LIA15828

POTENTIAL MARKET FOR LEAD IN PERMANENT MAGNETS

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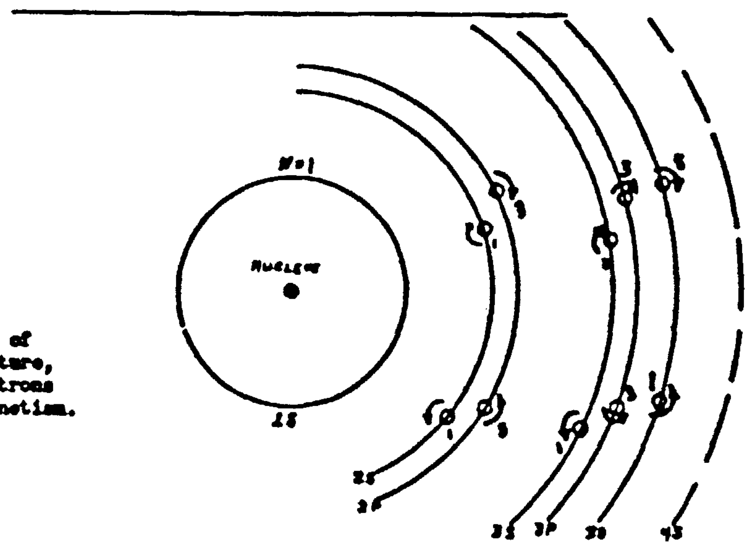
THEORY OF MAGNETISM

Modern physicists have defined magnetism as an external force due to electricity in motion, whether it be in a conductor such as copper wire or an electron spinning on its own axis. Present theory indicates that the origin of ferromagnetism in materials such as iron, cobalt, and nickle is due to spinning electrons within the third incomplete shell of the atoms. These electrons create a magnetic moment. In neighboring atoms the magnetic moments are held parallel by quantum mechanical forces; thus creating a region known as a domain. In an unmagnetized ferromagnetic material, the magnetic moments of the domains are randomly oriented and cancel one another. However, the magnetic forces are present and the application of an external magnetic field causes the domains to be realigned so that their magnetic moments are added to that of the applied field. This results in a manifold increase in the magnetic flux as compared to the applied field.

In some ferromagnetic materials or alloys, the application of comparitively small external fields will cause a large measure of realignment. However, upon removal of the external field, only a very small portion of the field so produced is retained as there is little restraining force within the structure. These ferromagnetic materials are low energy or soft magnetic materials.

Other ferromagnetic materials, due to restraining forces within the materials, require larger applied fields to cause orientation of the spinning electrons; but, due to the restraining forces, a large measure of the acquired orientation is retained when the external field is removed. These are high energy or hard magnetic materials used in permanent magnets.

The field produced by the myriads of spinning electrons can work for you.



Physical concept of inner atom structure, showing the electrons that produce magnetism.

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CLASSIFICATION OF FERRITE MATERIALS

A.	Soft Ferrites	Low coercive force, high permeabilities	Computers and general communications
B.	Hard Ferrites	Extremely high coercive force. High remanance, Low permeabilities	Permanent magnets
C.	Garnets	Extremely low coercive force. High saturation magnetization	For microwave components.

CLASSIFICATION OF FERRITE PERMANENT MAGNETS

A.	Oriented	Highest energy product (3.5×10^6)	Sintered
B.	Non-oriented	Intermediate energy product (1.1×10^6)	Sintered
C.	Rubber	Intermediate energy product (1.0×10^6)	Ferrite impregnated rubber. Flexible.
D.	Plastic Bonded	Low energy product. (0.6×10^6)	Highly reacted ferrite held in thermosetting plastic. Low temp. cure.

