Can Extractor for SONOCO
Final Report Draft

MEM-21
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Abstract

SONOCO is one of the leading suppliers of sustainable metal packaging for food and household products and the largest aerosol manufacturer in North America. Quality assurance checks are essential for can production, one of which occurs after attaching the bottom and top to the body of the can. Currently, cans are extracted from the production line manually which requires interruption of the high-speed process. Unfortunately, production numbers are partly limited by the current quality assurance check method as the production line speed must be significantly reduced or even halted in order to manually extract the cans for quality assurance. Can productivity could be improved if the process of diverting the cans for inspection was able to be performed without halting the line. The Can Extractor Project's objective is to increase the can production numbers by reducing downtime while the production line is at a standstill. This project will allow SONOCO's can manufacturing plant to maximize their production numbers and consequently increase company revenue by developing an electromagnetic device to divert cans seamlessly from the production line. The practicality of an electromagnetic can diversion process from the high-speed production line has been verified in practice since a similar device is used in a different stage of the manufacturing process. The electromagnetic can diverter will improve production, increase revenue, and decrease labor costs.

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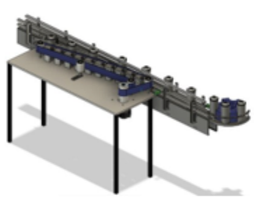
1. Executive Summary

The Senior Design team has managed to build a functioning prototype which demonstrates how the electromagnetic can extractor they designed operates. Several tests were run over a few weeks resulting in numerous revisions and versions of the prototype. In the end, the team was able to create a machine that the engineers at Sonoco could confidently implement onto the production line after a few minor changes.

2.Quad Chart

SONOCO CAN EXTRACTOR	
Problem: To extract cans from the assembly line for quality control the line must be slowed down or stopped for 1 minute every hour resulting in production losses. **Objective:** Create a device that will automate the can inspection process and reduce production losses.	**Results:** The initial prototype did not pull any cans off the line. After altering magnet strength, increasing magnet height, adding four more magnets, and increasing belt length, the prototype works well and reliably. A few more minor alterations before the 
Project Design: An electromagnetic conveyor diverter designed to have an electrically magnetized conveyor belt which will pull the cans off the production line into a catch. It will be controlled with a programmable logic controller. 	**Conclusion:** The entire design process took a few weeks longer than initially planned to complete due to technical difficulties with multiple CAD software. This taught that planning extra time in case of any setbacks is very important. The final cost for the device was just over \$3900, which was below the budget of \$5000 provided by the stakeholder. The team did all the machining which eliminated overhead cost. Overall, the project was a success and a sincere thanks goes to SONOCO for providing the opportunity to create this device.

3. Introduction

3.1. Motivation

When dealing with manufacturing, even small production losses that are incurred regularly can lead to significant annual losses for the company. SONOCO in Horsham, PA manufactures 3-piece aerosol cans with a weekly plant production of 25-35 million cans. They employ numerous line mechanics whose duties include maintenance, quality control, and rapid response to accidents and malfunctions. Their tasks can sometimes require short production pauses to complete, therefore much attention should be devoted to optimizing these tasks to reduce production downtime.

3.2. Problem Statement

The SONOCO plant in Horsham, PA has 5 assembly lines with a total of 5 seamers. The seamers are devices that attach the tops and bottoms of the can to the body. Often the tooling used to create the seal, the seamer heads, can become loose or worn, resulting in faulty seals. Quality control check must therefore be conducted in order to ensure that the seals are up to specifications. Every hour, the entire line must be slowed down or stopped for around thirty second or a minute to extract 6 cans from each of the seamers. The difficulty in this task is that the cans must be extracted in an order corresponding to the seamer head from which the can was ejected from. This results in significant hourly production loss as the lines typically run at 500-600 cans a minute. Cans can also be extracted in the wrong order due to human error. To resolve this issue, an automated sensorased system of extraction should be developed that can reliably extract the cans from the seamers in the correct order.

3.3. Stakeholder Needs

The project is based on market needs of the can making industry, at both Horsham as well as other SONOCO plants. The Horsham plant incurs significant annual losses due to the hourly production pause or slowdown on every line. While a minute or even thirty seconds lost every hour may not seem like much, when it is spread over 5 lines in a 24/7 facility the costs can add up to a significant amount over the course of a year. Therefore, the engineering team at SONOCO has requested our senior design team to develop a can extractor. While no specific requirements have been made, regarding reliability, it has been generally agreed that the can extractor must operate once an hour without regular maintenance, not cause any jams, and it must be cost-effective. It must also produce fewer erroneous results compared to a line mechanic doing the task on their own.

