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A practical guide to metal detection and X-ray inspection of food

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Overview

Keep consumers safe and protect your brand

Detecting foreign objects in food is integral to food safety and quality – and ultimately to your brand reputation and consumer safety.

This newly expanded and updated ebook is a primer on how to navigate the challenges of keeping food free from foreign objects. And, it offers insights to help you understand choices among metal detection and X-ray solutions.

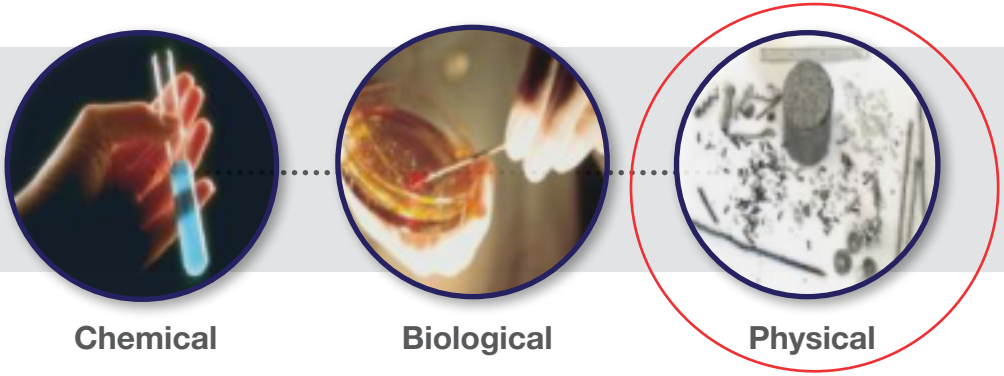
New technologies improve detection sensitivity to the extent that food processors can find virtually any foreign object in their packaged and unpackaged food products.

Contamination threats to food supply chain

Food supply chain from source to consumer:

Major sources of contamination

Threats exist in each step of the food chain.



Chemical | Biological | Physical

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Foreign contaminant in food recalls

Millions of pounds of food products were recalled in 2019 due to the presence of foreign contaminants. These recalls not only decrease profitability through lost sales and increased costs, but could also damage company reputations and put consumer health at risk. As you can see from this sampling from the U.S. FDA 2016 recall list, almost every packaged food is susceptible to foreign contaminant problems.

Note: http://www.fda.gov/Safety/Recalls/ArchiveRecalls/2016

- Plastic pieces in energy bar
- Piece of rubber in baby food
- Hard white pieces of plastic in wet dog food
- Clear plastic pieces in bread products
- Plastic mesh screen fragments in flour
- Small metal shavings in apple coffee cakes
- White plastic in ravioli
- Small pieces of plastic in mini muffins and brownie snacks
- Metal fragments in gourmet cookies
- Small metal fragments in sugar topping of baked items
- Metal fragments in sugar used in Asian sauce
- Plastic and/or metal pieces in cans of black beans
- Glass in peach slices, mandarin oranges, and mixed fruit
- Glass fragments in cans of red pepper strips
- Small pieces of glass in cashew snack packages
- Glass pieces in frozen pizza and frozen meals
- Wooden pieces in ice cream

Regulatory compliance

Compliance with global standards

- FDA HACCP (Hazard Analysis and Critical Control Points)
- GFSI (Global Food Safety Initiative)
- ISO (International Standards Organization)
- BRC (British Retail Consortium)
- Many industry-specific standards for meat, bakery, dairy, seafood and other products

Food Safety Modernization Act (FSMA) Preventive Controls (PC) rule

Manufacturers must identify hazards, define preventive controls to eliminate/reduce hazards, determine process parameters for these controls, and then implement and continue to monitor the process to ensure the system is working properly. Hazards can be biological, chemical and physical.

Preventive controls for physical hazards often include metal detectors and X-ray inspection systems.

