for her assistance, to Dr. M. LaMorte for sample preparation, and to Miss M. Gabler for the final processing.

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FERROELECTRICITY IN POTASSIUM NITRATE AT ROOM TEMPERATURE

James P. Nolta and Norman W. Schubring
General Motors Research Laboratories, Warren, Michigan

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Potassium nitrate (KNO_3) was reported to be ferroelectric in the phase-III modification which occurs stably in the temperature range of 110°C to 125°C at atmospheric pressure.[1] Now ferroelectric behavior, at room temperature, has been observed in KNO_3. The phenomenon, as evidenced by a hysteresis loop, completely vanished within several hours after the earlier samples were prepared. Therefore, our ferroelectric observation was thought to be due to the existence of phase III as a metastable state at room temperature. Subsequent x-ray diffraction analysis verified that we in fact had phase III at room temperature and atmospheric pressure, and further refinement in the fabrication technique has extended the lifetime to several weeks.

The samples were prepared from reagent grade KNO_3 powder which had been dried at 130°C under a vacuum of approximately 10 microns of mercury for several days. The dried powder was then melted onto a copper substrate which served as one of the electrodes. Various materials have been used as the second electrode, e.g., air-drying silver paint, colloidal graphite, mercury, and metallic foils attached while the KNO_3 was still molten. These elements have been made as thin as 2×10^{-3} cm. It has been noted that any moisture, either in the original powder or absorbed from the atmosphere after the layers are formed, greatly influences the ferroelectric behavior of these elements.

Figure 1 shows a typical hysteresis loop taken at 60 cycles per second using a standard Sawyer and Tower[2] circuit. The observed coercive field is of the order of 6 kV/cm and the value of the spontaneous polarization thus far observed is approximately 3.5 μC/cm^2. The flat part of the loop corresponds to a dielectric constant of about 16 while the steep part corresponds to a value of about 10^4. It can be seen from Fig. 1 that these layers show nearly perfect saturation. The ratio of the maximum slope to the minimum slope, i.e., the so-called "squareness ratio," for this sample was of the order of 600:1. Evidently, the thin layers show a high degree of orientation. This is supported by the fact that for layers of the order of thickness of 2×10^{-2} cm, the saturation is not nearly so perfect nor is the squareness of the loop so pronounced (of the order of 100:1). Furthermore, this material seems to demonstrate true coercivity as may be seen from Fig. 2 which shows a series of minor loops obtained by multiple exposure of the photographic plate for various applied fields. No definite information can be given as to the switching time of these elements

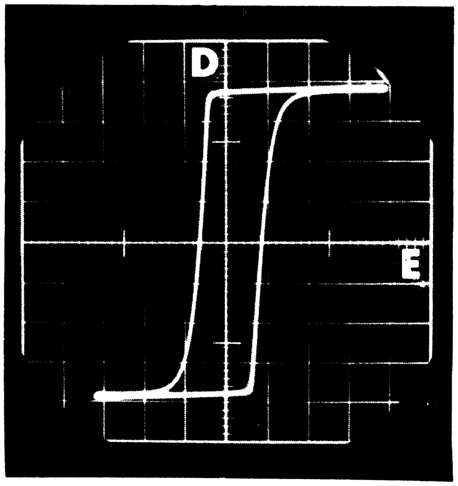

FIG. 1. Typical 60-cps hysteresis loop of KNO_3 at 20°C.

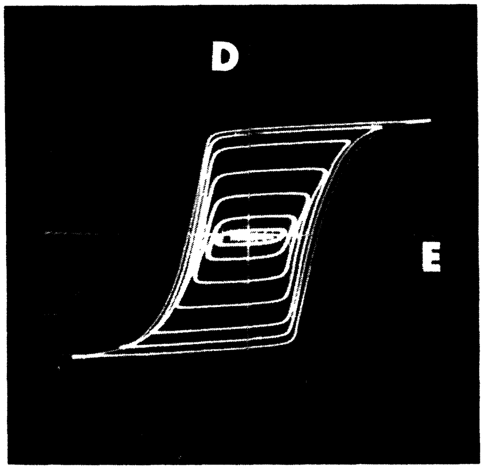

FIG. 2. D vs E characteristic of KNO_3 as a function of driving voltage.

but a hysteresis loop has been observed at frequencies up to 20 kc/sec which is currently the limit of our instrumentation.

A great deal of work still has to be done on understanding this effect. For example, it has been reported[3] that phase III can exist stably at room temperature but only under high pressure, whereas our samples were essentially prepared in a stress-free state. Therefore, our work is now directed toward understanding the variables affecting the phase transformations, especially III to II, in potassium nitrate.

