MECH 4860
ENGINEERING DESIGN

UNIVERSITY OF MANITOBA

Design of a Mobile Plastic Film Visual Inspection Unit

Final Design Report

Project Sponsor: Winpak Ltd.
Project Advisor: Kathryn Atamanchuk
Team 17 (Team B.L.A.N)
Date Submitted: 12/02/2013

Team Members:

Sayo Arowosegbe: ________________ David Blakley: ________________

Yao Liang: ________________ Kong Nguyen: ________________

Team 17
University of Manitoba
Winnipeg, MB
R3T 2N2

Elmer Sachvie
Manager, Laboratory Services
Winpak Division

Winnipeg, MB
Canada

Dear Mr. Sachvie,

Please find the attached copy of our report entitled “*Design of a Mobile Plastic Film Visual Inspection Unit*” which we are submitting in fulfillment of the requirements for the course *Mech 4860*. This report was prepared by Team 17, which consists of Kong Nguyen, Sayo Arowosegbe, Yao Liang, and David Blakley.

The purpose of this report is to explain in detail the design of a plastic film visual inspection unit and demonstrate how our team met the design criteria set out by you and your company. This report includes detail drawings, manufacturing, setup, operational procedure and cost for the inspection unit.

We would like to thank you for your time and allowing us to visit Winpak. We hope this report will exceed all your expatiations. If you have any question, please contact any of the group members by the emails provided: Kong Nguyen , Sayo Arowosegbe , Yao Liang , and David Blakley .

Sincerely,

Kong Nguyen
Sayo Arowosegbe
Yao Liang
David Blakley

Team 17
University of Manitoba
Winnipeg, MB
R3T 2N2

Paul Labossiere
Mechanical and Manufacturing Engineering Department
Room E1-546, EITC Building
University of Manitoba
Winnipeg, MB
Canada R3T 5V6

Dear Dr. Labossiere,

Please find the attached copy of our report entitled “*Design of a Mobile Plastic Film Visual Inspection Unit*” which we are submitting in fulfillment of the requirements for the course *Mech 4860*. This report was prepared by Team 17, which consists of Kong Nguyen, Sayo Arowosegbe, Yao Liang, and David Blakley.

The purpose of this report is to explain in detail the design of a plastic film visual inspection unit and demonstrate how our team met the design criteria set out by you and your company. This report includes detail drawings, manufacturing, setup, operational procedure and cost for the inspection unit.

With this report, we are confident we have met and exceeded all the requirements of the *Mech 4860* course. Thank you for your time. If you have any question, please contact any of the group members by the emails provided: Kong Nguyen , Sayo Arowosegbe , Yao Liang , and David Blakley .

Sincerely,

Kong Nguyen
Sayo Arowosegbe
Yao Liang
David Blakley

Table of Contents

List of Figures

List of Tables

Executive Summary

The purpose of this project is to design a mobile visual inspection unit for identifying defects in Winpak's bacon wrap product. The bacon wrap is a clear plastic film and consist of 4 layers; nylon, polyethylene, sealant, and a modified surface. Winpak is currently experiencing two types of defect in the bacon wrap product: one is impression and the second is gels defect. Impressions occur as a result of irregular resin deposit left on the nip-roller. Gels occur when the plastic pellets used to make the film does not fully melt when being extruded. Customer complaints due to defective product have made Winpak seek an alternative and better way of spotting defects in the bacon wrap. The goal of the mobile inspection unit is to aid the lab technicians in accurately identifying defects in the bacon wrap, thereby minimizing customer complaints.

The final design of the mobile inspection unit comprises of an overhead projector and a sliding mechanism. The overhead projector allows for more accurate detection of defects by enlarging the defects. All defects are enlarged by 6.5 times magnification with a distance of 1.5m from the projector screen. This magnification of defects allows technicians to better spot the minimum defect length of 1mm. The sliding mechanism of the design ensures the technician checks the entire area of the film sample. This is accomplished by allowing the technician to only check 11.25" by 11.25" at a time. The total time estimated to check the entire film is 2 minutes. The total cost of the inspection unit is $1871.61 before tax; this includes labor, manufacturing, and material cost.

The overhead projector chosen for the design is the Apollo 3400. This projector is the ideal choice for the final design because it is inexpensive, lightweight, has a large staging glass and the optimal brightness required for testing the film sample. The sliding mechanism is custom made as it was not possible to find any slider that has the required length or function needed for the design in the current market. The sliding mechanism consists of three main components: a roller, a

projector bracket, and a main bracket. The projector bracket is bolted to the side of the overhead projector; there are two projector brackets on each side of the overhead projector. The main bracket sits on top of the projector bracket and is capable of sliding along its length using the wheels on the projector bracket. The overall length and width of the projector is 1.1m and 0.45m. The unit is to operate in an aisle with 1.35 m clearance; which is more than enough room for which the unit is to operate.

The results from this project have demonstrated that the final design was able to satisfy all the client's specifications and needs. Therefore it is the team's recommendation Winpak incorporates this design in order to more accurately identify defects in the bacon wrap, which in turn will lower customer complaints.

1 Introduction

Winpak Ltd. is a company that manufactures and distributes high-quality packaging materials and innovative packaging machines. Winpak's packaging products are used mainly to protect perishable food, beverages and health care products from external environments.

Winpak challenged the team to design a visual inspection unit to identify defects in clear plastic film that is comprised of four layers: nylon, polyethylene, a sealant, and a modified surface. However, the film sample being inspected will exclude the modified surface layer as this layer is applied after the inspection procedure. In particular, the product being examined is Winpak's "bacon wrap," which is used in the packaging of bacon. The first step in manufacturing the bacon wrap is producing the nylon layer; the nylon layer is the core strength for the bacon wrap. Next, polyethylene is extruded on top the nylon; the polyethylene allows the bacon wrap to have flexibility. Lastly, a sealant is extruded on top of the polyethylene layer to give the bacon wrap protection from external environments.

Currently, two major defects that lower the quality of the bacon wrap are impressions and gels. Impressions occur as a result of irregular resin deposit left on the nip-roller, as shown in Figure 1. As the plastic film goes over the nip-roller, the resin deposit leaves an indentation in the film, reducing both thickness and quality of the film.

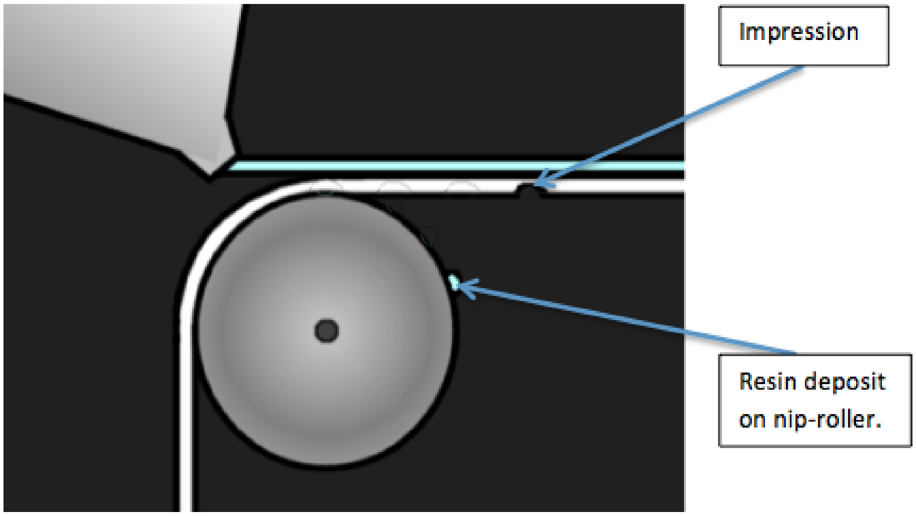

Figure 1: Impression defects

Gels are defects that look like beads on the bacon wrap, as shown in Figure 2. This defect mainly occurs when the plastic pellets used to make the film do not fully melt when being extruded.

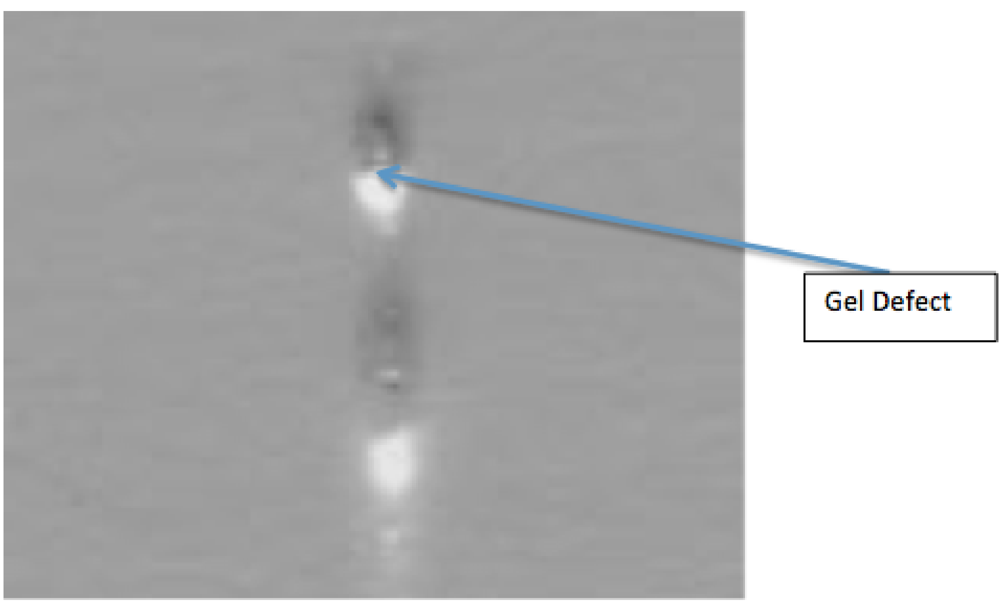

Figure 2: Gel defects

Currently, the common methods used to find defects in industry are fully automated machines. A scanner scans the film as it is being extruded and interprets data from the scanner with a computer software. These machines are large, not mobile, and expensive, which does not meet Winpak's specification. The target specifications for the inspection unit are list section 1.2.

1.1 Project Objective

The objective of this project is to design a mobile visual inspection unit that assists technicians in identifying defects in the bacon wrap. Winpak suggested we experiment with different lighting methods to find defects in the film, such as using different light sources or light angles. However, Winpak is open to any methods that we deemed is best for detecting defects.

Currently, there is no standardized way of inspecting the bacon wrap for defects at Winpak. Currently, technicians identify defects by holding the film sample up to any available light source, then visually spot defects in the film. This method is unreliable as it is prone to human errors. Technicians at Winpak take between 15-30 seconds to inspect a film size of 1m by 1.5 with the current method. Through meetings with our client and group discussions, the objectives for this project are as follow:

1. Standardize the operational procedure for finding defects in the film sample.
2. Show all defects accurately, thereby making it easier for the technicians to identify defects using the mobile inspection unit.
3. Make a device that has consistent results in finding defects.
4. Test the whole film sample in reasonable time.
5. Make the device easy to operate for technicians.
6. Ensure operator's safety when operating the device.
7. Make a device that is compact and mobile.

1.2 Target Specifications

The design of the inspection unit is fairly open ended; however, the key criteria that must be met in order to meet the client's needs are as follow:

1. The device has to assist operators in identifying defects that are 1mm or bigger in any dimension.
2. The unit must be able to check a film sample that is 1.5m by 1m.
3. The device has to be fit in a 1.35m wide aisle and be mobile.
4. Device must maximize accuracy in identifying defects.
5. Device must operate under current laboratory lighting conditions.

The following design criteria were not specified by the client, but the team's goal is to meet these criteria in the final design of the inspection unit. These values are subject to change as the design advances.

1. Allow operators to check the entire 1.5m by 1m film sample in two minutes or less.
2. Have a set up time of less than five minutes.

The target time above were based on the average time our team took to inspect the samples given to us by Winpak.

1.3 Constraints and Limitations

Physical constraints placed on the device are primarily related to the lab in which it will be utilized. The lab is made up of a series of desks with approximately 1.35m of clearance from the front and back, forming aisles that the device must be narrow enough to travel down. All the constraints and limitation on the design of the inspection unit are listed below.

- Device must fit in an aisle approximately 1.35m wide
- Device must be short enough to fit below the ceiling of the lab room about 2.5m high

- The unit has to perform all its functions even when exposed to external fluorescent light source from the lab, as external light sources can interfere with the light source from the inspection unit.
- Inspection unit cannot damage the film sample being inspected.
- The mobile inspection unit must cost less than $10,000 to manufacture.

With the above discussed specifications, constraints and limitations, the next phase was to generate feasible ideas to solve the client's problem. The first step was to generate all possible ideas that could satisfy their needs, these ideas are list in Appendix A. The 36 brainstormed ideas were grouped into feasible and non-feasible ideas. During the brain storming session, all ideas were considered. Therefore an initial screening of the brainstormed ideas was done in order to determine which ideas are feasible and which are not. Feasibility of the concepts was based on the team's intuition and experience on whether the idea would work for the design. Out of 36 initial ideas, a total of 19 ideas were considered feasible. A detailed description of feasible ideas is listed in Appendix B. The design chosen by the group is an overhead projector. This was chosen after a detailed concept selection process; which includes a weighted matrix, and concept scoring. Details on the weighed matrix and concept scoring can be found in Appendix C.

The detailed analysis of the final design and its components are discussed in the next section.

2 Final Design

Our final design, as seen in Figure 3, consists of a standard overhead projector with custom made rollers and sliding mechanism to accommodate the 1m by 1.5m film sample. The overhead projector chosen for our design was the Apollo 3400. This projector model was chosen because it is relatively inexpensive, lightweight, has a large staging glass, and the optimal brightness required for testing the film sample. The overhead projector head-mount and rollers are modified in order to accommodate the large size of the film sample. The rollers are 1.05m in length and are attached to a sliding mechanism that allows the rollers to slide along its length.

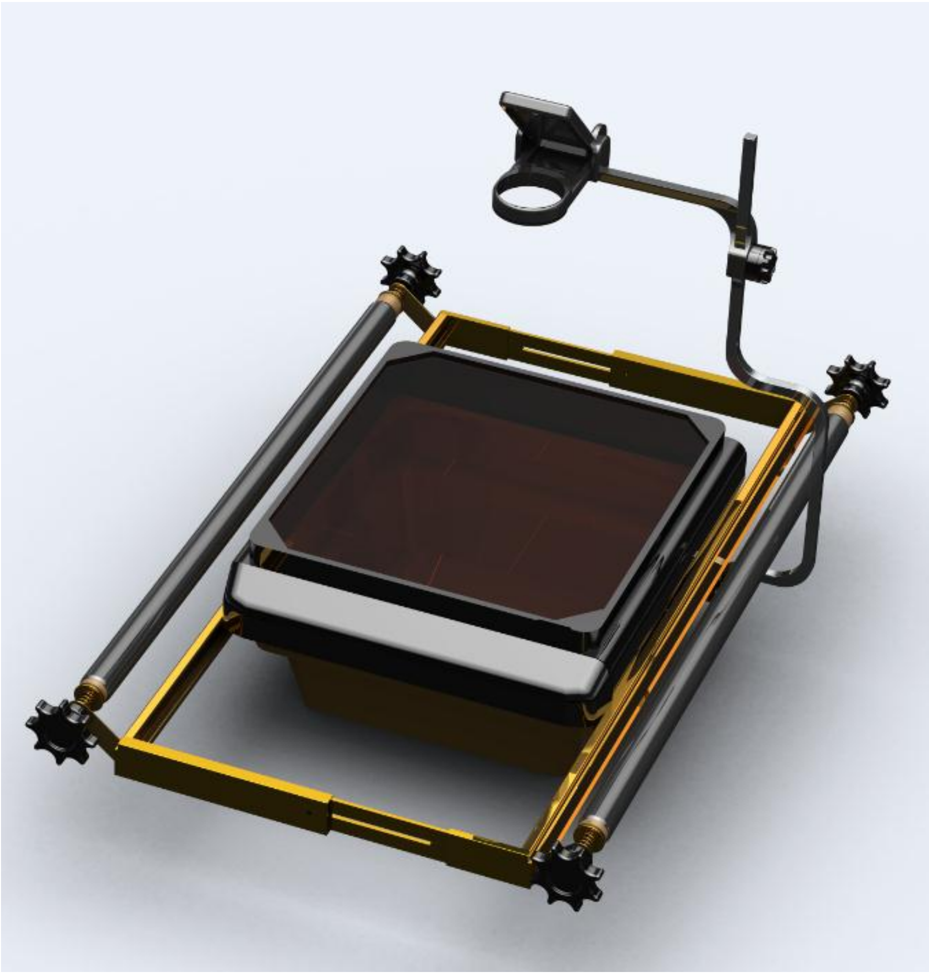

Figure 3: Render of final design

In order to check for defects, the technicians simply attach the film sample to the rollers on the projector, then check for the defects by using the sliding mechanism. Detailed operational procedures for checking defects are covered in section 3 of this report.

To get a better understanding of how the final design work, the key components of the design are discussed below. The key components of the inspection unit are:

1. Overhead Projector
2. Sliding Mechanism
3. Projector Head-mount
4. Projector Screen
5. Overhead Projector Stand

Detailed explanations of all the components in a standard overhead projector are covered in Appendix D.

2.1 Overhead Projector

The projector chosen for the final design was the Apollo 3400, as seen in Figure 4.

Figure 4: Apollo 3400 overhead projector [1]

This overhead projector is typically used in large conference or meeting rooms due to the fact that this model has a 4000 lumen output; this high lumen output is required to clearly display a picture with interferences from other light sources. Refer to Appendix D for a detailed explanation of “lumen”. The projector has dimensions of 15"L×14"W×27"H. Additional information regarding the Apollo 3400 is listed in Table I.

Table I: APOLLO 3400 SPECIFICATION [1]

Product Type	Transmissive Overhead Projector
Lamp Type	EVD
Lens Type	Triplet
Head Type	Open
Cord Length	15'
Depth	482.6 mm
Height	762.0 mm
Fold Down Arm	Yes
Lamp Changer	Yes
Hi/Low Lamp Switch	Yes
Weight	8.62 kg
Width	419.1 mm
Staging Size (Viewing Pane)	11.25''×11.25''

The Apollo 3400 is a transmissive light overhead projector with the light source located in the base unit under the staging glass. The triplet lens in this overhead projector delivers edge-to-edge sharpness and brightness; this results in clearer projection image of the defects. Thus allowing the technician to spot the defects in the film sample more easily. The cost for an Apollo 3400 overhead projector is $475 [1].

2.2 Sliding Mechanism

The sliding mechanism for the final design has to be custom-made, as it was not possible to purchase a sliding mechanism with the same specification or length required for the design. The chosen material for the sliding mechanism is 6061 Aluminum; this ensures low material cost and a lightweight design. There are four main components for the sliding mechanism: rollers, projector brackets, main brackets, and width adjustment unit. Figure 5 gives an overview of the sliding mechanism.

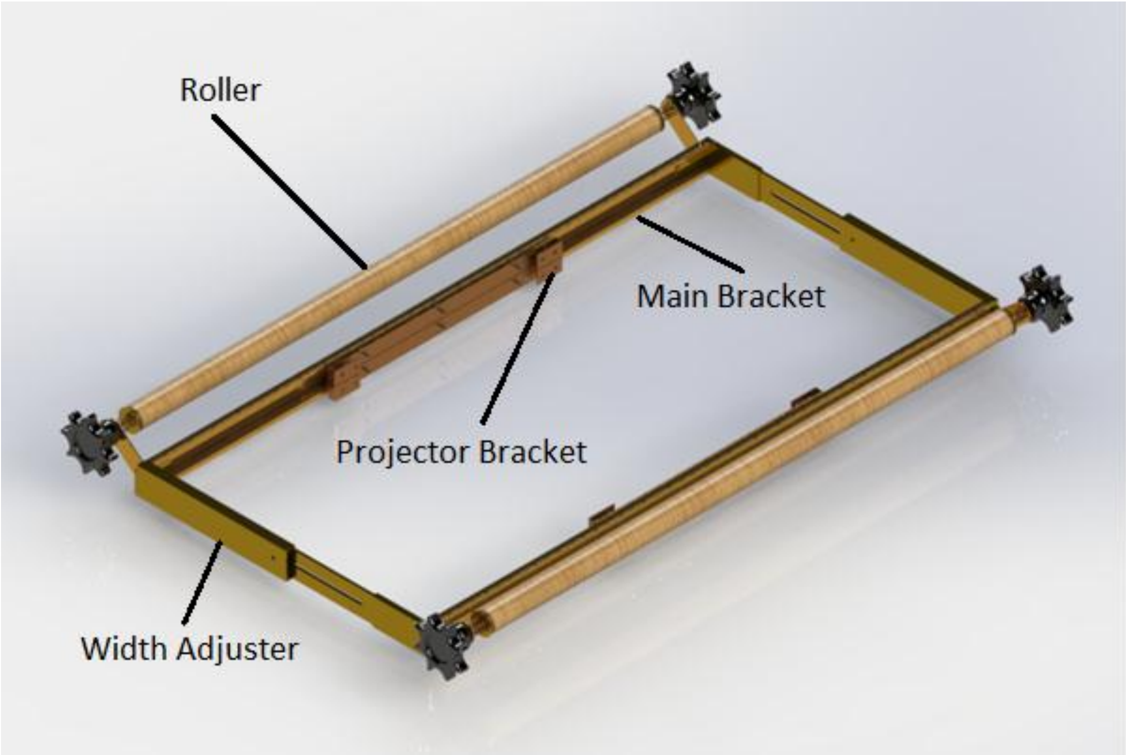

Figure 5: Assembled sliding mechanism

The rollers are used as place holder for the film sample, while the sliding mechanism will allow the technician to slide the rollers back and forth to check the whole length of the film sample. Detailed explanations of the sliding mechanism's components are discussed below.

