THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW SERIES OF STANDARD INDUCTORS

Also

IN THIS ISSUE

● **HIGHLY ACCURATE STANDARDS** of resistance, capacitance, and inductance, representing the basic parameters of an electrical network, are necessarily among the major tools used in any measurement and standardizing laboratory. For many years General Radio Company has endeavored to produce such high quality standards and to improve them from time to time as dictated by enhanced knowledge and advancement in the arts of measurement and manufacturing technique. At this time a new standard inductor, known as the Type 1482, which is superior in several aspects to the long-used Type 106 Standard Inductor, is announced.

For precise work, one naturally desires an inductance standard which is insensitive to its electrical environment and ambient humidity, and which has a known temperature coefficient of minimum value. In these respects, the new Type 1482 Standard Inductors are definitely superior to the old Type 106 units.

These new inductors are symmetrically wound toroids and have thus a much higher degree of astaticism than existed in the adjacent

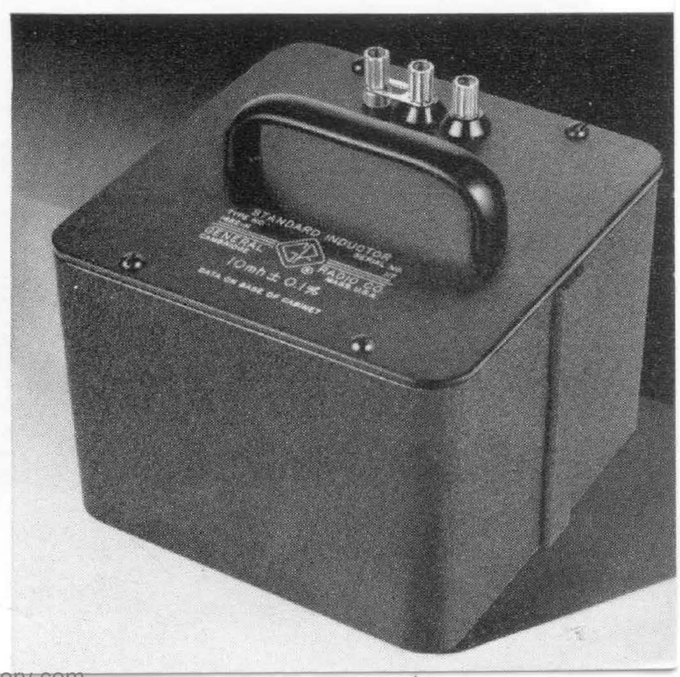
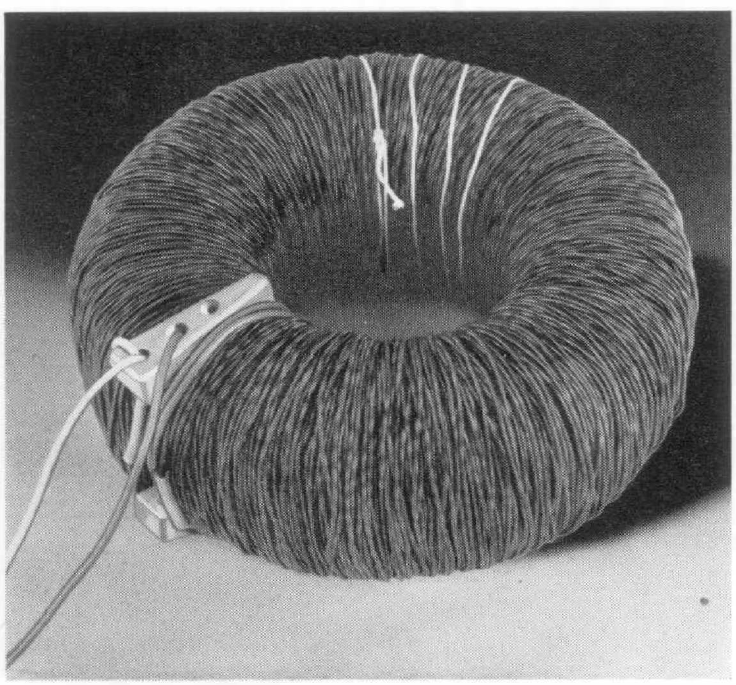


Figure 1. Panel view of the Type 1482 Standard Inductor.

pair of D-shaped coils used in the older type. They have essentially no pick-up from a moderately uniform electromagnetic field and, when energized, they produce no such field in their vicinity. Accordingly, they may be used close to each other or to other circuit components.

