

PIPELINE METAL DETECTORS

PRINCIPLES OF OPERATION & FUNCTIONALITY

Understanding electromagnetic detection, product effect, sensitivity, automatic rejection, validation and hygienic integration in pumped process lines.



**ENGINEERED TO DETECT.
DESIGNED TO PROTECT.**



WHY PIPELINE METAL DETECTION EXISTS

Product Cannot Be Protected By Appearance Alone



METAL CONTAMINATION CAN HAPPEN

Metal contamination can occur at any time during the manufacturing process—from raw material receipt to final packaging. Sources include worn or broken equipment parts, fasteners, tools, screens, and environmental debris. Even small pieces can compromise safety, damage equipment, and harm brand reputation.



INSPECTION BEFORE FILLING OR PACKAGING

Placing a metal detector in the pipeline before the filler or packager is the last line of defense. It ensures that only clean, contaminant-free product moves forward in the process—protecting consumers and safeguarding your brand.



A COMPLETE SYSTEM DOES MORE

Detection alone is not enough. A truly effective system must **INSPECT, DETECT, REJECT, and VERIFY**—responding automatically and confirming performance so contaminated product never reaches the consumer.

THE COMPLETE PROTECTION PROCESS



INSPECT

Continuously monitor the product stream to ensure the system is ready and the product is flowing properly.



DETECT

Identify metal contaminants—ferrous, non-ferrous, and stainless steel—even when embedded in product.



REJECT

Automatically and accurately remove contaminated product from the line before it can move forward.



VERIFY

Confirm system performance with automated validation and data tracking for complete process assurance.

THE INSPEX PHILOSOPHY

Metal detection should not simply identify contamination. It should control the process response to contamination.

WHERE PIPELINE DETECTORS ARE USED

Designed for Products That Can Be Pumped



FOOD & BEVERAGE

Ensure product purity and protect consumers with reliable detection of metal contaminants in pumped foods and beverages.



NUTRACEUTICAL & PHARMACEUTICAL

Safeguard health and ensure compliance by detecting metal contaminants in pumped supplements, liquids, and pharmaceuticals.



COSMETICS & PERSONAL CARE

Maintain product integrity and brand trust by detecting metal contaminants in lotions, creams, shampoos, and other personal care formulations.



CHEMICAL & INDUSTRIAL

Protect equipment and maintain process efficiency by detecting metal contaminants in pumped chemicals, additives, and industrial fluids.



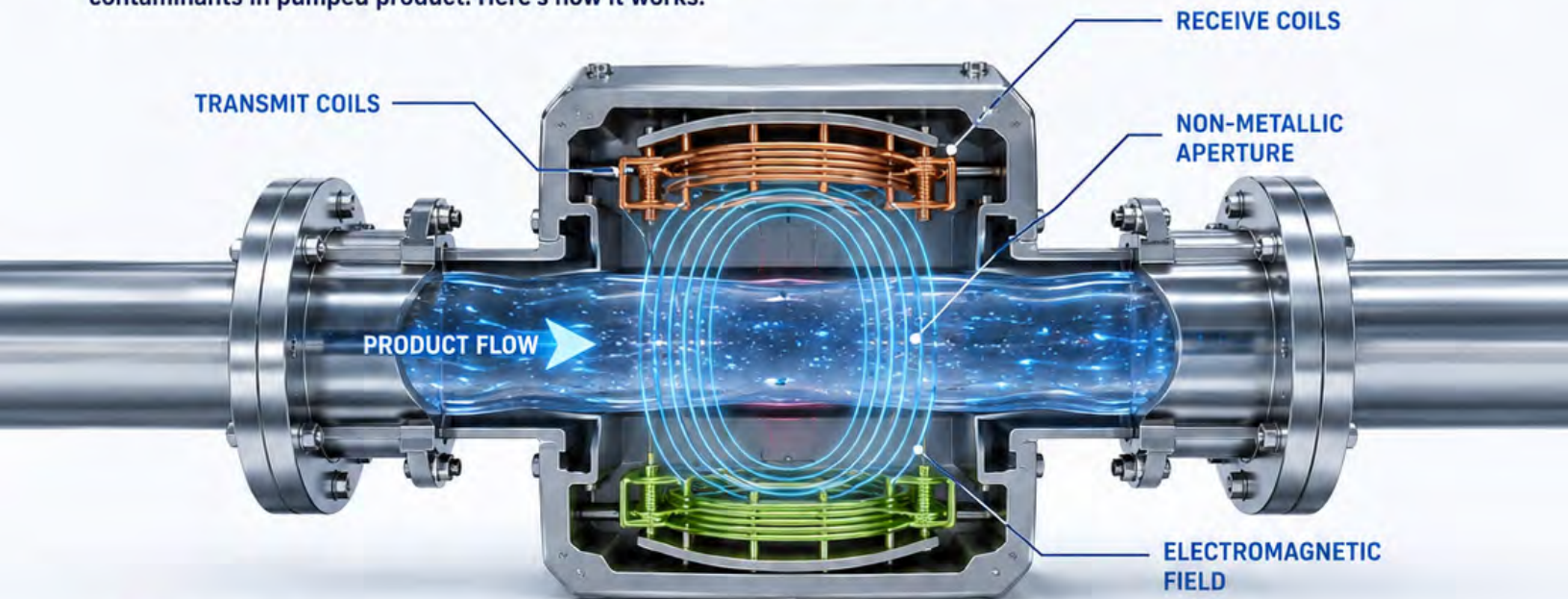
If the material can be transferred reliably through a sanitary pipe, a pipeline detector may often inspect it without exposing the product to the environment.



