Metal Control Technology
Frank Reda, Separation and Electronic Inspection Product Manager, Certified Food Safety HACCP Manager
Presentation Overview

- Principles of Magnetic Separators
  - Magnetic Material and Energy
    - Ceramic
    - Rare Earth
    - MGOe
  - Magnetic Circuit Design
  - Magnetic Separator Placement
  - Permanent magnetic separators and energy loss
  - Cleaning Your Magnetic Separators
- Principles of Metal Detection
  - Coil Size versus Sensitivity
  - Product Signatures
- Food Safety and FSMA
  - The 7 Principles of HACCP
  - Control Point or Critical Control Point
  - Monitoring and Validation
  - Reporting and Record-keeping Requirements
- X-ray – Applications in Milling
MPI: Company Overview

- Founded in 1981
- Located in Metro Detroit Michigan
- Design and build magnetic separation systems, assemble, distribute and service electronic inspection systems
- Experts in complete metal control systems
- In house fabrication facilities, AutoCAD Inventor design
- Approximately 60 employees
- Primarily operates in: foods, plastics, pharmaceuticals, recycling, textile, and material handling
- Strong emphasis on customer education
- Local Regional Managers & Manufacturing Representatives covering majority of the Americas
1981  
MPI begins operations in Walled Lake, Michigan

1982  
MPI introduces its free magnet audit services

1983  
- A Magnet Is Not Just A Magnet educational training is first given  
- MPI introduces the first generation of self-cleaning magnets

1991  
MPI patents the Reciprocating Drawer Magnet

1993  
MPI relocates to Highland, Michigan to a state-of-the-art manufacturing facility, doubling capacity

2010  
MPI becomes the exclusive US distributor for Cassel

2011  
MPI celebrates 30 years

2014  
MPI adds checkweigh and x-ray to its offerings

2015  
MPI receives USDA certification for several of its magnet models

2017  
All Regional Sales Managers become Certified Food Safety HACCP Managers (CFSHM) from The National Registry of Food Safety Professionals
Principles of Magnetic Separators

- **Magnetic Materials:**
  - **Ceramic Magnetic Material**
    - Developed in 1952
    - Manufactured of Iron Oxide and Strontium or Barium
    - Maximum MGOe of 3.5
  - **Advantages of Ceramic Magnets**
    - Low in cost
    - High Coercive Force
    - Highly resistant to corrosion
    - High Tmax (maximum normal operating temperature) of 572F, 300C
    - High Curie Temperature (temperature at which the magnet will become permanently demagnetized) 860F, 460C
  - **Disadvantages of ceramic magnets**
    - They can only be manufactured up to 3.5 MGOe which limits the amount of suitable applications where we may be looking for smaller mass ferrous tramp metal in high volume production lines
Magnetic Materials cont.

Rare Earth Magnetic Material

“Rare Earth” magnetic material is not rare. They are called “Rare Earth” because Samarium and Neodymium, both key ingredients in the magnets, fall under the Rare Earth portion of the Periodic Table of Elements.

Samarium Cobalt

- Developed in 1966
- Made with a blend of Samarium, Cobalt and Iron
- Maximum MGOe of 30

Advantages of Samarium Cobalt Magnets

- Their ability to be used in high temperature applications. Tmax of 572F (300C)
- Tcurrie of 1382F (750C) make them far superior than Neodymium in applications above 300F
- High energy product of up to 32MGOe
- Highly resistant to oxidation

Disadvantages of Samarium Cobalt Magnets

- Higher in cost than other rare earth magnets
- Are extremely brittle making them highly susceptible to physical damage

Principles of Magnetic Separators
Magnetic Materials cont.

