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Parallel Reversible Permeability Measurement Techniques From 50 kc/s to 3 Gc/s*

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(April 30, 1963)

New measurement techniques are described for determining the complex reversible permeability of ferrimagnetic materials from 50 kc/s to 3 Gc/s with d-c fields applied parallel to the rf fields in toroidal specimens. In the 50 kc/s to 50 Mc/s range, emphasis is directed towards recent improvements in the rf permeameter. For measurements in the 50 Mc/s to 100 Mc/s range, the feasibility of using variable length re-entrant cavities with quarter wavelength chokes is demonstrated. Two half-wave variable length cavities are described for obtaining reversible permeability data in the 100 Mc/s to 3000 Mc/s range. A technique for avoiding the use of quarter wavelines for isolating the d-c and rf circuits in these half-wave cavities is emphasized and represents a definite improvement over corresponding slotted line methods. A brief description of the d-c circuitry developed for these measurements as well as some typical spectrum data is also given.

1. Introduction

Considerable effort has been directed in recent years towards the study of the magnetic spectra of ferrite and garnet materials in the radio and microwave frequency ranges. This work is in general concerned with an evaluation of the frequency spectrum of the initial complex permeability ($\mu_i^* = \mu_i' - j\mu_i''$) in which only an rf field is applied to the sample or the measurement of the reversible complex permeability ($\mu^* = \mu' - j\mu''$) in which a d-c magnetic field is superimposed on the rf field. Several investigations of the dependence of the initial permeability spectrum on the composition of ferrites, the temperature environment, etc., have also been reported. However, the reversible permeability spectra studies with the applied d-c fields appears to be one of the more promising techniques for gaining further information concerning the resonance and relaxation phenomena observed in the magnetic spectra. Nevertheless, there has been relatively little work in this area compared to the effort that has been directed towards initial permeability spectra measurements.

Previous studies of the parallel reversible permeability spectra of ferrites as a function of frequency with applied d-c fields have been confined to measurements covering relatively limited frequency ranges such as the radiofrequency range or the microwave range [1–5].[1] These investigations have utilized primarily inductance coil measurements for obtaining data at lower frequencies or slotted line techniques for obtaining information at higher frequencies. It is the purpose of this paper to describe the use of the radiofrequency permeameter, and variable length re-entrant and half-wave length cavities for obtaining the reversible permeability of ferrimagnetic toroidal materials over the frequency range from 50 kc/s to 3 Gc/s with d-c fields applied parallel to the rf fields. Recent improvements in the permeameter as well as some of the advantages of variable length half-wave coaxial cavities over slotted lines for measurements of this type will be emphasized.

2. Radiofrequency Permeameter, 50 kc/s to 50 Mc/s

The advantages of the radiofrequency permeameter over inductance coil methods or coaxial transmission line techniques for initial permeability measurements at frequencies below 50 Mc/s have been discussed in the literature [6]. The satisfactory results obtained using the permeameter made it seem reasonable to extend its application to the measurement of reversible permeability. Therefore, the permeameter was modified to make parallel reversible permeability measurements by enclosing it in a d-c coaxial line as shown in figure 1. The d-c coaxial line may enclose the whole permeameter [7] as in figure 1a or only that part which encloses the sample, figure 1b. Both methods were used, and although the latter design is more difficult to make, it proved to be the better instrument. If the d-c coaxial line encloses the whole permeameter, the d-c field is applied to the primary core as well as to the sample being measured. The varying d-c field changes the characteristics of the primary which results in errors that are difficult to correct. The coupling between rf and d-c circuits is greater when the whole permeameter is enclosed, creating a need for filters in the d-c circuit from below 1 Mc/s to 50 Mc/s. When the primary was not enclosed by the d-c coaxial line, as in figure 1b, the primary was not affected by the d-c current, and filters were

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[1] Figures in brackets indicate the literature references at the end of this paper.

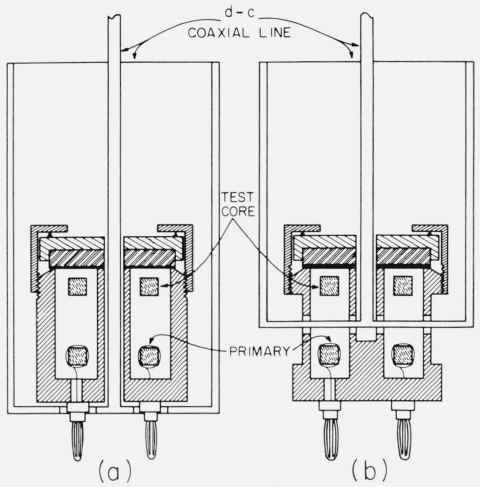

FIGURE 1. *Radiofrequency permeameter with d-c coaxial line to provide a d-c field parallel to the rf field.*

The d-c coaxial line in (b) cuts through the center of the permeameter to avoid applying the d-c field to the primary core.

needed only above 4 Mc/s. These filters are parallel L–C circuits tuned to have a maximum impedance at the frequency at which measurements are being made. The maximum impedance Z_{max} of such an L–C circuit at a frequency ω is approximately

$$Z_{max}=\frac{Q}{\omega C}$$

In addition to the requirements of high Q and low resonating capacitance, C, the characteristics of the filter must not change appreciably with greatly varying d-c currents. Good results were obtained with large powdered iron SF cores wound with bare No. 8 soft copper wire. The capacitors were small, variable mica capacitors. Up to 400 amps were applied for short periods of time with no significant change in Z_{max}. It was necessary to use a filter in both d-c leads to completely eliminate all external rf paths. Each filter was connected separately and tuned to give a maximum Q for the permeameter with the secondary closed and empty. These filters, the d-c leads, and connections for water cooling the center conductor of the d-c coaxial line are shown in figure 2. An exploded view of the permeameter and d-c coaxial line is shown in figure 3.

The measurement of reversible permeability is made in the same way as is the initial permeability, except for the application of the d-c field. A recent study of the permeameter equations for evaluating μ' and μ'' has resulted in a set of exact equations which are independent of the transformer characteristics [8]. The permeameter is represented by a T-network which is evaluated at a given frequency using a stable, low loss standard sample of known μ' and μ''. Using a standard sample in calibrating the permeameter, the procedure in measuring the reversible permeability of a sample is to measure the

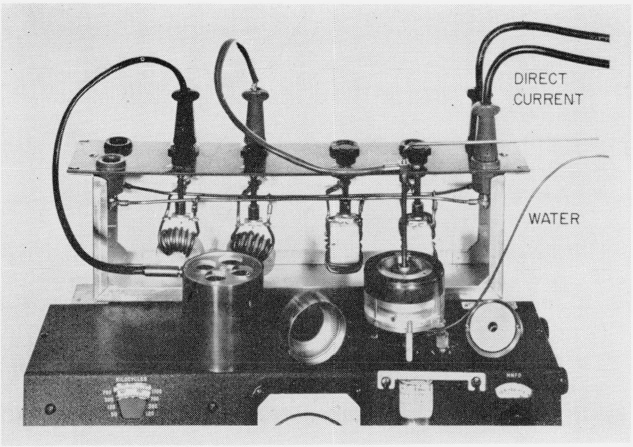

FIGURE 2. *Permeameter with d-c outer conductor (left) and shorting plate (right) removed.*

The filters are shown behind the Q-meter.

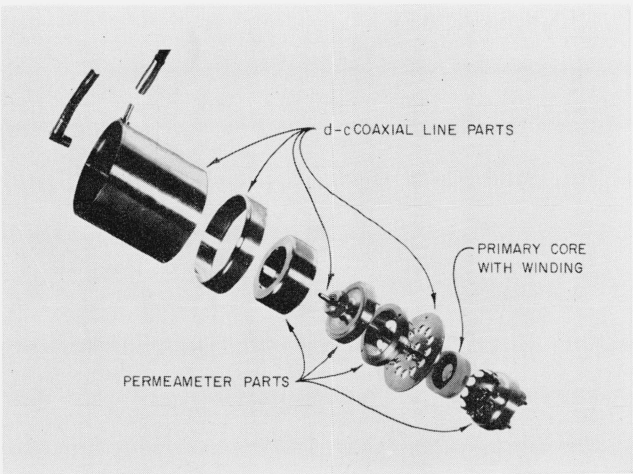

FIGURE 3. *Exploded view of permeameter of the type shown in figure 1b showing how d-c coaxial line is constructed through center of the permeameter.*

input impedance, Z_{in}, of the permeameter for the following conditions:

1. Secondary open; $Z_{in}\equiv Z_1$.
2. Secondary closed; no sample enclosed; $Z_{in}\equiv Z_0$.
3. Secondary closed; standard sample of known impedance Z_s enclosed; $Z_{in}\equiv Z_{f'}$.
4. Secondary closed; test sample enclosed; $Z_{in}\equiv Z_f$.

The d-c current is then turned on and Z_f measured at each desired value of current. The permeability, μ', and loss, μ'', of the test sample are then calculated at each current setting from

$$\mu''+j(\mu'-1)=\frac{Z_s}{\omega L_a}\left(\frac{Z_{f'}-Z_1}{Z_{f'}-Z_0}\right)\left(\frac{Z_f-Z_0}{Z_f-Z_1}\right) \qquad (1)$$

where L_a is the equivalent air inductance of the test sample and ω is the angular frequency. All input impedances (Z_1, Z_0, $Z_{f'}$, Z_f) are measured with the d-c leads connected to the coaxial line surrounding the permeameter.

3. Variable Length Re-entrant Cavity, 50 to 100 Mc/s

The upper frequency limit of the permeameter is about 50 Mc/s. Above 50 Mc/s slotted lines or cavities are in general used for initial permeability measurements. Slotted lines have been used in the 50 to 100 M/cs range but are cumbersome due to their large length. Somewhat smaller re-entrant cavities have also been used in the same frequency range by noting variations in either capacity or frequency for determining their resonant properties [9–12]. Measurements with a re-entrant cavity may also be made in terms of variations in length of the cavity [9]. The latter method has several advantages over the variable capacitance or the variable frequency method in that no capacity calibration need be made or no expensive frequency measuring equipment is needed. It is also possible to more easily minimize errors due to supports and discontinuities in the line which may become significant at higher frequencies.

On the basis of the above information, an investigation was carried out to determine if a variable length re-entrant cavity can be adapted for obtaining reversible permeability measurements. As in the case of the permeameter, it is necessary to isolate the d-c and rf circuit from each other. However, above 50 Mc/s it is difficult to use lumped circuit chokes for this purpose. On the other hand, the successful use of quarter wavelength transmission lines for this purpose by other investigators using slotted lines for their reversible permeability measurements suggests that the quarter wave choke method may also be applicable for re-entrant cavities.

The arrangement which we have found to give the best results is shown in figure 4. In this case the d-c current passes through the center conductor of the cavity in order to provide the circumferential field in the vicinity of the sample. The d-c current was confined to the center conductor by placing a thin sheet of insulation between the mounting flange of the quarter wavelength short and the cavity. No rf current could be detected in the d-c circuit outside of the cavity when the choke was tuned to approximately a quarter wavelength. It was observed that the setting of the quarter wavelength line is not critical for completely isolating the d-c and rf circuits.

The complex permeability may be evaluated from a determination of the change in the resonance length and Q of the cavity due to insertion of the sample. The equations and procedure for obtaining data are the same as those given in the next section describing variable length half-wave coaxial cavities. Essentially the same equations have also been given by van der Burgt, Gevers, and Wijn [9] who describe a variable length re-entrant cavity for initial complex permeability measurements. However, in their instrument, copper rings having the same dimensions as the sample were measured in order to obtain simplified equations.

