White Paper

SAFELINE
X-ray Inspection

# How to Guarantee
## All-round Glass Inspection

**Contents**



METTLER TOLEDO

White Paper

# How to Guarantee
# All-round Glass Inspection

**Glass is frequently the preferred packaging material for food and pharmaceutical manufacturers. However, checking for foreign bodies in a finished pack is critical, as just one shard could have catastrophic consequences.**

With food and drug safety regulations intensifying, compliance and traceability through every stage of a product's life cycle are growing in importance. X-ray inspection is increasingly being used by manufacturers to detect and reject contaminated products from their production lines in order to protect consumers, reduce the risk of product recalls and safeguard their reputations.

However, glass containers are one of the most difficult types of packaging to inspect.

This white paper begins by explaining why glass packaging is rising in the popularity stakes, before highlighting the associated risks of glass-in-glass contamination and describing how certain production processes increase these. It goes on to explore the capability of x-ray technology to detect glass-in-glass, focusing on factors that affect the sensitivity of detection. It then takes an in-depth look at the various inspection solutions and beam options available, along with transport system designs. An understanding of these, and their suitability for different types of detection challenges, is crucial to enable manufacturers to specify a system with optimal performance.

## 1. Why Use Glass to Package Products?

According to the British Glass Manufacturers' Confederation (BGMC), which represents the UK's glass industry, every family in the UK uses on average around 330 glass bottles and jars each year.

Made from all-natural, sustainable raw materials, glass is essential to modern life and the only packaging material rated 'GRAS' or 'generally regarded as safe' by the US Food and Drug Administration (FDA). With the retail sector striving to be eco-friendly, glass is rising in popularity as it is relatively inexpensive and 100 percent recyclable.

No other packaging material matches the shelf impact of glass. The clarity, shape, and feel of glass containers contribute to the premium perception of products ranging from fine perfumes to liquor, gourmet foods to beverages. In addition, research from the BGMC demonstrates that 70 percent of consumers believe glass packaging suggests quality.

Food manufacturers regularly use glass containers for a wide range of applications, including infant foods, cooking sauces, condiments, vegetables and pickles, beverages, oils and dressings (Figure 1). Glass is equally popular with pharmaceutical manufacturers who use vials and glass bottles to package medicines.

Figure 1: Glass containers are used for a wide range of food applications

## 2. Glass-in-Glass Contamination

Despite its popularity, glass packaging poses a significant safety risk and the effects of glass-in-glass contamination can be highly damaging. In 2010, almost a fifth of physical contamination incidents investigated by the Food Standards Agency (FSA) were a result of glass.

Finding a shard of glass in a product is an emotive subject. Despite it having the potential to be an intrinsic contaminant, evidence shows customers are much more likely to lodge a complaint than if they discovered a chicken bone in a chicken-based product.

A tiny fragment of glass can cause serious injury to a consumer and the subsequent adverse publicity, particularly if a baby or child was severely cut, combined with the high cost of product recalls, can have a devastating impact on business. Not only do product recalls mean lost revenue and a damaged reputation, evidence demonstrates that manufacturers' greatest asset, their brand, may never recover. In fact, research conducted in 2007 by Harris Interactive has shown that 21 percent of people would avoid purchasing any product associated with a recalled brand, while 15 percent would never buy the recalled brand again.

Corporate reputations have also become more fragile as consumers increasingly use the internet, and other media, to share and publicise information about defective products.

## 3. Packaging/Filling Processes

Although modern manufacturing techniques constantly strive to eliminate foreign bodies, processes or procedures inevitably break down. There is an inherent risk of contamination during the production process, such as breakages of glass jars and bottles on the production line as a result of conveyor vibrations or back pressure. There is also a risk during the filling process due to misaligned filling heads striking the top of containers or closures being over-tightened.

The probability of breakages leading to contamination is increased on high-speed bottling lines.

## 4. Safety Standards

Nowadays it is not enough to merely say you take product safety and quality control seriously, you have to prove it.

With retailers' brands and reputations dependent on the delivery of completely safe products they are demanding to know more about manufacturers' packaging safety processes and product safety is now a 'big business'. Many well-known brands have already integrated product inspection systems into their production lines to demonstrate due diligence and guarantee their products conform to the highest standards.

