Final Report

Automated Sealer

Nick Burchell, Brian Daley, Kenneth Win
MET 494
Dr. Dupen
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Introduction

This report provides an overall summary and details the results of the automated shrink-wrap sealer project for Wise Business Forms.

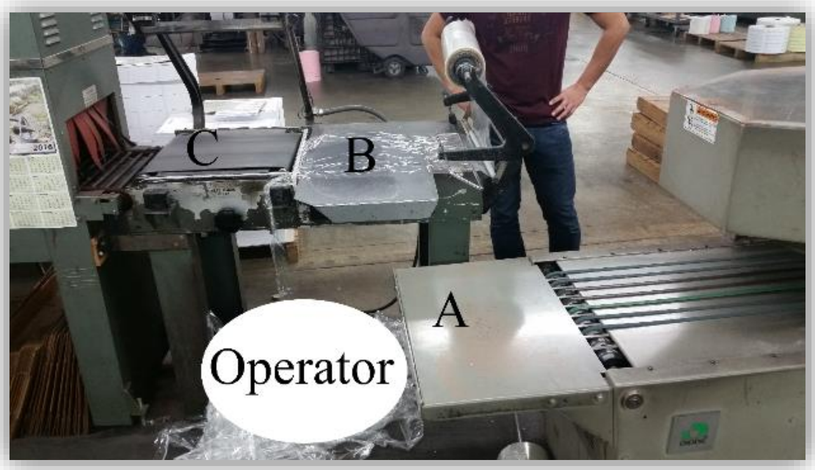
This senior design group consists of Nick Burchell, Brian Daley, and Kenneth Win. Our project has been graciously sponsored by Wise Business Forms where Kenneth Win is an intern at their plant in Fort Wayne, Indiana.

The Problem

During our meeting with the General Manager of Wise Business Forms, Sally Spurr, we toured the facility as she expressed her concerns regarding several problems in the plant. Our group decided to concentrate our efforts on the shrink- wrapping process due to its inefficiency in regards to wasted time and wasted resources.

The current operation has an operator sit in a non-swivel seat or stand upright. This forces the operator to twist his/her torso while picking up the paper product at A, placing the product into the plastic wrap at B, and sliding the product with the shrink-wrap into C as shown in Figure 1. Once the paper is located at C, the worker can then push down the L bar to cut the plastic to size. In doing so, the L bar actives a limit switch which powers on an electromagnet that holds the L bar in place and heats the shrink wrap enough to seal it. This dwell had a timer that would then demagnetize once a certain time expired, and then the L bar would be brought back up through the use of a spring and cylinder. In addition, this would also activate the conveyor taking the product to the heater to be finished.

Figure 1: Shrink Wrapping Process



Initial Project Plan

Our group's original solution to this problem was to automate the shrink-wrapping process in order to increase productivity while simultaneously employing the operator in a more manpower demanding process. The goal was to not only improve the shrink-wrapping process, but free the operator to contribute in other areas.

Our initial design idea was to allow the product to reliably leave the collator at location A in Figure 1 and direct it into the loading area at B. Once the product was correctly placed in the plastic wrap, a rack and pinion system would move the product onto C. Lastly, a pneumatic cylinder would then push the L bar down in order to cut the wrapping and direct the product into the heat tunnel.

In our proposal, we also noted the following criteria that we wanted to accomplish in regards to our design:

- Device can operate without operator oversight for 15 minute intervals.
- Process from the end of the collator to when the product arrives at the heat tunnel should take no more than 10 seconds.
- Device can operate reliably at various feed rates depending on various order sizes and scheduling requirements.
- In the event of a breakdown, the design would allow a safety factor large enough to ensure operator safety.
- In the event of a malfunction, remedial action should be quick and require the minimum number of tools necessary.

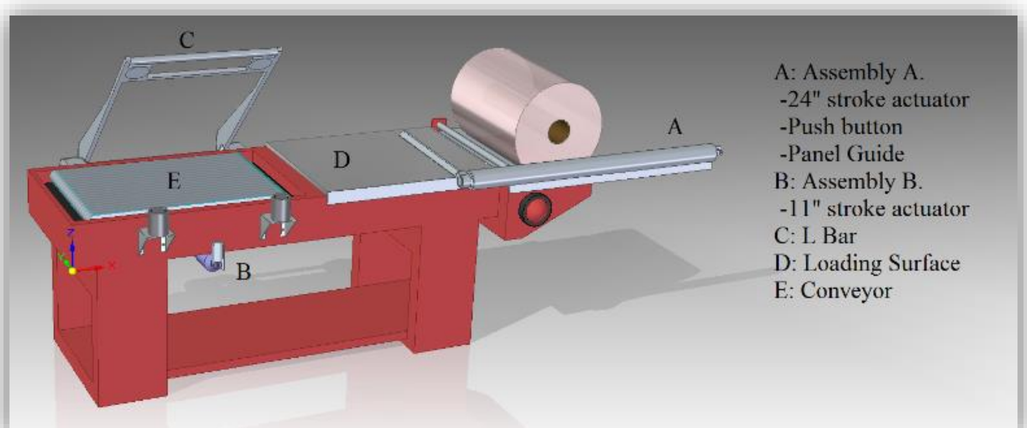
Project Plan Adaptation

During the course of this project, there have been various design changes due to problems that arose.

