White Paper

How to Detect Previously Undetectable Contaminants

Contents

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How to Detect Previously Undetectable Contaminants

Since the early 1990s, food manufacturers across the globe have been relying on x-ray technology to protect consumers, reduce the risk of product recalls and safeguard their brands.

However, despite providing unsurpassed detection of a wide range of dense foreign bodies, including metal, glass and calcified bone, x-ray technology has historically been incapable of detecting certain types of materials such as glass shards smaller than 2mm in diameter, rocks and low-density rubber and plastics, especially in products with complex density levels.

That was, until the advent of Material Discrimination X-ray (MDX) Technology.

But what exactly is MDX, how does it actually work, and what benefits does the technology offer food processors?

This white paper takes an in-depth look at the latest development in x-ray for product inspection, which is fast becoming a standard feature of food processing plants throughout the world.

It begins by discussing the capabilities and limitations of traditional x-ray technology, before focusing on how MDX works and the benefits x-ray systems with this technology afford food processors. In doing so, the paper incorporates real-life examples illustrating how MDX has significantly enhanced the foreign body detection capabilities of a potato processor in North America and a cereal manufacturer in Poland.

1. Traditional X-ray Technology

Standard x-ray systems are capable of detecting and rejecting a wide range of potentially-harmful foreign bodies. They give food manufacturers exceptional levels of detection for stainless steel and ferrous and non-ferrous metals. Traditional x-ray software is also extremely good at detecting glass, calcified bone, mineral stone and high-density plastics and rubber, regardless of their shape, size or location within a product.

However, standard x-ray systems are incapable of detecting thin glass or low-density plastics, rubber, stones and rocks in most food-based products.

In addition, finding dense foreign bodies in products with complex density levels (high variations in density) can also prove challenging for traditional x-ray software.

2. MDX Technology

Originally pioneered for the security sector, Material Discrimination X-ray (MDX) has been used since the mid 1990s to find contraband, weapons, explosives and stowaways in cargo containers.

Food processors worldwide have been relying on the technology since 2007 to detect materials previously unseen by x-ray or other conventional inspection means in difficult product applications, such as flat glass and low-density rocks, rubber and plastic[1].

As MDX is an enhanced form of x-ray technology, it is important to explain what x-rays are, and the main components and operating principles of an x-ray inspection system, before focusing specifically on how MDX technology works.

2.1 What are X-rays?

X-rays are one of several naturally-occurring sources of radiation and are an invisible form of electromagnetic radiation like radio waves. All types of electromagnetic radiation are part of a single continuum known as the Electromagnetic Spectrum (Figure 1). The Spectrum is arranged according to frequency and wavelength and runs from radio waves at one end (which have a long wavelength) to gamma rays at the other (which have a short wavelength).

The short wavelength of x-rays enables them to pass through materials that are opaque to visible light, but they do not pass through all materials with the same ease. The transparency of a material to x-rays is broadly related to its density - the denser the material, the fewer x-rays that pass through. Dense foreign bodies like glass, bone and metal show up because they absorb more x-rays than the surrounding product.

2.2 Principles of X-ray Inspection

In simple terms, an x-ray system uses an x-ray generator to project a beam of low energy x-rays onto a sensor or detector. X-ray inspection involves passing a product or pack through the x-ray beam before it reaches the detector. The amount of x-ray energy absorbed during the beam's passage through a product is affected by the product's thickness, density and atomic number.

When the product passes through the x-ray beam, only the residual energy reaches the detector and measurement of the difference in absorption between the product and a foreign body is the basis of foreign body detection in x-ray inspection.

