



# UNIVERSITY OF MANITOBA

MECH 4860  
Final Design Report

## SEALER DUST COLLECTION UNIT FOR BLOW OFF PROCESS

Sponsoring Company: Decor Cabinets

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Submission Date: Wednesday, Dec 7, 2016

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## Executive Summary

The Decor Cabinet Company approached the design team in order to design a system to capture the sealer dust during the blow off process in their stain department. Decor Cabinets current blow off process blows dust into the ambient air, which is a health concern for the employees and disrupts other processes. The objective of this project is to design a system capable of collecting the dust from the blow off process and return the clean air into the room. The system must capture the dust while not disrupting the process and the employees, as well as keep up with the current cycle time of the process.

The design teams met with the appropriate stakeholders at Decor Cabinets and determined a list of needs for the project. The needs were then developed into target specifications, which were used to brainstorm concepts to achieve the objectives. The design team explored multiple options for achieving the objectives while adhering to the constraints and limitations of the design scope. To acquire a better understanding of the needs of the system, the team did both internal and external research on different dust capturing systems. This research helped with the concept generation. From concept generation, 10 main concepts were generated, screened and narrowed down to the final concept. The final concept was called the Deluxe Concept, which was further designed to reach the final detailed design.

The design team successfully designed a practical solution for Decor Cabinets that addresses the problem at the blow off process. The system consists of two dust capturing systems with slot opening hoods. The team decided to divide the system into two separate units to make manufacturing simpler and also allow for smaller fans and motors for the units. The Green Heck BSQ 140, backward centrifugal fan-filter combination was selected to produce the required 2002 CFM for each unit. The key features of the capture unit include locking caster wheels and a flexible ducting section for mobility and access to all sides of the conveyor belt. The capture units contain two slots to capture dust from the table surface and above the surface. The top portion of the hood has a hinged Plexiglas baffle to contain the swirling dust projected upwards from the conveyor surface. The total cost for both units was \$9113.32 plus taxes and installation. Decor Cabinets did not indicate a budget for the design. However, the design team made economical decisions throughout, such as the selection of two smaller units as opposed to one large unit, in order to keep costs as low as possible.

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## 1.0 Introduction

The Decor Cabinet Company is an industry leader in specialized cabinetry including both custom kitchen and bath solutions. Decor operates two production facilities in Morden, Manitoba. The company has remained a family run business since it was founded in 1977 [1].

In the main facility, the cabinets are built and assembled from raw materials and undergo multiple finishing processes. The Second facility manufactures the cabinet doors and various proprietary moldings. The family operated business has thirty years of cabinet manufacturing experience and has expanded Decor's dealer network throughout Canada and the United States [1]. In the main facility, the cabinet components go through an extensive staining process of up to 10 different stations as shown in Figure 1.

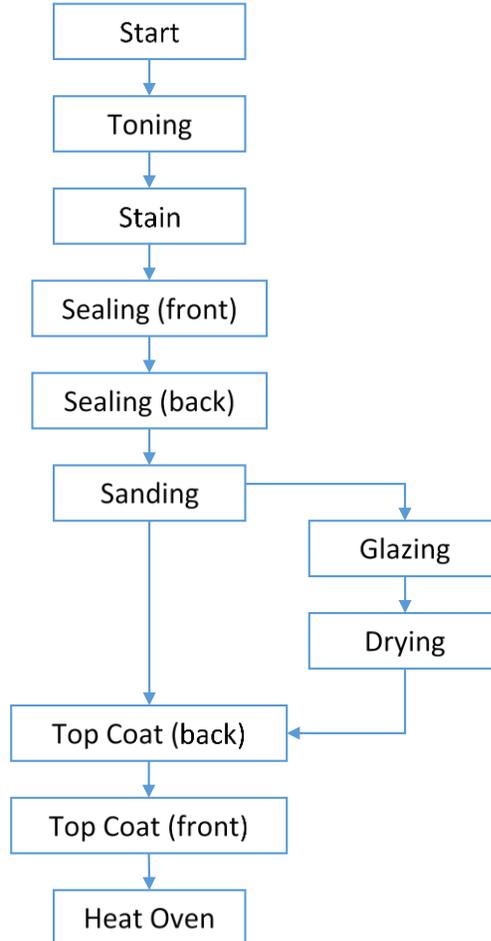


Figure 1: Stain process flow chart [2].

The components go through a toning station and staining station followed by two sealing stations and sanding. Following the sanding, the parts go to the glazing and drying section or directly to the top coat stations, then finally to the oven. The parts must be sanded extensively after the sealing stations to ensure a smooth surface finish and to allow for proper adhesion of the top coat. This sanding step generates a few problems in the process. The sealer dust accumulates on the surface of the parts and in crevices along the various profiles of the cabinet design. This dust is fine and has a sticky consistency, which makes it difficult to remove by conventional methods. An example of a part coming out of the sanding station is shown in Figure 2.



Figure 2: Fine sealer dust on the part [2].

Currently, the parts are placed on a conveyor belt and sprayed using a compressed air gun (or nozzle) and wiped with a cloth to remove all the dust on the surface and in the cracks. This cleaning step is referred to as the blow off process. During the blow off process, the airborne dust is projected into the ambient air, causing higher rework costs and health concerns for the employees [3]. The conveyor belt and surrounding area is shown in Figure 3. The cabinet components are placed within the white stripes on the conveyor system and then the sealer dust is blown off from either the right or left side. As shown in Figure 3, space beside the

conveyor system is limited. There are high traffic isle ways on either side of the conveyor belt. However, there is sufficient room above the conveyor belt surface towards the roof of the facility. This gives the design team the option to suspend equipment from the ceiling in order to maintain the current floor space.

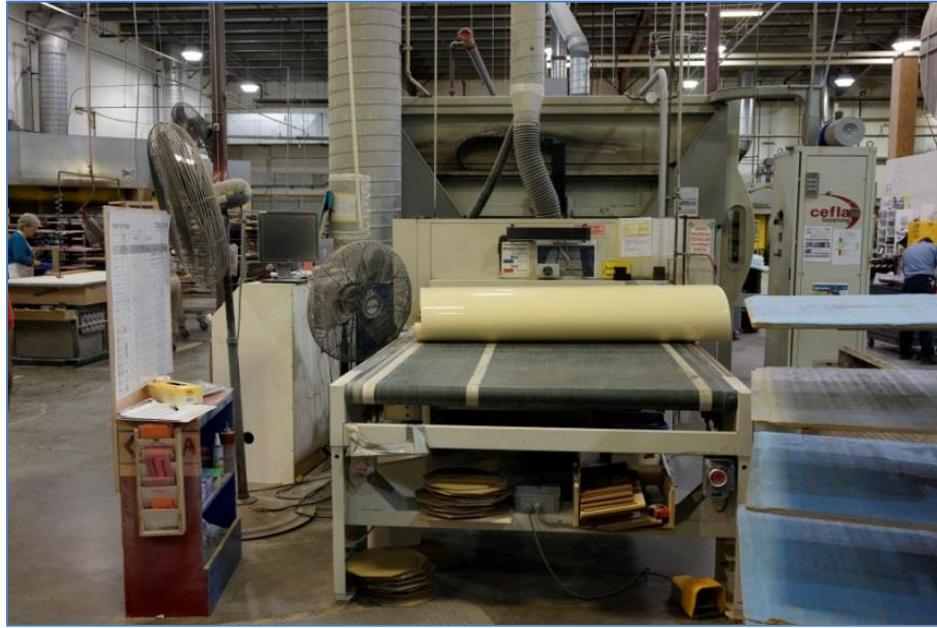


Figure 3: Conveyor belt system [2].

Decor Cabinets has requested that the design team create a solution to the blow off process problem. The solution needs to be easily integrated into the current processes and capture the sealer dust while improving air quality. The dust capturing system must be a standalone unit, fit into the allotted space and must not affect the current dust capturing system utilized in the rest of the facility.

## 1.1 Project Objectives

The primary objective of the project is to design a system to capture the sealer dust during the blow off process. Capturing the dust during the blow off will stop the spread of sealer dust contamination to other work in progress and, more importantly, increase the air quality of the facility for the employees. The design team did not consider the dust produced by other processes in the facility as it is out of the scope of this project.

## 1.2 Constraints and Limitations

In order to better understand the scope of the project, the constraints and limitations had to be identified. These constraints and limitations help set boundaries for the design project. The design team identified constraints as being external factors that limit the design and identified limitations as physical factors that limit the design. The constraints and limitations for this project are shown in TABLE I.

TABLE I: PROJECT CONSTRAINTS AND LIMITATIONS [2]

Constraints	Limitations
Designing a complete system within the time constraints of the project (3 months).	A system that occupies limited space of 49.5 ft <sup>2</sup> around the conveyer belt.
Designing an economical system.	A system that can be integrated onto the current process.
Designing a system that can meet the indoor air quality standards.	A system that requires minimal maintenance (change filters once every 4 months).
	A system that has noise levels below 90 dB.

TABLE I illustrates the constraints and limitations established for the project during the initial meeting with the customer. One of the main limitations for the project was the available space of 49.5ft<sup>2</sup> for the system. The system could not interfere with the current work flow and the system could only be implemented around the conveyor belt. One of the major constraints for the project that may hinder the schedule and workload is time. The design team had only three months to propose a solution for the customer. The design team kept to a strict project schedule to keep on track and ensure each deadline was met. Other constraints that were a factor for the design team were designing a low cost (economical) system and designing a system that could meet the indoor air quality standards. These limitations and constraints were used as restrictions during the concept development process and selecting a recommendation for the design project. In order to develop concepts to meet the project objectives, a quantitative analysis of the customer needs and target specifications was required. The following section breaks down the customer needs according to their importance and discusses the target specification associated with each need.

### 1.3 Customer Needs

In order to fully understand the customer needs, the design team visited Decor Cabinets to witness the problem and observe the manufacturing process. Upon observing the blow off process, the dust problem was apparent. Finding a solution to the problem would be difficult, since the process involved many steps and space would be an issue for any design concept. The design team established 11 customer needs that would capture all of the requirements of a successful design. The customer needs were then ranked with an importance factor from 1-5 in order to distinguish the most important needs that the design team should focus on. An importance factor of 5 indicates the most important factor whereas an importance factor of 1 indicates the least important factor. A complete list of the customer needs and associated importance factors approved by the client is shown in TABLE II.

TABLE II: CUSTOMER NEEDS AND IMPORTANCE FACTOR [2]

Label	Needs	Importance Factor
1	The system captures the sealer dust during the blow off process	5
2	The system filters the air back into the facility	5
3	The system keeps up with current cycle time	5
4	The system does not obstruct the floor plan	4
5	The system is compatible with the current conveyer system	4
6	The system is easy to operate	3
7	The system is easy to turn on and off (accessibility)	2
8	The system is quiet while operating	2
9	The system is easily maintained	1
10	The system is economical to implement and operate	1
11	The design is simple and not complex	1

As summarized in TABLE II, the most important customer needs were that the system captures the dust, filters it back into the facility and keeps up with the current cycle time. These three customer needs must be the top priority of any concept design. Other requirements, such as floor space and compatibility with the existing conveyer system, were found to be slightly less important. One factor that was indicated by the customer during the site visit was that the system should be easily operational with only one employee and must not slow down the pacing of the process. For this reason, it was important to understand the flow chart of the department

and understand the challenges associated with each station. Other needs such as accessibility, sound, maintenance, cost and complexity were listed lower on the importance of the customer needs.

## 1.4 Metrics and Target Specifications

After the customer needs were finalized, the design team focused on measurable target specifications that would be required to analyze the customer needs. A metrics list of engineering parameters was established and related to each customer need. In order to develop any concept design, target values had to be researched and determined to ensure the customer needs were met. TABLE III illustrates 12 engineering parameters, specification units, target values, importance factors and indicates the customer needs associated with each metric label.

TABLE III: PROJECT METRICS AND TECHNICAL SPECIFICATIONS [2]

Label	Needs	Engineering Parameters	Specification Units	Targets	Importance
1	1, 2	Motor size	Horsepower	Design dependent	5
2	1	Pressure	Inches of water gauge (in.wg)	Design dependent	5
3	1	Air flow capacity	Cubic feet per minute (CFM)	Design dependent	5
4	2	Filtration particle size	Microns	>5	5
5	6	Ease of operation	Required employees	1	4
6	4, 5	Overall dimensions	Inches	108 x 66	4
7	6	Weight	Kilograms	150	3
8	3, 6, 7	Fully operating lead time	Seconds	<3	4
9	9	Filtration change (maintenance)	Hours of operation	40	2
10	8	Noise level	Decibels	<90	2
11	11	Complexity	Subjective	Design dependent	1
12	10	Cost	Canadian dollars	Design dependent	1

The target values for parameters such as motor size, pressure, air flow capacity and cost were dependent on the specifics of the design concepts and were considered independently. The initial generalized values for the rest of the parameters were determined based on research from the ASHRAE application handbook (American Society of Heating, Refrigerating and Air-Conditioning Engineers) [4]. The same importance scale of 1-5 was used as described in TABLE II. The parameters associated with the most important customer needs are indicated as the most important parameters to measure for the design. For example, the parameters involved in air movement (motor size, pressure, air flow and filtration) were among the most important specifications to consider because they relate to the most important customer needs. The specific units chosen to describe the engineering parameters were based on common HVAC (heating, ventilating and air conditioning) units and dimensions used in industry [5]. The indoor air quality of the facility was analyzed by Decor Cabinets and can be used to evaluate the success of the design team's recommendation. The air quality value may act as a benchmark to compare the before and after conditions of the final design implementation. Unfortunately, the air value was not provided to the design team.

The design team used the customer needs, target specifications and parameters to research the project topics and brainstorm initial ideas, the initial research and detailed research done by the design team is outlined in Appendix B. A concept generation and selection process was completed to end up with the most suitable concept for a final detailed design. In order to determine the most suitable design, the design team generated multiple options for achieving the objective. The concepts were evaluated based on the customer needs while adhering to the constraints and limitations of the design scope. The final detailed design includes the implementation of the system with target specifications, a complete assembly list and part drawings, pricing and relevant supplier information. The next section describes the final detailed design chosen and the design parameters associated with it.

## 2.0 Detailed Design

The design team completed a concept generation process, which generated ten different hood designs. The different concepts were then narrowed down using a list of selection criteria and further compared using a weighted scoring matrix. The complete concept generation and selection procedure, with concept drawings, can be found in Appendix C. The concept selected during this process is shown in Figure 4.

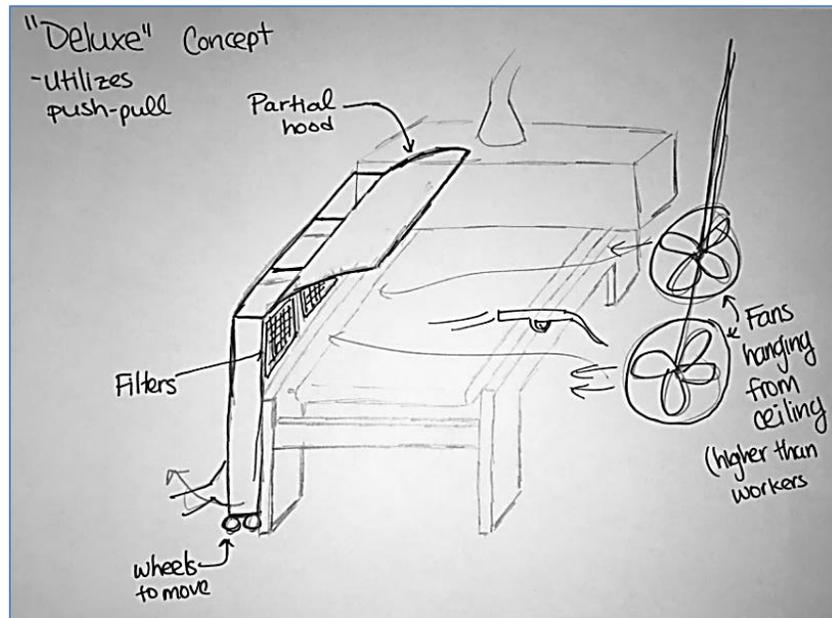


Figure 4: Final detailed design concept [2].

The final selected design is referred to as the Deluxe Concept, which is further discussed in the following section. The final detailed design section includes the initial design considerations, the single hood calculations, the final hood design, a computational fluid dynamics analysis and the fan selection. The following section goes into more detail on the specifications and parameters of the design.

## 2.1 Initial Design Considerations

In order to start the detailed design of the Deluxe Concept, it was necessary for the team to understand the different opening geometries commonly used in the industry as well as the basic nomenclature associated with them. The team also needed to determine the appropriate assumptions that could be made with the different system parameters. The initial design considerations will describe the preliminary hood designs, nomenclature and design assumptions.

### 2.1.1. Preliminary Hood Design

There are two main types of opening geometries that are commonly used in the HVAC industry. The two types are referred to as, plain openings or slot openings. The differences between the two openings are shown in Figure 5.

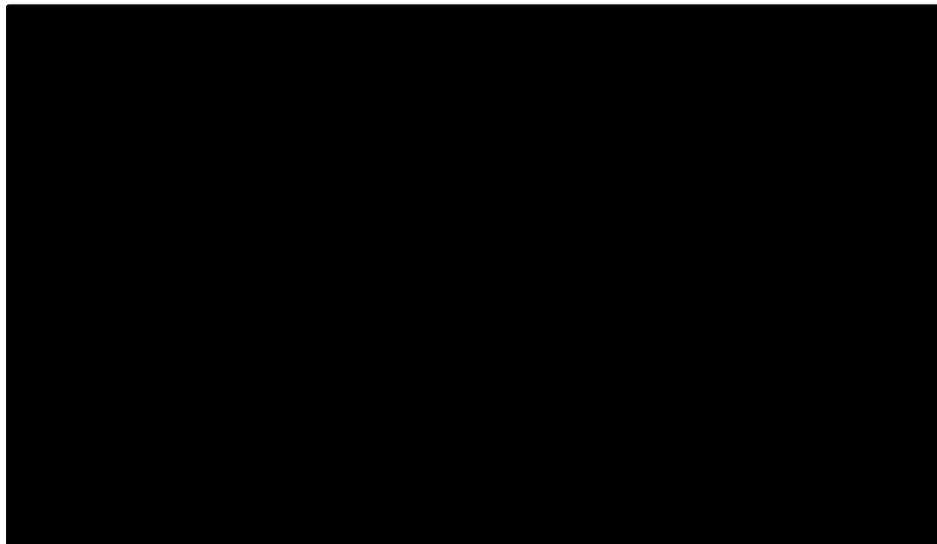


Figure 5: Hood opening geometries [6].

From the two types of openings, many configurations can be obtained by adding flanges or increasing the number of slots. The important aspects of the hood designs are the width, height, tapered section and duct size. The nomenclature shown in the Figure 5 are further discussed in the next section.

One of the first observations the team made about the design space was the long length that the capture unit had to cover. Based on the length requirements for the hood, the design team decided to implement two separate hood units in order to span the large distance. The two units are identical in size as well as shape and are approximately four feet in length. By having two units, the design can be kept more efficient, less complex and more economical. The height of the hood was selected next by the design team based on observations from site visits to the facility. It was observed that the majority of the sealer dust remained below two feet above the conveyor belt surface. For this reason, the design team decided that the height of the hood did not have to be higher than two feet. A height of two feet would also ensure that the hood would not obstruct any light or negatively impact the blow off process. The common parameters and design assumptions which will be used throughout the report are discussed in the next section.

### 2.1.2. Nomenclature and Assumptions

In order to move forward and present details of the design, some terminology needed to be established. TABLE IV summarizes the nomenclature used throughout the report and indicates some of the values.

TABLE IV: NOMENCLATURE [2]

Symbol	Name	Comparative Value	Units
$V_x$	Capture Velocity	85	ft/min
$X_{avg}$	Average Capture Distance	2.375	ft
$X_{max}$	Maximum Capture Distance	4.75	ft
$A_s$	Area of the Slot	Design dependent	ft <sup>2</sup>
$L_s$	Length of the Slot	Design dependent	ft
$W_s$	Width of the Slot	Design dependent	ft

Capture velocity ( $V_x$ ) refers to the minimum air velocity required to capture and carry the contaminant into the hood [7]. The capture velocity for small particle that corresponds to the conditions mentions in section 1.0 is between 50 to 100 feet per min (FPM). A value of 85 FPM was chosen to accommodate the design conditions. The maximum capture distance ( $X_{max}$ ) is the width of the conveyer belt which is 4.75 ft and the average capture distance ( $X_{avg}$ ) is half the maximum capture distance. The area of the slot, which is a design dependent parameter, is equal to the length ( $L_s$ ) of the slot multiplied by the width of the slot ( $W_s$ ). A visual

representation of the maximum capture distance, length of the slot and the width of the slot is shown in Figure 6.

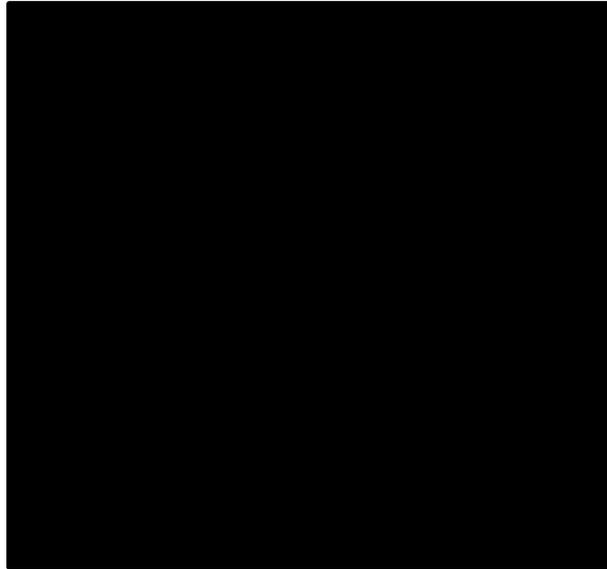


Figure 6: Hood with variables [7].

Along with the nomenclature, some assumptions were required for the calculations that are presented in the report.

### **Assumptions**

The velocities that are discussed in the design do not take into consideration the inertial effects of the dust particles in the fluid path. For particles below 20 microns, the effects can be ignored [7]. The particles are assumed to flow freely within the streamlines created by the hood openings. The specific density of the fine dust particles can also be ignored by assuming the temperature and moisture is constant throughout the system. By neglecting density, the system is assuming the air is incompressible.

One of the major design considerations for the exhaust system was the capture velocity distance. The unique parameter of the design is that the dust is blown off using a nozzle at 90 psig, which generates large cross flow velocities into the hood opening. For this reason, the design team assumed a capture distance of half the conveyor width. The capture distance was also determined considering the halfway distance is an average over the surface area where the

panels may be positioned. The blow off process enables the facility cross flow air paths to be minimized and simplified because of the addition of the large nozzle velocity.

## 2.2 Single Hood Unit Calculations

Once the initial design considerations were determined, the team then moved on to airflow calculations, duct sizing as well as pressure loss calculations. All the calculations made in the following sections are for a single unit as the two plenums collecting the sealer dust will be identical as discussed in Section 2.1.1.

### 2.2.1. Airflow Calculations

The airflow calculations for the final design were required in order to size the equipment necessary for the system and to finalize the plenum geometry. In order to design an economical system, the CFM required to capture the sealer dust should be as low as possible. A low CFM corresponds to a smaller motor and thus a lower capital investment and annual operating cost. The design team compared the CFM requirements for plain openings and slot openings to determine the most effective result. The following section goes through the calculations of the two types of configurations in order to determine the CFM required for each of the geometries.