One major change compared to our initial plan was being able to completely automate the process. It became apparent that the task would not be feasible with our current time constraints to take the paper from location A of Figure 1 and to lift it 8 inches up to location B. This task would have required a lift or conveyor that would not be feasible due to cost and the complexity with our semester time restraint.

The adapted design our group developed was to automate the majority of the shrink-wrapping system while still allowing for complete automation being a possibility in the future. This would be achieved by having the operator place the product at location D of Figure 2 and press the push button located under Assembly A.

Figure 2: Initial CAD design of Automated Sealer. Modeled in Solid Edge ST8 Student Version. Actuator dimensions courtesy of Progressive Automation [1].



Once the push button was activated, a 24” electric actuator would extend pushing the paper and shrink-wrap onto the conveyor at E. Cylinder A would then begin to retract, and cylinder B would begin to extend. This would, in turn, would close the L bar and cut and heat the shrink-wrap. The cylinder would then retract bringing the L bar back to its original position, and the conveyor would activate taking the product to the heater. This design would allow Wise Business Forms the option of fully automating the process in the future while reducing the risk of burn injuries to the operator. The machine, prior to any potential modifications, is shown in Figure 3.

Figure 3: Original machine configuration.

Part Ordering

After completing our initial design ideas, our group began to order our chosen components. However, we were notified that management would prefer to order through their normal distributor to acquire the parts. Wise Business Forms usually used McMaster-Carr for ordering, and unfortunately they did not carry the high-speed linear actuators that we were hoping to use.

Thanks to an abundance of airlines readily available on site, we looked into the pneumatic cylinders that McMaster-Carr carried.

Pneumatic Cylinder Construction & Specifications

The two cylinders that we decided on are constructed from an aluminum alloy with the bore tubing being made out of hard coated aluminum. Aluminum construction benefited this project by being corrosion resistant, having a low friction, and being lightweight relative to other metal alternatives. The piston rod, on the other hand, is constructed of a hard, chrome plated steel. The chrome allows for wear resistance while the steel gives a greater strength than aluminum [2].

The two cylinders were selected and listed in Table 1 and pictured in Figure 4.

Table 1: Pneumatic Cylinder Specifications [3], [4].

Shared Specifications	D12SENC SL10 RA1 SP	D12SENC SL24 RA1 SP
Bore Size: 1.25" Max Width: 1.8125" Rod Diameter: 0.375"	Stroke Length: 10" Length Retracted: 14.53" Length Extended: 24.53"	Stroke Length: 24" Length Retracted: 28.53" Length Extended: 52.53"

Figure 4: Motion Controls LLC model D12SENC SL24 RA1 SP (Top) vs D12SENC SL10 RA1 SP (Bottom). Six inch ruler for scale.

Cylinder Performance & Calculations

In order to calculate the needed PSI for our cylinders to work as intended, we needed to learn the forces that they would be moving.

The 24" stroke cylinder is tasked with moving the bundle of paper and returning to its original position. While in our design phase, we discussed with the plant manager what some of their larger orders could be, and we learned that some of the larger orders could weigh 9.8lbs. Meanwhile, the 10" stroke cylinder would require pushing the L bar down and back up. This was determined to take approximately 15lbs through the use of a pull gauge.

Both cylinders share the same dimensions besides stroke length and overall lengths. Both share the same surface area and are calculated below in Table 2:

Table 2: Calculating the Surface Area of the Cylinders for Extension and Retraction.

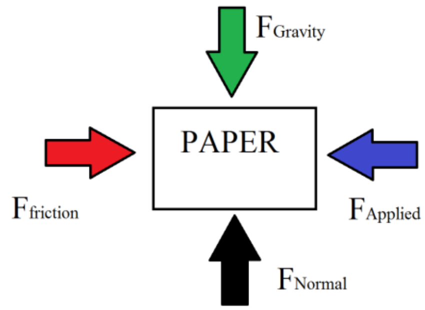
Calculate Surface Area of Circle (Extending): $A = \pi r^2$ » $A = \pi(\frac{1.25inch}{2})^2 = 1.227inch^2$
Calculate Surface Area of Circle (Retracting) $A = \pi(R1^2 - R2^2)$ » $= \pi(\left(\frac{1.25inch}{2}\right)^2 - \left(\frac{0.375inch}{2}\right)^2) = 1.117inch^2$

The 24" stroke cylinder's free body diagram is needed to find the force required to push a 10lb bundle of paper, and it is displayed in Figure 5. In addition, we learned that the coefficient of static friction for office/business paper can be as high as 0.65 [5].

