the GENERAL RADIO Experimenter

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

A NEW PRECISION CONDENSER

WORM-DRIVE air condensers have for many years been widely used as continuously-adjustable standards of capacitance. It has long been recognized that these condensers are subject to small variations from their desired characteristics caused by such factors as temperature, aging, worm eccentricity, backlash, and strains in the frame and plates, but, as a rule, the resultant errors have been negligible in all but the most precise measurements. In the Type 222 Precision Condenser these small variations were known and allowance could be made for them when necessary.

The availability of new materials and methods of construction, however, have made it possible to replace this condenser with one of completely new design, the Type 722 Precision Condenser, in which these factors are markedly reduced. The panel of the condenser assembly is shown in Figure 2 and the constructional details in Figure 1.

In designing the new condenser, the chief requirement has been stability of capacitance. Consequently both the material used and the mechanical arrangement have been selected with this end in view.

The whole condenser assembly is mounted in a cast frame which gives the assembly a degree of rigidity not otherwise possible. This frame, the stator rods and spacers, and the rotor shaft are made of an alloy of aluminum and copper, which combines the mechanical strength of brass with the weight and temperature coefficient of aluminum. Since the condenser plates are of aluminum, all parts have the same temperature coefficient of linear expansion, resulting in a low temperature coefficient of capacitance (0.002% per degree Centigrade).

NEW PRICE FOR TYPE 631-A STROBOTAC

Effective February 1, 1936, the price of the Type 631-A Strobotac will be $95.00, net, F.O.B. Cambridge.

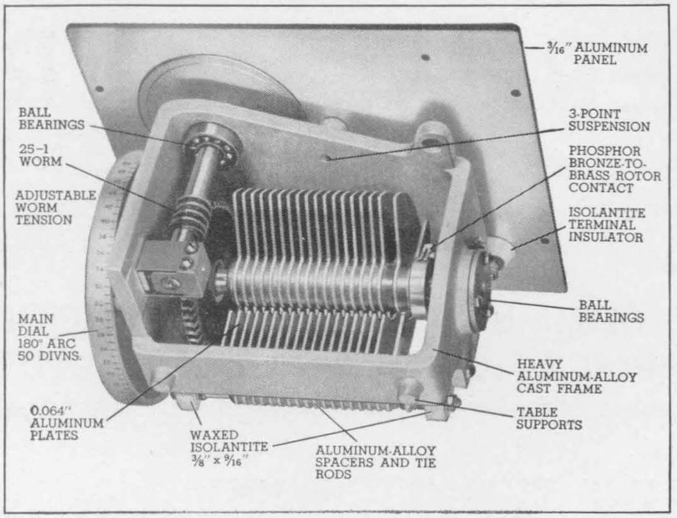


FIGURE 1. View of TYPE 722-H Precision Condenser with cabinet removed showing constructional details

Increased stability is also obtained by the use of plates 1/16-inch thick, which reduces materially the sagging which might normally occur with age, and, since the rotor shaft is horizontal, no constant stress exists which would cause the plates to bend in a direction parallel to the shaft.

The ball bearings used on both ends of the rotor shaft are conducive to both stability and smoothness of rotation.

Connection to the rotor is made, not through the bearing, but by means of a phosphor bronze brush running on a brass drum, which assures positive contact.

Since it is difficult to mount a worm gear on a shaft without some slight eccentricity, the worm in the TYPE 722 Precision Condenser is cut directly on the shaft. The dial end of the worm shaft runs in ball bearings; the other end is supported by an adjustable spring mounting.

This arrangement of bearings and drive mechanism results in a backlash of less than 1/2 worm division and a low worm correction. Since the capacitance per worm division for the new condenser is less than half that for the TYPE 222, the backlash in terms of capacitance has been considerably reduced.

It will be seen from Figure 1 that the usual dial arrangement is reversed, and that the drum dial is on the rotor shaft and the disk dial on the worm shaft. Because of this, both dials are read from a single window in the panel, and the condenser is driven from the panel without the use of bevel gears and their resultant backlash.

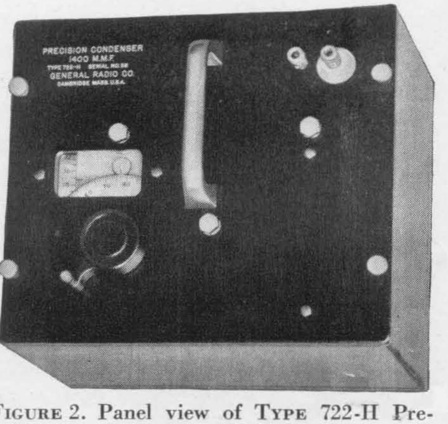


FIGURE 2. Panel view of TYPE 722-H Precision Condenser

The worm drives a 50-tooth gear, so that 25 revolutions of the worm rotate the main shaft through 180 degrees. One-half revolution (100 divisions) of the worm advances the main scale one division. Since the main scale carries 50 divisions, the 180-degree rotation is divided into 5000 worm divisions, each half of the worm dial being engraved 0 to 100.

The capacitance per worm division on the 1400-$\mu\mu$f model is approximately 0.28 $\mu\mu$f and on the 500-$\mu\mu$f model is 0.11 $\mu\mu$f. Since the scale can be set to about 1/5th of a worm division, the precision of setting for these two models is 0.06 $\mu\mu$f and 0.02 $\mu\mu$f respectively.

The over-all characteristics of the TYPE 722 Precision Condenser are similar to those of the older TYPE 222. The figure of merit, $R\omega C^2$, is 0.04 x 10^{-12} (or less) at 1 kc.

Isolantite is used for the insulating supports and, since a smaller amount of this solid dielectric is used, the figure of merit is lower than on the TYPE 222. As in other condensers, this factor is a function of temperature, humidity, and frequency, but is constant with scale reading over the usable range of the condenser.

The surface leakage is reduced to about one-third of the old value.

At 1 Mc the inductance is 0.06 μh and the metallic resistance is 0.024 Ω. The effect of these residual impedances at radio frequencies was discussed in a recent issue of the *Experimenter*.*

Two mounted models are available at present: TYPE 722-H, with a maximum capacitance of 1400 $\mu\mu$f, and TYPE 722-F, with a maximum capacitance of 500 $\mu\mu$f. These are supplied with a white wood shipping case.

Both sizes are also available unmounted. The casting is provided with three tapped holes for mounting. Since only a single panel window is necessary in order to read both dials, the ease of mounting is considerably improved. A template is provided for drilling the mounting holes.

Prices include a capacitance calibration table giving the capacitance at 26 points to 1 $\mu\mu$f or 0.1%, whichever is the larger. A worm correction calibration can be supplied accurate to 0.1 $\mu\mu$f or 0.1%, whichever is the larger.

TYPE 722 Precision Condensers will be supplied in the future on all orders calling for TYPE 222 Precision Condensers.

*Residual Impedances in the Precision Condenser, General Radio *Experimenter*, X, 5, October, 1935.

SPECIFICATIONS

Dimensions: (Mounted models) Panel, 8 x 9⅛ inches; depth, 8⅛ inches. (Unmounted models) Panel, 7¾ (length) x 6⅜ (width) x 7 (depth) inches.

Weight: 11⅛ pounds; 20¼ pounds with shipping case.

Type		*Capacitance*	*Code Word*	*Price*
722-HM	Cabinet Model . . .	1400 $\mu\mu$f	CUBBY	**$90.00**
722-HU*	Unmounted	1400 $\mu\mu$f	CUBBYPANEL	**70.00**
722-FM	Cabinet Model . . .	500 $\mu\mu$f	CUBIT	**85.00**
722-FU*	Unmounted	500 $\mu\mu$f	CUBITPANEL	**65.00**
Worm Correction Calibration Data			WORMY	**35.00**

*No calibration is supplied with unmounted models.

HIGH-SPEED MOTION PICTURES

There is a close analogy between the study of steady state conditions with the stroboscope in mechanical engineering and the oscillograph (or, more exactly perhaps, the oscilloscope), in electrical engineering. The equipment described here extends this technique to include the analysis of mechanical transients in the same way that the camera-oscillograph combination or the recording oscillograph provides a record of transient phenomena in electrical circuits.

THE study of repetitive motion in machinery at high speeds has been greatly simplified by the development of the stroboscope. There exists, however, a considerable demand for both apparatus and technique for studying mechanical transients and non-uniform motion.

For those applications where it is desirable to study a whole sequence of operations, the problem is best solved by photographing the motion and reprojecting it. Such a cycle does not have to be repeated and a single transient can be observed. When investigating cyclic motion, high-speed motion pictures provide a permanent record of the phenomenon, which may be examined later, whether or not the mechanism is still available.

Slow-motion pictures are, of course, no novelty and high-speed stroboscopic pictures are simply a further development of this familiar device. The value of all high-speed cinema work lies in projection at slow speeds. Slow-motion phenomena as seen in the motion-picture theater are obtained by photographing at speeds between 50 and 120 frames per second and projecting the film at the ordinary projection speed of approximately 16 frames per second. There is, however, an upper limit of practicability to slow-motion picture cameras using mechanical shutters. At picture speeds of several thousand per second, shutters would be required to operate at extremely high speeds, and the mechanics of such systems are complicated, unreliable, and expensive. The possibilities of speeding up a standard camera are further limited because of the mechanical problem of starting and stopping the film at high speeds.

The stroboscope presents an ideal solution for this problem. All of the complicated camera mechanism is eliminated and a simple, continuous-film

FIGURE 1. TYPE 621-H Stroboscope and TYPE 651-A Camera set up to photograph a machine for stitching leather

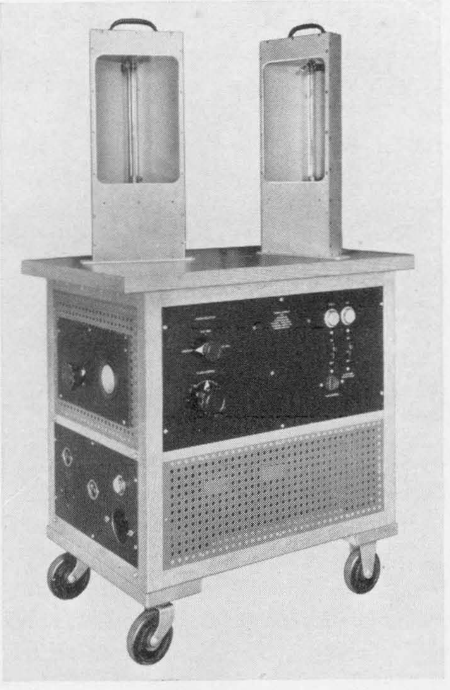


FIGURE 2. Control unit of the TYPE 621-H Edgerton Power Stroboscope showing the mercury lamps. The complete stroboscope consists of this unit and a 10-kw motor generator

camera is used. The exposure is obtained by illuminating the object intermittently with light flashes of such brief duration compared even to the highest film speeds that no provision for synchronization of the image is necessary — that is, the image can be impressed directly on the rapidly moving film without blurring.

