SAFELINE
Metal Detection

White Paper

# Improve OEE
## With Inline Metal Detection

Contents



METTLER TOLEDO

# 1. Preface

There's no room for complacency in today's highly competitive food production arena. No matter how safe or efficient your production line, you have to stay focused on continuous improvement because that's exactly what your competitors are doing. So, this white paper looks at how the latest generation of metal detectors can help you improve your overall equipment effectiveness (OEE), a key measure of production line efficiency.

The paper begins with the basics: descriptions of how a metal detector works and how to calculate OEE; skip Section 2 if you're familiar with OEE, or the principles of metal detection. The background is provided for readers who are new to the subject.

The White Paper then describes the limitations of traditional metal detectors, particularly how 'product effect' reduces detector sensitivity. Understanding these limitations helps you see how the latest detector technologies do more than improve product safety: they unlock the efficiencies that lift OEE and production line profitability. We show how each technological advance links directly to improved OEE.

The final section deals with collecting OEE data, integrating your metal detector into your production line network, and how PackML (short for Packaging Machinery Language) features can help extract vital performance data automatically from your metal detector.

# 2. Introduction to metal detection OEE

## 2.1. Why use an inline metal detector?

Product safety is paramount. If a food product containing metal contaminants reaches the market, the consequences can be disastrous: for a consumer's health, for product recall and damage limitation costs, and for long-term brand reputation. Since prevention is better than cure, responsible manufacturers do their utmost to keep contaminants out of the production line – and to remove any finished products containing contaminants that have slipped through the net.

The starting point for any food product-safety regime is an approach known as HACCP (Hazard Analysis Critical Control Points). The UN Food and Agriculture Organization defines HACCP as 'a system that identifies, evaluates, and controls hazards which are significant for food safety'. It's a complete approach to safety, directed as much towards keeping contaminants out of the production process as it is to catching them before products leave the factory.

The point about HACCP is that it's all-encompassing. On its own, a metal detector won't keep contaminants out of your products. But metal detection proves indispensable when adopted as part of a company-wide approach to contamination prevention that's driven by HACCP.

With careful management of suppliers and raw ingredients, rigorous production and maintenance standards, a well-run product inspection regime, and inspection equipment placed at the critical control points in your process, you can keep your products free of metal contaminants. You won't just be able to meet international standards of product safety, comply with all your legal requirements, or satisfy enhanced safety standards set by retailers – you'll be able to prove that you achieve everything that's expected of you.

## 2.2. How a metal detector works

At its most basic level, a metal detector consists of three sets of coils wound around a circular or rectangular former. The former has a central void or aperture through which products pass on a conveyor. Apart from the conveyor, there are no moving parts.

A high-frequency electric current running through the middle coil, known as the 'transmit' coil (Tx in Figure 1a), generates a magnetic field in the aperture. The two outer coils, known as 'receive' coils (Rx1 and Rx2 in Fig 1a) detect changes to the magnetic field when objects pass through the aperture. Since the outer coils are wound in opposite directions to each other (Figure 1b), changes to the magnetic field generate equal and opposite electrical effects in the two outer coils. If the two coils are in balance, the two effects will cancel each other exactly.

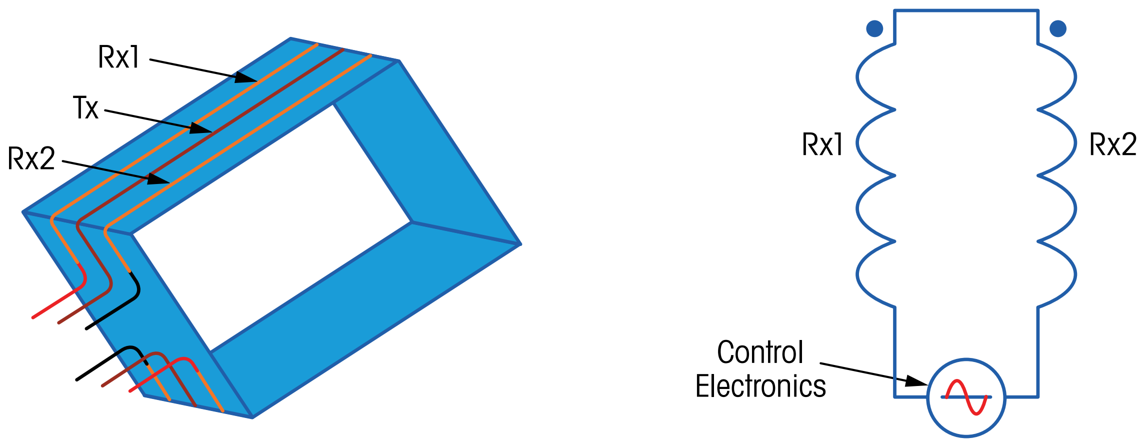


Figure 1a and Figure 1b

As a piece of metal passes through the aperture, it disturbs the magnetic field. The field disturbances affect the two receiving coils sequentially. Fig 2 shows how the advancing metal object alters the voltage in Rx2 before it creates an equal and opposite voltage change in Rx1.

