Final Design Report

Design of a Coin Roll Check Weighing System

December 5, 2011

Project Sponsor: The Royal Canadian Mint

Project Advisor: Dr. David Kuhn

Team Number: 10 (Team X)

Team Members:

Kevin Harder ______________________ ______________ Date

Christopher Jack ______________________ ______________ Date

Shadi Radwan ______________________ ______________ Date

Gelleen Sicat ______________________ ______________ Date

December 5, 2011

Randy Froese
Process Technologist
Royal Canadian Mint Engineering
520 Lagimodière Blvd.
Winnipeg, MB
R2J 3E7

Dear Mr. Froese:

Please find enclosed a copy of our report entitled "Design of a Coin Roll Check Weighing System" which Team 10 is submitting for the requirement of the course MECH 4860. Team 10 consists of Chris Jack, Gelleen Sicat, Kevin Harder, and Shadi Radwan.

In addressing the safety issues in previous check weighing designs at the Royal Canadian Mint, our team developed a safe and efficient system that completes the required tasks outlined. To solve and address those requirements, our team specified commercially available components and prototype designs for different aspects of the check weighing system. To begin the check weighing process, our team developed a prototype slide device to re-orient the coin rolls. Following this device, the rolls fall onto a prototype buffer drop mechanism, which outputs the rolls onto a main conveyor at the control of photoelectric sensors. Low-profile conveyors move the rolls up to a check weighing machine that weighs, records, and rejected faulty rolls. Following the check weighing system, the rolls are aligned once again using guide rails on another low-profile conveyor. Finally, the rolls are dropped onto a tiling machine conveyor using a prototype roll transfer mechanism.

Final analysis of our design showed that the cost of our system was $62.441.86, or $137,558.14 less than the budget given. Other constraints such as floor space, power, and output height were addressed and meet with our design.

With the completion of this report, we believe we have conducted due diligence within the time constraints given for the design of the coin roll check weighing system. If this project has created any questions or concerns, please contact any of the group members by the e-mails provided: Chris Jack – umjackc@cc.umanitoba.ca, Gellen Sicat – umsicat@cc.umanitoba.ca, Kevin Harder – umhard35@cc.umanitoba.ca, and Shadi Radwan – umradwas@cc.umanitoba.ca

Sincerely,

Kevin Harder

Chris Jack

Shadi Radwan

Gelleen Sicat

December 5, 2011

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

Dear Dr. Labossiere,

Please find enclosed a copy of our report entitled "Design of a Coin Roll Check Weighing System" which Team 10 is submitting for the requirement of the course MECH 4860. Team 10 consists of Chris Jack, Gelleen Sicat, Kevin Harder, and Shadi Radwan.

In addressing the safety issues in previous check weighing designs at the Royal Canadian Mint, our team developed a safe and efficient system that completes the required tasks outlines by our client. In addition to the safety issues, this design was also required due to a new coin production contract which required the coin rolls to be check weighed.

To solve and address the requirements outlined by our client, our team specified commercially available components and prototype designs for different aspects of the check weighing system. To begin the check weighing process, our team developed a prototype slide device to re-orient the coin rolls. Following this device, the rolls fall onto a prototype buffer drop mechanism, which outputs the rolls onto a main conveyor at the control of photoelectric sensors. Low-profile conveyors move the rolls up to a check weighing machine that weighs, records, and rejected faulty rolls. Following the check weighing system, the rolls are aligned once again using guide rails on another low-profile conveyor. Finally, the rolls are dropped onto a tiling machine conveyor using a prototype roll transfer mechanism.

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Sincerely,

Kevin Harder

Chris Jack

Shadi Radwan

Gelleen Sicat

Executive Summary

The purpose of this report is to detail the design and analysis of a coin roll check weighing system for the Royal Canadian Mint. The intent of this system is to check the number of coins per wrapped roll, reject if needed, and output onto the tiling machine conveyor. This system is required due to newly contracted coin production that requires coin rolls to check weighed. For our design, we choose to solve this problem, using off-the-shelf components and prototyped models.

To begin the check weighing system design, we recommended using the original attachments on the current four wrapping machines. After this attachment, our team prototyped a roll re-orientation slide and buffer mechanism. The re-orientation slide rotates the rolls 90° and outputs them onto the buffer attachments. Once the roll is queued on the buffer attachment a buffer drop mechanism is used to output a single when signalled by a photoelectric sensor along the main conveyor. These sensors detect openings along the belt between the four wrappers for coin rolls to be dropped. We recommend using the E3H2 Miniature photoelectric sensors from Omron to complete this task.

After the roll is dropped, it will begin moving towards the check weighing station. To complete this motion, two narrow flat belt conveyors from Mini Mover Conveyors were selected. These conveyors consist of a horizontal main conveyor under the buffer mechanism and an inclined conveyor to carry the roll up to the check weighing station. To ensure the rolls maintain the correct orientation during transport, adjustable side rail guides from Mini Mover Conveyors were selected. In order to optimize the use of the conveyors with different sized rolls, each conveyor section was fitted with a variable speed drive motor, also from Mini Mover Conveyors.

In order check weigh each coin roll after wrapping, an Ishida DASC-G-S015-12-SS check weigher was selected. This check weigher is able to process up to 400 items per minute with accuracy of 0.1 grams. These specifications, along with others, are more than adequate for the Mint requirements. Not only does this system include check weighing but also user defined software and a rejection system. Since these components are all integrated into a single station, the check weighing machine is capable of recording weighing data and outputting in RS232 format. The rejection system is also capable of not only rejecting faulty rolls, but also alerting the operator and stopping the process after 10 consecutive rolls have been rejected.

Following the check weighing the station, the coin rolls travel onto a final alignment conveyor, where similar used on the main and inclined conveyor, that re-aligns the coin rolls for the roll transfer attachment. This conveyor, guides, and motor were obtained from Mini Mover Conveyors as well.

Finally, after the rolls have been re-aligned, they are dropped onto the tiling conveyor using a prototype roll transfer attachment. This attachment is designed to be adjusted for different roll diameters and lengths to ensure the correct roll orientation onto the tiling conveyor.

Lastly, a cost analysis was performed for procuring the commercially available components and manufacturing the prototype components. The total cost of the system came out to be $62.441.86. It should be noted that this cost does not included prototype development and set-up costs. This constraint, along with the floor space size, output height, and power methods were all met with our system. The total floor space size for our designed check weighing system was 5.46 feet long by 2.2 feet wide and the output height to the tiling conveyor is 34.75 inches from the roll transfer attachment.

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Glossary of Terms

Buffer ramp – area for coin rolls to accumulate while waiting for open slots in the main conveyor

Buffer rotor – mechanism used to output a single roll onto the main conveyor

Check weighing machine – an in-motion conveyor machine that checks the weight of packaged commodities

Diffuse reflective photoelectric sensor – light beam sensor that detects its own beam's reflection off of nearby surfaces

Faulty rolls – coin rolls that contain an incorrect number of coins

Flat Belt conveyor – consists of two or more pulleys with a continuous loop of material - the conveyor belt - that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward.

"Good" rolls – coin rolls that contain the correct number of coins

Re-orientation slide – mechanism used to re-orient coin rolls by 90°

Roll transfer mechanism – mechanism that is used to transfer coin roll 90° onto a conveyor travelling in a perpendicular direction

Roll wrappers – machine that wraps completed coins into paper rolls

Tiling machine – packaging machine that shrink wraps coin rolls into packages of 5 rolls

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1. Introduction: Problem Description

The objective of this report is to provide a detailed design of a coin roll check weighing system for the Royal Canadian Mint. The final design began by re-evaluating and discussing with the client the design needs and specifications after the concept design process. See Appendix A for the complete conceptual design process, including concept screening & selection, and Appendix B for system concepts considered. Upon review with the client, we chose to further develop a particular design, using suggestions from the client, within the constraints and limitations given. Our final design of the check weighing system includes a detailed description of each area within the entire system along with prototype testing evaluations for key components. These system areas include the coin roll wrapping attachments, sensors, conveyors, in-motion check weighing scale, and final alignment mechanisms. Other aspects evaluated include the machine run sequence and control mechanisms within the system.

1.1 Problem Background & Statement

The Royal Canadian Mint is a Canadian Crown corporation that specializes in the production of circulation and non-circulation coins. The Mint handles contracts for the production of coins for Canada and many other countries. The Royal Canadian Mint currently operates in two facilities across Canada: Ottawa and Winnipeg. The Winnipeg Mint facility officially opened in 1976 [1] and is the only producer of Canadian circulation coins. The Mint facility actively uses advanced and cutting edge technology, giving it the capability to produce billions of coins per year [2]. Furthermore, the Mint not only produces coins, but also provides advice on coinage related issues to the Ministry of Finance. To meet high quality control standards, stringent process control at every stage of coin production is needed including the check weighing of wrapped coin rolls to ensure the correct number of coins.

For the purpose of this design, the Mint requires an accurate method of checking the number of coins in a roll prior to final packaging in the Winnipeg production facility. In addition, the new design will replace previous cumbersome and unsafe designs with one that improves quality and operator safety. Previous designs (Figure 1) proved to be unsafe for the operators, as components of the system posed as tripping hazards. In the previous design, the check weighing scales and conveyor occupied the majority of the aisle way used to access the wrapping machines. In order for the operators to replace the roll stock on the wrapping machines they are forced to step over the scales and conveyor. This procedure was deemed a tripping hazard and a new design was needed.

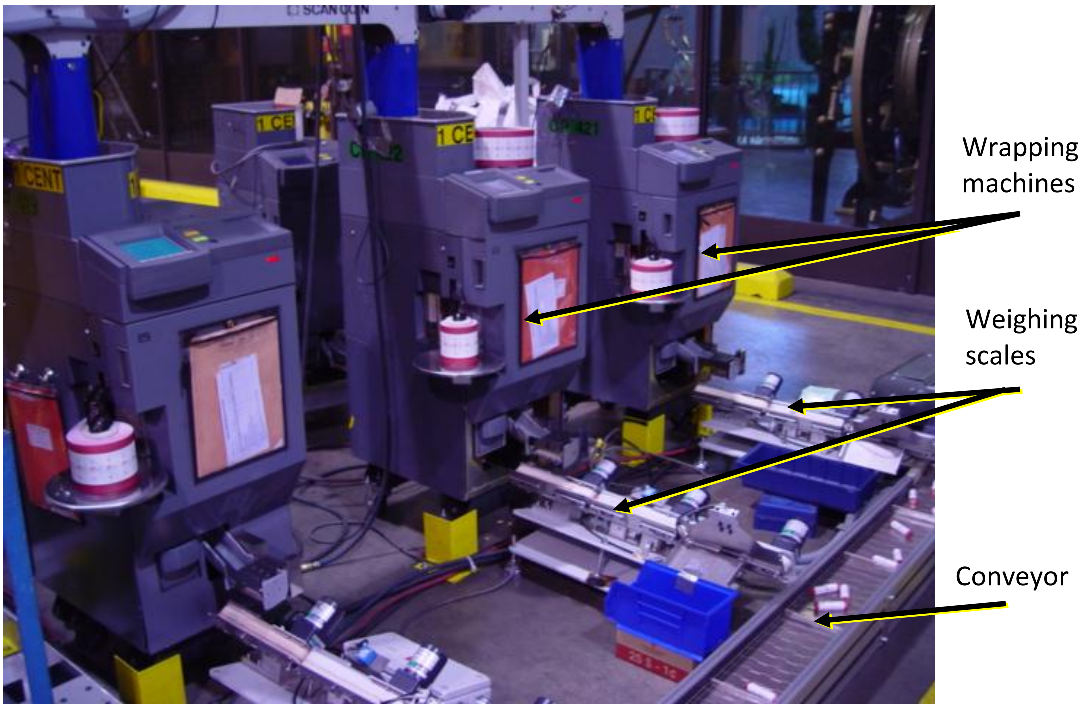

Figure 1. To access the roll stock on the wrapping machines (left), the operator must step over the conveyor and weighing scales (lower right). This operation was considered a tripping hazard [3] (Used by permission of the Royal Canadian Mint).

Since the previous design was deemed unsafe, current coin roll check weighing procedures are not being implemented and coin rolls are simply packaged without being checked. Recently, the Mint signed a contract for the production of a large number of coins for a new customer. Since this contract requires the Mint to check the number of coins in a roll, our team was commissioned to design a safe and reliable check weighing system.

1.2 Project Objectives and System Need Criteria

The objective of this report is to provide a detailed description of the new coin roll check weighing system. Drawings and sketches of the proposed components of the system will also be provided. Through client meetings and internal group discussion, we have identified the following list of need criteria for the coin roll check weighing system:

- Counts the number of coin per roll accurately
- Ensures operator safety
- Ensures minimum down-time during batch production runs
- Tracks coin roll check weighing throughput
- Accommodates different roll sizes (i.e. roll diameter and length)
- Aligns rolls for final packaging
- Implements a rejection system for faulty rolls
- Changes over between batch runs quickly
- Allows easy access for maintenance and repair

This list of need criteria outlines the specific functions and abilities that our system must comply with. In order to fully meet the expectations of our client, each need criteria listed has a corresponding specification and/or constraint that also must be met in the final design.

1.3 Target Specifications

In consultation with our client, a set of target specifications was given to aid in defining the design of the coin roll check weighing system. The final system must be able to meet the following specifications:

- Accurately weighs coin rolls to determine the number of coin per roll. Roll weights are held to a 2% weight variation at the Mint. When the individual coins are packaged into rolls, this 2% weight variation will always be less than the weight of an extra coin.

- Orients the coin rolls perpendicular to the movement of the output conveyor for final packaging as shown in Figure 2.
- Warns operator and stops system after 10 consecutive faulty rolls to adjust the roll weight tolerance window. Machine continues to run if consecutive rejections are fewer than 10.
- Adjusts method of operation depending on weight (75 – 425 grams), diameter (15.4 – 33.7 mm), and length (38 – 106 mm) of the coin rolls.
- Handles a maximum coin roll input rate of 100 rolls per minute. Rate may vary depending on size of coin roll.
- Complies with the Canadian Standards Association (CSA) for the overall design.
- Logs coin roll check weighing data using the RS232 connector standard.

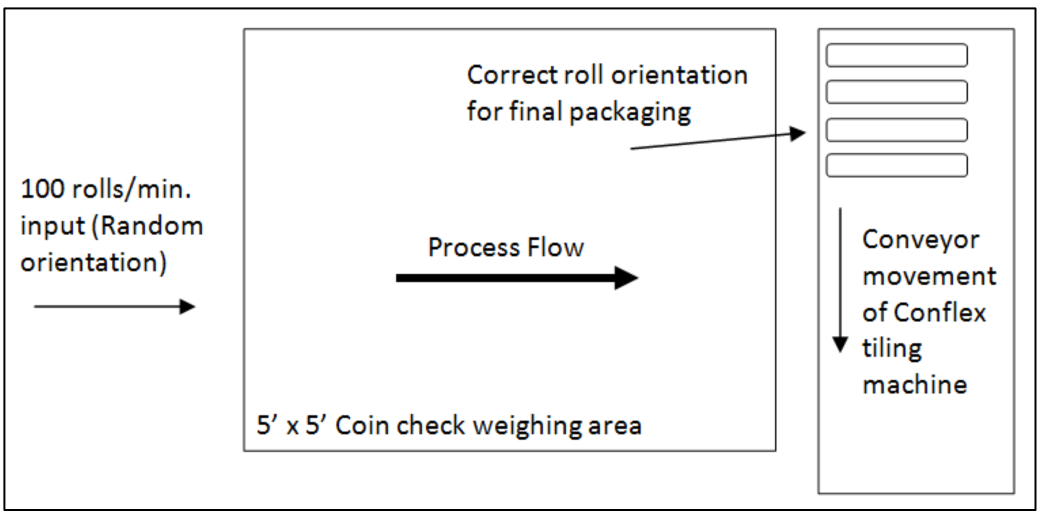

Figure 2. Coins rolls enter in check weighing area in random orientation (left). Roll must oriented perpendicular to the conveyor flow of the Conflex tiling machine (right).

Orientation of the coin rolls is required in order to correctly package the rolls of coins for the Conflex tiling machine (Figure 3).

Figure 3. Output of the check weighing cell placed on the input conveyor (lower left) of the Conflex tiling machine [3] (Used by permission of The Royal Canadian Mint).

Using the listed specifications, our team can use this information to specify adequate equipment and design key components of the check weighing system.

1.4 Constraints and Limitations

In every design scenario, a set of constraints and limitations are imposed on the design. These represent the boundaries or limitations of the problem. For the coin roll check weighing system the size of the cell must not exceed 5’ x 5’ in floor space after the end of the existing conveyor. The system must also output the checked rolls onto the Conflex tiling conveyor which is 34.75” from the ground. Energy supplied to the system is limited to electricity and air. Lastly budget constraints for the system are $200,000 for construction and implementation.

2. Check Weighing Cell Design

The final design of the coin roll check weighing system involves the integration of commercially available components and prototyped concept designs. Since some of the aspects of the system cannot be achieved using off-the-shelf components, we designed and prototyped working preliminary concepts. As a whole, our system begins with a device that re-orients the coin rolls after the wrapping machines. Once re-oriented, the rolls travel along a main conveyor and up a slight incline onto an in-motion check weighing scale. The coin roll is weighed and either allowed to pass or rejected depending on the coin's weight. After check weighing the rolls, they are realigned and dropped into a v-shaped roll transfer attachment that transfers the rolls 90° onto the tiling machine conveyor. Figure 4 outlines the layout of the system.

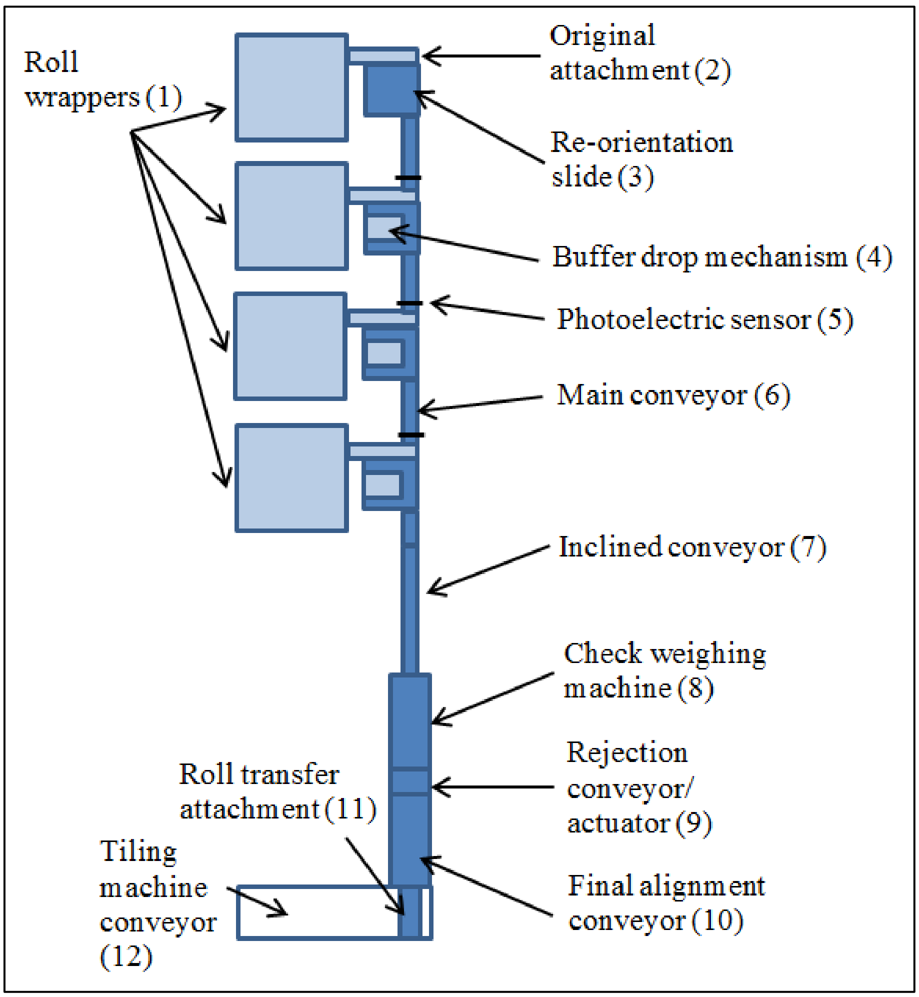

Figure 4. Layout and sequence of coin roll check weighing operations beginning at the coin roll wrappers and ending at the roll transfer to the tiling conveyor (Not to scale).

The standard running procedure of the coin roll check weighing system, outlined in Figure 4, is listed step-by-step, below, starting at the coin roll wrappers and ending with the roll transfer to the tiling conveyor.

Step 1. Roll exits the roll wrapping machine (1) via the original attachment (2).

Step 2. The roll is reoriented using the re-orientation slide (3) and arrives at the buffer drop mechanism (4).

Step 3. Photoelectric sensors (5) along the main conveyor monitor where rolls are located along the main conveyor (6). When a sufficient opening is presented the sensor signals its corresponding buffer to drop a single coin roll into the open position.

Step 4. After the coin has been placed on the main conveyor, the rolls moves up the inclined conveyor (7) and onto the in-motion check weighing machine (8). At this point the roll is weighed and the weight is recorded in the check weighing machine's memory.

Step 5. After the weight is checked, the coin roll passes onto the rejection conveyor (9) and is either allowed to pass or rejected to the side depending on the weight.

Step 6. After passing the rejection conveyor/actuator, the roll travels onto the final alignment conveyor (10) where the roll is prepared for the roll transfer attachment (11). The roll transfer attachment transfers the roll 90° onto to the tiling machine conveyor (12).

2.1 Coin Roll Wrapping Machine Attachments and Control

A significant key to the solution of our system was implied in the problem description. The previous check weighing system did not need orientation because the packaging was done manually. Since our system requires an automated transfer mechanism to a packaging machine, the coin roll orientation is very important. In order to eliminate problems on subsequent processes, we came up with a solution that achieves the correct orientation at the beginning of the check weighing process.

In addition to the orientation attachment, a mechanism was needed to ensure the flow of the system is steady. Although not a requirement of the design by our client we decided that steady flow would ensure that subsequent processes could perform efficiently. To address this issue we prototyped a buffer drop mechanism. This mechanism is controlled via photoelectric sensors along the main conveyor. Figure 5 below illustrates the mechanism within the check weighing system context.

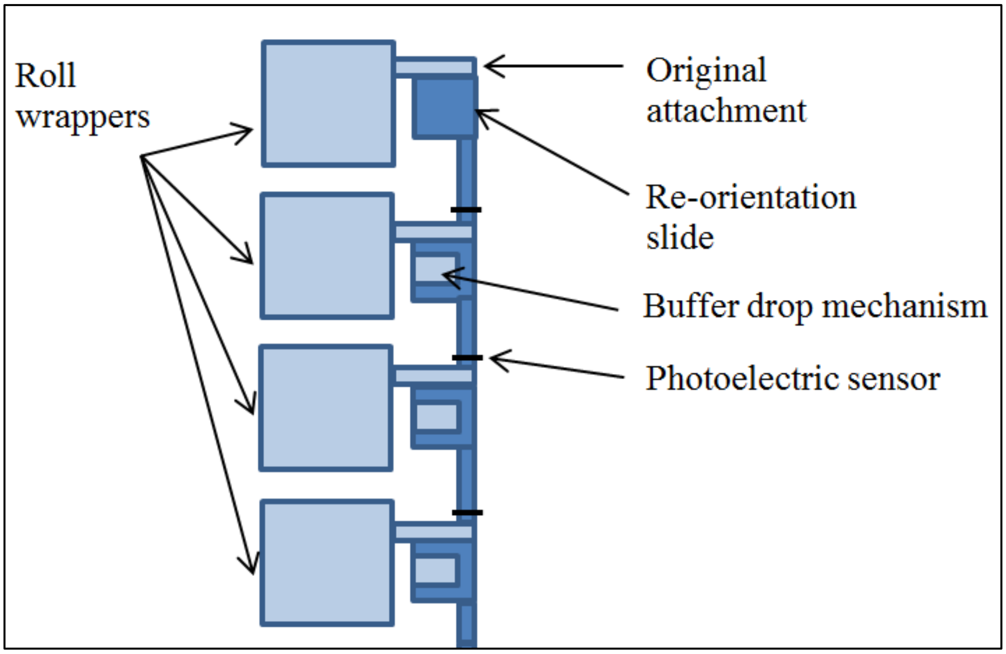

Figure 5. Coin roll wrapping attachments used to modify the orientation of the roll and flow of the check weighing system (Not to scale).

2.1.1 Re-Orientation Slide

Due to the lack of simple, relatively inexpensive, and commercially available products that can perform the operation of re-orienting coin rolls, our team designed a unique prototype solution. See Appendix C for experimental details. Figure 6 illustrates a CAD model of a re-orientation slide mechanism that achieves the following specification required by the system

- Orients the coin rolls perpendicular to the movement of the output conveyor for final packaging

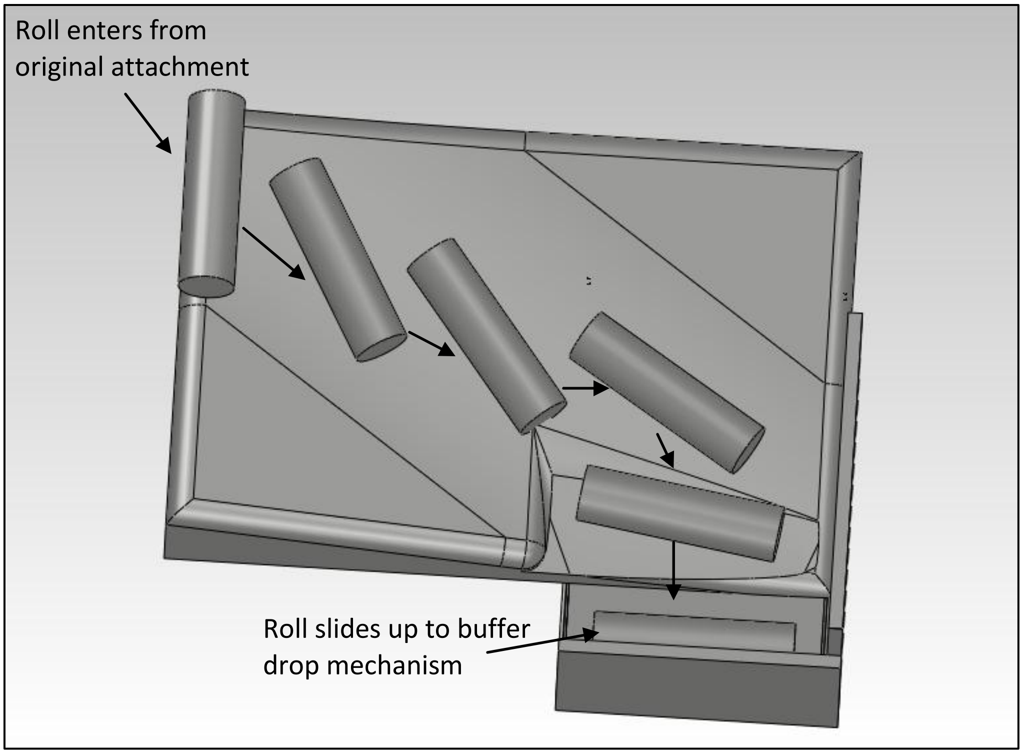

Figure 6. Re-orientation slide used to rotate a coin roll 90° along the path shown.

