THE General Radio EXPERIMENTER

VOLUME XXII No. 6 NOVEMBER, 1947

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A WIDE-RANGE OSCILLATOR FOR AUDIO AND SUPERSONIC FREQUENCIES

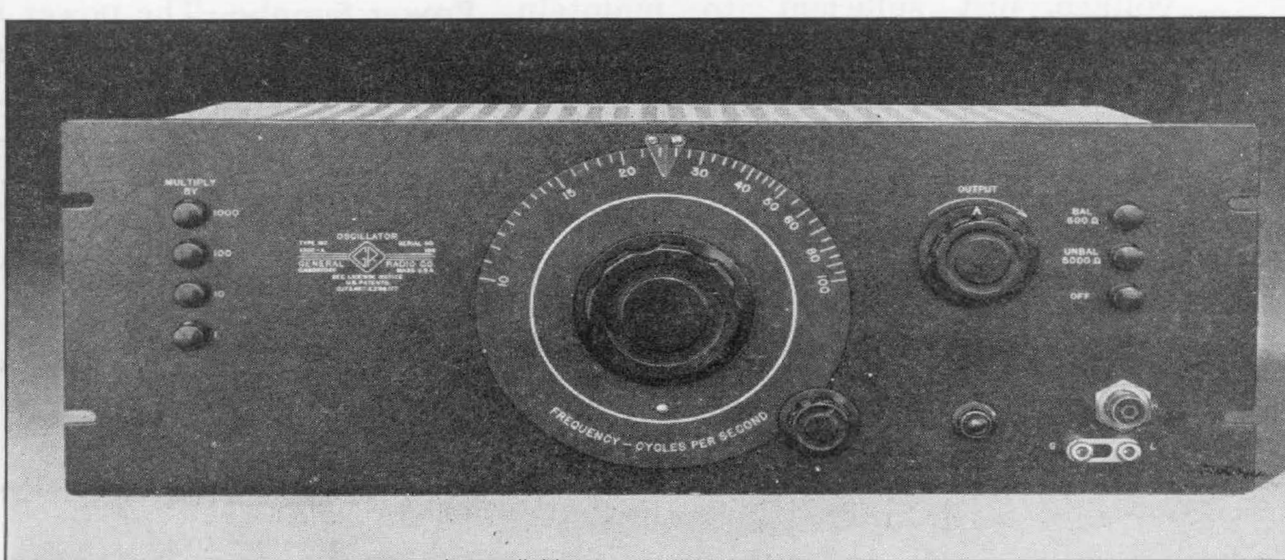
Also

IN THIS ISSUE

● **THE NEED** has long been apparent for a high-quality laboratory oscillator covering both audio and supersonic frequencies. Present-day laboratory measurements of gain, distortion, impedance, and frequency response require a power source covering frequencies well above the nominal audio-frequency limit of 20,000 cycles, and having as well the desirable characteristics of low distortion, stability of frequency, and uniform output over the frequency range. The TYPE 1302-A Oscillator has been designed to meet these requirements. In addition, the oscillator is easy and convenient to use, is stabilized against the effects of line-voltage changes, and has separate output circuits for high- and low-impedance loads. A discussion of the circuit will show how these features are achieved.

Oscillator—Figure 2 is an elementary schematic diagram of the oscillator. The basic oscillator circuit employs a two-stage amplifier and a

Figure 1. Panel view of the Type 1302-A Oscillator.



modified form of a Wien bridge. The output of this frequency-selective network balances to a null at one frequency and results in a negative feedback voltage at all others. Thus the amplifier has a maximum gain at the frequency at which the negative feedback voltage approaches zero. This condition can cause oscillations of the amplifier at one frequency, if a positive feedback voltage is introduced which has just sufficient amplitude to equal the losses around the loop. The amplitude of oscillation can thus be controlled by means of the positive feedback voltage, and to do this, a second set of bridge arms is added in parallel with the reactance arms of the modified Wien bridge. These additional bridge arms are resistive, but one is an incandescent lamp, which has a non-linear resistance.

