Letter of Transmittal

December 5th, 2018

Dr. Paul Labossiere, P. Eng.
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Dear Dr. Labossiere:

Please accept the accompanying technical design report, entitled "Bandsaw Safety Improvements" as Team 24: Honeycomb Badgers Industries' submission for the MECH 4860 Final Design Report. The date of submission is Wednesday, December 5th, 2018.

The purpose of the enclosed report is to document the design process to improve blade safety and dust safety of a bandsaw for a technician performing a core chamfering process at Boeing Canada Winnipeg. This report begins with the scope of the project, client needs, assumption and constraints of the project. The report then details the teams concept generation and selection process to come up with a final design concept. The report then expands on the final concepts for blade and dust safety and expands on the critical characteristics and discussion of the design and how it will be implemented to the current bandsaw. Following the summary and conclusion of the report, supplemental information on the design and the design process will be attached in appendices.

The design features a user-friendly blade guard with a pivoting head that protects the operator from the bandsaw blade while also applying pressure to the core to assist with keeping the core flush against the backboard and create consistent chamfers. The design also features a custom designed downdraft table to be implemented to the existing bandsaw table to remove the amount of airborne dust created during the core chamfering process and protect the operator.

Honeycomb Badgers Industries thanks you for your time and assistance throughout this project.

Sincerely,

Justin Huhtala
Manager – Team 24: Honeycomb Badgers Industries

Enclosed: Final Design Report

Bandsaw Safety Improvements

Project Client:

Boeing Canada Winnipeg

Date of Submission

Wednesday, December 5th, 2018

Project Advisor:

Dr. Paul. E. Labossiere

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MECH 4860: Engineering Design

Executive Summary

Boeing Canada Winnipeg (BCW) is one of the largest aerospace composite manufacturers in Canada [1], producing over 500 parts and assemblies for its parent company Boeing. BCW is currently faced with a safety issue related to the use of bandsaws during a core chamfering process. Bandsaw operators are at risk of cutting themselves on the bandsaw blade, as well as being exposed to hazardous core dust that is created during the chamfering operation. Team 24: Honeycomb Badgers Industries has been commissioned by BCW to propose a design to mitigate, or eliminate these risks.

The two constraints placed on the project are that it must be completed by December 5, 2018, and that the design must fit inside the BCW building. BCW outlined four requirements that must be met by the proposed design:

1. The design must protect the bandsaw operator from being cut on by the blade.
2. The design must minimize the bandsaw operator's exposure to core dust.
3. The design must function for various dimensions of cores.
4. The design must function for various chamfer angles.

Through a concept generation and selection process, a blade guard with a pivoting head and a downdraft table were chosen to be developed. The blade guard features a two-part construction with a pivoting head that encloses the bandsaw blade. The blade guard moves vertically on a track, and rests on the core during the chamfering operation. The downdraft table is located underneath the bandsaw blade, and it vacuums the core dust into a sink.

The deliverables requested by BCW are a 3D CAD model, preliminary assembly drawings, a detailed concept selection process, a detailed design process, and justification for the final design.

The project was broken into three phases. The first phase was problem identification and creating a project management plan, the second phase was concept generation and selection, and the third phase was concept development, final deliverables, and closeout procedures. This report covers phase three of the project.

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1 Introduction

In the modern commercial aerospace industry, composite panels are used to construct the outer surfaces of planes. This is due to the high stiffness and low weight of the composite panels. These panels are created using a composite skin on either side of a core. The cores used are typically made of Nomex paper coated with an epoxy resin. These cores typically have chamfered edges to reduce the number of sharp corners on the composite panels. An example of a company that manufactures these composite panels is Boeing Canada Winnipeg (BCW).

BCW creates over 500 parts and assemblies for its parent company Boeing and is one of the largest aerospace composite manufacturers in Canada [1]. BCW recently introduced a new safety initiative which aims to eliminate all workplace injuries and illnesses. This initiative is called Go for Zero [2]. BCW is currently faced with a safety issue related to the use of bandsaws during the core chamfering operation. Bandsaw operators are at risk of cutting themselves on the bandsaw blade, as well as being exposed to core dust. The epoxy resin in core dust is a respiratory irritant. Team 24: Honeycomb Badger Industries has been commissioned by BCW to propose a design to mitigate or eliminate these risks.

To ensure the reader has a complete understanding of the project, this report will give a detailed definition of the problem. This definition will include the background of the problem, requirements of the solution, and objectives of the project. Next, an explanation of the final design will be presented. This explanation will discuss all the components separately, along with an overview of their functions. Finally, an analysis of the final design will be performed.

The deliverables requested by BCW are a 3D CAD model, preliminary assembly drawings, a detailed concept selection process, a detailed design process, and justification for the design.

2 Project Definition

To ensure a proper understanding of how the project was analyzed, the project must first be thoroughly defined. This section will go over the problem statement, project objectives, and project requirements.

2.1 Problem Statement

The core chamfering operation occurs thousands of times per week at BCW, and the process currently puts the bandsaw operators at risk of injury and illness. The risk in the chamfering operation comes in the form of exposure to core dust, and exposure to an uncovered saw blade. BCW has commissioned Team 24 to develop a solution that will mitigate, or eliminate both risks without negatively impacting the current production times.

The specifics of the project objectives are presented in the following section.

2.2 Project Objectives

The team was given two primary tasks that must be met, while adhering to certain constraints. The primary tasks, constraints, and expectations of the team are described in the following sections.

2.2.1 Primary Tasks and Constraints

The team must develop a design that will do the following:

- The bandsaw operator must be protected from being cut by the bandsaw blade during the chamfering operation.
- People in the vicinity of the bandsaw must be protected from the core dust that is produced during the chamfering operation.

The team must accomplish these primary tasks while adhering to the following constraints:

- The design must be completed before December 5, 2018.
- The design must be able to fit inside the BCW building.

If any of the primary tasks or constraints are not met, the project will not be considered a success.

2.2.2 Expectations of the Team

The team is expected to create a design that will solve the primary tasks, while following the constraints. The team is expected to gain a thorough understanding of the current process, and determine how to effectively integrate the final design. While no budget was set, it is expected that the team will attempt to create a cost-effective design. The team is expected to provide the deliverables that BCW requested. The deliverables are:

- Detailed design processes
- Concept selection process
- 3D CAD Model of the final design
- Preliminary assembly drawings

Finally, it is expected that the team will maintain communication with BCW to ensure the design is feasible to implement. If all these expectations are met, the project will be more likely to satisfy the client. A detailed project schedule is provided in Appendix A.

2.3 Customer Needs

Along with the two primary tasks, the team identified other aspects that were considered factors in the success of the design. These aspects were identified through discussion with the client, and observation of the process. These aspects will be referred to as customer needs. Initially, five needs were identified, and they were:

- The design is compatible with the current cores that must be processed.
- The design is not unnecessarily expensive.
- The design is comfortable and enjoyable for the operators to use.
- The design is easy to implement.
- The design does not significantly increase the time required for the core chamfering process.

Throughout the concept screening phase, six more needs were identified. These supplementary customer needs were:

- The design does not significantly increase the time it takes to set up for a new core batch.
- The design does not prevent the bandsaw from being serviced, and/or is itself easy to service.
- The design is easy to replace if it is damaged.

- The design is not difficult for operators to learn how to use.
- The design does not significantly change the layout of the work cell.
- The design is not unnecessarily complex.

While most of the customer needs are non-quantifiable, the client did provide specifications that must be met. The specifications are listed in the following section.

2.4 Technical Specifications

The target specifications were determined through discussion with the client on the current performance standards. These specifications are listed in Table I with marginal and ideal values.

TABLE I
SPECIFICATIONS TABLE

Specification #	Specification	Units	Marginal Value	Ideal Value
S1	Size of the sides of triangular core	ft	$5 \times 5 \times 6$	$6 \times 6 \times 7$
S2	Size of rectangular core	ft	Length: 8 Width: 2	Length: 9 Width: 3
S3	Edge thickness	in	0-0.25	0-0.3
S4	Chamfer angle	degrees	10-45	0-45
S5	Time of operation for different cores	seconds	≤ 120	≤ 100

The marginal values correspond to the current production requirements, and the ideal values correspond to the limits of the bandsaw table. The following section provides a brief overview of the concept development phase of the project.

3 Summary of Conceptual Design Phase

Once the project was fully defined, the team performed market research to determine what solutions currently exist. With this information, the team had brainstorming meetings where concepts were shared and developed. It was decided that the blade protection system and the dust protection system would be developed separately. They would then be combined at a later stage of the concept development phase. The team brainstormed nine blade protection concepts, and six dust protection concepts.

Following the concept brainstorming phase, the team defined critical criteria that the concepts would be compared against. The criteria were put into a criteria weighting matrix to determine their relative importance. With the criteria weights determined, the blade protection and dust protection concepts were screened. This eliminated six of the nine blade protection concepts, and four of the six dust protection concepts.

Following the screening, the team combined the remaining blade protection and dust protection concepts to create eight complete solutions. To select the best solution for the project, the team performed a second concept comparison against the weighted criteria. To ensure that the team and client agreed on the merits of each design, the team and client scored the concepts independently. The team and the client both concluded that the blade guard and the downdraft table was the best concept combination to pursue. More information on the conceptual design process can be found in Appendix B.

4 Details of the Design

This section will discuss the final details of the design and is divided into four subsections. Section one will give a brief description of the entire design. Section two will discuss the body of the blade guard. section three will discuss the head of the blade guard. Finally, section four will discuss the downdraft table assembly. Each of the final three sections will describe the mechanism of the design, and the materials and manufacturing techniques required to create it.

4.1 Final Concept Overview

This subsection will briefly describe the individual components of the final design. There are seven different components that are critical to the function of the final design. These components are the air side, the blade guard body, the blade guard head, the downdraft table, the sink, the vacuum hose, and the reducer coupling. These are shown in Figure 1 and Figure 2.

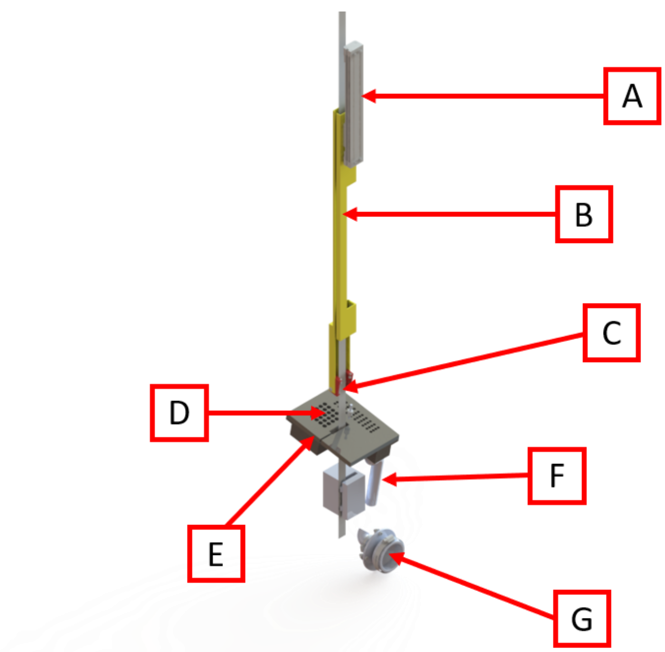

Figure 1. Full design assembly

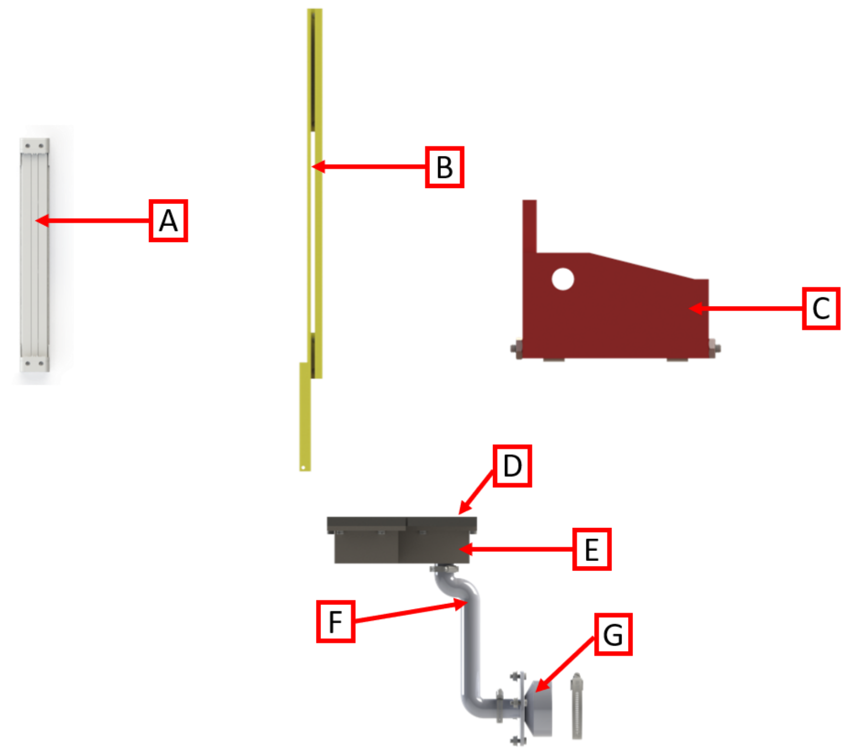

Figure 2. Separated components of full assembly

A. **Air Slide**: The rodless pneumatic air slide was sourced from McMaster Carr to provide linear motion to the blade guard assembly.

B. **Blade Guard Body**: The blade guard body is a device that covers the exposed bandsaw blade during the cutting process. The blade guard body is fastened to the air slide to allow for vertical motion.

C. **Blade Guard Head:** The blade guard head is a device that is fastened to the blade guard body, and can rotate freely. Its purpose is to rest against the core.

D. **Downdraft Table:** The downdraft table is designed to vacuum the core dust under the table. The downdraft table features the table itself, a vacuum hose, a blade insert, and blade slot.

E. **Sink:** The sink is designed to spread out the effective area of the vacuum that is attached.

F. **Vacuum Hose:** The vacuum hose will collect the dust and transport it to a central location in BCW.

G. **Reducer Coupling:** The reducer coupling is a component that reduces the hose size from smaller to larger bore.

4.2 Blade Guard Body

This section will display the final design of the blade guard body, and explain the reasoning behind its geometry. The purpose of the blade guard is to protect the operator from touching the exposed blade. To accomplish this, the blade guard body must cover as much of the blade as possible without hindering the regular operation. The final design is shown in Figure 3.

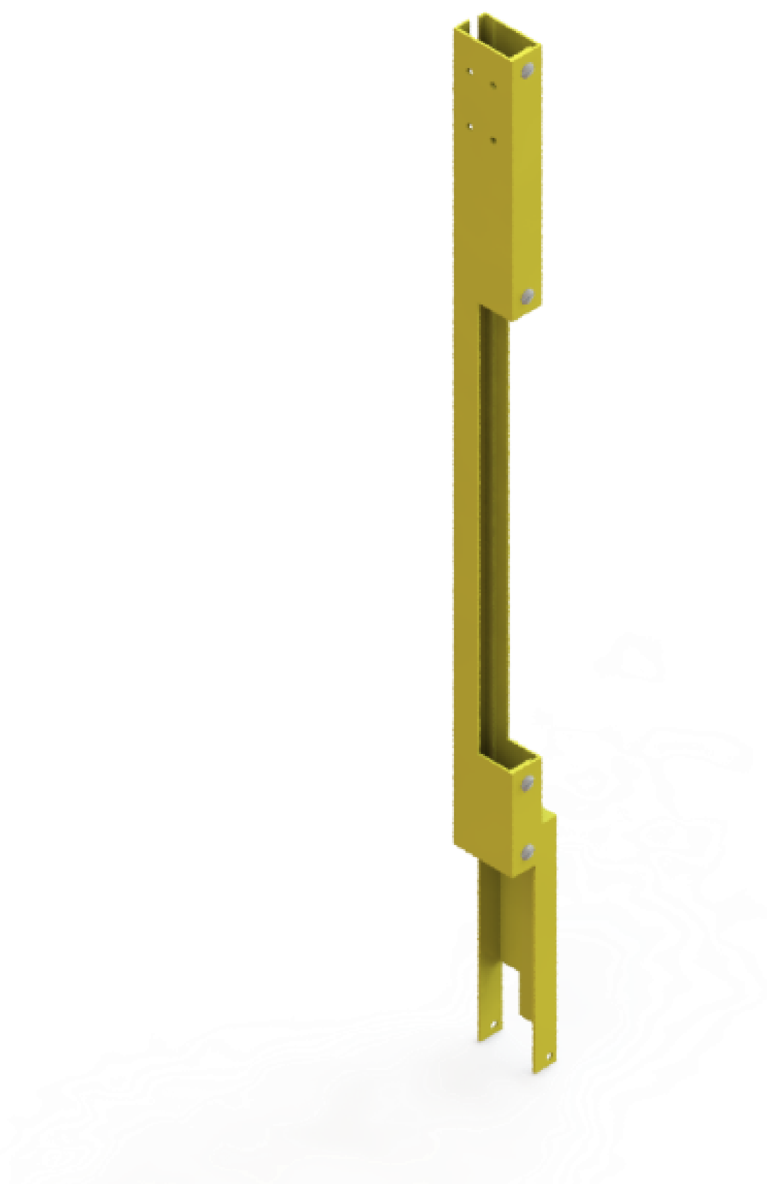

Figure 3. Final blade body guard design

To assist the explanation of the design, Figure 4 will show elements of interest.

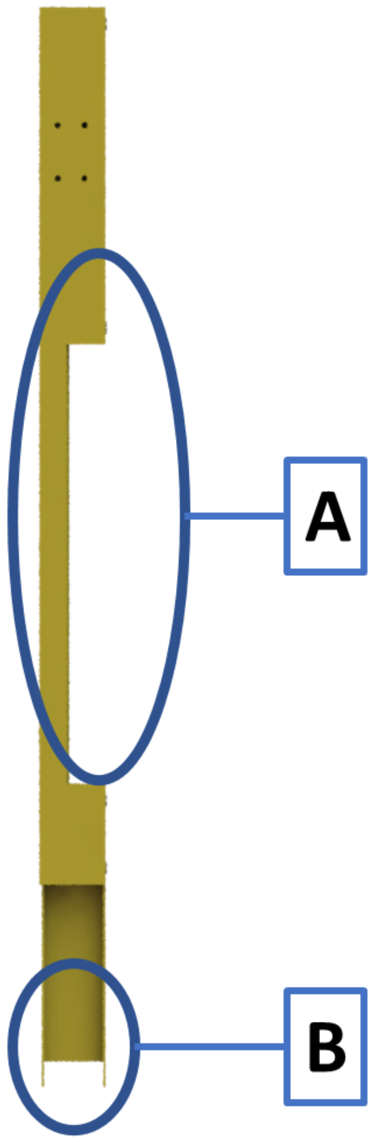

Figure 4. Final blade guard body design front view

In Figure 4, caption 'A' shows a large cut-out on the side of the blade guard body. This cut-out allows the bearing guides that are currently on the bandsaw to access the blade across the guard's entire range of motion. This is shown in Figure 5.

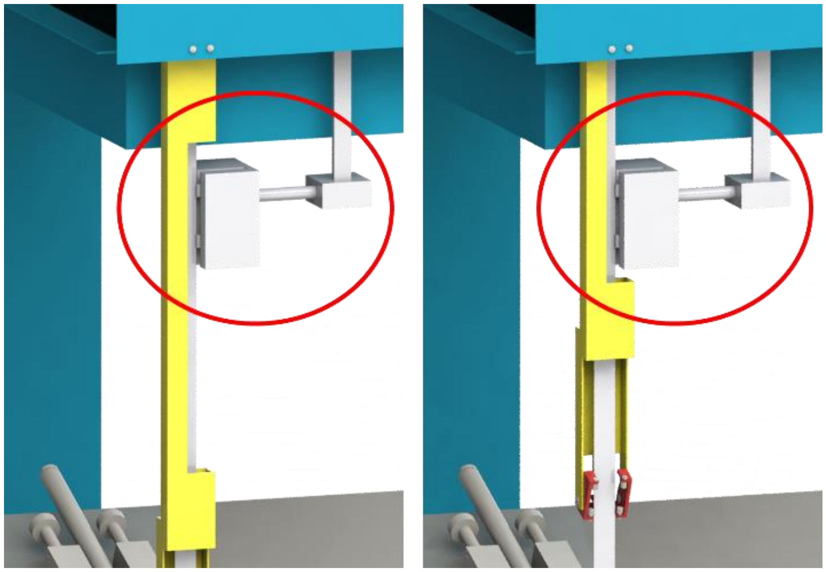

Figure 5. Blade guide cut-out

Caption 'B' from Figure 4 shows a cut-out at the base of the blade guard body. Its purpose is to allow the head to rotate freely. This is shown in Figure 6.

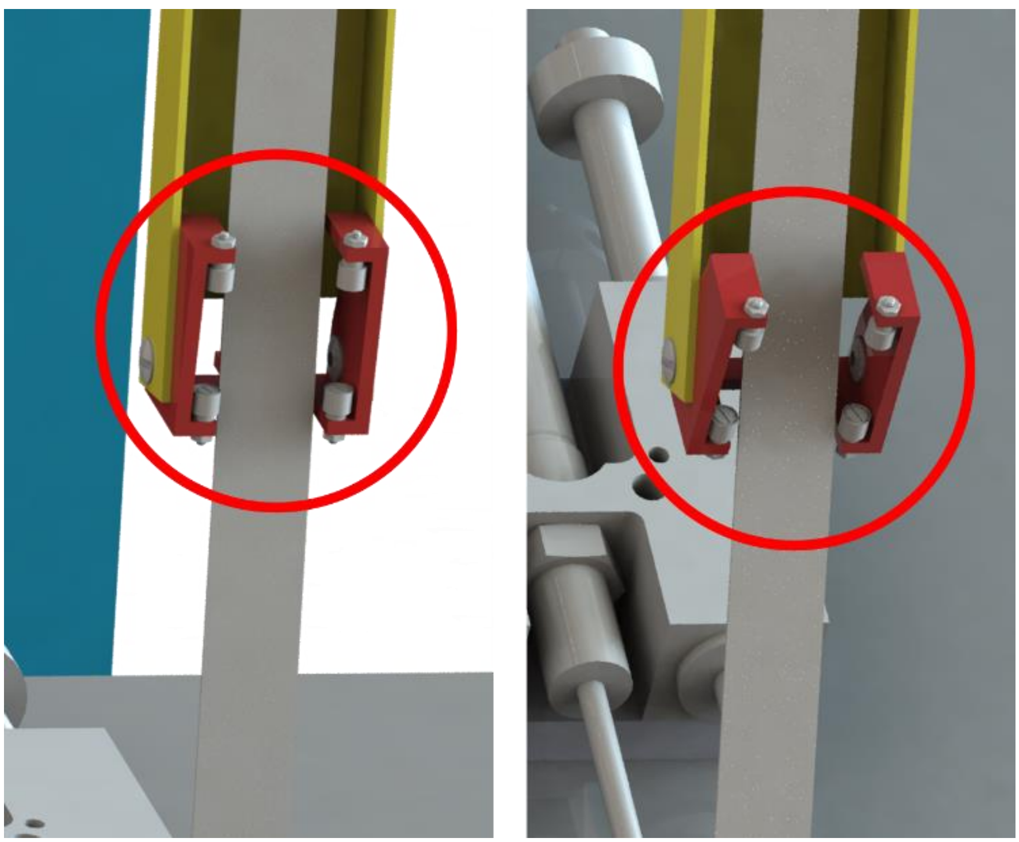

Figure 6. Blade guard head rotation cut-out

Figure 7 shows the side view of the final blade guard body, and points out two more elements of interest.

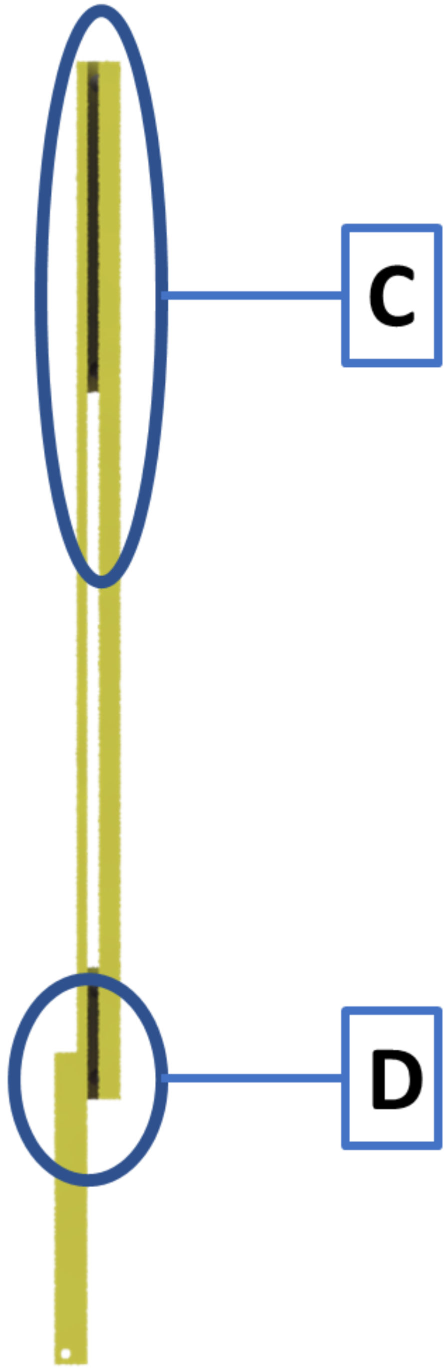

Figure 7. Final blade body guard design side view

Caption 'C' from Figure 7 shows a slot that extends the entire length of the blade guard body. The purpose of this slot is to allow the blade to be changed easily.

Caption 'D' from Figure 7 shows that the profile of the guard is not straight, and that the lower half of the guard is offset backwards. The purpose of the offset is to create space between the blade guard body and the core for low angle chamfers, while ensuring the guard is not in contact with the back half of the bandsaw. This is shown in Figure 8.

