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Engineering Note E-422

Electronic Computer Division
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: RECTANGULAR-LOOP MAGNETIC CORE MATERIALS

To: N. H. Taylor

From: W. N. Papian

Date: September 4, 1951

Abstract: There are ferromagnetic cores on the market today which are suitable for use in high-speed multi-dimensional storage arrays and in fast stepping registers. Tests made here indicate the high promise of Armco Mo-Permalloy-216, a metal, and Ferramic A, a ceramic. Gradual improvements in the characteristics of pertinent core materials are expected to continue.

A. INTRODUCTION

Three general classes of ferromagnetic materials are on the market today. They are:

1. Metallic materials
2. Ceramic materials
3. So-called powder or dust materials

The last mentioned class will not be discussed here because powder cores cannot now be made which combine rectangularity characteristics along with reasonable freedom from eddy-currents.

The metallic and ceramic classes both contain pertinent and promising materials for applications which require rectangular B-H loops and the freedom from eddy-currents which allows quick changes of magnetic flux to occur.[1,2]

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1. W. N. Papian, "Ferromagnetic Materials for Applications Requiring Rectangular Hysteresis Loops and Short Response Times," M.I.T. E.E. Seminar Paper, Jan. 1950.

2. W. N. Papian, "A Coincident-Current Magnetic Memory Unit," Project Whirlwind Report R-192, M.I.T., August 1950.

B. METALS

For the particular purposes of the group working on magnetic-core storage at this Project only ribbon-wound ring-shaped cores have been of significant interest in the metallic class. The materials will be discussed in a more or less chronological order, that is, in the order in which they came to our attention.

1. Deltamax

This material is a grain-oriented, 50% nickel-iron alloy made by the Allegheny-Ludlum Steel Corp. and marketed in special shapes by a subsidiary, the Arnold Engineering Co. Deltamax has an extremely rectangular B-H loop (see Fig. 1), very low coercivity, high maximum-flux density, and low resistivity; it is available in ribbon thicknesses as low as 1/4 mil.

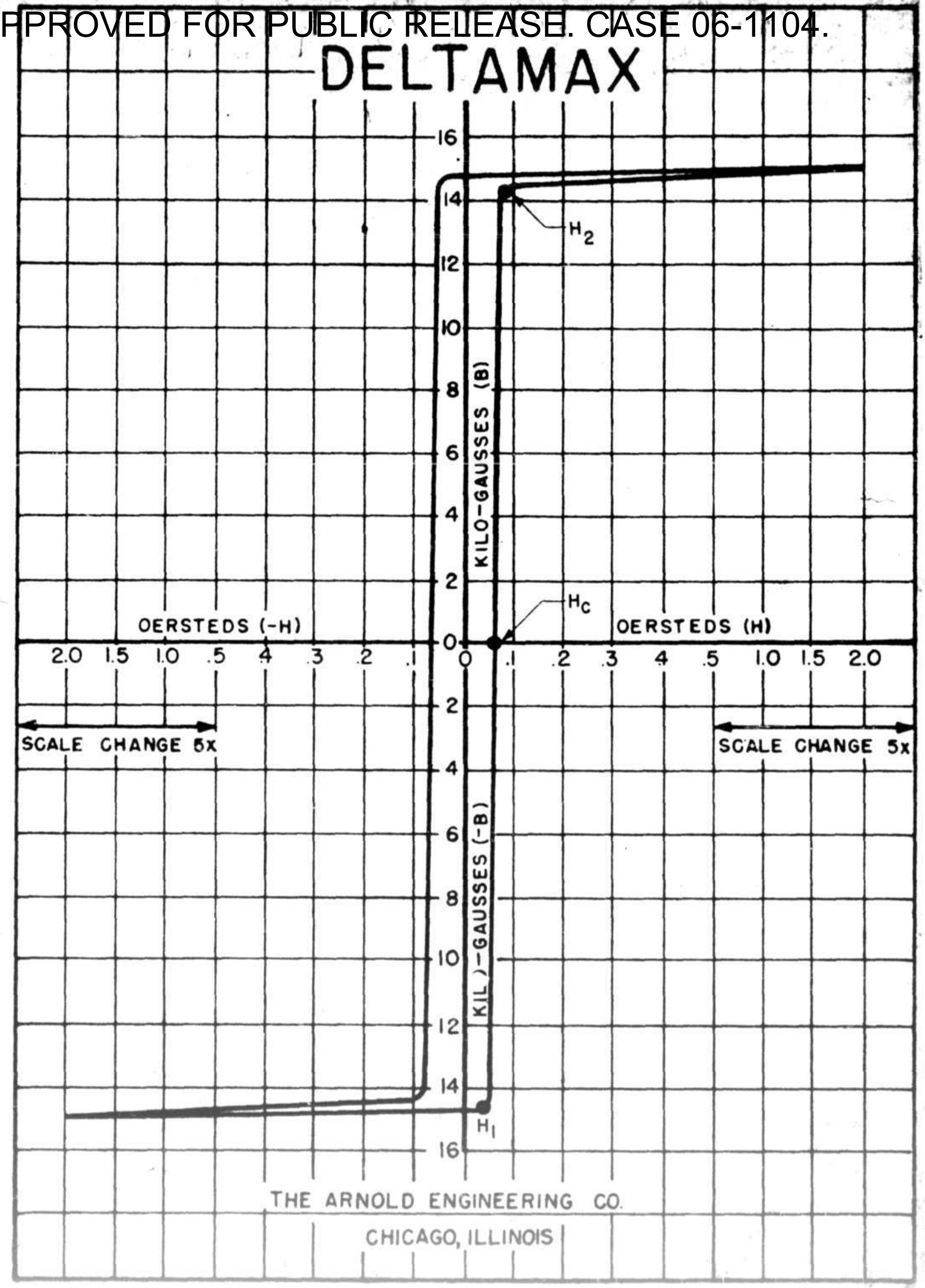
Interest in Deltamax is low here largely because of its extremely long switching times under low and medium excitations, and because of the large percentage of input energy which is lost in eddy currents under high excitations. As an example, a Deltamax core made of 1-mil ribbon takes of the order of 5 milliseconds to reverse its magnetic flux under an excitation which is about twice its coercivity. The same core can be switched in about 40 microseconds, but it requires an excitation value about 10 times its coercivity.