The operation of these circuits can be better understood by referring to Figure 3, which shows their development from the simple Wien bridge. An examination of Figure 2 will show that the voltage at the junction point of R_3 and R_4 can result in either positive or negative feedback around the loop, depending upon the relative magnitudes of R_3 and R_4. Feedback directly from the plate of V-2 produces regeneration; while feedback from the cathode results in degeneration.

Proper selection of the ratio of R_3 to R_4 will result in a positive feedback voltage just sufficient to maintain oscillations at the normal level. An increase in e_g will cause an increase in the total bridge voltage and thus result in a current increase through R_3 and R_4. Since the resistance of R_3 varies with the current through the lamp, the ratio of R_3 to R_4 has been changed in a direction so as to reduce the magnitude of e_2. This reduction in positive feedback compensates for the increase in e_g, thus producing a-v-c action.

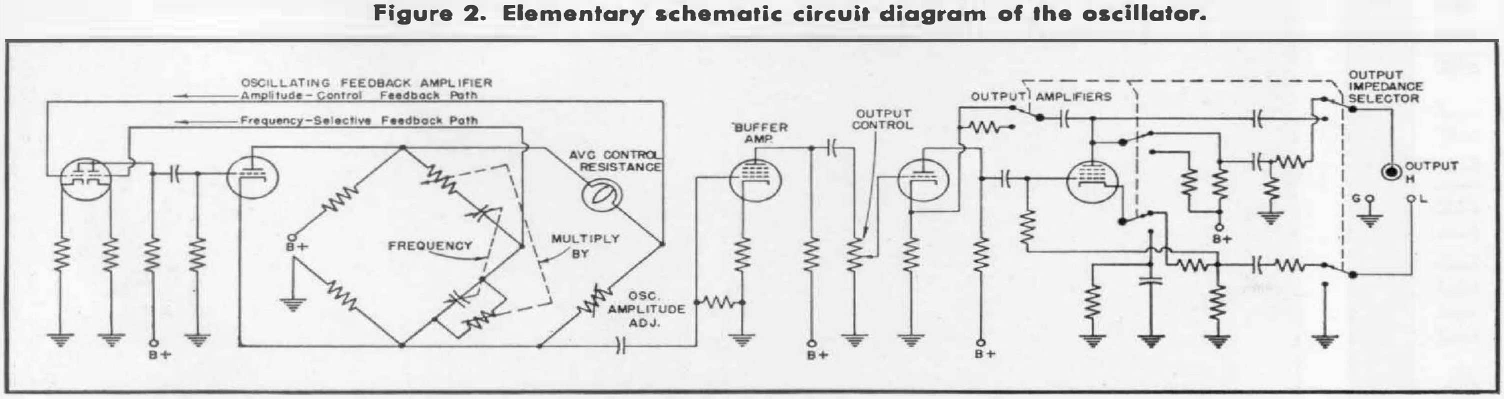
For frequency control elements, the two reactance arms of the modified Wien bridge are used. The two capacitances C_1 are ganged variable-air condensers driven by the main tuning dial; while the resistances R_2 are selected by means of the multiplier switches.

Amplifiers—A buffer amplifier is used to isolate the output control from the oscillator section and thus to prevent reaction of the control upon the frequency of the oscillator. The output control is located ahead of the final amplifier in order that it have no effect upon the balance and the magnitude of the load impedances.

Negative feedback is employed in the amplifier to reduce harmonic distortion, to provide a flat frequency response, and to minimize the effects of tube characteristics. Transformers are not used, because of the wide frequency range covered and the low distortion requirements at low frequencies.

Power Supply—The power supply employs an electronic voltage regulator,

Figure 2. Elementary schematic circuit diagram of the oscillator.



which combines the functions of plate voltage regulation and power-supply filtering. The power transformer is designed for 50- to 60-cycle operation and can be changed from 115-volt to 230-volt operation by changing taps on the transformer primary.

OPERATING CHARACTERISTICS

Frequency Range

The use of the Wien bridge as a frequency-determining circuit makes it possible to cover a wide range of frequency quickly and conveniently. The main dial is direct reading from 10 to 100 cycles, and multipliers of 1, 10, 100, and 1000 are provided.