This orientation device utilizes gravity and the contour of the slide surface to reorient the coin roll (Figure 6). As the roll leaves the coin roll wrapping machine, it slides down the original attachment, on the wrapper, and then falls onto the slide shown previously. At this stage the coin roll slides along the contoured surface eventually causing the roll to change direction.

Since this wrapping machine attachment is not commercially available, it will have to be custom made. Requirements for the slide include a smooth and polished surface to eliminate friction and any unwanted edges that might interfere with the rolls and a structurally stable surface to prevent unwanted deformation. These requirements could easily be met by manufacturing the slide out of machined aluminum. Refer to Appendix D for the full specifications and dimensions of the re-orientation slide.

2.1.2 Buffer Drop Mechanism

The second aspect to the coin roll wrapping machine attachments is the buffer drop mechanism. Appendix C details the experimental details used to design this component. This purpose of this mechanism is to drop a single roll onto the main conveyor when signalled by sensors along the conveyor. Details of the sensor operations will be covered in Section 2.1.3. The drop mechanism shown below in Figure 6 below the re-orientation slide consists of:

- a buffer zone, large enough to accommodate up to 6 rolls of the maximum diameter
- roll dispenser assembly, controlled using a motor that is activated by a sensor on the main conveyor belt

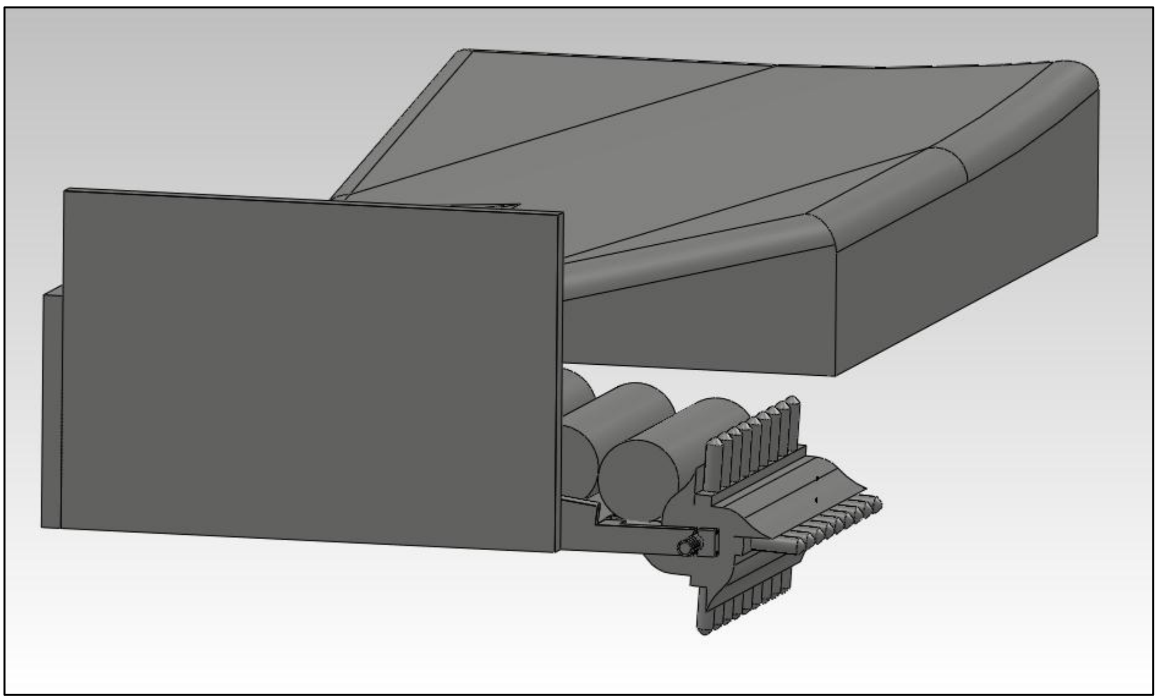

Figure 6. Buffer drop mechanism shown in context with the re-orientation slide.

The dropping mechanism is an attachment to the re-orientation slide. It acts as a buffer zone for the coin rolls as they are dropped onto the main conveyor belt. This buffer is needed in order to prevent the wrapping machine from dropping rolls on top of each other. Since the first wrapping machine does not encounter incoming coin rolls, a buffer zone is not needed at that machine.

The remaining wrapping machines will require the dropping mechanism, since rolls are already on the main conveyor from other wrapping machines. The operation of these dropping mechanisms will be controlled by photoelectric sensors placed on the main conveyor. When a sensor detects enough space to drop a coin roll, it sends a signal to the motor controlling the drop mechanism to drop a single roll. Since the original attachment of the wrapping machine is a fixed height off the ground, the re-orientation slide and buffer drop mechanism must fit between the attachment and the main conveyor. To minimize the amount of vertical distance occupied by the buffer ramp, our design uses a ramp angle of 15°. From our analysis is calculated that the roll would need approximately 4.027×10^{-3} N. This force is much less than the force of gravity on the roll and the rolling motion should easily be initiated. See Appendix E for the full analysis of the rolling friction of the coin rolls on the buffer ramp.

In addition to the buffer ramp, the drop mechanism must also be able to accommodate each of the different roll sizes. This will ensure minimal down time between batch runs as the rotor will not have to be replaced. Figure 33 illustrates the drop mechanism rotor designed to accommodate all the different diameters of rolls.

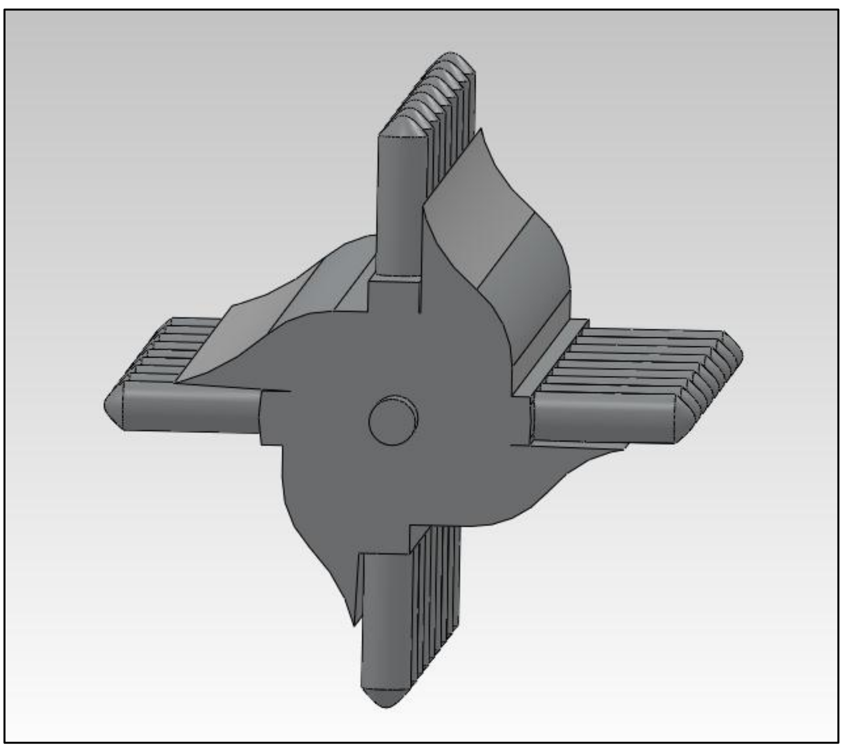

Figure 7. Buffer drop rotor, designed to accommodate different roll sizes.

When operating with the largest roll (33.7 mm in diameter), the length of each pin is slightly longer than the radius of the roll (allowing the mechanism to pick it up). When operating with the smaller rolls (15.4 mm in diameter) the length of each pin is less than three times the radius allowing it to pick only one roll rather leaving the second one behind. Additional machined material is left on the rotor to ensure that it does not pick up additional rolls. Figure 8 illustrates this concept.

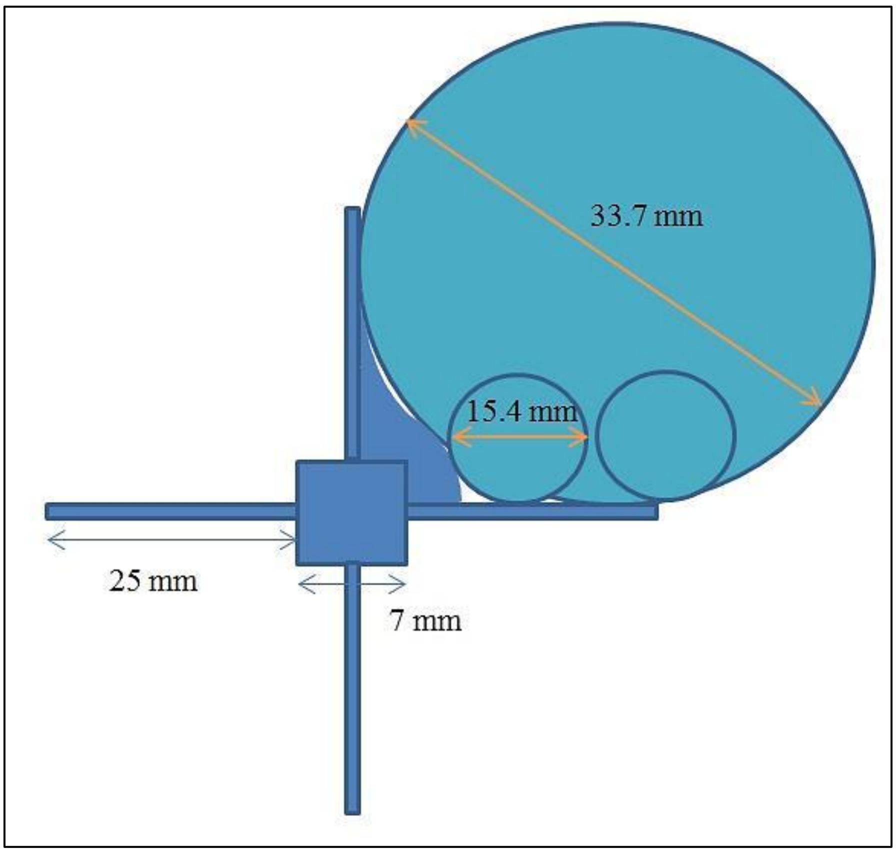

Figure 8. Schematic of rotor mechanism showing the contoured shape of the rotor allowing the mechanism to pick and drop a single roll regardless of the roll diameter (Not to scale).

Since a buffer dropping mechanism, similar to the one described, is not commercially available, it must be custom made. Physical requirements for the design include moderate dimensional accuracy for meshing with the inclined buffer teeth and elimination of sharp edges and corners to prevent coin roll damage. These requirements could easily be met by manufacturing the mechanism out of aluminum. See Appendix D for the full specifications and dimensions of the buffer drop mechanism. In addition, the material used would need to be able to endure repetitive load impacts from the coin rolls during operation. From out analysis, the maximum stress occurring during impact loading was calculated to be 0.6 MPa. This value is much less than the tensile and shear yield stress of aluminum (95 and 55 MPa respectively). See Appendix F for the analysis of the stresses in the pins under impact loading.

2.1.2.1 Buffer Drive Motor

Since the buffer drop mechanism will need to be rotated in discrete intervals to output a single coin roll, a stepper drive motor is needed. This motor will not only need to produce enough torque to output a single roll, but also resist torque when a rolls impact the pins on the drop mechanism. A NEMA frame size 23 drive motor from LIN Engineering [4] (Figure 9) is suggested as it meets the torque requirements using the heaviest coin roll (425 grams).

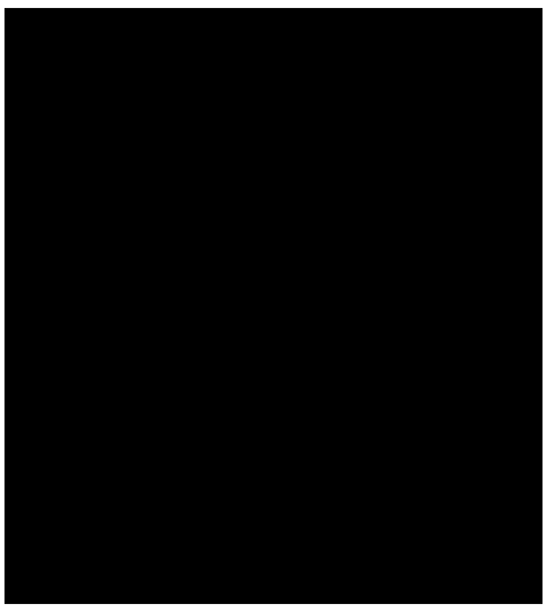

Figure 9. NEMA Frame Size 23 Model 5704 M stepper motor from LIN Engineering [4] (Used by permission of LIN Engineering).

TABLE I outlines the important specifications of the stepper motor specified.

TABLE I. IMPORTANT SPECIFICATIONS FOR MODEL 5704 STEPPER MOTOR [4]

LIN Engineering NEMA Frame Size 23 Stepper Motor	
Model Number	5704M
Holding Torque	0.99 N-m
Weight	1.5 lbs
Step Size	0.45°
Output Torque at 0.75 rev/s	0.65 N-m

From the stress calculation results in Section 2.1.2, the torque required to output the heaviest roll is less than the output and holding torque of the stepper motor specified. See Appendix G for additional specifications of the drive motor.

2.1.3 Sensors

In our design, sensors are an integral part of the overall cell and ensure a smooth running and efficient system. In order to control the flow of coin rolls down the main conveyor, a series of individual coin roll position sensors will be installed. Since the roll wrappers cannot be programmed to output rolls at discrete intervals, we have developed a buffer dropping attachment that will accumulate rolls on each wrapper and output them onto the main conveyor at discrete intervals. The operation of these buffer attachments will be controlled by sensors mounted before the roll wrappers along the main conveyor (Figure 10). The sensors will "tell" the buffer dropping attachment when an opening is present on the main conveyor and allow the buffer to drop a roll. This operation prevents rolls from being dropped on top of each other.

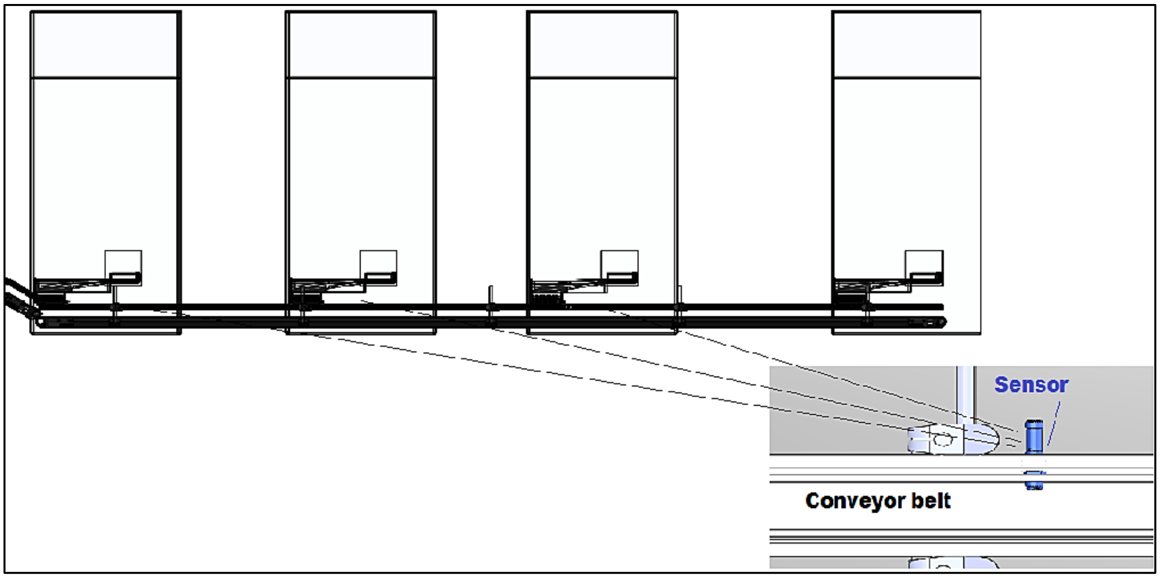

Figure 10. Coin roll position sensor integration with main conveyor (lower left) and placement of sensors relative to the roll wrapping machines (top right).

For our sensing operation, we have chosen to use the E3H2 Miniature photoelectric sensors (Figure 11) available through Omron [5]. These circular sensors are available with threading, allowing us to thread it onto the side guide rail of the main conveyor. Using the diffuse reflective variant of these sensors enables us to have a sensing range of 300 mm for the Omron E3H2-DS30 type, and also eliminates the need for an opposite receiver. Since the objects being detected are relatively close (less than 300 mm) to the sensor itself, the diffuse reflective configuration is an adequate type. Lastly, these types of sensors are generally available with a quick-disconnect connection, thereby minimizing downtime when replacing faulty sensors.

Figure 11. Omron E3H3 miniature photoelectric sensor [6] (Used by permission of Omron).

2.1.3.1 Sensing Strategy

In order to ensure that coin rolls will not back up on any buffer drop mechanism, a sensing strategy was developed. This strategy is needed since the coin position sensors function independent of each other. In order to prevent rolls backing up on the final buffer, the spacing of the rolls needs to be defined using the following assumptions:

- speed of the main conveyor is 50 feet/minute
- conveying the longest roll (106 mm or approximately 4.17 inches)
- output of the wrapping machines is 25 rolls per minute

Using the assumptions above, the number rolls per foot can be calculated after the first wrapping machine:

$$\frac{25\ rolls/min}{50\ ft/min} = 0.5\ rolls/ft$$

Therefore after the first wrapper, rolls will be occupying 2.085 in/foot of the conveyor. At this stage there will be plenty of room for the second buffer to drop coin rolls in the spaces between. Extending these calculations to the worst case (the last buffer), the conveyor will have 6.255 inches to drop the 4.17 inch roll allowing for 0.915 inches of room on both ends. It should be noted that the conveyor sourced for this design will have a variable speed option to allow for adjustment in the coin roll spacing if needed (Section 2.3). TABLE II below classifies the roll spacing at various conveyor speeds for the longest and shortest rolls.

TABLE II. CALCULATED ROLL SPACING AFTER FOURTH AND FINAL BUFFER DROP MECHANISM

Roll Length (mm)	Conveyor Speed (feet/min.)	Roll Spacing After Last Buffer (in/mm)
106	55	1.105/28.07
106	50	0.915/23.24
106	45	0.683/17.35
106	40	0.394/10.00
38	55	2.320/58.93
38	50	2.252/57.20
38	45	2.169/55.09
38	40	2.065/52.45

From TABLE II, it is shown that the longest roll lengths can be adequately accommodated while the smaller rolls could be processed at a slower conveyor speed reducing overall wear on the system.

2.2 Conveyors

The design of the coin roll check weighing system requires the coin rolls to travel a maximum horizontal floor space distance of 18.03 feet from the first wrapper, through the check weighing system, and finally to the tiling conveyor. This motion is facilitated using conveyors consisting of a main conveyor underneath the wrapper attachments and an inclined section up to the check weighing station. Figure 12 below illustrates the conveyors within the check weighing system context.

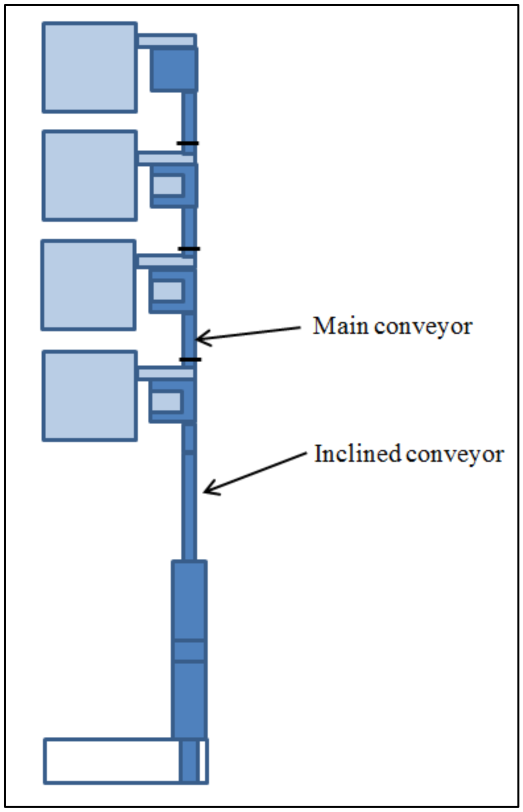

Figure 12. Main conveyor and inclined conveyor used to transport the coin rolls to the check weighing station (Not to scale).

Both of these conveyors must be able to move at different speeds depending on the coin roll sizes and weights. The rolls also have to be raised to height of 38.75 inches off the ground, as seen in Figure 13. This height has to be achieved in order for the rolls to be check weighed and eventually transferred using the drop mechanism to the tiling machine (Figure 3).

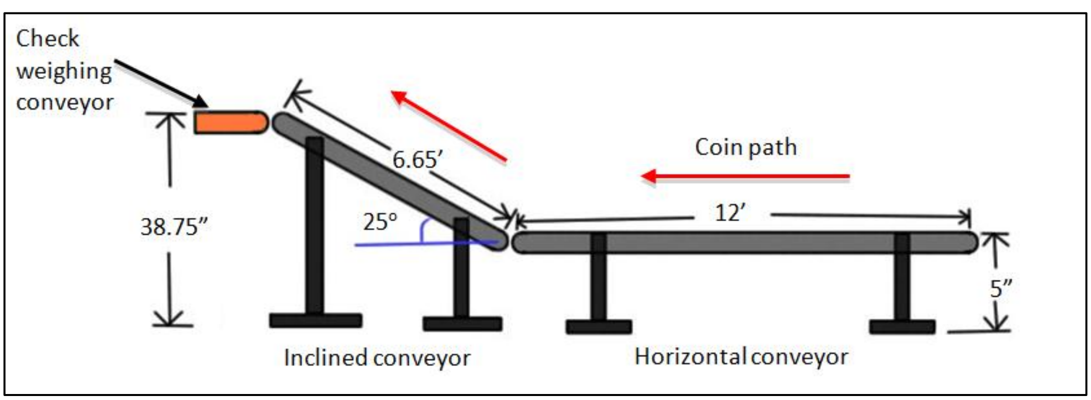

Figure 13. Main (horizontal) and inclined conveyor (side view – not to scale).

As mentioned in Section 2.1, the coin rolls produced by the coin roll wrapper will be re-oriented so that the rolls can be dropped onto the main conveyor and travel parallel to the direction of flow. These rolls are aligned and dropped by the drop mechanism onto the main conveyor which is 5 inches off the ground, as seen in Figure 13. The conveyor is raised to this height to allow easy access for maintenance, accommodate the dimensions of the re-orientation slide and dropping mechanisms, and provide adequate room for mounting the drive motors.

2.2.1 Low Profile Flat Belt Conveyors

The conveyor section from the wrappers to the check weighing machine consists of two low-profile flat belt conveyors. The main conveyor, which will be receiving the coin rolls from the buffer drop mechanisms, will transport the coin rolls from the wrappers onto the inclined conveyor to a height of 38.75 inches off the ground (Figure 13).

To choose an effective and efficient conveyor system, we selected the conveyors according to the following specifications and constraints:

- Handles a maximum coin roll input rate of 100 rolls per minute. Rate may vary depending on size of coin roll.
- Adjusts method of operation depending on weight (75 – 425 grams), diameter (15.4 – 33.7 mm), and length (38 – 106 mm) of the coin rolls.
- Carries coin rolls up an incline to final height of the tiling at 34.75 inches.

We were able to get in contact with an American based company called Mini Mover Conveyors [7], which specializes in the design and manufacturing of portable and low-profile small conveyors (Figure 14).

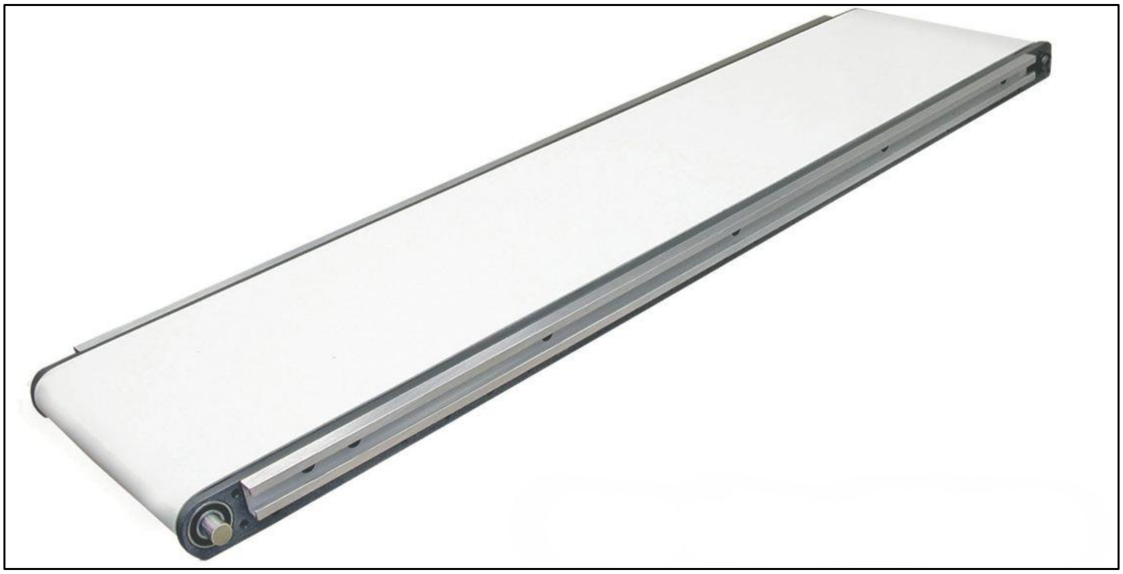

Figure 14. Low-profile flat belt conveyor from Mini Mover Conveyors [8] (Used by permission of Mini-Mover Conveyors)

From the dropping mechanism the rolls are dropped parallel to the direction of motion of the conveyor from a height of 2 inches onto the flat belt. The conveyor belt must be able to withstand the impact of a maximum of 400 gram coin rolls at 100 times per minute. Therefore, a cushioning and loading conveyor belt is used to avoid damage both to the conveyor and the paper wrapped rolls.