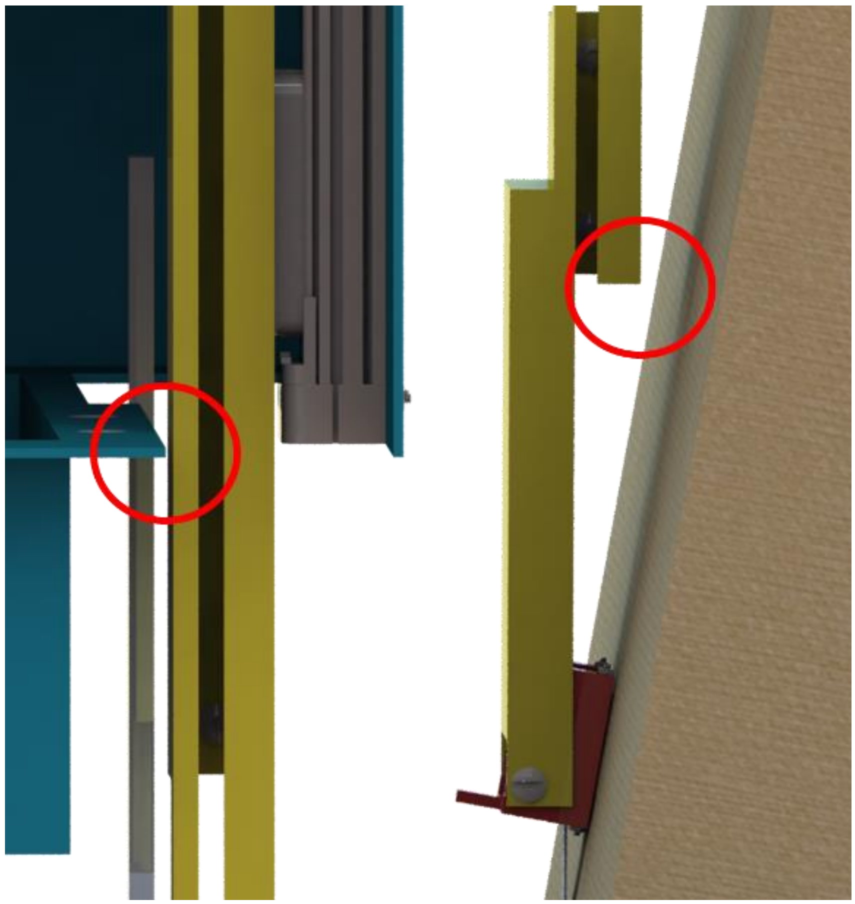

Figure 8. Blade guard body spacing

The following section will discuss the function of the guard.

4.2.1 Mechanism for Blade Guard Body and Rodless Air Slide

The purpose of the blade guard body is to protect the operator from contacting the blade during the core chamfering operation. To do this effectively, the guard should cover the maximum amount of exposed blade without impeding the operation. To accommodate different core thicknesses and chamfer angles, the guard must be able to change heights. An example of the change in height required is shown in Figure 9.

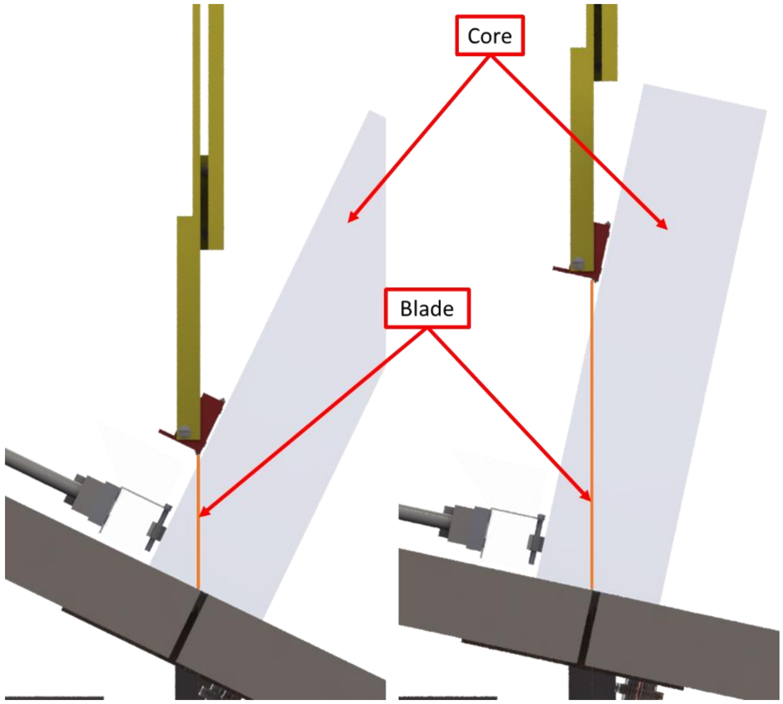

Figure 9. Change in height of the blade guard

To allow the guard to move in such a way, it is attached to a vertical pneumatically powered air slide. The air slide is then fastened to the bandsaw. This mechanism is shown in Figure 10.

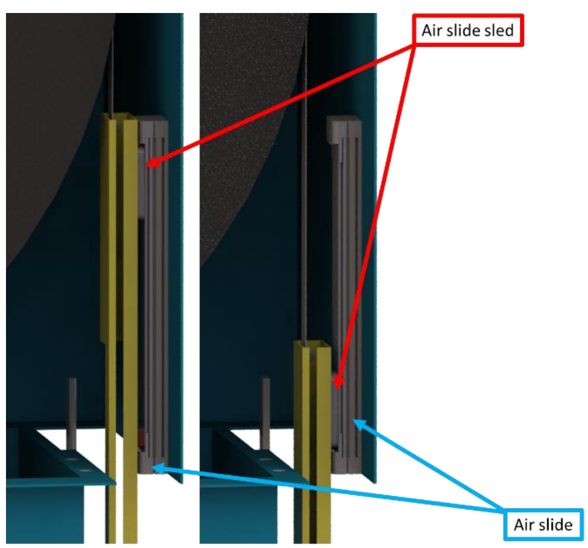

Figure 10. Air slide mechanism

The following section will discuss the materials and manufacturing of the guard.

4.2.2 Materials and Manufacturing for the Blade Guard Body

To simplify the assembly, the guard will be manufactured in two halves. The two halves will then be fastened together as shown in Figure 11.

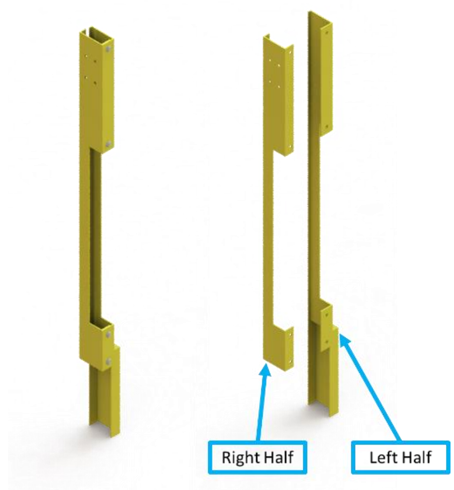

Figure 11. Guard assembly

The right half of the guard has four sheet metal components that will be welded together. The left half of the guard has six sheet metal components that will be welded together. Both halves will use 14 gauge carbon steel. Exploded views of the right and left half are shown in Figure 12 and Figure 13 respectively.

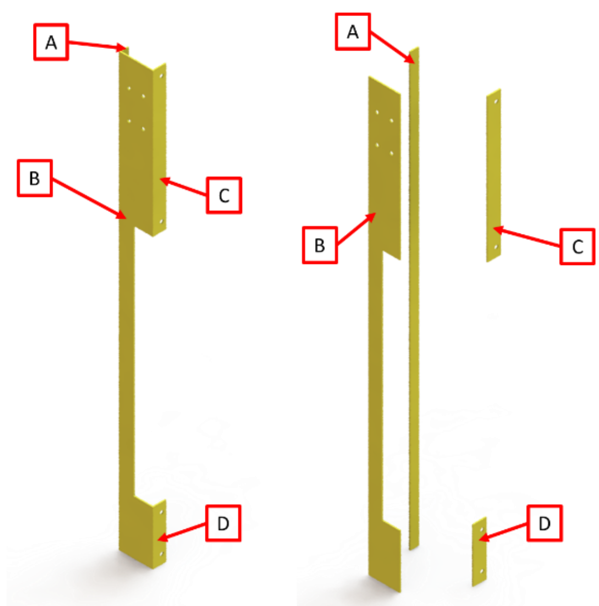

Figure 12. Right half of guard body assembly

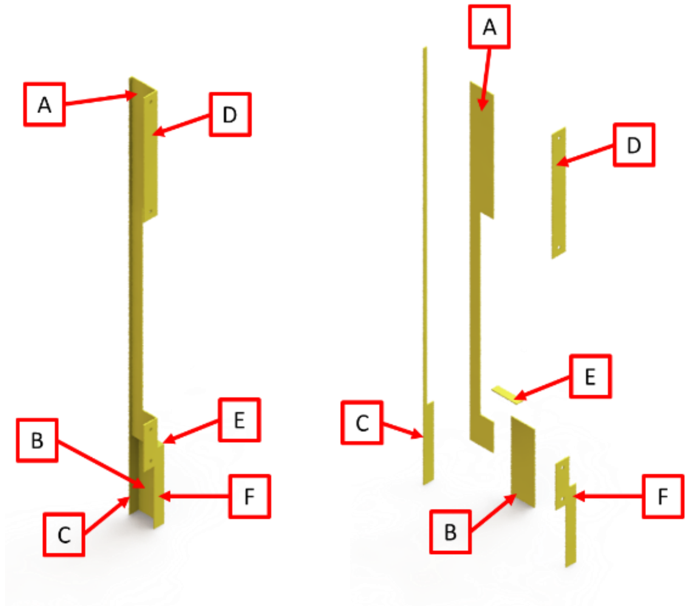

Figure 13. Left half of guard body assembly

The following section will cover the features and manufacturing of the head.

4.3 Blade Guard Head

This section will display the final design of the head and explain the reasoning behind its geometry. The purpose of the head is to allow the blade guard assembly to rest against various angles of cores. To accomplish this, the head must be able to pivot around the guard, and must not interfere with the blade. The final design is shown in Figure 14.

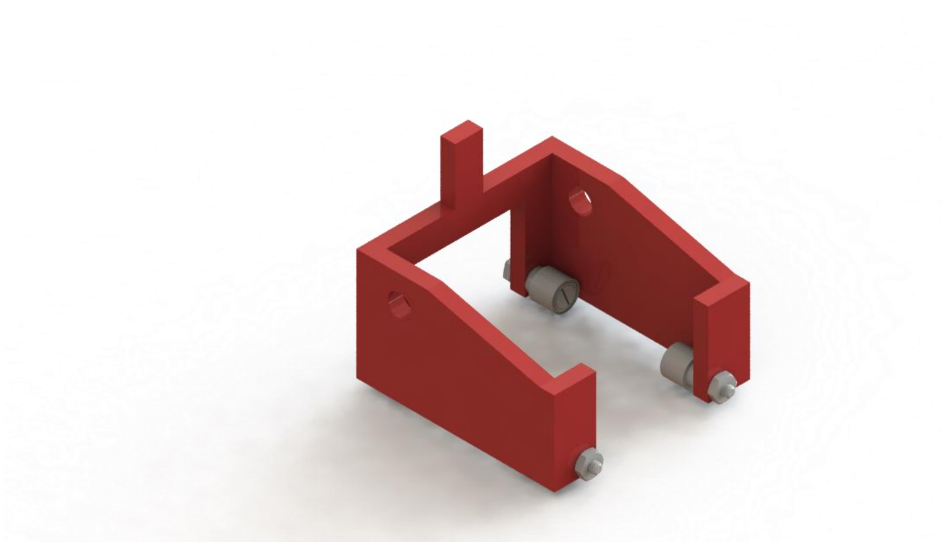

Figure 14. Final head assembly

Figure 15 and Figure 17 will be used to highlight features of interest on the design.

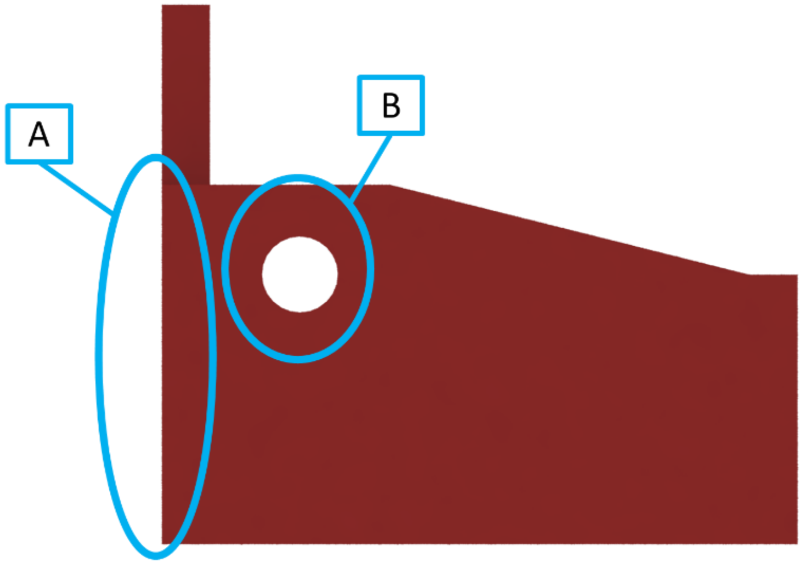

Figure 15. Final head assembly side view

Caption 'A' in Figure 15 is highlighting the flat back of the head. The purpose of this geometry is to allow the head to lie flush on the acrylic part of the pneumatic press if it is unable to reach the core. This is shown in Figure 16.

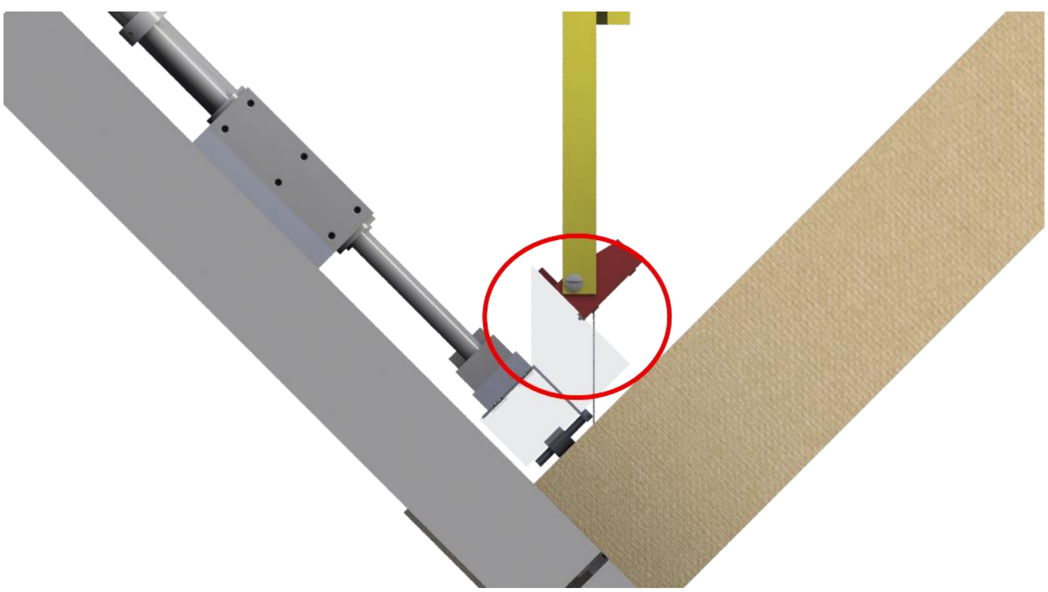

Figure 16. Head assembly resting on acrylic guard

Caption 'B' on Figure 15 shows the points where the head will be fastened to the guard.

Figure 17 shows two more features of interest on the design of the head.

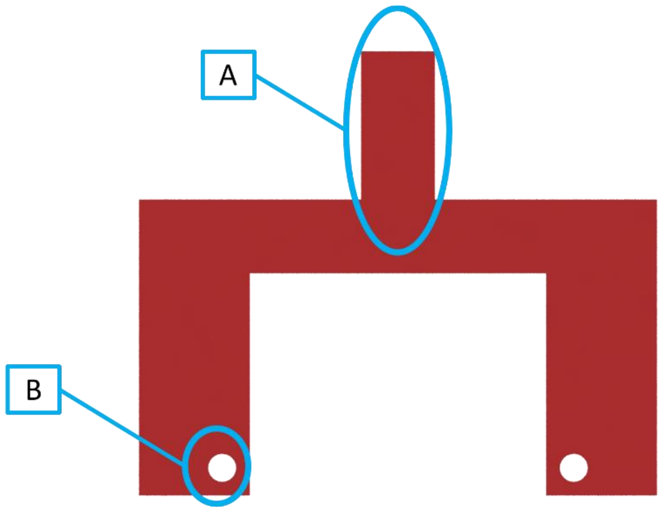

Figure 17. Final head assembly back view

Caption 'A' on Figure 17 highlights a tab that on the back of the head. The tab acts as a mechanical block to prevent the head from rotating forward on the guard. This is shown in Figure 18.

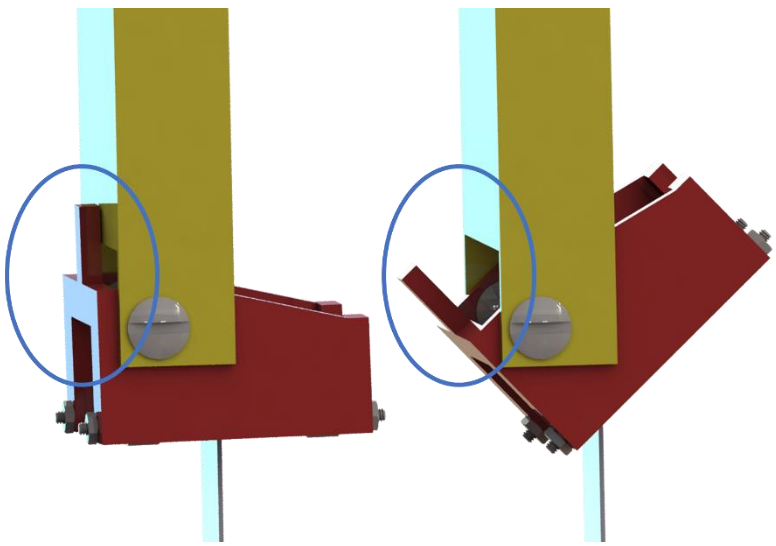

Figure 18. Head assembly not being blocked by the guard from over-rotating

If the head were able to rotate freely, the front of the head would attempt to hang straight down due to its uneven weight distribution. This would result in the back of the head interfering with the blade.

Caption 'C' in Figure 17 highlights the holes that the rollers will be placed in. These are shown in Figure 19.

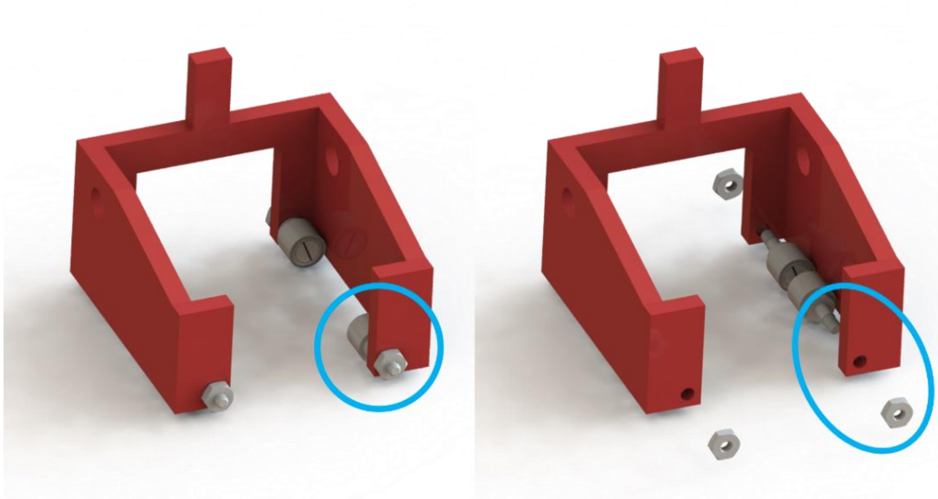

Figure 19. Head assembly roller holes

The following section will discuss the function of the head.

4.3.1 Mechanism for Blade Guard Head

The head was proposed as a method to simplify the design. Without the head, if the guard was lowered too far it would damage the core with its metal edges. To prevent this, sensors would need to be implemented to ensure the guard was not lowered too far. Implementing these sensors would increase the costs of the design significantly. With the head, the blade guard can be lowered onto the core without causing damage. This is shown in Figure 20.

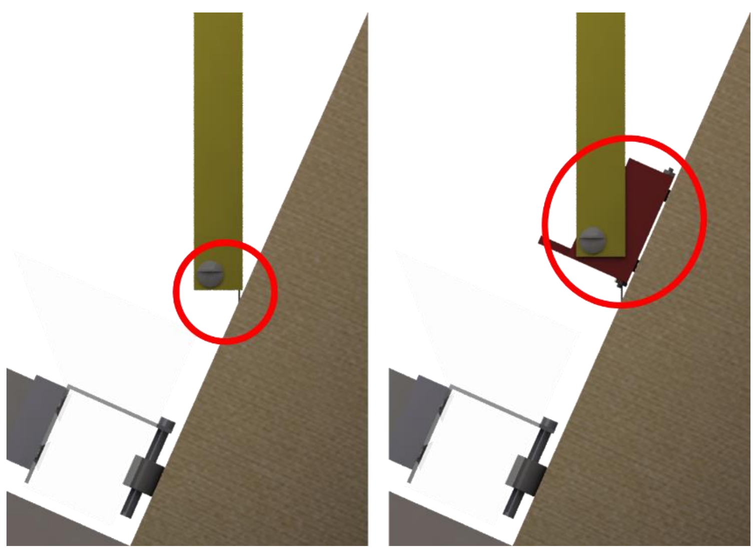

Figure 20. Guard with and without head

To ensure that the core can be fed past the blade, rollers were fastened to the front and back of the head as shown in Figure 19. These rollers minimize the friction between the head and the core. Without the rollers, the sharp metal edges of the head would cut into the core, and make it very difficult to feed it through the bandsaw blade

The following section will discuss the materials and manufacturing method for the head.

4.3.2 Materials and Manufacturing for Blade Guard Head

The head will be manufactured using 10-gauge carbon steel, and in five separate parts. These parts will then be welded together. This is shown in Figure 21.

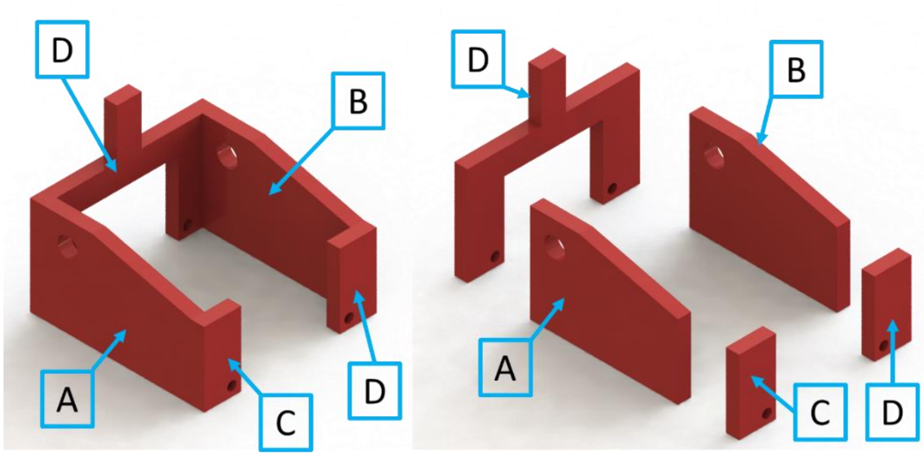

Figure 21. Head assembly and exploded assembly

Due to the symmetry in the head, parts captioned A and B in Figure 21 are identical, and the parts captioned C and D are identical and mirrored.

The following section will discuss the features and manufacturing of the downdraft table.

4.4 Downdraft Table Assembly

This section will display the final design of the downdraft table assembly and discuss the components. The purpose of the downdraft table assembly is to mitigate the amount of core dust that is released into the air. The assembly consists of a downdraft table, a sink, a vacuum hose, and a reducer coupling. There are two vacuum sources that downdraft table assembly may use. One source has a volumetric flow rate of 480 cubic feet per minute (CFM). To effectively collect the core dust, it is recommended that the airspeed through the vacuum holes is 4000 feet per minute (FPM) or greater [3]. The components of the downdraft table assembly will be further discussed and illustrated in the following sub-sections.

4.4.1 Downdraft Table

To implement the downdraft table, a portion of the current bandsaw table must be removed. Based on the geometry of the table and the location of other components, a six-inch by eight-inch section was selected. This section is shown in Figure 22 and Figure 23.

