



**University  
of Manitoba**

# **Noise Reduction of the Ultra-Span Hollow Core Extruder**

Team 1 - Good Vibrations

## **Phase III: Final Design Report**

*Required by MECH 4860: Engineering Design*

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Date: December 4, 2019

**ULTRA'SPAN**  
EXPERIENCE PERFORMANCE

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Dear Dr. Paul Labossiere,

On behalf of Team 1, Good Vibrations, we are pleased to submit our final design report on Wednesday December, 4, 2019. The purpose of this report is to present our final design which investigates the noise reduction of the hollow core extruder at Ultra-Span Technologies. This report contains three different designs to be implemented into a final noise reduction solution.

If you have any questions, comments or concerns, please feel free to contact our team manager Reginald Waddell at

Sincerely,

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Jason Neufeld

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## EXECUTIVE SUMMARY

Ultra-Span Technologies Inc. is a company that manufactures hollow core concrete slab extruders. The Ultra-Span EXT-400Si extruder currently operates at a sound level above 85 dB causing operator discomfort. The objective of this project is to propose a final design that reduces the decibel level to a safe operating condition. Customer needs, constraints, and target specifications were defined to ensure that the proposed design met project intent. Part of the defined customer requirements include a noise level target specification of 80 dB and budget of \$5,000.

Extruder testing was completed along with research on noise reduction products and competitor solutions to generate concepts. From the concepts generated, three solutions progressed as final design solutions, including an extruder door redesign, anti-vibration rubber isolation mounts, and acoustic dampening material.

The extruder door redesign was estimated to produce a 10 dB reduction in noise at a cost of \$185.28. VibraSystems anti vibration rubber isolation mounts were chosen for isolation between vibration sources and the cassette and hopper, to produce a vibration percent isolation of approximately 99%. The total cost for all parts associated with implementing the anti vibration mounts is \$483.54. Lastly, the addition of the closed-cell acoustic dampening material Pyrotek Decidamp sheets was estimated to reduce the noise by 20 dB, at a price of \$3,601.22.

The total cost of implementing the three designs is \$4,270.04, which falls within the \$5,000 budget. All three designs combined are expected to reduce the noise level by at least 20 dB, reaching the target specification of 80 dB. Core functionality was unaltered as well as slab quality and geometry expected are to stay the same. The team recommends the designs be implemented sequentially as listed, with testing completed after each change to evaluate effectiveness.

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# **1 INTRODUCTION**

This report introduces, evaluates, and proposes noise reduction designs for the Ultra-Span EXT-400Si hollow core concrete extruder. The following section outlines information including problem statement and objective, company and extruder overview, and client needs, constraints, and target specification. This information was used for the creation and evaluation of the proposed final design. Finally, this section summarizes the previously report and results of testing completed on the Ultra-Span extruder.

## **1.1 Problem Statement**

The focus of this project is to reduce the noise emitted from the Ultra-Span 8” hollow core concrete extruder from over 85 decibels to 80 decibels or fewer. Operators currently require single hearing protection during slab production due to excess noise generated during extruder operation. Because of the high noise levels the extruder currently does not meet the CSA Standards Z107.56 and Z1007 hearing conservation program [1]. The excess noise will be addressed by analyzing the current design and creating a simple yet effective noise reduction solution.

## **1.2 Problem Objectives**

The objective of this project is to deliver a theoretical design to reduce the noise emitted from the Ultra-Span hollow core extruder, a bill of materials for the proposed design, computer aided design (CAD) models for any new components, and sound measurements of an operating extruder through testing. The team outlined the scope, customer needs, target specifications, and constraints with input from Ultra-Span specialists to ensure that the correct problem is met. The goal of the project is to reduce the overall noise of the Ultra-Span extruder by investigating solutions in noise and vibration reduction.

## **1.3 Ultra-Span EXT-400Si Overview**

Displayed in Figure 1 is the concrete slab produced by the Ultra-Span EXT-400Si hollow core extruder. The slab is versatile due to offsite manufacturability and material efficient due to the

extrusion process which limits waste. These concrete slabs are commonly used for high strength applications such as the construction of buildings.



Figure 1: Completed hollow core concrete slabs produced by hollow core extrusion [2]

Ultra-Span's extruding machine achieves a consistent, high density, low water content, and high compressively strong slab sought after by construction companies around the world. A mixture of concrete is input through the hopper of the Ultra-Span extruder and produces the hollow core slab over top of pre-stressed cables, shown in Figure 2.

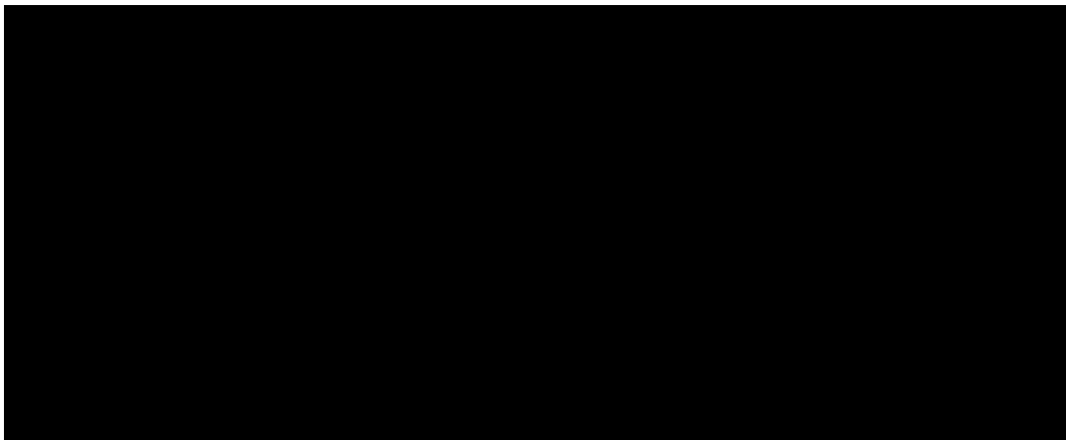


Figure 2: Ultra-Span hollow core extruder producing a concrete slab

The Ultra-Span EXT400Si consists of several key components that play a role in achieving premium slab quality. The following section describes the individual components of the extruder to gain context of each sub assembly required for design changes.



Ultra-Span is a manufacturer of several different concrete extruding machines. The model of focus in this report is the EXT-400Si with 8" cassette displayed in Figure 3, with hopper, housing, and cassette shown.

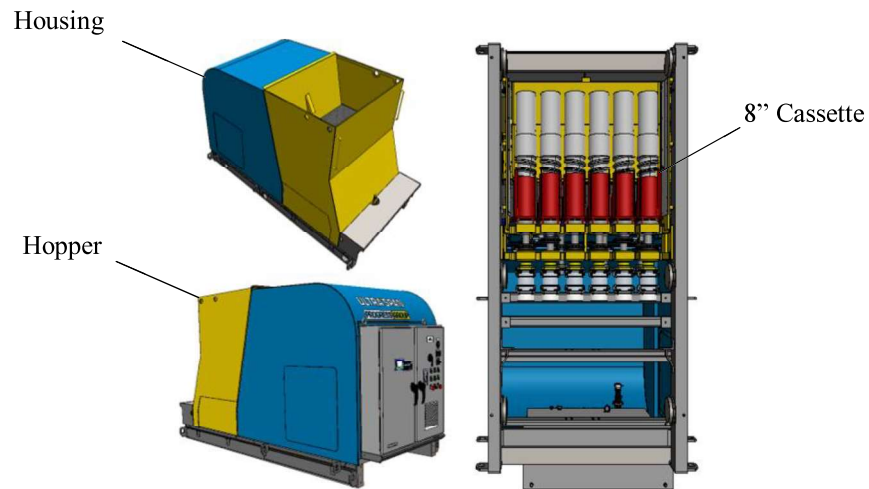


Figure 3: Ultra-Span EXT-400Si concrete extruder under-view and isometric views [2]

The extrusion process begins at the hopper, where concrete is loaded into the extruder. Figure 4 displays the hopper highlighted in yellow. This is where the premixed concrete materials are added and gravity fed into the augers below.

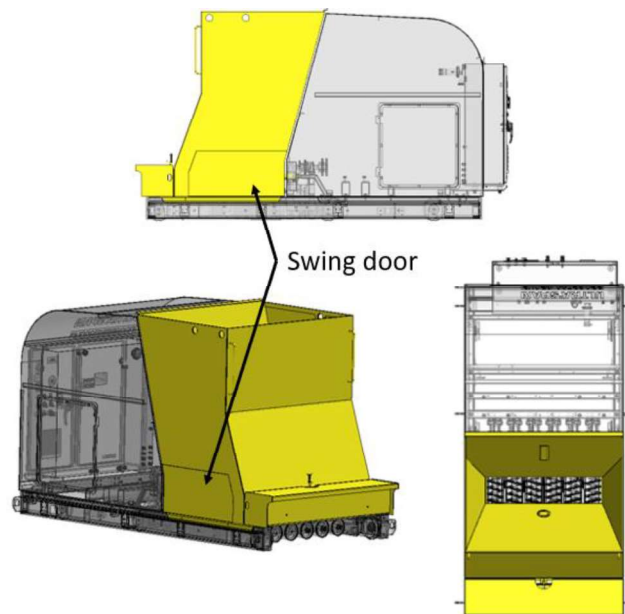


Figure 4: Ultra-Span EXT-400Si hopper side, isometric and top views

The hopper is made with 3/8" ASTM A36 steel, chosen for its availability, strength and abrasion resistance. Doors are located on each side of the hopper to provide access to the compacting motors and hammering plate shown in Figure 5. Because the doors are part of a vibration source enclosure, an open-cell acoustic insulation is applied to the inside of the door in an effort to reduce noise transmission.

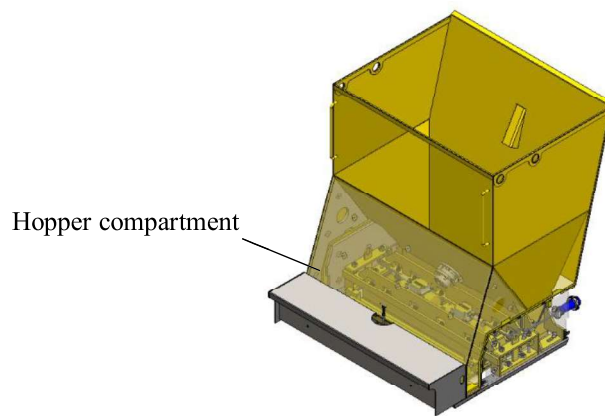


Figure 5: Ultra-Span EXT-400Si compactor system compartment

In addition to funneling the raw material, the hopper is also the compartment of the compacting system. The compacting system consists of vibration motors which produce a reciprocating motion to the hammering plate. Similar to the hopper doors, the hopper compartment contains an open-cell acoustic insulation to isolate vibration motor noise. Figure 6 displays an upper view of the motors and the hammering plate.

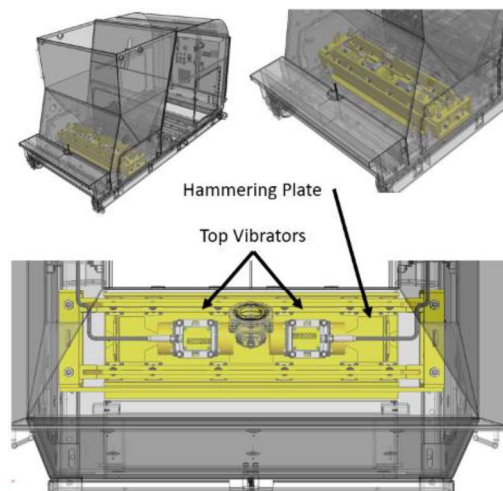


Figure 6: Ultra-Span EXT-400Si – Hammering plate and top vibrators upper-view

The hammering plate is shown in Figure 7 from the under-view.

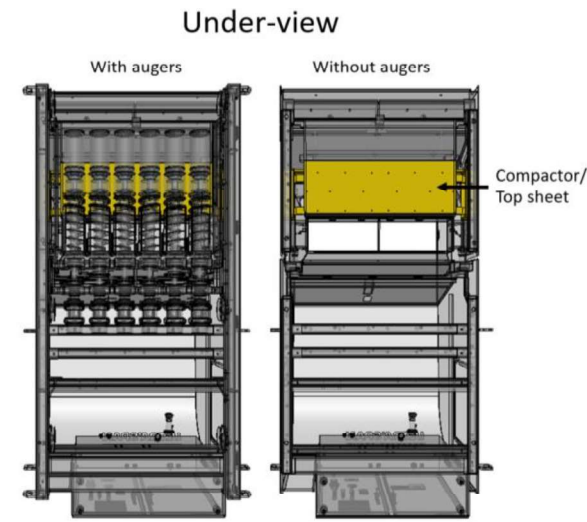


Figure 7: Ultra-Span EXT-400Si compacting system with and without cassette

The hammering plate packs the concrete to achieve a higher density and improve slab quality, and operates at a frequency determined by a Variable Frequency Drive (VFD). It spans the entire width of the extrusion area in order to achieve an even, consistent slab density.

The cassette is the sub assembly of the Ultra-Span extruder which contains rotating augers and the auger drive system. The hollow core is achieved by rotation of the augers, which pushes the concrete mix out and around the augers to define the shape of the concrete slab. Figure 8 provides views of the extruder augers and auger drive system.

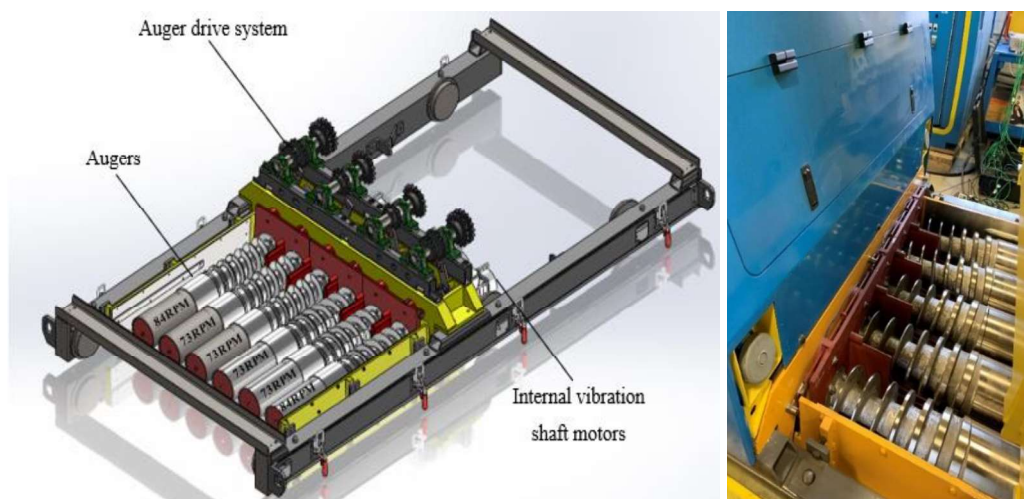


Figure 8: CAD drawing of extruder cassette component labels (left) and cassette augers in shop facility (right)

Inside of the augers are internal vibrators used to increase the density of the concrete mix. The internal vibrators operate at a frequency defined by the VFD, and is recommended to be set at a frequency of 130-135 Hz.

The housing of the extruder is the steel compartment shown in blue in Figure 9. Doors are located on each side of the housing for access to internal components

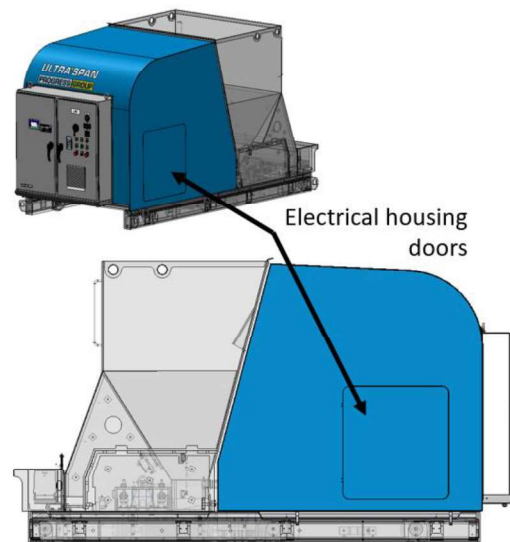


Figure 9: Ultra-Span EXT-400Si extruder housing

Inside the housing are several components of the extruder, including the auger drive motors, auger drive system, internal vibrators in the augers, and electrical components. The housing provides protection by preventing dust, debris, and concrete materials from reaching and damaging internal components. Additionally, the housing contains open-cell acoustic insulation on interior walls to isolate noise generated by the auger drive system and motors.

#### **1.4 Client Needs, Constraints, and Target Specifications**

A review of the project background and a client assessment with Ultra-Span were used in creating the following list of customer needs ordered by importance:

1. Design reduces extruder noise to a safe operating level
2. Design maintains or improves slab quality compared to currently produced slabs
3. Design is cost effective by minimizing and justifying expense
4. Design is safe by minimizing risks introduced

5. Design is easy to implement
6. Design minimizes the extruder footprint
7. Design is long lasting

Additionally, the project is restricted by the following constraints:

- Core functionality of the extruder vibration methods is to remain the same
- Input concrete mixture is defined by customer procurement and is independent of the project scope
- The slab geometry meets defined civil engineering specifications
- Design cost is below \$5,000 CAD
- Extruder footprint meets indoor extrusion bed 2' side access
- Project is delivered by December 5<sup>th</sup>, 2019

Table I lists the identified target specifications required.

TABLE I: TARGET SPECIFICATIONS AND QUANTIFIED MEASUREMENT REQUIREMENTS

| #  | Specification                                     | Goal     | Target Specification | Units           |
|----|---------------------------------------------------|----------|----------------------|-----------------|
| 1  | Noise Level                                       | Minimize | 80                   | dB              |
| 2  | Working Time Noise Comfort                        | Maximize | 30                   | min             |
| 3  | Cost                                              | Minimize | 5,000                | CAD Dollar      |
| 4  | Slab Cross-Section Cracking                       | Minimize | 3                    | %               |
| 5  | Web Slippage                                      | Target   | 0                    | mm              |
| 6  | Slab Cross-Section Surface Voids                  | Minimize | 10                   | %               |
| 7  | Number of Manufacturing Processes Introduced      | Minimize | 1                    | -               |
| 8  | Material Lead Time                                | Minimize | 6                    | week            |
| 9  | Manufacturing Time                                | Minimize | 40                   | hr              |
| 10 | Qualitative Operator Comfort                      | Maximize | -                    | Pass/Fail       |
| 11 | Operating Performance                             | Maximize | 8.6                  | Lineal m/m3     |
| 12 | High Abrasion Zone Material Hardness              | Maximize | 66                   | HRC             |
| 13 | Low Abrasion Zone Material Hardness               | Maximize | 160                  | HB              |
| 14 | No Abrasion Zone Qualitative Wear Test            | Maximize | -                    | -               |
| 15 | Design Footprint Extending from Extruder Exterior | Minimize | 6                    | in              |
| 16 | Risk Assessment                                   | Minimize | 3                    | Total Risk Unit |

Description of target specifications in Table I are outlined in APPENDIX A – TARGET SPECIFICATION DETAILS

## 1.5 Concept Generation and Selection Summary

The previous project report focused on the process of generating and selecting designs. The team primarily relied on results from vibration and noise level testing of the extruder to narrow the focus of concept generation. Accelerometers were used to measure acceleration of vibrating panels in the units of g's, and microphones were used to measure noise levels in Pascals which were converted to decibels. With the results of the Phase 1 test report shown in APPENDIX B – TEST SUMMARY, two conclusions were drawn.

First, microphones measured an average of 99 dB (SPL) from a distance of 3' from the extruder. The highest noise levels measured at the front and sides of the extruder. A reduction of approximately 20 dB (SPL) is therefore required to meet the 80 dB target specification. One contribution to the high noise level measured was the openings created by removing the extruder doors. Openings negatively affect the noise transmission loss of the extruder vibration source enclosures. Another contribution discovered from further research was the effectiveness of the open-cell acoustic insulation currently used. Research found that open-cell foams are commonly used in frequency applications greater than 1,000 Hz [3].

Second, accelerometers measured the highest vibrations closest to vibration sources which then spread to remaining extruder components. The element measured closest to the vibration sources was the extruder frame.

From the Phase 1 test results the following designs were selected:

*Concept 1:* Apply a more effective acoustic material to the extruder. This design investigates dampening materials such as coatings or acoustic mattings, which can be applied to the extruder to reduce noise transmission.

*Concept 2:* Redesign of the extruder doors. Extruder doors are currently being removed by concrete production companies. Designing a simplified extruder door will encourage door reinstallation leading to a reduction in noise transmission.

*Concept 3:* Installation of isolation mounts between vibration sources and extruder components to reduce vibration transmission. This may be done by introducing new mounting systems such as rubber isolation mounts.

*Concept 4:* Redesign of the extruder frame to reduce vibration by lowering the natural frequency. This may be accomplished by changing the frame design from a steel c-channel to a rectangular cross section.

After having completed Phase 1 testing, additional Phase 2 testing was conducted at the Ultra-Span Winnipeg facility to further vibration and noise level knowledge of the extruder. The extruder available for testing differed from the Phase 1 test extruder, by an included cable reel on the left side of the housing and different size cassette installed. Additionally, testing was completed without concrete passing through the extruder. All results of Phase 2 testing are summarized in APPENDIX B – TEST SUMMARY.

To understand the effect of removing extruder doors, the first objective of Phase 2 testing was to replicate the setup from Phase 1 testing and record both microphone and accelerometer data with the doors both on and off of the extruder. Although the noise level location shifted slightly with the adjusted door placement, a clear correlation between increased noise level at extruder sides caused by door removal could not be confirmed. This could be due to the previously listed differences in the extruder used for each test phase. The team recommends replicating testing with extruder doors on and off in a concrete extruding environment similar to Phase 1 testing. It is expected that the inclusion of concrete will ensure that noise exits from the front of the extruder when the doors are placed back onto the extruder, and a lower noise level at the side of the extruder will be measured.

The second goal of Phase 2 testing was to obtain measurements on remaining elements of the extruder including the cassette, hammering and troweling plate, motor and electrical panel frame, and cassette frame. Accelerometer results displayed that the vibration in the cassette frame c-channel was not as high as Phase 1 testing measurements. The high vibration appears to have been generated from the flat panel on the outside of the cassette frame rather than the c-channel. Vibration transmission may still occur through the c-channel to the other components of the extruder, but not enough to justify altering the dimensions of the c-channel. As a result, the design to alter the extruder frame geometry was removed from consideration.

Based on the Phase 1 and Phase 2 results, the designs considered for further analysis include an extruder door redesign, isolation mount designs, and a new acoustic material, which are outlined

throughout the following sections of the report. Each section introduces specific testing data as required to justify the design.



## 2 DETAILS OF DESIGN

Concept generation and selection resulted in three designs implemented in the final extruder design. These designs are, in order of ease of implementation and increasing cost, redesigning housing and hopper extruder doors, application of vibration rubber isolation mounts, and sourcing a new acoustic dampening material to be applied to housing and hopper panels. Each design subsection sources an appropriate product and discusses the manufacturing processes required for implementation. Next, the overall noise transmission reduction or vibration reduction, cost, and labor hours required for manufacturing were quantified. Risk assessments were also completed on introduced risks due to new designs. Testing results are used throughout this Details of Design section of the report, and further details on the setup and discussion of results can be found in APPENDIX B – TEST SUMMARY.

### 2.1 Extruder Doors

This section focuses on the redesign of the hopper and housing extruder doors to replace the current door design. The extruder doors are commonly removed by concrete production companies to regularly access internal extruder components, and require a design to promote reinstallation. The redesign simplifies the current door design by removing mechanical latches and replacing them with a grab handle and magnetic latch. The redesigned doors are displayed in Figure 10.



Figure 10: Redesigned hopper and housing extruder doors with safety warning signs

The remaining subsections specify the product selection process, assembly process, cost summary, and risk analysis of the design.

### 2.1.1 Door Redesign

Phase 1 testing at the concrete production facility found the highest noise levels at the front and sides of the extruder. Results of Phase 1 testing are summarized in Figure 11.

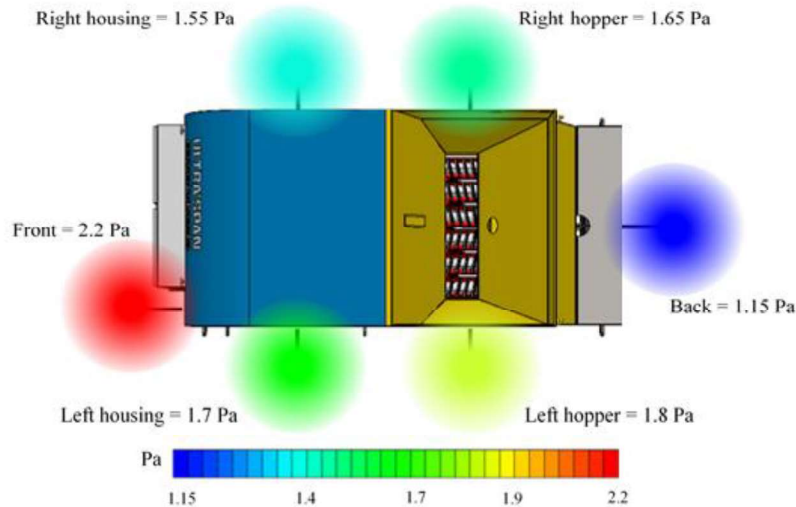


Figure 11: Phase 1 sound map microphone testing results summary

The noise levels at the sides, which are common working areas of the extruder, are 97.8 – 99.1 dB (SPL). The front of the extruder is a low worker occupancy zone due to the pre-stressed cables extending from the front of the extruder. The high noise levels are attributed to openings in both the hopper and housing enclosures which allow noise to reach operators. The effect of the door openings causes a noise level increase discussed later in this section.

The current hopper doors are designed with hinged pivot points, a damper used to maintain the open position of the doors, and two manual latching mechanisms per door. Figure 12 displays the hopper door in the closed and open positions.

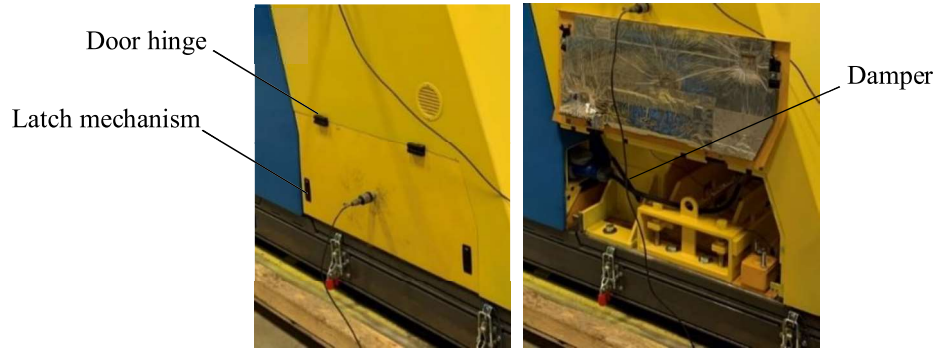


Figure 12: Hopper extruder door design including the closed position (left) and open position (right)

The current housing door, shown in the open position in Figure 13, includes a similar hinged pivot point and two manual latching mechanisms.

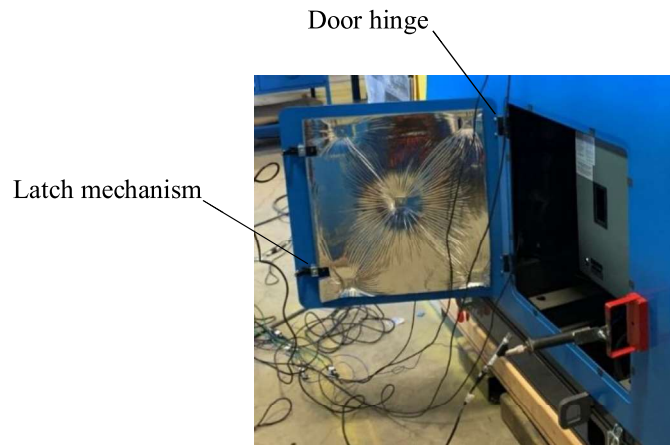


Figure 13: Housing extruder door design

The current latching mechanism requires separate motions to manually unlock the two latches, then pull the door open. It was noted during Phase 1 testing that the hopper and housing doors were removed by the concrete production company, as shown in Figure 14.



Figure 14: Front and left side housing (left) and right side housing (right) test setup

Discussion with Ultra-Span and the concrete production company highlighted importance to access internal components regularly, thus a door requiring two motions to open is not ideal and was reduced to one motion.

The hopper currently contains grab handles, shown in Figure 15, to aid operator's ability to investigate the concrete level of the hopper.



Figure 15: Hopper grab handle

An 8" long grab handle will be introduced to the extruder doors, made with the same A36 steel rod from the hopper grab handles. Extruder door grab handles make it easy for operators to articulate the door and maintain consistent manufacturing processes already used on the extruder hopper handles.

A magnetic latch removes the need to operate a mechanical latch and reduces opening and shutting of the door to one motion. K&J Magnetics offers magnets in varying sizes and pull

forces required to pull the magnet off of a metal surface. The BZ082 magnet shown in Figure 16 provides a pull force of 18.33 lb suitable for keeping the door closed during extruder operation.

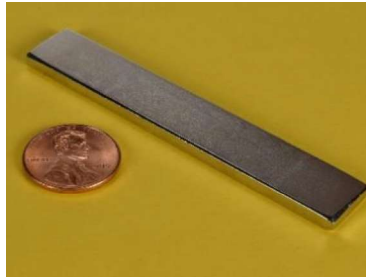


Figure 16: K&J Magnetics model BZ082 [4]

The BZ082 rectangular magnet is a 1/8" thick, 3" long, and 1/2" wide rectangle [4].