Some major retailers and the custodians of leading consumer brands have developed their own codes of practice that must be fulfilled, and adhered to, in order to satisfy supply agreements. Increasingly the implementation of a formal x-ray inspection programme is expected before supplier approval is granted.

In addition, x-ray inspection technology is widely acknowledged to provide an all-encompassing, reliable solution to help manufacturers comply with national and international legislative and regulatory standards such as Hazard Analysis and Critical Control Points (HACCP), the Global Food Safety Initiative (GFSI) and GMP (Good Manufacturing Practice).

## 5. X-ray Technology

The earliest glass-in-glass x-ray inspection systems were available in the 1980s and they were large units with quite basic inspection techniques. Over the last 30 years, the hardware and, most importantly, the software have radically advanced, to offer fully-automatic, optimised foreign body detection with minimum false rejection on high-speed production lines.

White Paper

As well as being detectors of glass and other foreign bodies, including metal, bone, mineral stone and high-density plastic, modern x-ray systems are multi-tasking defenders of product and brand quality. In a single pass, at high line speeds, x-ray systems can perform several inspection tasks simultaneously, helping to protect profitability, minimise product waste and avoid product recalls. These include monitoring fill levels, detecting damaged containers and checking closures.

However, glass containers are indisputably one of the most challenging types of packaging to inspect, mainly because the primary foreign body is glass - the same material and density as the packaging. Problems also occur because of the density of the packaging material and the fact that the base, sidewalls and neck of glass jars can all cause 'blind spots' - obscuration of the visual field. This means key parts of the product/packaging have the potential to mask dangerous foreign bodies.

## 6. Factors Affecting Detection Sensitivity

### 6.1 Physical Variations

Glass is made from readily-available domestic materials such as sand, soda ash, limestone and 'cullet' - the industry term for furnace-ready scrap glass. These components are mixed or 'batched', heated to a temperature of 2600 to 2800 degrees Fahrenheit and moulded into the desired shape.

However, the process used to produce glass jars creates variation and inconsistencies in form. While the overall weight and outer shape of the jar remain constant from the mould, the varying thickness of the glass walls, and particularly the distribution of the inner raised base, can be as much as 20 percent. This makes foreign body detection particularly challenging. In addition, other physical anomalies, such as molten beads or internal strands of glass known as 'bird swings', cause risks and also challenges for inspection.

### 6.2 Quality of Glass

The quality of glass impacts upon detectability. Furnaces produce hundreds of tonnes of glass every day, making it difficult to completely eliminate foreign bodies, which can cause problems later in the manufacturing process.

Impurities in the glass itself, such as metal foreign bodies from aluminium screw caps or fragments of denser Pyrex from recycled domestic glass, will affect foreign body detection.

Using glass containers from various suppliers can also prove troublesome for manufacturers. Despite containers looking identical physically, their different densities and chemical compositions affect x-ray absorption and hence detection sensitivity.

### 6.3 Container Features

The more complex the shape of the container, the more challenging it is to inspect. Round containers are the easiest to inspect. This is because they have no sharp changes in vertical edge profile which could produce blind spots or hard, dark edges where detection would be reduced. Additionally, they can be repeatedly presented as they have no orientation effect. Square, rectangular or hexagonal containers can also be (guided) presented well, but the side walls may require significant filtering, depending on the angle of the inspection. Oval containers are difficult to guide and therefore not ideal for x-ray inspection as the image can constantly vary. Embossing on the glass creates areas of higher absorption and requires exact repeatable presentation.

The lid area of a jar can prove particularly complex as it contains the metal closure and glass screw threads. These features, combined with variations in glass thickness in the jar's shoulder and natural variations in the physical profile of the rest of the container, contribute to making glass jar inspection a challenge.

### 6.4 Product Viscosity

The type of product being packaged and its viscosity have an influence on where a foreign body is likely to be and need to be taken into account at an early stage. The filling process of semi-solids or viscous products should be considered first since a foreign body could be in the container prior to filling. Quick, high-volume fills of these products can wash possible foreign bodies away from the base and higher in the container where they are held in suspension. While this process aids detection via x-ray inspection, it highlights that not just the base should be inspected (Figure 2).

