Automated Packaging Machine Modifications

Final Design Report

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Melet Plastics Inc. - Client

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Executive Summary

Melet Plastics utilizes an automated packaging machine to attach header cards to its injection molded egg holder product. However, the financial advantages of using automation have not manifested at Melet due to the high failure rate of the machine. This report was created by JAYS Mechanical Consulting to identify the machine failure modes, provide recommendations for modifications to reduce the occurrence of these failures, and provide detailed designs of these modifications.

A failure modes and effects analysis (FMEA) conducted by JAYS Mechanical Consulting identified four failure modes associated with the machine. These four modes are: stapler misfire, misshapen staples, incorrect positioning of the staple, and incorrect positioning of the header card. The positioning failure modes have low variability and frequency. JAYS Mechanical recommends systematic set-up procedures to prevent positioning errors incurred during set-up, and modifications to the header card and card dispenser to prevent operator error during card reloading. The stapler misfire and misshapen staple failure modes were found to be a result of the stapler used in the machine. The main mechanism of failure were interference of the egg holder handle on the stapling process and previous back plate modifications that prevent proper stapling. JAYS Mechanical Consulting is recommending two modification designs to deal with the stapling failure modes.

The first design addresses these failure modes by applying modifications to the stapler currently used in the machine. Immobilization of the staple back plate and material removal from the bottom arm of the stapler are the key features of the first design. Immobilizing the back plate in its intended position ensures proper stapling and the material removal allows clearance for the handle preventing any interference with the stapling process. The estimated cost of this first design is $195.72, well below the allowable budget of $5000, and the design is quick to implement.

The second design JAYS Mechanical Consulting recommends implements the Senior A16/L pneumatic stapler from Margreiter-Technik. The designed modifications are all based on making the stapling machine compatible with the Senior A16/L stapler. This stapler has the clearance necessary to prevent interference from the egg holder handle and comes with an immobile back plate. The Senior A16/L is an industrial stapler intended for packaging applications and therefore

is durable and provides reliable performance. The estimated cost of this second design is $1672.83, below the $5000 allowable budget, but requires more extensive modifications than the first design.

Both designs are capable of meeting the client needs and provide their own unique advantages. JAYS Mechanical has provided two different designs to Melet so that they have flexibility with regards to the type of stapler they would like to use and the cost of the modifications. JAYS Mechanical recommends that Melet initially implement the first design because it requires no modifications to the stapling machine and is low cost. If following commission of the first design Melet would like to try another stapler, the second design could be implemented.

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1.0 Introduction

This report was produced by JAYS Mechanical Consulting as a product of the Engineering MECH 4860 design course at the University of Manitoba and is intended to provide recommendations for the modification of the automated packaging machine at Melet Plastics. This report presents the project definition, a brief summary of our design methodology, and the project deliverables requested by Melet Plastics. The deliverables in this report consist of a failure modes and effects analysis (FMEA), recommendations for the modifications to the machine, detailed design drawings, and a cost analysis.

1.1 Project Background

Melet Plastics is a supplier for numerous manufacturing companies in North America and has established a reputation over the past 50 years for producing high quality injection molded parts [1]. One product Melet manufacturers is a plastic egg holder, which is a small yellow injection molded carrying case for eggs, and is often used for camping. In addition to manufacturing the egg holder, Melet is also responsible for attaching cardboard header cards to the egg holder handle. These header cards are the packaging which allows the egg holder to be stocked and displayed in distributing stores. Figure 1 illustrates the required arrangement of the product and packaging. Melet receives approximately four large orders for these egg holders per year, with each order taking approximately 100-150 hours of automated machine run time to complete.

Figure 1: Egg holder produced by Melet Plastics with the cardboard header attached [2].

In order to meet the demand from its client, Melet manufactures the egg holders by using automated machinery. The entire process occurs in four steps. First, an automated injection molding machine produces the parts; a robotic arm then removes the part from the molding machine and holds it in position in front of an automated stapling machine. The stapling machine then staples a header card to the egg holder. To conclude the process, the robotic arm places the egg holder on a conveyor belt. The scope of our project is centralized on the automated stapling machine.

1.2 Problem Statement

The stapling machine used to attach the header cards is a custom made machine which was constructed specifically for its purpose by a third party. The current performance of the stapling machine is not meeting the expectations of Melet Plastics. The problems experienced by the machine are either in the form of not completing the stapling process or by completing the process, but with an unsatisfactory result. Our team identified the main problems affecting the performance of the machine through communication with our contacts at Melet Plastics, interviews with the operators of the machine at Melet Plastics, and through a thorough investigation of the machine itself.

The machine fails to complete the process when the handle of the stapler is compressed but the staple is not released. This failure is referred to as a stapler misfire. The problems associated with producing incorrectly stapled headers are that the positioning of the header card on the egg holder is incorrect, the staple on the header is obstructing either the lettering or the barcode, and the staple is not dispensed properly, which results in a misshapen staple. Figure 2 shows a CAD model of the stapling machine and labels the problem area in red. All of these problems create product and packaging combinations which cannot be sold and must be reprocessed by manually removing the header and stapling on a new one.

The process produces two parts every 23 seconds under ideal conditions [3]. However, the stapler machine uptime is only 25%, which means that 75% of the time the machine is down for maintenance and the stapling process must be performed manually by one of the operators on site. Normal operation will require half an operator, although if the stapler malfunctions, Melet must to assign two full operators for manual stapling.

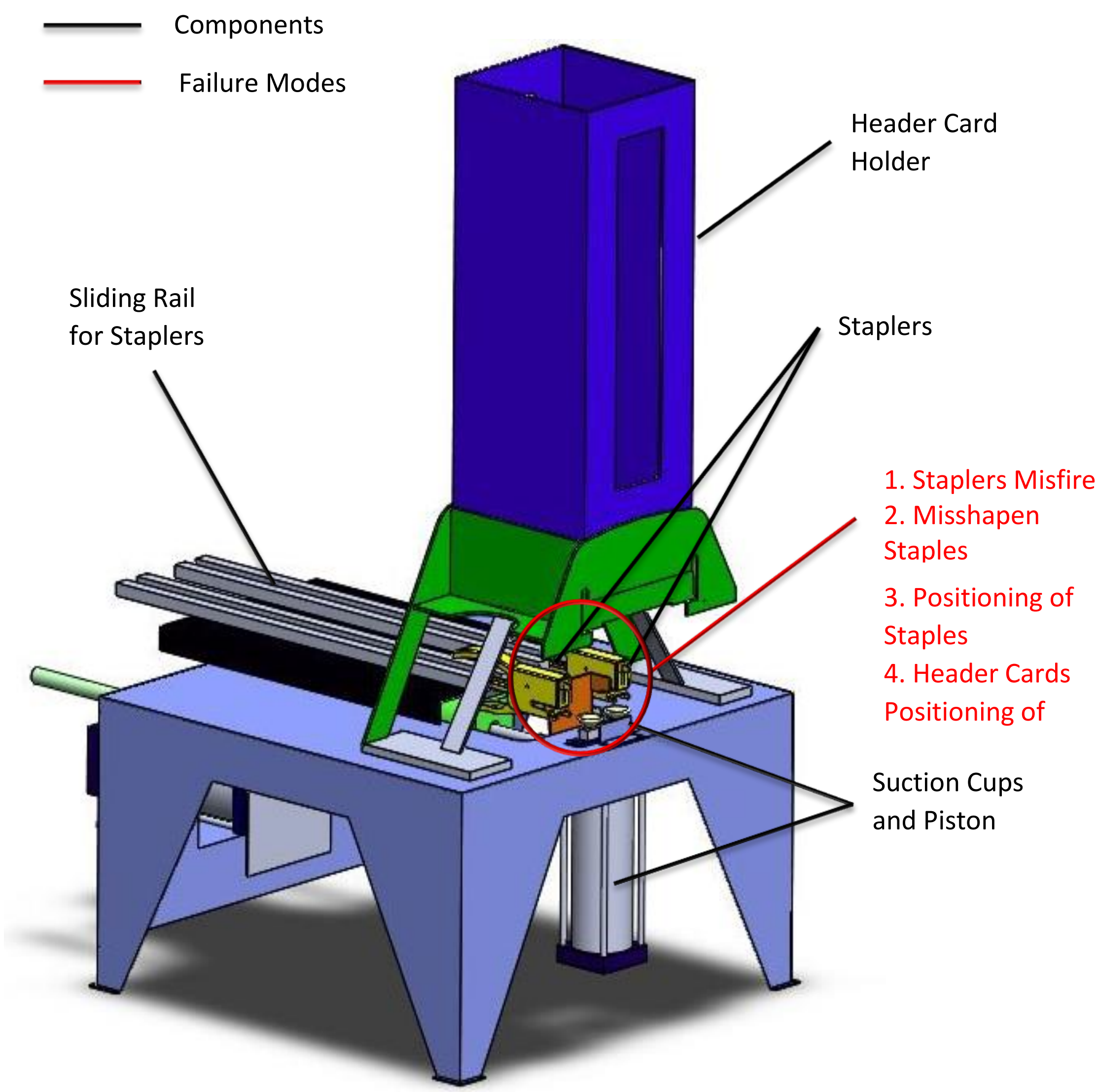


Figure 2: CAD model of the current automated stapling machine [4].

1.3 Project Objectives

JAYS Mechanical Consulting Inc. has been tasked by our contacts at Melet Plastics to perform an analysis of the failure modes of the automated machine used to staple cardboard headers to a plastic egg holder product. Our contacts at Melet Plastics are Noel Mattson, Vice-President of Engineering and Primary Contact; and Carl Rogers, Project Leader and Secondary Contact. The final deliverable requested by Mattson and Rogers is a recommendation which will outline how to eliminate both the downtime of this stapling machine and the manual reprocessing of incorrectly stapled headers. The recommendation may be in the form of modifications to the current machine or a design for a new machine to complete the fastening of cardboard headers to the egg holders. The recommendation includes a cost analysis of the proposed solution along with a prototype which demonstrates proof of concept.

Noel Mattson and Carl Rogers expect the recommendation provided by JAYS Mechanical Consulting to solve four issues found in the current stapling process: misfiring of the staplers, incorrect positioning of the staples on the card, misshapen staples, and incorrect positioning of the cardboard header card with respect to the egg holder.

1.4 Client Needs

Our team identified needs statements and organized them to form groupings of similar needs. Needs are prioritized by their importance to the Client using a scale from 1 to 5, with each number having an assigned definition listed in TABLE I. A list of the needs statements are given in TABLE II**Error! Reference source not found.**; bolded need statements represent a general need grouping and are followed by the specific needs that must be met to achieve the general need statement.

TABLE I: LEGEND FOR CLIENT NEED IMPORTANCE SCALE

Legend for Importance Scale	
Crucial to Client Satisfaction and Required for Project Success	5
Very Beneficial to the Client, without completion Project Success would be Partial	4
Very Beneficial to the Client but Not Required for Project Success	3
Moderately Beneficial to the Client but Not Required for Project Success	2
Slightly Beneficial to the Client but Not Required for Project Success	1

TABLE II: CLIENT NEEDS

#	Client Needs	Imp
1	**Attach a card correctly on the egg holder**	**5**
2	Stapled card is horizontally centered on the egg holder handle	4
3	Staples or secures card in the correct location on the card	5
4	Staples or secures the card without damaging the card	5
5	Staples pierce the cardboard and close completely	5
6	**Attach a card securely on the egg holder**	**5**
7	Staple or securing method can hold the weight of the egg holder when hanging	5
8	Staple or securing method does not damage the card when hanging	5
9	**Stapling or securing machine can operate long enough to complete an entire order**	**5**
10	Stapling or securing mechanism is resistant to failure and jamming	5
11	Card drawing mechanism is resistant to failure and jamming	5
12	Card drawing mechanism draws a single card at a time	5
13	**Stapling or securing machine is compatible with both molding machines**	**3**
14	Stapling or securing mechanism is capable of indexing to both molding machines	3
15	Stapling or securing machine indexes correctly to the molding machines	5
16	Stapling or securing machine can be loaded by both molding machines	3
17	**Stapling or securing device can complete an order without technician involvement**	**4**
18	Stapling or securing mechanism is automated	5
19	Stapling or securing machine can keep pace with molding machines	5
20	Stapling or securing mechanism can complete an order without reloading staples or other securing material	2
21	Card holder holds enough cards for an entire run	2
22	**Stapling or securing machine can be repaired quickly after a malfunction**	**4**
23	Failure of the stapling mechanism can be resolved quickly by a technician	4
24	Failure of card drawing mechanism can be resolved quickly by a technician	4
25	Card drawing mechanism is accessible for maintenance or repair	4
26	Stapling mechanism is accessible for maintenance or repair	4
27	Worn parts in the machine can be easily replaced	4
28	**Make technician operations mistake proof**	**3**
29	Design ensures the only way to load the cards in the card queue is in the correct orientation	3
30	Stapling or securing machine prevents incorrect indexing to the molding machine	3
31	**Machine will have a long operational life**	**4**
32	Stapling or securing mechanism parts are resistant to fatigue failure	4

The most important needs of the client, as shown in TABLE II, are attaching the card correctly, attaching the card securely, and ensuring the uninterrupted runtime of the machine is long enough to complete an order. Secondary needs are the ability to repair the machine quickly, operation without technician involvement, and having a long operational life.

1.5 Target Specifications

After interpreting the customer needs, our team identified target specifications for our recommendations to meet, which are listed in TABLE III. The specifications inherited their importance rating from their linked needs. Then, the target specifications were assigned marginal and ideal values based on current performance and consultation with the client. These specifications and values were used to generate selection criteria in order to evaluate our concepts and select final designs.

TABLE III: TARGET SPECIFICATIONS AND METRICS

Metrics#	Need #	Metrics	Imp	Units	Marginal Values	Ideal Values
1	9, 10, 11, 12,	Average length of operation time between failure renders it inoperable	5	hour	100	150
2	19, 21	Part throughput	5	sec/part	16	16<
3	1, 2	Distance from card centerline to the handle centerline	4	mm	15	0
4	1, 3	Distance between actual and desired staple location	5	mm	1	0
5	19, 20	Automated process	5	yes/no	yes	yes
6	24, 27, 28, 29, 30, 31	Average time from return to operation after jam	4	hours	2	0.25
7	16	Setup time to index stapler machine to mold machine	3	hours	2	0.25
8	15	Tolerance of index procedure to mold machine	5	± mm	5	2.5
9	22	Length of continuous operation until stapler refill	2	hours	1	8
10	23	Length of continuous operation until header card refill	2	hours	1	8
11	30, 31	Prevents loading cards in the incorrect orientation	3	yes/no	yes	yes

1.6 Overview Constraints and Limitations

After meeting with Melet Plastics, our team discovered some constraints and limitations which affect the design. The recommendation provided at the end of this project by JAYS Mechanical must adhere to three constraints set by Melet Plastics.

1. **Moving Constraints**

   The stapling or securing machine must be movable so it can be transported from the storage area to the area of operation. To facilitate safe transportation, the center of gravity of the machine must not be higher than 2 meters above the ground.

2. **Size Requirement**

   The stapling or securing machine must fit in the area of operation next to the injection molding machine, measured as $4m^2$. In addition, the machine must be able to fit through a pathway that is 2 meters in width and 5 meters in height.

3. **Cost of Design**

   The budget for the recommendations provided by JAYS Mechanical Consulting must be less than $5000 [3]. This budget includes the cost of all parts and installation.

1.7 Design Methodology

JAYS Mechanical Engineering used a structured design methodology with numerous tools for concept generation and selection in this project. This section outlines the methodology our team followed to generate the final designs presented in this report. A more detailed explanation of this methodology is available in APPENDIX B. JAYS Mechanical Engineering performed failure modes and effects analysis, discussed in detail in Section 2.0, at the start of this process to determine the failure mechanisms of the stapling machine. Once the failure mechanisms were identified, our team researched a number of topics related to automated packaging to help us come up with ideas to address these failure mechanism. Concepts were generated using components of both 3P and 7 Ways brainstorming techniques. These concepts were then screened based on criteria we developed and using the current design as a baseline for performance. The concepts that passed this screening process were then refined into more detail ideas and integrated with useful features from other concepts. These refined concepts went through a final selection phase where they were scored using weighted criteria. The results of concept scoring were review and changes were made to ensure compatibility with the stapling machine and the process. The results of this review are the concepts behind the designs presented in this report.

2.0 Failure Modes and Effects Analysis

Four modes of failure were identified by our team and are listed in . The failure modes were sorted by their corresponding failing components and are numbered based on these component(s) (i.e. Staplers – 1.0, Sliding Rack – 2.0, and Machine Indexing Arm & Card Holder – 3.0). Each failure mode is assigned a probability score and a severity score; the product of these scores gives the risk priority number (RPN) which is used to prioritize how we addressed these risks. The probability score is a measure of how likely the failure mode is to occur. The severity score is a measure of how badly the failure affects the stapling machine and process. Detection is another parameter that is often used in FMEAs. The detection parameter was removed from this analysis because our team found that each of these modes had equal rates of detection. The ranking scales used to assign the scores for probability and severity are shown in TABLE V and TABLE VI respectively.

Melet operates the header card machine four to five times a year for periods of approximately 100 to 150 hours. Only one of these operational periods was scheduled during the length of this project. For this reason, our team was limited to collecting data from just two different sessions; the first session was in person at Melet Plastics and the second was from a 30 minute video provided by Melet Plastics. The rankings seen in the FMEA were given using this data and from anecdotal information obtained from operators at Melet Plastics. There was little variability in the data we gathered and the information we collected so we are confident in the results of the FMEA.

