directions. Strain gauges are particularly suitable for making this type of measurement directly. Figure 6(b) shows differential expansion between [111] and [100], and (c), between [110] and [100]. The shape of these curves, obtained as the crystal warmed, was found to be independent of the condition of the crystal below the transformation.

V. TRANSFORMATION IN THE OTHER FERRITES

Several references have been made in the literature to a low temperature transformation in other ferrites, including those of cobalt,[12] nickel,[13] and manganese.[13] The most convincing evidence is the magnetization data of Guillaud for cobalt ferrite, which show discontinuities similar to those displayed by magnetite. However, present evidence is insufficient to determine whether any of the reported anomalies can be classified along with the magnetite transformation. Healy's microwave resonance absorption study[14] of nickel ferrite has shown that no sudden change in magnetic symmetry occurs between the Curie temperature and 78°K, although the anisotropy constants change in a manner somewhat similar to those of magnetite. If the interpretation of the magnetite transformation as an ordering phenomenon is correct, it is difficult to understand how a similar transformation could occur in other ferrites in the same temperature region, since ordering in any other ferrite would necessitate ionic motion.

[12] C. Guillaud and H. Creveaux, Comp. rend. **230**, 1256 (1950).
[13] T. Okamura and J. Simoizaka, Phys. Rev. **83**, 664 (1951).
[14] D. W. Healy, Jr., Phys. Rev. **86**, 1009 (1952).

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Magnetic Study of Low Temperature Transformation in Magnetite

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THE magnetic crystal anisotropy of magnetite has been investigated with special reference to the effect of cooling through the transformation at about $-160°C$ in the presence of a magnetic field. In a natural crystal we have found an anisotropy such that the difference in energy between the directions of easy and of hard magnetization is 1.07×10^6 ergs/cm^3. When the field is applied in a (100) plane parallel to a [001] direction, this direction becomes the easy direction whereas [010] becomes the hard direction. This confirms the observation first reported by Li.[1]

When fields are applied along other directions in this plane, the relation between the direction of applied field and the consequent direction of easy magnetization is shown in Fig. 1, and similar data for the (011) plane are given in Fig. 2. A set of torque curves for the (100) plane are shown in Fig. 3.

The results for the (100) plane can be explained as follows: When the field used during cooling was applied within about 40 degrees of a [001] direction, that direction becomes the direction of easy magnetization for all of the crystal; the directions [010] and [001] being hard directions. When the field during cooling is near a [011] direction, some portions of the crystal

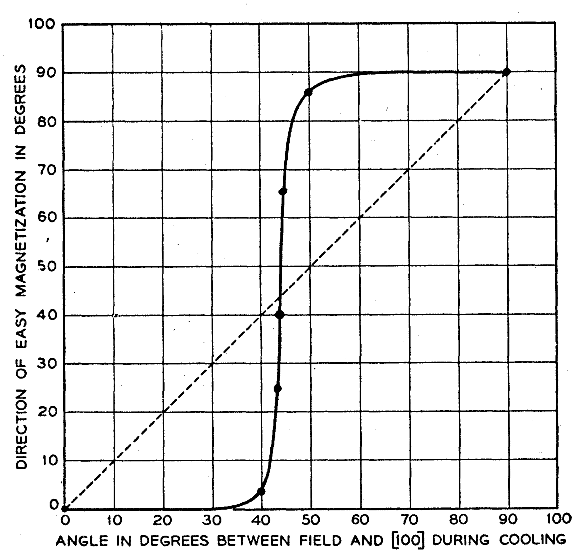

FIG. 1. Natural magnetite crystal, liquid N_2 temperature. Relation between direction of magnetic field present during cooling, and resultant direction of easy magnetization, in (100) plane.

[1] C. H. Li, Phys. Rev. **40**, 1002 (1932); see also Domenicali, Phys. Rev. **78**, 458 (1950).

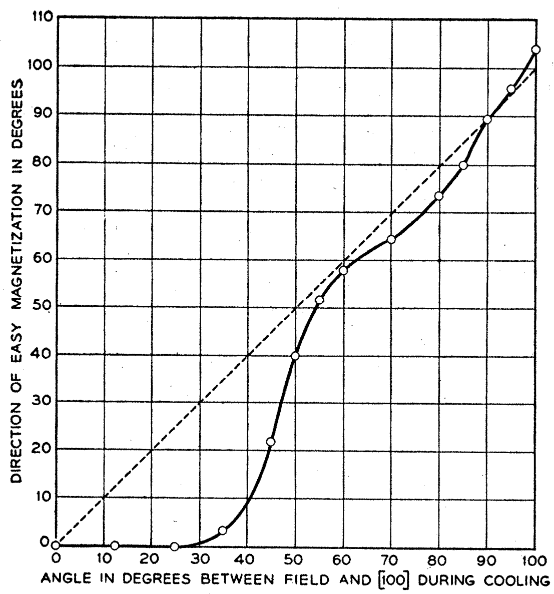

FIG. 2. Same as Fig. 1, except for (110) plane.

