

was surrounded by a bath of liquid helium II. Sealed to the bottom of the glass is a Kovar tube (*K*) into which was soldered a brass plug (*B*). The purpose of the glass frit (*F*) was to serve as a porous barrier against which the rouge could be packed. Above this frit are a heater (*H*) and a carbon resistance thermometer (*T*). At the top the system is joined to a small-diameter glass tube which extends up through the helium flask.

Helium gas from an outside supply was condensed in the inner system in such an amount that the liquid level at zero heater power in the helium II temperature range was in and near the bottom of the small-diameter glass tube. The bath temperature was held constant in the liquid helium II range and the height and temperature of the liquid above the frit were observed as a function of heater power.

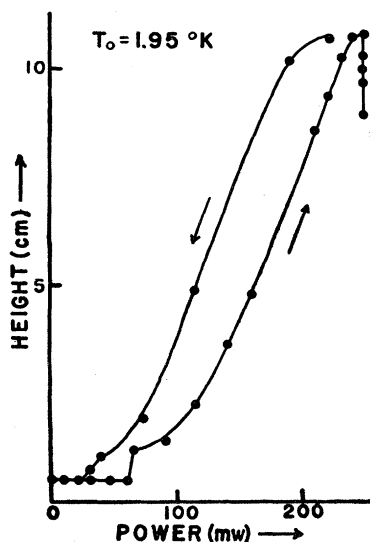


FIG. 2. Plot of the height of the inner liquid helium level above an arbitrary zero as a function of heater power input in milliwatts.

Figure 2 is a typical plot of the height of the inner helium level as a function of heater power (milliwatts). As the power was increased from zero there was at first a slight decrease in level which one would expect as the density of helium II increases with increasing temperature. At a certain power (here 61 mw) the level suddenly rose and continued to rise with increasing power until the temperature of the liquid above the frit exceeded the λ point. Here bubbling and a geyser effect took place. On decreasing the power it was found that the level was higher than on increasing power for the same value of power. However, at low powers the level returned to its original height.

The following results were found. (1) There is a linear relationship between power and temperature difference at low powers. The relationship becomes nonlinear in the power region in which the level begins to rise. (2) In the region of the level rise, the height is proportional to the temperature difference. (3) The level rise for a given temperature difference is much less than for the normal fountain effect.^{2,3}

It might be reason that the rise in level follows from the formation of a gas bubble in the gaps between the rouge particles. There are two points which tend to rule out this possibility. One is that there is no drastic change in the thermal conductivity and the other is that no bubbles were ever seen in the gap which eventually developed between the frit bottom and the top of the rouge. To eliminate the possibility that the frit was responsible for the effect and to demonstrate the necessity of the small channels in the rouge, a run was made with a similar apparatus minus the rouge. The only level change observed in this case was a continual decrease in height with increasing power and temperature difference as one would expect from the density-temperature dependence.

To test the hypothesis that this effect was less than the normal thermomechanical effect because of a downward Hooke's law type tension, runs were made with the identical apparatus except that the glass tube above the frit was replaced by one of different cross-sectional area. It was found then that it was more nearly the volume increase in the tube which corresponded to a given temperature difference rather than the height (or pressure).

The "difference" forces acting on a cross-sectional area of the channels in the rouge are considered to be (1) a downward hydrostatic force resulting from the level rise, (2) a downward force resulting from the increase in temperature and hence an increase of vapor pressure of the liquid above the frit, (3) an upward thermomechanical force ($\rho S \Delta T \times \text{area}$), and (4) a downward force proportional to the ratio of the elevated volume to the volume of liquid in the rouge (volume strain). The first two are small compared to the last two. A "compressibility" is then calculated.

TABLE I. Summary of data.