With no external magnetic field, these toroidal units can be housed in a metallic case and thus given an electrostatic shield with no complicated frequency correction of inductance due to eddy current reaction. Any attempted electrostatic shielding of the TYPE 106 Standard Inductors would have required abnormally large cases.

The TYPE 1482 Inductors are wound on a low thermal expansion ceramic core having an elliptical cross section to avoid sharp bends in the winding. After adjustment, they are packed in granulated cork into a cylindrical cardboard carton, together with a small amount of silica gel to insure dehydration. Having a simple geometrical construction and being uniformly supported at all points with no restraining clamps, it is expected that long-time observations will prove these "floating" inductors will have a high degree of stability. This belief is fortified by the results obtained in the accelerated aging techniques to which all of these inductors are subjected prior to final calibration. Furthermore, their temperature coefficient of inductance is definitely positive and of the order of 30 parts per million per degree C. This checks closely a theoretical value of twice the linear expansion coefficient of copper. For precise work, appropriate temperature corrections can thus be applied. This was not possible with the old TYPE 106 Inductors, whose thermal coefficients were indefinite both in sign and magnitude and could only be specified as less than ± 40 parts per million per degree C.



Continuing with the assembly, the cylindrical carton is supported on three wooden dowels and completely cast with a potting compound into the cubical aluminum case. These inductors are thus hermetically sealed and devoid of ambient humidity variations encountered in the older units.

The two extremities of the winding are brought out to a pair of insulated terminals. As calibrated and as ordinarily used, the LOW terminal is externally strapped to a third terminal which is grounded to the case. While so doing lowers the natural frequency of the unit slightly, it affords at the terminals a definite impedance, $R + j\omega L$, which is independent of the environs of the inductor. If desired, the ground link may be removed to afford a three-terminal ungrounded inductor.

A uniform progressive banked winding is applied around the ceramic core (single winding), avoiding overlapping at the extremities which would result in excessive distributed capacitance. Holes

Figure 2. View of the toroidal inductor before installation in cabinet.

fabricated in the core at the extremities of the winding allow the final turn to embrace either ⅓, ⅔ or all of the flux, thus permitting a finer degree of adjustment. While a toroidal winding is not, inherently, highly efficient with respect to copper loss, the maximum practical amount of copper has been used in all units to produce the highest possible low-frequency *Q* values. Inductors of 100 mh and less are wound of appropriate Litzendraht wire, and those of 1 mh and less are of "duplex" construction consisting of two paralleled semi-circumferential windings.

These inductors are offered in the convenient 1-2-5 unit values, which permits a precise direct comparison between them on a unity-ratio bridge. For example, the 2-unit may be compared with two 1-units in series, the 5-unit versus two 2-units plus a 1-unit in series, the 10-unit versus two 5-units in series, etc. Complete cross-checking is thus possible in a standardizing laboratory equipped with two sets of these inductors. As catalogued at the present time, inductance values extend from 100μh to 1 h inclusive. These are adjusted with a nominal limit of $\pm$ 0.1 per cent of absolute inductance except the 100-μh and 200-μh units for which the nominal limit is $\pm$ 0.25 per cent.

Additional inductors of 10h, 5h, and 2h have been made and can be supplied on special order. The nominal limit for these units is $\pm$0.1 per cent.

A certificate attached to the bottom of the case gives useful data for the precise use of each individual inductor. The series inductance at 100 cycles per second and at the indicated stabilized temperature is given as obtained by direct comparison, precise to better than 0.005 per cent, with a like standard which has been certified by the National Bureau of Standards with an indicated accuracy (see table). Since this comparison measurement is at least sixfold more precise than the Bureau certification, the absolute inductance of each inductor at 100 cps is known within the limits set by the Bureau for its particular magnitude.

It is well known that effective series inductance increases with frequency owing to the existence of distributed capacitance. While insignificant at low frequencies with the smaller-valued inductors, this increase may become appreciable with the larger-valued units. For convenience, the increments to be added to the 100 cycles per second value when operating at 200 cycles per second, 500 cycles per second, and 1 kc are tabulated when they are of significant magnitude. These increments are individually computed from the equation

$$\Delta L = L_2 - L_1 = \left(\frac{f_2^2 - f_1^2}{f_r^2 - f_2^2}\right) L_1 \qquad (1)$$

which is precise up to at least 10 per cent of the natural frequency f_r. Individual values of f_r and d-c resistance at the stabilized temperature are measured and tabulated. Using the latter, together with the resistive coefficient of copper, 0.00393, more precise thermal corrections can usually be made than by the use of thermometers.