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Hazard Analysis and Critical Control Points (HACCP)

FDA HACCP

- Hazard Analysis and Critical Control Points
- A guideline for best practices worldwide for food safety
- Principles used in the U.S. Food Safety Modernization Act (FSMA) of 2011

More info: https://www.fda.gov/food/guidance-regulation-food-and-dietary-supplements/food-safety-modernization-act-fsma

U.S. Food and Drug Administration
Protecting and Promoting *Your* Health

The seven key principles

1. Conduct a hazard analysis
2. Determine the critical control points (CCPs)
3. Establish critical limits
4. Establish monitoring procedures
5. Establish corrective actions
6. Establish verification procedures
7. Establish record-keeping and documentation procedures

More info: https://www.fda.gov/Food/GuidanceRegulation/HACCP/ucm2006801.htm

Regulatory compliance – Validation and verification

Validation, the process of ensuring that a hazard has been reduced to an acceptable level, is just one step in the overall verification process.

Verification procedures ensure that preventive controls have been effectively implemented and are performing as expected.

Other verification activities confirm that monitoring and corrective actions are occurring.

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Regulatory compliance – Imported food

FSMA gives the FDA the ability to ensure that imported foods are produced to the same standards and controls as foods produced within the U.S.

Basic requirements of the Foreign Supplier Verification Program (FSVP) are:

- Review the food product's compliance status, including background checking for previous issues with the product or supplier.
- Perform a hazard analysis and ascertain if the producer has control measures in place for each identified hazard.
- Establish a verification protocol to ensure that the control measures are adequate. This could include visits to the production site, audits, independent sampling, and food testing.
- Create corrective action procedures that are suitable and can be initiated if needed.

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Metal detection and X-ray inspection

The two key foreign object detection technologies.

Metal detection	X-ray inspection
Detects metal including aluminum and wires.	Detects most metals and many other solid contaminants.
Can be used almost anywhere in a process; conveyors, drop-throughs and pipelines.	Best used for conveyor or bulk inspection.
Operates over a wide range of speeds.	Speed must be constant, and range. may be limited.
Conductive (wet/salty) products are the most challenging.	Dense products with lots of texture will be most difficult to achieve good performance.
Performance dependent on aperture size, product effect and software.	Performance dependent on X-ray power, receiver, product texture, and software.
Long life in even the harshest environments.	Moderate life in harsh environments, best in controlled environments.
Detects metals down to <1.0 mm in diameter.	Detects metals down to <1.0 mm in diameter, also finds dense nonmetallic contaminants down to <3.0 mm in diameter.
Dry products, small products, unpackaged products, or products with nonconductive packaging have best sensitivity.	Most packaged products have high sensitivity including metal cans, glass bottles and products packaged with metallized film or seals.
Highly flexible, cost effective detection solution suitable for multiple inspection points.	Effective detection and product verification for the widest range of contaminants and package types.

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Inspection and detection

Foreign object detection is determined in three ways:

1. Detectable contaminant types
2. Minimum contaminant size
3. Probability of detection

Types of Packaging

Paper

Cardboard

Plastic

- Polyethylene terephthalate (PETE or PET)
- High-density polyethylene (HDPE)
- Polypropylene (PP)

Glass Jars/Bottles

Metal Cans

- Aluminum
- Tin
- Steel

Metallized packaging

- Aluminum laminated with polypropylene

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Detectable contaminants

Below are the general guidelines for detectable contaminant types by inspection technology. The best practice for understanding detection is to test many different contaminants prior to deployment to understand how the product and contaminant react in the inspection system.

Key	
● ● ●	Highest detectability
● ●	High detectability
●	Moderate detectability
	Not detectable

Detectable Contaminant Type	Metal Detectors	X-ray Systems	Comments
Ferrous metal	● ● ●	● ● ●	Ferrous, non-ferrous, and stainless steel different for MD, the same for XR
Non-ferrous metal e.g., brass or bronze	● ●	● ● ●	
316 Stainless steel	●	● ● ●	
Aluminum	● ●	● ●	Density similar to glass, thin foil only detectable by MD
Wires	● ●	● ●	Depends on diameter, length, and orientation for both MD and XR
Glass		● ●	Depends on density and size, ~ 3x less dense than stainless steel
Rock		● ●	Depends on density and size
Bone		●	Depends on density and size, calcified bone only
Plastic		●	Depends on density and size, light plastics not reliably detectable
Wood, pits, shells, insects, etc.			Nonconductive for MD, not dense enough for XR