Both the implementation of a handle and a magnetic latch promote reinstallation of the extruder doors, which increase the effectiveness of the hopper and housing enclosures ability to reduce noise transmission. The extruder door openings reduce the transmission loss of the enclosures that separate vibration sources from operators. Figure 17 relates the total decibels to be subtracted based on the percent of total area opening in an enclosure.

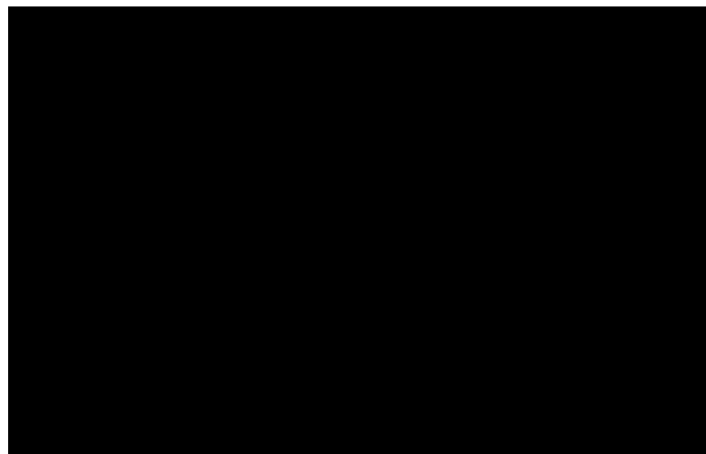


Figure 17: Transmission loss reductions based on a percent of total area opening [5]

The percent opening created by removing the doors of the hopper and housing was estimated to be 12% and 10% respectively. The transmission loss of the A36 steel doors was estimated using materials of similar density and bending stiffness to be 30 dB at an input frequency of 130 Hz [6]

[7] [8]. Plotting on Figure 17 with a ratio of covered to total area of 0.9 obtains a value of 10 dB to be subtracted from the material transmission loss. Therefore, by removing the doors of the extruder there is an additional 10 dB received by the listener [5].

### 2.1.2 Extruder Door Assembly

The extruder door grab handles require bending and welding of 5/8" A36 steel rod to the existing extruder doors. An image of the door grab handles is shown in Figure 18.

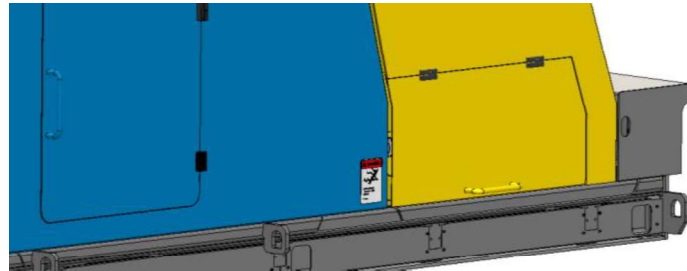


Figure 18: Hopper and housing door handles

The hopper and housing door handles are designed to match dimensions of the hopper grab handles to maintain consistency. Dimensions include a handle diameter of 5/8", bend radius of 3/4", distance from the extruder body of 2", and length of 8". Both the hinged pivoting mechanisms and the damper (only for the hopper doors) are installed as per current extruder door design.

The magnet is adhered using the two-part epoxy 3M DP-100 [9]. Both magnet and sheet metal surfaces are to be roughed by light sanding, cleaned with an oil-free solvent before applying the two-part epoxy 3M DP-100, and cured for 48 hours [10]. One magnet is used on both the hopper and housing door. The hopper door magnet location is shown in Figure 19.

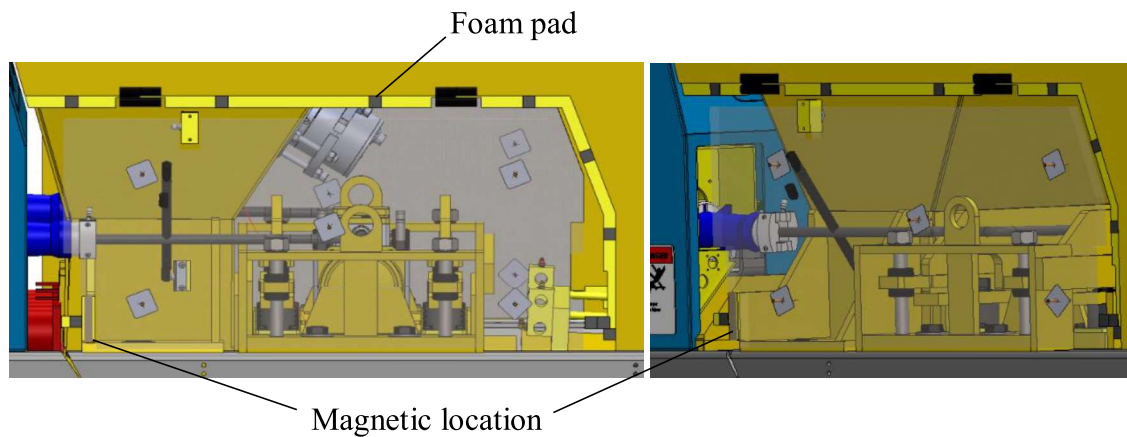


Figure 19: Hopper door magnet placement

A location on the hopper mount provides space for the magnet to sit flush with the foam pads located around the door, shown by black squares in Figure 19. Similarly, the housing magnet is placed flushed with the foam pads shown in Figure 20.

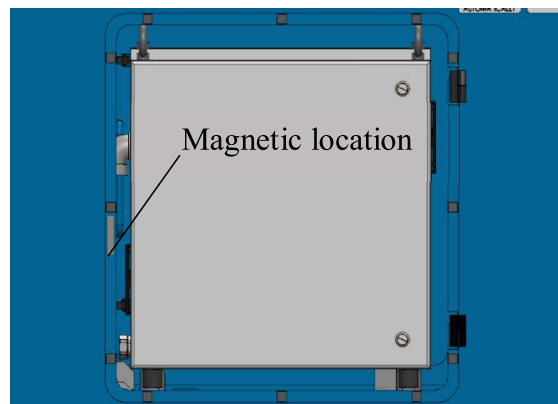


Figure 20: Housing door magnet placement

Due to the similarity between the current door design and proposed redesign, it was assumed that the manufacturing hours to install the magnet and handle are equivalent to that of the previous latching mechanisms.

The results of the magnet placement and door grab handles is a simplified design that maintains the original function of the current Ultra-Span door design. Additionally, shown in Figure 10, the placement of warning signs on extruder doors remind operators of both high noise levels when doors are open, and potential pinch points.

### 2.1.3 Door Redesign Cost Summary

Materials for the door redesign include 40” of 5/8” A36 steel rod, four BZ082 magnets, and one tube of 3M DP-100 epoxy to complete installation on the four extruder doors. The total cost of the extruder door redesign is summarized in Table II.

TABLE II: EXTRUDER DOOR REDESIGN COST SUMMARY

| Description                          | Source                           | Quantity | Cost [CAD]      |
|--------------------------------------|----------------------------------|----------|-----------------|
| <b>5/8” A36 Steel Rod</b>            | Metal Supermarkets Winnipeg [11] | 40”      | \$21.57         |
| <b>BZ082 3” x 1/2” x 1/8” Magnet</b> | K&J Magnetics [4]                | 4        | \$24.68         |
| <b>3M DP-100 Two-part Epoxy</b>      | 3M Canada [9]                    | 48.5 mL  | \$139.03        |
| <b>Total Cost [CAD]</b>              |                                  |          | <b>\$185.28</b> |

### 2.1.4 Door Redesign Risk Analysis

Two risks are identified in the door redesign application and were classified using the OSHA system [12]. A 2” obstruction was created from installation of the new grab handle, and a potential pinch point was introduced by use of a magnetic latch.

1. Installation of door grab handles results in an increase to the extruder footprint by 2”.  
This extruder footprint extension results in the risk running into the handle which has a low severity (1). Operators occasionally walk close enough beside the running extruder to contact the grab handle leading to an occasional likelihood of occurrence (2). The total risk introduced is categorized as moderate (2).
2. The introduction of a magnet to metal connection results in the risk of a finger pinch point, which has a low severity (1) if operators’ leave a hand in the closing door.  
Operators occasionally access the extruder internals leading to an occasional likelihood of occurrence (2). The total risk introduced is categorized as moderate (2).

To mitigate both risks, the team recommends installation of warning tape on the door to urge caution when utilizing and operating the door. The sample warning tape can be observed in Figure 10 on the hopper door.



## 2.2 Frame Rubber Isolation Mounts

This section focuses on the implementation of rubber isolation mounts between vibration sources and extruder components. The design recommends the VibraSystems SM-1 rubber mount to be installed between the cassette and extruder frame, as well as between hopper and extruder frame. Figure 21 displays the rubber mounts and custom steel components (shown by a clear plastic) required for mount installation.

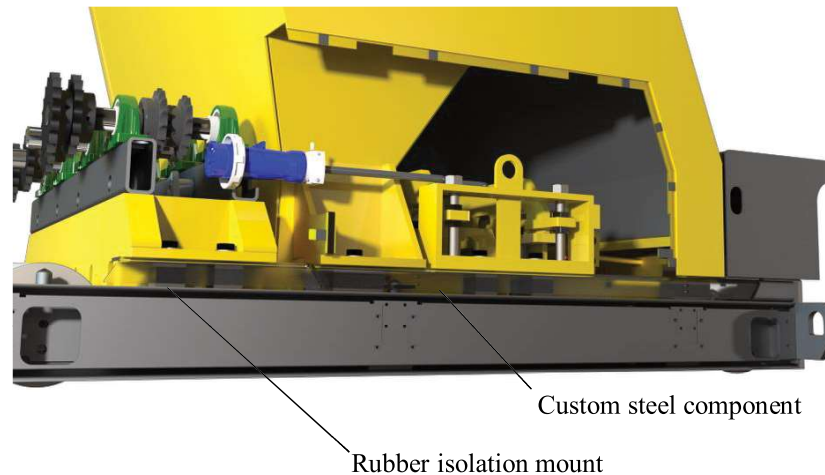


Figure 21: VibraSystems SM-1 rubber isolation mounts installed between the frame and extruder components

The remaining subsections specify the product selection process, assembly process, cost analysis, and risk analysis of the design.

### 2.2.1 Rubber Isolation Mount Selection

The focus of this section is to source anti vibration rubber mounts suitable for the extruder and to determine the locations required to isolate vibration. Anti vibration mount applications were considered for the three main components of the extruder being the cassette, hopper, and housing.

The hopper and housing mount to the top of the cassette frame. The augers, motors for the auger drive system and internal vibration, gears, and hammering plate all mount to the cassette frame and are vibration sources in the extruder. Testing results show highest vibrations generated at

these vibration sources and moving to the remaining hopper and housing components. Figure 22 is a visual illustration of testing results gathered on the left side of the extruder.

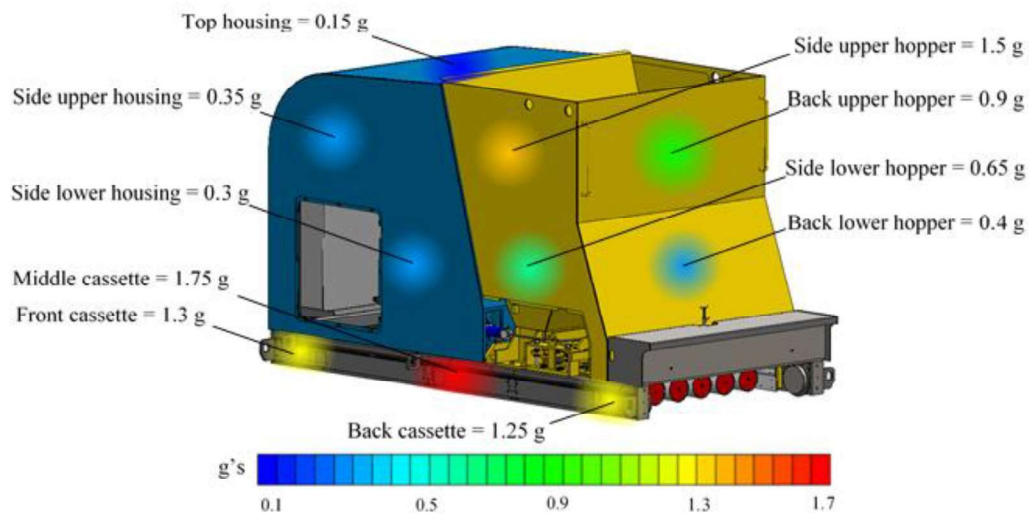


Figure 22: Left side external accelerometer testing results

The largest amount of vibration measured is located in the middle of the cassette frame at 1.75 g on the left side and 2.1 g on the right side. This is the mounting location of the augers, internal vibrators, and auger drive system to the cassette frame, and is the first location considered for the application of rubber isolation mounts. Application of rubber mounts at the auger drive system mount reduces vibration transmission through the rest of the frame by isolating the extruder vibration sources. Figure 23 displays the right side of the same testing.

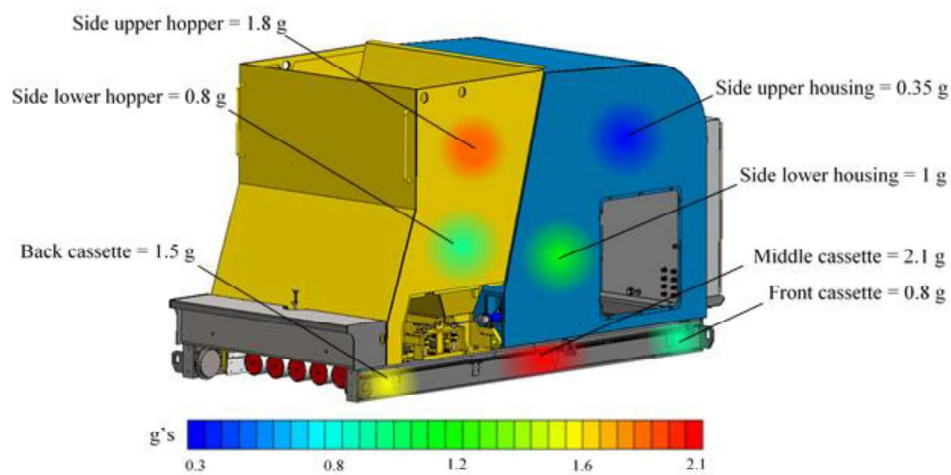


Figure 23: Right side external accelerometer testing results

Vibration was measured at 1.5 and 1.8 g on the upper portions of the hopper sides. The hopper is mounted on a steel tube along with the hammering plate such that the entire hopper and hammering plate assembly can be lifted from the cassette frame. This results in the hopper being rigidly mounted to a vibration source; the hammering plate and motors. Thus, anti vibration mounts will be used to mount the hopper as well.

Unlike the hopper, the housing is not mounted to a vibration source and instead receives vibration transmitted through the extruder frame. For this reason, housing mounts were not considered.

A design space was established to ensure that designs were easy to implement by minimizing interactions with adjacent components. Designs were constrained to the dimensions of the mounting channel displayed in Figure 24.

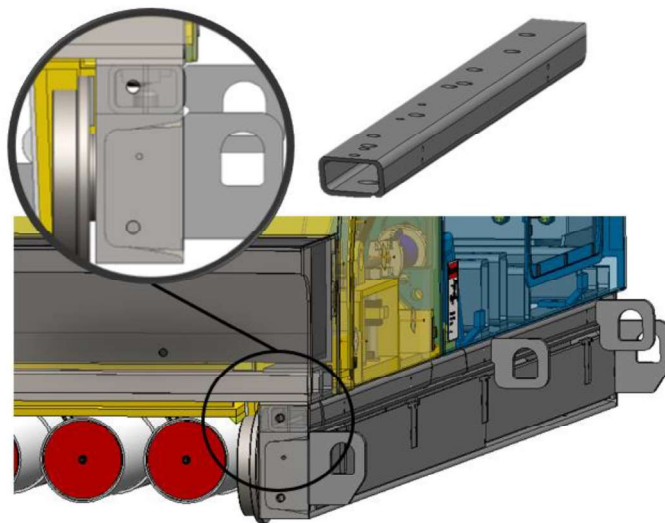


Figure 24: Mounting channel used as design space

VibraSystems produces a versatile anti vibration mount which can be drilled anywhere along its length [13]. The sandwich mount is displayed in Figure 25.

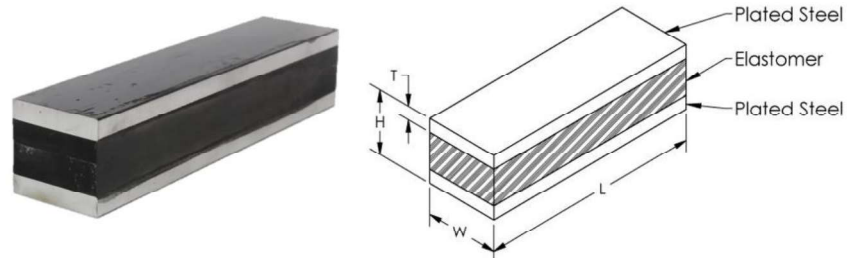


Figure 25: VibraSystems sandwich mount [13]

The VibraSystems sandwich mount was selected for several reasons, the first being a high load supporting capability which increase per unit length of the mount. Second, the sandwich mount dimensions are similar to those of the rectangular tube it is replacing. Both of these items allow for specific mounts to be selected depending on the spring rate required for the applied load.

Testing of isolation mounts made of various natural and synthetic rubbers was used to correlate a reduction in vibration to noise reduction. The following images in Figure 26 display both the loss factor based on frequency input and resulting transmissibility.

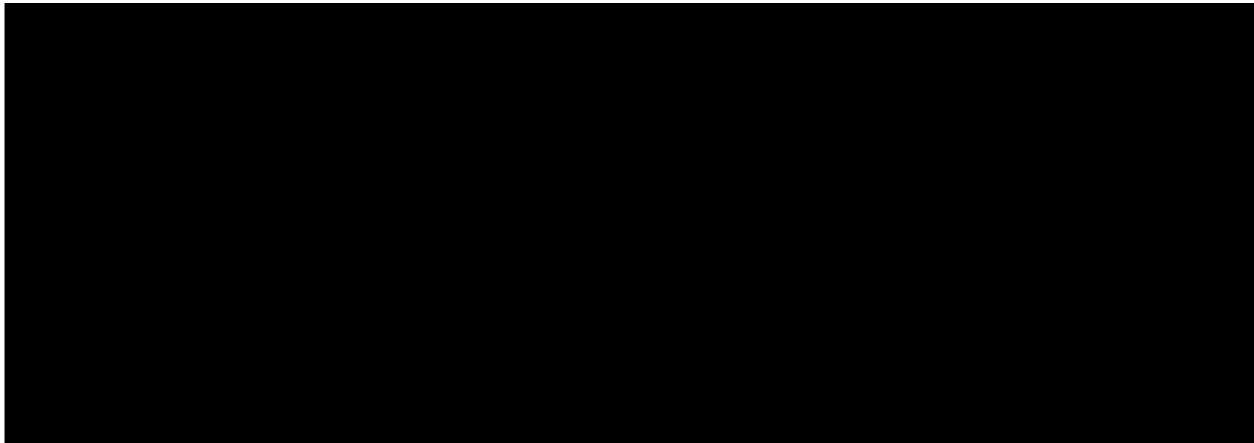


Figure 26: Relationship between loss factor and transmissibility based on frequency input for rubber isolation mounts [14]

The rubbers used in Figure 26 are not the same as the neoprene used in the SM-1 mounts, however represent similar rubber isolation mount products. At a frequency input of 135 Hz the loss factor for the rubbers in Figure 26 is approximately 60% and transmissibility of -40 dB [14]. Based on the shared properties of the rubbers used in Figure 26 and the SM-1 mount, implementation of the VibraSystems SM-1 mounts are expected to result in a considerable vibration reduction and consequent noise reduction.

### 2.2.1.1 Cassette Rubber Isolation Mount Selection

The cassette mounts are located above the point of highest vibration in the frame, shown in Figure 22 and Figure 23. This is the first location where rubber anti vibration mounts are to be applied and is shown in Figure 27.

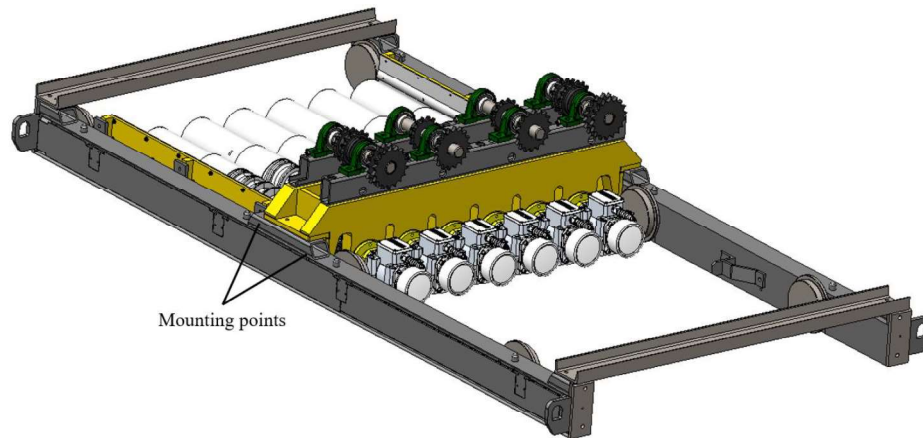


Figure 27: Cassette rubber isolation mounting points

The SM-1 mounts cut to 2" lengths were selected to be mounted in the locations displayed in Figure 27, using the mass of the cassette of 700 lbs [13]. The difference in height between the sandwich mount and the current existing rectangular tube is 1/4". To make up the difference, 1/4" A36 sheet metal is used to create a bent "L" shaped shim. This bent sheet metal covers the exposed sides of the rubber mounts to protect them from debris or damage and allows for any adjacent component mount locations to be maintained. The sheet metal and rubber mount assembly to be used is shown in Figure 28.

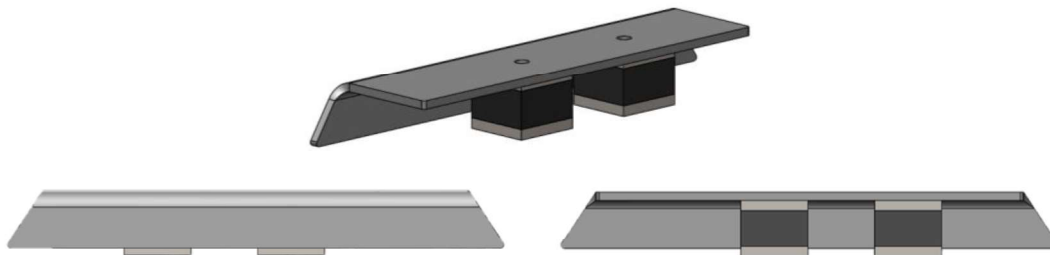


Figure 28: Cassette isolation mounts and sheet metal component isometric and side views

The maximum static deflection of the mounts is 0.0365", which should be accounted for during manufacturing to ensure tolerances are met for the cassette height. The use of the rubber mounts provides an analytical percent isolation of 98.5%, which reduces the vibration transmission from the vibration source into the cassette frame [13].

### 2.2.1.2 Hopper Rubber Isolation Mount Selection

The hopper sits on a length of rectangular tube in order to distribute its load across the cassette frame. In order to achieve a distribution of weight between the rubber mounts, four mounts per side will be used. The positioning of the mounts can be seen in Figure 29.

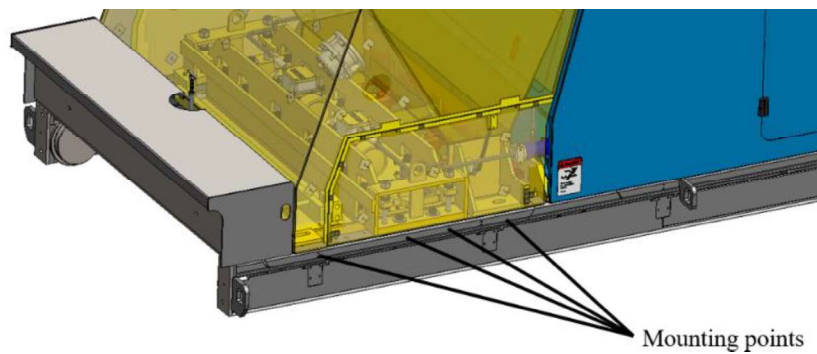


Figure 29: Hopper isolation mounting points

The hopper is positioned on top of the cassette frame with locating pins and clamped down, shown in Figure 30.

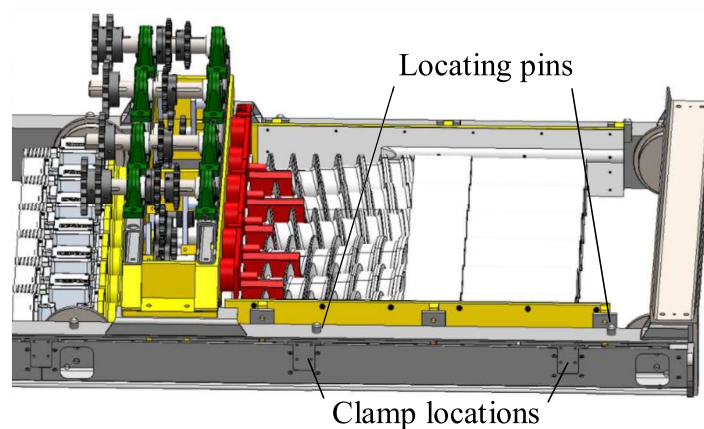


Figure 30: Hopper rubber isolation mount locations



Mounts were sourced using a total mass of the hopper, hammering plate, and concrete (assumed to fill the hopper) weighing a total of 3,900 lbs. The VibraSystems SM-1 mounts cut to 2" lengths were sourced for the hammering plate mount locations and 4" lengths were source for the hopper mounts locations [13].

Given that the hopper mounts are the same height and thickness to those of the cassette, the same sheet metal protecting shims designs were adapted and lengthened to accommodate the longer pre-existing rectangular tube. Figure 31 displays the sheet metal and rubber mount assembly that will be used to mount the hopper.

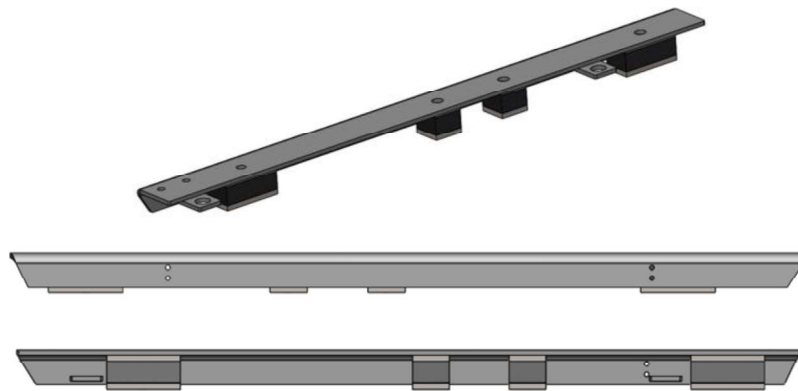


Figure 31: Hopper and hammering plate isolation mounts and sheet metal component isometric and side views

The maximum static deflection of the mounts is 0.0677", which should be accounted for during manufacturing. The use of the rubber mounts provides an analytical percent isolation of 99.2%, which reduces the vibration transmission into the hopper significantly [13].

### **2.2.2 Rubber Isolations Mount Assembly**

The following section analyzes each component of the rubber mounts and the manufacturing process required to validate the feasibility of the proposed design.

VibraSystems provides a service of cutting the sandwich mounts to a desired size in 2" increments, as well as pre-drill holes upon request [13]. Due to this service, manufacturing time surrounding the preparation of the mounts is negligible. The holes will be drilled to accommodate the 3/8" and 1/2" bolts currently used to fasten to the rectangular tubing being replaced. Figure 32 displays the centered positioning of the holes for both the 2" and 4" mounts.

The rubber mounts will be tapped in order to fasten them directly to the hopper. This process is different from the hopper mounts used for the cassette, as the cassette mounts are not tapped.

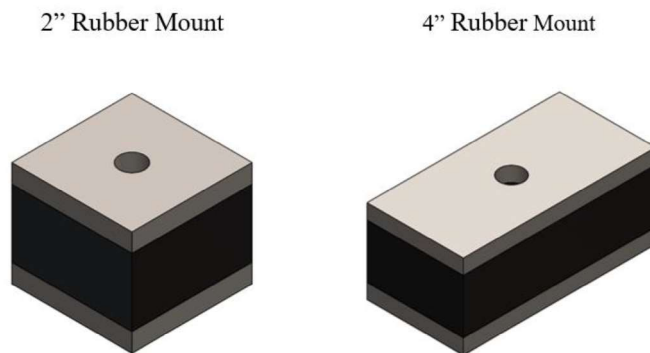


Figure 32: 2" and 4" VibraSystems SM-1 rubber mounts

One manufacturing process which is changed by introducing the rubber vibration mounts is repositioning the locating pins. The locating pins and locating tab used to position the hopper must be relocated by moving them towards the back of the extruder by 4.91" as seen in Figure 33.

