

Ask Orange™

Provides solutions
to process problems



How To

Choose & Use Industrial Metal Detectors

Complete guide to
Industrial Metal Detectors



World authority in advanced
technology for magnetic, vibratory
and metal detection applications.

It's not magic...it's ERIEZ

HOW TO CHOOSE AND USE METAL DETECTORS

	Page
INTRODUCTION	3
LIMITATIONS	3
DEFINITIONS	4
THE STATE-OF-THE-ART	4
PRINCIPLES OF METAL DETECTORS	5
WHERE SHOULD METAL DETECTORS BE USED?	5
BASIC LAYOUT OF A METAL DETECTOR	6
METAL DETECTOR STYLES	11
SELECTING THE RIGHT METAL DETECTOR	18
GETTING THE MOST FROM YOUR METAL DETECTOR	20
SUMMARY	25



Ask Orange™ is a collection of process solution case studies and how-to reference manuals designed to improve understanding and simplify specifying sophisticated magnetic, vibratory and metal detection equipment needed in most process industries. Most of this equipment requires an understanding of its intended use in order to determine proper application.

The "Professor" icon has been developed to help customers identify Ask Orange™ material in printed trade publications, company literature and on its web site. The Ask Orange concept and related images are a tribute to the company's founder, Orange F. Merwin, and his innovative ideas using magnets to remove metal contamination from various process flows.

HOW TO CHOOSE AND USE METAL DETECTORS

When Eriez Magnetics first opened its doors in 1942, the focus was on providing magnetic separation equipment—such as plate and grate magnets—to customers who wanted to remove tramp iron and steel from product flows. These magnetic devices, as well as others developed over the years, have proven effective at eliminating contamination by ferrous materials. However, many customers with ferrous contamination problems also experience contamination by non-ferrous metals, such as brass, aluminum, and stainless steel. To attack these problems, Eriez added a limited range of metal detectors to their product offerings in the early 1980's. In the ensuing decades, the product line has been expanded to include state-of-the-art metal detectors suitable for virtually all metal contaminant removal applications. This expansion has taken place both through in-house development—resulting in the highly advanced E-Z Tec® digital detectors—and through the acquisition of Pulse-Technology, a leading British metal detector producer.



Because every metal contamination problem is unique in some way, the appropriate equipment for detection (and rejection) is not always apparent, particularly to end users who may not be aware of all of the possible options, advantages and disadvantages of various detection (and rejection) methods. Over the years, Eriez has developed a large body of metal detector selection and application knowledge. This manual is intended to make the benefit of that knowledge to present and prospective metal detector users, to assist in planning for metal detector installations when and where they are needed.

E-Z Tec® is a registered trademark of Eriez Manufacturing Co.

LIMITATIONS

The discussions and illustrations in this manual pertain to industrial metal detectors as used for product quality control. This manual does not cover whole body personnel metal detectors or hand held metal detectors used for security screening, nor does it cover “beachcomber” type metal detectors used to locate underground metal objects. Eriez manufactures only industrial metal detectors.

Although equipment capability and technology statements are made as general as possible, we cannot presume to speak for our competitors. We believe Eriez expertise in metal detection to be second to none, and have based our application recommendations solely on that expertise. All illustrations are of Eriez metal detectors, which we also believe to be second to none in the industry.

We strongly recognize the application of Eriez metal detectors as quality control devices and are able to support virtually any customer requirements or specifications in the Quality Assurance area. This includes support of such systems as HACCP, commonly encountered in the US food industry. However, we have not attempted to discuss any of the specific requirements of the HACCP system or any other Quality Assurance system in this manual.

DEFINITIONS

For reference, here are some terms that will be used frequently in the following discussion.

COIL

A loop of wire, usually only one or two windings, that is used as a transmit and/or receive antenna to detect metal.

FILTER

Sometimes referred to as signal processor. The electronic component of a metal detector that evaluates the voltage emitted by the sensor and determines if that voltage indicates that metal is present. Modern filters can determine the type and size of metal by evaluating the amplitude and phase of the sensor voltage.

METAL-FREE ZONE

The region surrounding a metal detector must be kept clear of metal so that the presence of “tramp” metal can be sensed.

SENSITIVITY

The minimum diameter of the metal sphere that is consistently detected when presented to a metal detector under design conditions. Sensitivity is usually expressed in millimeters (mm). Most detectors will exhibit a different sensitivity for each type of metal. Note that a lower (poorer) sensitivity results in a higher numeric sensitivity value. A detector that can only reliably detect a 3 mm sphere is said to have a lower sensitivity than one that can reliably detect a 2 mm sphere.

SENSOR

The metal detector component that first reacts to the presence of metal by emitting a voltage signal. The sensor usually consist of one or more coils.

TRAMP METAL

Unwanted metal in the product stream.

THE STATE-OF-THE-ART

Metal detection technology has reached maturity for product quality assurance. Modern metal detectors operate reliably for long periods of time, frequently in adverse environments, with little attention or maintenance. They can be configured for minimal interference with established process flow. The power required to operate both the detector and the reject device (if any) is minimal, even if a special conveyor is required to pass the product through the metal detector. If a process cannot be stopped to deal with detected metal contamination, modern metal detectors can be configured to reject the contaminated product automatically, even if the possible rejection point is some distance from the detector. Or the detector can keep detailed records of detected metal-including estimated size and type-so that suspect product can be isolated, after the fact, based on time of processing.

The state of the art is typified by solid state, microprocessor-controlled detection equipment, generally incorporating sophisticated embedded signal processors, or networked to remote computers (or both). The state of the art metal detector has inherited all the reliability, ruggedness, accuracy and flexibility characteristic of modern electronics wedded to computer science. Such detectors can solve many formerly intractable problems, such as detection and rejection of very fine non-ferrous materials in free-falling products, interference from nearby moving metallic equipment, and unpredictable variations in conveyor speed that affect reject timing. As an example, the internal signal filtering algorithms in Eriez' latest E-Z Tec® Digital Signal Processing (DSP) models can identify the type of metal in detected contaminants, making it possible to focus the search for possible sources.

PRINCIPLES OF METAL DETECTION

Understanding the basics of metal detector operation will make one better able to select the correct equipment for a given task. It will also permit more effective metal detector operation.

For example, recognition that the “transmit-receive” type of detector actually “broadcasts” a signal, and that such a detector is sensitive to any imbalance in the signal received by two separate antennae, might lead to awareness that such a detector could induce erratically intermittent currents in loose members of its own supporting structure, and that those currents could in turn be detected as metal. This section of the manual will present such a basic description of metal detection principles, with some discussion of the advantages and disadvantages of each of the design options.

WHERE SHOULD METAL DETECTORS BE USED?

The state of metal detection technology now makes it possible to consider incorporating detection at several stages in a process, not just at the output. In fact, metal detectors should be used wherever there is the chance that metal particles may contaminate a product stream. This is especially true when the product is one that may be consumed by humans or animals (whether intentionally or not), when the product purity is a safety consideration (such as explosives), or when the contaminant particles may be of a size and type that could damage downstream processing equipment.