Table 3: Calculations for 24" stroke cylinder extending

<table>
<tr>
<td>Calculate Max Force:

$Fn = Fg$ » $Fg = m * g$
$Fg = Weight\ of\ Paper = \sim 10lbs$
$Force\ Required = 0.65 * 10lbs = 6.5lbs\ of\ force.$

Rounding the 6.50lbs to 7lbs to account for the negligible amount of force required to move the shrink-wrap and multiply by a factor of safety of 3, giving ~20LBS of force required.</td>
<td>Figure 5: Free body diagram 24" stroke cylinder

</td>
</tr>
<tr>
<td colspan="2">Calculate Required Pressure:
$F = p * A$ » $20LBS = p * 1.227inch^2$ » $p = \frac{20LBS}{1.227inch2} = 16.29\ PSI$
Therefore, we would need approximately 17PSI to have our cylinder overcome the weight and friction of a larger order.</td>
</tr>
</table>

Due to the 24” stroke cylinder not pulling a force back to its original position, the same 17 PSI can be utilized for retraction. The 10” stroke cylinder, on the other hand, will need this calculation in addition to the normal extension as showcased in Table 4.

Table 4: Calculations for 10" stroke cylinder extending and retracting

<table>
<tr>
<td>Calculate Required Pressure (Extending):
Force required to push the L Bar down is 15LBS via pull gauge measurements. Calculating with a factor of safety of 3 puts the force to 45LBs.

$F = p * A$ » $45LBS = p * 1.227inch^2$ » $p = \frac{45LBS}{1.227inch2} = 36.67\ PSI$
In order to push the L Bar down, the minimum pressure needed would be approximately 37PSI.</td>
</tr>
<tr>
<td>Calculate Required Pressure (Retracting):
$p = \frac{F}{A}$ » $= \frac{45LBS}{1.117inch^2}$ = 40.28PSI

In order to pull the L Bar back up, the 10” stroke cylinder would need to require approximately 41PSI.</td>
</tr>
</table>

Mounting Hardware & Fabrication

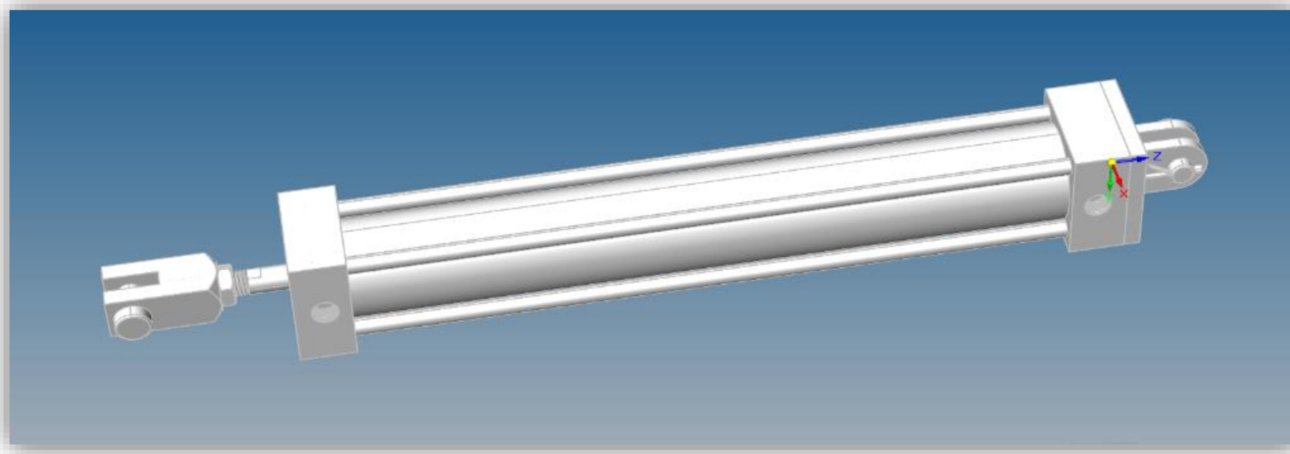
In addition to the cylinders ordered from McMaster-Carr, mounting pieces were also purchased. These parts are pictured in Figure 6 and comprise of:

- High Capacity Side-Mount Drawer Slides 20” Closed Length [6]. (Top)
- Flange Bar Set for 1.25” Bore Size Tie Rod Air Cylinder [7]. (Bottom Left)
- Clevis Bracket with Pin for 1.25” Bore Size Tie Rod Air Cylinder [8]. (Bottom Center)
- Rod Clevis with Pin for 1.25” Bore Size Tie Rod Air Cylinder [9]. (Bottom Right)

Figure 6: Mounting hardware.

The 10" stroke cylinder is designed to utilize both the Clevis Bracket and Rod Clevis to be mounted underneath the machine to push the L Bar support. The two pivot points will allow for a greater freedom of movement to ensure it operates successfully. This design can be seen in Figure 7. The Rod Clevis will attach directly to the L Bar support while the Clevis Bracket will require a "T" shaped support piece to be fabricated.

