Application of X-ray technology in contaminant management systems
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Application of X-ray technology in contaminant management systems Sandy Davidson This paper is to be a two-part presentation on the application of X-ray technology to the baking industry and its suppliers.

The first part Will be by myself on Holgran's use of the technology and the second part by Mike Broderick, sales and marketing manager of Graseby GK Intertest, on the technology itself and other potential applications.

Holgran Ltd is part of the Cereals Division of Ranks Hovis McDougall. We are a major ingredients supplier to the malted wheat grain and multigrain bread markets. We manufacture the malted wheat flakes for Granary malted grain bread and a range of seed based premixes for several Hovis brands. In addition we supply a range of ingredients including malted wheat products and seed based premix products to a number of major food manufacturers.

There has been a progressive increase in demand for these malted grain and multigrain products providing, as they do, the opportunity for bakers and retailers to sell premium breads to the consumer.

The reason for Holgran's acquisition of X-ray technology lies in the nature of the raw materials used and finished products manufactured:

1. The products are made up of whole, flaked and/or cut grains together with various types of seeds.
2. Potential contaminants are the same size, often weight and other physical characteristics, as the individual product components and are therefore difficult to separate using conventional cleaning methods.
3. The products are used as minor ingredients in consumer products. There is therefore a significant multiplier effect one tonne of our product goes into in excess of 10,000 loaves.
4. The raw materials are natural, primary grain seeds.
5. Holgran's policy of integration of BS5750 and HACCP systems meant that the people driven aspects of the quality system are integrated fully with the technical systems.
6. Brands have a high value to companies in the premiumisation of pricing, as such brand defence is an important consideration.
7. Legislation with regard to due diligence and HACCP is increasingly forcing the pace on product protection issues. The application of HACCP will be required by law for the food industry by the end of 1995 as a result of the issue of the European Council Directive on the Hygiene of Foodstuffs issued in June 1993. All reasonable and practical precautions must be taken.

Before purchasing the X-ray equipment in 1991, we already used the full range of conventional grain cleaning equipment together with appropriate regimes for maintaining them and for monitoring their effectiveness. However none of these physical methods of separation are 100% efficient and we continued to have problems with stones against which we could not demonstrate complete due diligence.

Colour separation by equipment that separates on colour differential was looked at but, again due to the nature of our materials in relation to potential contaminants, it did not prove effective.

Prior to the acquisition of the X-ray contaminant management system a series of trials were carried out by Holgran and GK Intertest, with input from the Lord Rank research centre, the RHM technical service resource.

The trials were carried out on a conventionally cleaned trial batch and they resulted in the removal of an average additional 12 contaminants per tonne. The system will find the following in our product range, dependant on X-ray opacity:

- most stones
- glass
- ferrous and non-ferrous metal including rust
- 'mud' balls
- harder rubbers
- ceramics

These are judged to be the contaminants which present the higher risk of ingress to our products and protection systems.

The system will not find items of predominantly low molecular weight in our product range:

- string
- some rubber and plastics with low molecular weight compounds
- soda glass
- shale
- paper/wood
- aluminium

These are judged to be materials which present a lower risk of ingress to our products and protection systems. In fact we have not only banned glass from our production areas, but also aluminium, although of course aluminium would be removed by our conventional metal detection systems.

The contaminant management system, on installation, was fully integrated into the product protection and manufacturing process. In fact as much was spent on the integration as upon the system itself. All malt, cereals and seeds processed by Holgran must pass across it.

There are a number of considerations which must be taken into account with the design and installation of such a system. These are:

1. The reject mechanism is as important as the detection system itself. There is no benefit in detecting if you cannot reliably remove the contaminant.

2. That there be no dragging or fouling on the sideguards of the machine as that would destroy the accuracy of the rejection system.
3. That the material under inspection is presented to the machine a consistent and regular profile
4. At the rates of throughput operated it is important that both the testing regime be correct and that sufficient training is carried out to ensure it is done properly including tests for radiation leakage.
5. Again, at the rates of throughput operated, it is important that should a fault occur the machine is failsafe. That is, it defaults to reject.
6. The appropriate authorities should be consulted such as the factory inspector and the fire officer.

The system is operated for 92 hours per week and detects contaminants down to a level of 0.8mm. Finding the contaminants can be a time consuming task but it is carried out from time to time. We also possess a rogues' gallery of materials detected or from historic complaints and these are passed across the system to confirm detection from time to time.

As we are working with bulk flow the system rejects a substantial amount of material with each reject, amounting to some one percent of all production. These rejects are stored and repassed at a later date at a significantly reduced rate (one quarter) of throughput to scavenge back 'good' material. A 70-90% recovery is achieved dependent on the material.

Finally maintenance costs should be taken into account. These are not cheap, some £2,000 per annum, but absolutely essential plus X-ray tube replacement at £5,500 approximately every three years.

We believe that there are significant benefits from the use of this system at Holgran, not least in terms of customer confidence in our products and the enhancement of a quality image.

It demonstrates due diligence in the protection of the consumer with consequent protection of our brands and those of our customers. Since installation we have found a reduction in the level of complaints. It has also provided us with a much stronger defence against customer complaints.

It should also avoid a major product recall incident. Shortly after our system was installed, a baking company had just such a problem with glass in a major branded product. The estimated cost of the subsequent product recall was in excess of £3 million.

