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LEAD INDUSTRIES ASSOCIATION, INC.

292 MADISON AVENUE
NEW YORK, N. Y. 10017
TELEPHONE — AREA CODE 212
OR 9-0620

May 10, 1965

To the Members of Lead Industries Association Inc.:

Attached is a reprint from the March, 1965 issue of Ceramic Age magazine entitled "Ceramic Permanent Magnets". This article was adapted from the speech given before the 36th Annual Meeting of the Lead Industries Association, Inc. last year by Mr. Theodore Q. Dziemianowicz.

We feel that the appearance of this paper in Ceramic Age will provide additional ammunition in our campaign to increase the use of ceramic permanent magnets and at the same time, to encourage adoption of a 20% lead ferrite.

Mr. Dziemianowicz' paper goes into considerable detail on ceramic processes, applications and potential markets for ceramic magnets in general and high-lead permanent magnets in particular.

A few extra copies of this pamphlet are available on request, and the remainder will be distributed at the Design Engineering Show and in answer to specific requests eminating from our advertising.

Very truly yours,

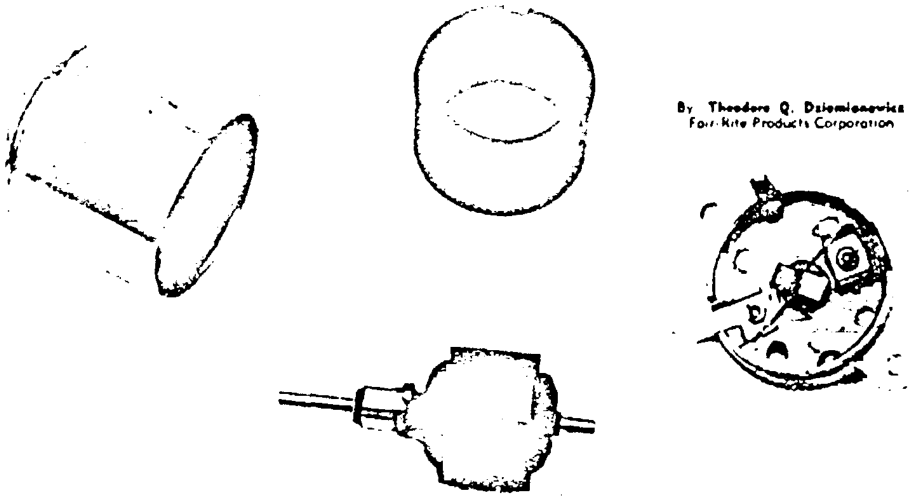
Jerome F. Smith

Jerome F. Smith

JFS:df
Attachment

Look Ahead with Lead

By Theodore Q. Dziemianowicz
Fair-Rite Products Corporation



These ferrite magnet motors, manufactured by Rowe Industries, Incorporated, are produced in the hundreds of thousands per week and are used in anything from electric tooth brushes to automobile windshield wipers. (Photo courtesy Rowe Industries, Inc.)

Ceramic Permanent Magnets

Based on chemistry, crystal structure and magnetic properties, ferrites can be classified into three basic categories: (A) soft ferrites, (B) hard ferrites, (C) garnets.

In ferrites, the terms "soft" and "hard" refer to the relative ease or difficulty with which the material is magnetized or demagnetized. The magnetic terminology used to designate this property is coercive force (Hc). Hard ferrites have high coercive forces (1700-3200 oersteds), and soft ferrites have low coercive forces (0.1-10 oersteds).

Because hard ferrites are difficult to demagnetize, they are considered permanent magnets.

How They Are Made

Basic ceramic techniques are utilized in the synthesis of any hard ferrite. For this reason, permanent magnet ferrites are often referred to as ceramic magnets.

