Magnets for Metal Fragment Control and Food Safety

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Introduction:

When analyzing existing and potential foreign material hazards, metal fragments are consistently identified as a major concern. Depending on the situation, the hazard analysis often results in the identification of hazards that must be controlled through a CCP or, at a minimum, through a prerequisite program (PRP) which includes the use of a metal detector and strategically placed magnets. When discussing food safety with quality assurance personnel, foreign material-related incidents are the most frequent hazards identified in the food industry today. Since these incidents usually affect a limited few, foreign material hazards do not receive the publicity as a pathogenic or bacterial contaminations, which have the potential to harm large numbers of consumers.

The objective must be to produce a product that is free of metal fragment contamination to an acceptable degree. This can be accomplished through the reduction of contamination, risks, and consequences via the previously mentioned controls (using effective PRPs or CCPs), alongside verification that the PRP or CCP is monitored and confirmed effective through well-defined programs such as Food Safety, GMP, and Management System Internal Audits.

The following article, written using the combined experience and knowledge of Debby Newslow[1] and Kevin Baker[2] provides a basic foundation for achieving success by controlling metal as a foreign material hazard. Control of metal begins with the control of raw materials by effectively communicating with suppliers through a well-defined, implemented, and on-going supplier management program along with a defined program for magnet testing of ingredients and incoming raw material supplies. This type of program includes metal detectors and magnets designed for specific functions and locations, strategically placed in the process. It also addresses the verification and validation of the equipment by a qualified external company and verification performed and managed through an effective internal preventive maintenance program.

Let's discuss the role of magnets in the process

It is critical that a magnet program be implemented and maintained in a manner that is effective to the process overall. It is recommended that the strength of the final magnet measure at 10,000 Gauss. Magnet strength must be monitored at a predefined frequency sufficient to provide confidence in the program. In addition, magnets must be cleaned and inspected for damage on a defined schedule. Findings must be evaluated to determine the source, and the source either corrected or eliminated.

It is recommended that the strength of the magnet be verified at least annually by an independent third party using a calibrated Gauss Meter, with records confirming traceability to a National Institutes of Standards and Technology (NIST) or equivalent known standard to confirm its accuracy. Depending on the process and information received through verification, the actual performance of the magnet for its application can also be validated. It is also recommended that depending on the process and product, verification using a calibrated Gauss Meter be performed internally as part of the preventive maintenance program either quarterly or semi-annually.

Depending on the nature of the product, the process may also be equipped with a well-designed metal detector and/or X-ray machine that is also strategically placed to evaluate the final products. It is critical that this equipment is also verified for effectiveness and accuracy by a third-party calibration service company on a predetermined frequency (minimum annually) based on the products and process. At a minimum, a prerequisite program requiring trained operators to monitor and record at a defined frequency (i.e., every 30 minutes) using control pieces appropriate for the specific process must also be defined, implemented, and maintained to confirm effectiveness of the metal detector.

This article provides more detail on the actual requirements for monitoring the effectiveness of process magnets, comparing the well-known Pull Test and Gauss Meter measurements. The complementary effect of a synergistic and strategically placed magnets and metal detectors in a process to monitor, control, and/or eliminate metal as a foreign material hazard is also reviewed.

The most common locations for the placement of magnets are:

- Product Intakes,
- Ingredient Intakes,
- Equipment Protection - High Impact,
- Indicator Magnets,
- Final Finished Product/Packing magnets, and
- Lab Magnets for testing finished products and ingredients.

Potential risks and consequences of inferior magnets which do not meet today's standards include:

- Product Contamination,
- Consumer Injury,
- Product Recall,
- Brand Name Risk,
- Equipment Damage/Failure - High Impact,
- Product Contamination,
- Loss of Product,
- Down Time,
- Costly Repairs, and
- Ongoing Maintenance.

Additional risks related to inferior or ineffective Metal Fragment Control programs include:

- Malfunctioning,
- De-Sensitization,
- Product Wastage,
- Nuisance Trips, and
- Down Time.