The initial horizontal flat belt conveyor or main conveyor is a low-profile design as seen in Figure 12 with dimensions of 12 feet long, 1.9 inches wide, and a thickness of 1.5 inches. The conveyor is held up by two 5 inch tall heavy duty adjustable stands (Figure 15). As stated previously, this height is chosen to give enough space for maintenance and also allow space for installing a drive motor, which will be discussed in Section 2.3.4.

Figure 15. Adjustable stands used to support conveyors [9] (Used by permission of Mini-Mover Conveyor)

The inclined flat belt conveyor is also a low-profile design with dimensions 6 feet long, 1.9 inches wide, and a thickness of 1.5 inches. The conveyor is held up with two heavy duty adjustable stands at a 25° incline. The incline of 25° was selected to have a gradual incline path while utilizing a minimum amount of length wise floor space to carry the coin rolls up to a height 38.75 inches to the check weighing conveyor. Or order to ensure the coin rolls will not slip in operation, contact was made with the manufacturer to ensure slippage would not occur. It was recommended that 25° would be adequate given testing results, done by the manufacturer, using similar products.

2.2.2 Conveyor Transitions

A challenging aspect of the design is to transfer the coin rolls from a flat surface up to a 25 degree inclined conveyor. Two low-profile conveyors can be used to accommodate this transition instead of one single belt Z-conveyor. Using two separate conveyors will be more effective as it offers less maintenance, better dependability, and is less expensive. The two low-profile conveyors can be installed close to each other (Figure 16) to make a smooth 25 degree transition.

Once the coin rolls have made it across the gap, the next step is to carry the rolls up the incline successfully. To facilitate the movement and avoid slippage, a grey rough top surface, high friction belt [10] will be used on both the horizontal flat bed and inclined conveyors.

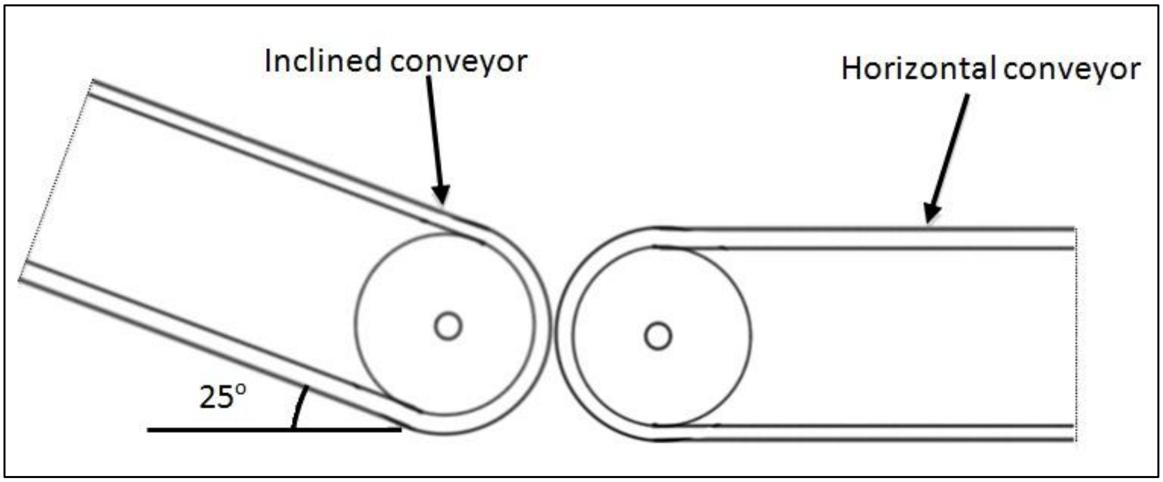

Figure 16. Main (horizontal) and inclined conveyor transition (side view – not to scale).

Once the coin rolls have made it to the top of the 25° incline, the rolls have to be transferred onto a horizontal check weighing conveyor. The low-profile construction of the inclined conveyor allows for a close and smooth merge to the check weighing conveyor (Figure 17).

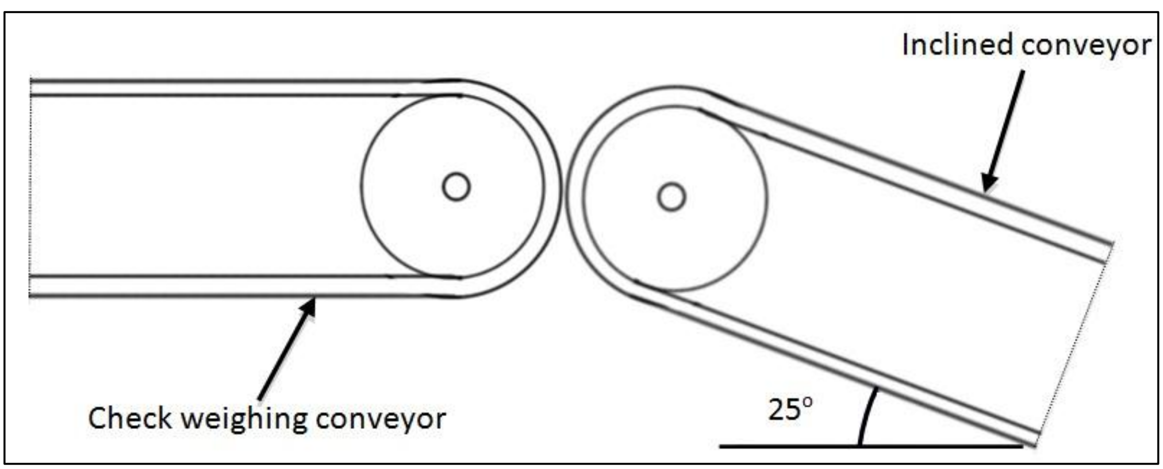

Figure 17. Inclined conveyor and check weighing conveyor transition (side view – not to scale).

2.2.3 Adjustable guide rails

The alignment of the coin rolls is a key factor that makes our design successful. Our goal is to align the rolls and carry them parallel to the motion of the conveyor from the beginning of the system at the drop mechanism to the end on the tiling conveyor belt. To achieve the correct orientation of the roll throughout its movement on the conveyor belts, two adjustable side rails are selected to be installed on each side.

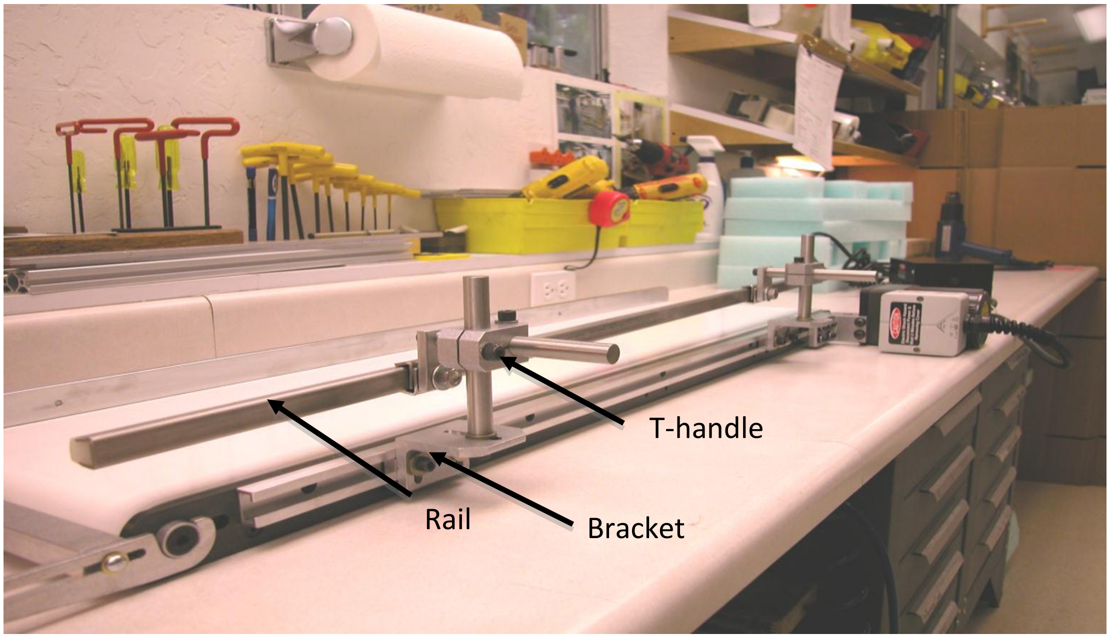

Figure 18. Adjustable brackets, T-handles, and rails for low-profile flat belt conveyor [11] (Used by permission of Mini-Mover Conveyor).

The adjustable side rails from Mini-Mover Conveyors are constructed of aluminum brackets, stainless steel adjustment rods and quick adjust T-handles [12] similar to that in Figure 18. The rails are equipped with a Ultra-High-Molecular-Weight (UHMW) polyethylene coating which will help maintain the correct alignment of the coin rolls as well provide a smooth operating motion along the belt. The guide rails can be easily adjusted up and down and side to side using an Allen key. For our design the side rails will be suspended 5 millimetres on top of the conveyor belt. This will ensure that the smallest roll cannot fall off the conveyor underneath the guides. The two rails will also be spaced 45 mm (1.77 inches) apart (Figure 18), to accommodate both the smallest and largest diameter coin rolls. The main conveyor will be fitted with three pairs of adjustable brackets and T-handles, as seen in Figure 18, to accommodate the 12 foot length of the initial horizontal flat belt conveyor. The inclined conveyor will be fitted with also be fitted with three pairs of brackets and T-handles along the 6.65 foot incline length.

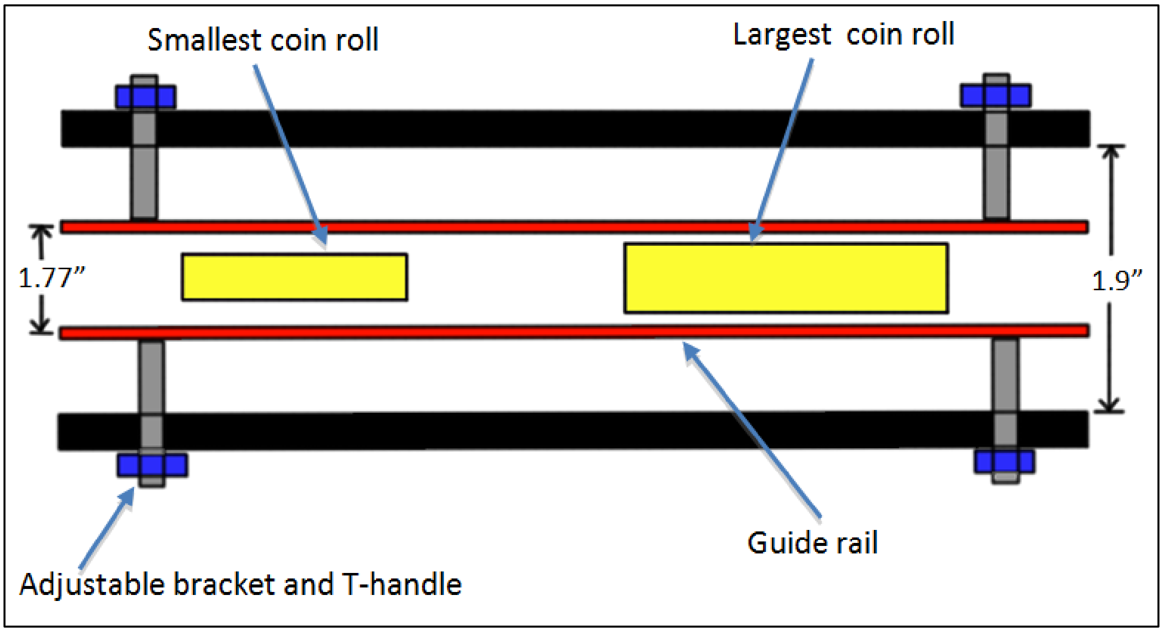

Figure 19. Dimensions of nominal guide rail spacing to process largest coin roll size (top view – not to scale).

To further assist with the coin roll path from the inclined conveyor to the check weighing conveyor system, 5” long adjustable guide rails will be installed on the beginning of the check weighing conveyor. These short guide rails will ensure that the coin rolls stay straight during their transition over the subsequent two check weighing conveyors. These guide rails are universal and can be mounted to the base of the conveyor via drilling and tapping holes to the sides of the check weighing conveyor.

Since the adjustable guide rails and brackets are constructed with stainless steel adjustment rods and quick adjust T-handles, the rods extend outside the width of the flat belt conveyor (Figure 18). Therefore to avoid any tripping hazards, Plexiglas walls will be erected beside the conveyors needed. These walls will be bolted to the ground, approximately 6 inches from the conveyors. These walls will consistently be 6 inches higher than the top of the low-profile conveyors.

2.2.4 Drive Motor Package

Since the horizontal and inclined conveyors are both low-profile types, a low profile series drive motor package will be used for each conveyor [13]. This package consists of a motor and a variable speed drive inverter (Figure 20).

Figure 20. Gear motor and variable speed drive inverter [14] [15] (Used by permission of Mini-Mover Conveyor).

The variable speed motor allows the flexibility of moving the coin rolls between 20 and 61 feet per minute [11]. Moving the coin rolls between these ranges allows us to output 100 coin rolls per minute regardless of the size, weight, and length of the rolls. A 1/18 hp, 115/60 VAC motor [13] will be attached to the sides of the discharge ends of the two conveyors (Figure 21). The motors can successfully carry a load capacity of 50 pounds +/- 5 pounds [11], which is adequate when the belts are fully loaded with the largest diameter (33.7 mm) coin rolls. This justification is outlined below:

$$Longest\ Conveyor\ Length = 12\ ft\left(12\frac{in}{ft}\right) = 144\ inches$$

$$Length\ of\ coin\ roll\ with\ largest\ diameter = 60.3\ mm\ (2.37\ inches)$$

$$Maximum\ number\ of\ coin\ rolls\ on\ conveyor\ belt = \frac{144}{2.37} = 60.76\ rolls$$

$$Maximum\ weight\ on\ conveyor\ belt = 60.76\ rolls\left(0.3025\frac{kg}{roll}\right) = \ 18.38\ kg\ (40.52\ lbs)$$

Since this analysis is a worst scenario where the rolls are aligned end-to-end with no gaps, the conveyor will be more than adequate for our application.

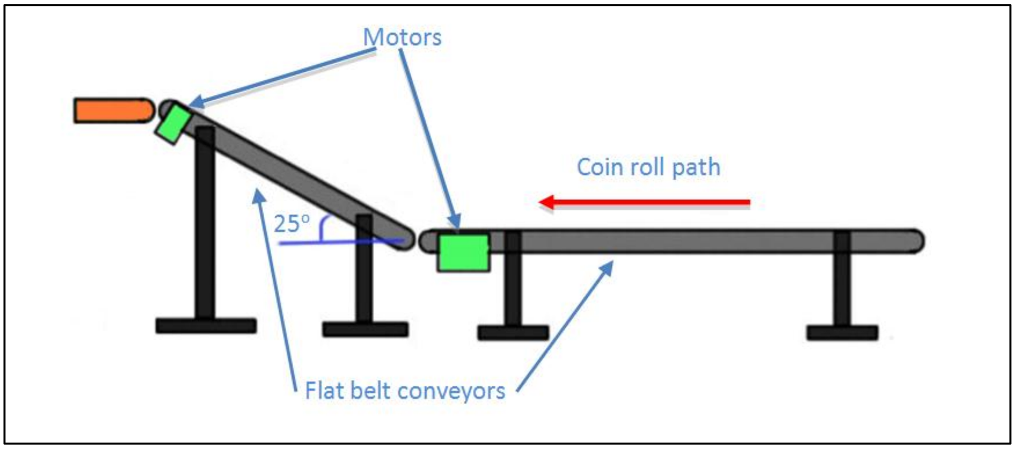

Figure 21. Motor placement locations on main and inclined conveyors (side view – Not to scale).

2.3 Check Weighing and Rejection System

In order to perform proper quality control of the wrapping machine, each coin roll dispatched must be weighed to determine the number of coins per roll. The rolls enter the check weighing station via the inclined conveyor and exit onto the final alignment conveyor. Figure 22 below illustrates the check weighing and rejection system within the check weighing system context.

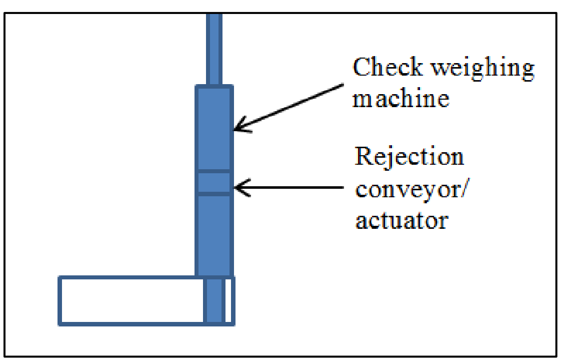

Figure 22. Check weighing machine used to weigh the coin rolls while moving. Rolls are either allowed to pass or rejected on the rejection conveyor via an actuator (Not to scale).

An Ishida DASC-G-S015-12-SS check weigher, as shown in Figure 23, has been selected for the task of weighing the coin rolls. This machine was selected to ensure that the following needs were met:

- Implements a rejection system for faulty rolls
- Changes over between batch runs quickly
- Tracks coin roll check weighing throughput

In addition to these needs, we also satisfied the following specifications:

- Handles a maximum coin roll input rate of 100 rolls per minute. Rate may vary depending on size of coin roll.
- Warns operator and stops system after 10 consecutive faulty rolls to adjust the roll weight tolerance window. Machine continues to run if consecutive rejections are fewer than 10.
- Logs coin roll check weighing data using the RS232 connector standard.
- Adjusts method of operation depending on weight (75 – 425 grams), diameter (15.4 – 33.7 mm), and length (38 – 106 mm) of the coin rolls.

Figure 23. Ishida DASC-G-S015-12-SS check weigher components [16] (Used by permission of Ishida).

Its technical specifications are listed in TABLE III. This check weighing machine not only consists of a (1) load cell weighing sensor but also (2) a software capable of customizable pre-set profiles & an embed counter, and (3) a rejection system to reject coin rolls with extra or missing coin for manual inspection.

TABLE III. IMPORTANT SPECFICATIONS OF THE ISHIDA DASC-G-S015-12-SS CHECK WEIGHING MACHINE [16].

DASC-G-S015-12-SS	
Weighing range	6 - 600 g / 15 – 1500 g (multi-range)
Minimum graduation	0.05 g / 0.1 g
Weighing speed	400 items/min
Weighing accuracy (3σ)	0.1 g / 0.2 g
Product dimensions: Length Width Height	 46 – 200 mm 20 – 160 mm 10 – 180 mm
Belt Width	160 mm (6.3 inches)
Belt Speed	10 - 55 metres/min (32.8 – 180.4 feet/min)
Total floor space dimensions	1055 mm L x 670 mm W (41.5 inches L x 26.4 inches W)
Machine weight	80 kg

2.4.1 Load Cell Weighing Scale

The Ishida check weigher process begins with a load cell weighing sensor which weighs coins as they pass over it. The DASC-G-S015-12-SS check weigher features a high output digital load cell sensor that features enhanced sensitivity over conventional models. The load cell's rigid design allows the weight to stabilize more quickly, making the check weigher capable of faster weighing speeds up to 400 items per minute. This speed is significantly higher than our requirement of 100 coin rolls per minute; therefore this check weighing scale is more than adequate. Also, the goal of this check weighing system is to accurately identify rolls with missing or extra coins. This implies that the weighing sensor must have a tolerance small enough to accommodate a single extra coin in the lightest roll. As can be seen from the TABLE III, the check weigher's accuracy is within 0.1 g in its 6 – 600 g range. Since the lightest coin weight is 1.5 grams, this accuracy is more than adequate.

2.4.2 Software

The Ishida DASC-G-S015-12-SS check weigher comes bundled with integrated software which receives weight information from the weighing scale. This information is displayed via a 7-inch color LCD screen and the user-friendly software is controlled through a command dial shown in Figure 24. This software is capable of counting “good” coin rolls after passing the weighing and rejection system. This is a requirement for our client that helps keep track of how many coin rolls are successfully dispatched within a day, week, etc. It also outputs data using the RS232 format which is another requirement from our client.

Figure 24. 7-inch LCD display on Ishida DASC-G-S015-12-SS check weighing machine [16] (Used by permission of Ishida).

In addition, the software can accommodate different roll sizes through a user input of upper and lower weight limits of each coin roll batch shown in Figure 25. For example, if a coin roll is supposed to weigh 187.8 g and a single coin of that roll weighs 3.76 g. The limits can be set to

187.8 ± 3.76 g and the rejection system will reject any roll that has a weight outside of these limits. Additionally these inputs can be programmed into pre-defined setting in the system (Figure 25) so that when the same batch has to be run again the user would require only a push of a button rather than typing the upper and lower limits again. This initiates changeovers between batches much more quickly.

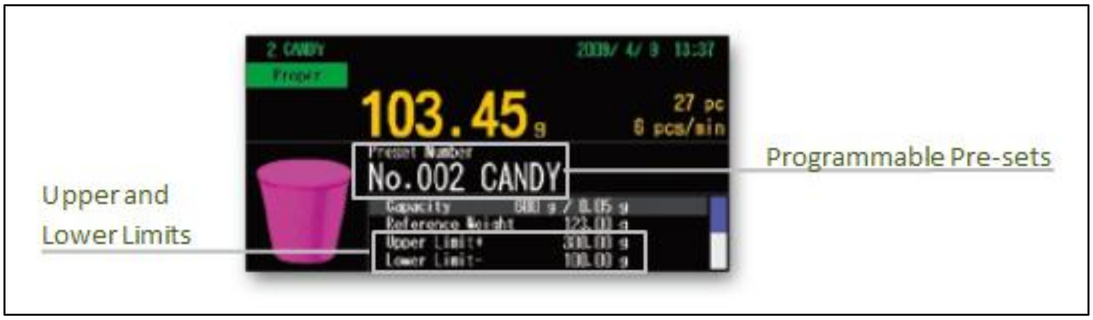

Figure 25. Software display in pre-set mode [16] (Used by permission of Ishida).

Another customer requirement that is satisfied by the use of Ishida DASC-G-S015-12-SS check weigher is that the entire system (from wrappers to tiling machine) can be stopped after the machine rejects 10 consecutive rolls. This feature is necessary so workers can manually check if these rolls are indeed rolled incorrectly (containing wrong number of coins) or if the check weigher needs to be re-calibrated since some batches of coins differ in weight in comparison to other batches. This feature is made possible by Ishida's software and is called the "continuous - no good signal" feature. This software feature allows the user to program the check weigher to either stop the machine or signal with an alarm when three, five, or ten consecutive rolls have been rejected. Therefore, this feature prevents numerous coin rolls from being rejected when they actually have the correct number of coins per roll but a slightly different out of tolerance weight. In this case, the workers need only to adjust the window of tolerance to accommodate the slightly heavier or lighter batches.

2.4.3 Rejection

Another component of the check weigher is the rejection system. The rejection system receives a signal from the software to either reject or let the coin roll pass through. Figure 26 shows two positions: when the lever is on the side (1) and when it sits diagonally across the conveyor (2). When the rejection system receives a signal that the coin roll is good it stays or moves to position 1 letting the roll continue down the conveyor. When the rejection system receives a signal that the coin roll has missing or extra coins the lever goes into position 2 where it blocks the coin roll and redirects it to the side of the conveyor where there will be a container to catch the roll. The rejection system is, of course, crucial so that no faulty rolls continue down the process line to be shipped to the end customer.

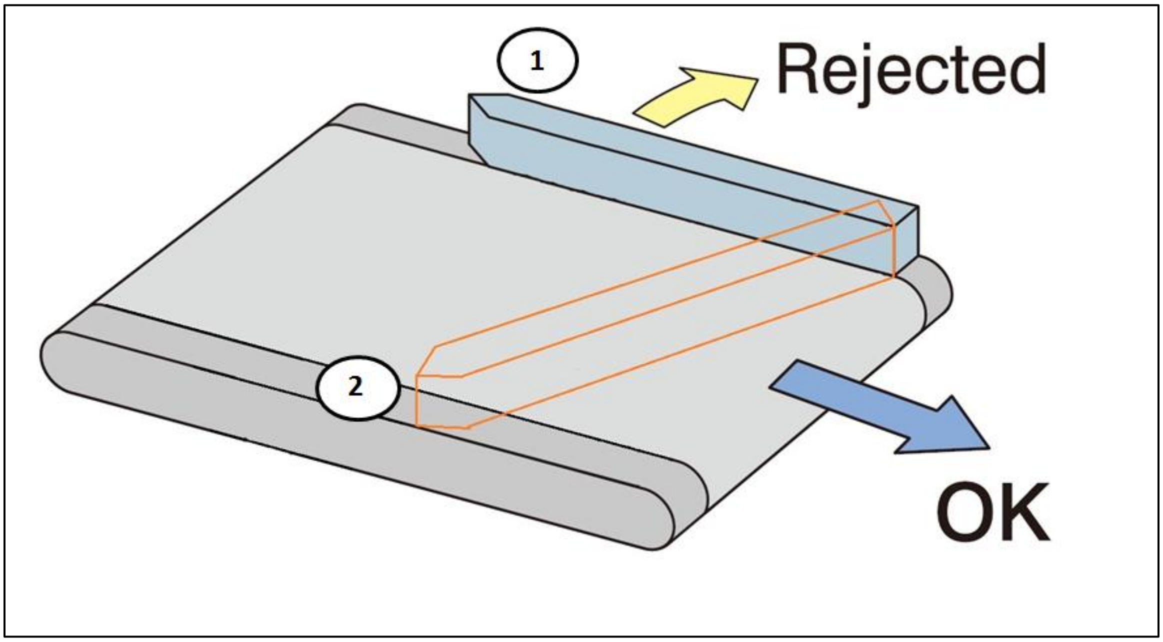

Figure 26. Rejection actuator used on the Ishida DASC-G-S015-12-SS check weigher. Rejection actuator moves between positions 1 and 2 [16] (Used by permission of Ishida).

Reviewing the Ishida DASC-G-S015-12-SS check weigher specifications and capabilities, its weighing scale can count coins with 0.1 g accuracy, weigh at a maximum rate of 400 items per minute. Its software can track coin roll throughput, allow user input of weight limits to accommodate different roll size batches, save coin roll weights for future use so that changeover between batch runs is much quicker, and output data in RS232 format. In addition, its rejection attachment can reject faulty rolls and stop the entire system after it rejects 10 consecutive faulty rolls. Therefore, it is recommended that this check weigher and its features and capabilities offer an ideal solution for the requirements given by the client.

2.4 Final Alignment Conveyor

Following the check weighing conveyor, the defective coin rolls will either be rejected in a side bucket, or successful rolls will proceed in the direction of the tilling machine. Figure 27 below illustrates the final alignment conveyor within the check weighing system context.