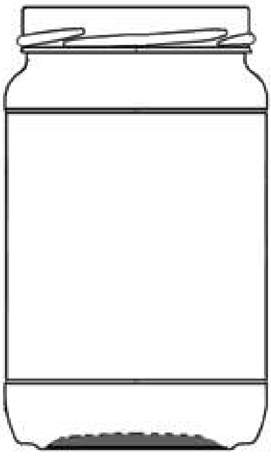


Figure 2: More than just the base area of glass jars should be inspected

A cold fill of a semi-solid or thick particulate product can also hold foreign bodies in suspension so the whole container should be inspected.

A hot fill of a semi-solid or thick particulate will mean the product is less viscous and a dense foreign body will move closer to the base. In fluids, a foreign body will most likely be in the base so inspection should be concentrated in this area too.

## 7. X-ray Systems

Selecting the right system is fundamental to guaranteeing optimum glass-in-glass detection. X-ray inspection equipment cannot solve contamination problems unless each element – from beam angle to reject mechanism – has been chosen to fit the line and the product. Knowledge of the various formats and their suitability for different types of detection challenges is therefore essential.

Factors that affect the specification for an x-ray inspection machine include the application, installation environment, desired sensitivity, best practice and accepted codes of practice. Time devoted to selection will be rewarded by smooth installation, avoidance of major modifications after integration, maximum operational efficiency and ease of verification testing.

Horizontal beam x-ray systems are best suited to glass-in-glass inspection.

### 7.1 Horizontal Beam Systems

A key factor in detection sensitivity is the depth of product the x-rays have to pass through. Horizontal beam systems usually offer better detection for packaged products that are taller than they are wide.

The x-ray generator, which is mounted in the side of the machine cabinet, scans through the side of the container (Figure 3).

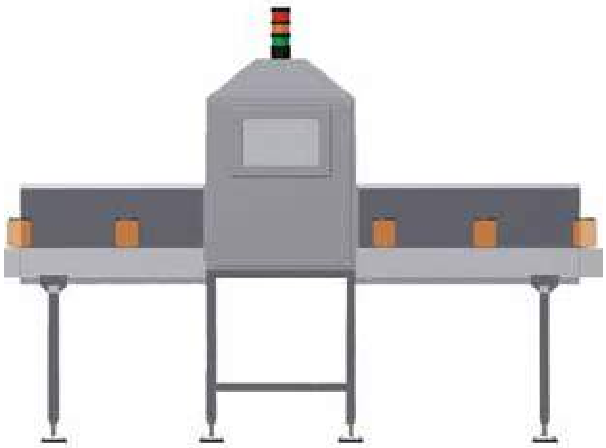


Figure 3: The x-ray generator scans through the side of containers

A side shot image also allows easy application of dynamic masking to the densest areas of the image, namely the perimeter of the container. This in turn optimises detection levels within the container and minimises false rejects due to small changes in the container profile.

Different-sized generators and types of detectors can be used to obtain the optimum detection set-up. Multiple x-ray generators and detectors can be used in the horizontal plane or combined with an additional generator and detector in the vertical plane.

### 7.1.1 Single, Perpendicular 'Upshooter' Beam for Glass Jars/Bottles

A single, horizontal x-ray beam system has one x-ray generator creating an x-ray beam that aligns with the surface of the conveyor belt (Figure 4).

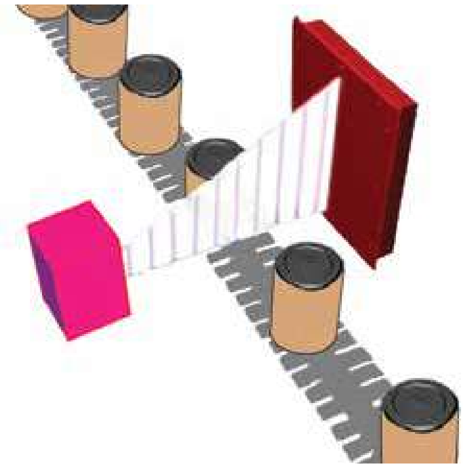


Figure 4: Single, horizontal beam x-ray system

By shooting level with the base of the container, a single, perpendicular beam provides good detection in the body of the jar, but inspection is not optimal in the base or top of the container.