Let's discuss Magnet Verification

Magnets and magnetic separators are used in the food industry worldwide to extract metal contamination from food product streams, reducing contamination risks and consequences and to satisfy PRP/CCP control and food safety audits. Magnets are often installed in the final and critical product locations as a safeguard against metal fragment contamination. Essential criteria for effective results include:

- Strength of the magnet at a minimum of 10,000 Gauss,
- Pole spacing at a maximum gap of 22mm in 1" and 1.5" diameter bar and grate magnets,
- Objective evidence (records) available confirming magnets are validated and verified to an NIST or known standard at time of installation and then a minimum of annually thereafter,
- Minimum coverage of approximately 80% of the product stream,
- Sizing at maximum product contact without product blockage or hang-up,
- Cleaned at a defined frequency either manually or automatically, and
- An efficiently designed retention area on the magnet to retain collections of magnetic contamination between magnet cleanings.

It is necessary to develop, implement, and maintain an effective magnet verification program because magnets CAN and DO lose strength over time - even very rapidly under some conditions of use. Even if a magnet appears to be extracting metal, the following questions must be asked:

- "What is getting past the magnet?"
- "Is the magnet strong enough for the application in which it is placed?"
- "What is the most effective means to determine the strength of the magnet and ensure that its function within the process is effective?"

Let's review the two main methods used to test the strength of magnets: The Pull Test and the Gauss Meter

The Pull Test

Pre-1960, the Pull Test was pioneered to determine the relative strength of magnetic equipment. The "pull test kit" consists of a hand-held scale device and a variety of test pieces. The test piece used depends on the type of magnet being tested. Although the Pull Test has been used for many years, even the pioneers of the method stated, “"We suggest you use the kit not to verify the values". Some major auditing and standards bodies now see the Pull Test method as outdated for magnet verification.

Is the Pull Test method accurate? Pull Test values can and will vary. It is not uncommon for different individuals to record different results. An experienced person performing this test on a regular basis may obtain meaningful comparisons of magnet strength over time; but again, results often vary, even with the same individual performing the test.

The Pull Test method was designed to put an approximate value on the holding force of a magnet or the pulling force (field depth) of a magnet (i.e., a plate magnet). It may more appropriately be called a “hold” test, as it is mainly used to compare the surface hold of one magnet to another. It is also important that some modern-day contaminants such as stainless steel fragments and magnetic stone may react weakly to a magnetic field. Such products must contact the magnet surface directly, which makes a pull test measuring force at a distance almost irrelevant.

The Gauss Meter

The Gauss Meter is used increasingly in the food industry because of its accuracy and ability to verify, validate, and accurately compare strength loss trends over time. This method uses a Gauss Meter reading, which is made on the surface of the magnet. This provides a flux density measurement. Gauss Meter technology is being rapidly adopted by major food companies because it does give a more definitive and specific measurement. The Gauss Meter must be calibrated to an NIST or other known standard with records (calibration certificate) maintained confirming its accuracy. The Gauss Meter is suitable for testing a wide range of magnet strengths between 1,000 and 13,000 Gauss. This test method is endorsed by HACCP International[3].

PULL TEST	GAUSS METER TEST
Used in all industries pre-1960 to present times.	Used increasingly in food industry since 2010.
Empirical Comparative.	Definitive, Accurate, Repeatable, Calibrated.
Originally used mainly on plate magnets up to 3,000 Gauss.	Plate magnets now used less in food industry.
The surface test for “hold” was mainly used on grate magnets below 5,000 Gauss.	Surface strength of magnets is generally 10,000 Gauss now for product security in food industry.
Safety issues can result from sudden release of a test piece from high strength magnets.	No safety issues with Gauss Meters.
No practical standards in earlier times for method of testing magnets in the food industry other than the pull test method.	Gauss Meter Test conforms to current standard for final Magnets in food industry.[1]
Rebound of release from magnets over 5,000 Gauss can cause inaccurate measurements.	Modern calibrated Gauss Meters can measure all strengths accurately from 1,000 Gauss > 20,000 Gauss.

Let's unpack this a little more

In today's world, it is evident that the older Pull Test method approximations are declining in acceptability wherever product and brand name security is critical.

