DETECTABLE PRODUCTS & MATERIALS

A white paper explaining the safe & successful use of detectable products and materials in food production environments

ABSTRACT

Metal detection and x-ray inspection systems are used in food production to detect and reject a wide range of foreign body contaminants. Food manufacturers often experience contamination issues and issue recalls, costing large amounts of time, money and brand confidence. Plastics & rubber remain as some of the most problematic contaminants and this guide will explain how to successfully address such foreign body risks without falling for some of the most common mistakes and assumptions.

MEET THE AUTHORS

Will Anderson is a technical & product manager at BST Detectable Products and has worked for the company since graduating university in 2012. Will spends most of his time developing new detectable products, offering technical product support to customers and identifying opportunities to improve and promote existing products and materials.

Joseph Armstrong-Gore is a business development manager at BST Detectable Products and has worked for the company since 2015. Joe's background as a graduate manager in high street restaurants gives him a unique insight into food safety practices. Joe spends most of his time supporting new and existing customers and delivering bespoke detectable product solutions.

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Corporate Support

Joseph and Will have formed close working relationships with leading inspection systems manufacturers to further their own knowledge and to extensively test and research the performance of detectable products and materials. They couldn't have collected and analysed so much data without the technical expertise and equipment offered by **Pete Higgins** and **David Hale** at **Metal Detection Services Ltd** (*Official UK Distributor for CEIA Metal Detectors*), **Tina Leitner** at **Multicheck A/S** (*Official Denmark Distributor for CEIA Metal Detectors*) and **Peter Walker** at **Minebea Intec** (*Leading X-Ray Inspection System Manufacturer*).

Of course none of this research would have been possible without the support of **BST Detectable Products**, their Managing Director **John S Teasdale**, and John's father **Brian S Teasdale** who first invented the concept of detectable products.

Joseph Armstrong-Gore
BA (Hons)

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INTRODUCTION TO DETECTABLE PRODUCTS & MATERIALS

Detectable products exist to address a very specific problem, commonly referred to as 'foreign body contamination'. The term foreign body refers to any extraneous material that finds its way into food or drink. Examples can include human hair, broken glass, paper and plastic. Detectable products and materials primarily address contamination risks posed by plastics and rubber.

Foreign body contamination in processed food represents a major risk to consumer health, damages brand integrity, and can also result in fines and punitive action against manufacturers. The scale of the problem is illustrated by '*figure a*', which outlines some major plastic and rubber contamination incidents in the first four months of 2017.

Figure a

Company	Location & Date	Product	Incident	Information Source
Schreiber Processing Corp	NYC, USA 9th January 2017	Chicken Tender	Recalled 2330 lbs of chicken tender products due to potential plastic contamination and misbranding.	US Department of Agriculture (USDA)
Thorntons	Derbyshire, UK 19th January 2017	Hollow Milk Chocolate Jolly Santa	Recalled all batches of hollow milk chocolate Santa's due to a plastic foreign body risk.	UK Food Standards Agency (FSA)
Waitrose	Berkshire, UK 25th January 2017	Hearty Minestrone Soup	Recalled all batches of hearty minestrone soup due to contamination from blue plastic pieces.	UK Food Standards Agency (FSA)
Douglas Willis	Wales, UK 22nd March 2017	Sausages & Burgers	Recalled as a precautionary measure due to potential contamination from small pieces of hard plastic.	UK Food Standards Agency (FSA)
H-E-B and Hill Country Fare	Texas, USA 20th April 2017	Sandwich Bread	Recalled as a precautionary measure due to the possible presence of a single rubber contaminant.	US Food & Drug Administration (FDA)
Foster Poultry Farms	Los Angeles, USA 27th April 2017	Frozen ready to eat chicken patty	Recalled approximately 131'880 pounds of frozen, ready-to-eat bready chicken patty products contaminated with foreign materials, specifically plastic.	US Department of Agriculture (USDA)

Because foreign body contamination covers such a large variety of materials – different measures have to be taken to address different contaminant types. (For example hair nets to reduce human hair contamination and magnetic filtration to remove ferromagnetic particles). Analysis of food safety risks can be done through an approach called HACCP (Hazard Analysis & Critical Control Points). This approach is applicable to biological, chemical, and physical contamination.

Critical control points commonly implemented into automated processes to combat physical, or 'foreign body' contaminants are metal detection and x-ray inspection systems. Used independently or together, such systems reduce the risk of metallic and physical contamination to levels deemed to be acceptable.

Plastic and rubber contaminants are disproportionally abundant when compared to other physical contaminants because they do not under normal circumstances exhibit electrically conductive, magnetic or high density properties needed to trigger a rejection through either metal detection or x-ray inspection systems. They are also very common materials in machinery and food processing equipment, as such they are at an increased risk of becoming foreign bodies. This is where the use of detectable plastic and rubber materials becomes more relevant, particularly as food manufacturers are under regulatory and moral obligation to display due diligence and take clear measures to minimise foreign body risks.

In short, a detectable product can be defined as any item that is modified to be easily identifiable by either a metal detector or x-ray product inspection system. The objective of this white paper is to explain how the technology works and how to successfully approach, consider and implement detectable products and materials into a food production environment.

The justification of this white paper is that detectable products and materials are becoming increasingly used throughout the food and beverage industry - but misinformation, inaccurate marketing and a lack of technical understanding by some is resulting in bad practice being observed.

The consequences of failing to prevent foreign body contamination

It could be said that the consequences of failure are better known than the cause. A common estimate is that the direct costs of a food recall to a manufacturer is around $10 Million / £7.7 Million. This estimate does not include the additional impacts of lost sales, damaged brand confidence and any drop in share price.

As with so many aspects of food production, the prevention is better than the cure. Good preventative maintenance, a duly diligent approach to food safety and a keen eye for risk management all save the company money in the long term, keep consumers safe and protect the company's reputation.

Despite huge developments in detectable materials and inspection technology foreign bodies remain the 5th most common cause of incidents recorded by the UK Food Standards Agency. According to the FSA 2015 annual report of incidents, foreign bodies still account for 5% of all incidents after pathogenic, allergenic, chemical and residual medicinal contamination.

Detectapens® are commonly used in food and pharmaceutical production environments to reduce foreign body contamination risks
Image © BST Detectable Products

A GUIDE TO INSPECTION SYSTEMS

In this section the basic principles of inspection systems commonly used by food manufacturers as part of HACCP will be outlined. The design of the inspection system in use will vary due to the differing needs of food manufacturers, however the basic principles of metal detection and x-ray inspection remain the same. The aim of this section is to give a basic understanding of how each system operates so that a greater understanding of using detectable products can be gained.

Food manufacturers will also use rejection systems alongside their choice of inspection system. Rejection systems work in various ways to discard a product from the line or process when a rejection has been triggered. The type used will vary by the product being manufactured. Large retail customers are likely to stipulate controls around rejection systems in order to have accountability for the checking of any products that have been rejected.

Metal Detection Systems

The most commonly used metal detection systems that are in use by food manufacturers operate on a principle known as the “balanced coil” system.