For dimensions of all the components in the sliding mechanism, please refer to Appendix F.

2.2.1 Rollers

There are two 1.05m long rollers attached to the side of the projector. Figure 6 gives a visual representation of the rollers used in the inspection unit.

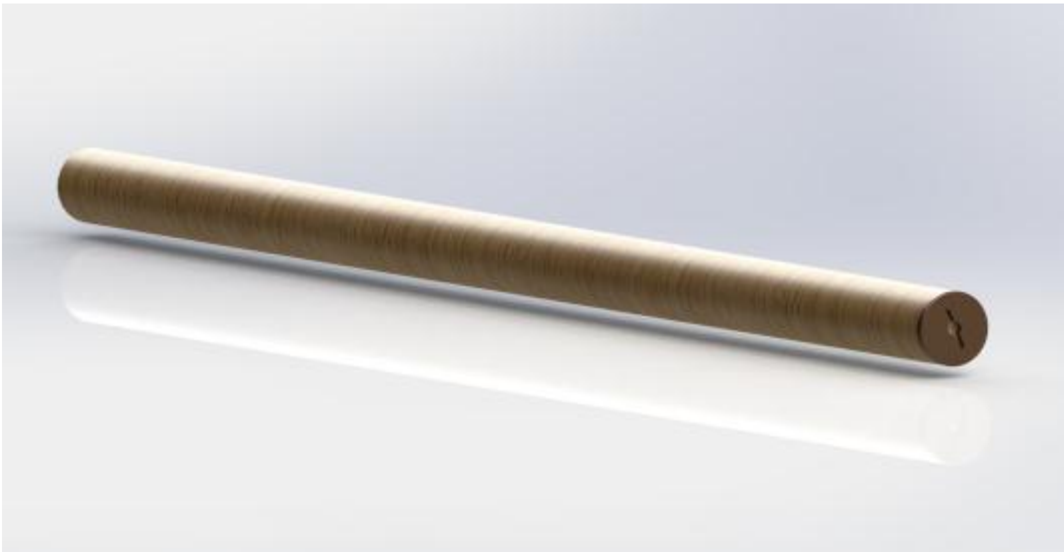

Figure 6: Rollers

The rollers are 2.5cm in diameter and are made out of dowel rods. The rollers are designed to be detachable from its holster. This is done by using a key, keyhole and spring mechanism, as seen in Figure 7.

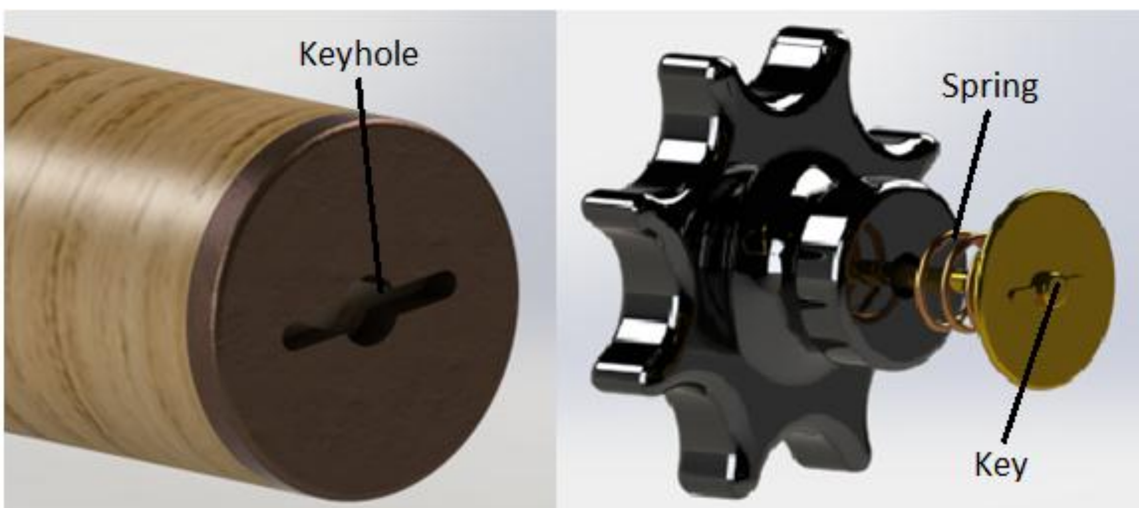

Figure 7: Key, keyhole, and spring mechanism

The spring pushes the roller's keyhole and the circular key together. To remove the rollers, the technician simply pushes the spring in; this will detach the key from the keyhole and allows for simple removal of the rollers. The rollers can be purchased on eBay for $11.94 for a pack of 3. The length of the purchased rollers are 3m long, it was not possible to find a wooden dowel with a specific length of 1.05m. The wooden dowels can be easily cut down to the proper size.

The rollers also have a 30cm buffer film. This buffer film is used to attach the sample film to the roller. One inch of the buffer is permanently fixed to the rollers with gorilla glue. Gorilla glue is extremely efficient at bonding wood and plastic. Gorilla glue can be purchased at Canadian Tires for $6.99. The buffer film can be made from the bacon wrap film from Winpak. This will reduce or eliminate the cost of acquiring the buffer film.

Scotch tape is used to tape the film sample to the buffer film together. Scotch tape is ideal because it is strong enough to hold the films together but will not damage the film or leave residue when taken off. Scotch tape can be purchased at Staples for $3.22.

2.3 Projector Bracket

A Figure of the projector bracket can be seen in Figure 8. The projector bracket is fixed to the side of the projector. There are two projector brackets on each side of the projector for a total of four projector brackets.

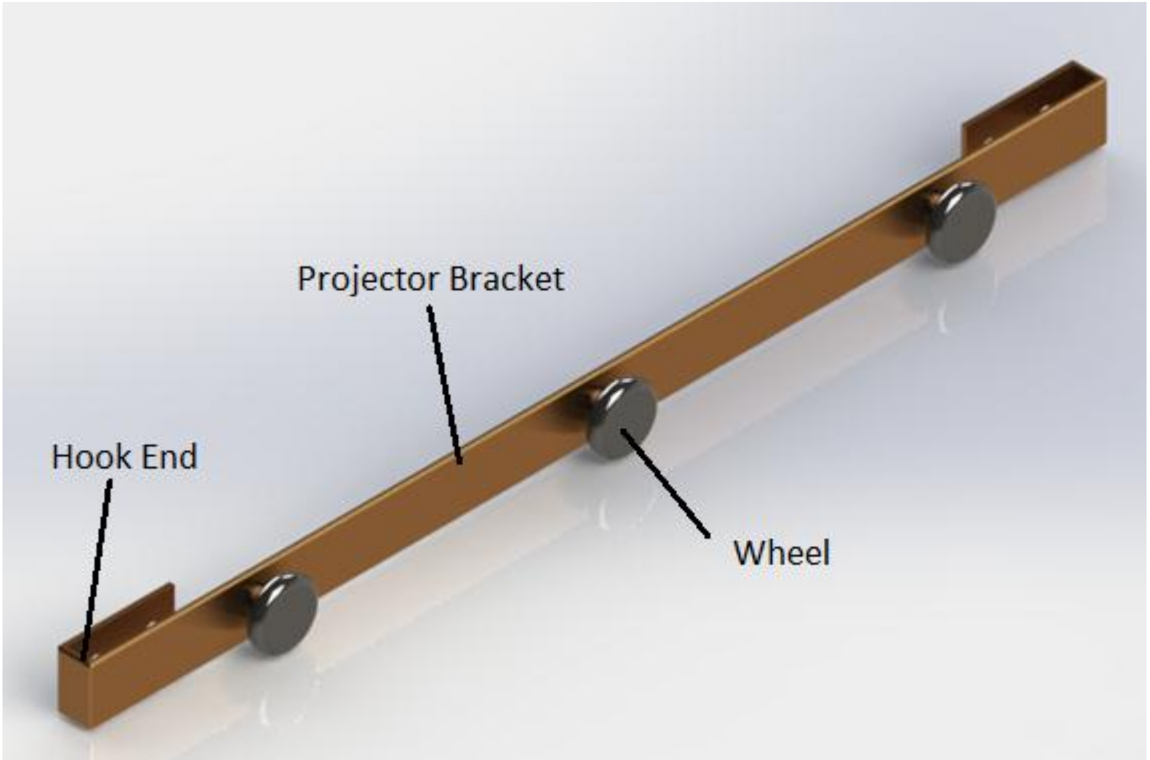

Figure 8: Projector bracket

Each hook end of the projector bracket is fixed to the overhead projector with 1/4" bolts and nuts. Figure 9 illustrates the fixture of the projector bracket to the overhead projector.

Figure 9: Projector bracket is bolted to projector

2.3.1 Main Bracket.

The main bracket, as seen in Figure 10, is 1.1m in length and is capable of moving back and forth using the wheels on the projector bracket. The claw on the main bracket hooks onto the wheels of the projector bracket. The overall weight of the two main brackets and two rollers is only 4.45kg; therefore wear and tear, and stress on the all the components are negligible.

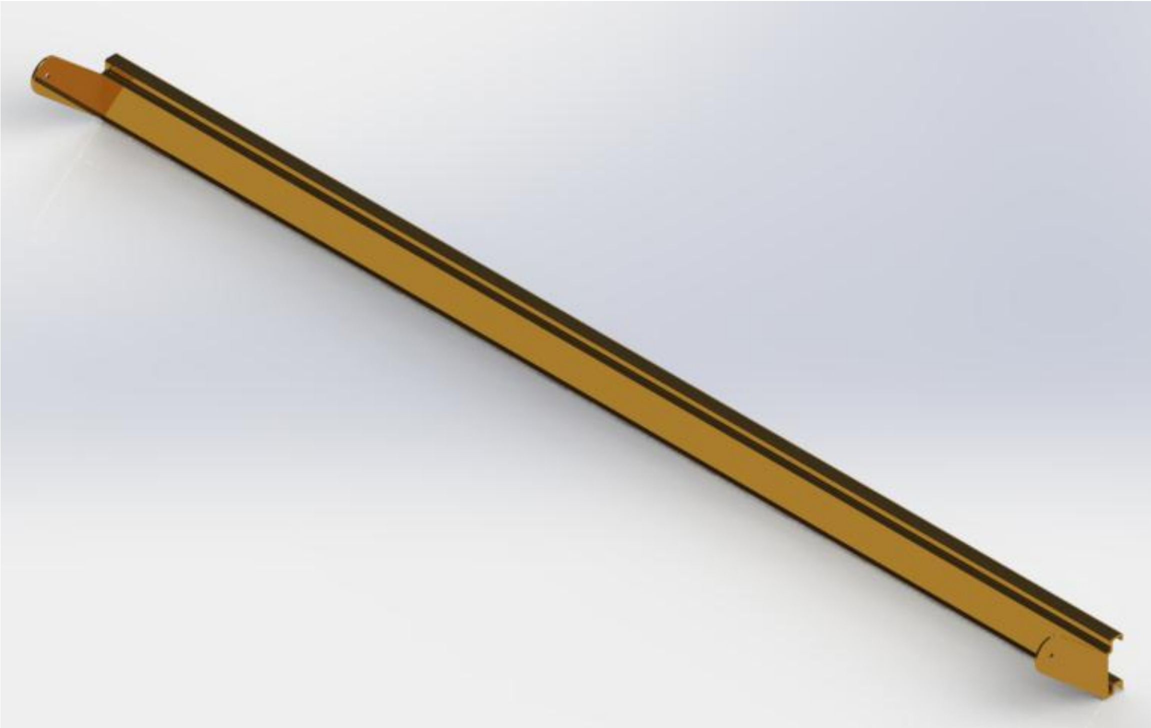

Figure 10: Main bracket

Figure 11 illustrates the main bracket being attached to the wheels of the projector bracket. The main bracket was design to stay on the projector even when technicians accidently push against it. The claw of the main bracket wraps tightly around the wheels of the projector bracket for a secure fit all directions.

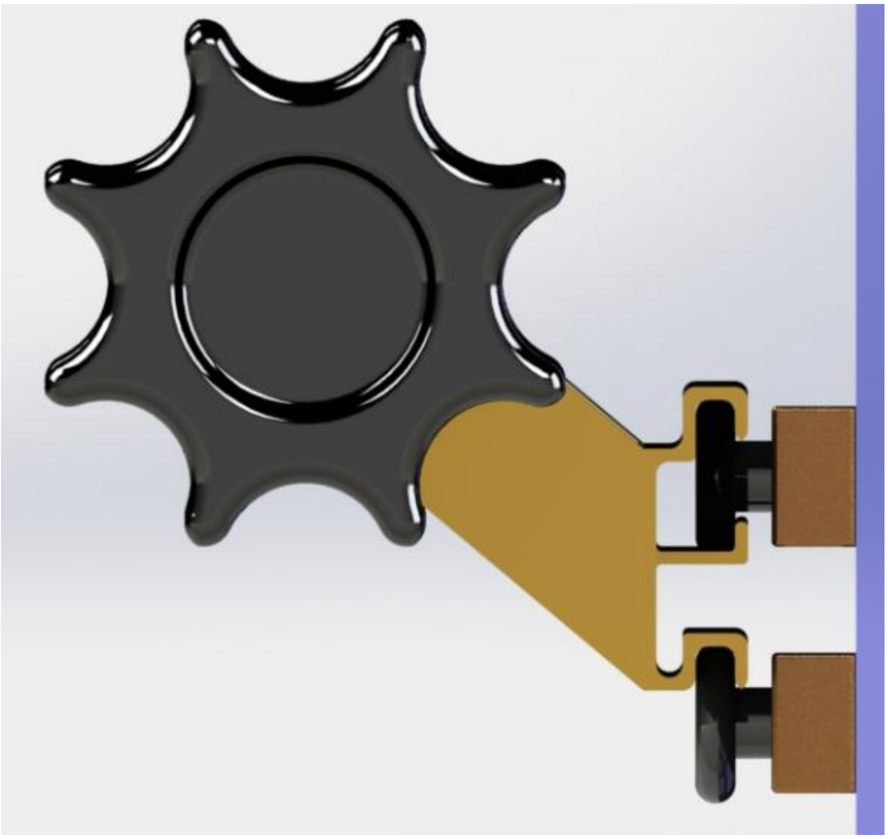

Figure 11: Main bracket and projector bracket fixture

2.3.2 Width Adjustment Mechanism

The ends of the main bracket also have a width adjustment mechanism, as seen in Figure 12. The width adjuster serves two functions:

1. To stop the sliding mechanism from falling off the projector when technician reaches the end.
2. To allow the sliding mechanism to fit varying width if the client decides to choose a different overhead projector.

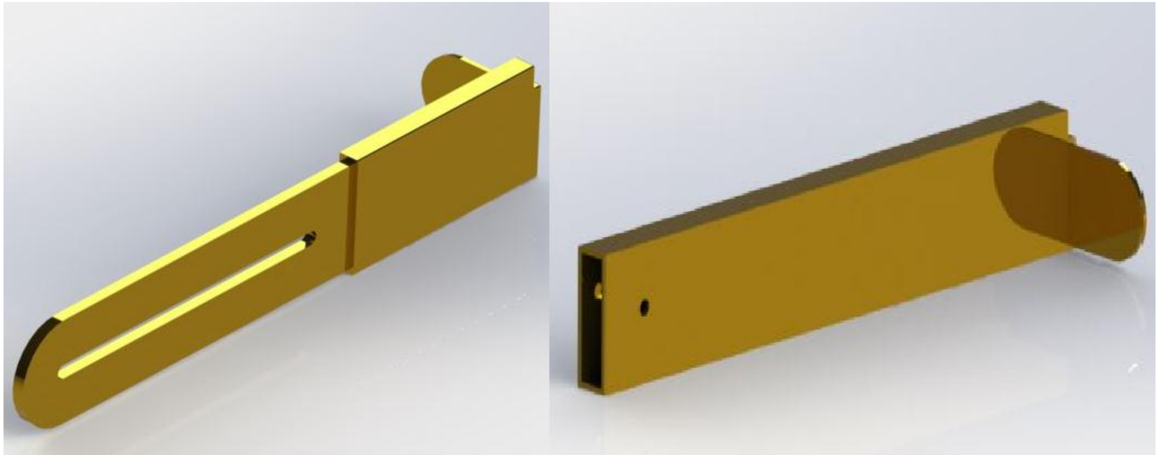

Figure 12: Width adjustment mechanism

The sliding mechanisms width can be adjusted to a maximum width of 0.5m. The width adjuster is fixed into the sliding mechanism by means friction. The fitting procedure of the width adjuster to the main bracket is illustrated in Figure 13.

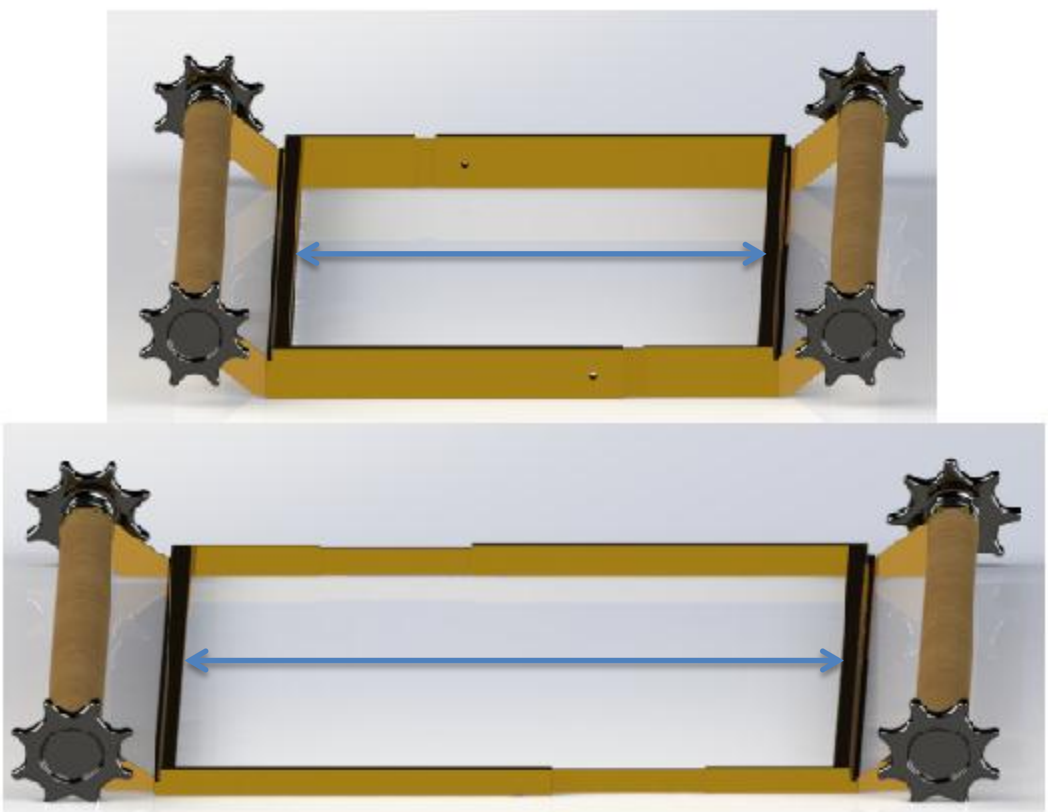

Figure 13: Width adjuster fits in main bracket

Instructions of how to install the sliding mechanism onto the projector are explained in Appendix E.

2.4 Projector Head-Mount

With the attachment of the rollers and sliding mechanism to the projector, the current head-mount on the projector must be moved and modified in order to fit the new design. As seen in Figure 14, the head-mount will protrude from the bottom of the projector and curve around the roller. The head-mount has to be custom made to accommodate the inspection unit.

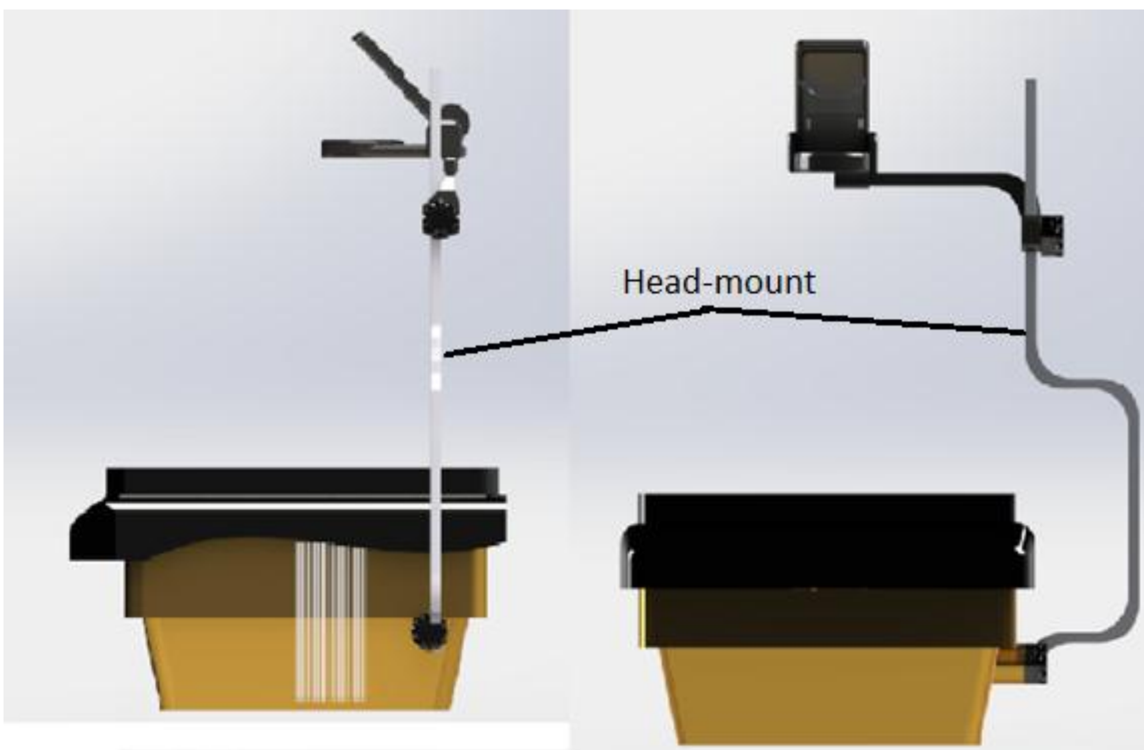

Figure 14: Custom projector head-mount

The new head-mount is attached to the projector in the same way as it was originally attached to the projector. The difference is that the head-mount is lowered down to the middle of the projector. The dimension of the head-mount can be found in Appendix F.