Historically, metal detection has been employed at the output of a process, primarily to reduce liability for contaminated product. Such a location will prevent the release of contaminated product and aid in identification of failing process equipment.

Metal detection at the input point of a process is also appropriate, sometimes vital, if the feedstock could be contaminated. Even if the contamination would not necessarily damage process equipment, product that would eventually be rejected by detectors at the output side could result in much processing cost wasted as a result of undetected contaminated feed. A single metal object in the feedstock, one that could be detected at the feed point and rejected at negligible cost, might be spread by processing so that an entire batch of product is ruined. This principle applies equally to intermediate steps in the processing of a product-if the output of an expensive process step is susceptible to rejection for metal contamination, both the input and the output of that step should be monitored by metal detectors.

Metal detectors can also be used to verify that desired metal objects ARE present in packaged products—such as novelties in breakfast food boxes. Here again, it is important to monitor the product both before and after the process step in which the metal item is to be inserted, to be certain that the detected metal at the output point is the desired object and does not include contamination carried from the input.

BASIC LAYOUT OF A METAL DETECTOR

An industrial metal detector consists of four main components as shown schematically in Figure 2:

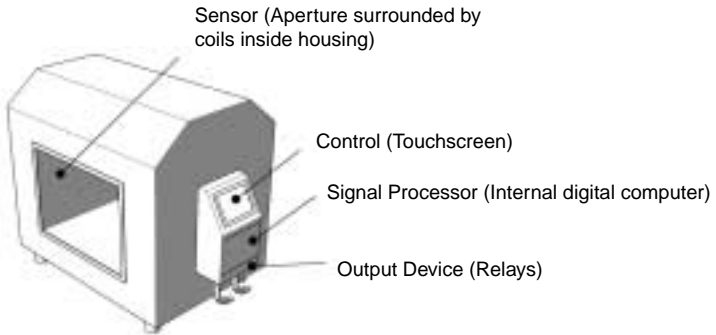


Figure 2.

Briefly, the sensor is a device that will react to the proximity of metal. The reaction of the sensor is transmitted to the filter, an electronic device that interprets the sensor signal. If the filter determines that the sensor has detected metal, it activates the output device, which may range from a simple display or alarm, to an array of timed relays. The operation of all of these components is governed by the control.

In addition to these four components, which are embedded in some form in all metal detectors, there are five auxiliary components frequently found in a metal detection system, as shown schematically in Figure 3:

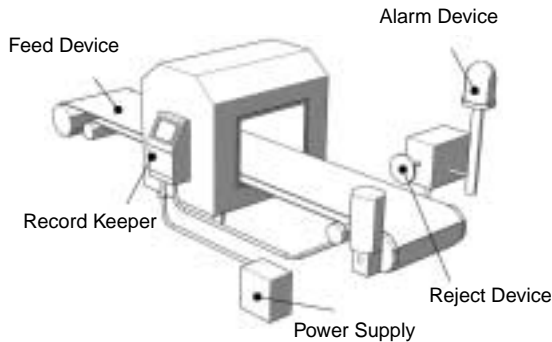


Figure 3.

The feed device presents the product that may be contaminated with metal to the sensor. Typically, the feed device is a conveyor, but other possibilities include chutes, pipelines, vibrating trays, and even manual presentation.

Metal detector power must typically be very “clean”, because detectors will frequently register any electrical upset as a metal detection. Consequently, special power supplies have been developed for the detectors and their auxiliary equipment.

Alarm devices include flashing lights, sirens, flag drops and computer displays, designed to draw the attention of a human operator to the detected presence of metal.

Reject devices are designed to remove the metal from the product stream. They include trap doors, pusher arms, air jets, retracting head pulleys and many others.

Record keeping software is frequently embedded in the metal detector control and/or in networked computers that can communicate with one or more detectors. In some cases, where the production and storage process is highly automated, by accurately tracking the time and magnitude of a metal detection, the record keeping device can enable contaminated product to be located and isolated after the fact, thus eliminating the requirement for immediate action on an alarm.



DID YOU KNOW...

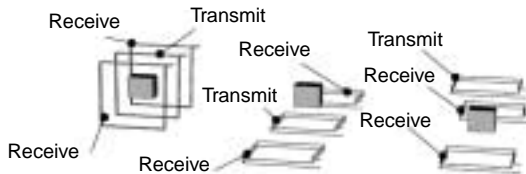
Eriez’ metal detectors and systems are often vital tools in developing HACCP quality assurance systems? Ask an Eriez representative about E-Z Tec’s software reporting capabilities.

SENSOR

Two basic types of metal detectors are commonly used in industrial applications. These are the “transmit-receive” type and the “pulse induction” type. They differ largely in the nature of the sensor used and in the electronic filter. This section will discuss briefly the operating principles of these two types.

TRANSMIT-RECEIVE SENSOR

A common layout for the sensor of a transmit-receive metal detector consists of a transmitter coil bracketed by two equidistant receiver coils. The coils may be arranged with their centers on a common axis (Figure 4a), with their faces in a common plane (Figure 4b), or in almost any other symmetrical arrangement (Figure 4c). The essence of the coil arrangement is that approaching metal should be “seen” by one receiver coil before the other.



(a) Coils on common axis, product moves through all coils along axis

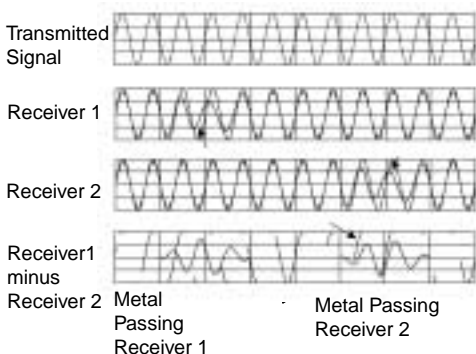
(b) Coils in common plane, product moves above plane, past faces of all coils

(c) Transmitter on one plane, receivers on another, product passes between the two planes

Figure 4. Coil Arrangements for Transmit-Receive Sensor. In each case the product is shown as a box moving from the plane of the picture “into” the page.

The transmitter coil emits a continuous varying electromagnetic field—generally at fairly low frequency—which is monitored by the two receiver coils. Under normal circumstances (no metal nearby) the voltage induced in the both receiver coils by the transmitter coil is equal, and the circuit is balanced.

Material being inspected is passed either through the centers of the coils (Figure 4a) or past the faces of the coils (Figure 4b or 4c). In either case, as the metal approaches the leading receiver coil, the eddy currents induced in the metal by the transmitted field will cause the two receiver coils to sense unequal signals. The circuit becomes unbalanced. Figure 5



illustrates this process in a simplified form. The details of this unbalance—the amplitude and the phase shift—are monitored and analyzed by the electronic package and appropriate output is generated, in the form of alarms, relay actuation, record generation, etc. The most sensitive metal detectors are generally of the transmit-receive type.

Figure 5. Unbalanced Electrical Signal in Presence of Metal in Transmit-Receive Detector.