THE BASIC PRINCIPLE

How Does a Metal Detector Actually Detect Metal?

Pipeline metal detectors use electromagnetic technology to detect all types of metal contaminants in pumped product. Here's how it works:



1

TRANSMIT

Transmit coils generate a high-frequency electromagnetic field within the aperture.

2

BALANCE

In the absence of metal, the receive coils detect a balanced signal.

3

DISTURB

When metal passes through the field, it induces eddy currents that disturb the field.

4

ANALYZE

Receive coils sense the disturbance and send the signal to the electronics.

5

DETECT

The system analyzes the signal and determines the presence of metal.

6

REJECT

If metal is detected, the system activates an alarm and/or reject mechanism.



IMPORTANT:

The detector does not "see" metal like a camera. It measures the electromagnetic disturbance caused when metal passes through its detection field.



THE THREE PRIMARY METAL CATEGORIES

Not All Metal Behaves the Same Way



FERROUS — Fe

Examples: Iron, Carbon Steel

Ferrous metals are magnetic, meaning they strongly interact with a metal detector's magnetic field. This creates a strong signal, making ferrous contaminants easier to detect—even in larger particle sizes or deeper within the product.

WHY THEY BEHAVE DIFFERENTLY

Their magnetic permeability is high, so they distort the magnetic field in a way that produces a strong and consistent response.



NON-FERROUS — NFe

Examples: Aluminum, Copper, Brass

Non-ferrous metals are not magnetic, so they do not interact with the magnetic field like ferrous metals. Detection relies on the metal's electrical conductivity, which induces a weaker signal. These metals often require smaller particle sizes or higher sensitivity settings to detect consistently.

WHY THEY BEHAVE DIFFERENTLY

Their lack of magnetic properties means they produce a weaker induced signal, making them harder to detect—especially in conductive or wet products.



STAINLESS STEEL — SS

Examples: 304, 316, 430 Stainless Steel

Stainless steel varies. Some grades (like 304, 316) are non-magnetic (austenitic) and behave like other non-ferrous metals. Others (like 430) are magnetic (ferritic) and behave more like ferrous metals. This is why stainless steel sensitivity is specified separately.

WHY THEY BEHAVE DIFFERENTLY

The crystal structure of stainless steel determines whether it is magnetic or not—changing how it interacts with the detector and the signal it produces.



SENSITIVITY IS NORMALLY SPECIFIED SEPARATELY:

Fe | Non-Fe | Stainless Steel

UNDERSTANDING SENSITIVITY

What Does '1.5 mm Sensitivity' Actually Mean?

Sensitivity indicates the ability of a metal detector system to detect a specific size of test sphere under defined test conditions.

