EML 4905 Senior Design Project

A B.S. THESIS
PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

"SUB-AUTOMATIC"

Final Report

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April 11, 2014

This B.S. thesis is written in partial fulfillment of the requirements in EML 4551. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Carlos Bonilla, Omar Tavarez, and Daniel Pijeira and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

With the increase of fast food restaurants, particularly the sandwich style eateries, a growing inefficiency in the preparation of the meal has become apparent. Our task is to design a small, inexpensive, safe, efficient and practical machine that will significantly reduce the time it takes to complete assembly of a sub. This type of approach has never been implemented in a high output commercial setting, but with the FDA and ISO regulations.

By providing a machine to automate the folding process, our machine can free up employees to focus on product preparation and increase revenue for the business. The cost of the machine will be low enough when mass manufactured, making it appealing to business owners.

1. Introduction

In today's economy we are constantly finding ways to make processes faster and cheaper. As engineers we can be approached with projects to do just that, whether they are analyzing and optimizing data, machines, assembly lines etc. In our case, an investor, who is trying to optimize a sandwich restaurant sub-assembly line, approached us.

The main issue was the amount of time employees devoting to wrapping, cutting and folding the sub-sandwich when they could be assisting other customers with their food. By improving on the wrapping step the amount of product made and the attention to the customers will increase.

The first sketch brought to our group was purely mechanical and it will still require an employee to operate. As a group we are going to combine electro-mechanical concepts and a new design for the machine so we would be able to take the tedious step of wrapping and folding the product. Having done this, we are going to free the employee from taking time to wrap and fold and instead they will be able to assist another customer and improve sells. In the process of wrapping we will pack the product in a sealed bag to prolong freshness and flavor.

2. Problem Statement

Design and build a sub folding machine that meets all governmental regulations and requirements while being a safe, efficient, practical and cost effective solution.

3. Motivation

A good portion of machines that are fabricated in today's society are generally created to fulfill a need. This project is not an exception to this statement. One of the main purposes of designing this system is to reduce a tedious, time consuming task that is nonetheless necessary in the workplace today. In doing so, our hope is that this improvement will allow employees of these various businesses to instead focus their attention to other tasks that could make them more efficient. In addition to easing the process, we aim to utilize technology to expand the life of the end product.

This project is multi-faceted in that it has business challenges in addition to the engineering and governmental challenges presented. This added complexity is brought on by the product's marketability and interaction with the consumer public. Meaning, the ultimate design and development of the solution must take into account aesthetics as well as ease-of-use, all the while remaining compliant with governmental regulations. In completing this project, we are also gaining valuable knowledge in how engineering problems are approached and how various solutions are presented and ultimately marketed.

4. Literature Survey

4.1 Machine Size Restrictions

The current space used for the wax paper at Subway is 16” x 16”, with this removed to make way for our machine and with an extra space of 12” that we were able to determine was available, our machine had to be confined to a length of 28” inches. The current length for our last iteration is 24” which is less than the space available.

4.2 Heat Sealing

When sealing an object inside of two or more pieces of plastic, the method used to weld them together is known as heat-sealing. This is achieved by pressing two sheets together using a punch press machine that is equipped with a heating sealing die. This is accomplished by using a lower and upper platen. Each platen normally consists of one or more bars, usually made of brass. Once the plastic sheet is placed between the two platen, they are pressed together and the machine is turned on, causing the sheets to fuse together. This fusion can occur from two sources: heat or radio frequency energy.

4.2.1 Constant Heat Sealing

Figure 1 - Constant Heat Sealer

Constant heat sealing technique is the most straightforward and commonly used method. The heat on the brass bars from the sealing die, in conjunction with the pressure applied, will melt the plastics together. The challenge found in this type of sealing is determining the amount of heat required to fuse the sheets of plastic together without burning them. The disadvantages of this process are that its parts are constantly hot and consume energy to maintain this temperature. In addition, the cooling process is not sped up in any way, and is left to effects of natural convection.

4.2.2 Impulse Heat Sealing

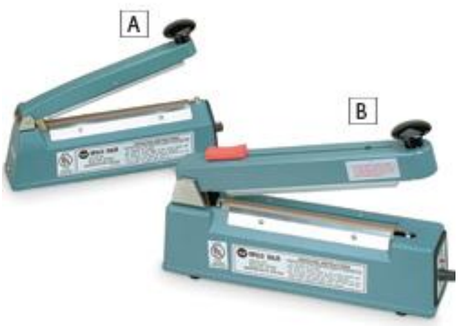


Figure 2 - Impulse Heat Sealer

Allows thermal sealing through thermal conductivity. When pressed down current and heat are delivered on impulse to the heat-sealing lever, then the current is stopped and the pressure still available to cool and provide a nice finishing. An advantage of this process is that it does not require warming up time after turning it on, electricity is only use during the plastic welding process, components are not always hot, and the cooling process happens under pressure.

4.2.3 Radio Frequency Sealing

Radio frequency sealing is different from heat sealing in that it uses radio frequency energy to seal the plastics, just like radio frequencies are used in inside a microwave oven to heat up food. Radio waves have different frequencies, the radio waves used for food and sealing plastics together are very powerful mostly thanks to the proximity of the product, food or plastics, to the transmitter and because of the high frequency.

The frequency of the radio waves in a microwave is such that it excites the water molecules in the food placed inside of it. When water molecules are excited and move fast they create heat, so the food heats up from the inside. For the purposes of sealing plastics together, some plastics have polar molecules, which in terms means that they can be excited by this “RF” energy found in some heat sealers. So the RF heat sealer working like an enclosed microwave can excite the polar molecules on the plastics, causing heat and finally sealing two or more sheets of plastic together.

With RF energy sealing just like in microwaves the response is faster because it does not require heating time, also the cooling down process is much faster. With a faster cooling process than regular heating, the integrity of the seal is better, it is safer to handle, and the product turn over faster.

4.2.3.1 Buffers

Another factor to take into a count is the need of a buffer when using RF energy. The buffer you should be used between the plastics and the lower platen. The purpose is to require the sealer to use *more* RF energy to weld the plastics together. While the RF energy is melting the plastics its electrical field is trying to complete a full circuit and the nearest place is the bottom of the sealing die, without a buffer the thinnest part of the welded plastic will be the easiest way to complete a full circuit and the RF energy would be flooded to the bottom platen and create a hole in your seal.

A buffer provides enough resistance to the RF energy and will keep it distributed through the seal being put by the die. This way the seal will not be unevenly heated and the seal will be uniform. The determination of what is too much power or too little is wider when the seal is being dealt evenly. Buffers also help with sticking of the material and the releasing after the seal is done, the heat sealing die being softer than the bottom plate usually made of steel, will use the buffer as landing place.

4.3 Vacuum Sealing

When food is exposed to the air, it ripens faster due to oxygen exposure than when food is vacuumed sealed. Food is undesirable and/or uneatable as a result of the exposure to oxygen. This exposure helps the growth of mold and bacteria. By removing the air from the bag we can effectively impede some mold and some bacteria growth. The life of fresh foods packed inside a vacuum is elongated and flavor and appeal conserved. This process is called vacuum sealing and is being investigated for our design.

This type of sealing refers to the process in which a product is introduced inside a plastic bag and the air accumulated inside the bag is evacuated. There are different types of vacuum sealers, we would research the different options available and determine which one could be used for our design. Some of the machines being considered are explained as follows.

4.3.1 External Sealer

The sealing during an external sealing process describes when a vacuuming machine does the sealing and vacuuming outside the actual machine. An example of this kind of machine is shown below in fig(3):

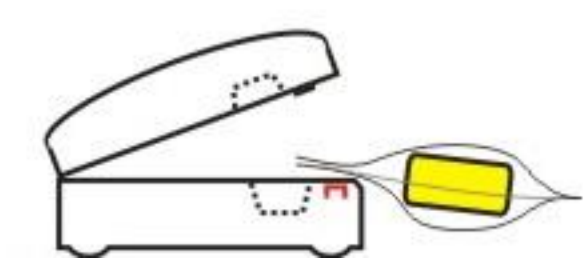


Figure 3 – External Sealer

This type of external vacuuming machine uses bags that have ridges, and it is mainly used for at home vacuum sealing. The air is vacuumed out of the bag by the use of cavities; these cavities are present where the machine, right at the bag's open edges, is holding the plastic bag. Another type of external sealing is used for commercial sealing, this machine uses a "snorkel" and smooth bags, as shown below in fig (4).

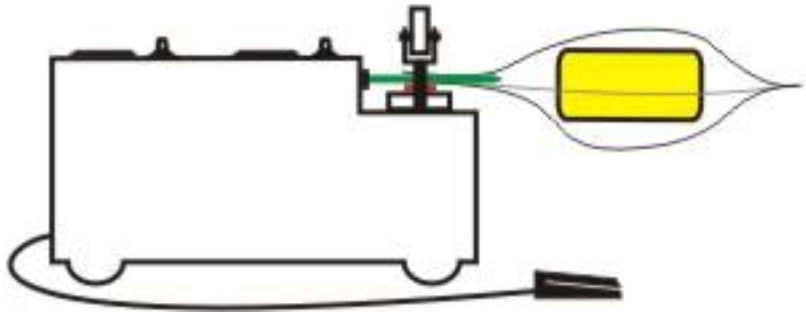


Figure 4 – External Vacuum Sealer

This external vacuuming machine evacuates the air from the smooth bag by means of a "snorkel", represented below as a probe inside the bag.

4.3.2 Vacuum Chamber Sealer

For this type of vacuuming smooth bags are used and the product is entirely inside the machine. A pump inside the machine extracts all the air inside the chamber, and after that the open edges of the plastic are heat sealed, closing in the bag and finishing the process. Some machines introduce inert gasses like nitrogen after air evacuation and before sealing. This produces a seal that not tight like the one with vacuuming alone, this is used for fragile products such as potato chips. Figure (5) shows a vacuum chamber machine schematic:

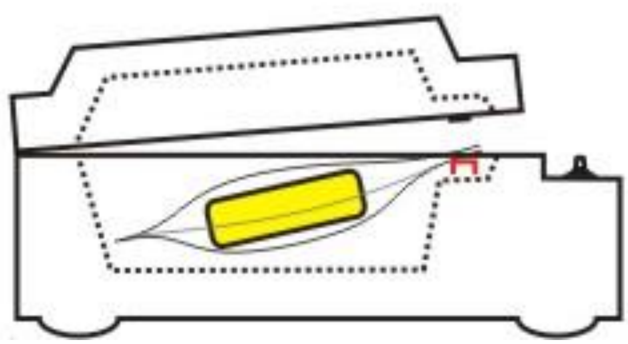


Figure 5 – Internal Vacuum Sealer

4.4 Plastics

Plastic wrapping can be made in different ways and depends on the type of machine used. Individual bags can be used, these are usually better for in home use. Another way to use plastic wrapping is to buy rolls of plastic and make your own pouches or bags. The latter one is more cost effective and better for commercial use.

Plastic sheets are also different as far as materials and thickness. For the purpose of our project we need only use FDA and USDA approved contact safe materials. TO determine if one ply or several ply sheets could be used; we would need to take into consideration how well the plastics keep freshness, the cost and their heat-sealing properties.

4.4.1 Poly/Nylon COEX

These types of bags for vacuuming are food contact safe and cost effective. They are a co-extruded vacuum pouches meeting FDA and USDA guidelines for food products. It is made of a mixture of polyethylene and nylon resins, and several layers allow it to be malleable and able to conform to different product shapes.

This material also has a high impact resistance and an oxygen transfer rate that is low. It is in a nutshell high in strength, clear, and flexible. It is resistant to oxygen transfer and vapor transmittance while meeting FDA and USADA rules.

4.5 Mechanism Selection

For our machine we need to determine which medium to use to produce the mechanical motion that we require to make the machine functional. To choose a way to produce this motion we investigated the following mechanisms.

4.5.1 Pneumatic

Pneumatics refers to the use of pressurized gas as the force to produce mechanical motion. By regulating the pressure of the gases inside a chamber, like a cylinder, the system can drive a piston to produce motion at the speed desired.

The use of compressed air is expensive, loud and not too practical. For our purposes we will discard this system.

4.5.2 Hydraulic

Like the pneumatic system, the hydraulic system uses a pressurized medium to deliver force for mechanical motion. In this system the medium used is hydraulic fluid; these fluids can be water or mineral oil.

This system represents a problem for our design because these systems can leak the hydraulic fluid and represent a health hazard.

4.5.3 Pure Mechanical

A mechanical system will deliver forces to cause the movement we need to operate our machine's design using power from a human operator and/or gravity.

As one of our main goals we want to limit the need of a human operator. The system could be mechanical but it would have to draw its power from an electrical motor.

4.5.4 Electro-Mechanical

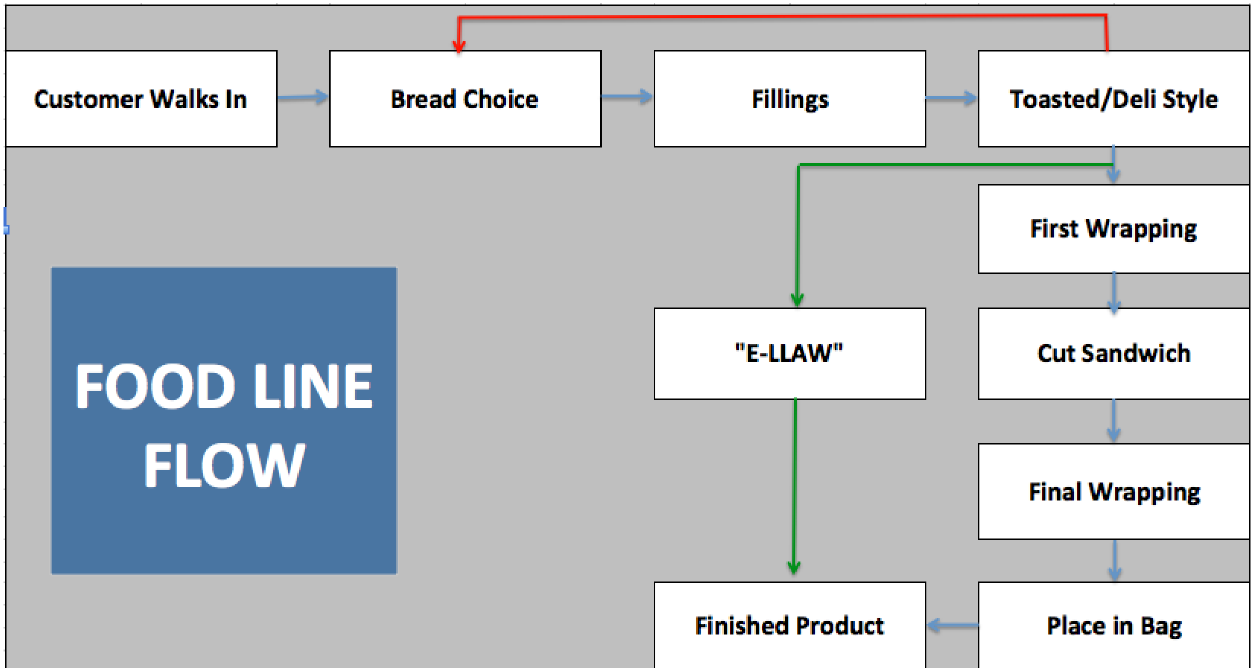
An electromechanical system is able to deliver the forces we need and it would be automated since the power comes from electric motors. This would help us achieve one of our goals of freeing employees from the wrapping process.

5. Project Objectives

We have four main goals that we must meet in our final prototype. The paramount goal being safety will be tackled by possibly automating some of this process, and our initial idea is to use some type of conveyor system. Secondly, to make this final system efficient, we will look at incorporating two steps into one simultaneously; folding the sub as it is being packaged. Lastly, we must design this system to be practical and cost-effective. We tackle these two tasks by designing a system that is modular, expandable and marketable. Moreover, we design the system to eliminate the tedious, yet necessary task of folding and wrapping sandwiches. We have also decided to go one step further in our design, and look to incorporate vacuum sealing technology to extend the lifespan of the sandwiches, adding value to the product and marketability.

6. Proposed Design

6.1 Process Flow Chart

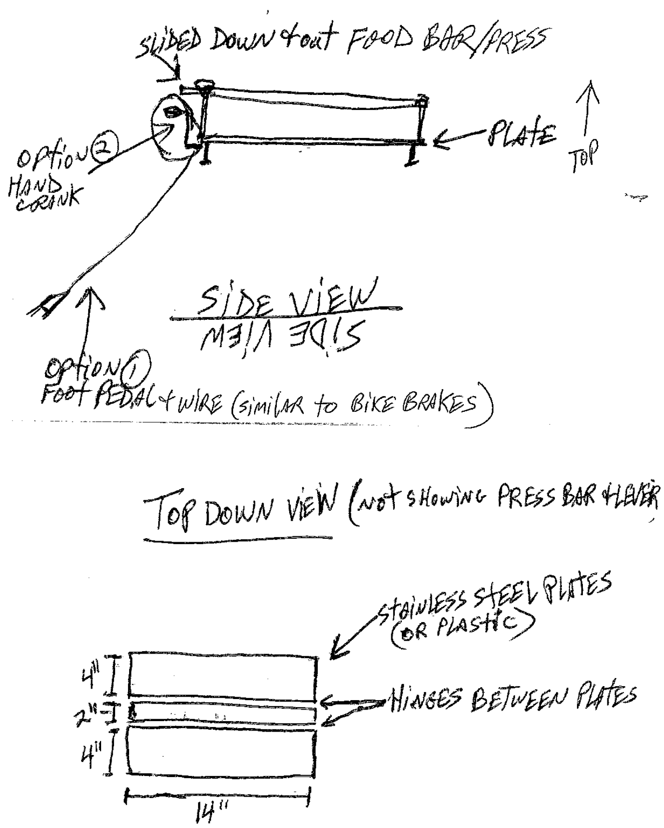


The chart above explains the normal process from the moment a customer walks into the store, to the time the customer receives the end product. In this process, the goal of our machine is to handle some of these steps so the employee is able to help the next customer. In the flow chart above, the process would be altered beginning at the first wrap, and would end in the final finished product.

The blue line path shows the current process followed by employees at a sub-shops, the red line shows what would be the new process that employees would follow. The interaction time an employee would be a part of in the completion of the sub making and is dramatically cut since the steps of wrapping, cutting and bagging are eliminated from their routine. The green line process represents the steps the machine would take over.

6.2 First Draft

The initial design was brought forth to us by our investor. The preliminary idea is of a machine that will achieve the ultimate goal of saving time by taking over the wrapping process of a sandwich in a restaurant. The following sketch represents these ideas:



This machine would be purely mechanical and need to be operated by an employee. This employee would need to use a crank or a foot pedal to allow the machine to fold and wrap the sandwich.

Pros:

- Small design for ease of adaptation in an existing sub-shop line

Challenges:

- Press bar and possible foot pedal represent high risk for the operator

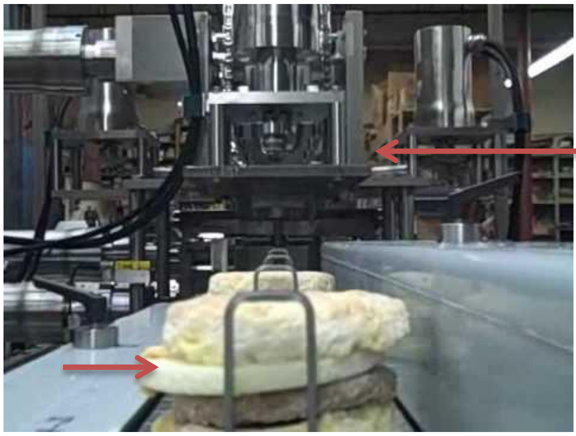
- No automation
- Added complexity in creating a functional design from scratch, rather than modifying an existing one
- Not easily disassembled for cleaning and sanitary reasons

The objective is to utilize existing technology and adapt it to a new design, while requiring the design of the least amount of parts to accomplish this retrofit.

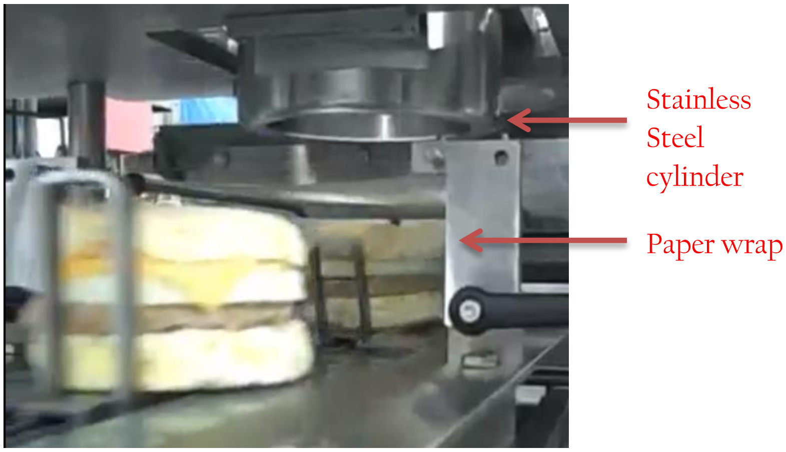
6.3 Alternative Designs

From the conducted research, it has been found that currently these types of machines are made for mass production in factories and not intended for small scale application. One of the many challenges is choosing a design that would be easiest to retrofit into a small scale application. The following represent types of machines that can be utilized.

