

The modulation system was particularly troublesome for two reasons: (1) the large amount of metal between external modulation coils and the sample restricted the modulation frequency to low values, and (2) impurities in the alumina microwave cavity gave rise to resonances which tended to obscure sample resonances.

The first condition led to the development of the superheterodyne system as mentioned above. Since crystal noise in the first detector drops off approximately inversely as the square of the frequency and since the large amount of metal prevents the use of external high frequency modulation of the sample, a local oscillator is used to form an appropriate difference frequency in the low noise range which carries the resonance information.

The second difficulty required the development of a modulation scheme which gives a large modulating field only in the immediate neighborhood of the sample. A single strip of silver $\frac{1}{8}$ in. wide by 0.001 in. thick placed perpendicular to the gross magnetic field carries the modulation current directly over the sample. This thin silver strip seems not to disturb significantly the symmetry of the pressure system: symmetry is essential for achieving high pressures. The return path for the current is through one of the beryllium-copper support washers (see under Pressure System, above). Several other schemes for the return current have also been successful. The development of this internal modulation scheme makes possible the use of high frequency modulation also. The sensitivities of 100-kc modulation and the superheterodyne system are comparable.

Low Temperature System

A low temperature apparatus has been incorporated into the system to provide another thermodynamic variable for the magnetic resonance studies. This feature permits studies to be made of many paramagnetic materials which have relaxation times too short at room temperature to give sufficiently narrow lines to be observed. It also provides valuable temperature dependent resonance information.

The sample is cooled by flowing liquid nitrogen onto the lower anvil at the desired rate. Cooling of the sample itself is considerably aided by the large thermal conductivity at low temperatures of alumina with which the sample is in contact. The temperature is monitored using a thermocouple near the sample. The flow system consists of a $\frac{1}{4}$ -in. thin-walled brass tube, which is insulated with Styrofoam, leading from the top of a Dewar containing liquid nitrogen under pressure. A valve at the top of the Dewar controls the rate of flow. With this system, temperatures between the boiling point of nitrogen and room temperature can be reached.

OPERATION

Brief descriptions of the cavity mode identification and selection, the pressure calibration, and a sample of the results for ruby are given here.

Identification and Selection of Cavity Modes

Due to the large dielectric constant of alumina (~ 9.37) and the large size of the cavity anvil many cavity modes can be excited in the tuning range of the klystron (8.5 to 10.0 kMc). These modes were somewhat displaced from their calculated frequencies presumably because of the slight taper in the cylinder and the deformation of the top of the cavity for the sample cell. The picture was further complicated by the presence of numerous modes in the system extraneous to the cavity, but these could generally be distinguished by their lower Q.

Identification of the cavity modes required a number of experiments including a study of the mode shifts produced by the taper and sample cell in a scaled air cavity, varying the method of mode excitation, and varying cavity geometry to verify expected mode shifts. The various modes were also studied for the signal-to-noise ratio and, as expected, the optimum modes were determined to be the TE_{113} and the TM_{112} , the latter being favored because of the ease with which it is excited.

Calibration

Pressure calibration of the small sample cell posed a special problem. To permit the use of resistance transitions in various metals as pressure calibration points, a lower anvil with an axial platinum wire 0.020-in. diameter was fabricated. The anvil material was AL-300 Wesgo resin-bonded, machinable alumina which, after machining, was fired to hard ceramic. During firing the alumina shrinks down tightly on the wire. This anvil is supported by a hardened beryllium-copper binding ring in the same way as the anvils described above. The sample of metal under test is crimped, soldered, or otherwise fastened to the platinum wire and the circuit is completed by grounding the other end of the sample to the wall of the copper sample cell.

Wire samples used were cerium (transition at $P_t \approx 7$ kilobars⁵), bismuth ($P_t = 25.4$ kilobars⁶), thallium ($P_t = 36.7$ kilobars,⁶ but difficulty in handling this metal in the minute sample cell has allowed only one successful pressure calibration run), ytterbium ($P_t \approx 39.5$ kilobars,⁷ this metal was used even though its resistance transition is not very sharp in order to provide a calibration point in the region of the thallium point), and barium ($P_t = 58.6$ kilobars⁸).

⁵ G. C. Kennedy and P. N. LaMori, Publication No. 195, Institute of Geophysics, University of California.

⁷ H. Tracy Hall, Inorg. Chem. (to be published).

⁸ J. D. Litster and G. B. Benedek, J. Appl. Phys. 34, 688 (1963), quoting G. C. Kennedy.