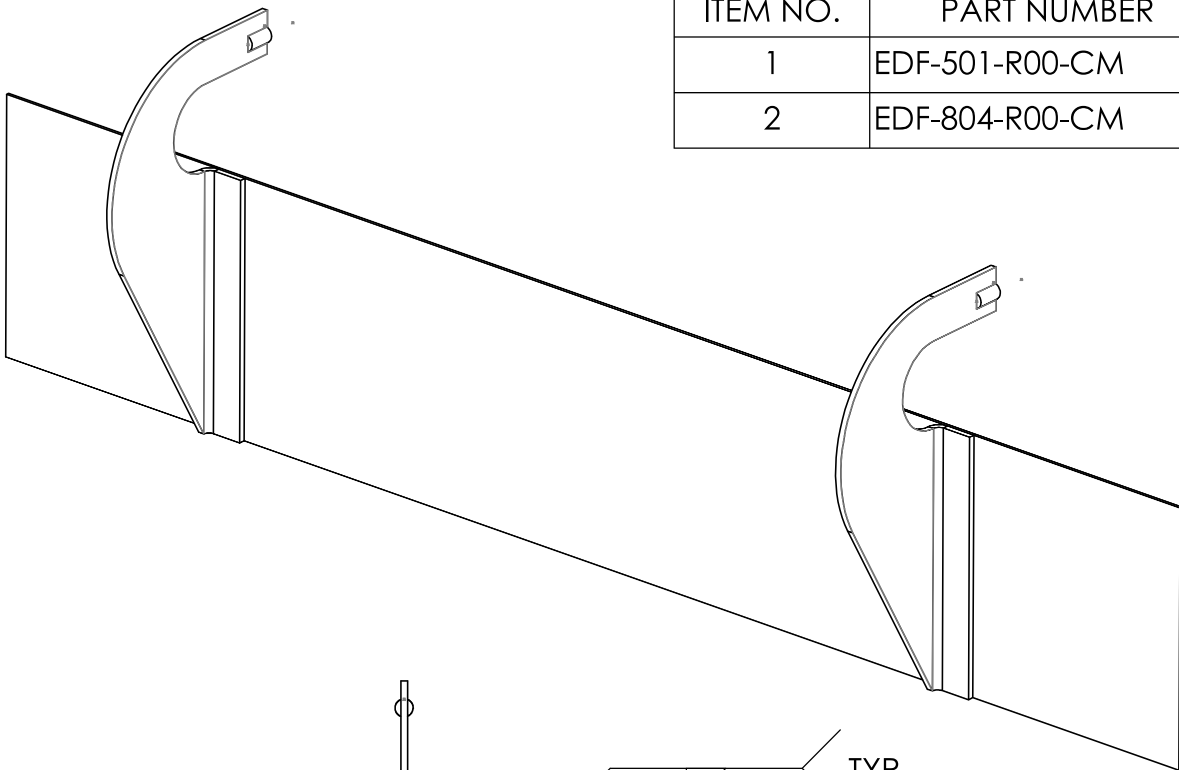


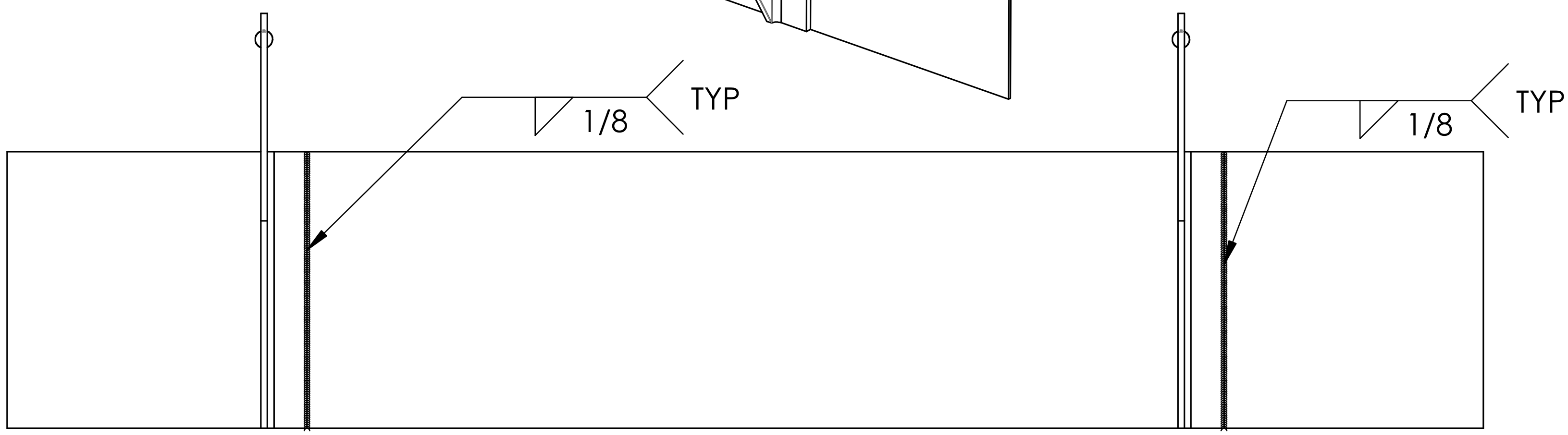
DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_803
	FINISH: AS PROCESSED		SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: BOX WELDMENTS	WEIGHT: 0.17LBS
	FIRST ISSUED: 27/11/2018	DESCRIPTION: LINEAR ACTUATOR NOSE MOUNT	EDF_511
	DRAWN BY: CM	SHEET 23OF 31	
	CHECKED BY: --	DO NOT SCALE DRAWING	



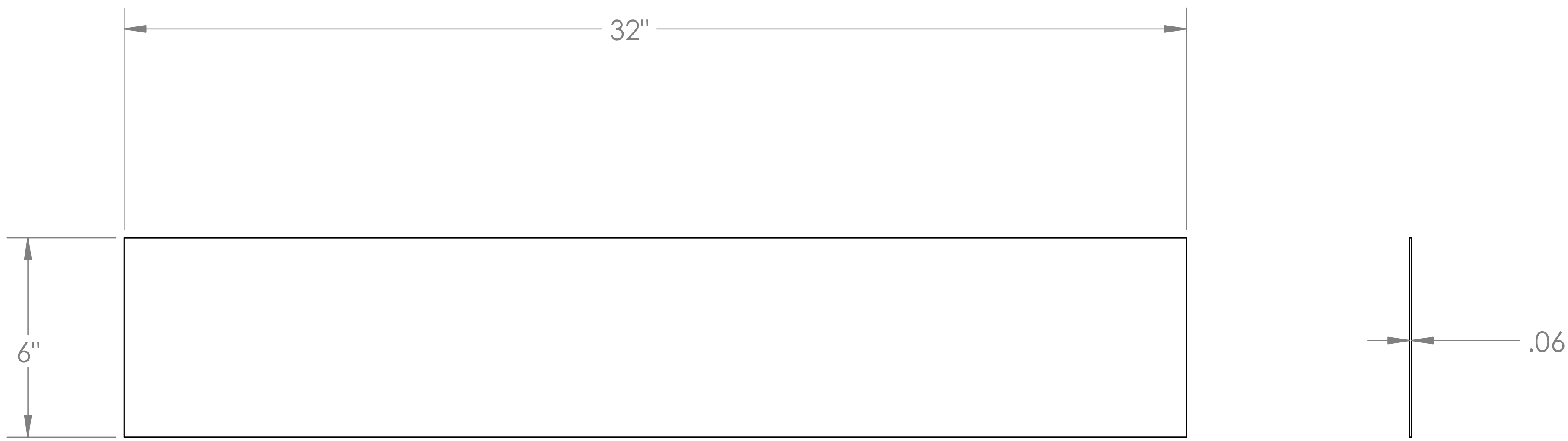
DIMENSIONAL UNIT: INCHES	MATERIAL:	316SS	UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: EDF_703
	FINISH:	AS MACHINED			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH:	BOX WELDMENT	WEIGHT: 0.01LBS
		DRAWN BY: CM	DESCRIPTION:	ACTUATOR PISTON MOUNT	EDF_549
		CHECKED BY: --	SHEET 24OF 31	DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-501-R00-CM	Adjustable Plate	1
2	EDF-804-R00-CM	Actuator Mounting Assembly	2



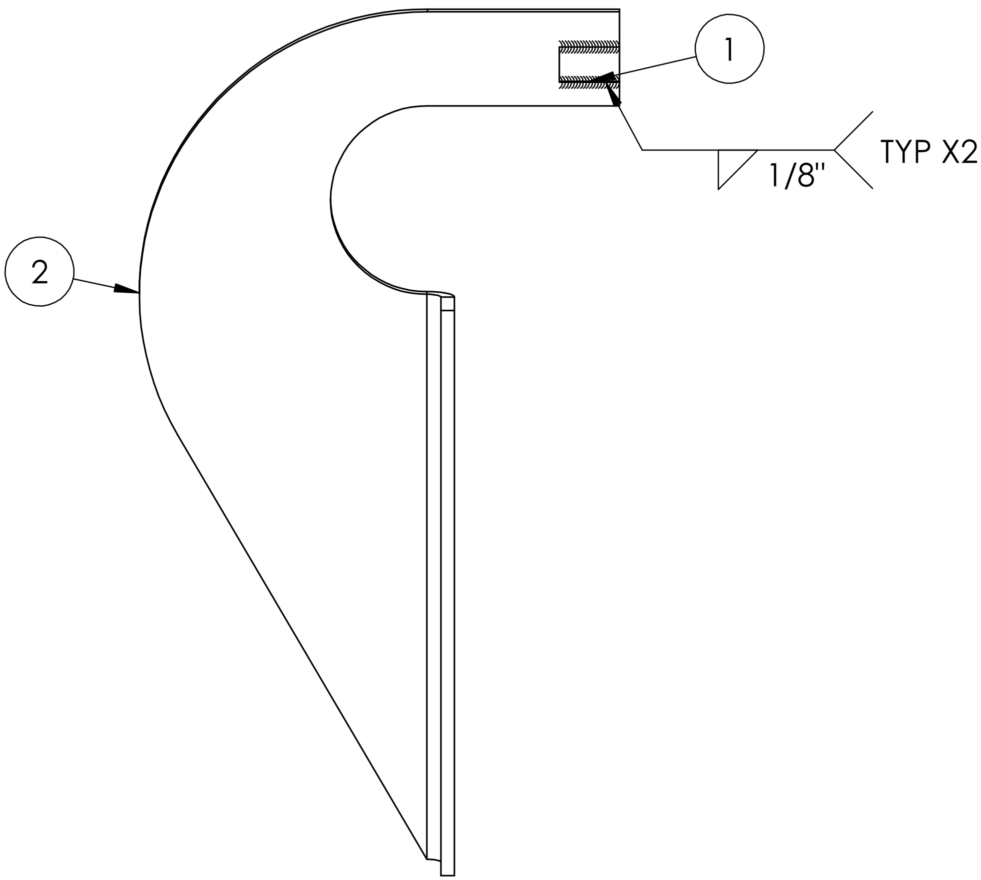


DIMENSIONAL UNIT: INCHES	MATERIAL:	SEE BOM		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF-803
	FINISH:	N/A			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/29/2018	USED WITH: BOX ASSEMBLY	WEIGHT: 5.4LBS
		DRAWN BY:	CM	DESCRIPTION:ADJUSTABLE PLATE ASSEMBLY	EDF_805
		CHECKED BY:	--	SHEET 25OF 31 DO NOT SCALE DRAWING	

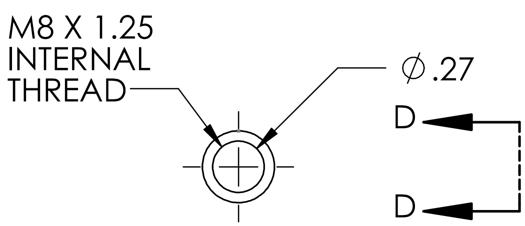


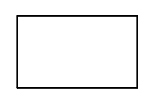
DIMENSIONAL UNIT: INCHES	MATERIAL: 16GAUGE 316SS		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_805
	FINISH: AS PROCESSED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: ADJUSABLE PLATE ASSEMBLY	WEIGHT: 3.5LBS
		DRAWN BY: CM	DESCRIPTION: EDF-501-R00-CM	EDF_501
		CHECKED BY: --	SHEET 26OF 31 DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-510-R00-CM	Actuator Mount	1
2	EDF-502-R01-CM	Closing Plate Mounts	1

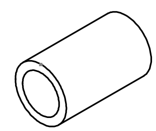


DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM FINISH: AS PROCESSED	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_805 SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/29/2018 DRAWN BY: CM CHECKED BY: --	USED WITH: ADJUSTABLE PLATE ASSEM DESCRIPTION: ADJUSTABLE PLATE MOUNT SHEET 27OF 31 DO NOT SCALE DRAWING	WEIGHT: 0.95LBS EDF_804

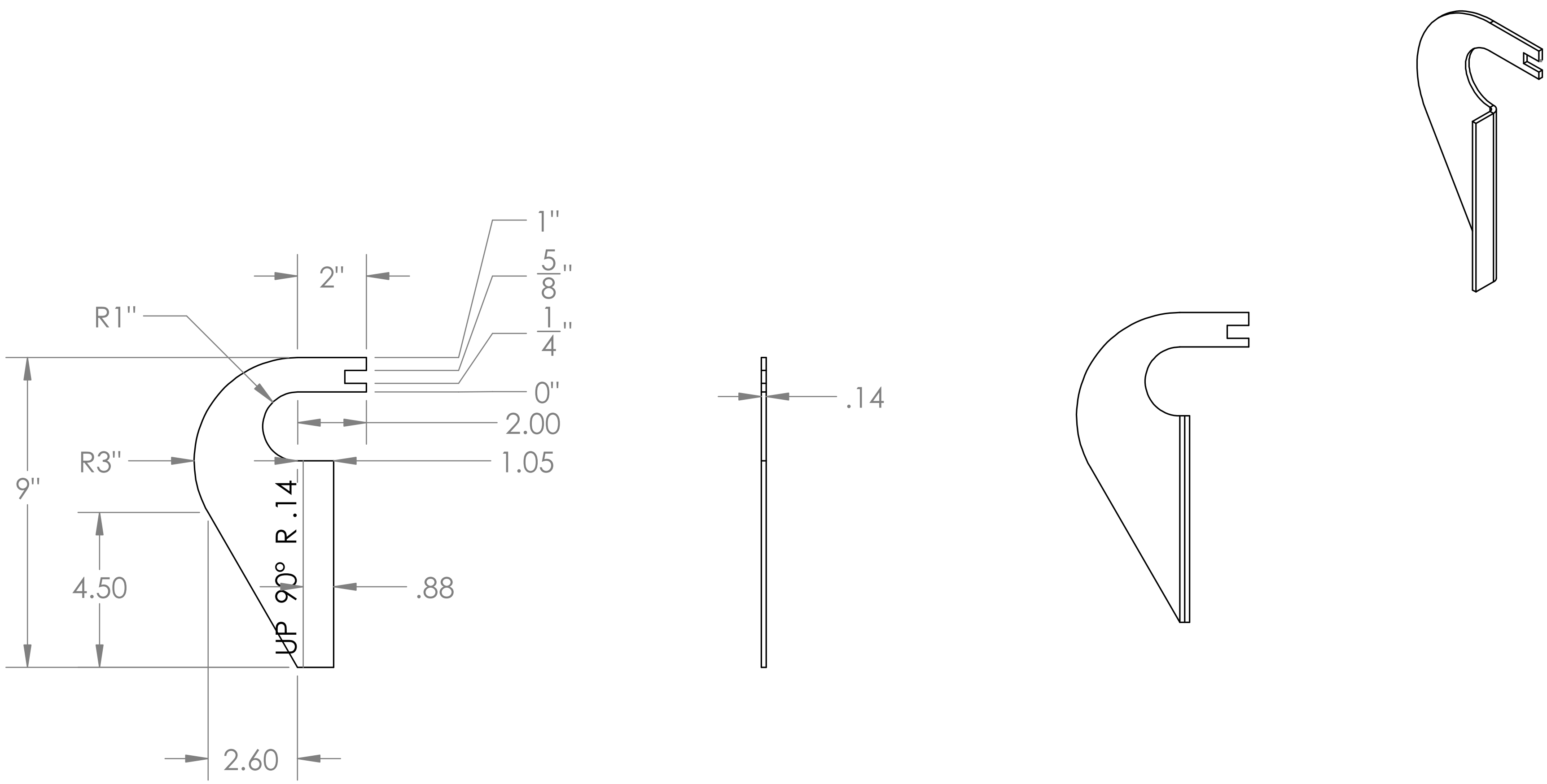




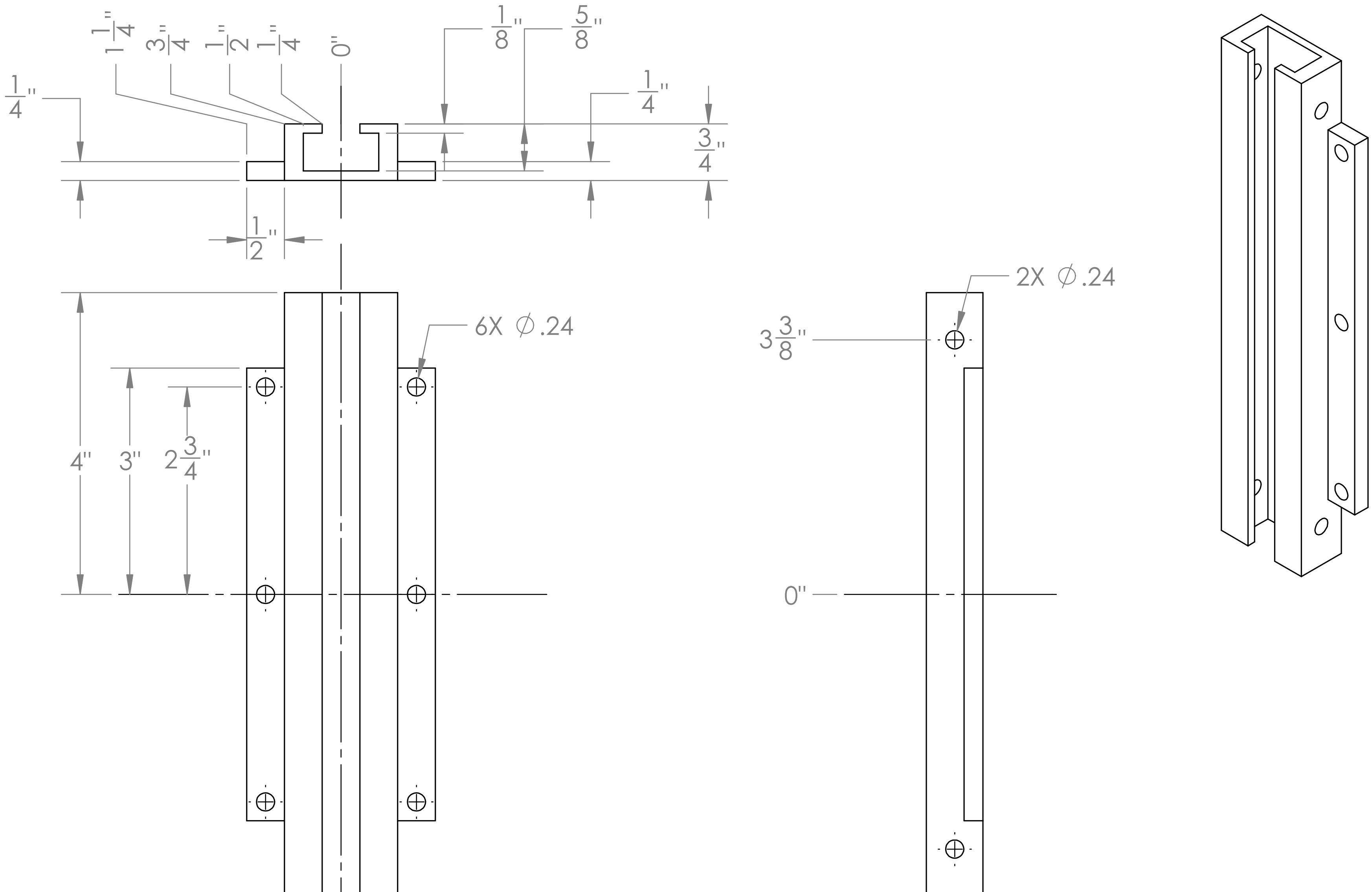
SECTION D-D
SCALE 1 : 1



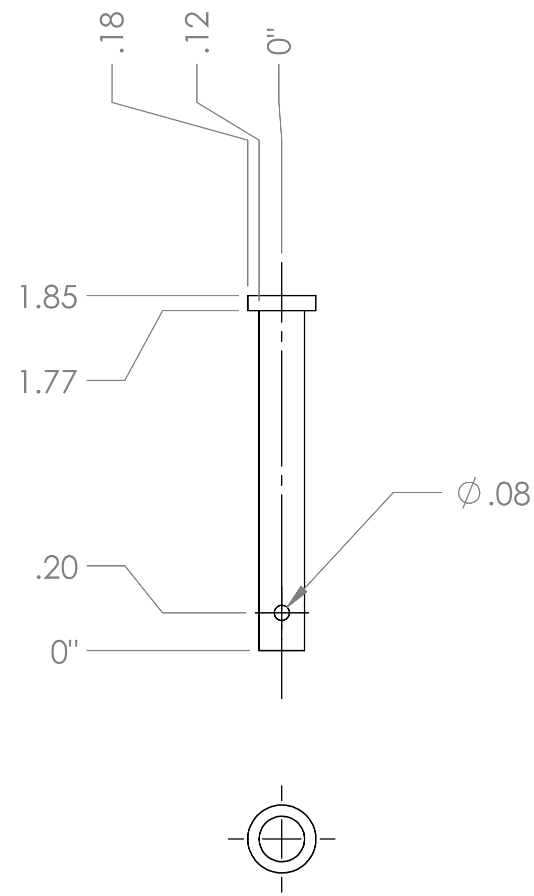
DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF-804
	FINISH: AS MACHINED			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: ADJSTABLE PLATE BRAKCET ASSEMBLY	WEIGHT: 0.01LBS
		DRAWN BY: CM	DESCRIPTION: INTERNAL THREAD	EDF-510
		CHECKED BY: --	SHEET 28OF 31 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_804
	FINISH: AS PROCESSED				SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	27/11/2018	USED WITH: PLATE MOUNT ASSEMBLY	WEIGHT: 0.94LBS
		DRAWN BY:	CM	DESCRIPTION: ACUATOR TO PLATE BRACKET	EDF_502
		CHECKED BY:	--	SHEET 29OF 31 DO NOT SCALE DRAWING	



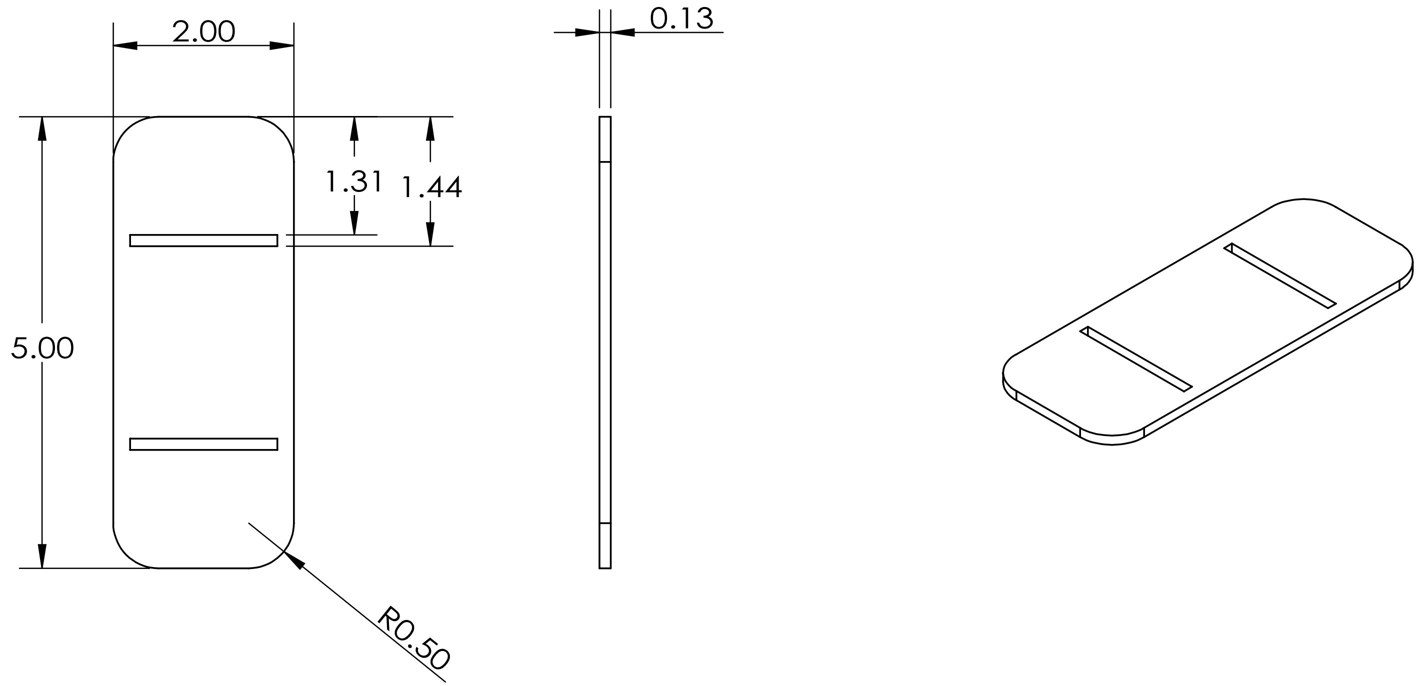
DIMENSIONAL UNIT: INCHES	MATERIAL: UHMW PE FINISH: AS MACHINED	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF_726 SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 27/11/2018 DRAWN BY: CM CHECKED BY: --	USED WITH: Box Assembly DESCRIPTION: Mating Guides Female Side SHEET 30OF 31 DO NOT SCALE DRAWING	WEIGHT: 0.22LBS **EDF-525**