3.4. State of the Art/Useful Literature

There are many pieces of literature written on the manufacturing of three-piece aerosol cans as it is an industry that has existed for nearly a century. All the assembly machinery have manuals written for them which give direct specifications. This can prove very useful when trying to make the can extractor compatible with the seamer. Other devices also exist that do extract cans from the assembly line but not in any order and not within the specifications of the project. These include an electromagnetic puller and an airjet ejector which are seen in other area of the plant but have completely different functions than the can extractor the team has to design.

3.5. Approach

The selected final design option is an electromagnetic conveyor diverter which is designed to have an electronically magnetized conveyor belt which will pull the cans off of the production line. There will be a track adjacent to the production line where the cans will be guided by a combination of rails, a conveyor belt, and electromagnets to transport the cans into an area for collection. This must be done without disrupting the flow of the main production line and without damaging the cans to ensure the quality control analysis remains accurate. The plan is to have a conveyor belt running vertically with electromagnets on one side of the belt and the cans being pulled off on the other side. The electromagnets will be controlled by a code run through a programmable logic controller (PLC) and would seamlessly divert the cans without causing disruption to the production line.

This design was selected over the other prospective ideas because of its comparative simplicity, perceived reliability, and overall feasibility. Both of the two prospective ideas that were not selected utilized an airjet as a method to divert the cans, however after discussion with the SONOCO team and analysis of the cans diverted from alternate production lines using an air jet, it was determined that the can structure would often suffer damage or the extraction process would not be smooth and seamless. The can structure has a much greater chance of remaining undamaged by using the electromagnetic diversion combined with guard rails and rollers, opposed to an air jet dispenser system. Because the cans are diverted for quality assurance checks, the can structure remaining undamaged is paramount which is why our group decided to move forward with the electromagnetic diverter design.

3.6 Analysis

To make sure that the pulleys could withhold the force of the tensioned belt, a load analysis was performed. With an assumed maximum of 30 lbs of force acting on each pulley, a simulation was run in Autodesk Fusion 360. The simulation showed that the system was well built, if not overbuilt. It was all well within a safety factor of 8. The results can be seen in figure 2 of the appendices.

In addition, several failure modes and analysis were thought up. First, was the possibility of the rods not being machined properly or just not being made flat with the aluminum baseboard, possibly due to poor threading as well. In such a case, the pulley would have a lean which might cause the belt to slip off overtime. Therefore, a slight crown on one of the pulleys was added to mitigate this. Another possible failure can be that the tension in the belt is too high. In such a scenario the belt would break after only a short time of operation. Therefore it was deemed wise to incorporate a belt tensioner into the system.

Other points of failure include electrical issues with powering the pulley motor or electromagnets, therefore extra precautions were made by making sure all the wiring was done through a properly grounded electrical box.

4. Materials and Methods

4.1 Hardware

Most of the components of the can extractor design are contained in the parts list attached in the appendix as figure 1. Because SONOCO is already a McMaster Carr customer, all required parts were ordered from them. Many parts were already available in house, and there is a column in figure 1 stating whether the part was acquired in house or purchased from a vendor. The team still took note of the pricing of parts that were already available and did not need to be ordered.

The parts start with the base of the device, which is an 18x44x¾ inch aluminum plate. This material was selected due to its high strength, lightweight, and reliability in high-load mechanical applications and will be used to provide a base for the electromagnets and device. A ¾ inch plate was also chosen because there is enough material to countersink and counterbore ⅜ inch hardware for a smooth and flush finish which helps avoid any sort of clearance issues. Several "L" brackets will be used to mount the device to the existing production line, ensuring that the device is lined up to the main assembly line conveyor, but the weight of the device will be supported by legs mounted to the base.

Electromagnets will be mounted onto adjustable brackets which will be mounted to the baseplate using nuts and bolts. The electromagnets will sit just behind the belt in order to be as close to the can as possible without rubbing on the belt.

