2018

VIBCO Bin Variation System

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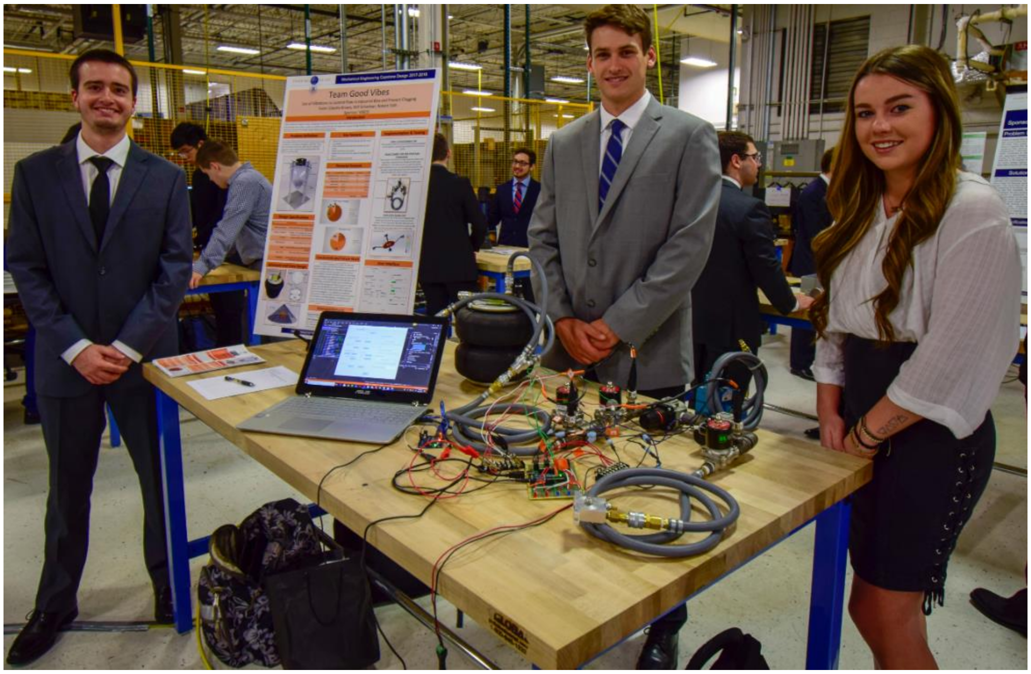

VIBCO

BIN VIBRATION SYSTEM

Team 19: Good Vibes

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Department of Mechanical Engineering

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Abstract

VIBCO vibrators has tasked the team in designing an internal bin fixture that aids in material flow for the food, pharmaceutical, and chemical industries. This bin fixture must be adaptable to various sized diameter bins in order to create a cost efficient product that does not require the customer to make any physical changes to their bin. Lastly the internal fixture must be capable of raising and lowering in a way that gives the customer the ability to control material flow. The team began research on competitor systems that are currently on the market in this industry. After completing this research, it was determined that all of the competitor systems require the customer to make physical changes to their bin in order to implement the system. This being said it was imperative that the team design an internal fixture that can be easily installed without requiring the customer to edit their bin. From here design specifications were determined and discussed with the VIBCO engineering team to ensure that all of the bases were covered.

In order to complete this task, the team began with brainstorming in order to determine some basic design specifications that would guide our 90 concepts generated. After analyzing each of the 90 concepts and a critical design review, two concepts were created by integrating and incorporating many elements of the entire spectrum of concept solutions. From here the team furthered research on different materials that would be strong, light weight, cost efficient, and high-corrosive resistant. After determining the different materials design work was furthered and a Solidworks design of the full internal bin system was created. Before finalizing any Solidworks designs the team crosschecked once again the proposed design with the competitors to ensure that this had not been done before. After completing and simulating a model of the proposed design the team performed a financial analysis and determined we are well under competitor pricing once this design is in full production. All of our other design specifications were met but the team would continue to make improvements. Once the design had been approved by VIBCO, parts were ordered and the build portion of the project began. Testing of the system soon followed at VIBCO using a bin they had on site. With the testing and data collected, redesign and improvements were able to be made to the original prototype.

Contents

Nomenclature

r	Radius (inches)
D	Diameter (inches)
H	Height (inches)
W	Weight (pounds)
V	Volume (m^3)
ρ	Density (lbs/m^3)

List of Tables

List of Figures

1 Introduction

This project is sponsored by VIBCO, currently located and operating in Wyoming, Rhode Island. This is a local company with global markets in distributing high quality, effective vibratory systems, used in various applications including construction, manufacturing, and packing. The company manufactures and designs over 1600 products and holds over 25 U.S. patents. They have three styles of vibrators, pneumatic, electric, and hydraulic, with the pneumatic being their premier vibrator. One of the focuses the company is steering towards is keeping material in bin silos from getting clogged. They have a few methods currently using vibrators attached to the outside of the bins or air cannons that blow air to unclog material build up. Considering that bin silos are used in various applications from farming to the pharmaceutical industry, making sure that the material flow out of bins is uninterrupted, is paramount. Powdery materials are usually the most likely to become clogged, rat hole, or bridge inside bins and are generally used in the pharmaceutical and food industries. Rat holes appear when the middle of the material in the bin flows out, but the material on the sides of the bin remains stationary. Bridging can occur when the bottom of the material falls down while the material above remains stuck in place. The figure bellows shows examples of material rat holing or bridging.

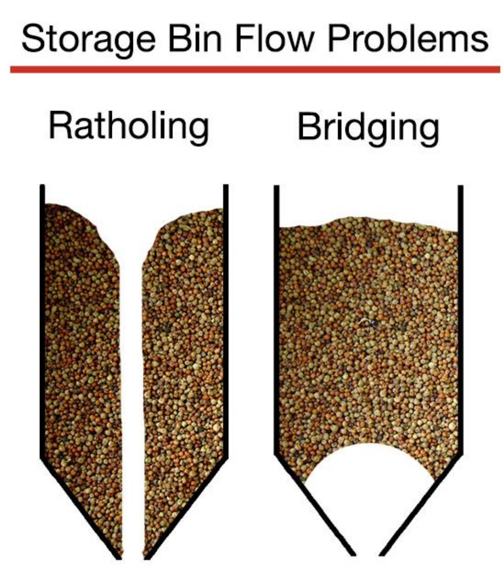


Figure 1: Rat Holes and Bridging Inside Bins

There are two methods to solving this material build up, external vibration or internal vibration. External vibration most often consists of attaching a single or multiple vibrators to the external walls of the bin, which allows the transfer vibrations from the bin walls to the material. Internal vibration requires placing a vibrator attached to a fixture inside the bin, generally towards the bottom, to transfer vibration to the material. VIBCO currently only offers external methods to vibrating material in bin silos. From customer input, they have found that the external method of vibration is not completely solving the problem of material flow, with material still being left in the bin with no way to get it out.

Figure 2: Material Remaining in Bin After External Vibration

External methods also are unable to control the amount of material flowing out of the bin. This can cause the flow of material in the bin to exceed the flow exiting the bin, leading to clogging at the bottom exit hole. These problems with external vibration, is what the project at hand is meant to solve.

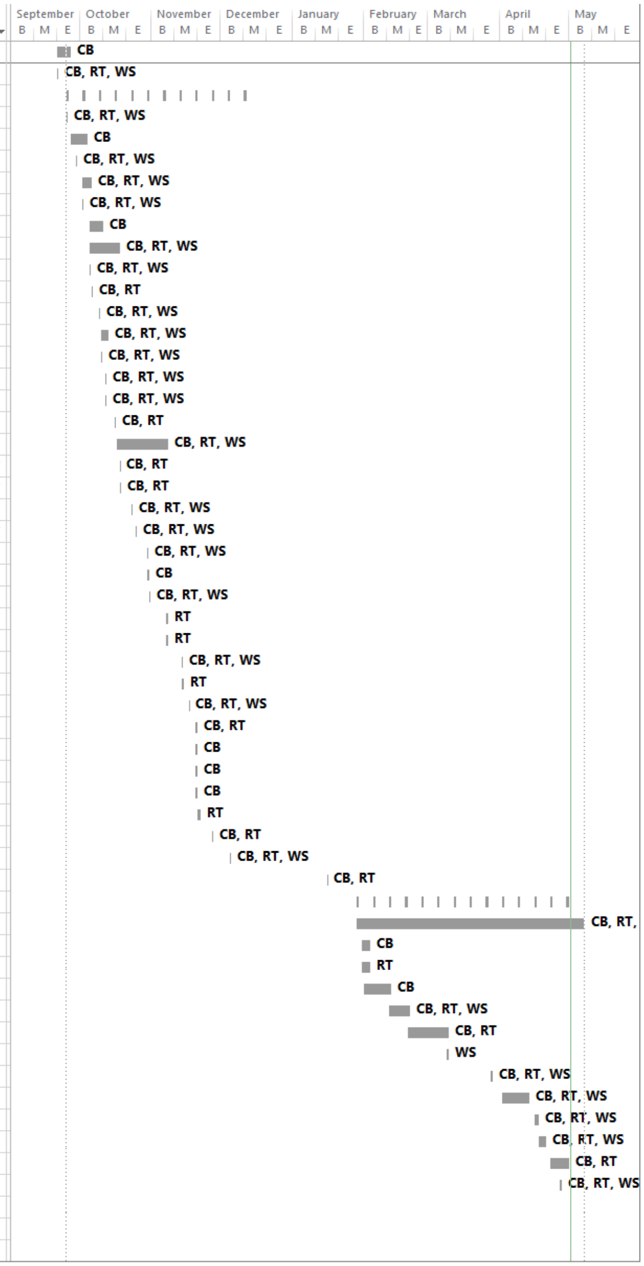
The project set forth to our team was to develop a method to vibrate material inside of bin silos, while additionally being able to control the flow of material exiting the bin. The intent was to create an internal vibratory system that is placed into a bin and will regulate the flow of material while keeping material from getting clogged. From the implication of this device, any company will be able to assemble and install the product into bins with varying dimensions. Additionally, the product must be able to perform under different weights and densities. Material of varying density needs varying vibration in order to flow, with higher density materials needing higher amounts of vibration. The system needed to ensure that all material is able to flow out of the bin with none left inside.

The team has created a full prototype that will rest on the top of bin silos with cables that extend down into the bin that suspend a vibrating cone fixture. The cone will be able to raise and lower in order to control the flow of material exiting the bin. The system will be able to be quickly modified to fit all bin designs and can be assembled by the customers. The target of the product is any industry using bin silos to control material, with the pharmaceutical and food industries being a more appealing target. This is due to the style of material in these industries and the system being able to keep the material from being contaminated. These two industries have FDA regulations they must follow, and material cannot by no means be contaminated or else the product will be deemed useless.

The initial research gave the assumptions that the concept of a cone has been used in the market before and has yielded improved results compared to the external methods of vibrating material. This however is still a relatively new concept with the cone being able to vibrate the material while additionally regulating the flow. There are many articles that discuss how material reacts under vibrations and also discuss the properties of specific material that the concept would be interacting with.

2 Project Planning

Microsoft Project software was used to create the Gantt Chart. The Gantt Chart was used to plan out the full project including, upcoming meetings, submission dates, and deadlines. This chart shows in detail all of the major project goals as well as the start of them, the deadlines for them, and which group members were involved with which projects. Time frames of the events are shown on the right side of the chart along with the initials of the group members who participated in the task. Below is the Gantt Chart and this is also featured in the appendix.



Task Name	Duration	Start	Finish	
Initial Project Plan	4 days	Thu 9/21/17	Tue 9/26/17	CB
Team Meeting 1	3 hrs	Thu 9/21/17	Thu 9/21/17	CB, RT, WS
Fall Progress Reports	**56 days**	**Mon 9/25/1**	**Mon 12/11/17**	
Team Meeting 2	1.5 hrs	Mon 9/25/1	Mon 9/25/17	CB, RT, WS
Project Plan	5 days	Wed 9/27/1	Tue 10/3/17	CB
VIBCO Meeting 1	2 hrs	Fri 9/29/17	Fri 9/29/17	CB, RT, WS
Patent Search	4 days	Mon 10/2/1	Thu 10/5/17	CB, RT, WS
Team Meeting 3	1.5 hrs	Mon 10/2/1	Mon 10/2/17	CB, RT, WS
Project Plan	4 days	Thu 10/5/17	Tue 10/10/17	CB
30 Concepts Due	9 days	Thu 10/5/17	Tue 10/17/17	CB, RT, WS
Team Meeting 4	3 hrs	Thu 10/5/17	Thu 10/5/17	CB, RT, WS
VIBCO Meeting 2	2 hrs	Fri 10/6/17	Fri 10/6/17	CB, RT
Team Meeting 5	2.25 hrs	Mon 10/9/1	Mon 10/9/17	CB, RT, WS
Design Specifications	3 days	Tue 10/10/1	Thu 10/12/17	CB, RT, WS
Team Meeting 6	4 hrs	Tue 10/10/1	Tue 10/10/17	CB, RT, WS
REVIEW MEETING 1	20 mins	Thu 10/12/1	Thu 10/12/17	CB, RT, WS
Team Meeting 7	2.5 hrs	Thu 10/12/1	Thu 10/12/17	CB, RT, WS
Team Meeting 8	4.5 hrs	Mon 10/16/1	Mon 10/16/17	CB, RT
Updated Design Specifications	16 days	Tue 10/17/1	Tue 11/7/17	CB, RT, WS
Team Meeting 9	2.25 hrs	Wed 10/18/1	Wed 10/18/17	CB, RT
QFD	4 hrs	Wed 10/18/1	Wed 10/18/17	CB, RT
Team Meeting 10	3 hrs	Mon 10/23/1	Mon 10/23/17	CB, RT, WS
Team Meeting 11	2.5 hrs	Wed 10/25/1	Wed 10/25/17	CB, RT, WS
Team Meeting 12	1.25 hrs	Mon 10/30/1	Mon 10/30/17	CB, RT, WS
SW - Cone	1 day	Mon 10/30/1	Mon 10/30/17	CB
Presentation 1: Critical Design Review	4 hrs	Tue 10/31/1	Tue 10/31/17	CB, RT, WS
SW - Upper Mounting Legs	1 day	Tue 11/7/17	Tue 11/7/17	RT
SW - Upper/Lower Mounting Plates	1 day	Tue 11/7/17	Tue 11/7/17	RT
Review MEETING 2	20 mins	Tue 11/14/1	Tue 11/14/17	CB, RT, WS
SW - Lower Legs	1 day	Tue 11/14/1	Tue 11/14/17	RT
VIBCO Meeting 3	1.5 hrs	Fri 11/17/17	Fri 11/17/17	CB, RT, WS
Team Meeting 13	7 hrs	Mon 11/20/1	Mon 11/20/17	CB, RT
SW - Top Bracket	1 day	Mon 11/20/1	Mon 11/20/17	CB
SW - Universal Mounting Plate	1 day	Mon 11/20/1	Mon 11/20/17	CB
SW - Channel for Bracket	1 day	Mon 11/20/1	Mon 11/20/17	CB
SW - Outer Ring Harness	1 day	Tue 11/21/1	Tue 11/21/17	RT
Team Meeting 14	3 hrs	Mon 11/27/1	Mon 11/27/17	CB, RT
Presentation 2: Proof of Concept	4 hrs	Tue 12/5/17	Tue 12/5/17	CB, RT, WS
VIBCO Meeting 4	2 hrs	Tue 1/16/18	Tue 1/16/18	CB, RT
Spring Progress Reports	**66 days**	**Mon 1/29/1**	**Mon 4/30/18**	
Final Report Due	71 days	Mon 1/29/1	Mon 5/7/18	CB, RT,
SW - Cone/Vibrator Mount	4 days	Wed 1/31/1	Sat 2/3/18	CB
SW - Bin Fixture/Supports	4 days	Wed 1/31/1	Sat 2/3/18	RT
Drawings for All Components	8 days	Thu 2/1/18	Mon 2/12/18	CB
Quotes Requested	7 days	Mon 2/12/1	Tue 2/20/18	CB, RT, WS
Parts Ordered	14 days	Tue 2/20/18	Fri 3/9/18	CB, RT
Misc. Components Ordered	1 day	Fri 3/9/18	Fri 3/9/18	WS
Presentation 3: Build and Test	1 day	Wed 3/28/1	Wed 3/28/18	CB, RT, WS
Build	10 days	Mon 4/2/18	Fri 4/13/18	CB, RT, WS
Test	2 days	Mon 4/16/1	Tue 4/17/18	CB, RT, WS
Refinement	3 days	Wed 4/18/1	Fri 4/20/18	CB, RT, WS
Final Test	6 days	Mon 4/23/1	Mon 4/30/18	CB, RT
Design Showcase	1 day	Fri 4/27/18	Fri 4/27/18	CB, RT, WS
Meeting with ERW		*TBD*		
VIBCO Meeting 5		*TBD*		
VIBCO Meeting 6		*TBD*		

Figure 3: Project Plan

The Gantt chart helped the whole team meet the deadlines for each part of the project. This was also helpful in getting the team focused on what needed to be done that week during the team meetings inside and outside the class.

The first major event in the planning part of this project was to work on an individual patent search. It gave a good idea of what was already patented and on the market. This also helped to guide the team in what direction was the most promising and gave a solid base to start thinking of concepts for this design. After the deadline for the patent search was reached, the next major design step was to design thirty concepts per member. These concepts should incorporate all aspects of the problem statement and attempted to solve all of these problems. At the end of this stage each team member had to then analyze each one of their concepts for positive and negative components

From the concepts in the case, a total of 90, the team brought all of them together and came up with two complete designs. These designs were created by taking each one of the concepts and incorporating the parts from concepts that solved the problem statement the best and fall within the design specifications. Another part of this stage was generating a complete QFD analysis of the two designs as well as a tradeoff analysis between the two.

Once these steps have been completed the team presented a Design Concept Presentation to the whole class. From this presentation, the team received feedback from Dr. Nassersharif and classmates. This was the first major milestone of the design process, as it was the first time that the designs were shown to anyone else. This gave the team excellent feedback because it brought outside options and ideas to the team's designs.

After the Design Concept Presentation, the team started preparing for the proof of concept of the design. This part of the design phase involved going into each one of the designs to do more research and calculations on which components from each design would work best to solve the problems stated in the problem statement. Once the best design was chosen from the original two designs the team focused on optimizing that design, which included meeting with the team's sponsor and running Solidwork's simulations of the design. After, the team knew that this was a design worthy of being pursued. Once the Proof of Concept Presentation was completed the only assignment left to do was the Final Design Report and turning in the team binder with engineering notebooks. This all was completed for the first semester.

For the building portion of the project and the second semester, it began with a meeting with VIBCO in which they gave us a new set of design specifications. This intern caused the building portion of the project to be moved back because the team needed three weeks to redesign our concept. Once the new concept had been design the team ordered all necessary parts through URI and the rest through VIBCO. The build presentation was then presented to the whole capstone class, which went very well.

After the presentation, the team focused on completing the build and finishing all necessary testing on the system. Another meeting was set up with VIBCO to go over the team's progress and some of the initial testing results. This meeting went very well and VIBCO was impressed with the build of our design. This then left the team with a final meeting with our professor and VIBCO to discuss the overall project and submitting out final report for our Capstone.

3 Financial Analysis

The financial analysis of this products design involved a couple major components. These pieces included the system, the controlling interface, and the human resources needed to complete the design concept.

3.1 Internal System

The vibration system, that is the system that physically rests inside the bin as well as the frame and lifting system that are attached to the top of the bin, have its costs detailed in this section. The system is made up of many components, each needing to be machined, welded, or manufactured in order to be assembled correctly. The whole prototype consists of the cone, the vibrator and vibrator mount, the frame, the airmounts, cables, and two plates that attached the airmounts to the frame. Most of the components will be composed of stainless steel for strength and durability. The figure below shows the costs of the components needed in order to construct the full internal system.

Component Name	Material	Quantity	Price	Total Cost
VIBCO Bin	Aluminum	1	N/A	N/A
Mounting Plates	Steel	2	$300.00	$600.00
U-Channel Bar Stock	Steel	2	$50.00	$100.00
Cone	Steel	1	$500.00	$500.00
Cables	Steeel	4	$25.00	$100.00
Airmount	Rubber	3	$250.00	$750.00
Steel Plate (8inx8inx8ft)	Steel	1	$100.00	$100.00
Vibrator Plate	Steel	1	$60.00	$60.00
		Total Cost		**$2210.00**

Table 1: System Estimated Cost

The total expected cost to buy and machine the materials is $2210.00. The bin silo that will be used for testing of the system will be donated by VIBCO. The team hopes to be able to save money by using vendors that VIBCO already uses or is in contact with. This will allow for better pricing when it comes to buying raw material. Many of the components will be able to be machined in house at VIBCO, which will also help cut costs.

3.2 Control Interface

The interface will be used to control the system inside the bin. The system will be mounted outside with lines running through holes in the side of the bin to the system. This interface will be composed of air hoses, connectors, actuators and circuit boards. The components will be able to regulate and adjust the airmount height and vibrator speed in the system all while being controlled via an app. These components can be very expensive when bought singularly which drives up the cost of our prototype. Below is the cost per component of the interface system with a full cost total.

	Component	Quantity	Price	Total Cost
Air Lines	1/2" Stainless Steel Electric Solenoid Valve 12 VDC Normally Closed	3	$38.99	$116.97
	1/2" Manual Pressure Regulator	2	$58.00	$116.00
	Autex 150 PSI Pressure Transducer Sender for Air	3	$29.89	$89.67
	3 Way, 2 position solenoid valve (NC)	1	$38.99	$38.99
	Low Pressure Pipe Fitting REDUCER	3	$0.63	$1.89
	FM Approved Low Pressure Iron Threaded Pipe Fitting	2	$6.74	$13.48
	Low-Pressure Pipe Fitting	3	$4.41	$13.23
	3/4" Plug	1	$0.50	$0.50
	1/2" Close Nipple	10	$1.01	$10.10
	90 Degree Fitting	2	$4.01	$8.02
	3/8" ID Hose	3ft		
	1/2" ID Hose	3ft		
	Low Pressure Pipe Fitting REDUCER	1	$1.96	$1.96
	Quick Connect	1	$1.25	$1.25
	Hose Barbs	2	$7.08	$14.16
		2	$10.58	$21.16
		2	$1.15	$2.30
		2	$5.67	$11.34
Electronics	Circuit Board Mount Terminal Block	4	$1.68	$6.72
	Ready to Use Circuit Board (Prototyping	1	$11.94	$11.94
	Relay SPDT Sealed	5	$1.95	$9.75
	12V Power Supply	1	$15.88	$15.88
	LED's	4		
	Resistors			
		Total Roll Cost		**$505.31**

Table 2: User Interface Estimated Cost

The total expected cost of the control interface will be $505.31 which will bring the cost total of materials from the entire system up to $2715.31. The team hopes to minimize costs of each component by recycling fittings that are leftover at the VIBCO building and also go through VIBCO vendors that will offer possible lower prices.

3.3 Human Resources

For the members of the Capstone design project, the total labor hours spent by each group member was determined from the team event and meeting log. This kept track of time spent on any project related activity. Research hours were recorded, along with team meetings, software designing time, and meetings with our sponsor. The pay rate for the Capstone team hours was kept constant for each member and the rate was based upon current beginning level engineering salaries.

The engineering hours on the project were those spent by employees of VIBCO, with personal meeting and assisting the group with the project. Advising hours were those spent with professors and employees of the university. The advising hours were kept to a minimum, while the engineering hours were critical in gathering useful information and design ideas for the project. Below is a breakdown of the total cost for labor hours working on the project up to this point in time.

Resource	Cost (per hour)	Hours	Total Cost
Capstone Team Hours	$30.00	512	$15,360.00
Engineering Hours	$65.00	75	$4,875.00
Advisor Hours	$65.00	20	$1,300.00
	Total Cost		**$21,535.00**

Table 3: Human Resources Estimated Cost

3.4 Projected Final Cost of Project

This project is funded by the University of Rhode Island's individual Capstone budget. Our team sponsor, VIBCO, is also providing necessary funds and resources for testing and manufacturing the prototype. This includes a full bin silo, access to vendors, and access to machining equipment.

The project, involves the creation of a vibrating system inside of bin silos, that can control the flow of material exiting the bin. The full cost of the project is based on all material costs, manufacturing hours, testing hours, and hours spent on the project by the Capstone group members along with members of our sponsor. Since the project is only halfway completed, the final cost of the completed project is estimated for the full year. We plan on having the cost to produce the system to remain the same while the cost for hours of members on the project to double. This would give a final cost for the project to be around $27,500 for the whole year.

3.5 Mass Production Cost

The mass production of this product will be a major factor in allowing the price per unit to be lowered and sold at a more competitive price. Based on research along with analysis of the market, VIBCO would be able to sell upwards of 100 units per year, with possible increases as the product shows its dominance in the market. The costs of the materials used to produce the system would decrease when bought in bulk and the tables below shows this.

Component Name	Quantity	Price (Non-Bulk)	Price (Bulk)	Total Cost
VIBCO Bin	1	N/A	N/A	N/A
Mounting Plates	2	$300.00	$230.00	$460.00
U-Channel Bar Stock	2	$50.00	$25.00	$50.00
Cone	1	$500.00	$425.00	$425.00
Cables	4	$25.00	$15.00	$60.00
Airmounts	3	$250.00	$250.00	$750.00
Steel Plate (8inx8inx8ft)	1	$100.00	$50.00	$50.00
Vibrator Plate	1	$60.00	$37.50	$37.50
		Total Cost		**1,832.50**

Table 4: System Estimated Bulk Cost

	Component	Quantity	Price (Non-BULK)	Price (BULK)	Total Cost
Air Lines	1/2" Stainless Steel Electric Solenoid Valve 12 VDC Normally Closed	3	$38.99	$29.24	$87.73
	1/2" Manual Pressure Regulator	2	$58.00	$43.50	$87.00
	Autex 150 PSI Pressure Transducer Sender for Air	3	$29.89	$22.42	$67.25
	3 Way, 2 position solenoid valve (NC)	1	$38.99	$29.24	$29.24
	Low Pressure Pipe Fitting REDUCER	3	$0.63	$0.47	$1.42
	FM Approved Low Pressure Iron Threaded Pipe Fitting	2	$6.74	$5.06	$10.11
	Low-Pressure Pipe Fitting	3	$4.41	$3.31	$9.92
	3/4" Plug	1	$0.50	$0.38	$0.38
	1/2" Close Nipple	10	$1.01	$0.76	$7.58
	90 Degree Fitting	2	$4.01	$3.01	$6.02
	3/8" ID Hose	3ft	$0.00	$0.00	$0.00
	1/2" ID Hose	3ft	$0.00	$0.00	$0.00
	Low Pressure Pipe Fitting REDUCER	1	$1.96	$1.47	$1.47
	Quick Connect	1	$1.25	$0.94	$0.94
	Hose Barbs	2	$7.08	$5.31	$10.62
		2	$10.58	$7.94	$15.87
		2	$1.15	$0.86	$1.73
		2	$5.67	$4.25	$8.51
Electronics	Circuit Board Mount Terminal Block	4	$1.68	$1.26	$5.04
	Ready to Use Circuit Board (Prototyping	1	$11.94	$8.96	$8.96
	Relay SPDT Sealed	5	$1.95	$1.46	$7.31
	12V Power Supply	1	$15.88	$11.91	$11.91
	LED's	4	$0.00	$0.00	$0.00
	Resistors	3	$0.00	$0.00	$0.00
			Total Bulk Cost		**$181.73**

Table 5: User Interface Estimated Bulk Cost

These prices include the cost of machining components. It can be seen that the cost to manufacture the units in a mass quantity greatly decrease. The overall cost reduction from producing one unit to 100 projected units per year would lower the cost by an estimated $701.08 which is crucial is being able to have competitive pricing in the market.

3.6 Return on Investment

In order for the product to be worthwhile for the company to invest in, the product must generate a significant profit. This will make back the money spent on designing and creating the product, while also generating profit to cover the cost to produce it. A general basic is that a product is sold for at least double the amount of money that it costs to manufacture. Other factors also contribute to the price, including competitor's pricing and the market demand. The product that was seen in the market closest to this system, had a price over $10,000 dollars. This was a price that our system could easily be cheaper than, so competitor pricing was not an issue. The market for the product would also influence the price, with a larger demand it allowed for pricing to decrease. For the market, it was estimated that, VIBCO would be able to sell around 100 units per year. This would be enough units sold to not drive up the price, while allowing VIBCO to make a large enough profit margin. It was then decided the price of the system would be two and a half times the cost to manufacture the product in bulk quantity, which would make the selling price per unit to be $5900.00. This price was well below competitor pricing which made it affordable for customers, and also gave a VIBCO a decent profit margin. With the pricing set for the product, it was then calculated how long it would take VIBCO to make back its initial investment from the creation of the product. The table below shows this.

Number of Units Sold	Price per Unit	Revenue	Cost to Manufacture	Profit
1	$5,900.00	$5,900.00	$2,014.23	$3,885.77
2	$5,900.00	$11,800.00	$4,028.46	$7,771.54
3	$5,900.00	$17,700.00	$6,042.69	$11,657.31
4	$5,900.00	$23,600.00	$8,056.92	$15,543.08
5	$5,900.00	$29,500.00	$10,071.15	$19,428.85
6	$5,900.00	$35,400.00	$12,085.38	$23,314.62
7	$5,900.00	$41,300.00	$14,099.61	$27,200.39
8	$5,900.00	$47,200.00	$16,113.84	$31,086.16
9	$5,900.00	$53,100.00	$18,128.07	$34,971.93
10	$5,900.00	$59,000.00	$20,142.30	$38,857.70
11	$5,900.00	$64,900.00	$22,156.53	$42,743.47
12	$5,900.00	$70,800.00	$24,170.76	$46,629.24
25	$5,900.00	$147,500.00	$50,355.75	$97,144.25
50	$5,900.00	$295,000.00	$100,711.50	$194,288.50
75	$5,900.00	$442,500.00	$151,067.25	$291,432.75
100	$5,900.00	$590,000.00	$201,423.00	$388,577.00

Table 6: Profit Made Over the First Year of Sale

With the price per unit, and initial estimated investment of $23,549.23, it would take VIBCO 7 units sold in order to see the return of investment. It is also shown in the table that for the estimated 100 units sold in the first year, it would generate VIBCO a net profit of $414,900.00. This profit margin is substantial and would make this product a leading asset in VIBCO's arsenal of products.

4 Literature and Patent Searches

4.1 Patent Searches

A patent search is critical in the research process prior to designing the product. The market needs to be analyzed in order to know what products currently have patents in order to make sure designs that have already been created are not infringed upon. The time it takes to design a product would be wasted if it had already been created. The patent searches help confirm that the design is original, while also giving insight into potential new ideas for designs. It gives a platform to build upon old ideas that can blossom into functional new concepts. The search can show certain downfalls and flaws in old designs that can be reworked and improved upon. The patents below are the most relevant to the project at hand.

US5960990 A/ Product Discharge Activator and Method of Use

Date: October 5, 1999

Rights owned by: Radosevich; Paul T.

Abstract: A flowable bulk product discharge activator and method of discharging flowable bulk products assures uniform, mass-flow discharge of loose, dry, flowable, bulk products from bulk storage containers that is void of any internal horizontal ledges to interrupt downward flow, while including sanitary features that impart a sifting/activating action to the flowable products discharging from the container. The product discharge activator has knife-sharpened and angled supports, a baffle, vertically oriented sifting plates all disposed in a vibratable chamber, the chamber joined to a vibrating motor.

Relevance: This patent gives an outline of a cone design that sits at the bottom of a bin with a vibrator attached to the outside. The cone additionally rotates in order to help move material. This patent provided a strong basis of creating a product with a cone design because that shape is proven to allow material to flow better.

US4062527 A/ Vibration Device for Silos for Bulk Materials

Date: December 13, 1977

Rights owned by: Schmitz; Josef

Abstract: A vibration device for a silo for bulk material having a funnel-shaped delivery outlet comprises an elastically suspended support carrying a jolting motor and provided with downwardly extending guide wings in the configuration of a rosette of blades extending into the outlet passage and a cage surrounding the guide wings and formed with downwardly converging walls parallel to the walls of the delivery funnel. The cage may be provided with an array of downwardly extending rods and is supported against the sides or walls of the funnel by elastic members or buffers, the entire assembly being elastically suspended in the funnel, e.g. by tension springs. Between the jolting motor and the cage, there are provided longitudinally and torsionally elastic spring elements so that the assembly comprises two independently vibrating masses set into vibration by the jolting motor.

Relevance: This patent has a design that is attached inside a bin and has plates that vibrate in order to move material and direct it to the exit hole of the bin. The patent is applicable due to the fact that it rests inside the bin and can vibrate material. This design does have many flaws in that it is unable to control flow and seems complex. This did not seem like a good direction to head in with a new design.

US6311438 B1/ Silo for the Storage of Powdery Products Having a Vibrating Bottom

Date: May 10, 2000

Rights owned by: Haquette; Michel

Abstract: A silo, in particular a vertical one, designed to store products in powder form, and having a vibrating bottom, suitable for favoring flow, and for equipping a fixing damper body of a silo by means of a joining element and a fixing damper, provided to ensure a tight connection between the body of the silo and the vibrating bottom, while, at the same time, preventing a transmission of vibrations from one to the other. According to the invention, the joining element takes the form of an elastically deformable, peripheral, self-supporting joint, interposed directly and freely between the body of the silo and the vibrating bottom, cooperating with the fixing damper to perform both a sealing function and a damping function, without discontinuity over its entire bearing periphery.

Relevance: This patent has a vibrator that sits on the outside of the bin and transfers vibration to the cone fixture inside. The system has isolators on the vibrator that keep vibrations from transferring to the bin itself, and this is something the design of the product is going to need with the vibrator. This a direction the design would head in, to isolate vibrations.

US6685060 B1/ Material Handling Apparatus

Date: February 3, 2004

Rights owned by: Lee; Charles

Abstract: Material handling apparatus for gravity discharge of flow able particulate material through an outlet of a container for such material which outlet is normally obdurate by a hollow cone valve member, the apparatus comprising actuator means having a flat surface and being adapted to engage the cone valve member adjacent the base thereof for raising and lowering same whereby to provide that the interior volume of the cone valve member remains substantially empty. In the embodiment, the apparatus is a component of a materials handling system in the form of a discharge station “D”, which is fixed for example in the floor of a facility for transferring flow able material from a (transportable) IBC to a process “P” such as mixing, blending, tableting the like which is below the discharge station D.

Relevance: This patent has a system that attaches to the bottom of the bin, with a cone that is able to raise and lower causing material to flow out. This is a direction the design is looking to go towards with a cone that is able to raise and lower. The cone will need to vibrate in the new design and also rest inside of the bin rather than attaching to the bottom.

4.2 Literature

Research literature on both material, bin silos, and vibrating material is important to learn more about the field the design is looking to attain. Most of the literature that was gathered was either provided from VIBCO or other sources found during research.

VIBCO provided a substantial amount of information on material that would be found inside of bins. The documents provided material characteristics such as density, in pounds per cubic foot, and the angle of repose, in degrees. These values would be used in calculations for the weight of material inside the bin and how the material would flow when set into motion. The company was also able to provide different methods that have been used in the past to agitate material inside bins. This included methods that had great success using cone shaped designs to induce material flow, with other designs using fins to give a stirring motion to the material.

5 Competitive Analysis

5.1 Evaluation of the Competition

VIBCO gave our team the objective to design a system that can vibrate material within a bin silo and also be able to control the flow of that material out of the bin. In order to see other products that have already been created by competitors in the market, research was conducted and compared to the system our sponsor was looking to create. This would allow for successes and flaws in competitor's products to be addressed and evaluated in order to improve our design. After research of the market for our system, three main competitors were found, Brock Bin, Vibra Screw and MATCON. All three products had similarities with using a cone shaped product that rested either inside or at the bottom portion of the bin with a vibrator attached to agitate the material. Brock Bin's design actually used a vibrator that VIBCO makes, while the other had other company's vibrators to create vibration. The evaluation in each competitor's product was crucial to make sure our system would work and thrive in the market.

5.2 Brock Bin

The first competitor is Brock Bin, which is a company that actually manufactures bin silos for many different settings. They have a module cone insert that is mounted inside a bin with chains and has a vibrator underneath in order to agitate material. There were three main problems that were seen with this product. The fixture was only designed to fit inside Brock's own bins which meant that customers with a bin already needed to buy one of Brock's in order to use the product. The fixture also was placed in the bin at a fixed height making it unable to control the flow out of the bin. Additionally, due to the size of the cone, a custom housing for the vibrator was required for the vibrator to attach to the underside of the cone. This intern increased the price of the fixture greatly for the customer.

5.3 Vibra Screw

The second competitor is Vibra Screw, which makes a cone fixture that mounts to the bottom of a bin and has a vibrator attached to the outside that transfers vibration inside to the cone. This system also had numerous problems including altering the bin, the vibrator location, and the mounts for the cone. The system attaches to the bottom of existing bins, which means that that bin bottom needs to be cut off and then the system must be welded rendering the bin useless if a company decided they do not want to use Vibra Screw anymore. The vibrator being mounted to the side of the system is also an issue because it causes uneven vibration of the cone with one side vibrating more than the other. This can cause material to flow unevenly and possibly clog. The cone is also hard mounted inside the system, causing dampening of the vibration and weakens its power in being able to move material.