PERMANENT MAGNET CHEMISTRY

General Formula: $MeO \cdot nFe_2O_3$ where Me = divalent metalic ions Ba, Sr, Pb, or Fe

Most Common Formulas:

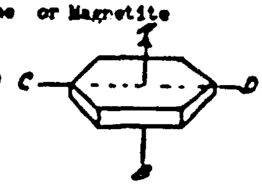
$BaO \cdot 5.6Fe_2O_3$ or $BaFe_{12}O_{19}$

$PbO \cdot 5.6Fe_2O_3$ or $PbO \cdot 3.4Fe_2O_3$

$SrO \cdot 6Fe_2O_3$ or $SrO \cdot 4Fe_2O_3$

$FeO \cdot Fe_2O_3$ or Fe_3O_4 or Lodestone or Magnetite

Crystallography: Hexagonal
Easy direction of magnetization (AB)
Magnetic Moment (CD)



ENCLOSURE-1

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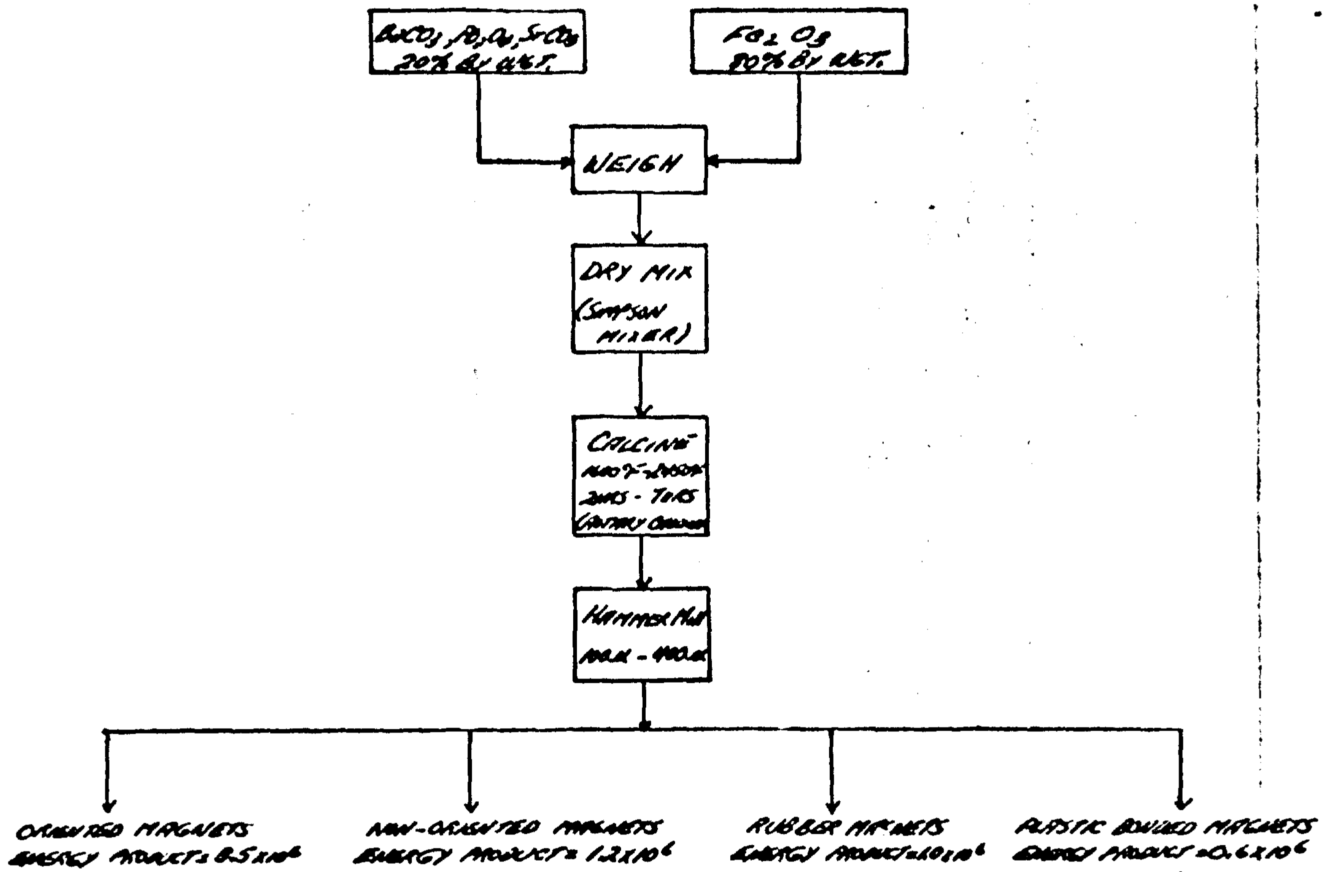
PROCESS FLOW IN THE MANUFACTURE OF CERAMIC PERMANENT MAGNETS