The ability of high-speed pictures to "stop" motion is derived from a very brief flash of light. In the Edgerton equipment this lasts from five to ten one-millionths of a second. A corollary requirement is a high intensity of illumination in order that the film may be properly exposed during this brief period.

A high-speed photographic system falls into two portions, the light source and the camera. As developed by Professor Edgerton and manufactured by the General Radio Company, the light source has been an outgrowth of the smaller visual types of stroboscopes.

As in the latter instruments, a condenser bank is discharged through a mercury tube. In order to assure regular discharges which can be accurately controlled, a reliable control system had to be worked out. This makes use of a thyratron tube and a mechanical contactor. The contactor, which is connected into the grid circuit of the thyratron, controlling the flashing cycle of the condenser bank, is driven on the camera shaft and assures accurate framing of the pictures for reprojection.

Power for charging the condensers can be provided from any suitable source of high-voltage direct current which is capable of withstanding instantaneous short circuits. A high-voltage motor-generator set has been

FIGURE 3. External view of TYPE 651-A Camera showing the commutator and drive motors

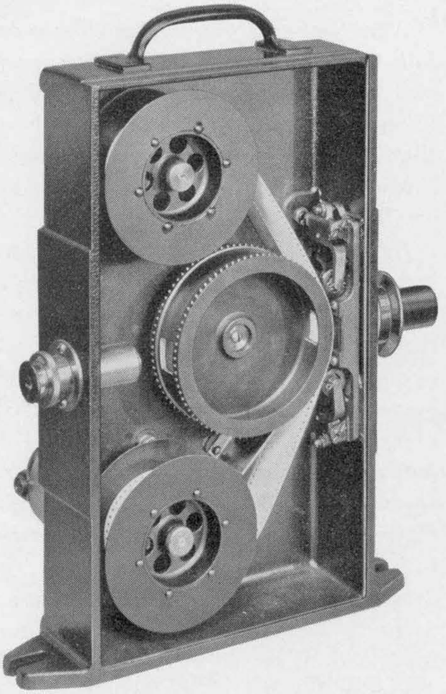


FIGURE 4. Interior view of TYPE 651-A Camera showing the film reels and sprocket

adopted as the most suitable equipment available for this purpose.

The power requirements are directly proportional to the flashing frequency. One thousand flashes per second require one thousand times as much energy as one flash per second and consequently a power supply of one thousand times as great a capacity.

The camera is reduced to a means for carrying the film past an aperture of proper dimensions at the desired speed. The structure of the camera is shown in Figure 4. The moving parts consist of the sprocket and two spools which are shown, the drive motors, and the commutator which controls the stroboscopic flash rate and serves to space the frames on the film properly for projection.

The principal problem in the design of the drive sprocket and reels was the elimination of inertia and the reduction of friction, since there is some fire hazard involved in passing film through the camera at very high speeds. The matter of inertia is of great importance because of the necessity of bringing the camera quickly to speed.

The film is held against the sprocket by an aluminum roller and a metal plow is provided under the sprocket to prevent the film being carried around by the sprocket teeth and breaking. The plow does not touch the film in normal operation, but will immediately correct any tendency to stick. The plow also prevents the film winding around the sprocket in case of breakage.

No mechanical connection is provided between the driving sprocket and the take-up reel. The take-up reel is driven by a series motor of sufficient torque to keep the film taut, but not to break it. The difference in speed required by the changing diameter of the reel as the film is taken up is thus automatically cared for by the slowing down of the motor. Extremely high acceleration rates can be provided for since it is possible to operate the motors at over-voltage. The time required to run 100 feet of film through the camera is only a second or two, and no damage results to the motors from such momentary overloading. The acceleration under these conditions is remarkably rapid. Full and constant speed is reached within less than 10 feet of the film length.

Standard lens equipment is used. Focusing is facilitated by a pair of openings spaced diametrically in the sprocket and an eyepiece in the back of the camera.

It will be observed that distortion in

the image will result in consequence of the curvature of the sprocket. This distortion can be minimized by the use of a sufficiently large sprocket diameter. In the camera described, the sprocket diameter is 4¾ inches, carrying twenty standard 35-millimeter frames on its periphery. The center of the picture is approximately 0.03-inch closer to the lens plane than the extreme upper and lower edges of the frame. This difference does not cause serious distortion or lack of focus with the subjects and lens systems normally used. When using 16-millimeter film the distortion is, of course, proportionately reduced.

Since the film moves through the camera continuously without shutters, the distribution of exposures on the film is determined by the rate of flash of the stroboscope light in relation to the film speed. If the film is to be projected, the images must be spaced properly along the film. In order to accomplish this a commutator is mounted on the sprocket shaft to provide electrical impulses setting off the stroboscopic flash at intervals of one frame on the film. A film thus exposed can be projected in standard projection equipment. The commutator presents a rather serious mechanical problem because the segments must be located with extreme precision. The film speed is so great that a minute irregularity in the spacing of the commutator segments will result in serious flicker.

The equipment illustrated in Figure 1, which has been found suitable to several typical industrial problems, is capable of taking pictures up to about fifteen hundred per second and will illuminate an area about one foot square to a sufficiently high intensity to take satisfactory photographs on high-speed film with an f/1.5 lens. The *maximum* speed is in the vicinity of two thousand per second. Pictures have been taken experimentally with similar apparatus with speeds as high as five thousand per second, but development of such equipment has not as yet reached a stage where it can be made commercially available.

Figures 5 and 6 illustrate an excellent example of the use of this equipment in the mechanical field. In redesigning an automatic tapping machine, it was desirable to know the speed-time characteristic throughout the cycle of operation.

The machine was fitted with a drum and cross hairs as shown in Figure 5, and high-speed pictures were taken of a

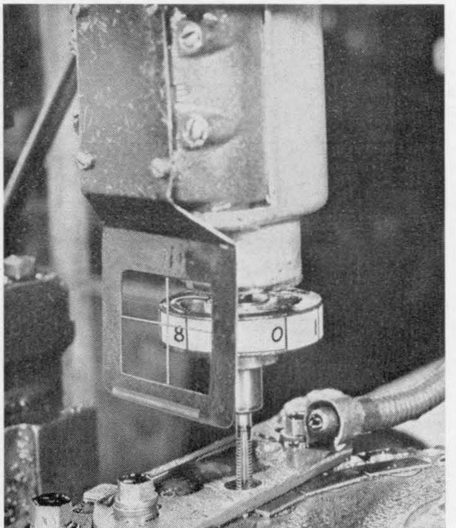
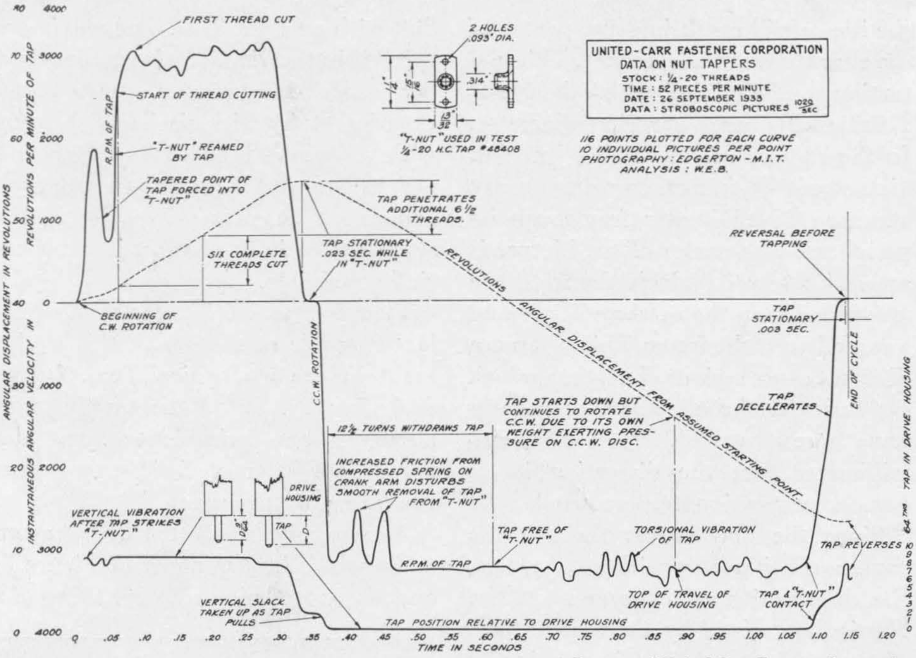


FIGURE 5. Photograph of the automatic tapping machine from which the data of Figure 6 was obtained. The drum, numbered in sections, and the cross hairs were attached in order that the pictures might be accurately analyzed. This arrangement makes it possible to measure the angular displacement accurately for each frame of the motion picture film



Courtesy of United-Carr Fastener Corporation

FIGURE 6. Plot showing angular displacement and instantaneous velocity of the automatic tapping machine over a period of one complete operation. From this data it was possible to redesign the machine to eliminate the irregularities shown in the plot

single cycle of operation at rated speed. In this case, it was not necessary to project the film. Examination of it yielded data for the plot of Figure 6, which shows clearly each irregularity of operation and the exact time at which it occurs in the cycle of operation. Compensation by means of cams could then be provided to give smoother operation. — CHARLES T. BURKE

The TYPE 621-H Edgerton Power Stroboscope is composed of the following units:

Control Unit	**$1950.00**
10-KW Motor Generator Set, mounted on truck and including switch	**600.00**
2 Single-Tube Reflecting Lamp Units	**400.00**
Total	**$2950.00**

This equipment is rated at 10 KW and gives a maximum flashing speed of 2000 per second. The motor is wound for 230-volt, 60-cycle, 3-phase service.

The complete 35-millimeter camera recommended for use with the TYPE 621-H Edgerton Power Stroboscope consists of:

Type 651-A Camera	**$360.00**
Motor, Base, and Switches	**70.00**
Commutator and Brush	**65.00**
Hugo Meyer f/1.5 2-inch Lens	**115.00**
Total	**$610.00**

The tripod shown in Figure 1 is not included.

If a 16-millimeter outfit is desired, the price is $635.00. The price with interchangeable parts for both 35-millimeter and 16-millimeter use is $775.00.

The above equipment is not carried in stock but can be built to order. Delivery at the present time can be made in about ten weeks from date of order.

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

MEASUREMENT OF THE IMPEDANCE OF THE HUMAN BODY

THE Horton Impedance Comparator described here was developed at the Electrical Engineering Department of the Massachusetts Institute of Technology and built by the General Radio Company. Although designed for use in medical diagnosis, it has a number of other applications in the physical sciences. It is already being used in physical chemistry to measure the impedance of solutions, where, by virtue of its four-terminal connection, it yields results which are independent of the impedance of the electrodes.