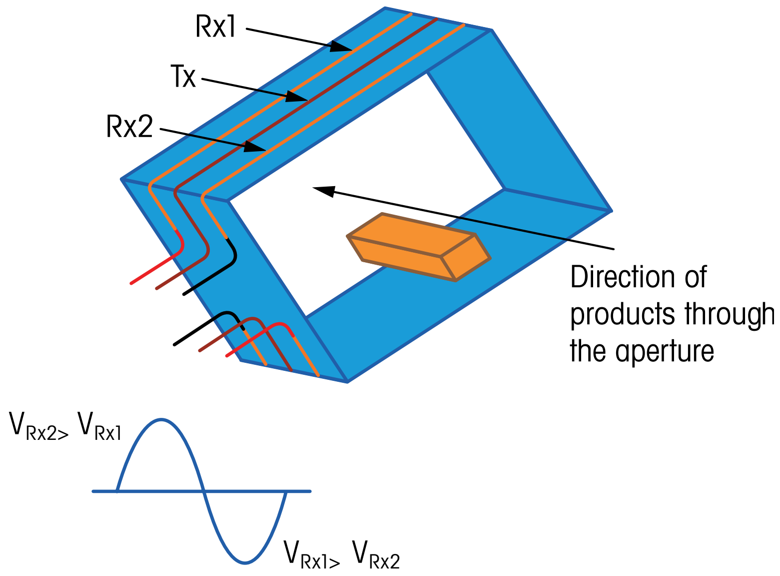


Figure 2

Metal contaminants are the most likely cause of these two sequential changes in coil voltages, although certain types of product can also cause disturbances – what's known as the 'product effect'. Improving sensitivity and eliminating product effects are the two big challenges of metal detector design.

In Section 4 we'll look at how the latest generation of metal detectors incorporate refined diagnostic tools to improve sensitivity, operational efficiency, and OEE.

## 2.3. OEE: a simple yet demanding measure of efficiency

OEE is a simple measure of production line performance. It expresses the actual output of a production line as a percentage of its maximum potential output.

$$\text{OEE} = \frac{\textbf{Actual good output}}{\textbf{Maximum potential output}} \times 100\%$$

Improving OEE is the big driver of operational efficiencies within the food manufacturing sector which is why supporting customers in their efforts to improve OEE is a big driver of developments in product inspection equipment.

To get to the heart of OEE, production line managers have to get to grips with the three components of OEE:

- availability
- performance
- quality

### 2.3.1. OEE Component: Availability

**Availability** deals with production downtime. It's the actual operating time expressed as a percentage of planned production time. Planned production time is the time that's available for production after deducting planned breaks (for meals, maintenance, and cleaning) from the total factory production time.

$$\text{Availability} = \frac{\textbf{Actual operating time}}{\textbf{Planned production time}} \times 100\%$$

### 2.3.2. OEE Component: Performance

**Performance** deals with loss of production speed. It's the actual line speed or run rate (number of pieces produced each minute) expressed as a percentage of the ideal line speed or run rate (number of pieces that should be produced each minute).

$$\text{Performance} = \frac{\textbf{Actual line speed}}{\textbf{Ideal line speed}} \times 100\%$$

### 2.3.3. OEE Component: Quality

**Quality** deals with failures to meet production standards. It's the number of good, saleable pieces expressed as a percentage of the total number of pieces made.

$$\text{Quality} = \frac{\textbf{Good pieces}}{\textbf{Total pieces}} \times 100\%$$

### 2.3.4. Calculating OEE

Combining all three components gives you the overall equipment effectiveness of your production line.

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}$$

Figure 3 provides a visual representation of the components of OEE and how they are derived. According to Vorne Industries, "OEE analysis starts with Plant Operating Time - the amount of time your facility is open and available for equipment operation.From Plant Operating time, you subtract a category of time called 'Planned Shutdown' (to get 'Planned Production Time'). OEE begins with 'Planned Production Time' and scrutinises efficiency and productivity losses that occur, with the goal of reducing or eliminating these losses. There are three general categories to consider - Downtime Loss, Speed Loss and Quality Loss."[1] - which correspond to availability, performance and quality elements respectively.

