Metal Detection and X-Ray Food Safety Capabilities

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Thermo Scientific Lab/Line Food Safety Solutions

Complete Solutions

On-line Product Inspection Solutions
Our Contract with Customers

**Confidence**
- Brand protection
- Production efficiency
- Compliance to policies
- Robust, easy-to-use solutions
- High performance technology
- World class service and support

**Commitment**
- Solutions that exceed requirements
- High quality and durability
- Outstanding results every day
- Honest and professional people
- Competitive value
- Peace of mind

Your Confidence is Our Commitment
Confidence In Action

- Finding contaminants in blueberries
  - Problem: Find < 2 mm metal in cases prior to shipment to fruit processor
  - Solution: High performance POWERx x-ray inspection

- Weighing pizzas at high speed
  - Problem: Verify product weight/ingredients are correct
  - Solution: High speed, easy to use VersaWeigh checkweigher

- Detecting metal fragments in mixed spices
  - Problem: Assure no metal fragments in spices mixed for snack foods
  - Solution: Easy to clean, zero false reject drop through APEX 300 metal detector

- Controlling moisture in corn chips
  - Problem: Broken or tough chips due to incorrect water content
  - Solution: Guided Microwave System (GMS) moisture control prior to frying
A Key Driver for Contaminant Detection Systems

- **FDA HACCP**
  - Hazard Analysis and Critical Control Point
  - [http://www.cfsan.fda.gov/~lrd/haccp.html](http://www.cfsan.fda.gov/~lrd/haccp.html)
  - Started in 1995 for Seafood, extended to Juice, Dairy and Retail/Food Service
  - A guideline for best practices

- The seven key principles
  1. Analyze hazards
  2. Identify critical control points
  3. Establish preventive measures with critical limits for each control point
  4. Establish procedures to monitor the critical control points
  5. Establish corrective actions to be taken when monitoring shows that a critical limit has not been met
  6. Establish procedures to verify that the system is working properly
  7. Establish effective recordkeeping to document the HACCP system
Other Drivers Influencing Deployment of MD/XR

- **Brand protection**
  - Negative PR, legal issues, …

- **End customer requirements**
  - Codes of practice, mandates

- **Protect delicate equipment downstream from equipment malfunctions and/or foreign objects**
  - Find metal, rocks, hard plastic … prior to entering processing equipment that could be damaged

- **Reduce scrap and save $$$**
  - Detect random occurrences so you don’t have to quarantine entire lots for further screening and possible disposal/return

- **Address concerns over importation to high quality/price countries (US, Japan, Germany…) from low cost production regions**
Many Possible Sources of Contamination

1. Raw material
   - Particulates including bones, shells, seeds, rocks
   - Bacteria and germs

2. Machinery
   - Parts and pieces (metal)
   - Lubricants, fluids, or gases

3. People
   - Accidental or intentional actions
   - Insufficient training

4. Process
   - By-product of ingredient production
   - Cross contamination from changeover
   - Poor sanitation processes
   - Time (cooking, freezing, holding)

5. Environmental
   - Construction in the plant, building failure
   - Rodents, insects
The key to a successful application is understanding the strengths and limitations of the technology.

**Metal Detectors**
- Utilize an RF transmitter, antennas and digital signal processor (DSP)
- Only sensitive to metals, not all metals are the same
- Some products can act like metal and/or can change a lot over time

**X-Ray Systems**
- Utilize ionizing radiation combined with computer analysis
- Can find dense, sharp objects and also provide for various inspections
- Some products “look” like the contaminants
## Overall Detection Capability Comparison