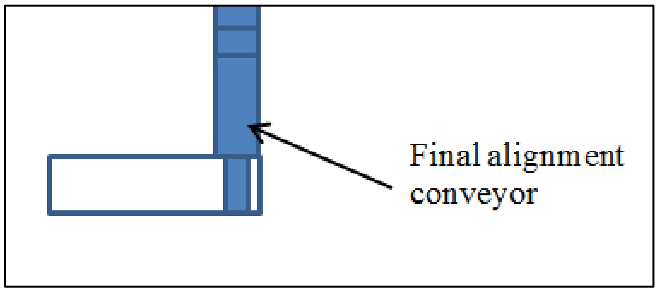

Figure 27. Final alignment conveyor used to align coin rolls after check weighing to prepare for transfer to tiling conveyor (Not to scale).

Since the check weighing conveyor is not fitted with side guide rails, there will be a tendency for slight misalignment when traveling over the conveyor transitions. To regain the alignment for the successful coin rolls, a final aligning flat belt conveyor will be installed between the check weighing system and the drop mechanism which leads to the tiling machine.

The same low – profile series conveyor as used in the beginning of the system is now used for the final alignment. This conveyor will have the same specifications as the previous main conveyors but have dimensions of 6.3 inches wide, 1.5 feet long and 1.5 inches thick. The conveyor is 6.3 inches wide which is the same width as the check weighing conveyor belt. This will allow the final alignment conveyor to realign any rolls that may be misaligned on the check weighing conveyor

Since the final aligning conveyor is much wider than the largest coin rolls, adjustable side guide rails are installed to put the coin rolls back into the correct alignment, if needed. The same adjustable rails and brackets used in the previous main conveyors are used for the final aligning conveyor. The rails are fitted with 2 pairs of brackets and adjusted at a height of 5 mm off the conveyor belt. In order to realign the coin roll, the guide rails will be installed at an angle to have an entry width of 6.3 inches and an exit of 1.45 inches. With the Ultra-High-Molecular-Weight (UHMW) polyethylene surfaced guide rails, the misaligned rolls will be realigned to be in the correct orientation as they enter the roll transfer attachment to the tiling machine (Figure 28).

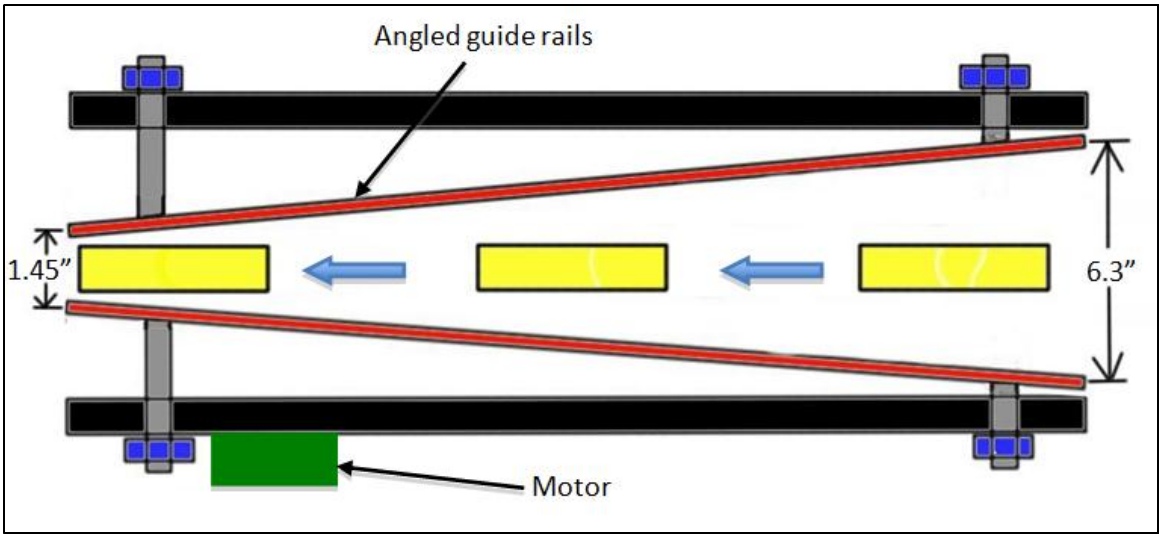

Figure 28. Final alignment conveyor guide dimensions and drive motor placement (Not to scale).

The conveyor is supported and mounted to a height of 38.75 inches from the ground using a pair of heavy-duty aluminum adjustable conveyor leg stands (Figure 15). To match the speed of the previous conveyors and also the check weighing conveyor, the final aligning conveyor is equipped with a low-profile series drive motor package [13]. This package also uses a variable speed gear motor allowing the conveyor system to be adjusted for various coin roll sizes. A 1/18 HP, 115/60 VAC motor will be attached to the right side of the discharge end of the conveyor (Figure 28).

2.5 Roll Transfer Attachment

The final stage of the coin roll check weighing system is to transfer the rolls onto the tiling machine conveyor. Figure 29 below illustrates the roll transfer attachment within the check weighing system context.

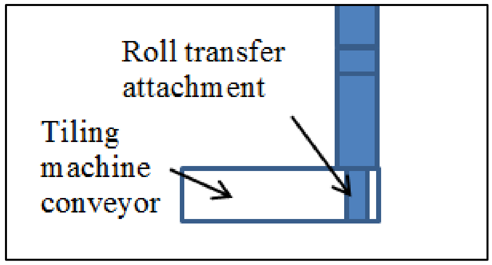

Figure 29. Roll transfer attachment used to move coin rolls 90° onto the tiling machine conveyor (Not to scale).

To perform this roll transfer motion, a v-shaped roll transfer mechanism has been prototyped and will be attached to the final alignment conveyor as shown in Figure 30. See Appendix C for experimental details.

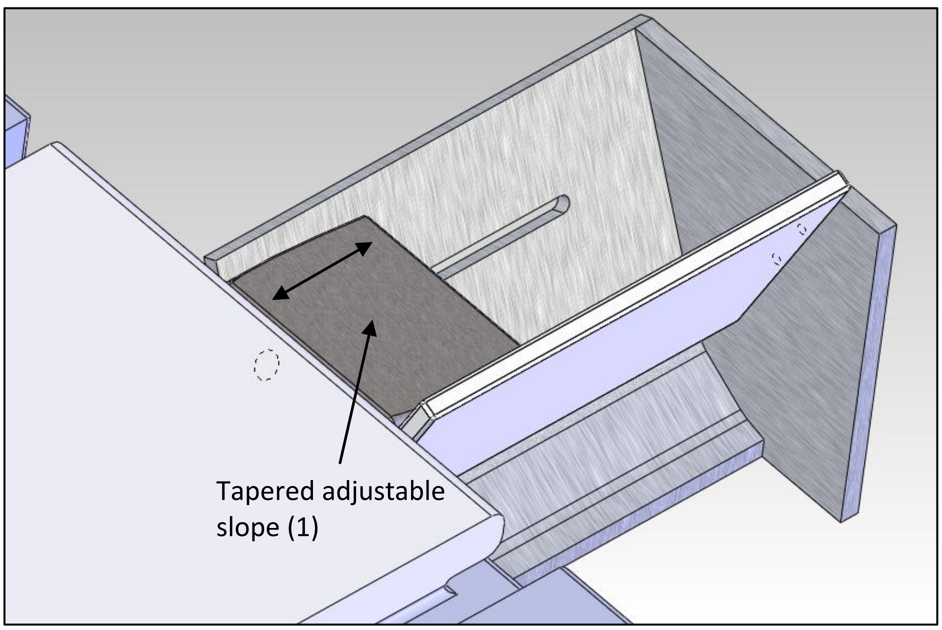

Figure 30. Roll transfer attachment with tapered adjustable slope to accommodate different roll lengths.

To begin, the roll drops off the end of the final alignment conveyor and then slides onto a tapered adjustable slope (1), shown in Figure 30. From here, the roll drops down and hits the first face of the transfer mechanism (2), as shown in Figure 31. The roll will then slide down the face until it hits the second flat surface (3). At point the roll will align itself via the bottom flange on the second face of the dropping mechanism (4). The roll then slides onto the tiling conveyor leading to the tiling machine (5).

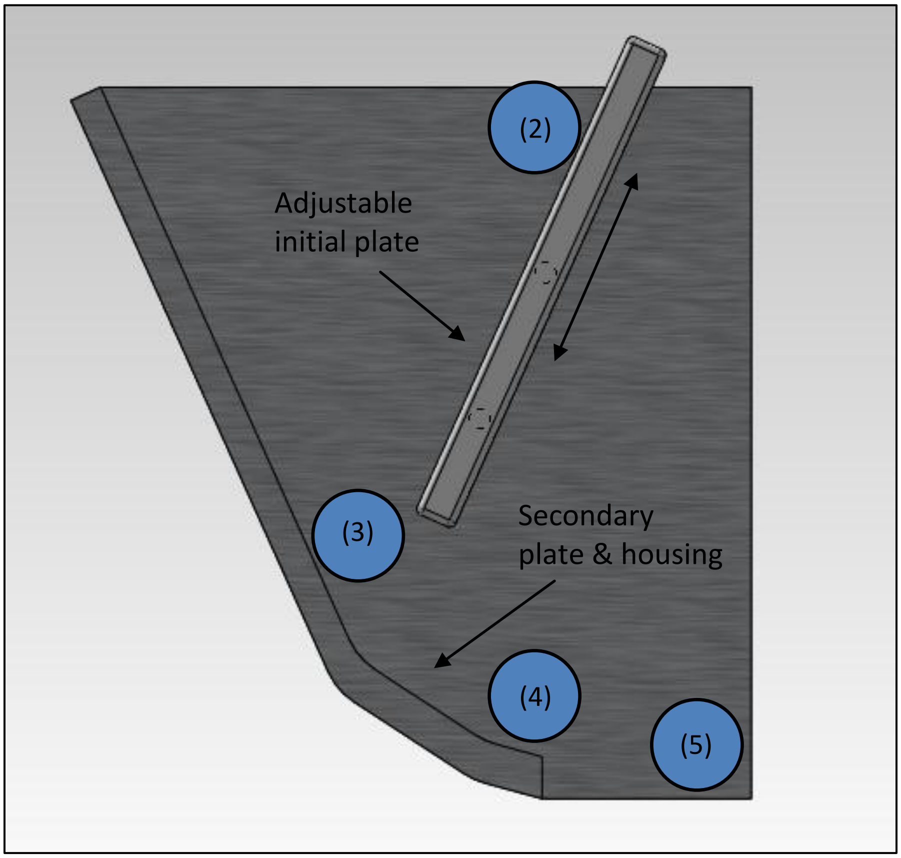

Figure 31. Section view of roll transfer attachment.

This v-shaped shaped mechanism consists of three sections: a tapered adjustable slope, adjustable initial plate, and the secondary plate & housing. The first part is the tapered adjustable slope that can be manually adjusted depending on the roll length being processed. This adjustable slope ensures that all sizes of rolls fall onto a consistent location on the tiling conveyor. By doing so, the need for manual alignment at the tiling machine is virtually eliminated. The second part is the adjustable initial plate can be manually adjusted to accommodate different coin roll sizes through the bottom opening as shown in Figure 31. By having one of the sides adjustable, the mechanism ensures that the roll doesn't change direction before it rolls onto the tiling conveyor. The third component of the mechanism is the secondary plate and housing. This plate ensures the roll is correctly aligned via the bottom flanges.

Since two plate of the tiling machine drop mechanism are relatively simple parts, it is recommended that it be built using aluminum or steel plate that can be bent into shape. For the adjustable slope it is recommended that it be machined out of aluminum to ensure a smooth and polished tapered surface. This is required since the coin rolls will be sliding across this part and any abrasive surface is not desired. Conventional threaded fasteners are recommended for assembling the three components. See Appendix D for the full specifications and dimensions of the roll transfer mechanism.

2.6 Machine Run Sequence

As with other production processes, a specific set of machine run sequences is needed to allow the coin roll check weighing system to run properly. The following section identifies the start-up & shutdown procedures.

2.6.1 Start up and Shut down

In order to prevent any build-up of coin rolls a specific start-up and shutdown sequence is needed.

Step 1. Turn all conveyors on. This step ensures that the conveyors are running before any coin rolls are produced.

Step 2. Turn on buffer attachments. If any coin rolls are remaining on the buffers attachments, they will begin to output the rolls on the already moving conveyor.

Step 3. Turn on coin roll wrappers. At this point the system can begin producing new coin rolls and inputting them into the buffer attachments.

The corresponding shutdown sequence would follow the steps listed below:

Step 1. Turn off coin roll wrappers. At this point the system will stop produce new coin rolls and inputting them into the buffer attachments.

Step 2. Turn off buffer attachments. If any coin rolls are remaining on the buffer attachments, they will stop outputting them onto the main conveyor.

Step 3. Turn off all conveyors. At this stage the system is stopped.

It should also be noted that two shutdown options should be implemented as well. The first shutdown option stops the machines in the order stated above but does not cut all power to certain functions of the cell such as the check weighing HMI and sensors. This shutdown procedure allows the cell to be restarted in a short amount of time and without removing any work in progress due to recalibration. The second shutdown option could be used as an emergency shutdown procedure where all power to all systems is cut. Obviously this procedure would require a larger amount of time to restart as the wrappers and check weighing conveyor would need to be recalibrated.

2.7 Cost Analysis

For this design project, as mentioned previously, we were given a budget of $200,000. TABLE IV lists the costs for obtaining the parts and components used in the final design of the system. The cost is either from materials and labour of manufacturing customized components (i.e. slide), or from buying the available-off-the-shelf product (i.e. check weigher). Therefore, this cost analysis does not include cost for labour in assembly or set up of the final system in the Royal Canadian Mint facility.

TABLE IV. COST BREAKDOWN OF VARIOUS SYSTEM COMPONENTS.

Component/Part	Company (if applicable)	Model (if applicable)	Cost per unit/hours	Quantity	Cost
Re-orientation slide	Custom				
• Materials			$500	4	$2,000.00
• Manufacturing			$100	30	$12,000.00
Buffer and dropping mechanism	Custom				
• Materials			$225	4	$900.00
• Manufacturing			$100	30	$12,000.00
• Stepper motor			$246.65	3	$739.95
Sensors	Omron Industrial Automation	E3H2-DS30C4M-2M	$106.00	3	$318.00
Flat conveyor	Mini Mover Conveyors	LP 40-02144-R-D-P3	$2,295.00	1	$2,295.00
• Bracket (T-slot frame mount)		LP 40-7033	$14.65	6	$87.90
Incline conveyor	Mini Mover Conveyors	LP 42-02079-R-D-P3	$1,781.00	1	$1,781.00
• Leg stand		30-7051-A	$164.12	4	$656.48
• Leg stand		30-7053-A	$164.12	8	$1,312.96
• Cross brace		30-7060	$44.35	7	$310.45
Quick adjust brackets	Mini Mover Conveyors	40-7251	$30.59	20	$611.80
Adjustable side rail	Mini Mover Conveyors	40-7234	$152.04	8	$1,216.32
Check weigher	Ishida Co. Ltd	DACS-G-S015-12/SS-I-S	$15,990.00	1	$15,990.00
• Rejection system attachment		RE-G-015-A2-14/SS-M	$4,775.00	1	$4,775.00
Final alignment conveyor					$0.00
• Short conveyor	Mini Mover Conveyors	LP 40-04018-R-D-P3	$1,347.00	1	$1,347.00
Roll Transfer Mechanism	Custom				
• Materials			100	1	$100.00
• Manufacturing			100	40	$4,000.00
				Total Cost	**$62,441.86**

As seen from TABLE IV, the total cost of all components is $62.441.86, which is much lower than the budget given. Therefore, our final design is within that constraints and can be easily implemented with no budget issues.

2.8 Summary

In order this project to be successful; our system design must meet the given constraints for this project as outlined below:

- Occupy no more than 5’ x 5’ area of floor space
- Output height of 34.75”
- Powered by either electricity or air
- Cost is below $200,000

Evaluating the floor space taken up by our system, we will add up the lengths of each mechanism as outlined below. It should be noted that the floor space requirement occurs after the inclined conveyor, and therefore we will only assume of those items after this conveyor.

- Check weighing machine (41.5 inches L x 26.4 inches W)
- Final Alignment conveyor (18 inches L x 6.3 inches W)
- Roll Transfer Mechanism (6 inches L x 4 inches W)

Therefore the total length, L of the system is 5.46 feet and width, W is 2.2 feet. From this calculation is shown that our system is 0.46 feet longer than the requirement given. Since this requirement was only an initial guide for our team; we deem this length to be acceptable, given that the check weighing machine uses 3.46 feet of that space.

The second constraint our system must meet is the output height of 34.75 inches. In our design, the inclined conveyor raised the coin rolls to a height of 38.75 inches and the roll transfer mechanism outputs the rolls at 34.75 inches from the ground. Therefore, our system complies with this requirement

The next requirement of our system is the power source. Since all of our components utilize electricity, this requirement is met.

Lastly, our system must be fall into a budget of under $200,000. From the cost analysis in Section 2.7, our system cost is $62.441.86. This cost does not include development for prototype designs and implementation costs. Given that our cost falls $137,558.14 below the given budget, it is reasonable to assume that the total cost will not exceed $200,000.

3. Conclusion

In conclusion, our coin roll check weighing design utilized commercially available components and prototype designs. This design satisfies each of the system needs, specification, and constraints. The components used for this system include a re-orientation slide, buffer drop mechanism, photoelectric sensors, conveyors, check weighing & rejection system and a roll transfer mechanism. A cost analysis of each of these mechanisms was performed and the overall budget was not exceeded. It was noted that the cost analysis performed did not include development and implementation costs.

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Appendix A – Concept Screening and Analysis

From the brainstormed ideas we gathered, the analysis and selection process of the final design consisted of three steps. An initial screening process (1) which evaluated all the brainstormed ideas, an elimination process (2) that rejected infeasible or redundant ideas, and a concept selection process (3) that weighed each selection criteria according to its relative importance and ranked each concept relative to each one another.

For a better understanding of the brainstorming concepts considered, the following is a list and brief description of each idea considered, based on the need criteria:

<u>Count coins accurately:</u>

- Strain gage based load cell: check number of coins in a roll by weighing rolls using a strain gage based load cell
- X-ray: check the coin rolls for the right amount of coins by using x-ray scanners to analyze pictures of the rolls possibly by a computer
- Weigh final package: checking coin rolls weight accuracy by weighing box of coin rolls before dispatch
- Weighing in series: weighing scales will be in a series configuration offering better accuracy
- Weighing in parallel: weighing scales will be in a parallel configuration to slow down the rate of input being weighed. This would be beneficial so that the weighing scale is not "rushed" and could provide more accurate readings
- Buffer conveyor: an extended conveyor at the end of the roll wrapping machine to delay dropping of coin rolls onto the conveyor to ultimately steady or control the output of the system
- Pulse conveyor scale: sensors used on the sides of the conveyor cause it to start or stop depending on whether the weighing scale is weighing an item
- Continuous conveyor scale: an in-motion check weigher that weighs coin rolls as it passes over the scale

Ensures operator safety:

- No sharp edges sticking out
- Move weighing scale upstream
- Light curtains: light sensors will enclose the system such that when the light beam is interrupted, the system will shut off
- Plexiglas with magnetic switches: Plexiglas with magnetic switches will enclose the system. Once the magnetic switches lose connection, system will shut off
- Thermal sensor: senses thermal body heat near the system and shuts off the system
- Closed glass: Whole system will be enclosed with glass
- Emergency button: place emergency buttons at strategic locations near the system
- Seclude the weighing apparatus
- Two buttons start-up: requires both hands of the operator to start up ensuring hands are in safe place before machine starts
- Lock-out/Tag out pad locks: physically locks the machine when not in use ensuring it will not be operated when maintenance is being performed

Ensuring minimum downtime:

- Highly reliable robotics: use robotics for most processes since they are reliable
- Decrease rate: separate streams of coins into two/parallel setups
- Machine fault sensors: computerized diagnostic system that tells the operator which sensor has been tripped. Operator can then fix problem area
- Two track system: adding to the “decrease rate” idea, one stream of coins will be able to run independently of the other to ensure the process can keep on running
- Extra scales: keeping an extra scale nearby for quick replacement in-case the current one breaks down
- Extra parts: keeping extra parts nearby for quick replacement in case any part breaks
- Operator training: suggest proper operator training to ensure machine will be running properly
- Recalibrate system and scale before each shift

Track coin roll throughput:

- Embedded counter: weighing scale/X-ray apparatus/software will have a built-in counter
- Optical sensor: an optical sensor will be placed after the rejection system such that as a coin roll passes it will break the light beam and signal a counter
- Mechanical counters: mechanically actuated counters that rotate and count as each coin roll passes by
- Software built in counter: similar to embedded counter but within the software instead
- Sensors integrated in scale: sensors mentioned in pulse system can have an additional feature to count coin rolls as well
- Barcode: use barcode to scan before and after weighing to keep track of coin roll throughput

Accommodate different roll sizes:

- Modifiable database with all dimensions: software can be inputted with individual dimensions of coin rolls such that part of the process can be automatically adjusted (ie. the check weigher)
- Robotic grippers wide enough for widest roll: in order to accommodate different sized rolls using robotic arms, they should be wide enough to accommodate the largest roll
- Orienting funnel to accommodate all roll sizes: if orienting funnel is to be used, funnel must accommodate all roll sizes

Align rolls to prepare for final packaging:

- Turntable: will rotate coin at 90 degree angle to the tiling machine assuming all rolls are aligned the same way already
- Aligning conveyor: long conveyor with strategically placed guides to reorient rolls
- ABB robotics: robotics will pick and place rolls to re-orient them
- Grooves with vibrating conveyor: vibrating motion will cause coin rolls to fall into aligned grooves
- Conveyor guides: conveyor with guides to “force” rolls into alignment
- Funnel with vibration cells: adding vibration to orientation funnel if implemented to ensure no rolls get stuck

- Piling system with conveyor slot: all rolls will be piled against a wall pushing other rolls into a small cut out on the wall where it can only pass if it is at the right orientation
- Roll pin conveyor: conveyor with rolls than move similar to a chain. Roll would maintain orientation while in the grooves between rollers
- Robotics with camera: robotics will process the current state of orientation through cameras and calculate necessary actions to orient it in proper position

Implement a rejection system for faulty rolls:

- Compact version of old system: utilizes similar design as old system but make it more compact to avoid tripping hazards and rid its negative outcomes
- Slide programmable actuator: actuated slide that redirect roll to different area
- Balance system: a mechanism that tips to one side when weight is not satisfied so that the coin roll can roll off
- Trap door: built in trap door within the conveyor
- Robotics: robotic arm picks up bad rolls and puts them aside
- Paddle rejection system: a paddle pushes the faulty coin rolls off the weighing scale and conveyor system

Change over between batch runs quickly:

- Computer with database with all coin sizes specified
- Punch cards: punch cards programmed for each different batches of coin rolls can be “punched” in to modify current settings of the system
- Barcode scan: similar to punch cards but uses a print-out barcode instead of punch cards
- RF ID tag: tag changes machine operation when near machine
- User selects predefined setup on computer interface: if modifiable database is used then it should be able to program pre-sets on the software so it is easily accessible for next batch
- Coin operated machine: a machine will be defined such that when coin is put into a slot, the machine will weigh and measure it and program the system according to these measurements. Similarities to a drink machine

<u>Allows access for maintenance and repair:</u>

- Use space carefully and use small equipment
- Access panels
- Links to safety switches
- Light curtains will allow full access: if light curtains are used, the setup will be very open for maintenance and repair
- Key components at waist height: this allows key components that may need to get replaced or repaired easily accessible
- Components easily disassembled: if cleaning is required inside the system, maintenance personnel can easily access by disassembly

<u>Allow for relocation between two machines (aspect was eliminated from the system after the conceptual design process):</u>

- locking wheels: caster wheels that can be locked and unlocked
- Forklift certified: system can be moved via a forklift
- Jack underneath machine: hydraulic jack under machine that raised machine and allows wheels to be deployed
- Self-powered moving system: cell is motorized and can move to different area
- Wheels
- Good structural integrity or easily disassembled: allows operators to handle equipment easily without it falling apart

<u>Applied date and shift number to rolls (aspect was eliminated from the system after the conceptual design process):</u>

- Attach separate printer after paper roll: printer print date and shift number onto the coin roll wrapper roll as machine is wrapping coins
- Conveyor guides coin rolls to a label applicator
- Label applicator that puts label anywhere on roll
- High speed stamping machine with ink pad
- Coin rolls roll over a label applicator

- Robotic print heads (qualified rolls, printed and aligned): Robotic arms print onto rolls and also realign at the same time
- Robotic arm picks up rolls and other robotic arm prints on roll

To organize which concepts were feasible within the need criteria and constraints, a screening chart was used to analyze each brainstormed solution based on its effect on each system objective and constraint. Each concept was given either a '1' for positive effect, '-1' for negative effect, or '0' for no effect relative to its corresponding selection criteria. These values were then summed and compared within each concept grouping to observe whether the concept produced either a positive, negative or neutral effect as a whole. Our group decided it would be beneficial for everyone to fill out a screening matrix independently and later compare within the group. By doing this, each person developed independent observations of how each concept affects the need criteria and constraints. These observations were then totalled and discussed within the group. The following tables are the initial screening matrices of each team member.

