Minebea intec
The true measure

Metal detection in production lines

Requirements, technology and application recommendations

GFSI BRC HACCP
multi-frequency technology
metal detection
IFS validation verification
prevention separation systems
CCP
product effect eddy current

academy
by Minebea Intec

- Requirements for prevention and detection, legal background
- Overview of preventative actions
- Introduction of metal detection technology
- Validation and verification of detection systems
- Processes for separation of contaminants and monitoring of metal detection systems

Content

1. An introduction to metal detection

Preventative measures and *foreign body management* have become increasingly important in the food industry. One reason for this is the changing requirements of food standards. Another reason is increased public sensitivity to contaminated and defective products. In the media age product recalls can mean much more than economic losses, and in the worst case scenario may damage the image of the company as a whole.

But what exactly are foreign bodies?
In food production they are usually solid (physical) objects which do not belong in the product. Food contaminated with foreign bodies often represents a health risk for the consumer.

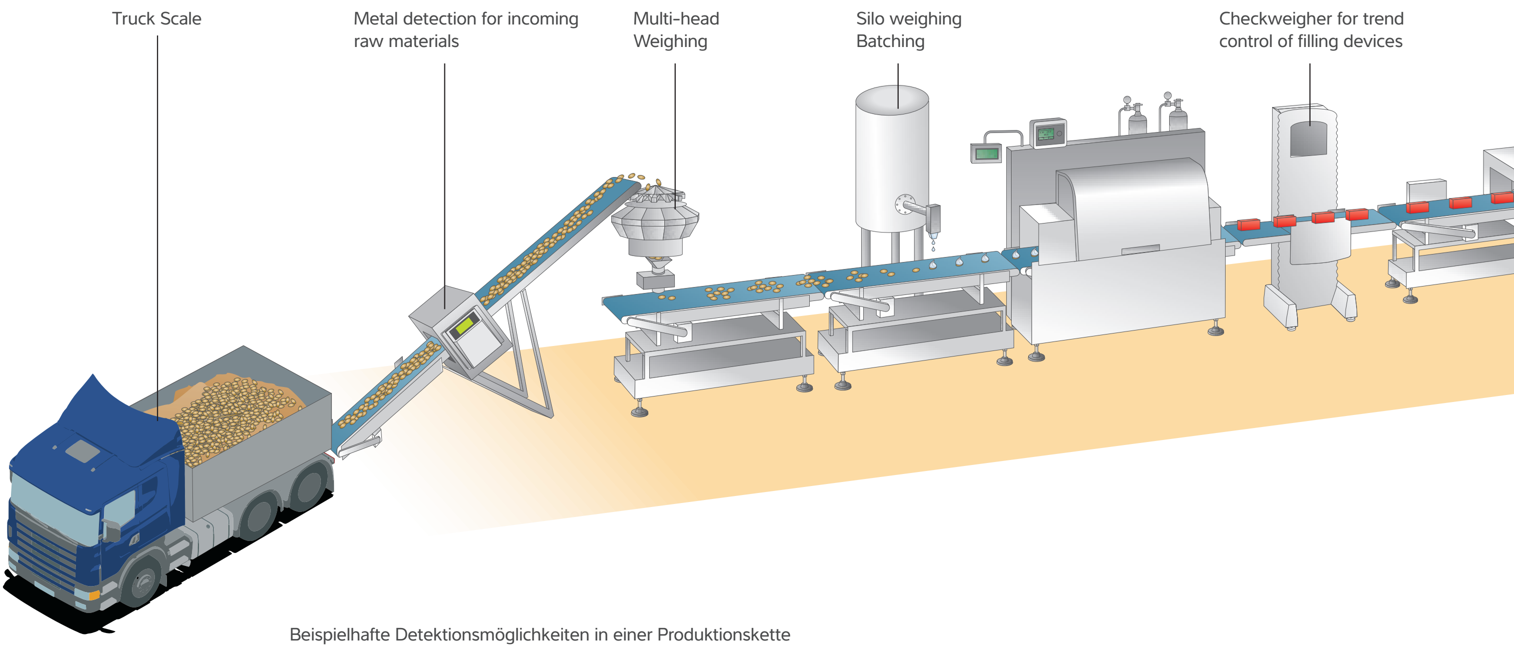
Possible injuries include injuries to the mouth, pharynx, oesophagus and the gastro-intestinal tract. These injuries may be caused by metal shavings, stones, fragments of glass, pieces of plastic or similar objects. Foreign bodies also include insects, chewing gum or hair.

It is true that these are not automatically a health risk for the consumer, but according to the common Food Hygiene Regulations, these foreign bodies are classified as a „negative influence in the form of nauseating damage‟, which may possibly result in a recall or withdrawal of the product.

Foreign bodies can get into a product *in various ways*.
For example, ingredients can cause a physical contamination of the products within the production and / or packaging process, for example due to metal shavings or screws. Or this may even happen during harvesting (e.g. metal, stones).

With the aim of minimising the risk to the consumer, in Europe companies in the food industry are obliged to implement a permanent procedure based on the *HACCP principles*. Article 5 of Regulation (EC) No 852 / 2004 of the *European Parliament and of the Council on the Hygiene of Foodstuffs* governs the hazard analysis and determination of the critical control points (CCPs) of the process steps.

These guidelines refer to the statutory European requirements as an important criterion in metal detection. These notes provide background information. Please observe the specific legislation and customer requirements of your country.



Beispielhafte Detektionsmöglichkeiten in einer Produktionskette

2. Recommendation on the procedure for implementing the IFS requirements in relation to foreign body prevention and detection

More than ever, both *law makers* and *consumers* expect the highest level of safety and the best possible quality from food. This requires *the entire production system* (including production, packaging, storage and transport) to be monitored diligently and consistently. International food, product and service standards are intended to ensure the conformity of a product and therefore the conformity of product quality.

1.1 HACCP

Regulation (EC) No 852/2004 requires that *each food business operator* involved in the preparation of primary products and associated processes in downstream production, processing and sales of food must set up, implement and maintain a procedure based on the *principles of HACCP* (Hazard Analysis and Critical Control Points).

The seven HACCP principles are:

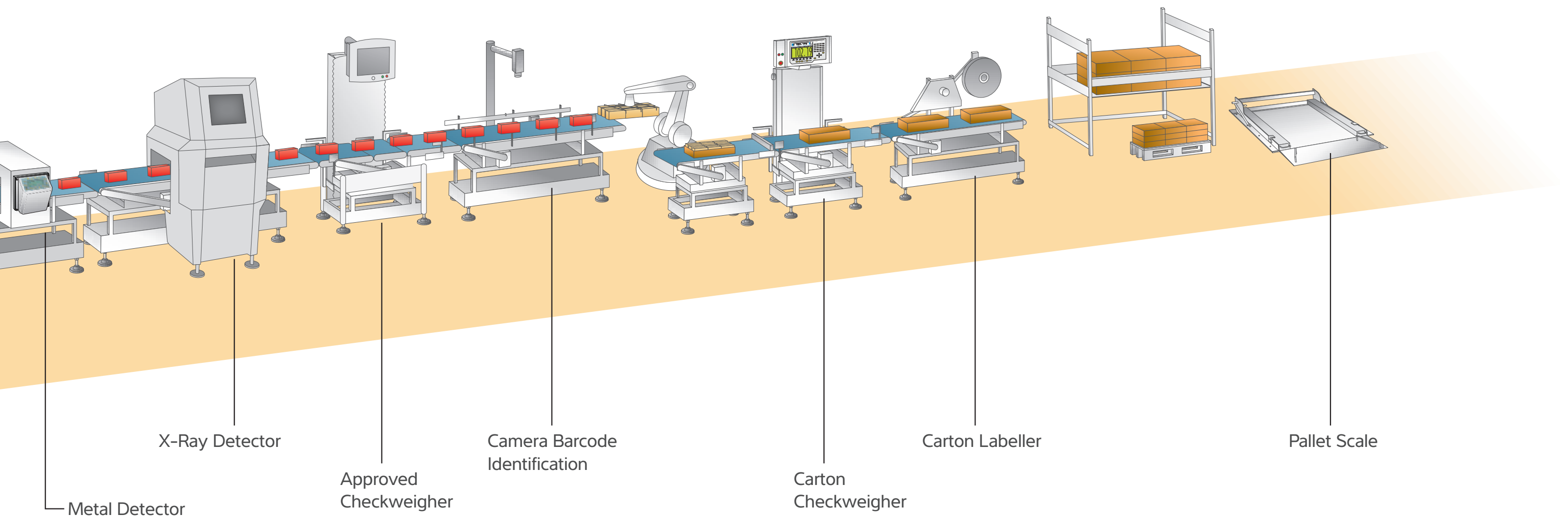
- Principle 1
  Conduct a hazard analysis
- Principle 2
  Determine critical control points (CCPs)
- Principle 3
  Establish critical limits
- Principle 4
  Establish monitoring procedures for each CCP
- Principle 5
  Establish corrective actions
- Principle 6
  Establish verification procedures
- Principle 7
  Documentation and record-keeping

One aim of HACCP is to *protect consumer health* by avoiding foreign body contaminations. In this case, it is sensible to check packaged products or products shortly before packaging if this has advantages in relation to the ability to detect foreign bodies (on the basis of the hazard analysis).

In addition, it may be sensible to use a foreign body detection system before each process step, which *could break up larger foreign bodies to the extent* that these parts could no longer be detected further along in the process.

In addition to avoiding foreign body contamination, the food industry also aims to *produce safe and high-quality products* for the consumer. The 7 HACCP principles have proved to be successful in implementing the requirements for foreign body prevention and removal.

On the basis of this structured approach possible hazard points are identified and recorded better, and measures to reduce or avoid these risks can be taken sooner. The principles will be explained in greater detail below.



Notes on principle 1:

Conduct a hazard analysis

The food business operator must consider which *health hazards for the consumer* may arise due to the consumption of the food. In this case, according to Regulation (EC) No 178 / 2002, a hazard is defined as a "biological, chemical or physical agent in, or condition of, food or feed with the potential to cause an adverse health effect". Foreign bodies therefore fall under the physical hazards.

The *FMEA methodology* has proven to be a successful approach to conducting a hazard analysis. FMEA stands for "Failure Mode and Effects Analysis".

However, there are of course other possible methods for hazard analysis and risk determination.

A hazard analysis should consider the following foreign body sources, among others:

- *Suppliers* (raw material collection from the ground, machines / tools for raw material collection etc.)
- *Raw material processing* (filter, sieve, mills etc.)
- *Product production* (mixing, cutting, kneading, grinding, heating, cooling etc.)
- *Transport* (internal / external)
- *Product shaping* (presses, templates, knives etc.)
- *Packaging* (bottler, bagging machine, cartoner etc.)
- *People / environment* (accessibility, care, resources and tools, tampering, protective clothing, personal behaviour etc.)
- *Operating environment*
- *Rework* (clips)

The specific sources of foreign bodies that are relevant obviously depend on the product group / sector and must be identified by the hazard analysis.

