Storeveyor System Design

MECH 4860: Final Design Report
McCain Foods
Advisor: Dr. Peng
Team #27

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LETTER OF TRANSMITTAL

December 4, 2019

Dr Paul E. Labossiere, P.Eng.
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Dear Dr. Labossiere,

This report was written to outline the final design of the project being completed by Team 27, which is the design of a storeveyor system for the hash brown line in the McCain Foods Carberry plant. McCain requires a temporary storage system for frozen hash brown patties that stores patties for 15 minutes and then returns them to the production line without breaking or deforming the patties. They have also specified that they desire the system to run without human interaction. This design is intended to replace their current system, which breaks and deforms an unacceptable amount of product.

The system that Team 27 has designed features a conveyor storage system, known as a storeveyor, that has been sourced from Precision Food Industries in consultation with their sales engineers. This storeveyor can safely store the product for the required time and then discharges the patties onto a conveyor system that the team has designed to return the patties to the production line. The team has also designed a set of diverters that allow McCain staff to choose to have patties use the new system or the old system as desired.

Deliverables for this project included a Bill of Materials, Critical Spares List, Engineering Drawings of the storeveyor, floor plan and elevation drawings of the layout, and a Failure Modes and Effects Analysis.

Thank you in advance for reviewing this report, and for any subsequent feedback you may provide.

Sincerely,

Mikayla Kozarchuk
On behalf of Team 27

EXECUTIVE SUMMARY

This report outlines the design of a conveyor storage system, known as a storeveyor, for the hash brown line in the McCain Foods Carberry plant. McCain requires a temporary storage system for frozen hash brown patties that holds patties for 15 minutes and then returns them to the production line. This design is intended to replace their current system, which stores hash browns in metal totes, breaking and deforming an unacceptable amount of product, which costs them money in wasted material and production time.

The system outlined in this report features a storeveyor that has been sourced from Precision Food Industries. This storeveyor consists of a vibratory infeed that spreads product evenly across a conveyor, which slowly moves to hold the product on the conveyor until the delay time is complete, then reverses to discharge the patties onto a conveyor system that the team has designed to return the patties to the production line. The team has also designed a set of diverters that allow McCain staff to choose to have patties use the new system or the old system as desired.

The client had three main objectives for this design: to reduce or eliminate the volume of product that is stored in metal totes, to reduce or eliminate damage to the product in the storage process, and to run without human interaction. This design accomplishes all three objectives by providing an alternative system to the tote system that features small drops and even distributions of product to prevent damage and runs entirely autonomously.

The cost of this design was determined from preliminary quotes from vendors contacted for this project and is roughly estimated to be at maximum $900,000. Although the client is confident that this cost estimate will be lower upon further and more thorough consultation with the vendors.

The project deliverables required by the client included a Bill of Materials, Critical Spares List, Engineering Drawings of the storeveyor, floor plan and elevation drawings of the layout, and a Failure Modes and Effects Analysis. These documents are included in this report.

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1 INTRODUCTION

McCain Foods Carberry and its only customer, McDonald's, both pride themselves in having quality products for its consumers. Thus, this project's client, McCain Foods Carberry, holds themselves to a high standard of quality. The client is continually striving to improve the quality of their products and processes. McCain Foods Carberry excel in the production, storing, packaging and distribution of its two products; frozen french fries and hash brown patties. The client has specified that their current temporary storage process for unpackaged frozen hash browns is unsatisfactory. They have identified that in the current state, far too many hash browns are being broken or deformed.

The source of the deformation and breakage appears to be the toting process, where frozen hash browns are stored in large metal totes that are then dumped into a hopper that feeds back onto conveyors leading to the packaging line. This process is shown in Figure 1. The client has tasked the team with finding a solution to this problem by designing a conveyor storage system, known in industry as a storeveyor.

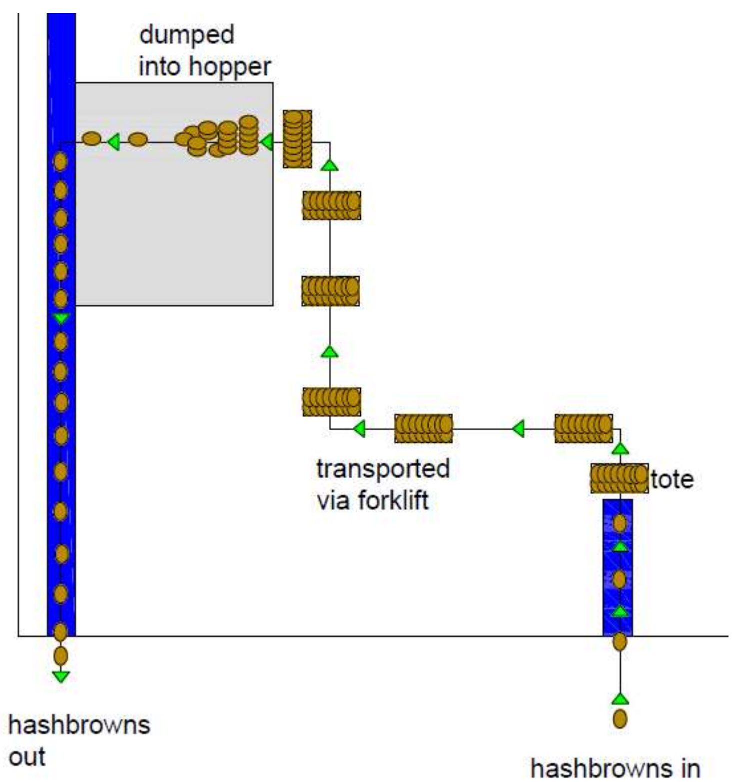

Figure 1. Current Process Map

The objective of this project is to cost effectively design a storeveyor system that will store hash browns for a short amount of time and slowly cycle them back onto the packaging line. The design should reduce the amount of product being toted resulting in fewer deformed and broken hash browns and freeing up employee time otherwise spent emptying totes.

The client has specified a list of project deliverables that must be provided throughout the design process and upon completion of the project. These deliverables provide necessary information about the design and demonstrate to the client that the design process was done thoroughly and diligently. The project deliverables are a Bill of Materials (BoM), Critical Spares list, Failure Modes and Effects Analysis (FMEA), a Floorplan and Elevation Drawing of the proposed layout, and an Engineering Drawing of the storeveyor.

Once the design is complete and is being implemented, the overall expectation of the design is to have a system that is cost effective, breaks fewer hash browns than the current system, allows the product to be toted off before and after the storeveyor, and reintroduces the frozen patties to the packaging line with no human intervention.

2 DESIGN METHODOLOGY

This section outlines the design of the storeveyor and floorplan layout process. Here the design requirements are detailed along with the storeveyor concept generation, screening, scoring, and selection. The development of the layout design is also covered, where the generation and selection process is discussed.

2.1 DESIGN REQUIREMENTS

A full list of project requirements was created based on discussions with the client. The client then had the opportunity to review the list and make any necessary changes. Next, each project requirement was ranked in terms priority and then tabulated.

The client has stated that the proposed design must be capable of running parallel to the current system, which means that an operator can choose to use either totes or the new conveyor system. This is to reduce the amount of product being toted while still retaining the tote system as a viable option for handling excess inventory. The client has also specified that the system eliminates breakage and deformation of hash browns by minimizing the height from which the patties are dropped. Additionally, the client requires the system to operate autonomously, needing less human intervention than the current tote system. These three criteria have been given the highest priority, as they are the core objectives of this project.

The full list of project requirements, as well as target specification and design constraints/limitations are listed in Appendix A.

2.2 CONCEPT SELECTION

To arrive at the best storeveyor design, the team went through a rigorous brainstorming and selection process. It started with some team members independently brainstorming original solutions while others explored current market solutions. Then the designs were narrowed down through discussion and concept screening. After this, several concept selection tools were used to narrow the selection down to a single design. Finally, the selection criteria, concepts, and the selected design were discussed with the client. The following portion of the report will go into further detail of each step of the generation and selection of design concepts.

To generate concepts, two members of the team investigated market solutions while the other two members generated original concepts for storeveyors. The two members brainstorming original concepts specifically avoided researching market storeveyors to avoid influencing or biasing the concept generation and promote the creative process. Each member attempted to generate or research 3 to 4 concepts each. All the generated concepts are shown in Appendix B.

The team then met to share and discuss each concept and followed this with another concept generation period where the team brainstormed new ideas and combining ideas from some of the concepts to develop new ones. After some discussion, a portion of the concepts were eliminated through a concept screening process. This eliminated some of the overly complex or obviously unpractical concepts. Additionally, to further screen some of the concepts, each concept was scored against another to help create a preliminary rank of the concepts. To do this, one concept was chosen to be compared against as the benchmark, and each other concept was rated as to whether it was better or worse than the benchmark at meeting each need, which was indicated with a +, -, or a 0 if it was the same. Then, after each concept was compared to the benchmark, the positives and minuses were tallied up to create a score. This allowed the team to have confidence in eliminating some of the designs.

Next, the team used a criteria weighting matrix to determine the most important of the needs. Each team member filled out the weighting matrix and summed the number of preferences each need got, then used the percentage of preferences to create that weighting. The average of each member's weightings was used as the final weighting for the needs. An example of an individual weighting matrix is shown in Appendix C.

To then score each of the concepts for final selection each team member individually rated each of the remaining concepts on its ability to meet each need. The ratings were given from 1 to 5, with 5 being the best rating. Once everyone had rated how each concept met the individual needs, the average rating between what every team member gave the concept was calculated. An example of the concept scoring is shown in Appendix C.

Finally, the averaged ratings were multiplied by the weightings found earlier in the concept selection process. The products were then tallied up for each concept to give the final scoring. The concept with the highest score was then selected as the concept to carry into detailed design.

Once a selection had been made, the team contacted the client to discuss the chosen concept. During this discussion the client emphasized his concerns about the durability and operation of the chosen concept. The client also stated the desire for a delay of approximately 15 minutes before product should come out of the storeveyor. From this, the team decided to reselect a concept out of only market solutions that had been researched. Precision Food Industries (PFI) was determined to be the company best able to provide a concept that would provide the required time delay. PFI was also an ideal choice because they have worked with McCain in the past and are therefore able to guarantee that they can meet McCain's food safe standards. The team worked with PFI sales staff and engineers to refine a design that met these new needs.

2.3 LAYOUT SELECTION

Before the layout generation process could happen the team first needed to examine the design space. To do this, the team scheduled a site visit to take measurements of the size of equipment, clearances and locations of potential obstacles or obstructions. The team also took pictures to help visualize the plant and use for later reference. To begin the layout generation process, each member of the team individually developed 2 to 3 layout concepts. The team attempted to keep in mind potential obstacles and restrictions that may interfere or make the design invalid when brainstorming potential solutions. The team then met to discuss each of the concepts developed. The concepts were compared and elements were combined between the concepts to develop new ones. Through some discussion, many of the generated layouts were eliminated due to space conflicts or for having great similarities with one or more of the other proposed layouts. If a layout had a space conflict, the team would brainstorm any potential way to design around the conflict, rather than just eliminated the concept outright. The layout concepts are all shown in Appendix B.

After thoroughly discussing the remaining concepts, to choose the final layout the team determined which concept resulted in the least amount of equipment relocation while maintaining a simple conveyor layout. The selected layout is described in detail in Section 3.2

3 PHYSICAL DESIGN ELEMENTS

To solve the hash brown breakage problem, a storeveyor was sourced from Precision Foods Industries (PFI) that holds product for a set amount of time. A conveyor system was then designed to bring hash browns to and from the storeveyor, and diverters were designed to redirect product to either the storeveyor or the totes as required. The details of these elements are described in the sections below.

3.1 PRECISION FOOD INDUSTRIES STOREVEYOR

During the concept generation phase of the project, numerous market storeveyors and several unique non-storeveyor design concepts were investigated. Upon consultation with the client, the goal of holding product for 15 minutes before returning it to the production line was emphasized. After comparing the options based on this consultation with the client, a First In Last Out storeveyor design by PFI was selected as the best design for the application [1]. A model of this design is shown in Figure 2.

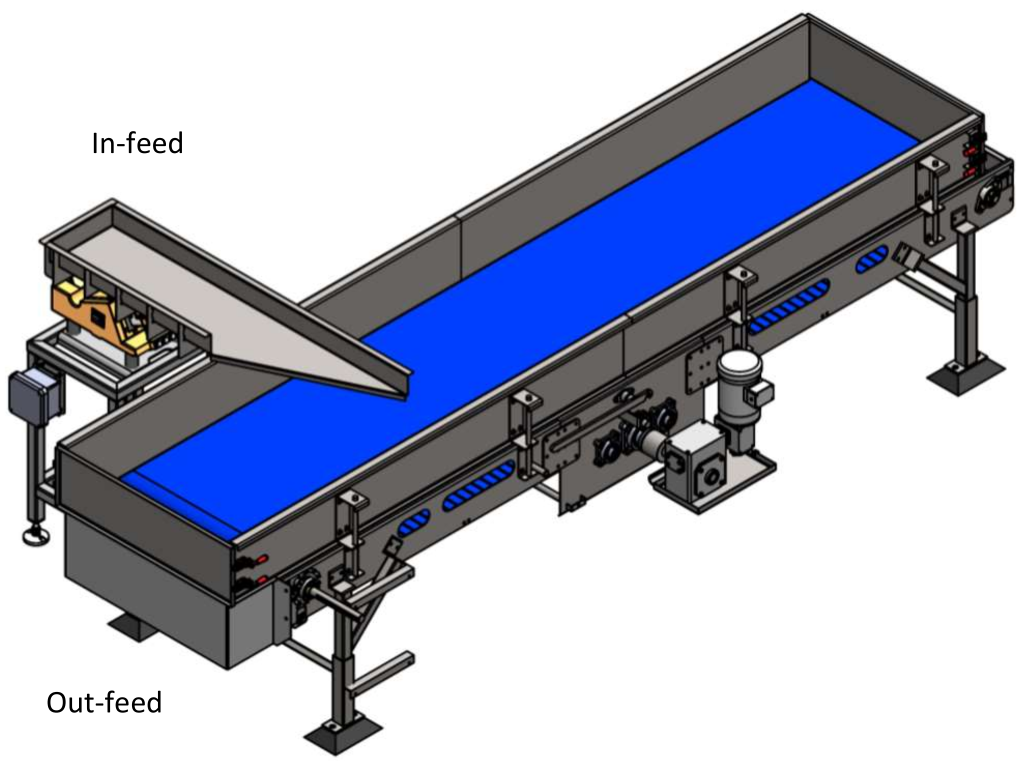

Figure 2. PFI storeveyor model

The storeveyor operates by having patties enter via a vibrating input feeder that evenly distributes them across the belt. To accumulate product, the belt slowly moves away from the out-feed. Once product has filled the entire belt, the belt reverses and sends product to the output hopper, which discharges onto a return conveyor. The design also has vision systems to detect excess piling on the conveyor belt so that product can be discharged early if the storeveyor is full.