BY CHANGING merely the last two letters, the word physician becomes physicist. Actually, even this small change is unnecessary because the physician secures the greater part of his data regarding the condition of a patient through observations on various physical quantities. Among the many properties which may have diagnostic significance, those of an electrical character have not been generally considered. They have, however, received occasional attention since Galvani in 1791 first demonstrated that living matter exhibits electrical phenomena.

The first serious attempt to correlate the electrical properties of a human body with its pathological condition was made in 1881 by the French scientist, Vigoreaux. He reported that there was a relation between the electrical resistance of the body and the degree of thyroid activity. Measurements of d-c resistance were, however, difficult owing to polarization at the electrode surfaces and no practical use was made of Vigoreaux's findings. Following the introduction of alternating-current technique into electro-chemical measurements, Gildermeister, in Germany, repeated Vigoreaux's investigations, using alternating current. This avoided the difficulty of electro-polarization as such. It was found, however, that there was an appreciable reactance component in the

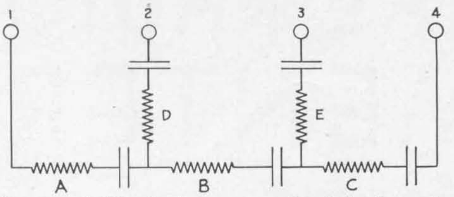


FIGURE 1. Equivalent network of the impedances joining four electrodes applied to the body. The electrodes are numbered *1*, *2*, *3*, and *4*. Path *B* is the impedance of the internal tissue between the inner electrodes *2* and *3*. Branches *D* and *E* are the surface tissue impedances under the inner pair of electrodes, while *A* and *C* are each the total impedance between one electrode of the outer pair and the junction of the impedances representing surface tissue and internal tissue under the corresponding inner electrode

measured impedance. This reactance has the sign of a capacitive reactance although it is probable that it is due to polarization within the tissues. Very recently Dr. Brazier, in England, has reported that there is a correlation between the resistance-reactance ratio and thyroid activity.

In an attempt to check Dr. Brazier's conclusions, an extensive investigation was carried out jointly by the Massachusetts Institute of Technology and the Massachusetts General Hospital.*† The first result of major importance was the discovery that there was a marked difference in behavior between internal and external tissues. The data on which these conclusions are based were obtained by applying four electrodes to the body. The current paths joining these four electrodes may be considered as made up of separate branches, some of which are composed wholly of external tissues and some wholly of internal tissues. By measuring with a bridge the impedance between each of the six possible terminal pairs, the impedance of these separate branches may be evaluated.

From studies made at different frequencies, it was evident that accurate observations of the reactance-resistance ratio could not be made for the external tissues at frequencies much higher than 10 kilocycles, nor for the internal tissues at frequencies much lower than this value. Consequently, 10 kilocycles was chosen as the most suitable frequency for subsequent investigations.

Data obtained by the bridge method indicated that the impedance of the internal tissues offered considerable promise as a diagnostic indicator. In order to simplify the measuring technique there has been developed a special form of alternating-current potentiometer by which the impedance of either internal or external tissues may be determined in a single measurement. This apparatus is designed to work only at 10 kilocycles and hence can be calibrated to read reactance in ohms directly.

The general arrangement of the potentiometer is shown schematically in

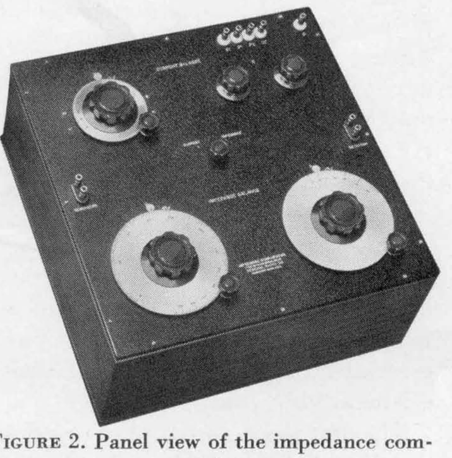


FIGURE 2. Panel view of the impedance comparator

* "The Electrical Impedance of the Human Body," J. W. Horton and A. C. VanRavenswaay, *Journal of the Franklin Institute*, Vol. 220, No. 5, November, 1935.

† "The Clinical Significance of Electrical Impedance Determination in Thyroid Disorders," Horton, Van Ravenswaay, Hertz and Thorn, *Endocrinology*, January, 1936, pp. 72-80.

Figure 3. Current is supplied independently by two identical transformers to one pair of electrodes on the patient and to a standard circuit including a fixed resistance and the primary winding of a mutual inductometer. These two currents are brought to identity with respect to both magnitude and phase by adding in series with the patient an impedance of such value that the loads on the two transformers are identical. This condition is indicated by equal voltage drops across the equal resistors R_1 and R_2 when the detector is switched to the dotted position. When this identity between the two currents has been established, the detector is switched so that it indicates the difference between the voltage set-up between the second pair of electrodes on the patient and a voltage composed of the resistance drop across the portion of the standard resistance and the induced voltage in the inductometer secondary. These last two components are adjusted until the differential voltage is zero. When this condition is established, the impedance of that portion of the patient which is common to the two current paths be-

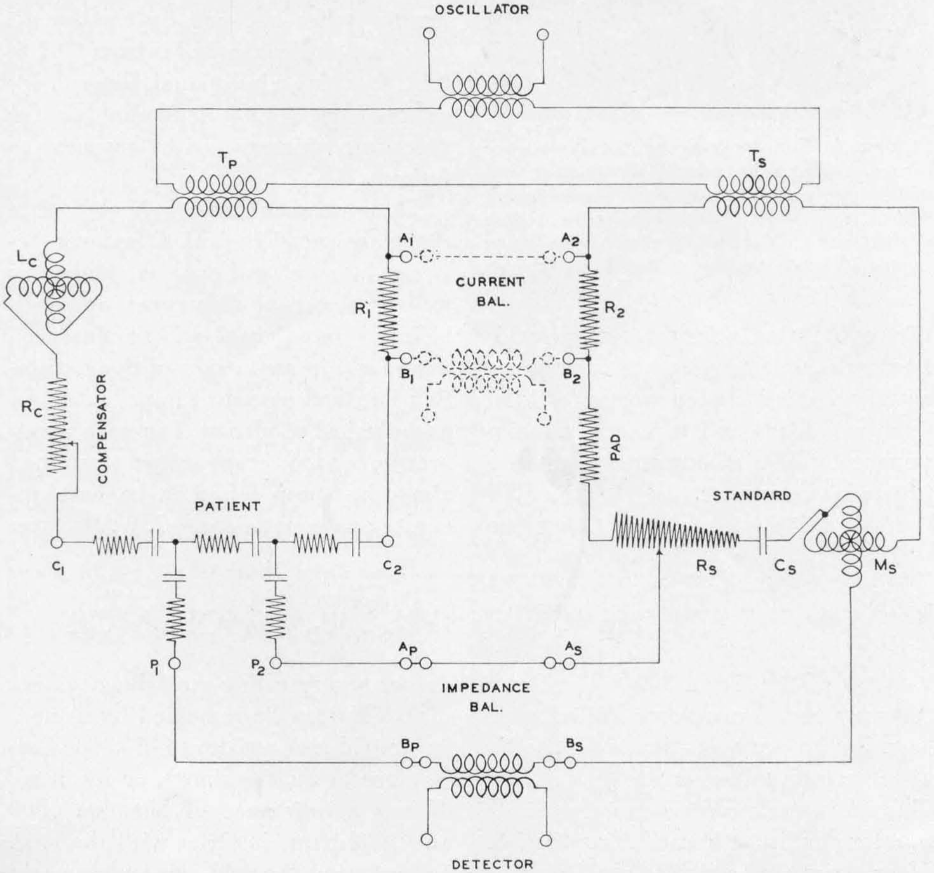


FIGURE 3. Schematic wiring diagram of the impedance comparator, including the network representing the patient. Since no current flows through electrodes P_1 and P_2 at balance, these act as potential terminals and measure the true internal impedance of the patient, corresponding to B in Figure 1

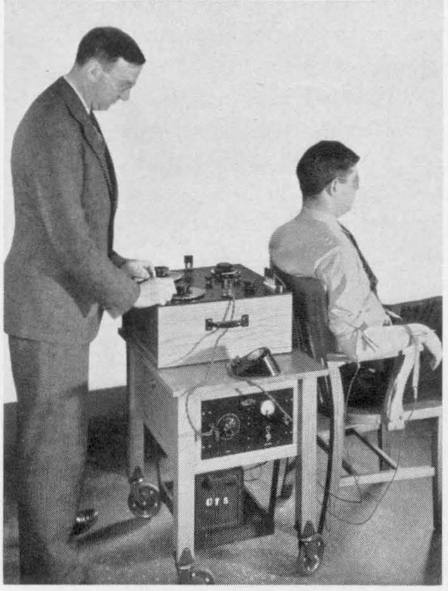


FIGURE 4. For convenience the impedance comparator and its associated amplifier and power supply are mounted on a "tea wagon." The author is shown measuring the impedance of a patient. On the patient's right arm are one inner and one outer electrode. The other pair of electrodes are on the left arm

tween the two pairs of electrodes is known to have a resistance component equal to the included portion of the fixed resistance and a reactance component equal to the mutual reactance of the inductometer.

Using this device, to which the name "impedance comparator" has been given, extensive measurements have been made of a wide variety of pathological cases. Extensive measurements have been made also of the variations occurring in a single individual. The results may be generalized briefly as follows:

Every person in normal health has a value of Q for the internal tissue which is characteristic of him as an individual. Any abnormal pathological condition will act to change this value, and changes of the order of 2 to 1 have been observed. For individuals in normal health Q lies between 0.10 and 0.07. The pathological spread is from 0.02 to 0.14. In a single individual, Q may vary as much as $\pm 10\%$ depending on the preceding history with respect to fatigue.

These studies have indicated that there are physiological differences between internal and external tissues as well as electrical differences, and it is believed that they should be measured separately in any study of the correlation between electrical impedance and pathological condition. For such measurements the comparator described above has been found to be both accurate and convenient.—J. W. HORTON

A NOTE ON THE USE OF TYPE 508-A OSCILLATOR

USERS of the TYPE 508-A Oscillator may experience some difficulty in securing proper operation with the 45-type vacuum tubes currently available. The new tubes produce an appreciably greater amplitude of oscillation than do older types. Intermittent oscillation at 3 kc and 4 kc may occur owing to a charge accumulating on the grid condenser and resulting excessive negative bias. This can be remedied by using a lower grid leak resistance (30,000 ohms in place of 50,000 ohms), or by introducing a resistance of between 1000 and 5000 ohms in series with the grid, i.e., between the grid coil and the grid itself. The latter method is preferable since it improves the waveform.