InspeX specifies sensitivity using **standardized spherical test pieces** made from ferrous (Fe), non-ferrous (NFe), and stainless steel (SUS).

EXAMPLE:

Fe: 1.2 mm

The system will reliably detect a 1.2 mm diameter ferrous (steel) sphere under standard test conditions.

FACTORS THAT INFLUENCE DETECTION PERFORMANCE

- ✓ Product Characteristics (type & composition)
- ✓ Product Temperature
- ✓ Salt Concentration
- ✓ Moisture Content
- ✓ Electrical Conductivity
- ✓ Product Velocity
- ✓ Pipe Diameter
- ✓ Detector Frequency
- ✓ Contaminant Orientation
- ✓ Contaminant Location in the Pipe
- ✓ Vibration
- ✓ System Setup & Configuration



KEY PRINCIPLE:

Sensitivity is a property of the **complete application** – not simply the detector head.

THE APERTURE EFFECT

Why Pipe Diameter Matters

In electromagnetic metal detection, aperture size has a direct impact on sensitivity. As the detection aperture increases, very small metal contaminants become more difficult to detect.

APERTURE SIZE vs. SENSITIVITY



BALANCING FACTORS



REQUIRED FLOW RATE

Higher flow may require a larger aperture



REQUIRED SENSITIVITY

Smaller apertures provide greater sensitivity



PRODUCT PRESSURE DROP

Smaller apertures can increase pressure drop



CLEANABILITY / PROCESS REQUIREMENTS

Consider product characteristics and cleaning needs



ENGINEERING PRACTICE

Select the smallest practical product path capable of handling the required flow without compromising the process.

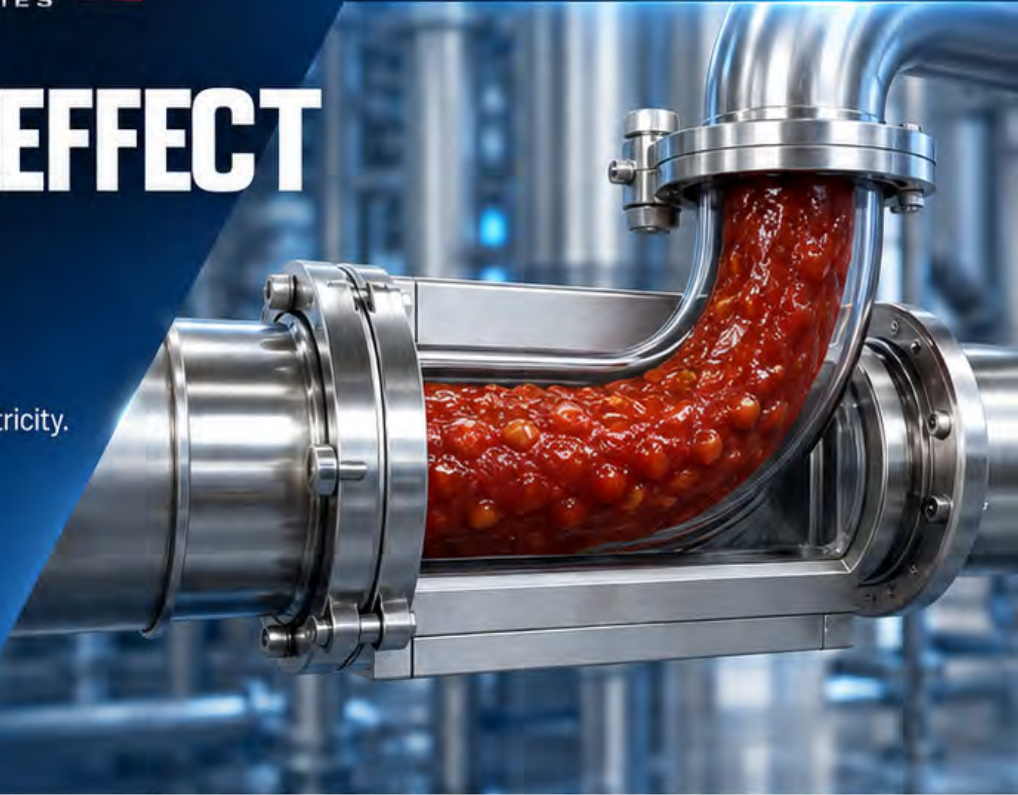


PRODUCT EFFECT

The Product Itself Can Look Like Metal

Many food products naturally conduct electricity. Moisture, salt, acids, and conductive ingredients can create a signal in the detector that may look like metal.