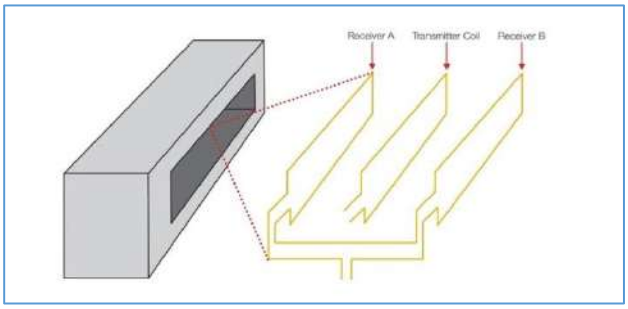


Figure b - A balanced coil metal detector head.
Image© BST Detectable Products

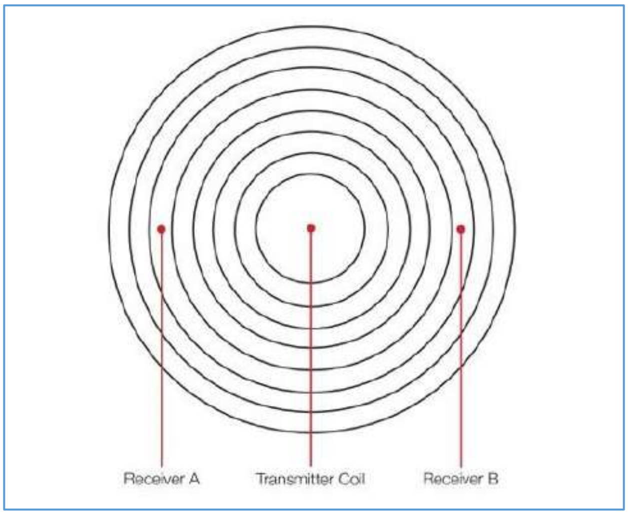


Figure c - A balanced coil magnetic field.
Image© BST Detectable Products

They operate by using three equally spaced coils which surround the opening (Aperture) through which products that are tested pass through. The centre coil is connected to an oscillator circuit which produces a magnetic field.

The two equally spaced receiving coils on either side of the centre coil receive an equal amount of this signal. (Figure b).

The net signal across the receiver coils is zero as the coils are wound in a way that opposes each other. When a contaminant passes through the aperture it changes the balance of the coils and the net signal is no longer zero. If the contaminant changes the balance across the receivers enough this will trigger a rejection. An illustration of the magnetic field around the coils is shown in figure c.

The weakest part of a metal detector is the geometric centre of the aperture and it is here where detection is at its most difficult. If at all possible it is at this point where contaminants should be tested when testing and calibrating the detector. (In order to give worst case results).

There are three main groups of metallic contaminants that can be picked up by a metal detector. Ferrous, non-ferrous and stainless steel.

Ferrous contaminants are the easiest to detect as they are electrically conductive and magnetic. Non-ferrous contaminants are not magnetic, however they offer good conductivity. The most difficult to detect are stainless steel contaminants as they tend to be non-magnetic and possess poor conductivity, meaning that metal detectors are able to reject a smaller size of ferrous material than that of stainless steel.

When sensitivity is discussed this refers to the smallest piece of contaminant that can be detected by the detector when set for a specific product to pass through, usually tested with a calibrated test piece containing a sphere of contaminant measured in millimetres. I.e. you may use a ferrous test piece which contains a 3mm size of contaminant sphere.

Metal detector sensitivity is dependant of varying factors which include:

1. Aperture size (The smaller the aperture, the more sensitive the detector)
2. Position of contaminant in the aperture
3. Type of contaminant
4. Contaminant size
5. Shape and orientation of the contaminant
6. Frequency of metal detector
7. Product being inspected
8. Line speed
9. Electrical interference
10. Temperature variation
11. Type of packaging in use – i.e. packaging with recycled content

It is important to work towards the lowest possible contaminant size, as even a small increase in diameter leads to a large increase in volume (due to the volume of a sphere). Increasing the sensitivity may also lead to an increase in false rejections, meaning that it is important to calibrate the machine professionally for each food product in order to achieve detection of the lowest possible contaminant size and reduce the risk of contamination as much as possible.

The newest multi-spectrum metal detectors can achieve very high levels of sensitivity and if an aged system is in use then it may be beneficial to consider upgrading to a new system, especially if the requirements of the manufacturer have changed since introducing the existing system. Regular service and testing of any detection system in use should be in place and documented by a professional in order to maintain the level of detection required. New metal detection systems are more sophisticated and more capable than ever at the detection of smaller contaminants, something which also aids in the detection of smaller sizes of detectable products materials.

In order to detect non-metallic foreign body contaminants such as stone, bone, glass and ceramics an x-ray inspection system is required which will be explained in the next section.

The BST Detectapen® (made from XDETECT®) is both metal detectable & x-ray visible.
Image © BST Detectable Products

X-ray Inspection Systems

An x-ray inspection system consists of three components – a computer, detection array and x-ray generator. It works by passing low energy x-rays (gamma radiation) through the product, which then passes through the detection array. Each product can absorb varying levels of x-ray energy including the foreign body (if any) within the product. The differences between the amount of energy absorbed by the product and the contaminant is then calculated and analysed by the computer. (As illustrated in figure d)

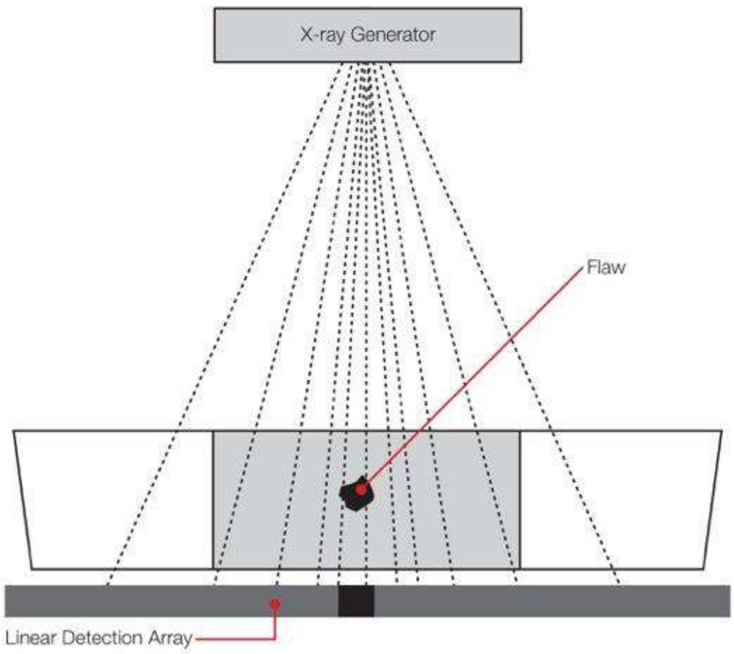


Figure d - A simplistic overview of an x-ray inspection system.
Image© BST Detectable Products

Through a calibration sequence the inspection system will have learnt the profile of the product which is passing through, meaning that it knows what a good product looks like and has been set up to know the different variations that may occur in a product with no contamination. If the system detects that there is contamination that falls outside of this good picture that the system has built then it will trigger an alarm and activate the rejection system. X-ray systems can also capture and store an image (radiograph) of where the contaminant has been found so that it can be easily investigated.

