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FOREIGN MATERIAL DETECTION
PRINCE EDWARD ISLAND POTATO BOARD

1.0 INTRODUCTION

Equaling over $1 billion dollars to Prince Edward Island’s economy annually, the potato industry is one of the largest in the province, and PEI is continually ranked as the largest potato producing province in Canada; responsible for growing one-quarter of the country’s potato crop.

PEI Potatoes are grown for the table, processing, and seed markets, with 60%, 30%, and 10% of the production destined for each respective market.

As the global market for potatoes continues to intensify, Prince Edward Island growers, and the board that represents them, must innovate to continually improve efficiency, yield, quality, and food safety. The purpose of this report is to examine the current technologies in use for Foreign Material (FM) protection in a sample of potato packing facilities on PEI and provide recommendations of technology that could be utilized to improve product security and safety.

Throughout this document, the following abbreviations appear:
- FM: Foreign Material
- NIR: Near Infra-Red
- CIT: Chemical Imagining Technology

2.0 SCOPE OF THE PROJECT

As originally outlined to PEI Potato Board representatives, this report by Llink was conducted by following the consulting process below:

A. Meet with representatives from the PEI Potato Board and potato packing facility representatives to understand the foreign material challenge regarding metal

B. Review current technology in use within the potato packing facilities on Prince Edward Island for foreign material protection at two representative operations

C. Investigate technologies available to reduce the risk of metal in the final product

D. Prepare a report summarizing research findings and identifying the following:
   ~ Recommendations of technology that could be utilized to improve product security and safety
   ~ Process flow drawings for recommended technologies
   ~ Provide a high-level budget and basic equipment drawing of recommended technology
   ~ Provide recommendations for next steps going forward

E. Any observations made during the process of preparing this report that may improve foreign material detection will be noted
3.0 APPROACH / METHODOLOGY

Our approach is consistent with our commitment to deliver the highest quality consulting services with attention to timelines and budgets. In order to facilitate this approach, Llink used the following methodology:

1. Llink met with representatives from the PEI Potato Board and potato packing facility representative at our office.

2. Llink reviewed the current FM technology in use at two (2) potato grading/packing facilities.

3. Coordinated a meeting with a representative from CEIA, an industry leader in metal detection technology, with representatives from Cavendish Farms, PEI Potato Board, and a farm to understand the capabilities of metal detection.

4. Following the meeting with all parties relevant to the project, Llink engaged in research to provide options for the Board’s consideration with regard to FM Detection.

5. Llink analyzed different technologies and product information from multiple suppliers to recommend a best fit application for PEI potato packing facilities.

6. Chris Matters contacted leading companies for metal detection, X-Ray, CIT, and NIR FM detection to gather information and expected performance criteria.


9. Llink made note of any additional recommendations for future consideration uncovered in the research process of this report.

10. Llink prepared this final report for presentation to the President and General Manager of the Prince Edward Island Potato Board for further consideration.
4.0 FOREIGN MATERIAL DETECTION TECHNOLOGIES

Evolving Technology
Foreign material technology is improving and evolving at a fast pace to meet the expected demands of the consumer for food safety. With increased automation in food production in addition to potential for intentional and random food contamination, the demands for advanced FM detection and removal systems has increased. There are a number of innovative product inspection companies that recognize this need and are continually working on more advanced solutions. Many of the leading companies have evolved from personal security, airport security and military backgrounds, therefore taking these technologies into food production.

It is important to note that there is no clear black and white solution for all foreign material, but there does exist a group of technologies that can be used individually, or in combination with one another, to reduce the risk of foreign material in the finished product.

Challenges of Random Versus Intentional FM
There are two groups of foreign material to be considered and to keep in mind as you read through this report.

The first group is RANDOM foreign material. This describes typical unwanted materials that can be harvested with the potatoes that includes rocks, sticks, garbage including metal cans, glass, bones, parts of equipment, golf balls, etc. Within this class of foreign material, random materials from within the packing plant can enter the product flow also, this could include metal parts/materials, conveyor pieces, etc. This is all classed as random foreign material and the technology available can do a good job in identifying and removing the unwanted material.

The second group of foreign material is INTENTIONAL unwanted materials, which are considerably more difficult to inspect for due to the immense amount of possible contaminates. This class of foreign material was publicized with recent events in the PEI potato industry, where the discovery of sewing needles embedded into potatoes on one farm shocked both growers and consumers. We are fortunate that there is technology to inspect and remove this, but there are other materials that would be much more difficult to detect and remove.

Therefore, as you read through the report on foreign material technologies, we will identify what each technology can inspect and remove, but clearly there exists no current technology available that can remove all the potential risk for intentional foreign material.