TABLE IV: FAILURE MODES ANALYSIS OF CURRENT DESIGN

Failure Mode Ref. Number	Failing Components	Failure Mode	Potential Cause(s)/Failure Mechanism	Probability, P	Severity, S	Risk (P*S)
1.1	Staplers	Stapler Misfiring	• Modified backing plate • Interference of the egg holder handle • Wear of the stapler • Jamming of stapler	5	4	20
1.2	Staplers	Misshapen Staples	• Modified backing plate • Interference of the egg holder handle • Wear of the stapler	5	3	15
2.1	Sliding Rack	Incorrect Position of the Staple	• Position setting of slide rack in the PLC	3	4	12
3.1	Machine Indexing Arm & Card Holder	Incorrect Position of the Card	• Indexing arm position setting • Minor variability in set-up position • Operator error in loading cards	3	4	12

TABLE V: FMEA PROBABILITY

Ranking	Likelihood
1	Extremely Unlikely (May occur once a year)
2	Rare (May occur once or twice in an order)
3	Occasional (Will likely happen multiple times in a week)
4	Probable (Will likely happen a multiple times every day)
5	Frequent (Will likely happen multiple times every hour)

TABLE VI: FMEA SEVERITY RANKINGS

Ranking	Severity
1	Does not affect resulting product.
2	Minor affect to resulting product and/or process but does not require reprocessing or immediate action.
3	Affects resulting product and/or process, requires reprocessing or immediate minor adjustment but machine ill remain in operation.
4	Affects resulting product and product requires reprocessing and immediate adjustment that requires the shutdown of the machine.
5	Disrupts the process, requires shutdown of the machine, and causes damage to the machine.

The results from the risk column in indicate that the highest risk priority numbers are related to the failure of the staplers: stapler misfire (risk level 20), and misshapen staples (risk level 15). These high risk numbers result from the high frequency of failure of the current staplers and their moderately high severity numbers. The stapling misfire and misshapen staple failure modes are very severe and cause the approximately 75% downtime of the machine. When these modes keep occurring operators shut down the machine and either try to fix problem, or decide that it is not worth the time to try to fix the machine and end up stapling all the header cards manually. The two incorrect positioning failure modes also have moderately high risk priority numbers (risk level 12). The probability of these modes is fairly low but the severity scores are high, which results from the fact that the machines would likely have to be shut down to resolve positioning issues. To simplify the problem of preventing these modes of failure our team divided the failure modes into two groups based on their root causes or failure mechanisms. These groups were the moderate risk positioning failure modes and the high risk stapling failure modes.

2.1 Positioning Failure Modes

When our team observed the machine in operation we noticed that both the positioning of the staples and the positioning of the cards had little variability. Our team did not observe any failures of staple positioning, however there was one instance where the machine was positioning the header card incorrectly. In this instance, the positioning of the header was precise but in the wrong location. This case in which the header card is incorrectly located on the egg holder handle is shown in Figure 3. The high precision of the machine and the low frequency of these failures indicates that the error is not a result of the machine hardware. These qualities are more indicative of failure associated with setting up the machine slightly off of the correct position. Because these types of failures occur infrequently and are consistently in the same place when they appear, we believe the main source of this failure is variability in the set-up location. Operators at Melet add that the incorrect positioning of the header cards can also be caused by operator error during loading of the header cards when the cards are loaded in the incorrect orientation.

Figure 3: A header card located incorrectly on the egg holder handle resulting in the stapler stapling into the handle [5].

Due to the above mentioned precision exhibited by the stapling machine, we believe that the probability of these failure modes can be reduced significantly by implementing post set-up inspection to ensure the machine is lined up correctly. Features can also be added to the machine to mistake-proof the process of loading header cards to prevent operator error. These recommendations will be discussed in further detail in Section 2.3.

2.2 Stapling Failure Modes

In comparison with the positioning failure modes, the failure modes related to the stapler have a much higher frequency and appear inconsistently. The main failure mechanisms are interference from the egg holder handle and modifications to the stapler back plate. Interference occurs as the mouth of the stapler closes to dispense the staple, the thickness of the egg holder handle obstructs the stapler arms and prevents complete closure. This interference is shown in Figure 4. If closure of the staple mouth is impeded by the handle, the staple cannot close entirely and the staple is left slightly open, leaving a misshapen staple. Operators at Melet Plastics have made modifications to the back plate of the stapler, as seen in Figure 4. The modifications change the angle at which the staple hits the back plate and the alignment of the staple with the folding grooves inset into the back plate. These factors affect the folding of the staple and can cause misshapen staple. Both the interference of the handle and the modifications to the back plate may cause jamming of the stapler and contribute to the stapler misfire failure modes. Additional factors that could be mechanisms for the stapling failure modes are wear of the stapler and jamming of the staples in the stapler feeding track.

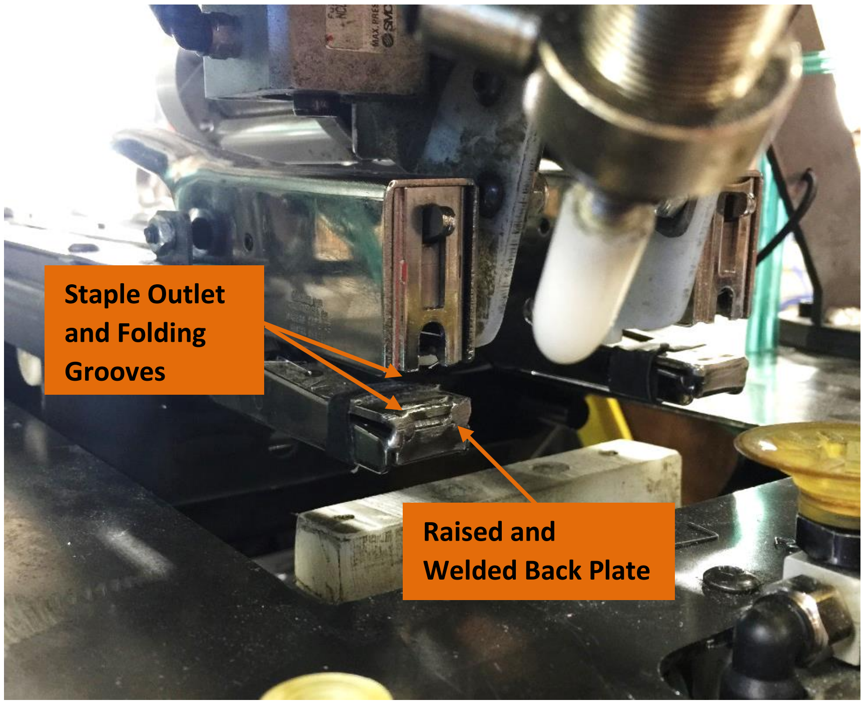


Figure 4: Current modifications to the Rapid Classic A1 stapler [6].

JAYS Mechanical Consulting has developed two designs that can mitigate these high risk stapling failure modes. The first design is a low cost solution that is quick to implement. This design involves the modification of the current stapler used in the machine, the Rapid Classic A1 stapler. The second design is higher cost and has a longer lead time but implements a highly reliable industrial stapler. This industrial stapler is called the Senior A16/L, and is designed for packaging applications [7].

The first design mitigates the handle interference by cutting out material to the rear of the back plate, creating space for the handle to sit during the stapling process. The second design mitigates the interference because the Senior A16/L has enough clearance for the egg handle. The Senior A16/L is fires the staple pneumatically and should give the staple enough momentum to avoid any issues related to staple closure. While both of these design solutions are capable of mitigating the failures discussed in this section, they have different prices points and each offer their own unique advantages. These designs will be discussed in further detail in Section 4.0.

3.0 Recommendations for Mitigating Positioning Failure Modes

As discussed in the FMEA, JAYS Mechanical Consulting believes that the position failure modes can be dealt with through the use of a standard procedure for set-up. Following set-up of the machine, we recommend that the operator inspects the first few egg holders to be processed to determine whether positioning is satisfactory. Clear requirements for the target position should be laid out to the operator. We recommend these requirements include a comparison between a sample egg holder and attached header card. Lines can be drawn on the header card to indicate acceptable zones for staple positioning. If the initial products do not meet the requirements, the operator can make appropriate adjustments to the machine cart location. These adjustments could include loosening bolts to the indexing arm, which attaches the stapling machine to the injection molding machine, and shifting the stapling machine to the correct the positioning. If necessary, washers could be added to the indexing arm bolts to increase the space between the arm and the cart. Once adjustments are made, the operator should then recheck whether the header cards and staples are position correctly. The process should be repeated until satisfactory results are achieved. To improve the consistency of this process, a log can be kept indicating in what direction the machine was adjusted. If these adjustments are consistently in one direction, we recommend altering the programing of the robotic arm or the PLC settings for the stapler slider to reduce the amount of adjustments required. By making these changes, the number of parts requiring reprocessing can be reduced.

Another cause of incorrect header card positioning is operator error during loading of the cards. To solve such issues we can attempt to “mistake-proof” the process, which is often referred to as poka-yoke in lean manufacturing. For this purpose, we recommend Melet Plastics contact Coghlan’s to request that the header card corner be removed. By removing the corner and adding a corresponding obstruction in the card holder the card will only be able to be loaded in a single orientation [8]. This configuration, illustrated in Figure 5, makes it impossible for the operator to load the header cards incorrectly.

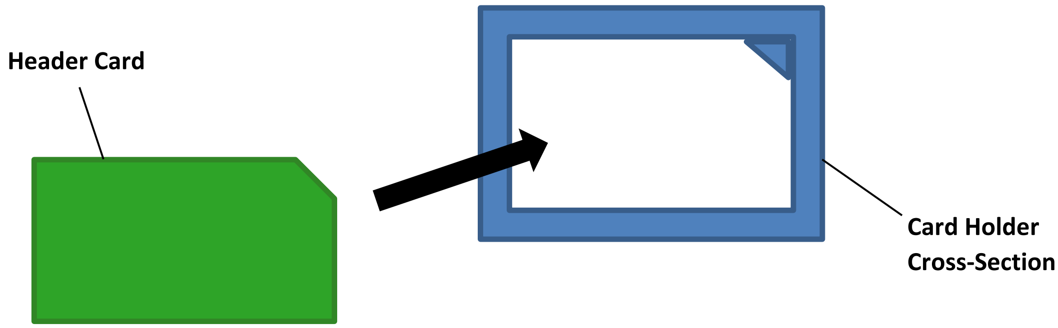


Figure 5: Card design to prevent operator error [9].

4.0 Recommendations for Mitigating Stapling Failure Modes

As discussed in the FMEA, JAYS Mechanical Consulting has developed two designs to reduce the effect of the stapling failure modes on the header attachment process. The first design is a modification of the Rapid Classic Stapler. Because this design is based on modifications to the stapler currently in use, it is both cost effective and can be installed immediately. JAYS Mechanical Consulting recommends the implementation of this design first because it is low risk and does not involve any modifications to the stapling machine structure. Commissioning can be performed on this design to determine its effectiveness. Following this commissioning, if Melet Plastics prefers an alternate solution, we recommend implementing the second design. The second design which is based on the use of the Senior A16/L pneumatic stapler provides industrial reliability and durability at higher cost. Details of each of these designs are discussed in the following sections.

4.1 Rapid Classic Interim Modification

The Rapid Classic stapler is recommended for attaching headers and is a durable design [10]. The current issues associated with the Rapid Classic stapler are not a result of poor design, but of poor compatibility with part it is stapling. With appropriate modifications the Rapid Classic stapler can properly attach the header cards to the egg holder. To mitigate the stapling failure modes, our modification must prevent the egg holder handle from interfering with the stapler process and should be introduced in a way that does not negatively affect the stapling process. Any current modifications that are negatively impacting the process will be removed.

4.1.1 Concept Overview

The Rapid Classic stapler has previously been modified by Melet Plastic employees. Our design for the stapler will incorporate two of the current modification. The modifications that will be used are those that allow the stapler to physically fit into the machine and those that are used to attach the stapler to the machine. These two modifications are removal of a portion of the bottom handle and a drilled hole in the stapler feeding track. The recommended design will not implement any of the current modifications to the stapler back plate because they are likely the root of the issues with the stapling process. The new features that will be introduced in the recommended design are fixing the back plate to in its original position and removing material in the bottom stapler arm. The complete modifications to the stapler are illustrated and labelled in Figure 6.

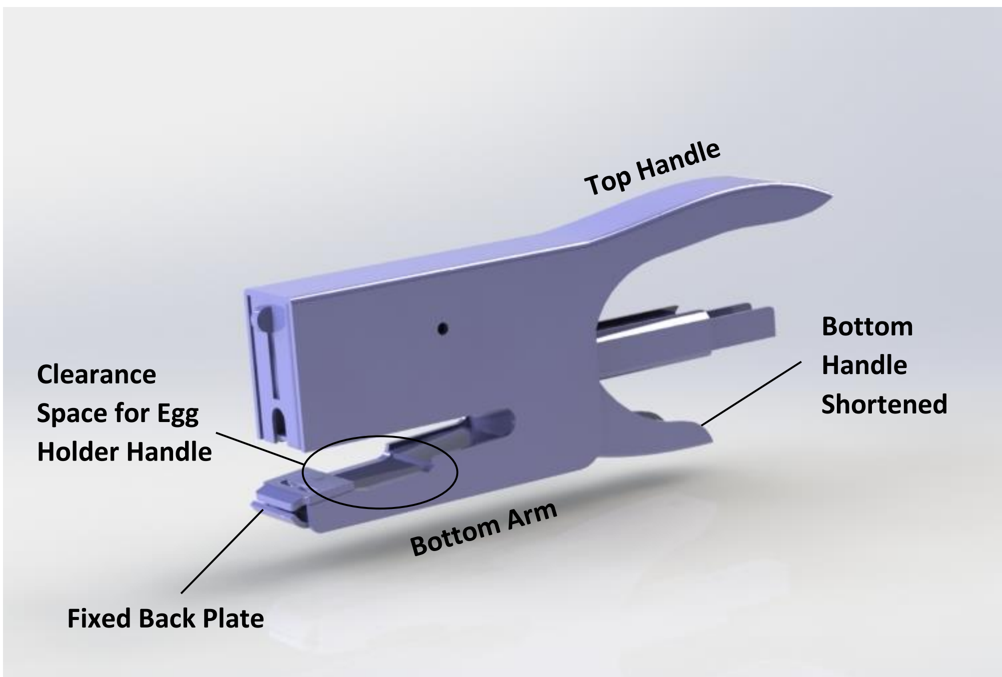


Figure 6: CAD render of the Rapid Classic stapler modifications [11].

4.1.2 Detailed Design

A complete set of drawings and bill of materials for the modification and assembly of the Rapid Classic Stapler Design are available in APPENDIX A – Engineering Drawings. The key modifications to this design are the immobilization of the back plate through the use of JB weld, and the removal of material from the back plate and the bottom stapler arm, creating a clearance area with a depth of 3.0 millimeters.

Installation of the staplers into the stapling machine will be consistent with the current method used by Melet plastics of using an M3 bolt through the staple feeder track. Changes may need to be made to the position settings of the robotic arm so that the egg handle is positioned to properly fit with the modified stapler.

By immobilizing the back plate in its intended position, we prevent misalignment of the back plate and the problems that result misalignment. Immobilizing the back plate also serves to prevent any motion during the removal of material from the bottom arm. Material is removed from the rear of the back plate and further into the bottom arm to provide space for the egg holder handle. By providing space for the handle we have prevented the handle from interfering with the stapling process and allowed complete closure at the stapler mouth. A prototype for this design has been produced to prove the concept. The benefits of providing clearance for the handle is demonstrated using the prototype in Figure 7.

UNMODIFIED	MODIFIED

Figure 7: Comparison of unmodified and modified stapler stapling the egg holder. Note the modified stapler is able to completely close while the unmodified stapler is capable of closing only part way [12].

The clearance space and the immobilization of the back plate prevent interference by the egg holder handle and the occurrence of misshapen staples thereby meeting the client's needs of attaching the card correctly and attaching the card securely. In turn these modifications also improve the reliability of the stapling process and contribute to lengthening the uninterrupted runtime of the machine. To reduce repair time, we recommend Melet Plastics orders and machines these staplers in batches of four to ensure there is always a replacement available.

4.1.3 Cost Analysis

Total cost of modification, parts, and labour for two Rapid Classic A1 staplers is estimated at $153.89. The breakdown of this cost estimate is presented in TABLE VII. Rapid staplers are commercially available in Winnipeg at Staples locations in the city, and JB weld is available at Canadian Tire. Labour cost were calculated using an average hourly rate for machinists in Canada [13] and the wage of operators at Melet Plastics [3]. The cost estimate for this design is below the budgeted cost of $5000.

TABLE VII: COST BREAKDOWN OF RAPID CLASSIC MODIFICATIONS

Cost Items	Quantity	Rate	Total
Rapid Classic Plier-Type Stapler A-1	2 units	$35.95/unit	$71.89
JB Weld	1 unit	$13.00/ unit	$13.00
Labour: Adhere Back Plates	0.5 hours	$23.00/hr	$11.50
Labour: Machining	3 hours	$23.00/hr	$69.00
Labour: Assembly	1 hour	$23.00/hr	$23.00
Labour: Commissioning	0.5 hours	$14.65/hr	$7.33
Total Cost			$195.72

4.2 Pneumatic Redesign Recommendation

The Senior A16/L Pneumatic stapler is recommended by its manufacturer for repeated long term use in industrial packaging applications making it a suitable alternative for Melet Plastic's application [14]. The staple used in this stapler is strong but thin. These staple features allow the stapler to easily staple through the carton header card and secure it without obscuring text or important features on the card. Because of its durability, size, and recommended applications, we believe the Senior A16/L Pneumatic stapler is suitable for the attachment of header cards to egg holders.

4.2.1 Concept Overview

The issues associated with the current design result from interference of the egg holder handle on the stapling process and the modifications to the stapler back plate. Our design which incorporates the Senior A16/L pneumatic stapler, shown in Figure 8, is capable of solving both of these problems. The Senior A16/L pneumatic stapler recommended for packaging applications, provides appropriate clearance for the egg holder handle, and comes equipped with a durable back plate that does not require modification. This means header cards will be attached correctly and with high reliability, drastically reducing machine downtime. The staplers are capable of handling the stresses of continuous operation and will have a long operational life. The majority of the design work for this stapler implementation is focused on modifying the stapling machine for compatibility.