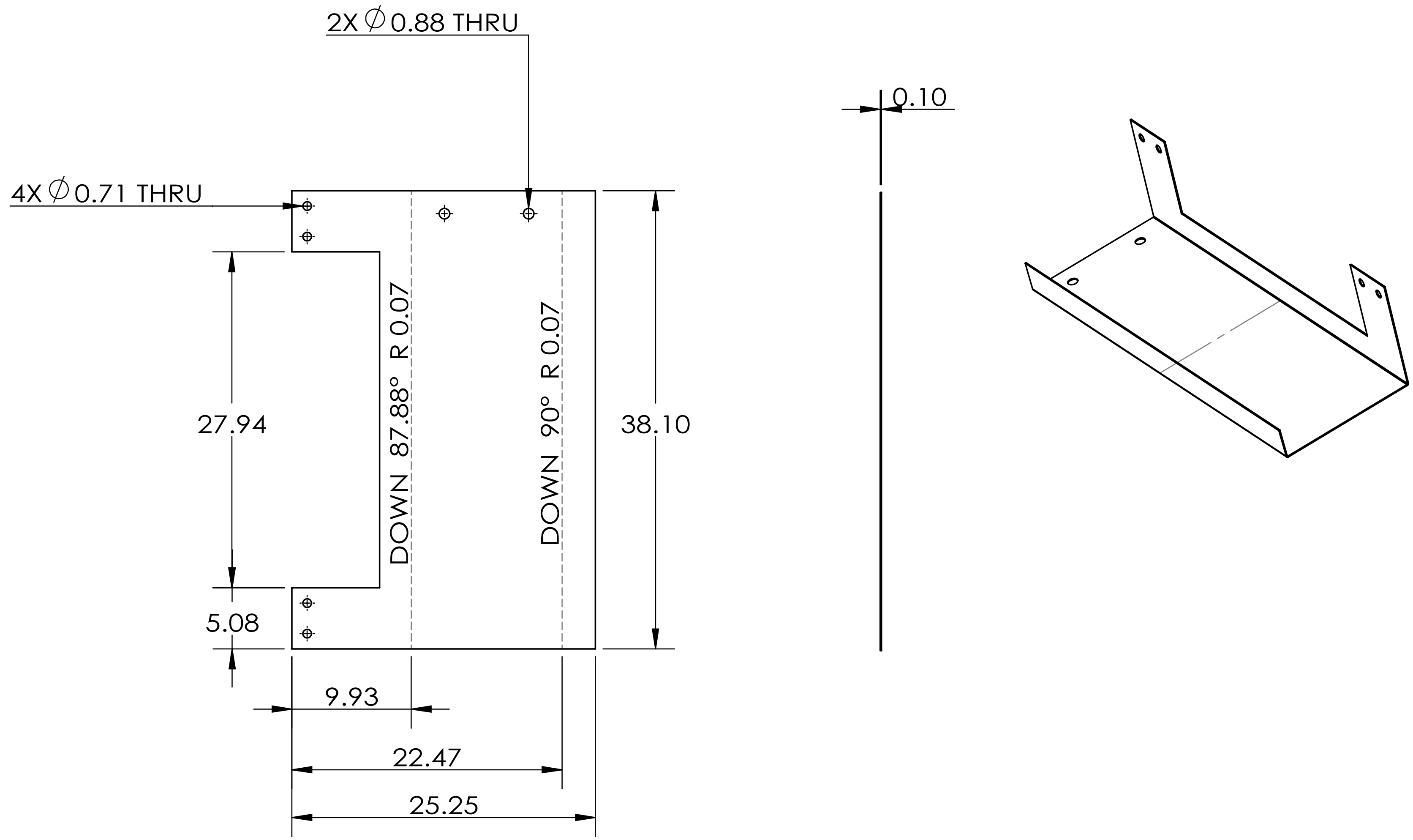
DIMENSIONAL UNIT: INCHES	MATERIAL: 316SS		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: EDF_726
	FINISH: AS MACHINED				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 27/11/2018	USED WITH: END EFFECTOR ASSEMBLY		WEIGHT: 0.02
		DRAWN BY: CM	DESCRIPTION: QUICK DTACH PINS		EDF_508
		CHECKED BY: --	SHEET 31OF 31	DO NOT SCALE DRAWING	

Preliminary Manufacturing Drawing Package
Horizontal Arm

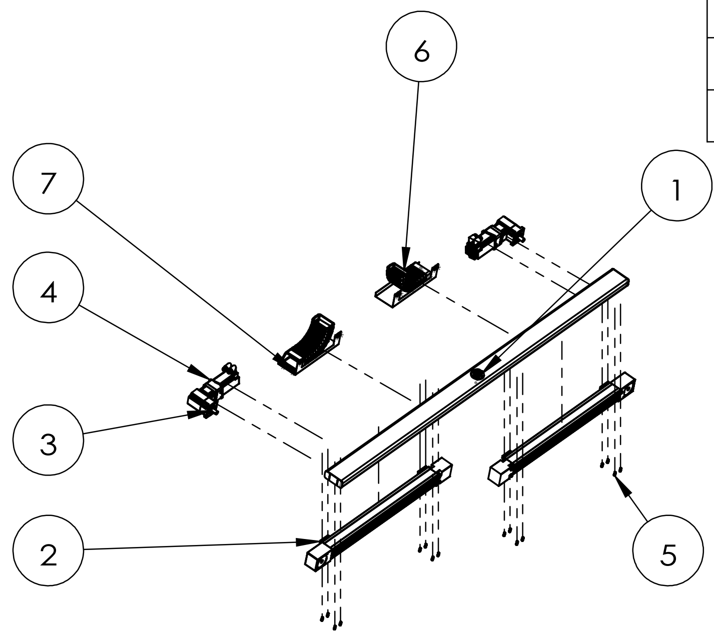
Appendix D



DIMENSIONAL UNIT: INCHES	MATERIAL:	316 Stainless Steel	University of Manitoba / HyLife Foods		NEXT ASSY:EDF-759
	FINISH:	--			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: XX/XX/XXXX	USED WITH:	Horizontal Arm	WEIGHT: 0.34lbs
		DRAWN BY: DL	DESCRIPTION:	Tube Cover	
		CHECKED BY: --	SHEET 1 OF 1	DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL:	316 Stainless Steel	University of Manitoba / HyLife Foods		NEXT ASSY: EDF-760
	FINISH:	--			SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: XX/XX/XXXX	USED WITH:	Cable Track	WEIGHT: 1.36 lbs
		DRAWN BY: DL	DESCRIPTION:	Cable Track Mount	
		CHECKED BY: --	SHEET 1 OF 1	DO NOT SCALE DRAWING	



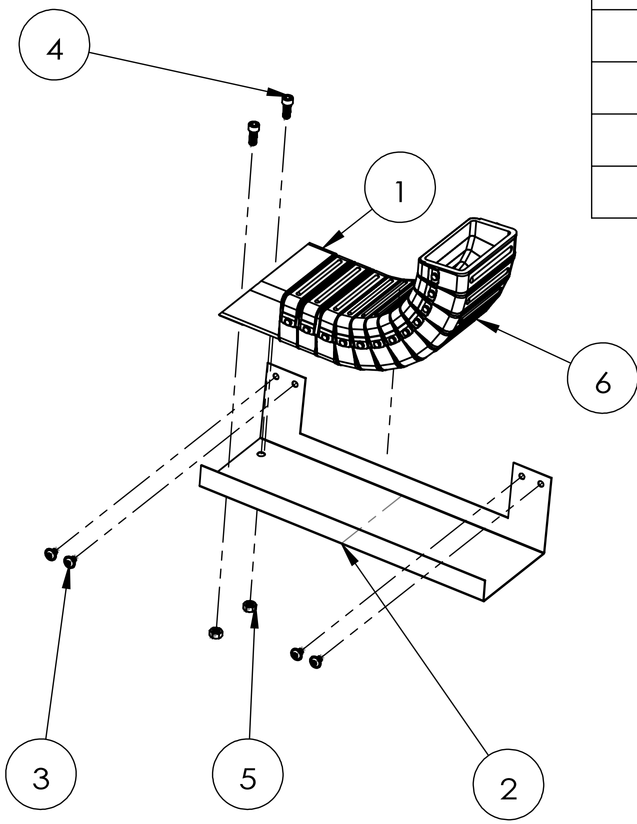
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-759-R02-KF	Rectangular Tubing	1
2	WH08Z200-00635-001185VN-0000	Linear Track Actuator	2
3	DTR090-005-0-RM090-39	Gearbox Reduction	2
4	EDF-751-R00-DL	Motor	2
5	91292A137	M6X20 Screws	16
6	EDF-760-R00-DL	Cable Track	1
7	EDF-763-R00-DL	Cable Track	1

DIMENSIONAL UNIT: INCHES

UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL:	SEE BOM
FINISH:	--
SIZE	A4
FIRST ISSUED:	XX/XX/XXXX
DRAWN BY:	DL
CHECKED BY:	--
USED WITH:	Horizontal Arm
DESCRIPTION:	Horizontal Arm
NEXT ASSY:	--
SCALE:	1:50
WEIGHT:	271 lbs

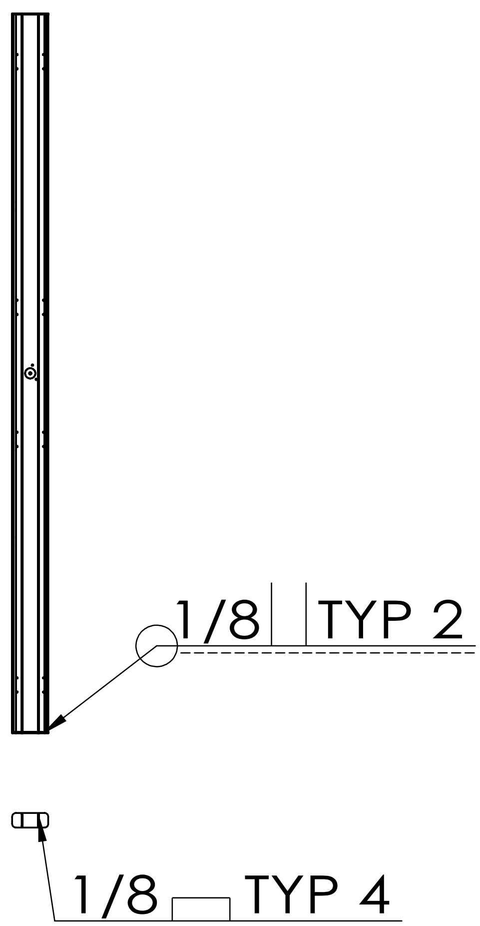
SHEET 1 OF 1 DO NOT SCALE DRAWING

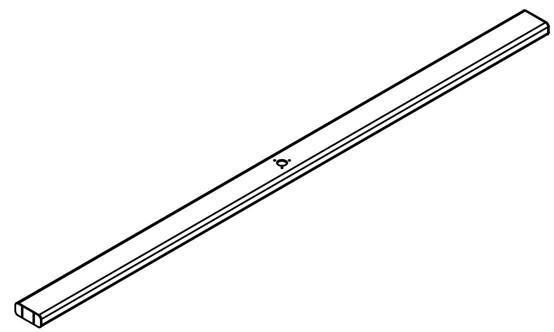


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	5608K531_DURA-GUARD CABLE AND HOSE CARRIER	Cable Track	1
2	EDF-574-R00-DL	Cable Track Support	1
3	90909A526	1/4"-20 Screw	4
4	92185A581	5/16"-18 Screw	2
5	92673A119	5/16"-18 Hex Nut	2
6	5608K35	Mounting Bracket	1

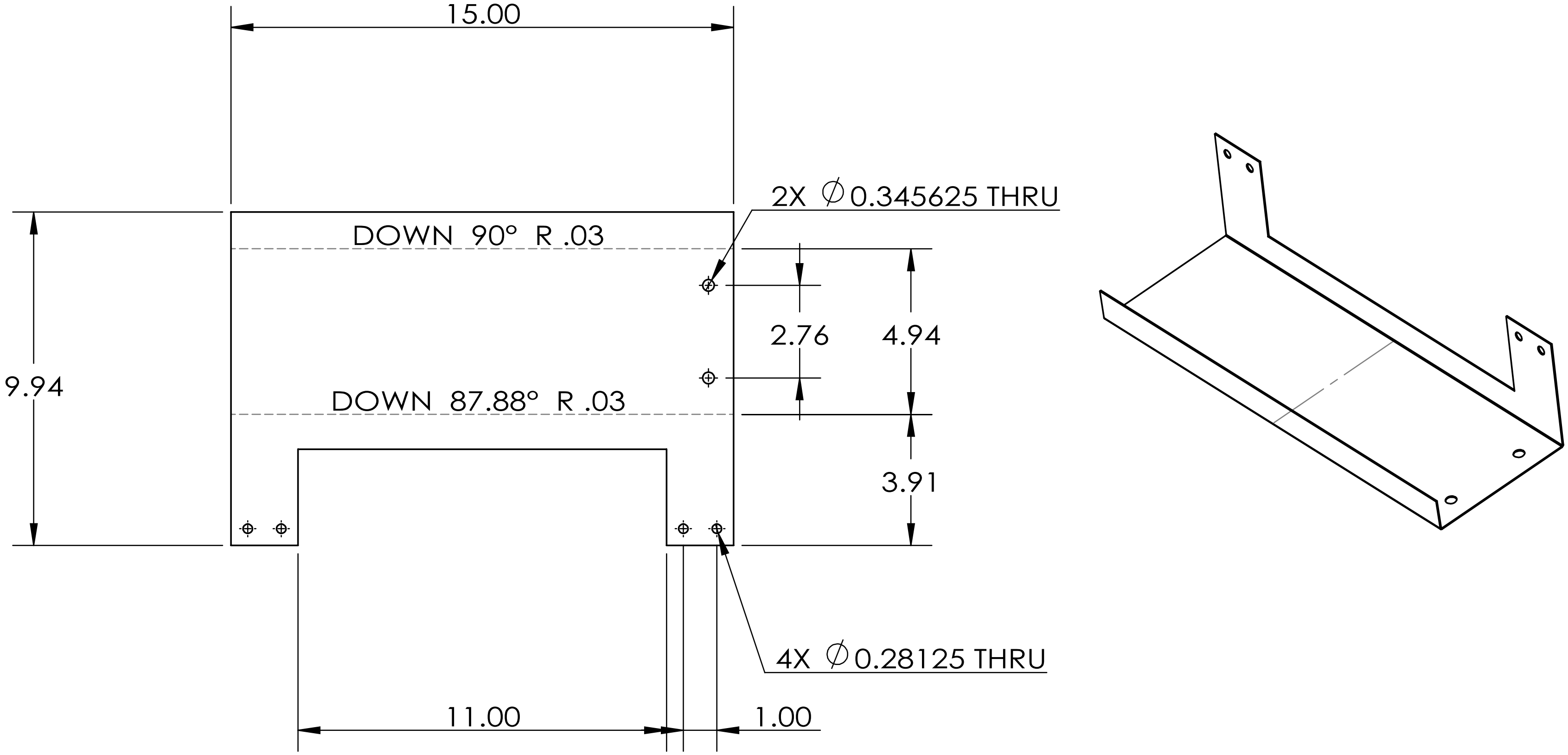
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM FINISH: --	UNIVERSITY OF MANITOBA · HYLIFE FOODS	NEXT ASSY: EDF-755 SCALE: 1:20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: XX/XX/XXXX DRAWN BY: DL CHECKED BY: --	USED WITH: Horizontal Arm DESCRIPTION: Cable Track SHEET 1 OF 1 DO NOT SCALE DRAWING	WEIGHT: 13.5 lbs

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	EDF-551-R01-DL	TUBE, RECTANGULAR 5.00 X 2.00 X .19	1
2	EDF-552-R01-KF		2
3	EDF-540-R00-KF		2

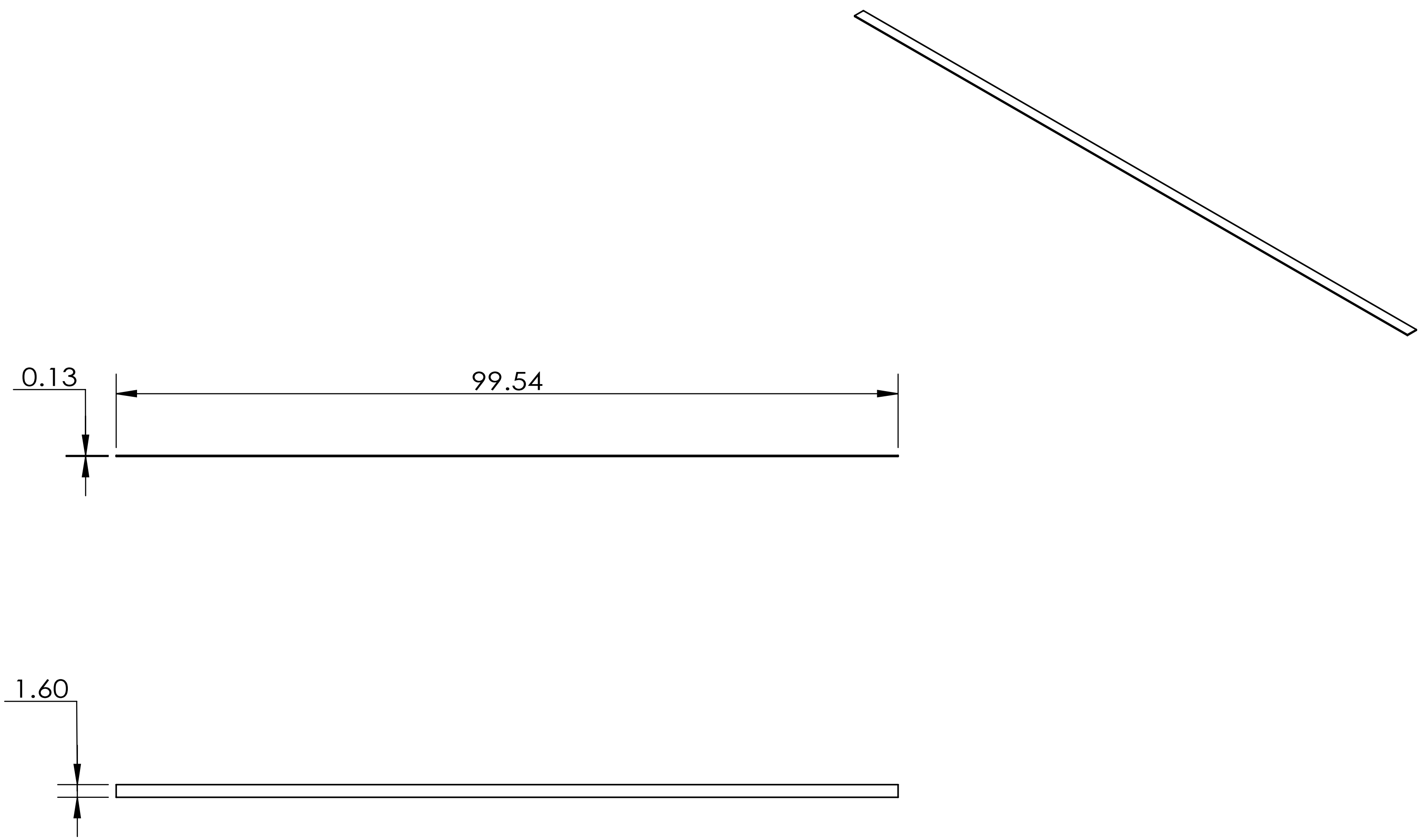




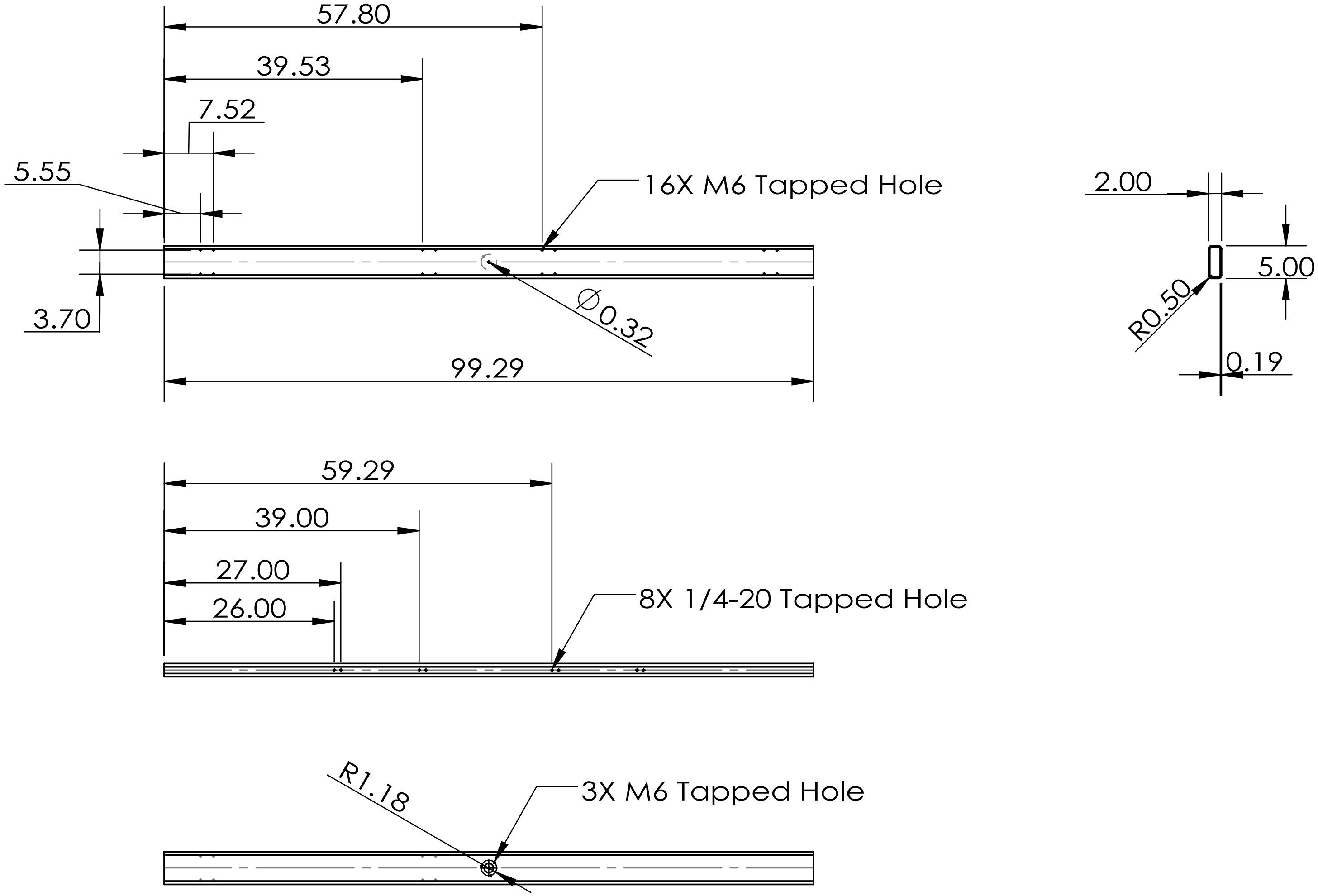
DIMENSIONAL UNIT: INCHES	MATERIAL: 316 Stainless Steel			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:EDF-755
	FINISH: --				SCALE: 1:25
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	XX/XX/XXXX	USED WITH: Horizontal Arm	WEIGHT: 79.27 lbs
		DRAWN BY:	DL	DESCRIPTION: Horizontal Arm	
		CHECKED BY:	--	SHEET 1 OF 1 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 316 Stainless Steel		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF-763
	FINISH: --			SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: XX/XX/XXXX	USED WITH: Horizontal Arm	WEIGHT: 1.3 lbs
		DRAWN BY: DL	DESCRIPTION: Cable Track Mount	
		CHECKED BY: --	SHEET 1 OF 1 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 316 Stainless Steel		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: EDF-759
	FINISH: --			SCALE: 1:20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: XX/XX/XXXX	USED WITH: Horizontal Arm	WEIGHT: 5.61 lbs
		DRAWN BY: DL	DESCRIPTION: Internal Support	501
		CHECKED BY: --	SHEET 1 OF 1 DO NOT SCALE DRAWING	