Technologies Identified
It was determined that current relevant technologies for foreign material detection include:

1. Metal Detection Technology
2. X-Ray Technology
3. Near Infra-Red (NIR)
4. Chemical Imaging Technology (CIT)

It is important to note that the first two technologies, Metal Detection and X-Ray are targeting embedded and loose FM. The other two technologies, NIR and CIT are focused on loose or surface FM.
4.1 Metal Detection Technology

In response to recent food tampering incidents on Prince Edward Island regarding needles appearing in potatoes from one farm, metal detection is a proven technology for consideration in potato packing facilities. Technology from CEIA was investigated. CEIA is recognized as a global leader in industrial metal detection systems, allowing for the interception of magnetic and non-magnetic metals and high-resistivity stainless steel. CEIA is recognized for supplying advanced security screening for airports and military around the world and continually develop leading technology in product inspection.

CEIA THS 21 Series

CEIA has indicated that this system, with its high sensitivity, high precision measuring aperture, is the best on the market to comply with Subpart E of the FDA Code Title 21 CFR119, requiring effective measures be taken to protect against the inclusion of metal in food. The functions listed below are of particular importance when considering the CEIA system.

1. Auto-Learn system: allows for optimization of the detection sensitivity to all metals with maximum speed and precision.
2. Continuous Auto-Test function: special electronic stimuli are sent to the transmission and reception chain of the THS 21, causing variations in the detection signals which are not visible to the user but provide checks on detection characteristics. The variations are compared with reference values, producing an automatic certified check of the systems sensitivity.
3. Automatic measurement of the installation quality and environmental compatibility: measurements include general mechanical and electromagnetic environmental compatibility, allowing the system to measure the total compatibility of its environment.
4. Bluetooth connectivity: local connection to the metal detector can be made directly via a Bluetooth device incorporated into the control power box module without physical contact. The connection can be used for programming, monitoring signals, and transferring data from the detectors memory.
5. Detectors are available in conveyor belt and free-falling product applications. Conveyor options can handle a maximum speed of 200’ per minute.

To achieve the best possible detection, the following details and best practices are important:

- **Metal Free Zone**: Metal detectors require a metal-free zone surrounding the unit. Placing other machinery and conveyors nearby requires special consideration. The supplier will provide specific details on the distances required around the unit to obtain this metal free area
- **Frequency Free Zone**: Metal detectors also require an area of non-moving metals, limited electrical cable, radios and cell phones which may cause frequency
- **Orientation Effect**: based on test results, the direction of a piece of metal when passing under the aperture may provide a stronger or weaker reading. The best results appear to occur when the metal needle is traveling parallel to the flow through the detector head
- **Metal Varieties**: Ferrous and non-ferrous metals are the easiest to detect, while stainless steel is more difficult to detect as it is not a good conductor
- **Aperture**: The aperture is the tunnel through which the product will pass and be scanned. The greater the vertical distance between the top and bottom of the aperture, the weaker the detection ability. The geometric centre of the aperture is the weakest point of detection. To optimize detection, the aperture should be as vertically narrow as possible. As shown, PEI potato packing facilities process and pack potatoes in various sized bags and boxes. The aperture width required to provide detection to a box of potatoes will weaken the detection ability of the system. Therefore, detection is best suited to pre-packing stages where the product is presented monolayer on conveyors.

- **Conveyor Design**: The conveyor belt feeding product through the metal detector is critical to the efficiency of detection, and of the overall efficiency of the system. The conveyor material, metal free zone, bearing construction material, vibration, among other points are critical. If the conveyor design is incorrect, the metal detector is not mounted properly, or the reject system has a poor design, the system will not effectively inspect and remove the metal.

Please note that typically the reject is full flow, meaning some good product will be rejected with the FM.

### 4.2 X-Ray Technology

X-Ray inspection offers a higher degree of foreign material detection, which would expand the ability of a processor or packager to detect non-metal foreign objects such as glass, plastic, hard rubber, etc., which is higher density than the potato. A system from Eagle was investigated. Eagle is a pioneer in X-Ray inspection technology, with worldwide market presence and enhanced product capabilities.

X-Ray is a form of electromagnetic radiation with short wavelengths that can pass through materials that are opaque to visible light. The transparency of a material to X-Rays is broadly related to its density, which is why X-Ray detection is useful in food manufacturing or processing settings. Hidden foreign materials, like glass and metal, will show up under X-Ray inspection because they absorb more X-Rays than the surrounding product.