#### 2.2.1.1. Plain Opening

A plain opening is characterized by having an aspect ratio of W/L greater than or equal to 0.2. The team decided to try 2 different configurations, an opening the size of the wall as well as an opening with a 0.2 aspect ratio. The following equation was used to determine the CFM required to capture the dust [7]:

$$Q_{Total} = V_x [5X^2 + A_f] \quad (1)$$

The total CFM changes due to change in the area of the opening as well as the capture distance X. The team decided to determine the CFM for 2 different slot area openings as well as the maximum and average slot distance.

### Plain Opening – 0.5 Aspect Ratio

The first configuration the team tried out was an opening the size of the plenum, where  $L_s = 4\text{ft}$  and  $W_s = 2\text{ft}$ . Using the equation (1), the following results were determined for both the average and the maximal capture distance. The required CFM for a plain opening and an aspect ratio of 0.5 is shown in TABLE V.

TABLE V: REQUIRED CFM FOR PLAIN OPENING AT 0.5 ASPECT RATIO [2]

Required CFM	
Maximum Distance	10,269 CFM
Average Distance	3,077 CFM

The required CFM obtained from TABLE V is high, since equation (1) depends on the area of the slot, reducing the aspect ratio would decrease the required CFM.

### Plain Opening – 0.2 Aspect Ratio

The next configuration the team tried was an opening with a 0.2 aspect ratio. This ratio was chosen as it was close to the aspect ratio limit for plain opening. To determine the size of the opening, the team decided to keep the length of the slot to be 4ft and the width of the slot was then determined to be  $W_s = 0.8\text{ft}$ . Using equation (1), the following results were determined for both the average and the maximal capture distance. TABLE VI shows the results of the plain opening CFM at an aspect ratio of 0.2.

TABLE VI: REQUIRED CFM FOR PLAIN OPENING AT 0.2 ASPECT RATIO [2]

Required CFM	
Maximum Distance	9,875 CFM
Average Distance	2,683 CFM

Both the CFM required for the maximum and average distance were lower than for the configuration with 0.5 aspect ratio. The team determined that as the opening of the plenum got smaller, less CFM would be necessary.

## 2.2.1.2. Slot Opening

A one slot hood is characterized by an opening with an aspect ratio of  $W/L$  less than or equal to 0.2. A slot opening is typically used because it provides uniform airflow over the length of the

slots. Compared to a hood with plain opening, a slot opening decreases the required airflow rate by 25% and reduces the static pressure in the hood. Equation (2) is used to calculate the required CFM for one slot opening [7].

$$Q_{Total} = 3.7LV_xX \quad (2)$$

### **One Slot Opening**

Since equation (2) does not depend on the aspect ratio, the team decided to use a slot length of  $L = 4\text{ft}$  which is the same length as the plain opening. The required CFM for both maximum and average distance  $X$ , is shown in TABLE VII.

TABLE VII: REQUIRED CFM FOR ONE SLOT OPENING [2]

Required CFM	
Maximum Distance	5,976 CFM
Average Distance	2,988 CFM

TABLE VII shows that a hood opening with one slot has the lowest required CFM at the maximum distance. Since the height of the hood will be 2ft, the team decided to calculate the required CFM for two slot opening to compare the results.

A two slot hood is characterized by an opening with an aspect ratio of  $W/L$  greater than or equal to 0.2. Equation (3) was used to determine the CFM required to capture the dust for a two slot opening [7].

$$Q_{Total} = 0.75V_x[5X^2 + A_f] \quad (3)$$

### **Two Slot Openings – 0.2 Aspect Ratio**

Following the required CFM calculations for one slot opening, the team moved onto calculating CFM for hoods with two slot openings. In order to compare the results with the plain opening, the team decided to use an aspect ratio of 0.2 with the length of the slot at 4ft and the width of the slot at  $W_s = 0.84\text{ft}$ . Using equation (3), the following results were determined for both the average and the maximal capture distance. TABLE VIII shows the results of the two slot opening CFM at an aspect ratio of 0.2.

TABLE VIII: REQUIRED CFM FOR TWO SLOT OPENING AT 0.2 ASPECT RATIO [2]

Required CFM	
Maximum Distance	7,294 CFM
Average Distance	2,002 CFM

The maximum and average distances were lower for two slot opening compared to both the plain opening and the one slot opening configuration. Having two slot openings reduces the required airflow for the same capture velocity.

A summary of all the calculated required CFM for different hood openings is shown in TABLE IX.

TABLE IX: SUMMARY OF REQUIRED CFM FOR DIFFERENT HOOD OPENINGS [2]

Geometry	CFM REQUIRED	
	Maximum Distance	Average Distance
Plain Opening, W/L =0.5	10,269 CFM	3,077 CFM
Plain Opening, W/L =0.2	9,861 CFM	2,669 CFM
One Slot Opening	5,976 CFM	2,988 CFM
Two Slot Openings, W/L =0.2	7,396 CFM	2,002 CFM

It can be seen from TABLE IX that the two slot opening has the lowest required CFM for the average distance. The team decided to select a two slot opening not only because it has the lowest CFM but also because two slots would cover more height capturing the dust that settles as well as the dust blown higher into the air.

### 2.2.1.3. Summary of Airflow Calculations

Calculations were performed to determine the minimum airflow required for each system. The constant variables used are shown in TABLE X.

TABLE X: VARIABLES USED IN THE PRELIMINARY CALCULATIONS [2]

Symbol	Name	Comparative Value	Units
$V_x$	Capture Velocity	85	ft/min
$V_f$	Face Velocity	2000	ft/min
$X_{avg}$	Average Capture Distance	2.375	ft
$X_{max}$	Maximum Capture Distance	4.75	ft
$N$	Number of Slots	2	
$A_{Total}$	Total face area of opening	3.2	ft <sup>2</sup>

The capture velocity for small particle that corresponds to the conditions mentioned in section 1.0 is between 50 to 100 feet per min (FPM), for an average capture distance of 2.375 ft, the capture velocity was determined to be  $V_x = 85$  FPM for the Deluxe Concept. A face velocity of 2000 FPM was used in order to establish uniform exhaust air distribution across the two slot openings. Finally, using an aspect ratio of 0.2, the total face area was found to be  $A_{Total} = 3.2$  ft<sup>2</sup>.

The total airflow ( $Q_{Total}$ ) for a two slot hood opening that rests on the table is given by equation (4) [7]:

$$Q_{Total} = 0.75(85)[5(2.375)^2 + 3.2] = 2001.95 \text{ CFM} \quad (4)$$

For the Deluxe Concept to work, both slots needed to have a face velocity of 2000 FPM and therefore the actual total area of both the slots was calculated using equation (5):

$$Q_{Total} = V_f A_{Total}$$

$$A_{Total} = \frac{Q_{Total}}{V_f} = \frac{2001.95}{2000} = 1.001 \text{ ft}^2 \quad (5)$$

Dividing the total area in half for both the top and bottom slots gives:

$$A_{St} = \frac{A_{Total}}{2} = 0.5 \text{ ft}^2 \quad (6)$$

$$A_{Sb} = \frac{A_{Total}}{2} = 0.5 \text{ ft}^2 \quad (7)$$

The width of the top slot and the bottom slot was determined using equations (8) and (9):

$$W_{St} = \frac{A_{St}}{L} = \frac{0.5}{4} = 0.1251 \text{ ft} = 1.50 \text{ in} \quad (8)$$

$$W_{Sb} = \frac{A_{Sb}}{L} = \frac{0.5}{4} = 0.1251 \text{ ft} = 1.50 \text{ in} \quad (9)$$

The minimum airflow required to maintain a face velocity of 2000 FPM at the top and the bottom slots are given by equations (10) and (11):

$$Q_{St} = V_f A_{St} = 2000(0.50) = 1000.97 \text{ CFM} \quad (10)$$

$$Q_{Sb} = V_f A_{Sb} = 2000(0.50) = 1000.97 \text{ CFM} \quad (11)$$

A summary of the results obtained from the preliminary calculations is shown in TABLE IX

TABLE XI: SUMMARY OF RESULTS [2]

Symbol	Description	Result
$Q_{Total}$	Total required airflow rate for one unit	<b>2002 CFM</b>
$Q_{St}$	Airflow required for top slot	<b>1001 CFM</b>
$Q_{Sb}$	Airflow required for bottom slot	<b>1001 CFM</b>
$W_{St}$	Width of top slot	<b>1.50 in</b>
$W_{Sb}$	Width of bottom slot	<b>1.50 in</b>

The airflow obtained for the preliminary calculations are expected and reasonable for the given parameters.

### 2.2.2. Duct Size and Hood Taper

The air flow requirement for a single hood design was 2002 CFM. In order to determine the appropriate ducting size, the preferred duct air flow velocity was required. The duct velocity for fine dust in a factory setting is approximately 3500 FPM [7]. Therefore, the ideal duct size can be determined using equation (12).

$$Q_{Total} = V_{duct} A_{duct}$$

$$A_{duct} = \frac{Q_{Total}}{V_{duct}} = \frac{2002}{3500} = 0.572 \text{ ft}^2 \quad (12)$$

The area can then be determined using the equation for the area of a circle, as shown in equation (13).

$$A_{duct} = \frac{\pi}{4} D^2 = \sqrt{(0.572) \left(\frac{4}{\pi}\right)} = 0.853 \text{ ft} = 10.24 \text{ inches} \quad (13)$$

Therefore, a duct size of 10 inches was chosen, which generates a duct velocity of 3670.60 FPM. The increased duct velocity, in comparison to other velocities in the system, is to ensure no particles deposit on the inside walls of the ducting during operation. Deposits on the inside of the ducting will lead to blockages and increase the fan and motor requirements.

The dimensions for the hood units are four feet in length, in order to cover the conveyor belt distance where the dust is blown off. The depth of the plenum was then required for the design of the hood taper and connection to the ducting. The most practical depth for the plenum is to have it the same size as the duct diameter. The taper would therefore be a uniform dimension and allow for a consistent pressure loss. A plenum width of 10 inches was chosen for the capture hood design. The width also ensures a much slower plenum velocity in comparison to the slot velocity, which is required for proper air flow through the system [7].

For the system to converge from the large plenum to the duct opening, a taper needed to be designed. As air flow converges, it increases in velocity and decreases in pressure according to Bernoulli's principle. In ducting systems, pressure losses are proportional to the fan and motor sizing. The larger the pressure losses are, the larger the motor is required to overcome the pressure changes. For these reasons, the team found that the most effective and practical taper was 45 degrees.

### **2.2.3. Pressure Losses**

The total static pressure losses for the local exhaust system were divided into hood losses, duct losses and filter losses. Static pressure is expressed as inches of water gage ("wg), which will be used to size a fan and motor for the exhaust system. Calculating the correct pressure changes throughout the system was necessary to select a fan and motor that could handle the operational parameters of the system.

#### **2.2.3.1. Hood Losses**

The first static pressure loss occurs as the airflow travels through the slots in the hood. As the air flows from the ambient conditions in the facility into the plenum, the increase in air flow velocity reduces the static pressure inside. The phenomenon is referred to as, vena contracta, which describes how the velocity pressure increases and static pressure decreases through an orifice [8]. The change in pressure creates a low pressure area inside the plenum and an even lower pressure within the duct opening. The low pressure creates the necessary suction power which draws in the air and immersed dust particles.

The static pressure losses associated with the hood design include the slot losses and contraction losses at the duct opening. Equation (14) represents the variables associated with the hood losses. The third term in the equation is the acceleration velocity pressure, which is typically the duct pressure loss, since it is usually the larger value.

$$SP_h = 2(F_s * VP_s) + (F_d * VP_d) + VP_d \quad (14)$$

Where the entry loss factors are  $F_s = 1.78$  and  $F_d = 0.25$ , using imperial units [7]. The more abrupt the duct transition is, the greater the loss factor. The most effective transition is a smooth, curved bend, which disrupts the air flow path the least amount. However, a long curved transition is not practical for most applications in industry. Therefore, the next best transition is a taper at 90 degrees from the duct centerline. The slot velocity was easily determined using equation (15). Using imperial units, the velocity pressure associated with the slot was determined using equation (16). The same calculations could be done for the duct parameters.

$$V_s = \frac{Q}{A_s} \quad (15)$$

$$V_s = \frac{1001}{(1.5 * 48)/144} = 2002 \text{ FPM}$$

$$V_d = \frac{2002}{0.545} = 3670.59 \text{ FPM}$$

$$VP_s = \left( \frac{V_s}{4005} \right)^2 \quad (16)$$

$$VP_s = \left( \frac{2002}{4005} \right)^2 = 0.25 \text{ "wg}$$

$$VP_d = \left( \frac{3670.59}{4005} \right)^2 = 0.84 \text{ "wg}$$

Using the calculated values, equation (14) was used to determine the total hood static pressure loss. The static pressure hood loss for each unit is 1.94"wg.

$$SP_h = 2(1.78 * 0.25) + (0.25 * 0.84) + 0.84 = 1.94 \text{ "wg}$$

### 2.2.3.1. Duct Losses

The duct loss for the local exhaust system was minimal, however needed to be considered for the design. The duct losses were divided into two different types, which include friction and fitting or bend losses.

The friction losses associated with the ducting are related to the roughness of the material chosen for the ducts. The roughness factor was determined and was used along with the Reynolds number to calculate the friction factor. The Reynolds number was calculated using equation (17), which yields a turbulent value.

$$Re = \frac{\rho dV}{\mu} \quad (17)$$

$$Re = \frac{(0.075 * 0.833 * 61.18)}{3.5e-7} = 10920630$$

Where the density of air is 0.075 lbs/ft<sup>3</sup>, the diameter of the duct is 10 inches, the velocity is 61.18 ft/s and the dynamic viscosity is 3.5e-7 lb s/ft<sup>2</sup> at 20 °F [9].

The friction factor was visually determined using a Moody plot, as shown in Figure 7, and then used in the Darcy-Weisbach equation (18) to yield a pressure loss.

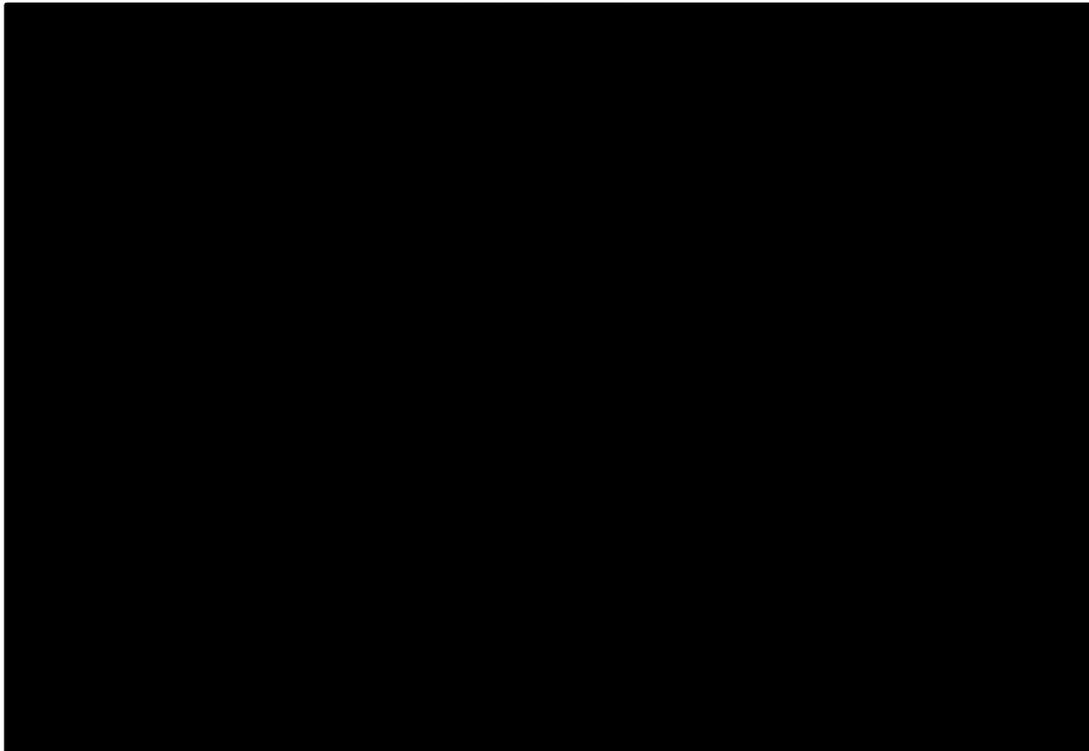


Figure 7: Moody plot [10].

The relative roughness of the spiral steel ducting is 0.0005 [8]. Using the Moody plot the friction factor is approximately 0.0165. Using the friction factor for the ducting, the pressure loss was calculated using equation (18). There is approximately three feet of metal ducting from the elbow to the fan and filter unit.

$$SP_d = hf = f * \frac{L}{D} * VPd \quad (18)$$

$$SP_d = 0.0165 * \frac{3}{0.833} * 0.84 = 0.0499 \text{ "wg}$$

The ducting for each unit will have a section of flexible ducting to allow for mobility of the hood and support table, as shown in Figure 8.



Figure 8: Flexible duct [11].

Additional friction losses are required for the flexible ducting as the relative roughness is greater. The manufacturer of the flexible ducting selected has a graph to determine the pressure loss associated with the product, as shown in Figure 9. Using the CFM of 2002 CFM and a duct size of 10 inches, the pressure loss associated with the flexible ducting was determined to be 1.1 “wg per 100 feet. There is five feet of flexible ducting for each unit, which equals a pressure loss of 0.055 “wg. The total friction duct loss is therefore, 0.050 + 0.55 = 0.105 “wg.

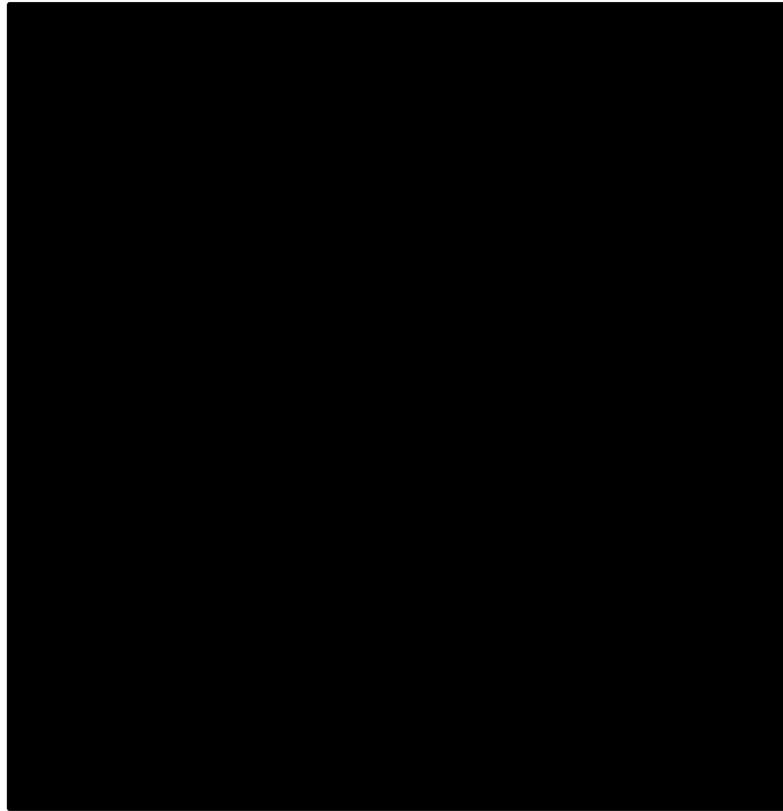


Figure 9: Flexible duct friction loss [11].

The other type of duct pressure loss is related to the connections, fittings and bends in the ducting. There is only one 90-degree elbow in the duct system for each unit. The friction loss was calculated using equation (19), with a friction loss coefficient of 0.25 [9].

$$SP_d = hf = f * \frac{V^2}{2g} \quad (19)$$

$$SP_d = hf = 0.25 * \frac{61.18^2}{2 * 32.174} = 14.54 \text{ ft}$$

The equivalent pressure loss was calculated using equation (16) for the additional 14.54 feet due to the 90 degree rounded duct elbow. Where the duct velocity in metric units is 61.18 ft/s and gravity of 32.174 ft/s<sup>2</sup> is used.

$$SP_d = 0.0165 * \frac{14.54}{0.833} * 0.84 = 0.242 \text{ "wg}$$

The total static pressure loss in the system due to the ducting is therefore, 0.105 + 0.242 = 0.347 “wg. This value was added to the hood losses to give a total static pressure loss in the system of 2.287 “wg.

### **2.2.3.2. Filter Losses**

The final static pressure loss occurs across the filters in the system. There will be an air flow resistance due to the dimensional characteristics of the filters for the given flow rate. The filter selection was based on the particulate size and could dramatically affect the cost of the system due to the fan size and energy requirements [5]. The sealant dust size was approximated by the design team to be less than 10 micros, as compared to similar fine dust in literature [7].

The operational parameters of a filter will change over time due to the accumulation of dust. Filter manufacturers typically have clean and dirty pressure drops that can be substantially different. In order to successfully select the correct motor and fan for the system, the larger pressure drop of a dirty filter is used. Filter manufacturers have a range of pressure losses for specific filter designs. The range of pressure losses are due to the changing system parameters as the filter becomes more and more clogged. As the filter becomes clogged with the contaminants, the pressure drop increase which is why the dirty state is used for the design applications.

Filters typically require lower velocities for proper containment of particles. For this reason, filter banks have large cross sections in comparison to the ducting in order to reduce the airflow velocity. If the air flow is too large for the specific filter, the dust particles will be pushed through the filter and exhausted into the facility.

The specifications and pressure losses for the design were calculated in section 2.5 as the design team selected a fan-filter combination that is sized together with the motor.

## **2.3 Final Hood Design**

The design team determined the air flow requirements and overall specifications of the slotted plenum hood design. The main components of the final hood design are outlined in the following section. First, the plenum and taper details are discussed followed by the additional components on the hood design.

### 2.3.1. Plenum and Taper Final Design

The first step in finalizing both the plenum and the taper was to decide on the material for both. The team decided that extruding either part would be costly, therefore the team opted for sheet metal instead which would be more suitable for the design. The team selected  $\frac{1}{8}$ in galvanized steel sheet metal for both the plenum and taper sections.

Once the material was selected, the team finalized the plenum dimensions taking into consideration their manufacturability. Since the plenums are made of sheet metal, the team decided that the easiest way to manufacture it would be to make the plenum into two parts; the face and bottom, and the back and sides. The plenum height and width were already determined to be 24in and 10in respectively, leaving only the length to be chosen. Since the slots through the face of the plenum are 48 in, the length of the plenum was selected to be 49in to ensure the face of the plenums were structurally sound. The extra inch also allowed for flanges to be welded from the sides of the plenum to the front. Figure 10 shows a close up of the flanges.



Figure 10: Plenum flanges for welding.

The flanges allow the two pieces of the plenum to be easily spot welded together. The flanged design feature ensures the hood will be sealed properly. The two slot openings are laser cut in

order to maintain a uniform dimension. To determine where the slots were cut, the correct slot heights were required to maximize the effectiveness of the dust capturing.