The detector must learn the “normal” product signal and then identify anything that deviates as a potential contaminant.



NORMAL PRODUCT vs. CONTAMINANT SIGNAL

NORMAL PRODUCT

Expected signal from the product



CONTAMINANT

Metal causes a stronger, different signal response



The detector compares incoming signals to the learned product profile. Deviations are flagged as potential metal.

EXAMPLES OF HIGH PRODUCT-EFFECT MATERIALS

-  Sauces (ketchup, BBQ, pasta sauce)
-  Marinades and brines
-  Cheese products
-  Meat emulsions (bologna, hot dogs)
-  High-moisture foods
-  Conductive slurries and suspensions
-  Mineral-rich formulations
-  Elevated-temperature products (heat increases conductivity)



GOAL:

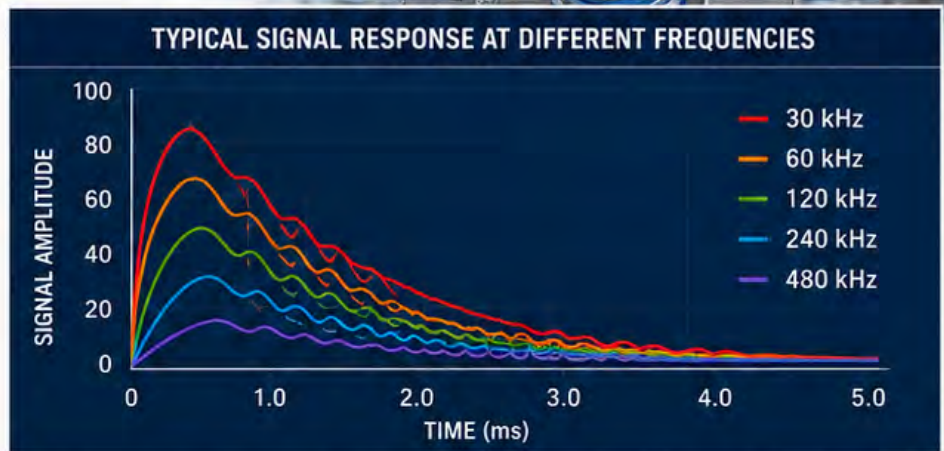
Teach the detector what “good product” looks like so it can recognize when something is different.

FREQUENCY & SIGNAL PROCESSING

WHY DETECTION FREQUENCY MATTERS

Detection frequency determines how the metal detector interacts with both the product and the contaminant. It affects signal strength, sensitivity to different metals, and the system's ability to reject product effect.

No single frequency is ideal for every application.



Lower frequencies offer greater penetration. Higher frequencies improve sensitivity to small targets. The right balance delivers optimal performance.

MODERN DIGITAL SYSTEMS PROVIDE THE FLEXIBILITY TO OPTIMIZE PERFORMANCE



1. SELECTABLE FREQUENCIES

Choose the best frequency for the product type and contaminant size.



2. MULTIPLE OPERATING FREQUENCIES

Run simultaneous frequencies to maximize sensitivity and stability.



3. PRODUCT COMPENSATION ALGORITHMS

Continuously learns and adjusts to product effect for consistent detection.



4. PHASE DISCRIMINATION

Separates metal signals from product effect for superior accuracy.



5. DIGITAL SIGNAL FILTERING

Advanced filtering removes electrical noise and improves signal clarity.



6. RECIPE-BASED SETTINGS

Save and recall optimized settings for repeatable performance across product runs.



THE TAKEAWAY:

A properly engineered system must balance **Sensitivity + Stability + Repeatability.**



THE PIPELINE DETECTION SEQUENCE

What Happens When Metal Is Detected?