Starting with very pure iron oxide and the oxides or carbonates of either barium, strontium or lead (Pb_3O_4 yields the best magnetic results in the lead system) in proper weight ratios (for example 20% Pb_3O_4 and 80% Fe_2O_3) to give the fixed composition ($PbO \cdot 5.6Fe_2O_3$), synthesis is carried out as follows: After intimate dry mixing, the mixed oxides are calcined, attrited dry, then wet ball milled to a controlled particle size of less than 1 micron. The milled material is dried. Then follows the wet incorporation of an organic binder, a controlled drying operation, granulation and classification or screening. The classified powders are fed to high speed presses where they are formed into compacts. Binder is removed from these compacts under controlled time-temperature programming, and they are fired and magnetized.

The end product of this synthesis is hard and brittle, lacking lustre and grayish black in color. It has an apparent density of about 4.80 gm/cc, and can be cut or ground, provided diamond tooling is used. Although hard ferrites lack the extremely high remanence magnetization of their alloy counterparts, their other magnetic properties are far superior.

Raw Materials

The hard ferrite industry has adopted the barium ferrite ($BaFe_{12}O_{19}$) as its standard permanent magnet materials system. It might be pointed out however, that barium ferrite per se will not yield the high quality magnets currently advertised by most manufacturers. In order to achieve advertised values of 1.0×10^6 gauss-oersted peak energy product, all manufacturers dope their materials with at least 1% PbO. Without this doping addition, peak energy products would average out at the lower figure of about 0.8×10^6 gauss-oersted.

Of the 16 active hard ferrite manufacturers, there is one, though small, that does manufacture a pure lead ferrite magnet. These lead magnets are synthesized to the fixed formula $PbO \cdot 6Fe_2O_3$, from the virgin materials Pb_3O_4 (20% by wgt.) and Fe_2O_3 (80% by wgt.). Over the past 3 years, these non-oriented lead ferrite magnets have outshone their competitors' magnets where magnetic, as well as physical, quality was concerned.

Lead Ferrites Versus Barium Ferrites

The little research conducted on lead ferrites in this country has been on the lower energy product material (the non-oriented magnet). Researchers at aircraft and radio cor-

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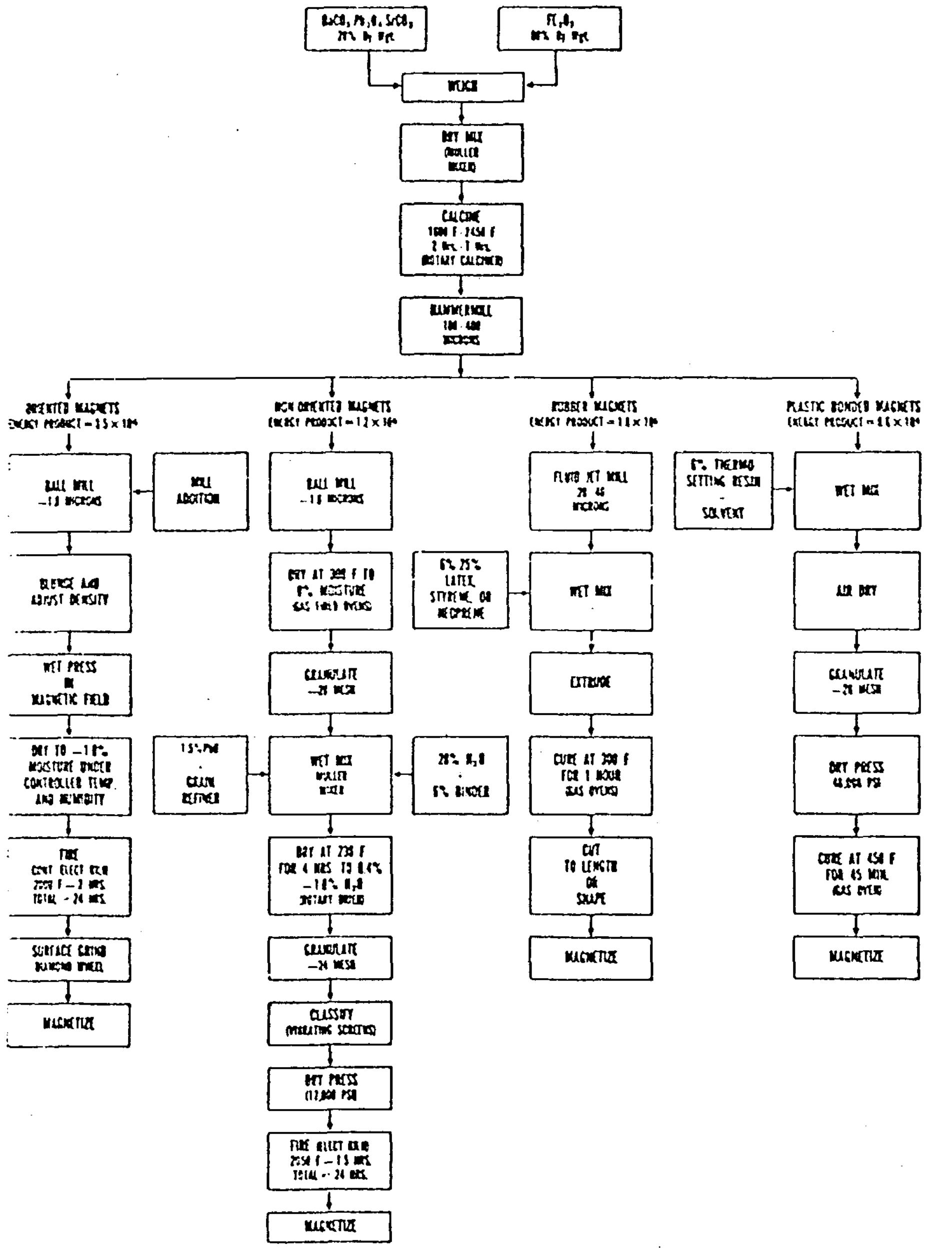
PROCESS FLOW IN THE MANUFACTURE OF CERAMIC PERMANENT MAGNETS



