Division 6 - Lincoln Laboratory
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

SUBJECT: FERRITE SYNTHESIS

To: David R. Brown

From: Francis E. Vinal

Date: September 15, 1953

Abstract: A systematic investigation of the MgO•MnO•Fe_2O_3 system has indicated that rectangular hysteresis loops can be obtained over a wide range of composition. Maximum squareness is obtained in the region of 33-percent MgO, 25-percent MnO, and 42-percent Fe_2O_3. A composition of 35-percent MgO, 30-percent MnO, and 35-percent Fe_2O_3 appears best for coincident-current memory application. Relationships between composition, squareness, coercive force, and switching time are indicated.

A systematic investigation of the MgO•MnO•Fe_2O_3 oxide system which has produced the most suitable memory cores, has been undertaken to establish the trends in electrical characteristics with changing composition. The compositions thus far prepared are shown in Figure 1, and for these, the hysteresis loop data are essentially complete. The midpoints of the base and right side of the ternary composition plot represent $MgFe_2O_4$ and $MnFe_2O_4$ respectively. On the straight line connecting these two points, lie all the compositions which are stoichiometric in character. To the left of the stoichiometric line lie those compositions deficient in iron oxide and to the right of the line lie those containing an excess of Fe_2O_3.

By plotting the maximum loop squareness obtained for each composition after extended firing trials it is possible to draw a contour "weather map" as shown in Figure 2. The mountain range pattern shown by the data indicate a maximum peak region of loop squareness in the region of 33-percent MgO, 25-percent MnO, and 42-percent Fe_2O_3. From this peak region, gradually diminishing ridges extend in two directions. One direction lies essentially parallel to and slightly to the left of the stoichiometric line while the second lies essentially parallel to and slightly to the right of a line connecting the MnO apex with the midpoint of the base, $MgFe_2O_4$. To the right and left of these ridges the squareness values drop precipitiously.

In Figure 3, a tentative interpretation of the squareness data is offered. All fair-to-good values of loop squareness lie in the area A + B + C while areas D and E are very poor. The basic area A of the region A + B + C is believed to contain a single phase, homogenious, spinel-structural system. Area B and C represent areas of limited solid solubility for MgO and Fe_2O_3, respectively, in the spinel phase. Such solubilities seem likely as the unit cell dimension of cubic MgO is almost exactly one half that for $MgFe_2O_4$ and Fe_2O_3 in the form is known to form solid solutions with the spinel lattice. Areas D and E represent two phase systems where the solubility limits of MgO and Fe_2O_3 respectively have been exceeded and a second phase of these materials has appeared.

The switching time and coercive force data for the compositions investigated are, by comparison, some what incomplete. Sufficient measurements have been made, however, to show some trends. The fast switching cores with high flux change lie on or very slightly to the right of the MnO-$MgFe_2O_4$ centerline and the coercive force decreases as one proceeds up this line from the base. A composition containing 35-percent MgO, 30-percent MnO, and 35-percent Fe_2O_3 appears to lie about in the optimum region for use as magnetic memory cores and offers quite satisfactory properties for the purpose which are shown in Figure 4. The electrical properties show a squareness ratio of 0.82 while the switching time is 1.35 microseconds and the coercive force 1.5 oersteds. Part B of Figure 4 shows the undisturbed-one output, the disturbed zero, and the half-selected zero signals. Part C shows that the undisturbed one output and the disturbed one output are virtually superimposed, hence the core is very stable to disturbing pulses. Also in Part C are shown the first half-selected one and subsequent half-selected one responses.

With respect to the actual manufacture of memory cores, the handling qualities for pressing of ferrite mixes has been considerably improved. This property is now closely tied to compositions but is extremely significant where one is automatically pressing a toroid about (unfired size) 0.100-in. outside diameter by 0.080-in. inside diameter by 0.025-in. high. The rebuilding of the automatic press has also brought much improvement in processing, but still leaves quite a bit to be desired over the operating qualities of the heavier and better designed rotary head multiple presses. A point has been reached, however, where production of cores on a pilot plant scale should be quickly attained.

In conclusion, it should be mentioned that the significance of the MnO-$MgFe_2O_4$ line in the composition diagram came as something of a surprise. It therefore becomes necessary to make a rather careful evaluation of the chemistry of the constituents and the modifications which may occur during processing before a sound interpretation of the data may be made.