2.5 Projector Screen

The purpose of a projector screen is to clearly display a projected image for the view of an audience. The projector screen chosen for our design is the EluneVision 60" x 60" Portable Tripod Projector Screen. This screen was chosen based on its portability and compact size. As seen in Figure 15, the screen can be folded up into a compact poll that is easy to transport and store. This projector screen can be purchase at Staples at a cost of $184.96 [2].

Figure 15: EluneVision projector screen

The specifications for the screen is summarize in Table II below.

Table II: ELUNEVISION PROJECTOR SCREEN SPECIFICARION [2]

Aspect Ratio	1:1
Diagonal Length	85”
Width	60”
Height	60”

Due to the space limitation in the lab room, the recommended distance between the overhead projector and screen is 1.5m. At this distance, an image of 53’’ by 53’’ will be projected onto the screen, the defects will also enlarged by 6.5 times magnification.

2.6 Overhead Projector Stand

In order to keep the inspection unit mobile, it is placed on an overhead projector stand. The overhead projector stand chosen for this design is the Flexor Endura. This stand was chosen for its mobility and compact size. The base of stand is 24" by 32", which will easily fit in the 1.35m wide aisle at Winpak. The stand can be purchased at Worthingtondirect.com for $224.95 [3]. The projector stand can be seen in Figure 16.

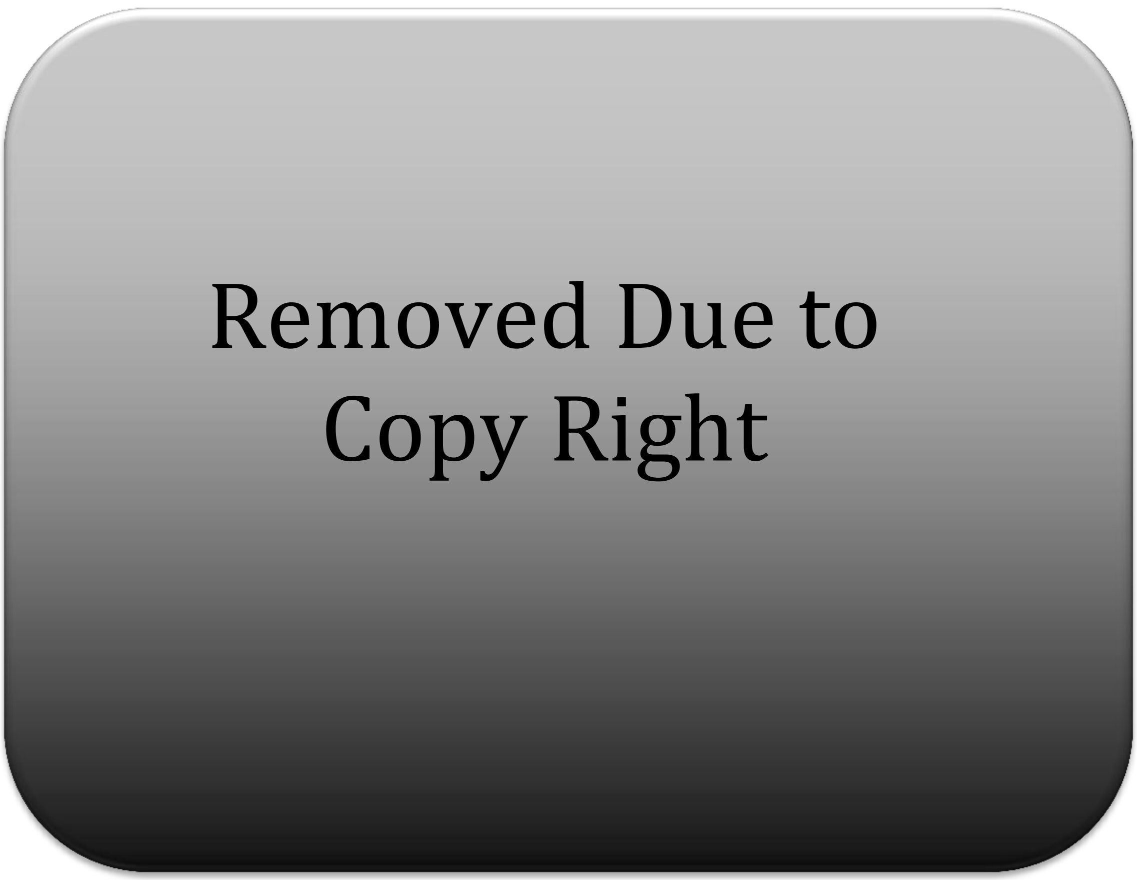

Figure 16: Lexor Endura overhead projector stand [3]

3 Operational Definition

This section gives a detailed description of the operational procedure for identifying defects in the plastic film sample. A summary of the operational procedures are listed in table III and IV.

A 1.05m film sample from the original film roll is needed for testing. The extra 0.5cm is needed for taping with the buffer film. The technician needs to measure and cut a 1.05m length of film from the original film roll, as demonstrate in Figure 17. The technician is advised to not fold or damage the film in anyway during the cutting process in order to improve defect detection accuracy.

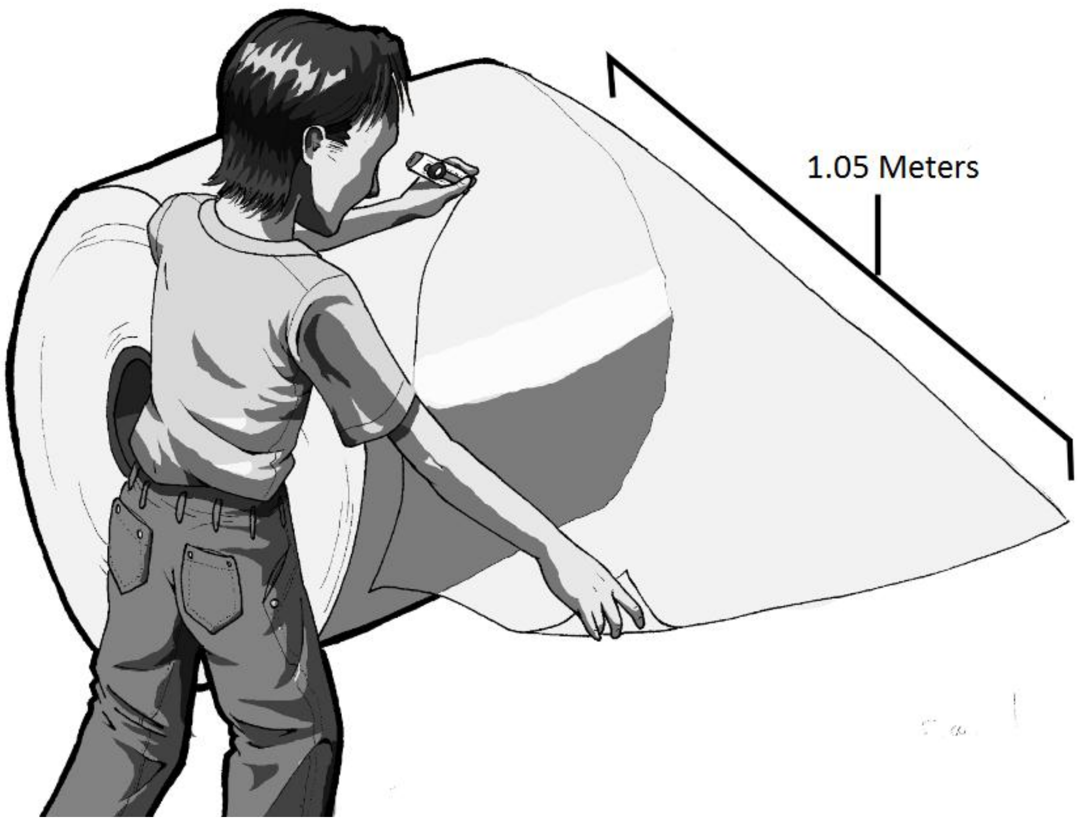

Figure 17: Cutting film roll

The next step is to attach the film sample onto the roller; the technician should bring the film sample to clean desk available in the plant to perform this process. The roller has a 30cm buffer film, the technician has to tape the edge of the 1.05m length of the sample film to the edge of the buffer film using scotch tape, as shown in Figure 18.

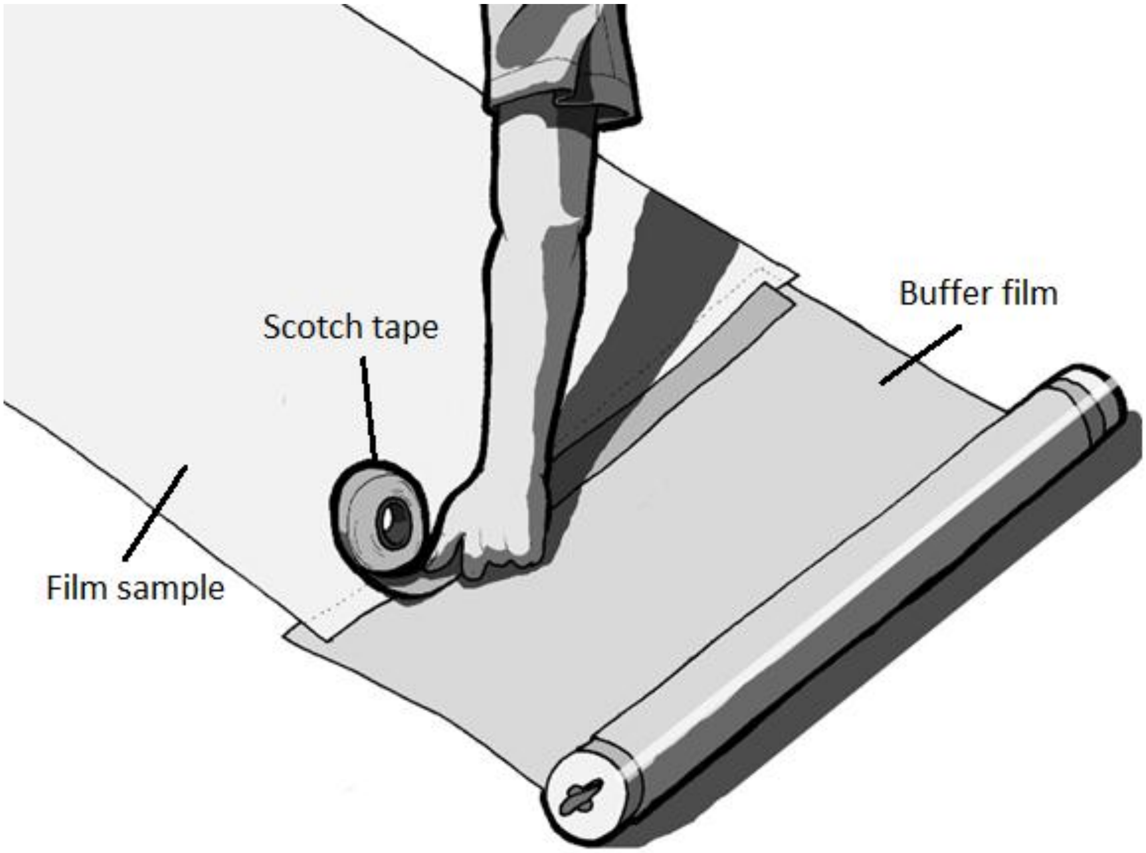

Figure 18: Taping sample film to buffer film

After attaching the film sample to the roller, the next step is to analyze the film sample for defects. To do this, the first step is to attach the rollers to the projector using the key, keyhole and spring mechanism, then tape the loose end of the film sample to the buffer on the second roller in the projector. This step is illustrated in Figure 19 and 20.

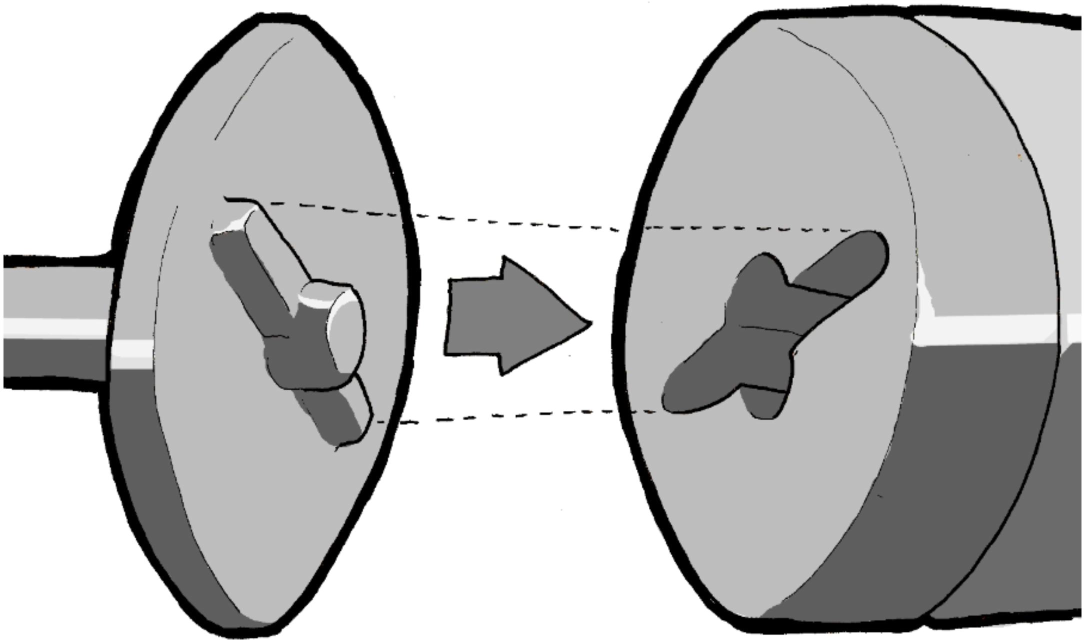

Figure 19: Put roller to projector with key, and keyhole mechanism

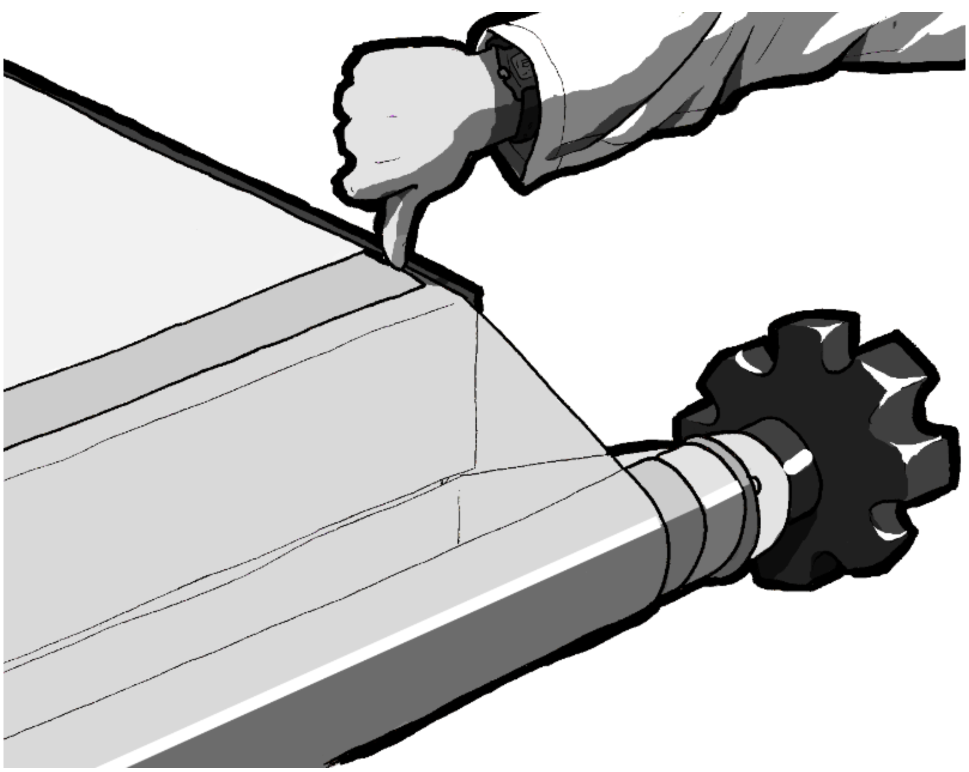

Figure 20: Taping loose film to buffer film on projector

After the sample film has been attached to the buffer, the technician can begin looking for defects. The projector's viewing pane is only 11.25" wide, so the film sample must be checked one section at a time. The technician must start at the right end of the slider. Figure 21 shows a schematic of this process.

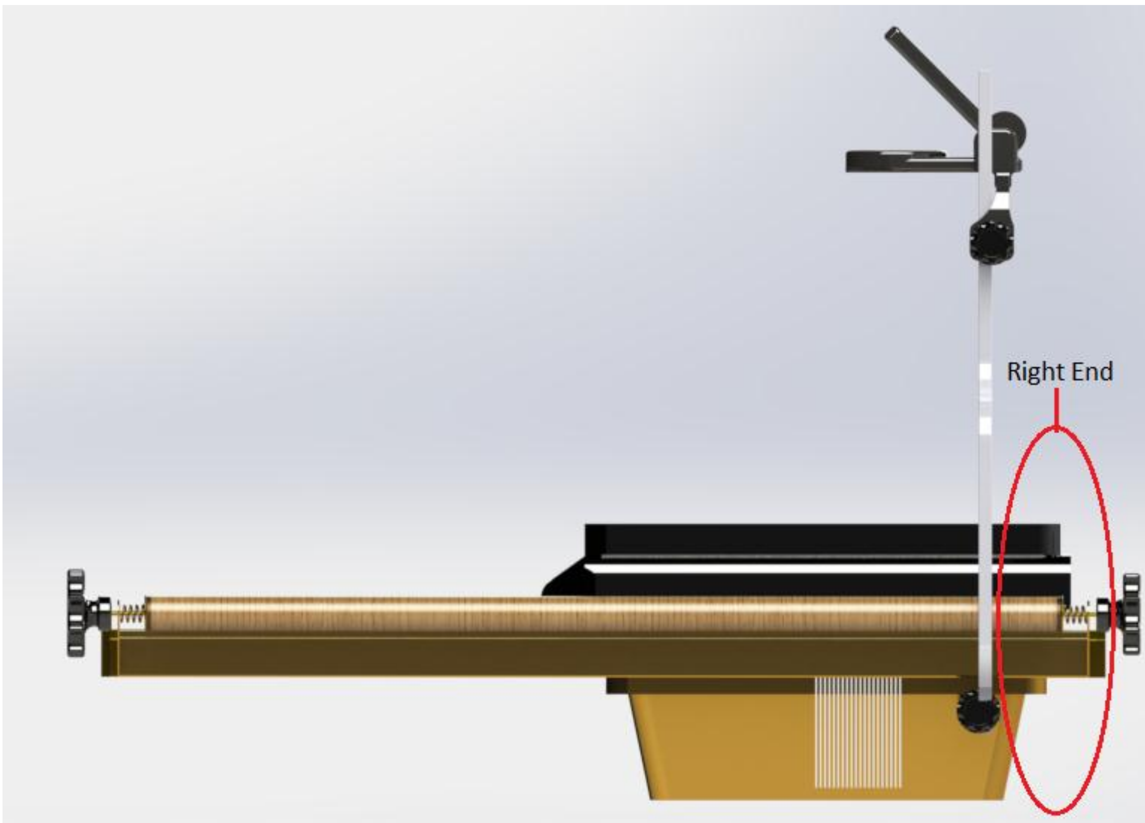

Figure 21: Right end of the projector

Once the current portion is fully analyzed for defects, the technician can slowly slide the film on to the next section, as seen in Figure 22.

