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DEVIATIONS FROM BLOCH'S LAW FOR THE SATURATION MAGNETIZATION IN SOME IRON-NICKEL ALLOYS

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The temperature dependence of the saturation magnetization of a number of iron-nickel alloys is measured in the temperature range from 4.2 to 70°K. It is shown that for most of these alloys the $T^{3/2}$ law of Bloch holds provided corrections for the effective internal field are introduced. It is shown that the deviations from this law, which are observed in a number of alloys above 30–40°K, can be described by Eq. (3).

THIS paper contains results of measurements of the temperature dependence of the saturation magnetization in a number of iron-nickel alloys, using a method previously described [1]. We have measured the change in the saturation magnetization $\Delta I = I_{4.2} - I_T$ caused by cooling the specimen from the temperature T to 4.2°K. The temperature dependence of the saturation magnetization can be represented in the form

$$I = I_0\{1 - CT^{3/2}[1 + g(T, H)] + f(T)\}. \quad (1)$$

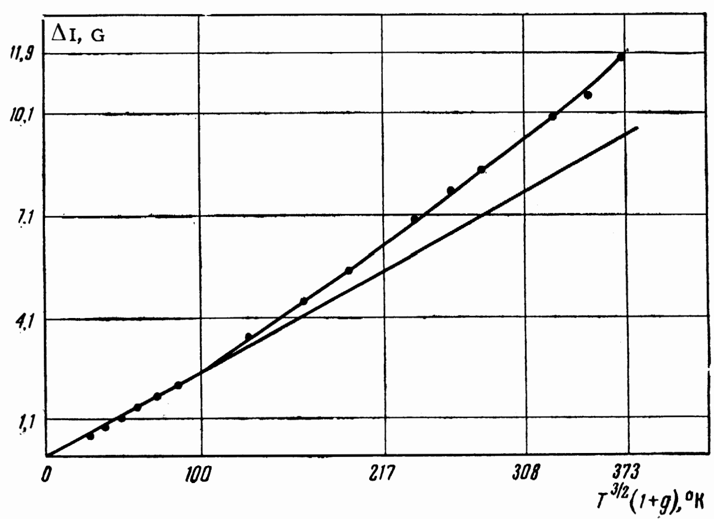

FIG. 1. Change of saturation magnetization ΔI against the quantity $T^{3/2}$ (1 + g) for an alloy containing 15% Ni.

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Values of the parameters C, μ, D, Δ, from the analysis of the measurements

Parameter	Ni concentration, %							
	15	25	30	34	41	50	59	74
C, $G/(^{\circ}K)^{3/2}$	$3\cdot10^{-2}$	$4.48\cdot10^{-2}$	$3.56\cdot10^{-2}$	$10\cdot10^{-2}$	$5.72\cdot10^{-2}$	$2.24\cdot10^{-2}$	$1.38\cdot10^{-2}$	$0.92\cdot10^{-2}$
μ_{exp}	2.18	2.04	1.97	1.33	1.84	1.71	1.58	1.02
μ_{theor}	2.2	2.15	2.00	1.82	1.80	1.70	1.52	1.20
Δ, °K	146	189	212	—	56	63.2	—	64.8
D, $G/(^{\circ}K)^{3/2}$	$1.83\cdot10^{-2}$	$5.55\cdot10^{-2}$	$6.9\cdot10^{-2}$	0	$1.21\cdot10^{-2}$	$0.83\cdot10^{-2}$	0	$-0.52\cdot10^{-2}$

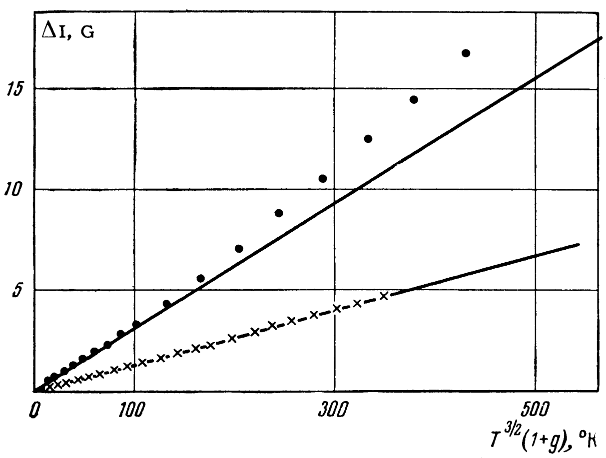

FIG. 2. Change in saturation magnetization ΔI against the quantity $T^{3/2}(1+g)$: ● – 30% Ni, × – 59% Ni.