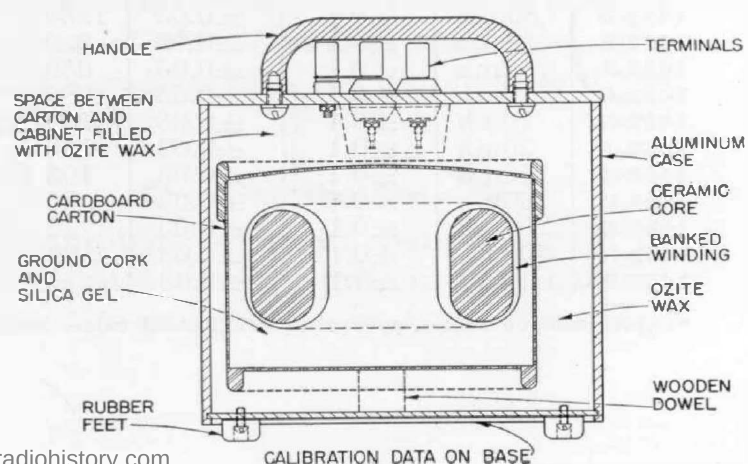


Figure 3. Cross-section drawing of the Type 1482 Standard Inductor showing details of construction and mounting.

Due to the effective thermal insulation afforded by the granulated cork, the input power should be limited to 3 watts, which produces a 20°C. temperature rise in the windings, and for precise work a limitation of 200 milliwatts, Δ T less than 1.5°C., may be taken. Corresponding current limitations may then be set in terms of resistance. These are recorded on the certificate. An auxiliary limitation of 500 volts at the terminals will rarely be encountered within a 20°C. rise in the windings.

At low frequencies, where the inductor is ordinarily used, the dissipation factor depends essentially on copper loss and is given by

$$D = \left(\frac{R_{d\text{-}c}}{2\pi L}\right)\left(\frac{1}{f}\right) = \frac{K}{f} \qquad (2)$$

For convenience, the numerical value of the coefficient K is recorded on the calibration certificate, f being in cycles per second.

The TYPE 106 Inductors are now obsolete and are superseded by the new TYPE 1482 series. The TYPE 1481 series of fixed toroidal inductors, announced two years ago*, will be continued. These are much smaller in size than the TYPE 1482 units and, having a ferromagnetic dust core, possess higher 100-cycle Q values at the expense of a voltage coefficient of inductance and a reduced accuracy of calibration.

— HORATIO W. LAMSON

*General Radio Experimenter, December, 1950.

SPECIFICATIONS

Inductance Range: 100μh to 1 h, inclusive. Inductors of 2h, 5h, and 10h are available on special order.

Accuracy: Nominal limits of adjustment, see table. Limits of measured certificate value, see table.

D-C Resistance: See table for approximate values.

Low Frequency Dissipation Factor: See table for K values used in Equation (2).

Resonant Frequency: See table.

Maximum Input Power:
For 20°C. rise, 3 watts.
For precise work, 1.5°C. rise, 200 milliwatts.
See table for corresponding current limitations.

Mounting: Aluminum cabinet with carrying handle and rubber feet, black crackle finish. Certificate data attached to base of cabinet.

Terminals: Two insulated jack-top terminals, plus ground terminal and strap.

Dimensions: 6½" x 6½" x 8" height overall.

Weight: 11½ pounds.