5.4 MATCON

The third and final competitor was Matcon, who created a FDA approved cone system, that was mounted to the bottom of the bin, and was able to raise and lower with vibration. This allowed the system to be able to control the flow of material out of the bin while additionally keeping material in the bin from clogging. MATCON's product also was FDA approved, which made it possible to be use in a pharmaceutical or food industry setting. The foreseen problems with this design was the price and the bin needing to be modified in order to install the system. MATCON's system was much more expensive than any of the other two systems above which could deter potential customers with a smaller budget. In order to install the system, the bottom of the bin needed to be cut out, intern rendering the bin useless if the company decided they did not want to use MATCON's system anymore. In order to gain an advantage on the market, each of the issues competitors had were analyzed in, why they had the problems, and solutions to these problems that could then be implemented in the design

6 QFD

Another way to analyze the requirements of the design was through a QFD, which stands for Quality Function Deployment. It is essential in helping determine a products design based on the requirements of customers and specifications set before the initial creation. The house of quality, is a tool used in the QFD which relates the customer requirements with the function requirements and gives a starting point of which requirements are most important when designing the product. The house of quality is comprised of seven sections; demanded quality, function requirements, competitive analysis, target values, relationship matrix, importance weight of function requirements, and the difficulty of satisfying each requirement. Each of these sections can be evaluated to find the most important characteristics the design of a product needs to have. The function requirements and demanded quality are compared two times in the house of quality, the first being with how the two interact with one another, whether or not the function requirements affect the demanded quality. The second time they are compared is in the relationship matrix and this shows if the relationship between the function requirements and demanded quality is weak or strong. The difficulty to implement each demand quality and function requirement in the design and the importance of each, combined with comparisons give a grade. This weighted grade allows for the designers to establish which characteristics need to be considered first. The full QFD house of quality is in the appendix.

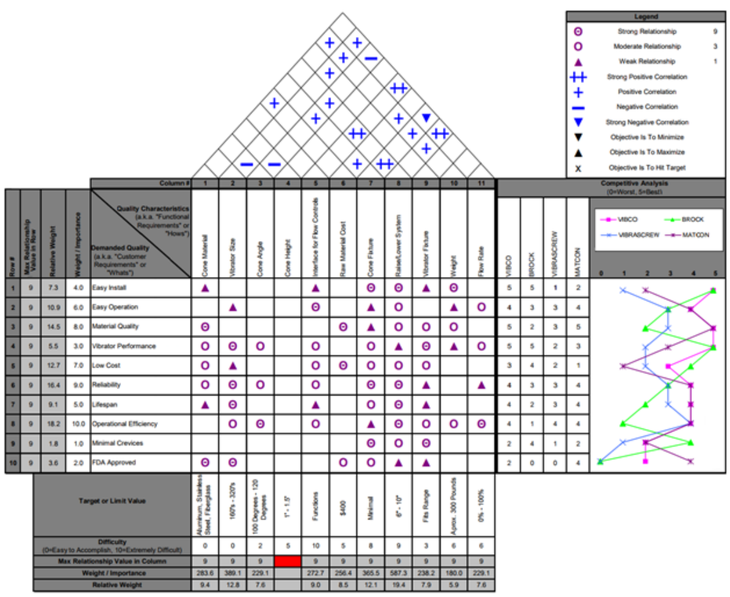


Figure 4: House of Quality

6.1 Demanded Quality vs. Quality Characteristics

Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Cone Material	Vibrator Size	Cone Angle	Cone Height	Interface for Flow Controls	Raw Material Cost	Cone Fixture	Raise/Lower System	Vibrator Fixture	Weight	Flow Rate
Easy Install	▲				▲		Θ	Θ	▲	Θ	
Easy Operation		▲			Θ		▲	O		▲	O
Material Quality	Θ					Θ	▲	O	O	O	
Vibrator Performance	O	Θ	O		O		O	▲	Θ	▲	O
Low Cost	O	▲			O	Θ	O	O	O		
Reliability	O	Θ	O		O		Θ	Θ	▲		▲
Lifespan	▲	Θ			▲		O	Θ	▲		
Operational Efficiency		O	Θ		O		▲	Θ	O	O	Θ
Minimal Crevices							Θ	O	Θ		
FDA Approved	Θ	Θ				O	O	▲	▲		

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1

Figure 5: Demanded Quality vs. Quality Characteristics Charts

In order to begin the house of quality, the demand qualities, or "customers wants" had to be addressed. The qualities that customers wanted in the system were easy installation, easy operation, material quality, vibrator performance, low cost, reliability, a long lifespan, operation efficiency, minimal crevices, and having it be FDA approved. The product needs to be easy to install because it will save time and money for the company to get it put into the bin and ready to run. The way to operate the system also must be easy for employees to use due to the fact that a company does not want to waste time to train employees how to run the product. The quality in the material of the product is important to customers because it shows that the manufacturer takes pride in their product and took the time to make sure the product is built in a way that it will not fail. Vibration performance is key to making sure the system keeps material from clogging within the bin, if it is unable to do so, it will be useless for customers. Cost is a very important part of a product when appealing to customers, if the product is built well and is at an affordable cost, customers will be very likely to purchase. A product must be reliable and have a long lifespan in the fact that it must work correctly every time it is called upon, repairs or replacement can cost time and money for companies. The product must be efficient because overuse of energy will result in lost money for customers. Minimal crevices in the product is important to keep material from getting stuck when it is exiting the bin. If material were to build up in crevices the company would have to stop operations to clean out the material. The last demanded quality is having the product be FDA approved and this is because customers in the pharmaceutical or food industries need to have the system FDA approved in order to use it. The second piece to creating the house of quality was deciding the quality characteristics, or "functional requirements" of what the system had to have or do in order to work. These characteristics were cone material, vibrator size, cone angle, cone height, an interface for flow control, raw material cost, the cone fixture, a raising and lowering system, a vibrator fixture, weight, and flow rate. The cone material is applicable in the cone being able to resist deformation under the material weight and also having the system be FDA approved. The size of the vibrator is important because it needs to have the correct amount of force to be able to vibrate certain density materials. The angle of the cone will determine how material flows and it must accommodate different material angle of reposes. The height of the cone applies to where in the bin it will touch when it is fully lowered and what size vibrator will be able to fit inside of it. An interface to control the system is required to control the vibrations and flow control, while also being easy to use for the operator. The cost of materials that make up the system are important to keeping the cost of the entire system low, while also making the system strong enough to work under the conditions it will be in. Fixing the cone to the bin is crucial in the system working correctly and it cannot get in the way of the flow of material. The raising and lowering system will be what lifts the cone and it has to have enough power to lift the material weight without failing. The vibrator fixture it what will transfer vibration from the vibrator directly to the cone and this has to be able to allow for different sized vibrators to attach to it. The system's weight cannot be too large or it will make the installation of it more difficult, while causing a greater pressure of the system on the bin walls. Flow rate is the last quality characteristic and the flow rate is key in managing the material output from the bin. The demanded qualities were then compared to each of the quality characteristics in order to see if they had a relationship.

6.2 Relationship Between Functional Requirements

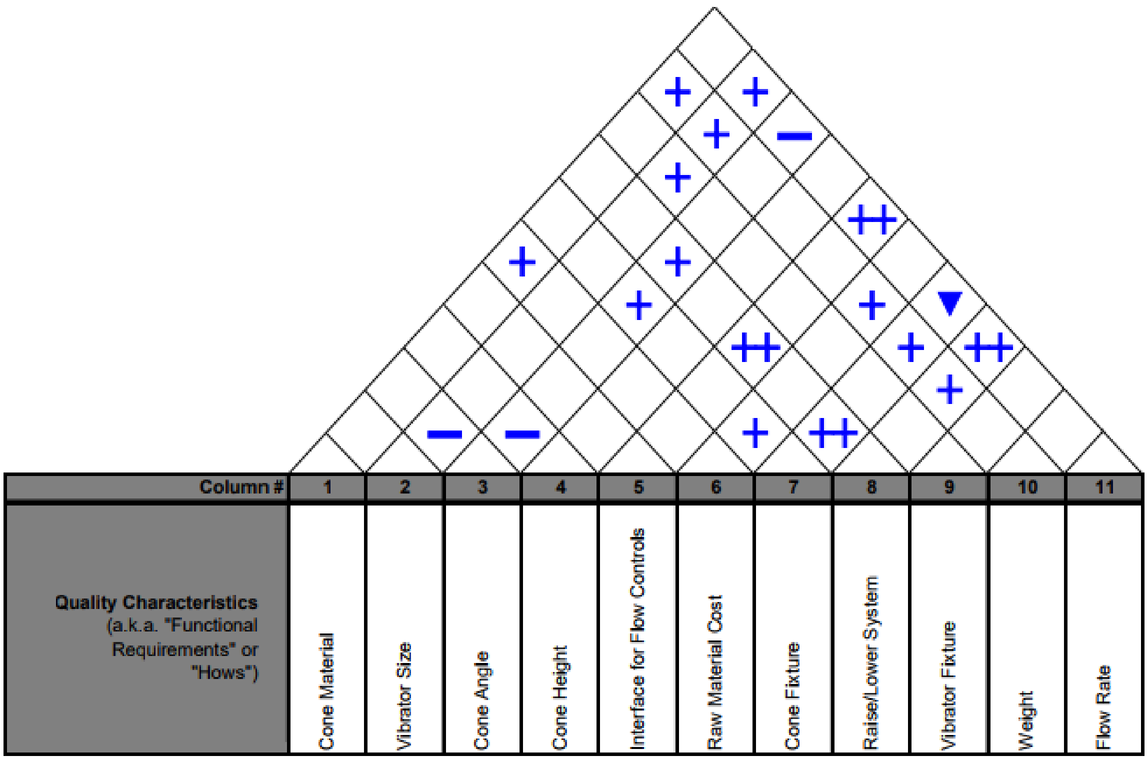


Figure 6: Relationship Between Functional Requirements

The top part of the house of quality shows how each of the quality characteristics relates to one another. There are three different correlations, negative, weak positive, and strong positive. The symbols are contained in the legend for the house of quality.

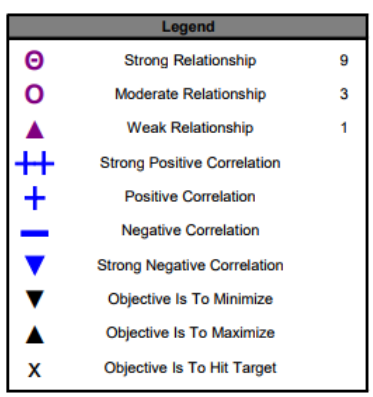


Figure 7: House of Quality Legend

6.3 Competitive Analysis

Row #	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Competitive Analysis (0=Worst, 5=Best)			
		VIBCO	BROCK	VIBRASCREW	MATCON
1	Easy Install	5	5	1	2
2	Easy Operation	4	3	3	4
3	Material Quality	5	2	3	5
4	Vibrator Performance	5	5	2	3
5	Low Cost	3	4	2	1
6	Reliability	4	3	3	4
7	Lifespan	4	2	3	4
8	Operational Efficiency	4	1	4	4
9	Minimal Crevices	2	4	1	2
10	FDA Approved	2	0	0	4

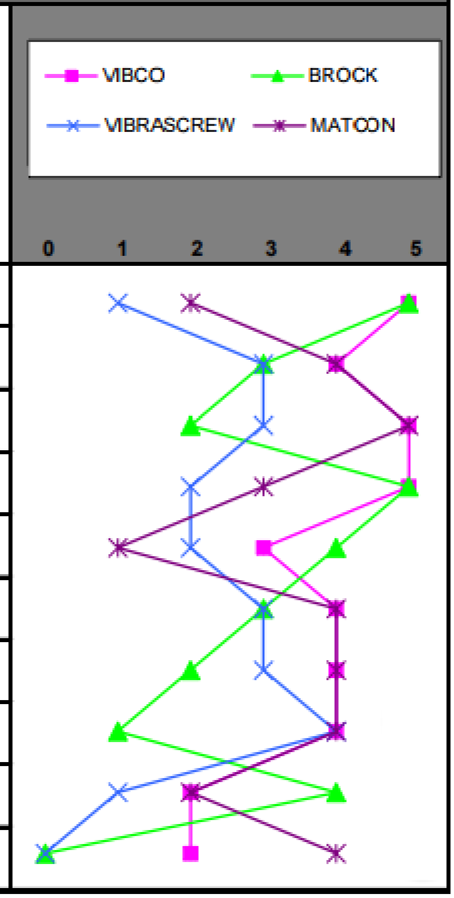


Figure 8: House of Quality Competitor Analysis

The competitive analysis was a comparison of competitors in the market with similar products. The analysis showed how every competitor met each of the demanded qualities from the customers. This gave observations of where the market could be improved and how the project's design could be given characteristics to stick out above other products. It was found that competitors were lacking when it came to easy installation, vibration performance, product quality, and the lifespan of the product. These were demanded qualities that were taken into account to improve the design of system. MATCON had a system that matched well with customer qualities besides easy installation and low cost. This is where it is hoped that our design can improve and get a leg up in the market above MATCON.

6.4 Tradeoff Analysis

The tradeoff analysis was completed in addition to the QFD, which gave the comparison of different types of designs that could possibly be implemented in the project. The analysis was done between whether or not the cone should be suspended with cables or held in the bin with legs that are below it. These designs were in the process of being completed and the tradeoff analysis gave the best option for design when moving forward into creating the actual system.

The most important aspect of the design of the cone was the difference between the cone being suspended with cables or held up with legs. After the situation was analyzed it seems that having legs hold the cone inside the bin was the best options for many reasons. The cables were evaluated to be more difficult to install to the top to the bin while making it difficult to isolate the vibrations to strictly the cone. Also, the cables would not be able to keep the cone from possibly shifting to one side of the bin if the material were to push it. This would make the cone very unstable under the immense weight of the material. The legs under the cone would be able to keep this shifting from happening while also making it easy to isolate vibration. The legs would also offer additional support to the cone under the material weight. The legs would have draw backs as well including that they would not be able to universally fit in bins and it would be complex for them to match the same contour as the bin.

6.5 Conclusions of QFD Analysis

The QFD analysis was a great asset to the group, and it greatly impacted the project's direction during the design process. The house of quality provided weighted results showing the importance of characteristics the product should have when designing. It showed the most important parts of the design were the vibrator size, the raising and lowering system, and the cone material. This gave the direction for our group to design a system that would raise and lower and that was attached to the bottom of the bin, with a vibrator mount that could accommodate different sized vibrators for different materials. The cone material would also be important in making the product FDA approved and strong enough to hold up against the weight of material in the bin.

7 Design for X

7.1 Product

When designing a product, there are characteristics to be considered, which can affect logistics of actually being able to create that design, the cost of the product, and many other factors in the product being a success in its market. Due to the fact that customer requirements are also related to the functionality requirements of the product, they need to be analyzed in order to see what kind of effect they will have on one another.

7.2 Installation

Easy installation is key to keeping cost low and also appeal to potential customers. The easier it is to install the system into the bin, the less down time a company will have to take and thus keep the loss of profit low. The ease of install was found to have a weak relationship with the cone material, the interface to control the system, and the vibrator fixture. The cone material and vibrator fixture would have a small effect on the weight of the system and the interface would have to be able to attach to the system and have it working quickly in order for the install to be easy. The weight of the system, the cone fixture, and the raising system for the cone were all found to have a strong relationship with the ease of install. The full weight of the system is comprised mainly of the cone fixture and the raising system for the cone. The lighter weight of these two components are crucial in making it easy to be placed inside the bin and installed correctly.

7.3 System Operation

Ease of operation using the interface helps customers get the system working efficiently and allow for workers to use it with minimal time and training. This will intern save the company hours in training employees and lower running costs with it regulating the efficiency in the system. The vibrator size, cone fixture, and weight all had a weak relationship to the ease of operation because they all related to the operation of the system but do not directly affect how it was operated by employees. The raising system for the cone and the flow rate had a moderate relationship to the ease of operation due to the fact that the cone had to raise up quickly in order to have material flow out of the bin almost immediately and the flow rate had to be consistent or else the needed amount material would not be flowing out of the bin. The interface for flow controls had the strongest relationship with how easy the system was to operate. The interface is what the employees would interact with in order to control the system. This not only had to control the system correctly, but do it in a way that allowed the operator to understand the controls of each component in the system.

7.4 Material Quality

Material quality is very important to customers because it shows that the system will last and was built to a high quality. Material quality had a weak relationship with the cone fixture because the cone fixture is will already be comprised to hold the cone and this will not be the component that would fail if the system were to. The raising system, vibrator fixture, and weight had moderate relationships with the material quality because the raising system had to be strong enough to lift the cone under the material weight while additionally not failing. The vibrator fixture needed to be able to transfer vibrations from the vibrator to the cone with little loss of vibration, so the material was crucial in it being able do this. The weight related to material quality by the fact that the weight of material wanted to be kept to a minimum while also making sure the material could hold the system and last. The raw material cost and the cone material had to strongest relationships to the material quality. The material cost wanted to be kept at a minimum to lower the cost of the system but the material could not be so cheap that it was not strong enough to keep the system from failing. The cone material also was crucial in material quality. The cone is what while directly be in contact with the material and also will be vibrated. The cone material could not corrode or contaminate the material within the bin, while also holding the weight of material without deforming.

7.5 Vibrator Performance

Vibrator performance is important to the customer because if the vibrator fails to work or does not work correctly, the whole unit will not perform to the desired customer needs. The raising system along with weight had a very weak relationship with the performance of the vibrator. The raising system would be used to isolate the vibrations to solely the cone but this would not play a huge role in the actual vibrator performance. Additionally, the weight could play a role in dampening the vibrations but a majority of the weight would be carried in the cone fixture and this would be isolated from vibration. The cone material, cone angle, interface to control the system, the cone fixture, and the flow rate related to the vibrator performance in a moderate way. The cone material would be a factor in transferring the vibration from the vibrator through the cone to the material. The flow rate and the cone angle would play a role in how the material was vibrated over the cone, if the cone angle was too small material would be vibrated but would not flow down over the cone, thus just compacting the material. The interface would be what controlled the vibrator and the amount of vibration put out. The cone fixture, as discussed before, will have some dampening effects on the vibration if the vibration is not isolated correctly. A strong relationship to the vibrator performance was between the vibrator size and vibrator fixture. Every material has different amounts of vibrations to flow, so if a vibrator that is too small is used the material will not flow. Fixing the vibrator to the cone is crucial in transferring the vibration directly from the vibrator to the cone.

7.6 Low Cost

Low cost is crucial in appealing to customers and beating competitors in the market. Customers will enjoy if the product is made with high quality products but is also at a price they can afford. The vibrator size had a weak relationship with the cost because VIBCO will be making this and the price is pretty well fixed for each one so a variation in cost is not seen to be an issue. Moderate relationships to the cost were the cone material, the interface, the cone fixture, the raising system, and the vibrator fixture. Each of these components can vary in size and material which can change the cost of the system for the customer. The strongest relationship was the raw material cost to the cost of the system for the customer. Being able to keep the amount of material and the cost of that material low is the most important part in reducing the price of the system.

7.7 Reliability

The system must be reliable no matter what time it is needed to run and for however long. If the system does not work, the material will not flow correctly and production will have to be halted resulting in lost profits. The vibrator fixture and flow rate were determined to have weak relationships to the reliability of the system. The vibrator fixture is a part that has a minimal chance of failing or causing the system to fail, while if flow rate were to stop it would be caused by another part of the system failing. Moderate relationships to the reliability were the cone material, the cone angle, and the interface to control the system. The cone material must have the strength to hold the full weight of the material without deforming. If it were to deform, the cone would not vibrate material correctly or control the flow of material. The cone angle would play a role in the flow rate and if it was too flat, material would be compacted inside the bin rather than flowing down the cone and out. Controlling the system with the interface could fail and cause the whole system to no work, but because it is outside of the bin and made of simple components the potential of this failing are minimal. The vibrator size, cone fixture, and the raising system for the cone are all seen to have strong relationships to the reliability of the system. Sizing the vibrator is important in the system being able to vibrate material out of the bin and keep it from clogging. If the vibrator is not strong enough to vibrate a certain density of material, the system will reliably make material flow in the bin. The cone fixture and raising system need to be have the strength to support the cone along with weight of material in the bin. These have the highest probability to fail and need to be taken into account when trying to improve the reliability of the system.

7.8 System Lifespan

The longevity of the product's lifespan is important because the customers want a product they can install and not have to touch or replace for years. A longer lifespan results in less repair costs and lost time for customers. The cone material, system interface, and the vibrator fixture are all seen to have a weak relationship to the lifespan because they all have a low probability of degrading while the system is in use. A moderate relationship to the lifespan of the system was the cone fixture. The cone fixture has a chance of weakening over time from the weight of both the system and the material, thus causing the system to fail in a shorter time. The lifespan of the system has a strong relationship with the vibrator size and raising system because these are the two main features of the system. If one of these were to stop working the system would have to be repaired immediately. If a vibrator that is too small is used in the system, it could be overworked and fail. While if a raising system is used that cannot hold the weight of the material it will not be able to raise and allow material to flow out of the bin.

7.9 Operational Efficiency

The operational efficiency of the system will result in less money having to be spent by the company to run the system. The less energy needed to power the system, the more money the company saves. A weak relationship to the efficiency was the cone fixture due to the fact the fixture only sits inside the bin and has minimal relation to the vibration or the raising system efficiency. The vibrator size, the interface for the system, the vibrator fixture, and the weight of the system all have moderate relation to the operational efficiency. The vibrator size is important in making sure the material is flowing out of the bin rather than just being compacted. The vibrator fixture has to transfer vibration from the vibrator to the cone in a manner that has minimal lost vibration. This also related to the weight because the heavier the system, the more the vibration will be dampened. The loss of vibration is a waste in power to run the vibrator and thus is a loss in efficiency. Controlling the system with the interface will allow the user to regulate the amount of vibration and flow of material out of the bin. This will help efficiency because if a smaller amount of vibration is needed at different times this can be controlled, keeping the loss of energy to a minimum. The raising system, cone angle, and flow rate of the system have the strongest relationship to the operation efficiency. The cone angle is directly related to the flow rate in the fact that each material has a different angle that causes them to flow, if the cone angle is not steep enough material will not flow and vibration will be wasted. Raising the system is also crucial in the operational efficiency because the system used to raise the cone must be able to not only work under the weight of the material but also do it in a way that does not draw large amounts of energy.

7.10 Manufacturability

Minimal crevices in the design of the system will result in better flow and less product that gets stuck coming out of the bin. This will improve the efficiency of the operation. The raising system, the cone fixture, and the vibrator fixture all have strong relationships to making sure the system has minimal crevices. These three pieces all lie beneath the cone which means the material flowing past the cone will also flow past these pieces. They cannot have places where material can get stuck or clogged, which then would result in a lower flow rate out of the bin or contamination of old and new material.

7.11 FDA Approval

The FDA approval of the product is very important in it being marketed to and used by food and pharmaceutical industries. The system must be FDA approved in order to be placed inside the bin and not contaminate products. Weak relationships to the system being FDA approved were the raising system and the vibrator fixture. The raising system will most likely be chosen so that it is already manufactured to be FDA approved, while the vibrator fixture is a small part that can easily be manufactured out of material that is FDA approved. The raw material cost and cone fixture have a moderate relationship to the system being approved by the FDA. FDA approved materials generally have a higher cost so this will increase the raw material cost. The cone fixture will be in contact with the material for limited amounts of time, so this is not as important as other components. The cone material and vibrator size have a strong relationship to the system being FDA approved. The cone will always be in contact with material, so it is very crucial to have the material be approved. While VIBCO does make vibrators that are FDA approved, it will be need to be able to fit inside the cone.

7.12 Design Specifications

Given the objective of creating a system that could vibrate material inside a bin silo while also control the flow of that material, the team set design specifications. The design specifications for the product gave a list of requirements that the product had to have or stay within. These specifications would capture the demands of the customer, while also reflecting the product our sponsor was wanting to create. In order to address design specifications for the product, the aspects and requirements for the project were assessed. This was done in the product identification chart located in the tables section of the report. Once the aspects of the project were identified, the design specifications were able to be created with specific, numerical parameters.

To begin, the customers in this market were looking for a product that could keep material in bin silos from clogging, getting rat holes, or bridging. Material tends to bind inside bins with the center of the material flowing out, while the material on the sides of the bin being stationary. The product needed to be able to vibrate material so that it would not get clogged within the bin. This related to the design specification of vibrator size, cone height, and limited crevices. Ten pounds of material require one pound of vibration in order to flow, with each material having different weights and densities, vibrators had to be between the turbine style sizes of 160-510 in order to handle the materials in the market. The height of the cone would also play a role in what size vibrator would fit inside the cone, so this height had to be large enough to accommodate the specified vibrator sizes from above. After determining the maximum height of the largest vibrator, the height of the cone had to be between 12-16 inches. Minimal crevices in the system were important to keep material from clogging and in order to limit crevices, any part of the system in contact with the flow of material could not be thicker than 3/16 of an inch.

In addition, customers also wanted the product to be able to control the flow of material out of the bin from 0-100% flow. This would give the customers the control on how much material was exiting the bin at a specific time. The flow controls and cone angle were the specifications that related to the control of material flow. The flow controls were how high the cone raised to allow for different amounts of material to flow. The maximum flow rate required the cone to raise a maximum of 6-8 inches for different sized bins. The angle of the cone also had to aid in the flow and would determine how easy material would flow while being vibrated. The angle of repose of materials determined the angle at which a material would being to flow. This related to the angle of the cone, so for the material that would be used, the cone angle had to be between 20-60 degrees.

In order to make the product marketable to a wider audience, it needed to be able to install into many different sized bins and install easily into those bins, while also being affordable. Bins come in different heights and bottom chute angles. The size or diameter of the cone had to be able to rest inside all the bins without being too low or too high. The optimal diameter of the cone had to be between 30-45 inches. The installation time and weight related to how easy it was for customers to install the product into their bin. In order to have a positive opinion on installing the product, the installation time had to be between 3-4 hours. Based on research of materials that could be stored in bin silos and using their densities, it was found that that system had to be able to withstand and lift 3 tons or 6,000 pounds of material. The biggest cost in manufacturing the product would be the raw material price. The price of the full system needed to be affordable to large and small customer budgets.

Parameter	Target Value
Attachment Method	Must be attached on the inside or on the top of the bin
Vibration of Material	Transfer 1 lb of vibration per 10 lbs of material directly above cone
Strength	Must be able to support 3 tons
Lifting Capacity	Must be able to lift 3 tons
Safety	Must be FDA approved for food grade materials
Ease of Use	Must have simple easy-to-use controls
Adaptabilty	Must be able to be implimented in bins ranging in 2-6ft diameters

Table 7: Design Specifications

8 Conceptual Design

8.1 Robert Toth Concept List

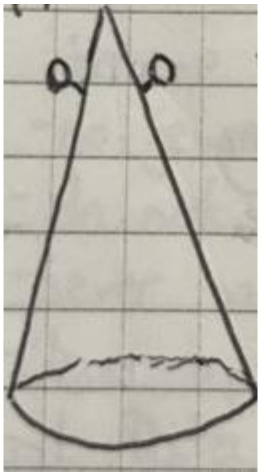


Figure 9: Simple Cone Fixture

1. Simple Cone: The simple cone shape has mounts on each side in order for it to be suspended from the bin. The vibrator will be mounted somehow either on the bottom or inside the cone. This will have to be constructed either using rolled metal or multiple sections of rolled metal.

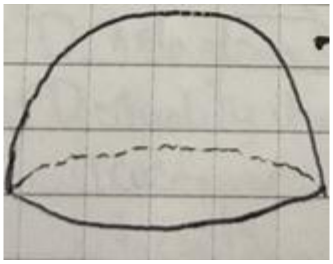


Figure 10: Dome Fixture

2. Dome: The Dome, half sphere shape will still allow material to uniformly flow past it within the bin. The vibrator can be mounted either on the bottom or inside. This will be

easy to manufactured with metal stamping technique. Mounts to hold the design can be placed anywhere near the top or fixed to the bottom.

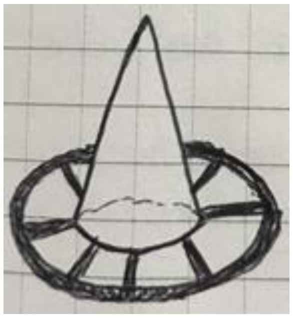


Figure 11: Cone with Base Fixture

3. Cone with Base: The cone shaped top has extensions that come out on the bottom to extend vibrations out through more material. The vibrator can be mounted to the cone part of the design or directly to the extensions on the bottom.

Figure 12: Lower Angle Cone Fixture

4. Lower Angle Cone: This is a cone shaped design but a lower slope on the cone, almost like a Chinese hat shape. The lower angle would give a bigger horizontal surface area for material to be vibrated. Additionally, it would give a better control of flow and the vibrator can be mounted to bottom.

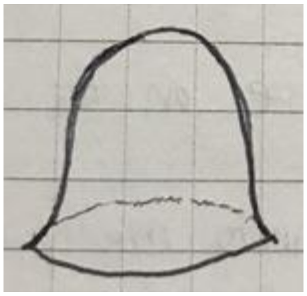


Figure 13: Bell Fixture

5. Bell: The bell shaped insert design will still allow for material to uniformly flow past. The flares on the bottom also give more surface area for material to be vibrated. This design will also most likely be able to manufactured with stamping metal technique which will be cheaper.

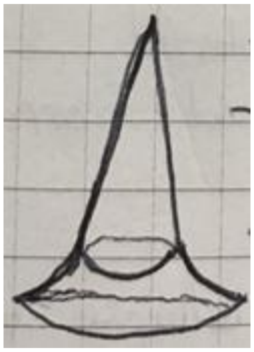


Figure 14: Bell Bottom Cone Fixture

6. Bell Bottom Cone: The cone shaped design with flare at the bottom which will allow the top to pierce through material which will make moving cone up and down easier. The flare will give a better control of material flow. A vibrator can be mounted on the bottom or inside the design.

Figure 15: Wagon Wheel Top Cone Fixture

7. Wagon Wheel Top Cone: The design has a circular, open shaped design almost like a wooden spoked wheel with cone on bottom. The top will extend vibrations out through material, and then material will be able to flow down the cone. Cone at the bottom will help regulate flow.

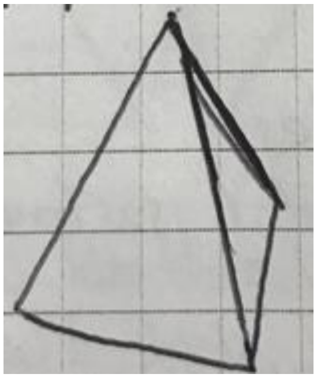


Figure 16: Pyramid Cone Fixture

8. Pyramid Cone: This is a pyramid shaped design. The flatter walls will offer a better surface for material to be vibrated. The pyramid shape will not allow for flow of material to be stopped completely.

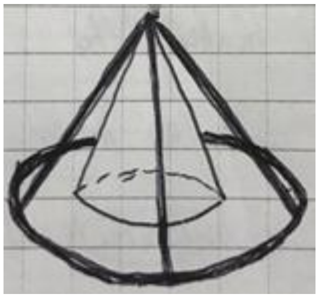


Figure 17: Cone Inside Cone Fixture

9. Cone Inside Cone: The design has a cone shape with a metal fixture on the outside that is also cone shaped. The metal fixture will extend vibration out further into the material. It will still allow for material to flow past the fixture and onto the cone which will control flow.

Figure 18: Bin Insert

10. Bin Insert: This design will be an insert that will go into bin and sit in the bottom funnel part of the bin. The three legs will be supports from the insert to the cone. The insert will help dissipate the forces exerted on the wall of the bin from the weight of the material on the cone.

Figure 19: Airbag Lift

11. Airbag Lift: The design has a cone fixture that will sit on rubber airbags to raise and lower. The rubber airbags will help isolate vibration and keep vibration from transferring to legs that hold cone up. There will already be air hoses in the bin from the pneumatic vibrator so this will be easy to install.

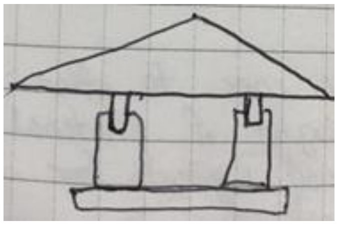


Figure 20: Double Piston Lift

12. Double Piston Lift: The cone in this design will sit on pistons that will move it up and down which will control flow. The pistons will be stronger and more rugged than using airbags, but vibration isolators will have to be put on the piston.

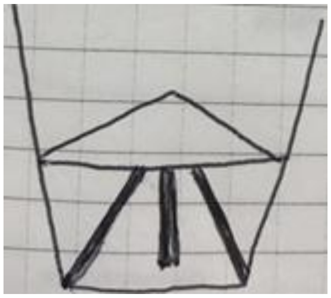


Figure 21: Three Leg Support

13. Three Leg Support: This is a set up comprised of three legs that would support the cone, vibrator, and raising system. The legs would extend from the cone to the walls of the insert. Additionally, the legs will most likely be attached to the walls of the insert with welds.

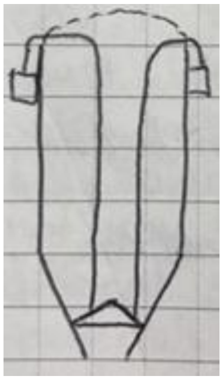


Figure 22: Outdoor Cable Winch

14. Outdoor Cable Winch: This design has a cable system that is able to hoist the cone up and down in order to change flow rate. Rubber connectors would have to be attached to the cables from the cone to isolate vibrations. The cables would extend to the top of the bin then go outside into winches. The winches would be attached to the outside of the bin near the top.

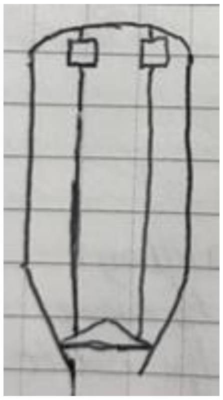


Figure 23: Indoor Cable Winch

15. Indoor Cable Winch: This design is also a cable system that would hoist the cone up and down. This system would be contained within the bin to make sure the material is not contaminated. The winches would be attached to the top of the bin and the cables would hang straight down.

Figure 24: Cone Inner Support

16. Cone Inner Support: This is a grid network that will sit inside the cone to offer support under the weight of the material. This will be made most likely out of steel rod. It will offer good contact points to transfer vibrations from vibrator to the cone.

Figure 25: Vibrator Mount

17. Vibrator Mount: The design has a leg-like structure that mounts inside of the cone that will be a mount for the vibrator. It will provide vibration towards the top portion of the cone, which is most important compared to vibration at the bottom of the cone.

Figure 26: Vertical Vibrator Mount

18. Vertical Vibrator Mount: The vibrator in this design will be mounted vertically inside the cone, which could offer a different style of vibration to the material. This could potentially give better flow rates of material within the bin.

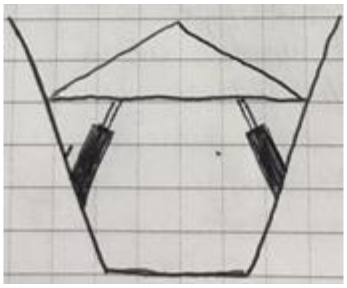


Figure 27: Pistons to Bin Wall

19. Pistons to Bin Wall: This design has the pistons, that would move the cone up and down, mounted directly to the walls of the insert inside the bin. This would remove legs needed to support the cone and cut down on material cost.

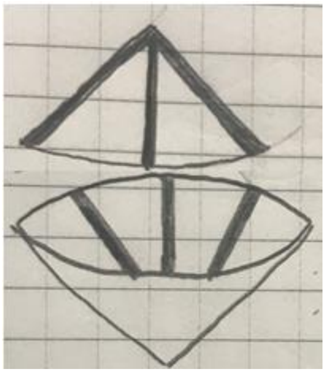


Figure 28: Cone Ribs

20. Cone Ribs: This cone is made out of multiple rolled sections that will be bolted together to form a full cone. This design shows each side of a section that will be bent in which will allow for each to be bolted to one another on the inside of the cone. The bent-in sides will also become ribs, that will offer support to the cone under the material weight. They will also provide good points for the vibrator to be connected.

Figure 29: Center Rod

21. Center Rod: This design has a rod hanging down that is attached to the top of the bin. A piston will be attached to the rod which will then be attached to the cone. The piston will be able to move the cone up and down based on material flow.

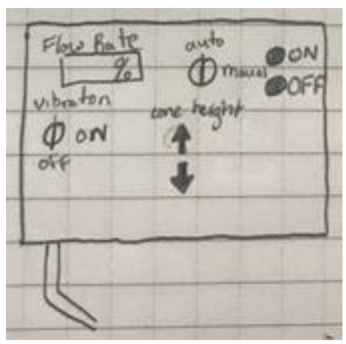


Figure 30: Control Interface

22. Control Interface: This is an interactive interface to control the vibration and cone movement within the bin. This will sit outside the bin and will have settings to either be manually controlled or put on an automated vibration and cone height. This will also show the flow rate as a percentage coming out if the bin.

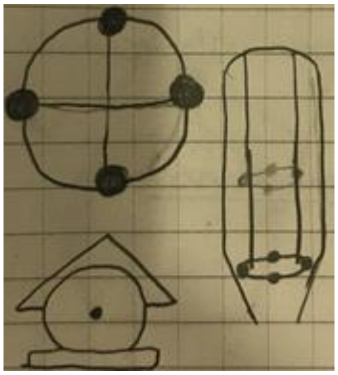


Figure 31: Quad Vibrators

23. Quad Vibrators: This is a fixture with 4 vibrators that are attached by a ring. Each vibrator will have a cone on top of it in order to move material down past it. This ring will then be suspended in the bin and connected to winches that will be able to move the fixture up and down.

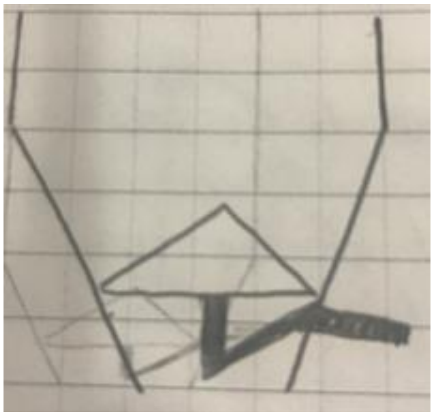


Figure 32: Manual Lift

24. Manual Lift: This lever system would move the cone manually up and down. Each joint would be pinned and there would need to be a piston attached to the lever in order to assist. There would be an interface to show the cone height at different lever positions.