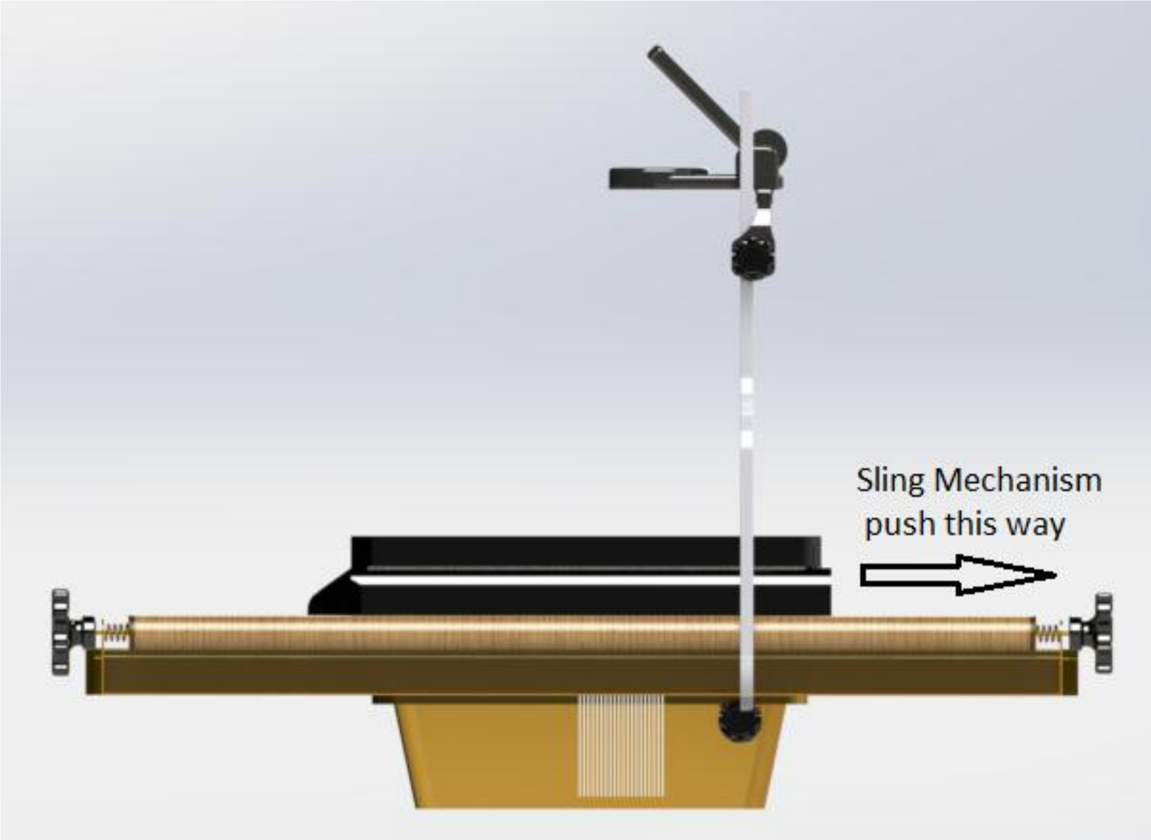

Figure 22: Sliding film sample to next section

Once the whole length of the film is checked for defects, the technicians must scroll the film to the next section. A total of 5.5 scrolls are required to check the whole film sample. This process repeats until the all of the film sample is checked. If a technician encounters a defect, the technician must circle the defect with a black marker. The technician has to then record the number of defects that occurred in the film sample into a logbook.

To take the film sample of the rollers, the technician simply has to remove the scotch tape attaching the buffer and roller film together. The film will then be free to be removed.

Below is the summary of the operational procedure.

Table III: FILM SAMPLE PREPARATION

Task Sequence	Task Definition (Brief Summary of Task)	Task Cycle Time (Seconds)
1	Cut a 1.05m long film sample from the original film roll	30
2	Bring film sample to a clean table	20
3	Tape the 1.05m long film edge of the film sample to the edge of the buffer film on the roller	15
4	Roll up the sample film tightly onto the roller	10
5	Bring the roller to the technician that checks for defects	30
	Total Time	105

Table IV: CHECKING FOR DEFECTS

Task Sequence	Task Definition (Brief Summary of Task)	Task Cycle Time (Seconds)
1	Attach roller onto overhead projector	10
2	Tape loose end of film sample to the buffer film of the second roller on projector	15
3	Checking for Defects • Begin by checking film sample starting at the right end of the projector • Once finished with current section of the film, slide the rollers up to the next section and continue checking for defects • Once the whole length of the roller is checked, scroll the rollers to the next portion of the film • A total of five and half scroll is required to check the film sample	120
4	When a defect is spotted, use a black marker to circle the defect.	5
5	Record number of defects into a log book	
	Total Time	150

The time estimated for each task was based on our teams experiment. As an example, for task 2 in table III, the desk is approximately 15m away from where the technician cuts the film sample. It takes on average each team member 12 seconds to walk a distance of 15m; we then chose 20 seconds as the task cycle time to overcompensate for any delay they the technician may encounter. The total time for the film preparation and checking for defects is 105 and 150 seconds, for a total time of 255 seconds. The time for just checking defects is 120 seconds, which is 90s longer than the current method, but is still a reasonable amount of time for ensuring accurate defect identification. The total setup time is 135 seconds, this is much less than the 5 minute we wish aimed to achieve.

4 Summary of Design

The final design of the mobile inspection unit consists of a modified Apollo 3400 overhead projector with an attached sliding mechanism. The Apollo 3400 overhead projector was chosen for its low cost and the fact it met all the design requirements. The sliding mechanism comprises of four main components: rollers, projector brackets, main brackets, and a width adjustment unit. There are two projector brackets bolted to each side of the projector. The main bracket is capable of sliding along its length using the wheels on the projector brackets. The longest dimension of the inspection unit is 1.1m, which will easily fit in the 1.35m aisle. The inspection unit is placed on a projector stand that allows it to move. With the use of the projector stand and the portable screen, the inspection unit is very mobile.

The mobile inspection unit provides accurate results by enlarging the potential defects in the film sample. All defects presented in the film sample are enlarged by 6.5 times magnifications when the projector is placed 1.5m away from a screen. This allows the technician to identify defects more easily rather than checking the sample without an aided device. The sliding mechanism of the design enables the technician to check the whole sample one portion at a time. The time required to check the 1m by 1.5m film sample is estimated at 2 minutes. This is 90 seconds longer than the current method but is reasonable for ensuring accurate defect detection. The detailed operational procedure for identifying defects will not only standardize how technicians check for defects but also keep results consistent.

The final design consists of custom-made and purchased parts. The total cost of the inspection unit is estimated at $1871.61. This includes labor, manufacturing, and material cost.

With the results from this project, we have satisfied all objectives and specifications for the inspection unit. A comparison how the inspection unit satisfies the all clients need and expectation is listed in Table V.

Table V: SUMMARY OF FINAL DESIGN VS. CUSTOMER EXPECTATION

Clients Expectations	Design of Inspection Unit
Standardize the operational procedure for finding defects in the film sample.	Clear operational procedures of how to identify defects will standardize how technicians check for defects.
Show all defects accurately, thereby making it easier for the technicians to identify defects using the mobile inspection unit.	All defects are enlarged and projected onto a clear white projector screen. This allows for the defects to be display clearly and allow technician to spot defects more easily.
Make a device that has consistent results in finding defects.	Clear operational procedures of how to identify defects will keep results in finding defects consistent.
Test the whole film sample in reasonable time.	Without setup time, the total time it takes to check for defect is 2 minutes, which is reasonable for ensuring accurate defect detection.
Make the device easy to operate for technicians.	The unit consists of a standard projector and sling mechanism, which is very easy to use.

Table V: SUMMARY OF FINAL DESIGN VS. CUSTOMER EXPECTATION CONTINUED

Clients Expectations	Design of Inspection Unit
The device has to assist operators in identifying defects that are 1mm or bigger in any dimension.	All defects are enlarged by 6.5 times magnification when the projector is 1.5m away from the screen. This makes much easier to see the 1mm defect on the film.
The unit must be able to check a film sample that is 1.5m by 1m.	The sliding mechanism allows the whole 1m by 1.5m film to be checked.
The device has to be fit in a 1.35m wide aisle.	The longest dimension of the unit is 1.1m, which easily fits in the 1.35m aisle.
The device has to be mobile.	With the use of a projector stand and portable screen. The mobility of the device is achieved.
Device must maximize accuracy in identifying defects.	All defects are enlarged and technician can only check one small section at a time.
Device must operate under current laboratory lighting conditions.	The overhead projector has a 4000 lumen output. This high output can accommodate the light interference from lights in the lab room.
Ensure operator’s safety when operating the device.	The unit consists of a standard projector and sliding mechanism, which is very safe to use.

5 Cost Analysis

The allowable budget specified by the client for this project is $10,000. We were unable to get the cost of the sliding mechanism from a manufacturer. However, by comparing our sliding mechanism to other sliders with similar functions and length, our team was able to get a rough estimate. The slider we compared our sliding mechanism to was a drawer slide made by Hettich. The cost of this drawer slide is $197.74 [4]. To account for the custom made factor of the design, the price of the drawer slider was multiplied by three to get a rough estimate. The Bill of Materials for final design is shown below.

Table VI: BILL OF MATERIAL FOR PURCHASED PARTS

Item	Description	Qty	Cost
1	Sliding Mechanism	1	$600
2	Bolts ¼ in	18	$15.80
3	Nuts	30	$3.3
4	Apollo 3400 Overhead Projector	1	$475
5	Roller	3	$11.94
6	Wheels	12	$19.40
7	Overhead Projector Stand	1	$180
8	Buffer Plastic	2	$1
9	Scotch Tape	1	$3.22
10	Gorilla Glue	1	$6.99
11	Projector Screen	1	$184.96
12	Turning Knob	4	$15.96
13	Head-mount Arm	1	$100
		Total	1601.61

The cost of installing the design is $90 per hour, the design will take approximately three hours to install. The total cost of the final design comes to $1871.61. This includes manufacturing, labor and material cost. This is below our budget constraints.

6 FMEA (Failure Mode and Effect Analysis)

An FMEA was performed on the final design and the process procedures to determine possible mode of failure. The purpose of an FMEA is to identify, estimate, prioritize and evaluate risk, the ultimate goal is at failure prevention. To perform an FMEA, critical input and process variable that affects the output quality is examined. Each input or process variable is then evaluated based on 3 criteria: severity, frequency and detection. Each criteria is rank out of 10, with 1 being it has minimal risk and 10 being it has the greatest risk for failure. A Risk Priority Number (RPN) is then determined by multiplying the three criteria together for a maxim score of 1000. The higher the RPN, the greater the risk of failure. Table VII is the FMEA for our final design and also the process of checking for defects.

Table VIII: FMEA

Steps in process / input	Potential failure mode	Potential impact of failures	SEVERITY	Potential causes	FREQUENCY	Current Process control	DETECTION	RPN
What is the step of the process and inputs on which the focus is?	How the key input can be faulty?	What is the impact on key variables output (customer requirements)?		What are the causes?		Which process/tool/method/system do we have to detect a problem?		
Cutting film sample	Inaccurate defect testing	Customer dissatisfaction	4	Technician not cutting the recommended sample length	3	none	6	72
Handling film sample	Inaccurate defect testing	Unable to check film sample for defects	5	technicians damaging film sample while handling film sample	2	none	6	60
Broken projector	Unable to check film sample for defects	Cannot send out film roll prior to checking for defects	5	Defective projector or malfunction due to prolong use	3	none	1	15
Checking for defects	Inaccurate defect testing	Customer dissatisfaction	9	Missing defects on film sample due to technician error	1	none	10	90
Broken sliding mechanism	Unable to check film sample for defects	Unable to check film sample for defects	5	Defective projector or malfunction due to prolong use	1	none	1	5

From the FMEA, the input “checking for defects” has the highest RPN value of 90. With the aid of the inspection unit, the frequencies of missing defects are minimized. However, if a technician misses a defect, this would cause extreme customer dissatisfaction. To prevent errors in detecting defects, technicians are advice to follow the procedures in the operational definition.

7 Conclusion

In conclusion, the inspection unit has satisfied all the client’s needs and expectations. The inspection unit is mobile and can easily fit in the lab room. Inspection of film samples has been standardized with the specified operational procedure. Consistent results can also be attained through the operational procedure by ensuring all technicians identify defects with the same method. Without setup time, identifying the defects take 2 minutes, which is reasonable for ensuring accurate results. The total cost of the unit is $1871.61, which is below our budget of $10,000.

8 Reference

[1] OfficeDepot. (2013, Nov.). *Apollo Concept 3400 Overhead Projector 03400* [Online]. Available: http://www.officedepot.ca/overhead-projectors/apollo-concept-3400-overhead-projector-03400.asp [November 12, 2013].

[2] Staples Canada Inc.. (2013, Nov.). *EluneVision 60'' x 60'' Portable Tripod Projector Screen* [Online]. Available: http://www.staples.ca/en/EluneVision-60-inch-x-60-inch-Portable-Tripod-Projector-Screen/product_169430_2-CA_1_20001 [November 29, 2013].

[3] Worthington Direct. (2013, Nov.). *Endura AV Carts by Luxor* [Online]. Available: http://www.worthingtondirect.com/av-equipment/tuffy-video-cart-by-h-wilson.htm [November 29, 2013].

[4] Amazon. (2013, Nov.). *Tools & Home Improvement* [Online]. Available: http://www.amazon.com/Drawer-Slide-Extension-Heavy-Capacity/dp/B0009O9SLE/ref=sr_1_4?s=hardware&ie=UTF8&qid=1385876471&sr=1-4 [November 29, 2013].

LIST OF APPENDICES

List of Appendix Figures

List of Appendix Tables

APPENDIX A

The team conducted a brainstorming session to list all the possible solutions that could be incorporated into our final design. Both individual and collective ideas enabled us to have a large pool of concept ideas to work with. During the brainstorming session, the team focused mostly on the client's criteria. With this we were able to get different ideas that match our client's core technical concept. The team also brainstormed ideas outside the client criteria in order to determine other concepts suitable for detecting defects. All the 36 brainstormed ideas are listed below.

Brainstormed Ideas

1. Hand scanner/wand
2. Dentist lamp
3. Angled light projector
4. Computer scanner for thickness
5. Liquid penetrants
6. Overhead projector against a black background
7. Suspended sample between projector and white background
8. Series of rollers to measure the thickness of depth
9. Ultrasound
10. Eddy current
11. Photo elasticity
12. Strain gage
13. Thermal imaging
14. Roller used to check one spot at a time
15. Classroom style overhead projector
16. Photography fluid
17. Measure permeability
18. Used light of different frequency

19. Laser detector
20. Precise angle of light by robotic arm
21. Black light
22. Miners hat
23. Hang projector on ceiling, screen on the wall and sampling in between
24. X-ray
25. Sensor to check the internal structure
26. Stress tests
27. Sealed the edge of the sample and blow up with balloon
28. Ink impression
29. Intermediate scanning plate
30. Magnifying glass
31. Smoke over the surface and see if there’s eddy forms
32. Sonar ultrasound
33. Radiation to check different layer structures
34. Wide beam light/ detector combination
35. Flash photograph
36. Fiber optic stile lighting

During the brainstorming session, all ideas were considered. An initial screening of the brainstormed ideas was done in order to determine which ideas are feasible and which are not. Feasibility of the concepts was based on the team’s intuition and experience on whether the idea would work for the design. Out of 36 initial ideas, a total of 19 ideas were considered feasible.

Feasible Ideas

1. Hand scanner/wand
2. Dentist lamp
3. Angled light projector
4. Computer scanner for thickness
5. Overhead projector against a black background
6. Suspended sample between projector and white background
7. Photo-elasticity
8. Thermal imaging
9. Roller used to check one spot at a time
10. Classroom style overhead projector
11. Measure permeability
12. Used light of different frequency
13. Precise angle of light by robotic arm
14. Miners hat
15. Hang projector on ceiling, screen on the wall and sampling in between
16. Magnifying glass
17. Flash photograph
18. Fiber optic stile lighting
19. Liquid penetrants

Non-Feasible Ideas

1. Strain gage
2. Photography fluid
3. X-ray
4. Sensor to check the internal structure
5. Stress tests
6. Sealed the edge of the sample and blow up with balloon
7. Ink impression
8. Smoke over the surface and see if there's eddy forms
9. Sonar ultrasound
10. Radiation to check different layer structures
11. Wide beam light/ detector combination
12. Laser detector
13. Series of rollers to measure thickness
14. Ultrasound
15. Eddy current
16. Intermediate scanning plate
17. Black light

APPENDIX B

The detailed explanation of the feasible ideas and their conceptual mode of operation are discussed below.

Fixed Angled Light and Film Sample

The goal of this method is to improve the current procedure of testing for defects. Currently, technicians hold the sample film with two hands up against the ceiling light for finding defects. They have to find the optimal light angle that can best detect the defects in the film. The concept aims to take away the guessing work of the technician to find the optimal angle by having a fixed stand for a light source and a fixed stand to hold the film sample. To look for defects, all the technician has to do is place the sample into the film fixture, turn on the light source and look for defects. This will keep results consistent. Figure B1 gives a clear visual of the fixed angled light and film sample

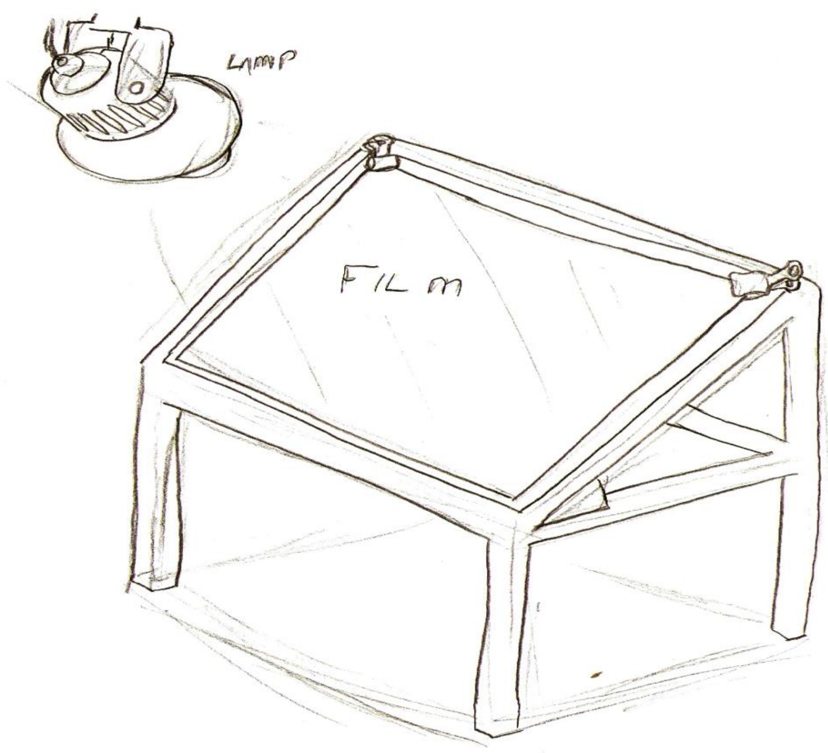

Figure B1: Fixed angled light and film sample

Photo-Elasticity

This design is based on the photoelastic effect. The idea is to apply tensile stress to the sample film and then looking for stress concentrations around the defects. However, this testing method would require large amount of training in the technician to be accurate. Figure B2 gives a clear visual of the photo-elasticity concept.

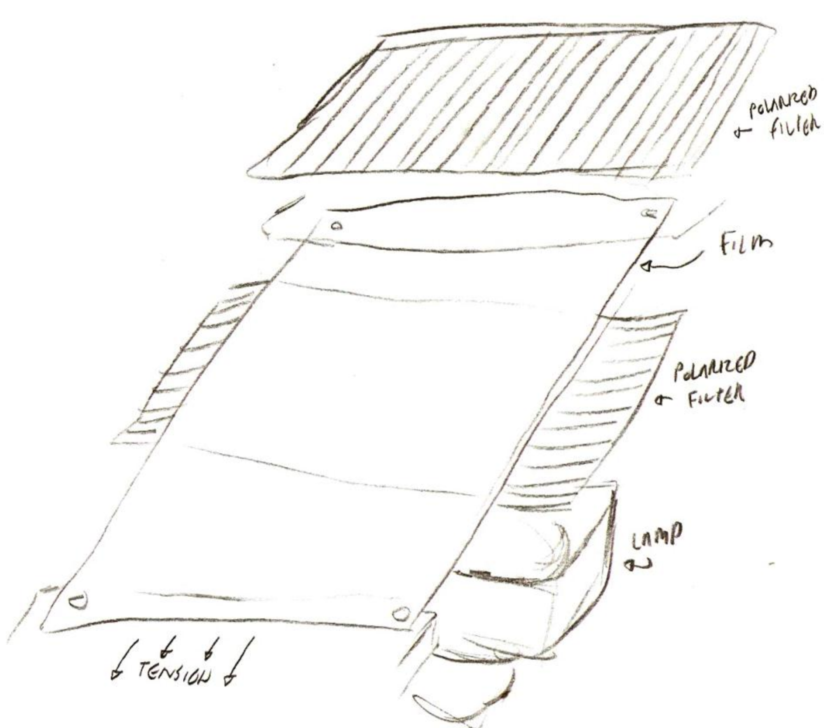

Figure B2: Photo-elasticity

Light Projector Roller

This idea aims to improve the accuracy of the testing method by only allowing the technicians to check one area of the film at a time. The film sample is place onto two rollers with a fixed light source pointing from the top.

The technicians slowly scroll the rolled film and thoroughly check for defects in the film one section at a time. This method makes sure all area of the film is inspected. Figure B3 shows the light projector roller.

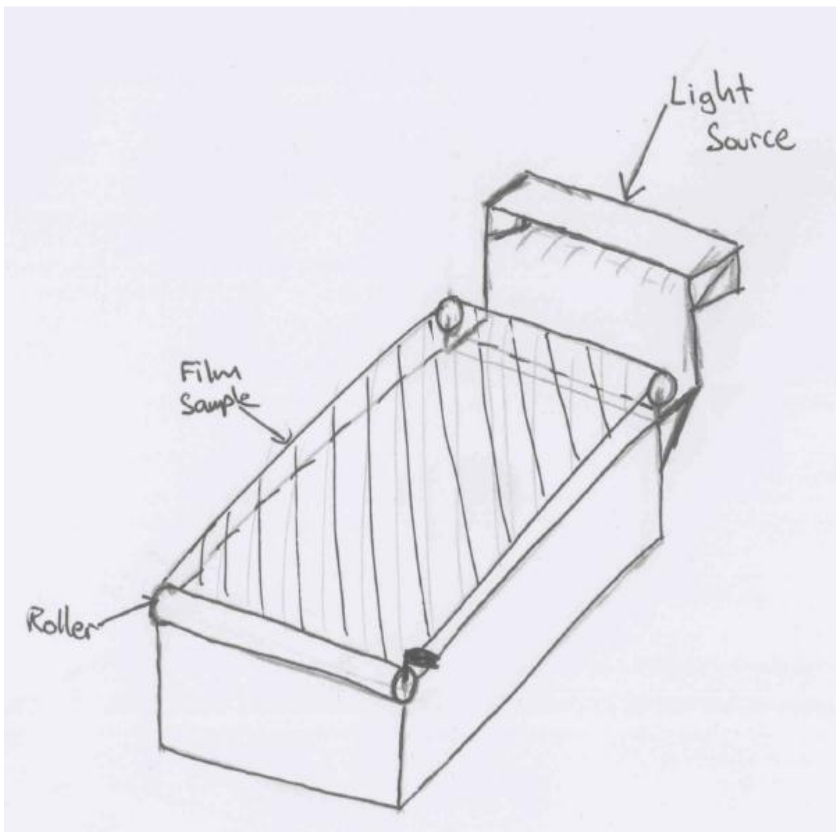

Figure B3: Roller

Flash Photography

The idea behind this design is to use the flash of a camera to find defects in the film. In theory, the defects in the film would cause a distortion of the lighting around it compared to the rest of the non-defective area, therefor allowing for easy detection of defects.