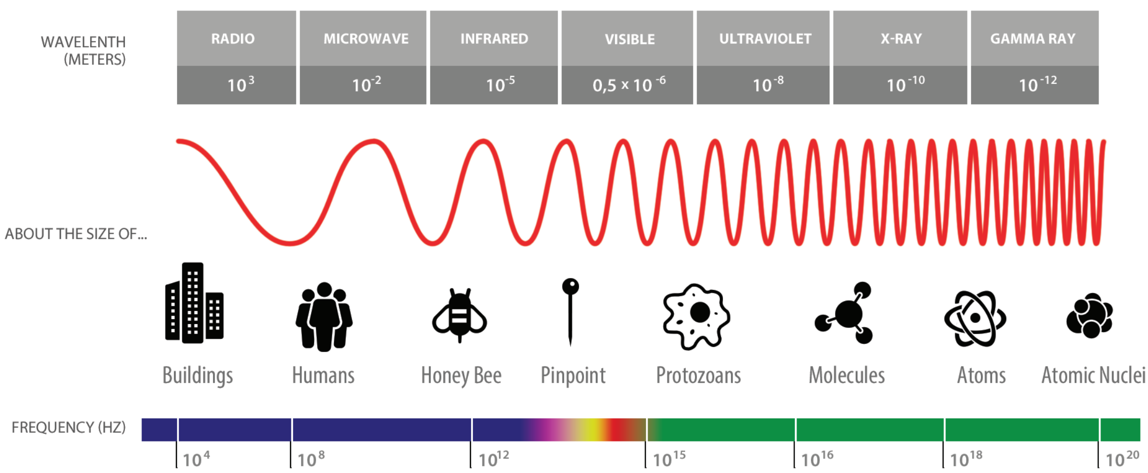

Figure 1: Electromagnetic Spectrum

2.2.1 What Makes up an X-ray System?

There are three key components of an x-ray inspection system:

- An x-ray generator (A)
- A detector (B)
- A computer (C)

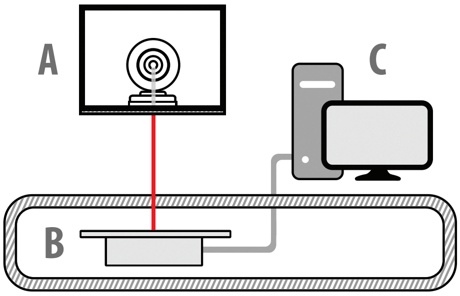

Figure 2: Components of an X-ray System

The x-ray beam is generated by an x-ray tube encased in the x-ray generator. It leaves via an exit window and travels in a straight line through a collimator (a device for narrowing the stream of x-rays to a smaller fan beam). The x-ray beam then passes through the product or pack being inspected, before finally reaching the detector.

2.2.2 X-ray Generator

The x-ray generator contains an x-ray tube, which generates an x-ray beam. Modern x-ray tubes consist of a glass envelope, a filament cathode, a copper anode and a tungsten target. The cathode (A) which is the source of the electrons is a tungsten filament heated to incandescence by an electrical current. The electrons are accelerated to the target (B) by applying a high voltage between the anode (C) and the cathode.

When the electrons hit the tungsten target mounted inside the copper anode, they decelerate rapidly and this deceleration creates the x-ray emissions. Depending on the application, different x-ray tubes can be selected to optimize the sensitivity of detection and overall performance.

2.2.3 X-ray Beams

Choosing the right system is fundamental to the success of x-ray inspection. Systems cannot optimally detect foreign bodies unless each element from beam angle to reject mechanism has been chosen to best fit the application. Most x-ray systems use a vertical x-ray beam from the generator to scan the product as it passes through the x-ray system.

2.2.4 X-ray Detector

An x-ray detector is to x-ray as a camera is to light, a way of capturing x-ray energy and converting it into an image form that can be processed by electronics. Regular x-ray systems contain one detector which consists of individual elements called diodes. Diodes convert the level of detected x-ray energy into an electrical signal that is sent back to the machine's on-board computer.

2.2.5 Building an Image

An x-ray inspection system is essentially a scanning device. When a product passes through the system at a constant speed, the x-ray detector captures a 'greyscale' image of the product. This is generated by measuring the amount of x-ray energy reaching the detector.

Each image is made up of 'pixels' and the x-ray energy absorbed by each pixel creates a value on a greyscale (from black 0 to white 65535). As the product or pack passes over the detector, each line of grey level data is added to previous lines, much like slices of bread can be added to form a loaf, resulting in a complete product image.