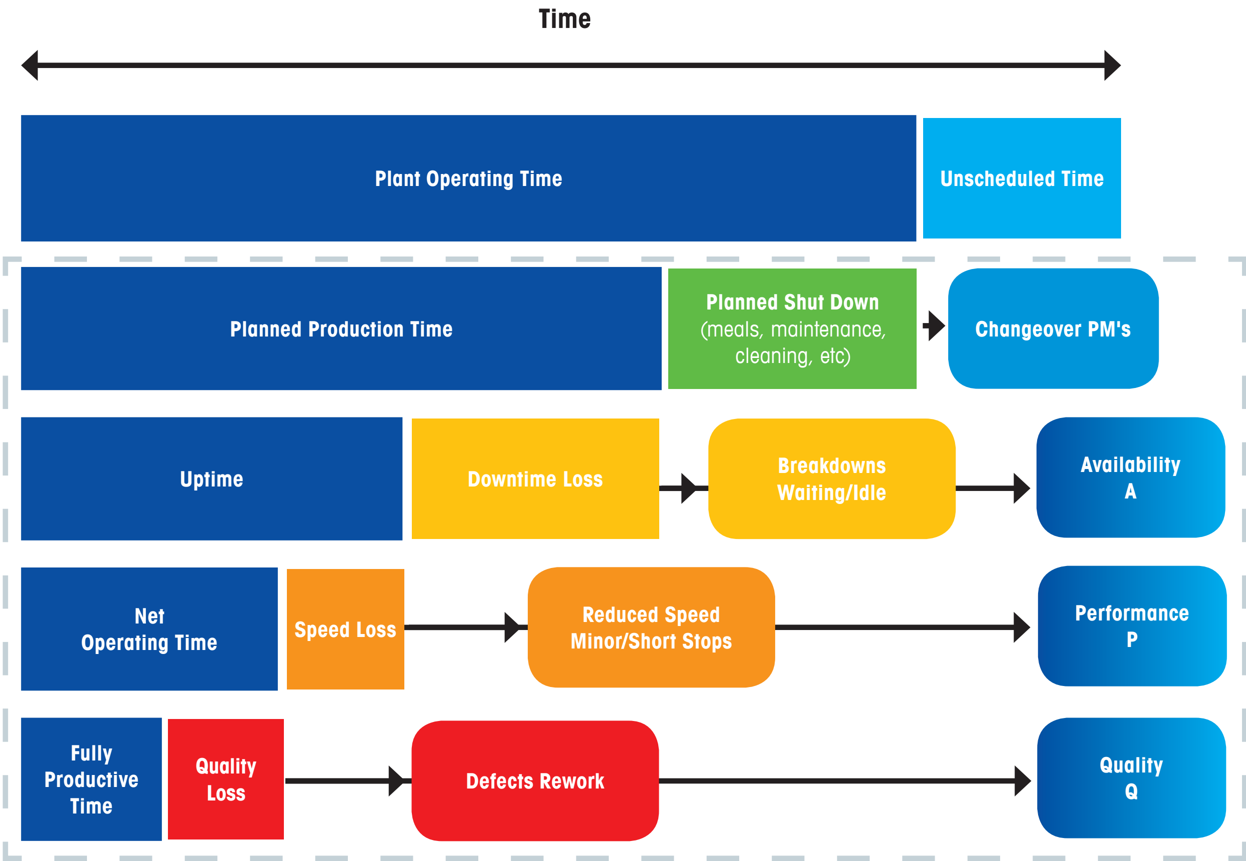


Figure 3: A visual representation of OEE Factors

Although the maths behind OEE is straightforward, improving OEE turns out to be an extraordinarily tough challenge. World-class OEE is about 85%[2], yet the average for manufacturing companies is somewhere in the region of 60%. There's a yawning gap between what's possible and what businesses achieve. Anything a supplier of product inspection equipment can do to help manufacturers raise their OEE should be welcomed with open arms.

Although OEE is a good general guide to operational performance, no one should follow it blindly. That's because improvements to one aspect of production can sometimes have negative effects on other aspects of production.

Consider the following two examples. To simplify things we've kept availability static at 90%. The only change between Examples 1 and 2 is an improvement in performance (from 78% to 85%) and a decrease in quality (from 96% to 92%). It's an exaggerated version of exactly the sort of thing that can happen in real life: in-

[1] Source: www.OEE.com/oee-factors.html
[2] http://www.oee.com/world-class-oee.html

creased line speeds lead to more substandard product.

**Example 1**
Availability = 90%
Performance = 78%
Quality = 96%
OEE = 90% × 78% × 96% ≈ 67%

**Example 2**
Availability = 90%
Performance = 85%
Quality = 92%
OEE = 90% × 85% × 92% ≈ 70%

On the face of it, the change has been good: OEE has risen from 67% to 70%. But the improvement comes at the cost of a doubling of rejected pieces. If it's a high-value product, the cost of those rejects could easily outweigh the advantages of increased production. As in all things to do with production line management, there's a balance to be struck between the positive and negative effects of change.

OEE is also heavily influenced by variability in its components. For example, adding 20% to 1 component in the equation and simultaneously decreasing another by subtracting 20%, does not result in the same OEE figure derived if all 3 components provide an equal contribution percentage i.e. 40% × 60% × 80% (= 19.2%) does not result in the same OEE figure as 60% × 60% × 60% (= 21.6%). And yet exactly this sort of variability could be a feature of what you're producing and how your line works.