Implementing the Senior A16/L pneumatic stapler into the current design involves modifications to the machine configuration which serve to generate clearance for the height of the stapler, maintain the stroke length of the stapler's horizontal translation, connect the stapler with the staple feeding track, and trigger the stapler to release the staple. The overall cost for this design is higher than for the first design due to the industrial nature of the stapler and the large amount of modifications required.

Figure 8: Senior A16/L pneumatic stapler with height and length dimensions [14].

4.2.2 Detailed Design

The first modification creates clearance so that the Senior A16/L stapler is capable of fitting in the machine. The Senior A16/L pneumatic stapler is approximately 5 cm taller and 5 cm longer than the current stapler. To account for these additional dimensions, the card holder will be raised and the slider mechanism will be altered to maintain the desired stroke length. These changes are shown in Figure 9. Extruded T-slot aluminum will be used to lift up the card holder, and two brackets will be repositioned on the slider to maintain the stroke length. A complete set of drawings and bill of materials for the modification and assembly of the Senior A16/L Design are available in APPENDIX A – Engineering Drawings. It is important to note that we were not able to acquire dimensioned drawings of the Senior A16/L pneumatic staple from its manufacturer, Margreiter-Technik. Therefore all of the models of this stapler were constructed using known dimensions of a few stapler features, and comparing these known dimensions with images of the stapler to scale the rest of the features. For this reason, please be aware of the uncertainty in our drawings and check dimension prior to the machining of any parts.

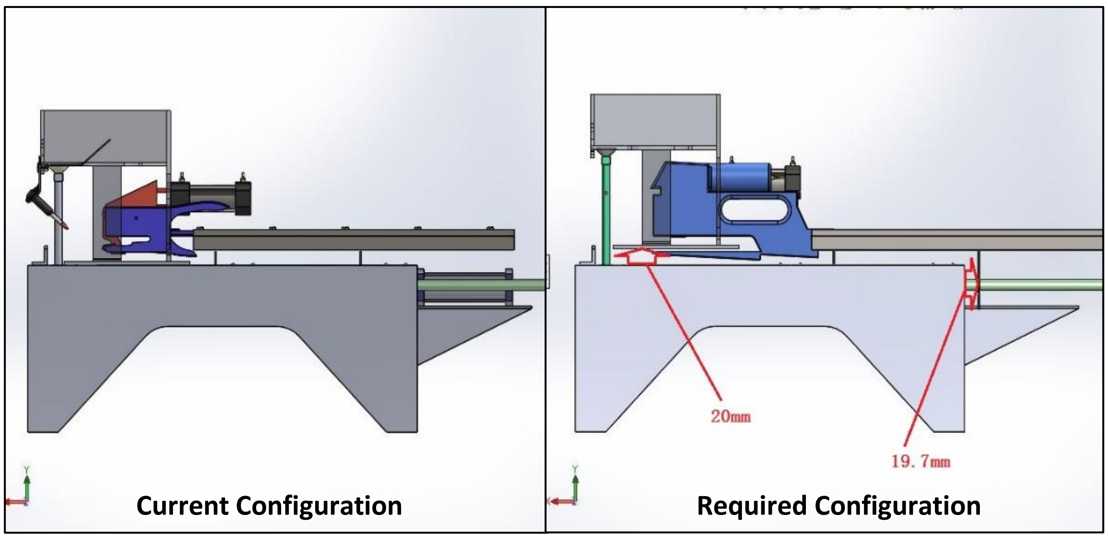


Figure 9: Comparison of current machine dimensions with the dimensions required for the Senior A16/L pneumatic stapler [15].

The pneumatic stapler will be attached to the machine by the staple inlet of the stapler. A bolt will go through the base of the staple inlet attaching it to the stapler track. A bracket will also be attached by the same bolt to help carry the weight of the stapler. The details of this attachment and the bracket are shown in Figure 10.

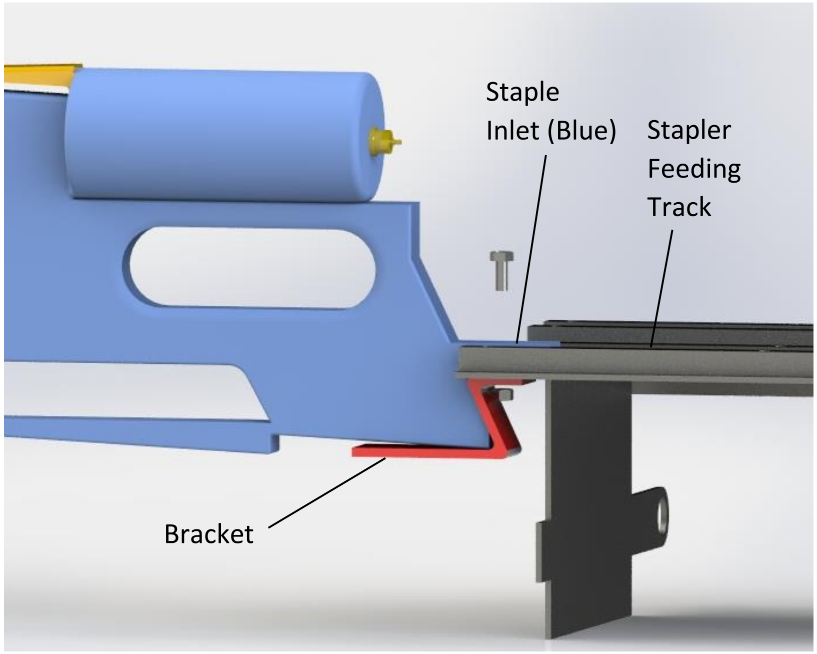


Figure 10: CAD render of the Senior A16/L pneumatic stapler mounting bracket [16].

The final modification to the machine is outfitting a trigger mechanism to fire the staple. The current position of the linear actuator trigger mechanism will not work with the pneumatic stapler because the stapler trigger is located too far forward. When the stapler is in position to fire the staples, the trigger is located directly underneath the opening of the header card dispenser. Linear actuators cannot be positioned above the trigger because they would obstruct the card dispenser. To circumvent this issue a single linear actuator will be mounted to the card folder mechanism. This actuator will be outfitted with an arm manufactured from acrylonitrile butadiene styrene (ABS) plastic. When both the stapler and folder are at their end positions over the card, the linear actuator will pull the arm down triggering both staplers simultaneously, as shown in Figure 11. The linear actuator specified in the drawing is capable of providing approximately 40 lbs of force which will be more than sufficient to pull down both triggers.

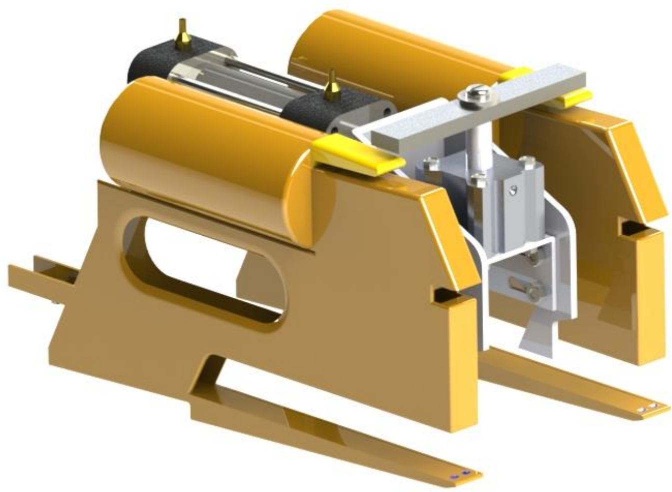


Figure 11: CAD render of the Senior A16/L pneumatic staplers with the trigger mechanism [17].

4.2.3 Cost Analysis

Total cost of modification, parts, and labour for the Senior A16/L pneumatic staplers is estimated at $1672.83, details are available in TABLE VIII. The pricing for the Senior A16/L pneumatic staplers was quoted from Margreiter Technik [14]. Labour cost were calculated using an average hourly rate for machinists in Canada [13] and the wage of operators at Melet Plastics [3]. The cost estimate for this design is below the budgeted cost of $5000.

TABLE VIII: COST BREAKDOWN OF SENIOR A16/L MODIFICATIONS

Cost Items	Quantity	Rate	Total
Senior A16/L pneumatic stapler	2 units	$712.66/unit (shipping incl.)	$1425.32
80/20 Inc. (Amazon) Part No. 25-2550-1220	1 X 1220 mm units	$27.91/unit (shipping incl.)	$27.91
Linear Actuator SMC NCDQ2A20-10T	1 unit	$52.30/unit (shipping incl.)	$52.30
Labour: Machining	2 hr	$23.00/hr	$46.00
Labour: Assembly	4 hr	$23.00/hr	$92.00
Labour: Commissioning	2 hr	$14.65/hr	$29.30
Total Cost			$1672.83

5.0 Conclusion

In this report JAYS Mechanical Consulting has compiled project details, analyses, final recommendations, and detailed drawings for Melet Plastics. The objective of this project was to provide recommendations to Melet Plastics that would mitigate a number of issues with the automated header card stapling machine and significantly reduce the machine downtime. The primary client needs for this project were attaching the card securely, attaching the card correctly, and improving reliability to reduce the machine downtime.

JAYS Mechanical Consulting conducted a failure modes and effects analysis (FMEA) which identified four modes of failures: stapler misfire, misshapen staples, incorrect positioning of the header card, and incorrect positioning of the staple. These four modes were divided into two groups based on the mechanism which caused the failure. These two groups were positioning failure modes and stapling failure modes. The failure mechanisms for the positioning failure modes were identified in the FMEA as variability in set-up position of the machine and operator error during loading of the header cards. The failure mechanisms for the stapling failures were identified as interference from the egg holder handle and misalignment of the stapler back plate.

To prevent the occurrence of positioning failure modes JAYS Mechanical Consulting has provided recommendations that focus on the procedure of machine set-up. To reduce variation in the machine set-up position, we recommend operators perform post set-up inspections of the first few egg holders the machine produces. A comparison should be performed between these first few egg holders and a target sample to determine whether the position of the machine is correct. If the egg holders fail this inspection, we have recommended correcting the positioning and performing another inspection. JAYS Mechanical Consulting has also provided recommendations to prevent operator error during loading of the header cards. Incorrect loading of the header cards can be prevented by slightly changing the geometry of the card and the card dispenser so that incorrect loading is impossible. We recommend removal of a corner of the header card and installation of a triangular obstruction in the dispenser to achieve this result. These two recommendations will increase the reliability of the machine, and correspondingly decrease the machine downtime, by reducing the number of positioning errors.

JAYS Mechanical Consulting has decided to submit two design recommendations for mitigating the stapling failure modes. The first design is based on modifications of the Rapid Classic A1 stapler, and the second design implements an industrial packaging stapler called the Senior A16/L. The modified Rapid Classic A1 stapler mitigates the stapling failure modes by preventing interference from the handle and misalignment of the back plate. This is achieved by providing a clearance cut-out in the bottom arm of the stapler and immobilizing the back plate in its original position using JB weld. Implementation of this design will improve the reliability of the stapling machining and reduce the current 75% downtime to a much lower percentage. By mitigating the misshapen staple failure mode, this design has also met the client needs of attaching the header card correctly and securely. This design is cost effective, reliable, and can be implemented with ease because it does not involve any modifications to the machine, just slight modifications to the staplers. The estimated cost of this design is $195.72 which is significantly under the allowable budget of $5000. This design has been prototyped and tested manually but requires commissioning in the stapling machine to ensure compatibility and durability of the design.

If Melet Plastics prefers implementing a different stapler than the one currently in use, we recommend pursing the second design option. The Senior A16/L pneumatic stapler, which is designed for use in packaging, will provide industrial level reliability and durability. The Senior A16/L pneumatic stapler provides appropriate clearance for the egg holder handle and comes equipped with a durable back plate that does not require modification. Both of these features mitigate the stapling failure modes thereby meeting the client needs of attaching the header card correctly and securely. This stapler is highly reliable and therefore will also significantly reduce machine downtime. Modifications to the stapling machine are required to implement this design due to the size of the Senior A16/L. The estimated cost of the Senior A16/L design is $1672.83. This is below the allowable budget of $5000 and it is important to note that the amount of labour hours are significantly less than those required to manufacture a new machine.

Each of these two designs is capable of meeting the three primary client needs. They also have different costs, lead times, and advantages that would improve Melet’s automated stapling machine. JAYS Mechanical Consulting has provided these two recommendations to Melet so that they can make a deliberate and responsible expenditure of capital that suits their business strategy.

References

[1] Melet Plastics Inc. (2015). Melet, engineered plastics + composite solutions [Online]. Available: http://www.meletplastics.com/ [Sept. 27, 2015].

[2] JAYS Mechanical Consulting Inc. "Egg holder produced by Melet Plastics with the cardboard header attached." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Sept. 25,2015.

[3] N. Mattson. (2015, Oct. 1). "RE: Questions for Eng. Design Project." Personal e-mail.

[4] JAYS Mechanical Consulting Inc. "CAD model of the current automated stapling machine." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Nov. 14, 2015.

[5] JAYS Mechanical Consulting Inc. "A header card located incorrectly on the egg holder handle resulting in the stapler stapling into the handle." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Nov. 14, 2015.

[6] JAYS Mechanical Consulting Inc. "Current modifications to the Rapid Classic A1 stapler." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Nov. 14, 2015.

[7] Margreiter-Technik Hans Hilscher GmbH, "Pneumatic stapling plier L53," [Online]. Available: https://www.margreiter-technik.com/products/stapling-pliers/stapling-plier/pneumatic-stapling-plier-53l. [Oct. 28, 2015].

[8] C. Rogers (private communication), Oct. 12, 2010.

[9] JAYS Mechanical Consulting Inc. "Card design to prevent operator error." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Nov. 14, 2015.

[10] StaplerWarehouse.com. (2013). *Rapid Classic K1 Manual Plier Stapler* [Online]. Available: http://www.payscale.com/research/CA/Job=Machinist/Hourly_Rate [Nov. 28, 2015].

[11] JAYS Mechanical Consulting Inc. "CAD render of the Rapid Classic stapler modifications." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Nov. 19, 2015.

[12] JAYS Mechanical Consulting Inc. "Comparison of unmodified and modified stapler stapling the egg holder. Note the modified stapler is able to completely close while the unmodified stapler is capable of closing only part way." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Dec. 1, 2015.

[13] Payscale, Inc. (2015). *Machinists Salary (Canada)* [Online]. Available: http://www.payscale.com/research/CA/Job=Machinist/Hourly_Rate [Nov. 30, 2015].

[14] Margreiter-Technik Hans Hilscher GmbH. (2015, Nov. 26). "Senior A16L." in *Quotation - Senior A16L.* Personal e-mail.

[15] JAYS Mechanical Consulting Inc. "CAD render of additional dimensions required for the Senior A16/L pneumatic stapler." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Dec. 1, 2015.

[16] JAYS Mechanical Consulting Inc. "CAD render of the Senior A16/L pneumatic stapler mounting bracket." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Dec. 1, 2015.

[17] JAYS Mechanical Consulting Inc. "CAD render of the Senior A16/L pneumatic staplers with the trigger mechanism." Winnipeg: Design Eng.,Univ Manitoba, Winnipeg, MB, Dec. 1, 2015.

APPENDIX A – Engineering Drawings

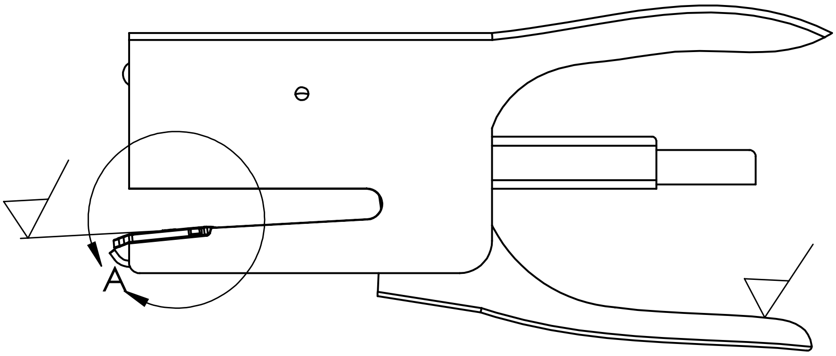
JAYS Mechanical Consulting has produced engineering drawings for all of the major modifications and parts required for the modified Rapid Classic stapler design and the Senior A16/L. For parts require modification, we have provided a few of the current configuration and a view of the modified configuration. Due to time constraints we were not able to acquire all the reference dimensions from the stapling machine that were required for these drawings. For dimension we do not have, we have referenced where to find the required dimension on the stapling machine. If you have any questions about these design drawings please contact us.

APPENDIX B – Concept Selection

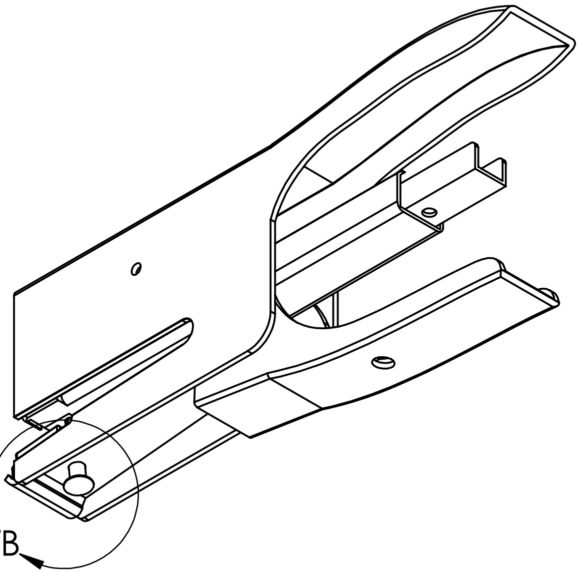
ITEM NO.	DESCRIPTION	QTY.
1	RAPID CLASSIC A-1 PLIER STAPLER	1

NOTES:

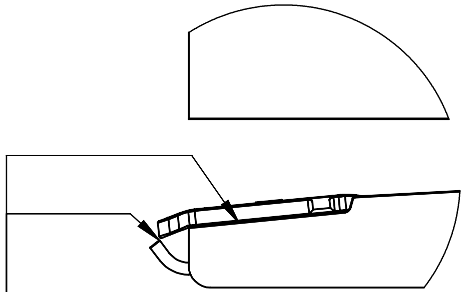
1. FOLLOW DIRECTIONS FOR APPLICATION PROVIDED ON THE JB WELD PACKAGING.