The restrictions on the use of such instruments noted by the above authors such as high Q, small

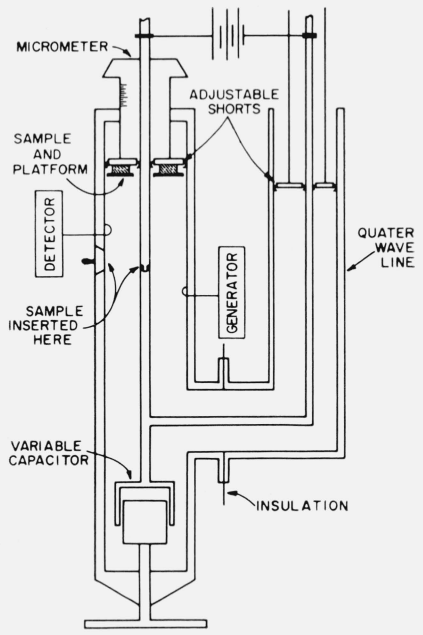

FIGURE 4. *Variable length re-entrant cavity with quarter wavelength line used from 50 to 100 Mc/s.*

The length of the quarter wavelength line relative to the reentrant cavity will in general be somewhat greater than indicated in the above simplified schematic.

length changes, etc., are also applicable to our instrument. A Q of several hundred, obtained with our instrument, appears to be satisfactory for determining the loss of most materials from 50 to 100 Mc/s. In addition, we have found it necessary to give consideration to possible errors due to temperature changes of the center conductor resulting from the large d-c currents required to obtain the bias fields. Such errors can be either eliminated by water cooling the center conductor or corrected for by making two identical runs, one with the sample in the cavity and one with the cavity empty. In our case, the latter method proved to be more feasible since some mechanical difficulty was experienced in obtaining water cooling in a cavity of this type.

4. Variable Length Half-Wave Cavities, 100 to 3000 Mc/s

The combination lumped and transmission line circuitry used in the previously described re-entrant cavity may result in somewhat more difficulty in the mechanical design of the instrument and in the rigorous analysis of the working equations than is the case for completely distributed parameter systems. As such, most magnetic spectra studies of the initial complex permeability in the range above about 100 Mc/s have utilized slotted line techniques. Somewhat less information has been reported on the use of variable length coaxial half-wave cavities for obtaining data of this type [13].

The measurement of parallel reversible permeability at these higher frequencies has been confined exclusively to the use of slotted lines in which the d-c circuit is isolated from the rf circuit by means of a quarter wavelength line [1, 3, 4]. On the other hand, an examination of variable length cavities suggests that an insulated d-c conductor could be placed through a hollow rf center conductor of such a cavity and thereby isolate the d-c from the rf signal without the use of a quarter waveline. Because of this advantage and our previous successful use of variable length cavities for initial permeability measurements, we developed two variable length cavities with hollow center conductors containing insulated d-c conductors. No coupling between the rf and d-c circuits was observed in either instrument. Since complete isolation is obtained without the use of a quarter waveline, this is a distinct advantage over slotted line techniques for reversible permeability measurements.

The design of both of these cavities was based on the Chipman method for impedance measurements [14]. Both cavities were mounted in a vertical position in order to avoid any supports on the center conductor. One of the instruments was designed for measurements below 300 Mc/s, while a smaller, more precise instrument was used for obtaining data above 300 Mc/s.

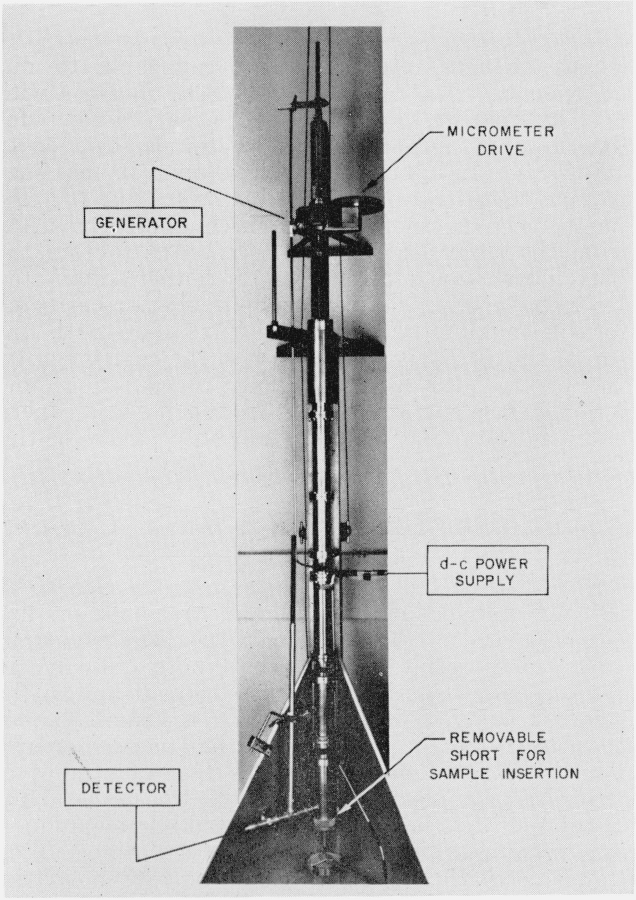

FIGURE 5. *Half-wave variable length cavity used at 100 Mc/s, 200 Mc/s, 300 Mc/s, etc.*

The larger instrument shown in figure 5 is presently designed for obtaining data at frequencies in the vicinity of 100, 200, and 300 Mc/s using 1, 2, or 3 half wavelengths respectively. The Q at these frequencies varies from 400 to 700. Continuous frequency coverage at these low frequencies would require a rather long micrometer drive. In lieu of this approach, the line has been constructed in removable sections to provide for coarse adjustments in length if information at other frequencies should be desired in the future. The general features of the instrument are similar to those shown in figure 6 which is actually a schematic for the higher frequency cavity described below.

Although the above described cavity can be used above 300 Mc/s, it was more convenient to design and construct a smaller, more precise instrument capable of continuous frequency coverage for measurements from 300 to approximately 3000 Mc/s. As in the case of the larger cavity, multiple half wavelengths can be used to obtain resonance at the higher frequencies. In addition, this cavity has the added advantage of a continuously variable coarse adjustment of length for changing the frequency range of the instrument. This adjustment was obtained by

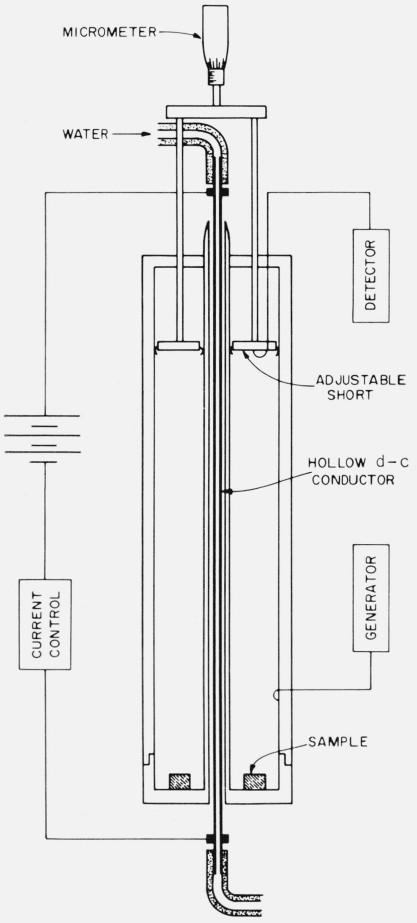

FIGURE 6. *Drawing of the 300–3000 Mc/s variable length cavity.*

A d-c field is applied to the sample by sending direct current through a d-c conductor which is placed inside of and insulated from the hollow rf center conductor.

threading the outside conductor of the cavity for a considerable distance as can be seen in figure 7. The cavity also has a higher Q, ranging from 500 to 3000, depending on frequency. To avoid any discontinuities near the sample at high frequencies, the center conductor and shorting plate of the 300 to 3000 Mc/s cavity were constructed as one piece as can be seen in figure 6. This arrangement gives a uniform distribution of rf current around the center conductor where it joins the shorting plate, and hence a uniform rf field for the sample which rests on the shorting plate. The cavity is opened for inserting the sample by removing the whole center conductor-short assembly. The cavity was prevented from heating up when the direct current was applied by making the d-c conductor out of ⅛ in. tubing through which water was circulated for cooling.

The complex permeability may be readily evaluated from a determination of the changes in resonant length and Q of the cavity when the sample is inserted. The toroidal sample which is placed against the shorted end of the line has a thickness small compared to a quarter wavelength in the material in order that dielectric effects do not influence the magnetic permeability measurements. Our experience has indicated that it is not difficult to obtain sufficiently thin ferrites so that the dielectric effect is negligible at least to 1 Gc/s and in some cases to 3 or 4 Gc/s.

For sufficiently small changes in the parameters of high quality lines, the complex permeability ($\mu^* = \mu' - j\mu''$) may be calculated from the equations

$$\mu' - 1 = \frac{\Delta L}{d}$$

$$\mu'' = \frac{\Delta \ell_f - \Delta \ell_e}{2d}$$

where it is assumed that the sample of thickness d has the same radial dimensions as the coaxial line. The remaining quantities in the equations are obtained from the following length measurements.

ΔL=The difference between the resonance length of the empty cavity and the resonance length of the cavity when the sample is placed against the short.

$\Delta \ell_e$=The difference between the two lengths of the empty cavity for which the power level is ½ the maximum value at resonance.

$\Delta \ell_f$=The difference between the two lengths of the cavity with the sample for which the power level is ½ the maximum value at resonance.

An excellent analysis of variable length cavities for initial permeability measurements in which these equations are developed in essentially the above form has been given by Eichacker [13, 15]. His work also demonstrated that variable length lines and slotted lines both work with the same evaluation formula. In this respect, it should be noted that the above equations have also been obtained in similar form by other authors using slotted line techniques [16].

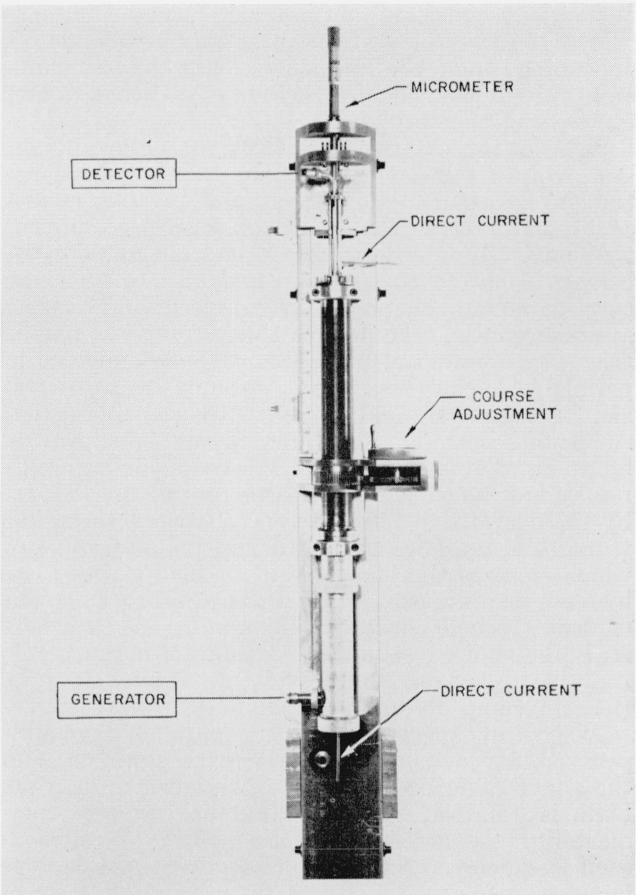

FIGURE 7. *Half-wave variable length cavity used at 300–3000 Mc/s.*

In many cases, it may not be convenient to obtain samples which have the same radial dimensions as the coaxial line. However, following the approach used by Bady and Franklin [10], the above equations may be written in the following form for loose fitting samples.

$$\mu' - 1 = \frac{\log \frac{B}{A}}{\log \frac{b}{a}} \frac{\Delta L}{d}$$

$$\mu'' = \frac{\log \frac{B}{A}}{\log \frac{b}{a}} \frac{(\Delta \ell_f - \Delta \ell_e)}{2d}$$

where the toroidal sample of inner radius a and outer radius b is located in the coaxial line of radii A and B.