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Technology

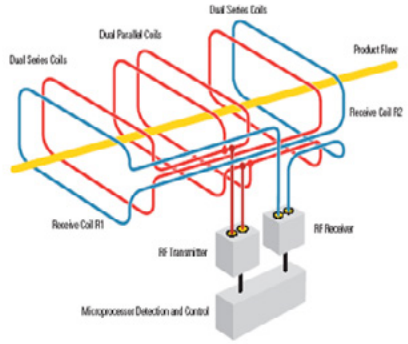
How metal detectors work

Metal detectors find small particles of ferrous, non-ferrous and stainless steel using coils wound on a non-metallic frame and connected to a high-frequency radio transmitter.

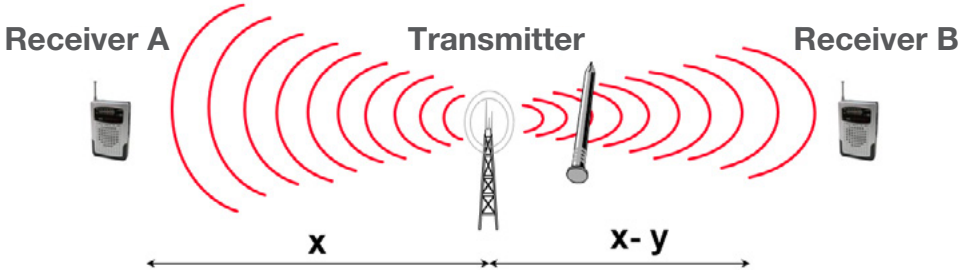
When a particle of metal passes through the coils, the high frequency field is disturbed under one coil, changing the voltage by a few microvolts.

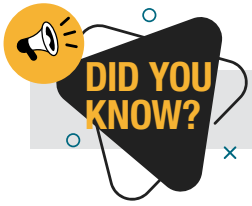
The output is used to detect metal.

Metal Detector Coil Systems



Multicoil metal detector design





Modern metal detector designs are less susceptible to noise and demonstrate improved sensitivity.

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Multiscan and Selectscan technologies

With advanced metal detection technologies, the critical control point (CCP) will be protected with a device armed to find metal types and sizes previously undetectable. Flexible single-frequency and broad-spectrum approaches reduce the probability of a costly escape.

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Selectscan

- One fully flexible frequency optimized per application.
- Automatic frequency selection using Autolearn.
- Best for dry, inert products.
- Provides a high level of food safety.
- Easy to set up and maintain.

Download the white paper:
Achieve a higher level of food safety with Selectscan metal detection

Multiscan

- Five-frequency broad-spectrum approach, like five metal detectors in one.
- Different frequencies optimized for different metal types.
- Best for wet, conductive products and the strictest performance requirements.
- Provides the highest level of food safety.

Download the white paper:
Why multiscanning technology improves metal detection and food safety

Factors that affect metal detector sensitivity

1 Product size, packaging and conductivity

Best sensitivity in dry product with low product effect

Packaging should be nonconductive

Product should pass through the aperture center

2 Software

Digital signal processing is needed to filter noise and compensate product effect

3 Aperture size

A smaller aperture means smaller metal sizes will be detectable

The correct aperture size will be selected based on product size

4 Technology

More frequencies means better metal detection for conductive, challenging products

A modern feature set ensures performance is optimized

10 factors to consider in selecting a metal detection system

1 Performance

Metal detectors must be able to reliably find pieces of ferrous, non-ferrous, and stainless steel metal contaminants.

2 Environment

The metal detector must be able to withstand the operating environment. Factors like temperature, humidity and sanitation must be accounted for before purchase.

3 Frequency selection

Choosing the optimal operating frequency(ies) will provide the highest level of detection. The optimal frequency will be a function of many factors including product effect, product size and moisture.

4 Ease-of-Use

A powerful software feature set should be easy to use so that anyone, not only expert personnel, can harness optimal performance.

5 Product handling

Orderly, sealed packages with sufficient spacing work best with a photo eye to align the rejection system. Disorderly, irregularly shaped product works best with a bulk system that has no photo eye.

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10 factors to consider in selecting a metal detection system

6 Training

Understanding the basic principles of metal detection will aid setup and comprehensive audits.

