SEPARATION OF MAGNETIC PARTICLES FROM BULK SUGAR FLOWS

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THE PROBLEM

In the past, our concerns and analyses in regard to metallic contamination of sugar have been directed toward detecting and eliminating foreign particles which were generally visible to the naked eye or, at least, obvious in numbers on a patch under the laboratory microscope. Generally, if you couldn't see it, it wasn't a problem.

Things are changing. Due, in part, to specifications by some of the users of our industrial customers' final products and increasingly stringent checks and controls by government on pharmaceutical type companies' raw materials, some of our important customers have begun to look for very fine magnetic materials in our sugar. Some have installed bulk flow magnetic separators to collect and quantify ferrous contaminations.

This situation calls for a review of the methods employed and equipment available for the prevention and removal of ferrous material from our finished product and new ways of analyzing for its existence. This paper will discuss the materials and equipment currently available to accomplish this goal.

DEFINITIONS

When we speak of separating magnetic materials from bulk sugar, the following general definitions should be kept in mind:

Tramp Iron - Generally considered to be foreign pieces of ferrous material larger that one millimeter in size.

Fine Iron - Particles of ferrous material as small as one micron (.00003937 inches).

Flux - Technical name for magnetic field.

Gauss - Unit of measure of the density of the flux.

Gradient - Term used to indicate change in magnetic strength (flux density) between points measured at different distances perpendicular to the magnetic field. The greater the change in flux density, the greater the magnetic attraction.

Energy product - A method of comparing available strength in a magnetic material similar to a battery being rated by AMP draw.

PRESENTLY INSTALLED EQUIPMENT (at Brawley)

The typical magnetic separator currently installed for the removal of ferrous particles from sugar flows consists of a single row of 1" diameter Alnico magnet tubes spaced 2" apart. These devices are usually installed in an 8" or 10" pipe and arranged in a 12" X 12" grid. These units don't even qualify for tramp iron removal under current design specifications.

MAGNETIC MATERIAL

The elements which exhibit magnetic properties are Iron, Cobalt, Nickel, and some of the Rare Earths. Materials in common current use to produce industrial permanent magnets are:

Alnico (aluminum, nickel, cobalt, and iron)

Ferrite or Ceramic (barium ferric oxide)

"Rare Earth" (Samarium Cobalt or Neodymium Iron Boron)

Electromagnets are also available, but their high cost and application barriers don't make them a viable choice for our product at this time.

BACKGROUND OF MAGNETIC SEPARATORS AND MATERIALS

Using magnets to remove ferrous material from products began as an industry in the early 1940s. The ferrous materials of concern at that time were nuts, bolts, and broken pieces of equipment that could cause a spark within the grain or feed mill chutes. The first practical magnetic separator to be used for this purpose was the plate magnet which used an Alnico casting as its power source. The plate magnets were sold to grain and feed mill operators to prevent fires.

During World War II, B.F. Goodrich was looking for a method to remove tramp metal from their processing line. The permanent magnetic head pulley, which was designed to replace the standard head pulley, performed the additional function of removing tramp metal from the product being conveyed on a belt. Over the next fifteen years a variety of equipment was designed (using permanent magnetic material) to remove tramp metal from products. This equipment included magnetic drum separators, magnetic grates, magnetic traps, and many variations of each.

In the 1960s, customers began trying to upgrade product quality using magnets. The initial efforts were geared toward multiple passes over permanent magnets hoping that, at some time, enough ferrous contaminant would come in contact with the magnetic tube or plate to be removed. The method proved cumbersome and the results were limited. At the same time, various electromagnetic separators were designed to attack the problem of removing the fine ferrous material from the product, upgrading its quality, and therefore increasing its value. In many cases, however, the expense of an electromagnet could not be justified by the increase in product value.

Since the 1940s, there has been a substantial change in the materials used to manufacture magnetic separators. As mentioned earlier, the material used in the first practical magnetic separator, the plate magnet, was an Alnico casting. Most people are familiar with this casting in its horseshoe shape. It consisted of a foundry casting of Aluminum, Nickel, Cobalt, and Iron. Once made, it could not be easily machined or drilled because of its hardness. As far as strength capabilities, in a standard tube magnet, it produced a gauss level of 1,000 to 1,200 in a circuit.

In the late 1960s, as the problems in South Africa drove up the price of Cobalt, manufacturers began searching for a substitute for Alnico castings. At this point in time, manufacturers considered using a Ferrite pressing in their magnetic separators. Being a ceramic pressing, it was easy to work with because it could be cut in any direction, assembled into a circuit, and then charged as a complete unit. It was of comparable strength in the tube magnet as the Alnico castings (1,000 to 1,200 gauss in a circuit), and its only basic limitation was that it had a greater reversible loss at high temperatures. The Ferrite pressings became the standard in permanent magnetic separators until the early 1980s.