especially where extremely high fields are required and other magnetic material parameters are of no consequence. Even with a maximum theoretical remanence of 5400 gauss, the ceramic magnet could never approach alnico's current 12,000 gauss. In many applications however, remanence is not of prime importance, and such factors as high coercivity, weight, cost, and space come into play. It is in these applications that ceramic magnets have made great inroads in the alloy magnet market in the past 4 years on a straight substitution basis. The following are some of the more common of these applications.

Door Latch Magnets: Probably the most common use for sintered non-oriented magnets. Sandwiched in between two soft steel plates, the energy of the magnet is concentrated along the running edges of the steel plates, through a gap. This assembly requires 5-7 pounds of pull to part it from its keeper, which makes up the latch. There were approximately 45 million of these magnets sold last year. The going price was $0.03 per magnet. Other applications utilizing ceramic magnets based on the same principle are:

Can Opener Magnets. Hold lid of can after it has been cut away.

Auto Blinker Light (Distress Signal) Anchors

Anchors for the Religious Figurines Found on Auto Dashboards

Pot Holders, Kitchen Magi-Boards, Magnetic Utensil Kitchen) Holders, Magnetic Screw Drivers, Magnetic Flashlight Holders, etc.

TV Corrector Magnets, commonly called pin cushion magnets, used to correct for inaccuracies in the electron gun assembly—differentiating the electrons from the ions, they direct the electrons to the screen and divert the ions. They are simple bar magnets 1 to 2" long by 0.2" square cross-section. At two to a TV set, there were 15 million of these sold last year.

Thermostats. The natural movement of thermo-sensitive elements is so slow that if they were used to operate contacts directly, the low pressures at opening and closing would produce over-heating and arcing and the thermostat would hunt. By affixing a ferrite magnet to the moving thermo-sensitive elements, positive make and break is assured.

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Magnetic Dipstick for the measurement of liquid in an aircraft fuel tank without exposure of the liquid. This is a vertical tube closed at the top and open at the bottom, fitted into the bottom of the tank. A float carrying a ring magnet slides on the tube on ball bearings and the dipstick, which also carries a magnet attached to its top, fits inside the tube. To measure the fluid, the dipstick is released and descends until its magnet is held opposite to that on the float. The level is then shown by the calibrated scale on the dipstick protruding from the bottom of the tank.