To ensure that the system captured the majority of the dust, it was important to place the slots such that their range covered as much area as possible. In order to determine the ideal slot placement, the team observed the blow off process and noticed that the pieces placed on the conveyor belt varied in thicknesses. The slots would not function effectively if the cabinet panels blocked a portion of the slot opening. Therefore, the correct placement of the bottom slot is essential to the effectiveness of the design. The maximum thickness of the cabinet panels is approximately 2in. The team decided that a slot 3in from the bottom would capture the majority of the dust and avoid any panels blocking the bottom slot. In order to capture the dust that rose up off the table, a second slot was placed one foot away from the first slot. The placement of the second slot was chosen in consideration to the height of the plenum and maintaining a symmetrical plenum face. The baffle at the top of the plenum contains the dust and directs it into the top slot. The baffle will be discussed more in Section 2.3.2. The final dimensions of the plenum are shown in Figure 11 and detailed drawings can be found in Appendix A.

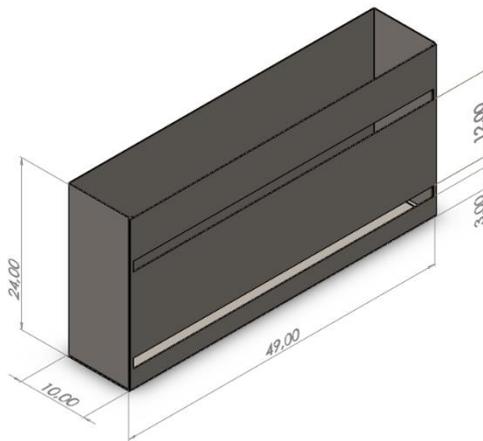


Figure 11: Plenum dimensions [2].

Once the dimensions of the plenum were finalized, the team then moved on to finalizing the taper dimensions. As mentioned previously, the tapered angle is at 45 degrees from the horizontal, to allow for the most practical and efficient reduction to the 10 inches ducting. Similarly, to the plenum, the taper was chosen to be made out of  $\frac{1}{8}$ in galvanized steel sheet

metal. The team decided that the easiest way to manufacture the taper would be to have 5 separate pieces; 2 face pieces, 2 side pieces and the ducting attachment. The different pieces of the taper are shown in Figure 12.



Figure 12: Exploded view of taper [2].

Since the taper is slipped onto the plenum, the dimensions of the bottom of the needed to be larger than those of the plenum. The side of the taper was set to be 10.5in allowing half an inch to account for tolerances. The length of the plenum was established to be 49.75in; half an inch to account for tolerances and  $\frac{1}{4}$ in for the flanges fixing the sides of the taper to the faces. The top of the taper connecting the taper to the ducting was chosen to make out of a 12x12in piece of sheet metal to allow the piece to be punched without warping. The neck of the taper, where the ducting will be attached, was set to 1.5in high with an outer diameter of 9.75in. The final dimensions of the taper for the plenum are shown in Figure 13.

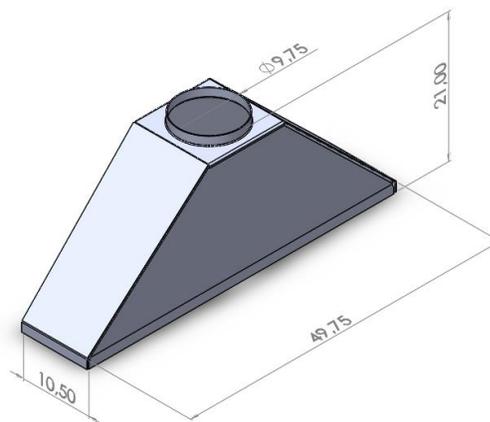


Figure 13: Taper dimensions [2].

As seen in Figure 13, the taper also has a lip, to easily slip, weld and seal the taper onto the plenum. The assembly of the plenum with taper is shown in Figure 14.



Figure 14: Plenum hood with slots [2].

The taper seamlessly slips onto the plenum and is spot welded into place. The whole plenum and taper assembly is also sealed with a gasket to ensure the plenum is airtight.

### **2.3.2. Additional Components**

In addition to the plenum and taper, the Deluxe Concept also includes a baffle, to contain the dust, and sits on a moveable support table. The two components were included to meet the needs of the client. The baffle helps contain the dust and is hinged, to ensure it does not get in the way of the workers. The table is on wheel as it was important for the client that the system be mobile. The two components enhance the effectiveness of the system.

The top of the capture hood has a hinged Plexiglas baffle that contains the sealer dust that blows up off the surface of the conveyor belt. The baffle increases the effectiveness of the capture unit by directing air flow into the top slot of the hood as shown in Figure 15.



Figure 15: Hinges with Plexiglas [2].

The baffle shown above spans over half the distance of the conveyor belt surface but is designed not to interfere with the blow off process or placement of cabinet components. The hinged brackets, shown in Figure 16, allow the baffle to be moved to account for rotating large components without affecting the technician's mobility.



Figure 16: Hinge [2].

The baffle can be placed at 90° during the blow off process to contain the dust then moved to the upright position when large pieces need to be turned over. To further accommodate for large parts, the plenums were placed on movable tables so the parts can be wiped during the blow off process.

The capture hood plenum and taper section are supported by a solid table is constructed with 2x2 inch square steel tubing. The table is strengthened with gussets and welded together. The table weight is much heavier than the capture hood, which makes the combined units center of gravity low to increase its stability. The table is supported by four locking caster wheels, which

increase the mobility of the unit and make it easy to roll back and forth. The table and locking caster wheels are shown in Figure 17. The capture hood is attached to the support table by brackets located at each corner. The engineering drawings of the table are illustrated in Appendix A.



Figure 17: Support table [2].

## 2.4 Computational Fluid Dynamics

Once the hood dimensions were finalized, the team decided to confirm the results found in the airflow calculations using Computational Fluid Dynamics (CFD). The team started out by modeling the complete hood design in SolidWorks. The plenum was then duplicated and placed in a 100x125x200in box in order to be able to observe the flow through the plenums. The setup for the CFD is shown in Figure 18.

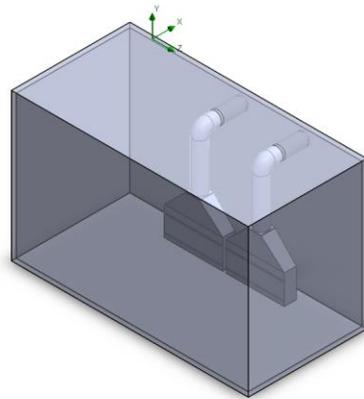


Figure 18: CFD set up [2].

The box around the plenums was designed to simulate the real conditions surrounding the plenums; the bottom was set as a real wall and the 4 side walls and top were set to be at atmospheric pressure. Lids were placed at the end of each of the ducting and the outlets volume flow rate were set to 2002CFM each. The first condition the team decided to confirm was the slot velocities, plenum velocities and duct velocity. The team had calculated that the slot velocities should be 10m/s at the face of the slots, the plenums' velocities should be about half the slot velocity and the ducting velocity should be 3500FPM. Figure 19 shows a cut plot of the velocities through one of the plenums.

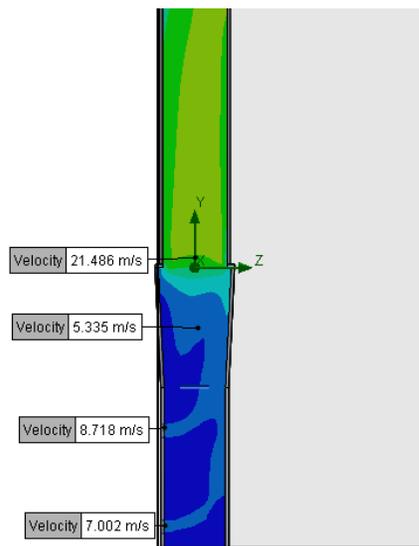


Figure 19: Velocity plenum and ducting [2].

From the Figure 19, we can observe that the slot velocity is faster through the first slot at 8.72m/s and slower through the bottom at 7.00m/s. The faster top slot was predicted by the team and was deemed close enough to 10m/s, especially since the plenum is not balanced in the model. Reducing the area of either slot would lead to faster slot velocities. The plenum velocities drop to 5.34m/s, which concurred with our expectations that the plenum velocity should be half of the slot velocity. Then speed through the ducting was found to be 4232 FPM (21.5m/s), which was higher than expected but the construction of the ducting being straight could account for this discrepancy. The model was constructed using straight pipe when in reality the duct will be made for 5ft of flexible ducting which would reduce the duct velocity.

Once the velocity calculations were confirmed, the team decided to simulate the dust in the room.

In the calculations, the main assumption was that the average dust would be 28.5in away from the plenum. For this reason, the team decided to do a particle study. A plane was modeled 28.5in from the plenums, the plane was the length of the conveyor belt and 3 feet tall. 50 dust particles were placed on this plane to see if the Deluxe Concept could capture these particles. Figure 20 shows the results of this particle study.

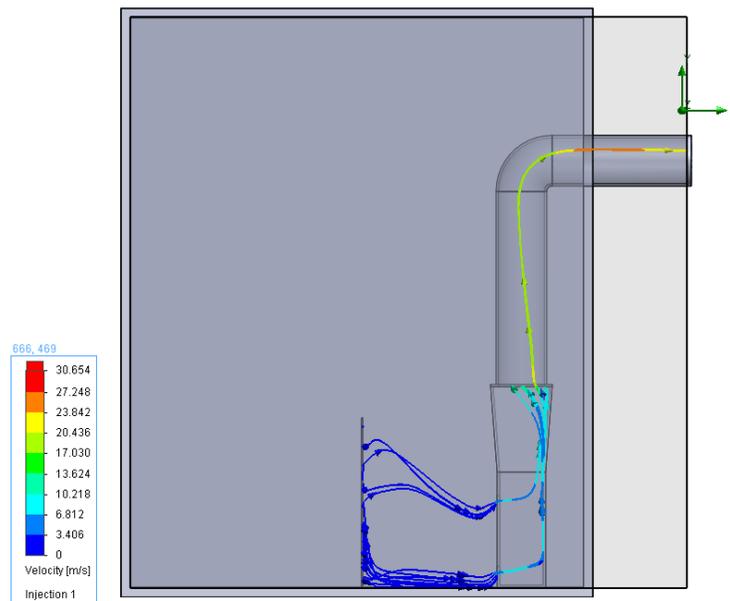


Figure 20: Particle study [2].

The particle study proves that the Deluxe Concept has the capabilities to capture immobile dust 28.5in away. It is important to note that the CFD analysis does not take into consideration that the dust will be moving towards the plenum during to the blow off process. The air nozzle will add additional momentum to the dust particle airflow, which will increase the effectiveness of the slot capturing dynamics. The CFD results indicate that the calculated CFM and slot dimensions will successfully capture stagnant air from the required distance. This confirms the success of the design and ensures the design team that the dust particles will be captured with a high degree of certainty. Once the airflow calculations were confirmed with the CFD, the team could then move onto selecting the proper fan and motor.

## 2.5 Fan Selection

Fans are an important parameter in a dust capturing system as they provide the energy to move the air through the system. Fans used in industrial ventilation systems can be divided into two categories; axial flow fans and centrifugal fans. Axial flow fans allow the air to travel parallel to shaft of the fan and are generally suited to handle large volumes of clean air through a straight ducting [7]. Axial fans are not suitable for dust handling applications and therefore they will not be discussed in detail. For the purpose of design, the team focused on centrifugal fans.

### 2.5.1. Centrifugal Fans

Centrifugal fan consists of an impeller mounted on a rotating shaft that can be used to move air. The air enters the impeller and exits at a 90-degree angle. The kinetic energy of the impeller is transferred to the air moving through the blades of the fan. The fan is enclosed within a housing unit and as the air moves through the housing, it slows down and the kinetic energy of the air is converted into static pressure as the air exits from the fan [7]. The schematic of a centrifugal fan is shown in Figure 21.

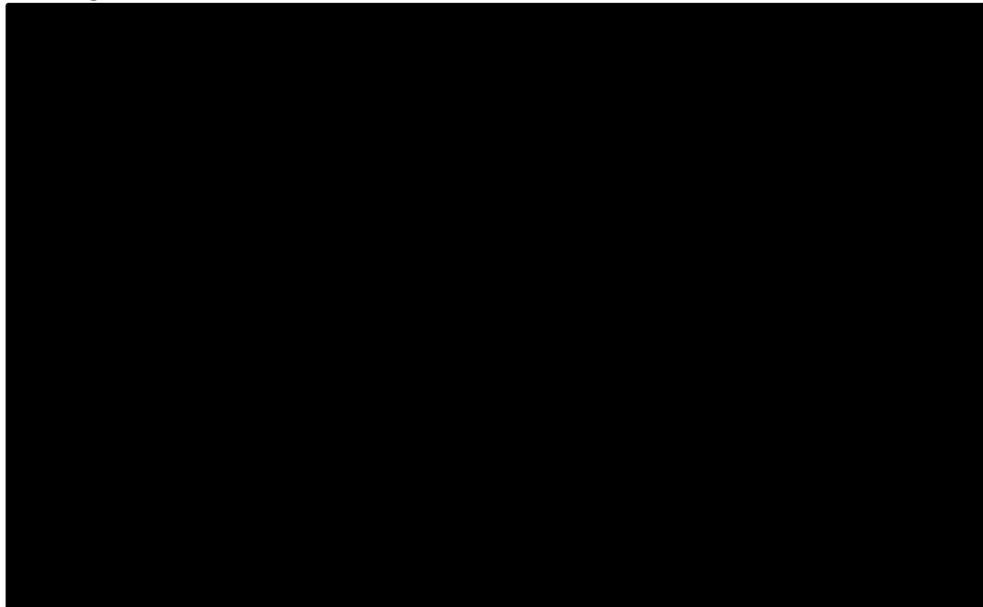


Figure 21: Schematic of a centrifugal fan [12].

The system is enclosed within a casing and the impeller lies in the center of the system and consists of series of fan blades. As the impeller rotates, the air moves through the ducting,

enters the fan inlet, gets caught by the spinning blades of the impeller and is discharged at an angle due to centrifugal force. Centrifugal fans can be divided into three categories depending upon the geometry of the fan blades, backward inclined, forward inclined and radial. The geometry chosen for the design was the backward inclined centrifugal fan.

The backward inclined (BI) fan blades are inclined opposite to the direction of rotation. This allows the fan to run at higher RPM for the same static pressure and volumetric flow rate in comparison to forward inclined fans or radial fans [7]. Figure 22 shows the schematic of a backward inclined centrifugal fan.

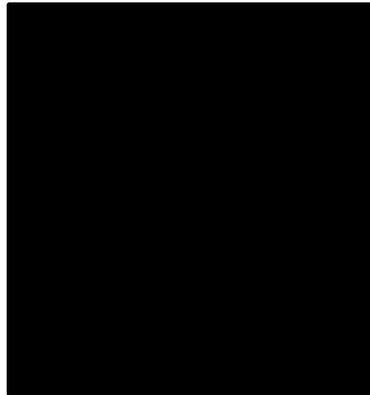


Figure 22: Geometry of an impeller with backward inclined blades [12].

In comparison to other types of fans, BI fans are more efficient and produce less noise. The geometry of the blades is particularly suited to handle light dust/moisture making it suitable for the dust collection applications [7]. The fan inlet unit can be placed against the filter media to avoid to contamination of the blades.

### 2.5.2. Fan Size Criteria

An improper fan selection could result in a fan that could be too large or small for the system. A fan running at a higher speed than required would result in excessive airflow noise, higher maintenance, and energy costs [13]. The following section will describe the criteria that needed to be considered to select the correct fan size that would meet the airflow and static pressure requirements for the dust collection system.

### **Flow rate requirement**

To select the appropriate fans size, the total volumetric flow rate needed to be taken into consideration. This volumetric flow rate indicates the amount of air that the fan will need to move inside the unit. The total volumetric flow rate of 2002 CFM per system, considered during preliminary calculations was used to determine the required fan size.

### **Pressure requirement**

Predicting pressure requirement for the fan was important to avoid a poor system design. Air moving through the hood slots, ducting and filter results in static pressure losses. The total static pressure at the inlet of the fan needed to be taken into consideration to select a correct fan. The total static pressure loss was calculated to be 2.287 "wg (570 Pa).

### **Altitude requirement**

Operating a fan above sea level is similar to a fan operating at temperature greater than the standard room temperature of 70° F (21°C) [14]. To select an appropriate fan size, the altitude above sea level on which the fan will operate, needed to be taken into consideration. A height of 998.02 ft. [15], which is the altitude of town of Morden above sea level, was used to select the correct fan.

There are many different manufacturers of centrifugal fans that can successfully operate at the design parameters indicated. The design team selected the Green Heck company to choose a fan model. Green Heck has a large selection of fans that fit the requirements of the design and offer CAD models and dimensions online through their website. Green Heck also manufactures fan-filter combination units and isolating connectors for hanging equipment from the ceiling which were ideal for this project. Green Heck is supplied through many local distributors and is well established in the industry.

### 2.5.3. Green Heck Model BSQ-140

Based on the requirements from fan selection criteria, Model BSQ-140 by Green Heck manufacturing was chosen for the final design. Figure 23 shows the graph that was used by the team to select the appropriate model. Figure 23 indicates they key components of the fan and motor that are required to produce the system requirements, including RPM and horse power.

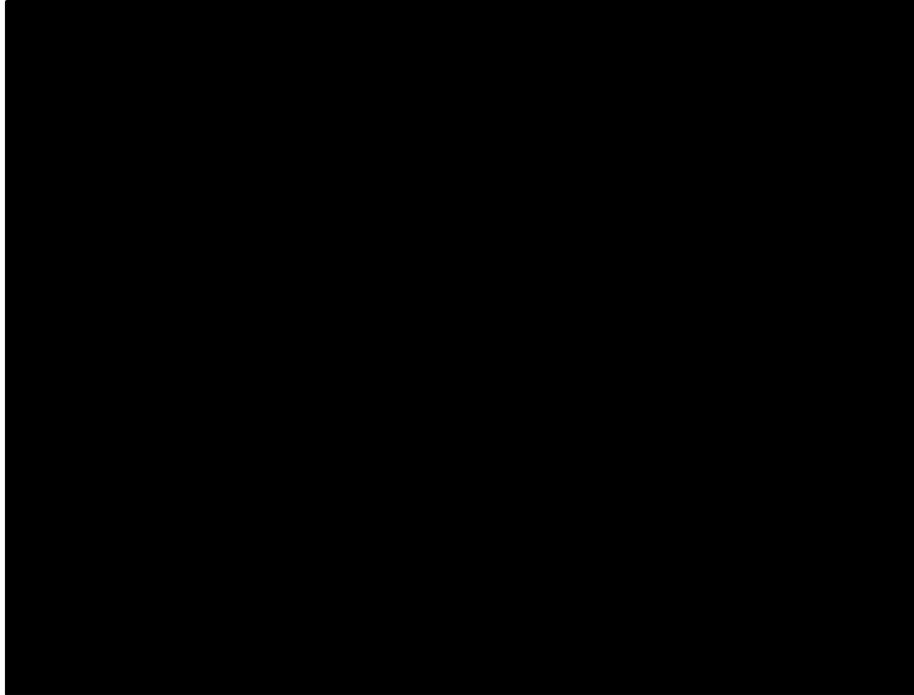


Figure 23: Static pressure vs. CFM [16].

The x and y axis of the graph represent the CFM and static pressure requirements for the fan respectfully. Based on standard conditions, static pressure of 2.287" wg and CFM of 2002, a fan around 1890 RPM and 1.5 hp was be selected. In addition to Figure 23, Green Heck also has an online fan selection tool, which was used to select an exact model based on the CFM, pressure, and altitude requirement. The detailed features of the fan and dimensions are discussed in the following sections.

BSQ model by Green Heck is a backward inclined centrifugal fan that can be used for indoor clean air applications. The housing of the fan is made of rigid structural members and formed galvanized steel. The impeller wheel is statically and dynamically balanced to deliver maximum efficiency. The fan comes with an inlet and discharge duct collars for easy duct connection. The square design of the fan provides a large discharge area in comparison to other types of fans.

The housing comes with removable access panels allowing or easy access to interior components. The fan housing can be configured to discharge air from the left, right or in line with the direction of inlet air. The model BSQ can be configured with or without an additional filter package. Figure 24 shows a schematic of the Model BSQ-140 with no filter box attachment.

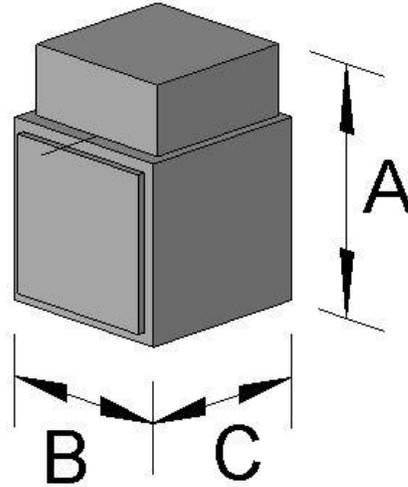


Figure 24: Schematic of Model BSQ-140 [16].

The overall height (A), width (B) and length (C) of the unit is 36.375, 23.125 and 22 inches respectively. The unit comes equipped with a motor size of 1.5 hp and weighs 124 pounds.

The BSQ model comes with an option to add a factory installed filter box at the inlet of the fan to allow for compact and convenient solution. The fan-filter combination unit was a key factor for choosing Green Heck as it eliminates the need to design a separate filter box assembly. Removable side panels are incorporated into the housing to allow for easy replacement of filters. Since a filter box is an optional feature, a filter factor needed to be taken into consideration to allow for filter pressure drop because of filters. Filter factor (F) was calculated using Equation (20).

$$P = F \cdot \left( \frac{CFM}{10000} \right)^2 \quad (20)$$

Where P is the filter pressure drop and F is the filter factor. For Model BSQ-140, filter factor for a 2-inch thick filter was found to be 5.82 using the table provided by the manufacturer. Filter pressure drop (P) were be found by substituting the value of F and CFM in equation (20).

$$P = 5.82 \cdot \left( \frac{2002}{10000} \right)^2 = 0.23 \text{ "wg}$$

$$\text{Total Pressure drop} = 2.287 \text{ "wg} + 0.23 \text{ "wg} = 2.517 \text{ "wg}$$

The total pressure drop of 2.517"wg and CFM of 2002 was used to revise the model selection. The addition of the filter pressure drop required a larger motor and fan, resulting in a higher RPM to move the same volume of air. Figure 25 shows a schematic of model BSQ-140 with a factory installed filter box.

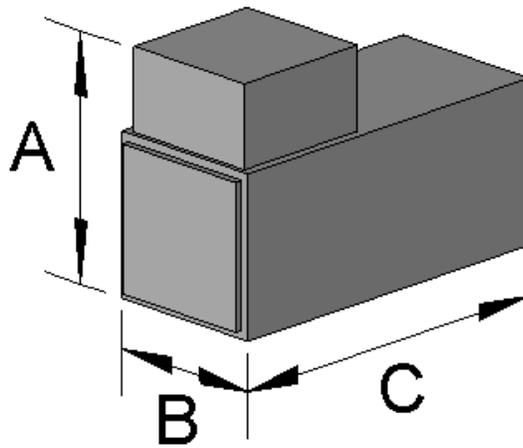


Figure 25: Schematic of BSQ-140 with filter box [16].