Signed FEVinal
Francis E. Vinal

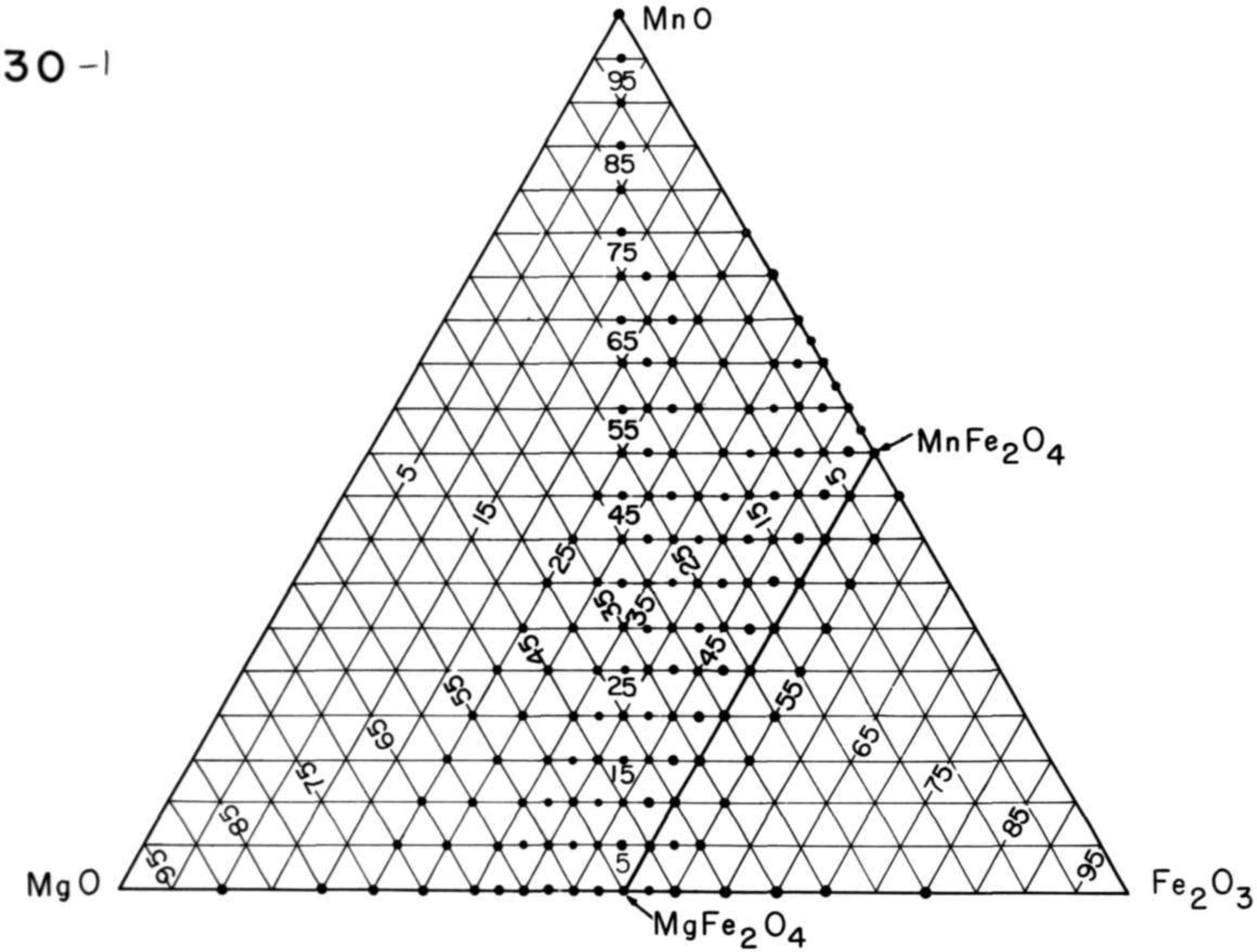
Approved DRB
David R. Brown

FEV/jk

Drawings attached:

Figure 1 - B-56130 Figure 3 - B-56368
Figure 2 - B-56411 Figure 4 - A-56532

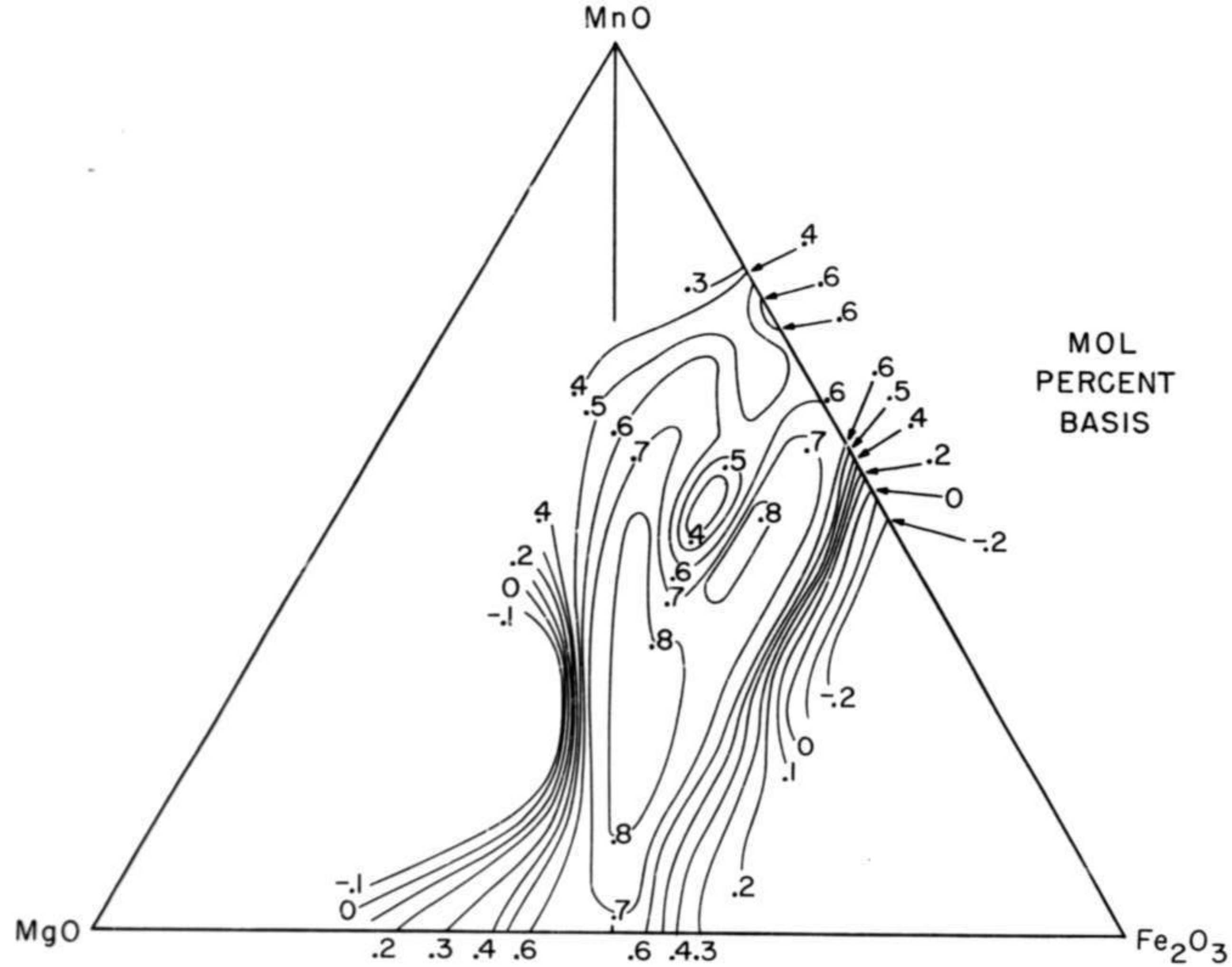
B—56130-1
F-2146
SN-657
MN



COMPOSITIONS INVESTIGATED IN THE

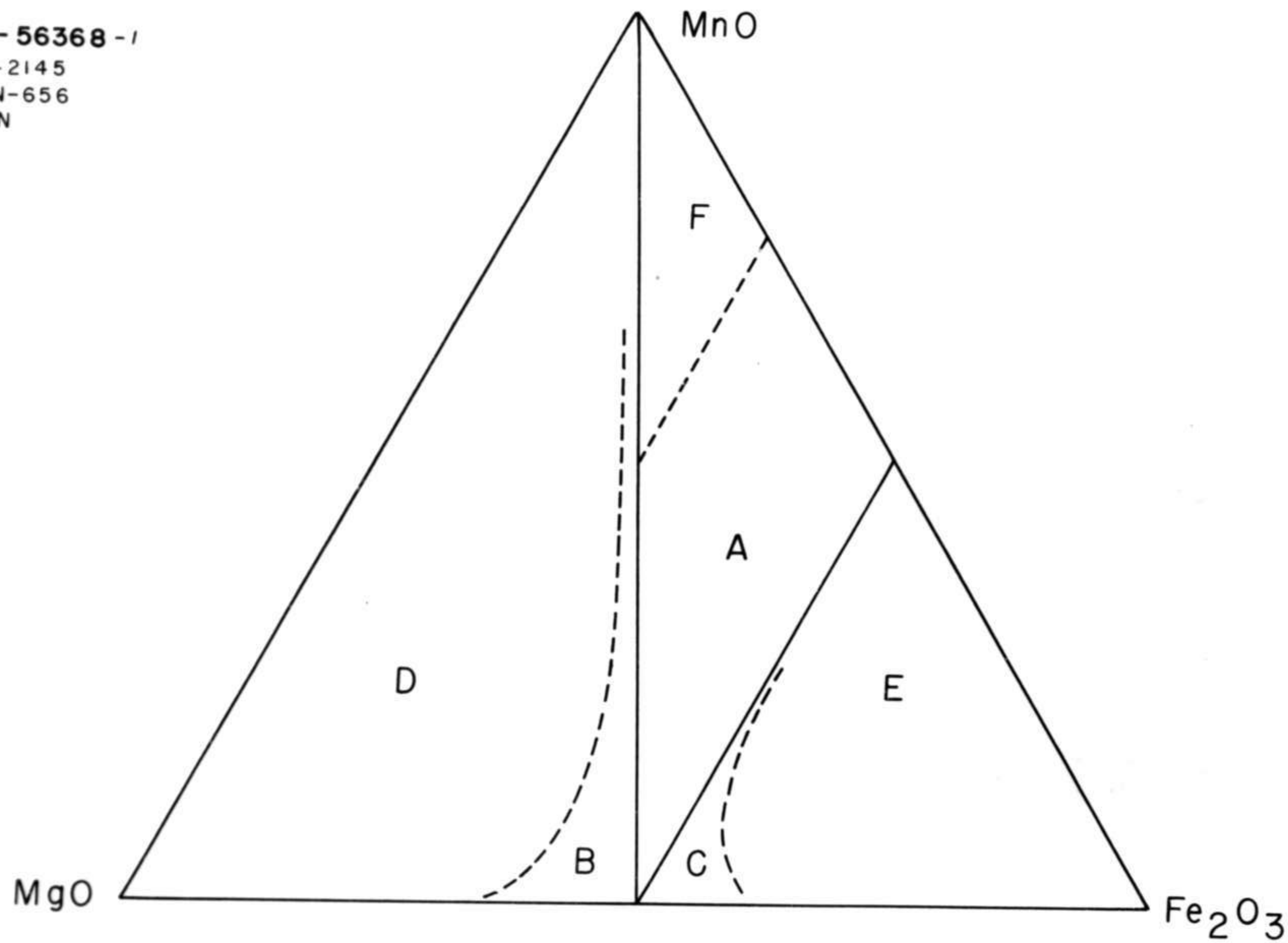
MgO·MnO·Fe$_2$O$_3$ OXIDE SYSTEM MOL PERCENT BASIS

C-56411-1
F-2154