PULSE INDUCTION SENSOR

The sensor of a pulse induction type metal detector also commonly consists of a transmitter coil, bracketed symmetrically by two receiver coils (Figure 6a). However, such a symmetrical arrangement is not an inherent feature of this type of sensor; the transmitter coil may be accompanied by only a single receiver coil (Figure 6b), or the transmitter coil may even serve as its own receiver (Figure 6c). A distinct difference between the pulse induction type of detector and the transmit-receive detector is that in the pulse induction type the approaching metal may be permitted to be “seen” simultaneously and equally by all receiver coils. This allows, for example, installations of a transmitter coil under the floor of a chute with receiver coils on both sides.

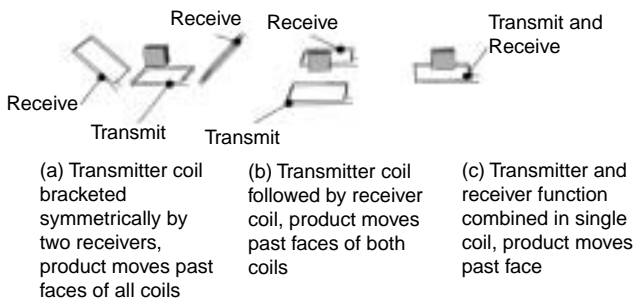


Figure 6. Coil Arrangements for Pulse-Induction Metal Detectors. In each case the product is shown as a box moving from the plane of the picture “into” the page.

The transmitter coil emits periodic field pulses that are received by the receiver coils, resulting in signals with characteristic amplitudes and decay times. When metal is present, some of the transmitter energy is absorbed by the generation of eddy currents in the metal, and those eddy currents themselves generate fields that are sensed by the receiver coils (along with the modified-emitted pulse). Thus, the characteristic amplitude and decay time of the received signals are affected by the metal (as shown in Figure 7), and these effects are identified and reported by the electronic filter package.

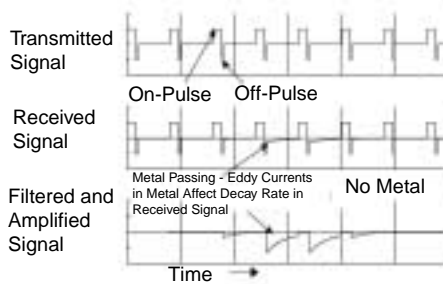


Figure 7. Signal Decay Affected by Metal in Pulse Induction Detector.



DID YOU KNOW...

Pulse induction detectors are generally not as sensitive as transmit-receive detectors. However, because they do not depend on an initial balanced condition they are well adapted to applications in which there may be continuous intervening metal between the target contaminant and the sensor (as in inspection of foil packs of cereal).

ELECTRONIC FILTER (SIGNAL PROCESSOR)

The received signal from the sensor is fed to the electronic filter. In modern metal detectors the filter is always solid state, and is generally digital in operation. Lower cost or special purpose detectors may incorporate analog filters. Each manufacturer develops its own signal processing circuitry (or licenses from other developers) and each emphasizes features and performance areas that it considers most important. Erez signal processing circuitry is almost 100% in-house developed, and emphasizes sensitivity, stability and durability.

OUTPUT DEVICES

The most basic output device is a voltage measured at the output terminals of the electronic filter. The presence, absence, or sign of this voltage—depending on the design of the particular detector—indicates that metal has been detected. In practice, either solid-state or mechanical relays are generally incorporated into the output side of the detector so that external device(s) can be actuated when metal is found.

CONTROL

Controls range from simple on/off switches to sophisticated touch screens with embedded computers. As with the signal processing circuitry, each manufacturer develops (or licenses) its own controls, and each emphasizes features that it considers important. Eriez metal detector controls are in-house developments, and consistently target ease of user input, simplicity and clarity of output.

A point to keep in mind when selecting a detector is that there is such a thing as too much control. When production line conditions are essentially constant there is no need to absorb the extra cost of an extremely flexible digital touch-screen control (for example). In fact, providing the flexible control only provides additional opportunities for detector settings to be inadvertently and improperly adjusted. Eriez makes an effort to offer a selection of controls for each type of metal detector that is consistent with the applications of that detector.

FEED DEVICE

Material may be fed to the metal detector in a myriad of ways. The simplest is probably to present manually the object being tested on the end of a wooden (or other non-metallic) paddle. Other common feed devices are chutes, conveyor belts, pipes or ducts and vibrating feeders. It is important that feed devices control the rate and (if appropriate) the orientation of product as it approaches the detector. An example of a conveyor is shown to the left.



DID YOU KNOW...

Eriez offers a combination vibratory conveyor/metal detector unit. These systems provide a high level of accuracy.

POWER SUPPLY

Most metal detectors are sensitive to power supply variations, and special power supplies are commonly used. These supplies incorporate noise filters and “quench arc” circuits to eliminate false tripping by the metal detector when it is switched on or off, or when another component in the system (conveyor drive motor, for example) is switched.

ALARM

The most common alarm is a flashing beacon, activated by the metal detector output relay. A siren, horn, or bell may also be used, with or without the beacon. Other commonly used alarm devices are flag drop markers, paint spray markers, and flashing computer displays (on networked detector systems). In most cases the alarm device is used together with a reject device, or at least with an interconnection that halts the automatic feed.

REJECT DEVICE

Manual rejection is the simplest reject device. In such a system, contaminated material that is fed to the detector either manually or automatically is simply removed manually from the product stream when the detection alarm is activated. Manual removal usually requires packaged products and an operator stationed continuously at the metal detector, or, at least, an automatic feed stop and alarm when the metal is detected. More commonly used are automatic reject devices, which physically remove the contaminated product from the stream without operator intervention. These are typically activated by relays in the metal detector. They include retracting conveyor head pulleys, swing arms, pusher arms, air jets, trap doors, diverter valves and others.

A critical issue with respect to automatic reject devices is to ensure that the timing of the reject action is synchronized properly with the detection, so that the portion of product rejected contains the detected metal. In the case of reject devices located some distance downstream of the detector, this requires carefully calibrated time delays, and may even require synchronizing with a conveyor belt if the belt motion is variable. In the case of systems that must reject metal from vertically free falling material, the use of very fast-acting diverter valves is required, and there also may be restrictions on the geometry of the system so that there is sufficient time for the valve to actuate before the detected metal reaches it.

RECORD KEEPER

The most sophisticated modern metal detectors keep records of all detections occurring in a previous time period. These are stored internally and may be accessed on demand by the operator or by remote command from networking software. An individual record will typically include details of the product being processed and the detector settings when the detection occurred, as well as the exact time and the characteristics (at least the magnitude) of the detection signal. The recorded detection time is critical to identification of possibly similarly contaminated product as well as for identification of the plant upset that might have caused the contamination. For this reason, detectors with a capacity for record keeping normally will also be able to synchronize time with an external clock, either manually or via a network. The recorded detection characteristics, particularly the type and size of contaminant, can be very useful in identifying the metal source.

METAL DETECTOR STYLES

The “style” of the metal detector, as used here, refers to the particular geometry of its coil, control and reject layout that makes it suitable for some family of applications. With some exceptions, most styles can be produced with either the transmit-receive or pulse induction type of sensor, and with either analog or digital electronics (signal processors and controls). The most commonly used styles are as shown in the following table, which presents the characteristics of each style in general terms. For more detail on detector styles, particularly with respect to the Eriez models mentioned, see the text following the table.