The overall height (A), width (B) and length (C) are 36.375, 23.125 and 59.0625 inches respectively. A 2 hp motor was required to meet the total demands of the total static pressure loss and the CFM of 2002. The unit weighs 132 pounds, a schematic of the centrifugal-filter combination is shown in Figure 26.



Figure 26: Centrifugal-filter combination [16].

The BSQ-140 system will provide the required 2002 CFM at a reasonable size and cost. The flexible ducting will connect to a 90-degree elbow, which is connected on the other side to ridged metal ducting. The metal ducting then tapers to the larger filter end of the model BSQ-140. The filter section is made up of two MERV 8 filters capable of collecting particles less than 10 microns. Figure 27 shows an image 20"x 25"x 2" MERV-8 filter. The pleated manufacturing creates a larger surface area and more efficient particle filtration.



Figure 27: MERV 8 filter [17].

#### **2.5.4. Fan Mounting**

The space above the aisle way and conveyor belt area was available for suspending the system equipment. The fan will be hung from the ceiling via a 7x19 strand aircraft cables. An aircraft cable is a galvanized wire rope made of forged steel. The 7 x 19 specification refers to the cable having 7 strands and 19 wires in each strand. This arrangement makes the cable more flexible and strongest out of all other arrangements [18]. The working load limit for the cable is 7000 lb., surpassing the team's requirement of 132 pounds. The fan will require four cables attached at each corner for stability. Figure 28 shows the picture of 7x19 strand aircraft cable.

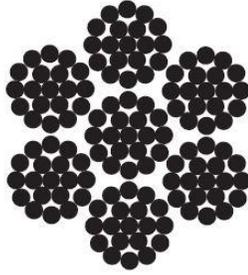


Figure 28: 7x19 strand aircraft cable [19].

To reduce the vibrations and shock because of moving parts, the team decided to use isolation kits with either spring or neoprene isolators provided by Green Heck. The isolators are attached to the bracket that can be mounted on corners edges of the fan. The isolators and the brackets are sized to match the weight of the specific fan size. Figure 29 shows a schematic of a hanging neoprene isolator.

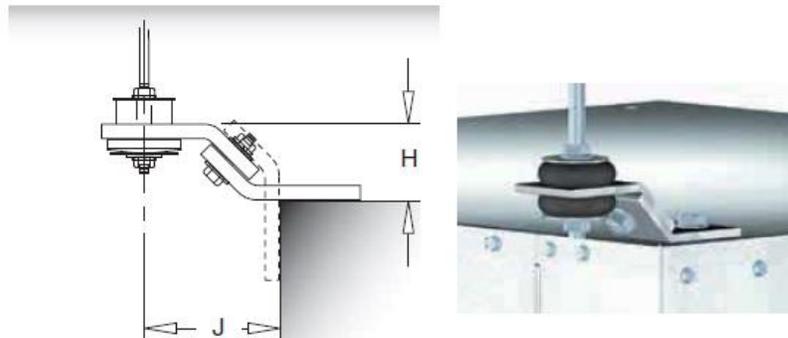


Figure 29: Hanging neoprene isolator [16].

For model BSQ-140, the distance (J), from the side edge of the fan housing to the center of neoprene isolator is specified as 2 inches and the height (H) from the top edge of the fan housing to the top edge of the bracket is 1.375 inches. The bracket will be attached to the aircraft cable for easy suspension.

### 3.0 Complete System – Double Hood Unit

The final detailed design consists of two identical units that span the length of the conveyor belt. For each unit, the design includes a table with four large, six-inch locking wheels, which allow for mobility as well as sturdy support when operating. The mobile table supports the capture hood and allows for access to the far side of the conveyor belt, if required. The table is constructed from 2x2 inch square steel tubes welded together with gussets for structural integrity. The two units are shown in Figure 30.

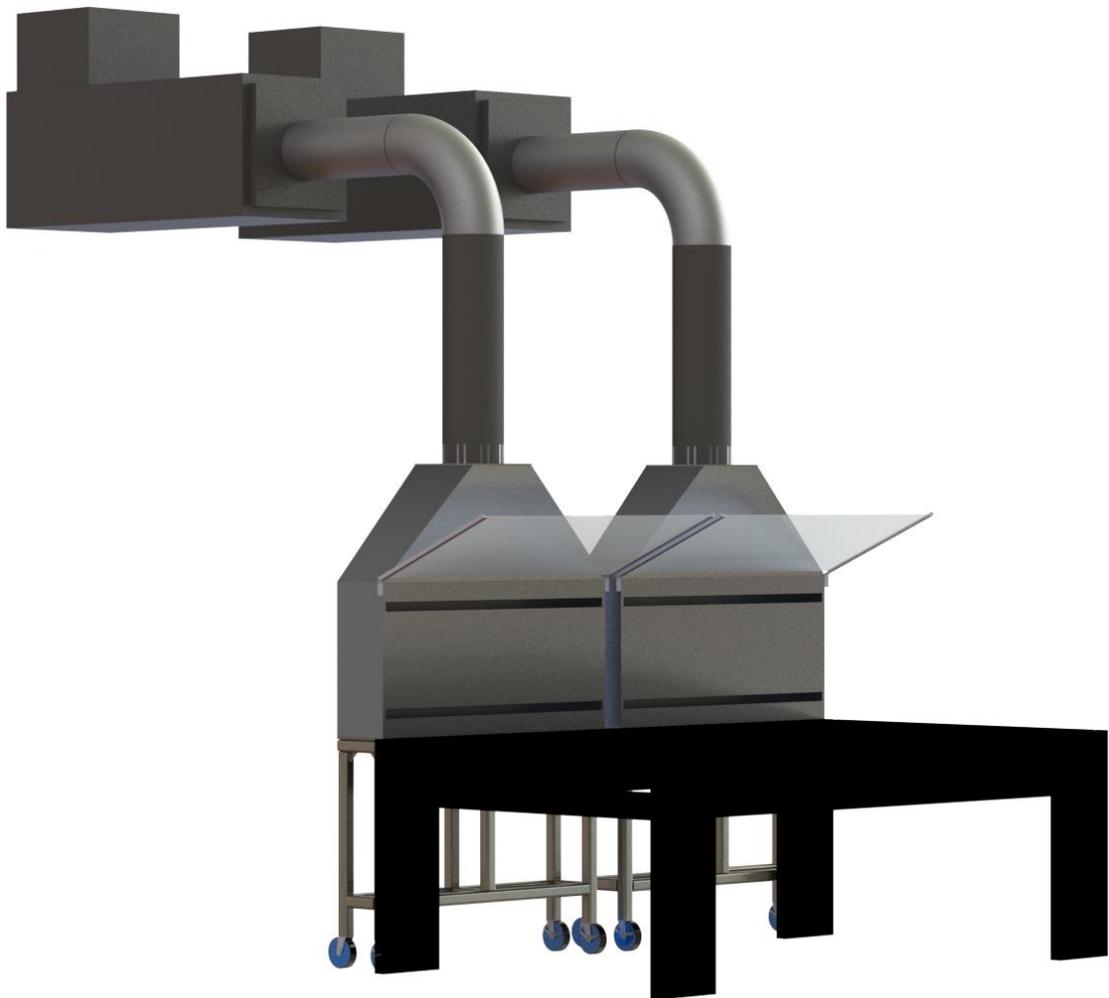


Figure 30: Rendered image of system [2].

The capture hoods are composed of 1/8 in sheet metal with bent flanges to allow for easy manufacturing and welding. Each unit contains two slots, one at the bottom and one at the top of the face fronting the conveyor belt. Adjustable Plexiglas baffles increase the effectiveness of the hood design.

The tapered hood section is also composed of 1/8 in sheet metal, which contours to the 10in diameter duct connection. Commercial duct sealer is recommended for all duct connection points to ensure the system is completely closed. The addition of a flexible ducting section (indicated in black) will connect the top of the taper to the 90-degree elbow suspended from the ceiling. The flexible ducts along with the caster wheels allow for access to all sides of the conveyor surface. The clients required complete access to all sides of the conveyor system.

The backward inclined centrifugal fan and motor is shown at the top of Figure 30. The BSQ-140 model is composed of the backward inclined fan, a 2 hp motor and a filter box manufactured by Green Heck. The filter box holds two 2 in Merv 8 pleated filters. The parameters that influenced the fan selection are the 2002 CFM and 2.517 "wg for each unit. Ten inch metal ducting connects the elbow to the filter side of the model BSQ-140. The fan-filter combo is suspended by neoprene isolating hangers to reduce vibrations in the suspension cables.

## 4.0 Bill of Materials

The completed blow off process dust capture system was divided into two identical separate units to maintain a simple design and reduced the fan size and motor requirements. The cost of the components for each unit as well as the bill of material is described in the following section. The final detailed design material cost and manufacturing of the hood, ducting, filters, fan and motor are outlined in TABLE XII.

TABLE XII: SYSTEM COST [2]

Components	Estimated cost
Capture hood (manufacturing cost)	\$410.00
Support table (manufacturing cost)	\$750.00
Locking caster wheels	\$100.96 (set of 4)
Plexiglas baffle and hinges	\$16.00 (plexiglas 4x6 sheet) \$16.00 (custom hinges x2)
Suspension cables and connections	\$100.00 (cable wire 100 ft) \$45.00 (grippers \$4.50 each x10)
10in Ducting 22 gauge elbow	\$62.00
10in Ducting 22 gauge	\$19.00 (4 feet)
10in Flexible urethane ducting	\$505.00 (25 ft length)
Duct sealer	\$38.00 (gallon)
BSQ-140 (Fan, motor and filter system)	\$2398.30 (1.35 exchange)
Merv 8 filters	\$96.40 (2 filters)
<b>Total per unit</b>	<b>\$4556.66 + tax and installation</b>
<b>Total for both units</b>	<b>\$9113.32 + tax and installation</b>

The system costs do not include the cost of installation for any of the components or equipment. Additional costs associated with the design include the operating costs of the BSQ-140 motor. The annual operating costs are approximately \$373 for each fan [16]. The client did not indicate the budget for the design. However, the design team feels the cost of the system is reasonable with similar industry systems. The main costs of the design relate to the BSQ-140 unit and the manufacturing of the capture hood and table.

## 5.0 Recommendation and Conclusion

Decor Cabinet Company tasked the design team to develop a solution to capture the fine sealer dust blown into the ambient air after the blow off process. The solution would help alleviate health concerns for the employees and eliminate rework on other parts in progress because of the suspended dust in the air. The design team went through a two-phase design process to analytically determine the most suitable design. The team met with the appropriate stakeholders at Decor Cabinets and determined a list of needs for the project. The needs were then developed into target specifications, which were used to brainstorm concepts to achieve the objective. A rigorous concept generation and selection process was followed to weigh the pros and cons of each concept and come up with the deluxe concept. This process led the team into final detailed design phase in which the specifications for the Deluxe Concept, chosen from the concept development phase were finalized.

The dust capture system was divided into two separate units for ease of manufacturing and allow the use of smaller fans and motors for the units. A hood with slot geometry was finalized based on the low CFM and static pressure requirements. The capture units contain two slots to capture dust from the table surface and above the surface. The total airflow rate required for one unit was found to be 2002 CFM, based on the airflow calculations. Total pressure losses based on geometry of hood and ducting were calculated to be 2.517 "wg including filter losses. Parameters such as pressure losses, CFM requirement and altitude were used to select the appropriate fan. The Green Heck BSQ-140, backward centrifugal fan-filter combination was selected to produce the required pressure and CFM requirement for each unit. The total cost for both units was estimated to be \$9113.32 plus taxes and installation.

The key features of the capture unit include locking caster wheels and a flexible ducting section for slight mobility and access to all sides of the conveyor belt. The top portion of the hood has a hinged Plexiglas baffle to contain swirling dust projected upwards from the conveyor surface. Since, space is limited, the equipment is suspend from the ceiling using an 7x19 strand aircraft cables. Each fan unit weighs 132 pounds and utilizes neoprene isolating kits on each corner to reduce vibrational effects because of moving parts.

It is also recommended to potentially have two fans placed on the opposite side of the dust capturing units and directed towards the conveyor belt system from behind the operator. The

dust will be directed towards the capturing units creating a push-pull system, which increases the likelihood of capturing the majority of the sealer dust.

It would be ideal if the product could be tested and compared against the current air quality standards of the facility to check for improvements. Decor Cabinets had indicated they had performed an air quality analysis however did not provide the data for the design process. The design team also recommends performing a focus group for employees working near the affected area that could refine and improve the design further. A training session of the features of the design would be required to ensure the unit is operated correctly.

Overall, the project was a success and the design team was able to complete all the required tasks assigned by Decor Cabinets. The deliverables indicated in the beginning of the design process that were achieved include an implementation ready design, assembly and part drawing for the unit and structure including bill of materials, component specifications with pricing and information on the supplier and the project report.

## 6.0 Works Cited

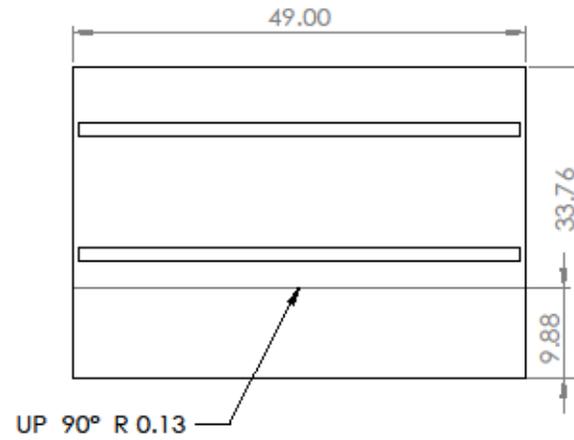
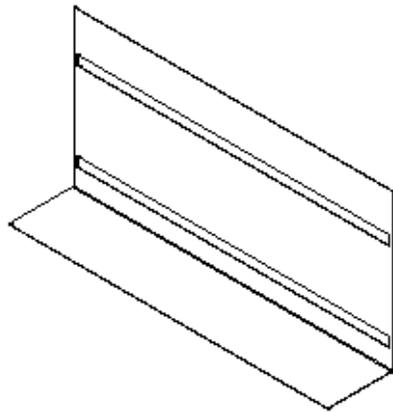
- [1] Decor Cabinet Company, "About Us: Decor Cabinet Company," [Online]. Available: <http://decorcabinets.com/history>. [Accessed 26 September 2016].
- [2] Team 3, "Consulting Group," Winnipeg, 2016.
- [3] R. Burbano, Interviewee, *Information on the problem*. [Interview]. 15 September 2016.
- [4] ASHRAE, "Industrial Local Exhaust Systems," *ASHRAE Applications Handbook*, 1999.
- [5] F. C. McQuiston, J. D. Parker and J. D. Spitler, Heating, Ventilating, and Air Conditioning 6th Edition, USA: John Wiley & Sons, Inc., 2005.
- [6] P. Breyse and L. S. J. Peter, "The Johns Hopkins University," 2006. [Online]. Available: <http://ocw.jhsph.edu/courses/PrinciplesIndustrialHygiene/PDFs/Lecture12.pdf>. [Accessed 16 November 2016].
- [7] ACGIH, Industrial ventilation- A manual of recommended practice for design, Cincinnati, Ohio: Signature Publications, 2016.
- [8] ACGIH, "Industrial Ventilation," *A Manual of Recommended Practice*, 1998.
- [9] "The Engineering Toolbox," [Online]. Available: <http://www.engineeringtoolbox.com>.
- [10] P. J. Pritchard, Introduction to Fluid Mechanics, Hoboken, NJ: John Wiley & Sons, Inc, 2011.
- [11] Quietflex Manufacturing Co., LP, "Quietflex," [Online]. Available: <http://www.quietflex.com/uninsulated-flex-connector/>. [Accessed 10 10 2016].
- [12] CIBSE Journal, "Module 35: Fans for ducted ventilation systems," [Online]. Available: <http://www.cibsejournal.com/cpd/modules/2011-12/>. [Accessed 1 12 2016].
- [13] M. Stevens, "Fan performance," AMCA INTERNATIONAL, ILLINOIS.
- [14] The newyork blower company, "Engineering letter," [Online]. Available: <http://www.nyb.com/pdf/Catalog/Letters/EL-04.pdf>. [Accessed 22 11 2016].

- [15] "Find your altitude," [Online]. Available: [http://www.altitude-maps.com/city/36\\_491,Morden,Manitoba,Canada](http://www.altitude-maps.com/city/36_491,Morden,Manitoba,Canada). [Accessed 22 11 2016].
- [16] Greenheck, "Centrifugal inline fans. Model SQ and BSQ. Direct and belt drive.," May 2013. [Online]. Available: [http://www.greenheck.com/media/pdf/catalogs/SQBSQ\\_catalog.pdf](http://www.greenheck.com/media/pdf/catalogs/SQBSQ_catalog.pdf). [Accessed 1 12 2016].
- [17] Home depot, "Flanders PrecisionAire," [Online]. Available: <http://www.homedepot.com/p/Flanders-PrecisionAire-20-in-x-25-in-x-2-in-Prepleat-40-Air-Filter-Case-of-12-80055-022025/203144035>. [Accessed 4 12 2016].
- [18] Bergen cable technology, "Cable 101," Bergen cable technology, [Online]. Available: [http://www.bergencable.com/technology/technology\\_cable101.html](http://www.bergencable.com/technology/technology_cable101.html). [Accessed 27 11 2016].
- [19] Lexco cable mfg., "7 x 19 Galvanized aircraft cable," Lexco, [Online]. Available: <http://catalog.lexcocable.com/viewitems/cable-stainless-steel-galvanized/7-x-19-galvanized-aircraft-cable?>. [Accessed 27 11 2016].
- [20] K. R. Mobley, "Plant Engineer's Handbook," Butterworth-Heinemann, Boston, 2001.
- [21] "Pleated Air Filter," Direct Air Filter, 2016. [Online]. Available: <https://directairfilter.com/>. [Accessed 27 October 2016].
- [22] M. Yost, "University of Washington School of Public Health and Community Medicine," 2012. [Online]. Available: [http://courses.washington.edu/envh557/Class%20Documents/9-GC\\_HoodDesignandEntryEffects.pdf](http://courses.washington.edu/envh557/Class%20Documents/9-GC_HoodDesignandEntryEffects.pdf). [Accessed 16 November 2016].

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SOLIDWORKS Educational Product. For Instructional Use Only

SEALER DUST COLLECTION UNIT				TEAM 3	
UNLESS OTHERWISE SPECIFIED: USE #1.01 IN FOR TWO DECIMAL PLACES USE #1.000 FOR THREE DECIMAL PLACES				TITLE:	
MATERIAL 1/8" GALVANIZED STEEL	NAME	DATE	SIZE <b>A</b>	Plenum Face	REV <b>0</b>
FINISH AS MATERIAL	DRAWN AA	11/28/14	SCALE: 1:15		SHEET 1 OF 1
DO NOT SCALE DRAWING	CHECKED				

Figure A - 1: Plenum face [2].

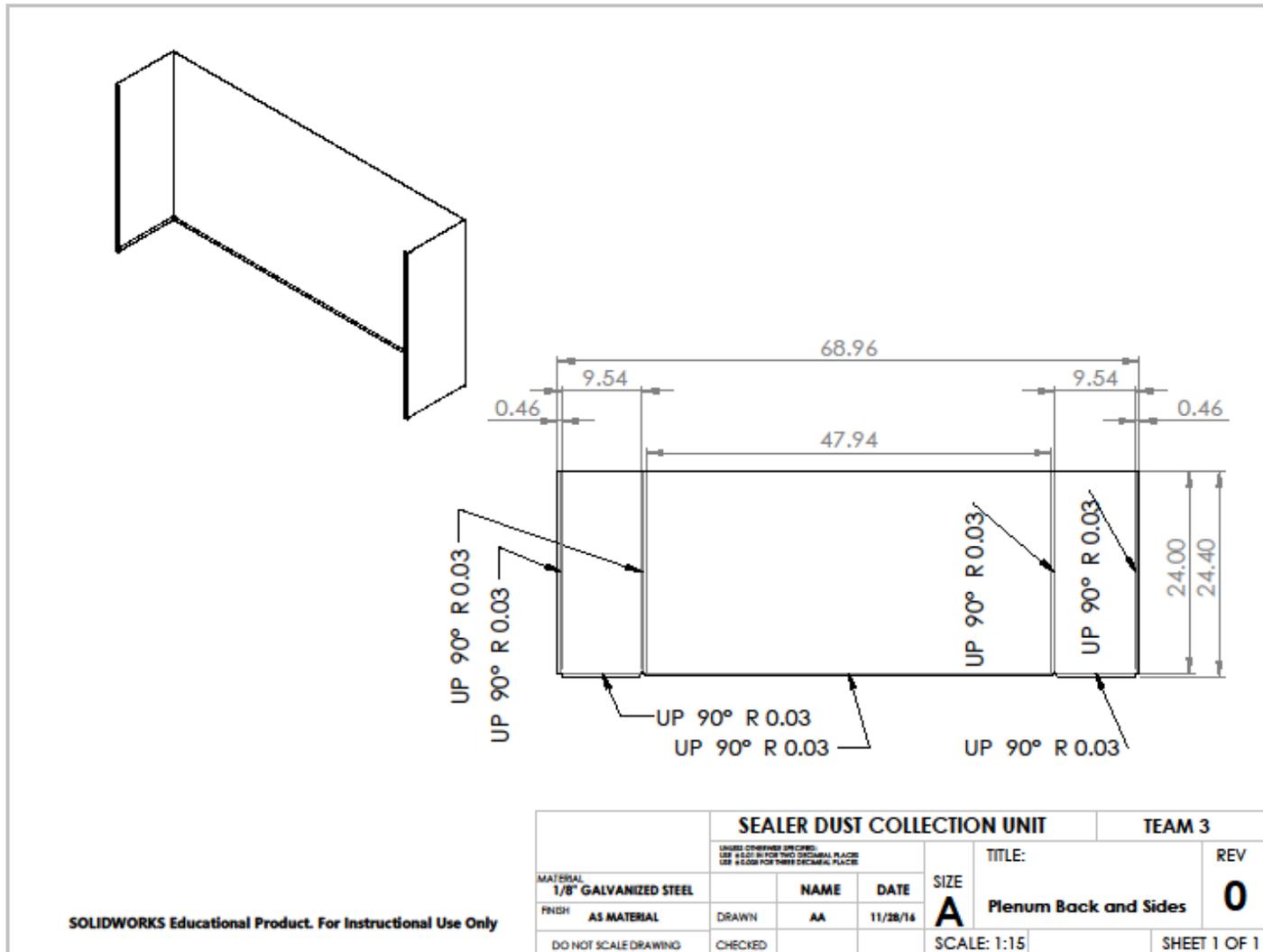


Figure A - 2: Plenum back and sides [2].