— R. F. FIELD

CARRIER ENVELOPE ANALYSIS WITH THE WAVE ANALYZER

FOUR years ago[1] this company announced a distortion factor meter which gave the root-mean-square distortion of a 400-cycle signal. This instrument, when used in conjunction with a modulation meter to rectify the r-f signal, gave corresponding results for the carrier envelope of a radio signal modulated at 400 cycles. A more recent instrument[2] combines these functions in a single unit.

Although distortion measurements at the standard test frequency of 400 cycles are adequate for all routine checks on broadcast transmitters, the larger stations, groups of stations and transmitter manufacturers often wish to make these measurements at other test frequencies or throughout the audio-frequency range. While instruments have been built to order for single test frequencies, the heterodyne-type wave analyzer[3] is the best answer to this need because it is not limited to a single-frequency fundamental.

There is still one missing link—the application of the audio-frequency heterodyne wave analyzer to a radio-frequency carrier envelope. This need has been taken care of to some extent by providing "ENVELOPE" terminals on the TYPE 732-A Distortion and Noise Meter, which makes the demodulated output of its linear rectifier accessible for further analysis. This, however, is a compromise because the distortion and noise meter is designed primarily for 400-cycle operation, and its characteristics are not entirely satisfactory when much higher modulation frequencies are used (above a 2000-cycle fundamental, for example).

A simple linear rectifier to plug into the TYPE 636-A Wave Analyzer is not difficult to construct. Figure 1 is a photograph of one used in the laboratories of the General Radio Company. The circuit is shown in Figure 2.

It will be noticed that the circuit is entirely conventional except for the choice of constants and the physical arrangement. The very high leak resistor is made possible by the fact that full-scale deflection on the wave analyzer is obtained with a current of only 0.01 microampere. This freedom in the choice of constants makes a

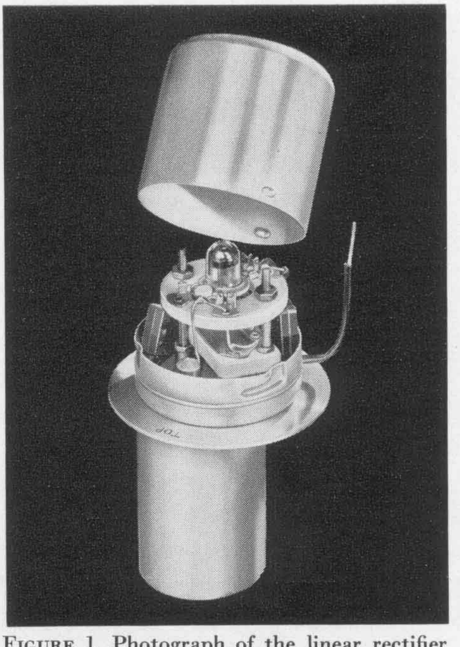


FIGURE 1. Photograph of the linear rectifier assembly

[1] W. N. Tuttle, "Direct Measurements of Harmonic Distortion," General Radio *Experimenter*, VI, 6, November, 1931.

[2] L. B. Arguimbau, "Monitoring of Broadcasting Stations," General Radio *Experimenter*, IX, 10, March, 1935.

[3] L. B. Arguimbau, "Wave Analysis," General Radio *Experimenter*, VIII, 12–13, June-July, 1933.

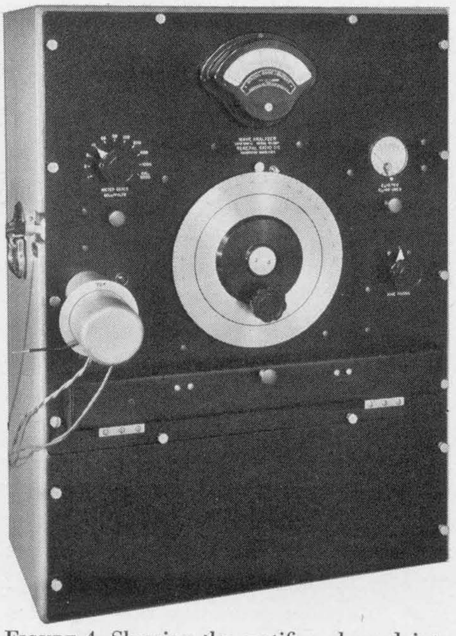


FIGURE 4. Showing the rectifier plugged into the input terminals of a TYPE 636-A Wave Analyzer

highly linear detector possible. The acorn type of tube was chosen primarily because its inter-electrode capacity from plate and grid to cathode is only 2.4 $\mu\mu$f, which permits the use of a small series condenser with consequent improvement of the audio-frequency characteristic. Incidentally, the effective carrier-frequency input impedance is increased.

Although not necessary, the meter shown in the circuit diagram is useful in measuring the magnitude of the radio-frequency input voltage.

The metallized 10-megohm resistor is mounted as a direct connection between two shielded compartments, the ends being in different compartments. No attempt has been made to measure the equivalent direct shunting capacity across this resistor, but it is less than 0.1 $\mu\mu$f and is probably very much smaller than this. This method of mounting is very important since a capacity as large as 1.0 $\mu\mu$f would begin to cause trouble at 10 kc.

The circuit as drawn is satisfactory at modulation frequencies up to 2000 cycles with almost perfect linear detection even when 100% modulation is exceeded. At modulation frequencies up to about 10 kilocycles it will work linearly, provided the modulation percentage is not allowed to approach 100%.

If the series resistor is replaced by a 1-megohm pad, as shown in Figure 3, the linearity will not suffer very much, and the unit may then be used at 10 kilocycles with 100% modulation. It turns out that, if the time constant of the CR combination is chosen in such a way that the net impedance presented to the tube at the modulation frequency is less than that presented to the rectified direct current, the extreme negative peaks of modulation will be somewhat clipped, generating distortion. — L. B. ARGUIMBAU

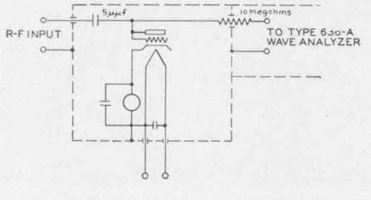


FIGURE 2. Circuit diagram of the linear rectifier

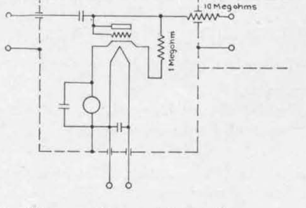


FIGURE 3. Alternative wiring diagram using a one-megohm pad

VARIAC LIGHTING CONTROL IN THE LITTLE THEATER

LIGHTING control in the little theater presents a problem which taxes even the ingenuity of the amateur property man, who must reconcile limited funds and a need for flexibility with the necessary requirement of complying with the underwriters' rules.

The *VARIAC* provides a convenient and efficient way of solving the problem. It provides a smooth variation of illumination and eliminates the waste of power which is inherent in resistive controls. In addition, the *VARIAC* can be used on any load up to its maximum capacity, while resistance dimmers are designed for a single load.

Figure 1 shows a lighting control unit built by East End Electric of Meadville, Pennsylvania, and used in the little theater at the College of William and Mary. It is entirely portable so that it can be moved from the theater to any part of the campus where it is needed. By the use of *VARIACS*, any size lamp load up to 2 kw can be dimmed from full intensity to black out.

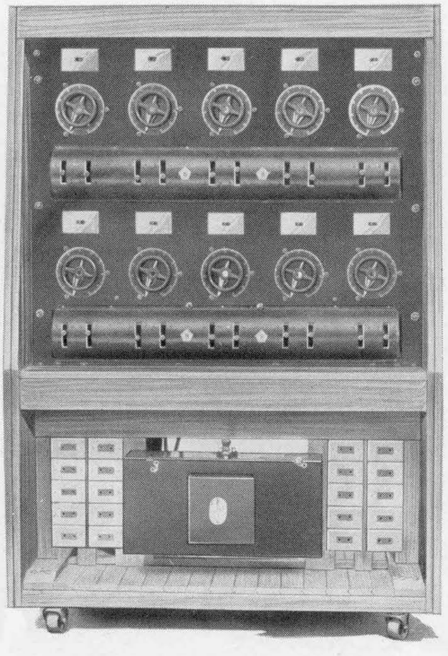


FIGURE 1. Photograph of the lighting-control panel

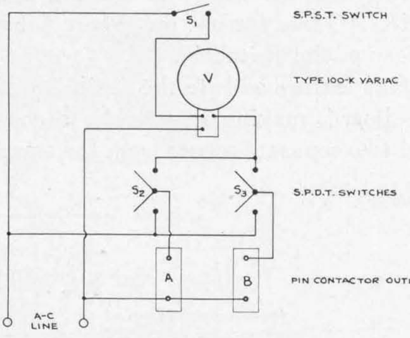


FIGURE 2. Wiring diagram showing connections for one *VARIAC*

The board has a total load capacity of 33 kw and is supplied with a large stage cable that connects to the control board at the rear of the main safety switch at the base of the unit. All lighting equipment under control is plugged into the pin connector outlets on either side of the main switch.

Ten separate circuits are provided with controls arranged on the panel in two horizontal rows. The *VARIACS* are below the row of toggle flush switches (corresponding to S_1 in Figure 2), and below the *VARIACS* are the enclosed single-pole double-throw knife switches (S_2, S_3).

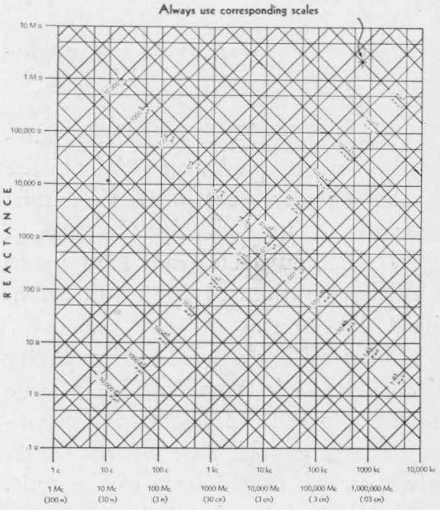
Figure 2 is a wiring diagram showing how each *VARIAC* is connected. Referring to Figure 2, if S_2 is in the upper position, outlet A is connected to the *VARIAC*, and its voltage may be varied from zero to full line voltage. The switch may then be thrown to the lower position, connecting outlet *A* directly to the line and leaving the *VARIAC* free for use on circuit *B* by means of the switch S_3.

This feature adds to the flexibility of the board, making it possible to control two separate scenes from the same *VARIAC* and to switch from one scene to the next without loss of time.

While the control board described here approaches the proportions of a professional installation, smaller amateur units can be built along the same lines, using smaller types of *VARIACS*.