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Materials Handling applications are currently using oriented ceramic magnets in large quantities.

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Pulley Separators—For conveyors.

Automatic Drum Separators—In chute type operations for handling of granular and pulverized products.

Ferrous traps in Liquid Systems—Three to four times more magnetic area.

Floor Sweepers—Pick-up ferrous metals from tables, floors, parking lots, etc.

Magnetic Chucks—Surface grinders, drill presses.

Sheet Fanners—For feeding and handling sheet steel from cutting room to punch press, stamping press, etc.

Fishing Magnets—recovering objects from tanks.

Holding sheet plate to overhead conveyors.

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Plastic Bonded Magnets as stators, battery operated shavers, pencil sharpeners, tooth brushes, toy motors.

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Loudspeaker Magnets. High fidelity speakers only. 1½ million sold last year for a dollar volume of $3,500,000. Oriented ferrite magnets, en- of hard ferrite.

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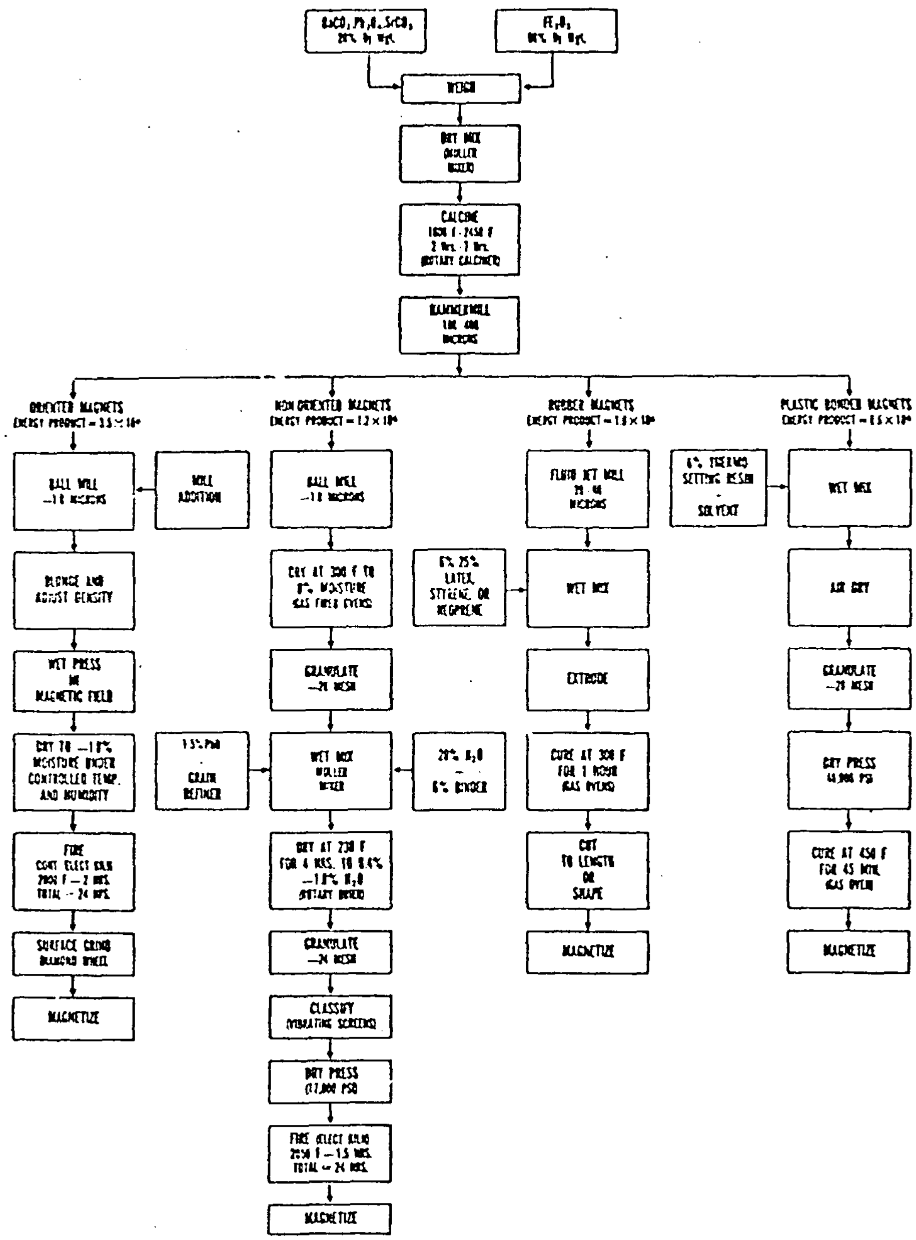
In the overall picture, this can be said of the ceramic magnet: most of the high fidelity speakers built in this country today, which represent only a small fraction of the total speaker market, utilize ceramic magnets, 90% of all toy and novelty magnets are of the ceramic type, better than 50% of all work handling and separator magnets are of the ceramic type; almost all television magnets, other than loudspeakers, are ceramic magnets, however, only a fraction of all motor and instrument applications utilize ceramic magnets.