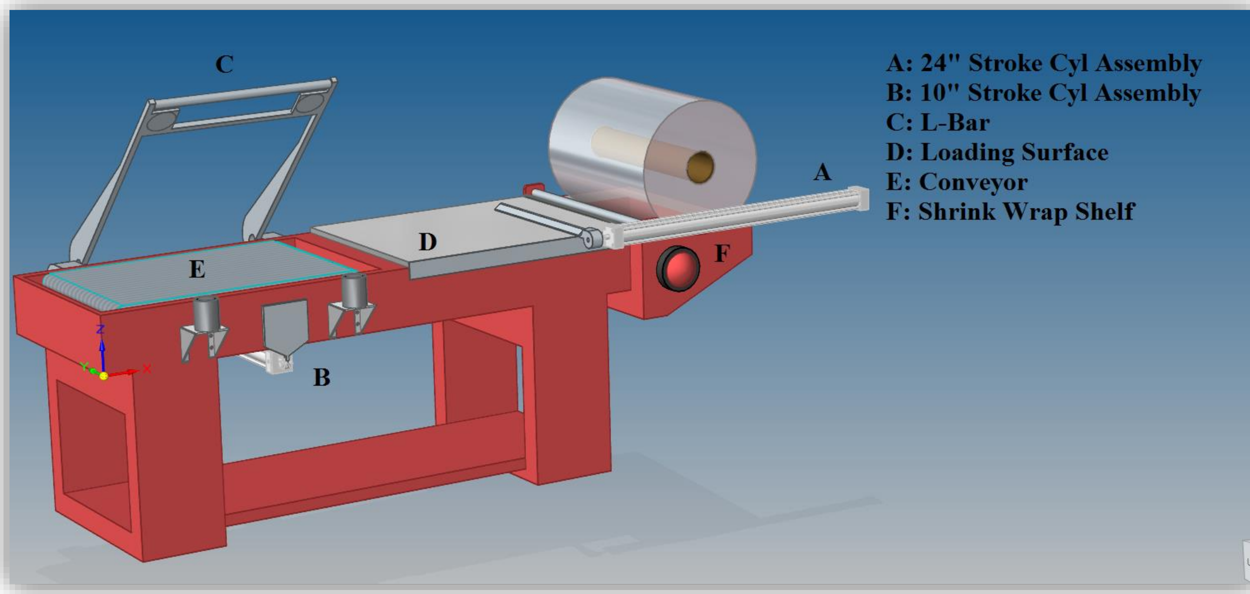
Figure 7: 10" stroke cylinder with Rod Clevis (Left) and Clevis Bracket (Right) attached. CAD models courtesy of McMaster-Carr and assembled via Solid Edge ST8 Student Version [3], [8], [9].



The 24" stroke cylinder's mounting system will be made in house by using 80/20 extruded aluminum T slotted framing. The 80/20 will also have a sliding system that will house the paper shovel, which will reduce any bending moment on the piston rod to ensure a more reliable operation.

The last piece is the side mount drawer slides. These were purchased as a quality of life improvement for the operator that will allow him/her to quickly adjust the alignment of the shrink-wrap roll at a faster rate. This piece was added in between the shrink-wrap shelf and the main body of the machine, which can be seen in the updated CAD model in Figure 8.

Figure 8: Automated Shrink Wrapping Systems with Pneumatic Cylinders. CAD rendered and assembled in Solid Edge ST8 Student Edition.



Fabrication Process & Completed Fabrication

Due to the nature of this project and utilizing various parts produced by different manufactures, our mounting systems needed to be fabricated. Wise Business Forms features its own basic machine shop which gave us access to the tooling required to fabricate the custom mounting equipment.

The first step in our fabrication process was removing the shrink-wrap shelf from the machine and determining the best way to remount it utilizing the purchased slides. Once removed, our team was able to utilize the original bottom holes and bolts, but we had to drill new holes higher up. This allowed us to utilize the same mounting screws that we knew would be sturdy enough to hold the shelf in place. A retracted and slightly extended image of the installed slide mount can be seen in Figure 9 and Figure 10.

Figure 9: Sliding mechanism attached and retracted.

Figure 10: Sliding mechanism attached and slightly extended

Our next step was fabricating the additional hardware to mount the 10” stroke cylinder underneath the machine. We were able to utilize the Rod Clevis and attach it to pre-existing attachment points in the L-Bar support. The only fabrication that our team had to accomplish was to create a T shaped structure that would allow us to mount it to the front of the machine and to also fit in the Clevis Bracket. The mounted cylinder and fabricated piece can be seen in Figure 11 and Figure 12.