During testing however, it was found that using reflective light is not the best method as it caused strong glare from the film making it hard see the defects. Figure B4 gives a visual of the flash photography.

Figure B4: Flash photography

Handheld Scanner

The hand scanner is basically a device that is meant to scan the surface of the plastic film. The way it works is that it is meant to indicate if there is a defect on the surface of the film, by checking for its thickness or something else and give an indication.

This method aims to incorporate current technologies available for detecting defects in plastic film into a small portable handheld scanner. The handheld scanner uses a source of light to illuminate the surface of the plastic film and relays the image captured to a computer. Using software, the computer then interprets and analyzes the data from the handheld scanner for defects. The only issue about this concept is the cost of integrating the software. Figure B5 gives a visual of the handheld scanner in operation.

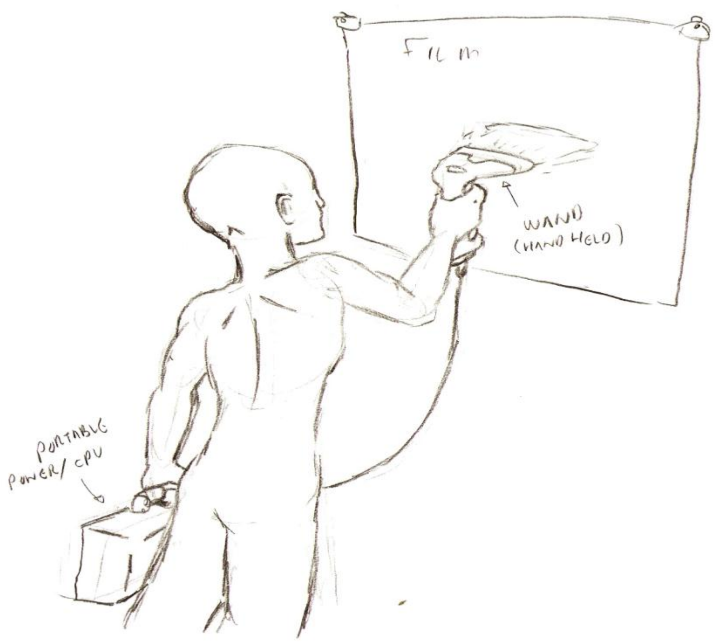

Figure B5: Handheld scanner

Computer Scanner for Thickness

This concept makes use of a horizontal scanning slot. The scanning slot in use has a feeder, through which the plastic film is fed. The scanner checks for the thickness of the plastic film. Computer software is then used to relay the data from the scanner and interpret it in terms of contour lines.

By analyzing the contour lines, it is possible to identify where the defects are. Similar to the first idea, the major con about this concept is the cost. Figure B6 show a visual of the computer scanner in operation.

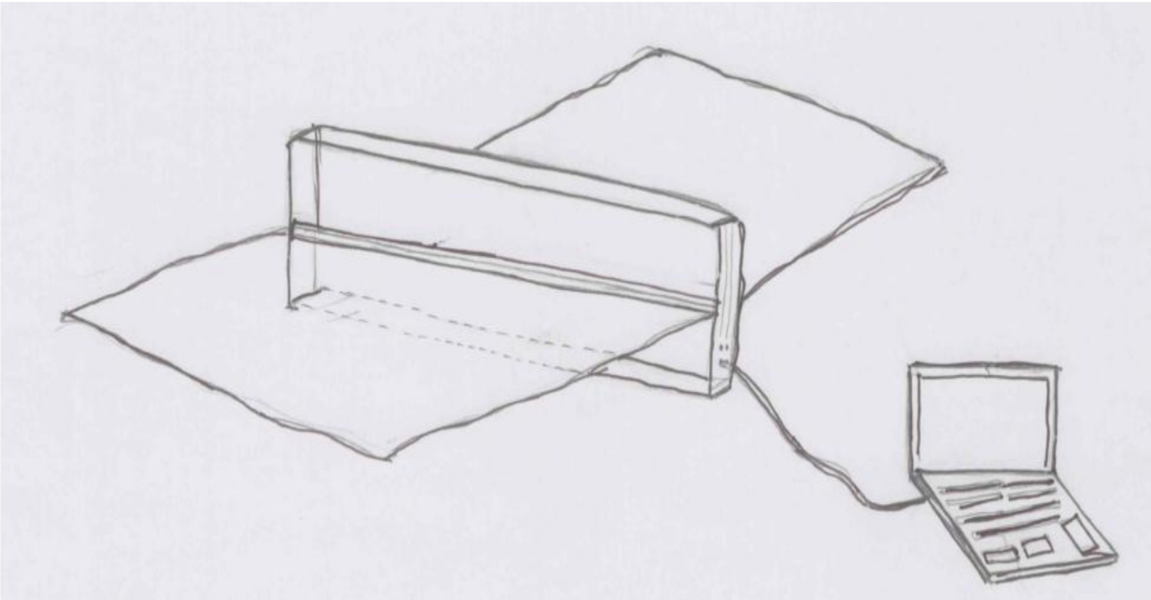

Figure B6: Computer scanner for thickness

Head Mounted Lamp

This concept integrates a headgear with a light source attached to it. With the light source attached to the technician’s head, this method allows the technician to freely adjust the light angle that is best for finding defects. The miner’s hat is a relatively cheap concept. Figure B7 gives a clear visual of the head mounted lamp.

Figure B7: Head mounted lamp

Magnifying glass

The magnify glass enlarges the portion of the film being inspected, allowing technician easily identify small defects. This method would increase the accuracy of finding defects but would take a lot of time. Figure B8 gives the visual of a magnifying glass.

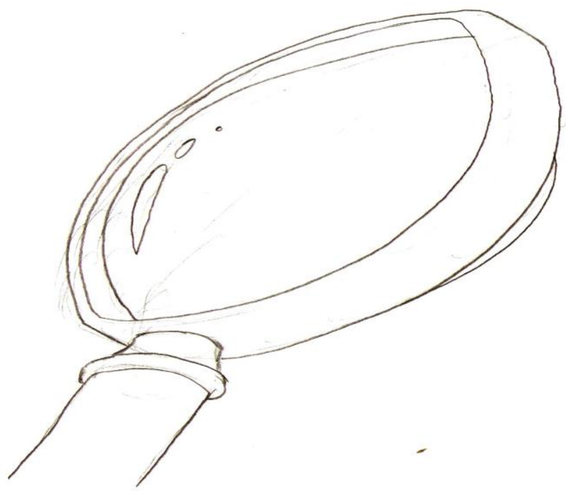

Figure B8: Magnifying glass

Overhead Light Source with Black Background

This concept uses reflected light as means to highlight the defect in the plastic. The film is placed over a black background, and a light is placed overhead. In theory, when light is reflects off the surface of the plastic film, areas with defects will scatter differently compared to areas with defects allowing for easy detection of defects. However, during testing the glare from the reflective light made it difficult to identify the defects. Figure B9 gives a visual of the overhead light source with black background.

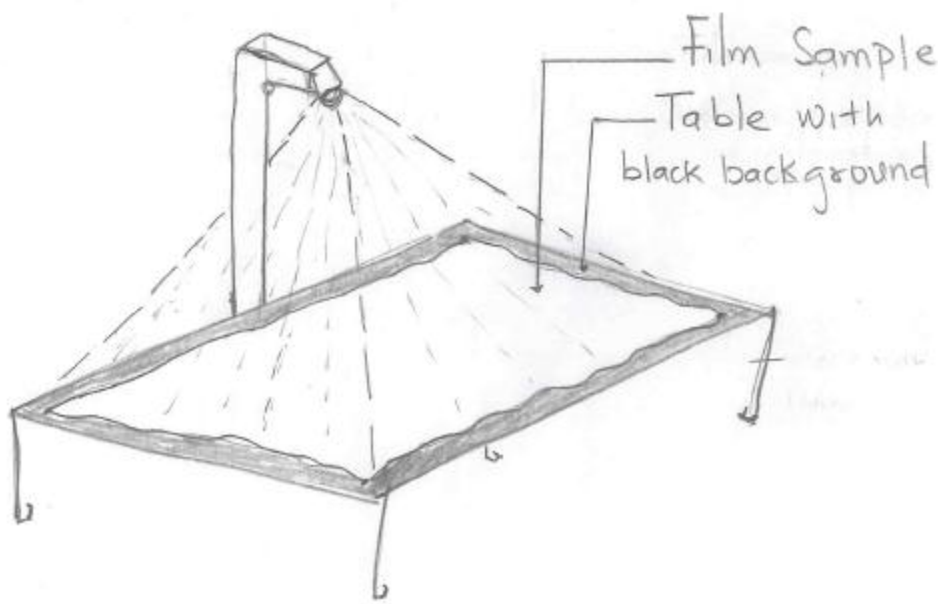

Figure B9: Overhead light with black background

Transmitted Light through Sample

The idea behind this concept is to transmit light through the edge of the film using a laser. This light would travel through the length of the film, and upon hitting a defect in the inner surface of the plastic; some of the light would scatter, causing the defect to show up to an observer. Figure B10 gives a visual of the transmitted light though sample concept.

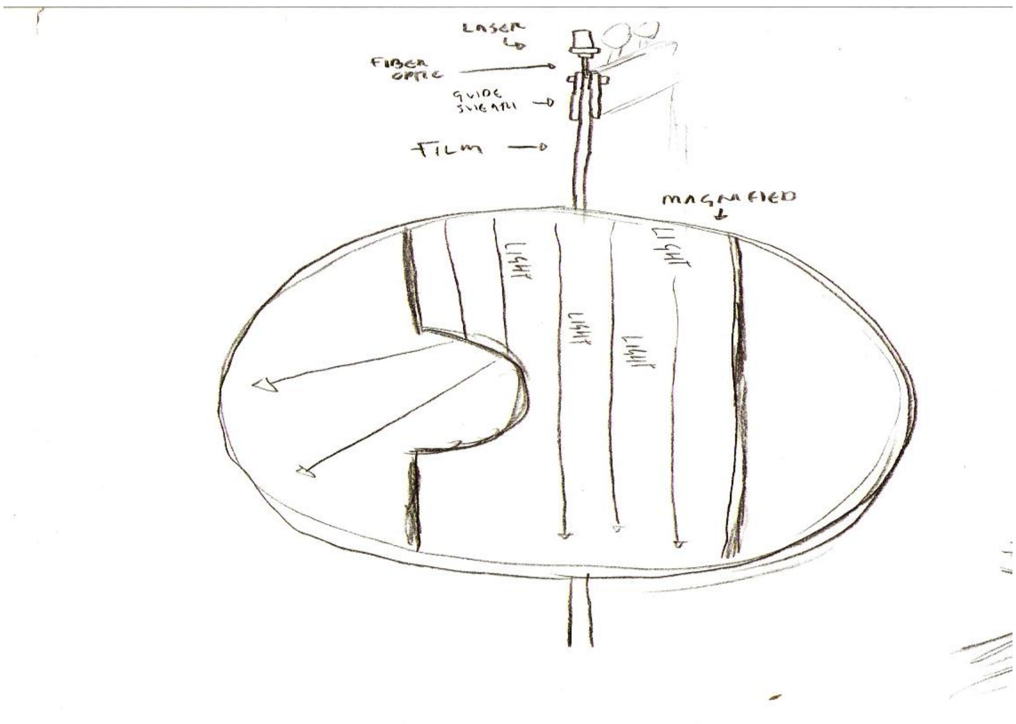

Figure B10: Transmitted light through sample

Thermo Imagery

This concept is supposed to highlight changes in the thickness of the plastic by using changes in thermal conductivity. A heating element is placed below the plastic, and an infrared camera is placed over it. Areas where the plastic is thinner would have poorer insulation, and would transmit more heat, showing up as warmer spots than the rest of the film. Figure B11 gives a visual of the thermal imagery concept at work.

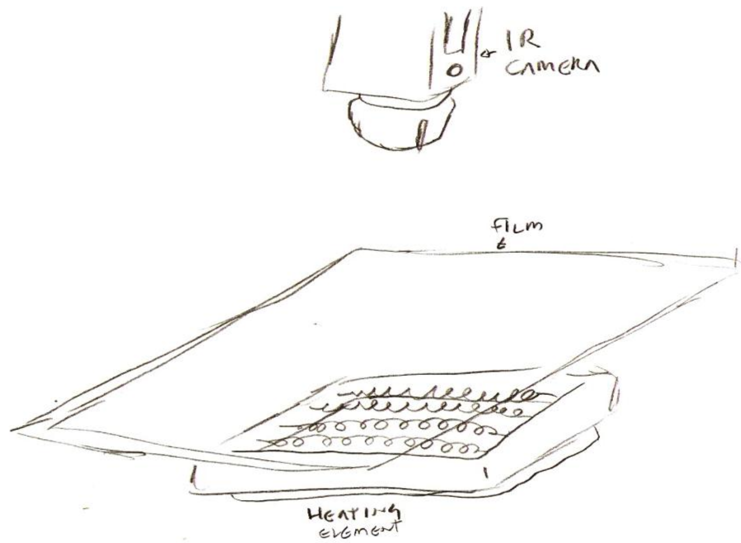

Figure B11: Thermal imagery

Different Frequencies

The idea behind this concept was that light of different frequencies might react differently to different imperfections in the plastic film. Different angles of incidence, angles of reflection, and sizes of defects could cause certain frequencies of light to be more effective than others.

However, no test was been done, as we do not have access to different light sources. Figure B12 gives a visual of the different light frequency concept.

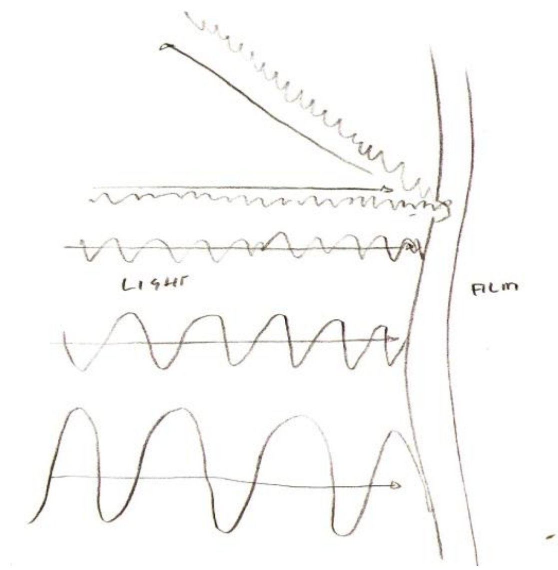

Figure B12: Different light frequency

Robotic Arm

For this idea, we decided to regulate the position of the light with a robotic arm. The plastic film is a 1m by 1.5m, so if we are using a point light source, the angle of incidence would be different for different points on the film. Additionally, if the operator moved his/her head to examine different sections of the film, the angle they would be seeing the light at would also change.

The idea of a robotic arm would be to regulate the angle and react to the head position of the operator so that the angle of lighting is always consistent. Figure B13 is represented by the visual below.

Figure B13: Robotic arm

Dentist Lamp

A dental lamp is a piece of dental equipment that is used for locating cavities, gum disease and other health problems hidden in the teeth. This concept can be used in clear plastic film for defect detection. The arm of the dentist lamp is long and adjustable, able to turn or bend as needed. The lamp also delivers over a range of wavelengths. Figure B14 gives a clear visual of the dentist lamp.

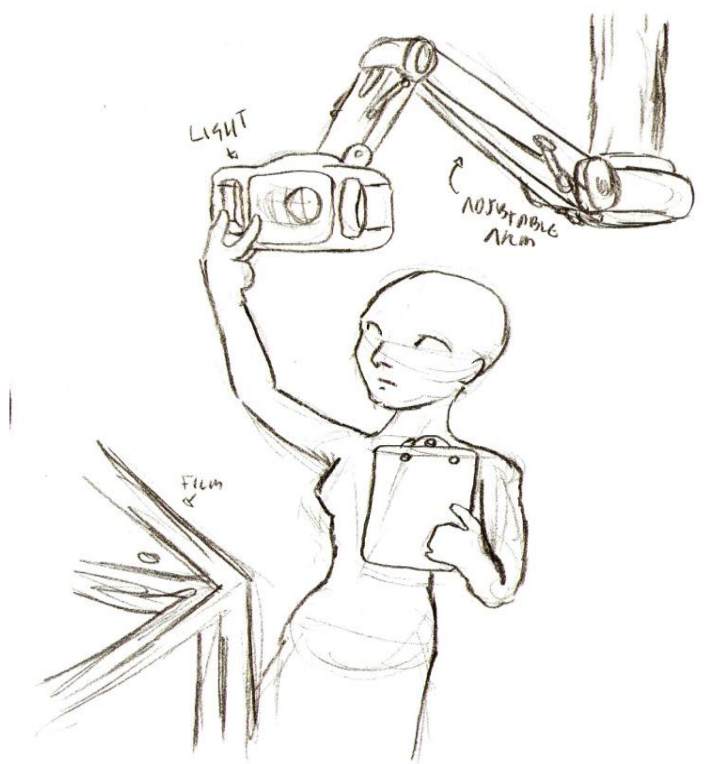

Figure B14: Dentist lamp

Suspended Sample between Projector and White Background

The operation of this device is similar to a classroom style overhead projector. A plastic film sample is hanged between the projector and white background, then using the light source from the projector to check defect on the surface of the plastic film. Figure B15 shows a visual of the suspended sample between projector and white background.

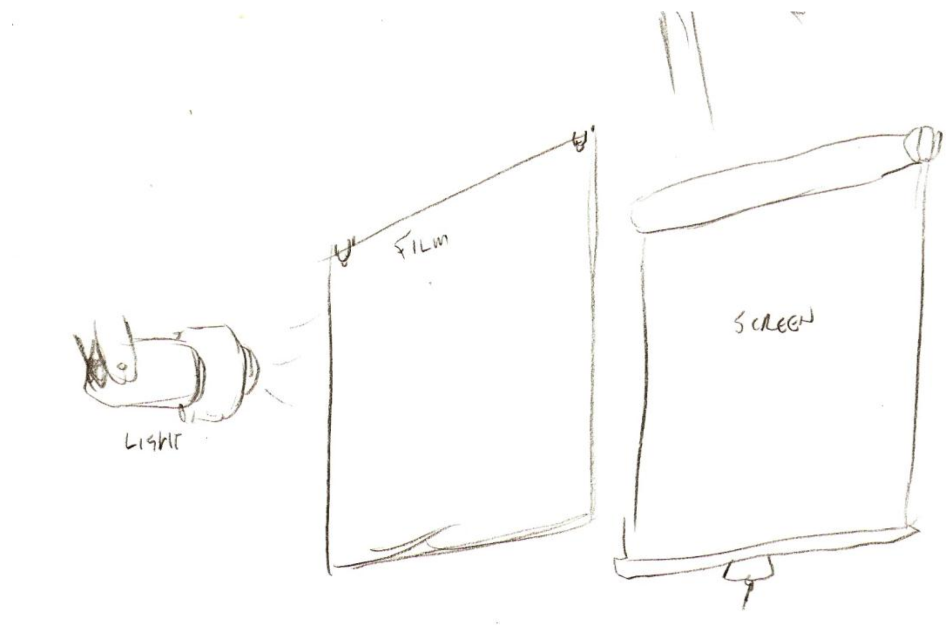

Figure B15: Suspended sample between projector and background

Classroom Style Overhead Projector

An overhead projector is used to display images to an audience. It consists of a large box containing a very bright lamp, a large Fresnel lens, a mirror and lens on a long arm. Transparencies are placed on top of the lens for displace. A plastic film sample will be placed on the transparencies, and a clear image of the sample will be showing on the screen of the projector. Figure B16 show a visual of the classroom style overhead projector.