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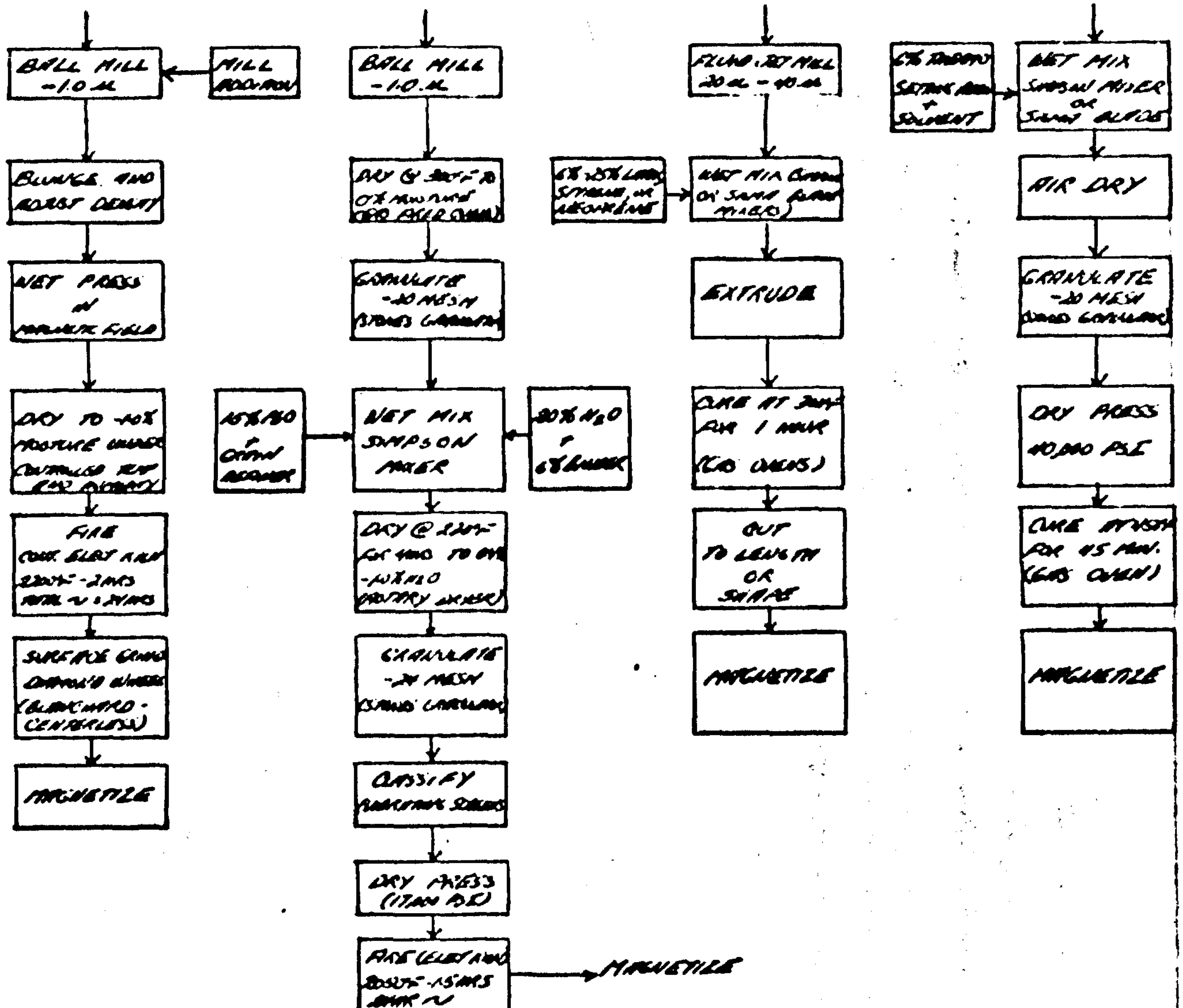