When a product passes through an X-Ray, it captures a gray-scale image of it. The software within the X-Ray system analyzes the image and compares it to a pre-determined acceptance standard. It is with this basis of comparison that the system accepts or rejects the material. There are various automatic reject systems to remove the product from the production line with full flow, but laned reject systems are available at a higher capital cost.
Eagle Bulk 370 System

Eagle’s Bulk 370 system is designed for X-Ray inspection of high-volume, bulk-flow products. The system provides superior contaminant detection and automatic rejection of: glass shards, metal fragments, mineral stone, some plastic and rubber compounds, and calcified bone. The functions below are of importance when considering the Eagle system:

1. A/C cooling: standard on all models
2. Application-specific reject: options are available to reduce the amount of rejected product
3. Proprietary SimulTask: software ensures compliance with HACCP principles and global safety regulations by providing on-screen diagnostics, advanced image analysis, and quality assurance traceability.
4. TraceServer: software for enhanced data collection
5. Built in modem and Ethernet Card: for remote technical support
6. System coverage: 368mm (14.5") of detection coverage, belt speed up to 120' per minute

4.3 Near Infra-Red (NIR)

TOMRA’s unique Near Infra-Red (NIR) sensors scan each individual item ‘in flight,’ allowing for an unobstructed view of the product with high capacity sorting ability. The sensors analyze for soil clods, stones, foreign material, and rot. The Field Product Sorting (FPS) system from TOMRA Sorting Solutions was evaluated.

TOMRA Odenberg FPS System

A world leader in industrial sorting solutions, TOMRA has designed and manufactured the Odenberg FPS, field potato sorter, which is a new sensor based food sorter for unwashed potatoes. The system acts as a first sorting station installed after soil removers, removing additional soil clods, stones, and foreign material. The system is built for high volume and high capacity growers and packers and its robust design is ideal for variable crop conditions. The functions below are of importance when considering the TOMRA Odenberg FPS system:

1. Unique multi-spectral NIR: near infrared sensors scan each item ‘in flight.’
2. Gentle rejection: gentle product handling assured through design. First grade gently passes through machine while second grade, soil clods, stones, and foreign material are sorted by intelligent finger ejectors with precision and accuracy.
3. Significant labor reduction: system allows harvesting to continue regardless of conditions, labor shortages, etc.
4. High capacity and low maintenance: simple belt feed system keeps installation and running costs low and reduces the risk of stoppages
5. Simple controls and feedback: robust touch screen makes it easy to adjust sorting criteria
Additional notes regarding TOMRA’s Odenberg FPS System:

A. This technology is not developed or proven for product exceeding 10 inches in length. At this time only potatoes under 10 inches in length can run through the system. For the North American large size potatoes, you must have a two way mechanical sorter prior to the FPS. This, in the majority of cases, will not be a problem because most of the FM falls through the mechanical sorter with the small product.

B. FPS comes in three sizes; 1200mm, 1800mm, 2400mm. These three sizes with the average North American product, results in 70,000 pounds per hour, 100,000 pounds per hour, and 150,000 pounds per hour.

C. TOMRA’s FPS sorter will provide additional implementation of value for the producer, including quality and product size with real time data.

D. The FPS sorting technology was officially released into potato sorting in late 2013. There has been great success with the technology in Europe over the last year and it is presently being introduced into North America.

4.4 Chemical Imaging Technology

Chemical Imaging Technology (CIT) is a new and highly innovative technology which makes invisible defects visible. Using the chemical structure in foods, colour images are created in high resolution, enabling classification and sorting on a highly industrial level. Insort GmbH has developed CIT based on near infrared spectroscopy which is capable of permanently controlling food processes.

Insort Sherlock Observer

Insort has developed the Sherlock Observer CIT system which allows for extremely powerful foreign material detection, including: glass, plastic, metal, wood, cardboard, plants, or animals, all of which do not correspond to the spectral range of the conforming product. Differences in colour, shape, or surface density are not relevant. Upon detection of foreign bodies, the system will trigger a signal that can be used either to stop the process or automatically reject the product. The benefits of the Sherlock Observer are automatic detection of foreign substances, monitoring the product stream by chemical composition, and easy installation into existing lines. The functions below are of importance when considering the Insort system:

1. CIT: offers advanced sorting and classification abilities as well as foreign material detection. Accuracy of foreign material detection is much higher than other visual optical sorting processes. Anything that is chemically different to the potato will automatically be identified as being a foreign object, no matter the colour, shape, or surface density (i.e. easy detection of golf balls)

2. Chemical composition: in addition to foreign material detection, is it possible to acquire difference in the chemical structure of the potato and use this information for industrial purposes

This technology currently is the most advanced lose product solution for both detection/removal and piece size.
5.0 TEST RESULTS AND SENSITIVITIES

With regard to the foreign material food tampering issue that arose in the fall of 2014 on Prince Edward Island which involved the use of non-ferrous sewing needles embedded in whole potatoes on a single farm, suppliers for the before mentioned technologies were asked to test the sensitivities of their systems reflecting the same scenario. The following are results obtained from participating suppliers highlighting their systems effectiveness at detecting non-ferrous metal sewing needles in potatoes. We have also mentioned when applicable, the other various FM contaminants that can be detected and removed from the product flow.