Notes on principle 2:

Specification of the critical control points (CCPs) / risk assessment and definition of device parameters and CCP and / or CP

In order to determine the risk, consideration is given to the probability of each hazard occurring and the effect on the consumer (see also Regulation (EC) No 178 / 2002). The following generally applies here: *The higher the risk for the consumer, the more necessary* it is to install prevention and control measures to reduce the risk in the process to an acceptable level.

Depending on the risk classification, preventative measures will need to be used, however in some cases these measures will already have been installed in the event of a higher assessment of an individual factor (probability or effect). For example, the probability of occurrence may be classified as low, but the effect on the consumer would be so serious that preventative measures would need to be introduced in this case.

In addition, *the hazard analysis also determines* whether for example a metal detector or x-ray detector will be installed as a CCP (Critical Control Point), CP (Control Point), oPRP (operational Prerequisite Program) or as an in-process control. Not every detector is automatically classified as a CCP if, for example, it is only installed as preventative machine protection or a potential risk cannot be sufficiently reduced. There must also be examination of whether additional facilities have been installed or should be installed in the remainder of the process in order to avoid foreign bodies. In this case the decision tree of the *Codex Alimentarius* can be used as a decision-making aid.

It is also possible to install *several CCPs* in a process in relation to different risks, e.g. a metal detector to detect and remove metallic foreign bodies.

For the next level, the specification of the system, the results of the risk analysis must be considered because these may influence the layout or the requirements for the devices.

Notes on principle 3:

Establishing critical limits / specification of the system

In order to achieve the *best possible detection / removal of foreign bodies*, it is important to already create *informative specifications* during the procurement process.

The following points, among others, must be considered when producing specifications:

- *Description* of the technological *requirements* and statutory requirements (e.g. EC Reg. 1935 / 2004 on materials and articles intended to come into contact with food)
- *Product-specific properties* of the product to be processed (e.g. temperature, composition, course of the process)
- *Requirements* of the Machinery Directive 2006 / 42

Other criteria which should be considered in the specification of the system:

- Process step with *highest contamination risk* (assessment of empirical values in relation to typical contamination candidates)
- Process step with *highest achievable detection accuracy* (knowledge of detection technologies)
- Process step for *packaged individual products* (exclusion of subsequent contamination)

The specifications or the product specifications generated from the system manufacturer's specifications should be *checked* by all relevant people in terms of the requirements *before approval*.

Notes on principle 4:

Establishing a monitoring system for each CCP / establishing monitoring and verification

During the *implementation of a device for foreign body detection or foreign body prevention*, effective monitoring and verification also needs to be established. In this case, the two terms monitoring and verification are defined as follows:

- **Monitoring**
  All measures for the monitoring / observance or measurement of control parameters, such as compressed air monitoring, watchdog, discharge inspection, start / stop controls.

- **Verification**
  Regular (e.g. hourly or daily) checking of metal detectors with test pieces, as well as separators and surveillance / monitoring functions.

Verification is an *important part of monitoring*.
Monitoring must be included in the HACCP concept. The interval for checking the monitoring or verification *depends on the risk analysis*. However, in this case it must be considered that if there is a possible error during the monitoring, the goods can still be accessed by the company. Verification once per day or leaving verification until the end of a production period (day or week) is usually not sensible.

Training of *staff* on monitoring and the effectiveness of this training also must be checked.

Notes on principle 5:

Establishing corrective measures / commissioning the system and initial validation

Internal commissioning on site is indispensable. In addition to the safety-related acceptance and sufficient user training / instruction on the new system, checks must be carried out to establish the extent to which

- the *HACCP concept / hazard analysis needs to be updated* and related measures need to be taken,
- flow diagram adjustments are required,
- cleaning and maintenance plan revisions are required,
- all documents required by law, e.g. in relation to Regulation EC 1935 / 2004 on materials and articles intended to come into contact with food, are present,
- if necessary, requirements from the Machinery Directive 2006 / 42 have been considered.

Only *when all information is available* can a system be validated. In this case, internal "commissioning checklists", which include the individual criteria, have proven successful.

Starting production without validating the system must be avoided.

Notes on principle 6:

Establish verification procedures

- **Monitoring / verification**
  Step 4 establishes the monitoring. Following the commissioning (step 5) of the devices, the intended monitoring / verification measures are introduced and implemented in the actual production process.

Notes on principle 7:

Documentation and record-keeping

Revalidation

In addition to initial validation during commissioning, systems and methods for foreign body detection should also be revalidated, i.e. *validated again*, regularly or in the event of certain incidents (see list) in order to confirm that the system is effective.

Reasons for revalidation

General

- Increased complaints relating to foreign bodies
- Changes in the production process (e.g. belt replacement)
- Requirements of customers / sector standards
- Interval dependent on hazard analysis, however at least annually
- Necessary if problems occur during verification

Metal detection & x-ray detection

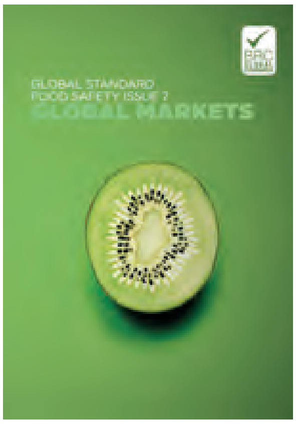
- Product change (e.g. recipe, packaging material)
- Repair, replacement of components
- Increased complaints relating to foreign bodies
- Change in belt speed
- Change in throughput
- Change in product infeed
- Change to the foreign body detection system and to relevant setup parameters (electrical, mechanical)

2.1.1 GFSI – Global Food Safety Initiative

The *GFSI* was set up in 2000. In April, the directors of a group of commercial enterprises operating internationally agreed at a conference that *consumer confidence in foods and food safety* needed to be increased.

The aim of the initiative is therefore *to continually improve quality management systems* in the area of food safety, cost efficiency in the supply chain and, above all, food safety for consumers around the world. The GFSI currently recognises *five standards*.

The widely-used standards which are important in Europe include the *IFS* and the *BRC*. *SQF 2000* is almost irrelevant in Europe and is purely restricted to the USA. The other recognised standards are *Global Standard Food Version 5* and *Dutch HACCP*. These two are becoming less important and are now only encountered rarely. The standard *ISO 22000*, which is currently not yet recognised by the GFSI, is increasingly gaining importance, e.g. in Russia.



BRC: British retailers

IFS: EU retailers

SQF 2000: US retailers

ISO22000: Global standard

2.1.2 IFS International Featured Standard

In autumn 2001, *German business* decided to develop its own standard for the auditing of private brand manufacturers and to submit this standard to the GFSI. The IFS is now the most widely-used standard in Europe.

In principle, the IFS does not require that a detector is installed in the process. This depends on the result of the risk analysis. This is in comparison with the BRC, where a detector is mandatory. In this case it would be necessary to prove that there was no risk in order to be granted a derogation.

2.1.3 BRC – British Retail Consortium

The *BRC Global Standard Food*, Version 5, is a companion to the IFS standard required in the rest of Europe. Both the BRC and IFS are represented and recognised as standards in the GFSI (Global Food Safety Initiative). An important additional aspect of BRC certification is the *testing house*.

In some cases British companies have clear requirements about which testing house must carry out the certification. In general, only certification bodies *accredited by UKAS* are approved.

Similarly to IFS, on gaining the *BRC Global Standard Food certificate* the company is included in a database which is used by many retailers around the world. The requirements of the customers and the markets on which the product is intended to be placed decide on the need for certification as per BRC.

2.1.4 Conclusion

The calls for *standardisation of the standards* for manufacturers and suppliers in the food sector are growing ever so louder. For the most part, each standard only covers one sub-area, or does not resolve other sub-areas, which are also important. This results in multiple certifications.

It is noticeable that large European chains currently only accept the most widely-used standards, such as *IFS* or *BRC*. In addition, it is quite common for chains to *audit producers themselves*. However, this means that the actual aim is taken to absurdity, because the standards were originally only developed so that each trading company did not have to audit its producers itself in order to save time and money.

3. Preventative measures

3.1 Preventative programmes to avoid contaminations in the supply chain

The risk of contamination starts well before the production line. Often *raw materials* in particular are already contaminated with foreign bodies during collection. However, the *working environment* also contains a number of possible foreign body contamination risks. Therefore, in addition to the *detection and removal of foreign bodies* from the product, the focus of a company's foreign body policy is to *avoid contamination*.

In this case, consideration must be given to the following points, among others:

- raw material suppliers (e.g. metal or stones during harvest),
- packaging material suppliers,
- service providers in the supply chain (e.g. co-manufacturer or co-packer, transport, storage),
- other service providers e.g. cleaning of clothing, external maintenance / repair.

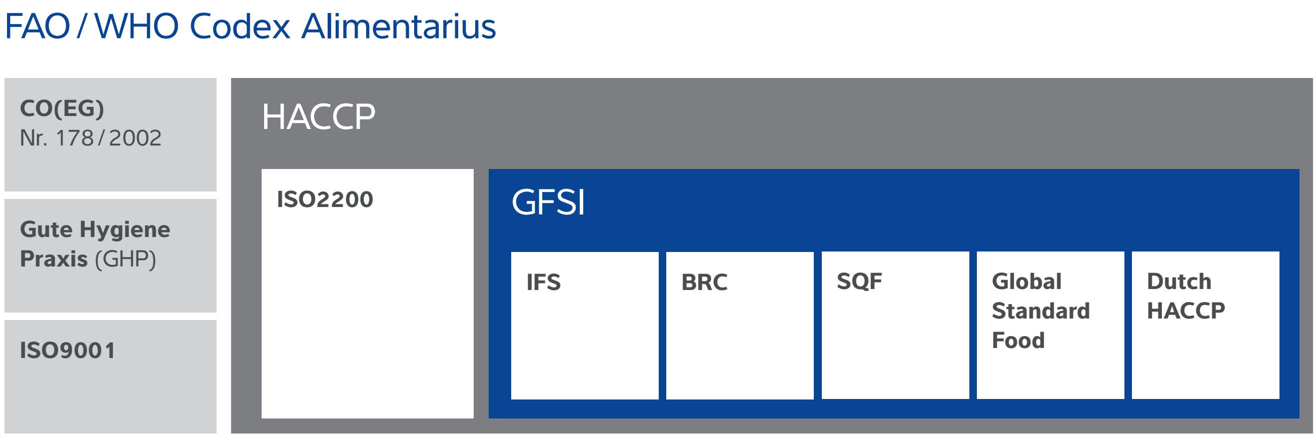
It is therefore hugely important to integrate the assessment of external processes into the internal hazard analysis. There should be checks of whether sufficient devices to avoid foreign body contaminations are present in the *supply chain* (e.g. digital visual inspections, magnet, sieves, detectors).