In a similar vein, at the height of the deliberate contamination of baby food episode, on one day the company concerned did not sell one jar of baby food. The cost of the whole incident was in excess of £38 million.

In summation, we believe this was a significant advance on any conventional technology in the market place. It is fully integrated into the production systems. The system currently records levels of rejects between 2,000 and 4,000 per week. While these figures sound horrendous, they are consistent with the rates found in our initial trial work. All of these rejects represent contaminants that conventional cleaning systems would not remove although some of these are contaminants that the consumer might not have noticed anyway.

Given the risks associated with contaminants, it is our policy that this represents the best available due diligence defence in the face of the ever increasing demands of legislation, the consumer and our customers and that it thus represents the future for the industry and the highest degree of reassurance for the customer.

How the system works in more detail

Mike Broderick

The X-ray system employed by Holgran was designed and built by Graseby Intertest following extensive trials at our factory in Wellingborough and on site at Holgran's factory in Burton on Trent.

The main purpose of the system is to prevent mineral stones and other dense contaminants, which are left after the conventional cleaning processes, from leaving the mill and going on to the consumer.

The objective of the trials was to assess the sensitivity of the system in terms of contaminant detection and rejection as well as coping with the throughput and the production environment. An additional factor was the integration of the Xray system into the automated product handling system planned for the site.

The basic design of the system is as a conveyor format, with the X-ray beam generated in the base of the central section and the linear array detector positioned in the beam above the conveyor. The conveyor passes along a flat bed, hence vertical guide rails are used to contain the product. The length of the conveyors and the covers are dictated by the need to contain the radiation as well as accommodate the product loading and rejection device.

The system's own computer is interfaced to an external PLC which controls the flow of products from all parts of the mill and is capable of selecting the correct product from the system's memory in order to inspect the flow. The system also interfaces with the PLC to warn of any faults or stoppages, ensuring that if the inspection system is not operational product will not be allowed to pass.

In order to minimise the amount of product rejected with each detected contaminant, the system incorporates a computer system which within its software divides the width of the conveyor into 'lanes'. Each 'lane' has an individual pneumatically operated reject flap at the outflow end. This is activated only when a contaminant is in that lane. Currently there are four lanes in the rejection system and as little as 250 grammes are rejected per contaminant.

To assess the effectiveness of the system the trial employed a sample of 14 tonnes of malted wheat flake, the main product. This was fed through the system using a hopper with a controlled outfeed gate such that it deposited a consistent depth layer onto the belt. As the product passed beneath the linear array detector the amount of X-rays reaching the detector was measured and the system's computer determined whether this was below a pre-set value.

Once the product had been inspected without producing a low level value output on a series of passes, brightly coloured mineral stones and other contaminants of known sizes were introduced into the flow and their detection logged (as seen by a 'freeze' on the video display) as well as an incremental count on the reject total display. The operation of the rejection device was also monitored and each contaminant recovered. During the initial passes 214 mineral stones were found and removed in what was precleaned product!

The level of detection is determined by the differential attenuation of the X-rays; this is usually expressed in terms of grey level, as interpreted by the system computer in a scale of 0 (black) to 255 (white). The differential between 'product' grey level and 'contaminant' grey level is set such that there are at least 20 levels difference.

The same methodology was applied to the other grain products in the Holgran range as well as some of the seeds. A table of grey levels was formulated for each product or group. The system's eight named' product memories can be easily employed to deal with all the range.

At the throughput rate of nine tonnes per hour the system can reliably detect the following contaminants:

Mineral stone	3 mm
Stainless steel	1.75 mm
Glass	2 mm
Dense rubber	5 mm
Rust	1 mm

The technology has expanded since the installation of the system at Holgran and newer, smaller systems have been introduced. Examples of applications within the baking industry include:

Fruit pies

A manufacturer whose products are packed in foil trays has not only benefited from the dense contaminant detection capabilities but has eliminated its number one customer complaint - missing pies in the pack. This is achieved using a series of electronic masks which overlay the position which should be occupied by a product and rejects if there is a lack of density in that area. This inspection is performed simultaneously with the dense contaminant detection at speeds up to 40m/min using a system with an inspection width of 340mm and the dense contaminant rejects are delivered into a separate bin to the 'underfills'.

Doughnuts

Another example of systems being used in more than one mode is a manufacturer of jam filled doughnuts.

In this example the incidence of dense contaminants is extremely low, the main reason for implementing the technology is to check for the absence of the jam filling within each doughnut. This may appear to be another straightforward instance of applying a missing product mask, until the problem is examined in more detail.

There are different sizes of doughnut, in different pack formats with variations in the 'appearance of the jam - it doesn't possess a regular shape as the injection process places the jam inside the dough and it takes the path of least resistance, spreading out randomly. The 'image' of the doughnut is further complicated by the compression of the dough where the individual doughnuts are packed together.

In this instance, high speed morphometric analysis is applied to allow recognition of the 'shape' of the compressed region and distinguish it from other features. The speed of data processing required to perform this task is a phenomenal 12 million instructions per second, performed by the latest generation system CDX.

Bread

An area which we would like to investigate is that of bread. Conventional metal detectors are already widely used in this application, but stainless steel wire originating from sieves or other plant machinery could probably be detected with improved resolution using an X-ray system. It may even be possible to quantify the distribution of fruit in cakes and pies.

The technology of X-ray inspection is improving constantly. It is Graseby Intertest's practice to work with food manufacturers in applying the technology at the most appropriate points in the production process.