

THE

General Radio EXPERIMENTER



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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

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A HIGH-FREQUENCY VOLTAGE STANDARD

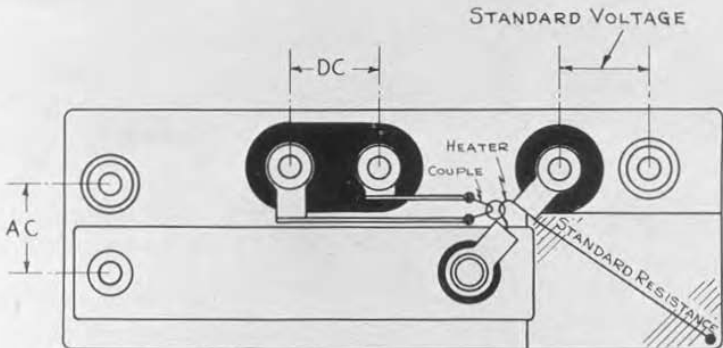
● **IN DESIGNING** vacuum-tube voltmeters and standard-signal generators, it is frequently necessary to have a voltage standard which is good at high frequencies. A convenient standard is the voltage drop across a standard resistor when the current through

it is measured by means of a thermocouple. This arrangement can be calibrated on direct current by reference to a standard cell and, provided the frequency characteristics of the elements are known, is quite usable for high frequencies. In practice, the best solution is to design couples and resistance elements having negligible frequency error at the frequencies where it is desired to work.

A few years ago, sufficient accuracy was obtained with an Ayrton-Perry-wound resistor and an ordinary vacuum thermocouple, because

(Continued on page 2)

FIGURE 1. Voltage standard, making use of a ribbon resistor separated from the metal return path by 1-mil mica



accurate measurements were not required above a few megacycles. Present-day requirements are more severe, calling for measurements at much higher frequencies.

Considerable work* has recently been done on computing the characteristics of acorn-tube voltmeters and comparing the performance of different tubes with each other and with theoretical considerations.

In order to obtain an independent calibration of voltage indicators, a thermovoltmeter standard for direct measurements at high frequencies has been devised at the General Radio Company.

Errors in the thermocouple-resistor system are caused by (1) skin effect and capacitance to ground in the thermocouple heater and (2) skin effect, inductance, and ground capacitance in the standard resistor.

The design of a thermocouple for use at frequencies up to hundreds of megacycles is not difficult. The heater can be made from wire of small diameter, keeping skin

*L. S. Nergaard, "Electrical Measurements at Wavelengths Less Than Two Meters," *Proc. I.R.E.*, September, 1936.

FIGURE 2. Photograph of the final model of the high-frequency voltage standard, using a $\frac{1}{16}$ -inch length of 0.0004-inch resistance wire as an impedance standard. A transparent disc covers the unit to protect the parts and to avoid errors in readings resulting from air currents



effect at a low value. The skin effect in a piece of manganin wire 2 mils in diameter amounts to only 1% at 100 megacycles. It is possible to draw a wire to 0.25 mils and this would have a calculated skin effect of 1% at 4000 megacycles.

The heating effect can be measured by using a thermocouple whose junction is insulated from the heater. The insulator can be made to have a capacity of less than 0.1 μf so that the capacitive current from the heater to ground can be kept negligible if the impedance from the heater to ground is kept low. Thus it appears that the current flowing in the heater of a thermocouple can be known accurately, but it is another matter to make use of this knowledge.

When a thermocouple is used for measuring voltages, an impedance standard is necessary. Probably the best impedance is a pure resistance. While this cannot be strictly realized, it may, by proper design, be approached. The circuits must be so arranged that the current flowing through the thermocouple is the same as that flowing through the standard impedance. Further, the standard voltage should be essentially equal to the voltage drop in the resistor, that is, there should be no induced emf in the leads to the standard terminals.

One arrangement made five or six years ago for testing signal generators is shown in Figure 1. The resistance unit consisted of a short length of 2-mil manganin wire rolled into a ribbon 10 mils wide and separated from a grounded slab of metal by a 1-mil sheet of mica. This rather unconventional design was used in an attempt to avoid the large inductive reactance associated with low-resistance units. The reduction was accomplished by treating the resistor as a transmission

line and attempting to make $\sqrt{\frac{L}{C}}$ about equal to R . Actually, a still closer spacing would have been desirable.