ENCLOSURE-2

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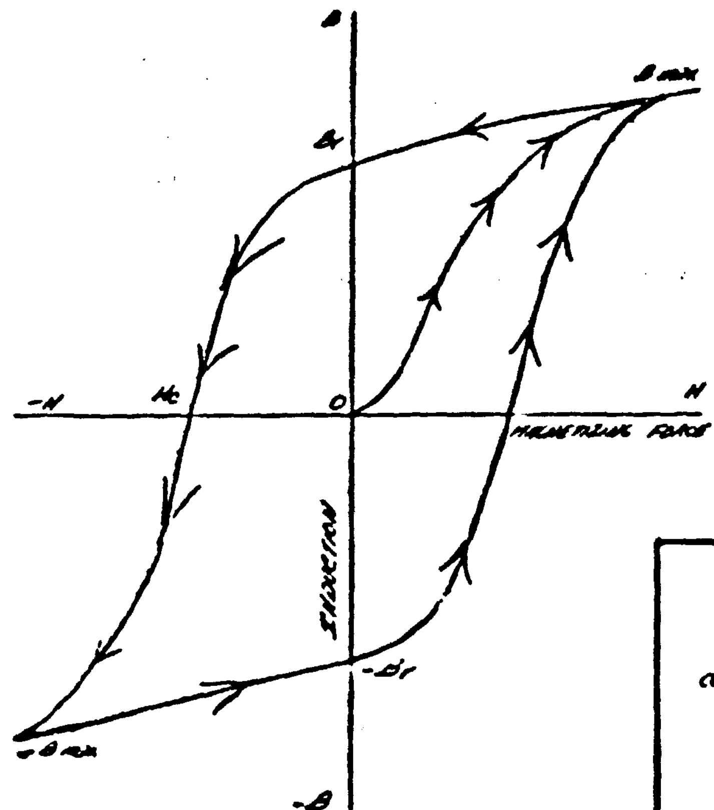