REACTANCE CHART

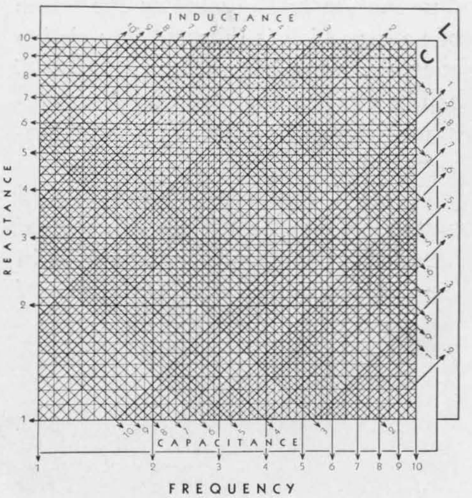
Always use corresponding scales



FREQUENCY

FIG. 1

Always obtain approximate value from Figure 1 before using Figure 2



FREQUENCY

FIG. 2

The accompanying chart may be used to find:

(1) The reactance of a given inductance at a given frequency.

(2) The reactance of a given capacitance at a given frequency.

(3) The resonant frequency of a given inductance and capacitance.

In order to facilitate the determination of magnitude of the quantities involved to two or three significant figures the chart is divided into two parts. Figure 1 is the complete chart to be used for rough calculations. Figure 2, which is a single decade of Figure 1 enlarged approximately 7 times, is to be used where the significant two or three figures are to be determined.

TO FIND REACTANCE

Enter the charts vertically from the bottom (frequency) and along the lines slanting upward to the left (inductance) or to the right (capacitance). Corresponding scales (upper or lower) must be used throughout. Project horizontally to the left from the intersection and read reactance.

TO FIND RESONANT FREQUENCY

Enter the slanting lines for the given inductance and capacitance. Project downward and read resonant frequency from the bottom scale. Corresponding scales (upper or lower) must be used throughout.

Example: The sample point indicated (Figure 1) corresponds to a frequency of about 700 kc and an inductance of 0.5 henry, or a capacitance of 0.1 μμf, giving in either case a reactance of about 2,000,000 ohms. The resonant frequency of a circuit containing these values of inductance and capacitance is, of course, 700 kc, approximately.

USE OF FIGURE 2

Figure 2 is used to obtain additional precision of reading but does not place the decimal point which must be located from a preliminary entry on Figure 1. Since the chart necessarily requires two logarithmic decades for inductance and capacitance for every single decade of frequency and reactance, unless the correct decade for L and C is chosen, the calculated values of reactance and frequency will be in error by a factor of 3.16.

Example: (Continued) The reactance corresponding to 0.5 henry or 0.1 μμf is 2,230,000 ohms at 712 kc, their resonant frequency.

GENERAL RADIO COMPANY • 30 STATE STREET, CAMBRIDGE, MASS., U.S.A.

We still have available a number of large reactance charts similar to that shown above. These charts are 19 x 24 inches and are suitable for mounting on the wall. Copies will be sent free to all who request them.

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

The GENERAL RADIO
EXPERIMENTER

VOL. X. No. 10 — MARCH, 1936

ELECTRICAL COMMUNICATIONS TECHNIQUE
AND ITS APPLICATIONS IN ALLIED FIELDS

A NEW PRECISION WAVEMETER

FOR the rapid and convenient measurement of frequency with a minimum of equipment, the tuned-circuit absorption-type wavemeter has enjoyed a long and useful career. While for precise measurements it has long since been displaced by the more modern heterodyne instruments and the quartz-crystal standard of reference, its usefulness remains unchallenged in that wide field of measurement where only a moderate accuracy is demanded and where simplicity is an important requirement.

The absorption-type wavemeter consists fundamentally of a condenser, one or more coils, and a resonance indicator. Improvements in the design of these components make possible considerably improved performance in the wavemeter.

FIGURE 1. TYPE 724-A Precision Wavemeter

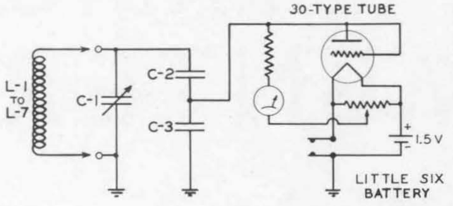


FIGURE 2. Circuit of TYPE 724-A Precision Wavemeter

The TYPE 724–A Wavemeter is a new instrument replacing the older TYPE 224. As a result of the re-design of coils, condensers, and resonance indicator, the new wavemeter has a wider frequency range and a greater sensitivity than its predecessor. The condenser is similar in constructional details to the TYPE 722 Precision Condenser recently described.* This condenser is built around an integrally cast frame of an aluminum alloy, with the rotor shaft, stator rods, and spacers of the same material. Ball bearings support the main shaft. The drive is of the worm-gear micrometer type with the worm cut directly on its shaft. In the wavemeter design, the effective angular rotation is about 270°.

The condenser setting is indicated on the dial and drum and is controlled from the front of the panel. There are 7500 divisions for the entire effective angular rotation of the condenser rotor. The precision of condenser setting is better than one part in 25,000. The plates are shaped to give an approximately linear variation in frequency with scale setting. This makes it possible to use calibration charts in tabular form and to interpolate between points in the table.

Seven coils are used to cover a frequency range between 16 kilocycles and 50 megacycles. The coils are wound on isolantite forms to give low losses and a high degree of stability. Each coil is enclosed in a moulded bakelite case. The plug-in mounting allows the coil to be rotated to obtain different degrees of coupling.

The resonance indicator is a rectifier-type vacuum-tube voltmeter, a distinct advantage over the thermocouple formerly used, since the danger of overloads burning out the indicator is eliminated. The rectifier is coupled to the tuned circuit through a capacitive voltage divider as shown in the circuit diagram, Figure 2.

— ARTHUR G. BOUSQUET

*"A New Precision Condenser," General Radio *Experimenter*, Vol. X, No. 8, January, 1936.

SPECIFICATIONS

Frequency Range: 16 kc to 50 Mc.

Accuracy: 0.25%.

Condenser: Precision worm-drive type.

Coils: Wound on isolantite forms.

Indicator: Rectifier-type vacuum-tube voltmeter.

Net Weight: With carrying case, 35¼ pounds; without carrying case, 18¾ pounds.

Dimensions: Carrying case, 17⅞ x 13 x 12½ inches over-all.

Code Word: WOMAN.

Price: $190.00.

MEASUREMENTS AT LOW FREQUENCIES WITH THE RADIO FREQUENCY BRIDGE

THE TYPE 516-C Radio Frequency Bridge,[1] although designed to operate throughout the broadcast band of frequencies and up to 5 megacycles, can be used at all lower frequencies: carrier frequencies and audio frequencies, and even the power frequency of 60 cycles. The only important changes that must be made are the replacement of the ratio arms and output transformers. This may be readily accomplished because both units are easily detachable and are mounted on the subpanel just below the removable cover. The accuracy of measurement obtainable at the lower frequencies is for all cases superior to that for 1 megacycle. At a frequency of 1 kilocycle the accuracy of substitution measurements is limited only by that of the capacitance and resistance standards used.

The circuit used in the bridge is shown in Figure 2. When an unknown condenser is connected to the terminals in the P arm, the bridge is balanced for capacitance by adjustment of condenser C_N, and for resistance either by the decade resistor N or by the power factor condenser C_A. The calibration of these three controls is such as to make the bridge direct reading in capacitance, resistance, and power factor.

The features of this bridge which make possible its use as a direct reading bridge at 1 Mc are the equality of the ratio arms A and B, the use of a decade resistor[2] N compensated to maintain a constant inductance at all settings and the equalizing of the capacitance arms for series inductance and parallel capacitance by the addition of the inductor L_P and the condenser C_{PO}.

The ratio arms furnished with the bridge have resistances of 100Ω. The power factor condenser C_A has a maximum capacitance of 50 $\mu\mu$f, giving a power factor range at 1 Mc of 3%. The condenser C_B placed across the arm B serves merely to balance out the zero capacitance of C_A. The calibration of the power factor dial is proportional to both the resistance of the ratio arm and to frequency. Hence, when the bridge is used at frequencies below 1 Mc, the range of the power factor condenser C_A can be restored by increasing the ratio arms. This is conveniently done in multiples of ten, that is, 1000-ohm arms for 100 kc,

[1]C. E. Worthen, "Improvements in Radio Frequency Bridge Methods for Measuring Antennas and Other Impedances," General Radio *Experimenter*, Vol. VIII, No. 7, December, 1933.

[2]R. F. Field, "Constant Inductance Resistors," General Radio *Experimenter*, Vol. VIII, No. 10, March, 1934.

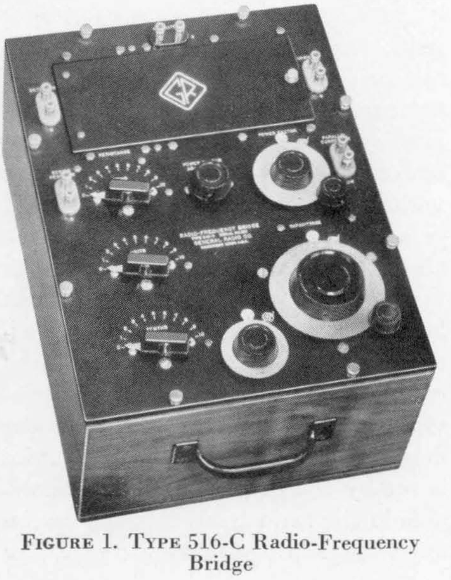


FIGURE 1. TYPE 516-C Radio-Frequency Bridge

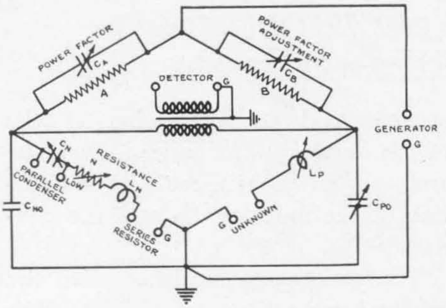


FIGURE 2. Circuit of the radio-frequency bridge. Circuit constants are as follows:

$A, B = 100\ \Omega$
$C_A = 0\text{–}50\ \mu\mu f$
$C_B = 15\ \mu\mu f$, adjustable
$C_N = 1000\ \mu\mu f$, maximum
$N = 0\text{–}111\ \Omega$
$C_{NO}, C_{PO} = 35\ \mu\mu f$
$L_P = 1.2\ \mu h$, approximately

10,000-ohm arms for 10 kc, and 100,000-ohm arms for 1 kc. For the power frequency of 60 cycles the arms should be 1.667 megohms. Ratio arms of these sizes are now available.

The power factor range may be extended by adding a condenser across the arm A with its shield connected to the junction of the ratio arms, so as not to increase the parallel capacitance C_{PO}. At a frequency of 1 kc with 100,000-ohm ratio arms, a total capacitance of 1600 $\mu\mu$f will give a dissipation factor of unity.