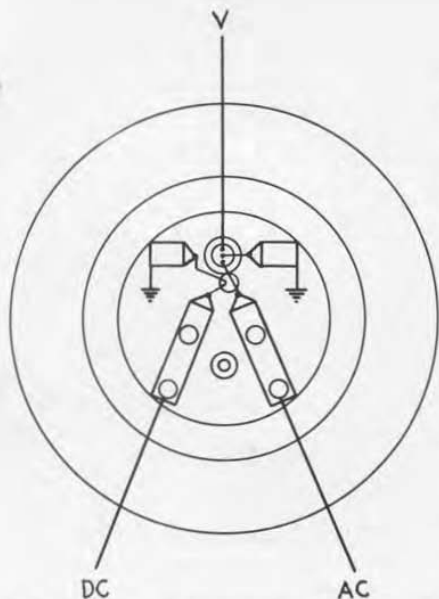


FIGURE 3. Diagram of connections for the standard of Figure 2. The return paths are through the grounded brass case

It will be noticed that the potential terminals are connected to the resistor in a manner calculated to eliminate wiring inductance in a sort of high-frequency analogue of the conventional four-terminal resistor commonly used for direct currents.

Another and more satisfactory way of decreasing the inductance (and the capacitance as well) is to decrease the necessary length by using much finer wire. Figure 2 shows a unit consisting of a piece of resistance wire 0.0004 inch in diameter, only $\frac{1}{16}$ inch long, and having a resistance of about 7 ohms.

In this case, as with the resistor of Figure 1, the thermocouple heater was joined directly to the resistor in air rather than risk errors inherent in the long lead wires of the usual glass bulb construction of a vacuum couple.

The inductance of the second resistor unit is computed at about 1.6 cm (1.6×10^{-9} h) which gives an inductive reactance

of 1 ohm at 100 Mc. Since this is added in quadrature to the resistance, the impedance is only increased 1%. As previously mentioned, the skin effect is entirely negligible.

Wire is now available having a diameter of 0.00025 inch. A unit of the same size as the present one, if made of such wire, would have an inductive error of 1% at 250 Mc. Another improvement over the present unit would consist in using the thermocouple heater itself as the standard resistance, taking the same precautions to minimize mutual inductance.

The voltage standard of Figure 2 has been used in measuring the error of indication as a function of frequency in the TYPE 726-A Vacuum-Tube Voltmeter and the variation of output voltage with frequency in the TYPE 605-A Standard-Signal Generator. This voltage standard in conjunction with a heterodyne method of measuring attenuation ratios provides an absolute voltage calibration for standard-signal generators. The complete system will be described in an early issue of the *Experimenter*. —L. B. ARGUMBAU

FIGURE 4. Outside view of the voltage standard of Figure 2, indicating shielding of the output terminals from the ground leads. The standard was made as a detachable unit so that it could be used in several assemblies





AT THE SILVER ANNIVERSARY CONVENTION

● THE PHOTOGRAPH above shows the General Radio booth at the Silver Anniversary Convention of the Institute of Radio Engineers, held in New York,

May 10 to 12. A number of the newer instruments were displayed, and several members of the engineering staff were in attendance.

NEW DIAL PLATES



● THE TYPE 318-A DIAL PLATE, intended for use with General Radio rheostat-potentiometers, has been replaced with a new model, TYPE 318-B. The new plate has ten numbered divisions, each subdivided into five equal parts. This total of fifty divisions covers a rotational angle of 298°. The scale is photo-etched, with raised nickel-silver graduations on a flat black background. Mounting holes coincide with those of General Radio rheostat-potentiometers having a three-hole mounting.

The diameter is 3 inches and the plate is intended for use with a 1 $\frac{5}{8}$ -inch knob, such as TYPES 637-G, -H, -J, and -K.

Type
318-B

Code Word
DEVIL

Price
\$0.35

GENERAL RADIO 4



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AN IMPROVED OUTPUT METER

● **THE HIGH IMPEDANCE** and inherent ruggedness of the copper-oxide-rectifier type voltmeter are advantages which more than offset its accuracy limitations. Because of this, the TYPE 483 Output Meter, which consists of a copper-oxide voltmeter and a resistive multiplier network for extending the range, has been widely used in laboratories where audio-frequency measurements are made.

Recent improvements in rectifier-type instruments have resulted in a meter with much better characteristics than were possible a few years ago. Using this new instrument, the General Radio Company has designed a new model of the TYPE 483 Output Meter. In addition to better electrical performance, the new TYPE 483-F Output Meter has several improved features of mechanical design. The characteristics of the instrument are discussed below.

Full-scale deflection on the indicating instrument is 2 volts. The L-type multiplying network provides full-scale ranges of 2, 4, 10, 40, 100, and 200 volts. A schematic diagram of the circuit is shown in Figure 1, a photograph of the instrument in Figure 2.

Errors in copper-oxide instruments fall into two classes: (1) errors in the voltage indication as a function of frequency, temperature, and waveform, and (2) changes in impedance as a function of voltage.

