The agreement between experiment and the calculation of Koppe, as shown in Figs. 1 and 2, is on the whole striking, although the departure from the curve in Fig. 1 of the low temperature points for niobium and vanadium is beyond the limit of experimental error. Nevertheless, the general fit of Koppe's curve suggests a real regularity displayed by all superconductors, a regularity which may be regarded as an approximate "law of corresponding states."

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Evidence for Domain Structure in Antiferromagnetic CoO from Elasticity Measurements

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Young's modulus in CoO on cooling undergoes a large decrease near the Néel point.[1] Street and Lewis[1] suggest that this is due to the influence of an applied stress on the preferred orientation of the spin vectors in antiferromagnetic domains. A more detailed study and explanation of the elasticity of CoO is herein reported.

A rod of CoO was prepared by pressing powdered CoO and sintering at 1130°C in N_2. X-rays revealed only the CoO structure; the apparent density after sintering was 86 percent of the density of CoO.

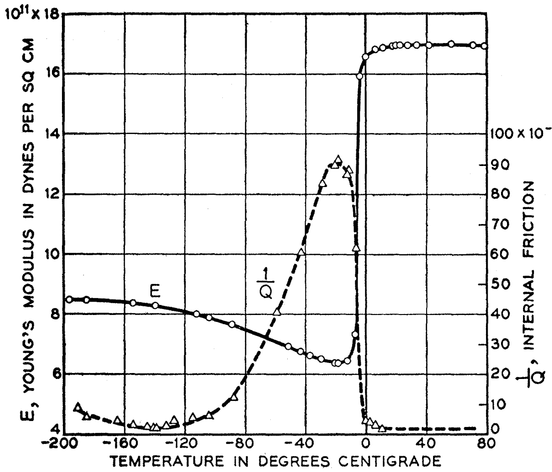

FIG. 1. Young's modulus and internal friction of CoO.

Young's modulus (E) and the internal friction ($1/Q$) were measured from 80 to -196°C in the pressed and sintered rod, employing both electromagnetic and piezoelectric excitation and detection of longitudinal vibrations (35 to 60 kc sec^{-1}). On cooling from 20 to -20°C, as shown in Fig. 1, E drops from 17 to 6.3×10^{11} dynes cm^{-2}, the region of maximum change being 0 to -8°C. (The Néel temperature, determined from paramagnetic susceptibilities, is -2°C.[2]) The effect persists to low temperature, for at -196°C E is 8.5×10^{11} dynes cm^{-2}. The internal friction ($1/Q$) for a constant maximum strain amplitude of 10^{-7}, also shown in Fig. 1, rises on cooling from 2×10^{-4} (the background) to a peak value of 91×10^{-4} at -20°C, then decreases to a minimum at -150°C and rises again to 8.5×10^{-4} at 190°C. At room temperature and -20°C, increasing the maximum strain amplitude from 10^{-8} to 10^{-5} has little effect on E or $1/Q$, but at -190°C E decreases 1 percent and $1/Q$ increases from 5 to 25×10^{-4}.

The general course of our modulus-temperature curve and that reported by Street and Lewis[1] are in substantial agreement; however, our modulus values are larger by approximately a factor of 5, and the Néel temperature appears to be -2°C in our sample rather than 16°C. The discrepancy among modulus values and Néel points may be due to composition and porosity variations.

In considering possible explanations the following properties of CoO seem important: The formation of antiferromagnetism causes an increase in volume; the coefficient of linear expansion is high in the temperature range 5 to -75°C, with a peak of 22×10^{-6} deg C^{-1} at -2°C. Antiferromagnetism distorts CoO from cubic (NaCl structure) to tetragonal;[3,4] c/a becomes increasingly less than one as the temperature is decreased, being 0.9884 at -180°C.[3] The antiferromagnetically aligned atomic magnetic moments are parallel to $\langle 100\rangle$.[5] Presumably it is this direction that becomes shortened.

The large decrease in E implies that an applied stress produces strains in addition to, and in some cases even larger than, the normal elastic strain. In antiferromagnets an effect analogous to the stress-induced change in domain structure in ferromagnets is suggested.[6] Neighboring domains within a crystal are postulated, differing as to which of the three possible orientations of the c axis is present. Then, for example, tension would increase the area of those domains whose c axes are nearly perpendicular to the stress axis, thereby increasing the sample length. The amount of strain from a given amount of domain boundary movement would increase on cooling since c/a decreases, but domain boundary movement becomes more difficult owing to the lattice strain produced. Thus, E from this effect would not continuously decrease on cooling. Stress-induced antiferromagnetic domain boundary movement, like domain movement in ferromagnets, is expected to be hysteretic; consequently, the proposed mechanism seems especially reasonable for low temperatures where $1/E$ and $1/Q$ increase with strain amplitude and, furthermore, well-defined domains are expected.

Near the Néel temperature, where the magnetic moments are loosely coupled, another mechanism which may yield a strain and internal friction is a stress-induced change in the degree of antiferromagnetic order. The strain would come from the resulting change in volume and tetragonality. E and $1/Q$ are more conceivably independent of strain amplitude by this mechanism.

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Errata

The Symmetrical Pseudoscalar Meson Theory of Nuclear Forces, MAURICE M. LÉVY [Phys. Rev. **86**, 806 (1952)]. In the last portion of Eq. (3), replace $[(2/\pi)K_0(\mu r)]^2$ with $(\mu/2M)[(2/\pi)K_1(\mu r)]^2$.

Angular Distribution of Shower Particles as a Function of Depth, L. EYGES AND S. FERNBACH [Phys. Rev. **82**, 287 (1951)]. Equation (1) should read: $\pi(E_0, E, \theta, t)2\pi\theta d\theta dE = \pi_{\mathrm{long}}(E_0, E, t)dE\cdot P(x, s)\theta d\theta\cdot(E/E_s)^2$. The present addresses