SN-665
MN

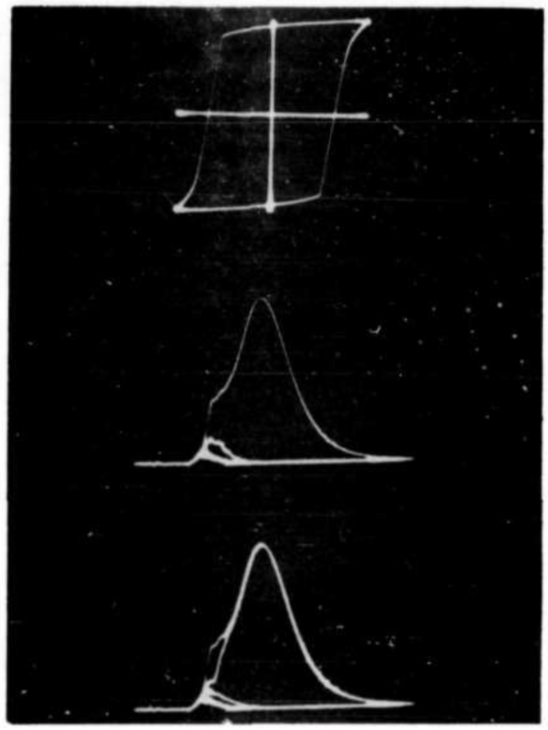


LOOP SQUARENESS VS. COMPOSITION FOR THE $MgO \cdot MnO \cdot Fe_2O_3$ SYSTEM

B-56368-1
F-2145
SN-656
MN



INTERPRETATION OF HYSTERESIS-LOOP-SQUARENESS



A

B

C

FIG. 4

HYSTERESIS LOOP AND PULSE RESPONSE OF FERRITE DCL-2-134A-1

A-565