As the densest part of the jar, the base (crown) proves the biggest challenge (Figure 5) as foreign bodies that lie in the base channel can go undetected if they are directly in front of, or behind, the crown. This is because there is not enough increase in x-ray absorption from the additional glass fragment to be readily detected.

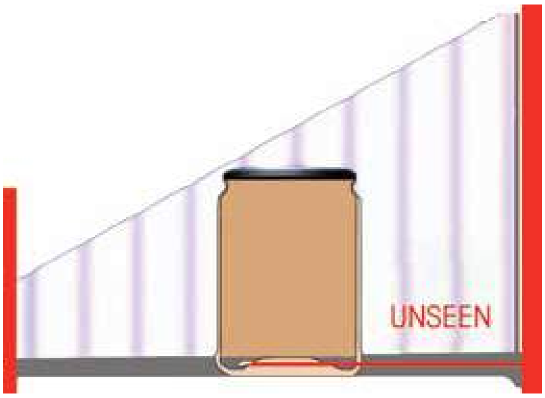



Figure 5: Foreign bodies that lie in the base channel can go undetected

### 7.1.2 Dual Beam for Glass Jars/Bottles

The probability of detecting foreign bodies in glass jars can be improved by using two separate generators to create two separate, angled x-ray beams directed towards two detectors (Figure 6).

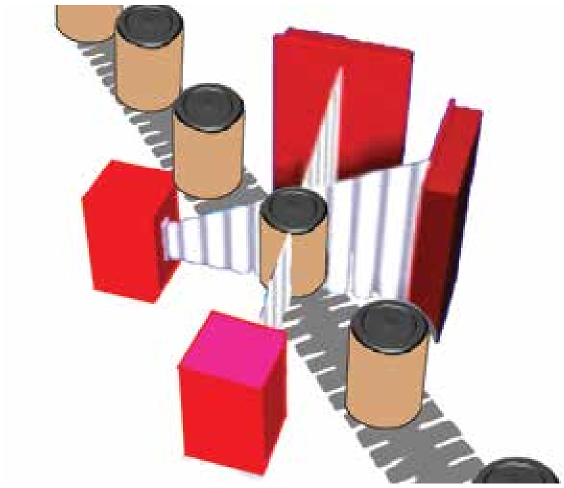


Figure 6: Dual, horizontal beam x-ray system

Creating images showing the view through the jar from two different angles enables a larger area of the base (crown) to be inspected and also makes it easier to spot foreign bodies on the side wall.

A foreign body that appears on the side wall in one image will be moved away from the side wall into the body of the container on the other image, where it is easier to detect.

When using multiple, horizontal beams, due to the angle between the beams, it is important to allow adequate product spacing (pitching) to ensure each product can be independently inspected.

Dual beams cannot always offer 100 percent inspection of high-absorption packaging like glass jars. For this reason, a combination of vertical and horizontal beams is the next advancement for increasing the coverage and optimising detection in more difficult areas.

### 7.2 Combination Beam for Glass Jars/ Bottles

By reducing blind spots in the most challenging areas – the base, sidewalls and neck, combination beam x-ray systems significantly increase the overall inspection coverage in glass containers.

Figures 7 and 8 compare the coverage offered by a single, vertical beam with that offered if a central, perpendicular horizontal beam is added.

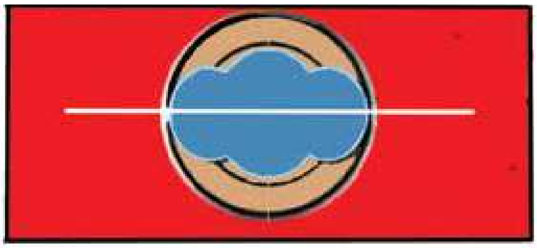


Figure 7: Blue shading indicates the coverage from a single, vertical beam

Figure 8: Dark blue shading indicates the coverage if a central, perpendicular horizontal beam is added

Figure 9 shows how adding two angled, horizontal beams raises the coverage in the base (crown) area of the jar (Figure 9).