Software within the x-ray system analyzes the image and compares it to a pre-determined acceptance standard.

On the basis of this comparison, the system either accepts or rejects the image (and the product/pack it represents). In the case of rejection, software sends a signal to an automatic reject system, which then removes the product from the production line.

2.3 How Does MDX Technology Work?

Like standard x-ray systems, MDX technology involves using a generator to project an x-ray beam onto a detector and passing a product through the beam.

However, MDX diverges from regular x-ray inspection as it uses two energy spectrums to discriminate between high and low channel x-rays, as well as a dual-layer detector. While the top detector is sensitive to lower energy (longer wavelength x-rays), the bottom detector is sensitive to higher energy (shorter wavelength x-rays). The two detectors are separated by a small copper plate which filters out the low-energy x-ray and only allows the high-energy x-ray to pass through to the high-energy detector.

When an x-ray beam is projected through a product, some of the energies will be absorbed while others will pass through. What gets absorbed and what passes through depends on the product's composition.

Materials are made up of elements and each element has its own atomic number. For a given x-ray energy, as the atomic number increases, the element absorbs more x-ray energy and passes less. So carbon, with an atomic number of 6, absorbs much less x-ray energy than lead, with an atomic number of 82. Lead absorbs almost all x-ray energies which is why it is commonly used as shielding in places like medical x-ray labs.

As elements have different atomic numbers, it is possible to measure differences in absorbance based on the elements in a material. The amount of x-ray absorbance a given element has depends on the x-ray energy and, as MDX has a detector array that gives values at two different energies – high and low, it is convenient to express these as a ratio.

Two separate images are generated by the two spectra of energy and a relative ratio of energy absorbed can be calculated to determine a material's composition.

So, in effect, MDX measures the ratio of two different sets of x-ray energies that pass through a product and this measurement enables organic and inorganic materials to be differentiated. Foreign body detection is therefore based on chemical composition (atomic number) rather than just density variation.

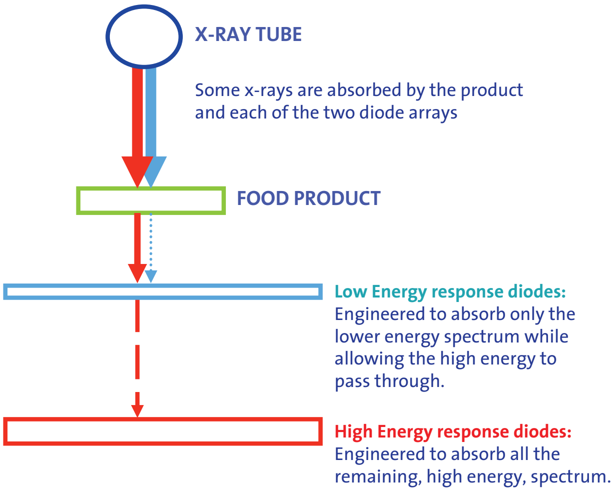

Figure 3: How Does MDX Technology Work?

2.4 Foreign Body Detection Based on Chemical Composition

Traditional x-ray technology used to inspect food products for contamination is very effective at detecting objects that exhibit an x-ray absorption spike relative to the surrounding product's absorption.

However, MDX technology is better at detecting objects that show a very small x-ray absorption variation. This means that dense foreign bodies in dense products are more easily detected with MDX than with standard x-rays. For example, MDX makes it possible to detect flat glass and stone in mixed nuts, both of which can be challenging to detect using standard x-ray systems, depending on the application.

MDX technology essentially removes most of the effect of product thickness variations and leaves an image that shows density difference based on chemical composition. Food products are typically organic in composition and, if solid or liquid, contain water. Chemically, food products consist primarily of hydrogen, carbon and oxygen. Any foreign body containing an element of a higher atomic number than carbon or oxygen becomes more easily detectable using MDX technology.

Traditional x-ray methods typically find foreign bodies that are visible in an x-ray image, but many foreign bodies that are not readily visible in an x-ray image may be detected with MDX technology. For example, MDX technology brings a distinct advantage when detecting inorganic foreign bodies, such as stones, flat glass (as opposed to cylindrical glass), bone, rubber and some plastics. Plastics and rubber that have inorganic filler or have a component of chlorine, bromine or fluorine also fall into this category.