Increasing the resistance of the ratio arms as the frequency is lowered serves also to keep their resistance comparable to the reactance of the capacitance arms. In general, this condition gives to a bridge its maximum sensitivity of balance. Bridge sensitivity also depends on the relative position of generator and detector with respect to the various bridge arms, usually being greatest for that connection which allows the greatest current input to the bridge. With ratio arms much lower in impedance than the capacitance arms, the generator should be connected across the ratio arms, provided the input impedance of the detector is high. A limit to this practice is set by the power dissipation allowable in the ratio arms. For this reason low voltage bridges have the generator connected across the ratio arms and high voltage bridges between the junctions of ratio arms and capacitance arms. The terminals of this bridge are marked for the latter connection, but generator and detector may be transposed as occasion demands.

The lower limit of frequency of the air core transformer furnished with the bridge is about 500 kc. For the lower frequencies TYPE 578 Shielded Transformers[3] are available in two models, having the two frequency ranges 2 kc to 500 kc and 20 cycles to 5 kc. These transformers have nearly complete shields around both windings with an air space between the shields. This construction makes the effective terminal capacitance to be placed across the capacitance arms about 40 $\mu\mu$f. Adding this to the 35 $\mu\mu$f already in the bridge increases the value of C_{PO} to about 70 $\mu\mu$f. This may differ by ± 10 $\mu\mu$f between transformers, and the two terminal capacitances in any one transformer may differ by 3 $\mu\mu$f. Because of this latter difference in capacitance the parallel condenser C_{PO} should be reset for each transformer, as must also the zero adjustment condenser C_B. The exact value of this capacitance may be measured by a direct capacitance measurement on a

[3] "Shielded Transformers for Impedance Bridges," General Radio *Experimenter*, Vol. X, No. 5, October, 1935.

TYPE 650-A Impedance Bridge.[4] It may also be measured on the bridge in which it exists by changing one of the ratio arms a known amount, such as by shunting it with a ratio arm of ten times its resistance.

The capacitance and resistance ranges of the bridge are set by the inductance and resulting natural frequency of the capacitance arms, and by the impossibility of compensating a decade resistor much above 100Ω. As the frequency is lowered these limits can be extended. Terminals are provided for the addition of parallel capacitance and series resistance. Since natural frequency varies as the square root of the total capacitance, it ceases to be an important limitation in capacitance below 100 kc. For the same reason, resistors need no longer be compensated for inductance below that frequency; but the capacitance to ground of the rotor of the standard condenser and of the three decade resistors, amounting to about 100 μμf, will be placed across this added resistance. This shunt capacitance sets limits of perhaps 1000 ohms at 100 kc and 100,000 ohms at 1 kc.

[4] R. F. Field, "Direct Capacitance and Its Measurement," General Radio *Experimenter*, Vol. VIII, No. 6, November, 1933.

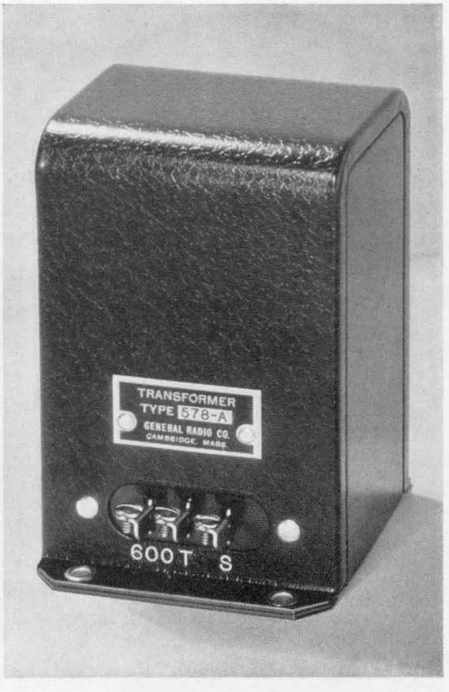


FIGURE 3. TYPE 578 Transformers are available on plug-in bases for use with the radio-frequency bridge. The model shown in the photograph can be used between the bridge and the a-c line for 60-cycle measurements

The accuracy of the bridge for direct reading at the lower frequencies is essentially the same as for radio frequencies. At a frequency of 1 kc the errors are, for capacitance, 5 μμf or 1%, whichever is the greater, and for resistance 0.1 ohm or 2%, provided the proper preliminary adjustments of the bridge have been made. For power factor the error is 0.0002 or 5% if the error caused by the parallel capacitance C_{PO} is taken into account.[5]

Substitution measurements in which the unknown condenser is connected in parallel with the standard condenser are more accurate than direct measurements across the bridge. The preliminary adjustments of the bridge are replaced by an initial balance with the unknown disconnected. Losses in the standard condenser are eliminated except at high frequencies where the ohmic resistance of the condenser is significant.[6]

When the calibrated condensers mounted in the bridge are used as standards, any fixed condenser of

[5] All power factor readings must be increased by the factor $(1+\frac{C_{PO}}{C_P})$.

[6] "Residual Impedances in the Precision Condenser," General Radio *Experimenter*, Vol. X, No. 5, October, 1935.

suitable size may be connected in the P arm to complete the bridge circuit, together with sufficient resistance to make possible a resistance balance with the added resistor N or the power factor condenser C_A. The error for capacitance is that of the standard condenser, 5 $\mu\mu$f or 1%. Small capacitances of less than 20 $\mu\mu$f can be measured to an accuracy of .2 $\mu\mu$f or 2% by using the small condenser which is connected in parallel with the main condenser.

When an external precision condenser is used as a standard, it is connected in the P arm and the calibrated condenser in the bridge used merely as a balancing condenser. The unknown condenser is then connected across the precision condenser. The error for capacitance is that of the precision condenser, 1 $\mu\mu$f or .1% for a direct reading on the TYPE 222-M Precision Condenser or .1 $\mu\mu$f or .1% with the application of its worm correction.[7] The resistance balance can be made by means of the added resistor N, an external decade resistor connected in series with the precision condenser or the power factor condenser C_A.

The power supply for the bridge may be either a modulated or unmodulated vacuum-tube oscillator, depending on the type of detector used.

Above 150 kc an all-wave radio receiver makes a very satisfactory detector when used in conjunction with a modulated oscillator. A short-wave receiver arranged for the reception of c-w signals may be used with an unmodulated oscillator.

[7]R. F. Field, "Increased Accuracy with the Precision Condenser," General Radio *Experimenter*, Vol. X, No. 5, October, 1935.

Below 100 kc a resistance coupled amplifier, having a gain of 80 db and using a copper-oxide rectifier or vacuum-tube voltmeter, forms the most convenient detector. It must, however, be tuned sufficiently to have a discrimination of at least 20 db against the second harmonic, both to remove the error resulting from harmonics and to sharpen the bridge balance.

In the narrow band of audio frequencies lying between 0.5 and 5 kc, head telephones may be used and the amplifier gain somewhat reduced. At the power frequency of 60 cycles certain precautions must be taken if power is taken from the a-c line. The 60-cycle static and magnetic fields in the average laboratory are often sufficiently intense to provide appreciable coupling between generator and detector. While the effect of the electrostatic field may be removed by shielding, the effect of magnetic fields at 60 cycles can be reduced only by removing their source to a sufficient distance or by using astatic transformers. At other frequencies it is also important that the generator have a negligible external magnetic field.

The TYPE 484-A Modulated Oscillator, which may be used either modulated or unmodulated, covers the frequency range down to 10 kc. TYPES 713-A and 613-B Beat-Frequency Oscillators extend the frequency range to 10 cycles. The TYPE 508-A Oscillator covers the audio-frequency range from 200 cycles to 4 kc in 10 discrete steps, while the TYPES 213 and 813 Audio Oscillators operate at the single frequencies, 400 cycles and 1 kc. TYPES 514-A and 714-A Amplifiers are resistance coupled amplifiers having gains of 45 and 80 db, respectively, up to 50 kc, the latter being a-c operated.

A Type 578-A Shielded Transformer may be used to connect the bridge to the 110-volt 60-cycle supply. It should be used step up when connected to the generator terminals and step down when connected to the detector terminals. In the former case about 400 volts will be applied across each condenser, in the latter 3 volts.

—R. F. Field

RATIO ARMS FOR TYPE 516-C RADIO FREQUENCY BRIDGE

Type	*Resistance*	*Frequency*	*Price*
516-P2	10 Ω	10 Mc	$6.00
*516-P3	100 Ω	1 Mc	6.00
516-P4	1 kΩ	100 kc	6.00
516-P5	10 kΩ	10 kc	6.00
516-P6	100 kΩ	1 kc	8.00
516-P7	1667 kΩ	60 c	10.00

SHIELDED TRANSFORMERS

Type	*Frequency Range*	*Price*
*516-P10	5Mc—10Mc	$8.00
578-A	60 c supply	15.00
578-AR	50 c—10 kc	20.00
578-BR	20 c— 5 kc	20.00
578-CR	2 kc—500 kc	20.00

*Furnished with the bridge.

A DIRECT-READING CONDENSER FOR SUBSTITUTION MEASUREMENTS

For capacitance measurements by the substitution method,[1] a variable air condenser reading negative increments of capacitance directly on its scale is a great convenience. The Type 222-M Precision Condenser, which has been widely used for this purpose, has now been discontinued and is replaced by the Type 722-M Precision Condenser. The new instrument is similar in details of construction to the Type 722-H and Type 722-F Precision Condensers recently described.[2]

The maximum capacitance of the condenser is in the vicinity of 1100 $\mu\mu$f, which provides a direct-reading range of 1000 $\mu\mu$f.

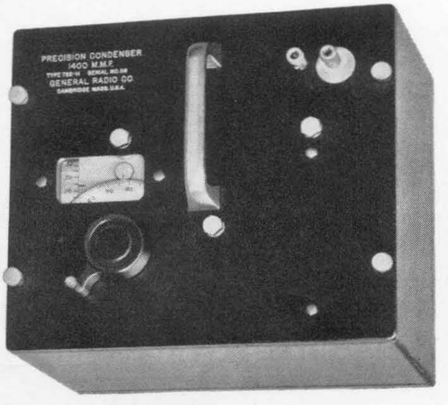


Figure 1. External view of a Type 722 Precision Condenser

[1] R. F. Field, "An Equal-Arm Capacitance Bridge," General Radio *Experimenter*, Vol. IV, No. 8, January, 1930.

[2] "A New Precision Condenser," General Radio *Experimenter*, Vol. X, No. 8, January, 1936.

SPECIFICATIONS

Capacitance Range: Direct reading in capacitance *removed* from circuit over a range of 1000 $\mu\mu$f.

Accuracy: 1 $\mu\mu$f or 0.1%, whichever is larger.

Dimensions: Panel, 8 x 9⅛ inches; depth, 8⅛ inches.

Net Weight: 11⅛ pounds; 20¼ pounds with carrying case.

Type	*Code Word*	*Price*
722-M	COMIC	$100.00

TYPE 713-A BEAT-FREQUENCY OSCILLATOR

WHEN originally announced in the July, 1935, issue of the *Experimenter* the TYPE 713-A Beat-Frequency Oscillator was calibrated between 10 and 16,000 cycles per second. The actual frequency range covered is greater than this, and, in order to take full advantage of the capabilities of the instrument, the upper limit of calibration has been extended to 20,000 cycles. Units currently available are calibrated over this larger range.