5.1 Metal Detection:

CEIA
For this specific application using whole washed potatoes, CEIA is able to confirm in writing the following sensitivities applicable for a MS21 detector head.

Test 1, MS21 600mm X 200mm (23.6 inches x 7.9 inches): Monolayer of washed potatoes. Metal testing results with FM 90˚ to flow and parallel to the flow.

<table>
<thead>
<tr>
<th>Washed Potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 mm Ferrous Metal</td>
</tr>
<tr>
<td>2.0 mm Non-Ferrous Metal</td>
</tr>
<tr>
<td>3.0 mm Stainless Steel</td>
</tr>
</tbody>
</table>

Test 2, MS21 350mm X 150mm (13.8 inches x 5.9 inches): Monolayer of washed potatoes. Note this is a smaller aperture. Metal testing results with FM 90˚ to flow and parallel to the flow.

<table>
<thead>
<tr>
<th>Washed Potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 mm Ferrous Metal</td>
</tr>
<tr>
<td>1.8 mm Non-Ferrous Metal</td>
</tr>
<tr>
<td>2.5 mm Stainless Steel</td>
</tr>
</tbody>
</table>

5.2 X-Ray Detection:

Eagle
For this inspection test, Eagle used their Eagle Pack 720. The system has Hi-Ray tubes, X-Ray energy levels of Hi-Ray 9 at 140 kV and 2.0 mA), and a 1.2 mm Diode Pitch dual energy detector. Conveyor belt speed as tested: 120 feet per minute.

Test Contaminants:
- Low mineral glass: 2, 3, 4, 6 mm at 2.5 g/cm³
- Stainless steel: 0.4 – 1.5 mm at 7.93 g/cm³
- Aluminum: 3.0, 3.5, 4.0, 4.5 mm at 2.78 g/cm³
- Golf ball (piece of ball’s centre): 3, 4, 5, 6, 7, 8 mm at 1.12-1.17 g/cm³
- Stainless steel needles: 1.0 mm x 50 mm, 1.5 mm x 50 mm, 0.75 mm x 40 mm at 7.93 g/cm³
- Golf ball (whole): 40 mm at 1.12-1.17 g/cm³
Test 1, Bulk Russet Potatoes, Pack 430, Hi-Ray 9, 1.2 MDX Dual Energy Detector

Detection specifications listed as smallest detectable size and smallest contaminant size detectable on 1200 of 1200 passes. Monolayer washed bulk russet potatoes tested.

<table>
<thead>
<tr>
<th>Bulk Russet Potatoes</th>
<th>Detection Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
<td>1.2 - 1.5 mm</td>
</tr>
<tr>
<td>Aluminum</td>
<td>4.0 - 4.5 mm</td>
</tr>
<tr>
<td>Low Mineral Glass</td>
<td>4.0 - 6.0 mm</td>
</tr>
<tr>
<td>Golf Ball Series</td>
<td>3.0 - 4.0 mm</td>
</tr>
<tr>
<td>1.0 mm x 50 mm Needle</td>
<td>1200/1200 passes</td>
</tr>
<tr>
<td>1.5 mm x 50 mm Needle</td>
<td>1200/1200 passes</td>
</tr>
<tr>
<td>0.75 mm x 40 mm Needle</td>
<td>1200/1200 passes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bulk Russet Potatoes</th>
<th>x / 1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>False Tags</td>
<td>1/1200 (0.08%)</td>
</tr>
</tbody>
</table>

X-Ray Product Images

5.3 Near InfraRed

TOMRA has indicated the following as the foreign material removal performance for the TOMRA Odenberg FPS System.

Test Results, TOMRA Odenberg FPS 1200, 1800, 2400. Detection specification shown in percent removed from monolayer, unwashed field potatoes.

<table>
<thead>
<tr>
<th>Unwashed Potatoes</th>
<th>Detection Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks (&gt;20mm - 3/4&quot; dia)</td>
<td>90%+ Removal Rate</td>
</tr>
<tr>
<td>Soil Clod (&gt;20 mm - 3/4&quot; dia)</td>
<td>90%+ Removal Rate</td>
</tr>
<tr>
<td>Loose Foreign Material</td>
<td>80% + Removal Rate</td>
</tr>
<tr>
<td>(metal, wood, bone, glass)</td>
<td></td>
</tr>
<tr>
<td>Rotten Potato</td>
<td>50% Removal Rate</td>
</tr>
</tbody>
</table>

Stones

Soil

Foreign Material
This technology cannot locate embedded FM. It does a rough sort for loose, larger FM, however smaller loose FM will go directly through the sorter undetected. The technology can provide important potato information in addition to loose FM detection such as product size and quality data.

