respectively. After deformation the velocities were found to have the lower values 0.4608, 0.4672, 0.4729, and 0.4746 at 10, 30, 50, and 70 Mc/sec, respectively. The results are shown in Fig. 1.

It is to be noted that the deformation has increased the size of the dispersion from about 0.5% to 4% and the value of the frequency, at which the velocity change is half complete has decreased. The total change found in C_{11} (approximately 8%) is larger than typical values found at kilocycle frequencies[3] for small deformations. Our deformations are not, however, strictly comparable with those of reference 3. For very high frequencies, the measured velocities approach each other.

It does not seem likely that the effect can be a vacancy pair reorientation or similar mechanism[4] because preliminary measurements have shown that the location of the dispersion shifts gradually to higher frequencies with increasing recovery time. If the effect is accepted as a dislocation effect, estimates of the dislocation density and average loop length can be made from the present data. According to the pinned dislocation loop theory,[1] the velocity change as a function of frequency should be given by

$$\frac{\Delta v}{v_\infty}=\left(\frac{\Delta v}{v_\infty}\right)_0\frac{1}{1+(\nu/\nu_0)^2}, \tag{1}$$

where

$$(\Delta v/v_\infty)_0=6\Omega\Lambda L^2/\pi^2, \tag{2}$$

and

$$\nu_0=(\pi C/2B)(1/L^2). \tag{3}$$

In these equations, v_∞ is the velocity measured at infinite frequency and Δv is the difference between the velocity at infinite frequency and the velocity at the measured frequency ν. Ω is a factor relating the resolved shear stress on the slip systems to the applied stress, Λ is the dislocation density, L is the dislocation loop length, C is the tension in the dislocation line, and B is a damping constant. Equation (1) applies strictly only when all loop lengths are equal. For a distribution of loop lengths, a somewhat more complicated relation must be used. This calculation for a distribution of loop lengths has not yet been carried out, but by application of Eq. (1) to the present results, one should obtain the correct orders of magnitude. When the results are analyzed in this way, one finds v_∞ to be 0.4786 and 0.4788 cm/μsec for the before and after deformation conditions, respectively. These values of v_∞ may be regarded as coincident and equal to the velocity of a wave propagating in a medium with no dislocations. The corresponding value of C_{11} is 4.961×10^{11} dynes/cm^2 which compares well with the value[5] of 4.9×10^{11} in the literature. Additional results are listed in the following table:

	ν_0 (Mc/sec)	$\Delta v/v_\infty$	Λ (cm^{-2})	L (cm)
Before deformation	74	0.50×10^{-2}	7.8×10^6	1.5×10^{-4}
After deformation	35	4.1×10^{-2}	30.0×10^6	2.1×10^{-4}

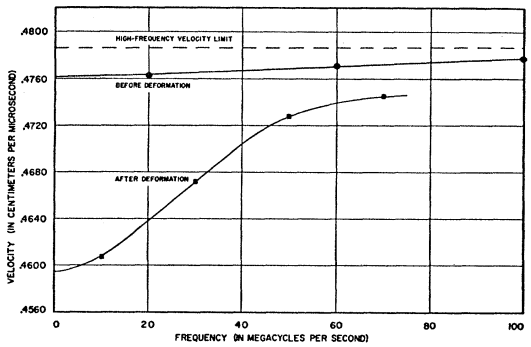

FIG. 1. Velocity dispersion for compressional elastic waves propagating in the [100] direction in NaCl. Deformation increases the magnitude of the dispersion from about 0.5% to 4%, and moves it to lower frequencies.

For these calculations the values $\Omega=1/10$, and $B=C=1.2\times10^{-4}$ (cgs units) were used.

The values found appear to be reasonable and indicate that the dislocation density increased by a factor of four as a result of the deformation.

Experiments are planned for which both the attenuation and velocity will be measured simultaneously. At present there are difficulties with the attenuation measurement since other sources of sound loss are present. Studies of the recovery of attenuation and velocity as a function of annealing time and temperature (in both salts and metals) are planned.

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Hyperfine Coupling Specific Heat in Cobalt Metal

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THE investigations of the nuclear orientation[1] produced in cobalt crystals by the hyperfine interaction led us to suggest[2] the evaluation of the hyperfine coupling in transition metals by the measurement of the low-temperature specific heats. Preliminary measurements of the atomic heat of metallic cobalt between 0.6 and 3.0°K indicate the existence of this hyperfine coupling.