7 Equipment lifetime

The system and its components should foster a long lifetime without compromising performance. IP69k and ingress protection rating coupled with heavy-duty design will keep dust, liquid and thermal shocks from damaging electronics.

8 Traceability

Important information such as rejection statistics and user logs should be stored within the software automatically and be available for download.

9 Cost of ownership

Consider the long-term costs associated with a metal detector including installation, preventative maintenance and potential downtime.

10 Vendor experience

Consider working with a vendor who has a proven track record of keeping food safe utilizing new, innovative technologies.

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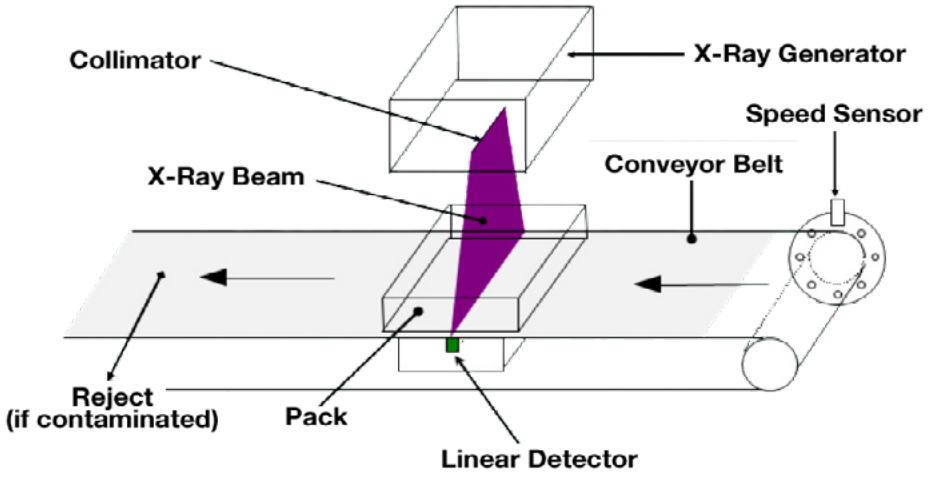
How X-ray inspection systems work

X-ray inspection systems are based on the density of the product and the contaminant.

As an X-ray penetrates a food product, it loses some of its energy. A dense area, such as a contaminant, will reduce the energy even further.

As the X-ray exits the product, it reaches a sensor. The sensor then converts the energy signal into an image of the interior of the food product. Foreign matter appears as a darker shade of grey and helps identify foreign contaminants.



X-rays

X-rays are simply light waves that we can't see. Other light waves that we can't see include ultraviolet (UV) light (which gives you a suntan), infrared light (which warms you up), and radio waves. X-rays have a very short wavelength, which corresponds to a very high energy.

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Factors that affect X-ray system sensitivity

1. Product thickness, density and texture

- Thin, lightweight, homogeneous products are best
- Containers should be invisible to the system
- X-ray beam should be oriented to pass through the least material

2. Detection software

- Many types of algorithms are needed to find anomalies

3. Line speed

- Performance can degrade at very high speed

4. Detector pixel size

- Smaller pixels are sometimes better; they take more power to expose

5. Detection optimization

- Balance system performance between high sensitivity with higher false reject rate
- Reduced sensitivity, no false rejects but increased possibility of escape

Are X-ray systems safe?

Food X-ray inspection systems do not use radioactive materials to generate X-rays, instead they use high voltage X-ray tubes to generate images. When the tube is turned off, no X-ray energy is emitted.

Below are local regulations and best practices that should be followed, including filling out annual radiation surveys and registering X-ray equipment with local regulatory authorities.

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Examples of X-ray Inspection Regulatory Standards

Country	Regulatory Standard
United States	Code of Federal Regulations 21 Part 1020.40 (cabinet X-rays)
Canada	RED (Radiation Emitting Devices) Act
United Kingdom	IRR 1999
France	NCF-74-100
Spain	UNE 73-302
China	GB18871-2002

PDF

For more details, read about these safety requirements and protocols in this white paper: **X-ray Inspection of Food Products: The Safety Facts You Need to Know.**

How safe is X-ray of food compared to other forms of exposure?