In addition, Rare Earth materials began to surface as a potential supply for magnetic material in a permanent magnetic separator. With Rare Earth materials, the increase in energy products relative to its size offered an opportunity to make a magnetic separator of much greater strength than the Alnico or Ferrite separators within the same space limitations or smaller. (See Attachment I)

The term "Rare Earth" is a misnomer. It derives its name, not because it is rare, nor because it is earth. It was named "Rare Earth" because part of its make-up is one of the Lanthanide elements of the Periodic Table between 57 and 71. There are 14 elements which are referred to as "The Rare Earth Elements". The first material used in the early 1980s was Samarium Cobalt. It was called a "Rare Earth" material because it contained Samarium, which is no. 62 on the Periodic Table. Samarium Cobalt was capable of producing over 4,100 surface gauss in a tube magnet circuit, compared to the 1,000 to 1,200 in the Alnicos and Ferrites. The next "Rare Earth" product to hit the market was Neodymium Iron Boron. Again called a "Rare Earth" because Neodymium like Samarium, is one of the Lanthanides. The first Neodymium Iron Boron that came to market had an energy product of approximately 24 million and developed a surface gauss of approximately 4,800 in a tube-type circuit. In the approximate four years since Neodymium Iron Boron came to market, there have been at least four increases in its available energy product. Currently, Neodymium Iron Boron can be purchased in 24 million, 28 million, 32 million, or 35 million energy product. This increase in energy product has raised the attainable gauss level in a tube-type circuit to over 7,000.

SEPARATOR DESIGN CONSIDERATIONS

The energy product available for the permanent magnetic material is just one part of the puzzle to successfully remove fine ferrous material from products. A circuit is the combination of permanent magnetic material with steel or other supporting substances. The magnetic strength of a circuit is a function of its design. Three important variables in designing a permanent magnetic circuit are the energy product of the magnetic material; the size and shape of the magnetic material; and the size and shape of the steel. The arrangement of these three variables determine the type of a magnetic field produced. A magnetic field can be designed to reach out, hold up close, or a combination of both.

For many years, the magnet manufactures developed circuits that would reach out, because the problems they were attacking were large pieces of ferrous such as nuts and bolts in a product stream. Alnico and Ferrite circuits successfully removed these nuts and bolts. However, a different circuit design must be used when using Rare Earth materials to remove fine ferrous particles in a product stream. Based on Physics, the force that a magnetic separator exerts upon a particle is proportional to the size, shape, and permeability of the particle involved. A good example would be to place a paper clip on a table and lift it with a magnet. Then place your hand over the paper clip and try to pull the paper clip through your hand. Of course it will never happen. The largest magnet will not pull the paper clip through your hand. This is because the paper clip determines the maximum force that can be obtained and the force of your hand is greater than that of the paper clip.

For this reason, a fine ferrous particle fully saturated with magnetic flux can not move very far through most products to a magnetic separator. It is then the goal to bring this particle in contact with the magnetic separator and hold the particle to the magnetic separator. It is useless to design a circuit that is good at holding 1" X 3" X 1/8" test pieces, unless you have 1" X 3" X 1/8" pieces in your sugar that you are trying to remove.

The circuit must be designed to maximize the holding power of the magnetic separator. This is necessary because the same forces that prevented that fine ferrous particle from moving easily through the sugar to the magnetic separator, are the forces that are going to attempt to strip that particle off the magnetic separator.

The advent of the Rare Earth permanent magnetic materials have enabled magnetic separator manufacturers to design circuits capable of removing fine ferrous particles that formerly had to be removed by larger electromagnetic separators. The cost of these permanent magnetic separators has positioned them between the less effective Alnico and Ferrite separators and the more expensive electromagnetic separators. With a separator in this price range, the upgrade in product quality justifies the cost of using rare earth type separators and makes them a viable solution.

As mentioned earlier, for many years typical permanent magnetic separators used Ceramic magnet pressings or Alnico castings as their power source. When built with properly designed circuits, these separators provide good magnetic fields for a nominal cost and satisfactorily remove both tramp and some fine iron contaminants in most applications. Many products, however, require a higher level of purification than standard permanent magnetic separators can provide. Prior to the Rare Earth magnetic separators, the only other option was electro-magnetic separators. Although, electromagnetic separators provide excellent removal of weakly magnetic or very fine iron, they are large, expensive, and require auxiliary equipment.