1-mil Deltamax is the material now being used in the Harvard, Alden, Wang, and Burroughs stepping-register (Static Magnetic Delay Line) cores.

2. Silectron

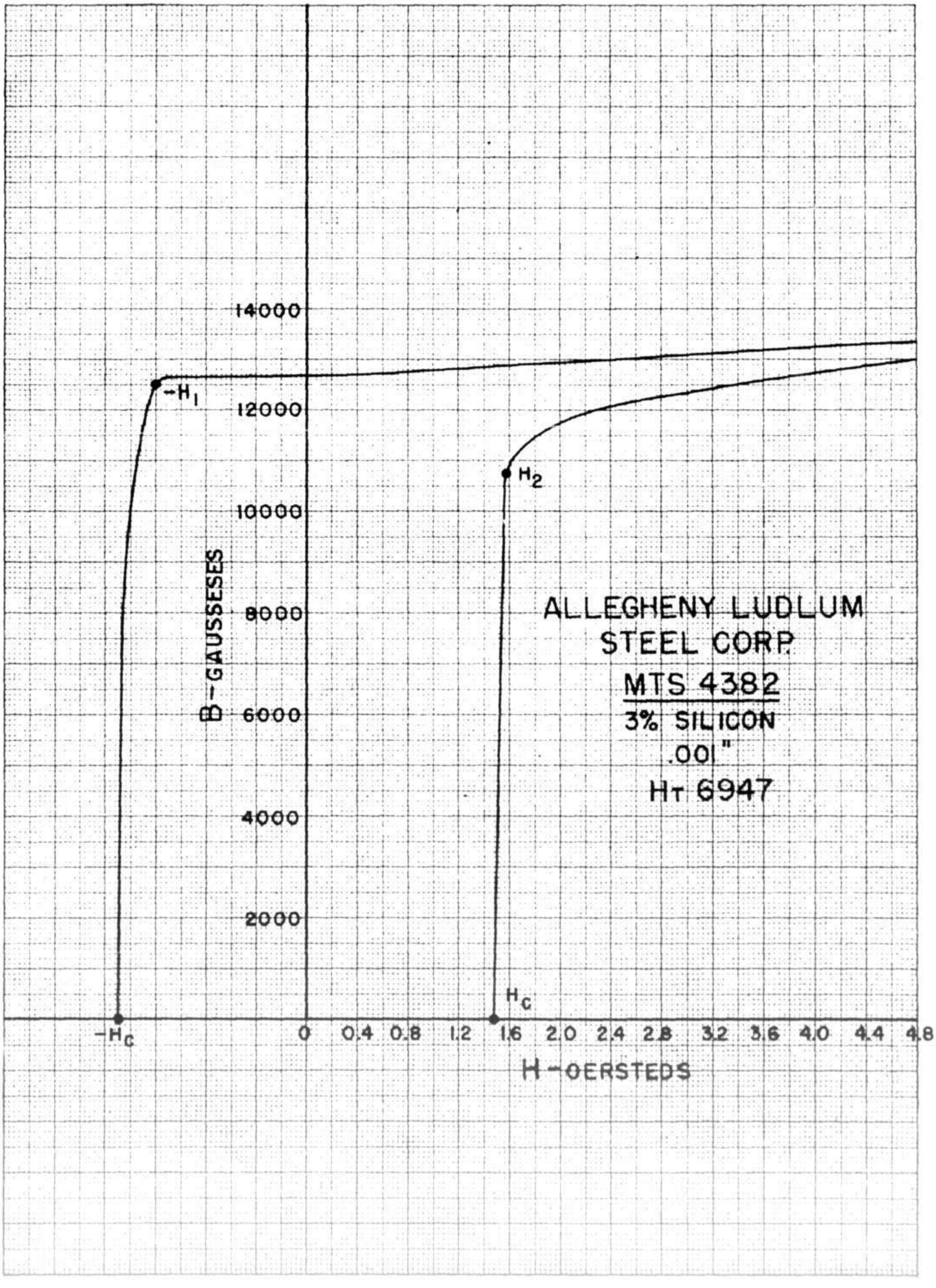
This is the familiar 3% silicon-iron alloy known as electrical sheet, but with a partial grain and domain orientation produced for us by Allegheny Ludlum. It has the very rectangular B-H characteristic shown in Fig. 2. Coercivity and maximum-flux density are high, resistivity is low and the material was available to us in the 1-mil thickness.