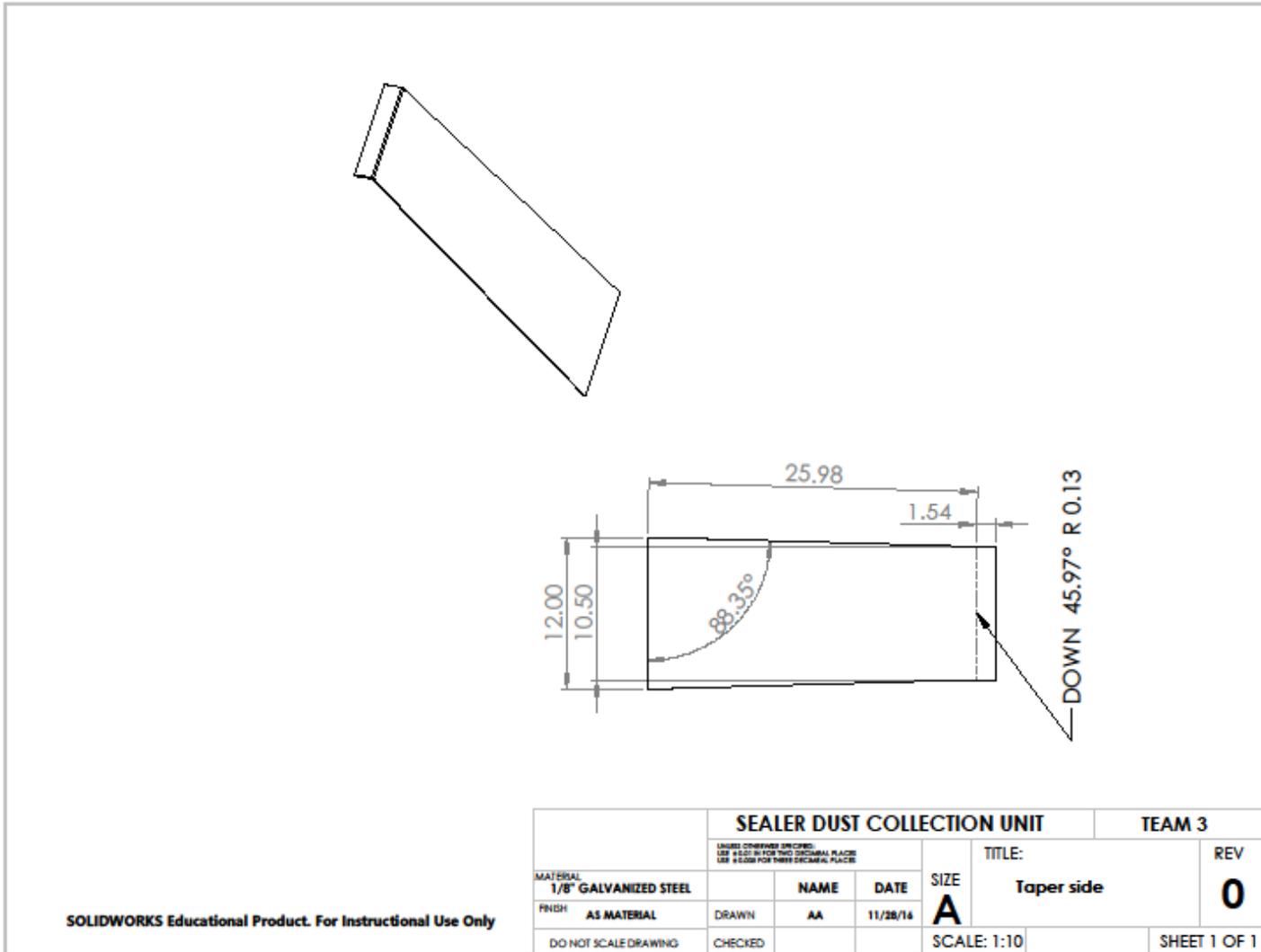


Figure A - 3: Taper side [2].

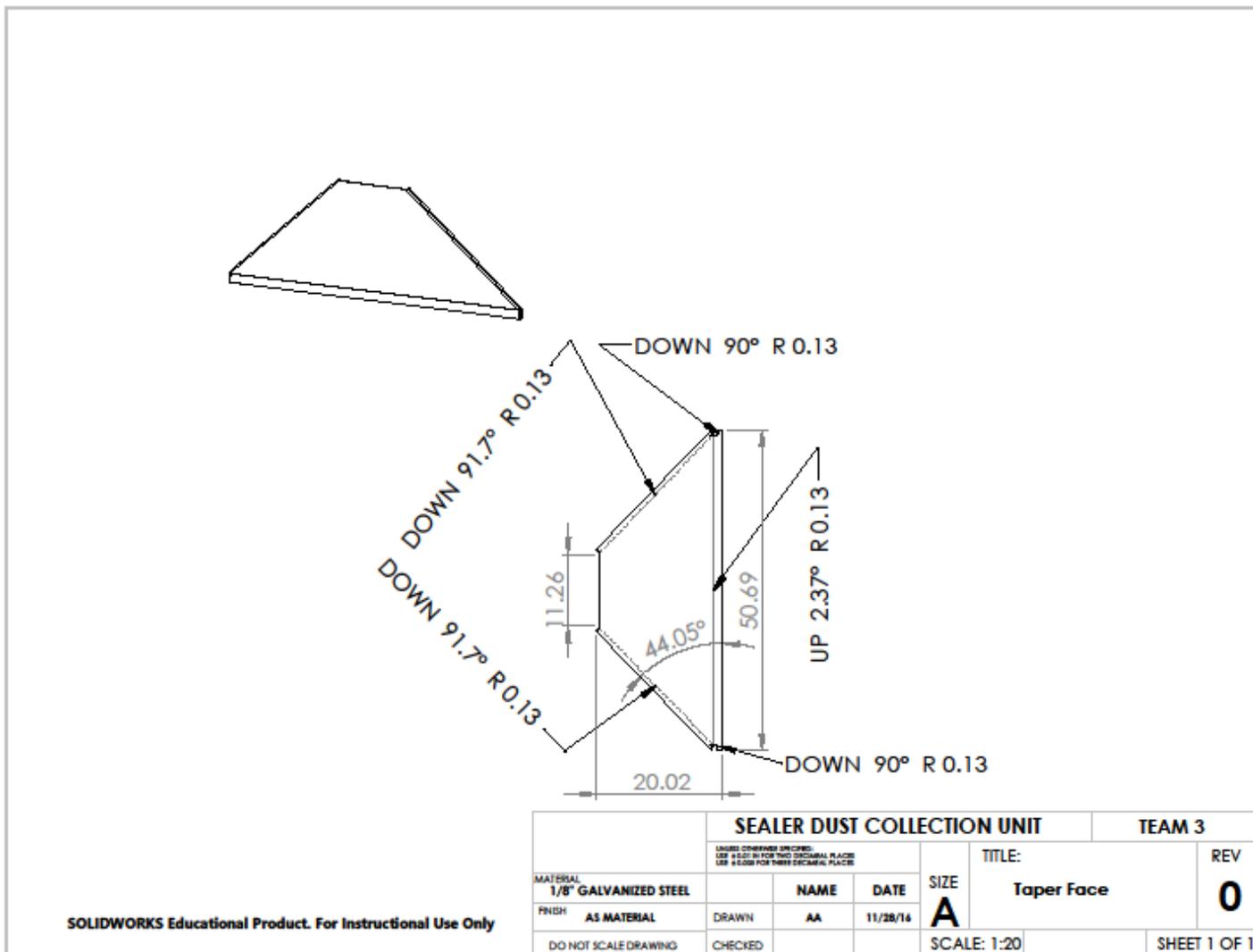


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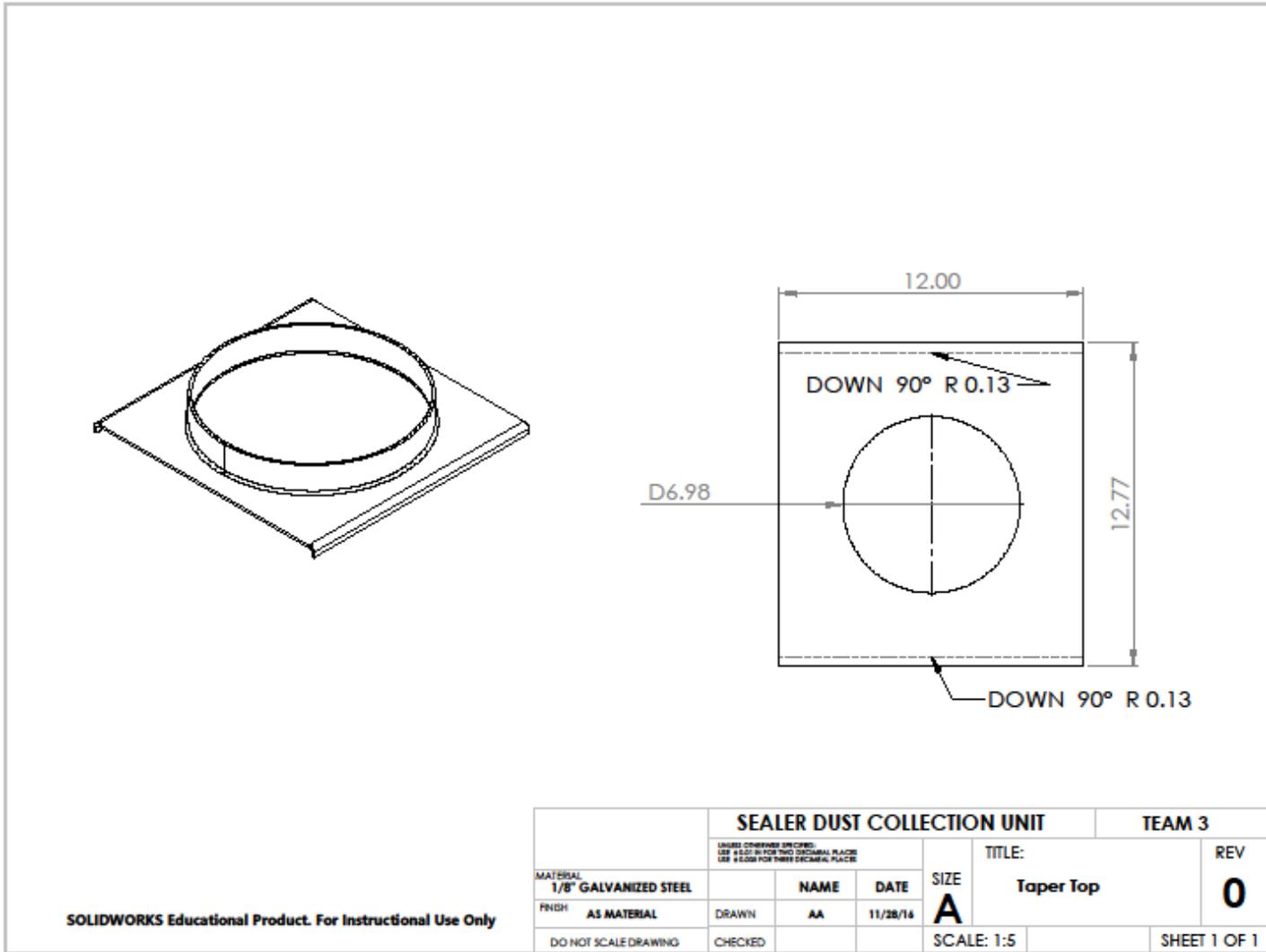


Figure A - 5: Taper top [2].

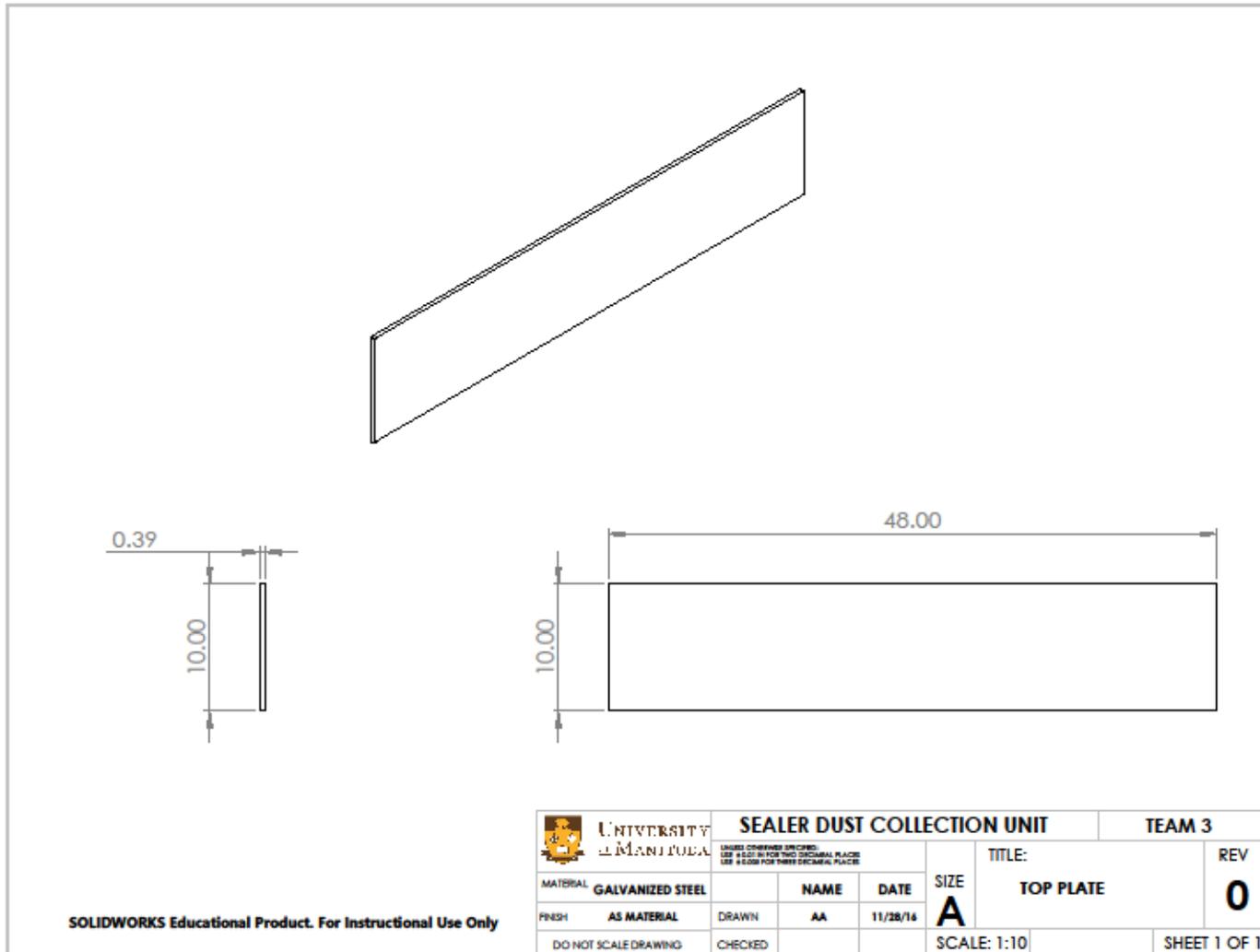


Figure A - 6: Top plate [2].

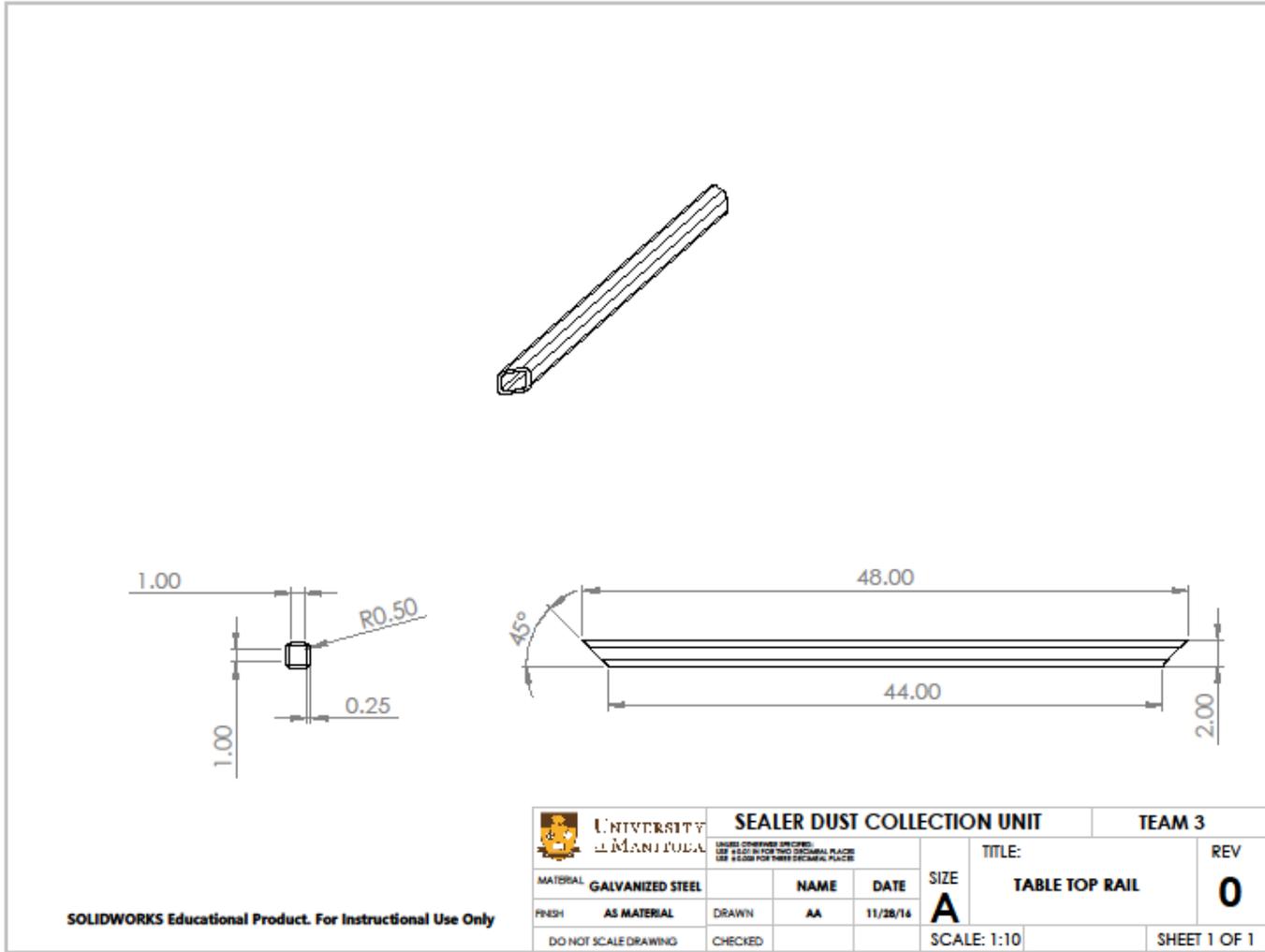


Figure A - 7: Table top rail [2].

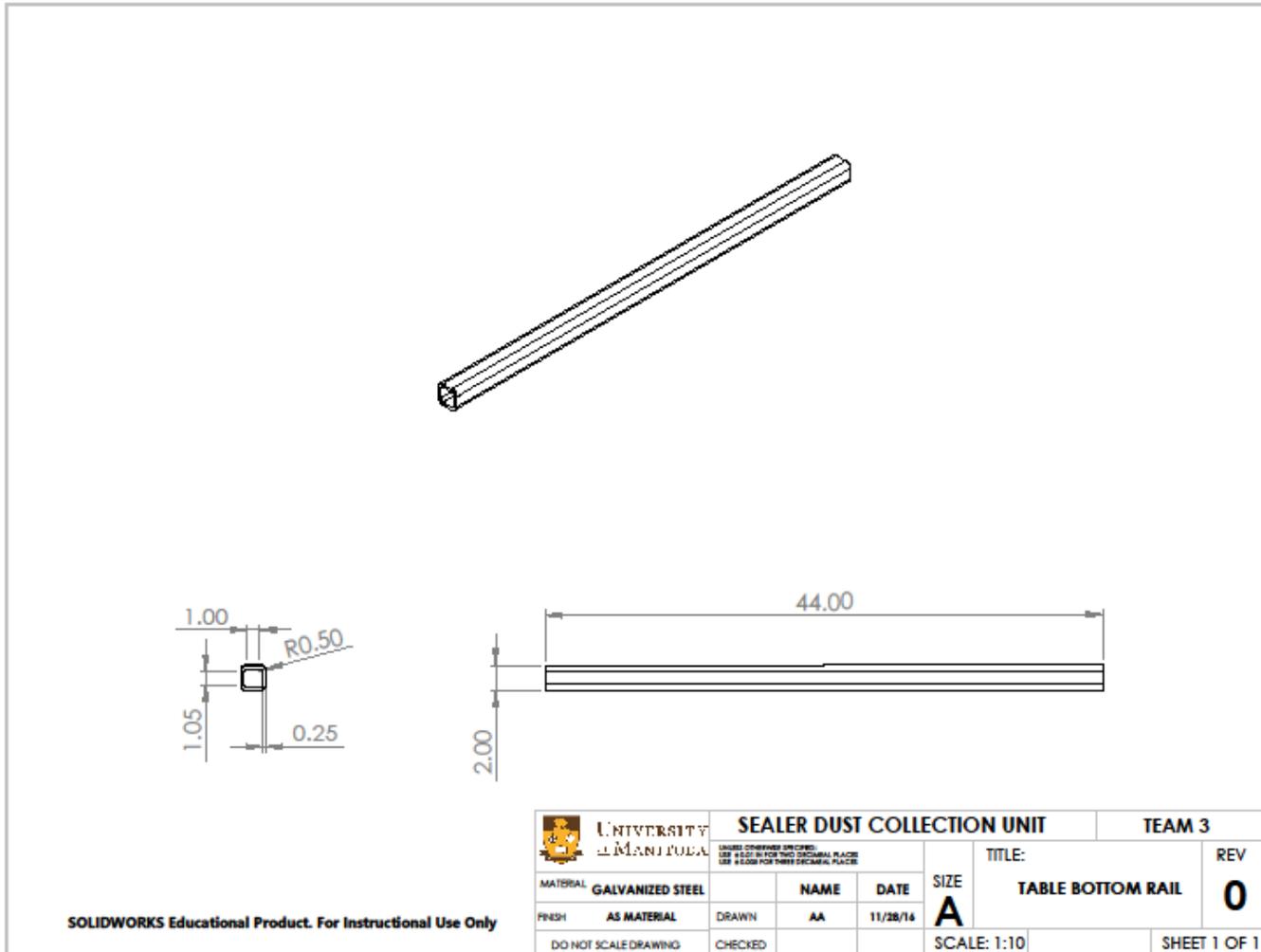


Figure A - 8: Table bottom rail [2].