Gauss tests are now recognized as the *accurate* form of magnet strength validation using an International System of Units (SI) universally recognized unit of measurement, the gauss or tesla. It is a requirement of the HACCP International 0909 MAGSEP 1-2010 Standard[4] that such instruments used for magnet validation must be calibrated at least annually, as well as checked against a calibrated standard reference magnet immediately prior to the annual magnet validation for audit purposes.

Qualified organizations such as HACCP International[4] do not recognize Pull Tests in their standards because results vary according to the width of internal pole plates, diameter of test ball, operator technique, etc. This provides misleading results when compared to magnets designed to extract with maximum efficiency. Such magnets can remove fine weakly magnetic contaminations typical of modern food manufacture, such as stainless steel wear fragments and magnetic stone particles.

Pull Tests using a mild steel test ball give higher readings on magnets designed to extract medium and large mild steel tramp iron of former days. This was primarily monitored for protection against machinery damage. Today, metal contaminates from machinery are more likely to be stainless steel bolts and washers, which are reliably detected by metal detectors. The "Pull Test" should more aptly be named a "hold" test.

The pull test method is not a reliable means of comparing one magnet manufacture/brand against another, but can be used in-house if desired for monitoring *decline* in magnetic strength over time, *on the same set of magnets*.

Why must magnets be verified and validated?

Four very good reasons include:

- Initially confirming that new, final magnets are within specified strength when purchased,
- Verifying that the specified strength has been maintained,
- Confirming full exposure to the product stream or flow, and
- Confirming magnet is effectively controlling the hazard or potential hazard of concern.

A magnet that does not cover the product stream can be useful as an indicator but is not a sufficient magnetic separation magnet for product security. Magnet verifications are very important, especially at CCPs and final process locations, to confirm that the magnet is within tolerance. A Magnet Verification & Validation Report should be provided initially by the magnet supplier and then conducted at a defined frequency (recommended annually) on intakes and plant protection magnets. Magnet verifications must be conducted with a calibrated Gauss Meter using properly endorsed procedures, and service providers must supply a record that includes the testing results and traceability certificate of the Gauss Meter used. The instrument used to test the meter must have a current NIST or known standard certificate. Validation activities must be performed per defined requirements. This activity must provide the data (objective evidence, records) that the magnets are effectively controlling the hazards.

Understanding the term "verification" vs. "validation"

We have used the terms "***verification***" and "***validation***" many times in this text. Before further discussion, it is important to revisit the definition of these two terms as defined in ISO 22000: 2005[5].

Verification: "Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled". In other words, the operation is doing what it says it is doing, following its own defined requirements.

Validation: [as related to food safety] "Obtaining evidence that the control measures managed by the HACCP plan (CCPs) and by the Operational PRPs (OPRPs) are capable of being effective." In other words, data is available to confirm that what is being done is the correct activity to control the hazard.

Food Safety Management System programs (FSSC 22000, SQF, BRC, etc.) and basic HACCP Principles require verification and validation of magnets and metal detectors identified as a CCP or PRP. It is strongly recommended that magnets be verified using a calibrated Gauss Meter instrument a minimum of once every 12 months in accordance with the 0909MAGSEP1-2010 magnet standard[4.] An effective magnet program includes a magnet verification/validation report with the annual calibration provided by an independent third party specialized magnet service provider that:

- Confirms individual magnets meet current standards,
- Confirms whether individual magnets are still as effective as when first installed,
- Provides the estimated coverage and magnetic strength for each magnet,
- Identifies potential risks of metal contamination,
- Provides specifications to address magnet needs, and
- Suggests vendor options as to who can provide 0909MAGSEP 1-2010[4] and meet the specification to maximize product protection.

Many food companies also test their magnet strengths in-house between annual third-party audits. This is a good practice; if a critical magnet is exposed to demagnetizing factors or damaged, for example, it may never be within specification. Related to metal detectors, most processes have a defined program for running calibrated test pieces through a metal detector at regular intervals to verify that the metal detector is in conformance. Additionally, all magnets must be cleaned regularly to ensure that their efficiency is maintained. A magnet can be "shorted out" by many fine magnetics which lower its separation efficiency. It is recommended that calibrated Gauss Meter Kits be obtained for in-house testing and monitoring potential decline in magnet strength magnets between annual third party evaluations.

