White Paper

SAFELINE
X-ray Inspection

X-ray Inspection

More Than Just Contamination Detection

Contents

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What Can X-ray Inspection do for Quality Control?

Since the early 1990s, the food and pharmaceutical industries have relied on x-ray technology to detect potentially harmful contaminants, such as glass and metal, to protect consumers, and maintain brand reputations.

But can x-ray inspection do more? Could x-ray technology be a multi-tasking defender of product safety and brand quality?

This white paper looks at the potential of x-ray inspection to solve a wide range of product safety and quality control issues typically found within food and pharmaceutical manufacturing. It explores how x-ray inspection can detect faulty products before they leave the factory, avoiding product recalls and customer disappointment. It describes how in a single pass – and at high line speeds – x-ray systems can perform several inspection tasks simultaneously.

1. Why Use X-rays to Inspect Products?

Food and pharmaceutical manufacturers use x-ray inspection technology to ensure product safety and quality. X-ray inspection gives them exceptional levels of detection for stainless steel and ferrous and non-ferrous metals. The technology is also extremely good at detecting other foreign bodies such as glass, stone, bone, high density plastics, and rubber compounds. X-ray systems can, however, simultaneously perform a wide range of other in-line quality checks, such as measuring mass, counting components, identifying missing or broken products, monitoring fill levels, inspecting seal integrity, and checking for damaged product and packaging.

Increasing line speeds and consumer expectations have put pressure on manufacturers to adopt more reliable methods of product inspection. Although there are no legal requirements to use x-ray inspection, guidelines such as Hazard Analysis Critical Control Points (HACCP), the Global Food Safety Initiative, and Good Manufacturing Practice, as well as ad hoc standards set by individual retailers put the onus on manufacturers to establish reliable product inspection programmes.

Incorporating x-ray inspection systems into a company-wide product inspection programme to ensure product safety and quality helps manufacturers comply with national and international regulations, local legislation, and standards set by retailers.

2. How Does X-ray Inspection Work?

X-rays are invisible. Like light or radio waves, they're a form of electromagnetic radiation. Because their wavelength is short, x-rays can pass through materials that are opaque to visible light. But they don't pass through all materials with the same ease. The transparency of a material to x-rays is broadly related to its density, which is why x-ray inspection is so useful in the food, beverage and pharmaceutical industries. The denser the material, the fewer x-rays that

pass through. Hidden contaminants, like glass and metal, show up under x-ray inspection because they absorb more x-rays than the surrounding product.

An x-ray system is essentially a scanning device. When a product passes through the unit, it captures a grey-scale image of the it (Figure 1).

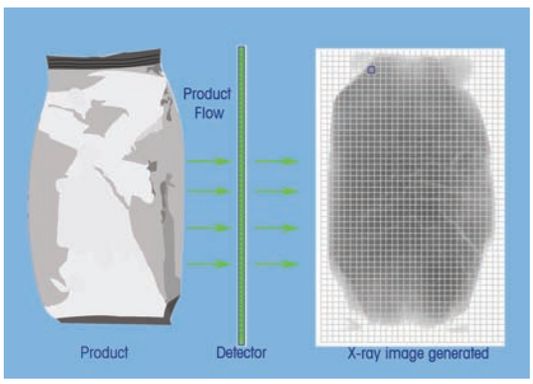

Figure 1: Creating an x-ray image

The software within the x-ray system analyses the grey-scale image and compares it to a predetermined acceptance standard. On the basis of the comparison, it accepts or rejects the image. In the case of a rejection, the software sends a signal to an automatic reject system which removes the product from the production line.*

3. X-ray Inspection Sees What You Can't See

By exploiting simple density differences and analysing the resulting grey-scale x-ray images, x-ray inspection equipment has moved beyond product safety into other areas of quality control.

One X-ray System – Many Quality Control Functions

Modern x-ray systems are multi-tasking defenders of product and brand quality, as well as detectors of contaminants. In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously, including:

- measuring product length, width, area, and volume
- identifying missing or broken products
- monitoring fill level
- measuring mass
- inspecting for compromised seals

…while still catching contaminants.

3.1 Measurement of Product Length, Width, Area, and Volume

Measurement of the length, width, area, and volume of a product is the simplest form of product inspection used in conjunction with contamination detection. The process is known as 'object finder'.

As previously explained, an x-ray image is a grey-scale image. The darker the grey, the more product is in the path of the x-ray beam. By converting those grey tones into a 3D image, the software can calculate, for example, the area of the product.