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Metal Detectors</th>
<th>X-Ray Systems</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous, non-Ferrous and Stainless Steel</td>
<td>0.3 - 5mm</td>
<td>0.5 – 2.5mm</td>
<td>Easy to set-up and use</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Yes</td>
<td>Depends on size</td>
<td>X-ray can penetrate low density aluminum</td>
</tr>
<tr>
<td>Wires and needles</td>
<td>Yes</td>
<td>Depends on size</td>
<td>Diameter, composition, orientation and hollow/solid…</td>
</tr>
<tr>
<td>Glass</td>
<td>No</td>
<td>&gt;=2mm soda lime composition</td>
<td>Depends on density, position and product type (glass jar)</td>
</tr>
<tr>
<td>Stones/Rocks</td>
<td>No</td>
<td>&gt;=3mm for dense materials</td>
<td>Many types possible, must test to determine performance</td>
</tr>
<tr>
<td>Plastics</td>
<td>No</td>
<td>Sometimes</td>
<td>PVC easiest, must test to determine performance</td>
</tr>
<tr>
<td>Bones</td>
<td>No</td>
<td>Sometimes</td>
<td>Must be calcified</td>
</tr>
<tr>
<td>Pits and shells</td>
<td>No</td>
<td>Sometimes</td>
<td>Usually very difficult</td>
</tr>
<tr>
<td>Insects</td>
<td>No</td>
<td>No</td>
<td>Not dense enough</td>
</tr>
<tr>
<td>Wood</td>
<td>No</td>
<td>No</td>
<td>Not dense enough</td>
</tr>
</tbody>
</table>
Basic Metal Detection
Theory of Operation
The Basic Principle of Metal Detection

• A transmitter sends a signal out
• Two receivers equal distance from the transmitter receive them
• The signals from the receivers are subtracted and the result is zero - a balanced condition
What Happens When Metal is Present

- Metal objects between the coils “unbalance” the system and thus metal may be detected.
- A digital signal processor analyzes the signals to find the metal and ignore the product.
Metal Can Have Two Effects

**Magnetic Effect**

- Magnetic: Metal Present
- Field Distorted
- Induced Voltage Increased

**Conductive Effect**

- Non Magnetic: Metal Present
- Field Distorted
- Induced Voltage Decreased

*In the APEX Magnetic = X and Conductive = R*
What is Phase Angle?

- All real contaminants have a combination of both magnetic and conductive effects.
- The ratio of the two effects can be measured by the phase angle of the out of balance voltage.
- All products and metals have phase angles. The product must be ignored, the metal must be detected.
Factors That Affect Metal Detector Sensitivity

Sensitivity is typically expressed as the minimum sphere diameter that can be detected 100% of the time

1. Operating Frequency (50-500 khz)
   - Higher freq detects SS better, but Fe worse. Higher freq also can make conductive (wet) product effects worse.

2. Aperture Size
   - The closer the aperture is to the product the better the sensitivity

3. Product Effect
   - Most difficult when the product (X and R) look like the metal you want to find

4. Orientation Effect
   - Important when metal wire is an important hazard

High Sensitivity, False Rejects  ⇌  No False Rejects, Possible Escapes
Key Applications for Metal Detectors

- **Package products – conveyor**
  - Any product you see in the grocery store
- **Bulk products – gravity or conveyor**
  - Unpackaged discrete or bulk flow products
  - Detect prior to packaging
- **Pipelines**
  - Sauces, slurries, soups, meat…
- **Pharmaceutical**
  - Post tablet press or capsule production
- **Unique applications**
  - Recycled plastic pellets
  - Automotive web needle detection
A Calibrated Test Process

- Independent measurements on X and R signals
  (non Ferrous metal used typically)
Test Pieces for Performance Testing/Auditing

- Metal detector customers request sensitivity in diameter (mm) for:
  - Ferrous
  - Non-Ferrous
  - 316 Stainless Steel (non-magnetic alloy)
- Thermo Scientific test piece styles
  - Cards (conveyors)
  - Sticks (conveyors too)
  - Disks (drop through, pipeline)
  - Disks (pharma)
- All test pieces have Certificate of Conformance (C of C)
- 100s of sizes, must specify at order time
Basic X-Ray Training

Thermo Fisher Scientific
The world leader in serving science
X-Ray Inspection Basic Principle of Operation

- Same familiar approach used in medical/baggage x-ray systems
  - Density image generation created by ionizing radiation
- Manual x-ray systems “read” by humans
  - Sometimes with image enhancement or multiple views
- Industrial x-rays “read” by image analysis software
  - Image processing and analysis algorithms
  - Can use enhancement and/or multiple views too
Current flows through a filament in a tube (mA)

Electrons leave the filament and are accelerated by a high voltage (kV) from a cathode (-) to a tungsten covered anode (+)