The point is that OEE is a good indicator of overall performance but not the only measure. The devil is in the detail. You need to look at each component of OEE – and the data that comes from each step along your line – to understand exactly what's going on in your factory.

# 3. Limitations on the effectiveness of traditional metal detectors

## 3.1. Can metal detection play a part in OEE improvement?

The primary purpose of metal detection inspection systems is to protect consumers and safeguard your brand reputation. A metal detector helps protect your business from the catastrophic costs of a product recall or a storm of bad publicity.

As we shall see later, the latest generation of metal detectors can also help you improve OEE by running a more efficient production line. To get a sense of how they change the game, we need to understand the limitations of traditional metal detection.

## 3.2. It's a mistake to think of product inspection as a drag on OEE

Every piece of equipment and every operation on a production line has the potential to reduce OEE. The more complex your line, the more opportunities there are for equipment failure and human error, and the harder it is to make a quick and trouble-free changeover from one product to another.

A faulty metal detector would indeed reduce your OEE (and should be serviced or replaced immediately), but a system that's properly configured, managed, and validated is your ally in the fight to improve OEE. By identifying metal contaminants it tells you that systems or processes upstream are degrading product quality and harming your OEE. A metal detector helps you work out where to hunt for and eliminate metal contaminants – and thereby improve your OEE.

| How metal detectors can affect OEE | Impact on Availability % | Impact on Performance % | Impact on Quality % |
|---|---|---|---|
| Production line down time due to MD failure or fault | Yes | Yes | No |
| MD stopped due to product changeover | Yes | Yes | No |
| False rejects due to product signal changes / variation | No | No | Yes |
| Lost production time and products destroyed during PV* testing | Yes | Yes | No |
| Packs rejected due to metal contamination | No | No | Yes |

*PV = Performance Verification

Figure 4: How metal detection systems can affect OEE

Metal detectors from METTLER TOLEDO Safeline are inherently stable and reliable. They contain no moving parts (apart from the conveyor) and perform better than many other pieces of equipment on your line. Each METTLER TOLEDO Safeline metal detector reports its own OEE availability, which is typically much higher than the availability for your entire line.

## 3.3. The 'product effect' reduces the sensitivity of traditional metal detectors

Metal detectors have traditionally worked best on what are known as dry products. Dry products aren't necessarily completely moisture-free – although they do typically have low levels of moisture. 'Dry' is a catch-all term for food and pharmaceutical products that respond well to inspection by a metal detector. They're easy products to work with because they don't generate false or ambiguous signals.

Wet products exhibit something called a 'product effect.' This means that an element of the product is capable of conducting electricity and creating a magnetic disturbance within the aperture of the metal detector.

A product packed in brine is a good example. Salt water is a good conductor of electricity. Luckily it's not as easily magnetised as iron – in technical language, it has low magnetic 'permeability' – which means that the magnetic effect is much less than that generated within a piece of iron. But metal detectors are highly sensitive items of equipment designed to detect tiny pieces of metal in a big product. If the volume of salt water is large enough, it will create a magnetic effect that's as strong as that created by a small piece of metal. That's when the product effect becomes a problem. It means that the product itself can create as big a disturbance in the magnetic field as would be created by a flake of metal contaminant.

In practical terms, the product effect reduces inspection sensitivity because the metal detector cannot distinguish between the magnetic effects caused by the actual product and those caused by metal contaminants smaller than a critical size. For production line managers, it's a dilemma: do they accept reduced sensitivity and let relatively larger contaminants through undetected (compromising consumer safety) or maintain sensitivity and live with a metal detector that registers more false rejects (compromising OEE)?

A wide range of products exhibit the product effect, including bread, dairy products, fresh meat, poultry and fish. In many cases, the product effect can vary from item to item. Products that have been marinated, for example, are not identical, even when they weigh the same. The proportion of meat to marinade can vary from one item to the next. This makes it even harder for the software in a metal detector to determine whether a magnetic signal is the result of a contaminant or an above-average volume of marinade.

## 3.4. Other factors that create a product effect

The conductivity of a product varies with its temperature. If the ambient temperature in a production unit varies, the product effect can vary too.

When frozen products are exposed to warm damp air, condensation forms on the outer packaging which creates a product effect. Defrosting could potentially convert a dry product into a wet one. When frozen meat (a dry product) thaws, it becomes a wet product.

An even greater effect is the way that changes in temperature alter the phase angle of the voltage in the metal detector's receive coil. A change of just 5°C will create a shift in phase angle that's significant enough to make detection of contaminants much harder.

Variations in the size and shape of products, their density, and their position or orientation within the metal detector also affect detector sensitivity. A chicken that passes through the aperture lengthways presents a much smaller cross-section than one that passes through sideways. From the viewpoint of the metal detector, the lengthways chicken appears smaller than the sideways one.