5.4 Chemical Imaging Technology Detection

For this inspection, Insort tested a Sherlock Separator system for 50,000 lbs per hour capability. While there are several benefits to CIT technology, the test results for a needle inside a potato were discouraging. Insort noted that, much to their surprise, the potatoes were influencing the magnetic field and appear to cover the needle inside from being detected. Insort suggests the best solution for the overall performance on foreign material would be a CIT system followed by an X-Ray system.

Test results, Sherlock Separator 1200 (mm) for 50,000 pounds with one CIT camera based on a defect load of 50-600 FM detections per hour:

<table>
<thead>
<tr>
<th>Unwashed Potatoes</th>
<th>Loose FM Detection / Removal Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks (&gt;15mm - 1/2&quot; dia)</td>
<td>99% Removal</td>
</tr>
<tr>
<td>Soil Clod (&gt;15mm - 1/2&quot; dia)</td>
<td>99% Removal</td>
</tr>
<tr>
<td>Other loose FM (&gt;15 mm - 1/2&quot; dia)</td>
<td>99% Removal</td>
</tr>
</tbody>
</table>

Expected detection results on smaller working widths and additional CIT unit:

<table>
<thead>
<tr>
<th>Number of CIT Units</th>
<th>Working Width</th>
<th>Approximate Loose FM Minimum Detection Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Observer</td>
<td>300 mm</td>
<td>4 mm – 5/32”</td>
</tr>
<tr>
<td>2 - Observer</td>
<td>840 mm</td>
<td>4 mm – 5/32”</td>
</tr>
<tr>
<td>2 - Observer</td>
<td>1200 mm</td>
<td>5 mm – 3/16”</td>
</tr>
</tbody>
</table>

For 100,000 pounds per hour capacity, two Sherlock Separators at 1200 mm wide would be required.

All test results failed to locate a needle completely embedded inside a potato. This is a highly advanced technology for loose FM, but not for embedded materials. When the peel is removed it provides a much more advanced embedded FM inspection.
6.0 BUDGET PRICING

The following estimates are based on high level capital equipment costs and do not include line items like taxes or commissioning. The pricing below is converted into Canadian dollars using exchange rates from December 3, 2014 from the US dollar (1.14) and Euro (1.41).

These price options are based on technologies capable of two different capacity rates for comparison. The rates are 50,000 pounds per hour and 100,000 pounds per hour. All of the following systems can be scaled to meet desired rates.

Please keep in mind that prices are just the FM detection system and rejecter. Other necessary equipment and cost will vary depending on the installation. However it is important to allow additional costs for:

- Product infeed and pick up equipment
- Surrounding support equipment
- Services, including electricity and compressed air
- Install costs
- Shipping
- Commissioning

### Metal Detector:

<table>
<thead>
<tr>
<th>Option</th>
<th>Capacity</th>
<th>Dimensions</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong>: 50,000 pounds per hour</td>
<td>THS / MS21 – 500 x 150 1200 mm (19.7 inches) W x 150 mm (5.9 inches) H</td>
<td>Belt conveyor for metal detector, stainless steel wash-down construction 72&quot; long, 18&quot; wide belt, reject flap gate</td>
<td>CDN $36,000</td>
<td></td>
</tr>
<tr>
<td><strong>Option 2</strong>: 100,000 pounds per hour</td>
<td>THS / MS21 - 950 x 150 950 mm (37.4 inches) W x 150 mm (5.9 inches) H</td>
<td>Belt conveyor for metal detector, stainless steel wash down construction 72&quot; long, 36&quot; wide belt, reject flap gate</td>
<td>CDN $43,000</td>
<td></td>
</tr>
</tbody>
</table>

### X-Ray:

<table>
<thead>
<tr>
<th>Option</th>
<th>Capacity</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong>: 50,000 pounds per hour</td>
<td>Eagle Pack 720 (30&quot; belt)</td>
<td>IP65 X-Ray Inspection System with Simultask Image Recognition Single Lane Retracting Nose Conveyor, IP69K Sanitary Construction Conveyor Single Lane Double Product Guides (Recommended for bulk inspection)</td>
<td>CDN $178,000</td>
</tr>
<tr>
<td><strong>Option 2</strong>: 100,000 pounds per hour</td>
<td>Two systems of the Eagle Pack 720 (30&quot; belt)</td>
<td>IP65 X-Ray Inspection System with Simultask Image Recognition Single Lane Retracting Nose Conveyor, IP69K Sanitary Construction Conveyor Single Lane Double Product Guides (Recommended for bulk inspection)</td>
<td>CDN $356,000</td>
</tr>
</tbody>
</table>