The belt speed can be adjusted to produce whatever time delay is desired as long as the input flow rate does not exceed the maximum input flow rate determined by the capacity of the storeveyor. The calculations that define this relationship are shown below, where *capacity* is the total volume of the system, *l* is the length, *w* is the width, *h* is the height, *v* is the belt speed, *TimeDelay* is the amount of time the first hashbrown spends in the system, and *MaxInputFlowRate* is the largest volumetric flow rate of the system. However, no sample calculations or values are shared by request of the client to preserve certain company confidences.

$$Capacity = l * w * h \qquad \text{Equation 1}$$

$$TimeDelay = \frac{l}{v} \qquad \text{Equation 2}$$

$$MaxInputFlowRate = v * \frac{Capacity}{l} \qquad \text{Equation 3}$$

By having very small fall distances and minimal product depth, this design prevents breakage of patties by removing the opportunity for patties to fall long distances in large numbers, which is how it is theorized that the toting system is currently breaking patties.

This design is completely autonomous with built-in vision systems and controls so that no human interaction is required for daily operation. This reduces the number of employee hours that are required for daily operation in the freezer room.

PFI, as a food equipment manufacturer, can meet the food safe standards outlined by McCain, which include all metal-detectable materials, welds in place of fasteners, and removable easy-clean walls. The complete set of food safe standards required by McCain are listed in Appendix D.

Using PFI to manufacture this product has the added benefit that the system has already been tested and used elsewhere in industry, which means that there is far less risk of finding unexpected design flaws or failures. PFI also offers operational support, which further ensures that the design can be successfully implemented.

Detailed product specifications and a preliminary budgetary quote are found in Appendix E, and preliminary engineering drawings can be found in Appendix F.

3.2 CONVEYOR SYSTEM

Once the design for the storeveyor itself had been selected, the supporting system of conveyors could be designed. The design space for this project is the freezer room, where excess french fries and hash browns are stored in metal bins called totes until they can be dumped onto conveyors that return them to the production line. While the hash brown line is the only one being adapted in this project, the final design needed to work around all the objects in the space. Figure 3 shows the current floorplan of the freezer room with blue elements representing conveyors and grey elements representing hoppers and equipment.

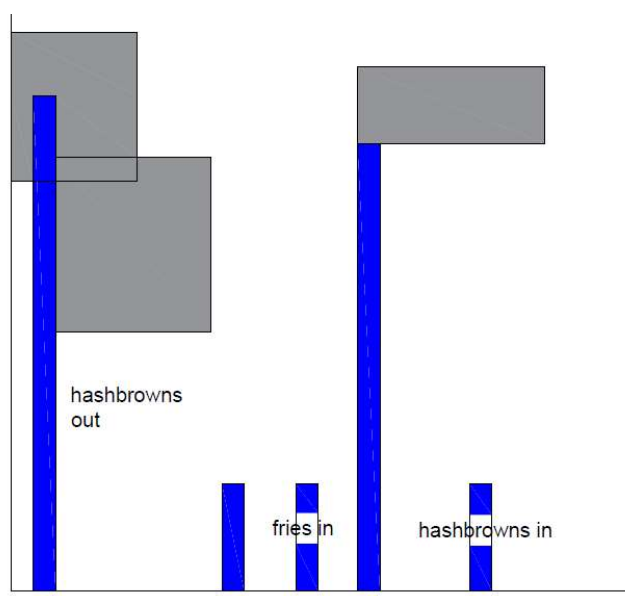

Figure 3. Current floorplan of freezer room

Design constraints within this space were as follows:

- The design could not interfere with any ceiling fans, which are spaced periodically throughout the freezer room.
- The design could not prevent forklifts from accessing the totes for either fries or hash browns.
- The design should require as little equipment to be relocated as possible.

The layout that was created is shown in Figure 4. Most french fry system elements were omitted from this image for simplicity.

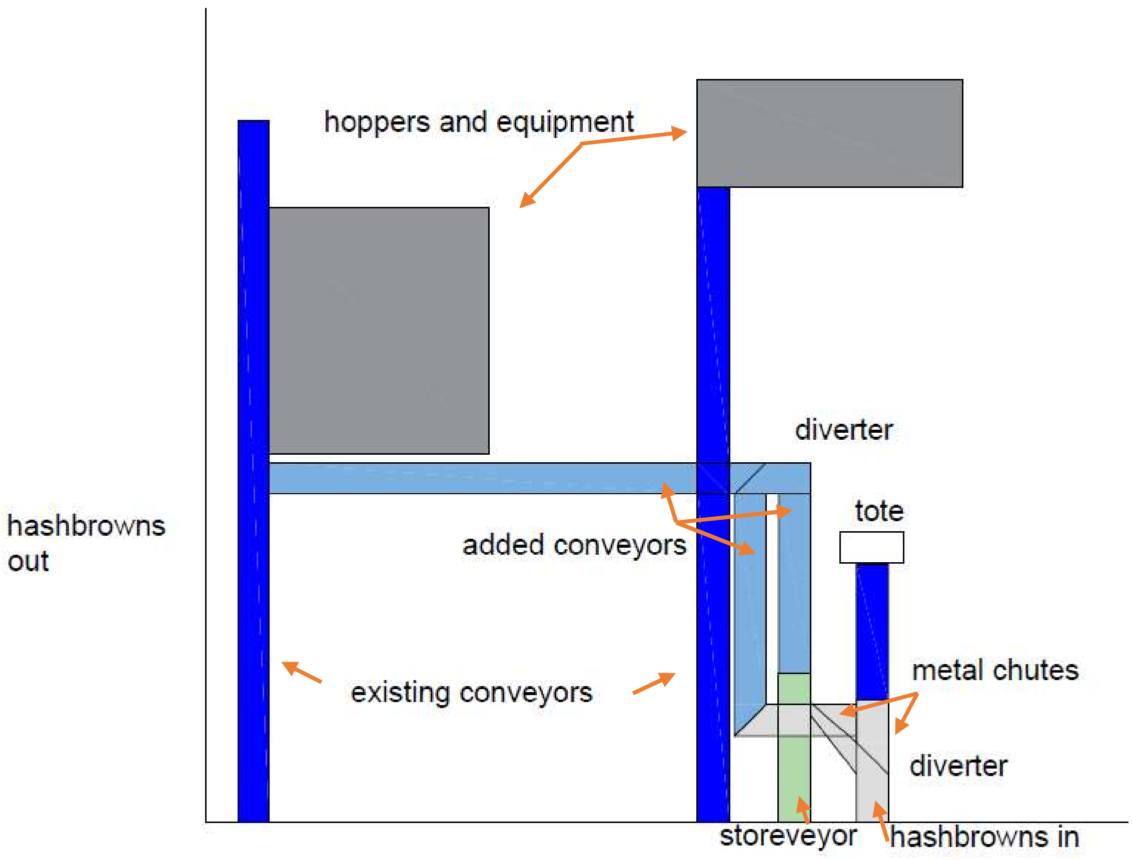

Figure 4. Proposed floorplan with integrated storeveyor

This design was determined to be the optimal solution for several reasons:

- It required minimal relocation of existing equipment
- It required only minimal changes to existing conveyors

- It utilized currently empty floor space for the storeveyor
- It provides minute process control by using multiple diverters, which are simple mechanisms that change the path of a product.

3.2.1 Operational Routes

The two diverters in this design create three possible paths for a hash brown to take depending on what is required at a given time.

The first path is for the hash browns to go first to the storeveyor and then to the output conveyor afterwards. This is the intended regular use case of this system, as the storeveyor holds the product for a set amount of time and then automatically cycles the product back onto the line without needing to be toted, preventing breakage. This path is shown in Figure 5.

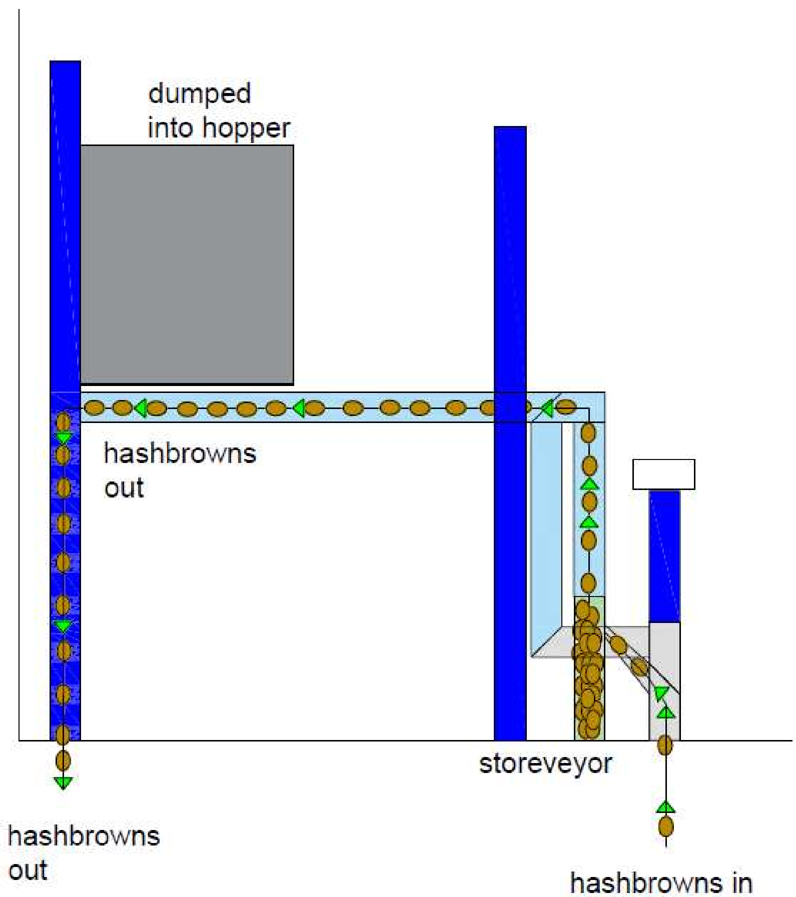

Figure 5. Hash brown path 1

The second path is for product to go straight into a tote, which is intended to only be used when product needs to be stored for longer than the storeveyor's intended delay period. This path is shown in Figure 6, where totes carried by forklifts pass beneath overhead conveyors.

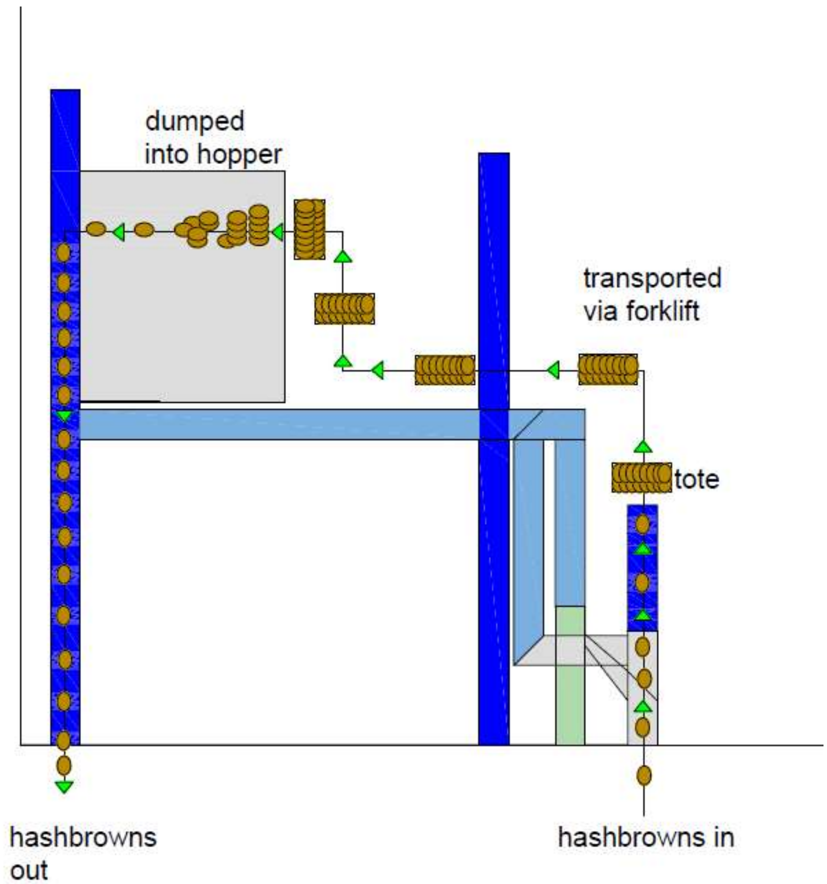

Figure 6. Hash brown path 2

The third path is to be diverted to the storeveyor, but to then be diverted back to the totes afterwards. This was added at the client's request so that if the packaging line stops and will remain stopped for longer than the hold time of the storeveyor, or if product in the storeveyor becomes contaminated, the patties can be redirected to a tote rather than being cycled back to the production line. This path is shown in Figure 7.

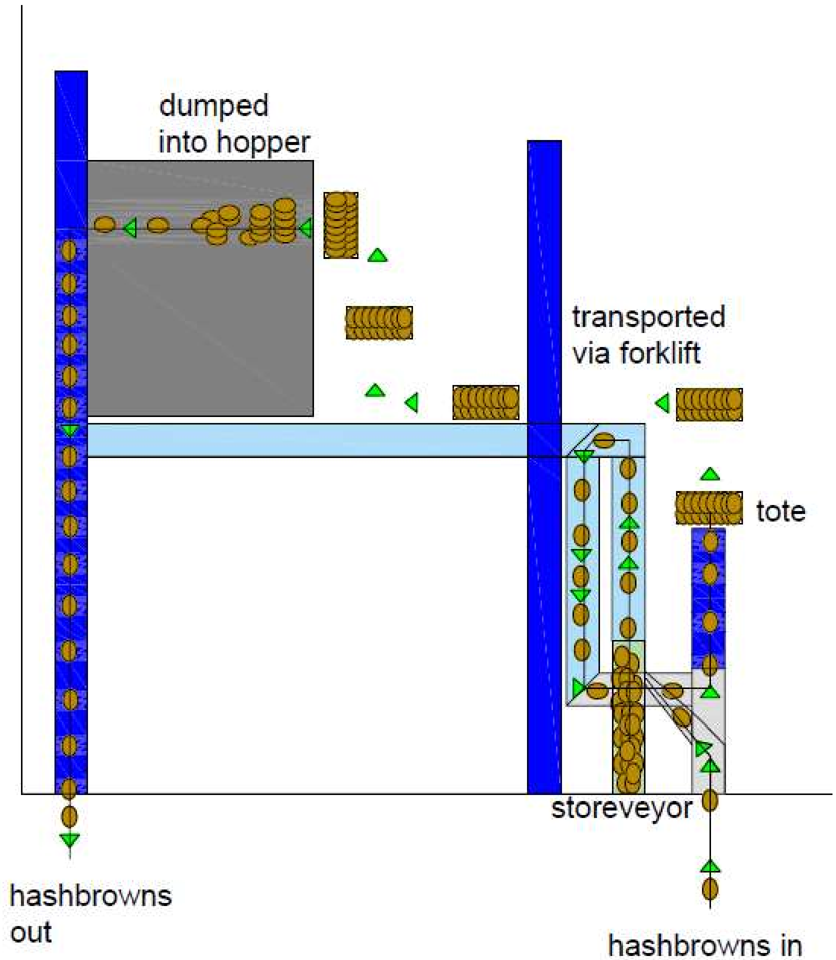

Figure 7. Hash brown path 3

3.2.2 Conveyor System Detailed Design

Since forklift access to the totes is important, the conveyors that are added in this design had to be elevated whenever possible to allow forklift traffic to pass underneath. To show the heights that the different elements will be located at, drawings of the various elements were made. The conveyors have been numbered to make interpreting these drawings simple, and these numbers are shown in Figure 8.