Ceramic Magnet Market

In 1955, magnet manufacturers were faced with a problem on the discovery of ceramic magnets; these required plants for powder production, presses, and high-temperature sintering furnaces. This was a departure from the traditional method of alloy magnet production of melting the elements together in one induction furnace. To maintain their competitive status however, most of the larger magnet producers in the principal industrial countries of the world are now producing ceramic magnets on a large commercial scale.

The introduction of permanent magnet ferrites as a mass produced media by a major magnet manufacturer in 1950 was the first major advancement in permanent magnet materials technology since the introduction of alnico by the Japanese in

PROCESS FLOW IN THE MANUFACTURE OF CERAMIC PERMANENT MAGNETS



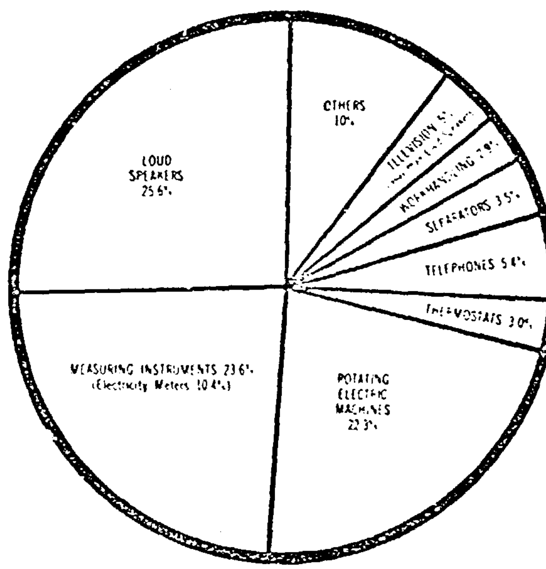
potations, as early as 1958, reported marked improvements (in some cases as high as 50%) in the overall magnetic quality of ceramic magnets when 100% substitution of lead oxide for barium oxide was made. Present production run lead ferrites consistently exhibit 15% higher peak energy products than competitive barium ferrite magnets (1.0×10^6 gauss-oersteds versus 1.25×10^6 gauss-oersteds). Their magnetic fields are far more uniform, a quality of extreme importance in traveling wave tube applications. Furthermore, they appear to be much softer and exhibit better machining properties than conventional barium ferrite magnets—another desirable quality for traveling wave tube applications where machined tolerances must be held to ±0.0001". Finally, they calcine and fire at considerably lower temperatures than barium ferrite magnets, resulting in lower power consumption, where electric kilns are used, and higher output levels for comparable process flow.

Although these improvements were noted in non-oriented type magnets, there is nothing to indicate that similar improvements are not possible in oriented lead ferrites.

The European magnet manufacturers appear to be more active in researching lead ferrites than American manufacturers. Recent investigations conducted on lead ferrites in Germany indicated that orientation in lead ferrites could be produced by pressing alone, without the application of a magnetic field, providing small doping additions of silica were used. Magnets thus produced, exhibited magnetic strength three times greater than conventionally pressed magnets in the barium ferrite system. Recent work in the $PbO \cdot 3.4Fe_2O_3$ system, again in Germany, also indicated magnetic properties superior to those of conventional barium ferrites.