Here are the average doses of radiation people receive from exposure to these common products/situations.

One Banana	Food X-ray Inspection	Dental X-ray	Trans-Atlantic Flight	Full Body CT Scan
.01 mrem	0.5 mrem/ hour**	1.5 mrem	2.5 mrem	1,000 mrem

***When in operation, food inspection systems can emit this maximum level of radiation per hour, typically very close to the input/output of the aperture only. Because human operators spend limited time in this location they would receive much less (usually zero) radiation dose in an average work shift.*

PDF Click here to download the full infographic.

10 factors to consider in selecting an X-ray system

1 Meets safety standards

X-ray units should meet or exceed safety standards such as the U.S. FDA Code of Federal Regulation 21 Part 1020.40 and the more stringent United Kingdom IRR 1999 limits.

2 Maintenance schedules

Perform preventive maintenance every 6-12 months, including: checking air filters, conveyor bearings, rollers and belts, door gaskets and locks, safety switches, radiation shielding curtains, and more.

3 Sufficient X-ray power and beam size

X-ray source and detector selection helps ensure the X-ray beam is powerful enough to penetrate dense product and wide enough to inspect all portions.

4 Sophisticated, easy-to-use software

Multiple algorithms enable you to find anomalies that are dense, sharp or have a certain shape or contrast. Remote tools should be available to support PC/Windows-based systems.

5 Positioning flexibility

Test multiple packages of each type and vary the contaminant type and position. If possible, vary the product position inside the package and its position on the conveyor belt.

10 factors to consider in selecting an X-ray system

6 Training

Understand basic principles, from inspection triggering to detection algorithm setup to calibration and rejection reviews, among others.

7 Component lifetime

Choose a system that warns when a source or detector is nearing end of life to enable you to schedule its replacement and avoid surprise downtime.

8 Clear visuals

Make sure the product and the contaminant are visible on the screen. The ability to save rejected product images facilitates record-keeping, system adjustment and fine tuning.

9 Low total cost of ownership

Consider all the projected costs over 5-10 years, including: purchase and installation; preventive maintenance; possible repairs and associated downtime; and source and detector replacement.

10 Reputable vendor

Consider the vendor's experience in X-ray equipment for the food processing industry and their commitment to customer satisfaction.

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Equipment

Overview

The following pages show various types of equipment and their applications, considerations before buying, and best practices when you own equipment.

Thermo Scientific™ Xpert™ Conveyor X-Ray Inspection Systems

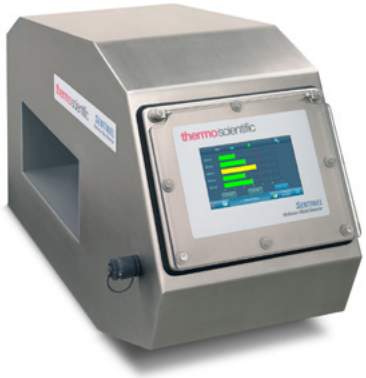
Product details ›

Thermo Scientific™ VersaWeigh™ Checkweigher with Thermo Scientific™ Sentinel™ 3000 Multiscan Metal Detector

Product details ›

Thermo Scientific™ NextGuard™ Conveyor X-ray Detection System

Product details ›



Thermo Scientific™ Sentinel™ 5000 Multiscan Metal Detector

Product details ›

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Metal detection with multiscan technology

By scanning up to five user-selectable frequencies running at a time, metal detectors with multiscan technology provide unmatched sensitivity and the highest probability of finding ferrous, non-ferrous, and stainless steel metal contaminants in challenging applications such as dairy, meat, poultry, bread, and other applications with high product effect.

Overcome the limitations of fixed single or dual frequency metal detectors with the **Thermo Scientific™ Sentinel™ 5000 Multiscan Metal Detector**.

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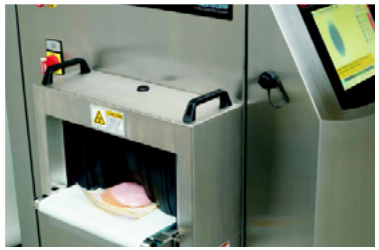
Metal detection with selectscan technology

Metal detection systems provide reliable, cost-effective protection from even the smallest metal contaminants found anywhere in a food production process. They can also help improve operational efficiency and eliminate expensive downtime, service costs and repair bills. There are many uniquely designed metal detectors suited for a wide range of demanding food processing and packaging environments.