Rare Earth Magnetic Material

Neodymium

- In 1983 joint research between General Motors, Sumitomo Special Metals and the Chinese Academy of Sciences developed the first Neodymium magnet
- Made with a blend of Neodymium, Iron and Boron
- Currently 52 MGOe is the maximum energy readily available on the market

Advantages of Neodymium magnets

- They have a very high energy product at 52MGOe+ enabling them to remove fine metal particulate in high volume applications

Disadvantages of Neodymium Magnets

- They are easily oxidized
- They have low corrosion resistance
- They have only moderate temperature stability with a Tmax of 302F (150C) and Tcurie of 590F (310C)
- They are brittle so are subject to damage from shock or vibration
Principles of Magnetic Separators

- Magnetic Material Energy
  - MGOe
    - MGOe is the unit of measurement used when stating the maximum energy product, or maximum amount of energy for a given material used in making a magnet
    - Since MGOe is finite, every manufacturer using the same MGOe material will have the same amount of magnetic energy (flux density) available to use when designing the magnetic circuit
    - Where you focus the energy with the magnetic circuit design determines the effectiveness of the magnetic separator for any given application
      - Focusing more energy at the surface of the magnet results in higher pull test holding values and gauss readings at the surface of the magnet, but less flux density away from the surface of the magnet
      - Focusing more energy away from the surface of the magnet results in greater “reach out,” or higher flux density away from the surface of the magnet, but lower pull value holding force or gauss level readings at the surface of the magnet
Magnet Design

Rare Earth Magnets (Nickel Plated Exterior-Standard on all MPI magnets)
Carbon Steel Poles
Stainless Steel Tubing
Principles of Magnetic Separators

So if all the manufacturers are using the same MGOe material, how can there be claims that “We have the strongest magnet on the market"?

Composite Material Construction – Competitive Compromise

- Reducing Air Gap
  - Thinner Tubes – less steel between the magnet and product

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased holding value</td>
<td>Decrease in durability – tubes are easily dented and product can quickly wear through completely</td>
</tr>
<tr>
<td>Increased Gauss</td>
<td></td>
</tr>
</tbody>
</table>

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# Competitive Compromise

- Reducing Air Gap
  - Uncoated magnet block
  - Inadequate protective coating

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased holding value</td>
<td>Oxidization (similar to rusting) breaks down the structure of the magnet which then changes permanently, resulting in a progressive loss of magnetic performance, during which the magnet will weaken and break down into a powder</td>
</tr>
<tr>
<td>Increased Gauss</td>
<td></td>
</tr>
</tbody>
</table>
## Composite Material Construction

<table>
<thead>
<tr>
<th>Brand/Construction</th>
<th>MPI (Hi-G)</th>
<th>Brand “X”</th>
<th>Brand “Y”</th>
<th>Brand “Z”</th>
</tr>
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<tbody>
<tr>
<td>Wall Thickness</td>
<td>Less 47%</td>
<td>Less 21%</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Gauss @ Surface</td>
<td>10,650</td>
<td>10,848</td>
<td>10,500</td>
<td>9,136</td>
</tr>
<tr>
<td></td>
<td>+1.8%</td>
<td>+1.9%</td>
<td>-1.5%</td>
<td>-16.6%</td>
</tr>
<tr>
<td>½” Pull Value @ Surface (lbs)</td>
<td>15.5</td>
<td>15.8</td>
<td>15.08</td>
<td>16.24</td>
</tr>
<tr>
<td></td>
<td>+1.9%</td>
<td>-2.8%</td>
<td>+4.8%</td>
<td></td>
</tr>
<tr>
<td>¼” Pull Value @ Surface (lbs)</td>
<td>5.8</td>
<td>6.1</td>
<td>5.72</td>
<td>5.55</td>
</tr>
<tr>
<td></td>
<td>+5%</td>
<td>-1.5%</td>
<td>-4.5%</td>
<td></td>
</tr>
</tbody>
</table>
Magnetic Circuit Design: How do Magnetic Separators Work?

The 3 Magnetic Circuits

Type A

Type B

Type C
Circuit “Type A” Magnet Examples

- Pneumatic Line Magnets
- Drawer Magnets
- Grate Magnets
“Type B” Principles of Application

Mounted to Bottom of an Angled Chute

Cross-Mounted in a Vertical-Flow Gravity Chute

Suspended Over a Conveyor Belt or an Angled Chute
Circuit “Type B” Magnet Examples

- Plate Magnets
- Hump Magnets
- Magnetic Chutes
“Type C” Principles of Application

- Free Flow Cylinder Magnets
- Tramp Metal Retention Area
- Tramp Metal Discharge Area
- Drum Separator, Housings, and Magnetic Head Pulleys
Circuit “Type C” Magnet Examples