The sample consisted of 11.4 moles of cobalt metal of 99.9% purity, kindly supplied by the African Metals

Corporation. A calorimeter suitable for the measurement of the specific heats over this broad range of temperatures is shown in Fig. 1. The sample was rigidly mounted by a fiber tube and completely enclosed in a copper shield connected directly to the upper reservoir. The magnetic refrigerator, similar to that previously constructed,[3] is used to maintain the sample shield at a temperature of 0.35°K throughout the specific heat measurements made below 1.6°K. A carbon resistor thermometer and heater coil were mounted on the sample, and a similar thermometer (270 ohm *IRC*—$\frac{1}{3}$ watt) was mounted on the copper shield. The thermometers were calibrated against the helium bath, and in addition the shield thermometer was calibrated against the paramagnetic salt of the upper reservoir to a temperature of 0.35°K. This latter calibration indicated that one can extrapolate with some confidence the helium temperature calibration to temperatures below 1°K. The refrigerant and reservoir salts were of similar construction, differing from previous design[3] only in that manganous ammonium sulfate crystals packed in toluene replaced the less stable iron ammonium alum. These salts showed no deterioration over a period of six months. Thermal contact between the sample and the shield was provided by a piece of copper wire. Specific heat measurements were made, in general, from the rate of cooling with different amounts of Joule heating, a technique recently described by Logan, Clement, and Jeffers.[4] Some data were obtained from the usual heating curves and these were in good agreement with the slope data. A continuous record of the resistance thermometer emf was obtained with a recording Brown potentiometer (0–100 microvolts) in series with a Rubicon potentiometer (Type B).

The experimental results are shown in Fig. 2, together with Duykaerts'[5] data in this temperature region. The experimental data seem reasonably fitted by the solid curve, which is given by the equation

$$C/R=233(T/443)^3+5.7\times10^{-4}T+4.0\times10^{-4}T^{-2}. \quad (1)$$

Each term in this equation is shown separately with broken curves in the figure. The lattice specific heat term is the smallest, and for this we have used Duykaerts' value of 443 degrees for the Debye temperature. The coefficient of the Sommerfeld electronic heat is of course somewhat smaller than Duykaerts' value, since his analyses did not include the T^{-2} term.

The term proportional to T^{-2} is attributed to the hyperfine interaction between the Co^{59} nucleus, $I=\frac{7}{2}$, and the electronic magnetic moment of the atom. The magnitude of CT^2/R from this work is compared in Table I with that of some of the ionic salts of cobalt. If, as a first approximation, one considers the problem of the cobalt atom in the hexagonal metal as similar to the ion in the strong crystalline electric field of axial symmetry in the cobalt salts, the Hamiltonian of the interaction can be written as $AS_zI_z+B(S_xI_x+S_yI_y)$. The specific heat[6] can be written as $CT^2/R=(A^2+2B^2)\times I(I+1)/12$. Assuming that B is small compared to A as in the cobalt salts, A may be evaluated from the T^{-2} term in the atomic heat. The value of A/k

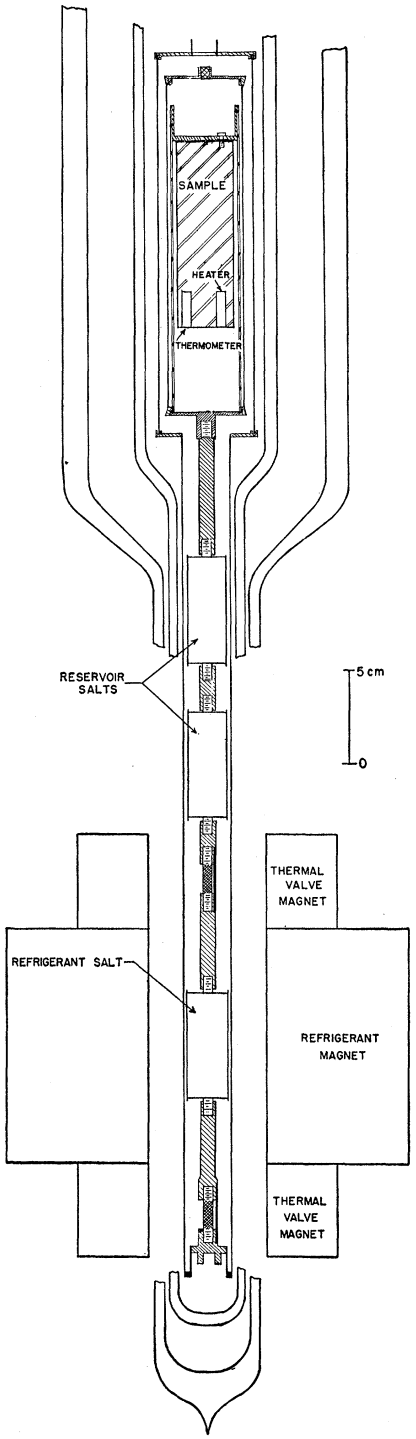

FIG. 1. Magnetic refrigerator-calorimeter.