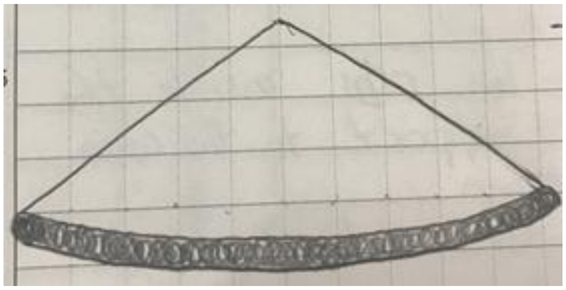


Figure 33: Rubber Ring

25. Rubber Ring: This design is a cone with a rubber bottom. The rubber bottom will keep the metal bottom of the cone from touching the insert or bin walls. This would also create a good seal to block material flow out of the bin when the cone is fully lowered.

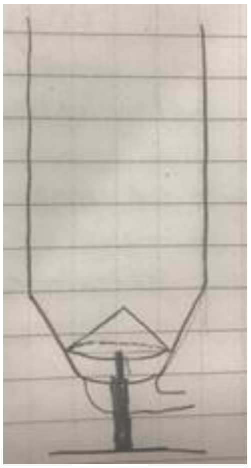


Figure 34: Bottom Piston

26. Bottom Piston: This piston fixture will move cone up and down. Piston goes through exit hole in the bottom of the bin, through a seal in the outflow pipe and mounts to the floor. This will provide plenty of support to the cone under the weight of the material.

Figure 35: Upper Pistons

27. Upper Pistons: This design has pistons that are mounted above the cone to the side walls of the bin. The pistons would be able to move the cone up and down. The pistons would be up and out of the way from the flow of the material below the cone which is most important.

Figure 36: Closed Vibrator in Cone

28. Closed Vibrator in Cone: The vibrator is mounted upright to the bottom of the cone. The bottom will be covered to keep the vibrator from contaminating the material within the bin. Gives ample air space around the vibrator to keep it cool especially if it is an electric vibrator.

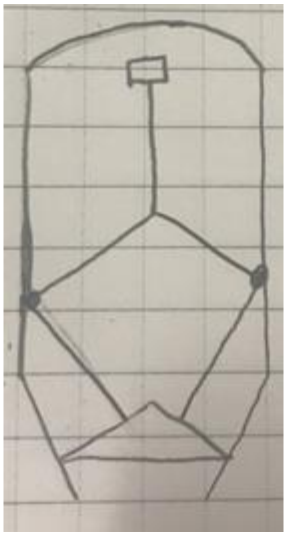


Figure 37: Pulley Winch

29. Pulley Winch: This is a cable system that suspends the cone within the bin. Pulleys on each side of the bin walls will direct 4 cables, attached to the cone, up to one central cable. This will allow for multiple contact points on the cone while also only having one central winch to control them.

Figure 38: Strip Mounts

30. Strip Mounts: This is an insert that supports the legs to the cone. They will be 1-foot wide strips of metal, rather than a full sleeve that sits in the bottom portion of the bin. The strips will be able to distribute forces from the cone over a big area while cutting down on amount of material that will need to be used compared to using a full sleeve.

8.2 Claudia Brown Concept List

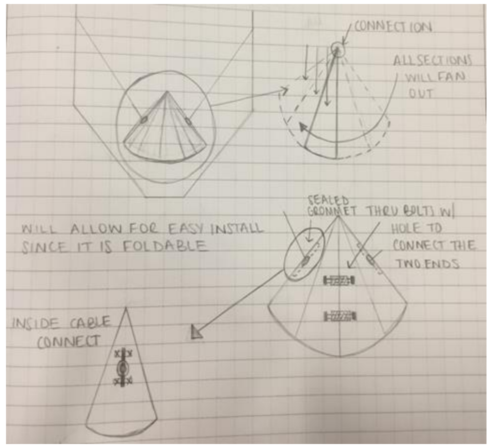


Figure 39: Fan Cone

1. Fan Cone for Easy Install: This concept is accommodating to the idea that the door into the bin is of a fixed small size that does not allow for a large fixture to fit through. The cone will essentially act as a fan that will open up and the way it will stay together will be by the top attachable bracket that will connect to the cords to raise and lower the fixture. It is a plausible concept because it will be an easy install and will consist of multiple simple components so its manufacturability will be very practical and inexpensive.

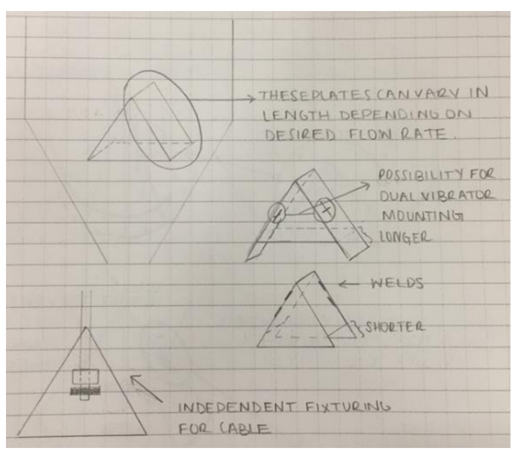


Figure 40: Extended Prism

2. Extended Prism Design: This design of the internal fixture is more rigid than a cone in the sense that all the sides will be comprised of plates rather than curved surfaces. This would allow for dual vibrator mounting underneath the fixture that may be something customers would like to be able to have. Also the side plates shown in the picture would be able to be customized in length to what the customer needs (aka the customers bin diameter and material in it.)

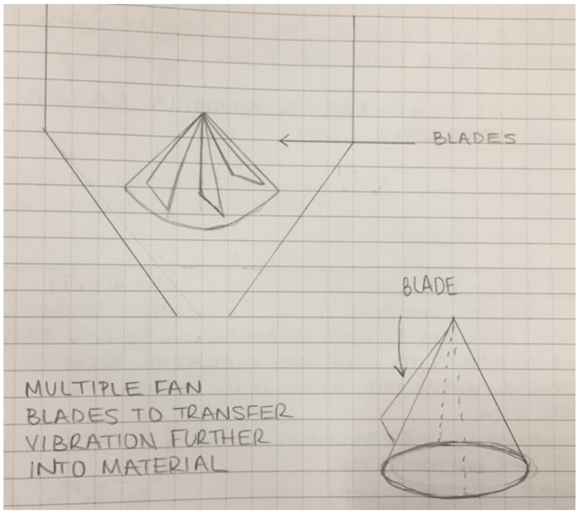


Figure 41: Blades

3. Blades: This design would allow for more material to be affected by the vibration since the surface area of the fixture will be greater. It will be designed strategically in order to aid in magnifying the vibration opposed to dampening it. Having the blades will allow for the material to be able to flow better through the portion of the bin with the fixture. When it comes to raising and lowering the fixture the blades will aid in cutting better into the material as it moves upward which will put less stress on the top of the cone.

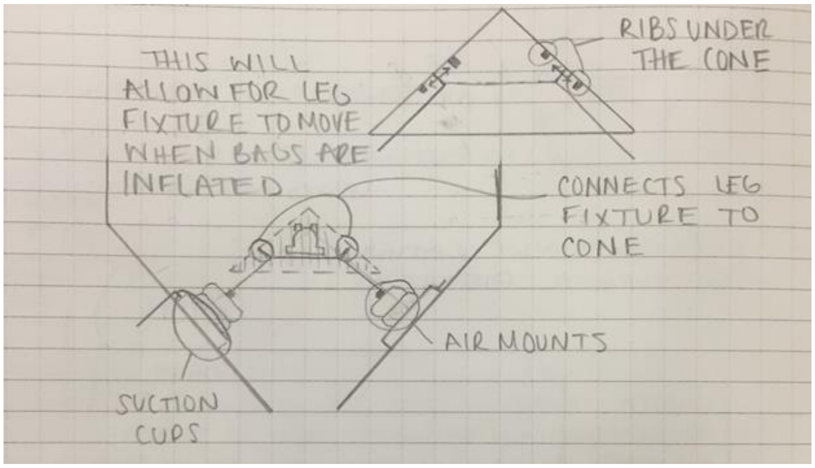


Figure 42: Airmount System

4. Airmount System: This design will be pneumatically actuated with inflatable air mounts. There will be two air mounts attached to either side of the bin that will allow for a larger range of up and down movement. The first set of bags will go from partially inflated to fully inflated and then the second ones will follow. Also having this system use air mounts they will act as vibration isolators for the side of the bin that will aid in preserving the structural integrity of it.

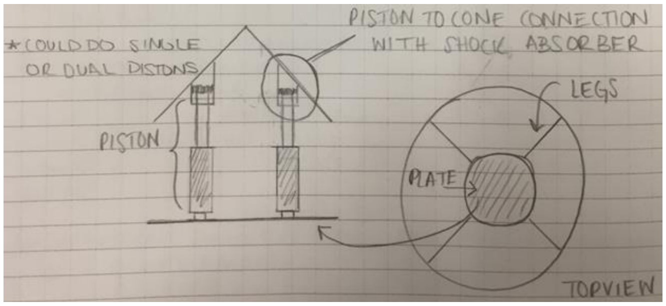


Figure 43: Piston System

5. Piston System: This system is comprised of a circular insert that will rest close to the slanted portion of the bottom of the bin. The insert will have for bars that branch to a center plate. On the center plate there will be two pistons that will be attached to the

underside of the cone. This will allow for upward movement of the cone without interfering with the material since these components will all be covered by the cone.

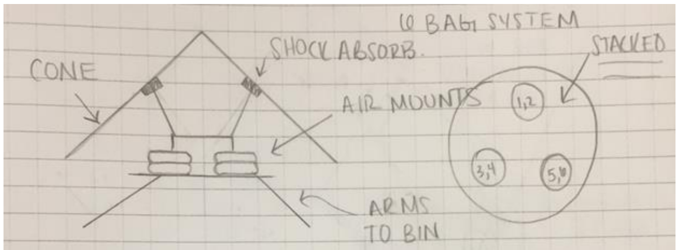


Figure 44: Concealed Airmount

6. Concealed Airmount Design: This design will be totally encapsulated by the cone which will minimize the chance of the material being affected by any of the components. It will also be a great advantage to have everything covered since it will also prevent from premature wear on any of the components due to contact with whatever material is in the bin. Arms will be attached to the inside of the bin that branch off to a center plate. This center plate will have 6 air mounts (3 stacks of 2). Each stack of air mounts will then be attached to underside wall of the cone with shock absorbers so that way the vibration transfer throughout the cone will not transfer to the fixture moving the cone.

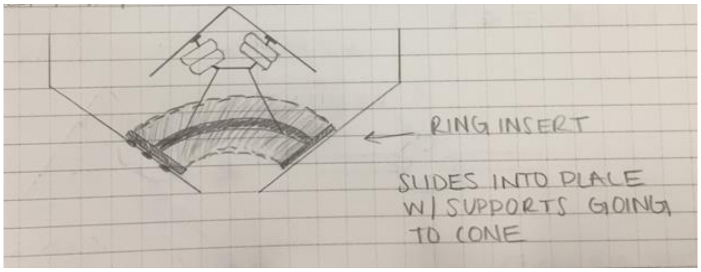


Figure 45: Ring Insert Fixture

7. Ring Fixture Insert: This will consist of fitted slanted ring that will slide into the bottom slanted portion of the bin. This design is geared towards a very easy install since there will not involve any direct mounting to the actual bin itself. This would be something that is accommodating to customers since they will not have to change anything that they have currently in order to implement it.

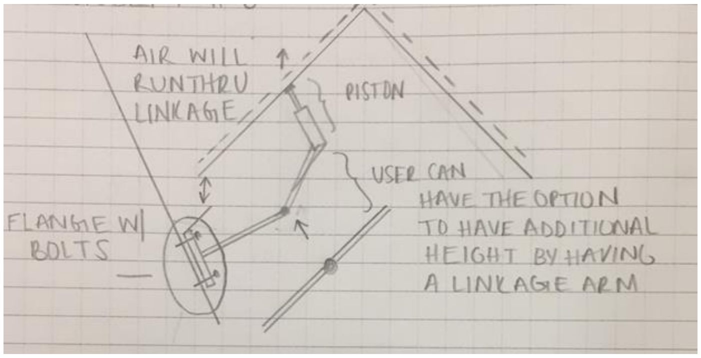


Figure 46: Mechanical Arm

8. Mechanical Arm Design: This design will use small internal pistons on the underside of the cone that will then be attached to a linkage system attached to the inside of the bin. This design would involve more components due to the linkage system but will allow for smaller pistons to be used in order to move the cone.

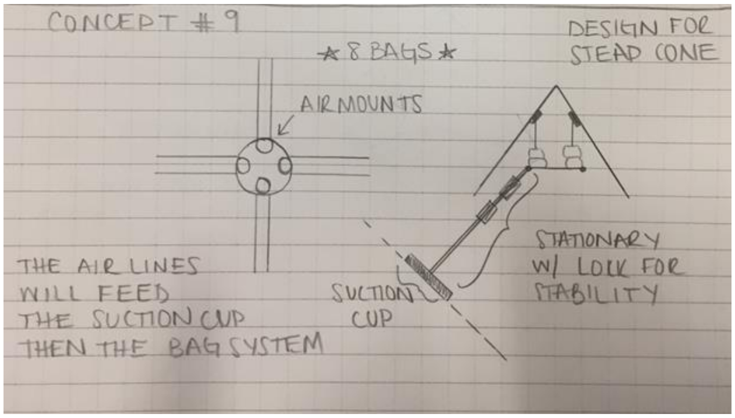


Figure 47: Suction Fixture

9. Suction Fixture: A suction cup will be used to attach the fixture to the inside of the bin. This will allow for easy install for the customer and will also be linked to the entire system. One air system will be used to activate the suction cup, inflate the bags, as well as operate the pneumatic vibrator being used. This will aid in saving energy since air could be recycled.

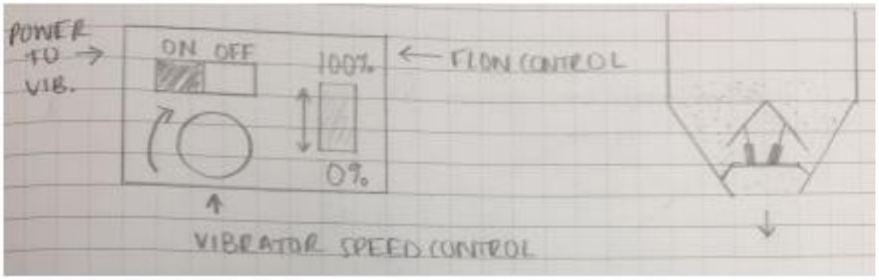


Figure 48: Electric Flow Control System

10. Flow Control System for Electric Vibrator: This concept is for the design of the interface controls for the entire system. It is geared for the use of an electric vibrator since the speed can be controlled and it will also be the means for sending power to it. It will also allow for the flow rate to be varied from 0% - 100%. This control system can be adapted to any cone design that is installed.

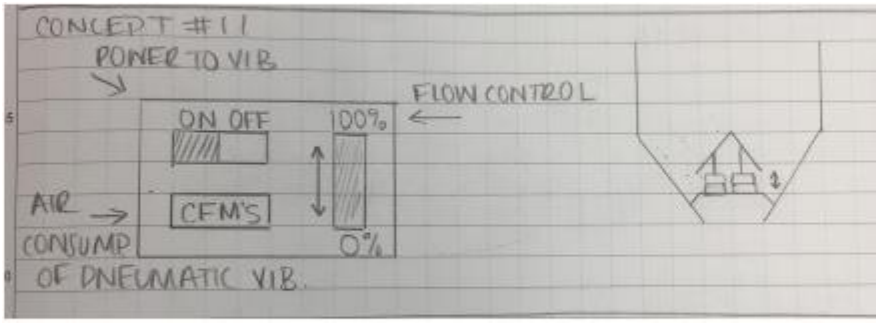


Figure 49: Pneumatic Flow Control System

11. Flow Control System for Pneumatic Vibrator: This control system will be implemented when using a completely pneumatically operated system. The flow will be sent through

the air mounts, and to the vibrator. Also on the interface the air consumption will be displayed for the operator since that may be important monitor based off of the customer.

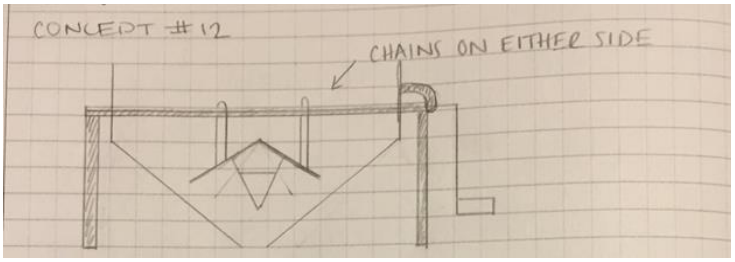


Figure 50: Chain Driven Lift

12. Chain Driven Lift: This concept is going to consist of having a chain driven cone that will be suspended. There will be an external ring outside of the bin to allow the chains to able to be shorter rather than running them all the way up to the top of the bin. This will aid in saving material as well as prevent the more internal components that need to be covered in the bin to prevent them from coming in contact with the material.

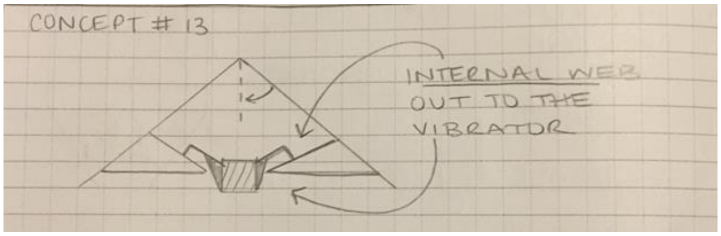


Figure 51: Low Attaching Fixture

13. Low attaching fixture for vibrator: This will be a fixture for the vibrator to be mounted to a plate that will web out to the underneath of the cone. This will allow for vibration to be transferred to more than just one section of the cone. Another benefit will be that since it is attached to the lower portion of the cone it will prevent material from hanging up right before it exits.

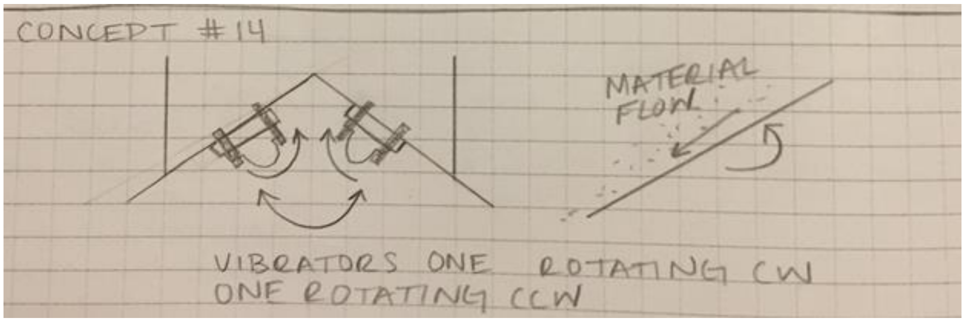


Figure 52: Dual Mount for Vibrator

14. Dual mount for turbine vibrators under the cone: For this design there will be symmetrical dual mounting for two turbine vibrators on the underside of the cone. They will be mounted so that the rotation of the vibration will move the material down the cone. Having two vibrators will maximize the amount of vibration being transferred to the material and also ensure that one side of the cone does not have more material resting on the top of it than the other.

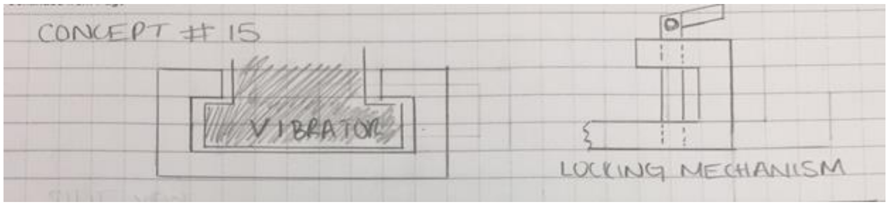


Figure 53: Vibrator Slide Fixture

15. Vibrator Slide Fixture: This mount for vibrators will allow for any vibrator to be mounted to a standard sized plate. This plate will be one standard size because it is going to slide into place under the cone and lock in. This will be very beneficial for customers since now they will be able to attach many different VIBCO vibrator products to the underside of the cone. This will be necessary for if the material contents of the bin are changed and they need either more or less vibration.

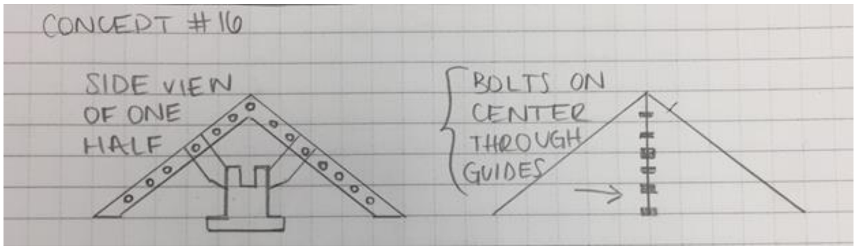


Figure 54: Two Part Cone

16. Two Part Cone held together with vibrator: This cone will be separated into two parts and bolted together, and it will be held together with the fixture attached to the vibrator. Ribs will go down the center to allow for it to bolt together.

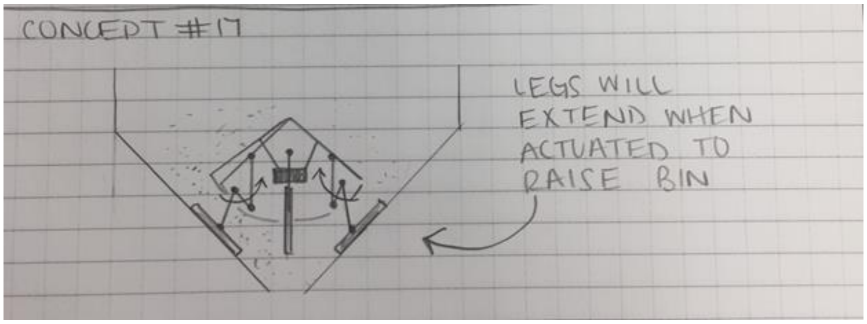


Figure 55: Extended Leg Fixture

17. Extended Leg Fixture: This will consist of legs that will be comprised of metal with some type of rubber on the side that will be making contact with the bin. At this point they will branch off to the cone in order to hold it into place. The legs will be beneficial for any customer seeking a very simple install of the system since they will simply slide into the bin and lock themselves into place.

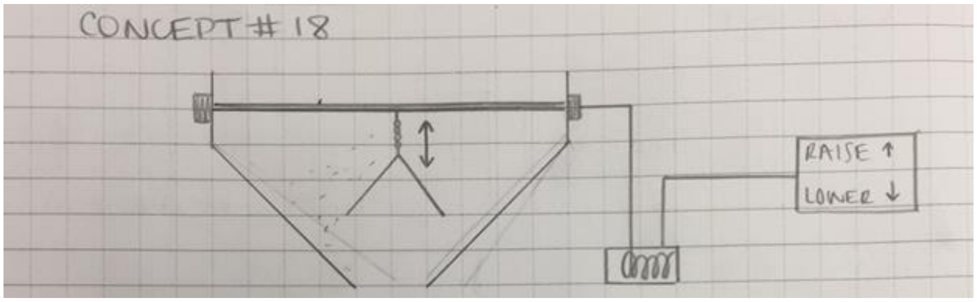


Figure 56: Bar Bin

18. Bar Bin: This concept will consist of a bar that slides down into place into the bin and bolts from the outside of the bin. The cone will be suspended in the center of it and a chain will be connected in the center of it. The bar will be partially hollow to allow for the chain to run through it and to the outside of the bin where it can be raised or lowered.

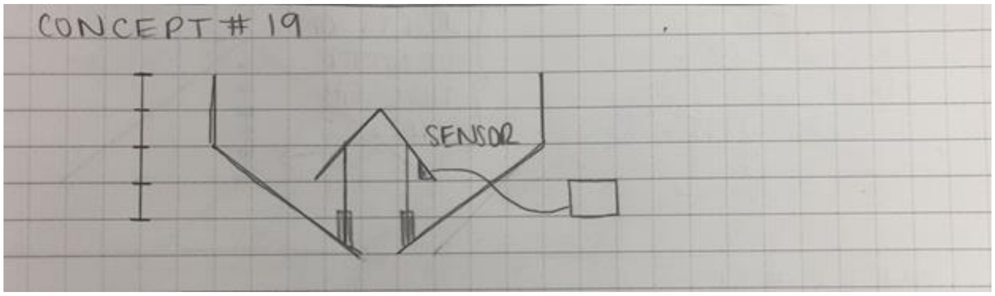


Figure 57: Flow Rate Measure

19. Flow Rate Measure: This will contain a sensor within the cone fixture that will speak with the interface. This will help give the user an actual distance that the cone is traveling in the bin and how much further it has to go before it bottoms out and does not allow any material to pass by it. This point is extremely necessary since the customer certainly does not want the cone fixture hitting the bin while in use since it would stop flow.

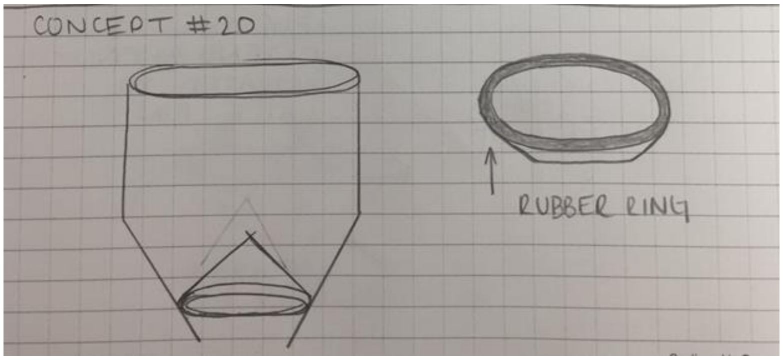


Figure 58: Bottoming out Prevention

20. Bottoming out prevention: In order to prevent the cone from hitting the bin when it gets to low and possibly ruining the bin this fixture will be put into place. It will be a receiving ring mounted internally in the bin that will receive the edge of the cone when it is lowered. The fixture will have a rubber lining to prevent vibration from being transferred to the bin. This will be very useful for when the user is actually trying to stop material flow since this will provide a more reliable seal for preventing material flow.

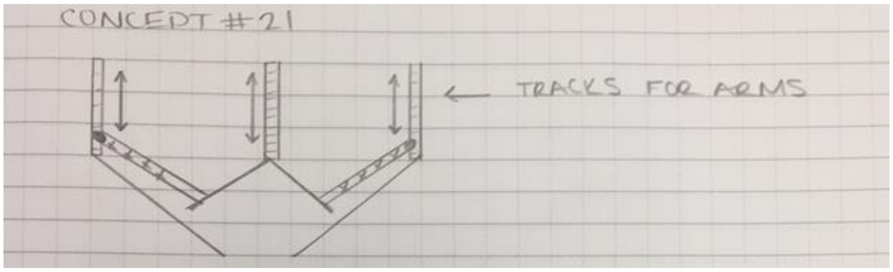


Figure 59: Track System

21. Track system: This will require the install of four tracks into the bin. They will be encapsulated with a slot and around that slot there will be a seal in order to prevent the tracks from being affected negatively by coming in contact with the material. These tracks will be attached to the cone and controlled by motors that will move the cone up and down.

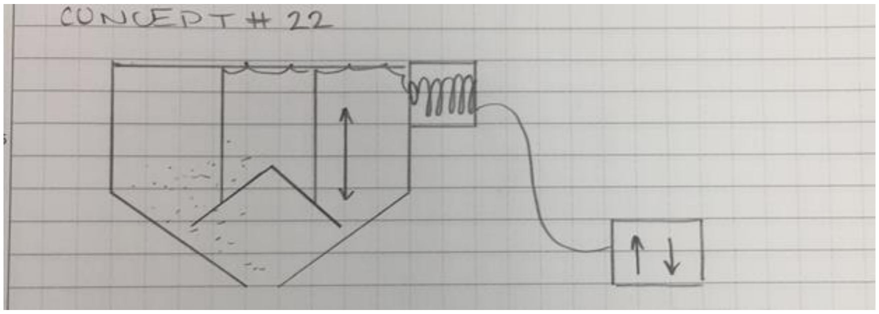


Figure 60: Top Mount

22. Top Mount: This will be for when the cone is suspended a top mount on the bin will act as a reel to either raise or lower the cone. This is going to be controlled by a motor with variable speed for the user to adjust.

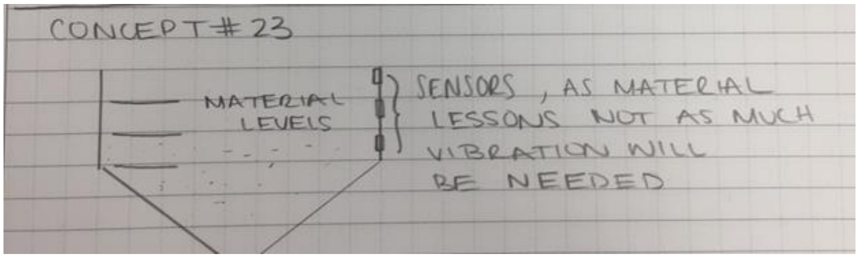


Figure 61: Material Measurer

23. Material Measurer: This device is going to aid the user in determining the amount of material that resides within the bin. It will be intertwined with the interface for controlling the vibrator and the raising and lowering system of the fixture. This will require sensors that will be placed within the bin that will essentially act as checkpoints. These checkpoints can also be visible externally so the user can both see where they are as well as output it to an interface.

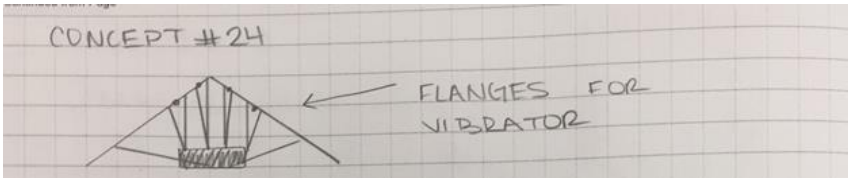


Figure 62:Vibrator Fixture Net

24. Vibrator Fixture Net: This vibrator fixture design beneath the cone is going to be comprised of multiple metal legs that will hold the cone together as well as be the fixture for the vibrator. The purpose of this design is to help maximize the vibration transfer to the material. Having the assortment of legs will also add structure beneath the cone to prevent it from deforming under the load of the material.

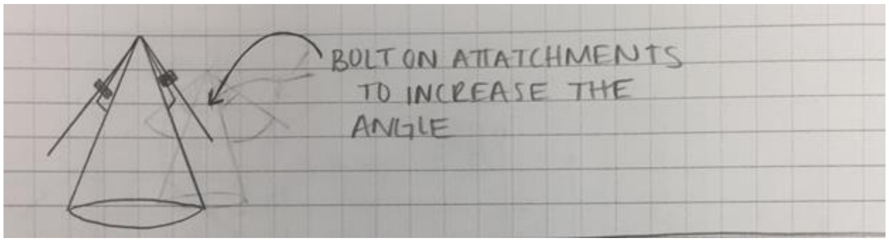


Figure 63: Angle Changer

25. Angle Changer: This cone design will allow for attachments that can change the angle of the cone. This will be extremely beneficial to customers especially if they run different material through their bin. Different material means a different angle of repose which results in needing a different cone angle in order to optimally flow the material.

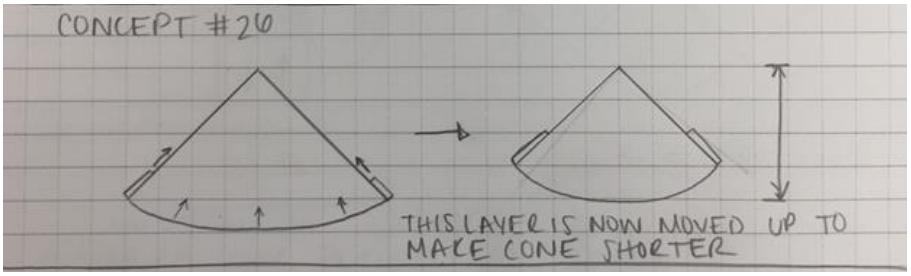


Figure 64: Collapsible Cone

26. Collapsible cone: This cone will have a collapsible bottom so that way the height of it can be varied depending on customer needs. This will allow for the accommodation of various different bin sizes. Depending on what the customer has for a bin this will be beneficial because if they have multiple bins in their facility that are different than the fixture will be transferable.

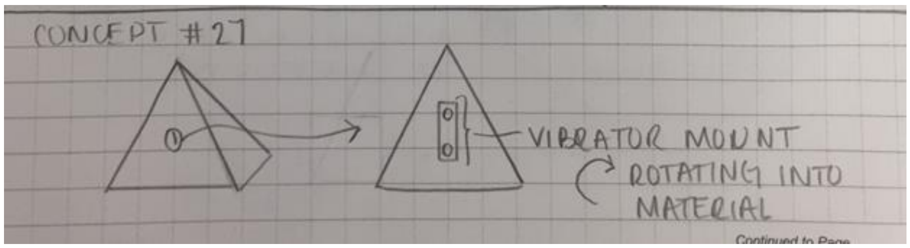


Figure 65: Pyramid Shaped Fixture

27. Pyramid: Changing the internal fixture to be the shape of a pyramid opposed to a cone will allow for the outer sharper edges to break further into the material. This will aid in material flow when the industrial vibrator is turned on. Also mounting to a flat wall opposed to a contour of a cone will allow for fewer components to be used in order to get the vibration to transfer throughout the fixture.

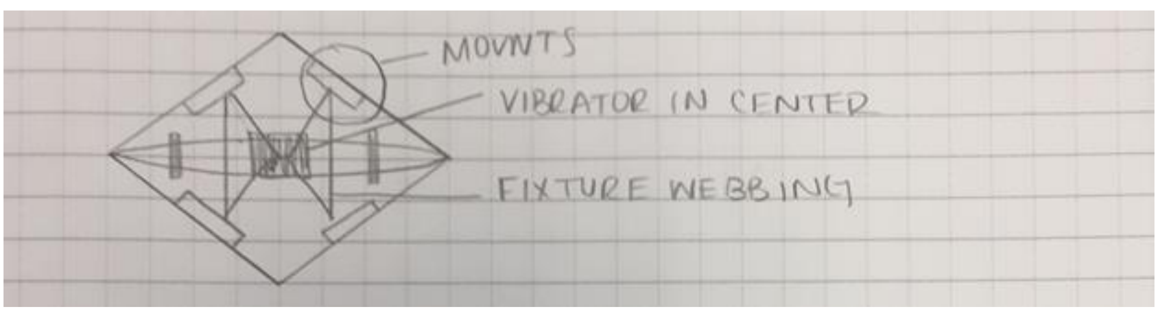


Figure 66: Diamond

28. Diamond: This would essentially be two cones fused together that would encapsulate the vibrator as well as its fixture beneath the cone. This will allow for the possible use

of a non – FDA approved vibrator since it will have zero direct contact with the material.

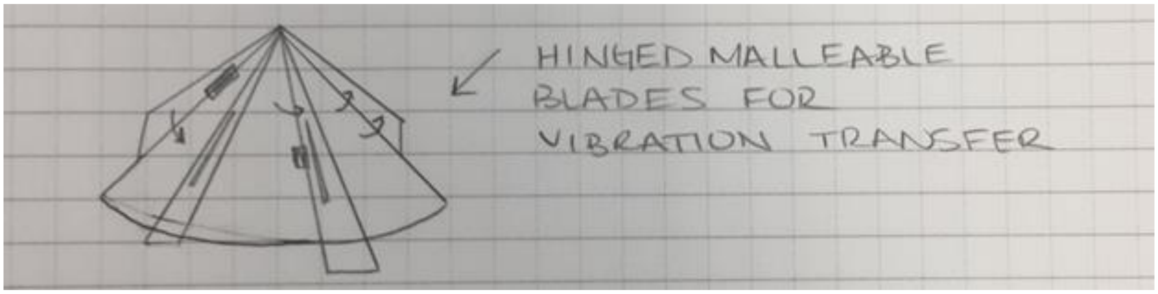


Figure 67: Malleable Blades

29. Malleable Blades: Using a more malleable material that resonates at a lower frequency than the material of the total fixture blades will be created on top of the cone. Since it resonates at a lower frequency, when the vibrator is running the vibration transfer will cause these arms to vibrate much more than the actual fixture. This will aid in preserving the life of the fixture as well as the cables that raise and lower it. Possible to have replacement blades, maybe ones that are specific to certain units.

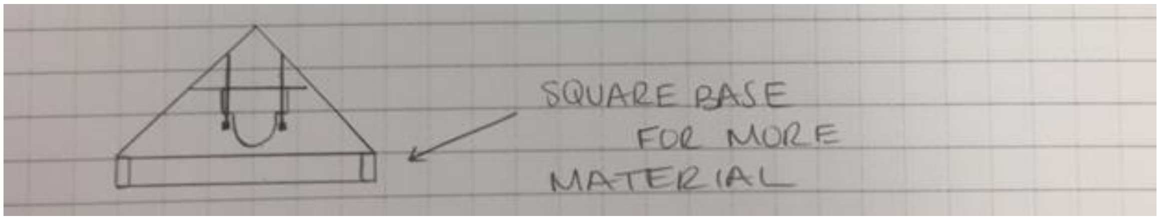


Figure 68: Square Base

30. Square Base: Have a cube type fixture that has two walls that reach a peak and the other two walls are rectangular and are attached to the peaked walls. This will help gain a larger range of effected material. The rigid edges will break into the material to help create better flow. This design will be able to be hung easily by its corners. This rigid cube design will be less likely to get twisted or hung up when moving up and down.