Selectscan technology enables food processors to have an easy way to rapidly identify the single best frequency, from 50 to 1000kHz, for an application. Selectscan tunes out product effect and adapts results to account for temperature changes and electromagnetic interference. At the same time it provides documentation of results from each production run. It is easy to use by operators of varying skill level.

X-ray inspection

X-ray inspection systems provide protection from metal, glass, stone and other dense foreign objects for most any type of packaged, bulk, or piped product.



Find metallic and non-metallic foreign objects and eliminate "wet" product effects common with metal detectors with the **Thermo Scientific™ NextGuard™ X-ray Detection Systems**. Designed for a wide variety of food applications, NextGuard systems offer enhanced capabilities to inspect packaged products for missing pieces or components, under and over-fills, and other quality problems with easily customizable vision software. Both the C330 and C500 models are easy-to-use, cost effective and thoughtfully designed systems that eliminate common barriers when migrating from metal detection to X-ray inspection.

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X-ray inspection

Protect food safety and improve quality with the **Thermo Scientific™ Xpert™ Conveyor X-ray Inspection Systems**. These high performance vertical X-ray beam (top down) systems perform X-ray contaminant detection and product inspection for bags, boxes and other flat packages, quickly identifying contaminants and quality defects that other systems miss. Xpert Conveyor systems meet HACCP and retailer food safety and quality requirements, can be configured for any application or challenging factory environment, and include powerful software to eliminate false rejects.

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X-ray inspection

Protect product integrity with flexible X-ray inspection systems that detect a range of contaminants and product flaws in nearly any size or shape packaged food product. **The Thermo Scientific™ Xpert™ Bulk X-Ray Inspection Systems** find contaminants such as metal, rock, plastic and glass and remove them prior to further processing, providing instant cost savings.

Detect foreign objects anywhere in cans and bottles with the **Thermo Scientific™ Xpert™ Sideshoot X-Ray Inspection System**. This high speed, high performance horizontal X-ray beam (back to front) system provides single beam X-ray inspection for tall, upright packages and includes software specifically tailored to detect objects in all regions of cans and bottles.

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Best practices to get the most out of your X-ray inspection system

Follow these five simple principles of test, protect, adjust, educate, and maintain to get the most value out of your X-ray inspection system. This will assure the highest level of food safety and the lowest downtime, false rejects, scrap, and rework costs.

1 Test

Use a sample of 5-10 packages, not just one, to determine sensitivity.

Move the contaminants around inside the package to ensure reliable detection.

Ask for a guaranteed detection level and the probability of finding smaller objects.

Use test spheres and real world contaminants.

2 Maintain

Check the detector for degradation. Recalibrate or replace as needed.

Plan for replacement of the X-ray source based on hours used.

Clean or replace filters to avoid overheating the system.

Inspect gaskets, glands and covers for water leaks in washdown environments.

3 Check

Check set-ups at regular intervals to make sure they are optimized.

Review false reject images and make changes to eliminate them.

Always retest with audit samples after any change.

Review any new types of contaminant risks and see if the system can detect them.

4 Educate

Set realistic expectations about what can and cannot be detected.

Share with workers a report showing actual contaminants being detected.

Train operators on how to use and audit the system correctly.

Eliminate contaminant sources if possible and switch to detectable plastic materials when you can.

5 Protect

Enable security systems to avoid desensitization by operators.

Utilize reject confirmation and bin full sensors to verify rejects are removed.

Lock the reject bin and install covers on the conveyor so only good products pass through.

Make sure the production line can't be run until the X-ray system is on.

Click here to download the full infographic.

5 features to consider when selecting bulk X-ray equipment

For centuries, food producers have used simple techniques to sort out physical contaminants from bulk agricultural products. A screen, for example, allows bigger items to stay on one side while smaller ones fall to the other side. Separating magnets and gravity have been exploited as well to remove ferrous metals and dense materials, respectively. The original detection equipment-trained workers can visually inspect for just about anything, but can be costly and less accurate than machines as people can tire.