There are only specific foreign bodies that can be detected by an x-ray system. Most food items have densities similar to water (specific gravity of 1.0). Items that are less dense than water (or below 1.0) are generally difficult to detect. Whilst an x-ray system can detect ferrous, non-ferrous and stainless steel contaminants they can also detect stone, bone, glass and ceramics as these are typically a higher, contrasting density to most food products.

X-ray inspection systems may have trouble in detecting the below:

- Fruit stones
- Insects
- Low-density plastics
- Stalks
- String
- Wood

As with metal detection there are varying factors which affect the sensitivity of the inspection system:

- **Inconsistency of product**
  (It is harder to look for changes in something that varies in appearance)
- **Relative density of contaminant**
  (If a contaminant is of the same density as the food then it's invisible to the computer)
- **Aluminium**
  (The low density of aluminium makes it difficult to detect with x-ray)

The inconsistency of product that a product may have, i.e. a very loose dry product with varied ingredients that is likely to be different each time it passes through the inspection system. Though contaminants will still be found in products such as this, there is a less potential for detection due to the changes in product being accounted for by the systems calibration.

If the product being inspected is dense, then the relative density of potential contaminants needs to be considered further. For example red meat is a dense product. If the meat was contaminated with something less dense it is extremely unlikely to trigger a rejection as it will have been masked by the density of the meat. Food manufacturers whose product is of a high density should take extra precaution when introducing new materials to their environment.

As well as detecting foreign body contamination a modern x-ray inspection system can also measure a product's dimensions (length, width, height, area, volume) and weight. An x-ray inspection system is also able to detect missing or broken parts and damaged packaging. They may also be used to monitor fill levels and count product within packaging.

XDETECT® Tie ID Tags are used for colour co-ordination and are dual detectable, food grade and shatter resistant.
Image© BST Detectable Products

APPLICATION OF DETECTABLE PRODUCTS & MATERIALS

Through HACCP analysis, audit, incident or by accident - you may become aware of an item that represents a foreign body contamination risk. If that item is essential to your process and it is not possible to remove or otherwise make the item more secure - it should be a considered whether that item can be made from detectable materials.

There may already be a detectable product available to suit your needs, or a new type of detectable product may be required - in either case it's important to be aware that not all detectable materials are the same.

What works with one metal detector may not work with another, what works with a metal detector doesn't necessarily work with an x-ray inspection system, and most of all making an item detectable doesn't automatically make it safer to use.

A common plastic style pen would represent a significant foreign body risk in a food production environment

These assumptions are covered in a later chapter, but here we will explain the differences between the types of detectable products, how they work, and also in some cases how they don't work!

Detectable products and materials can be broken down into four key types:

1. Metal Detectable
2. Part Metal Detectable
3. X-Ray Visible
4. Dual Detectable

The type required will depend on the inspection system being used and the product in question. Here we will explain each type of product in turn, starting with the original metal detectable products.

Metal Detectable Products

The first detectable products were used in food production in the late 1980's and featured iron filings embedded within or stuck to high risk items, in order to trigger the end of line metal detector should they inadvertently be introduced to the food product.

Metal detectable plastics typically exhibit paramagnetic properties. Image © Hellermann Tyton

This basic approach in today's age is much more scientific, refined, regulated, and researched. The ferromagnetic additives used have an ultra-fine particle size and carry full FDA and EU food safety approvals. Their dispersion in carrier polymers and rubbers should be homogeneous and at a level that does not compromise the mechanical integrity of the material.

A product manufactured in this way is the most common approach for plastic and rubber articles. The ferromagnetic content within the material triggers a metal detector rejection in exactly the same way as a standard metallic contaminant, i.e. by distributing the balanced magnetic field of the metal detector. Because detectable materials only contain a small percentage of metal content - they do not trigger a metal detector as easily as fully metallic contaminant.

Current technology means that in most food production settings, detectable plastic and rubber fragments around the size of a 10mmØ sphere can be reliably detected by metal detectors, subject to correct calibration. This compares to around a 1mmØ sphere for a pure ferrous contaminant.

In specific environments such as nutraceutical manufacturing, smaller metal detector apertures can achieve very high ferrous sensitivity levels meaning that individual detectable plastic brush bristles of 0.6mm width can be reliably detected.

Batch identification tags, self-adhesive labels, self-adhesive tapes, mob caps, beard snoods, overshoes, oversleeves and plasters are all examples of items that can feature aluminium foil to provide metal detectable properties. This approach is cost effective and offers outstanding performance on most types of industrial metal detector.

Food processors should be aware that detectable products featuring aluminium foil for detectability will not perform well when used with a metal detector inspecting food with aluminium packaging. This affects prepared meals in foil trays and aluminium canned foods, as the signature of the packaging makes small aluminium contaminants invisible to the metal detector. (An extreme example of product effect).

BRC Global Standards for Food Safety issue 7 states that: "7.2.3; All cuts and grazes on exposed skin shall be covered by an appropriately coloured plaster that is different from the product colour (preferably blue) and contains a metal detectable strip. These shall be site issued and monitored. Where appropriate, in addition to the plaster, a glove shall be worn. 7.2.4; where metal detection equipment is used, a sample from each batch of plasters shall be successfully tested through the equipment and records shall be kept."

Part Metal Detectable Products

It is not always possible or practical to make the entire composition of an item metal detectable. Examples include woven polypropylene mesh hair and beard nets which contain steel clasps to provide metal detectable properties. By being part metal detectable the foreign body contamination risk is significantly reduced, however food manufacturers should be conscious of the fact that if the item is fragmented through a process such as cutting, blending or mixing, then non-detectable fragments will remain. This should be documented as part of risk assessment.

X-Ray Visible Products

As explained in the earlier chapter on inspection systems, x-ray inspection works in a completely different way to metal detection. As such, products and materials require completely different modifications to become x-ray visible. It is a common mistake to assume that a metal detectable product is also x-ray visible.

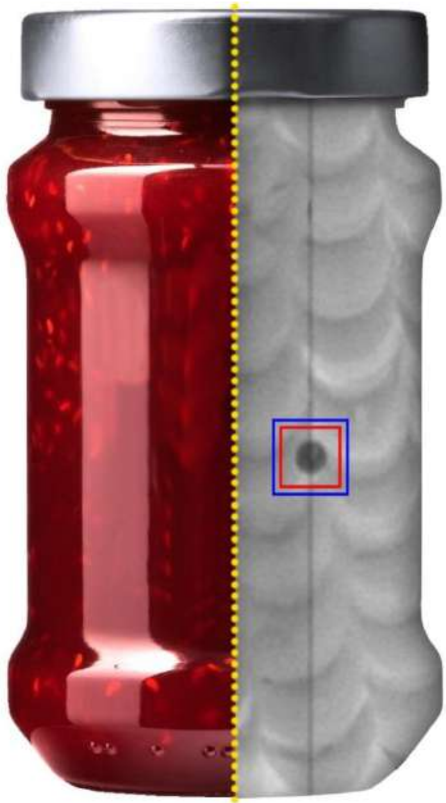
Ferromagnetic additives are used to make a plastic or rubber detectable for the purpose of metal detectability, but food safe ultra-dense additives (with a high atomic number) must be used to achieve good x-ray contrast performance. When these additives are introduced to polymers at the correct ratios, x-ray inspection systems can detect fragments as small as 3mmØ.