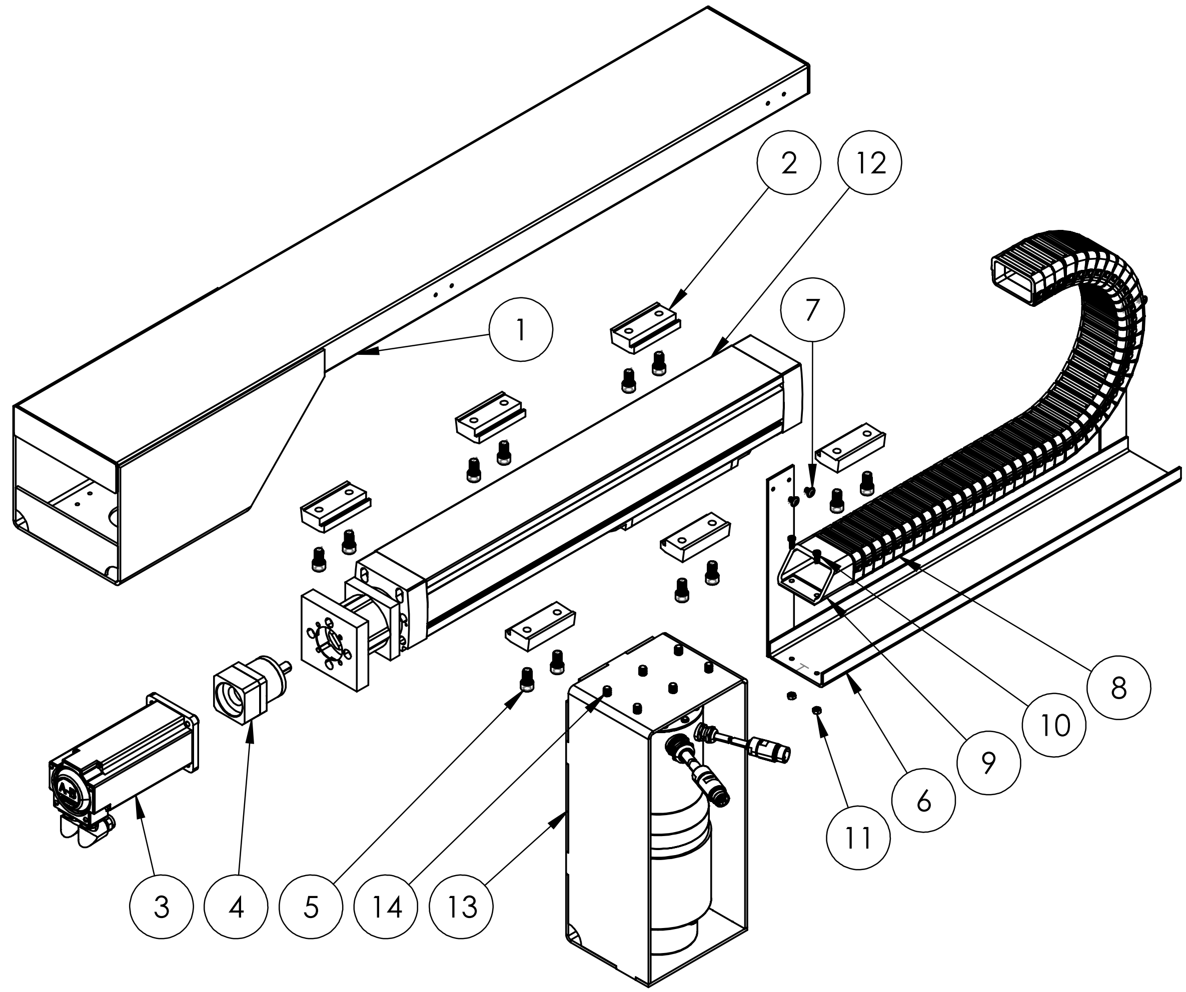
DIMENSIONAL UNIT: INCHES	MATERIAL: 316 Stainless Steel		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: EDF-75?
	FINISH: --				SCALE: 1:25
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: XX/XX/XXXX	USED WITH:	End Effector	WEIGHT: 67 lbs
		DRAWN BY: DL	DESCRIPTION:	Rectangular Tubing	
		CHECKED BY: --	SHEET 1 OF 1	DO NOT SCALE DRAWING	

Preliminary Manufacturing Drawing Package

Main Arm

Appendix D

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM_800	MAIN ARM WELDMENT	1
2	ARM_204	M100 LINEAR TRACK MOUNT BRACKET	6
3	ARM_205	ROCKWELL FOOD GRADE SERVO MOTOR (MPF-330)	1
4	ARM_206	THOMSON XTEND 3:1 INLINE GEARHEAD (XT060-033-0)	1
5	ARM_210	316 SS SOCKET HEAD CAP SCREW (M10 x 20mm)	12
6	ARM_802	WIRE TRACK GUIDE WELDMENT	1
7	ARM_207	316 SS FLANGED BOLT (1/4"-20 x 3/8")	4
8	ARM_208	SS CABLE AND HOSE CARRIER	1
9	ARM_209	SS MOUNT FOR CABLE AND HOSE CARRIER	1
10	ARM_211	TYPE 18-8 SS LOW PROFILE SOCKET CAP SCREW	2
11	ARM_212	TYPE 18-8 SS HEX NUT	2
12	ARM_200	M100 LINEAR TRACK	1
13	ARM_701	HORIZONTAL ARM ROTARY ASSY	1
14	ARM_203	316 SS M10 x 1.5mm Thread x 16mm	6

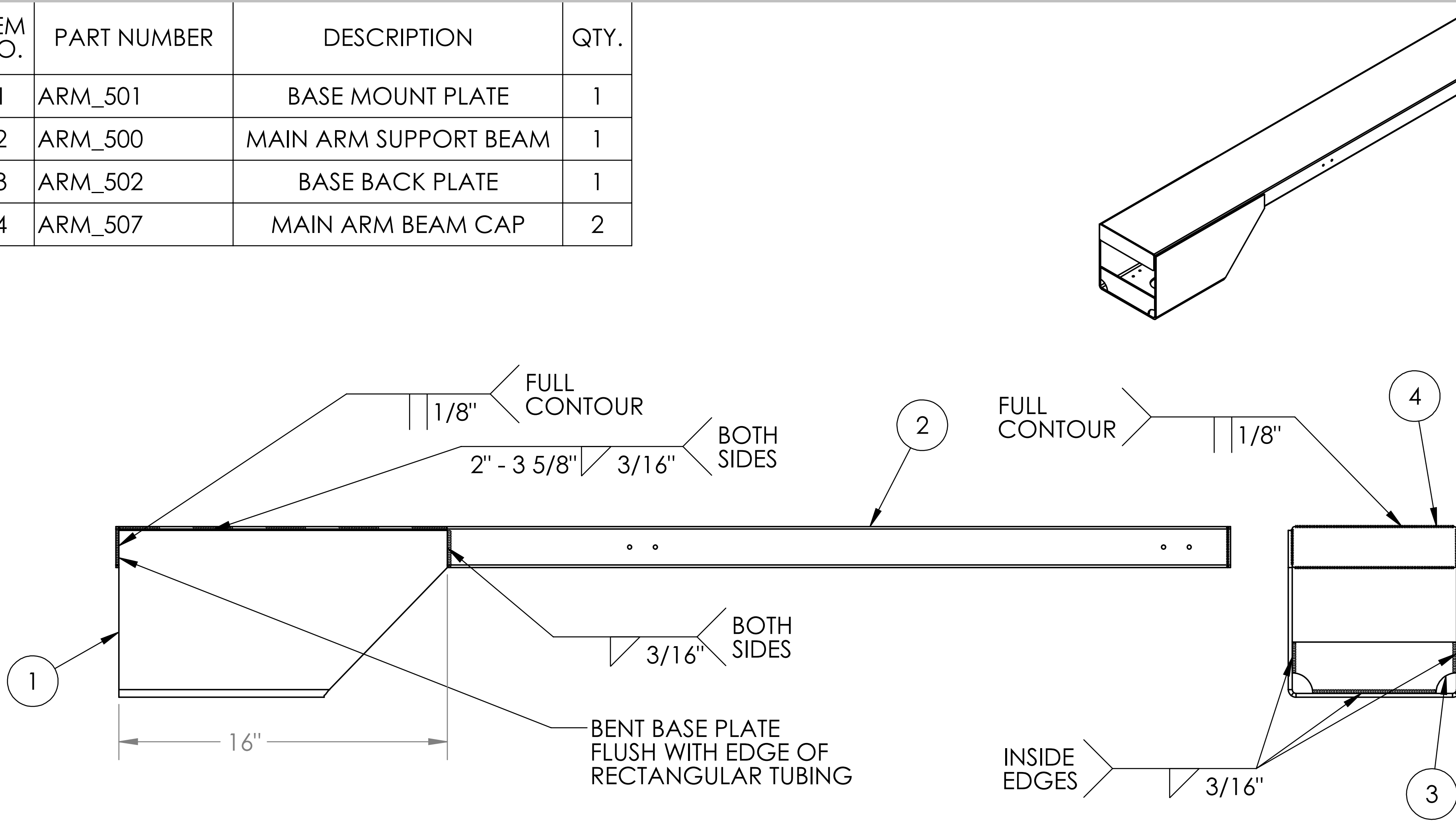


DIMENSIONAL UNIT: INCHES

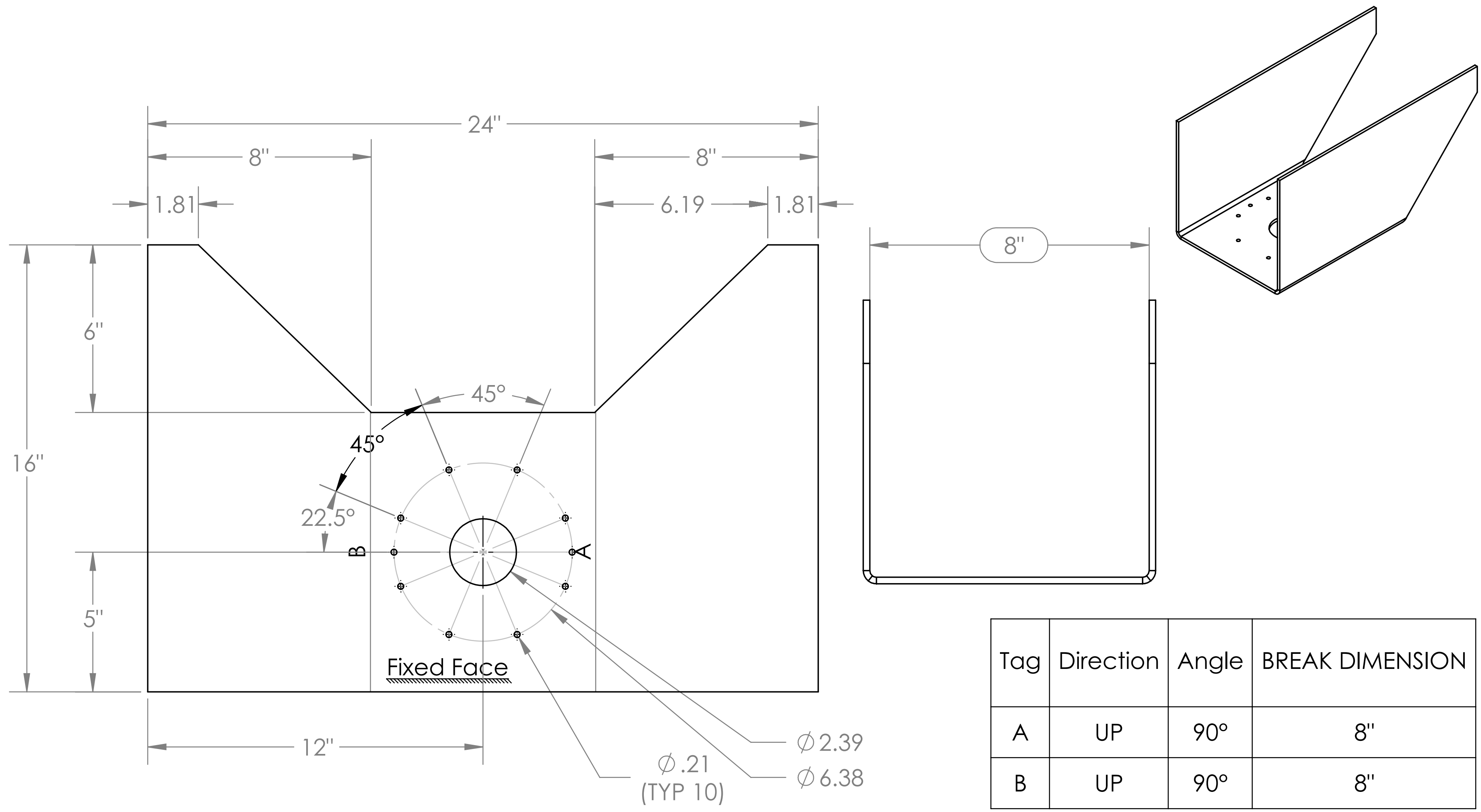
UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL:	See BOM	NEXT ASSY:	N/A
FINISH:	AS SHOWN	SCALE:	1:10
SIZE A4	FIRST ISSUED: 28/11/2018	USED WITH: N/A	WEIGHT: 208.53 LBS
	DRAWN BY: DV	DESCRIPTION: MAIN ARM ASSEMBLY	ARM_700
	CHECKED BY: --	SHEET 1 OF 13 DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM_501	BASE MOUNT PLATE	1
2	ARM_500	MAIN ARM SUPPORT BEAM	1
3	ARM_502	BASE BACK PLATE	1
4	ARM_507	MAIN ARM BEAM CAP	2

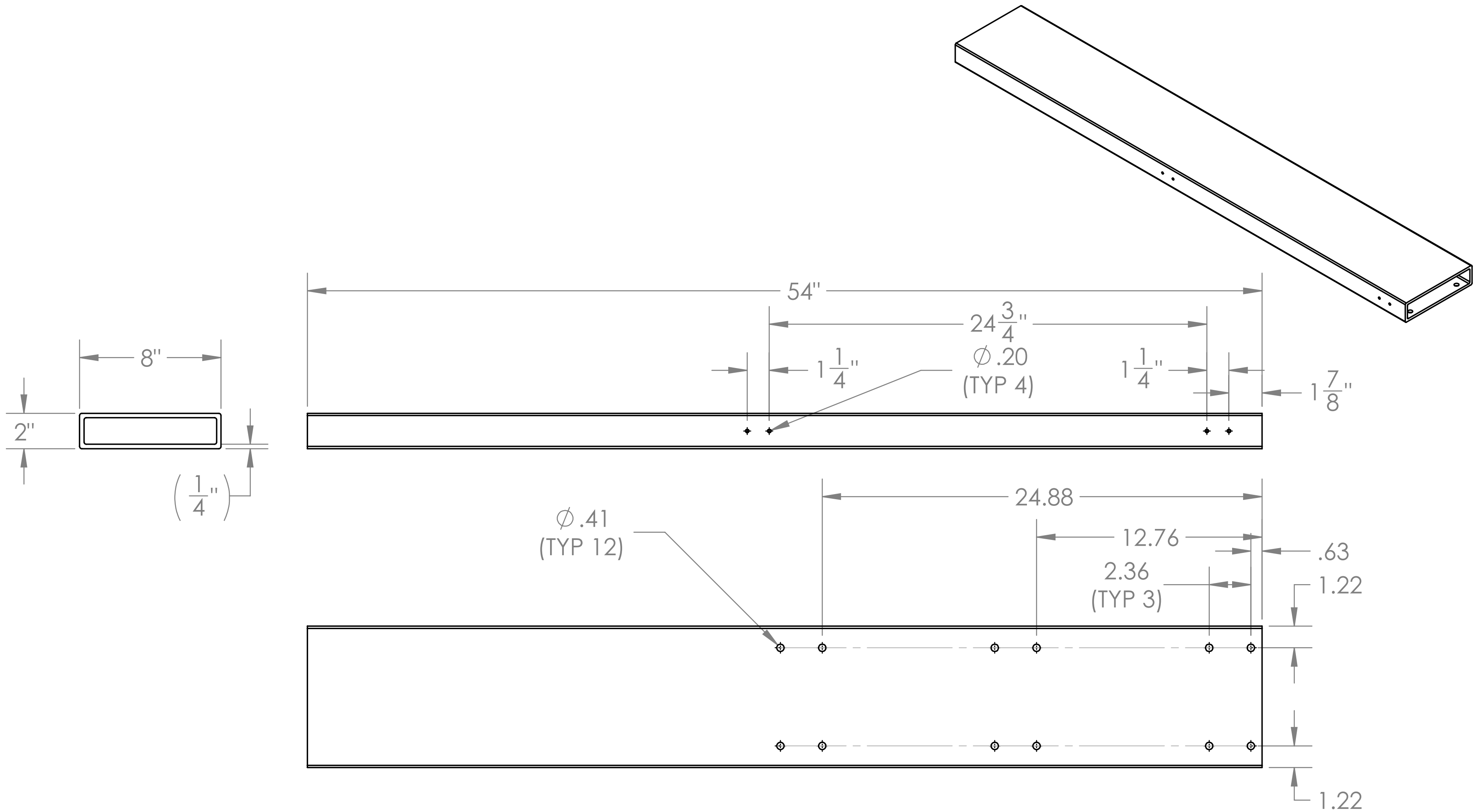


DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM FINISH: AS SHOWN	UNIVERSITY OF MANITOBA HyLIFE FOODS	NEXT ASSY: ARM_700 SCALE: 1:7
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 28/11/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: MAIN ARM ASSEMBLY DESCRIPTION: MAIN ARM WELDMENT SHEET 2 OF 13 DO NOT SCALE DRAWING	WEIGHT: 92.22 LBS **ARM_700**

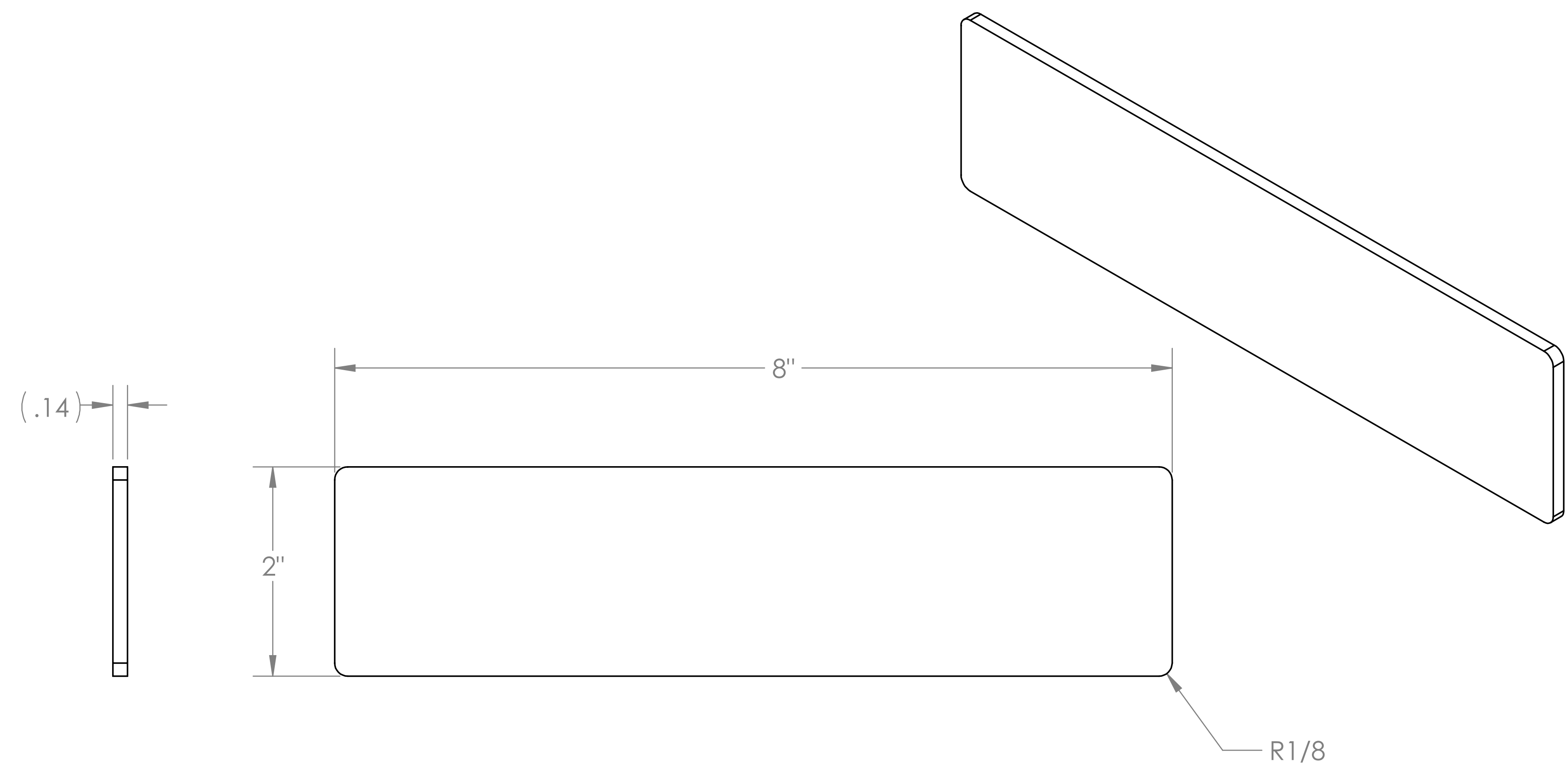


Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	8"
B	UP	90°	8"

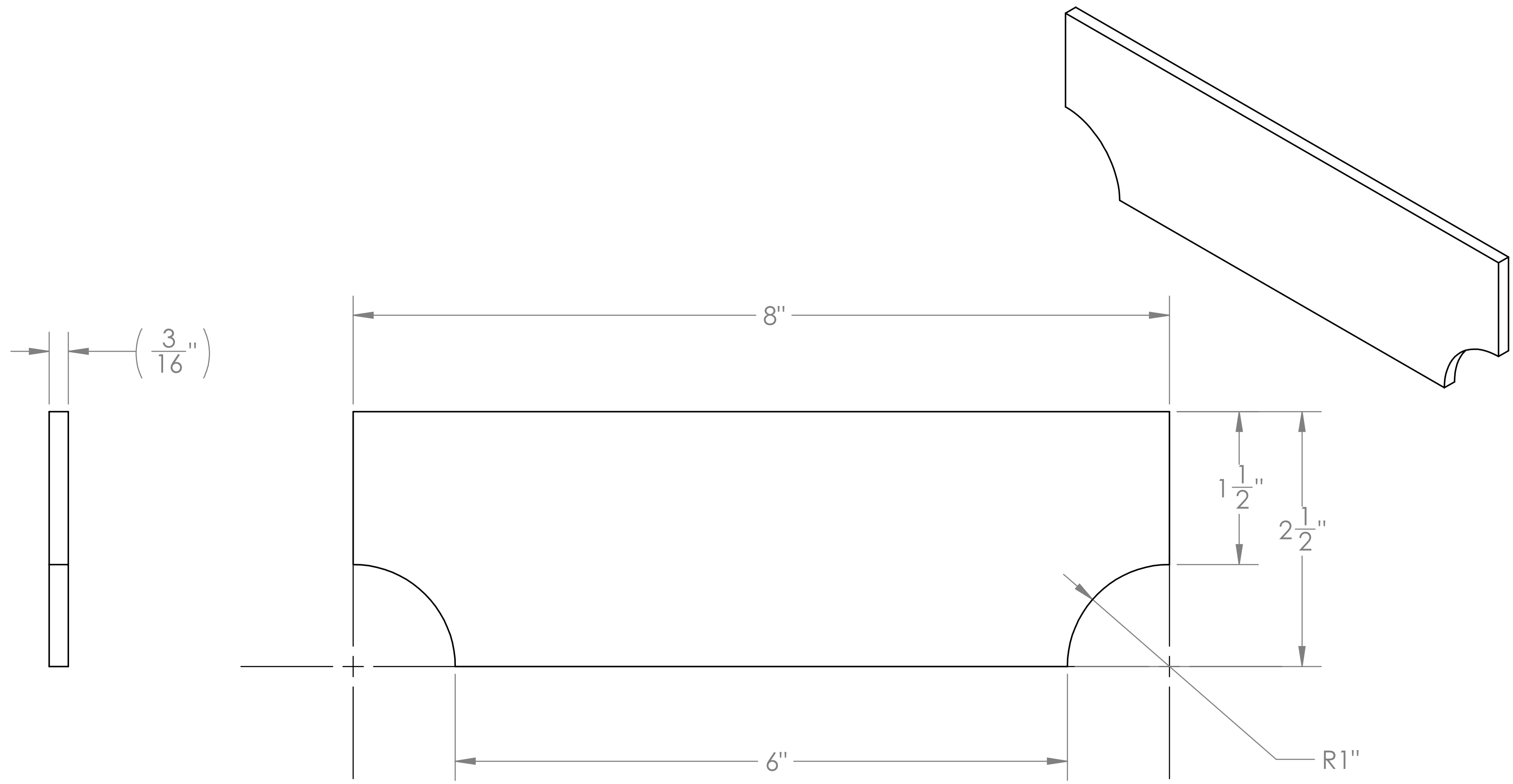
DIMENSIONAL UNIT: INCHES	MATERIAL: 7GA 316 SS SHEET FINISH: N/A	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_800 SCALE: 1:7
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 28/11/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: MAIN ARM WELDMENT DESCRIPTION: BASE MOUNT PLATE SHEET 3 OF 13 DO NOT SCALE DRAWING	WEIGHT: 15.93 LBS ARM_501



DIMENSIONAL UNIT: INCHES	MATERIAL: 8" x 2" x 0.25" 304 SS REC TUBING	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_800
	FINISH: N/A		SCALE: 1:7
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 — FIRST ISSUED: 28/11/2018; DRAWN BY: DV; CHECKED BY: --	USED WITH: MAIN ARM WELDMENT	WEIGHT: 74.01 LBS
		DESCRIPTION: MAIN ARM SUPPORT BEAM SHEET 4 OF 13 DO NOT SCALE DRAWING	ARM_500