Type	Geometry	Characteristics and Applications	Eriez Models
Horizontal Aperture	Also known as tunnel type. Consists of a stainless steel housing with a horizontal aperture of rectangular cross-section (the tunnel) passing through it. Uses a transmit-receive sensor. Three coils are arrayed along, and concentric with, the axis of the aperture. Product passes through the aperture for inspection. Housing dimensions are optimized for max sensitivity.	The most sensitive style. Suitable for most dry or nearly dry products, either bulk or packaged. Feed is usually carried on horizontal or inclined conveyor belts, or on non-metallic vibratory pan conveyors. The pharmaceutical sub-type includes a very small aperture with an integral chute on down sloped stand for pharmaceutical (pills) inspection.	E-Z Tec Aperture E-Z Tec DSP Aperture Pharmaceutical
Vertical Aperture	Consists of a housing with a vertical aperture. The aperture may be either rectangular or more commonly circular in cross section. Usually uses a transmit-receive sensor. The coils are arrayed along, and concentric with, the axis of the aperture. Product falls freely or is conveyed downward by airflow in a duct passing through the aperture. Housing dimensions are optimized for maximum sensitivity.	Somewhat less sensitive than horizontal aperture type due to the presence of the duct surrounding the product stream. Used primarily for bulk product during a vertical transfer stage in processing. Almost always provided as part of a system, including a fast-acting reject valve. Often free standing for batch processing, with an input hopper and discharge into bins at floor level or below.	E-Z Tec Vertical Reject E-Z Tec DSP Vertical Reject Metalarm Model PL Metal Detector (pulse induction)
Low Profile Vertical Aperture	Consists of a housing with vertical aperture. The aperture is circular in cross-section. Uses a transmit-receive sensor. Three coils are arrayed along, and concentric with, the axis of the aperture. Product falls freely or is conveyed downward by airflow in a duct passing through the aperture. Housing dimensions are optimized to minimize vertical dimension, at some sacrifice in sensitivity.	Somewhat less sensitive than the horizontal aperture due to the necessary tighter coil spacing and reduced shielding from the low profile housing. Used for bulk product during a vertical transfer stage, primarily in retrofit or new applications where headroom is limited. The Eriez VFS models are reduced still in height for application in form, fill and seal equipment.	E-Z Tec Low Profile E-Z Tec DSP Low Profile E-Z Tec VFS E-Z Tec DSP VFS
Liquid Line	A circular aperture style detector with an embedded section of pipe, which may be separable or integral with the aperture liner. Uses a transmit-receive sensor. Three coils are arrayed along, and concentric with, the axis of the aperture. The aperture may be oriented at any angle. Housing dimensions optimized for sensitivity.	Sensitivity may be reduced in versions with a separate feed pipe through the aperture because of presence of the pipe. Product (liquid or semi-liquid) flows through the aperture for inspection. This style of detector is almost always provided as part of a system including a fast-acting reject valve.	E-Z Tec Liquid Line E-Z Tec DSP Liquid Line

Type	Geometry	Characteristics and Applications	Eriez Models
Single Surface	Coils are embedded just inside one surface (usually the upper) of a shielded housing. The number and arrangement of coils depends on the type, which may be either transmit-receive or pulse induction. The detection zone is the region just outside and close to the surface in which the coils are embedded.	Less sensitive than an aperture detector, except for situations where target metal is found immediately adjacent to the sensor surface. Usually used below conveyor belts where it is impractical to cut the belt and where running the return belt through the aperture of an aperture style detector is impractical. The VC model-of the same general configuration as the troughed belt conveyors-can be installed directly as part of the pan of a vibrating pan conveyor.	Slim Tec Single Surface (transmit-receive) Metalarm Model PL (pulse induction) Metalarm™ Model VC (pulse induction)
Webbing	Distinguished by its very great width (across the feed direction) relative to its length (along the feed direction), a webbing metal detector may be either aperture or single surface in design, and may use either transmit-receive or pulse induction sensor technology. Multi-zone versions incorporate several coil sets within the width of the sensor housing so that detected metal can be isolated more accurately.	Used to inspect web-like products such as paper, fabric, etc. Also for particulate product spread shallowly on wide belts. Because its field is totally enclosed, the aperture style will be more sensitive than the single surface. Also, the aperture style can be used with thicker web products than the single surface. However, the single surface may be more practical where it is inconvenient to "thread" the web or product belt through a detector aperture.	Slim Tec Single Surface (transmit-receive) Slim Tec Aperture (transmit-receive) Metalarm SS (pulse induction)
Under-belt Troughed	The troughed style incorporates a horizontal coil and two or more inclined coils, all embedded in polyethylene and unshielded, and mounted to conform to the bottom and side idler geometry of standard troughed belt conveyors. The sensors are pulse induction. Electronics are remote, connected to the sensors via cable.	Used under standard troughed conveyor belts where ease of installation is a primary concern. Models are offered pre-designed to conform to the dimensions of most standard idler manufacturers.	Metalarm TR
Bridge	Detector coils are arrayed under the conveyor belt and additional coil(s) are housed in a removable bridge that crosses above the conveyor burden. Sensors may be transmit-receive or pulse induction. Electronics may be remote or integral.	Used for flat or troughed conveyors carrying bulk materials with burden depths too great for inspection from under belt coils. The transmit-receive variety is excellent for mineralized products (ie: where the product signal itself is significant), and for use when nothing smaller than a given size should be detected.	Metalarm BR (pulse induction) 1200 series (transmit-receive)
Hand-Held	A single housing with a handle contains a miniaturized sensor, electronics, power supply and control. The sensor is pulse induction.	Used manually to isolate metal found by a stationary detector in product carried on a conveyor or embedded in a web.	Metalarm HH-10

HORIZONTAL APERTURE STYLE

The E-Z Tec and E-Z Tec DSP metal detectors in the horizontal aperture style are commonly applied in situations where the greatest achievable sensitivity is required. They are custom designed to fit each application. For optimum shielding, sensitivity, and stability, neither the detector coils nor the stainless steel housing may be “split” to allow insertion of one leg only of an endless conveyor belt. Therefore, when a belt conveyor is used to present product for inspection, both the feed and return leg of the belt must pass through the detector aperture, or the belt must incorporate a non-metallic splice. Optimum performance is reached when the product passes through the center of the aperture.



VERTICAL APERTURE STYLE

The E-Z Tec and E-Z Tec DSP vertical aperture metal detectors use the same technology as the horizontal aperture style. An example is shown to the left. They are intended for use where the greatest achievable sensitivity is required, and where the product to be inspected is in free fall or is being transported pneumatically. Although standard models exist, these detectors are almost always custom-designed for each application. Vertical aperture detectors are also generally supplied complete with a section of non-metallic, static-resistant ducting to contain the product. A fast-acting diverter valve is also usually part of the system.



