UNIVERSITY OF MANITOBA

Transfer System Spillage Solution

Final Report

Team #17

MECH 4860- Engineering Design

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2016-12-07
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Dr. Paul Labossiere

Dear Dr. Labossiere,

I am pleased to present you with the Final Report, *Transfer System Spillage Solutions*, of Team 17, whose client is the Royal Canadian Mint.

The enclosed report provides a brief problem overview, identifies conceptual design methodologies and considerations, presents testing analysis, describes final designs and provides recommendations to the client. The problem overview integrates information on the project objectives, customer needs, technical specifications and expectations for the design. The concept generation process describes the methodology followed for both internal and external searches. The testing analysis identifies the procedures followed to assess the top concepts and the results from prototype operation. The final designs are described in detail, considering design features, manufacturing, installation and costs. Finally, a number of recommendations are made regarding system operating conditions that influence process performance. This Final Report serves to provide a comprehensive overview of the final designs that address the project needs.

I would like to thank you on behalf of myself and the project team for your support and consideration. I hope that this report will meet your satisfaction and any feedback will be greatly appreciated.

Sincerely,

James Riese

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Glossary

Acronym	*Meaning*
CAD	Computer Aided Design
FEA	Finite Element Analysis
VFP	Vibrating Feed Plate
VFPR	Vibrating Feed Plate Rear
WIP	Work in Progress
RCM	The Royal Canadian Mint
REF	Reference
PPE	Personal Protective Equipment
WBS	Work Breakdown Structure
QFD	Quality Functional Deployment

Term	*Definition*
Blanks	Coins without any image [1]
Belt Cleats	The part of the conveyor belt that divides the length into discrete sections. Cleats align perpendicular to the direction of belt travel
Belt Ribs	The lateral parts of the conveyor belt that enclose the sides. Belt ribs are oriented parallel to the direction of belt travel
Client	The Royal Canadian Mint
Coining	The process of making coins by stamping metal [2]
Feed Hopper	A funnel-shaped chamber or bin in which loose material is temporarily stored, being filled through the top and dispensed through the bottom [3]. This type of hopper feeds material to the coining conveyance system
Lines	A linear grouping of machines that are similar in design, function and operation. Lines are spread between different processes, like plating and coining, and within each creating sub processes
Plating	The process of adding a thin outer coating of metal [4]

Pre-press Hopper	A funnel-shaped chamber or bin in which loose material is temporarily stored, being filled through the top and dispensed through the bottom [3]. This type of hopper feeds material to the coining press
Scope Creep	A project management term referring to uncontrolled changes in a project's scope

Executive Summary

The Royal Canadian Mint is currently experiencing issues with coin blanks spilling from their conveyance system in the coining department. There are eight (8) machines in the D-line and four (4) machines in the F-line. The request by the client is to achieve zero spillage in the coining area, reducing the noise generation by 25% and provide safe operator and trade access to the area for maintenance and changeovers. The main areas of spillage and noise generation were found to be the rear of the vibrating feed plate for preventative blank spillage, the transfer point between the feed plate and the conveyor for blank spillage and lastly, the upper hopper transfer point for noise generation.

The team developed seven (7) main concepts to go forward into testing and prototyping. Three (3) concepts were for the for the main transfer point between the feed plate and the conveyor, two (2) concepts for the rear of the vibrating feed plate, and the last two (2) for the upper hopper. The three concepts for the main transfer point were prototyped and tested on the equipment to determine the best design by how well each met the objectives. A main objective the team decided was to manufacture and install all products onto the conveyance system before the project timeline was over, but due to scope creep and a delay in other areas of the project, prototyping occurred for the main transfer area with foam board and not the actual prototypes from the final designs.

The best concept was the Blank Catch, which is a guard around the conveyor with a scoop at the top to catch any spilled blanks from the conveyor and guide walls to keep blanks from falling off the belt. The Blank Catch is fully adjustable along the conveyance system to meet a client's new objective of standardized products. The last major feature of the Blank Catch is the flap that moves by the aid of hinges up and down with the belt cleats to keep the blanks on the belt. The Mesh Block is a metal mesh on the rear of the feed plate to keep blanks from spilling out the back and for visibility of the operator to check for any leftover blanks after pressing is complete. The last design for this project is the NeoDamp. The NeoDamp is a thin sheet of neoprene to dampen the noise in the upper hopper where most generation was located. This is achieved by softening the fall of the blanks as they fall into the hopper. Before installation of the designs we recommend the belts be repaired, centered and the feed plate output rate set to 15 blanks/cleat on each conveyor for the best results.

1.0 Introduction

The Royal Canadian Mint (**RCM**) produces all of Canada's circulation coins and manufactures various coins on behalf of other nations. The RCM's high-tech manufacturing facility in Winnipeg produces upwards of one billion coins each year. Coins are produced through various manufacturing processes. The process begins by punching circular workpieces out of large coiled strips of steel to produce **blanks**. Blanks are refined through deburring, rimming, annealing and cleaning, before they are electroplated for protection. Finally, the dried and polished coins are imprinted by a high-speed **coining** press and ready for distribution. Each of the various processing stages require the transfer of blanks and coins along conveyance systems [1].

1.1 Problem Background

The Royal Canadian Mint (RCM) has retained Minty Transfer to investigate the occurrence of blank spillage along conveyance systems in their facility. Spillage of blanks was observed to most often occur in two primary conveyance systems, the **plating** and coining conveyance systems. This project focuses on developing a solution for the coining systems only. Figure 1 illustrates a simplified coining conveyance system, in which blanks, or **WIP**, are conveyed to a coining press. The manufacturing floor runs several **lines**. This project focuses its efforts on the D-line and F-line systems.

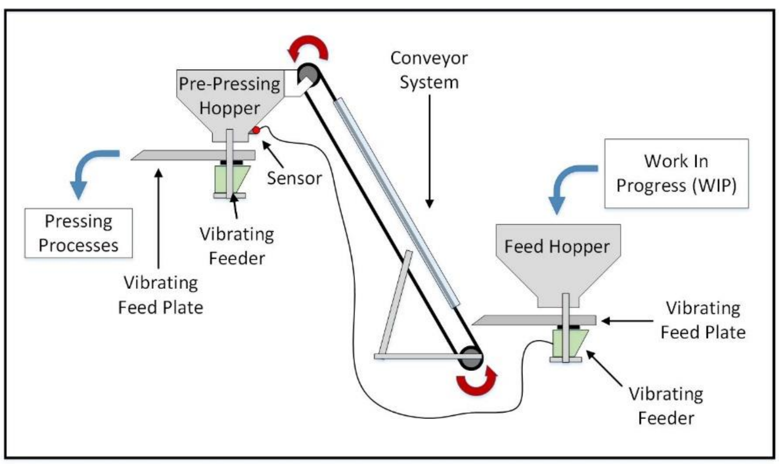


Figure 1. Coining system representation [5].

The D-line and F-line consist of eight (8) and five (5) coining conveyance systems, respectively. Various health and safety issues arise due to coining operations. The preliminary request of the client is a solution which:

- Achieves zero blank spillage in a specified area of coin blank transfer where spillage occurs
- Reduces noise generation by 25%
- Provides safe operator and trade access to the area for maintenance and changeovers

1.2 Project Objectives and Scope

The objectives of this project, established by the RCM, are the following:

- Identify causes of blank spillage and noise generation
- Design a product(s) that eliminates or drastically reduces blank spillage and noise generation
- Prototype the selected design for testing and optimization
- Implement a final design that can be applied across all coin press lines

This project has experienced **scope creep** since the release of the Project Definition Report (PDR) and now has additional requirements for the project and the desired outcome. This is primarily due to miscommunications with the industry contact and not asking the right questions on the part of our team. As mentioned in Section 1.1, the project now also considers blank spillage in F-line coining systems. The F-line conveyance systems have differing part geometries than the D-line systems. In addition, the industry contact has suggested that we develop a solution for a test conveyance system. The test conveyance system is expected to have some similarities to the D-line conveyance systems, except that the test system's **VFP** is capable of pivoting laterally. The test conveyance system will likely be the new standard for all future coining conveyance system designs. Finally, the industry contact has encouraged the development of a standardized design that can be implemented across the various systems. This means that a solution will need to be developed for 14 systems that have varying part geometries. These changes bring new considerations to the project plan and will affect how the project needs are evaluated.

The scope of the project includes the following areas:

- Determine and prioritize the needs of the RCM
- Create metrics to determine success for the design and its features
- Design a solution for the D-line, F-line and test conveyance systems
- Create conceptual designs to prevent the spilling of blanks
- Compare, screen, score and select preliminary designs
- Analyze and improve upon the preliminary designs
- Research, validate and test the aspects of top ranked design(s)
- Determine product performance with **FEA** and numerical analysis if necessary
- Conduct physical tests on a prototype to further verify a final design
- Implement and test the final design at the RCM

1.3 Project Assumptions and Constraints

Certain aspects of the product and the design process are known while others can only be assumed. A list of assumptions and constraints applicable to this project are shown in TABLE I.

TABLE I

PROJECT ASSUMPTIONS AND CONSTRAINTS

Assumptions	Constraints
There will be no major changes in the RCM's needs and provided budgets after discussed and finalized.	The length of the project is three months, including a one-month background check.
No significant upgrades or changes of current RCM machines and manufacturing procedures will take place during this project.	The limited project timeline includes design, manufacturing and implementation of the system.
The RCM workshop is available and resources are well prepared to manufacture.	The team cannot monitor, re-design and repair the design after the project closes in December 2016.
Engineers working hours occur on a 7:00am - 5:00pm schedule.	The positions of the conveyor, vibrator and the hopper are mounted to the plant floor.
The RCM will provide related technical information and experts as needed.	The slope of conveyor cannot be decreased due to space restrictions for forklift traffic.

Assumptions	Constraints
The speed of the conveyance system is constant.	The possible space used for the project is limited to the area around the equipment due to various health and safety concerns.
It is safe to work in the RCM with required PPE and following the RCM Safety Code.	The factory has a high security level. Each member has to go through a security check before every entrance. The RCM metal free policy must be followed.
All coins will exhibit approximately the same behaviors within the conveyance system **[6]**.	The time the group can stay in the plant is limited. The group must follow the RCM engineer daytime working schedule.
The project closes from the University side in December 2016. RCM engineers should monitor further performance of the design.	The personal budget for this project cannot exceed $400, only used for printing, travel, posters, etc.
-	The manufacture of designed parts follows a lead-time established by the RCM and after work orders that are in front.
-	The group must keep a balance between time, cost, scope and quality of the project.

Each group member also has scheduled university classes during weekdays and must share time with exams, reviews, projects and assignments for other courses. The time to work on the project for each member is limited.

1.4 Project Needs, Specifications and Metrics

It is essential to determine the most important project needs in order to appropriately focus efforts and determine design tradeoffs. Using rating matrixes, each need is compared against one another and the weight of the need is established. The weights are rounded whole integers and have a sum of 100%. Relative importance (denoted "Imp." In TABLE II) ranges between one (1) and five (5) and is established equating the weights to their respective importance: 0-2% = 1, 3-4% = 2, 5-6% = 3, 7-8% = 4, 9-11% = 5. The RCM approved the RCM needs and the importance levels with the importance ranking for each need.

TABLE II

PROJECT NEEDS COMPARISON MATRIX RESULTS

#	Need		Hits	Weight	Rank	Imp.
1	The design	Prevents spills between hopper and conveyor.	16	10%	3	5
2	The design	Prevents spills between secondary transfer areas.	15	8%	4	4
3	The design	Prevents spills caused by belt ribs.	14	8%	5	4
4	The design	Performs precisely.	11	6%	8	3
5	The design	Survives heavy use.	8	5%	11	3
6	The design	Maintains other process conditions.	11	7%	8	4
7	The design	Maintains its own condition.	3	2%	16	1
8	The design	Is aesthetically pleasing (Instills pride).	1	1%	18	1
9	The design	Is quiet.	5	3%	13	2
10	The design	Functions under high vibration.	10	4%	10	2
11	The design	Fits within current process limits.	12	7%	7	4
12	The design	Is easy to install.	6	3%	12	2
13	The design	Is lightweight and easily maneuverable.	4	2%	14	1
14	The design	Maintains the original blank appearance.	17	10%	2	5
15	The design	Is easily manufactured.	4	3%	14	2
16	The design	Is easy to repair and replace.	3	2%	16	1
17	The design	Is safe in and out of use.	18	11%	1	5
18	The design	Is standardized.	13	8%	6	4
19	The design	Stays clean.	0	0%	19	1

The associated metrics and the targets specifications are established in TABLE III, and an importance rating accompanies each. This importance is determined according to the number of the needs each metric helps to verify and the weight of those needs.

TABLE III

METRICS AND THE ASSOCIATED NEEDS

Metric #	Needs #s	Metric	Imp.	Target	Units
1	1,2,3	Number of spilled blanks in one (1) hour	5	0	blanks/hr
2	4	Standard deviation of lost blanks over a week of shifts	3	1	blanks/shift
3	5,7	Stress and strain on parts of unit	4	5	MPa
4	6	Process output	4	100%	blanks/day
5	8	Survey of operators, engineers, and mechanics	2	Positive	Subjective
6	9	Noise level with a sound meter	4	<85	dB
7	10	Vibrations at peak function	4	60	Hz
8	11,13, 18	Dimensions of the product	5	0.5x0.5x0.5	m
9	12,16, 18	Time required to install and remove	4	30	min
10	13	Mass of the product	3	3	kg
11	14	Relative hardness of the product	4	70	HRB
12	14	Count the number of damaged blanks in one (1) hour	5	0	blanks/hr
13	15	Cost to manufacture	3	300	$
14	15	Time required to manufacture	3	1 day	hrs/days
15	15	Number of manufacturing processes required for final product	3	<4	processes
16	16	Time to replace individual components of the product	4	0.5	hr
17	17	Number of workplace injuries filed in one (1) week due to product	4	0	incidents
18	18	Number of areas of concern that product can be used in	3	12	areas
19	19	Discolouration area	2	0.25	m^2
20	19	Change in mass of device right after use and right after cleaning	2	± 0.01	kg

The number of spilled blanks is very important and the design must reduce spilling in order to be successful.

2.0 Project Management

The project success depends on completing goals and meeting deadlines. Scheduling, cost, quality and risk management all aid to identify key elements, potential costs, quality tradeoffs and potential risks for the project and its objectives.

2.1 Scheduling

To effectively monitor and control the project's status, various project management-scheduling tools are utilized. A work breakdown structure list, work breakdown structure schematic, Gantt chart and timeline are used to ensure team success.

2.1.1 Work Breakdown Structure (WBS)

Our work breakdown structure illustrates the project phases, work packages and tasks necessary to complete the project successfully. A WBS list identifies five (5) levels of tasks: Initiation, Planning, Execution, Monitor and Control and Closing.

After reviewing the WBS, the list was modified to omit unnecessary tasks. Tasks 2.2.3 – Critical Path Method and 2.5.1 – Resource Breakdown Structure are removed from the list, as they are unnecessary to project success. The modified WBS task list is shown in TABLE IV.

TABLE IV

WORK BREAKDOWN STRUCTURE LIST

WBS Code	WBS Title	WBS Code	WBS Title
1.0	**Initiation**	**3.7**	**Optimization**
1.1	Obtain Project Description	**3.7.1**	Further CAD Analysis
1.2	Assemble Team	**3.7.2**	Alternative Analysis
1.3	Meet with client & Project Advisor	**3.8**	**Final Design Selection**
2.0	**Planning**	**3.8.1**	Design Criteria Analysis
2.1	**Project Scope**	**3.8.2**	Confirm Customer Acceptance
2.1.1	Identify Customer Needs	**3.9**	**PHASE II**
2.2	**Schedule Plan**	**3.9.1**	Concept Design Report

WBS Code	WBS Title	WBS Code	WBS Title
2.2.1	WBS	**3.10**	**Implementation**
2.2.2	Gantt Chart	**3.10.1**	**Prototype Manufacturing**
2.3	**Cost Budget Plan**	**3.10.1.1**	Create Part Drawings
2.3.1	Identify Customer Budget	**3.10.1.2**	Outline Processes Used
2.4	**Quality Plan**	**3.10.1.3**	Contact Suppliers/Machinists
2.4.1	Identify Metrics	**3.10.1.4**	Part Estimates
2.4.2	Identify Specifications	**3.10.1.5**	Place Part Orders
2.4.3	QFD	**3.10.2**	**Testing**
2.5	**Human Resource Plan**	**3.10.2.1**	Gather Instrumentation
2.5.1	RACI Matrix	**3.10.2.2**	Gather Data
2.6	**Communication Plan**	**3.10.2.3**	Analysis of Data
2.6.1	Create Agenda and Meeting Minutes Template	**3.10.3**	**Modification**
2.7	**Risk Management Plan**	**3.10.3.1**	Redesign
2.7.1	Risk Matrix	**3.10.3.2**	Determine Customer Acceptance
2.7.2	Risk Responses	**3.10.3.3**	Create Part Drawings
2.8	**Procurement Plan**	**3.10.3.4**	Alter Manufacturing Processes
2.8.1	Procurement Process	**3.10.4**	**Installation**
2.9	**Stakeholder Plan**	**3.10.4.1**	Develop Installation Procedure
2.9.1	Stakeholder List & Registry	**3.10.4.2**	Develop Maintenance Procedure
2.10	**PHASE I**	**3.11**	**PHASE III**
2.10.1	Project Definition	**3.11.1**	Draft Report
2.10.2	Project Report	**3.11.2**	**Develop Poster**
2.10.3	Oral Presentation	**3.11.2.1**	Design
3.0	**Execution**	**3.11.2.2**	Assemble
3.1	**Gather Baseline Metrics**	**3.11.3**	Create Final Presentation
3.1.1	Examine Current System	**3.11.4**	Create Final Report
3.2	**Conceptual Design**	**4.0**	**Monitor & Control**
3.2.1	Clarify Problem	**4.1**	Progress Reports
3.2.2	Problem Decomposition	**4.2**	**Schedule Updates**
3.3	**Concept Generation**	**4.2.1**	Gantt Chart Updates
3.3.1	External & Internal Search	**4.3**	Budget Updates

WBS Code	WBS Title	WBS Code	WBS Title
3.3.2	Systematic Exploration	**4.4**	Risk Management
3.3.3	S.C.A.M.P.E.R. Method	**4.5**	Risk Assessments
3.4	**Preliminary Selection**	**4.6**	Update Risk Log
3.4.1	Concept vs Needs Comparison	**4.7**	Quality Updates
3.5	**Model Concepts**	**4.8**	**Stakeholder Management**
3.5.1	Basic CAD Analysis	**4.8.1**	Update Stakeholder Registry
3.6	**Research**	**4.8.2**	Update Stakeholders
3.6.1	Material Comparison	**5.0**	**Closing**
3.6.2	Manufacturing Process Comparisons	**5.1**	Debrief with Customer
3.6.3	Cost Estimates	**5.2**	Lessons Learned Document

A WBS visual schematic is shown in Figure 2. The schematic highlights, which tasks have been completed to date and if those tasks were completed late or per scheduled dates. The schematic also illustrates future tasks, current tasks and their progress. The schematic must be read with the WBS list to determine level three tasks.

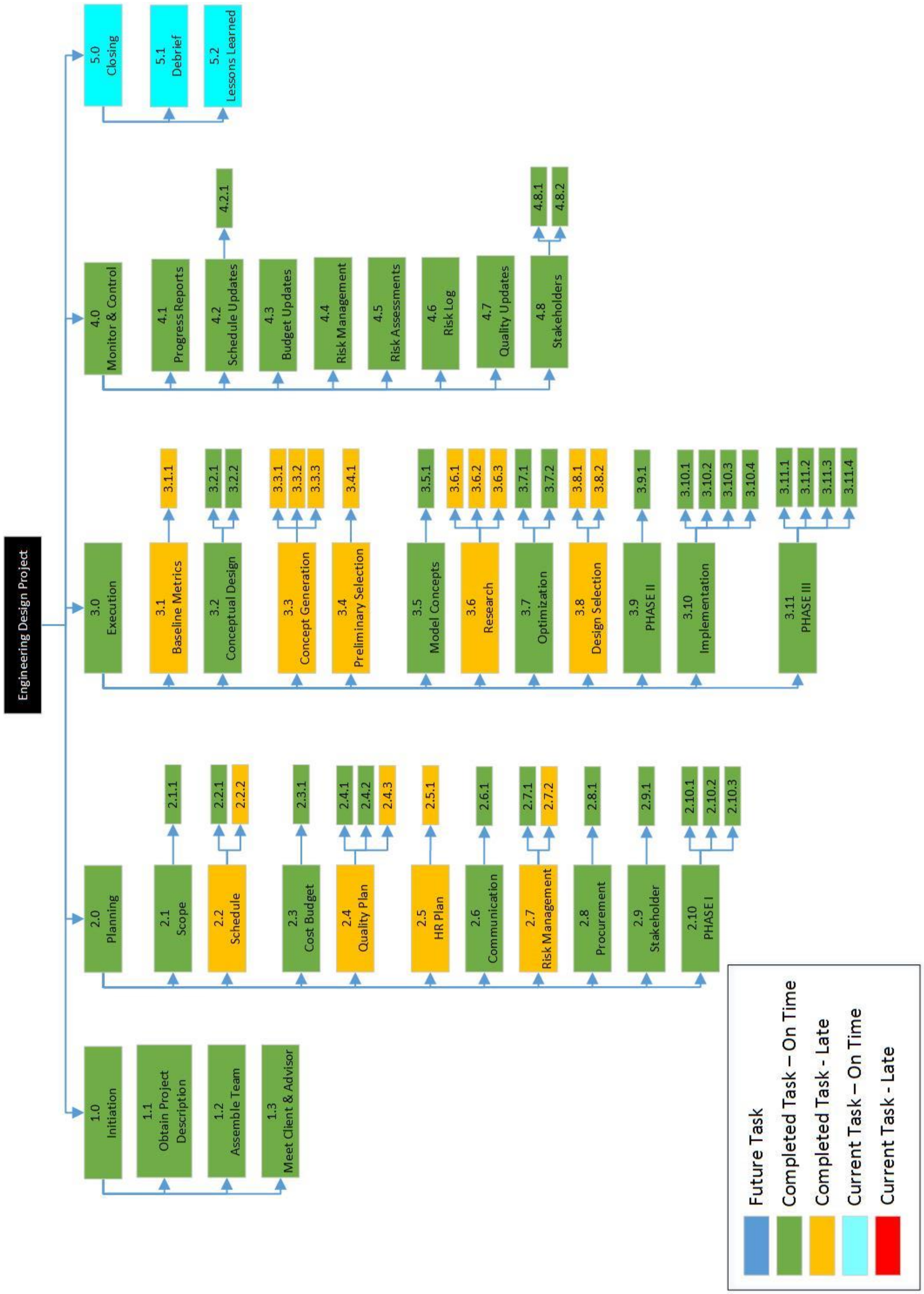


Figure 2. Work breakdown structure

2.1.2 Gantt Chart

The Gantt chart is used for the entire project duration to determine critical deadlines, identify risks and determine progress to date. The project Gantt chart includes the dates that tasks started and finished. The planned finish dates of each task are identified to use as a comparison. Most tasks have an allowable slack of approximately one (1) to six (6) days, as they are scheduled according to internal deadlines. The determination of baseline metrics and other tasks that depend on the RCM are given longer slack times due to security and scheduling reasons. The updated project Gantt chart can be seen in Appendix A.

2.2 Cost Management

The client provided the preliminary budget for our project. The RCM has given us a maximum of $10,000 to use for manufacturing, materials, labor, machining and testing. If a solution is available for purchase, then the manufacturing of a new solution is unnecessary. The materials are sourced from local shops, saving money and time by avoiding the shipping process. The labor, machining, and testing are conducted in-house which will save money as well, but the machining costs must still be accounted for. The testing equipment is available through the RCM or can be rented if necessary. Below in TABLE V, we have shown where we plan to spend the money and how much money we have allocated for each designated area. The budget is for the prototype and any testing and modifications needed to implement the prototype into the process line for all machines. Once the prototype fits and meets all criteria, all subsequent products will cost less as each unit has a set process for manufacturing and implementation.

TABLE V

PRELIMINARY BUDGET INCLUDING THE PROTOTYPE

Budget Line	Amount
Material	$800
Machining	$700
Labor	$500
Test Rentals	$500

Budget Line	Amount
Other Manufacturing	$200
Total for Prototype	$2700

2.3 Quality Functional Deployment (QFD)

The QFD resembles a house with the base of the house ranking the metrics and showing the relations between the RCM needs and the metrics. The roof of the house relates each metric to each other in a good, bad, neutral either way, or not at all. With the RCM needs along the left side of the QFD and the metrics along the top of the house, the inside of the house holds all the relations. The RCM needs have correlated weights or importance resulting from a RCM need screening seen in TABLE II. From Figure 3, the number one metric ranked from the QFD was clearly the spilled blanks, which a target of zero has been set, and a second metric slightly behind is the process output. If the blanks are not spilled, the process output should theoretically increase. The competitor section of the QFD was not used since there are no competitors in the area. Only the top 10 RCM needs were used in the QFD, since all other needs were of low importance and would not fit inside the house of quality template used.

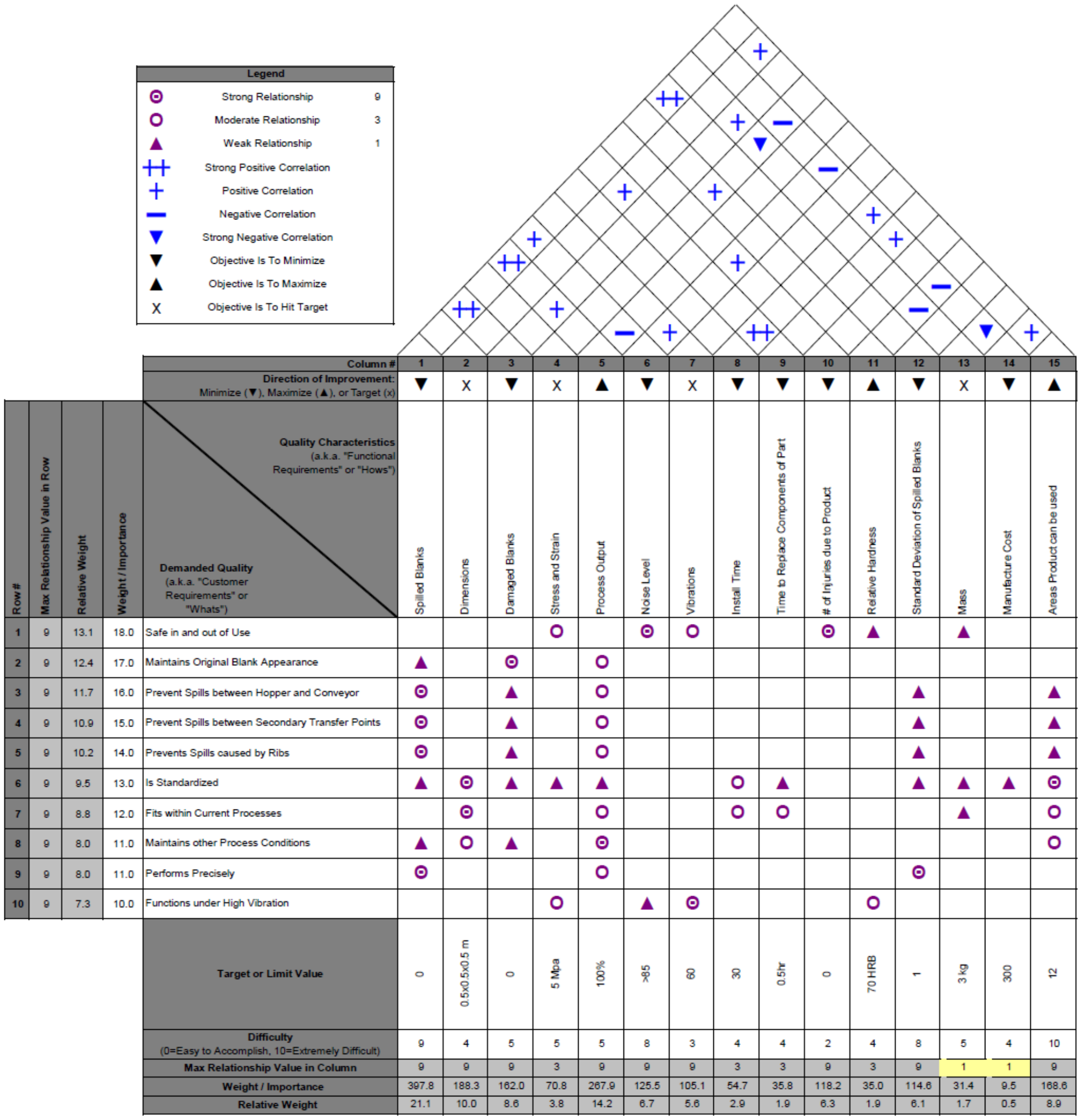


Figure 3. House of Quality to Compare the RCM Needs to the Metrics

The QFD was helpful in finding which metrics were most important by how many client needs required that specific metric. The top metrics that need to be addressed and met are the blank spill rate, process output, and the dimensions. Safety in the RCM is critical and is considered, even though it was not a major metric. The designs add little danger to the workplace so the difficulty to achieve a safe design is set at two (2).

2.4 Stakeholder Management

Maintaining stakeholder engagement through timely communication methods is necessary to this project's success. The primary project stakeholders include the team members, faculty advisor, university sponsor, industry contact and industry sponsor. A complete list of stakeholders, information shared, modes and frequency of communication, persons responsible for communication and stakeholder influence are shown in APPENDIX A TABLE I in APPENDIX A. All primary sponsors have received status reports, sharing project details and plans, over the duration of the project.

2.5 Risk Management

A risk analysis identifies any risks that could potentially arise within the course of the project. Each risk has its own risk ID, probability of occurrence and a consequence rank that correlates to that possible risk. A team meeting with brainstorming resulted in 17 risks. Currently, some risks have occurred, such as scope creep, and the mitigation plan has been started for these risks. Initially the D-line was our only major area. However, we learned shortly after the project definition report that the F-line also requires a solution for spillage. The set-up of the F-line hoppers and conveyors is slightly different than D-line, therefore another section is considered in the design and implementation. Without the mitigation plan for each of the top risks, the project is highly unlikely to succeed. Each risk must have measures that can mitigate the impact of the risk and, in the best case, avoid it. The team chose the top seven (7) risks that could potentially cripple our project. The seven (7) risks were found by using a likelihood vs. probability chart, which can be found in Appendix A Figure 1. Likelihood vs Consequence in Appendix A. The top risks were scope creep, member availability, client availability, machine availability, and more. All risks and mitigation plans are found in APPENDIX A TABLE IV and in APPENDIX A TABLE V within Appendix A.

3.0 Concept Generation

The concept generation stage involves a thorough exploration of alternatives in order to satisfy the RCM's needs. A strategic concept brainstorming methodology was followed to effectively and imaginatively create conceptual designs.

3.1 Concept Brainstorming Methodology

Preliminary concepts were developed through problem decomposition, external searches of current and potential purchase solutions, internal searches and systematic exploration.

3.1.1 Problem Decomposition

The first step of problem decomposition is to clarify the problem to identify what exactly causes blank spillage and noise generation in the current system. Blank spillage was observed to be caused by various mechanisms in each spill area. The noted observations will be discussed in the following sections.

Blank Spillage at the VFPR

When blanks spill at the **VFPR**, it is due to a large mass of blanks sitting in the VFP from the output of the **feed hopper**. The high number of blanks exiting from the feed hopper bottom creates a pushing force that drives some blanks up and over the VFPR edge, thus spilling onto the floor. A factor that could affect this result is the shape of the VFP; however, we have decided not to alter process equipment. A temporary cover made from plastic and duct tape on a VFPR is shown in Figure 4.

Figure 4. VFPR temporary cover and conveyance system [7].

Noise Generation Areas

The primary noise generation areas surrounding a coining conveyance system include the pre-press hopper, seen in Figure 5, and the point at which blanks transfer from the VFP to the conveyor belt. The noise in both areas is caused due to metal-on-metal contacting, either as blanks contact other blanks or other metal surfaces, such as pre-press hopper. The loudest point of all conveyance systems is it the entrance to the pre-press hopper. The conveyor belt drops the blanks into metal funnels or chutes, which feed into the pre-press hoppers on specific D-line systems. All other D-line and F-line systems operated quietly in comparison. The ambient noise level of the manufacturing area is quite high (hearing protection is required) and contributes to the noise heard from the D-line and F-line areas.

Figure 5. Transfer point from conveyance system to pre-press hopper [7].

The primary cause of the noise in the pre-press hopper region is from metal-on-metal contact as blanks fall into the pre-press chute funnel and chute. A side view of the pre-press hopper chute and funnel are shown in Figure 5.

Blank Spillage from Belt

Observations of the conveyor belt in operation revealed that the spillage of blanks was due to bent, damaged or missing **belt ribs**, missing or damaged **belt cleats**, bouncing off the belt or blank overflow. Most blank spills occur off the sides of belts through damaged or missing belt ribs and cleats. Many blanks fall from the VFP to the belt during transfer and some blanks will bounce off the belt and pass beside the conveyance system. When numerous blanks are transferred to a single area of the belt, the blanks pile up and fall over the belt cleats. The transfer point between the VFP and the belt is shown in Figure 6.

Figure 6. VFP to belt transfer point [7].

Blank Spillage from the VFP to Conveyor

The VFP to conveyor transfer point is the primary blank spill area. Blanks were observed to spill at a higher rate here than any other area. Blank spillage occurs due to damaged or missing belt ribs and cleats, passage through belt cover openings and blank splatter. Figure 7 shows a conveyor belt cover that has duct tape placed over the side openings to prevent blank spills. When blanks fall from the VFP to the belt, sometimes the blanks splatter or spread out onto the belt quickly and shoot off the conveyance system.

Figure 7. Metal fender at the outfeed of the VFP [7].

3.1.2 Current Solutions

The RCM currently uses two (2) solutions to prevent the spilling of blanks. The first solution is a plastic or cardboard plate, cut out manually, to fit over the vibrating feed plate rear (VFDR) wall behind the hopper. These plates are temporary, affixed with bolts and/or duct tape, and are not professional in appearance. Cracking occurs when blanks press up against the plate because of the mass of blanks descending from the feed hopper. This solution is shown in Figure 4.

The second solution is a metal fender, extending from one side of the conveyor to the other, as seen in Figure 7. This fender prevents bouncing blanks from leaving the belt, but does not protect the sidewalls from letting blanks escape. The operators, using duct tape and cardboard to decrease spilling, reinforce the edges of the fender.

3.1.3 Possible Purchase Solutions

After conducting research, no off the shelf products could be found to help with the RCM conveyor spillage. Conveyor manufacturers have hoppers and chutes that are manufactured specifically for their conveyance systems, as will be discussed later. In addition, a patent search did not yield any designs that addressed spillage issues similar to those seen in the RCM.

Metal-Tech Industries Inc. from Winnipeg, MB designs, orders and repairs the belts inside the RCM. With their assistance, a new belt design is a viable option. One option suggested by Metal-Tech would be to alter the angle of the belt cleats in relation to the belt surface. Presently, the cleats are set at approximately 90° along the belt, but by reducing the angle to 75°, the cleats could create a near perpendicular relationship with the facility floor. This angle will prevent blanks from falling off the belt. The conveyor itself, however, was designed and built by Barlow Manufacturing from Stoney Creek, ON and is similar in design to the one shown in Figure 8.

Figure 8. Inclined conveyor designed by Barlow Manufacturing [8].

There are solutions from other manufacturers, but each needs to be modified or custom ordered for the conveyor. EMI Corporation offers an accumulation hopper that can be ordered for belt widths ranging from 6”to 48” [9]. The hoppers can be ordered with options such as lining to prevent product damage, a pivoting flapper to keep product on the conveyor belts and adjustable portions to adapt the hopper to different conveyors. An accumulation hopper designed specifically for an EMI conveyor is shown in Figure 9.

Figure 9. Accumulation hopper with flapper made by EMI Corp. [10].

Other manufacturers offer conveyance systems with pre-installed features and/or accessories to prevent material from falling off the belt. Dorner has a sanitary chute/hopper that can be added onto the AquaPruf and AquaGard conveyance systems, as seen in Figure 10 [11]. The two (2) part hopper connects to the sides of the conveyor rails and bolts together at the top corner of the rear face, as seen in image 2. The hopper, made from stainless steel, increases the infeed functionality and performance of the conveyor belt.

Figure 10. Dorner designed conveyor hopper [11].

Another idea for reducing conveyor spillage is the use of flexible interfaces between transfer points. Concrete conveyance systems, like that made by ConSpare Ltd. and seen in Figure 11, act as a barrier between the transfer point and the conveyance system [12].

This reduces spilling and the spread of dust. An interface like this will stop blanks from slipping past the bottom of the belt and prevent damage to the conveyor belt and blanks.

Figure 11. SPILL-EX Conveyor Skirt Sealing System by ConSpare Ltd. [12].

There are many ideas and products designed to prevent spills, such as accumulation hoppers, flexible interface between the transfer points and different belt configurations. However, none of these designs are made for universal fit across different conveyance systems, so we can only use them as reference and inspiration for our own ideas.

3.1.4 Internal Search

We relied on creative thinking in order to imagine a number of concepts relating to the ideas of our problem areas. Using a quantitative method, each member created at least three (3) conceptual designs per problem area and the various concepts were considered and combined. Section 4.0 Preliminary Concepts illustrates this process in more detail.