Steel shafts with pulleys will be mounted on top of the baseplate and will be secured with counterbored bolts from underneath. The pulleys will be made of aluminum and will have bearings pressed in from the top and bottom, and the whole pulley will be pressed onto the shaft. A tensioner bracket will also be mounted to the baseplate so that when the belt is put onto the pulleys, the tension of the belt can be easily adjusted. Lock collars will be added to the shafts to ensure that none of the pulleys walk off of the shafts. One of the idler pulleys will also be crowned so that the belt tracks in the middle of the pulleys and does not walk off of the pulleys. A 3 inch wide rubber belt which is used throughout the plant will be the belt of choice for our application. The belt will be measured, cut, spliced, and joined in house using existing belt making equipment. This belt will be wrapped around the several pulleys and will be used to transport the cans from the production line to the collection area.

The guide rails will keep the diverted cans in line and on track as they are pulled from the production line as well as preventing them from falling. Steel sheets will be used as housing/guarding for the main device when it is completed and implemented into the production line. A variable frequency drive will be used to control the motor powering the conveyor belt. Programmable logic controllers (PLC's) will be programmed with the code to count the cans coming off of the production line using a light sensor input. All of the wiring and related electrical components required will be mounted and stored under the device in an electrical box.

4.2 Software

All CAD design plans for this project were created using Fusion 360. 3D models were created for all the parts and then compiled into one complete assembly. Fusion 360 was also used to make 2D drawings for any custom part that needed to be created and machined in house. All programming for the can extractor will be done in the PLC language that is used throughout the plant in order to make it maintenance and modification friendly for future use. This adds less complexity to the project and keeps our device uniform with other machines in the plant.

5. Specifications and Results

5.1. Specifications, Constraints, and Standards

The can extractor design had to follow certain specifications as dictated by SONOCO. Mainly, the can extractor should not be more than 5 feet in length along the conveyor track and should not extend more than a foot and a half from the length of the conveyor track. These specifications were given because the can extractor should not interfere with movement along the production floor as well as maintaining clearance for electrical panels. In addition, it was desired that the can extractor be made with a reasonable minimum amount of moving parts to increase durability and reliability, so as to not overburden the responsibilities of the plant's maintenance crew.

In terms of codes or regulations to follow, the can extractor should meet the safety standards of the plant. There should be sufficient guarding in order to safely cover any moving parts of the machine to prevent any sort of accidents. There should also be an electrical disconnect for the motor and electromagnets with a lock out point to comply with the lock out tag out safety procedures at the plant.

5.2. Concepts

Several concepts were developed to meet the required specifications as dictated by SONOCO. However, to fulfill these concepts it needed to be broken down into three separate parts.

5.2.1 Sensors

Central to the entire operation of the can extractor are the various sensors that control the timing of the entire system. Without reliable sensors that remain consistent, the whole system will fail completely. Therefore it was important to pick out the right ones.

The team decided to go with two varieties of sensors. The starwheel removes cans from the seamer and corresponds to each numbered seamer head. For this, magnetic sensors would be the most practical. Magnetic sensors will allow the computer to detect when the starwheel is in the correct position to initiate the can extraction process. Essentially, it will start the sequence of codes that will determine when the cans will need to be pulled off the conveyor line. The second variety of sensors the team has decided to utilize are light breaking sensors. These are already widely used at SONOCO so they will most certainly not be unfamiliar to the operators at the plant. The light sensors will merely be utilized to count individual cans as they pass down the assembly line. This is how we will know when all 6 cans are pulled off the line.