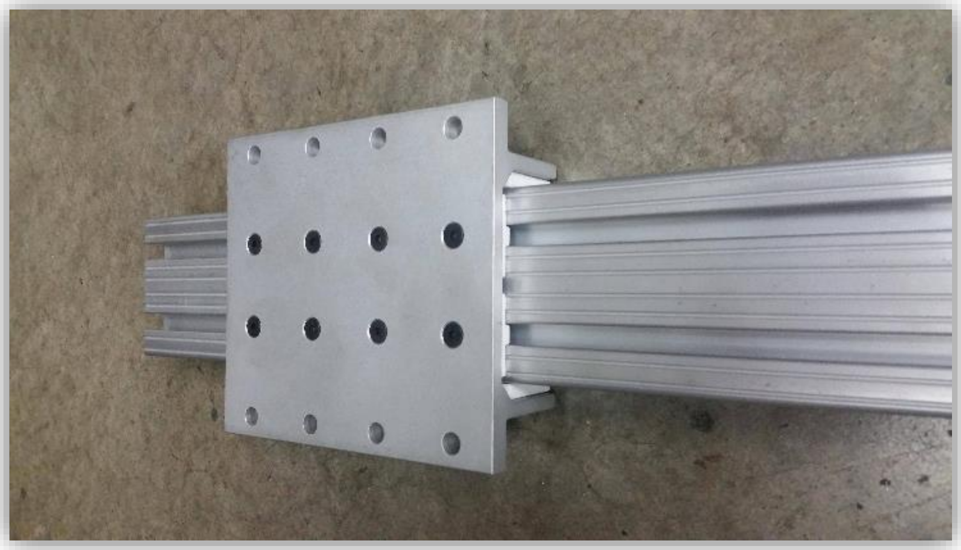
Figure 11: L Bar support connection to 10" stroke cylinder.

Figure 12: Machine body connection to 10" stroke cylinder.

Fabrication to be Completed

During the fabrication process for our 24” stroke cylinder, we decided to utilize a piece of extruded aluminum from 80/20 and a slide system to house our paper shovel. Design wise, it also reduces the stress placed on the piston rod as the force moment will be placed on the linear bearing and not our piston rod. The 80/20 arrived 21APR2016, and its dimensions were measured in order to cut it to size once the electronics were finalized. The 80/20 and linear bearing can be viewed in Figure 13.

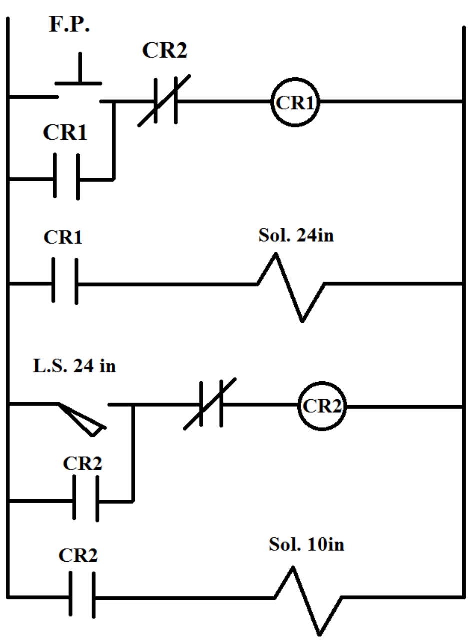
Figure 13: 80/20 linear bearing attached to 80/20 aluminum framing.



Electronics

Equally as important to this project as the fabrication of the mounting system was the correct implementation of electronics consisting of sensors, wires, and solenoid valves in order for the machine to perform as required.

Figure 14: Placeholder Ladder Diagram



Our current ladder diagram can be seen above in Figure 13, and it is designed to function as described below:

1. Operator presses foot pedal. Energizes CR-1.
2. 24” stroke cylinder extends and pushes the paper product onto the conveyor.
3. Limit switch is tripped and activates CR-2, which in turn allows the spring return of the solenoid to retract the 24” stroke cylinder.
4. Concurrently, the 10” stroke cylinder will be activated and begin extension which closes the L Bar.
5. CR-2 shuts off which will allow the spring returned solenoid to retract the 10” stroke cylinder.

The setbacks to the ladder diagram include not yet receiving the two spring returned solenoid valves that are used to switch the cylinders from extension to retraction and vice versa. Additionally, during the final weeks of brainstorming the ladder diagram, we were ultimately perplexed as how to shut off CR-2.

The electronics proved to be an additional issue in the project due to the fact that the current draw of the solenoid valves exceeded the power delivered by the factory stepdown transformer; thus, we will have to install a new power supply to accommodate the additional current draw. The current line in voltage is set at 220 volts AC and passes through a step down transformer that downgrades it to 24 volts AC with a rating of 40W.

The problem that is of concern is that the transformer is only producing 1.6AMPS, and therefore needs the additional power supply to provide the same 24V. The calculation for this is shown in Table 5 below. This will ensure the longevity of the transformer as well as the electronics equipment. The needed solenoid valves for this project are rated at 24V DC which will allow them to run off the new power supply through a rectifier.

Table 5: Equation and calculation for produced amps.