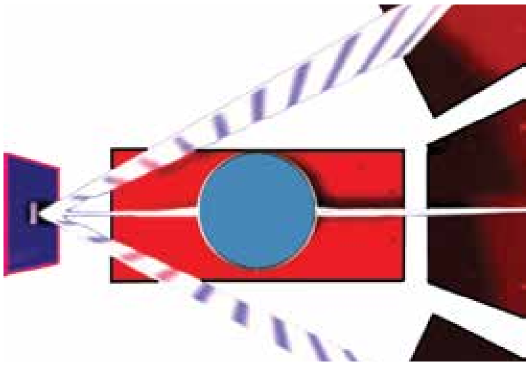


Figure 9: Coverage in the base is optimised when two angled, horizontal x-ray beams are added

While combination beam systems were traditionally deemed to offer the best possible detection for glass jars, advancements in technology have since taken glass-in-glass inspection to a new level.

#### 7.2.1 Single, Perpendicular 'Downshooter' Beam for Glass Jars/Bottles – A New Angle on Product Safety

The latest technology incorporates a single, perpendicular beam that shoots down through the base area while simultaneously inspecting through the side of containers, providing all-round glass-in-glass inspection (Figure 10).

By opening up the base and lower body of glass jars, the crown now appears flat and traditional blind spots are removed, greatly increasing base detection sensitivity. The beam passes level with the shoulder and top area (below the complex threads and cap) of the container. This means a much less complex image, enhancing detection ability. This angle of inspection also provides exceptional full-height fill level checking, with high accuracy at high speeds. The position of the generator is vertically adjustable to suit a wide range of different container sizes.

Figure 10: Latest technology removes traditional blind spots, providing all-round glass inspection

X-ray systems with this technology offer unprecedented inspection of a wide-ranging portfolio of food, beverage and pharmaceutical products and their containers, as well as a full spectrum of viscosities. In addition to detecting 3mm of glass and 1.5mm of stainless steel, they also provide unsurpassed fill level accuracy.

Problems with product spacing, associated with multiple beam systems, are also surmounted as the beam configuration allows containers to run touching, enabling very high throughputs.

A black crescent shape is created on the image where the x-ray beam must pass through the longest cross section of the container (and product). Sensitivity is reduced in this area, but can be optimised if an optional second x-ray beam images the container from the opposite angle.

## 8. Transport System Designs

A number of designs for transport systems are available. For optimal glass-in-glass inspection, the following features are recommended. Other options are available for different applications.

### 8.1 Shielding

Most x-ray systems use tunnel curtains that hang in the entry and exit apertures of the machine to shield x-ray dose to personnel. However, removal of curtains is customary on horizontal x-ray beam systems as they can provide a level of resistance to containers passing through. A simple solution to controlling emissions involves side-to-side transferring product by offsetting the x-ray system from the main production line so the direct line of sight to the primary x-ray beam is removed (Figure 11).

Figure 11: Offsetting the x-ray machine from the main production line removes the direct line of sight to the primary x-ray beam

Extended in-feed and out-feed tunnel guards also remove the need for curtains and enable jars to pass smoothly through the x-ray system, negating possible jams.

### 8.2 Belt Types

A number of factors must be considered when choosing a suitable belt material. A single, 'upshooter' x-ray beam system has one x-ray generator creating an x-ray beam that skims across the surface of the conveyor belt. However, on combination beam and 'downshooter' x-ray beam systems, the x-ray beam passes through the product and the belt.

As the belt absorbs a small amount of the x-ray and is part of the final captured image, its material must be low density and as thin as possible, yet still strong and durable. Specialist x-ray transparent modular belts are available, which are suitable for high-speed, highly-abrasive glass container lines. These offer robust conveying, smooth transfers and easy maintenance without any loss in detection capability.

### 8.3 Guide Rails

Guide rails should be fully adjustable for easy set up and have the minimum surface area required to guide containers well through the machine.

### 8.4 Product Transfer

Poor transfers on and off the x-ray conveyor can cause product jams and x-ray imaging issues.