This type of image analysis takes quality control to a new level of sophistication. It identifies products that don't look right, even if they're the correct weight, in the correct position, and free of contaminants. It's hugely useful for manufacturers of products that depend on visual appeal. For example, one of the three meat patties shown in figure 2 has a hole in it. It shows up as a light patch amid the uniform grey.

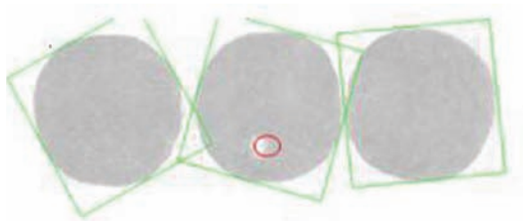

Figure 2: Void in patty 5mm

One of the three patties shown in figure 3 is misshapen.

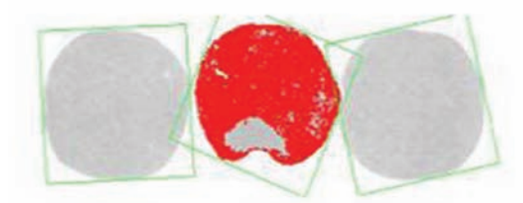

Figure 3: Malformed patty +/- 5%

The two flow-wrapped garlic baguettes (Figure 4) take the process further still. The quality control issue here is the potential underfilling of garlic butter in each slot because the butter injection machine could block up or run out of butter. Since the x-ray system can see the individual blobs of butter, it can analyse each

*More information how x-ray inspection works can be found under www.mt.com/xray-guide

zone separately. It checks that the surface area or volume in each zone meets a preset standard. If it doesn't the product will be rejected from the line.

Figure 4: Shows two garlic baguettes with one low-fill

3.2 Identification of Missing or Broken Items

X-ray inspection will also detect faulty and missing products.

Examples are:

1. **Detection of damaged products**
- Crushed, missing, and partial tablets in a blister pack
- Dented, squashed, or deformed packaging
- Checking that box contents are intact and unbroken

2. **Detection of missing products**
- Counting components to check they're all there
- Checking that the locking lever of an asthma inhaler is in place

3. **Insert inspection**
- Identification of missing components such as lids and instruction leaflets
- Checking for the presence of promotional giveaways

These inspection routines are just as effective when a product is packed in multiple layers, such as blister packs.

3.2.1 Detection of Damaged Products

The detection of damaged products relies on the same principles as length and volume measurement. By setting minimum and maximum sizes for pack width, height, volume or surface area, x-ray analysis software can spot a deformed pack. In figure 5, a check for surface area was enough to catch deformed cartons and reject them from the production line. The x-ray software assigned a surface area value of 100 for good packs, and rejected any that fell below 90.

Figure 5: X-ray image of a squashed soup pack

3.2.2 Detection of Missing Products

X-ray systems can look inside the final sealed packaging to check that all components are present. It can count products and components that cannot be seen or counted by cameras or human eyesight. For example, it can count needles and syringes in a box, check for the locking lever in an asthma inhaler, count cheese cubes in a tray, or pralines in a gift box.

Spotting the missing sausage in figure 6 was easy. The software found five dark zones in the grey-scale x-ray image when it was programmed to expect six.

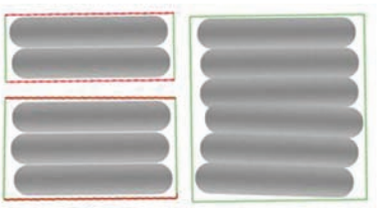

Figure 6: Detected of missing sausage

Spotting the presence of caps or lids could be done by human eye, but the process is far faster and far more reliable with x-ray technology. If the cap is missing the cap area appears brighter and the product will be rejected from the production line (Figure 7).

Figure 7: Detection of missing cap

3.2.3 Insert Inspection

If x-ray inspection can identify objects that shouldn't be in a pack, it can also find ones that should be there, such as leaflets and promotional gifts.

Figure 8 shows boxes of contact lenses which, according to industry regulations, must include handling guidelines and product information. By checking that the leaflet is in place, x-ray inspection verifies compliance.

Figure 8: Leaflet inspection

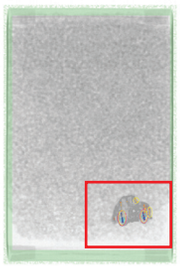

Figure 9: Checking for the presence of giveaways

Figure 9 is an x-ray image of a cereal carton containing a promotional giveaway – a toy. If the software can find the toy, it's a good pack. At the same time x-ray inspection can inspect for contaminants. By eliminating the toy from the image, the x-ray system can check the rest of the pack. It's a simultaneous process in which the promotional giveaway doesn't interfere with contamination detection.