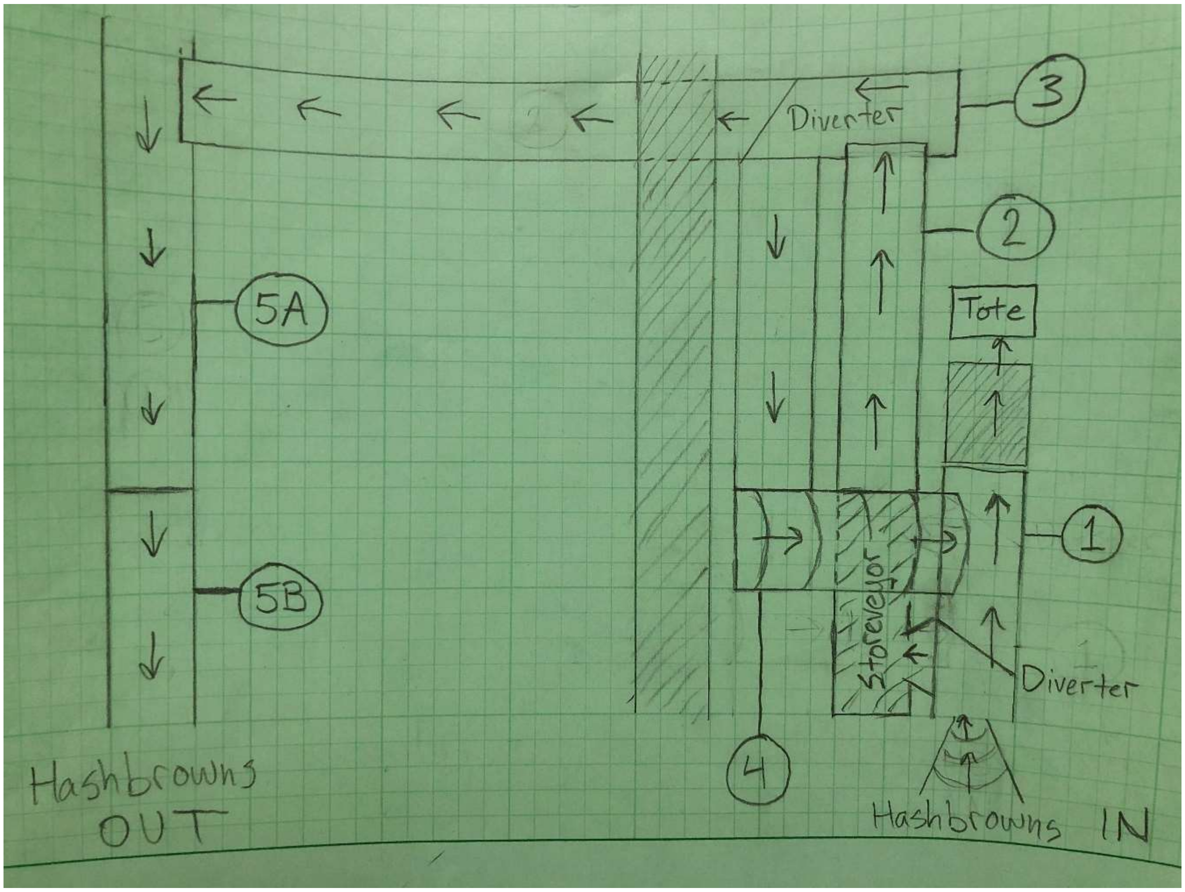

Figure 8. Top view of conveyor belt system with labelled conveyors

Conveyor 1 is where hash browns enter the system. This conveyor has two inputs of hash browns: one from production and one from the return path from the storeveyor. Additionally, it has two outputs for hash browns: one to the storeveyor via the diverter and one to the totes via the direct route. Thus, the length of this conveyor must accommodate the two inputs and the diverter. Giving an average of 4-feet of length for each of these, conveyor 1 is just under 12-feet long. Conveyor 1 is 10-feet high, which allows for a small drop down a metal chute and onto the existing conveyor leading to the totes. No changes in elevation are necessary, resulting in a flat horizontal conveyor, shown in Figure 9.

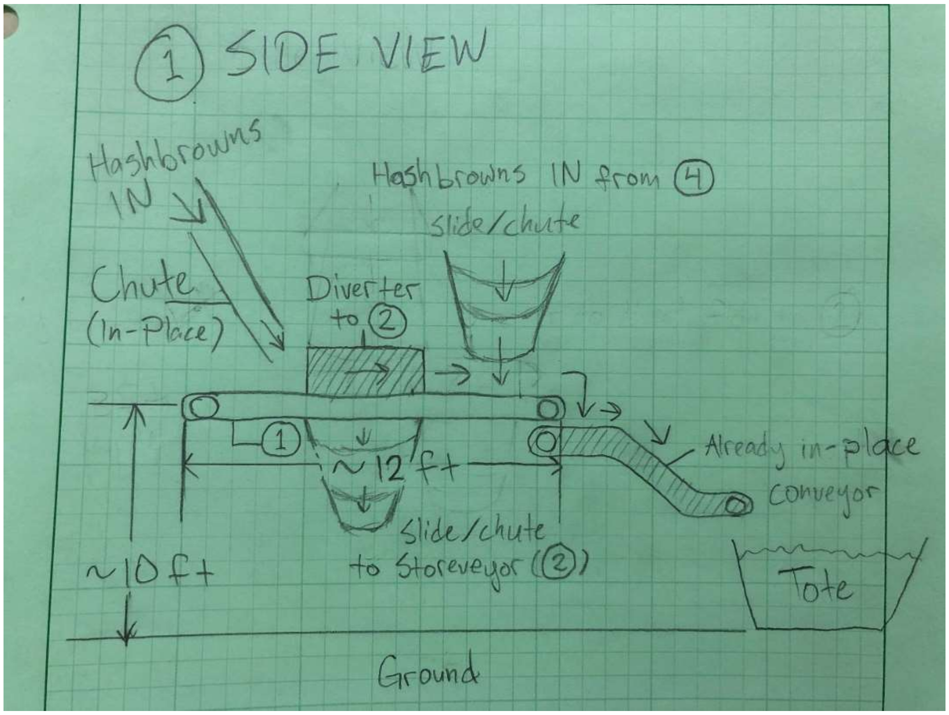

Figure 9. Conveyor #1 side view with adjacent equipment

Conveyor 2 has the objective of taking hash browns from the storeveyor and transporting them 17-feet across and 14-feet up to conveyor 3. This results in a conveyor that is 25-feet long with a 40-degree incline. This conveyor includes flights and sidewalls to prevent hash browns from falling and is shown in Figure 10.

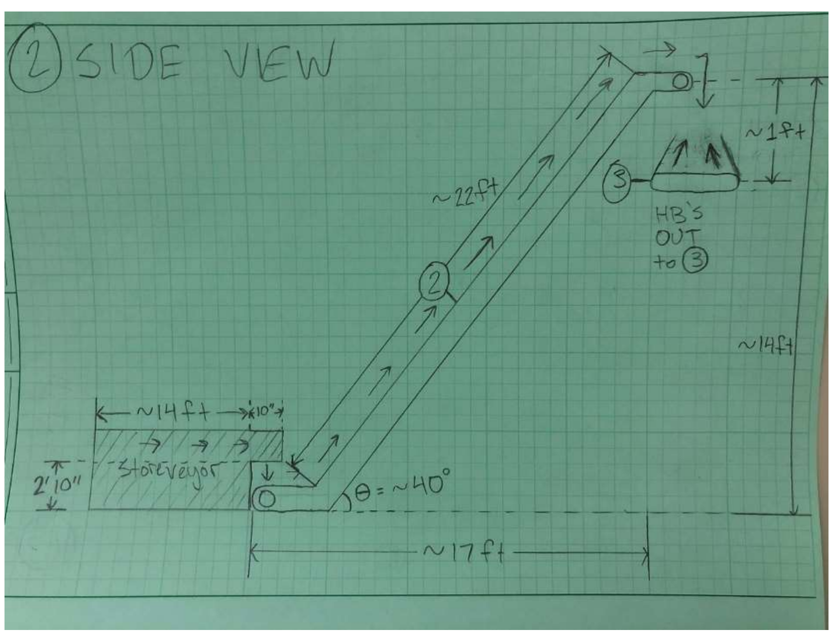

Figure 10. Conveyor #2 side view with adjacent equipment

Conveyor 3 is a simple horizontal conveyor running from conveyor 2 to conveyors 4 and 5.

This conveyor:

- Could not cross the path of any ceiling fans
- Must be high enough that forklifts could pass underneath it
- Must either pass above or below the fry return conveyor that crosses the center of the freezer room.

The constraints resulted in a conveyor 13-feet high and suspended from the ceiling to provide forklift pathways underneath. This results in it passing 1-foot below the existing fry return conveyor. Immediately after the hash browns fall from conveyor 2, a diverter is placed that can actuate to send hash browns on a return path leading to conveyor 4 and the totes. If the diverter is not activated, the hash browns are sent to conveyor 5 via a metal chute, returning hash browns to production. Conveyor 3 leads directly to the flat, horizontal section in-between the two ramps of conveyor 5, where the hash browns are dumped and return to production. This conveyor is shown in Figure 11.

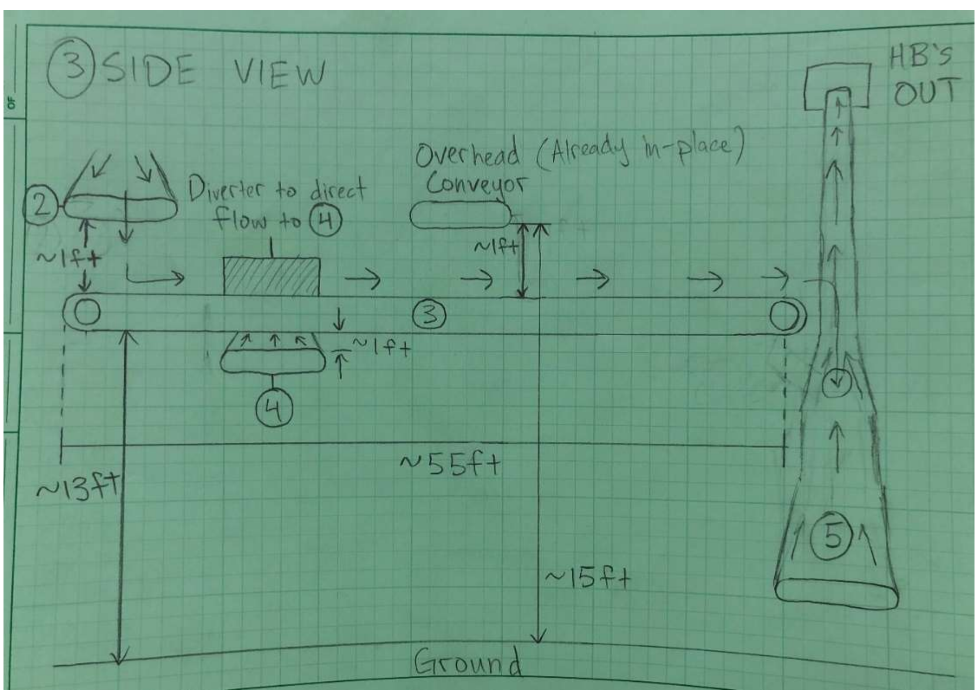

Figure 11. Conveyor #3 side view with adjacent equipment

Conveyor 4 is the return conveyor belt implemented in case the hash browns need to be sent from the storeveyor to the totes rather than to production. Diverting from conveyor 3, the hash browns make an approximate 1-foot drop onto conveyor 4. Conveyor 4 is located 12-feet high and has a length of 25-feet and is suspended from the ceiling. Conveyor 4 leads to a metal chute that is perpendicular to the conveyor. The chute is 8-feet in length and declines an elevation of 3 feet to conveyor 1. It is shown in Figure 12.