The following are recommended for all companies using magnets for metal fragment control:

- Monitor magnet strength and maintain records of compliance,
- Ensure minimized pole band spacing related to the magnets' functions in your operation,
- Ensure and monitor (inspection and cleaning) product to magnet coverage,
- Maintain internal knowledge and access to pertinent reference information,
- Maintain familiarity with current international magnet standards such as 0909MAGSEP 1-2010[4], and
- Review Codex Alimentarius design of experiments example for validation of magnets at: GUIDELINES FOR THE VALIDATION OF FOOD SAFETY CONTROL MEASURES (CAC/GL 69 – 2008) [6]

The following are the seven "secrets" for effective metal fragment control:

1. Magnet Strength: A minimum of 10,000 Gauss.
2. Pole Spacing: Maximum gap of 22mm, unless magnet bar diameter is 35 mm or greater.
3. Documentation: All magnets verified with a calibrated Gauss Meter at installation and then annually thereafter.
4. Magnet strength life and safety: High vacuum resinizing and the use of high grade RE80™ magnet compound in manufacture.
5. Coverage: Minimum coverage of approx. 80% of product stream.
6. Magnet Sizing: Maximum contact of product with the magnet without product blockage or hang-up.
7. Magnet Cleaning: Regular manual or automatic magnet cleaning.

Figure 1 demonstrates an example of what can happen to an inferior magnet in the process.

Figure 1. Mechanical and magnetic failure of a low-cost finger magnet

This magnet initially measured 8-10,000 Gauss; however, in its damaged state, it is measuring 1,000 Gauss. "What does this say about its current effectiveness?" Additional good questions to ask would be "What measures have been taken to guard against the most common causes of demagnetization?" "What are these…?"

Following is an extract from a recent joint Publication[7] by MAGNATTACK™ Global and AMR Consulting:

1/ MAGNET COMPOSITION OR ALLOY:

To envisage the extremes - soft iron has nil coercive force, RE80™HT has close to highest coercive force ratings available to modern technology, adaptable for practical commercial use.

Coercive force is the opposing magnetic strength or energy needed to de-magnetise a magnet to zero.

So, in magnet selection where maintenance of magnetic strength is important, we choose a high grade for preference. The higher the coercive force, the harder to de-magnetise the selected magnet.

To attain required field pattern for magnetic separation efficiency, such as close high strength pole centres (collection bands) and specified flux density (gauss), we select a material with highest energy output (BH Max) commensurate with highest coercivity rating, for example RE80™HT.

2/ WORKING TEMPERATURE:

*Another factor to consider when selecting magnets is the temperature rating of the magnet element composition. In the rare-earth range of Neodymium magnets, we have 3 practical choices, RE80™ which has a theoretical rating of 80°C and is the cheaper option, next we have RE80™HT rated 150°C, then we have RE80™HTP rated 180°C. Ratings are a **guide only** and must be considered along with other factors including shape and field design required to achieve a purpose or specification. For instance, choosing RE80™HTP with higher temperature rating would not be appropriate as the energy output with specified pole centres would be only approximately 9,000 gauss before any de-magnetisation occurred and its additional cost prohibitive.*

Temperature ratings are important but are a general guide only. Intrinsically, it means a bare magnet out of circuit, heated above the temperature rating will suffer partial loss of magnetic strength and may require factory repair – re-magnetising or replacement.

If heated over the Curie point of the magnet alloy, the magnet strength loss is complete and irreversible.

Experience has also shown that cold magnets measure higher in gauss than hot magnets. Generally, regardless of the temperature rating, the colder the magnet, the higher the gauss reading and the higher the temperature, the lower the gauss reading. Note that this may be partially due to the effect of temperature on the small magnet of the gauss meter instrument's hall probe.

Generally, if not heated above the rated temperature, the magnet will regain its normal gauss reading on returning to ambient temperature. Avoid thermal shock, e.g., plunging a hot magnet into cold water or suddenly heating a cold magnet.