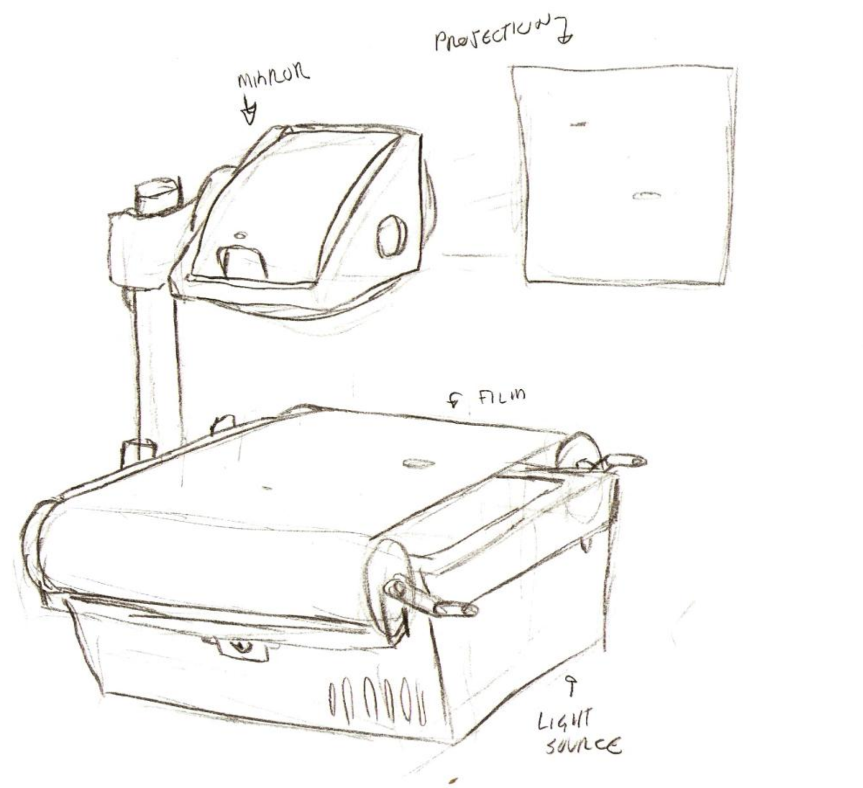

Figure B16: Overhead projector

Laser Detector

Laser detector produces infrared light, which is then manipulated by crystals to adjust its wavelength to the desired visible wavelengths. The infrared light is used to for defect detection. Figure B17 gives a clear visual of the laser detector concept.

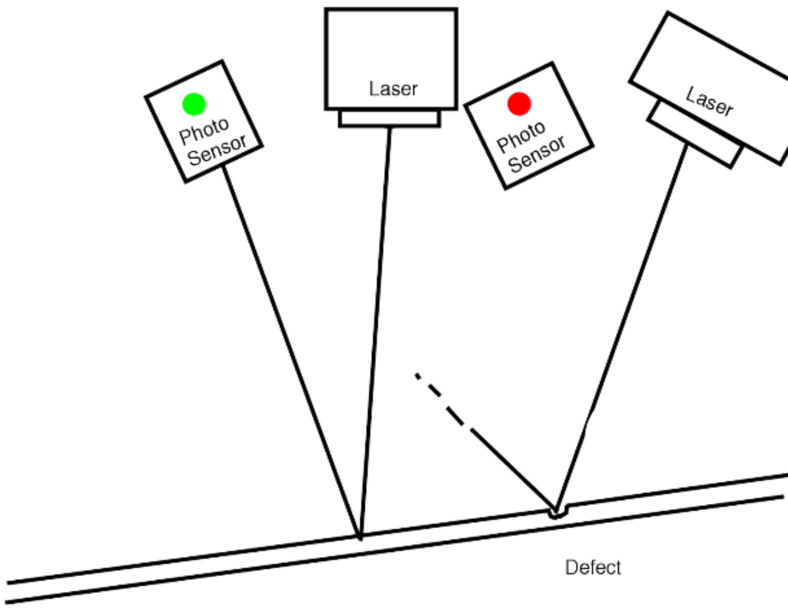

Figure B17: Laser detector

Liquid Penetrants

This method is used to spot surface defects by applying a penetrant to the surface of the item being inspected. The penetrant is allowed to settle and soak into any defects. After the penetrant dries up, excess penetrant are removed from the surface by the application of a developer. The developer draws out the penetrants from the defects onto the surface to form a visual indicator of where the defects are located. Figure B18 show the visual for the liquid penetrants application.

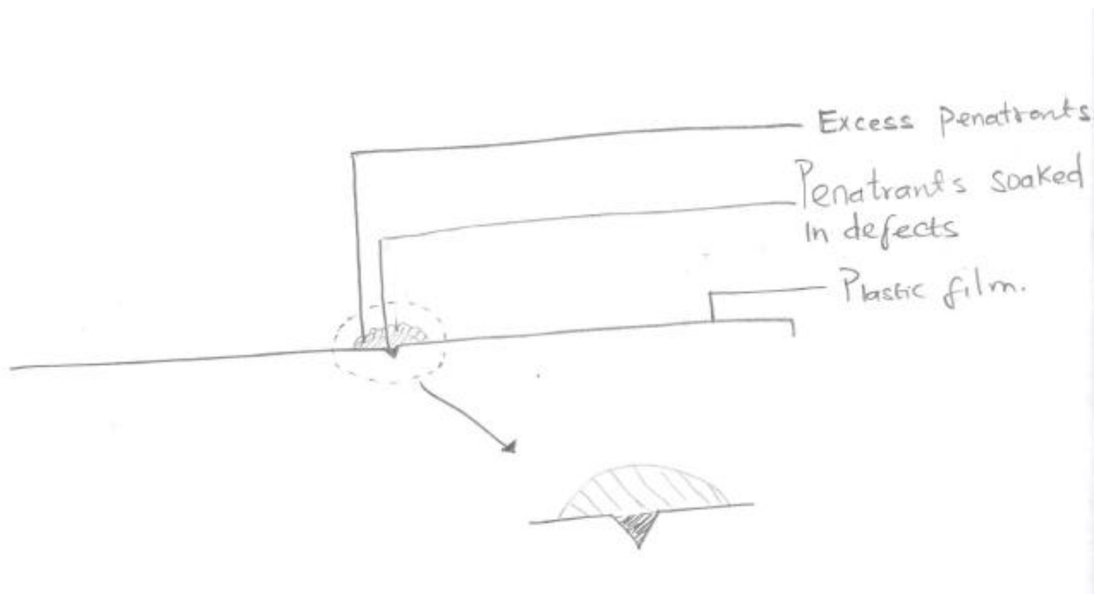

Figure B18: Application of liquid penetrant

Permeability

The role of the plastic film is to create an airtight seal around the product; if any air gets through the plastic film, it can be considered to be defective. The idea behind this concept was to develop a mechanism that detects if a test gas is passing from one side of the film to the other, since if that is the case, the film would be defective. Figure B19 gives a visual of the permeability concept

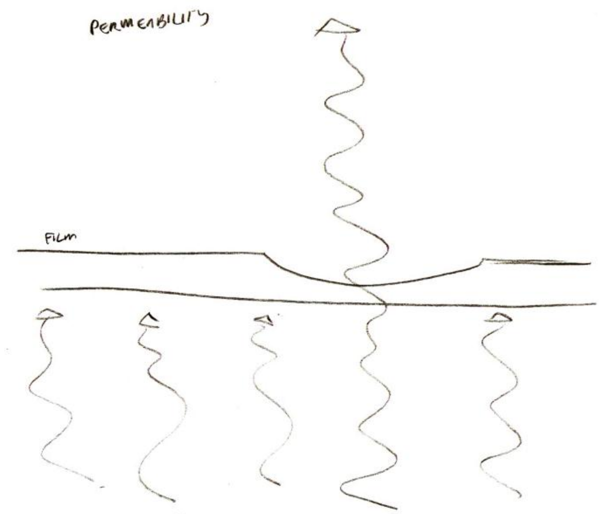

Figure B19: Permeability

APPENDIX C

Concept Analysis & Selection

From our brainstorming session, our team came up with over 36 possible ideas for identifying defects in the plastic film. The list of the brainstormed ideas is in appendix A. An initial screening of the brainstormed ideas was done in order to determine which ideas are feasible and which are not. Feasibility of the concepts ideas was based on the team's intuition and experience on whether the idea would work for the design. Out of 36 initial ideas, a total of 19 ideas were considered feasible.

A concept screening process was done on the remaining feasible ideas to determine which ideas our team should focus on. Using "*Overhead Projector against Black Background*" as the reference concept, all other feasible concepts were compared with the reference based on the criteria listed in Table C1. The description and images of the concepts can be found in Appendix B

Table C1: CONCEPT SCREENING MATRIX

Selection criteria	Handheld Scanner	Dentist Lamp	Angled Light Projector	Computer Scanner for Thickness	Sample Between Projector & White Background	Photoelasticy	Thermal Imaging	Rollers with Light	Overhead Projector	Measurement of Permeability	Different Light Frequency	Laser Scanner	Precise Light Angle Using Robotic Arms	Head Mounted Lamp	Sample Between Projector & Screen	Magnifying Glass	Flash Photography	Fiber Optic	Overhead Projector Against Black Background (REF)
Clarity of Defects	+	0	+	+	+	-	-	+	+	-	0	+	+	0	+	+	-	+	0
Accuracy	+	0	+	+	+	-	-	+	+	-	0	+	+	0	+	+	-	+	0
Space	+	-	-	-	0	-	-	+	+	-	-	-	-	+	-	+	0	+	0
Cost	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	0
Ease of Use	0	+	0	-	0	-	-	0	0	-	-	-	-	+	0	+	0	-	0
Portability	+	-	0	-	+	0	-	+	+	-	-	-	-	+	-	+	0	-	0
Plusses	4	1	2	2	3	0	0	4	4	0	0	2	2	4	2	6	0	3	0
Minuses	1	3	2	4	1	5	6	1	1	6	4	4	4	0	3	0	3	3	0
Same	1	2	2	0	2	1	0	1	1	0	2	0	0	2	1	0	3	0	6
Net	3	-2	0	-2	2	-5	-6	3	3	-6	-4	-2	-2	4	-1	6	-3	0	0

From Table C1, the brainstormed ideas with the positive net values where determined to be the following.

1. Magnifying Glass
2. Head Mounted Lamp
3. Overhead Projector
4. Rollers with Light
5. Handheld Scanner
6. Sample Between Projector & White Back Ground

After determining which concept to move on with, a weighted matrix to determine the importance of each criteria was done. The way the weighing matrix work is that we chose between two criteria and decided the importance of each criterion relative to each other. Importance of each criterion was based on our client's specification. As an example, when deciding the importance between cost and accuracy, we decided that accuracy is the more important criteria compared to cost. As a result, more weight is given to accuracy. The weights are in percentages and all add up to 100. Table C2 is a summary of the weighted matrix.

Table C2: WEIGHTED MATRIX

	A	B	C	D	E	F	
A	-	B	A	A	A	A	Clarity of Defects
B		-	B	B	B	B	Accuracy
C			-	C	C	C	Space
D				-	D	F	Cost
E					-	F	Ease of use
F						-	Portability
G							Durability
TOTAL	5	6	4	2	1	3	21
Weights (%)	23.81	28.57	19.05	9.52	4.76	14.29	

From the weighted matrix, our team agreed that "Accuracy" was the most important criteria in our design as it scored 28.57% and "Ease of Use" was the lowest weighted criteria with a score of 4.76%. A final scoring matrix for each of the chosen design was done in order to determine the best concept out of the six concepts that passed the screening process. Table C3 shows the rating and final score for each concept.

Table C3: CONCEPT SCORING

		Hand scanner		Sample btw projector		Rollers		Projector		Miners hat		Magnifying glass	
Criteria Selection	Weights	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Clarity of defects	23.81	2	47.62	2	47.62	1	23.81	3	71.43	1	23.81	1	23.81
Accuracy	28.57	2	57.14	2	57.14	2	57.14	3	85.71	1	28.57	1	28.57
Space	19.05	3	57.15	1	19.05	2	38.1	2	38.1	3	57.15	3	57.15
Cost	9.52	0	0	2	19.04	2	19.04	2	19.04	2	19.04	3	28.56
Ease of use	4.76	1	4.76	3	14.28	1	4.76	2	9.52	3	14.28	2	9.52
Portablity	14.29	2	28.58	2	28.58	2	28.58	2	28.58	3	42.87	3	42.87
Total score			195.25		185.71		171.43		252.38		185.72		190.48

The rating score is an estimate of effectiveness of a concept at fulfilling criteria, with 3 being "Exceptional", 2 being "Average", 1 being "Bad", and 0 being

“Undesirable”. For example, Hand Scanner has a rating of 0 for cost because it is probably the most expensive of all our options, but it got a 3 for space because it is small.

Finally, the rating we give each concept is multiplied by the weight of each criteria to give us a weighted score. The scores are added up to find the total weighted score for each concept. The concept with the highest weighted score is the concept with the highest ratings in the areas we thought were most important. The overhead projector was the best having a score of 259.95 out of 300. The worst scoring concept was the Magnifying Glass, which only had 173.3.

APPENDIX D

A detailed explanation of the overhead projector components are discussed in this section. Other concepts such as the lumen brightness and the focal length of the projector are also covered. The overhead projector components and concepts are as follows:

- Fans
- Lamps
- Lumen brightness
- Lens
- Mirrors
- Focal length

Fans

When the overhead projector is in operation for a long period, the lamp in the projector produces a large amount of heat. The temperature of the projector should not exceed a critical temperature of 125 degrees Fahrenheit, because temperatures any higher could melt the sample being tested. A fan is needed in order to keep the operating temperature below the critical temperature. The function of the fan is to move heated air away from the overhead projector components and bring in cooler air. It is easy to replace a damaged motor fan when considering a long-term use of an overhead projector. The cost of a new fan is about $30 [1]. A typical projector fan can be seen in Figure D1 below.

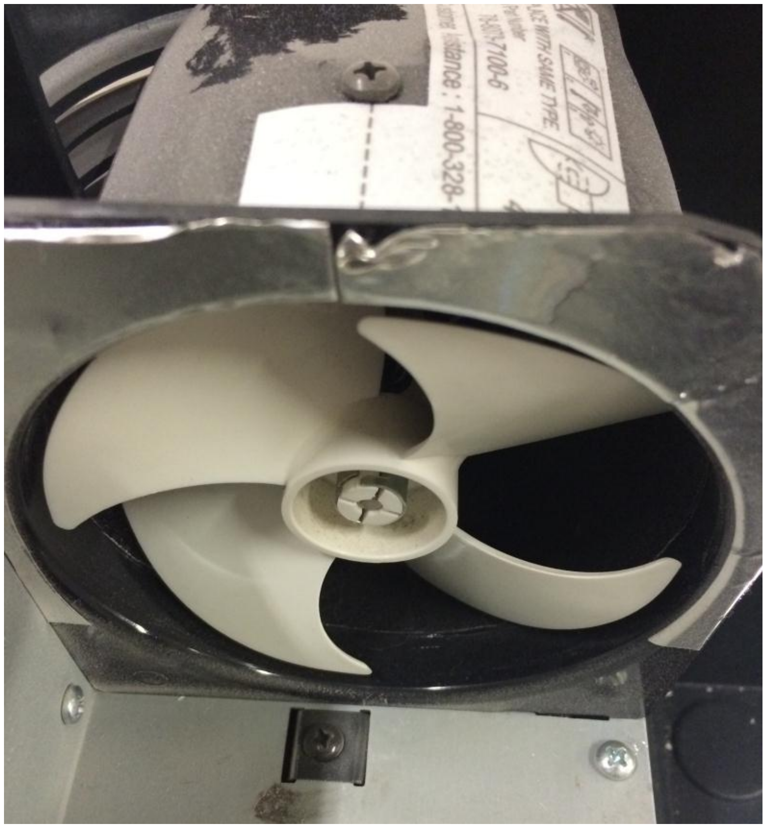

Figure D1: Typical overhead projector fan

Lamps

Light is a source of energy represented in the form of electromagnetic radiation. For the overhead projector, the light source is from a halogen lamp, as seen in Figure D2. There are various reasons halogen lamps are ideal for an overhead projector. Halogen lamps are small in size, lightweight and low in cost. Halogen lamps also have a better color temperature compared to regular incandescent lamp. The color temperature range for halogen lamps are usually within 2800-3400K [2]. The color temperature is an indication of how bright the light is, which is of major importance in our overhead projector.

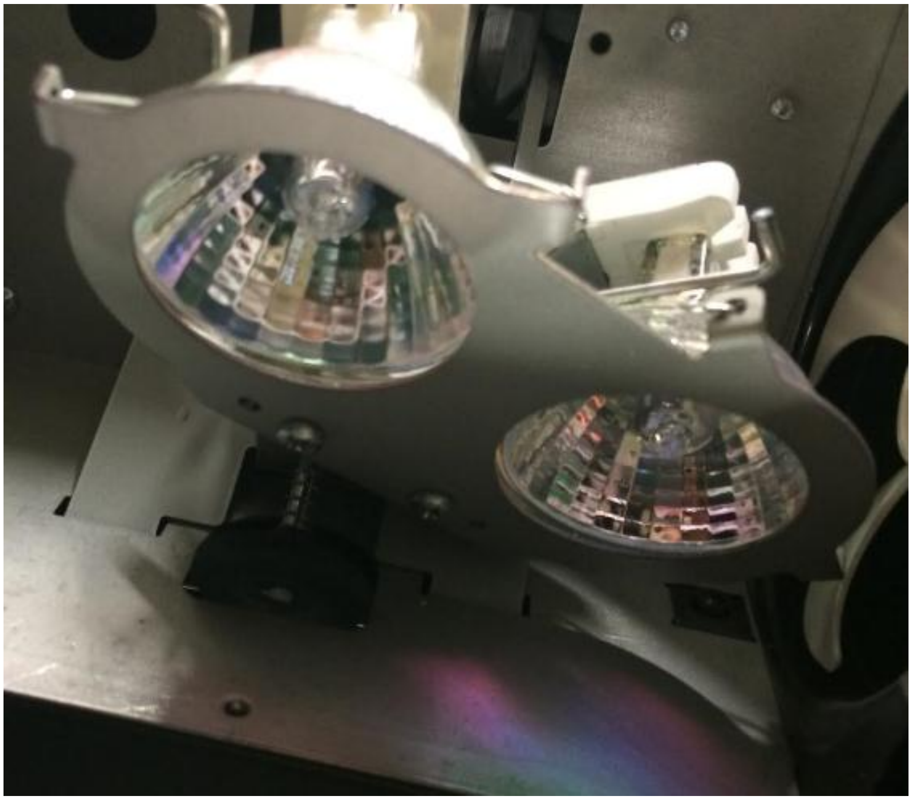

Figure D2: Projector lamp

Due to the ability of halogen lamps to perform at high temperature and for prolonged use, they are very effective in the projector. The specific lamp used in the projector under consideration is the FXL (82 volts, 410 watts). The FXL lamp is fairly inexpensive and can be obtained for a price of $35.89 [3]

Lumens Brightness

Despite the lumen brightness not being a physical component of the overhead projector, it is however a major concept that needs to be understood. The lumen brightness is a related to the light source of the projector, as it is dependent on the power of the lamp. Lumen is a unit of measurement to gauge the amount of light present in a certain area. The luminous intensity of a light source is the power of light generated. It is defined in a given direction and is measured in candela [cd]. For an overhead projector, a higher lumen output means the quality of an image will be brighter. The film sample is being inspected in a brightly lit lab room; therefore an output of 3000-4000 lumens is required [4]. The

Apollo 3400 overhead projector has an output of 4000 lumens, thus satisfying the required output. Figure D3 gives a visual of a typical lumen generation.

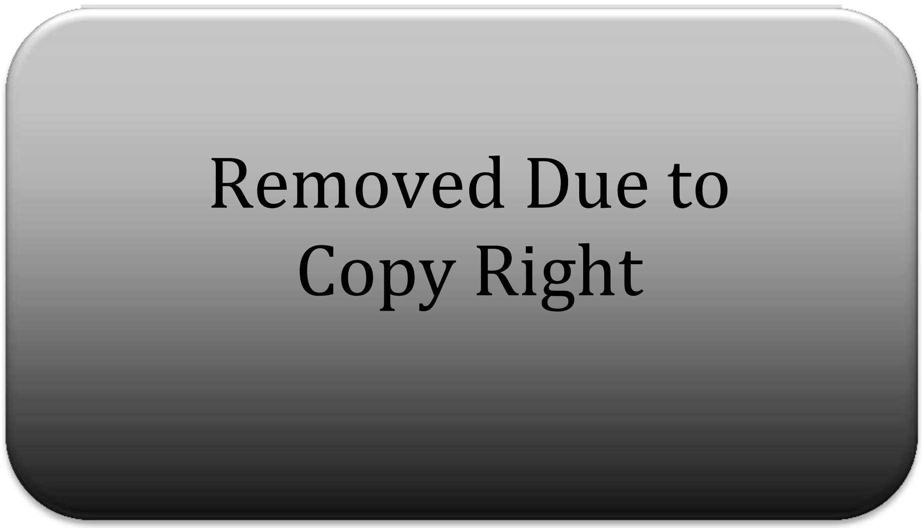

Figure D3: Generation of a lumen [5]

Lenses

A lens is an optical device use to transmit and refract light. The main purpose of the lenses in this projector is to collect and redirect light, which is accomplished by refraction. The Apollo 3400 projector, which is our recommended projector for this project has two lenses: one projector lens and one Fresnel lens. The first lens, as seen in Figure D4, is a projector lens and is fitted on to the bottom of the projector head unit and focuses the light against a reflective mirror and project an image onto a screen.

Figure D4: Projector lens

The larger Fresnel lens, in Figure D5, is about 11 ¼" by 11 ¼", and sits underneath the staging glass. It is used to align the light from the light bulb with the head unit.

Removed Due to Copy Right

Figure D5: Fresnel lens [6]

This lens is used to redirect light from the light source. When light is emitted from the lamp, it is spread out in all directions. The Fresnel lens is needed to collimate all the light in one direction and into the head unit, or else the loss of light will cause the projector to produce a blur or dim image.

Mirrors

Choosing the right kind of mirror is crucial for an overhead projector, as the quality of the projected image is dependent on the type of mirror used. The major types of mirror under consideration are standard surface mirror and optical mirror are discussed below.

Standard Surface Mirrors

Standard surface mirrors are often regarded as basic mirrors. Despite the clarity and popularity of this type of mirrors, they can’t be used for projection purposes. This is due to fact that the mirror will generate reflection and create ghost images. The figure below gives a clear visual of a standard mirror and the creation of ghost images.