The very successful metallic core used in the early experiments and the cores used in the experimental 2 x 2 x 1 array were made of this material. Resultant speeds were good (about 20 microseconds with a 2:1 selection ratio) and signal ratios were very high. The main disadvantage of Silectron is the high coercivity which calls for high driving ampere-turns, and the rather high switching energy as indicated by its large B-H loop area. Silectron was the most promising metal until a few months ago when the material to be discussed below appeared on the scene.



A-48019-G

FIG. 1



A-38999 -G

FIG. 2

3. Mo-Permalloy-216

Mo-Permalloy-216 is Armco Steel Corporation's special version of that 79% nickel, 4% molybdenum iron alloy. They obtain the good rectangular B-H loop shown in Fig. 3 by a special magnetic anneal. Coercivity and maximum flux density are low, resistivity average, and it is available in thicknesses down to 1/6 mil.

Interest in Mo-Permalloy-216 is high; it has virtues for application either as a coincident-current unit in a multi-dimensional array or as a memory unit in a stepping register. Mo-Permalloy-216 cores switch rapidly at all excitations due in part to the following characteristics: availability of extremely thin material, low flux densities, not-too-high maximum-differential permeabilities, and an apparent freedom from fractional-second lags in magnetization at very low excitations. The small loop area also accounts for the low switching energies required.

Small cores of this material will be used in the 16 x 16 array now in design. They are also being considered by ourselves, and by Burroughs at our urging, for use in faster, lower-energy versions of the stepping register.