have easy directions parallel to [001] and some parallel to [010]. One can always explain the form of a torque curve for the (100) plane by assuming a distribution between these two directions, and torque curves so determined are given as dotted lines in Fig. 3 where they show agreement with the observed curves. However, a more complicated mechanism is necessary to explain the data for the (110) plane.

An artificial crystal cut parallel to a (110) plane showed a behavior different from that of the natural crystal just described. The direction of easy magnetization was always the [001] direction, and could not be influenced by cooling in a field using field strengths up to 9000 oersteds. Higher fields have not yet been tried.

At room temperature the crystal anisotropy constant was observed to be −144 000 for the natural crystal, and −122 000 for the artificial crystal. These may be compared with the value, −112 000, observed by Bickford[2] in his experiments on ferromagnetic resonance.

We gratefully acknowledge the assistance of Miss M. Goertz throughout the course of the work.

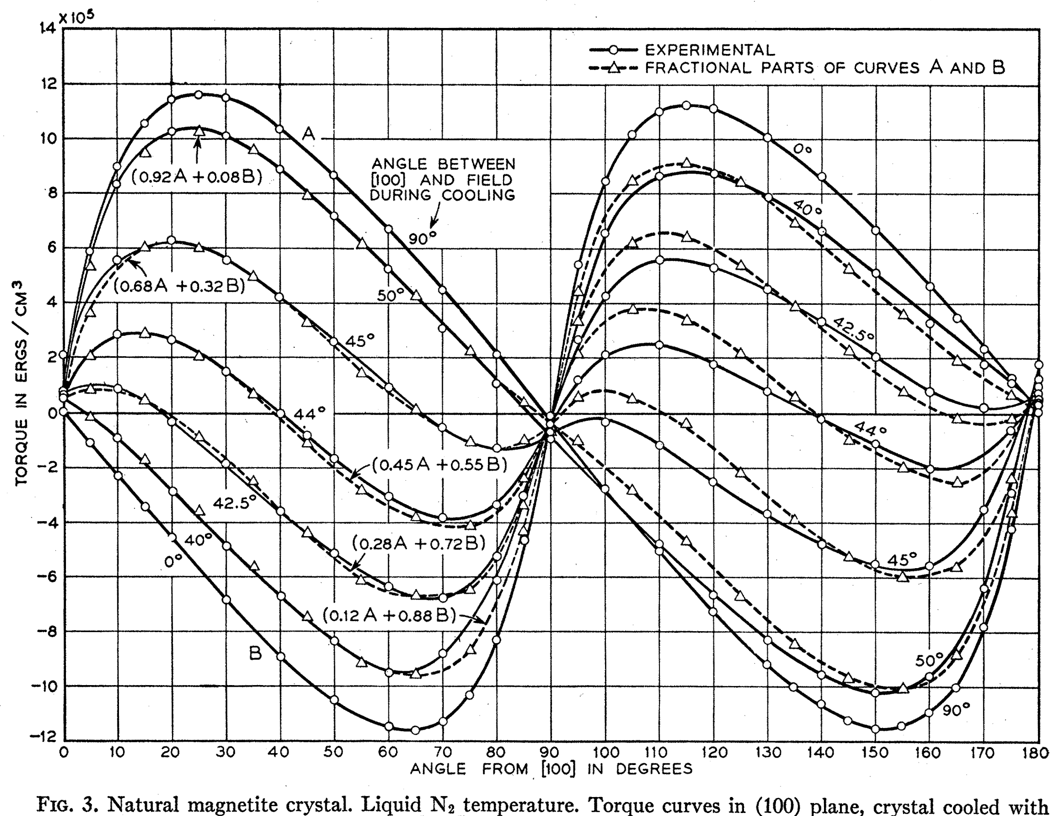

FIG. 3. Natural magnetite crystal. Liquid N_2 temperature. Torque curves in (100) plane, crystal cooled with magnetic field applied at various angles to [001] direction. Broken curves are calculated assuming various fractions of crystal having easy directions of [001] and [010].

[2] L. R. Bickford, Phys. Rev. **78**, 449 (1950).