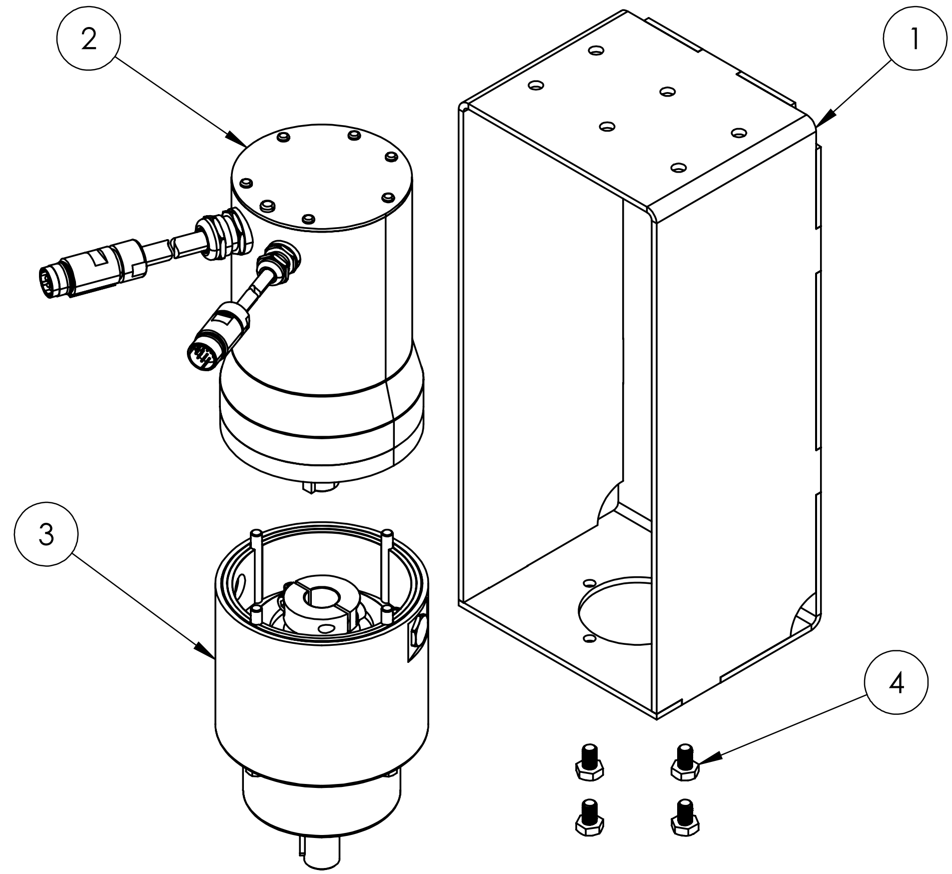


DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316 SS SHEET FINISH: N/A	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_800 SCALE: 2:3
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 28/11/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: MAIN ARM WELDMENT DESCRIPTION: MAIN ARM BEAM CAP SHEET 5 OF 13 DO NOT SCALE DRAWING	WEIGHT: 0.65 LBS **ARM_507**



DIMENSIONAL UNIT: INCHES	MATERIAL: 7GA 316 SS SHEET			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_800
	FINISH: N/A				SCALE: 2:3
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	28/11/2018	USED WITH: MAIN ARM WELDMENT	WEIGHT: 0.97 LBS
		DRAWN BY:	DV	DESCRIPTION: BASE BACK PLATE	ARM_502
		CHECKED BY:	--	SHEET 6 OF 13 DO NOT SCALE DRAWING	

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM_801	HOUSING WELDMENT	1
2	ARM_201	ROCKEWELL IP69K SERVO MOTOR	1
3	ARM_202	THOMSON AQUATrue 20:1 GEARHEAD	1
4	ARM_203	316 SS M10 x 1.5mm Thread x 16mm	4



DIMENSIONAL UNIT: INCHES

UNLESS OTHERWISE STATED
NONTOLERANCED DIMENSIONS ARE 1/32"
CAD MODEL IS BASIC
NONDIMENSIONED GEOMETRIES PER CAD MODEL

MATERIAL: See BOM
FINISH: AS SHOWN

SIZE A4

FIRST ISSUED: 28/11/2018
DRAWN BY: DV
CHECKED BY: --

UNIVERSITY OF MANITOBA
HYLIFE FOODS

USED WITH: MAIN ARM ASSEMBLY

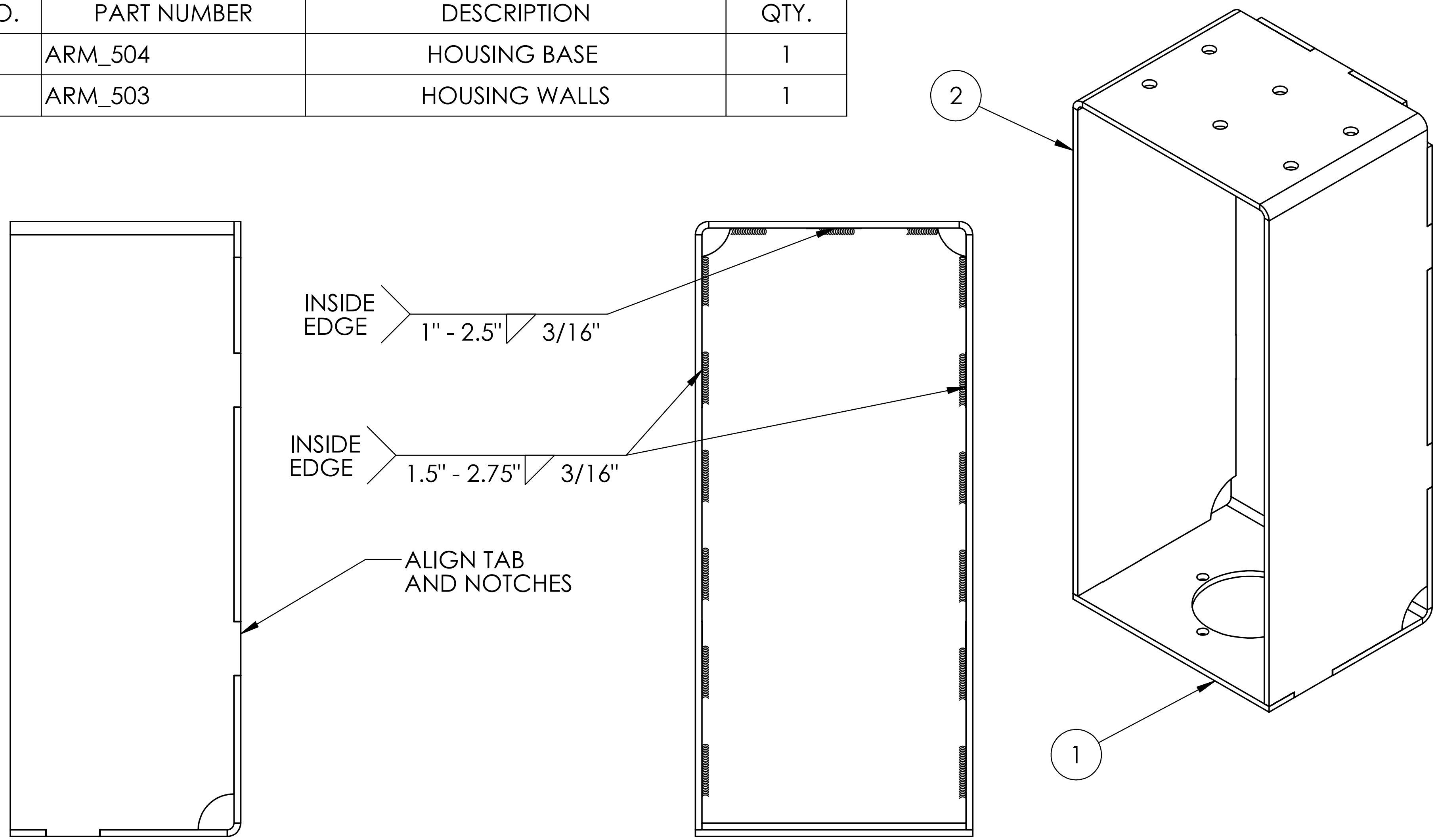
DESCRIPTION: HORIZONTAL ARM ROTARY ASSY

SHEET 7 OF 13 DO NOT SCALE DRAWING

NEXT ASSY: ARM_700
SCALE: 1:5
WEIGHT: 31.96 LBS

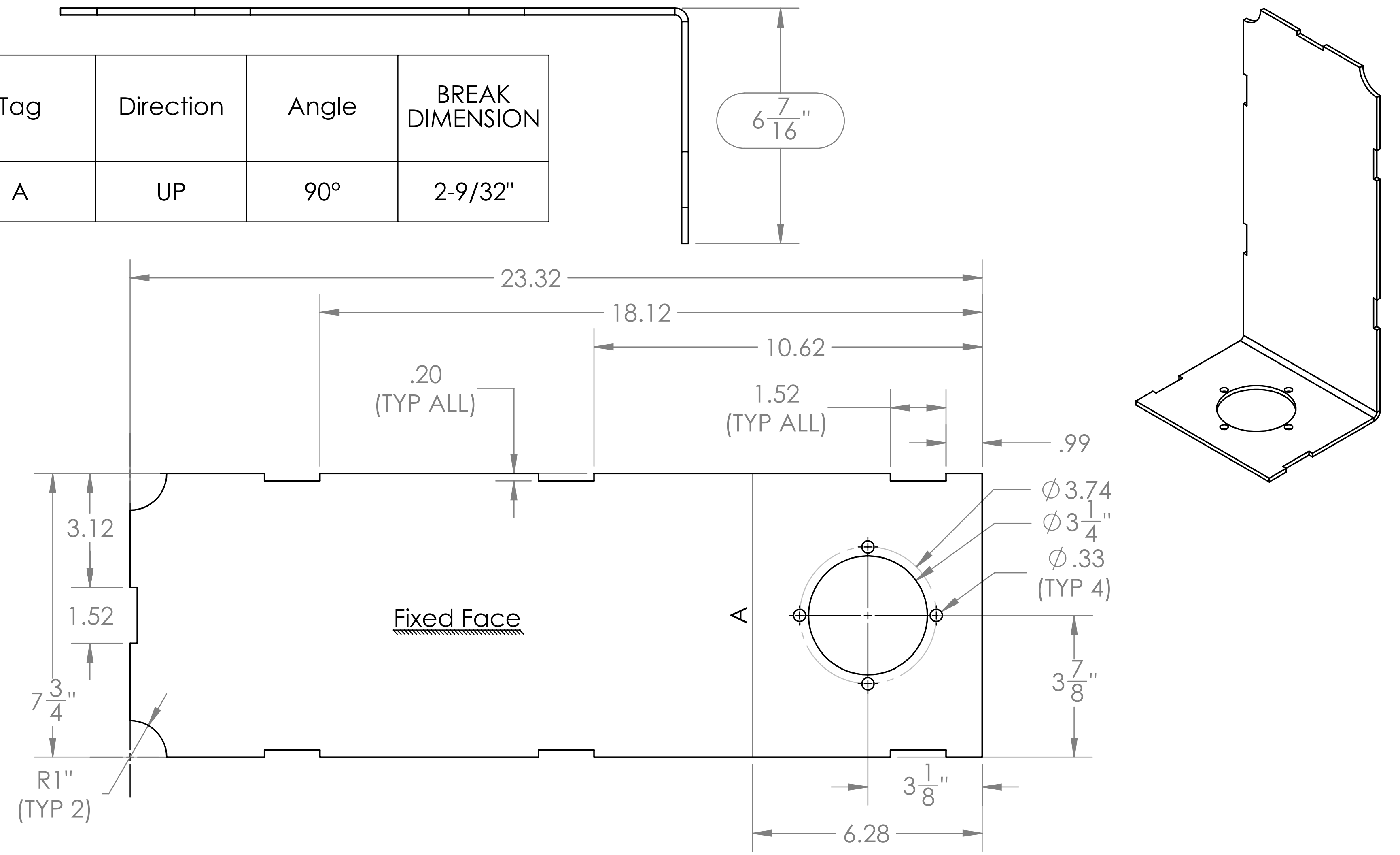
ARM_701

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM_504	HOUSING BASE	1
2	ARM_503	HOUSING WALLS	1



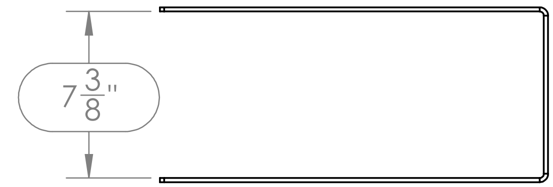
DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_701
	FINISH: AS SHOWN		SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 28/11/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: HORIZONTAL ARM ROTARY ASSY DESCRIPTION: HOUSING WELDMENT SHEET 8 OF 13 DO NOT SCALE DRAWING	WEIGHT: 22.69 LBS **ARM_801**

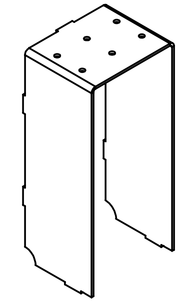
Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	2-9/32"

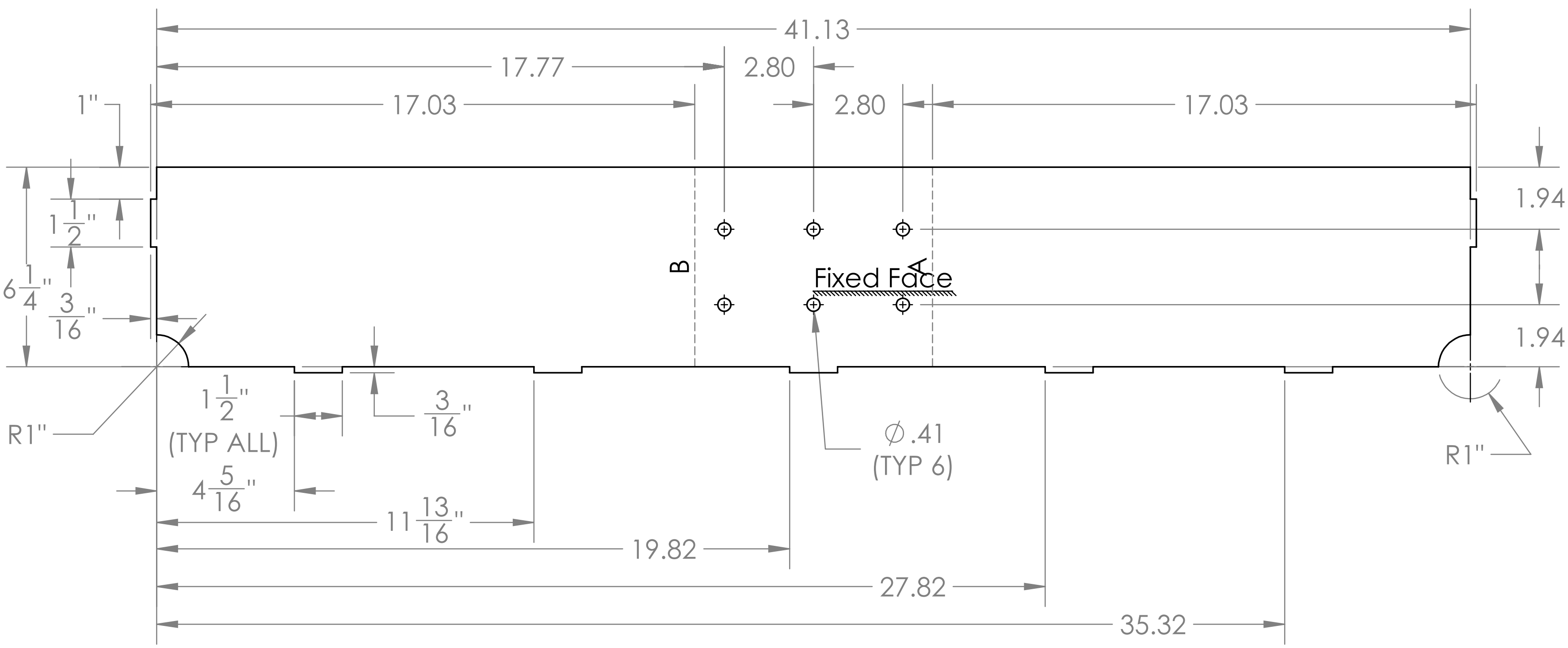


DIMENSIONAL UNIT: INCHES	MATERIAL: 7GA 316 SS SHEET	UNIVERSITY OF MANITOBA · HYLIFE FOODS	NEXT ASSY: ARM_801
	FINISH: N/A		SCALE: 1:4
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 · FIRST ISSUED: 28/11/2018	USED WITH: HOUSING WELDMENT	WEIGHT: 9.12 LBS
	DRAWN BY: DV	DESCRIPTION: HOUSING BASE	ARM_504
	CHECKED BY: --	SHEET 9 OF 13 · DO NOT SCALE DRAWING	

Tag	Direction	Angle	BREAK DIMENSION
A	DOWN	90°	17-1/32"
B	DOWN	90°	17-1/32"

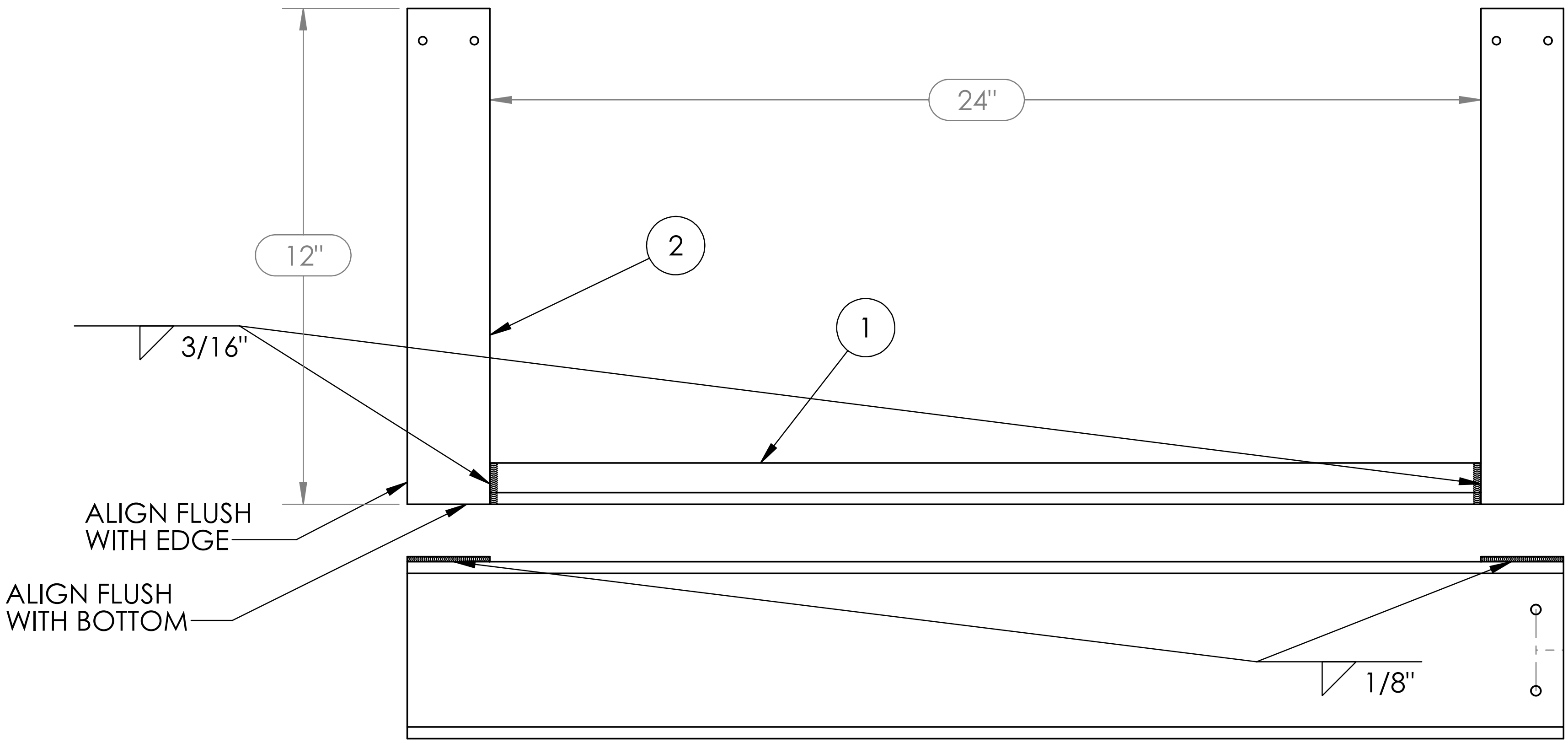




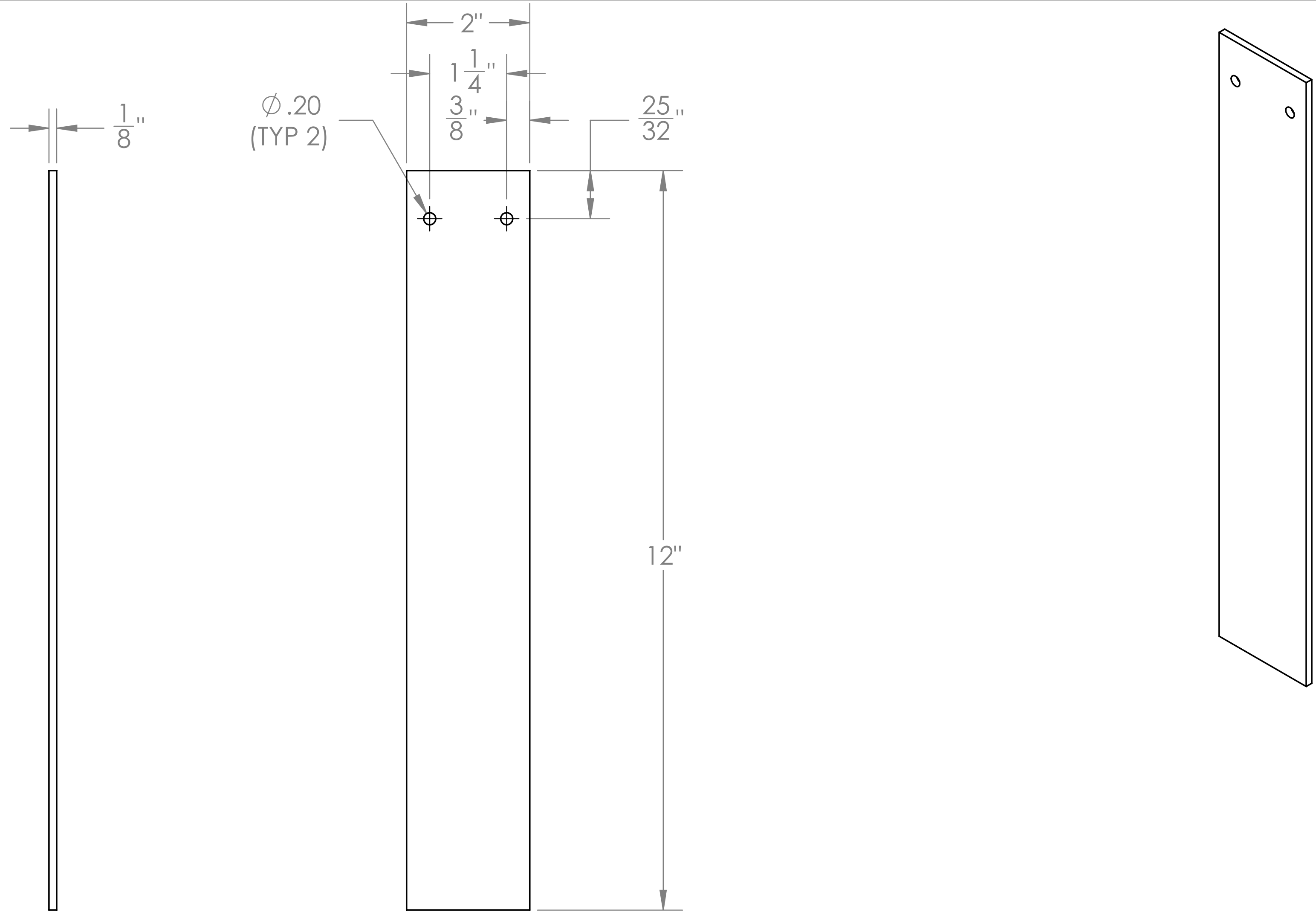


DIMENSIONAL UNIT: INCHES	MATERIAL: 7GA 316 SS SHEET FINISH: N/A	UNIVERSITY OF MANITOBA · HYLIFE FOODS	NEXT ASSY: ARM_801 SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 28/11/2018 DRAWN BY: DV CHECKED BY: --	USED WITH: HOUSING WELDMENT DESCRIPTION: HOUSING WALLS SHEET 10OF 13 DO NOT SCALE DRAWING	WEIGHT: 13.91 LBS **ARM_503**