Type	Nominal Inductance	Nominal Limits %	Limits of Certificate Value %	*Resonant Frequency kc	*D-C Resistance ohms	*K Values Eq. (2)	*Maximum Milliamperes rms for 200mw	3w	Code Word	Price
1482-B	100μh	±0.25	±0.10	3500	0.26	400	870	3400	INDUCTOTAG	**$48.00**
1482-C	200μh	±0.25	±0.05	2300	0.37	300	740	2800	INDUCTOTED	**48.00**
1482-D	500μh	±0.1	±0.05	1250	0.54	170	600	2400	INDUCTOTIM	**55.00**
1482-E	1mh	±0.1	±0.05	820	1.03	165	390	1500	INDUCTOTOP	**55.00**
1482-F	2mh	±0.1	±0.05	650	2.00	150	310	1250	INDUCTOTUB	**55.00**
1482-G	5mh	±0.1	±0.05	380	4.4	140	210	800	INDUCTOVAT	**55.00**
1482-H	10mh	±0.1	±0.03	250	8.0	127	160	600	INDUCTOVEX	**60.00**
1482-J	20mh	±0.1	±0.03	170	18	145	105	400	INDUCTOWAD	**60.00**
1482-K	50mh	±0.1	±0.03	105	46	145	66	250	INDUCTOWET	**60.00**
1482-L	100mh	±0.1	±0.03	65	90	145	47	180	INDUCTOWIG	**60.00**
1482-M	200mh	±0.1	±0.03	42	120	96	40	160	INDUCTOWOW	**60.00**
1482-N	500mh	±0.1	±0.03	26	350	110	24	100	INDUCTOYAK	**60.00**
1482-P	1h	±0.1	±0.03	16	590	94	18	70	INDUCTOYES	**60.00**

*Representative values, approximate. Actual values indicated on certificate.

A CALIBRATION-CHECK SERVICE FOR SOUND METERS

Our Sales and Engineering Offices in Cambridge, New York City, Chicago, and Los Angeles now offer a new, free service to owners of General Radio Sound-Level Meters and Sound-Survey Meters[1] in those areas. When circumstances of a measurement problem call for assurance, or reassurance, that results be highly accurate, or when a possible calibration error is indicated or suspected, it is desirable to check the over-all calibration of the instrument in question. An accurate yet simple check can be made using the Type 1552-A Sound-Level Calibrator[2] plus a suitable oscillator and voltmeter. However, the majority of General Radio sound-meter users have no need for frequent checks, and purchase of calibrating equipment is in these instances difficult to justify, particularly for the owner of a Type 1555-A Sound-Survey Meter,[3] for whom the calibrating equipment would cost[4] more than the instrument to be calibrated. The new calibration-check service, available at our branch offices, is expected to meet the needs of the majority of sound-meter owners.

To use the service, just take the sound meter to a Sales and Engineering Office, addresses of which appear on the last page of the *Experimenter*. The calibration check requires only a few minutes, and no charge is made for it. Someone qualified to make the check is generally available, but it is suggested this be verified by telephone beforehand. We request that instruments be delivered personally or via messenger, and that no instruments be shipped to us for this service, since our field office shipping facilities are very limited. If the calibration check indicates that the instrument requires repair, the repair work should be handled in the usual manner by our factory or by an authorized repair facility.

— W. R. Thurston

[1] For a description of these instruments, see the March and April, 1952, issues of the *Experimenter*.

[2] E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

[3] Type 1555-A Sound-Survey Meter, $125; carrying case, $10.

[4] Type 1552-A Calibrator, $45; 400-cycle oscillator, $60 to $85; simple, rectifier-type voltmeter, $25 (available from meter manufacturers or supply houses).

THE BASIS FOR FIELD CHECKING SOUND-METER CALIBRATION

1. SOUND-LEVEL METER

A sound-level meter includes a microphone, an amplifier, an attenuator, and an indicating meter. The stability of these four elements determines the over-all calibration stability of the instrument, so it is important that they hold their initial, factory-calibrated characteristics over long periods of time in field use. Since the attenuators and rectifier-type indicating meters used give very little difficulty at their present stage of development, this discussion deals mainly with the amplifier and the microphone.

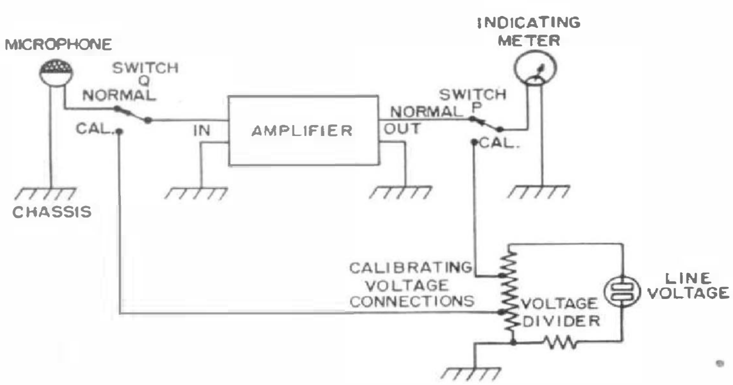
Checking the Amplifier

Amplifier gain can change slightly as a result of normal drift in tube characteristics and changes in *A* and *B* battery voltages. There is also the possibility of a sudden, abnormal change in some component that could affect gain and cause incorrect readings. To prevent errors of this type, all General Radio Sound-Level Meters, old and new, have built-in calibration circuits for checking amplifier gain, plus an adjustment for correcting slight, normal variations from the proper value.