Run	Bath temperature (°K)	Tube cross-section area (cm ²)	Slope height vs temp. diff. $H/\Delta T$ (cm/°K)	Compressibility (atmos ⁻¹)
1	2.001	0.128	121	0.30
2	1.950	0.128	115	0.29
3	1.946	0.398	59	0.46
4	1.821	0.128	100	0.30
5	1.817	0.398	43	0.35

Table I is a summary of some of the data. Comparing runs 2 and 3 which were made at about the same temperature, it is seen that the value of $H/\Delta T$ is less for the run with the wider tube; the same comparison may be made for runs 4 and 5. The last column lists the calculated "compressibility." The order of magnitude is to be noted—the normal compressibility of liquid helium is approximately 1.3×10^{-2} /atmos.⁴ Thus this "compressibility" is about 25 times the normal compressibility.

The "open" fountain effect was measured after a hole was drilled in the brass plug; the experimental result agreed substantially with that calculated from H. London's equation.

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Further work is in progress and a detailed paper will be submitted shortly for publication.

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† An earlier report was given as a ten-minute paper before the New England Section of the American Physical Society at Storrs, Connecticut, Nov. 7, 1953 and at the Third International Low Temperature Conference at the Rice Institute, Dec. 17–22, 1953.

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Temperature Dependence of Ferromagnetic Resonance Line Width in a Nickel Iron Ferrite: A New Loss Mechanism

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WE have measured the ferromagnetic resonance line width in the [111] direction on two single-crystal spheres of a nickel-iron ferrite at 24 000 Mc/sec as a function of temperature from the boiling point of helium to approximately 400°K. The composition of these crystals, which were obtained from the Linde Air Products Company, was approximately $(\text{NiO})_{0.75}(\text{FeO})_{0.25}$

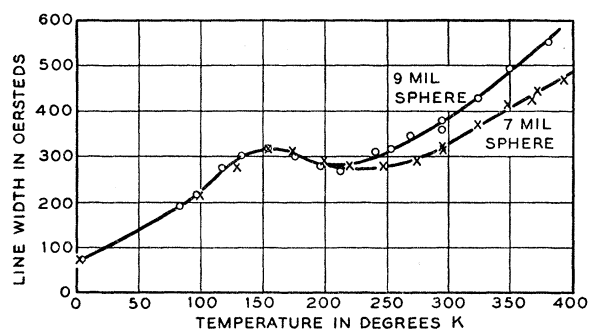


FIG. 1. Ferromagnetic resonance line width vs temperature for $(\text{NiO})_{0.75}(\text{FeO})_{0.25}\text{Fe}_2\text{O}_3$. Frequency 24 000 Mc/sec.

Fe_2O_3 . The crystals were not fixed rotationally, but were oriented crystallographically by the dc magnetic field required for resonance. The method used was otherwise similar to one previously described.¹ The experiments will be described in more detail in a later publication.

The width of the line at half-power points is plotted in Fig. 1 for both spheres as a function of temperature. The rise at high temperature is due to the loss arising from the increasing conductivity of these crystals at high temperatures. This is confirmed by the fact that the size dependence characteristic of the relatively high conductivity ferrites² is observed in this region, and by the fact that the material from which these spheres are cut has a resistivity of only about 1 ohm-cm at room temperature. The high-temperature end of the curves may therefore be understood at least qualitatively in terms of a loss mechanism (eddy currents) which is not new and not of primary importance in understanding the losses in ferrites generally. If we ignore the contribution of conductivity, the data leads to a damping constant λ of approximately 2×10^7 at room temperature.

The low-temperature portion of the curves in Fig. 1 (below room temperature), however, is quite another matter. The bulk of the loss on this region is clearly due to a mechanism whose effectiveness is a maximum in the neighborhood of 160°K. We suggest that these losses arise from a relaxation in short-range order among the divalent and trivalent iron ions. Order-disorder of this sort was suggested by Verwey and his co-workers as the explanation of the low-temperature transition in Fe_3O_4 .³ This relaxation is the same mechanism as that suggested by Wijn and van der Heide to explain observations at much lower frequencies in other ferrites.⁴ The existence of some remnant of the Fe_3O_4 transition in our case is established by the results of ultrasonic measurements of elastic constants made on other crystals of the same composition by Fine⁵ of these Laboratories.