Selenium Cobalt magnets have much higher temperature ratings but much lower energy output and much higher cost – not normally considered for magnetic separation purposes.

3/ "SETTLING IN" MAGNET STRENGTH LOSS:

Over years, we have found that magnets in a repulsion assembly such as grate magnet bars, when placed in service, experience a small initial strength loss compared to the test figures provided using a calibrated gauss meter on supply. This is no more than 10% and usually around 5% – 7%. This phenomenon occurs regardless of the service temperature rating but tends to be more pronounced in high temperature service. Usually the settling in strength loss occurs in the first month of service.

*If there are no other adverse factors of de-magnetisation, the pattern with RE80™ and RE80™HT is to lose very little over the next 10 years of service. For this reason, MAGNATTACK™ Global strives to design for **above** specification gauss on supply and use the highest energy output, coercive force and temperature ratings as standard practice.*

4/ CORROSION OR OXYGEN ABSORPTION:

Rare earth magnets are very susceptible to oxidation, especially in hot liquid lines and if assemblies are not double seal welded. First evidence of internal magnet oxidation is loss of strength. This is soon followed by visible swelling of the magnet tube as the corrosion swells the magnet elements. Rapid decline of magnet strength occurs until the magnet has no strength at all. Because this does happen, the handler should guard against mechanical damage to the magnet casing or ends as corrosion will start at the slightest pinhole. Oxygen or liquid can be drawn in during overnight temperature changes and the corrosion process begins. Plating of internal magnet elements has little effect, as the plating itself is porous to oxygen. Any ingress of moisture and/or product can become a serious bacterial hazard.

In order to minimize corrosion, means should be taken to ensure this risk is minimized.) contact MAGNATTACK™ Global for more information on this topic… www.magnattackglobal.com

5/ ELECTRIC FIELDS FROM MOTOR WELDING LEADS, WELDING ARC & LIGHTNING:

If you bring a rare earth magnet within a metre or so of the alternating fields of an electric motor, the magnet buzzes in your hand. This can have a de-magnetizing effect on magnets. Alternating fields are used to de-magnetize magnets. Alternating electric fields can cause magnet elements of a bar or grate to resonate in repulsion; this is thought to have a potential de-magnetizing effect. To minimize this possibility, MAGNATTACK™ Global magnets are resin encapsulated under vacuum as described in point 4 above. This seals and prevents resonation between magnets.

6/ EXCESSIVE VIBRATION OR ROUGH HANDLING, SUCH AS BANGING AND DROPPING:

Although modern rare earth magnets of high grade have high resistance to de-magnetization, experience shows magnets visibly showing scratches, dents and other evidence of rough handling, tend to have lower ongoing gauss readings.

7/ COMBINATION OF ADVERSE FACTORS AND HEAT:

This may be a reason for premature failure of magnets to hold up in high heat conditions even though they are operating within the temperature rating of the magnet elements – not adequately evaluated.

General experience is, all magnets in hot conditions tend to lose more strength and lose it quicker than in cold working conditions. Best practice is to minimize any short term temperature spikes, locate magnetic separators at lowest temperatures possible e.g., downstream where further cooling has taken place, select a high temp rating, high coercivity and a high energy rating and minimize all possible adverse factors.

8/ WELDING ON A MAGNET:

This will always cause de-magnetization of a substantial length of the magnet bar and should never be attempted on an enclosed magnet, either by electric or silver soldering etc. Explosion has occurred.

9/ GAUSS INSTRUMENT TOLERANCE:

This is a little thought of reason for slightly lower or higher than historical gauss readings.

Instrument tolerance and operator method can account for plus or minus 5% variation in readings using different instruments and operators, even after the same instrument has been re-calibrated. Remember, magnets which are read by a gauss meter whilst hot, will give lower readings than when measured cold. If over the magnet's rated temperature has been experienced, there will be magnet strength loss, which will not return when the magnet cools.

10/ HEAT DAMAGE TO GAUSS METER:

Gauss meter manufacturer advises hall probes can be damaged by testing hot magnets! The sensor magnet may be damaged or crack, resulting in low readings on both hot and cold magnets. They suggest it may be safer to use an Aluminium hall probe or better still, only check magnets in a cold state.