A full decade of frequencies is covered by a 180-degree rotation of the dial. Decade changes in frequency can be obtained by depressing the panel multiplier switch. This arrangement is particularly convenient when bridge measurements are to be made over several decades of frequency.

The variable air condensers used as the frequency-controlling elements give complete freedom from the contact irregularities usually encountered with variable resistance elements. Precision fixed resistors are used to provide multiplier ranges.

Frequency Stability

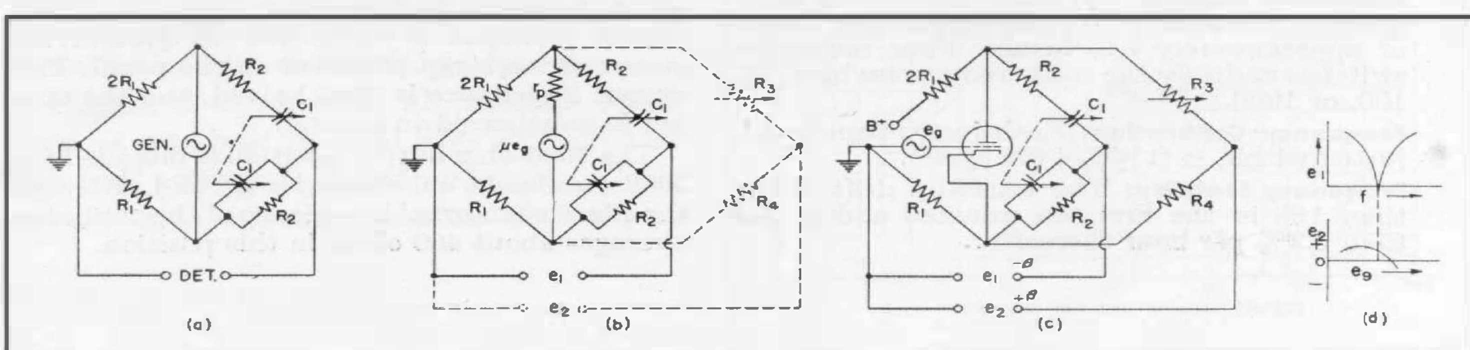
For many applications, among them bridge measurements at low frequencies, it is desirable that any frequency drift be a constant percentage of the operating frequency rather than a constant number of cycles, as in a beat-frequency oscillator. Any drift occurring in the TYPE 1302-A Oscillator is of this type. The use of air condensers and precision resistors holds frequency drift to an extremely small value—not more than 0.2% per hour after a warm-up period of 10 minutes.

In measurements, one source of considerable annoyance is the erratic fluctuation of the frequency and amplitude of an oscillator, caused by sudden shifts in the power line voltage. In many industrial laboratories line voltage surges are common and occur whenever heavy intermittent loads are switched on or off in the plant. It is necessary to compensate the oscillator for transient voltage surges, as well as for the average line voltage shifts, if these effects are to be minimized. The voltage-regulated power supply in this oscillator has been designed so as to eliminate the effects of line voltage variations between the limits of 105 to 125 (210 to 250) volts.

Waveform

Bridge measurements, the measurement of the transmission characteristics of filters, distortion measurements, and a number of others require good waveform in the power source. The Wien

Figure 3. Development of the oscillator circuit from the basic Wien bridge; (a) shows the frequency-selective Wien bridge circuits; (b) the circuit with a second pair of arms shown dotted; (c) the complete oscillator feedback circuit; (d) amplitude and frequency characteristics of the two feedback circuits.



bridge circuit inherently suppresses harmonics, as shown in Figure 2, while the degeneration practically eliminates distortion in the amplifier. The total distortion at any frequency is less than 1%.

Output Circuit Characteristics

There are two output circuits provided: one unbalanced and designed to work into any load impedance down to 5000 ohms, and a second, balanced, output for use with a 600-ohm load. The 600-ohm balanced output may also be operated into a 300-ohm load with one side grounded. These impedances cover a sufficient range for most bridge measurements. For matching other load impedances, the Type 578 Shielded Transformers are recommended.