- 01 PRODUCT FLOWS**
Product flows through the stainless-steel pipeline and into the detector.
- 02 CONTAMINANT ENTERS THE FIELD**
A metal contaminant enters the detection field with the product.
- 03 DETECTOR IDENTIFIES THE EVENT**
The detector senses a change in the electromagnetic field caused by the metal contaminant.
- 04 OUTPUT SIGNAL IS GENERATED**
The detector processes the signal and generates a reject output.
- 05 PRODUCT IS DIVERTED**
The reject mechanism is activated to divert contaminated product.
- 06 CONTAMINATED PRODUCT IS ISOLATED**
The contaminated portion is moved to a sealed reject collection chamber.
- 07 REJECTION IS VERIFIED**
The system confirms the reject event was successful.
- 08 EVENT IS RECORDED**
The event is logged with time, date, and detection details for traceability.
- 09 PRODUCTION RESUMES**
The system resets automatically and production continues.



DETECT → DIVERT → CONFIRM → RECORD → RESUME



AUTOMATIC REJECTION

DETECTION WITHOUT EFFECTIVE REJECTION IS ONLY HALF A SYSTEM

The reject mechanism is the critical final step in product protection. When a contaminant is detected, the reject system instantly diverts the tainted product away from the good-product path and directs it to the reject path—ensuring only safe, compliant product reaches your customers.