The density of a material can be compared using 'specific gravity', which is the ratio of the mass of a substance against the mass of a reference substance for the same given volume. Specific gravity is noted as grams per cubic centimetre. For example water has a specific gravity of 1.00g / cm^3, which is often used as a fixed point of comparison. Any solid material with a SG of <1.0 will float in water and anything of 1.0+ will sink.

Polypropylene has a specific gravity of 0.95g cm^3, wood around 0.60g / cm^3 and steel 7.50g / cm^3.

Whilst it is true that ferromagnetic additives alone do increase the specific gravity of a base polymer, they do not always do so sufficiently to achieve reliable x-ray visibility. Not all manufacturers of detectable products correctly distinguish between metal detectable and x-ray visible materials which further fuels the industry wide confusion.

At BST we only classify a product as x-ray visible if it is constructed entirely from metal or a polymer that specifically contains high density additives to enhance x-ray contrast.



High density additives are essential for optimum x-ray contrast. Image © BST Detectable Products
**Illustration purposes only*

Dual Detectable Products

In 2009 BST were the world's first company to develop a high performance dual detectable polymer. This is a plastic compound that contains the appropriate levels of *both* ferromagnetic and high density additives to trigger metal detection and x-ray inspection systems, whilst still functioning as a high performance polymer.

Dual detectable products represent a huge step forward in food safety as they are safe to be used in factories that may use metal detection on one product line and x-ray inspection on another.

Food manufacturers should exercise caution when sourcing detectable products, as the term detectable is used loosely and can mean different things from different manufacturers. If you think you are buying a dual detectable product then be sure to ask the manufacturer if the product in question specifically contains high density additives for x-ray visibility.

Particularly when sourcing overseas, the term detectable can often just translate to 'visually detectable' – which simply means that the product is a bright colour, and is not detectable metal detectable or x-ray visible at all.

Understanding Detectability Performance

In order to safely and successfully implement detectable products and materials into your food production area it is essential to have a strong understanding of the capabilities of your inspection system, and also the **relative** performance of the detectable products and materials in use. The word relative is stressed for a good reason.

The performance capabilities of any inspection system are influenced by the product it is inspecting, the accuracy of its calibration and other specific factors within the production environment. It's important to know the capabilities of your individual product inspection systems and successfully test and document all detectable products and materials used in production areas.

That said, it is possible to test detectable products in laboratory conditions and with the help of some leading inspection system manufacturers, we have built a very useful dataset to help illustrate the expected performance of some of the most popular detectable products.

Metal Detector Performance Examples

The testing demonstrated in this section was carried out using CEIA THS MS21 multi-spectrum metal detectors, kindly supplied by Metal Detection Services Ltd and Multicheck A/S. The data, results and conclusions given are intended as a guide for best use of detectable products and are offered without warranty.

In all cases the metal detector was calibrated to inspect a dry product [750g Box of Muesli Cereal] and the contaminant was placed in worst case orientation within the product and aligned as much as possible to the geometric centre of the detector aperture, which is the least sensitive area. (In order to achieve fair – worst case scenario results). Readings were all taken in triplicate and an average calculated. Blatant anomalies were discounted.

The following table (figure e) shows the average signal strength (amplitude) given by industry standard test pieces using the above methodology.

A CEIA THS MS21 Metal Detector with lockable reject bin. Image © CEIA

Figure e

Contaminant (mm)	Mean Signal (Db)
Ferrous 1.0 Sphere	13.2
Ferrous 1.2 Sphere	18.4
Ferrous 1.5 Sphere	25.2
Ferrous 1.8 Sphere	30.8
Ferrous 2.0 Sphere	32.8
Ferrous 2.2 Sphere	35.7
Ferrous 2.5 Sphere	39
Ferrous 2.8 Sphere	41.9
Non Ferrous 1.0 Sphere	9.1
Non Ferrous 1.2 Sphere	11.9
Non Ferrous 1.5 Sphere	16.7
Non Ferrous 1.8 Sphere	20.2
Non Ferrous 2.0 Sphere	21.7
Non Ferrous 2.2 Sphere	23.9
Non Ferrous 2.5 Sphere	26.2
Non Ferrous 2.8 Sphere	28
SS 316 1.0 Sphere	4.3
SS 316 1.2 Sphere	10.6
SS 316 1.8 Sphere	25.2
SS 316 2.0 Sphere	28
SS 316 2.2 Sphere	32.7
SS 316 2.5 Sphere	33.8
SS 316 2.8 Sphere	36.47

The following table (figure f) shows the average signal strength (amplitude) given by detectable product contaminants and how those readings relate to the closest industry standard test contaminant for reference.

Figure f

Contaminant	Mean Signal (Db)	Ferrous Test Piece Equivalent (Approximate)
BST XDETECT® Plastic 7.0mm Sphere	4.7	0.8 mm
BST XDETECT® Plastic 11.0mm Sphere	16.9	1.1 mm
Hellermann Tyton Detectable Cable Tie Head	22.7	1.4 mm
Hellermann Tyton Detectable Cable Tie 20mm Length	19.6	1.3 mm
Hellermann Tyton Detectable Cable Tie 50mm Length	28.1	1.8 mm
BST Detectapen® (Full Product)	59.7	2.8 mm +
BST Detectapen® (Empty Casing)	36.4	2.3 mm
BST Detectapen® (Insert Only)	31.2	1.9 mm
BST Detectapen® (Refill Only)	59.6	2.8 mm +
BST Detectamark™ Marker Pen (Full Product)	38.2	2.5 mm
BST Detectamark™ Marker Pen (Cap Only)	30.5	1.8 mm
BST ECO Detectapen® (Full Product)	54.7	2.8 mm +
BST ECO Detectapen® (Empty Casing)	34.8	2.2 mm
BST Detectable Tag / Label Material $5mm^2$	28.0	1.6 mm
BST Detectable Tag / Label Material $10mm^2$	43.4	2.8 mm +
BST Detectable Tag / Label Material $20mm^2$	57.6	2.8 mm +

As demonstrated by the data, a high metal detector ferrous sensitivity of at least 1.0mm FE will help reliably detect most detectable products and detectable material fragments of 10mmØ sphere / $0.52cm^3$ volume / an 8mm cube) and above.