Free-Flow Cylinders

Magnetic Pulleys / Separation Rolls
Magnetic Separator Placement

Primary
Secondary
Finishing
Primary Applications

**Function:**
- Process high volume product flows
- Remove incoming ferrous tramp
- Retain large volumes of ferrous tramp between magnet cleaning cycles
- Vendor monitoring

**Where is It Used?**
- Plant receiving areas

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Primary Installation
Secondary Applications

Function:
- Protect specific plant equipment
- Detect process equipment malfunctions

Where is It Used?
- Hammer mills
- Airlocks
- Screw & drag conveyors
- Sifters
- Roller mills
- Bucket elevators
- Screeners
- Pumps
Secondary Installation
Finishing Applications

Function:
- Maintain end-product quality
- Ensure that the product to be shipped from the plant does not contain any ferrous contaminants
- Consumer protection
- Brand protection

Where is It Used?
- Packing systems
- Bulk load-out areas
Magnet Life Expectancy

Modern magnets boast an estimated loss of life equal to less than one half of one percent every 100 years.
Heat - Heat above the maximum level rated for the magnet material in your separator will decrease the strength of the magnet. Standard rare earth material from MPI has a maximum temperature of 176°F and standard ceramic material has a maximum temperature of 400°F. Higher temperature materials are available and may have been used in your system. Consult the factory if you have questions on what the maximum temperature is for your system.

Impact - Sharp impacts to the magnet from physical abuse or handling can result in the decreased magnet strength. The magnet material inside your separator is brittle and these impacts can lead to fractures in the material, weakening its strength.

Welding - Welding on or around the magnet can lead to decreased magnet performance. This can be a result of the heat or current generated from the welding process.

Liquid ingress - If your magnet housing is compromised, moisture can enter the housing of the magnets. This can lead to oxidation of the magnet material which will eventually lead to a weakened magnetic system. If the housing is compromised, the magnet should also be replaced for sanitary concerns.
Cleaning Your Magnets

Establishing the cleaning schedule

1. After installation, inspect your magnet after the first hour of production
2. If an insignificant amount of metal is observed, return in 2 hours to inspect magnet
3. If magnet continues to have insignificant amount of tramp metal, you may continue to back off frequency
4. If significant amount of metal is found on magnet, increase the cleaning interval as required to ensure the magnet does not reach maximum tramp metal capacity
5. Once your cleaning schedule is established, refer to MPI’s Magnetic Separator Cleaning and Testing Recommendation for further guidance
Cleaning Your Magnets

It really doesn’t matter how strong this magnet is...

...Once it gets to this
Principles of Metal Detection
The Theory of Metal Detection
Design of the Search Head

- Modern metal detectors operate on the balanced triple coil system
- Transmitter in the center and two receivers, on the leading and trailing edge
- The transmitter produces an electromagnetic field with a frequency chosen for the application and product
- The transmitters magnetic field produces a voltage in the two receiver coils. The voltages are subtracted from each other and the difference is amplified and filtered. The output voltage of a correctly aligned receiver circuit is zero
The Theory of Metal Detection

How the Electromagnetic Field Works

- The signals from the receiving coils are connected in opposition to each other so when no disturbance is occurring there will be a net signal across the coils of zero, they are balanced.
The Theory Of Metal Detection
How the Electromagnetic Field Works

- Every material that is electrically or magnetically conductive causes asymmetry in the magnetic field of the receivers as it passes through the coils, therefore, magnetic and conductive materials can be detected.
The Theory of Metal Detection
How We See Metal

- As metal passes into the detector coil the magnetic field of the leading receiver is affected and the first half of the wave is produced.
- When metal is exactly at the transmitter coil the influence to the magnetic field is equal on both sides of the coil so the signal is zero.
- As the metal piece moves toward the trailing receiver the opposite wave is produced.
- If the speed is constant a sine wave signal is produced.
The Theory of Metal Detection
What Influences the Electromagnetic Field?
The magnetic field is effected in two different ways:

**Magnetic Conductivity- Reactive Effect**
- A paramagnetic material results in the amplification of the signal. Iron, ferrite, nickel and cobalt are good magnetic conductors and have high permeability. (Why they are used in magnetic material)

**Electric Conductivity- Resistive Effect**
- On the surface of electrically conductive materials eddy currents are produced as soon as they are exposed to the magnetic field. The higher the frequency of the magnetic field, the stronger the eddie currents are. The eddie currents produce their own magnetic field which resists the original field. Because of this, energy is subtracted from the original field. This creates a “resistance” to the receiver coil called “Resistive Effect” which causes a phase signal in the receiver. (The higher the detection frequency, the stronger the eddie currents. This is why we can detect smaller non-ferrous metals with a higher frequency unit. However, more conductive products cause more product effect)
**Sensitivity**

- The fundamental way most people judge a metal detector is by its detection ability or "sensitivity"

- The sensitivity of a metal detector depends on the following factors:
  - Aperture size and type of detector
  - Kind of metal
  - Position of the metal inside the detector
  - Environmental conditions
  - Product effect of the material being examined
  - Orientation of metal
  - Detection frequency
Sensitivity: Aperture size and type

- Tunnel style detectors are more sensitive than flat coil systems.
- The larger the aperture, the less sensitivity therefore we build them only as large as necessary.
Sensitivity: Kind of Metal

The different types of metal:

- Ferrous – Iron and magnetic steel: have a high permeability and are good electric conductors. They are the easiest to detect.

- Non-ferrous – Brass, copper and aluminum: have low permeability but are good conductors. They are less detectable than ferrous.

- Stainless Steel: Has low permeability and are not good conductors, which is why it is the most difficult to detect. Keep in mind there are varying grades of stainless steel and its characteristics may vary.
Sensitivity:
Position of the metal inside the detector

- Inside a tunnel style detector the least sensitive area is in the center of the tunnel. The field is less concentrated here.
- The highest sensitivity is directly on the aperture surface. With rectangular coils the corners are even more sensitive.
External “noise” and bad working conditions affect the detectors signal stability and lead to false tripping and a reduced sensitivity setting.

The most common sources of “noise” are:

- Vibrations – A metal detector sees vibration near 90 degrees phase angle, almost identical to ferrous metal.
- Frequency interference caused by other electrical equipment (vfd’s).
- Moving metals inside the metal free zone.
- Intermittent eddie-current loops in the construction of the conveyor.
- Static electricity on the production floor.
- Direct sunlight, rain, wind.
- Coil not isolated during mounting.
- Conveyor belt, antistatic material or contamination in belt.
Almost all products cause an effect to the magnetic field. We call this “Product Effect” and categorize this into two basic groups:

- Non conductive or “Dry Products” such as powder, grain, plastics, textiles, etc. Dry products cause a weak reactive effect that can be easily learned.

- Conductive products or “Wet Products” such as meat, cheese, sauces, dressings, or anything else that contains moisture or minerals such as salt. Wet products cause mostly a resistive effect which is usually strong and changes constantly.

If product effect is produced during inspection it must be compensated for or “learned” in order to not have false rejects. When we learn a product signature, we also lose detection ability, especially with the kind of metal closest to the effect.
Sensitivity: Frequency

- In general, the higher the frequency, the higher the sensitivity. Dry products tend to utilize a higher frequency as there usually is little product effect while wet conductive products are built with lower frequencies.
- The frequency is chosen by the factory based upon the application details including the product to be examined.
Food Safety, HACCP and FSMA

- 7 Principles of HACCP
- Control Point or Critical Control Point
- Monitoring and Validation Requirements
- Reporting and Record Requirements
7 Principles of HACCP

- Conduct a Hazard Analysis
- Determine Critical Control Points
- Establish Critical Limits
- Establish Monitoring Procedures
- Establish Corrective Actions
- Establish Verification Procedures
- Establish Record-keeping and Documentation Procedures
Control point or critical control point?