The output level is held constant within ±1 db over the entire frequency range by the bridge-type automatic amplitude control. Approximately 80 milliwatts into a 5000-ohm unbalanced load, or 40 milliwatts into a balanced 600-ohm load, can be obtained. Open circuit output voltages are approximately 22 and 10 volts, respectively.

The effective output impedances are: between 250 and 750 ohms for the 5000-ohm position and 550 ohms, constant, for the 600-ohm position. The 600-ohm position is intended to match into 500-ohm/600-ohm lines.

General Applications

Because of its wide frequency range and flat output voltage characteristic, this oscillator is well adapted for taking frequency response characteristics on amplifiers, telephone lines, filters, etc. Extremely rapid "spot checks," at frequencies exactly one decade apart, are possible owing to the decade switching feature. The wide frequency span, extending well into the ultrasonic range, is useful in checking the overall phase shift characteristics of audio amplifiers employing feedback circuits.

The instrument is reasonably well shielded, and the output is available through coaxial-type connectors, features which make the oscillator suitable for bridge measurements using sensitive detectors. The output terminals are arranged to be used with either Type 274 (pin-type) or Type 774 (coaxial) connectors.

The frequency range includes all frequencies at which the Type 716-C Capacitance Bridge is direct-reading, and consequently it is an excellent oscillator for use with that bridge.

—C. A. Cady

SPECIFICATIONS

Frequency Range: 10 to 100,000 cycles, in four ranges. Each range covers a decade (10-100 cycles, 100-1000 cycles, 1000-10,000 cycles, and 10,000-100,000 cycles) continuously variable.

Frequency Control: The main control dial is engraved from 10 to 100 cycles over a scale length of approximately 8¾ inches. Four multiplier switches multiply the scale frequencies by 1, 10, 100, or 1000.

Frequency Calibration: Each instrument is adjusted within ±(1½%+0.2 cycle).

Frequency Stability: The warm-up drift is less than 1% in the first ten minutes and is less than 0.2% per hour thereafter.

Output Impedance: Two output circuits are provided, balanced 600 ohms and unbalanced 5000 ohms.

The internal impedance of the 600-ohm output is constant at 550 ohms unless the LOW output terminal is connected to ground by means of the strap provided on the panel. The output impedance is then halved, and the output is unbalanced to ground.

The 5000-ohm output position is intended for 5000-ohm loads, unbalanced to ground, although the effective internal impedance of the oscillator averages about 400 ohms in this position.

Output Voltage: Approximately 20 volts open circuit on 5000-ohm output and 10 volts open circuit on 600-ohm output. The output voltage is constant within ±1.0 db over the entire frequency range.

Output Power: A maximum power output of 80 milliwatts can be obtained into an unbalanced 5000-ohm load. A maximum of 40 milliwatts can be obtained into a balanced-to-ground 600-ohm load (20 milliwatts into an unbalanced 300-ohm load).

Waveform: Harmonic content is less than 1% for all output values and at all frequencies.

A-C Hum: 5000Ω output, 24 millivolts, maximum. 600Ω output, 12 millivolts, maximum.

Terminals: Jack-top binding posts with standard ¾-inch spacing and standard General Radio Type 774 coaxial terminals are provided on the panel. The separate ground terminal has a strap which can be used to ground the LOW output terminal.

Mounting: The instrument is normally supplied for relay-rack mounting but can be easily adapted for table mounting by the addition of two walnut frames at the ends of the panel (see price list below).

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles.

Total power consumption is about 90 watts.

Tubes: The following tubes are used and are all supplied with the instrument.

2—6SL7-GT	1—6V6
2—6B4-G	1—6J5
1—6AK6	1—5V4-G
1—6F6	1—0D3/VR-150

Accessories Supplied: A line connector cord, coaxial connector for output, multipoint connector, and Type 274-M plug.

Dimensions: (Length) 19⅜ x (height) 7½ x (depth) 14¼ inches, over-all.

Net Weight: 30 pounds.

Type		*Code Word*	*Price*
1302-A	Oscillator	FINAL	$365.00
ZFRI-412-P1	End Frames	ENDFRAMDIG	16.50 Pair

This instrument is manufactured and sold under the following U. S. Patents and license agreements:

2,173,427 **2,298,177**

Patents of the American Telephone and Telegraph Company.