5. Associated Equipment and Results

The rf equipment used with the half-wave cavities and re-entrant cavity consisted of commercially available signal sources with pads and matching stubs for the input circuit as well as facilities for monitoring the frequency of the system. The out-

put circuit consisted of matching stubs and calibrated IF detector systems or standing wavemeters depending upon the frequency. For the permeameter, the impedances are measured with a Q meter or Maxwell-type bridge.

Since in the cavities as well as the permeameter, large currents are needed to obtain d-c fields large enough to saturate many samples, a 6 v nickle-cadmium battery capable of high discharge current was used. It was desirable to be able to vary the current from 0.5 to 500 amp and also to have the current remain constant at any desired value during a measurement. To do this the current was passed through a number of power transistors connected in parallel. The large current I_c through the transistors can be varied or held constant by controlling the small bias current I_B. The circuit is shown in figure 8. The voltage drop V_s across the high current shunt is compared to a control voltage, V_c, set by the operator. The difference between these two voltages is amplified and used to drive a servomotor which changes the bias current in such a way as to increase or decrease I_c until V_s is equal to V_c. The current I_c is held constant at a value $I_c = V_c/R_s$ where R_s is the shunt resistance. A millivoltmeter across the shunt is used to measure I_c above 10 amp. Below 10 amp a clip on d-c ammeter is used.

A typical spectrum of the parallel reversible permeability of a magnesium ferrite obtained with the above described equipment is shown in figure 9. Data is obtained by measuring the reversible permeability and loss as a function of the d-c field at each frequency. An example of curves of this type for μ' only is given in figure 10. A complete set of these curves at all desired frequencies enables the spectrum to be obtained for any desired current. This data indicates that the above described equipment provides a highly satisfactory method for obtaining reversible permeability spectra information.

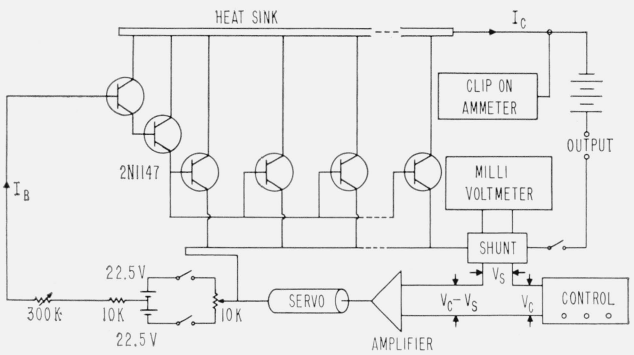

FIGURE 8. *Direct current control for varying or holding constant large d-c currents.*

The output current I_c passed by the power transistors is controlled by the bias current I_B. A control voltage V_c is compared to V_s and the difference amplified to drive a servo which adjusts I_B in such a way so as to increase or decrease I_c until $V_s = V_c$. I_c is changed by changing V_c.

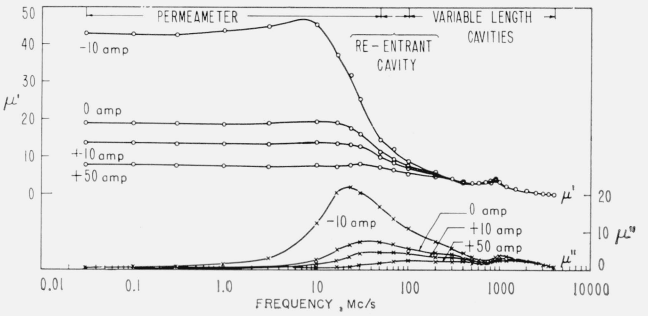

FIGURE 9. *Typical spectrum of the parallel reversible permeability of a magnesium ferrite.*

Data obtained from curves such as shown in figure 10. Sample dimensions outside diameter=0.961 in., inside diameter=0.678 in., thickness=0.040 in.

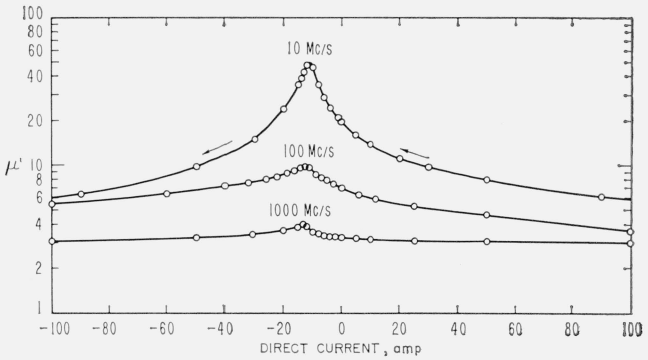

FIGURE 10. *Typical results of parallel reversible permeability versus applied d-c current.*

The sample was cycled at ±100 amps several times before measurements were made in the direction indicated by the arrows.

The authors thank W. A. Pittman for making the many measurements and calculations, and M. B. Lindell and G. A. Boschen for construction of the instruments.

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Publications of the National Bureau of Standards*

Selected Abstracts

An absolute calibration of the National Bureau of Standards Thermal Neutron Flux, E. J. Axton, *J. Research NBS* **67A** (*Phys. and Chem.*), *No. 3, 215–230* (*May–June 1963*).
The NBS Thermal Neutron Flux has been calibrated in terms of the gold thermal neutron capture cross section. The effective thermal neutron (below cadmium cutoff energy) flux density is estimated to be 4307 ± 2 percent n/cm^2 sec in September 1961. This figure is in agreement with a recent value quoted by the NBS.

Purity analysis of highly purified materials by time-temperature cryometry, G. S. Ross and H. D. Dixon, *J. Research NBS* **67A** (*Phys. and Chem.*), *No. 3, 259–263* (*May–June 1963*).
Visual observation of the freezing and melting of compounds in cells used for the determination of purity has uncovered some heretofore unexpected behavior. This behavior has been correlated with certain difficulties experienced in the measurement of purity, particularly when the sample is very pure. Means for partially reducing these difficulties are proposed and procedures for increasing the accuracy of purity measurements are described.

Analysis of families of curves, J. Mandel and F. L. McCrackin, *J. Research NBS* **67A** (*Phys. and Chem.*), *No. 3, 271–279* (*May–June 1963*).
A systematic approach is presented for fitting empirical expressions to data depending on two variables. The problem can also be described as the simultaneous fitting of a family of curves depending on a parameter.
The proposed method reduces a surface fitting problem to that of fitting a few functions of one variable each. First, the surface is expressed in terms of these one-variable functions, and using an extension of two-way analysis of variance, the accuracy of this fit is assessed without having to determine, at this point, the nature of one-variable functions. Then, the one-variable functions are fitted by customary curve-fitting procedures.
For illustration, the method is applied to two sets of experimental data.

A controlled atmosphere chamber, C. L. Gordon and R. B. Johannsen, *J. Research NBS* **67A** (*Phys. and Chem.*), *No. 3, 281–283* (*May–June 1963*).
An inert atmosphere chamber for the transfer of reactive materials is described. It has the advantages of being inexpensive and easily cleaned, and can be evacuated.

The meaning of Betti's reciprocal theorem, C. Truesdell, *J. Research NBS* **67B** (*Math. and Math. Phys.*), *No. 2, 85–86* (*Apr.–June 1963*).
It is demonstrated that Betti's reciprocal theorem represents a criterion for the existence of a stored-energy function.

Effect of molecular weight on viscoelastic properties of polymers as predicted by a molecular theory, H. Oser and R. S. Marvin, *J. Research NBS* **67B** (*Math. and Math. Phys.*), *2, 87–90* (*Apr.–June 1963*).
Calculations have been made covering the predictions of a model representing the viscoelastic behavior of rubberlike polymers for molecular weights greater then M_c, M_c being the lower limit of the range in which the viscosity is proportional to $M^{3.4}$. A pronounced difference in the character of G'' is predicted for polymers with molecular weights between 5 and 10 times M_c as compared with those whose molecular weights are outside this range.

Asymptotic behavior of the current on an infinite cylindrical antenna, K. S. Kunz, *J. Research NBS* **67D** (*Radio Prop.*), *No. 4, 417–431* (*July–Aug. 1963*).
An asymptotic expression is obtained for the currnet distribution on the outside surface of an infinitely long, perfectly conducting, hollow cylindrical antenna that is fed by an infinitesimally narrow circumferential gap. This asymptotic expression involves two series. The first series is expressed in reciprocal powers of $\log (2|z|/j\Gamma^2 ka^2)$, where $|z|$ is the distance from the gap, $\log \Gamma$ is Euler's constant, k is the propagation constant, and a is the radius of the antenna. The second series is a similar series multiplied by 1 $(k|z|)$. The first series is dominant and its first five terms yield values for the magnitude and phase of the current that for even moderately thick antennas (circumferences as large as $\lambda/3$) are accurate to within about one percent in as close as $\lambda/3$ of the gap. This is shown by a comparison of the values of the current obtained from these terms with the numerically computed values of Duncan (1962). Asymptotic expressions for the current found in the literature resemble the first term of this dominant series and are accurate only at relatively large distances from the gap—except for very thin antennas.

On the statistical theory of electromagnetic waves in a fluctuating medium (I), K. Furutsu, *J. Research NBS* **67D** (*Radio Prop.*), *No. 3, 303–323* (*May–June 1963*).
The subject of electromagnetic wave scattering by a randomly varying medium is reviewed giving special emphasis to the technical method of approach. The symbolic representation of Maxwell's equations is introduced to make it easier to survey the whole subject and to formulate the equations. The Feynman diagram method is applied to the computation of the correlation of the fields at different points in space to any order of approximation. The differential equation to be satisfied by the latter correlation function is also derived from another point of view. Then the theory is developed on the "renormalization" of the constants, i.e., the effective propagation constant in a fluctuating medium and the effective coupling constant between the field and the medium, etc.; the explicit expression of the former is obtained to the first order of approximation. The dispersion relation is derived as a connected problem. In Part II of this series of papers, a fundamental theory of statistics of the electromagnetic field in a fluctuating medium will be developed. In Part III, a few applications to tropospheric scattering will be given.

Analysis and synthesis of nonuniform transmission lines or stratified layers, G. Latmiral, G. Franceschetti, and R. Vincinguerra, *J. Research NBS* **67D** (*Radio Prop.*), *No. 3, 331–345* (*May–June 1963*).
Nonuniform lossless or lossy transmission lines or layers used as broadband matching or absorbing devices are studied. When the refraction index, $n(x)$, and the characteristic impedance $Z_0(x)$, are given, the reflection spectrum, $\rho_0(\eta) = \rho_0\ (4\pi/\lambda)$, for $x=0$ can always be computed by solving numerically a Riccati differential equation (RDE). (Analysis) Conversely, not only for $n=$const [Bolinder, 1950, 1956] but also for $n(x)$ real and $\mu=\mu_0$, a tapered transformer can be synthesized starting from a given $\rho_0(\eta)$ spectrum by using Fourier transform techniques. (Synthesis)
For broadband absorbers, the synthesization procedure can be approximately applied, under certain conditions, to only the part of the spectrum which represents the reflection of the matched (lossy) line.