SIDE VIEW
(UNMODIFIED STAPLER)

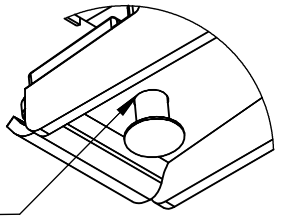


ISOMETRICVIEW
(UNMODFIED STAPLER)



DETAIL A

1. LIFT UP BACK PLATE AND APPLY JB WELD TO THE SURFACES INDICATED. ONCE THE JB WELD IS APPLED PRESS DOWN ON THE BACK PLATE TOENSURE IT IS RESTS IN ITS ORIGINAL POSITION. CLAMP THE BACK PLATE IN PLACE.



2. APPLY JB WELD AROUND THE ENTIRE PIN. ALLOW JB WELD TO CURE FOR 24 HOURS.

DETAIL B

REV	DATE	DESCRIPTION	BY	CKD	APP
00	2015-NOV-21	FOR INSTALLATION	JS	SL	JS

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
DEBUR AND BREAK SHARP EDGES

TOLERANCES:

NO DEC	X DEC	XX DEC	ANGLES/DEG
+/- 1.5	+/- 0.38	+/- 0.13	+/- 2.0

	NAME	SIGNATURE	DATE
DRAWN	J. SAFINIUK		2015-NOV-21
CHK'D	S. LIU		
APPV'D	J. SAFINIUK		
MFG	-		
Q.A	-		

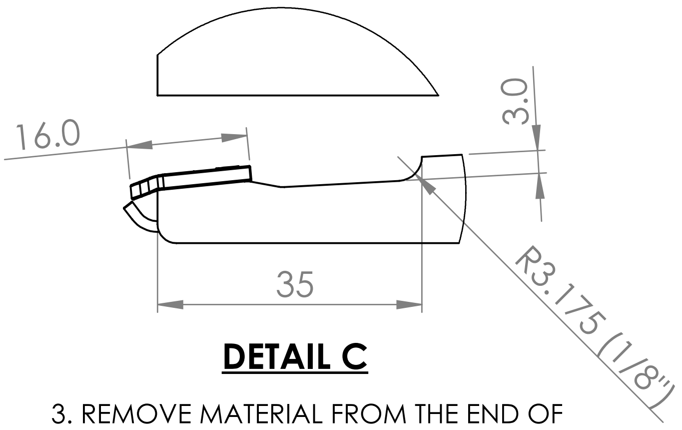
JAY'S MECHANICAL CONSULTING INC.

TITLE: MODIFICATIONS OF RAPID CLASSIC A-1 STAPLER

DWG NO. D4-0001

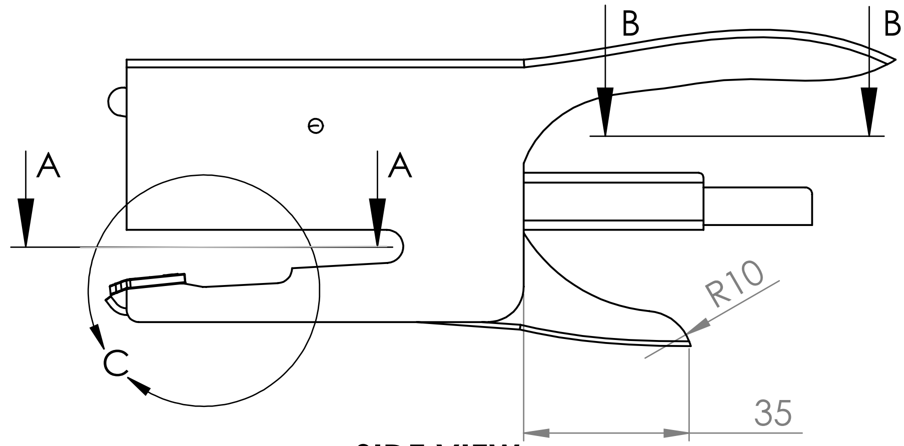
A4

SHEET 1 OF 2

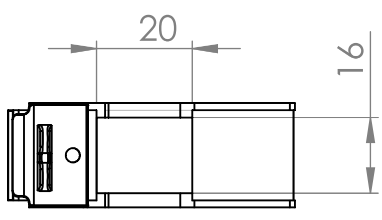


DETAIL C

3. REMOVE MATERIAL FROM THE END OF THE BACK PLATE.
4. USING A 1/4" MILL BIT PROCEDE TO MAKE THE DIMENSIONED CUT IN THE ARM.

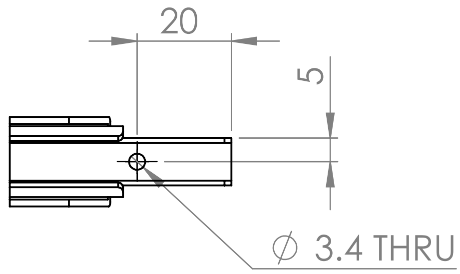


SIDE VIEW
(MODIFIED STAPLER)



SECTION A-A

5. REMOVE REMAINING MATERIAL FROM THE PREVIOUS MILL OPERATION IN THE DIMENSIONED AREA



SECTION B-B

6. DRILL MOUNTING HOLE

REV	DATE	DESCRIPTION	BY	CKD	APP
00	2015-NOV-21	FOR INSTALLATION	JS	SL	JS

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
DEBUR AND BREAK SHARP EDGES

TOLERANCES:

NO DEC	X DEC	XX DEC	ANGLES/DEG
+/- 1.5	+/- 0.38	+/- 0.13	+/- 2.0

	NAME	SIGNATURE	DATE
DRAWN	J. SAFINIUK		2015-NOV-21
CHK'D	S. LIU		
APPV'D	J. SAFINIUK		
MFG	-		
Q.A	-		

JAY'S MECHANICAL CONSULTING INC.

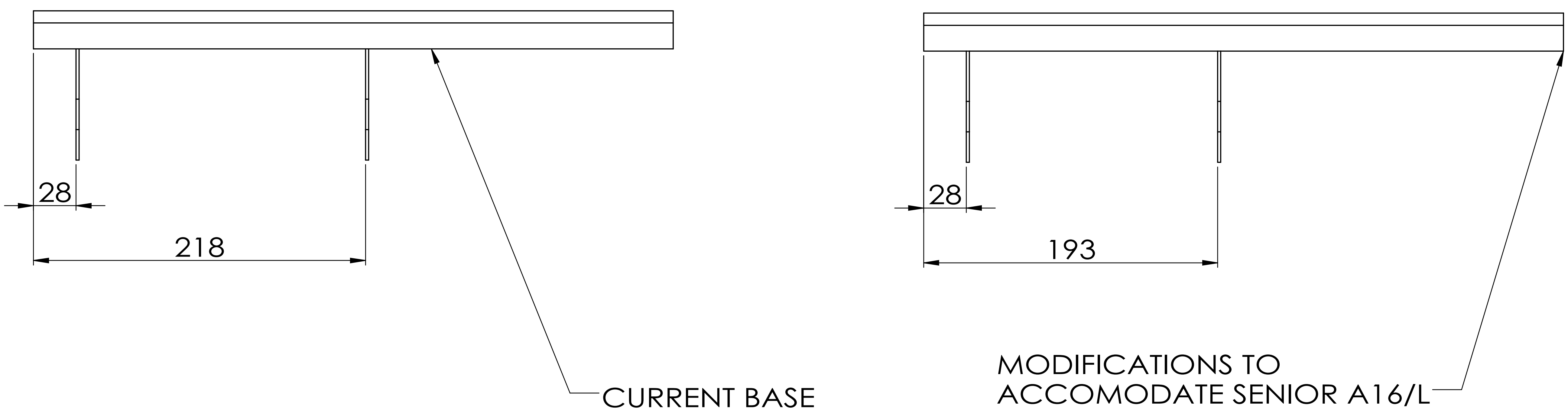
TITLE:
MODIFICATIONS OF RAPID CLASSIC A-1 STAPLER

DWG NO. D4-0001

A4

NOTE;

1. TO MODIFY CURRENT CONFIGURATION CUT OFF EXISTING BRACKET AND WELD AT NEW SPECIFIED LOCATION



UNIVERSITY OF MANITOBA

MELET engineered plastics + composite solutions

MECH 4860
Engine Design

UNLESS OTHERWISE SPECIFIED:	UofM MECHANICAL ENGINEERING			
DIMENSIONS ARE IN MILLIMETERS	INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE	
TOLERANCES:	DO NOT SCALE DRAWING	DRAWN	S.L	2015/11/30
ANGULAR: MACH±0° 30'	MATERIAL Steel	CHECKED	S.L	2015/12/7
TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	FINISH	NUMBER	7670313	

TITLE: STAPLER TRACK MODIFICATIONS PNEUMATIC STAPLER		
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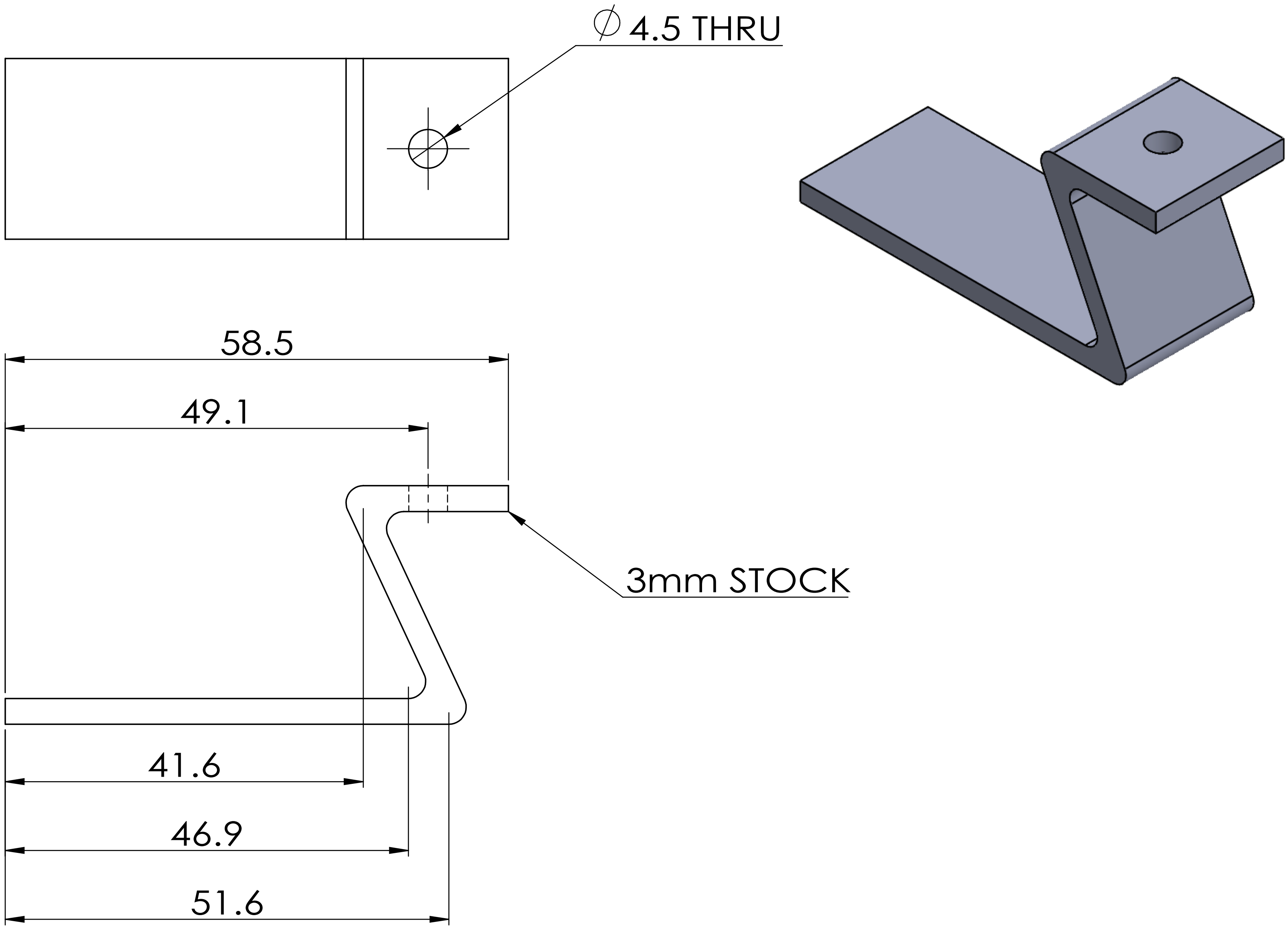
		SHEET 1 OF 1



UofM MECHANICAL ENGINEERING

TITLE: **PNEUMATIC STAPLER MOUNTING BRACKET**

MECH 4860

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TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994

DO NOT SCALE DRAWING

MATERIAL Steel

FINISH

	NAME	DATE
DRAWN	S.L	2015/11/30
CHECKED	S.L	2015/12/7
NUMBER	7670313	

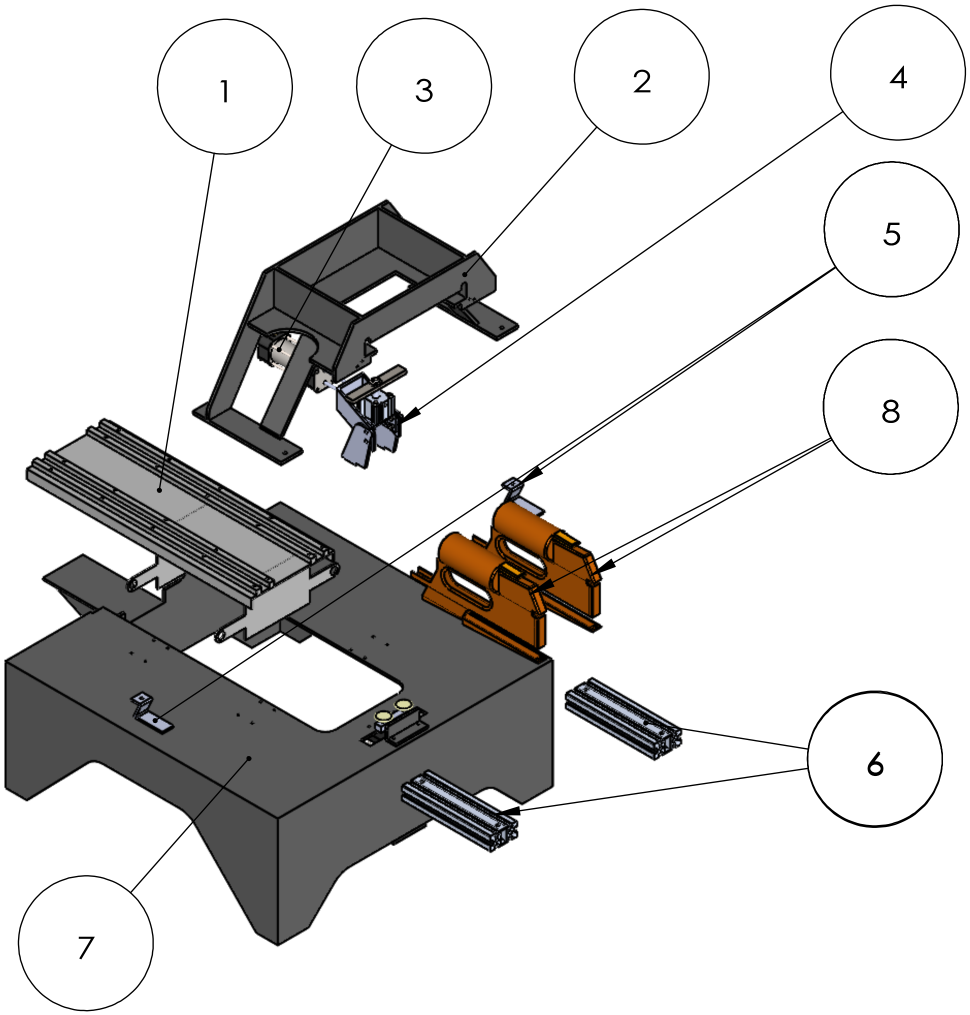
SIZE A

DESCRIPTION: MANUFACTURING DRAWING OF PNEUMATIC STAPLER BRACKET

REV 0

SHEET 1 OF 1

5 4 3 2 1



ITEM NO.	PART NUMBER	QTY.
1	STAPLER TRACK	1
2	CARD DISPENSER SUPPORT	1
3	CARD FOLDER CYLINDER	1
4	CARD FOLDER	1
5	STAPLER MOUNTING BRACKET	2
6	EXTRUDE ALUMINUM SPACER	2
7	MACHINE BASE	1
8	SENIOR SPACE A16/L PNEUMATIC STAPLER	2