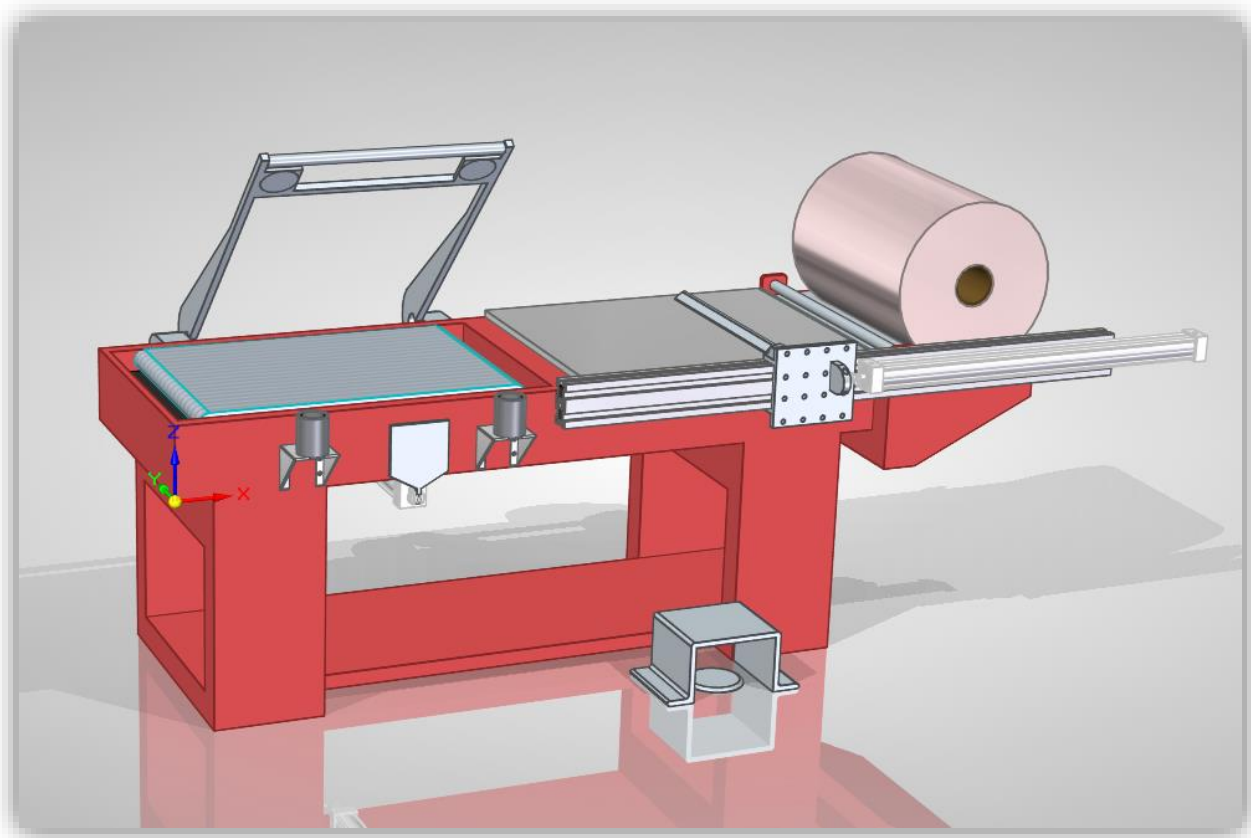
$$P = E * I$$
$$Watt = Volts * Amps$$
$$40W = 24V * Amps$$

Amps = $\frac{40W}{24V}$ = 1.6 Amps

Finalized Design

During the fabrication process, we were required to adapt our design from using a push button to a foot pedal and the inclusion of the 80/20 and linear bearing. Our final design is displayed in Figure 15 below. Our current progress for this project is documented in our Gantt chart. Please refer to Annex A: Group Gantt Chart and Annex B: Excel Gantt Chart Guide.

Figure 15: Finalized design constructed in Solid Edge ST8 Student Version.



Unit Cost

The cost breakdown for this design is shown in Table 6 on the following page. Our projected costs, depending on the power supply, will put the design at a price between $891 - $1001. This places our design well within our projected project cost of $1500 per unit that we estimated during our initial proposal.

Table 6: Price breakdown by part

Current Costs		
Assembly	Part	Cost
Assembly A	24 inch Cylinder – McMaster-Carr [4] Flange Bar Set – McMaster-Carr [7] Additional Mounting Hardware - Fabricated in house Panel Guide - Fabricated in house 80/20 T-Slotted Framing – McMaster-Carr [10] 80/20 End Caps x2 – McMaster-Carr [11] 80/20 Linear Bearings – McMaster-Carr [12]	$217.85 $24.96 Labor Labor $67.30 $3.60 $97.68
Assembly B	10 inch Cylinder – McMaster-Carr [3] Clevis Bracket w/ Pin for 1.25" Bore Cylinder – McMaster-Carr [8] Rod Clevis w/ Pin for 1.25" Bore Cylinder – McMaster-Carr [9] Additional Mounting Hardware - Fabricated in house	$156.24 $20.99 $18.84 Labor
Wiring	Control Relays - Available in stock at Wise Limit Switches – Available in stock at Wise Wires - Available in stock at Wise Foot Pedal – Available in stock at Wise Power Supply Parker Fluid Control ¼" 24V Spring Returned 5Way Air Valve x2 – IFP [13] Parker Fluid Control 24V 3Pin Connector x2 – IFP [13]	Free Free Free Free $40-$150* $95.00 $28.70
Assembly F	High Capacity Side Mount Slide – McMaster-Carr [6]	$119.96
		Total Costs: $891.12 - $1001.12* *Projected cost depending on power supply