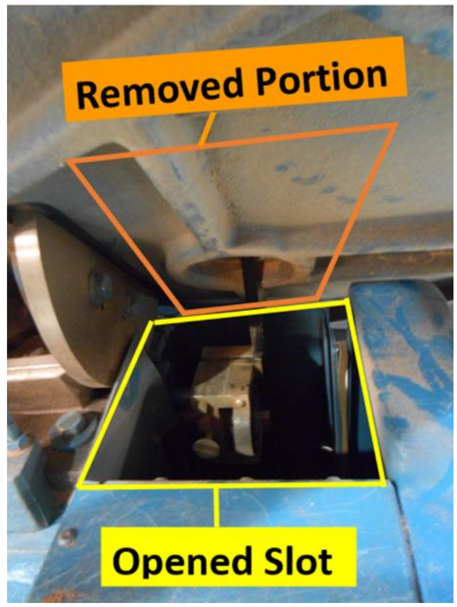

Figure 22. Removed rectangular portion from the current table

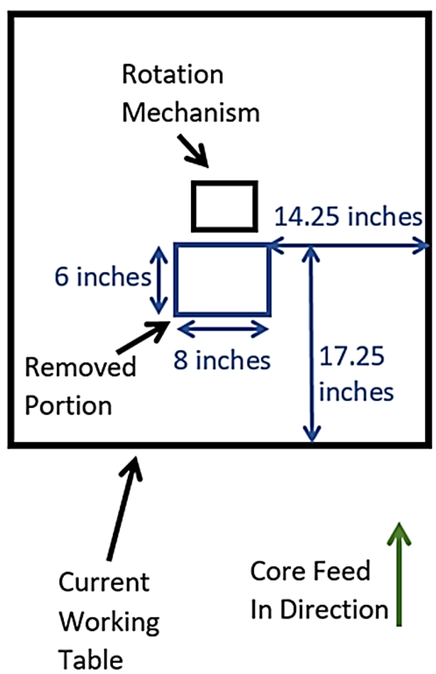

Figure 23. Schematic diagram of removed portion on the current working table

A model of the downdraft table is shown in Figure 24.

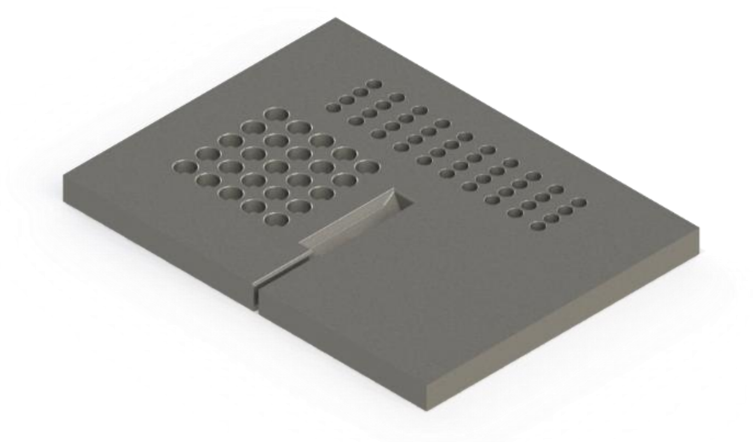

Figure 24. Isometric view of the downdraft table CAD model

There are three main features on the downdraft table; the vacuum holes, the blade insert and the blade slot. Figure 25 highlights these features.

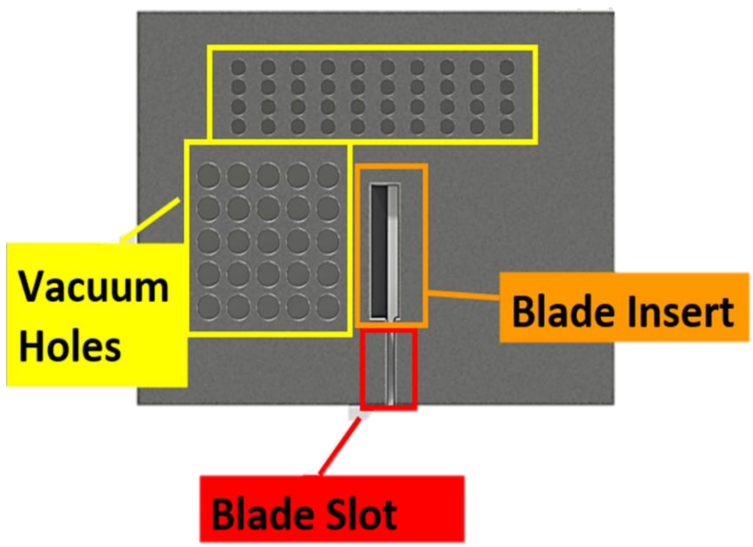

Figure 25. Top view of the downdraft table CAD model

There are two different sizes of holes on the vacuum table. The holes above the blade insert have a diameter of 0.25 inches, while the hole to the left side of the blade insert have a diameter of 0.375 inches. These hole sizes were chosen based on market research [4]. With the available volumetric flow rate of 480 CFM, the calculated airspeed through each vacuum hole is approximately 14000 FPM. This exceeds the required airspeed for dust collection.

The blade slot is an opening on the downdraft that allows for easy replacement of the blade. The blade slot has a width of 0.1 inches, and a length of 3.35 inches. The length of the blade slot was determined by the location of the blade, and size of the downdraft table.

The blade insert is a modified section of the blade slot which allows the table to change angles without interfering with the blade. To create this, the blade slot is chamfered with a 45° angle, and a 30° angle on either side. Figure 26 illustrates this modification.

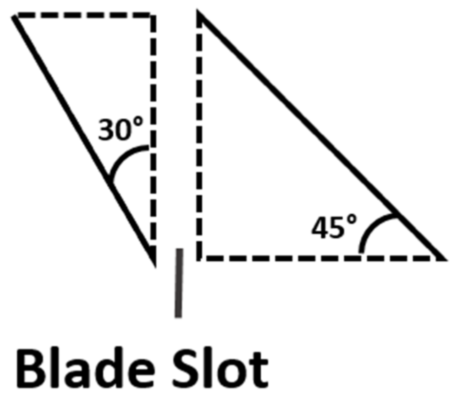

Figure 26. Schematic diagram of the chamfering modification to the blade slot

The dotted lines in Figure 26 represent the blade slot before chamfering, and the solid lines represent the blade insert after chamfering.

4.4.2 Sink

The purpose of the sink is to spread the vacuum over the bottom surface of the downdraft table. The sink has an L shape to avoid interference with the blade. Figure 27 shows the top view of the sink.

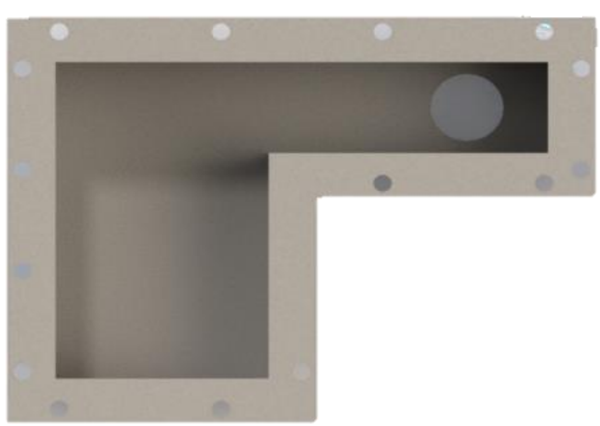

Figure 27. Top view of the sink

The sink has a height of 2 inches, and there is an outlet hole at the right top corner to allow the dust to be removed by the vacuum. Figure 28 shows the isometric view of the sink.

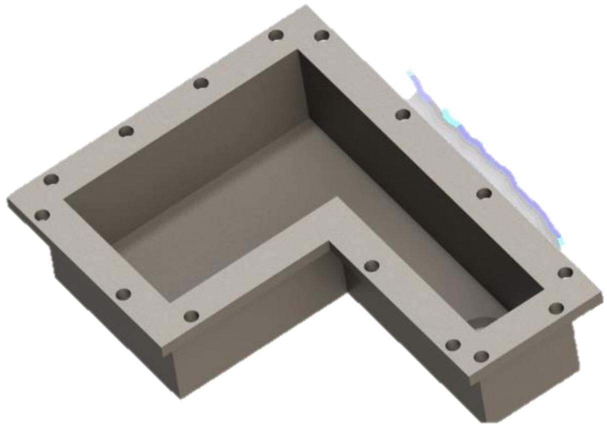

Figure 28. The isometric view of the sink

The outlet is a sub-component of the sink. It is a hollow cylinder with an outer diameter of one inch and is shown in Figure 29.

Figure 29. The isometric view of the outlet

The outlet is inserted into the sink through the outlet hole and welded to the sink. The size of the outlet can be varied based on the dimensions of the selected vacuum hose. The vacuum hose is attached to the outlet and tightened using a hose clamp.

4.4.3 Vacuum Hose

Due to space limitations, the vacuum hose currently in use at BCW is too large. The team decided to use a vacuum hose with a one-inch diameter, which was sourced McMaster Car.

4.4.4 Reducer Coupling

The reducer coupling is a nozzle with a flange that allows hoses of different diameters to be connected. To connect the selected vacuum hose to the BCW vacuum hose, this reducer coupling is required. Figure 30 shows an isometric view of the reducer coupling.

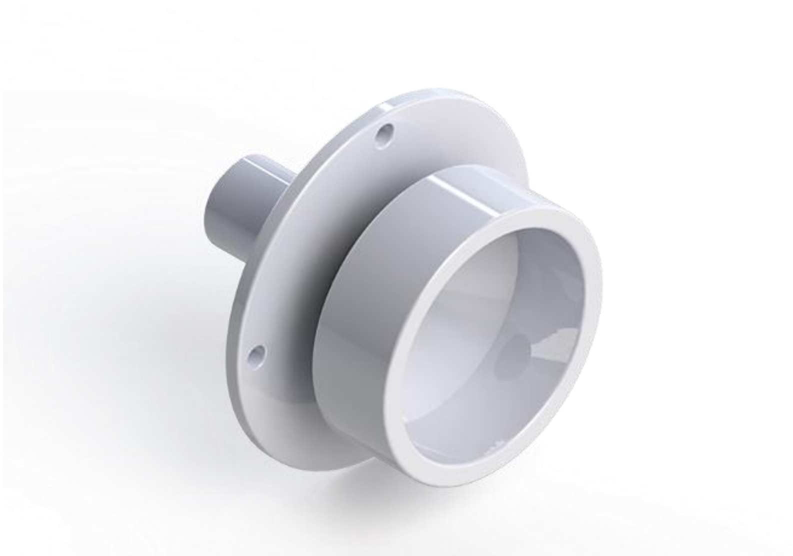

Figure 30. The isometric view of the reducer coupling

The inlet and outlet of the reducer coupling have the outer diameters of one inch and three inches, respectively. Figure 31 shows the side view and the back view of the reducer coupling.

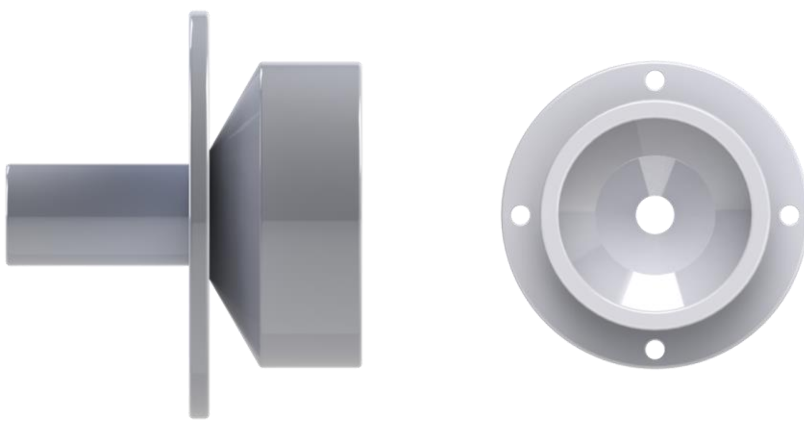

Figure 31. The side view and back view of the reducer coupling

There are four holes on the flange so that the reduced coupling can be fastened to the bandsaw machine.

4.4.5 Material and Manufacturing

The downdraft table will be manufactured with the same material as the rest of the bandsaw table, while the sink and the outlet will be made of carbon steel. The reducer coupling will be 3D printed with Acrylonitrile Butadiene Styrene (ABS). The following section will cover the analysis of the design and will include a bill of materials.

5 Detailed Engineering Analysis

This section will discuss the final cost of the design, the raw materials that will be required, and any parts or fasteners that will be purchased. This section will also cover a failure modes and effects analysis to identify any high-risk aspects of the design.

5.1 Bill of Materials and Cost Analysis

In this section, the material and part cost of this design will be discussed. The cost of manufacturing and installation of the design will not be covered. Table II shows the bill of materials, and associated cost of each item. All materials, fasteners, and parts were sourced from McMaster-Carr.

TABLE II
BILL OF MATERIALS

Part No.	Description	Qty.	Item Cost	Total Cost
2738T180	Double Acting Air Slide	1	246.69	246.69
94887A112	1/8"-3/16" Screw and Barrel	4	1.202	4.808
94887A123	1/4"-3/8" Screw and Barrel	2	1.224	2.448
91841A005	18-8 Nut	4	0.0291	0.1164
90298A147	18-8 Bolt	4	4.95	19.8
92323A589	Serrated Flange Screw	4	0.1186	0.4744
3668K3	Track Rollers	4	39.02	156.08
90480A003	2-56 Nut	4	0.01	0.04
4459T285	0.071" x 36" x 36" - 4130 Alloy Steel Sheet	1	122.64	122.64
4459T287	0.100" x 36" x 36" - 4130 Alloy Steel Sheet	1	144.74	144.74
5011T241	15/16"- 1-1/2" Hose Clamp ID	2	1.49	2.98
5415K23	2-5/16" to 3-1/4" Hose Clamp ID	1	1.056	1.056
90807A111	1/4"-20 Screw	9	3.34	30.06
93615A415	1/4"-20 Screw	4	0.552	2.208
94612A101	1/4"-20 Nut	4	0.0868	0.3472
5136K18	1" Flexible Hose	2	2.77	5.54
89885K236	1/2" x 8" x 6" Tool Steel	1	97.75	97.75
9143K743	2" x 8" x 6" Carbon Steel	1	131.64	131.64
1317N39	ABS 3D Printer Filament	3	32.81	98.43
Total				1067.848

As shown in Table II, the materials costs for this project are approximately $1070 USD.

5.2 Design Failure Modes and Effects Analysis

The team completed a preliminary design failure modes and effects analysis (FMEA) to aid BCW with the implementation of the blade guard and downdraft table. The primary purpose of a design FMEA is to identify the ways that the design could fail. This allows the team to identify and quantify the modes of failure. Due to time restraints and complexity, the team only performed a preliminary FMEA. Further FMEA can be performed by BCW as required throughout the manufacturing and installation of the design.

5.2.1 Design Tree

The first step of the FMEA is to separate the design into systems and components. This can then be summarized in a design tree. The design tree for the final design is shown in Figure 32.

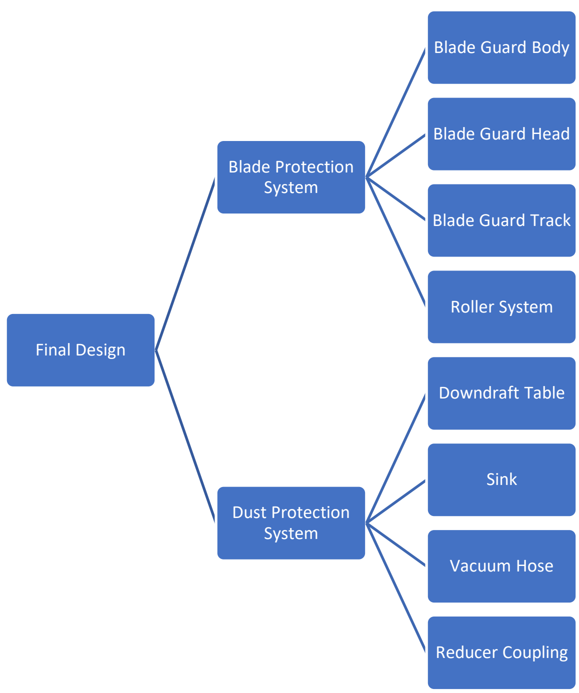

Figure 32. Design tree

5.2.2 Function Tree

Next, the function of the overall design, the design systems, and the system components were determined and listed in function trees. The function tree for the overall design is shown in Figure 33.

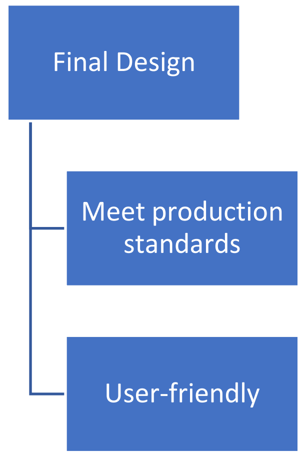

Figure 33. Function tree – overall design

The function trees for the design systems are shown in Figure 34.

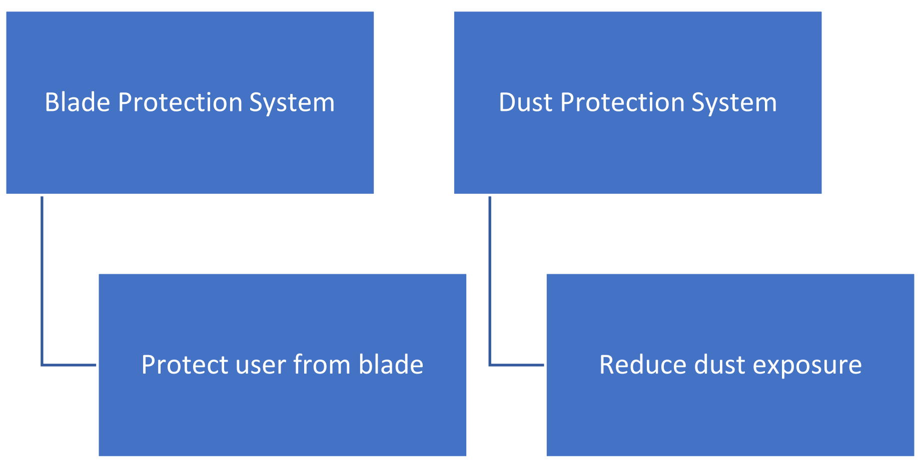

Figure 34. Function tree – design systems

The function trees for the components are shown in Figure 35.

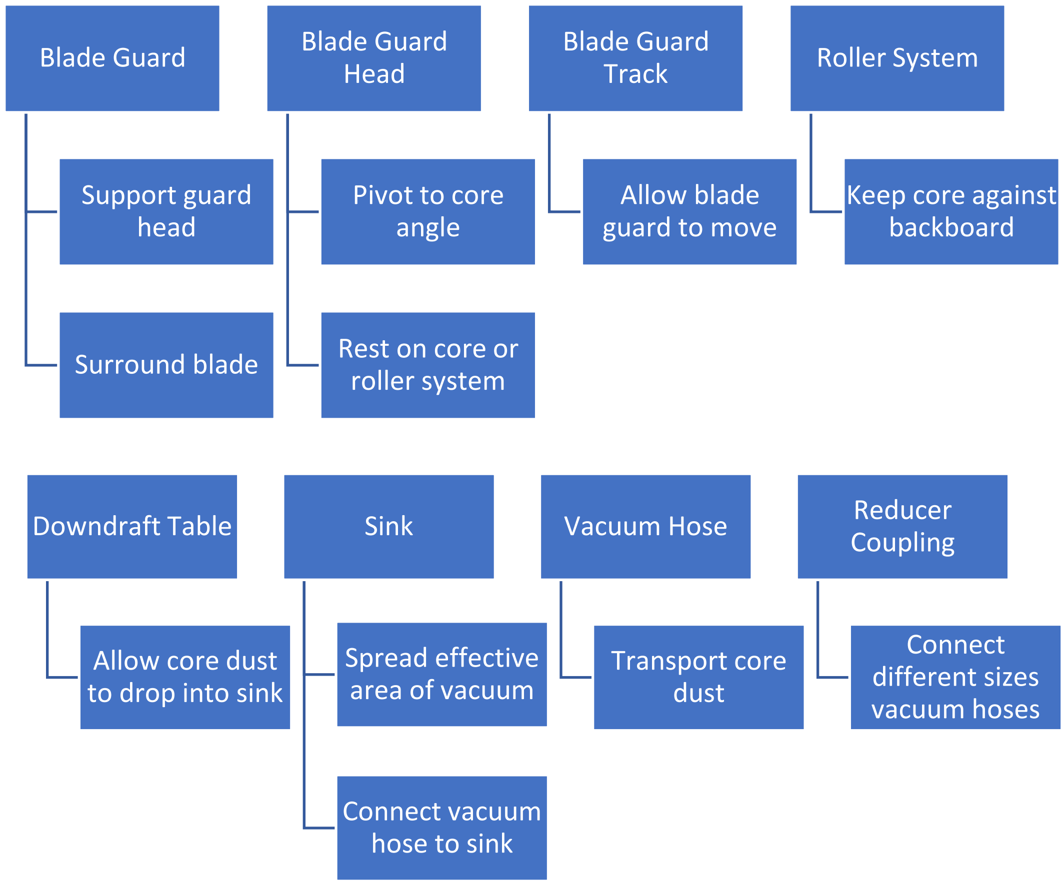

Figure 35. Function tree – components

5.2.3 FMEA Form

A design FMEA determines which failure modes pose the highest risk using a risk priority number (RPN). The RPN is a function of the failure mode's severity of failure, frequency of failure, and detectability. The severity, frequency, and detectability are given a score from 1 to 10 using criteria from Table III, Table IV, and Table V, respectively.

TABLE III
SEVERITY RATING SCALE

Severity of Effect		Ranking
Minor	No substantial effect on performance or operation. Customer unlikely to notice or care about failure.	1
Low	Customer will likely notice only minor degradation of performance. Might cause annoyance with customer.	2,3
Moderate	Failure causes some customer dissatisfaction. Customer might become uncomfortable or annoyed by failure.	4,5,6
High	Failure can cause significant decreases in performance. Customer will likely be very dissatisfied.	7,8
Very High	Failure causes serious personal safety concerns. Death and/or lawsuits possible if failure occurs.	9,10

TABLE IV
FREQUENCY RATING SCALE

Probability of Failure		Ranking
Minor	Extremely unlikely.	1
Low	Unlikely.	2,3
Moderate	Regular frequency by industry standards.	4,5,6
High	Likely to occur.	7,8
Very High	Almost certain.	9,10

TABLE V
DETECTION RATING SCALE

Likelihood of Detection		Ranking
Very High	Almost certain to detect.	1
High	Greater than 75% chance to detect.	2,3
Moderate	50/50 chance to detect.	4,5,6
Low	Less than 25% chance to detect.	7,8
Minor	Very little chance of detection.	9
Certain of Non-Detection	No chance of detection.	10

Once the severity, frequency, and detectability for the failure mode are determined, the criteria values are multiplied to calculate the RPN. This is shown in equation (1).

$$RPN = Severity \times Frequency \times Detection \quad (1)$$

A higher RPN represents a failure mode that must be addressed, while a lower RPN represents a failure mode that should be monitored, however, it is not necessary to address. Using the rankings and identified failure modes, a completed design FMEA is shown in Table VI.

TABLE VI
PRELIMINARY DESIGN FMEA

FMEA No.	Component / Function	Failure Mode	Potential Effect of Failure Mode	Severity	Potential Cause	Frequency	Current Controls	Detection	RPN	Action Recommendations
1	Final Design / Meet production standards	Significant TAKT time increase	1) Production rate decrease 2) Design is removed/not used	7	1) Difficult to use 2) Doesn't meet customer requirements	5	1) Visual 2) TAKT time	3	105	Investigate time improvement methods.
2		Doesn't process all required cores	Design is removed/not used	7	Design interferes/doesn't work for certain core types	2	Visual	1	14	Investigate how design can be altered.
3	Final Design / User-friendly	Operators don't use design	Design is removed/not used	6	1) Difficult to use 2) Long setup time	4	Visual	2	48	Interview operators and determine how design can be improved.
4	Blade Protection System / Protect user from blade	Doesn't significantly improve blade safety	Design is removed/not used	6	1) Operators don't use design 2) Doesn't surround blade	5	Visual	3	90	Investigate how design can be improved.
5	Dust Protection System / Reduce dust exposure	Doesn't significantly improve dust safety	Design is removed/not used	6	1) Not enough vacuum suction 2) Downdraft table clogged	5	Visual	4	120	Investigate how design can be improved.
6	Blade Guard Body / Support guard head	Guard head falls off	Blade is exposed	9	Connection point breaks	3	Visual	1	27	Increase strength of connection point.
7	Blade Guard Body / Surround blade	Some of the blade exposed	Blade is exposed	9	1) Design error 2) Damage caused to guard	2	Visual	2	36	Improve blade guard strength/design geometry.
8	Blade Guard Head / Pivot to core angle	Doesn't adjust to core angle	Blade is exposed	9	1) Design error 2) New core design/process situation.	2	Visual	2	36	Improve guard head range.
9	Blade Guard Head / Rest on core or pneumatic press	Head doesn't sit flush on core	Blade is exposed	9	1) Head doesn't pivot enough 2) Interference by blade guard	2	Visual	1	18	Improve guard head range and design.
10	Blade Guard Track / Allow blade guard to move	Blade guard does not move easily/at all	Blade guard moves slow or not at all	3	Core dust plugged up system	3	Visual	1	9	Create scheduled inspection and cleaning operation if required.
11	Pneumatic press / Keep core against backboard	Too much pressure	Core crush	7	Too much air pressure	2	1) Gage 2) Visual	2	28	Reduce air pressure
12		Too little pressure	Inconsistent chamfer cut	7	Too little air pressure	2	1) Gage 2) Visual	3	42	Increase air pressure
13	Downdraft Table / Allow core dust to drop into sink	Doesn't remove enough dust	Harm to operator lungs	9	Holes get clogged	3	Visual	3	81	Increase hole size or suction. Create scheduled inspection and cleaning operation.
14	Sink / Spread effective area of vacuum	Sink leaks core dust	Harm to operator lungs	9	System seal failure	4	Visual	2	72	Improve seal design. Inspection.
15	Sink / Connect vacuum hose to sink	Leaks core dust	Harm to operator lungs	9	Connection failure/leak	4	Visual	2	72	Improve connection design. Inspection.
16	Vacuum Hose / Transport core dust	Doesn't remove enough dust	Harm to operator lungs	9	Not enough suction	4	Visual	3	108	Increase suction.
17	Reducer Coupling / Connect different sizes of vacuum hoses	Leaks core dust	Harm to operator lungs	9	Connection failure/leak	4	Visual	2	72	Improve connection design. Inspection.

6 CAD Model of Final Design

This section will provide a final overview of the design, which was created in SolidWorks. The final design is shown in Figure 36 and Figure 37.