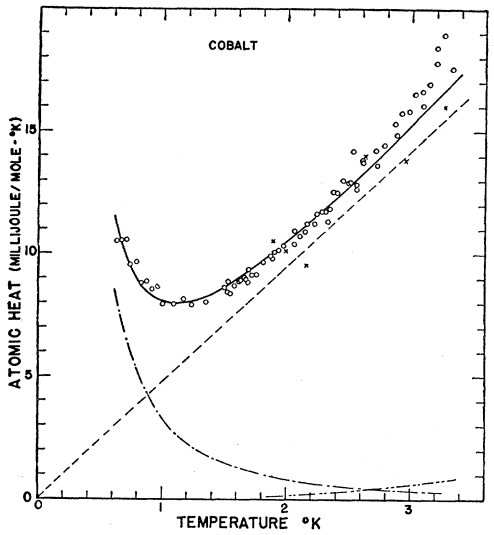

FIG. 2. Atomic heat of cobalt metal. × Duykaerts' values. The solid line (——) is the sum of the lattice specific heat (— — —), the electronic specific heat (— — —), and the nuclear specific heat (— — —).

$=0.0175°K$ is comparable in magnitude with the cobalt salts in which the hyperfine splitting is believed to be predominantly due to the orbital moment of the $3d$ electrons.[7] It is of interest to note that the ratio of the hyperfine interaction to the magnetic moment is remarkably alike for the bulk metal and the ionic compounds as is shown in Table I. This suggests that even in the metal the predominant interaction is between the nucleus and the $3d$ electrons.

Modifications are now being made on the apparatus which will permit the measurements to be extended to considerably lower temperatures, $\sim 0.3°K$; and will at the same time allow for a more reliable calibration of the resistance thermometers in the region below 1°K.

We wish to acknowledge the assistance of Mr. J. S. Stroud in the development of the magnetic refrigerator-calorimeter system, the grant from the Ohio State University Development Fund for the construction of the apparatus, and the National Science Foundation for funds for personnel during the period of this investigation.

TABLE I. Hyperfine coupling data for cobalt and cobalt salts.

Material	CT^2/R	A/k (°K)	μ/β	$A\beta/\mu k$ (°K)
Cobalt metal	4.0×10^{-4}	1.75×10^{-2}	1.71[c]	1.02×10^{-2}
Cobalt ammonium sulfate	16.0×10^{-4} [a]	3.52×10^{-2} [b]	3.22[d]	1.09×10^{-2}
Cobalt potassium sulfate	25.1×10^{-4} [b]	4.11×10^{-2} [b]	3.28[d]	1.25×10^{-2}
Cobalt fluosilicate	10.1×10^{-4} [b]	2.64×10^{-2} [b]	2.91[d]	0.91×10^{-2}
Cobalt sulfate (dilute)	18.0×10^{-4} [b]	3.65×10^{-2} [b]	3.45[d]	1.06×10^{-2}

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Quenching of the Negative Glow by Microwaves in Cold-Cathode Gaseous Discharges

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QUENCHING of the afterglow of an interrupted electrical gaseous discharge by the application of microwaves or dc fields to the decaying plasma has been reported.[1,2] It is presumed that the effect results from a reduction in the rate of volume recombination of positive ions and electrons, brought about by elevation of the mean electron energy in the presence of the field.

In present experiments a quenching by microwaves of the visible radiation from the negative glow region of a cold-cathode dc discharge has been observed, and preliminary results indicate the usefulness of the effect in a study of fundamental plasma processes. In particular, the possibility of separation of the fraction of emitted radiation due to a recombination process from that due to direct excitation provides a new experimental approach toward resolution of the long-standing controversy[3] concerning the mechanism for population of excited states.

A cold-cathode discharge, confined to a 0.4-inch i.d. Pyrex tube, was established by a 500-microsecond dc excitation pulse in the center of an RG 52/U wave guide with the lower and upper inner surfaces of the wave guide as cathode and anode. The microwave field was measured to be reasonably uniform throughout the enclosure of the Pyrex tube. Radiation emitted from the discharge and appropriate to the experiment was detected through the side of the wave guide by a type 6217 photomultiplier in such a manner that approximately 0.025-inch resolution was obtained axial to the discharge.

Figures 1(a), (b), and (c) show the oscilloscope presentation of detected radiation from the last portion of the pulsed dc discharge in helium at 10.2 mm Hg. Time is read left to right at 40 microseconds per major division. Figure 1(d) shows the crystal-detected 40-microsecond pulse of microwave energy at 9375 Mc/sec