8.3 Will Schartner Concept List

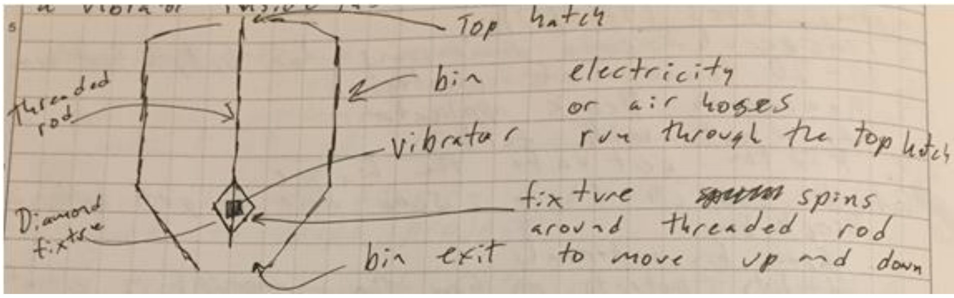


Figure 69: Diamond Shaped Fixture

1. Diamond Shaped Fixture: This design has a diamond shaped fixture that is attached to a threaded rod. The rod is suspended from the top of the bin with a vibrator attached to the inside of the diamond fixture. This design does not require the bin to be taken apart for the installation.

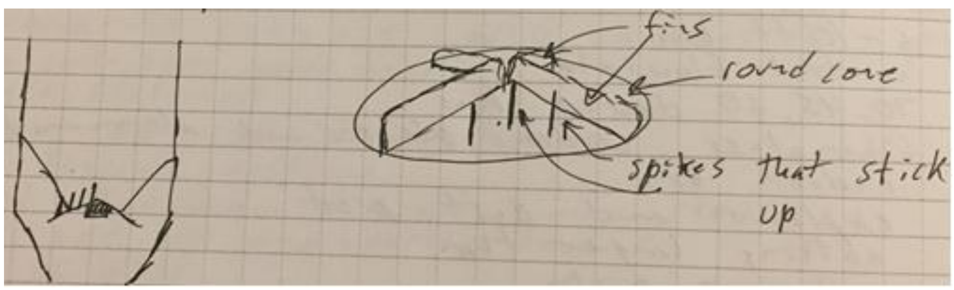


Figure 70: Fins

2. Fins: This design is a conventional cone shape that has fins or spikes to help break up the material. The fins could also help distribute vibrations through the material better.

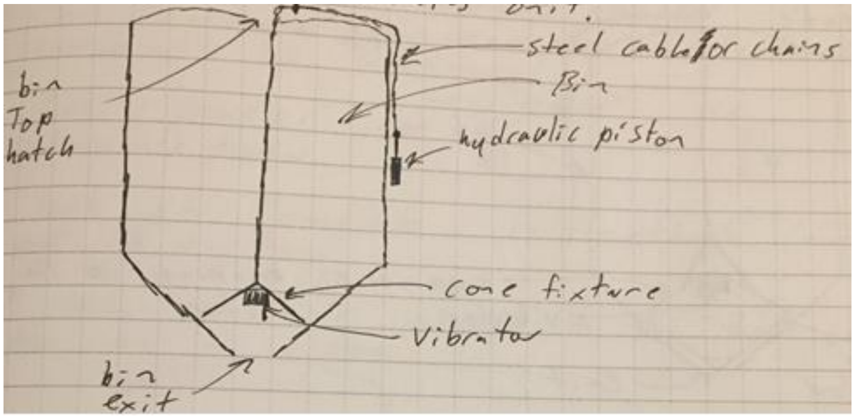


Figure 71: Hydraulic Lever

3. Hydraulic Lever: This is a design where the cone is raised and lowered by a hydraulic lever on the outside of the bin. A cable will attach the lever to the cone. The lever will also have marks to show cone height. This concept tries to solve the issue of controlling flow rate while keeping the bin free of contaminants.

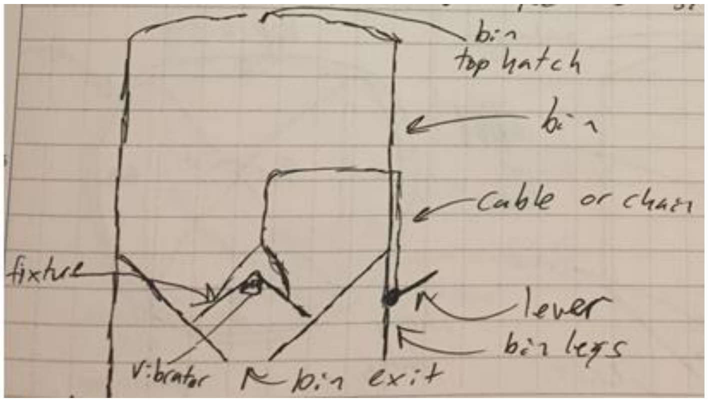


Figure 72: Mechanical Lever

4. Mechanical Lever: This fixture is raised and lowered by a mechanical lever on the outside of the bin. This is similar to the 3rd concept but hydraulics would not be needed.

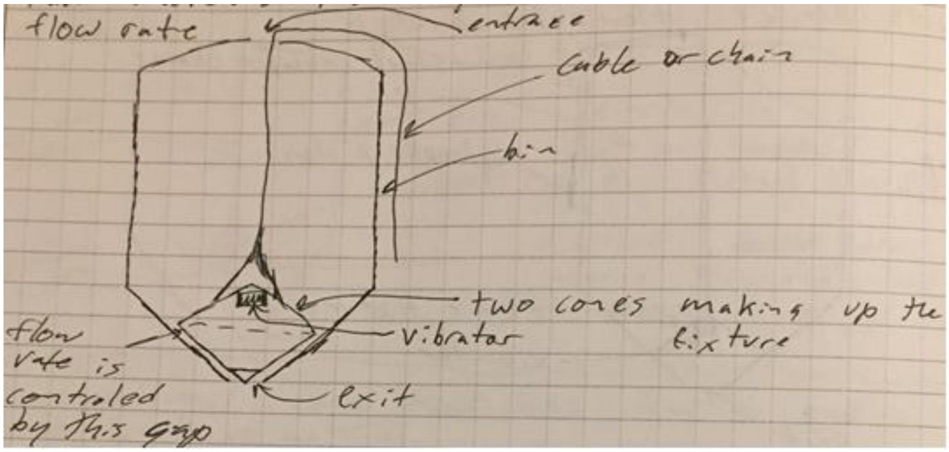


Figure 73: Double Cones

5. Double Cones: This concept has two cones attached to each bottom to bottom so that when it comes down the bottom cone sits perfectly into the bottom of the bin to control flow rate.

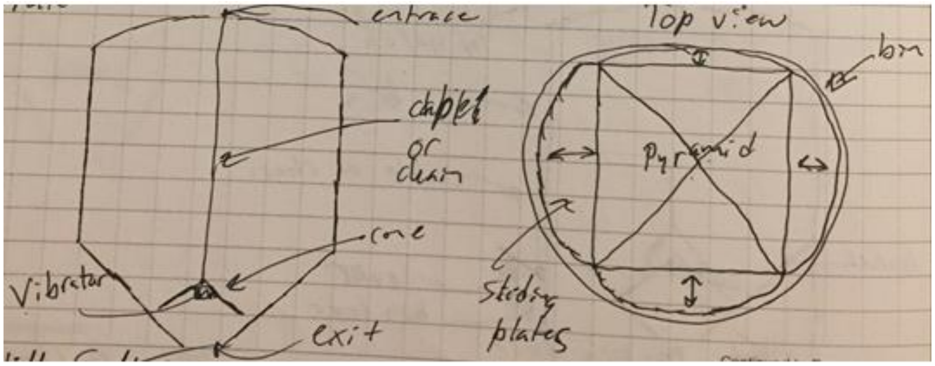


Figure 74: Pyramid with Sliding Plates

6. Pyramid with Sliding Plates: This design had a pyramid shaped fixture with sliding plates that come off the bottom edges in order to control the flow rate. This would solve the issue of controlling the flow rate without having to move the full fixture.

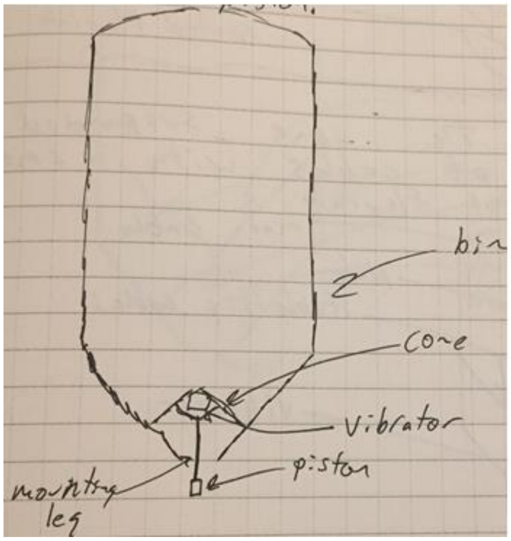


Figure 75: Bottom Mounted Piston

7. Bottom Mounted Piston: This is a cone that is has a piston mounted to the bottom of it. The piston will extend down through the bin to the floor of the building. The piston would come in contact with material which could pose a problem.

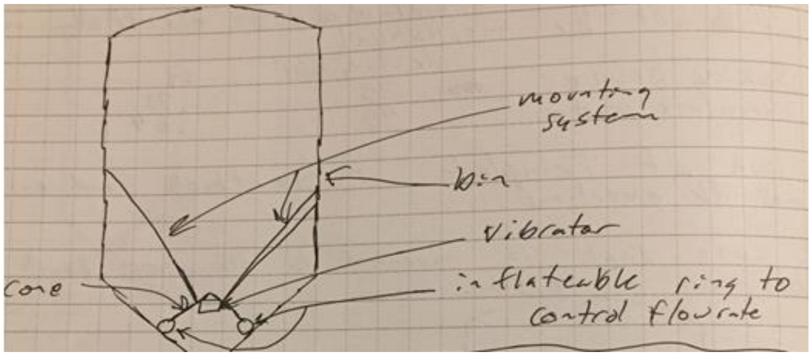


Figure 76: Inflatable Ring

8. Inflatable Ring: This design has a ring around the cone that will inflate or deflate to lift and lower the cone. It would allow the flow rate to be controlled and eliminates the need for a fixture to raise and lower the system.

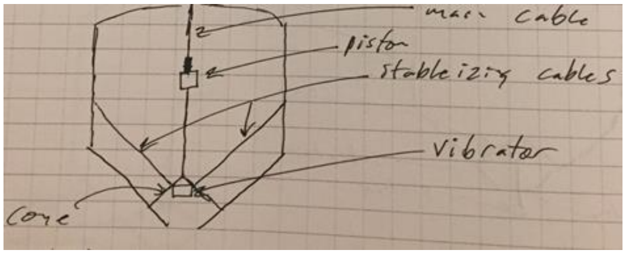


Figure 77: Cable with Piston

9. Cable with Piston: The cone will be suspended by a series of cables with a central cable to control the fixture moving up and down. A piston will pull the cable up or release it down.

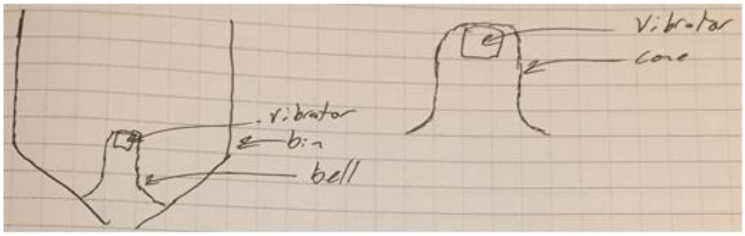


Figure 78: Bell Shaped Fixture

10. Bell Shaped Fixture: Rather than having a cone shaped top, this is a bell shape. It still has a circular bottom to control the flow and this shape would be easier to manufacture than a cone.

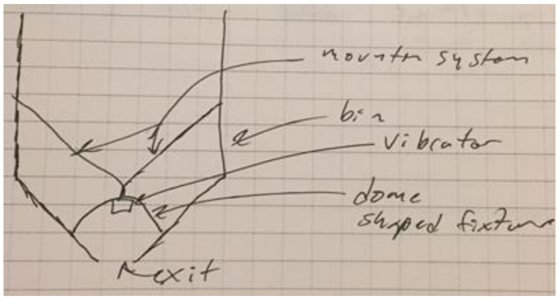


Figure 79: Dome Shaped Fixture

11. Dome Shaped Fixture: This has a dome shaped top that the vibrator will mount to. It's a different shape than the cone and still allows for flow to be controlled. Also could be manufactured using a stamping method.

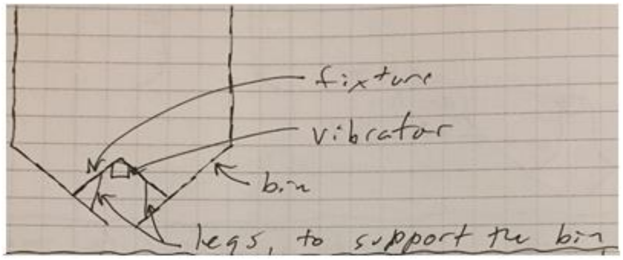


Figure 80: Wall Mounted Legs

12. Wall Mounted Legs: This design will mount the cone fixture in the bin using legs that are again the sides of the bin. It is self-contained within the bin which will keep material from being contaminated.

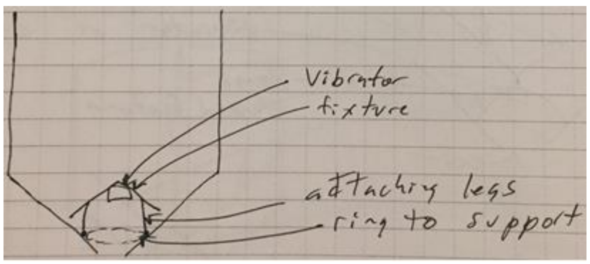


Figure 81: Hard Mounted Ring

13. Hard Mounted Ring: This mount will hold the fixture inside the bin using a ring that sits on the sides of the bin. The ring will help distributed forces evenly to the bin walls.

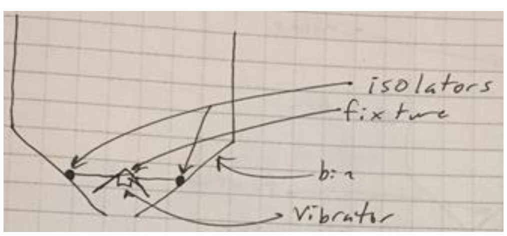


Figure 82: Vibration Isolators

14. Vibration Isolators: This design mounts the bin fixture using vibration isolators to prevent vibrations from reaching the sides of the bin. The concept will also give support to the cone.

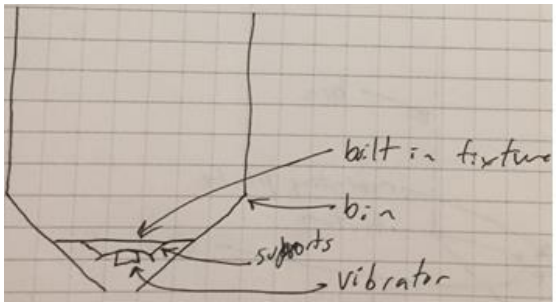


Figure 83: Flow Calculator

15. Flow Calculator: This design consists of an insert for the bin that has a vibrator and flow calculator within the unit. This will give control on the system and allow operators to see the amount of flow rate exiting the bin.

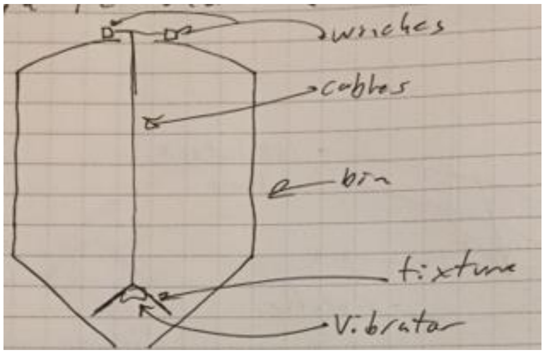


Figure 84: Winch System

16. Winch System: The design uses winches to raise and lower the fixture through the material with cables. This is a cheaper and simpler method while minimizing outside contact with the material.

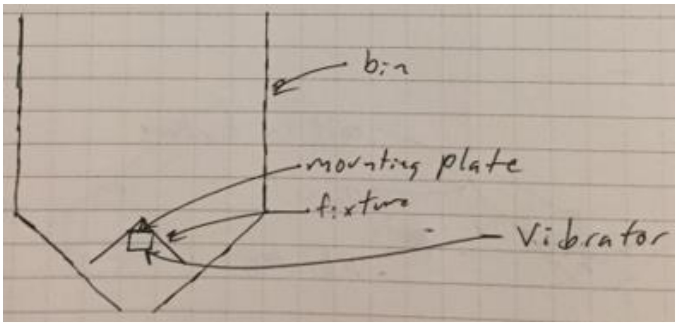


Figure 85: Upside Down Vibrator

17. Upside Down Vibrator: he vibrator will be mounted to the fixture upside down in the top portion of the fixture. There will be a mounting plate that the attaches the vibrator directly to the fixture, maximizing vibration output.

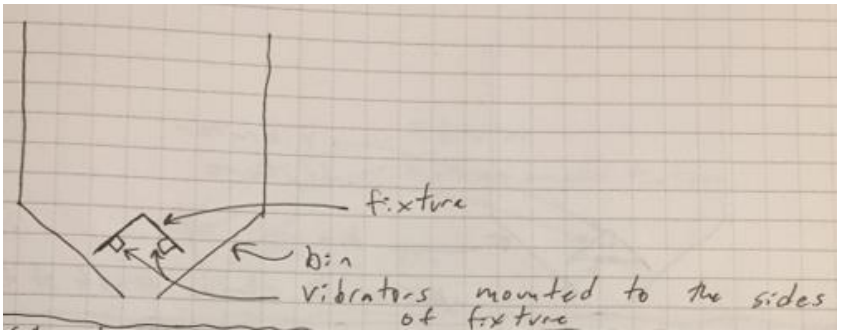


Figure 86: Multiple Vibrators

18. Multiple Vibrators: This design will have multiple vibrators that are mounted to the sides of the fixture. This could possibly maximize the vibrations directly to the material in the bin.

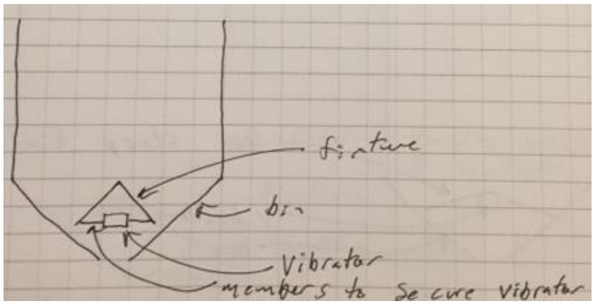


Figure 87: Upright Vibrator

19. Upright Vibrator: This has the vibrator mounted upright to the fixture and is supported by cross-members on the bottom. This will evenly distribute vibrations out to the edges of the fixture.

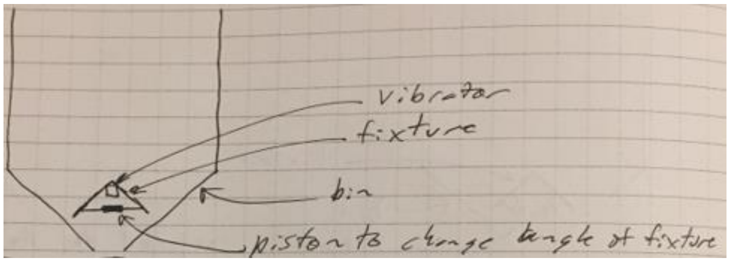


Figure 88: Angle Changing Piston

20. Angle Changing Piston: The design has the fixture with a hydraulic piston that changes the fixture angles. This would help with different sized bins and angles on those bins.

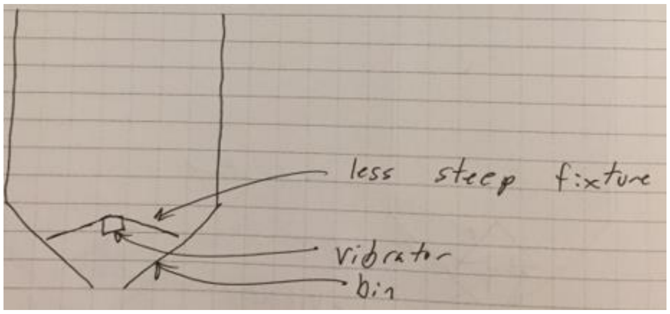


Figure 89: Low Angle Cone

21. Low Angle Cone: This design has a cone angle that is smaller which will allow vibrations to effect material for a longer time.

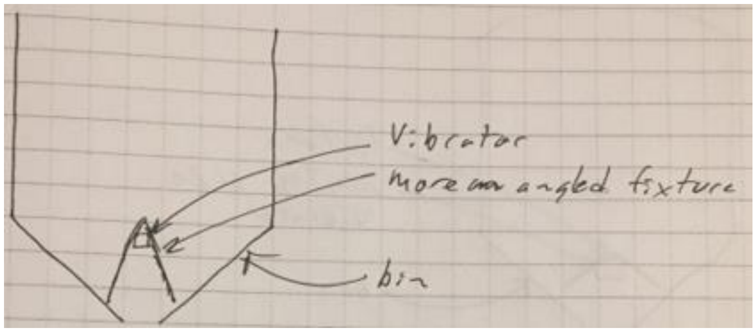


Figure 90: Steep Angle Cone

22. Steep Angle Cone: This cone design has a steeper angled cone to give vibrations to a higher portion of material in the bin. It will also make lifting the cone up through the material easier.

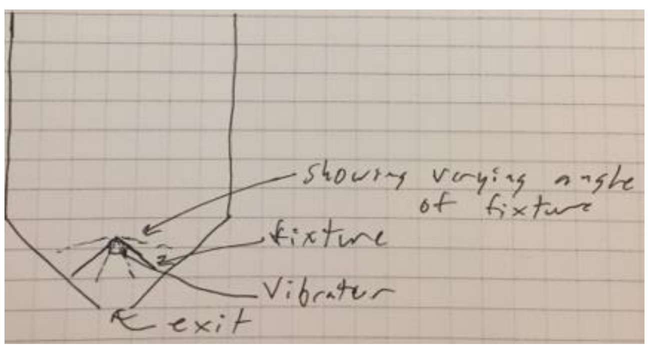


Figure 91: Cone Angle Adjustment

23. Cone Angle Adjustment: This design would make the cone angle for different materials in the bin. Materials have different angles that will make them flow so this design will take that into account.

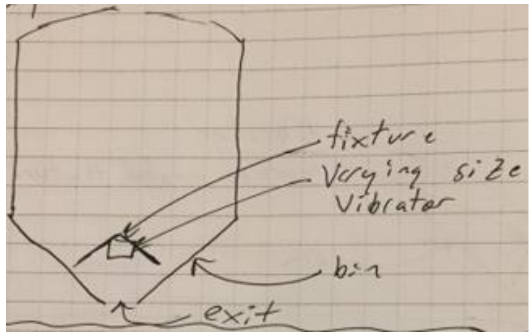


Figure 92: Changing Vibrator Size

24. Changing Vibrator Size: The vibrator size will be dependent on the material in the bin. The denser the material is the larger the vibrator will need to be.

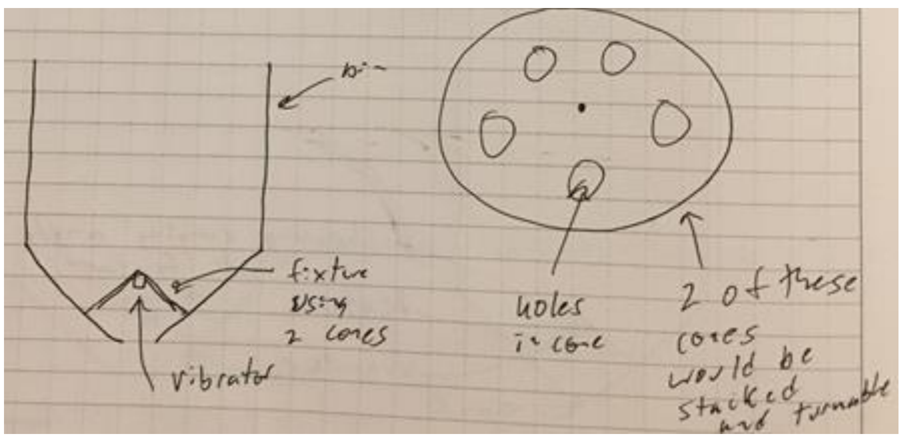


Figure 93: Rotating Cone Pieces

25. Rotating Cone Pieces: This design consists of two cone pieces that will rotate to adjust the flow. This would take care of the flow rate and the rotating could add additional movement to keep material from clogging.

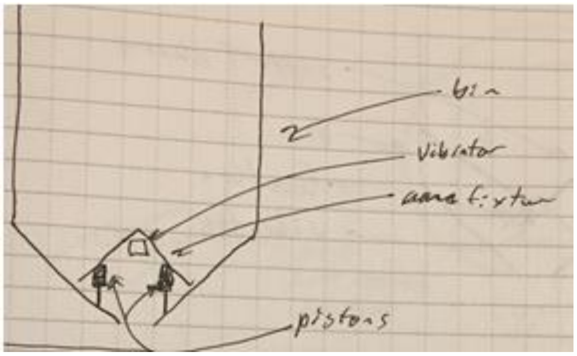


Figure 94: Leg Pistons

26. Leg Pistons: This design will use pistons as legs to hold the fixture in the bin and also to move it up and down. This will support the cone while also controlling the flow rate.

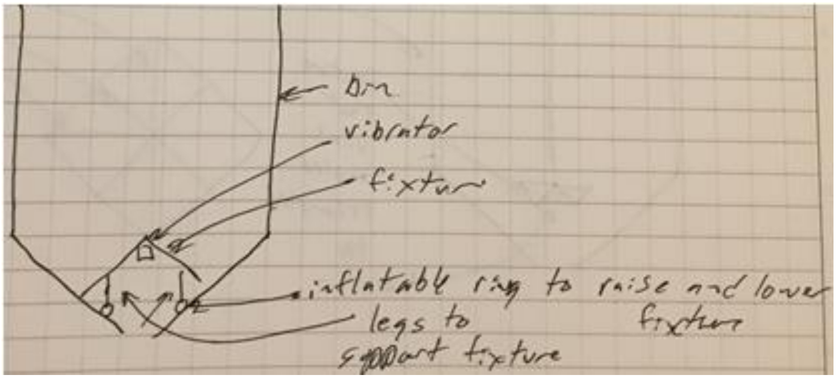


Figure 95: Inflatable Ring with Legs

27. Inflatable Ring with Legs: This design consists of legs that will support the cone and underneath those legs will be an inflatable ring that will lift the whole fixture up and down. The ring could also help isolate the vibrations to the cone.

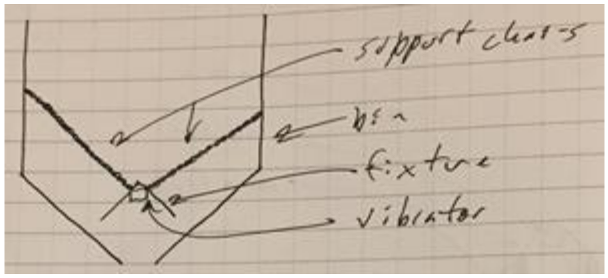


Figure 96: Suspended by Chains

28. Suspended by Chains: The design will suspend the fixture inside the bin using chains. This would help keep material from getting clogged, but it would not be able to control the flow of material exiting the bin.

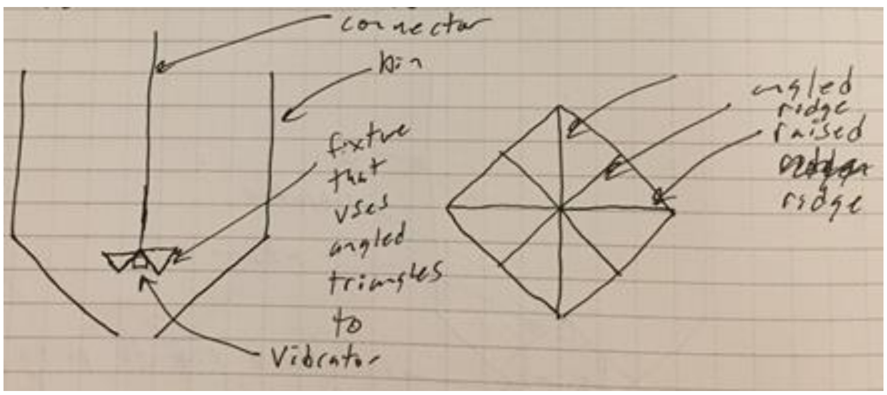


Figure 97: Ridges

29. Ridges: This design will make the fixture with ridges going out to the sides to maximize the surface area. Maximizing the surface area will help extend vibrations to more material in the bin.

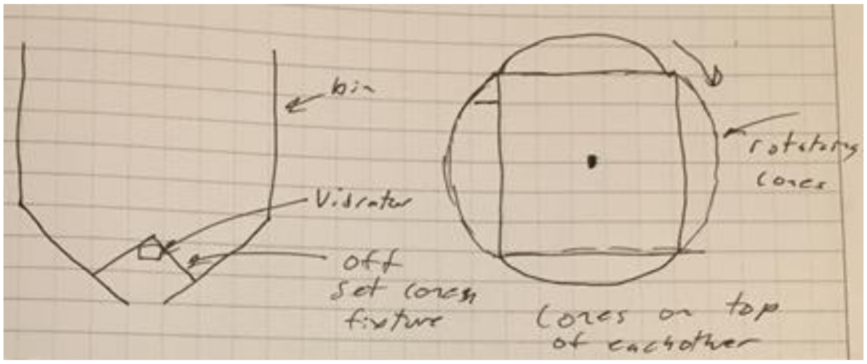


Figure 98: Offset Cones

30. Offset Cones: The fixture will have 2 offset cones that will reduce and regulate the flow rate in the bin. This has two turning plates and will keep the material clean.

9 Project Specific Details & Analysis

This project is a part VIBCO's effort to expand into new markets with new manufactured products for many different applications. The main goal is to design a product that can fit into bin silos and vibrate material while controlling the flow of that material out of the bin. A system that can not only vibrate and control the flow of material, but also be universal with different bin designs, creates a very unique product. The cost of the system will low in the market because of VIBCO in house manufacturing and a VIBCO vibrator being used. This would increase the sale of the product because it is expanded into all corners of the market with all bin sizes and materials. This product sold with a vibrator as good as VIBCO's, is likely to be received well due to its superiority in the field. The vibrators are proven to work correctly under many different environments, and is proven to give a good result. The team's study will have opened a platform in the market of bin silos and given an exciting new look to products in that market.

VIBCO supplies product all over the country including international markets. Many businesses depend on companies producing locally in order for time-efficiency in receiving product quickly and being able to send them back if repairs are needed. There is an endless array of industries in the East Coast that depend on silos to store product during manufacturing. These can include farms, pharmaceutical producers, and food industries with large to small scale productions that would benefit greatly from this product. Implementation of the system with a control interface would allow for better control of the system and regulation of material. Ensuring that the material does not get clogged inside the bin is the largest goal when consumers are looking for a product in this market. An innovative product that ensures that material does not clog inside the bin must be guaranteed to all customers that purchase.

10 Detailed Product Design

VIBCO has been gracious to provide the team with any size vibrators ranging from BVS160 to BVS510. These units are pneumatic, weigh around 16 pounds, with adjustable speeds that can exert a force output of 900 pounds. The BVS510 is the largest vibrator that can fit into the cone and will be used for the highest density materials. VIBCO has additionally allowed for the use of their own bin silo for both mechanical testing and fitment testing of the system.

The vibration and flow control system produced by the team will be able to allow the flow of material out of bin silos, while preventing clogging. This system along with an interactive interface, will give the user full control of cone height inside the bin and the amount of vibration output into the material. This section will dive into each component of the system and how they all work together in order to reach the intended goal.

10.1 Cone

The cone shaped fixture was determined, through research to be the best shape to initiate the flow of material. The cone was design to be assembled from three sections in order for shipping size and cost. Each section will be composed of 1/8-inch steel plate that is rolled into a fourth of a cone. The sides will be bent down to form ribs that will offer support and rigidity. Bolt holes will be drilled through the ribs to give a method to attach the sections together and offer attachment points for the mounting legs and vibrator. The cones dimensions are set to give it a diameter of 36 inches and a height of 12.12 inches. The angle of the cone will be 30 degrees and this was determined from the angle of repose of the spectrum of materials that the system will be working with.

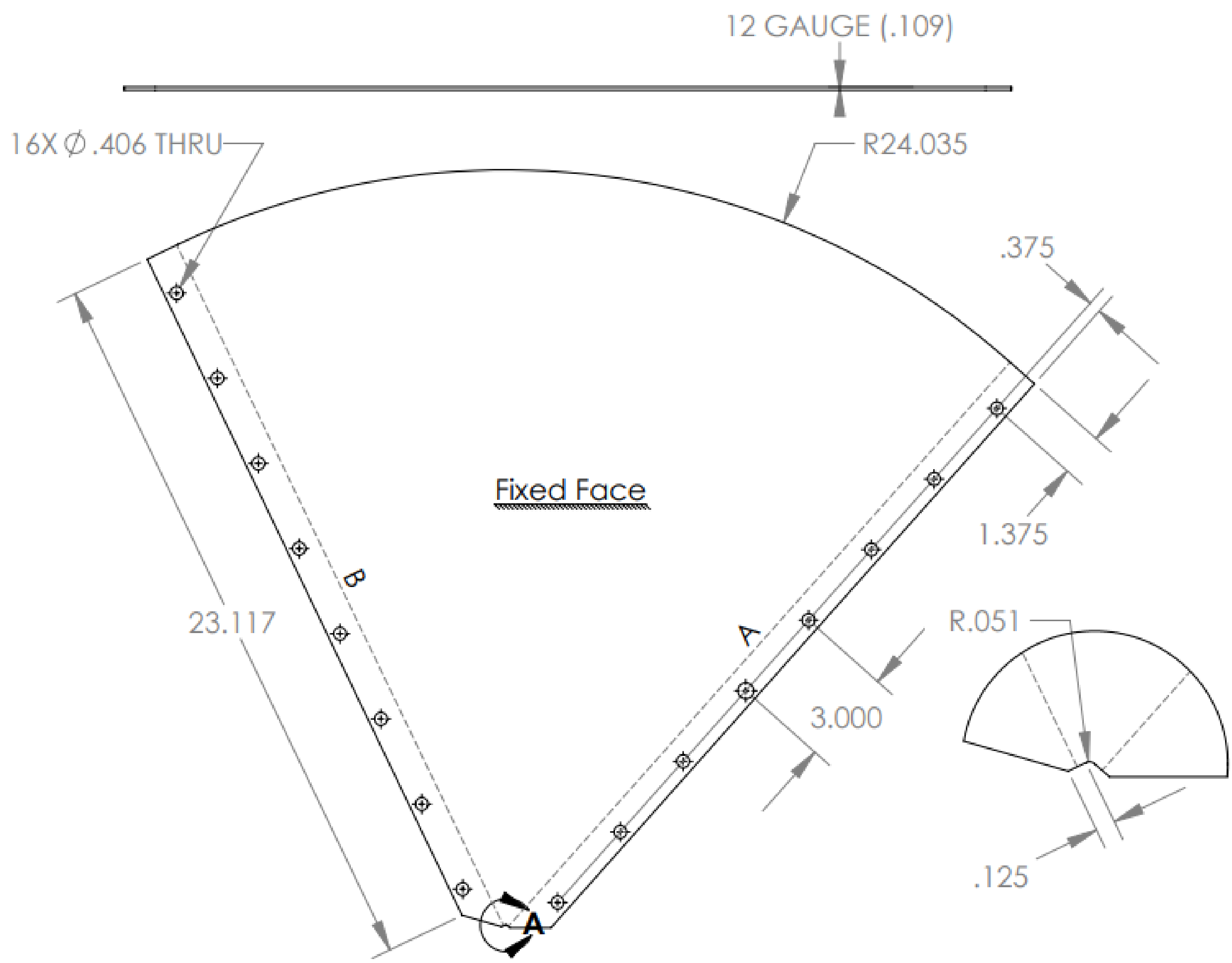


Figure 99: Cone Piece

10.2 Vibrator Mount and Vibrator

Vibrations are key part of the product and in order to transfer as much vibration as possible into the material, a vibrator mount was needed. The vibrator mounted also had to be able to accommodate the vibrator size range of BVS160-BVS510. The vibrator mount was designed out of ½ inch steel plate that was bolted to mounts similar to the upper legs that would then bolt to the upper holes on the cone ribs. The mounts consist of a triangular leg with a channel top that the cone rib will sit into. The plate has universal bolt holes drilled through it to accommodate the bolt holes on the vibrators. Manufacturing of the plate will be using a waterjet to cut the plate and bolt holes. The dimensional drawing of the vibrator plate and mounts are shown below. The characteristics of the vibrators were discussed in the first part of this section and are shown below.