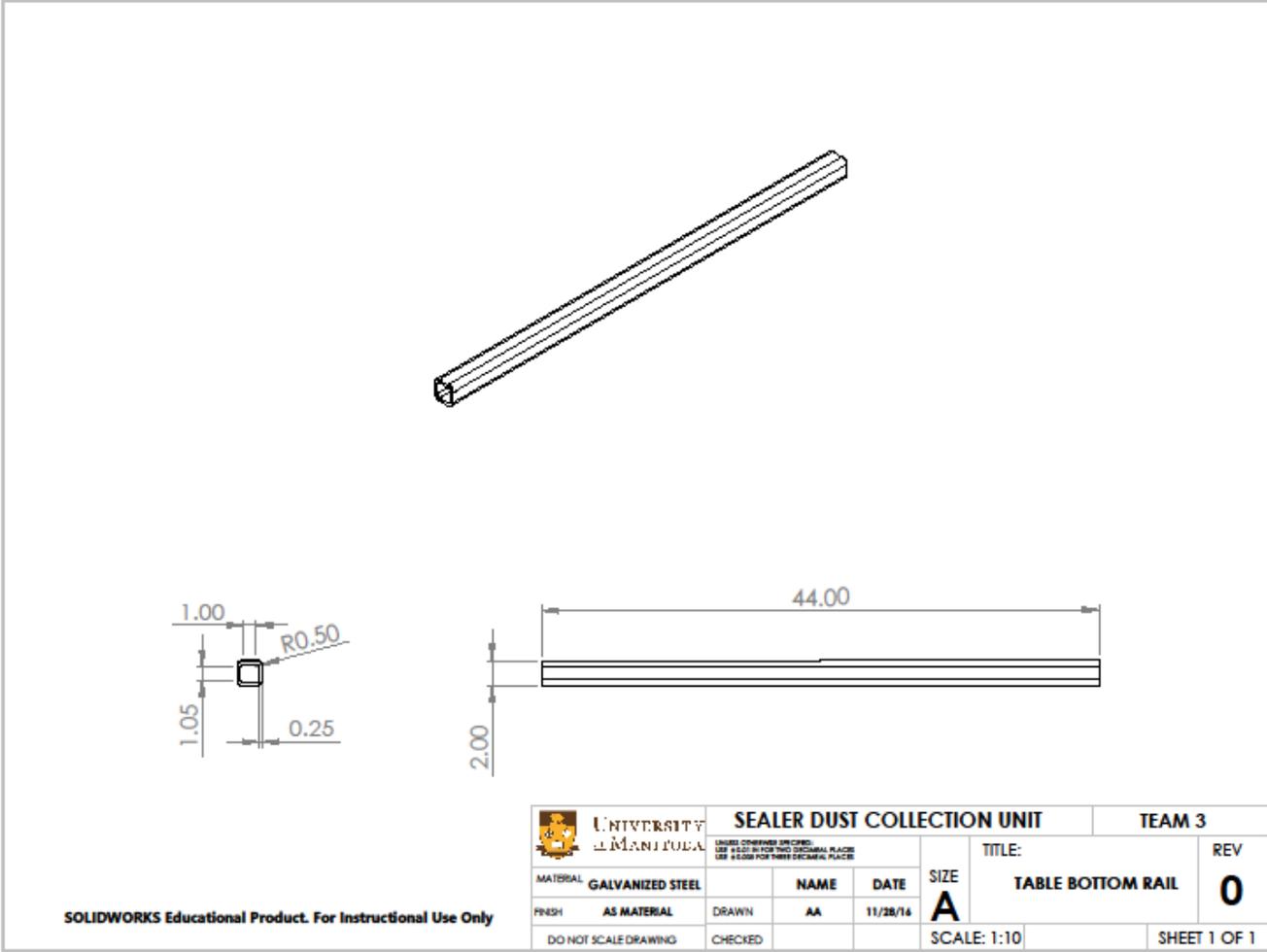


Figure A - 9: Table side rail [2].

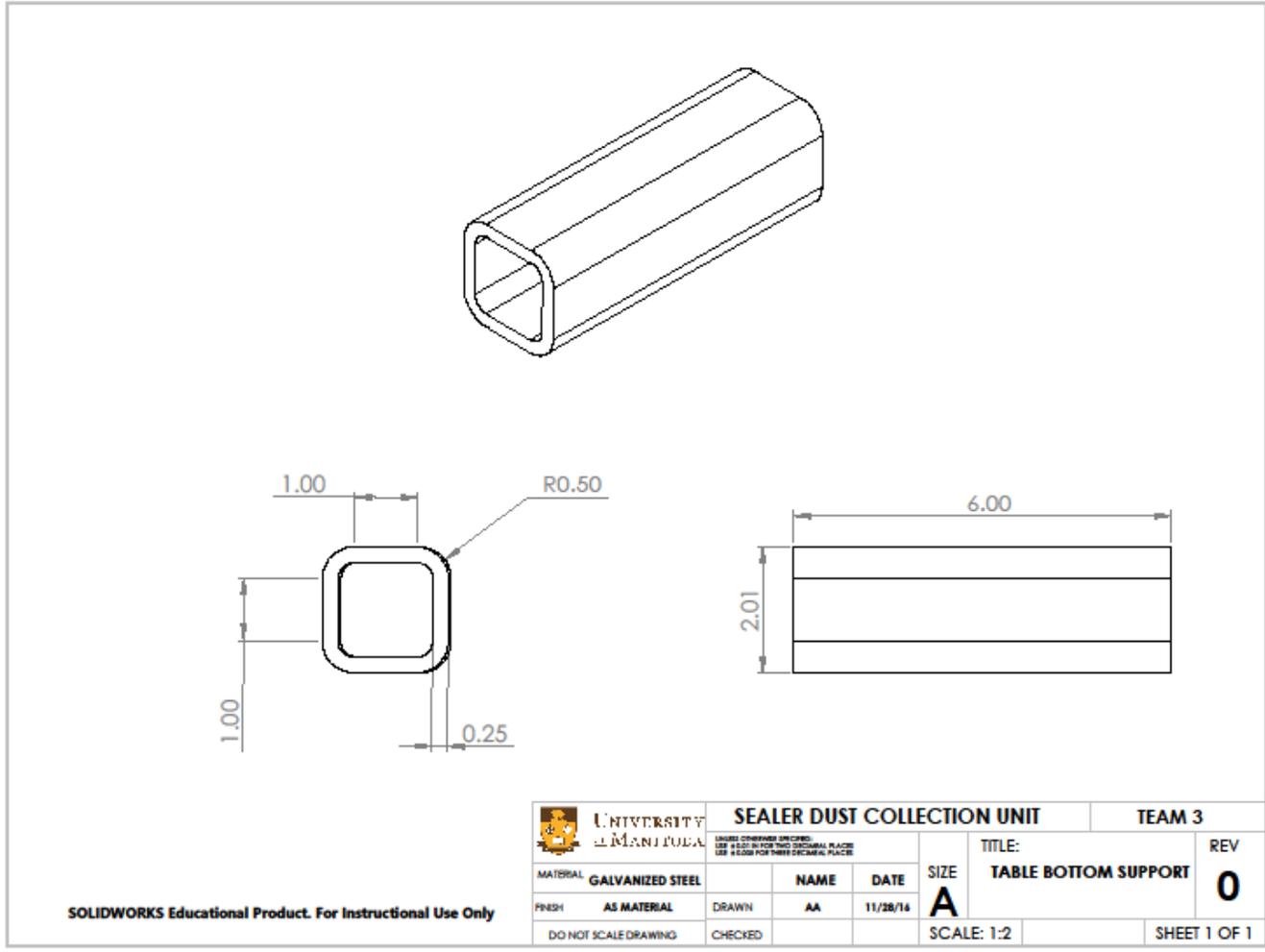


Figure A - 10: Table bottom support [2].

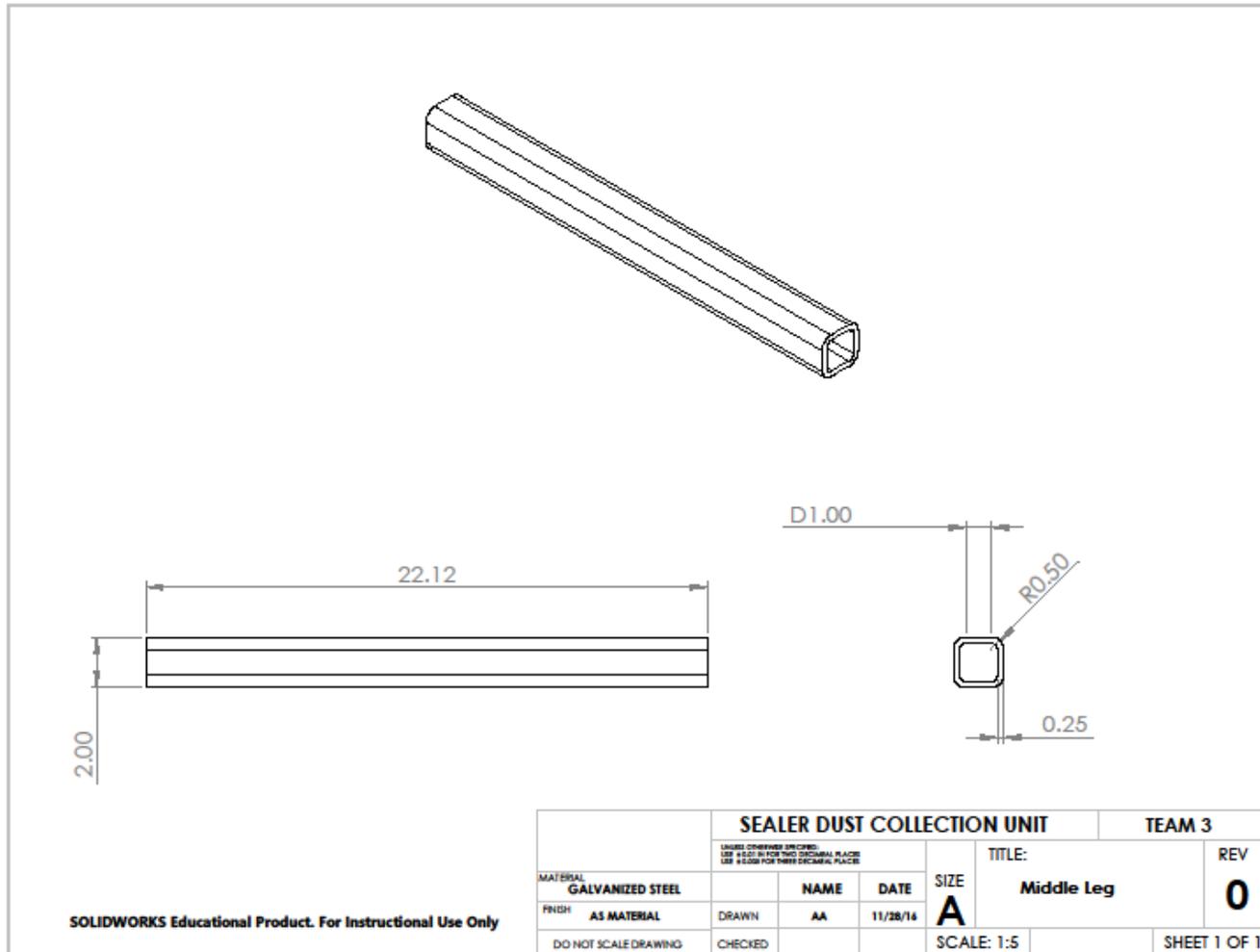


Figure A - 11: Middle leg [2].

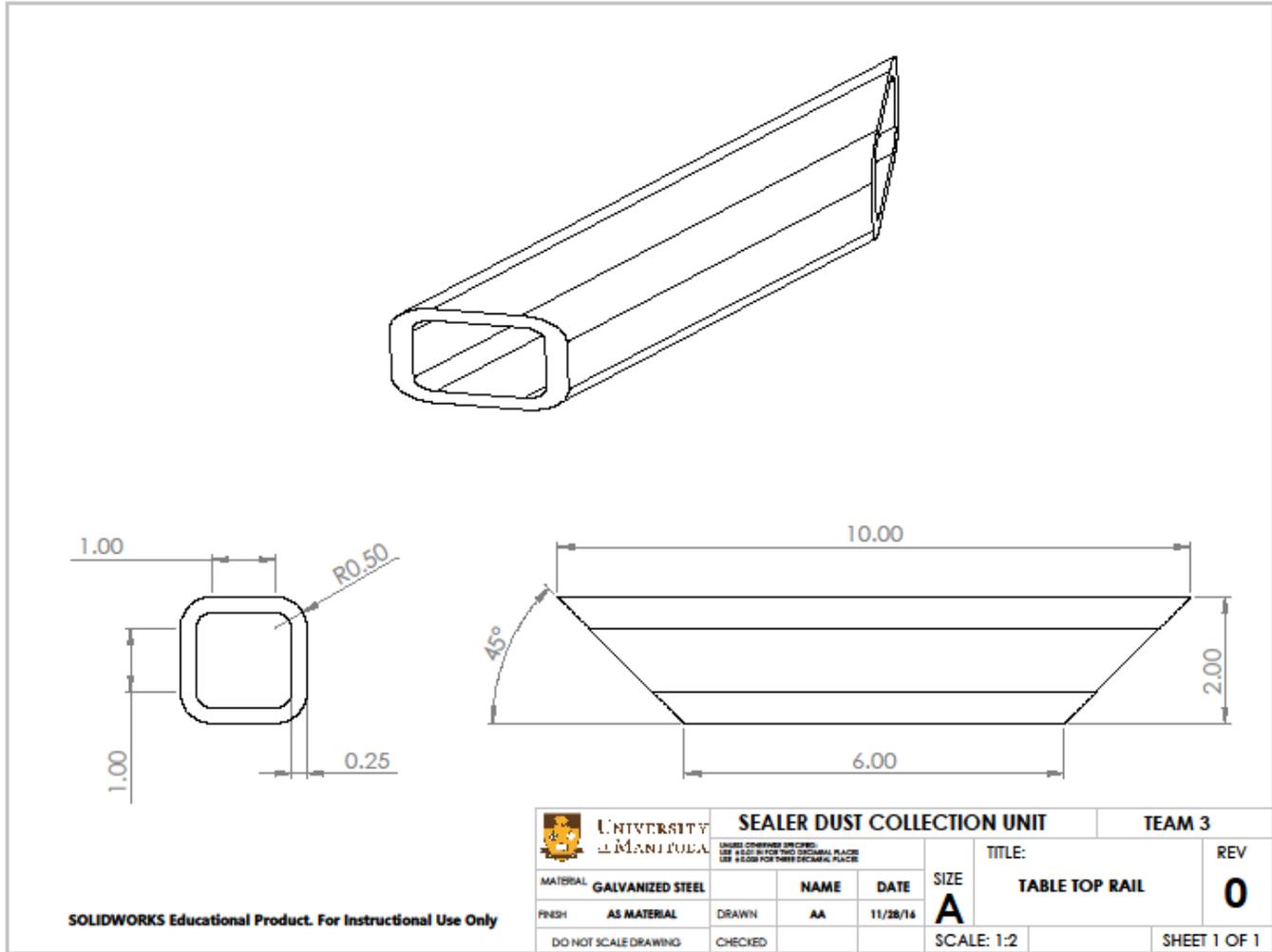


Figure A - 12: Table support [2].

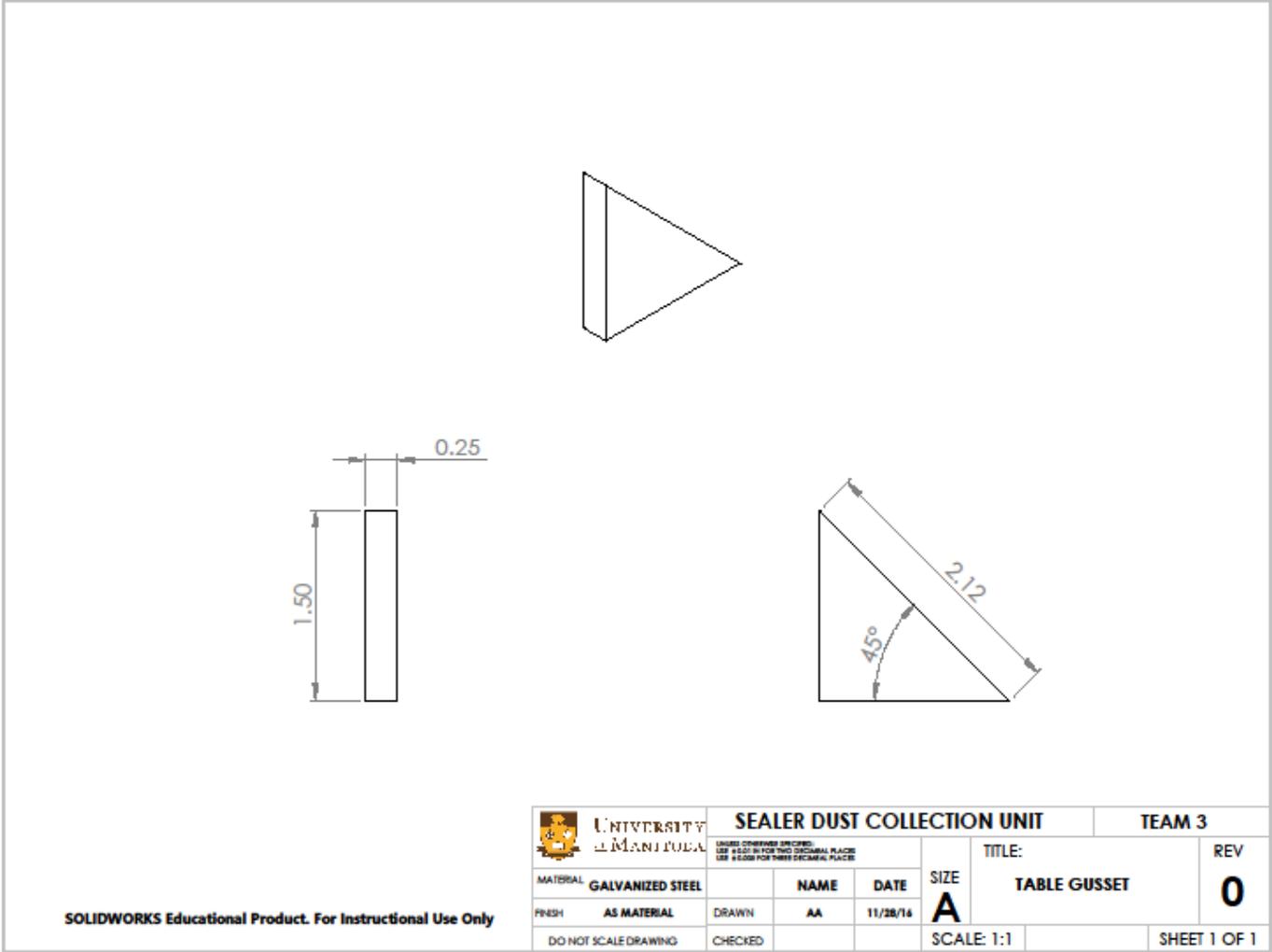


Figure A - 13: Table gusset [2].

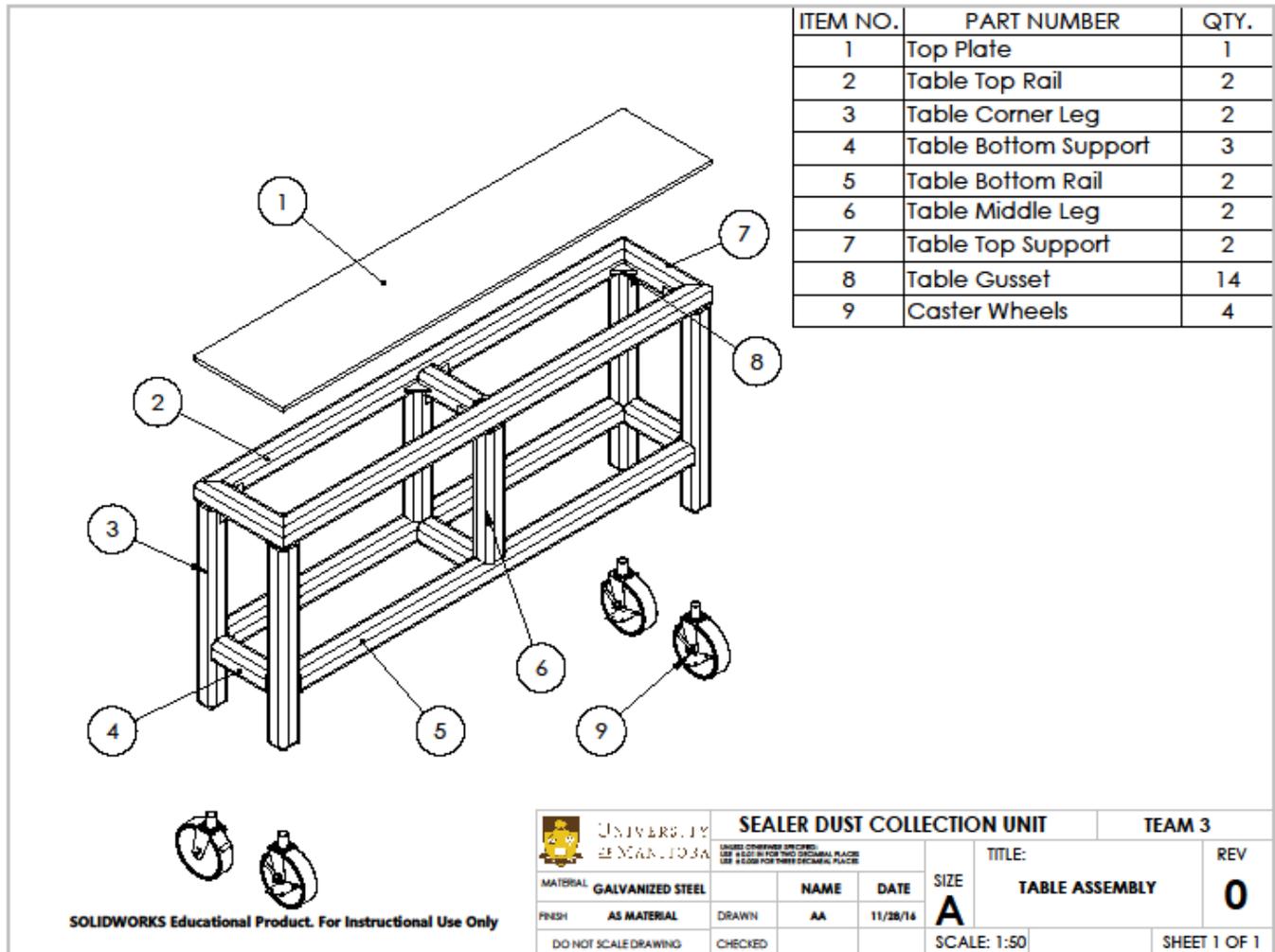


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## **Appendix B: Additional Research**

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## **1.0 Research**

In order to better facilitate the concept generation process, the design team had to first become familiar with general ventilation equipment. More specifically, the target specification parameters identified in the previous section had to be researched and understood. The team divided the research into initial background information followed by more specific detailed research.

### **1.1 Initial Research**

The research process began with a site visit to Decor Cabinets where the team was introduced to the procedures and processes involved with the design. The initial site visit also introduced the team to different filtration and collection systems that were being utilized in other departments of the facility. The other areas, however, did not have the same constraints and limitations that the blow off process demanded, so a different design is necessary. The majority of the sanding stations in the facility utilize downdraft techniques which will not work for the blow off process because of the conveyer belt system. The spraying procedures used in the facility are comprised of large booths which required a significant amount of space and large volumetric flow rates, both of which are not possible for the blow off process design. The site visit gave a clear understanding of the design and allowed the team to visualize possible solutions. The site visit also allowed the team to have a meaningful discussion with the stakeholders involved at Decor Cabinets. The discussions outlined the cycle time requirements and the loading techniques for the components on the conveyer belt. The cycle time and loading process are important parameters to consider for the concept designs phase.

### **1.2 Detailed Research**

After the team became familiar with the design space, the next step was to perform online research and become more familiar with the technical aspects of a dust capturing system. The information gathered during this phase of the design was important in order to complete the concept generation and selection process. The detailed researched topics include dust collection systems, separation techniques and fan selection and flow path assistance.