Magnet validations should only be carried out on cold or ambient magnet surfaces

The Role of the Metal Detector

Let's discuss the magnet and the metal detector working as a team

It is important to understand that an effective metal foreign material control program includes both a high-grade magnet strategically placed in the process, and an efficient metal detector. Many respected organizations share the view that it is of ultimate importance that Ultra High Intensity Magnets be installed upstream from high sensitivity Metal Detectors and/or X-ray units. An efficient metal detector is one that reliably indicates the presence of stainless steel or brass bolts, stainless steel nuts and washers, copper wire, and aluminum foil. Such a metal detector is invaluable to the process, and more specifically, the foreign material control program.

Stainless steel fragments and wires measuring 3mm and under are usually work-hardened. This means such fragments can be extracted magnetically along with other contaminants such as magnetic stone. The likelihood is great that without efficient magnets, much fine ferrous metal and fine magnetic fragments will pass through even the most sensitive metal detectors. Without efficient magnets, larger pieces will be detected by the Metal Detectors, but excessive product rejection may occur where the detector is properly calibrated. The causes of these rejections are often difficult to locate in bags or bins of bulk product. Consequently, it is much better to pull ferrous and other magnetics out using effective magnets. Keep in mind that even the small fragments can result in product recalls. As stated previously, it has been generally accepted in many operations that metal detectors work much more efficiently in both wet and dry products when the metal detector is preceded by a magnet strategically placed upstream of the metal detector. It is common with such processes that metal detectors become more efficient when used in tandem with effective magnets.

Combining ***MAGNETS*** and ***METAL DETECTORS*** for an effective program is outlined in Figure 2: **Combining Magnets & Metal Detectors.** This figure provides a good focus of the limitations of both and how a magnet and a metal detector together complement the functions of each other, which results in a sound foundation for an effective foreign material hazard program.