When the electrons impact the anode x-rays are emitted

A collimator/slit is used to focus or shield the x-ray beam

Voltage \approx \text{penetration/punch through}
Current \approx \text{brightness/intensity}
**X-Ray Detection Method**

- X-rays penetrate the object being bombarded and those that pass through strike a detector assembly.
- The detector has a scintillator crystal that converts x-rays into photons that are “counted” by a photo diode.
- The spacing between these diodes defines the image pixel size (1.5mm to 0.2mm, 0.8mm typical).
- Usually x-ray systems can detect contaminants slightly larger than the diode size.
Block Diagram of A Complete X-Ray System

Collimator

X-Ray Generator

Speed Sensor

Conveyor Belt

X-Ray Beam

Reject (if contaminated)

Pack

Linear Detector

Designed to meet FDA CFR 21 part 1020.40/IRR 199 and many other worldwide standards for safety
Some Typical Image Analysis Tools (Filters)

Filter No. 1
Pack Edge
Masking

Filter No. 2
Product Area
Measure

Filter No. 3
Gradient Image
Processing
More Filter Examples

- Simple Threshold
- Contaminant Area Measure
Some Sample X-Ray Images/Contaminants

- Bread sticks (1.5mm metal)
- Candies (2mm glass)
- Milk Powder (1mm SS)
- Cookies (1.5mm glass)
- #18 SS Needle in 100mm of Pork
- Ice Cream Bars (1.5mm metal)
X-Ray Systems are Certified/Tested to be Safe

- Meet or exceed FDA CFR 21 part 1020.40 (and the more stringent UK IRR 1999 limits)

- Built-in safety features
  - X-ray annunciation lamp, key switch, door safety interlocks, dual lead curtains, emergency stop, lockable power switch, on-screen x-ray off button

- Radiation surveys done by Thermo Fisher at the factory and after installation

- Thermo Fisher Scientific meters available too
Key Applications

- Horizontal packaged products – conveyor
  - Contaminants and product inspection
  - Metallized film a popular application

- Bulk products – conveyor
  - Nuts, seeds, grains, fruit, beans, …
  - Remove rocks, metal, glass, … early in the process

- Pipelines

- Vertical packaged products - conveyor
  - Contaminants and fill level
  - Glass-in-glass
The double side view is a unique technology that improves:

- Detection performance on the *bottom area* of the container
- Detection performance on the *sidewalls* of the container
- Detection performance of *large but thin* contaminants
Bottom Area Inspection Basics

FIRST VIEW
Due to jar/beam orientation the contaminant can be hidden behind the bottom glass contour

SECOND VIEW
The contaminant appears clearly in the image taken at 90 degrees from the first view
Sidewall Inspection Basics

FIRST VIEW
Depending on jar orientation, the contaminant may be hidden by the shadows caused by the thickness of the sidewalls

SECOND VIEW
The contaminant appears clearly in the middle of the image
Large But Thin Contaminant Basics

**FIRST VIEW**
The contaminant is large but thin, so it has a low contrast and weak edges and can’t be detected.

**SECOND VIEW**
The contaminant appears clearly because of its thickness in this direction.
Key Detection and Application Differences

**Metal Detection**

- Detects metal including aluminum and wires
- Can be used almost anywhere in a process; conveyors, drop through and pipelines
- Operates at just about any speed
- Conductive (wet/salty) products most difficult
- Performance dependent on aperture size, coil configuration and software
- Long life in harsh environments
- Metal only usually > 1 mm in size
- Dry products, small products, piped or bulk products have best sensitivity
- Sensitive to metallic packaging

**X-Ray Inspection**

- Detects most metals and many other solid contaminants
- Conveyor, bulk and pipeline; not for gravity applications
- Speed must be constant and may be limited
- Dense products with a lot of texture most difficult
- Performance dependent on X-ray source, receiver, power and software
- Controlled environments best, shorter life
- Typically can find smaller contaminants than metal detectors and also nonmetallic contaminants
- Large packaged products and cases can be inspected; cans and bottles too
- Ideal for metalized film and foil packages
Why Customers Prefer Us?

- Customer Focus
- Range of Solutions
- Application Expertise
- Service and Support
- Global Footprint
Questions