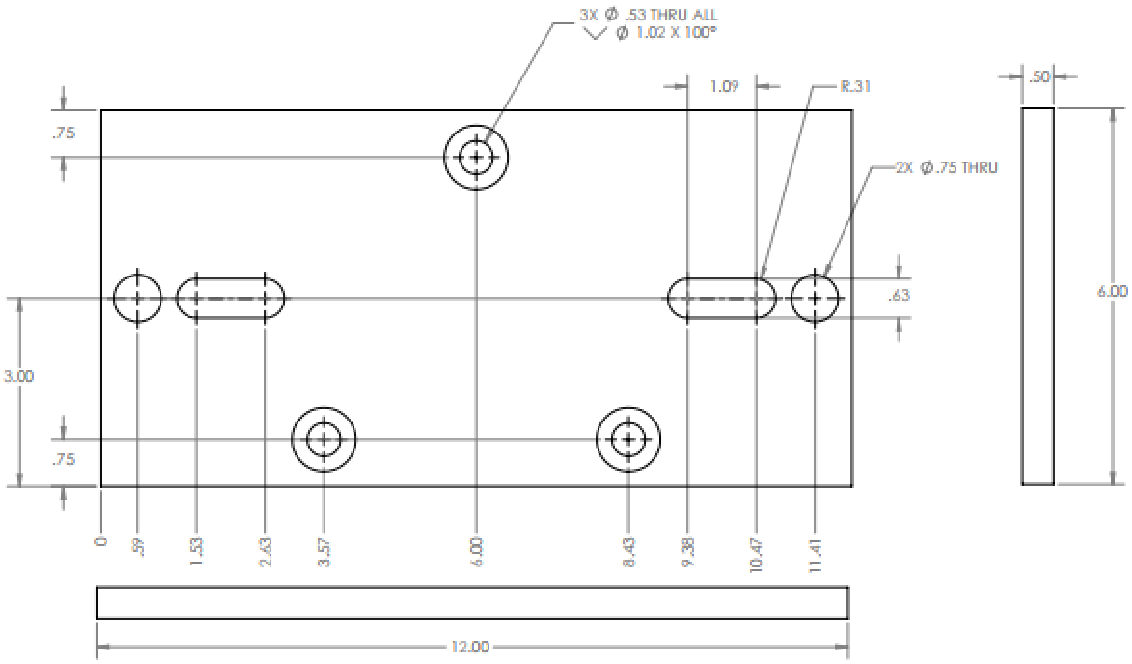


Figure 100: Vibrator Mounting Plate

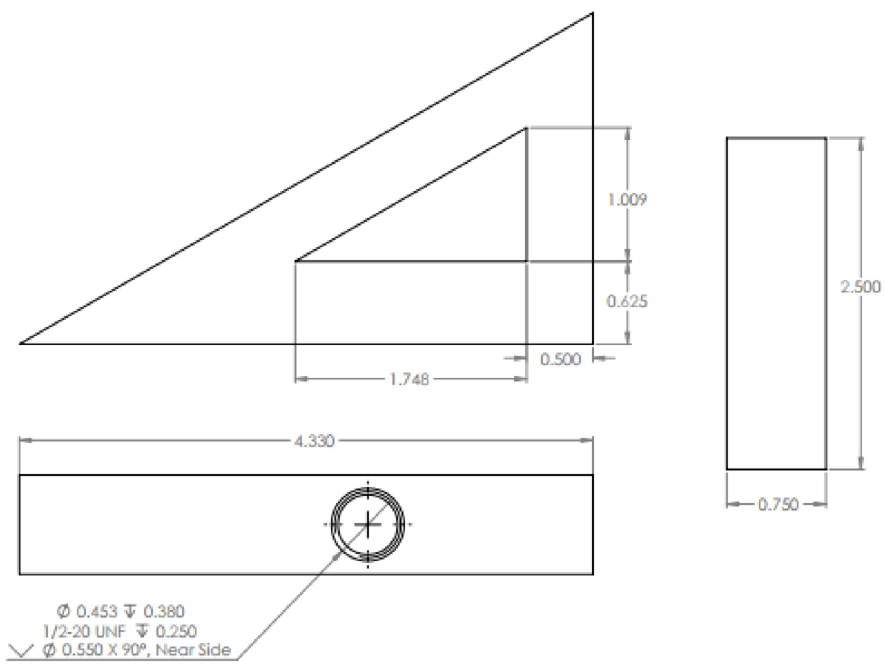


Figure 101: Vibrator Mounting Leg Bottom

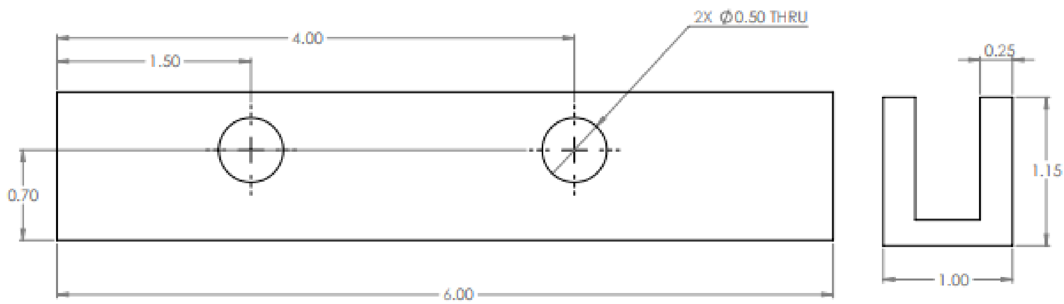


Figure 102: Vibrator Mounting Leg Channel

Figure 103: VIBCO BVS-160 Vibrator

Figure 104: VIBCO BVS-510 Vibrator

10.3 Frame and L-Brackets

The frame will sit on the top of the bin and will support the lifting system as well as the cone. The frame is composed out of two 3 inch U-channel bar stock that will be welded together in the middle. The frame extends to the edges of bin and will give four points of attachment to the bin. The frame will sit directly above each of the four legs of the bin that run down the side of the bin to the ground. L-brackets will bolt to the top of each of the legs and then bolt to the frame. These will be in place to connect the frame to the bin and also disperse the weight of the frame over a larger surface area. The L-brackets will be composed of two 1/8-inch by 8-inch-wide steel plate that will be welded together at VIBCO to create a L shaped bracket. Bolt holes will also be drilled through the bracket in order to bolt both the legs of the bin and frame.

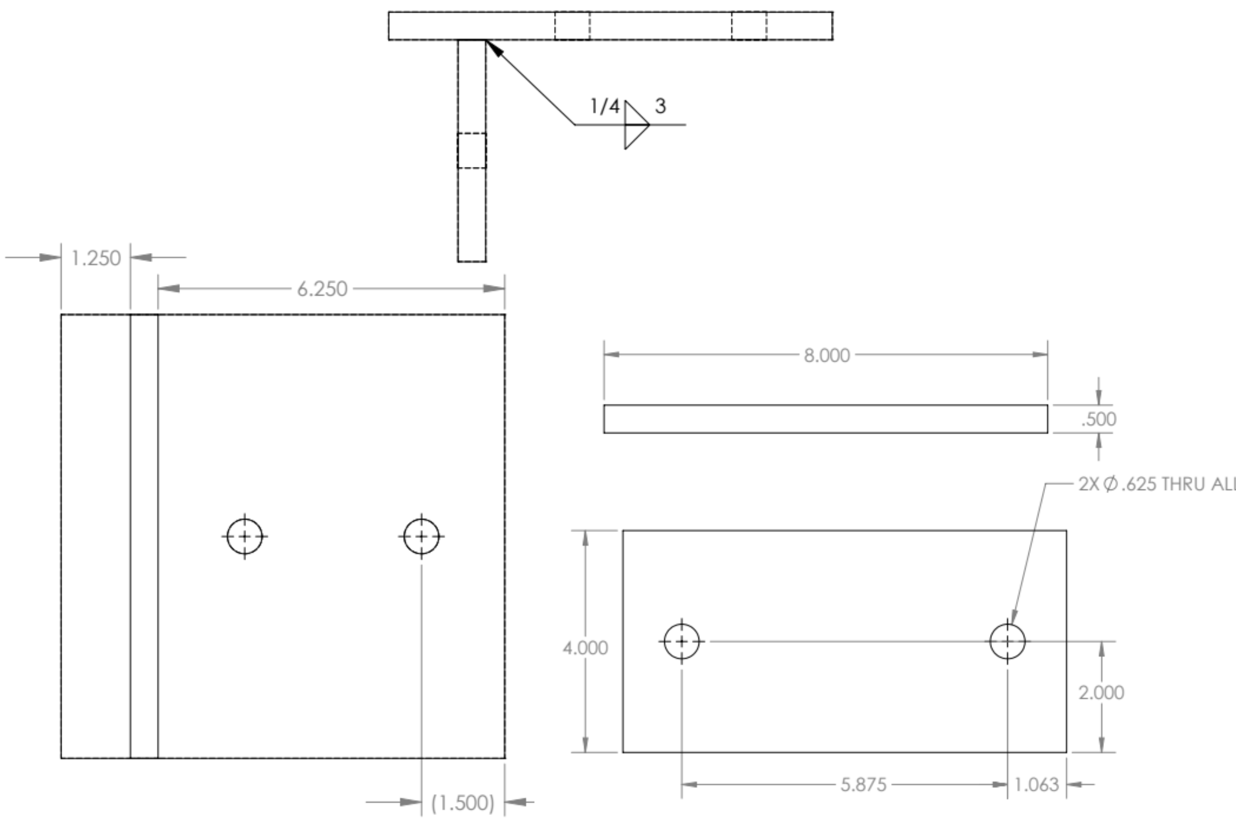
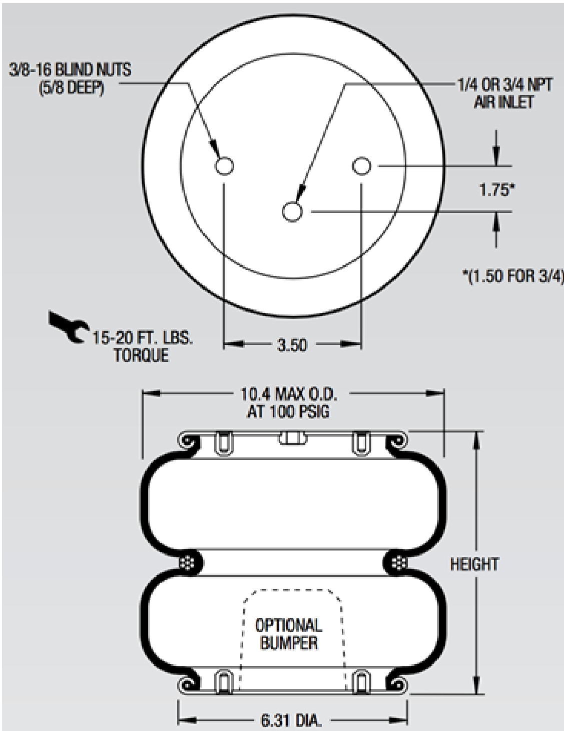


Figure 105: L-Brackets

10.4 Airmount with Upper and Lower Plates

The Firestone Airmount model 20-2, is implemented in the design as part of the lifting system in order to raise and lower the cone. This airmount is able to lift between 1,184-3,238 lbs. at 40-100 psi, with an optimal pressure of 80 psi. The airmount has a minimum deflated height of 3.3 inches and a design, fully inflated, height of 10.7 inches giving an acceptable stroke of 7.4inches. Firestone's airmount weighs 7.7 pounds and needs a force of 17 pounds to fully collapse to its minimum height. The airmount has a diameter of 10.4 inches at 80 psi and three of these airmounts will be implemented in the design to have a total lifting capacity of around 9,500 lbs. at 100 psi. The plates for the top and bottom will need to have a diameter of 36 inches. The plates will be 3/8-inch thick and will have holes cut out for the bolts to mount the airmounts as well as for the airlines to each airmount. Additionally, the plates have a 15-inch hole cut out of the middle to allow for material to fall through and down past the lifting system when the bin is being filled. These will be manufactured using waterjets to cut the overall diameter of the plates out of steel plate, while additionally cutting the bolt holes. The bottom plate will be welded to the middle of the frame and the top plate will be directly bolted to the top of the airmounts. The airmount will be acting as the vibration isolator. Keeping vibrations from the cone from traveling frame and bin.



Force Table

Height (in.)	@20 PSIG	@40 PSIG	@60 PSIG	@80 PSIG	@100 PSIG
11.0	449	951	1,517	2,122	2,753
10.0	572	1,184	1,848	2,531	3,238
9.0	673	1,384	2134	2,880	3,661
8.0	759	1,554	2,377	3,193	4,049
7.0	836	1,704	2,590	3,485	4,416
6.0	907	1,845	2,786	3,753	4,748
5.0	975	1,979	2,954	3,968	5,005

Dynamic Characteristics at 10.0 in.

Gage Pressure (PSIG)	Load (lbs.)	Spring Rate (lbs./in.)
40	1,184	376
60	1,848	534
80	2,531	669
100	3,238	813

Figure 106: Firestone Airmount Style 20-2

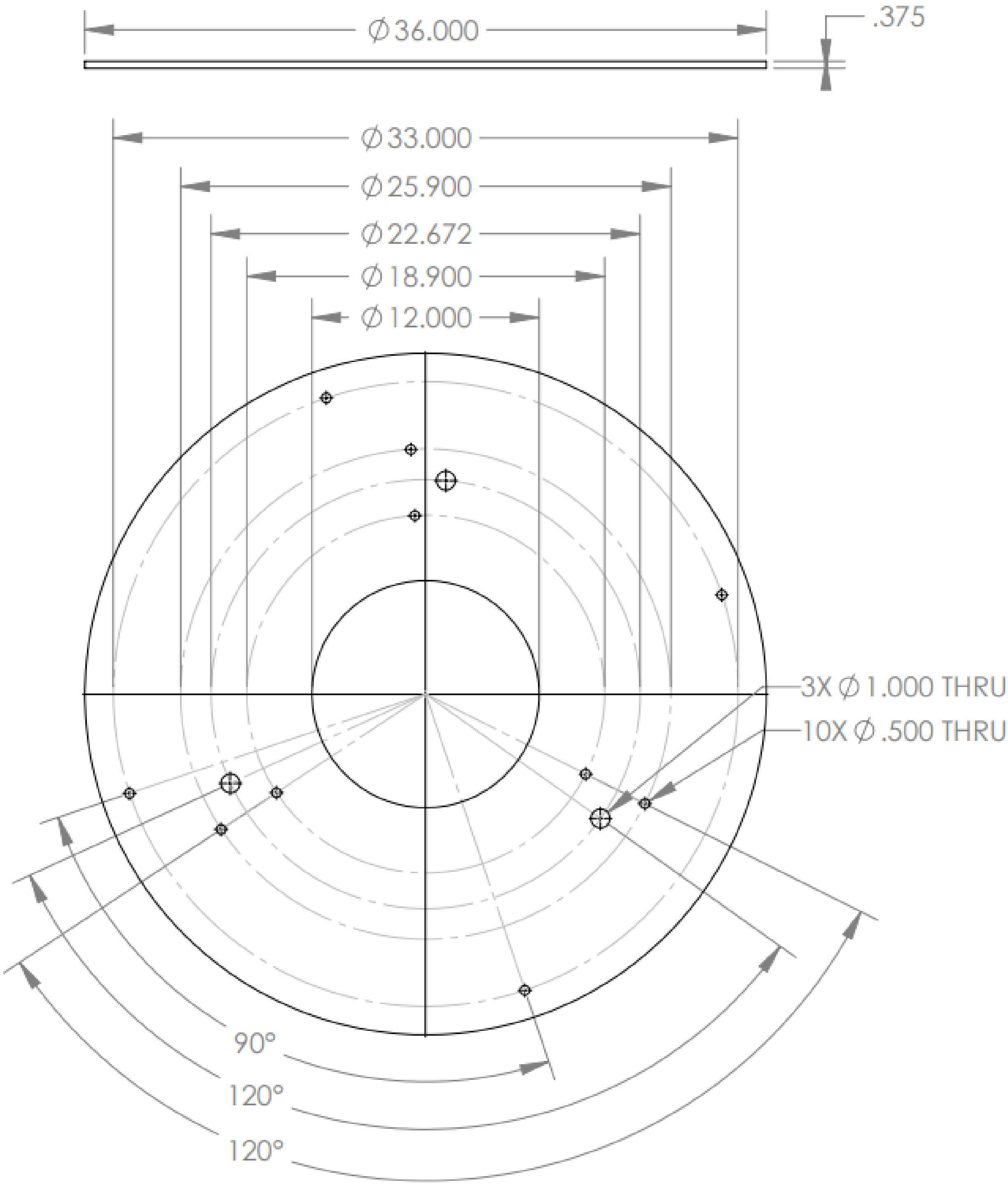


Figure 107: Airmount Top and Bottom Plate

10.5 User Interface

The user interface was incorporated into the design for a means of controlling the system by regulating the air pressure in both the vibrator and airmount. The interface lies outside of the bin with air lines that feed into the side of the bin via access holes. The air lines will feed pressure to the vibrator and airmount. The interface will be Bluetooth controlled from a mobile device that the operator will use. The touch screen capabilities of the device give the operator full control of the cone height and speed of vibrations the vibrator is outputting. The interface will also allow for manual control or full automation of the system. Figures of the user interface are within the proof on concepts and engineering analysis sections.

11 Engineering Analysis

11.1 Internal System Analysis

The engineering analysis gave perspective into why certain components were designed a certain way and also did analysis testing on components. To begin the engineering analysis, the main goal of the design, to vibrate material, needed to be calculated. For a basis, VIBCO gave insight into how vibrations affect material. It is known that in order for material to flow it needs a specified force of vibration and for this it was found that 10 pounds of material required 1-pound force of vibration over a horizontal surface. Due to the fact that a VIBCO vibrator would be used in the system, the data on force outputs of vibrators was already available. It was found that the largest vibrator that was going to be used could output a force of vibration of 900 pounds. This incorporated with a downward sloping cone, would be enough vibration force needed to initiate flow in the densest material.

The next part of the analysis was to calculate the amount of force that would be exerted over the cone. This was found by calculating the maximum material weight and the surface area of the cone, and then finding the amount of force would be exerted on a square inch of the cone. This value could then be compared with known strengths of steel.

Below was the equation used to find the weight of material in the bin

$$W_{Material} = (V_{Bin})(\rho)$$

where $W_{Material}$ is the weight of material in the bin, V_{Bin} is the volume of the Bin, and ρ is the density of the material in the bin.

The largest bin volume and highest density material was used for this calculation in order to get a maximum weight that the system would need to handle. The maximum material weight was calculated to be 6,000 pounds. This calculation was used in many aspects when designing components of the prototype including the raising system and lower legs.

The next equation to determine the forces on the cone, was the cones lateral surface area.

$$L.S.A. = \pi r(\sqrt{h^2 + r^2})$$

where r was the radius of the cone and h was the height.

With a cone radius of 18 inches and a height of 12.12 inches, it was calculated that the lateral surface area of the cone was 1223.33in^2. This meant that the material would be exerting a force on 1223.33 square inches of the cone. In order to find how much force would be applied to one square inch of the cone the material weight was divided by the lateral surface area of the cone.

The equation used for this was

$$Force\ per\ in^2 = \frac{W_{Material}}{L.S.A.}$$

After inputting the maximum material weight and the cone's lateral surface area, it was found that the material would exert 4.91 lbs. of force on every square inch of the cone. This value was then compared with the known strengths of steel that could possibly be used for the system. It was found that the steel that would be used for the cone would have a strength to hold 4.91 pounds per square inch.

Angling the cone in a way that would aid in material flow was crucial to the design. This angle needed to be based upon the angle of repose of material. The angle of repose is defined as the largest angle a sloping surface of loose material is stable. This angle made into a cone would intern make material with smaller angle of repose material flow if placed on it. After research into relative material angles, it was found that the range was between 20-60 degrees angle of repose. Some of these values are shown in the figure below.

Material	*Angle of Repose*
Ashes	40°
Bran	30–45°
Chalk	45°
Clover seed	28°
Coconut (shredded)	45°
Coffee bean (fresh)	35–45°
Flour (corn)	30–40°
Flour (wheat)	45°
Malt	30–45°
Sand (dry)	34°
Sand (water filled)	15–30°
Sand (wet)	45°
Urea (Granular)	27°
Wheat	27°

Table 8: Angle of Repose of Materials

Because vibration would also be affecting the material, the angle of the cone could be smaller than the angle of repose of material. This cone angle also had to accommodate all the materials between the 20-60-degrees angle of repose. In order to find a cone angle that was universal the mean angle of repose of material that would be found in the market was calculated and it was found to be 33.69 degrees. This would allow for any material with an angle of repose lower than 33 degrees to already begin flowing with the cone alone, and any material with an angle of repose larger would begin flowing once the vibrator was activated.

The amount of material flowing out of the bin was also a possible issue in the design. If the material of flow was too excessive it could build up at the exit hole of the bin and begin to back up into the under sections of the system, which could cause failure in the vibrator or contamination of product. The team needed to guarantee that this issue could be solved. In order to do so, it was found that the buildup of material was due to the volume of material flowing past the cone being larger than the volume of material flowing out of the exit hole. This was able to be quantified in the area between the cone and the bin could not exceed the area of the exit hole in order to have no buildup of flow. This was given by the equation below which states the maximum diameter of the bin the cone can raise to.

$$D_{Bin} = 2 * \sqrt{\left(\frac{D_{Exit}}{2}\right)^2 + \left(\frac{D_{Cone}}{2}\right)^2}$$

Where the diameter (D) of the bin is found using the diameter of the exit hole and cone. This equation will give the maximum height the cone can be raise for different bin sizes. The data for different bin sizes and exit holes will be gathered and a sheet of maximum cone heights for bins will be able to be made. This will then be used when setting up the maximum height in the controller interface.

11.2 User Interface Analysis

The user interface serves to control the internal bin system that is implemented. Its purpose is to allow the user to control the flow of material exiting the bin. This is done through both the use of Visual Basic as well as Arduino. Through the use of these two programs the user will be able to control a series of solenoid valves in line with the vibrator and airmount to control the vibrator speed as well as the height of the airmount. Shown in the figures below is the current prototyped system. It consists of four 2-way/2-position solenoid valves, two manual pressure regulators, and three pressure transducers that will feed back the pressure of the lines to the user. Figure 114 depicts the wiring configuration consisting of four relays, five LED’s, five resistors, and an Arduino.

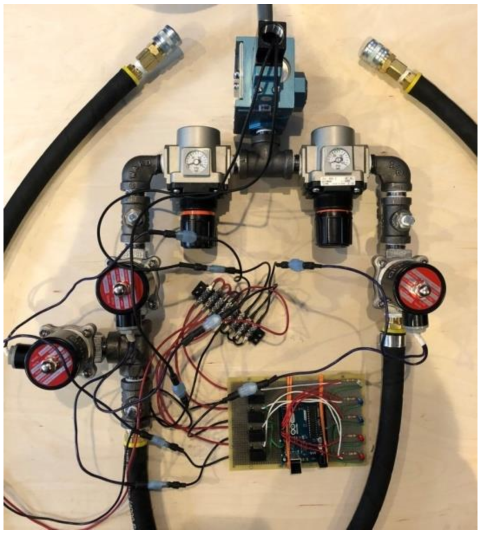


Figure 108: Control System Components

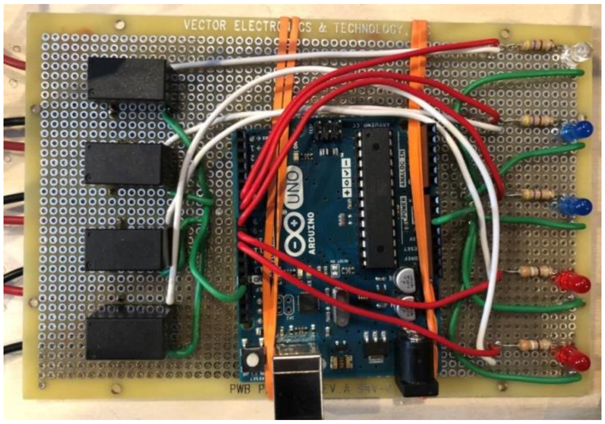


Figure 109: Wiring Configuration for Control System

The components that make up the system are displayed in the table below. Shown in the table is the voltage, amperage, and assortment of other specifications that determined whether or not the component would be used. It was important to not overload the control system with the current, and also not to exceed the allotted voltage. The Arduino can only supply 5 volts due to its 5-volt max regulator. Most of the components require a minimum of 12 volts which is why a power supply had to be implemented in order to support these components.

Component	Used for…	Specs			
		Attachment	Pressure Range	Voltage	Current
1/2" Stainless Steel Electric Solenoid Valve 12 VDC Normally Closed	Air On/Off	(2) 1/2" NPT (Female)	0-145 PSI	12 VDC	1.5A
1/2" Manual Pressure Regulator	Regulating Pressure	(2) 1/2" NPT (Female)	0-150 PSI	N/A	N/A
Autex 150 PSI Pressure Transducer Sender for Air	Feedback Pressure	(1) 1/8" NPT (Male)	0-150 PSI	5V	.02A
3 Way, 2 position solenoid valve (NC)	Control Air on/off to the air mount	(3) 1/2" NPT (Female)	25-150 PSI	12 VDC	0.5A
Relay SPDT Sealed	To power solenoids	N/A	N/A	12 VDC	5A
12V Power Supply Adapter	Additional Voltage	N/A	N/A	12 VDC	5A
LED's	Indicators	N/A	N/A	5VDC	
Resistors	LED's	N/A	N/A	N/A	N/A

Table 9: Electronic System Components

11.2.1 Visual Basic Environment

Visual Basic will be the interface that allows the user to control the entirety of the system. The code consists of an assortment of cases that include pressurizing the manifold, allowing the air to flow to the airmount, allowing the air to flow to the vibrator, and lastly allowing air to blow off from the airmount in order to decrease the height. This code works side by side with Arduino in order to control this system. Fail safes are built into Visual Basic in order to prevent system failure. One of these fail safes include not allowing the user to activate air to the airmount unless the vibrator is activated. The purpose of this is to prevent the airmount from failing trying to move the applied load from the material on top of it without the help of vibration. Another fail safe includes not allowing the user to exit the program without depressurizing the lines. This is critical as it will ensure the safety of the operator.

Another key component of the Visual Basic interface is that it will allow the user to see real time the operating pressure of the system. There are three pressure transducers that will be feeding back to the program. The first two will indicate the line pressure going to either the airmount or the vibrator. The third sensor will tell the user the current pressure of the airmount. The reason that the line pressure going to the airmount will be different than the actual airmount is because the operator has the control to decrease the airmount thus translating to a decrease in pressure.

Shown in the figure below is what the operator will see. As of right now everything is hard wired so the user must connect to a serial port in order to enable the connection with the Arduino. The operator will then have to enable air to the manifold. From here the vibrator must be turned on before any operation of the airmount. Once the vibrator has been initialized the user has the capability to increase and decrease the pressure in the airmount at three different rates. These three different rates are depicted by the "Feed Adjustment" box. The three different options for feed rate are course, medium, and fine as indicated by radio buttons that the operator must select.

Also indicated in the feed adjustment box are two commands labeled "Max Feed" and "Stop Feed". These two commands are in reference to the airmount. If the operator does not intend to adjust the height of the airmount they can set it at max feed which will completely inflate the airmount. If the stop feed button is chosen this will completely deflate the airmount, thus lowering it to its initial position within the system.

Lastly all the way to the left of the Visual Basic form is the pressure indicators. These pressure indicators will show values in green to indicate the current system operating pressure is within specifications. If it begins to exceed the user defined operating pressure due to either a malfunction or error in operator input the exceeded values will be shown in yellow and give the user a chance to make necessary changes. If these changes are not made in a certain amount of time the values will go red and shut down the system automatically in order to prevent any sort of system failure or safety issues.

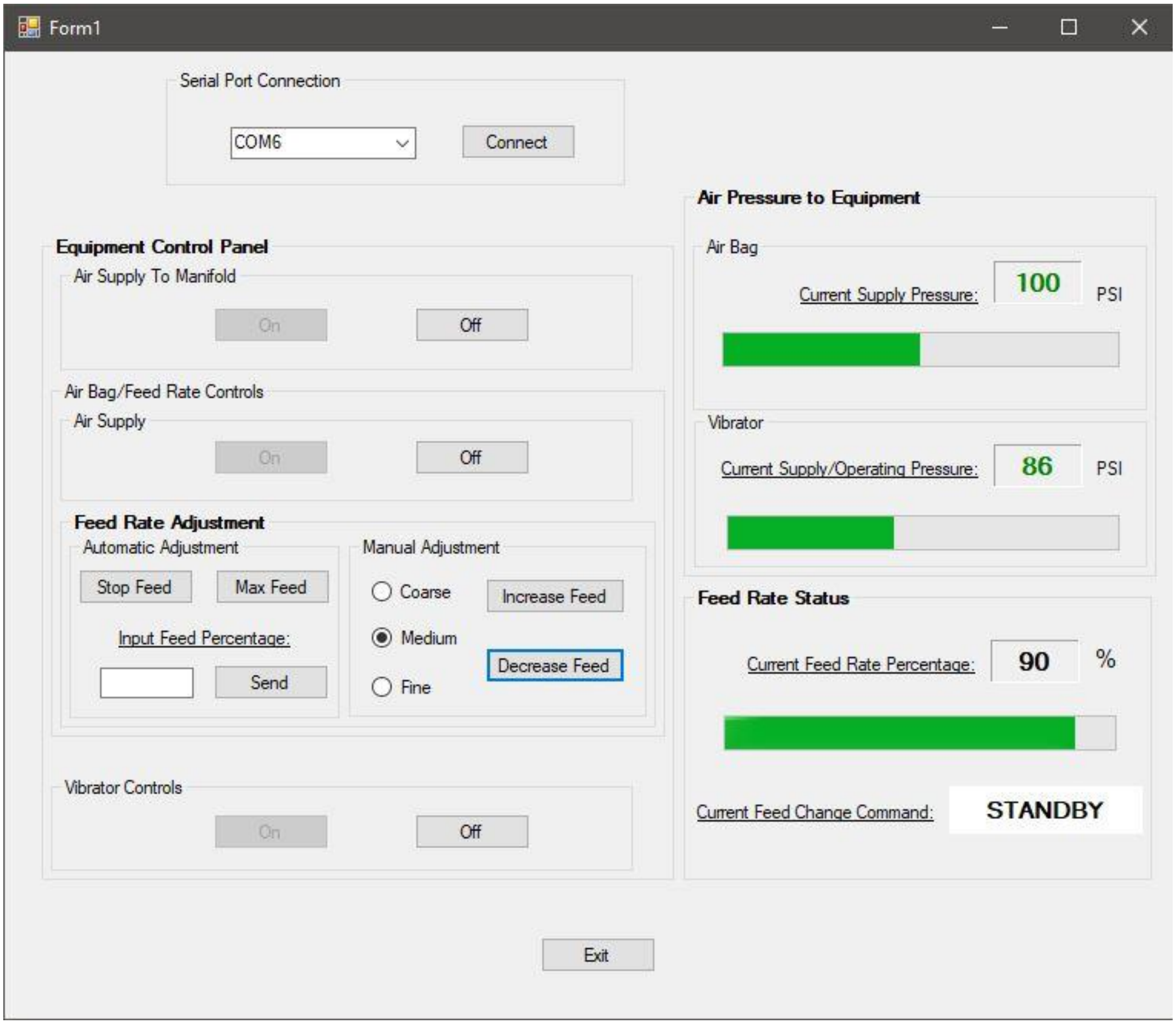


Figure 110: Visual Basic Interface

11.2.2 Arduino Environment

The Arduino is the main source of control for the system. Visual Basic acts as simply a user interface that initializes code within Arduino. The Arduino is what is connected to all of the resistors, LED's, relays, and solenoid valves through the use of a prototyping board. Please refer to Figure 121 for the layout of the prototyping board. The Arduino is also connected to a USB that provides 5 volts, an external brick power source that also provides 5 volts but supports higher amperage than a computer port. Lastly through a connection with a terminal block there is another power source that supports 12 volts which is what will support the solenoid valves. Along with actuating the solenoids the Arduino also controls five different LED's that will indicate to the operator what components in the system are actuated (contain pressurized lines). This is going to aid in a visual representation of the system status and help to prevent any misuses of the system.

12 Proof of Concept

It was decided that a simulation and full Solidworks assembly would be the most cost effective and time efficient way to provide a clear path moving forwards in the development of the actual product. There are three different main sections of the prototype itself, which when put together will produce one working product. The four sections consist of, the cone with the vibrator and vibrator mount, the frame and lifting system, and the user interface. These three sections will be discussed in greater detail in the following pages.

12.1 Cone, Vibrator, and Vibrator Plate

The cone is the component that will be in contact with the material. The cone will be made out of steel preferably stainless, in order for the material not to corrode the cone. Four sections will bolt together through ribs underneath to form a full cone. From these bolt holes, a vibrator plate will be able to be mounted directly to the upper portion of the cone. The vibrator then will bolt upside down directly to the mounting plate and be able to directly transfer vibrations to the cone. This vibrator will range in size base on material density, so the mounting plate has universal holes in order to fit a VIBCO pneumatic vibrator from size BVS160-BVS510. The space inside the cone between the mounting plate and the top plate of the airmount is also large enough to fit these sizes. The mounting legs are what will attach the cone to the airmount system. The leg mounts will also provide the cone with additional support under the material weight. The figures below show the components.

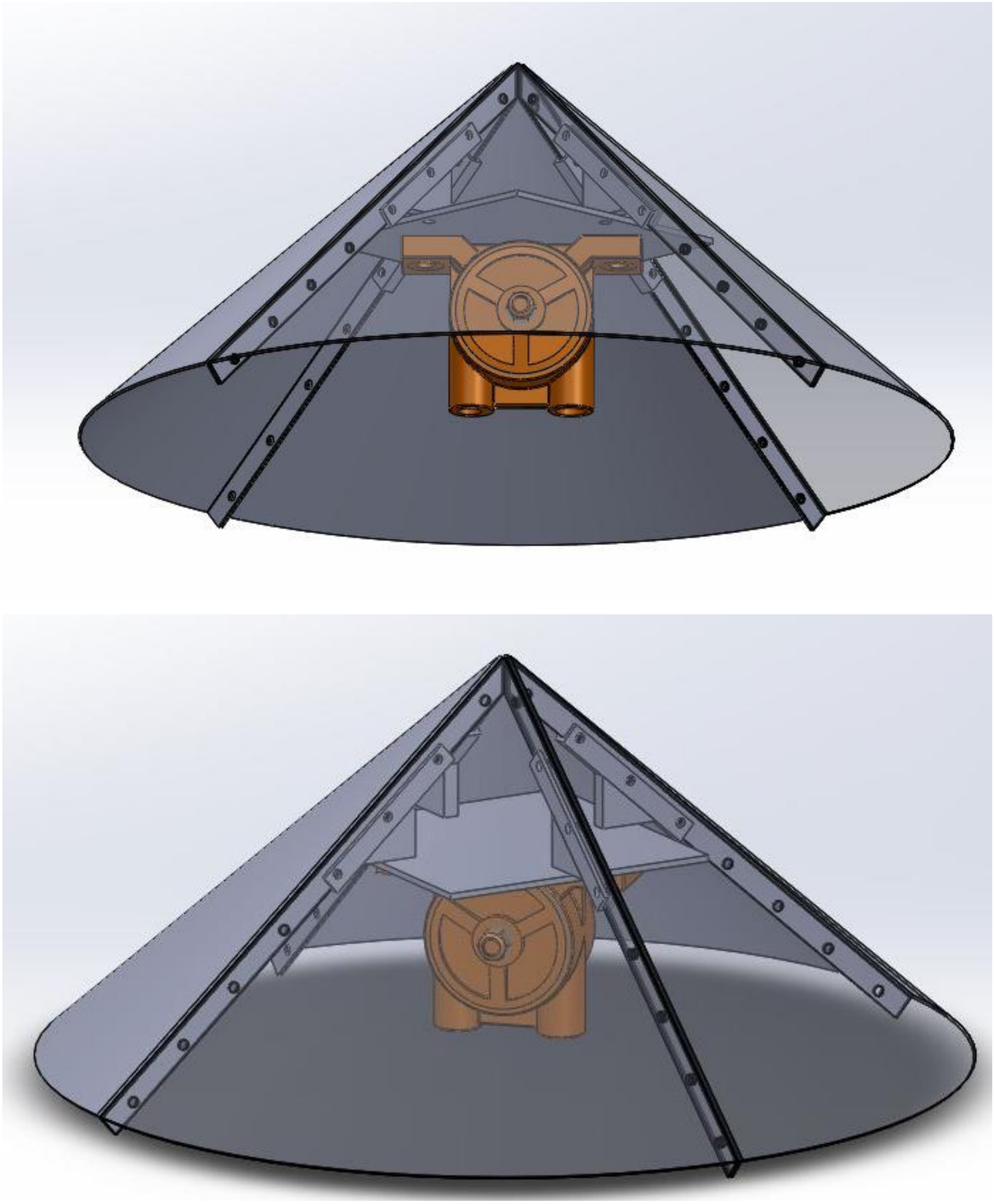


Figure 111: Vibrator Mounted Inside of Cone

12.2 Lifting System

The lifting system is the component that will raise and lower the cone fixture allowing for the flow rate to be controlled. It is composed of lower and upper plates, and three double-convoluted airmounts that will raise as air is fed into it. The airmounts are manufactured and sold by Firestone which is already a vendor of VIBCO. The style 20-2 airmount was chosen for the system due to the amount of weight it can lift and its size. Its diameter of 10.4 inches gives is small enough to fit 3 in the lifting system. The airmount also has a lifting load of 2,531 pounds at 80 psi, which would give the entire lifting system a capacity of over 7,500 lbs. The airmount has a maximum height of 10.7 inches and minimum height of 3.3 inches, which also allows the cone to be able to raise at least 6 inches. It was calculated that the maximum weight of material that would be inside the bins would be 6,000 pounds. This gives the system a factor of safety of 1.27 which is more than enough to ensure the lifting system will not fail under that weight. Isolating the vibrations of the cone from the bin walls and the frame was also a necessity. Due to the airmount's airbag portion being composed of rubber, this will act as a vibration isolator, separating vibrations of the cone coming up the cables that suspend the cone and into the frame and bin. Two plates, both 36-inches in diameter will be on the bottom and top of the airmounts and will be the attachment point for the airmounts. They will have bolt holes as well as holes for the air lines the feed into the airmounts and holes for the cables that attach to the cone. There will be four cables that attach to the two plates that sandwich the airmounts. The cables will mount to the top plate and extend down into the bin to attach the cone and suspend it in the bin.