6.3.1 Wax Paper Folding



This design pushes the sandwich from a 'ground' level to a higher level while it is wrapped and folded in this transition.



From the picture above, the wax paper is placed on top of the sandwich while the stainless steel cylinder is oriented above it. The sandwich is then pushed through the opening, thus wrapping the paper around it as shown by the following picture:

When the sandwich is pushed through the cylinder, the task then becomes to fold the loose ends that are on the bottom of the sandwich. Also from the picture above, the use of a folding arm accomplishes this task as the sandwich is pushed through. Once these tasks are accomplished, another arm is used to help move the sandwich along the conveyor belt towards the packing section.

Pushing arm

<u>Pros</u>:

- Design already exists
- Fully automated

<u>Challenges</u>:

- Large design and multi-level movement is complicated
- High risk if not fully enclosed
- Expensive

6.3.2 Plastic and Heat-Sealing Wrapper

One that is currently available is the horizontal flow wrapper, which is used for vacuuming, wrapping and sealing food. This technology currently exists on a mass production scale as well as a table top application for the home

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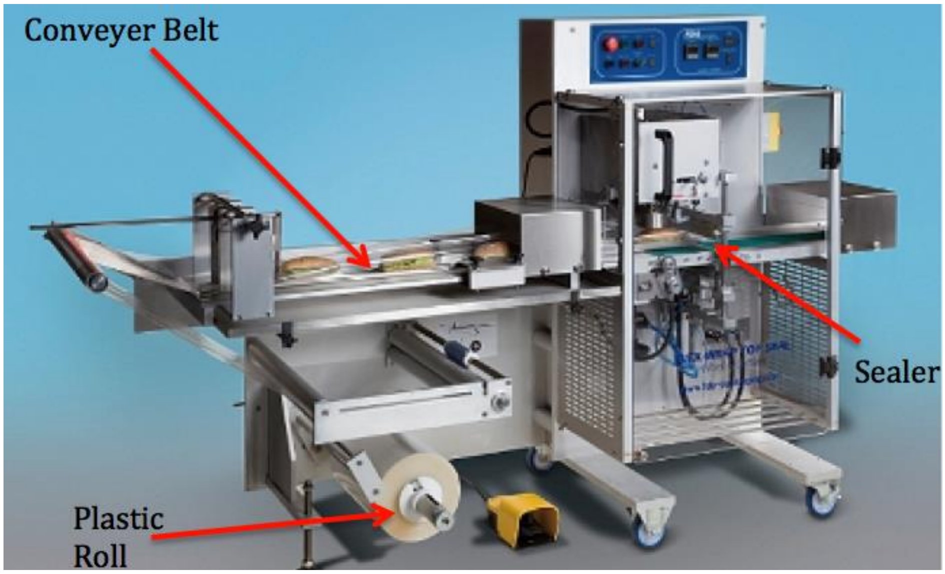


In the picture above, the sandwich is placed on the beginning of the conveyor belt where a sheet of plastic is oriented above it. It then undergoes a process where the air inside of the plastic is vacuumed out and then it is hermetically sealed. This same process can be purchased for use in the home, as shown by the following picture:

While this is a great alternative for personal use, it would take too much time operating the machine to be efficient in a restaurant setting.

<u>Pros</u>:

- Vacuum sealing technology will increase the longevity and freshness of the product, in turn increasing customer satisfaction and sales
- A possible conveyor system would automate the wrapping and folding process, allowing the employee to perform other tasks

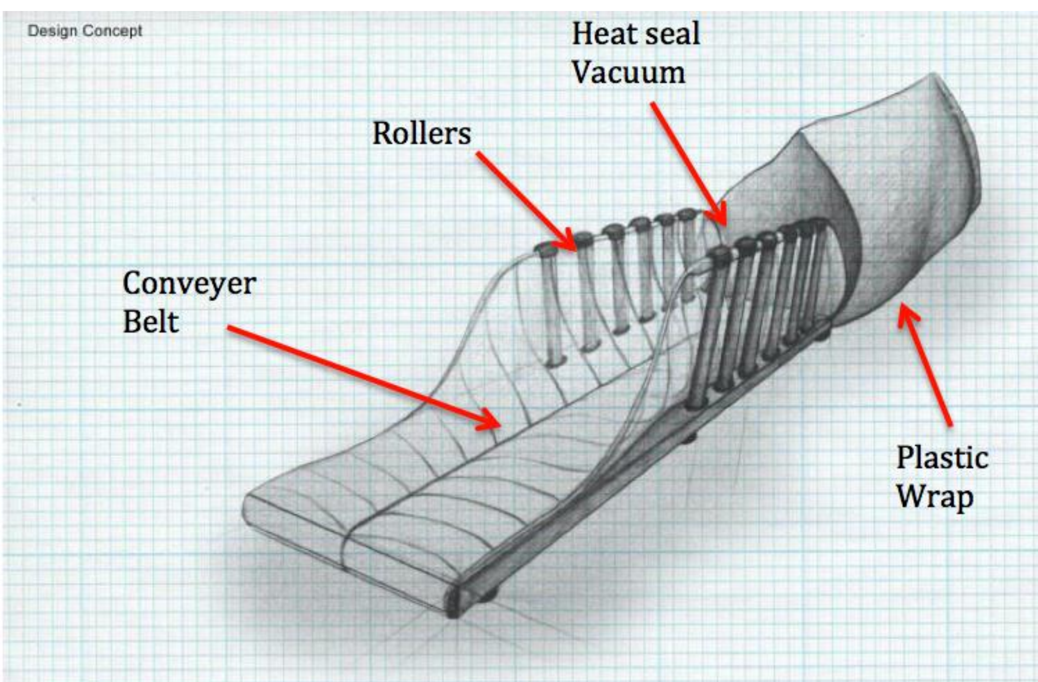
Challenges:

- Design the machine within a constrained amount of space
- Keep design cost at a minimum

An agreement was made that a machine that could vacuum and seal the sandwich would be a great selling point, since it would increase the freshness and hopefully increasing overall sales. It was then that another decision was made to use existing table-top applications of this technology and retrofit it into a new design.

The ultimate goal of designing this machine is to allow the employee to use their time elsewhere, rather than wrapping and folding a sandwich.

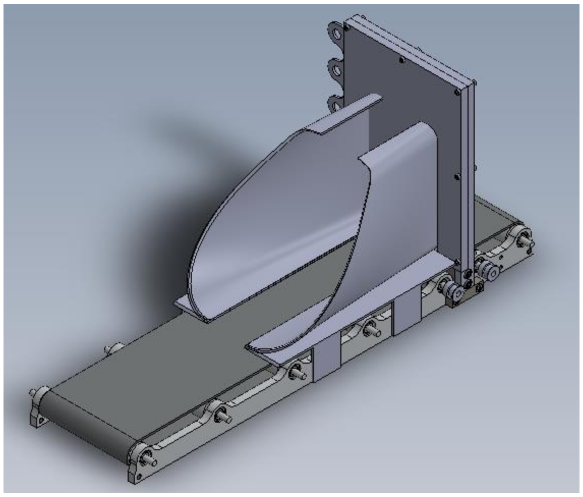
6.4 First Design Revision



"Sub-Automatic"

The picture above represents the concept design, which acts as the starting point for the prototype. The process incorporates all of the research and concept ideas that have been mentioned thus far. The sandwich will be placed at the start of the conveyor system where it will be moved along through the narrowing opening, folding the sandwich as it is pushed into a bag to be vacuum-sealed.

6.4.1 Second Design iteration:



Our first iteration features a modular design. The different parts include: a conveyor belt, cutter, and a folding tunnel.

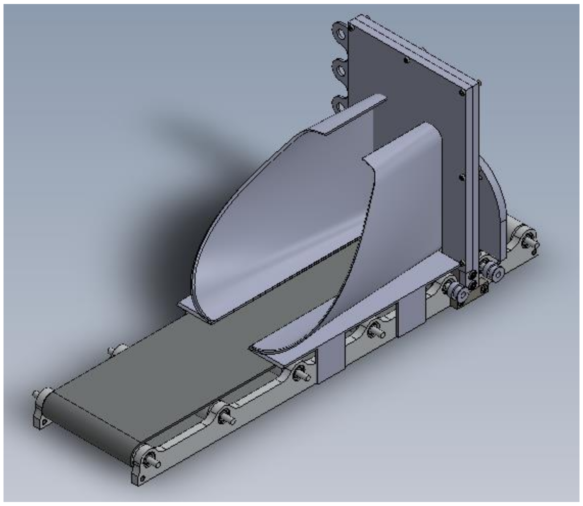
Conveyor Belt: This feature is made up of rollers, bearings, railings, and belt. It is composed of 2 separate conveyors that can be disassembled to allow easy sanitation. The purpose of this part is to take over the sub form the employee and carry it throughout the folding and wrapping motions. The size of the railings will fit a regular restaurant dishwasher

Folding Tunnel: This feature will fold the sub while it is transported on the conveyor belt. It will be attached to the railings with pins, to allow easy disassembling and cleaning. It will fit a restaurant dishwasher

Cutter: The cutter will be optional; it will cut the sandwich in half before the wrapping happens.

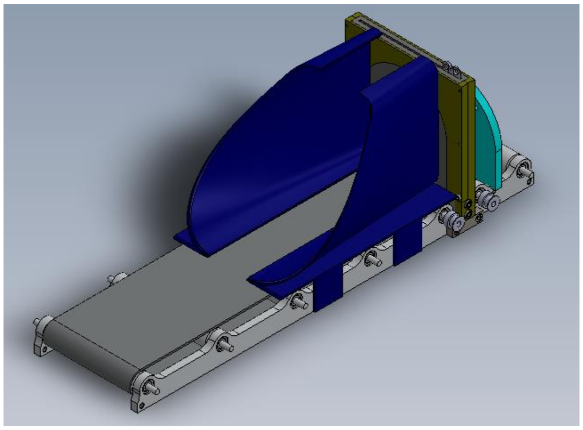
Vacuum: After testing the vacuuming feature ruined the sandwich by squashing it, and it took a long time to complete. Vacuuming of food is used for long term storing of foods and the purpose of our packaging is meant to last for less than a day. After these discoveries we decided to go with the heat-sealing alone.

6.4.2 Third Design Iteration:



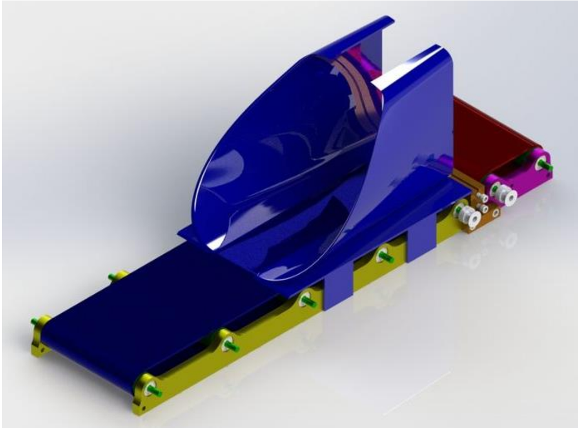
For this iteration we included the bag holder to be included in the design, instead of in a separate attachable feature. This holder will simply hold the plastic sleeves in which the sub will be put into. This part will also fit a dishwasher, the bags would be heat sealed to preserve the product.

6.4.3 Forth Design Iteration:



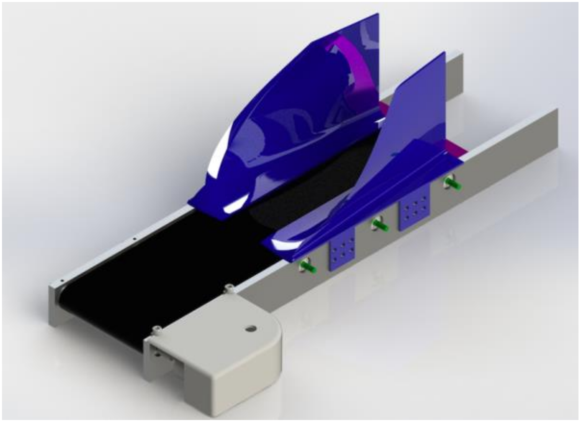
In this iteration the cutter was changed to a horizontal position, this cutter was meant to be automated. After the cut the product would go into the bag holder.

6.4.4 Fifth Design Iteration:



Moving forward with the design we decided to focus in the folding channel and conveyor belt, these parts would automate the folding process. We also decided to leave the cutting to the operator. This is why this new revision does not have an automated cutter added. In the future one could be built and assembled easily through the use of screws to the cutting board.

6.4.5 Sixth Design Iteration:



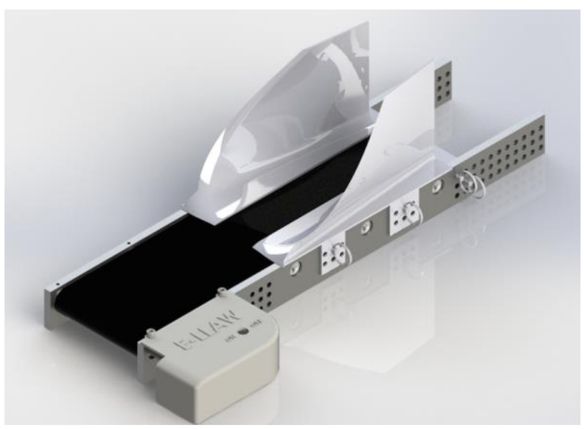
This design changed in several ways. The first was the removal of vacuuming feature to a heat-sealing alone one. Also the rails will extend from beginning to end of the machine instead of them being separated into different parts.

Railings: After reaching out to manufactures in the field, we decided to change our railing to one that extends throughout the machine. This allows for more flexibility in the placing of the bag holder and cutter; it is more cost effective while adding stability and less time for disassembling of the machine. The new length of the railings will still be able to fit a dishwasher for sanitizing.

Bearings: For our bearing selection we found stainless steel, enclosed, FDA approved ones. These bearings will facilitate the conveyor belt motion. By choosing enclosed bearings we guarantee that the machine could keep operating even with food particles falling into them.

Motor: A DC motor is required to power the conveyor belt. We chose whose speed could be adjusted. By doing this we can select an appropriate speed for the carrying of the sub through the process.

6.4.6 Seventh Design Iteration:



In this design we added railings with multiple holes to optimize the location of the parts to find the best position for the components. This also allowed us to position the motor in a way where gears could be added to reduce the speed of it if needed. This new design was meant to allow flexibility in the component positions since this machine is not in existence we had to be able to try many different alternatives

After using 3D printed parts for the prototyping, we finalized the location of the folding rails and the motor. Also we were able to use the bearings and shafts we previously selected. A motor cover was added to protect the user and the circuit needed to run the motor. Pins and screws were also finalized; these hold the motor cover, bearings, folding channel and cutting board.

7. Project Management

7.1 Overview

The idea for this project was brought out by Mr. Norman Wartman. After meeting with him once we learned that he expects us to select alternatives for the project, cost estimation, final designs etc. For the fall semester we will have a 25% of the report ready in which we will have a preferred design and be ready to start drafting and simulating on CAD. For the spring semester starting on winter break we will construct and test and provide a final report including lessons learned as requested by Mr. Wartman.

7.2 Gantt Chart

Figure 6 - Timeline for Fall and Spring

7.3 Breakdown of Responsibilities

Carlos	Current Facility Research	Danny	FDA Regulation
	Patent Lookup		Material Specification and Selection
	Instruction Manual Production		Data Analysis
	Sealer Selection		Motor Analysis

Omar	SolidWorks Design	All	Literature Survey
	SolidWorks Simulation		Conceptual Design
	ISO 22000 Regulation		Construction
	ISO 9000 Facility Allocation		Test Analysis

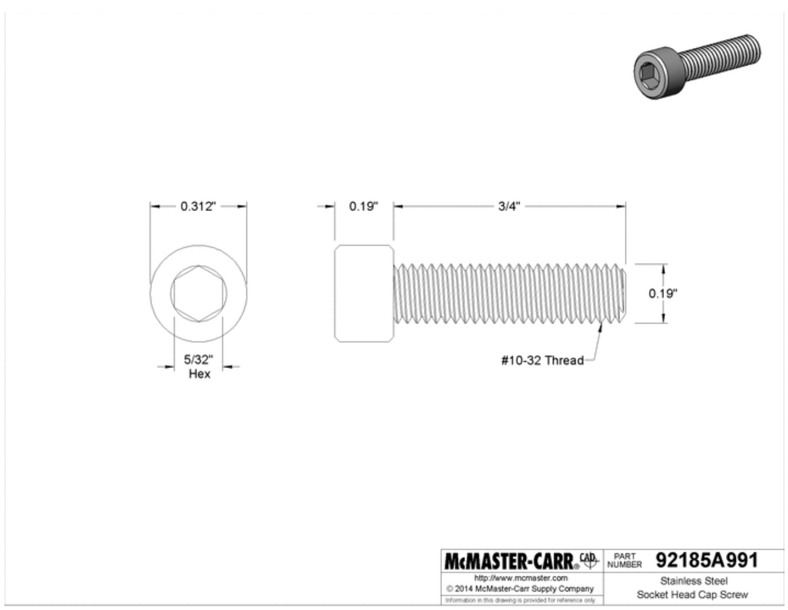
Table 1: List of responsibilities for each team member

8. Miscelaneous Components

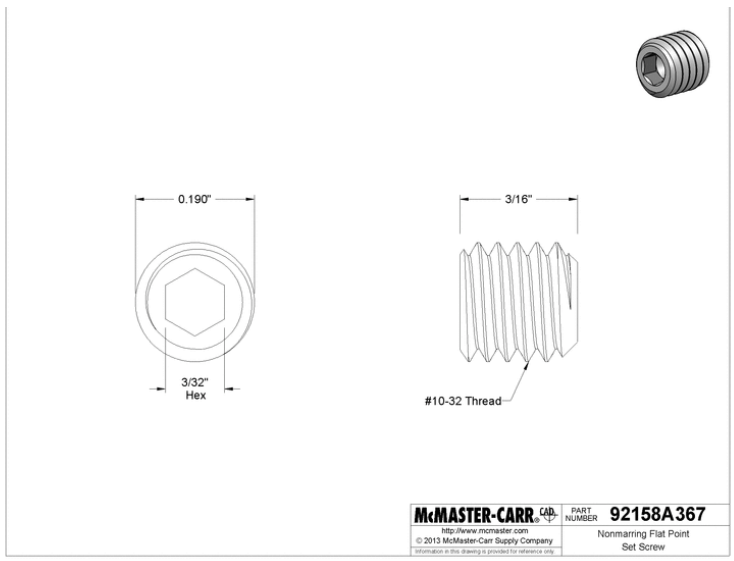
8.1 Shaft & Fasteners

The design was made to fit type 316 Stainless Steel Socket Head Cap Screw.