For jar and bottle inspection on horizontal beam systems, an in-line transfer can be difficult as the containers are unstable and tend not to self transfer across dead plates. Unless special handling devices are used for in-line transfers, containers will fall over or lose pitching. A common method of transfer for these containers is a side-to-side transfer from the main conveyor line onto the x-ray conveyor line and back again.

## 8.5 Automatic Reject Systems

Poor design and ineffective reject systems are probably the weakest link in most detection systems and lead to foreign bodies not being effectively and reliably removed from the line.

A correctly specified machine should be foolproof and capable of rejecting all suspect containers under all circumstances, independent of the frequency of occurrence or the location of the foreign body inside the pack.

A number of different reject systems are available and the correct choice depends on a number of factors, such as the type of environment, belt speed and weight and size of the container.

### Side Punch/Pusher Rejects

As a punch, a side-mounted cylinder is normally used on high-speed, glass-in-glass inspection lines. Designed to punch containers off the line, this reject mechanism is favoured as it has a very short stroke, enabling it to quickly push the reject container before moving back out of the path of the next container on the line (Figure 12).

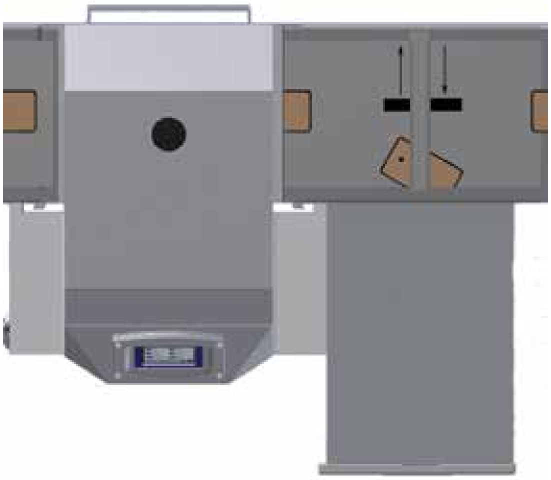


Figure 12: Rejected packs are punched off the production line

For very high-speed applications, other more advanced reject systems can be used. These smoothly divert containers at high speed onto parallel, enclosed reject conveyors. However, these are specialist applications and the x-ray system provider should be consulted at the design stage, as having the correct reject system is critical to a complete system solution.

## 8.6 Adaptive Filtering Technology

For products packaged in glass containers with dense edges, the high-absorption dark areas can be filtered out so that detection is optimised elsewhere in the image. Since container physical tolerances can vary, the use of fixed-width filters mean a thinner side wall may allow a foreign body to pass undetected, as it would be hidden in the filter. In addition, a thicker side wall will emerge outside the filter into the inspected area and cause a false reject.

Glass container thicknesses can vary by 20 percent. Dynamic filtering overcomes this issue by changing to suit the profile of each and every single container, optimising sensitivity and minimising false rejects.

## 8.7 Product Handling

With inspection perpendicular to the direction of product flow, the latest technology means glass jars and bottles can run touching, negating the need for scrolls, tilting or rotating. For traditional multiple, horizontal beam systems, scrolls or star-wheels will be needed to ensure the correct gap is created between packs.

## 9. Product Testing Procedures

Testing the performance of x-ray inspection equipment is an essential part of any well-designed quality management system in the food or pharmaceutical industry. To guarantee accurate and reproducible results when using test samples, the density of the glass sample should be known and compared to the density of the container glass being used on the production line.

Problems may arise if a high-density glass sample is used for testing, but the actual jars and bottles used in the production line (and which are likely to be the main source of glass contamination) are made from lower-density glass. In this case, the glass test piece would be detected, but not the container glass, giving a false and unreliable result. Good practice is to use soda-lime glass as it is the most prevalent type of glass and as close as possible to domestic container glass.

Designed specifically for use with x-ray systems, test samples provide the means of ensuring performance standards are being met and are available in a variety of sizes and carriers. Test pens (Figure 13) are ideal for testing liquids, slurries and semi-solids and can also be used in verification procedures to confirm compliance with ISO certification requirements, country specific retailer codes of practice, HACCP and GMP standards.