SolidWorks

MECH 4860

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994

DO NOT SCALE DRAWING

MATERIAL Steel

FINISH

	NAME	DATE
DRAWN	S.L	2015/11/30
CHECKED	S.L	2015/12/7
NUMBER	7670313	

TITLE: **PNEUMATIC ASSEMBLY**

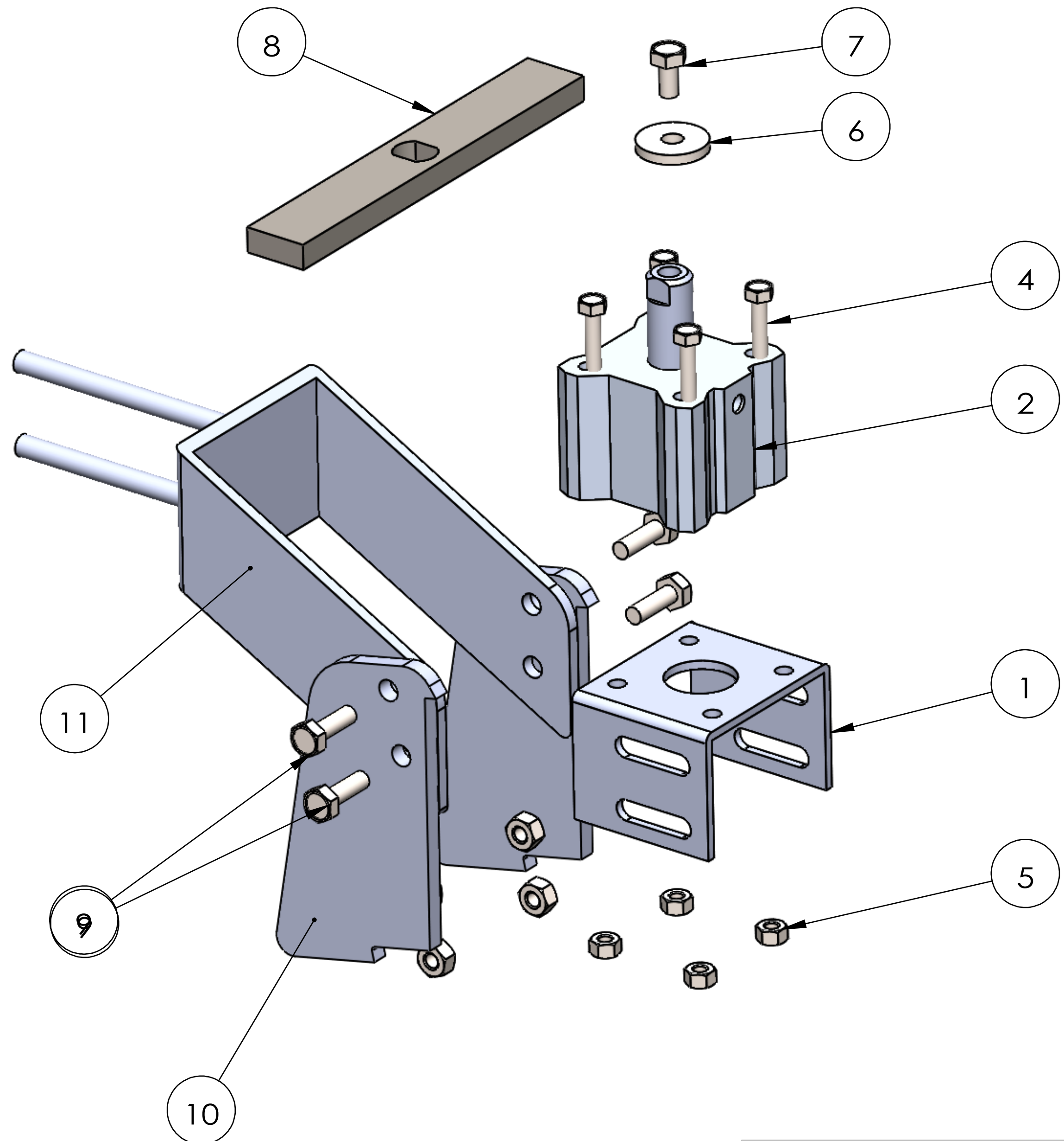
SIZE A

DISCRIPTION:

REV 0

SCALE: 1:10 WEIGHT: SHEET 3 OF 11

5 4 3 2 1



ITEM NO.	PART NUMBER	QTY.
1	ACTUATOR MOUNTING BRACKET	1
2	SMC - PART NO. NCDQ2A20 10T	1
3	HEX NUT M4 x 0.7	4
4	HEX MACHINE SCREW M3.5 x 0.6 x 35	4
5	HEX NUT M3.5 x 0.6	4
6	PLAIN WASHER 4 MM	1
7	HEX MACHINE SCREW M4 x 0.7 x 8	1
8	TRIGGER BAR	1
9	HEX MACHINE SCREW M4 x 0.7 x 13	4
10	CARD FOLDER	2
11	CARD FOLDER BRACKET	1

SolidWorks

MECH 4860

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994

DO NOT SCALE DRAWING

MATERIAL Steel

FINISH

	NAME	DATE
DRAWN	S.L	2015/11/30
CHECKED	S.L	2015/12/7
NUMBER	7670313	

TITLE:
ASSEMLBY OF TRIGGER MECHANISM

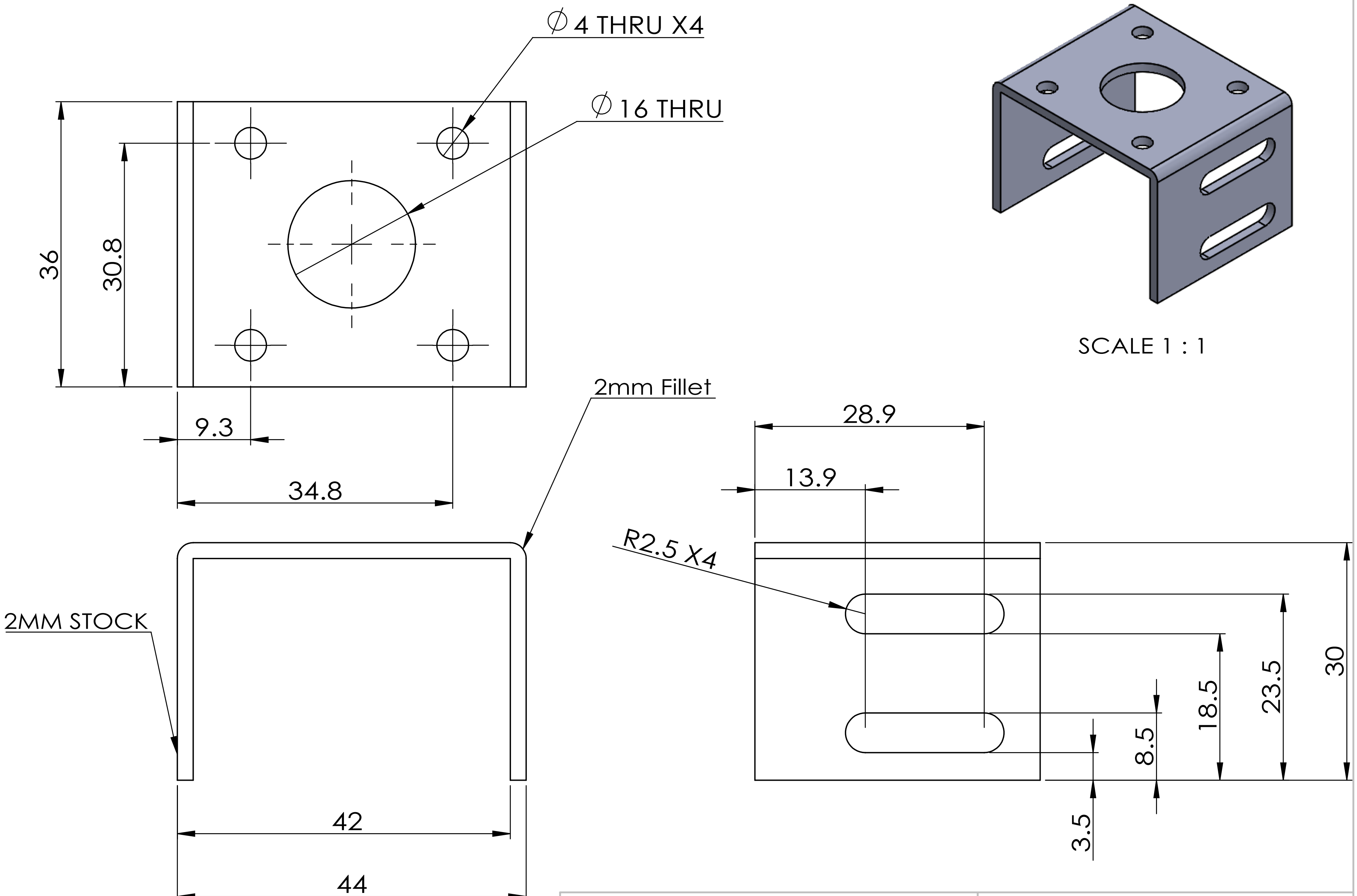
SIZE A

DESCRIPTION:
TRIGGER MECHANISM FOR THE PNEUMATIC STAPLER MOUNTED ON THE CARD FOLDER

REV 0

SHEET 1 OF 1

5 4 3 2 1



UofM MECHANICAL ENGINEERING

MECH 4860

UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	S.L	2015/11/30
MATERIAL Steel	CHECKED	S.L	2015/12/7
FINISH	NUMBER	7670313	

TITLE:
MOUNTING BRACKET FOR ACTUATOR

SIZE	DESCRIPTION:	REV
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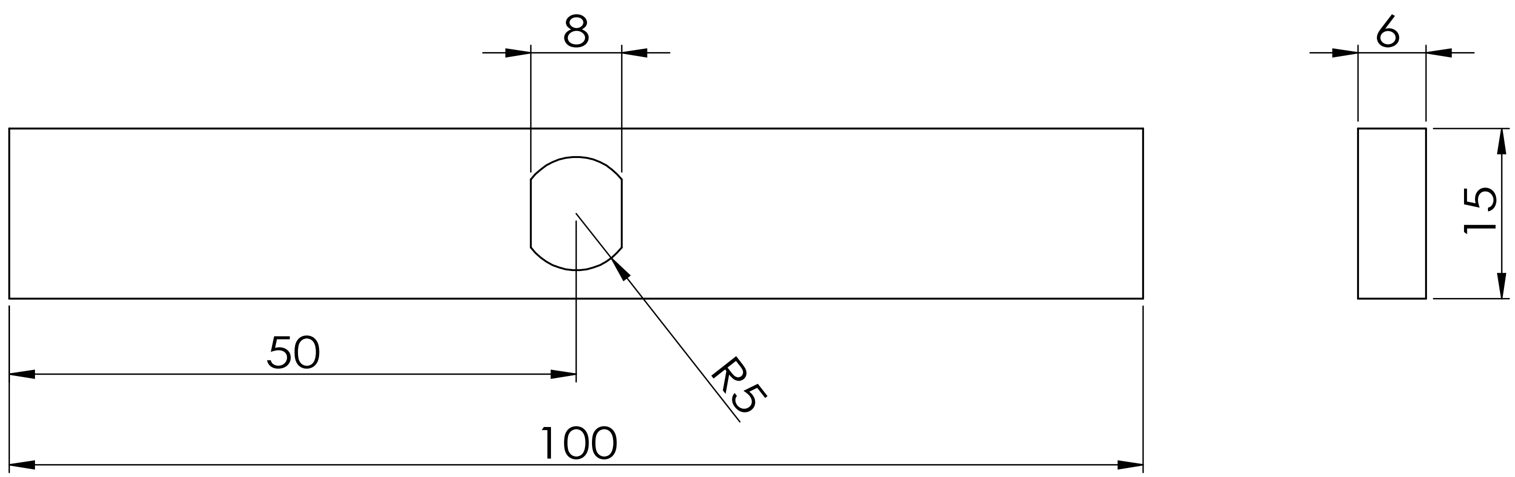

TRIGGER BAR

MACHINE FROM ABS PLASTIC

SolidWorks	MECH 4860	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ANGULAR: MACH±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	UofM MECHANICAL ENGINEERING		TITLE: TRIGGER BAR
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			MATERIAL Steel	CHECKED S.L 2015/12/7	REV 0
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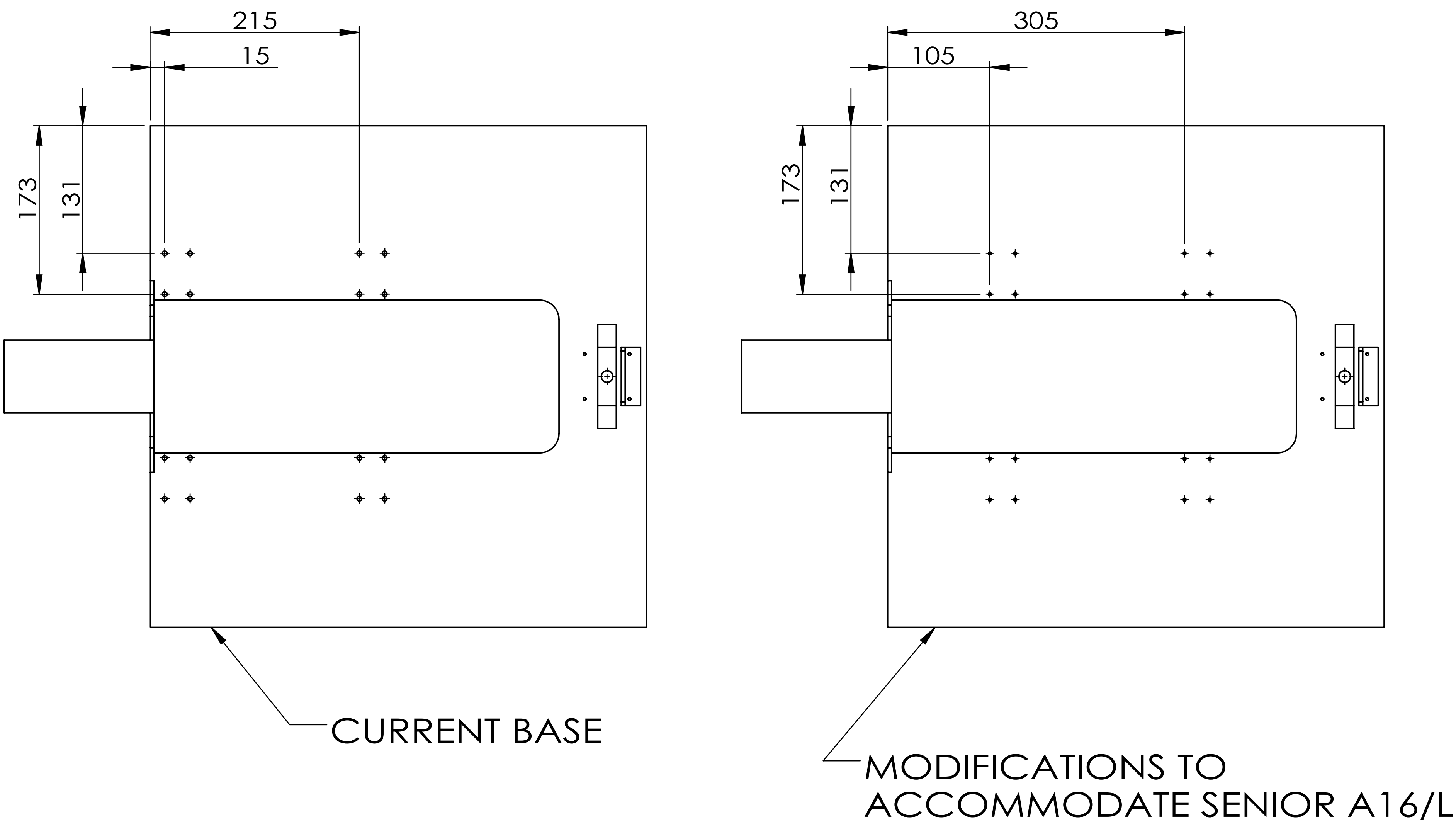
5 4 3 2 1

NOTE:
DRILL HOLES PATTERN AS THE MODIFICATED DIMENSION SHOWN



UofM MECHANICAL ENGINEERING			TITLE: MODIFICATIONS TO BASE MOUNTING HOLES FOR THE STAPLER TRACK	
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE	SIZE A	DESCRIPTION:
DO NOT SCALE DRAWING	DRAWN S.L	2015/11/30	REV 0	
MATERIAL Steel	CHECKED S.L	2015/12/7		
FINISH	NUMBER	7670313	SCALE: 1:6	WEIGHT: SHEET 7 OF 11