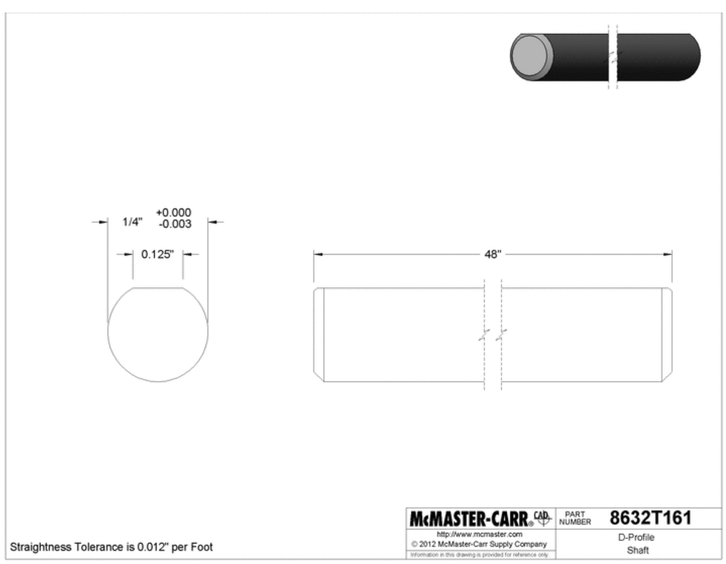
10-32 Thread, 3/4" Length; these screws would be used to hold the motor cover and the front bearings in place. The specifications are shown below:



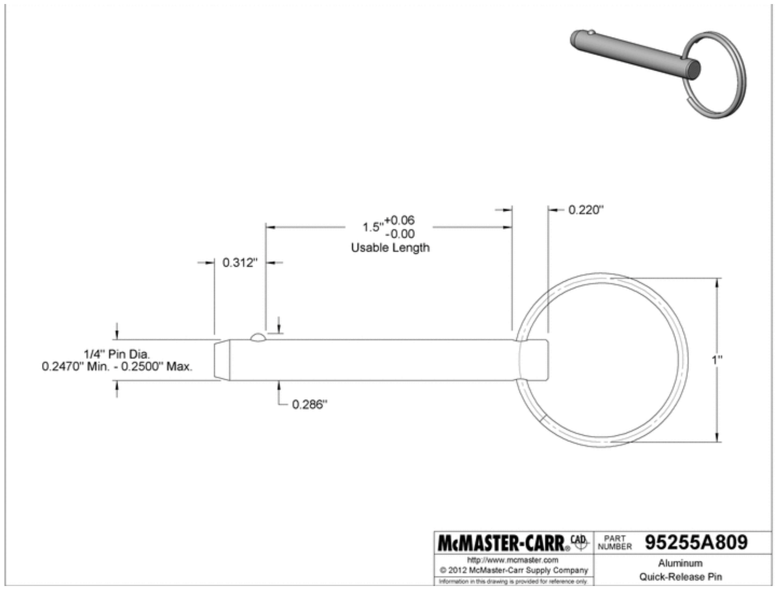
To hold the rest of the bearings, non-marring flat point socket set screws Type 316 Stainless Steel, 10-32 Thread, 3/16" long, were used. These would not extend out of the railings allowing the channels and other parts to be mounted on top of them. Their specifications are shown below:



A D-Profile Shaft Type 303 Stainless Steel, 1/4" OD, 48" length, was cut into 6 inch smaller shafts for the conveyor belt. The specifications are shown below:



Other parts used were the pins, (Quick-Release Pin Aluminum, 1/4" Diameter, 1.5" Usable Length), to hold the channels and cutting board in place and we also needed. Their specifications are shown below:



8.2 Material

There were many different types of resin available. The following guide was used to eliminate the materials that were not food safe:

		Mechanical properties		
Resin generic name	Some brand names	Strength	Impact resistance	High temp. strength
Polypropylene	Maxxam, Profax	Low	High	Low
High Density Polyethylene (HDPE)	Dow HDPE, Chevron HDPE	Low	High	Low
Polystyrene	Styron	Medium-Low	Low	Low
Acrylic	Plexiglas, Acrylite	Medium	Low	Low

Moldability Characteristics							
Resin generic name	Warp and dimen-sional accuracy, molded	Fills small features	Voids in thick sections	Sink in thick sections	Flash	High temp. hard on mold & ejectors	Relative cost
Polypropylene	Fair	Excellent	Poor	Poor	Poor	Good	Low
High Density Polyethylene (HDPE)	Fair	Excellent	Unknown	Poor	Poor	Good	Low
Polystyrene	Good	Good	Unknown	Fair	Fair	Good	Low
Acrylic	Good	Fair	Excellent	Good	Good	Good	Medium

We also eliminated materials that were too costly; after narrowing down to these materials, we used the cost for one of the parts for comparison:

Resin Material Cost			
Material	Material Type	Cost	Half Moon at 25
Acetal Copolymer, Black (Celcon M90 CD3068)	Resin	Low	1989.50
Acetal Copolymer, Natural (Celcon M90 CF2001)	Resin	Low	1989.50
Acrylic (PMMA), Clear (Plexiglas V052-100)	Resin	Low	1989.25
HDPE, Natural (Marlex 9006 HID)	Resin	Low	1983.50
HDPE, Natural (Unipol DMDA 8007)	Resin	Low	1986.25
LDPE, Natural (Dow LDPE 722)	Resin	Low	1987.25
LLDPE, Cherry Red UN3788 (Dowlex 2517)	Resin	Low	1986.50
LLDPE, Natural (Dowlex 2517)	Resin	Low	1986.50
PET, Black 35% Glass Mica Low Warp (Rynite 935 BK505)	Resin	Low	1992.00
PP Homopolymer, Natural (Profax 6323)	Resin	Low	1984.75
PP Homopolymer, Natural (Profax 6523)	Resin	Low	1984.00
PP Homopolymer, Purple UN55094 (Profax 6523)	Resin	Low	1984.00
PP Random Copolymer, Natural (FHR PP P5M6K-048)	Resin	Low	1984.25
TPE, Black (Santoprene 111-35)	Resin	Low	1987.25

After eliminating the materials available for the parts that required CNC manufacturing, taking into account which were not food safe and the ones that are too costly, we narrowed down to the following materials and compared the cost for the same part as the resin:

CNC Material Cost			
Material	Type	Cost	Half Moon at 25
Aluminum - Gray (Aluminum 6061-T651)	Soft metal	Low	1175.00
Aluminum - Gray (Aluminum 7075-T651)	Soft metal	Low	1225.00
Stainless Steel - Gray (Stainless Steel 316/316L)	Hard metal	Very High	4700.00
HDPE - Natural (White) (High Density Polyethylene)	Plastic	Low	725.00
PMMA - Clear (Acrylic)	Plastic	Low	850.00
PP Homopolymer - Black (Polypropylene Homopoly)	Plastic	Low	950.00
PP Homopolymer - Natural (Polypropylene Homopoly)	Plastic	Low	950.00
PP Copolymer - Natural (Polypropylene Copoly)	Plastic	Low	925.00
PVC - Gray (PVC)	Plastic	Low	825.00
UHMW - Natural (UHMW)	Plastic	Low	775.00

The material we decided to go with was 6061 aluminum for CNC machining. Aluminum is cheap and has higher weight which would make the machine rigid and keep it in place. We chose 6061 aluminum over 7075 for cost, and 7075 is zinc based which could be detrimental to health if there is accidental consumption. On the other hand 6061 is made partly of silicon, magnesium and iron, which would not be detrimental if accidental ingestion, occurs.

For molding, Acrylic (PMMA), Clear (Plexiglas V052-100), Acetal Copolymer, Black (Celcon M90 CD3068), and Acetal Copolymer, Natural (Celcon M90 CF2001) were selected. Cost was not a factor since the resin materials were about the same, but using the guide we showed above we took into account what was the strength, impact resistance, the void in thick sections etc.

9. Analytical Analysis and Structural Design

9.1 Motor Specification

To maintain simplicity of the machine, the decision was made to use a small DC gear motor to provide the torque needed to move the conveyor belt. This motor would be mounted on the side of the aluminum rails, perpendicular to the rollers of the conveyor belt. The use of bevel gears is necessary to allow the transmission of power at a 90 degree angle.

In order to be able to specify a motor based on analysis, design specifications must be introduced. To maintain the safety of the machine, it was decided to limit the pitch line velocity of the gear driving the roller to 1 inch per second. In addition to limiting the velocity, a minimum torque of 7 lb·in will be necessary to move the sandwich along the conveyor system and to be able to overcome the friction of the sandwich passing through the narrowing channel. This torque was also selected to add a safety measure so that in the motor is much less likely to stall during operation, causing possible permanent damage. The following table summarizes the design specifications:

v_t (pitch line velocity)	1 in/s
T (minimum torque)	7 lb·in
Design Factor (for stress analysis)	1.2

In addition to the design specifications from the table above, we will consider the use of a 2:1 and 3:1 gear ratio for the analysis. The following table summarizes the gear characteristics that will be used in the calculations:

	2:1 Steel Pinion	2:1 Steel Gear	3:1 Steel Pinion	3:1 Steel Gear
P_d (diametral pitch [teeth/in])	16	16	16	16
N [# of teeth]	20	40	20	60
F (face width [in])	0.312	0.312	0.312	0.312
d_p (pitch diameter [in])	1.25	2.5	1.25	3.75
Pressure Angle [°]	20	20	20	20

The following gear analysis will be conducted as per ANSI/AGMA 2003-B97 guidelines. According to these guidelines, for bevel gears, the equations for contact stress and bending stress are as follows:

Contact Stress	$S_c = \sigma_c = C_p \sqrt{\frac{W^t}{F d_p I} K_o K_v K_m C_s C_{xc}}$
Contact Strength	$S_{wc} = (\sigma_c)_{all} = \frac{S_{ac} C_L C_H}{S_H K_T C_R}$
Bending Stress	$S_t = \sigma = \frac{W^t}{F} P_d K_o K_v \frac{K_s K_m}{K_x J}$
Bending Strength	$S_{wt} = \sigma_{all} = \frac{S_{at} K_L}{S_F K_T K_R}$

Since the process of specifying a motor to meet certain criteria is an iterative process, we will begin by assuming the rpm and torque of a motor so calculations can be made. Once these calculations have been made, we can compare the results of the assumed motor to the design specifications. From this point, we are able to see what changes need to be made about the motor to satisfy the guidelines. Once the guidelines are met, we compare the optimal findings of the motor to those that are readily available for purchase on the market. Further iterations may be necessary if a motor specification turns out to be a special order, or should a different motor be found to satisfy cost requirements.

Since this process is an iterative one, the use of a spreadsheet will drastically reduce the calculation time. Before proceeding, the following table summarizes the assumed initial performance of a certain DC gear motor:

RPM	20
Torque (@ max rpm)	11.56 lb·in

Based on the performance of this motor, we can calculate the rpm and torque of the bevel gear using the following relationship:

$$H = T\omega$$

This relationship states that the power of a motor is equal to the product of torque and angular speed. To further use this relationship, we further assume that the power loss from gear friction is negligible in this case, allowing us to state that the input power is equivalent to the output power. Therefore:

$$H_{in/out} = T_{in/out}\omega_{in/out} \therefore \; T_{in}\omega_{in} = T_{out}\omega_{out}$$

This then leads to the relationship which allows us to calculate the output torque:

$$T_{out} = T_{in}\left(\frac{\omega_{in}}{\omega_{out}}\right) \; where \; the \; factor \, \frac{\omega_{in}}{\omega_{out}} \; is \; the \; gear \; ratio$$

The following table summarizes the torque output for the 2:1 and 3:1 gear ratio:

	2:1 ratio	3:1 ratio
T [lb·in]	23.12	34.68

Based on the gear ratios, we can also calculate how the angular speed changes between each gear:

	2:1 ratio	3:1 ratio
ω [rpm]	10	6.67

Now that the angular speed and torque are known for each gear, these will be the input factors for the stress analysis that follows.

For the stress analysis, various terms in the stress equations need to be addressed before calculations can be made. The following table summarizes all of the assumptions that were made when performing calculations:

Q_v	*Quality of the material*. Since we are using steel gears, we have assumed a value of 7.
R	*Gear reliability*. Assumed value of 99% (or 0.99)
N_L	*Number of cycles*. An acceptable standard to use for this is 10^6 cycles, which is our assumed value.
K_m	*Load-Distribution factor*. This value accounts for how the gears are mounted: one, both or neither as straddle-mounted. We have assumed neither (K_m = 1.25)
C_{xc}	*Crowning factor*. Accounts for wether the teeth are crowned or not. We assume uncrowned teeth (C_{xc} = 2)
C_p	*Elastic Coefficient.* For steel, this is a value of 2290.
S_{at}	*Material Bending Strength.* For steel, we assume flame or induction hardened with unhardened roots, giving a strength of 15,000 psi.

S_{ac}	*Material Contact Strength.* For steel, we assume flame or induction hardened, giving a strength of 175,000 psi.

From the table of assumptions, we can now perform the required calculations. We begin by finding the bending stresses, using the AGMA equation:

$$S_t = \sigma = \frac{W^t}{F} P_d K_o K_v \frac{K_s K_m}{K_x J}$$

The transmitted loads have been calculated and are summarized in the following table:

	2:1 Steel Pinion	2:1 Steel Gear	3:1 Steel Pinion	3:1 Steel Gear
W^t [lb]	20.82	21.13	20.08	13.45

Now that the transmitted loads are known, the remaining variables in the equation are taken from gear specifications as well as the table of assumptions. The Bending stresses for both cases are as follows:

	2:1 Pinion	2:1 Gear	3:1 Pinion	3:1 Gear
S_t [psi]	3,433	3,485	3,311	2,231

We now calculate the bending strength using the AGMA equation:

$$S_{wt} = \sigma_{all} = \frac{S_{at} K_L}{S_F K_T K_R}$$

Using a design factor of 1.2, the material strength for both cases was calculated to be 15,020 psi.

Using the following relationship, we can calculate the bending factor of safety:

$$S_F = \frac{\sigma_{all}}{\sigma} = \frac{S_{wt}}{S_t}$$

It is important to note, that when calculating the factor of safety, the material strength must be recalculated using $S_F = 1$. Based on this, the bending factor of safety is summarized in the following table:

	2:1 Pinion	2:1 Gear	3:1 Pinion	3:1 Gear
Bending Factor of Safety	5.25	5.17	5.44	8.08

We can now calculate the contact stresses by using the AGMA equation:

$$S_c = \sigma_c = C_p \sqrt{\frac{W^t}{F d_p I} K_o K_v K_m C_s C_{xc}}$$

Using the transmitted loads previously calculated, as well as the gear specifications and values from the table of assumptions, the contact stresses are as follows:

	2:1 Pinion	2:1 Gear	3:1 Pinion	3:1 Gear
S_c [psi]	65,084	46,366	63,918	30,295

Just as with the bending stress, to calculate the contact factor of safety, the material strength must be recalculated using $S_H = 1$. Based on this, the contact factor of safety is summarized in the following table:

	2:1 Pinion	2:1 Gear	3:1 Pinion	3:1 Gear
Contact Factor of Safety	4.08	5.72	4.15	8.76

Since all of the gears are not in danger of failure, the iterations can now begin. We can calculate the optimal rpm of the motor to satisfy our main design specification of 1 inch per second pitch line velocity. We can do this using the following equation:

$$v_t = \frac{\pi d_p n}{12} \quad \rightarrow \quad n = \frac{12 v_t}{\pi d_p} = \frac{12 * (5\ ft/min)}{\pi * (1.25\ in)} = 15.28\, rpm$$

From this we have determined that to meet the requirement of 1 inch per second pitch line velocity, the input of the motor needs to be approximately 15.28 rpm. Since the original assumption of 20 rpm was used to do initial calculations, we now go back and recalculate all of the values to reflect this new optimal rpm. Since a spreadsheet was used for the iteration process, by changing one number we can perform all calculations instantaneously. The following table summarized the stresses based on the optimal 15.28 rpm:

	Gear 1 (pinion)	Gear 2 (output gear)
S_t (bending stress, [psi])	**2,566**	**2,604**
S_{wt} (bending strength, [psi])	**15,020**	**15,020**
Bending FoS	**7.03**	**6.92**
S_c (contact stress, [psi])	**56,266**	**40,084**
S_{wc} (contact strength, [psi])	**221,060**	**221,060**
Contact Fos	**4.71**	**6.62**

Table 2 - Stress Calculations based on rpm = 15.28 rpm (2:1 ratio)

	Gear 1 (pinion)	Gear 2 (output gear)
S_t (bending stress, [psi])	**2,475**	**1,666**
S_{wt} (bending strength, [psi])	**15,020**	**15,020**
Bending FoS	**7.28**	**10.82**
S_c (contact stress, [psi])	**55,258**	**26,181**
S_{wc} (contact strength, [psi])	**221,060**	**221,060**
Contact Fos	**4.80**	**10.13**

Table 3 - Stress Calculations based on rpm = 15.28 (3:1 ratio)

It is important to note that because of this iterative process, we have been able to increase the factor of safety for all gears in both cases by optimizing the motor speed of operation. Based on the calculations, the final recommended motor specs are as follows:

Motor Specifications	
Operating RPM	~15.28
Torque [lb·in]	11.56

While those conditions represent the optimal motor specifications, it does not necessarily mean a cost effective motor will be found to meet these requirements. The market must be searched to find motors that closely meet these requirements while being cost effective. Should a different motor be found, stress analysis must be performed once more since input criteria has been changed.

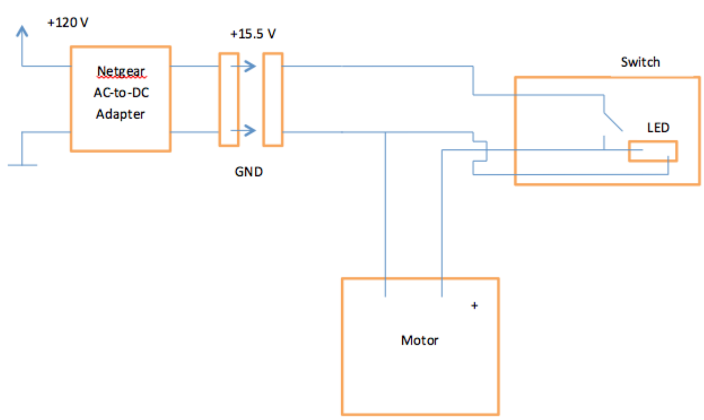
9.2 Motor Circuit Design

Now that the ideal motor has been chosen, initial testing must be performed before the design of the circuit to connect the switch, power source and motor can begin.

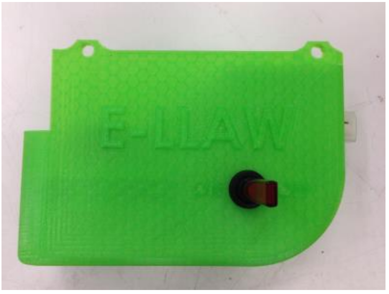
The first test was to determine the voltage that is output from the selected source. For our source, we decided to use an old Netgear AC-to-DC power adapter that was formerly used to power a broadband router. The end was spliced and fitted with a new interface to make attaching it to the motor cover safe and easy. Once the splicing was done and fitted with the proper hardware, a multi-meter was used to measure the output voltage of the adapter. According to the labeling on the adapter, the output should be 12V 1A. After measuring the actual output, it was determined to be 15.5V.

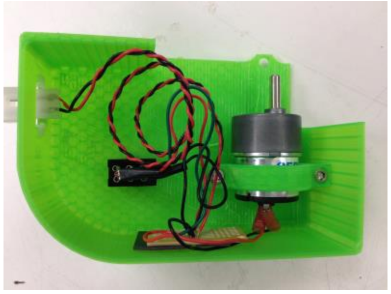
The second test was to effectively measure the amperage the motor used at maximum performance. To do this, we attached a 1kg mass to the motor shaft at a distance of 6”. This mass was enough to be able to test the motor’s maximum output without causing it to stall. Once the motor was fitted with the test mass, the multi-meter was connected in series with the motor using the modified adapter and then turned on to measure the amperage. Video was taken of this experiment, and from playback, the max amperage measured was 340 mA. This amperage is under the 500 mA stall current according to the motor data sheet, and well below the maximum output of the adapter of 1A.

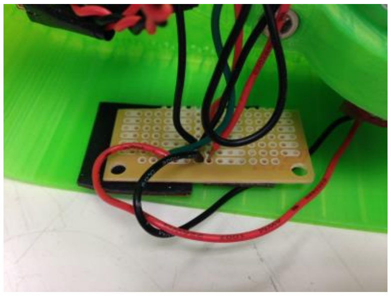
Once these two tests were conducted, the circuit design could begin since all voltage and current sources are known. The circuit design was to be simple: connect the motor to the modified power source and use an LED switch to turn the motor on and off. The following diagram represents the circuit schematic:



From the schematic, a physical circuit was soldered with all the mentioned components. The following are pictures of the completed circuit:

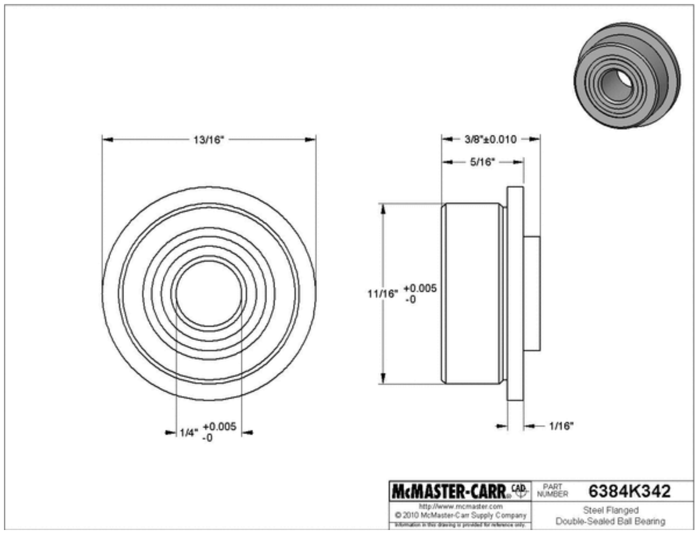






9.3 Bearing Analysis

Our bearing selection was made based on the dimensions needed to fit the specifications of the design we came up with. The design was to be small and made to fit on an existing sub shop to facilitate the integration of the machine. The need for a conveyor belt meant that we needed bearings, a motor, and shafts. After selecting the shafts to be ¼" in diameter, we went out and found bearings to fit them. Also the bearings were flanged for easy assembling and dissembling for cleaning. The bearings we selected were also sealed and food safe. They are shown below:



The bearings selected were matched to fit the design; the next step was to conduct analysis to make sure that they will last for the rated life of the machine. The first step was to check the catalog dynamic load rating and comparing it to that of our design. This rating is calculated by using the equation below:

$$C_{10} \doteq a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}} \right]^{1/a} \qquad R \geq 0.90$$

We collected the known values needed to complete this calculation; they are shown below:

Known Factors			
af	1.2	Ld[hours]	27000
Xo	0.02	n[revs]	20
sigma	4.459	Fr	10
a	3	Fa	1
b	1.483	V	1.2
R	0.9	X	1
Lr	1000000	Y	0

Where:

a_f = Application factor

R = reliability

x_0 = guaranteed, or “minimum,’’ value of the variate

θ = characteristic parameter corresponding to the 63.2121 percentile value of the variate

b = shape parameter that controls the skewness

a = 3 for ball bearings

L_r = Rating Life

L_d = Guaranteed life hours

n = Revolutions per minute

F_r = Radial Load [lb]

F_a = Axial Load [lb]

V = Rotation factor (outer rings rotates)

X = Ordinate intercept

Y = Slope of the line

The calculated factors were acquired by using the following equations:

$$F_e = X_i V F_r + Y_i F_a \qquad x_D = \frac{L_D}{L_R} = \frac{60 \mathcal{L}_D n_D}{L_{10}}$$

The final calculated factors needed are shown below:

Calculated	
Xd	32.4
Fd	12

F_d = Equivalent load [lb]

X_d = Life measure dimensionless variate, L/L10

Most of these factors help take into account overload and uncertainty on the loads applied to the bearings. The assumptions of the axial and radial load are also over estimated at 1lb and 10 lb respectively. For the life of the machine we estimated the amount of hours a restaurant is open for 5 years, and for the revolutions we used the maximum motor output without load (20 rpm).