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM_505	WIRE TRACK GUIDE	1
2	ARM_506	WIRE TRACK MOUNT BRACKET	2

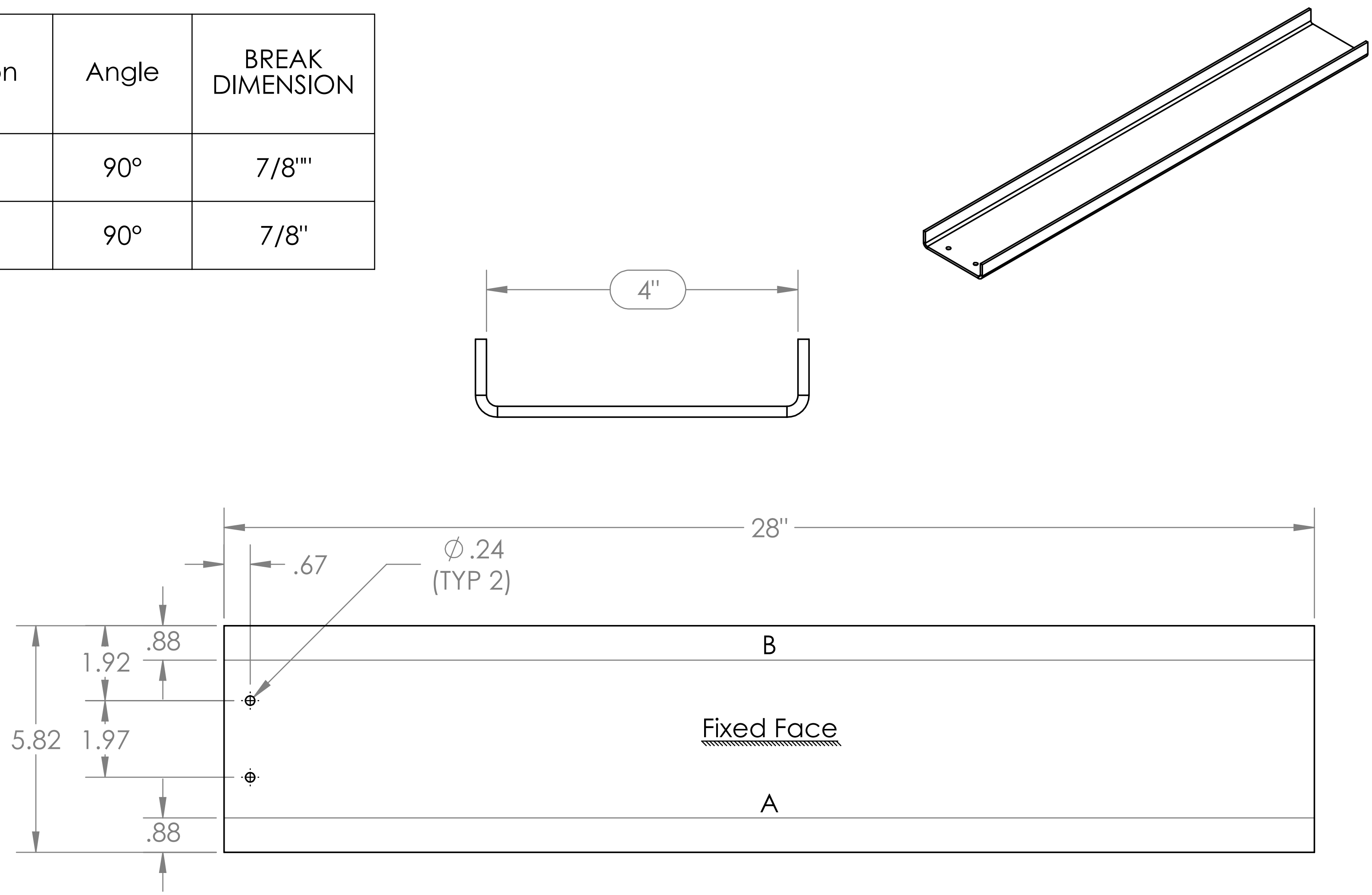


DIMENSIONAL UNIT: INCHES	MATERIAL: See BOM	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_700
	FINISH: AS SHOWN		SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: MAIN ARM ASSEMBLY	WEIGHT: 8.37 LBS
	FIRST ISSUED: 28/11/2018	DESCRIPTION: WIRE TRACK GUIDE WELDMENT	ARM_802
	DRAWN BY: DV	SHEET 11OF 13	
	CHECKED BY: --	DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 2" x 0.125" 304 SS FLAT			NEXT ASSY: ARM_802	
	FINISH: N/A			SCALE: 2:5	
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 28/11/2018	USED WITH: WIRE TRACK GUIDE WELDMENT	WEIGHT: 0.86 LBS	
		DRAWN BY: DV	DESCRIPTION: WIRE TRACK MOUNT BRACKET	ARM_506	
		CHECKED BY: --	SHEET 12OF 13 DO NOT SCALE DRAWING		

Tag	Direction	Angle	BREAK DIMENSION
A	UP	90°	7/8""
B	UP	90°	7/8"

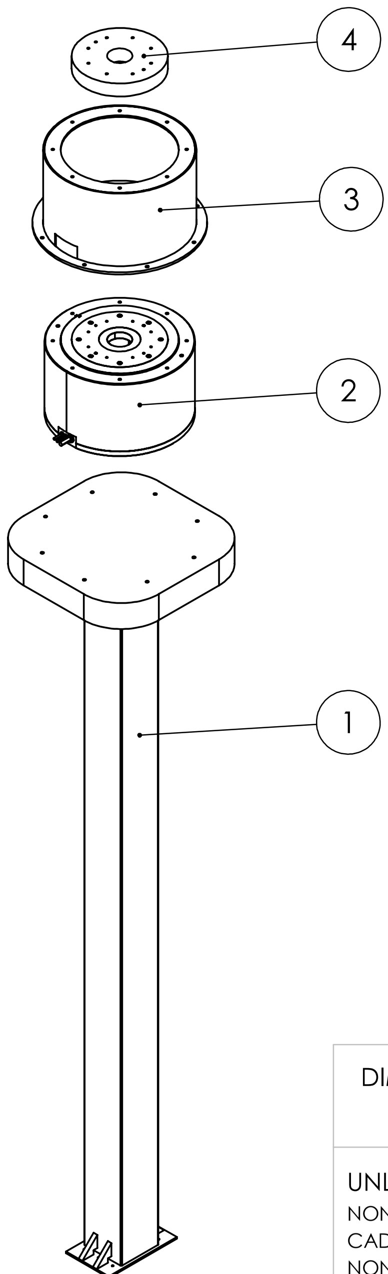


DIMENSIONAL UNIT: INCHES	MATERIAL: 10GA 316 SS SHEET	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM_802
	FINISH: N/A		SCALE: 1:8
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: WIRE TRACK GUIDE WELDMENT	WEIGHT: 6.64 LBS
	FIRST ISSUED: 28/11/2018	DESCRIPTION: WIRE TRACK GUIDE	ARM_506
	DRAWN BY: DV	SHEET 13OF 13	
	CHECKED BY: --	DO NOT SCALE DRAWING	

Preliminary Manufacturing Drawing Package
Arm Base

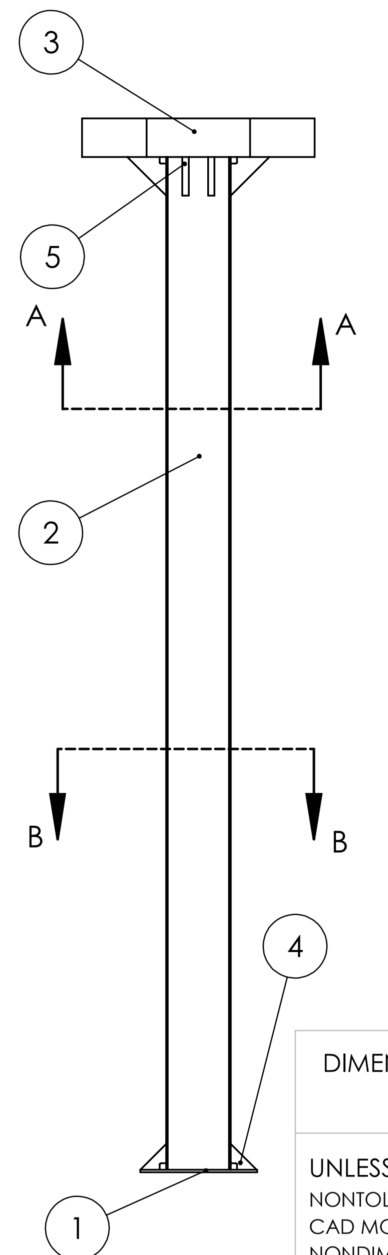
Appendix D

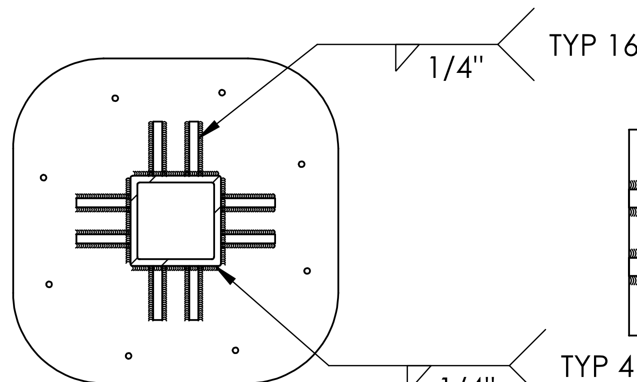
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM-803-R00-KF	MAIN ARM SUPPORT	1
2	ARM-202-R00-KF	ROTARY TABLE	1
3	ARM-802-R00-KF	ROTARY TABLE CONTAINER	1
4	ARM-526-R01-KF	ROTARY TABLE TO MAIN ARM SPACER	1



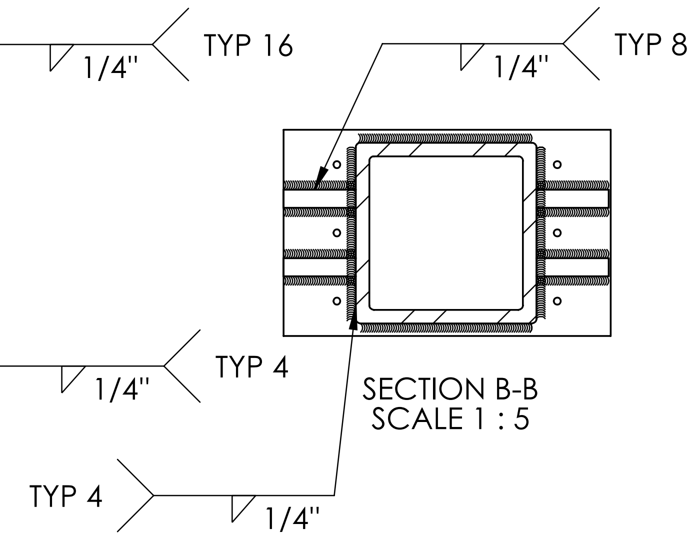
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM FINISH: AS SHOWN	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: -- SCALE: 1:17
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: ARM DESCRIPTION: ARM BASE SHEET 1 OF 12 DO NOT SCALE DRAWING	WEIGHT: ARM-703

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM-511-R00-KF	MOUNT PLATE TO TRACK	1
2	ARM-510-R01-KF	MAIN ARM SUPPORT COLUMN	1
3	ARM-509-R02-KF	ROTARY TABLE PLATEFORM	1
4	ARM-507-R00-KF	COLUMN STIFFENER BOTTOM	4
5	ARM-508-R00-KF	COLUMN STIFFENER TOP	8



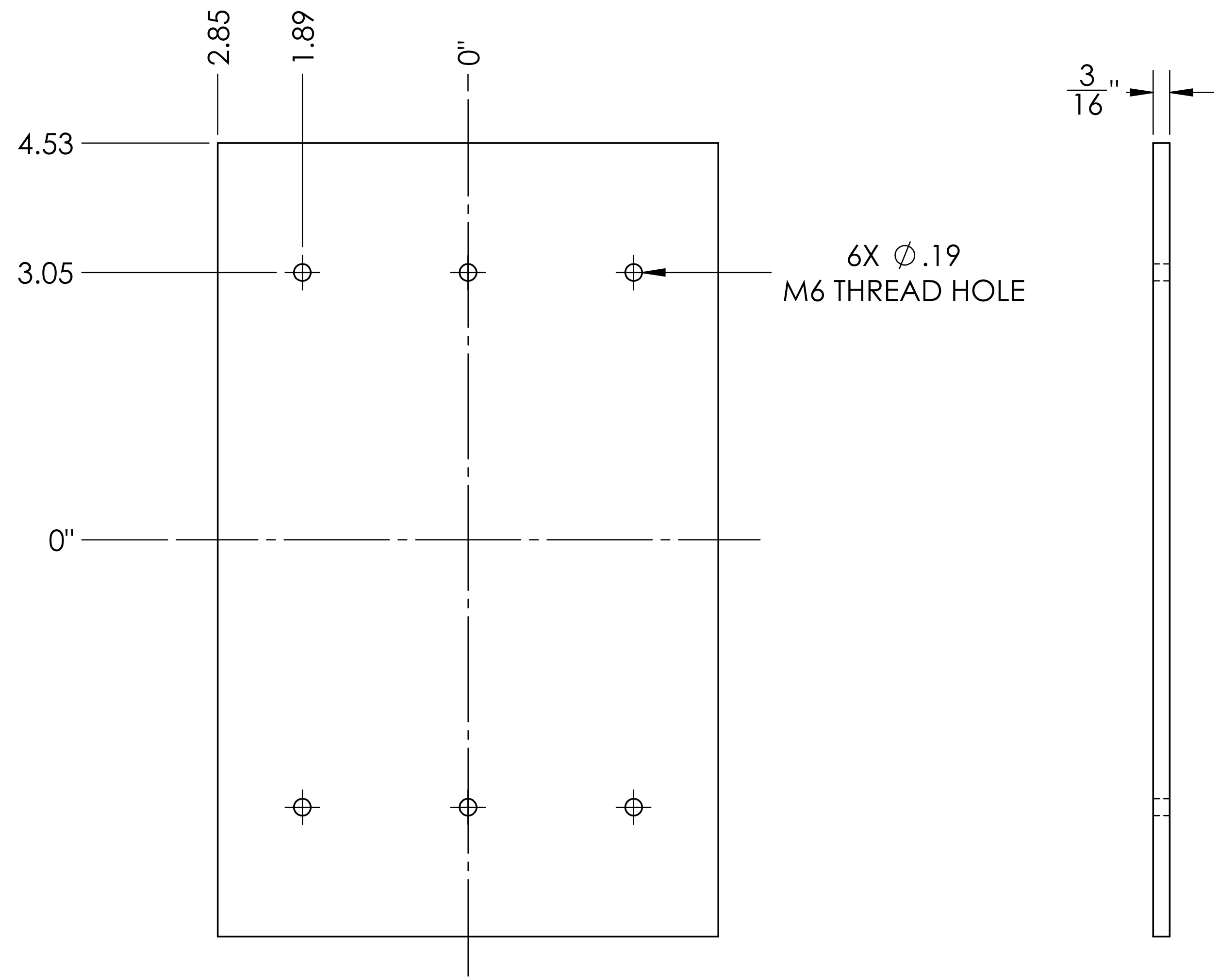


SECTION A-A
SCALE 1 : 10

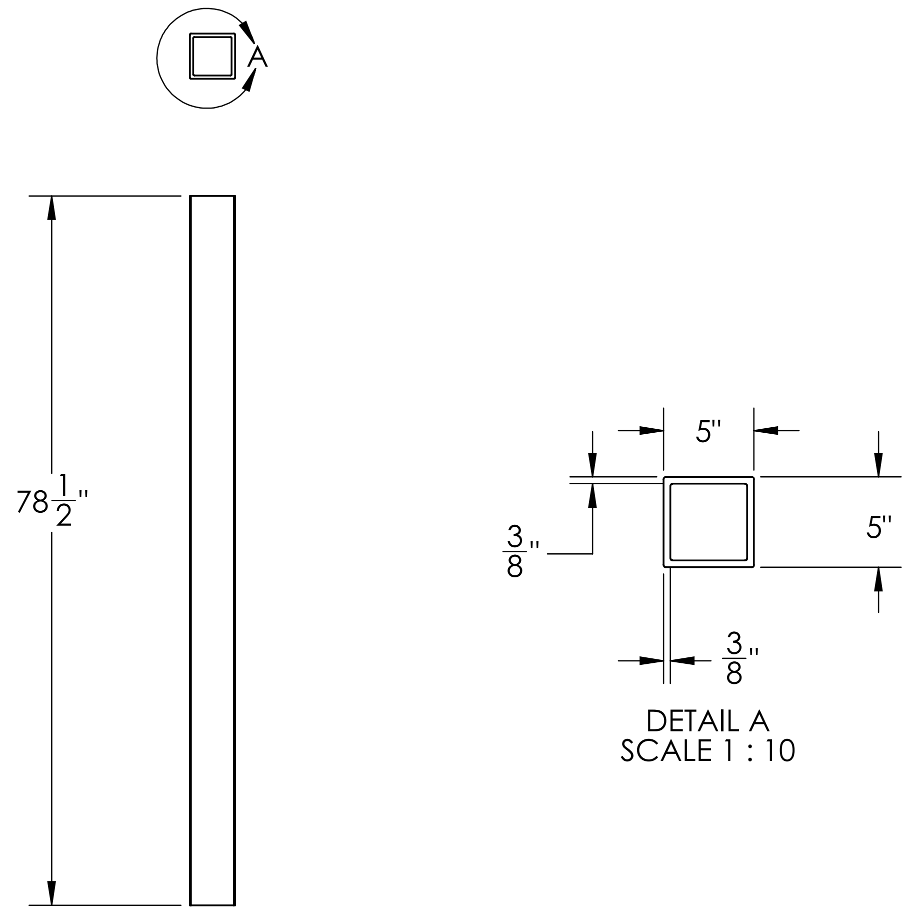


SECTION B-B
SCALE 1 : 5

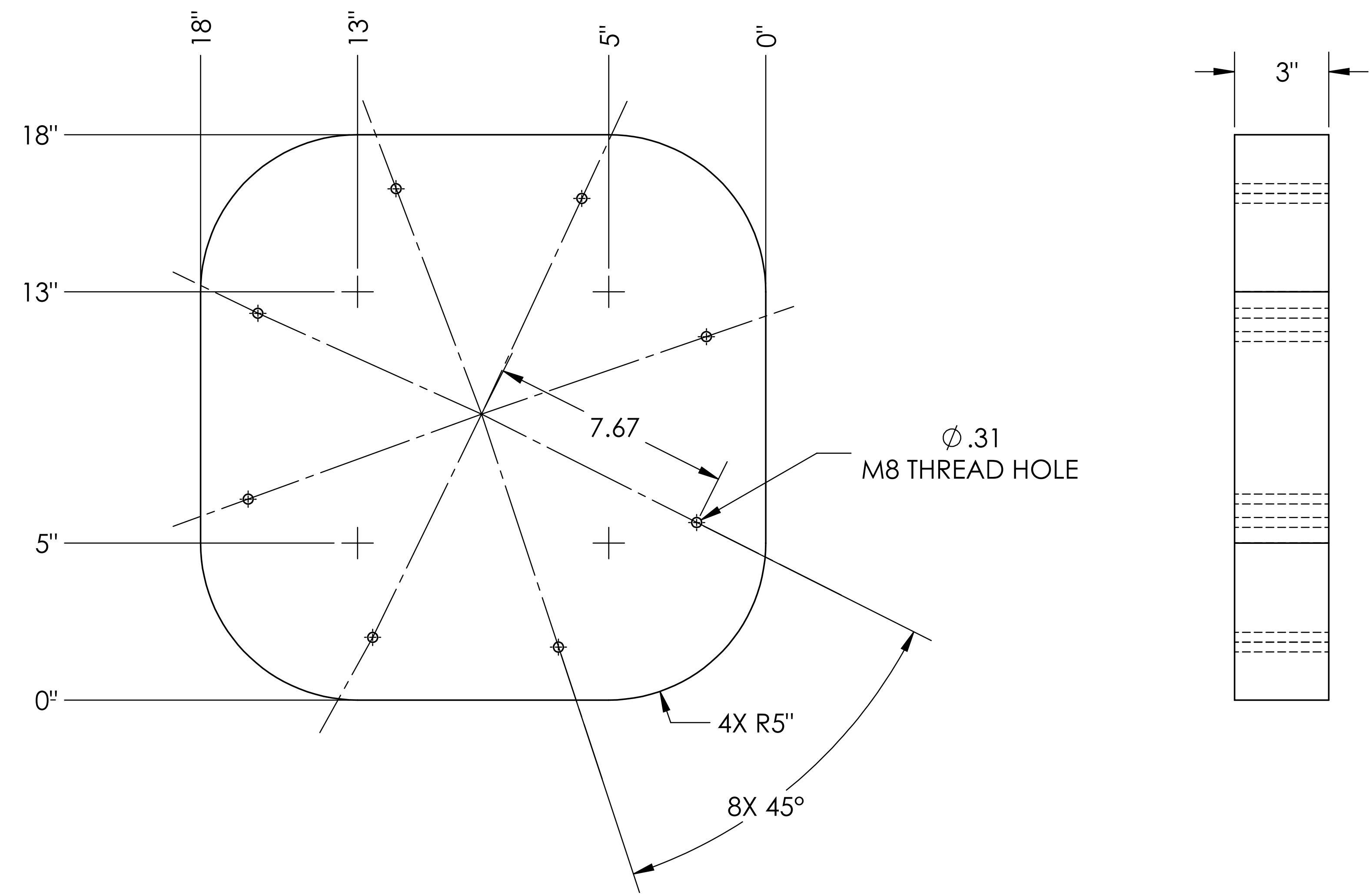
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM	FINISH: AS SHOWN	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:ARM-703	SCALE: 1:14
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: ARM BASE DESCRIPTION: MAIN ARM SUPPORT SHEET 2 OF 12 DO NOT SCALE DRAWING	WEIGHT:	ARM-803



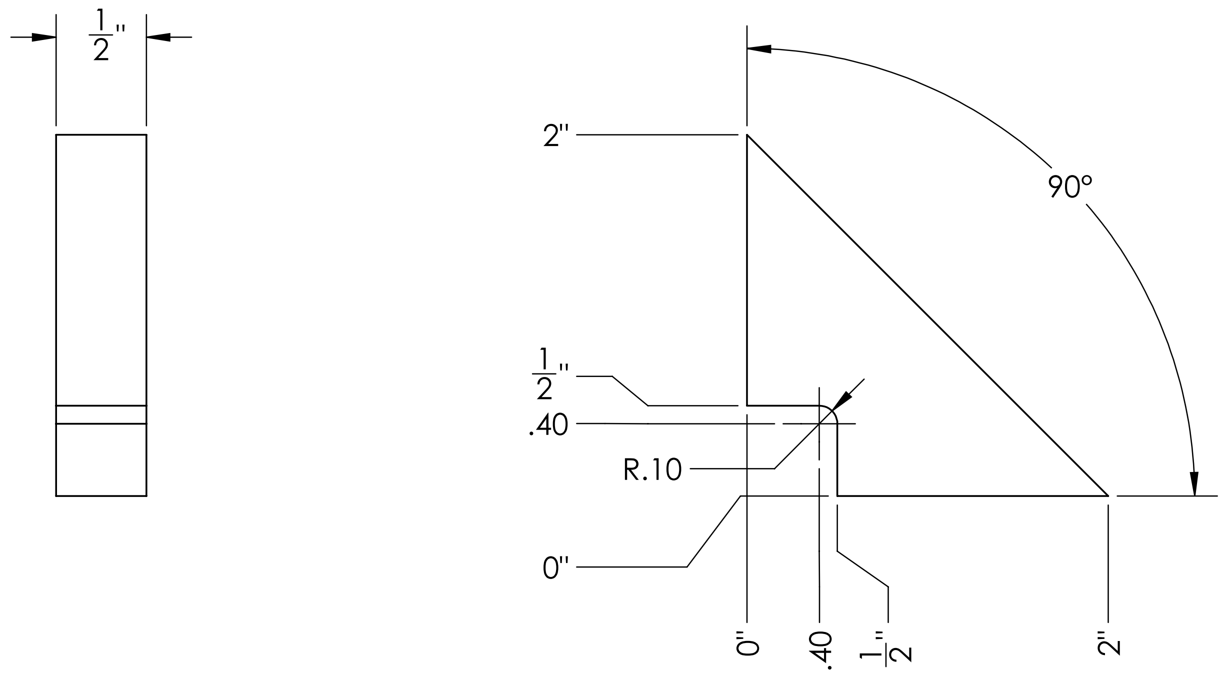
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-803
	FINISH: 125			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: MAIN ARM SUPPORT	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: BASE TRACK MOUNT PLATE	ARM-511
		CHECKED BY: --	SHEET 3 OF 12 DO NOT SCALE DRAWING	



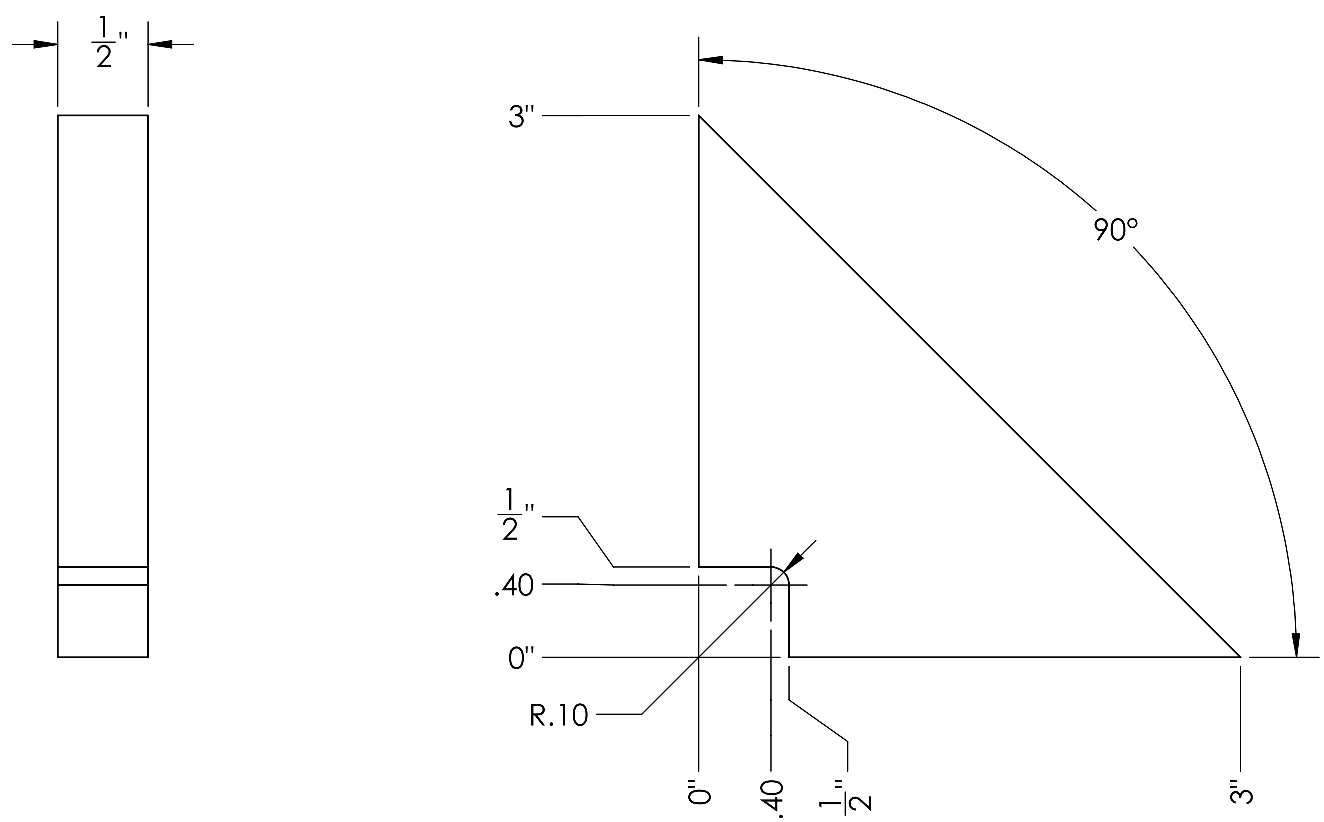
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY:ARM-803 SCALE: 1: 20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: MAIN ARM SUPPORT DESCRIPTION: MAIN ARM SUPPORT COLUMN SHEET 4 OF 12 DO NOT SCALE DRAWING	WEIGHT: ARM-510



DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:ARM-803
	FINISH: 125			SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: MAIN ARM SUPPORT	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: ROTARY TABLE PLATEFORM	ARM-509
		CHECKED BY: --	SHEET 5 OF 12 DO NOT SCALE DRAWING	

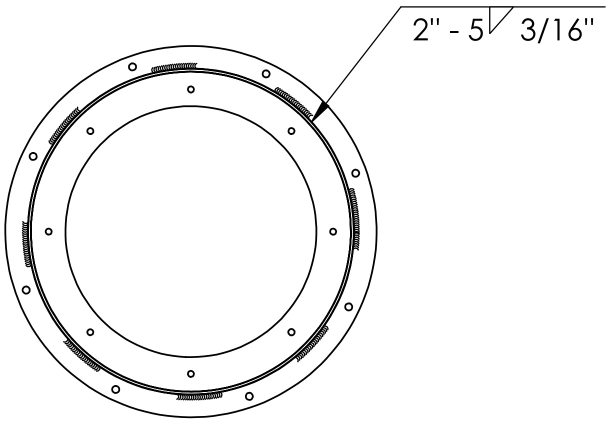


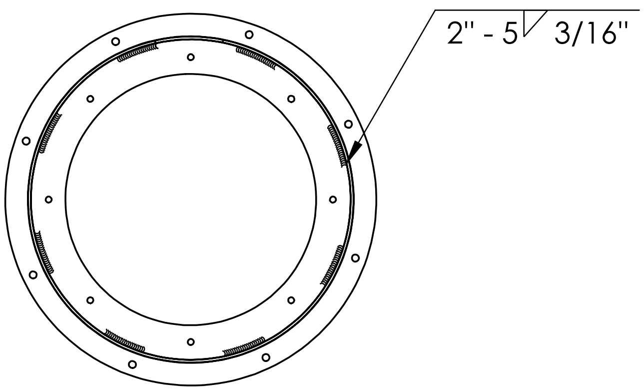
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-803
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: MAIN ARM SUPPORT	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: BASE COLUMN STIFFENER BOTTOM	ARM-507
		CHECKED BY:	--	SHEET 6 OF 12 DO NOT SCALE DRAWING	

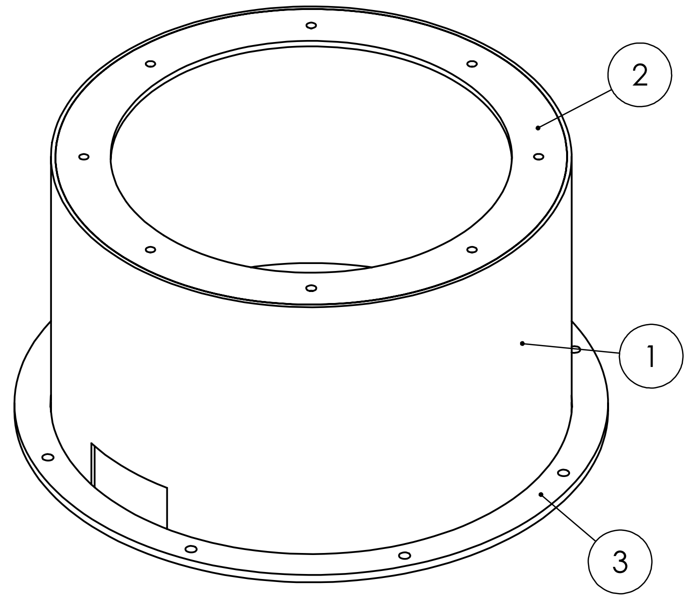


DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: ARM-803
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: MAIN ARM SUPPORT		WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: BASE COLUMN STIFFENER TOP		ARM-508
		CHECKED BY: --	SHEET 7 OF 12	DO NOT SCALE DRAWING	

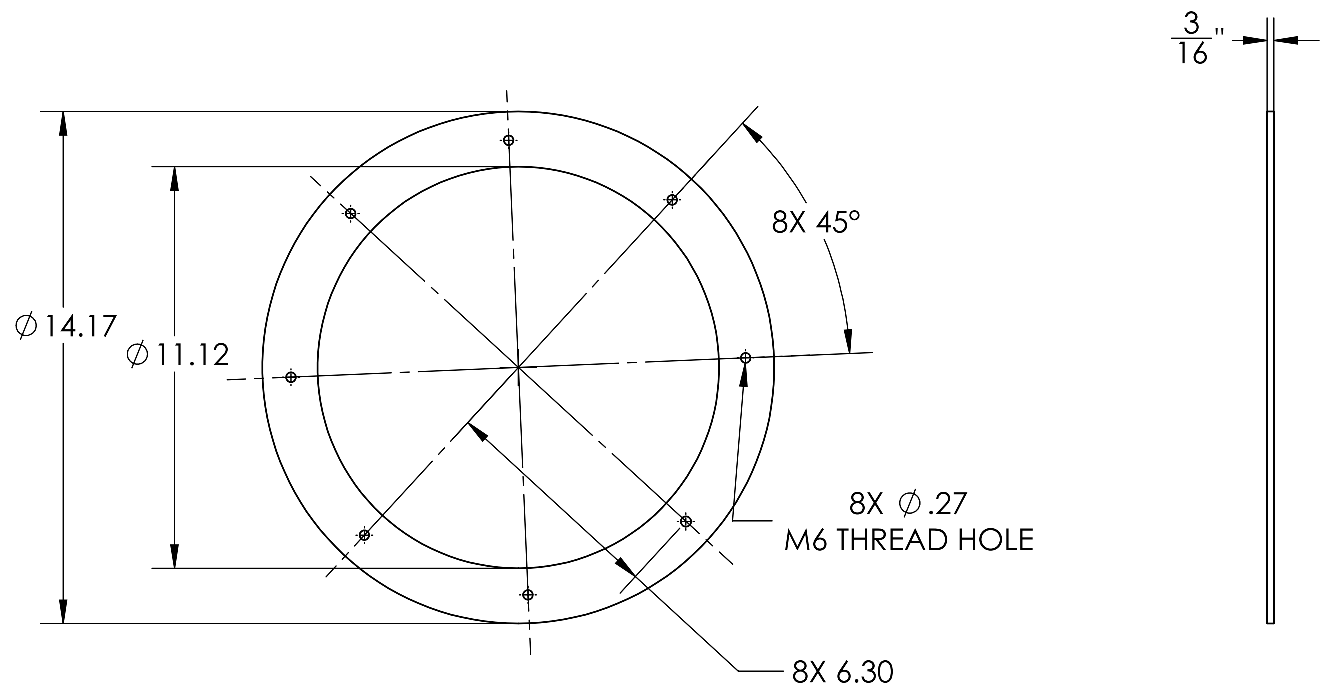
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ARM-524-R00-KF	ROTARY CONTAINER SHELL	1
2	ARM-523-R00-KF	ROTARY CONTAINER TOP	1
3	ARM-525-R00-KF	ROTARY CONTAINER BOTTOM	1



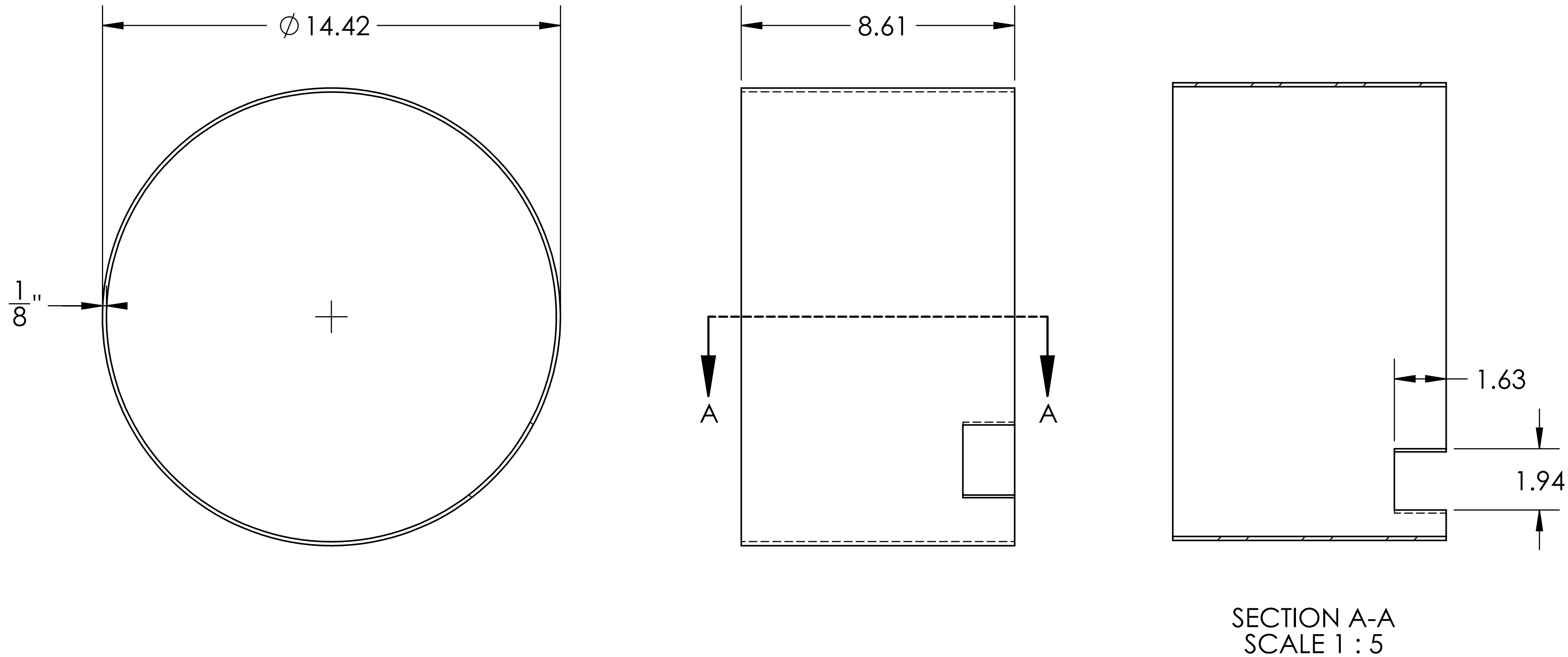




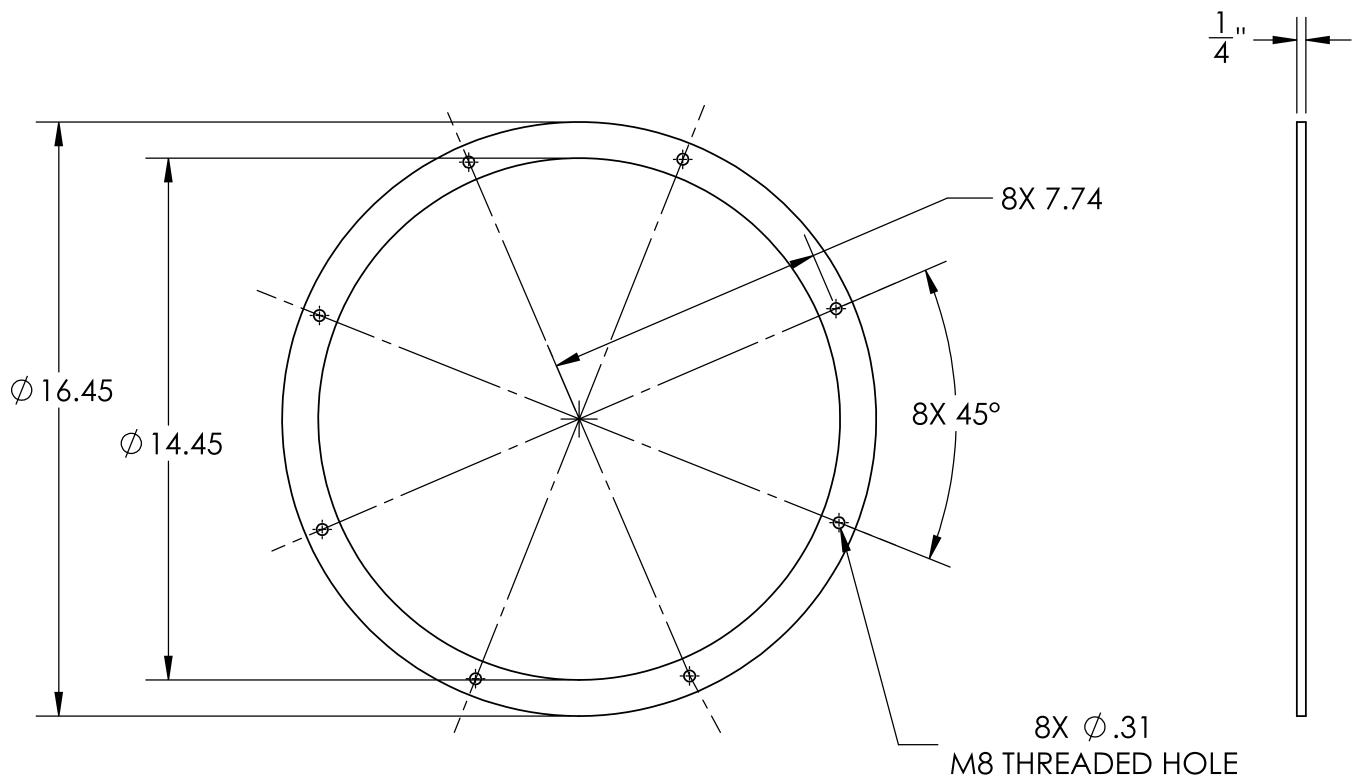
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-703
	FINISH: AS SHOWN		SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	USED WITH: ARM BASE	WEIGHT:
	FIRST ISSUED: 11/28/2018	DESCRIPTION: ROTARY TABLE CONTAINER	ARM-802
	DRAWN BY: K.F	SHEET 8 OF 12 DO NOT SCALE DRAWING	
	CHECKED BY: --		



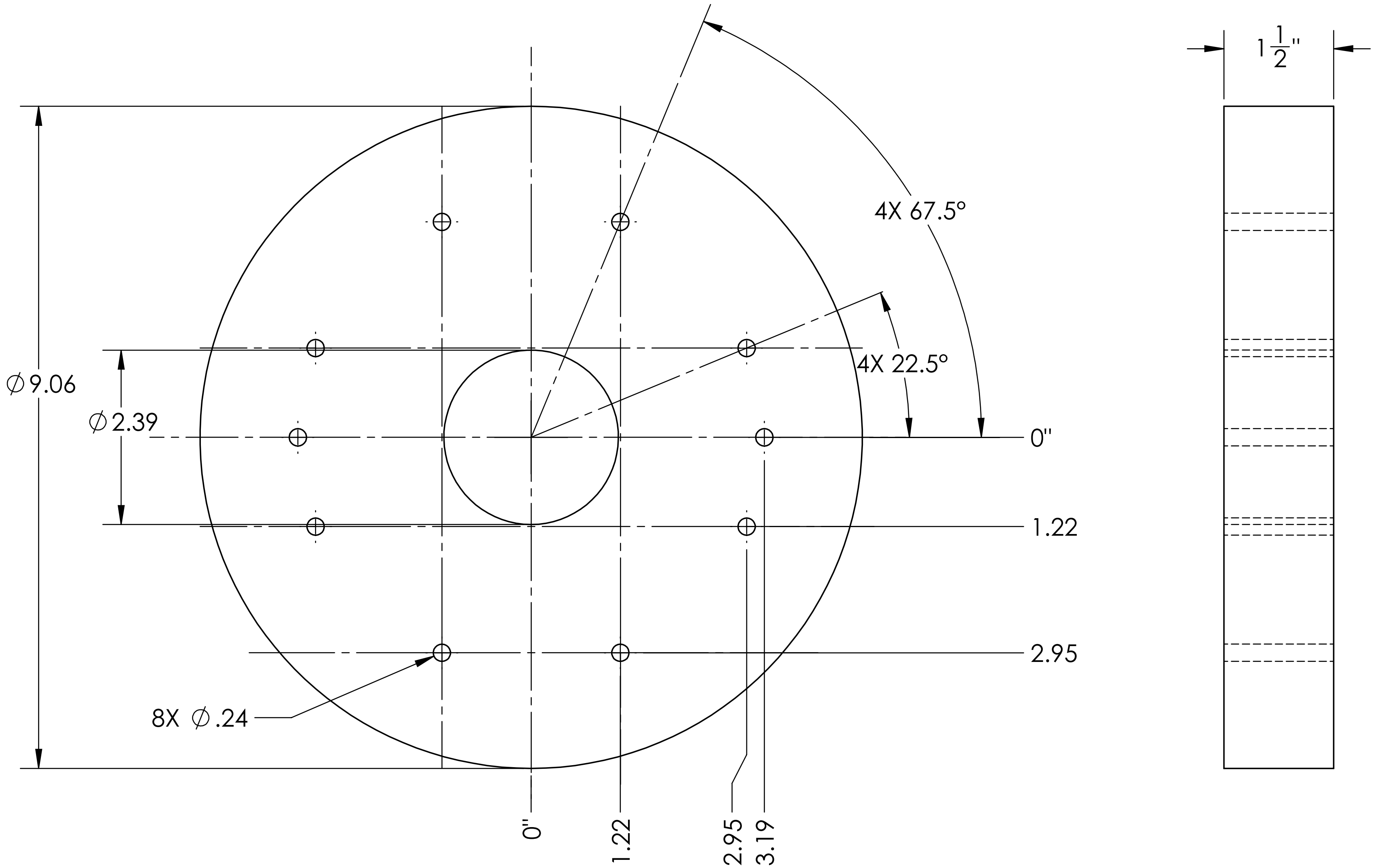
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-802
	FINISH: 125			SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ROTARY TABLE CONTAINER	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: ROTARY TABLE CONTAINER TOP	ARM-523
		CHECKED BY: --	SHEET 9 OF 12 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-802
	FINISH: 125			SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ROTARY TABLE CONTAINER	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: ROTARY TABLE CONTAINER SHELL	ARM-524
		CHECKED BY: --	SHEET 10OF 12 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:ARM-802
	FINISH: 125			SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ROTARY TABLE	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: ROTARY TABLE CONTAINER BOTTOM	ARM-525
		CHECKED BY: --	SHEET 11OF 12 DO NOT SCALE DRAWING	

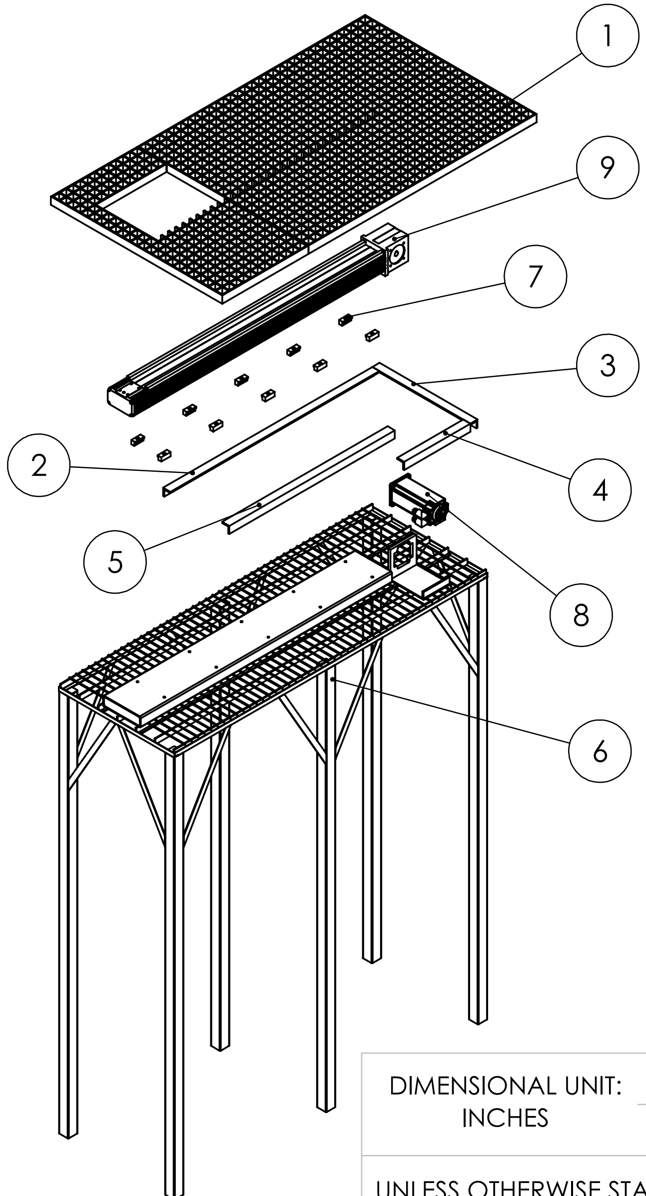


DIMENSIONAL UNIT: INCHES	MATERIAL: HDPE		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-703
	FINISH: 125			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: MAIN ARM TO ROTARY TABLE SPACER	ARM-526
		CHECKED BY: --	SHEET 12OF 12 DO NOT SCALE DRAWING	

Preliminary Manufacturing Drawing Package

Arm Base Support

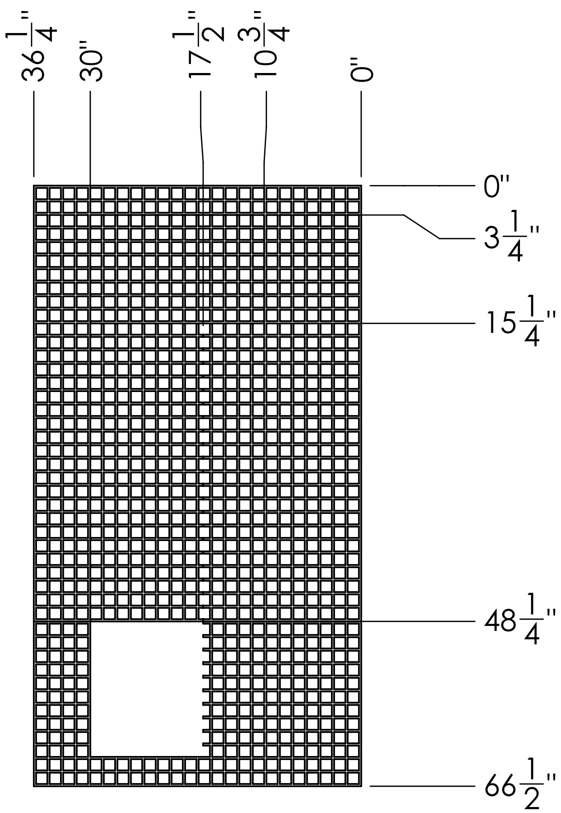
Appendix D

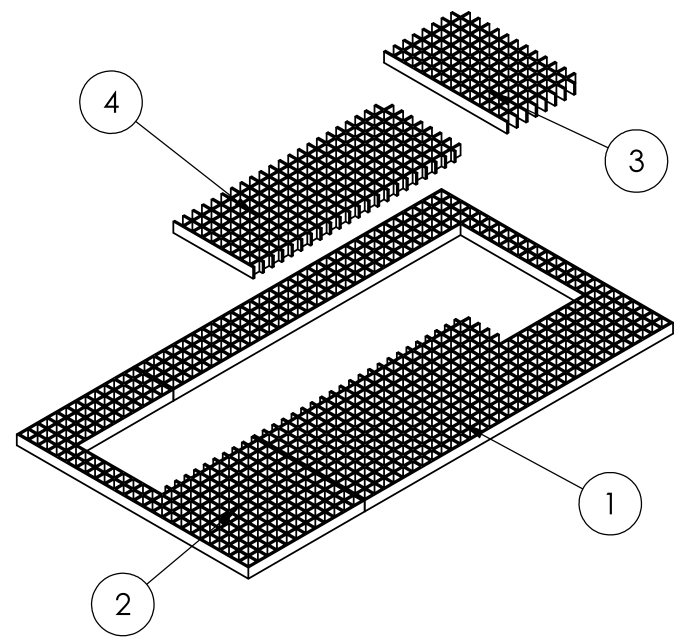


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	7075T89	NEW FLOOR GRATING	1
2	ARM-527-R00-KF	GRATING SUPPORT A	1
3	ARM-528-R00-KF	GRATING SUPPORT B	1
4	ARM-529-R00-KF	GRATING SUPPORT C	1
5	ARM-530-R00-KF	GRATING SUPPORT D	1
6	ARM-807-R00-KF	BASE SUPPORT PLATFORM	1
7	ARM-702-R00-KF	TRACK MOUNT BRACKETS	10
8	ARM-203-R00-KF	BASAE TRACK MOTOR	1
9	r13_2a_01496_1a000_1_0_01	BASE TRACK	1

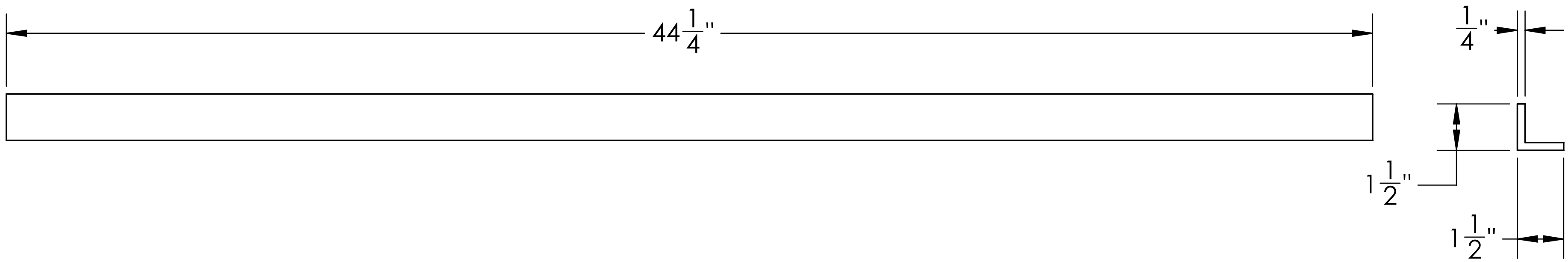
DIMENSIONAL UNIT: INCHES	MATERIAL: SEE BOM FINISH: AS SHOWN	UNIVERSITY OF MANITOBA HYLIFE FOODS	NEXT ASSY: -- SCALE: 1: 30
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: -- DESCRIPTION: ARM BASE SUPPORT SHEET 1 OF 22 DO NOT SCALE DRAWING	WEIGHT: 515.48 ARM-706