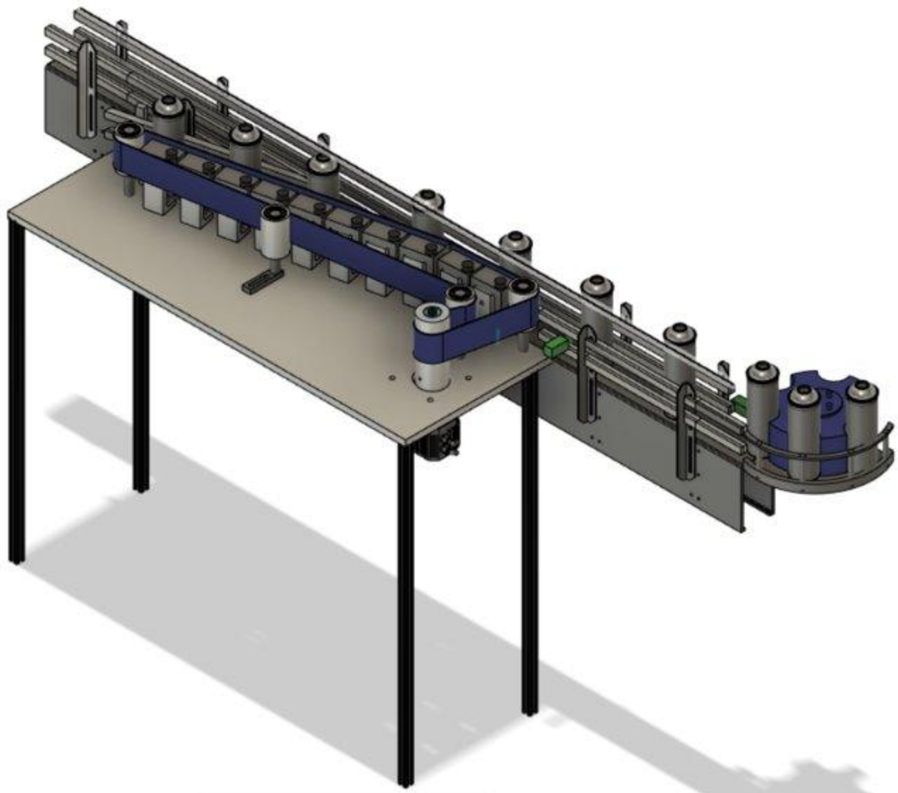
5.2.2 Computer

The computer is a crucial component in making sure the operation runs smoothly. The team decided to go with PLCs because of their ubiquitous use throughout the whole plant. PLCs are already very familiar to the plant engineers and electricians who use them on a daily basis. The PLC can effectively control the operation of the whole can extractor by using the sensors and inputs and raw power to the extractor's motor and electromagnets as outputs.

5.2.3 Can Extractor

Of course, the biggest and most complex item on the list is the physical can extractor itself. While initially several designs were proposed such as hydraulic cylinders, air jets, and electromagnets; it was decided to settle on electromagnets. By using electromagnets to physically pull the cans off the assembly line, the team can use a minimal amount of moving parts. In addition, electromagnets will provide the most seamless extraction of cans from the assembly line.

5.3 Detailed Design



5.3.1 Model Description

The model shows how the magnetic can extractor will fit alongside the conveyor belt. On the right hand side, the cans pass through the starwheel (shown in blue) which spaces out the cans. The star wheel also corresponds to which seamer head (type of tooling) made that specific can, being seamer head 1 through 6. There is a sensor (green) next to the starwheel so its exact position is known. The cans then travel down the line, where they encounter another sensor (green). This sensor sequentially actuates the electromagnets (grey squares with black circles on top) behind the vertical conveyor belt.The cans will then be pulled by the magnetic field and the conveyor belt will direct their path to an off ramp where they will stop and then be collected by an operator. After the green sensor counts 6 cans, it will sequentially turn off the electromagnets and the flow of cans will return to their normal path undisrupted.

5.3.1.1 Initial Prototype

The initial prototype was not able to pull cans off of the line at all. The magnetic force in the conveyor was too strong for the electromagnets to overcome.

5.3.1.2 Revision 1.0

To address the problem of the strong conveyor magnet's force, we lowered the electromagnets on the bracket so the electromagnets would attract the lower part of the can. The idea with this is that there is more material and the magnet would be able to exert a stronger force on the overall can. This resulted in cans actually being pulled off the line, but sometimes cans would get pulled back onto the assembly line from the conveyor magnet. The conveyor magnet would also make the cans unstable and would sometimes cause them to fall.

5.3.1.3 Revision 1.1

To address both of those issues, the magnet inside the conveyor was lowered which reduces its magnetic field so it does not attract the cans as strongly. A sheet of teflon was also added to the baseplate where the cans would slide in order to reduce friction which would reduce the likelihood of the cans tipping over. The flow of the cans was much smoother than it was before, but some cans still fall over and there is no area for the cans to pile up to be collected.

5.3.1.2 Revision 2.0

The overall length of the belt was extended and a strong permanent magnet was put in place behind the length of the new belt. It was a little tricky to position the magnet in a place where it wouldn't be too strong or too weak. Eventually after some trial and error the permanent magnet worked. Some cans would still fall over.