The gap between low and high intensity magnetic separators has been filled with Rare Earth permanent magnets. They have more strength at a greater distance, higher gradients, and increased holding as compared to conventional permanent magnets. This means that they can hold the fine, weakly magnetic contaminants so tightly that it is unlikely that the flow will wipe them off.

EXAMPLES OF SEPARATOR DESIGN

There are numerous types of magnetic separators designed for use in bulk materials. Some examples are (See Attachment II):

PULLEYS, DRUMS, AND ROLLS - These are usually used as head pulleys on conveyor belts. In the drum form, they consist of a segmental permanent magnet inside of a rotating outer shell. Particles are separated, then released separately from the product, similar to the typical beet chip roll in some of our factories.

TRAPS - Used in liquid flows, these usually consist of a set of magnetic tubes through which the liquid flows.

PLATES - Available in numerous forms, these are either suspended above the product or installed in the flow of the product.

HUMPS - This is a variation of the plate and may have some application in sugar flows. The product is made to change direction in a housing equipped with plate magnets. The change in direction forces the product to spread out and impinge upon the magnetic plates.

ROTA-GRATES - This is a series of magnetic tubes forming the circumference of a rotating drum through which the product flows. The design is intended for handling materials that tend to stick, clog, or bridge easily.

GRATES - These come in many shapes, forms, and arrangements of magnetic tubes. They can be positioned externally or installed in a housing. There are vibratory arrangements to keep product flowing and self cleaning models. This type seems most suited to our applications.

PRACTICAL DESIGN OF GRATE MAGNETS FOR SUGAR

The design recommended for the most effective fine iron grate magnet would include four banks of 1" diameter Rare Earth tube magnets spaced 1 1/2" apart. Sizing in a 10" sugar pipe would be 24 1/2" X 22" and the unit would be enclosed in a stainless steel housing. The current estimated cost of such a device is $ 48,594 !

Besides the cost, there are other problems with such a design as it applies to sugar. The 1 1/2" spacing of the magnet tubes leaves only 1/2" clear space between tubes for the sugar to pass. Since sugar tends to bridge and lump, this could cause some major flow problems. There is an option to add a vibrating device to the housing which may alleviate such problems, but this is an unknown. In our case, it may be sufficient to use the "tramp iron" design (Tubes spaced 2" apart) with only two magnet banks. The use of the Rare Earth magnets in this design may give us sufficient protection at this time. A magnet of this design for 10" pipe is currently estimated to cost $ 20,857.00.

Another consideration worth noting is that most of the magnetic separators for use in gravity flow lines depend on being installed in a vertical section for good performance. This is to insure that the sugar gets evenly spread over the magnetic surfaces or changes direction on the magnetic surface (in the case of a hump type). Most of the magnets currently installed at Brawley are not in vertical lines.

SUMMARY

During the 1989 campaign at Brawley, a customer became very concerned about fine magnetic material in our sugar. Since our eyes were unable to see any contamination in the sugar and the laboratory patches did not indicate anything out of the "ordinary", we had a difficult time identifying the customer's concern. After learning just how few and how fine the particles were that caused the problem, we began to review current materials and designs available for the removal of such particles as well as our method of detecting and quantifying them. Attachment III is the method of analysis we now use to report ferrous particles in sugar samples. As an emergency measure, we purchased a double row circular grate magnet with Rare Earth elements for use in railroad car and truck loading hatches. We also purchased a single row Rare Earth grate unit that would interchange directly in our current magnet housings. These units made a tremendous improvement in our finished product and allowed us to meet this particular customer's specifications as long as we slowed the loading rate.

Typical sugar handling and conveying equipment is the source of fine ferrous particles sometimes found in our products. There is no substitute for maintaining this equipment in a fashion that minimizes this material. However, as customers become more and more concerned with the presence of such materials, we must equip ourselves to eliminate them. Advances in the magnetic separator industry have made it possible to deal with the problem if we pay attention to design and budget for the installation of these protective devices.

ACKNOWLEDGEMENTS

Information in this report was obtained from technical articles written by, or direct conversations with, the following persons and companies:

Michael W. Latimer - Rare-Earth Magnetic Separators: A Cure for Hard-to-Remove Contaminants