FIG. -B-

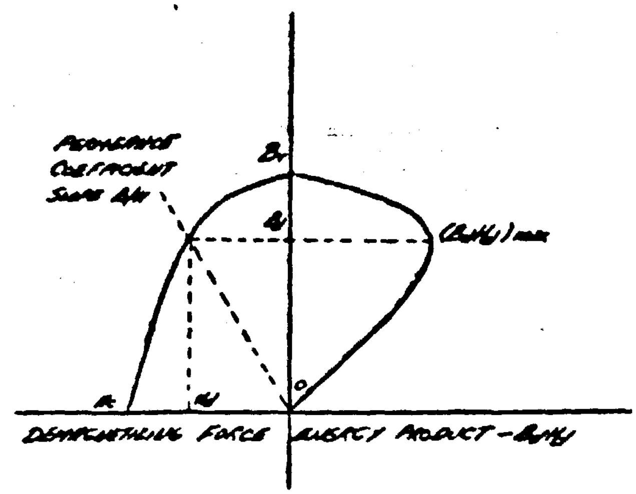


FIG: -C-

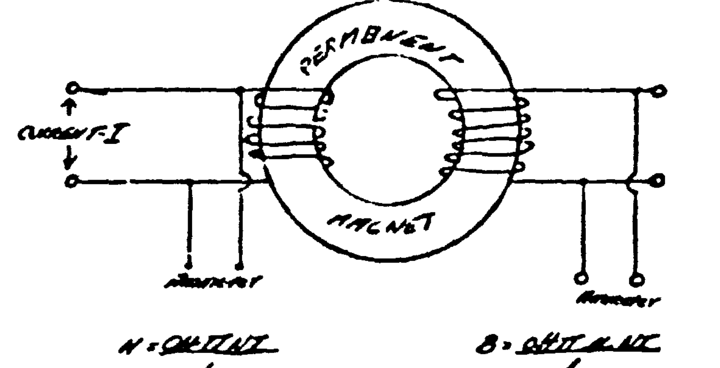


FIG: -A-

ENCLOSURE -3

COMPARISON OF PROPERTIES

Alloy Magnets (Alnico V)

versus

Ferrite Permanent Magnets
(Indiana Steel's Indox V)

	ALNICO V	INDOX V
MAGNETIC CHARACTERISTICS		
Peak Energy Product (B_dH_d) max x 10^6	5.25	3.50
Residual Induction, B_r (kilogauss)	12.5	4.00
Coercive Force, H_c (oersteds)	600	2000
Permeance Coeficient, B/H @ (B_dH_d) max.	20	1.06
Induction, B_d @ (B_dH_d) max (kilogauss)	10.2	1.85
Mmf per unit length, H_d @ (B_dH_d) max (oersteds)	512	1755
Incremental Permeability	2.2	1.05
Peak Magnetizing Force Required, H_p (oersteds)	3000	10,000
APPLICATION AND DESIGN FACTORS		
Ability to withstand demagnetizing fields	Good	Superior
Approx. temp. permanently affecting matl. (°F)	1000	1200
Preferred magnetic orientation	Yes	Yes
Importance of working at (B_dH_d) max	Most	Least
Weight (lb per cu in.)	0.27	0.18
Mechanical Properties	Hard&Brit.	Hard&Brittle
Critical Materials Present	Co and Ni	None
Electrical resistivity @ 25°C (u-ohm cm)	47	10^{10}
Tensile Strength (psi)	5450	Low
Coefficient of thermal expansion (per deg C x 10^{-6})	11.3	10

ENCLOSURE 4

BREAKDOWN OF CURRENT FERRITE MARKET

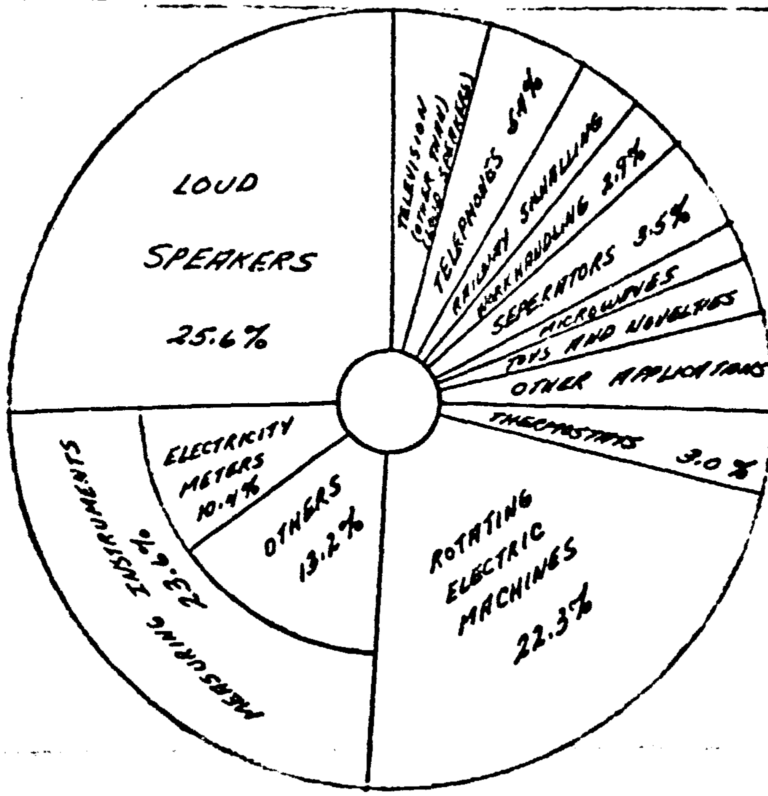
CATEGORY	END USE	TYPE	MATERIAL SYSTEM	MASS PROD. INTRO.	INTRODUCED BY	DOLLAR VOLUME SALES IN 1963	% OF FERRITE MARKET
Deflection Components	TV Yokes TV Transformers	Soft	$NiZnFe_2O_4$ $MnZnFe_2O_4$	1949	General Ceramics	$5,550,000	8.94
Antenna Rods	Radio Receivers	Soft	$NiZnCoFe_2O_4$	1951	Henry L. Crowley Co.	$1,500,000	2.42
Square Loop Ferrites	Computer Switch and Memory	Soft	$MnZnMgFe_2O_4$	1952	General Ceramics	$30,000,000	48.35
Specialties	Communications & Computers as Cup Cores, Tuning Slugs, Hi-Freq. Transformers, Recorder Heads, Magnetostrictive Transducers	Soft	Many	1953-	Many	$8,000,000	12.89
Microwave Components	Waveguides, Gyrators, Isolators, Etc.	Garnets Soft	$NiZnAlFe_2O_4$ $Y_2Fe_2O_6$	1954	Ferroxcube, General Ceramics	$6,000,000	9.66
Permanent Magnets	Many	Hard	$BaFe_{12}O_{19}$	1955	Indiana Steel	$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 by Indiana Steel. 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 by Indiana Steel. 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 by Leyman Rubber Co. 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