Where Permanent Magnets Go

(Based on 1959-60 dollar volume sales)



Application Of Permanent Magnets

(Based on world census of permanent magnet makers)

Application	% By Weight
Loudspeakers	46.5
Magnetos, generators, and motors	16.8
Measuring instruments	12.4
Electronic devices, thermostats, automatic controls, and microwave applications	8.2
Toys and novelties	5.7
Telephones	4.4
Workholders and latches	2.5
Separators	1.9
Other applications	1.6

Raw Material Costs

Permanent magnet manufacturers, who are aware of the magnetic advantages of lead ferrites, when asked what their objections were toward mass producing lead ferrite magnets listed raw material cost as the prime objection.

How critical is raw material cost? The current grade of iron oxide used in the manufacture of hard ferrites sells for $0.15 a pound in carload lots. Precipitated barium carbonate sells for $0.09 a pound in truckload lots. Taking the standard formulation currently used, 20% $BaCO_3$ and 80% Fe_2O_3, we find that each pound of process barium ferrite contains $0.12 worth of iron oxide and $0.18 worth of barium carbonate, for a total raw material cost of $0.138 per pound. Using the same formulation, but replacing the barium carbonate with Pb_3O_4, which we are told currently sells for $0.20 per pound in commercial lots, we find the iron oxide cost per pound to be the same, or $0.12 per pound. Lead oxide per pound of processed materials, however, was $0.04 per pound, giving a total raw material cost for lead ferrites of $0.16 per pound. This means that raw material costs could increase by $0.022 per pound of processed powder in the system transition. Now one pound of processed hard ferrite powder will yield 40 standard door latch magnets. Transition to the lead ferrite system would increase each unit cost by $0.0005, hardly a prohibitive cost for 15% increase in magnetic quality.

It is certain that none of the current ferrite manufacturers will make this transition within the near future. The first to make the break would surely lose his competitive standing, at least for a time a gamble that few manufacturers are willing to take in this highly competitive field.

Although permanent magnetism is centuries old, practical applications of permanent magnetism are only of recent vintage. Unfortunately, the magnet manufacturer has not only been called upon to make magnets, but has also been expected to design and dictate their applications to his customers. So one can be sure that new material systems will not be investigated by the leading magnet manufacturers until design limitations on present materials dictate a transition.

Where Do Permanent Magnets Go?

Permanent magnets may be classified into four basic categories. **Oriented:** These are the premium magnets. They fully sintered and of high magnetic strength—The strongest in the ceramic line. Having a maximum energy product of 3.5×10^6 gauss-oersteds, these magnets find use in loudspeakers, traveling wave tubes, and heavy handling and holding applications. Approximately 55% of the hard ferrite market falls into this category. Extremely high strength (magnetic) is imparted to these magnets by forming or pressing them in a strong magnetic field. They exhibit properties in one plane only—in the direction of pressing or orientation.

Non-Oriented: These are the original ceramic magnets. They are fully sintered with only a moderately high energy product—1.1×10^6 gauss-oersteds. Pressed dry, without benefit of a magnetic field, these magnets exhibit uniform magnetic properties in all directions. They constitute 25% of the current hard ferrite market. They are used primarily in simple holding devices such as door latches, can openers, screw drivers, flashlights, etc. They are also used as TV correction magnets, and have been adopted for automobile windshield wiper motors.

Rubber Magnets: Flexible magnets used primarily in holding devices—more specifically, as refrigerator door holding gaskets. Moderately strong, having a maximum energy product of 0.9×10^6 gauss-oersteds, they are fabricated by heavily loading rubber (natural or synthetic) with highly reacted hard ferrite, extruding, and then curing at low temperature. They exhibit no directional properties, and their chief advantages are flexibility and ease of shaping (can be cut with knives, scissors, etc.), which makes them an ideal material for device assembly. They constitute 20% of the total hard ferrite market.