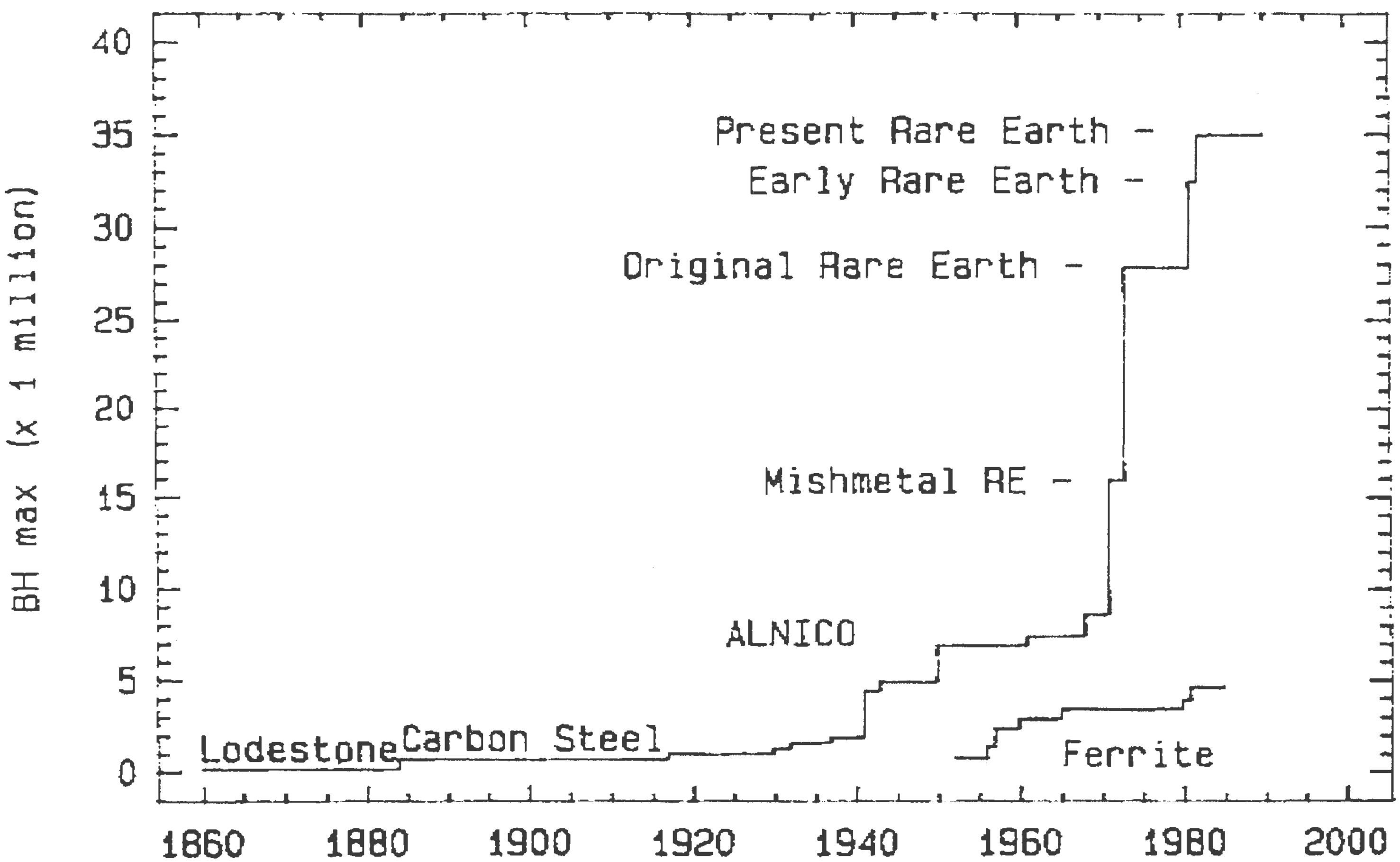
A.F. Israelson, P.E. - Magnetic Fundamentals Simplified

Eriez Magnetics

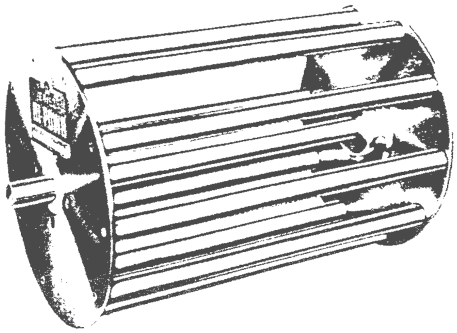
Applied Magnetic Systems, Inc.