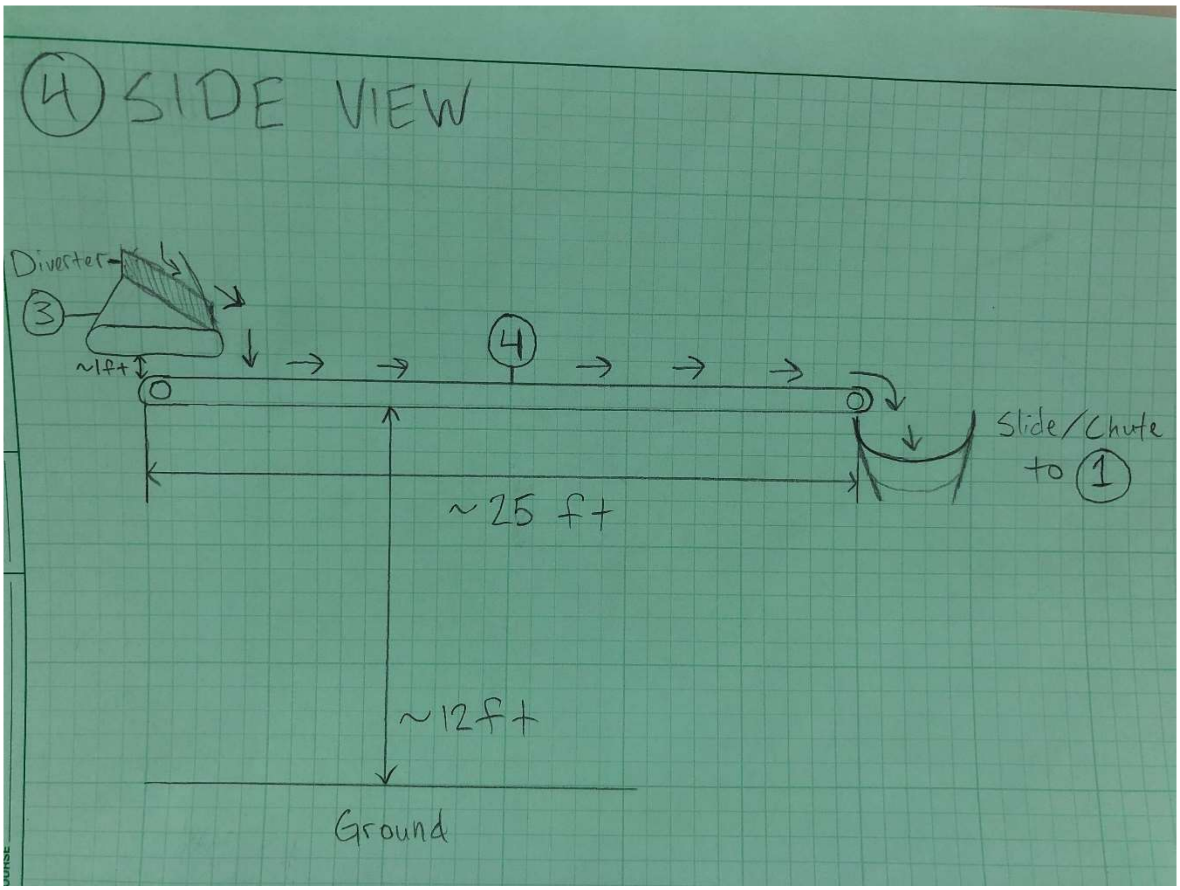

Figure 12. Conveyor #4 side view with adjacent equipment

Conveyor 5 is an existing conveyor belt that requires modifications, the purpose of which is to include a safe landing point for the hash browns coming from conveyor 3. These modifications have the following constraints:

- The modified conveyor should use the existing support structure if possible
- The modified conveyor must continue to go over a hopper that the existing conveyor is currently above

- The point where the storeveyor hash browns are dumped must be level and low enough to accommodate the conveyor unloading onto conveyor 5.

The resulting conveyor 5 includes two individual inclined conveyors labelled 5A and 5B that waterfall from one to the next. This is not a single conveyor belt because there have been issues in the past using ThermoDrive belting on a double incline as required in our project. It is extremely difficult for the belt to navigate multiple transitions and form a straight-line path from the infeed to the discharge shafts. Thus, the design implements two single ramp conveyors at angles of approximately 40-degrees. The ending horizontal section of conveyor 5A is below the end of conveyor 3 to create the safe landing point for the hash browns. The hash browns then waterfall onto conveyor 5B and are sent out to production. The different lengths and angles are shown in Figure 13.

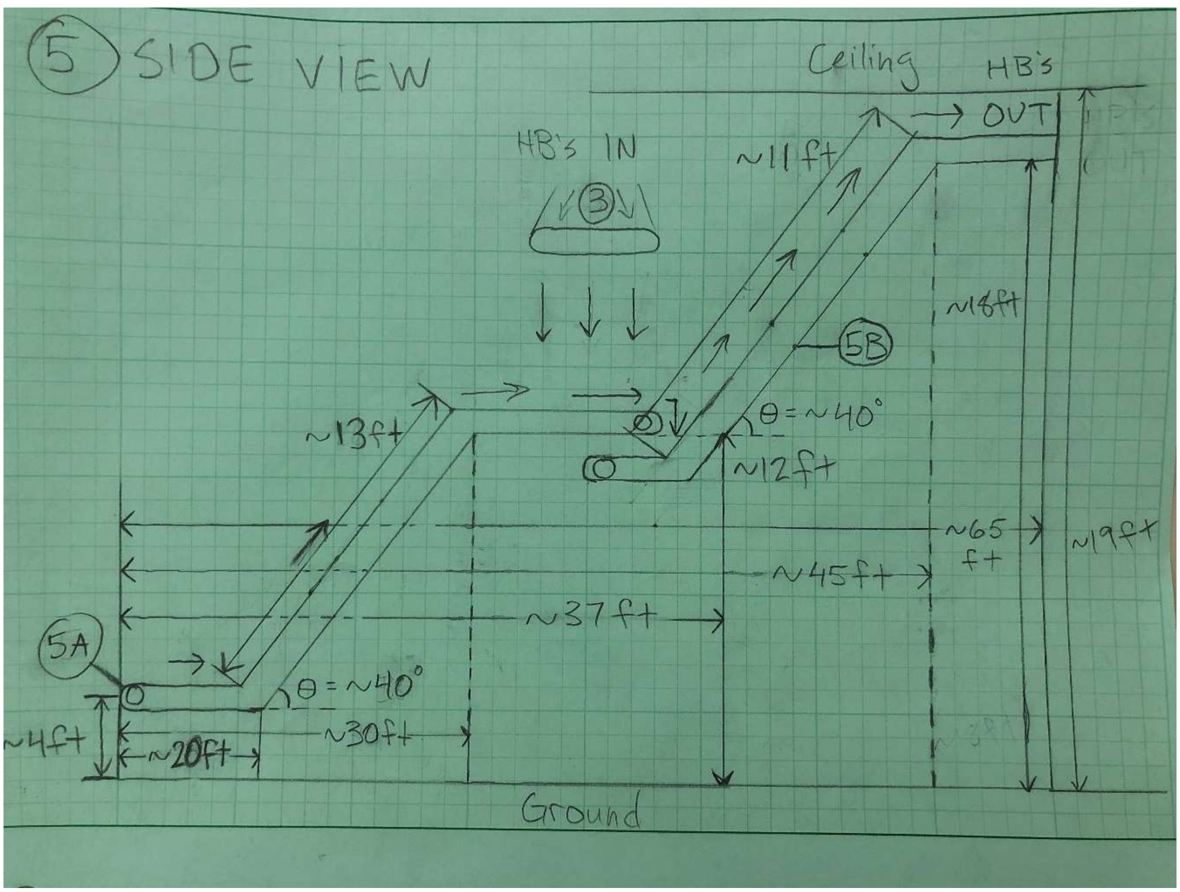

Figure 13. Conveyor #5 side view with adjacent equipment

In total this system has 6 conveyor belts, 2 diverters, and 3 metal chutes. Conveyors with inclines will include flights to keep product from sliding down the belts.

This system is consistent with the rest of McCain's plant because it is sourced from the same manufacturers that they use for their existing conveyor belt systems. This means the use of similar belts, support structures, 1-foot high sidewalls, and belt widths of 3-feet. This also allows the system to be easily maintained as its maintenance can be incorporated with the maintenance of the rest of the plant, including similar parts, equipment, tools, etc. These reasons make the conveyor belt system the most convenient solution for transporting hash browns to and from the storeveyor.

3.3 DIVERTER

Throughout the conveyor system there are numerous instances where it is desired to change the path of a product. In order to do this, the facility currently makes use of diverters. Diverters are simple mechanisms that use an air cylinder to actuate a portion of the conveyor sidewall to divert product off the conveyor. Diverters are used throughout the facility for several different purposes, whether it be to send product to waste or to divert product to different machines to spread the load. An image of one of the current diverter mechanisms in use on the hash brown packaging line is shown in Figure 14.

Figure 14. Diverter diverting product towards the packaging area

In the case of this project, there are two new points where diverting product is necessary. These two diverters are located at points before and after the storeveyor. In case the storeveyor becomes full, the hash browns need to be sent to the totes in order to keep production running. But the client also needs to be able to reject product after the storeveyor in case of long packaging line delays or contamination of the product. If the diverting at the latter location was not integrated, to reject product from the storeveyor, the product would have to cycle around back through the packaging and inspection area and be diverted before the storeveyor. In the case of contamination, the contaminated product would be mixed with a potentially large volume of uncontaminated product which would then become contaminated as well. Thus, the client has specified that there must be a way to reject product before that point of mixing. Therefore, it was necessary for the team to design two diverter systems and determine how to integrate it into the storeveyor system.

For the diverter after the storeveyor, the design is very similar to that of the one shown in Figure 14. However, there will not be a dividing wall that separates the conveyor product flow like that seen in Figure 14. Since the product will be running on a flat conveyor with no flights, the same type of diverter design is valid. The diverter system at this location consists of a diverter arm of length 4-feet 3-inches that directs the product off the side of the conveyor. To divert product, the diverter arm will actuate to a 45-degree angle to the conveyor belt. This requires that a 3-foot portion of the conveyor wall opposite the diverter arm be vacant to allow product to fall off the side. The starting point of the vacant section of the wall should begin at the point opposite of the pivot point of the diverter arm. Under this portion of vacant wall there is a metal chute that directs product to a perpendicular conveyor running beneath the former conveyor, which then delivers the hash browns to the totes.

The diverter before the storeveyor required more of a custom solution. This is because the facility originally had hash browns entering the freezer room through a metal chute that would dump onto a conveyor that slopes downwards. The problem here is that conveyors that accommodate elevation changes use flights on the conveyor belt to prevent the product from sliding down the gradient. These flights therefore do not allow for the product to be diverted using the standard diverter. Therefore, the team brainstormed potential designs. A design was developed that was as similar as possible to the diverters currently in the facility, and is shown in Figure 15.

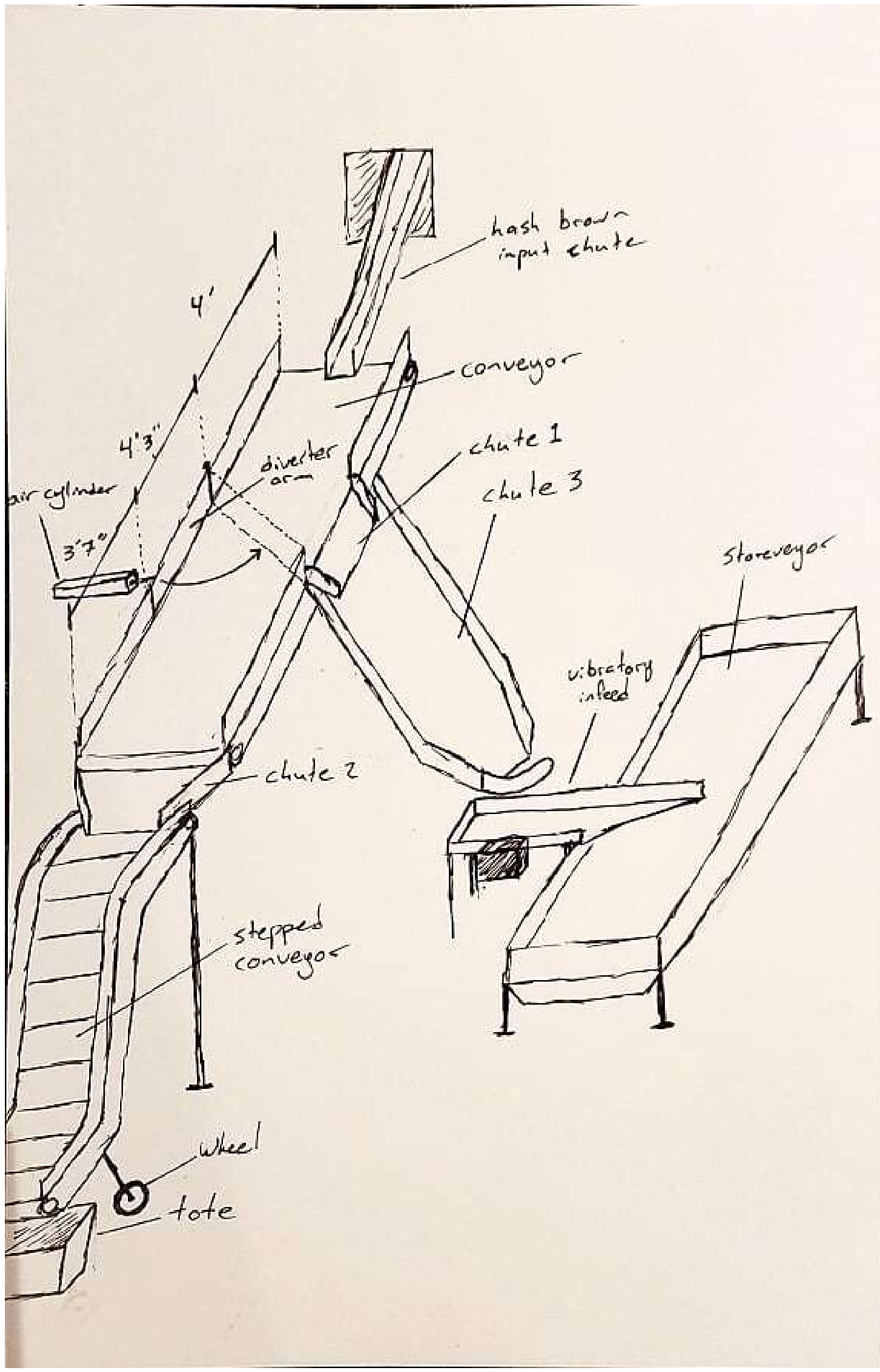

Figure 15. Intermediate conveyor concept

This design was chosen because the input chute would not need to be modified in any way and would unload hash browns as it currently does. This was ideal for the fact that adding a trap door or a diverting arm to the chute would likely require fasteners, which is undesirable and would not meet the food safety codes. Additionally, by choosing this design the method of diverting the product remains familiar to McCain Foods as it utilizes all the same equipment located elsewhere in the facility and is very similar to their standard diverter design.

For the selected design, the hash browns are set onto the flat conveyor which is located 1-foot away from the wall. The conveyor, which features 1-foot high side walls, carries the hash browns towards the stepped conveyor and onto chute 2 which directs product onto the stepped conveyor. This stepped conveyor then leads to the totes as it does currently. If the product is to be sent to the storeveyor, the air cylinder actuates the diverter arm 45-degrees. The product will then fall off the conveyor's side onto the small chute 1 which is an intermediate chute that guides the product onto chute 3. To stop product from skipping off the vibratory infeed of the conveyor, chute 3 has a stopping plate at the end of the chute much like ones elsewhere in the hash brown production line. If there is a concern with the speed that the hash browns slide down this chute, it is suggested that the storeveyor is placed on a platform to decrease the vertical distance that the hash brown must slide. Not shown in the sketch is the return conveyor that returns the product that is diverted after the storeveyor for toting. This was done for simplicity of the sketch; however, the return conveyor unloads product on the portion of the flat conveyor between the free end of the diverter arm and the stepped conveyor.