4.0 Preliminary Concepts

The current coining system at the RCM relies on temporary solutions such as duct tape and machined plastic covers to prevent blank spillage. We created 43 preliminary concepts to meet the project needs effectively. The concepts are compared, screened and combined to culminate in the optimal design solution. Section 4.1 covers the Pre-press Hopper Transfer Point, 4.2 covers the VFP Rear (VFPR) and 4.3 covers the VFP to Conveyor Transfer Point.

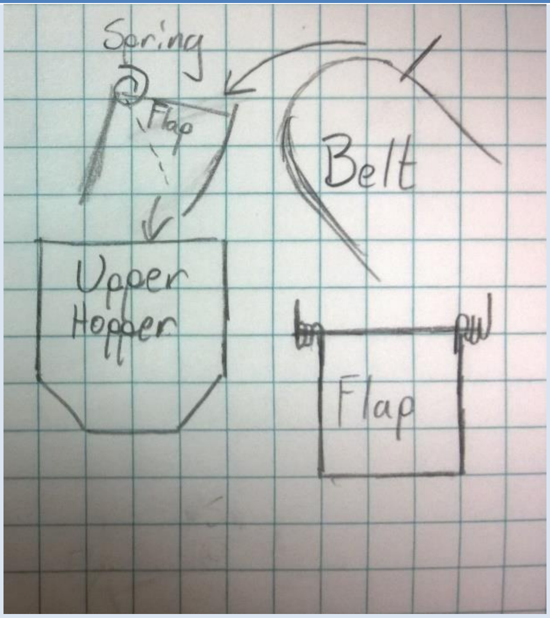
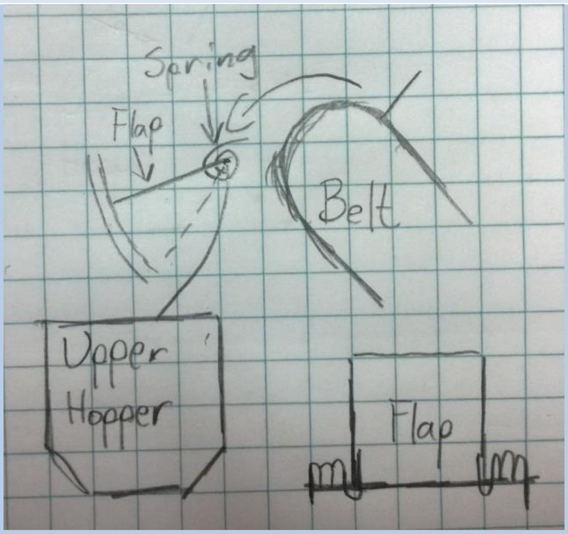
4.1 Pre-press Hopper Transfer Point

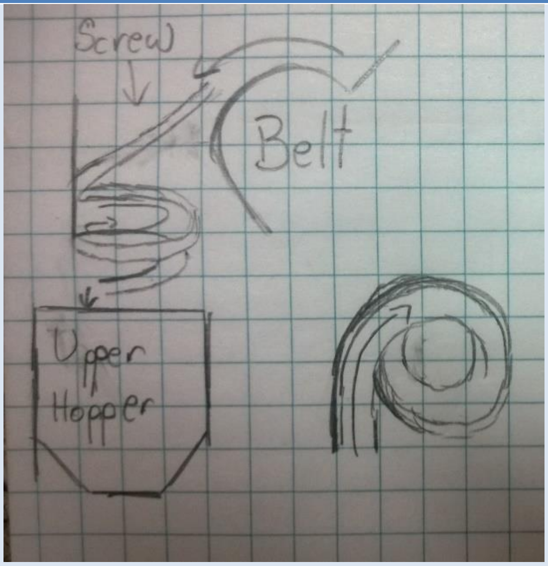
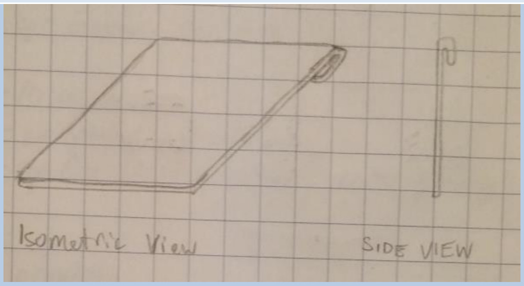
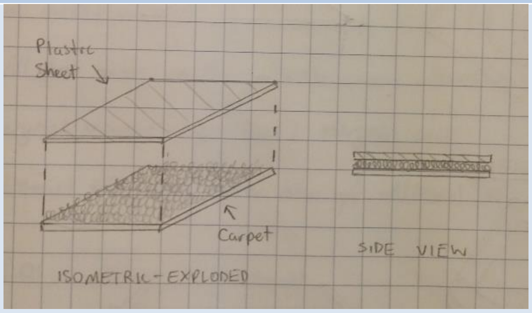
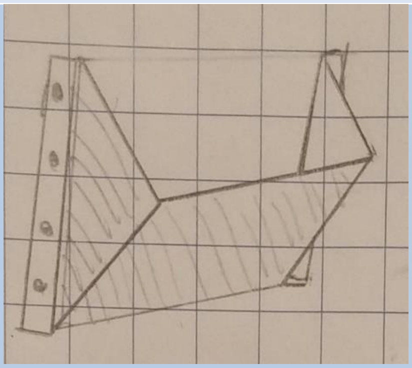
The pre-press hopper is located on the top of the coining press and holds the blanks prior to them being fed into the press. The blanks are dropped from the conveyance system and into the pre-press hopper. This area is excessively noisy and is within the design scope of this project. There are 11 concept designs that eliminate noisy contact points and/or dampen the effect of impact and are available for screening. The concepts, descriptions and respective illustrations, where applicable, are found in TABLE VI.

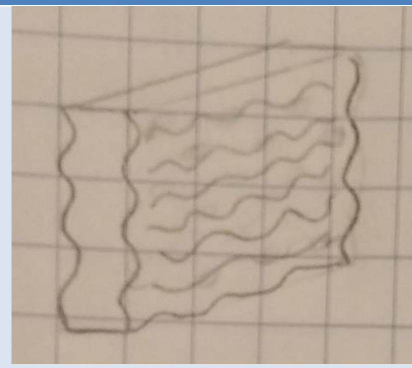
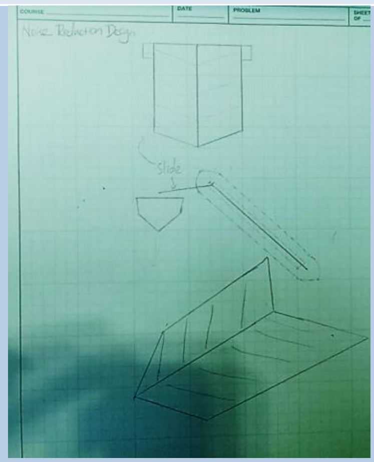
TABLE VI

PRE-PRESS HOPPER NOISE SOLUTION

#	Name	Description	Figure
1	Polly	A thin film polycarbonate is applied to the existing hopper to dampen the impact and reduce noise generation. Adhesive or screws can be used to fasten the film to the hopper.	N/A
2	Paint	A thick paint is applied to the already existing hopper. The paint dampens the impact of the blank on the hopper surface and reduces noise generation.	N/A
3	Bed Liner	A layer of bed liner or undercoat is applied to the already existing hopper. The bed liner dampens the impact of the blank on the hopper surface and reduces noise generation.	N/A

#	Name	Description	Figure
4	Mouse Trap	Blanks are dumped onto a flap with a hinged pivot at the far end, away from the belt. The hinge has springs that slow the movement of the blanks into the upper hopper. The blanks now travel more slowly as they enter the pre-press hopper (shown as upper hopper) reducing the impact and noise generation.	
5	Reverse Mouse Trap	Blanks are dumped onto a flap with a hinge pivoted at the near end, nearest to the belt. The hinge has springs that slow the movement of the blanks onto a chute and into the upper hopper. The blanks now travel more slowly as they enter the pre-press hopper (shown as upper hopper) reducing the impact and noise generation.	

#	Name	Description	Figure
6	Screw	Blanks are dumped onto the inclined spiral (shown as screw). The blanks would travel down the ramp and into the pre-press hopper (shown as upper hopper). The spiral shaped ramp slows the descent of the blanks and reduces the impact and noise generation.	
7	Flat Hooked Plate	A flat plate extending over the current pre-press hopper chute inside face. The plate acts as a slide to reduce the impact and noise generation. A curved lip along the plate's top edge allows attachment to the lip of pre-press hopper chute.	
8	Magic Carpet	A plastic cover adhered to a cut area of carpet is attached to the inner face of the pre-press hopper chute. The carpet would dampen the impact of the blank on the hopper surface and reduce noise generation.	
9	Plastic Chute	An identical chute is designed, but the sheet metal is replaced with a plastic material. The plastic material absorbs more of the energy of the falling blanks reducing the impact and noise generation.	

#	Name	Description	Figure
10	Baffling	Sound baffling is affixed to the sides of the pre-press hopper and dampens the noise generated by the impact of the blanks on each other and the hopper components.	
11	Slide	A V-shaped slide directs the blanks from the belt into the pre-press hopper. The slide reduces the noise generated by the rattling of the blanks inside the chute. The slide is affixed to the conveyor frame. Slide is made from 316 stainless steel.	

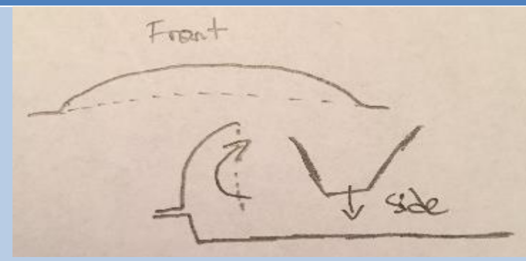
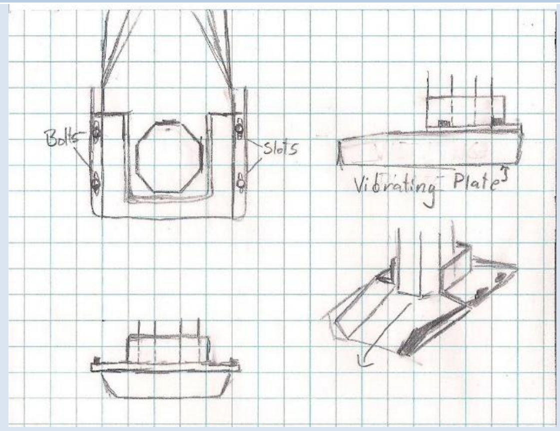
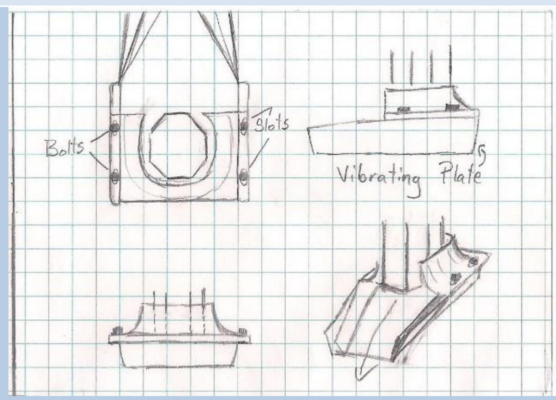
4.2 VFP Rear (VFPR)

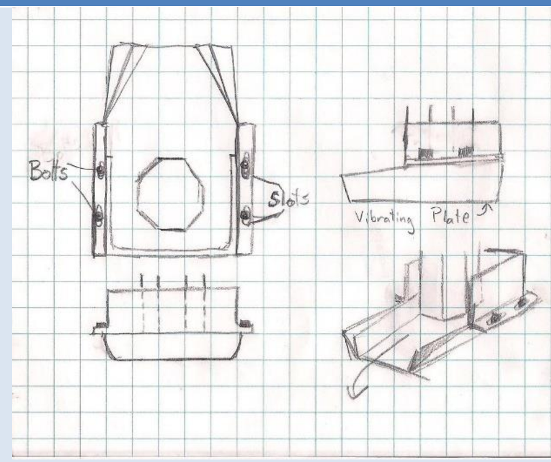
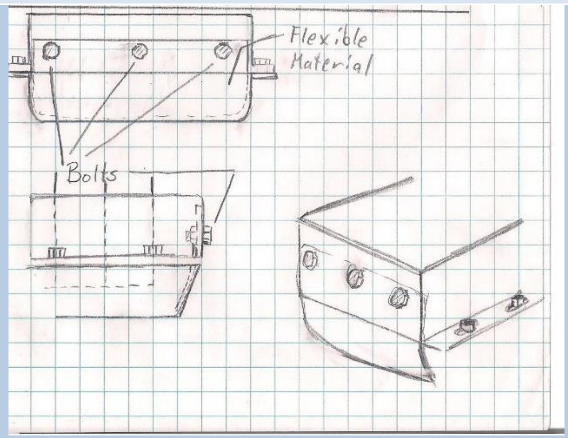
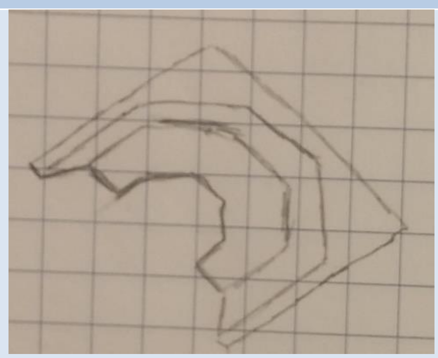
Each VFPR area currently functions with an open top, duct-taped top or loose plastic top. The temporary measures prevent spilling but are not standardized across all the vibrating feed plates and are not aesthetically pleasing, therefore a permanent design is required that meets all objectives.

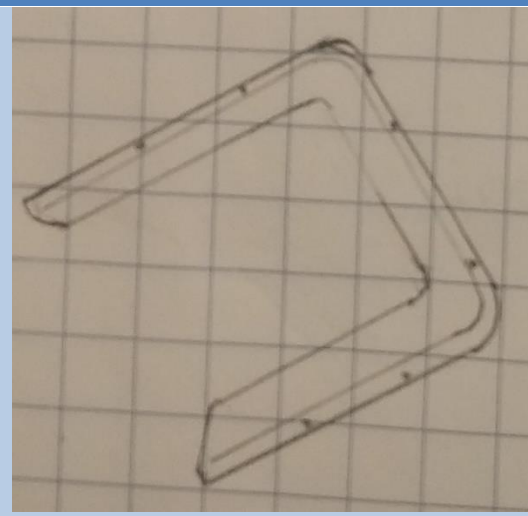
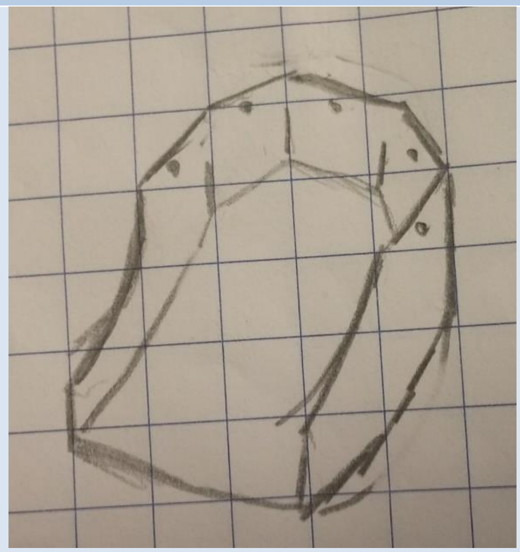
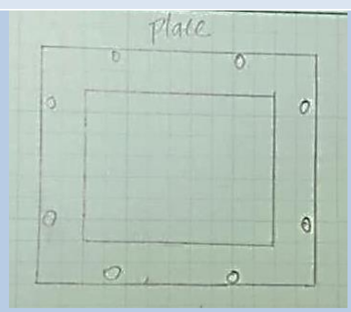
Nine (9) conceptual designs were created prior to the screening process. Each design aims to prevent blank spillage by redirecting blank travel, restricting blank movement and limiting spill areas along the VFP. The VFPR concepts, illustrations and respective descriptions are found in TABLE VII.

TABLE VII

REAR OF THE VIBRATING FEED PLATE SPILLAGE PREVENTION

#	Name	Description	Figure
1	Back Catcher	A small curved plastic guard is affixed to the VFDR. The Back Catcher redirects the blanks away from the VFDR and toward the VFD transfer point. As blanks push up and over the sides of the VFD the Back Catcher pushes them forward.	
2	Plastic Chimney	A plastic plate is fastened atop the VFP. The plate has four slots to bolt it to the VFD. Moving in from the edge of the VFP the plate turns 90 degrees to be parallel to the outfeed of the feed hopper. The walls of the Plastic Chimney do not come into contact with the outfeed. Three sides of the outfeed are surrounded. Blanks are prevented from climbing over the VFP wall.	
3	Funnel	A plate is fastened atop the VFP. The plate has four slots to bolt it to the VFP. Moving in from the edge of the VFP the plate surface slopes upward until it is parallel to the outfeed of the feed hopper. The walls of the funnel do not come into contact with the outfeed. Three sides of the outfeed are surrounded by the Funnel. Blanks are prevented from falling over the VFP wall and as the height of blanks increases, the curved walls push the blanks toward the VFP transfer point. This also helps reduce the stress experience by the Funnel.	

#	Name	Description	Figure
4	Wall	A plate is fastened atop the VFP. The plate has four slots to bolt it to the VFP. The plate turns 90 degrees to be parallel to the outfeed of the hopper at the outer edges of the VFP. Three sides of the outfeed are surrounded by the walls. Blanks are prevented from climbing over the VFP wall and, as the Wall doesn't experience any upward force caused by blanks, stress is virtually eliminated.	
5	Doggie Door	A plate is fastened atop the VFP. The plate has four slots to bolt it to the VFP. The plate turns 90 degrees to be parallel to the outfeed of the hopper at the outer edges of the VFP. A flexible piece of material (rubber or polymer) is bolted through holes in the rear wall and sits inside the VFPR. The blanks hold the Doggie Door against the VFPR. Three sides of the outfeed are surrounded by the Walls. Blanks are prevented from climbing over the VFP wall by the Wall and blanks along the back end do not slip underneath due to the presence of the flexible material.	
6	Dome	Dome-shaped, slanted guard extends from feed hopper outfeed to the VFPR. Foam tape or a similar adhesive is placed in between VFP and the flanges along the outer edge of the Dome. Blanks are prevented from climbing over the VFP wall and as the height of blanks increases, the angled walls push the blanks toward the VFP transfer point.	

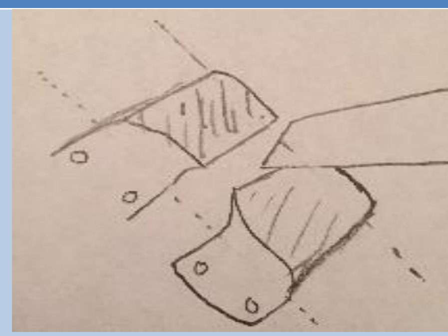
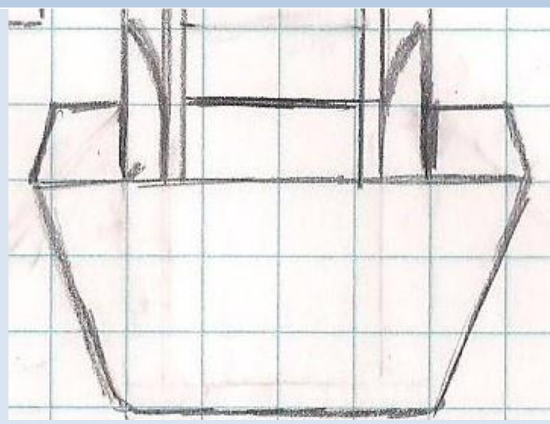
#	Name	Description	Figure
7	Perimeter Guard	Short 45-degree angled wall runs along the flanges of VFP. Foam tape or a similar adhesive is placed in between VFP and the flanges along the outer edge of the Perimeter Guard. Blanks are prevented from climbing over the VFP wall and as the height of blanks increases, the angled walls push the blanks toward the VFP transfer point.	
8	Output Chute	A three sided chute with a fitted top edge is affixed to the feed hopper's outfeed. The Output Chute is angled toward the front of VFP directing the blanks and preventing them from travelling to the VFPR. By restricting the spread of blanks to the VFPR the height of blanks is prevented from reaching the top of the VFP wall and spilling is eliminated.	
9	Cap	A metal plate is cut to fit atop the VFP. CNC machine. Eight (8) holes allow bolting of the Cap to the VFP. The center of the plate has a rectangular hole cut out to accommodate the feed hopper outfeed. Blanks are prevented from climbing over the VFP wall.	

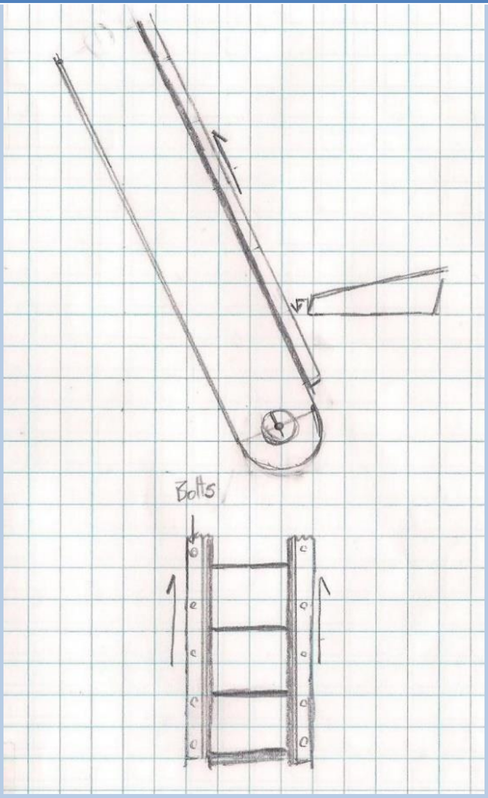
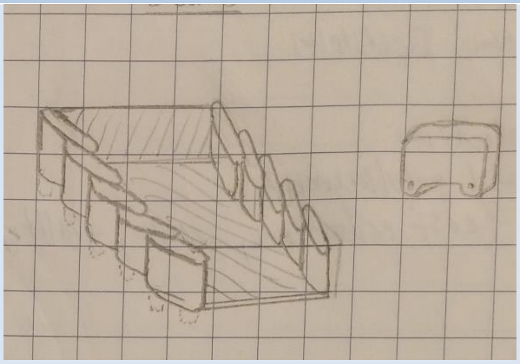
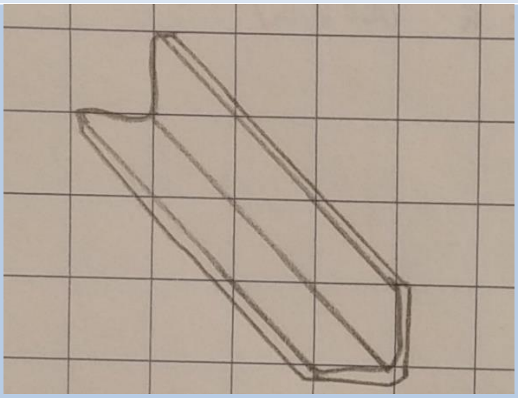
4.3 VFP to Conveyor Transfer Point

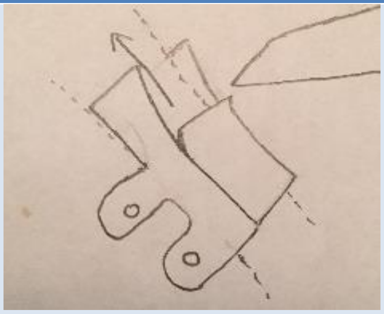
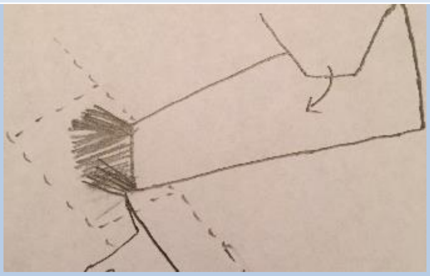
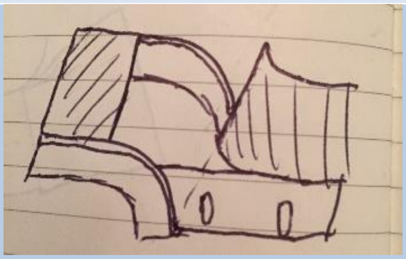
The definition of the VFP to conveyor transfer point is where the blanks leave the VFP and reach the conveyor belt. Spillage results from blanks missing the belt, bouncing off the belt and rolling down the belt between the belt cleats. More solutions were brainstormed in this area than all other areas. A total of 23 designs were initially compiled for concept screening. The designs aim to eliminate one or more causes of blank spillage. Each concept, illustrated and respective definitions are found in TABLE VIII.

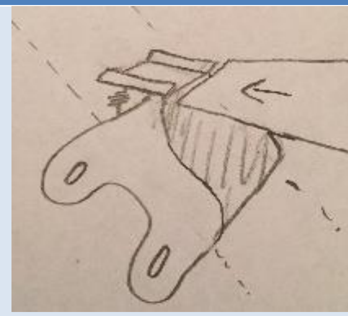
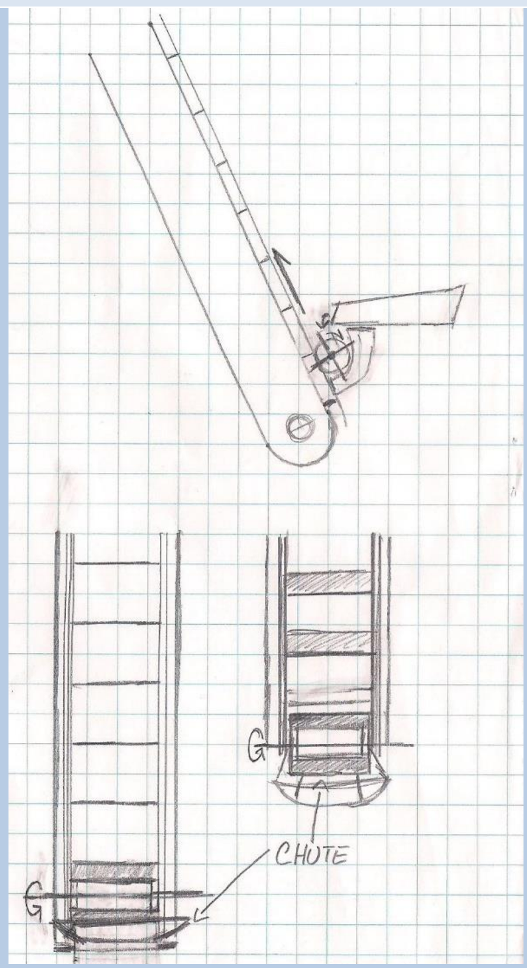
TABLE VIII

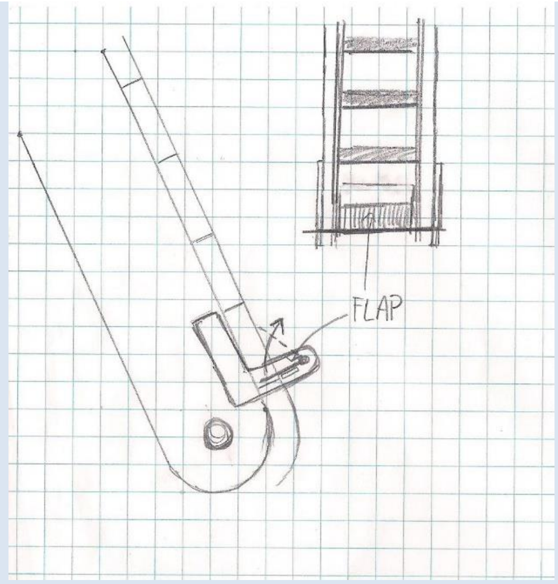
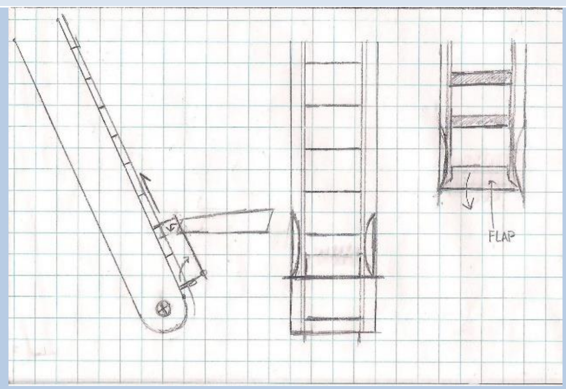
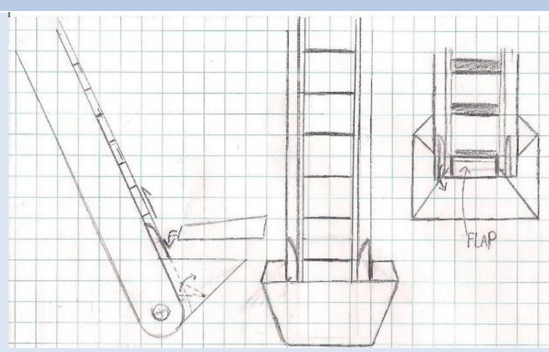
VFP AND CONVEYOR TRANSFER POINT SPILLAGE CONCEPT DESIGNS

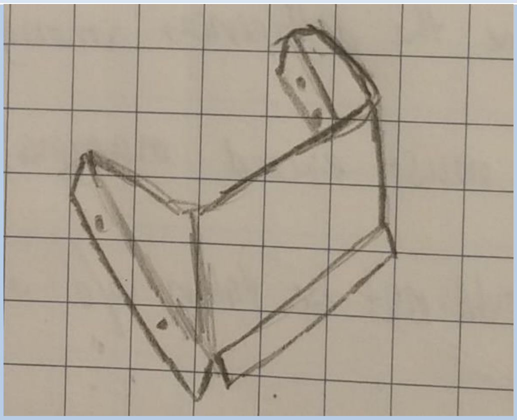
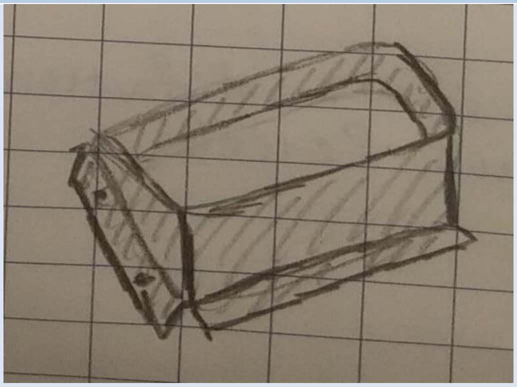
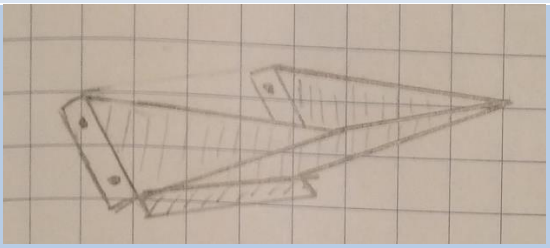
#	Name	Description	Figure/Sketch
1	The Sled	Two (2) fenders identical to the existing fender are used, with one (1) fender located at the current location and the other turned 180° and placed above the VFP transfer point. The Sled creates a square opening for the blanks to be dropped onto the belt. The upper fender deflects bouncing blanks down and pushes blanks that extend over the cleats back into the belt pocket.	
2	Catcher	A large, angled, bucket-like fixture sits at the base of the conveyor belt. The Catcher collects any blanks falling down and off the belt. The angled walls direct the blanks back onto the belt.	

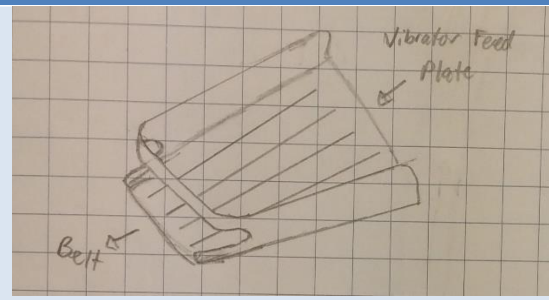
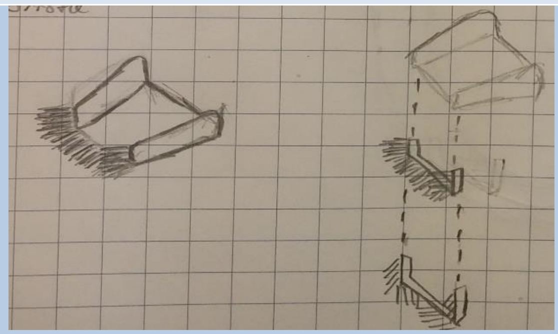
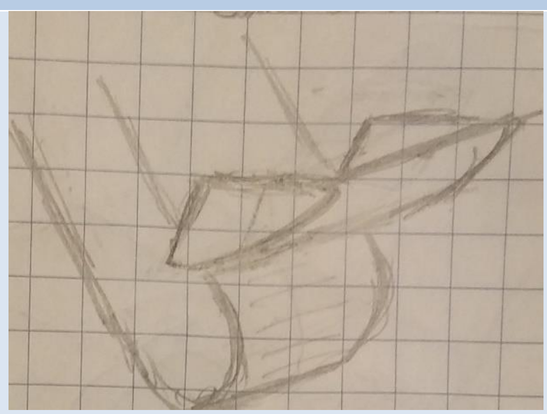
#	Name	Description	Figure/Sketch
3	Autobahn	A low friction angled material runs along the edge of the belt, holding the sides of the belt in place and preventing any and all blanks falling through the ribs of the belt. The Autobahn is bolted through holes in the bottom flange and run along both sides of the belt, top to bottom.	
4	Scales	The Scales replace missing ribs in the belt. The Scales are made up of small, round-edged slabs of belting material, and are attached to the belt using thin metal pins that insert perpendicular to belt travel. Blanks can no longer fall out the sides of the belt through damaged sections	
5	L-Guard	A short L-shaped bracket, made from belting material, is installed onto the belt, repairing sections where two (2) or more ribs were damaged/missing. Vertical slots are cut into the upper portion to allow the L-Guard to bend around the conveyor belt rollers. Blanks can no longer fall out the sides of the belt through damaged sections.	

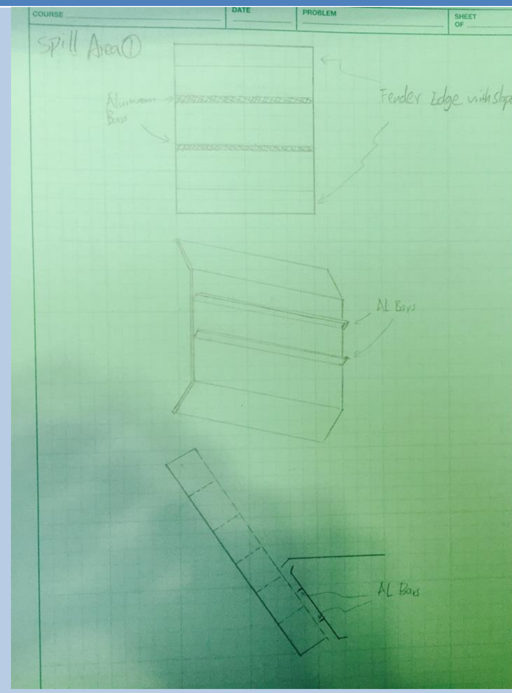
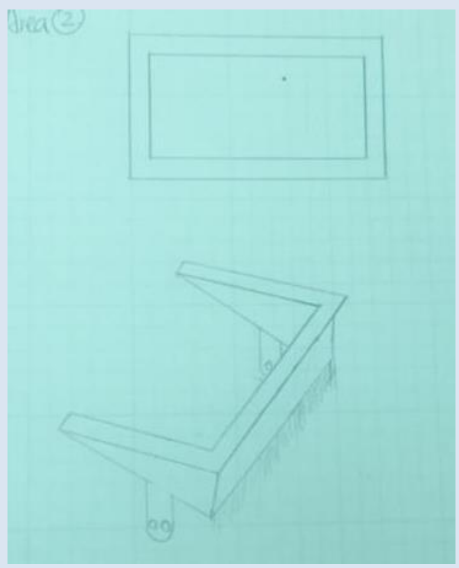
#	Name	Description	Figure/Sketch
6	Extended Fender	Extended sides are added to the existing fender. The Extended Fender prevents blanks from bouncing off of the belt and requires little modification to the current system.	
7	Bristle Guide	Bristles, like those on a medium-coarse brush, are affixed to the end of the VFP and extend down to the belt surface. The bristles guide the blanks onto the belt but can bend and flex when the belt cleats pass. also bending for the ribs and slots. The Bristle Guide is located on three (3) sides of the VFD to prevent blanks from falling over the belt ribs.	
8	Extended VFP Weld Guard	The welded guards on the VFP are extended and are set at a larger outward angle. The Extended VFP Weld Guard increases the accuracy of the falling blanks by reducing the distance that the blanks fall and directing them more toward the belt center.	N/A
9	Robin Hood	The existing fender is extended above the VFP transfer point. The Robin Hood creates a square window for blanks to be transferred to the belt. The new extension deflects bouncing blanks down and knocks piles of blanks over, so as to prevent them from tipping over the belt cleats further up the conveyor and falling off of the conveyance system entirely.	

