ON THE RECTANGULARITY OF THE HYSTERESIS LOOP
OF SOLID SOLUTIONS BELONGING TO THE SYSTEM
\( \text{Mn}_{1+x}\text{Fe}_{2-x}\text{O}_4 \), \( -0.1 < x < 0.14 \)

In a previous communication [1] it was shown that the dependence of the ratio \( B_t/B_{\text{max}} \) on \( x \) for polycrystalline samples of the system \( \text{Mn}_{1+x}\text{Fe}_{2-x}\text{O}_4 \), where \(-0.13 < x < +0.14\), resembles the course of the magnetocrystalline anisotropy constant \( |K_1| \) in the given range of \( x \). It was simultaneously confirmed experimentally that for \( x \approx 0 \) at room temperature the magnetostriction constant changes sign and thus the ratio of the magnetoelastic energy in the sum of the energies describing the magnetization process becomes zero \( (\lambda \sigma_1 \approx 0) \). It was also assumed that in the remanence state it holds with sufficient approximation that \( \lambda \approx \lambda_{111} \) for \( K_1 < 0 \). This assumption was justified by the fact that interpolation of the values \( \lambda_{111} \) obtained by other authors on single crystals at a temperature of 20°C [3, 4] actually shows the change in sign of \( \lambda_{111} \) for \( x \approx 0.1 \). A comparison of the values of \( \lambda_{111} \) given in papers [3, 4] and the values of \( |K_1| \) according to [5] shows, however, that \( |K_1| \geq 10 \lambda_{111} \sigma_1 \) for all \( x \geq -0.10 \) is satisfied even for the intensity of internal stresses \( \sigma_1 = 5 \times 10^8 \text{ dyne} \cdot \text{cm}^{-2} \), equalling the intensity of the stresses in a cold-rolled nickel sheet.

Since, therefore, the magnetoelastic anisotropy does not substantially assert itself in any way, it may be inferred from the similarity of the courses of \( B_t/B_{\text{max}} \) and \( |K_1| \) that the magnetocrystalline anisotropy decides on the shape of the hysteresis loop. The decrease in rectangularity, however, cannot be explained on the basis of the well-known Gans model [2], at least not in the range \(-0.1 \leq x < 0 \). The shape of the hysteresis loop must therefore also be given by other components of the crystal energy, not included in previous considerations.

All the samples studied had a conformable shape; they were very homogeneous, showed almost an identical microstructure and their density was \( 4.85 \pm 0.05 \, \text{g} \cdot \text{cm}^{-3} \) independently of the value of \( x \). The part of the shape anisotropy connected with the shape of the sample, with the presence of pores or precipitates, could not therefore be taken into consideration. The magnetic energy connected with the boundaries of grains, which are at the same time places of equilibrium positions of Bloch walls, had to be taken as the only real supplementary part of the energy. Goodenough [6] tried to evaluate their

---

1) \( \lambda \) changes sign for \( x \approx -0.15 \) (20°C) and \( \lambda_{100} \) is negative in the whole range of the studied values of \( x \).
influence on the shape of the hysteresis loop assuming that magnetization processes take place by domain-wall displacement.

According to [6], when entering the decreasing part of the hysteresis loop in a polycrystalline ferromagnet, for which the condition $|K_1| > |\lambda a_1|$ is satisfied, the effort to decrease the magnetic energy density on the crystal boundaries, in which the vectors $I_n$ are arranged in different directions, can lead to the formation of magnetization reversal nuclei (nucleation) resulting in a decrease in

$$R_{\text{max}} = \frac{B_r}{B_{\text{max}}}$$

The degree of rectangularity of the hysteresis loop is expressed either by the