The calibration circuit consists of a resistance-type voltage divider and two switches, as shown in Figure 1. For checking the calibration, the voltage divider is connected to a convenient power line having a nominal voltage corresponding to the value on the instrument nameplate (115 or 230 volts), and this divider provides two calibrating voltages, the ratio of which is factory set to equal the proper value of amplifier gain. Operation of switch *P* applies the larger calibrating voltage directly to the indicating meter. Operation of switch *Q* applies the smaller calibrating voltage to the amplifier input, so that this voltage is multiplied by the gain of the amplifier and then applied to the indicating meter. Clearly, if the second meter reading equals the first, the amplifier gain equals the voltage-divider attenuation and is therefore at its correct value.[1] It should be noted that the absolute value of the equal readings obtained, which depends on line voltage, is not important, and that the long-term accuracy of this check depends only on the stability of resistors.

[1] For power frequencies other than 60 cycles, the second reading should be less than the first by specific amounts at specific frequencies, owing to the frequency characteristic of the amplifier.

Figure 1. Schematic diagram of the calibration circuits in the sound-level meter.



Checking the Microphone

The microphone can be checked by applying to it a known sound-pressure level. This is conveniently done with the sound-level calibrator,[2] a small, enclosed, highly stable speaker, which fits over the sound-level-meter microphone. This device provides an over-all check on the calibration, from microphone to meter. Since the amplifier can be checked independently, and since the attenuator and indicating meter seldom cause any difficulty, an over-all check is, in effect, a check of the microphone.

When 2 volts at 400 cycles, obtained from an oscillator and measured by a voltmeter, are applied to the terminals of the TYPE 1552-A Sound-Level Calibrator, the sound-pressure level is 85 decibels for the TYPE 9898 Crystal Microphone supplied with TYPE 759 and TYPE 1551-A Sound-Level Meters. The level produced has other values for other types of microphones, because of differences in cavity shapes and sizes and acoustic leakage between the calibrator housing and the microphone. A reading that differs from the proper value by a small amount, say less than 2 decibels, probably indicates a mere shift in microphone sensitivity and can properly be compensated by resetting the amplifier gain adjustment. If the difference is large, however, it may be the result of more serious microphone trouble, in which case a factory check and possible repair are suggested in accordance with our regular repair procedure.

[2] E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

This calibration check is a single-frequency measurement and does not explicitly indicate what the performance will be at other frequencies. The single-frequency test, however, will show whether or not the microphone has been damaged, and, in the absence of damage, it is reasonable to assume that the frequency characteristic has not materially changed.

2. SOUND-SURVEY METER

The sound-survey meter includes the same four basic elements as does the sound-level meter, but it is relatively inexpensive and highly miniaturized. Giving the greatest possible portability and convenience of use, the sound-survey meter is intended for the many less exacting applications requiring sound-level measurements and does not include amplifier calibrating circuits. The over-all calibration is readily checked by the use of the sound-level calibrator.

— W. R. Thurston

MORE USEFUL VARIAC CIRCUITS

The note entitled "A Useful Variac Circuit," appearing in our August issue, has evoked letters from readers who have used similar but still more useful circuits. Mr. G. M. Brown, Electronics Engineer for the New York Central System, offers the circuit of Figure 1, which includes a manual switch to give control over a 245-volt range. A similar circuit was submitted by Mr. G. D. Stark of Allis-Chalmers Manufacturing Company.