Initial Screening Matrix - Chris

			Counts coins accurately							
		Selection Criteria	Strain gauge based load cell	X-Ray	Weigh Final package	Weighing in Series	Weighing in Parallel	Buffer conveyor	Conveyor scale: pulse	Conveyor scale: continuous
1	**Needs**	Count coins accurately	1	1	-1	1	1	1	1	1
2		Ensure operators safety	0	-1	1	0	0	0	0	0
3		Ensure minimum down-time during batch ru	1	0	1	1	1	0	1	1
4		Tracks coin roll throughput	0	1	0	1	0	0	0	0
5		Accommodate different roll sizes	1	1	0	1	1	1	1	1
6		Align rolls to prepare for final packaging	0	0	0	0	0	0	0	0
7		Implements a rejection system for faulty ro	1	0	-1	-1	-1	0	0	0
8		Change over between batch runs quickly	0	1	0	0	0	0	0	0
9		Allows access for maintenance and repair	0	0	0	0	0	0	0	0
10		Allows for relocation between two machines	1	1	0	0	0	0	0	0
11		Applies date and shift number to rolls	0	0	0	0	0	0	0	0
12	**Constraints**	cost	1	-1	1	-1	-1	-1	0	0
13		size / output size	1	1	1	1	1	0	1	1
14		power	1	1	1	1	1	1	1	1
15		**Number of 1's**	8	7	5	6	5	3	5	5
16		**Number of 0's**	6	5	7	6	7	10	9	9
17		**Number of -1's**	0	2	2	2	2	1	0	0
18		**Total Score**	8	5	3	4	3	2	5	5

Initial Screening Matrix - Chris

	Ensure operators safety									Ensure minimum down-time during batch runs							
	No sharp edges sticking out	Move weighing scale upstream	Light curtains	Plexiglas panel with magnetic switches	Thermal sensor	Closed glass	Emergency button	Seclude the weighing apparatus	Two buttons for start-up	Highly reliable robotics	Decrease rate (separating stream of coins into 2)	Machine fault sensors	Two track system (individual track shut down)	Extra scales	Extra parts	Operator training	Recalibrate system and scale before each shift
1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	1	1	0	0	-1	0	0	1	0
3	0	0	1	-1	1	-1	1	-1	1	1	1	1	1	1	1	1	-1
4	0	-1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	-1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
7	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	-1
9	0	0	1	1	1	-1	1	1	1	0	0	0	1	1	1	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	1	-1	-1	-1	1	1	-1	1	-1	1	0	-1	1	1	1	0
13	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
14	0	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0
15	1	4	5	4	5	4	7	4	6	7	5	2	4	3	3	5	0
16	13	7	8	8	8	8	7	8	8	6	9	12	8	11	11	9	12
17	0	3	1	2	1	2	0	2	0	1	0	0	2	0	0	0	2
18	1	1	4	2	4	2	7	2	6	6	5	2	2	3	3	5	-2

Initial Screening Matrix - Chris

	Track coin roll throughput						Accommodate different roll sizes			
	Embed counter in strain gauge or X-ray	Optical sensors (sensor beam - transmitter and receiver)	Mechanical Counters	Software built in counter	Sensors integrated with the scale	Barcode on printing paper (scan before and after process)	Modifiable database with all dimensions	Robotic grippers wide enough for widest roll	Programmable scale and robotic arms	Orienting funnel accommodating all roll sizes
1	1	1	-1	1	1	1	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0
3	1	-1	-1	1	1	1	1	0	1	0
4	1	1	1	1	1	1	0	0	0	0
5	1	1	-1	1	1	0	1	1	1	1
6	0	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0	0	0	0	0
8	1	0	0	1	1	1	1	0	1	0
9	-1	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	1	-1	1	1	-1	1	1	1	1	0
13	1	0	0	0	0	0	0	0	0	0
14	1	1	0	1	0	0	0	0	0	0
15	9	4	2	7	5	5	4	2	4	2
16	4	8	9	7	8	9	10	12	10	12
17	1	2	3	0	1	0	0	0	0	0
18	8	2	-1	7	4	5	4	2	4	2

Initial Screening Matrix - Chris

	Align rolls to prepare for final packaging									Implements a rejection system for faulty rolls					
	Turn table to rotate coin roll to the edge in correct orientation	Aligning conveyor	ABB robotics	Grooves in vibrating conveyor	Conveyor guides	Funnel with vibration cells	Piling system with conveyor slot	Roll pin conveyor	Robotics with camera	Compact system with conveyor for rejected coin rolls (similar to previous system)	Programmable actuator (slide)	Balance system (tips if weight is not satisfied)	Trap door	Robotic arm that picks rolls away	Paddle rejection system
1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	1	-1
3	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0
4	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0
5	1	1	1	-1	1	1	-1	1	1	-1	1	-1	1	1	1
6	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	-1	0	-1	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	-1	1	-1	-1	0	1	-1	1	1	1	1	-1	1
13	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	5	5	5	4	4	4	2	5	6	3	4	3	4	7	4
16	8	8	7	8	8	8	10	8	7	8	9	7	9	6	9
17	1	1	2	2	2	2	2	1	1	3	1	4	1	1	1
18	4	4	3	2	2	2	0	4	5	0	3	-1	3	6	3

Initial Screening Matrix - Chris

	Change over between batch runs quickly						Allows access for maintenance and repair							
	Computer with database with all coin sizes specified	Punch cards	Bar code scan for each batch of coins	RF ID approximate tag	User selects predefined setup on computer interface	Coin operated machine (weighs and measures)	Use space carefully and use small equipment	Access panels	Links to safety switches	Light curtains will allow full access	Key components are at waist height	Robotics with very little maintenance	Lock out / Tag out pad locks	Very easy to disassemble parts
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	0	1	-1	1	1	1	1	1	1	1	1
3	1	0	1	1	1	-1	0	0	0	1	0	1	0	1
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	1	1	-1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	1	1	1	1	1	1	1	1
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	1	-1	1	1	1	1	-1	-1	1	-1	1	1
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	4	2	4	2	4	1	3	3	2	4	3	3	3	4
16	10	12	10	11	10	10	11	11	11	9	11	10	11	10
17	0	0	0	1	0	3	0	0	1	1	0	1	0	0
18	4	2	4	1	4	-2	3	3	1	3	3	2	3	4

Initial Screening Matrix - Chris

	Allows for relocation between two machines						Applies date and shift number to rolls							
	Locking wheels	Forklift certified	Jack underneath machine (raises machine and deploys wheels)	Self powered moving system	Wheels	Good structural integrity or easily disassemble	Attach separate printer after paper roll	Conveyor guides rolls to label applicator	Label applicator which puts label anywhere	High speed stamping machine with ink pad	Rolls roll over top of a label applicator	Stamping machine if all rolls are in same orientation	Robotic print heads (qualified rolls, printed and aligned)	Robotic arm picks up rolls and other robotic arm prints on roll
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	-1	-1	-1	1	-1	1	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	1	1	1	1	-1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
12	1	1	0	-1	1	1	-1	1	-1	1	1	0	-1	-1
13	1	1	1	1	1	1	-1	-1	-1	0	1	0	0	-1
14	0	0	0	-1	0	0	1	0	1	1	1	1	1	1
15	3	3	2	3	3	4	3	3	3	4	5	2	4	3
16	10	10	11	9	10	10	9	10	9	10	9	11	9	9
17	1	1	1	2	1	0	2	1	2	0	0	1	1	2
18	2	2	1	1	2	4	1	2	1	4	5	1	3	1

Initial Screening Matrix - Gelleen

		Selection Criteria	Counts coins accurately							
			Strain gauge based load cell	X-Ray	Weigh Final package	Weighing in Series	Weighing in Parallel	Buffer conveyor	Conveyor scale: pulse	Conveyor scale: continuous
1	Needs	Count coins accurately	1	1	0	1	1	1	1	1
2		Ensure operators safety	0	0	-1	0	0	0	1	-1
3		Ensure minimum down-time during batch ru	0	0	0	0	1	1	0	0
4		Tracks coin roll throughput	0	0	0	0	0	1	1	0
5		Accommodate different roll sizes	1	1	1	1	1	1	1	1
6		Align rolls to prepare for final packaging	0	0	0	0	0	1	0	0
7		Implements a rejection system for faulty ro	0	0	-1	0	0	0	0	0
8		Change over between batch runs quickly	0	0	1	0	0	0	0	0
9		Allows access for maintenance and repair	0	0	0	0	0	0	0	0
10		Allows for relocation between two machines	0	0	1	0	0	0	0	0
11		Applies date and shift number to rolls	0	0	-1	0	0	1	1	0
12	Constraints	cost	1	0	0	-1	-1	-1	-1	0
13		size / output size	0	0	0	0	-1	0	0	0
14		power	0	0	0	0	0	0	0	0
15		**Number of 1's**	3	2	3	2	3	6	5	2
16		**Number of 0's**	11	12	8	11	9	7	8	11
17		**Number of -1's**	0	0	3	1	2	1	1	1
18		**Total Score**	3	2	0	1	1	5	4	1

	Ensure operators safety									Ensure minimum down-time during batch runs							
	No strain gauge sticking out	Move weighing scale upstream	Light curtains	Plexiglas panel with magnetic switches	Thermal sensor	Closed glass	Emergency button	Seclude the weighing apparatus	Two buttons for start-up	Highly reliable robotics	Decrease rate (separating stream of coins into 2)	Machine fault sensors	Two track system (individual track shut down)	Extra scales	Extra parts	Operator training	Recalibrate system and scale before each shift
1	0	0	0	0	-1	0	0	-1	0	0	1	1	0	1	0	1	1
2	1	1	1	1	1	1	1	1	1	-1	1	1	1	0	0	1	0
3	0	0	0	0	-1	0	0	0	0	1	1	1	1	1	1	1	1
4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	-1
9	0	1	0	0	0	-1	0	0	0	1	0	0	0	1	1	1	0
10	0	1	0	0	0	-1	0	1	0	-1	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
12	0	0	-1	-1	-1	-1	0	0	0	-1	-1	-1	-1	-1	-1	0	0
13	1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0
14	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0
15	2	3	1	1	1	1	1	2	1	7	5	4	2	3	2	5	3
16	12	11	12	12	9	10	13	11	13	4	7	9	11	10	11	9	10
17	0	0	1	1	4	3	0	1	0	3	2	1	1	1	1	0	1
18	2	3	0	0	-3	-2	1	1	1	4	3	3	1	2	1	5	2

Initial Screening Matrix - Gelleen

	Track coin roll throughput						Accommodate different roll sizes			
	Embed counter in strain gauge or X-ray	Optical sensors (sensor beam - transmitter and receiver)	Mechanical Counters	Software built in counter	Sensors integrated with the scale	Barcode on printing paper (scan before and after process)	Modifiable database with all dimensions	Robotic grippers wide enough for widest roll	Programmable scale and robotic arms	Orienting funnel accommodating all roll sizes
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	1	1	0
4	1	1	1	1	1	1	0	0	1	0
5	0	0	0	1	0	0	1	1	1	1
6	0	0	0	0	0	0	0	1	1	1
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	1	0	1	0	0	0	0
9	-1	0	0	0	0	0	0	1	1	0
10	0	0	0	0	0	0	0	-1	-1	0
11	0	0	0	0	0	1	0	1	1	0
12	0	-1	0	-1	-1	-1	0	-1	-1	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	1	1	1	3	1	3	1	5	6	2
16	12	12	13	10	12	10	13	7	6	12
17	1	1	0	1	1	1	0	2	2	0
18	0	0	1	2	0	2	1	3	4	2

	Align rolls to prepare for final packaging									Implements a rejection system for faulty rolls					
	Turn table to rotate coin roll to the edge in correct orientation	Aligning conveyor	ABB robotics	Grooves in vibrating conveyor	Conveyor guides	Funnel with vibration cells	Piling system with conveyor slot	Roll pin conveyor	Robotics with camera	Compact system with conveyor for rejected coin rolls (similar to previous system)	Programmable actuator (slide)	Balance system (tips if weight is not satisfied)	Trap door	Robotic arm that picks rolls away	Paddle rejection system
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	-1	-1	0	-1	0	0	-1	0	0	0	0	-1	-1
3	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0
7	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0
12	0	0	-1	-1	-1	-1	1	-1	-1	0	0	0	0	-1	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0		0	0	0	0	0
15	3	3	6	3	3	3	4	3	5	0	1	1	1	5	1
16	11	11	6	9	10	9	10	10	7	13	13	13	13	7	12
17	0	0	2	2	1	2	0	1	2	0	0	0	0	2	1
18	3	3	4	1	2	1	4	2	3	0	1	1	1	3	0

Initial Screening Matrix - Gelleen

	Change over between batch runs quickly						Allows access for maintenance and repair							
	Computer with database with all coin sizes specified	Punch cards	Bar code scan for each batch of coins	RF ID approximate tag	User selects predefined setup on computer interface	Coin operated machine (weighs and measures)	Use space carefully and use small equipment	Access panels	Links to safety switches	Light curtains will allow full access	Key components are at waist height	Robotics with very little maintenance	Lock out / Tag out pad locks	Very easy to disassemble parts
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	1	0	1	0	1	0	0	0
3	0	-1	-1	0	0	-1	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	1	1	1	1	1	0	0	0	0	0	1	0	0
6	0	0	0	0	0	0	0	0	0	0	0	1	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	1	1	1	0	0	0	0	0	0	0	0
9	0	0	0	0		0	1	1	1	1	1	1	1	1
10	0	0	0	0		0	0	0	0	0	0	0	0	1
11	0	0	0	0		0	0	0	0	0	0	0	0	0
12	-1	-1	-1	-1		-1	0	0	0	0	0	-1	0	0
13	0	0	0	0		0	0	0	0	0	0	0	0	0
14	0	0	0	0		0	0	0	0	0	0	0	0	0
15	3	2	2	2	2	2	2	1	2	1	2	3	1	2
16	10	10	10	11	6	10	12	13	12	13	12	10	13	12
17	1	2	2	1	0	2	0	0	0	0	0	1	0	0
18	2	0	0	1	2	0	2	1	2	1	2	2	1	2

Initial Screening Matrix - Gelleen

	Allows for relocation between two machines						Applies date and shift number to rolls							
	Locking wheels	Forklift certified	Jack underneath machine (raises machine and deploys wheels)	Self powered moving system	Wheels	Good structural integrity or easily disassemble	Attach separate printer after paper roll	Conveyor guides rolls to label applicator	Label applicator which puts label anywhere	High speed stamping machine with ink pad	Rolls roll over top of a label applicator	Stamping machine if all rolls are in same orientation	Robotic print heads (qualified rolls, printed and aligned)	Robotic arm picks up rolls and other robotic arm prints on roll
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	-1	0	0	1	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	0	0	0		1	1
10	1	1	1	1	1	1	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
12	0	0	-1	-1	0	0	-1	0	-1	-1	0	-1	-1	-1
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	2	1	1	1	3	2	2	2	2	2	2	4	4
16	12	12	11	12	13	11	11	12	11	11	12	10	9	9
17	0	0	2	1	0	0	1	0	1	1	0	1	1	1
18	2	2	-1	0	1	3	1	2	1	1	2	1	3	3

Initial Screening Matrix - Kevin

			Counts coins accurately							
		Selection Criteria	Strain gauge	X-Ray	Weigh Final package	Weighing in Series	Weighing in Parallel	Buffer conveyor	Conveyor scale: pulse	Conveyor scale: continuous
1	**Needs**	Count coins accurately	1	1	-1	1	1	1	1	1
2		Ensure operators safety	1	-1	1	0	0	-1	-1	1
3		Ensure minimum down-time during batch ru	1	1	1	-1	1	-1	1	-1
4		Tracks coin roll throughput	1	1	0	0	0	0	0	0
5		Accommodate different roll sizes	1	1	1	1	1	1	1	1
6		Align rolls to prepare for final packaging	0	0	0	0	0	0	0	0
7		Implements a rejection system for faulty ro	0	0	-1	-1	0	0	0	0
8		Change over between batch runs quickly	1	1	1	0	0	-1	0	0
9		Allows access for maintenance and repair	0	-1	0	0	0	1	0	0
10		Allows for relocation between two machines	0	-1	-1	0	0	-1	0	0
11		Applies date and shift number to rolls	0	0	0	0	0	0	0	0
12	**Constraints**	cost	1	-1	1	-1	-1	-1	0	0
13		size / output size	1	-1	1	-1	-1	-1	0	0
14		power	1	1	1	1	1	1	1	1
15		**Number of 1's**	9	6	7	3	4	4	4	4
16		**Number of 0's**	5	3	4	7	8	4	9	9
17		**Number of -1's**	0	5	3	4	2	6	1	1
18		**Total Score**	9	1	4	-1	2	-2	3	3

Initial Screening Matrix - Kevin

	Ensure operators safety									Ensure minimum down-time during batch runs							
	No strain gauge sticking out	Move weighing scale upstream	Light curtains	Plexiglas panel with magnetic switches	Thermal sensor	Closed glass	Emergency button	Seclude the weighing apparatus	Two buttons for start-up	Highly reliable robotics	Decrease rate (separating stream of coins into 2)	Machine fault sensors	Two track system (individual track shut down)	Extra scales	Extra parts	Operator training	Recalibrate system and scale before each shift
1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	1
2	1	1	1	1	-1	-1	1	1	1	0	1	1	-1	0	0	1	1
3	-1	0	0	0	0	0	0	-1	0	1	-1	1	1	1	1	1	1
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
6	0	-1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1
7	0	-1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	-1
8	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	-1
9	1	1	1	1	1	-1	0	-1	0	0	-1	-1	1	1	1	1	0
10	0	1	-1	1	1	-1	0	0	0	0	-1	-1	-1	1	1	1	1
11	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	1	-1	-1	1	0	0	0	-1	-1	0	-1	-1	-1	-1	0
13	0	-1	-1	1	-1	1	1	-1	1	1	-1	0	-1	0	0	0	0
14	0	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	0
15	2	3	4	4	3	2	3	1	3	6	5	4	7	7	5	7	6
16	11	7	8	9	8	9	11	10	11	7	4	8	3	6	8	6	6
17	1	4	2	1	3	3	0	3	0	1	5	2	4	1	1	1	2
18	1	-1	2	3	0	-1	3	-2	3	5	0	2	3	6	4	6	4

Initial Screening Matrix - Kevin

	Track coin roll throughput						Accommodate different roll sizes			
	Embed counter in strain gauge or X-ray	Optical sensors (sensor beam - transmitter and receiver)	Mechanical Counters	Software built in counter	Sensors integrated with the scale	Barcode on printing paper (scan before and after process)	Modifiable database with all dimensions	Robotic grippers wide enough for widest roll	Programmable scale and robotic arms	Orienting funnel accommodating all roll sizes
1	1	0	0	0	1	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	-1	0	0	-1	0	0	0	-1
4	1	1	-1	1	1	1	0	0	0	0
5	0	0	-1	0	0	0	1	1	1	1
6	0	0	0	0	0	0	0	1	0	1
7	0	0	0	0	0	0	0	0	0	0
8	1	1	-1	1	1	1	1	1	1	-1
9	-1	1	1	1	-1	1	1	1	1	-1
10	0	-1	1	1	0	1	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	-1	0	-1	-1	-1
13	1	0	-1	0	0	-1	0	0	0	-1
14	1	1	0	1	1	1	1	1	1	0
15	5	4	2	5	4	5	4	5	4	2
16	8	9	7	9	9	6	10	8	9	7
17	1	1	5	0	1	3	0	1	1	5
18	4	3	-3	5	3	2	4	4	3	-3

	Align rolls to prepare for final packaging									Implements a rejection system for faulty rolls					
	Turn table to rotate coin roll to the edge in correct orientation	Aligning conveyor	ABB robotics	Grooves in vibrating conveyor	Conveyor guides	Funnel with vibration cells	Piling system with conveyor slot	Roll pin conveyor	Robotics with camera	Compact system with conveyor for rejected coin rolls (similar to previous system)	Programmable actuator (slide)	Balance system (tips if weight is not satisfied)	Trap door	Robotic arm that picks rolls away	Paddle rejection system
1	0	0	0	-1	0	-1	0	0	0	-1	0	-1	0	0	0
2	-1	0	0	0	0	-1	-1	-1	0	-1	0	1	-1	0	0
3	-1	0	1	-1	0	-1	-1	0	1	-1	1	-1	1	1	1
4	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0
5	1	1	1	-1	1	1	1	1	1	1	1	-1	1	1	1
6	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1
7	0	0	0	0	0	0	0	0	0	-1	1	-1	1	-1	1
8	0	1	1	1	1	1	-1	1	1	0	0	-1	0	0	0
9	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1
10	0	-1	1	-1	-1	1	1	-1	1	-1	1	-1	1	1	1
11	0		0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	-1	1	1	1	1	1	-1	0	0	0	0	-1	0
13	0	-1	1	-1	-1	-1	-1	-1	1	-1	1	1	1	1	1
14	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
15	5	5	8	5	4	6	5	6	8	4	8	4	8	7	8
16	7	6	5	4	8	4	5	5	5	3	6	3	5	5	6
17	2	2	1	5	2	4	4	3	1	7	0	7	1	2	0
18	3	3	7	0	2	2	1	3	7	-3	8	-3	7	5	8

Initial Screening Matrix - Kevin

	Change over between batch runs quickly						Allows access for maintenance and repair							
	Computer with database with all coin sizes specified	Punch cards	Bar code scan for each batch of coins	RF ID approximate tag	User selects predefined setup on computer interface	Coin operated machine (weighs and measures)	Use space carefully and use small equipment	Access panels	Links to safety switches	Light curtains will allow full access	Key components are at waist height	Robotics with very little maintenance	Lock out / Tag out pad locks	Very easy to disassemble parts
1	0	0	0	0	0	0	-1	0	0	0	0	1	0	0
2	0	0	0	0	0	0	-1	1	1	1	1	0	1	1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	1	-1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	-1	0	0	0	0	1	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	-1	1	1	1	-1	-1	1	0	0	1	1	1	1
9	1	-1	1	1	1	-1	-1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	-1	1	1	1	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	-1	-1	1	-1	-1	1	1	-1	1	-1	1	1
13	1	-1	1	1	1	-1	1	1	1	-1	1	1	1	1
14	1	1	1	1	1	1	0	0	1	1	0	1	0	-1
15	6	3	5	5	6	3	2	6	6	3	6	7	6	6
16	8	8	8	8	8	7	5	8	8	8	8	6	8	7
17	0	3	1	1	0	4	7	0	0	3	0	1	0	1
18	6	0	4	4	6	-1	-5	6	6	0	6	6	6	5

Initial Screening Matrix - Kevin

	Allows for relocation between two machines						Applies date and shift number to rolls							
	Locking wheels	Forklift certified	Jack underneath machine (raises machine and deploys wheels)	Self powered moving system	Wheels	Good structural integrity or easily disassemble	Attach separate printer after paper roll	Conveyor guides rolls to label applicator	Label applicator which puts label anywhere	High speed stamping machine with ink pad	Rolls roll over top of a label applicator	Stamping machine if all rolls are in same orientation	Robotic print heads (qualified rolls, printed and aligned)	Robotic arm picks up rolls and other robotic arm prints on roll
1	-1	0	0	0	-1	1	0	0	0	-1	0	-1	0	0
2	-1	0	0	0	-1	1	-1	0	0	-1	0	-1	0	0
3	0	0	0	0	0	0	-1	1	1	1	1	1	1	-1
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	1	0	0	-1	1	-1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	-1	-1	1	1	-1	1	1	1	-1	1	1	1
10	1	1	1	1	1	1	-1	1	1	-1	1	-1	0	0
11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
12	1	1	0	-1	1	-1	1	1	1	0	1	0	-1	-1
13	1	1	1	-1	1	-1	-1	-1	1	0	-1	0	-1	-1
14	0	0	0	-1	0	0	1	0	1	1	1	1	1	1
15	4	4	2	1	4	4	4	5	7	4	6	4	5	4
16	8	10	11	9	8	8	5	8	7	6	6	6	7	7
17	2	0	1	4	2	2	5	1	0	4	2	4	2	3
18	2	4	1	-3	2	2	-1	4	7	0	4	0	3	1

Initial Screening Matrix - Shadi

			Counts coins accurately							
		Selection Criteria	Strain gauge	X-Ray	Weigh Final package	Weighing in Series	Weighing in Parallel	Buffer conveyor	Conveyor scale: pulse	Conveyor scale: continuous
1	**Needs**	Count coins accurately	1	1	1	1	0	1	1	0
2		Ensure operators safety	0	0	0	0	0	0	0	0
3		Ensure minimum down-time during batch ru	0	0	0	0	0	1	0	0
4		Tracks coin roll throughput	0	0	0	0	0	1	1	0
5		Accommodate different roll sizes	0	0	0	0	0	0	0	0
6		Align rolls to prepare for final packaging	0	0	0	0	0	1	0	0
7		Implements a rejection system for faulty ro	0	0	-1	0	0	0	0	0
8		Change over between batch runs quickly	0	0	1	0	0	0	0	0
9		Allows access for maintenance and repair	0	0	0	0	0	0	0	0
10		Allows for relocation between two machines	0	0	1	0	0	0	0	0
11		Applies date and shift number to rolls	0	0	-1	0	0	1	1	0
12	**Constraints**	cost	1	0	0	-1	-1	-1	-1	0
13		size / output size	0	0	0	0	-1	0	0	0
14		power	0	0	0	0	0	0	0	0
15		**Number of 1's**	2	1	3	1	0	5	3	0
16		**Number of 0's**	12	13	9	12	12	8	10	14
17		**Number of -1's**	0	0	2	1	2	1	1	0
18		**Total Score**	2	1	1	0	-2	4	2	0

Initial Screening Matrix - Shadi

	Ensure operators safety									Ensure minimum down-time during batch runs							
	No strain gauge sticking out	Move weighing scale upstream	Light curtains	Plexiglas panel with magnetic switches	Thermal sensor	Closed glass	Emergency button	Seclude the weighing apparatus	Two buttons for start-up	Highly reliable robotics	Decrease rate (separating stream of coins into 2)	Machine fault sensors	Two track system (individual track shut down)	Extra scales	Extra parts	Operator training	Recalibrate system and scale before each shift
1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
3	1	1	0	0	0	-1	1	0	0	0	0	1	1	1	1	1	1
4	0	0	0	0	0	0	0	0	0		1	1	1	1	0	0	1
5	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
6	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1
8	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	1	1
9	0	1	-1	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	-1	-1	0	0	0	0	-1	-1	-1	-1	-1	0	0	0
13	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	4	1	1	1	1	2	2	1	6	6	5	6	6	3	5	6
16	11	10	12	12	12	11	12	11	13	6	7	8	6	6	11	9	8
17	0	0	1	1	1	2	0	1	0	1	1	1	2	2	0	0	0
18	3	4	0	0	0	-1	2	1	1	5	5	4	4	4	3	5	6

Initial Screening Matrix - Shadi

	Track coin roll throughput						Accommodate different roll sizes			
	Embed counter in strain gauge or X-ray	Optical sensors (sensor beam - transmitter and receiver)	Mechanical Counters	Software built in counter	Sensors integrated with the scale	Barcode on printing paper (scan before and after process)	Modifiable database with all dimensions	Robotic grippers wide enough for widest roll	Programmable scale and robotic arms	Orienting funnel accommodating all roll sizes
1	1	1	1	1	1	0	1	1	1	0
2	0	0	0	0	1	0	0	1	1	0
3	1	1	1	1	1	1	1	0	0	-1
4	1	1	1	1	1	1	1	1	1	0
5	0	0	0	1	0	0	1	1	1	1
6	0	0	0	0	0	0	0	0	1	1
7	1	1	0	1	1	0	1	1	1	0
8	1	0	1	1	0	0	1	1	1	1
9	0	0	0	0	0	0	0	0	-1	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	-1	1	0	-1	-1	0	-1	0	0
13	0	0	0	1	1	1	1	0	0	-1
14	0	0	0	0	0	0	0	0	0	0
15	5	4	5	7	6	3	7	6	7	3
16	9	9	9	7	7	10	7	7	6	9
17	0	1	0	0	1	1	0	1	1	2
18	5	3	5	7	5	2	7	5	6	1