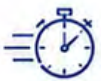
COMMON REJECT STYLES



Three-Way Sanitary Diverter Valves



Pneumatic Reject Valves



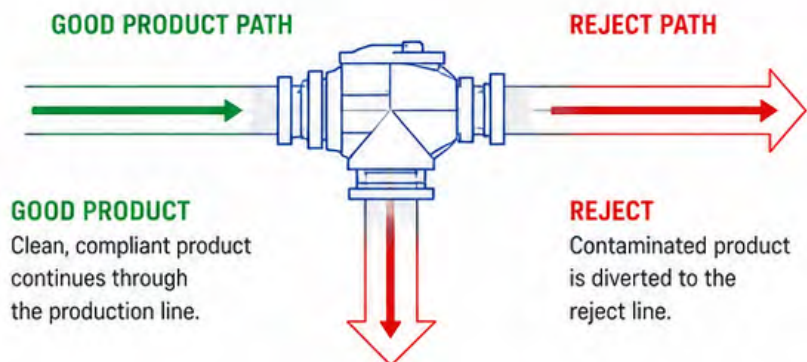
High-Speed Sanitary Valves



Double-Seat or Mixproof Arrangements



High-Viscosity Reject Assemblies



THE REJECT INTERVAL MUST ACCOUNT FOR

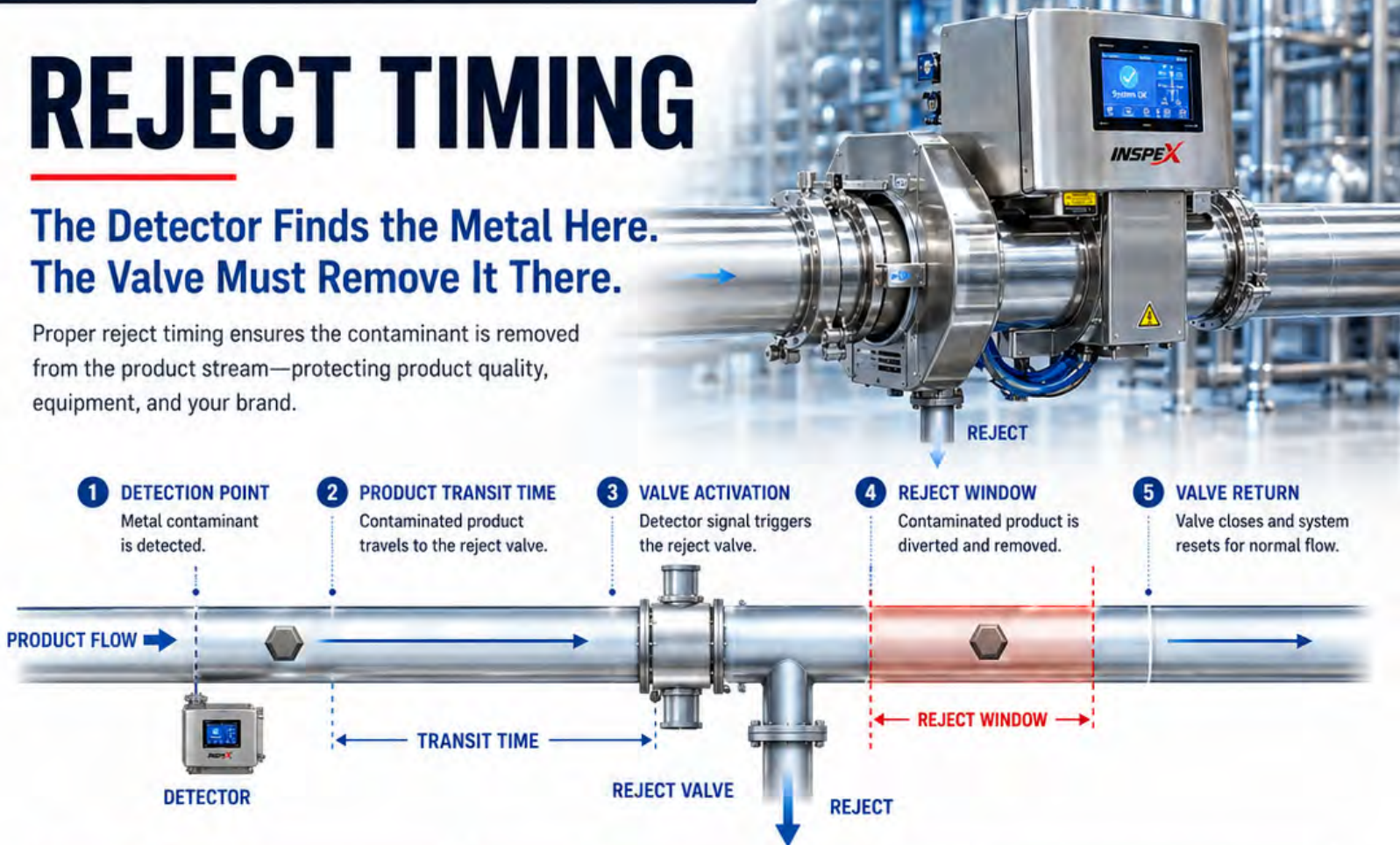
- ✓ Product Velocity
- ✓ Distance to Valve
- ✓ Valve Response Time
- ✓ PLC Response Time
- ✓ Pipe Diameter
- ✓ Flow Profile



REJECT TIMING

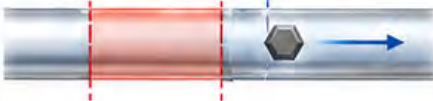
**The Detector Finds the Metal Here.
The Valve Must Remove It There.**

Proper reject timing ensures the contaminant is removed from the product stream—protecting product quality, equipment, and your brand.



❌ TOO EARLY

Valve opens before the contaminant arrives.
CONTAMINANT NOT REMOVED.



Results in product contamination and potential recall risk.

❌ TOO LATE

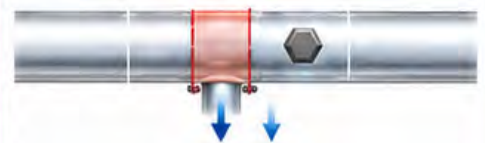
Valve opens after the contaminant has passed.
CONTAMINANT NOT REMOVED.



Results in product contamination and potential recall risk.

✅ CORRECTLY TIMED

Valve opens within the reject window.
CONTAMINANT REMOVED.



Protects product quality, equipment, and brand integrity.

FACTORS THAT AFFECT REJECT TIMING



VALVE ACTUATION TIME

The time it takes for the valve to fully open and direct product.



FLOW VARIATIONS

Changes in flow rate impact transit time and timing accuracy.



VISCOSITY CHANGES

Thick or varying viscosity affects product movement speed.



PUMP PULSATION

Positive displacement pumps can cause timing inconsistency.



PROCESS PRESSURE

Pressure fluctuations can alter flow and timing.



CONTROL LATENCY

Detector processing time and system communication delays.