### 1.2.1. Dust Collection Systems

There are typically two types of dust collection techniques used in industry, which include local and general exhaust systems [8]. Local exhaust systems are designed for a specific type of process with a specific type of contaminant in single location. General exhaust systems are designed for multiple processes with multiple contaminants, for an entire facility. Decor Cabinets has a general system already in place for the bulk of their dust collection; therefore, the team focused on local alternatives that can be adapted to the area around the stain department's blow off process. Decor Cabinets mentioned that they want the captured air to be cleaned and recirculated back into the department. The general dust collection system that Decor already has in place requires large ductwork to and from the various processes and also requires make up air to maintain constant pressures in the building. Since the team is designing a local collection system, the complications of large duct losses and make up air will be minimized. The local system will be able to collect, separate and filter the dust and then return clean air back to the department all within the design space.

The main categories for local dust collection systems include updraft, side draft, downdraft or full containment type hoods [4]. Updraft, side draft and downdraft categories direct the air and contaminants vertically upward, away towards one side and vertically downward respectively. The differences between the various non enclosed categories are shown in Figure B - 1.

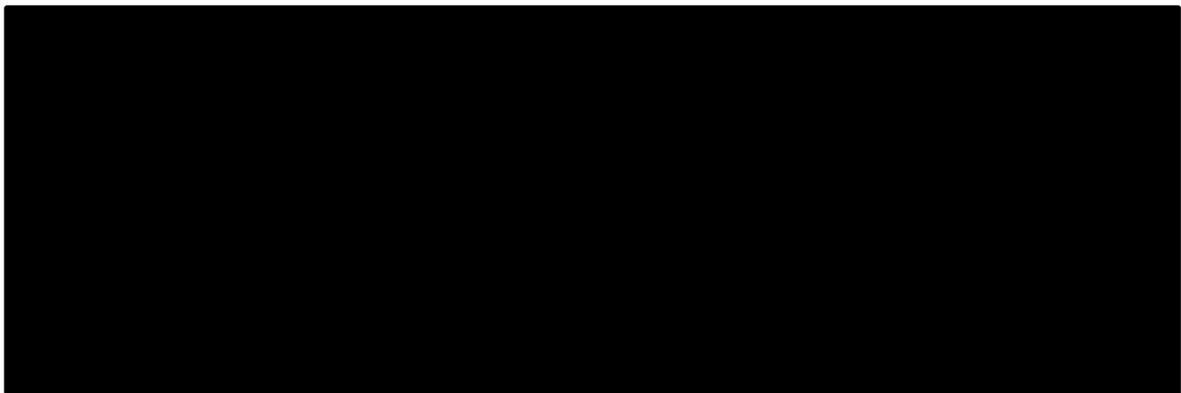


Figure B - 1: Local non-enclosed collection categories [4].

Some of the non-enclosed categories were observed during the initial site visit and allowed the design team to visualize the systems more clearly. The geometry of the system can be enclosed or non-enclosed, which will affect the size of the fan and motor to achieve the necessary dust

capture velocity [20]. The more enclosed the geometry of the design, the less power and air velocity will be required to capture the dust.

### 1.2.2. Separation Techniques

There are two common methods to capture and separate dust particles, which include cyclonic separation and filters. The two common methods are illustrated in Figure B - 2.



Figure B - 2: Separation techniques [20] [21].

Cyclonic separation is a common and effective method to separate dense particles from air. Cyclonic separation works by taking advantage of inertial forces on particles caused by centrifugal acceleration [20]. The design of a cyclonic separator is typically a cone shape, which allows the dust to collect at the bottom section and allows the air flow to continue through the top section of the device. This technique, however, is not efficient for small dust particles, such as the fine sealer dust. The separation method is dependent on the mass of the particulates in the airstream [20].

Filters are another common method to separate dust particles from air. The proper filter selection can have efficiencies approaching 100 percent [20]. Corrugated filter screens, such as the one illustrated in Figure B - 2, were also observed on many of the local exhaust systems during the site visit. The filter separation works by allowing the smaller air particles to pass

through the fabric, while capturing the larger contaminants on the surface. The size, shape and material of the filter can affect the operation of the collection system's fan and motor by creating an increasing pressure drop across the filter. The drop in pressure will vary throughout the operation of the system as more and more dust is collected on the surface of the filter, creating a dust film [20]. The dust film must be monitored and cleaned regularly to maintain the proper operating parameters. An advantage to a filter is that it acts directly at the source of contamination and can be made to fit a variety of geometries, allowing for more flexibility. The cyclonic separator requires a certain dimensional shape which does not allow for the same level of flexibility as the filter. For this reason, a filter separation system is a more beneficial for the design.

### **1.2.3. Fan Selection**

The selection of the proper fan or blower for a collection system depends on the volume and pressure requirements of the system [20]. Typical fans used for air movement include centrifugal (forward curve, backward curve or paddle) and axial fans. The various types of fans are designed for specific applications. Paddle and backward type centrifugal fans are effective for movement of dust and fumes, similar to the sealer dust [20]. The size and shape of the collection unit will determine the air distribution and air flow velocity. Push-pull systems are an additional method used to increase the effectiveness of a dust collection system. A fast moving stream of air moving over top of the dust source will help direct and contain the dust particles. The particles will flow into the stream and then be blown into a filter or separation system. The capture velocity of a system is the necessary velocity of the air to overcome opposing currents [8]. The specific parameters for the fan and motor will be dependent on the design geometry and the size of the ducting or plenum.

After completing the detailed research, the design team concluded that many of the technical parameters outlined in the introduction depend on the geometry of the design. For this reason, the design team will move to the next phase of the design process and develop different options for the geometry of the dust collection system. The concept generation process will focus on designs that will occupy the space around the blow off process conveyer belt. After the recommended concept is selected based on an analytical approach, the technical specifications can be outlined in detail and determined for the final design phase.

### 1.2.3.1. Forward Curved Centrifugal Fans

The forward inclined centrifugal fans consist of the fan blades that are curved towards the direction of rotation of the shaft. These fans are used in applications that require the static pressures of up to 5"wg such as in heating and air conditioning equipment's. Figure B - 3 shows the geometry of forward inclined centrifugal fan.

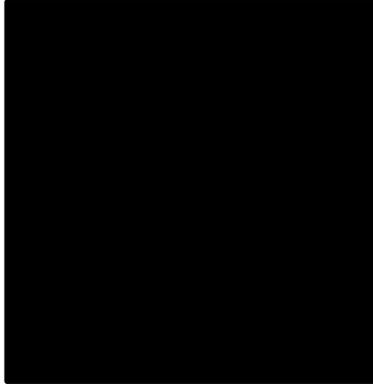


Figure B - 3: Geometry of an impeller with forward curved blades [12].

These types of fans are not recommended for application in which particles could adhere to the blades of the fan which could cause imbalance and reduced performance [7]. Since, the dust being captured has a sticky consistency, it is not recommended to use a centrifugal fan with forward inclined blades for the purpose of the design.

### 1.2.3.2. Radial Impellers

Radial impellers tend to have a simple design. The configuration of the blades can be radial or straight. The housing of the radial impellers have small inlets and outlets which allows the air to move with high velocity. Figure B - 4 shows the geometry of a radial impeller.



Figure B - 4: Geometry of an impeller with radial blades [12].

The large spaces between the blades of the impeller make it less likely to adhere to any particulate matter. However, a major disadvantage of these kinds of fans is that it is the least efficient out of all types of fans used for industrial applications [7].

## **Appendix C: Concept Selection**

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## **1.0 Concept Generation**

In the concept generation process, the team mainly focused on the geometry of the systems that collected dust rather than specific technical parameters such as motor, fan and filtration systems. This section demonstrates different creative thinking techniques that were utilized to generate concept and presents advantages and disadvantages of the concepts generated.

### **1.1 Concept Generation Method**

In order to generate as many concepts as possible, the team employed different concept generation methods in both the individual and the group concept generation. The team started concept generation by producing concepts individually and each team member was tasked of creating a minimum of three different concepts. The individual concept generation was done using the brainstorming method. During the individual concept generation, the team members used their knowledge of the different types of collection system found during research to help with brainstorming. Brainstorming was selected since it is the most commonly used creative thinking technique and the team was already familiar with the technique. Brainstorming is an efficient technique for generating ideas rapidly. It enables the creative thinking part of the brain and concepts can be generated without interruptions. As a result, each team member was able to generate four concepts for a total of 20 concepts.

After the initial individual concepts were generated, the team used a concept classification tree to eliminate any non-feasible designs. A concept classification tree is a tool used to sort different ideas into sub categories which eliminates any similarities between the design concepts. Using the concept classification tree, the 20 concepts were sorted into four different categories: hood, containment, portable and attachment shown in Figure C - 1. There were eight hood concepts, six containment concepts, two portable concepts and four attachment concepts. For the hood category, some concepts were almost identical in design so the team narrowed it down to two concepts. The Containment category had six concepts but two of them were non-feasible design so the team selected four concepts for this category. For the Attachment category, two out of the four concepts were too complex for the problem and were discarded.

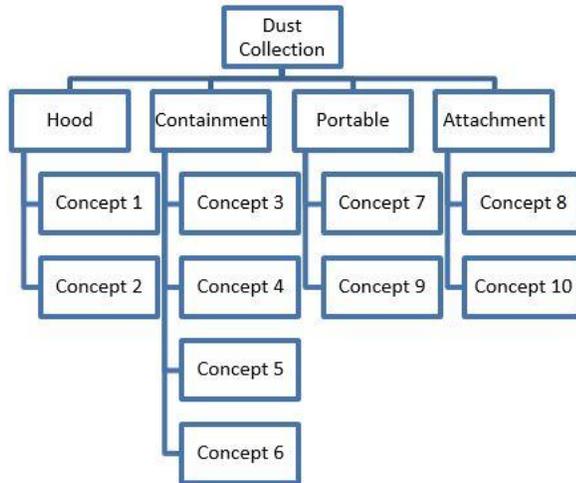


Figure C - 1: Concept Classification Tree method used to categorize concepts [2].

As a result of using this method, the team was able to eliminate any non-feasible and similar design concepts. Using the concept classification tree method, the team was left with 10 concepts to move forward to concept screening.

## 1.2 Concepts

A detailed description of the 10 concepts that were selected using the Concept Classification Tree method is presented in this section. A table of advantages and disadvantages for each of the 10 concepts is also presented in this section.

### 1.2.1. Concept 1: Regular Hood Design

The first concept shown in Figure C - 2 is a typical hood type design that is similar to a kitchen hood or the hood fumes found in chemistry labs.

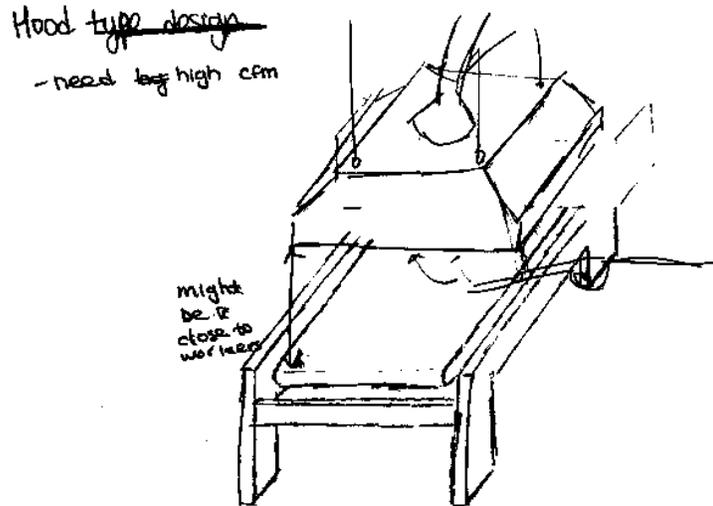


Figure C - 2: Regular hood design concept similar to kitchen hoods [2].

The design consists of a hood system that covers the entire conveyor belt and is suspended from the ceiling using thin cables. A dust collection system is attached at the top which may or may not filter air out, depending on the collection system. As the dust is blown off the cabinet parts using compressed air, the hood will capture majority of the airborne dust. The hood can be made out of thin sheet metal with rust resistive coating for easier maintenance. The distance from the conveyor belt to the hood determines the CFM needed and will depend on the motor and fan selections.

### 1.2.2. Concept 2: Hood with Moving Walls

The second concept shown in Figure C - 2 is a modification to the first concept of the regular hood design. It consists of a moving wall that is attached to the hood for better containment.

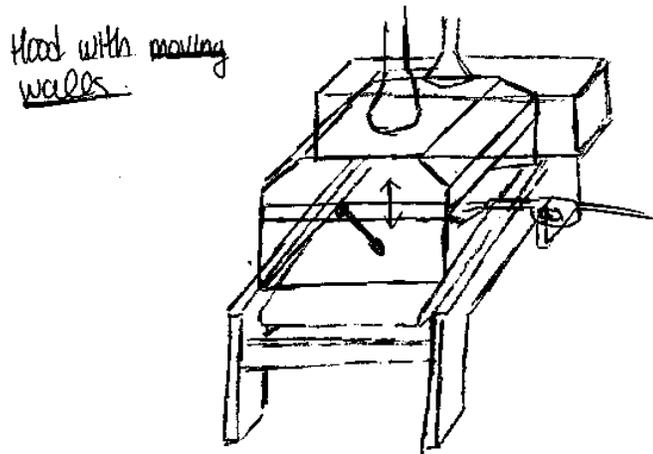


Figure C - 3: Hood design with moving walls to collect dust more efficiently [2].

The walls attached to the hood move vertically, which will help with containment. Having a system that is contained will be beneficial when selecting a motor, as less CFM will be required in a contained system. The moving wall has a handle that the operator can use to move the wall as needed. The material of the wall can be rubber or plastic to avoid obstruction when loading the parts onto the conveyor belt.

### 1.2.3. Concept 3: One Wall

The third concept consists of a vacuum wall with filters located on the left side of the conveyor belt, as shown in Figure C - 3.

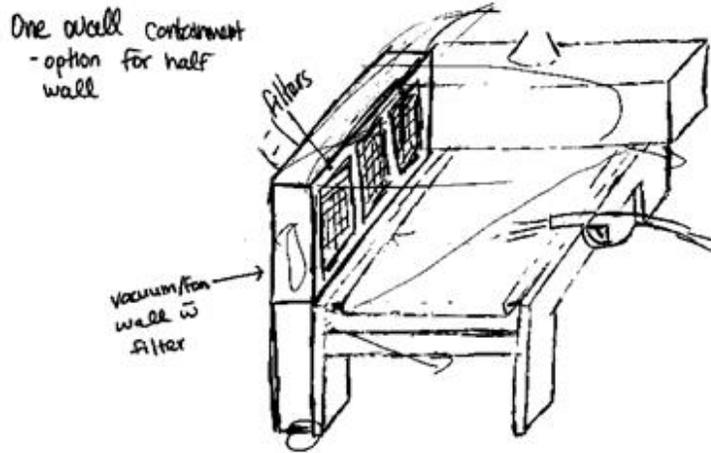


Figure C - 4: One wall with filters located on the left side of the conveyor belt [2].

The vacuum wall covers the entire conveyor belt and can filter air out the back. It is a simple push pull design that requires minimal space and can be effective since the dust will be blown towards the wall. The wall is located on the left side as the right side has aisle that cannot be obstructed.

### 1.2.4. Concept 4: Hinge Containment

The fourth concept, shown in Figure C - 5, consists of a wall similar to the third concept with hinges for containment.

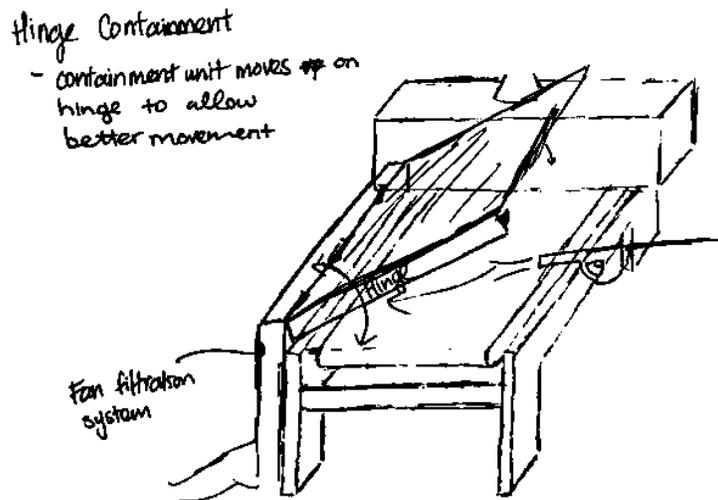


Figure C - 5: Wall with hinges for containment [2].

The design is similar to the third concept but with hinges on the left side. The hinges allow the wall to close down onto the conveyor belt if needed for better suction. The wall with a handle is large enough to cover the entire conveyor belt and can be operated by one operator.

### 1.2.5. Concept 5: Conveyor Belt Containment

The fifth concept consists of rubber or plastic walls that cover the entire conveyor belt, and is shown in Figure C - 6.

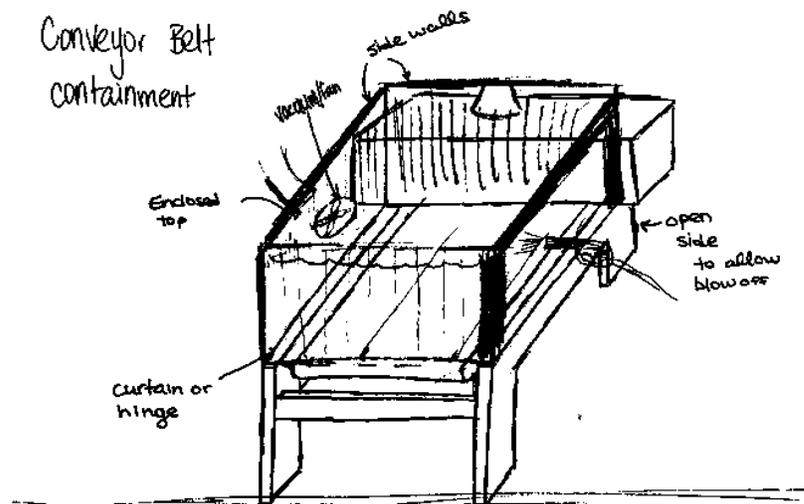


Figure C - 6: Conveyor belt containment [2].

The design has rubber flaps or curtains around three sides and an opening on the right side to avoid interrupting the current workflow. The rubber flaps or curtains can have the ability to move out of the way if needed. Vacuum systems will be located on the top two corners and, since the conveyor belt is well contained, lower CFM would be required.

### 1.2.6. Concept 6: Total Containment

The sixth concept shown in Figure C - 7 consists of a plastic wall that surrounds the entire workstation.

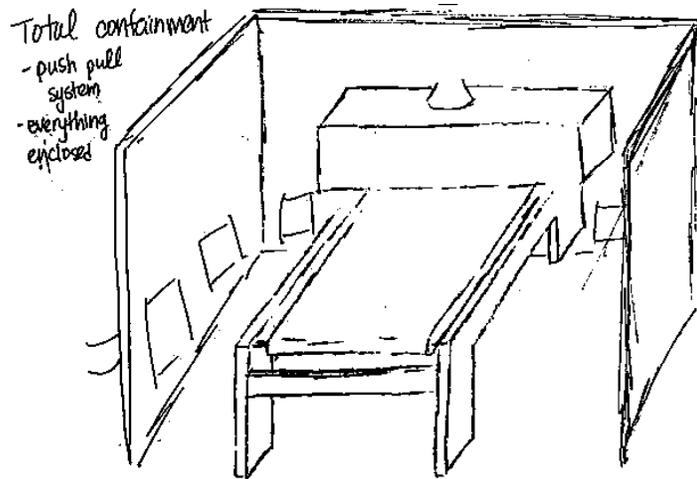


Figure C - 7: Total area containment [2].

The concept is similar to the fifth concept but instead of local containment, it contains the entire workstation. The vacuum or fans will be located either on the top two corners, as the fifth concept, or have ventilation systems on the bottom similar to Figure C - 7.

### 1.2.7. Concept 7: Brush Attachment

The seventh concept includes a brush attached to a vacuum hose that is connected to a dust collection unit mounted under the conveyor belt system. Upon loading the parts on the conveyor belt system, the worker would use this on the cabinets to brush and suck up all the dust particles. This vacuum will allow the sealer dust on the parts to be drawn into the dust collection unit. A sketch of the concept is found in Figure C - 8.

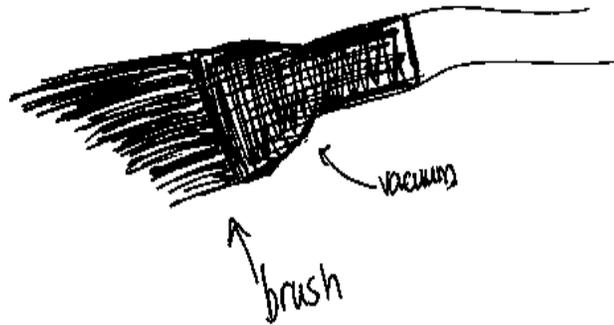


Figure C - 8: Brush attachment [2].

The brush attachment is effective and may decrease the work process. The brush attachment eliminates the step where the parts are wiped off with a piece of cloth after the blow off process. Using the brush over the parts will agitate the dust sticking to the part, allowing it to move freely into the vacuum hose. A concern that the team has is that the brush could potentially damage the part if it is rubbed too hard on the surface of the part.

### 1.2.8. Concept 8: Vacuum Attachment

The eighth concepts consist of a vacuum attachment around the compressed air nozzle. This type of attachment will work on the basis push-pull system. After loading the parts on the conveyor belt system, the worker will follow the regular method of blowing off dust using the compressed air nozzle. The vacuum attachment placed close to the nozzle will suck the dust that is suspended in the air into the vacuum and further into the dust collection unit. Figure C - 9 shows a sketch of the vacuum attachment.

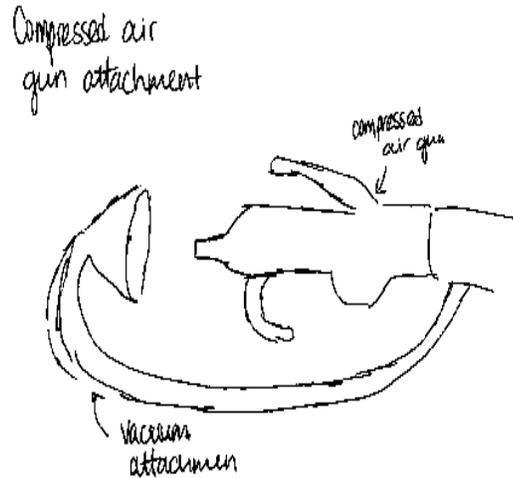


Figure C - 9: Vacuum attachment [2].

The vacuum attachment will have low cost and it is easy to assemble. However, this sort of attachment will need to be custom made. The attachment can only be operated from one direction and will need to be angled correctly for maximum dust collection.

### 1.2.9. Concept 9: Portable Vacuum

The ninth concept features a portable dust capturing unit. The concept has an adjustable hose and an attachment with a handle for easy maneuverability. In operation, when the sealer dust is blown off the parts, the hose can be pulled closer to the part via the handle, which will help direct the dust into the dust capture unit. A sketch of the portable vacuum is shown in Figure C - 10.