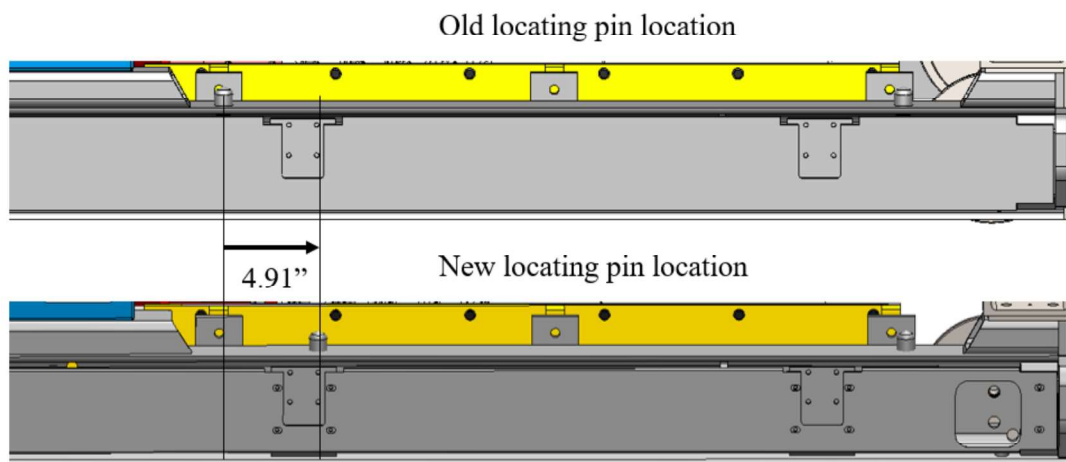


Figure 33: Cassette frame locating pin relocation

The second component which must be considered is cutting and bending sheet metal. Cutting the sheet metal is outsourced and completed by laser cutting. The laser cut flat patterns required to make the sheet metal shims for the cassette and hopper mounts are displayed in Figure 34.



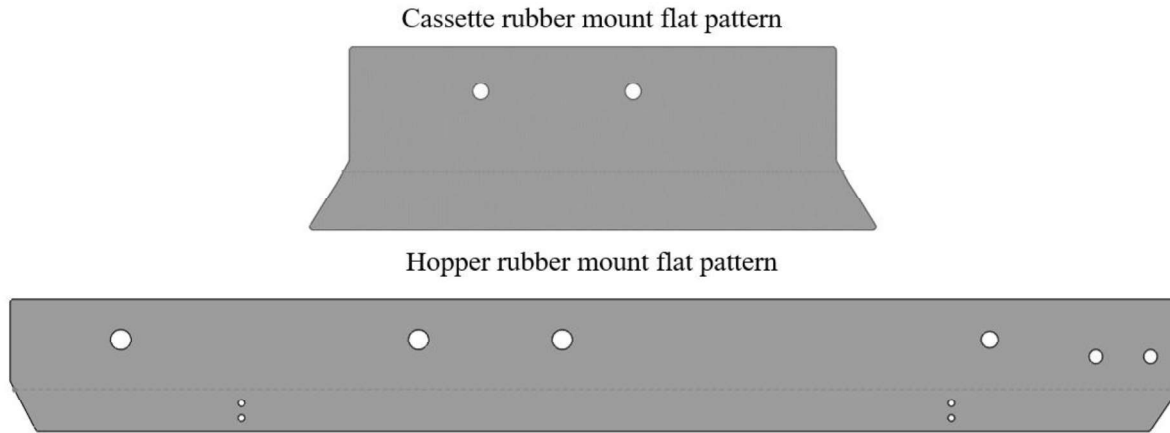


Figure 34: Sheet metal flat patterns

Dotted lines displayed in Figure 34 represent break points, where the sheet metal should be bent. Both breaking points should be bent to 90 degrees and is outsourced for fabrication. Part drawings for all custom designed steel pieces were created and are displayed in APPENDIX E – PART DRAWINGS.

Due to outsourcing the laser cutting and 90-degree break, the manufacturing hours required to create the custom sheet metal component are negligible. The cost of labour time must also be considered. Implementing the new rubber mounts involves removing the process of installing the rectangular tube and instead bolting the new rubber mounts along with the shims. This is a replacement process instead of a new process so it will create a negligible change in labour time required to manufacture the extruder.

### 2.2.3 Rubber Isolation Mount Cost Summary

The total price of the design includes the cost of the SM-1 mounts and the custom laser cut bent steel components. The design utilizes the current hardware for installation and is not included in the final cost. The price of the 2” and 4” sandwich mount material is based on the sizes available. VibraSystems offers larger sizes with the option to cut to any required size in 2” increments, as well as drill and tap holes to desired specifications. The most cost-effective size available on the VibraSystems website is the 48” size costing \$183.54 CAD, which is the required size to be able to make all mounts [13]. An email quote for the custom sheet metal components was used to

specify the overall cost and can be found in APPENDIX C – ISOLATION MOUNT SAMPLE CALCULATIONS AND QUOTE. Each custom metal component costs \$75 per part.

Table III displays the quantity of each component along with their corresponding price.

TABLE III: RUBBER MOUNTS COST BREAKDOWN

| Description                                     | Source                      | Quantity | Cost [CAD]      |
|-------------------------------------------------|-----------------------------|----------|-----------------|
| <b>VibraSystems SM-1 2x2 Threaded Mount</b>     | VibraSystems Inc. [13]      | 4        | \$183.54        |
| <b>VibraSystems SM-1 2x2 Bolt Through Mount</b> | VibraSystems Inc. [13]      | 4        |                 |
| <b>VibraSystems SM-1 2x4 Threaded Mount</b>     | VibraSystems Inc. [13]      | 4        |                 |
| <b>Custom Metal Cassette Sheet</b>              | Parr Metal Fabricators [15] | 2        | \$150.00        |
| <b>Custom Metal Hopper Sheet</b>                | Parr Metal Fabricators [15] | 2        | \$150.00        |
| <b>Total Cost [CAD]</b>                         |                             |          | <b>\$483.54</b> |

#### 2.2.4 Rubber Isolation Mount Risk Analysis

The following risk was identified introducing the new VibraSystems SM-1 mounts and was classified using the OSHA system [12]. The deflection of the rubber mounts may affect the quality of the slab produced by alteration of the cassette height.

1. The extruder cassette is installed at a specific set height during the manufacturing process and is important to the slab output quality. The added rubber mount may affect the cassette height and consequently diminish slab quality, leading to a high risk (3). The VibraSystems SM-1 maximum calculated static deflection is 0.0677” and will be accounted for during installation. The operating deflection will be insignificant because the natural frequency of the mounts (10 - 15 Hz) is low compared to the input frequency (135 Hz). Both considerations result in a rare likelihood of occurrence (1). The total risk introduced is categorized as moderate (3).

## 2.3 Acoustic Dampening Materials

This section focuses on the selection of a new acoustic dampening material to replace the currently used open-cell foam. The design recommends the closed-cell Pyrotek Decidamp acoustic material sheets adhered to the extruder interior panels using the two-part Pyrotek DC30 epoxy. Sheets are placed in the housing and hopper compartments of the extruder shown in Figure 35.



Figure 35: Acoustic dampening material sheets applied to the housing and hopper compartments

The remaining subsections specify the product selection process, application process, cost analysis, and risk analysis of the design.

### 2.3.1 Acoustic Material Selection

Ultra-Span currently applies an open-cell foam dampening material inside of the housing and hopper compartments. Open-cell foams are commonly selected for 1,000 – 4,000 Hz frequency applications resulting in an approximate noise reduction of 6 dB at 250 Hz [3]. Closed-cell foams that are compact, dense, and heavy show improved noise transmission loss for frequency applications less than 1,000 Hz, like that of the extruder [5]. The Pyrotek Decidamp tile shown in Figure 36 is a closed-cell structural damping product engineered to reduce noise transmission and absorb large amounts of mechanical energy from vibrating structures [16].



Figure 36: Pyrotek Decidamp Tile [16]

Pyrotek Decidamp is available in 40” by 54” sheets, with varying thickness depending on application requirements. For steel panels on the extruder, application of sheets at a one-to-one thickness ratio of Decidamp sheet to metal is required to achieve optimum vibration and noise reduction. The product is capable of panel vibration reduction of 60% at 135 Hz and sound transmission reduction of 21 dB [16]. All Pyrotek Decidamp tile specifications are displayed in APPENDIX D – PYROTEK SUPPLIED DOCUMENTS.

### 2.3.2 Acoustic Material Application

Pyrotek Decidamp sheets work by both reducing noise transmission as well as reduce panel vibration. Noise transmission should be limited by placing Decidamp sheets in the hopper compartment and the housing to limit transmission through the noise path from vibration sources to operators. The extruder panels chosen for Decidamp application are displayed in colour in Figure 37.

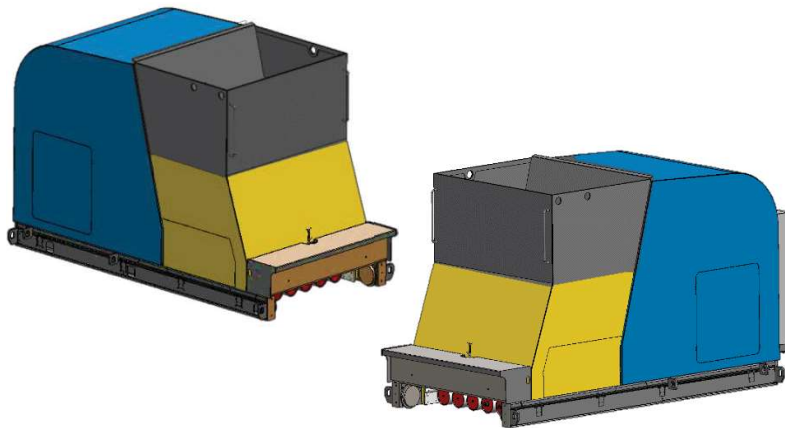


Figure 37: Acoustic material areas of application on extruder exterior panels

Each panel shown in Figure 37 as well as at the back and front of the housing require acoustic material applied to the interior flat surfaces of the sheet metal.

Areas where Decidamp sheets are not applied fail to separate operators from vibration sources, and are expected to remain areas of high noise, such as at the front of the housing shown in Figure 38.

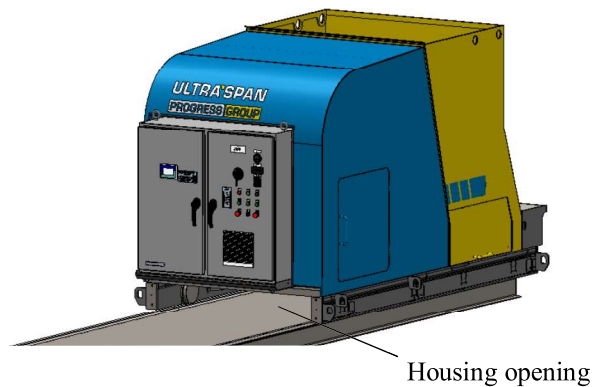


Figure 38: Hammering plate view from below the hopper

This opening is required for pre-stressed cables that run through the concrete slab and design of a component to cover the area was not considered. However, to receive optimal noise transmission reduction enclosures should not contain any openings. The team recommends for the design of a component to cover the housing opening for future consideration.

Results of microphone data from Phase 1 testing shown in Figure 39, confirm the location of highest noise at the front of the extruder at 100.8 dB (SPL).

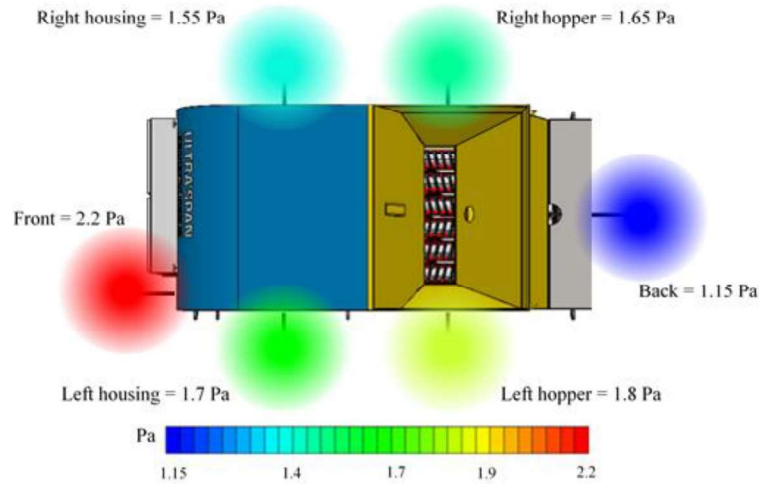


Figure 39: Working area of extruder

Operators were noted to commonly work on either side and at the back of the extruder. The front was minimally occupied to avoid the pre-stressed strands, hence excess noise projecting to the front of the extruder was deemed acceptable. Pyrotek Decidamp sheets also reduce vibration in extruder panels. Phase 2 testing of the extruder without concrete, summarized in Figure 40, measured high vibration levels in the internal hopper panels.

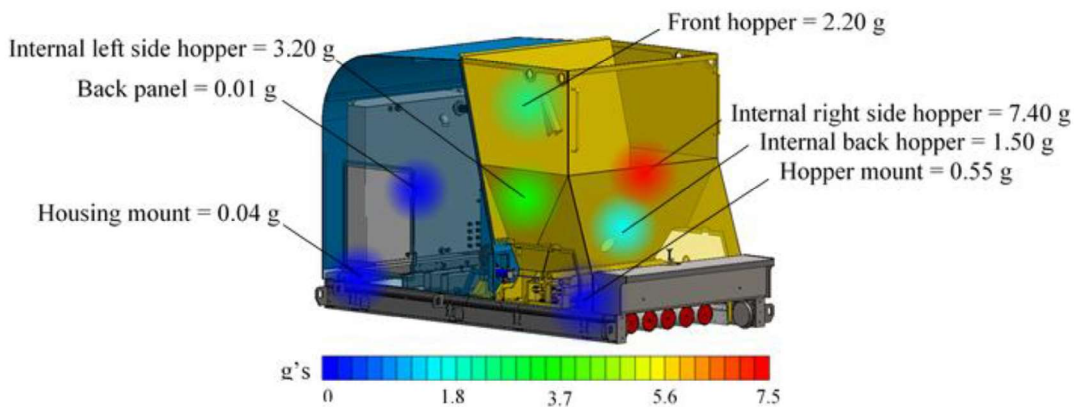


Figure 40: Internal accelerometer Phase 2 testing results summary

Decidamp sheets should be applied to the internal hopper panels to reduce vibrations during instances of low concrete levels during operation, such as when emptying concrete from the hopper at the end of a production run. Interior hopper panels requiring Decidamp application are shown in colour in Figure 41.

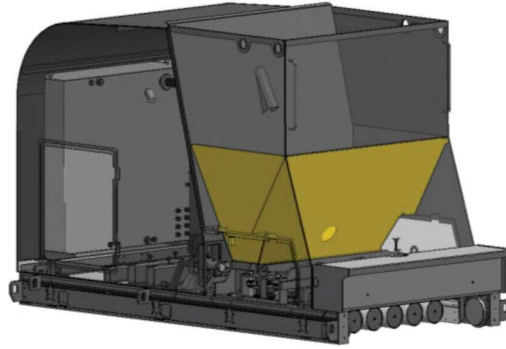


Figure 41: Acoustic material areas of application on extruder interior panels

All extruder panels except for the extruder doors and internal hopper panels require 1/4" thickness Decidamp sheets to satisfy a one-to-one thickness ratio. The extruder doors and internal hopper panels require a thickness of 1/8". Sheets are to cover 80% or greater surface area of any flat extruder panel. Application to curved panels is not achievable due to Pyrotek Decidamp sheet properties, however the team recommends application of a pliable closed-cell foam on curved panels for future consideration.

Housing interior panel surfaces requiring Decidamp sheets are numbered for identification in the following Figure 42.

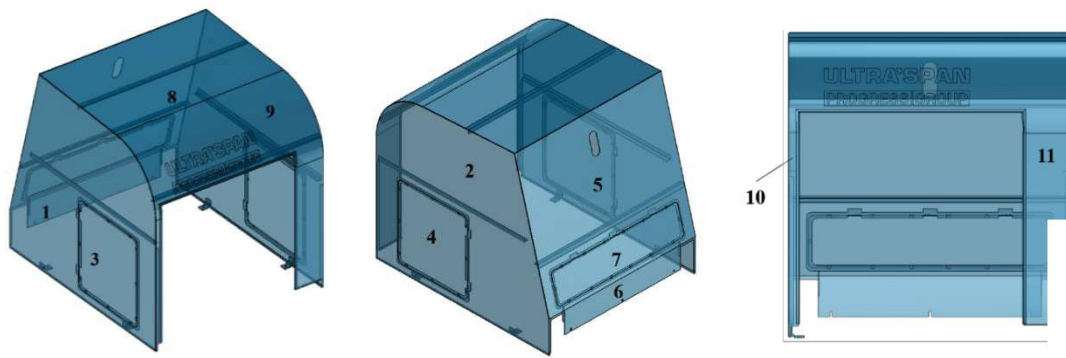


Figure 42: Housing numbered panels to receive acoustic material

Table IV summarizes the application of Decidamp sheets on the housing, where the thickness of each panel is listed along with the Decidamp tile thickness required to satisfy a one-to-one thickness ratio. Low area panels such as the two doors of the housing can be covered using a single sheet and are represented by a 0.5 number of sheets each.

TABLE IV: PYROTEK DECIDAMP SHEET APPLICATION SUMMARY ON HOUSING

| Housing                                     |                   |                      |                                 |                                 |                            |
|---------------------------------------------|-------------------|----------------------|---------------------------------|---------------------------------|----------------------------|
| #                                           | Part              | Thickness<br>[gauge] | Decidamp tile<br>thickness [in] | Part area<br>[in <sup>2</sup> ] | Number of sheets<br>needed |
| 1                                           | Left Side         | 10                   | 1/4                             | 3,265                           | 2                          |
| 2                                           | Right side        | 10                   | 1/4                             | 3,265                           | 2                          |
| 3                                           | Left side door    | 12                   | 1/8                             | 845                             | 0.5                        |
| 4                                           | Right side door   | 12                   | 1/8                             | 845                             | 0.5                        |
| 5                                           | Back cover        | 10                   | 1/4                             | 2,643                           | 2                          |
| 6                                           | Back base         | 10                   | 1/4                             | 444                             | 1                          |
| 7                                           | Back door         | 12                   | 1/8                             | 594                             | 1                          |
| 8                                           | Top flat panel    | 10                   | 1/4                             | 2,246                           | 1                          |
| 9                                           | Top curved panel  | 10                   | -                               | 1,589                           | -                          |
| 10                                          | Front left panel  | 10                   | 1/4                             | 416                             | 0.5                        |
| 11                                          | Front right panel | 10                   | 1/4                             | 86                              | 0.5                        |
| <b>Total number of 1/4" sheets required</b> |                   |                      |                                 |                                 | <b>9</b>                   |
| <b>Total number of 1/8" sheets required</b> |                   |                      |                                 |                                 | <b>2</b>                   |

Hopper panels requiring Decidamp sheet application are numbered for identification in the following Figure 43.

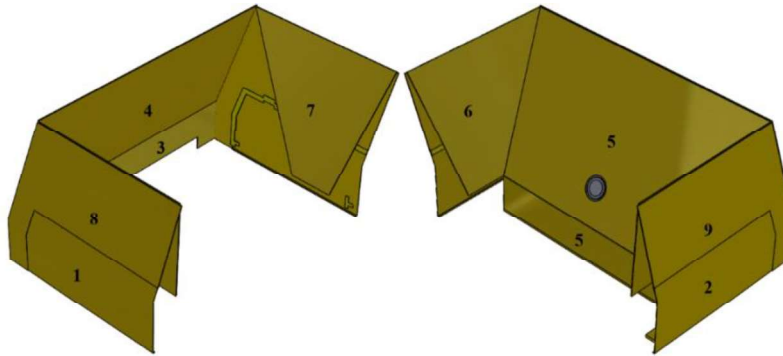


Figure 43: Hopper numbered panels to receive acoustic material

Panels 1, 2, 5, 6, 7, 8, and 9 require application on respective non-visible sides, as seen in Figure 43. The summary of material application on the hopper is shown in the Table V.



TABLE V: PYROTEK DECIDAMP SHEET APPLICATION SUMMARY ON HOPPER

| Hopper                                      |                      |                      |                                 |                            |                              |
|---------------------------------------------|----------------------|----------------------|---------------------------------|----------------------------|------------------------------|
| #                                           | Part                 | Thickness<br>[gauge] | Decidamp tile<br>thickness [in] | Area<br>[in <sup>2</sup> ] | Number of<br>sheets required |
| 1                                           | Left side door       | 12                   | 1/8                             | 551                        | 0.5                          |
| 2                                           | Right side door      | 12                   | 1/8                             | 551                        | 0.5                          |
| 3                                           | Back panel           | 7                    | 1/4                             | 345                        | 1                            |
| 4                                           | Back top panel       | 7                    | 1/4                             | 1,742                      | 1                            |
| 5                                           | Front top panel      | 7                    | 1/4                             | 1,890                      | 1                            |
| 6                                           | Internal right panel | 7                    | 1/4                             | 682                        | 1                            |
| 7                                           | Internal left panel  | 7                    | 1/4                             | 682                        | 1                            |
| 8                                           | Left side            | 7                    | 1/4                             | 876                        | 1                            |
| 9                                           | Right side           | 7                    | 1/4                             | 876                        | 1                            |
| <b>Total number of 1/4" sheets required</b> |                      |                      |                                 |                            | <b>7</b>                     |
| <b>Total number of 1/8" sheets required</b> |                      |                      |                                 |                            | <b>1</b>                     |

From Table IV and Table V the total number of sheets required are sixteen 1/4" sheets and three 1/8" sheets. An interior view of the right extruder wall with the Pyrotek Decidamp acoustic material sheets applied is shown in Figure 44.

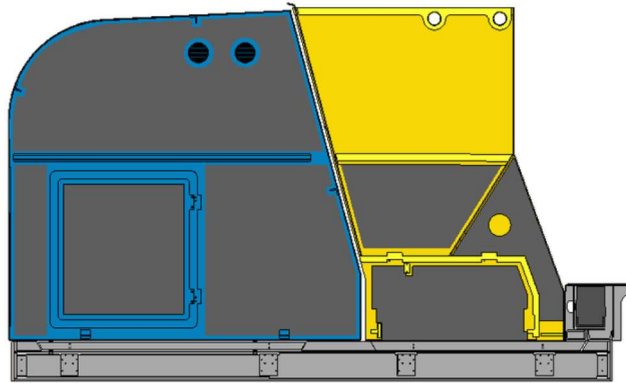


Figure 44: Cut view of extruder with applied Pyrotek Decidamp acoustic material

Decidamp sheets are cut using standard tools such as a circular saw, table saw, or band saw to match the area required on flat panels on the extruder. The sheets are adhered to the extruder using the Decidamp DC30 two-part epoxy. The application process of Decidamp DC30 is shown in Figure 45 [16].



Figure 45: Pyrotek DC30 polyurethane adhesive applied to a Decidamp tile [16]

The DC30 epoxy covers 1 m<sup>2</sup> per 1.3 kg of product applied at a 1 mm thickness. 20 kg of Decidamp DC30 epoxy is required for the total area of the extruder [16]. Technical specifications of Pyrotek DC30 epoxy can be found in APPENDIX D – PYROTEK SUPPLIED DOCUMENTS.

The total application process is expected to take 16 hours for both the housing and hopper installation of the Decidamp sheets. Installation of the current open-cell foam currently takes approximately 20 hours due to requirement of weld on tabs to hold the foam in place. Therefore, application of the Decidamp sheets will save approximately 4 hours of labour.

### 2.3.3 Acoustic Material Cost Summary

The cost of Pyrotek Decidamp sheets are \$178.21 CAD and \$91.26 CAD for the 1/4" and 1/8" sheets. The Pyrotek DC30 two-part epoxy adhesive costs \$199.50 CAD per 10 kg of component A and \$38.54 CAD per 1 kg of component B, mixed at a 10:1 ratio of component A to B. Two 10 kg buckets of component A and two 1 kg buckets of component B are required [16]. The total cost of the acoustic dampening material design is summarized in Table VI.

TABLE VI: ACOUSTIC MATERIAL DESIGN COST SUMMARY

| Description                        | Source       | Quantity  | Cost [CAD]        |
|------------------------------------|--------------|-----------|-------------------|
| <b>Pyrotek Decidamp 1/4" Sheet</b> | Pyrotek [16] | 16 sheets | \$2,851.36        |
| <b>Pyrotek Decidamp 1/8" Sheet</b> | Pyrotek [16] | 3 sheets  | \$273.78          |
| <b>Pyrotek DC30 Part A Epoxy</b>   | Pyrotek [16] | 20 kg     | \$399.00          |
| <b>Pyrotek DC30 Part B Epoxy</b>   | Pyrotek [16] | 2 kg      | \$77.08           |
| <b>Total Cost [CAD]</b>            |              |           | <b>\$3,601.22</b> |

A Pyrotek contact and material quote can be found in APPENDIX D – PYROTEK SUPPLIED DOCUMENTS.

### **2.3.4 Acoustic Material Risk Analysis**

Two risks were identified introducing the new acoustic material Pyrotek Decidamp sheets and were classified using the OSHA system [12]. The mass of the product is greater than the less dense open-cell foam currently used, and the new sheet use an epoxy instead of a mechanical fastener to be held into place.

1. The extruder is commonly lifted by industrial machinery to transport between production beds. The added mass of the product may not allow the extruder to be lifted. Not allowing the extruder to be transported easily has a high severity (3) affecting a company's ability to use the extruder. The total mass from the Decidamp panels is approximately 300 lbs therefore it is not adding a significant amount of mass to the extruder, resulting in a rare likelihood of occurrence (1). The Total risk introduced is categorized as moderate (3).
2. The Decidamp tiles utilize an epoxy adhesive instead of a mechanical fastener during application. If a sheet falls there is the risk of interfering with the auger drive assembly and damaging drive train components, which has a high severity (3). The epoxy sourced is commonly used industrial applications for long term adhesion leading to a rare likelihood of occurrence (1). The Total risk introduced is categorized as moderate (3).

### 3 FINAL DESIGN

The final proposed noise reduction solution combines the three previously outlined designs to create a quieter Ultra-Span hollow core extruder. A render implementing all three designs is shown in Figure 46, including modelling of the extrusion bed as well as a concrete slab being produced from the back of the extruder.



Figure 46: Final design CAD render of designs

The following subsections outline a brief summary of each design and the interaction between designs when all are implemented. Recommendations from the team are included in each applicable section. Next, a bill of materials is presented that summarizes the total cost and where to source each component. Finally, the design is compared to the technical specifications outlined in the introduction of this report.

#### 3.1 Implementation Design Summary and Recommendations

The final design proposed is the combination of the three designs presented in the previous section of this report. However, it is recommended that these design changes not be implemented

simultaneously, and should instead be implemented in the following order based on ease of implementation and increasing cost:

1. Extruder door redesign
2. VibraSystems SM-1 rubber isolation mounts
3. Pyrotek Decidamp acoustic sheets

The intended goal of the door redesign is to promote to customers that the doors must remain on the extruder to maintain as much of an enclosure around vibration sources as possible. To accomplish this goal three measures are proposed. First, the number of motions required to open the door has been reduced from two to one by redesigning the door with a grab handle and magnetic latch. Second, the team recommends installation of formal signage on the inside of extruder doors, warning operators of high sounds levels when doors are open. Third, customers should be notified that noise emission values can only be obtained by operating the extruder as designed and supplied (with doors installed). The result of reinstallation of the doors is an expected noise level decrease of 10 dB in common working zones [5].

The effectiveness of the reinstalling the extruder doors should be measured using a hand-held dosimeter. The team recommends visiting a concrete production facility and testing both setups with the doors on and off the extruder, with a setup similar to Phase 1 testing. Measurements should be taken in the common working zones at either side and the back of the extruder at approximately 3'.

After testing the effectiveness of the extruder doors, the next design to be implemented is the VibraSystems SM-1 isolation mounts. Research of similar isolation mount rubbers suggest that by installing the VibraSystems mounts and isolating vibration by 98.5 – 99.2% on both the cassette and hopper, a large reduction in noise will be achieved [13] [14]. It is the expectation of the team that the rubber isolation mounts will effectively reduce vibration through most components of the extruder, resulting in the highest noise reduction.

To test the effectiveness of the rubber mounts the team recommends two forms of testing. First, Phase 1 testing should be replicated to investigate both the reduction in vibration and noise levels using accelerometers and microphones. Second, slab quality testing should be inspected to ensure that the mounts do not introduce unwanted deflection. The team does not expect a

decrease in slab quality because the static deflection is known and can be accounted for in manufacturing, and the operating deflection will be low based on the natural frequency of the mounts. It is recommended to test the effectiveness in noise reduction after mount installation, to evaluate if further vibration reduction and noise transmission reduction is necessary by means of installing the Pyrotek Decidamp matting.

Finally, after testing of both door reinstallation and the vibration mounts, the new Pyrotek Decidamp acoustic matting should be installed if further vibration reduction and noise transmission reduction is required. Coverage should be at least 80% of the panels specified, to ensure that the noise transmission loss is as high as possible [16]. However, if customers continue to remove extruder doors, the team does not recommend installation of Pyrotek Decidamp sheets, based on the negative effect to transmission loss with increasing openings in an enclosure. The Pyrotek Decidamp matting provides a noise reduction of 21 dB as well as reduces vibrations by 60% [16]. Compared to the current extruder with open cell-foam matting that is estimated to reduce noise by 6 dB, the overall expected noise reduction of implement the Pyrotek Decidamp sheets is 15 dB [3]. The effect of the added mass to the hopper from installation of Pyrotek Decidamp sheets was accounted for in the design of the VibraSystems SM-1 mounts and the proposed design does not change if the acoustic matting is installed.

Testing the effectiveness of the new acoustic material can be completed similar to the door reinstallation tests using a dosimeter or microphone.

### **3.2 Bill of Materials**

A bill of materials including total cost of the three noise reduction designs is displayed in Table VII.