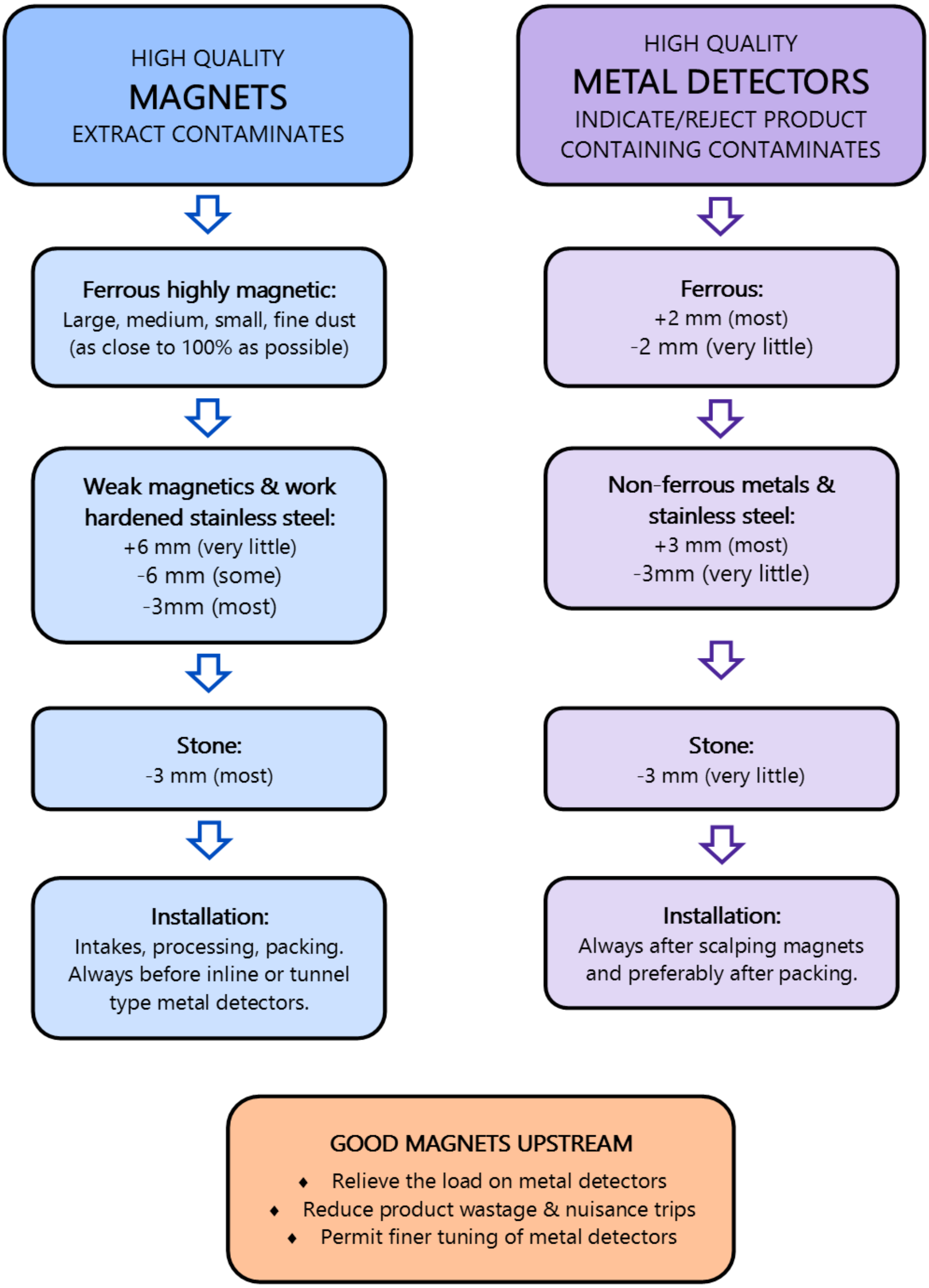

Figure 2: Combining Magnets & Metal Detectors

Conclusion:

In conclusion, when evaluating the effectiveness of your magnets, the following are essential characteristics to ensure the effectiveness of your program:

- Final product lines without magnetic protection,
- Under-strength existing magnets,
- Inadequate magnetic coverage (less than 80%),
- Lack of feature to "retain" collections against product flow, and
- Low cost imported magnet assemblies.

In our experience, in today's world of processing, magnets have become either a forgotten piece of equipment or equipment that although placed in the lines, is an effective manner so to remove fragments and protect the final products. Unbelievably, it is not unusual to find magnets in a process that management doesn't even know are there. Also, many times magnets are placed where they fit in the process, not necessarily where they would be best for the process. Others have magnets, but have no idea how often they are cleaned and what purpose they are serving. At a minimum, an effective magnet program should meet the following guidelines:

- High Strength 10,000 gauss magnets for all final and critical magnets (8,000 Gauss minimum may be accepted depending on location and function of the magnet),
- 10,000 gauss magnets for critical equipment protection,
- Maximum of 22mm pole centers for adequate coverage,
- Demagnetization features,
- Magnetic verifications by an independent external body performed at a minimum of every 12 months,
- Internal magnet verifications performed with a Gauss Meter,

Records must be identified and maintained to confirm compliance that magnets continue to meet current magnet specifications for performance and effectiveness. **Remember,** in our experience, the Pull Test is not a recommended means to obtain consistent and meaningful information related to the strength and effectiveness of a process magnet!

References:

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2. Kevin Baker is Technical Support Manager. USA, Magnattack Global kevin.baker@magnattackglobal.com, 630-994-3310, www.magnattackglobal.com,
3. AMR Consulting Co., www.amrconsulting.com info@amrconsulting.com
4. The International Magnet Standard (0909MAGSEP 1-2010 Food Safety Standard). HACCP International. http://www.haccp-international.com, debby.n@haccp-international.com
5. ISO 22000:2005. "Food safety management systems – Requirements for any organization in the food chain", https://www.iso.org/standard/35466.html,
6. GUIDELINES FOR THE VALIDATION OF FOOD SAFETY CONTROL MEASURES (CAC/GL 69 – 2008) http://www.codexalimentarius.org/input/download/standards/11022/cxg_069e.pdf
7. *What are the reasons ferromagnetic materials lose strength as measured by calibrated gauss meter and how can this be minimised? – www.amrconsulting.co*