Testing

Due to the current state of the project, no testing has been able to be conducted. Future testing would begin with the cylinders. This testing would begin by extending the cylinders at the lowest PSI necessary to move the needed load and to gradually increase the PSI in order to obtain a desirable cycle time for extension and retraction. Testing would also be performed with various sizes and weights of paper product to ensure flawless execution for the majority of Wise's work.

Conclusion

While we were not able to complete a working prototype for our design, we were able to develop a cost effective method for Wise Business Forms to reduce the risk of burns for their employees and leave future automation a possibility. Since Kenneth Win is an intern at Wise Business Forms, he will be able to work on the completion and see it come to fruition.

Overall, this project served as an excellent hands on learning experience. It provided our group the opportunity to utilize concepts that we learned in the classroom and apply them to solve real world problems.

Special Thanks

Lastly, we would like to thank Wise Business Forms and Sally Spurr for their support and sponsorship of this project. We would also like to thank Martin Hubley for his technical expertise and assistance in tooling. Finally, to Dr. Dupen, Dr. Narang, and Dr. Lin for their guidance during this project.

Bibliography

[1] *PA-15 Linear Actuator*. Progressive Automations. PDF.

[2] *Series K Cylinder*. Motion Controls LLC. PDF.

[3] McMaster-Carr, "Sensor Ready Tie Rod Air Cylinder 10" Stoke," *McMaster-Carr*, 2016. Web. 06 Mar. 2016.

[4] McMaster-Carr, "Sensor Ready Tie Rod Air Cylinder 24" Stroke," *McMaster-Carr*, 2016. Web. 06 Mar. 2016

[5] "Properties of Paper, (Paper Properties)." *Properties of Paper, (Paper Properties)*. Web. 05 Feb. 2016.

[6] McMaster-Carr, "High Capacity Side-Mount Drawer Slide," *McMaster-Carr*, 2016. Web. 08 Mar. 2016

[7] McMaster-Carr, "Flange Bar Set," *McMaster-Carr*, 2016. Web. 09 Mar. 2016.

[8] McMaster-Carr, "Clevis Bracket with Pin," *McMaster-Carr*, 2016. Web. 07 Mar. 2016.

[9] McMaster-Carr, "Rod Clevis with Pin," *McMaster-Carr*, 2016. Web. 07 Mar. 2016.

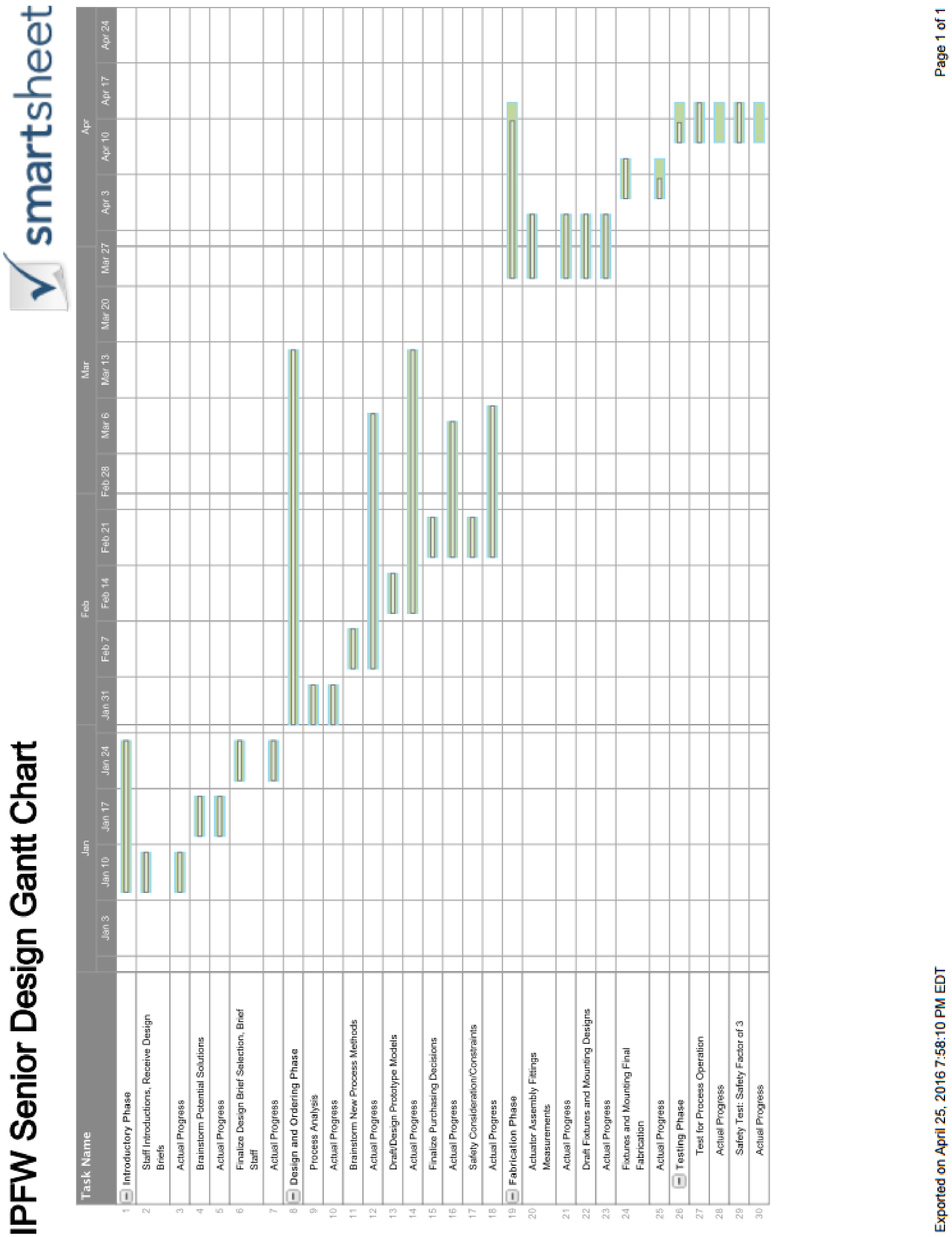
[10] McMaster-Carr, "Aluminum T-Slotted Framing Extrusion," *McMaster-Carr*, 2016 Web. 04 Apr. 2016.