TABLE VII: NOISE REDUCTION DESIGN BILL OF MATERIALS

|                                           | Part # | Description                              | Source                           | Quantity  | Cost [CAD]        |
|-------------------------------------------|--------|------------------------------------------|----------------------------------|-----------|-------------------|
| Doors                                     | 1      | 5/8" A36 Steel Rod                       | Metal Supermarkets Winnipeg [11] | 40"       | \$21.57           |
|                                           | 2      | BZ082 3" x 1/2" x 1/8" Magnet            | K&J Magnetics [4]                | 4         | \$24.68           |
|                                           | 3      | 3M DP-100 Two-part Epoxy                 | 3M Canada [9]                    | 48.5 mL   | \$139.03          |
| <b>Door Redesign Total Cost</b>           |        |                                          |                                  |           | <b>\$185.28</b>   |
| Mounts                                    | 4      | VibraSystems SM-1 2x2 Threaded Mount     | VibraSystems Inc. [13]           | 4         | \$183.54          |
|                                           | 5      | VibraSystems SM-1 2x2 Bolt Through Mount | VibraSystems Inc. [13]           | 4         |                   |
|                                           | 6      | VibraSystems SM-1 2x4 Threaded Mount     | VibraSystems Inc. [13]           | 4         |                   |
|                                           | 7      | Custom Metal Cassette Sheet              | Parr Metal Fabricators [15]      | 2         | \$150.00          |
|                                           | 8      | Custom Metal Hopper Sheet                | Parr Metal Fabricators [15]      | 2         | \$150.00          |
| <b>Mount Design Total Cost</b>            |        |                                          |                                  |           | <b>\$483.54</b>   |
| Acoustic Matting                          | 9      | Pyrotek Decidamp 1/4" Sheet              | Pyrotek [16]                     | 16 sheets | \$2,851.36        |
|                                           | 10     | Pyrotek Decidamp 1/8" Sheet              | Pyrotek [16]                     | 3 sheets  | \$273.78          |
|                                           | 11     | Pyrotek DC30 Part A Epoxy                | Pyrotek [16]                     | 20 kg     | \$399.00          |
|                                           | 12     | Pyrotek DC30 Part B Epoxy                | Pyrotek [16]                     | 2 kg      | \$77.08           |
| <b>Acoustic Matting Design Total Cost</b> |        |                                          |                                  |           | <b>\$3,601.22</b> |
| <b>Design Total Cost</b>                  |        |                                          |                                  |           | <b>\$4,270.04</b> |

### 3.3 Design Comparison to Target Specifications

Target specifications were determined as part of the project definition report to ensure that the final design had a quantifiable measure of meeting customer needs. Details of the target specifications can be found in APPENDIX A – TARGET SPECIFICATION DETAILS.

The following list compares each numbered target specification from Table I to the final design:

1. Noise Level – The estimated noise reductions of the extruder door redesign and new acoustic material are 10 dB and 15 dB respectively [5]. Additionally, the rubber isolation mounts decrease vibration by 98.5 - 99.2% and noise level by an unknown amount [13]. Due to the interaction of each design when all three are implemented, a value of noise

reduction is not easily quantified. However, research indicates that implementation of the presented design will reduce noise to target specification of 80 dB or less. To quantify a value of noise reduction the team has suggested various stages of further testing.

2. Working time noise comfort – This test requires implementation of the design to determine how long an operator is comfortable working around the extruder.  
Implementation results in a reduction in extruder noise, thus it is expected that operators can either meet or exceed the working time of 30 minutes.
3. Cost – The total cost of the design is displayed in the bill of materials in Table VII and is \$4,270.04. This value is below the target specification of \$5,000.
4. Slab cross-section cracking – This test requires implementation of the design to determine the percent of cross-section cracking. The final design does not affect core functionality of the extruder and is expected to maintain slab quality.
5. Web slippage – This test requires implementation of the design to determine the measurement of web slippage. The final design does not affect core functionality of the extruder and is expected to maintain slab quality.
6. Slab cross-section surface voids – This test requires implementation of the design to determine the percent of surface voids. The final design does not affect core functionality of the extruder and is expected to maintain slab quality.
7. Number of manufacturing processes introduced – One manufacturing process of epoxy application is introduced to the Ultra-Span production facility. Epoxy is required to install both the magnet latch on the redesigned extruder doors as well as the Pyrotek Decidamp matting.
8. Material lead time – All materials were sourced from companies within Canada or the United States of America, such that lead time was assumed to be minimized to 4 weeks or less.
9. Manufacturing time – Both the additional manufacturing time of the door redesign and rubber isolation mounts was assumed negligible. The implementation of the Pyrotek Decidamp matting was assumed to take 4 hours less than that of the current open-cell foam insulation, based on that weld on tabs would no longer be required for the new matting.



10. Qualitative operator comfort – No major alterations were made such that operator comfort would be affected when operating the extruder.
11. Operating performance – No major alterations were made such that the extruder performance would be affected as well as core functionality of the extruder was not altered.
12. High abrasion zone material hardness – No material was introduced in areas of high abrasion.
13. Low abrasion zone material hardness – No material was introduced in areas of low abrasion.
14. No abrasion zone qualitative wear test – All materials introduced are sourced from companies appropriate for the application of concrete extrusion. Conversations with both VibraSystems and Pyrotek confirmed that the mounts and matting introduced are capable of the extruder’s operative requirements. Additionally, all products are to be installed as per manufacturers recommendations.
15. Design footprint extending from extruder exterior – The additional of extruder door grab handles extends the extruder footprint by 2”.
16. Risk assessment – Risk assessments of each design result in a highest total risk assessed of 3 total risk units.

The following Table VIII inserts a column into Table I that summarizes the design specification values outlined previously, compared to target specifications. As each target specification was not able to be determined without implementation of the design, a value denoted by a “+” symbol represents that the design specification maintains or improves the target specification value.

TABLE VIII: FINAL DESIGN COMPARISON TO TARGET SPECIFICATIONS

| #  | Specification                                     | Goal     | Target Specification | Design Specification | Units           |
|----|---------------------------------------------------|----------|----------------------|----------------------|-----------------|
| 1  | Noise Level                                       | Minimize | 80                   | +                    | dB              |
| 2  | Working Time Noise Comfort                        | Maximize | 30                   | +                    | min             |
| 3  | Cost                                              | Minimize | 5,000                | 4,270.04             | CAD Dollar      |
| 4  | Slab Cross-Section Cracking                       | Minimize | 3                    | +                    | %               |
| 5  | Web Slippage                                      | Target   | 0                    | +                    | mm              |
| 6  | Slab Cross-Section Surface Voids                  | Minimize | 10                   | +                    | %               |
| 7  | Number of Manufacturing Processes Introduced      | Minimize | 1                    | 1                    | -               |
| 8  | Material Lead Time                                | Minimize | 6                    | 4                    | week            |
| 9  | Manufacturing Time                                | Minimize | 40                   | - 4                  | hr              |
| 10 | Qualitative Operator Comfort                      | Maximize | -                    | +                    | Pass/Fail       |
| 11 | Operating Performance                             | Maximize | 8.6                  | 8.6                  | Lineal m/m3     |
| 12 | High Abrasion Zone Material Hardness              | Maximize | 66                   | N/A                  | HRC             |
| 13 | Low Abrasion Zone Material Hardness               | Maximize | 160                  | N/A                  | HB              |
| 14 | No Abrasion Zone Qualitative Wear Test            | Maximize | -                    | +                    | -               |
| 15 | Design Footprint Extending from Extruder Exterior | Minimize | 6                    | 2                    | in              |
| 16 | Risk Assessment                                   | Minimize | 3                    | 3                    | Total Risk Unit |

Comparison of the design specifications to the target specifications concludes that the design meets the needs of the project.

## 4 CONCLUSION

The following Design Report Summary section summarizes the results of the design report, including a brief description of the problem and the designs proposed to satisfy that problem. A Future Work section outlines information required to continue installation and understanding of the proposed design. Finally, a Lessons Learned section details several key learnings noted by the team during completion of this project.

### 4.1 Design Report Summary

This project was initiated to reduce the operating sound level of the Ultra-Span EXT-400Si hollow core concrete extruder. The noise level target specification was set to 80 dB to conform to the CSA Standards Z107.56 and Z1007 hearing conservation program [1]. The extruder operating at 80 dB appeals to customers because of diminished noise pollution and decreased risk of hearing damage caused to the operators. Decreasing the noise of the extruder was accomplished by implementing three different designs: redesigned extruder doors, rubber anti vibration mounts, and a new acoustic dampening material. The extruder currently operates at an average noise level of 99 dB, therefore, a noise reduction of approximately 20 dB was required in order to meet the target specification.

The final design solution incorporates three different design concepts to meet the target noise reduction of 20 dB: redesigned doors, rubber anti vibration mounts, and the application of acoustic dampening matting. Figure 47 shows the three different designs proposed. The top left image displays the Pyrotek Decidamp sheets applied to the inside of the motor housing and the hopper. The bottom left image displays the door which has been redesigned with a handle and magnetic latching system. The bottom right image displays the VibraSystems SM-1 rubber mounts supporting both the cassette and the hopper.



Figure 47: Summary of three design implementations

The extruder door was redesigned to increase accessibility to extruder internals and promote reinstallation of the doors at concrete production companies. Substituting the two small latches currently used on the door for a simple handle and magnetic latching system will increase the ease of opening and closing the door. When the doors are removed, operators are exposed to an additional recorded 10 dB of noise [5]. Redesigning the doors so that they are more convenient for the operators will rid the need to remove them.

VibraSystems anti vibration rubber isolation mounts were sourced to reduce the transmission of vibration throughout the extruder. VibraSystems are capable of cutting and drilling the mounts as required and implementation of the rubber mounts will not change the manufacturing time or the assembly process of the extruder components. The VibraSystems SM-1 rubber mounts are capable of analytically reducing the vibration at the cassette mounting locations by 98.5% and at the hopper mounting locations by 99.2% [13]. The corresponding reduction in noise associated with a reduction of vibration is difficult to confirm, so it is recommended that the noise level be tested after the implementation of the rubber mounts.

The acoustic damping material is sourced as well. It comes in rolls which can be cut to fit the geometry of the insides of the motor housing and the hopper. After the acoustic damping material is cut to the right size it is adhered to extruder using epoxy. Finally, Pyrotek Decidamp sheets were sourced to improve noise transmission loss from the currently used open-cell foam. The Decidamp sheets are cut to shape to cover at least 80% of extruder panels and are adhered using the Pyrotek DC30 epoxy. Pyrotek Decidamp sheets are able to achieve a vibration reduction of 60% and a sound transmission reduction of 15 dB [16].

It is recommended that the designs be implemented sequentially as presented in this report. Following the recommendation would mean first implementing the door redesign. The estimated cost of the door redesign is \$185.28. This is the least expensive of the designs and requires the smallest amount of change to the extruder. The second design, involving the application of the rubber anti vibration mounts, will cost an estimated \$483.54. The final design, installing acoustic dampening material, will cost an estimated \$3,601.22. The estimated total cost of implementing all three design recommendations come to \$4,270.04. The cost of implementing all three designs successfully meets the target specification budget of \$5,000.

Further comparison with target specifications found that the design meets customer needs by maintaining core functionality, slab quality, slab geometry, manufacturability, durability, and operability. Finally, risk assessments of each design confirm that the final design is safe to operate.

Overall, the final design minimizes alterations to the current extruder design to maintain customer product expectations. The result is a simple design that meets customer requirements while reducing the noise of the concrete extruder.

## **4.2 Future Work**

This final design report provides theoretical designs to reduce noise of the extruder. Future work details steps required by Ultra-Span in order to successfully implement the designs, as well as further understanding the noise emitted from the extruder.

As previously stated, testing should be completed to measure the effectiveness of each applied element of the final design. Testing should closely replicate operating conditions by recreating the setups from test Phase 1.

Areas without Decidamp sheets applied fail to separate operators from vibration sources and are expected to remain areas of high noise, such as on curved extruder panels, start and stop edges of sheets, and at the front housing opening. The team recommends for future consideration: the installation of a pliable closed-cell material on curved panels, to ensure that all sheets are installed to the edge of panels, and the design of a component to cover the housing opening.

SolidWorks has the capability of performing frequency studies to estimate the natural frequency of extruder components. Investigation by the team found that considerable repairs must be made to the extruder CAD model to ensure results are reliable. Understanding of the extruder component natural frequencies can aid in identifying excessively vibrating components and limit vibration transmission.

### **4.3 Lessons Learned**

The process of developing the designs presented in this report allowed for development of engineering consulting skills such as the use of measurement equipment, analyzing of measured data and application of acquired data. Additionally, skills were developed in collaborating customer needs with detailed design engineering.

One lesson learned through the process of developing design solutions is the consideration of cost versus effectiveness. This is especially applicable to designs with lower budgets similar to the extruder. Understanding the outcome for the invested cost is crucial when making implementation decisions. This is associated with the recommendation to apply the acoustic dampening material as a final step of the noise reduction design process, as it is the most expensive in relation to the extent that it can reduce noise transmission.

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## 6 APPENDIX A – TARGET SPECIFICATION DETAILS

The following list outlined details of the project target specifications:

- Specification 1 is a measure of the noise level of an operating extruder using a noise dosimeter from a working distance of 3' to the extruder [1].
- Specification 2 is a timed measure of the amount of time an operator can comfortably work around the operating extruder.
- Specification 3 sets a maximum budget of \$5,000 CAD to the design but is to be minimized and justified.
- Specifications 4, 5, and 6 are determined through a visual inspection of the cross-section area of an extruded slab for cracking, web slippage, and surface voids [17] [18] [19].
- Specification 7, 8, and 9 analyze the manufacturing effort required to implement a design, including number of manufacturing processes introduced, material lead time, and manufacturing hours.
- Specification 10 is a qualitative measure of whether the extruder has become ergonomically difficult to operate.
- Specification 11 ensures that the applied design does not adversely affect the current performance of 8.6 lineal meters of slab per 1 cubic meter of input material as measured by Ultra-Span testing personnel [20].
- Specification 12 and 13 are related to the wear resistance of a material given the location of where on the extruder the material is placed, by comparison to the hardness of chrome plating and A36 steel [21] [22].
- Specification 14 offers an additional test for materials apart from metals, with a qualitative test through specialist visual inspection of installation of materials such that they are not vulnerable to wear.
- Specification 15 limits design to maintain the compact design of the current extruder. This is accomplished by a setting a maximum allowable distance of 6" from the current extruder geometry.

- Specification 16 utilizes the Occupational Safety and Health Administration (OSHA) system of risk analysis already adopted by Ultra-Span to assess the risks introduced by an implemented design [12]. The low to moderate range was determined to be the maximum total risk range of a chosen design.

## 7 APPENDIX B – TEST SUMMARY

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## 7.1 Testing Introduction

Testing equipment was acquired from the Industrial Technology Centre (ITC), which is a Winnipeg based company that provides a range of services including technical expertise, specialized services, and equipment to Manitoba companies and University of Manitoba student groups [23]. ITC specialists recommended the use of a SOMAT data acquisition system shown in Figure B 1.

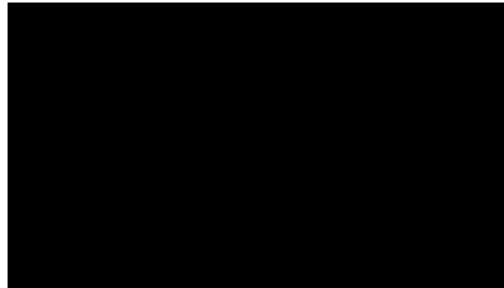


Figure B 1: SOMAT data acquisition system instrument [24]

The SOMAT shown in Figure B 1 contains multiple inputs for both accelerometer and microphone devices. Accelerometers are used to measure the amplitude of vibration in g's, while microphones measure sound pressure in Pa. ITC provided 12 accelerometers to measure the acceleration of panels from extruder vibration. Each accelerometer contained a magnetic end capable of sticking to metallic objects. Additionally, 4 microphones were provided to measure the noise of the running extruder. Several days of training and equipment testing granted the team the expertise to run a full vibration and noise analysis on the Ultra-Span extruder.

## 7.2 Phase 1 Testing at Field Location

The location provided to conduct Phase 1 testing was an anonymous local concrete producer in Manitoba. This company creates precast hollow core slabs using the Ultra-Span hollow core extruder in an indoor facility shown in Figure B 2.



Figure B 2: Operating Ultra-Span hollow core extruder

The extruder was made available to the group for approximately one hour in an outdoor environment. This meant the following for planning Phase 1 testing: accelerometer and microphone locations were strategically placed such that minimal setups were required, accelerometer and microphone placement was efficient to conserve time, device setup was weather resistant, and the team did not interfere with the slab production.

To minimize the number of setups during Phase 1 testing, accelerometers were placed on the hopper, electrical housing, and cassette frame which were readily accessible during operation of the extruder. The placement of accelerometers was determined using a SolidWorks Finite Element Analysis (FEA) Frequency study software on the Computer Aided Design (CAD) model hopper section provided by Ultra-Span. The hopper was isolated and fixed at the frame mounting points shown in Figure B 3.

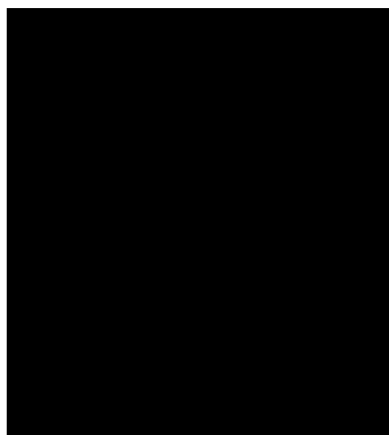


Figure B 3: Isolated hopper with mounting point fixtures



The frequency analysis applies vibration to yield the first 5 vibration modes, of which the following modes 2 and 5 were of interest and shown in Figure B 4.



Figure B 4: Hopper frequency study results of mode shape 2 (left) and 5 (right)

The left image in Figure B 4 of mode shape 2 displays an internal panel vibrating panel that passing through the external steel side of the hopper. This shape is occurring due to the way the CAD model was constructed, without attachments at locations that are welded during fabrication. Although this shape is not feasible it highlighted that panels only accessible through the hopper door openings must be considered for vibration testing. The left image of mode shape 5 confirmed placing accelerometers on the largest panels at the center of the panel, furthest from structural geometry such as corners or welded joints. Results of FEA were used for qualitative assessment of mode shapes in order to further knowledge of vibration on the hopper. A convergence study was also not completed for this preliminary analysis. Repairs to the CAD model to represent manufacturing fixtures as well as a convergence study will be completed in detailed design if the hopper requires further analysis.

With review and input from Ultra-Span, the following hopper accelerometer placements were determined and shown in Figure B 5. Locations such as the front of the hopper, the back of the housing, and side doors were not included based on accessibility at the test site.

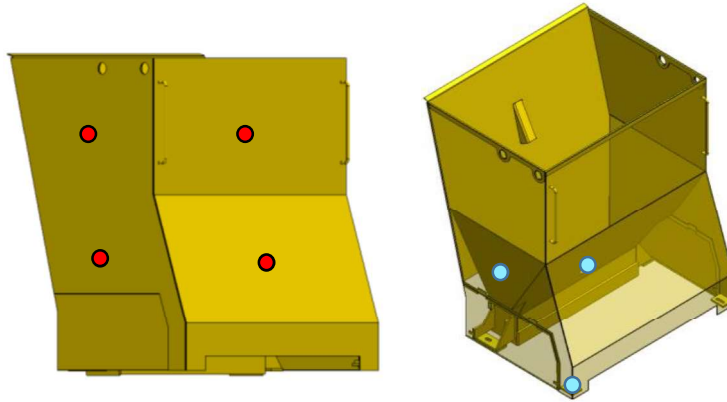


Figure B 5: Accelerometer hopper placement on internal and external panels

Accelerometer placement on the electrical housing is shown in Figure B 6.

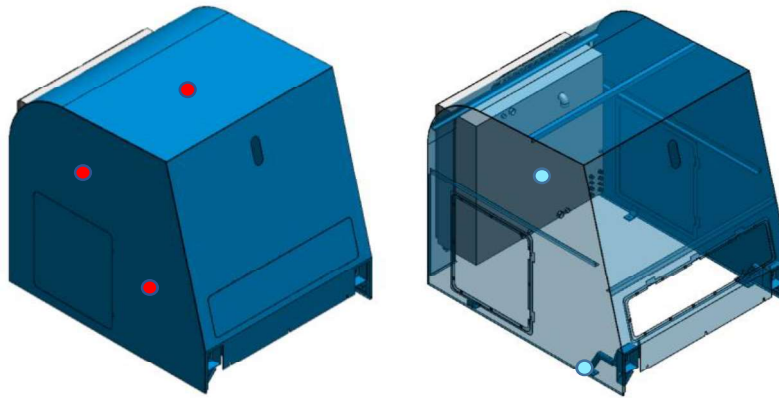


Figure B 6: Accelerometer housing placement on internal and external panels

In both Figure B 5 and Figure B 6, red points represent an externally accessible accelerometer location, while blue points represent an internally accessible accelerometer location.

Accelerometer placement on the cassette frame is shown in Figure B 7.

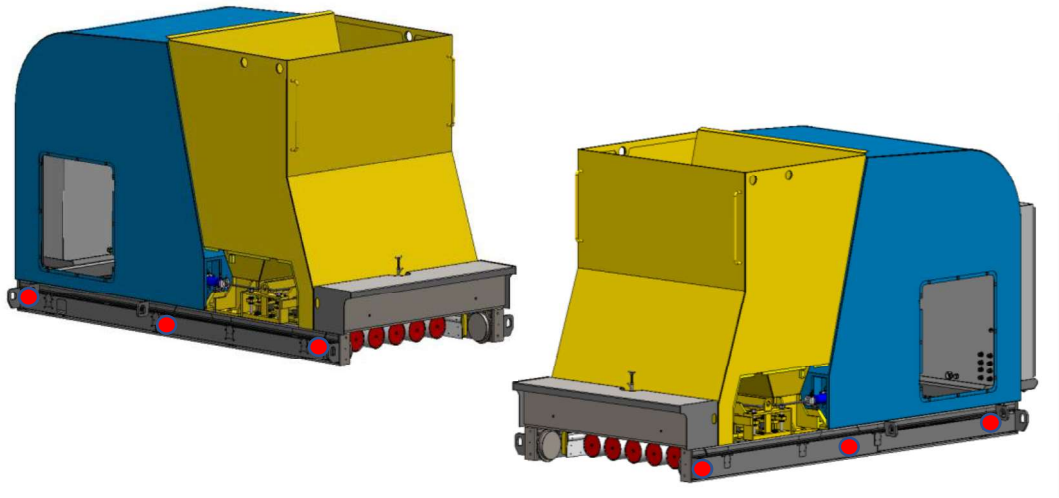


Figure B 7: Accelerometer cassette placement on both left side (left) and right side (right)

Six accelerometers were evenly placed around the cassette frame to provide an overview of cassette vibration. Microphones were placed around the extruder to attempt to create a 360-degree sound map, shown in Figure B 8.

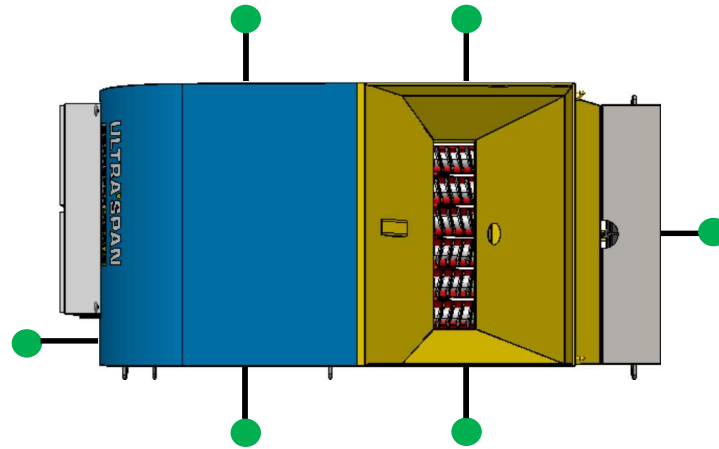


Figure B 8: Microphone placement on extruder shown in green points

The locations in Figure B 8 are at an approximate distance of 3', which represents common working zones of extruder operators. Two additional shorter microphone stands were created and were placed in locations to be determined during the test where the team believed sound was the highest.

Trial tests using a weatherproof Rubbermaid storage device for the SOMAT were completed to ensure that the setup was organized, efficient, and weather resistant. An image of the rear, left side, and right side hopper accelerometer and microphone placements are shown in Figure B 9.

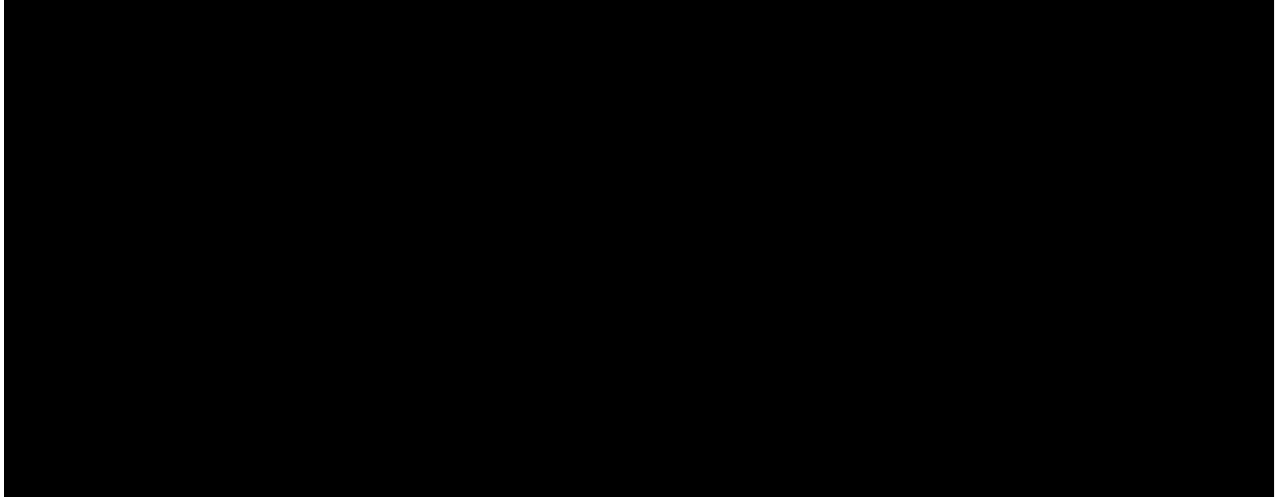


Figure B 9: Rear and left side hopper (left) and right side hopper (right) test setup

Figure B 10 displays both the front and left side housing accelerometer and microphone testing setup, as well as the right side housing setup.

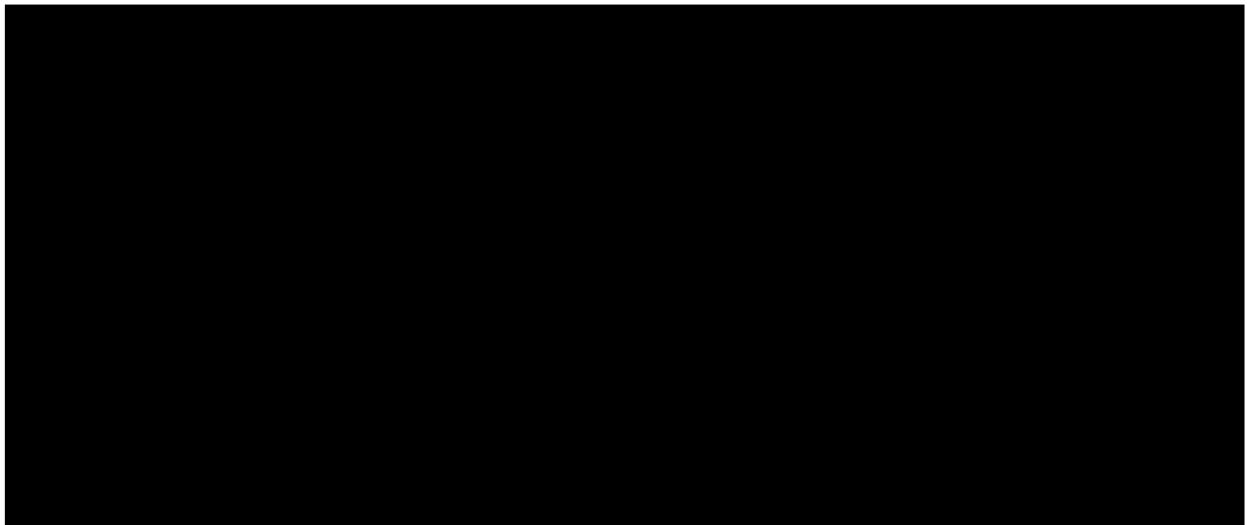


Figure B 10: Front and left side housing (left) and right side housing (right) test setup

And finally, Figure B 11 displays the left side cassette accelerometer test setup which was mirrored to the right side of the cassette.

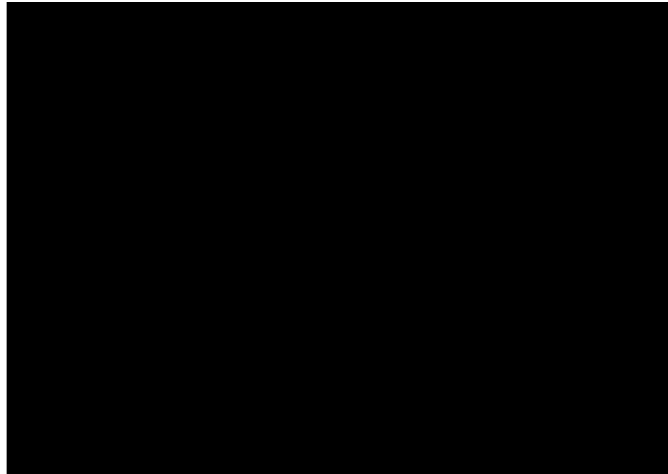


Figure B 11: Left side cassette accelerometer test setup

As observed in Figure B 9, Figure B 10, and Figure B 11 the hopper and housing doors are absent. Companies regularly remove doors for ease of access to internal components.

A total of 5 tests were completed: two on the hopper setup, two on the housing setup, and one on the cassette. The accelerometer results of hopper test 1 are shown in Figure B 12.