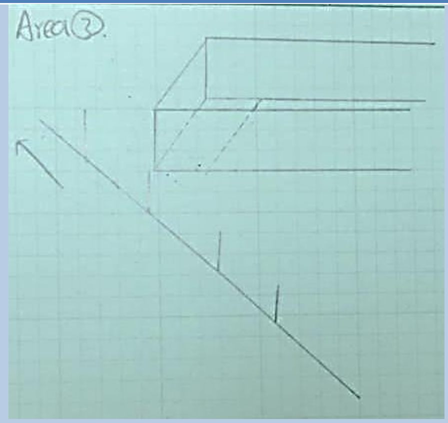
#	Name	Description	Figure/Sketch
10	Hinged Chute	A chute is hinged on the current fender, just beneath the VFD. The edges of the chute are bent upward and create a slide for the blanks. The Hinged Chute extends into the belt pockets and reaches behind the VFP transfer point. A spring on the hinge lightly pushes the chute down onto the belt. As the belt moves up, the chute is lifted by the cleat and then returns to the belt surface after it passes. The chute prevents blanks from spilling over the belt ribs and over the belt cleats and out the bottom of the belt.	
11	Water Wheel	A paddle wheel, with vanes that extend into the pockets of the belt, sits beneath the VFD. Blanks drop from the VFD and are cradled between the wheel's paddles. As each cleat passes, the wheel turns 90° and dumps the blanks within it onto a chute. The chute directs the blanks onto the belt.	

#	Name	Description	Figure/Sketch
12	Flap Guide	A flap with a pivot is positioned at the bottom of the conveyor belt. The pivot sits above the conveyor cleats. The flap stops and holds the blanks as they fall down the belt. As the belt cleat passes it lifts the flap and carries up the collected blanks. Once the cleat has passed, the Flap Guide falls back into position against a stop mounted on the pivot bracket.	
13	3-Sided-Flap	A flap with a pivot is positioned at the bottom of the conveyor belt. The pivot sits above the conveyor cleats. Blanks transferring onto the belt are prevented from bouncing over the belt ribs by contoured side walls. The 3-Sided Flap stops and holds blanks as they fall down the belt. As the belt cleat passes it lifts the flap and carries up the collected blanks. Once the cleat has passed, the flap falls back into position against a stop mounted on the side walls.	
14	Catcher	A large, angled, bucket-like fixture is positioned at the bottom of the conveyor belt. The Catcher collects blanks that spill off the belt and fall down the conveyor. The angled walls direct the blanks back onto the conveyor belt. At the bottom of the bucket is a flap with a pivot above the belt pockets. The flap stops and holds blanks at the bottom of the Catcher. As the belt cleat passes it lifts the flap and	

#	Name	Description	Figure/Sketch
		carries up the collected blanks. Once the cleat has passed, the flap falls back into position against a stop mounted on the Catcher's base.	
15	Simple Catch	A 3-sided chute with flanged edges is bolted to the conveyor frame beneath the VFD. As blanks bounce off or miss the belt surface, the Simple Catch redirects them onto the belt. The bottom lip slides under the current fender.	
16	Simple Hood Catch	A 3-sided chute with flanged edges is bolted to the conveyor frame beneath the VFD. As blanks bounce off or miss the belt surface, the Simple Hood Catch redirects them onto the belt. The bottom lip slides under the current fender. Above the VFD transfer point a flat surface extends across the belt that prevents blanks from piling up and tumbling over the belt cleats further up the conveyor.	
17	Catch Fender	A 3-sided chute with flanged edges is bolted to the conveyor frame and extends up to the bottom of the VFD. As blanks bounce off or miss the belt surface, the Catch Fender redirects them onto the belt. The bottom lip slides under the current fender.	

#	Name	Description	Figure/Sketch
18	Main Vein	A grooved chute sits just beneath the VFD and extends to just above the top of the belt cleats. The outfeed of the chute has a bar that extends across to prevent blanks from piling up too high and causing additional spilling. The Main Vein uses the grooves to evenly distribute the blanks across the belt, perpendicular to its travel.	
19	Twin Bristle	Two (2) layers of bristles, like those on a medium-coarse brush, are affixed to the output end of the VFP and extend down to the belt surface. The bristle layers are set perpendicular with respect to one another. The bristles guide the blanks onto the belt but can bend and flex when the belt cleats pass. also bending for the ribs and slots. The second layer of bristles prevent blanks that are standing on their narrow edge from passing through. The Twin Bristle is located on the three (3) sides of the VFP to prevent blanks from falling over the belt ribs.	
20	Same Catcher	A large 3-sided chute is secured to the conveyor belt frame with bolts through the flanges. The sides of the chute redirect stray blanks onto the belt and prevent them from spilling off of the belt.	

#	Name	Description	Figure/Sketch
21	Catch Bar	An angled fender, of similar design to the old fender, is bars, the fender has same geometry compare with the existing one. The existing fender can block most of the blanks, except the ones slide straight through the gap between the conveyor and the fender. We can weld two small aluminum bars to form an uneven surface on the surface, blanks will hit the bars and bounce back to the conveyor. Material of the bars are 316 stainless steel. The fender is held on the side of the conveyor belt, just like existing setup.	
22	3 Sided Fender	A 3-Sided Fender is placed at the bottom of the conveyor belt. The fender catches any blanks falling down the belt and directs them back onto the belt. The holes employed by the old fender are used to bolt the 3-Sided Fender to the conveyor frame. The fender is made from 316 stainless steel.	

#	Name	Description	Figure/Sketch
23	Vertical Paddles	A new belt is installed with a new cleat orientation. The cleats are set at an angel of 90° to the floor. The new vertical orientation of the cleats prevents blanks from bouncing and falling over them.	

5.0 Concept Selection and Analysis

The selection process involves the screening and scoring of various concepts to determine suitability to the project's needs systematically. This section considers conceptual designs for the three problem areas of the coining systems, the pre-press hopper transfer point, the rear of the vibrator feed plate and the vibrator feed plate to conveyor transfer point.

The concept screening process compares each concept against a reference design, the RCM's currently implemented design, and determines if the concept is better or worse than that reference for a specific project need. The screening process only compares against the top 11 needs, as they are most critical to design performance. The project needs' ranking can be seen in TABLE IX.

Concept scoring moves one step further and compares the preliminary concepts against all the project needs. Each concept is ranked 1-5 against a certain need and then multiplied by the respective need's weight to create a final score. The ranking values are identified as,

1 = Insufficient

2 = Poor

3 = Average

4 = Good

5 = Excellent

Finally, the most suitable concepts are selected for further detailed analysis. Material, manufacturing, dimensions and several other factors will be considered in Section 7.0.

TABLE IX

PROJECT NEEDS RANKING

Letter	Project Needs	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	prevents spills between hopper and conveyor.		A	A	A	A	A	A	A	A	A	A	A	A	N	A	A	Q	A	A
B	prevents spills between secondary transfer areas.			B	B	B	B	B	B	B	B	B	B	B	N	B	B	Q	B	B
C	prevents spills caused by belt ribs.				C	C	C	C	C	C	C	C	C	C	N	C	C	Q	C	C
D	performs precisely.					D	F	D	D	D	D	K	D	D	N	D	D	Q	D	D
E	survives heavy use.						F	E	E	E	J	K	E	E	N	E	E	Q	R	E
F	maintains other process conditions.							F	F	F	J	K	F	F	N	F	F	Q	F	F
G	maintains its own condition.								G	I	J	K	L	M	N	G	P	Q	R	G
H	is aesthetically pleasing (Instills pride).									I	J	K	L	M	N	O	P	Q	R	H
I	is quiet.										J	K	L	M	N	I	I	Q	R	I
J	functions under high vibration.											K	J	J	N	J	J	Q	R	J
K	fits within current process limits.												K	K	N	K	K	Q	R	K
L	is easy to install.													L	N	O	L	Q	R	L
M	is lightweight and easily maneuverable.														N	O	P	Q	R	M
N	maintains the original blank appearance.															N	N	Q	N	N
O	is easily manufactured.																O	Q	R	R
P	Is easy to repair and replace.																	Q	R	R
Q	is safe in and out of use.																		Q	Q
R	is standardised.																			R
S	stays clean.																			
	HITS	16	15	14	11	8	11	3	1	5	10	12	6	4	17	4	3	18	13	0
	Weight	0.049	0.046	0.043	0.034	0.025	0.034	0.009	0.003	0.015	0.031	0.037	0.019	0.012	0.052	0.012	0.009	0.056	0.040	0.000
	Rank	3	4	5	8	11	8	16	18	13	10	7	12	14	2	14	16	1	6	19

5.1 Pre-press Hopper Transfer Point

There are 11 concepts designs for the pre-press hopper transfer point. A reference concept is set which was the current design of the bare metal pre-press hopper that creates noise that, when not isolated from ambient noise, exceeds 80db and requires the use of PPE. After the screening was final and we received the top results, the scoring process and the sensitivity analysis resulted in the final concept.

5.1.1 Concept Screening

The concept screening of the 11 conceptual designs resulted in the top five (5) designs. A 12th need (the design is quiet) is used for comparison in this section as this section pertains directly to noise reduction. The screening matrix is seen in TABLE X.

TABLE X

PRE-PRESS HOPPER CONCEPT SCREENING MATRIX

			Concepts										
Letter	**Needs**	**REF**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
A	Prevents spills between hopper and conveyor.	0	0	0	0	0	0	0	0	0	0	0	0
B	Prevents spills between secondary transfer areas.	0	0	0	0	0	0	0	0	0	0	0	0
C	Prevents spills caused by belt ribs.	0	0	0	0	0	0	0	0	0	0	0	0
D	Performs precisely.	0	0	0	0	0	0	0	0	0	0	0	0
E	Survives heavy use.	0	-	-	+	-	-	0	0	-	-	0	0
F	Maintains other process conditions.	0	-	-	-	0	0	0	0	-	0	0	0
J	Functions under high vibration.	0	0	0	0	0	0	-	0	0	0	-	0
K	Fits within current process limits.	0	0	0	0	-	-	-	0	0	0	0	0
N	Maintains the original blank appearance.	0	+	+	-	+	+	+	+	+	+	0	+
Q	Is safe in and out of use.	0	0	+	+	-	-	0	+	+	+	0	0
R	Is standardized.	0	0	+	+	-	0	0	0	0	0	0	+
I	Quiet	0	+	+	+	+	+	+	+	+	+	+	+
	PLUS	0	2	4	4	2	2	2	3	3	3	1	3
	MINUS	0	2	2	2	4	3	2	0	2	1	1	0
	NEUTRAL	12	8	6	6	6	7	8	9	7	8	10	9
	SCORE	0	0	2	2	-2	-1	0	3	1	2	0	3
	RANK	7	7	3	3	12	11	7	**1**	6	3	7	**1**

These top designs are Thick Paint, Bed Liner, Flat Hooked Plate, Plastic Chute, and the Slide.

5.1.2 Concept Scoring

There were five (5) designs that arose on top resulting from the screening matrix and these five designs were brought to the scoring matrix and further analyzed to result in two (2) final designs that potentially can be implemented into the pre-press hopper for reducing the noise. The design that meets the most needs or the highest weighted needs is the determined to be the final design. TABLE XI shows the scoring matrix for the pre-press hopper noise-reduction solutions.

TABLE XI

PRE-PRESS HOPPER SCORING MATRIX WITH THE TOP FIVE CONCEPTS

			Concepts				
Letter	**Needs**	**Weight**	**2**	**3**	**7**	**9**	**11**
A	Prevents spills between hopper and conveyor.	10%	1	1	1	1	1
B	Prevents spills between secondary transfer areas.	8%	1	1	1	1	1
C	Prevents spills caused by belt ribs.	8%	1	1	1	1	1
D	Performs precisely.	6%	5	5	5	4	4
E	Survives heavy use.	5%	4	5	5	4	4
F	Maintains other process conditions.	7%	5	3	5	5	5
G	Maintains its own condition.	2%	5	3	5	5	5
H	Is aesthetically pleasing (Instills pride).	1%	4	4	4	3	3
I	Is quiet.	3%	3	5	4	4	2
J	Functions under high vibration.	4%	5	5	4	4	4
K	Fits within current process limits.	7%	5	5	4	4	4
L	Is easy to install.	3%	4	4	5	3	3
M	Is lightweight and easily maneuverable.	2%	5	4	5	4	4
N	Maintains the original blank appearance.	10%	5	2	5	5	5
O	Is easily manufactured.	3%	5	5	4	4	4
P	Is easy to repair and replace.	2%	4	3	4	4	4
Q	Is safe in and out of use.	11%	4	4	4	4	4
R	Is standardized.	8%	5	5	4	4	4
	Score		3.68	3.27	3.57	3.37	3.31
	Rank		**1**	**5**	**2**	**3**	**4**

The Paint, the Flat Hooked Plate and the Plastic Chute ranked as the top three (3) designs. Since only the top two (2) ranking designs are taken into further consideration, only the Paint and the Flat Hooked Plate are analyzed further.

5.1.3 Sensitivity Analysis

The score difference between the first and second designs is 0.11 and 0.2 between second and third designs. The 0.31 scoring gap between the top three (3) designs is large. Therefore, a sensitivity analysis was unnecessary and the final concepts to be further discussed were clear. The paint performed better in several key systems, such as fitting within process limit, functioning under high vibration and is standardized for all machines.

5.2 VFP Rear

To select the concept to develop into the project solution, the preliminary concepts are screened and scored by using a matrix and comparing the RCM's needs to the conceptual designs. The nine (9) concepts are screened, combined and improved, scored and, if necessary, a sensitivity analysis is performed.

5.2.1 Concept Screening

The nine (9) preliminary concepts for the VFP rear are screened against the top 11 project needs. A reference design acts as the reference point for needs comparisons. The reference design is the duct-tape/plastic flat VFP lids that the RCM currently uses. TABLE XII shows the concept screening scores and ranks compared to the reference design. A plus, minus and zero represent that the concept fulfills a need better, worse or the same as that the reference design, respectively.

TABLE XII

VFP REAR CONCEPT SCREENING

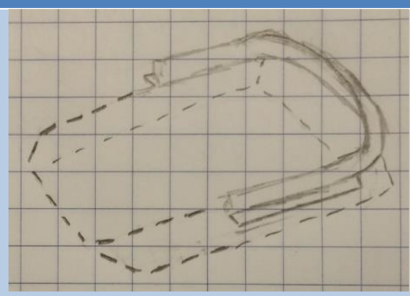
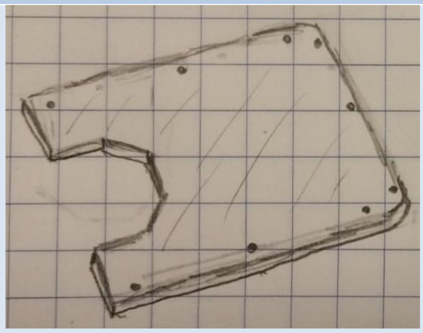
	Concepts									
Needs	**REF**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Prevents spills between hopper and conveyor.	0	0	0	0	0	0	0	0	-	0
Prevents spills between secondary transfer areas.	0	+	+	+	+	+	+	+	+	+
Prevents spills caused by belt ribs.	0	0	0	0	0	0	0	0	0	0
Performs precisely.	0	0	0	0	0	-	0	0	-	0
Survives heavy use.	0	+	+	+	0	0	0	0	0	0
Maintains other process conditions.	0	0	0	0	0	0	0	0	0	0
Functions under high vibration.	0	+	-	+	0	0	0	-	+	0
Fits within current process limits.	0	0	0	0	0	0	0	0	0	0
Maintains the original blank appearance.	0	0	0	0	0	0	0	0	0	0
Is safe in and out of use.	0	+	0	0	+	+	0	+	+	+
Is standardised.	0	0	0	0	+	+	0	0	+	0
PLUS	0	4	2	3	3	3	1	2	4	2

		Concepts								
Needs	**REF**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
MINUS	0	0	1	0	0	1	0	1	2	0
NEUTRAL	0	7	8	8	8	7	10	8	5	9
SCORE	0	4	1	3	3	2	1	1	2	2
RANK	**-**	**1**	**4**	**2**	**2**	**3**	**4**	**4**	**3**	**4**

The Back Catcher, Funnel, and the Wall were ranked the top three (3) designs respectively. From these three (3) designs, there were another two (2) designs created by combining and improving the original designs. These two (2) designs are the Back Catcher with Side Walls and the Simple Cover, shown in TABLE XIII with full descriptions of each new concept.

TABLE XIII

COMBINED AND IMPROVED CONCEPTS FOR VFPR

#	Name	Description	Figure
10	Back Catcher with side walls	Small curved plastic guard that extends upwards from the rear flange of the VFP. The guard also extends as a wall along the side flanges. The concept guides blanks forwards and centrally to the front of the plate.	
11	Simple cover	This is a cover that resembles the currently installed temporary guard. This cover is more robust than the current guard and sits on a dampening media (ex. foam tape). The dampening media is installed between cover and flanges of VFP to minimize vibrations in the cover and securing hardware. The shape of the cover fits to the VFP flanges and downward edge of the feed hopper output. This concept restricts upward and rearward blank movement.	

The two (2) new concepts and the top three (3) concepts from the screening matrix are scored further against each other.

5.2.2 Concept Scoring

The screened concepts are ranked by how well they satisfy the project needs. The top three (3) concepts move on to the scoring process, as they performed better than the reference design for at least three (3) needs.

Several concepts are now combined to create improved concepts. The Back Catcher with Side Walls and the Simple Cover, shown in TABLE XIII, are improved or combined ideas that are considered in the concept scoring. The scoring involves ranking the concepts according to every weighted need and determining the best fit. TABLE XIV identifies the scoring of concepts 1, 3, 4, 10 and 11, which are the Back Catcher, the Funnel, the Wall, Back Catcher with Side Walls, and the Simple Cover, respectively.

TABLE XIV

VFPR CONCEPT SCORING

Letter	Need	Weight	Concepts 1	3	4	10	11
A	Prevents spills between hopper and conveyor.	10%	1	1	1	1	1
B	Prevents spills between secondary transfer areas.	8%	4	5	5	5	5
C	Prevents spills caused by belt ribs.	8%	1	1	1	1	1
D	Performs precisely.	6%	5	5	5	5	5
E	Survives heavy use.	5%	4	4	3	4	4
F	Maintains other process conditions.	7%	5	5	5	5	5
G	Maintains its own condition.	2%	5	5	5	5	5
H	Is aesthetically pleasing (Instills pride).	1%	3	3	3	3	4
I	Is quiet.	3%	5	5	5	5	5
J	Functions under high vibration.	4%	4	3	3	3	4
K	Fits within current process limits.	7%	5	5	5	5	5
L	Is easy to install.	3%	5	5	5	4	5
M	Is lightweight and easily maneuverable.	2%	5	4	5	5	5
N	Maintains the original blank appearance.	10%	5	5	5	5	5
O	Is easily manufactured.	3%	3	3	5	3	5
P	Is easy to repair and replace.	2%	5	5	5	5	5
Q	Is safe in and out of use.	11%	5	4	5	5	5
R	Is standardised.	8%	3	3	3	3	3
	Score		3.87	3.78	3.92	3.88	4.02
	Rank		**4**	**5**	**2**	**3**	**1**

The Simple Cover, the Wall and the Back Catcher with Side Walls ranked as first, second and third, respectively. It can be observed that the scores for the first and second place designs vary by 0.10 points, while the scores of the second and third most suitable designs vary only by 0.04 points. This suggests that the design ranked first performs marginally better than the other designs and should be considered for further analysis through a sensitivity analysis.

5.2.3 Sensitivity Analysis

After changing the weight and the rank for a few needs for each concept, the Wall continued to rank better than the Back Catcher with Side Walls by a score of 0.01. The changes made were changes to “survive heavy use” and to “ease of manufacturing the design”. The Wall is more easily manufactured than the Back Catcher with Side Walls; therefore, the Back Catcher with Side Walls cannot score better than the Wall for that need. Therefore, the final concepts going forward are the Simple Cover and the Wall.

5.3 VFP to Conveyor Transfer Point

The VFP to conveyor transfer point is where blanks are moved from the VFP to the conveyor belt. We brought 23 concepts together through brainstorming, group discussions and research into current conveyance system spill solutions. These concepts were screened, combined and improved, scored and scored once again using a sensitivity analysis. The results came from the scoring matrix and result in three (3) final concepts to further the development and testing.

5.3.1 Concept Screening

Like all other areas that were screened, the designs are compared against a reference design, a fender that blocks the belt and a lip that bounces blanks back onto the belt. This fender is made from steel, cardboard, and held together with duct tape or bolts. The comparison matrix is shown in TABLE XV.

TABLE XV

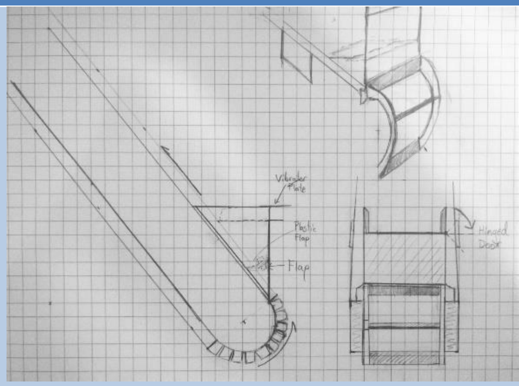
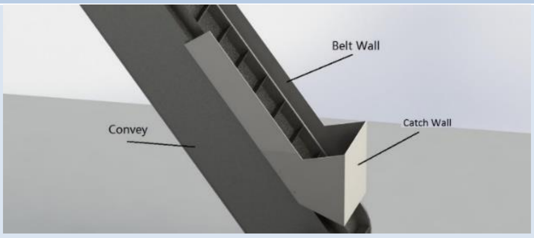
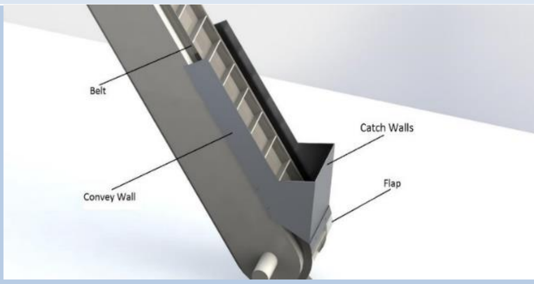
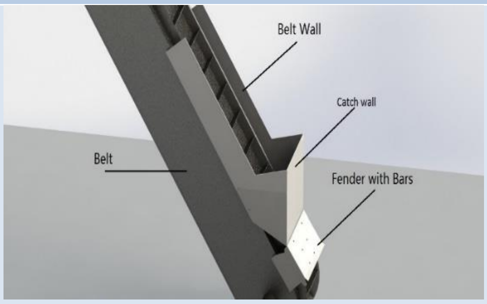
VFP TO CONVEYOR TRANSFER POINT CONCEPT SCREENING MATRIX

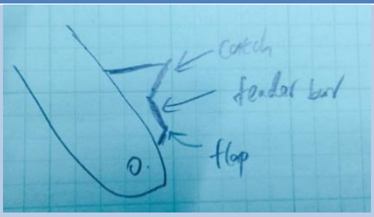
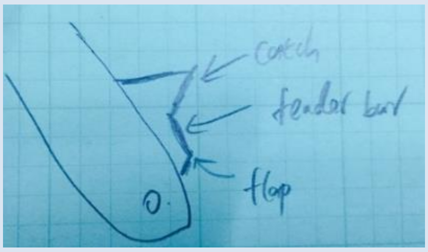
Need	**Concepts**																						
-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	23
prevents spills between hopper and conveyor.	0	0	0	0	0	0	+	0	+	+	+	0	+	+	+	+	+	+	0	+	0	+	0	0
prevents spills between secondary transfer areas.	+	0	0	0	0	0	0	0	0	0	-	+	+	+	0	0	0	0	+	+	+	+	+	0
prevents spills caused by belt ribs.	0	+	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
performs precisely.	0	0	0	0	0	0	-	0	0	-	+	0	+	0	+	+	+	-	0	+	+	0	+	0
survives heavy use.	0	0	0	-	-	0	-	0	0	-	-	-	-	-	0	0	0	-	0	-	0	0	0	0
maintains other process conditions.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
functions under high vibration.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0
fits within current process limits.	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0	0	-	0
maintains the original blank appearance.	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0
is safe in and out of use.	0	+	0	0	0	0	0	0	0	-	-	-	-	-	0	0	0	0	-	-	0	0	0	0
is standardised.	0	0	+	0	0	0	+	0	0	+	+	+	+	+	0	0	0	+	+	+	+	+	0	0
PLUS	1	2	2	1	1	1	3	0	1	2	3	2	4	3	2	2	2	3	2	4	3	3	2	0
MINUS	0	0	0	1	1	0	2	0	0	3	4	2	2	2	0	0	0	2	2	4	0	0	1	0
NEUTRAL	10	9	9	9	9	10	6	11	10	6	4	7	5	6	9	9	9	6	7	3	8	8	8	11
SCORE	1	2	2	0	0	1	1	0	1	-1	-1	0	2	1	2	2	2	1	0	0	3	3	1	0
RANK	**9**	**3**	**3**	**16**	**16**	**9**	**9**	**16**	**9**	**23**	**23**	**16**	**3**	**9**	**3**	**3**	**3**	**9**	**16**	**16**	**1**	**1**	**9**	**16**

From the 23 designs, the top five (5) go to a secondary brainstorming session to develop combined and improved designs. These combined and improved designs are shown in TABLE XVI.

TABLE XVI

COMBINED AND IMPROVED CONCEPTS FROM PRELIMINARY CONCEPTS

#	Name	Description	Figure
16 A	Catch with Flap	This design consists of the original catch, but a flap is installed on the lower portion of the basket. The flap is mounted toward the belt and does not allow any blanks from slipping between the belt and the catch.	
17 A	Catch Wall	The design is a combination of belt walls and the catch. A simple basket that catches all coins that fall from the belt and has walls that guide the blanks toward the belts if the blanks fall diagonally away from the belt.	
17B	Catch Wall with Flap	The design is a combination of belt walls, catch and a flap. This is the same design as the Catch Wall but implements a flap underneath the basket.	
17 C	Catch Wall with Fender Bar	The design is a combination of belt walls, catch and a fender bar. The fender bar is welded to the lower portion of the catch and acts as a bumper to guide the blanks back onto the belt.	
22 A	Catch with Fender Bar	This design is a combination of belt walls, a catch and a fender bar.	

#	Name	Description	Figure
			
22B	Catch with Fender Bar and Flap	This design is a combination of belt walls, a catch, a flap and a fender bar.	

These new concepts resulted from combining concepts that excelled in certain areas and including secondary properties of other concepts that excelled in other areas. The concepts were improved by changing the material or the shape of the product.

5.3.2 Concept Scoring

The entire list of concepts were scored, from one (1) being poor to five (5) being exceptional in TABLE XVII. Each score for the specific need is multiplied by the respective weight of the need, placing more importance on the needs with higher importance.

TABLE XVII

COMBINED CONCEPTS FOR VFP TRANSFER POINT SCORING MATRIX

Letter	Needs	Weight	Concepts 16A	17A	22A	17B	22B	17C
A	Prevents spills between hopper and conveyor.	10%	5	5	3	5	3	5
B	Prevents spills between secondary transfer areas.	8%	4	2	4	4	5	4
C	Prevents spills caused by belt ribs.	8%	3	4	3	4	3	4
D	Performs precisely.	6%	3	3	3	3	4	3
E	Survives heavy use.	5%	3	5	5	3	3	5
F	Maintains other process conditions.	7%	3	4	4	3	3	4
G	Maintains its own condition.	2%	3	4	4	3	3	4
H	Is aesthetically pleasing (Instills pride).	1%	3	2	2	3	3	2
I	Is quiet.	3%	4	4	4	4	4	4
J	Functions under high vibration.	4%	4	4	4	4	4	4
K	Fits within current process limits.	7%	3	3	3	3	3	3
L	Is easy to install.	3%	4	4	4	4	4	4
M	Is lightweight and easily maneuverable.	2%	3	4	3	4	3	4
N	Maintains the original blank appearance.	10%	4	4	4	4	4	4
O	Is easily manufactured.	3%	3	4	3	3	2	3
P	Is easy to repair and replace.	2%	4	4	4	4	4	4
Q	Is safe in and out of use.	11%	4	4	4	4	4	4
R	Is standardised.	8%	3	4	3	4	3	4
	Score		3.61	3.84	3.59	3.79	3.52	3.97
	Rank		**4**	**2**	**5**	**3**	**6**	**1**

The top designs were scored in TABLE XVII with the combined and improved designs. The final designs that are being developed and further analyzed are the Catch Wall, Catch Wall with Flap, and the Catch Wall with Fender Bar.

5.3.3 Sensitivity Analysis

The Catch Wall with Fender Bar has the highest score and its rank cannot be exceeded by any others since there is a gap of 0.13 with second place. However, if we increase the ranking of the "easily manufactured" for the Catch Wall with Flap and lower the rank of "survives heavy use" for the Catch Wall, the scoring is different and the Catch Wall with Flap increases in rank and becomes the new second choice. Therefore, all three designs were selected for further analysis and optimization.

6.0 Final Concepts

The purpose of the final stage is to provide details of selected concepts from previous sections. In this section, we will provide two concepts design for the pre-press hopper transfer point, two for the VFB rear area and three for the VFP to conveyor transfer point.

6.1 Concept in Pre-Press Hopper Transfer Point

In the existing system, blanks are carried by conveyor belt from the VFP to the pre-press hopper area and fall into the hopper. This transfer point is a major noise-generating source. Paint and the Flat Hooked Plate are considered as potential solutions.

6.1.1 Paint

At the pre-press hopper transfer point, one of the most suitably ranked concepts was paint. We have identified that localized noise is generated by metal-to-metal collisions in the pre-press hopper. Applying a coating of paint to the inner walls of the hopper may provide ideal noise dampening. An idea that we have considered is to apply a thick paint layer to create a slightly softer surface to provide more dampening if needed. Furthermore, considering the implementation of this solution, all affected lines would need to be temporarily shut down in order to paint the pre-press hopper components and to dry. Since the coining presses function at a high rate (~750 RPM), a chip-resistant paint with a short drying time would be ideal for use, to minimize downtime costs. In order to remain safe for use, the paint coating cannot chip or deteriorate, otherwise, secondary quality problems would be created further down the process line. Once all the paint chips off, the metal-on-metal contact will resume, resulting again in excessive noise generation. This consideration is unavoidable and, due to the high likelihood of paint chipping, we will not consider this solution as a feasible option any further. Theoretically, a paint design can effectively solve the noise generation problem, but practically, it presents a great risk to product quality.

6.1.2 Flat Hooked Plate

In this design, we apply a flat hooked plate on the inner surface of the pre-press hopper chute. The design is meant to be self-supporting, using the curved upper edge to fix its location on the hopper chute. A potential material of the design is plastic, for creating a soft, yet durable interface at the chute-blank collision surface. A second material consideration is to create the plate from sheet metal and coat it with polyurethane, similar to other products at the RCM. Coating metal with polyurethane is a more complex, expensive and time-consuming option, but has been found to work effectively. Ideally, the Flat Hooked Plate material would not chip or alter blank appearance while in use. A desired material/coating hardness must be determined in order to verify this outcome. The yellow layer shown in Figure 12 represents the Flat Hooked Plate.

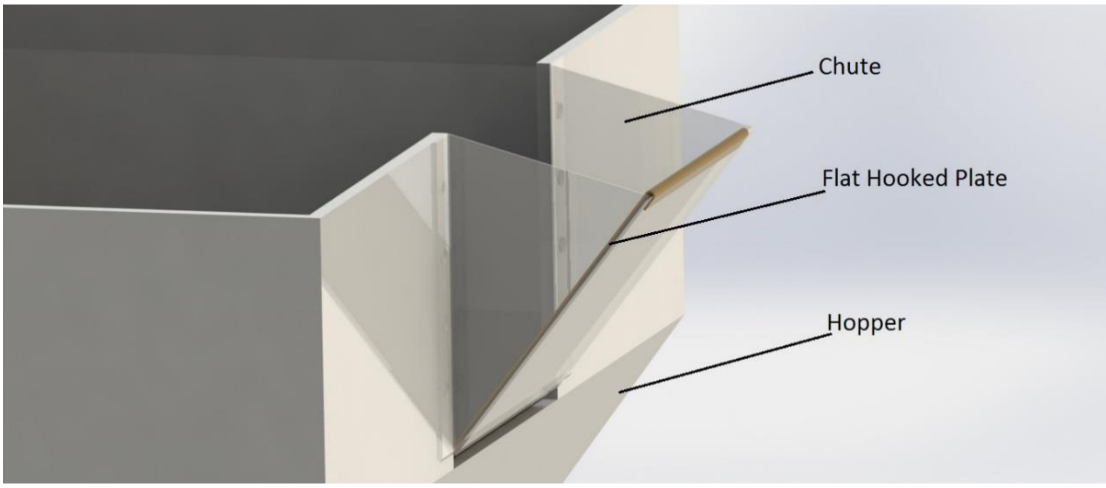


Figure 12. Detailed design of "Flat Hooked Plate"

The design is also easy to install and replace, if needed. The Flat Hooked Plate can prevent noise generation and damage to blanks due to collisions.

6.1.3 Selection

Both the paint and Flat Hooked Plate concepts appear to be effective in reducing noise generation in coining systems. Due to the high likelihood of paint chipping, we will not consider this solution as a feasible option any further. The Flat Hooked Plate is the final design concept for the pre-press hopper area and will be subject to further design alterations, material selection and manufacturing considerations.

6.2 VFPR

In the current system, blanks are forced to the VFPR and over the rear edge, onto the manufacturing floor. This area is one of the main blank spillage areas, especially when a large number of blanks is suddenly dumped into the feed hopper and onto the VFP. The Wall and the Simple Cover will be considered as possible solutions.

6.2.1 The Wall

The Wall aims to prevent blank spillage effectively by extending the rear and side edges of the VFP. Figure 13 shows a representation of The Wall while installed on the VFP.

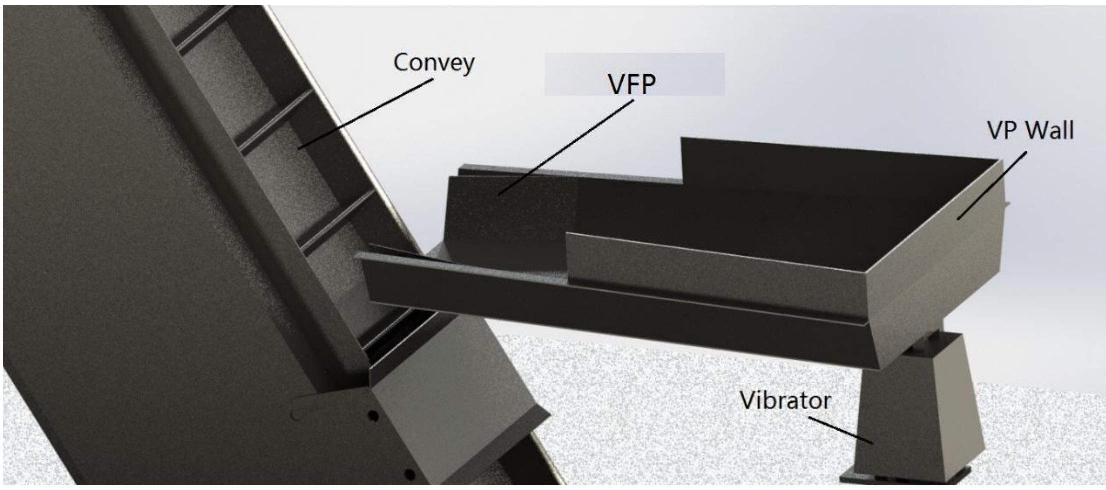


Figure 13. Detailed design of "The Wall"

The VFP vibrates so that blanks slide towards the conveyor belt and the wall acts to increase the effective storage capacity of the VFP, preventing blanks from bouncing out of the VFP while the blanks quickly exit the feed hopper. The installation and mounting of The Wall has been considered in two ways. The first is to replace the whole VFP with a higher edge at the end. The second, and cheaper option, is to fasten a bent material on the top of the VFP to raise the height of plate boundary. This could present challenges in developing a standardized solution, as some VFP's do not have a rear flange mount point, while others do. The primary material under consideration is stainless steel due to its malleability, corrosion resistance and its common use in industry. The Wall will be considered for further analysis in Section 6.2.3.

6.2.2 Simple Cover

This design is inspired by the current temporary solution at the RCM. The design shape follows the contours of the feed hopper output, however, does not contact the feed hopper. The design of the simple cover is shown in Figure 14.

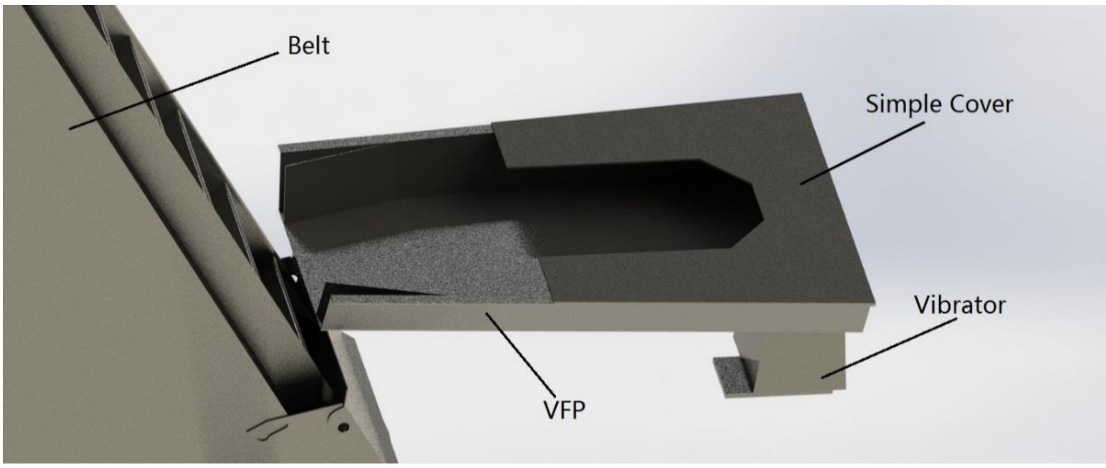


Figure 14. Detailed design of "Simple Cover"

This is to prevent blanks from moving rearwards and upwards along the VFP, while maintaining function under high vibration by not contacting the stationary feed hopper. The design is expected to be installed over a dampening media, such as foam tape, that is placed on the VFP flanges. This would be completed to ensure that no noise is generated due to vibrations. This design is simple, can be easily manufactured and installed. The flat cover serves in similar function with the current plastic boards, but should be more robust in order to replace the temporary solution with a permanent one. The materials under consideration are plastic and sheet metals such as stainless steel, steel and aluminum. This design aims to replace the temporary solution with a suitable product effectively.