NBS viscometer calibrating liquids and capillary tube viscometers, R. C. Hardy, *NBS Mono. 55* (*Dec. 26, 1962*), *20 cents.*
Most measurements of viscosity are made with relative viscometers. These instruments must be calibrated with

liquids whose viscosities are known. NBS provides a series of 10 oils for this purpose. Their viscosities range from 0.02 to 450 poises and their temperature coefficients of viscosity range from 2.1 to 9.4 percent per degree C. When properly stored the oils may remain usable for from two months to one year but prompt use is recommended. The less viscous oils are more stable. Representative types of glass capillary tube viscometers and their use are discussed briefly. Contrary to common belief, it is not necessary to calibrate these instruments at the temperature of use since the temperature coefficients of the instruments are small and correction if necessary can be calculated. Instruments in which the effective volume of charge is not adjusted at the test temperature may require adjustment of their calibration constants to compensate for thermal expansion of the test liquid. Correction formulas for this and other errors or conditions are presented.

Equipment characteristics and their relation to system performance for tropospheric communication circuits, A. F. Barghausen, F. O. Guiraud, R. E. McGavin, S. Murahata, and R. W. Wilber, *NBS Tech. Note 103 (Jan. 15, 1963), $1.00.*

The performance of a tropospheric communications system, either within the line of sight or beyond the line of sight, is directly dependent on the operating characteristics of the equipment.

Performance predictions of a communications system are made on the basis that equipment will operate in a prescribed manner. The degree of success of the communications system will depend largely upon how well these predicted values correspond to the actual operating values.

Consideration is given to those portions of the equipment that have definite effect upon the operating performance. Specific items of equipment and methods for determining their performance are considered. Representative results in light of the present state of the art permits an evaluation of an actual system in terms of realizing an "optimum" system.

In systems that do not have the "optimum" characteristics desired, consideration is given to laboratory devices which may alleviate these deficiencies. Future systems should consider incorporating these devices as development permits.

The construction of calorimeters for the measurement of absorbed dose, B. Petree and G. Ward, *NBS Tech. Note 163 (Nov. 1962), 25 cents.*

Direct measurements of energy locally absorbed in irradiated materials can be made with adiabatic calorimeters of suitable design. Design criteria imposed by requirements of accuracy include limitations on size and complexity. Small calorimeters of simple design with precision better than one percent at dose rates above one rad per second have been developed. Details of fabrication, auxiliary equipment and performance are described.

Detection of high altitude nuclear detonations using the VLF phase shift technique, A. G. Jean and D. D. Crombie, *IEE Trans. Nuc. Sci.* **NS–10,** *242–253 (Jan. 1963).*

It is well known that nuclear detonations at heights of about 30 km or more can create large increases in the electron density of the upper atmosphere not only in the general area of the blast but also in areas remote from it. In this paper, the effects of such nuclear explosions on the lower ionosphere are considered. The influence of these ionospheric changes on the propagation of VLF signals is then discussed from the point of view of the detection of such nuclear explosions.

The measurement of voltage by the use of the Stark effect, Y. Beers and G. L. Strine (*Intern. Conf. Precision Electromagnetic Measurements, Boulder, Colo., 1962*), *IRE Trans. Instr.* **I–II,** *171 (Dec. 1962).*

The theory of the Stark effect is reviewed with regard to its possible application of measuring voltages. It is pointed out that the effect can be used only to measure relative voltage and that the accuracy is likely to be limited by the accuracy with which the electrode separation can be determined. Therefore, the most sophisticated types of molecular frequency standards may not be required. The Stark method appears to hold a particular advantage for the measurement of high voltage since no voltage divider is required. Also, two possible methods of comparing ac voltages to dc voltages are discussed. Finally, an expermental Stark voltmeter employing a millimeter wave Fabry-Perot absorption cell is discussed. Calculations concerning $J=2\rightarrow3$ transition of methyl cyanide at 55 Gc indicate that in principle the precision obtainable with a field strength of 10^4 volts/cm should be in the neighborhood of one part in a million, if field inhomogeneities can be neglected.

A National Bureau of Standards gas thermometer, L. A. Guildner, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 151–155 (Reinhold Publ. Corp., New York, N.Y., 1962).*

At the National Bureau of Standards a constant-volume gas thermometer will be used to determine differences between the International Practical Temperature Scale of 1948 and the Kelvin thermodynamic scale. The gas thermometer bulb is a 500 cc sphere of platinum-20% rhodium alloy. It is connected to a pressure-sensitive diaphragm for separating the gas thermometer from a mercury manometer. With large menisci, the positions of the mercury crowns can be accurately detected by capacitance. The height of mercury is measured by Hoke end standards. A "tilt meter" measures variations of the manometer base from level.

Intensive effort is being made to reduce random and systematic errors. The bulb is thermostated uniformly by a copper furnace. The physical characteristics of the gas thermometer will be determined experimentally. Measurements will be made with a second thermometer bulb and with more than one gas. Determinations will be made for different masses of each gas in order to extrapolate to zero pressure.

It is planned to measure near the fixed points and at intermediate temperatures from 100 °C to 960 °C. A final set of measurements will determine the ratio of the thermodynamic temperatures of the steam and triple points of water.

Quartz crystals at low temperatures, P. R. Simpson and A. H. Morgan, *Proc. 13th Annual Symp. Frequency Control, pp. 207–231 (Aug. 1959).*

The results of measurements performed at NBS Boulder Laboratories on certain characteristics of high precision quartz crystal oscillator units at temperatures below the normal ambient range are described with particular emphasis on frequency stability. Included are some details on the cryogenic ovens used, their temperature control devices and performance. The oscillators developed for driving the crystal units and the frequency measuring systems employed will also be discussed. Various disturbing influences such as recharging the cryostats with refrigerant, shock and vibration, filament voltage variations on the oscillator tubes, and others, will be mentioned.

Resistance thermometry in the liquid helium temperature region, M. H. Edlow and H. H. Plumb, *Book, Temperature, Its Measurement and Control In Science and Industry* **3,** *Pt. 1, 407–411 (Reinhold Publ. Corp., New York, N.Y., 1962).*

Carbon and impurity doped germanium resistors have been investigated for use as precision secondary thermometers in the liquid helium temperature region. Three germanium resistors supplied by Bell Telephone Laboratory (86Ω, 59Ω, and 21Ω) have been thermally cycled from 300 °K to 4.2 °K and their resistances have been found to be reproducible to within 1 millidegree when temperatures were derived from a controlled surface vapor pressure, and within ⅓ millidegree (except for one that had been repaired) when temperatures were derived from a vapor pressure thermometer whose tubing is jacketed through most of the liquid helium. Five impurity-doped germanium resistors supplied by Texas Instruments Inc. have been thermally cycled from 300 °K to 4.2 °K and yield reproducibilities ranging from 2 to 10 millidegrees. Preliminary calibrations of the Bell Laboratory 59Ω and 21Ω and the Texas Instruments Inc. 125Ω resistors have been made from 4.21 °K to 2.16 °K at every 0.1 °K. The data were fitted to a curve of the form $\log R+k/\log R=A+B/T$ by means of the 704 computer. The standard deviations of the data from this equation for the 125Ω and 59Ω resistors are $\leqq1$ millidegree; for the 21Ω resistor, the standard deviation is $\leqq3.3$ millidegrees.

An improved resistance thermometer bridge, J. P. Evans, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 285–289 (Reinhold Publ. Corp., New York, N.Y., 1962).*
Details of an improved Mueller bridge are given. The bridge has a range 0 to 422 ohms in 1 microhm steps. The important new features are (1) the addition of a decade with 1 microhm steps, (2) the use of mercury wetted contact switches for the 1, 0.1, and 0.01 ohm decades as well as for the 10 ohm decade and the 100 ohm coils, (3) the use of totally enclosed wafer type switches for the four lower decades, (4) the inclusion of a circuit which permits the instrument to be used as a four terminal decade resistor, (5) provision for digital read-out of the bridge dial settings, and (6) electrical guarding and shielding of the measuring circuit so that sensitive electronic null detectors may be used.

Lasers, T. R. Lawrence, *J. Wash. Acad. Sci.* **53,** *25–34 (Feb. 1963).*
A general survey on the present state of lasers is presented.

Thermophysical properties of zirconium hydrides, R. L. Beck and T. B. Douglas, *Trans. Am. Soc. Metals* **55,** *1075–1076 (1962).*
Attention is called to the emphasis by metallurgists and physical chemists of different sets of properties of metal hydrides, but it is pointed out that almost all properties indicate and are influenced by the phase-field boundaries. The author (of the paper discussed) shows commendable caution in interpreting data in terms of these boundaries. More two-way approach to immobile equilibria is recommended, and the writer cites some of his own experience. One heat capacity reported, while not precise, agrees with a recent correlation by the writer of the Zr-H system. The writer criticizes the implication that two coexistent phases have the same heat capacity. He points out that an ideal heat-capacity curve has a discontinuity on entering a two-phase field and that for a given simple composition the heat capacity in the latter field is always greater than in an adjacent one-phase field.

Measurement of electron density and temperature in dense plasmas by application of line broadening theory, J. B. Schumaker, Jr., and W. L. Wiese, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 575–579 (Reinhold Publ. Corp., New York, N.Y., 1962).*
The electron density and temperature in arc plasmas have been determined by the deliberate introduction of a trace of hydrogen as a thermometer. The electron density is obtained by spectrophotometric measurement of the line profile of one of the Balmer lines and comparison with the theoretical profiles recently calculated by Griem, Kolb, and Shen. The temperature is then calculated from the electron density using the usual equilibrium equations of statistical mechanics for reacting gases.

A study of stability of high temperature, platinum resistance thermometers, J. P. Evans and G. W. Burns, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 313–318 (Reinhold Publ. Corp., New York, N.Y., 1962).*
The National Bureau of Standards is studying the performance of platinum resistance thermometers in the range 630.5° to 1063° C. A number of thermometers with temperature sensing resistors of several designs, various protecting tube materials, and two types of platinum wire have been constructed. Thermometer stability was tested by heating the thermometers for long times at high temperatures and periodically determining the thermometer resistance at 100° and 0° C. The constancy of the ratio of these resistances, R_{100}/R_0, is taken as an indicator of thermometer stability. It is shown that stable thermometers can be made. The stability of the thermometers is found to be affected by the rate of cooling from high temperatures. This cooling rate effect is explained by the quenching-in of point defects in platinum.

Theory and methods of optical pyrometry, H. J. Kostkowski and R. D. Lee, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 449–481 (Reinhold Publ. Corp., New York, N.Y., 1962).*
A detailed review of the theoretical methods of optical pyrometry and the application of these methods at the National Bureau of Standards in realizing and dispersing the International Practical Temperature Scale above 1063° C is presented. In the theoretical presentation, the concepts of effective and mean effective wavelengths are introduced, and various equations relating these parameters to each other and other physical quantities are derived. The important features of precision visual optical pyrometers are discussed and a number of blackbody sources and tungsten strip lamps described. Detailed experimental procedures and results of primary and secondary calibrations of optical pyrometers at NBS are given. Finally, recommendations for achieving high precision and accuracy and the fundamental limitations in visual optical pyrometry are presented.