3.4 MATERIALS AND COST

This section outlines the materials required to implement the system, as well as their costs, and any critical spares that the team recommends McCain keep on hand.

3.4.1 BILL OF MATERIALS

The assembly level Bill of Materials, is presented in Table I. Component level BOMs for each of these assemblies can be obtained from their suppliers, listed in the table, with

Eastern Fabricators [2] listed as EF and McCain listed as MC. Eastern Fabricators sources their conveyor belts from Intralox [3].

TABLE I: BILL OF MATERIALS

BOM Level	Component Name	Supplier
0	Storeveyor	PFI
0	Conveyor 1	EF
1	Input Chute	MC
1	Diverter 1	MC
1	Chute to Storeveyor	EF
1	Conveyor to Totes (existing)	MC
0	Conveyor 2	EF
0	Conveyor 3	EF
1	Diverter 2	MC
0	Conveyor 4	EF
1	Chute to Input	EF
0	Conveyor 5A	EF
0	Conveyor 5B	EF

3.4.2 Critical Spares List

The team created a list of critical spare parts based on the importance of the parts to the operation of the system and the part's likelihood of failure. The team decided not to include critical spares for the storeveyor, since failure is unlikely, and in the case of a failure the system can always divert to the totes until parts can be obtained, therefore the cost of carrying inventory for the storeveyor is not justified. Additionally, fasteners such as nuts and bolts have not been included in the list upon the assumption that McCain has these spare parts and the parts will be compatible due to using the same manufacturers for the system. This list can be found in Table II.

TABLE II: CRITICAL SPARES LIST

Mechanical Spare Parts List		
Conveyor Belt System		
Description	**QoH**	**Unit**
Belt: S8050 FT Dura E 7.0mm Blue **Width**: 36” **Length**: 34’	1	Each
Belt: S8050 FT Dura E 7.0mm Blue **Width**: 36” **Length**: 55’ **Flights**: 6” 7mm 90-degree flights on 12” centers with 2” indents and 2” center notch	1	Each
Belt: S8050 FT Dura E 7.0mm Blue **Width**: 36” **Length**: 117’	1	Each
Belt: S8050 FT Dura E 7.0mm Blue **Width**: 36” **Length**: 55’	1	Each
Belt: S8050 FT Dura E 7.0mm Blue **Width**: 36” **Length**: 28’ **Flights**: 6” 7mm 90-degree flights on 12” centers with 2” indents and 2” center notch	1	Each
Sprockets: 7.7” PD with 1.5” square bore	2	Each
Support Wheels: 7.7” OD with 1.5” square bore	2	Each
Retainer Rings: SS Heavy Duty Split with 1.5” square bore	5	Each
Position Limiters: EZ Clean Universal Mount	2	Each
Compressed Air Cylinder	1	Each

3.4.3 Cost Analysis

In addition to the quote given by PFI for the storeveyor, several companies were contacted for quotes on the conveyors and diverters in the system. Preliminary budgetary information from Eastern Fabricators is presented in Table III [2]. All pricing is in Canadian Dollars and is subject to change based on US/Canadian tariffs. All taxes are extra.

TABLE III: PRELIMINARY BUGETARY INFORMATION

Item	Quantity	Supplier	Description	Unit Price
1	1	Eastern Fabricators	Conveyor Budget	$689,628.00
2	1	Eastern Fabricators	Installation Budget	$82,544.00
3	1	Eastern Fabricators	Crating & Loading Budget	$3,150.00
4	1	Eastern Fabricators	Shipping Budget	$8,250.00
5	1	PFI	Storeveyor	$104,805.00
			Total	$888,377.00

This quote was made based on previous work that Eastern Fabricators has done for McCain. Both the team and the client suspect that the quote is much higher than the actual cost of the system, since the conveyor support structures needed for this design are much simpler than many that are used elsewhere in the facility. The support structure used in the budget was determined by Eastern Fabricators and may not actually be the optimal design, thus cost reductions may be possible through redesign of the support structure. Further, the client suspects that the price could be further reduced by reusing or modifying existing conveyors.

When discussing this budgetary information with the client, they stated a project budget of $200,000 as an estimate but were uncertain how much the project would actually cost. Given that the conveyor system utilizes the shortest paths reasonably possible along with using equipment already used throughout the facility, it is believed that the system was designed to be near the lowest price possible to implement.

4 OPERATION

This section contains all the operational details of the design, including the risk analysis that was performed on the system, the cleaning considerations, the PLC logic that should be used to run the system, and team recommendations for future work.

4.1 RISK ANALYSIS

Risk analysis is an important part of any design process. Defects in a design are often detected through extensive testing and predictive modeling in later stages of development. However, finding a defect at this instance can add significant cost and delays to the project schedule. Risk analysis eradicates this problem by evaluating the quality and reliability of a design at the beginning of the process which increases the probability of detecting these defects. Upon detection, several actions must be taken to reduce risks and sources of risks that are present in any given system.

4.1.1 Identification and Assessment of Risk in System

The first step of risk analysis is risk identification, which involves creating a list of possible risks for each stage of the system. This list must contain all possible risks and sources of risk that will disrupt the system and prevent it from achieving its goals. The second step is to perform analysis on these identified risks to determine which area of the production system the risk occurs and which area is affected by the highest amount of risk. The third step of risk analysis is to measure and determine the extent of the impact each risk will have on the system. A Failure Modes and Effect Analysis (FMEA) is a qualitative and systematic tool, usually created within a spreadsheet, to help practitioners anticipate what might go wrong with a product or process. In addition to identifying how a product or process might fail and the effects of that failure, FMEA also helps find the possible causes of failures and the likelihood of failures being detected before occurrence [4].

4.1.2 Determining the Risk Priority Number (RPN) in FMEA Method

The procedure for using the FMEA method is as follows: determine the operations in the process, identify the risk factors that are present in the process, determine the effects that are caused by the presence of these risk factors, and then find the possible causes. Next, assign numeric values to the parameters shown in Table IV [4].

TABLE IV: CHARACTERISTICS OF THE PARAMETERS USED IN THE FMEA METHOD FOR DETERMINING RPN

Parameter symbol	Parameter name	Description
SEV	Severity	How severe is the failure mode (1-10)
FREQ	Frequency	How frequently the failure mode occurs (1-10)
DET	Detection	How capable the current control scheme is to detect or prevent the failure mode from occurring (1-10)

The Risk Priority Number (RPN) describes the extent of the risk and is calculated for each of the selected areas of the system using the formula:

$$RPN = SEV * FREQ * DET \qquad \text{Equation 4}$$

The obtained value for the RPN is then used to assess the estimated risk and serves as a reference point for the corrective actions that should be taken. Since each of the parameters are ranked on a scale of 1-10, the value of the RPN will range from 1-1000. A high RPN value corresponds to a high risk in the process. Therefore, if the RPN value of a risk is high, steps should be taken to mitigate said risk. Corrective actions should be prioritized in the areas with the highest RPN values because these risks are most critical.

Numerical values corresponding to levels of risk for each parameter are shown in Table V, Table VI, and Table VII [4].

TABLE V: LEVEL OF RISK AND ITS CORRESPONDING NUMERIC VALUES FOR THE FREQUENCY PARAMETER

Level of Risk	Characteristics	FREQ (RANK)
Remote	Failure improbable	1
Low	Single occurrences	2 - 3
Moderate	Occasional failure	4 - 6
High	Failure occurs with high frequency	7 - 8
Very high	Failure is almost inevitable	9 - 10

TABLE VI: EFFECT RATE AND ITS CORRESPONDING NUMERIC VALUES FOR THE SEVERITY PARAMETER

Effect Rate	**Characteristics**	**SEV (RANK)**
None	No effect	1
Minor	Minor disturbances; only noticed by some workers	2 - 3
Low	Minor disturbances; minor impact on safety; some activities are burdensome without reduction in performance	4 - 5
Moderate	Minor disturbances; affects the safety in less than 100%; working is burdensome without reduction in performance	6
High	Minor disturbances; affects the safety in less than 100%; a reduction in performance without loss of equipment function	7
Very high	Significant disturbances; affects the safety in 100%; loss of equipment function	8
Hazardous with warning	Hazardous to workers, significantly affects the safety, the condition is inconsistent with regulations and standards, the hazard occurs with warning	9
Hazardous without warning	Hazardous to workers, significantly affects the safety, the condition is inconsistent with regulations and standards, the hazard occurs without warning	10

TABLE VII: LEVEL OF RISK AND ITS CORRESPONDING NUMERIC VALUES FOR THE DETECTION PARAMETER

Detection Rate	**Probability of detection of a failure by control**	**DET (RANK)**
Almost certain	Process is protected against the occurrence of failure; failures always detected	1
Very high	Controlling and finding failure stops process; failures almost always detected	2
High	High probability failure will be detected	3 - 4
Moderate	Control may detect the occurrence of failure	5 - 6
Low	Control has a low chance to detect failure	7 - 8
Very low	Control probably will not detect failure	9
Absolute uncertainty	Control will not detect failure	10

4.1.3 PERFORMING FMEA ON THE SYSTEM

The team divided the system into three stages; initiation of the conveyor system, running of the conveyor system, and analysis and cleaning of the conveyor system. Next, the team compiled a list of all possible risks in each of the three stages of the system. The risks were then separated and organized into specific groups that correspond to the failure mode of the system. These groups were aligned with the stages of the system that they occur in and inserted into the FMEA table. Using the FMEA table, each failure mode was assigned ranks for severity, occurrence, and detection on a scale of 1-10. These numbers were used to calculate the Risk Priority Number for each of the potential failure modes. The complete FMEA breakdown is displayed in Table VIII.

TABLE VIII: FAILURE MODE AND EFFECT ANALYSIS OF THE SYSTEM

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
Initiation of conveyor system	Transmission system failure	Wasted time - System will not run	8	Coupling failure, Motor failure, Gearbox failure, Pulley failure	4	Ensuring operator has necessary training and follows proper instructions	3	96	More training and better instructions for starting conveyor belt
	Tensioning system failure	Potentially dangerous and inefficient - System will be misaligned	9	Electric winch failure, Coupling failure, Tension drum failure, Guide pulley failure, Diverter pulley failure	3	Ensuring operator has necessary training and follows proper instructions	2	54	More training and better instructions for starting conveyor belt
	Product contamination	Product fails food safe standards Dangerous to consumer and company	9	Use of non-food safe materials. Outside contaminants introduced into system	6	Only using food safe materials. Aware of possible contaminations.	4	216	Eliminate all sources of outside contamination. Ensure the use of food safe materials
Running conveyor system	Belt damage	Dangerous - Belt will break when not properly maintained	9	Joint breakage, Cracking, Chipping, Notching, Tearing, Cutting, Deformation, Belt slip-off	6	Periodic inspections	5	270	More frequent and more diligent inspections examining the conveyor belts
	Product buildup	Inefficient - Delay in transportation of product	2	Product forms blockages along conveyors	8	Routine cleaning	3	48	More frequent cleaning and a better system for filtering waste

TABLE VIII CONTINUED

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
Running conveyor system	Product damage	Costly - Wasted product	3	Damage from dropping to totes and conveyors	9	Product passes through inspection	1	27	Create smaller drops in the system so that the product is not damaged
	Wear and tear of conveyor components	Wasted time - System will break down	8	No periodic diagnostics, Lack of proper lubrication	5	Periodic inspections	4	160	Keep up with preventative maintenance on equipment
Analysis and cleaning of conveyor system	Lack of personnel	Inefficient - System is not optimized	1	Operating and servicing diagnostic systems, Interpreting results	5	Electronic controls via PLC	6	30	Perform studies that measure the performance of the system
	Lack of data	Misinformation - Mistakes will be repeated and/or go unnoticed	2	Data about operational events are not recorded. Lack of data about actual duration of components and operation time of individual subassemblies. Lack of diagnostic systems	5	Unknown	6	60	Keep records that will track the performance of the system and the important occurances
	Cleaning failure	Dirty equipment and/or surfaces	4	Poor sanitation practices	7	Periodic cleanings	4	112	More frequent and thorough cleanings

4.1.4 FMEA Results

According to the FMEA analysis, the three main areas of concern are belt damage, product contamination and wear and tear of conveyor components. Corrective actions should be taken to mitigate the effects of these risk areas. It is recommended that the conveyor belts be examined frequently and diligently to ensure that there is no damage present. It is also recommended that all sources of outside contamination are eliminated, and the use of non-food safe materials is prohibited. Additionally, preventative maintenance on equipment in order to reduce wear and tear of the conveyor components is important for long term use. These actions will reduce the risk associated with the implementation of the system.

By ensuring that the risks are minimized within the system, both human safety and product quality can be guaranteed.

4.2 FOOD SAFETY

In addition to human safety and equipment reliability, the system must also be food safe to ensure high product quality. This means the system must adhere to the food safe guidelines provided by McCain Foods [5]. These guidelines describe the types of materials that may be allowed in the system and the specific instructions for handling and care of the product. The system also requires absolute minimum possibility of contamination from both inside and outside threats. All the suppliers used in this design adhere to McCain's food safe guidelines, using materials and construction practices that meet those standards.

The other preventative practice McCain uses to maintain food safety is regular cleaning and sanitization of all production surfaces. A proper cleaning procedure is crucial in ensuring that the appropriate food safety guidelines are met. The designed system accounts for this need and has many features that make cleaning easier. Removable walls are featured on the storeveyor and all conveyors to provide ease of access for cleaning. The system has washable surfaces that are accessible by hoses and other cleaning apparatuses. This simplifies the cleaning process and makes it more efficient. The system design also ensures there are no hard to reach areas which would make cleaning difficult. While this system is working, proper sanitation practices must be followed. These include washing hands when entering the facility and before touching a food contact surface. These also include keeping an eye out for possible sources of contamination from both inside and outside the system. The system requires frequently scheduled and thorough cleanings throughout the entire process.

4.3 DIVERTER PLC CONSIDERATIONS

The system design incorporates two diverters into the process. The first diverter is located before the storeveyor and sends hash browns to either the storeveyor or straight to the tote. The second diverter is located after the storeveyor and sends hash browns to either the output or back around to the tote. This is a feature that has been requested by the client because they may need to empty the contents of the storeveyor into a tote for longer duration storage or in the case of contamination.

There are two options for controlling the diverters in the system. The first option is to have both diverters connected to the same switch. This will result in all the product (both the input and what is being held in the storeveyor) to be diverted directly into the totes at the same time. The second option is that both diverters have separate switches and act independently. This option provides more flexibility and customization. Ultimately, it will be up to the client to select one of the two options. The team has been told that connecting the system to the PLC system is outside the scope of this design project.