6.2.3 Selection

Our client's needs are the basis for the two considered concepts, however, our industry contact's design recommendations aid in the final concept selection. The RCM has suggested that the design in the VFPR area maintain functionality and provide accessibility to maintenance workers and operators, both visually and physically. On this basis, we identified that both designs effectively prevent spills. However, the Wall design does not prevent upward blank movement while the Simple Cover does. Both designs satisfy other customer needs, such as maintaining process conditions, maintaining blank appearance and operating safely. In terms of physical accessibility, both designs should be designed to include removal without the use tools to save time and unnecessary work orders. Considering visual accessibility, the Simple Cover design would need to use a material such as metal wire mesh or clear plastic that provides visual access. The Wall design sufficiently provides access to operators. The two considered designs can effectively satisfy customer needs and recommendations, and so we choose the simpler design, the Simple Cover. The Simple Cover has a simpler geometry, is relatively compact and is more likely to be a standardized solution.

6.3 VFP to Conveyor Transfer Point

The VFP to conveyor transfer point is located at the bottom end of conveyor, where blanks spill off the VFP onto the conveyor. The Catch Wall, Catch Wall with Flap and Catch Wall with Fender Bar is briefly discussed below.

6.3.1 Catch Wall

The Catch Wall design prevents belt related blank spills by having extended sidewalls that prevent lateral blank movement. The design also uses a catch design, similar to that seen in industry products, to collect and direct fallen blanks back onto the conveyor belt. Figure 15 shows a representation of this concept. The Catch Wall has no moving parts, effectively prevents spillage, fits process limits, is safe and can be standardized.

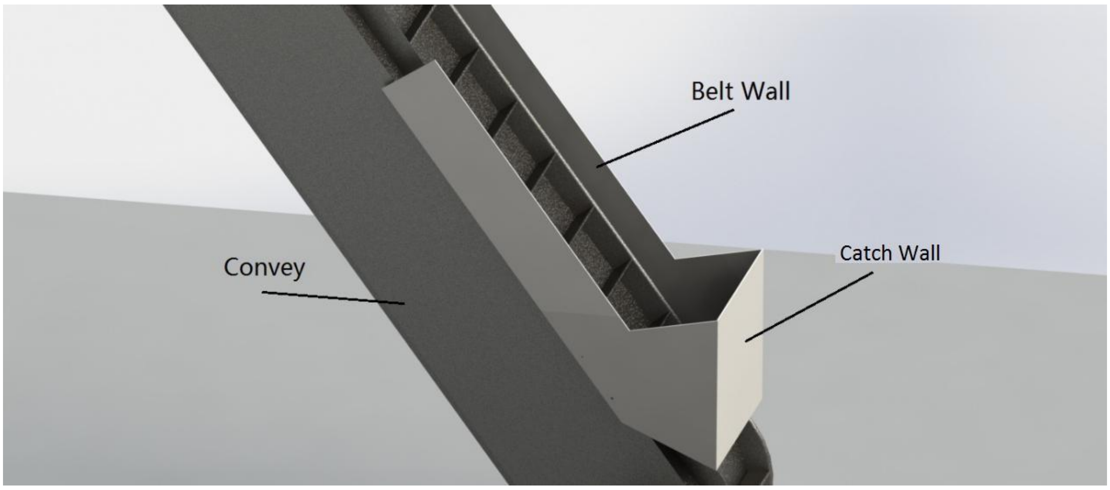


Figure 15. Detailed design of "Catch Wall"

The design is shaped to be easily manufactured and provides operator access for troubleshooting and monitoring.

6.3.2 Catch Wall with Flap

The Catch Wall with Flap is essential the same as Catch Wall, but includes a small, free-moving flap whose purpose is to catch any blanks that fall to the bottom of the belt. The flap serves as a failsafe feature to ensure zero blank spillage. This design was ranked slightly lower than the Catch Wall with Fender Bar as the flap is a moving part that could wear and disturb belt performance. As belt paddles move, they will contact the flap edge and move it upwards. When the belt paddles have moved too high and are no longer in contact, the flap will fall to its resting position and release any fallen coins back onto the belt. A representation is shown in Figure 16.

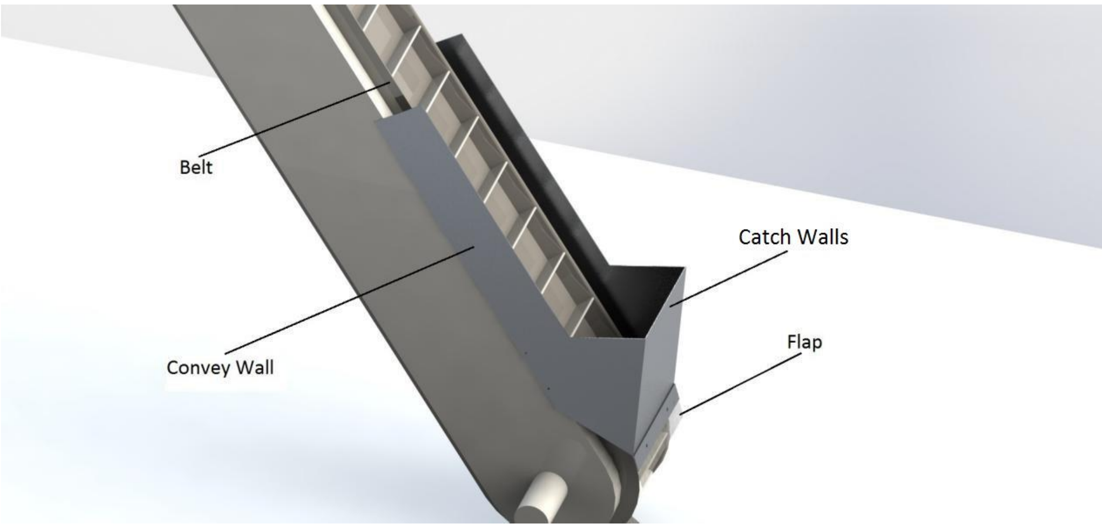


Figure 16. Detailed design of "Catch Wall with Flap"

The flap is expected to be made of a soft, non-belt-damaging material, such as plastic, and it is bolted, pinned or fastened on the tail part of the catcher.

6.3.3 Catch Wall with Fender Bars

The Catch Wall with Fender Bars ranked highest of all the designs. This is because this concept has no moving parts, includes fail-safe fender bar features and operates safely. The upper part attaches to the conveyor frame in the same way as the Catch Wall; however, the lower portion contains a fender with two internally positioned catch bars to prevent spillage at end of the catcher. The geometry of the fender with bars is similar with the existing fender, but with two V-shaped bars bolted on the inner face, to create an uneven surface. Any blanks that fall downward will collide with the bars, and bounce back to the belt. The initial fender bar shape was selected to redirect falling blanks towards the inside of the belt, but this shape can be later optimized. This design is shown in Figure 17.

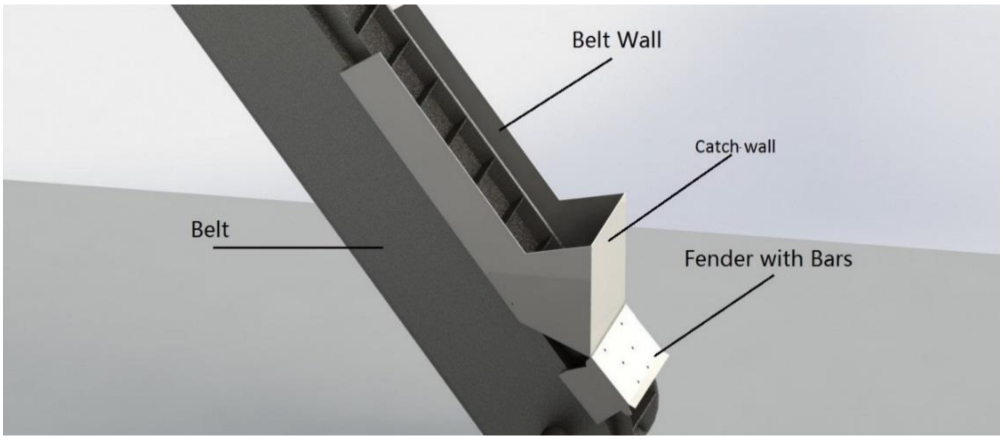


Figure 17. Detailed design of "Catch Wall with Fender Bars"

The representation in Figure 18 shows how the fender bars will interact with the current system.

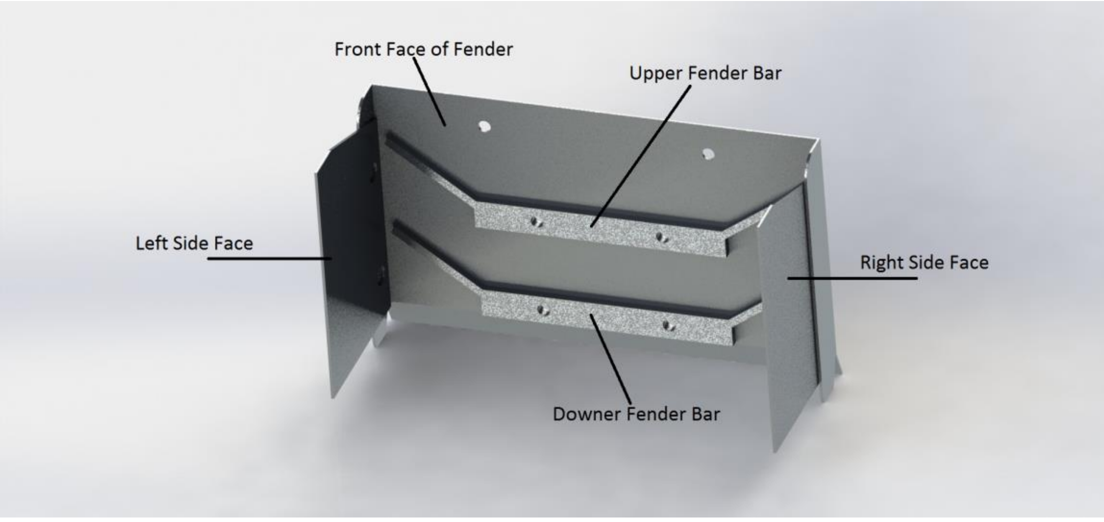


Figure 18. Detail structure of fender with U-shape bars

The fender assembly includes left and right side faces, downer and upper fender bars and a front face. All components are bolted together, and the side face is fixed on the side of current belt seat. The gap between fender bar and belt ribs must be minimized for the final design.

6.3.4 Selection

The three solutions in presented in this section are very similar in design. Since this Catch Wall concept is a simplification of the Catch with Fender Bar and Catch with Flap, it will not be considered as a final solution for transfer point spills. Furthermore, we have decided that testing of prototypes must be completed before a final concept can be selected. Testing the concepts will provide data for comparisons and more insight into which design is best suited as a system solution.

6.4 Preliminary Cost Analysis for Final Concepts

The cost for each final concept depends on five (5) variables, which are the material used, machining time, labor hours, test equipment rentals, and other manufacturing. The following two tables, TABLE XVIII and TABLE XIX show the time and cost for one (1) prototype, six (6) designs in the previous sections.

TABLE XVIII

ESTIMATED TIME TO MANUFACTURE AND BUILD CONCEPT PROTOYYPES

	Final Concepts	Material Type	Machining Time (h)	Labor hours(h)	Test Rentals (h)	Other Manufacturing (h)	Total time for Prototype (h)
Pre-press Hopper Area	Paint	Paint	0	2	3	1	6
	Flat Hooked Plate	plastic	3	1	3	1	8
VFPR	The Wall	316 SS	1	1	1	1	4
	Simple Cover	316 SS	1	1	1	1	4
VFP to Conveyor Transfer Point	Catch Wall with Flap	316 SS	11	6	1	1	19
	Catch Wall with Fender Bars	316 SS and plastic	12	7	1	1	21

TABLE XIX

COST OF PROTOTYPE FOR TOP CONCEPT DESIGNS

	Final Concepts	Material Type	Material Cost (CAD)	Machining (CAD)	Labor (CAD)	Test Rentals (CAD)	Other Manufacturing (CAD)	Total cost for Prototype (CAD)
Pre-press Hopper Area	Paint	Paint	100	0	70	75	30	275
	Flat Hooked Plate	plastic	200	90	35	75	30	430
VFPR	The Wall	316 SS	150	30	35	25	30	270
	Simple Cover	316 SS	150	30	35	25	30	270
VFP to Conveyor Transfer Point	Catch Wall with Flap	316 SS	300	330	210	25	30	895
	Catch Wall with Fender Bars	316 SS and plastic	300	360	245	25	30	960

In TABLE XIX, we assume:

- The cost for machining is $30 CAD per hour
- The cost for labor is $35 CAD per hour
- The cost for test rentals is $25 CAD per hour, and

- The cost for other manufacturing is $30 CAD per hour

Recall the cost management in section 2.2, the cost limit to build one prototype should not be exceeding $2700 CAD. In the final combination, we need to choose at least one concept for each application area. If we assume the most expensive concepts are selected, we can conservatively estimate total costs. According to cost table above, the total cost is $1660 CAD, which is less than our $2700 CAD budget. We can conclude that all combinations of final concepts are available in the term of budget management.

7.0 Testing and Analysis

The Catch with Fender Bar and the Catch with Flap were tested on two (2) D-line conveyance systems. A confirmation of design performance was desired to determine what concept would be pursued and developed.

7.1 Testing Plan

A test plan is required to track the prototype performance under full processing conditions. During testing there were a few parameters tested to validate that the product meets all objectives. These parameters are shown in TABLE XX along with the way that each parameter will be measured.

TABLE XX

PARAMETERS USED FOR TESTING THE PROTOTYPE AND THE MEASURING METHODS FOR EACH PARAMETER

Parameter	Measuring Method
Noise Level	Using a decibel meter, the noise level is measured before and after the product is installed, as well as, measured before and after the machine is running.
Pinch Points	Once installed, all aspects of the product are observed and areas where safety hazards may appear are recognized.
Spilled Blanks	The blanks that fall past the product or get caught in the belt are measured by weighing or counting the blanks that fall into the tray under the conveyance system.
Damaged Blanks	The blanks that get caught in the belt or are show deep scratching due to the product are measured by counting each damaged blank.

Fitment on Different Machines	Since a standard product is one of the goals of the project, creating a solution that can be implemented on multiple different conveyance systems is a main goal. To test if the product is standard for many machines, the product is installed onto a few different conveyance systems to verify if it is standard.

To test these different parameters, initial prototypes were made from a pliable foam material. This was done so that interference is not an issue and all areas of the designs fit within the conveyance system. The prototypes were installed on specific conveyance systems and the spilled blanks measured using the methods from TABLE XX. All tests were conducted on parallel D-line presses (D2 and D6). All prototypes were installed onto the conveyance system during a shift change.

7.2 Prototypes

Of the final concepts relating to each problem area, only the Catch with Flap, Figure 19a, and Catch with Fender Bar, Figure 19b, were developed into prototypes.

a) b)

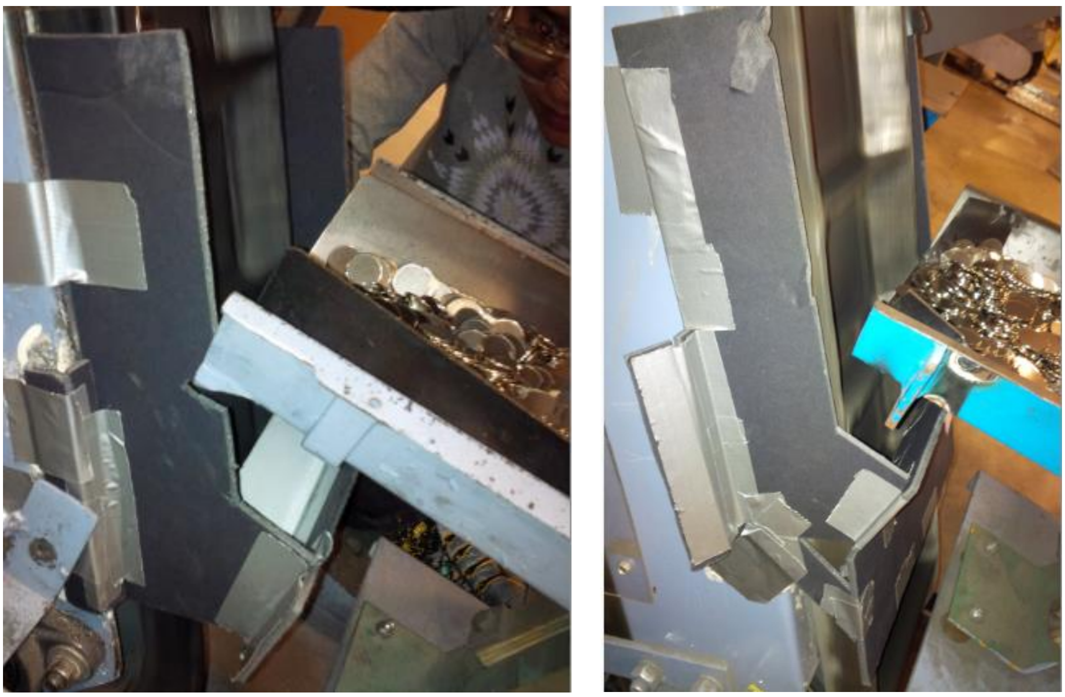


Figure 19. Prototyped Catch with Flap (a) and Catch with Fender Bar (b)

Designs that are very similar to the Simple Cover design are currently used as temporary solutions at the RCM and prove to prevent spillage. The Flat Hooked Plate design was not prototyped because the pre-press hoppers for the different coining presses have great variation in geometries. A further assessment of the various pre-press chute internal geometries must be confirmed before the design can be deemed an effective and standard solution.

As mentioned, the prototypes were created from a pliable foam material that remains stiff during use but allows for easy modification, if necessary. Tape and construction paper were also used to secure various prototype components and provide a method of fastening to the tested system. The total cost for the two initial prototypes was less than $10 CAD.

7.3 Prototype Analysis

The Catch with Fender Bar and Catch with Flap have been tested and data has been collected on their performance. Each prototype was setup on a different conveyance system and subject to one hour of conveyance system operation. The prototypes were aligned in relation to the conveyor belt and then secured to the frame of the conveyance systems using duct tape, for easy removal if modification was required. To compare the results of the two tests we must compare the testing conditions. The testing conditions are shown in TABLE XXI.

TABLE XXI

PROTOTYPE TESTING SYSTEM CONDITIONS

Prototype	Catch with Fender Bar	Catch with Flap
Coining System	D6	D2
VFP Electronic Controller Setting	6-8	4-6
Blanks transferred to belt (per cleat)	~30-45	~25-40
Belt Speed	0.5ft/s	0.5ft/s
Press Output	750 RPM	750 RPM

The testing scenarios are not ideal for an identical and accurate comparison. The process restrictions, set by the RCM, govern which coining systems could be used and the output of each system. The most notable difference is the number of blanks transferred to the belt per system. This value is in proportion to the VFP electronic controller setting, which controls the frequency at which the VFP vibrates. The results of the tested Catch with Fender Bar prototypes are in TABLE XXII.

TABLE XXII

CATCH WITH FENDER BAR PROTOTYPE I TESTING

Catch with Fender Bar			
Run #	Duration (minutes)	Spilled Blanks	**Notes**
1	2	25	-Fender bars became dislodged during run
2	3	17	-Adjusted upper wall in and added deflector to top fenders
3	1	3	-All blanks fell out right side of the belt
4	3	6	-One (1) blank fell out left side of the belt
5	6	1	-Fender bars are contacting belt and act slightly like a flap
6	2	0	-Fender bars are contacting belt and act slightly like a flap

Each run represented the operating time when the VFP was transferring blanks to the conveyance system. Various modifications to the prototype were made between consecutive runs in order to eliminate spill areas. The primary area where blanks were found to spill off the conveyance system was between the outer edge of the belt and the inside edge of the prototype side walls. This was due to the settling of coins and cleat overfilling. When coins are transferred to the belt, gravitational forces and the dynamic forces of the moving belt cause blanks to settle or shift in relation to one another. These shifts result in blanks shifting over the edge of a belt rib wall or belt cleat. Similarly, when cleats are overfilled with blanks they spill over the cleat and gain downward momentum that can dislodge other blanks. To prevent spillage, the prototype fender bars were reinforced, the sidewalls were narrowed and a lateral deflector was added. The number of spills for each consecutive run was found to be decreasing.

The results of the tested Catch with Flap prototype are in TABLE XXIII. There are seven runs are recorded for testing Catch with Flap prototype. The durations of each run were around two minutes.

TABLE XXIII

CATCH WITH FLAP PROTOTYPE I TESTING

Catch with Flap			
Run #	Duration (minutes)	Spilled Blanks	**Notes**
1	2	3	-The side wall of prototype interferes with the VFP. We cut an opening on the side for fitting. All blanks spill through right side gap between the outer sides of belt ribs and catch
2	2	4	-Three (3) blanks fell out through right side gap, one(1) fell out due to bad belt shape
3	2	4	-All blanks fell out through right side gap
4	2	4	-Three (3) blanks fell out through the right side gap and one(1) passed through the flap until the testing end
5	2	4	-Two (2) blanks fell out the left side gap and two (2) fell out due to bad belt shape
6	2	0	-No spillage
7	2	1	-The blank fell out the left side gap

The test shows sixteen (16) out of twenty (20) blanks were found to spill through the left gap, and three (3) blanks spilled due to the damaged belt and one spill was caused by the material of prototype.

The shape of the sidewall is required to be changed due to interference with the bottom ribs of VFP. In D2 line, the belt is not located on the center of convey seat, it is shifted along the drive and driven rollers to the left side and a large gap is left between the outer side of belt and prototype flap on right side. Meanwhile, the right side of the prototype is worn by the belt due to shifting. During the test, some blanks are clamped in the belt due to its poor condition, and carry down for a loop travel instead of dropping into the pre-press hopper. The last cause of spillage is rare and unlikely to occur in an actual design. The spilt blank fell onto the prototype flap and adhered to the tape that we used to tape the flap to the catch body. The blank stayed on the flap until the end of testing.

7.4 Test Results

For each design concept, there are other considerations to take into account before the design is ready for use. Included are the method of fastening each design, material selection, determination of dimensional clearances and interferences, additional features and installation methods. These considerations will be defined for each final concept.
The testing plan called for an analysis of the noise level, pinch points (safety), spilled and damaged blanks and dimensional accuracy of the prototype.

7.4.1 Noise Generation

The noise generation in the areas where the prototypes were installed was negligible compared to the surrounding noise of the manufacturing floor (>85dB). The primary local noise generation area is at the entrance to the pre-press hopper. For these reasons, the noise level was not determined for the initial prototypes. The noise level should be measured for the final prototype of the pre-press hopper area design to confirm effectiveness.

7.4.2 Pinch Points

On both prototypes, the pinch points were identified in the following regions:

- Between the flap/fender bar and belt
- Between the inside catch walls and the outer edge of the belt

We will adjust the dimensions of our designs in order to eliminate pinch points.

7.4.3 Spilled Blanks

The number of spilled blanks was determined and is shown in TABLE XXII and TABLE XXIII. The Catch with Fender Bar prototype had 27 spilled blanks in 17 minutes of operating time, averaging 1.6 blanks spilling per minute. The majority of these spills occurred on the first run and were due to large gaps between the outer belt edge and inside catch wall. The Catch with Flap had 20 spills in 14 minutes of operating time, averaging 1.4 blank spills per minute. The spillage was fairly constant over each run and was primarily caused by poor belt condition and gaps between the flap and side catch walls. We aim to achieve zero blank spillage and all adjustments made to the prototypes must be considered in the design development and final design.

7.4.4 Damaged Blanks

The tests resulted in zero blanks damaged by the prototypes during testing and is unlikely to occur when a real guard is implemented.

7.4.5 Fitment

The fitment of the prototypes on conveyance systems was assessed. Installing the prototypes was not possible without dismantling them into two (2) components due to space restrictions. The height of the sidewalls of the prototypes also contacted the VFP. The sidewalls proved to be too short at the end furthest from the VFP and did not prevent blank spillage effectively. The fenders bars rubbed against the belt cleats during use and the flap resulted in being an insufficient length, allowing blank spillage in the narrow spaces between the belt ribs and flap. The length of the Catch with Fender Bars also made installation between the belt and the VFP difficult. These parameters must be adjusted accordingly in the final design. These changes will be discussed in Section 8.0.

7.5 Process Observations

Several observations regarding the conveyance system operating conditions were observed during testing. It was noted that the conveyor belts on each system have 56 belt cleats and therefore 55 blank carrying belt sections. It was also noted that the belt speed is 0.5ft/s = 6in/s. Each belt section (cleat to cleat) is five (5) inches long and each coining press was observed to have an output of approximately 700-800 coins per minute. An ideal number of blanks to be transferred per belt section can be determined such that the coining press is constantly being fed. The ideal number of blanks transferred from the VFP to a belt section is:

$$\frac{Blanks}{BeltSection} = Press\ Output/(\frac{BeltSectionsRotated}{minute})$$

$$\frac{Blanks}{BeltSection} = \frac{800RPM}{\frac{72}{minute}} = \mathbf{12\ Blanks/BeltSection}$$

Therefore, we can say that the electronic controller settings on each system should be adjusted such that approximately 12 blanks are transferred to each belt section.

7.6 Testing Summary

After creating and testing the prototypes, the design chosen is the Catch with Flap. This design experienced a lower spill rate of 1.4 blanks/min than the Catch with Fender Bars at 1.6 blanks/min. Another benefit of the Catch with Flap is the compact length, allowing it to be installed in smaller spaces. There will need to be procedural recommendations for the conveyance systems, as a standardized VFP feed rate would give more control and less spillage than by operator intuition.

8.0 Design Development

For each design concept, there are issues that need to be addressed before implementation. Some considerations include the method of fastening, material selection, determination of dimensional clearances and interferences, installation methods and need fulfillment. These considerations will be defined for each final concept.

8.1 Flat Hooked Plate

The various modifications to the Flat Hooked Plate concept are considered in detail in this section. Design modifications are made to ensure the final design will satisfy customer needs. The pre-press hopper chute was analyzed to determine points of noise generation and geometric restrictions. A simple representation of the pre-press hopper chute geometry is shown in Figure 20.

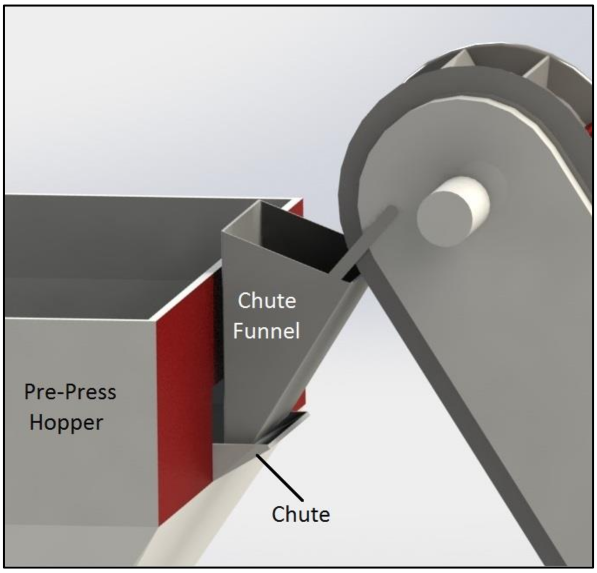


Figure 20. Pre-press hopper, chute and funnel representation.

It was observed that noise is produced as the blanks contact the vertical face of the chute funnel and the bottom face of the pre-press hopper chute. There is minimal clearance between the chute funnel and chute as well as between the chute funnel and conveyor belt.

8.1.1 Design Features

The initial Flat Hooked Plate concept was expected to simply secure onto the edge of the pre-press chute using a curve hook. After identifying the chute input geometry, it was determined that there is insufficient space to secure our concept design without increasing the risk of contacting the moving conveyor belt. We decided that eliminating the curved hook and using an adhesive backing, would allow for a standardized method of securing the Flat Hook Plate. This method would also eliminate the risk of contacting the conveyor belt.

Next, we analyzed current and past solutions to noise generation problems at the RCM. We found that using a polyurethane, or similar material of adequate hardness, will almost entirely eliminate the noise from falling blanks. The polyurethane or similar material should cover the surfaces regularly contacted by falling blanks. We decided that using a material with adhesive backing would be ideal. The desired material hardness was selected according to our calculations of expected impact forces of falling blanks. The mass of five (5) loonies, toonies and quarters were measured as 34, 37 and 23 grams, respectively. Assuming that an average of 30 blanks are transferred into the pre-press hopper at any one time, as an average value determined from test data, we can determine the impact force of 30 blanks. Using the mass of 30 toonies, as they are the heaviest coin manufactured, we find that the force of blanks on the NeoDamp surface is:

$$F = m_{30}a = \ (m_5 * 6)a = (0.037grams * 6) * \frac{9.81m}{s^2} = 2.2N$$

The Shore durometer hardness scale measures the hardness of a material in resistance to impact loading. The durometer A type resists a 1.40mm diameter indenting steel rod that applies a spring force of 8.06N. When the durometer scale reaches a number of 100A, the tested material is not indented at all. Since the expected force of 2.2N is much less than 8.06N the design is sufficient. To create a force of 8.06N would require more than 100 blanks and this does not occur during operating conditions, so we select a durometer Shore hardness of 70A. This value is deemed hard by ASTM and materials with this hardness will exhibit properties similar to that of automotive tire tread [13].

The pre-press hopper chutes on each system varied in size and shape. Our selected design is easily adapted to these various chute geometries, is easy to install and effectively dampens noise.

8.2 Catch with Flap

The transfer point between the VFP and conveyance system must prevent the spill of blanks. The Catch with Flap is fastened onto the conveyor frame and sits beneath the VFP. This design must fit within process limits, perform safely and achieve a zero blank spillage rate.

The various modifications that allow this design satisfy the project needs will be discussed in detail.

8.2.1 Design Features

As the testing data showed, there were several shortcomings of the Catch with Flap design. The first is that the catch side plates, running parallel with the belt, leave excess space for blanks to spill through. Consequently, we changed the side plates to a stepped design with a lower portion that is secured to the belt frame and the upper portion can fit tightly to the belt. This will eliminate the blank spills along the belt sides.

Secondly there were installation issues with the prototypes due to the limited space under the VFP. We split the Catch with Flap design into three (3) pieces that can easily be installed within the limited space. The pieces attach on a common flange edge as shown in Figure 21 and Figure 22.

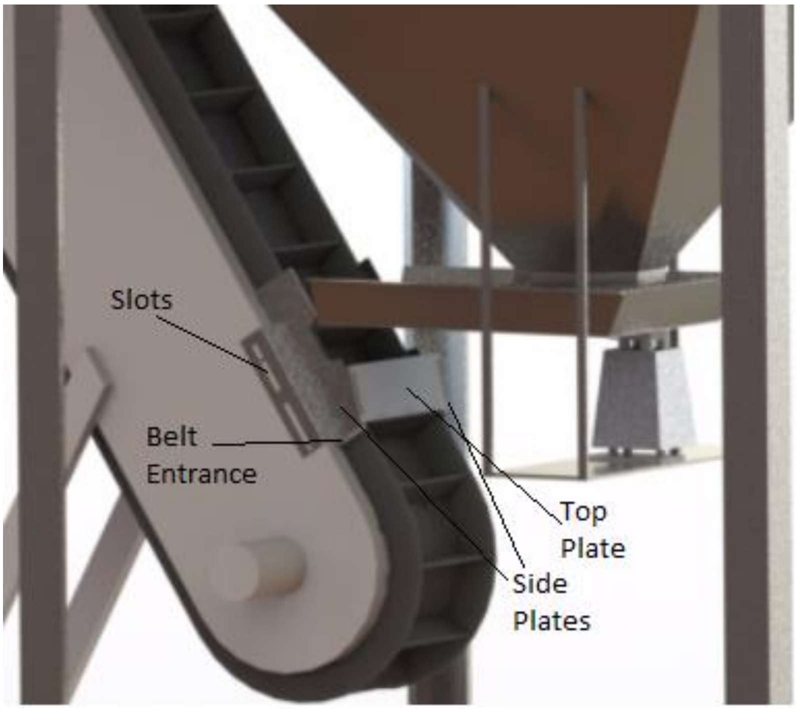


Figure 21. Blank Catch installed onto a D-line conveyance system

During testing the Catch with Flap, the walls had to be cut out down to install around the VFP. The height of the side plate walls were adjusted to be installed around the VFP without interference.

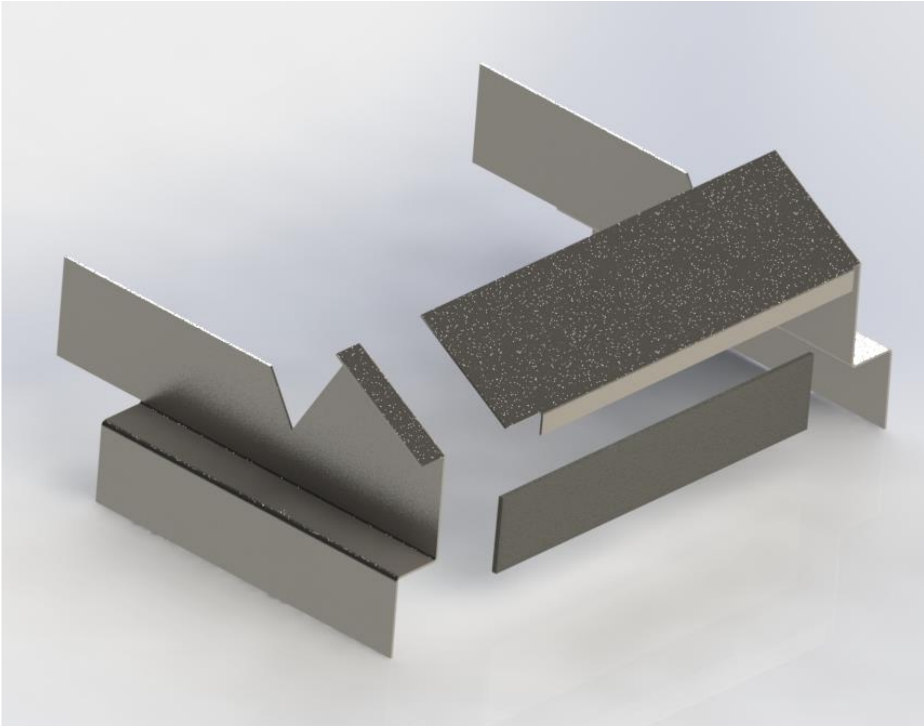


Figure 22. Exploded view of design features on the catch with flap.

To prevent sudden and violent interaction between the catch and belt ribs as the belt feeds through the catch, angled lower flanges were created. These flanges serve to gently guide the belt into the catch walls as the belt ascends the conveyor.

The catch’s flap sits perpendicular to the belt surface when at rest, but is pushed up by the ascending cleats. The flap pivots on two (2) hinges mounted onto the top plate to freely allow belt cleats to pass through. To prevent the flap from swinging too far back and jamming the oncoming cleat the range of motion must be restricted by a stop. This motion can be seen in Figure 23.

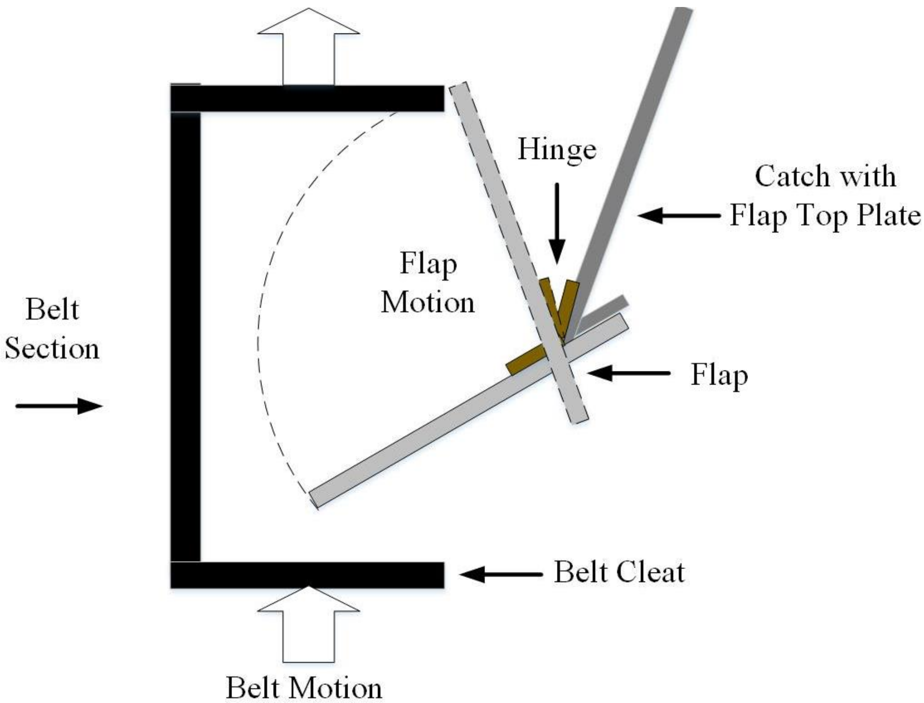


Figure 23. Flap motion representation.