The role of temperature in our measuring system, A. G. McNish, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 129–132 (Reinhold Publ. Corp., New York, N.Y., 1962).*
Temperature is taken, together with length, mass, and time, as one of the completely independent quantities which form the basis of our measuring system. This is noteworthy in that temperature is an intensive quantity while the other three are extensive quantities. The unit of temperature, like the units of length, mass, and time is independent of all units of the system, being like them, embodied in its proper standard.
It is possible to construct a system in which temperature is not regarded as an independent quantity but one expressible in terms of length, mass, and time. However, in such a system the unit of temperature could not be realized with anything like the accuracy required for good measurements This is because the relationship between temperature and length, mass, and time has not yet been measured with an accuracy approaching that with which each of these quantities itself can be measured. Specifically, the gas constant has never been very accurately determined.
The present practice of regarding temperature as an independent quantity affords a procedure for the most accurate measurement of temperature.

The determination of absolute temperatures from sound velocity measurements, G. Cataland, M. H. Edlow, and H. H. Plumb, *Book, Temperature, Its Measurement and Control in Science and Industry* **3,** *Pt. 1, 129–132 (Reinhold Publ. Corp., New York, N.Y., 1962).*
Absolute temperatures were derived from determinations of the velocity of sound in a gas and the acoustical interferometer was used for the velocity measurements. For an ideal gas, the velocity of sound is directly proportional to the square root of the absolute temperature; in the case of a real gas, corrections must be made which involve virial coefficients of the gas in a pressure expansion. Since these corrections are a function of pressure, it is desirable that velocity measurements for absolute temperature determinations be conducted at the lowest practical pressures (the real gas approaches the state of an ideal gas).
An acoustical interferometer has been constructed at the National Bureau of Standards and has been used, with helium gas as a thermometric material, to determine absolute temperatures at 4.2° K. When temperatures thus derived are compared with absolute temperatures associated with liquid helium vapor pressures, the difference between the two temperatures is 10 millidegrees. While this result is of a preliminary nature, it does justify continued investigations for determining absolute temperatures by sonic methods.

Ranking laboratories by roundrobin tests, W. J. Youden, *Mater. Res. Std.* **3,** *No. 1, 9–13 (Jan. 1963).*
This paper presents a scoring method for laboratories participating in roundrobins. For each material the laboratory with the highest numerical result is given the rank of one, the laboratory with the next highest result is given the rank of two, and so on until the lowest of L results is given the rank L. A laboratory is scored by summing its ranks for all the materials. The paper includes a new statistical table that gives lower and upper limits for scores that correspond to five percent probability. Because systematic

errors operate to produce extreme scores, the table should be useful in singling out laboratories with pronounced systematic errors.

The error rate in a multiple-frequency-shift system and the output signal/noise ratio in a frequency modulation and a pulse-code-modulation/frequency-shift system, H. Akima, *Intern. Conf. Satellite Communication, pp. 305–310 (Nov. 22–28, 1962).*
Based on the assumption of a fading-free signal and an additive white Gaussian noise, the element and symbol error rate in an MFS (multiple-frequency-shift) system are evaluated, and the output SNR (signal-to-noise ratio) in an FM (frequency-modulation) and a PCM-FS (pulse-code-modulation-frequency-shift) system are determined theoretically. The signal to noise characteristics of an SSB (single-sideband), an FM, and a PCM-FS system are compared with each other.

A differential thermocouple voltmeter, J. E. Griffin and F. L. Hermach, *AIEE Trans., Pt. I. Communications and Electronics No. 63, Article No. 62–819, 338–344 (Nov. 1962).*
An a-c voltmeter has been developed to indicate directly in percent the difference between an unknown voltage and the settings of the dials of the instrument. It is accurate to 0.05% from 5 cps to 10 kc at 1 to 700 volts. Two 10-ma thermoelements are used; one in series with an a-c decade resistor, and the other energized from a constant-voltage d-c source (zener diode). A built-in galvanometer, calibrated in percent of the input voltage, indicates the difference between the two thermocouple output emfs and has a resolution better than 0.01%. The instrument was designed for rapidly calibrating other voltmeters. It can also be used for ac-dc difference measurements (frequency response tests) to 0.02%.

Cavitation problems in cryogenics, R. B. Jacobs and K. B. Martin, *J. Basic Eng.* **82,** *756–757 (Sept. 1960).*
Cavitation problems in cryogenics are not unique to cryogenics. A basis for the prediction of cavitation characteristics is developed and discussed. Cavitation problems with cryogenic pumps, flow meters and flow of saturated liquids are discussed. It is concluded that research into basic problems involving metastability, nucleation, vapor-phase dynamics, etc., is needed.

Color tests for antioxidants, E. J. Parks, L. T. Milliken, and F. J. Linnig, *Rubber Age* **92,** *No. 257–261 (Nov. 1962).*
A method involving the use of color and precipitation tests is presented for the qualitative identification of five antioxidants commonly used to protect crude SBR. They are: PBNA (phenyl-beta-naphthyl-amine), BLE (reaction product of acetone and diphenylamine), Stalite (mixture of heptylated and octylated diphenyl amines), Wingstay S. (mixture of styrenated phenols), Polygard (mixture of aklylated aryl phosphites). The use of several series of selected tests avoids the need to distinguish between shades of color and helps to eliminate uncertainties resulting from contamination or the possible presence of other stabilizers. The method stresses simplicity and rapidity of operation. Laboratory instrumentation is not involved. Only 10 to 15 minutes are required to complete the series of tests necessary for the identification of antioxidants present in normal quantities. Traces (10 to 100 ppm) of staining antioxidants (PBNA and BLE) are also detected in rubber protected primarily by usual amounts (about 1.25%) of nonstaining antioxidants (Stalite, Wingstay S., and Polygard). The individual tests necessary to detect these trace quantities require no more than 30 minutes in some cases, and as little as 10 minutes in others.

Widely separated clocks with microsecond synchronization and independent distribution system, T. L. Davis and R. H. Doherty, *IRE WESCON, Conv., Pt. 5, pp. 3–17 (1960).*
In a majority of timing applications, a problem exists in setting two or more clocks to agree with one another. Present techniques using WWV or other high frequency broadcasts allow clocks to be synchronized within 1 millisecond. This paper describes a method which offers an improvement in synchronization of three orders of magnitude.
Microsecond synchronization is obtained by use of the Loran-C navigation system as the link between a master clock at Boulder, Colo., and any slaved clock anywhere in the Loran-C service area.
The timing system also includes a unique method for distribution of several time code formats on a single UHF channel.

A low impedance Maxwell bridge for measuring torodially-shaped magnetic materials from 1 Kc to 100 Kc, A. L. Rasmussen and R. C. Powell, *Proc. IRE* **50,** *2505–2506 (Dec. 1962).*
A specially designed Maxwell bridge extends the range of coaxial magnetic measurements several orders of magnitude lower in frequency and complex permeability than possible with previous equipment. This bridge measures from 1 Kc to 100 Kc the quantities of 10^{-11} to 10^{-6} henrys, $10^{-7} \times$ (frequency in Kc) to 10^{-1} ohm and loss tangent (the reciprocal of the Q) 10^{-3} to 10 using toroidally-shaped magnetic materials without the difficulties normally encountered from multiple windings and contact resistance.

Germanium vacuum ultraviolet Ritz standards, V. Kaufman and K. L. Andrew, *J. Opt. Soc. Am.* **52,** *No. 11, 1223–1227 (Nov. 1926).*
The number of Ge I Ritz standards below 2000Å has now been increased to approximately 100 lines with estimated uncertainties not exceeding 0.0009Å, 68 of which have estimated uncertainties of 0.0003Å. This extension is the end product of a systematic Fabry-Perot interferometric investigation which has extended the former interferometric region of 2019–4685Å to 12069Å. Ninety-five interferometrically determined levels of Ge I are given, 72 of which have been improved by this effort.
Twenty-three lines of Ge II were also measured interferometrically leading to 20 improved energy levels of this spectrum and to estimated splittings of the $ng^2G(n{=}5, 6, 7)$ terms. From the improved levels, twelve Ge II Ritz standards from 999 to 1966Å have been calculated with estimated uncertainties not exceeding 0.0009Å. An improved series limit of Ge II calculated from the nf^2F and ng^2G term series is 128 521.3 cm^{-1}. This value made use of improved levels of this work and as yet unpublished data furnished by Shenstone.

Microwave Doppler measurements of the ionization front in cylindrical shock waves from exploding wires, D. L. Jones and R. M. Gallet, *Exploding Wires* **2,** *127–144 (1962).*
Strong cylindrical shock waves from exploding wires have been measured by microwave Doppler techniques. The results obtained simultaneously on two or three independent frequencies are in very good agreement and show that the ionization front is well defined. The Taylor-Lin similarity blast wave theory for the shock wave propagation is well verified over distances up to 6 or 7 cm under the present conditions. Systematic results for the determination of shock wave energy and the efficiency for shock production in air over a range of pressures, wire diameters, and stored electrical energy are presented. Relative to optical methods used in the same problem the present technique is more sensitive and perhaps more precise.
It is remarkable that very good reflections are still consistently obtained when the shock Mach number falls below 3 in air. From the calculated temperature and ionization in the shock front, the expected electron density should then be negligible. This effect is probably a result of the pre-excitation of the gas ahead of the shock front, caused by ultraviolet radiation from the wire explosion or from the advancing shock front itself. There is also a relatively weak precursor ionization, for which recent microwave absorption measurements have indicated electron densities of the order of 10^{11} cm^{-3} several centimeters ahead of the front.
The good reflection at low Mach numbers permits one to show that the similarity theory is still valid until Mach number 4 or below, and permits one also to record the departure from this relation at larger radii.

Tests for contingency tables and Markov chains, S. Kullback, M. Kupperman, and H. H. Ku, *Technometrics* **4,** *No. 4, 573–608 (Nov. 1962).*

A number of useful tests for contingency tables and finite stationary Markov chains are presented in this paper based on the use of the notions of information theory. A consistent and simple approach is used in developing the various test procedures and the results are given in the form of analysis-of-information tables. Beginning with tests of hypotheses for a one-way table, tests of hypotheses of specified probabilities, independence, conditional independence, homogeneity of classifications, and symmetry are developed for contingency tables of two, three, four, and higher order classifications. For the Markov chains, the tests include the hypotheses of a specified matrix of transition probabilities, Markovity, and homogeneity of several realizations of Markov chains. Worked examples are given throughout the paper.

Comments on the limits to the refractive index at ground level as a radiometeorological parameter, B. R. Bean and G. D. Thayer, *Proc. IRE* **48,** *No. 8, 1498–1501 (Aug. 1960).*
This letter is in rebuttal to M. Misme's criticism of the authors' earlier article in the Proc. IRE. M. Misme points out that, granting his hypothesis, an exponential decrease of N with height is impossible in regions of the world where the specific humidity is greater than 10 gms/kg. He then reaches the conclusion that certain common applications of meteorological data to radio engineering problems are also not valid in these same areas of high atmospheric humidity. The authors' rebuttal consists of a demonstration that the experimental evidence is in marked disagreement with M. Misme's conclusions. By testing both M. Misme's hypothesis and their own original conclusions with new and independent experimental data from the arctic and the tropics, the authors conclude that their original model refractive index atmospheres have even broader application than originally supposed.

Interpretation of *p*H measurements in alcohol-water solvents, R. G. Bates and R. A. Robinson, *Proc. 7th Intern. Conf. Coordination Chemistry, Stockholm, Sweden, pp. 342–344 (1962).*
The liquid-junction potential between an aqueous salt bridge-reference electrode and solutions in ethanol-water solvents is shown to be dependent, as a first approximation, only on the solvent composition and not on the nature of the solute. The *p*H* appears to be the most practical unit for measuring the acidity of partially aqueous media.

The significance of transients and steady-state behavior in nonlinear systems, W. J. Hartman, *Proc. IRE Correspondence Section* **49,** *No. 3, 637 (Mar. 1961).*
The purpose of this note is to correct some mathematical errors made in a letter to the editor of the IRE by Wolf.