After calculating the dynamic load rating of the bearing receiving the most force, we found the load needed or to be exceed was **46.56 lbf**. Since the bearings bought were rated at **255 lbf** our factor of safety was **5.48**. This meant the selected bearings exceed the need load rating.

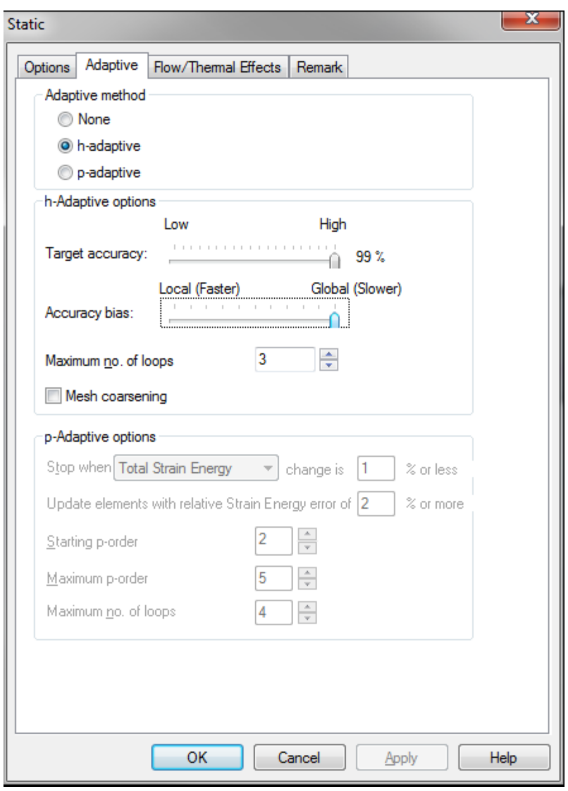
9.4 Failure Mode & Effects Analysis (FMEA)

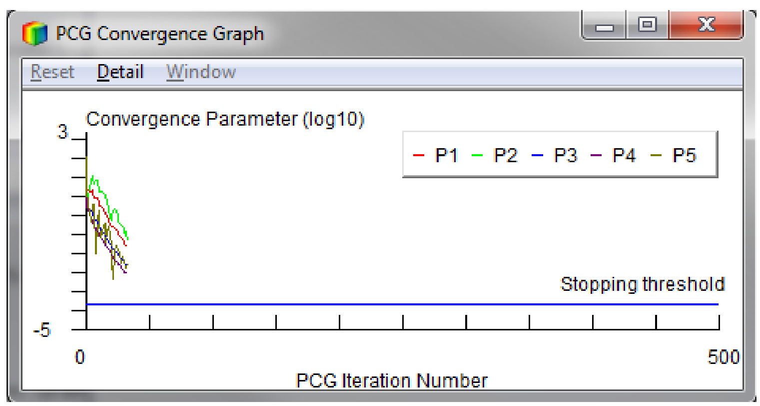
This analysis is conducted to aid in finding faults in product design. This process involves identifying components that can fail, and assess the severity if failure should occur. In addition to these steps, for the components that have a high likelihood of failure, suggestions for maintenance and prevention are highly recommended to ensure early detection. Based on the FMEA that we performed, the electrical components are more likely to fail, mainly being the motor, switch and printed circuit board (PCB).

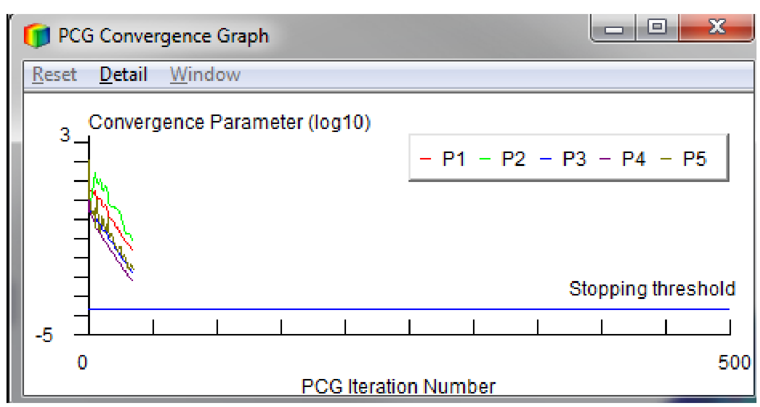
Please refer to Appendix F which contains the excel worksheet used to perform this analysis.

9.5 Structural Simulation

SolidWorks software was used for the analysis of the railings. With an applied load of **10 lbf** per item, a standard "fixed geometry" static fixture located at the bottom face of the railings, an h-adaptive convergence study was applied, h-adaptive is a method of convergence study that caters the meshing to each individual shape. This convergence method used 3 loops and a target accuracy of 99% and maximum global accuracy biased. We were able to show definitively that the rail could support the needed loads with a high safety factor. A screenshot of the parameters used and graphs of the convergence graphs are shown below. These graphs further prove the accuracy of the study because it eliminates divergence between the mesh studies.

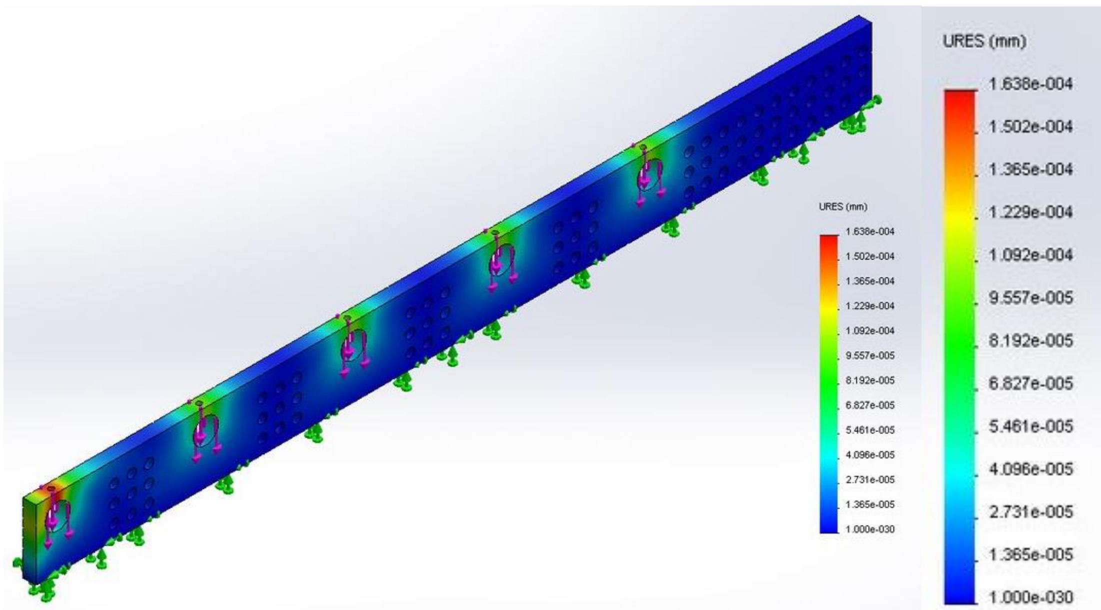




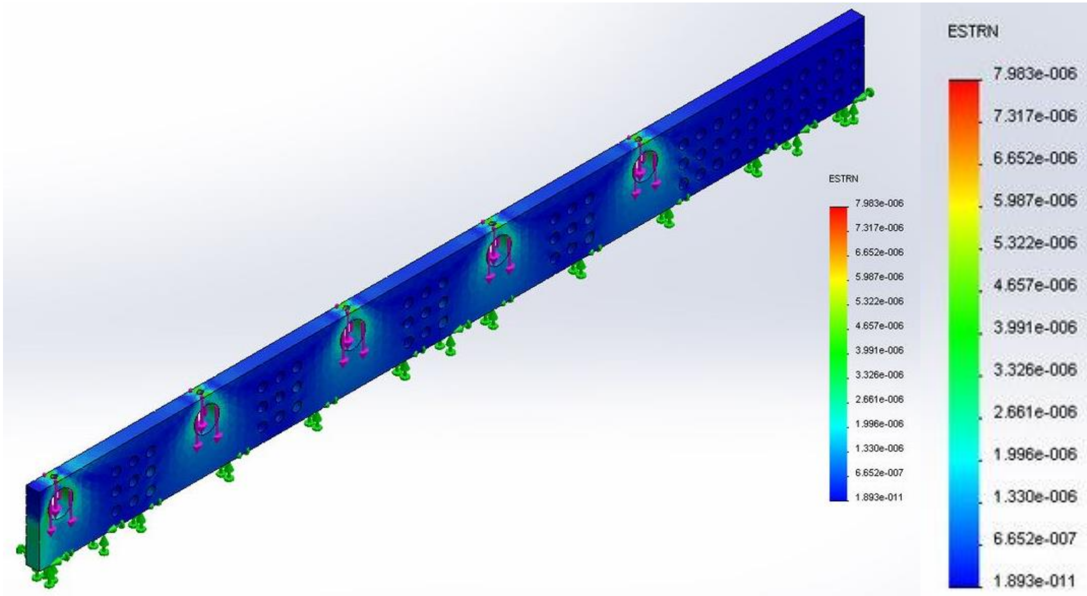


The threshold lines show the minimal allowed convergence, while the color lines show a given system specified parameter as it approaches the threshold line. Once the parameters intercept this line analysis convergence has been completed, this means that this is the most optimal mesh size. This signifies a plateau region within the meshing parameters, which results in a more accurate simulation.

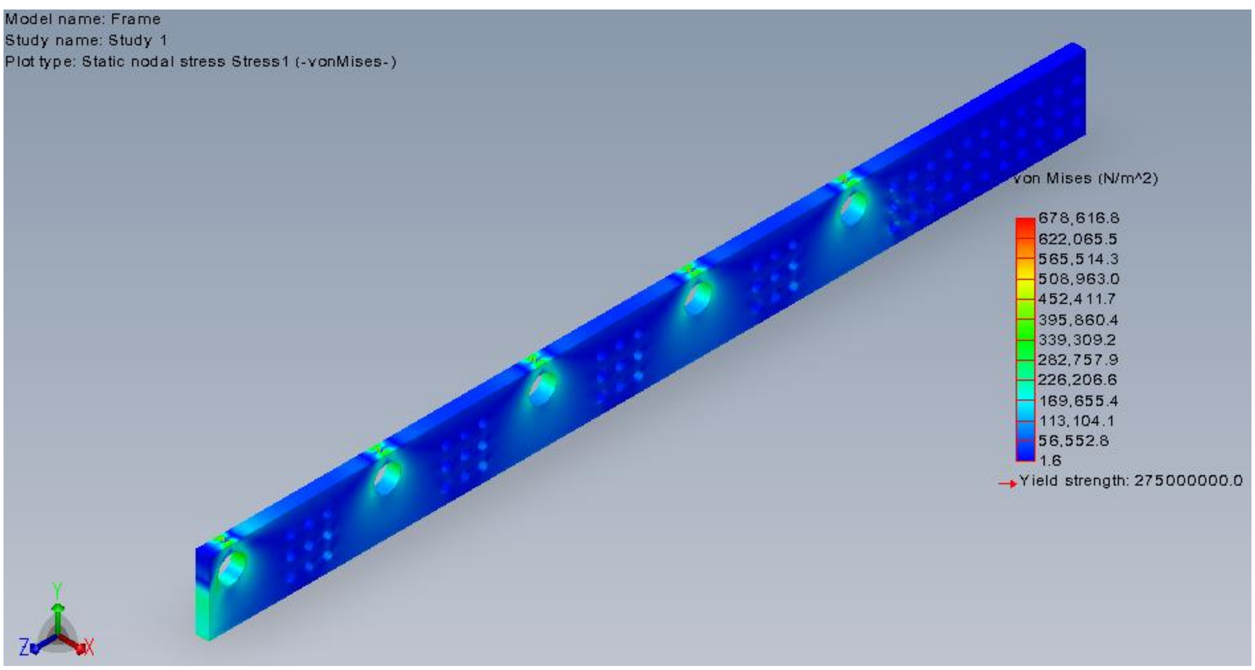
Aluminum 6061 was the material of choice for the railings and the shafts. The maximum yield strength of this material is 275 Mpa. The displacement, maximum stress, and safety factor results are shown below:



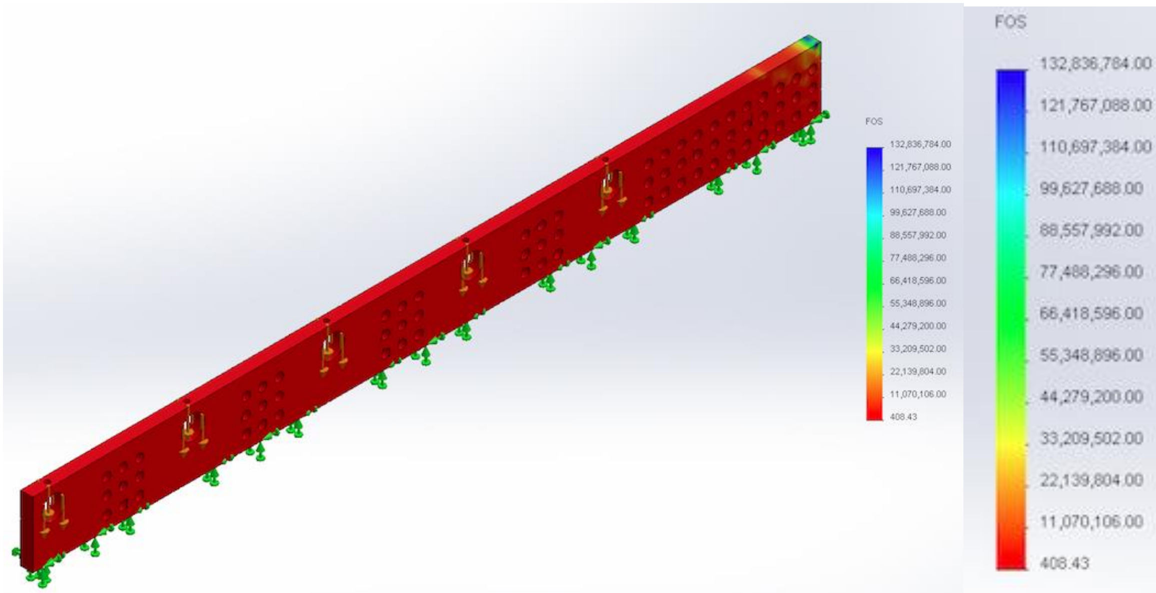
The maximum displacement is located at the red area and it measures at 163 μm.



The maximum strain measures in at 7.98 μ units

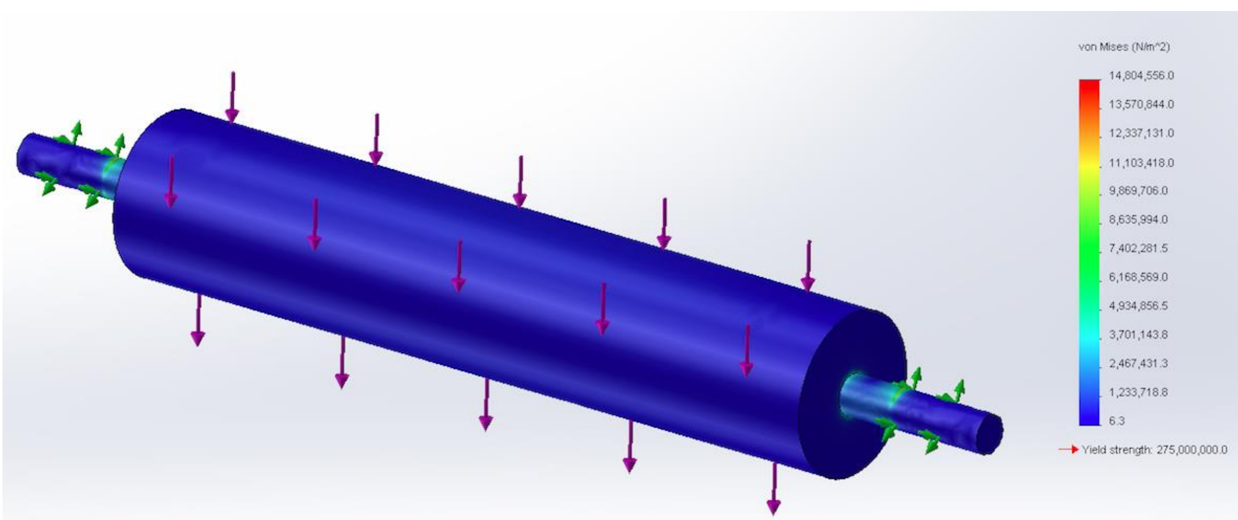


The maximum Von Mises stress measured at 678 Kpa.

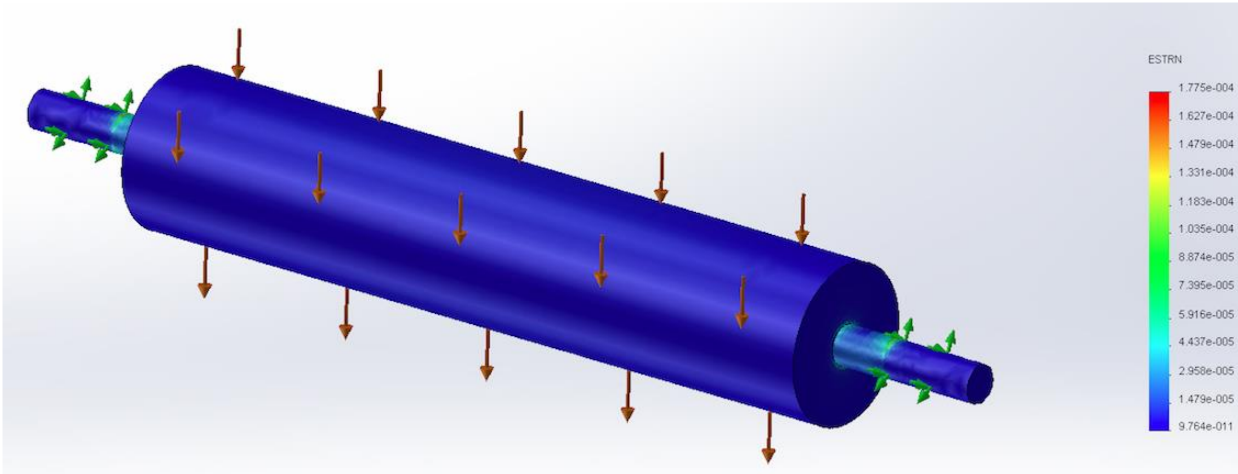


The factor of safety study yielded one of 408, which is extremely high and it boosts our confidence on the design and material selection.

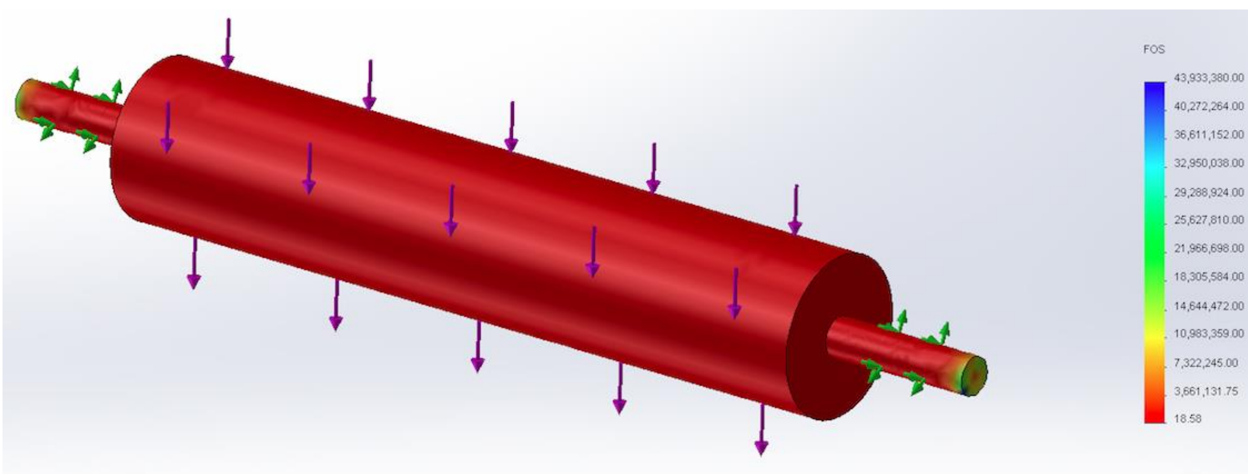
Following the same simulations we ran the studies for the shaft.