ENCLOSURE B

WHERE PERMANENT MAGNETS GO
(Based on 1959-1960 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	1.4
Workholders and latches	2.5
Separators	1.9
Other applications	1.6

ENCLOSURE 6

U.S. FERRITE MAGNET MANUFACTURERS

MANUFACTURER	LOCATION	TYPES
Indiana Steel, Division of Indiana General Corp.	Valparaiso, Indiana	All
General Magnetics, Div. of Muter Corp.	Detroit, Michigan	Oriented Only
Arnold Engineering, Div. of Allegheny Ludlum	Marengo, Illinois	Oriented and Plastic Bonded
Stackpole	St. Marys, Penna.	Oriented and Non-oriented.
Magnatronics, Div. of Crucible Steel	Elizabethtown, Ky	Oriented and non-oriented.
D.M. Steward	Chattanooga, Tenn.	Oriented and non-oriented.
Allen Bradley	Milwaukee, Wisconsin	Oriented and non-oriented
Westinghouse	Blairstown, Penna.	Oriented only
Goodyear Rubber	Akron, Ohio	Rubber only.
Goodrich Rubber	Marieta, Ohio	Rubber only
Leyman Rubber	Cincinnati, Ohio	Rubber only
Automation Industries	Boulder, Colorado	Oriented and non-oriented
National Moldite	Newark, N.J.	Non-oriented
Kearfott	Clifton, N.J.	Non-oriented
Magneco, Div. of Advance Ross Electronics Corp.	Addison, Ill.	Non-oriented
Magno-Ceram	South Plainfield, N.J.	Oriented and Rubber

ENCLOSURE 7

U.S. ALLOY MAGNET MANUFACTURERS
(Doing and annual business of approx. 43 million dollars.)

MANUFACTURER	LOCATION
Indiana Steel Products Division, Indiana General Corp.	Valparaiso, Indiana
Crucible Steel Corporation	Harrison, N.J.
General Magnetics Div., Muter Corporation	Detroit, Michigan
Arnold Engineering Div., Allegheny Ludlum	Marengo, Ill
General Electric Corporation	Schenectady, N.Y.
Westinghouse Corporation	Blairstown, Penna.
Thomas and Skinner	Indianapolis, Ind.
Simmonds Steel and Saw	Lockport, N.Y.
U.S. Alloy and Magnet Corp.	Bloomfield, N.J.

ENCLOSURE 8