V-LINE VARIAC REGULATION CURVES

Variac continuously adjustable autotransformers are extremely efficient voltage controlling devices. They have, however, a small regulation drop under load. The accompanying curves are illustrative of typical performance of the new General Radio V-line Variacs.

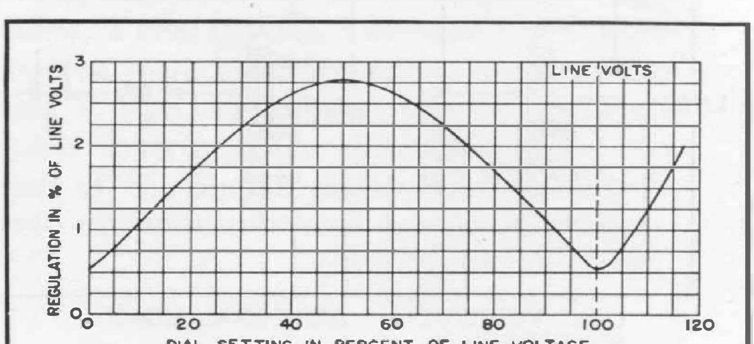
Figure 1 applies to all models operated normally *at rated load current*. Normal operation implies 115-volt supply for low voltage models and 230-volt supply for "H" models. Values are not substantially changed by the use or omission of the overvoltage feature.

Figure 2 applies to all models operated at one-half normal line voltage and one-half normal rated current. This covers such special cases as the use of an "H" model to secure 0 to 270 volts from a 115-volt line.

Regulation varies directly with load current as follows:

$$\% \text{ Reg.} = \left(\begin{matrix}\% \text{ Reg. at} \\ \text{rated load}\end{matrix}\right) \times \frac{\text{actual load}}{\text{rated load}}$$

Figure 1. Percentage regulation as a function of output voltage for Variacs operated normally.



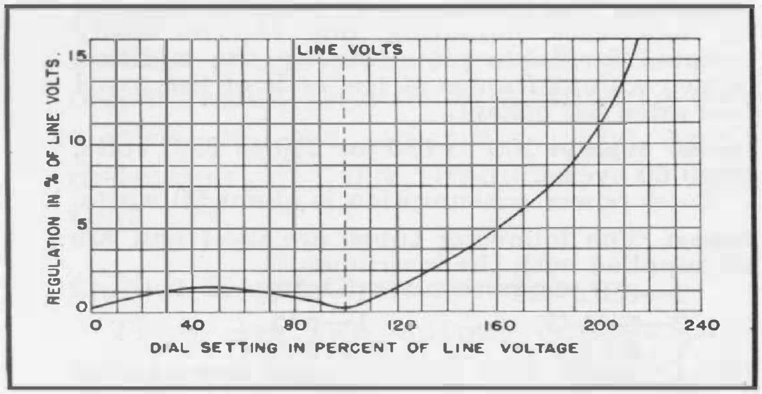


Figure 2. Percentage regulation as a function of output voltage when input voltage is one-half normal line voltage.

Where "H" models are operated at one-half rated voltage for 25 cycle applications, the regulation values of Figure 1 must be doubled, owing to the halving of the supply voltage.

Note that the normal values of Figure 1 are comparable to the regulation of any good auto-transformer, and that, at their maximum, they are but half the regulation of a conventional double wound transformer.

Values given are typical. Individual Variacs will differ slightly from these curves, but the difference will not be significant.