Figure B 12: Hopper test 1 accelerometer results

Figure B 12 displays a stacked plot of all accelerometers with peak amplitudes occurring at the input frequency of 135 Hz and the first two harmonic frequencies of 270 Hz and 405 Hz. This concludes that majority of noise occurs due to the input vibration sources which operate at the VFD controlled frequency of 135 Hz. Similar plots for the remaining tests were obtained and the maximum value of vibration in g's was recorded and transferred to summary diagrams. Figure B 13 displays results of the left side external components of the extruder.

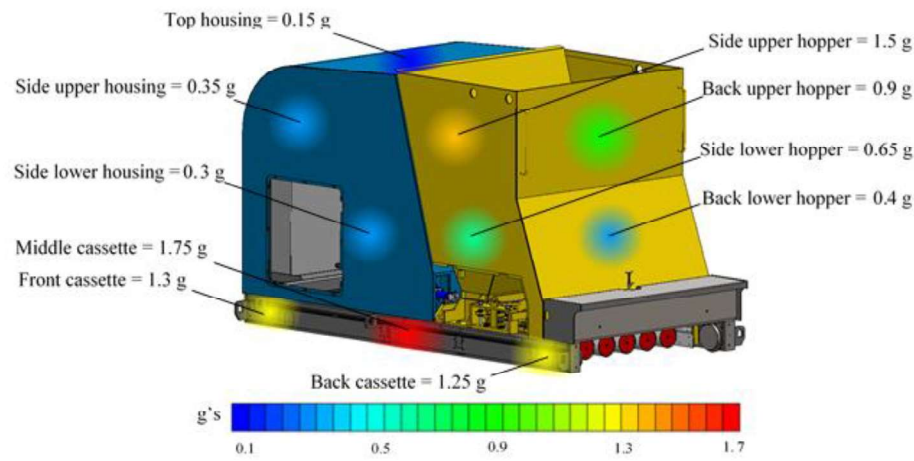


Figure B 13: Left side external accelerometer testing results summary

Figure B 13 displays the maximum value of vibration measured in g's occurring at the middle of the cassette and decreases as accelerometers are placed away from the location of maximum vibration. Similar results of the right side external components are shown in Figure B 14.

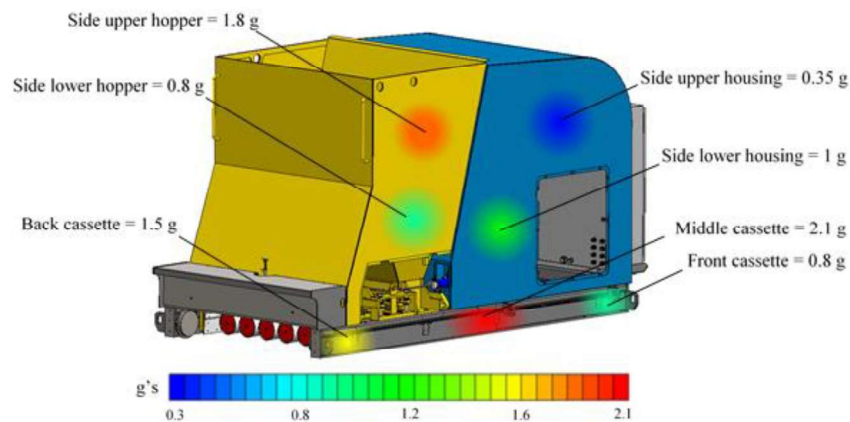


Figure B 14: Right side external accelerometer testing results summary

An anomaly to the maximum frequency surrounding the cassette occurs on the upper portions of the hopper. Concrete acts as a form of dampening as well as mass addition when pressed against the steel hopper and components. This results in both vibration reduction due to dampening and the shift in natural frequency from added mass. During the first hopper test, the concrete level was noted to be low resulting in greater amplitude of vibration. Figure B 15 provides a waterfall plot confirming the increase in vibration with reducing level of concrete.

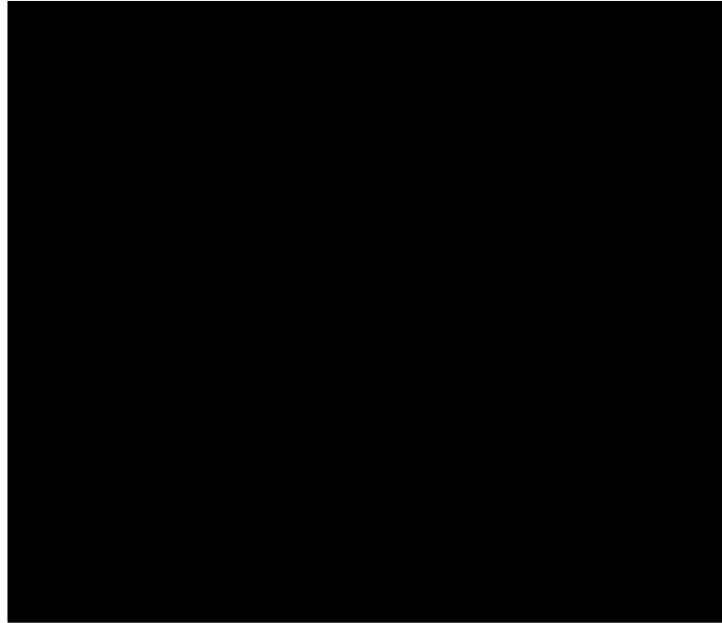


Figure B 15: Waterfall plot of accelerometer number 5 hopper test 1 results

At the frequency of 135 Hz, the intensity of vibration increases until a point when the extruder is loaded with concrete and is followed by an instant decrease in vibration. As the concrete level lowered in the hopper, the amplitude of vibration increased again.

The results of internal panel vibrations and mounts are shown in Figure B 16.

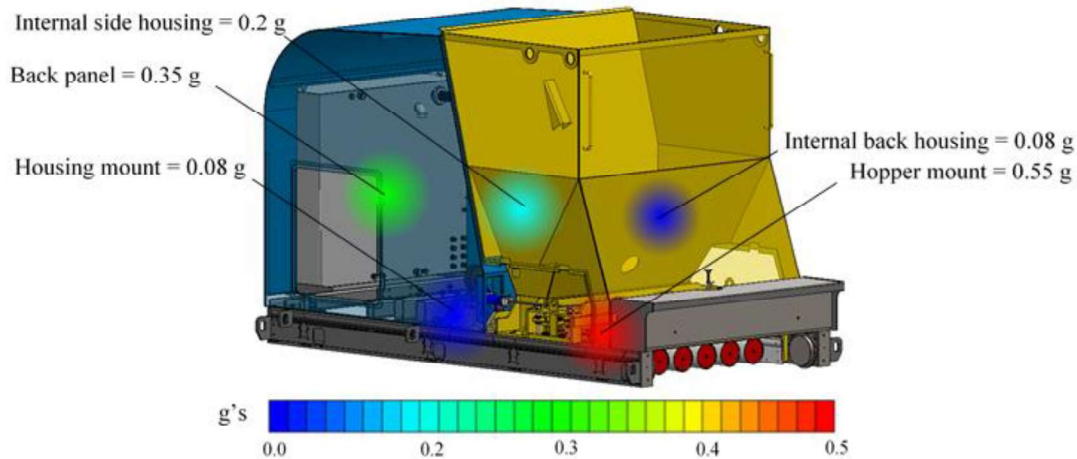


Figure B 16: Left side internal accelerometer testing results summary

Due to the internal hopper panels constant contact with concrete, the values of internal vibration are low. Similar low vibration levels were observed on all internal accelerometer results.

A summary sound map of the microphone data is shown in Figure B 17.

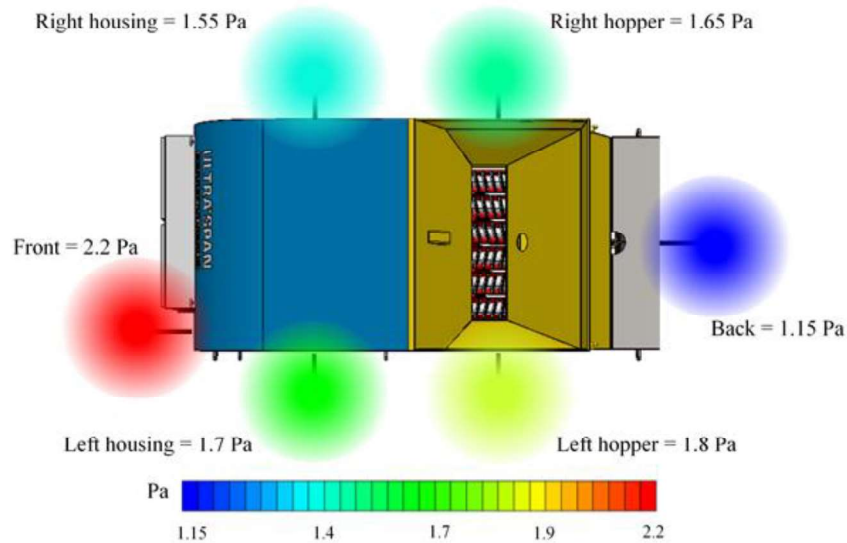


Figure B 17: Phase 1 sound map microphone testing results summary

The highest readings in pascals were observed at the front of the extruder, however, it was noted that minimal operator working time occurred at the front of the running extruder. Most operators were positioned on either side or behind the extruder. The sound pressure levels were converted to dB sound pressure level (SPL) and displayed in Table B I [25].



TABLE B 1: PHASE 1 TESTING MICROPHONE RESULTS CONVERSION TO DECIBELS

| Microphone Location               | Pa   | dB (SPL) |
|-----------------------------------|------|----------|
| <b>Front</b>                      | 2.20 | 100.83   |
| <b>Right housing</b>              | 1.55 | 97.79    |
| <b>Right hopper</b>               | 1.65 | 98.33    |
| <b>Back</b>                       | 1.15 | 95.19    |
| <b>Left hopper</b>                | 1.80 | 99.08    |
| <b>Left housing</b>               | 1.70 | 98.59    |
| <b>Short mic 1 – hopper door</b>  | 2.80 | 102.92   |
| <b>Short mic 2 – housing door</b> | 2.35 | 101.40   |

The largest dB (SPL) value was measured by the short microphones placed by the hopper and housing door openings, measured at 102.92 dB (SPL) and 101.40 dB (SPL) respectively. This was expected due to their closer distance to the noise source. The average dB (SPL) measured with the six microphones placed around the extruder was approximately 99 dB (SPL).

### 7.3 Phase 2 Testing at Ultra-Span

Phase 2 testing was completed at the Ultra-Span production floor located in Winnipeg, MB. The extruder was made available placed on a replication extrusion bed without concrete input into the extruder. Therefore, without concrete it was expected that noise and vibration levels would vary to results of Phase 1 testing. Additionally, the extruder made available contained a cable reel on the left side of the housing, shown in Figure B 18, which differed to the extruder used in Phase 1 testing. Initial Phase 2 testing setups replicated Phase 1 conditions.



Figure B 18: Ultra-Span hollow core extruder at the Ultra-Span fabrication facility

Accelerometers were attached in the same locations as Phase test 1 on the hopper and housing and included orientations with both the hopper and housing doors open and closed, as shown in Figure B 19.

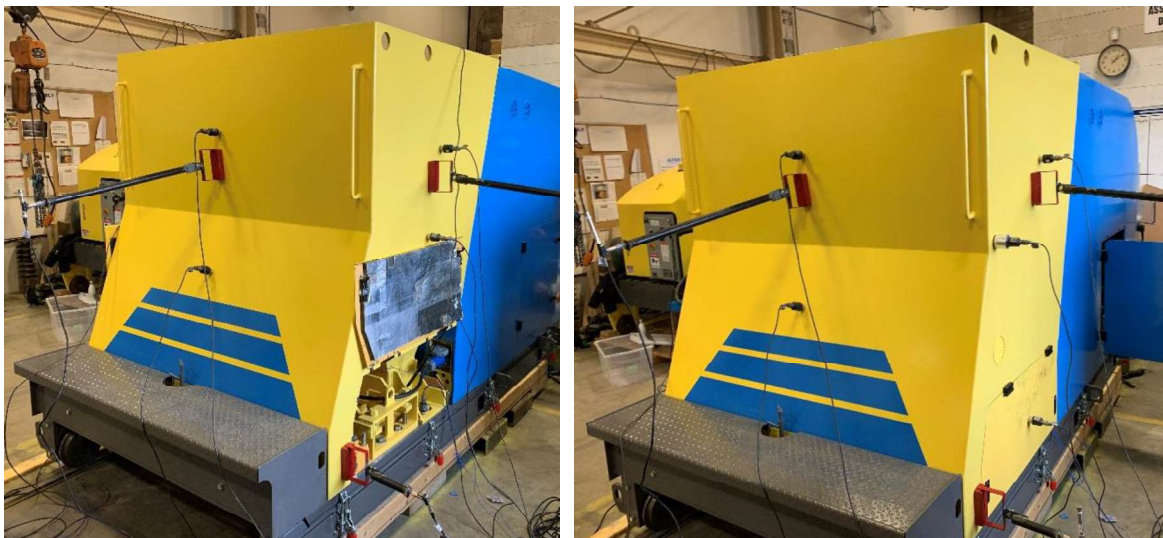


Figure B 19: Phase 2 hopper testing with doors open (left) and doors closed (right)

Similar to the hopper setups in Figure B 19, the housing setups included both doors open and closed setups on the right side, and a setup on the left side cable reel, shown in Figure B 20.

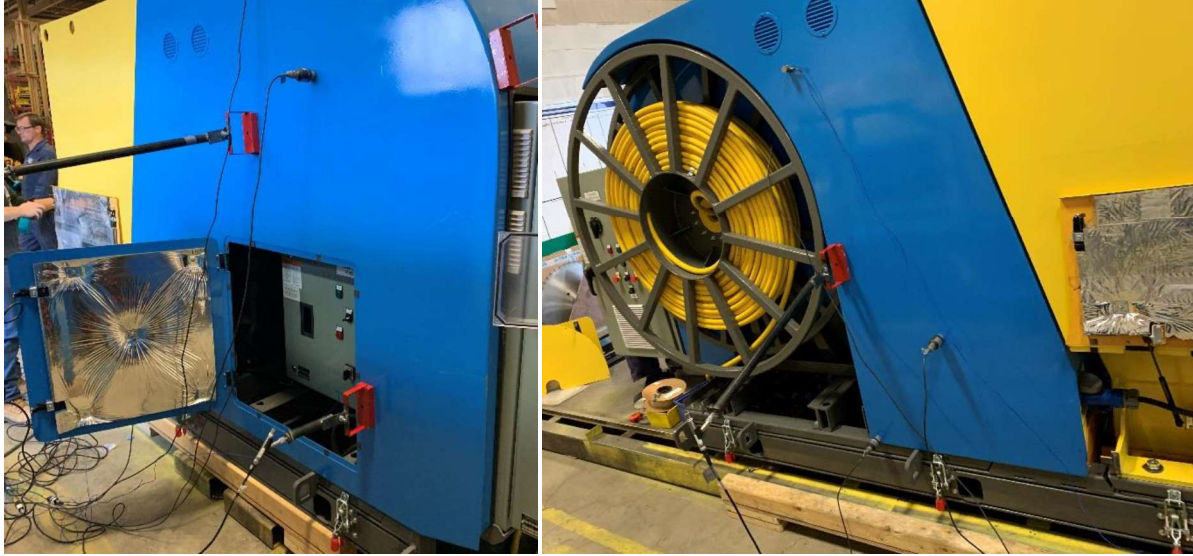


Figure B 20: Phase 2 housing testing with doors open (left) and left side cable reel (right)

The left side of the extruder (not including the left housing setup to be discussed further in this report) with doors open results are summarized in Figure B 21.

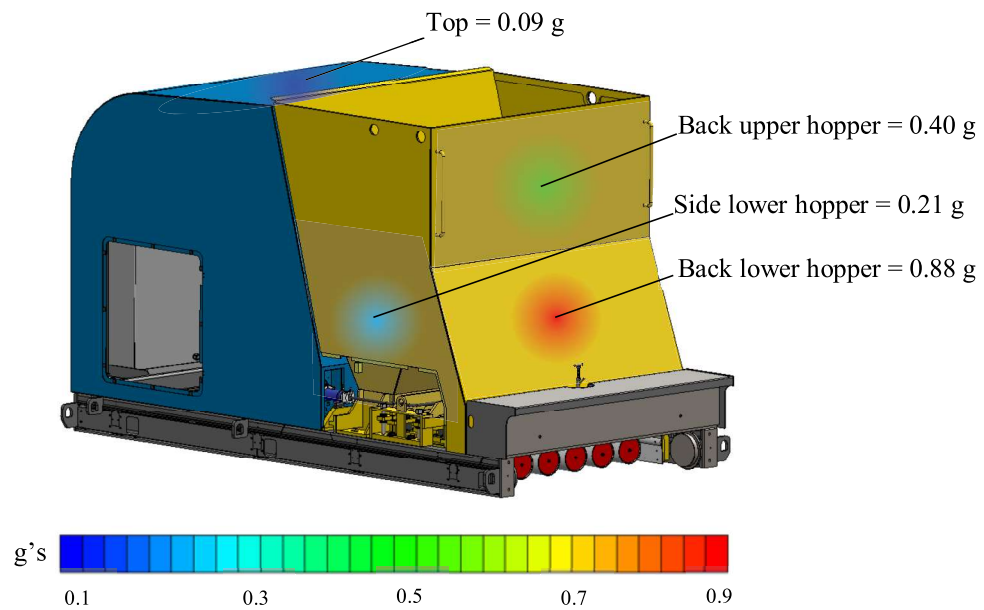


Figure B 21: Left side external accelerometer testing results summary with doors open

Noted during testing, the upper left hopper accelerometer did not function properly thus was not included in the results summary. Accelerometer results of the right side of the hopper with doors open are displayed in Figure B 22.

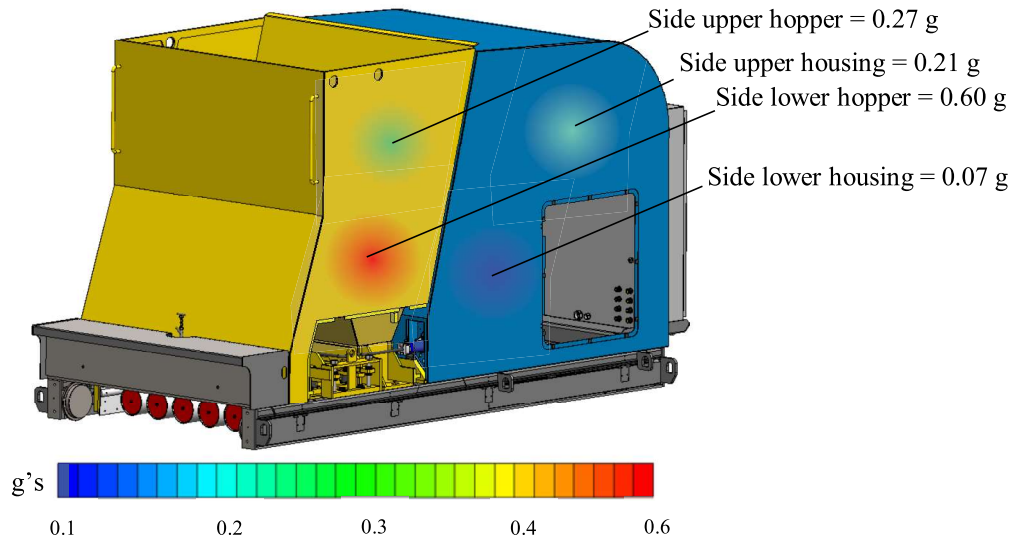


Figure B 22: Right side external accelerometer testing results summary with doors open

Results of the extruder vibration with the doors removed displayed low vibration amplitude below 1 g in all accelerometer locations. The results of the left side of extruder with the doors closed are summarized in Figure B 23.

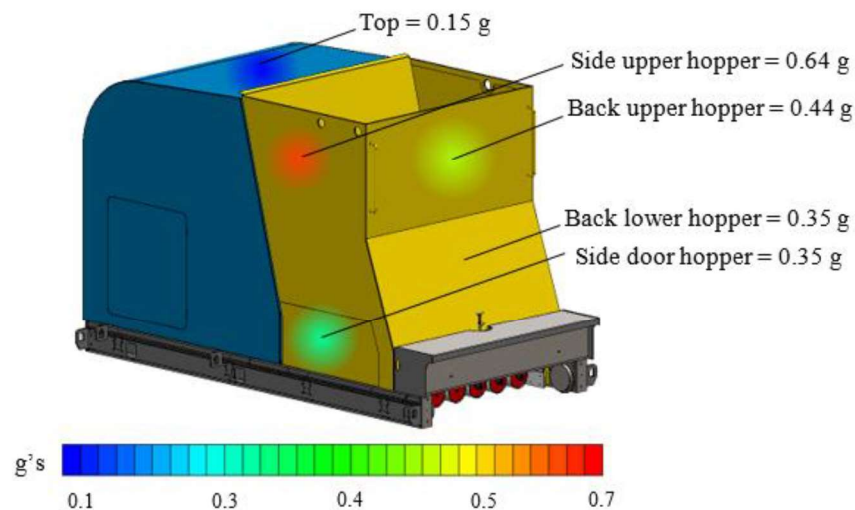


Figure B 23: Left side external accelerometer testing results summary with doors closed



The results for the right side of the extruder with doors closed are summarized in Figure B 24.

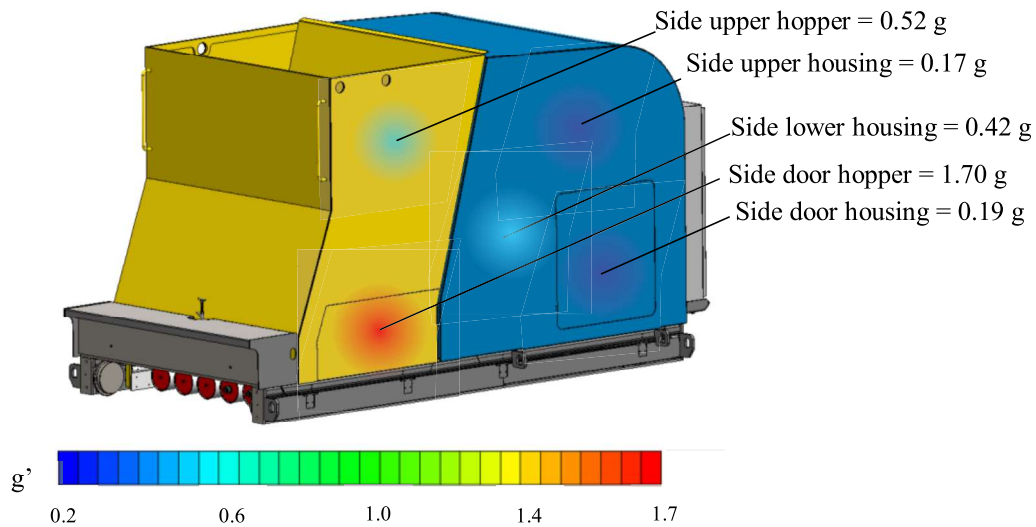


Figure B 24: Right side external accelerometer testing results summary with doors closed

The highest level of 1.7 g vibration was located on the right hopper door, from testing with the doors closed. Apart from the right door, vibration levels remained below 1 g for both doors open and doors closed setups.

A summary of the left housing cable reel is summarized in Figure B 25. Accelerometer locations for both doors open and closed tests remained the same on the left side of the housing.

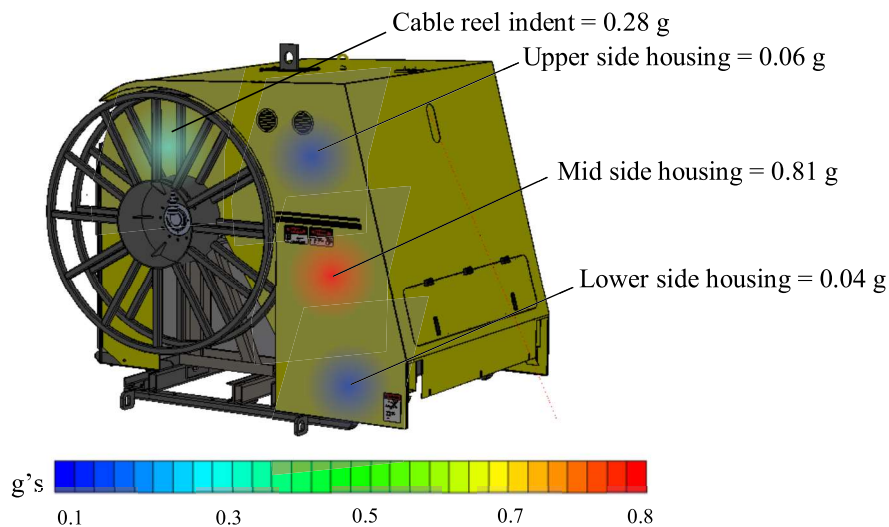


Figure B 25: Left side housing with cable reel external results summary

Results of the external extruder accelerometer locations displayed an overall low vibration. Internal extruder vibration results are summarized in Figure B 26.

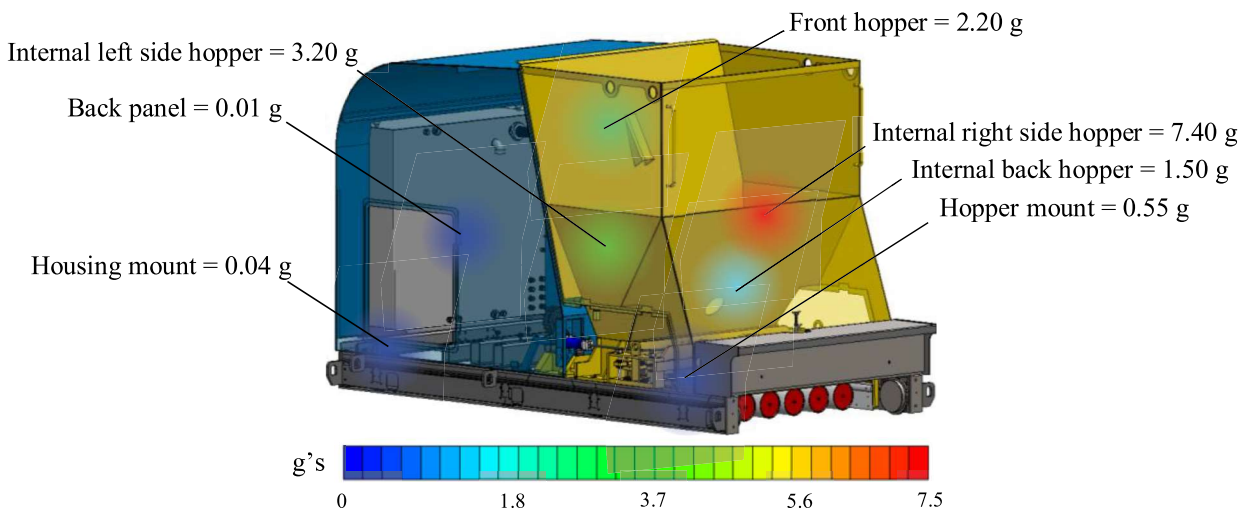


Figure B 26: Internal accelerometer testing results summary

Results of internal components displayed high vibration levels on the hopper. Without the additional mass of concrete against the un-insulated panels the front, internal left and right side, and internal back of the hopper noted vibration from 1.5 – 7.4 g. These results confirmed the results of Phase 1 testing, that as the level of concrete lowers vibration amplitude increases. Results display that at times when the extruder operates at a low concrete level the vibration amplitude is highest, thus the noise level is at its highest.

After recreating Phase 1 test setups, Phase 2 progressed with testing components of the cassette, hammering and troweling plate, motor and electrical panel frame, and cassette frame.

Accelerometer placement was decided based on discussions within the team as well as with Ultra-Span specialists. A sample of cassette and frame accelerometer placements are shown in Figure B 27.

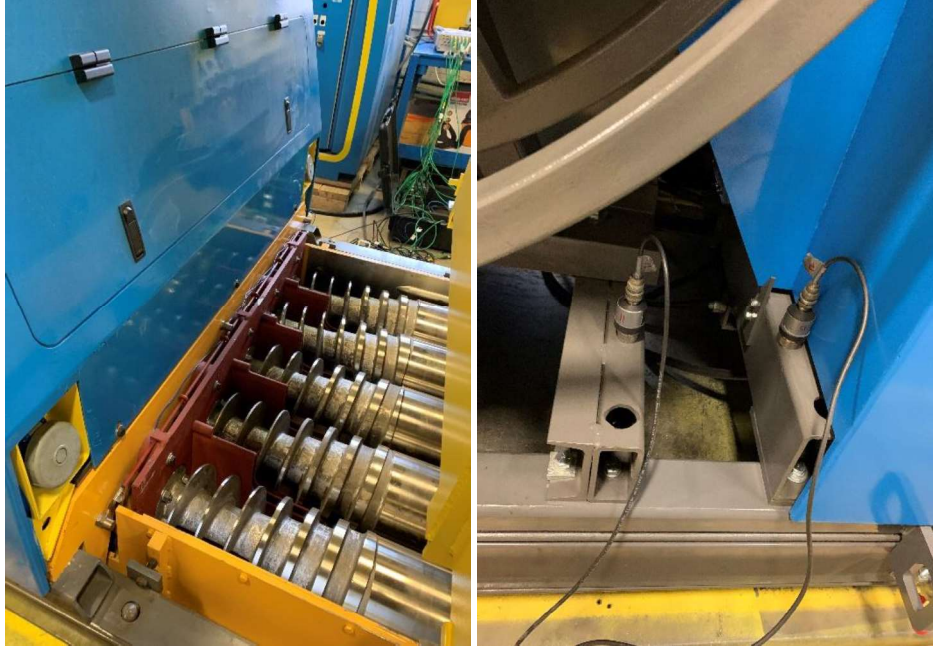


Figure B 27: Phase 2 testing on cassette material shield (left) and motor frame (right)

The results of the back components including a portion of the auger drive system and a frame, material shield, hammering plate, and troweling plate are summarized in Figure B 28.