Most industrial metal detectors operate in conditions in which the product flow parameters can be completely determined by the plant design. This is not true for vertical aperture style detectors. The product velocity, particle density, etc. at the point of detection are determined by the laws of aerodynamics and physics, operating over the inlet distance (distance from point where product entered the vertical chute to inlet of detector aperture). The time available for reject valve operation is determined by those same laws operating over the reject distance (distance from the point of detection to the “cutoff” point of the valve). The design of a detector and valve system to operate properly in such conditions requires a good deal of experience and application knowledge. Proper timing of the reject also requires an assessment of the characteristics of the likely metal contaminants. For example, metal needles will fall faster in still air than metal flakes of the same mass. If a wide range of contaminant sizes and shapes must be accommodated, the reject distance and valve timing must be adjusted accordingly, frequently at the expense of a larger percentage of rejected “good” product at each detection. Eriez has developed an extensive data sheet, available on request, that should be filled out, submitted and evaluated by Eriez experts for each potential application, before determining that a vertical aperture style detector system is even feasible. Vertical reject applications are so individual that catalog claims regarding free fall distance, system height, etc. are virtually meaningless without such an expert assessment.

LOW PROFILE VERTICAL APERTURE STYLE

Essentially similar to the “full height” vertical aperture style, the low profile style (shown to the right) has been reduced in height and the internal coil spacing decreased to minimize the total system height. The signal processing and control electronics are essentially the same in the low profile style as in the full height systems. The reject valve systems, when supplied, are also similar. The reduced detector height reduces metal sensitivity slightly, but permits application of these detectors in restricted-headroom locations where it would otherwise not be possible to install a detector at all.



The extreme case of the low profile vertical aperture style is the Eriez VFS model, which is designed to be incorporated directly into Vertical Form, Fill, and Seal machines.

LIQUID LINE STYLE

In some ways similar to the vertical aperture detectors, the sensor in the liquid line detector style surrounds a separate pipe which carries the product for inspection. However, unlike the vertical aperture detectors, the medium within the pipe is now liquid. The liquid may be carrying particulate product as a slurry, or may be the product itself. In either case, the pipe is generally under internal pressure, and frequently carries a hot product. It may be horizontal or vertical. Because of the liquid medium, static is not generally a problem. The internal pressure and temperature often mandate a relatively thick pipe wall and a gap between the pipe and the inner surface of the detector aperture, and these constraints tend to reduce the achievable sensitivity of the liquid line style. Also, the necessary high pressure (and sometimes high temperature) diverter valves required for liquid lines tend to increase the cost of liquid line systems.



For these reasons, when evaluating where metal detectors should be inserted in a process, it is usually best to consider stages in which the product is dry or packaged as preferable to liquid stages. Offsetting this, when testing highly conductive products, it is important to minimize the product effect to optimize sensitivity. This can often be achieved by using a liquid line detector with a relatively small diameter pipe, as opposed attempting to inspect the product after it has been packaged.

SINGLE SURFACE STYLE

The single surface detector style incorporates sensor coils embedded in one surface of a shielded housing. The field emitted by the transmitter extends outward from the surface for a few inches. Metal is detected when it passes through this field and thereby disturbs the signals at the two receiver coils (located adjacent to the transmitter coil).



Because the field is not “contained” within an aperture, it varies in intensity, decreasing as one moves farther from the coil surface. Thus, the detector sensitivity itself will decrease with increasing distance from the detector surface. When quoting required sensitivity, or evaluating proposed sensitivity, for a single surface detector, it is important to know at what distance from the surface this sensitivity applies.

The advantage of the single surface style, of course, is that the product does not have to be passed through an aperture. Aperture style detectors require either a vulcanized belt or an arrangement in which the return belt also passes through the aperture. The single surface detector is not subject to this limitation; it can be placed between the runs of an endless belt. Because of the limited field, the product bed on the conveyor must be restricted, and, if packaged products are being examined, the packages must be knocked down to lie with their shortest dimension perpendicular to the belt.

The Model VC Metal Detector with a pulse induction sensor can actually be installed as part of the pan of a vibrating pan feeder, a conveyor or chute. The coil panels of this detector are arranged in a “U” shape to conform to conveyors with vertical sides.



WEBBING STYLE

Webbing style detectors are optimized for examination of sheet-formed product, such as paper, textiles, board, plastic, floor tile, etc. and are available in both single surface and aperture configurations. Because the contaminant is by

definition presented to the detector in a very limited area, quite close to the detector coils, at least theoretically there need not be any great difference in sensitivity between the aperture and single surface detectors of this style. The aperture configuration may allow for more variation in web position without losing sensitivity, offset by the need to thread the web through the aperture and the possibility of the web touching the top or bottom of the aperture if too much position variation is allowed.



The sensor module in a pulse induction webbing detector can be provided with a series of detection coils dispersed across the width of the web. With electronics (signal processor and control) that evaluate signals from each coil separately, this detector can indicate where across the web metal was detected. It can be combined with a paint or ink spray to mark the approximate metal location.



UNDER-BELT TROUGHED STYLE

The TR troughed style sensor consists of several coil panels, each one designed to conform to a segment of the specific troughed belt cross-section for which it is applicable. The belt cross section is determined by the idler pulley configuration, which, although nearly standardized, does differ in detail between idler manufacturers. Eriez stocks “generic” TR sensors, and also maintains records of the idler configurations offered by the most popular manufacturers. The generic TR sensors can be customized to fit exactly each of those configurations.



BRIDGE STYLE

This style may be wired in either a transmit-receive or series mode. It is similar to the aperture style in that the conveyor belt passes through the sensor array, but it differs from the aperture style in that the sensor array can be “opened” to allow assembly around one leg of an endless belt. This style may also consist of separate transmit and receive coils arranged above and below the conveyor. At least partly because of the split-able aperture, this style does not generally offer sensitivity as great as the aperture style.



The bridge style is particularly appropriate for conveyors handling heavy burdens of bulk material, such as coal, ore or aggregate. Eriez’ 1200 series detectors, in this style, are particularly suited to detection of both ferrous and non-ferrous metals embedded in heavy burdens of highly mineralized ores.



HAND-HELD STYLE

Hand-Held detectors use a pulse-induction sensor, which helps to maximize its ability to accommodate varying target positions, detector orientations, and motion. Uniquely, the sensor of the Hand-Held detector is intended to be brought to the target metal, rather than having the metal presented to it. A single value of sensitivity is inappropriate for a Hand-Held detector, because, in theory, the sensor can be brought as close to the target as desired.



The most frequent function of a Hand-Held detector in industrial quality control is to isolate metal that has already been detected and rejected (together with a certain amount of good product) by an “in-line” metal detector. The Hand-Held is used to scan the rejected material and to find the contaminants.

SELECTING THE RIGHT METAL DETECTOR

There clearly are many available types and styles of industrial metal detectors, and the selection process may seem confusing at first. However, the answers to a few simple but critical questions can narrow the choices dramatically, to the point where one can understand the situation well enough to ask more detailed questions and make more detailed decisions that will lead to a “best” choice from several likely candidates. This section is intended to ask those first critical questions, for rough planning purposes. Eriez metal detector specialists should then be called on to make final model, size, and optional feature decisions.