The loading cycles are proportional to the lifetime of the product and the movement speed. We assume that the speed of the flap is one (1) cycle per second and the flap is being used whenever the conveyance system is used. The press is used for two (2) shifts eight (8) hour shifts per day. The press runs for five (5) days a week for a full year. If we assume a life of 10 years for the Blank Catch we can calculate the load cycles for the flap using the equation below.

$$Load\ Cycles = Lifetime * speed$$

$$Lifetime = (10years * 5days * 52weeks * 16hours * 60mins * 60seconds)$$

$$Load\ Cycles = 149{,}760{,}000\ cycles$$

Since the load cycles are quite high, we decided to use a rubber with a higher material hardness. A shore value of 70A was chosen which correlates to a shoe sole hardness for the rigidity and the strength of this type of rubber.

The top plate has slots that allow bolts to pass through and fasten the top plate and the side plates together. These slots also offer adjustability to move the flap closer for further from the belt as desired. Figure 24 shows the final modified design.

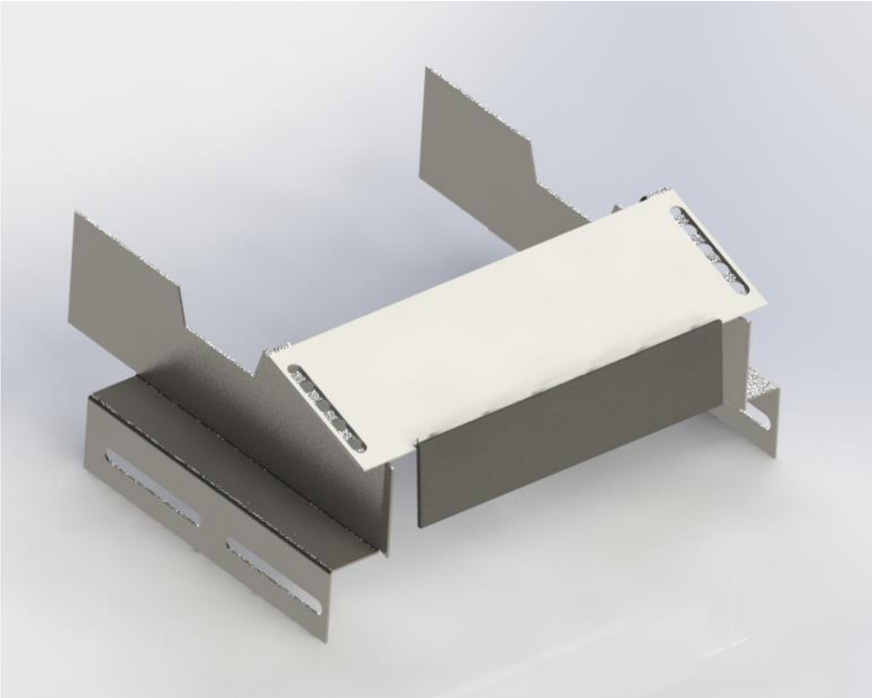


Figure 24. Catch with flap modified design.

The design is expected to be installed using current bolt holes on the belt frame. Each conveyor has different displacements between existing bolt holes. As a result, we created mounting slots on the lower portion of the two side plates of the catch to allow for adjustability and accommodate the differing belt frames. The mounting slots on the side plates also allow for positional refinement along the direction of the belt, to accommodate to the varying VFP shapes and sizes.

8.3 Simple Cover

The Simple Cover prevents blanks from spilling out of the VFPR. The inspiration for this design are the temporary solutions in place across D-line. Plastic and cardboard plates have been cut out and fastened to the VFPs. Various concept design modifications will be considered to enhance performance.

8.3.1 Design Features

The Simple Cover is designed to maintain visual accessibility, safety, withstand vibrations, maintain conditions and prevent spillage. Operators must see through the cover to determine if the VFP is empty of blanks, especially when changing between currencies. Mixing blank types can damage the press and cause delays in manufacturing. We selected a wire mesh design. The cut edges of the mesh can be sharp so an edge trim is placed along the outer edge. The design is also expected to function under high vibrations and be safely and easily removed without tools, negating the need for a mechanic's assistance or a work order. Several candidate hardware fasteners were considered including Nord-lock washers and spring-loaded pins. Using Nord-lock washers, a bolt and a wingnut would adequately fasten the design to the VFP. However, if the wingnut is overtightened, tools will be needed to remove it. We decided that the Simple Cover be fastened to the VFP through four (4) bolts or clevis pins. A clevis pin requires no tools to remove, but will maintain a tight fit in a high vibration area if used with a spring. By compressing a spring on the clevis, the cover will stay tightly sealed against the VFP flange. The four (4) holes that the pins will slide into are located along the side flanges of the VFP, as some VFP designs do not have rear edge flanges. The VFP area must maintain functionality and accessibility for mechanics and operators.

8.4 Material Selection

We chose a primary group of materials to access use in the final design. The chosen materials are mild steel, aluminum 6061, stainless steel 304, high density polyethylene (HDPE), neoprene, polyurethane, steel mesh and Noiseless Steel. The manufacturing processes are broken down into bendability, machinability, weld ability and workability. A material with a high ranking receives a score of three (3), while a low ranking receives a one (1). TABLE XXIV shows the scores of each material's manufacturability.

TABLE XXIV

MANUFACTURABILITY OF SELECTED MATERIALS

	Bend	Machine	Weld	Workability	Score
Mild Steel 1018 [14]	High	Medium	High	High	11
Aluminum (6061) [15]	Medium	High	High	High	11
Stainless (304) [16]	High	High	High	Medium	11
HDPE (Rigid)	Medium [17]	Medium	Medium [18]	Medium	8
Neoprene	High	Low	Low	Low	6
Polyurethane [19]	Low	High	Low	Low	6

	Bend	Machine	Weld	Workability	Score
Steel Mesh	Medium	Medium	High	Medium	9
Noiseless [20]	High	High	Low	Medium	9

The aluminum, mild and stainless steel score the highest at 11 while polyurethane and neoprene only receives a score of six (6). TABLE XXV quantifies each material by manufacturability, cost, coefficient of friction, surface finish and quietness.

TABLE XXV

MATERIAL PROPERTIES FOR MANUFACTURING

Material (48”x48”x$^{1}/_{8}$”)	Manufacturability	Cost [USD]	Coefficient of Friction [21]	Surface Finish	Quietness [22]	Endurance Limit [MPa]
Mild Steel (Zinc-Galvanized) ($^{1}/_{16}$” thick)	High	$140.30 [23]	0.62	Must be painted	Low	270 [24]
Aluminum (6061)	High	$285.61 [25]	0.47	Good	Low	None
Stainless (304)	High	$298.77 [26]	0.64	Good	Low	240 [27]
HDPE (Rigid)	Medium	$36.56 [28]	0.18 [29]	Good	Medium	None [30]
Neoprene Peel and Stick (50”x40”x$^{3}/_{32}$”)	Low	$45.54 [31]	2.2 [32]	Good	High	Unknown but synthetic rubber is high
Polyurethane	Low	$193.94 [33]	0.4-1 [34]	Good	High	Unknown but synthetic rubber is high
Steel Mesh (2x2 Mesh, 0.063” wire)	Medium	$32.76 [35]	~0.8	Good	High	<240
Noiseless Steel	Medium	>$300	0.64	Good	High [36]	~240

Using a material matrix and scoring from one (1) to five (5), the best material can be selected for the catch design, the simple cover, and the upper hopper design by ranking each choice shown in TABLE XXVI.

TABLE XXVI

MATERIAL SELECTION MATRIX

	Cost	Manufact.	Coefficient of Friction	Surface Finish	Endur. Limit	Quietness		
Weight	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**	**0.2**	**Score**	**Rank**
Mild Steel (1018)	3	5	4	2	5	1	3.3	6
Aluminum (6061)	2	5	4	4	1	1	2.8	8
Stainless (304)	2	5	4	4	5	1	3.6	2
HDPE (Rigid)	5	3	5	4	1	4	3.4	5
Polyurethane	3	1	3	4	5	5	3.6	4
Steel Mesh	5	3	3	4	3	4	3.6	2
Noiseless Steel	1	3	4	4	4	3	3.3	6
Neoprene	5	1	2	4	5	5	3.7	1

The steel mesh allows for high noise dampening, high visibility and a moderate manufacturability which make it a good selection for the VFPR design. The cut edges of the mesh should be covered with rubber guarding to prevent operator injury. Stainless steel 304 has high manufacturability, has a high endurance limit and doesn't cost as much as Noiseless steel, so the Catch with Flap body will use stainless steel 304 for construction. We select polyurethane as the material for the flap as it has a great endurance limit and is very quiet in operation. Neoprene is recommended in compact and oddly shaped areas experiencing noise due to impact, as it is excellent at dampening noise, such as the pre-press hopper.

8.5 Design Names

The concept names no longer suffice in accurately describing the designed products. The Flat Hooked Plate, Catch with Flap and Simple Cover will be hereafter called NeoDamp, Mesh Block and Blank Catch. These names represent the final designed products, which will be discussed in detail in the following section.

9.0 Final Design

The final designs aim to fulfill the primary objectives of the Royal Canadian Mint, namely, to achieve zero blank spillage, reduce noise, and increase operator access and safety. To address these issues we designed the NeoDamp, the Mesh Block, and the Blank Catch to address. The NeoDamp is a designed to dampen noise generated by blanks, as they fall from the belt into the pre-press hopper. The Mesh Block eliminates blank spillage from the vibrating feed plate. Lastly, the Blank Catch directs falling blanks from the VFP onto the belt. Collectively the designs satisfy the primary objectives and have special features that meet the client's needs. The features and how they meet the client's objectives, manufacturing, installation, bill of materials and cost will be discussed in this section.

9.1 Pre-Press Hopper: NeoDamp

The pre-press hopper area is the main source of noise generation for all coining systems. There is no spillage at this area and it is beyond the reach of operators and technicians, therefore it is deemed safe. The NeoDamp design features, installation considerations and components adequately address the client's primary objectives.

9.1.1 Design Features

The NeoDamp consists of a neoprene sheet with adhesive backing. The size of the design is determined in relation to the specific conveyance system chute that it will be installed on. The dimensions of a NeoDamp design are shown in Figure 25. The NeoDamp thickness is selected in relation to the material's hardness and such that the surface will contact the bottom edge of the chute funnel. The NeoDamp solution is a simple, safe and an effective noise reducing design.

9.1.2 Manufacturing

The manufacturing of NeoDamp is simple and quick. A purchased ¼" thick, 36" x 12" neoprene sheet should be cut to size according to the conveyance system on which it is installed. The sheet must be cut using a knife and straight edge. The manufacturing of the NeoDamp design allows for easy adaptation to various geometries.

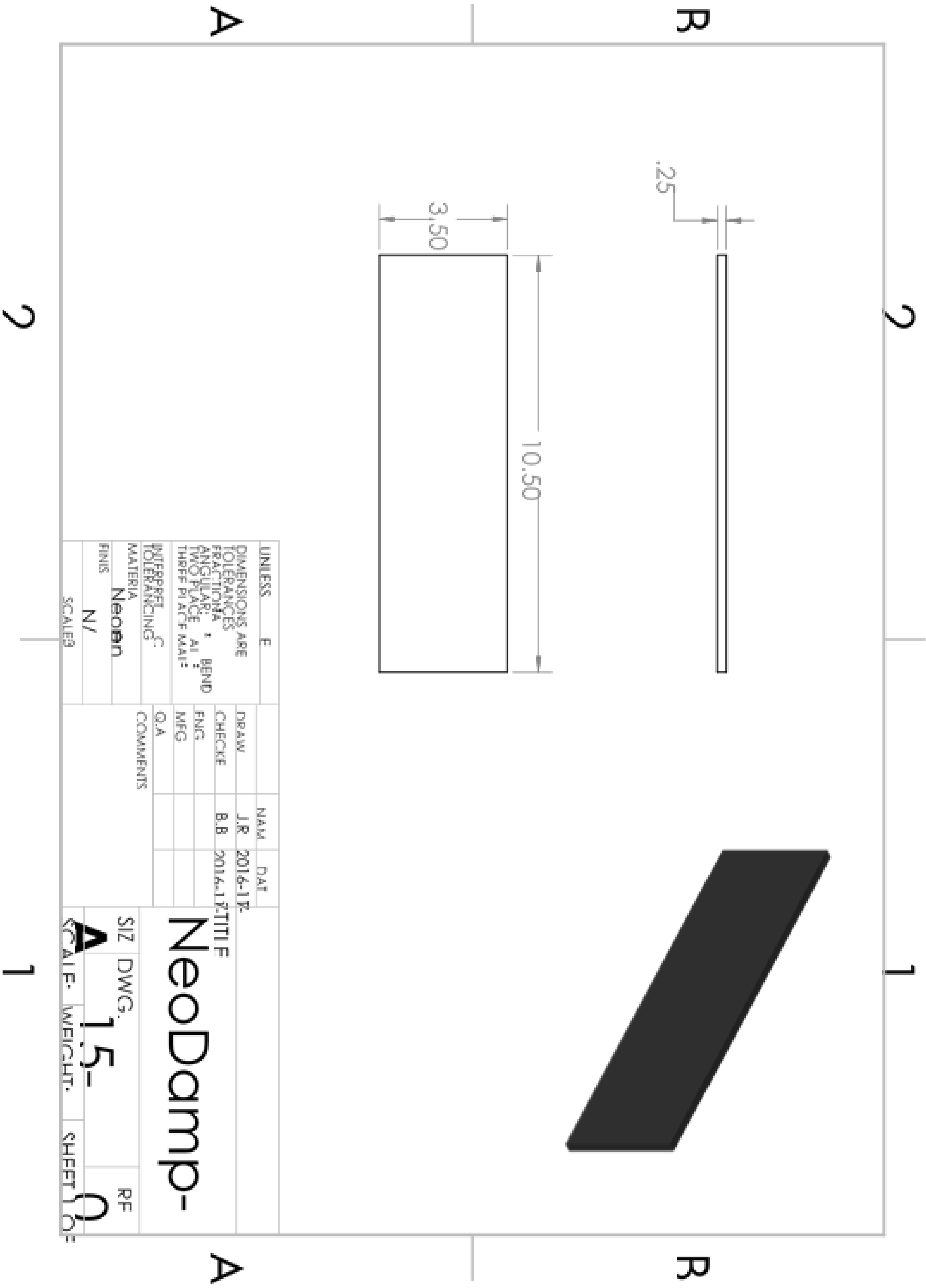


Figure 25. NeoDamp dimensions for manufacturing

9.1.3 Installation

The installation of this design is simple and can be completed without tools. The chute surface must be clean before removing the protective film covering the adhesive backing of the neoprene sheet and installing, with the adhesive backing face down, on the inside face of the pre-press hopper chute. The inside faces of the neoprene sheet and the chute should be aligned flush, as shown in Figure 26.

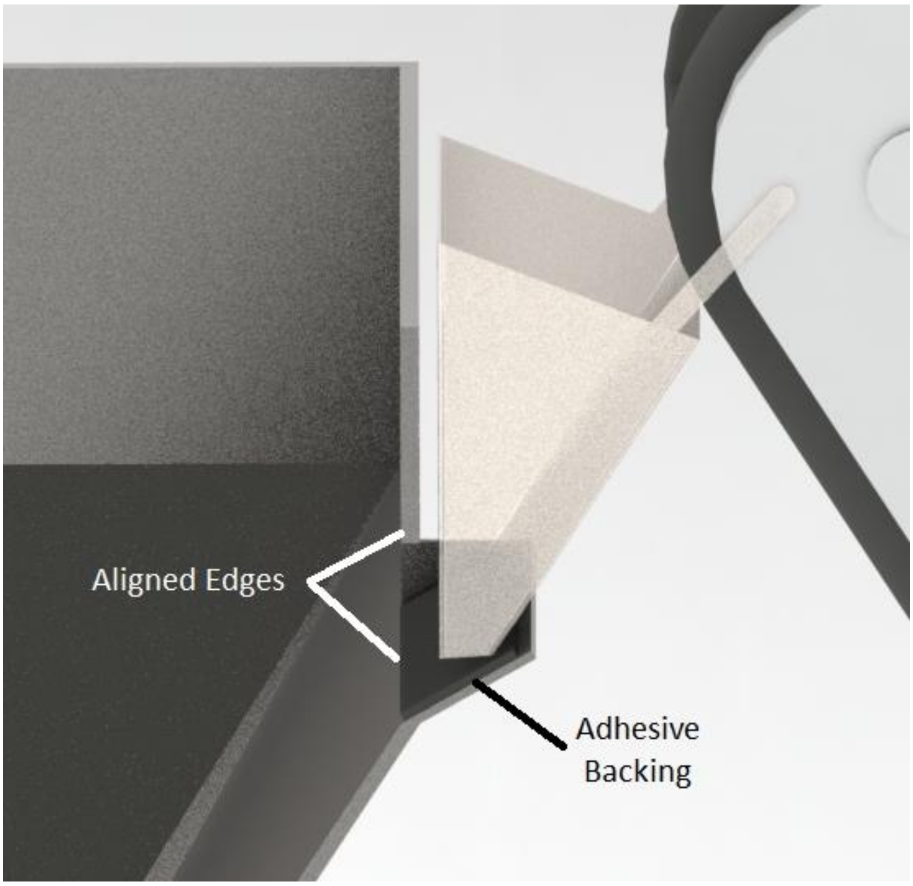


Figure 26. Section view of installed NeoDamp design

The NeoDamp should be in contact with the funnel bottom surface in order to dampen resonation and noise. The NeoDamp fits within process limits, is easily installed and can be used on various component geometries.

9.1.4 Bill of Materials and Cost

The bill of all materials needed for the pre-press hopper design and associated costs are shown in TABLE XXVII. The table includes the part number, description, quantity needed, supplier, quantity sold by supplier, supplier P/N, costs and applications for all parts in the NeoDamp.

TABLE XXVII

BILL OF MATERIALS FOR NEODAMP DESIGN

PART NO.	DESCRIPTION	QTY REQUIRED	Supplier	Supplier P/N	QTY Sold	Price
1	Rubber, Neoprene, 1/4"Thick, 36"x12", 70A	1	Acklands Grainger	1DWY4	1	$ 77.80

This design uses cut sections of a ¼” thick, 36” x 12”, 70A neoprene sheet. Since the size of one (1) sheet is large enough to manufacture 10 Neodamp designs of approximately 10.5”x3.5” size (the largest required size for any one conveyance system) the cost remains at $77.80 CAD for up to 10 units.

9.2 VFP to Conveyor Transfer Point: Blank Catch

The main objectives for the VFP to conveyor transfer point design include reducing the blank spill rate to zero, reducing the noise level by 25% and operational safety. Additionally, the product should be easily installed and removed. To achieve all these objectives, designing and testing were performed. The final design for this location consists of a guard that arches over the belt and catches any blanks that fall off the belt or bounce off the cleats, called the Blank Catch, shown in Figure 27.

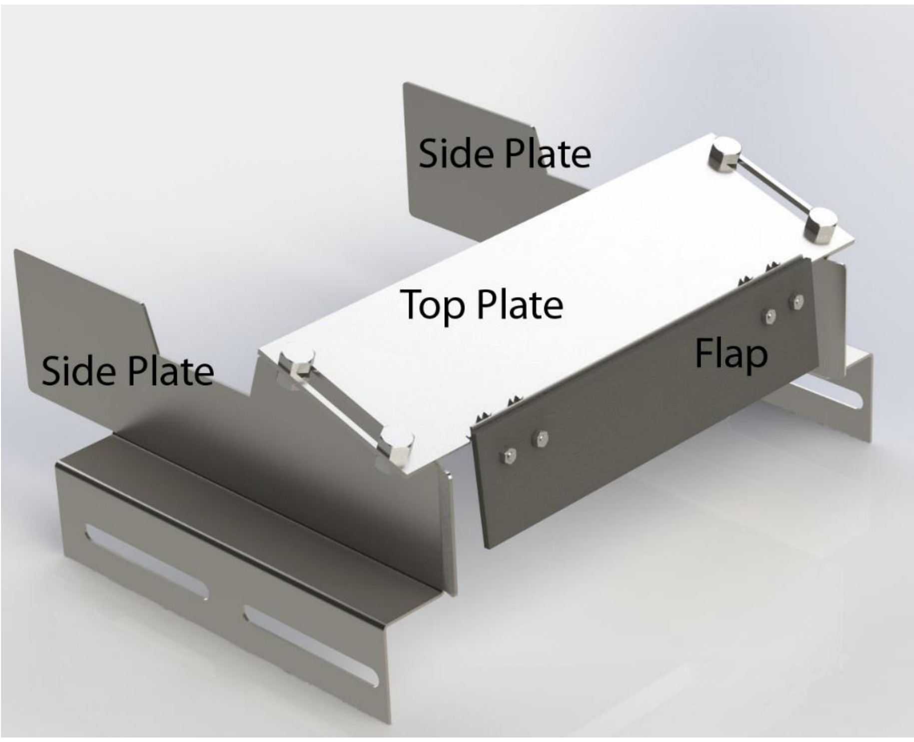


Figure 27. The Blank Catch design for deterring blanks from spill off conveyance system

The Blank Catch has extended walls that run along the sides of the belt to stop blanks from falling through missing belt ribs. The sides also direct falling blanks t from an upper cleat towards the catch plate. The last major feature of the solution for the blank spillage is the flap attached to the catch plate. The flap keeps blanks on the belt by holding the blanks on the rubber flap and transferring them to the belt as a cleat passes by the flap.

9.2.1 Design Features

The Blank Catch is made from three (3) parts for ease of installation. The parts are broken into the two (2) side plates and the top plate. The side plates are stepped, flanged and slotted to be bolted to the conveyance system frame. The side plates are shown in Figure 28.

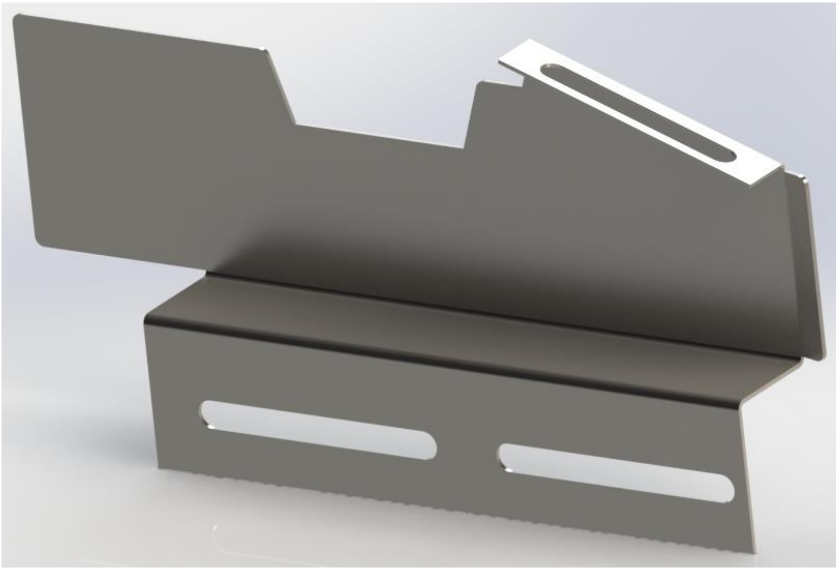


Figure 28. Side plate for the Blank Catch

The top plate is flanged for mounting of the flap and fastening hardware. This plate is also slotted, to be secured to the side plates. The top plate is shown in Figure 29 below.

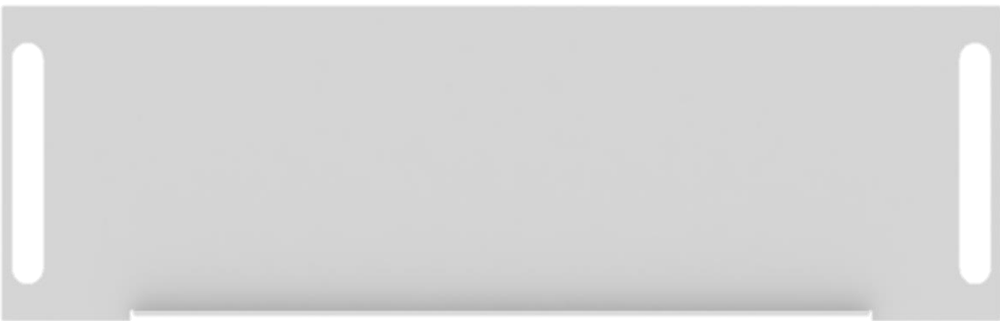


Figure 29. Top plate that mounts to the two side plates for the Blank Catch

The sides of the Blank Catch are sized to stand closely against the belt, leaving a 0.2-inch gap on both sides. The sides are designed to be close enough to the belt to hold any blanks that pass through the ribs on the belt. There is enough room between the wall and the belt to let the belt shift left and right but not enough to let it fall out of alignment. Angled flanges align the belt into the Blank Catch and prevent interference between the belt and the Catch, shown in Figure 30.

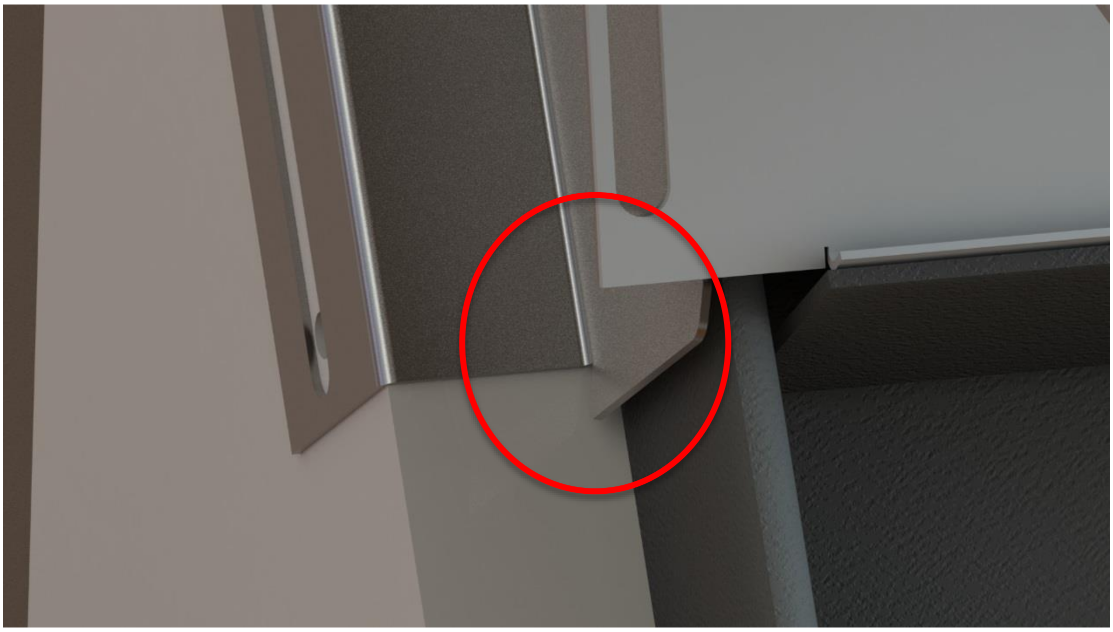


Figure 30. Guides to keep the belt centered on the conveyance system

The mounting points are slotted to allow for adjustment of the Blank Catch. The Blank Catch can move forward and backward along the conveyance system creating a standard design for all systems and feed plates. The slotted portion of the side plates on the Blank Catch is shown in Figure 31.

Figure 31. Slots for adjustability on the side plates of the Blank Catch

The top plate has slots for mounting similar to those on the sides. The slots allow the installation of the Blank Catch on more machines without the need of large modification. The slots provide the plate with adjustment along the conveyance system and minimize the space between the VFP and the belt and between the flap and the belt shown in Figure 29.

The last feature of the Blank Catch is the flap. The flap is made from a rubber that withstands many cycles of loading, due to its expected contact with the belt cleats. The flap is the only moving part of the design is made of 70A polyurethane.

The flap does not reach to the bottom of the belt so there is room for blanks to sit on the belt and not constantly on the flap. The flap moves along the cleats as the belt is brought upwards by the motor and eventually when the cleat and the flap are not touching the flap will fall back down to the next cleat. The flap rotates on a set of hinges and returns to its original downward position due to gravity. Hinges were chosen as the way of movement because if the flap was to be bent constantly due the motion of the belt. If the flap was simply secured to the flange mount, wear and creasing would occur resulting in fatigue failure. Therefore, the hinges allow the flap to stay rigid and does not need to bend to perform its task. The flap with the hinges are shown in Figure 32.

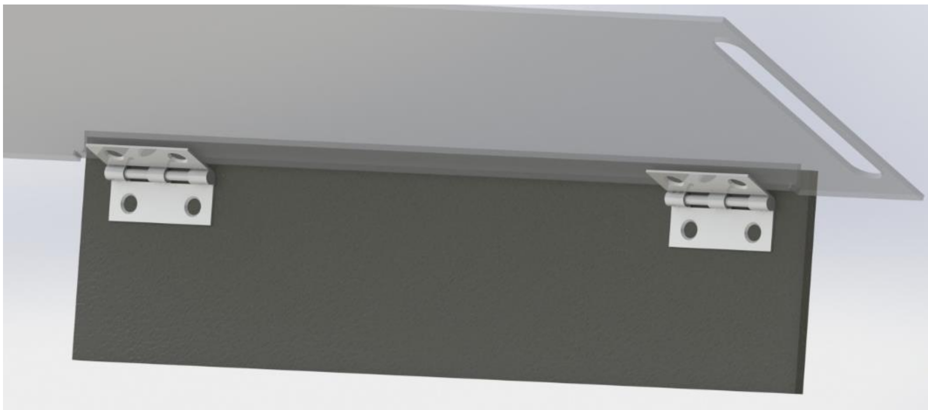


Figure 32. The flap and hinges attached to the top plate

The flap can potentially move past the second cleat on the way down from the first cleat and stay in that position missing all other cleats and allow blanks to slip between the belt and the flap. A stop for the flap was designed for the purpose of solely keeping the flap on the belt at all times. The stop is aligned to hinder the flap from moving to a position where it is no longer contacted by the belt and thus no longer effective. This stop feature is seen in Figure 33.

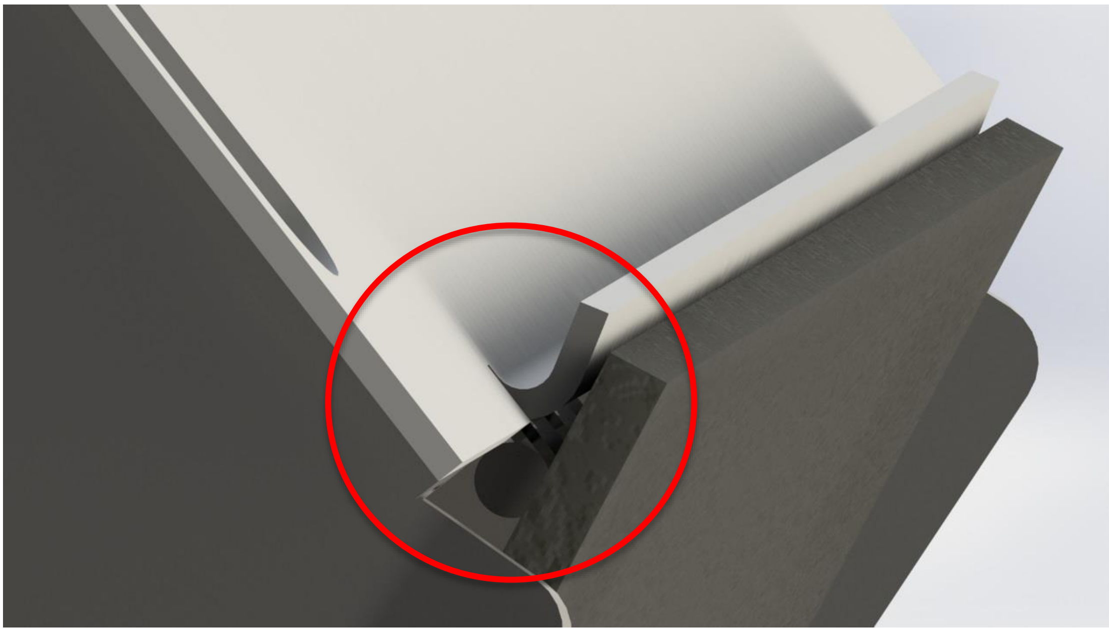


Figure 33. The flap stop to hinder the flap from moving past vertical

The final design of the Blank Catch on the conveyance system shows the mounting points and each feature together. Figure 34 shows the where the design fits and functions within the conveyance system.

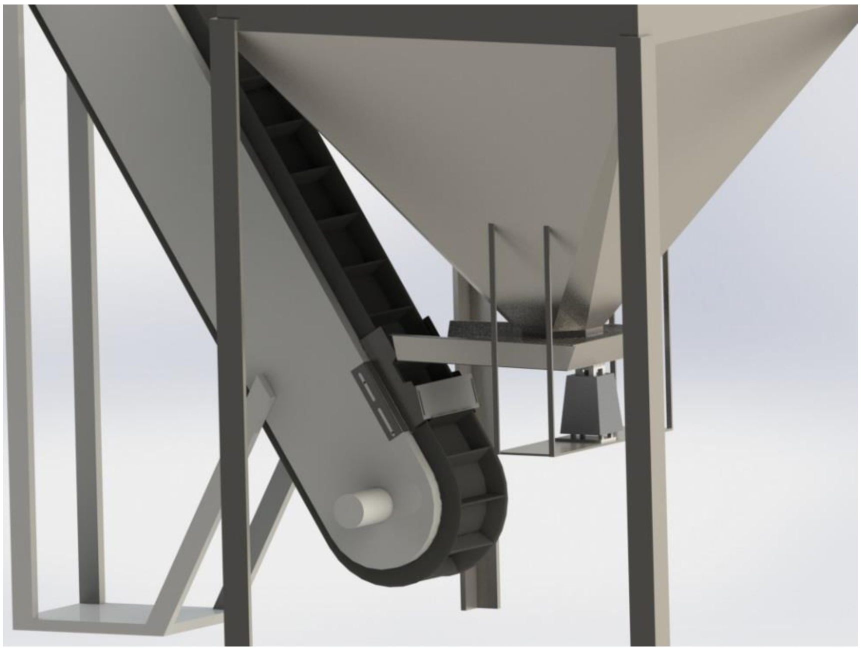


Figure 34. Entire conveyance system with the Blank Catch

Figure 35 magnifies the same view of Figure 34 and rotates to show the special features of the Blank Catch.

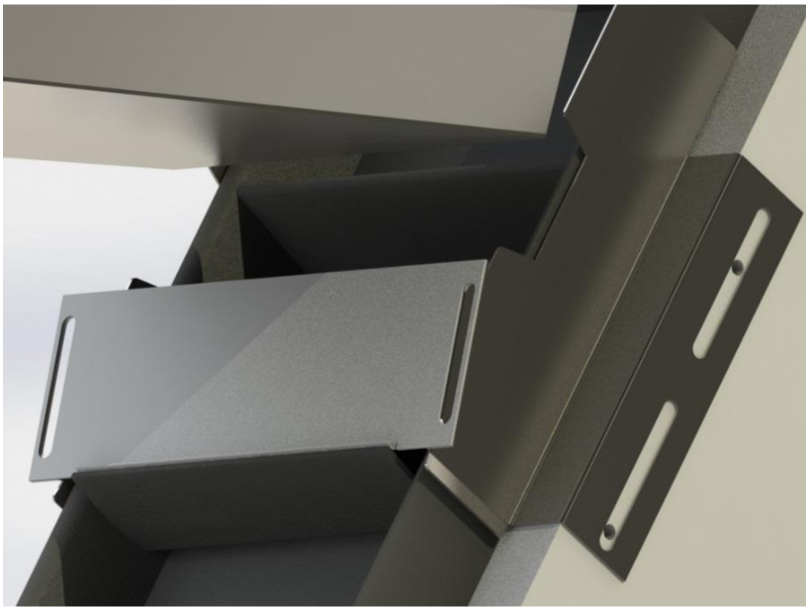


Figure 35. Magnified version of the Blank Catch to show all features on the conveyance system

All these features of the Blank Catch assist to decrease the number of spills, reduce the noise and increase the ease of installation and repair for the operators and mechanics.

9.2.2 Blank Catch Manufacturing

The manufacturing process for all parts included in the Blank Catch are different since they are different materials and different shapes. The three main stainless steel parts used to guide the blanks onto the belt are laser cut using a DXF file and the flat parts are bent to the correct angles and bend radii using the drawings below for both sides and the upper catch. The side plate shown in Figure 36 has all dimensions necessary to manufacture by hand if required.