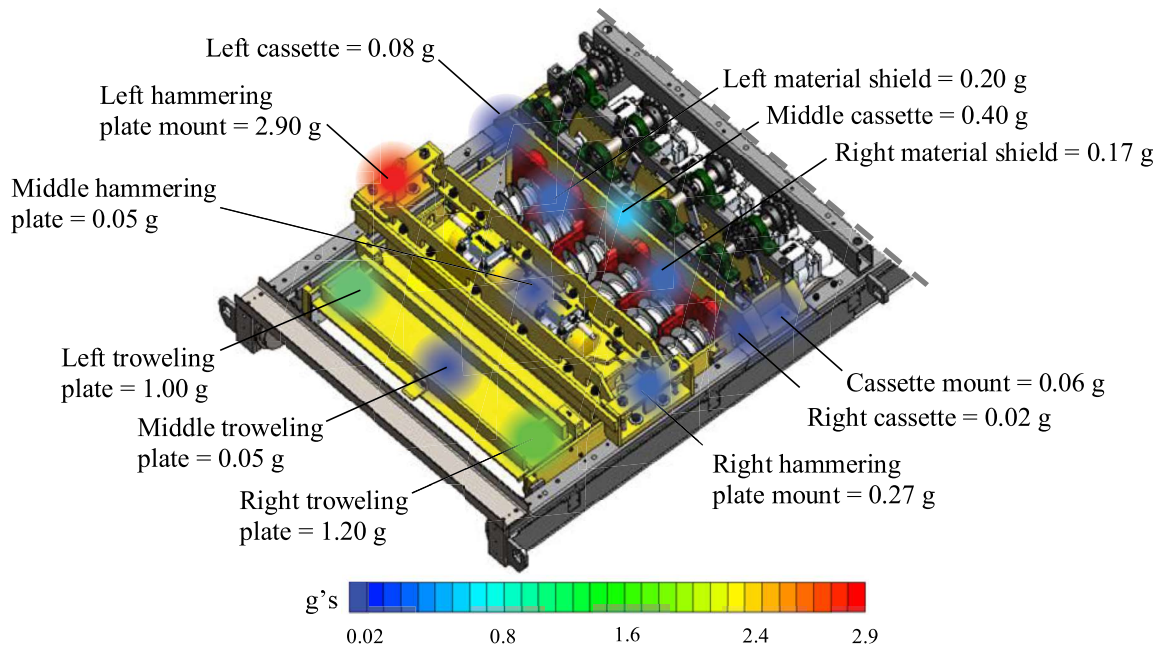


Figure B 28: Auger drive system and frame, material shield, hammering plate, and troweling plate results summary

Results of Figure B 28 displayed overall low levels of vibration below 1 g. Exceptions include a vibration level of 1 – 1.2 g at the troweling plate as well as 2.9 g on the left hammering plate mount. The results of the motor and electrical panel frame are summarized in Figure B 29.

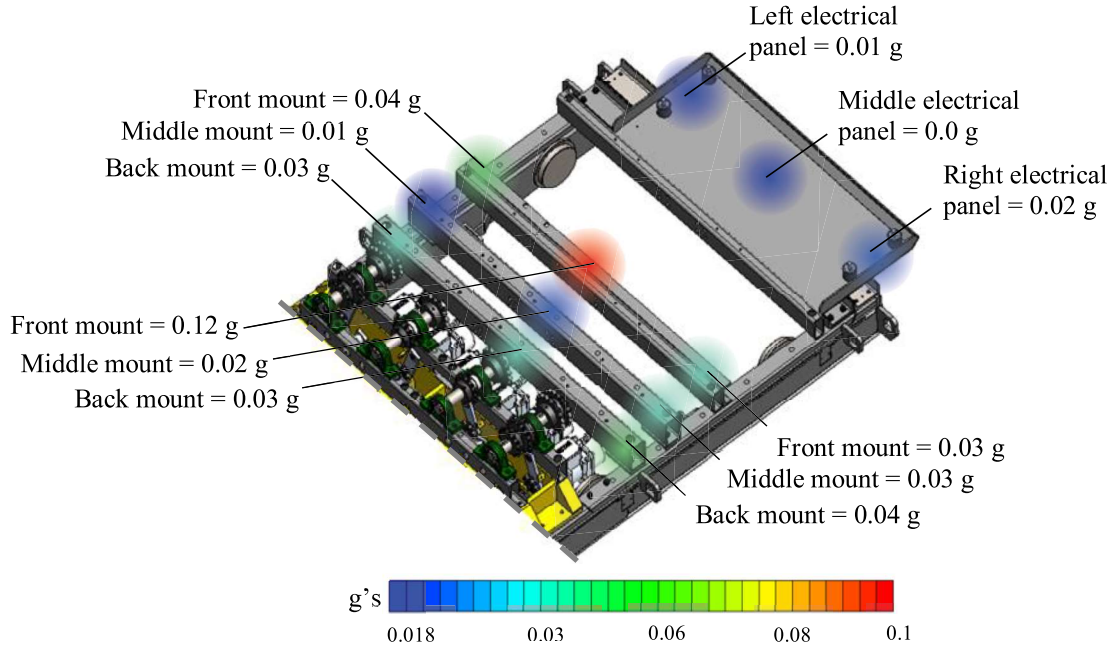


Figure B 29: Motor and electrical panel frame results summary

All results in Figure B 29 displayed low vibration levels below 0.1 g. The remaining cassette component results of the side plate and auger drive system supports are summarized in Figure B 30.

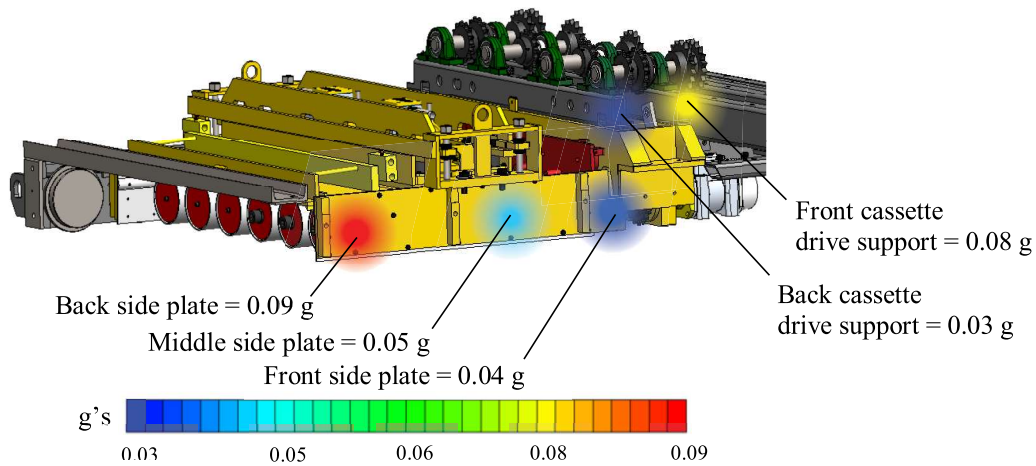


Figure B 30: Cassette side plate and auger drive system supports results summary



Similar to results in Figure B 29, Figure B 30 displays low vibration levels below 0.1 g.

Phase 1 testing displayed high vibration levels on the cassette frame, thus accelerometers were placed in the same locations on the outside portions of the frame. Additionally, accelerometers were placed on the inside c-channel component. Results of this setup are displayed in Figure B 31.

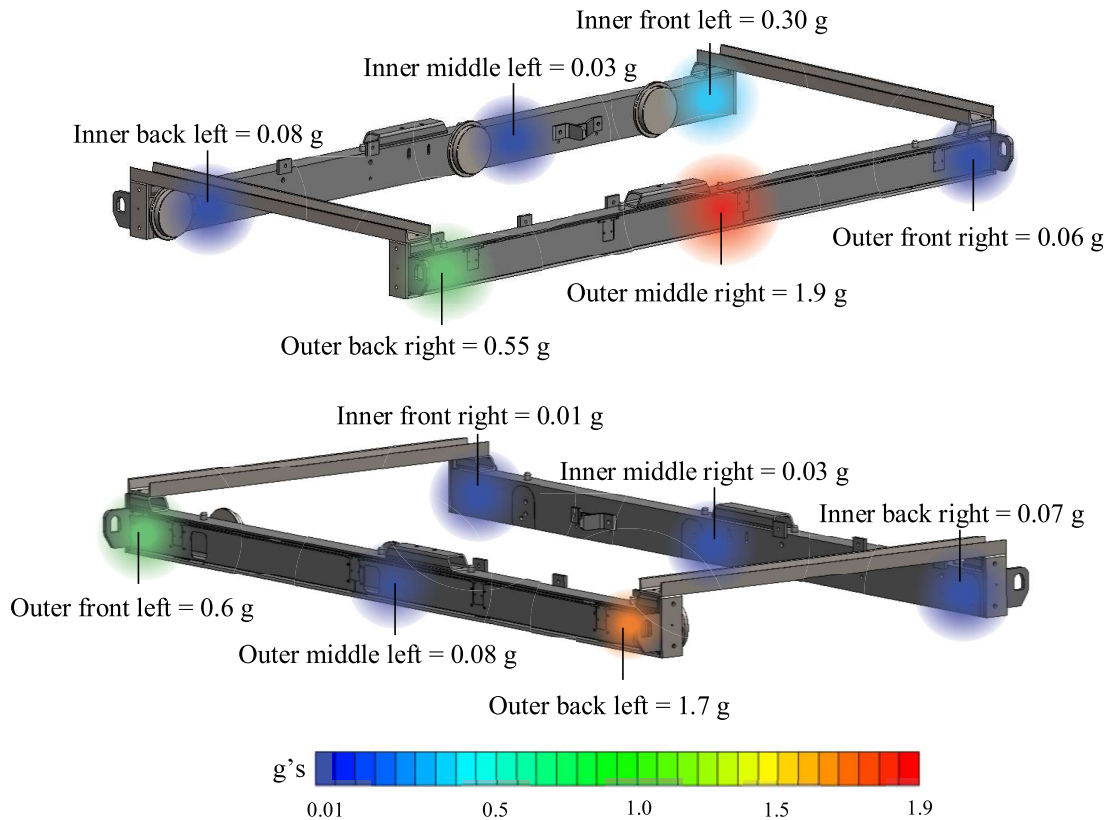


Figure B 31: Cassette frame results summary

Accelerometers attached to the inner locations (c-channel component of frame) had vibration amplitudes of 0.3 g or less. Whereas, outer locations (front plate component of frame) at the back left and middle right locations had vibration amplitudes of above 1.5 g. Phase 1 testing results led the team to investigate the stiffness of the c-channel and front plate frame components, with a recommendation to alter the c-channel. However, Phase 2 results display that the c-channel is experiencing low vibration and thus alteration to the front plate may be more impactful to noise reduction.

Microphones were used to investigate the effect of the extruder operating with hopper and housing doors open and closed. A sound map summary with the extruder doors open and with the doors closed is shown in Figure B 32.

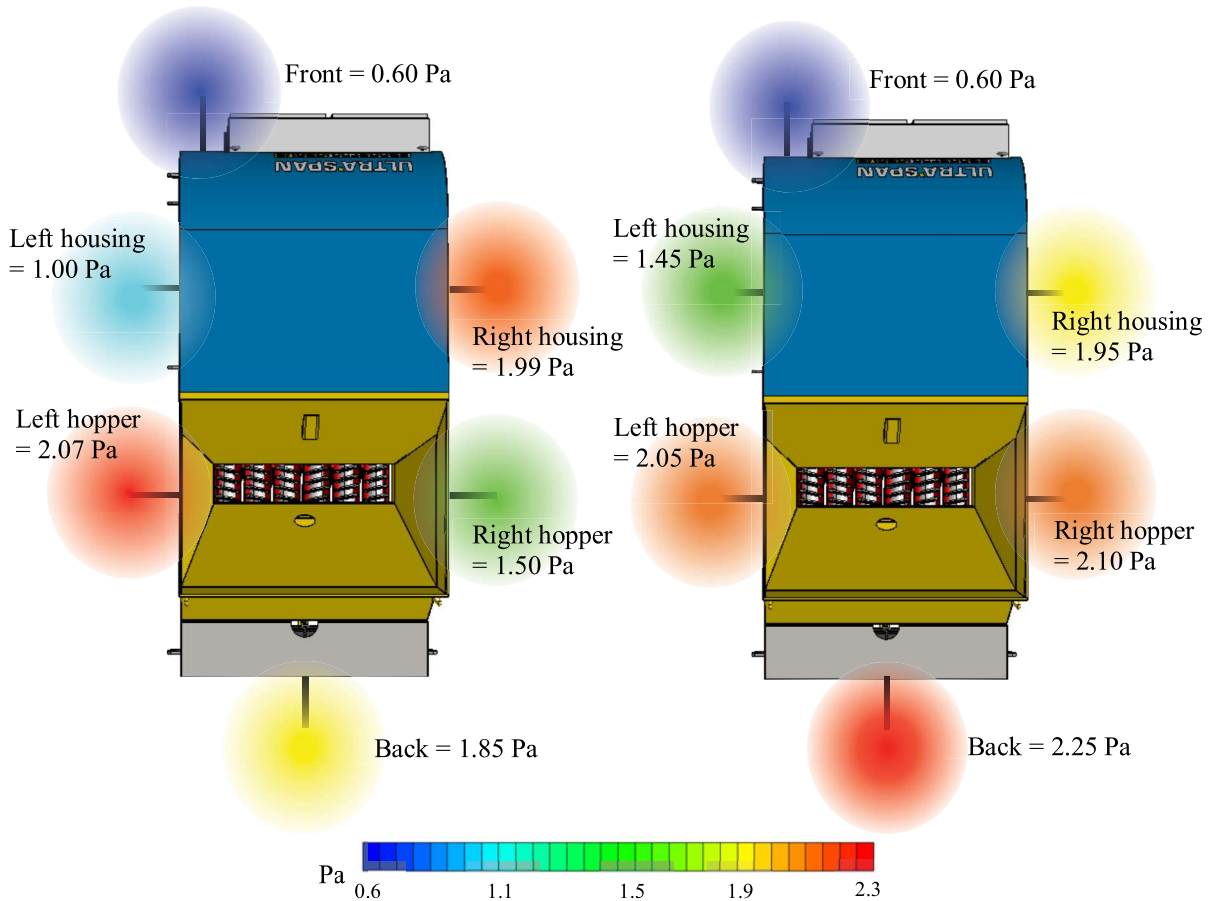


Figure B 32: Phase 2 sound map microphone testing results summary with doors open (left) and doors closed (right)

With the extruder doors open the highest noise level was noted at the location of the left of the hopper and the right of the housing. A significant level of noise was noted at the back of the hopper. Closing the extruder doors increased the noise emitted from the back of the hopper as well as the left of the housing, both of which were consistently open areas of the extruder. The location of maximum noise shifted when doors were placed on the extruder. However, a clear correlation between increased noise level at side locations caused by door removal could not be confirmed. This could be due to the difference in extruder setup between each test phase. The

team recommends replicating testing with extruder doors on and off, but in a concrete extruding environment similar to Phase 1 testing.

The sound pressure levels were converted to dB sound pressure level (SPL) and displayed in Table B II [25].

TABLE B II: PHASE 2 TESTING MICROPHONE RESULTS CONVERSION TO DECIBELS

| Microphone Location                            | Pa   | dB (SPL) |
|------------------------------------------------|------|----------|
| <b>Front (doors open)</b>                      | 0.60 | 89.54    |
| <b>Right housing (doors open)</b>              | 1.99 | 99.96    |
| <b>Right hopper (doors open)</b>               | 1.50 | 97.50    |
| <b>Back (doors open)</b>                       | 1.85 | 99.32    |
| <b>Left hopper (doors open)</b>                | 2.07 | 100.30   |
| <b>Left housing (doors open)</b>               | 1.00 | 93.98    |
| <b>Short mic – hopper door (doors open)</b>    | 0.93 | 93.35    |
| <b>Short mic – housing door (doors open)</b>   | 1.75 | 98.84    |
| <b>Front (doors closed)</b>                    | 0.60 | 89.54    |
| <b>Right housing (doors closed)</b>            | 1.95 | 99.78    |
| <b>Right hopper (doors closed)</b>             | 2.10 | 100.42   |
| <b>Back (doors closed)</b>                     | 2.25 | 101.02   |
| <b>Left hopper (doors closed)</b>              | 2.05 | 100.21   |
| <b>Left housing (doors closed)</b>             | 1.45 | 97.21    |
| <b>Short mic – hopper door (doors closed)</b>  | 1.40 | 96.90    |
| <b>Short mic – housing door (doors closed)</b> | 2.60 | 102.28   |
| <b>Short mic - Inside housing</b>              | 2.55 | 102.11   |
| <b>Short mic - Inside hopper</b>               | 5.70 | 109.10   |

## **8 APPENDIX C – ISOLATION MOUNT SAMPLE CALCULATIONS AND QUOTE**

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## 8.1 Introduction

The following sections outline the calculations necessary for sourcing the VibraSystems mounts required for the extruder application, as well as a quote for the custom sheet metal components necessary for the design.

## 8.2 VibraSystems Mount Calculations

A comparison between the dimensions of the SM-1 mounts and the rectangular tube being replaced are displayed in Table C I, where dimensions refer to the labelling notation in Figure 25 [13].

TABLE C I: SANDWICH MOUNTS AND RECTANGULAR TUBE DIMENSIONS [13]

| Dimension            | Rectangular tube | SM-1                            | SM-2 | SM-3                             |
|----------------------|------------------|---------------------------------|------|----------------------------------|
| <b>Width [W]</b>     | 3"               | 2"                              | 3"   | 4"                               |
| <b>Height [H]</b>    | 2"               | 1 <sup>3</sup> / <sub>4</sub> " | 2"   | 2 <sup>5</sup> / <sub>16</sub> " |
| <b>Thickness [T]</b> | 1/4"             | 5/16"                           | 3/8" | 1/2"                             |

The three different sandwich mounts have varying spring rates displayed in Table C II [13].

TABLE C II: SANDWICH MOUNTS SPRING CONSTANTS [26]

| Mount       | Spring constant [(lbs/in)/in length] | Maximum load [lbs/in] |
|-------------|--------------------------------------|-----------------------|
| <b>SM-1</b> | 2,400                                | 300                   |
| <b>SM-2</b> | 3,000                                | 450                   |
| <b>SM-3</b> | 4,800                                | 600                   |

Figure C 1 displays the load versus deflection chart of the different available sized sandwich mounts.

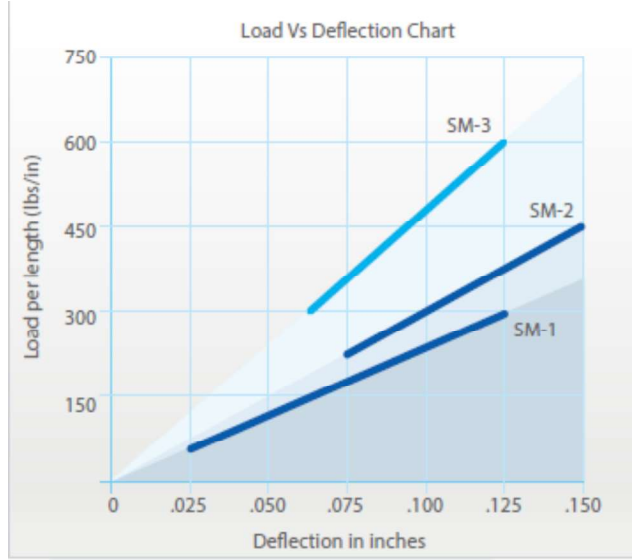


Figure C 1: VibraSystems SM Load Vs Deflection Chart [13]

SM-1 is rated for lighter loads than SM-2 and SM-3 mounts. The application of the spring's constants and the Figure C 1 load versus deflection chart are applied to the following series of equations to select the most suitable mounts and determine the percent isolation the mounts can provide.

Assuming equal load distribution over the mounts, the load per mount can be calculated using Eq. 1 [26].

$$\text{Load per mount} = \frac{\text{Total load}}{\text{Number of mounts}} \text{ (lbs)} \quad \text{Eq. 1}$$

To calculate the natural frequency required for 80 percent isolation, the disturbing frequency ( $f_d$ ) of 135 Hz was used. The natural frequency can then be calculated using Eq. 2 [26].

$$\text{Natural frequency}(f_n) = \frac{f_d}{2.45} \text{ (Hz)} \quad \text{Eq. 2}$$

Substituting the disturbing frequency yields a natural frequency of 55.10 Hz. The required static deflection can be obtained using the natural frequency previously calculated using Eq. 3 [26].

$$\text{Static deflection}(d_s) = \frac{9.8}{f_n^2} \text{ (in)} \quad \text{Eq. 3}$$

Applying the natural frequency to Eq. 3 yields a static deflection value of 0.00323”.

The required spring rate to achieve the desired natural frequency can be calculated using Eq. 4 [26].

$$\text{Spring rate } (K) = \frac{\text{Load per mount}}{d_s} \text{ (lbs/in)} \quad \text{Eq. 4}$$

After these initial calculations, a proper mount was selected. The selected mount must have a maximum load rating equal to or greater than the load per mount, and a spring rate ( $K$ ) less than the spring rate calculated. The mount must not be overloaded as it may lead to premature failure. Underloading the mount will not allow it to deflect enough to provide any vibration isolation [26].

Next, the actual deflection was calculated using Eq. 5 and the spring rate of the chosen mount [13]. Since sections of mounts were used, the spring rate was converted to pounds per inch in this calculation.

$$\text{Actual deflection } (d) = \frac{\text{load per mount}}{\text{Actual mount spring rate}} \text{ (in)} \quad \text{Eq. 5}$$

From the actual deflection the actual natural frequency can be calculated using Eq. 6 [26].

$$\text{Actual natural frequency } (f_{n,a}) = \sqrt{\frac{9.8}{d}} \text{ (Hz)} \quad \text{Eq. 6}$$

Using the actual natural frequency and the disturbing frequency, the transmissibility is found with Eq. 7 [26].

$$\text{Transmissibility } (T) = \frac{1}{\left(\frac{f_d}{f_{n,a}}\right)^2 - 1} \quad \text{Eq. 7}$$

Lastly, a percent vibration isolation can be calculated by using Eq. 8 [26].

$$\text{Percent isolation} = (1 - T) (100) \quad \text{Eq. 8}$$

### Cassette Mount Selection

The total weight that is to be supported by the cassette mounts is 700 lbs. The weight breakdown is displayed in Table C III.

TABLE C III: WEIGHT SUPPORTED BY CASSETTE MOUNTS

| Component           | Weight [lbs] |
|---------------------|--------------|
| Auger               | 150          |
| Gearbox             | 350          |
| Vibration Motors    | 200          |
| <b>Total Weight</b> | <b>700</b>   |

Applying Eq. 1 yields a load per mount value of 175 lbs, under the assumption of even distribution over the four mounts. The load per mount can then be applied to Eq. 4 to determine the required spring rate of the mount, equating to 6,777.31 lbs/in. Referring back to Figure C 1, it was determined that the SM-1 would be suitable for the application. The mount must be shortened so it is able to deflect when the loads are applied. The mount can be manufactured in multiples of 2” so it was decided that four 2” mounts would be installed at existing cassette mount locations.

Table C IV summarizes mount properties calculated using Eq. 5 through Eq. 8.

TABLE C IV: CASSETTE MOUNT PROPERTIES

| Property                                          | Value  | Units |
|---------------------------------------------------|--------|-------|
| <b>Actual Deflection, d</b>                       | 0.0365 | in    |
| <b>Actual Natural Frequency, <math>f_n</math></b> | 16.39  | Hz    |
| <b>Transmissibility, T</b>                        | 1.497  | %     |
| <b>Percent Isolation</b>                          | 98.503 | %     |

### Hopper Mount Selection

The hopper sits on top of the cassette frame, positioned using location pins secured using mechanical clamps. The combination of the hopper, the hammering plate, and the hopper filled with concrete weigh a total amount of 3,900 lbs. The breakdown of the weight is displayed in Table C V.



TABLE C V: WEIGHT SUPPORTED BY HOPPER MOUNTS

| Component           | Weight [lbs] |
|---------------------|--------------|
| Hopper              | 1,700        |
| Hammering Plate     | 600          |
| Concrete            | 1,600        |
| <b>Total Weight</b> | <b>3,900</b> |

Applying Eq. 1 yields a load per mount value of 487 lbs, under the assumption of even distribution over the eight mounts. The load per mount can then be applied to Eq. 4 to determine the spring rate of the mount, equating to 6,293.22 lbs/in. Applying the same methodology as was used in sourcing cassette mounts, the SM-1 mounts was chosen for application to the hopper.

Applying Eq. 5 through Eq. 8 the properties of the mounts were calculated and are summarized in Table C VI.

TABLE C VI: HOPPER MOUNT PROPERTIES

| Property                                          | Value  | Units |
|---------------------------------------------------|--------|-------|
| <b>Actual deflection, <math>d</math></b>          | 0.0677 | in    |
| <b>Actual natural frequency, <math>f_n</math></b> | 12.03  | Hz    |
| <b>Transmissibility, <math>T</math></b>           | 0.80   | %     |
| <b>Percent isolation</b>                          | 99.19  | %     |

### 8.3 Custom Bent Steel Quote

The following is a quote from Parr Metal Fabricators for the custom bent steel components required for the rubber isolation mount design.

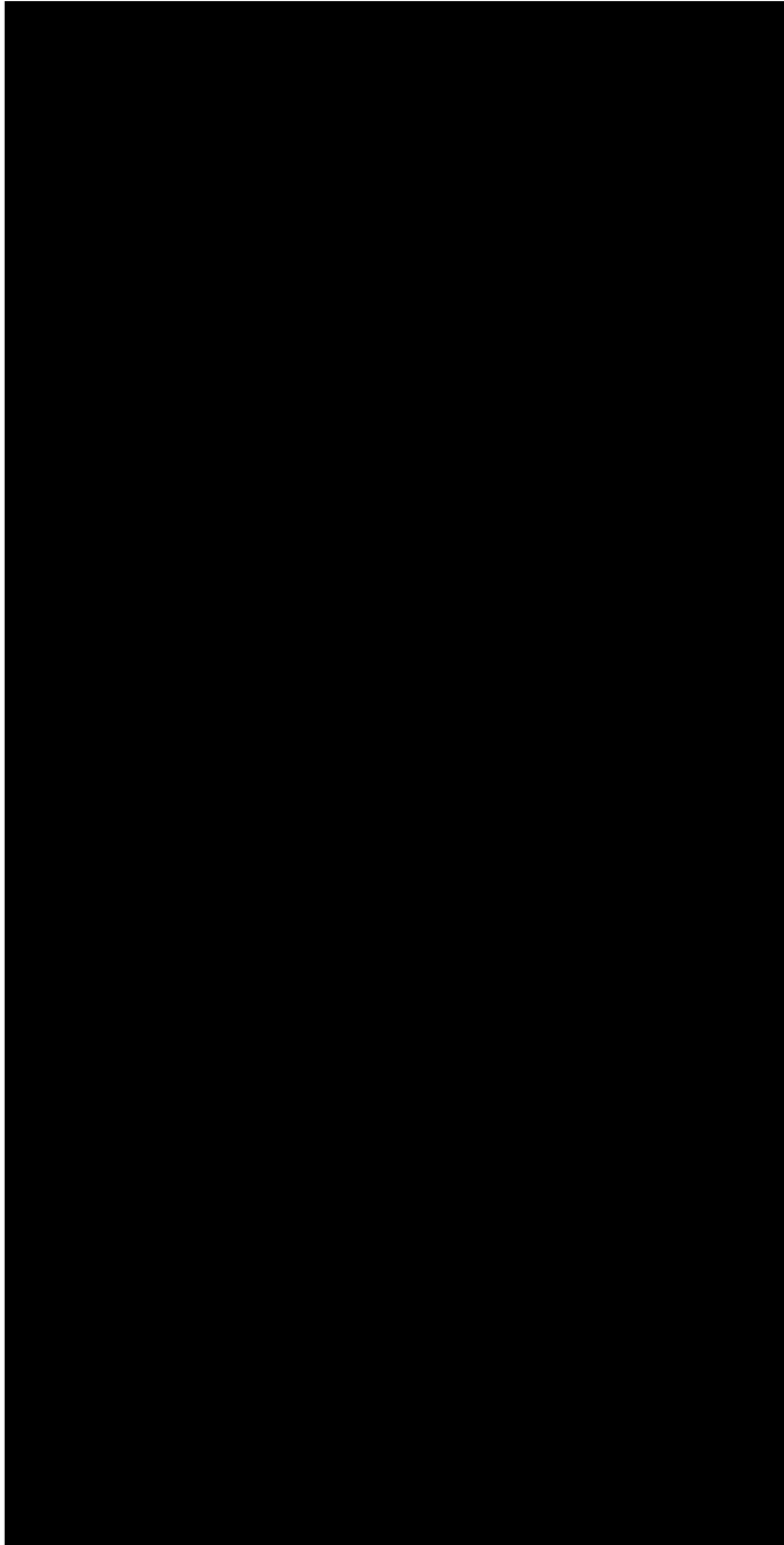


Figure C 2: Custom bent steel component quote from Parr Metal Fabricators [15]

## 9 APPENDIX D – PYROTEK SUPPLIED DOCUMENTS

### LIST OF FIGURES

|                                                                              |      |
|------------------------------------------------------------------------------|------|
| Figure D 1: Pyrotek Decidamp Tile technical data sheet page 1 of 3 .....     | D-3  |
| Figure D 2: Pyrotek Decidamp Tile technical data sheet page 2 of 3 .....     | D-4  |
| Figure D 3: Pyrotek Decidamp Tile technical data sheet page 3 of 3 .....     | D-5  |
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| Figure D 7: Pyrotek Decidamp DC30 installation guide sheet page 2 of 3 ..... | D-9  |
| Figure D 8: Pyrotek Decidamp DC30 installation guide sheet page 3 of 3 ..... | D-10 |
| Figure D 9: Pyrotek Decidamp quote for supply .....                          | D-11 |

The following documents were provided from Pyrotek to be used for the acoustic dampening material section of this report. The following images include technical specification documents for Pyrotek Decidamp sheets and DC30 epoxy, an installation guide, and material quote.