2.5 Typical Applications

MDX's ability to discriminate materials by their chemical composition is especially valuable for inspecting bulk and packaged products that contain complex density levels (high variations in density). The nature of cereals, nuts, bagged salads, confectionery and other similar products results in 'busy' x-ray images, which makes detection of foreign bodies more difficult for conventional x-rays.

X-ray systems with MDX technology are also ideal for inspecting products in innovative pack styles.

Figure 4: Cereals

Application Example:
The Northwestern United States has over half of the U.S. potato acreage[2]. Potatoes are a big business and shipped for processing into French fries, potato wedges, chips, as well as various other finished products. However, the repercussions of customers finding foreign bodies in potatoes are of growing concern to the industry, especially with the Asian market driving small foreign body detection, with a particular emphasis on small rocks.

Potatoes are grown in the ground next to rocks that are very dense, as well as those that are known as caliche and have a very low density. If a customer finds a contaminated batch of potatoes, they will often reject the whole container without paying for it, which can be devastating for business. For example, a potato processor recently had several million dollars worth of product discarded by a local hamburger chain after rocks were found in French fries.

Another problem that blights potato processors is golf balls. Golf balls landing in potato fields are increasingly ending up in factories where tubers are processed into frozen French fries.

As golf balls are the same size as potatoes and act very similarly, they get through a lot of sorting systems. In addition to the hard rubber spheres creating serious problems, both mechanically and operationally, they have a tendency to get diced into products.

By enabling potato processors to find previously undetectable foreign bodies, MDX-based x-ray systems are playing a key role in helping them achieve the confidence of their customers that their potatoes are safe.

In fact, one processor admits that by allowing them to detect low-density rocks and golf balls, MDX technology has helped them grow their market share, as well as outperform competitors. With four companies all fighting for the same market share, being able to guarantee the quality of their potatoes has enabled them to secure a better price and gain market share.

Application Example:
Eight MDX systems are playing a critical role in helping a Polish cereal manufacturer protect consumers and their reputation. Prior to installing their first MDX system in 2008, the manufacturer had received several complaints from customers after they discovered glass in their cereal. However, since installing the systems to the end of their production lines, complaints have ceased.

As well as being much more sensitive at detecting glass in final packaged products than standard x-ray systems, the technology has proved indispensable in detecting and eliminating other potentially-harmful foreign bodies, such as stainless steel, rubber and stone, before products are distributed throughout Europe.

2.6 Benefits of MDX

As well as helping manufacturers meet ever-changing trends in the food industry, systems with MDX technology can increase brand protection, enhance customer safety and save costs.

A growing consumer trend affecting manufacturers is the desire for multi-textured foods, such as bags of mixed salad leaves. These types of packaged foods have many density levels, resulting in a crowded x-ray image, which makes identifying foreign bodies a challenge using traditional x-ray technology.

In addition to being excellent at finding historically undetectable inorganic foreign bodies, MDX technology lends itself to inspecting 'difficult' or 'busy' images that contain varied density distribution.

Additionally, MDX allows detection of foreign bodies in increasingly popular packaging designs such as fold-out cardboard sandwich packaging and corrugated card encasements that plague traditional inspection tools.

By enabling contaminated products to be removed before they reach customers or hit supermarket shelves, MDX technology can help avoid product recalls, as well as play a key role in protecting manufacturers' brands and the welfare of consumers.

Furthermore, like standard x-ray systems, machines equipped with MDX can help manufacturers optimize their lines by simultaneously performing a number of in-line quality checks, reducing maintenance and operating costs by reducing equipment requirements.

For example, MDX-based systems are capable of measuring product mass and counting components. They also enable completeness checking, such as ensuring promotions or inserts are included in packaged goods i.e. toys in cereal boxes or missing flavour packets.