(1) ERRORS IN INDICATION

The frequency error is caused by the shunting effect of input capacitance and is not serious below 6 or 7 kilocycles. Figure 3 shows an average frequency characteristic for a number of meters as well as the maximum deviation from the average within the group tested.

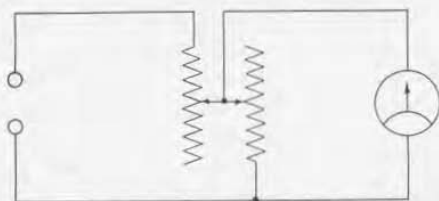


FIGURE 1. Schematic wiring diagram of the TYPE 483-F Output Meter

All copper-oxide rectifiers show temperature effects, but the new design used in the output meter has a zero temperature coefficient in the normal range of room temperatures. This is shown in Figure 5.

The indication of a copper-oxide instrument depends upon the average value

FIGURE 2. Photograph of the new output meter



of the applied voltage over a complete cycle. TYPE 483-F Output Meters are calibrated in r-m-s values on a sine-wave source. When used to measure non-sinusoidal voltages, the error in indication will depend upon the degree by which the ratio of rms to average for the applied voltage differs from that for a sine wave. Consequently, this error is affected by both magnitude and phase of harmonics.

(2) IMPEDANCE ERROR

The impedance characteristic of the copper-oxide instrument itself as a function of voltage applied is shown in Figure 4. This indicates the average impedance error which occurs on the 1 multiplier. The impedance of individual instruments may deviate from the values shown by as much as 10%.

When the multiplying network is in circuit, the error decreases and, for the 100 multiplier, the impedance is 20,000 ohms $\pm 2\%$. The error in impedance increases as the multiplier setting is reduced,

but, since the meter impedance error decreases with applied voltage, the minimum impedance error for a given voltage measurement will occur at the multiplier setting which gives the highest on-scale reading. In other words, with 2 volts applied, the reading should be taken at full

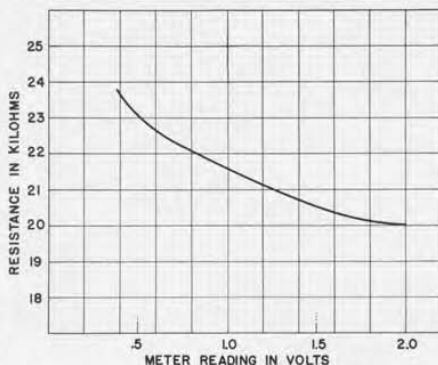
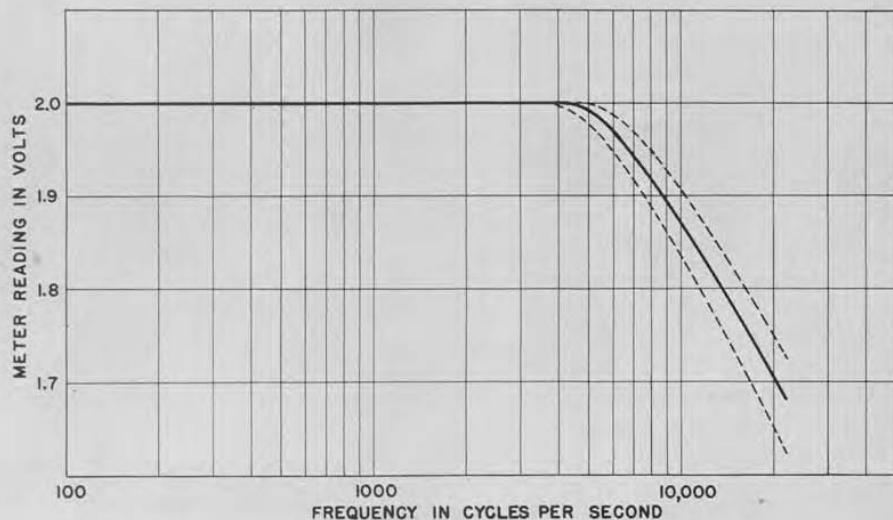


FIGURE 4. The frequency characteristic of the oxide-rectifier meter itself as a function of applied voltage. The maximum variation from the curve shown is $\pm 10\%$

scale on the 1 multiplier, rather than at half-scale on the 2 multiplier.