## DECIDAMP® TILE

### vibration damping tile

Decidamp® Tile is a high performance structural damping product, engineered to reduce vibrational resonances in thick panel constructions. It was developed to meet market requirements in the industrial, marine, rail and heavy vehicle industries.

Decidamp Tiles are formulated using a blend of new generation polymer compounds which provide exceptional damping over a broad temperature range of 10 to 50°C. The tiles are designed to comply with Type 2 Navy damping tile specifications of MIL-PRF-23653D\*.

Structures from materials such as steels, fibreglass and alloys, that have minimal internal damping properties, resonate at their natural frequencies and vibrate on impact. Decidamp tiles are one of the most effective forms of extensional damping materials that can be easily bonded to vibrating surfaces to reduce impact-generated noise and resonant vibration at its source. Being specifically engineered to reduce vibration in heavy gauge structures, the semi-rigid tiles have a unique combination of good mechanical strength and visco-elastic properties that enable them to absorb large amounts of mechanical energy from vibrating structures. The tiles dissipate the vibrational energy through the structure thereby reducing radiated noise-levels.

Decidamp tiles can be installed using Pyrotek's 'Decidamp' DC30® - which is a two-part polyurethane system. The acoustic and non-slumping properties of the adhesive allows the damping tiles to be installed without the use of mechanical aids such as screws or pins, while adding to the acoustic performance of the damped system. In certain applications, a military specified epoxy adhesive such as Lord Corporation's 306 or ITW's Phyllybond TA-30 adhesives may be preferred.

### SPECIFICATIONS

|           |                                       |
|-----------|---------------------------------------|
| Packaging | Tile size:<br>308 x 308 mm (12 x 12") |
|-----------|---------------------------------------|



### applications

- Marine vessels in shipboard applications such as bulkheads, hull construction, tank tops, engine bed girders and the structure above props
- Military armoured vehicles, personnel carriers
- Rail cars
- Heavy vehicles: buses, trucks, tractors
- Industrial: heavy machinery, mining equipment, salvage equipment, hoppers and chutes can have radiated noise reduced and maintenance periods extended.
- Large structures: power generators, oil rigs, I beams

### features

- Exceptional structural damping material with high mechanical strength
- Designed to dampen substrates up to 20mm in thickness
- Good thermal, chemical and flame resistance properties
- Reduces vibrational resonances and impact-induced noise
- Reduces airborne noise - increases transmission loss
- Complies to UL 94 V-0 and FMVSS302 to meet low flame spread requirements
- Conforms to flame retardance criteria defined in MIL-PRF-23653D
- Can be installed on metal structures in accordance with MIL-STD-2148 by using a two-component epoxy adhesive from the Qualified Products List QPL-24456.
- Non-conductive, eliminating galvanic corrosion
- Easy to apply, mould and cut into various shapes
- Compatible with most adhesive systems
- Available in various thicknesses and custom dimensions



Figure D 1: Pyrotek Decidamp Tile technical data sheet page 1 of 3 [16]

## PRODUCT SPECIFICATIONS

| Thickness*<br>(mm) | Weight**<br>(kg/m <sup>2</sup> )                 | Tile size*<br>(mm)      | Operating temperature<br>range<br>(°C)                                              | Minimum<br>application temp.<br>(°C) | Adhesion<br>strength<br>(Pyrotek tile<br>adhesive) |
|--------------------|--------------------------------------------------|-------------------------|-------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------------|
| 3.1 mm (1/8")      | 4.5 kg/m <sup>2</sup> (0.9 lb/ft <sup>2</sup> )  | 308 x 308 mm (12 x 12") | 10-50 °C<br>(50-122 °F)<br>(Continuous)<br><br>110 °C<br>(230 °F)<br>(Intermittent) | 15 °C<br>(59 °F)                     | 100 °C<br>(212 °F)                                 |
| 6.3 mm (1/4")      | 9.5 kg/m <sup>2</sup> (2 lb/ft <sup>2</sup> )    | 308 x 308 mm (12 x 12") |                                                                                     |                                      |                                                    |
| 9.5 mm (3/8")      | 13.2 kg/m <sup>2</sup> (2.7 lb/ft <sup>2</sup> ) | 308 x 308 mm (12 x 12") |                                                                                     |                                      |                                                    |
| 12.5 mm (1/2")     | 18.8 kg/m <sup>2</sup> (3.8 lb/ft <sup>2</sup> ) | 308 x 308 mm (12 x 12") |                                                                                     |                                      |                                                    |
| 15 mm (5/8")       | 21.9 kg/m <sup>2</sup> (4.4 lb/ft <sup>2</sup> ) | 308 x 308 mm (12 x 12") |                                                                                     |                                      |                                                    |

\*Tolerances: \*Nominal dimensions (+/-10%); \*\*Weight (+0/-4%)

## FLAMMABILITY PROPERTIES

| Test method  | Index                                    | Results                            | Report No.                    | Description                                                                                                                              |
|--------------|------------------------------------------|------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| ASTM D635-10 | Linear Burn rate - mm/min                | Self Extinguishing<br>No burn rate | Report No.<br>01.17791.04.026 | Standard test method for rate of burning and/or extent of time of burn of plastics in horizontal positions as outlined in MIL-PRF-23653D |
| UL94         | After flame, burn rate and flaming drops | V-0                                | Report No. 18613-PH1          | Vertical burn test for plastic materials.                                                                                                |
| FMVSS-302    | Burn rate - mm/min                       | Self extinguishing                 | Report No. 18613-PH2          | Automotive burn rate test.                                                                                                               |

 CHEMICAL RESISTANCE (MIL-PRF NO. 20013-PH 1-1.851D / Q ASM D543 / ISO 173)

| Chemical            | Distilled water | Seawater  | Mineral oil | Kerosene  | Gasoline  | Sulfuric acid (2M) |
|---------------------|-----------------|-----------|-------------|-----------|-----------|--------------------|
| Exposure rating     | Excellent       | Excellent | Excellent   | Very good | Very good | Excellent          |
| Weight change (+/-) | < 0.1%          | < 0.1%    | < 0.3%      | < 0.5%    | < 0.3%    | < 0.1%             |

## APPLICATION GUIDE

| Substrate       | Tile thickness                      |
|-----------------|-------------------------------------|
| Steel           | ≥ 2/3 x T*                          |
| Aluminium       | ≥ 1/3 x T*                          |
| FRP (laminated) | ≥ 1/4 x T*                          |
| FRP (composite) | ≥ 1 x thickness of fibreglass layer |

\*T: Substrate Thickness



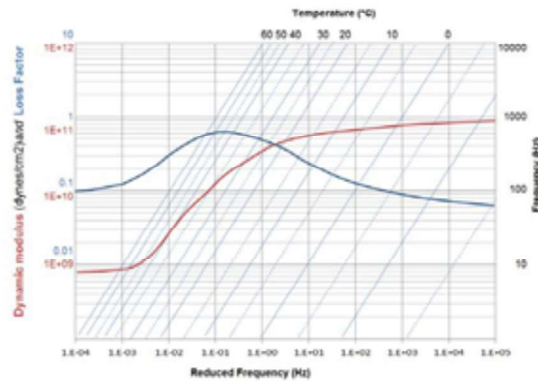
Figure D 2: Pyrotek Decidamp Tile technical data sheet page 2 of 3 [16]

## SYSTEM LOSS FACTOR

Tested to ISO 6721-3:1994 (Report No. 19313-PH)

| THICKNESS DECIDAMP/SUBSTRATE 2:1                     |       |           |      |
|------------------------------------------------------|-------|-----------|------|
| Temp °C                                              | Steel | Aluminium | FRP  |
| -20                                                  | 0.05  | 0.06      | 0.09 |
| -10                                                  | 0.04  | 0.09      | 0.13 |
| 0                                                    | 0.07  | 0.13      | 0.20 |
| 10                                                   | 0.11  | 0.21      | 0.32 |
| 20                                                   | 0.23  | 0.46      | 0.68 |
| 30                                                   | 0.25  | 0.50      | 0.76 |
| 40                                                   | 0.19  | 0.38      | 0.57 |
| 50                                                   | 0.10  | 0.20      | 0.31 |
| 60                                                   | 0.05  | 0.10      | 0.15 |
| Max. estimated noise reduction on a large panel (dB) | 24    | 27        | 29   |

| THICKNESS DECIDAMP/SUBSTRATE 1:1                     |       |           |      |
|------------------------------------------------------|-------|-----------|------|
| Temp °C                                              | Steel | Aluminium | FRP  |
| -20                                                  | 0.02  | 0.03      | 0.05 |
| -10                                                  | 0.02  | 0.04      | 0.07 |
| 0                                                    | 0.03  | 0.07      | 0.10 |
| 10                                                   | 0.05  | 0.11      | 0.16 |
| 20                                                   | 0.11  | 0.23      | 0.34 |
| 30                                                   | 0.13  | 0.25      | 0.38 |
| 40                                                   | 0.10  | 0.19      | 0.29 |
| 50                                                   | 0.05  | 0.10      | 0.15 |
| 60                                                   | 0.03  | 0.05      | 0.08 |
| Max. estimated noise reduction on a large panel (dB) | 21    | 24        | 26   |



Reduced Frequency Nomogram (Report No. 19313-PH)

### How to read a reduced frequency nomogram:

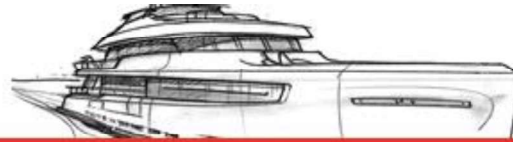
1. Start by selecting the frequency (Hz) on the right-hand vertical axis.
2. Follow this value horizontally to the left to where the diagonal temperature isotherm intersects.
3. Draw a vertical line through the frequency and isotherm intersection, find the point where this line intersects the modulus and loss factor curves.
4. Draw horizontal lines from these points to the left-hand vertical axis to read the values.

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Figure D 3: Pyrotek Decidamp Tile technical data sheet page 3 of 3 [16]



## DECIDAMP® DC30

### two component damping paste compound

Decidamp® DC30 is a two-component polyurethane based damping paste, which works best in a constrained layer configuration (sandwich system) where its excellent viscoelastic damping properties result in substantial reductions in structure-radiated airborne sound.

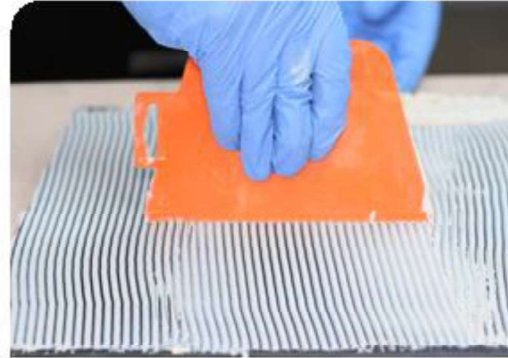
Structural vibration caused by engines, impact noise and footfall is converted to airborne noise, often resulting in excessive noise levels in another part of the structure. By utilising its viscoelastic damping properties, Decidamp® DC30 effectively reduces the spread of vibration throughout the structure.

Decidamp® DC30 is applied to a metal or plastic counter plate which is then bonded to the surface that needs to be treated. During curing, it will bond to both the counter plate and surface substrate, creating an excellent damping medium.

It is corrosion resistant, highly thixotropic and is used on horizontal and vertical surfaces without slumping.

#### SPECIFICATIONS

|           |                                                         |
|-----------|---------------------------------------------------------|
| Colour    | Brown to beige                                          |
| Available | Available in 11 kg pack consisting of Part A and Part B |
|           | Part A 10 kg                                            |
|           | Part B 1 kg                                             |



### applications

- Marine: hull, engine, vibration noise and structure borne noise
- Propeller and shaft vibration noise
- Floors - to reduce impact noise
- Heavy construction industries such as earthmoving equipment
- Portable generator and pump units
- Transport: automotive and rail industry

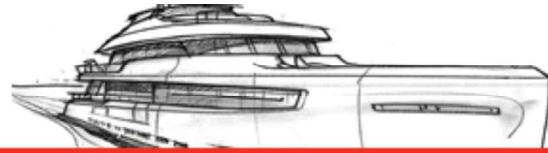
### features

- Tested to international marine fire standards
- Reduces the spread of vibration throughout the structure
- Improve internal noise levels
- High coverage rate, fast application & curing
- Excellent adhesion, even to steel, aluminium and glass composite substrates
- Highly effective reducing structure borne noise
- Suitable for outdoor exposure
- Excellent flame resistance, self-extinguishing
- Broad temperature range
- Low-weight, viscoelastic damping
- Cures without shrinking or cracking
- Low odour



Figure D 4: Pyrotek Decidamp DC30 technical data sheet page 1 of 2 [16]





### PRODUCT SPECIFICATIONS

| Product name          | Pack size (kg) | Mix ratio A:B w/w | Thickness of applied compound |
|-----------------------|----------------|-------------------|-------------------------------|
| Decidamp® DC30 Part A | 10             | -                 | -                             |
| Decidamp® DC30 Part B | 1.0            | -                 | -                             |
| Decidamp® DC30 mixed  | -              | 10:1              | 1 mm                          |

### APPLICATION PROPERTIES

| Material       | Colour         | Density (g/cm³) | Viscosity (Brookfield T-F spindle at 1 RPM) | Recommended application temperature range (°C) | Pot life at 25 °C | Full cure at 25 °C | Counter plate              |
|----------------|----------------|-----------------|---------------------------------------------|------------------------------------------------|-------------------|--------------------|----------------------------|
| Decidamp® DC30 | brown to beige | 1.3             | 2,250 Pas                                   | 10 to 35 °C*                                   | 20 to 30 minutes* | 24 hrs             | 1/3 of substrate thickness |

\*Based on cure of bulk material in a full cure of 10 kg

### MATERIAL PROPERTIES

| Test method            | Property                                                      | Report no.               | Results                                                     |
|------------------------|---------------------------------------------------------------|--------------------------|-------------------------------------------------------------|
| IMO FTP Annex 1 Part 5 | Surface flammability                                          | 327544                   | Complies for bulkheads, walls or ceiling linings and floors |
| IMO FTP Annex 2        | Smoke and toxicity                                            |                          |                                                             |
| MED B                  | EC Type Certificate (Module B) for Marine Equipment Directive | 164.112/1121/MED80000413 |                                                             |
| MED D                  | EC Type Certificate (Module D) for Marine Equipment Directive | MEDD000015N              |                                                             |

Results were obtained in systems utilizing solid counter plates.

### ACOUSTIC PROPERTIES

| System Loss Factor (ISO 6721-3)         |                | Decay Rate (Based on ISO 7626-5)                    |                               |
|-----------------------------------------|----------------|-----------------------------------------------------|-------------------------------|
| Substrate material & thickness          | 1.9 mm steel   | Substrate material & thickness                      | 5 mm steel                    |
| Constraining layer material & thickness | 0.5 mm steel   | Constraining layer material & thickness             | 1.5 mm steel, 13% perforation |
| Decidamp® DC30 thickness                | 0.5 mm         | Decidamp® DC30 thickness                            | 1.5 mm                        |
| System loss factor (23 °C)              | 0.11 at 200 Hz | Decay rate – substrate only (23 °C)                 | 6 dB/second                   |
|                                         |                | Decay rate – with DC30 + constraining layer (23 °C) | 700 dB/second                 |

Test Report Number: 7077448

For further information and contact details, please visit our website [pyrotek.com](http://pyrotek.com)

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Figure D 5: Pyrotek Decidamp DC30 technical data sheet page 2 of 2 [16]

## DECIDAMP® DC30

This Installation Guide provides recommendations to maximise the service life in various applications.

### KEY INSTALLATION REQUIREMENTS

Decidamp® DC30 is a two-component polyurethane based damping paste, supplied in kit form consisting of:

|                               |           |
|-------------------------------|-----------|
| Part A: Decidamp DC30 Paste   | 10 kg tin |
| Part B: Catalyst/curing agent | 1 kg tin. |

### PRE-TREATMENT OF SURFACES

- All substrates must be prepared to the yard standard: Clean, dry and free of any contaminants such as liquid, dirt, oil, flaky paint, rust, wax, grease, fibreglass release agents.

Clean surfaces using a suitable water-based or solvent-based cleaning agent. (A Silane based primer is best.) Compatibility with cleaning agents must be tested beforehand. Priming is recommended on corroded surfaces.

- Smooth surfaces: must be scuffed back to ensure a good bond. Rough surfaces only need to have dust and grease removed
- Uneven surfaces:
  - Horizontal: On warped horizontal surfaces or where surface has contours greater than 1-2mm, apply a levelling compound (Decidamp® SLC or equal) to smoothen out surfaces and allow it to set before using DC30 with the counterplate. Alternately level the surface, by trowelling in DC30 itself, before applying product with the counterplate.
  - Vertical surfaces: Fill in dips by trowelling in DC30, to provide a levelled surface. Then proceed to apply product as per instructions stated overleaf.

Alternately, place a screed of DC30, before applying product.

### NOTES PRIOR TO APPLICATION

- Ensure substrate temperatures are 10 to 35°Celsius (based on cure of bulk material in a full mix of 10kg)
- Note "Pre-treatment of surfaces" Mixing curing times and 'counter plate to substrate' ratios in order to achieve a good damping result.
- Measure and mark the grid that the Decidamp DC30 product and counter plates will be installed in.
- Bond strength: A correctly mixed product, will usually be able to hold about 16kg/m<sup>2</sup> steel counter plate, in an overhead position without the use of props or temporary mechanical fastening. Heavier counterplates can be bolted on to the substrate without compromising performance, however individual tests are recommended.
- Installation on fire rated boundaries: Take extra care in measurements. On structural fire protection, insulation pins should be installed before applying Decidamp DC30.



*Both parts are supplied in the required ratio of ingredients with a weight based mixing ratio of 10:1 of part A to B and must be mixed thoroughly before use.*

*Decidamp® DC30 with its visco-elastic damping properties works best in a constrained layer configuration (sandwich system), where the product is applied to counter plates that are then mounted onto substrates.*

### applications

- Marine: on hulls, deck and bulkheads to reduce vibration noise and structure borne noise
- Propeller and bow thruster area
- Floors, to reduce impact noise
- Heavy construction industries such as earthmoving equipment
- Portable generator and pump units
- Highly suited for Automotive / transport / rail industry

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Figure D 6: Pyrotek Decidamp DC30 installation guide sheet page 1 of 3 [16]

Ensure proper preparation and application for best results.  
Decidamp® DC30 should always be bonded to surfaces that are clean, dry and free of contaminants.

#### MIXING

Add Part B to Part A and Thoroughly mix together using a power drill on low speed with a ribbon or paddle mixer. Allow approximately 3-5 minutes of mixing time for a full kit. Make sure to scrape the sides of the container allowing a better mix and dispersion of the curing agent (Part B).

If mixing in smaller quantities, precise measuring of DC30 paste versus curing agent is essential in establishing the correct viscosity and ensuring proper curing and a good bond between substrate and counter plate.

Once the two components are mixed, allow to set for up to 10 minutes. During this time, the product will thicken and increase in viscosity.

*Do not overwork as this will start curing process.*

#### APPLICATION

Use a 2mm notch trowel to apply Decidamp DC30 to the counter plate, not to the substrate. Applying DC30 on substrate results in much more product being used than is necessary. Final layer thickness achieved is approximately 1/3 of the tooth depth. i.e. 2mm spreader gives a 1mm final layer.

Once applied to the counter plate, position the counter plate on to the substrate. Apply firm, even pressure, whilst gently sliding the counter plate back and forth a few times (within a small field of movement less than 1cm) and give a firm tap with a hammer to avoid air-pockets and ensure the product has spread evenly. This is essential for a good bond, and for maximising performance.

If there is any slumping or slippage on the initial application of product, allow the mixed product to set for a further 5 minutes. You will then have 35 minutes to install the counter plates and Decidamp DC30 (at 25°C and 35% humidity).

*Failure to follow these guidelines may result in a poor bond, and may affect dampening performance.*

#### TILE SPACING

A sufficient gap between counter plates(1-2mm) is recommended

Ensure that counter plates do not come in direct contact with each other, or any structural component of the vessel/equipment, as this will adversely effect the performance.

Tile spacing also allows for expansion gaps during vibration, heat induced expansion or substrate swelling.

Counter plates can be mounted with or without spacers. However, 1mm tee spacers if used for vertical surfaces would effectively support and accurately space each plate.



**NB:** Notch direction to run perpendicular between surfaces



Figure D 7: Pyrotek Decidamp DC30 installation guide sheet page 2 of 3 [16]

## COUNTER PLATE TO SUBSTRATE RATIO

Counter plates need to be 1/3rd the thickness of the substrate. (e.g. For a 6mm steel substrate use a 2mm steel counter plate.)

For GRP/FRP sandwich substrates, counter plate thickness should be equal to the thickness of the glass skin in contact with the product.

Counter plate tile dimensions to be as large as possible with a minimum size of 200 X 200mm. Thickness of tile would depend on substrate

Pre-forming of counter plates may be necessary before application, particularly when installed on bow thruster tubes or on any curved surface



## PRODUCT INFORMATION

**Substrates:** Can be used on Steel, Aluminium, GRP/FRP Laminate, GRP/FRP Sandwich and wooden structures, using the counter plates mentioned.

**Counter plates:** Depending on the structure, counter plates would normally be steel, aluminium, glass laminate, or plastic. Refer to 'Counter plate to substrate ratio' for more information.

**Coverage:** 1.3kg (mixed) of DC30 will provide a 1mm thick cured layer over an area of 1m².

**Water resistant:** Decidamp DC30 is water resistant, however where regular exposure is expected, Decidamp DC30 and its counter-plate should always be sealed with a suitable commercial waterproofing sealant/coating, applied well after complete curing of the material. This is to prevent corrosion of metal counter-plates and/or ingress of water behind the plates.

**Cure time and process:** Decidamp DC30 takes approximately 24 hours to fully cure. Once the two components are mixed, setting will start within 30 -45mins at 25°C and 35% humidity. Working in warmer climates with higher humidity, will shorten curing times. Polyurethane reacts with moisture and its reaction rate is effected by heat, working in warmer climates with higher humidity will shorten curing times.

**Operating temperature range:** Once cured, Decidamp DC30 can be used over a temperature range from 0°C to +50°C

### Shelf life and Storage:

Part A and Part B - 24 months from date of supply in sealed containers.

Un-opened kits to be stored between 10 and 30°C. Do not allow to freeze.

Opened kits (unmixed) must be resealed and used within 2 months

(Frequent opening of seal must be avoided)

Mixed kits must be used immediately.

### Clean up and Safety:

Clean up with mineral turpentine or equivalent solvent.

Once cured, Decidamp DC30 can only be removed by sanding back.

Personal Protection Equipment (PPE) including eye protection, gloves and safety clothing are highly recommended.

Please contact Pyrotek® for further information or detailed advice on your specific application.



Counterplate being applied to substrate

Figure D 8: Pyrotek Decidamp DC30 installation guide sheet page 3 of 3 [16]





Pyrotek Inc.  
3808 N. Sullivan Rd, Bldg 27K  
Spokane Valley, WA 99216  
509-340-8741

Customer: Univ. of Manitoba  
Contact: Reg Waddell  
Address: Winnipeg, MB  
E-mail: [regwaddell@gmail.com](mailto:regwaddell@gmail.com)  
Phone: 204-210-0329

Date: 11/22/19  
Quote Valid Until: 12/22/19  
Quote Id: Q191122JD

Page: 1 of 1

**Quote for Supply :**

Supply of: Decidamp sheet/tile and Decidamp DC30  
- Prices are in \$USD

**Quote Details:**

| Item | Qty. | UOM   | Pyrotek P/N | Description                                | Unit Price | Ext'd Price | Current Stock |
|------|------|-------|-------------|--------------------------------------------|------------|-------------|---------------|
| 1    | 1    | sheet | 17761502-S  | DECIDAMP 1/8" (THK) X 40" (W) x 54" (L)    | \$68.62    | \$68.62     | 20 sheets     |
| 2    | 1    | sheet | 17761501    | DECIDAMP 1/4" (THK) X 40" (W) x 54" (L)    | \$133.99   | \$133.99    | 30 sheets     |
| 3    | 1    | each  | 17051084    | DECIDAMP TILE 9 MM (THK) X 308 MM X 308 MM | \$17.93    | \$17.93     | 742 tiles     |
| 4    | 10   | Kg    | 17051065-3  | DECIDAMP DC30 NATURAL (PART A) 10KG PAIL   | \$15.00    | \$150.00    | 10 pails      |
| 5    | 1    | Kg    | 17051061    | DECIDAMP DC30 PART B-1KG PAIL              | \$28.98    | \$28.98     | 10 pails      |

Shipping: ExWorks - Spokane Valley, WA

Payment Terms: credit card -or- due net 30 days on approved credit

Submitted by: Jeff Dawson

Pyrotek, Inc - Sales Engineer  
E-mail: [jeffdaw@pyrotek.com](mailto:jeffdaw@pyrotek.com)  
509-340-8741

**"All sales are subject to Pyrotek's Standard Terms and Conditions, visible at <https://www.pyrotek.com/company-info/about-pyrotek/legal/buying-from-pyrotek/> which include warranty disclaimers and liability limitations. In no event shall Pyrotek be liable for incidental or consequential damages."**

Figure D 9: Pyrotek Decidamp quote for supply [16]

## **10 APPENDIX E – PART DRAWINGS**

The following section contains part drawings required for the door redesign and installation of the rubber isolation mount design. Each drawing is identified by a drawing number (DWG. NO.) and a title that describes the part:

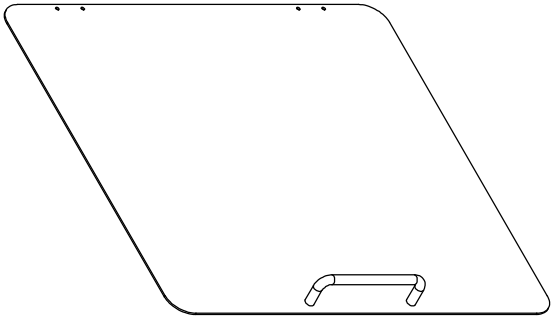
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|-------------|----------------------------------|
| DWG. NO. 1  | Left Housing Door                |
| DWG. NO. 2  | Left Hopper Door                 |
| DWG. NO. 3  | Left Cassette Sheet Metal Cover  |
| DWG. NO. 4  | Right Cassette Sheet Metal Cover |
| DWG. NO. 5  | Left Cassette Mount Assembly     |
| DWG. NO. 6  | Left Hopper Sheet Metal Cover    |
| DWG. NO. 7  | Right Hopper Sheet Metal Cover   |
| DWG. NO. 8  | Locating Tab                     |
| DWG. NO. 9  | Left Hopper Mount Assembly       |
| DWG. NO. 10 | Right C-Channel Frame Rail       |

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4X R1.63

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4x  $\phi$ .25

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R1.07

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| UNLESS OTHERWISE SPECIFIED:  |  | NAME      | DATE     |
|------------------------------|--|-----------|----------|
| DIMENSIONS ARE IN INCHES     |  | BP        | 11/28/19 |
| TOLERANCES:                  |  | JN        | 11/28/19 |
| ANGULAR: BEND $\pm$ 1 DEGREE |  |           |          |
| TWO PLACE DECIMAL $\pm$ .02  |  |           |          |
| MATERIAL                     |  | COMMENTS: |          |
| ASTM A36                     |  |           |          |
|                              |  |           |          |
|                              |  |           |          |

TITLE:

Left Housing Door

| SIZE       | DWG. NO. | REV          |
|------------|----------|--------------|
| B          | 1        | 00           |
| SCALE: 1:8 |          | SHEET 1 OF 1 |

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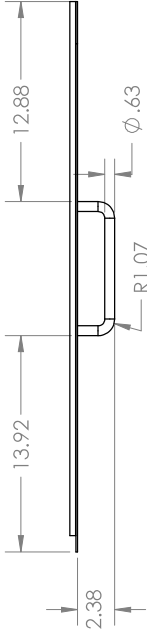
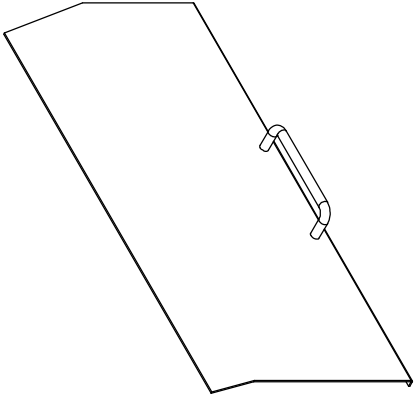
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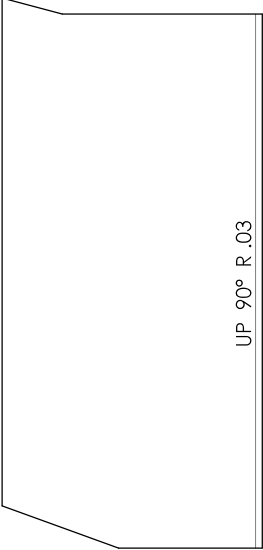
2