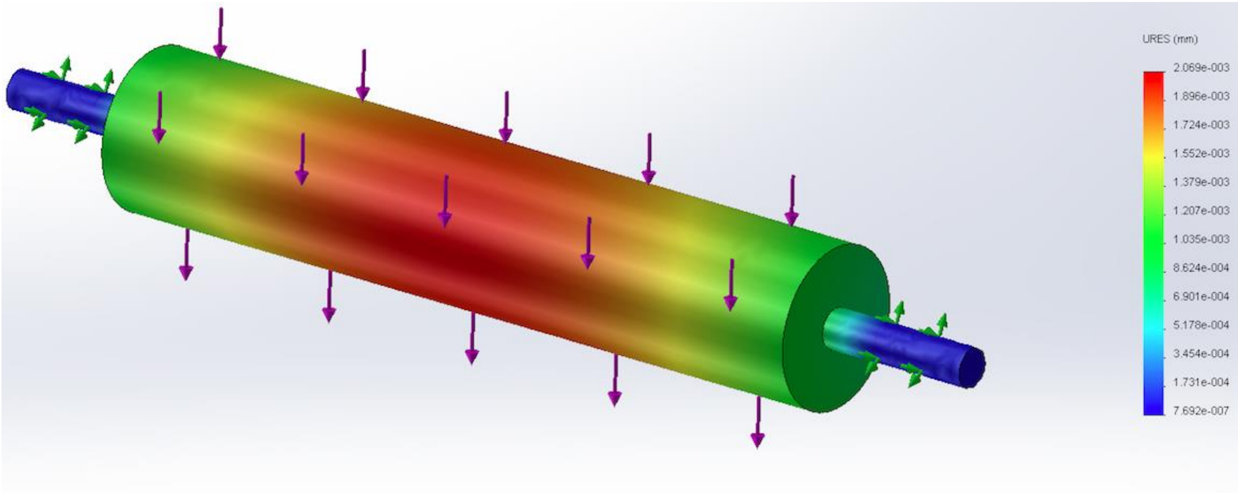
The maximum Von Mises stress was measured at 14 Mpa.



For the strain study the maximum value was measured at 177 μ units. A value small enough that it could be neglected.

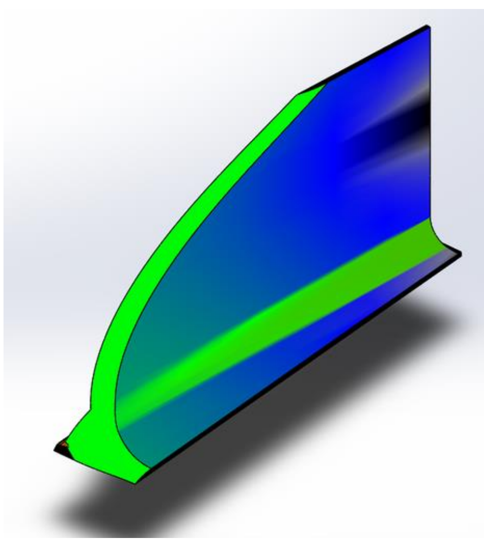


The safety factor was one of 18.58, a very high value.

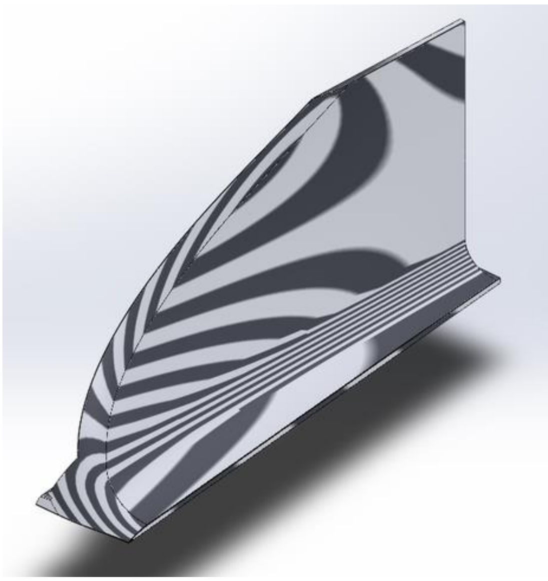


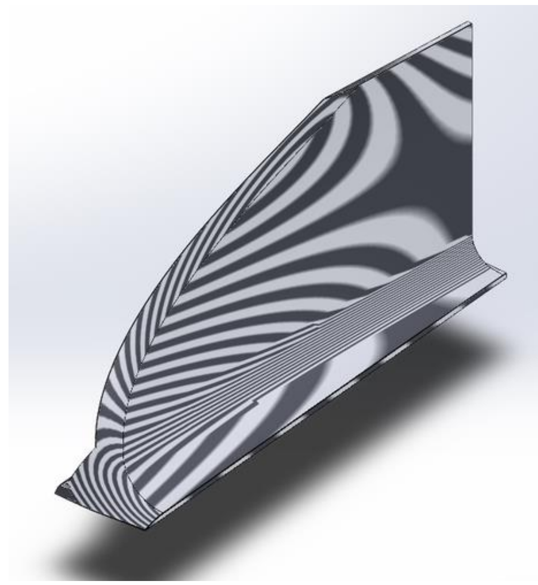
The displacement could also be neglected since the value was very small, measured at 2.069 μm.

A curvature analysis was done for the folding channels. The channels needed to have curvature to show that a sub sandwich can fit in and be folded, but too much curvature would be detrimental to the design. Color coded and a zebra patterned studies are shown below:

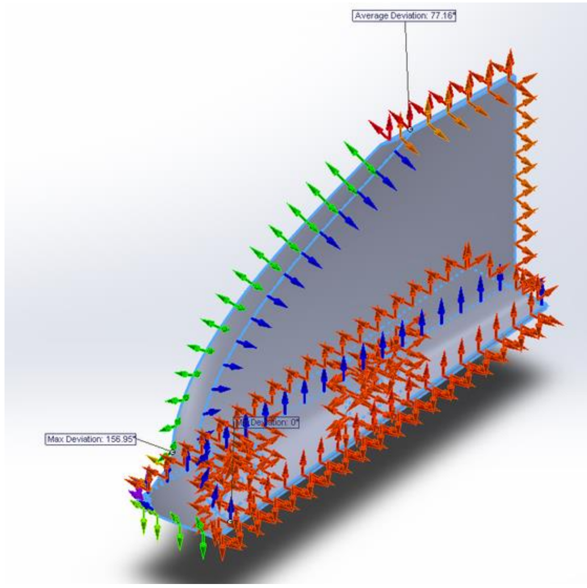


The green color shows where the curvature is more prominent. It is also important to notice that less curvature will help simplify the manufacturing of the part.





Also by doing a zebra patterned curvature study we can visualize how difficult it would be to machine the part, shown by where the lines are the closest.



The study above shows deviation analysis of the folding channel. Maximum deviation is 157 degrees, Average deviation is 77.16 degrees, and minimum deviation is 0 degrees. After prototyping with different 3D printed channels we found this deviation to be optimal for the folding motion.

10. Cost Analysis

10.1 Component Estimates

The parts were separated into 2 different types of manufacturing, CNC machining and molding. The parts that would be molded with their respective prices from "ProtoQuote" are shown in the table below:

ProtoQuote Quote					
Part Name:	Quantity:	Material:	Total Price:	Price Per Unit	Tooling Cost
Cover (Rev2)	100	HDPE, Natural (Marlex 9006 HID)	$8,551.00	$2.91	$8,260
Guide Plate (1)	100	Acrylic (PMMA), Clear (Plexiglas V052-100)	$7,912.00	$5.17	$7,395
Guide Plate (2)	100	Acrylic (PMMA), Clear (Plexiglas V052-100)	$7,907.00	$5.17	$7,390
Cutting Block	100	HDPE, Natural (Marlex 9006 HID)	$9,104.00	$6.99	$8,405
Total			$33,474.00	$20.24	$31,450

The parts that would be CNC machined are shown in the table below:

First Cut Quote				
Part Name:	Quantity:	Material:	Total Price:	Price Per Additional Unit
Frame (Rev3)	100	Aluminum - Gray (Aluminum 6061-T651)	$52,100.00	$521.00
Shaft	100	Aluminum - Gray (Aluminum 6061-T651)	$13,600.00	$136.00
Half Moon	100	Aluminum - Gray (Aluminum 6061-T651)	$4,400.00	$44.00
Total			$70,100.00	$701.00

Chinese CNC machining:

Xiamen Xinchuanghui Industry & Trade Co., Ltd.				
Part Name:	Quantity:	Material:	Total Price:	Price Per Additional Unit
Frame (Rev3)	100	Aluminum - Gray (Aluminum 6061-T651)	$11,210.00	$112.10
Shaft	100	Aluminum - Gray (Aluminum 6061-T651)	$3,110.00	$31.10
Half Moon	100	Aluminum - Gray (Aluminum 6061-T651)	$1,283.00	$12.38
Total			$15,603.00	$155.58

Total price adding the other parts:

Item:	Vendor:	Country of Origin:	Comment:	Cost:
1	McMaster-Carr	USA	Misc Nuts and Bolts	$12,269.28
2	First Cut	USA	Frame (Rev3)	$52,100.00
3	First Cut	USA	Shaft	$13,600.00
4	First Cut	USA	HalfMoon	$4,400.00
5	First Quote	USA	Cover (Rev2)	$8,551.00
6	First Quote	USA	Guide Plate (1)	$7,912.00
7	First Quote	USA	Guide Plate (2)	$7,907.00
8	First Quote	USA	Cutting Block	$9,104.00
9	Warco Biltrite	USA	Belt	$1,125.60
10	ServoCity	USA	Motor	$2,499.00
11	ServoCity	USA	Coupler	$499.00
			Total	$119,966.88
			Price Per Unit	$1,199.67

As seen, the price per unit is about $1,200. This price is true for when the parts are bought in a bulk of 100.

10.2 Funding and Sponsors

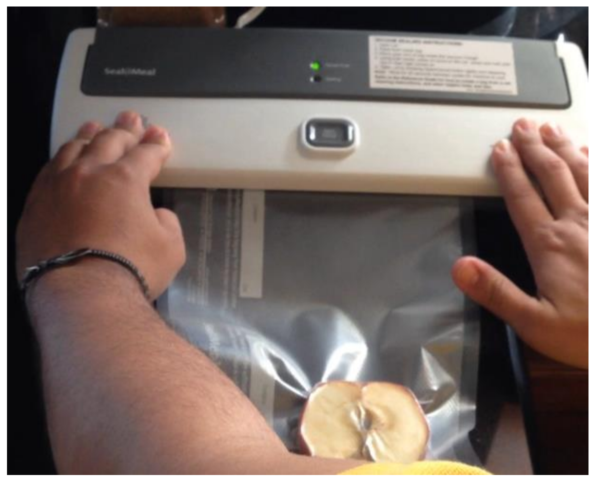
Mr. Norman Wartman is our project sponsor. He estimates the cost to be about $5,000, broken down in the following way: $1000 short term, $1,000 Mid Term, and $3,000 long term. A short-term review will provide alternative designs, and options with pros and cons. A midterm review will include preferred alternatives, final design, and cost to build. Finally out long term goal is to build the machine, test it and provide a final report, including lessons learned

10.3 Man-Hour

The total hours spent by the group were about 500. The detailed log of these hours can be found in appendix C.

11. Prototype System

The first idea for the design was included vacuum sealing technology. After testing this technology we soon discovered the pressure of the pumps to be too high, this translated into a ruined sandwich once the bag was fully vacuumed. Another issue we encounter was that the vacuum took a long time, about 20 to 30 seconds to vacuum seal a small sample. A linear increase in time will be encountered if a sandwich the size of the ones we are aiming to wrap was to be vacuumed. Also we were afraid that food would be pulled by the pump and create cross contamination and difficulty in sanitation. The pictures below show the result of a few tests ran.

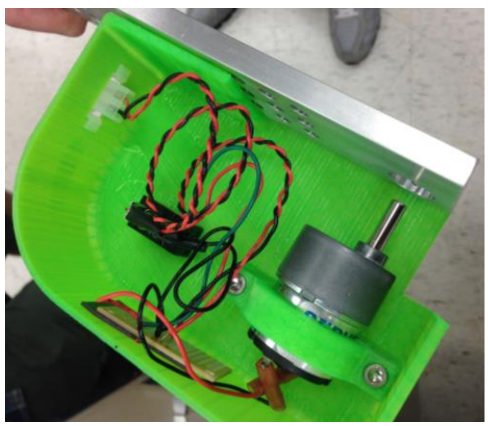


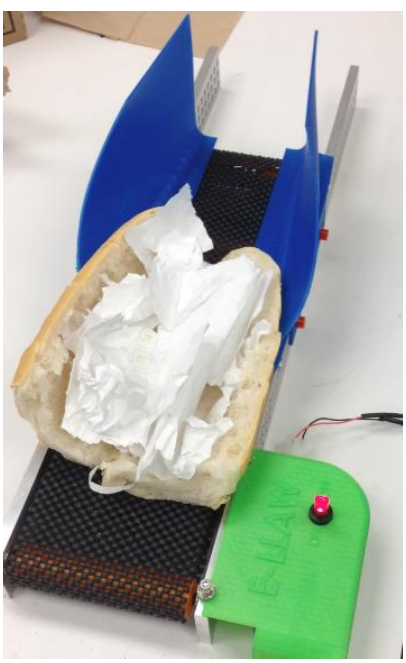
We decided to consider heat sealing alone. Heat sealing is used for its simplicity and cost; the idea was to automate the sealing actions and have a fully automated folding and wrapping machine that will free up the employees to focus on other tasks.

A conscious decision was made to focus on construction of the primary folding mechanism. The railings of the folding mechanism would permit the addition of the cutting and bagging mechanisms at a latter time.

To achieve the folding action new components were designed and because of time and money constraints a rapid prototyping machine was selected, the MakerBot Replicator 2 was chosen for its size, affordability and ease of use. Using the 3d printer we iterated the components until we had measurements that will effectively fold the sub. Furthermore the use of the MakerBot was used to prototype other parts like a motor cover and shaft attachments, that process would have traditionally taken months and thousands of dollars to achieve. With the 3d printer it took hours to make iterations of the components, instead of taking days and more money when done through a manufacturer.

An example of one of the parts that we prototype was the motor cover, a picture of it is shown below, we had to printed a couple times before getting the right fit, a process that would have taken a lot longer through a manufacturer.





When the parts were finalized through 3D printed, we were able to send the dimensions to manufacturer to get the quotes found in appendix B.

In the picture to the left the 3d printed folding channels, motor cover and shaft attachments are shown. The railings, bearings, shafts, screws motor, and circuit are the actual ones that would be used for the machine in the market. But it is important to notice that the belt is not food safe, it was also chosen to be cost effective since we would have to adjust different lengths for testing. These components were the result of multiple iterations and the ones that gave us the dimensions used for the quotes in the appendix section.

12. Testing

12.1 Folding Test

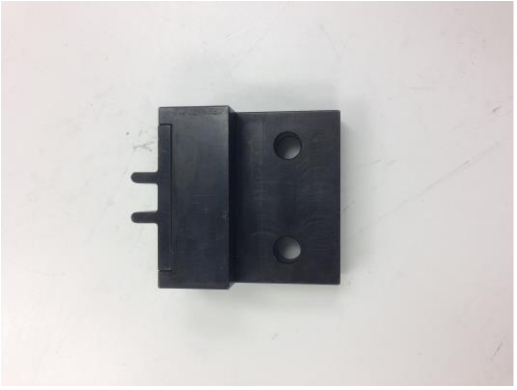
During the testing phase of our design process, a nominal specimen was used. The specimen measured roughly 6in in length and we added weight to simulate a real sandwich. We estimated the weight to be about 1.5 lbs. Since the main goal was to fold the sandwich we measured the sub at its longest width and ran it through the machine. The picture of it before it went into the machine is shown below:

The width of the pre-folded sub measured at 4.95 in. we then ran it through the machine and measured again at the spot of the original measurement.

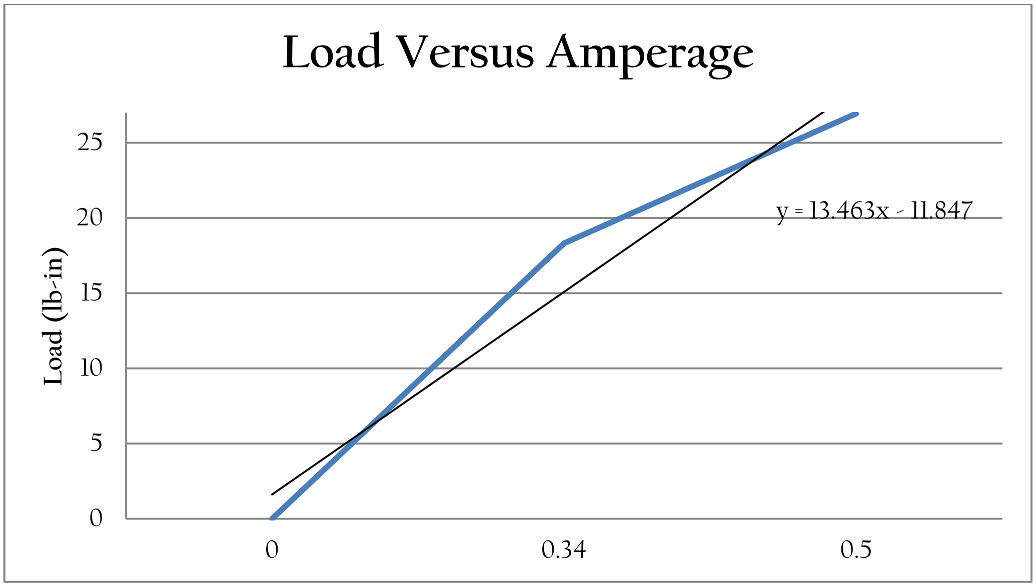
The new measurement was 1.8 inches, meaning that we achieved a reduction in size of 3.15 in. The after-folding picture is n the left.

12.2 Motor Test

To test the motor's capabilities and endurance a simple test was devised using a known weigh at a known distance. A 3.59 pound Chromemoly at a distance of 5.1 in from the center which caused an 18.309 in-lbs, while only drawing 340mA.



While the motor is rated for a stall current of 500mA. This means that if a linear current draw is assumed, the motor selected would stall at a 26.925 lb-in or a 5.279 pound at a 5.1 in.



With this data the conclusion can be stated that the motor selection is more than accurate because at our distance the motor can take a lot more than what we are working with.

13. Conclusion

This project was a multi-faceted assignment that challenged us in many different aspects. Challenges From Mechanical design and components, to electrical wiring and circuit design were necessary in addition to the various business components. Teamwork and time management were also essential to the success of the project. Another Challenging aspect of this project was the fact that a product development was to be performed in less than 6 months, as opposed to the normal minimum 18 months in industry given a full team of engineers and a larger budget.

This project also helped us understand that engineering design is a highly iterative process. the use of rapid prototyping drastically aids in making this process more efficient. The ability to 3D print parts within a few hours is much more cost effective and more reliable than outsourcing the parts with a much greater turnaround time.

For our prototype we iterated the components many times to optimize a working model. From this working model, we were able to select materials that meet the criteria of our design. With this information, we were able to further refine our design while maintaining our design criteria, mainly being cost and safety.

After we achieved our first goal of folding the sub, we took the dimensions of the 3D printed components and had them evaluated for cost and acquired estimates for manufacturing. These quotes are found in the appendix section.

Our prototype achieves the task of folding a sub, and it remains modular for future additions.

14. Appendix A – FDA Regulations

U.S. Department of Health and Human Services – Food and Drug Administration

When it comes to dealing with food, very strict guidelines and regulations must be followed to ensure the health and safety of the consumer. For this reason, we deemed it paramount to research the Food and Drug Administration (FDA) regarding food grade materials for our final design. The following represents the expectations the FDA has for anyone or anything dealing with food, and contains direct quotations from the U.S. Public Health Service Food Code.