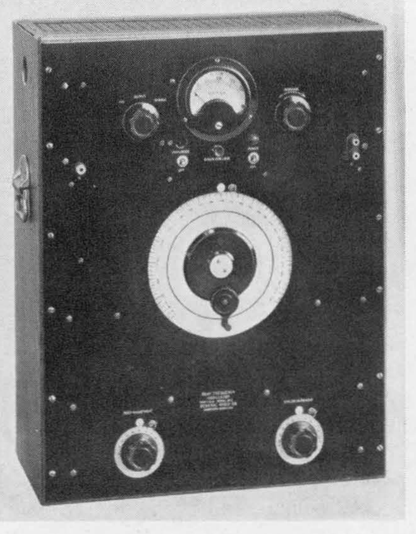


FIGURE 1. TYPE 713-A Beat-Frequency Oscillator

THE 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.

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

The GENERAL RADIO EXPERIMENTER

VOL. X. No. 11 — TWENTY YEARS OF GENERAL RADIO COMPANY 1915–1935 ELECTRICAL APPARATUS MANUFACTURE — APRIL, 1936

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

BETTER MIXER CONTROLS

THE introduction of the General Radio Type 653 Volume Control early in 1933 was the beginning of the almost universal present practice of using step-by-step mixer controls in low-level circuits. The step-by-step design eliminates the three objections common to wire-wound controls: excessive noise, uncertain or fragile contact, and difficulties of cleaning and maintenance. Properly designed step-by-step controls combine very low electrical noise level with rigid mechanical construction and simplicity of cleaning.

Several thousands of the Type 653 Volume Controls are now in everyday use in hundreds of broadcast studios and sound motion picture installations in the United States and abroad. The past three years of experience with these controls has led to the development of a new design which incorporates several important improvements. The new unit is illustrated on page 2.

Two of the most essential features of any mixer control are a very low noise level (particularly since they are often used in low-level microphone circuits), in order that adjustments during a program are inaudible, and absolute dependability. Both the three-bladed switch arm and the contacts of the new Type 653 are made of beryllium-copper alloy. Since the switches and contacts are the same material, although differently tempered, electrical contact-potential noise is completely eliminated. Beryllium copper, which is a relatively recent development for this purpose, possesses remarkable strength, springiness, and wearing properties. Less tough contact materials when improperly lubricated may have a tendency to cut. The new alloy largely eliminates this difficulty. As a result, this switch assembly has indefinitely long life.

All contact surfaces which receive as much wear as a mixer control should, however, be cleaned and lubricated as a matter of routine maintenance. The dust cover of the new control is in two sections, and only the rear section can be taken off after installation. Removal of this section exposes the contacts but leaves all of the windings completely covered by the other section, so that there can be no possibility of damage to the windings during cleaning. In fact, all fine-wire windings and leads are completely covered at all times, except when the unit is removed from its panel mounting.

In redesigning the unit the depth has been shortened, and it now requires only 2³⁄₁₆ inches clearance behind the panel. The diameter is 2¾ inches, making it possible to mount six in a row on a standard 3½-inch relay-rack panel. New soldering terminals which are smaller in size and mechanically stronger have been added.

Another useful feature is the addition of a button on the skirted control knob, so that the setting can be determined in dimly lighted monitoring booths or without looking away from the program. The design of the skirted control knob was the result of a considerable investigation to find the size and shape most comfortable for long periods of manipulation. After three years of use the "feel" of the knob is still generally approved. The index button is added for improved utility.

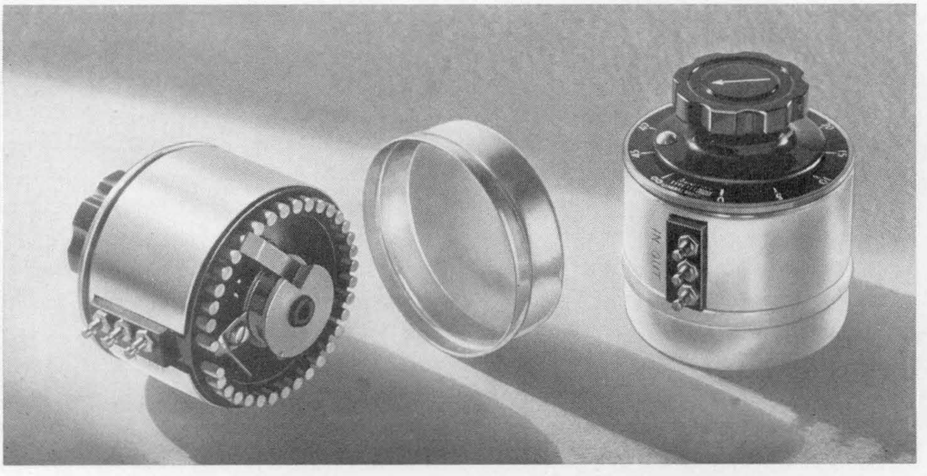
The attenuation system is a ladder network having 33 attenuation steps of 1.5 decibels per step over most of the range but increasing increments toward infinite attenuation. The impedance is essentially constant over the entire attenuation range and is constant with frequency up to 30 kilocycles. The unit is arranged for panel mounting using the etched-metal dial plate for a drilling template. The dial plate is calibrated to show the approximate attenuation in decibels at all settings.

Four impedance sizes are available: The usual 50-, 200-, and 500-ohm values, and, in addition, a new 250-ohm size for use in the many present-day voice circuits of that impedance.

— Arthur E. Thiessen

Type	*Impedance*	*Code Word*	*Price*
653-MA *	50 Ω	CLUMP	$12.50
653-MB	200 Ω	COACH	12.50
653-MD *	250 Ω	CARAT	12.50
653-MC	500 Ω	COAST	12.50

* Delivery after May 1.



Photograph of the new Type 653 Volume Control

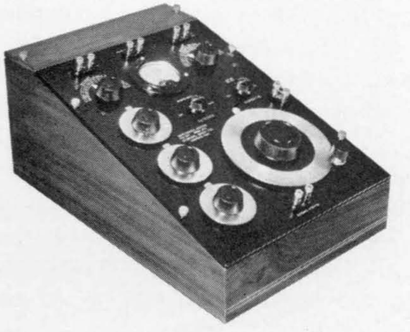
DIRECT MEASUREMENTS WITH GENERAL RADIO INSTRUMENTS

As a result of the continued demand of the commercial engineer and the academic research worker for accurate and convenient means of measurement of electrical quantities in their laboratories, the General Radio Company has, from time to time, in the course of the twenty years of its existence directed the abilities of the engineers to the solution of the measurement problems that have come to its attention. The General Radio *Experimenter* for June, 1935, gives, in the anniversary license of reminiscence, a brief historical account of the resulting developments.

Irrespective of sequence, where has the Company arrived?

It is not the function of instrument makers to solve their customers' major problems, but rather to anticipate their minor ones. The worth of the instrument lies in the extent to which it supplies the desired information and leaves the worker free to achieve a guided solution to the primary problem. We all hesitate twice before using a spineless tape measure, yet are quite unperturbed by doubts while inspecting the fine graduations of a steel scale of a reputable manufacturer.

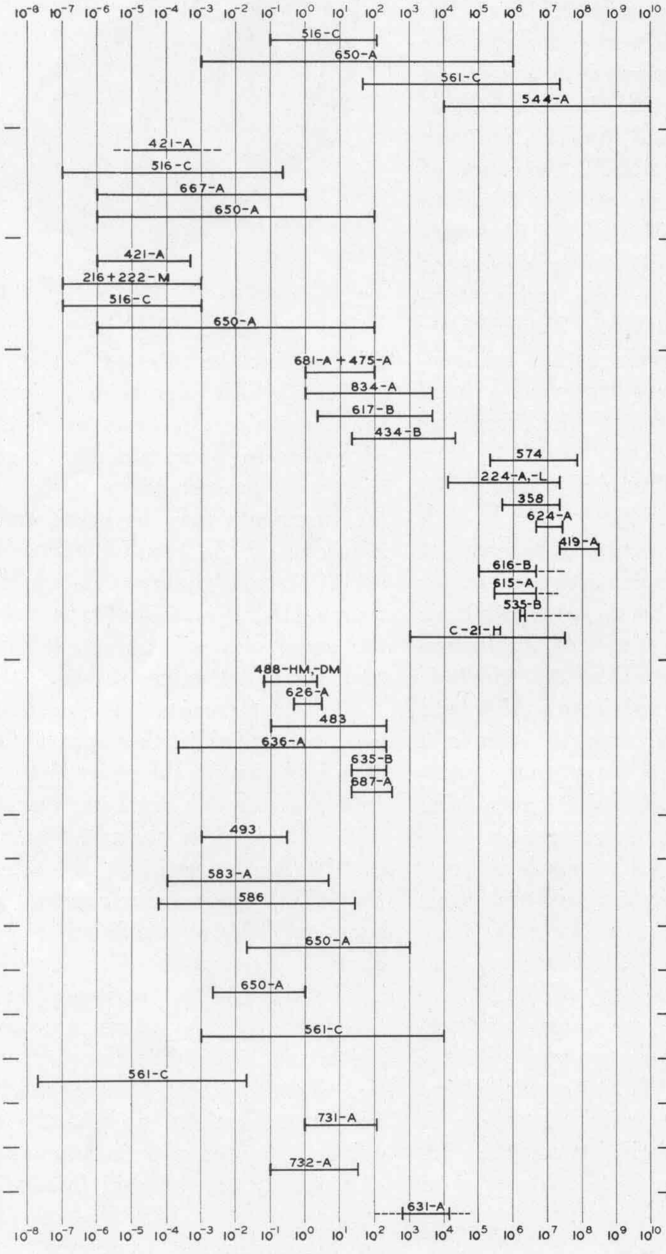
It is the belief of the Company that it has transferred many of the laboratory routine and secondary measurements from the tape-measure to the steel-scale class. The prerequisite that range and accuracy limits be known is no worse in simile than the few moments taken with the scale to ascertain its length and the fineness of its graduations.



The accompanying chart shows in brief outline the thorough coverage of all fields which have been achieved in the composite development of a line of measuring instruments, together with the frequencies at which the measurements may be made and the accuracy of the results. For extreme conditions of high impedances and high frequencies, it is to be expected that the accuracies will be somewhat less than the rated values shown.