Measurements of effective temperatures of microwave noise sources, J. S. Wells, W. C. Daywitt, and C. K. S. Miller, *IRE Intern. Conv. Record, Pt. 3, 1200–1208 (Nov. 1962).*
The need for the calibration of gas discharge noise sources has existed for some time. In an effort to accommodate this need, work has been completed on a comparison system in X-band that uses a heated resistive wedge as a standard source of noise power.
The reference standard is based on Nyquist's Theorem and consists of a high temperature waveguide terminated by a suitably matched resistive element. The waveguide itself is one continuous piece with a heat sink on the flanged end. Two standards are in use; one of platinum—13 percent rhodium waveguide and the other of gold waveguide.
The comparison system is a modified radiometer of the type used by Dicke, the principal modification being the use of one arm for comparison purposes and the other arm for a reference. The powers from an unknown noise source and a standard noise source are compared through a single arm, and an indication of the ratio of the power levels is read as an attenuation difference on a precisely calibrated variable attenuator. The noise temperature of the unknown source is then determined from the attenuation difference, the temperature of the attenuator, and the effective noise temperature of the standard.
An error analysis includes sources of errors in the comparison system and in the standard source. The errors due to the comparison system consist of: mismatch and calibration errors associated with the precision variable attenuator; chart resolution uncertainty; switch uncertainty; and the ambient temperature uncertainty of the attenuator. For the standard source the errors include the mismatch factor of the standard (and also the corresponding one for the unknown source), errors due to the uncertainty in the temperature of the hot load, and the uncertainties in the calculation of the effective noise temperature.
All of these uncertainties will give a total error of 0.07 db in the excess noise ratio of a suitable unknown noise source to be calibrated.
The evidence of good repeatability in a set of measurements is presented along with the determination of the excess noise ratio of a commonly used, terminated, tube-in-mount noise source.

The calibration of temperature standards on the international practical temperature scale of 1948, J. P. Evans. *Proc. 17th Ann. Instrument.-Automation Conf. Exhibit, Instr. Soc. Am. Preprint No. 21-1-62 (New York, N.Y., Oct. 1962).*
The International Practical Temperature Scale of 1948 is maintained in this country by the National Bureau of Standards. This paper describes techniques used at NBS to calibrate temperature measuring devices on the scale and methods of transferring the scale to industrial temperature standards.

Mechanical properites of materials, R. H. Kropschot, *Book, Applied Cryogenic Engineering, Ed. R. W. Vance and W. M. Duke, 44–59 (John Wiley & Sons, Inc., New York, N.Y., 1962).*
The principal mechanical properties of materials from room temperature 300 °K (80 °F) to 4 °K (−452 °F) are summarized. The discussion includes the tensile strength, yield strength. toughness properties and why some materials having a certain crystal structure (face centered cubic) are more suitable for low temperature applications. The behavior of the materials that are commonly used in missile and space vehicles are portrayed by graphs and tables.

A sing-around velocimeter for measuring the speed of sound in the sea, M. Greenspan and C. E. Tschiegg, *Book, Underwater Acoustics, Lecture* **5,** *p. 87–101 (Plenum Press, Inc., New York, N.Y., 1962).*
The NBS–ONR underwater velocimeter is an instrument which automatically measures the speed of sound in the sea (it also finds use in the laboratory). The stability and precision of the instrument are adequate for all current uses. Models now being manufactured are transistorized and battery-powered, so that they can be used in the abyss. The principle of operation, together with construction details and performance characteristics, are given. The history of such instruments is briefly outlined, and the distribution of current models is indicated.

Refraction and dispersion of synthetic sapphire, I. H. Maltison, *J. Opt. Soc. Am.* **52,** *No. 12, 1377–1379 (Dec. 1962).*
The refractive indices of synthetic sapphire (Al_2O_3) were measured at selected wavelengths and the values of index range from 1.834 at 0.265 μ in the ultraviolet to 1.586 k at 5.58 μ in the infrared. A three-term Sellmeier dispersion equation of the form

$$n^2-1=\sum_i \frac{A_i\lambda^2}{\lambda^2-\lambda_i^2}$$

was fitted to the experimental data. Dispersive quantities were computed which estimate the optical performance to be expected from sapphire.

Polysulfide sealants: Part I. Formulation and application properties, D. A. George, L. Dunlap, and P. Stone, *Adhesives Age* **6,** *No. 2, 32–36 (Feb. 1963).*
The chemistry, formulation modifications, working properties, and factors affecting the working proportions of polysulfide sealants are discussed. The investigations shows that the working properties necessary for various applications can be obtained in polysulfide sealants.

Low temperature insulation, R. H. Kropschot, *Book, Applied Cryogenic Engineering, Ed. R. W. Vance and W. M.*

Duke, P. 152–169 (John Wiley & Sons, Inc., New York, N.Y., 1962).
The subject of cryogenic insulation has been divided into five categories: (1) high vacuum, (2) multiple layer, (3) powder, (4) rigid foam, and (5) supports. Recent data on the thermal conductivity and other properties of these insulations is presented in tabular and graphical form. Application of these insulations to cryogenic devices is discussed. In particular, the use of multiple layer insulation for insulating liquid helium and hydrogen containers is described. Some criteria for the comparison of different types of insulation are presented.

Precision of methods for measuring tensile strength, stretch, and tensile energy absorption of paper, T. W. Lashof, *Tappi* **46,** *No. 1, 52–59 (Jan. 1963).*
An interlaboratory study was conducted to evaluate the methods for tensile strength and stretch, and to evaluate a proposed method for measuring tensile energy absorption of paper. The study was made in accordance with Mandel's statistical linear model described in the tentative TAPPI Testing Practice T 1200. It is concluded that between-laboratory variability as compared with the within-laboratory variability is appreciable for the stretch method, but of only slight or negligible importance for the other methods. At higher values of stretch and tensile energy absorption the results are affected by the type of gripping jaw (flat or line) used, being greater for flat jaws. Values of precision are reported for within-laboratory replication, for within-laboratory comparison of materials, and for comparison of results between laboratories. Twelve replicate measurements are recommended; i.e., test results should be based on averages for 12 specimens.

Dimensional changes in dentures, G. C. Paffenbarger, J. B. Woelfel, and W. T. Sweeney, *Dental Practitioner* **13,** *No. 2, 64–69 (Oct. 1962).*
Four technic dentures and usually eight clinical dentures were made with eight different types of acrylic resins, a polystyrene, a vinylacrlyic copolymer, an epoxy resin and hard rubber. The dentures were processed with the equipment recommended by the manufacturer.
Thick dentures had less shrinkage on processing and less dimensional change during use, when wetted, dried in air and heated in water. Therefore, the denture should be made as thick as comfort and function will permit.
None of the dimensional changes of dentures that occurred during processing or in use could be detected clinically. The conventional acrylic resins processed with the usual dental technic of compression molding produced dentures that were just as stable in dimension as those produced by special resins and appliances.

Tunneling between a normal metal and a superconductor, J. Harden and R. S. Coller, *Cryogenics* **2,** *No. 6, 369–370 (Dec. 1962).*
The expression for the tunneling current through an insulating film between a normal metal and a superconductor was used to obtain a functional relationship between the energy gap and the inflection point of the current-voltage characteristic. For temperatures near the critical temperature, a more sensitive functional relationship was obtained between the energy gap and the slope at the origin of the current-voltage characteristic. The results are given in both graphical and tabular form.

Dislocations and chemical etch pits in copper, A. W. Ruff, Jr., *J. Appl. Phys.* **33,** *No. 12, 3392–3400 (Dec. 1962).*
The relation between chemical etch pits and dislocations has been studied in thin single crystal foils of copper. Both deformed and as-grown crystals in [111] orientations were employed. A procedure was developed for etching thin foils so that both the etch pits and dislocations were simultaneously revealed by transmission electron microscopy methods. Results are also presented from companion studies of unetched foils and replica studies of etched surfaces. Although a general relation was found between etch pits and dislocation emergence points, a one-to-one correspondence did not exist. A discussion is presented of other defects which may nucleate etch pits, including some experimental results on deformation-produced prismatic dislocation loops. The relation of the present results to dislocation studies by etching methods alone is mentioned.

Properties of a silica-reinforced polymer for dental restorations, R. L. Bowen, *J. Am. Dental Assoc.* **66,** *No. 1, 57–64 (Jan. 1963).*
The incorporation of vinylsilane-treated silica powder into an organic polymer reinforced the material. This reinforcement gave a number of properties more nearly matching those of hard tooth tissues than those obtained with unreinforced dental resin. When vinylsilane-coated silica (70%) was combined with a comonomer solution (30%), and the material allowed to harden, the hardening shrinkage and the coefficient of thermal expansion were decreased and the compressive strength, the modulus of elasticity, and the resistance to indentation were increased relative to direct filling resins. Compared with silicate cements, the reinforced resin had lower solubility and disintegration in water, was less affected by desiccation, and had higher tensile strength, but lower compressive strength.
The same resin filled with silican not having the vinylsilane surface treatment had inferior properties after equivalent immersion in water.

Mechanical basis of diffusion, C. Truesdell, *J. Chem. Phys.* **37,** *No. 10, 2336–2344 (Nov. 1962).*
Four types of theory of diffusion are distinguished, presented, and compared: kinematical, hydrodynamical, kinetic, thermodynamic. A simple mechanical theory, based upon recognizing the diffusive drags as forces that produce motions, is shown to include and unify all earlier attempts. In this theory a hypothesis of binary drags is formalized and shown to lead to the symmetry relations proposed originally by Stefan. The Onsager relations for pure diffusion are proved to be equivalent to Stefan's relations. Known results show that these relations hold as a first approximation in the kinetic theory of monatomic gas mixtures. Whether or not they hold in higher approximation is unknown.

Realistic estimates of error, W. J. Youden, *J. Instr. Soc. Am.* **8,** *No. 10, 57–58 (Oct. 1962).*
This paper emphasizes that the concept of the error in a measurement has meaning only in terms of the use to which the measurement is put. A method for the experimental estimate of realistic errors is given together with some efficient methods of tracking down the most important sources or error in a measurement.

Gas evolution from metal surfaces during fatigue stressing, W. L. Holshouser and J. A. Bennett, *Am. Soc. Testing Mater. Preprint* **62** *(June 1962).*
Numerous bubbles were observed to form under transparent pressure-sensitive tape applied to the surface of flat specimens stressed in reversed torsion. The bubbles were produced by hydrogen evolved at the surface of aluminum alloy or carbon steel specimens and appeared to be evidence of surface reactions associated with fatigue damage and crack propagation. Gas evolution started before any fatigue cracks could be detected. The effect was also observed on specimens stressed in reversed bending, but could not be produced by fluctuating stress smaller than that necessary to produce cracks nor by a single application of load of any magnitude. No gas evolution associated with fatigue damage could be observed on specimens of copper, brass, cadmium, nickel, stainless steel, tin, titanium, or zinc. The presence of the tape retarded the development of fatigue cracks in aluminum alloy and carbon steel specimens.

Conductive floors, F. L. Hermach, *Intern. Assoc. Elec. Inspectors News Bull., pp. 40–44 (July 1962).*
Electrically conductive floors are used to minimize hazards from electrostatic sparks in munitions plants and hospital operating rooms. This paper briefly describes such floors and their function, and discusses the safe limits of resistance.