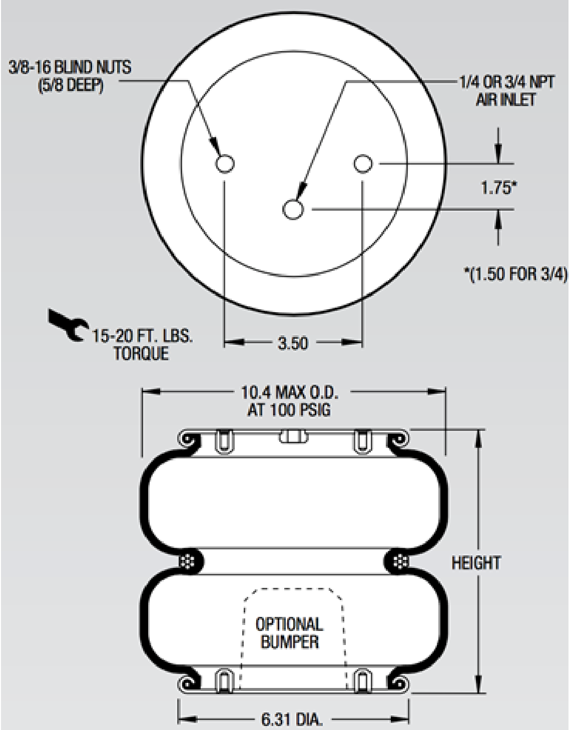


Figure 112: Firestone Airmount Style 20-2 Dimensions

12.3 Frame and L-Brackets

The frame and L-brackets are what will connect to the top of the bin and support the lifting system as well as the cone. The frame is going to be made out of U-channel steel bar stock and will be orientated to form an x-shape over the top of the bin. The channel will extend to the edges of the bin where the L-brackets will connect the frame to the legs of the bin. The bin has legs that run from the ground all the way to the top. The L-brackets will sit on top of these legs and bolt both to the legs and the frame. The U-channel of the frame will sit on top of the L-brackets in order to disperse the weight of the system evenly over the legs of the bin. The bottom plate of the lifting system will be directly welded to the middle of the frame. This will give a strong and firm place for the airmounts to then be mounted to.

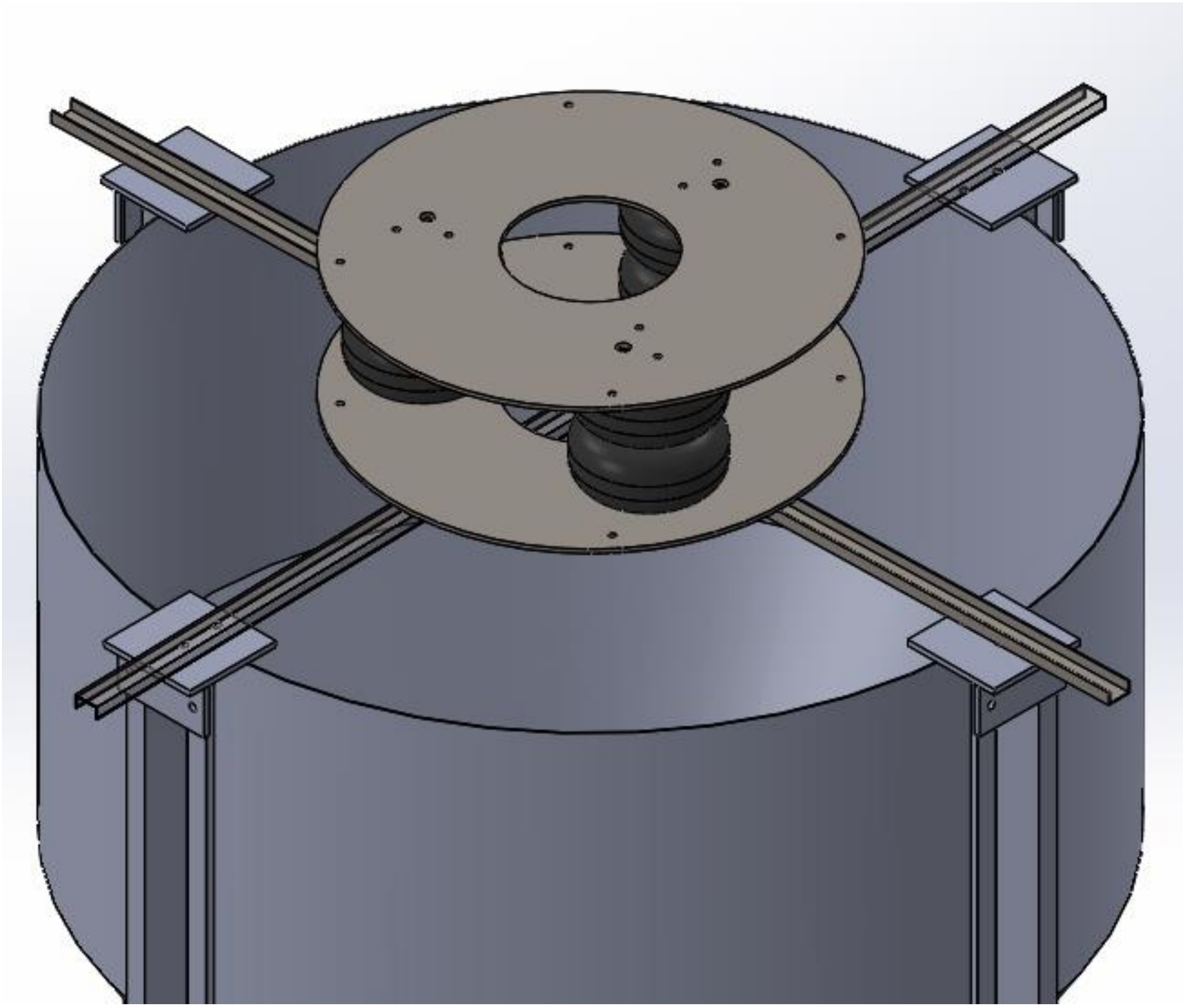


Figure 113: Frame with L-Brackets and Lifting System

12.4 User Interface

The purpose of the user interface is to control all of the pneumatics within the system. Pneumatics including the vibrator and the airmount which is what will be used to raise and lower the inner assembly to allow material to flow. The user interface consists of two different programs, Visual Basic, and Arduino. The Visual Basic interface will be what the user is going to make changes to the system. These changes include allowing air to flow to either the air mount or the vibrator, decreasing the volume of air in the airmount (lowering), and increasing the volume of air in the air mount (raising). The user interface will be equipped with failsafe's such as code that does not allow the airmount to be activated without the activation of the vibrator. This interface is going to be controlling a series of solenoid valves connected in line with the airmount and vibrator. Visual cues of the interface will include a panel equipped with LED's in order to ensure the user that certain components are in fact activated. Output pressure of certain points within the airlines will be displayed to the user real time so that the user can ensure that all components are operating at the desired pressures. Below are the electrical components of the user interface.

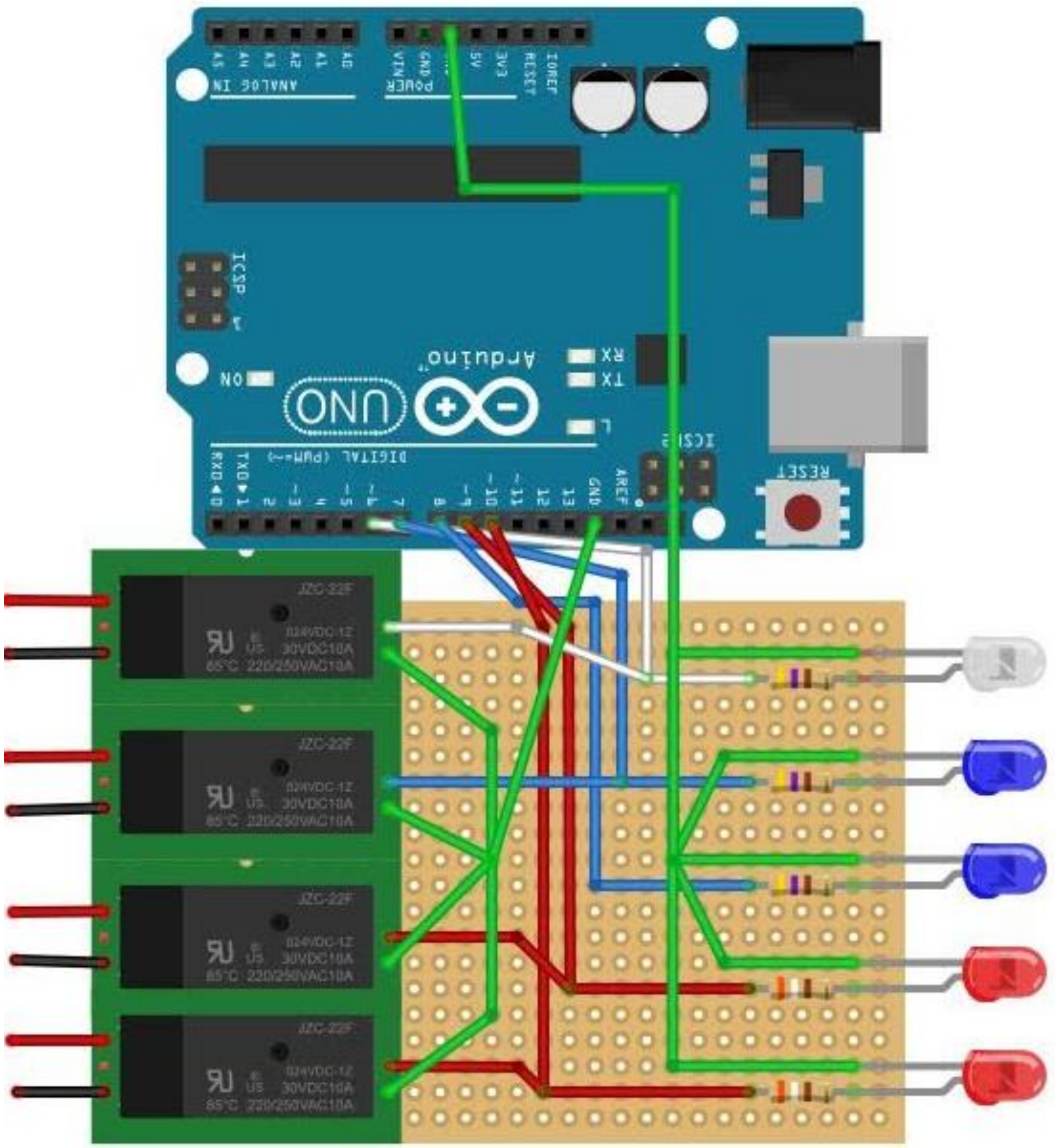


Figure 114:User Interface

12.5 Concept Simulation/ Inside of Bin

Once the system is attached to the bin and the interface is connected to the system with air hoses running through portholes in the side of the bin to the vibrator and running to the top of the bin for the airmounts, the product is ready for use. The system can be controlled using the interface. The controller can adjust the amount of vibration as well as the height of the cone. The flow of material can be changed from 0% flow coming out all the way to 100% flow depending on the customer needs. The type of material in the bin will dictate how high of a frequency vibration is needed to initiate flow. This can also be adjusted depending on customers' needs. The figure below shows the system implemented in the bin.

Figure 115: Cone and Lifting System Implemented in Bin

13 Manufacture and Build

To begin the manufacturing and building of our prototype, the first parts that were ordered were the airmounts from firestone. These were ordered these first because the specifications of maximum load and air pressure were already known and no testing on the actual airmounts were needed. The parts for the Arduino and control system including airlines and connectors had already been ordered and assembled in the first semester of the project.

To begin building the frame and lifting system, two 8ft long, 3 inch U-channel steel that was ordered through VIBCO because this is already a product they use. These U-channels were cut to 7ft lengths, to allow they to overhang the edges of the bin a little on each side. The two channels were then crossed in the middle to form a x-shaped frame. One of the channels was flipped upside down and slots were cut out of the other channel's side walls in order for the upside down channel to fit where they cross. They were then welded together where they meet.

The bottom plate of the lifting system would then sit on top of this U-channel frame. Both the top and bottom plates are the same, so this aided in being able to manufacture both places quickly and efficiently. These plates were manufactured through ERW, a steel company specializing in steel manufacturing. The plates were water jet cut out of 3/8-inch steel plate to the desire design and specifications set forth in the plans given to ERW. Once these plates had been manufactured and delivers to VIBCO, the bottom plate was welded to the frame directly and the airmounts were then bolted through that plate. The top plate was placed on the top of the airmounts and also bolted to them.

In order for the frame to sit on the top of the bin and be secured, L-brackets needed to be manufactured to allow for the frame to bolt to the legs of the bin. The L-brackets consists of two plates, a horizontal plate of dimensions 8x8 inches with a thickness of a ¼-inch and a vertical, down facing plate of dimensions 8x4 inches with a thickness of a 1/4 inch. The vertical plate was then drilled with two holes to allow for bolts to connect the bracket to the legs of the bin. The vertical plate was then welded to the bottom of the horizontal plate, offset 1 and 5/16 inches from the edge of the horizontal plate to allow for a stronger weld connecting both plates. The horizontal plate had two holes drilled through it to match up with two holes on the U-channel frame in order for the brackets to secure the frame. Four total L-brackets were built, one for each of the four legs on the bin.

Due to cost of manufacturing and budget for the project, it was decided that the cone would not be manufactured for the prototype. If the frame and lifting system proved to work and VIBCO could move forward with the project and manufacture the cone in a high quantity which would decrease the cost. Manufacturing just one cone was not seen to be worth the cost for just testing. It is already known that a cone design is the best shape for vibrating material inside of bin silos and this is known from already existing bin vibration systems.

Without the cone inside the bin, the vibrator and vibrator mount will be suspended from the cables. The vibrator will be selected from orange of sizes that VIBCO already has in stock and no manufacturing on our team's end will need to be performed. The vibrator mount will be a rectangle cut from a 3/8-inch steel plate and holes will be drilled through it to universally fit different sized vibrators. Holes will also be drilled in the plate to attach the cables that extend down from the lifting system. The cables are a 1/4-inch stainless steel and will be attached using cable camps ones the lifting system and frame are installed on the top of the bin.

14 Testing

Testing for the system was divided into three cycles, testing of the control system, testing of the control system with the small scale components, and testing of the over system in a dry environment. A dry environment describes the system being tested with no material inside the bin. During the first cycle the measurements of amperage and air consumption will be tested for the control system. This test also was performed to prove that the electronics of the control system were functioning correctly and to make any additional changed to the user interface if needed.

For the second cycle, the measurements of displacement and height of the lifting system were taken. These measurements were taken with the user interface controlling both the lifting system and the pneumatic vibrator. The goal of the cycle was to ensure that pressure was being maintained throughout the system and to check the function of the pressure sensors. Additionally, adjustment of the allotted time that the solenoids open and close would be done as the test was ran. There were four modes of the user interface that were going to be tested, the maximum air pressure feed, fin increase and decrease, medium increase and decrease, and coarse increase and decrease of air pressure in both the vibrator and lifting system.

The third cycle will be conducted to test the overall function of the system implemented into the bin. Due to the fact that the cone will not be implemented in this cycle of testing, the cables that extend down from the lifting system will attach to the vibrator mount. The team will be measuring the VPM's as well as the G's of acceleration produced from the vibrator inside the bin. We will also be measuring the amount of vibrations that travel up the cables to the lifting system. These will be measured using vibrations sensors already provided at VIBCO. The cycle will also include testing on the fitment of the system when implemented on the bin. This will ensure all bolt holes line up in their correct positions as well at the frame seating correctly on top of the legs of the bin. Additionally, the lifting system will be tested to see how well it is able to raise and lower the cables that extend down into the bin, while also making sure there is not interference with the cables and any components of the system.

15 Redesign

In the beginning of the second semester, the team met with our sponsor, VIBCO, to discuss our concept and moving forward into the build stage. At this meeting new design specifications were set for the project and it was agreed that the original concept needed to be redesigned both for simplicity and to fit the new specifications. VIBCO wanted the lifting system to be placed outside of the bin, in order to have minimal components directly touching the material. They did want to keep a couple of the components from the original design. The company liked that the team used airmounts as the lifting system for the prototype and the cone design inside the bin was the best to initiate the flow of material. They also wanted to keep how the vibrator was mounted directly underneath the cone. In order for the team to create a new system many new components had to be designed and tested.

To begin the redesign of our original concept, the team had to determine the new weight range the cone would be experiencing when the bin was fully loaded. It was calculated that the maximum weight the cone would be subject was 6,000 lbs. This allowed us to reduce the thickness of the cone from 1/4 –inch to 1/8-inch steel. The cone also was redesigned to be composed to 4 sections rather than 3. This was done to give an additional point of attachment for the vibrator mount as well as for the cables that would suspend the cone in the bin. The cone also needed to be reduced in size because the bins that it would be going in would be at the largest 6 feet. In order to have a universally sized cone the team redesigned the cone to have a 36-inch diameter rather than its original 42-inch diameter.

In the original design, the cone was lifted using one single airmount below it, but with the new design the airmount would be fixed on the top of the bin. Based on cost and lifting capacity, the team decided to use three smaller airmounts to raise and lower the cone. Firestone airmount style 20-2 was chosen for the system because of its size and lifting capacity. Each airmount could lift over 2,500 lbs. which meant that the system would need to have three of these airmounts in order to raise the cone under the calculated 6,000 lbs. while additionally having a factory of safety over 1. Purchasing 3 of these airmount was determined to be around $500 cheaper than purchasing the one airmount from the original design. This was essential in keeping the price of the whole system to a minimum.

Due to the fact that the lifting system was moved to the top of the bin, a frame had to be designed in order to home the airmounts and suspend the cone inside the bin. To begin this design, research had to be completed on different styles of bin tops. Bin silos come in many shapes and sizes depending on manufacturer, so the frame needed to be able to fit as many styles as possible in order to appeal to as many potential customers as possible. After research was completed, the team determined that the best option for a frame was to have two U-channel cross members extend to the walls of the bin and cross in the middle. This would provide a stable platform for the lifting to be attached in order to hold up under the material weight inside the bin on the cone.

No redesigns have yet to be completed on the new design due to the delays with the build and testing. The team does have plans for future redesigns which include using different materials and improving efficiency. The design of the cone was found to be difficult to manufacture in small scale, and improving the design with ease of manufacturing in mind will most likely be completed in the coming month. For the prototype, common steel was used for cost but for an actual manufactured product, the system will be redesigned to be made out of stainless steel in order to make it FDA approved for food and pharmaceutical industries. The team additionally is going to try to reduce the weight of the system, while not compromising the strength by reducing plate thickness in the lifting system.

16 Results and Discussion

16.1 Cycle One Results

After completing cycle one of testing, it was found that all electronics for the user interface were working in correct order. The Arduino system, prototype board, and computer generated interface were working with one another to control both the airmounts and vibrator. No components on the prototype board were found to be over heating due to over exertion. The results of this cycle showed that the user interface was ready to be connected to the airmounts and vibrator for cycle two. The Function Report below shows the results from cycle one of testing.

FUNCTION REPORT FORM

TEST: Cycle 1 Test 1

DATE: 3/28/18

Initial Readings	
Pressure Regulator #1	N/A
Pressure Regulator #2	N/A
Incoming Tank Pressure	N/A

1: EQUIPMENT CONTRAL PANEL

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Air supply to manifold functions it just takes two clicks to initiate the system. Need to re-adjust the code to correct this issue. Priority: Minor

2: FEED RATE TEST #1- Automatic Adjustment

Max Feed	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

The max feed and stop feed functions do not work in a simulated test. Since there is no pressure running through the system, the sensors feel no pressure so max and stop feed continue firing continuously.

Stop Feed	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Shut down system

1: EQUIPMENT CONTRAL PANEL

Pressure Reading

Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

2: FEED RATE TEST #2 – Manual Adjustment

Fine Adjustment

Fine Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Fine Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Medium Adjustment

Medium Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A

Vibrator	N/A
Feed Rate Status	N/A

Medium Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Coarse Adjustment

Coarse Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Coarse Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Shut down system

1: EQUIPMENT CONTRAL PANEL

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

2: FEED RATE TEST #3 – Input Feed Adjustment

Input Feed	Input High:___N/A____	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Input Feed	Input Low:___N/A____	YES☐	NO☐

Pressure Reading	
Air Bags	N/A
Vibrator	N/A
Feed Rate Status	N/A

Shut down system

16.2 Cycle Two Results

The completion of the second cycle also gave very promising results. The airmounts and vibrator were tested connected to the user interface. The user interface was able to correctly turn on the vibrator and then send air to the airmounts in order to inflate them. The interface also did not allow the airmounts to be inflated without the vibrator being turned on, which is critical to lowering the amount of strain on the frame. The interface needed to be adjusted because it was found that when inflating the airmounts, the increments of inflation were too large and the airmounts were over-inflating. These increments were reduced to give a finer control over the inflation and deflation of the airmounts. This fine control would be essential when setting the height, the cone should be raised to in variable sized bin and needed flow rates. The test also proved that pressure was being maintained throughout the system, with variable control over the airmounts and vibrator. The Function Report below shows the results from cycle two of testing.

FUNCTION REPORT FORM

TEST: Cycle 1 Test 2

DATE: 3/28/18

Initial Readings	
Pressure Regulator #1	60 PSI
Pressure Regulator #2	60 PSI
Incoming Tank Pressure	120 PSI

1: EQUIPMENT CONTRAL PANEL

Pressure Reading	
Air Bags	58 PSI
Vibrator	59 PSI
Feed Rate Status	3 PSI

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI
Vibrator	59 PSI
Feed Rate Status	3 PSI

Air supply to manifold functions it just takes two clicks to initiate the system. Need to re-adjust the code to correct this issue.

Priority: Minor

2: FEED RATE TEST #1- Automatic Adjustment

Max Feed	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI
Vibrator	58 PSI
Feed Rate Status	55 PSI

For max feed be sure to adjust based off of what the manual pressure regulators max are set at.

Stop Feed	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI

Vibrator	58 PSI
Feed Rate Status	4 PSI

Shut down system

1: EQUIPMENT CONTRAL PANEL

Pressure Reading	
Air Bags	59 PSI
Vibrator	60 PSI
Feed Rate Status	1 PSI

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	59 PSI
Vibrator	60 PSI
Feed Rate Status	1 PSI

2: FEED RATE TEST #2 – Manual Adjustment

Fine Adjustment

Fine Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI
Vibrator	58 PSI
Feed Rate Status	10 PSI

Fine Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI
Vibrator	58 PSI

Feed Rate Status	2 PSI

Medium Adjustment

Medium Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	58 PSI
Vibrator	58 PSI
Feed Rate Status	15 PSI

Medium Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	57 PSI
Vibrator	58 PSI
Feed Rate Status	3 PSI

Coarse Adjustment

Coarse Increase	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	57 PSI
Vibrator	58 PSI
Feed Rate Status	30 PSI

Coarse Decrease	Clicks:__3__	YES☐	NO☐

Pressure Reading	
Air Bags	57 PSI
Vibrator	58 PSI
Feed Rate Status	5 PSI

Shut down system

1: EQUIPMENT CONTRAL PANEL

Pressure Reading	
Air Bags	57 PSI
Vibrator	58 PSI
Feed Rate Status	2 PSI

Air Controls		
Air Supply to Manifold Function	YES☐	NO☐
Vibrator Controls Function	YES☐	NO☐
Air Supply Controls Function	YES☐	NO☐

Pressure Reading	
Air Bags	57 PSI
Vibrator	58 PSI
Feed Rate Status	2 PSI

2: FEED RATE TEST #3 – Input Feed Adjustment

Input Feed	Input High:___50____	YES☐	NO☐

Pressure Reading	
Air Bags	58 PS
Vibrator	59 PSI
Feed Rate Status	47 PSI

Input Feed	Input Low:___15____	YES☐	NO☐

Pressure Reading	
Air Bags	58 PS
Vibrator	59 PSI
Feed Rate Status	13 PSI

System only begins to get within plus or minus 5 due to the code but the system appears to be operating more accurately than the given predicted boundaries.

Shut down system

16.3 Cycle Three Results

The testing of cycle three has not yet been completing due to delays in manufacturing of the mounting plates for the lifting system. The plan is to have cycle three of testing completed by the end of the month along with a full prototype built.

17 Operation

17.1 Air System

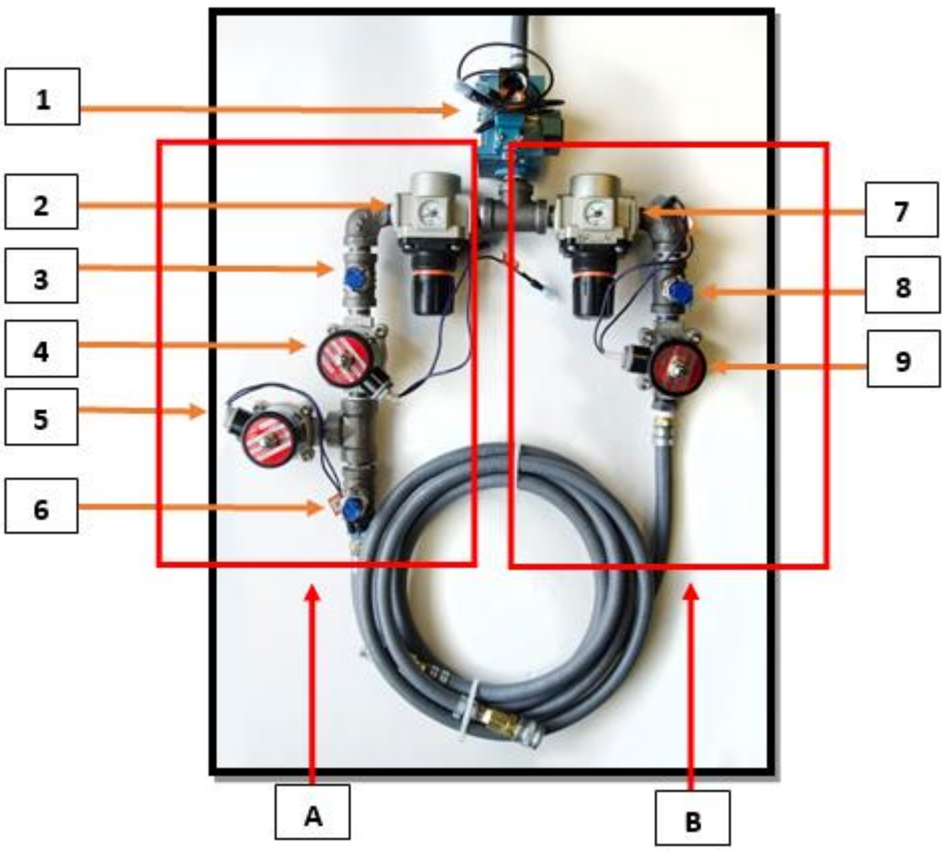


Figure 116: Airlines and Pneumatic Actuators of Control System

A. Air Mount Lines
B. Vibrator Lines
1. Overall Air Control Solenoid (Pressurizes Lines up to Component 4 & 9)
2. Air Mount Manual Pressure Regulator (Set to Max System Pressure Desired)

3. Air to Air Mount Pressure Sensor
4. Air to Air Mount Solenoid
5. Air Mount Blow Off Solenoid
6. Air Mount Pressure Sensor
7. Vibrator Manual Pressure Regulator (Set to Max System Pressure Desired)
8. Vibrator Pressure Sensor
9. Air to Vibrator Solenoid

17.2 Electronics Board

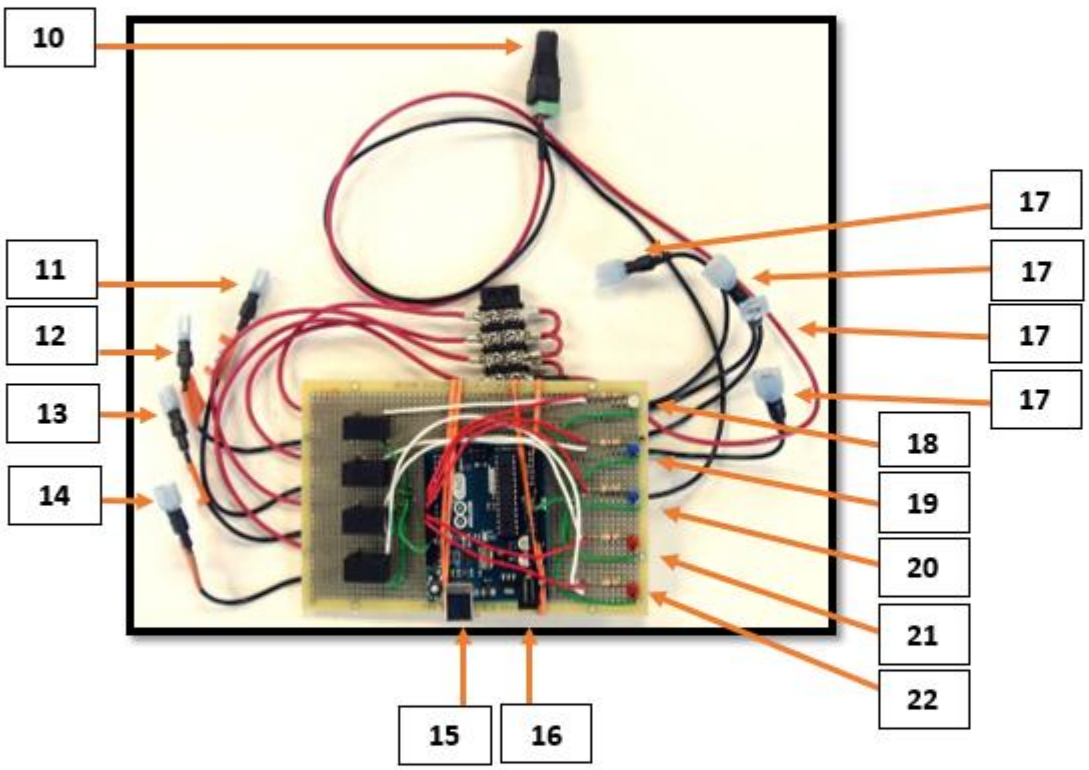


Figure 117: Control Board of User Interface

10. 12V Wall Connection
11. Component 9 Solenoid Control Connection
12. Component 1 Solenoid Control Connection
13. Component 4 Solenoid Control Connection

14. Component 5 Solenoid Control Connection
15. USB to Laptop Connection
16. 5V Wall Connection
17. Ground Connections for Solenoids (Does Not Matter Which One is Connected to What)
18. System Ready Indicator Light
19. Component 1 Solenoid Indicator Light (Indicates Solenoid is Open)
20. Component 9 Solenoid Indicator Light (Indicates Solenoid is Open)
21. Component 4 Solenoid Indicator Light (Indicates Solenoid is Open)
22. Component 5 Solenoid Indicator Light (Indicates Solenoid is Open)

17.3 System Start Up

In order to initiate the system, the user must ensure that that all connections to the electronics board and air system are properly connected. From here the user can launch the Arduino software and load the necessary program onto the Arduino being used. Program named "Capstone_Program_Arduino_Real". After loading the program exit the Arduino software.

Next the user must initiate the Visual Studio interface and load the Form necessary to control the system. Form named "Capstone Bin Controller Program". To initiate control over the system, click on the green start arrow at the top of the Visual Studio Window, and then the control form will pop up and allow the user to begin controlling the system.

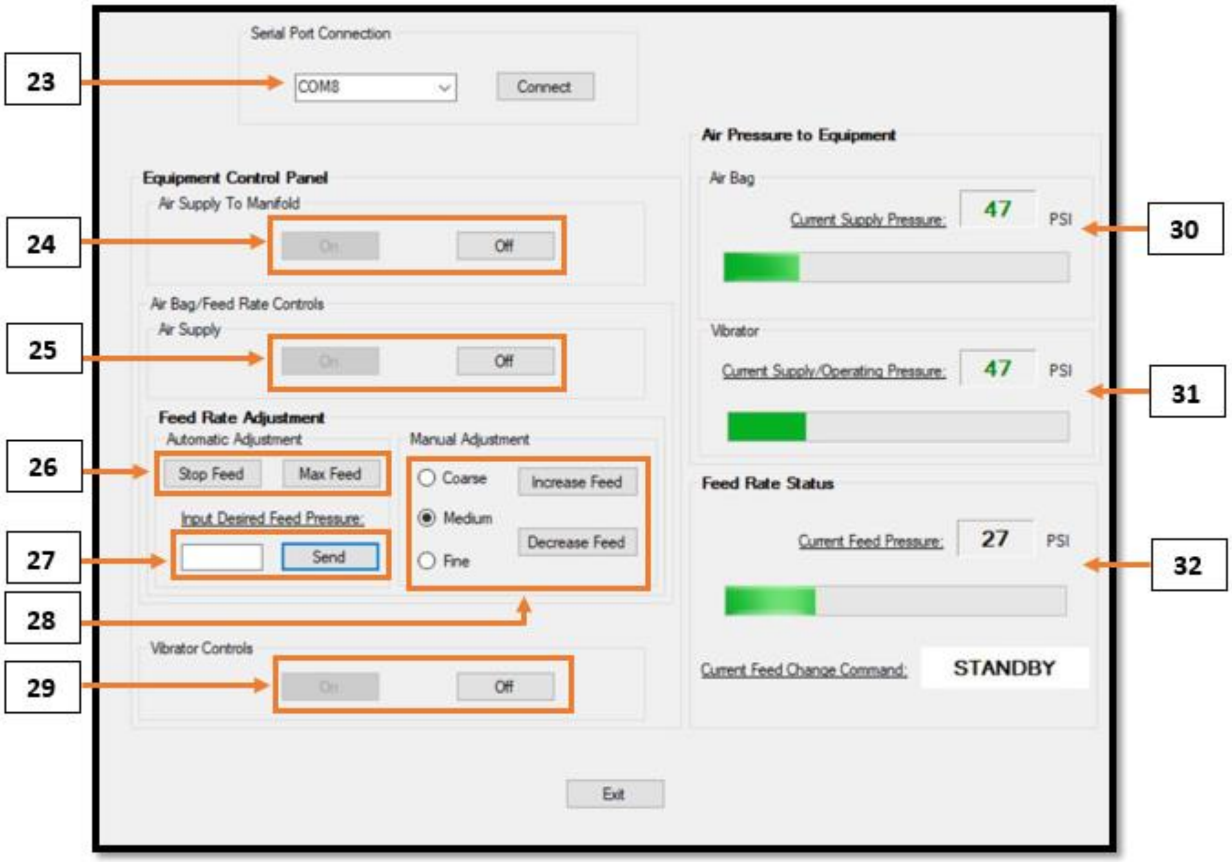


Figure 118: System Control Diagram

23. Comport Selection (Whichever Com Port that Component 15 is Connected to
24. Initiates System Operation (Will Light Component 18)
25. Initiates Component 1 Solenoid & Component 19 Will Light
26. "Stop Feed" Will Decrease Air Mount Pressure to about 0 PSI (Read on Component 30) This will continuously fire Component 5 Solenoid and Light Component 22. "Max Feed" Will Increase Air Mount Pressure to about the overall manual system pressure (Read on Component 30) This will continuously fire Component 4 Solenoid and Light Component 21
27. This will allow the user to either increase or decrease the Air Mount pressure to anything desired, indications will follow identical conventions as Component 26
28. This will allow the user to incrementally increase or decrease the Air Mount pressure. Just simply choose one of the adjustments and it will fire either Component 4 or 5 respectively.

29. Initiates Component 9 Solenoid & Component 20 Will Light
30. Will indicate real time pressure of the line feeding air to the Air Mount
31. Will Indicate the operating pressure of the vibrator

18 Maintenance

One consideration that needs to be accounted for in the maintenance of the system. The system will need to be assembled on site by the customer and installed in the bin but there should be no other hardware to keep track of for the system. The system as designed to have minimal maintenance and upkeep. The cone, frame, and lifting system will be built out of stainless steel, so corrosion is not seen to be an issue. A visual inspection of the cone and lifting system should be performed every time the bin is empty. This check should consist of looking for fatigue on any of the components as well as possible material build up on the cone. It will also be possible for the system to be taken out of the bin disassembled and cleaned if deemed necessary by the customer. This would be done if the bin was going to store a different material than it previously stored or material building up on the cone was seen to be dampening the vibrations. The lifting system and vibrator are both pneumatic which means that they will be using shop air to be powered. The air in the air in the vibrator cannot contaminate the material inside the bin, so air filters will need to be placed in the air compressor in order to filter out any harmful pathogens. These air filters will need to be changes regularly to prevent them from getting clogged and causing the air compressor to fail.

The user interface will also need maintenance in order to continue controlling the system. The interface uses software to control the Arduino boards using code. This software will need to be updated every so often to make sure that is running efficiently and at high speeds. Also if an app is created for the user to control the system, the app will need to updated accordingly.

19 Additional Considerations

19.1 Economic Impact

Bin silos are essential in the production process to help store bulk materials and then dispense them when needed. When material gets clogged or rat holes inside the bin, production is halted which thus results in lost profit and additional running costs for the company. Time is a very valuable and important aspect of production, with companies always looking to speed up their process. This system once fully implemented and developed would eliminate any clogging of material in the bin. This would allow companies to have efficient production with no hiccups along the way. With a more efficient production, it would either mean more profit for the companies using our system, or a trickledown effect of savings to the customers on products. Currently, there are some other bin vibration systems in the market that can be used for the same process, but these systems generally are very expensive to buy and require the company to modify their bin. Our system will be manufactured to be sold at an affordable price while not requiring any modifications to be made to the companies preexisting bin. This will result is saved expenses for the customer as well as a quicker installation time of the system, allowing the company to begin production quicker.