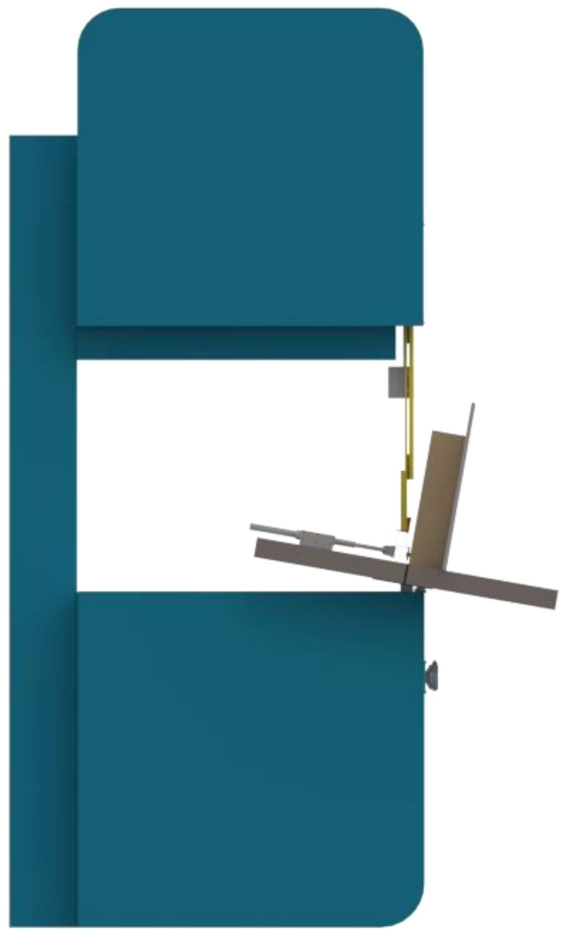

Figure 36. Front view of final design

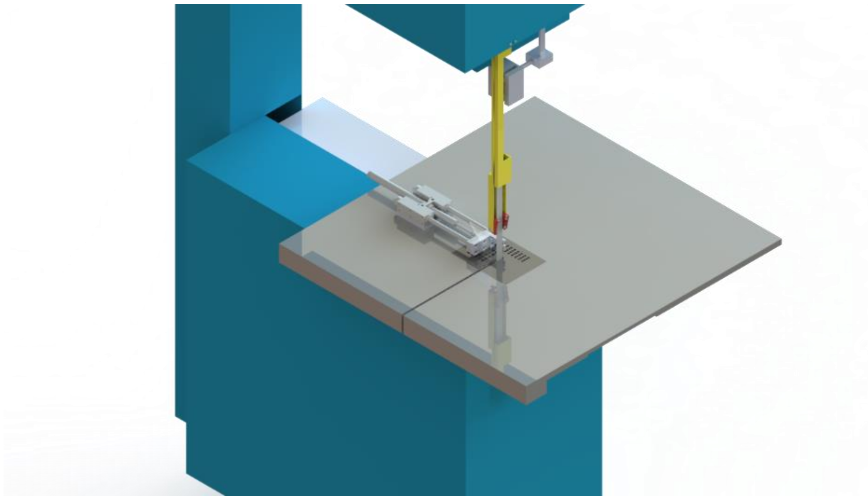

Figure 37. Close isometric view of final design

The final design consists of seven components. The blade guard system will provide proper protection to the exposed blade and it is also adjustable so that the operator can adjust to the height according to the thickness of the core. The downdraft table system will provide proper dust collection system in which the core dust will be collected into the sink and then transported to where it will be finally collected. This system will maintain clean working surface while the operator is performing chamfering operation. A closer view of blade guard system and downdraft table system is shown in Figure 38 and Figure 39.

All seven components are designed or sourced in such a way that it will improve the overall safety of the operator while performing chamfering operations. In addition, the team believes that current production standards will also be maintained.

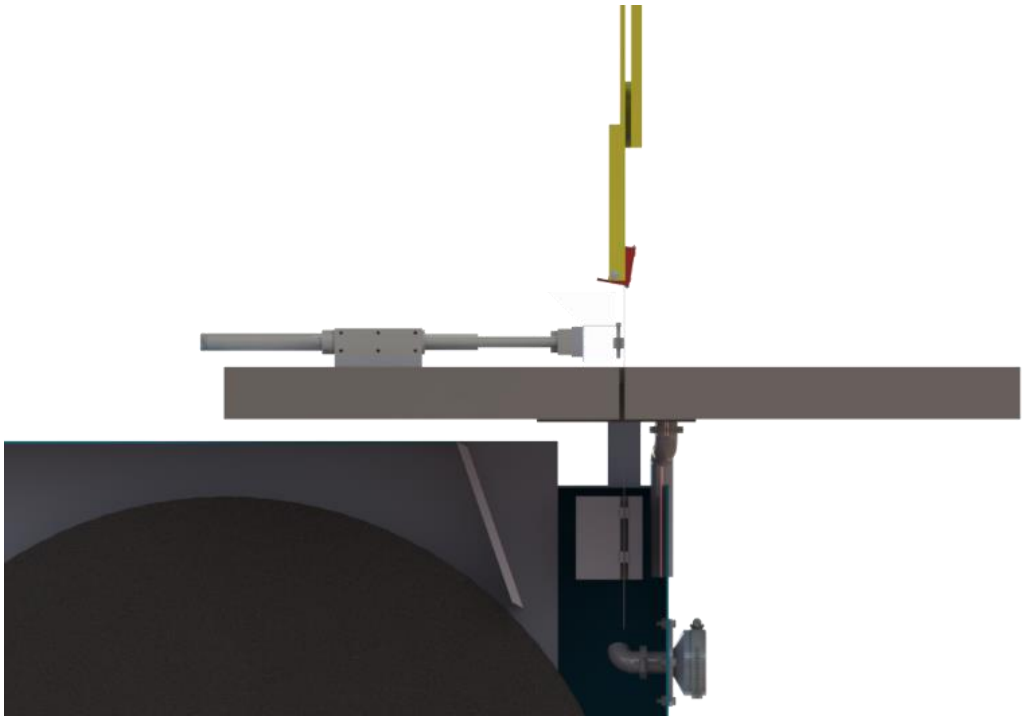

Figure 38. Close side view for the final blade guard

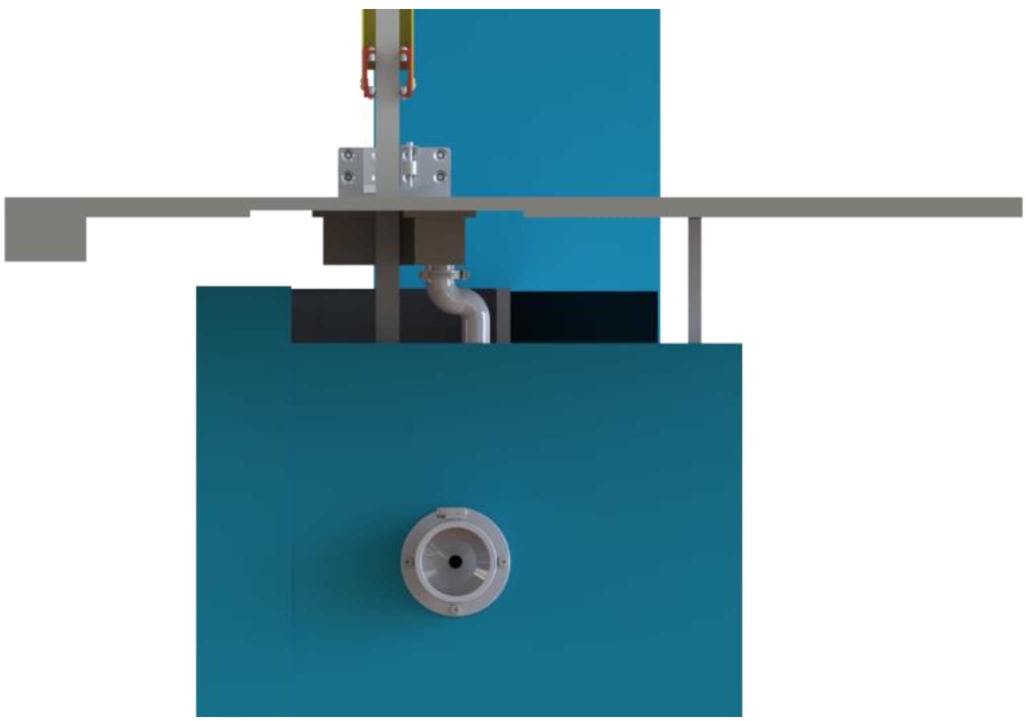

Figure 39. Side view of the final downdraft table assembly

7 Final Design Summary

This section will give full design summary of the blade guard and downdraft table. Each product summary includes, dimensions, material properties, cost, and other specifications. The summaries for the blade guard body, the blade guard head, and the downdraft table assembly are shown in Table VII, Table VIII, and Table IX, respectively.

TABLE VII
BLADE GUARD SUMMARY

Blade Guard Body Summary	
Specifications	
Width	26"
Height	1.75"
Thickness	0.07"
Weight(lbs)	2.4
Material	
Name	4130 Alloy Steel
Gauge	14
Material Thickness	0.071"
Weight/Sq Foot	2.86lbs
Cost [36" x 36"]	122.64USD
Manufacturing Process	
Right Half	Four Sheet Metal Components
Left Half	Six Sheet Metal Components
Combined	Welding, Fasteners
Other Specifications	
Total Cost	394.53 USD
Environmental Conditions	Normal
Total Parts	2

TABLE VIII
BLADE GUARD HEAD SUMMARY

Blade Guard Head Summary	
Specifications	
Width	1.50"
Height	1"
Thickness	0.38"
Weight	0.16
Material	
Name	4130 Alloy Steel
Gauge	10
Material Thickness	0.100 inches
Weight/Sq. Foot	4.032 lbs
Cost [36" x 36"]	144.74 USD
Manufacturing Process	
Combined	Welding
Other Specifications	
Total Cost	303.27 USD
Environmental Conditions	Normal
Total Parts	5

TABLE IX
DOWNDRAFT TABLE ASSEMBLY SUMMARY

Downdraft Table Assembly Summary	
Part 1: Downdraft Table	
Length	8"
Width	6"
Thickness	0.50"
Nominal Volume	24 in^3
Actual Volume	20.17 in^3
Weight	5.91 lbs
Material	
Name	ASTM A681
Density	0.28 lbs/in^3
Part 2: Sink	
Length	8"
Width	6"
Height	2"
Nominal Volume	96 in^3
Actual Volume	18.85 in^3
Weight	5.38 lbs
Part 2: Outlet (sub-component of sink)	
Major Diameter	1"
Minor Diameter	0.80"
Thickness	0.75"
Nominal Volume	0.212 in^3
Actual Volume	0.21 in^3
Weight	0.06 lbs
Material	
Name	ASTM A108
Density	0.28 lbs/in^3
Part 3: Reducer Coupling	
Flange Diameter	4"
Length	3.50"
Nominal Volume	43.98 in^3
Actual Volume	6.86 in^3
Weight	0.25 lbs
Material	
Name	ABS
Density	N/A
Manufacturing Process	
Combined	Welding, Fasteners
Other Specifications	
Total Cost	370 USD
Environmental Conditions	Normal
Total Parts	4

8 Conclusion

Through a thorough concept development process, Honeycomb Badgers Industries was able to develop a design for BCW to improve the safety of the bandsaw operators. The final design features a blade guard to provide protection from the blade, and a downdraft table to provide protection from the core dust. The blade guard is mounted on a pneumatic slide, and rests on top of the core during the chamfering operation. The guard features a pivoting head that allows it to function for a wide range of chamfer angles. The downdraft table is built into the bandsaw table and is designed to vacuum core dust away from the operator during the chamfering process.

In phase one of the project, the team identified 11 requirements for the design. The requirements were:

- The design is compatible with the current cores that must be processed.
- The design is not unnecessarily expensive.
- The design is comfortable and enjoyable for the operators to use.
- The design is easy to implement.
- The design does not significantly increase the time required for the core chamfering process.
- The design does not significantly increase the time it takes to set up for a new core batch.
- The design does not prevent the bandsaw from being serviced, and/or is itself easy to service.
- The design is easy to replace if it is damaged.
- The design is not difficult for operators to learn how to use.
- The design does not significantly change the layout of the work cell.
- The design is not unnecessarily complex.

The team believes that the blade guard and downdraft table, if implemented, will meet these requirements.

Verification that the design would be able to chamfer all cores was done by visual inspection of extreme cases in SolidWorks. The final design has a material cost of $1070USD. The final design is easy to use. The blade guard is designed to be easily fastened to the bandsaw. The downdraft table requires the table to be taken off the bandsaw which is the greatest challenge of the final design, but once implemented, the downdraft table is easy to use with current chamfering processes. The team believes that the design will not significantly impact the process and setup time, however, testing will need to be performed to provide verification. The final design is comprised of easily manufactured parts, and if replacement is required, can be easily be removed from the bandsaw. The final design has no major impact on the work cell layout since it is contained to just the bandsaw, and finally, the design itself is simple and not overly complex.

Honeycomb Badgers Industries was able to provide BCW with their requested deliverables of a detailed design process, concept selection process, 3D CAD model of final design, and preliminary assembly drawings. By meeting all customer needs and specifications and providing all requested deliverables to BCW by the required deadlines, Honeycomb Badgers Industries believes that the project has been a success.

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Appendices

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Appendix A Project Schedule

A.1 Introduction

To ensure the team can deliver a design that meets BCW's requirements within the allotted timeframe, a project schedule was created. The project schedule is comprised of a work breakdown structure (WBS) and a Gantt chart.

The project schedule is initially introduced in the project definition report submitted October 1st, 2018. The project schedule was updated for the concept design report submitted on November 26th, 2018. This project schedule will feature an updated version of the project schedule from the concept design report and describe alterations and deviates made to the project schedule.

A.2 Work Breakdown Structure

The WBS for the project is broken down into three major phases: phase one: project definition, phase two: conceptual design, and phase three: final design. The project was broken into three major work packages since the project has three distinct report deliverables to the client and the team advisor at the end of each major work phase. These major work packages summarize the tasks necessary to successfully complete the project and are shown in Figure 1.

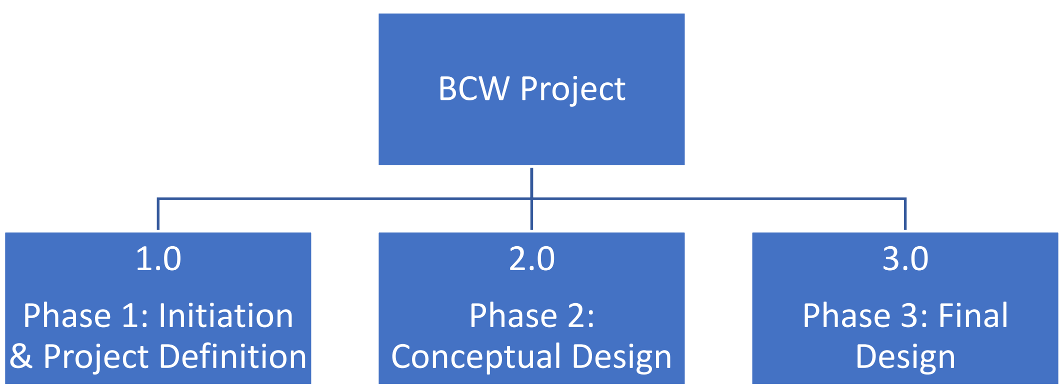


Figure 1. Major work packages WBS

Phase one is comprised five work packages: project kickoff, preliminary work, define project problem, project management plan, and the project definition report (PDR). Some work packages of to highlight in the phase one major work package is a project kickoff, define project problem, creation of a project management plan, an oral presentation, and a detailed process of how the team will create the project definition report. The WBS of the phase one major work package is shown in Figure 2.

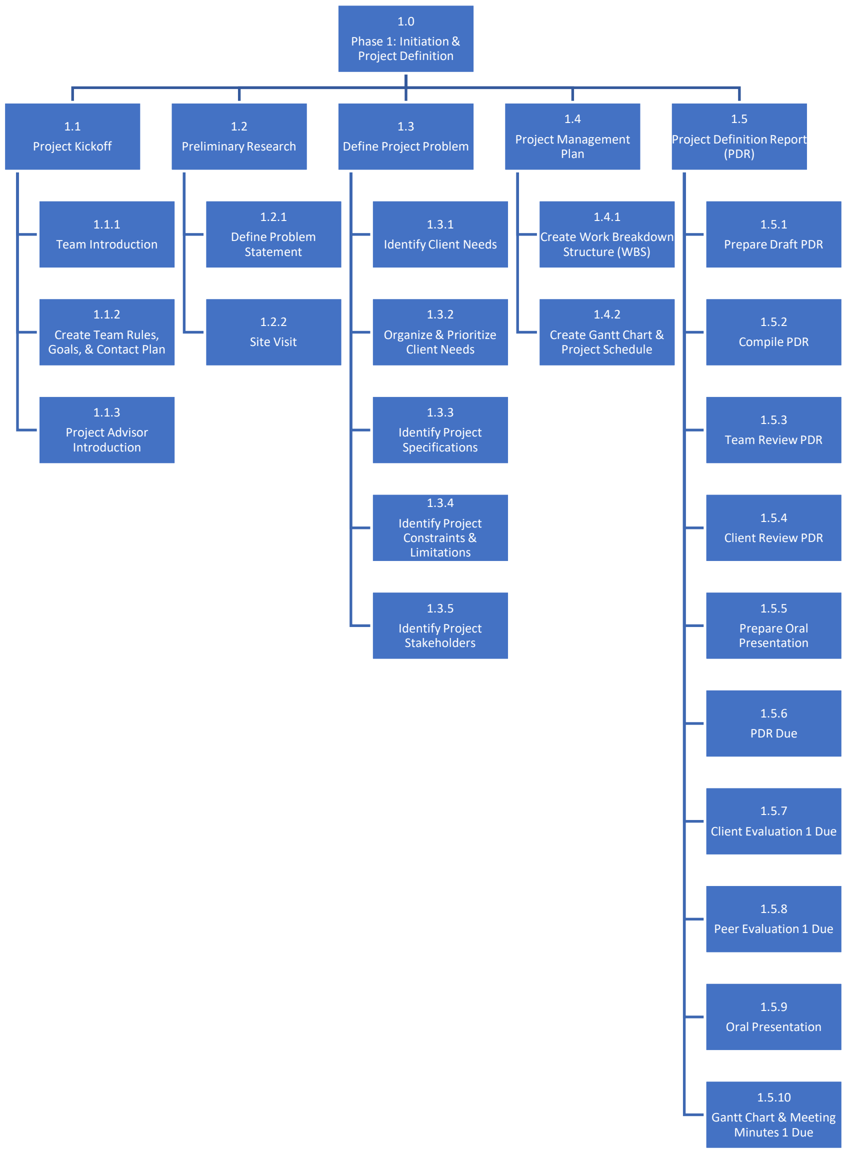


Figure 2. Initiation and project definition work package WBS

The phase two major work package is comprised of four work packages: concept generation, concept analysis and evaluation, concept selection, and a concept design report (CDR). The concept generation, analysis, evaluation, and selection will be an iterative approach that will feature brainstorming meetings, research and patent search, creating criteria weightings, and performing concept screening. This process will be followed to come up with a final concept selection. The concept generation process will be summarized in a concept design report that will be submitted to the client and team advisor. The WBS of the phase two major work package is shown in Figure 3.

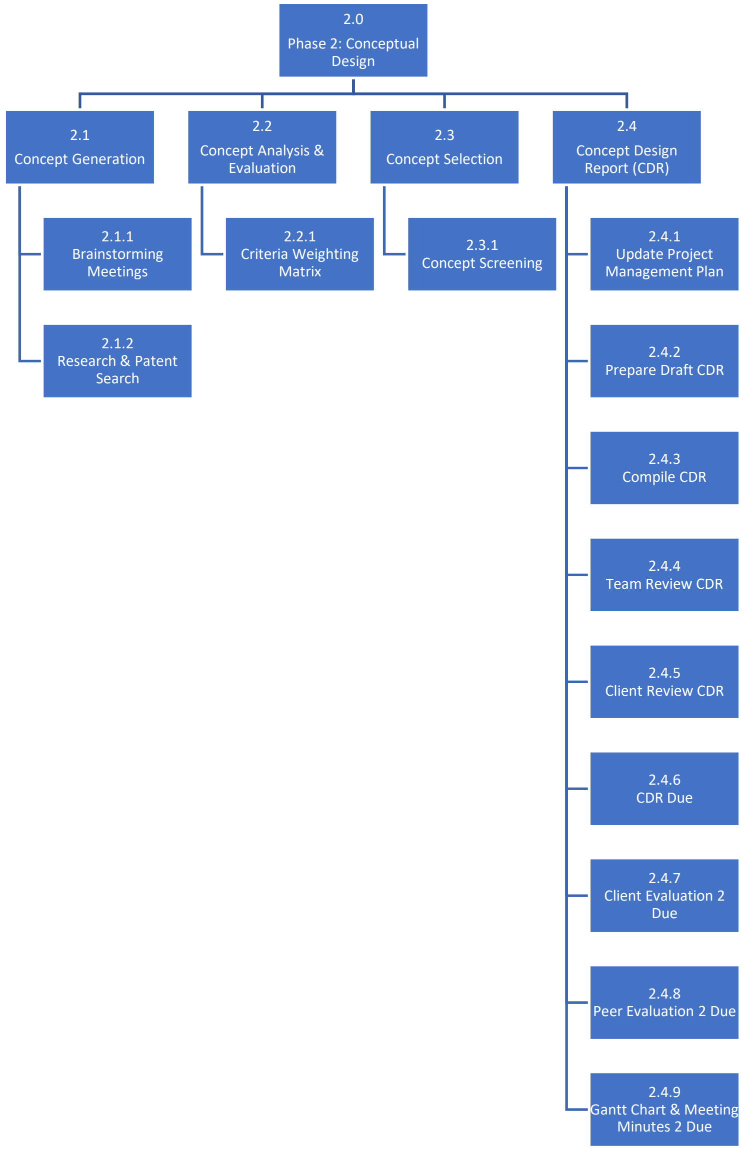


Figure 3. Conceptual design work package WBS

The phase three major work package is comprised of finalizing the selected concept of the CDR, creating a final design report, a poster presentation, and project closeout procedures. The details and implementation final selected concept from the CDR will be more thoroughly detailed and designed. The final concept will feature fully detailed CAD models and assembly drawings. The CAD models and assembly drawings will be submitted to the client and faculty advisor in the final design report along with the step by step processes on how the team reached the final design details. In addition to the FDR, the team will present the final design in an oral presentation. The WBS of the phase three major work package is shown in Figure 4.