Multiuse 4-101.11 - Characteristics

"Materials that are used in the construction of UTENSILS and FOOD-CONTACT SURFACES of EQUIPMENT may not allow the migration of deleterious substances or impart colors, odors, or tastes to FOOD and under normal use conditions shall be: P

(A) Safe; P

(B) Durable, CORROSION-RESISTANT, and nonabsorbent;

(C) Sufficient in weight and thickness to withstand repeated WAREWASHING;

(D) Finished to have a SMOOTH, EASILY CLEANABLE surface; and

(E) Resistant to pitting, chipping, crazing, scratching, scoring, distortion, and decomposition." [1]

Multiuse 4-101.12 – Cast Iron Use Limitation

"(A) Except as specified in ¶¶ (B) and (C) of this section, cast iron may not be used for UTENSILS or FOOD-CONTACT SURFACES of EQUIPMENT.

(B) Cast iron may be used as a surface for cooking.

(C) Cast iron may be used in UTENSILS for serving FOOD if the UTENSILS are used only as part of an uninterrupted process from cooking through service.” [1]

Multiuse 4-101.13 – Lead Use Limitation

“(A) Ceramic, china, and crystal UTENSILS, and decorative UTENSILS such as hand painted ceramic or china that are used in contact with FOOD shall be lead-free or contain levels of lead not exceeding the limits of the following UTENSIL categories:

UTENSiL Category	Ceramic Article Description	Maximum Lead MG/L
Beverage Mugs, Cups, Pitchers	Coffee Mugs	0.5
Large Hollowware (excluding pitchers)	Bowls > 1.1 Liter (1.16 Quart)	1
Small Hollowware (excluding cups & mugs)	Bowls < 1.1 Liter (1.16 Quart)	2.0
Flat TABLEWARE	Plates, Saucers	3.0

(B) Pewter alloys containing lead in excess of 0.05% may not be used as a FOOD-CONTACT SURFACE. P

(C) Solder and flux containing lead in excess of 0.2% may not be used as a FOOD-CONTACT SURFACE.” [1]

Multiuse 4-101.14 – Copper Use Limitation

“(A) Except as specified in ¶ (B) of this section, copper and copper alloys such as brass may not be used in contact with a FOOD that has a pH below 6 such as vinegar, fruit JUICE, or wine or for a fitting or tubing installed between a backflow prevention device and a carbonator. P

(B) Copper and copper alloys may be used in contact with beer brewing ingredients that have a pH below 6 in the prefermentation and fermentation steps of a beer brewing operation such as a brewpub or microbrewery.” [1]

Multiuse 4-101.15 – Galvanized Metal Use Limitation

“Galvanized metal may not be used for UTENSILS or FOOD- CONTACT SURFACES of EQUIPMENT that are used in contact with acidic FOOD. P” [1]

Multiuse 4-101.16 – Sponges Use Limitation

“Sponges may not be used in contact with cleaned and SANITIZED or in-use FOOD-CONTACT SURFACES.” [1]

Multiuse 4-101.17 – Wood Use Limitation

“(A) Except as specified in ¶¶ (B), (C), and (D) of this section, wood and wood wicker may not be used as a FOOD-CONTACT SURFACE.

(B) Hard maple or an equivalently hard, close-grained wood may be used for:

(1) Cutting boards; cutting blocks; bakers' tables; and UTENSILS such as rolling pins, doughnut dowels, salad bowls, and chopsticks; and

(2) Wooden paddles used in confectionery operations for pressure scraping kettles when manually preparing confections at a temperature of 110oC (230oF) or above.

(C) Whole, uncut, raw fruits and vegetables, and nuts in the shell may be kept in the wood shipping containers in which they were received, until the fruits, vegetables, or nuts are used.

(D) If the nature of the FOOD requires removal of rinds, peels, husks, or shells before consumption, the whole, uncut, raw FOOD may be kept in:

(1) Untreated wood containers; or

(2) Treated wood containers if the containers are treated with a preservative that meets the requirements specified in 21 CFR 178.3800 Preservatives for wood." [1]

Multiuse 4-101.18 – Nonstick Coatings Use Limitation

"Multiuse KITCHENWARE such as frying pans, griddles, saucepans, cookie sheets, and waffle bakers that have a perfluorocarbon resin coating shall be used with nonscoring or nonscratching UTENSILS and cleaning aids." [1]

Multiuse 4-101.19 – Nonfood-Contact Surfaces

"NonFOOD-CONTACT SURFACES of EQUIPMENT that are exposed to splash, spillage, or other FOOD soiling or that require frequent cleaning shall be constructed of a CORROSION-RESISTANT, nonabsorbent, and SMOOTH material." [1]

Single-Service and Single-Use 4-102.11

"Materials that are used to make SINGLE-SERVICE and SINGLE-USE ARTICLES:

(A) May not:

(1) Allow the migration of deleterious substances, P or

(2) Impart colors, odors, or tastes to FOOD; and

(B) Shall be:

(1) Safe, P and

(2) Clean.” [1]

Cleanability 4-202.11 Food-Contact Surfaces

“(A) Multiuse FOOD-CONTACT SURFACES shall be: (1) SMOOTH; Pf

(2) Free of breaks, open seams, cracks, chips, inclusions, pits, and similar imperfections; Pf

(3) Free of sharp internal angles, corners, and crevices; Pf

(4) Finished to have SMOOTH welds and joints; Pf and

(5) Except as specified in ¶ (B) of this section, accessible for cleaning and inspection by one of the following methods:

(a) Without being disassembled, Pf

(b) By disassembling without the use of tools, Pf or

(c) By easy disassembling with the use of handheld tools commonly available to maintenance and cleaning personnel such as screwdrivers, pliers, open-end wrenches, and Allen wrenches. Pf

(B) Subparagraph (A)(5) of this section does not apply to cooking oil storage tanks, distribution lines for cooking oils, or BEVERAGE syrup lines or tubes.” [1]

Functionality 4-204.15 Bearings and Gear Boxes, Leakproof

“EQUIPMENT containing bearings and gears that require lubricants shall be designed and constructed so that the lubricant cannot leak, drip, or be forced into FOOD or onto FOOD- CONTACT SURFACES.” [1]

Appendix B – Quotes

WARCO® BILTRITE®
ISO 9001:2008 Certified

Quotation

Quote#: 113879
Date: 4/02/14
Time: 12.25.26
By: Ron Damore

WARCO Tel: (714) 532-3355
WARCO Fax: (714) 532-2238
BILTRITE Tel: (800) 245-8748
BILTRITE Fax: (662) 837-2903

Visit our webstore at warco.com

Quoted To

Company: FIU DEVELOPMENT GROUP
Address:

FLORIDA

RFQ:
Telephone:
Fax:
Attention: OTAVA
Email: otava001@fiu.edu

Sales Contact

Name: Ron Damore
Telephone: 617-846-8470
Email: rdamore@warco.com

Shipment Info and Lead Time

Lead Time: PROD 4 WKS ARO
FOB: Ripley, MS

3,000 lb shipments of sheet and matting roll goods qualify for FREE FREIGHT
(Excludes extruded and molded products)

PLEASE REFERENCE OUR QUOTATION NUMBER WHEN PLACING ORDER

Item	Description	Quantity	Price
1	1/8"X 24"X 80FT BLK GEN.PURP.SANTOPRENE 64D WARCO 101-M-64 NON STOCK ITEM MINIMUM WIDTH 24" CUSTOMER TO SLIT MATERIAL TO 6" MINIMUM ORDER QTY=500LBS/APPROX.400LFT+/-10" SHIPPING POINT-RIPLEY,MS This quotation is valid for 30 days. ** ±10% Manufacturing Variance Actual quantity delivered may vary ±10% due to manufacturing variances. Invoice total will reflect actual quantity delivered. Please visit www.warco.com/terms for our Terms and Conditions of Sale. **	MIN 400 LFT	14.07/LFT

Form WXQ0120 Rev E Date: 06/20/13

Xiamen Xinchuanghui Industry & Trade Co., Quotation

215# TianFeng Road,
North of Jimei industrial ,Xiamen 0592-5236671

TO:
FIU Development Group
10555 W Flagler St
Miami, FL 33174

SHIPPED TO:
Same

INVOICE NUMBER	536524
INVOICE DATE	March 14, 2014
OUR ORDER NO.	726278
YOUR ORDER NO.	1
TERMS	
SALES REP	Alice Huang
SHIPPED VIA	DHL
F.O.B.	
PREPAID or COLLECT	

QUANTITY	DESCRIPTION	UNIT PRICE	AMOUNT
100	Frame Rev3	112.10	$11,210.00
100	HalfMoon	12.38	1,238.00
100	Shaft	31.10	3,110.00
		SUBTOTAL	15,558.00
			PAY THIS AMOUNT

The following was added to your cart: (50) (10.05.02) 20 RPM Gearmotor (RZ12-150-20RPM)

QTY	PRODUCT	STATUS	UNIT PRICE	LINE TOTAL
100	**(10.05.02) 20 RPM Gearmotor (RZ12-150-20RPM)** Product # 638174		$24.99 $0.00 Discount	**$2499.00** **$0.00 Discount**

update cart

Empty the cart

Continue Shopping

Discount: $0.00

Subtotal: $2499.00

Discount code: Apply How do I get a discount code?

COMODO SECURE

Secure Checkout

QTY	PRODUCT	STATUS	UNIT PRICE	LINE TOTAL
100	**(10.05.02) 20 RPM Gearmotor (RZ12-150-20RPM)** Product # 638174		$24.99 $0.00 Discount	**$2499.00** **$0.00 Discount**
100	**(12.12.04) 1/4 inch to 1/4 inch Set Screw Shaft Coupler** Product # 625104		$4.99 $0.00 Discount	**$499.00** **$0.00 Discount**

update cart

Empty the cart

Continue Shopping

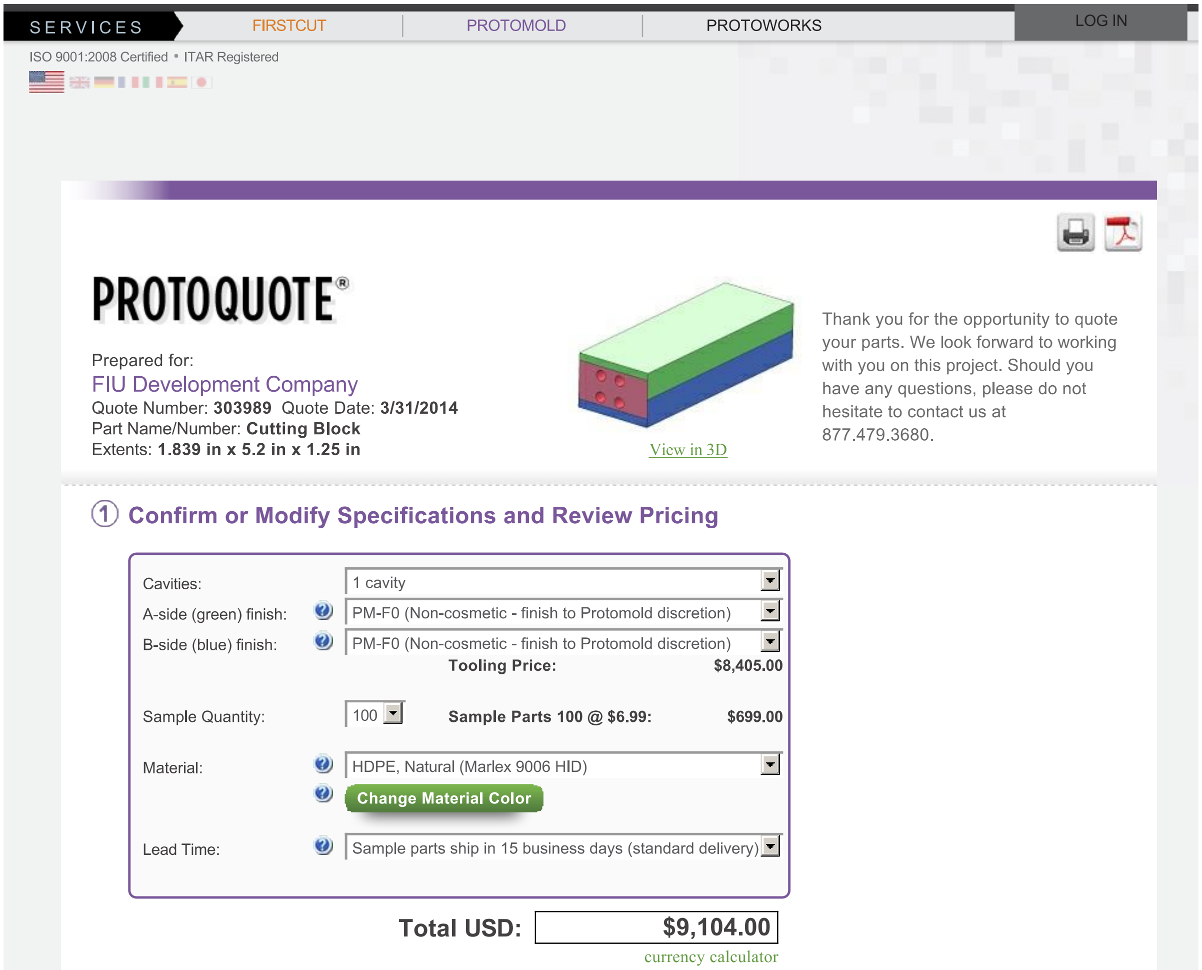
Discount: $0.00

Subtotal: $2998.00

Discount code: Apply How do I get a discount code?

COMODO SECURE

Secure Checkout



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PROTOQUOTE®

Prepared for:
FIU Development Company
Quote Number: **303989** Quote Date: **3/31/2014**
Part Name/Number: **Cutting Block**
Extents: **1.839 in x 5.2 in x 1.25 in**

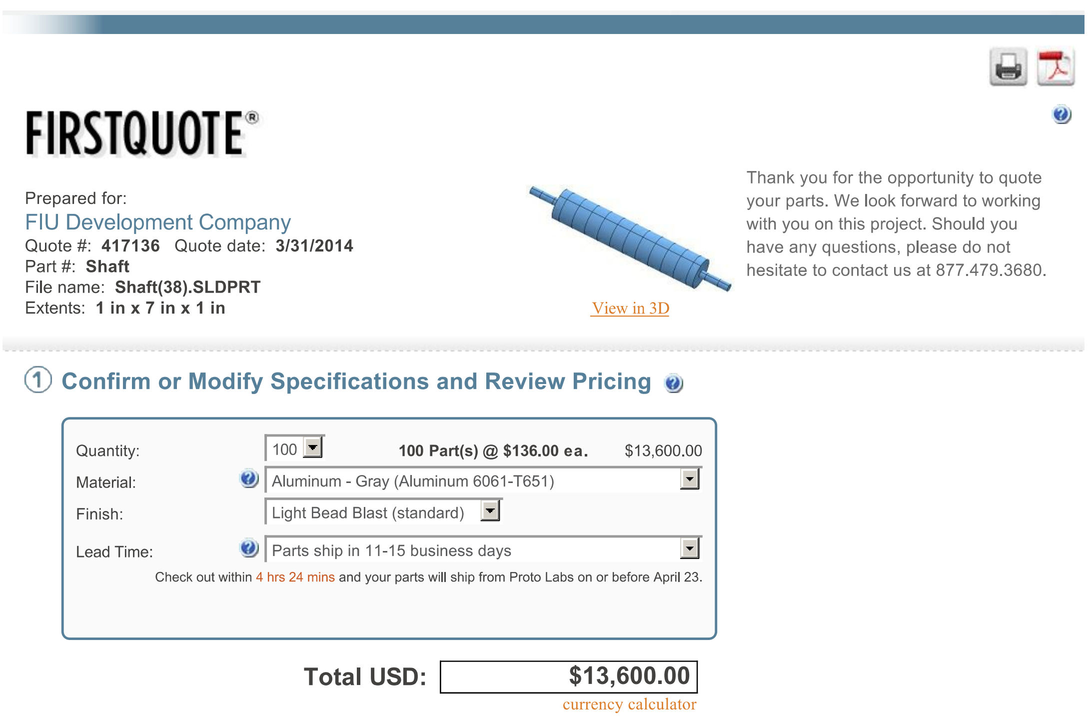
View in 3D

Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Cavities: 1 cavity
A-side (green) finish: PM-F0 (Non-cosmetic - finish to Protomold discretion)
B-side (blue) finish: PM-F0 (Non-cosmetic - finish to Protomold discretion)
Tooling Price: **$8,405.00**
Sample Quantity: 100 **Sample Parts 100 @ $6.99:** **$699.00**
Material: HDPE, Natural (Marlex 9006 HID)
Change Material Color
Lead Time: Sample parts ship in 15 business days (standard delivery)

Total USD: **$9,104.00**
currency calculator



FIRSTQUOTE®

Prepared for:
FIU Development Company
Quote #: **417136** Quote date: **3/31/2014**
Part #: **Shaft**
File name: **Shaft(38).SLDPRT**
Extents: **1 in x 7 in x 1 in**

View in 3D

Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Quantity: 100 **100 Part(s) @ $136.00 ea.** $13,600.00
Material: Aluminum - Gray (Aluminum 6061-T651)
Finish: Light Bead Blast (standard)
Lead Time: Parts ship in 11-15 business days
Check out within 4 hrs 24 mins and your parts will ship from Proto Labs on or before April 23.

Total USD: **$13,600.00**
currency calculator

“Sub-Automatic”

FIRSTQUOTE®

Prepared for:
FIU Development Company
Quote #: **417191** Quote date: **3/31/2014**
Part #: **Frame Rev3**
File name: **Frame Rev3.SLDPRT**
Extents: **0.375 in x 2 in x 24 in**

View in 3D

Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Quantity:	100	**100 Part(s) @ $521.00 ea.**	$52,100.00
Material:	Aluminum - Gray (Aluminum 6061-T651)		
Finish:	Light Bead Blast (standard)		
Lead Time:	Please select a lead time option.		

⚠ You must select a lead time before continuing.

Total USD: $52,100.00

currency calculator

PROTOQUOTE®

Prepared for:
FIU Development Company
Quote Number: **303989** Quote Date: **3/31/2014**
Part Name/Number: **Guide Plate (1)**
Extents: **10.149 in x 6.75 in x 2.377 in**

View in 3D

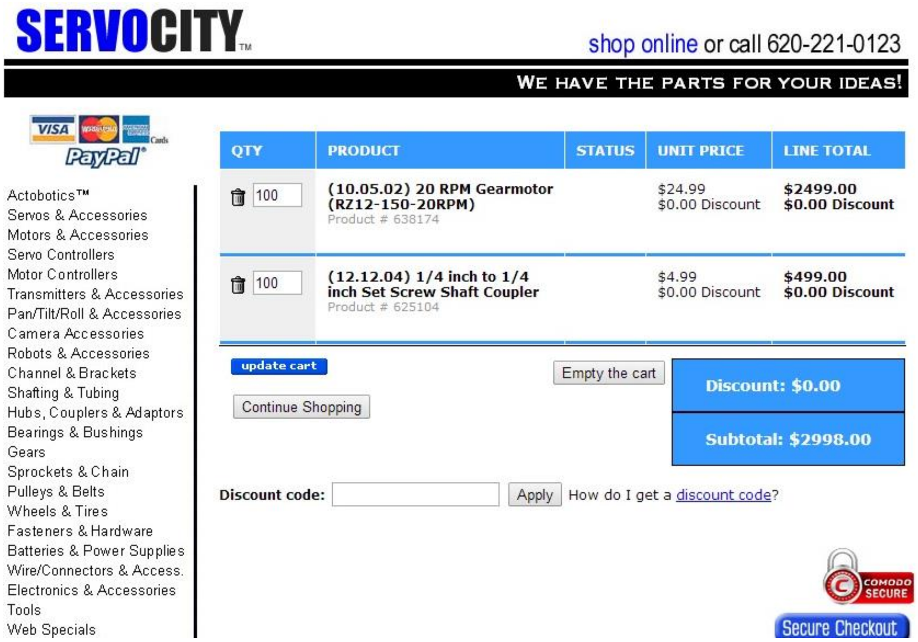
Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Cavities:	1 cavity		
A-side (green) finish:	PM-F1 (Low-cosmetic - most toolmarks removed)		
B-side (blue) finish:	PM-F0 (Non-cosmetic - finish to Protomold discretion)		
		Tooling Price:	**$7,395.00**
Sample Quantity:	100	**Sample Parts 100 @ $5.17:**	**$517.00**
Material:	Acrylic (PMMA), Clear (Plexiglas V052-100)		
	Change Material Color		
Lead Time:	Sample parts ship in 15 business days (standard delivery)		

Total USD: $7,912.00

currency calculator



SERVOCITY™ shop online or call 620-221-0123

WE HAVE THE PARTS FOR YOUR IDEAS!

QTY	PRODUCT	STATUS	UNIT PRICE	LINE TOTAL
100	(10.05.02) 20 RPM Gearmotor (RZ12-150-20RPM) Product # 638174		$24.99 $0.00 Discount	$2499.00 $0.00 Discount
100	(12.12.04) 1/4 inch to 1/4 inch Set Screw Shaft Coupler Product # 625104		$4.99 $0.00 Discount	$499.00 $0.00 Discount

update cart | Empty the cart | Continue Shopping

Discount: $0.00

Subtotal: $2998.00

Discount code: Apply How do I get a discount code?