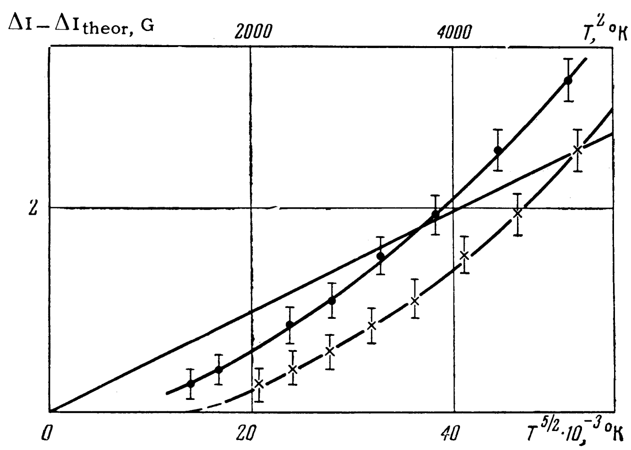

FIG. 3. Deviation from Bloch's law for alloys containing 25% Ni: ● – against $T^{5/2}\,10^{-3}$, × – against T^2.

Here

$$g(T,H) = -1.36(T_g/T)^{1/2} + 0.56T_0/T,$$

$$kT_g = \mu_{eff}\left(H + H_A + \frac{4\pi}{3}M_0\right), \qquad (2)$$

where μ_{eff} is the magnetic moment per atom, H the external field, H_A the anisotropy field, and $4\pi M_0/3$ the demagnetizing field of the spin wave.

The measurements were carried out in a field of 20 kOe. In such a field the effect of the magnetic anisotropy on the temperature dependence of the saturation magnetization is negligible, as has been shown elsewhere [2,3].

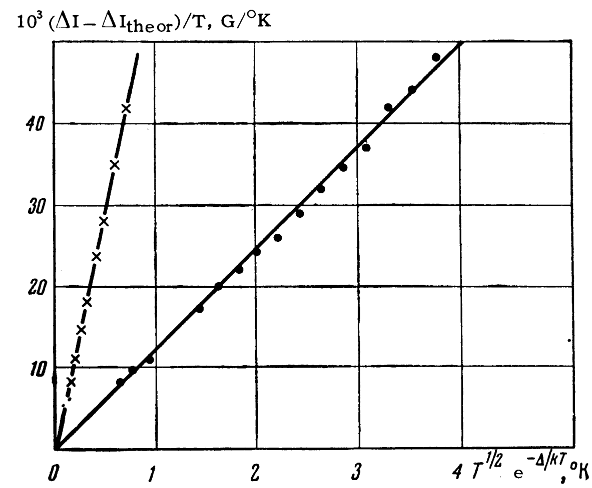

FIG. 4. Deviation from Bloch's law divided by T against $T^{1/2}e^{-\Delta/kT}$: ● – 41% Ni, × – 25% Ni.

In order to determine the coefficient C and to check the validity of the Bloch law, ΔI was plotted against the quantity $T^{3/2}(1+g)$ [g being defined in (2)] for each alloy. These curves are shown in Figs. 1 and 2, and the values of C are given in the table. The error in the determination of ΔI is 3–5%, and that in C is 3%.

Our measurements show that in nearly all the alloys which have been studied there are deviations from Bloch's law at high temperatures. Figure 3 shows that these deviations cannot be described by the theoretically predicted power laws $f(T) \sim T^{5/2}$ (Dyson [4]) or $f(T) \sim T^2$ (collective electron model [5]). Wohlfarth[6] suggests introducing a term f(T) of the form

$$f(T) = DT^{3/2}e^{-\Delta/kT}, \qquad (3)$$

where Δ is the energy gap between the top of the sub-zone which is completely filled with electrons with downward spins and the Fermi level. It turned out that for all alloys studied the deviations, if any, from the Bloch law are well described by (3), as is seen from Fig. 4.

The values of the parameters D and Δ are given in the table.

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Translated by R. E. Peierls
1