Figure D6: Standard surface mirror [7]

As a result of this ghost image, the standard surface mirror would not be a viable option to obtain the highest level of clarity needed in a projector. This leads us to the second type of mirror, which is known as the first grade optical mirror or first surface mirror.

First Surface Mirrors

First surface mirrors are mirrors that tend to have reflective coating applied to the front of the mirror (the side nearest to the viewer), this makes it ideal for projecting a clear and sharp image [8]. The following figure shows a clear visual of a first surface mirror.

Figure D7: First surface mirror [7]

Figure D7 shows the reflection of singular image without the ghosting effect, this is the result of the reflective coating on top of the glass base in the mirror. First surface mirror are made for applications that requires strict reflection criteria (no ghosting effect), such as the overhead projector.

Focal Length

The focus and the screen alignment of an overhead projector can be adjusted in order to obtain a better picture clarity. The focus can be adjusted by using the focusing knob of the overhead projector. The focusing knob is attached to the projector's arm, and is used to movie the head unit towards or away from the Fresnel lens. The higher the head unit, the further the projector needs to be away from a screen. If an image have either blue or brown fringe around the outside edge, this is the result of the mirror being too far or too close to the Fresnel lens.

APPENDIX E

Installation Manual

This section focuses on how the sliding mechanism is attached to the Apollo 3400 overhead projector. The Apollo 3400 overhead projector is already assembled separately, so the installation procedure will not be included in this section. The components of the sliding mechanism are listed in the figure below.

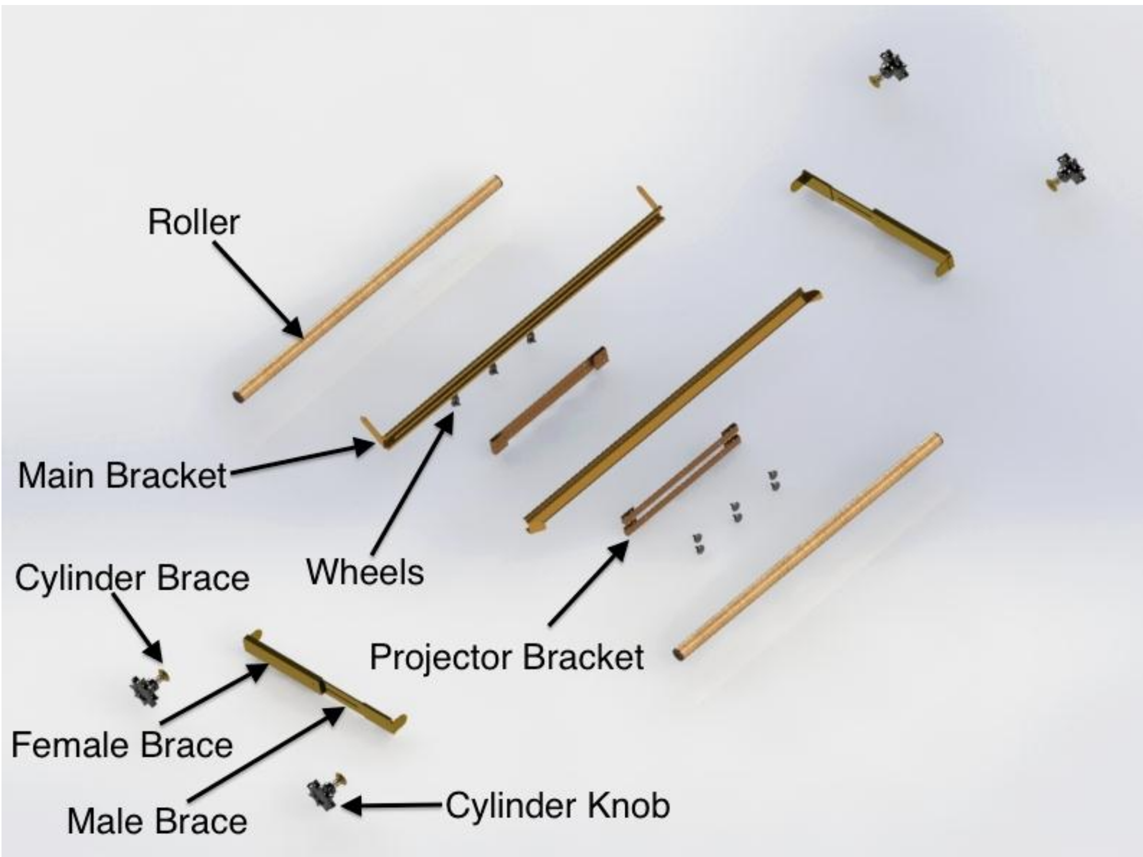

Figure E1: Exploded view of sliding mechanism

Table E1 summarized the components of the final design.

Table E1: LIST OF PARTS FOR INSALLATION PROCEDURE

Item	Description	Quantity
1	Apollo 3400 Overhead Projector	1
2	Roller	2
3	Wheels	12
4	Overhead Projector Stand	1
5	Main Bracket	2
6	Projector Bracket	4
7	Male Brace	2
8	Female Brace	2
9	Cylinder Cap	4
10	Cylinder Brace	4
11	Cylinder Spring	4
12	Nuts	30
13	Bolts ¼ in.	18

Installation Tools

1. Measuring tape
2. Screw driver [Manual and Powered].
3. Pencil.
4. M5 Allen wrench

Installation Procedures

Step 1

Attach the wheels onto the projector bracket. The wheels have built-in bolts, they are inserted in the holes in the projector bracket and fastened with nuts at the back. Figure E3 gives a visual of what a successful assembly of the wheel to the projector bracket looks like.

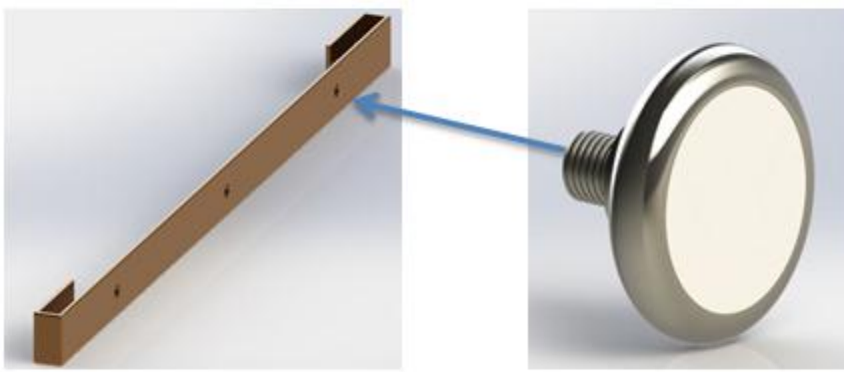

Figure E2: Connection of wheels to projector bracket

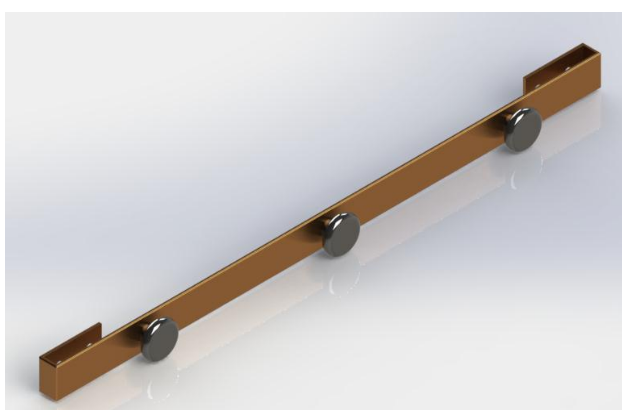

Figure E3: Projector bracket and wheels

Step 2

Attach the projector bracket to the base body of the projector. Figure E4 below shows the complete projector bracket with wheels attached to the projector.

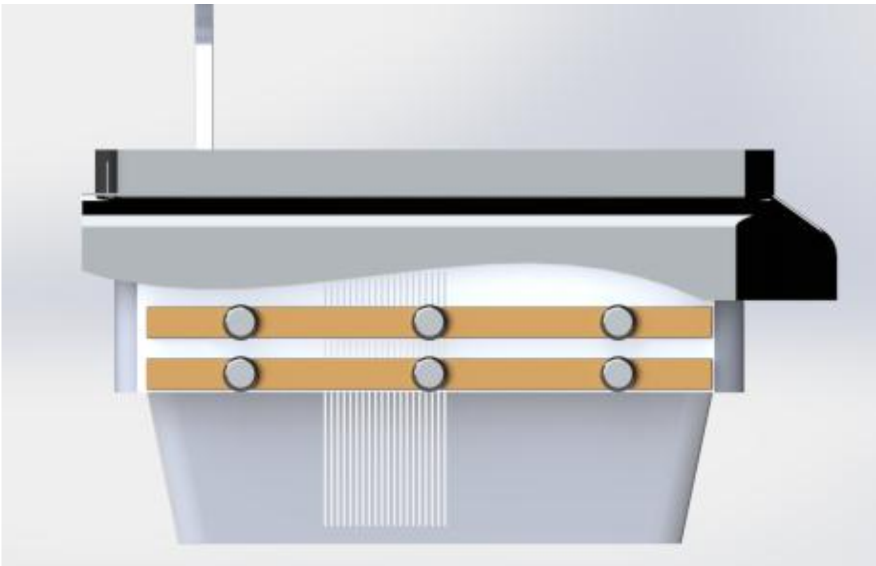

Figure E4: Attached projector bracket to projector base

Step 3

Attach the cylinder brace onto main bracket. This is done by slipping the cylinder brace through the hole in the shoulder of the main bracket. Then tighten the cylinder brace onto the knob.

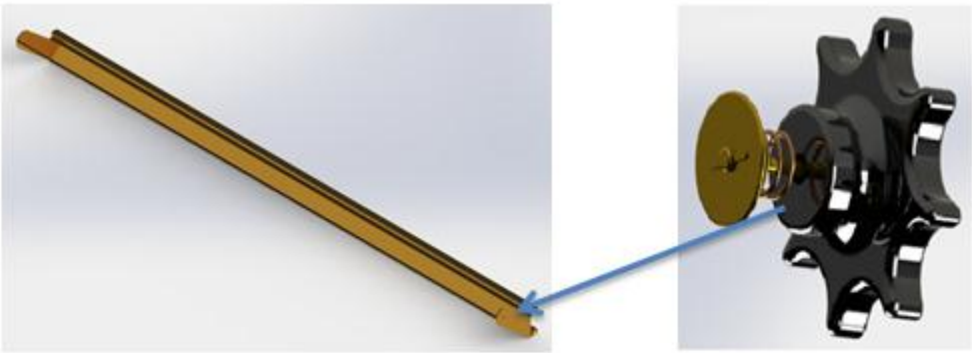

Figure E5: Attachment of cylinder brace on main bracket

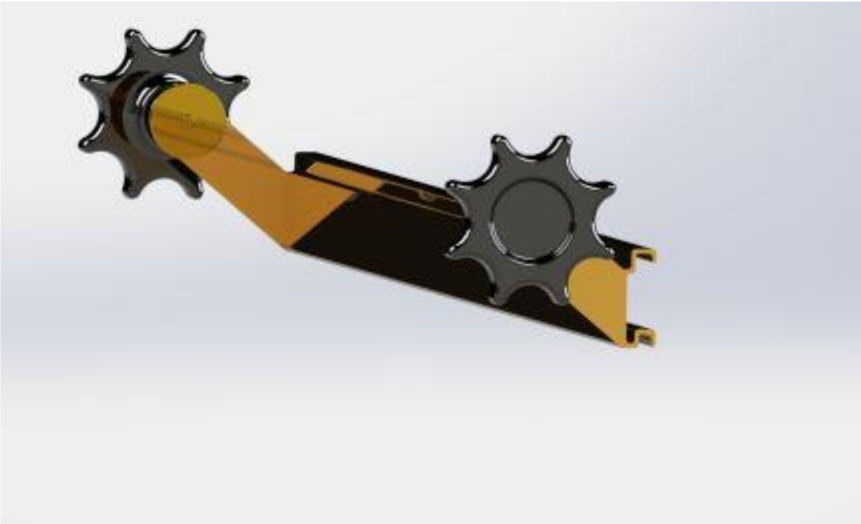

Figure E6: Final image of attached cylinder brace to main bracket

Step 4

Attach the rollers onto the main bracket. In order to do this, the cylinder caps must be attached to each end of the rollers. The cylinder caps are pushed in gently to fit in the rollers. The image below shows the cylinder cup being attached to each end of the roller

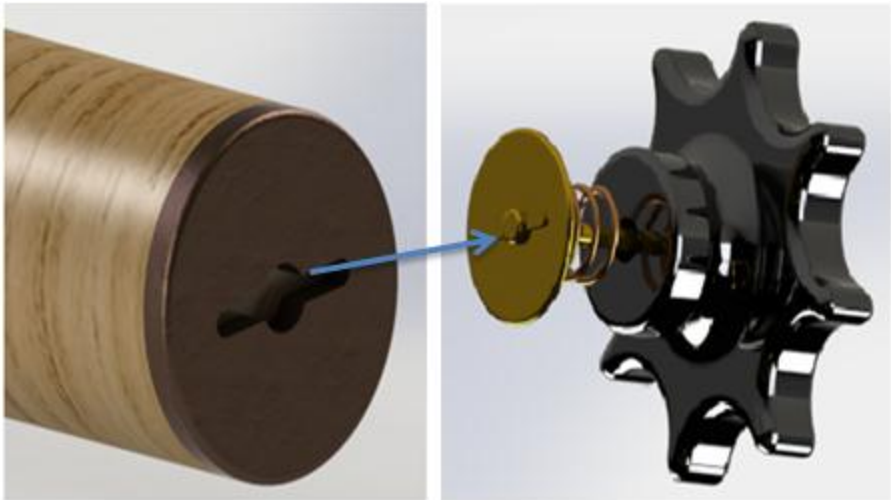

Figure E7: Attachment of roller end to cylinder cup on main bracket

Once the cylinder caps are attached the roller, the roller is then attached to the main bracket by fitting it onto the cylinder brace.

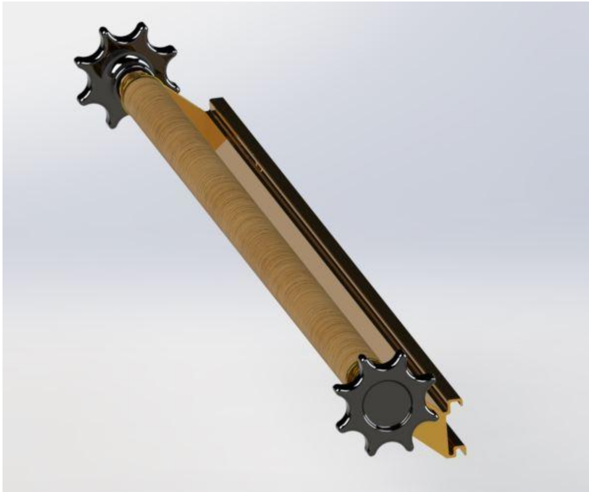

Figure E8: Final image of rollers on main bracket

Step 5

Attach main bracket to the projector bracket. The main bracket is placed on the projector, by sliding it on the wheels. The image below shows what the assembly should like if done correctly.

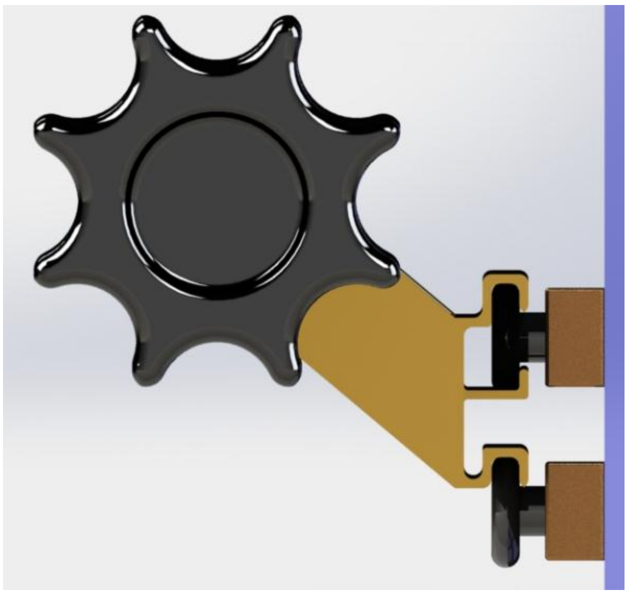

Figure E9: Placement of main bracket on projector bracket

Step 6

Attach the male and female brace together. A bolt is used to hold the female and male brace together to keep them from slipping out. Attach the male and female brace onto the respective ends of the main bracket. The male and female brace are friction fitted in the ends of the main bracket.

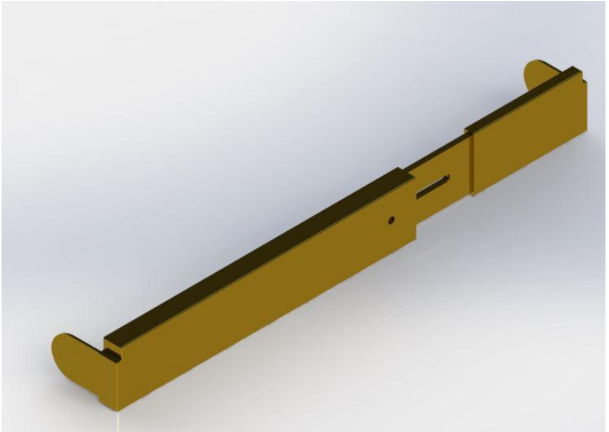

Figure E10: Attachment of male and female brace

After the whole installation is finished the complete design mechanism should look like this.