Most non-metallic packaging materials do not create a product effect. The exception is metallised film. The thin layer (roughly half a micron) of aluminium on the surface of the film is enough to generate eddy currents and disturb the magnetic field. Historically if you were packing product in metallised film it was often best to inspect the product prior to packaging as was the norm in the snack food industry with the use of "throat" type metal detectors, however now with recent developments in metal detection technology inspection in the final pack is a real alternative as sensitivity levels are much closer aligned to those obtained when inspecting products in plain "non metallised" film.

## 3.5. Traditional Low and high-frequency metal detection

Metal detectors run at frequencies from 25kHz to 900kHz. The choice between a low and high frequency depends on the application. If product effects didn't exist, you'd be more likely to choose a metal detector running at a higher frequency because it's more sensitive.

At high frequencies, the polarity of the magnetic field within the aperture of the metal detector switches rapidly. The maximum instrument power is limited at high frequencies, which means that the magnetic field is weaker. But the rapid switches generate more pronounced eddy currents within a metal contaminant, which makes it easier to detect. The trouble is that the eddy currents generated within the actual product are also more pronounced. At high frequencies, the product effect is more likely to mask the contaminant effect.

At low frequencies, you can use a higher power to generate a stronger magnetic field, but the eddy currents are weaker. Although overall sensitivity is reduced, the product effect is less likely to mask the contaminant effect.

In short, high frequencies suit dry products; low frequencies suit wet products. Striking a balance between operating frequency and detection sensitivity is a perennial problem in metal detection. It's all about finding the optimal frequency for your application.

## 3.6. Contaminants do not come in regular shapes

Metal detector sensitivity is traditionally quoted in terms of standard spherical metal balls. The sensitivity of any given system is the minimum diameter of spherical ball it will detect. Trouble is, metal contaminants don't come in neat geometric shapes. Swarf and wire are long and thin. Weight-for-weight, contaminants are harder to detect than standard test pieces and this is one of the reasons why increasing the spherical sensitivity of a metal detector should always be high up on any user's agenda.

# 4. Overcoming the limitations of traditional metal detectors

## 4.1. Increased sensitivity with fewer false rejects will improve your OEE

▶ Improves OEE quality and availability

If a metal detector can overcome the traditional limitations on sensitivity whilst reducing the incidence of false triggering, it opens the way to improving your OEE. You'll have fewer false rejects (improves quality) and you'll be able to spot potential upstream equipment problems sooner (improves both quality and availability by detecting the contamination and averting potential causes of downtime). Most important of all, you'll have a safer product for consumers to put their trust in.

## 4.2. Inspecting multiple products on a single setting will improve your OEE

▶ Improves OEE availability

Manufacturers are under increasing pressure to operate flexibly – to manufacture a wide range of products from production lines that can quickly switch from one product to another. But frequent product changes increase downtime and provide more opportunities for costly operational mistakes.

Metal detector manufacturers have risen to this challenge with intuitive clustering technology – a way of grouping multiple products under the same system setting. Intuitive clustering lets you change products seamlessly with absolutely no loss of metal detectoravailability and more importantly no loss in sensitivity and no increase in false triggering.

## 4.3. Extending performance-verification intervals will improve your OEE

▶ Improves OEE availability and performance

To run a world-class product inspection regime, you have to check the performance of your system. Monitoring tests are an unavoidable feature of product inspection – a routine source of downtime/interruption to production performed at specified intervals.

The maximum interval between tests is determined by the facility's ability to store and quarantine all product inspected since the last successful test. If the metal detector fails the next verification test, the product that has passed through since the last successful test has to be considered suspect. The chosen interval is determined operationally. It's a balance between the downtime costs of more frequent monitoring tests and the costs of storing and re-inspecting larger batches of quarantined product.

Modern metal detectors can help in two ways: with condition monitoring and predictive analytics.

- Condition monitoring continuously monitors the critical functions of a metal detector. If something's not right, it serves as an early warning of a potential fault.
- Predictive analytics provides another early warning, but it comes at the problem from a different angle. It monitors changes in detector sensitivity, and uses this information to predict when performance may fall below the factory specification.

Both features give operators greater confidence that a metal detector is performing exactly as it should. This gives them the option to increase the interval between monitoring tests because they know that the detector is performing well enough to pass its next test. Condition monitoring and predictive analytics reduce monitoring downtime/interruption to production by reducing the chance that a metal detector might fail a monitoring test. OEE performance also increases because the line is stopped less often to run the performance monitoring tests.

## 4.4. METTLER TOLEDO Safeline Profile Advantage metal detectors improve sensitivity by up to 50% and improve your OEE

Mettler Toledo Safeline Profile Advantage metal detectors incorporate all the features described in sections 4.1-4.3. They operate using groundbreaking Multi Simultaneous Frequency technology to build up a more detailed picture of the product being inspected. Built in Product Signal Suppression software modifies the active product signal in such a way that it makes it virtually invisible to the metal detector. This in turn eliminates the incidence of false triggering whilst delivering typical sensitivity improvements of as much as 50%. Both features are major contributory factors in improving users' OEE quality percentage.