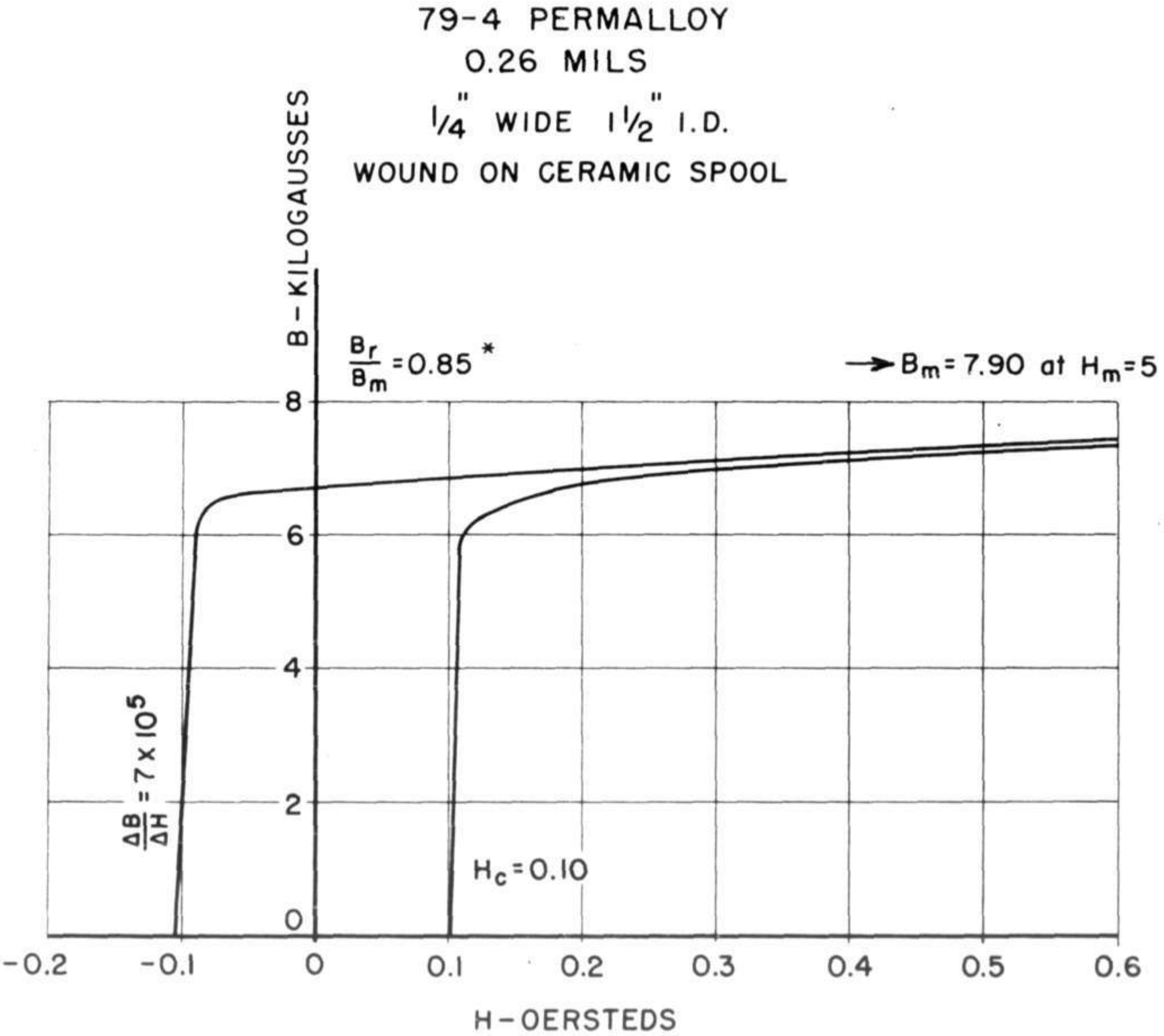
The material is relatively new so that production and uniformity difficulties are being experienced by our core supplier, Magnetics, Inc., and by others. There is, however, perfectly reasonable expectation that these difficulties will be ironed out in a short time.

C. CERAMICS

Where fractional-microsecond switching times are needed, the metals in their present form are unsuitable, largely due to eddy currents. The development during this last decade of a group of semi-insulator ceramics which have ferromagnetic characteristics answers the above need. These materials are called magnetic ferrites by some and ferrospinels by others. They are homogeneous compounds of various metal oxides (not metals) with resultant mechanical properties resembling those of dry-process porcelain.

In general, the ceramic materials have low B-H rectangularity, high coercivities, low flux densities, but phenomenally high resistivities. Quite a few materials have been considered, but only two are worth mentioning.

D-C HYSTERESIS LOOP
CORE NO. 216



* $\frac{B_r}{B_m} = 0.915$ for $B_m = 7.45$

CURVE NO. 5112
ARMCO RESEARCH LABORATORIES
4-13-51

FIG. 3

A-50265

1. Ferroxcube IV

This material was the first ceramic to exhibit any rectangularity. However, it did so to any marked extent only when it was under some applied mechanical strain. Because of this, and its not-too-high resistivity, interest in it waned early.