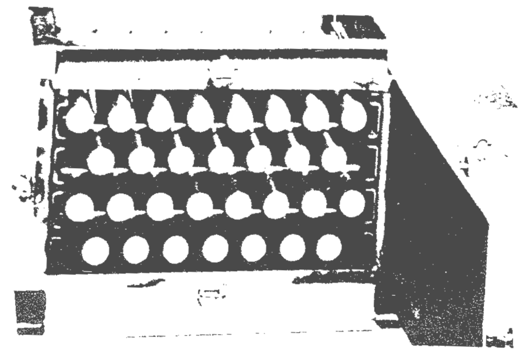
Cesco Magnetics

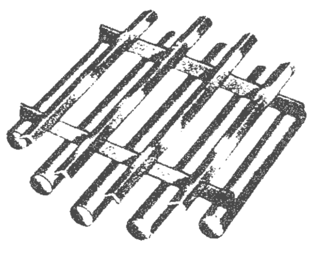
Increase in Available Magnetic Energy

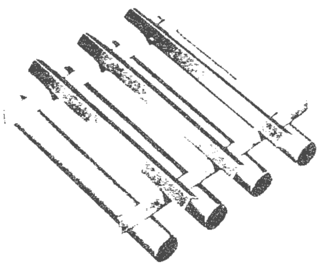


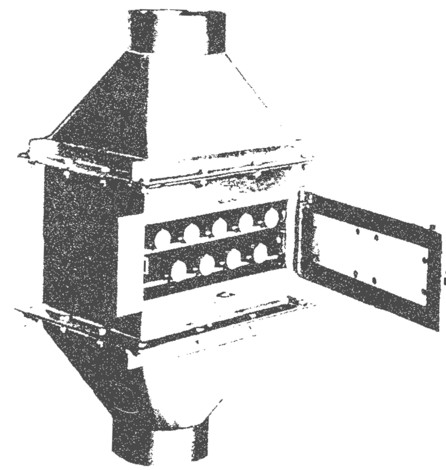
ATTACHMENT I

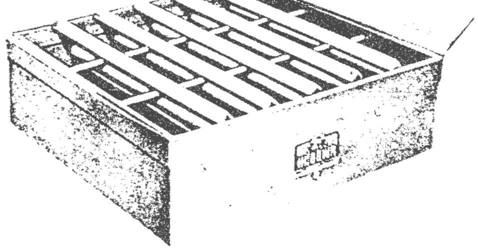


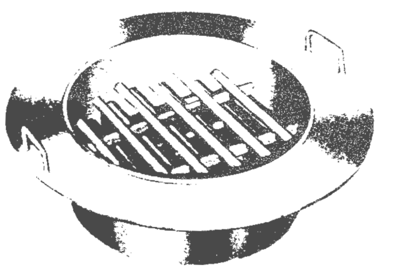


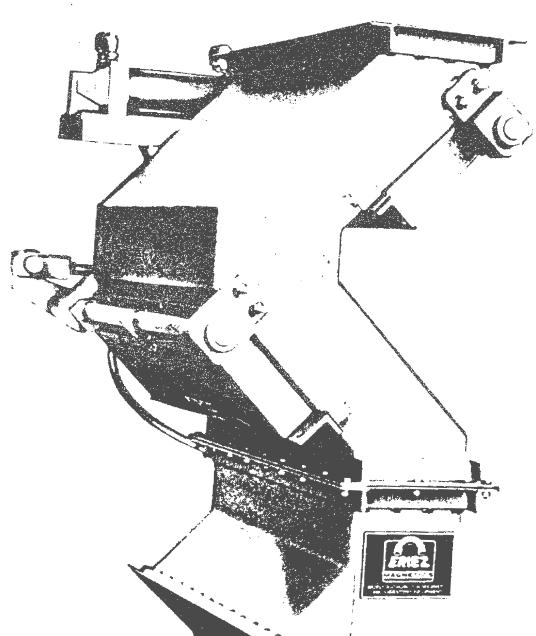












ATTACHMENT II

METAL IN WHITE SUGAR
(ferrous)
Method of Analysis

Apparatus

Ziplock Plastic Bag (1 gallon Heavy Duty)

Magnetic Stir Bar (6" X 1")
Available from: Dynalab Corp.
Rochester Scientific
P.O. Box 112
Rochester, NY 14692
1-800-828-6595
Catalog No. 444-0003

Sample Splitter (Riffle-type)
Available from: Fisher Scientific
2761 Walnut Avenue
P.O. Box 9800
Tustin, CA 92681
714-669-4600
Catalog No. 04-942B

Procedure:

1) Split sample down to one (1) pound using Riffle Sampler discarding half of sample on each split until one (1) pound is reached.
2) Transfer one (1) pound sample to Ziplock bag.
3) Place large stir bar magnet free of any metal inside bag with sugar. (Any metal found on the magnet before placing it in the bag may be removed with a piece of masking tape.)
4) Seal bag tightly and tumble magnet and sugar for at least sixty (60) seconds.
5) Carefully remove magnet and count pieces of metal on its surface.
6) Report results in "particles per pound".

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This method was adapted from a procedure used by American Sweeteners.

ATTACHMENT III