If the hazard analysis identifies that the *raw material*, a *packaging material* or the *service* has an increased risk, then preventative measures must be implemented to avoid this. Depending on the risk level, before the start of delivery these suppliers must be put through a *supplier audit* and consideration must in particular be given to the preventative measures to avoid or reduce physical contaminations.

For example, the following must be checked:

- if products are filled into glass bottles by an external service provider: preventative measures e.g. air cleaning, rinser, bottle check
- if a mill is used, the sensible application and use of magnets and sieves
- in the event of slaughter the use of metal detectors or x-ray devices (example: metal found in the tongues of cows).

The results of the hazard analysis must be considered in the supplier approval and in the regular supplier assessment.



Overview of international standards

Today, the *HACCP concept* is internationally recognised as a suitable, *food-specific concept* for prevention. *In each phase of food production* potential health hazards, such as nausea or death due to chemical, biological or physical foreign bodies, are identified and monitored.

There is then an *overview of all potential hazards* according to the HACCP concept. The subject of *metal detection* is the focus for *physical hazards*.

Potential hazards in the food industry

3.2 Preventative programmes to avoid contaminations within a company

A number of foreign bodies get into the products via internal production and storage processes. Therefore effective *environmental hygiene* is hugely important.

In this case, the type and scope of preventative measures also *depend on the hazard analysis* and the associated risk to the consumer´s health.

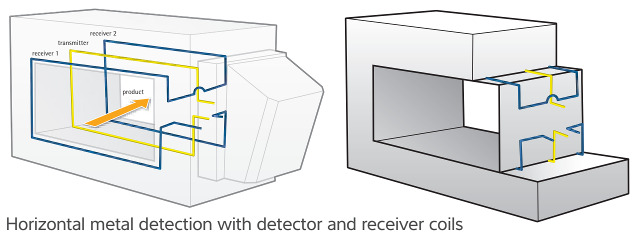
The following table provides some *examples of effective preventative measures*:

Preventative measure	Example for implementation
Systems	■ Monitoring of knives, scrapers and other tools (e.g. dough scraper)
	■ Tool boards at defined places in the company
	■ Defined contents of tool boxes, incl. regular monitoring
	■ Detectable cable ties
	■ Regular inspection of machine components (e.g. injector needle or cylinder breakage)
	■ No open process steps (incl. transport belts) where not explicitly necessary for technological reasons
	■ Regular inspection of the quality of system parts which come into contact with the product (e.g. plastic belts)
Personal hygiene	■ Ban on jewellery etc.
	■ Ban on artificial finger nails
	■ No open external pockets on work clothing
	■ No buttons, straps, eyelets or other parts which might become loose on the work clothing
	■ Avoiding glass and / or porcelain or other containers in the social areas
	■ Detectable plasters, protective helmets
	■ No personal objects in the production area; if not possible only in sealed, transparent bags provided by the company
	■ Use of writing implements without parts which come loose, if necessary detectable
Glass management	■ Protection of all glass objects in the production and storage area, including in social and sanitary areas
	■ Utensils (brush, dust pan etc.) also provided in the event of possible glass breakage
	■ Change of work clothing and shoes after glass breakage
Work environment / infrastructure	■ Avoidance of paper clips or similar items in the production / storage area
	■ Masking or replacement of glass windows
	■ Regular inspection of glass and hard plastic objects
	■ No flaking paint (ceiling, walls)
	■ No pipes etc. above the open product

4. Metal detection

4.1 Structure

In the food and alcohol, tobacco and drugs industries, *metal detectors* are used to avoid metal contaminations. They have a tunnel-shaped or round opening, through which the product is guided. Irrespective of the shape, the inside of a metal detector consists of *detector and receiver coils*, which are described in detail below.



Horizontal metal detection with detector and receiver coils

In simple terms, the metal detector is based on *three coils*. These are usually made of copper and are wound around the detector channel. The *dimensions* of the metal detectors are tailored to the standard *product dimensions in the production environment* of the food industry. At the same time, the design of the devices gives consideration to optimum alignment of the coils to the product. Round and rectangular detector coils are the standard shapes.

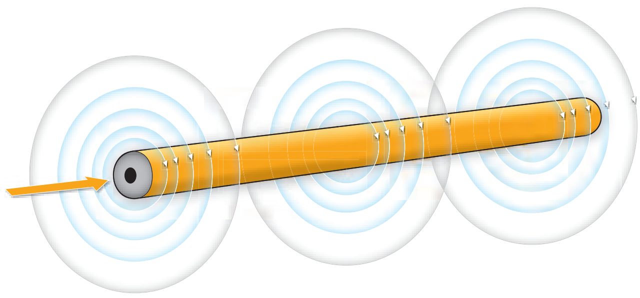
The middle coil is known as the *transmitter coil*. It transmits a high-frequency alternating electro-magnetic field. The two outer coils are the *receiver coils*. The receiver coils are mounted in opposite directions. The product is guided through the detection channel that this creates.

The *production quality* should therefore be considered at an early stage during the choice of a metal detector in order to prevent the signals drifting apart during the life cycle. High-quality *evaluation electronics* with "auto-calibration function" can also help to support the detection sensitivity throughout the lifetime.

The evaluation electronics connected to the transmitter and receiver coil is either integrated into the housing or put in a separate housing depending on the housing dimensions. As a rule, the operating unit (HMI) is also housed in this evaluation electronics housing but this is not mandatory.

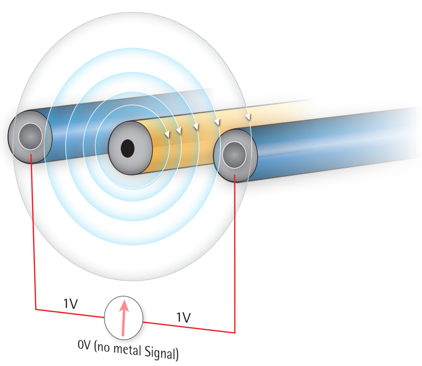
4.2 Mode of operation

A *constant equal spacing* between the three coils is required in order to achieve a reliable detection result. In order to guarantee this, the *coils must be secured* in a suitable manner. This is usually carried out by embedding in moulds intended for this purpose, which in turn are housed in a metal housing. Filling this housing with a suitable filling material prevents relative movement of the coils in relation to the stainless steel housing. At the same time, the housing has a shielding effect.


Schematic representation of a magnetic field around the transmitter

An optimum *evaluation* requires the signal of the two receiver coils to be perfectly balanced with each other. The decisive factors also include the *detection channel* and the *evaluation electronics*. In this area many metal detectors differ in terms of their quality and the resulting detection sensitivity.

The inductive coupling of the three coils is the basis of the metal detection. The two *receiver coils* are electrically connected together so that the voltages induced by the transmitter cancel each other out.



If the detector coil is perfectly balanced, the voltage is 0 Volts.

In the idle state, the total receiver voltage is ideally zero and changes if magnetic or electrically conductive objects are guided through the detector coil.

The reason why a metal can influence the electromagnetic field can be explained as follows: As soon as metal is subjected to a magnetic alternating field, a small eddy current is induced. The eddy current generates another magnetic field, which in turn is opposite to the field of the detector coil and influences this field.

The voltage, which is now different from the balanced status, then increases and is *electronically processed via software*, which can communicate a metal message if necessary, e.g. via a switch relay.

The *magnetic field*, which reaches the *receivers* from the *transmitter*, therefore changes its field strength, the amplitude as well as the phasing of the voltage within the receiver coils.

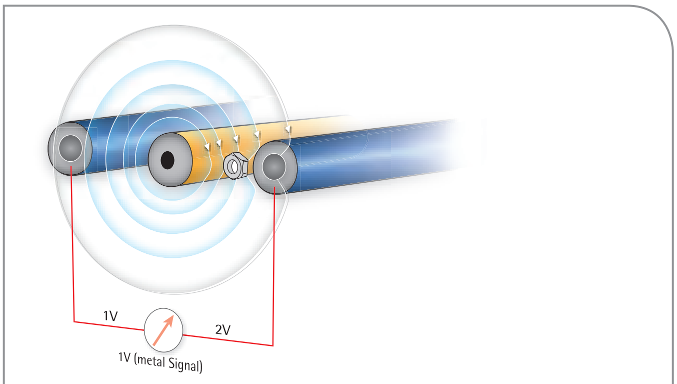
The *characteristic of metal* which allows it to generate an eddy current is known as "*conductivity*". Put simply: the ability of metal to conduct electricity.

The *"permeability"* of a material in metal detection identifies the ability of the material to be magnetised. A metal with a high permeability allows the eddy current *to flow through the metal easier than through air* due to its low resistance. Other materials, on the other hand, behave in the opposite way and obstruct the eddy current in comparison to air due to a high resistance. As these have different effects on the detector coils, in this case a differentiation must be made between magnetic and non-magnetic metals.

In principle, it is possible to differentiate between *two modes of action* of the metals to be detected on the generated electromagnetic field:

- Field concentration
- Field suppression

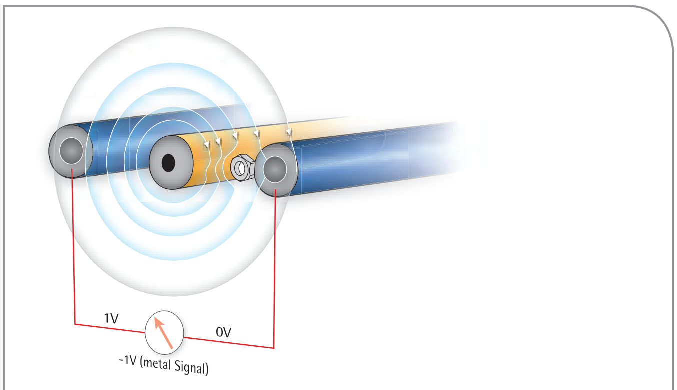
Field concentration
A concentration of the magnetic field lines is caused by all *ferromagnetic metals* (iron) and *ferrites*.



Concentration of the magnetic field lines

This effect is identified as *reactive*. Depending on the permeability (*ferromagnetic metals*, "*Fe*") this effect has varying strengths, but is always stronger than the effect of field suppression described below. At the point where the metal is located in the detector channel, there is local concentration of the field lines. This *change within the transmitter field* leads to different induction voltages on the two receiver coils and therefore to a *metal signal that can be evaluated*.

Field suppression
In the case of diamagnetic and paramagnetic metals (*stainless steels and non-ferrous metals*) there is *no field concentration* due to the permeability. In actual fact, the *alternating field of the transmitter* induces a voltage in these metals. A current forms depending on the electrical conductivity; in this context we also refer to "eddy current formation", which in turn creates a magnetic field.