4.4 FUTURE WORK AND RECOMMENDATIONS

There are several areas of this project that were outside the scope of the project. These included outside connections that are needed by the system; PLC, electrical, and compressed air. These also include cleaning guidelines and sanitation procedures. Additionally, the client has stated that system analysis will be done internally to make sure the design is viable, as well as a Return on Investment analysis.

The team recommends that the client reviews the specifics of the design to ensure safety and reliability of the equipment and procedures. Although the client typically does not keep CAD models and engineering drawings for their systems, the team recommends that these be considered for this design.

Moving forward, the design specifics of the storeveyor will need to be reviewed with PFI to create a request for expenditure authorization. Finally, a project schedule must be created for the implementation of this design. Upon successful implementation, the team recommends that the client consider designing a conveyor storage system for their french fry process, since it shares the same difficulties as the current hash brown system.

5 CONCLUSION

McCain Foods has partnered with the University of Manitoba IDEA program to commission the design of a conveyor system for hash brown patties that will temporarily store the patties using a storeveyor and continuously cycle them back onto the production line. The team designed a conveyor system that stores and transports hash browns from the input chute to the output conveyor to be recycled through the existing system. At the beginning of the system there is a diverter that directs the hash browns to either the storeveyor or a tote. The design features a storeveyor that was sourced from Precision Food Industries that can hold hash browns for a set amount of time or until the storeveyor is full. After the hash browns get released from the storeveyor, they are transported via an inclined conveyor onto an elevated conveyor. The elevated conveyor features a diverter that, if activated, transfers the hash browns onto a separate conveyor that sends them into a tote. If the diverter is not activated, the hash browns will be conveyed across the room and dropped onto the refeed conveyor that recycles the hash browns back into production. A redesign of the refeed conveyor was necessary in order to create a safe place to drop the hash browns.

There are three primary project requirements that the team identified based on discussions with the client. The first requirement is to reduce the amount of product being toted, which is met by having the new system working parallel to the tote system. The second requirement is to reduce patty breakage and deformation. The new system accomplishes this by not having the hash browns drop on top of each other in large quantities and by reducing the drop height of the hash browns to a maximum of 12-inches. The third requirement is to eliminate time spent emptying totes, which is met by having the new system be completely autonomous.

Since the hash brown process and the french fry processes are very similar, McCain Foods may want to consider implementing a similar conveyor storage system design for their french fry process as well. Implementing this design in the french fry process will save time by making the process autonomous while also making the process more efficient. Similar equipment and design will achieve this result.

The cost of this design was determined from preliminary quotes from vendors contacted for this project and is roughly estimated to be at maximum $900,000, although the client is confident that this cost can be reduced by further consultation with the vendors.

This design accomplishes all three objectives set forth by the client by providing an alternative system to the tote system that features small drops and even distributions of product to prevent damage and runs entirely autonomously.

REFERENCES

[1] Precision Food Industries, *Quote 11141,* Othello, 2019.

[2] Eastern Fabricators, *Q2712 R0,* Georgetown, 2019.

[3] Intralox, *TD Quote,* 2019.

[4] G. Forrest, "QUICK GUIDE TO FMEA (FAILURE MODE AND EFFECTS ANALYSIS)," [Online]. Available: https://www.isixsigma.com/tools-templates/fmea/fmea-quick-guide/. [Accessed 3 December 2019].

[5] McCain Foods (Canada), *Food Process Equipment Sanitary Desing and Construction Guidlines.*

APPENDIX A

Table of Contents

List of Tables

This appendix outlines the design needs, specifications, and constraints determined by the team in the first phase of the project.

Design Requirements

A full list of project requirements was created based on discussions with the client. The client then had the opportunity to review the list and make any necessary changes. A table of the current list of project requirements was made, in which each requirement has been assigned an index number for reference as well as a priority number. Priority was ranked from 1 to 3, with 1 being highest priority and 3 being lowest priority. The list is organized by priority from highest to lowest and is shown below in Table A1-I.

TABLE A1-I: PROJECT REQUIREMENTS

#	Priority	Need
1	1	Operates in tote room temperature (-18deg C)
2	1	Breaks fewer hash browns than existing tote system
3	1	Allows for either toting off or new system as desired
4	1	Is safe in all human interactions
5	1	Users know how much product is available at all times
6	1	Can reject product at outlet
7	2	Reliable and easily maintained
8	2	Operates at a range of flow rates
9	2	Minimizes Cost
10	2	Controlled by a Programmable Logic Controller
11	2	Operates autonomously
12	3	Delivers product to existing system immediately upon activation
13	3	Requires little relocation of existing equipment
14	3	Simple to clean

Target Specifications

A list of target specifications was created using the information gathered during a site visit to McCain. These specifications must be followed in order to reach the standards required by McCain. If the specifications are not met, the design will likely not be implemented. Each specification correlates to a need identified earlier in the project definition process, and therefore each specification shares the priority level of its associated need. If no design can meet all the specifications, designs meeting the higher priority specifications will be considered more acceptable than those that do not. A full list of specifications, labelled with the associated need, priority, nominal value, and limits are shown in Table A1-II.

TABLE A1-II: TARGET SPECIFICATIONS WITH ASSOCIATED PRIORITIES AND DATA

Need #	Priority	Target Specifications	Nominal	Limits	Units
1	1	Lowest operating temperature without decrease in performance	-25°C	-18°C	°C
2	1	Maximum product drop height	6	12	In
3	1	Time to change between storeveyor and tote systems	2	10	S
3	1	Steps involved in change between systems	1	3	#
4	1	Number of potential risks to physical safety	100	300	--
5	1	Instantaneous product level displayed	True	True	--
6	1	Time to initiate rejection process	2	10	S
6	1	Steps involved to initiate rejection process	1	3	#
7	2	Number of preventative maintenance activities	4	12	#/year
8	2	Maximum achievable flowrate	5000	4000	lbs/hr
9	2	Total implementation cost	150000	200000	CAD
10	2	Controlled by a Programmable Logic Controller	True	True	--
11	3	Number of human interactions	1	7	#/wk
12	3	Time between storeveyor activation and output	20	120	S
12	3	Maximum storage capacity	1125	900	Lbs
13	3	Number of assets relocated	0	3	#
13	3	Number of assets requiring redesign	0	2	#
14	3	Proportion of food contact surfaces accessible by hose	80	0-100	% surface area

The nominal values and limits for each specification in the table above were determined in communication with the client.

Design Constraints

A list of constraints and limitations was also created using the information gathered during a site visit to McCain Foods. If the final design does not abide by the constraints, the design will not be able to be used by the client. Many of the constraints and limitations are based on health and safety standards for food handling, while others are standards for the cleaning methods used by McCain. Since McCain cleans their products often, the design must be able to withstand many cycles of cleaning using chemicals and power washers. The project specific constraints and limitations are:

- All equipment is food safe, as outlined in the McCain Food Process Equipment Sanitary Design Guidelines
- Allows for cleaning of all food contact surfaces using sprayed water via hose
- Constructed of food grade and corrosion resistant materials
- Contains no threaded adapters
- Accommodates current hash brown dimensions
- Does not thaw hash browns
- Does not obstruct forklift aisle ways
- Utilizes little to no custom equipment
- Conveyor systems do not turn corners
- Runs parallel to current system

Additional constraints related to food safety can be found in McCain's Food Process Equipment Sanitary Design Guidelines [1].

REFERENCES

[1] McCain Foods (Canada), *Food Process Equipment Sanitary Desing and Construction Guidlines.*

APPENDIX B

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List of Figures

This appendix shows both the original preliminary concepts and market designs that were pursued to find the ideal design.

External Concepts

In order to understand the products offered by companies that currently build storeveyor products, research was done into which companies currently make storeveyors. Six companies were contacted for details on their product specifications. These companies were Gough Engineering, Cox and Plant, Project Services Group Inc, Precision Food Innovations, Cusinato, and NCC Automated Systems. Of these six companies, Gough, NCCAS, and PFI responded with basic design details, Cusinato stated that they did not have the expertise to work with frozen product, and C&P and PSG never responded to our inquires.

All three companies that are being considered would be able to meet the food safe standards set by McCain [1], and none have limitations associated with supplying a Canadian facility.

Gough

Gough proposed a 1m by 1m by 1m cube hopper design where product is dropped into the hopper via the input conveyor. At the bottom is a belt conveyor to remove product at a stable rate. A drawing made of this design is shown in Figure A2-1.

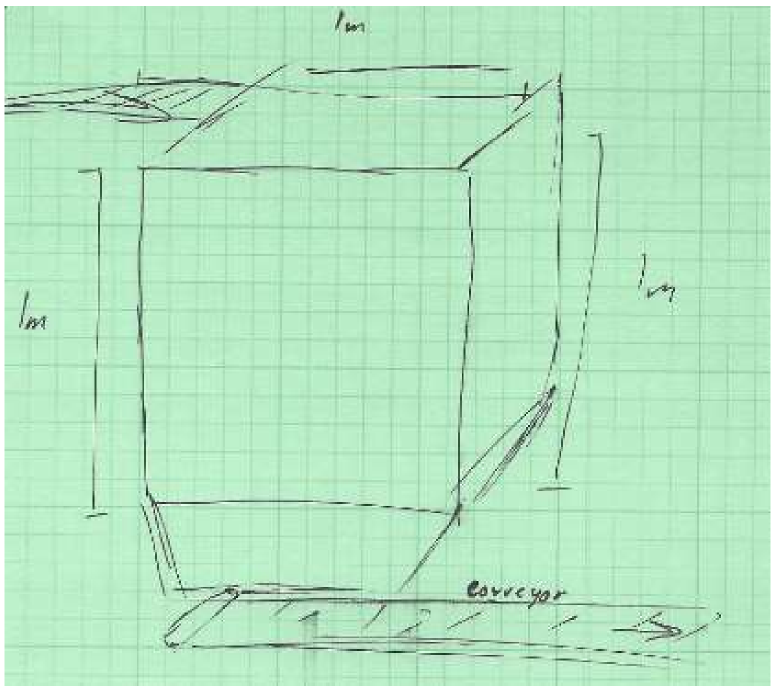

Figure A2-1. Gough concept drawing

NCC Automated Systems

NCC Automated Systems proposed a 3’ wide, 10’ long, 2’ deep hopper with a belt conveyor at the bottom to remove product at a stable rate. Product drops into the system from above via the input conveyor and piles in the long hopper. When desired, the product will move forward and drop off the edge onto the output conveyor. A drawing made of this design is shown in Figure A2-2.

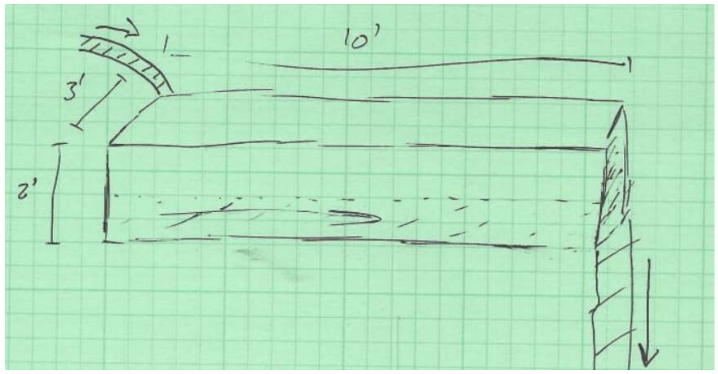

Figure A2-2. NCC concept drawing

Precision Food Innovations

PFI only provided a proposal after the initial concept selection phase, and therefore was not considered in the first round of concept selection. The design they eventually proposed is explained in detail in the body of this report.

Internal Concepts

To develop unique non-market solutions, concepts were brainstormed and sketched out with some noted features and details of the concept to assist in conveying the design.

Chute

The chute concept is a large enclosed incline that will allow the system to hold a large amount of product. At the bottom of the incline is a door mechanism that will control the output of product onto the outlet conveyor. The Chute is shown in Figure A2-3.

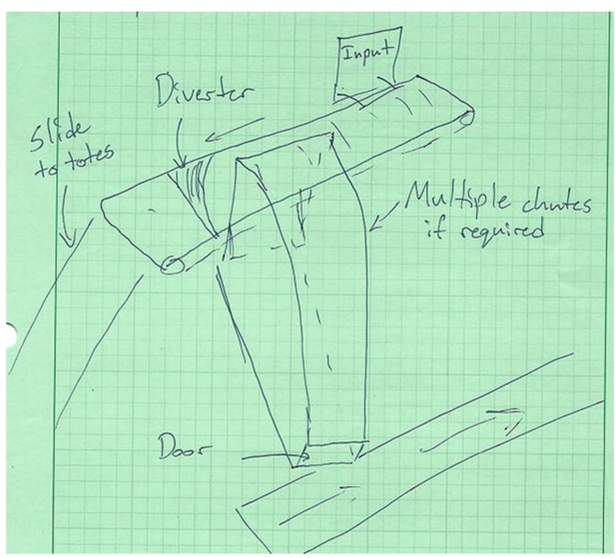

Figure A2-3. Chute concept drawing

Dumping Bucket

The dumping bucket would have product enter at the back of the bucket and slide down to be stored. To return product to the packaging line, the bucket will tip about the bottom axle and dump onto the output ramp. The output ramp would consist of a long series of rollers which would eventually lead to the output conveyor. The dumping bucket is seen in Figure A2-4.

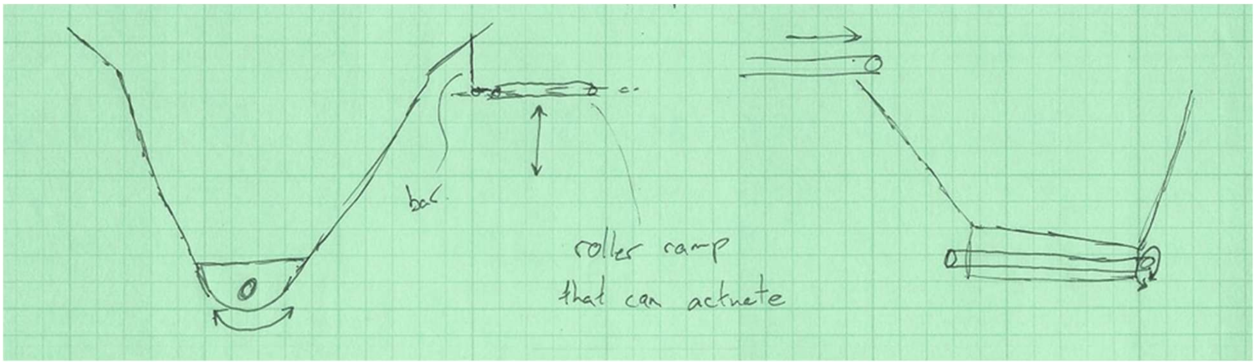

Figure A2-4. Dumping bucket concept drawing

Funnel

The funnel concept consists of hash browns entering the system via the input conveyor where the patties will either drop into the center or along the inner slope. At the bottom of the funnel would be a door that can open and close to regulate the output. The funnel concept is shown in Figure A2-5.