MECH 4860

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

SolidWorks

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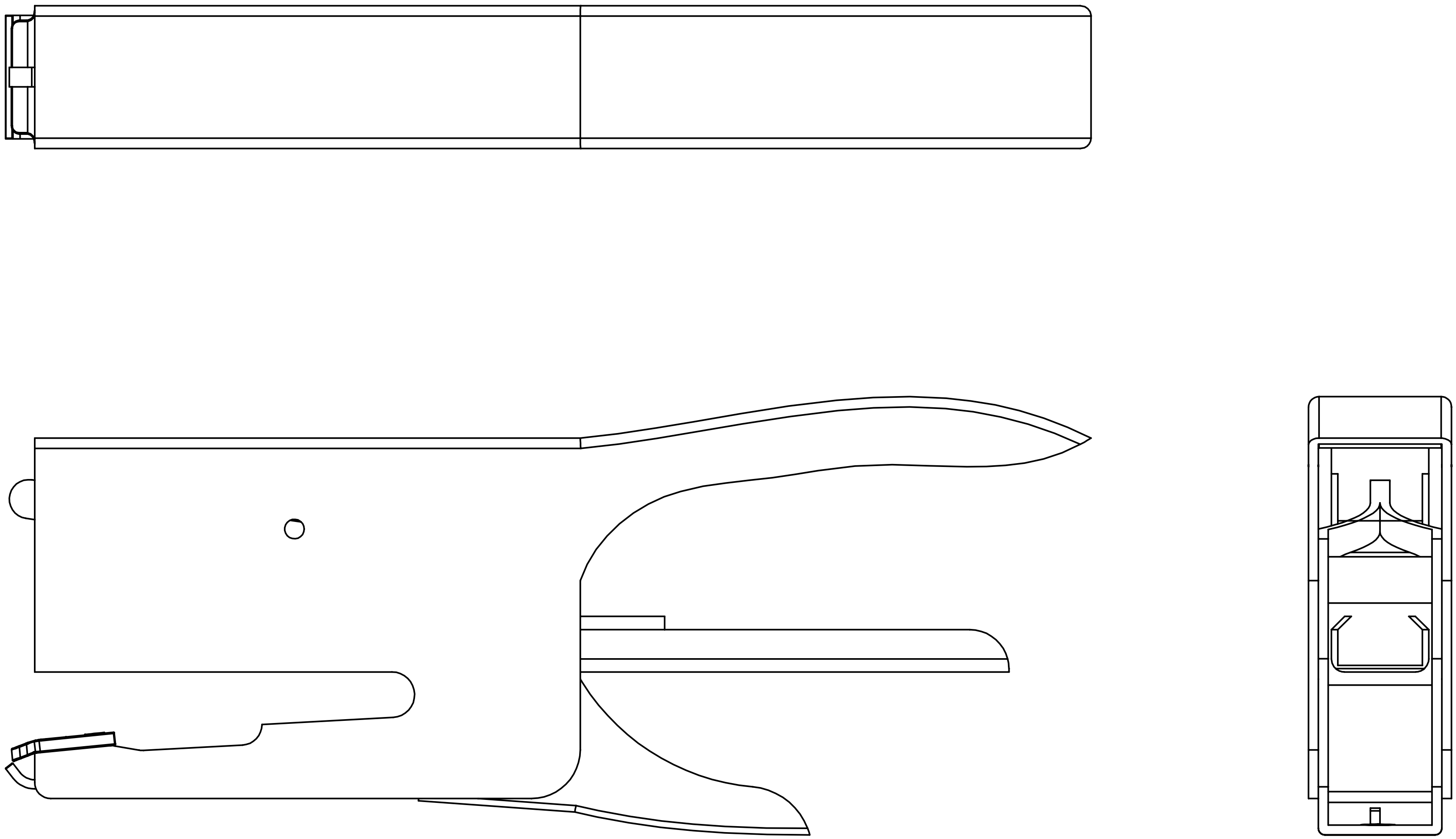


SolidWorks

MECH 4860

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	S.L	2015/11/30
MATERIAL Steel	CHECKED	S.L	2015/12/7
FINISH	NUMBER	7670313	

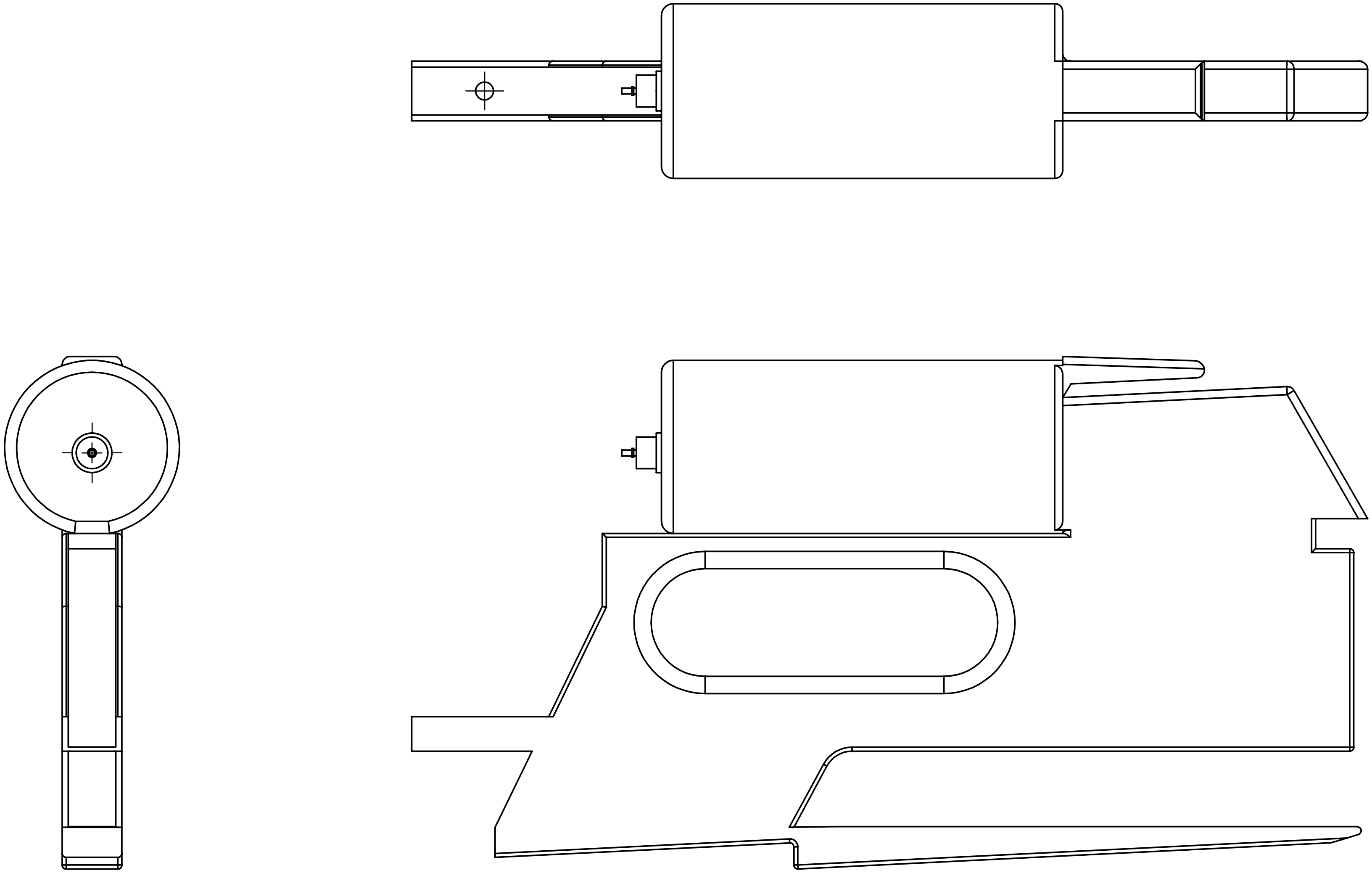
TITLE:

Rapid Stapler

SIZE	DISCRIPTION:	REV
A		0

SCALE: 1:1 | WEIGHT: | SHEET 8 OF 11

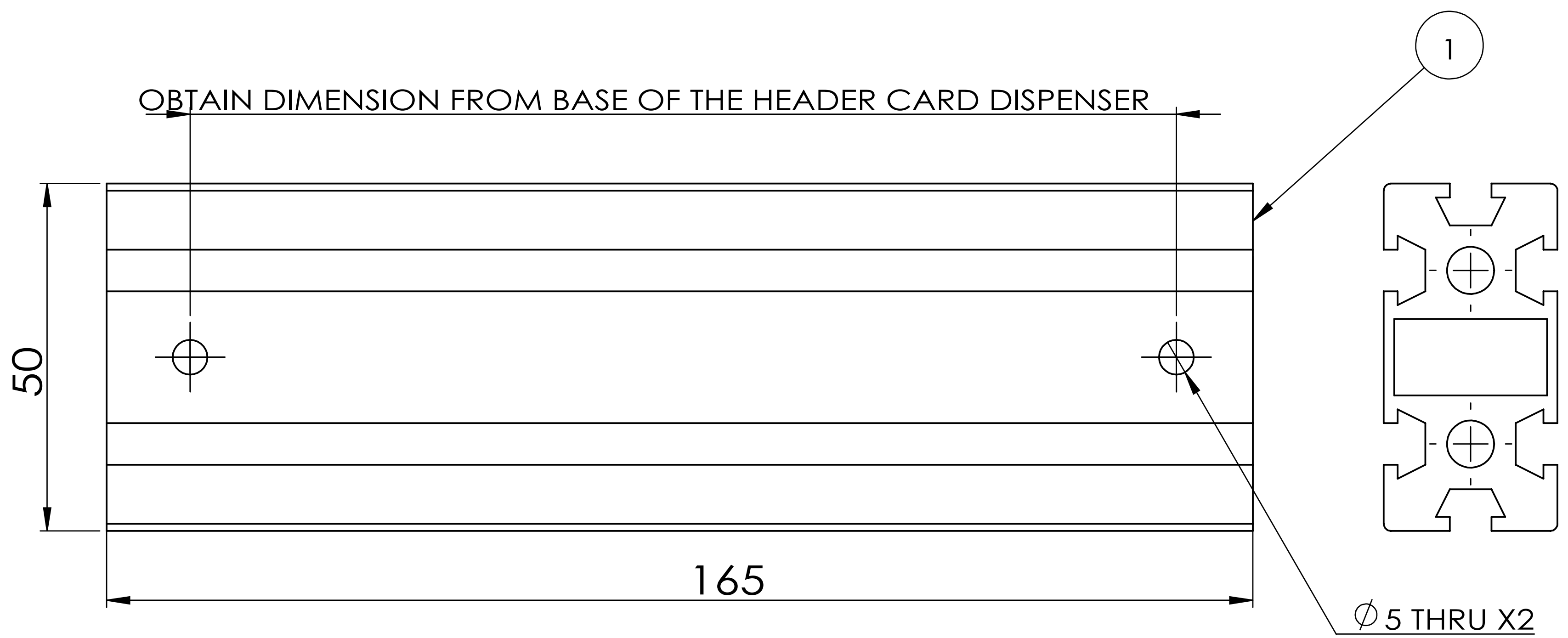
5 4 3 2 1



MECH 4860	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ANGULAR: MACH ±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	UofM MECHANICAL ENGINEERING			TITLE: Stapling plier 53
		INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE	SIZE A
		DO NOT SCALE DRAWING	DRAWN S.L	2015/11/30	DISCRIPTION:
		MATERIAL Steel	CHECKED S.L	2015/12/7	REV 0
		FINISH	NUMBER	7670313	SCALE: 1:1.6 WEIGHT: SHEET 9 OF 11

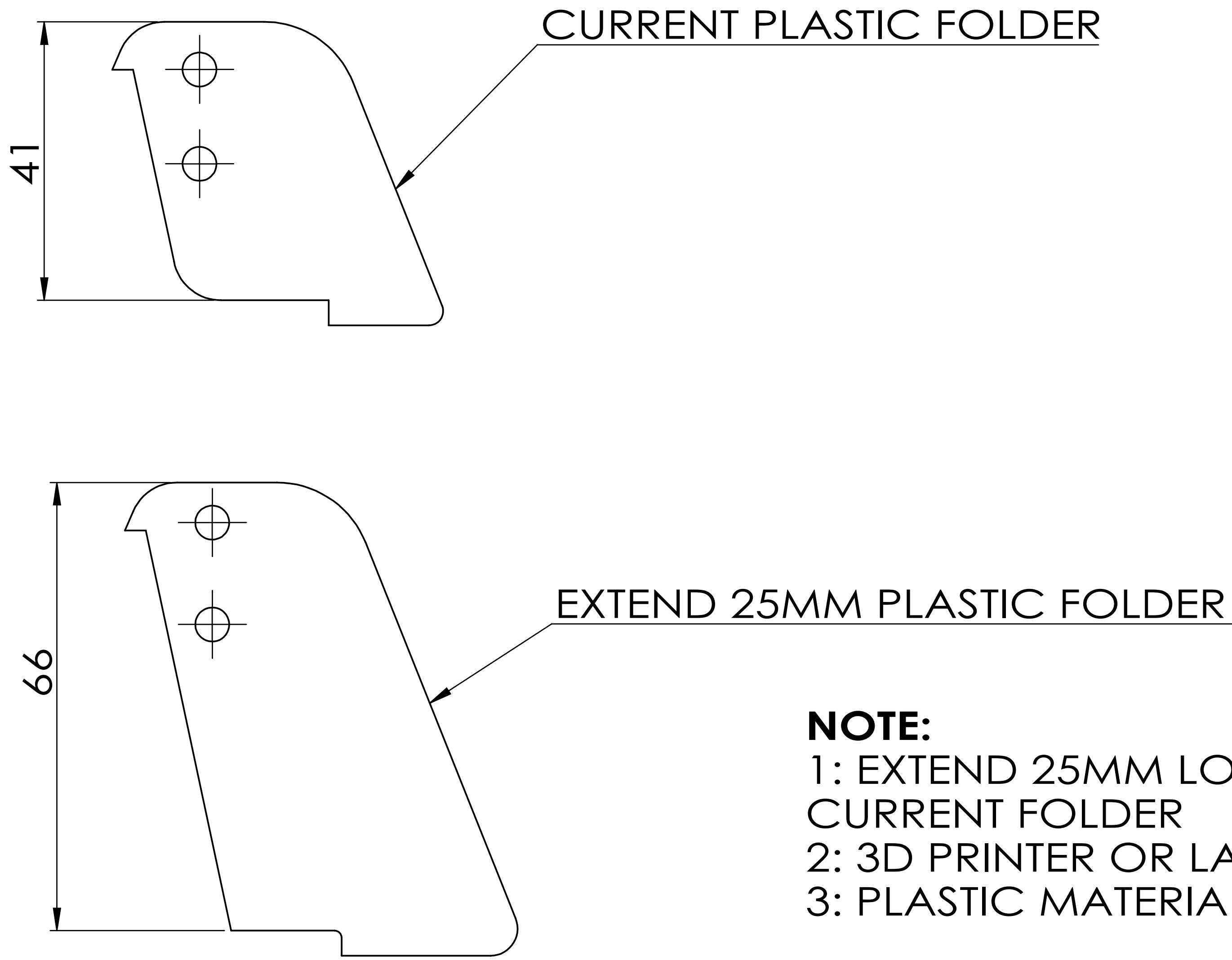
5 4 3 2 1

ITEM NO.	PART NUMBER	QTY.
1	80/20 INC. PART NO. 25-2550-1220	1



MECH 4860	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ANGULAR: MACH ±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	UofM MECHANICAL ENGINEERING		TITLE: EXTRUDED ALUMINUM SPACER
		INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME / DATE	SIZE: A
		DO NOT SCALE DRAWING	DRAWN S.L 2015/11/30	DISCRIPTION: ALUMINUM SPACER USED TO RAISE THE HEADER CARD DISPENSER
		MATERIAL Steel	CHECKED S.L 2015/12/7	REV 0
		FINISH	NUMBER 7670313	SCALE: 1:1 WEIGHT: SHEET 10 OF 11

5 4 3 2 1



NOTE:

1: EXTEND 25MM LONGER THAN CURRENT FOLDER

2: 3D PRINTER OR LASER CUTTER

3: PLASTIC MATERIAL AS CURRENT

UofM MECHANICAL ENGINEERING

TITLE: **FOLDER MODIFICAITON**

MECH 4860

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	S.L	2015/11/30
MATERIAL Plastic	CHECKED	S.L	2015/12/7
FINISH	NUMBER	7670313	

SIZE A | DISCRIPTION: | REV 0

SCALE: 2:1 | WEIGHT: | SHEET 11 OF 1

5 4 3 2 1

APPENDIX B - Concept Selection

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1.0 Introduction

This appendix documents the concept selection process implemented by JAYS Mechanical Consulting to produce the recommendations in the attached report. The design methodology consists of four primary stages followed by a review process. To begin, a preliminary research stage is conducted in which packaging machines and methods of attachment were researched. This was followed by a concept generation stage in which a wide range of possible design concepts were produced. Then, these concepts were refined and less functional designs were removed through a comparison process in the concept screening stage. A similar refinement and removal of weaker designs was also performed in the concept scoring stage using a quantitative scoring process to compare the designs. A design was selected at the end of this stage. Revision of this design, and further refinement and comparisons were performed to reach our final designs.

2.0 Preliminary Research

Internal and external research methods were used by our team to stimulate problem solving and idea generation. From our discussions with our client and our advisor, we identified two paths of research to pursue prior to the concept generation process. These paths were identifying alternative modes of attachment (e.g. different types of staples, adhesives, or tapes) and alternative processes used in attachment (e.g. different ways of actuating the stapler, or types of staplers).

Figure 1: Modes of header card attachment [1].

Our team's approach to identify alternative modes of attachment was to drive out to a Home Depot store and visually identify the modes of attachment used on product headers. From this trip, as well as multiple searches online, we found modes of attachment such as stapling, rivets, eyelets, adhesive header cards, adhesive tape, and heat seal. Figure 1 shows, from the top left and continuing clockwise, header cards attached with rivets, eyelets, adhesive headers, and adhesive tape.

To identify alternative processes, we searched for patents or competitive machines that demonstrated different ways of attaching a header card. From our research of competitive machines in the header attachment market we identified Action Packaging Automation, Inc. (APAI) as a major manufacturer of header card attachment equipment. APAI sells equipment that utilizes two forms of attachment methods. The first method utilizes staplers and the second method utilizes a heat seal. The stapling machine produced by APAI is called the AutoCard ST, shown in Figure 2, and uses pneumatically powered industrial staplers. The heat seal machine

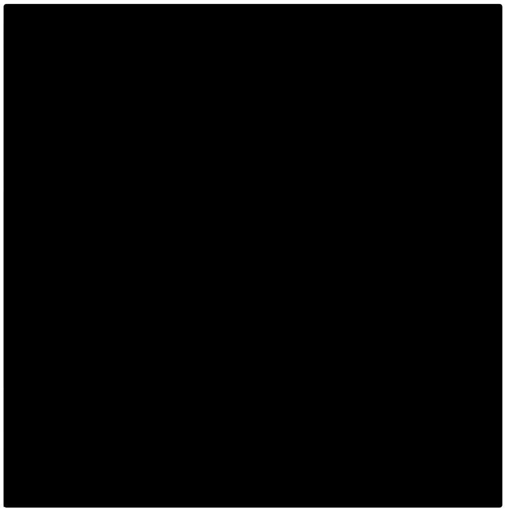


Figure 2: Jumbo AutoCard ST stapling a header card onto a bag of straws [2].