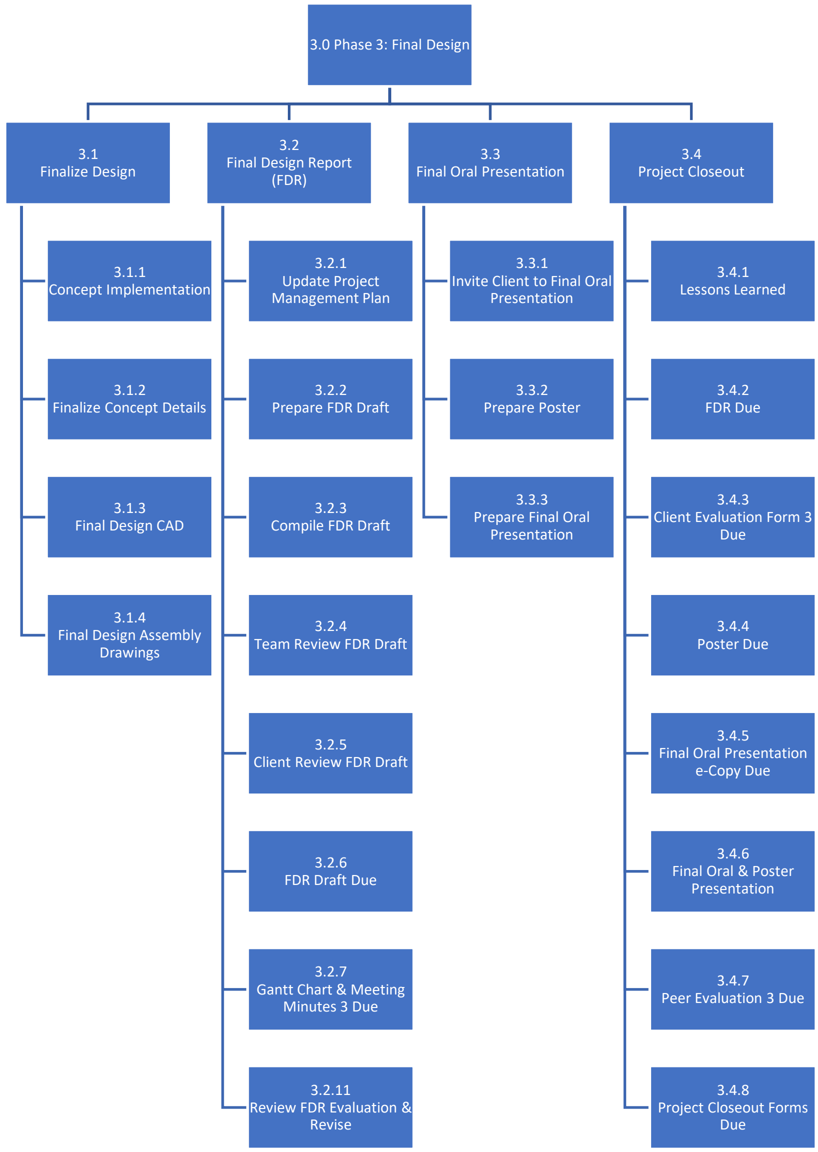


Figure 4. Final design work package WBS

A.3 Gantt Chart

Using the work breakdown structure, a Gantt chart was created to be used by the team throughout the project. The project schedule features start dates, expected end dates, submission due dates. In addition, the project schedule shows the predecessors of the work packages throughout the entire project and the resources assigned that are responsible for ensuring that the tasks are completed on time. Slack time is also included in the project schedule to account for unexpected delays that may occur during the project time. The Gantt chart for the project is shown in Figure 5

ID	WBS	Task Name	Start	Finish
1	**1**	**Phase 1 - Initiation & Project Definition**	**Wed 18-09-05**	**Wed 18-10-10**
2	**1.1**	**Project Kickoff**	**Wed 18-09-05**	**Wed 18-09-12**
6	**1.2**	**Preliminary Research**	**Thu 18-09-13**	**Sun 18-09-16**
9	**1.3**	**Define Project Problem**	**Fri 18-09-14**	**Wed 18-09-19**
15	**1.4**	**Project Management Plan**	**Fri 18-09-14**	**Thu 18-09-20**
18	**1.5**	**Project Definition Report (PDR)**	**Tue 18-09-18**	**Wed 18-10-10**
29	**2**	**Phase 2 - Conceptual Design**	**Tue 18-10-09**	**Wed 18-10-31**
30	**2.1**	**Concept Generation**	**Tue 18-10-09**	**Mon 18-10-15**
33	**2.2**	**Concept Analysis & Evaluation**	**Tue 18-10-16**	**Tue 18-10-16**
35	**2.3**	**Concept Selection**	**Thu 18-10-18**	**Thu 18-10-18**
37	**2.4**	**Concept Design Report (CDR)**	**Tue 18-10-16**	**Wed 18-10-31**
47	**3**	**Phase 3 - Final Design**	**Mon 18-10-29**	**Fri 18-12-07**
48	**3.1**	**Finalize Design**	**Mon 18-10-29**	**Sat 18-11-17**
49	3.1.1	Concept Implementation	Mon 18-10-29	Fri 18-11-02
50	3.1.2	Finalize Concept Details	Sat 18-11-03	Wed 18-11-07
51	3.1.3	Final Design CAD	Thu 18-11-08	Tue 18-11-13
52	3.1.4	Final Design Assembly Drawings	Wed 18-11-14	Sat 18-11-17
53	**3.2**	**Final Design Report (FDR)**	**Sun 18-11-11**	**Fri 18-11-30**
54	3.2.1	Update Project Management Plan	Wed 18-11-14	Thu 18-11-15
55	3.2.2	Prepare FDR Draft	Sun 18-11-11	Sat 18-11-17
56	3.2.3	Compile FDR Draft	Mon 18-11-19	Mon 18-11-19
57	3.2.4	Team Review FDR Draft	Wed 18-11-21	Wed 18-11-21
58	3.2.5	Client Review FDR Draft	Thu 18-11-22	Fri 18-11-23
59	3.2.6	Draft FDR Due	Mon 18-11-26	Mon 18-11-26
60	3.2.7	Gantt Chart & Meeting Minutes 3 Due	Wed 18-11-28	Wed 18-11-28
61	3.2.8	Review FDR Evaluation & Revise	Wed 18-11-28	Fri 18-11-30
62	**3.3**	**Final Oral Presentation**	**Mon 18-11-19**	**Tue 18-12-04**
63	3.3.1	Invite Client to Final Oral Presentation	Mon 18-11-19	Wed 18-11-28
64	3.3.2	Prepare Poster	Wed 18-11-28	Tue 18-12-04
65	3.3.3	Prepare Final Oral Presentation	Tue 18-11-27	Tue 18-11-27
66	**3.4**	**Project Closeout**	**Fri 18-11-30**	**Fri 18-12-07**
67	3.4.1	Lessons Learned	Fri 18-11-30	Mon 18-12-03
68	3.4.2	FDR Due	Wed 18-12-05	Wed 18-12-05
69	3.4.3	Client Evaluation Form 3 Due	Wed 18-12-05	Wed 18-12-05
70	3.4.4	Poster Due	Thu 18-12-06	Thu 18-12-06
71	3.4.5	Final Oral Presentation e-Copy Due	Thu 18-12-06	Thu 18-12-06
72	3.4.6	Final Oral & Poster Presentation	Thu 18-12-06	Thu 18-12-06
73	3.4.7	Peer Evaluation 3 Due	Fri 18-12-07	Fri 18-12-07
74	3.4.8	Project Closeout Forms Due	Fri 18-12-07	Fri 18-12-07

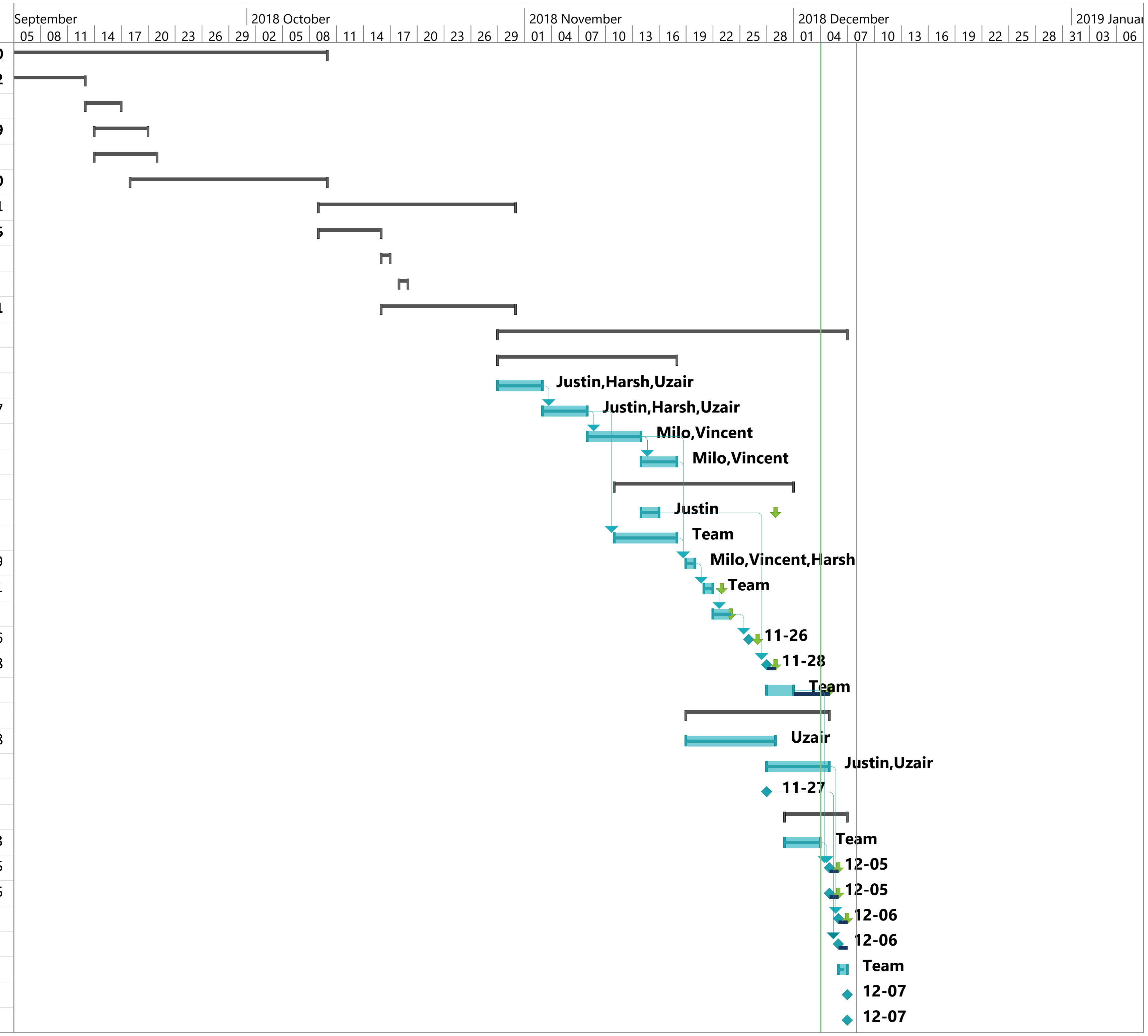


Figure 5. Gantt chart, December 5th, 2018

Appendix B Concept Generation and Selection

An overview of the concepts generated for blade protection and dust protection will be introduced and discussed below.

B.1 Concept Generation

Based on the project objectives, the team began generating potential solutions. The concept generation process began with a brainstorming meeting, which transitioned into external research on the initial ideas. The external research returned one relevant patent.

Because the project has two independent objectives, the concepts were split into two categories. The first category is concepts which focus on protecting the operator from the bandsaw blade, and the second category is concepts which protect the operator from core dust. Each concept section will briefly explain what inspired the concept, give a description of the concept, explain how the concept addresses the project objectives, and if relevant, will discuss any external research or patents.

B.1.1 Blade Safety

Seven concepts were initially generated during the brainstorming and research phase. These were improved PPE, powered rollers, a moving table, a CNC, a blade brake, a belt sander and a blade guard. Two more blade safety concepts were generated after the concept screening. These were a push stick, and a moving blade. All nine of these concepts will be explained in this section.

B.1.1.1 Improved PPE

Currently the bandsaw operators are required to wear hearing protection, safety glasses, steel toed boots, disposable coveralls, and latex gloves when operating the bandsaw. The gloves are to minimize contact with the core dust and provide no protection from the bandsaw blade. The improved PPE concept is a glove or guard that would be resistant to being cut. This concept would improve the operator safety by preventing their hand from contacting the blade directly.

B.1.1.2 Powered Rollers

This concept was inspired by the current roller system used at BCW. The roller system keeps thin cores pushed against the backboard during the chamfering operation. The powered roller concept would be similar to the current system, however the range of core sizes that could be accommodated would increase, and the rollers would be driven. The driven rollers would hold the core against the backboard and feed the core through the bandsaw. This would allow the operator to keep their hand away from the blade on the final stroke of the core chamfering operation. The final stroke of the core chamfering operation is the dangerous part of chamfering thin cores. On thick cores, the dangerous part is holding the core against the backboard. This system would eliminate both problems, greatly increasing blade safety.

B.1.1.3 Moving Table

This concept was inspired by table saws where the part being cut is fixed to the table, and the table moves along the blade. This concept would work in a similar fashion; however, the table saw blade would be replace with a bandsaw blade. The core would be fixed to the table, and the table would be able to rotate along one axis. This would allow chamfers to be performed at the correct angle. The moving table improves blade safety as the operator's hand will not need to be close to the blade. This concept would however be limited to flat cores.

B.1.1.4 CNC and Laser-cutter

Computer Numerically Controlled (CNC) machines are automated machining devices that produce parts based on a CAD models. The "CNC with pin table" concept will be composed of a pin table, and a robotic arm. The robotic arm will be able to select cores from an automated shelf, place the part on the table, and clamp it. The robotic arm will then chamfer the core and place it into an output section.

The fixed pin table design is based on inFORM technology [1]. The table will have thousands of pins per square meter. These pins will be able to move up and down and will be controlled by a computer. Using a CAD model, the pins will form to the shape of core.

The robotic arm will be equipped with milling tools, or a laser cutter. Milling tools are fast and widely available but create a lot of waste material and dust.

Laser cutters use a high intensity laser to melt, burn, or vaporize material, leaving very accurate cuts with good surface finishes. Laser cutters are also relatively fast; however, they might be tricky to use with flammable paper-based honeycomb cores. These two concepts would improve safety by removing human exposure to the blade and core dust.

B.1.1.5 BladeStop

Initially this concept was inspired by the SawStop table saw technology, however the concept evolved from using conduction sensors, to using optical sensors. The optical sensor would detect if a hand was too close to the bandsaw blade and apply a brake. Upon researching this concept, it was found that a patent already existed for a bandsaw with the commercial name BladeStop [2]. The team decided purchasing the BladeStop technology would be a good solution to the blade safety issue. The BladeStop 400 band saw from Scott automation would be retrofitted with an adjustable angle table. This would allow the core chamfering operation to continue as normal.

B.1.1.6 Belt Sander

This concept was generated in a brainstorming session and has no traceable inspiration. The concept would eliminate the use of a blade in favour of a belt sander. The belt sander would be used to remove the core material to meet chamfer specifications. This would improve the blade safety because contact with a belt sander has relatively low consequences, and potential injuries would be minor.

B.1.1.7 Blade Guard

The blade guard concept was inspired by circular saw blade guards. The blade guard would be adjustable so that it could accommodate many thicknesses or cores, and the end would pivot to accommodate different chamfer angles. The blade guard would create a physical block which would prevent operators from touching the bandsaw blade.

B.1.1.8 Push Stick

The push stick concept was inspired by one of the bandsaw operators. This bandsaw operator used a piece of core to keep distance between his hand and the blade. The push stick concept would improve blade safety because it would allow operators to maintain pressure between the core and the backboard, while keeping a safe distance between their hands and the blade.

B.1.1.9 Moving Saw

The moving saw concept was inspired by the moving table concept discussed earlier. The moving saw concept would be like a track saw, with the additional feature that the cutting angle is able to change. The moving saw would improve the blade safety because instead of the operator moving a piece of core past an exposed blade, the operator would be moving the blade past the core. This would allow a safe distance to be kept from the blade, however it would also be limited to flat cores.

B.1.2 Dust Safety

Five concepts were generated during the brainstorming and research phase. The concepts were a dust shield, a hose inlet filter, a downdraft table, a respirator mask, and a "bubble." These concepts will be explained in this section.

B.1.2.1 Dust Shield

The dust shield concept was inspired by the shields installed on bench grinders. The dust shield would be a piece of transparent material located between the operator's head and the saw blade. The purpose of this is to prevent the dust from bouncing back into the operator's face. By preventing core dust from bouncing towards the operator, the air quality around the operator's head would be improved.

B.1.2.2 Adding Hose Inlet Filter

During the site visit, the operator explained and demonstrated an issue that occurred while using the vacuum during the chamfering operation. The offcuts from thin cores would become lodged in the vacuum, causing a delay while the operator unclogged it. To avoid this problem, the operators would remove the vacuum while chamfering thin cores, which would allow core dust to accumulate. This inspired the concept of a hose inlet filter. The hose inlet filer would be a mesh that would prevent core offcuts from being vacuumed into the hose, while allowing smaller dust particles to pass. This concept would improve dust safety by allowing the vacuum to be used during the chamfering of thin cores.

B.1.2.3 Downdraft Table

This concept was inspired by the current design of the bandsaw backboard. The current bandsaw backboard has holes drilled near the bandsaw blade which vacuum some of the dust. A downdraft table is a table covered in holes that are connected to a vacuum. Any dust produced during the saw's operation is vacuumed into the holes, not allowing dust to collect. The downdraft table concept would improve dust safety by vacuuming the bulk of the core dust created, while being difficult to clog.

B.1.2.4 Respirator Mask

On the teams site visit, the operators performing the core chamfering processes were using disposable paper dust masks. Dust masks are effective against most small airborne dust particles; however, they can be ill fitting and allow fumes, and smaller dust particles to be inhaled.

Currently respirator masks are available at BCW, however, operators are not required to use them. This is because the airborne dust particles are below a specific "parts per million" standard. It is up to the discretion of the operator to use the respirator masks. This concept would improve dust safety because of the better fit of the mask.

B.1.2.5 Bubble

The bubble concept was derived from the clean rooms already implemented at BCW. The bubble concept would be a structure built around the core chamfering band saw area, which would then be covered in a plastic sheet to prevent dust from escaping. This design would improve air quality outside of the bubble by trapping all the dust particles. This may however decrease the air quality inside the bubble, requiring operators to wear a more robust dust mask.

B.2 Summary

Due to the high volume of cores being processed at BCW, and the Go for Zero initiative, ensuring the safety of bandsaw operators is a high priority. The constraints on the project are the timeframe of the MECH 4860 course, and the design space at BCW. The main objectives for the design are as follows:

1. The design must protect the bandsaw operator from being cut on the blade.
2. The design must minimize the bandsaw operator's exposure to core dust.
3. The design must function for various dimensions of cores.
4. The design must function for various chamfer angles.

Concepts that focused on blade and dust safety were generated, and then screened separately. The concepts which remained after the screening were combined into complete solutions and scored to determine which combination was the best. The client and the team agreed that the best concept was the blade guard, and the downdraft table.

To ensure the success of the project, the team will continue to give the client frequent progress updates and ask for input. The team will continue to have internal meetings, as well as meetings with the project advisor.

The team will now move on to the third phase of the project; final design optimization, and closeout procedure. The deliverables that will be provided to BCW at the end of this phase are a 3D CAD model, preliminary assembly drawings, a detailed design process, and justification for the design.

Appendix C Preliminary Assembly Drawings

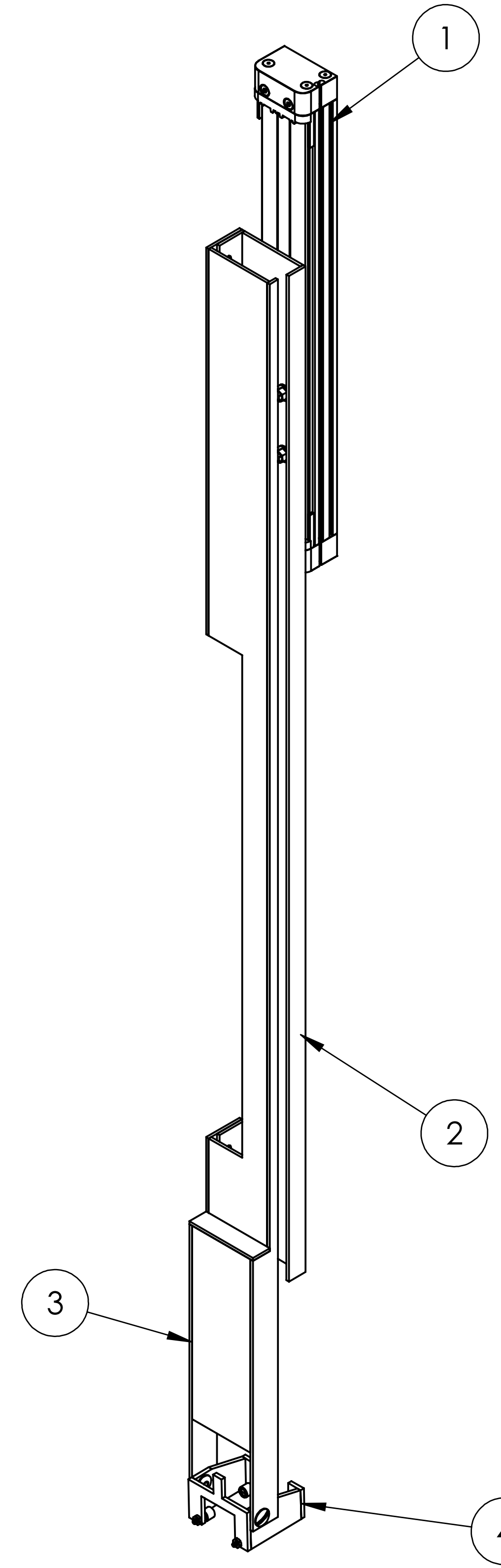
The preliminary assembly drawings for the blade guard and downdraft table final design are attached at the end of the report.

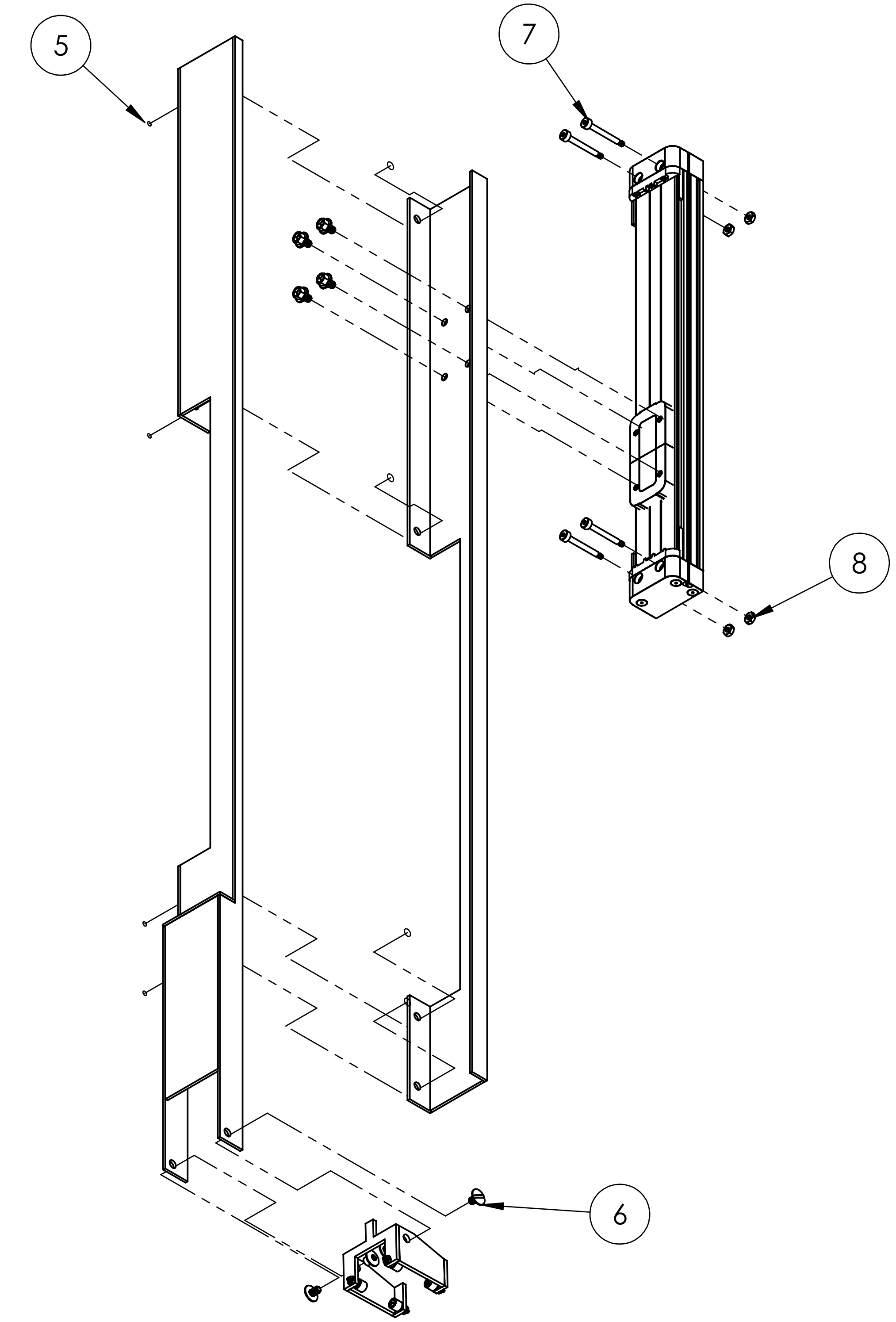
Appendix References

[1] S. F. A. O. A. H. H. I. Daniel Leithinger*, "Tangible Media Group," 2013. [Online]. Available: http://tangible.media.mit.edu/project/inform/. [Accessed 22 10 2018].

[2] SCOTT, "BladeStop 400 Bandsaw," [Online]. Available: https://www.scottautomation.com/products/bladestop/. [Accessed 14 Octorber 2018].