[11] McMaster-Carr, "End Cap for 3" High Double Aluminum T-Slotted Framing Extrusion," *McMaster-Carr*, 2016 Web. 04 Apr. 2016.

[12] McMaster-Carr, "Linear Bearings for T-Slotted Framing," *McMaster-Carr*, 2016 Web. 04 Apr. 2016.

[13] *Viking Valve Series*. Parker. PDF

ANNEX: A GROUP GANTT CHART



ANNEX:B Excel Gantt Chart Guide

Task Name	Start Date	End Date	Duration	% Complete	Assigned To
Introductory Phase	**01/11/16**	**01/29/16**	**15d**	**100%**	
Staff Introductions, Receive Design Briefs	01/11/16	01/15/16	5d	100%	Group
Actual Progress	01/11/16	01/15/16	5d	100%	Group
Brainstorm Potential Solutions	01/18/16	01/22/16	5d	100%	Group
Actual Progress	01/18/16	01/22/16	5d	100%	Group
Finalize Design Brief Selection, Brief Staff	01/25/16	01/29/16	5d	100%	Group
Actual Progress	01/25/16	01/29/16	5d	100%	Group
Design and Ordering Phase	**02/01/16**	**03/18/16**	**35d**	**100%**	
Process Analysis	02/01/16	02/05/16	5d	100%	Group
Actual Progress	02/01/16	02/05/16	5d	100%	Group
Brainstorm New Process Methods	02/08/16	02/12/16	5d	100%	Group
Actual Progress	02/08/16	03/10/16	24d	100%	Group
Draft/Design Prototype Models	02/15/16	02/19/16	5d	100%	Nicholas Burchell
Actual Progress	02/15/16	03/18/16	25d	100%	Nicholas Burchell
Finalize Purchasing Decisions	02/22/16	02/26/16	5d	100%	Kenneth Win
Actual Progress	02/22/16	03/09/16	13d	100%	Kenneth Win
Safety Consideration/Constraints	02/22/16	02/26/16	5d	100%	Brian Daley
Actual Progress	02/22/16	03/11/16	15d	100%	Brian Daley
Fabrication Phase	**03/28/16**	**04/18/16**	**16d**	**90%**	
Actuator Assembly Fittings Measurements	03/28/16	04/04/16	6d	100%	Nicholas Burchell/ Kenneth Win
Actual Progress	03/28/16	04/04/16	6d	100%	Nicholas Burchell/ Kenneth Win
Draft Fixtures and Mounting Designs	03/28/16	04/04/16	6d	100%	Brian Daley
Actual Progress	03/28/16	04/04/16	6d	100%	Brian Daley
Fixtures and Mounting Final Fabrication	04/07/16	04/11/16	3d	100%	Group
Actual Progress	04/07/16	04/11/16	3d	50%	Group
Testing Phase	**04/14/16**	**04/18/16**	**3d**	**50%**	
Test for Process Operation	04/14/16	04/18/16	3d	100%	Group
Actual Progress	04/14/16	04/18/16	3d	0%	Group
Safety Test: Safety Factor of 3	04/14/16	04/18/16	3d	100%	Group
Actual Progress	04/14/16	04/18/16	3d	0%	Group