Plastic Bonded Magnets: Poor quality magnets, having a maximum energy product of only 0.6×10^6 gauss-oersteds. They are fabricated by mixing highly reacted hard ferrite material (usually hard ferrite scrap) with small amounts of thermosetting resin, pressing at 40,000 psi and then curing the formed compacts at low temperatures. Their chief use is in cheap battery operated motors. They exhibit no directional properties, and their chief advantage is that close tolerances can be held because of the low temperature cures that the compacts are subjected to giving a mechanically precise magnet at a low price (although magnetic strength is poor). They constitute about 5% of the total hard ferrite market.

Applications

With their remnant magnetization (B_r) three times as great as ferrite magnets, there will always be applications for the alnico family of magnets

Current Ferrite Market

Category	End Use	Mass. Prod. Intro.	Dollar Volume Sales In 1963	% of Ferrite Market
Deflection Components	TV Yokes TV Transformers	1949	$5,550,000	8.94
Antenna Rods	Radio Receivers	1951	$1,500,000	2.42
Square Loop Ferrites	Computer Switch and Memory	1952	$30,000,000	48.35
Specialties	Communications & Computers as Cup Cores, Tuning Slugs, Hi-Freq. Transformers, Recorder Heads, Magneto-strictive Transducers	1953	$8,000,000	12.89
Microwave Components	Waveguides, Gyrators, Isolators, etc.	1954	$6,000,000	9.66
Permanent Magnets	Many	1955	$11,000,000	17.75

Ferrite Magnet Market Development

Year	Remarks	Annual Sales
1955	Non-oriented barium ferrite magnet introduced to the U. S. market—Energy Prod.—0.8×10^6	
1956	Consumer acceptance for TV focusing, toys, and holding. Other ferrite manufacturers have entered field.	$1,000,000 (approx.)
1957	Oriented barium ferrite magnet introduced. Energy Product—3.0×10^6.	$2,500,000 (approx.)
1959	Oriented magnet accepted by loud speaker manufacturers. Found acceptable for separators and heavy handling.	$6,000,000
1960	Rubber magnets introduced—Other ferrite manufacturers enter oriented magnet field. Oriented magnets accepted for Traveling Wave Tube applications and some motor applications.	$7,500,000 (approx.)
1963	Impact of rubber magnets is felt. Increased application of oriented magnets. Sixteen major companies are now manufacturing ceramic permanent magnets.	$11,000,000

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The introduction of permanent magnet ferrites as a mass produced media by a major magnet manufacturer in 1956 was the first major advancement in permanent magnet materials technology since the introduction of alnico by the Japanese in

1931, and has done much to advance ceramics as a precise science.

Throughout the world, excluding the Communist bloc, there were approximately 70 magnet manufacturers in 1960. These were made up of 14 in Great Britain, 10 in the United States, 17 in Japan, 10 in West Germany, 3 in France and another 12 in the rest of Europe, the remainder being in South America and the Commonwealth countries. The total quantity of magnets produced annually was over 40,000,000 pounds, or roughly 20,000 tons, representing over 800 million individual magnets.

In 1963, the United States' share of the world's total permanent magnet market was approximately \$54,000,000–\$11,000,000, or almost 20% of which was in ceramic magnets—quite startling in view of the fact that alloy magnets have been produced in this country since 1901, while ceramic permanent magnets have only been manufactured in this country since 1956.

At an average selling price of \$2.00 per pound, the current \$11 million hard ferrite market represents an annual finished hard ferrite market of 5.5 million pounds. At the current industry yield of 70%, this represents an annual raw material input of approximately 7.9 million pounds.

Growing Market

Ceramic magnets are of particular interest to ferrite manufacturers because, unlike their soft ferrite counterpart, they are not tied to any one particular product line.

They are a delight to the ferrite manufacturing engineer, for unlike soft ferrites, their properties are not markedly affected by process contaminants; they do not require specially controlled heat treating atmospheres, and they can be sintered over a broad range of temperatures and still exhibit acceptable properties.

For the lead industry alone they currently represent a potential annual outlet for 1.5 million pounds of lead oxide.