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	2738T180	DOUBLE ACTING AIR SLIDE	1
2	BLDGRD-A002	RIGHT GUARD SUB-ASSEMBLY	1
3	BLDGRD-A003	LEFT GUARD SUB-ASSEMBLY	1
4	BLDGRD-A004	HEAD SUB-ASSEMBLY	1
5	94887A112	1/8"-3/16" SCREW AND BARREL	4
6	94887A123	1/4"-3/8" SCREW AND BARREL	2
7	91841A005	18-8 NUT	4
8	90298A147	18-8 BOLT	4
9	92323A589	SERRATED FLANGE SCREW	4





INSTALLATION INSTRUCTIONS:

1. INSTALL THE PNUMATIC RAIL (1) TO THE BANDSAW FRAME USING FOUR BOLTS (7) AND NUTS (8). USE OF GENERIC SELFLOCKING WASHER OR THREADLOCKER HIGHLY RECOMENDED.
2. INSTALL RIGHT GUARD (2) ON TO PNUMATIC RAIL (1) USING FOUR SCREWS (9).
3. NSTALL HEAD ASSEMBLY (4) ON TO THE LEFT GUARD (3) USING TWO SCREWS AND BARREL NUTS (6).
4. INSTALL THE LEFT GUARD (3) ON TO THE RIGHT GUARD (2) USING FOUR SCREWS (5)

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			CKD NAME #	
			DWN NAME #	
			CKD NAME #	
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			CKD NAME #	

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DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

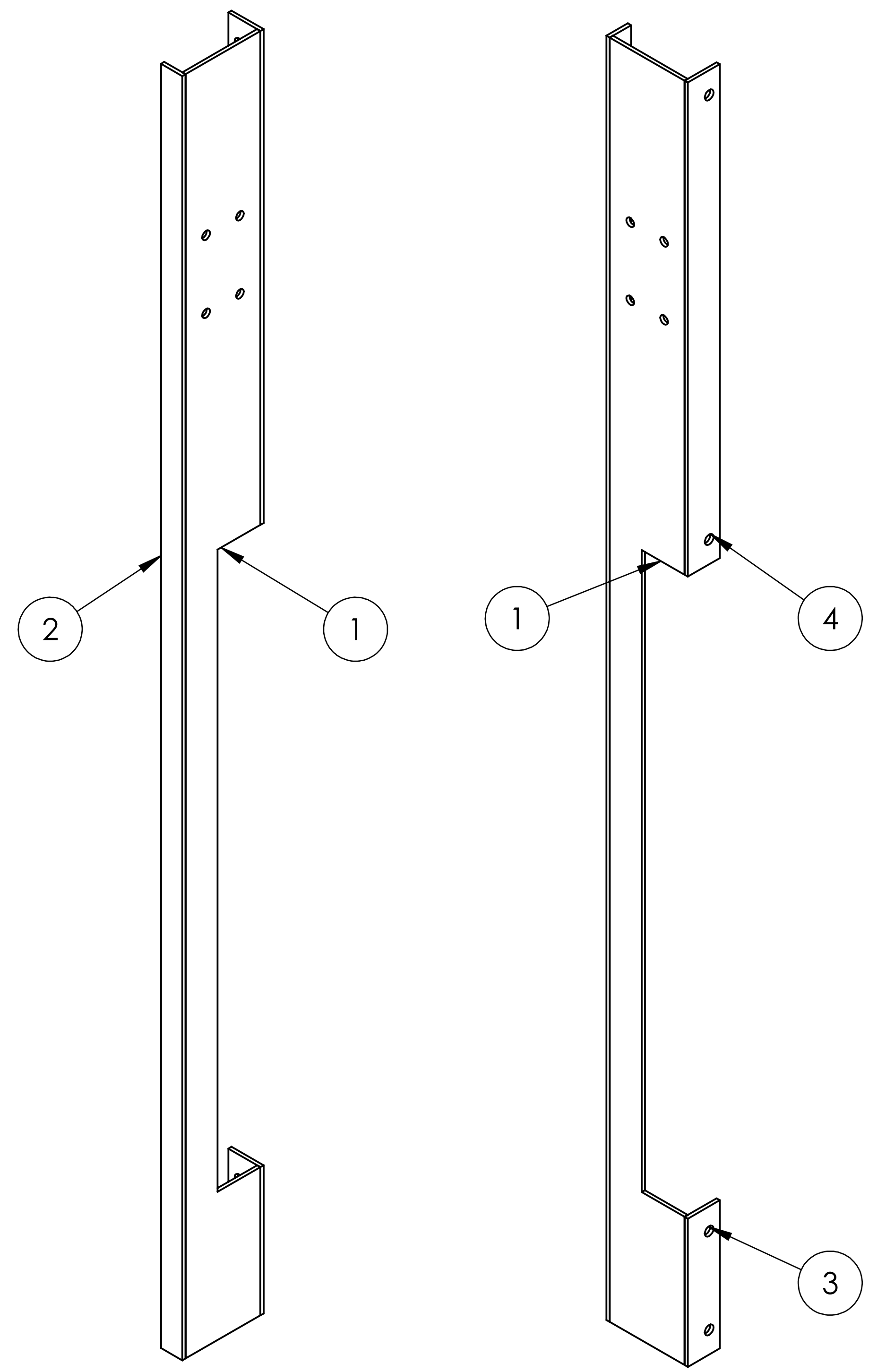
TITLE: **TOP LEVEL ASSEMBLY DRAWING BLADE GUARD**

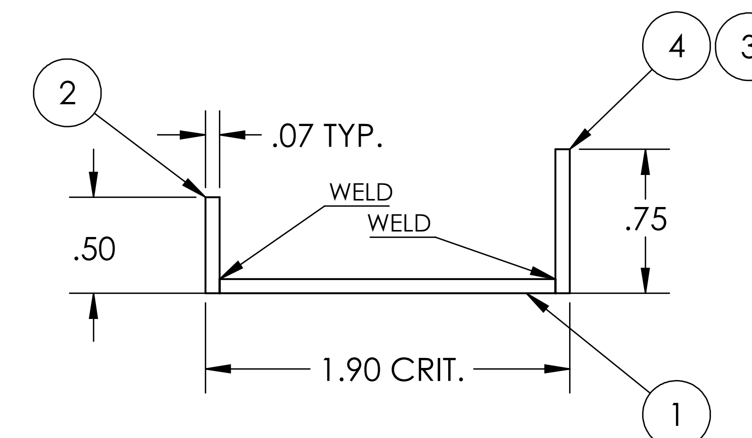
SIZE	DWG. NO.	REV
B	BLDGRD-A001_V001	0

SCALE: 1:4 | WEIGHT: N/A | SHEET 1 OF 1

DWG. NO. BLDGRD-A001_V001 REV 0

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	BLDGRD-P002	RIGHT PANEL	1
2	BLDGRD-P001	FRONT PANEL	1
3	BLDGRD-P003	BACK UPPER PANEL	1
4	BLDGRD-P004	BACK LOWER PANEL	1





TOP VIEW
SCALE 1:1

MANUFACTURING INSTRUCTIONS:

1. SECURE RIGHT PANEL (1) ON A WELD TABLE.
2. USING A COMPACT MAGNETIC WELDING SQUARE, ALLIGN PANELS (2)(3)(4) ON THE OUTSIDE OF THE PANEL (1).
3. TACK WELD ALL PANELS IN PLACE AND REMOVE WELDING SQUARES.
4. RUN A WELD BEAD ON THE INSIDE CORNERS OF ALL PANEL JOINTS.
5. BREAK ALL SHARP CORNERS, LIGHTY SAND AND CLEAN SURFACE, AND PAINT THE ASSEMBLY.

REV	DATE	DESCRIPTION		
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			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	

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DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

TITLE:

SUB-ASSEMBLY RIGHT GUARD

SIZE	DWG. NO.	REV
B	BLDGRD-A002	0

SCALE: 1:4 WEIGHT: N/A SHEET 1 OF 1

REV 0 BLDGRD-A002 DWG. NO.

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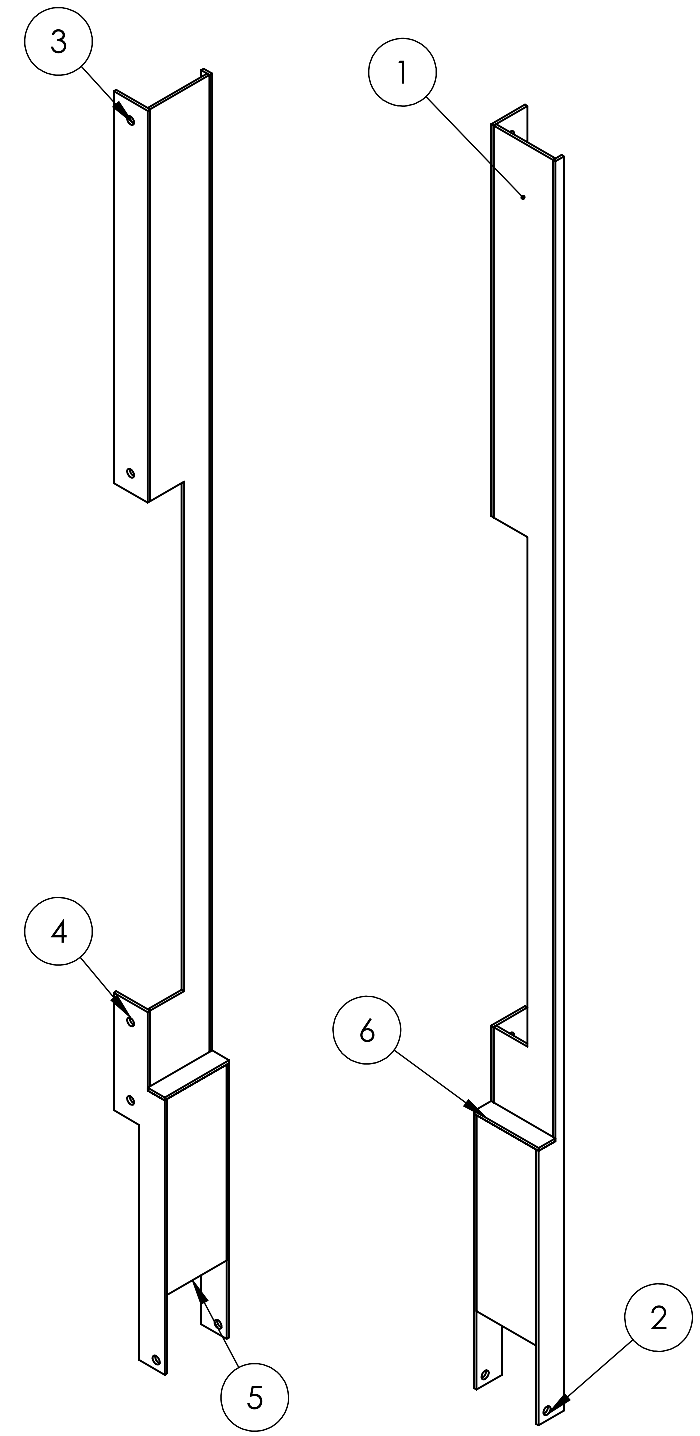
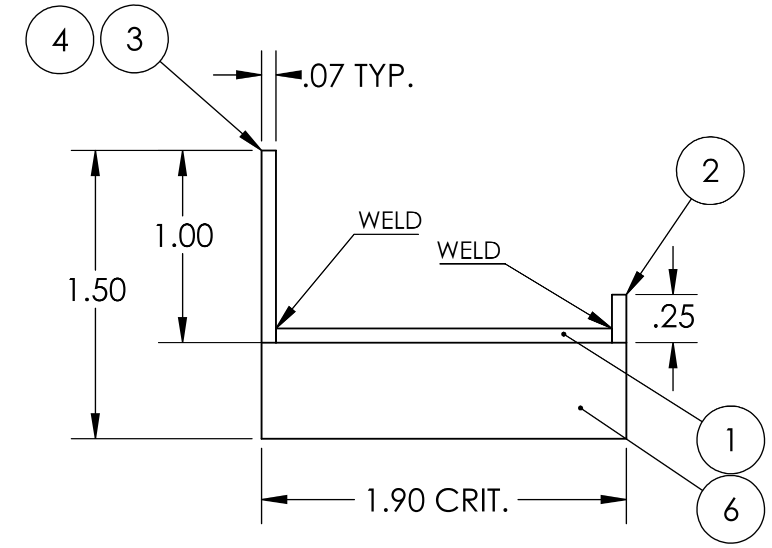
2	BLDGRD-P006	FRONT PANEL	1
3	BLDGRD-P010	BACK UPPER PANEL	1
4	BLDGRD-P011	BACK LOWER PANEL	1
5	BLDGRD-P008	LEFT LOWER PANEL	1
6	BLDGRD-P009	TOP PANEL	1





TOP VIEW
SCALE 1:1

MANUFACTURING INSTRUCTIONS:

1. SECURE RIGHT PANEL (1) ON A WELD TABLE.
2. USING A COMPACT MAGNETIC WELDING SQUARE, ALLIGN ALL OTHER PARTS (1).
3. TACK WELD ALL PANELS IN PLACE AND REMOVE WELDING SQUARES.
4. RUN A WELD BEAD ON THE INSIDE CORNERS OF ALL PANEL JOINTS.
5. BREAK ALL SHARP CORNERS, LIGHTY SAND AND CLEAN SURFACE, AND PAINT THE ASSEMBLY.

REV	DATE	DESCRIPTION		
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			DWN NAME # / CKD NAME #	
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DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

TITLE:

SUB-ASSEMBLY LEFT GUARD

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SCALE: 1:4 | WEIGHT: N/A | SHEET 1 OF 1

DWG. NO. BLDGRD-A003 REV 0

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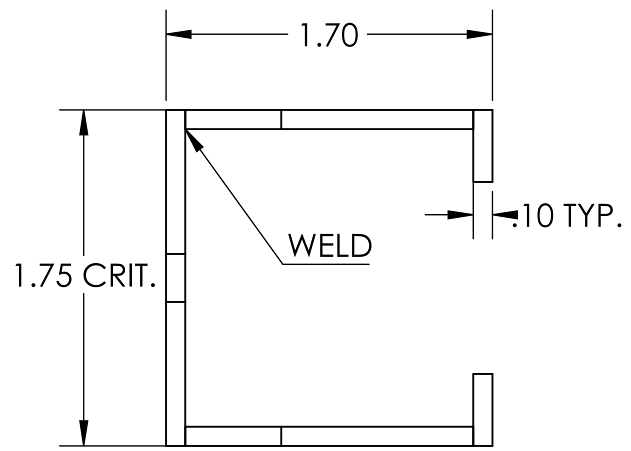
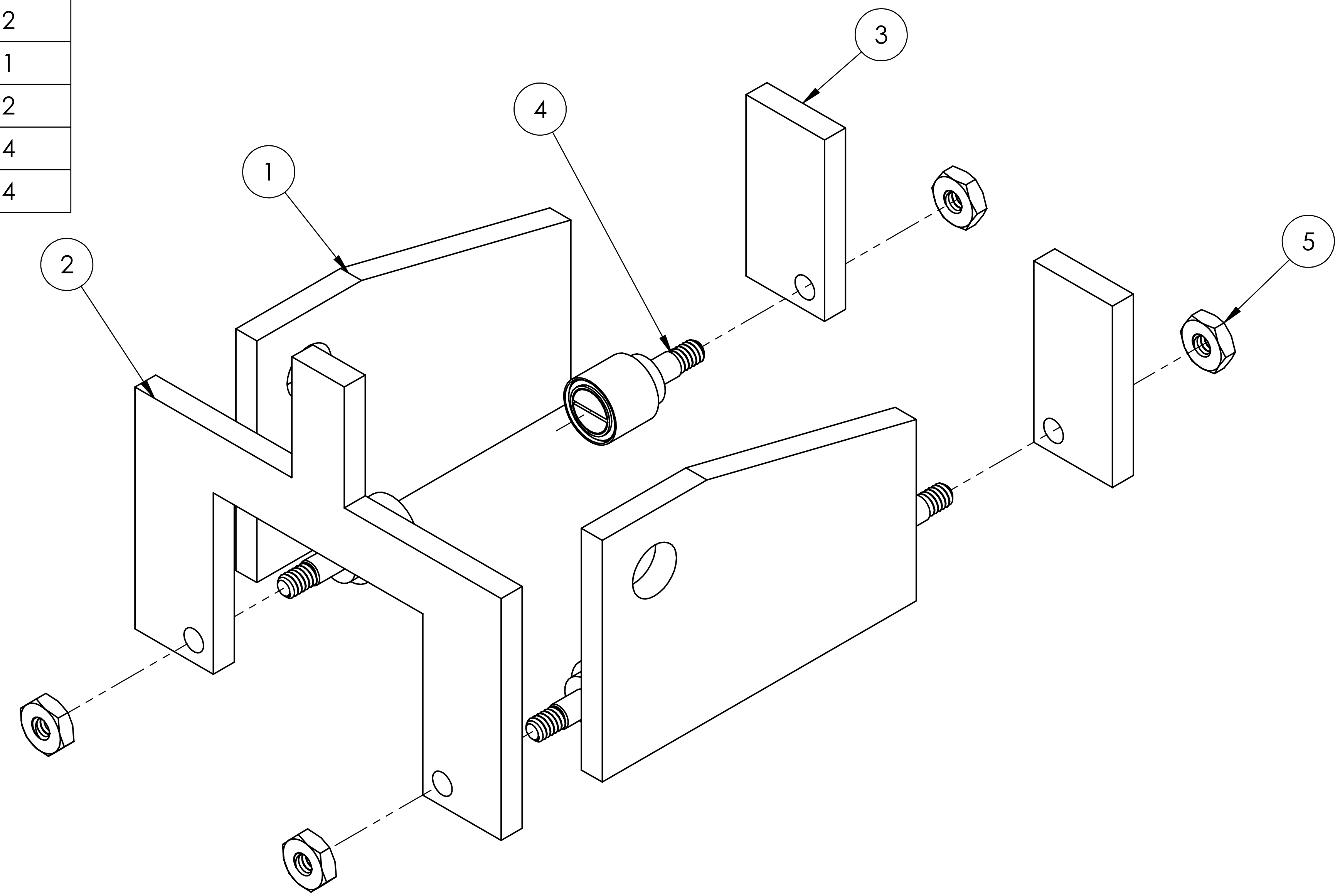
1	BLDGRD-P014	SIDE PANEL	2
2	BLDGRD-P015	LEFT PANEL	1
3	BLDGRD-P013	RIGHT PANEL	2
4	3668K3	TRACK ROLLERS	4
5	90480A003	NUT	4





MANUFACTURING INSTRUCTIONS:
1. ALLIGN ALL PANELS (1)(2)(3)(4) USING COMPACT WELDERS MAGNETIC SQUARE.
2. TACK WELD ALL PANELS.
3. RUN A WELD BEAD ON THE INSIDE EDGES OF ALL PANEL JOINTS
4. INSTALL THE FOUR ROLLERS (4) USING NUTS (5) AND THREADLOCKER.

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DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

TITLE:

SUB-ASSEMBLY
GUARD HEAD

SIZE	DWG. NO.	REV
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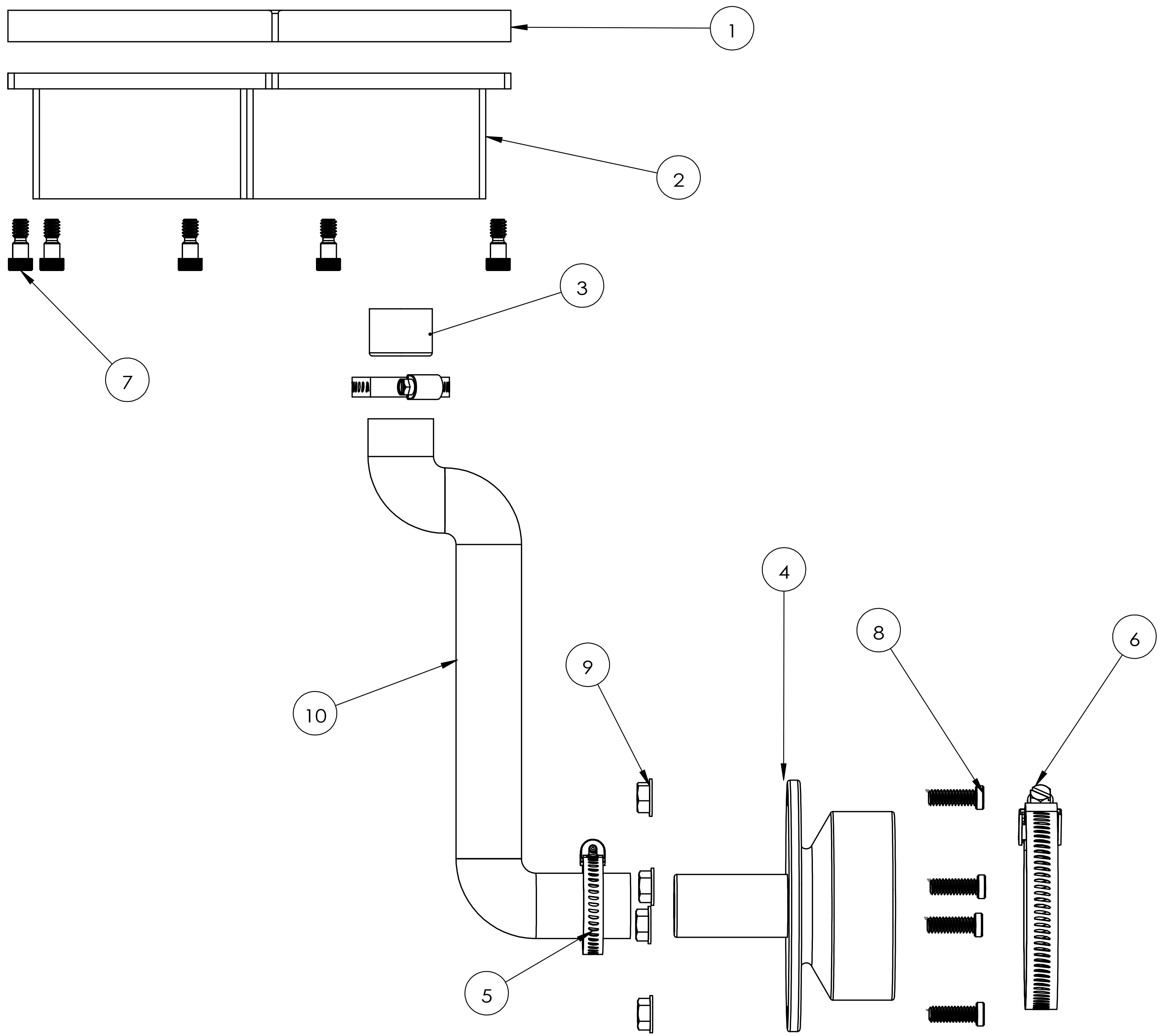

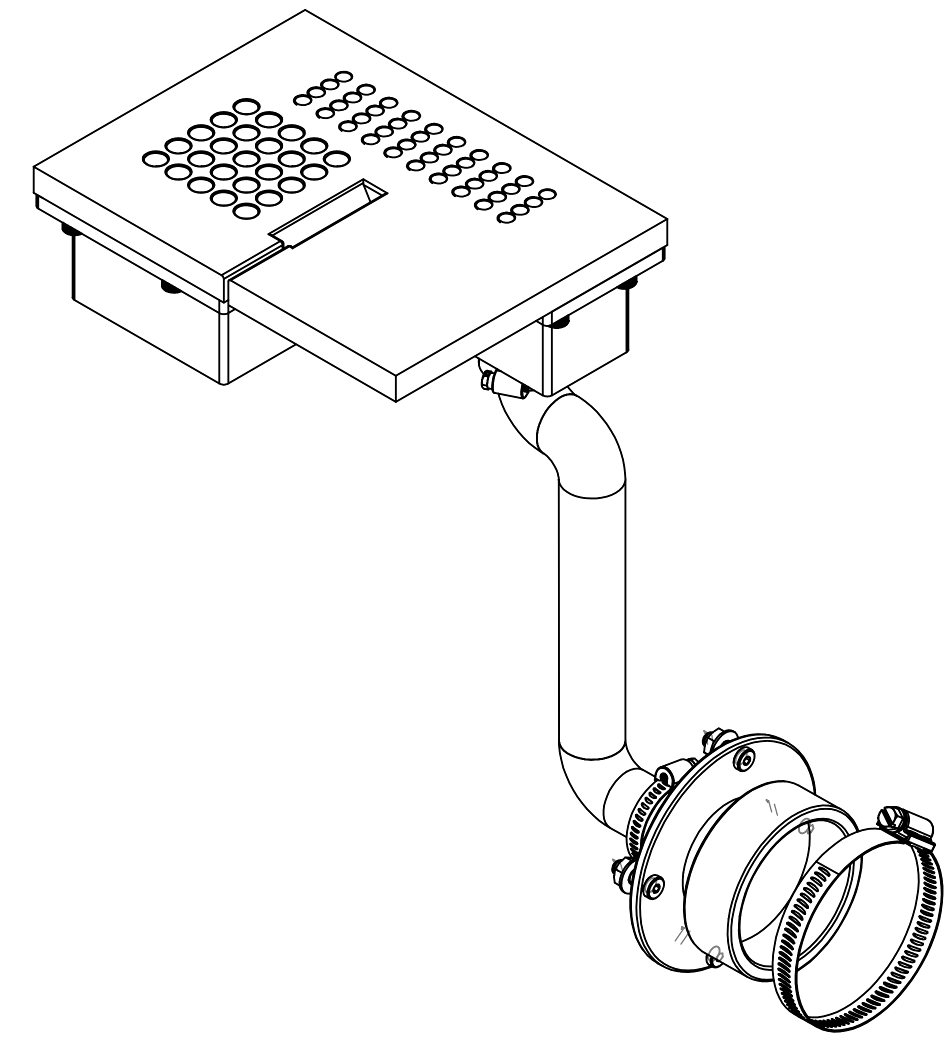

DOWNDRAFT TABLE - A001 | REV 0 | DWG. NO.

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REV	DATE	DESCRIPTION		

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DIMENSIONAL UNIT: INCHES

UNIVERSITY of MANITOBA | MECH 4860 ENGINEERING DESIGN

TITLE:
Preliminary Assembly Drawing
Downdraft Table

SIZE	DWG. NO.	REV
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SCALE: 1:4	WEIGHT: N/A	SHEET 1 OF 2

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2	DOWNDRAFT TABLE - P002	Sink	1
3	DOWNDRAFT TABLE - P003	Outlet	1
4	DOWNDRAFT TABLE - P004	Reducer Coupling	1
5	5011T241	GENERAL PURPOSE WORM-DRIVE CLAMP FOR FIRM HOSE AND TUBE	2
6	5415K23	GENERAL PURPOSE WORM-DRIVE CLAMP FOR FIRM HOSE AND TUBE	1
7	90807A111	SAME-SIZE THREAD ALLOY STEEL SHOULDER SCREW	9
8	93615A415	18-8 SS LOW-PROFILE SOCKET HEAD SCREW	4
9	94612A101	HIGH-STRENGTH STEEL FLANGE NUT - GRADE 8	4
10	5136K18	ABRASION-RESISTANT VERY FLEXIBLE DUST HOSE FOR DUST	1

MANUFACUTRING PROCESS:

1. LATERALLY LAYING THE SINK ON THE WELD TABLE SECURELY
2. PLACE A PLATE INTO THE SINK AND LET THE PLATE AGAINST THE INNER BOTTOM SURFACE
3. INSERT THE OUTLET INTO THE SINK THROUGH THE OUTLET HOLE UNTIL THE OUTLET AGAINST THE PLATE
4. REMOVE THE PLATE AND MAKE SURE THE INNER BOTTOM SURFACE OF THE SINK IS SMOOTH
5. WELD THE CONNECTION EDGE BETWEEN THE OUTLET AND THE SINK

REV	DATE	DESCRIPTION		
			DWN / CKD	
			DWN / CKD	
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TITLE: **Preliminary Assembly Drawing Downdraft Table**

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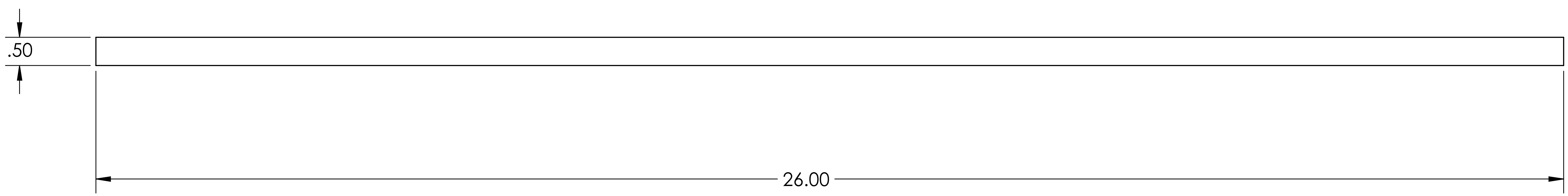

BLDGRD-P001 | REV 0 | DWG. NO.