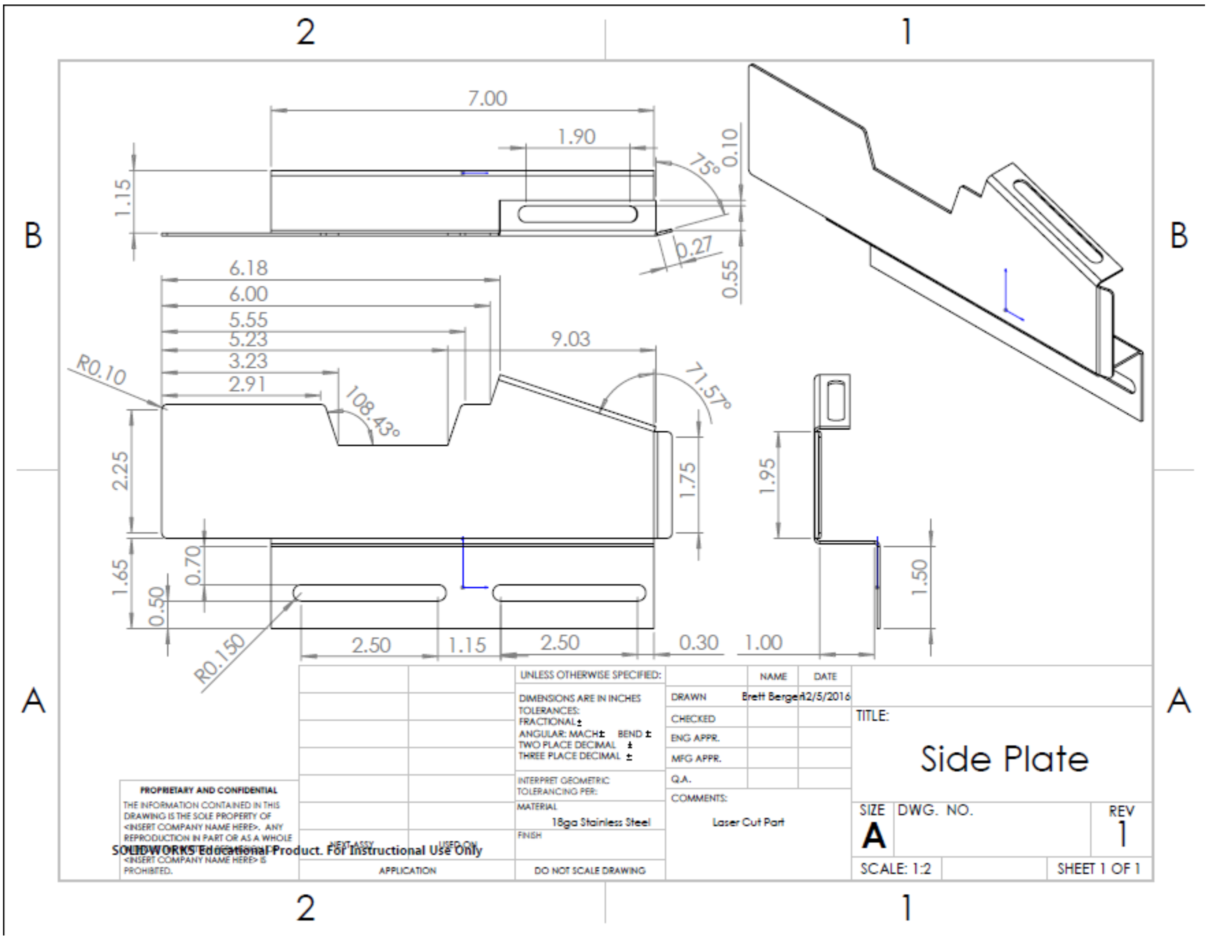


Figure 36. Side plate drawing for manufacturing by hand if necessary

The top plate is manufactured by laser cutting with the side plate but can be manufactured by hand if necessary and can use the drawing in Figure 37 to do so.

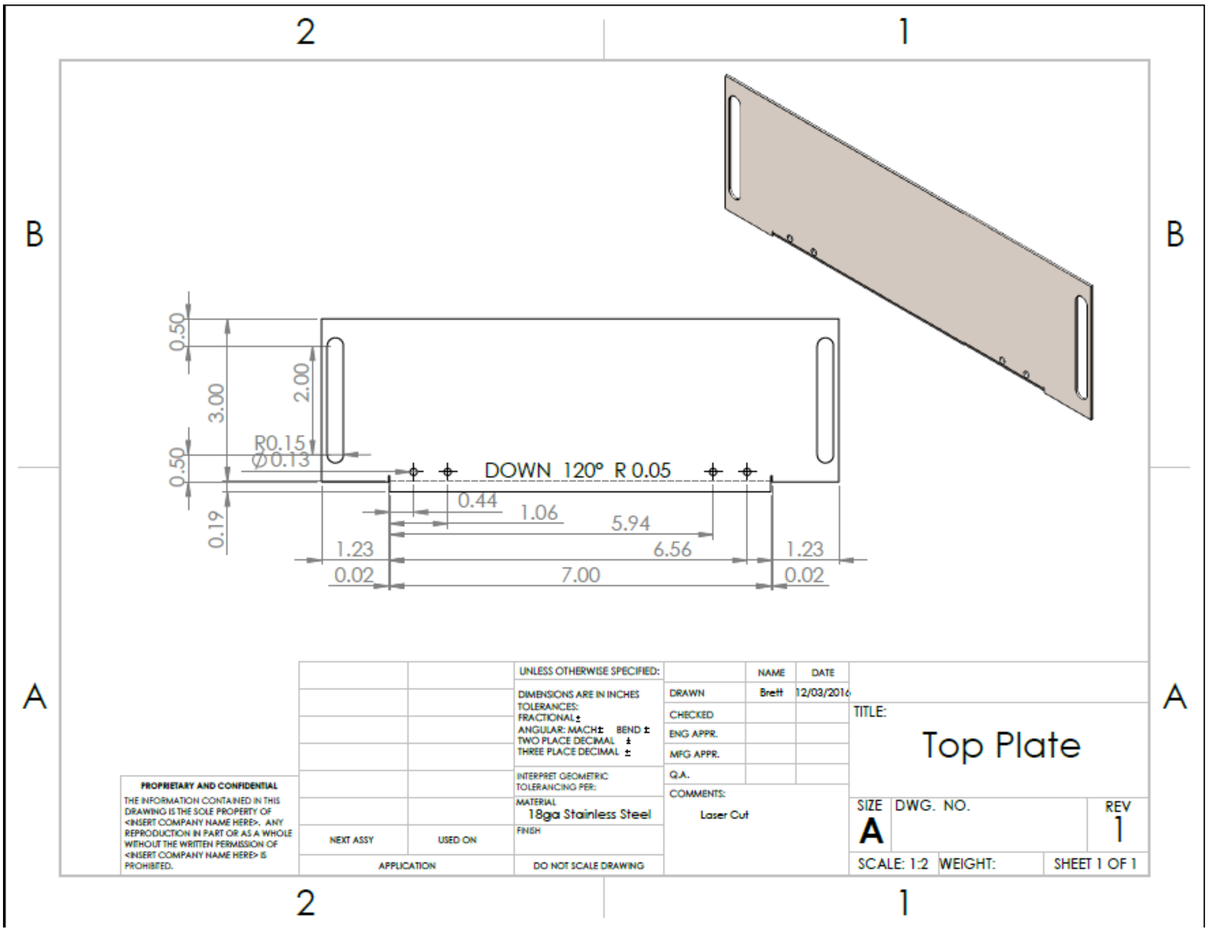


Figure 37. Drawing of the top plate of the Blank Catch

The flap is cut from a piece of rubber with a material strength of shore 70A using a knife or a shear. A shear will ensure that the cut lines are straight and will have a higher accuracy and precision than by using a knife by hand. The dimensions of the flap are shown in the drawing in Figure 38.

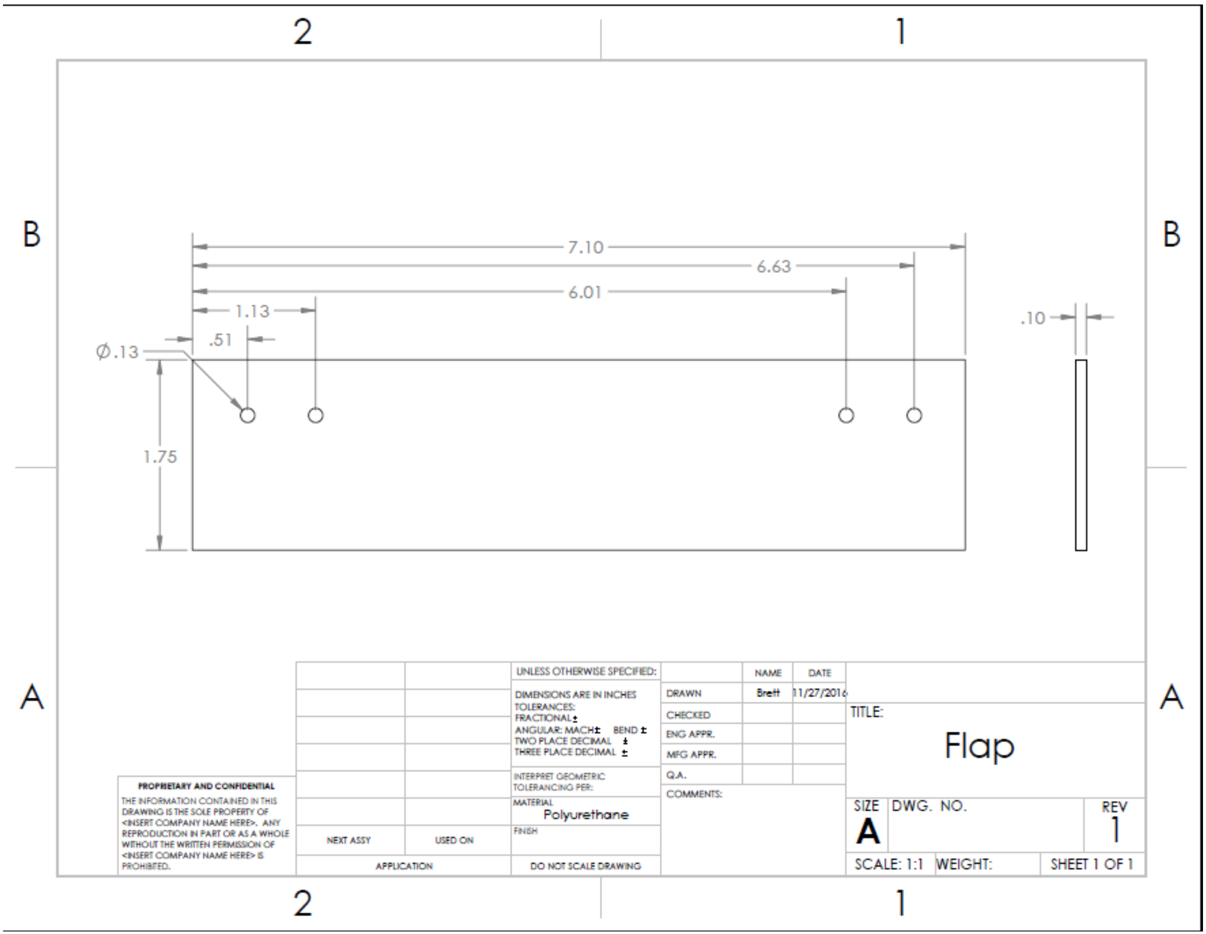


Figure 38. Drawing the of the flap for the Blank Catch

Using all three (3) drawings the Blank Catch can be manufactured by hand or DXF files can be sent to a laser cutter and the drawings can be used to bend the part in the specific locations with the proper bend radius.

9.2.3 Blank Catch Installation

The installation of the Blank Catch is simple. Both sides are mounted to the frame of the conveyance system via two bolts on each side. The top plate is attached via two bolts on each side that hold the top plate to the sides of the Blank Catch. The top plate holds the hinges and the flap before being installed onto the two sides. Once the bolts attach all pieces, the sides and the top plate can be adjusted by sliding the bolts along the slots to put the top plate 1cm from the VFP and the guide walls 1cm from touching the VFP by sliding the entire Blank Catch across the conveyance system. This may not be possible, but the Blank Catch should get as close as possible to the VFP without touching to avoid any vibration into the Blank Catch. Figure 39 shows how the top plate can adjust according to where the VFP is and how close it can get without contacting the VFP and catch stop all blanks from spilling.

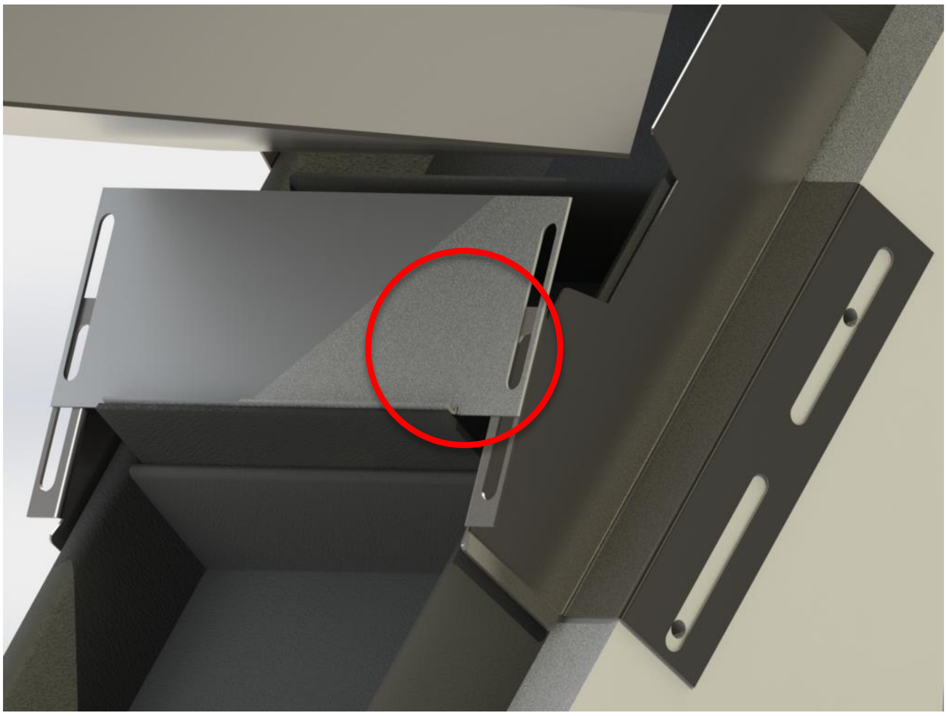


Figure 39. Adjustability for the top plate and the flap to shorten gap at the VFP

The adjustability of the Blank Catch allows the product to be installed on all conveyance systems. This standardized objective was only an issue once the full project was understood and the scope of the project had increased. Therefore, adjustability was the solution to standardizing the Blank Catch to fit all conveyance systems in the coining department.

9.2.4 Bill of Materials and Cost

The bill of materials for the Blank Catch includes the parts, fasteners, materials, quantity, cost, and from where the parts can be purchased. The bill of materials, BOM, shows the cost for the single design and for the total cost for all Blank Catches made for the entire conveyance system on D-line and F-line. The bill of materials and a single Blank Catch is shown in TABLE XXVIII.

TABLE XXVIII

BILL OF MATERIALS

P/N	Description	QTY	Supplier	Supplier P/N	QTY Sold	Price	Secures
2	18-8 Stainless Steel Socket Head Screw 0-80 Thread Size, 1/4" Long	8	McMaster Carr	92196A055	100	$6.21	Side Plate to Frame
3	Low-Strength Steel Hex Nut Zinc-Plated, 0-80 Thread Size	4	McMaster Carr	90480A001	100	$5.02	Side Plate to Frame
4	18-8 Stainless Steel Washer	4	McMaster Carr	92141A029	100	$5.00	Side Plate to Frame
5	Left Side Plate	1	Metal Supermarket	10x5.5	1	$6.66	-
6	Right Side Plate	1	Metal Supermarket	10x5.6	1	$6.66	-
7	Top Plate	1	Metal Supermarket	-	1	$3.33	-
8	Surface-Mount Hinge Bright Brass, Nonremovable Pin, 1" High, 3/4" Wide	2	McMaster Carr	1603A3	1	$1.61	To Cross Support
9	Black-Oxide Alloy Steel Hex Drive Flat Head Screw 2-64 Thread Size, 1/2" Long	4	McMaster Carr	91253A091	5	$11.90	Hinge to Flap
10	Low-Strength Steel Hex Nut Zinc-Plated, 2-64 Thread Size	4	McMaster Carr	90480A135	100	$1.50	Hinge to Cross
11	Zinc-Plated Steel SAE Washer for Number 2 Screw Size, 0.094" ID, 0.219" OD	16	McMaster Carr	90126A501	100	$1.59	Hinge to Cross
12	Polyurethane Rubber Sheet 12" x 12", 1/4" Thick, 70A	1	McMaster Carr	8716K921	1	$95.64	-
13	Passivated 18-8 Stainless Steel Hex Drive Flat Head Screw 2-56 Thread Size, 3/4" Long	4	McMaster Carr	92210A085	50	$7.25	Hinge to Flap
14	Low-Strength Steel Hex Nut Zinc-Plated, 2-56 Thread Size	4	McMaster Carr	90480A003	100	$0.97	Hinge to Flap
15	18-8 Stainless Steel Washer for Soft Material Number 2 Screw Size, Regular ASME Designation	8	McMaster Carr	92217A355	25	$8.65	Hinge to Flap
				Total		$161.98	

The cost for the Blank Catch is $161.98 for the first product including the materials, fasteners and accessories, but not manufacturing. The fasteners listed in the BOM are not the exact fasteners required but are placeholders to show the type of fasteners required and their potential cost. The client can use any fasteners they wish since the fasteners are not load bearing. The manufacturing for laser cutting is $31 for the side plates and the top plate, therefore by adding the manufacturing cost and the material and fastener cost, the final cost is $193 for a single Blank Catch.

The cost for all 10 Blank Catches would not cost 10 times the amount for one Blank Catch because many parts are purchased as bulk and are sufficient for all products made. The material and manufacturing make up the most of the cost for the Blank Catch and the final cost for one (1) product to 10 products is found in TABLE XXIX.

TABLE XXIX

TOTAL COST FOR THE BLANK CATCH FOR THE PRODUCTION OF MULTIPLE PRODUCTS

	# of units									
	1	2	3	4	5	6	7	8	9	10
Parts Cost	$162	$192	$222	$261	$279	$310	$350	$380	$410	$437
Manufacturing	$31	$62	$92	$123	$154	$185	$216	$246	$277	$308
Total Cost	$193	$254	$315	$384	$433	$494	$565	$626	$687	$745

With a total cost of $745, the preliminary budget of 10,000 is barely contributed to by the Blank Catch, even if all 10 are produced.

9.3 VFPR: Mesh Block

The main purpose of design at VFP Rear region is to achieve zero spillage between the lower hopper and VFP. The product must be visually accessible to operators and it is recommended that product is installed and removed easily without the use of mechanical tools. Mesh Block, the final design, is comprised of a metal mesh cover with rubber edge trim and fastening hardware. The final design sits on the top of the VFP with an opening at the center, which follows the contours of the feed hopper output. The mesh is fixed onto the VFP by an adjustable Clevis pin and Cotter pins placed in tension by a spring to account for the vibration the VFP undergoes during blank delivery. This type of fastener was chosen since most bolt and nut fasteners would require a tool to remove, or in the case that it would not require a tool, the vibration of the VFP would loosen the fastener over time. We decided to consider the Mesh Block for seven (7) out of eight (8) lines, due to the existing VFP wall design located on conveyance system 7b.

9.3.1 Design Features

The Mesh Block consists of a custom sized galvanized wire mesh cover, rubber edge trim and fastening hardware. The design covers the top of the VFP with rubber trim around the outer edges to guard the operator from any sharp edges that may cause injury. The specific shape of the wire mesh cover follows the contours of the feed hopper outlet flange and then extend to the side and rearward edges of the VFP. The galvanized steel mesh was chosen for its rigidity, cost and ability to provide visual accessibility. A main objective the client required was for the blanks having clear visibility in the VFP to check for any blanks leftover after the press has finished manufacturing that certain coin. If the area is not visible, a mixture of different types of coins can enter the press and jam the machine or a customer receives their product with coins that are not the right size or shape. The features of the Mesh Block including the material chosen, trim and custom fasteners are shown in Figure 40.

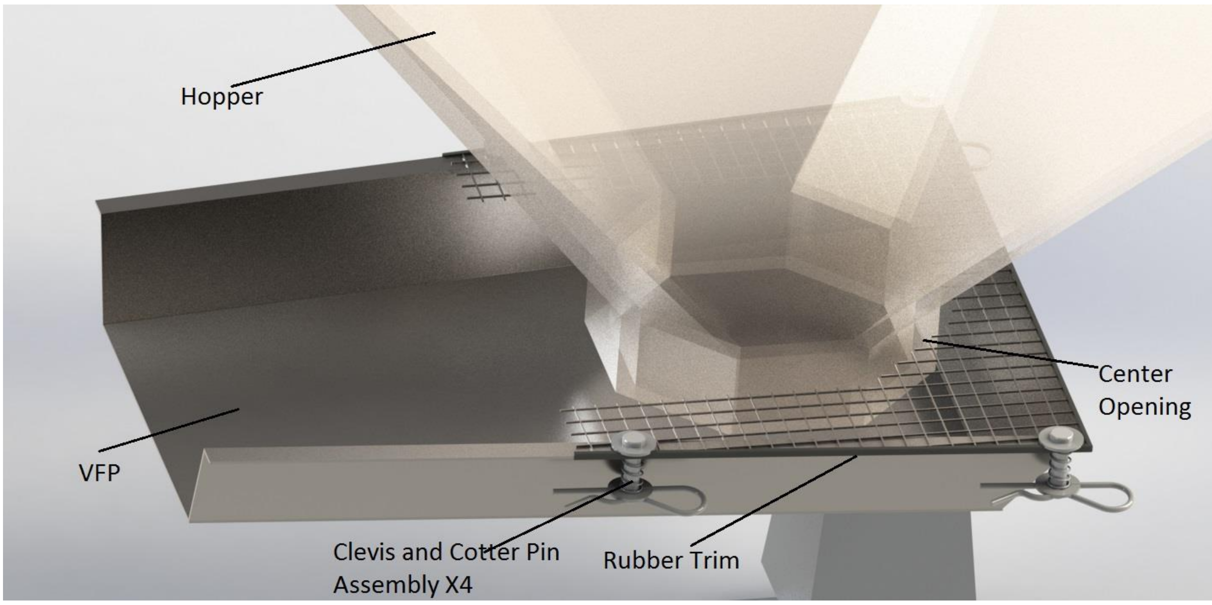


Figure 40. Detail Design of VFP Rear Region

There are four (4) holes drilled in the VFP currently, which will be utilized by the Clevis and Cotter pin fasteners. The pins can be installed or removed with zero tools by removing the reusable cotter pin and lifting the spring and clevis pin from the VFP hole. Once the fastener is removed, the Mesh Block can easily be slid off the VFP for access to the VFP or lower hopper output.

9.3.2 Manufacturing

Mesh Block consists of a steel mesh cover, rubber edge trim and fastening hardware. A 4’x5’ sheet of galvanized weave mesh was sourced from Ferrier Wire Goods Company. This sheet is large enough to cut ten (10) pieces for seven (7) mesh applications. Figure 41 shows a sample CAD drawing of the weave mesh piece corresponding to the D5a system on the D-line. The drawings of D2a, D2b, D5b, D6a, D6b and D7a are shown in Appendix B.

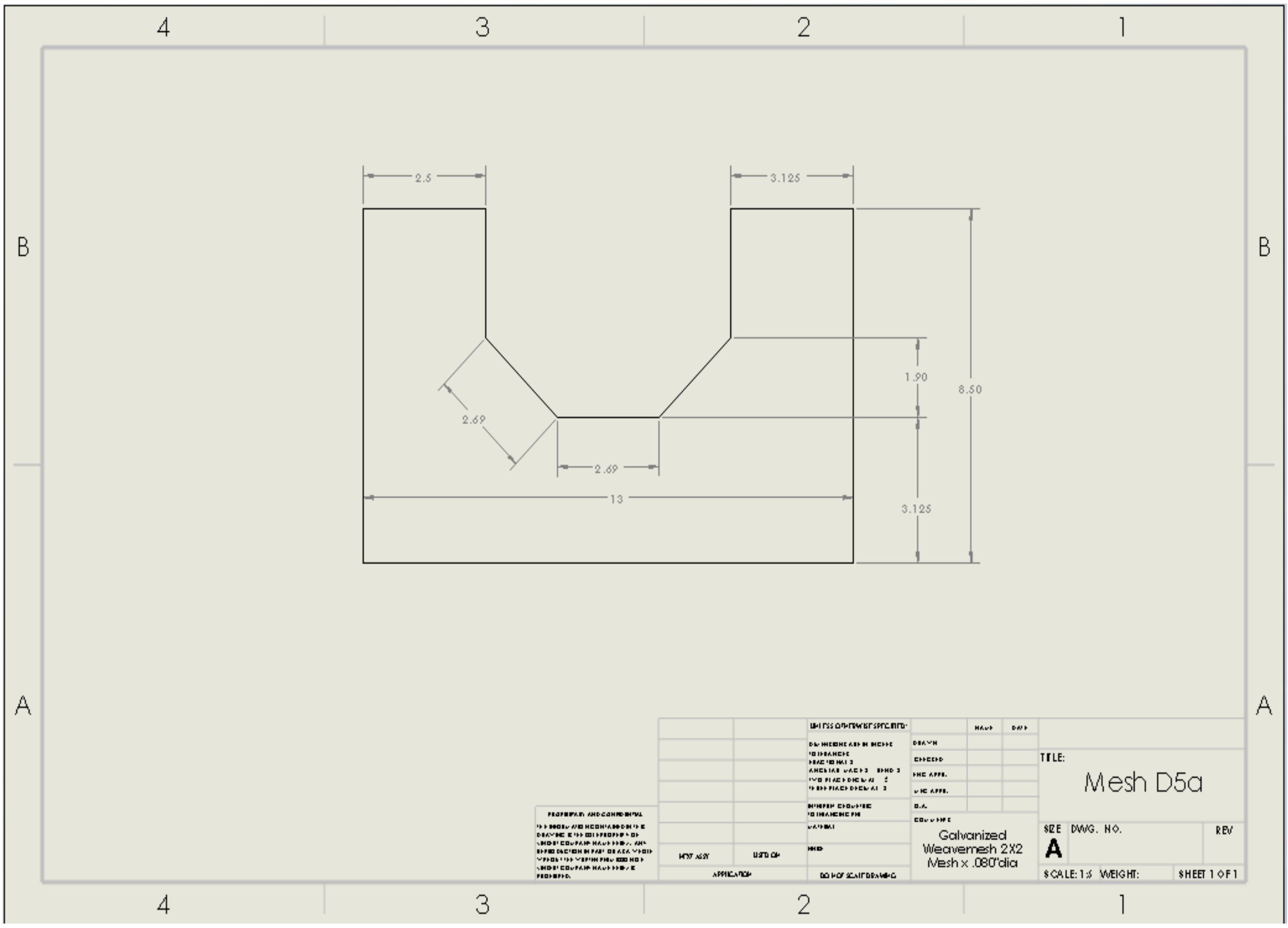


Figure 41. CAD Drawing of D5a Line VFP Rear

Once the wire mesh cover has its shape, rubber edge trim must be measured, cut and applied to the back and side edges of the mesh piece. The edge trim covers sharp edges of the wire mesh cover. The edge trim also acts as a soft, vibration resistant material between the wire mesh cover and the VFP flanges. All other components in the Mesh Block assembly do not require manufacturing and are ready for installation.

9.3.3 Installation

The Mesh Block installation process is simple, quick and toolless. The mesh cover with edge trim aligns with the VFP to which it is installed. Once aligned, the location for a 7/16" hole is to be marked on the VFP flange. The hole must be on the flange such that there is clearance to install the bottom washer. Next, the fastener assembly is installed. Each assembly consists of an adjustable length clevis pin, two (2) washers, a reusable cotter pin and a spring, as seen in Figure 42.

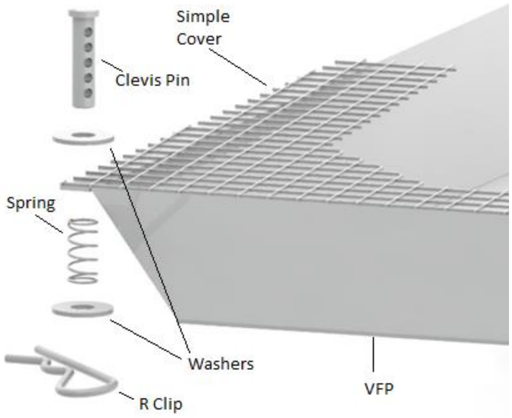


Figure 42. Simple Cover installed onto the VFPR

The clevis pin runs through a top washer, wire mesh cover, a hole in the VFP flange, spring and bottom washer. The spring must be compressed and then the reusable cotter pin is inserted into the highest hole possible, just below the bottom washer. This will ensure the Mesh Block has tight fit to the VFP and can function under high vibrational conditions. The installation is complete.

9.3.4 Bill of Materials and Cost

The bill of materials for the Mesh Block design is shown in TABLE XXX.

TABLE XXX

BILL OF MATERIALS AND COST FOR MESH DESIGN

P/N	Description	QTY	Supplier	Supplier P/N	QTY Sold	Price	Applications
16	Galvanized Weave mesh 2X2 Mesh x .080"dia wire 1 sheet 4' x 5'	1	Ferrier Wire Goods Company Ltd	N/A	1	$ 106.20	Mesh Piece Body
17	Edge PVC Trim 0.032' to 0.125' edge thickness White Pebble texture 100ft. roll	1	Trimlok Inc.	1600SW3-1007	1	$ 59.40	Mesh Piece Edge Trim

P/N	Description	QTY	Supplier	Supplier P/N	QTY Sold	Price	Applications
18	Adjustable-Length Clevis Pin Zinc-Plated Steel, 3/8" Diameter, 1-1/2" Length	4	McMaster Carr	98330A235	10	$ 5.55	Clevis and Cotter Pins Assembly
19	Copper Washer for 3/8" Screw Size, 0.39" ID, 1" OD	8	McMaster Carr	93744A160	10	$ 7.71	Clevis and Cotter Pins Assembly
20	Zinc-Plated Steel Reusable Cotter Pin Hairpin, Fits 3/4"-1-1/8" Pin Diameter, 3-3/8" Length	4	McMaster Carr	98335A085	25	$ 8.07	Clevis and Cotter Pins Assembly
21	Steel Compression Spring Zinc-Plated Music Wire, 1.00" Long,.500" OD,.041" Wire	4	McMaster Carr	9657K312	12	$ 10.35	Clevis and Cotter Pins Assembly

The table includes the part number, description, quantity needed, supplier, quantity sold by supplier, supplier P/N, costs and applications for all parts in the Mesh Block. The costs for up to 10 Mesh Block units are shown in TABLE XXXI.

TABLE XXXI

COST OF MESH BLOCK PER QUANTITY PRODUCED

P/N	Costs	# of Mesh Block Units Produced									
-	Part Cost	1	2	3	4	5	6	7	8	9	10
16	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20	$ 106.20
17	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40	$ 59.40
18	$ 5.55	$ 5.55	$ 5.55	$ 11.10	$ 11.10	$ 16.65	$ 16.65	$ 22.20	$ 22.20	$ 22.20	$ 22.20
19	$ 7.71	$ 7.71	$ 15.42	$ 23.13	$ 30.84	$ 30.84	$ 38.55	$ 46.26	$ 53.97	$ 61.68	$ 61.68
20	$ 8.07	$ 8.07	$ 8.07	$ 8.07	$ 8.07	$ 8.07	$ 8.07	$ 16.14	$ 16.14	$ 16.14	$ 16.14
21	$ 10.35	$ 10.35	$ 10.35	$ 10.35	$ 20.70	$ 20.70	$ 20.70	$ 31.05	$ 31.05	$ 31.05	$ 41.40
	Total Cost	$ 197.28	$ 204.99	$ 218.25	$ 236.31	$ 241.86	$ 249.57	$ 281.25	$ 288.96	$ 296.67	$ 307.02

The price of a 4’x 5’ weave mesh sheet and 100ft. roll of edge trim is spread across all conveyance systems. The total cost of material for one (1) Mesh Block design is $197.28 CAD. There are seven (7) D-line systems that the Mesh Block must be installed on and several candidate systems that may or may not require a Mesh Block. The total price for all seven (7) coining systems is $281.25 CAD.

9.4 Operating Procedure

All the D-line coining presses run at approximately the same output rate, 750 coins/min. The VFP feed rates are different from press to press, leading to overloading of belts. Overloading the belt allows blanks to pile up and spill over the top of the cleats. The VFP feed rates are directly in proportion to the VFP electronic controller setting. Each operator sets the VFP controller level (frequency) by personal preference so performance varies widely between presses. Several different types of VFPs and electronic controllers are seen across the various coining system. This causes each system to perform differently.

We recommend a standardized feed rate between the VFP and the belt. First, each VFP should be run at all 10 points on the electronic controller dial, and the corresponding frequency be measured with a laser accelerometer. The quantity of blanks transferred per minute and the number of spilled blanks should similarly be tabulated. The results will indicate the VFP performance respective to the dial setting. TABLE XXXII shows a sample testing data sheet.

TABLE XXXII

STANDARDIZATION TESTING OF COINING PRESS EXAMPLE

Press and Conveyor: D2-A			
Dial Setting	**Frequency (Hz)**	**Feed Rate (blanks/min)**	**Spilled Blanks (per hour)**
1	10	50	0
2	25	300	1
…			
10	60	1500	150

The optimum VFP dial setting is able to feed greater than 750 blanks/min to meet process demand while producing the lowest number of spilled blanks. The belts feeding the pre-press hopper pass 89 cleats underneath the VFP per minute. If the process aims to run constantly then the belt needs to carry 8.424 blanks/cleat. At a level of less than nine (9) blanks, the belt will prevent overflows. Another consideration is to center the VFP along the belt, feeding blanks onto the center of the belt cleats. This alignment prevents blanks from falling over the belt ribs.

9.5 F-line Considerations

The inclusion of the F-line in the project scope was a late addition/oversight and contained different conveyor angles, lengths, VFP transfer systems and belt design. The F-line does not show VFPR blank spillage, due to higher walls. The noise generated at the pre-press hopper and entire F-line system is negligible in comparison to ambient noise. The five (5) F-line coining presses are shown in Figure 43, with F5 being at the near end of the row and F1 at the furthest end.

Figure 43. F-line coining presses and conveyance systems [6].

The VFPs on F5 and F4 have different designs; however, they both feed well onto the center of the conveyance systems. The transition points, however, use cardboard and duct tape to block the edges of the conveyor, as seen in Figure 44.

Figure 44. VFP from F-line conveyance system on F5 press [6].

F1 through F3 have very similar VFPs, but each has added angled walls at the out feed. The out feed walls direct the blanks toward the center of the belt. None of the VFP walls is angled in far enough on both sides to prevent the blanks from spilling out between the VFP and plastic cover. In addition, F1 and F3 have one (1) or more missing belt ribs where blanks fall out. The VFP on F3 is shown in Figure 45.

Figure 45. VFP from F-line conveyance system on F3 press [6].

The issues and recommendations for each F-line press are shown in TABLE XXXIII.

TABLE XXXIII

F-LINE ISSUES AND RECOMMENDED ACTIONS

Press	Issues	Recommendation
F1	• Blanks spill through missing belt rib • Blanks fall between VFP and plastic belt cover	• Replace/repair belt • Add angled wall to south-facing portion of VFP output
F2	• Blanks fall between VFP and plastic belt cover	• Extend VFP discharge or • Cut out plastic cover and install angled edges
F3	• Blanks spill through missing belt ribs • Blanks fall between VFP and plastic belt cover	• Replace/repair belt • Add angled wall to south portion of VFP output
F4	• Temporary guards and covers made from cardboard and duct tape between VFP and belt	• Install Blank Catch
F5	• Temporary guards and covers made from cardboard and duct tape between VFP and belt	• Install Blank Catch

10.0 Recommendations and Conclusion

The Royal Canadian Mint has three (3) issues requiring solutions. Firstly, there are blanks spilling from the conveyance systems on the D and F coin press lines. Secondly, blanks spill over the rear wall of the vibrating feed plate during operation. Lastly, there is noise generated at the pre-press hopper when blanks are fed into the press. The solutions should be safe, prevent spilling and be standardized across all D and F-line systems.

Through concept development and testing of prototypes, we refined our seven (7) initial concepts into three (3) final designs. We did not meet our objective of manufacturing and implementing a fully functional prototype due to timeline restrictions and scope creep. In addition, creating a solution that fit across all F-line systems as well as the D-line was not possible within our period. However, recommendations for the operation and repair of the coining press conveyance systems were recognized.

10.1 Recommendations

The standard operating condition and practices of the coining presses and the conveyance systems will reduce spills, waste and noise generation.

10.1.1 Operating Practices Recommendations

The vibrating feed plates control how blanks enter the coining system. Blanks should be fed onto the conveyor belt at a standard rate across all presses. For a coining press operating at 720 coins/min, a feed rate of 15 blanks/second will allow the VFP to run near continuously to not starve the presses, while limiting the number of blanks fed onto the conveyor belt. The VFPs should also be centered on the conveyor to prevent blanks from collecting along and falling over the belt ribs.

10.1.2 Operating Condition Recommendations

The F-line has two (2) belts, on F1 and F3, with missing ribs and blanks fall through these areas without impedance; these belts should be repaired or replaced. MetalTech Inc. provides almost all of the RCM belts and can be an asset for this recommendation. This procedure should be followed for D-line systems if continued spillage is a concern.

10.2 Conclusion

Three (3) designs are prepared for the RCM to use at the pre-press hopper, the vibrating feed plate rear and the transfer point between the VFP and the belt.

The pre-press design is the NeoDamp. It is a ¼" thick 70A neoprene sheet with an adhesive backing and a cross section of 3.5"x10.5". The design is a refinement of the Hooked Plate concept, which we determined would not have adequate space to mount within the pre-press hopper chute of all the coining presses. The NeoDamp can be cut with a knife from a large sheet and applied to the cleaned pre-press hopper chute surface. The neoprene sheet absorbs the impact of the blanks and reduces the noise generated. The cost manufacture one (1) NeoDamp is equivalent to that of 10, as a single sheet of ¼"x36"x12" 70A neoprene with adhesive backing costs $77.80 CAD. The NeoDamp is ready to install on all pre-press hoppers in the D-line.