Ferrites were introduced as a mass produced media in this country in 1949. In 15 years, they have grown to \$62,000,000 industry. Note that ceramic permanent magnets, latecomers in this field, have already captured 17.73% of this market, second only to square loop ferrites.

Future of Hard Ferrites

A processing breakthrough has already been made on motor magnets. After five years of perserverence, the automotive industry early this year adopted ceramic magnets as stators in windshield wiper motors. At 0.25 pound of magnet material per motor, this will amount to an annual consumption of 1.1 million pounds of hard ferrites.

It is currently projected that by 1970, each auto will have an additional 4 pounds of hard ferrite incorporated in its motors or generators (fuel pump, heater motor, generator, power seats, power windows, speedometer, and ignition systems). This would amount to 22 million pounds of hard ferrite.

Ceramic Engineering Index
- Raw Materials
- Forming
- Drying
- Firing
- Application

Adopted from a paper presented at the 36th Annual Meeting of the Lead Industries Association, Inc., April 22, 1964.

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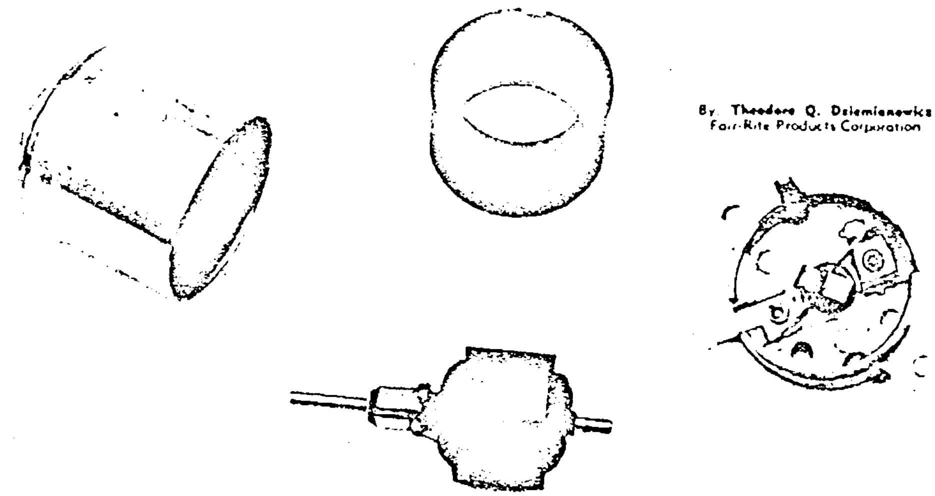
By Theodore Q. Dziemianowicz
Fair-Rite Products Corporation



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The end product of this synthesis is hard and brittle, lacking lustre and grayish black in color. It has an apparent density of about 4.80 gm./cc, and can be cut or ground, provided diamond tooling is used. Although hard ferrites lack the extremely high remanance magnetization of their alloy counterparts, their other magnetic properties are far superior.

Raw Materials

The hard ferrite industry has adopted the barium ferrite ($BaFe_{12}O_{19}$) as its standard permanent magnet materials system. It might be pointed out however, that barium ferrite per se will not yield the high quality magnets currently advertised by most manufacturers. In order to achieve advertised values of 1.0×10^6 gauss-oersted peak energy product, all manufacturers dope their materials with at least 1.5% PbO. Without this doping addition, peak energy products would average out at the lower figure of about 0.8×10^6 gauss-oersted.

Of the 16 active hard ferrite manufacturers, there is one, though small, that does manufacture a pure lead ferrite magnet. These lead magnets are synthesized to the fired formula $PbO \cdot 6Fe_2O_3$, from the virgin materials Pb_3O_4 (20% by wgt.) and Fe_2O_3 (80% by wgt.). Over the past 3 years, these non-oriented lead ferrite magnets have outshone their competitors' magnets where magnetic, as well as physical, quality was concerned.

Lead Ferrites Versus Barium Ferrites

The little research conducted on lead ferrites in this country has been on the lower energy product material – the non-oriented magnet. Researchers at aircraft and radio cor-