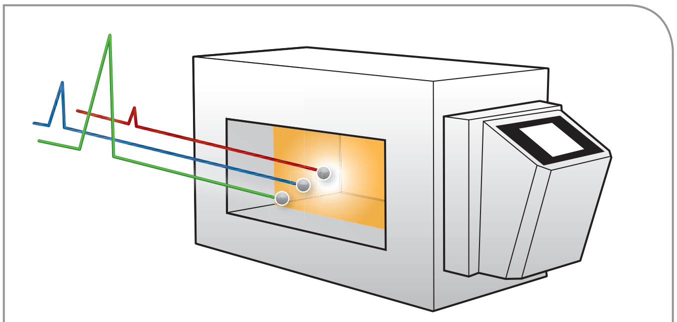
Field suppression in the area of the metal particle

According to "*Lenz's law*", the magnetic field created in the metal particle is opposed to the exciter field. The two fields repel each other and create *field suppression in the area of the metal particle*. The change caused to the received signal by the process leads to a measured voltage on the receiver coils, which is assessed as a metal signal.

4.3 Detector sensitivity progression within the outlet opening

The *detector sensitivity* of a metal detector within the tunnel-shaped opening is not homogeneous. This is due to the *field distribution in the detector tunnel* the proximity to the transmitter / receiver. The detection sensitivity decreases at a distance from the transmitter / receiver.

This means that the *least sensitive position is in the centre of the outlet* and/or at the point where the distance from the detector tunnel is the greatest. Therefore in detection sensitivity tests the metal part to be tested should preferably be guided *through the middle* of the detector coil opening in order to simulate the worst case. As a rule, every other position would produce a better detection result and therefore *feign a higher detection sensitivity.*



A test ball generates signals of different strength depending on its position within the detector tunnel

4.4 Factors influencing the detection result

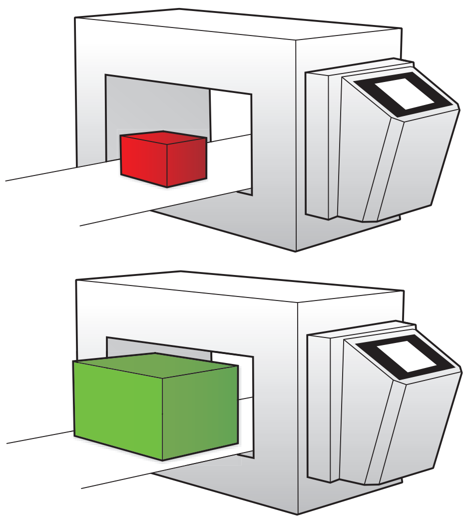
A number of factors may influence *the detection result that can be achieved*. These are explained in detail in the sub-sections below.

1. *Size of the detector coil outlet opening*
2. *Conductivity of the product (product effect)*
3. *Conveyor speed*
4. *Operating frequency of the detector coil*
5. *Different metals*
6. *Shape, location and position of the metal part to be detected*
7. *Ambient influences*

4.4.1 Size of the detector coil and / or outlet opening

The size of the *outlet opening* in a metal detector must be adjusted to the product to be examined.
The rule is: *the smaller the outlet opening, the higher the detection sensitivity that can be achieved*.

By implication, this means that oversized detector coils usually have a correspondingly lower detection sensitivity. When examining products with a high product effect (high conductivity), however, the detector tunnel dimensions should not be too small, because in this case reverse effects can occur if the "tunnel filling level" is too high. *As a rule of thumb, a filling level of 70% must not be exceeded for highly conductive products.*



Highly conductive products should not exceed a filling level of 70%

4.4.2 Product effect (electrical conductivity)

Some products from the food industry display a phenomenon known as "product effect". We speak of the *product effect* of a product to be examined if the product *causes a signal in the metal detector*.. Basically all products are conductive to a certain extent. The range varies from negligible to significant. Each product has different factors which influence its conductivity. This means that for some products the product effect can be ignored but for others these factors have a *significant influence on the detection sensitivity that can be achieved* (detection accuracy).

Metals are not the only materials which can be conductive and therefore generate magnetic fields. Salt water, for example, is a very good conductor with a very low permeability in comparison with metal. As soon as salt water is subjected to an electro-magnetic field, as already explained, eddy currents create a magnetic field.

If the product effect created by the product is big enough to cause the same magnetic field disturbance as a potential contamination, then the detection result becomes inaccurate.

4.4.2.1 Factors which influence the product effect

There are many factors which influence the properties of the product. These factors are also difficult to monitor during production. In order to consider the variance of all factors and to reduce incorrect eliminations, often the *detection sensitivity of the detector coil is reduced*. The more stable the influence factors, the more precise the detection result with a low incorrect separation rate.

- **Moisture and salt content**
  These influence factors may vary from product to product. The rule is: *the more inhomogeneous the product, the greater the effect*. A good type of this is meat: Each piece may be different depending on the cut and type of animal, mixture of marinade or consistency of the piece of meat.

- **Consistency / recipe**
  If the consistency and the recipe of the individual products are different, the permeability and conductivity, and therefore the influence on the magnetic field, will also be different. This applies in particular for *ready meals,* where the recipes for the individual packs may vary. The greater the variance / homogeneity of the recipe, the bigger the product signal that needs to be overcome.

- **Conductive and less conductive products**
  Due to the considerably larger volume in comparison with a metal part, it is easy to assume that the signal of a very conductive product may be greater than the signal of a small metal contamination. Therefore the product effect must be considered at all times.

As a rule of thumb, a differentiation can be made between "wet" (conductive) and "dry" (barely conductive) products:

Typical wet products	Typical dry products
Meat, cheese, bread, dairy products, fish, fruit, vegetables, ready meals and sauces	Frozen products, dry baked goods e.g. biscuits, cereals etc.

Metal detectors are able to *mask the product effect* or to minimise its signals. It is therefore important that consideration is given to any *changes in the product*, which influence the product effect. A change in the detection sensitivity can lead to *erroneous product ejections* (e.g. recipe change, temperature change, change in packaging material etc.). If these changes can be predicted or are planned, then corresponding "product variants" should be created in the product sort memory.

- **Temperature**
  The temperature of the product has a great effect on the *conductive capability* and its ability to generate a magnetic field. On a *frozen product* that is exposed to a higher temperature, *condensate* starts to form or the product may even start to melt. The *increased moisture* allows the eddy current to flow better than in the completely frozen product. *Even small changes of say 5°C* influence the signal received by the detector coil.

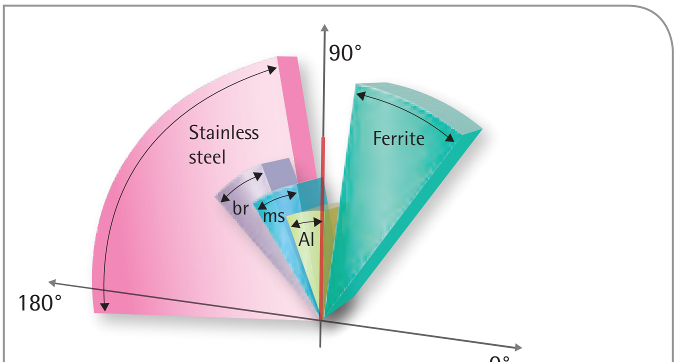
- **Product orientation**
  If even the *size* and the *shape* can influence the magnetic field, then it is understandable that the *direction* in which a product is guided through the detector can also have a similar effect.
  If, for example, a rectangular product is guided through with the head forward, then it looks smaller to the metal detector than if it is guided through sideways.
  It can be difficult to *control the direction* in the production line. It is not unusual for several products to pass the detector at the same time. This dramatically changes the variance of the product signal. The *position of the product* is therefore significant for the detection result. Remember that the centre of the metal detector has the weakest detection sensitivity.
  A product that passes the detector at the side of the device achieves a stronger signal due to the product effect.

- **Shape and size of the product and / or product amount / dimensions**
  Pre-packed foods usually have *comparable to identical product characteristics* in terms of shape and size. This is in contrast to products not produced conventionally, which may differ in terms of size, shape and recipe.

- **Packaging & material**
  Nowadays there is a large range of packaging materials in the food and pharmaceutical industry. Many of them only have a small effect on the detection sensitivity. Packaging made of aluminium foil, on the other hand, has an effect that should not be underestimated. Its thin aluminium layer may indeed have a similar magnetic permeability to air, but the high conductivity has a great influence on the magnetic field in the metal detector.
  Using aluminium foil can therefore make metal detection harder. As a rule, it is therefore recommended that the product should go through detection before it is packaged.

4.4.2.2 Masking the product effect

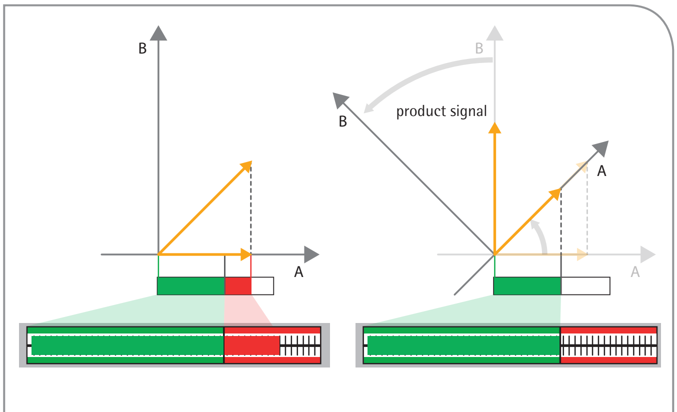
It is possible to consider a *metal signal as a vector*, whereby the *phase angle describes the metal type* and the *amplitude describes the metal size*. This relationship is shown by the graph – a vectorial diagram for a particular working frequency. The different metal types iron (Fe), non-ferrous metals (Al, Ms, Br) and non-magnetic stainless steel (wide range depending on the alloy) have considerably different phase angles. Magnetic stainless steels such as 1.4034 behave like iron, and the strong ferromagnetic effect is used for detection.



Vectorial diagram for different metal types

The masking or also "*learning of the product effect*" (minimising) is achieved by *recognising the product signal vector angle (phase angle)* and then minimising this (see graph). It is not only metals, but also conductive products, which have a quite specific phase angle.

In this case it must be considered that when masking product effects with a phase angle similar to a particular type of metal, this can cause a *reduction in the detection sensitivity* for this particular metal type.