The optimum metal detector selection depends at least as much on the product and on the process as on the metal to be detected. Sometimes the existing form of the product-or, more frequently the process-leads to a very difficult, expensive, or “impossible” metal detection problem. An example of this would be an existing process line that, because of space, only permits addition of a metal detector at the very end, and the product is soup in aluminum cans-virtually impossible to check for metal contamination. Clearly, the entire process needs to be reconsidered in such a case, or else a very special detector will be required. These are the situations where early consultation with Eriez will be particularly valuable, because serious review of what is feasible may eliminate travel down many blind planning paths.

To use the selection guide, start with Question 1 and answer ‘yes’ or ‘no’. Then proceed to either Question 2 or Question 5, as directed in the ‘Yes’ or ‘No’ column. Proceed in this manner from question to question. Stop when you reach a shaded cell containing a metal detector recommendation. That will be the ‘basic’ recommendation for your application. For example, suppose your task is to separate metal contaminant from free-falling rice, you have a relatively large amount of available headroom for a metal detector, and you do not require internal record keeping within the metal detector. You would answer ‘no’ to Question 1 because internal record -keeping is not required, following the instruction in the ‘No’ column you would then go to Question 5 and answer ‘no’ again, go to Question 6 and answer ‘no’, go to Question 7 and answer ‘yes’, go to Question 8 and answer ‘no’, and find the recommendation ‘E-Z Tec Vertical Aperture’ in the shaded ‘No’ column.

Use the recommendation derived from this chart only for rough planning of your metal detector system. For more detailed consideration of your needs and available options, contact Eriez.

No.	Question	Yes	No
1	Is internal record-keeping (within the metal detector) required?	Go to Question 2	Go to Question 5
2	Is the product bulk liquid?	E-Z Tec DSP Liquid Line	Go to Question 3
3	Is the product falling (or being pumped) through an essentially vertical duct?	E-Z Tec DSP Vertical Reject	Go to Question 4
4	Can the product be conveyed through an aperture?	E-Z Tec DSP Horizontal Aperture	E-Z Tec DSP Single Surface
5	Is the metal detector to be used only for localization of embedded metal previously detected by a stationary metal detector?	Metalarm HH-10	Go to Question 6
6	Is the product bulk liquid?	E-Z Tec Liquid Line	Go to Question 7
7	Is the product falling (or being pumped) through vertical pipe?	Go to Question 8	Go to Question 9
8	Is there a limited amount of vertical space available for installation of a metal detector?	E-Z Tec Low Profile Vertical Aperture or E-Z Tec VFS	E-Z Tec Vertical Aperture
9	Is the product bulk pills or tablets?	E-Z Tec Pharmaceutical	Go to Question 10
10	Is the product web-like (such as textile)?	Go to Question 11	Go to Question 14
11	Can the web-like product be threaded through an aperture?	Go to Question 12	Go to Question 13
12	Is the target contaminant metal very fine?	Slim-Tec Aperture	Go to Question 13
13	Is it important to localize the contaminant metal in the product (widthwise)?	Metalarm SS Multi-Zone	Slim-Tec Single Surface or Metalarm SS
14	Is the product conveyed on a belt or feeder that can be threaded through an aperture?	Go to Question 15	Go to Question 18
15	Is the product coarse material and/or in a thick bed on the conveyor?	Go to Question 16	Go to Question 17
16	Is the product mineralized (containing metallics)?	Eriez 1200 Series	Metalarm BR or Eriez 1200 series
17	Is there a tight restriction on space available for installation of a metal detector?	Slim-Tec Aperture	E-Z Tec Horizontal Aperture
18	Is the product conveyed on a troughed belt?	Metalarm TR	Go to Question 19
19	Is the product conveyed on a conveyor pan?	Metalarm VC	Go to Question 20
20	Is the target contaminant metal very fine?	E-Z Tec Aperture	Metalarm PL or Model BR

GETTING THE MOST FROM YOUR METAL DETECTOR

The most important rule to follow to get the most from your metal detector is to obtain and read the Installation, Operation and Maintenance Manual (IOM). A modern industrial metal detector is a major investment, and rightly so, because it pushes the limits technically. Such a device should not, and cannot, be installed, operated and maintained by applying simple rules of thumb, or by using techniques that have been “OK” for years.

The IOM for each metal detector shipped by Eriez provides more relevant and specific information for that detector than this manual could possibly provide in a reasonable amount of space. Each type, style and model of detector has its own requirements that are addressed in those IOM’s. However, there are general principles that apply to almost all industrial metal detection systems.

INSTALLING

When handling the detector for installation, avoid contact with the sensor surfaces. This precaution is particularly apt for aperture style detectors, because the aperture is an inviting lifting surface. However, the inner surfaces of the aperture are almost always non-structural, non-metallic materials selected primarily not to degrade the sensor operation. Do not handle an aperture style detector by inserting anything into the aperture.

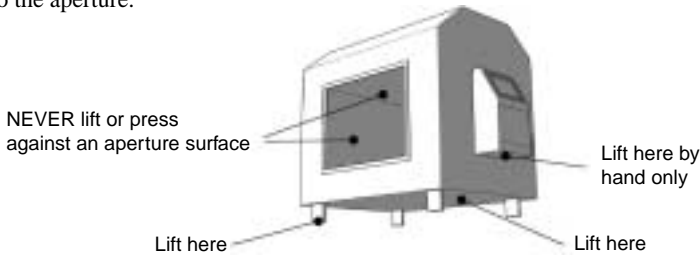


Figure 8.
Aperture Detector Handling Guidelines.

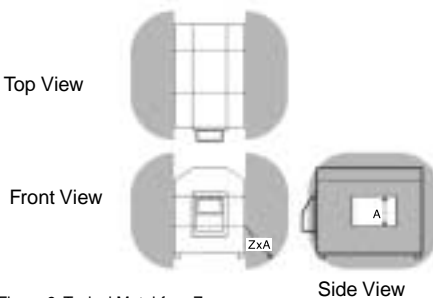


Figure 9. Typical Metal-free Zones.

Respect the metal-free zone. The metal-free zone is the volume of space adjacent to the sensor of a metal detector within which the detector will respond to the presence of metal. The zone is called “metal-free” because it must be kept clear of all metal objects other than the target metal. The metal-free zone will be specified in the IOM for your particular model of detector. In some cases there will be separate required metal-free zones for stationary metal and for moving metal. Metal structure, cables, wires, belts, etc., must be kept out of the metal-free zone at the detector location.

APERTURE DETECTORS

Distance from the aperture to the nearest metal in supports and surrounding equipment must be greater than Z times A , where A is the smaller aperture dimension and Z is typically 1.0 for stationary metal and 2.0 for moving metal.

Install the detector in a location with easy access. Even in a situation where the detector is not expected to require frequent service, as a quality control device its operation should be verified regularly. Inconvenient access will make this quality check less likely.

Avoid areas subject to vibration. If vibration exists, modify supporting structure to eliminate it. Vibration that is perceptible to a person standing at the proposed detector location is likely to have an adverse effect on the detector operation. This will be less for pulse-induction type sensors than for transmit-receive.