19.2 Environmental Impact

Eliminating the need to shut down production and unclog bins will result in less wasted tie for the company. This stop in production is a decrease in efficiency which will cause unneeded resources to be used. An increase in inefficiency will use more energy during the process and it is known that producing energy can be hazardous to the environment. If a company is able to reduce its energy consumption, it is reducing possible pollution to the environment. The system also has an environmental impact in the sense of disposing of the system once it has reached its lifespan. Even though our team has designed the system to be durable and reliable, there will come a time when it is too worn out to be used. This will mean that the system will need to be taken apart and disposed of. Most of the system is composed of stainless steel or plain steel, which can be recycles and reused. Other components such as the airmounts contain rubber, which will be have be disassembled and then the rubber can also be recycles. Additionally, electrical components in the user interface can be recycled at different facilities in the country. Being able to reuse and recycle as many components of the system as possible is important to keeping the impact on the environment to a minimum. If components cannot be recycled they will be placed in the landfill, where there is potential for pollution to many different aspects of the environment including drinking water and greenhouse gases.

19.3 Political Impact

VIBCO is a company that prides itself in using American companies in all aspects of their production and manufacturing and primarily focus on using companies in the New England area. The company is also involved in local and state affairs including its support with the University of Rhode Island and participation in legislation. The bin vibration system will go along nicely with VIBCO values because of the fact that most components have already been manufactured or bought through VIBCO's existing vendors. This will be a product that VIBCO can easy brand to be made entirely in the USA, which is a very important aspect to marketing to potential customers. It is also not only able to be manufactured and made in the USA but is also able to be sold to customers at a very affordable price compared to competitors.

19.4 Ethical Considerations

Ethics were not a priority of this project and system, but like any other product that is available for sale, it does affect the public. Safety for people around the system is the ethical portion of this project, while also helping improve the world for future generations. This system will not be directly controlled or touched by workers so there did not need to be a large factor of safety, but the team did still design the components of the product to have a factor of safety above 1. Additionally, the system is going to help improve and speed up production using bin silos which will aid in potential improvements in production for future generations.

19.5 Sustainability Considerations

The sustainability of this system ties directly into keeping the environmental impact of the product to a minimum. The system has been desired to be reliable and durable for the customer. The lifespan of the product is going be maximized by using very high quality materials to build the system. This includes stainless steel for the cone in order to keep it from corroding due to material in the bin. The vibrator is already tested and manufactured for durability by VIBCO, so this is a component the team believes will be very sustainable. The frame will be composed of high strength steel and the airmounts that make up the lifting system have already been tested by Firestone and are proven to be reliable. The user interface does have potential o short or become over used over time, but after extensive testing on it and the written code that controls it, it does not seem like the user interface will fail. The entire system is very simple, with minimal components, which will allow for any broken parts to be easily removed and fixed if there is any trouble in the system. The entire product has also been designed to have a factor of safety above 1, which also helps improve its sustainability over time.

20 Conclusions

While transferring vibration, the system also needed to be able to control the flow of that material exiting the bin. It was decided, the team would pursue a product that could be inserted into bin silos, with a conical design that could raise and lower with vibration being implemented in the upper cone fixture. The internal design was the best route, as VIBCO had already explored external methods with limited success. Research had also proven that a cone shaped design was the best method in vibrating material inside bins and allowing that material to exit.

The concept and design do meet the design specifications that were set at the beginning of the project. The design specifications are shown below.

Parameter	Target Value
Attachment Method	Must be attached on the inside or on the top of the bin
Vibration of Material	Transfer 1 lb of vibration per 10 lbs of material directly above cone
Strength	Must be able to support 3 tons
Lifting Capacity	Must be able to lift 3 tons
Safety	Must be FDA approved for food grade materials
Ease of Use	Must have simple easy-to-use controls
Adaptabilty	Must be able to be implimented in bins ranging in 2-6ft diameters

Table 10: Design Specifications

In this paper the concept design, design development, and prototype testing of a bin vibration system for VIBCO vibrators was presented. The system was designed to vibrate material within bin silos as well as control the flow of material coming out of the bin. The system was designed to have many components including a frame, a lifting system, a cone, a vibrator with a mount, and a control system to inflate the lifting system and turn on the vibrator. The majority of the system was built from basic steel, while the lifting system used Firestone airmounts to raise and lower, and vibrations were generated from a VIBCO manufactured vibrator. The speed of the vibrator as well as the height of the airmounts were both controlled through a user interface. The user interfaced used compressed air and check valves to inflate and deflate the airmounts depending on the height needed for a specific flow rate out of the bin. The interface additionally allowed the speed of vibrations to be variable based on the amount of air pressure fed into the vibrator. This was done to improve the systems efficiency in different bin silo material settings. The full system was designed to sit on top of existing bin silos, and extend 4 cables into the bin that would suspend the cone and vibrator within. This was foreseen as the best way to implement the system into existing bin due to installation time and cost. During the design of the system we faced many challenges, including redesigning our original concept as well as cost and time of manufacturing specific parts. It was decided that our original design was too complex and a new design did not need to be fully placed inside the bin. That is why the redesign was made to fit on the top of the bin. Manufacturing one cone was found to be very difficult and costly, so it was discussed to carry on with the build without the cone and if testing of the system went well then the approval to manufacture the cone would be given. The system that the team has developed is expected to be much cheaper than competitor products due to its simplicity and VIBCO's in-house manufacturing. Also, as the prototype is converted to an actual product, cost of materials and manufacturing is seen to decrease greatly. Several tests on the system were performed to confirm that the lifting system and vibrator were working correctly, as well as testing the strength of the frame and fitment of the system on the top of the bin.

21 Further Work

After the completion of the prototype, the team has set a plan and goals moving forward. The first steps are to finish all testing on the prototype including dry and wet testing. The system has been able to be tested attached to the bin but no material has been added to see how both the vibrator holds up as well as the lifting system. These tests will help collect data on the amount of vibration needed for different materials and different cone heights to give certain material flow out of the bin. This data will be compiled to give a sheet of possible materials that the system will encounter and then this data will be used to help customers control the system.

The team is continuing to try to find a manufacturer to build the cone to the designs we have created. We have been able to find manufacturers that can build the cone but not exactly to our designs and to a price that will make the cost of the system affordable. We are hoping to solve this problem by potentially redesigning the cone again with emphasis on manufacturing and the rice to build one cone verse multiple at a time will greatly influence the price. If systems are built in larger quantities the price of the cone will decrease to a price that is affordable for VIBCO.

More work will need to be done on the user interface to either have a control screen module to run the system or design and create an app that will have a Bluetooth connection to the user interface. This is essential is making it very easy for customers to begin using the system as well as being able to adjust the cone height and vibrations based on material in the bin. Data of different materials will eventually be able to be uploaded to the interface allowing the customer to have multiple options to controlling the lo out of the bin.

The team will also continue trying to improve efficiency of the system including reducing weight while not compromising strength. Reducing weight can be done by simply reducing the thickness of metal used in certain components or by selecting new high strength materials that are lightweight and corrosive resistant.

22 Acknowledgements

We would like to thank everyone who helped mentor and guide us during the course of this entire project. This includes our sponsor, VIBCO, will endless help and insight into vibrating material and giving us the resources for building and testing. Additionally, we would like to thank Dr. Nassersharif, for guiding our team through the process of concept generation, design, and testing of our prototype.

23 References

[1] Hassibi, Mohamad. Chemco System LP. *Material Flow Characteristics Within A Silo*, May 2015.

[2] Jofriet, J.C. *A Numerical Model for Flow of Granular Materials in Silos. Part 3: Parametric Study*. Journal of Agriculture Engineering Research, 18 Apr. 2002

[3] Kulinowski, *Piotr*. *Properties Bulk Solids.* Department of Mining, Dressing, and Transport Machines, Aug. 2005

[4] Tishkov, Ya., and E.G. Shevchuk. *Influence Exerted by the Design Parameters of Vibrating Feeder on Loose Material Discharge from Hopper.* Journal of Mining Science, 5 Nov. 2002.

[5] VIBCO Vibrators. *VIBCO Variable Speed Control*. N.p., N.d.Web. 10 Dec. 2016. *http://www.VIBCO.com/docs/flyers/spc-speed-controller-flyer.pdf*

[6] United States Patent and Trademark Office. *U.S. Patent 5,960,990* [Web] [Cited 20 October 2017.]

[7] United States Patent and Trademark Office. *U.S. Patent 4,062,527* [Web] [Cited 27 October 2017.]

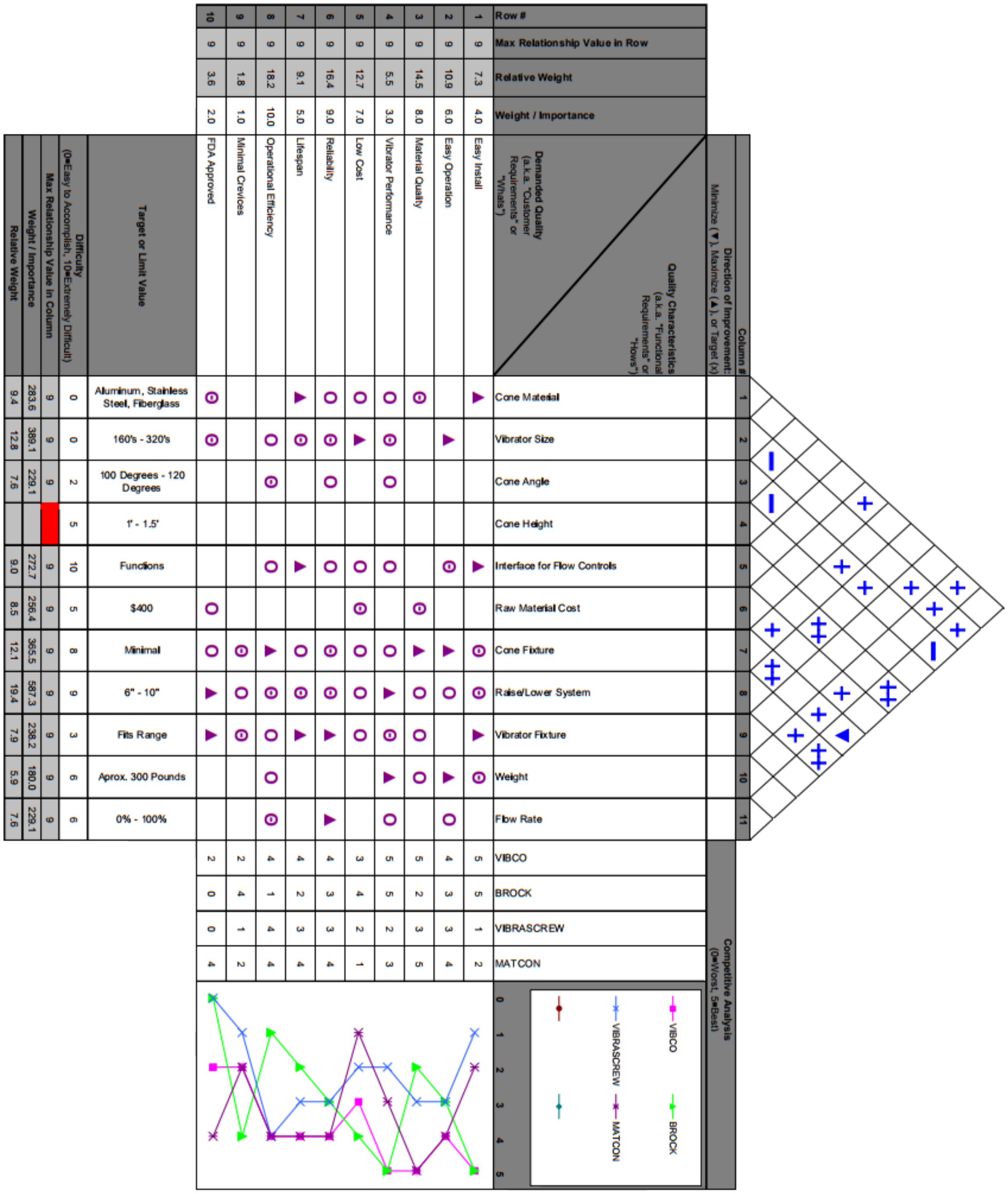
[8] United States Patent and Trademark Office. *U.S. Patent 6,311,438* [Web] [Cited 5 November 2017.]

[9] United States Patent and Trademark Office. *U.S. Patent 6,685,060* [Web] [Cited 13 November 2017.]

[10] Ltd, Matcon. *Cone Valve Technology*. The Cone Valve, June 2017, N.d. Web. http://www.matconibc.com/powder-handling-experts/the-cone-valve.

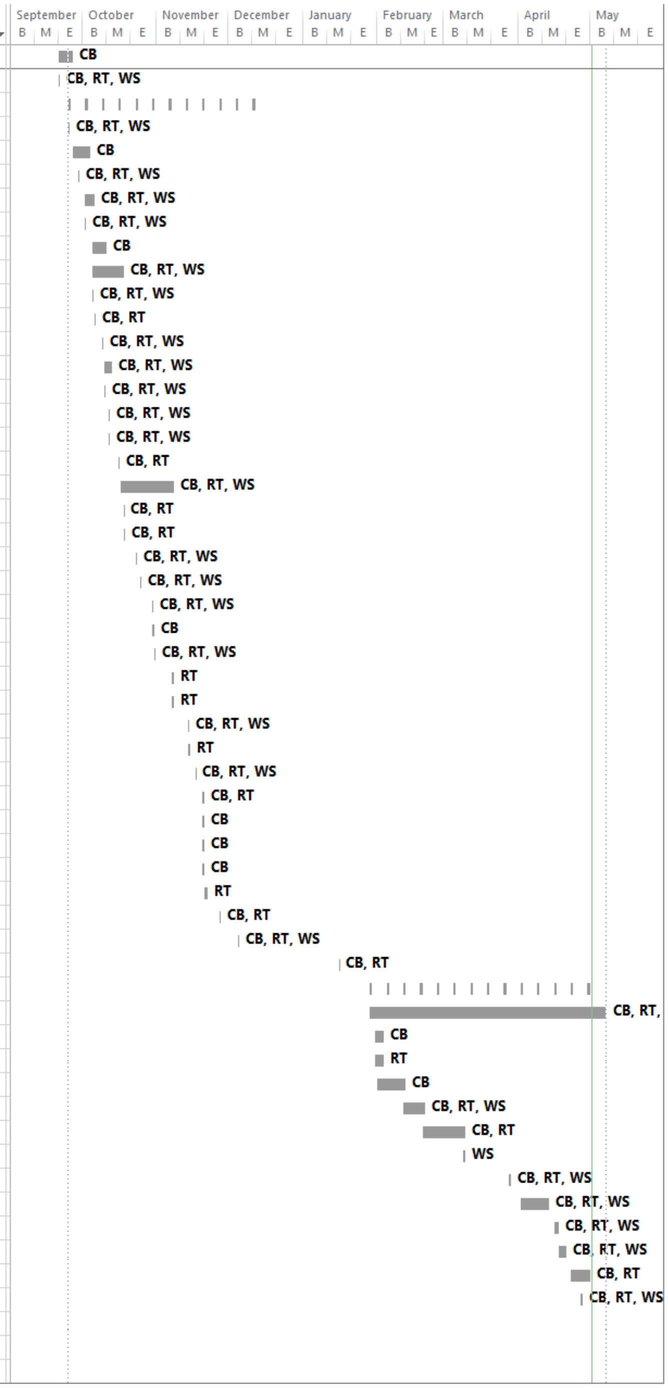
24 Appendices

A.1 QFD Chart

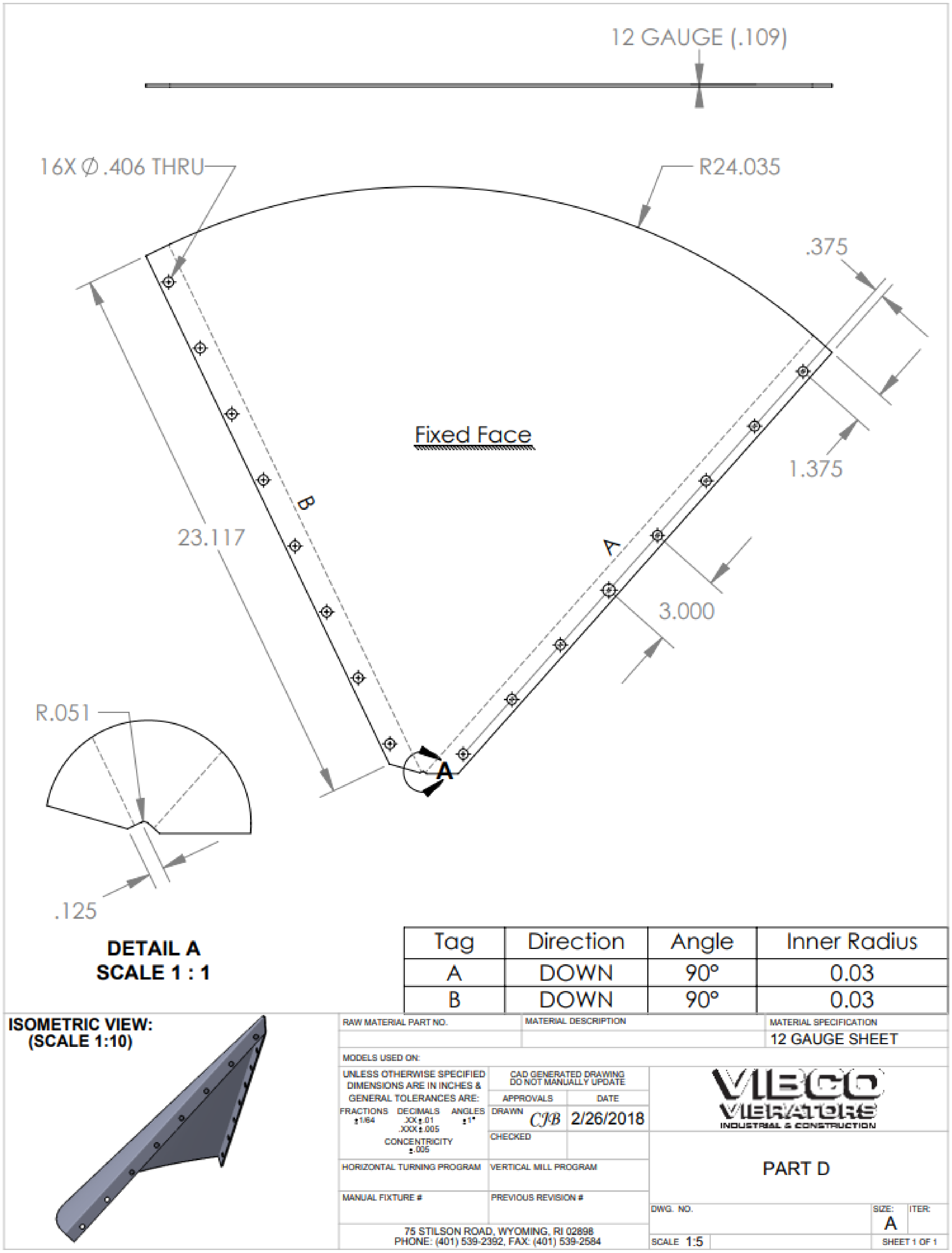


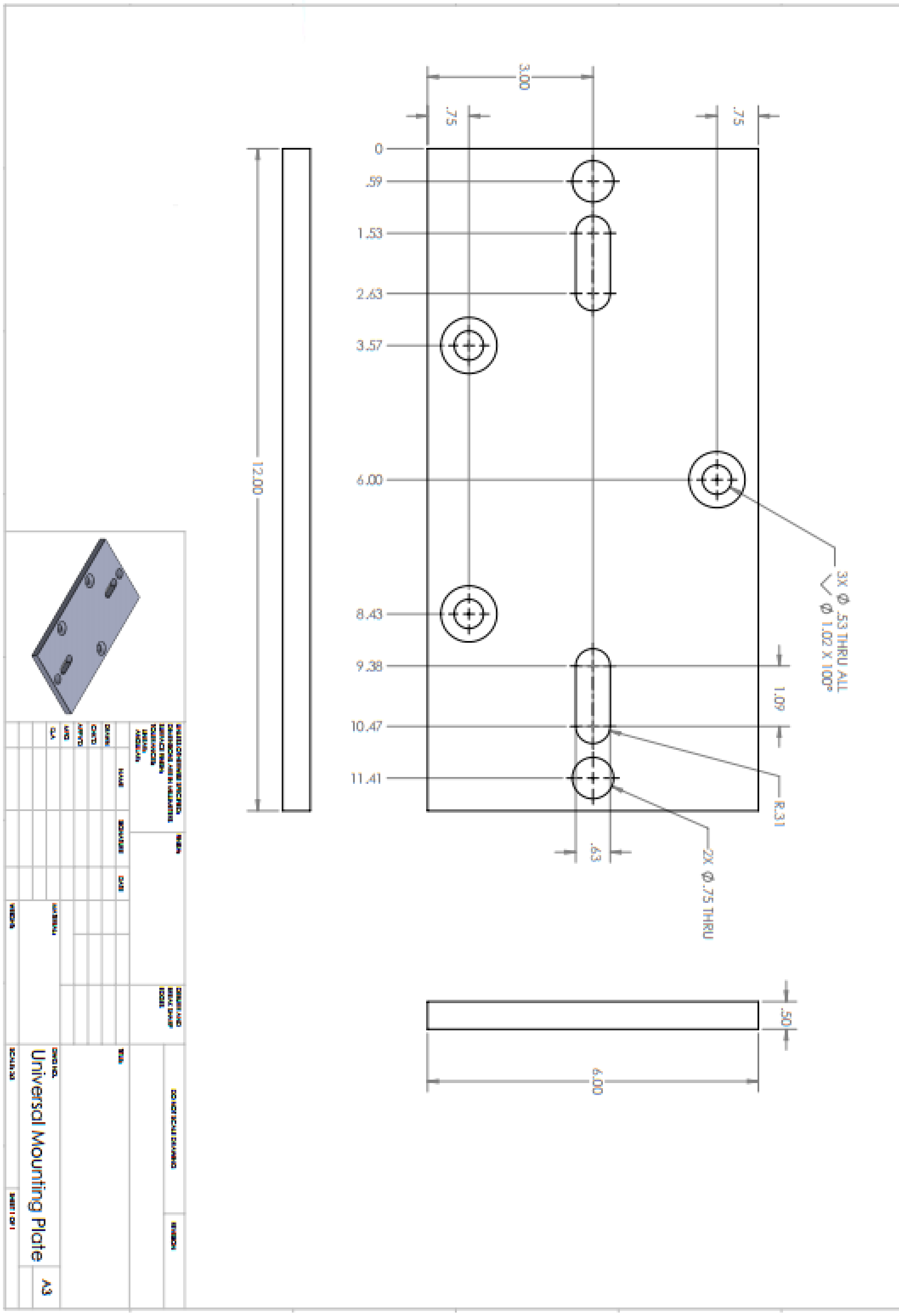
A.2 Detailed Project Plan

Task Name	Duration	Start	Finish
Initial Project Plan	4 days	Thu 9/21/17	Tue 9/26/17
Team Meeting 1	3 hrs	Thu 9/21/17	Thu 9/21/17
Fall Progress Reports	56 days	Mon 9/25/17	Mon 12/11/17
Team Meeting 2	1.5 hrs	Mon 9/25/17	Mon 9/25/17
Project Plan	5 days	Wed 9/27/17	Tue 10/3/17
VIBCO Meeting 1	2 hrs	Fri 9/29/17	Fri 9/29/17
Patent Search	4 days	Mon 10/2/17	Thu 10/5/17
Team Meeting 3	1.5 hrs	Mon 10/2/17	Mon 10/2/17
Project Plan	4 days	Thu 10/5/17	Tue 10/10/17
30 Concepts Due	9 days	Thu 10/5/17	Tue 10/17/17
Team Meeting 4	3 hrs	Thu 10/5/17	Thu 10/5/17
VIBCO Meeting 2	2 hrs	Fri 10/6/17	Fri 10/6/17
Team Meeting 5	2.25 hrs	Mon 10/9/17	Mon 10/9/17
Design Specifications	3 days	Tue 10/10/1	Thu 10/12/17
Team Meeting 6	4 hrs	Tue 10/10/1	Tue 10/10/17
REVIEW MEETING 1	20 mins	Thu 10/12/1	Thu 10/12/17
Team Meeting 7	2.5 hrs	Thu 10/12/1	Thu 10/12/17
Team Meeting 8	4.5 hrs	Mon 10/16/1	Mon 10/16/17
Updated Design Specifications	16 days	Tue 10/17/1	Tue 11/7/17
Team Meeting 9	2.25 hrs	Wed 10/18/1	Wed 10/18/17
QFD	4 hrs	Wed 10/18/1	Wed 10/18/17
Team Meeting 10	3 hrs	Mon 10/23/1	Mon 10/23/17
Team Meeting 11	2.5 hrs	Wed 10/25/1	Wed 10/25/17
Team Meeting 12	1.25 hrs	Mon 10/30/1	Mon 10/30/17
SW - Cone	1 day	Mon 10/30/1	Mon 10/30/17
Presentation 1: Critical Design Review	4 hrs	Tue 10/31/1	Tue 10/31/17
SW - Upper Mounting Legs	1 day	Tue 11/7/17	Tue 11/7/17
SW - Upper/Lower Mounting Plates	1 day	Tue 11/7/17	Tue 11/7/17
Review MEETING 2	20 mins	Tue 11/14/1	Tue 11/14/17
SW - Lower Legs	1 day	Tue 11/14/1	Tue 11/14/17
VIBCO Meeting 3	1.5 hrs	Fri 11/17/17	Fri 11/17/17
Team Meeting 13	7 hrs	Mon 11/20/1	Mon 11/20/17
SW - Top Bracket	1 day	Mon 11/20/1	Mon 11/20/17
SW - Universal Mounting Plate	1 day	Mon 11/20/1	Mon 11/20/17
SW - Channel for Bracket	1 day	Mon 11/20/1	Mon 11/20/17
SW - Outer Ring Harness	1 day	Tue 11/21/1	Tue 11/21/17
Team Meeting 14	3 hrs	Mon 11/27/1	Mon 11/27/17
Presentation 2: Proof of Concept	4 hrs	Tue 12/5/17	Tue 12/5/17
VIBCO Meeting 4	2 hrs	Tue 1/16/18	Tue 1/16/18
Spring Progress Reports	66 days	Mon 1/29/18	Mon 4/30/18
Final Report Due	71 days	Mon 1/29/18	Mon 5/7/18
SW - Cone/Vibrator Mount	4 days	Wed 1/31/18	Sat 2/3/18
SW - Bin Fixture/Supports	4 days	Wed 1/31/18	Sat 2/3/18
Drawings for All Components	8 days	Thu 2/1/18	Mon 2/12/18
Quotes Requested	7 days	Mon 2/12/18	Tue 2/20/18
Parts Ordered	14 days	Tue 2/20/18	Fri 3/9/18
Misc. Components Ordered	1 day	Fri 3/9/18	Fri 3/9/18
Presentation 3: Build and Test	1 day	Wed 3/28/18	Wed 3/28/18
Build	10 days	Mon 4/2/18	Fri 4/13/18
Test	2 days	Mon 4/16/18	Tue 4/17/18
Refinement	3 days	Wed 4/18/18	Fri 4/20/18
Final Test	6 days	Mon 4/23/18	Mon 4/30/18
Design Showcase	1 day	Fri 4/27/18	Fri 4/27/18
Meeting with ERW		TBD	
VIBCO Meeting 5		TBD	
VIBCO Meeting 6		TBD	

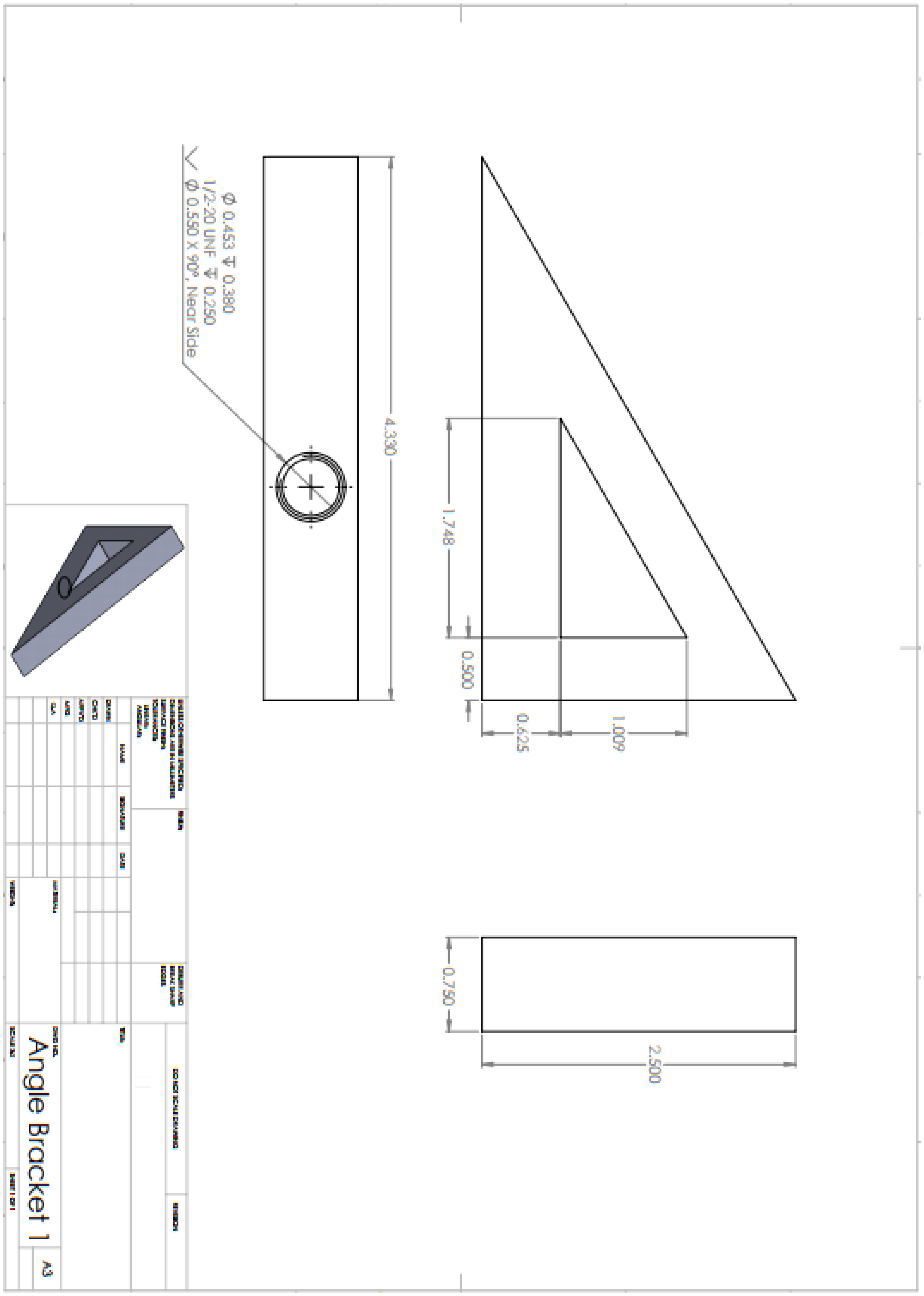


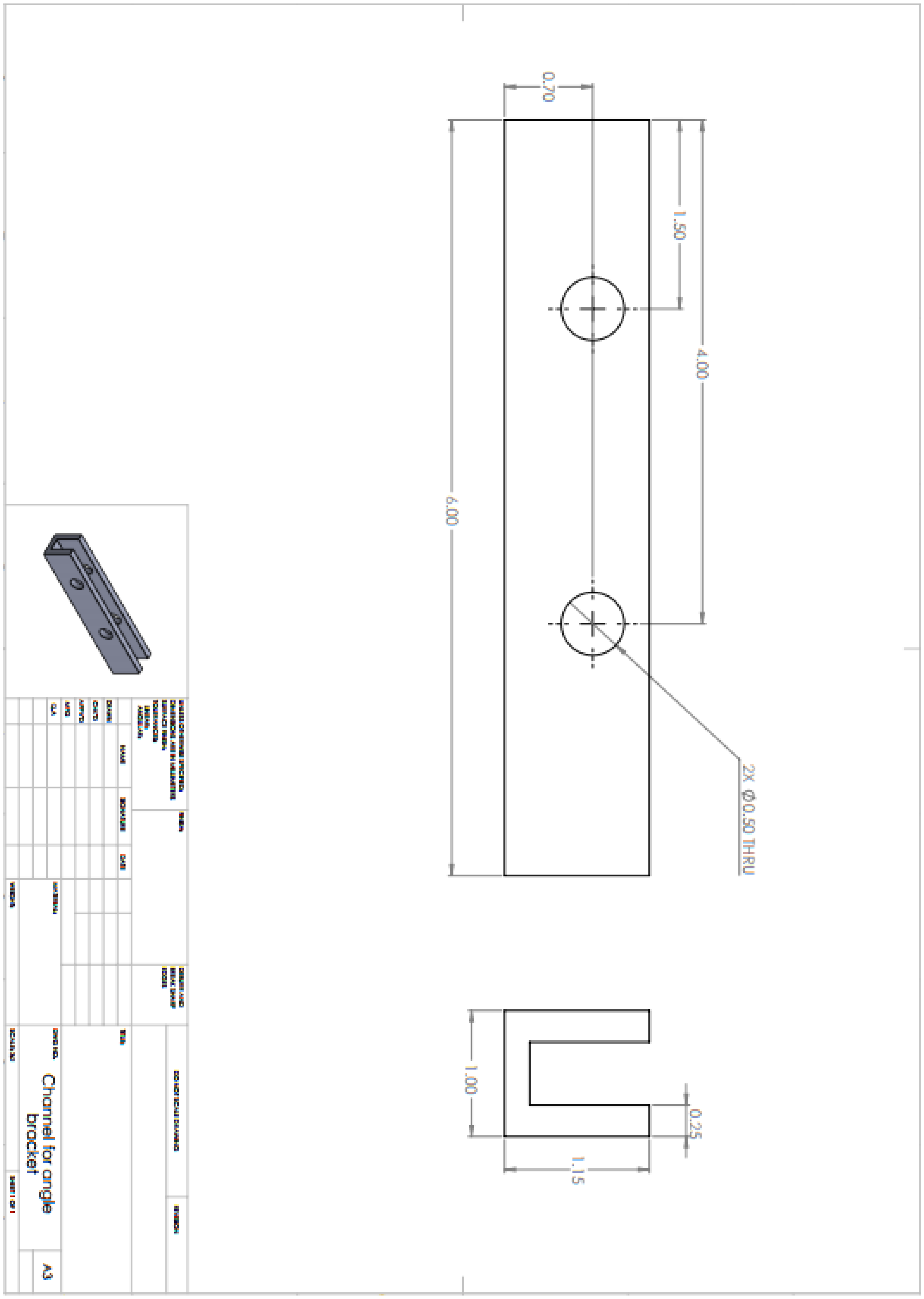
A.3 Part Drawings

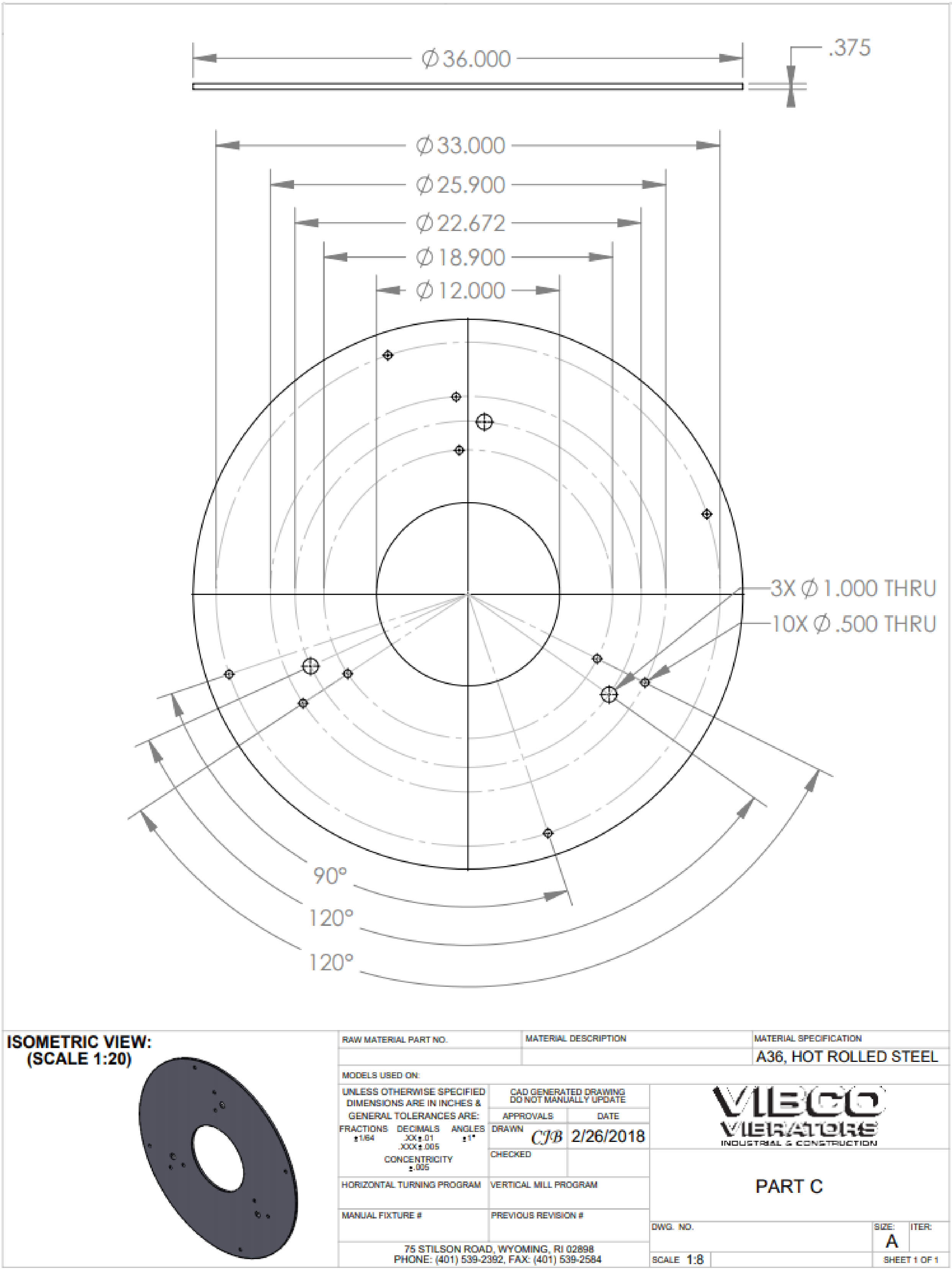




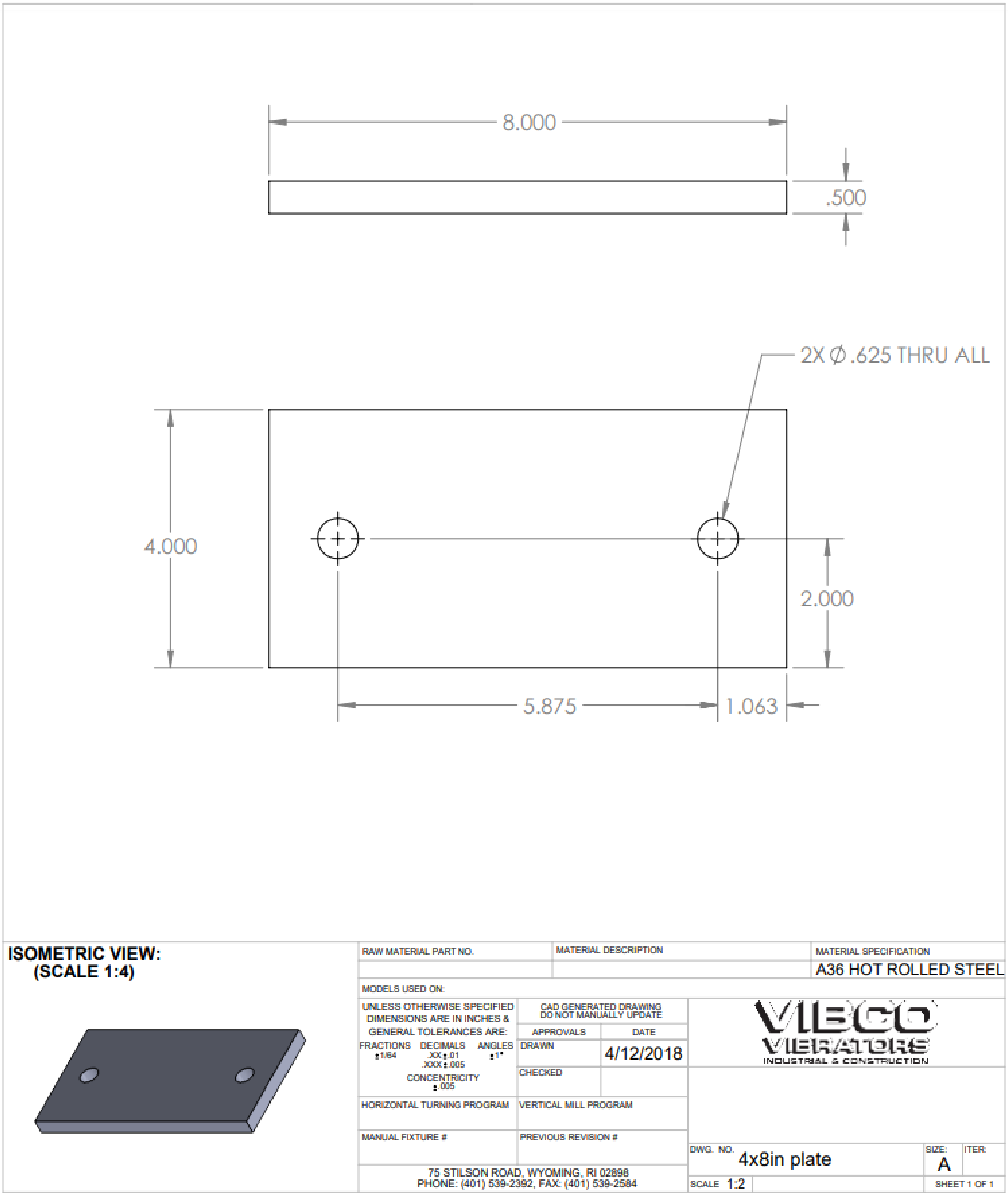
Universal Mounting Plate
A3
3.00
.75
.75
0
.59
1.53
2.63
3.57
6.00
8.43
9.38
10.47
11.41
12.00
3X Ø .53 THRU ALL
Ø 1.02 X 100°
1.09
R.31
.63
2X Ø.75 THRU
.50
6.00