Different phase angles allow for targeted reduction of the product signal

4.4.3 Detection sensitivity of a metal detector in the production environment

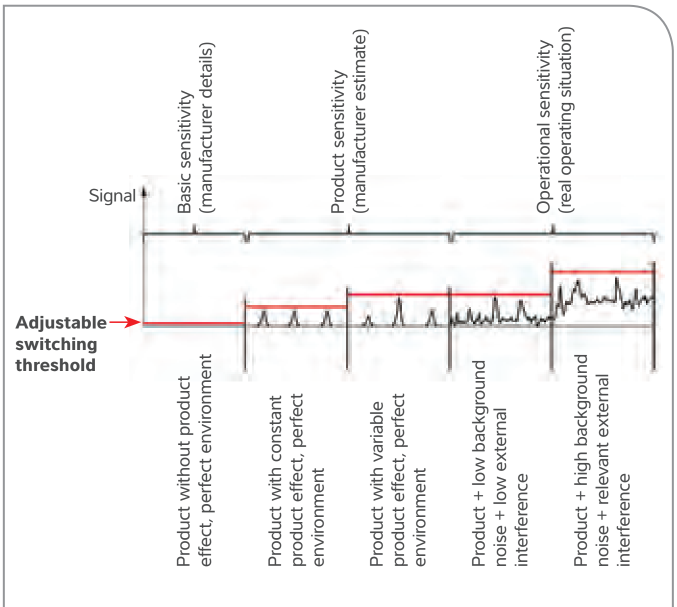
As it is almost impossible to predict or to measure the *conductivity of a product*, a statement about the detection sensitivity that can be achieved can only be considered as an "estimate based on empirical values" without a test with original products.

When assessing the *performance of a metal detector* in this context, the *terminology* relating to detection sensitivity is also important. In this case the manufacturers differentiate between *basic sensitivity, product sensitivity* and *operational sensitivity:*

- **Basic sensitivity**
  The basic sensitivity of a metal detector *is the maximum sensitivity that can be achieved excluding any ambient disruptions*. The proof of the basic sensitivity is provided in a setting defined for the metal detector type.
  With closed coil bodies, the basic sensitivity must always be able to be achieved when passing through the detection tunnel. For lower belt detection coils, the basic sensitivity depends on the distance from the detector coil.

- **Product sensitivity**
  The product sensitivity of a metal detector is the maximum achievable sensitivity that can be achieved *at every position in the product* in a product conveyed through the detector coil. It depends on the conductivity of the product (product effect), the amount of the product which is shortly before and after and within the detector coil at the same time, on the properties of the product and on the type of product transport.

- **Operational sensitivity**
  The operational sensitivity of a metal detector is the *maximum achievable sensitivity in consideration of possible ambient disruptions* such as e.g. the transport type (continuous / discontinuous), the conveyor speed, the conveyor belt etc., as well as other possible restricting factors which may result from the application, such as e.g. non-compliance with the metal-free zone (MFZ), shorted windings, joints, etc. In addition, for example, existing static charges and discharges and sources of magnetic disruption may result in a reduced operational sensitivity.

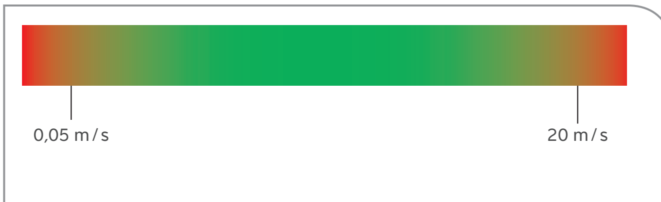


Product and environment determine the detection sensitivity of a metal detector

4.4.4 Conveyor speed

Metal detectors are able to guarantee *consistent detection sensitivity* over a large range of conveyor speeds. Only in the event of conveyor speeds of *less than approx. 0.05 m / s* (e.g. in the case of wide conveyor belts with lots of products positioned in parallel) or *more than approx. 20 m / s* (e.g. in the case of overpressure or vacuum tube transport) is it possible that the attainable detection sensitivities may differ from normal values.

In the case of *discontinuous conveyor speeds* (e.g. stop & go operation), it must be considered that there will therefore be reduced detection sensitivity when the critical conveyor speed is not met.

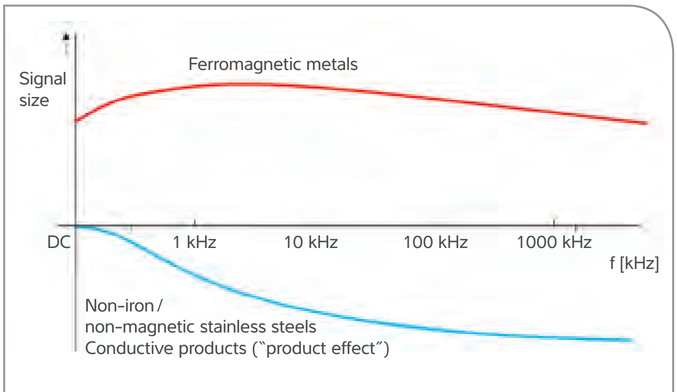


Consistent detection sensitivity across a large range of conveyor speeds

The minimum and maximum values for the transport speed usually *do not limit the performance* of metal detectors. This is particularly true for applications with belt systems. The *limits* vary depending on the manufacturer. Minor modifications may be able to increase the maximum speed still further. In the case of inspections in *pneumatic conveyor systems*, the performance limit is reached at speeds in the range of 20 m / s.

4.4.5 Operating frequency of the detector coil

Metal detectors work with *fields* in ranges between approx. 1 kHz and 1 MHz. In principle, *stainless steels* and *ferrous metals* can be detected better at high frequencies due to the electromagnetic field mechanisms already described.



Metal properties and product effect influence the signal

However, as the *product effect* of the products to be investigated often generates even greater (disruptive) signals at higher frequencies, the choice of higher operating frequencies is not always productive and if necessary there may need to be a *compromise in the choice of frequency*.

Metal detectors should be able to set the *optimum frequency range* using suitable *teach-in procedures*. However, a constant detection sensitivity *across the entire speed range* is more important than the minimum and maximum speed. The speed ranges may vary from manufacturer to manufacturer.

4.4.6 Different metals

In addition to the differentiation between *field concentration* and *field suppression*, metal produces other differences due to its characteristic *metal properties*.

Each metal produces its own typical metal signal in relation to the transmitter voltage. This therefore results in different detection sensitivities of metals for each metal type.

For convenience, for metals it is possible to differentiate between three categories.

- **Ferromagnetic metals ("Fe")**
  All metals which can be easily attracted by a magnet (e.g. steel). Iron is the easiest metal to detect.

- **Non-ferromagnetic metals ("NonFe")**
  Non-magnetic metals with high conductivity (e.g. aluminium). Due to their conductivity, these metals generate a similar signal to iron in dry products.

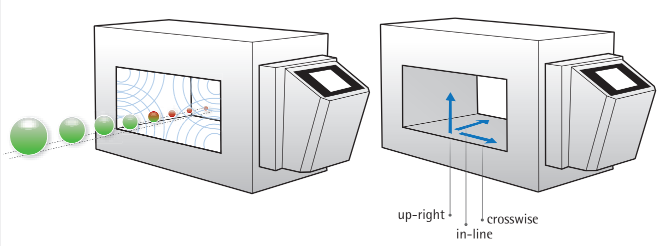
- **Non-magnetic stainless steel (SS)**
  Stainless steels of higher quality from the AISI 300 series (e.g. AISI 304). Due to their low conductivity and permeability, these metals are relatively hard to detect.

Metal type	Magnetic permeability	Electrical conductivity	Detectability
Ferrous (chrome steel)	Magnetic	Good electrical conductor	Not detectable
Non-ferrous (brass, lead, copper)	Non-magnetic	As a rule good or very good	Relatively easy to detect
Stainless steel (various alloys)	As a rule not magnetic	As a rule poor conductivity	Relatively hard to detect

Overview of the effect of different metal types on a metal detector

4.4.7 Shape, location and position of the metal part to be detected

The *detectability* of *metal objects* depends on the position in which the metal particles go through the detector tunnel. A ball always has the same geometric proportions, no matter which direction it is facing. However, a metal part that is not symmetric, such as a piece of wire, will cause smaller or larger signals depending on how many "field lines" are influenced.



Depending on how many "field lines" are influenced, the signal is stronger or weaker

As already described, an *electromagnetic field is generated in the metal detection tunnel.* This results in a particular field line distribution and field alignment. *The extent to which the field symmetry is disrupted* is decisive for the detectability of metals. The transmitter field can only induce voltage in those metal particles which are in a different direction to the magnetic field lines. This results in direction dependence for the best sensitivity for wires, which is also dependent on the metal type. The following table shows that iron, for example, behaves in a contrasting manner to stainless steel and non-ferrous metal. In the worst case, the detectable dimension corresponds only to the diameter of the wire and not to its length.

	Metal type		
Location of the metal part in relation to the transport direction	**Iron (Fe)**	**Stainless steel (VA)**	**Non-ferrous metal**
■ Lengthwise	good	poor	poor
■ Upright and crosswise	poor	good	good

Position dependence within the detector coil

In this case it is assumed that the wires are homogeneous entities. The comparison becomes much more difficult if you act on the basis of the shavings that occur in practice. The structure of a shaving is inhomogeneous, porous and therefore produces less signal than a wire.

For reasons relating to the reproducibility of test results, it is therefore not productive to use test parts which are asymmetric.

Therefore *only balls* are suitable for use in tests. Balls are symmetrical and always generate the same, *reproducible*, position-independent measurement results, no matter how they are rotated or turned.

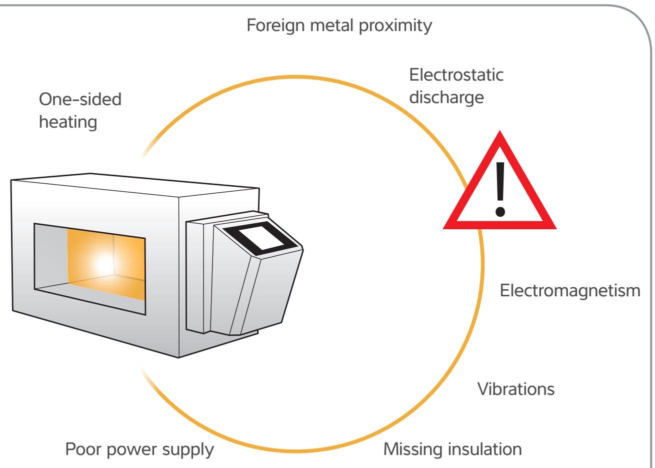
Precision balls allow for precise measurement results

Test balls should generate signals which do not exceed *specific tolerances*. Therefore metal detector manufacturers should *check the signal amplitude and phasing* of test balls before using them as measuring tools.

The carrier material for the test balls must *not generate any significant signal falsification*, as ultimately it is the metal ball that needs to be measured and not the signal of the carrier material. As long as this is ensured, it is not significant whether plastic cards, balls, rods, tablets etc. are used, whereby the labelling and unique identification of the test pieces is problematic for some shapes (e.g. balls). In these cases, *reference tests with say test cards*, which can usually be labelled most completely, are recommended.

Example images of test pieces with integrated test ball

4.4.8 Ambient influences



Overview of factors which influence the metal detector

Ambient influences may *affect the detection result*. The following measures should therefore be used to avoid/minimise disruptive ambient influences.

- **Power supply**
  Shielded cables must be used for the power supply lines to motors and inverters, in which case the shielding must be on both ends to ground. However, if cables in the area of the detector coil need to be laid outside of the "metal-free zone", then importance must be placed on getting the *greatest possible distance* and on the shielding precautions. Cables must be placed *lengthways* to the detector coil passage (= direction of transport) and never crosswise to the passage.