Figure 3: AutoCard HS heat sealing a header card with a pre-applied adhesive [2].

produced by APAI, shown in Figure 3, is called the AutoCard HS and uses a constant temperature heat seal which seals a pre-coated header card to a package. Videos of these two machines were studied closely to understand how they function and to generate ideas for improvement of the machine at Melet Plastics [2]. As a team, we were unable to identify any patents that were relevant to our specific topic of processes used for header attachment.

3.0 Concept Generation

In order to generate concepts in an organized manner, our team focussed on creating concepts that would mitigate the failures discussed in the failure modes and effects analysis. The flow diagram, Figure 4, outlines the complete process. The concept generation process was initialized by our performing preliminary research. Following the research concepts were generated by using components of both 3P and 7 Ways brainstorming. Each team member presented the concepts they generated to the team and like-concepts were compiled into groups. All of the concepts were screened using a comparative screening process.

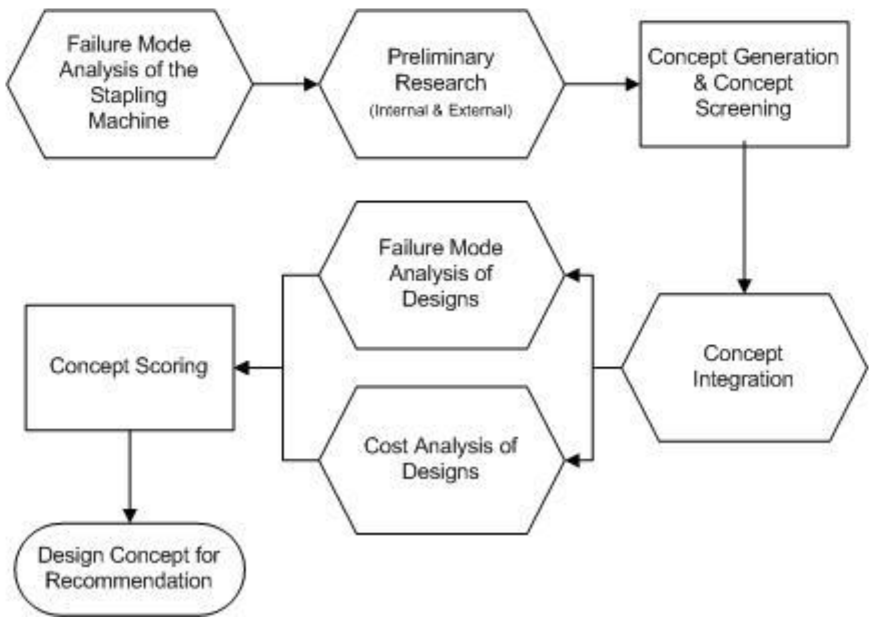


Figure 4: Flow diagram for the concept generation process [3].

Ideas that passed the screening process were refined by groups of two team members who were in charge of integrating the selected ideas with useful components of ideas that did not pass the screening process. Each idea was refined to a very specific design to ensure accurate scoring during the concept scoring process. Additionally, a preliminary failure mode analysis was performed on each idea to predict likely failure modes along with a simplified cost analysis to gauge the cost of implementing the design. These analyses were used to reduce subjectivity in the scoring of the reliability and cost criteria. Using the design descriptions and the supplementary analyses, our team scored the remaining designs in a concept scoring matrix and through this method determined which design was to be recommended to Melet Plastics.

3.1 Concept Descriptions

The process of attaching the header card consists of two primary functions, to secure the header card in place as it is folded over the egg holder handle and to attach both header card ends to each other around the handle. Our client, Melet Plastics, has given us the design freedom to look into all options of attaching the header card, not only the current stapling method. As observed in the failure modes and effects analysis, the main potential causes of this phase involve the stapler, therefore our top priority will be either to integrate innovative uses of a more industrial-made stapler or to integrate a different attachment methods into our design.

To address the causes and risks of these failure modes, our team developed seven initial design concepts:

Stapler with Handle Clearance

This concept is meant to eliminate the issues associated with the egg holder handle interference. In this design, the current staplers are substituted for high-quality industrial-use staplers preferably with a small clearance for the egg holder handle. If no such stapler is found through external research, another industrial stapler will be used and a clearance will be machined out. This clearance gives the egg holder handle a space to move into so that it doesn't obstruct the stapling motion.

Currently, the stapler must be pressed over the egg holder handle before it reaches the header card. This obstruction gives a pressure loss to the stapler which results in an incomplete folding of the staple. In addition, if a more high-quality stapler could be incorporated into this machine seamlessly, it could minimize design costs while increasing reliability.

Hot Glue and Arm Applicator

This concept uses an innovative attaching method, hot glue, which is applied to the open header card using a robotic arm. Then, the header card is folded over the egg holder handle and pressed down using the existing pneumatic system to operate a simple press.

This design should alleviate many of the issues caused by the stapling method. However, the robotic arm and hot glue could introduce new failures to the machine. Hot glue, similar to a staple, is a resource that must be replenished once used which may require an additional operator supervisor. In addition, the cost of parts for another robotic arm may be an issue.

Stapler with Actuating Bottom Plate

This idea was based on the fact that many of the staplers we found in our research did not have a back plate on which the staples were folded. Instead the staplers would be used to staple into a substrate without the need for folding. To circumvent this issue, our design attaches the bottom plate to the suction cup drawing mechanism. The back plate would be situated so that when the stapler dispenses the staple into the card, the plate is pressed up against the back of the card. When the staple hits the plate it folds and secures itself in place.

Heat Seal Application

The heat seal concept involves the application of thermally-activated adhesives to attach the header cards. First, an adhesive is applied to the header card using an actuating arm. Then, the header card is folded over the egg holder handle and heat is applied using an actuating press, as seen in Figure 5.

Figure 5: APAI AutoCard HS Heat Seal Header Card Machine [2].

This design should also alleviate many of the issues caused by the stapling method. However, further external research must be conducted to find potential costs, reliability and application procedures of this method.

Actuating Stapler with Narrow Head

The actuating stapler with narrow head design concept utilizes a narrow headed stapler to address failures related to the thickness of the egg holder handle. As discussed in the FMEA section, the current stapling mechanism cannot close all the way due to the handle thickness, which results in poor staple closure. This issue can be avoided by using a stapler that has a head that is narrow enough to fit in the gap provided by the egg holder.

There are numerous commercially available staplers with narrow heads. Figure 6 illustrates one possible stapler that could be used for this concept. It is important to note that the narrow headed stapler will have to be moved in a two-step process, laterally and vertically, prior to releasing the staple. This requirement is due to the design of commercially available staples in this format. Unlike the current design, the stapler head of narrow headed staplers remains stationary and must be manually pressed against the card.

Figure 6: Isometric view of a pneumatic stapler with a narrow stapling head [4].

Rotating Stapler Arm

Some staplers require actuation both laterally and vertically to correctly position the stapler. To simplify this motion, the stapler can be swung in an arc as opposed to linearly translating it. This would require extra clearance above the stapling area to allow for the swinging motion.

4.0 Concept Selection

Once the initial concepts were clearly defined through the concept generation stage, our team began the concept selection stage. Our team followed the concept development funnel shown in Figure 7 as it accurately depicts how to arrive at an optimal conceptual design.

[redacted]

Figure 7: Concept development funnel [5].

To begin, our team completed the concept generation stage, in red, which gave us a total of seven main design concepts. The concept screening process, which is labelled in purple on Figure 7, will reduce this number further.

The concept screening will assign scores to each design so that they can be ranked sequentially, thereby allowing us to select the top three concepts. After this stage, we will expand upon these main concepts by conducting a refinement research. This will add further definition to each concept and will lead us to the concept scoring stage, labelled in blue. The concept scoring will include a simplified technical and cost analysis which will allow us to fully examine each concept.

Finally, the top ranking concepts will be assessed and any possible design integrations will be made to create an optimal final design that will undergo further examination in our upcoming testing stage.

4.1 Evaluation Methods

JAYS Mechanical Consulting selected a few methods to evaluate our concepts in the concept screening process. In order to go through the concept screening process, we must first define our selection criteria, our customer needs which will be used to rank the design. These selection criterion will then be assigned a quantitative value from our importance weighting matrix, values which will in turn be put into our house of quality and concept screening matrix to assign scores to each design concept based how it satisfies the selection criteria.

4.1.1 Criteria Definitions

In order to accurately screen our concepts, we must identify a list of selection criteria. The selection criteria should directly reflect the customer needs specified previously during the project definition stage. TABLE I lists the selection criteria chosen by our team and also includes a definition of each term along with an expected goal to either maximize or minimize each item.

TABLE I: SELECTION CRITERIA DEFINITIONS

Selection Criteria	Definition	Goal
Durability	Length of the expected life of components and frequency of repair	↑
Reliability	Success rate of the attachment method	↑
Cost	Overall price of modifications or redesign of the machine	↓
Simplicity	Number of components and manufacturability of parts in the design	↑
Accessibility	Simplified access to machine components and replacement parts	↑
Portability	Overall weight of the machine and additional time required for set-up	↑
Safety	Potential to inflict harm to the machine operators or the environment	↑

4.1.2 Criteria Weighting Matrix

Our team worked closely with Mattson and Rogers, our contacts from Melet Plastics, to develop a criteria importance weighting matrix. Using this matrix allows us to take a systematic approach to identify the priority of customer needs. Each customer need will be given a weighted score based on its individual importance to the overall project. Then, the weighted score will be used in our House of Quality to engage in technical analysis. As seen in Figure 8, Mattson and Rogers identified the overall reliability of the machine to be the highest priority of our design, and the portability to be the lowest. Portability is not an issue with the current model as it is outfitted

		Durability	Reliability	Cost	Simplicity	Accessiblity	Portability	Safety
Criteria		A	B	C	D	E	F	G
A	Durability		B	A	A	A	A	A
B	Reliability			B	B	B	B	B
C	Cost				C	E	C	G
D	Simplicity					E	D	G
E	Accessiblity						E	E
F	Portability							G
G	Safety							
	Total Hits	5	6	2	1	4	0	3
	Weightings	0.238	0.286	0.095	0.048	0.190	0.000	0.143

Figure 8: Picture of criteria importance weighting matrix [6].

with four casters.

While the weight of the machine will directly affect its portability, the machine is not constrained to be within a certain weight range. If the force required to move the machine exceeds the threshold of a single worker, then it may require multiple personnel to be moved into place. The reliability of the machine directly affects the success rate of the end product, which is ultimately what Melet needs to accomplish. Due to the high number of products produced by this automated packaging machine, durability is the second highest priority; the machine should be able to last throughout the duration of the order, which can see a usage time of up to 150 hours per order.

As seen in Table II, the three most important criteria that this design must satisfy are reliability, durability and accessibility. Together, these three items account for 71.4% of the design's overall importance. Therefore, a successful design choice should satisfy all three of these criterion.

TABLE II: CRITERIA IMPORTANCE RANKING

Selection Criteria		Rank	Importance Percentage
Reliability		1	28.6%
Durability		2	23.8%
Accessibility		3	19.0%
Safety		4	14.3%
Cost		5	9.5%
Simplicity		6	4.8%
Portability		7	0.0%

4.1.3 House of Quality

In certain cases, the difficulty in design lies in the concept development phase due to the lack of quantifiable design variables. For these situations, a house of quality is often used to translate customer requirements into quantifiable variables, referred to as engineering metrics. The automated packaging machine will benefit from a house of quality because the design is evaluated primarily on a pass or fail basis. This method begins by identifying the relationship strength between specific customer needs and engineering metrics, and ends with a list of target values. Using the weighted scores from the criteria importance weighting matrix, we can rank these engineering metrics and use this data to better understand our criteria and score our concepts.

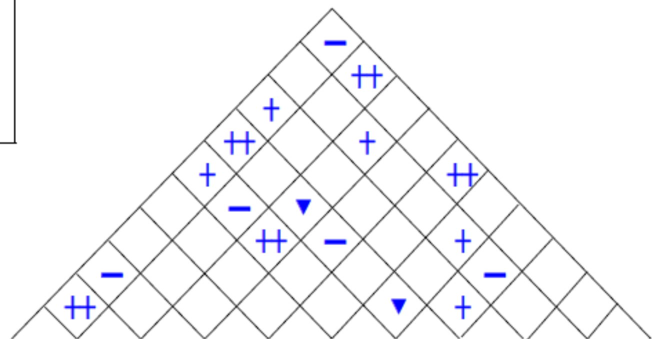
The criteria and criteria weights used in our house of quality, shown in Figure 9, are the same ones which will be used to screen and score our concepts. The engineering metrics were generated by our team by evaluating the current stapling machine and identifying measurable parameters which could be used to quantify its performance. Target values were set for each of these metrics to benchmark how well we would like the machine to perform following this project. The engineering metrics used are cost of materials and components, strength of materials, total repair and maintenance time, process cycle time, set-up time, maintenance cost (labour and parts), success rate, strength of attachment method, number of moving components, and overall weight.

The target value for the cost of components and materials is defined by the project budget set by Melet Plastics. The strength of materials metric was implemented to quantify the strength of structural and actuating components in the machine. Due to the need for a long machine life and the cyclical nature of the machine, we wanted to design a machine which was mostly made of aluminum or steel and therefore set the target material strength to 200 MPa which is a low end strength for aluminum [7]. The repair time was an important metric for this project because the current machine has a high percentage of downtime due to the high frequency of repair and the long repair times. To minimize machine downtime, our team set a target maintenance time of 0.5 hour over the course of a 150 hour order time. The cycle time of the injection molding machine, which is 32 seconds, defines how quickly the header cards must be attached to the egg holders. There is no benefit to attaching headers significantly faster than the rate of production therefore the target cycle time was set equal to 30 seconds. The set-up time of the machine is time spent that could have been used to process the order. To minimize wasted time our team set a target set-up time of 10 minutes. A good benchmark for manufacturing companies' maintenance cost is 2% of the equipment's replacement value [8]. Using this rule of thumb, we set a target value for a maintenance cost of $150 per year. Our target success rate for an order was set at 100% which would be the ideal value for Melet Plastics.

The attachment method used must be strong enough to hold the suspended weight of the egg holder, which is an important consideration for adhesive methods of attachment that tend to be weaker. The weight of the egg holder is approximately 3 N and a factor of safety of 10 was applied to account for the unknown loads involved with handling of the product giving us a target value of 30 N. The three primary moving components of the current stapler machine are the suction cups, the probes for holding the card open, and the staplers. We set the target of number of moving components to three, the same as the current machine, to limit the addition of complexity and degrees of freedom added to our new design. The machine must be moved around between orders and will likely be placed on a rolling platform. We set a target weight to limit the weight of the machine which prevents potential worker injuries and ensures that extra cost was not incurred by requiring a heavy duty cart on which to mount the machine. Based on these considerations, a target value of 100 pounds was set.

The vertical relative weights in this house of quality are a measure of the importance of the criteria and were calculated using the criteria weighting matrix. The horizontal relative weights give a measure of the importance of each engineering metric are calculated from their vertical counterparts and their relationship ratings. From this, we can see that the two most important targets to meet are maintenance related. Another important feature to note in this diagram are the difficulty ratings which measures how difficult it would be to reach the target. The difficult ratings were assigned to each engineering metric and corresponding target value. Three of our top four weighted metrics have a difficulty rating of 8 or 9. This means we will likely have difficulty satisfying all our needs.

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlatior	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlatio	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▼	x	▼	▼	x	x	▼	▼
				Criteria / Engineering Metrics	Cost of Materials & Components	Strength of Materials	Total Repair & Maintenance Time	Process Cycle Time	Set-up Time	Maintenace Cost (Labour & Partd)	Success Rate	Strength of Attachment Method	Number of Moving Components	Overall Weight (Amount of Force required)
1	9	27.1	0.3	Durability	Θ	Θ	Θ			Θ	▲		O	O
2	9	27.4	0.3	Reliability	O	▲	O			O	Θ	O	▲	
3	9	9.1	0.1	Cost	Θ	Θ	O	▲	▲	Θ	Θ	O	O	▲
4	9	4.6	0.0	Simplicity	O		Θ		▲	Θ	▲		Θ	▲
5	9	18.2	0.2	Accessibility			Θ			Θ			O	
6	9	0.0	0.0	Portability	▲				O				▲	Θ
7	9	13.7	0.1	Safety	O				▲				Θ	O
				Target or Limit Value	$5,000	200 Mpa	0.5 hours/order	32 seconds	10 minutes	$150/year	100.00%	30 N	3	100 lbs
				Difficulty (0=Easy to Accomplish, 10=Extremely	4	3	9	1	6	8	8	3	4	6
				Max Relationship Value in Column	9	9	9	1	3	9	9	3	9	9
				Weight / Importance	462.5	352.9	558.1	9.1	27.4	612.6	359.8	109.4	354.9	136.0
				Relative Weight	15.1	11.5	18.2	0.3	0.9	20.0	11.7	3.6	11.6	4.4

Figure 9: House of quality for the automated packaging machine [9].

4.2 Concept screening

For the concept screening process, all of the initial designs are evaluated in comparison to the original design using the selection criteria. If the new design represents an improvement or diminishment over the current design in a specific category, it will receive a plus or minus sign, respectively, in that corresponding box. Meanwhile, if the new design is approximately the same as the current design in a given category, it will receive a zero.

Then, each concept will be given a net score based the amount of pluses, zeros, and minuses it has accumulated. A plus sign given to the concept refers to a gain for a given selection criteria and a minus sign refers to a loss. Each plus will contribute +1 to the net score while each minus will contribute -1 to the net score. A zero sign given to the concept refers to neither a gain nor a loss for a given selection criteria. As zero is a neutral integer it will not contribute to the net score. Finally, a net score will be calculated mathematically by inputting the numerical value for each amount of pluses, zeros, and minuses. The result of this process is shown in **Error! eference source not found.**.