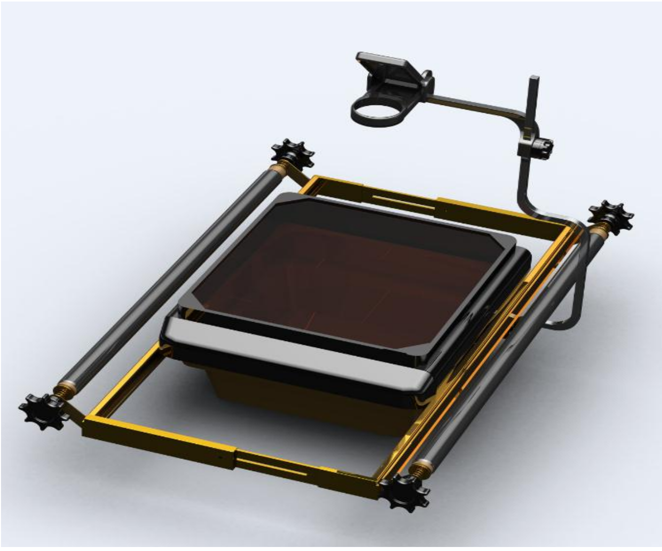

Figure E11: Final assembly

APPENDIX F

2-D drawings of sliding mechanism’s components

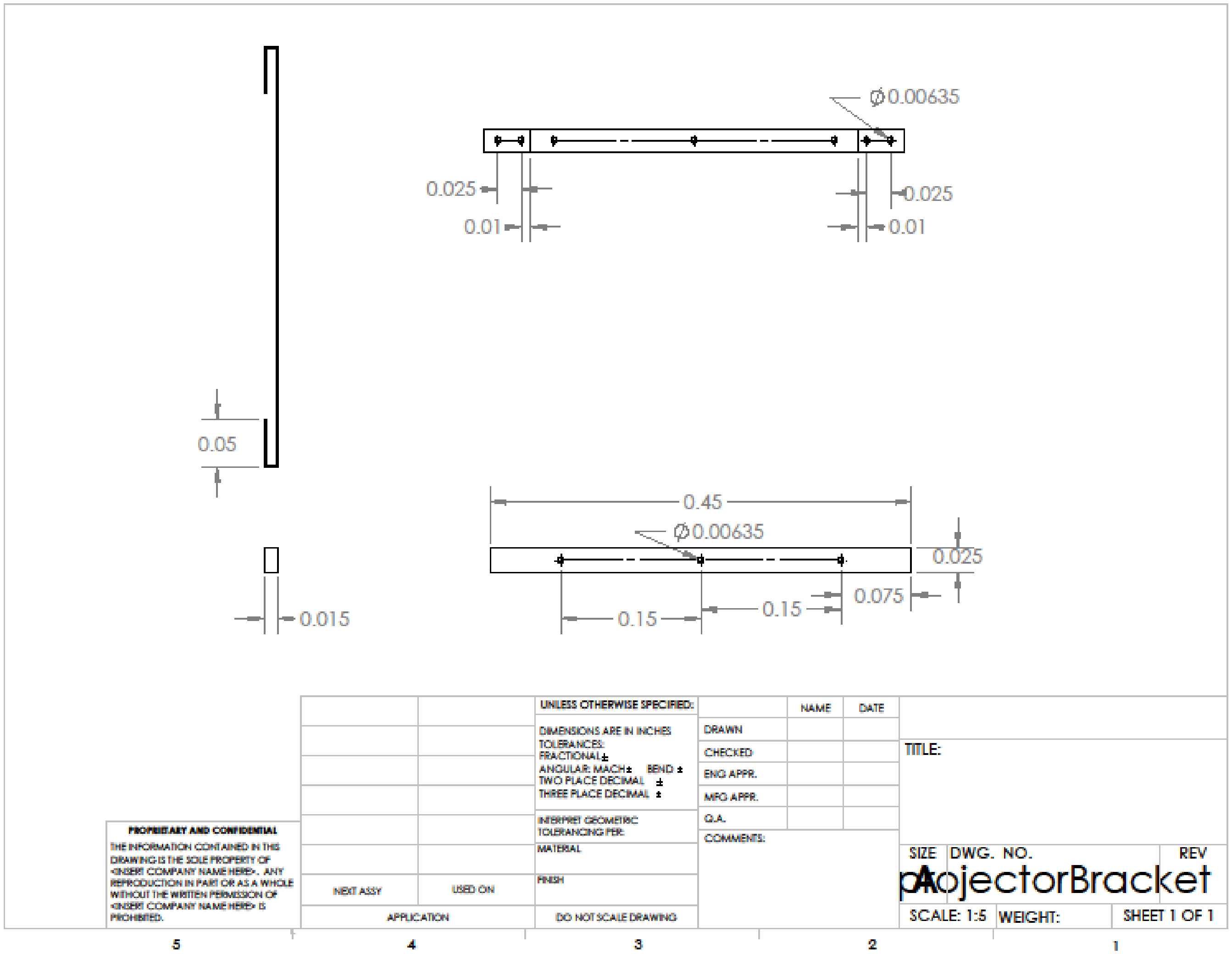

Figure F1: Projector bracket

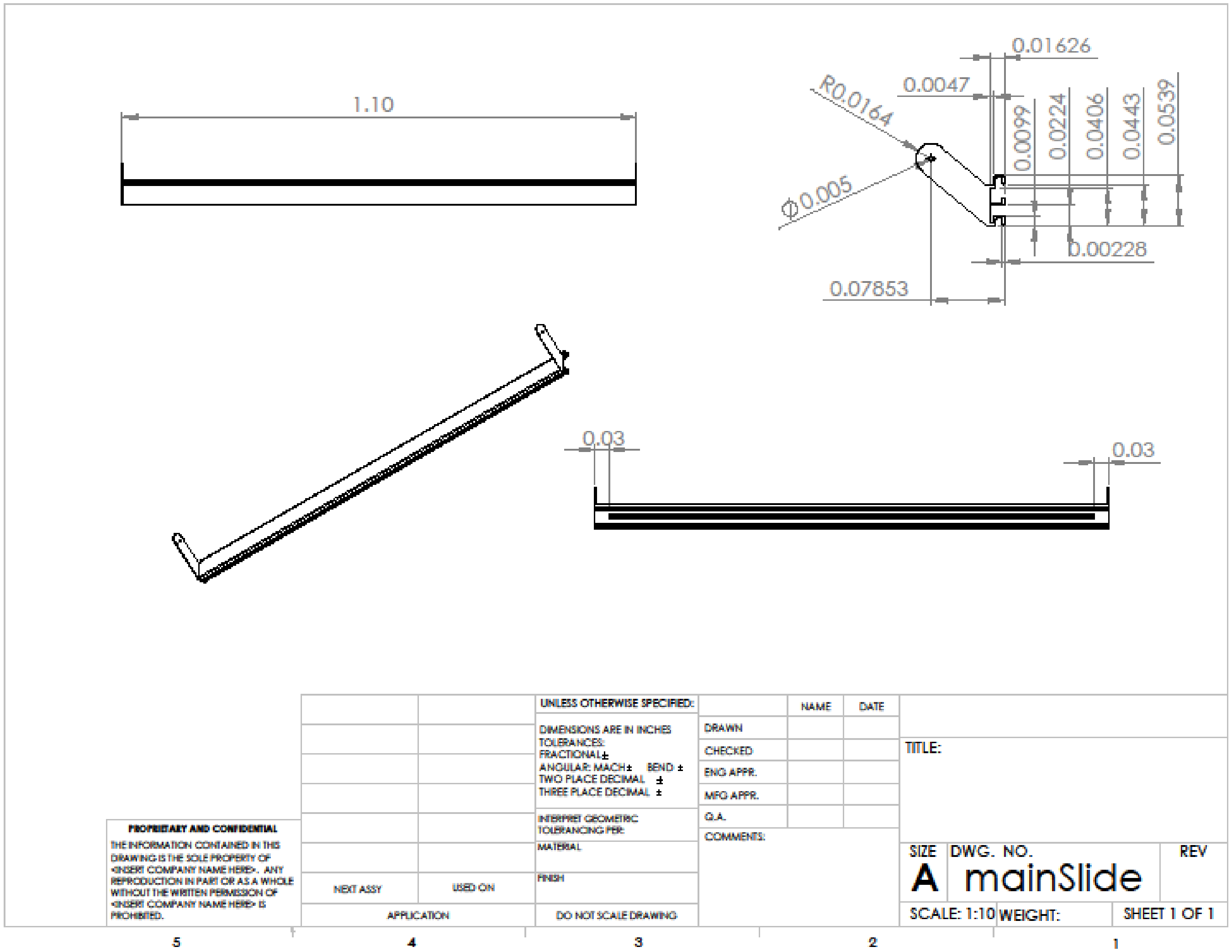

Figure F2: Main Bracket

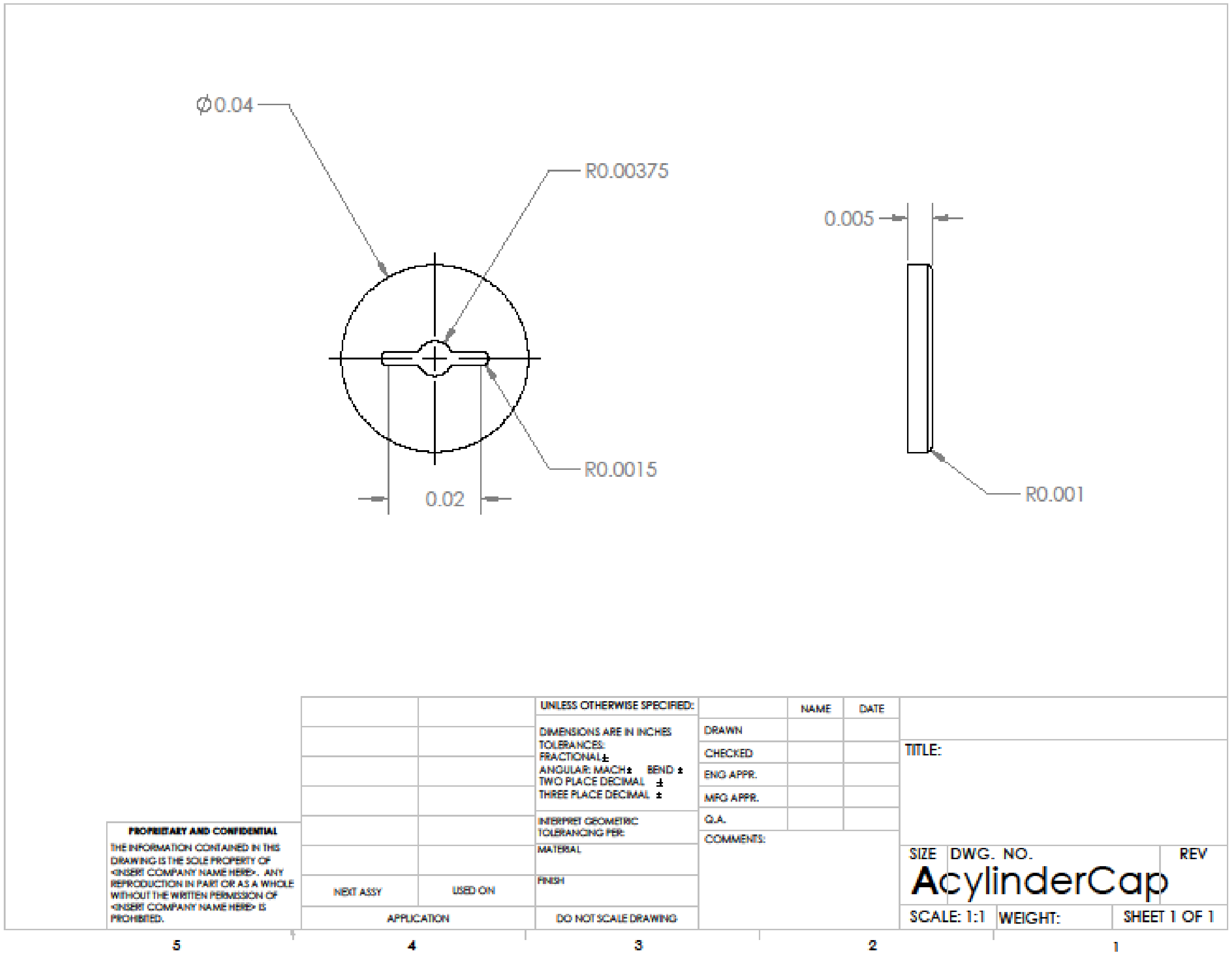

Figure F3: Cylinder cap

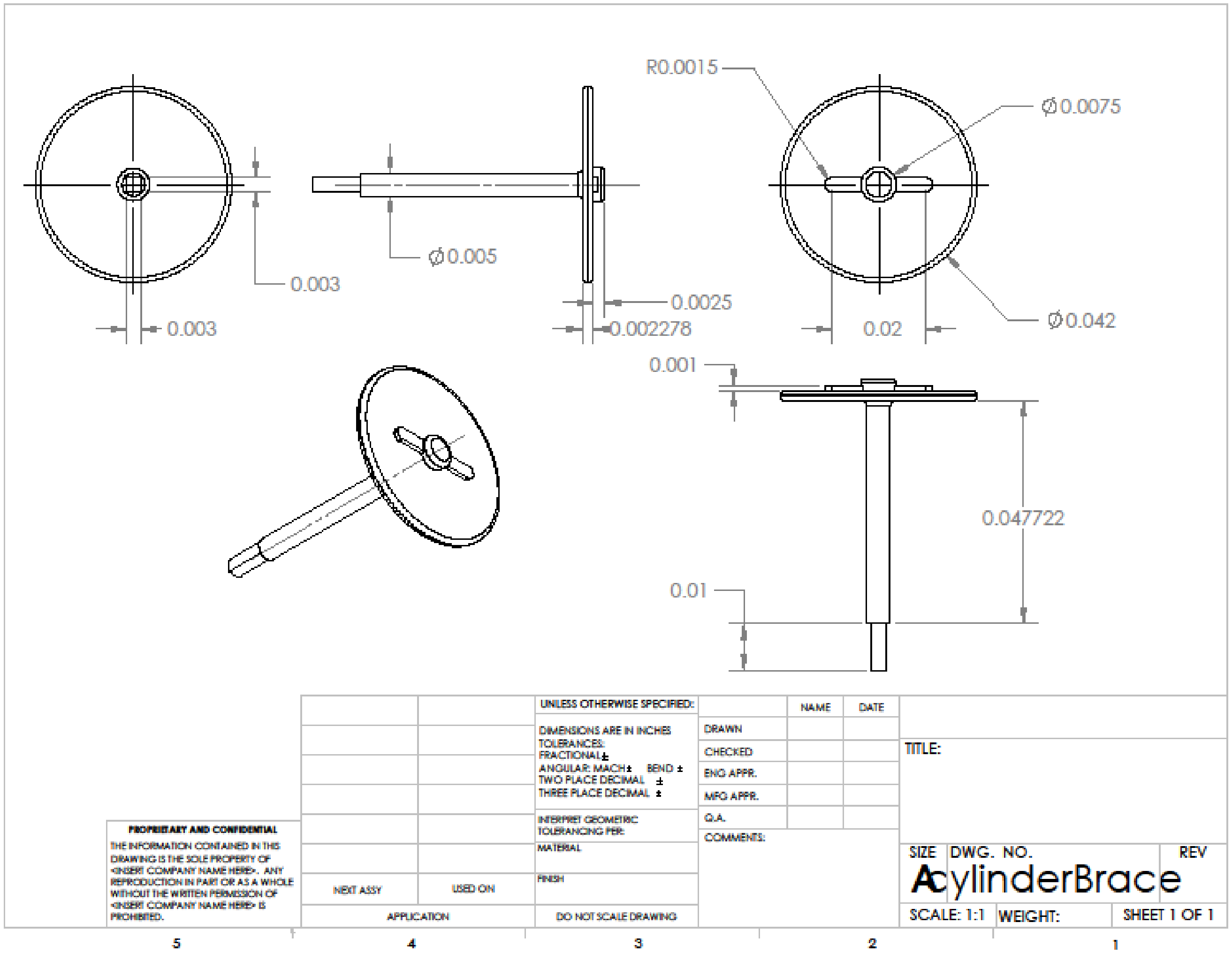

Figure F4: Cylinder brace

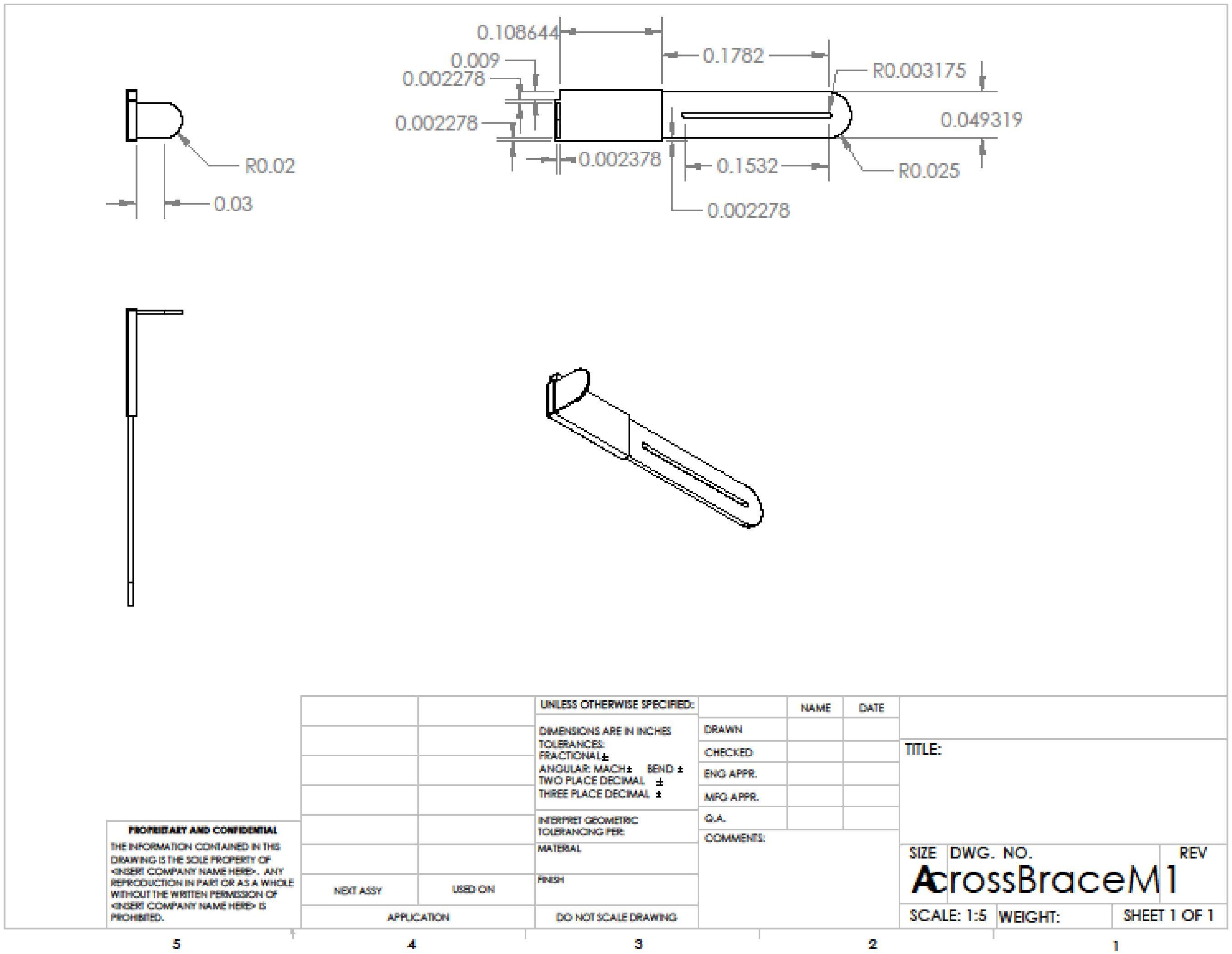

Figure F5: Male brace

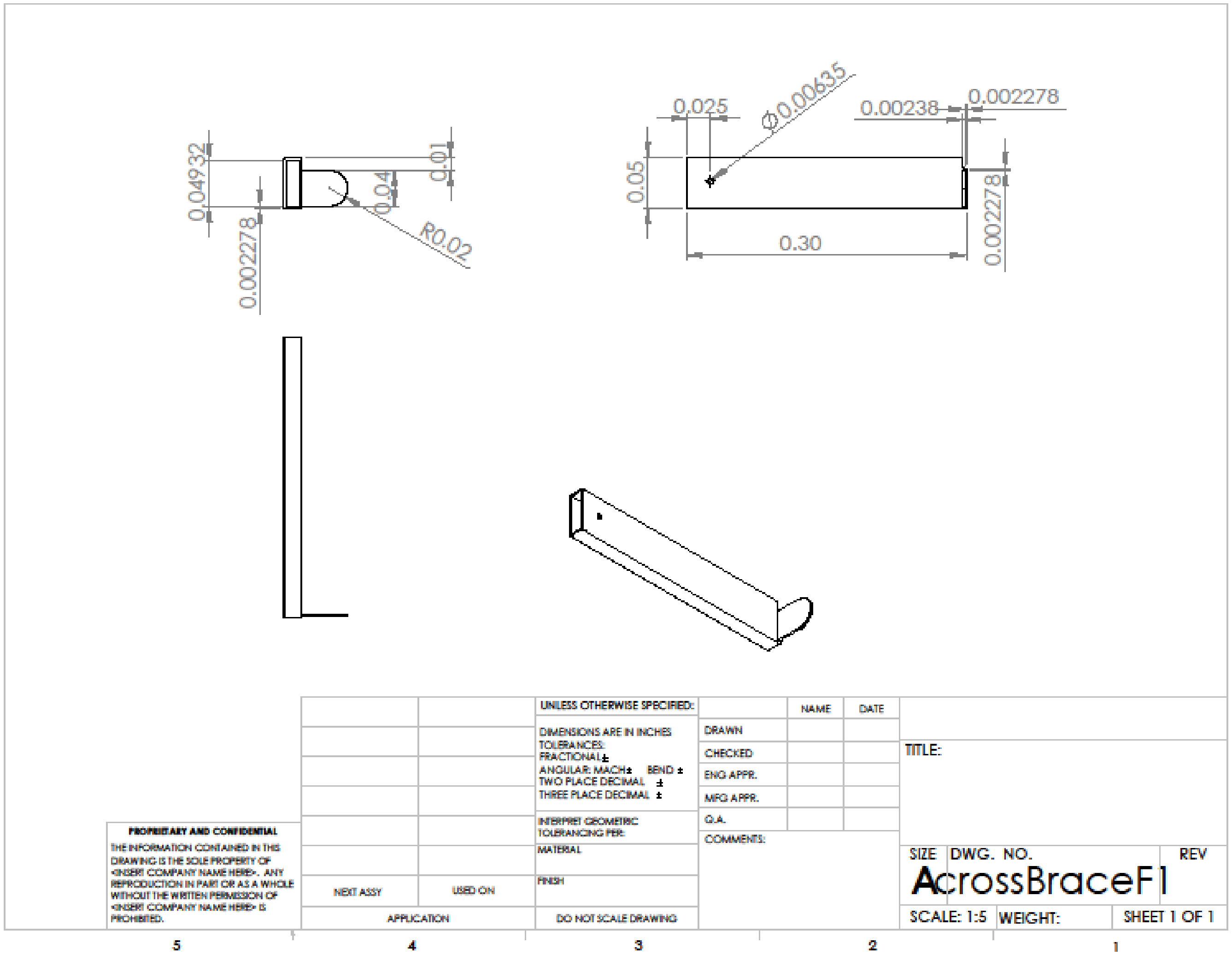

Figure F6: Female brace

APPENDIX REFERENCES

[1] Ebay. (2013, Nov.). *3M Overhead Projector Replacement Motor Fan* [Online]. Available: http://www.ebay.com/itm/3M-overhead-projector-replacement-Motor-FAN-78-8120-2914-4-for-1700-1800-/400317090441 [November 12, 2013].

[2] Robinson Lighting & Bath Centre. (2013, Nov.). *How Does A Halogen Bulb Work?* [Online]. Available: http://www.rlrbc.com/lighting_tips_and_resources.php?tip=6 [November 21, 2013].

[3] SHOP.CA. (2013, Nov.). *Apollo Replacement Lamp – 410 W Projector Lamp - FXL* [Online]. Available: http://www.shop.ca/c/acco-brands-corporation-apollo-replacemant-lamp---410-w-projector-lamp---fxl-22489225?gclid=CIS0wLWN5boCFWJBQgodeEUAIw [November 12, 2013].

[4] DNP. (2013, Nov.). *Luminous Intensity* [Online]. Available: http://www.dnp-screens.com/DNP08/Technology/Basic-Visual/What-is-light/Luminous-intensity.aspx [November 12, 2013].

[5] DNP. (2013, Nov.). *Luminous Flux* [Online]. Available: http://www.dnp-screens.com/DNP08/Technology/Basic-Visual/What-is-light/Luminous-flux.aspx [November 12, 2013].

[6] Te Ara - Encyclopedia of New Zealand. (2013, Jul. 09). *Fresnel Lens* [Online]. Available: http://www.teara.govt.nz/en/diagram/6675/fresnel-lens [November 12, 2013].

[7] DNP. (2013, Nov.). *What are optical mirrors?* [Online]. Available: http://www.dnp-screens.com/DNP08/Technology/Basic-Visual/Optical-mirrors.aspx [November 12, 2013].

[8] DuraVision. (2013, Nov.). *First Surface Mirrors* [Online]. Available: http://www.duravision.net/mirror-range/first-surface-mirrors [November 12, 2013].