Letters to the Editor

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Dislocations, Cavities, and the Approach to Magnetic Saturation

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IN discussing the approach to magnetic saturation, Stoner[1] writes: "In a related paper dealing with the a/H term, and also describing work virtually completed in 1945, Néel (1948a) points out that no mechanism involving perturbing forces can give rise to a rigorous law of this type, which implies an indefinitely large work of magnetization. This rules out most of the suggestions that have been made, including those of Brown (1940b, 1941), whose study of the effect of point, line, and plane concentrations of force, or, less formally, of dislocations, is none the less of great interest."

Apparently Néel[2] misunderstood my dislocation formulas,[3] and Stoner accepted his interpretation. Any result obtained by integrating the formulas to $H = \infty$ is meaningless, because they are based on approximations that break down at very high field intensities. This fact does not impair the validity of the formulas over the range in which they were intended to be applied; nor can it discredit the physical hypothesis on which the calculation was based.

Throughout, the dislocation radius was treated as vanishingly small. This approximation is permissible if the magnetic decay distance (proportional to $H^{-\frac{1}{2}}$) is large in comparison with the dislocation radius, i.e., with the lattice spacing. At the highest field intensity considered, 6000 oersteds, the decay distance is about 2×10^{-6} cm—still 100 times the lattice spacing.

Formulas (25) and (45) of reference 3, based on the "doublet" approximation, are applicable to actual dislocation pairs only if the decay distance is large in comparison with the separation distance. Because of this restriction, the doublet formulas were used only as a basis for qualitative discussion; in particular, for estimating the importance of magnetic interactions, which could be taken into account more easily in the doublet calculation than in the main calculation.

The numerical calculations were based, not on the doublet formulas, but on the formulas of Sec. 3. In the working formula (41), the resolution into terms a/H, b/H^2, and $\chi(H)$ depends on a classification of the separation distances into three groups, explicitly defined (p. 144, column 2, lines 5–15) with reference to "the range of fields under investigation." If the range is shifted upward, the number of dislocation pairs in the a/H group will decrease and the number in the b/H^2 group will increase. There is therefore no question of a rigorous a/H law or of an infinite magnetization work. (The more general formulas (28)–(32) would give a finite magnetization work, but it would be incorrect because of the approximation in regard to dislocation radius.)

When my approximations are permissible, the integration over a stress singularity—to which Néel objected—is also permissible. What makes it so is the term $\nabla^2\alpha$ in Eq. (17). Néel's omission of this term in his cavity calculation is equivalent to setting the decay distance equal to zero. His formula therefore holds only if the decay distance is small in comparison with the cavity dimensions.

That the coefficient a increases with plastic flow is an experi-

mental fact, independent of any theoretical calculation. It is this experimental fact that I interpreted by use of dislocation theory. Plastic flow is a shear process, not explicable in terms of cavities. Néel's cavity formula no doubt describes correctly the behavior of his samples of porous iron; but they were specially designed to exhibit the behavior described by the formula. His theory does not explain the effects of plastic flow, and it therefore affords no all-inclusive explanation of the origin of the a/H term in an arbitrary specimen.

[1] Edmund C. Stoner, *Reports on Progress in Physics* (The Physical Society, London, 1950), Vol. 13, pp. 83–183. See especially pp. 142–143.
[2] L. Néel, J. de phys. 9, 184 (1948).
[3] William Fuller Brown, Jr., Phys. Rev. 60, 139 (1941).

Notes on the Electrical and Thermal Conductivities of Graphite and Amorphous Carbon

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ACCORDING to the theory proposed by Wallace,[1] the electrical conductivity σ in the direction parallel to the basal plane of a graphite crystal is given by the following expression

$$\sigma = (16\pi e^2\tau/h^2c)kT \log2,$$

where τ = relaxation time of the conduction electrons, c = lattice constant in the direction normal to the basal plane, T = temperature, and other notations have their usual meanings. The conductivity in the direction normal to the basal plane is far smaller than the former, so that the apparent conductivity of a polycrystalline material will be determined almost solely by σ. Hence, specific resistance times temperature will be proportional to $1/\tau$. The resistivity of artificial graphite is known to decrease with the graphitization temperature. This relation has been made clear by the experiments of Nishiyama[2] on the graphitization of carbon filaments in connection with the temperature dependence of the resistivity. From his data, values of ρT were calculated. These are plotted in Fig. 1 against temperature. These curves corresponding to different heat treatments are nearly parallel to each other, which indicates that the relation $1/\tau = (1/\tau_0) + 1/\tau'$ holds fairly well for each curve, where the first term on the right-hand side represents the reciprocal of the relaxation time for pure graphite, and the second term depends on the temperature at which the heat treatment was carried out. This situation is analogous to that of common metals containing impurities. Hence, the second term bears a closer resemblance to the residual resistance of metals than to the temperature dependent resistivity of semiconductors
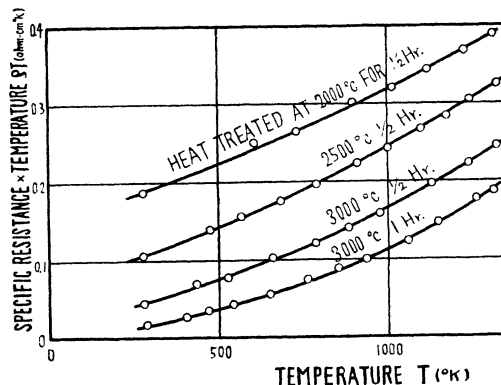

FIG. 1. Temperature dependence of ρT; i.e., the resistivity of carbon filaments graphitized at different temperatures times absolute temperature. ρT is inversely proportional to the relaxation time of the conduction electrons.