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	7075T89	STATIONARY GRATING	1
2	7075T89	STATIONARY GRATING	1
3	7075T89	REMOVABLE GRATING	1
4	7075T89	REMOVABLE GRATING	1



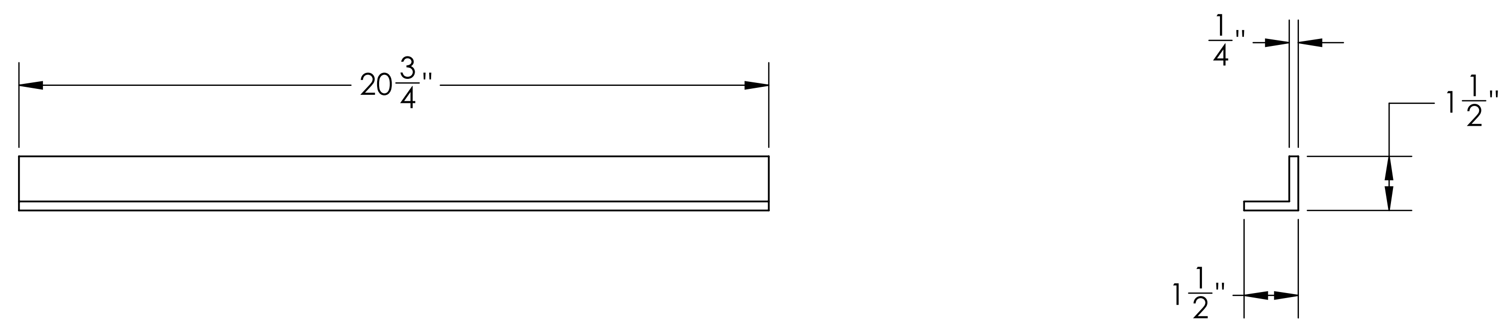


DIMENSIONAL UNIT: INCHES	MATERIAL: AS PURCHASED FINISH: AS PURCHASED	UNIVERSITY OF MANITOBA HyLIFE FOODS	NEXT ASSY: ARM-706 SCALE: 1: 20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: ARM BASE SUPPORT DESCRIPTION: NEW FLOOR GRATING SHEET 2 OF 22 DO NOT SCALE DRAWING	WEIGHT: 7075T89



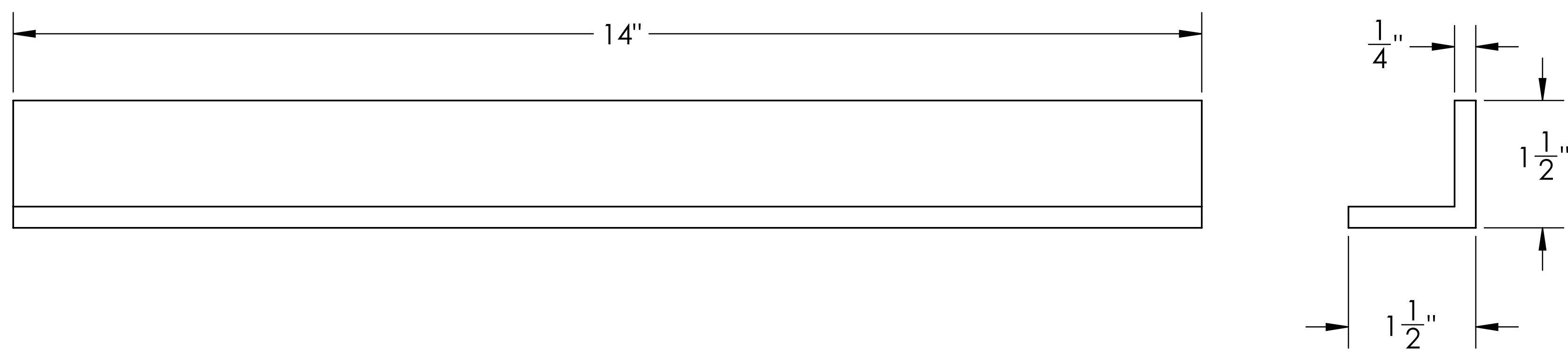
NOTE:
1.5 X 1.5 X 0.25 L-BRACKET

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706
	FINISH: 125				SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: FIBERGLASS BAR GRATING	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: GRATING SUPPORT A	ARM-527
		CHECKED BY:	--	SHEET 3 OF 22 DO NOT SCALE DRAWING	



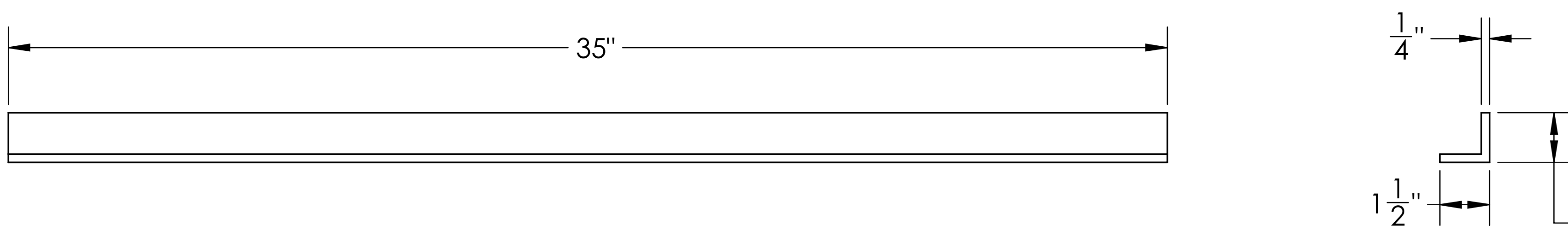
NOTE:
1.5 X 1.5 X 0.25 L-BRACKET

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706
	FINISH: 125			SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: FIBERGLASS BAR GRATING	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: GRATING SUPPORT B	ARM-528
		CHECKED BY: --	SHEET 4 OF 22 DO NOT SCALE DRAWING	



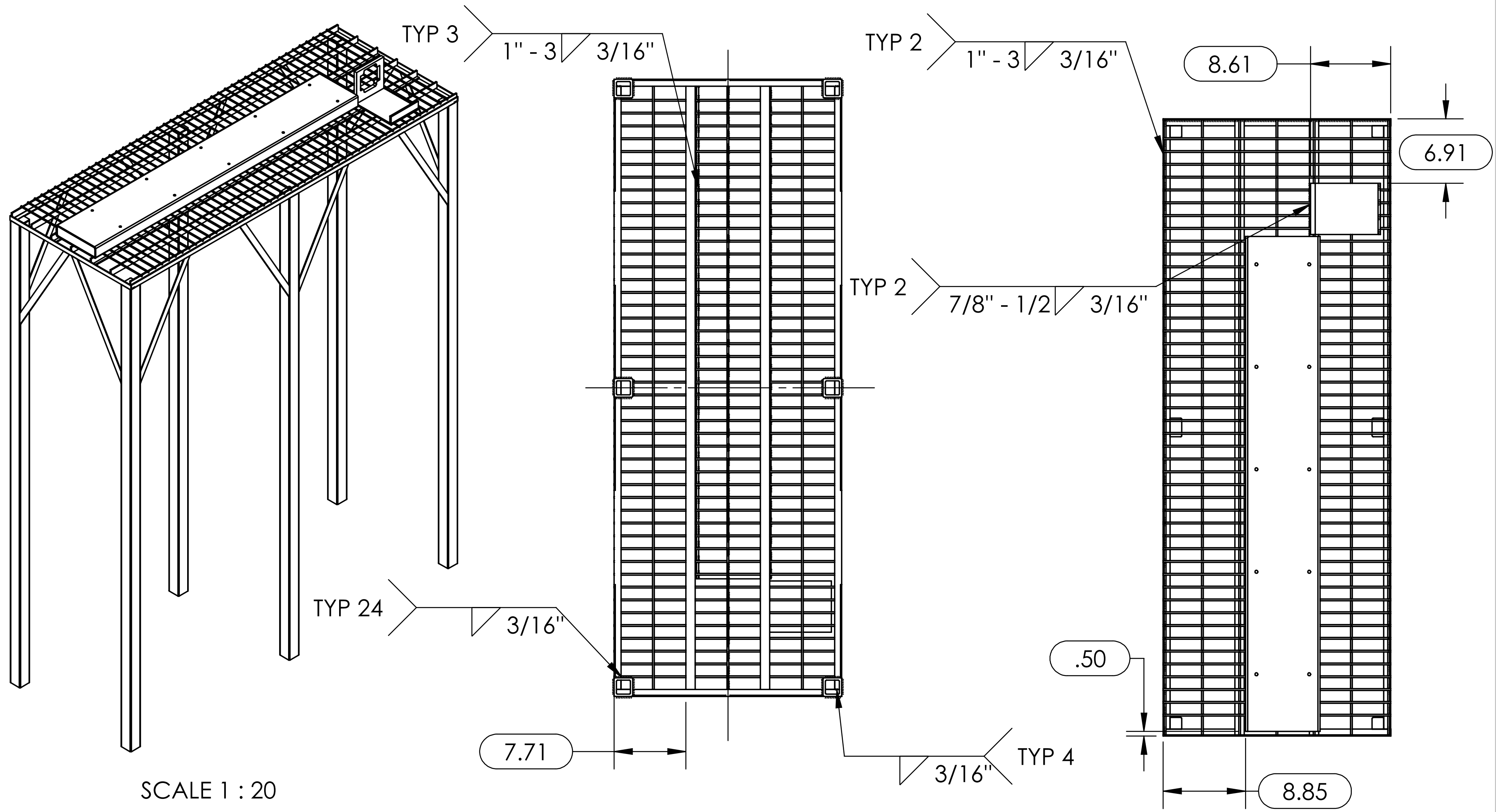
NOTE:
1.5 X 1.5 X 0.25 L-BRACKET

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL	FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: FIBERGLASS BAR GRATING DESCRIPTION: GRATING SUPPORT C SHEET 5 OF 22 DO NOT SCALE DRAWING	SCALE: 1:2 WEIGHT: ARM-529

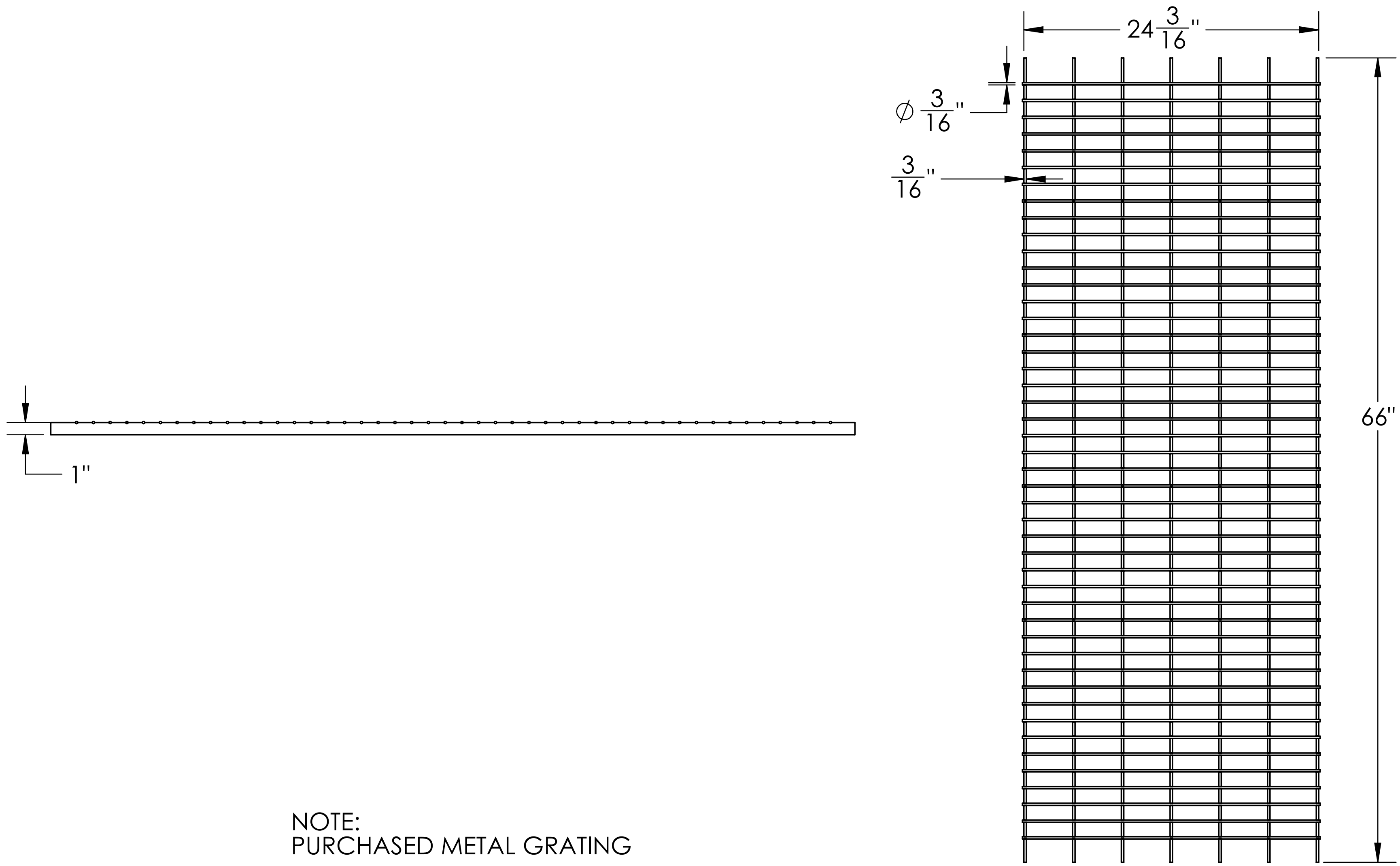


NOTE:
1.5 X 1.5 X 0.25 L-BRACKET

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706 SCALE: 1:5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: FIBERGLASS BAR GRATING DESCRIPTION: GRATING SUPPORT D SHEET 6 OF 22 DO NOT SCALE DRAWING	WEIGHT: ARM-530

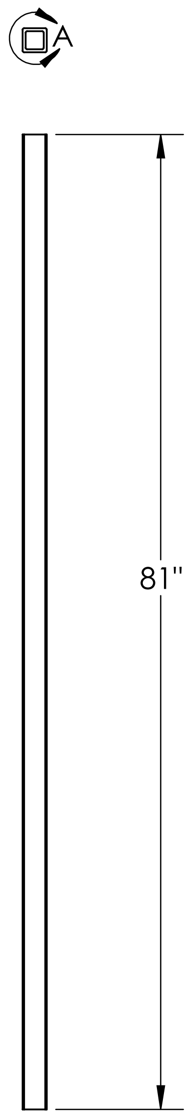


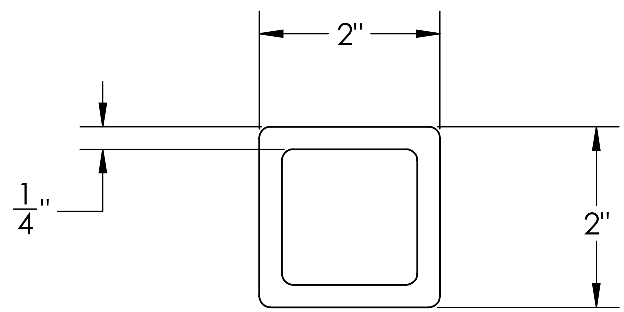
DIMENSIONAL UNIT: INCHES	MATERIAL: AS SHOWN		UNIVERSITY OF MANITOBA HYLIFE FOODS	NEXT ASSY: ARM-706
	FINISH: 125			SCALE: 1:15
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE SUPPORT STRUCTURE	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: ARM BASE SUPPORT PLATFORM	ARM-807
		CHECKED BY: --	SHEET 7 OF 22 DO NOT SCALE DRAWING	



NOTE:
PURCHASED METAL GRATING

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HyLIFE FOODS	NEXT ASSY: ARM-807
	FINISH: AS PURCHASED				SCALE: 1:12
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: METAL BAR GRATING	G43161
		CHECKED BY:	--	SHEET 8 OF 22 DO NOT SCALE DRAWING	

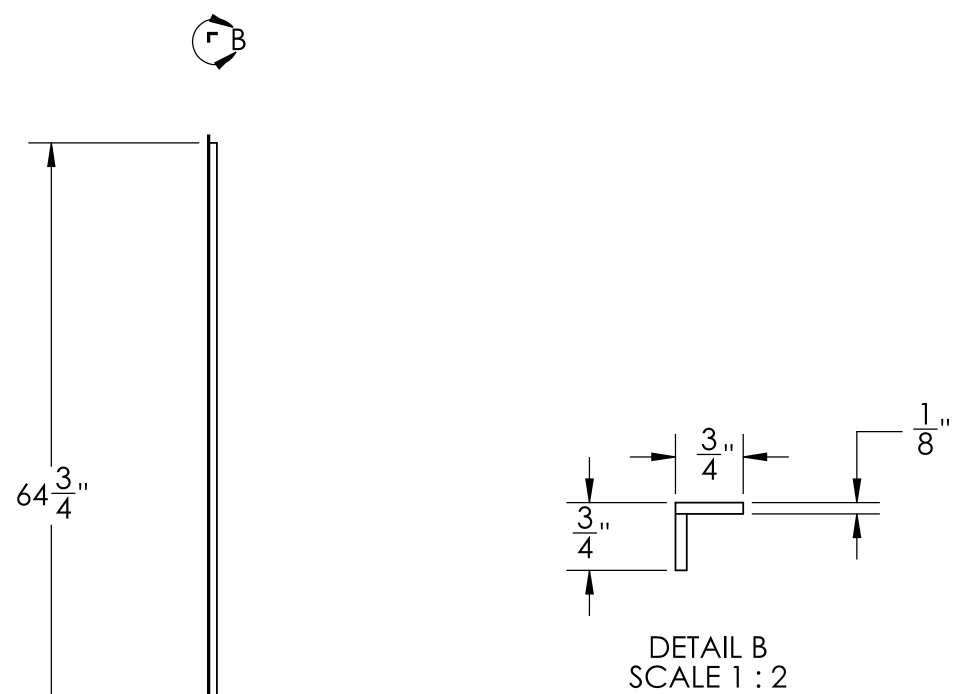




DETAIL A
SCALE 1 : 2

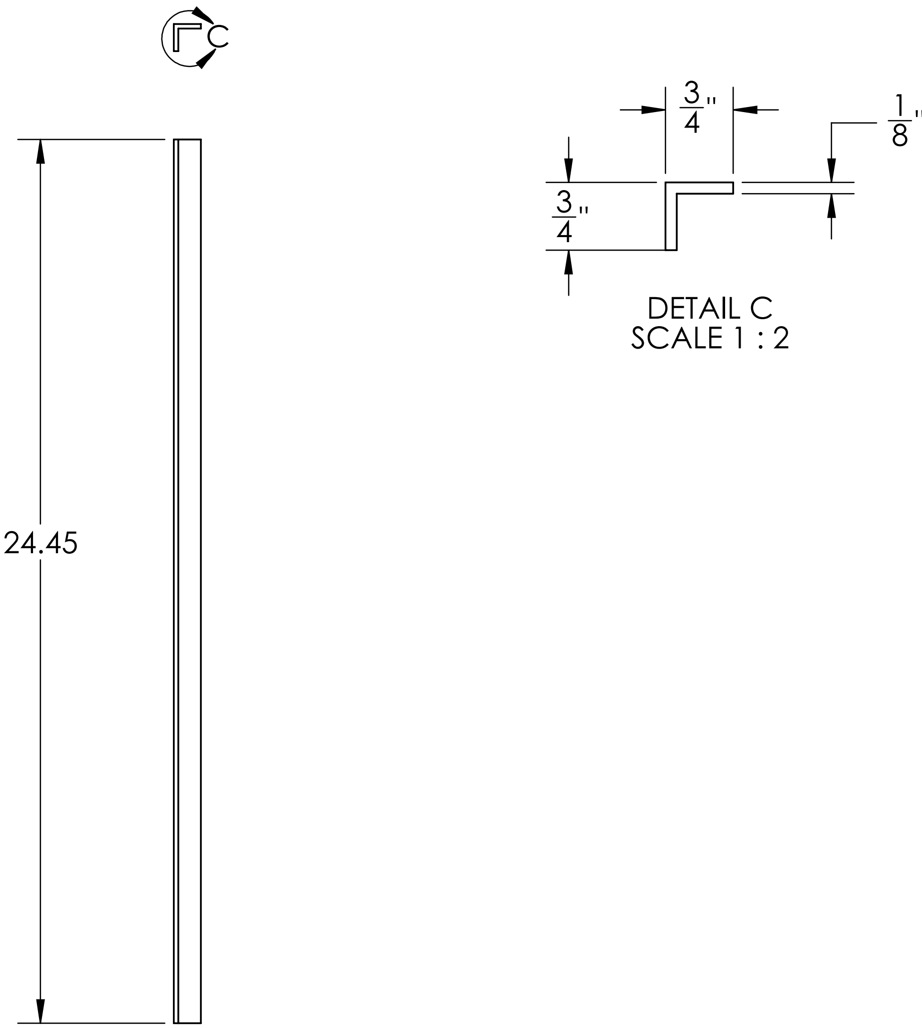
NOTE:
2-INCH BY 2-INCH
WITH 0.25 THICKNESS
BAR STOCK

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807
	FINISH: 125			SCALE: 1:20
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: METAL GRATING SUPPORT LEG	ARM-512
		CHECKED BY: --	SHEET 9 OF 22 DO NOT SCALE DRAWING	



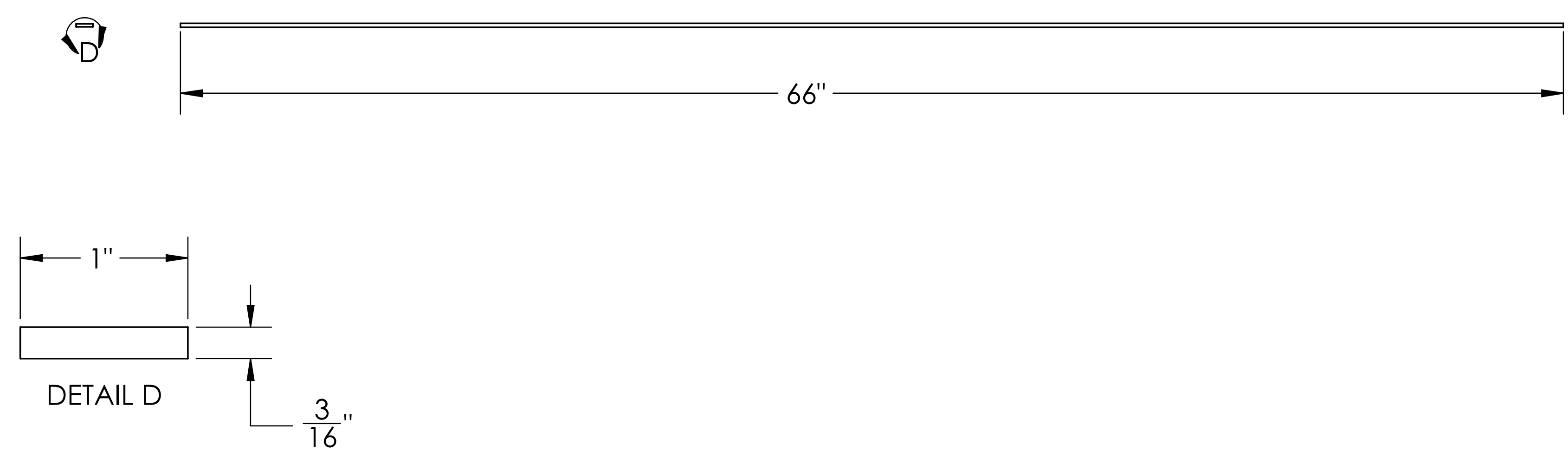
NOTE:
0.75 X 0.75 X 0.125 L-BRACKET

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807 SCALE: 1:15
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: ARM BASE SUPPORT PLATEFORM DESCRIPTION: METAL BAR GRATING BRACKETS SHEET 10OF 22 DO NOT SCALE DRAWING	WEIGHT: ARM-513