### 4.4.1. Impact on OEE - Traditional versus New Technology

Figure 5 illustrates the impact on OEE of traditional metal detection technology. Figure 6 illustrates the relative improvements in OEE that can be achieved using the latest technology.

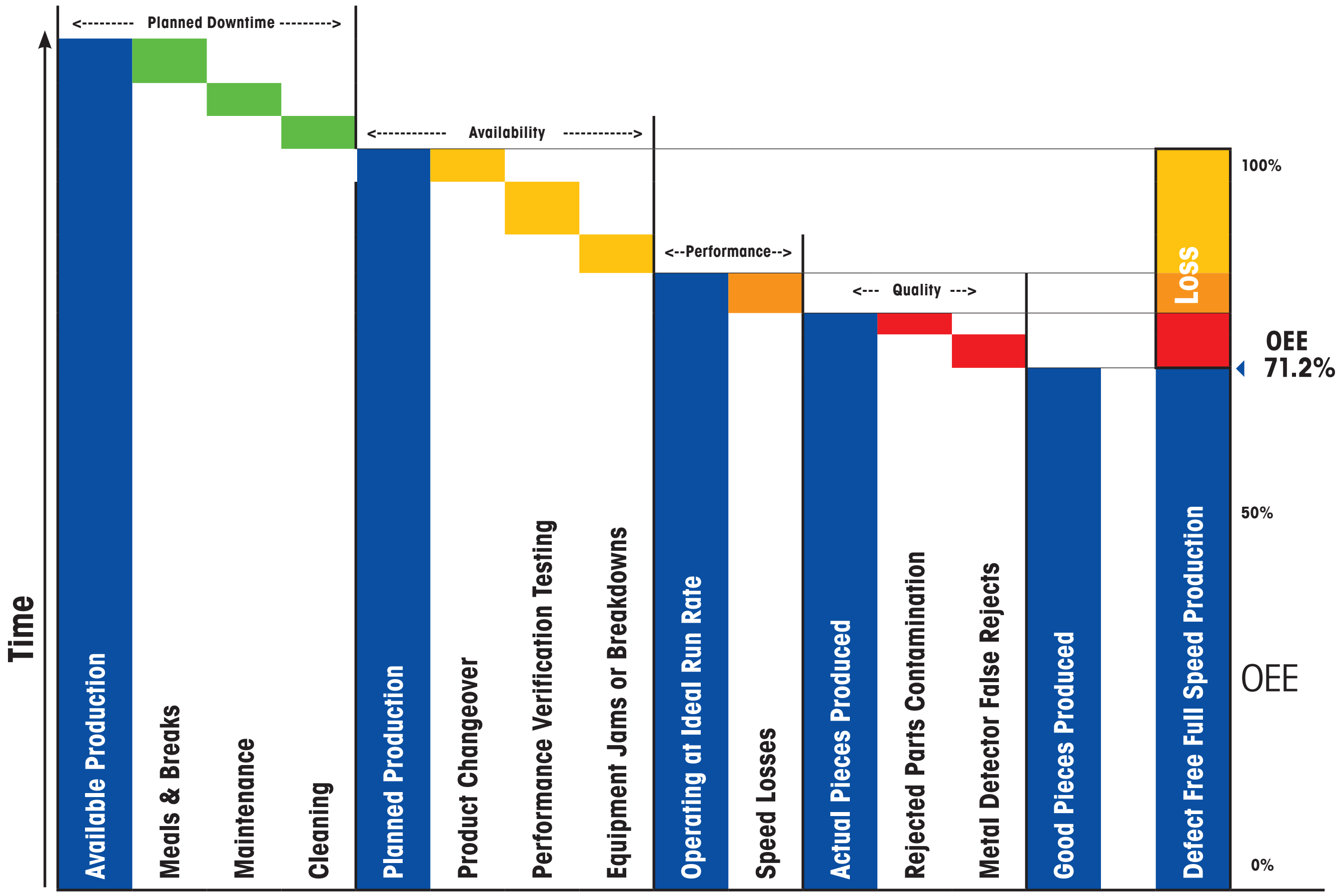


Figure 5: The effect on OEE of a **traditional** metal detector

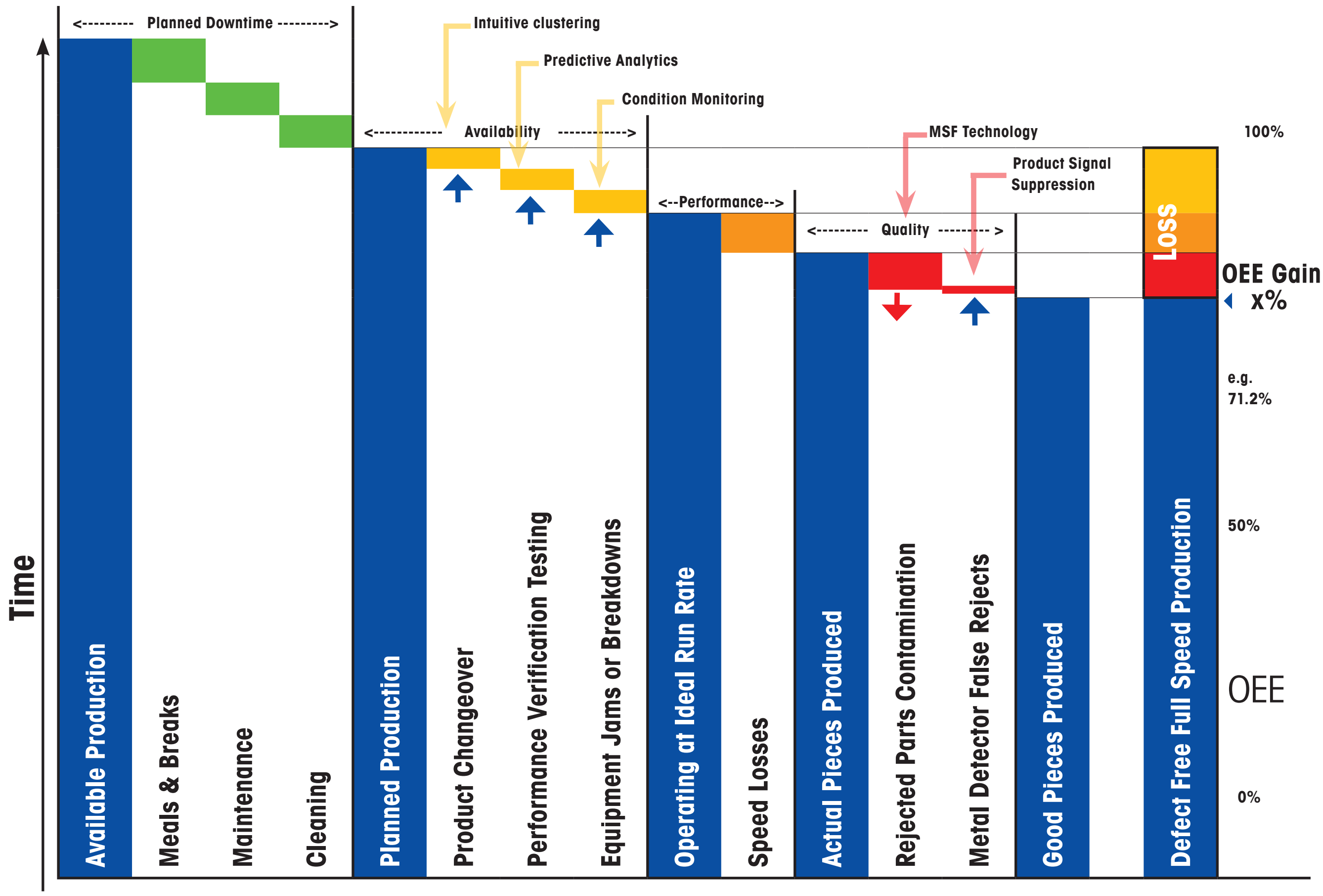


Figure 6: Improvements in OEE **generated by the latest generation of metal detectors** – METTLER TOLEDO Safeline Profile Advantage

# 5. Data collection is at the heart of OEE

## 5.1. If you don't measure it, you can't control it

Accurate production data is at the heart of OEE improvement. If your performance data is faulty or incomplete, you'll be misinformed and looking for improvements in the wrong place. You could even be making things worse.

Manual data collection won't do. The process is labour-intensive and guaranteed to be inaccurate, no matter how well-trained your team. You can't, for example, expect busy operators to log downtime accurately. When the line stops, the pressure is on to get it running again, not to reach for a stopwatch and a pen. Manual collection of data is subject to human error and variability. No two people will record events in exactly the same way, which makes the data inconsistent and untrustworthy. Data collected manually is slow too. Between the event and the presentation of the data, there could be days of delay and several stages of transcription and consolidation. Every step introduces an opportunity for error or judicious editing.

To be reliable, production performance data has be collected digitally, automatically, and in a consistent format that everyone understands and trusts.

## 5.2. OEE data from your metal detector

The latest generation of metal detectors automatically output performance data for OEE analysis. For example, all Safeline Profile Advantage, Profile, Signature Touch and Touch LS metal detectors give you OEE data, constantly recalculated every second. Our latest firmware has two extra running-mode screens for OEE and PackML. The OEE screen (Fig 7) displays the production line OEE as measured at the metal detector.

The displayed OEE data reflects the performance of your line from the perspective of the metal detector. Metal detectors typically achieve a better availability than other items of production line equipment.