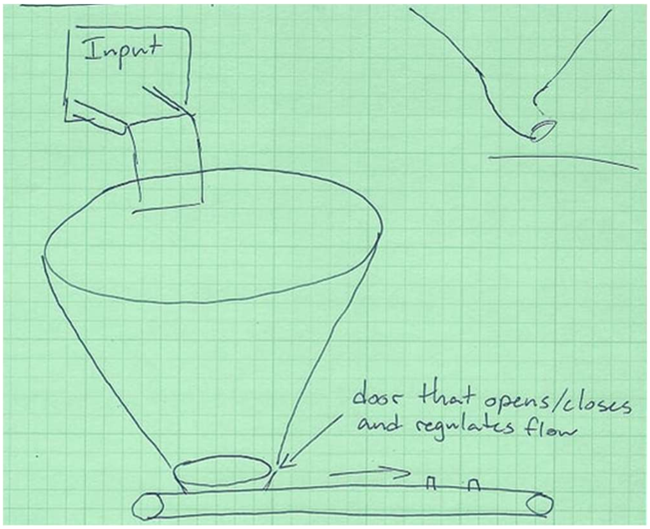

Figure A2-5. Funnel concept drawing

Spiral

In the spiral design the product enters via the input conveyor which drops onto the spiral face. From there, the hash browns slide down the spiral and pile onto a stationary conveyor. To return product to the packaging line the conveyor will move the product to the outlet conveyor. The spiral is seen in Figure A2-6.

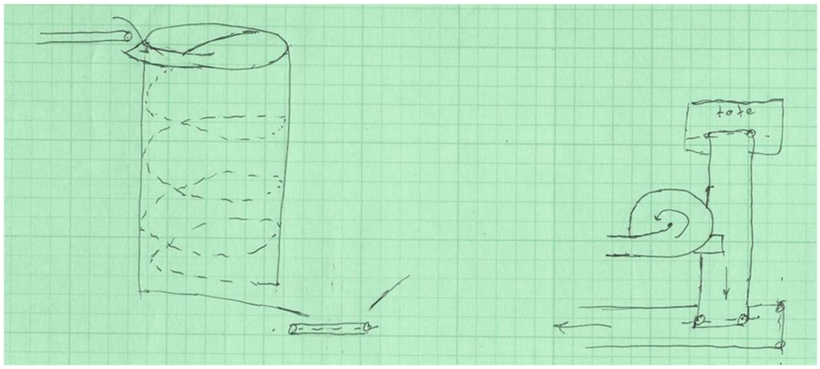

Figure A2-6. Spiral concept drawing

Toilet Bowl

This concept consists of a large hopper bin that will hold the bulk of the stored product. Leading to the hopper is a ramp that allows the hash browns to slide down to the outlet. To return product to the packaging line, the conveyor will pull product to the output conveyor. The toilet bowl is shown in in Figure A2-7.

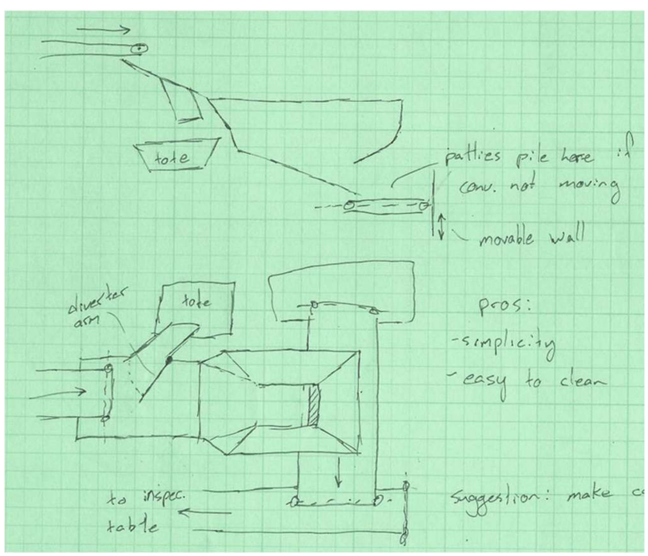

Figure A2-7. Toilet bowl concept drawing

Group Concept Generation

The team worked together as a group to brainstorm new ideas and two more concepts were generated as a result and were given the names NCCb and Corkscrew Slide. These two designs are detailed below.

Corkscrew Slide

The corkscrew slide concept was a variant of the Spiral design. The team critically analyzed the Spiral design and determined that cleaning and maintenance would be difficult given the complex, enclosed geometry. To mitigate this issue, the team developed a design that made use of the spiral geometry but did not enclose the slide. This concept works identical to the Spiral design. This concept is shown in Figure A2-8.

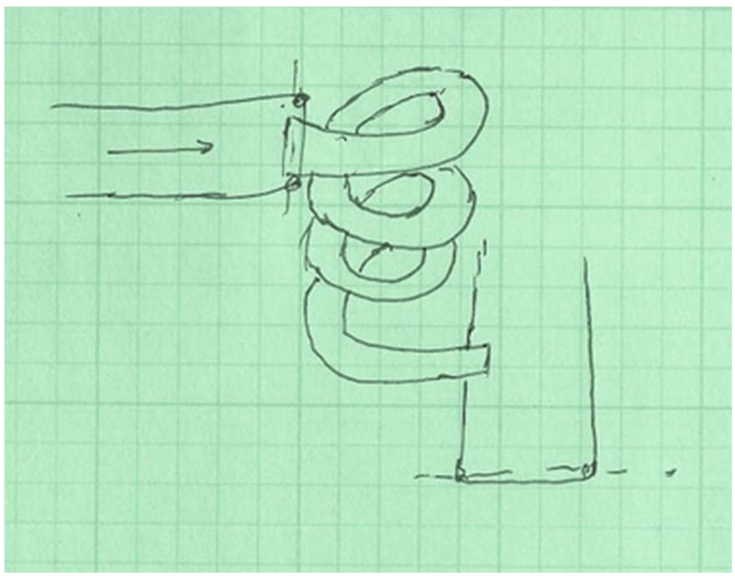

Figure A2-8. Corkscrew slide concept drawing

NCCb

A variant of the NCC design was made to utilize the simplicity of the design, but prevent piling of hash browns and variable volumes exiting the output of the design. This included an incline and a vibrating bottom to fix the piling and output issues. The design operates in the same was as the NCC concept. The NCCb is shown in Figure A2-9.

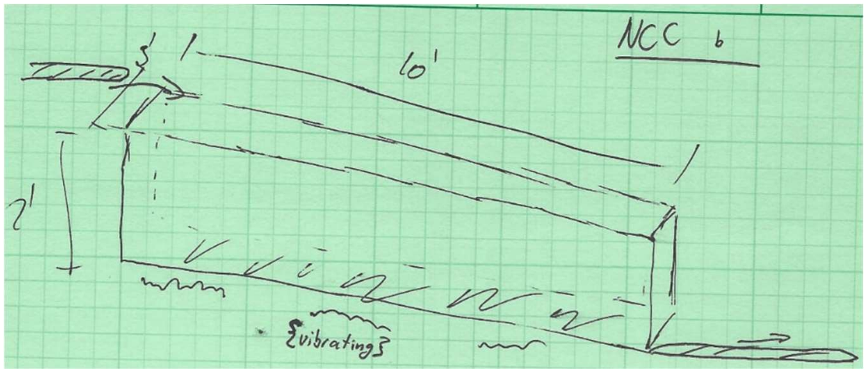

Figure A2-9. NCCb concept drawing

REFERENCES

[1] McCain Foods (Canada), *Food Process Equipment Sanitary Desing and Construction Guidlines.*

APPENDIX C

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List of Tables

This appendix shows the concept screening and selection process used in the second phase of the project.

Concept Screening

The initial screening process used was to compare each concept against an arbitrarily selected standard. For this purpose, Gough was used as the standard. The rest of the concepts were then rated as better or worse than Gough for each basic project need. The needs used for this comparison were obtained from Table A1-I in Appendix A. If the concept was rated better than the standard, it was indicated by a '+'. If the concept was rated worse than the standard, it is indicated by a '-'. If the concept was roughly equal to the standard, it is indicated by a '0'. After filling in the table, the +'s are added and the -'s subtracted, leaving a net sum that will indicate whether or not the concept is thought to be better than the standard. The higher the net sum, the more desirable the concept. This method does not indicate how the concepts compare to each other, only how they compare to the standard. The concept screening method is shown in Table A3-I, though for the sake of space some of the eliminated concepts were omitted.

TABLE A3-I: CONCEPT SCREENING

Needs	Gough	Toilet Bowl	Corkscrew Slide	Chute	Dumping Bucket	Funnel	NCC
Breaks fewer hash browns	0	+	+	+	0	+	+
Delivers product to existing system immediately upon activation	0	0	0	0	-	0	-
Operates at a range of flow rates	0	0	-	-	+	0	+
Users know how much product is available at all times	0	0	-	0	0	0	-
Operates autonomously	0	0	0	0	0	0	0
Reliable (know that it works)	0	-	-	0	-	0	0
Easily Maintained (mechanical simplicity)	0	0	+	+	-	+	-
Ease of Cleaning	0	+	-	-	+	+	-
Manufacturability	0	-	-	0	-	0	0
Human safety	0	0	0	+	-	0	0
0s	10	6	3	5	3	7	4
+s	0	2	2	3	2	3	2
-s	0	2	5	2	5	0	4
sum	0	0	-3	1	-3	3	-2

Moving forward, any concept that was rated equivalent to or better than the standard was chosen to move onto detailed concept selection. The four designs that met this criteria were Gough, Toilet Bowl, Chute, and Funnel.

Weighted Decision Matrix

Once the number of concepts had been reduced to four, a weighted decision matrix approach to selecting a single concept was used, where a matrix is created to score each concept against each need and multiply the evaluated score by the weighting assigned to that need based on its importance to the success of project. To establish the weights each member of the team completed a criteria weighting matrix and then the weights were averaged to get the final weight. An example of one of the completed weighting matrix is seen in Table A3-II.

TABLE A3-II: CRITERIA WEIGHTING MATRIX EXAMPLE

	Criteria	A	B	C	D	E	F	G	H	I	J
A	Breaks fewer hash browns		A	A	A	A	F	A	A	A	A
B	Delivers product to existing system immediately upon activation			C	D	E	F	B	H	I	J
C	Operates at a range of flow rates				D	E	F	G	H	I	J
D	Users know how much product is available at all times					E	F	D	D	D	J
E	Operates autonomously						F	E	E	E	J
F	Reliable (know that it works)							F	F	F	F
G	Easily Maintained (mechanical simplicity)								H	I	J
H	Ease of Cleaning									H	J
I	Manufacturability										J
J	Human safety										
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
	Total Hits	8	1	1	5	6	9	1	4	3	7
	Weightings	0.2	0	0	0.1	0.1	0.2	0	0.1	0.1	0.2

Scores

After the weightings were obtained, the team members individually scored each concept against each need from 1 to 5, with 1 being the lowest score and 5 being the highest score. Once each team member had determined their personal scores, the average of the individual scores was used for the decision matrix. An example of the personal scoring system is shown in Table A3-III.

TABLE A3-III: CONCEPT SCORES AGAINST NEEDS EXAMPLE

	Gough	Toilet Bowl	Funnel	Chute
Breaks fewer hash browns	3	5	4	5
Delivers product to existing system immediately upon activation	5	5	5	5
Operates at a range of flow rates	2	1	1	1
Users know how much product is available at all times	4	2	4	4
Operates autonomously	5	5	5	5
Reliable (know that it works)	5	3	4	5
Easily Maintained (mechanical simplicity)	3	4	5	5
Ease of Cleaning	4	4	5	2
Manufacturability	5	2	4	3
Human safety	4	4	4	5

Final Weighted Decision Matrix

The scores were then multiplied by the weight of the need and the results were summed for each concept. The concept with the highest net sum was deemed the best concept. All decisions were made based on project needs to try and come up with the best functioning design. Based on the decision matrix, the chute is considered the overall best concept. Next is Gough, and nearly tied for third are the funnel and the toilet bowl. The overall averaged matrix is given in Table A3-IV.

TABLE A3-IV: AVERAGED CRITERIA WEIGHTING MATRIX

	Weights	Gough		Toilet Bowl		Funnel		Chute	
Breaks fewer hash browns	0.17	3.00	0.50	4.75	0.83	4.25	0.67	4.75	0.83
Delivers product to existing system immediately upon activation	0.06	3.50	0.19	3.50	0.28	3.50	0.22	3.50	0.28
Operates at a range of flow rates	0.01	2.25	0.01	2.00	0.01	1.75	0.02	1.50	0.02
Users know how much product is available at all times	0.11	4.75	0.50	4.00	0.21	4.25	0.42	3.50	0.53
Operates autonomously	0.13	4.25	0.54	4.75	0.64	4.25	0.51	4.00	0.64
Reliable (know that it works)	0.14	4.75	0.69	3.50	0.43	3.25	0.43	3.75	0.43
Easily Maintained (mechanical simplicity)	0.05	2.75	0.14	3.00	0.20	3.25	0.20	2.75	0.20
Ease of Cleaning	0.10	4.00	0.40	4.75	0.40	5.00	0.50	2.25	0.50
Manufacturability	0.05	4.75	0.24	3.00	0.10	3.50	0.15	3.50	0.20
Human safety	0.19	4.50	0.85	4.50	0.76	4.50	0.76	4.75	0.94
Net Sum			4.06		3.86		3.88		4.58

Based on the results of the weighted decision matrix, the chute design is the best option.

Client Re-evaluation

Once the concept selection process was complete, the team reviewed the results with the client, who expressed that despite agreeing with the process, wanted a market solution to the problem as it was deemed more reliable and likely to succeed. The team returned to the market solutions and re-evaluated based on the concerns of the client, and decided to proceed with the design then provided by PFI.

APPENDIX D

This appendix contains the food safety and sanitary design construction guidelines used by McCain [1].

1. Sanitary Design Criteria

1.1 The following addendum is a list of sanitary equipment design principles and criteria that the equipment manufacturer must follow, but not limited to its content, to ensure adequate food safety and sanitary design is achieved during design, fabrication, construction and installation of the food processing equipment they are supplying to McCain Foods Ltd.