Since the magnetization is coupled to the lattice by the magnetostriction, motion of the magnetization produces varying stresses in the lattice. These variations in stress cause the arrangement of the divalent and trivalent iron ions to vary, but with a time lag which causes a loss of energy.

We have made a preliminary calculation of the losses in the crystal lattice due to the phase lag between stress and strain which arises from this mechanism. It gives the right temperature dependence if we calculate the relaxation time from the activation energy associated with conductivity, but it is too small by about an order of magnitude (damping constant $\lambda \approx 10^6$ at room temperature). A more accurate calculation may make it possible to explain the whole effect this way, but at present it appears that other aspects of the mechanism are involved.

Domain wall motion experiments of the sort previously reported at room temperature in Fe_3O_4 ⁶ have been carried out on crystals of this composition as a function of temperature by one of us (J.K.G.). The above mechanism should also largely determine the losses observed in these experiments, and the data obtained bear out this expectation. There is a large increase in the viscous

damping of domain walls at low temperatures. We mention these results since Wijn does not indicate clearly that this mechanism will contribute to domain wall damping as well as to losses associated with domain rotation processes. This mechanism also explains, of course, why domain wall damping in Fe_3O_4 ⁶ is much larger than that in a nickel-iron ferrite.⁷ We agree with Wijn and van der Heide that it also explains the permeability vs frequency observations of Galt, Matthias, and Remeika.⁸

We wish to emphasize the fact that the width of the low-temperature maximum is such that the mechanism produces significant losses over a very large range in temperature. This suggests to us that a major contribution to the losses in many or even perhaps all ferrites is due to the relaxation associated with this and other crystallographic transitions characterized primarily by electronic rearrangements. It should be noted that such transitions might be effective in causing losses even though the likelihood of their occurrence was small in the absence of large stresses.

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Neutron Diffraction Study of the Ferroelectric Modification of Potassium Dihydrogen Phosphate*

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THE ferroelectric modification of KH_2PO_4 which exists at temperatures below 121°K has been examined by single-crystal neutron diffraction techniques at 113°K. Complete data from the (hhl) zone of a cylindrical specimen cut parallel to this zone axis were collected at neutron wavelength 1.062Å to $\sin\theta/\lambda=0.77$. The data were analyzed by the Fourier synthesis method after applying a modification function¹ $\exp[-3.5(\sin\theta/\lambda)^2]$ to ameliorate termination-of-series errors. Initial phases were computed from the parameters reported by Frazer and Pepinsky² with the hydrogen atoms placed 1.08Å from oxygen atoms O_1 along the hydrogen bonds. A total of four Fourier projections were prepared from the experimental structure factors. At each stage, correction was made by the back-shift method³ for residual termination-of-series errors, the correction being based on the initial model of the structure for the first three stages of refinement and on essentially final parameters for the last stage. The final parameters,⁴ which are doubly shifted⁵ from the corrected output of the fourth Fourier map (maximum shift 0.0005), are listed in Table I. The

TABLE I. Atomic parameters for ferroelectric KH_2PO_4 .^a

	O_1	O_2	H	K
x	0.1160	-0.0345	0.1880	0
y	0.0345	0.1160	-0.0375	0
z	0.1310	-0.1235	0.1355	0.512

^a Based on orthorhombic space group $Fdd2$, $a_0=10.53\text{Å}$, $b_0=10.44\text{Å}$, $c_0=6.90\text{Å}$ (reference 2). Parameters are relative to P at (000). Equivalent positions are (xyz) , $(\bar{x}\bar{y}z)$, $(\frac{1}{2}-x, \frac{1}{2}+y, \frac{1}{2}+z)$, $(\frac{1}{2}+x, \frac{1}{2}-y, \frac{1}{2}+z)$, face centered for O and H; $(00z)$, $(\frac{1}{2}, \frac{1}{2}, z+\frac{1}{2})$, face centered for K and P. Temperature factor coefficients in Å² are: O and P, 0.6; K, 0.4; H, 2.0.