Some may suggest that a 10mm sphere is a very large contaminant, and that plastic contaminants are likely to be, and are often smaller than 10mm, so what's the point in this technology? The point is that contamination doesn't occur in isolation. For example if a detectable pen is dropped into a slicing machine, the fragments would be of assorted sizes and would contaminate at least several products. The larger of the fragments would trigger the inspection system and a rejection would occur. Having been made aware of the problem by the rejection, the entire batch of product should then be subsequently quarantined. As opposed to a non-detectable plastic item being fragmented – metal detection and x-ray inspection could miss all the contamination.

Too many times we have heard customers expecting that all detectable plastic fragments would be found. **This is a very dangerous assumption** and is covered in the 'Best Practices' section later in this paper.

X-Ray Inspection Performance Examples

The testing carried out in this section was done using a Minebea Intec Dylight x-ray inspection system kindly supplied by Minebea Intec UK; along with the technical expertise of Peter Walker. A range of food products were used for testing including dry packed and boxed Muesli, chilled cottage pie ready meals and chilled tubs of pasta salad.

In each case the inspection systems new product calibration sequence was successfully run and the machine optimised for the specific food product. As well as a definitive positive / negative result, the radiographs stored by the machine tell us to what extent different products and materials are visible though x-ray inspection. Through these images we can learn the importance of high density additives, the variation in performance amongst different manufacturers and also the impact of product effect when looking for plastic and rubber foreign bodies.

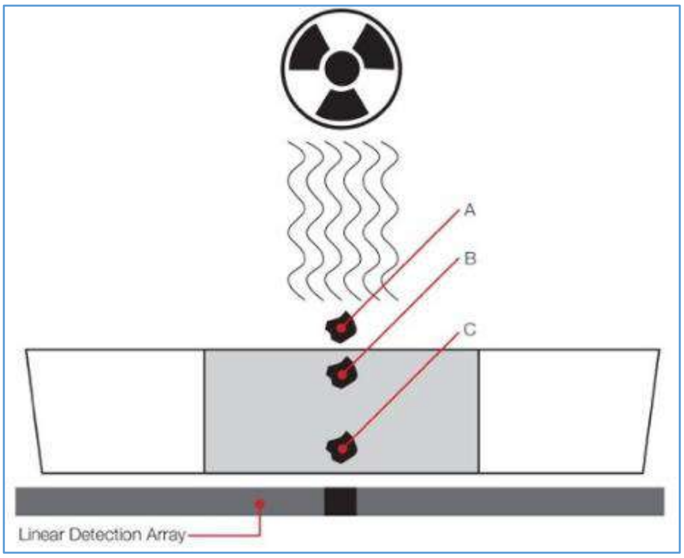


Figure g - The vertical position of the contaminant has negligible effect.
Image © BST Detectable Products

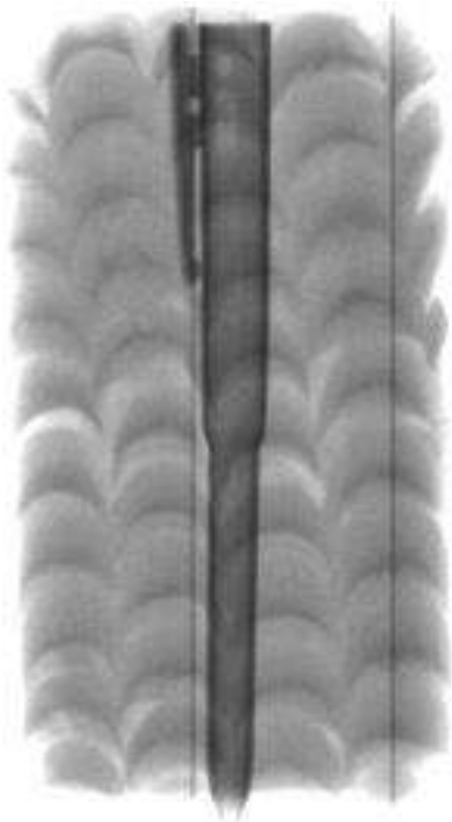
Detectable vs Non Detectable

This first set of radiographs (figure h) show the difference between a non-detectable plastic pen casing, and a detectable plastic pen casing – both pens are laid on top of a chilled 450g cottage pie ready meal. The vertical position of the contaminant has little to no effect on the radiograph as the gamma rays are still absorbed by contaminant to the same degree regardless as to whether they pass through the contaminant first, the product first or any other combination.

This is shown in figure g, where potential contaminant positions include A, B and C. Regardless of position, the resulting two dimensional radiographs would be the same.

Will Anderson testing detectable products in January 2017 using a Minebea Intec X-Ray Inspection System.
Image © BST Detectable Products

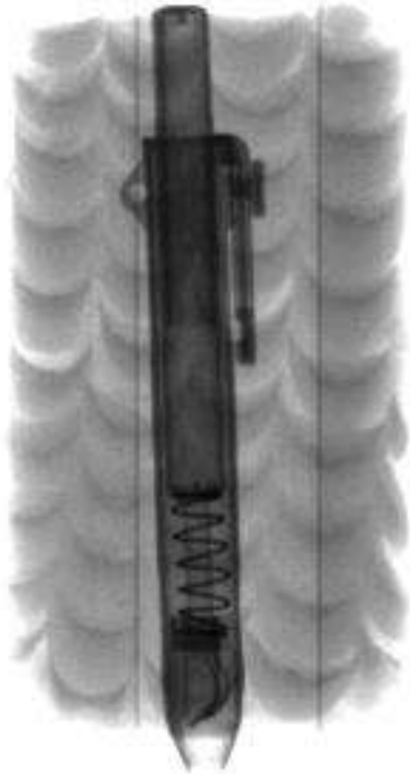
Figure h

Standard Polypropylene Pen Casing	XDETECT® Pen Casing
	
The faint outline of the pen casing is visible on the radiograph, however as the density of the polypropyne is similar to that of the food product surrounding it, the inspection sytem cannot indentify any contamination. **NOT REJECTED**	The high density additives within the XDETECT® material absorb more gamma rays, making the pen casing appear darker. This strong contrast with the surrounding food product means that it's easier for the inspection system to identify the contaminant. **REJECTED**