Note on the Kubelka method of measuring water absorption of leather, R. L. Hebert and A. E. McDonell, *J. Am. Leather Chemists' Assoc.* **LVII,** *No. 9, 461–496 (Sept. 1962).*
The work done by the Joint ALCA–ASTM Committee on

the absorption of water by leather with the Kubelka method is described. The data for water absorption by leather obtained by two laboratories and an analysis for the precision of the Kubelka method are presented. A comparative statistical analysis of variance is also shown for the Kubelka and the ALCA E–30 methods. The committee decided that the results did not justify the adoption of the Kubelka method.

Intercomparisons of laboratory test results, J. Mandel. *Proc. Instr. Soc. Am. Paper* **44-3,** *5 pages (1962).*
The presence of experimental error in measurements makes it necessary to represent the process in terms of a statistical model. Such a model is presented and its use for the characterization of precision, both within- and between-laboratories, is illustrated.

Coatings formed on steel by cathodic protection and their evaluation by polarization measurements, W. J. Schwerdtfeger and R. J. Manuele, *Corrosion* **19,** *No 2, 59t–68t (Feb. 1963).*
Three steel specimens were continuously exposed in the laboratory for almost 5 years in city water to which was added 3 percent by weight of sodium chloride. Two of these specimens were under continuous cathodic protection, one by current from a zinc anode and the other by current from a rectifier through a carbon anode. The third specimen was left to corrode freely.
As a result of the cathodic protection, carbonates and silicates formed protective coatings which eventually reduced the current density required for protection from about 5 to 0.02 ma/ft.^{2}. A coated specimen, after being without protective current for 32 days (including 12 days out of the salt water), required only 0.3 ma/ft.^{2} for initial protection.
The instantaneous corrosion rates on the coated specimens (scratched and unscratched) while without protective currents were measured by changes-in-slope (breaks) in polarization curves. The currents at which breaks occurred in the cathodic curves were found to be related to $\Delta V/\Delta I$ values from the curves which values in turn bore a relation to the corrosion rates as measured by weight loss.

Variance of radio frequency caused by atmospheric turbulence in line-of-sight transmissions, K. A. Norton, E. C. Barrows, M.C. Thompson, Jr., and H. B. Janes (*Intern. Conf. Precision Electromagnetic Measurements, Boulder, Colo., 1962*), *IRE Trans. Instr.* **I–II,** *153 (Dec. 1962).*
The frequency stability of a radio signal propagated over a line-of-sight path is reduced by time variations in phase velocity along the path. This instability caused by the atmosphere will produce errors in frequency measurements made by averaging a standard frequency transmission over a period of time T and also in time interval measurements made by counting the number of cycles of the standard frequency received during a period of time T. Recent measurements of the variations in phase of a received signal at microwave frequencies permit estimation of both types of error as a function of T. These atmosphere-induced errors are compared to the errors inherent in the best currently available oscillators and it appears that the latter source of error is dominant for line-of-sight paths through the atmosphere. The level and slope of the frequency spectra have been observed to vary over wide ranges with time and geographical location. The spectral form $W(f) \sim 2/3$ expected on the basis of the Obukhov-Kolmogorov theory of atmospheric turbulence has a slope which lies well within the range of observed slopes for the range of fluctuation frequencies from one cycle per day to one cycle per second.

Instrument for the continuous measurement of the density of flowing cryogenic fluids, C. E. Miller, R. B. Jacobs, and J. Macinko, *Rev. Sci. Instr.* **34,** *24–27 (Jan. 1963).*
This paper describes the development of a new electromechanical method of measuring the densities of flowing cryogenic fluids. The instrument uses a movable section of flow passage, vibrated transversely at a constant amplitude and frequency, as the sensing element. A Dynamometer, inserted between the flow passage and driver, continuously measures the acceleration reaction (a product of mass and acceleration) of the fluid in the passage. A measure of this reaction is also a measure of the fluid density in the passage. Performance results indicate that the densitometer should be well suited for service in liquid oxygen and nitrogen single and two phase flow systems, and with only minor changes for use with liquid hydrogen.

Third International Conference on Precision Electromagnetic Measurements, W. D. George, *Nature* **139,** *No. 4858, 921–929 (Dec. 8, 1962).*
A summary of the 1962 International Conference on Precision Electromagnetic Measurements.

Measurement of RF peak pulse power by a sampling-comparison method, P. A. Hudson, W. L. Hudson, W. L. Ecklund, and A. R. Ondrejka (*Intern. Conf. Precision Electromagnetic Measurements, Boulder, Colo., 1962*), *IRE Trans. Instr.* **I–II,** *280 (Dec. 1962).*
A method is described whereby rf peak pulse power may be measured by comparison with cw power at the same frequency. Comparison is made by first sampling the power in a small portion of the rf pulse width and subsequently sampling the same portion of the cw signal whose power level is accurately known. Sampling is accomplished with a fast SPDT coaxial solid-state switch synchronized with the rf pulse. A time delay network allows the sample to be taken anywhere along the rf pulse width. Estimated maximum error for peak power levels to 10 KW is 3%. High cw levels are not necessary since the switch is used in conjunction with directional couplers to cover the power ranges of interest.

Radiation of sound by ocean waves, R. K. Cook, *Proc. 4th Intern. Congress Acoustics, Preprint 043 (Organization Committee, Copenhagen, Denmark, 1962).*
Wave trains of finite or semi-infinite length and traveling at subsonic speeds on the surface of water can radiate sound power into the atmosphere. Radiation integrals for the trains are used to compute the amount of atmospheric infrasound produced by ocean waves. The computed amounts are compared with measured infrasound having periods near five seconds.

Calorimetric determination of half-cell entropy changes, J. M. Sherfey, *J. Electrochem, Soc.* **110,** *No. 3, 213–221 (Mar. 1963).*
The reversible heat effects ($T\Delta S$) of half-cell processes have been measured in a twin calorimeter consisting of a Dewar flask divided into two halves by means of a vertical partition. Both compartments contain the same electrolyte and each has an electrode. A hole in the partition, covered by filter paper, permits the passage of electrolytic current between the compartments. The total heat effect and the heat due to irreversible phenomena are measured separately for each compartment. The difference between these two gives the desired reversible heat.
The half-cells studied include copper in acid copper sulfate, silver in acid silver perchlorate, and silver-silver chloride in various chloride solutions. The effect of "transport entropies" on these measurements is outlined. Presently accepted theories of the "irreversible" or "steady-state" thermodynamics of electrolytic cells predict the equivalence of half-cell entropy data obtained by the present calorimetric method and data obtained from thermocell studies. This predicted agreement was not obtained in the case of the half-cell silver-silver perchlorate.

Measurement and standardization of dielectric samples, H. E. Bussey and J. E. Gray (*Intern. Conf. Precision Electromagnetic Measurements, Boulder, Colo., 1962*), *IRE Trans. Instr.* **II–I,** *162 (Dec. 1962).*
The selection of a material suitable for use as a standard of dielectric properties at microwave frequencies is discussed, and tests are described which indicate that a glass and a glass-ceramic are satisfactory for such standards. The probable accuracy of measurement of the real part of the dielectric constant is estimated at $\pm 0.3\%$. Loss measurements are discussed. A correction is developed for the error resulting from the small airgap often present around the sample in transmission line measurements. The effects of humidity and temperature variations are examined, and preliminary results of measurements to 800 °C are given.

Polysulfide sealants, Pt. II. Service Properties, D. A. George, F. Roth, and P. Stone, *Adhesives Age* **6**, *35ff (Mar. 1963).*
The service properties of 28 2-part polysulfide sealants normally used as aircraft and spacecraft cabin sealants were investigated. The tensile strength, peel strength, resistance to elevated temperatures, resistance to corrosion, and their effects on the surface of an acrylic plastic were found to vary widely with some formulations being excellent in one or more properties. Excellent adhesion was found between some of these formulations and such substrates as acrylic plastics, glass, aluminum alloys, magnesium alloys, stainless steel and titanium.

Spectrum analysis of extremely low frequency variations of quartz oscillators, W. R. Stkinson, L. Fey, and J. Newman, *Proc. IRE* **51**, *379 (Feb. 1963).*
The spectral density of the frequency fluctuations of quartz oscillators has been determined over a decade range centered at 1×10^{-6} c/s and over a two-decade range centered at 0.2 c/s. Throughout all of the lower range and the lowest decade of the upper range the spectral density was observed to increase with decreasing frequency. It is pointed out that theoretical treatments of oscillator noise often consider thermal noise as the source of frequency fluctuations, but that the results of such analyses do not yield spectra similar to those observed. A computational difficulty encountered in utilizing the measurements is mentioned and possible ways of avoiding this difficulty are suggested.

Improved sample holder for X-ray diffractometer furnace, E. M. Levin and F. A. Mauer, *J. Am. Ceram. Soc.* **46**, *No. 1, 59–60 (Jan. 1963).*
An improved sample holder for the NBS X-ray furnace is described. Advantages and disadvantages are discussed.

Pitfalls in determinations of the compressive strength of concrete, J. R. Dise, *Mod. Concrete* **26,** *No. 3, 48–51 (July 1962).*
Information about the causes of variation in results of compressive strength tests of concrete is widely scattered through the literature on concrete testing. Certain portions of this information have been assembled and correlated with field observations in a general discussion which should be of interest, and perhaps benefit, to concrete technicians who have not had an opportunity to do this for themselves.

Determination of lead in leaded steels by X-ray spectroscopy, B. A. Kilday and R. E. Michaelis, *Appl. Spectry.* **16,** *No. 4, 136–138 (1962).*
The determination of lead in leaded steel by X-ray spectroscopy is highly dependent on proper surface preparation because of the tendency toward smearing or removal of the lead. A metallographic preparation technique using diamond dust as the abrasive is shown to provide reproducible and accurate results even with large changes in the particle size of the lead. This work is part of a cooperative program with the United States Steel Corporation in the preparation of a leaded-steel spectrochemical standard. Although certain inhomogeneities, both linear and radial, were observed by X-ray spectroscopy in the rods tested, suitable material has been selected for use as the NBS spectroscopic standard.

Infrasonics, R. K. Cook, *McGraw-Hill Yearbook of Science & Technology, pp. 275–276 (1962).*
This is a summary article on natural sounds in the atmosphere at infrasonic frequencies. The article is based on
(1) STR 2528 in the Dec. 1960 issue of the Technical News Bulletin.
(2) NBS Report 7172 on sound waves caused by magnetic storms, approved for publication in the Jour. of Geophysical Research.
(3) S. K. Mitra, "The Upper Atmosphere," published in India in 1952.

Image-gloss test; Apparatus and procedure, W. N. Harrison, *Proc. Porcelain Enamel Inst. Forum* **23,** *154–163 (1962).*
Several improvements in an image-gloss test apparatus and procedure are described, some of which provide greater convenience and adaptability. Others yield a large increase in reproducibility. The attribute measured is psychophysical in nature, involving the observer's visual response to one aspect of gloss; much of the diminution in scatter of test results is attributable to the incorporation of testing principles that have proven effective in psychophysical research.
Modifications in the apparatus and procedure make it possible to obtain a given precision of a determination with one-fifth the man-hours required for observations before the improvements were made.
Results of a roundrobin test are given. Observations by a contingent who did not follow instructions had substantially greater scatter than readings on the same specimens made by the recommended procedure.

Shear strength of beams without web reinforcement containing deformed bars of different yield strengths, R. G. Mathey and D. Watstein, J. *Am. Concrete Inst.* **60,** *No. 2, 183–207 (Feb. 1963).*
The behavior of reinforced concrete beams failing in shear was investigated in a series of tests in which the shear span to depth ratio and the ratio of reinforcement were varied. Six types of deformed bars with nominal yield strengths ranging from 40,000 to 100,000 psi and different stress-strain characteristics were used as tensile reinforcement.
The diagonal tension crack formed in all the beam specimens at stresses in the reinforcement which were within the range that was essentially elastic. The shear strengths at diagonal tension cracking decreased roughly linearly as the corresponding maximum stresses in the reinforcement increased for beams with the same shear span to depth ratio.
An empirical formula is presented for estimating the shear strength corresponding to the diagonal tension cracking load of beams rectangular in cross section without web reinforcement. The shear strengths developed in the beam specimens are compared with values given in the ACI Building Code (1956) and with values computed from the formula recently proposed by the ACI–ASCE Joint Committee on Shear and Diagonal Tension (1962).