### NIR

<table>
<thead>
<tr>
<th>Option</th>
<th>Capacity</th>
<th>Dimensions</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong>: 50,000 pounds per hour</td>
<td>3,514 mm x 1,980 mm x 1,980 mm dimensions with a 1200mm (47.2 inches) wide infeed belt</td>
<td>CDN $127,000</td>
<td></td>
</tr>
<tr>
<td><strong>Option 2</strong>: 100,000 pounds per hour</td>
<td>3,540 mm x 2,515 mm x 1,976 mm dimensions, with a 1600mm (63 inches) wide</td>
<td>CDN $198,000</td>
<td></td>
</tr>
</tbody>
</table>
CIT
Option 1: 50,000 pounds per hour
Sherlock Separator 1200 mm (47.2” belt), low defect loads with one CIT camera  CDN $318,000

Option 2: 100,000 pounds per hour
Two systems of the Sherlock Separator 1200 mm (47.2” belt), low defect loads with one CIT camera  CDN $636,000

These pricing estimates are compared in the following chart:

* Capital Equipment Cost for Detector and Reject System
7.0 INSTALL BEST PRACTICES

The various technologies within this report have the following best practices that should be taken into consideration when designing and selecting the technology for foreign material inspection and removal.

1. **Potato FM Percentage Ratio**
   The removal of typical foreign and unwanted material, such as rocks, dirt, sticks, etc. from the potatoes with proper mechanical equipment will allow the advanced foreign material systems to work with greater accuracy and less rejects. This reduction in rejects will reduce the amount of good product rejected in the process.

2. **Even Flow**
   Presenting the potatoes in a controlled flow with even flow or surge systems is critical to optimizing the inspection process. All foreign material detection and removal systems will not operate correctly with surges of product above the design. To obtain the maximum capacity of the systems, it is important to have consistent infeed.

3. **Monolayer**
   Monolayer of product for the inspection system is critical to unmask the foreign material and increase the rejection rate of small size foreign material. With a properly designed infeed system to the foreign material detector, this is achievable.

4. **Aperture Size**
   Aperture size of the inspection zone should be as small as possible to increase the sensitivity of inspection. If the maximum diameter of the product is 4 inches, selecting a 6 inch aperture will allow the product to flow through while avoiding having the product touch the inspection device. This is why it is recommended to inspect monolayer in bulk form, rather than in boxed or bagged product to improve the inspection of small foreign material.

5. **Plant Install Conditions**
   Foreign material detection technology should be mounted in a location where there is no vibration to the unit. Vibration will result in maintenance issues and a reduction in the size of foreign material detection and rejection.

6. **Reject System Location**
   The technology provider should be responsible for the rejection system, and if at all possible have the rejection device close to the automatic inspection area to improve timing and positive rejection.

7. **Reject System Design**
   When selecting the style of reject system if possible select an in-line reject rather than a system that includes a 90° transfer of the FM. The other important criteria is to reduce the amount of good product with the bad. Select a laned solution, if possible.

8. **FM Removal Guarantee**
   When a location and foreign material technology is identified, ensure to obtain in writing from the supplier an approval of the design and location and an identification of the size and type of foreign material they guarantee to detect.

9. **Inspection of Rejected Material**
   There are two reasons to review and allow for space to inspect the rejected material. The first is to be aware of the FM within your product for additional investigation. The second is to inspect and recover the good product which has been rejected with the FM. If this is done manually, ensure the product has to pass through the FM sorting system for re-inspection.
8.0 FM SORTING TECHNOLOGY OVERVIEW

The technology related to food security is increasing at a faster rate than in previous years. Many technologies from the military, airports and other advanced fields are moving into the food industry. Some are being modified and adapted focused on the needs of the food industry. The most advanced sorting companies in the world such as the ones investigated within this report are advancing quickly with new improvements and integration of multiple technologies to meet the needs of the food producing industry. It is clear to see at the recent technology shows directly focused on food production, such as the Pack Expo in Chicago and the Interpomme in Belgium in November of this year have advanced innovations regarding food safety. This reduces the risk of the food producers, but also helps make the various food industries more sustainable by reducing product waste. In the past, entire lots of product would have been destroyed with the possibility of contamination, now there is more and more technology to avoid this potential waste stream.

Within the report presented, there are two distinct sorting technology solutions available to integrate into unprocessed potato operations.

1. The first is sorting loose FM from the process flow. There are two levels of technology as we have seen within the report. One is using NIR, a more common and affordable technology than the second technology, CIT. Depending upon the desired amount of risk to reduce within the process along with the amount of automation one technology is selected over the other. CIT is a more advanced technology, capable of seeing smaller pieces of loose FM and has a better reject system than NIR produced by TOMRA. The cost difference between the two technologies reflects the level of risk reduction, however in the majority of cases, the NIR technology is most suitable when taking into consideration the cost versus the added benefit of CIT.