- **One-sided heating**
  When specifying the installation location of the detector coil, it must be ensured that the detector coil is not subjected to *one-sided direct solar irradiation*. Solar irradiation or another one-sided strong heat source, such as a furnace, leads to uneven heating of the detector coil housing and therefore to mechanical warping, which may lead to failures.

- **Foreign metals**
  Vibrating or moving metal parts, such as rollers, guide plates, sheet metal coverings, covers, walkways etc. may not be located in the area of the "*metal-free zone*". Moving metal parts (passive disrupter) have a direct effect on the magnetic field and result in failures. *Magnetic steels* and *stainless steels* have a greater effect on the magnetic field than *non-magnetic stainless steels*.
  This means that non-magnetic stainless steels, which cause smaller disturbances than comparable magnetic materials, can be brought nearer to the outlet opening of the detector coil if necessary.

- **Electrostatic discharge / conveyor belts**
  If possible, an "*antistatic*" belt must be used.
  "Antistatic" belts have no influence on the magnetic field of the detector coil and are therefore optimally suited for use in conjunction with metal detectors.
  It must be ensured that the "non-antistatic" belt does not become electrically charged resulting in electrostatic discharge. If an electrostatically chargeable belt needs to be used for technical procedural reasons, then it must be anticipated that there will be interferences with the sensitivity due to the disruptive signal caused by the belt connection points. The conveyor belt must not have *any metallic inclusions*.
  Metallic inclusions may occur if there is welding or grinding on the belt structure and welding or grinding beads fall on the belt and anneal there. If the conveyor belt is separated for installation of the detector coil, then it must be ensured that no metal shavings penetrate when roughening the surface for adhering (do not use steel brushes) and that adhesive containing metal is not used during curing. Rubberised rollers can be used in order to avoid metallic contaminations of the inside of the conveyor belt caused by heavy wear on the top and bottom rollers.
  In order to achieve the *greatest possible detection sensitivity*, it must therefore be ensured that the belt does not come into contact with normal steel, i.e. pulleys and runners must be coated with plastic.

- **Electromagnetism**
  Motor drives, in particular regulated DC drives and three-phase drives, with or without frequency converters and their supply lines must be mounted / installed as far as possible from the detector coil. The *EMC Directives* must be observed throughout the operation, in particular in relation to cable shielding of frequency-regulated drives.

- **Vibrations**
  In order to *minimise relative movements* between the belt structure and the detector coil, the *rubber-bonded metals are replaced with fixed insulation pieces*. In this case, twisting of the detector coil must be prevented. The belt structure must not cause any strong vibrations which transfer to the detector coil. This can be corrected using a *separate bracket* or a *separate base*.
  The bracket must consist of a *securely welded* structure.
  The bolted brackets can form a variable shorted winding, which leads to accidental activations.
  The *footboards* of the conveyor belt and bracket must be securely *anchored* in the base so that the two structures cannot shift or move relative to each other. The detector coil must not be subject to any relative movements in relation to metallic parts in the area of the detector coil magnetic field.
  The detector coil is secured to the belt structure or to a separate bracket using rubber-bonded metals.
  The detector coil may not be earthed externally.

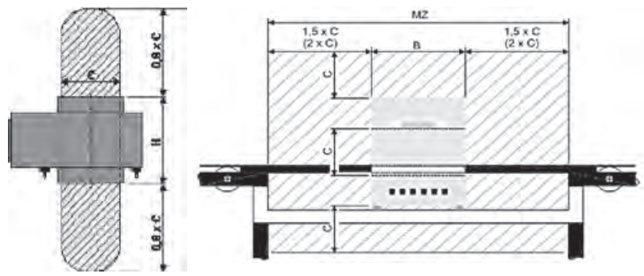
- **Insulation**
  Bolted belt structures, loose plates, walkways, chain drives or non-insulated roller stations lead to *shorted windings*. The critical point about shorted windings is that they *suddenly appear* or *disappear* depending on *vibration* or *temperature*.
  This can be corrected by insulating possible shorted windings (recommended) or using fixed welding (caution: observe the notes on welding work). Feed and discharge belts must be neither mechanically nor electrically connected with the metal detector belt.

The *base feet of the detector coil body* must usually be equipped with rubber buffers, which have three functions:

- electrical *insulation* of the detector coil body in relation to the supporting structure (e.g. conveyor belt frame)
- *absorption* of vibrations from the supporting structure
- *prevention of bending and torsion forces* in the detector coil body due to bolting to the supporting structure.

4.4.9 Metal-free zone

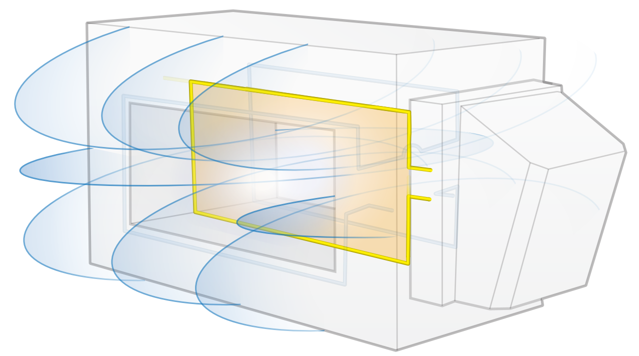
The *stainless steel housing of the metal detector* ensures that the majority of the magnetic field lines remain within the housing. Nonetheless, a few field lines come out of the outlet opening and close in the surroundings of the metal detector. This effect can be minimised using special housing measures, but it can never be completely prevented. *Detector coils with reduced metal-free zone* are current state of the art. Field lines penetrating outside can obviously also be influenced outside of the metal detector. Therefore it is common for metal detectors to provide a zone directly in front of the outlet opening in which there must not be any metal.



The metal-free zone is usually 1.5 times the tunnel height, and for round shapes between 0.64 and 0.8 times

The *dimensions of this metal-free zone which must be maintained* can be found in the data sheets from the relevant manufacturers. However, as a rule it is a distance on both sides of 1.5 times the tunnel height, or for round shapes between 0.64 and 0.8 times the tunnel diameter.

In this zone in particular there must not be any moving / vibrating conductive objects / structures such as metals. For particularly large moving metal parts, it may be necessary to maintain a larger metal-free zone.



Part of the electro-magnetic field is outside of the detector tunnel.
Therefore a "metal-free zone" must be taken into consideration in this area.

5. Validation & verification

When implementing an *effective procedure for foreign body detection*, various terms are frequently used.

Due to the particular relevance, this chapter provides an explanation of the terms *validation* and *verification* as well as their different meanings.

5.1 Validation

The term "valid" comes from the Latin "validus". In order to control hazards related to foods, *monitoring measures are used throughout the entire food chain* from primary production, through to processing and right up to consumption by the consumers. In this case, validation of the monitoring measures (e.g. CCP, CP) is very important. Through validation you get proof that the control measure or combination of control measures selected for a particular hazard or risk *is able to control this particular hazard*. Therefore consideration is given to the specific use / application. This is not the case for verification. An example may make this clearer: A CCP is regularly examined in terms of compliance with the intended limits. A target-actual comparison is carried out, i.e. a verification. During the *validation of the CCP*, there is an analysis of the extent to which the intended use or purpose of the CCP is fulfilled. The purpose is to reduce the risk for the consumer to an acceptable risk.

This can only be assessed, or validated, if *information is collected and assessed over a defined period* which proves the effectiveness of the CCP. If, for example, there is a CCP in the area of metal detection and there are increased customer complaints relating to metallic foreign bodies in the product, then this is an indication that the CCP is not valid. Further measures need to be taken in this area.

The process validation must be carried out on the basis of the relevant data collected for product security and processes. This will also be discussed in the sections below. If significant changes are made to processes and / or systems, then validation must be carried out again.

5.1.1 Validation in practice

The origin and type of any foreign bodies that are screened out must be checked. In this case, there must be not only visual checks, but also a *systematic examination of the separated products* using other procedures, e.g. a detector. This means that possible hazard points in the company can be detected and reduced or avoided via process or system adjustments.

5.1.2 Validation of metal detector systems

Validations must be recorded in writing. The records contain, among other things, the following *information*

- the tester
- the test procedures
- the test objects
- the test equipment
- the test results and
- date and time

It is recommended that the following system is used for the procedure, but this may vary depending on the system and equipment:

1. *Examination of the scope of delivery*
2. *Examination of the application*
3. *Examination of the machine functions*
4. *Examination of user training*
5. *Examination of compliance with all local statutory requirements (only X-ray)*

Note on point 1:

Examination of the scope of delivery

Checking the delivery mainly involves comparing the order with the order confirmation to the scope of delivery, e.g.:

- Checking for transport damage
- Checking machine type / no
- Checking the machine dimensions
- Checking the dynamic specifications (speed, movement direction etc.)
- Checking all mechanical options
- Checking the software (e.g. version, languages, activation of options)
- Checking all documents, e.g.
  - Customer specification
  - Offer
  - Order papers
  - Order confirmation
  - Material certificate
  - CE certificate
  - Transport + installation instructions
  - Commissioning instructions
  - Operating instructions
  - Spare parts list
  - Maintenance instructions
  - Calibration instructions
  - Mechanical drawing
  - Cable plan

Note on point 2:

Examination of the application

The examination of the application considers the comparison of the stated project request application data with the current actual application data, for example:

- Description
- Contents
- Packaging
- Weight
- Temperature
- Length
- Width
- Height
- Throughput (production units / min)
- Feed speed
- Miscellaneous

Note on point 3:

Examination of the machine functions

The *examination of the machine functions* checks the extent to which the requested functions match the supplied functions.

This includes

- Complete *initial commissioning* according to the operating instructions (which it is sensible to do with assistance from a service technician from the device manufacturer).
- Setting up all *relevant product types* according to the operating instructions.
- Checking the *detection sensitivity* (for each CCP, appropriate critical limits must be defined in order to be able to clearly identify when a process is not under control.)
- If possible, *all product variants* must be tested.
- Test series of *60 products* each are common, or more depending on the variation in the product characteristics.
- The test must be carried out under *production conditions that are as real* as possible.
- Product settings must be found for which *non-contaminated products* do not cause incorrect ejections.
- At the same time, product settings must be found which reliably achieve any possible contractually agreed, internally specified or determined detection sensitivities. Suitable test equipment (test balls in carrier material) will be required for this purpose.
- In relation to the test procedure, refer also to the explanation of verification in the next section.
- Test of the ejection function.

There must be examination to ensure that there is *correct product ejection* at all defined belt speeds, product dimensions, product spacings etc.

- Test of the monitoring functions
  - Separation monitoring
  - Fill level monitoring
  - Compressed air monitoring
  - Collection container door monitoring
  - Light barrier cross-check
  - Product distance monitoring
  - End position monitoring (for drop shaft systems)

It is necessary to check that there is a *correct error message / signalling* (lights, belt stop etc.) by intentionally causing an error (e.g. compressed air regulation, interrupting the power supply, light barrier interruption etc.)