- Control Point: Any step at which biological, chemical or physical factors can be controlled
- Critical Control Point: A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level
- Critical Limit: A maximum and/or minimum value to which a biological, chemical or physical parameter must be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence of a food safety hazard
Monitoring and Validation

- Monitoring: Ideally monitoring is continuous but if not continuous, it should be done on a batch basis.
- When it is not possible to monitor on a continuous basis, it is necessary to establish a monitoring frequency and procedure that will be reliable enough to indicate that the CCP is under control.
- Statistically designed data collection or sampling systems lend themselves to this purpose.
- Examples of monitoring activities include visual observations.
- Monitoring should be completed at a frequency level and conducted by personnel as described in the HACCP plan.
- Monitoring equipment must be carefully calibrated for accuracy.
Monitoring and Validation

- Validation is defined as those activities, other than monitoring, that determine the validity of the Hazard Analysis and Critical Control Point plan that the system is operating in accordance to the plan.

- Validation activities should be scheduled by the HACCP Coordinator and conducted yearly or upon HACCP system change.

- Information for validation often include expert advice and scientific studies and in-plant observations, measurements, and evaluations.
Reporting Requirements and Records

- All records and documents associated with Critical Control Point Monitoring should be dated and signed or initialed by the person doing the monitoring.

**Maintenance Inspection Log**

<table>
<thead>
<tr>
<th>Plant Location:</th>
<th>Department:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet ID #:</td>
<td>Magnet Location:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th>Inspected By:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comments:</td>
<td></td>
</tr>
</tbody>
</table>

**Magnet Cleaning Log**

<table>
<thead>
<tr>
<th>Plant Location:</th>
<th>Department:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet ID #:</td>
<td>Magnet Location:</td>
</tr>
</tbody>
</table>

Magnet should be cleaned every ________ hours.

<table>
<thead>
<tr>
<th>Date</th>
<th>Inspected By</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Magnet Inspection Report

<table>
<thead>
<tr>
<th>Plant Location:</th>
<th>Department:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet ID #:</td>
<td>Magnet Location:</td>
</tr>
</tbody>
</table>

#### Magnet Application Type: System Description:
- Primary
- Secondary
- Replacing

#### Magnet Product Type: Magnet Info/Description:
- General
- Rare Earth
- Other

<table>
<thead>
<tr>
<th>Manufacturer’s Name:</th>
<th>Model Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products Handled/Characteristics:</td>
<td></td>
</tr>
</tbody>
</table>

Flow Capacity (Min Max) Typical:

<table>
<thead>
<tr>
<th>Magnet Pull Test Results:</th>
<th>Pull 1</th>
<th>Pull 2</th>
<th>Pull 3</th>
<th>Average</th>
<th>Using</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>Gap</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Personal assessment of magnet performance, cleaning success, and highlights for application:
  - Very Difficult
  - Satisfactory
  - Easy

**Magnet Cleaning Method:**

**Inspected By:**

**Date of Inspection:**

---

### Calibration Report

#### General Information

- **Contact Name / Title:**
- **Company / Address:**
- **Machine Type:**
- **Check Date:**
- **Machine Serial:**
- **Next Calibration Due:**

#### Physical Checks

- **Dissipation:**
- **Safety Circuit:**
- **Roller/Bearing:**
- **Report System:**

#### Product Description

- **Product Name:**
- **Description:**
- **Use:**

#### Inspection of Sensitivity

<table>
<thead>
<tr>
<th>+/- Product</th>
<th>Non-Ferrous (lb)</th>
<th>Stainless Steel (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous (lb)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non Ferrous (lb)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stainless Steel (lb)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Detection Reliability:**

The detection reliability describes the product’s ability to detect the test object. It is critical in our regard to the same product, and settings, the reliability may be the enhancement of the testing product characteristics and the reduction of the test object.

**Authorized Service Engineer:**

- **Name:**
- **Date:**

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X-Ray

- X-ray technology is not in widespread use in the milling industry.

- X-ray technology is a density separator and because flour itself is dense, it does not lend itself well for use of the technology.

- Metal Detection and Sifter technologies lend themselves much better to milling than x-ray.
Contact

Frank Reda
Product Manager - Separation & Electronic Inspection

m. 720.883.8177
e. frank.reda@mpimagnet.com

MPI
Protecting and Moving the World through Innovation

683 Town Center Drive
Highland, MI 48357

800.544.5930
info@mpimagnet.com | www.mpimagnet.com