Metal Detectable vs Dual Detectable

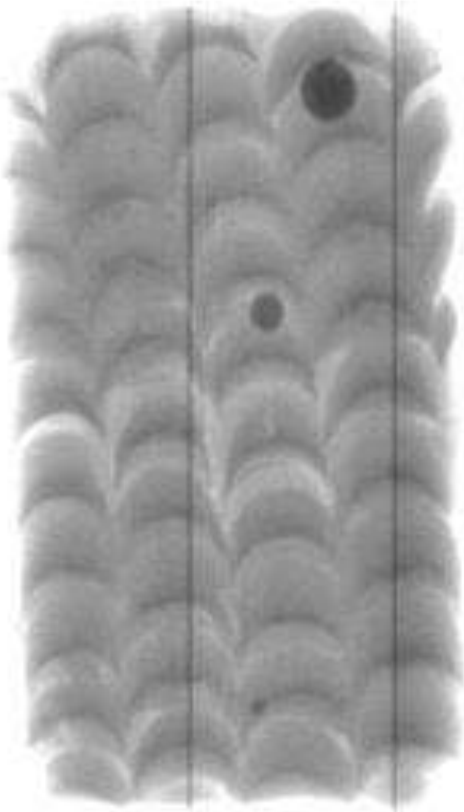
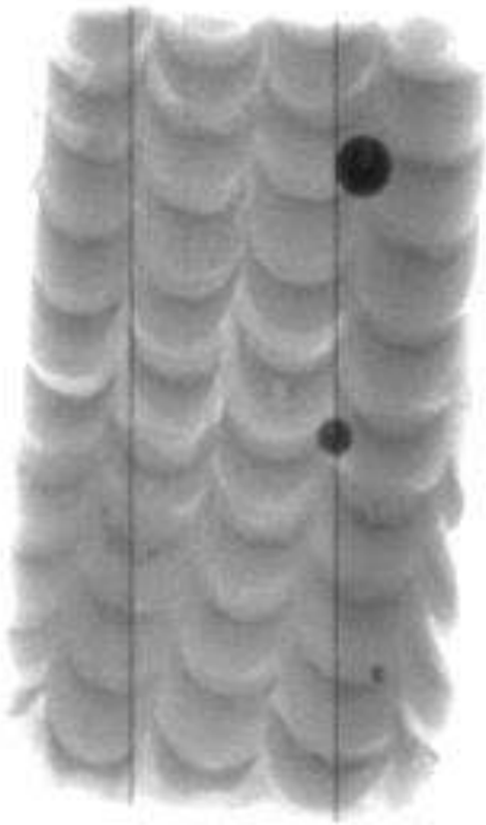
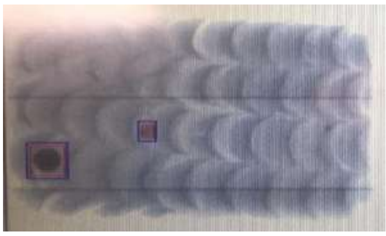
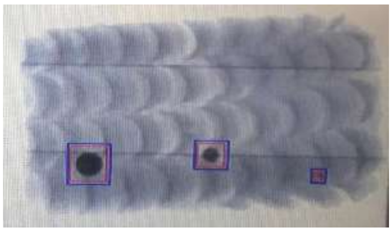
The next radiograph (figure i) illustrates the difference between a metal detectable and a dual detectable polymer. Products and materials sold as 'detectable' are not always optimised for x-ray visibility and food producers should exercise caution when selecting products and materials. The marker pen on the left is relying solely on ferromagnetic additives for its x-ray visibility, whereas the marker pen on the right contains additional high density additives.

Figure i

Detectable Retractable Marker Pen	XDETECT® Retractable Marker Pen
	
This particular detectable marker pen is advertised as 'detectable' but does not specify whether it is metal detectable, x-ray visible or both. Many may assume that is x-ray visible – however it does not provide a strong contrast on the radiograph. Although the fully intact product did trigger a rejection, if this product was fragmented – it's quite likely that the fragments would not be identified. **REJECTED**	This prototype retractable marker pen is made using XDETECT®, which is a dual detectable plastic compound formulation. The high density additives within the compound absorb more gamma rays, giving the product extra contrast on the radiograph. If this product was fragmented, it is more likely that the fragments would be identified. **REJECTED**

The next radiograph (figure j) again highlights the difference between a non-x-ray optimised material and an x-ray optimised material.

Figure j

Detectable Plastic Spheres [3, 7 & 11 mm Ø]	XDETECT® Plastic Spheres [3, 7 & 11 mm Ø]
	
This material is advertised as both metal detectable and x-ray visible, however relies solely on ferromagentic additive. All three spheres are clearly visible on the radiograph, however the inspection system could only identify the 11 mm and 7 mm contaminants.  **REJECTED 2/3**	The XDETECT® material does contain additional high density additives, so shows up darker (with increased contrast) on the radiograph. This resulted in all three contaminants being identified, including the smallest 3mm contaminant.  **REJECTED 3/3**

Product Effect for X-ray Inspection

Just as with metal detection, the food being processed has a direct impact on the sensitivity of the x-ray inspection system. The example shown here in figure k is a 750g box of muesli containing XDETECT® test spheres of 11mm, 7mm and 3mm diameter.

Whilst a 3mm XDETECT® sphere resulted in consistent rejections in the cottage pie ready meal, the system could not successfully identify the same 3mm contaminant within the muesli.

The cottage pie has a consistent structure and even distribution of ingredients making it quite easy for the inspection system to spot when something is wrong. However in Muesli, the dispersion of product within the packaging is inconsistent, as is the density of the different ingredients making up the product.

The almonds and hazelnuts within the muesli absorb x-rays as much as a 3mm XDETECT® fragments, providing zero contrast and illustrating the importance in understanding the limitations of detectable plastics and x-ray inspection systems.

Borderline cases with strong product effect demonstrate where it is especially important to use high quality detectable materials with high density additives.

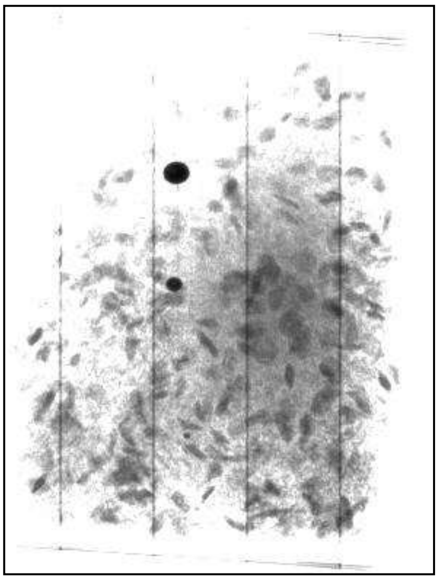
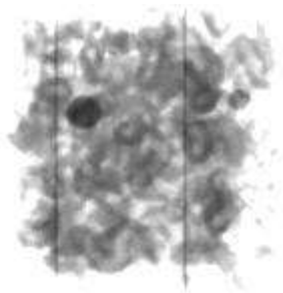
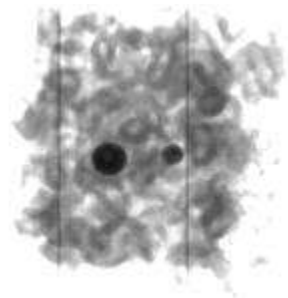


Figure k - XDETECT® Contaminants within a muesli breakfast cereal. Image © BST Detectable Products

The below pasta salad tub is another food product that presents a complex radiograph (figure l). Non-x-ray optimised detectable plastic spheres (left) are lost in the product due to poor contrast. X-ray optimised detectable plastic spheres (right) have greater contrast and are more likely to be identified.