- Checking the interfaces, e.g.
  - External outputs
  - Data transmission
  - Belt drive control
  - Emergency stop functions

It is necessary to check that there is correct interface functionality by activating any relevant events.

Note on point 4:

Examination of instruction and user training

Organisation of the required basic knowledge for the relevant operating personnel.

- Who has been trained?
- For which individual subjects was training provided?
- Who conducted the training?
- When was the training conducted

It is necessary to check whether the process can be carried out adequately without external assistance.

Note on point 5:

Examination of compliance with statutory regulations

Comparison of fulfilment of all locally required regulations. This includes checking the extent to which the following points are required:

- qualification of the operator
- qualification of the maintenance personnel
- type approval

It is necessary to check whether the system can be operated safely and legally in the long term.

5.2 Verification

The term "veritas" comes from Latin and means "truth". The *verification* takes place *during or after implementing an inspection measure*, e.g. a CCP.

This includes, among other things, inspection of the monitoring activities and assessment of records. The verification provides continuous confirmation that the inspection measures implemented work as justified in the hazard analysis.

The verification of the *detection sensitivity* may depend on its application. In the case of freefall applications in particular, there are more complicated conditions in comparison with applications on the conveyor belt.

5.2.1 Verification of the detection sensitivity of the metal detector

5.2.1.1 Verification on the conveyor/metal detector belt

- **Test piece and product together**
  The signal recognised by the metal detector is always made up of the metal and product signal together. For a product with product effect, it is therefore important that the detection sensitivity test is carried out with a prepared original product. In this case the test part must not be placed on or under the product, but instead within the packaging.

- **Testing different metal types**
  Standard practice is to carry out a test for each metal category FE, NonFE & SS (see "Different metals" section). In this case, the metals which actually represent a risk should be used. – If necessary, additional metals with a particular contamination risk.

- **In the centre of the detection coil**
  In tests of metal detectors, the metal part should always be guided through the middle of the detector coil opening in order to simulate the worst case. Only in this way can the worst case be represented and tested. When inserting the test piece into the product, the user must ensure that this position is used.

- **Check product separation**
  When there is automatic product separation, the response characteristics should also be checked. The question is, among other things, does the separation unit discharge at the right time? Therefore tests should also be carried out with a test piece at the start, in the middle and at the end of the test product. The three test pieces should be checked in the stated order within the defined product distance. Only in this way is it possible to ensure that there is sufficient time between the signal which was caused by a contamination and the separation of the product.

- **Documentation of the result**
  Consistent documentation allows for *complete tracking*. The document should include the following points as a minimum:

  - *Identification of the test device* (e.g. serial number)
  - *Product description* (e.g. item, batch number)
  - *Description of the test procedure* (e.g. "test with 1 mm stainless steel ball")
  - *Test result*
  - *Name of the person conducting the test*
  - *Date, time and if applicable, shift*
  - *Corrective measures taken after error message*
  - *Note about possible incidents* (e.g. production downtime, machine failure)

In addition, all metal messages, error messages and batch-relevant data not due to the test must be recorded so that any problems can be reacted to promptly.

5.2.1.2 Verification of the freefall application / drop shaft

All *requirements* which apply for the conveyor / metal detection belt also apply for the drop shaft. However here, due to the application, the implementation is different because there are *more complicated basic conditions*.

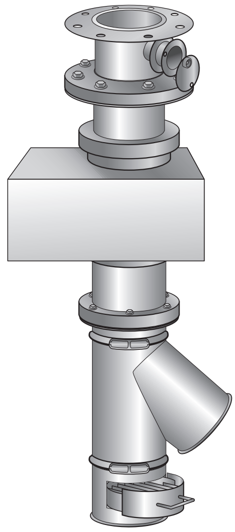
There are systems specifically for drop shaft applications, which allow for *verification and validation of the detection sensitivity in the product flow*. This means that regular testing of the metal detector can be cost-effective. These systems offer various components which ensure *realistic performance validation*.

Test piece opening
This is an access point above the detector coil, which can be shut off and prevents the product from escaping. Test pieces, usually test balls, can be inserted at this access point with a "test piece applicator". The applicator ensures that the test piece is dropped precisely *in the middle* of the conveyor tube and falls *through the least sensitive part* of the detector coil.

Test piece stopper
A *safety grid* is positioned underneath the separator in the *good flow*. The testing of a detection system aims to bring it to its limits in order to determine limit values. This also includes exceeding the limits. If the foreign bodies do not generate a *sufficient signal* during the performance test or the separators do not reach the separation position *at the correct time*, then the *test piece stopper* prevents the test piece going into the subsequent production process.

Depending on the structure of the *bad flow* for the separate product, it is recommended that this kind of test piece stopper should also be used for this area to simplify the removal of test pieces.

The safety grid can be permanently removed so that the product flow is not impeded outside of the verification process. For applications with bulk materials, the test with three test pieces at various positions in the product is not used in the way that is familiar for piece goods.



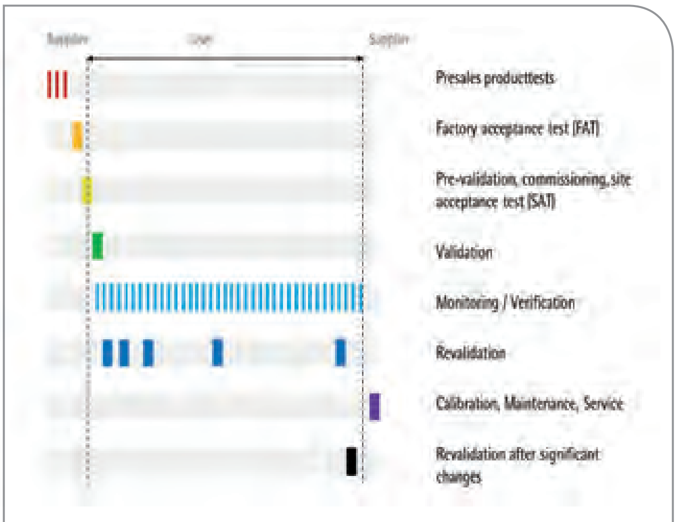
The test piece can be guided into the middle of the detector coil via an opening above the coil (test piece opening). The test piece stopper in the good flow catches the test piece.

Errors detected by verifications:
Recommended measures
Examination of the system before restarting production and repeat detection of all products which have moved through this CCP since the last positive test.

Error message from fail safety function:
Recommended measure
Belt stop, inspection and maintenance of the system before restarting production.

The measures listed in this section are *recommendations* and are not binding but may become mandatory or even be extended as a result of customer requirements.

5.2.1.3 Verification interval



Overview of all tests on the metal detector

The *test frequency* depends on *batch size and duration*. After a detection system error has been detected, all corrective measures must be introduced which were implemented for the last positive inspection. Possible measures are then to put the produced products through detection again or to discard them.

The test frequency is mainly based on economic considerations. Sensible test intervals would be: *at the start of a batch, end of a batch, shift change, product change, after repairs and in the event of parameter changes*. In addition, hourly checks are indeed common but they are also not a mandatory requirement.

5.2.1.4 Metal detector maintenance

The following criteria are relevant where necessary (depending on device type) for metal detector maintenance:

- **Daily checks**
  - Checking and, if necessary, cleaning of light barriers / sensors
  - Checking for interference signals e.g. belt contaminations
  - Early warning messages for the system

- **Monthly checks**
  - Checking the ball bearing for wear
  - Checking the conveyor unit (motor in particular)
  - Checking the transport belt
  - Checking the separator unit

- **Annual checks**
  - Annual maintenance by service technician from the manufacturer

An inspection of the *test equipment used* (test balls) and their interval should be carried out via hazard analysis. Magnetisation of the test pieces could be a possible cause of faults. The inspection should be carried out by specialist companies.

6. Separation process for metal detectors

Depending on the result of the *risk analysis within the HACCP concept*, metal detectors are used within the production line or at the end of a production line.

It is inevitable that some of your products will not meet the safety requirements and risks must be detected via the critical control points.

If this case arises, then *separation* will be needed via the separation process. The different forms of product separation will be shown and explained in detail below.

These systems are often an *integral part of the metal detector*, but free-standing or independent mechanical solutions are not uncommon.

6.1 Manual sorting of the contaminations with belt stop and alarm message

Metal detectors allow for the *activation of a signal lamp* and an *acoustic signal emitter*, as well as the triggering of a belt stop. The user is now responsible for removing the product from the production process. This solution is used in particular for very heavy products where automated separation would be complicated.

The key *disadvantages of this approach* in comparison with the automatic separation units listed below is the risk of the operator acting incorrectly (human error) and the reduction of overall system efficiency.

6.2 Automatic separation mechanisms

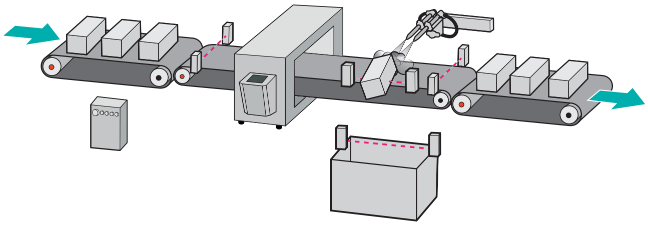
Various types of separation systems are available. The choice of the correct system depends on numerous factors, such as type of environment, belt speed, product weight and product size.

6.2.1 Pulse blow out ejector

A simple *compressed air nozzle* is the ideal solution, for example, for packages under 500 g. Stronger compressed air nozzles can also be used for heavier products.

This sorting system consists of a compressed air nozzle which emits a *high-pressure air pulse*. The air flow that this creates blows the contaminated product off the conveyor belt.

Whether or not this solution is feasible greatly depends on the *air resistance* of the product. The *product distribution within the packaging* also has an influence. It requires constant availability of compressed air.



Metal detector belt with pulse blow out ejector

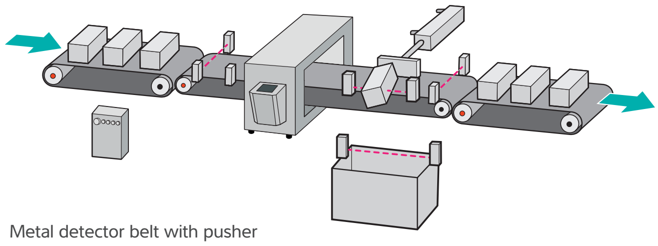
6.2.2 Pusher

Pushers can be used for a *variety of products*. They consist of a *compressed air cylinder* and a *plate*. During separation, compressed air is used to extend the plate, which pushes the product from the conveyor belt. This separator is suitable *for light products* up to 7 kg.

For very flat products, there is a risk of *squashing under the pusher plate*. It is therefore recommended that a brush should be fixed under the pusher plate for flat products.