Another example comes from the meat packing industry. Many meat-based products contain oxidisers (known as 'scavengers') to help keep the product fresh. Oxidisers can be quite dense, which could reduce the effectiveness of contamination detection. Figure 10 show how, in a packet of cooked ham, the x-ray system not only checks that the oxidiser is present, but also removes it from the x-ray image for optimum contamination detection.

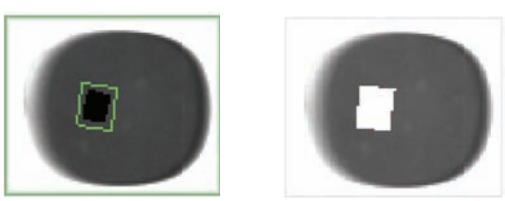

Figure 10: X-ray's check if the oxidiser in ham is present

3.3 Measuring Mass and Monitoring Fill Levels

Maintaining the correct mass and fill levels of a product is a constant challenge in food and pharmaceutical manufacturing. Measuring overfills and underfills has an effect on manufacturing costs as well as consumer satisfaction.

X-ray inspection can analyse:

- the overall mass of a product
- the individual masses within various zones or compartments of a product
- the overall fill level of a product
- the individual fill levels within various zones or compartments of a product

3.3.1 Overall Mass Measurement

As explained under point 3.1 an x-ray image shows up as varying tones of grey. By converting those grey tones into a 3D image, the x-ray software can calculate how much product is in the pack. This 3D volumetric check is also used for mass measurement.

The x-ray system has an auto-learn facility whereby an acceptable weight pack (close to the nominal weight) is passed through the x-ray system, typically 10 times. The gross weight of the pack is then entered into the system (The user must have previously weighed this pack on a set of calibrated static scales offering a suitable weight range and accuracy.). That way the analytical software can calculate the weight of subsequent packs by comparison to the weight of its learned reference pack. The x-ray inspection system can now compare all future products against its ideal reference product. If the calculated mass falls within a programmed tolerance, the package is good. If it deviates, the package will be rejected.

Figure 11 shows a box containing six foil-wrapped cereal bars packed in two layers. The middle cereal bar is missing from the upper layer, which is why another cereal bar has moved out of place. It shows as shadows outside the normal range on the grey-scale x-ray image, hence the product will be rejected.

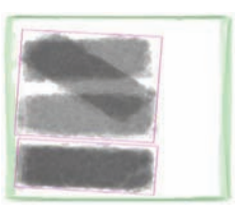

Figure 11: Pack of cereal bars with one missing

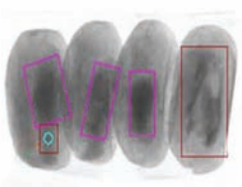

Figure 12: Pack of doughnuts with one low-fill and one contaminated

The quantity of jam inside a doughnut is another example of how x-ray inspection can be used to exert better quality control. From the outside, a doughnut with too much or too little jam in the centre looks perfect. No one knows till they take a bite. Too much jam increases production costs. Too little jam leads to disappointment. With x-ray inspection, every doughnut can be checked, even when the line runs at 600 doughnuts a minute. The x-ray inspection software examines each grey-scale x-ray image. From the overall level of blackness, it calculates the mass of jam inside the doughnut. If the mass meets the preset standard, the doughnut passes the test. If it fails, it's rejected from the line and the manufacturer can adjust filling equipment to maintain the standard (Figure 12).

The relationship between mass and total product x-ray absorption is not a straight line. Using a single product auto-learn feature is quite accurate when production pack weights are near the target weight. More sophisticated systems use a three product auto-learn process: the low rejection point, the target weight, and the high rejection point. This method allows calculation of the mass from variations in x-ray absorption within a narrower range. It provides greater accuracy than that offered by the normal production weight range.

Accuracy of mass measurement is good on homogeneous packs (e.g. a block of butter), but less good on loose packed products (e.g. sausages in a bag, or products for which ingredients can vary between batches). X-ray mass measurement is particularly effective for high-speed applications where traditional in-line weighing systems may not offer the same level of accuracy. It lets manufacturers comply with minimum weight, EU average weight, or US zoned weight regulations. In every case, the system produces relevant statistics on rejects.

Mass measurement does not offer a global solution to weights and measures compliance. Some countries expect R51 type approval, which only applies to gravitational weighing systems.

3.3.2 Zoned Mass Measurement

For products that are presented in defined compartments, such as a box of chocolates or a two-compartment ready meal, mass measurement can provide results for each individual zone/compartment. It lets manufacturers check the overall mass of a product and the masses within each compartment.