Thermometric cells for calibration of liquid-in-glass thermometers, D. P. Enagonio, *Book Temperature, Its Measurements and Control in Science and Industry* **3,** *Pt. 2, 219–230 (Reinhold Pub. Corp., New York, N.Y., 1962).*
The freezing temperatures of purified compounds contained in sealed glass cells were studied as standards for the calibration of mercury-in-glass thermometers. Methods of using cells containing phenol, naphthalene, and phthalic anhydride for this purpose are given, together with the reproducibility of the maximum freezing temperature as measured with mercury-in-glass and with platinum resistance, thermometers.

Cryogenic testing of structural solids, R. M. McClintock, *Eng. Quart.* **2,** *No. 1, 28–35 (Feb. 1962).*
The features of a new tensile cryostat are presented to exemplify techniques used in the design of equipment and the measurement of temperature and strain at low temperatures. This cryostat allows tensile testing of metals or plastics at any temperature between 4 and 300 °K.
Typical data illustrative of the behavior of solids at low temperatures are also presented.

Uncertainties in calibrations, W. J. Youden, *IRE Trans. Instr.* **I-II,** *Nos. 3 & 4, 133–138 (Dec. 1962).*
This paper discusses the errors in calibrating standards under the headings:
Introduction
Determination of the Uncertainty Associated with a Specified Comparison Procedure
How Should the Uncertainty be Stated?
Discussion
Summary

Experimental determination of the frequency ratio of optical harmonics, H. S. Boyne and W. C. Martin, *J. Opt. Soc. Am.* **52,** *No. 8, 880–884 (Aug. 1962).*
The frequency ratio of the fundamental 6940 A radiation from a pulsed ruby optical laser and the second harmonic generated piezoelectric crystals has been investigated by comparing the wavelengths of the first and second harmonics with known thorium spectral lines on photographs taken with a 15,000-lines per-inch grating spectrometer.
Two piezoelectric crystals, potassium dihydrogen phosphate

and quartz, and one ferroelectric crystal, triglycine sulfate, were used to generate the second harmonic. In each case the generated second harmonic is twice the frequency of the primary radiation to within the limits imposed by the line width of the primary radiation and the resolution of the instrument. These restrictions limit the accuracy of the experiment to ± 3 parts per million (ppm) for KDP, ± 6 ppm for quartz, and ± 4 ppm for TGS. Some spectral characteristics of high energy pulses from the ruby optical laser as they might affect this experiment are given.

Energy use and power demands in all-electric houses equipped with air-to-air heat pumps, J. C. Davis and P. R. Achenbach, *ASHREA J.* **4,** *No. 9, 87–95 (Sept. 1962).*
An analysis was made of metered electrical-energy usage and power demand for all purposes in 16 sample houses from a total of 1,535 houses constructed at Little Rock Air Force Base. The energy used for cooling and heating by the air-to-air heat pumps installed in these houses and the effect of the electrical energy used by other appliances on the heating and cooling loads of the houses were of primary interest. The data from the sample houses showed an average annual energy usage of 25,300 kwh per house, of which about half was used by the heat pump and its auxiliary resistance heaters, about one-fourth for water heating, and the remainder for the electric range and miscellaneous devices. The electrical energy used for heating and cooling each averaged about 2 kwh/degree-day per thousand square feet of inside floor area, using a 65 °F base for determining the degree-days in each case. It was found that the energy used by appliances, other than the heat pump, which contributed toward heating the house was about half the amount used by the heat pump during the winter months. The analysis revealed that the monthly maximum power demand for the entire housing area was probably caused by a moderately high sustained demand in many houses rather than a coincidence of the maximum demands in a smaller number of houses.

Ferroelectric switching and the Sievert integral, P. H. Fang and I. R. Stegun, *J. Appl. Phys.* **34,** *No. 2, 284–286 (1963).*
A connection between some ferroelectric switching functions and the Sievert integral is established. Switching functions of Landauer *et al.* and of Franklin are computed and discussed.

Temperature dependence of elastic constants of vitreous silica, S. Spinner, *J. Am. Ceram. Soc.* **45,** *No. 8, 394 (Aug. 1962).*
The relation between the elastic moduli and temperature from room temperature to about 1300 °C was determined for a group of vitreous silica specimens by a dynamic resonance method. All the curves were approximately parabolic in shape reaching a maximum near 1050° to 1200° C. At the maximum value, Young's modulus was more than 11% higher and the shear modulus was about 9% higher than their room-temperature values. Poisson's ratio was then computed to rise from about $\frac{1}{6}$ at room temperature to about $\frac{1}{5}$ at the temperature of maximum elastic modulus. Small but significant differences were observed in the temperature-modulus curves for specimens from different sources. These differences were found to be related to differences in the infrared transmission curves.

On the realistic measurement of precision and accuracy, C. Eisenhart, *ISA Proc. Eighth Natl. Aero-Space Instrumentation Symp., Washington, D.C., pp. 75–83 (May 1962).*
The nature and objectives of measurement. Measurement as a production process. Measurement processes as realizations of methods of measurement. Essential features of the correction of measurements; of the adjustment of measurements. The concepts of limiting mean, true value, bias, precision, and accuracy. The strong law of large numbers and mathematical formulation of the bias and the precision of a measurement process. Importance of being clear on exactly what variations of procedure, apparatus, observers, and environmental conditions are allowable in "repeated" applications of what is to be considered the *same* measurement process (or, the *same* method of measurement) applied to measurement of the *same* quantity under the *same* conditions.

Other NBS Publications

Journal of Research 67A (Phys. and Chem.), No. 3 (May–June 1963) 70 cents.
An absolute calibration of the National Bureau of Standards Thermal Neutron Flux. E. J. Axton. (See above abstract.)
Absorption bands of carbon dioxide from 5.3 to 4.6 microns. A. G. Maki, E. K. Plyer, and R. J. Thibault.
Infrared spectrum of the $\nu_2-\nu_5$ band of $C^{13}C^{12}H_6$. W. J. Lafferty and E. K. Plyler.
Self-broadening of carbon monoxide in the 2ν and 3ν bands. E. K. Plyler and R. J. Thibault.
Thermodynamic properties of polyethylene predicted from paraffin data. M. G. Broadhurst.
Spectrophotometric determination of the thermodynamic pK value of picric acid in water at 25 °C. M. M. Davis and M. Paabo.
Purity analysis of highly purified materials by time-temperature cryometry. G. S. Ross and H. D. Dixon. (See above abstract.)
Synthesis of isomers of eugenol. G. M. Brauer, R. W. Morris, and W. B. Howe. (See above abstract.)
Analysis of families of curves. J. Mandel and F. L. McCrackin. (See above abstract.)
A controlled atmosphere chamber. C. L. Gordon and R. B. Johannsen. (See above abstract.)

Journal of Research, 67B (Math. and Math. Phys.), No. 2 (Apr.–June 1963), 75 cents.
Maximum cellular Boolean functions and perfect Gray codes. A. J. Goldman and B. K. Bender.
The meaning of Betti's reciprocal theorem. C. Truesdell. (See above abstract.)
Effect of molecular weight on viscoelastic properties of polymers as predicted by a molecular theory. H. Oser and R. S. Marvin. (See above abstract.)
Selected bibliography of statistical literature: supplement, 1958–1960. L. S. Deming.

Journal of Research 67D (Radio Prop.), No. 3 (May–June 1963), 70 cents.
Effects of radio wave propagation through mid-latitude 6300 A arcs. J. R. Roach.
Comparison of observed atmospheric radio refraction effects with values predicted through the use of surface weather observations. B. R. Bean and G. D. Thayer.
Ionospheric scattering effects in long-distance propagation. H. A. Whale.
Concerning solutions of the VLF mode problem for an anisotropic curved ionosphere. J. R. Wait.
On the statistical theory of electromagnetic waves in a fluctuating medium (I). K. Furutsu. (See above abstract.)
Reception of skywave signals near a coastline. J. B. Andersen.
Analysis and synthesis of nonuniform transmission lines or stratified layers. G. Latmiral, G. Franceschetti, and R. Vinciguerra. (See above abstract.)
Resonant characteristics of a corrugated sphere. J. R. Wait and C. M. Jackson.
Impedances of long antennas in air and in dissipative media. D. W. Gooch, C. W. Harrison, Jr., R. W. P. King, and T. T. Wu.
Reflection of VLF radio waves from an inhomogeneous ionosphere. Part I. Exponentially varying isotropic model. J. R. Wait and L. C. Walters.

Journal of Research 67D (Radio Prop.), No. 4 (July–Aug. 1963) 70 cents.
Influence of the lower ionosphere on propagation of VLF waves to great distances. J. R. Wait.
Comments on a paper "Auroral Sporadic-*E* Ionization" by Robert D. Hunsucker and Leif Owren. J. M. Bullen and G. A. M. King.
Reply to J. M. Bullen and G. A. M. King's "Comments on a paper 'Auroral Sporadic-*E* Ionization' by R. D. Hunsucker and L. Owren." R. D. Hunsucker and L. Owren.
Optimum reception pattern of the Beverage wave antenna at very low frequencies. E. W. Seeley.

Effect of a dissipative medium of finite size on antenna measurement. K. Iizuka and R. W. P. King.

Some implications of aircraft interference patterns in troposcatter reception. J. A. Bradshaw.

Asymptotic behavior of the current on an infinite cylindrical antenna. K. S. Kunz. (See above abstract.)

A dipole approximation of the backscattering from a conductor in a semi-infinite dissipative medium. M. B. Kraichman.

Small electric and magnetic antennas with cores of a lossy dielectric. J. Galejs.

The thermodynamic properties of nitrogen from 114 to 540 °R between 1.0 and 3000 psia, Supplement A (British units), T. R. Strobridge, NBS Tech. Note 129A (Feb. 1963), 50 cents.

Fading correlation bandwidth and short-term frequency stability measurements on a high-frequency transauroral path, J. L. Auterman, NBS Tech. Note 165 (Oct. 1962), 40 cents.

Profiles of electron density over the magnetic equator obtained using the incoherent scatter technique, K. L. Bowles et al., NBS Tech. Note 169 (Mar. 16, 1963), 25 cents.

Lectures on ion-atom collisions, M. R. C. McDowell, NBS Tech. Note 185 (Mar. 15, 1963), 40 cents.

Transmission and reflection of electrons by aluminum foils, M. J. Berger, NBS Tech. Note 187 (April 1, 1963), 15 cents.

The following National Bureau of Standards Technical Note is available by purchase from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (please order by PB number).

An atlas of whistlers and VLF emissions, A survey of VLF spectra from Boulder, Colo., D. L. Jones, R. M. Gallet, J. M. Watts, and D. N. Frazer, NBS Tech. Note 166 (PB181454) (Jan. 1963), $2.25.

Heats of formation of two isomers of difluorodiazine, G. T. Armstrong and S. Marantz, J. Chem. Phys. **38,** No. 1, 169–172 (Jan. 1963).

Intramolecular rearrangements. V. Formation of ethylene in the photolysis of ethyl acetate from 4 to 500° K, P. Ausloos and R. E. Rebbert, J. Phys. Chem. **67,** No. 1, 163–167 (Jan. 1963).

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