Pushers for heavy loads are available. They cause very strong forces, which must be considered in the structure and in machine safety and therefore are only recommended in rare cases.

For *successful separation*, it is important that the pusher meets the middle of the product and that the product does not absorb the impact by buckling. This can damage products.

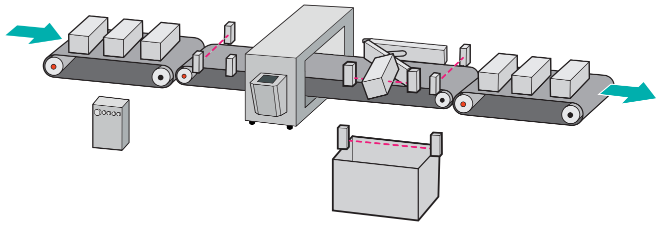


Metal detector belt with pusher

Swivel arm

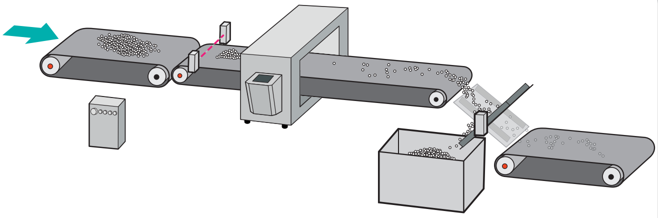
A swivel arm can *carefully deflect* the product flow of products. It is particularly useful in comparison with pulse blow out ejectors or pushers in the case of *fragile products*. In this case it is also recommended that a brush should be used for flat products.

The separation device is also used in combination with gravity roller conveyors. In this case the product usually remains *undamaged in its original position* and does not tip over like in a collection container. *Low-friction conveyor belts* are beneficial here so that the product can be moved across the belt without a lot of resistance.



Metal detector belt with swivel arm

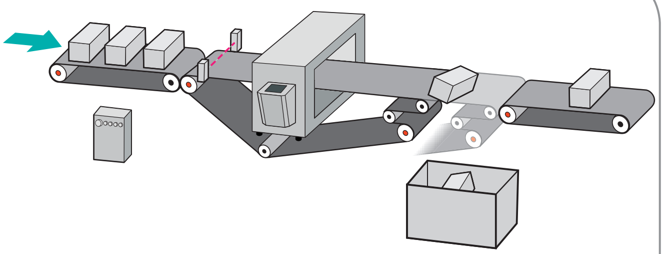
Flap / trapdoor
For this type of separation there needs to be a *height difference in the production line*, which is bridged by a *slope* in the belt system. The pivot point can be varied according to the application. This ejection type is suitable for small, non-ordered individual products or unpackaged bulk goods (dry or sticky) which are transported on a flat, wide or curved belt system.



Metal detector belt with flap

6.2.3 Telescopic conveyors

The *tensioner* at the end of the conveyor belt is retracted, which creates a *gap in the conveyor belt* through which the product can fall. As soon as the separation process is complete, the tensioner returns to its original position and closes the conveyor belt. This is particularly suitable for multiple track applications.



The telescopic conveyor separation system allows products to fall through a gap

6.2.4 Separation mechanisms in the freefall application

Bulk goods applications are very different from piece goods when it comes to product separation.

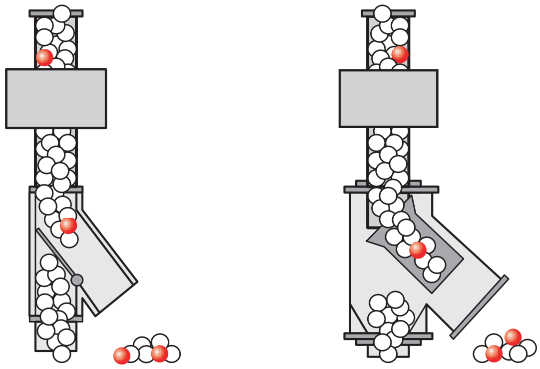
In comparison to piece goods applications, the detection units usually consist of *very small detector coil openings* with a *very high throughput*. There is often also a very *high detection sensitivity* in comparison to metal detection on the conveyor belt.

The *separation* is comparable with the swivel arm, which diverts the product flow into the bad flow. It is possible to differentiate between two different procedures.

- In the *first procedure*, a *flap* is operated which interrupts the product flow and diverts it into an opening that is created. In the case of *fine product*, dust deposits can form in this area. For very fine grain sizes, it is therefore recommended that the *dust-proof separator* is used, as otherwise there is product loss at the opening to the bad flow.
- In the *second procedure*, the *entire conveyor tube is diverted.* There is a permanent, but small, interruption in the tube, but this cannot be sealed to be dust-proof.

Both procedures use a compressed air cylinder in order to move to the separation position.
In this case it must be considered that there must be sufficient space between the metal detector and separation unit. This ensures that the separator is completely and reliably in the separation position before the contaminated product reaches this process.

This process should be carried out *without batches or backing up*. The freefall systems are not suitable for backing up because it is not possible to trace the contamination in the bulk material within the tube.



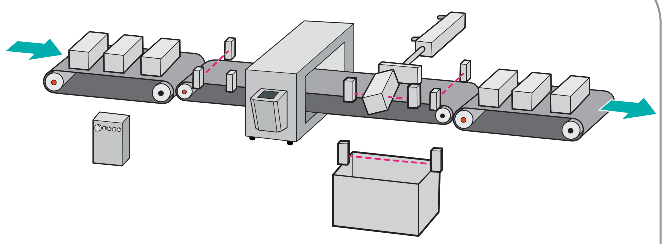
Separators in drop shaft systems A) with flap B) with swivel tube

7. Monitoring of metal detector systems at the critical control point

Metal detectors initially do not sort contaminations out of the production process, but instead simply report the critical product status. The contaminated product must then be removed *from the flow* using a suitable separation system.

The *correct functioning* of this separation system is therefore just as important as the functioning of the detectors. Therefore monitoring and checking of both the detector and the separation system are indispensable.

Continuous monitoring (permanent monitoring)



Overview of the monitoring functions on the metal detector belt

7.1 Metal detector

As a critical control point, metal detectors must be monitored regularly. There are various programs available for this purpose.

7.1.1 Watchdog

Programs of *individual processors* which continuously exchange vital signs with each other and expect these signs. This ensures that a program crash of any assembly immediately leads to an error message. The term watchdog is also used sometimes.

7.1.2 Internal error monitoring

Programs which carry out an internal error search and allow for corresponding error analysis.

7.1.3 Audit trail

In this case *all warning and error messages are recorded* and logged. In addition, all activities are recorded on the device. If settings which influence the detection sensitivity are changed, it is particularly important to record when this is carried out.

The audit trail is rounded off with the *event log*, which records any activity, in particular validation and verification processes or, for example, a *software backup*.

7.1.4 User management

Via user management on the metal detector, *various authorisation levels* are assigned to certain users. In particular if there are several users with identical authorisation, there must be *person-specific user recording*. Access should be protected and authorisations in the metal detector should be *designed according to system relevance*. For example, for safety in the process it is very important that an error due to a technical defect can only be confirmed by an *appropriate technical officer*.
If an unauthorised user confirmed a warning message without restoring production safety in the critical control point, then the CCP would no longer be valid.

In conjunction with the audit trail, the safety status of the critical control point can be tracked at any time. This is the highest level of security in comparison with a key switch.

7.2 Conveyor unit

Rotary pulse encoder
If the *belt system runs at variable speed* or can be stopped while the contaminated product is between the detector and the separation system, it can be a great challenge to *precisely determine the separation time*. As the product does not move to the separation position within a constant time frame, it is not possible to work with a simple time delay.

In this case, an electronic shift register is used, with which it is possible to monitor the belt movement and the position of the product. A *shift register* is a device that emits an *output signal* after receiving a certain number of *input pulses*. The input pulses are generated by a pulse encoder installed on a roller shaft of the belt system. The shaft usually consists of a *metal disc* with teeth or openings.

7.2.1 Protective covers

As *protection against access for the user* in particular, the separation process should be protected within a protective cover. The protective cover therefore prevents the risk of removing a contaminated product.

It should not be possible to remove the protective cover without using tools. Access openings which may be needed to resolve a potential product blockage must be equipped with a protective switch.

7.2.2 Lockable collection container

Following *separation of the contaminated product*, this is still in the direct proximity of the production line. A *lockable collection container* prevents access by unauthorised persons. In this case it is also recommended that a *key-free system* should be used. Modern metal detectors are equipped with *user management* and only allow access to the container *following identification* of an authorised user. When choosing the container, it is necessary to ensure that it always remains closed. In addition, access should be protected by a *timer*, which requires that the operator closes the container after a particular time.

7.3 Separation system

Where possible, *automatic separation* of the contaminated product is preferable. With this unit, *the operator is relieved* of the responsibility, which involves a great risk and is often also the biggest hazard.

A belt stop should only be used where the application does not allow for automatic separation and there needs to be manual removal from the process.

7.3.1 Compressed air monitoring

Most separation systems are based on *compressed air*. A constant air pressure is indispensable for the correct functioning of this system. As soon as the compressed air supply falls below a *critical minimum*, it immediately generates an error message.

7.3.2 Air tank

In order to maintain a stable compressed air supply even in the event of *series separation*, it is recommended that an air tank should be used as a power reserve. When designing this air tank, consideration must be given to the air consumption of the pneumatic unit.

7.3.3 Synchronisation light barrier

Synchronisation light barriers bring the *separator* in line with the *piece goods*. The best but also only solution is separation with a pusher. This consists of precisely determining the position of the packaging and triggering the separation device at the correct moment.

Irrespective of the position of the metal particle in the packaging, *precise separation* is therefore guaranteed by the synchronisation. It is essential for other monitoring functions such as separation monitoring or product flow monitoring because these are also based on the position of the product.

7.3.4 Separation monitoring

This function is based on sensors (e.g. light barriers), which monitor correct separation in the good or bad flow and report incorrect separations.

7.3.5 Product flow monitoring

This function consists of a total of *three light barriers*.
One *synchronisation light barrier* and one *light barrier* each in the *good and bad flow*.
The entire progress of the product is monitored. There is also monitoring to check that no products leave their critical control point or are added within the application but after the detection coil.

Due to the mutual synchronisation, there is also immediate detection of a defective light barrier or, in the worst case, a product getting back into the product flow.
One example would be a failed separation, in which the product does indeed break through the light barrier in the bad flow, but goes back onto the conveyor belt.

7.3.6 Collection container fill level monitoring

Sensors report the exceeding of a pre-defined maximum collection container filling level in order to prevent an incorrect message from separation monitoring. In addition, this function also prevents products falling back into the production process due to overfilling of the collection container.

7.3.7 End position monitoring

For bulk material applications, only the *positions of the separation mechanisms* can be checked.
In this case, there is inspection of reaching the separation position and reaching the end position. It is not possible to trace the contamination as in the case of piece goods.

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