2. Ferramic A

Ferramic is the smart trade name which the General Ceramics and Steatite Corp. gives to its magnetic ferrites. Although there are nearly ten different Ferramics, only the A material has thus far shown sufficient rectangularity to operate as a coincident-current memory unit.

This material has a B-H loop shape as shown in Fig. 4. Coercivity is high and maximum flux density low, even relative to the other ceramics. Its resistivity is extremely high, and it appears to have no significant magnetization time lags in the microsecond region.

Interest in this material is also high. It is a potential candidate for use in high-speed multi-dimensional arrays and stepping registers. Improvements in the material's characteristics are desirable in the two directions of lower coercivity (reduced driving ampere-turns) and better B-H rectangularity. It is also desirable, but difficult, to get cores made in very small shapes and sizes. Development work in these and other directions is going on and is being encouraged by the laboratory. Some slightly improved versions of this core material have been received and tested, and other improved samples are expected in the future.

Ferramic A cores have been operated here as coincident-current units with 2:1 and 3:1 selection ratios at switching speeds of about 1/2 microsecond. They have also been operated by Buck and Guditz in a 4-core stepping register at speeds over 100,000 digit-transfers per second, using outsize cores and other parameters not truly optimized for the job.

D. CONCLUSION

Presently available rectangular-loop ferromagnetic cores for high-speed storage and pulse applications contain a few which show a great deal of promise. Armco's Mo-Permalloy-216 is, at the moment, the most interesting among the metals; the most promising ceramic is a slightly improved Ferramic A core. Both materials are useful as they stand, and continued improvements are expected.

Signed by William N. Papian
W. N. Papian

Approved by N H Taylor
N. H. Taylor

WNP:kst

Drawings Attached:
Fig. 1 - Drawing No. A-48019-G, Page 3
Fig. 2 - Drawing No. A-38999-G, Page 4
Fig. 3 - Drawing No. A-50265 , Page 6
Fig. 4 - Drawing No. SA-50264 , Page 8

SA-50264

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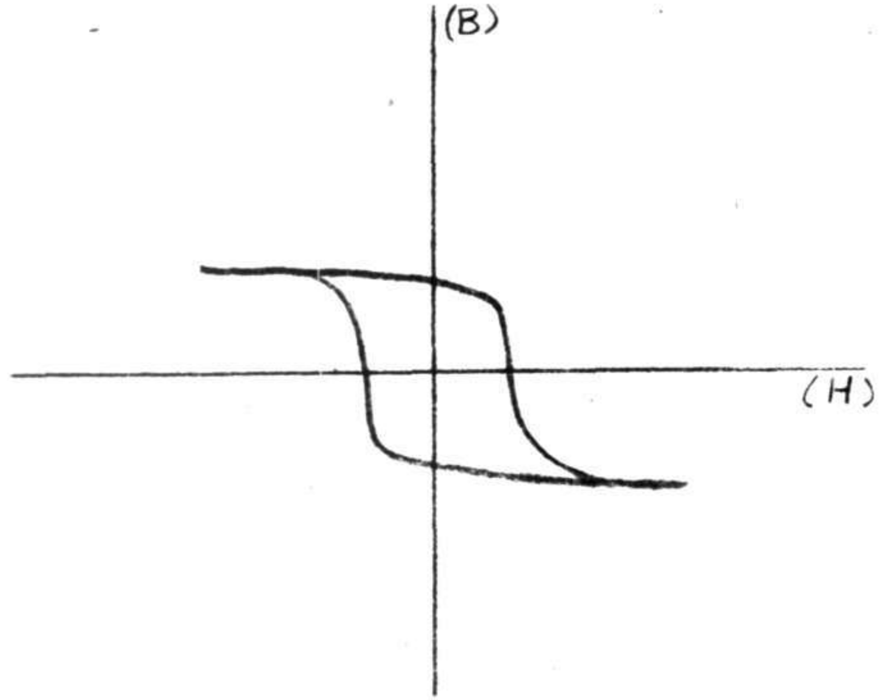

SERVOMECHANISMS LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY DIVISION OF INDUSTRIAL COOPERATION PROJECT NO.				
B-H LOOP SHAPE – IMPROVED FERRAMIC A			CORE #1	
SCALE:		DR. B.W.		SA-50264
ENG. B.W.	CK.	APP.		

FIG. 4