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1 Flexible Placement

You should be able to accept product from the front, back or side in a flexible manner. The system should accommodate your requirements, not vice versa.

2 Stack Metering

The metering system should help ensure that the product isn't stacked too high on the belt because that would potentially allow hidden material to be out of the range of the detectors.

3 Belt Guides

The belt should have suitable guides so the product stays in the inspection area and doesn't get trapped under the belt, on the rollers or over the detector (which avoids frequent cleaning.)

4 Multi-lane Monitoring

A multilane software and rejection system that monitors the flow through each lane and helps minimize the amount of food rejected, maximizing throughput.

5 Interlock Safety

The system should include door and cover interlocks to assure that the X-ray source is turned off when undergoing maintenance, cleaning or repair.

PDF Click here to download the full infographic.

Product testing

Product testing is a complimentary service from Thermo Fisher Scientific to help determine the optimal inspection solution and provide an accurate performance estimation.

Customers send samples of real product (or, if this is not possible, similar product can be purchased locally) to our product testing laboratory. The samples will be used to calibrate the device under test. The minimum contaminant sizes detected reliably will be determined. The results are compiled into a report.

The result is that customers can better understand their equipment's performance capabilities. Any technical suggestions for improving detection will be provided too. Product testing help set up food processors up for success.


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METAL DETECTOR PRODUCT TEST REPORT

Date testing completed: 11/27/2019
Testing completed by: Alex Kinne
Company name: XYZ Bakery
Address: 123 Jackson Dr, Somewhere, Ontario, CA

Series Requested: Sentinel
Model Requested: 5000

Contact name:
Phone:
Email:

Required Sensitivity		
ferrous	nonfer	stainless
2	2.5	3

Product Description	Package Type	Dimensions w.r.t flow: Length	Width	Height	Weight	Temp	Speed
rye bread	loaf				50 lbs		
multigrain bread	loaf						

Product Image

Special Test Comments

SENSITIVITY ESTIMATE: SENTINEL 5000 350X150			
ALL PRODUCTS	ESTIMATED DETECTABLE METAL SIZES		
	FE	NFE	SST
Minimum Size	1.8	2.5	2.5
Results subject to change in production setting			

Width (mm)	Height (mm)	Weight (g)	Temp (C)	Speed (m/min)
		50		

HMI version
SCU version

Metals Detected		
ferrous	nonfer	stainless
size		
best freq		
AL score		

Special Test Comments

FE: SENTINEL 5000 350X150		
Estimated detectable sizes		
ferrous	nonfer	SST
Minimum sizes		
Results subject to change in production setting		

1

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Thermo Scientific Product Inspection

Protect your brand with leading in-line solutions to ensure safety, quality and production efficiency by detecting physical contaminants, validating net content, verifying product integrity and analyzing constituents. We supply systems worldwide and have over 35,000 customers including the majority of the top 50 food companies in the world. We also provide critical service, technical support and parts to keep production lines running 24x7x365.

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Watch the video to see why Cedar's Foods doesn't even consider other food safety equipment manufacturers:

> **We know that Thermo Fisher has been there, they support us, they're always innovating, and they haven't let us down. Why would I ever even want to consider anything else. To me it's the Cadillac of that technology, not just because of the equipment, it's because of the people, the support system that goes along with it...the relationships built with my people with them, I just think it helps us every single day.**

- Nick Scangas, Chief Operating Officer, Cedar's Foods

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About Thermo Fisher Scientific

Thermo Fisher Scientific is the world leader in serving science. Our Mission is to enable our customers to make the world healthier, cleaner and safer. Whether our customers are accelerating life sciences research, solving complex analytical challenges, improving patient diagnostics and therapies or increasing productivity in their laboratories, we are here to support them. Through our industry-leading brands, including Thermo Scientific, Applied Biosystems, Invitrogen, Fisher Scientific, Unity Lab Services and Patheon – we offer an unmatched combination of innovative technologies, purchasing convenience and pharmaceutical services.

For additional information or to request a quote, please click below.

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thermofisher.com/productinspection

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