FAIL-SAFE SYSTEM DESIGN

What Happens When Something Goes Wrong?

A fail-safe inspection system continuously monitors critical functions and takes automatic action to protect your product, equipment, and brand.



TYPICAL MONITORED CONDITIONS INCLUDE:



Reject-Valve Position



Compressed-Air Pressure



Detector Fault Condition



Reject Confirmation



Reject-Bin Status



PLC Communication



Emergency-Stop Condition



Pump or Upstream-Machine Status

Metal Detected

Reject Commanded

Reject Position
Not Confirmed

STOP THE
PRODUCT PUMP

INHIBIT UPSTREAM
PRODUCTION



**A FAIL-SAFE INSPECTION SYSTEM
DETECTS FAILURES IN THE INSPECTION SYSTEM ITSELF.**

VALIDATION & CHALLENGE TESTING

How Do You Know the Detector Is Still Working?

Validation and challenge testing confirm that your metal detector is performing as intended—protecting your product, your brand, and your customers.

Routine testing with certified test pieces verifies detection capability and ensures the entire system responds correctly.



CERTIFIED TEST STANDARDS

Use certified test pieces traceable to recognized standards to challenge the detector's performance.



FE
Ferrous



NFE
Non-Ferrous



SS
Stainless Steel

THE COMPLETE SYSTEM RESPONSE IS TESTED



DETECTION

Metal is detected at or below the specified threshold.



ALARM

The alarm is activated to alert operators.



REJECT

The reject device activates to remove the contaminated product.



REJECT CONFIRMATION

The system confirms that the contaminated product was successfully rejected.



EVENT RECORDING

The event is logged for traceability and recordkeeping.

TESTING SCHEDULES MAY INCLUDE:

- ✓ Start of Production
- ✓ Product Changeover
- ✓ Scheduled Intervals During Production
- ✓ After Maintenance
- ✓ After Cleaning
- ✓ End of Production



TESTING FREQUENCY SHOULD BE ESTABLISHED BY:

- Risk assessment
- HACCP or HARPC plan
- Customer requirements
- The applicable quality system

HYGIENIC & PROCESS ENGINEERING

A Detector Is Part of the Process Piping

ENGINEERING CONSIDERATIONS

-  Sanitary Stainless-Steel Product Path
-  Appropriate Surface Finish
-  Minimal Product-Retention Zones
-  Drainability
-  Hygienic Seals
-  Sanitary Connections
-  Tool-Free or Rapid Disassembly
-  CIP Compatibility
-  Washdown Environment
-  Ingress Protection
-  Product Pressure
-  Product Temperature
-  Viscosity
-  Pump Characteristics
-  Valve Cleanability



ENGINEER THE WHOLE SYSTEM —

Product → Pump → Detector → Reject Valve → Downstream Process

Not simply: Buy a detector.

INSPEX | ENGINEERING THE CRITICAL CONTROL POINT BEYOND METAL DETECTION



DETECTION IS ONLY THE BEGINNING.
WE ENGINEER THE RESPONSE.



✓ ELECTROMAGNETIC DETECTION

High-sensitivity detection of ferrous, non-ferrous and stainless steel contaminants.



✓ APPLICATION ENGINEERING

Tailored system design for your product, process and production environment.



✓ PRODUCT COMPENSATION

Automatic learning and real-time compensation for consistent accuracy and stability.



✓ AUTOMATIC REJECTION

Reliable, hygienic reject systems designed for your product and line conditions.



✓ REJECT VERIFICATION

Confirms every reject to eliminate false rejects and ensure product integrity.



✓ FAIL-SAFE CONTROL

Designed to protect product quality—fails safe to an alarm state on any fault.



✓ VALIDATION

Supports commissioning, validation and compliance with global food safety standards.



✓ DATA & TRACEABILITY

Built-in data capture, reporting and connectivity for full process visibility.

COMPLETE INSPEX SOLUTIONS



PIPELINE
METAL DETECTION



CONVEYOR
METAL DETECTION



FOIL PACKAGE
INSPECTION



DYNAMIC
CHECKWEIGHING



COMBINATION
INSPECTION SYSTEMS