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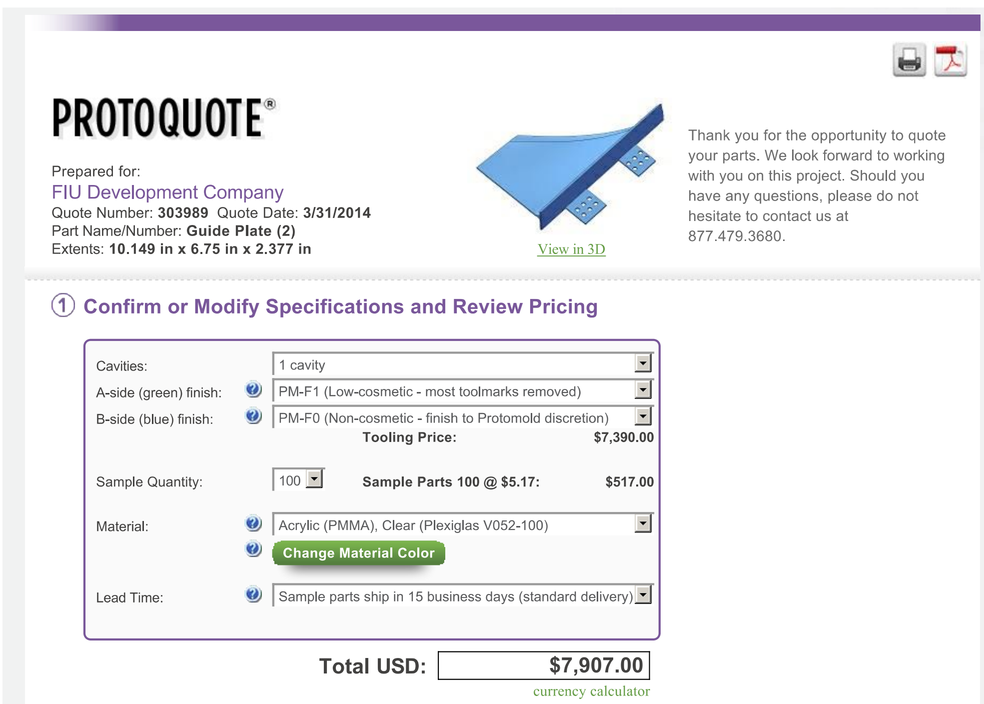
Servos & Accessories
Motors & Accessories
Servo Controllers
Motor Controllers
Transmitters & Accessories
Pan/Tilt/Roll & Accessories
Camera Accessories
Robots & Accessories
Channel & Brackets
Shafting & Tubing
Hubs, Couplers & Adaptors
Bearings & Bushings
Gears
Sprockets & Chain
Pulleys & Belts
Wheels & Tires
Fasteners & Hardware
Batteries & Power Supplies
Wire/Connectors & Access.
Electronics & Accessories
Tools
Web Specials

COMODO SECURE

Secure Checkout



PROTOQUOTE®

Prepared for:
FIU Development Company
Quote Number: **303989** Quote Date: **3/31/2014**
Part Name/Number: **Guide Plate (2)**
Extents: **10.149 in x 6.75 in x 2.377 in**

View in 3D

Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Cavities:	1 cavity		
A-side (green) finish:	PM-F1 (Low-cosmetic - most toolmarks removed)		
B-side (blue) finish:	PM-F0 (Non-cosmetic - finish to Protomold discretion)		
		Tooling Price:	**$7,390.00**
Sample Quantity:	100	**Sample Parts 100 @ $5.17:**	**$517.00**
Material:	Acrylic (PMMA), Clear (Plexiglas V052-100)		
	Change Material Color		
Lead Time:	Sample parts ship in 15 business days (standard delivery)		

Total USD: $7,907.00

currency calculator

McMASTER-CARR

Date	April 3, 2014
Purchase order	
Order created by	()

Ship to	Send invoice to
Shipping method Ground	Payment method

Line	Quantity	Product		Ships	Unit price	Total
1	16 packs	92185A988	Type 316 Stainless Steel Socket Head Cap Screw, 10-32 Thread, 3/8" Length, packs of 25	today	$3.98 pack	63.68
2	40 packs	92313A825	Type 316 Stainless Steel Cup Point Set Screw, 10-32 Thread, 1/4" Long, packs of 25	today	$3.19 pack	127.60
3	200 packs	91833A132	18-8 Stainless Steel Round Knurled Thumb Nut, 10-32 Thread Size, 1" Head Diameter, 7/16" Overall Height	today	$5.84 pack	1168.00
4	1000 each	6384K342	Steel Ball Bearing, Flanged Double Sealed for 1/4" Shaft Diameter, 11/16" OD	200 today 800 in 2 weeks	$6.53 each	6530.00
5	1200 each	95255A256	Quick-Release Pin, Type 316 Stainless Steel, 1/4" Diameter, 0.5" Usable Length	1 week	$3.65 each	4380.00

Merchandise total $12269.28

Applicable shipping charges and tax will be added.

FIRSTQUOTE®

Prepared for:
FIU Development Company
Quote #: **417136** Quote date: **3/31/2014**
Part #: **Half Moon**
File name: **Half Moon.SLDPRT**
Extents: **2.578 in x 0.9 in x 0.472 in**

View in 3D

Thank you for the opportunity to quote your parts. We look forward to working with you on this project. Should you have any questions, please do not hesitate to contact us at 877.479.3680.

① Confirm or Modify Specifications and Review Pricing

Quantity:	100 **100 Part(s) @ $44.00 ea.**	$4,400.00
Material:	Aluminum - Gray (Aluminum 6061-T651)	
Finish:	Light Bead Blast (standard)	
Lead Time:	Parts ship in 11-15 business days	

Check out within 23 hrs 4 mins and your parts will ship from Proto Labs on or before April 24.

Total USD: $4,400.00

currency calculator

Appendix C – Time Log

Carlos

Topic:	Duration	Comment:
researching types of vacuum sealers	3.00	
researching types of plastics used in vacuum sealing	3.25	
Design progression paper	3.00	
Report Editing	15.25	
Report Editing	25.00	
Report Editing	52.00	
Revision Design Section	16.25	

Danny

Topic	Duration	Comment
FDA Regulation	9.50	navigating through the FDA website to find pertinent information based on materials that are allowable when dealing with food
Report Editing	18.00	this accounts for senior 1 report editing
Report Editing	3.00	accounts for time spent on 50%
Report Editing	36.25	
Report Editing	42.00	
Motor Selection	22.15	
Circuit design	22.50	

Text

Omar

Topic	Duration	Comment
ISO research	9.25	
OSHA research	13.00	
Part Research	2.50	researching suitable vacuum sealers for purchase for testing
CAD Design 1st and 2nd iteration	36.25	
3rd revision	25.12	
4th revision	20.25	
5th revison	20.00	
6th revision	15.75	
7th revision	12.20	
Quoting	23.10	

Totals

Title	Duration	Comment
Omar's Research	177.42	
Danny's Research	153.40	
Carlos' Research	117.75	
Research Totals	448.57	
Meeting Totals	52.50	
Total Totals	501.07	

Meetings

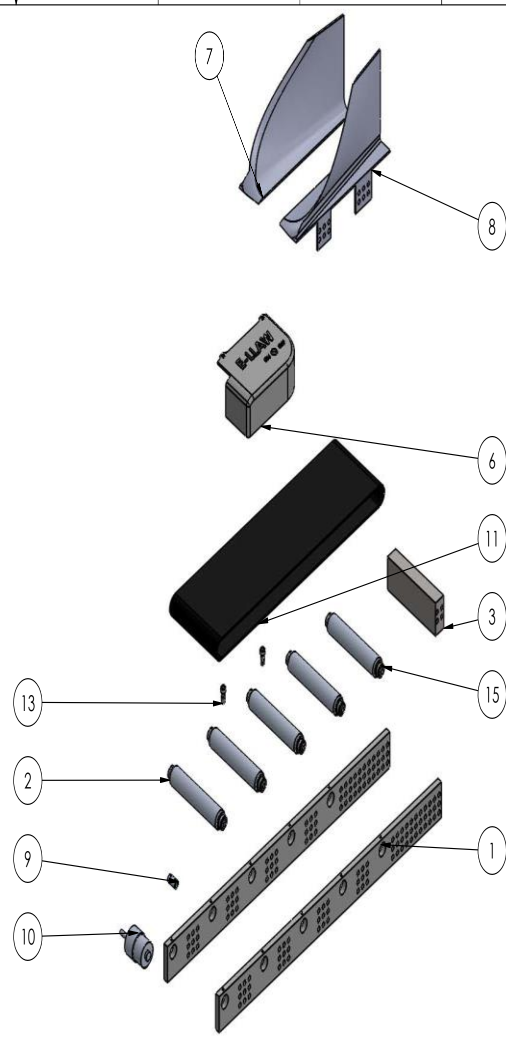
Attendies	Date	Duration
Advisor Meeting	1/9/2014	0.75
Advisor Meeting	1/16/2014	0.75
Research Meeting (Carlos, Omar)	1/18/2014	3.50
Planning Meeting (Danny, Omar)	1/19/2014	2.33
SolidWorks meeting (All)	1/20/2014	2.00
Advisor meeting	1/23/2014	0.50
Zicarelli meeting	1/23/2014	3.00
advisor meeting	1/30/2014	2.00
Omar's house meeting	2/1/2014	3.00
Omar's house meeting	2/2/2014	2.50
Omar's house meeting	2/6/2014	3.20
Omar's house meeting	2/8/2014	3.30
Omar's house meeting	2/9/2014	5.00
Omar's house meeting	2/13/2014	10.00
Omar's house meeting	2/15/2014	5.00
Omar's house meeting	2/16/2014	2.00
Omar's house meeting	2/22/2014	3.00
Omar's house meeting	2/232014	3.25
Omar's house meeting	3/1/2014	4.25
Omar's house meeting	3/2/2014	4.00
Omar's house meeting	3/8/2014	5.25
Omar's house meeting	3/9/2014	6.25
3D Printer	3/10/2014	8.25
3D Printer	3/11/2014	9.25
3D Printer	3/12/2014	10.00
3D Printer	3/13/2014	6.00
3D Printer	3/14/2014	8.00
3D Printer	3/15/2014	9.25
3D Printer	3/16/2014	6.50
3D Printer	3/22/2014	5.25
Report	3/23/2014	4.25
Report	3/24/2014	3.25
Construction	3/25/2014	5.50
Construction	3/26/2014	2.25
Construction	3/27/2014	3.50
Construction	3/28/2014	8.50
Construction	3/29/2014	8.00
Construction	3/30/2014	9.00
Construction	3/31/2014	3.50
Construction	4/1/2014	3.75
Construction	4/2/2014	6.25
Advisor meeting	4/3/2014	0.50
Advisor meeting	3/27/2014	0.50
Advisor meeting	3/20/2014	1.00
Advisor meeting	3/13/2014	0.50
Advisor meeting	3/6/2014	0.50
Advisor meeting	2/27/2014	0.50
Advisor meeting	2/20/2014	0.50
Advisor meeting	2/13/2014	1.00
Advisor meeting	2/6/2014	1.00
Investor Meeting	2/13/2014	4.00

Appendix D – List of Tasks

Task	Person	Date Initiated:	Date Completed:	Comment:
ISO 22,000 & 9,000 research	Omar	11/25/2013	10/15/2013	(Danny) to add info to report
Concept Design	Danny	11/25/2013	11/15/2013	update the conceptual design to most current
Poster: Timeline	All	11/25/2013	11/30/2013	finalize the timeline which will show on poster and in report (choose dates correctly, e tc…)
Report Section (Cost Analysis)PPT	All	11/25/2013	12/4/2013	
Poster	Danny	11/25/2013	12/4/2013	finalize poster information and figure out how this is going to be printed at FIU
Email Karla	Danny	1/18/2014	1/19/2014	
Contact Norman	All	1/18/2014	1/18/2014	
Contact Minions	Danny	1/18/2014	1/19/2014	
Vacuum Sealer Research	Carlos	11/25/2013	1/26/2014	Work In Process: research on the various vacuum sealers as well as the plastics used
Group Work Breakdown	All	11/25/2013	completed	Work In Process
Report Section (Major Components)	All	11/25/2013	completed	need to add the components we expect to use, with a brief description
First iteration of design (SolidWorks)	All	1/18/2014	1/20/2014	Work on Monday 1/20/2014
Design revision (50% Report)	Carlos	1/18/2014	1/25/2014	Take from Norman's update
Material Selection (50% Report)	Danny	1/18/2014	completed	
Mechanism Selection (50%)	Carlos	1/18/2014	1/25/2014	
Review First Order 1/18/2014	All	1/18/2014	completed	Tuesday 1/21/2014.Omar to take order
Cost Analysis (75% Report)	Carlos	1/18/2014	completed	
Mold CNC	Omar	1/18/2014	completed	
Research Silicone Belt	Omar	1/18/2014	completed	
Bearing Analysis (75%)	Carlos	1/18/2014	completed	
FMEA (100%)	All	1/18/2014	completed	
ULINE & McMaster Purchase Status	Omar	1/18/2014	1/21/2014	Omar to ask if we can purchase from ULINE (poly bags)
Email Karla Again	Danny	1/19/2014	completed	Our Decision for here help- received her advise
Stats From Subway	All	1/19/2014	completed	Weight of a fully loaded sub, avergae number of employed and wages
Find Task For minions	All	1/19/2014	completed	
alternative forms of manufacturing	Omar	1/19/2014	completed	
Bearing For Food	All	1/20/2014	1/26/2014	FDA approved Mcmaster
rder sheet (3D filament, Belt, bearings	Omar	1/26/2014	completed	
Second iteration of design (SolidWorks	Omar	1/20/2014	1/24/2014	
Third iteration of design (SolidWorks)	Omar	1/20/2014	completed	
finalize belt	All	2/1/2014	completed	
motor order	All	2/3/2014	completed	Calculations approximate velocity needed
heat sealer	All	2/14/2014	completed	
Velocity calculations	Danny	3/5/2014	completed	Determine with velocity
Work on roller diameter	Omar	3/5/2014	completed	
switch circuit	Danny	3/6/2014	completed	
Contruction	All	3/6/2014 - 3/30/2014	completed	
Refinement	All	3/29/2014 - 4/3/2014	completed	
Future Consideration	All	4/2/2014 - 4/10/2014	completed	

Appendix E – 2D Drawings

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	PAGE
1	Frame	Side Rails For Sub-Automatic Folder	2	2
2	Shaft	Shafts For Sub-Automatic Folder	5	3
3	Cutting Block	Cutting Block For Sub-Automatic Folder	1	4
6	Cover (Rev2)	Cover For Sub-Automatic Folder	1	5
7	Guide Plate (1)	Guide Panel One For Sub-Automatic Folder	1	6
8	Guide Plate (2)	Guide Panel Two For Sub-Automatic Folder	1	7
9	Coupler	ServoCity Coupler	1	N/A
10	Motor	ServoCity Motor	1	N/A
11	Belt	Werco Biltrite - Santoprene	1	N/A
12	91251A340	Black-Oxide Alloy Steel Socket Head C ap Screw, 10-32 Thread, 3/8" Length	4	N/A
13	92185A539	Type 316 Stainless Steel Socket Head Cap Screw, 1/4"-20 Thread, 5/8" Length	4	N/A
14	92185A144	Type 316 Stainless Steel Socket Head Cap Screw, 6-32 Thread, 1/4" Length	1	N/A
15	6384K342	Steel Ball Bearing, Flanged Double Sealed for 1/4" Shaft Diameter, 11/16" OD	10	N/A



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005

	NAME	DATE
CHECKED	OAT	4/17/2013
Q.A.	N/A	N/A

COMMENTS:

MATERIAL: Not Applicable

FINISH: Not Applicable

DO NOT SCALE DRAWING

PROPRIETARY AND CONFIDENTIAL

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TITLE: Sub-Automatic

SIZE: B DWG. NO. Assembly REV5

SCALE: 1:2 SHEET 1 OF 7

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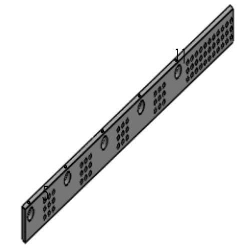
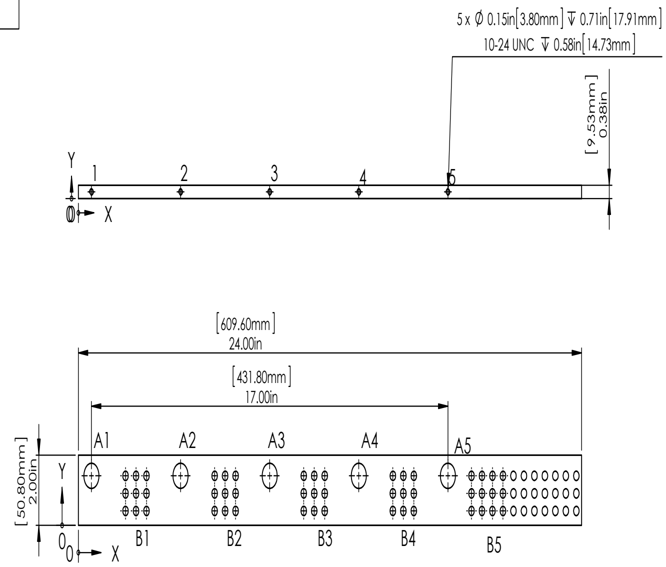
TAG	X LOC	Y LOC	SIZE
A1	0.63	1.41	Ø 0.72 THRU ALL
A2	4.88	1.41	Ø 0.72 THRU ALL
A3	9.13	1.41	Ø 0.72 THRU ALL
A4	13.38	1.41	Ø 0.72 THRU ALL
A5	17.63	1.41	Ø 0.72 THRU ALL
B1	2.75	0.91	Ø 0.27 THRU ALL
B2	7.00	0.91	Ø 0.27 THRU ALL
B3	11.25	0.91	Ø 0.27 THRU ALL
B4	15.50	0.91	Ø 0.27 THRU ALL
B5	19.25	0.91	Ø 0.27 THRU ALL





TAG	X LOC	Y LOC	SIZE
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2	4.88	0.19	Ø 0.15 ↧ 0.71 10-24 UNC ↧ 0.58
3	9.13	0.19	Ø 0.15 ↧ 0.71 10-24 UNC ↧ 0.58
4	13.38	0.19	Ø 0.15 ↧ 0.71 10-24 UNC ↧ 0.58
5	17.63	0.19	Ø 0.15 ↧ 0.71 10-24 UNC ↧ 0.58

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DIMENSIONS ARE IN INCHES
TOLERANCES:
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005

	NAME	DATE
CHECKED	OAT	4/17/2013
Q.A.	N/A	N/A

COMMENTS:

MATERIAL 6061-T6 (SS)

FINISH As Machined

DO NOT SCALE DRAWING

TITLE: Sub-Automatic

SIZE B DWG. NO. Assembly REV5

SCALE: 1:2 SHEET 2 OF 7

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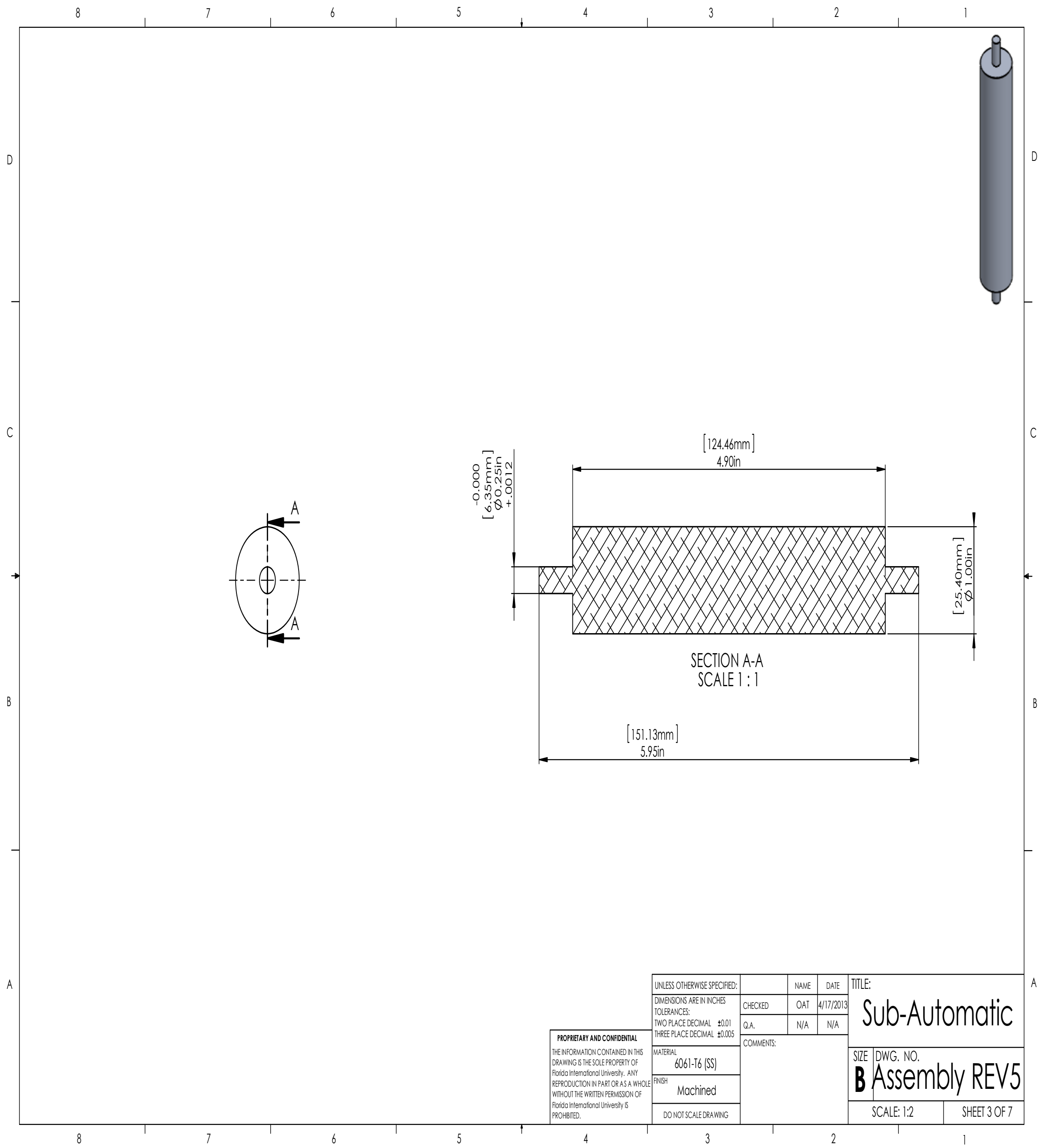