Initial Screening Matrix - Shadi

	Align rolls to prepare for final packaging									Implements a rejection system for faulty rolls					
	Turn table to rotate coin roll to the edge in correct orientation	Aligning conveyor	ABB robotics	Grooves in vibrating conveyor	Conveyor guides	Funnel with vibration cells	Piling system with conveyor slot	Roll pin conveyor	Robotics with camera	Compact system with conveyor for rejected coin rolls (similar to previous system)	Programmable actuator (slide)	Balance system (tips if weight is not satisfied)	Trap door	Robotic arm that picks rolls away	Paddle rejection system
1	0	0	1	0	0	0	0	0	1	1	0	1	0	1	0
2	-1	0	1	0	0	0	0	0	1	1	1	1	1	-1	0
3	0	0	1	0	-1	0	0	0	0	0	1	1	0	1	1
4	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0
5	0	1	1	1	1	1	0	1	0	1	1	0	0	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0	1	0	0	0	0	0	0	1	0	0	1	0	1	1
8	1	1	1	0	0	0	-1	0	1	1	0	0	-1	0	0
9	1	1	-1	1	1	1	0	0	-1	-1	-1	1	1	-1	0
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	-1	0	-1	-1	0	0	-1	-1	-1	0	0	-1	0
13	0	-1	0	0	-1	-1	-1	0	0	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	5	6	3	3	3	1	2	6	8	5	6	3	6	4
16	10	8	6	11	8	9	11	12	6	4	7	8	10	5	10
17	1	1	2	0	3	2	2	0	2	2	2	0	1	3	0
18	2	4	4	3	0	1	-1	2	4	6	3	6	2	3	4

	Change over between batch runs quickly						Allows access for maintenance and repair							
	Computer with database with all coin sizes specified	Punch cards	Bar code scan for each batch of coins	RF ID approximate tag	User selects predefined setup on computer interface	Coin operated machine (weighs and measures)	Use space carefully and use small equipment	Access panels	Links to safety switches	Light curtains will allow full access	Key components are at waist height	Robotics with very little maintenance	Lock out / Tag out pad locks	Very easy to disassemble parts
1	1	0	1	0	1	0	0	0	0	0	0	1	0	0
2	1	0	0	0	1	0	1	1	1	1	1	1	1	1
3	0	1	1	1	1	0	1	1	1	0	1	1	1	1
4	1	0	1	1	1	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	-1	0	0	0	0	0	0	0
6	1	1	1	1	1	1	0	0	0	0	0	0	0	0
7	1	0	1	0	0	1	-1	0	0	0	0	1	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-1	0	-1	-1	0	0	1	1	1	1	1	1	1	1
10	0	0	0	0	0	0	0	1	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	-1	1	-1	-1	0	1	0	0	0	0	0	-1	0	0
13	0	0	0	0	0	0	1	1	0	0	1	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	7	3	5	3	5	3	4	5	3	2	4	5	3	5
16	5	11	7	9	9	11	8	9	11	12	10	8	11	9
17	2	0	2	2	0	0	2	0	0	0	0	1	0	0
18	5	3	3	1	5	3	2	5	3	2	4	4	3	5

	Allows for relocation between two machines						Applies date and shift number to rolls							
	Locking wheels	Forklift certified	Jack underneath machine (raises machine and deploys wheels)	Self powered moving system	Wheels	Good structural integrity or easily disassemble	Attach separate printer after paper roll	Conveyor guides rolls to label applicator	Label applicator which puts label anywhere	High speed stamping machine with ink pad	Rolls roll over top of a label applicator	Stamping machine if all rolls are in same orientation	Robotic print heads (qualified rolls, printed and aligned)	Robotic arm picks up rolls and other robotic arm prints on roll
1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2	1	1	0	1	1	1	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	1	0	0	0	1	1	1	0
5	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	1	1	1	0	1	0	0	0	0	0	0	0
10	1	1	1	1	1	1	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	1	1	1	1	1	1	1	1
12	1	-1	1	-1	1	-1	-1	0	-1	-1	1	1	0	-1
13	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	5	3	3	3	4	2	3	1	2	1	3	3	3	3
16	9	10	11	10	10	11	9	13	11	12	11	11	11	10
17	0	1	0	1	0	1	2	0	1	1	0	0	0	1
18	5	2	3	2	4	1	1	1	1	0	3	3	3	2

This following tables shows the results of the ranking and the eliminated concepts which are shaded in blue. The elimination of some ideas were based on two observations, one basis is that certain concepts received low scores by each team member in the initial screening process. The other observation is the redundancies in ideas within need criterions and these ideas were therefore eliminated. Other variations of certain ideas were explored in the process later on of choosing a final design where every design detail was examined.

Elimination Matrix

Counts coins accurately									
Team Member	Stain gauge based load cell	X-Ray	Weight Final package	Series	Parallel	Buffer conveyor	Conveyor scale: pulse	Conveyor scale: continuous
Gelleen	2	1	1	0	-2	4	2	0
Chris	8	5	3	4	3	2	5	5
Kevin	3	2	0	1	1	5	4	1
Shadi	9	1	4	-1	2	-2	3	3
Total	22	9	8	4	4	9	14	9

Ensure operators safety									
Team Member	sticking out	Move upstream / seclude	Light curtains	Plexiglas s	Thermal sensor	Close glass	Emergency button	Seclude	Two buttons
Gelleen	3	4	0	0	0	-1	2	1	1
Chris	1	1	4	2	4	2	7	2	6
Kevin	2	3	0	0	-3	-2	1	1	1
Shadi	1	-1	2	3	0	-1	3	-2	3
Total	7	7	6	5	1	-2	13	2	11

Highlighted concepts were eliminated.

Ensure minimum down-time during batch runs								
Team Member	robotics	Decrease rate	Machine fault sensors	Two track sys	Extra scales	Extra parts	Operator training	Recalibration after each shift
Gelleen	5	5	4	4	4	3	5	6
Chris	6	5	2	2	3	3	5	-2
Kevin	4	3	3	1	2	1	5	2
Shadi	5	0	2	3	6	4	6	4
Total	20	13	11	10	15	11	21	10

Track coin roll throughout						
Team Member	Embeded counter	Optical sensors - separate device	Mechanical Counters	Software counter	Sensor integration	Barcode on printing
Gelleen	5	3	5	7	5	2
Chris	8	2	-1	7	4	5
Kevin	0	0	1	2	0	2
Shadi	4	3	-3	5	3	2
Total	17	8	2	21	12	11

Accommodate different roll sizes				
Team Member	Modifiable DB	Robotic grippers	Programable scale	Orienting funnel
Gelleen	7	5	6	1
Chris	4	2	4	2
Kevin	1	3	4	2
Shadi	4	4	3	-3
Total	16	14	17	2

Align rolls to prepare for final packaging									
Team Member	Turn table	Aligning conveyor (before weighing)	ABB robotics	Grooved conveyor	Conveyor guides (after weighing)	Funnel with vibration cells	Pilling system	Roll pin conveyor	Robotics with camera
Gelleen	2	4	4	3	0	1	-1	2	4
Chris	4	4	3	2	2	2	0	4	5
Kevin	3	3	4	1	2	1	4	2	3
Shadi	3	3	7	0	2	2	1	3	7
Total	12	14	18	6	6	6	4	11	19

Implements a rejection system for faulty rolls						
Team Member	Compact system (similar to old system)	Programable actuator	Balance system	Trap door	Robotic arm	Paddle rejection
Gelleen	6	3	6	2	3	4
Chris	0	3	-1	3	6	3
Kevin	0	1	1	1	3	0
Shadi	-3	8	-3	7	5	8
Total	3	15	3	13	17	15

Change over between batch runs quickly						
Team Member	Database	Punch cards	Bar code	RF ID	User defined presets	Coin operated
Gelleen	5	3	3	1	5	3
Chris	4	2	4	1	4	-2
Kevin	2	0	0	1	2	0
Shadi	6	0	4	4	6	-1
Total	17	5	11	7	17	0

Allows access for maintenance and repair								
Team Member	small equipments	Access panels	safety switches	Light curtains	waist height	Robotics min maintenace	Lock out / Tag out	easy to disassemble parts
Gelleen	2	5	3	2	4	4	3	5
Chris	3	3	1	3	3	2	3	4
Kevin	2	1	2	1	2	2	1	2
Shadi	-5	6	6	0	6	6	6	5
Total	2	15	12	6	15	14	13	16

Allows for relocation between two machines						
Team Member	Lock in wheels	Forklift certified	Jack underneath	Self powered	Wheels	easily disassemble
Gelleen	5	2	3	2	4	1
Chris	2	2	1	1	2	4
Kevin	2	2	-1	0	1	3
Shadi	2	4	1	-3	2	2
Total	11	10	4	0	9	10

Applies date and shift number to rolls									
Team Member	Attach separate printer after paper roll	Conveyor guides rolls to label applicator	Label applicator which puts label anywhere	High speed stamping machine with ink pad	Rolls roll over top of a label applicator	Stamping machine if all rolls are in same orientation	Robotic print heads (qualified rolls, printed and aligned)	Robotic arm picks up rolls and other robotic arm prints on roll	Imaje printing system
Gelleen	1	1	1	0	3	3	3	2	3
Chris	1	2	1	4	5	1	3	1	5
Kevin	1	2	1	1	2	1	3	3	7
Shadi	-1	4	7	0	4	0	3	1	4
Total	2	9	10	5	14	5	12	7	19

After the screening and elimination process, only feasible concepts were left to be evaluated. In order to efficiently and accurately decide which of the feasible concepts were best suited for the design, a concept selection matrix was used for each need and constraint criteria (selection criteria). This selection matrix allowed us to apply weights to the need criteria and constraints, and then rate each concept relative to one another.

Through weighing the selection criteria, the concept selection matrix scores concepts that are effective at solving high priority needs with a higher net score. For example, a concept that is effective at counting coins, but is unsafe for the operator, will receive a lower net score. Therefore, we assigned weight values to each selection criteria based on its relative importance. See matrix below for each selection criteria weighting

Also, within each selection criteria, each concept was given a ranking of 1, 2, 3, 4, or 5 based on how well it achieves the given selection criteria in relation from one concept to another. This ranking is more effective in comparison to the 1, 0, -1, criteria used earlier in the initial screening process. For example, from the initial screening matrix, we can see that both x-ray and strain gage based load cells are potentially capable of counting coins accurately. However in the matrix below, the strain gage based load cell could receive a 5 because it is capable of counting coins more accurately than x-ray equipment, which would receive a 3.

Concept Selection Matrix

	Selection Criteria	Weight	Strain Gage		X-Ray	
			Rank	Weighted Score	Rank	Weighted Score
1	Count coins accurately	14.60%	5	0.73	3	0.44
2	Ensure operators safety	13.30%	5	0.67	3	0.40
3	Ensure Minimum down-time during batch runs	7.40%	4	0.30	4	0.30
4	Track coin roll throughout	6.40%	5	0.32	2	0.13
5	Accommodate different roll sizes	12.00%	4	0.48	3	0.36
6	Align rolls to prepare for final packaging	8.50%	0	0.00	0	0.00
7	Implements a rejection system for faulty rolls	8.50%	0	0.00	0	0.00
8	Change over between batch runs quickly	4.00%	5	0.20	4	0.16
9	Allows access for maintenance and repair	3.20%	3	0.10	3	0.10
10	Allows for relocation between two machines	1.60%	4	0.06	2	0.03
11	Applies date and shift number to rolls	0.50%	0	0.00	0	0.00
12	Cost	0.30%	5	0.02	1	0.00
13	Size / output size	6.40%	4	0.26	2	0.13
14	Power	13.30%	5	0.67	3	0.40
15		**Net Score**	49	3.79	30	2.44
16		**Rank**	1		2	
17		**Continue?**	Yes		No	

	Light Curtains		Plexiglass	
	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00
2	5	0.67	5	0.67
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	0	0.00	0	0.00
8	0	0.00	0	0.00
9	3	0.10	2	0.06
10	2	0.03	3	0.05
11	0	0.00	0	0.00
12	2	0.01	4	0.01
13	2	0.13	4	0.26
14	3	0.40	5	0.67
15	17	1.33	23	1.71
16	2		1	
17	No		Yes	

	Embedded Counter		Optical Sensor		Barcode reading	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00
2	0	0.00	0	0.00	0	0.00
3	4	0.30	3	0.22	3	0.22
4	4	0.26	4	0.26	5	0.32
5	5	0.60	5	0.60	5	0.60
6	0	0.00	0	0.00	0	0.00
7	3	0.26	0	0.00	3	0.26
8	5	0.20	4	0.16	5	0.20
9	3	0.10	5	0.16	4	0.13
10	5	0.08	3	0.05	2	0.03
11	0	0.00	0	0.00	0	0.00
12	3	0.01	4	0.01	2	0.01
13	5	0.32	5	0.32	3	0.19
14	3	0.40	3	0.40	3	0.40
15	40	2.51	36	2.18	35	2.35
16	1		2		3	
17	Yes		Yes		No	

	Turntable		Aligning Conveyor		Grooves vibrating conveyor		Conveyor guides		Funnel	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
2	3	0.40	2	0.27	2	0.27	2	0.27	4	0.53
3	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
4	0	0.00	0	0.00	0	0.00	0	0.00	3	0.19
5	5	0.60	5	0.60	4	0.48	5	0.60	4	0.48
6	5	0.43	5	0.43	5	0.43	5	0.43	5	0.43
7	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
8	2	0.08	3	0.12	3	0.12	3	0.12	2	0.08
9	3	0.10	4	0.13	4	0.13	4	0.13	3	0.10
10	4	0.06	2	0.03	2	0.03	2	0.03	3	0.05
11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
12	3	0.01	2	0.01	3	0.01	2	0.01	3	0.01
13	4	0.26	3	0.19	3	0.19	3	0.19	3	0.19
14	3	0.40	3	0.40	3	0.40	3	0.40	3	0.40
15	32	2.33	29	2.17	29	2.05	29	2.17	33	2.45
16	3		4		4		4		2	
17	Yes		Yes		No		Yes		Yes	

	Roll pin conveyor		Robotics		Actuator		Trap door	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00	0	0.00
2	3	0.40	4	0.53	0	0.00	0	0.00
3	0	0.00	0	0.00	2	0.15	1	0.07
4	0	0.00	3	0.19	1	0.06	0	0.00
5	4	0.48	5	0.60	0	0.00	0	0.00
6	5	0.43	5	0.43	0	0.00	1	0.09
7	0	0.00	3	0.26	0	0.00	0	0.00
8	3	0.12	3	0.12	1	0.04	0	0.00
9	4	0.13	4	0.13	1	0.03	2	0.06
10	2	0.03	4	0.06	4	0.06	3	0.05
11	0	0.00	3	0.02	0	0.00	0	0.00
12	3	0.01	2	0.01	1	0.00	3	0.01
13	2	0.13	3	0.19	2	0.13	1	0.06
14	3	0.40	3	0.40	2	0.27	5	0.67
15	29	2.12	42	2.93	14	0.75	16	1.01
16	4		1		2		1	
17	No		Yes		Yes		Yes	

	Database		Barcode		RFID	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00
2	0	0.00	0	0.00	0	0.00
3	4	0.30	5	0.37	5	0.37
4	3	0.19	5	0.32	5	0.32
5	5	0.60	5	0.60	5	0.60
6	0	0.00	0	0.00	0	0.00
7	3	0.26	4	0.34	4	0.34
8	5	0.20	4	0.16	4	0.16
9	4	0.13	3	0.10	3	0.10
10	5	0.08	3	0.05	2	0.03
11	0	0.00	0	0.00	0	0.00
12	5	0.02	4	0.01	3	0.01
13	5	0.32	4	0.26	3	0.19
14	4	0.53	3	0.40	2	0.27
15	43	2.62	40	2.60	36	2.39
16	1		2		3	
17	Yes		No		Yes	

	Lock in Wheels w/ Jack		Lock in Wheels w/o Jack		Forklift	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00
2	4	0.53	2	0.27	4	0.53
3	0	0.00	0	0.00	0	0.00
4	0	0.00	0	0.00	0	0.00
5	0	0.00	0	0.00	0	0.00
6	0	0.00	0	0.00	0	0.00
7	0	0.00	0	0.00	0	0.00
8	0	0.00	0	0.00	0	0.00
9	0	0.00	0	0.00	0	0.00
10	4	0.06	3	0.05	5	0.08
11	0	0.00	0	0.00	0	0.00
12	4	0.01	4	0.01	2	0.01
13	3	0.19	3	0.19	3	0.19
14	4	0.53	4	0.53	3	0.40
15	19	1.33	16	1.05	17	1.21
16	1		3		2	
17	Yes		Yes		Yes	

	Roll applicator		Robotics		Imaje Printing System		Stamping Machine	
	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score	Rank	Weighted Score
1	0	0.00	0	0.00	0	0.00	0	0.00
2	4	0.53	4	0.53	4	0.53	3	0.40
3	2	0.15	5	0.37	4	0.30	3	0.22
4	0	0.00	0	0.00	0	0.00	0	0.00
5	3	0.36	5	0.60	4	0.48	3	0.36
6	0	0.00	0	0.00	0	0.00	0	0.00
7	0	0.00	0	0.00	0	0.00	0	0.00
8	2	0.08	5	0.20	3	0.12	2	0.08
9	2	0.06	4	0.13	3	0.10	3	0.10
10	4	0.06	3	0.05	3	0.05	3	0.05
11	3	0.02	5	0.03	4	0.02	3	0.02
12	4	0.01	1	0.00	3	0.01	3	0.01
13	3	0.19	3	0.19	3	0.19	3	0.19
14	3	0.40	2	0.27	3	0.40	3	0.40
15	30	1.87	37	2.36	34	2.19	29	1.82
16	3		1		2		4	
17	No		Yes		Yes		Yes	

Appendix B – System Concepts Considered

Through group discussion and observations from the concept selection matrix, we combined concepts based on compatibility and net scores. From this compilation, we identified four main subsystems within the coin roll check weighing system: orientation, weighing, rejection, and printing. It should be noted that at the point of compiling the first two systems, the printing objective was still required. The third and last system described eliminates the printing aspect.

<u>System I:</u>

Our first system concept starts as the input conveyor moves coin rolls from the roll wrappers. This input flow is unsteady and coin rolls are often in a misaligned orientation. In order to create a steady flow and proper orientation for the following processes, robotic machines would be used to analyze and orient the rolls using gripper attachments on a high speed robotic arm. After orientation, the conveyor leads the coin rolls onto a weighing machine. This weighing machine would be able to accept preprogramed data such as the weight of the coin roll and the acceptable weight tolerance. At this stage, the weighing machine will be able to detect whether a coin roll has the correct number of coins via the roll weight. Also, the weighing machine wil have an embedded counter that is capable of counting the coin roll throughput. Once the weighing machine determines whether the coin roll is 'good' or 'bad', a rejection system would be used to reject 'bad' rolls and allow 'good' rolls to continue. This rejection system would use two conveyors in series, with one that is able to retract and the other one remain fixed. When the weighing machine detects a 'bad' roll it signals the retractable conveyor to open, creating a hole in the process flow. The subsequent roll then drop below into a holding container for the operator to retrieve. A schematic of the overall system is shown in Figure 32.

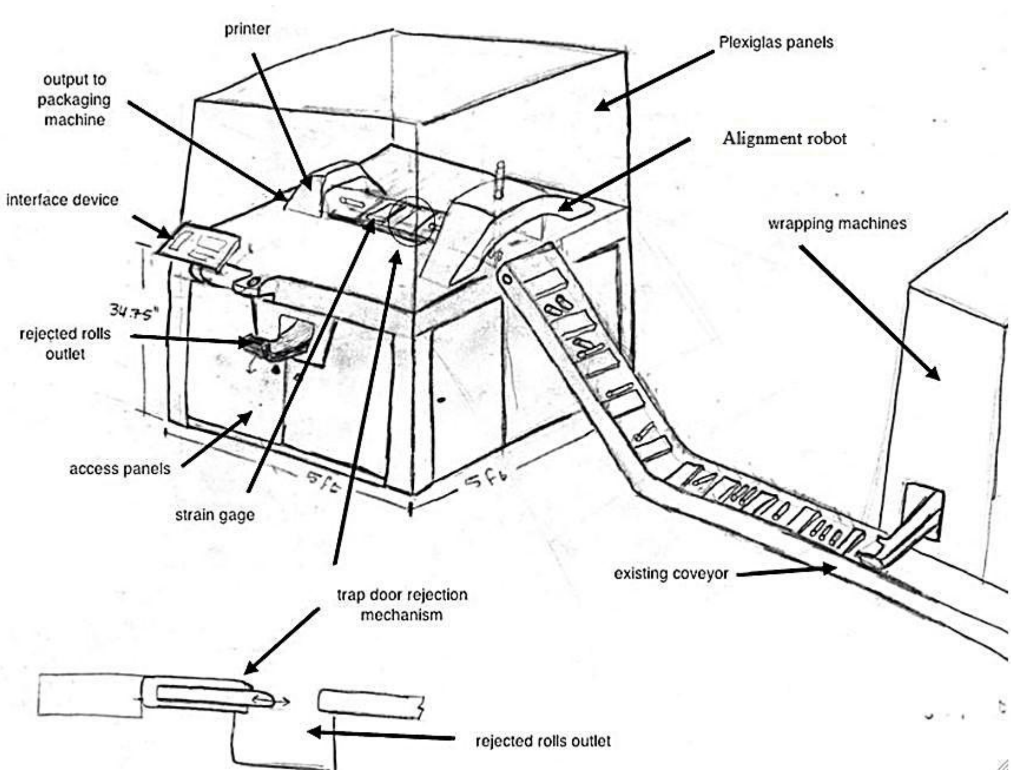


Figure 32. Layout of system concept 1 with trap door rejection mechanism (Not to scale).

Figure 33 below identifies a similar rejection system to that mentioned previously. This particular system is available from Shuttleworth, LLC.

Figure 33. Shuttleworth rejection system that uses a retractable mechanism allowing the rejected to fall below as shown here [17] (Used by permission of Shuttleworth, LLC)

In order to print the date and shift number onto the coin rolls, we decided to use the Imaje printing systems. Since the Mint currently has an extra printer, we decided that we could use something they already had. This type of printing system may be operated using robotics stationed at a fixed location to print on each roll as it passes by. Once the roll has been printed, it can then be fed onto the tiling machine conveyor in the correct orientation (same as existing).

Upon consultation with our client, it was suggested to pursue a simpler solution than using robotics. Also, the printing aspect was removed from the requirements of the system.

<u>System II:</u>

Our second system concept takes on a more simplified approach to the problem. For this design, the coin roll input remains the same, while the orienting process uses a funnel instead of robotics. Figure 34 displays this concept below.

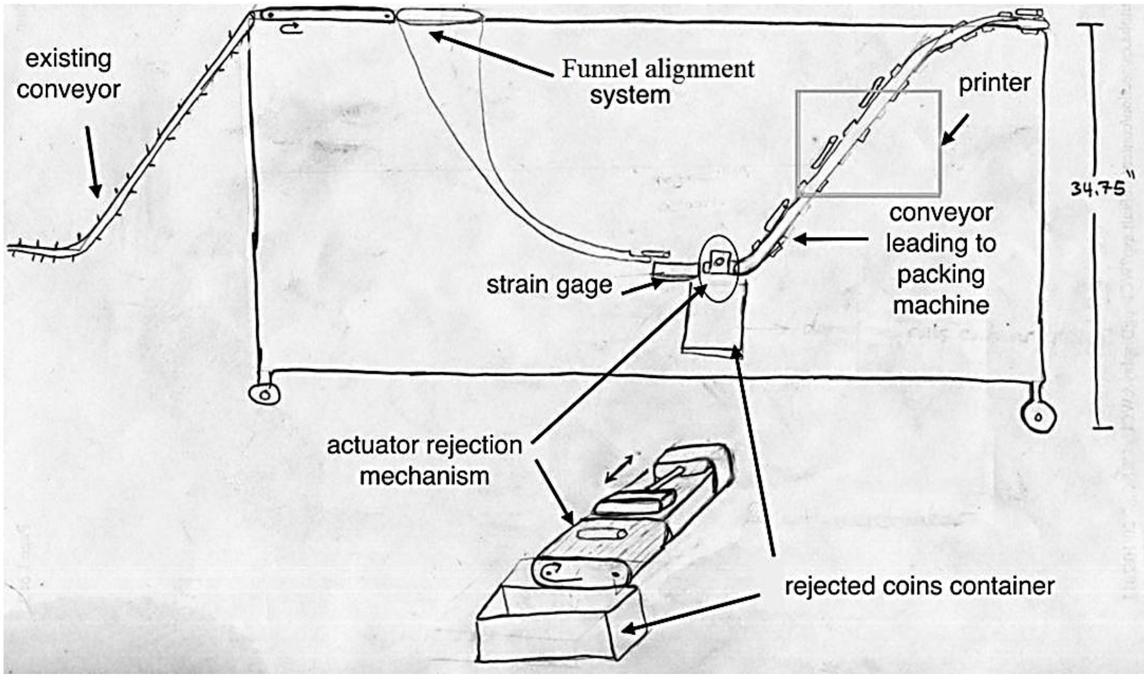


Figure 34. Layout of system concept 2 with actuator rejection mechanism (Not to scale).

The funnel shown in Figure 34 uses gravity and the shape of the funnel to orient the rolls into the correct position. From this point, the coin roll is weighed in a similar fashion to System I, and a rejection actuator rejects the roll to the side. A sketch of this rejection system is also shown in Figure 34. After passing by the rejection actuator, the roll enters a stamping machine. This stamping machine uses different stamp heads depending on the coin roll size to imprint the date and shift number onto the coin roll. In order for this process to work a steady coin roll input and correct orientation must be achieved for this to work efficiently. Figure 35 shows a secondary view of this system identifying the orientation of the aforementioned devices.