2. The second group of sorting technologies is more focused on internal or embedded FM detection. This includes metal detection and X-Ray technologies. It is also important to note that both can remove, to some degree, loose FM (metal detecting only metal), but due the amount of product rejected when each detects FM, it is not the ideal technology to remove common FM without a great deal of good product being removed. Both Metal detecting and X-Ray should be installed with the purpose to detect and remove random, uncommon FM within the product flow. This is why it is important to have a either a loose FM sorter or have a mechanical/manual removal process.

3. Below are summary tables of test results indicating which technology can detect certain foreign material. Red checkmarks represent a testing condition that is not ideal based either on the specifics of the system, and/or the test results. To note: while metal detection and X-ray are capable of detecting loose foreign material, the systems operate more efficiently when loose FM has already been removed.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Loose Foreign Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td>Metal Detector</td>
<td>✓</td>
</tr>
<tr>
<td>X-Ray</td>
<td>✓</td>
</tr>
<tr>
<td>CIT</td>
<td>✓</td>
</tr>
<tr>
<td>NIR</td>
<td>✓</td>
</tr>
</tbody>
</table>
The table below highlights the specific results achieved when testing for embedded metal in washed and unwashed potatoes using metal detectors and X-ray.

<table>
<thead>
<tr>
<th>Embedded Foreign Material</th>
<th>Technology</th>
<th>Metal Detection (7.9&quot; Aperture)</th>
<th>X-Ray</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ferrous Metal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 mm</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Non-Ferrous Metal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 mm</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>4.0 mm</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Stainless Steel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 mm</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.0 mm</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Aluminum</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 mm</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>4.5 mm</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
9.0 RECOMMENDED FM TECHNOLOGY AND LOCATION

Upon completion of discussions with representatives within the potato industry, the following technology for foreign material detection is suggested. These recommendations highlight the technologies and flow of equipment to improve the level of product security and public safety, reducing the risk to the packing facility and producer.

This section of the report will explain the suggested locations to integrate the FM technology based on two distinct end customers. The first will be a description and explanation for a producer who is selling product to a potato packing or processing operation, and the second example is a fresh pack potato line. The following list includes each step in the process and a description of the purpose.

9.1 Unwashed Potato Option

<table>
<thead>
<tr>
<th>Unwashed Potato Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Product Delivery</td>
</tr>
<tr>
<td><strong>2.</strong> Evenflow</td>
</tr>
<tr>
<td><strong>3.</strong> Dry Dirt Eliminator</td>
</tr>
<tr>
<td><strong>4.</strong> Two Way Sizer</td>
</tr>
<tr>
<td><strong>5.</strong> FPS NIR Sorter</td>
</tr>
<tr>
<td><strong>6.</strong> Manual Inspection</td>
</tr>
<tr>
<td><strong>7.</strong> Evenflow conveyor</td>
</tr>
<tr>
<td><strong>8.</strong> Metal Detector</td>
</tr>
<tr>
<td><strong>9.</strong> Inspected Product</td>
</tr>
</tbody>
</table>

NOTE: Manual inspection of reject FM flow for investigation and recovery of good product is optional.
## 9.2 Fresh Pack Facility Option

### Fresh Pack Operation

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Product Delivery</td>
<td>With Trucks or conveyors from storage</td>
</tr>
<tr>
<td>2. Evenflow</td>
<td>All downstream equipment will work most efficient with a consistent product flow</td>
</tr>
<tr>
<td>3. Dry Dirt Eliminator</td>
<td>Removal of loose soil and small FM as much as possible with mechanical, uncomplicated equipment</td>
</tr>
<tr>
<td>4. Two Way Sizer</td>
<td>10 inch long plus potatoes must bypass the FPS sorter, majority of lose FM will fall through with the under 10 inch long product</td>
</tr>
<tr>
<td>5. FPS NIR Sorter</td>
<td>Under 10 inch long product is fed through the sorter to remove unwanted loose FM including stones, glass, wood, metal, etc. Cover 20mm diameter</td>
</tr>
<tr>
<td>6. Collection conveyor</td>
<td>The inspected under 10 inch and uninspected over 10 inch are merged together</td>
</tr>
<tr>
<td>7. Wet Destoner</td>
<td>Remove stones from the process</td>
</tr>
<tr>
<td>8. Washer System</td>
<td>Wash the soil from the product</td>
</tr>
<tr>
<td>9. Felt Dryer</td>
<td>Remove surface moisture from the product</td>
</tr>
<tr>
<td>10. Quality Sorter</td>
<td>Sort product by size and quality</td>
</tr>
<tr>
<td>11. Bin Storage</td>
<td>Product holding area prior to packaging</td>
</tr>
<tr>
<td>12. Bin Discharge Conveyor</td>
<td>Product selected for transport to packaging line</td>
</tr>
<tr>
<td>13. Metal Detection</td>
<td>Monolayer pre-packaged inspection for metal contaminates</td>
</tr>
<tr>
<td>14. X-Ray</td>
<td>Inspect for embedded FM including various forms of plastic, glass, etc. materials of higher density than the potato. (Note this is optional advanced FM inspection for contaminates outside the normal situation)</td>
</tr>
<tr>
<td>15. Packaging Line</td>
<td>Inspected product is packaged into the various forms, foil wrapping, bag, box, etc....</td>
</tr>
</tbody>
</table>