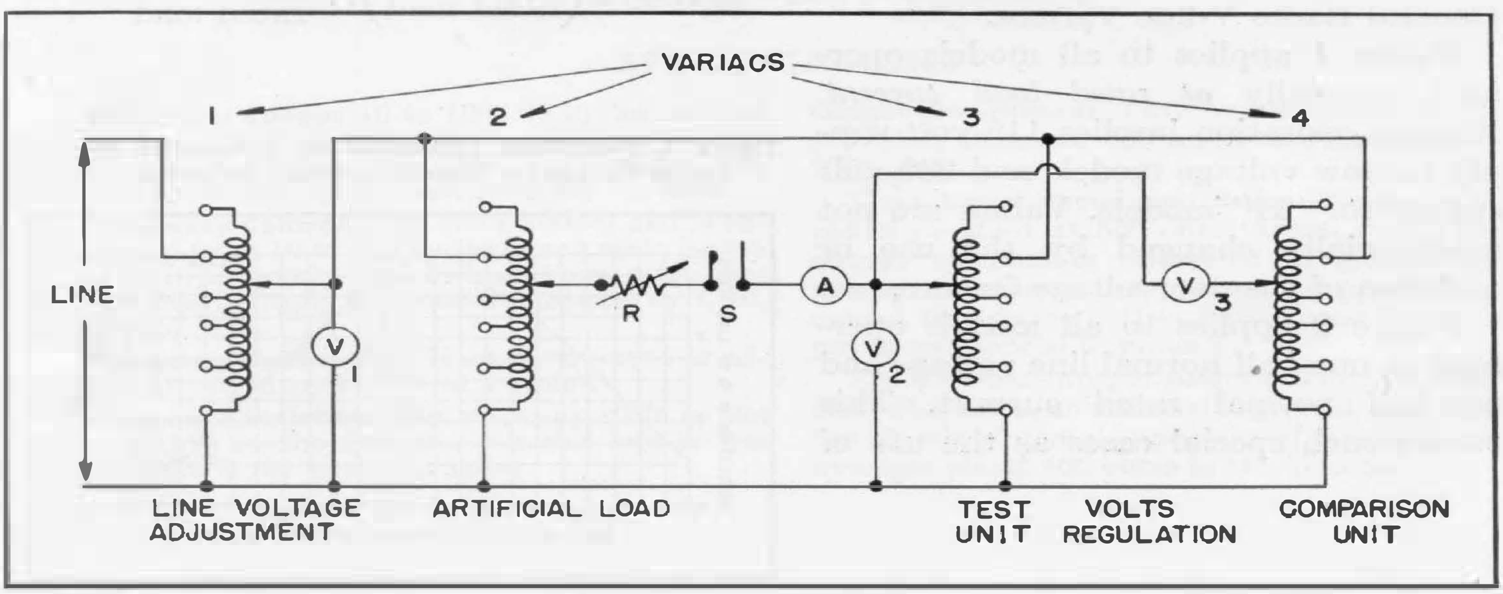
—Gilbert Smiley

A VARIAC CIRCUIT FOR REGULATION MEASUREMENTS

The typical regulation curves for the new V-line Variacs, appearing on page 5 of this issue of the *Experimenter*, were derived from measurements made by a method which differs markedly from conventional regulation measurement methods. Usually no load and full load voltages are measured, the difference being the regulation voltage drop, a satisfactory procedure where regulation is fairly large and accuracy tolerances are not close.

When, as in the case of the Variac regulation measurements on page 5, the drop is but a fraction of a volt out of one or two hundred volts, the difference in reading is so slight, and is so greatly changed by even minor fluctuations of the supply voltage during measurement, reasonable accuracies cannot be obtained by conventional methods. Obviously, a better method had to be found, a method that would read regulation voltage directly with reasonable

Figure 1. Circuit for regulation measurements.



freedom from error introduced by minor line voltage variations.

Figure 1 illustrates a circuit developed to meet these requirements, by the use of which accurate regulation measurements were easily obtained. This circuit is readily separated into functional divisions, as noted on the diagram.

Variac 1 and voltmeter, V_1, comprise the means for maintaining supply volts at an approximately correct level. Variac 1 needs be but large enough to supply the circuit losses. As an example, a V-5 (5 ampere rating) is adequate for measurement of all sizes up to V-20 (20 ampere rating).