We tested the best concepts for preventing spills between the VFP and feed belt, called the Catch with Fender Bars and Catch with Flap designs with simple prototypes and found that the Catch with Flap performed at a lower spill rate (1.4 versus 1.6 blanks/min). We refined the Catch with Flap design and renamed it the Blank Catch. The Blank Catch body is made from three (3) parts, two (2) side plates and one (1) top plate. The modular design allows for easy installation, adjustment, removal and is standardized across eight (8) D-line presses and two (2) F-line presses. The Blank Catch bolts to the conveyor frame and features a scoop beneath the VFP to direct blanks onto the belt. At the bottom of the design, a 70A polyurethane flap is mounted on a hinge. The flap prevents blanks from falling over belt cleats and pivots up and down to allow the cleats to pass freely. The cost to manufacture one (1) Blank Catch is $161 CAD and $437 CAD to manufacture 10, which equips the entire D-line and F5 & F4.

Blanks spill over the back wall of the VFP when being loaded into the feed hopper. From to two concepts, the Simple Plate and the Wall, the Simple Plate was selected for its high visibility and renamed Mesh Block. The design is made from a 2x2 galvanized weave mesh with 0.08" diameter wire and is cut to fit on top the VFP, from the rear wall and around the in feed hopper. The Mesh Blocks are 8" ½ long and vary from 11" ¾ to 13" ¼ wide across the rear wall of the VFP. To allow for tool less removal four (4) adjustable length clevis pins fasten the Mesh Block to the VFP. The Mesh Block is held tightly against the VFP by springs installed on each clevis pin. The cut edges of the Mesh Block are protected with PVC trim.

The cost for one (1) unit is $197.28 CAD but only $281.25 CAD to produce for all seven (7) D-line VFPs. The F-line and D1 VFPs do not require any additional spill prevention.

Installing the NeoDamp, Blank Catch and Mesh Block and implementing operational recommendations for the belts and VFP will prevent spilling, reduce noise generation and allow for improved mechanic and operator access to the manufacturing equipment.

References

[1] "Coin Production," Royal Canadian Mint, 2016. [Online]. Available: http://www.mint.ca/store/mint/learn/coin-production-1200012?cat=Coin+Production&nId=1200012&nodeGroup=Learn. [Accessed 25 Oct 2016].

[2] Dictionary.com, "coining," The American Heritage® Dictionary of Idioms by Christine Ammer, [Online]. Available: http://www.dictionary.com/browse/coining. [Accessed 25 Oct 2016].

[3] Dictionary.com, "hopper," The Dictionary of American Slang, [Online]. Available: http://www.dictionary.com/browse/hopper. [Accessed 25 Oct 2016].

[4] Dictionary.com, "plating," The American Heritage® Dictionary of Idioms by Christine Ammer, [Online]. Available: http://www.dictionary.com/browse/plating. [Accessed 25 Oct 2016].

[5] J. Reise, *Coining System Representation*, Winnipeg, MB: Unpublished, 2016.

[6] Royal Canadian Mint, "Visit the Mint Winnipeg Facility," Royal Canadian Mint, 2016. [Online]. Available: http://www.mint.ca/store/mint/visit-the-mint/winnipeg-location-8900024;. [Accessed 28 October 2016].

[7] P. Nowak, "IMG_20160927_160005," Royal Canadian Mint, Winnipeg, 2016.

[8] Barlow Manufacturing, "BELT CONVEYORS," Barlow Packaging Plus, 2013. [Online]. Available: http://barlowpackaging-com.factorepreview.ca/products/5-belt-conveyors. [Accessed 21 October 2016].

[9] EMI Corporation, "Accumulation Hoppers," EMI Corporation, 2016. [Online]. Available: http://www.emicorp.com/conveyor/hoppers.php. [Accessed 25 October 2016].

[10] EMI Corporation, "Signature Line Incline Belt Conveyor, Model RMC," EMI Corporation, 2016. [Online]. Available: http://www.emicorp.com/conveyor/standard-signatureline-incline.php. [Accessed 25 October 2016].

[11] Dorner Mfg. Corp., "DORNER Conveyor Blog," Dorner Mfg. Corp., 21 Ocotber 2011. [Online]. Available: http://www.dornerconveyors.com/News-

Blog/Blog/Article/123/New-Sanitary-Accessories-Add-Functionality-to-Dorner-Conveyors.aspx. [Accessed 24 October 2016].

[12] ConSpare Limited, "Conveyor Components," ConSpare Limited, 2016. [Online]. Available: http://www.conspare.com/conveyorcomponents. [Accessed 25 October 25 2016].

[13] Wikipedia, "Shore durometer," Wikipedia, 2016. [Online]. Available: https://en.wikipedia.org/wiki/Shore_durometer. [Accessed 27 Nov 2016].

[14] Azom, "AISI 1018 Mild/Low Carbon Steel," AZO Materials, 5 July 2012. [Online]. Available: http://www.azom.com/article.aspx?ArticleID=6115#4. [Accessed 13 November 2016].

[15] Azom, "6061 Aluminum," AZO Materials`, 26 March 2006. [Online]. Available: http://www.azom.com/article.aspx?ArticleID=3328. [Accessed 13 November 2016].

[16] Aalco, "Stainless Steels - Stainless 304 Properties, Fabrication and Applications, Supplier Data by Aalco," AZO Materials, 18 May 2005. [Online]. Available: http://www.azom.com/article.aspx?ArticleID=2867. [Accessed 13 November 2016].

[17] MAAC MACHINERY CO., "THERMOFORMING: Determining the Right Temperature for Thermoforming," The Plastics, 2000. [Online]. Available: http://www.plasticsmag.com/thermoforming.asp?fIssue=Mar/Apr-03. [Accessed 13 November 2016].

[18] GEHR Plastics Inc, "GEHR Plastics PE-HD Polyethylene HDPE," MatWeb, 2016. [Online]. Available: http://www.matweb.com/search/datasheettext.aspx?matguid=422462a3944043019f269e31616235d1. [Accessed 13 November 2016].

[19] G. Thomas, "Polyurethanes and Soft Tooling - An Interview with Mitchell Johnson," AZO Materials, 4 April 2014. [Online]. Available: http://www.azom.com/article.aspx?ArticleID=10881. [Accessed 13 November 2016].

[20] K. Ginter, Interviewee, *Process Engineer.* [Interview]. 8 November 2016.

[21] Engineering Toolbox, "Friction and Friction Coefficients," Engineering Toolbox, 2016. [Online]. Available: http://www.engineeringtoolbox.com/friction-coefficients-d_778.html. [Accessed 8 November 2016].

[22] ONDA, "Tables of Acoustic Properties of Materials," ONDA, 2016. [Online]. Available: http://www.ondacorp.com/tecref_acoustictable.shtml. [Accessed 13 November 2016].

[23] McMaster-Carr, "General Purpose Low-Carbon Steel," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#standard-low-carbon-steel-sheets/=14y87vq. [Accessed 8 November 2016].

[24] The Engineering Toolbox, "Steels- Endurance Limits and Fatigue Stress," The Engineering Toolbox, 2016. [Online]. Available: http://www.engineeringtoolbox.com/steel-endurance-limit-d_1781.html. [Accessed 24 November 2016].

[25] McMaster-Carr, "Multipurpose 6061 Aluminum," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#standard-aluminum-sheets/=14y81w2. [Accessed 8 November 2016].

[26] McMaster-Carr, "Multipurpose 304 Stainless Steel," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#standard-stainless-steel-sheets/=14y85if. [Accessed 8 November 2016].

[27] Total Materia, "Fatigue of Metals: Part Three," Key to Metals AG, August 2010. [Online]. Available: http://www.totalmateria.com/page.aspx?ID=CheckArticle&site=kts&NM=282. [Accessed 24 November 2016].

[28] McMaster-Carr, "Rigid HDPE Polyethylene," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#hdpe/=14y89ba. [Accessed 8 November 2016].

[29] S. Dhouibi, M. Boujelbene, M. Kharrat, M. Dammak and A. Maalej, "Friction Behavior of High Density Polyethylene (HDPE) Against 304L Steel: An Experimental Investigation of the Effects of Sliding Direction, Sliding History and Sliding Speed," Ecole Nationale d'Ingénieurs de Sfax, 2013. [Online]. Available: https://www.researchgate.net/publication/. [Accessed 8 November 2016].

[30] R. Khelif, A. Chateauneuf and K. Chaoui, "Statistical analysis of HDPE fatigue lifetime," December 2008. [Online]. Available: https://www.researchgate.net/publication/226133025_Statistical_analysis_of_HDPE_fatigue_lifetime. [Accessed 24 November 2016].

[31] Foam Order, "Neoprene Sheets, Neoprene Rubber, Neoprene Fabric," Foam Order, 2016. [Online]. Available: http://www.foamorder.com/neoprene/neoprene.html. [Accessed 25 November 2016].

[32] Advanced Polymer Alloys, "Alcryn," Scribd, 1998. [Online]. Available: https://www.scribd.com/doc/129575581/Neoprene-and-Steel-Friction-Cefficients. [Accessed 25 November 2016].

[33] McMaster-Carr, "Abrasion-Resistant Polyurethane Rubber Sheets, Bars, and Strips," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#standard-polyurethane-sheets/=14y8axi. [Accessed 8 November 2016].

[34] Gallagher Precision Polyurethane Molding, "Polyurethan Coefficient of Friction," Gallagher Corporation, 2016. [Online]. Available: http://gallaghercorp.com/polyurethane-coefficient-friction/. [Accessed 8 November 2016].

[35] McMaster-Carr, "Steel Mesh," McMaster-Carr, 2016. [Online]. Available: https://www.mcmaster.com/#steel-mesh/=14y8chv. [Accessed 8 November 2016].

[36] Paragon Manufacturing Inc., "Acoustic Properties," Paragon Manufacturing Inc., 2016. [Online]. Available: http://www.noisedamp.com/acoustic-properties.aspx. [Accessed 13 November 2016].

[37] "Canadastop100," [Online]. Available: http://www.canadastop100.com/national. [Accessed 28 09 2016].

Appendix A: Project Management Tools

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A1.0 Stakeholder Registry

The stakeholder registry illustrates the project stakeholders, information shared, modes and frequency of communication, persons responsible for communication and stakeholder influence

APPENDIX A TABLE I

PROJET STAKEHOLDER REGISTRY

Stakeholder Register	Information Shared	Communication Channel	Frequency	Responsible Person	Influence	Action
Faculty Advisor: Nan Wu	Status Reports Budget Requirements Strategies Technology Schedule Change	Meetings Reports Emails	Weekly Or as needed	Project Manager Secretary Team Members	High	Show Consideration
Project Manager: Brett Bergen	Status Reports Budget Requirements Strategies Technology Schedule Change Potential Problems	Meetings Reports Emails Informal discussions Demonstrations	Several times per week	Secretary Team Members	High	Key Player
Secretary: Dustin Brandt	Status Reports; Meeting Minutes Schedule Changes Documentation Upkeep	Meetings Reports Emails Informal discussions Demonstrations	Several times per week	Project Manager Team Members	High	Key Player
Team Members: James Riese Tianyu Peng	Status Reports Technology Requirements Schedule Changes Potential Issues	Meetings Reports Emails Informal discussions Demonstrations	Several times per week	Project Manager Secretary Team members	High	Key Player
Royal Canadian Mint (RCM)	Final Design	Kevin Ginter Paul Nowak	As and when needed	Project Manager	High	Key Player
Industry Sponsor: Paul Nowak	Status Reports Final Design	Kevin Ginter Email Formal Meetings Formal Presentations	As and when needed	Project Manager	High	Key Player
Industry Contact: Kevin Ginter	Status Reports Final Design Potential Issues	Email Informal Meetings Formal Meetings Formal Presentations	Weekly updates at minimum	Project Manager Secretary Team Members	High	Key Player
Royal Canadian Mint Mechanics	Standard Operating Procedures Final Design	Informal Meetings	As and when needed	Industry Contact Project Manager Secretary	Medium	Show Consideration

Stakeholder Register	Information Shared	Communication Channel	Frequency	Responsible Person	Influence	Action
				Team Members		
Royal Canadian Mint Operators	Standard Operating Procedures	Informal Meetings	During research and when implemented/as needed	Industry Contact Project Manager Secretary Team Members	Medium	Show Consideration
Royal Canadian Mint Cleaners	Standard Operating Procedures Final Design	Informal Meetings	During research and when implemented/as needed	Industry Contact Project Manager Secretary Team Members	Medium	Show Consideration
University Sponsor: Dr. Paul Labossiere	Project Reports Design Reports Status Updates Schedule Change	Formal Reports Emails Formal Meetings Informal Meetings Formal Presentations	At Phase update stages As and when needed	Project Manager Secretary Team Members	Medium	Show Consideration
Mechanical Engineering Department	Project Report	Formal Reports Formal Presentations	As and when needed	Project Manager Secretary	Low	Show Consideration
University of Manitoba	Project Report	Formal Reports Formal Presentations	As and when needed	Project Manager	Low	Show Consideration

A2.0 Risk Management

The risks for the project are listed below along with the mitigation plans for the top seven risks. The process of receiving the top seven risks and how they were ranked by using the likelihood matrix.

APPENDIX A TABLE II

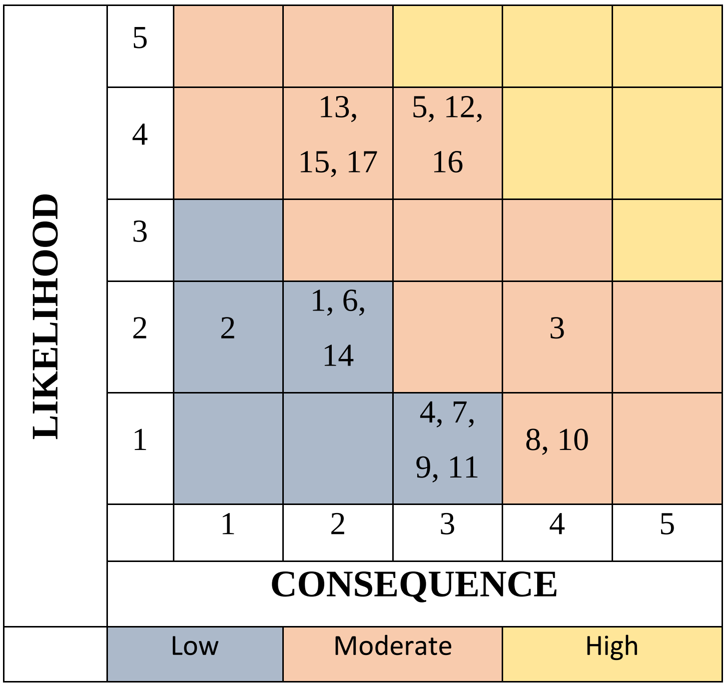
PROBABILITY RANKING

Probability Ranking	Percentage
1	0-19
2	20-39
3	40-59
4	60-79
5	80-100

APPENDIX A TABLE III

CONSEQUENCE RANKING

Consequence Rank	Consequence
1	Insignificant to no impact
2	Minor issue; ability to achieve goal is likely
3	Moderate issue; ability to achieve goal is uncertain
4	Major issue; ability to resolve issue would have great difficulty
5	Inability to achieve goal



Appendix A Figure 1. Likelihood vs Consequence

APPENDIX A TABLE IV

RISK CLASSIFICATION AND RANKING

Risk ID	Risk Description	Probability (%)	Consequence (1-5)	Probability Ranking (1-5)
R.1	Client unavailable for meeting	25	2	2
R.2	Member unavailable for meeting	25	1	2
R.3	Unable to get onto plant floor	20	4	2
R.4	Maintenance on machine	15	3	1
R.5	Unable to shut machine down for testing	60	3	4

Risk ID	Risk Description	Probability (%)	Consequence (1-5)	Probability Ranking (1-5)
R.6	Client changes expectations during project life	30	2	2
R.7	Member leaves the group	10	3	1
R.8	Abnormal PO approval process length	15	4	1
R.9	Misunderstanding with manufacturer about product	10	3	1
R.10	Injury on site	2	4	1
R.11	Need for outsourcing manufacturing of prototype	10	3	1
R.12	Prototype not meeting all expectations	50	4	3
R.13	Scope creep	20	4	2
R.14	Users conflict with change	25	2	2
R.15	Manufacturing of product unavailable till later date	20	4	2
R.16	Member availability	40	4	3
R.17	Team unable to keep up with workload	30	4	2

APPENDIX A TABLE V
RISK MITIGATION OF TOP RISK

Risk ID	Potential Impact	Measures to be taken
R.3	Cannot observe, test, or fit prototype onto machines	Notify the Royal Canadian Mint 1 week before the need to get onto the floor plant to verify that it is available and any testing or implementing.
R.5	Cannot observe, test, or fit prototype onto machines	Notify the Royal Canadian Mint 1 week before the need to get onto the floor plant to verify that it is available and any testing or implementing. Also, notify the tasks needed completion and arrange beforehand for a time slot put aside for the testing or implementing.
R.12	Client unhappy, prototype not fitting or working properly	Understand the problem, rigorous design concept selection, double check all measurements and have a second person look over the work to ensure that all designs are completed to what the client expects and to the dimensions available and all mounting points are properly placed. As for the

Risk ID	Potential Impact	Measures to be taken
		prototype meeting all needs/deliverables, the only way to ensure that is by trial and error with the prototype. A failed prototype is not expected, but minor adjustments may be needed afterwards.
R.13	When scope creep occurs, the project seems open-ended. This leads to failing to meet deadlines, adding unneeded features, or going over budget.	The scope must be clearly defined with no gaps or holes that could potentially grow into a larger project. Make a clear budget. Lastly, discuss with the client exactly what they expect and be critical with any ideas the client has come up with to not let the client do the project, but let us work on it.
R.15	Normally a machine shop can get very busy when machines break, therefore if our prototype needs to go on the back burner for other parts we will be delayed in the manufacturing and implementing phase of our project. This delay would most likely hinder us from completing all objectives of the project.	Notify the Royal Canadian Mint within 1 week of needing any manufacturing done, or a prototype made. This gives Royal Canadian Mint time to move other parts around and give a time slot to get our prototype finished and any modifications can be made shortly after.
R.16	If members are not available to meet or the schedules of each student does not mesh, there will not be a time slot that can be set aside for work sessions or time to meet with the client as a group.	A student's schedule is what it is. There is a definite time slot that fits everyone since it is when we all share a class that is specifically for meeting, but other than that time slot each student must make themselves extremely available to meet and work together to get the project done.
R.17	If the team cannot keep up with the workload, the group will fall behind for each phase and will have to work very hard at the	Stay on top of the workload and distribute the workload evenly with each member so that all the work is done at the same time and no one does more work than others do. We do not want to overwhelm anyone. Weekly work sessions should be available to work together and individual work

Risk ID	Potential Impact	Measures to be taken
	end of each phase to meet the deadline. This could lead to all night work sessions, members doing more work than others do, or in the worst case, a member being overwhelmed with the work and giving up.	sessions must happen as well to finish individual work on time.

Appendix B: CAD Drawings for VFP Rear Region

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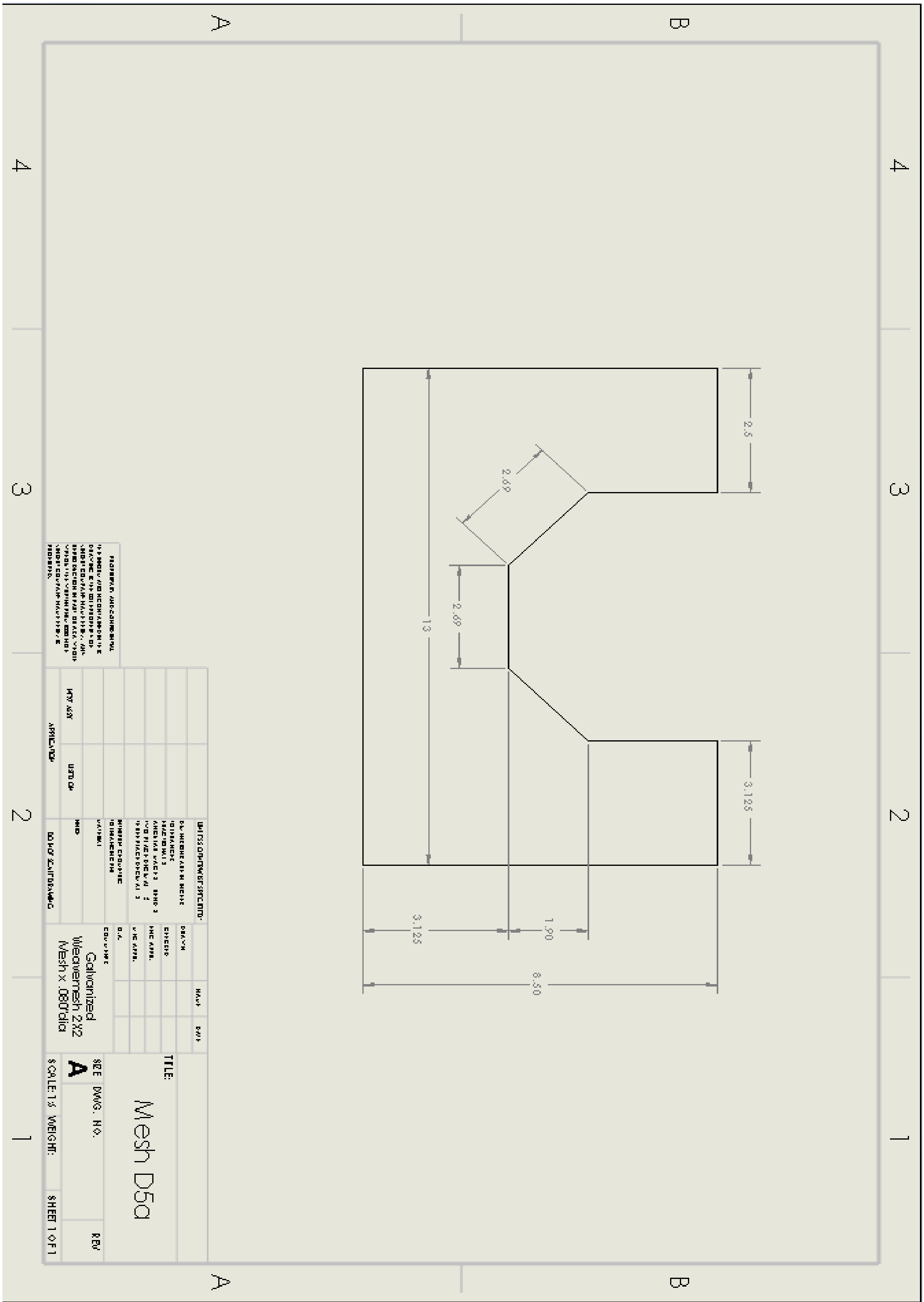
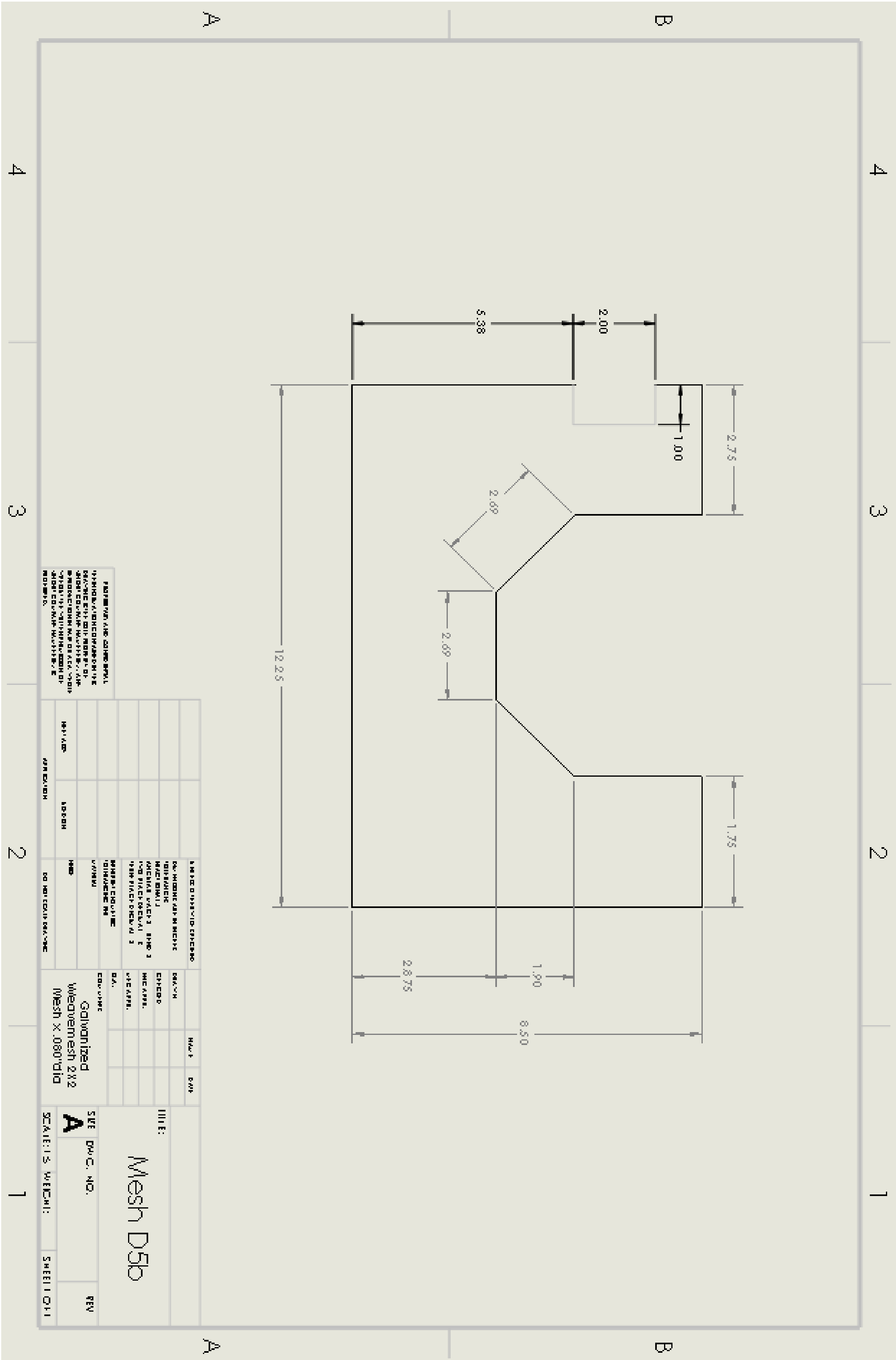
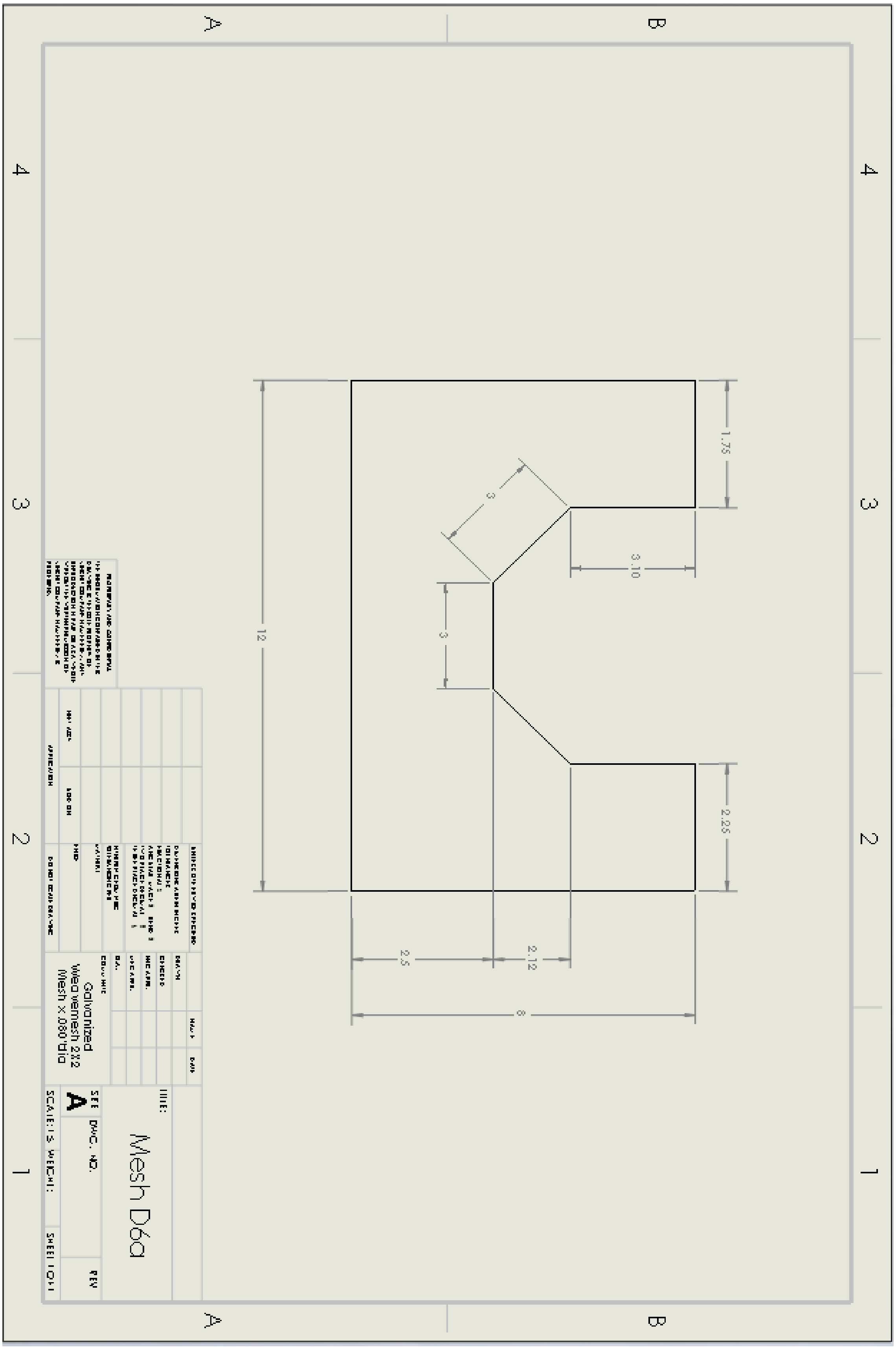


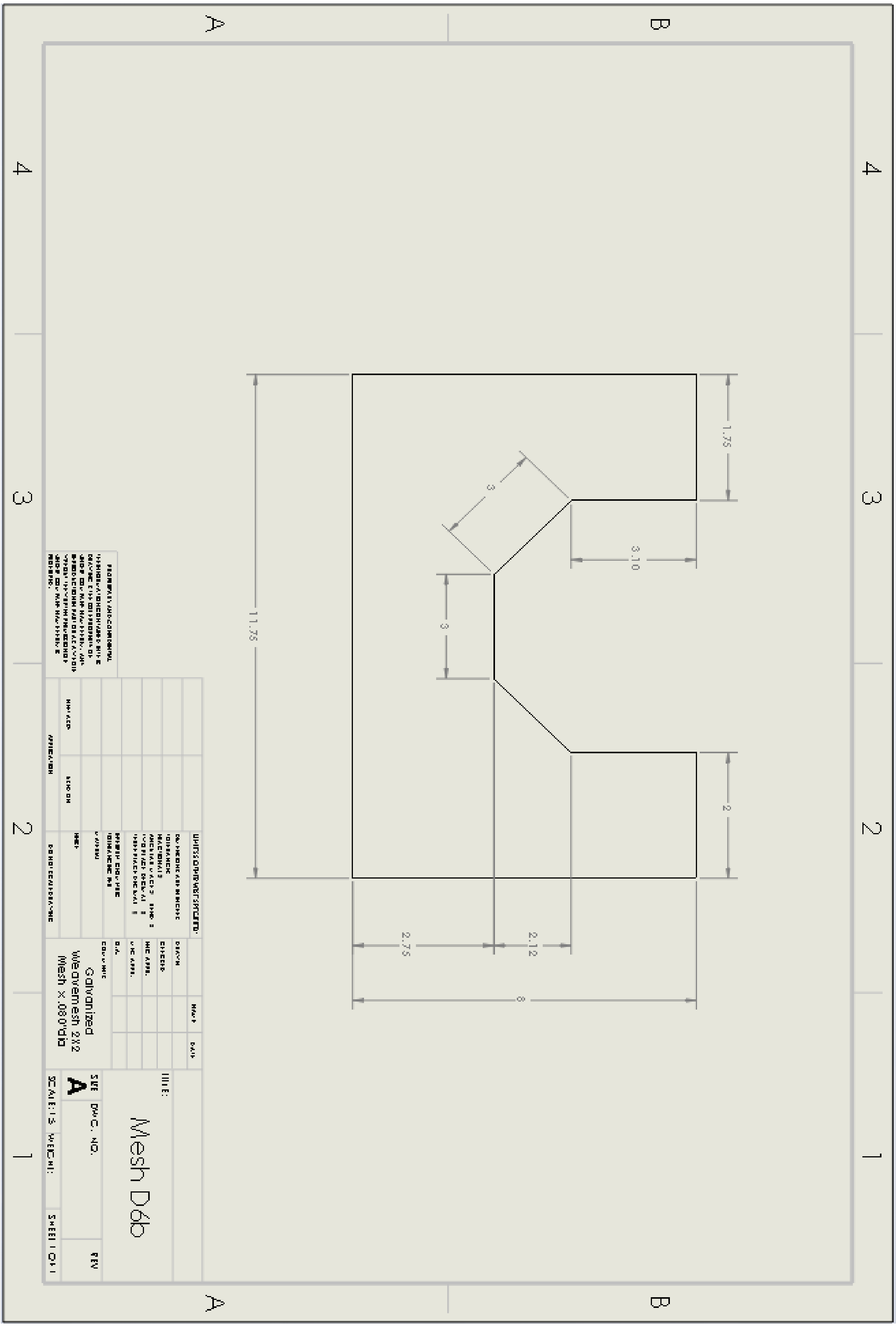
Appendix B Figure 1. CAD Drawing for VFP Rear in Line D5a



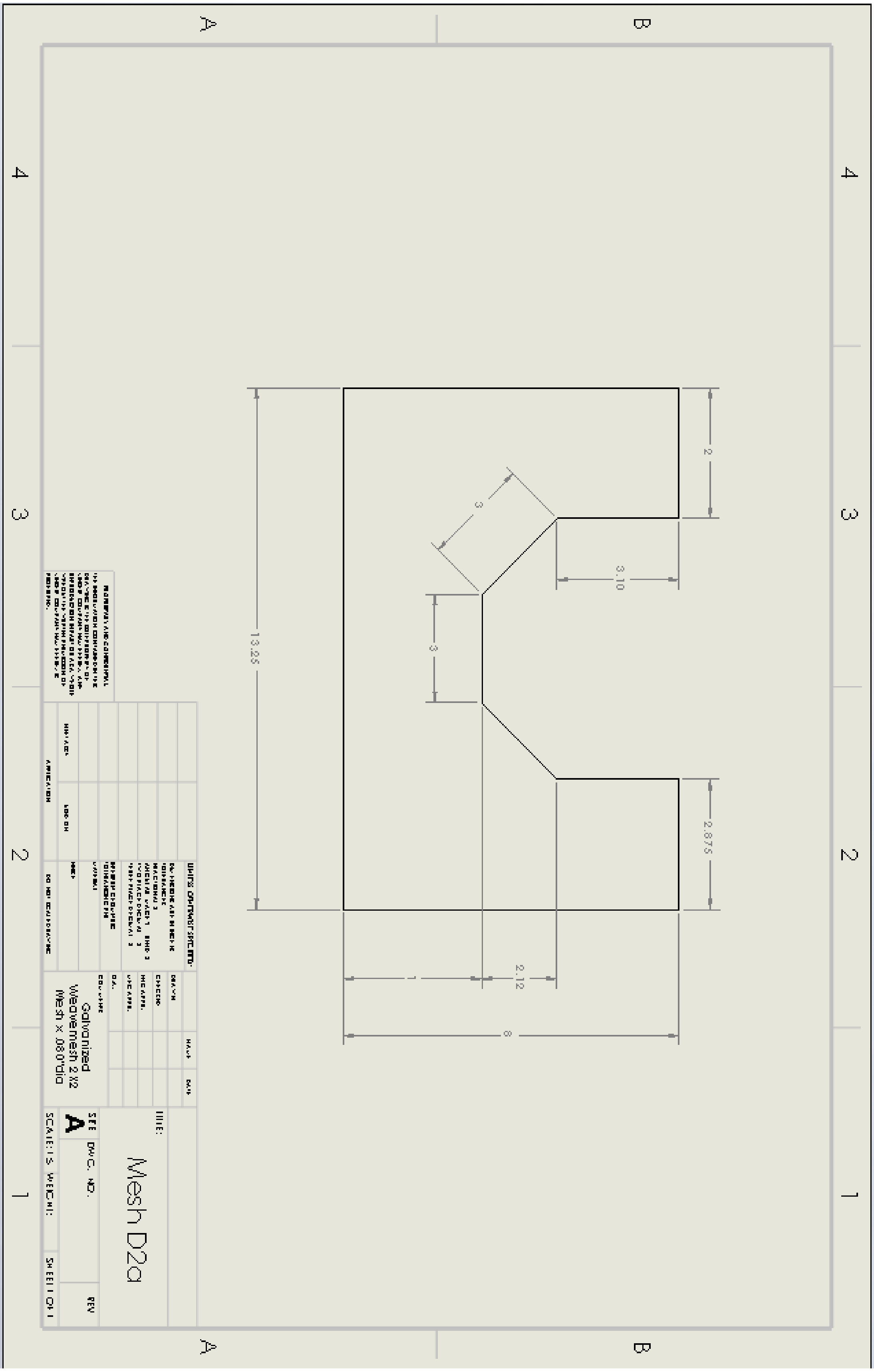
Appendix B Figure 2. CAD Drawing for VFP Rear in Line D5b