5.3.1.3 Revision 2.1

Guard rails and a stop were added to keep all the cans contained and to reduce having the cans tip and fall over. This generally worked but there was still a problem of some cans tipping over. This revision works as a great proof of concept but it is not ready to be implemented into production due to its lack of reliability. It worked well about 50% of the time.

5.3.1.4 Revision 3.0

Four additional electromagnets were installed in place of the permanent magnet. There are now 8 magnets in line at an angle to the main conveyor. The coding also changed, and now it is coded so that the main conveyor moves slower than the belt on the extractor. Additionally, another permanent magnet within the conveyor was lowered in order to reduce its force on the cans.

5.3.2 Results

The complete prototype has been built and tested. The testing was done over the course of about 3-4 weeks while the assembly was down for major maintenance. There have been several revisions and improvements to the design, with each revision having an improvement from the previous one. Currently, the can extractor works well and reliably, but it still needs a few tweaks to iron out very minor glitches as well as have it run a bit faster.

The power is currently controlled with a button which turns on power to all components for 15 seconds, and no sensors are currently in place. This is also when the line is running at half speed, so more testing would be needed to be able to run the line at full speed. Despite the challenges faced, the design still seems to be promising and will hopefully get to the point where it works as it was fully intended to. Further testing will be done until it works very reliably and is approved to be used on the line.

Also, it was determined that the cans were falling over due to the excess amount of friction between the bottom of the can and the track that they are sliding on. The cans would get caught, tip a tiny bit, catch onto the surface they are sliding on, and then fall over. This was not planned for in the original design, and teflon was added to the track to reduce friction. This still not enough, and a sheet of polished stainless steel or several thin stainless steel rods will be used to make a track that has even less friction. Another solution the team figured out is to increase the speed of the belt on the extractor relative to the main conveyor, causing the can to accelerate forward. This forward force on the can seems to cancel out the force of friction pulling the can back. This change in belt and conveyor speeds helped stabilize the can significantly, improving from a 50% success rate to a near 90% success rate.

5.3.3 Lessons Learned

One of the lessons that was learned from this was that the expected results do not always match the real results. When designing sometimes there is a lot of trial and error, and surprise problems come up which can delay the project or require a change in the design. For example, we did not anticipate that the conveyor magnet would be so strong, considering we bought very strong magnets rated to pull 700lbs. However, we did not account for the fact that the conveyor magnet is grabbing the can from the base which has a lot of metal. The electromagnets only grab the side of the can which is a very small surface area. The amount of friction between the can and the extractor was also underestimated and we did not anticipate it to be such a big problem. All of these issues had to be addressed one by one and each issue took several days to work out, but the end result was overall very successful.

5.4 Additional Analysis

Based on the many issues that came up during the process of making and testing the machine, an analysis should be made to prevent such issues from arising in future plans and projects. First foremost was the difficulty in dealing with the constant toppling of the cans as they continued to fall over. If a more thorough force analysis was conducted, it might have saved a lot of time and resources when troubleshooting these issues. After all, the team did not account for friction forces or interfering magnetic forces coming from the main conveyor during the initial design analysis.

Another mistake that the team made was treating the initial model as a final design, rather than a prototype. The team was a little too eager to make the model seem “clean” and went through extra lengths to secure components at a level beyond what was required. This led to issues when constantly rearranging components because many of the bolts were secured with lock washers and what not. Treating the initial model as a final design instead of a prototype wasted a lot of time and resources that could’ve been reserved for a more refined design after initial testing.

6. Discussion

Development of the electromagnet diversion device from ideation and brainstorming to CAD design has unveiled some key revelations. The process of brainstorming and forming initial product ideas allowed the group to assess multiple different ideas all with the same goal, and thereby evaluate which components of each would be most viable in the final design option. The process of refining the final design option forced the group to contemplate and compare the pros and cons of each aspect. Evaluation of the positives and negatives for each component allowed the group to pinpoint the design flaws and resolve them before creation of the CAD model. Because some errors were found and fixed before creation of the CAD model, the process was able to become a bit more streamlined. There was only 1 very minor miscalculation when building the can extractor from the blueprints made in CAD, proving the accuracy of our model and design. The CAD design process for our device didn’t present technical challenges, however it did present timeline challenges.