Figure 13: Test pens

**Testing Glass Jar/Bottle Inspection Systems**

There are various regions of glass containers that could contain foreign bodies and detection of glass in these locations needs to be verified. Figure 14 shows the five locations in a jar where detection has traditionally proved most challenging. Although in theory a test sample should be placed in each area, in practice it is not feasible to make up such complex test jars. It is recommended therefore that producers and packers of products in glass containers primarily check in the corner of the base and on the side walls in the body area.

A number of test sample containers should be produced, each containing glass at a different location within the jar. These should then be fed into the production line to verify the system is detecting and rejecting foreign bodies to the agreed specifications. The test procedure should be repeated at specified time intervals during production, typically every 30 or 60 minutes.

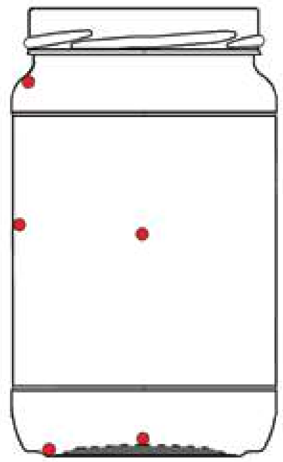


Figure 14: Five locations in a glass jar where detection has traditionally proved most challenging

**10. Conclusion**

Glass packaging is rising in popularity. The risk of glass-in-glass contamination and its highly-damaging effects, combined with increasingly stringent safety regulations worldwide, mean it is more important than ever for manufacturers to have x-ray systems that offer the most sensitive product inspection.

The base of glass jars has traditionally presented a challenge for x-ray inspection systems. However, innovations in technology mean systems are now available offering all-round inspection of a wide-ranging portfolio of food, beverage and pharmaceutical products and their containers.

Choosing the right system is fundamental. X-ray inspection equipment cannot solve contamination or production problems unless each element from beam angle to reject mechanism has been chosen to fit the line and product.

An understanding of factors that affect detection sensitivity, in addition to the various formats and their suitability for different types of detection challenges, is crucial to allow manufacturers to specify a system that provides the best detection in order to stay ahead in the most challenging food and pharmaceutical industries.

## 11. Glossary

### Sources

US Food and Drug Administration (FDA)
www.fda.gov

British Glass Manufacturers' Confederation
www.britglass.org.uk

Glass Packaging Institute www.gpi.org

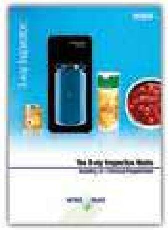
Food Standards Agency www.food.gov.uk



Notes

# Further Information about X-ray Inspection

## Free Technical Guide
Make an informed decision



METTLER TOLEDO has published an authoritative product inspection guide for x-ray inspection systems.

The 73 page guide enables you to select the right x-ray inspection system for your production line. It supports you to install an all-encompassing product inspection programme and to achieve compliance with standards, regulations and legislation.

Register today for your **Free** copy: **www.mt.com/xray-guide**

## Free White Papers
Browse our constantly growing White Paper library to learn more about x-ray inspection.

### How Safe is X-ray Inspection of Food?
Some of the most popular misconceptions about x-ray inspection of food are tackled in this White Paper. It is an indispensable white paper for food manufacturers who consider x-ray inspection to comply with food-safety regulations and legislations.

### How to Select Crital Control Points For X-ray Systems
This white paper helps food and pharmaceutical manufacturers improve product safety by choosing the most effective locations for x-ray inspection systems on their production line. X-ray inspection systems can be used at different points on the production line to detect physical contaminants, ensuring product safety.

To see all available White Papers and download your **Free** copy:
**www.mt.com/xray-whitepapers**

## On-Demand X-ray Webinars 24/7
Our on-demand webinars give you the opportunity to learn more about x-ray inspection. View our library of webinars at your own convenience.


### X-ray - More Than Just Contamination Detection
Find out more about the features of an x-ray inspection system and how it can help to protect your customers and ensures your product's quality.

For more information visit our x-ray inspection download library: **www.mt.com/xray-library**

**www.mt.com/xray-glass**
For more information

MIX
Paper from responsible sources
FSC® C019301

**Mettler Toledo Ltd**
64 Boston Road
Beaumont Leys
LE4 1AW
Leicester
Tel. 0870 066 3150
Fax. 0116 236 6399
Email: pi.mtuk@mt.com