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MAGNON RENORMALIZATION IN FERROMAGNETS NEAR THE CURIE POINT*

Micheline Bloch†
Department of Physics, University of California, Berkeley, California

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As pointed out by Kittel,[1] Dyson's results[2] extrapolated to high temperatures suggest that magnon-magnon interactions in ferromagnets may be relatively weak even at the Curie temperature: The mean free path of a magnon of energy $k_B T_C$ in an assembly of magnons in thermal equilibrium at T_C is about 50 lattice constants in a simple cubic lattice for spin $\frac{1}{2}$. It appears not entirely unreasonable to explore the possibility of treating a ferromagnet as a gas of weakly interacting magnons, up to the Curie point. A quasi-particle model of magnons has been studied with the exchange Hamiltonian limited in its expansion to terms of fourth order in magnon variables. The energy of the quasi-magnons is derived as a solution of an implicit equation. The remarkable result is found that no solution of the implicit equation exists above a maximum temperature which is within several percent of the Curie temperature calculated[3] by the methods of Bethe-Peierls-Weiss (BPW) and Kramers-Opechowski (KO). The temperature dependence of the renormalized magnon energy and of the magnetization is given from absolute zero to $t_{\max}$. To the order considered, all calculations are carried out exactly: Full account is taken of the finite extent of the Brillouin zone, in the dispersion relation and in the limits of integration.

The diagonal part of the exchange Hamiltonian is

$$H=\sum_{\vec{k}} n_{\vec{k}} \epsilon_{\vec{k}} - JN^{-1} \sum_{\vec{k},\vec{k}'} n_{\vec{k}} n_{\vec{k}'} (\gamma_0 + \gamma_{\vec{k}-\vec{k}'} - \gamma_{\vec{k}} - \gamma_{\vec{k}'}), \tag{1}$$

where

$$\epsilon_{\vec{k}} = 2JS(\gamma_0 - \gamma_{\vec{k}}), \qquad \gamma_{\vec{k}} = \sum_{\vec{\delta}} \exp(i\vec{k}\cdot\vec{\delta}); \tag{2}$$

here $\vec{\delta}$ denotes the vectors to the nearest neighbors. For a simple cubic lattice, H can be rewritten exactly as

$$H=\sum_{\vec{k}} n_{\vec{k}} \epsilon_{\vec{k}} - (24JNS^2)^{-1} \sum_{\vec{k},\vec{k}'} n_{\vec{k}} n_{\vec{k}'} \epsilon_{\vec{k}} \epsilon_{\vec{k}'}. \tag{3}$$

The free energy is

$$F = U - TS = \sum_{\vec{k}} \langle n_{\vec{k}} \rangle \epsilon_{\vec{k}} - (24JNS^2)^{-1} \sum_{\vec{k},\vec{k}'} \langle n_{\vec{k}} \rangle \langle n_{\vec{k}'} \rangle \epsilon_{\vec{k}} \epsilon_{\vec{k}'} + k_B T \sum_{\vec{k}} [\langle n_{\vec{k}} \rangle \ln \langle n_{\vec{k}} \rangle - (\langle n_{\vec{k}} \rangle + 1) \ln (\langle n_{\vec{k}} \rangle + 1)], \tag{4}$$

using the standard result for the entropy of a boson gas. The free energy is an extremum with

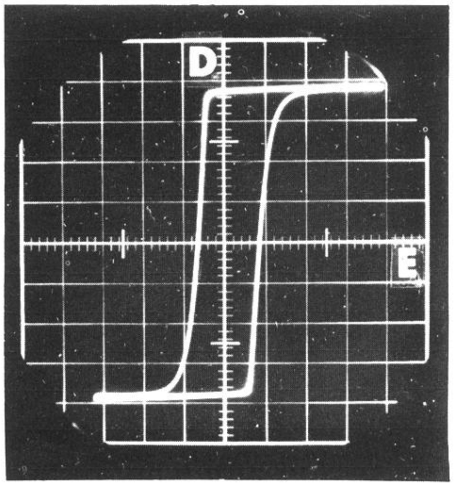

FIG. 1. Typical 60-cps hysteresis loop of KNO_3 at 20°C.

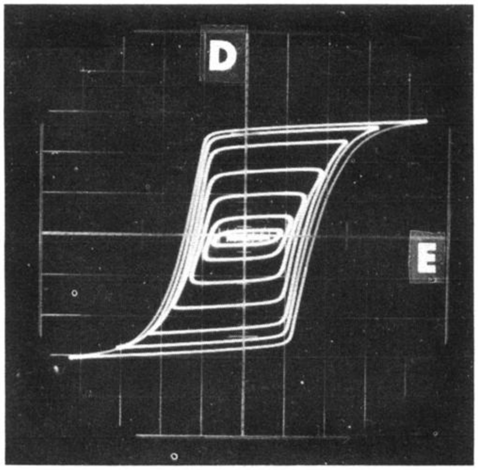

FIG. 2. D vs E characteristic of KNO_3 as a function of driving voltage.