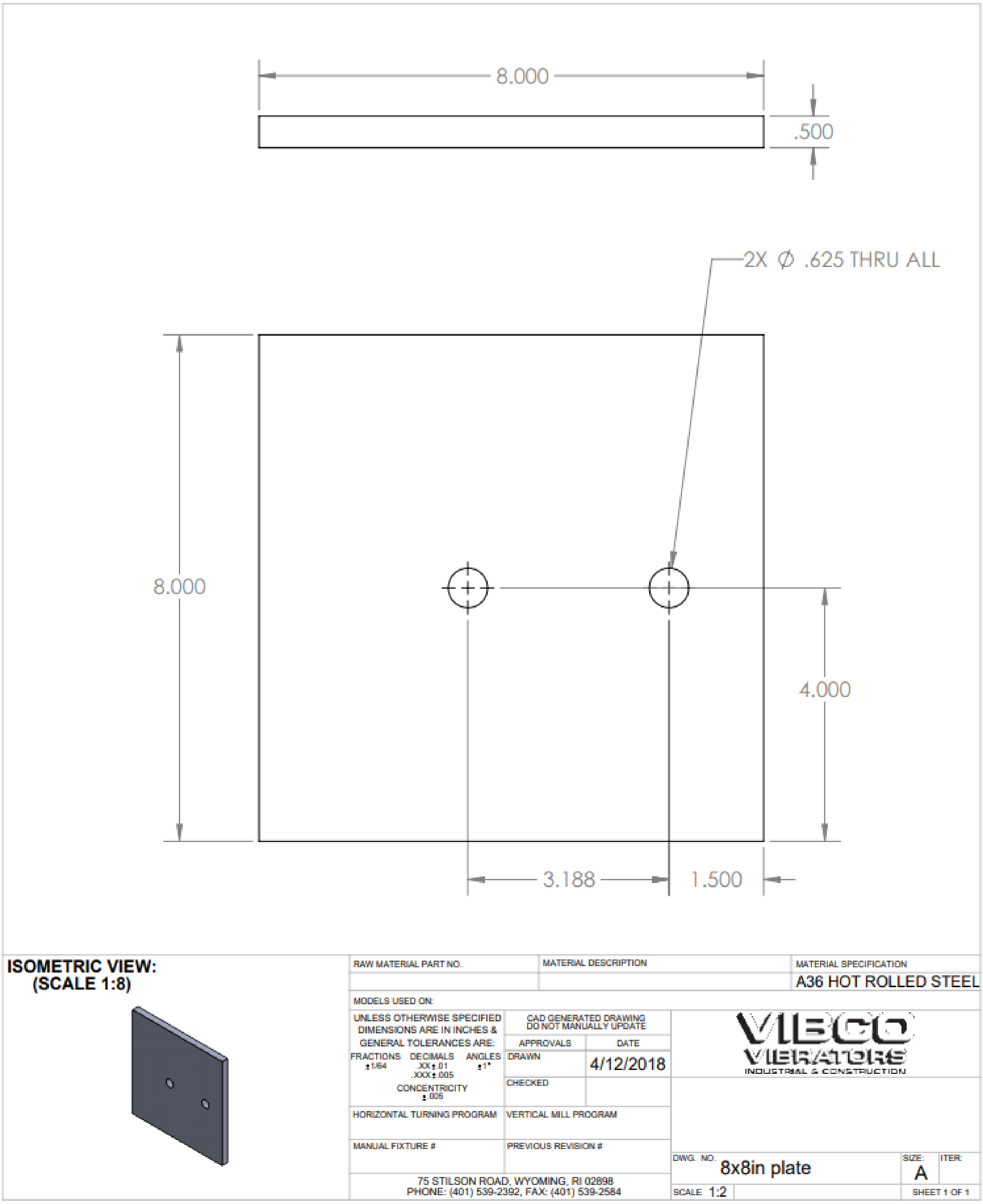

Ø 0.453 ↧ 0.380
1/2-20 UNF ↧ 0.250
Ø 0.550 X 90°, Near Side
4.330
1.748
0.500
0.625
1.009
0.750
2.500
Angle Bracket 1
A3

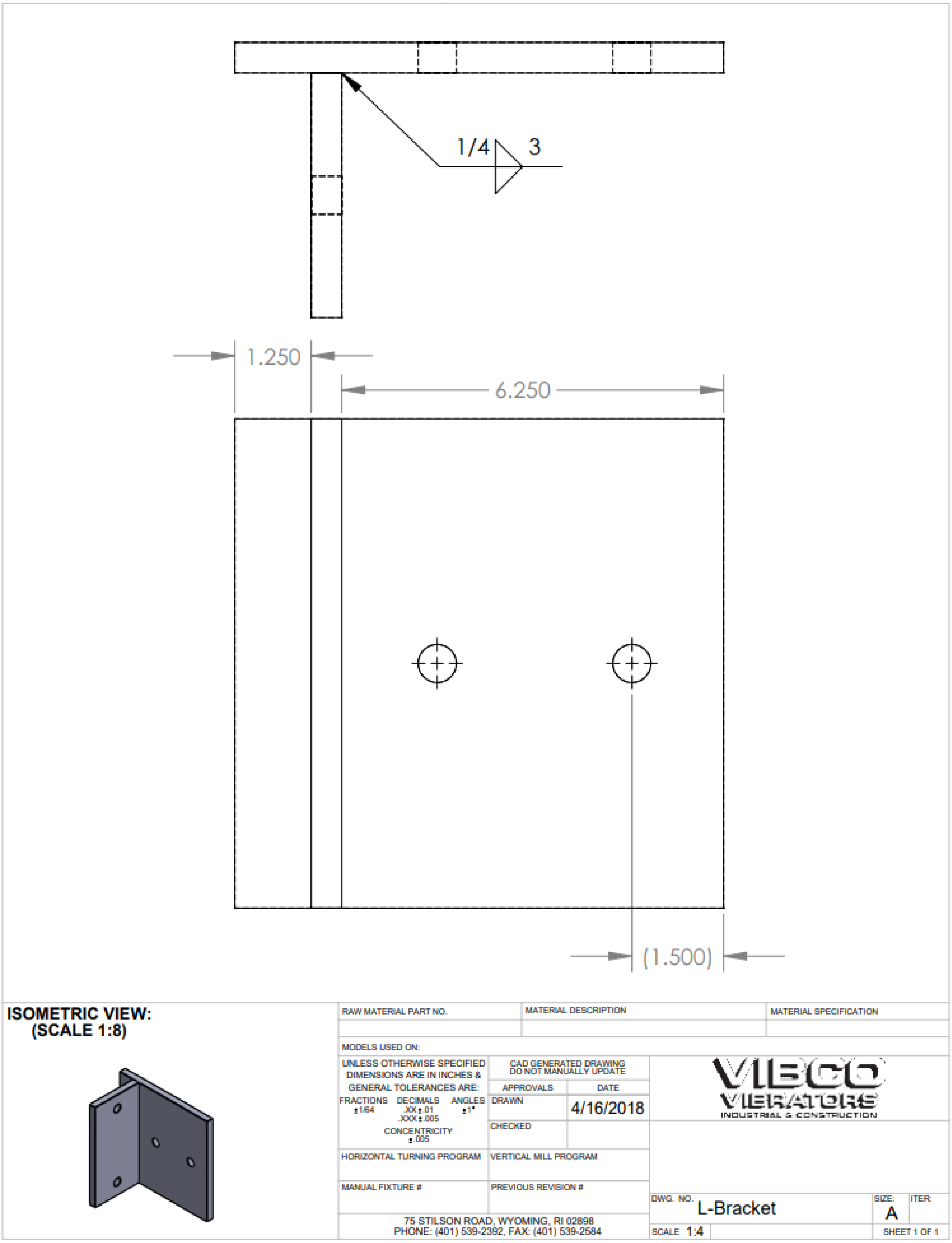

0.70
1.50
4.00
6.00
2X Ø0.50 THRU
1.00
0.25
1.15
Channel for angle bracket
A3



Ø36.000
.375
Ø33.000
Ø25.900
Ø22.672
Ø18.900
Ø12.000
3X Ø1.000 THRU
10X Ø.500 THRU
90°
120°
120°
ISOMETRIC VIEW:
(SCALE 1:20)
RAW MATERIAL PART NO.
MATERIAL DESCRIPTION
MATERIAL SPECIFICATION
A36, HOT ROLLED STEEL
MODELS USED ON:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES & GENERAL TOLERANCES ARE:
FRACTIONS ±1/64
DECIMALS .XX±.01 .XXX±.005
ANGLES ±1°
CONCENTRICITY ±.005
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
CJB
2/26/2018
CHECKED
VIBCO
VIBRATORS
INDUSTRIAL & CONSTRUCTION
HORIZONTAL TURNING PROGRAM
VERTICAL MILL PROGRAM
PART C
MANUAL FIXTURE #
PREVIOUS REVISION #
DWG. NO.
SIZE:
A
ITER:
75 STILSON ROAD, WYOMING, RI 02898
PHONE: (401) 539-2392, FAX: (401) 539-2584
SCALE 1:8
SHEET 1 OF 1


8.000
.500
2X ∅ .625 THRU ALL
4.000
2.000
5.875
1.063
ISOMETRIC VIEW:
(SCALE 1:4)
RAW MATERIAL PART NO.
MATERIAL DESCRIPTION
MATERIAL SPECIFICATION
A36 HOT ROLLED STEEL
MODELS USED ON:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES & GENERAL TOLERANCES ARE:
FRACTIONS ±1/64
DECIMALS .XX ±.01 .XXX ±.005
ANGLES ±1°
CONCENTRICITY ±.005
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
4/12/2018
CHECKED
VIBCO
VIBRATORS
INDUSTRIAL & CONSTRUCTION
HORIZONTAL TURNING PROGRAM
VERTICAL MILL PROGRAM
MANUAL FIXTURE #
PREVIOUS REVISION #
DWG. NO.
4x8in plate
SIZE:
A
ITER:
75 STILSON ROAD, WYOMING, RI 02898
PHONE: (401) 539-2392, FAX: (401) 539-2584
SCALE 1:2
SHEET 1 OF 1


8.000
.500
2X ∅ .625 THRU ALL
8.000
4.000
3.188
1.500
ISOMETRIC VIEW:
(SCALE 1:8)
RAW MATERIAL PART NO.
MATERIAL DESCRIPTION
MATERIAL SPECIFICATION
A36 HOT ROLLED STEEL
MODELS USED ON:
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES &
GENERAL TOLERANCES ARE:
FRACTIONS ±1/64
DECIMALS .XX ±.01 .XXX ±.005
ANGLES ±1°
CONCENTRICITY ±.005
CAD GENERATED DRAWING
DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
4/12/2018
CHECKED
VIBCO
VIBRATORS
INDUSTRIAL & CONSTRUCTION
HORIZONTAL TURNING PROGRAM
VERTICAL MILL PROGRAM
MANUAL FIXTURE #
PREVIOUS REVISION #
DWG. NO.
8x8in plate
SIZE:
A
ITER:
75 STILSON ROAD, WYOMING, RI 02898
PHONE: (401) 539-2392, FAX: (401) 539-2584
SCALE 1:2
SHEET 1 OF 1


1/4
3
1.250
6.250
(1.500)
ISOMETRIC VIEW:
(SCALE 1:8)
RAW MATERIAL PART NO.
MATERIAL DESCRIPTION
MATERIAL SPECIFICATION
MODELS USED ON:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES & GENERAL TOLERANCES ARE:
FRACTIONS ±1/64
DECIMALS .XX ±.01 .XXX ±.005
ANGLES ±1°
CONCENTRICITY ±.005
CAD GENERATED DRAWING DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
4/16/2018
CHECKED
VIBCO VIBRATORS
INDUSTRIAL & CONSTRUCTION
HORIZONTAL TURNING PROGRAM
VERTICAL MILL PROGRAM
MANUAL FIXTURE #
PREVIOUS REVISION #
75 STILSON ROAD, WYOMING, RI 02898
PHONE: (401) 539-2392, FAX: (401) 539-2584
DWG. NO. L-Bracket
SIZE: A
ITER:
SCALE 1:4
SHEET 1 OF 1

A.4 Arduino Code

```
// define properties of air pressure sensors for mapping raw output to pressure
int bagpressminRAW = 0, bagpressmaxRAW = 1023, bagpressminACT = 0, bagpressmaxACT
= 200;
int vibepressminRAW = 0, vibepressmaxRAW = 1023, vibepressminACT = 0,
vibepressmaxACT = 200;
int bagpositionminRAW = 0, bagpositionmaxRAW = 1023, bagpositionminACT = 0,
bagpositionmaxACT = 100;

int y;

void setup() {
  // put your setup code here, to run once:
  pinMode(10, OUTPUT); //Deflate air bag/decrease feed rate
  pinMode(9, OUTPUT); //Inflate air bag/increase feed rate
  pinMode(6, OUTPUT); //Manifold air switch on/off light
  pinMode(8, OUTPUT); //Bag air switch on/off light
  pinMode(7, OUTPUT); //Vibrator air switch on/off light
  Serial.begin (115200); //start data connection with computer

}

void loop() {
  //int a = analogRead(A2);  //uncomment this line and the next in order to calibrate to each
potentiometer. analog read either A1 or A0 depending on what potentiometer you are doing.
  //Serial.println(a);       //once you have the max and min values read from each potentiometer,
use them to update the respective "bagpressminRAW", "bagpressmaxRAW",
"vibepressminRAW" and "vibepressmaxRAW" properties declared at the beginning of the code.
  int message;
  int x;
  //  int y;
```

```
if (Serial.available()) {
  delay(100);
  while (Serial.available() > 0) {
    message = Serial.read();   //reads the value sent from Visual Basic

    switch (message) {
      case 'M'://turn air to manifold ON
        digitalWrite(6, HIGH);
        break;
      case 'm'://turn air to manifold OFF
        digitalWrite(6, LOW);
        break;
      case 'B'://turn air to bag ON
        digitalWrite(8, HIGH);
        break;
      case 'b'://turn air to bag OFF
        digitalWrite(8, LOW);
        break;
      case 'V'://turn air to vibrator ON
        digitalWrite(7, HIGH);
        break;
      case 'v'://turn air to vibrator OFF
        digitalWrite(7, LOW);
        break;
      case 'P'://report air bag regulator pressure to VB interface
        ReadBagRegulatorPressure();
        break;
      case 'p'://report vibrator regulator pressure to VB interface
        ReadVibeRegulatorPressure();
        break;
      case 'S'://report fill status (position) of air bag to VB interface
```

```
  ReadBagPosition();
  break;
case 'F': //increase feed rate/inflate air bag
  delay(10);
  x = Serial.read();
  switch (x) {
    case 'X':
      y = 100;
      IncreaseFeed();
      break;
    case 'Y':
      y = 20;
      IncreaseFeed();
      break;
    case 'Z':
      y = 5;
      IncreaseFeed();
      break;
  }
  break;

case 'f': //decrease feed rate/deflate air bag
  delay(10);
  x = Serial.read();
  switch (x) {
    case 'X':
      y = 3000;
      DecreaseFeed();
      break;
    case 'Y':
      y = 1500;
```

```
          DecreaseFeed();
          break;
         case 'Z':
          y = 200;
          DecreaseFeed();
          break;
        }
        break;
      }
    }
  }
}

void ReadBagRegulatorPressure()
{
  int bagpressregreading = analogRead(A0);
  bagpressregreading = map(bagpressregreading, bagpressminRAW, bagpressmaxRAW, 
bagpressminACT, bagpressmaxACT); //map raw analog data from air bag regulator pressure 
sensor to actual PSI value
  Serial.println(bagpressregreading);
}

void ReadVibeRegulatorPressure()
{
  int vibepressregreading = analogRead(A1);
  vibepressregreading = map(vibepressregreading, vibepressminRAW, vibepressmaxRAW, 
vibepressminACT, vibepressmaxACT); //map raw analog data from vibrator regulator pressure 
sensor to actual PSI value
  Serial.println(vibepressregreading);
}
```

```
void ReadBagPosition()
{
  int bagpositionreading = analogRead(A2);
  bagpositionreading = map(bagpositionreading, bagpositionminRAW, bagpositionmaxRAW,
bagpositionminACT, bagpositionmaxACT);
  Serial.println(bagpositionreading);
}

void IncreaseFeed()
{
  digitalWrite(9, HIGH); //open valve to let air into bag for x amount of time before closing valve
again
  delay(y);
  digitalWrite(9, LOW);
  Serial.println(1);
}

void DecreaseFeed()
{
  digitalWrite(10, HIGH); //open valve to release air from bag for x amount of time before
closing valve again
  delay(y);
  digitalWrite(10, LOW);
  Serial.println(1);
}
```

A.5 Visual Basic Code

```
Imports System.IO.Ports
Imports System.IO
Imports System.Threading

Public Class Form1
    Public serprt As New SerialPort
    Public serprtname As String
    'Public Rnumber As Integer
    Public Rstring As String
    Public Sstring As String
    Public State%
    Public NextState%
    Public porttraffic As Boolean
    Public feedchange As Boolean
    Public feedincrease As Boolean
    Public feeddecrease As Boolean
    Public BagON As Boolean
    Public VibeON As Boolean
    Public Rint1 As Integer
    Public Rint2 As Integer
    Public Rint3 As Integer
    Public FeedDelay As Integer

    Private Sub Form1_Load(sender As Object, e As EventArgs) Handles MyBase.Load
        EquipmentControlGroup.Enabled = False
        EquipmentIndicationGroup.Enabled = False
        FeedRateStatusGroup.Enabled = False
        BagON = False
        VibeON = False
        Timer1.Interval = 400 'update manifold pressure readings every 300ms
```

```
        'set parameters for serial connection with Arduino Uno
        serprt.BaudRate = 115200
        serprt.DataBits = 8
        serprt.Parity = Parity.None
        serprt.StopBits = StopBits.One
        serprt.Handshake = Handshake.None
        serprt.Encoding = System.Text.Encoding.ASCII
    End Sub

    Private Sub ExitBut_Click(sender As Object, e As EventArgs)
        If (ManifoldOn.Enabled = False And EquipmentControlGroup.Enabled = True) Then
            MsgBox("Please shut off air manifold before closing application!")
            GoTo 10
        End If
        serprtname = PortBox.Text
        If serprtname = "" Then
            Me.Close()
        Else
            serprt.Close()
            Me.Close()
            End
        End If
10:
    End Sub

    Private Sub SerialConnectBut_Click(sender As Object, e As EventArgs) Handles
SerialConnectBut.Click
        serprtname = PortBox.Text
        If serprtname = "" Then
            MsgBox("Please select a serial port.")
```

```
        Else
            serprt.PortName = serprtname
            serprt.Open()
        End If

        EquipmentControlGroup.Enabled = True
        ManifoldOff.Enabled = False
        BagControlGroup.Enabled = False
        VibeControlGroup.Enabled = False

        Do While (2 > 1) 'take constant pressure readings while mainfold is pressurized
            Application.DoEvents()
            Call SequenceTask()
        Loop

    End Sub

    Private Sub UpdateSerPortList()
        Dim serprtname As String = Nothing
        Dim x As String
        PortBox.Items.Clear()
        For Each x In IO.Ports.SerialPort.GetPortNames()
            PortBox.Items.Add(x)
        Next x
    End Sub

    Private Sub PortBox_SelectedIndexChanged(sender As Object, e As EventArgs) Handles
PortBox.DropDown
        UpdateSerPortList()
    End Sub
```

```
    Private Sub ManifoldOn_Click(sender As Object, e As EventArgs) Handles
ManifoldOn.Click
        NextState = 1
    End Sub

    Private Sub ManifoldOff_Click(sender As Object, e As EventArgs) Handles
ManifoldOff.Click
        NextState = 2
    End Sub

    Private Sub BagAirOn_Click(sender As Object, e As EventArgs) Handles BagAirOn.Click
        NextState = 3
    End Sub

    Private Sub BagAirOff_Click(sender As Object, e As EventArgs) Handles BagAirOff.Click
        NextState = 4
    End Sub

    Private Sub VibeOn_Click(sender As Object, e As EventArgs) Handles VibeAirOn.Click
        NextState = 5
    End Sub

    Private Sub VibeOff_Click(sender As Object, e As EventArgs) Handles VibeAirOff.Click
        NextState = 6
    End Sub
    Private Sub IncreaseFeed_Click(sender As Object, e As EventArgs) Handles
IncreaseFeed.Click
        If VibeAirOn.Enabled = True Then
            MsgBox("Vibrator must be running to adjust feed rate!")
            GoTo 10
        End If
```

```
        NextState = 8
10:
    End Sub

    Private Sub DecreaseFeed_Click(sender As Object, e As EventArgs) Handles
DecreaseFeed.Click
        If VibeAirOn.Enabled = True Then
            MsgBox("Vibrator must be running to adjust feed rate!")
            GoTo 20
        End If
        NextState = 9
20:
    End Sub

    Private Sub MaximizeFeed_Click(sender As Object, e As EventArgs) Handles
MaximizeFeed.Click

    End Sub

    Public Sub SequenceTask()
        State% = NextState%

        Select Case State%
            Case 1 'Air manifold commanded ON
1:
                If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                    GoTo 1
                Else porttraffic = True
                End If
                ManifoldOn.Enabled = False
```

```
            ManifoldOff.Enabled = True
            Sstring = "M"
            Call SendArduinoCommand()
            BagControlGroup.Enabled = True
            BagFeedGroup.Enabled = False
            BagAirOff.Enabled = False
            VibeControlGroup.Enabled = True
            VibeAirOff.Enabled = False
            EquipmentIndicationGroup.Enabled = True
            porttraffic = False
            If Timer1.Enabled = False Then
                Timer1.Enabled = True
            End If
            NextState = 0

        Case 2 ' Air manifold commanded OFF
2:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 2
            Else porttraffic = True
            End If
            ManifoldOn.Enabled = True
            ManifoldOff.Enabled = False
            If BagON = True Then
                Sstring = "b"
                Call SendArduinoCommand()
                BagON = False
                BagAirOn.Enabled = True
            End If
            If VibeON = True Then
```

```
            Sstring = "v"
            Call SendArduinoCommand()
            VibeON = False
            VibeAirOn.Enabled = True
        End If
        Sstring = "m"
        Call SendArduinoCommand()
        BagControlGroup.Enabled = False
        VibeControlGroup.Enabled = False
        porttraffic = False
        Timer1.Enabled = False
        NextState = 0

    Case 3 'Air bag supply commanded ON
3:
        If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
            GoTo 3
        Else porttraffic = True
        End If
        BagAirOn.Enabled = False
        BagAirOff.Enabled = True
        BagFeedGroup.Enabled = True
        FeedRateStatusGroup.Enabled = True
        FeedCMDStatus.Text = "STANDBY"
        MediumAdjust.Checked = True
        Sstring = "B"
        Call SendArduinoCommand()
        BagON = True
        porttraffic = False
        NextState = 0
```

```
        Case 4 'Air bag supply commanded OFF
4:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 4
            Else porttraffic = True
            End If
            BagAirOn.Enabled = True
            BagAirOff.Enabled = False
            BagFeedGroup.Enabled = False
            FeedRateStatusGroup.Enabled = False
            Sstring = "b"
            Call SendArduinoCommand()
            BagON = False
            porttraffic = False
            NextState = 0

        Case 5 'Vibrator supply commanded ON
5:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 5
            Else porttraffic = True ' set to true to declare data transfer is ocurring and port not
available.
            End If
            VibeAirOn.Enabled = False
            VibeAirOff.Enabled = True
            Sstring = "V"
            Call SendArduinoCommand()
            VibeON = True
```

```
            porttraffic = False
            NextState = 0

        Case 6 'Vibrator Supply commanded OFF
6:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 6
            Else porttraffic = True
            End If
            VibeAirOn.Enabled = True
            VibeAirOff.Enabled = False
            Sstring = "v"
            Call SendArduinoCommand()
            VibeON = False
            porttraffic = False
            NextState = 0

        Case 7 'Take equipment supply pressure readings and feed rate percentage
7:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 7
            Else porttraffic = True
            End If
            Sstring = "P" 'string to request air bag reguator pressure
            Call SendArduinoCommand()
            System.Threading.Thread.Sleep(100)
            Call ReadArduinoStringData()
            Rint1 = CInt(Rstring)
            If (Rint1 >= 105 And Rint1 <= 125) Then
```

```
        BagPress.ForeColor = Color.Yellow
        BagPressBar.ForeColor = Color.Yellow 'this only works with XP theme disabled -_-
    ElseIf Rint1 > 125 Then
        BagPress.ForeColor = Color.Red
        BagPressBar.ForeColor = Color.Red 'this only works with XP theme disabled -_-
    Else
        BagPress.ForeColor = Color.Green
        BagPressBar.ForeColor = Color.Green 'this only works with XP theme disabled -_-
    End If
    BagPressBar.Value = Rint1
    BagPress.Text = Rint1

    Sstring = "p" 'string to request vibrator regulator pressure
    Call SendArduinoCommand()
    System.Threading.Thread.Sleep(100)
    Call ReadArduinoStringData()
    Rint2 = CInt(Rstring)
    If (Rint2 >= 105 And Rint2 <= 125) Then
        VibePress.ForeColor = Color.Yellow
        VibePressBar.ForeColor = Color.Yellow 'this only works with XP theme disabled -
_-
    ElseIf Rint2 > 125 Then
        VibePress.ForeColor = Color.Red
        VibePressBar.ForeColor = Color.Red 'this only works with XP theme disabled -_-
    Else
        VibePress.ForeColor = Color.Green
        VibePressBar.ForeColor = Color.Green 'this only works with XP theme disabled -_-
    End If
    VibePressBar.Value = Rint2
    VibePress.Text = Rint2
```

```
            If BagAirOff.Enabled = True Then 'only want to update the feed rate bar if the bag air
supply is turned on
                Sstring = "S"
                Call SendArduinoCommand()
                System.Threading.Thread.Sleep(100)
                Call ReadArduinoStringData()
                Rint3 = CInt(Rstring)
                FeedRateBar.Value = Rint3
                FeedPercentage.Text = Rint3
            End If

            porttraffic = False
            NextState = 0

        Case 8 'Increase feed rate/inflate air bag
8:
            If porttraffic = True Then 'check for active serial data transfer. if true, loop until not
true.
                GoTo 8
            Else porttraffic = True
                Timer1.Enabled = False
            End If
            feedchange = True
            FeedCMDStatus.Text = "INCREASING"
            Me.Refresh() 'this commnad redraws form. if this isn't called, FeedCMDStatus.text
change on previous line will not process until the current case has been finished.
            Me.Cursor = Cursors.WaitCursor

            Sstring = "F" 'string to command feed increase
            Call SendArduinoCommand() 'send initial feed increase command
            If CoarseAdjust.Checked = True Then
```

```
            Sstring = "X"
            Call SendArduinoCommand()
            System.Threading.Thread.Sleep(3000) 'delay to allow for adjustment to finish (this
allows for accurate FeedCMDStatus)
        ElseIf MediumAdjust.Checked = True Then
            Sstring = "Y"
            Call SendArduinoCommand()
            System.Threading.Thread.Sleep(1500)
        ElseIf FineAdjust.Checked = True Then
            Sstring = "Z"
            Call SendArduinoCommand()
            System.Threading.Thread.Sleep(200)
        End If
        'send command to specify coarse/medium/fine adjustment
        If feedchange = True Then
            Call ReadArduinoStringData()
            If Rstring = 1 Then
                feedincrease = False
                FeedCMDStatus.Text = "STANDBY"
                Me.Cursor = Cursors.Arrow
                Timer1.Enabled = True
                feedchange = False
            End If

        End If
        porttraffic = False
        NextState = 0

    Case 9 'Decrease feed rate/deflate air bag
9:
```

```
If porttraffic = True Then 'check for active serial data transfer. if true, loop until not true.
    GoTo 9
Else porttraffic = True
    Timer1.Enabled = False
End If
feedchange = True
FeedCMDStatus.Text = "DECREASING"
Me.Refresh() 'this commnad redraws form. if this isn't called, FeedCMDStatus.text change on previous line will not process until the current case has been finished.
Me.Cursor = Cursors.WaitCursor

Sstring = "f" 'string to command feed increase
Call SendArduinoCommand() 'send initial feed increase command
If CoarseAdjust.Checked = True Then
    Sstring = "X"
    Call SendArduinoCommand()
    System.Threading.Thread.Sleep(3000) 'delay to allow for adjustment to finish (this allows for accurate FeedCMDStatus)
ElseIf MediumAdjust.Checked = True Then
    Sstring = "Y"
    Call SendArduinoCommand()
    System.Threading.Thread.Sleep(1500)
ElseIf FineAdjust.Checked = True Then
    Sstring = "Z"
    Call SendArduinoCommand()
    System.Threading.Thread.Sleep(200)
End If
'send command to specify coarse/medium/fine adjustment
If feedchange = True Then
    Call ReadArduinoStringData()
```

```
            If Rstring = 1 Then
                feedincrease = False
                FeedCMDStatus.Text = "STANDBY"
                Me.Cursor = Cursors.Arrow
                Timer1.Enabled = True
                feedchange = False
            End If

        End If
        porttraffic = False
        NextState = 0

    Case 10 'Maximize Feed Rate
        FeedCMDStatus.Text = "Filling"

  End Select
End Sub

Private Sub ReadArduinoStringData()
  Rstring = serprt.ReadLine()
End Sub

Private Sub SendArduinoCommand()
  serprt.Write(Sstring)
End Sub

Private Sub Timer1_Tick(sender As Object, e As EventArgs) Handles Timer1.Tick
  NextState = 7
End Sub

End Class
```

16 Tables

Product Identification	
Basic functions of the product:	Vibrate material within bin silos to keep it from clogging.
Special features of the product:	The system will be able to raise and lower, controlling the flow of material exiting the bin.
Key performance targets:	Should generate enough vibration to make material flow, while allowing the flow rate to be controlled from 0-100% flow.
Service environment:	Product will be placed inside bin silos of varying size, and be in contact with materials that vary in both density and corrosiveness.
User training required:	The operator will need limited training on system and will only need to operate from a user friendly interface, that will need limited hours to learn.
Market Identification:	
Description of target market:	The product will be marketed to industries that use bin silos to store material. This can includes but is not limited to farm, food, and pharmaceutical industries.
Anticipated market demand:	200 for the first year with a steady increase over time following improvements made to the system.

Competing products:	External and other internal methods of keeping material from clogging inside bin.
Branding strategy:	Have a VIBCO designed logo for the new system, with brochures highlighting operating features and benefits that will be published in an assortment of catalogs.
Key Project Deadlines:	
Time to complete project:	December 18: Final Report Fall 2017, April: Final Report Spring 2018
Fixed project deadlines:	October 31: Critical Design Review Presentation November 9: Design Review Meeting, December 5: Proof of Concept Presentation, April 27: Design Showcase, May 7: Final Design Report
Physical Description:	
Design variable values (fixed prior to conceptual design process):	The system must be able to fit inside of bin silos that can have varying diameters and heights.
Constraints:	Has to support 3 tons of weight, with bin diameters between 2-6 feet.

Financial Requirements:	
Pricing policy over life cycle:	Retail will be 2X the manufacturing cost. Discounts are as follows… 10% for Resellers 25%-35% for Distributors 25%-45% for O.E.M.'s Higher discounts for either higher quantity or total order price.
Warranty policy:	1-Year warranty
Expected financial performance and rate of return on investment:	1-Year ROI
Level capacity investment required:	Possible tools/Machinery to produce certain components as well as in initial investment of the raising and lowering system.
Life Cycle Targets:	
Useful life and shelf life:	Continuous use for 20 years with limited maintenance
Cost of installation and operation:	Installation costs will vary for each customer, depending on the bin size/type as well as the facility the bin is in. Operational costs will consist of the air or

	power supplied to the vibrator as well as to the airmount.
Maintenance schedule and location:	Should be unnecessary for the cone fixture. VIBCO Vibrators do not need maintenance and are designed to last under standard operating conditions. (Pneumatic Vibrators will only require maintenance if the customer is not filtering the air which can result in the unit running incorrectly.)
Reliability:	Minimum of 5 years
End-of-life strategy:	The design will all be able to be recycled. Only non-recyclable parts will be the airlines that carry air to the vibrator.
Social, Political, Legal Requirements:	
Safety and environmental regulations:	The product does not need to follow any regulation other than FDA approval if it is working with food or pharmaceutical products.
Standards:	Building codes, bin codes will be examined before installation into bin silos.
Safety and product liability:	The intended factor of safety is around 1.5 but this system poses no risk to employees because it is contained within the bin.

Intellectual property:	Care will be taken in order to not infringe on any patents or other known intellectual property.
Manufacturing Specifications:	
Manufacturing requirements:	Key suppliers will be vendors that currently used waterjet methods to cut steel,. Assembly and other metal work will be done in house.
Suppliers:	Key suppliers will be Firestone for their airmount system. The steel will be purchased through VIBCO's vendor.