Variac 2, resistor, R, switch, S, and ammeter, A, are "pump-back" connected to form an artificial load. While the pump-back connection is old in both principle and practice, a short description of the theory involved may be of interest to some of our readers. The circuit is based on the fact that, as long as full-load current is supplied by the transformer under test, this transformer may be considered to be fully loaded, provided only that the phase of the load current is correct. In the pump-back method, the potential difference between the loaded and loading transformers is made just sufficient to establish the desired current output from the loaded transformer. The loading transformer, Variac 2, returns to the line the power supplied by the loaded transformer, Variac 3, minus only such losses as occur in the transformers and the connecting circuit. Resistor, R, is included to facilitate close adjustment of current. Obviously, Variac 2 and resistor, R, must be capable of handling the current supplied by Variac 3. Voltmeter, V_2, indicates the output voltage of Variac 3 for each measurement point, and should be read with switch, S, open.

The novelty in the circuit is contained in the use of Variac 4 as a comparison or reference unit, and the use of voltmeter, V_3, to read regulation voltage drop directly. With the line voltage at a proper value and with Variac 3 set to a desired voltage, switch, S, is opened. Variac 4 is then adjusted until voltmeter, V_3, reads zero. Switch S is then closed and Variac 2 and resistor, R, are adjusted to the desired current reading on ammeter, A. V_3 will now read regulation voltage drop directly. Effectively, Variac 4 has been set at the no-load voltage of Variac 3 and maintains this voltage throughout the measurement. Minor fluctuations in line voltage change the voltage output of Variac 4 by exactly the same amount as they would change the no-load voltage of Variac 3, thus offsetting errors from this cause. Voltmeter, V_3, should, of course, have a scale to agree with the anticipated regulation voltage drop, which, as it is read directly, may be determined with satisfactory accuracy.

A voltage-divider, "potentiometer," may be substituted for Variac 4 if measurements are not to exceed line voltage. When, as with Variacs which have an overvoltage feature or with step-up transformers, measurements must be made at values exceeding line voltage, a Variac in this position enables the method to be applied.

Voltmeters, V_2 and V_3, should have sufficiently high impedance to be a negligible load on their respective circuits. TYPE 1800-A Vacuum Tube Voltmeters were used to obtain the data for the V line regulation curves. Multiple scale instruments, particularly in the case of V_3, permit closer reading of both zero adjustments and measured values.

— GILBERT SMILEY

MISCELLANY

Melville Eastham

Arthur E. Thiessen

HONORS—Certificates of Commendation have been awarded by the Navy Department, Bureau of Ships, to Melville Eastham, Chief Engineer, and Arthur E. Thiessen, Vice-President of the General Radio Company, for their contributions to the successful prosecution of the war.

The award to Mr. Eastham was made for his "outstanding leadership, vision, and perseverance, as Director of the Loran Development, Radiation Laboratory, in the development of the Loran system from its inception to its culmination as an operating system."

Mr. Thiessen's certificate was awarded for his "outstanding cooperation in the rapid expansion of the facilities of the General Radio Company from peacetime manufacture to wartime production of large quantities of superior quality electronics test equipment."

Technical Papers — presented by R. A. Soderman of the Development Engineering Staff: "U-H-F Measurements," Seattle Section, I.R.E., September 17; "A V-H-F Bridge for Impedance Measurements at Frequencies Between 20 and 140 Mc," Portland Section, I.R.E., September 18, and at the West Coast Convention, I.R.E., September 25; both papers at Los Angeles before the Electronics Section, A.I.E.E., September 30, and the San Diego Section, I.R.E., October 1.

— presented by W. R. Thurston of the Development Engineering Staff: "U-H-F Measurements" at the October 21 meeting of the U.R.S.I. at Washington, D. C.; "Coaxial Elements and Connectors" at the National Electronics Conference, Chicago, November 3.

Recent visitors to our laboratories: B. V. Baliga, M. L. Sastry, and N. N. Pai, of All-India Radio, New Delhi; C. J. Gorter, Director, Kamerlingh Onnes Laboratory, University of Leyden; and J. Hers, Union Observatory, Johannesburg.

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TROWBRIDGE 4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WORTH 2-5837

LOS ANGELES 38, CALIFORNIA
950 NORTH HIGHLAND AVENUE
TEL.—HOLLYWOOD 6201

CHICAGO 5, ILLINOIS
920 SOUTH MICHIGAN AVENUE
TEL.—WABASH 3820

PRINTED IN U.S.A.