NOTE: Manual inspection of reject FM flow for investigation and recovery of good product is optional.

In both situations there will be limitations based on the space available, services, capacity, budget and level along with risk willing to be taken by the grower or packer. Therefore it is very difficult to estimate a total project cost to implement either of the suggested layouts. Each operation will have to review their specific situation before moving forward. The following pages highlight a visual description of the process.
9.1 Unwashed Potato Option – Flow Diagram

Unwashed Potato Operation Flow Diagram
9.1 Unwashed Potato Option – Visual Diagram
9.2 Fresh Pack Facility Option – Flow Diagram

Fresh Pack Operation Flow Diagram

- Product Delivery → Even Flow → Dry Dirt Eliminator → Two Way Sizer → 10 inch and Under → FPS → Good Product
- Product Delivery → Even Flow → Dry Dirt Eliminator → Two Way Sizer → 10 inch and Over → Wet Destoner
- Product Delivery → Even Flow → Dry Dirt Eliminator → Two Way Sizer → 10 inch and Under → FPS → Good Product
- Packaging Line → X-Ray (Optional) → Metal Detection → Bin Storage → Quality Sorter → Felt Dryer → Washer
- Foreign Material → Foreign Material → Foreign Material
9.2 Fresh Pack Facility Option – Visual Diagram
10.0 CONCLUSIONS

Managing and implementing change to improve product safety is a difficult challenge. As seen within the report there are various combinations of FM detection and removal to choose from with very different capabilities. All of the technologies will add value in reducing risk to the potato industry and people, but there is not one technology that can remove all the possible contaminants when targeting loose and embedded FM.

Potato operations have evolved and changed in the recent number of years:

Fresh Pack Operations:

The traditional Fresh Pack operations have changed over the recent years to produce more value added products. More and more of the products produced in a fresh pack operation are prepared for cooking with little human inspection:

- Foil wrapped
- Microwave ready
- Fingerlings
- Small bite size products

In the past, fresh pack potatoes would be washed, potentially peeled prior to cooking, then cut or mashed before being consumed allowing for inspection. Presently, some products are crossing over into a consumer-ready format that will not receive a critical level of inspection prior to consumption.

Processor Growers Operations:

Within the process industry there is a great deal of demand to eliminate FM as early in the process as possible. This includes loose FM as well as embedded FM. It is important to eliminate FM before the cutting operation. For example, mechanical cutters can slice FM into smaller, undetectable pieces. The processors have invested in some or all of the technologies investigated within this report in various stages of the process.

Summary

If we review the embedded sewing needle FM experienced earlier this year, metal detection technology can detect and remove it. Should another material other than metal, or a metal piece smaller than 2.0 mm become embedded, metal detection would not be capable of inspection and removal.

Going forward, it is important to look at each specific potato operation to determine what one technology, or combination of technologies, best meets their needs. In most situations, metal will be the common ‘non-intentional’ embedded FM due to the equipment involved in the farming and handling of potatoes. When reducing the potential loose FM reaching the various customers, you can add manual inspection labour. However, people are not as capable of detection and removal as one of the two loose FM detection systems investigated. Therefore, a form of loose FM removal technology in combination with metal detecting can achieve the largest cost vs. risk reduction benefit to the majority of potato operations.

As expected, this investment in FM detection and removal comes at an additional cost to potato operations. My estimation for capital equipment cost for an operation of 100,000 pounds an hour involving a FPS NIR sorter for loose FM followed by a metal detector would be approximately $350,000. This assumes that the space is available without a lot of modifications. In addition to this cost will be surrounding support equipment as seen in the layouts within this report if it does not already exist in the operation.
It is critical to make steps forward to reduce the risk of FM reaching the end customer and integrate known FM technologies. However, I recommend that each operation investigate carefully due to several different situations/variations within their specific operation for the best overall solution before making large investments into the reported technologies.

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