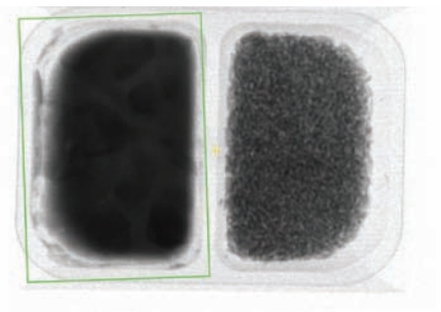

Figure 13: Twin compartment ready meal

Figure 13 shows a twin compartment ready-meal (TV dinner). The x-ray software is simultaneously checking the overall mass of the pack and that of each compartment. In this case the overall weight is right, but there is low fill in the rice compartment, so the pack is rejected.

3.3.3 Overall Fill-Level Inspection

Fill-level inspection is different to mass measurement. It's a 2D process based on a simple inspection process: you set maximum and minimum fill levels and reject any product that falls outside them. It doesn't matter what the product is made of, or the mass of it. It simply has to reach a certain height within the pack or container. Fill level becomes a simple 2D image check instead of the 3D volumetric check required for mass measurement.

The tube of crisps in figure 14 is an example of fill-level check. As you can see, the stack of crisps has collapsed on its side and some crisps are broken. By checking the height of the stack, x-ray analysis can tell that the fill level has dropped below an acceptable standard, and reject the pack.

Figure 14: Composite tube of crisps stacked

Figure 15: Yoghurt pot with low fill level

You could also add an optional feedback to the filling machine to adjust the fill level. This is especially relevant for fluid products like yoghurt drinks or loose / powder products like milk powder (Figure 15).

3.3.4 Zoned Fill-Level Inspection

X-ray inspection is as good at checking zoned fill-levels as it is at checking zoned mass measurements. An underfill in one pot of, say, a yoghurt multipack could potentially be compensated by an overfill in another pot.

Another example could be the fill level inspection of each pot in a six-pack of yoghurts. X-ray inspection will examine the fill level in each pot. If any one of them is underfilled, the entire pack would be rejected (Figure 16).

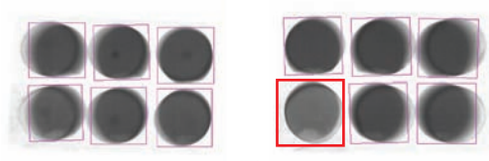

Figure 16: Twin lane inspection of six-pack yoghurts with one low fill

3.4 Product-in-Seal Inspection

The integrity of airtight seals is a vital quality control issue for manufacturers of sealed food and pharmaceutical packs. The safety and sterility of pharmaceutical products and freshness of food products depends on the seals, yet they're easily compromised by stray particles of product, contaminants, or misplaced products. Anything trapped within the seals could mean that the pack is no longer airtight. The seal inspection x-ray tool can identify particles as small as 1mm caught in the seal areas.

Figure 17: Pack of chocolates with particles trapped in seal

On low-density packaging, a special ultra-high contrast detector system can simultaneously check for contaminants and seal integrity. Figure 17 shows the x-ray image of a sealed pack of chocolate. The system checks for the presence of dense material between the inner and outer edges of the seal. If it detects material in this area, it rejects the product.

An example from the pharmaceutical industry is the inspection of surgical wound dressings (Figure 18). Here, the analytical software is checking that no wound dressings are trapped within the seal, thereby compromising pack sterility.

Figure 18: Wound dressing trapped within the seal

4. Conclusion: No Shocks or Surprises – X-ray Inspection Enforces Brand Values

X-ray inspection equipment gives manufacturers the tools to maintain quality control and product integrity at every stage of production for raw, bulk, pumped, and packaged products.

By setting appropriate parameters and fine-tuning the sensitivity, manufacturers can investigate numerous quality issues from catching contaminants to checking that a product looks exactly as a customer expects it to look. The product that successfully passes x-ray inspection contains no shocks, surprises, or disappointments. The manufacturer knows that it fulfils its brand promise.

As the examples in this white paper have shown, modern x-ray systems are multi-tasking defenders of product and brand quality as well as detectors of contaminants. In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously. They can measure product mass, count components, check fill levels, identify faulty products, inspect seal quality, spot missing giveaways – and still catch contaminants.

In short, x-ray inspection is a highly effective tool for maintaining production costs and product integrity. Most of all, it's a tool for keeping customers happy – for checking that a product looks and performs exactly as they expect.

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 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 Paper
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.

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- **X-ray - More than just Contamination Detection**

There is more to x-ray inspection than just contamination detection. X-ray technology can simultaneously spot a wide range of product faults, ensuring product integrity.

- **Principles of X-ray Inspection**

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- **Building an Effective X-ray Inspection Programme**

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