The entire design process took a few weeks longer than initially planned to complete, and there were some technical difficulties, however the lesson taught by this was invaluable. Because we learned this lesson early into project development, the group was able to properly reevaluate the overall schedule for product design and account for the extra time that would be required should problems arise in order to be able to complete the project on time. Preemptively accounting for extra time required to solve unknown design issues proved to be immensely useful when it came to the production phase of the project. There was an error when calculating the force required to divert the cans from a moving production line and it turned out that the first batch of electromagnets purchased were too weak. Because of this the first batch had to be returned and another, stronger set had to be purchased. Normally, a delay like this could set the project back, but because the group had already allotted time just in case something like this happened the project was able to stay on schedule.

To recap, the design process from ideation to design presentation to the stakeholder has accentuated four major truths that can make or break a project; open-mindedness in design, truthful evaluation of concepts, proper time management, and flexibility. Utilizing these four insights during product development will result in a more refined product and promote more valuable use of time and resources.

7. Budget Update

The budget of this project was capped at five thousand dollars by the stakeholder. The final cost of the device far exceeded initial expectations from the Fall and Winter quarters, however the final cost was still able to remain well within the allotted budget. The final cost for the device amounted to just over $3900, excluding labor. The main cause for the increase in price was a result of the group underestimating the electromagnetic strength required to divert the cans from the line. Because of this estimating error, the cost per electromagnet was much higher than initially calculated, and additional magnets had to be ordered as well. The motor required to drive the belt created another large cost to the list. Even with these unexpected price hikes, the device was able to remain easily under budget because our team did almost all of the machining, assembly, and any modifications needed to the can extractor thanks to the resources provided to us by SONOCO. If the group had to pay for the machining of all required parts, the overall cost would have certainly exceeded the provided budget.

8. Project Management

The team experienced technical difficulties with the availability of Creo/licensing, but it has almost been entirely resolved. All CAD models were moved from creo into Fusion 360 to avoid any future technical difficulties with licensing and so everyone in the team could have access to the CAD model. Splitting up work went as planned. The team also arranged several in person meetings to work on the project together. Any other work was finished up by two of the team members who had more time on their hands to work on the project. The other team members worked on tasks that didn't require them to show up in person.

9. References

10. Appendices

Last Updated:	4/18/2022					**Total Cost:**	
						3887.67	

Part	Part Description	Part Number	Vendor	Quantity	Cost	Total Cost	Provided in House
DC-Powered Electromagnet	Electromagnet 700lb pull	5698K414	McMaster-Carr	10	189.34	1893.4	No
Heavy Duty Shelf Bracket	Bracket for base	2736A716	McMaster-Carr	2	8.40	16.8	No
Leeson 1hp IEC Metric Motor	Motor for pulley system	C80T17FZ6C	Leeson	1	400	400	Yes
Permanently Lubricated Ball Bearing	Bearings for pulleys	2342K191	McMaster-Carr	8	27.78	222.24	No
Crowned Pulley	Pulley for belt drive	In House	Ball	1			Yes
Flat Pulley	Pulley for belt drive	In House	Ball	3			Yes
Multipurpose 6061 Aluminum Rod 3" (2 Feet)	For making pulleys	8974K82	McMaster-Carr	1	176.7	176.7	No
1" Diameter Steel Shaft (3 feet)	Shafts for pulleys and idler shaft	1346K39	Ball	1	53	53	
1" Clamping Two-Piece Shaft Collar (2)	Shafts for pulleys	6436K18	McMaster-Carr	8	8.52	68.16	No
Aluminum Plate 3/4" 18"x4'	Baseplate		PA Steel	1	525	525	No
3" x 84" Belt	Belt for vertical Conveyor	In house	Ball		150	150	Yes
Aluminum Bar 3/4"	Tensioner Bracket	9057K314	McMaster-Carr	1	46.14	46.14	No
Angle Aluminum 5"	For Magnet Brackets	8982K7	McMaster-Carr	1	70.99	70.99	No
3/8-16 1.25" Socket Head Screw (25)	Hardware	91251A626	McMaster-Carr	1	12.6	12.6	No
5/16-18 1.25" Socket Head Screw	Hardware	In House	Ball	1			Yes
Aluminum Extrusion, T-Slotted Framing (10 ft)	For legs and leg supports	5537T103	McMaster-Carr	2	75.56	151.12	Yes
Aluminum Extrusion, T-Slotted Framing (3ft)	For legs and leg supports	5537T103	McMaster-Carr	4	25.38	101.52	Yes