Figure l

Detectable Plastic Spheres [7 & 11 mm Ø]	XDETECT® Plastic Spheres [7 & 11 mm Ø]
	
REJECTED 1/2	REJECTED 2/2

Additional Safety & Performance Factors

Impact & Shatter Resistance

Adding metallic additives to a polymer weakens its structure. There are many examples of low quality detectable materials which are too heavily loaded with additive. People many assume that these materials are better because they are more likely to trigger a detector – when in fact they are more likely to cause contamination due to their poor tensile strength, low flexural modulus and low impact resistance.

If a detectable material doesn't break in the first instance, it isn't at risk of becoming a foreign body. The purpose of a detectable material is to lower risk and this needs to be considered from multiple aspects.

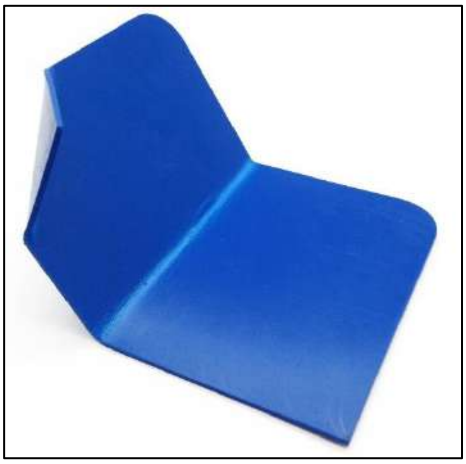
Reducing one risk by increasing another does not lower the risk, it just changes it. High quality detectable plastics should offer durability as well as detectability.

To achieve optimum overall mechanical strength the ratio of additives to polymer needs to be carefully formulated through years of research, development and testing. The optimum level is not consistent from polymer to polymer and varies hugely again when working with silicone and rubber materials.

The actual base polymer also needs to be considered. The most common XDETECT® formulation is a polypropylene co-polymer which incorporates other materials (plasticisers) to allow the material to flex rather than snap or shatter.

In bespoke applications such as machinery parts it's also particularly important to match the base polymer to the application of the part, thinking specifically about what chemicals are going to come into contact with the part as well as the required thermal and mechanical properties such as the rigidly and abrasion resistance needed.

Low quality detectable plastics can increase foreign body risks Image © BST Detectable Products



High quality detectable plastics offer durability as well as detectability. © BST Detectable Products

Antimicrobial Technology

The natural sterilising properties of silver can be harnessed through innovative carrier mechanisms in polymers. These enable the controlled release of silver ions and have been laboratory tested to be effective against harmful bacteria and mould including E.Coli, MRSA and Salmonella.

Although not suitable for all detectable product applications, this technology is particularly relevant for items such as factory pens, which can pass infections from one person or surface to another. Antimicrobial protection is built in to all models of BST Detectapen® as an additional safety benefit.

Unlike metallic and high density additives silver ion master batch is mixed into a polymer at extremely low levels so does not negatively affect or compromise the physical properties of the material. Many detectable products are now antibacterial and detectable but do not make assumptions, check with your manufacturer to be sure.

Detectable products are all about lowering risk – by reducing foreign body and infection risks simultaneously you are not only taking steps to improve safety through lowering risks, you are also getting added value out of the product you have purchased.

Food Contact Approvals

Many detectable products are intended to come into direct contact with food and it is important that all detectable materials used for food contact carry the appropriate approvals. The below summary (figure m) explains the key sections of EU legislation that food contact plastics must comply with.

Figure m

Regulation	Issuing Body	Description
EU Regulation 10/2011 on plastic materials and articles intended to come into contact with food.	European Union	This regulation replaced directive 2002/72/EC and its amendments and sets out clear food contact requirements for plastic materials and articles. It specifies that all materials should be migration tested (to avoid leaching of chemicals into food) and sets out the documentation requirements for food processors and plastics manufacturers.
EU Regulation 1935/2004 on food contact materials	European Union	This regulation lays down a general safety requirement aimed at ensuring that substances migrating from materials into the food do not endanger human health.
EU Regulation 2023/2006/EC on good manufacturing practice for materials and articles intended to come into contact with food.	European Union	This Regulation lays down the rules on good manufacturing practice (GMP) for the groups of materials and articles intended to come into contact with food listed in Annex I to Regulation (EC) No. 1935/2004 and combinations of those materials and articles or recycled materials and articles used in those materials and articles.

Other governing bodies include the US FDA (Food & Drug Administration) who have equivalent legislation. When complying with FDA regulations it is important that mineral additives and the colour pigments used are GRAS (Generally Recognized As Safe) or are FDA cleared under specific FDA citations.

Not all detectable materials carry EU or FDA approvals, so if a detectable product is going to be specifically used in a food contact application it is important to request the supporting documentation from your manufacturer and keep this on file for client / BRC audits.

XDETECT® is available in 8 bright colours
Image © BST Detectable Products

Colour Brightness

Colour co-ordination is an important part of HACCP and vital for managing allergen risks. Ferromagnetic pigments are naturally dark in colour so a high dose of food grade pigment is required to overcome this and achieve the bright colours required in a modern food factory. Low quality detectable plastics often do not use enough colour pigment resulting in 'sludgy' colours – particularly in yellow, green, orange and red. Unclear colour co-ordination is an unnecessary safety risk so food producers should be mindful of this when sourcing colour co-ordinated detectable products.

Detectable stationery & PPE are some of the most common examples of detectable products.
Image © BST Detectable Products

MISTAKES, ASSUMPTIONS & BEST PRACTICE

Mistakes and Assumptions

Unfortunately dangerous mistakes and assumptions are made about detectable products every day. These mistakes and assumptions have not been helped by conflicting information within the detectable products industry. As we have discussed so far, the properties needed to make a material metal detectable are different those needed to trigger a rejection by an x-ray inspection system. Below we hope to dispel some incorrect assumptions and mistakes that have been seen in the past.

Assumption: All pieces of detectable material can be found by my inspection system. No matter how small.

The facts: One of the most dangerous assumptions to be made about detectable products is that a piece can be detected no matter the size. In the same way that an inspection system won't find a piece of metal below its range of sensitivity it will also not find the smallest pieces of detectable material. This is especially true of detectable materials as they contain only a percentage of detectable additives and as such a larger piece is required to trigger a rejection.

Assumption: A metal detectable material / product will also be found by an x-ray inspection system.

The facts: As the properties needed to make a material metal detectable or x-ray visible differ, a product or material designed to be metal detectable won't necessarily trigger a rejection from an x-ray inspection system. Food manufacturers must be wary of products that claim to be detected by both systems and carry out their own relevant tests to ensure that this is the case before introducing the product into the manufacturing environment.

Assumption: I don't need to pay the same attention to my detectable items that I do my regular items.

The facts: All items used in production area's need to be subject to the same level of care and attention. Whilst detectable products do offer an extra layer of protection from foreign body contamination, care still needs to be taken to ensure the maximum benefit is achieved. Detectable products and materials are a last line of defence – not an absolute fail safe.

Assumption: The more detectable additive in a material the better.