	Concept Variants - Attaching Phase							
Selection Criteria	Stapler with Handle Clearance	Hot Glue & Arm Applicator	Stapler with Bottom Plate Raiser	Heat Sealer	Actuating Stapler with Narrow Head	Vertical Feeding of the Egg Holder	Rotating Stapler Arm	Current Design
Durability	0	-	0	+	0	0	-	0
Reliability	+	+	+	+	+	0	0	0
Cost	0	-	-	-	+	0	-	0
Simplicity	0	-	-	-	-	-	-	0
Accessibility	0	0	0	0	0	0	-	0
Portability	0	-	0	0	0	0	0	0
Safety	0	-	0	0	0	0	-	0
PLUSES	1	1	1	2	2	0	0	0
SAMES	5	1	4	3	4	6	2	7
MINUSES	0	5	2	2	1	1	5	0
NET	1	-4	-1	0	1	-1	-5	0
RANK	1	7	5	3	1	5	8	3
CONTINUE?	YES	NO	NO	YES	YES	NO	NO	-

Figure 10: Concept screening matrix [10].

For the concept screening matrix, seen in Figure 10, our team selected the Stapler with Handle Clearance, the Heat Sealer, and the Actuating Stapler with Narrow Head attaching concept designs. Again, our team selected the only designs to have a net score of zero or greater. The Stapler with Handle Clearance and the Actuating Stapler with Narrow Head both ranked first with a positive net score. These concepts will be further expanded pending a refinement research workshop. Both concepts improved the overall reliability of the machine, meanwhile the "Actuating Stapler with Narrow Head" concept resulted in a reduced cost and a more complex design.

The concept screening matrix was able to successfully reduce the amount of total concepts from 12 to 5. Next, our team has conducted a refinement research workshop to further expand upon these designs before the concept scoring stage begins.

4.2.1 Concept Refinement, Integration, and Research

In this phase of concept generation, our team further refined our designs until we understood exactly what components were involved and how they would function. Designs that were selected in the screening process were refined, researched, and integrated with desirable parts of the designs that did not pass the screening process

The five design concepts are focused on the method of attachment used to attach the header card to the egg holder handle.

Rapid PRO R28E Manual Stapler

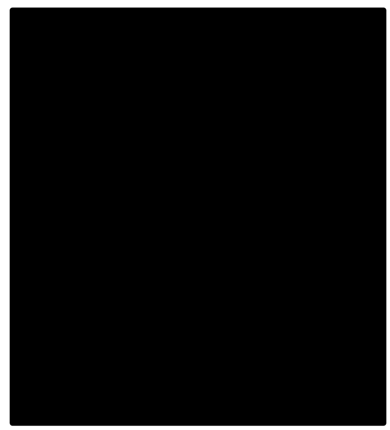


Figure 11: Isometric view of the Rapid PRO R28E stapler [11].

The Rapid PRO manual stapler design evolved from the narrow head stapler design. The Rapid PRO stapler, seen in Figure 11, is a commercially available stapler with a narrow head that provides enough clearance for the handle. The Rapid PRO would have to be positioned behind the attachment area at the start of the process to allow for the drawing process to occur. It would then be translated forward and then down onto the card where a pneumatic would press the handle to dispense the staple. To staple effectively, the Rapid Pro stapler would require a back plate to fold the staple. Back plates could be attached to the vacuum cup mount similar to the stapler with bottom plate raiser design as previously mentioned. The current machine does not have enough clearance for the Rapid PRO to be installed therefore a new design is necessary to apply this idea. The new design would be the same as the current design but with extra height clearance to fit the height of this stapler.

Pneumatic Rapid Airtac PS101

Figure 12: Isometric view of the Rapid Airtac PS101 [12].

The pneumatic Rapid Airtac is a second design which evolved from the narrow head stapler design. It has a narrow head to prevent issues associated with the handle thickness, and is pneumatic which will decrease issues associated with component durability. The design and process for applying the Rapid Airtac is very similar to the Rapid Pro. The Rapid Airtac requires a back plate as well so we will integrate the idea of attaching the back plate to the vacuum cups as presented in the stapler with back plate raiser design. The Rapid Airtac, seen in Figure 12, is too tall to be successfully incorporated into the current design and would require a redesigned machine with higher clearances. The process of attaching cards with the Rapid Air Tac would require a horizontal and vertical translation to position it correctly for stapling.

Rapid Classic with Cut-out

This design is based on the stapler with handle clearance concept which is an alternative method to deal with the handle thickness during the stapling portion of the process. The current stapling machine uses Rapid Classic staplers shown in Figure 14. This design is based on the idea that the bottom arm of the stapler could be modified to provide clearance for the egg holder handle. The bottom arm would require approximately 4 mm of materials to be removed to provide enough space. Figure 13 is a model of what this design might look like. The modified Rapid Classic staplers with this cut out could easily be incorporated to the current design with no changes to the stapling process.

Figure 14: A Rapid Classic stapler, the same type used in the Melet Plastic stapling machine [13].

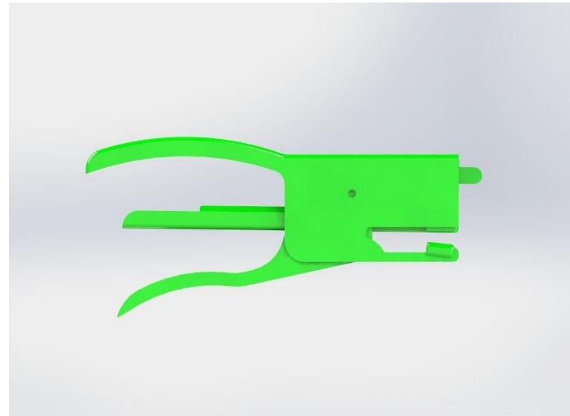


Figure 13: Stapler with handle clearance [14].

Rapid Classic without Bottom

This design is similar to the cut-out design but instead of making a shallow cut out, we will remove the entire bottom arm. To replace the bottom arm we will attach the back plate for the stapler to the vacuum cup mount so that when the stapler presses down it will press the header card against the back plate. This design solves with the issue of stapling over the handle thickness and can be easily incorporated into the current design. Figure 15 illustrates what the Rapid Classic Stapler would look like with the bottom arm removed.

Figure 15: Side view of rapid classic without bottom [15].

Pneumatic Stapling Plier 53L

Durability is a significant issue with the current stapler configuration which uses the Rapid Classic stapler. The springs in the Rapid Classic stapler wear out and the stapler becomes less consistent. To circumvent this issue, this design concept relies on the use of a heavy duty industrial pneumatic stapler called the Stapling Plier 53L, which is shown in Figure 16. The Stapling Plier 53L design will be based on the stapler with handle clearance design concept. Modifications will be made to the back plate of the Plier 53L to mitigate issues caused by the handle thickness. Because of its similarity in size and geometry to the Rapid Classic, the Stapling

Figure 16: Side view of the pneumatic stapling plier 53L [16].

Plier 53L can be implemented with minimal modifications to the current design. The stapler will translate forward then be actuated from above by a pneumatic cylinder.

4.3 Concept Scoring

For the concept scoring process, our team used the same selection criteria defined in **Error! eference source not found.** and given importance weightings in to assign scores to each of the refined concepts. These concepts were given scores ranging from 1-5 based on how they meet each specific criteria, with a score of 5 meaning that the concept completely meets the expectations of the criteria.

Concept Variants - Attaching Phase		Heat Sealer		Actuating Stapler with Narrow Head				Stapler with Header Clearance					
Refined Concepts		**Heat Sealer**		**Rapid PRO Manual Stapler**		**Pneumatic Rapid Air Tac**		**Rapid Classic with Cutout**		**Pneumatic Stapling Plier 53L**		**Classic without bottom**	
Selection Criteria	**Weight**	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Durability	0.238	4	0.952	4	0.952	5	1.19	4	0.952	5	1.19	3	0.714
Reliability	0.286	5	1.43	3	0.858	4	1.144	3	0.858	4	1.144	2	0.572
Cost	0.095	2	0.19	3	0.285	2	0.19	5	0.475	4	0.38	5	0.475
Simplicity	0.048	2	0.096	3	0.144	3	0.144	5	0.24	4	0.192	3	0.144
Accessibility	0.190	3	0.57	5	0.95	5	0.95	4	0.76	5	0.95	4	0.76
Portability	0.000	1	0	3	0	3	0	5	0	4	0	4	0
Safety	0.143	4	0.572	5	0.715	5	0.715	5	0.715	5	0.715	5	0.715
TOTAL SCORE		3.81		3.90		4.33		4.00		4.57		3.38	
RANK		5		4		2		3		1		6	
CONTINUE?		NO		NO		NO		NO		YES		NO	

Figure 17: Picture of concept scoring matrix [17].

In Figure 17, we evaluated the six refined concepts and decided to move forward only with the top ranking concept, the Pneumatic Stapling Plier 53L. From the failure modes analysis, our team concluded that there were too many problems associated with the current design and it would be best to evaluate more reliable designs. The second ranked concept, the Pneumatic Rapid Air Tac, also scored high in durability, reliability, and accessibility; however, its cost and simplicity showed signs of weakness. After further research, we found the size of the Rapid Air Tac stapler model to be too big for the current pressurized stapling process, which would require a complete overhaul of the machine. Another honourable mention, the Rapid Classic with Cut-out, is the simplest and cheapest of all the six refined attaching concepts. However, this design utilizes the existing stapler model which may not be as durable or reliable as the other concepts.

The concept scoring matrix was influenced by the data obtained through sensitivity and cost analyses. The sensitivity analysis finds the cause of potential uncertainty in the design which will affect the reliability and durability of the design, while the cost analysis will examine the cost of machine parts and labor for the design. These three criteria, reliability, durability, and cost, combine to account for 61.9% of the overall importance of the design.

4.3.1 Sensitivity Analysis

Sensitivity analysis is used to determine how uncertainty in the output of a design can be the cause of combined sources of uncertainty in the model input. Although a thorough sensitivity analysis will be conducted once our concept selection stage ends and our optimization stage begins, it is useful to consider the results of a preliminary sensitivity analysis during the concept scoring process.

Figure 18: Core methodology of sensitivity analysis [18].

As seen in **Error! Reference source not found.Error! Reference source not found.**, the thodology of sensitivity analysis involves gathering input data, creating a simulation model with varying parameters, evaluating the output of the design, and using the analysis of the output to provide feedback to the input.

This analysis is used primarily to test the robustness of the results of a model and examine the relationships between input and output variables in the model. In addition, understanding these relationships allows us to identify specific inputs that cause uncertainty in the output and therefore reduce the overall uncertainty in the design. Many methods of sensitivity analyses exist, such as one-at-a-time (OAT), local methods, scatter plots, variance-based methods, and screening.

In the preliminary stage, many parameters and variables of this design are not fully defined. To that extent, our team has decided to use the screening method, a method designed to identify the inputs that contribute to uncertainty in the output rather than to quantify the sensitivity.

While analyzing the current automated packaging machine overall, the input variables identified are the pressure and cycle speed. The pressure line measurements will be recorded by Melet Plastics and sent to JAYS Mechanical Consulting during the optimization phase. This is a key variable because it directly affects one of the failure modes, as the incorrect stapling is a result of insufficient pressure being applied to the staplers. It is unclear whether the cycle speed has a direct effect on any of the failure modes or the overall success rate, however it is possible that a rushed cycle may result in an incomplete process.

Once the optimization stage begins, JAYS Mechanical Consulting will look into the one-at-a-time (OAT) approach for sensitivity analysis, one of the most commonly used methods. This approach involves changing one input variable at a time while keeping the other variables at their original values, to see what effect is produced on the output. One disadvantage of using this method is the simplicity, as this method does not examine the effects of simultaneous variation of multiple input variables however, our design utilizes minimal input variables, which will allow us to use this method without consequence.

4.3.2 Cost analysis

In order to score each concept for its ability to satisfy the cost portion of the selection criteria, we must conduct a cost analysis on all concepts, shown in TABLE III. This means that for the concept scoring matrix in **Error! Reference source not found.**, the score for the cost of all three esigns will be equal.

TABLE III: COST ANALYSIS [19].

Concepts	Cost of Parts	Cost of Installation	Total Cost	Rank
Heat Sealer	$ 1,000.00	N/A	$ 1,000.00	6
Rapid PRO Manual Stapler	$ 130.54	$ 200.00	$ 330.54	4
Pneumatic Rapid Air Tac	$ 348.06	$ 200.00	$ 548.06	5
Rapid Classic with Cutout	$ -	N/A	$ -	1
Pneumatic Stapling Plier 53L	$ 100.00	$ 50.00	$ 150.00	3
Classic without Bottom	$ -	N/A	$ -	2

We researched the cost of parts and installation for each concept. For the Heat Sealer concept, we recommend purchase of the AutoCard HS Heat Seal model from Action Packaging Automation, Inc. (APAI) which would result in a high cost of parts but a negligible installation cost. Although APAI was not available to give our team a quote for the price of this machine, we estimate the overall price to be upwards of $1,000.00, which is easily our most expensive design. The Rapid PRO Manual Stapler and Pneumatic Rapid Air Tac concepts are relatively similar, as they both require the addition of robust, industrial staplers. The cost of these staplers were found through the popular online shopping website, Amazon. The values we found on Amazon were then converted to Canadian dollars (from British pounds) and multiplied by a two, as the machine requires two functioning staplers. Unfortunately, these staplers are too large to fit in the current machine and will require additional installation. We approximated values for the installation of these staplers to be $200.00, while the Pneumatic Stapling Plier 53L requiring a quarter of the installation time due to its compatible size. The company that manufactures the Pneumatic Stapling Plier 53L, Margreiter Technik, was also unavailable for a quote which lead our team to estimate a value of $100.00, due to the fact that smaller stapling pliers are generally lower in cost than large industrial staplers. Our team excluded shipping costs in our analysis as we expect to find these parts (or variations of them) in Canada or the United States. Currently, the Rapid PRO Manual Stapler and Pneumatic Rapid Air Tac are shipped out of the United Kingdom and the Pneumatic Stapling Plier 53L is shipped out of Austria. The two highest-ranking concepts, the Rapid Classic with Cut-out and without Bottom, are very similar as well. They both utilize the existing stapler model, the Rapid Classic 1, combined with machining of the part. Assuming that all machining will be done in-house, we excluded these costs from our analysis. However, the Rapid Classic with Cut-out requires much less machining and therefore will be given the top rank for this cost analysis.

References

[1] JAYS Mechanical Consulting Inc. “Modes of header card attachment.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 25, 2015.

[2] “APAI AutoCard HS Heat Seal Header Card Machine,” YouTube. n.d. [Online] Available: https://www.youtube.com/watch?v=5VynYPy0lPc [October 19, 2015].

[3] JAYS Mechanical Consulting Inc. “Flow diagram for the concept generation process.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 23, 2015.

[4] ITW Industrial Fastening. (2008). SureShot 3118 Duo-Fast [Online]. Available: http://www.itwindfast.com/tools/index.cfm/toolID/14/Staplers/Fine-Wire/SureShot%C2%AE-3118/. [Oct 20, 2015].

[5] “Concept Generation & QFD 2015,” class notes for MECH 4860, Department of Mechanical and Manufacturing Engineering, University of Manitoba, 2015.

[6] JAYS Mechanical Consulting Inc. “Picture of criteria importance weighting matrix.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 25, 2015.

[7] E. R. J. J. J. T. D. D. F. M. Ferdinand P. Beer, Mechanics of Materials Sixth Edition, New York: McGraw-Hill, 2012.

[8] LIFETIME RELIABILITY SOLUTIONS CONSULTANTS. (2015). Liftime Reliability Solutions Consultants Global Consulting Services and Training [Online]. Available: http://www.lifetime-reliability.com/consulting/enterprise-asset-management/asset-replacement-value.html. [Oct. 27 2015].

[9] JAYS Mechanical Consulting Inc. “House of quality for the automated packaging machine.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 25, 2015.

[10] JAYS Mechanical Consulting Inc. “Concept screening matrix.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 25, 2015.

[11] Esselte. (2015). Rapid PRO R28E Staple Gun Cable [Online]. Available: http://www.rapid.com/en-US/Products/Rapid-PRO-R28E-Staple-Gun-Cable_20511750/. [Oct. 27 2015].

[12] Esselte. (2015) Rapid Airtac PS101 Pneumatic stapler [Online]. Available: http://www.rapid.com/en-GW/Products/Pneumatic-Staplers---Nailers/DIY/Rapid-Airtac-PS101-Pneumatic-stapler_5000051/. [Oct. 26 2015].

[13] JAYS Mechanical Consulting Inc. “A Rapid Classic stapler, the same type used in the Melet Plastic stapling machine.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 26, 2015.

[14] JAYS Mechanical Consulting Inc. “Stapler with handle clearance.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 26, 2015.

[15] JAYS Mechanical Consulting Inc. “Side view of rapid classic without bottom.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 26, 2015.

[16] Margreiter-Technik Hans Hilscher GmbH, "Pneumatic stapling plier L53," [Online]. Available: https://www.margreiter-technik.com/products/stapling-pliers/stapling-plier/pneumatic-stapling-plier-53l. [Oct. 28, 2015].

[17] JAYS Mechanical Consulting Inc. “Picture of concept scoring matrix.” Winnipeg: Design Eng.,Univ Manitoba,Winnipeg, MB, Oct. 26, 2015.

[18] Wikipedia, the free Encyclopedia (2015). Sensitivity Analysis [Online]. Available: https://en.wikipedia.org/wiki/Sensitivity_analysis [Oct. 22, 2015].

[19] ShopMania, (2015). Home & Garden [Online]. Available: http://www.shopmania.co.uk/tools/filter-brand-rapid [Oct. 27, 2015]