2.7 Limitations of MDX

Although MDX is especially good at detecting small aluminium (and other lower-density foreign bodies i.e. glass, stone and bone) as it has a low density like rock, there is generally a trade-off involved between detecting low-density and high-density foreign bodies. Standard x-ray systems (with smaller/single-energy detectors) are better suited to detecting very small pieces of high-density material.

MDX cannot find organic and near-organic (low atomic number) foreign bodies, for example wood and insects, in most food (organic-based) products. In addition, plastic detection depends on plastic types and requires actual product testing.

3. Conclusion

MDX is an acronym for Material Discrimination X-ray, an enhanced form of x-ray technology.

As this white paper shows, MDX shares some similarities with regular x-ray inspection, but also diverges.

MDX's ability to discriminate materials by their chemical composition (atomic number) affords food processors heretofore unprecedented contamination detection capabilities.

As well as enabling the detection of historically undetectable inorganic foreign bodies, MDX-based x-ray systems allow food processors to inspect products with complex density levels and in innovative pack styles.

For this reason, the technology is indispensable for manufacturers of bulk and packaged food products keen to enhance quality, safety and productivity on their lines, as well as meet ever-increasing customer demands.

Notes

[1] Plastic detection is dependent on plastic types and requires actual product testing

[2] Journal of Pesticide Reform/Winter 1997. Vol 17. No 4

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What is DEXA Technology and How Does it Measure Fat Content?

More and more meat processors are relying on Dual Energy X-ray Absorptiometry (DEXA) technology for measuring the chemical lean (CL) or fat content of meat trimmings and ground beef. DEXA is capable of inspecting 100 percent of throughput in real time and has the power to help meat processors save costs.

But what exactly is DEXA technology? How does it actually work? What benefits does it offer the meat industry? This white paper takes an in-depth look at a technology that's fast becoming the global standard for CL measurement.

X-ray More Than Just Foreign Body Detection

X-ray inspection can detect numerous quality shortfalls that lie hidden within product packaging or deep within the product itself. This white paper explains that x-ray inspection is no longer just a technique for catching foreign bodies; its become a wide-ranging tool defending brand values and keeping customers happy.

How to Select Critical Control Points

X-ray systems can be installed at any point during the production process, but choosing the most effective location/s – the critical control points (CCPs) - can prove a challenge. This white paper discusses the relevance of x-ray inspection to each stage of the production process, from raw ingredients to packaged products. It includes real-life examples to illustrate how cost-effectiveness and the efficiency of foreign body detection help determine the optimal location.

BRC Global Standard for Food Safety

This white paper takes an in-depth look at one of the GFSI's biggest standards - the BRC Global Standard for Food Safety (issue 6) and its latest requirements. Focusing in particular on traceability, quality control, foreign body detection, hygienically-designed equipment and equipment calibration; it explores how the implementation of a product inspection programme that incorporates x-ray inspection equipment helps food manufacturers achieve compliance, which is vital to stay ahead in the highly competitive food industry.

How Safe is X-ray Inspection of Meat?

Some of the most popular misconceptions about x-ray inspection of meat are tackled in this white paper. It is indispensable white paper for slaughterhouses who consider x-ray inspection to comply with meat-safety regulations and legislations.

Can you Guarantee Your Chemical Lean Values

With a number of recent trends calling for highly accurate and rapidly-obtained Chemical Lean (CL) values, it's more important than ever for meat processors to be able to guarantee their CL values, and Eagle's brand-new white paper is essential reading for anyone involved in the production or processing of meat.

What are the Benefits of Fat Analysis to Slaughterhouses?

With worldwide meat consumption on the rise and global competition becoming increasingly fierce, slaughterhouses are under constant pressure from many different stakeholders to deliver meat within specification, as well as rapid traceability and consistent profits. Reliable fat analysis is crucial to meet today's demands and Eagle's latest white paper shows how more and more plant and quality managers of slaughterhouses are realizing the benefits of Dual Energy X-ray Absorptiometry (DEXA) technology.

By enabling manufacturers of raw meat to manage fat in order to secure the best value and save costs, this white paper shows how DEXA technology is a prerequisite for slaughterhouses keen to define themselves in a cutthroat international marketplace.

Notes

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