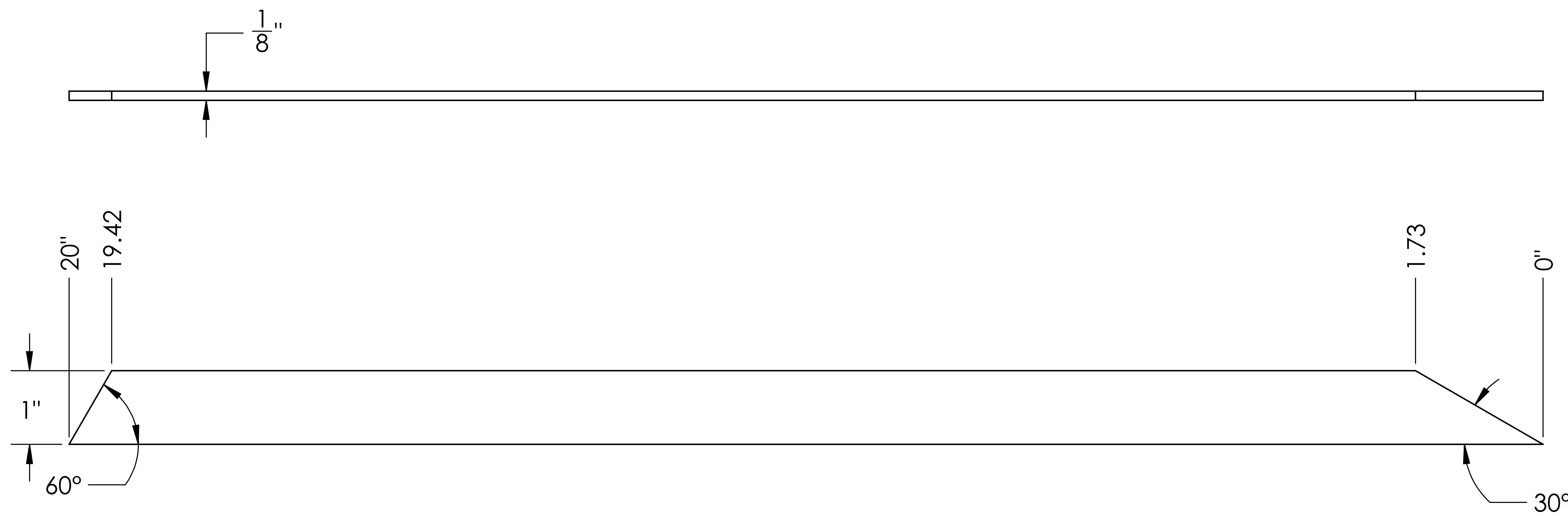


NOTE:
0.75 X 0.75 X 0.125 L-BRACKET

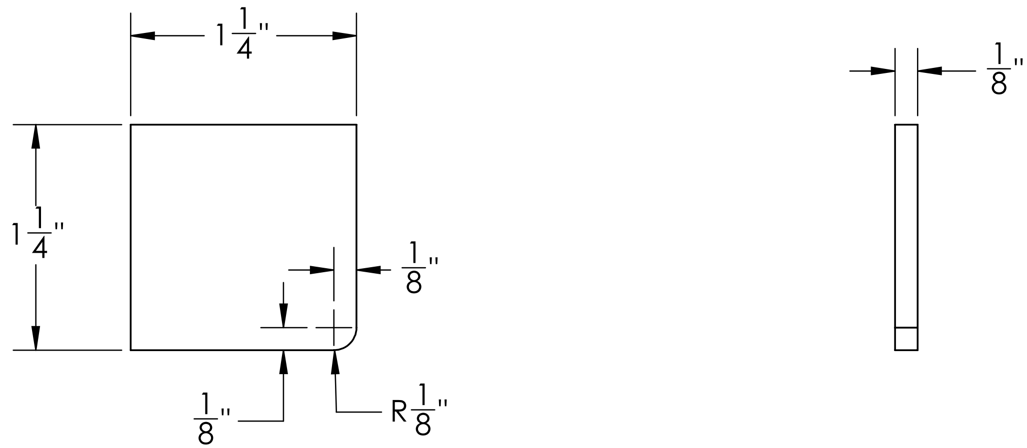
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807 SCALE: 1: 5
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: ARM BASE SUPPORT PLATFORM DESCRIPTION: METAL BAR GRATING BRACKET SHEET 11OF 22 DO NOT SCALE DRAWING	WEIGHT: ARM-514



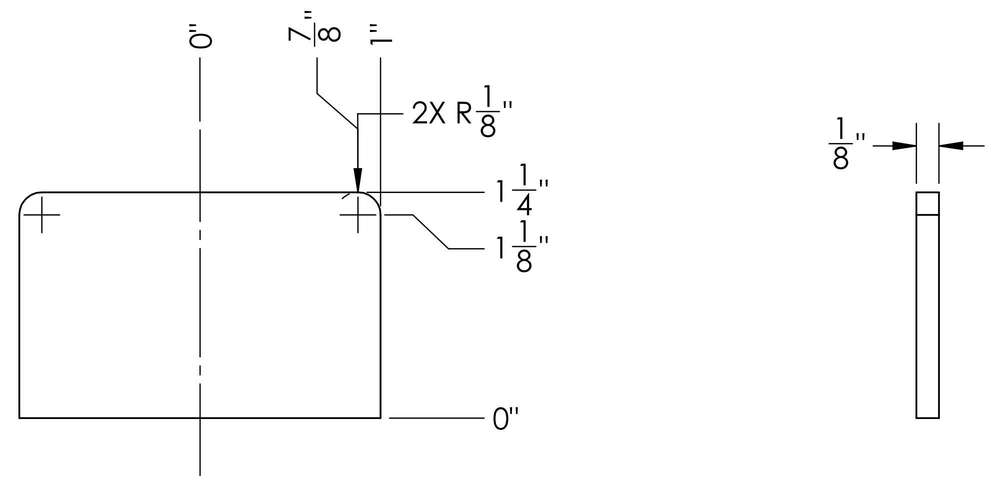
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY:ARM-807
	FINISH: 125			SCALE: 1:10
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: METAL GRATING SUPPORT PLATE	ARM-515
		CHECKED BY: --	SHEET 12OF 22 DO NOT SCALE DRAWING	



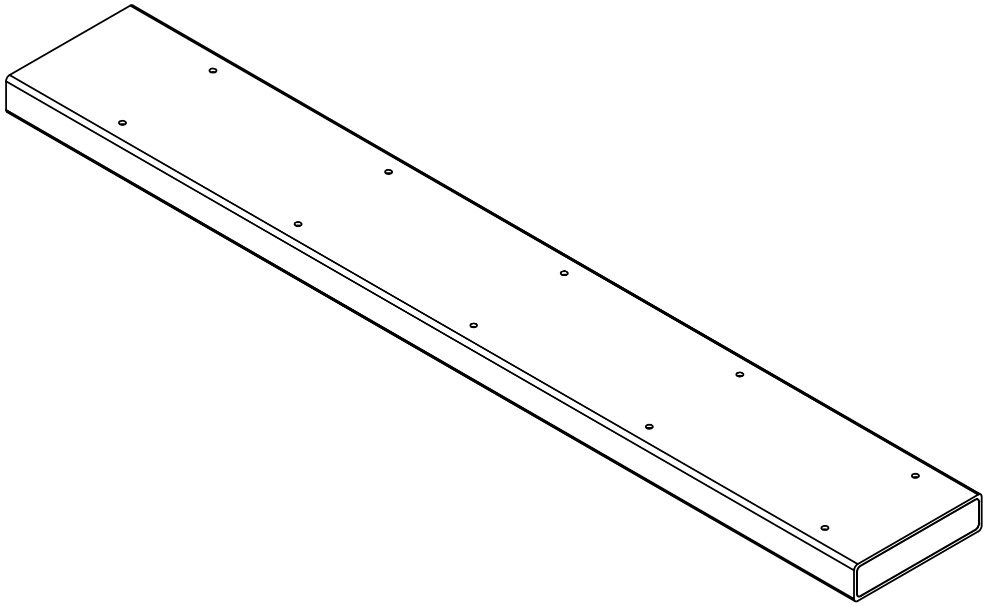
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807
	FINISH: 125			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: METAL GRATING SUPPORT TRUSS	ARM-516
		CHECKED BY: --	SHEET 13OF 22 DO NOT SCALE DRAWING	

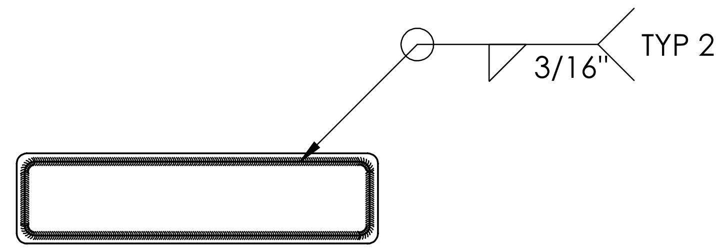


DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: SUPPORT LEG ENCLOSURE PLATE	ARM-517
		CHECKED BY:	--	SHEET 14OF 22 DO NOT SCALE DRAWING	



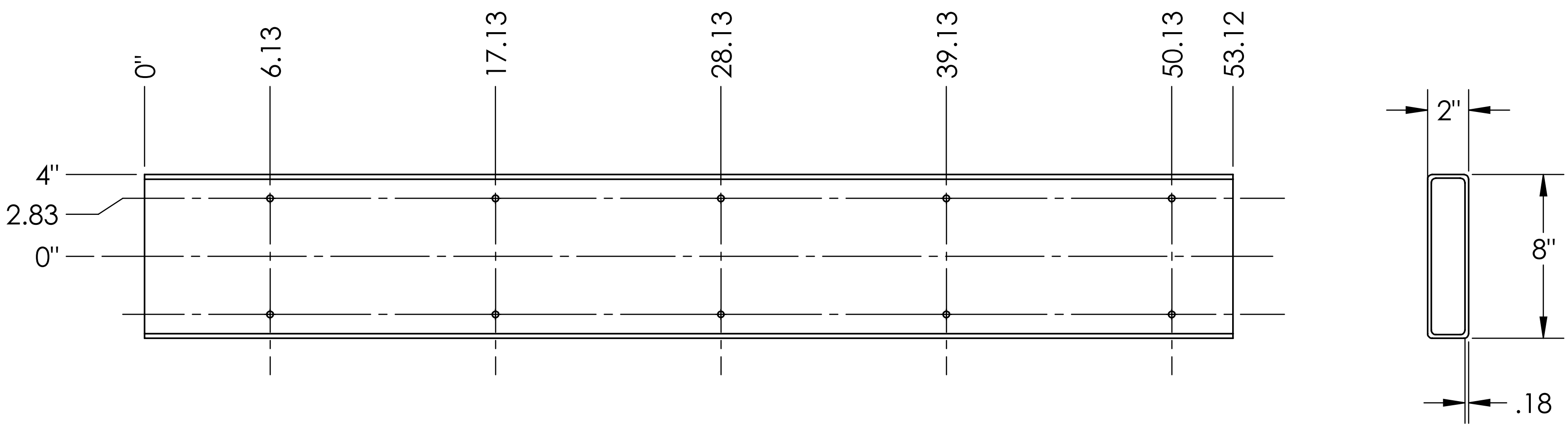
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-807
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: ARM BASE SUPPORT PLATEFORM	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: SUPPORT LEG ENCLOSURE PLATE	ARM-518
		CHECKED BY:	--	SHEET 15OF 22 DO NOT SCALE DRAWING	





SCALE 1 : 4

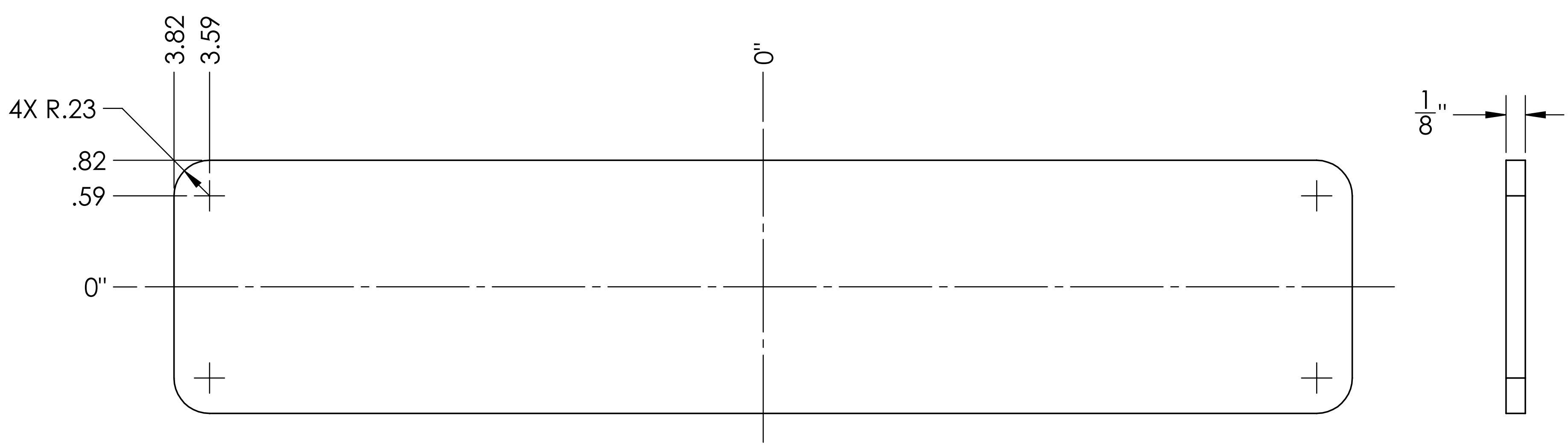
DIMENSIONAL UNIT: INCHES	MATERIAL: AS SHOWN			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706
	FINISH: 125				SCALE: 1 : 8
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: ARM BASE SUPPORT	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: ARM BASE TRACK SPACER	ARM-808
		CHECKED BY:	--	SHEET 16OF 22 DO NOT SCALE DRAWING	



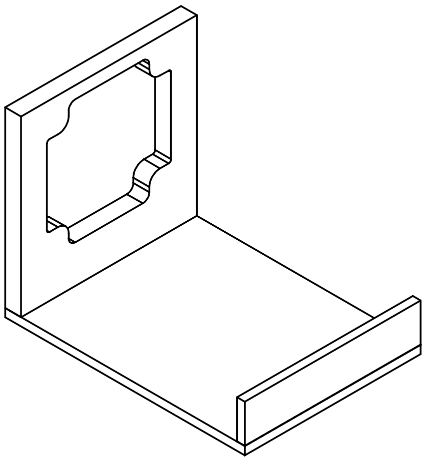
NOTE:
8 X 2 X 0.175 TUBE

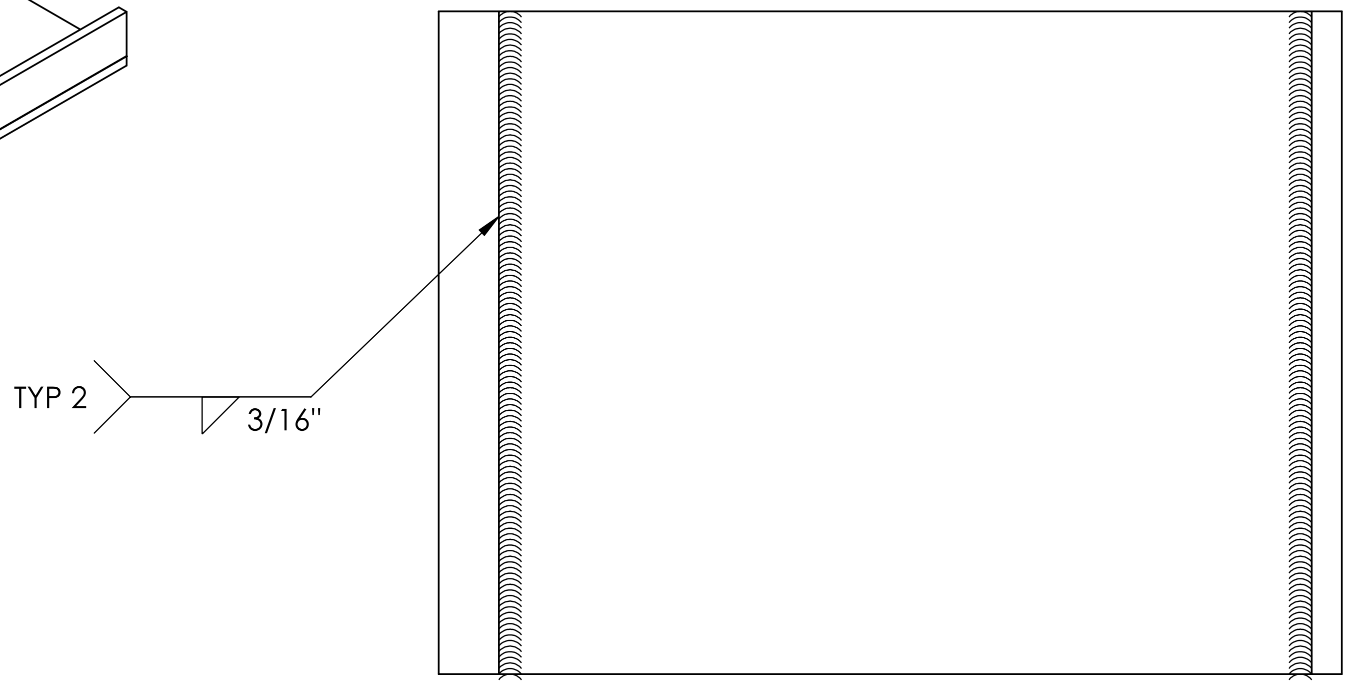
DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL	FINISH: 125		NEXT ASSY: ARM-808
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: BASE TRACK SPACER	SCALE: 1: 8
		DRAWN BY: K.F	DESCRIPTION: BASE TRACK SPACER TUBE	WEIGHT:
		CHECKED BY: --	SHEET 17OF 22 DO NOT SCALE DRAWING	ARM-519

UNIVERSITY OF MANITOBA
HYLIFE FOODS

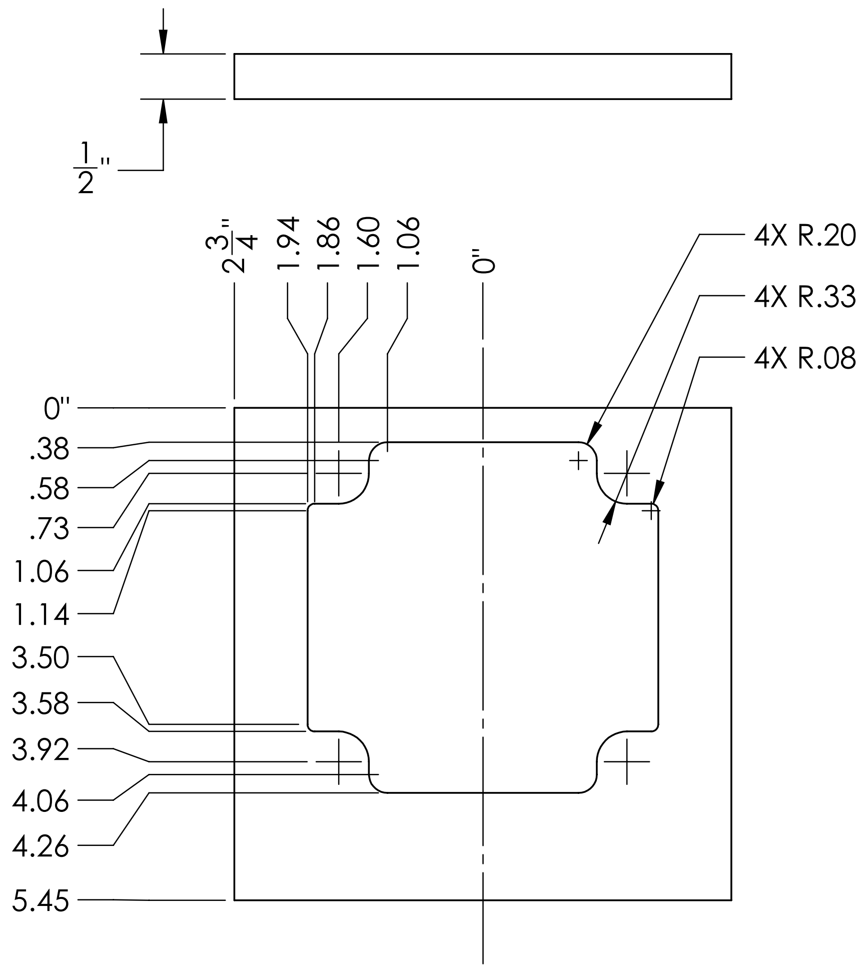


DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL			UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-808
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED:	11/28/2018	USED WITH: ARM BASE TRACK SPACER	WEIGHT:
		DRAWN BY:	K.F	DESCRIPTION: SPACER ENCLOSURE PLATE	ARM-531
		CHECKED BY:	--	SHEET 18OF 22 DO NOT SCALE DRAWING	



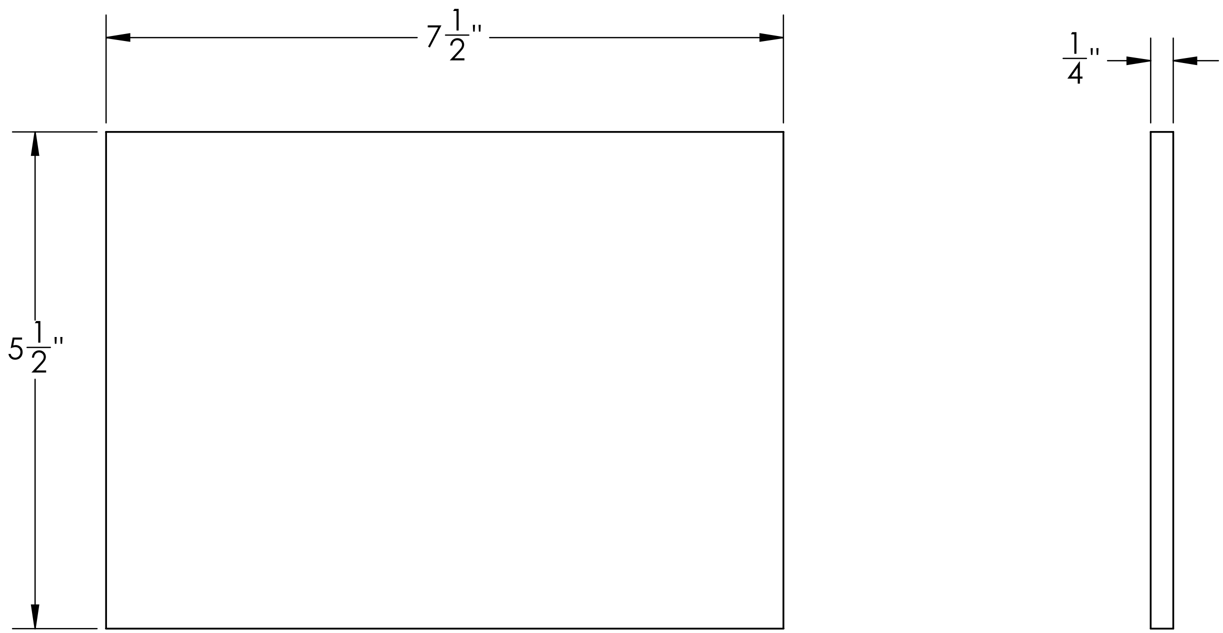


DIMENSIONAL UNIT: INCHES	MATERIAL: AS SHOWN		UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-706
	FINISH: 125			SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE SUPPORT	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: BASE TRACK MOTOR MOUNT	ARM-806
		CHECKED BY: --	SHEET 19OF 22 DO NOT SCALE DRAWING	

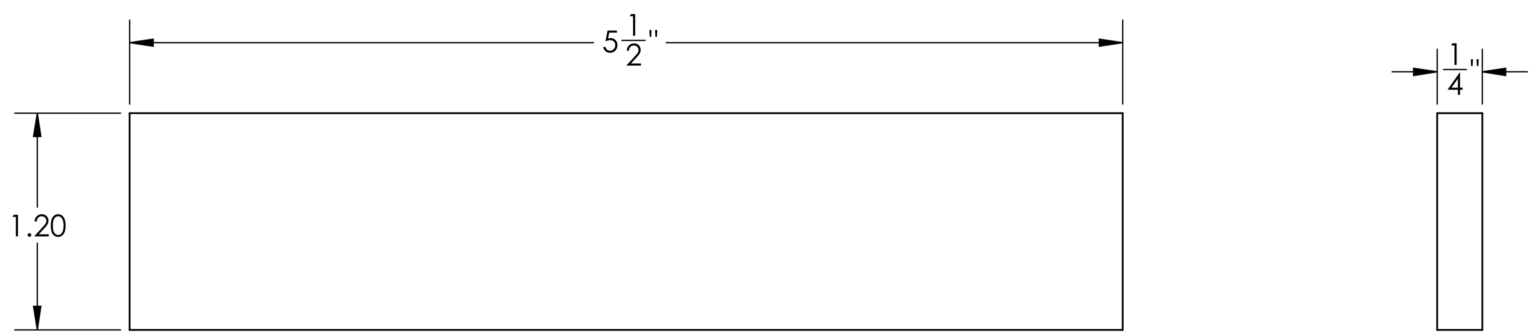


NOTE:
LASER CUT PART

DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL FINISH: 125	UNIVERSITY OF MANITOBA / HYLIFE FOODS	NEXT ASSY: ARM-806 SCALE: 1: 2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4 FIRST ISSUED: 11/28/2018 DRAWN BY: K.F CHECKED BY: --	USED WITH: BASE TRACK MOTOR MOUNT DESCRIPTION: BASR TRACK MOTOR MOUNT PLATE SHEET 20OF 22 DO NOT SCALE DRAWING	WEIGHT: ARM-520



DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA · HYLIFE FOODS	NEXT ASSY: ARM-806
	FINISH: 125			SCALE: 1:2
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: BASE TRACK MOTOR MOUNT	WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: BASE MOTOR MOUNT BOTTOM PLATE	ARM-521
		CHECKED BY: --	SHEET 21OF 22 DO NOT SCALE DRAWING	



DIMENSIONAL UNIT: INCHES	MATERIAL: 304 STAINLESS STEEL		UNIVERSITY OF MANITOBA / HYLIFE FOODS		NEXT ASSY: ARM-806
	FINISH: 125				SCALE: 1:1
UNLESS OTHERWISE STATED NONTOLERANCED DIMENSIONS ARE 1/32" CAD MODEL IS BASIC NONDIMENSIONED GEOMETRIES PER CAD MODEL	SIZE A4	FIRST ISSUED: 11/28/2018	USED WITH: ARM BASE TRACK MOTOR MOUNT		WEIGHT:
		DRAWN BY: K.F	DESCRIPTION: BASE TRACK MOTOR MOUNT REAR PLATE		ARM-522
		CHECKED BY: --	SHEET 22OF 22	DO NOT SCALE DRAWING	