Use clean power. Detectors are subject to electromagnetic noise from power lines. The best installations use a dedicated line directly connected to the plant mains.

Provide a solid ground connection—only one. The best ground connection is direct from the detector ground terminal to a known or dedicated earth ground. Although the instructions in some IOM's may differ, and should be followed when they do, in general all ground lines from other equipment associated with the detector should be brought to the detector ground terminal, so that there is a single earth ground for the system.

Avoid locations where airborne electromagnetic radiation may be expected. The primary sources of this radiation are variable-frequency motor controllers, that may be used on other plant machinery, conveyor drives, etc. Airborne electromagnetic noise originating several hundred feet away can affect detector operation, and plant floors are generally not an effective barrier.

Supporting structure and conveyors should be designed and constructed to avoid intermittent electrical ground loops, both at the time of installation and for the life of the system. Ground loops (continuous electrical paths) in the framework will generally be invisible to the detector as long as they are constant. However, a loose frame connection can cause an intermittent ground loop that can result in false detections. This means that metallic cross-members, braces, etc., should all be firmly welded to connecting members. When such a connection cannot be a weld for some reason, it should be insulated to prevent formation of a loop. In the rare case where an un-insulated, bolted connection must be used, the integrity of this joint should be the subject of regular periodic inspection as the structure ages.

⊗ All moveable connections (such as bearings) that could create a current loop within the possible field leakage area of the metal detector should be insulated at one end only.

✦ All permanent frame connections that could create a current loop within the possible field leakage area of the metal detector should be welded.

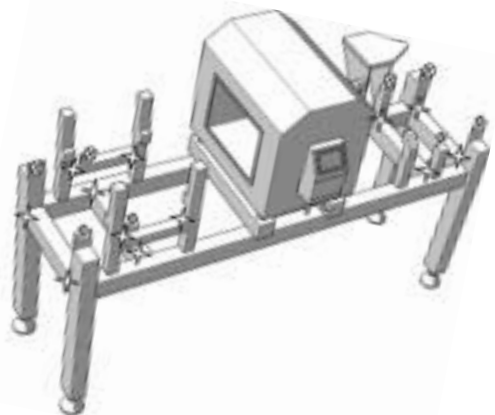


Figure 10.
Avoiding Intermittent
Ground Loops in Structure.

Provide a safe product reject collection area. Some metal detector / rejection systems reject contaminated product by pushing it off a conveyor belt, retracting a conveyor pulley, opening a reject trap-door, or other means by which rejected material may suddenly and unexpectedly be propelled into a plant aisle or workspace. This can create a personal injury hazard. No matter how infrequent rejects are expected to be, an appropriate bin or other collection device should be provided to isolate potentially contaminated product.

Provide security for the power switch. A metal detector that is not operating looks very similar to one that is operating, but it is not nearly as effective. As a critical quality control device, the metal detector should be wired so that it is always on if the product line is running.

OPERATING

When starting the product line, verify that the associated metal detector(s) is/are operating. If the detector has been properly wired it should always be on, or it should have turned on automatically when the line started. However, it is always possible for fuses to blow.

Periodically, preferably on a regular schedule, verify the metal detector function. Pass a metal object that represents the target metal required to be detected through the detector in a way that simulates the normal product path. The detector should indicate a detection. If it does not, find the reason and correct it.

Verify the performance of the reject system on a regular basis. When a metal target is detected, the reject system should operate reliably at the correct time to reject the metal.

It is common for conveyor speeds in plants to be changed for a variety of reasons. When this occurs, if there is a metal detector with a timed reject device on the conveyor, the timing of the reject device must be appropriately adjusted. Failure to do this will create an insidious situation in which it will appear that the detector and reject device are working properly. However, although the detector will detect metal, the reject device-improperly timed-will reject good product. The metal will be passing through to the output of the line.

If the detector incorporates a record-keeping function, synchronize the clock with a known clock at frequent intervals.

MAINTAINING

Three of the chief enemies of an industrial metal detector are electrical noise, impact, and water. While the damage caused by impact and water is usually visible if time is taken for a close inspection, electrical noise in the environment can affect the operation of the detector at least as seriously as the more visible damage. You should guard against all of these.

ELECTRICAL NOISE

Electrical noise often causes a degradation in detector operation or reliability, to the point that the detector is taken off-line because of apparently erratic operation, and the protection it had originally offered is lost. Detectors are sensitive to both radiated and line noise. Radiated electrical noise in today's industrial environment most commonly comes from variable

frequency motor controls. Line noise may arise from any significant changes in the loading of the electrical mains feeding the detector. If the reliability or stability of your detector degrades over time, and if there have been electrical equipment changes in the neighborhood of the detector, investigate the possibility of noise as the cause. The simplest method is to remove all possible sources of noise and observe the operation of the detector. If operation is restored to



normal, then one of the removed sources was the cause of the improper operation. (If operation is not restored to normal, then electrical noise was not the problem). Further identification of the culpable noise source may be achieved by restoring, in turn, each of the sources that was removed. When the metal detector performance again degrades, the most recently restored noise source is the likely cause. Keep in mind that (a) there may be more than one cause, and (b) it is not easy to identify all potential noise sources. In searching for noise, consider equipment on different floors, the floor where the detector is located and equipment that only operates intermittently.

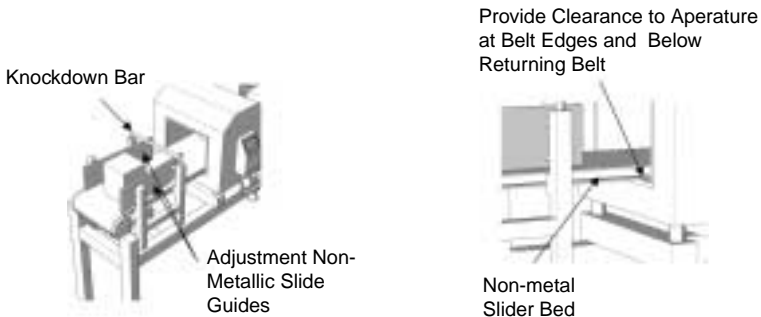
Some detectors, notably the E-Z Tec and E-Z Tec DSP lines, allow separate control of the transmitter and receiver in a troubleshooting mode, to identify and isolate line-borne or airborne electrical noise. Request a troubleshooting guide (or advice) from Eriez for assistance in making use of these capabilities.

IMPACT AND WEAR

With the exception of the 1200 series detectors (transmit-receive design) with swing away coils, almost all metal detectors can be severely damaged by impact of product in the sensor area. The incentive to switch off a damaged metal detector, with the production line still running, or just to let the detector operate in a damaged condition, is often compelling, due to production schedules, service availability, etc. In many cases, damage to a metal detector is not noticed until a significant, and unknown quantity of product has passed, uninspected. Obviously, in such situations, the protection offered by the detector is compromised if not totally lost. Even if the detector does not sustain significant damage, impacts particularly if repeated, indicate poor control over product position as it is presented to the detector, and, therefore, unreliable detection of metal. Prevention of product impact, or expressed another way, proper control of product position within the detector, are vital to a reliable quality control.

