

Fig. 2—Schematic diagram illustrating a method for maintaining an elevated constant operating temperature for a nonreciprocal device.

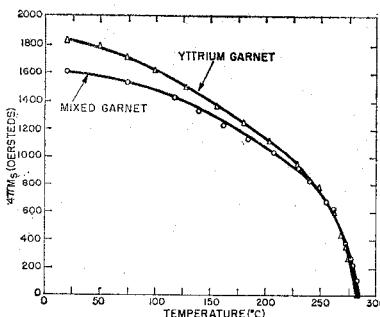


Fig. 3—Saturation magnetization as a function of temperature of yttrium iron garnet and a mixed garnet,  $2.5 \text{ Y}_2\text{O}_3 \cdot 0.5 \text{ Gd}_2\text{O}_3 \cdot 5 \text{ Fe}_2\text{O}_3$ .

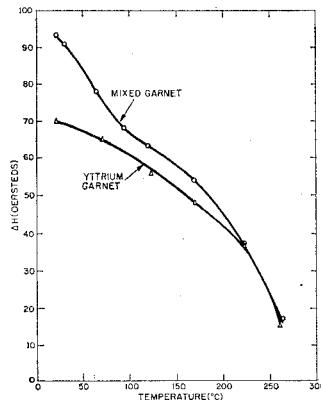


Fig. 4—Ferromagnetic resonance line width of yttrium iron garnet and the  $2.5 \text{ Y} \cdot 0.5 \text{ Gd}$  mixed garnet as a function of temperature.

temperatures over the required frequency band.

The design of very low microwave frequency nonreciprocal devices is also significantly enhanced by this method. Essential for the design of such devices are ferromagnetic materials with both narrow resonance line width and small saturation magnetization. Narrow line width materials are required for avoiding the overlap between the inevitable low magnetic field losses, which are reciprocal, and the desired nonreciprocal resonance losses. A small saturation magnetization is highly desirable to ensure stability of operation through definite saturation of the material at the small ap-

plied fields required for operating devices at low frequencies ( $\omega = \gamma H$ ). To date, the materials most nearly fulfilling these requirements are mixed garnets in which the *c* sites are shared by yttrium and gadolinium ions.<sup>1</sup> However, as Figs. 3 and 4 show, the desired reduction in saturation magnetization is accompanied by an increase in the line width. Hence, mixed garnets represent, at best, only a compromise solution.

As seen in Figs. 3 and 4, both the line widths and saturation magnetizations of rare earth garnets decrease with increasing temperature. By maintaining ordinary yttrium ion garnet at  $150^\circ\text{C}$ , a  $4\pi M_s$  of 1300 oersteds and a  $\Delta H$  of 50 oersteds may be easily obtained. Thus, by this relatively simple means, an improvement over the previously best material for nonreciprocal low microwave frequency applications of almost 20 per cent in saturation magnetization and 50 per cent in line width is achieved.

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<sup>1</sup> B. Ancker-Johnson and J. J. Rowley, "Mixed garnets for nonreciprocal devices at low microwave frequencies," *PROC. IRE*, vol. 46, pp. 1421-1422; July, 1958. See also M. H. Sirvetz and J. E. Zneimer, "Microwave properties of polycrystalline rare earth garnets," *J. Appl. Phys.*, vol. 29, pp. 431-433; March, 1958.

### Characteristics of Argon Noise Source Tubes at S-Band\*

During the design of equipment for applications in radio astronomy, various tests were performed on argon plasma noise source discharge tubes, with emphasis on the Bendix 6358/TD-12 which is Model A148 of Johnson and DeRemer.<sup>1</sup> In view of the wide use of these tubes as secondary standards of microwave noise power, a brief summary of the results obtained will be given. A description of the test equipment and experimental procedures used would be repetitive of much that has been reported by Sees<sup>2</sup> and Hughes,<sup>3</sup> but is available from the writer if desired.

An absolute calibration at 2885 mc was made on the TD-12, matched to its standard waveguide mount, and operating at the recommended discharge current of 250 ma. The value obtained for the effective noise temperature,  $T_D$ , was  $10,700^\circ\text{K}$ , with a probable error of  $150^\circ\text{K}$ . ( $T_D$  is defined by taking the available noise power equal to  $kT_D df$ , where

\* Received by the PGM TT, April 10, 1959.

<sup>1</sup> H. Johnson and K. R. DeRemer, "Cascaded discharge super-high frequency noise source," *PROC. IRE*, vol. 39, pp. 908-914; August, 1951.

<sup>2</sup> J. E. Sees, "Fundamentals in Noise Source Calibrations at Microwave Frequencies," *Naval Res. Lab. Rep. No. 5051*; January, 1958.

<sup>3</sup> V. A. Hughes, "Absolute calibration of a standard temperature noise source for use with S-band radiometers," *Proc. IEE*, pt. B, vol. 103, pp. 669-672; September, 1956.

$k$  is Boltzmann's constant and  $df$  is the frequency bandwidth.) In estimating the probable error, allowance was made for the fact that individual tubes are not precisely the same in noise emission. Relative measurements were made on a sample of twenty tubes consisting of twelve A148 (Bendix TD-12), and eight A147 (Bendix TD-10 and Philco L1306A) mounted and matched in S-band waveguide; the difference between any two was in most cases about  $50^\circ$  or less, with an extreme of  $80^\circ$  between the highest and lowest.

Hughes<sup>3</sup> value of  $T_D$  for the British CV1881,<sup>4</sup> which is somewhat similar to the A147, was  $11,140 \pm 130^\circ\text{K}$  (frequency 2860 mc, discharge current 180 ma,  $90^\circ$  E-plane mount). Our tests on the CV1881 yielded a result of  $10,900 \pm 160^\circ\text{K}$  (frequency 2885 mc, discharge current 180 ma,  $20^\circ$  and  $30^\circ$  E-plane mounts).

Less accurate calibrations on the TD-12 were also taken at a few different frequencies between 2750 and 2910 mc. The results, although not very informative, were at least consistent with the theory that any variation of emission with frequency is small.<sup>5</sup>

The consistency of output of a single tube operating over a period of time is very good. Relative accuracies of one part in two or three thousand were obtained with the TD-12 (frequency 2885 mc) over selected two-hour periods; and one part in one thousand over fifteen-hour periods. For these particular tests, the discharge current was set at 300 ma. Although the emission is slightly higher and less critical to small changes in discharge current at the usual setting of 250 ma., the audio frequency oscillations characteristic of these tubes<sup>1</sup> were more intense and irregular, with correspondingly poorer results as to consistency of output reading over a period of time. Whether the fault should be ascribed to the tube or the particular measuring equipment used, it is probably preferable to operate at 300 ma discharge current when extreme accuracy is desired. The A147 tubes gave satisfactory results at their recommended discharge current of 250 ma.

Whether this degree of consistency of output can be maintained over much longer periods of time has not been established. Several tubes were retested after intermittent operation, continuous operation, repeated on-off cycling, or shelf-life of several months; some of these appeared to have changed in emission by as much as  $50^\circ$ , but these changes were not clearly related to the history of the tube. On this basis, the relative accuracy to be expected from the operation of a single tube, either continuously or intermittently, over periods of months, may not be better than one part in two hundred.

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<sup>4</sup> N. Houlding and L. C. Miller, "Discharge tube noise sources," *Radar Res. Est., Great Malvern, Worcs., Eng.*, T.R.E. Memo. No. 593; October, 1953.

<sup>5</sup> P. Parzen and L. Goldstein, "Current fluctuations in D.C. gas discharge plasma," *Phys. Rev.*, vol. 79, p. 190; July, 1950.