The Facts: Whilst this will make material more detectable, the consequences of overloading a polymer with detectable additive need to be considered. Adding additive to make a material metal detectable will also reduce its mechanical strength and make it more prone to breakage and shattering. As such there needs to be a trade-off between optimum detectability and material strength. If a material is ultra-detectable, but shatters extremely easily the risk of a small piece of contamination being missed will be greatly increased and defeat the purpose of using the product.

Assumption: All detectable materials are equally as detectable each other.

The Facts: There are many different varieties of detectable material available, made by an array of manufacturers. As such there are materials which perform well and others less so. It is up to the food manufacturer to ensure that any relevant testing of detectable materials has been done to ensure that they are suitable for the intended requirements. Inconsistent methods are used to produce detectable products and some manufacturers use a blanket term of "detectable" and do not differentiate between metal detectability, x-ray visibility and dual detectability.

Assumption: The same size piece of detectable material will be found within different food product types

The facts: No. This is due to how different products are "seen" by inspection systems. Foods are often referred to as wet or dry, with dry products generally being the easiest for metal detection. Wet products react differently and require a metal detector to use a different frequency for detection and compensate more for the increased product signature. Denser and inconsistent products increase the difficulty of x-ray inspection meaning lower sensitivity.

Assumption: All detectable materials are food safe and migration tested.

The facts: As with normal plastics not all are designed to come in direct contact with food. If a manufacturer is considering using a detectable material or product that will come into direct contact with food they should check with the manufacturer and refer to the technical specification where needed to ensure that the product is fit for purpose.

Mistake: Purchasing a detectable product on price and not suitability.

Our Advice: As with any product used, there should be a consideration of quality and suitability for intended requirements. If the wrong material is used for the job because of consideration based on price alone this may lead to risks involved both in contamination and early failure of parts meaning that they have to be purchased more regularly, potentially costing much more.

Mistake: Not having the relevant technical specification on file for the products used.

Our advice: Whilst many do ensure that along with ordering a product they also receive the technical specification to back up the product when considering a new detectable material or product, this is not always the case. It is best practice to ensure that you have reviewed and stored an accessible copy for reference and in case of query from an auditor.

Mistake: Not testing detectable materials as part of your quality checks to ensure detection & rejection

Our advice: Different products are made using different grades of detectable plastic. Ask your manufacturer for test spheres / cubes of the material. If such pieces are not available then test the product in your inspection system. Break the product down into smaller pieces, record and document the results so that the limits of detection are understood and the level of risk known.

Mistake: There is a detectable version of a material or product that I use, if I replace the non-detectable version I will be safer.

Our advice: The suitability of the detectable alternative needs to be considered. If this product will make your environment safer and it has been tested to make sure it is detectable to a reasonable size that may be missed by visual inspections then it is likely the product is suitable. However there are detectable materials and products available which although detectable in large quantities/pieces, are redundant due to the large amount needed to trigger a rejection. Products that need to be considered closely are thin sheet plastic such as tote bin covers, stretch wrap and aprons. As discussed previously, the material still needs to behave as the product it is intended to be, meaning that a thin sheet plastic will contain a minimal amount of the additive needed to trigger a rejection. When considering using these products manufacturers should be extremely wary as they may be paying a premium for a detectable product promising a layer of protection, when it would be more effective applying extra care and attention to a non-detectable version.

These mistakes and assumptions are real life and have been encountered over the years by Will, Joe and other BST team members. Whilst there are many technical managers who understand the principles of detection and detectable products, there are those who are not as confident.

This unfortunately leads to conflicting information within food manufacturers. Problems and confusion can also occur when responsibility for standard detectable products is passed on to employee's outside the quality and technical departments who do not have the same knowledge and training.

Detectable material best practice

Consideration and care should be taken when introducing any detectable product to your manufacturing environment, be this a detectable pen or a bespoke solution. Everything discussed so far in this paper should be taken into account when choosing the products suitable for your manufacturing environment.

Below are some practical steps that can be taken into consideration when introducing a new product or indeed switching your detectable product supplier in order to gain the biggest benefit.

- Consider the product that you would like to purchase and its suitability in the manufacturing environment, ensuring that decisions are made on quality and relevance to the task required.
- Take into consideration the benefit that will be received from changing a non-detectable material or product to a detectable alternative.
- If possible discuss with your detectable product manufacturer your needs and requirements; they may be able to offer help and advice. They may even have a solution already based on an enquiry from a different manufacturer.
- Review the technical information of any proposed material or product to ensure that it has the properties that you require.
- If possible obtain a sample and test through your inspection system to determine how small a piece will trigger a rejection. Record and store this for future use if required.
- If this piece is larger than expected, or larger than would be physically capable of being enclosed in the products packaging then re-consideration of the product or material may be required.
- Once you are happy with the detectable product ensure that you have a file with any necessary technical data sheets which may accompany it for review by an auditor.
- Ensure that the product is included in any daily / weekly / quarterly checks as deemed necessary on site.
- Educate supervisors on the basic principles of detectable products, as they are on the front line of safety for food manufacturers. The more knowledge that they have of the limitations of the detectable product, the greater the chance of using the product most effectively.
- Detectable products are more expensive than their non-detectable counterparts, ensure that employees are aware of this, to take care of the product and ensure as far as possible that they are not removed from the manufacturing environment where they add no value.

By following these steps food manufacturers stand a far better chance of making the most of their investment made into detectable products. If there is any question about the suitability of the detectable material or product in use this should be raised with the supplier or manufacturer who should be equipped to help further.

As the use of detectable products has become more widespread by food, pharmaceutical, cosmetic and nutraceutical manufacturers, there are now more standard detectable products available than ever before. These range from stationery items through to engineering parts. When choosing a standard product the steps outlined above should be followed in order to ensure satisfaction with the product, all claims made by a detectable product manufacturer should be checked over before committing to introducing anything new.

It is common practice for food manufacturers who are customers of large retailers to be contracted to abide by codes of practice. Within these codes of practice it is often stipulated that the manufacturer must use a detectable version of a standard product if they require the use of such an item in their environment. Technical managers and auditors for large retail establishments would benefit from being aware of the best practices described in this white paper so when they do stipulate the use of a detectable product they understand the benefit that the product offers to the manufacturer, retailer and end user by reducing the risk of foreign body contamination.

If it is appropriate, food manufacturers may benefit from on-site help with detectable products. Where a representative of the detectable product manufacturer visits the site to discuss the individual needs for detectable products and offer the best solution to meet those needs whether that be with standard products or new bespoke products. A service providing technical expertise and guidance to minimise the risk of foreign body contamination to maximum effect!

CONCLUSION

It is our aim that after reading this white paper the reader is now equipped with the knowledge to make informed decisions regarding the implementation and usage of detectable products and materials.

If anything is taken from this white paper, let it be the following key points:

1. Know and understand your inspection system and its limitations
2. Test all detectable products and materials on your inspection system
3. Remember that not all detectable materials perform the same
4. Choose a detectable product / material based on its quality and suitability
5. Follow the best practices proposed in this paper and as set by standards bodies and retailers
6. If in doubt – don’t assume, ask your detectable product manufacturer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