Figure 1: Parts list

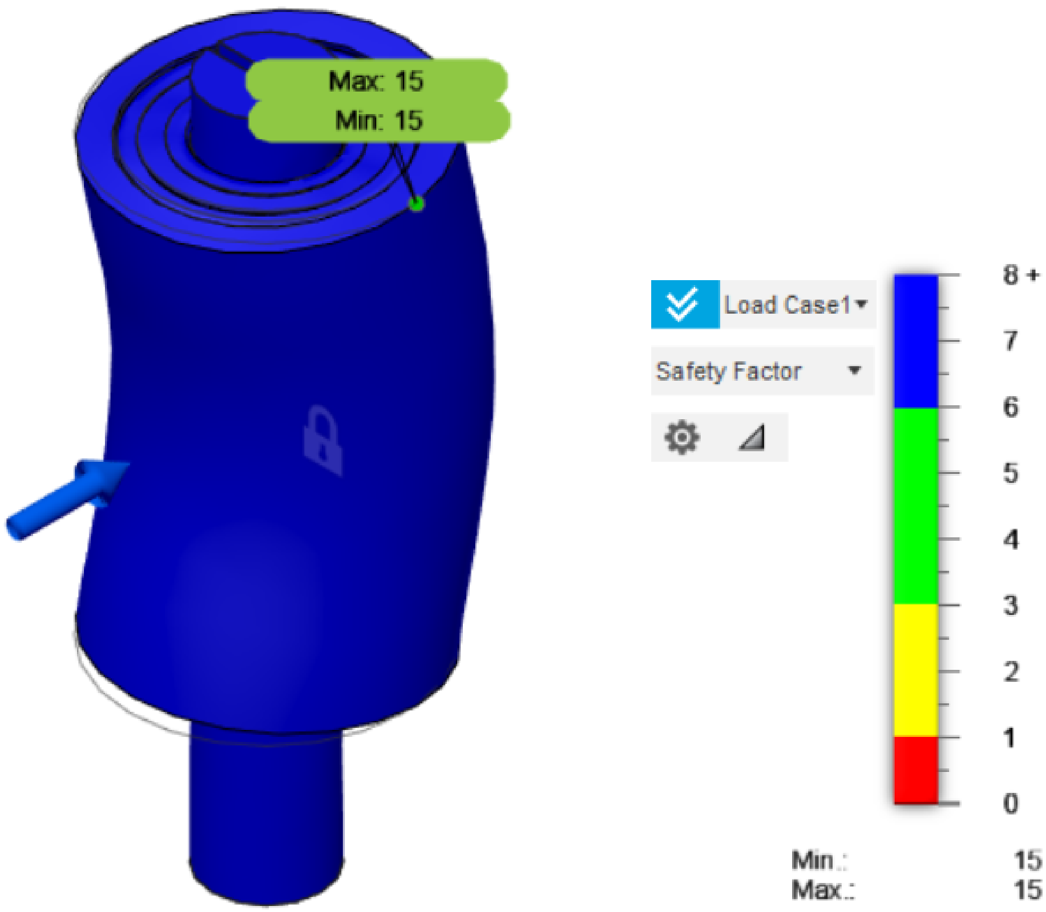


Figure 2: Force Analysis on the Pulley

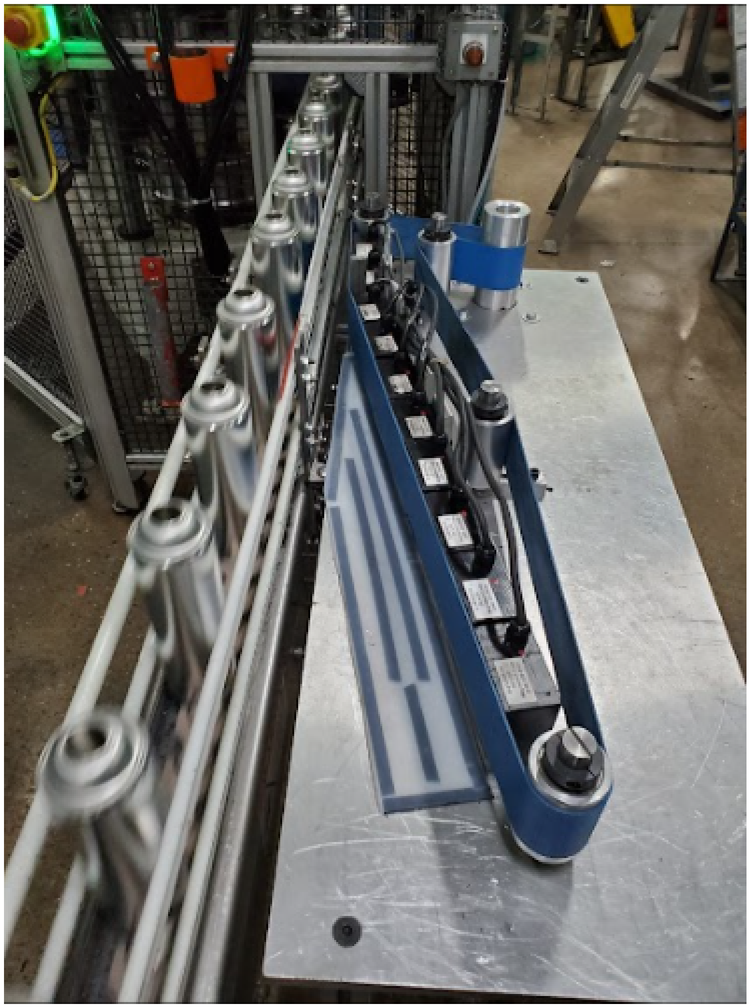


Figure 3: Latest version of the can extractor

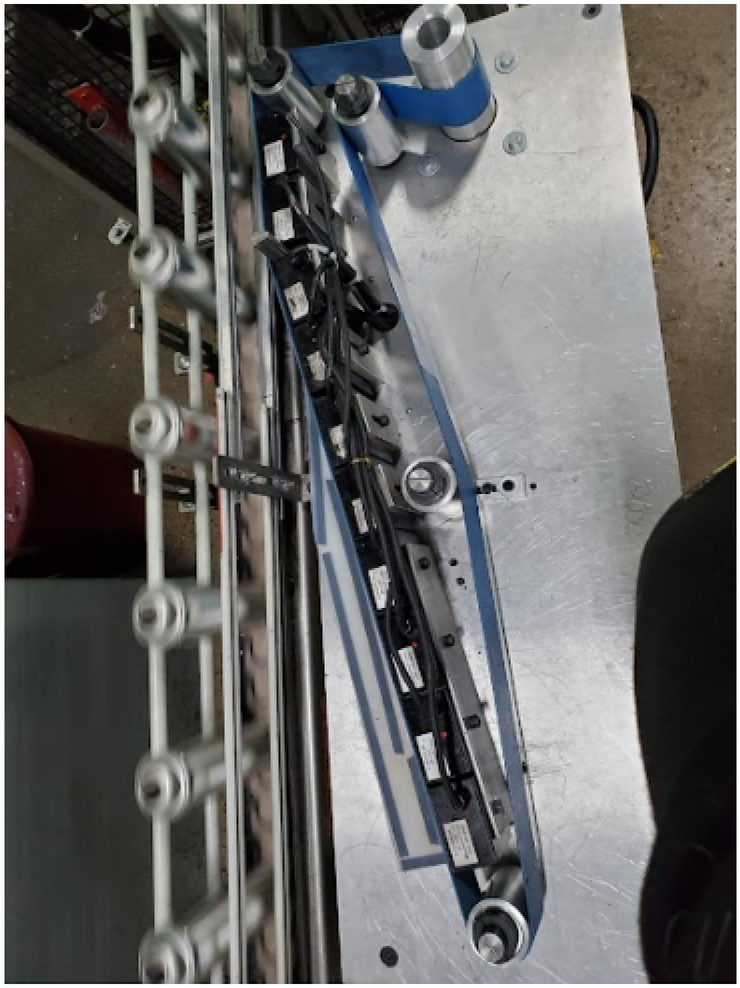


Figure 4: Latest version of the can extractor Top-down view

Figure 4: Earlier version of the can extractor prior to belt extension and rails

Figure 5: Team members machining brackets for electromagnets