1

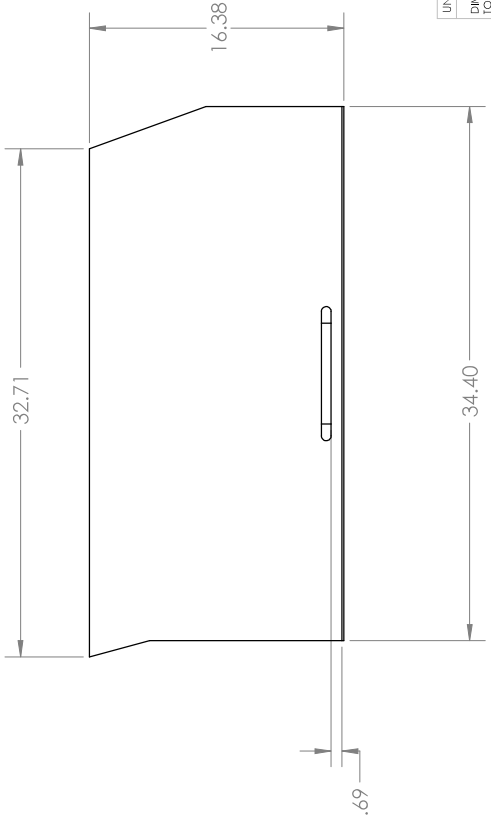
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|                                                                                                                               |         |      |          |
|-------------------------------------------------------------------------------------------------------------------------------|---------|------|----------|
| UNLESS OTHERWISE SPECIFIED:<br>DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>ANGULAR: BEND ± 1 DEGREE<br>TWO PLACE DECIMAL ± .02 | DRAWN   | NAME | DATE     |
|                                                                                                                               | CHECKED | BP   | 11/28/19 |
|                                                                                                                               |         | JN   | 11/28/19 |
|                                                                                                                               |         |      |          |
| MATERIAL ASTM A36                                                                                                             |         |      |          |
| COMMENTS:                                                                                                                     |         |      |          |
|                                                                                                                               |         |      |          |
|                                                                                                                               |         |      |          |

TITLE:

Left Hopper Door

|            |          |              |
|------------|----------|--------------|
| SIZE       | DWG. NO. | REV          |
| B          | 2        | 00           |
| SCALE: 1:8 |          | SHEET 1 OF 1 |

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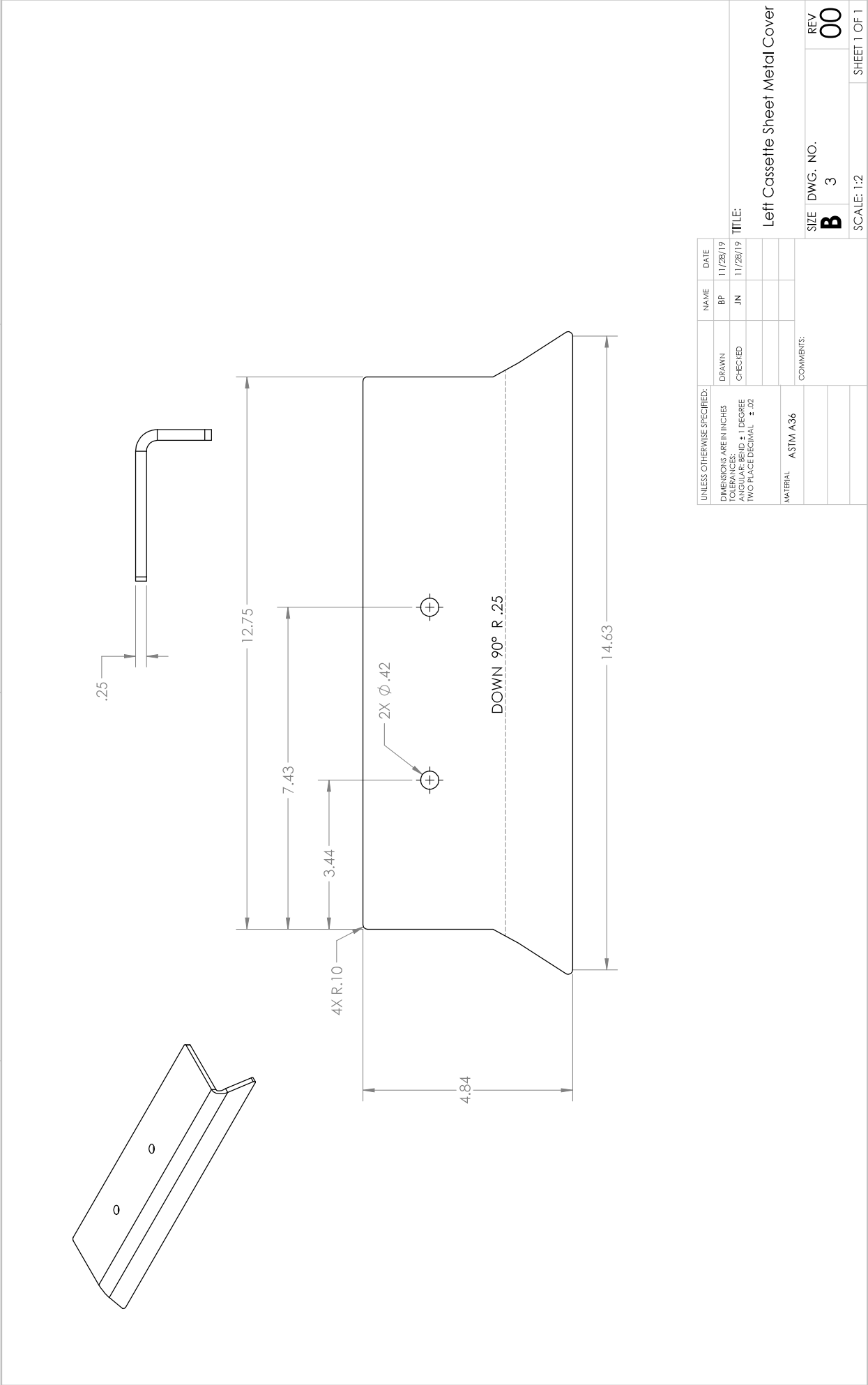


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| UNLESS OTHERWISE SPECIFIED: | DRAWN    | NAME | DATE     |
|-----------------------------|----------|------|----------|
| DIMENSIONS ARE IN INCHES    | BP       | BP   | 11/28/19 |
| TOLERANCES:                 | CHECKED  | JN   | 11/28/19 |
| ANGULAR: BEND ± 1 DEGREE    |          |      |          |
| TWO PLACE DECIMAL ± .02     |          |      |          |
| MATERIAL                    | ASTM A36 |      |          |
| COMMENTS:                   |          |      |          |
|                             |          |      |          |
|                             |          |      |          |
|                             |          |      |          |

TITLE:

Left Cassette Sheet Metal Cover

SIZE DWG. NO. REV  
**B** 3 **00**

SCALE: 1:2 SHEET 1 OF 1

1

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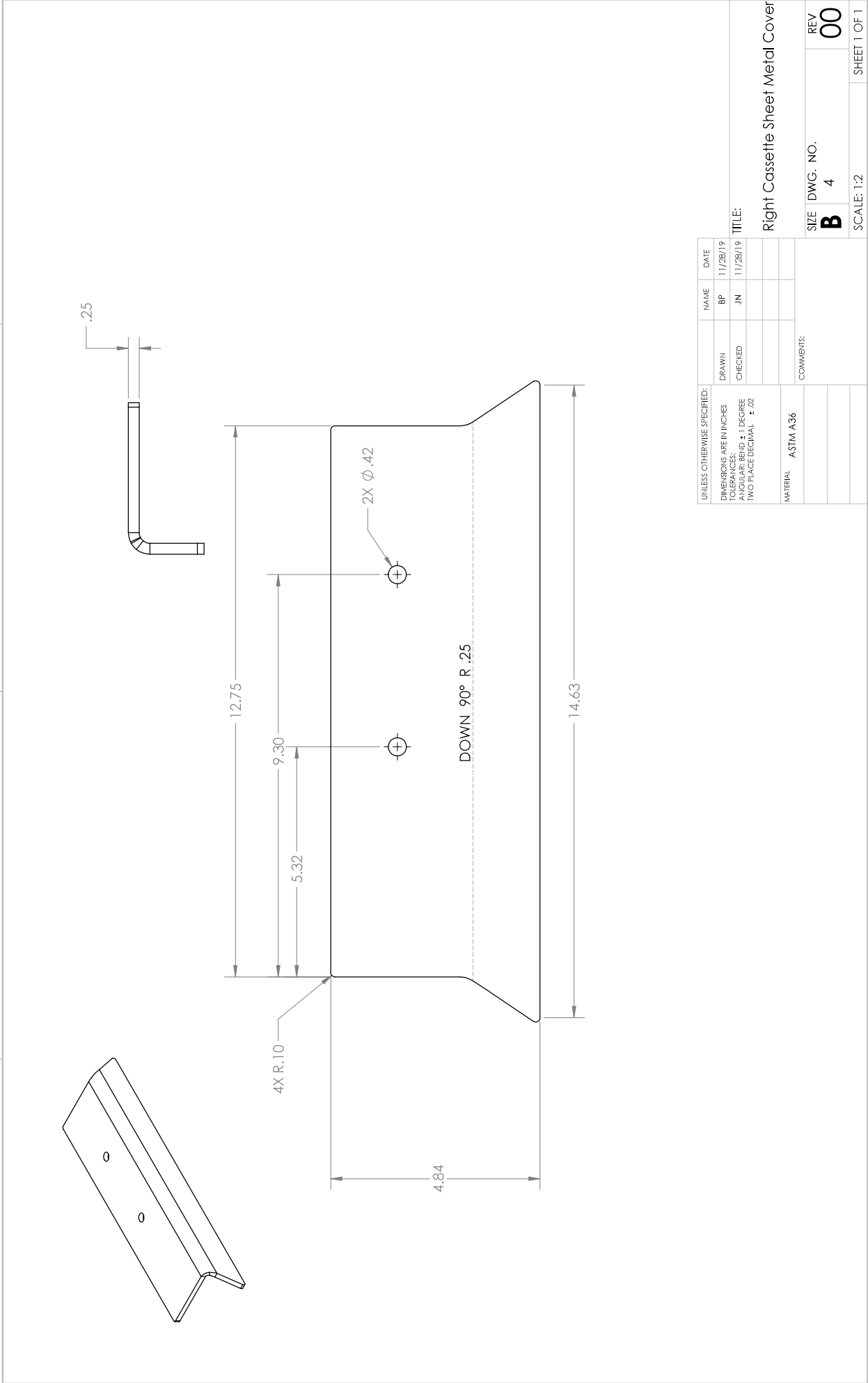
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| UNLESS OTHERWISE SPECIFIED: | DRAWN    | NAME | DATE     |
|-----------------------------|----------|------|----------|
| DIMENSIONS ARE IN INCHES    | BP       | BP   | 11/28/19 |
| TOLERANCES:                 | CHECKED  | JN   | 11/28/19 |
| ANGULAR: BEND ± 1 DEGREE    |          |      |          |
| TWO PLACE DECIMAL ± .02     |          |      |          |
| MATERIAL                    | ASTM A36 |      |          |
| COMMENTS:                   |          |      |          |
|                             |          |      |          |
|                             |          |      |          |
|                             |          |      |          |

TITLE:

Right Cassette Sheet Metal Cover

|            |          |              |
|------------|----------|--------------|
| SIZE       | DWG. NO. | REV          |
| B          | 4        | 00           |
| SCALE: 1:2 |          | SHEET 1 OF 1 |

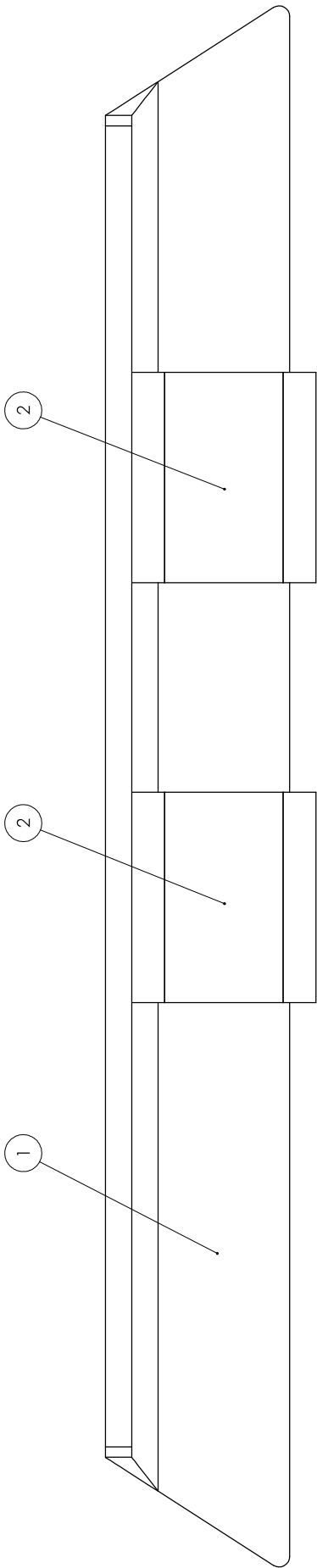
4 3 2 1

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| ITEM NO. | DESCRIPTION                  | QTY. |
|----------|------------------------------|------|
| 1        | Sheet Metal Cover - Cassette | 1    |
| 2        | 2X2 SM-1 Mount               | 2    |

|                              |  |           |          |
|------------------------------|--|-----------|----------|
| UNLESS OTHERWISE SPECIFIED:  |  | NAME      | DATE     |
| DIMENSIONS ARE IN INCHES     |  | BP        | 11/28/19 |
| TOLERANCES:                  |  | CHECKED   | JN       |
| ANGULAR: BEND $\pm$ 1 DEGREE |  |           |          |
| TWO PLACE DECIMAL $\pm$ .02  |  |           |          |
| MATERIAL                     |  | COMMENTS: |          |
| ASTM A36                     |  |           |          |
|                              |  |           |          |
|                              |  |           |          |

TITLE:

Left Cassette Mount Assembly

|            |          |              |
|------------|----------|--------------|
| SIZE       | DWG. NO. | REV          |
| B          | 5        | 00           |
| SCALE: 1:1 |          | SHEET 1 OF 1 |

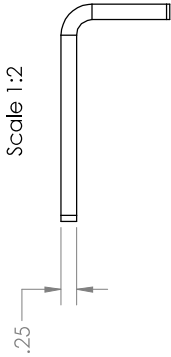
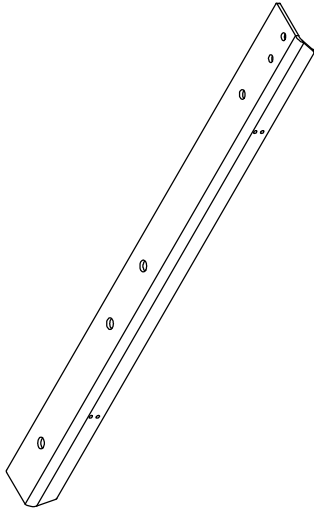
4 3 2 1

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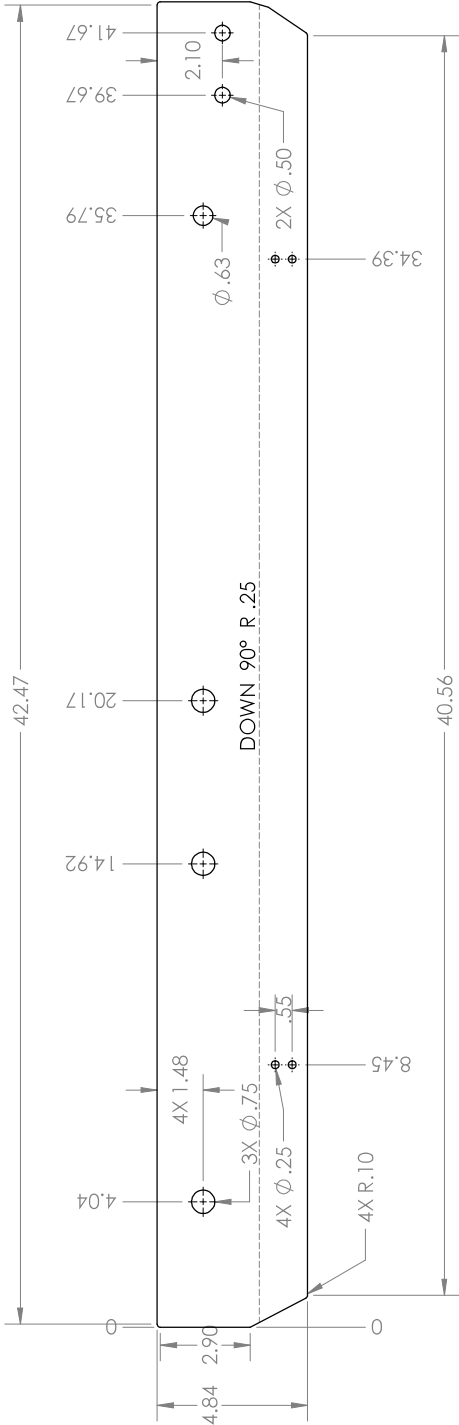
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| UNLESS OTHERWISE SPECIFIED:  | DRAWN     | NAME | DATE     |
|------------------------------|-----------|------|----------|
| DIMENSIONS ARE IN INCHES     | BP        | BP   | 11/28/19 |
| TOLERANCES:                  | CHECKED   | JN   | 11/28/19 |
| ANGULAR: BEND $\pm$ 1 DEGREE |           |      |          |
| TWO PLACE DECIMAL $\pm$ .02  |           |      |          |
| MATERIAL                     | COMMENTS: |      |          |
| ASTM A36                     |           |      |          |
|                              |           |      |          |
|                              |           |      |          |

TITLE:

Left Hopper Sheet Metal Cover

|            |          |              |
|------------|----------|--------------|
| SIZE       | DWG. NO. | REV          |
| B          | 6        | 00           |
| SCALE: 1:4 |          | SHEET 1 OF 1 |

4

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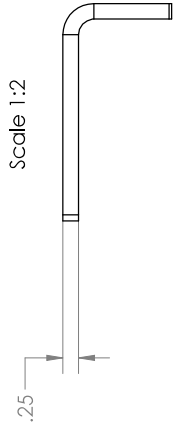
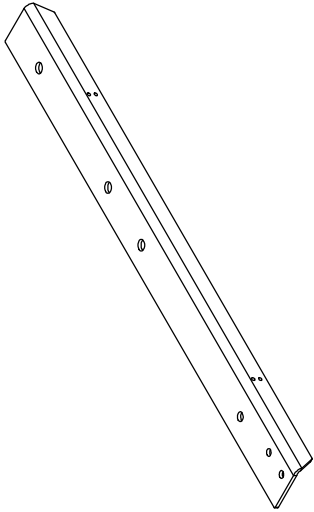
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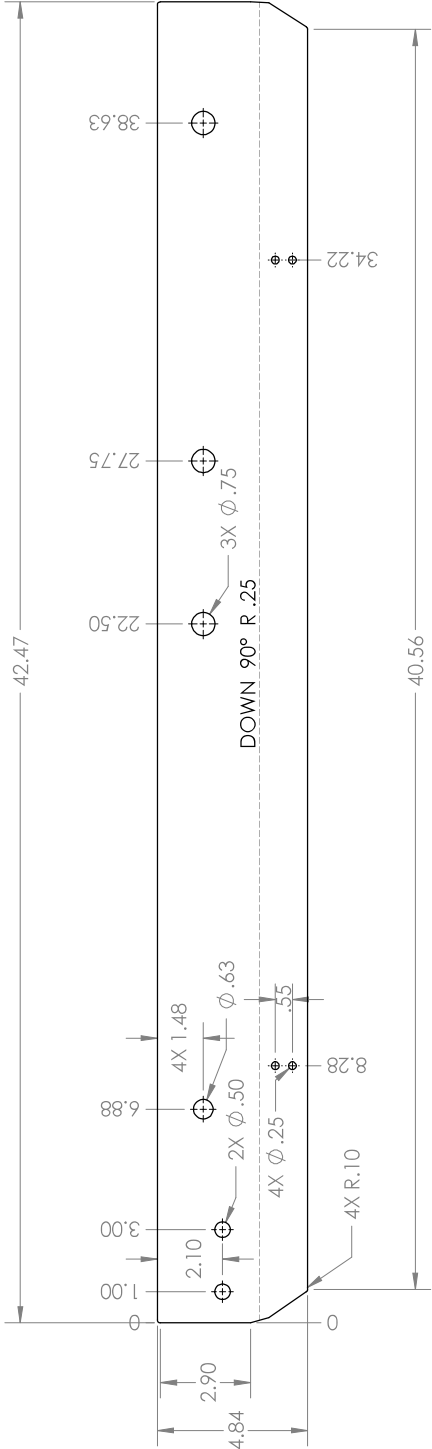
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|                              |           |      |          |
|------------------------------|-----------|------|----------|
| UNLESS OTHERWISE SPECIFIED:  |           | NAME | DATE     |
| DIMENSIONS ARE IN INCHES     | DRAWN     | BP   | 11/28/19 |
| TOLERANCES:                  | CHECKED   | JN   | 11/28/19 |
| ANGULAR: BEND $\pm$ 1 DEGREE |           |      |          |
| TWO PLACE DECIMAL $\pm$ .02  |           |      |          |
| MATERIAL                     | COMMENTS: |      |          |
| ASTM A36                     |           |      |          |
|                              |           |      |          |
|                              |           |      |          |

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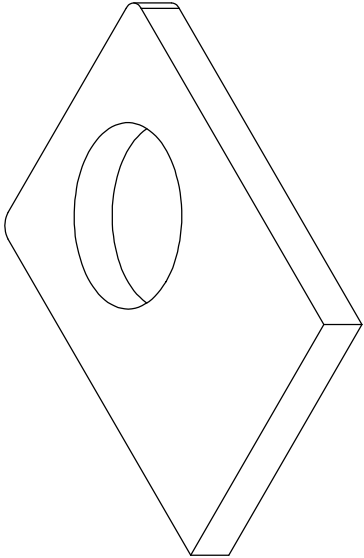
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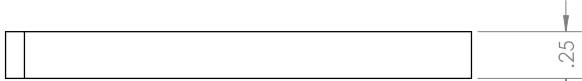
3

4



2X R.10

$\phi 1.00$



2.50

1.70

.88

1.75

.25

| UNLESS OTHERWISE SPECIFIED: |  | NAME      | DATE     |
|-----------------------------|--|-----------|----------|
| DIMENSIONS ARE IN INCHES    |  | BP        | 11/28/19 |
| TOLERANCES:                 |  | JN        | 11/28/19 |
| ANGULAR: B10 ± 1 DEGREE     |  |           |          |
| TWO PLACE DECIMAL ± .02     |  |           |          |
| MATERIAL                    |  | COMMENTS: |          |
| ASTM A36                    |  |           |          |
|                             |  |           |          |
|                             |  |           |          |

TITLE:

Locating Tab

|            |          |              |
|------------|----------|--------------|
| SIZE       | DWG. NO. | REV          |
| B          | 8        | 00           |
| SCALE: 3:2 |          | SHEET 1 OF 1 |

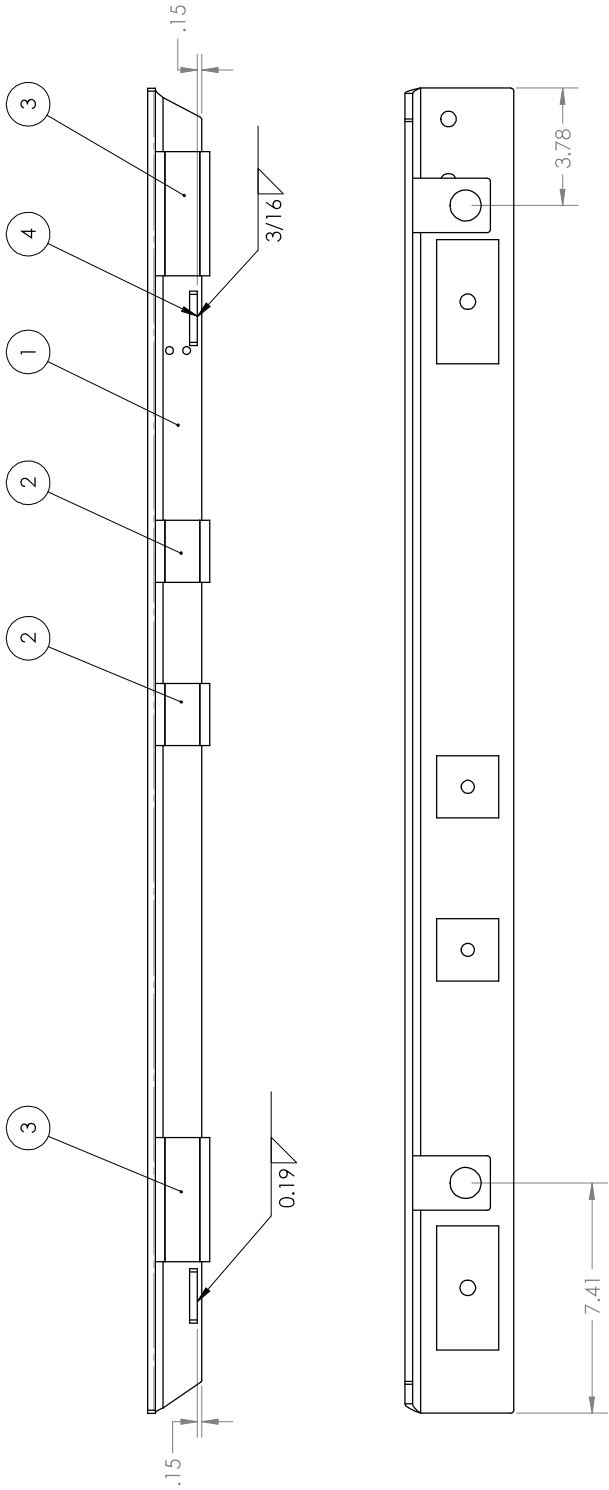
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4 3 2 1



| ITEM NO. | DESCRIPTION                | QTY. |
|----------|----------------------------|------|
| 1        | Sheet Metal Cover - Hopper | 1    |
| 2        | 2X2 SM-1 Mount             | 2    |
| 3        | 2X4 SM-1 Mount             | 2    |
| 4        | Locating Tab               | 2    |

|                             |  |           |          |
|-----------------------------|--|-----------|----------|
| UNLESS OTHERWISE SPECIFIED: |  | NAME      | DATE     |
| DIMENSIONS ARE IN INCHES    |  | BP        | 11/28/19 |
| TOLERANCES:                 |  | JN        | 11/28/19 |
| ANGULAR: BEND ± 1 DEGREE    |  |           |          |
| TWO PLACE DECIMAL ± .02     |  |           |          |
| MATERIAL                    |  | COMMENTS: |          |
| ASTM A36                    |  |           |          |

|                       |  |              |          |     |
|-----------------------|--|--------------|----------|-----|
| TITLE:                |  | SIZE         | DWG. NO. | REV |
| Hopper Mount Assembly |  | B            | 9        | 00  |
| SCALE: 1:4            |  | SHEET 1 OF 1 |          |     |

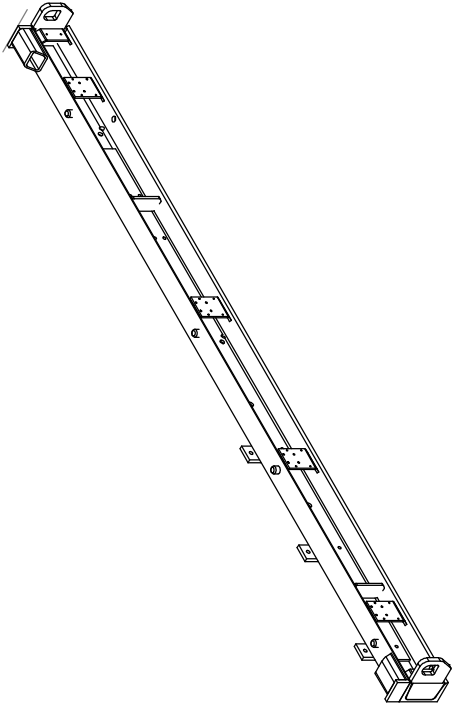
4 3 2 1

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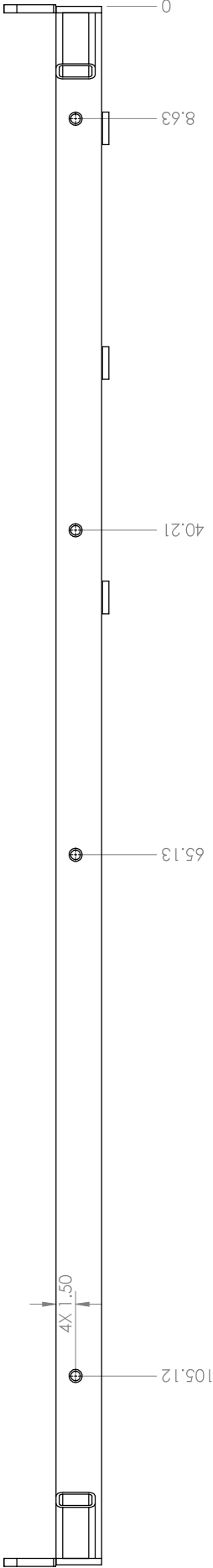


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|-------------------------------------------------------------------------------------------------------------------------------|-----------|--------------|-----------|
| UNLESS OTHERWISE SPECIFIED:<br>DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>ANGULAR: BEND ± 1 DEGREE<br>TWO PLACE DECIMAL ± .02 | DRAWN     | NAME         | DATE      |
|                                                                                                                               | CHECKED   | BP           | 11/28/19  |
|                                                                                                                               |           | JN           | 11/28/19  |
| MATERIAL<br>ASTM A36                                                                                                          | COMMENTS: |              |           |
|                                                                                                                               |           |              |           |
|                                                                                                                               |           |              |           |
| TITLE:<br>Right C-Channel Frame Rail                                                                                          |           | SIZE<br>B 10 | REV<br>00 |
| SCALE: 1:8                                                                                                                    |           | SHEET 1 OF 1 |           |

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4