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			CKD NAME #		
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR	
			CKD NAME #		
REV	DATE	DESCRIPTION			

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

NOTE:
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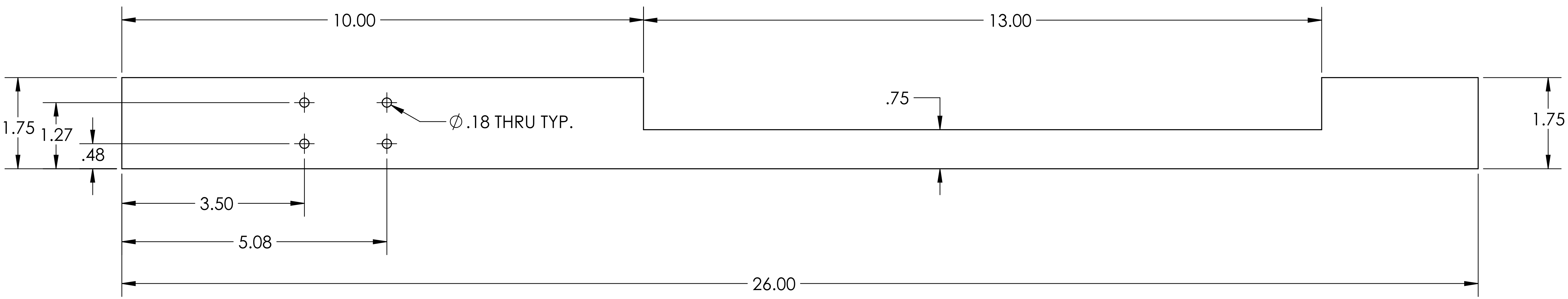
TITLE:
PART DRAWING
FRONT PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE	DWG. NO.	REV
B	BLDGRD-P001	0

DIMENSIONAL UNIT: INCHES

SCALE: 1:2 | SHEET 1 OF 1



REV	DATE	DESCRIPTION		
			DWN NAME #	
			CKD NAME #	
			DWN NAME #	
			CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR
			CKD NAME #	

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MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA

MECH 4860 ENGINEERING DESIGN

TITLE:

PART DRAWING
RIGHT PANEL

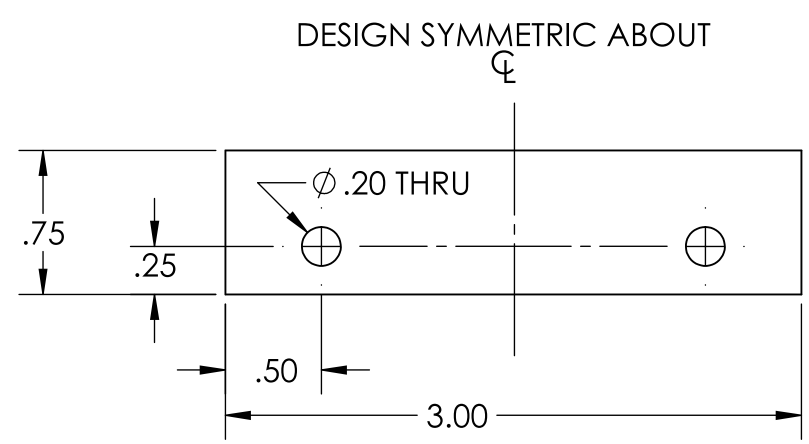
SIZE	DWG. NO.	REV
B	BLDGRD-P002	0

SCALE: 1:2

SHEET 1 OF 1

DWG. NO. BLDGRD-P002 REV 0

DWG. NO. BLDGRD-P003 REV 0



REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	

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MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

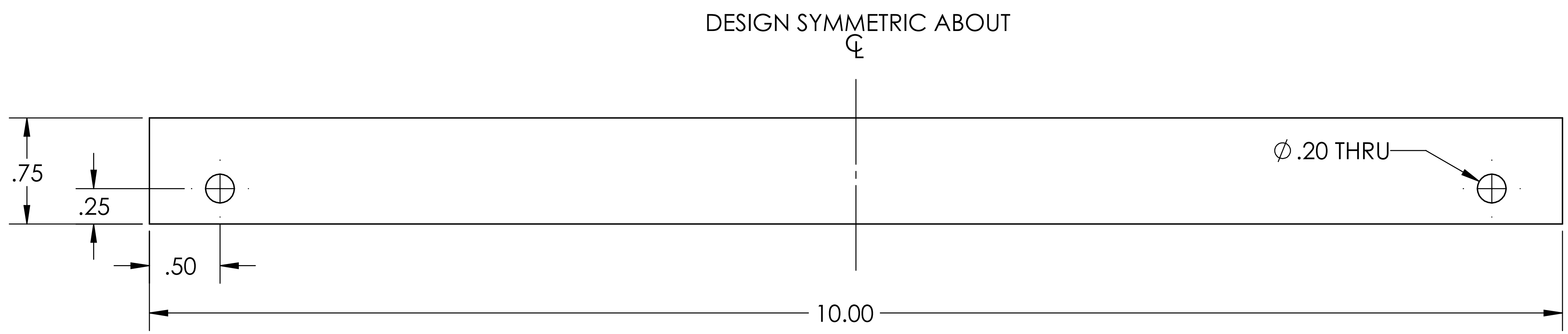
DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

TITLE:
PART DRAWING
BACK UPPER PANEL

SIZE: B | DWG. NO.: **BLDGRD-P003** | REV: 0

SCALE: 1:1 | SHEET 1 OF 1



			DWN NAME #	
			CKD NAME #	
			DWN NAME #	
			CKD NAME #	
			DWN NAME #	UZAIR
0	18/11/27	PRELIMINARY DRAWING	CKD NAME #	
REV	DATE	DESCRIPTION		

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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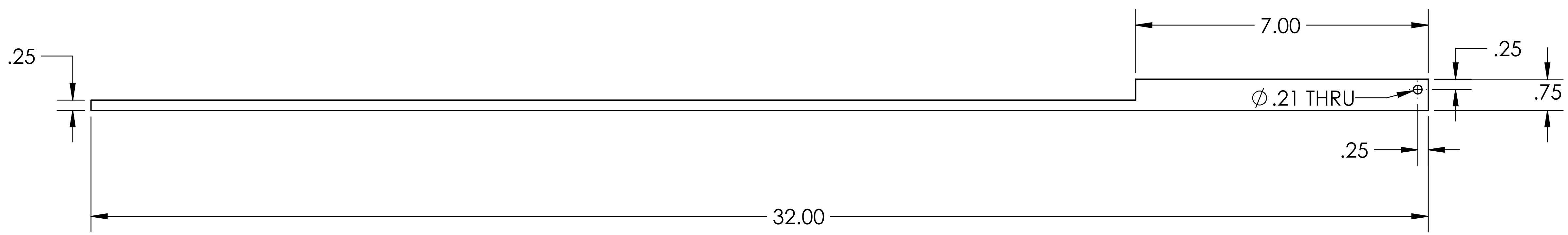
TITLE:
PART DRAWING
BACK LOWER PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE: **B** | DWG. NO. **BLDGRD-P004** | REV 0

DIMENSIONAL UNIT: INCHES | SCALE: 1:1 | SHEET 1 OF 1

DWG. NO. BLDGRD-P004 REV 0



			DWN NAME #		
			CKD NAME #		
			DWN NAME #		
			CKD NAME #		
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR	
			CKD NAME #		
REV	DATE	DESCRIPTION			

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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TITLE:

PART DRAWING
FRONT PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE **B**

DWG. NO. **BLDGRD-P006**

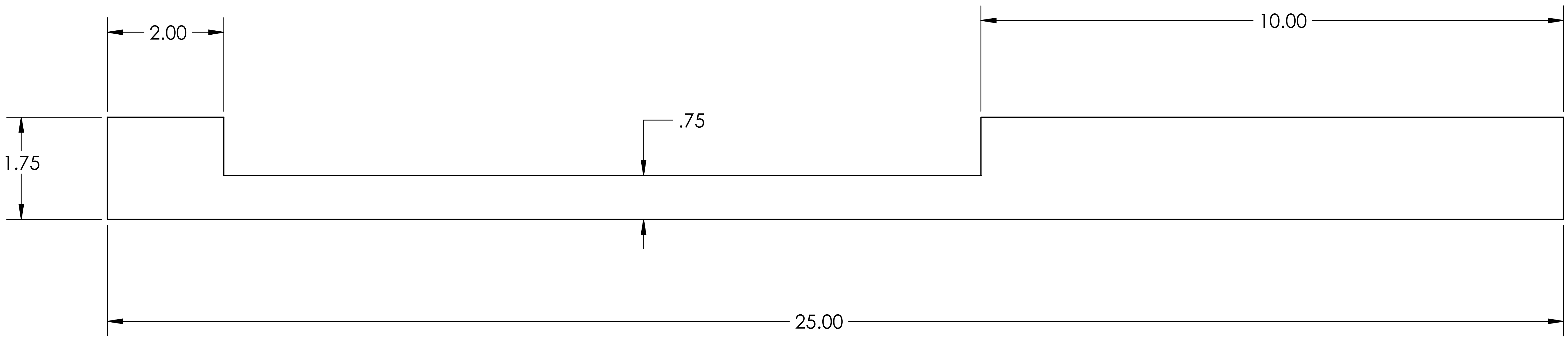
REV 0

DIMENSIONAL UNIT: INCHES

SCALE: 1:3

SHEET 1 OF 1

DWG. NO. **BLDGRD-P006** REV 0



			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	
REV	DATE	DESCRIPTION		

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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TITLE:

PART DRAWING
LEFT UPPER PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE: **B**

DWG. NO.: **BLDGRD-P007**

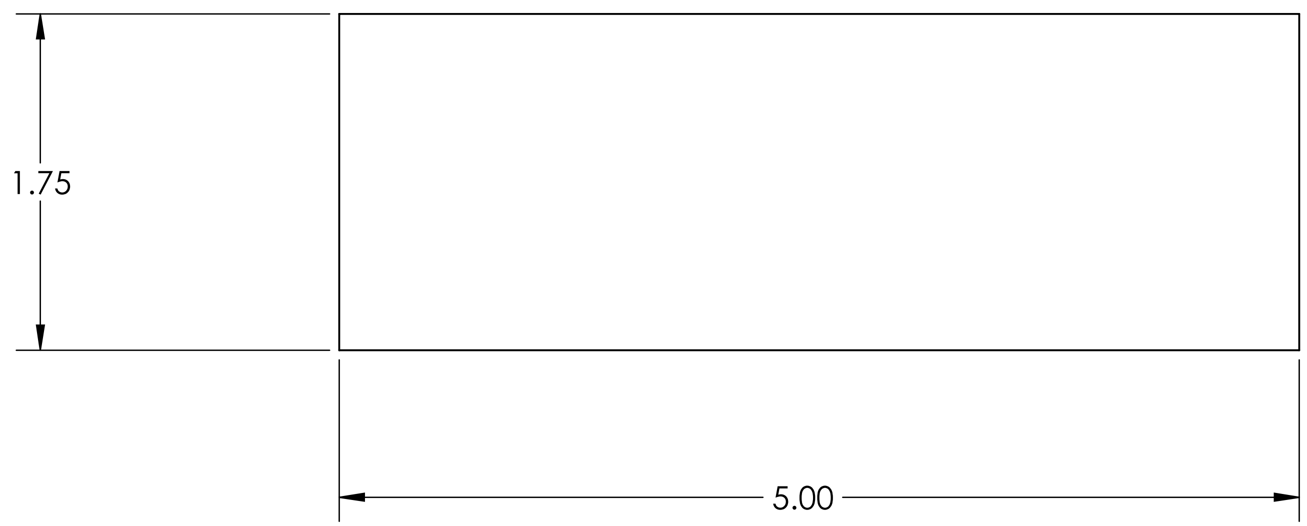
REV: 0

DIMENSIONAL UNIT: INCHES

SCALE: 1:2

SHEET 1 OF 1

DWG. NO. **BLDGRD-P007** REV 0



REV 0

DWG. NO. BLDGRD-P008

			DWN	
			CKD	
			DWN	
			CKD	
0	18/11/27	PRELIMINARY DRAWING	DWN	UZAIR
			CKD	
REV	DATE	DESCRIPTION		

NOTE:
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MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA

MECH 4860 ENGINEERING DESIGN

TITLE:

PART DRAWING
LEFT LOWER PANEL

SIZE **B**

DWG. NO. **BLDGRD-P008**

REV 0

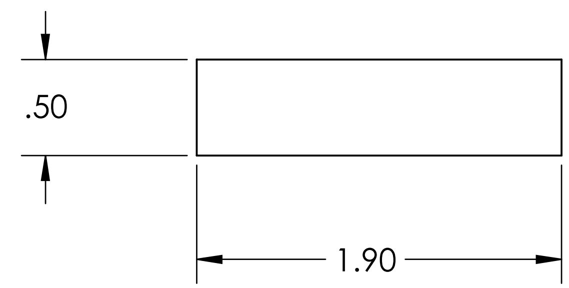
SCALE: 1:1

SHEET 1 OF 1

BLDGRD-P009

DWG. NO.

REV 0



REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	

UNIVERSITY OF MANITOBA

MECH 4860 ENGINEERING DESIGN

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TITLE:

PART DRAWING
TOP PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE: B

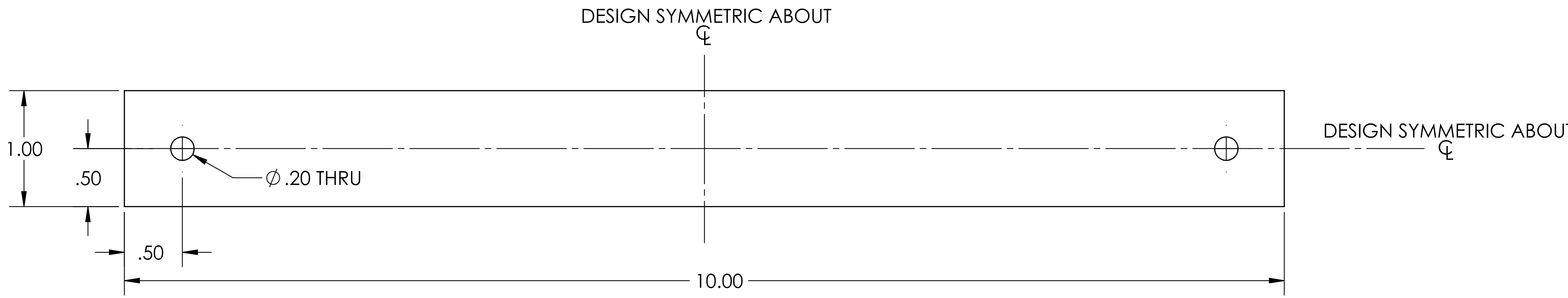
DWG. NO. **BLDGRD-P009**

REV 0

DIMENSIONAL UNIT: INCHES

SCALE: 1:1

SHEET 1 OF 1



REV 0
DWG. NO. BLDGRD-P010

			DWN NAME #		
			CKD NAME #		
			DWN NAME #		
			CKD NAME #		
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR	
			CKD NAME #		
REV	DATE	DESCRIPTION			

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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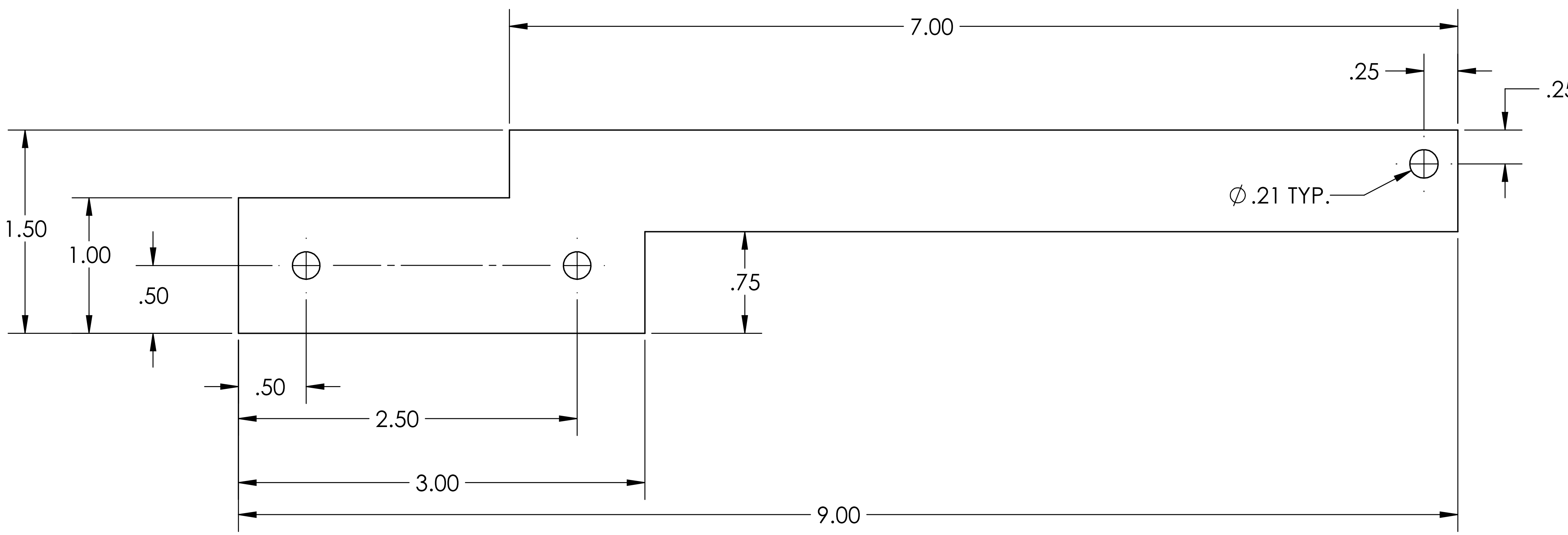
TITLE:
PART DRAWING
BACK UPPER PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE: **B**
DWG. NO. **BLDGRD-P010**
REV 0

DIMENSIONAL UNIT: INCHES
SCALE: 1:1
SHEET 1 OF 1



DWG. NO. **BLDGRD-P011** REV 0

REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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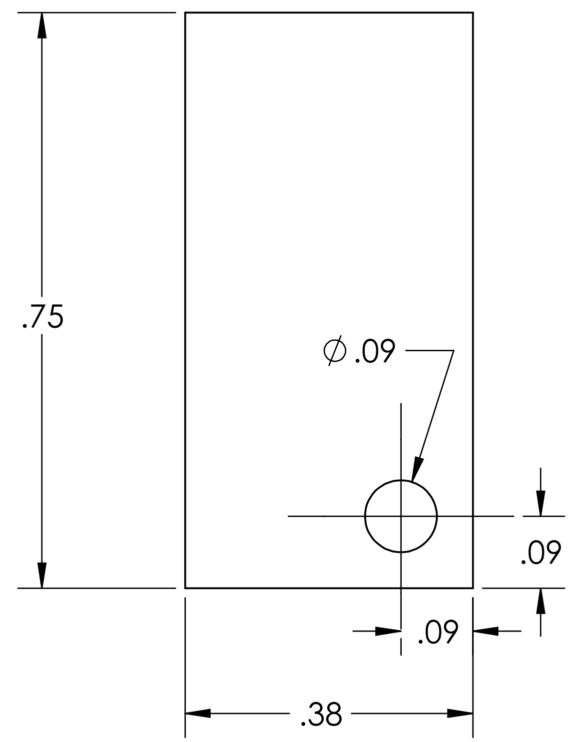
TITLE:
PART DRAWING
BACK LOWER PANEL

MATERIAL: 0.071" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T285

SIZE **B** | DWG. NO. **BLDGRD-P011** | REV 0

DIMENSIONAL UNIT: INCHES | SCALE: 1:1 | SHEET 1 OF 1



BLDGRD-P013 | REV 0 | DWG. NO.

			DWN NAME #	
			CKD NAME #	
			DWN NAME #	
			CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR
			CKD NAME #	
REV	DATE	DESCRIPTION		

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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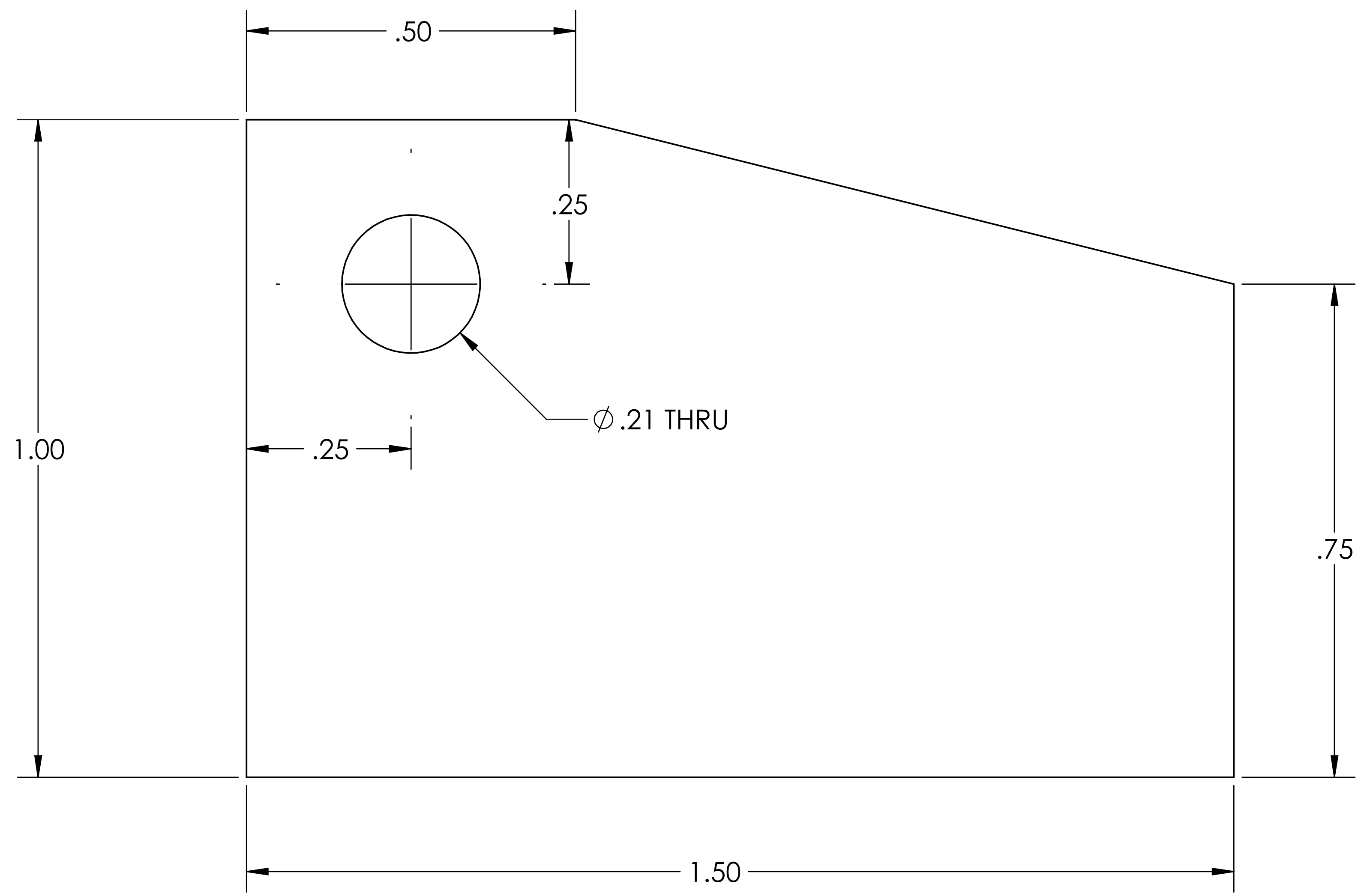
TITLE:

PART DRAWING
RIGHT PANEL

MATERIAL: 0.100" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T287

SIZE **B** | DWG. NO. **BLDGRD-P013** | REV 0

DIMENSIONAL UNIT: INCHES | SCALE: 4:1 | SHEET 1 OF 1



REV 0

DWG. NO. BLDGRD-P014

			DWN NAME #		
			CKD NAME #		
			DWN NAME #		
			CKD NAME #		
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	UZAIR	
			CKD NAME #		
REV	DATE	DESCRIPTION			