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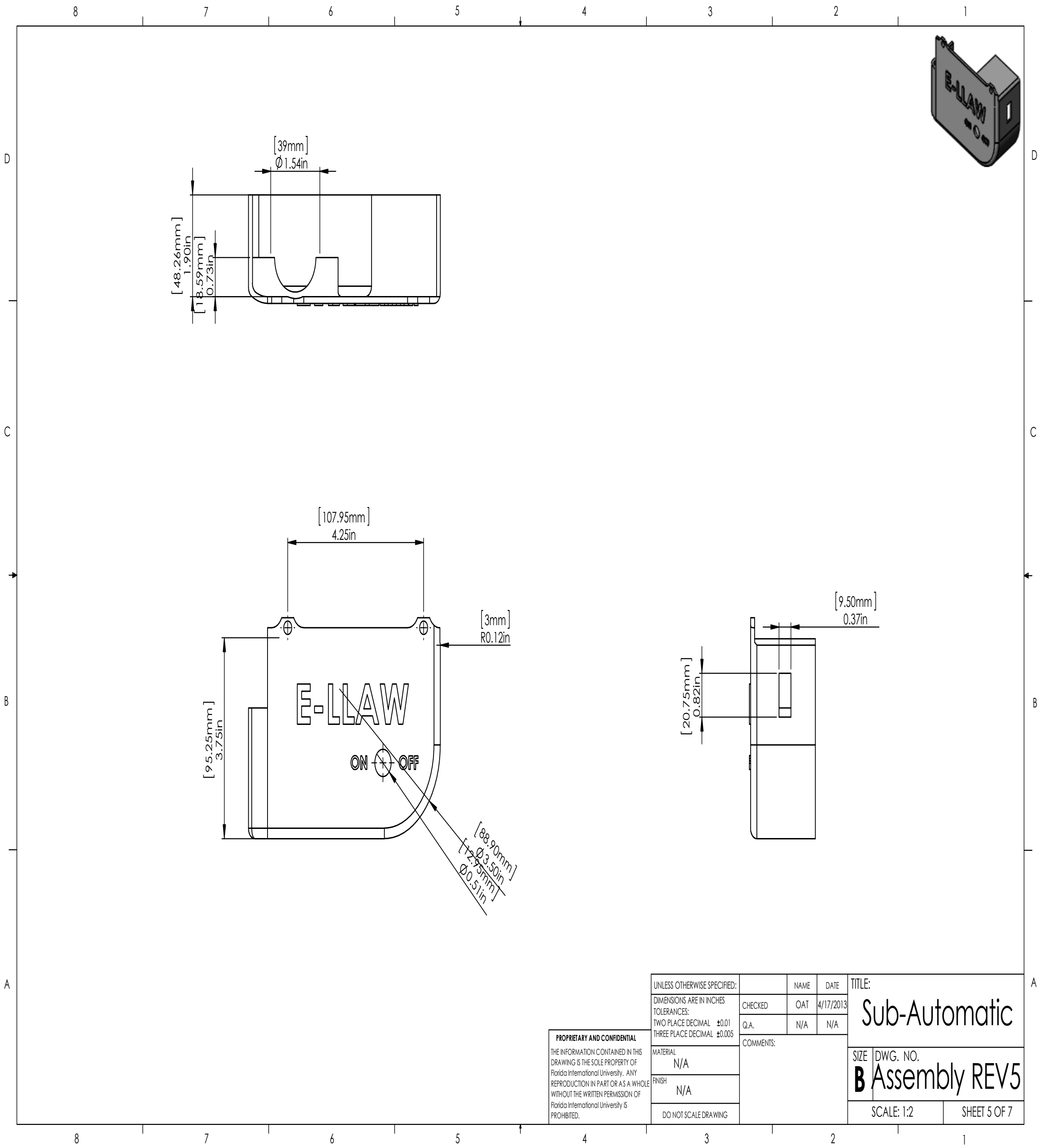

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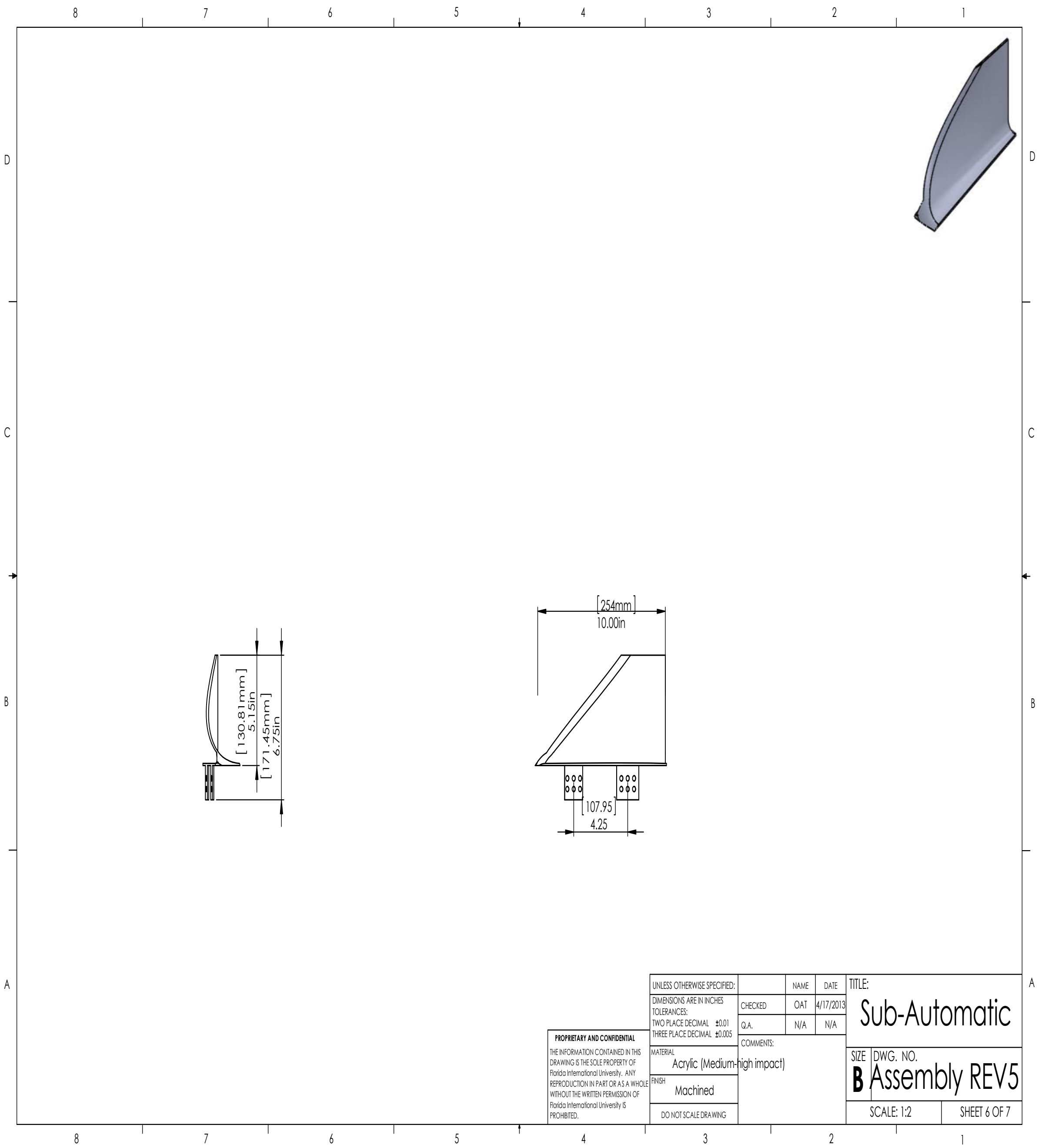

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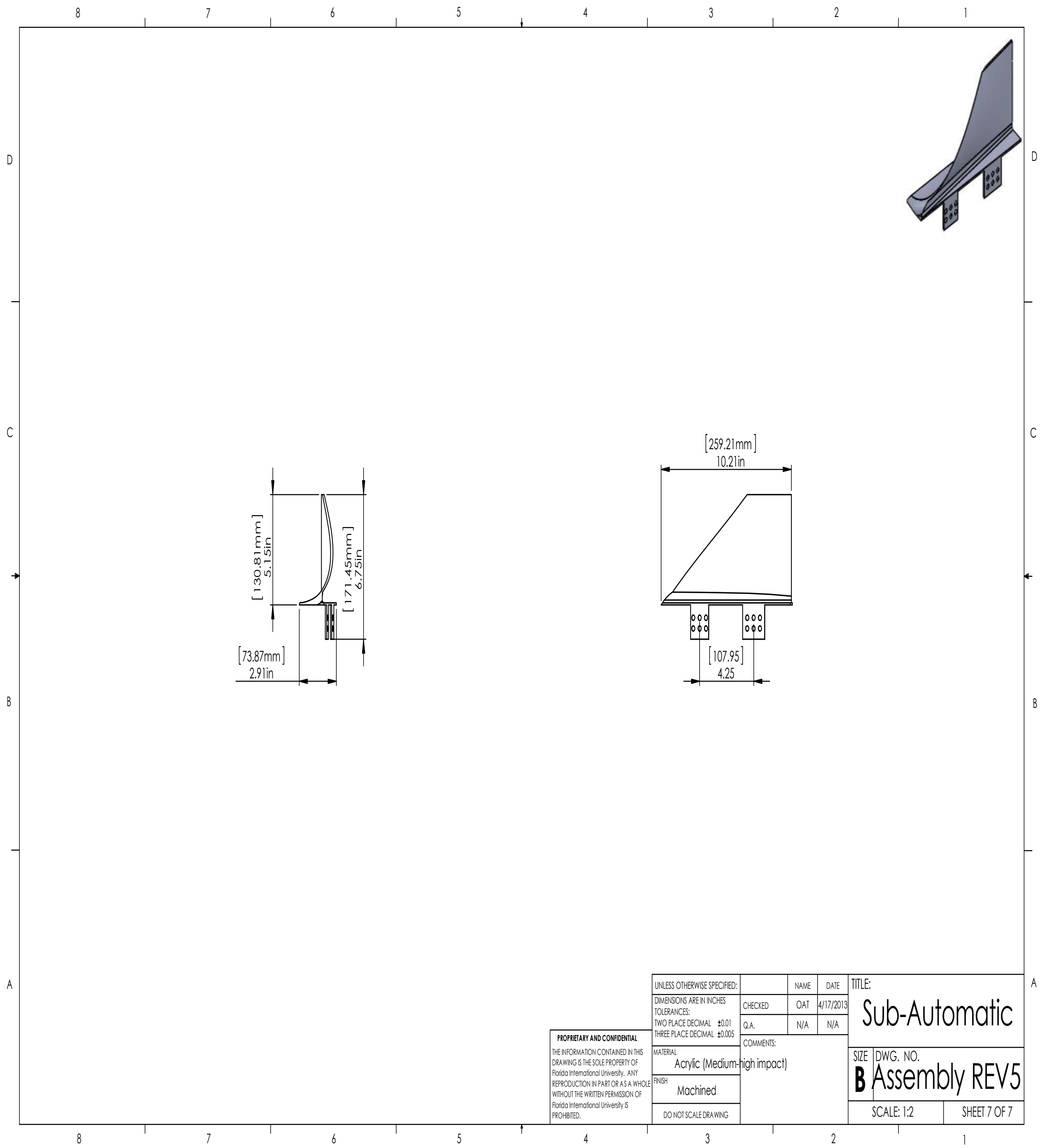
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4.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
NAME
DATE
CHECKED
OAT
4/17/2013
Q.A.
N/A
N/A
COMMENTS:
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MATERIAL
Acrylic (Medium-high impact)
FINISH
Machined
DO NOT SCALE DRAWING
TITLE:
Sub-Automatic
SIZE
B
DWG. NO.
Assembly REV5
SCALE: 1:2
SHEET 7 OF 7

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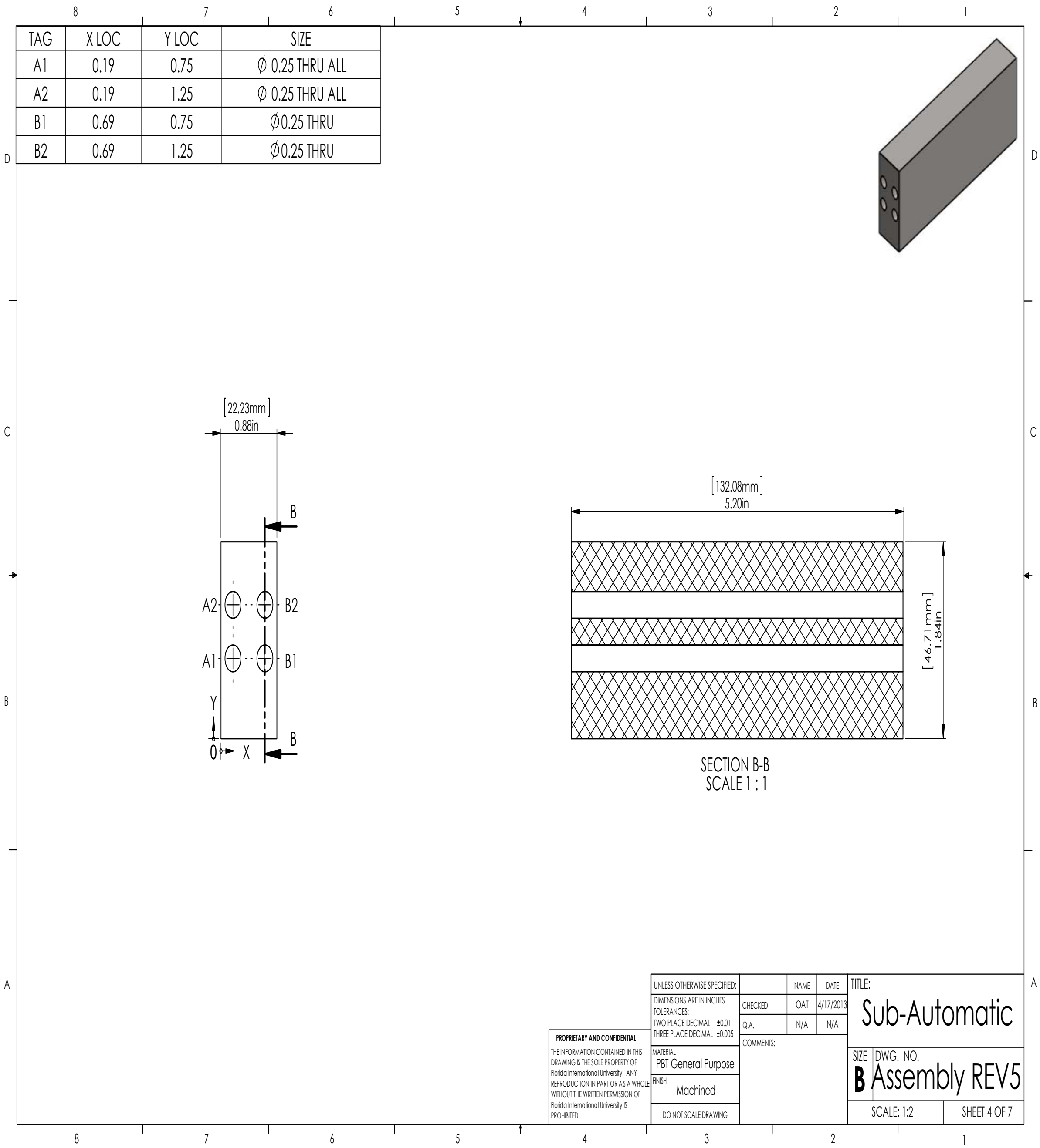
A2	0.19	1.25	∅ 0.25 THRU ALL
B1	0.69	0.75	∅0.25 THRU
B2	0.69	1.25	∅0.25 THRU



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Appendix F – Failure Mode & Effects Analysis (FMEA)

Process step	Potential failure mode	Potential failure effects	S E V	Potential causes	O C C	Current process controls	D E T	R P N	Actions recommended	Responsibility (target date)	Actions taken	N S e E w V	N O e C w C	N D e E w T	N R e P w N
What is the step?	In what ways can the step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	10	What causes the step to go wrong? (i.e., How could the failure mode occur?)	10	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	10	**1000**	What are the actions for reducing the occurrence of the cause or for improving its detection? You should provide actions on all high RPNs and on severity ratings of 9 or 10.	Who is responsible for the recommended action? What date should it be completed by?	What were the actions implemented? Include completion month/year (then recalculate resulting RPN).	10	10	10	**1000**
2	Bearing Failure	Depending on the number of bearings that fail, the impact is different. Machine has 10 bearings total. Should one or two fail, the machine would still be able to function; however any more than that the integrity of the machine may be compromised	6	Exceed the catalog rating of the bearings	1	Visual Inspection	2	**12**	Ensuring that only sandwiches are placed on the machine	Employees/Manager	N/A	6	1	1	**6**
1D	Switch Failure	Should the switch fail, the motor will not have power routed to it and therefor would not deliver power to the conveyor belt	8	Possible electrical failure; the switch could have been poorly soldered during manufacturing and assembly; possibility of a defective switch	1	None	1	**8**	Possibility of increasing quality control on motor modules before assembling with the final machine	Manufacturer/Assembler	N/A	8	1	1	**8**
1C	Motor Failure	Motor does not work and the conveyor belt does not have power being delivered to it	8	Check that the power is properly connected; that the switch is turned 'on'. If the previous two methods do not produce working results, replacement of the motor module may be necessary	4	None	2	**64**	Using quality built DC motors could reduce the possibility of a mechanical failure. Although the motor is enclosed, ensure no debris is able to affect the motor	Employees/Manager	N/A	8	4	1	**32**
1B	Sandwich gets folded incorrectly	The sandwich may not enter the narrowing channel correctly or get caught, causing it to not be folded correctly	4	Placing the sandwich incorrectly on the conveyor belt; placing the cut end first could potentially cause the sandwich to catch on the edge of the folding channel.	9	Properly instruct the operator	1	**36**	Instruct the operator to place the sandwich 'butt-end' first instead of the cut end, to prevent this from occuring	Employees/Manager	N/A	4	7	1	**28**
1A	Conveyor Belt malfunction	The machine will not be able to perform the designed function of folding the sandwich	7	Possible fraying of the actual belt; a small cut could propagate along the belt causing the entire belt to separate	3	Daily visual inspection	1	**21**	Increase the number of inspections from weekly to daily, or daily to twice a day (before opening and after closing)	Employees/Manager	N/A	7	2	1	**14**

16. References

[1] *Fda.gov.*

Food Code 2009

In-text: (Fda.gov, 2013)

Bibliography: Fda.gov. 2013. *Food Code 2009*. [online] Available at:

http://www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM2019396.htm [Accessed: 5 Nov 2013].

Vacuum Schematics

http://www.pleasanthillgrain.com/vacuum_packaging_machine_food_sealer_packing_machines.aspx

Heat Sealers

http://www.industrialsupplies.com/displayproductdetail.do?skuSearch=Q52634&mr:referralID=NA&itemGroupOID=165408&origin=pla&cid=pla_goog&9gtype=search&mr:filter=51436252777&baseItemOID=165408&mr:ad=25000371577&mr:trackingCode=F1763EA3-02AF-E011-87D9-001B21A69EB8&source=google_pla&sku=199730&mr:device=c&mr:adType=pla

Shigley's Mechanical Engineering Design, Richard G. Budynas, J. Keith Nisbett, Ninth edition, January 29 2010.