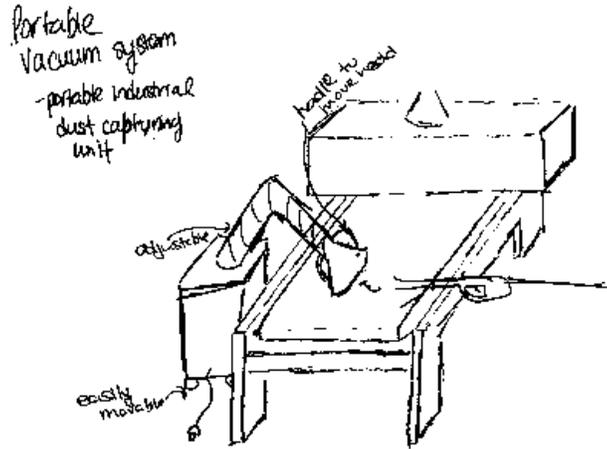


Figure C - 10: Portable vacuum [2].

The design is easy to maintain and is low in cost compared to the hood or wall designs. The fact that it is a portable system makes it easier for it to be moved to other stations if needed. The design does not require any changes to current processes. However, it could slow down the current cycle time as the workers will need to use both their hands to maneuver the vacuum attachment and blow the dust off. To capture the majority of the dust, the vacuum attachment would have to be placed closed to the compressed air nozzle.

### 1.2.10. Concept 10: Portable Fan

Finally, the tenth concept consists of a portable high CFM fan that is mounted on top of the dust collection unit. The fan which will be located on the left side of the conveyor belt is rotatable, allowing the workers to move the fan in any direction as required. The sealer dust drawn in after the blow off process is transferred to the dust collection bag via a hose. Figure C - 11 shows the sketch of the concept.

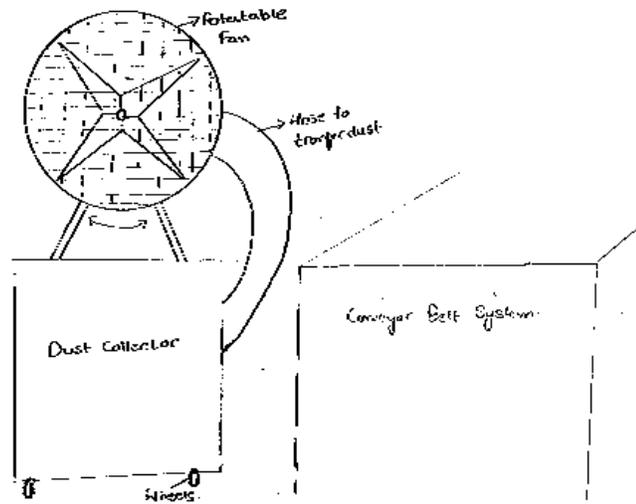


Figure C - 11: Portable fan [2].

The portable fan design is easy to maintain and operate. The system could be moved to other stations if required. The current workflow process of blowing off the sealer dust can be maintained through this system. However, this system could cause obstruction in the left side of the conveyor belt. Regular maintenance to empty out the dust bag is also required if this system is installed.

### 1.2.11. Advantages and Disadvantages

The advantages and the disadvantages of the 10 concepts that were selected to move forward are listed in Table C - I.

Table C - I: LIST OF THE 10 DESIGN CONCEPTS WITH ADVANTAGES AND DISADVANTAGES [2]

Concept	Advantages	Disadvantages
1 Regular Hood Design	<ul style="list-style-type: none"> <li>• Captures all the dust</li> <li>• Doesn't obstruct the sides</li> <li>• Maintain current process</li> </ul>	<ul style="list-style-type: none"> <li>• Requires high cfm</li> <li>• Restricts Operator movement</li> <li>• Obstructs light</li> </ul>
2 Hood with Moving Walls	<ul style="list-style-type: none"> <li>• Requires less CFM</li> <li>• Captures all the dust</li> </ul>	<ul style="list-style-type: none"> <li>• May slow down current process</li> <li>• Obstruct light</li> <li>• Restricts operator movement</li> </ul>
3 One wall	<ul style="list-style-type: none"> <li>• Doesn't obstruct light</li> <li>• Limited movement restriction</li> </ul>	<ul style="list-style-type: none"> <li>• May not capture all the dust</li> <li>• Fixed to the left side</li> </ul>
4 Hinge Containment	<ul style="list-style-type: none"> <li>• Captures majority of the dust</li> <li>• Can be moved out of the way if needed</li> </ul>	<ul style="list-style-type: none"> <li>• May slow down current process</li> <li>• Obstructs light</li> </ul>
5 Conveyor belt Containment	<ul style="list-style-type: none"> <li>• Captures all the dust</li> <li>• Requires low CFM</li> <li>• Does not obstruct light</li> </ul>	<ul style="list-style-type: none"> <li>• Harder to move parts onto the station</li> <li>• May slow down process</li> <li>• Limits operator movement</li> </ul>
6 Total Containment	<ul style="list-style-type: none"> <li>• Captures all the dust</li> <li>• Lower cfm</li> <li>• Does not obstruct light</li> </ul>	<ul style="list-style-type: none"> <li>• Obstructs the side</li> <li>• May slow down current process</li> <li>• Harder to move parts onto the table</li> </ul>
7 Brush attachment	<ul style="list-style-type: none"> <li>• System wipes off and draws dust at the same time</li> <li>• Easy to maintain</li> <li>• Dual purpose system saves time</li> </ul>	<ul style="list-style-type: none"> <li>• May require fabrication of the part.</li> <li>• Brush could potentially cause damage to the part</li> </ul>
8 Vacuum attachment	<ul style="list-style-type: none"> <li>• Low installation cost</li> <li>• Attachment easily removable</li> <li>• Maintains cycle time</li> </ul>	<ul style="list-style-type: none"> <li>• Customized part, needs fabrication</li> <li>• Can only be operated from one direction</li> <li>• Need to be angled correctly for maximum dust collection</li> </ul>
9 Portable vacuum	<ul style="list-style-type: none"> <li>• Can be moved to other stations if required</li> <li>• Easy to maintain</li> <li>• Low/no installation cost</li> <li>• Maintains current workflow process</li> </ul>	<ul style="list-style-type: none"> <li>• Blocks left side of the conveyor belt system</li> <li>• Slows down current cycle time</li> <li>• May not capture majority of the dust</li> </ul>
10 Portable Fan	<ul style="list-style-type: none"> <li>• Moveable</li> <li>• Maintains current process and cycle time</li> <li>• Easy installation</li> </ul>	<ul style="list-style-type: none"> <li>• May obstruct movement of the workers</li> <li>• Regular maintenance required to empty the bag of collected dust</li> <li>• Higher cost for high CFM fan</li> </ul>

The most common advantage among all of the concepts was that the system maintains current process which is the most important parameter in customer needs. Some advantages or disadvantages such as captures all the dust, light obstruction and ability to move are things that were mentioned by the clients and these will be important in selecting the final design. The advantages and disadvantages will be used as a guide in concept screening.

### **1.3 Concepts Summary**

In summary, the team generated 20 design concepts during the initial brainstorming session. The team then used a concept classification tree method to categorize the concepts into four categories: Hood, containment, attachment and portable. As a result of using a concept classification tree, two hood, four containment, two attachment and two portable concepts were selected to move forward. A list of advantages and disadvantages were presented for each of the 10 concepts and will be further analyzed to determine the optimal concept design.

## 2.0 Concept Analysis and Selection

In order to select the most suitable concept for the final detailed design, an iterative and converging analytical approach was used. Each concept was put through a series of evaluations in order to eliminate some of the less desirable concepts and develop new combinations of preferred design characteristics. The analysis included a list of important selection criteria, an initial screening matrix and then a more rigorous weighted scoring evaluation.

### 2.1 Selection Criteria

The selection criteria chosen for the screening process consisted of nine basic customer needs, which were important to achieve the design goals. The selection criteria are illustrated in Table C - II.

Table C - II: SELECTION CRITERIA [2]

	Selection Criteria
1	Dust capture effectiveness
2	Floor plan obstruction
3	Compatibility with current conveyer system
4	Easy to operate
5	Cycle time effectiveness
6	Complexity
7	Light obstruction
8	Moveable
9	Maintenance difficulty

Customer needs such as cost, sound and filtration parameters have been neglected for the selection criteria but will be considered for the final detailed design. The neglected needs will not substantially differentiate the initial concepts therefore are not required for the selection process. The top designs developed during the concept generation process have slight differences in each of the selection criteria parameters which will allow for an effective comparison. Each of the selection criteria will be discussed briefly to illustrate the analytical approach the team followed to narrow down the concepts.

The dust capture effectiveness will distinguish the amount of dust that each concept will capture. Concepts that are more enclosed will be able to better capture the majority of the dust particles in comparison to the more open concepts. Next, the floor plan obstruction will differentiate the concepts that require more floor space from ones that require little floor space, such as the suspended designs. As previously discussed, the design space has critical aisle ways on either side of the conveyer belt that may not be negatively obstructed. Therefore, the compatibility with the conveyer system will also differentiate concepts which may interfere with proper conveyer operations. The concepts should be easy to operate, which will differentiate concepts that require skillful operator interaction from those that are more automated. Other selection criteria that will be used in the selection analysis will be the time required for the concepts to complete the blow off process. The stain department follows certain cycle times that are critical to meet production demands. Concepts that require time to set up, operate and clean will therefore be illustrated in the selection criteria. During the initial site visit, Decor Cabinets indicated that that a simple design would be the most efficient in regards to integration and new training for employees. Therefore, it is necessary to compare the complexity of each concept.

A new selection criterion that the team uncovered during the concept generation process was light obstruction. It is important that the operator have complete and unobstructed views of the panels to ensure all the dust has been removed from the corners and crevices. Therefore, light obstruction was introduced as a selection criterion to help differentiate the concepts. Another important factor that was added to the selection criteria that was not included in the initial customer needs was for the design to be moveable. The moveable selection criterion will differentiate concepts that will be able to allow for custom sized panels and not constrain the space around the conveyer belt system. The final selection criterion chosen for the screening process was the maintenance requirements. Concepts on the floor would be more easily worked on than concepts suspended from the ceiling or that have complex mechanisms.

## **2.2 Concept Screening Matrix**

A concept screening matrix was performed on the top ten concepts using the previously discussed selection criteria. The design team selected concept one to be used as a reference

benchmark in order to compare all of the other concepts to a single standard. The reference benchmark was chosen arbitrarily from the top ten concepts by the design team. A screening score of +, - or 0 was used to illustrate if each concept scored higher, lower or the same respectively for each selection criterion. The concept screening process is shown in Table C - III. The concept screening process was generated by all members of the design team in order to eliminate biased opinions and ensure an accurate selection process.

Table C - III: CONCEPT SCREENING [2]

CONCEPT SCREENING										
	Concepts									
Selection Criteria	1 (ref)	2	3	4	5	6	7	8	9	10
Dust capture effectiveness	0	+	+	+	+	+	+	0	-	+
Floor plan obstruction	0	0	-	-	0	-	+	+	-	-
Compatibility with current conveyer system	0	-	0	-	-	+	0	+	0	+
Easy to operate	0	-	0	-	-	+	-	-	-	0
Cycle time effectiveness	0	-	0	-	-	-	-	-	-	+
Complexity	0	-	+	-	-	0	0	-	+	-
Light obstruction	0	0	+	+	+	+	+	+	+	+
Moveable	0	0	+	+	0	0	+	+	+	+
Maintenance difficulty	0	-	+	-	0	+	-	-	+	0
Sum +'s	0	1	5	3	2	5	4	4	4	5
Sum -'s	0	5	1	6	4	2	3	4	4	2
Sum 0's	9	3	3	0	3	2	2	1	1	2
<b>Net Score</b>	0	-4	4	-3	-2	3	1	0	0	3
Rank	5	10	1	9	8	2	4	5	5	2
<b>Continue?</b>	N	N	Y	N	N	Y	N	N	N	Y

Upon completion of the screening process, the design team was able to reduce the top ten concepts down to a new top three. The top three concepts included one wall design, the total containment design and the portable fan concept. The rankings from the screening process were determined based on the summation of +, - and 0 scores for each selection criterion. By adding the totals of each score numerically, a net score was calculated for each concept. The top three net scoring concepts will be further analyzed using a weighted scoring matrix.

In addition to the team screening, the concepts were also shown to the Decor Cabinet stakeholders as to get feedback on the concepts. The team decided not to tell the stakeholders the results of the team screening process in the interest of not skewing their opinions. Instead of an in-depth analysis, the stakeholder gave their opinion of the pros and cons of each concept. From this meeting, the stakeholders explained that concept number 7, the brush attachment, could not be implemented in their current system as some parts have glazing on them and the brush attachment would remove said glazing. The stakeholders approved all concepts excluding the brush attachment and also gave advice on which concept would work best based on similar past projects and work experience.

### **2.3 Additional Concept Generation**

During the screening process and the meeting with the stakeholders, a new concept was generated. The concept, deluxe concept, is a combination of two concepts: the one wall and the hood concepts. The deluxe concept utilizes certain aspects of both concepts to improve the system's ability to capture dust. Similar to the one wall concept, there will be a movable wall on the left hand side of the conveyor belt with filters to collect the dust. The deluxe concept will also have a partial hood attached to the wall in order to contain the dust comparable to the hood design. Figure C - 12 represents a rough schematic of the deluxe concept.

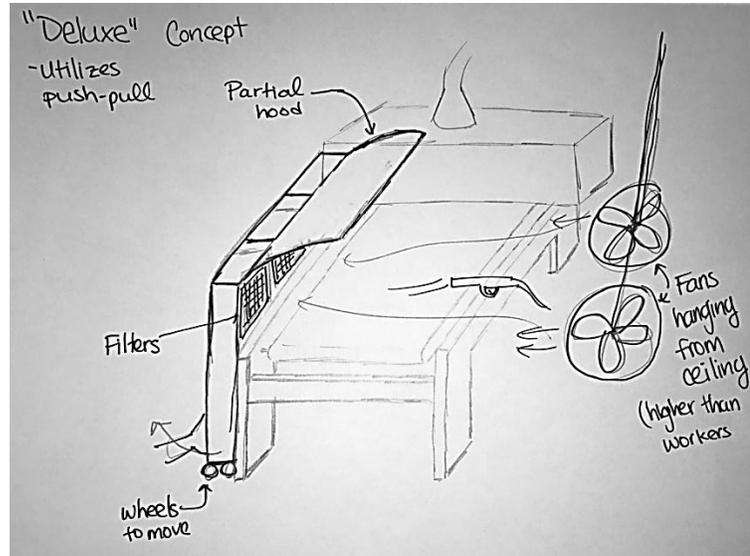


Figure C - 12: Deluxe concept [2].

In addition to the combination of the wall and hood concept, fans were placed on the opposite side of the wall, as seen in Figure C - 12, to utilize the push-pull system described in the research. This concept utilized the ability of the one wall design to capture dust while containing the dust to ensure it does not interfere with other processes.

## 2.4 Selection Criteria Weighting

To accurately score the top three concepts selected during the concept selection in addition to the new deluxe concept, a criteria weighing chart was used to weigh the importance of each selection criteria. The weighing was done by placing the criteria in a table both on the horizontally and vertically axis and comparing each criterion to one another. When comparing, the criterion deemed more important was written down in the corresponding box. When a letter was written in one of the boxes of the table it was considered a hit for that criterion. the next criterion was compared. The score of each criterion was determined by dividing the total number of hits by the criterion's number of hits. Similar to the concept screening process, the criteria weighing was generated by all members of the design team in order to eliminate bias opinions and ensure an accurate weighing process. The process as well as the results of the criteria weighing are shown in Table C - IV.

Table C - IV: CRITERIA WEIGHING MATRIX [2]

CRITERIA WEIGHING									
	A	B	C	D	E	F	G	H	I
<b>A</b>	Capture dust	A	A	A	A	A	A	A	A
<b>B</b>	Does not obstruct floor plan		C	D	E	B	B	B	B
<b>C</b>	Compatible with current system			C	E	C	C	C	C
<b>D</b>	Easy to operate				E	F	D	D	D
<b>E</b>	Maintains current cycle time					E	E	E	E
<b>F</b>	Complexity						F	H	I
<b>G</b>	Light obstruction							G	G
<b>H</b>	Moveable								H
<b>I</b>	Easily maintained								
<b>Total Hits</b>		8	4	6	4	7	2	2	1
<b>Weighting</b>		0.22	0.11	0.17	0.11	0.19	0.06	0.06	0.03

The table above displays the process and result of the weight analysis chart; it is important to notice that all criterion got at least one hit, which indicates that all the criteria are relevant to the project. Capturing the dust scored the highest, which was expected as this was also the most important need and the goal of the project. The next criteria that scored the most were maintains current cycle time and is compatible with current system. These two criteria were also anticipated to score high as if the system is not compatible with the system and slows down the process the workers are less likely to use it. The lowest scoring criterion was easily maintained, as this is not crucial but rather an advantage to the system. The scores determined for the selection criteria were then used in the weighted scoring matrix.

## 2.5 Concept Scoring

A concept scoring matrix was used to determine which of the concepts would best suit the needs of the project. The deluxe concept as well as the top three concepts found with the concept screening matrix were rated for each selection criteria and assigned a score from 1 to 5, 1 being the worst and 5 being the best. The ratings for each criterion were then multiplied by the weight of the criterion determined previously. The weighted scores for each concept were then tallied and the concept were ranked by score, the higher score meaning the better the concept. The result of the concept scoring process is shown in Table C - V. The concept scoring

was generated by all members of the design team in order to eliminate biased opinions and ensure an accurate scoring process.

Table C - V: CONCEPT SCORING [2]

CONCEPT SCORING									
		Concepts							
		One Wall		Total Containment		Portable Fan		Deluxe Concept	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Capture dust	0.22	3	0.67	5	1.11	2	0.44	4	0.89
Does not obstruct floor plan	0.11	3	0.33	1	0.11	4	0.44	4	0.44
Compatible with current system	0.17	5	0.83	4	0.67	5	0.83	5	0.83
Easy to operate	0.11	4	0.44	4	0.44	4	0.44	4	0.44
Maintains current cycle time	0.19	3	0.58	5	0.97	4	0.78	4	0.78
Complexity	0.06	4	0.22	3	0.17	5	0.28	3	0.17
Light obstruction	0.06	3	0.17	4	0.22	5	0.28	2	0.11
Moveable	0.06	1	0.06	1	0.06	5	0.28	5	0.28
Easily maintained	0.03	4	0.11	3	0.08	4	0.11	4	0.11
<b>Total Score</b>		<b>3.42</b>		<b>3.83</b>		<b>3.89</b>		<b>4.06</b>	
<b>Rank</b>		<b>4</b>		<b>3</b>		<b>2</b>		<b>1</b>	
<b>Continue?</b>		<b>No</b>		<b>Yes</b>		<b>Yes</b>		<b>Yes</b>	

The results from the concept scoring were similar for the total containment, portable fan and deluxe concept as shown in Table C - V. To ensure that the best concept was chosen, the team decided a sensitivity scoring test was needed. It was decided that the top three concepts would be scored using a sensitivity scoring matrix and that the fourth rank concept would not move on.

## 2.6 Sensitivity Scoring

To ensure that the best concept was chosen, the team performed a sensitivity scoring of the three concepts that scored similarly in the concept scoring. One of the main assumptions the team made in the scoring and screening was that if the machine was complex it would be harder to operate and train employees, but this may not be the case for all designs. Therefore, the

team decided to re-score the concepts by allotting a zero weight to the complexity criterion and analyzing those results. The results of the sensitivity scoring are shown in Table C - VI.

Table C - VI: SENSITIVITY SCORING [2]

<b>SENSITIVITY SCORING</b>							
		<b>Concepts</b>					
		<b>Total Containment</b>		<b>Portable Fan</b>		<b>Deluxe Concept</b>	
<b>Selection Criteria</b>	<b>Weight</b>	<b>Rating</b>	<b>Weighted Score</b>	<b>Rating</b>	<b>Weighted Score</b>	<b>Rating</b>	<b>Weighted Score</b>
Capture dust	0.22	5	1.11	2	0.44	4	0.89
Does not obstruct floor plan	0.11	1	0.11	4	0.44	4	0.44
Compatible with current system	0.17	4	0.67	5	0.83	5	0.83
Easy to operate	0.11	4	0.44	4	0.44	4	0.44
Maintains current cycle time	0.19	5	0.97	4	0.78	4	0.78
Complexity	0.00	3	0.00	5	0.00	3	0.00
Light obstruction	0.06	4	0.22	5	0.28	2	0.11
Moveable	0.06	1	0.06	5	0.28	5	0.28
Easily maintained	0.03	3	0.08	4	0.11	4	0.11
<b>Total Score</b>		<b>3.67</b>		<b>3.61</b>		<b>3.89</b>	
<b>Rank</b>		<b>2</b>		<b>3</b>		<b>1</b>	
<b>Continue?</b>		<b>No</b>		<b>No</b>		<b>Yes</b>	

Changing the weight of the complexity criterion caused the total containment and the portable fan to swap positions but the deluxe concept remained ranked first. The team therefore decided to move forward with the deluxe concept as it ranked first in both the scoring and the sensitivity scoring.

### 3.0 Final Design: Deluxe Concept

The Deluxe concept was selected as the final design based on the score concept screening. As mentioned in the additional concept generation section, the deluxe concept, is a combination the one wall and the hood concept. The deluxe concept consists of a movable wall located on the left hand side of the conveyor belt with filters to collect the dust. The deluxe concept will also have a partial hood attached to the wall in order to contain the dust comparable to the hood design. Figure C - 13 shows a rough sketch of the concept.

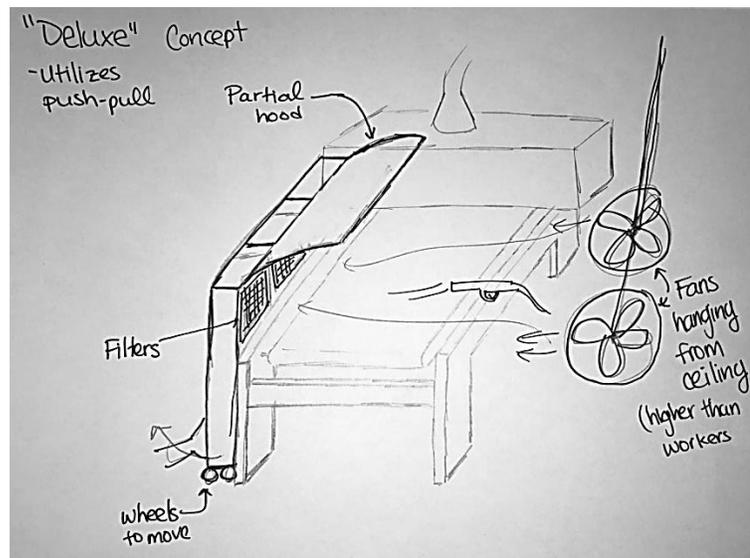


Figure C - 13: Final Design Concept [2].

In addition to the combination of the wall and hood, fans will hang from the ceiling on the opposite side of the wall, as seen in Figure C - 12, to utilize the push-pull system. This concept utilizes the ability of the one wall design to capture dust while containing the dust to ensure it does not interfere with other processes. Now that the geometry of the concept has been selected, the next phase will be to determine the technical parameters associated with this concept.