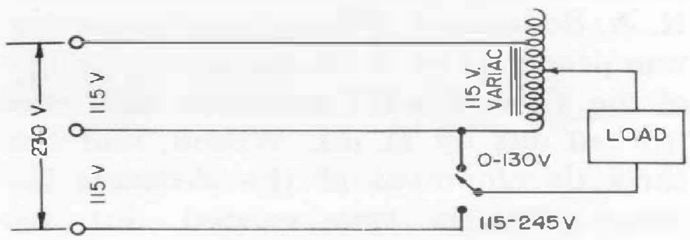
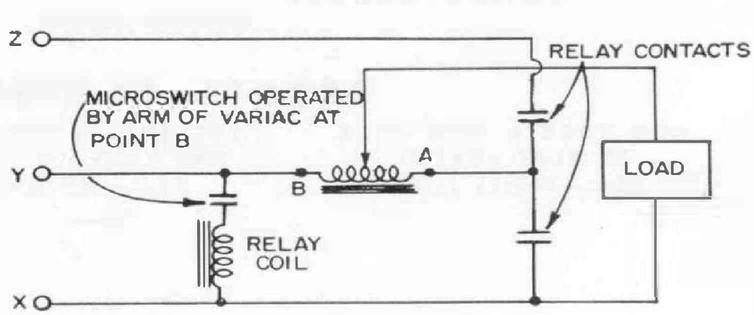


Figure 1.

Mr. J. H. ●denheimer, Plant Engineer, Switchgear Department, General Electric Company, Philadelphia, states that he has used the circuit published in the *Experimenter* and also the modification shown in Figure 2, which gives full control at double the rating. He describes this circuit as follows:

"This modification involves a limit switch (or micro switch) accurately mounted on the Variac in such a way that the switch is operated by the Variac arm just as it reaches the extreme end of its travel in the increasing (clockwise) voltage direction. This limit switch actuates a latching-type transfer relay which transfers end *A* of the Variac winding from the *X* side of power to the *Z* side. In this position, counterclockwise rotation of the Variac continues to increase the output voltage up to 230 V. Voltage is reduced in a similar manner by going through two rotations of the Variac. The interrupting duty on the contacts of the transfer relay is not severe since the transfer is made with only magnetizing current flowing through the Variac winding."

Figure 2.



The arrangement of Figure 3 was submitted by Mr. E. M. Shores of General Laboratory Associates, Ltd. Here, the switching from one range to the other is performed by push buttons and a relay.

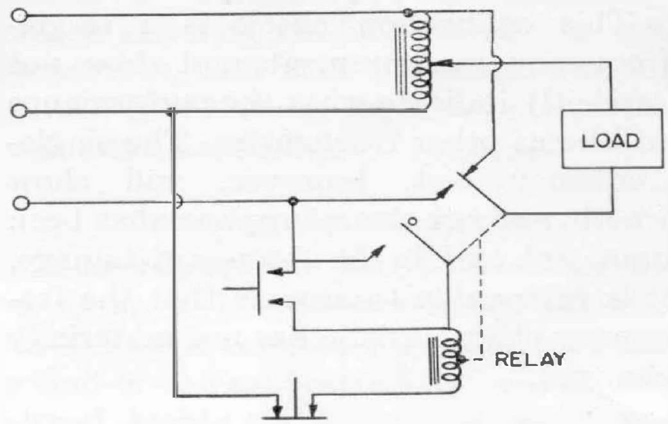


Figure 3.

MISCELLANY

CREDITS — The new additions to the 874 series of coaxial elements announced in last month's issue were developed by R. A. Soderman. The original connector was proposed by E. Karplus, the design of the TYPE 874-B Connector itself was worked out by H. M. Wilson, and the early development of the elements incorporating it was carried out by W. R. Thurston.

THIRD CONFERENCE ON HIGH-FREQUENCY MEASUREMENTS — Under the joint sponsorship of AIEE, IRE, and the National Bureau of Standards, the Third Conference on High-Frequency Measurements will be held in Washington on January 14-16, 1953. This conference will follow the pattern of similar meetings held in 1949 and 1951 and will be devoted exclusively to the techniques and problems of high-frequency measurements, with particular emphasis on new developments.

RECENT VISITORS to the General Radio plant and laboratories include: Mr. Carl Schrader of the firm Radiometer, Copenhagen, Denmark; Mr. John C. Lagercrantz, exclusive representative for General Radio products in Sweden; Mr. Morisaburo Katakami, Engineer, Yokogawa Electric Works, Ltd., and Mr. Hanzo Omi, Chief Engineer, Fuji Communications, App Mfg. Co., Ltd., Tokyo, Japan; Mr. Georg Kurlbaum, General Manager, Metrawatt, A. G., Nuremberg, Germany; and Mr. Magan Pancholy, Senior Scientific Officer, National Physical Laboratory of India, New Delhi.

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