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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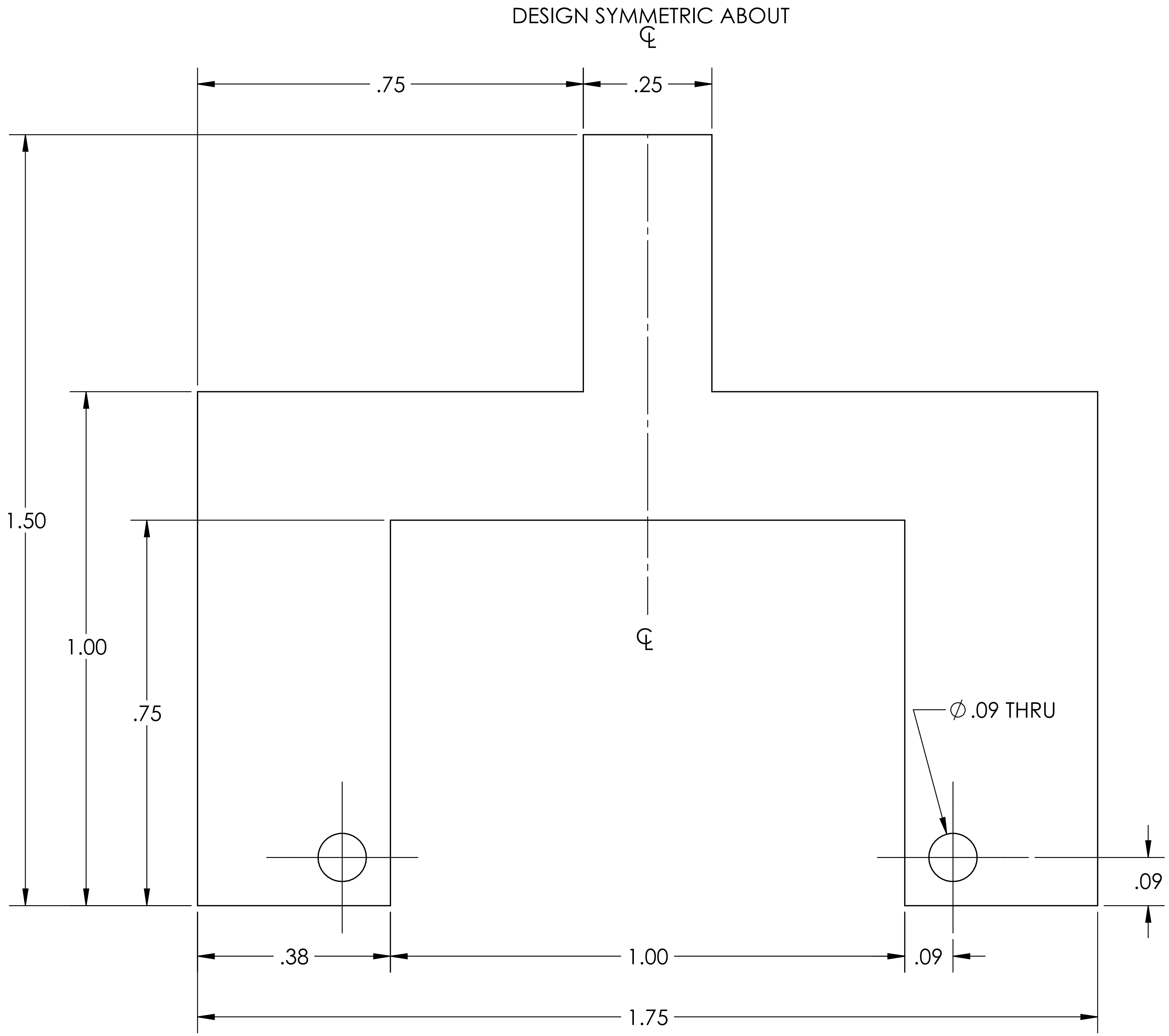
TITLE:

PART DRAWING
SIDE PANEL

MATERIAL: 0.100" x 36" x 36"
4130 ALLOY STEEL SHEET
P/N: 4459T287

SIZE **B** | DWG. NO. **BLDGRD-P014** | REV 0

DIMENSIONAL UNIT: INCHES | SCALE: 4:1 | SHEET 1 OF 1



REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # UZAIR / CKD NAME #	

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

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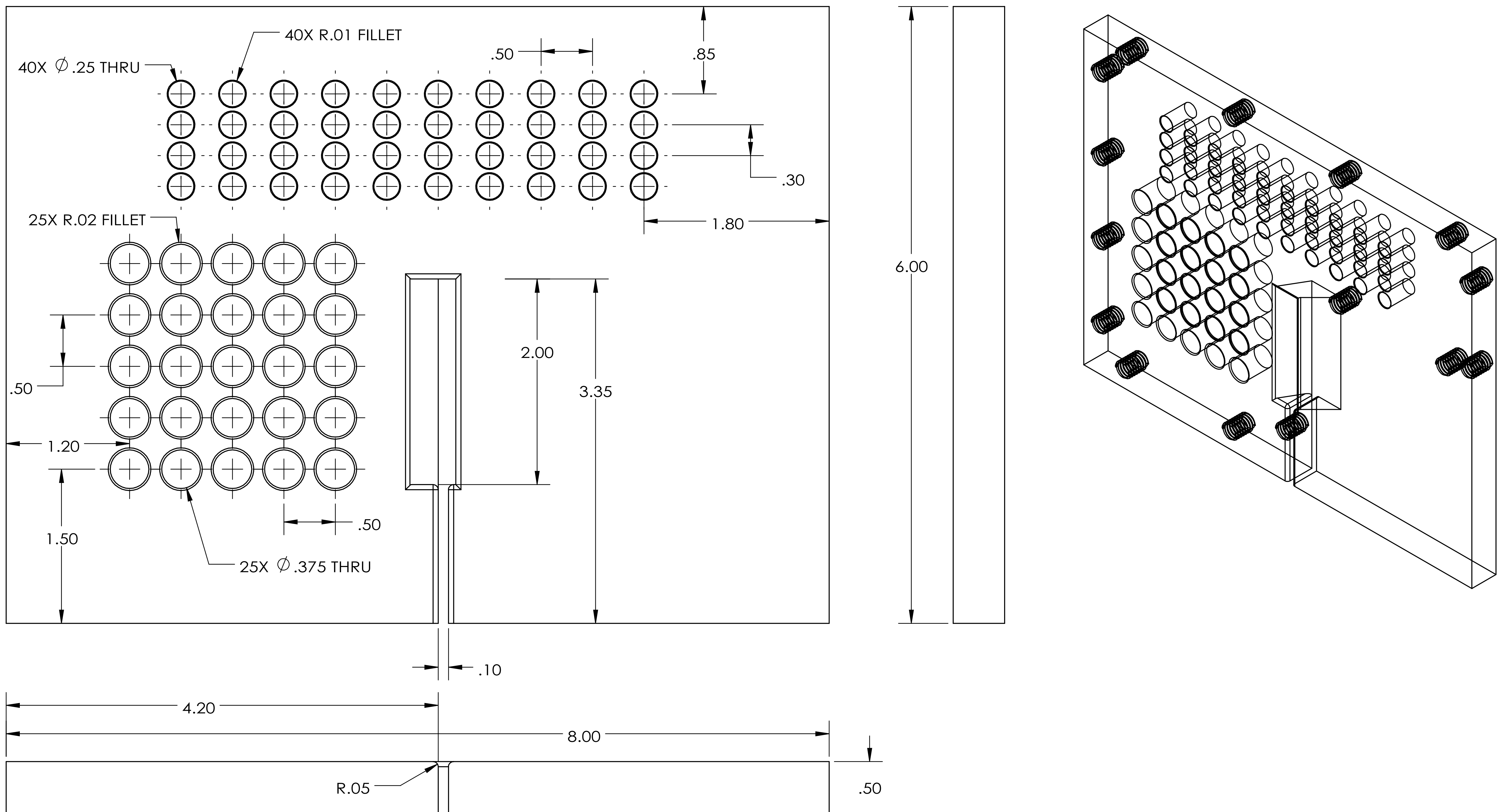
TITLE: **PART DRAWING LEFT PANEL**

MATERIAL: 0.100" x 36" x 36" 4130 ALLOY STEEL SHEET P/N: 4459T287

SIZE: **B** | DWG. NO. **BLDGRD-P015** | REV 0

DIMENSIONAL UNIT: INCHES | SCALE: 4:1 | SHEET 1 OF 1

DWG. NO. **BLDGRD-P015** REV 0



NOTE:

THERE IS AN 0.05-INCH RADIUS FILLET ALONG BLADE SLOT AND 2-INCH LONG BLADE INSERT

MATERIAL: 1/2" X 8" X 6" WEAR-RESISTANT A2 TOOL STEEL P/N: 89885K236

DIMENSIONAL UNIT: INCHES

UNIVERSITY OF MANITOBA

MECH 4860 ENGINEERING DESIGN

TITLE:

Preliminary Part Drawing Downdraft Table

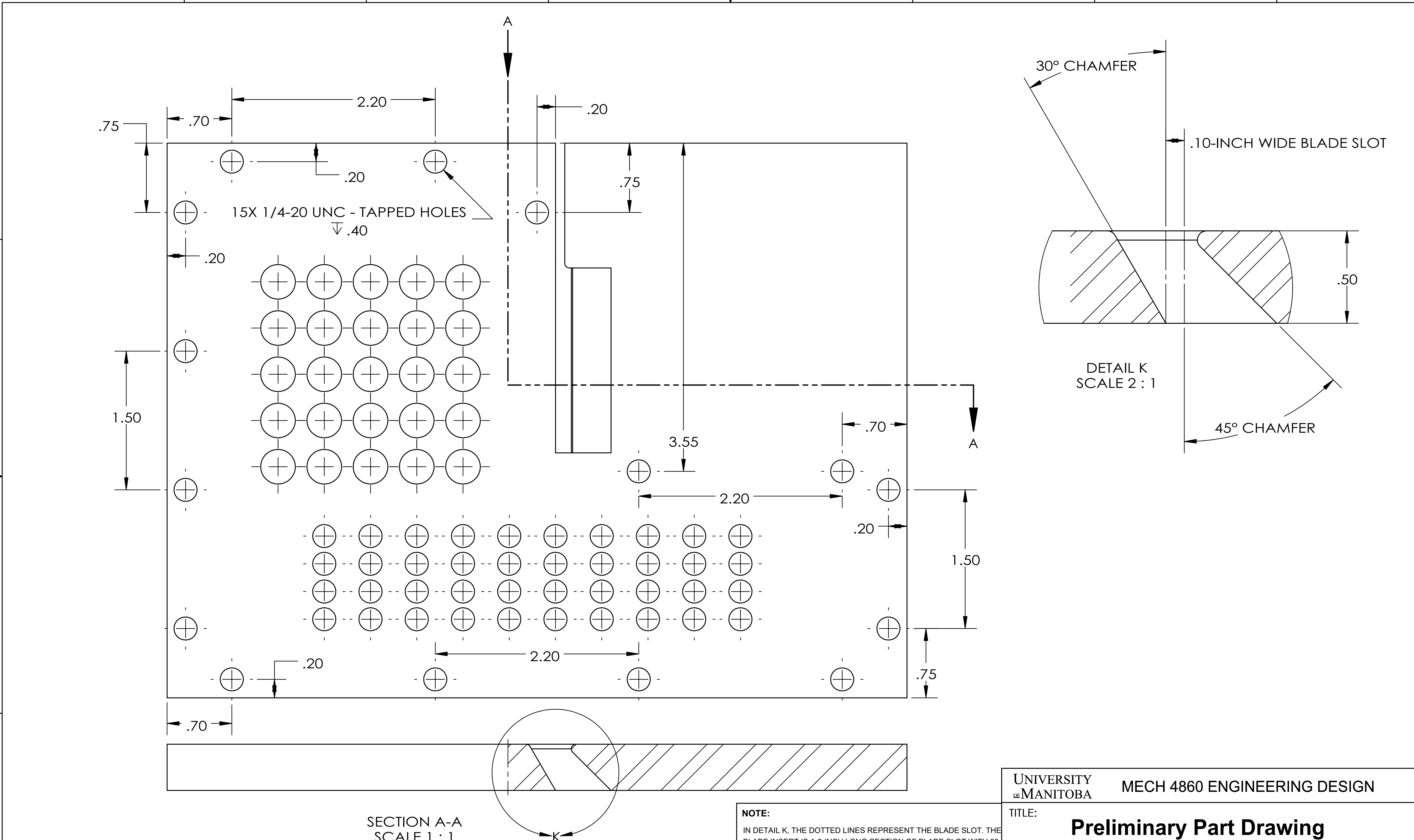
SIZE	DWG. NO.	REV
B	**DOWNDRAFT TABLE - P001**	0
SCALE: 1:4		SHEET 1 OF 2

REV	DATE	DESCRIPTION		NAME
			DWN # / CKD #	
			DWN # / CKD #	
0	18/11/27	PRELIMINARY DRAWING	DWN # / CKD #	Weicheng Wu

REV 0

DOWNDRAFT TABLE - P001

DWG. NO.



UNIVERSITY OF MANITOBA

MECH 4860 ENGINEERING DESIGN

NOTE:

IN DETAIL K, THE DOTTED LINES REPRESENT THE BLADE SLOT. THE BLADE INSERT IS A 2-INCH LONG SECTION OF BLADE SLOT WITH 30 DEGREE AND 45 CHAMFERS.

TITLE:

Preliminary Part Drawing Downdraft Table

MATERIAL:

1/2" X 8" X 6"
WEAR-RESISTANT A2 TOOL STEEL
P/N: 89885K236

DIMENSIONAL UNIT: INCHES

SIZE: B

DWG. NO. DOWNDRAFT TABLE - P001

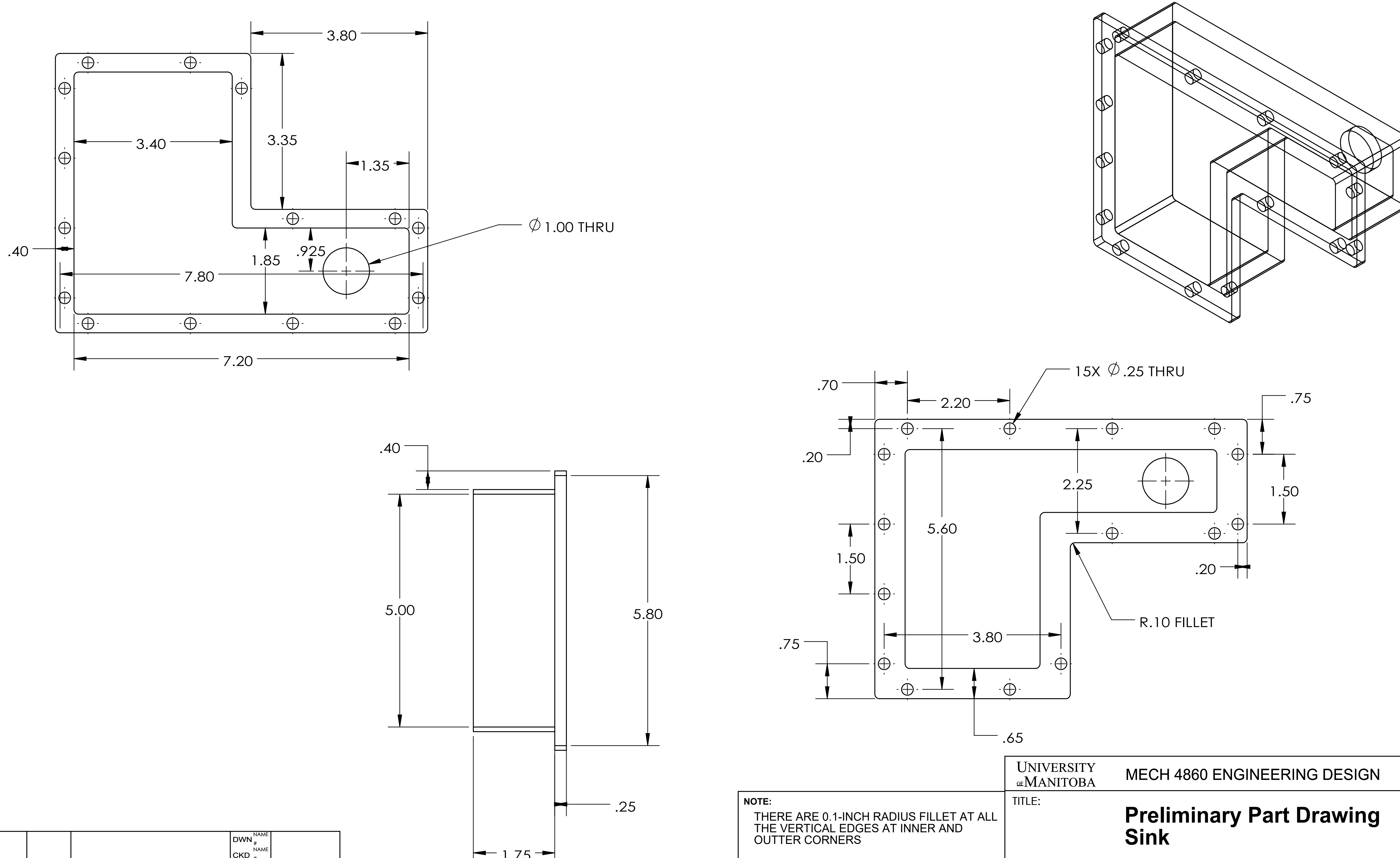
REV 0

SCALE: 1:4

SHEET 2 OF 2

REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # / CKD NAME #	Weicheng Wu

DOWNDRAFT TABLE - P001 | REV 0 | DWG. NO.



			DWN / CKD	
			DWN / CKD	
0	18/11/27	PRELIMINARY DRAWING	DWN / CKD	Weicheng Wu
REV	DATE	DESCRIPTION		

UNIVERSITY of MANITOBA — MECH 4860 ENGINEERING DESIGN

NOTE:
THERE ARE 0.1-INCH RADIUS FILLET AT ALL THE VERTICAL EDGES AT INNER AND OUTTER CORNERS

TITLE: **Preliminary Part Drawing Sink**

NOTE: 2" X 8" X 6" LOW-CARBON STEEL BARS P/N: 9143K743

SIZE: **B**

DWG. NO. **DOWNDRAFT TABLE - P002**

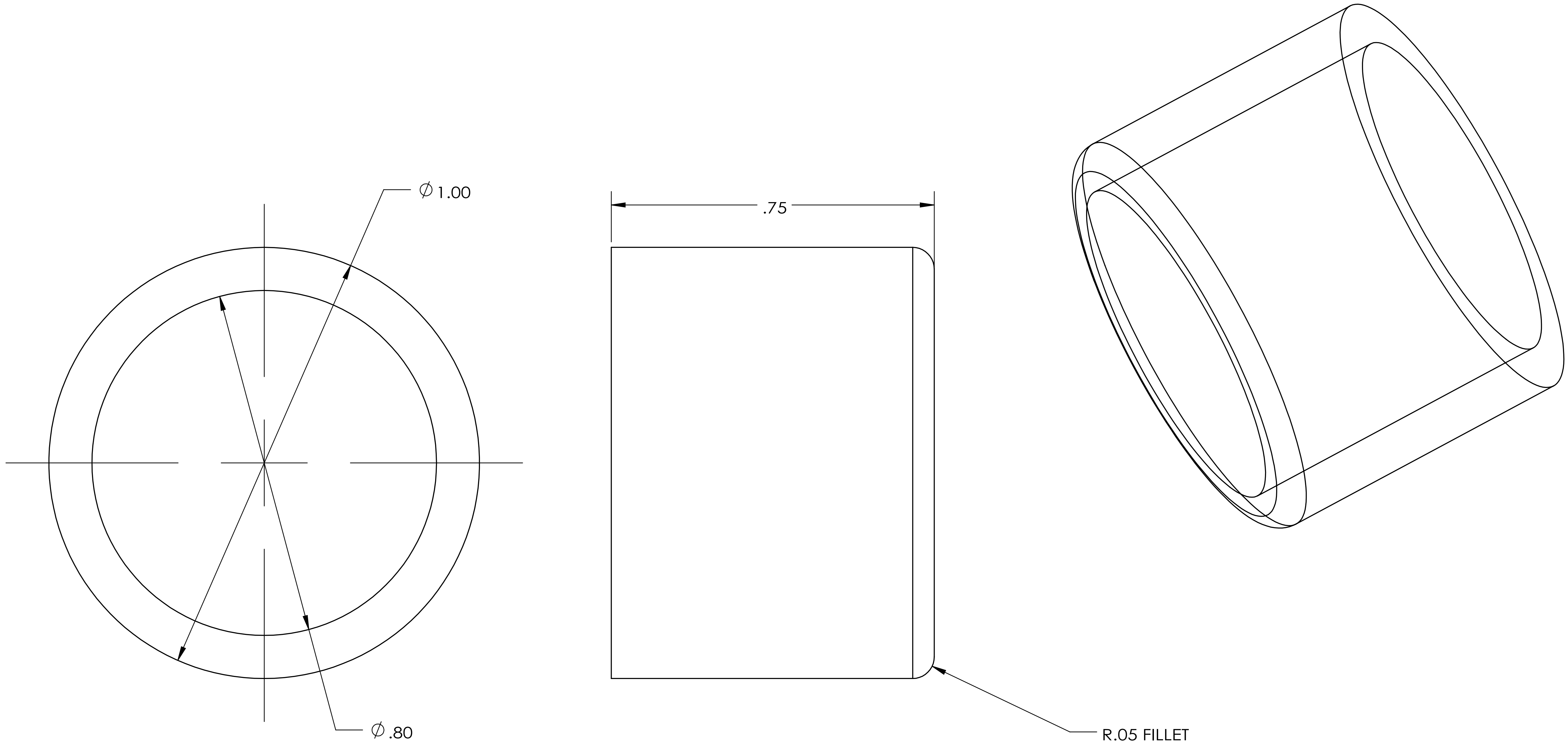
REV: 0

DIMENSIONAL UNIT: INCHES

SCALE: 1:4

SHEET 1 OF 1

DOWNDRAFT TABLE - P002 (DWG. NO.) REV 0



DOWNDRAFT TABLE - P003 REV 0 DWG. NO.

REV	DATE	DESCRIPTION		
			DWN NAME #	
			CKD NAME #	
			DWN NAME #	
			CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME #	Weicheng Wu
			CKD NAME #	

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

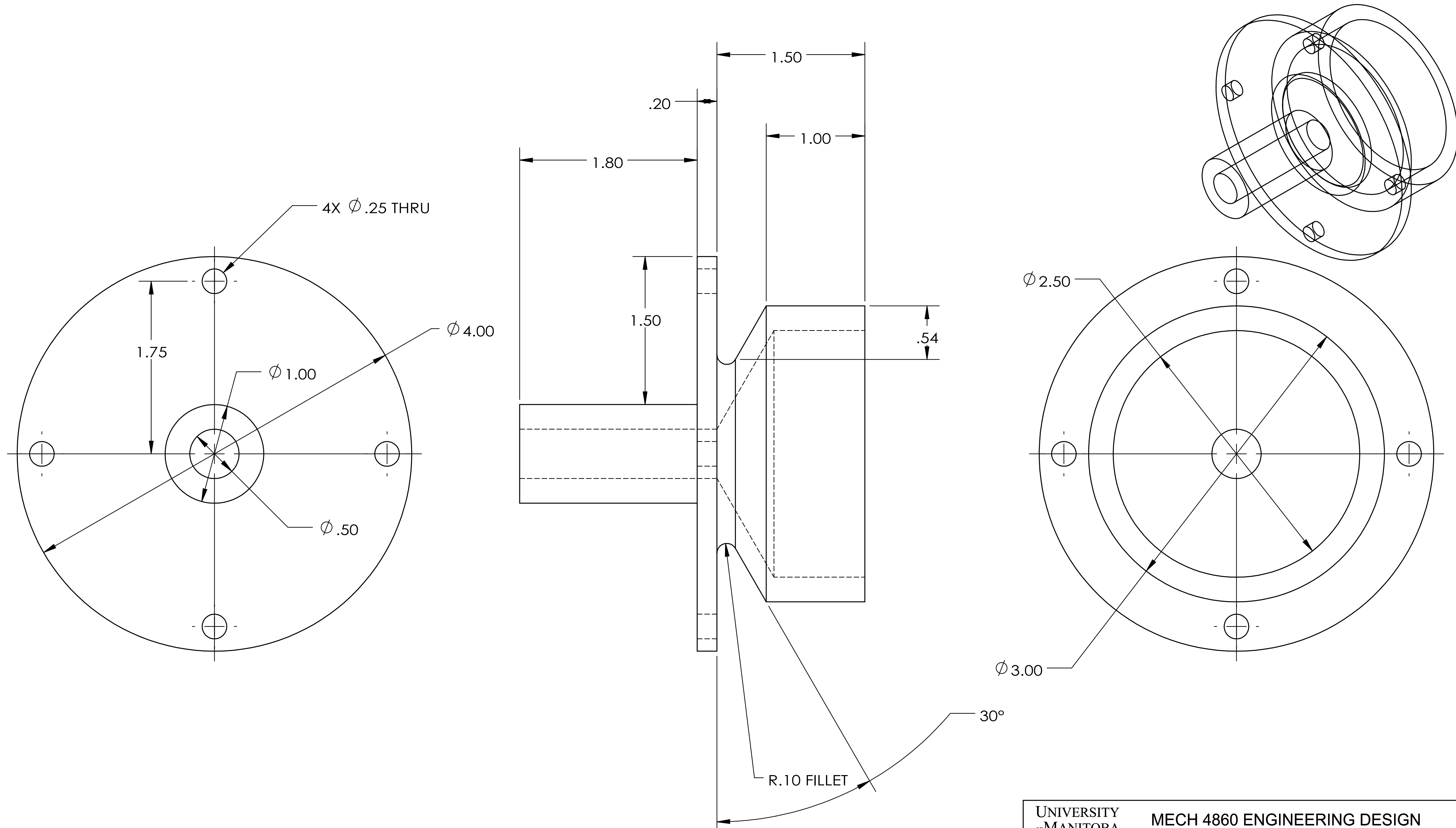
NOTE:
THE OUTLET IS WELDED TO THE SINK WHILE THE OUTLET IS INSERTED INTO THE SINK THROUGH THE OUTLET HOLE AND THE TOP OF THE OUTLET IS AT THE SAME PLANE WITH THE INNER BOTTOM SURFACE OF THE SINK

TITLE:
Preliminary Part Drawing
Outlet

MATERIAL: 0.75" x 1" x 1"
LOW-CARBON STEEL BARS
P/N: 9143K743

SIZE **B** DWG. NO. **DOWNDRAFT TABLE - P003** REV **0**

DIMENSIONAL UNIT: INCHES SCALE: 1:4 SHEET 1 OF 1



DOWNDRAFT TABLE - P004
DWG. NO.
REV 0

UNIVERSITY OF MANITOBA — MECH 4860 ENGINEERING DESIGN

NOTE: THIS COMPONENT IS MADE USING 3D PRINTING

TITLE:

Preliminary Part Drawing Reducer Coupling

MATERIAL: ABS 3D PRINTER FILAMENTS P/N: 1317N39

SIZE: B | DWG. NO. **DOWNDRAFT TABLE - P004** | REV 0

DIMENSIONAL UNIT: INCHES

SCALE: 1:4

SHEET 1 OF 1

REV	DATE	DESCRIPTION		
			DWN NAME # / CKD NAME #	
			DWN NAME # / CKD NAME #	
0	18/11/27	PRELIMINARY DRAWING	DWN NAME # / CKD NAME #	Weicheng Wu