Bulk product conveyed through an aperture or bridge style detector should be guided by stationary (but adjustable) side guides to keep it centered on the conveyor. The bed depth should be controlled by a knock-down device upstream of the detector. The knock-down should precede the side guides. Both devices should center the product bed to provide clearance between the product and the metal detector sensor surfaces at least equal to the average size of a single product "chunk". If this clearance cannot be provided, the detector aperture or bridge surfaces should be protected by rugged non-metallic side-walls and/or ceiling. The conveyor belt itself should be carefully centered in the detector aperture, and should be checked and adjusted periodically.

Packaged products should be conveyed through (or past) the detector in a consistent orientation, centered relative to the sensor. Besides minimizing the chance of impact with the sensor, this practice will improve the reliability of metal detection. If there is a package orientation that will cause impact with a metal detector surface, that orientation should be modified by knock-down bars or side guides as appropriate. For packages, the knockdown does not necessarily precede the side guides as long as the package orientation remains controlled. Package spacing on the conveyor must allow room for any reorientation that may be required.



Aperture style detector systems frequently incorporate an endless conveyor belt arrangement in which the lower, or “return” leg also passes through the detector aperture. Care should be taken to be sure this part of the belt run does not move out of adjustment and contact the inner surface of the aperture. Even the slightest contact can result in relentless wear that will eventually destroy the aperture liner, allow moisture inside the housing, and cause the detector to be inoperable. Similar care should be applied to under-belt detector installations, to be sure that the belt sag does not increase and cause detector wear.

WATER

Water is one of the primary enemies of a metal detector. Water that enters the metal detector housing can cause immediate or long term corrosion and malfunction of the electronics. This may result in obvious failure, or, worse, long term loss of sensitivity without other malfunctions. All detectors are carefully designed to resist water penetration. However, the necessity of shielding the detector circuitry from external electromagnetic noise, and the requirement that the detector itself not emit significant stray electromagnetic radiation, cause challenging and conflicting seal design problems. Electromagnetic sealing favors metallic seals; moisture sealing favors compliant seals.

Although modern industrial metal detectors generally address these problems successfully, and are designed and constructed to resist water penetration, conservative maintenance practice requires that high pressure cleaning jets not be directed unnecessarily at control panels, access doors, aperture seals, and similar potentially vulnerable points. Even a detector designed, constructed, tested and advertised to operate entirely submerged under, say, 10 feet of water, has only a resistance to approximately 4 psi external water pressure. Cleaning jets may operate at 500 to 1000

times this pressure. Still worse, the pressure in a cleaning jet is not constant, but oscillates at high frequency, causing seals that could withstand this much pressure statically to fail under the multiple impacts. When cleaning jets must be operated in the vicinity of a metal detector, it is strongly recommended that auxiliary shields be added to prevent direct impact on the control panel (at least).

The other potential source of internal moisture in a metal detector is condensation. Some air necessarily passes in and out of any detector housing, and when the detector is subjected to a cooler environment, internal condensation is likely to occur. This can cause corrosion and malfunction problems in the same way as injected water. Due to heat from the electronics, detectors are not generally subject to condensation problems as long as they are operating. Therefore, the primary method of preventing condensation is to keep the detector "ON" as much as possible. Detectors should be stored only in dry environments—employing desiccant in any packing used, and when returned to service, they should be allowed to acclimatize to the new environment at least overnight before being operated. Some detectors, such as handheld models, are designed to be turned on and off frequently, and these condensation-avoidance precautions are not necessary. As always, consult the IOM for your particular metal detector model.

SUMMARY

This manual has attempted to present general information on industrial metal detection to enable you to make a more informed selection and application of the types and options that are available. Keep in mind that the best metal detector installations are those that have been planned for from the beginning stages of production line design. Because reject timing and metal-free zones are critical issues with most detectors, the simple provision of adequate space for a detector at the early stages of planning a production line can be the most important metal detection decision you will make.

Eriez offers "standard" metal detectors to fill almost any industrial quality-control requirement. In addition many of our detector applications have been highly customized for the individual user. Our design process is computerized, and even the most customized detector is optimized for highest sensitivity and best noise rejection. We also have designed and built conveyor / rejection systems for applications ranging from logs to pharmaceutical tablets. We have lab facilities to test your specific product under realistic operating conditions and with known contaminants to assist in detector selection and optimization. Feel free to draw on this extensive metal detector application experience by consulting our experts at any stage in your design process.

FOR MORE INFORMATION on circular, rectangular or any mechanical vibratory separator or system available for automation, material movement, separation, purification, beneficiation, reclamation and pollution control, write or call

ERIEZ MAGNETICS WORLD HEADQUARTERS

2200 Asbury Road, P.O. Box 10608, Erie, Pennsylvania 16514, U.S.A.
800/345-4946 or 814/835-6000

Plate Magnets

Grate Magnets

Ferrous Traps

Magnetic Humps

Suspended Magnets

Magnetic Pulleys

Magnetic Sweepers

Dry Magnetic Drums

Wet Magnetic Drums

High Intensity Separators

Electrostatic Separators

Superconducting HGMS

Rare Earth Magnetic Roll Separators

Magnetic Flocculators

Demagnetizing Coils

Metal Detectors

Eddy Current Separators

Magnetic Rails

Magnetic Rolls

Sheet Fanners

Lifting Magnets

Holding Magnets

Coolant Cleaners

Magnetic Conveyors

Vibrating Conveyors

Mechanical Conveyors

Vibratory Feeders

Volumatic Feeders

Bin Vibrators

Precipitator Vibrators

Screen Separators

NOTES:

***For solutions to
your process problems
contact your nearest
Eriez representative
and just: Ask Orange.***



CONTACT ERIEZ

With manufacturing plants on five continents and a global network of factory-trained representatives, getting professional assistance is just a call away.

Country Code:	Telephone:	E-mail:
AUSTRALIA61.....	3-9305-4099	eriezaus@eriez.com.au
CANADA01.....	905-795-0444	eriezcanada@eriez.ca
CHINA86.....	21-5046-2123	eriez@eriez.com.cn
EUROPE44.....	29-208-68501	eriez@eriezeurope.co.uk
INDIA91.....	80-845-5381	emil@emil.co.in
JAPAN81.....	473-546381	thomma@eriez.co.jp
MEXICO52.....	5-565-3855	operaciones@avante.net
SOUTH AFRICA27.....	11-444-9160	eriezmag@iafrica.com
UNITED STATES01.....	814-835-6000	eriez@eriez.com





*World authority in advanced technology for magnetic,
vibratory and metal detection applications*

Eriez manufactures magnetic lift and separation, metal detection, materials feeding, screening, conveying and controlling equipment for application in the process, metal working, packaging, recycling, mining, aggregate and textile industries among others. Eriez manufactures and markets these products through nine international facilities located on five continents... Australia, Brazil, Canada, China, England, India, Japan, Mexico, South Africa, as well as the United States.

0104-5M-AH-PC