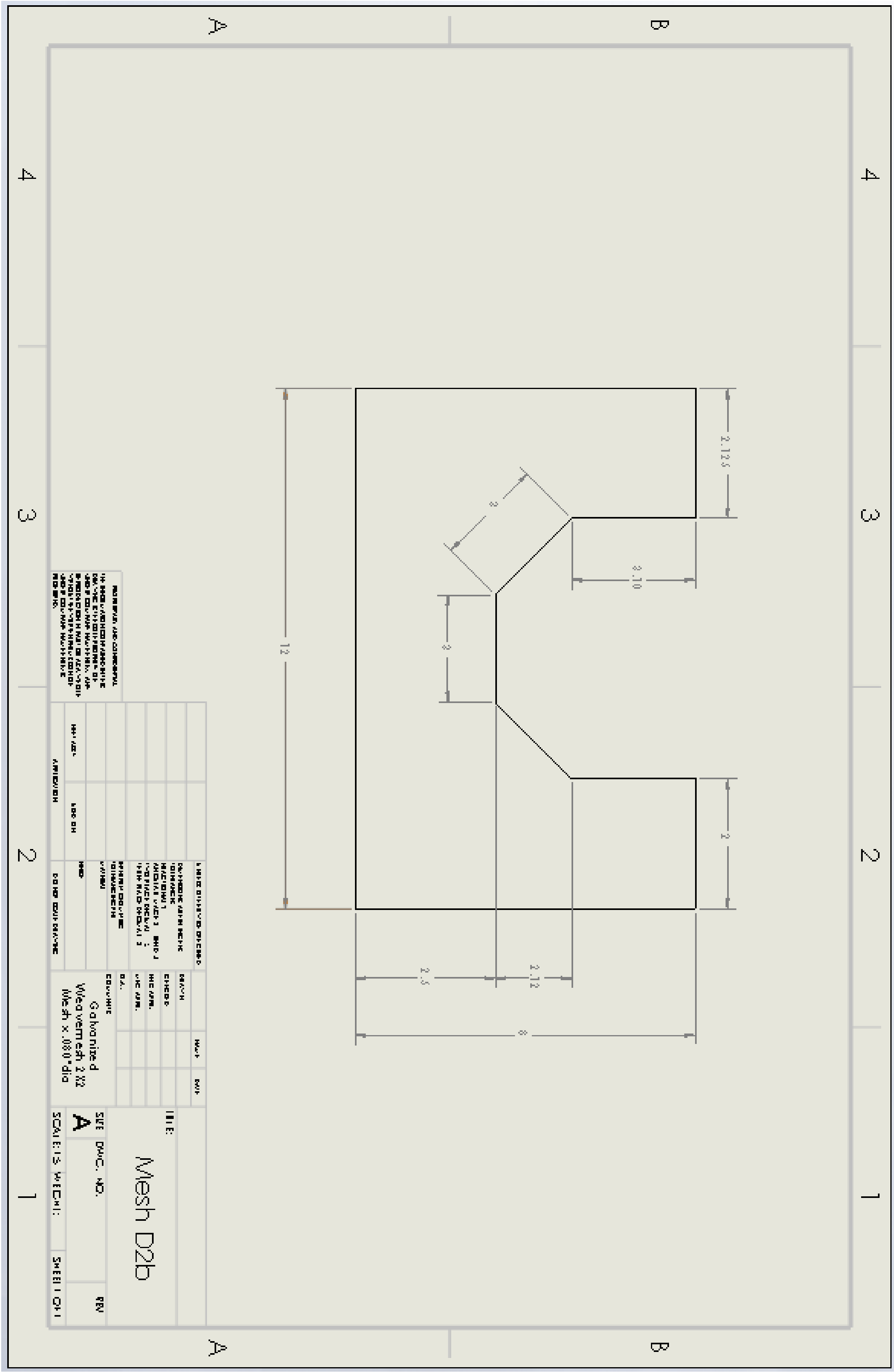
Appendix B Figure 3. CAD Drawing for VFP Rear in Line D6a



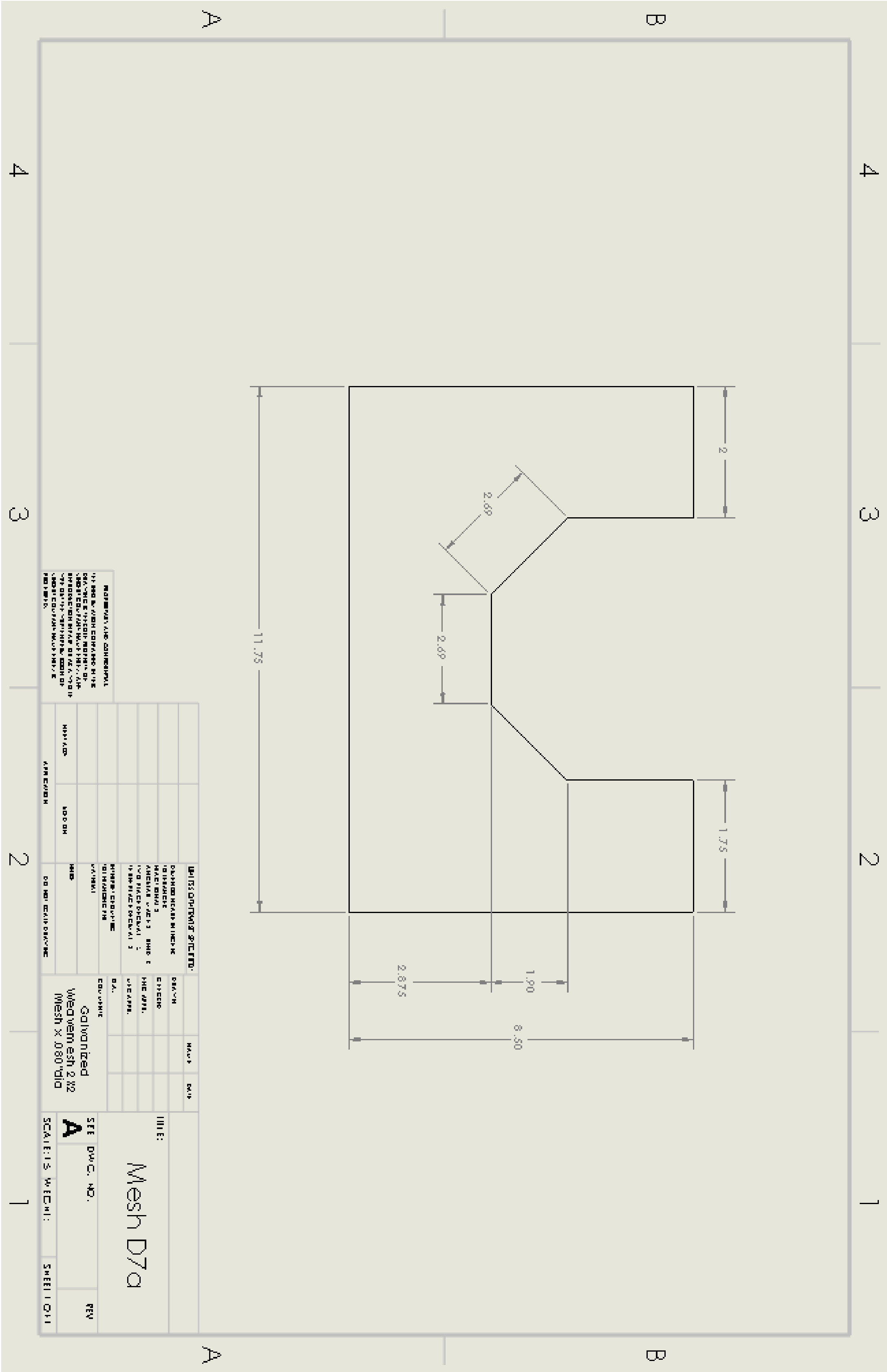
Appendix B Figure 4. CAD Drawing for VFP Rear in Line D6b



Appendix B Figure 5. CAD Drawing for VFP Rear in Line D2a

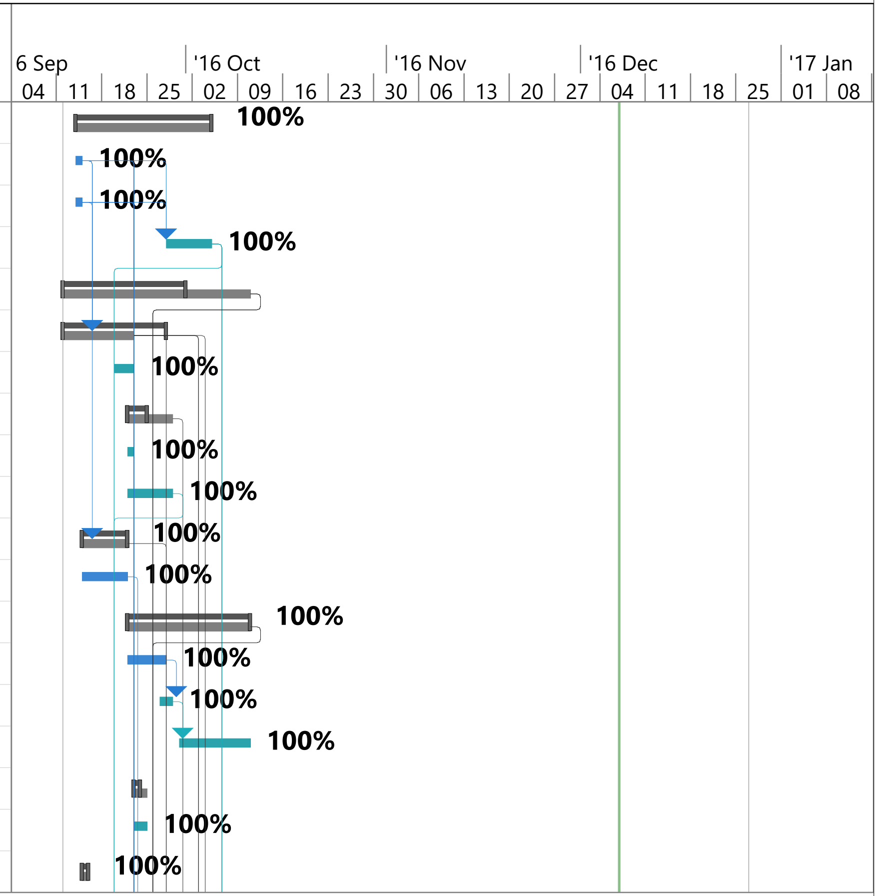


Appendix B Figure 6. CAD Drawing for VFP Rear in Line D2b



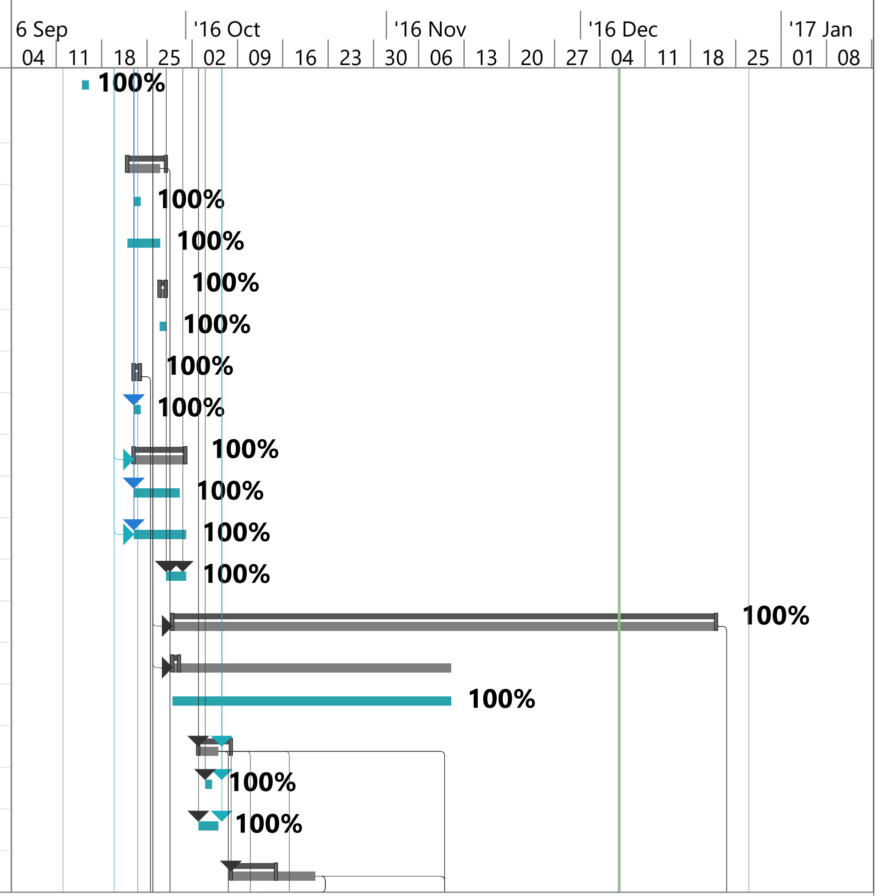
Appendix B Figure 7. CAD Drawing for VFP Rear in Line D7a

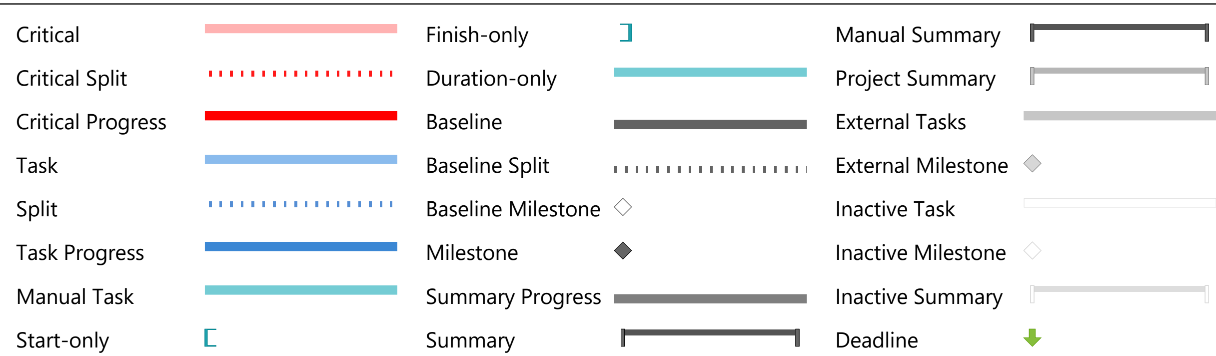
ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
1	**1**	**Initiation**	**15 days**	**Wed 16-09-14**	**Tue 16-10-04**	**Tue 16-10-04**		
2	1.1	Obtain Project Description	1 day	Wed 16-09-14	Wed 16-09-14	Wed 16-09-14		All
3	1.2	Assemble Team	1 day	Wed 16-09-14	Wed 16-09-14	Wed 16-09-14		
4	1.3	Meet with client & Project Advisor	5 days	Wed 16-09-28	Tue 16-10-04	Tue 16-10-04	2,3	All
5	**2**	**Planning**	**15 days**	**Mon 16-09-12**	**Fri 16-09-30**	**Mon 16-10-10**		**All**
6	**2.1**	**Project Scope**	**12 days**	**Mon 16-09-12**	**Tue 16-09-27**	**Tue 16-09-27**	**2,3**	**All**
7	2.1.1	Identify Customer Needs	3 days	Tue 16-09-20	Thu 16-09-22	Thu 16-09-22		
8	**2.2**	**Schedule Plan**	**3 days**	**Thu 16-09-22**	**Sat 16-09-24**	**Wed 16-09-28**		**James**
9	2.2.1	WBS	1 day	Thu 16-09-22	Thu 16-09-22	Thu 16-09-22		
10	2.2.2	Gantt Chart	5 days	Thu 16-09-22	Wed 16-09-28	Wed 16-09-28		
11	**2.3**	**Cost Budget Plan**	**5 days**	**Thu 16-09-15**	**Wed 16-09-21**	**Wed 16-09-21**	**2**	**Brett**
12	2.3.1	Identify Customer Budget	5 days	Thu 16-09-15	Wed 16-09-21	Wed 16-09-21		
13	**2.4**	**Quality Plan**	**13 days**	**Thu 16-09-22**	**Mon 16-10-10**	**Mon 16-10-10**		**Dustin,Terry**
14	2.4.1	Identify Metrics	4 days	Thu 16-09-22	Tue 16-09-27	Tue 16-09-27		
15	2.4.2	Identify Specifications	2 days	Tue 16-09-27	Wed 16-09-28	Wed 16-09-28	14	
16	2.4.3	QFD	7 days	Fri 16-09-30	Mon 16-10-10	Mon 16-10-10	15	
17	**2.5**	**Human Resource Plan**	**1 day**	**Fri 16-09-23**	**Fri 16-09-23**	**Sat 16-09-24**		**James**
18	2.5.1	RACI Matrix	2 days	Fri 16-09-23	Sat 16-09-24	Sat 16-09-24		
19	**2.6**	**Communication Plan**	**1 day**	**Thu 16-09-15**	**Thu 16-09-15**	**Thu 16-09-15**		**Brett**



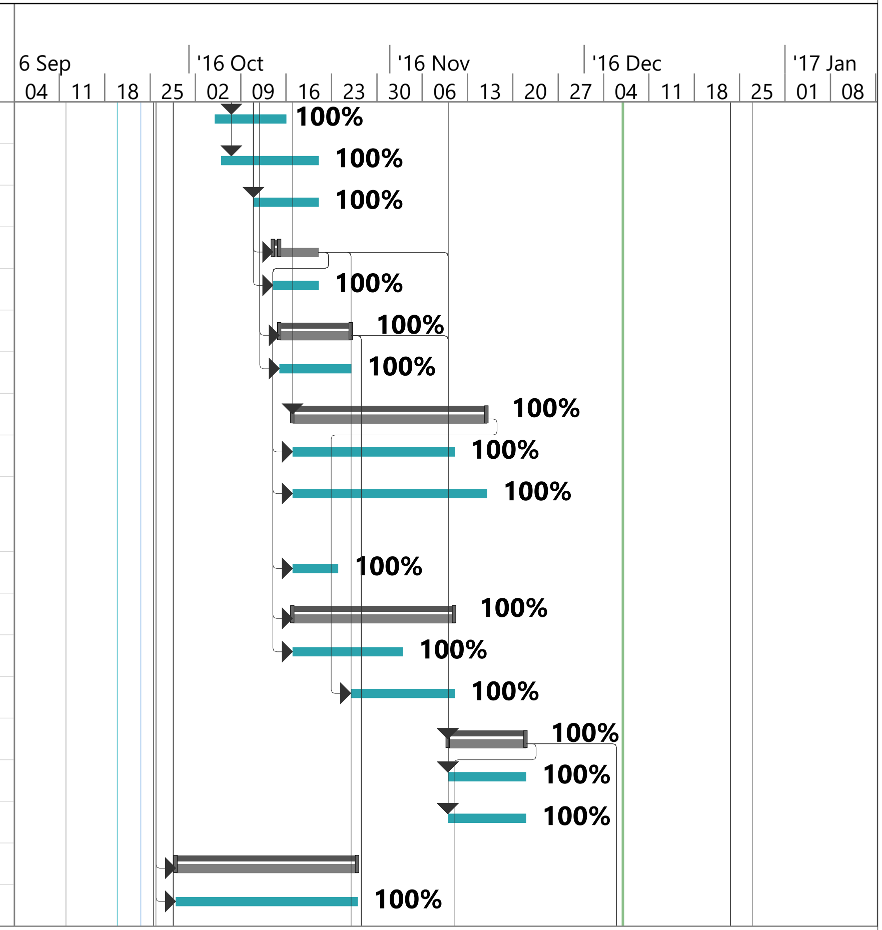
Critical		Finish-only		Manual Summary	
Critical Split		Duration-only		Project Summary	
Critical Progress		Baseline		External Tasks	
Task		Baseline Split		External Milestone	
Split		Baseline Milestone		Inactive Task	
Task Progress		Milestone		Inactive Milestone	
Manual Task		Summary Progress		Inactive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

ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
20	2.6.1	Create Agenda & Meeting Minutes Template	1 day	Thu 16-09-15	Thu 16-09-15	Thu 16-09-15		
21	**2.7**	**Risk Management Plan**	**4 days**	**Thu 16-09-22**	**Tue 16-09-27**	**Tue 16-09-27**		**Brett**
22	2.7.1	Risk Matrix	1 day	Fri 16-09-23	Fri 16-09-23	Fri 16-09-23		
23	2.7.2	Risk Responses	3 days	Thu 16-09-22	Mon 16-09-26	Mon 16-09-26		
24	**2.8**	**Procurement Plan**	**1 day**	**Tue 16-09-27**	**Tue 16-09-27**	**Tue 16-09-27**		**Terry**
25	2.8.1	Procurement Process	1 day	Tue 16-09-27	Tue 16-09-27	Tue 16-09-27		
26	**2.9**	**Stakeholder Plan**	**1 day**	**Fri 16-09-23**	**Fri 16-09-23**	**Fri 16-09-23**		**Dustin**
27	2.9.1	Stakeholder List & Registry	1 day	Fri 16-09-23	Fri 16-09-23	Fri 16-09-23	2,3	
28	**2.10**	**PHASE I**	**6 days**	**Fri 16-09-23**	**Fri 16-09-30**	**Fri 16-09-30**	**4**	**All**
29	2.10.1	Project Definition	5 days	Fri 16-09-23	Thu 16-09-29	Thu 16-09-29	2,3	
30	2.10.2	Project Report	6 days	Fri 16-09-23	Fri 16-09-30	Fri 16-09-30	2,3,4	
31	2.10.3	Oral Presentation	3 days	Wed 16-09-28	Fri 16-09-30	Fri 16-09-30	6,8,11,21	
32	**3**	**Execution**	**60 days**	**Thu 16-09-29**	**Wed 16-12-21**	**Wed 16-12-21**	**5**	
33	**3.1**	**Gather Baseline Metrics**	**1 day**	**Thu 16-09-29**	**Thu 16-09-29**	**Thu 16-11-10**	**13**	**All**
34	3.1.1	Examine Current System	31 days	Thu 16-09-29	Thu 16-11-10	Thu 16-11-10		All
35	**3.2**	**Conceptual Design**	**5 days**	**Mon 16-10-03**	**Fri 16-10-07**	**Fri 16-10-07**	**4,6**	**All**
36	3.2.1	Clarify Problem	1 day	Tue 16-10-04	Tue 16-10-04	Tue 16-10-04	4,6	All
37	3.2.2	Problem Decoposition	3 days	Mon 16-10-03	Wed 16-10-05	Wed 16-10-05	4,6	James
38	**3.3**	**Concept Generation**	**5 days**	**Fri 16-10-07**	**Fri 16-10-14**	**Thu 16-10-20**	**35**	**All**





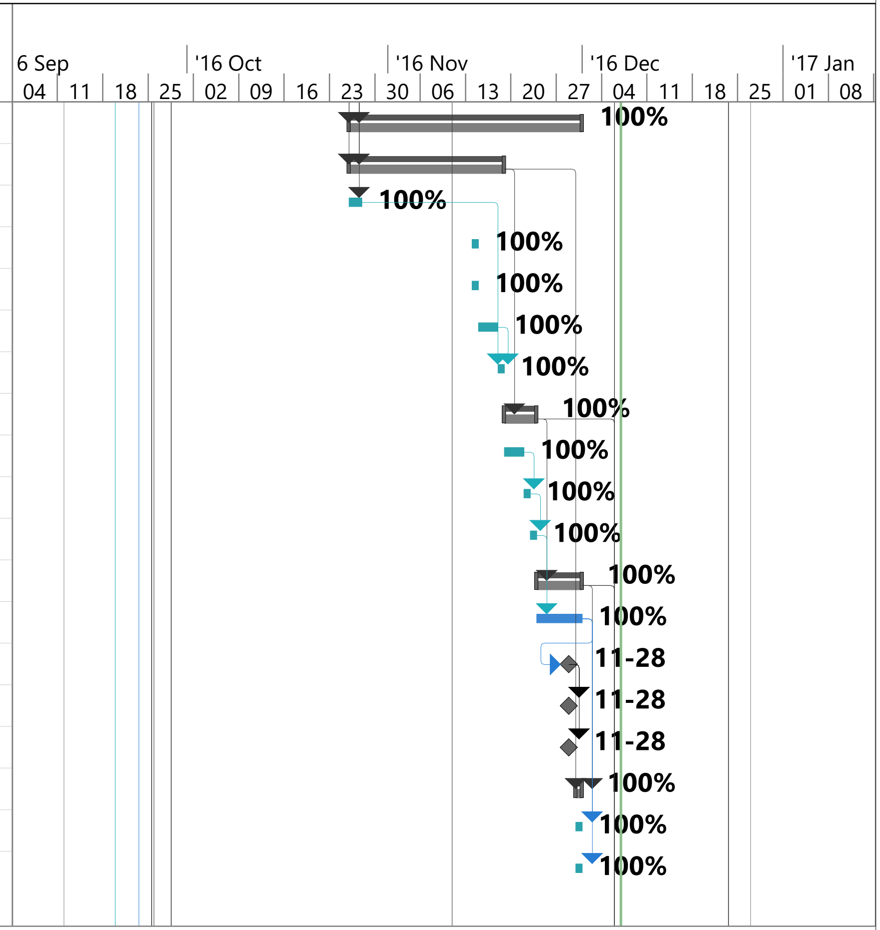
ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
39	3.3.1	External & Internal Search	9 days	Tue 16-10-04	Sat 16-10-15	Sat 16-10-15	35	Dustin
40	3.3.2	Systematic Exploration	11 days	Wed 16-10-05	Thu 16-10-20	Thu 16-10-20	35	All
41	3.3.3	S.C.A.M.P.E.R. Method	8 days	Tue 16-10-11	Thu 16-10-20	Thu 16-10-20	35	All
42	**3.4**	**Preliminary Selection**	**1 day**	**Fri 16-10-14**	**Fri 16-10-14**	**Thu 16-10-20**	**38**	**All**
43	3.4.1	Concept vs Needs Comparison	5 days	Fri 16-10-14	Thu 16-10-20	Thu 16-10-20	38	All
44	**3.5**	**Model Concepts**	**7 days**	**Sat 16-10-15**	**Tue 16-10-25**	**Tue 16-10-25**	**38**	**Terry**
45	3.5.1	Basic CAD Analysis	8 days	Sat 16-10-15	Tue 16-10-25	Tue 16-10-25	38	Terry
46	**3.6**	**Research**	**22 days**	**Mon 16-10-17**	**Tue 16-11-15**	**Tue 16-11-15**	**35**	**All**
47	3.6.1	Material Comparison	19 days	Mon 16-10-17	Thu 16-11-10	Thu 16-11-10	42	Dustin,James
48	3.6.2	Manufacturing Process Comparisons	22 days	Mon 16-10-17	Tue 16-11-15	Tue 16-11-15	42	Dustin,James
49	3.6.3	Cost Estimates	6 days	Mon 16-10-17	Sun 16-10-23	Sun 16-10-23	42	All
50	**3.7**	**Optimization**	**19 days**	**Mon 16-10-17**	**Thu 16-11-10**	**Thu 16-11-10**	**42**	**All**
51	3.7.1	Further CAD Analysis/Modelling	13 days	Mon 16-10-17	Wed 16-11-02	Wed 16-11-02	42	Terry
52	3.7.2	Alternative Analysis	12 days	Wed 16-10-26	Thu 16-11-10	Thu 16-11-10	46	All
53	**3.8**	**Final Design Selection**	**8 days**	**Thu 16-11-10**	**Mon 16-11-21**	**Mon 16-11-21**	**44,42,38,35**	**All**
54	3.8.1	Design Criteria Analysis	8 days	Thu 16-11-10	Mon 16-11-21	Mon 16-11-21	44,42,38,35	All
55	3.8.2	Confirm Customer Acceptance	8 days	Thu 16-11-10	Mon 16-11-21	Mon 16-11-21	44,42,38,35	All
56	**3.9**	**PHASE II**	**20 days**	**Thu 16-09-29**	**Wed 16-10-26**	**Wed 16-10-26**	**5**	**All**
57	3.9.1	Concept Design Report	20 days	Thu 16-09-29	Wed 16-10-26	Wed 16-10-26	5	All



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

Gantt Chart V1.10-tracked.mpp

ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
58	**3.10**	**Implementation**	**26 days**	**Wed 16-10-26**	**Wed 16-11-30**	**Wed 16-11-30**	**42,44**	**All**
59	**3.10.1**	**Prototype Manufacturing**	**18 days**	**Wed 16-10-26**	**Fri 16-11-18**	**Fri 16-11-18**	**42,44**	**All**
60	3.10.1.1	Create Part Drawings	2 days	Wed 16-10-26	Thu 16-10-27	Thu 16-10-27	44	Terry,Brett
61	3.10.1.2	Outline Processes Used	1 day	Sun 16-11-13	Mon 16-11-14	Mon 16-11-14		James
62	3.10.1.3	Contact Suppliers/Machini	1 day	Mon 16-11-14	Mon 16-11-14	Mon 16-11-14		Dustin,James
63	3.10.1.4	Part Estimates	3 days	Tue 16-11-15	Thu 16-11-17	Thu 16-11-17		James,Brett,Dustin
64	3.10.1.5	Place Part Orders	1 day	Fri 16-11-18	Fri 16-11-18	Fri 16-11-18	60,63	James
65	**3.10.2**	**Testing**	**3 days**	**Sat 16-11-19**	**Wed 16-11-23**	**Wed 16-11-23**	**59**	**All**
66	3.10.2.1	Gather Instrumentation	2 days	Sat 16-11-19	Mon 16-11-21	Mon 16-11-21		Brett,Terry
67	3.10.2.2	Gather Data	1 day	Tue 16-11-22	Tue 16-11-22	Tue 16-11-22	66	All
68	3.10.2.3	Analysis of Data	1 day	Wed 16-11-23	Wed 16-11-23	Wed 16-11-23	67	All
69	**3.10.3**	**Modification**	**5 days**	**Thu 16-11-24**	**Wed 16-11-30**	**Wed 16-11-30**	**65**	**All**
70	3.10.3.1	Redesign	5 days	Thu 16-11-24	Wed 16-11-30	Wed 16-11-30	68	Terry,Brett
71	3.10.3.2	Determine Customer Acce	0 days	Mon 16-11-28	Mon 16-11-28	Mon 16-11-28	70	All
72	3.10.3.3	Create Part Drawings	0 days	Mon 16-11-28	Mon 16-11-28	Mon 16-11-28	71	Brett,Terry
73	3.10.3.4	Alter Manufacturing Proce	0 days	Mon 16-11-28	Mon 16-11-28	Mon 16-11-28	71	All
74	**3.10.4**	**Installation**	**1 day**	**Wed 16-11-30**	**Wed 16-11-30**	**Wed 16-11-30**	**59,69**	**All**
75	3.10.4.1	Develop Installation Proce	1 day	Wed 16-11-30	Wed 16-11-30	Wed 16-11-30	70	All
76	3.10.4.2	Develop Maintenance Procedure	1 day	Wed 16-11-30	Wed 16-11-30	Wed 16-11-30	70	All



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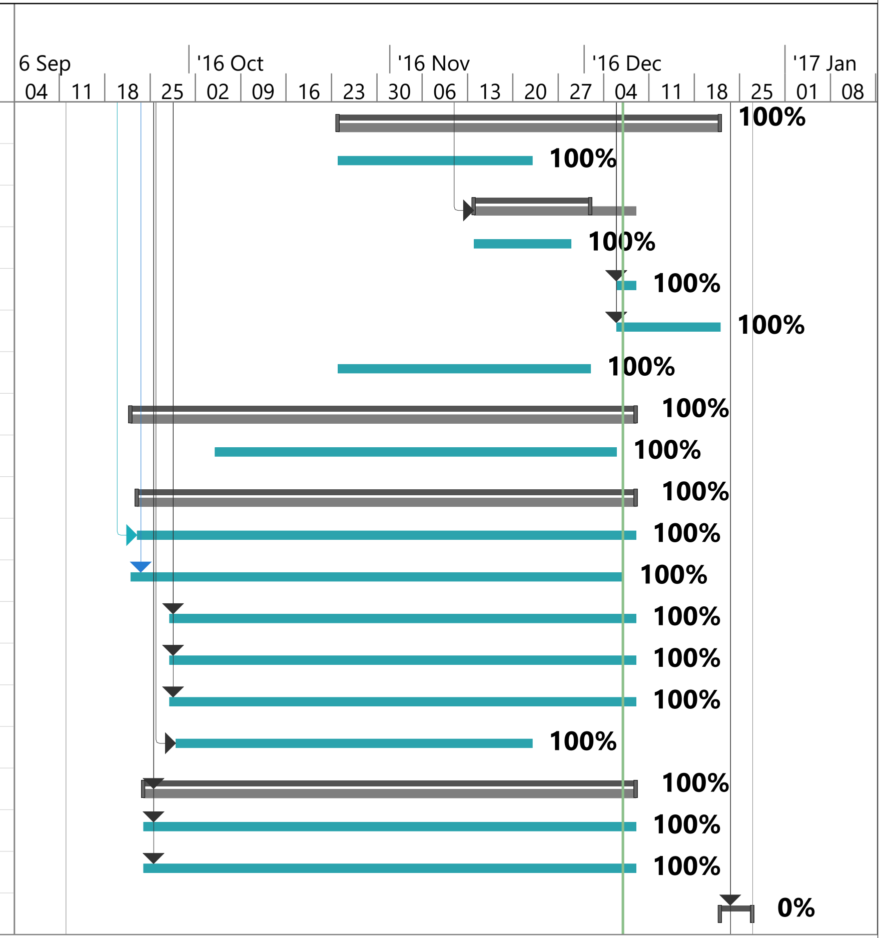
Task Progress	Milestone	Inactive Milestone
Manual Task	Summary Progress	Inactive Summary
Start-only	Summary	Deadline

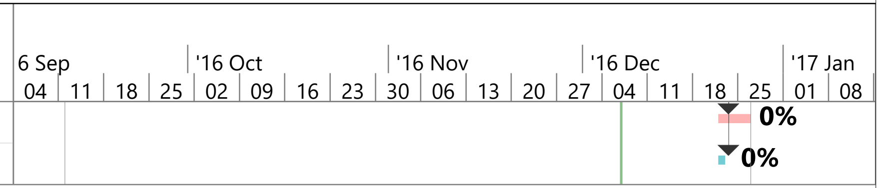
Gantt Chart V1.10-tracked.mpp

ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
77	**3.11**	**PHASE III**	**43 days**	**Mon 16-10-24**	**Wed 16-12-21**	**Wed 16-12-21**		**All**
78	3.11.1	Draft Report	22 days	Mon 16-10-24	Tue 16-11-22	Tue 16-11-22		All
79	**3.11.2**	**Develop Poster**	**14 days**	**Mon 16-11-14**	**Thu 16-12-01**	**Thu 16-12-08**	**53**	**All**
80	3.11.2.1	Design	11 days	Mon 16-11-14	Mon 16-11-28	Mon 16-11-28		Dustin
81	3.11.2.2	Assemble	3 days	Tue 16-12-06	Thu 16-12-08	Thu 16-12-08	53,65,69	All
82	3.11.3	Create Final Presentation	12 days	Tue 16-12-06	Wed 16-12-21	Wed 16-12-21	53,65,69	All
83	3.11.4	Create Final Report	29 days	Mon 16-10-24	Thu 16-12-01	Thu 16-12-01		All
84	**4**	**Monitor & Control**	**56 days**	**Thu 16-09-22**	**Thu 16-12-08**	**Thu 16-12-08**		**All**
85	4.1	Progress Reports	44 days	Wed 16-10-05	Mon 16-12-05	Mon 16-12-05		Brett
86	**4.2**	**Schedule Updates**	**55 days**	**Fri 16-09-23**	**Thu 16-12-08**	**Thu 16-12-08**		**James**
87	4.2.1	Gantt Chart Updates	55 days	Fri 16-09-23	Thu 16-12-08	Thu 16-12-08	10	James
88	4.3	Budget Updates	54 days	Thu 16-09-22	Tue 16-12-06	Tue 16-12-06	12	Brett
89	4.4	Risk Management	52 days	Wed 16-09-28	Thu 16-12-08	Thu 16-12-08	21	Brett
90	4.5	Risk Assessments	52 days	Wed 16-09-28	Thu 16-12-08	Thu 16-12-08	21	Brett
91	4.6	Update Risk Log	52 days	Wed 16-09-28	Thu 16-12-08	Thu 16-12-08	21	Brett
92	4.7	Quality Updates	39 days	Thu 16-09-29	Tue 16-11-22	Tue 16-11-22	13	Terry
93	**4.8**	**Stakeholder Management**	**54 days**	**Sat 16-09-24**	**Thu 16-12-08**	**Thu 16-12-08**	**26**	**Dustin**
94	4.8.1	Update Stakeholder Registry	55 days	Sat 16-09-24	Thu 16-12-08	Thu 16-12-08	26	Dustin
95	4.8.2	Update Stakeholders	55 days	Sat 16-09-24	Thu 16-12-08	Thu 16-12-08	26	Dustin
96	**5**	**Closing**	**0 days**	**Thu 16-12-22**	**Mon 16-12-26**	**NA**	**32**	**All**



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

ID	WBS	Task Name	Actual Durati	Start	Finish	Actual Finish	Predeces	Resource Names
97	5.1	Debrief with Customer	0 days	Thu 16-12-22	Mon 16-12-26	NA	32	All
98	5.2	Lessons Learned Document	0 days	Thu 16-12-22	Thu 16-12-22	NA	32	All



Critical	Finish-only	Manual Summary
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