Mechanically, improvements in the out-

FIGURE 3. Average frequency characteristic of the meter. The dotted lines show the maximum deviation from average



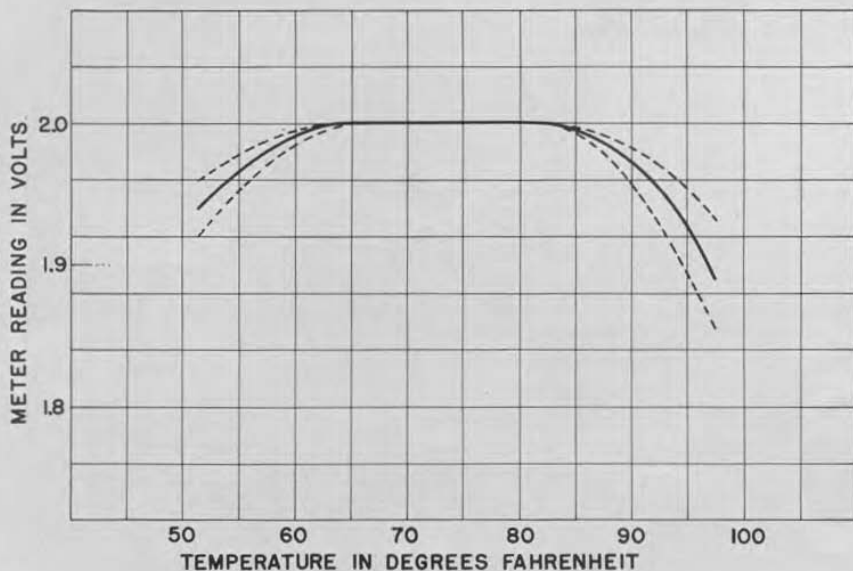


FIGURE 5. This shows the effect of temperature on the meter indication. It will be noted that in the normal room temperature range the temperature coefficient is practically zero. The dotted lines indicate the maximum deviations to be expected

put meter consist of using a TYPE 510 Switch with concealed, dustproof contacts, and mounting the assembly on an aluminum panel finished in black crackle lacquer.

From the foregoing it is evident that the TYPE 483-F Output Meter is not a precision standard of voltage. Its accuracy is, however, sufficient for most rou-

tine laboratory measurements. By far its greatest field of usefulness is in comparison measurements of various types, where the meter is used to match two voltages. Here temperature and frequency errors cancel, and even waveform errors are seldom important, because usually a single voltage source is used.

—W. G. WEBSTER

SPECIFICATIONS

Voltage Range: Below 0.5 volt to 200 volts in seven steps.

Input Impedance: Nominally 20,000 ohms.

Frequency Characteristic: See Figure 3.

Temperature Characteristic: See Figure 5.

Accuracy: $\pm 5\%$ of full scale, which is

equivalent to ± 0.1 volt multiplied by the multiplier setting. This figure holds only when frequency and temperature fall on the flat portion of the curves of Figures 3 and 5 and when the waveform of the applied voltage is sinusoidal.

Net Weight: 3 pounds, 9 ounces.

Dimensions: (Length) $9\frac{3}{8}$ x (width) $4\frac{1}{4}$ x (height) $5\frac{1}{4}$ inches, over-all.

Type	Code Word	Price
483-F	AVOID	\$54.00

This instrument is manufactured and sold under U. S. Patent No. 1,901,343.

7 EXPERIMENTER



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MISCELLANY

● **THE GENERAL RADIO COMPANY** cordially invites readers of the *Experimenter* to inspect its exhibit of laboratory and industrial apparatus at the Fortieth Annual Meeting-Exhibit of the American Society for Testing Materials. The exhibition will be held June 28 through July 2 in the Astor Gallery of the Waldorf-Astoria Hotel, Park Avenue and 49th Street, New York City.

Mr. Robert Field, design engineer responsible for the development of the TYPE 516-C Radio-Frequency Bridge, the TYPE 544-B Megohm Bridge, and the TYPE 716-A Capacitance Bridge, and Mr. Frederick Ireland of the general engineering department will be in attendance at the exhibit.

Because of their particular interest to the members of the A.S.T.M., the new TYPE 716-A Capacitance and Power Factor Bridge and the new TYPE 544-B Megohm Bridge will be on display. Industrial devices such as the TYPE 548-B Strobe-

scope, the TYPE 631-A Strobotac, the TYPE 759-A Sound-Level Meter, and the TYPE 725-A Color Comparator will be presented for the inspection of engineers less interested in electrical measurements.

● **THE CHAIRMAN** of our Board of Directors, Mr. Henry S. Shaw, has just been honored by being elected a Fellow of the American Academy of Arts and Sciences.

● **ON MAY 21**, H. H. Scott, of the General Radio engineering staff, spoke before a joint meeting of the Detroit section of the Institute of Radio Engineers and the Engineering Society of Detroit. Also present were members of the American Society of Mechanical Engineers and the Cleveland Engineering Society. Mr. Scott's subject was "The Stroboscope and the Sound-Level Meter, Electronic Aids in the Elimination of Noise." The talk was illustrated by lantern slides and high-speed motion pictures.

***T**HE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company name, company address, type of business company is engaged in, and title or position of individual.*

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