The metal detector measures what's happening at a particular point in the line. So OEE availability for the production line is the time it spends actively inspecting product compared to the total time available. MD Availability is simply the percentage of time that the metal detector has been healthy (i.e. not in a faulted state).

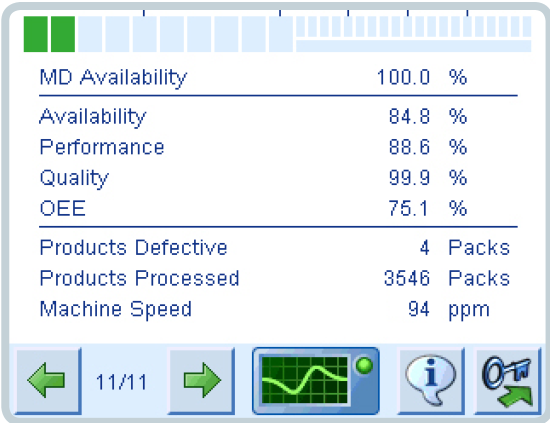


Figure 7

## 5.3. Connect your metal detector to your automated production line

For serious OEE analysis you need a metal detector that you can connect to your production line network. For Safeline metal detectors, you can buy a Fieldbus Interface Module (FIM) to connect to automation equipment such as a programmable logic controller. METTLER TOLEDO Safeline supply FIMs for EtherNet/IP, Profinet IO and Modbus TCP Fieldbus networks, as well as OPC DA server interfaces that allow PackML and OEE data to be easily accessible to SCADA/MES Systems. The FIM is the bridge between the metal detector and your fieldbus network.

## 5.4. PackML - the language of OEE improvement

The real-time data you need for OEE analysis and improvement comes in the standard PackML format. PackML is not covered in detail here but is becoming widely adopted as a standard by many major food manufacturers.

PackML is a standard set of terms for describing the operational state of equipment used in packaging processes. A common language makes it possible to integrate disparate equipment within a single production line and to communicate vital production line data to the management team. The latest version, PackML v3.0, was developed by the Packaging Workgroup within the Organisation for Machine Automation and Control (OMAC).

The PackML standard describes three categories of information:

- States - indicate the operational condition of the machine. Metal detectors use only four states: Stopped, Suspended, Execute, and Aborted.
- Modes - say how a machine is operating. They add more detail to the basic State. Metal detectors use

only four modes: Automatic / Producing, Maintenance, PVR, and Setup.
- PackTags - are named data elements applicable to open-architecture, interoperable data exchange. They identify operational characteristics such as speed (items per minute), number of rejected packages, and time spent in different States.

The three categories are interrelated. To interpret a State, for example, you need to know which Mode it's associated with.

For anyone interested in improving OEE, PackML is the standard format for vital performance data that you can take from metal detectors and other pieces of production line equipment.

All Safeline Profile Advantage, Profile, Signature Touch, Signature Touch LS and Touch LS metal detectors now generate real-time PackML v3.0 data, accessible through the FIM.

PackML data has other benefits including:
- A consistent look and feel for operators
- A foundation for vertical and horizontal integration
- Packing line plug-and-play functionality

## 6. Summary

When used as part of a company-wide approach to product safety, a metal detector is an essential item in the mission to protect consumers and brand reputations. But like all technologies, metal detection has its limitations. Now a new generation of metal detectors are employing imaginative technologies and sophisticated analytical tools to improve detection sensitivity by up to 50%. These detectors can identify metal fragments that are half the size of the smallest previously detectable. This is good news for consumers and for quality control managers.

Improved sensitivity does away with many of the operational compromises that have traditionally dogged product inspection. Managers can achieve their own factory standards for product safety without compromising production efficiency. They can detect small contaminants with more certainty whilst generating fewer false rejects and lowering their OEE quality.

Intuitive clustering technology is a software improvement that enables metal detectors to switch products without any downtime whatsoever. Seamless switching improves OEE availability and cuts labour costs. Other developments that improve OEE availability involve self-diagnostics and predictive analytics. These tools reassure operators that a metal detector is performing well or alert them to potential problems before they happen. Armed with this vital knowledge, they can increase the interval between performance validation routines, which reduces downtime even further.

To achieve continuous improvement, production line managers have to attack OEE from every angle. A metal detector can help them. Sophisticated on-board analytical tools give them real-time data on production line OEE and metal detector OEE. The data is easily extracted because it comes in PackML format, and because the metal detector is easily connected to a production line network managed by a programmable logic controller or SCADA/MES system .

At any moment in time, managers can see how their line is performing. They have the data at their fingertips that invites them to delve deeper – to see where they can make the critical changes that raise their OEE ever closer to the world-class target of 85%.

# 7. Literature References

1 - Vorne Industries Inc. (2012). "OEE Factors" retrieved from http://www.oee.com/oee-factors.html

2 - Vorne Industries Inc. (2012). "World Class OEE" retrieved from http://www.oee.com/world-class-oee.html

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