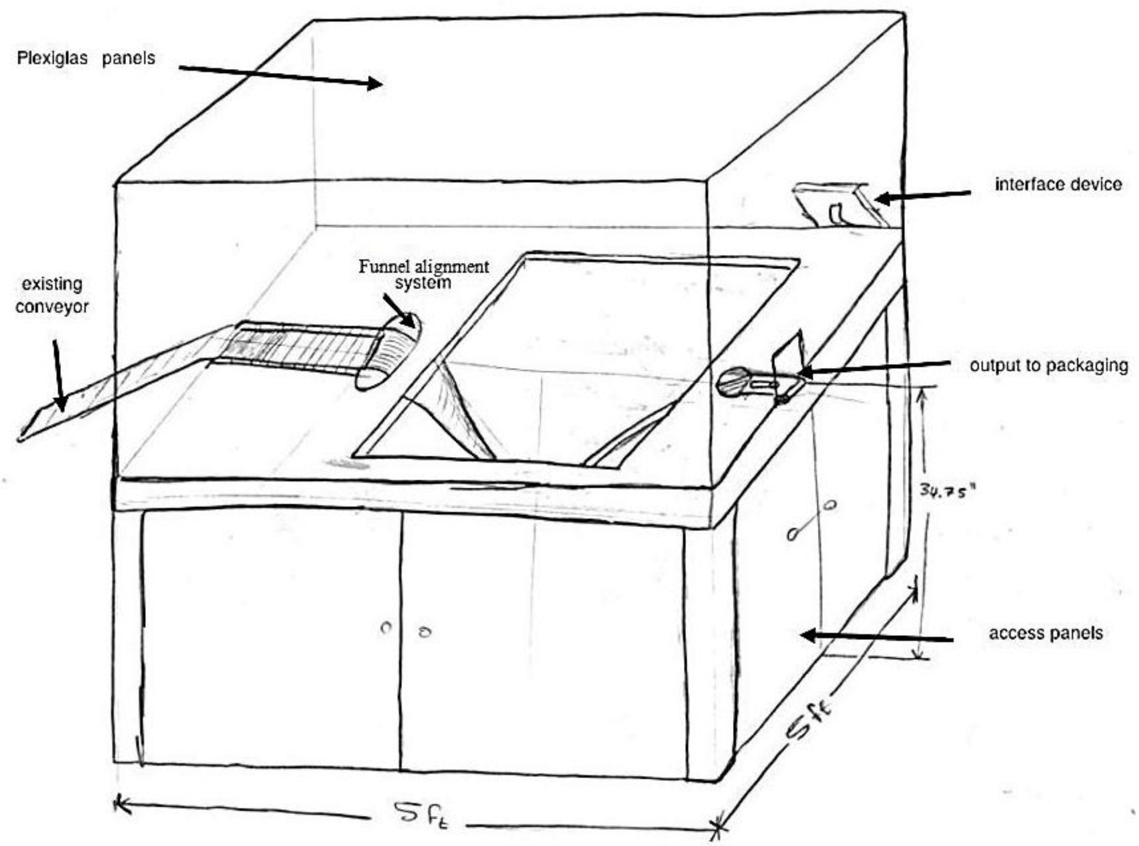


Figure 35. Overview of the system concept 2 (Not to scale).

Since safety is a key priority to our client, each of the two systems aforementioned will be enclosed in a Plexiglas structure for operator safety. These Plexiglas panels could be hinged and could contain magnetic closure switches (i.e. if these switches were disengaged the entire system would shut off). Other safety features that could be implemented include two-button start-up, lock out/tag out tags, and emergency shut-off buttons. The two-button start-up would ensure the operator is not physically touching any part of the machine during start-up. Lock out/tag out tags ensure the machine is physical locked down via a pad lock when the system the system is undergoing maintenance or repair. Lastly, strategically placed emergency buttons could be implemented so that the operator can shut off the system, if needed, as quickly as possible.

As mentioned previously, a smooth and consistent coin roll flow is needed for each of the first two systems. Concepts such as using a buffer conveyor and parallel flow could be used to achieve this type flow. The buffer conveyors would be a pulse type conveyor between the wrapper machines and a main conveyor. The buffer would only allow rolls to drop onto the main conveyor when a space is available. Parallel flow, could be utilized to decrease the rate of rolls entering the devices. This could prove beneficial in cases where the device cannot handle rates that are around 100 items per minute. Regardless of the option either method would have to be implemented in order for the system's processes to function properly.

Upon consultation with our client, it was suggested that the funnel system might be difficult to manufacture and perfect into a working solution. Also, upon consultation, the printing aspect of the project was eliminated as well.

System III (4 conveyors):

The third concept our team developed attempted to solve the unsteady flow issue from the first two concepts. In order to prevent coin rolls from dropping on top of each other from the wrappers, we choose to utilize four separate narrow parallel flow conveyors. Since the rolls from each conveyor needed to be merged into a single conveyor for weighing, a stop light mechanism was devised. This mechanism would control the movement of the four conveyors by only allowing rolls to continue from a single conveyor at a time. The "stoplight" mechanism would work on the basis of first-come first-served and only allow a single roll to pass at a time. This method of operation would be controlled by a set of sensors on each of the four conveyors and a central processing microcontroller. See Figure 36 for a description of the stoplight mechanism.

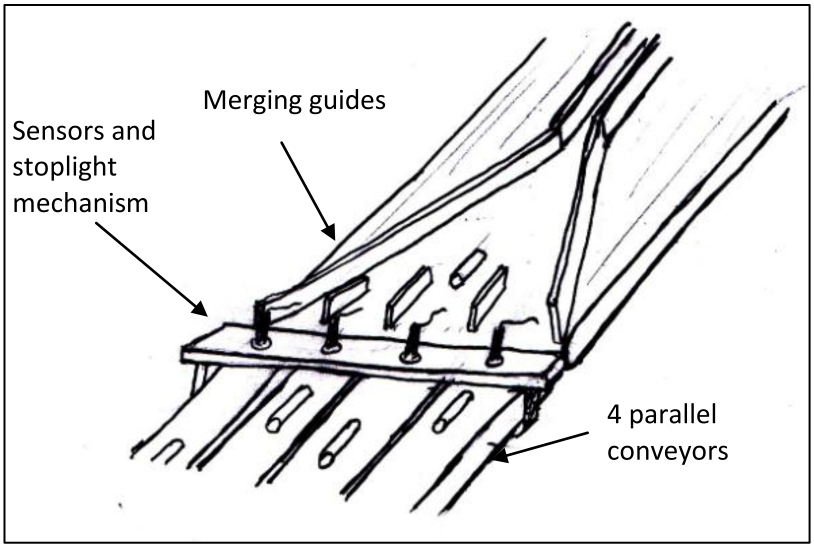


Figure 36. Merging process from 4 parallel conveyors (Not to scale).

After the merging process, the coin rolls would be weighed using an in-motion check weighing scale. After weighing, each roll would pass a rejection system and onto a 90° transfer attachment that would transfer the rolls to the tiling conveyor. See Figure 37 for a layout of this process. Note this process is very similar to the design process except with four parallel conveyors and a merging section.

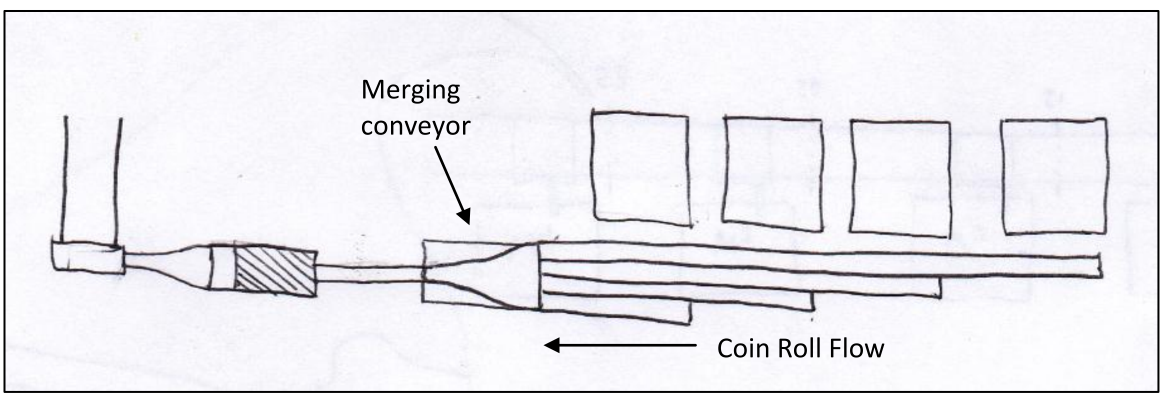


Figure 37. Layout of system concept 3 (Not to scale).

After team discussion and consultation with our advisor, we choose to use a single main conveyor and instead of controlling four individual conveyors, it suggested to control four separate buffer mechanisms. This idea would eliminate the procurements of the additional three conveyors and potential complication on the stoplight mechanism.

Appendix C – Prototype Testing of Wrapping Machine Attachments and Roll Transfer Mechanism

Slide Testing:

In order to achieve a 90° rotation of a coin roll, our team designed a prototype model out of a cardboard box. Figure 38 below shows the model that was built.

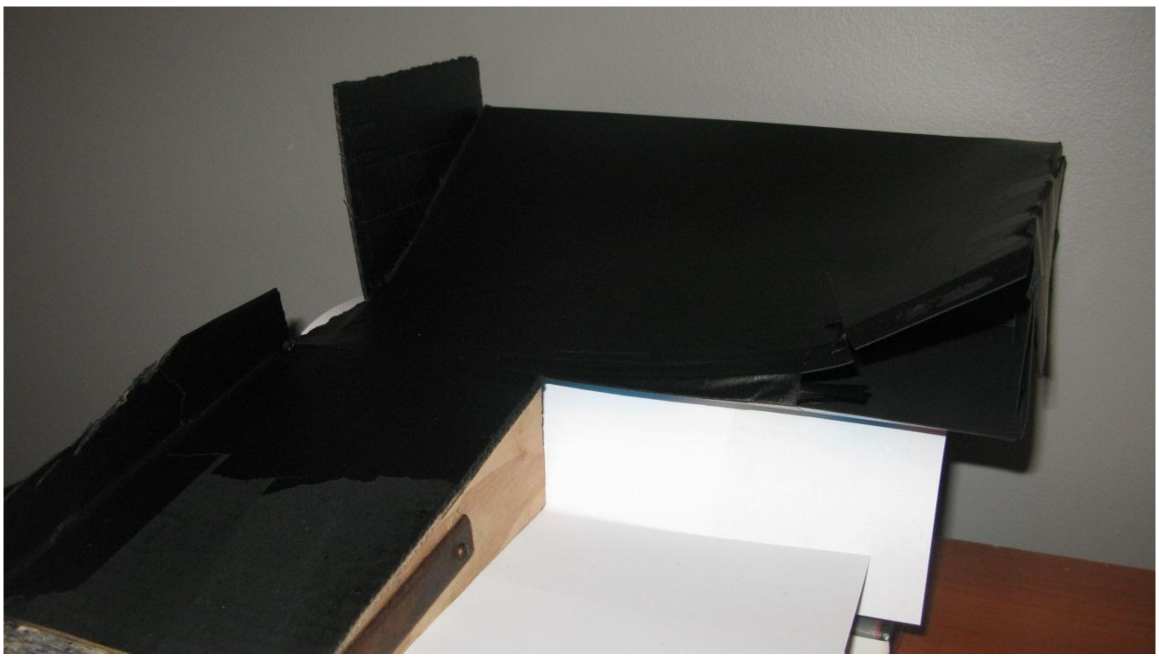


Figure 38. Prototype re-orientation slide used for testing

This slide produced results that would indicate a successful re-orientation slide design. Through our testing we noticed that surface finish was a major factor in how the roll rotated along the contour. In our design we utilized masking tape to attach the slide to the ramp shown in the lower left of Figure 38. This transition of surfaces affected the performance of the slide and additional experimentation was required. From this additional experimentation we also realized that roll drop location and side wall finish were also critical. These factors could easily be mitigated by using Teflon coated side walls and a stop on the original attachment to control the drop locations precisely.

Buffer Testing:

In order to drop a single roll onto the main conveyor, our team devised a prototype drop mechanism. Figure 39 below shows the buffer ramp and rotor mechanism.

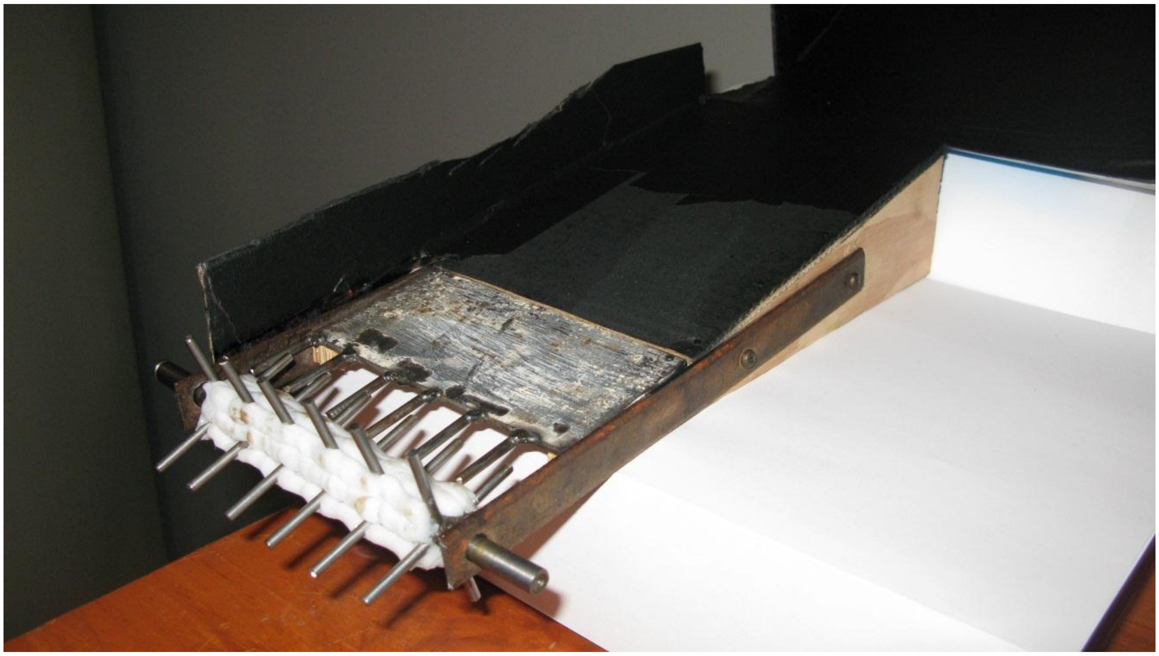


Figure 39. Buffer ramp and drop mechanism used to drop single rolls onto the main conveyor

This buffer slide was built using plywood and steel plates. The rotor utilized a square stock steel shaft with circular pin welded onto the four sides of the shaft. The ends of the rotor were machined into a cylindrical shaft in order to rotate on the rotor supports. Mating teeth on the ramp were welded to the steel plate of the buffer ramp.

Initial testing of this mechanism, produced mixed results when testing the largest and smallest roll size diameter. Silicone caulking was added to the middle of the rotor to prevent the mechanism from picking up two of the smaller sized rolls. Final testing showed that the mechanism could pick up rolls that were outside of the limits presented by the smallest and largest coin roll diameters.

Roll Transfer Mechanism Testing:

In order to transfer a roll onto the tiling conveyor on the same orientation, our team developed a roll transfer mechanism. Figure 40 below, shows the mechanism.

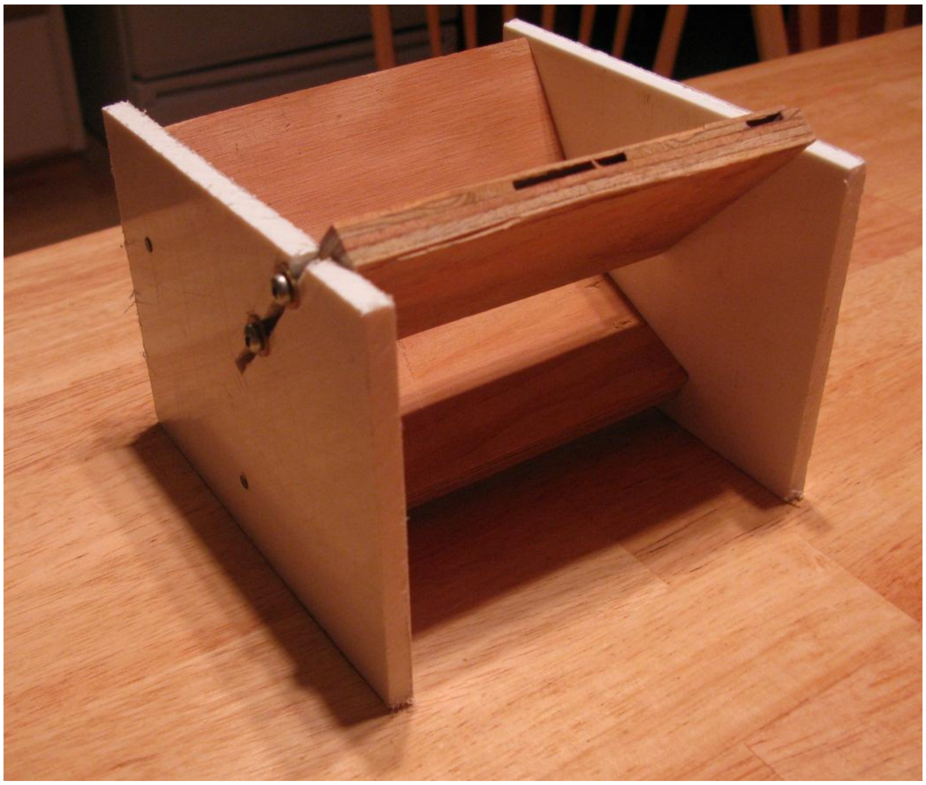
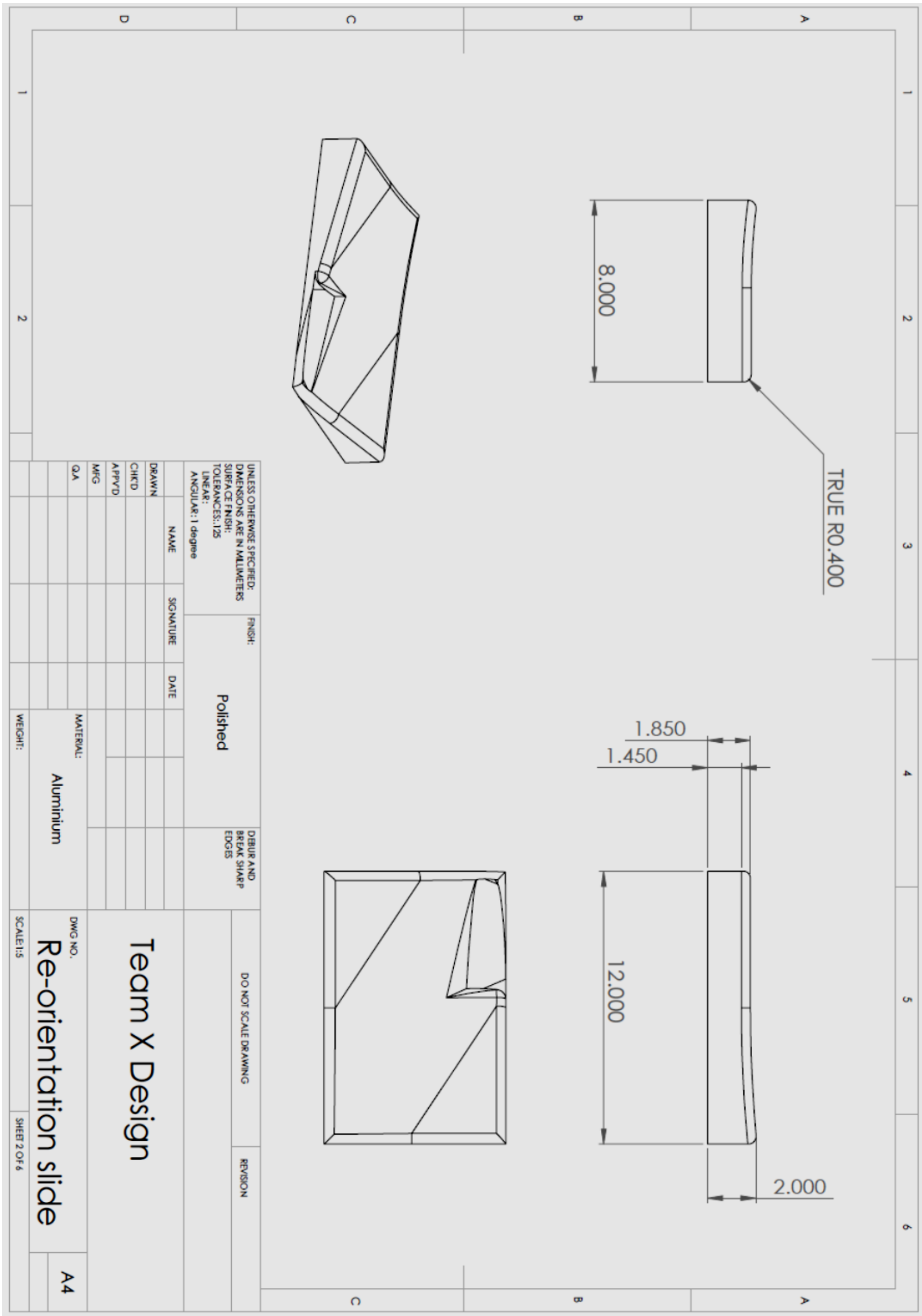
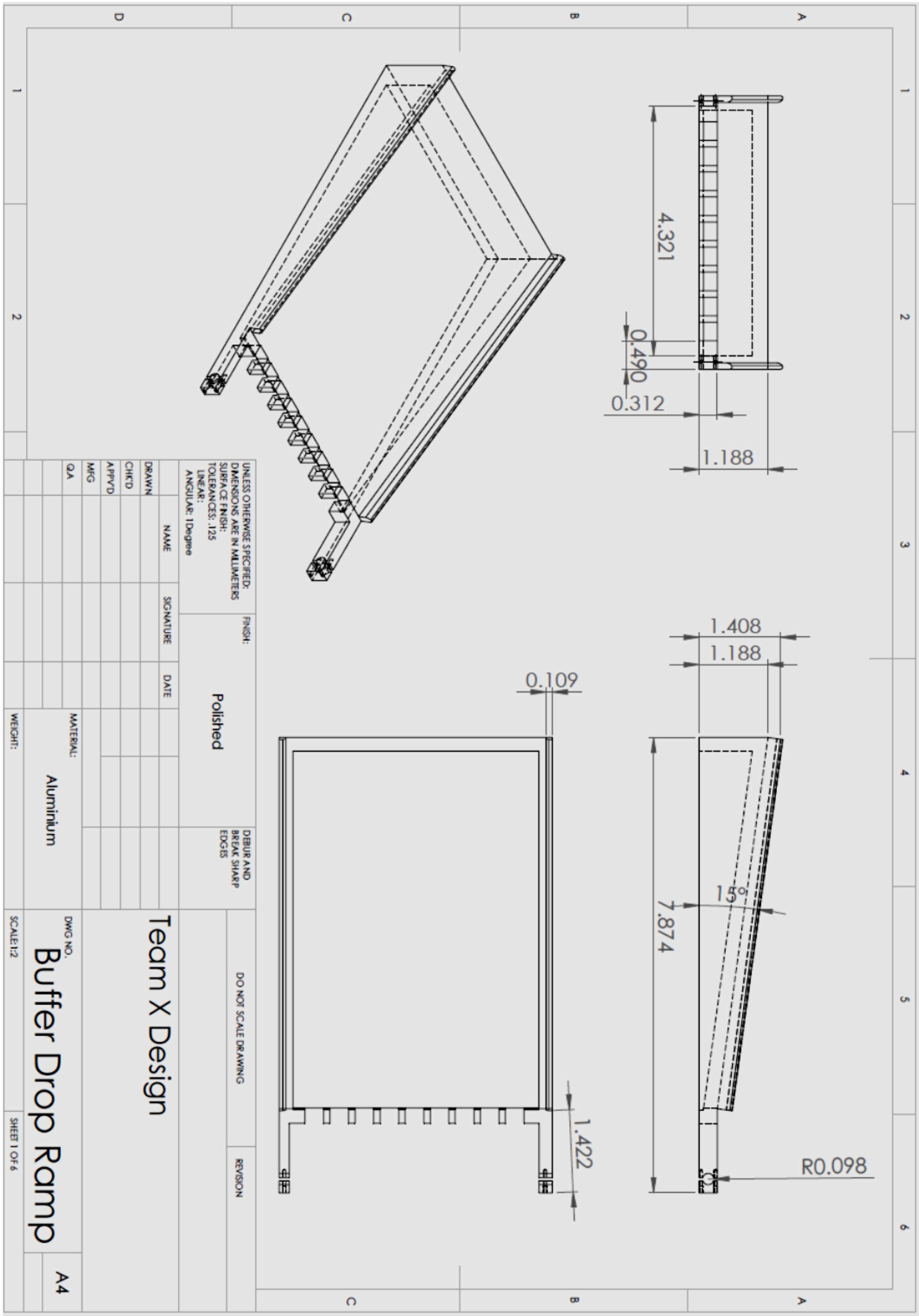


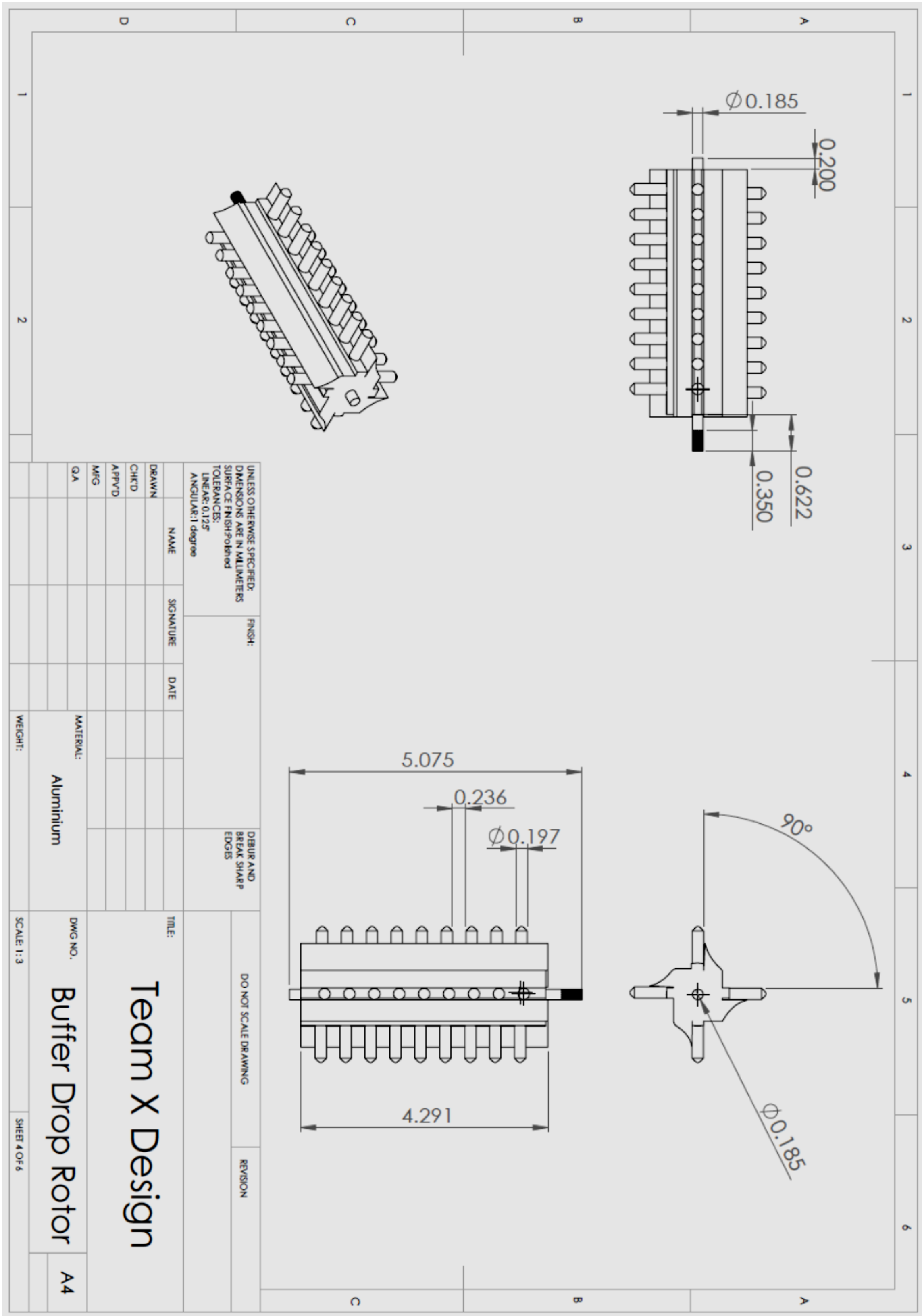
Figure 40. Roll transfer mechanism used for transferring coin rolls onto the tiling conveyor

This transfer mechanism was built using plywood and puck board. Adjustment screws were added to adjust the mechanism's performance based on various coin roll sizes. Testing of the mechanism indicated that the prototype built was too short for longer coin rolls. Due to time constraints we were unable to modify the prototype. Successful testing was performed though using rolls of pennies.