1.2 The equipment manufacturer is responsible for following local, provincial, federal regulatory agencies guidelines for equipment's general sanitary fabrication, construction, installation and clean ability Good Manufacturing Practices (GMPs). Yearly training on sanitary design should engage equipment manufacturers to understand and produce a better cleanable design for new customer requirements.(i.e. microbiological standards.)

1.3 During normal operations the food processing equipment must perform so it does not contribute to unsanitary conditions or the harborage and growth of bacteria.

1.4 The following organizations have acceptable sanitary standards and guidelines for manufacturing of food processing equipment:

- Canadian Food Inspection Agency (www.inspection.gc.ca)
- AIB International (www.aibonline.org)
- Food and Drug Administration (www.fda.gov)
- 3-A Sanitary Standards Inc. (www.3-a.org)
- National Sanitation Foundation (www.nsf.org)
- USDA Food Safety and Inspection Service (www.fsis.usda.gov)
- American Meat Institute (www.meatami.com)
- European Hygienic Design Group (www.ehedg.org)
- Underwriters Laboratories (www.ul.org)
- Sanitary Design (www.sanitarydesign.com)

2. General Aspects Sanitary Design and Construction

2.1 General Sanitary Design Principles : Clean is clean the same principles apply for RTE or NRTE plant.

2.1.1 **Cleanable to a microbiological level:**

2.1.1.1 Food processing equipment must be designed and constructed to ensure effective and efficient cleaning of the equipment over its life span. CIP systems added to equipment that is difficult to clean i.e. freezers and spiral freezers are preferred, spray bars and/or an array of cleaning systems must be developed to help cleanability of these areas.

2.1.1.2 The equipment should be designed as to prevent bacterial ingress, survival, growth and reproduction on both produce and non-product contact surfaces of the equipment. We need to have smooth and easy to clean surfaces, no knurled or diamond cut conveyors on equipment.

2.1.2 **Made of compatible materials:**

2.1.2.1 Construction materials used for equipment must be completely compatible with the product, environment, cleaning and sanitizing chemicals and the methods of cleaning and sanitation.

2.1.3 **Accessible for inspection, maintenance, cleaning and sanitation:**

2.1.3.1 All parts of the equipment shall be readily accessible for inspection, maintenance, cleaning and sanitation without the use of tools. Closed conveyors and equipment should have access ports included into their design for easy inspection and cleaning. Belting needs to be removed easily and/or tension can be removed easily (Guide bar underneath the belt should be removable easily without tools for inspection and cleaning), Equipment design need to provide 12” clearance to the floor, clearance for the ceiling is 30” and from the nearest stationary object is 36”. Products catch pans are easily removable for easier cleaning.

2.1.3.2 All equipment needs to have access to both sides to facilitate sanitation, catwalks and mezzanines are preferred instead of rolling staircases. If rolling staircases are used, sanitors should be able to reach, touch and see if the equipment is visibly clean.

2.1.4 **No product or liquid collection:**

2.1.4.1 Equipment should be self-draining to assure that liquid, which can harbor and promote the growth of bacteria, does not accumulate, pool or condense on the equipment. Ledges or surfaces where product accumulates during production needs to be modified to prevent product accumulation.

2.1.5 **Hollow areas should be hermetically sealed:**

2.1.5.1 Hollow areas of equipment such as frames and rollers must be eliminated whenever possible or permanently sealed.

2.1.5.2 Bolts, studs, mounting plates, brackets, junction boxes, nameplates, end caps, sleeves and other such items should be continuously welded to the surface, not attached via drilled, tapped holes or riveted.

2.1.6 **No niches:**

2.1.6.1 Equipment parts should be free of niches such as pits, cracks, corrosion, recesses, open seams, gaps, lap seams, protruding ledges, inside threads, bolt rivets and dead ends. Belt scrapers do not have lap joints and are removed easily without tools (Counterweigt scraper recommended). Press or shrink fit metal guides with teflon inserts should not be used.(Solid teflon guides are preferred. If other kinds are to be used they should be cleaned and swabbed to confirm they are sanitary)

2.1.6.2 If scrapers are difficult to clean in place, they should be easily removable for cleaning in a COP tank or sanitation area.

2.1.7 **Sanitary operational performance:**

2.1.7.1 During normal operations, the equipment must perform so it does not contribute to unsanitary conditions or the harborage and growth of bacteria. Special care should be given to overhead structures and equipment so as not to contaminate the food contact surfaces. As much as possible no cooling units should be over product or near product contact surfaces or if absolutely needed pans and drain pipes should be directed to the nearest floor drains and insulated to prevent condensation falling into product.

2.1.8 **Hygienic design of maintenance enclosures:**

2.1.8.1 Maintenance enclosures and human machine interfaces such as push buttons, valve handles, switches and touch screens, must be designed to ensure food product, water or product liquid does not penetrate or accumulate in or on the enclosure or interface.

2.1.8.2 Physical design of the enclosures should be sloped or pitched to avoid use as storage area and when fixed to a surface should not be over product contact areas and need to have spacers (1/2”) when fixed to a flat surface for ease of cleaning. Nema 4X enclosures are preferred over any other enclosures. If they are not available, regular inspections should be performed to prevent moisture and food ingress.

2.1.9 **Hygienic compatibility with other plant systems:**

2.1.9.1 Equipment design should ensure hygienic compatibility with other equipment and systems, such as electrical, hydraulics, steam, air and water.

2.1.9.2 Electrical cable trays must be designed to be cleanable, made of stainless steel and covered in the production area to permit easier cleaning.

2.1.9.3 Electrical cables should be designed to be cleanable, vertical as much as possible and held into a small cable tray, using a stainless steel pig tail or encased in a stainless steel metal tubing for easier cleaning and contamination prevention.

2.1.10 **Validate cleaning and sanitizing protocols:**

2.1.10.1 Procedures for cleaning and sanitation must be clearly written, designed and proven effective and efficient.

2.1.10.2 Fabricators should send to the sanitation department, as soon as possible, their manual including their recommendations for dismantling and sanitation of their equipment or structures.

2.1.10.3 Chemicals recommended for cleaning and sanitation must be compatible with the equipment and the manufacturing environment.

2.2 Hygienic Construction and Fabrication

2.2.1 Equipment being constructed and/or fabricated for processing and handling of food products must be designed, fabricated, constructed and installed according to sound sanitary design and construction principles.

2.2.2 Cross functional team (including sanitation department) must be involved in the review of the construction and participate in project review meetings early enough to be able to influence the design or installation to ensure cleanability is achieved.

2.2.3 Equipment being constructed and/or fabricated for processing and handling of food products must be designed to ensure that the equipment can be adequately cleaned, sanitized and that all surfaces are resistant to daily exposure to corrosive food products and cleaning / sanitizing chemicals.

2.2.4 Food processing equipment must be designed and fabricated in such a way that all food contact surfaces are free of sharp corners and crevices.

2.2.5 All mating surfaces must be continuous (e.g. substantially flush)

2.2.6 Design and construction of all food handling or process equipment shall allow for easy disassembly for cleaning and inspection.

2.2.7 Where appropriate (e.g. vessels, chambers, tanks) equipment should be self draining and pitched to a drainable port with no potential hold up of food materials or solutions.

2.2.8 Piping systems not designed for routine disassembly must be sloped to drain.

2.2.9 Piping systems installed in modern food processing systems designed for clean-in-place (CIP), require special consideration and close monitoring with regard to drainage.

2.2.10 Product must be protected from environmental and other contaminants. Where necessary covers should be installed over tanks, hoppers, flumes, conveyors and other open equipment to prevent debris from entering the system.

2.2.11 Electrical cabling needs to be sealed in a stainless steel tubing and made sanitary if over or close to food contact area. Twist ties (must be metal detectable) and numbers must be reduced to a minimum and covered or the entire electrical system needs to be made cleanable. Cable trays cannot be over product contact surfaces but if need be, need to be cleanable or sealed so as not to contaminate food products.

2.2.12 Equipment fabricators and installation contractors must follow yearly sanitary design training and be held responsible if contamination occurs due to their equipment or installation that does not follow the sanitary design recommendations of this document.

2.3 Contact Surfaces

2.3.1 Food processing equipment surfaces are divided into two categories;

- food product contact surfaces, and
- non-product contact surfaces

2.3.2 *Food Product Contact Surfaces* is defined as a surface in "direct contact with food residue, or where food residue can drip, drain, diffuse or be drawn". Because these surfaces, if contaminated, can directly result in food product contamination, rigid sanitary design criteria must be followed.

2.3.3 *Non-Product Contact Surfaces* is defined as a surface and/or part of the equipment that does not directly contact food. As contamination of non-product contact surfaces can cause indirect contamination of the food product, sanitary design criteria must be followed.

2.4 Food Product Contact Surfaces

2.4.1 All food product contract surfaces, in terms of sanitary design, shall be:

- Smooth
- Impervious
- Free of cracks and crevices
- Nonporous
- Nonabsorbent
- Non-contaminating
- Non-reactive
- Corrosion resistant
- Durable and maintenance free
- Non-toxic
- Cleanable

2.5 Non Product Contact Surfaces

2.5.1 Non-product contact surfaces of food equipment are a well documented source for environmental contamination of a food facility with pathogens (especially *Listeria monocytogenes*). Therefore, care should be used in evaluating these surfaces of equipment with regard to sanitary design and construction.

2.5.2 Non-product surfaces of equipment should be constructed with appropriate materials and fabricated in such a manner as to be reasonably cleanable, corrosion resistant and maintenance free.

2.5.3 Tubular steel equipment framework should be entirely sealed and not penetrated (e.g., bolts, studs), to avoid creating niches for microorganisms.

2.5.4 Attachments should be welded to the surface of the tubing and not attached via drilled and tapped holes.

2.5.5 Maintenance enclosures and human machine interfaces such as push buttons, valve handles, switches and touch screens, must be designed to ensure food product, water or product liquid does not penetrate or accumulate in or on the enclosure or interface.

2.5.6 Physical design of the enclosures should be sloped or pitched to avoid use as storage area.

2.5.7 Equipment design should ensure hygienic compatibility with other equipment and systems, such as electrical, hydraulics, steam, air and water.

~~2.5.8 Floor mounted equipment should be sealed to the floor, platform, or pedestal or (and should be no less than 6 inches from the floor.?)~~

2.5.9 Table mounted equipment should be sealed to the table, or be no less than 4 inches from the counter top.

3. Materials

3.1 Depending upon the application, various metals as well as non metals (e.g., plastics, rubber) are used. Some materials are not recommended and should be avoided.

3.2 Galvanized iron, glass and wood are not recommended and shall be avoided in food processing design and fabrication.

3.3 Metals

3.3.1 **Stainless steel** is the preferred general use metal for food contact surfaces because of its corrosion resistance and durability in most food applications.

3.3.1.1 304 or 316 stainless steel acceptable for most surfaces.

3.3.1.2 As temperatures approach 150ºC, even AISI-316 stainless steels may suffer from stress-corrosion cracking. Here AISI-410, AISI-409, AISI-329 may be required for their high strength and/or high corrosion resistance. (Water temperaqture required for cleaning should be between 130°-140° F, 55-60°C)

3.3.1.3 It is recommended that stainless steel surfaces be passivated (using nitric acid or other strong oxidizing agents) initially to maintain a passive (non-reactive) oxide film on the surface.

3.3.2 **Aluminum** is used in certain parts and components where lighter weight is desired. However, aluminum has poor corrosion resistance and can become pitted and cracked with continued use.

3.3.3 **Carbonized metal** and **cast iron** are only used for frying and cooking surfaces, and similar applications in food service.

3.4 Non-Metals

3.4.1 A variety of non-metal materials are used as food contact surfaces in specific applications of food equipment (e.g., probes, gaskets, membranes). These materials should meet the same sanitary design and clean ability requirements as metals when used in these applications.

3.4.2 **Plastics**, **rubber**, and **rubber-like** materials should be food grade and meet sanitary design and fabrication requirements. Multi-use plastics, rubber, and rubber-like materials may also be considered as *indirect food additives* under FDA regulations.

3.4.3 **Ceramics** are used primarily in membrane filtration systems. They may also be used in other limited applications if wear resistance is necessary.

3.5 Surface Texture / Finish

3.5.1 If any surface is ground, polished, or textured in any way, it must be done so the final surface is smooth, durable, free of cracks and crevices, and meets the other sanitary design requirements described above.

3.5.2 Ground or polished stainless steel surfaces after a weld must meet a No. 4 ground surface.

3.5.3 Unpolished surfaces meet a No. 2B or mill finish.

3.6 Lubricants

3.6.1 Equipment should be designed such that lubricants do not come into contact with products.

3.6.2 Where contact may be incidental, lubricants should be listed in the "Reference Listing of Accepted Construction, Packaging Materials and Non-Food Chemical Agents", published by the local, provincial and/or federal regulatory authority or the manufacturer should have "a letter of no objection" from the local, provincial and/or federal regulatory authority.

3.7 Thermal Insulation

3.7.1 Thermal insulation of equipment must be carried out in such a way that the insulation material cannot be wetted by ingress of water from the outside environment (e.g. hosing down, condensation on cold surfaces).

3.7.2 The insulation material may not contain chloride. Ingress of water may otherwise lead to a build up of chloride on the stainless steel surfaces, resulting in stress corrosion cracking or pitting corrosion.

3.7.3 Ingress of water may also result in loss of insulation performance.

4. Equipment Validation

4.1 Procedures for cleaning and sanitation must be clearly written, designed and proven effective and efficient.

4.2 Chemicals recommendation for cleaning and sanitation must be compatible with the equipment and the manufacturing environment.

4.3 Irrespective of the amount of know-how and experience with hygienic design which is applied when designing and fabricating, practice has shown that inspection, testing and validation of the resulting design to check if the requirements are met is very important. In critical cases it may be necessary to check the hygiene level as part of the maintenance procedures. The designer has to make sure that relevant areas are accessible for inspection and/or validation.

5. Manuals

5.1 The manufacturer must provide an effective written operation and preventative maintenance program to ensure that equipment that may impact on food safety functions and are used as intended. This includes, but not limited to:

5.1.1 The installation instructions, the operation instructions and cleaning instructions.

5.1.2 List of equipment requiring regular maintenance. Such as rubber and plastics which have limited operational life because over time and become brittle and susceptible to cracking. These cracks become sites for microbial contamination.

5.1.3 The maintenance procedures and frequencies, eg., equipment inspection, adjustments and part replacements as based on the equipment manufacturer's manual or equivalent, or based on operating conditions that could affect the condition of the equipment.

- END OF SECTION –

REFERENCES

[1] McCain Foods (Canada), *Food Process Equipment Sanitary Desing and Construction Guidlines.*

APPENDIX E

This appendix contains the quote provided by Precision Food Industries for a storeveyor.

APPENDIX F

This appendix contains the engineering drawing provided by Precision Food Industries.