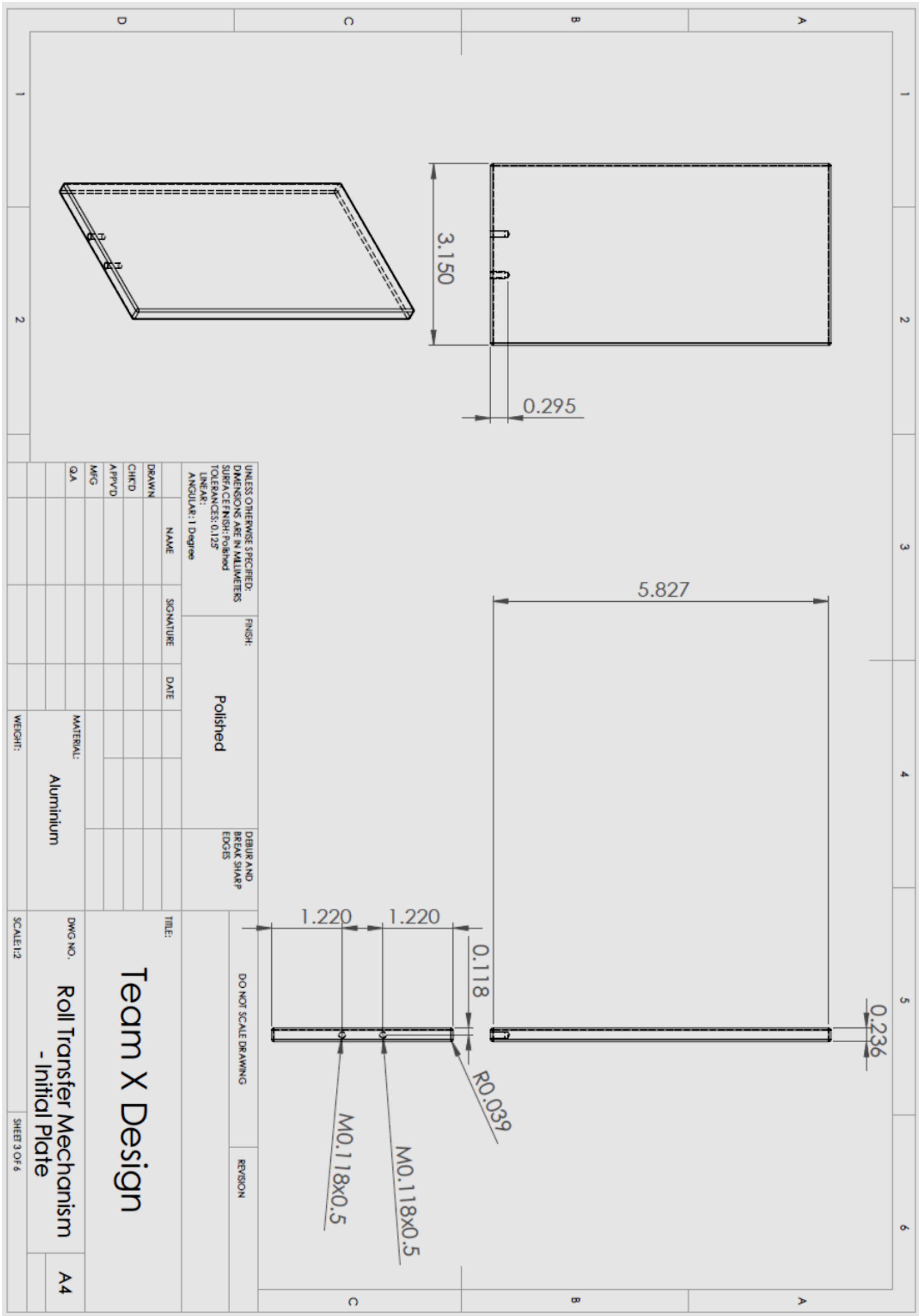
Appendix D – CAD Drawings of Wrapping Machine Attachments and Roll Transfer Mechanism

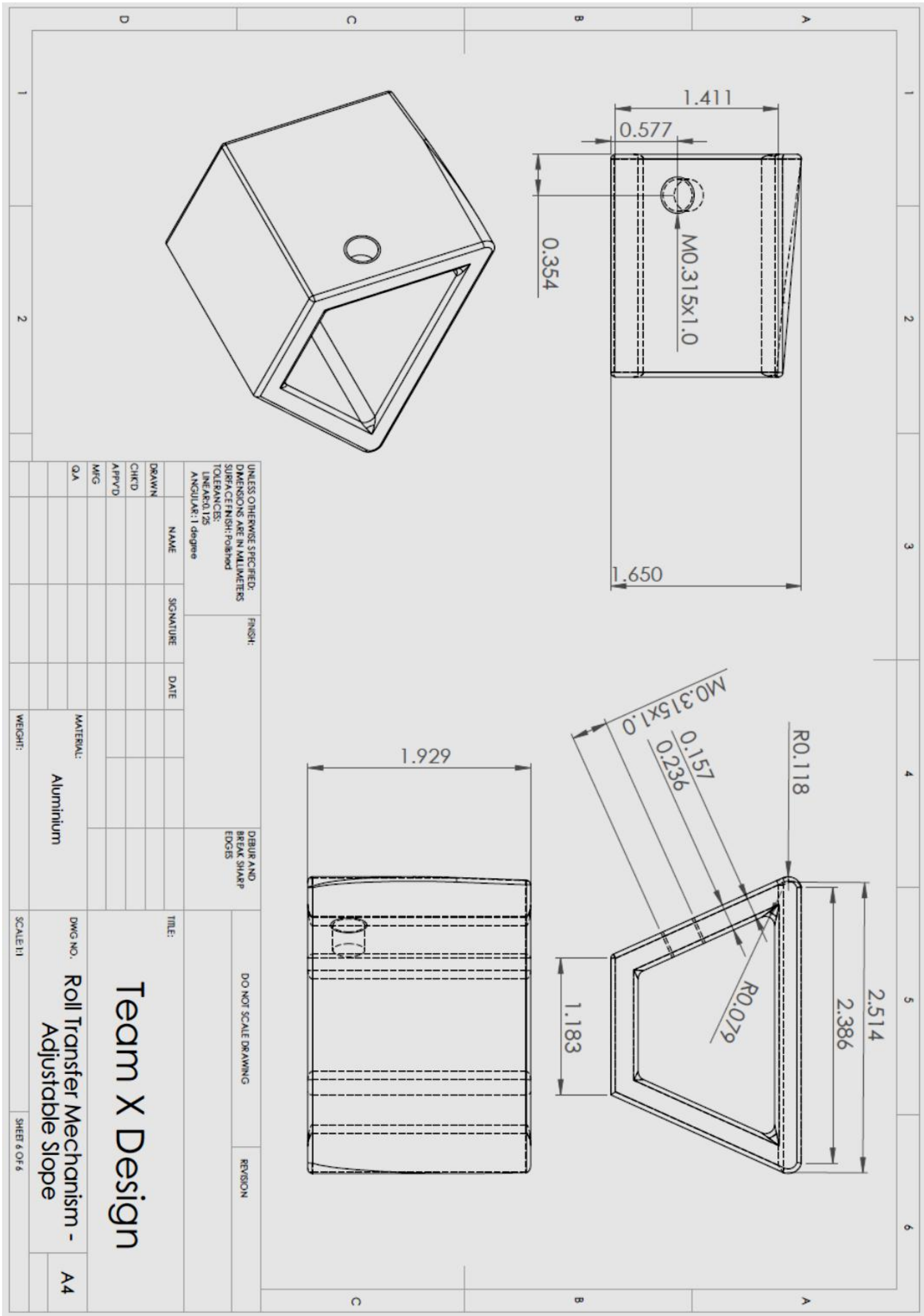


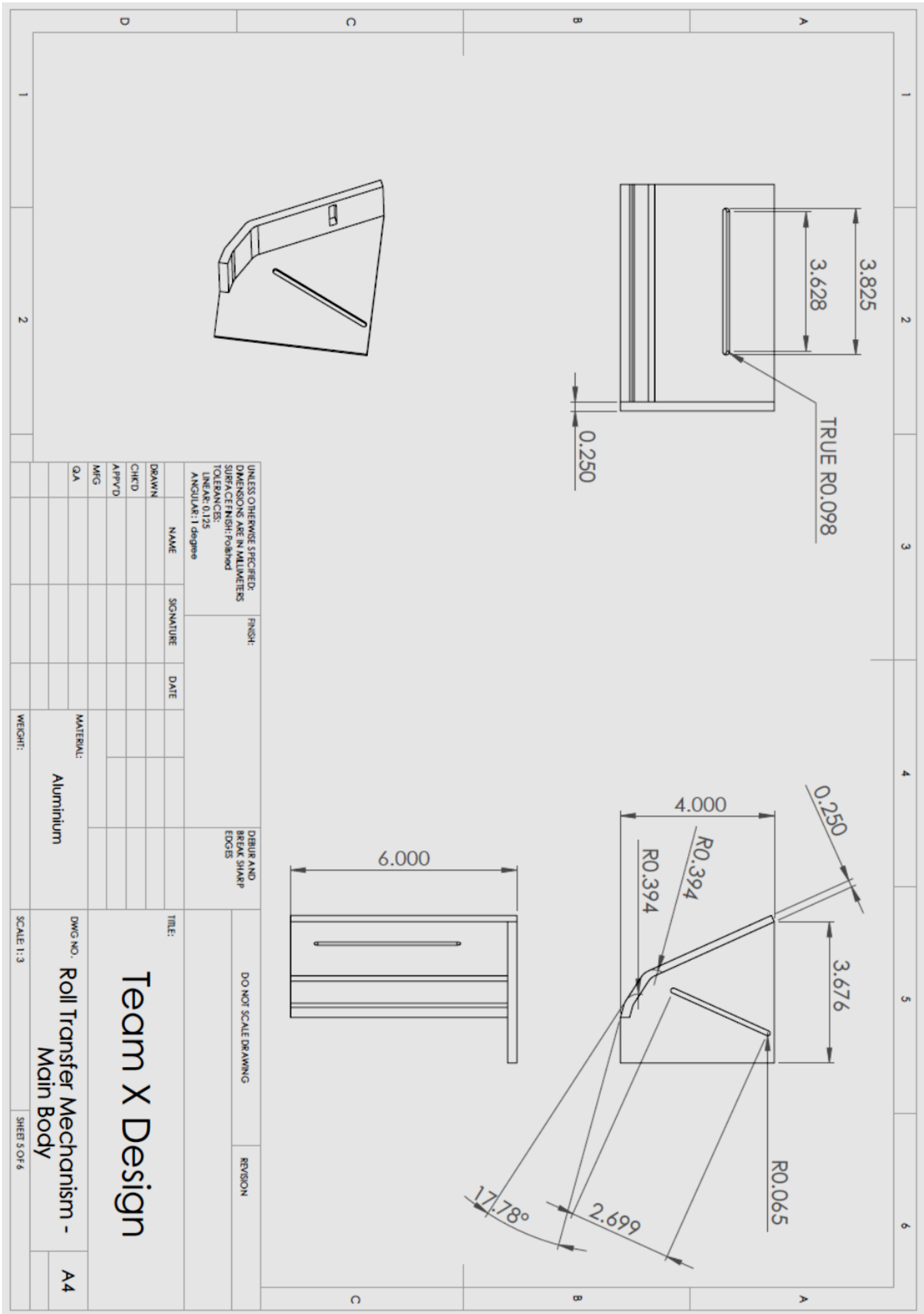

4.321
0.490
0.312
1.188
1.408
1.188
0.109
15°
7.874
1.422
R0.098
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES: .125
LINEAR:
ANGULAR: 1Degree
FINISH:
Polished
DEBUR AND BREAK SHARP EDGES
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
Team X Design
DO NOT SCALE DRAWING
REVISION
DWG NO.
Buffer Drop Ramp
A4
SCALE:1:2
SHEET 1 OF 6



Ø0.185
0.200
0.622
0.350
5.075
0.236
Ø0.197
90°
Ø0.185
4.291
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:Polished
TOLERANCES:
LINEAR: 0.125
ANGULAR:1 degree
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
TITLE:
Team X Design
DWG NO.
Buffer Drop Rotor
A4
WEIGHT:
SCALE:1:3
SHEET 4 OF 6


3.150
0.295
5.827
1.220
1.220
0.118
0.236
R0.039
M0.118x0.5
M0.118x0.5
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: Polished
TOLERANCES: 0.125"
LINEAR:
ANGULAR: 1 Degree
FINISH:
Polished
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Team X Design
DWG NO.
Roll Transfer Mechanism
- Initial Plate
A4
SCALE:1:2
SHEET 3 OF 6


1.411
0.577
0.354
M0.315x1.0
1.650
M0.315x1.0
0.157
0.236
R0.118
1.929
2.514
2.386
1.183
R0.079
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: Polished
TOLERANCES:
LINEAR: 0.125
ANGULAR: 1 degree
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Team X Design
DWG NO.
Roll Transfer Mechanism - Adjustable Slope
A4
SCALE:1:1
SHEET 6 OF 6



3.825
3.628
TRUE R0.098
0.250
4.000
0.250
R0.394
R0.394
3.676
6.000
R0.065
17.78°
2.699
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: Polished
TOLERANCES:
LINEAR: 0.125
ANGULAR: 1 degree
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Aluminium
WEIGHT:
TITLE:
Team X Design
DWG NO.
Roll Transfer Mechanism - Main Body
A4
SCALE 1:3
SHEET 5 OF 6

Appendix E – Buffer Drop Mechanism Ramp Analysis

The rolling friction force, F_r was calculated using the following formula:

$$F_r = cF_N$$

Where F_r is the force required to initiate rolling, c is the rolling resistance coefficient and F_N is the normal force on the rolling object calculated using the following formula. Figure 41identifies these variables.

$$F_N = mgcos\theta$$

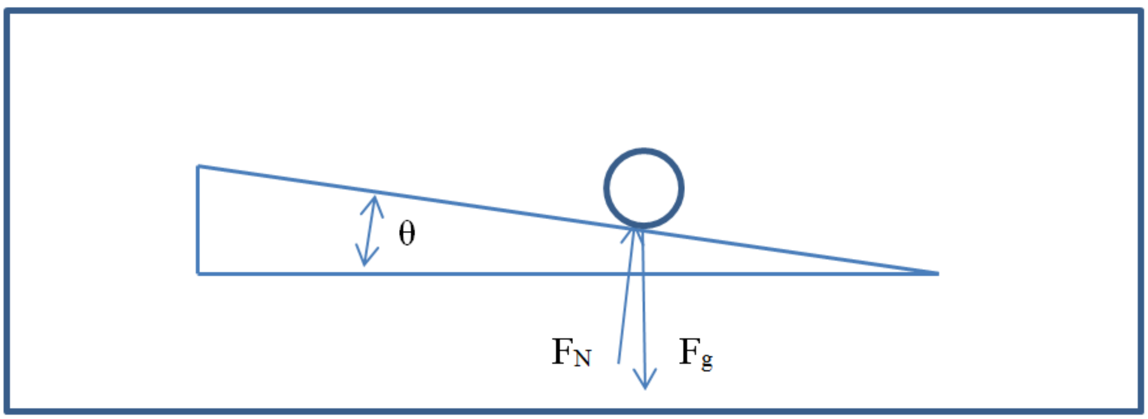


Figure 41. Coin roll forces while on the buffer ramp

TABLE V below displays the results using the using the lightest and heaviest rolls.

TABLE V. CALCULATION RESULTS FOR ROLLING FRICTION FORCES

Forces	Heaviest Roll (0.425 kg)	Lightest Roll (0.075 kg)
F_N	4.027 N	0.711 N
F_r	4.027×10^{-3} N	7.11×10^{-4} N

A value of 0.001 was used for c (steel on steel) as it was the closest value to a paper covered metallic object on a metallic ramp. It is our objective to minimize the amount of force required to initiate the rolling action. Our calculations indicate a low force required to initiate the rolling which can be produced by the gravitational force on the roll.

Appendix F – Buffer Drop Mechanism Stress Analysis

Preliminary testing was done on the proposed re-orientation and buffer attachments. Further testing of materials and profiles will be needed but due to time constraints, we are not able to perform such extensive testing. As for stresses in the pins of the dropping mechanism, calculations were carried out to ensure the assembly can withstand the impact of the coin rolls hitting them. The following assumptions were made for when completing the calculations:

- The assembly stays stationary at impact (motor does not move due to impact)
- Rotor and pins are machined using a single piece of aluminum
- Initial velocity at the ramp is zero

This analysis, calculates the impact stress the coin rolls will exert on the drop mechanism's rotor teeth. To begin the analysis we used experimental results to calculate the average velocity of a coin roll on the re-orientation slide.

$$V = \frac{d}{t} = \frac{25\ cm}{0.4\ s} = 62.5\ \frac{cm}{s} = 0.625\ \frac{m}{s}\ (conservative\ value)$$

Assuming an initial velocity of 0 m/s at the start of the slide, a final velocity is approximated to be 1.25 m/s from our experimental results.

For a rolling object, the kinetic energy (K) is equal to:

$$K = \frac{1}{2}\ mV^2 + \frac{1}{2} I\omega^2$$

Since the moment of inertia, I = mr^2 and angular speed, w = vr, the equation above becomes:

$$K = \frac{1}{2} mV^2(1 + r^4)$$

Where m is the mass of the largest roll (m = 0.425 kg) and r is the largest radius (r = 0.017 m).

From conservation of energy, the kinetic energy = gravitational potential energy (assuming friction effect is insignificant as illustrated previously).

Therefore substituting gravitational potential energy into the left side of the equation yields the following:

$$mgh = \frac{1}{2}mV^2(1 + r^4)$$

Where h is the dropping distance (h = 0.25sin(15)).

Solving for V yields a theoretical velocity, V = 1.2 m/s, which is very close to our experimental calculations. For the stress analysis, we will round it up to 2 m/s. For a transverse load on the teeth of the roller, stress needs to be calculated to ensure that failure will not occur. The maximum load takes place when the heaviest roll and largest diameter hits only one of the pins as shown in Figure 42.

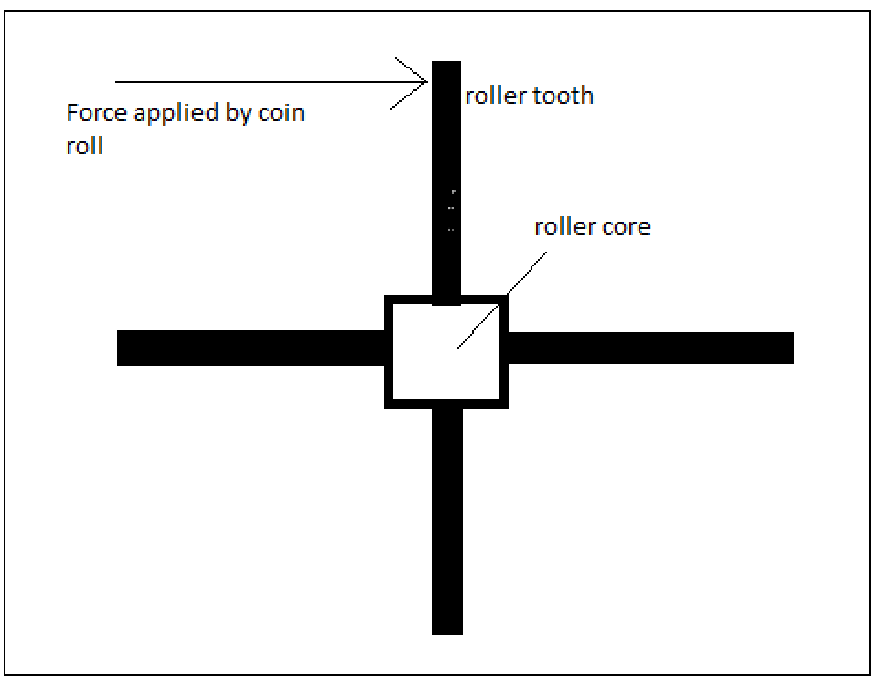


Figure 42. Force applied by coin roll on the drop mechanism teeth

For a transverse load, P:

$$P = \sqrt{\frac{6\,U_m EI}{L^3}}$$

The stress formula yields the following relationship:

$$\sigma_m = \frac{Mc}{I} = \frac{P_m Lc}{I}$$

Where P is the load applied, σ_m is the maximum stress at the bottom of the pin, U_m is potential energy, E is modulus of elasticity and c is the maximum distance from neutral axis of bending.

The combination of the two equations yields:

$$\sigma_m = \sqrt{\frac{6mgE_{Al}}{L}}$$

Substituting the following design values into the previous equation:

C = 0.0025 m

L = 0.015 m

h = 0.25sin (15) m

m = 0.6 kg

E_{al} = 70 MPa

$$\sigma_m = \sqrt{\frac{6(0.6)(9.81)0.25\sin(15))(7 * 10^6)}{0.15}} = 0.6\,MPa$$

Calculating an equivalent static force, P, yields the following (approximate shape):

$$P = \sigma_m A = 600000(\pi)(0.0025^2) = 12\ N$$

Calculating the torque required to turn the motor (at the centre):

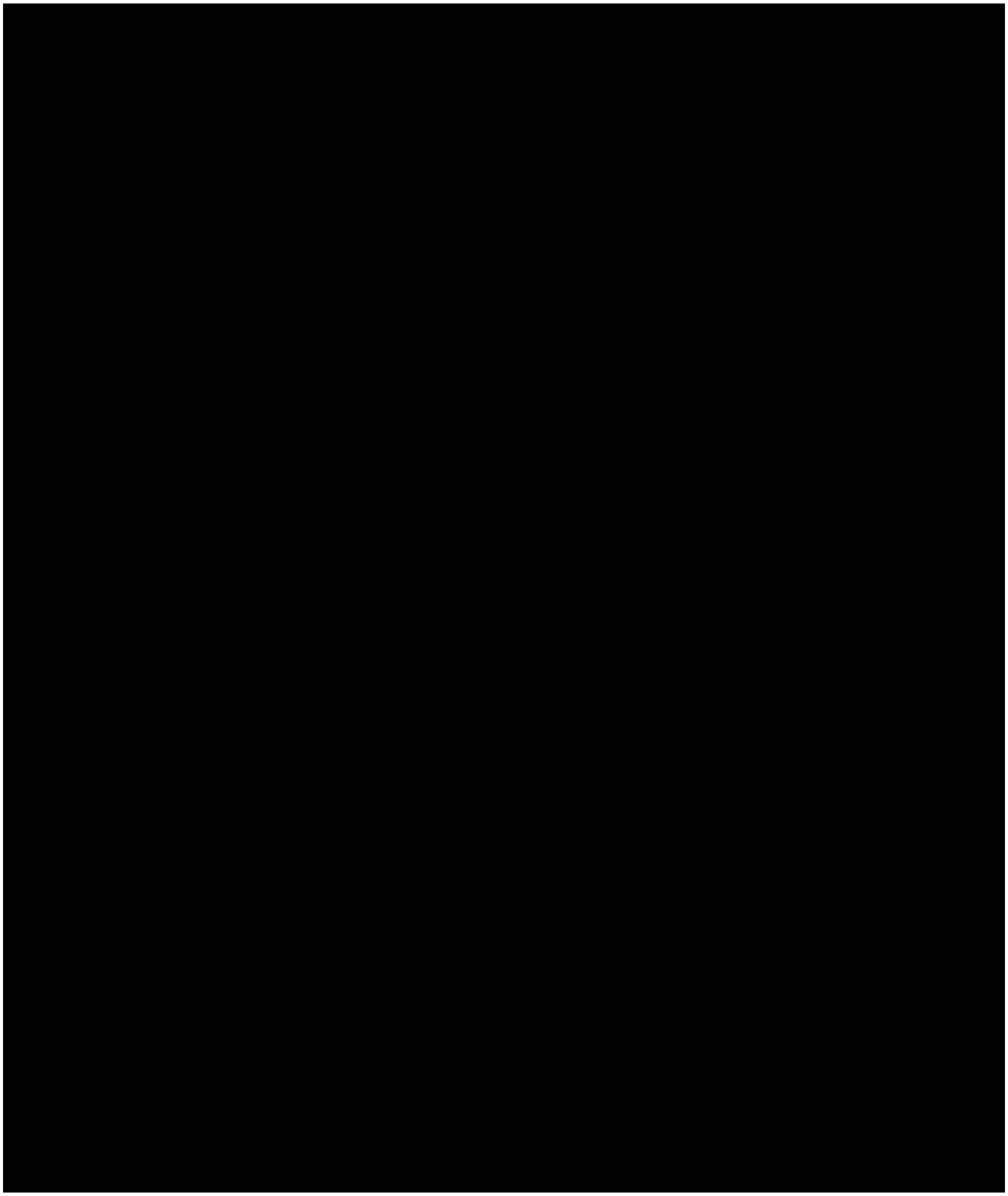
$$T = 12(0.0025 + 0.02) = 0.25\ N - m$$

Evaluating the stresses in the drop mechanism to the two stress criteria in 1100-H14 aluminum which are:

- normal stress (limited to 95 MPa) [18]
- shear stress (limited to 55 MPa) [18]

Using our stress analysis we found σ_m = 0.6 MPa which is the maximum stress at a single pin (diameter = 5 mm). This value is much less than both the tensile stress (95 MPa) and shear stress (55 MPa) while still using a reasonable safety factor. Note that this is a very conservative calculation since coin rolls will hit more than one pin at a time. It is not recommended to make the pins smaller since manufacturing them would become more difficult than bigger pins and costly due to the small tolerances involved.

Appendix G – LIN Engineering 5704 Step Motor [4]



[redacted]