The instruments are commercial products; price is therefore a factor. This is shown on the chart in that the wide ranges are in each case associated with a decrease in the rated accuracy, or with an increase in the cost above that of less accurate instruments in the same field. There stands out as well a clear demonstration of the restriction in working range previously necessitated by an increased range of operating frequencies. It is in this characteristic of the chart that the results of present investigations will be most evident. As the new instruments are announced, the inked-in lines will be longer than those they replace without an accompanying frequency restric-

DIRECT MEASUREMENT RANGES
OF GENERAL RADIO INSTRUMENTS



Unknown	Unit	Instrument	Accuracy	Frequency Range
R	Ohms	516-C	1%	0–5 megacycles
		650-A	1%	0–10,000 cycles
		561-C	0.5%	1000 cycles
		544-A	3%	direct current
L	Henries	421-A	0.25%	125–4000 kilocycles
		516-C	1%	60 c.–5 megacycles
		667-A	0.2%	60–10,000 cycles
		650-A	2%	10–10,000 cycles
C	Mfds.	421-A	0.25%	125–4000 kilocycles
		216+222-M	0.1%	200–10,000 cycles
		516-C	1%	60 c.–5 megacycles
		650-A	1%	10–10,000 cycles
~	Cycles per Second	681-A + 475-A	±5 c.	direct indicating
		834-A	2%	direct indicating
		617-B	±1 c.	direct reading
		434-B	0.5%	direct reading
		574	1%	direct reading
		224-A, -L	0.25%	by calibration
		358	0.25%	by calibration
		624-A	0.1%	by calibration
		419-A	1%	by calibration
		616-B	0.1%	by calibration
		615-A	0.1%	by calibration
		535-B	0.5%	by calibration
		C-21-H	0.00005%	with aux. equip.
E	Volts	488-HM, -DM	10%	10–10,000 cycles
		626-A	1–4%	0–4 megacycles
		483	10%	10–10,000 cycles
		636-A	5%	20–16,000 cycles
		635-B	waveform only	0–15 Mc.
		687-A	waveform only	0–50 Mc.
I	Amps.	493	2%	0–30 megacycles
W	Watts	583-A	4%	10–10,000 cycles
		586	2.5%	10–10,000 cycles
Q	X/R	650-A	15%	1000 cycles
D	R/X	650-A	15%	1000 cycles
μ		561-C	0.5%	1000 cycles
G_m	Mhos	561-C	0.5%	1000 cycles
Modulation	%	731-A	2%	50–50,000 kilocycles
Distortion	%	732-A	1%	400 cycles
	Rpm	631-A	2%	direct reading

tion, and will tend to cluster to the sides of the chart.

Considering the individual sections, the outstanding position of the Type 650-A Impedance Bridge as a laboratory instrument is at once evident. Not only dominating each impedance field by its audio-frequency working range, its value is further enhanced by its triple appearance and its consequent general usefulness.

The narrowed working range of the Type 516-C Radio-Frequency Bridge for resistance and capacitance as shown on the chart is that within which the bridge is direct reading at all frequencies between sixty cycles and five megacycles. Measurement of impedances beyond these ranges is not a difficult matter, involving only the necessity of establishing series or parallel combinations that come within the direct-reading range of the bridge.

In the field of frequency measurements first appears the direct-indicating type of instrument previously available only for the measurements of voltage, current, and power. The Type 834-A Electronic Frequency Meter indicates directly the frequency of an applied audio-frequency voltage, while the combination of the Type 681-A Deviation Meter and a reference standard indicates directly the deviations from any desired point in the radio-frequency spectrum.

Harmonic extension methods are as useful as the fundamental ranges in heterodyne frequency meters and, where usable, are shown as dashed extensions on the chart.

The Class C-21-H Standard Frequency Assembly, together with its auxiliary interpolation equipment, constitutes a primary standard for the measurement of frequencies within the range and with the accuracy shown. Perfectly usable for secondary measurements, its range and accuracy are included on the chart for purposes of comparison.

For the measurement of current and voltage the instruments shown are those valuable beyond a-c and d-c meter movements because of individual advantages. These vary from the 10-megohm input impedance of the Type 626-A Vacuum-Tube Voltmeter to the single-frequency selectivity of the Type 636-A Wave Analyzer. The cathode-ray oscillographs are shown for their ability to give a visual picture of the waveform of voltages within the ranges marked. The value of the Type 493 Thermocouples is their ability to permit related measurements to be made with direct and radio-frequency currents, for the effect of frequency on their indications may be neglected over a wide frequency range.

The varied fields at the bottom of the chart illustrate the usefulness of General Radio instruments in specialized tests. Each of the quantities may be obtained as the result of the comparison of two or more measurements of the types listed above, but the use of the instruments results in an economy of apparatus, labor, and time. The uses are specialized, but the applications are not. Each unit performs the same measurement regardless of the primary purpose and under a variety of experimental conditions.

— F. Ireland

THE FREQUENCY STANDARD AT GENERAL RADIO COMPANY

Among the important developments of modern communication engineering is the primary frequency standard. Frequency standardization, of vital importance to the user of communication measuring instruments, is even more essential to the manufacturer, who must be able to work to a far greater accuracy.

The frequency standardization laboratory at the General Radio Company has three important uses: First, it provides a central standard which is used throughout the plant for all frequency calibrations and frequency and time measurement. Secondly, it is used as a proving ground for all advances made in the design of frequency standards and associated equipment. Finally, it is an operating exhibit of a large number of the frequency- and time-measuring instruments manufactured by the Company. The complete frequency standard is shown in the photograph of Figure 1. A very brief listing of the equipment provided will be made here, the balance of the description being made from the functional viewpoint. Referring to the photograph, from left to right, the equipment in the various racks is as follows:

Rack 1: Class C-21-H, Series 690, Primary Frequency Standard with full alternating current operation. Crystal

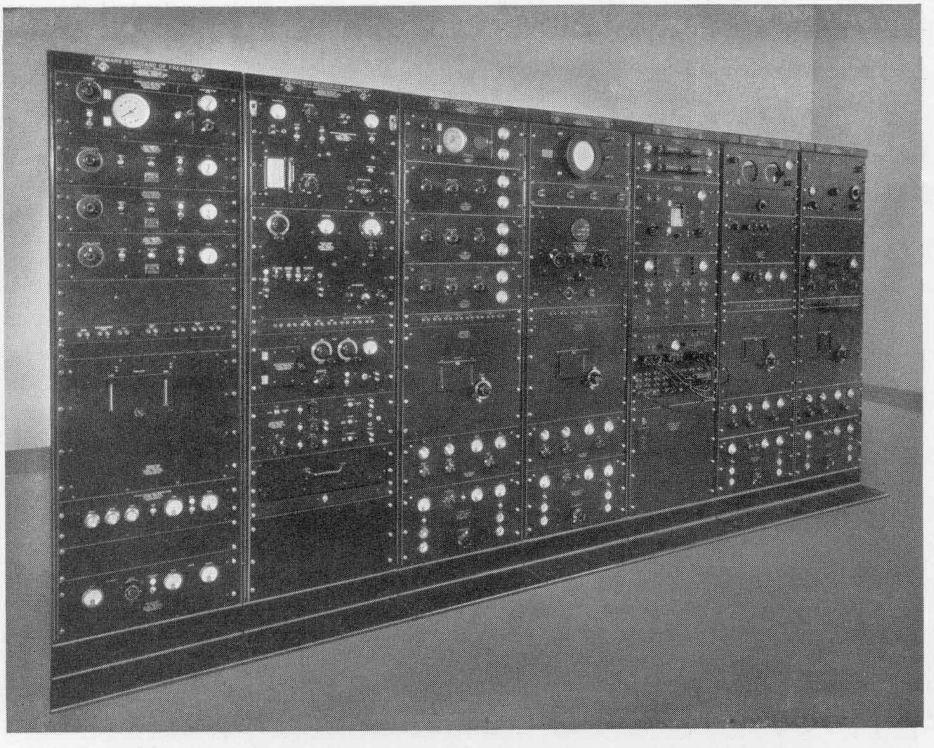


Figure 1. The primary frequency standard at General Radio Company

Oscillator No. 1 is in this rack.

Rack 2: Auxiliary and Interpolation Equipment for frequency measurements. Racks 1 and 2 constitute a complete frequency measuring system.

Rack 3: Class C-21-H, Series 590, Primary Frequency Standard, with floating battery operation. (Crystal Oscillator No. 2.) This unit was placed in service in the fall of 1929 and it has been in continuous service ever since, except for minor shutdowns to move the equipment from one location to another in the building.

Rack 4: Crystal Oscillator No. 3, Cathode-Ray Oscillograph equipment, and direct-reading audio-frequency meter (Type 834-A).

Rack 5: Power distribution panel, signal distribution amplifiers and line connections, beat-frequency recorder and integrator.

Rack 6: Crystal Oscillator No. 4, power supply equipment for stroboscope, recorder, etc., and high-speed stroboscopic clock.

Rack 7: Crystal Oscillator No. 5; selective amplifier (for 1 kc multiples), time signal receiver, and automatic time switch.

The five 50-kc crystal oscillators are maintained in continuous operation, with two of them operating complete multivibrator and timing systems. These two syncro-clocks are checked several times each day against the U. S. Naval Observatory Time signals as transmitted hourly through N.A.A. on 113 kc. If desired, the timing systems may be connected to any other pair of crystal oscillators.

Time comparisons between syncro-clocks, or between the syncro-clocks and the time signals, are made by means of the high-speed stroboscopic clock. This clock has two high-speed hands, one turning once per second, and the other ten times per second. This latter hand travels over a scale of 100 divisions, each division representing one millisecond. The slower hand travels over a scale of ten divisions, each one-tenth of a second, or each one representing a complete revolution of the high-speed hand. These high-speed hands are viewed in the light from a stroboscope lamp permanently mounted in the clock case.

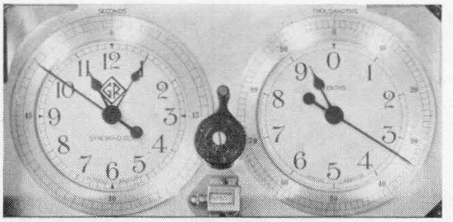


Figure 2. The dial of the high-speed stroboscopic clock. The right-hand dial carries two hands, the shorter rotating once each second, the longer ten times per second

The stroboscope lamp is flashed each dot of time signal, the flash lasting but a few microseconds. When seen in the flash, the high-speed hand appears perfectly stationary, and its position may be read to one-fifth of a division or 0.0002 seconds.

The five crystal oscillators constitute the hearts of five frequency standards, two of which are checked against time, the others being checked in terms of these two by beat-frequency methods. One oscillator (No. 5, actually) is purposely maintained about eight parts in a million low in frequency, so that definite beat frequencies can always be obtained between this oscillator and each of the other four.

In the intercomparing recorder system four detectors and amplifiers are

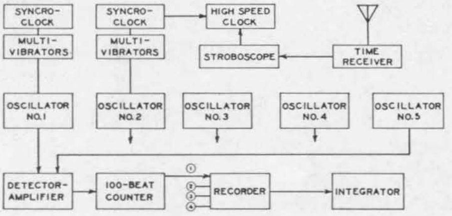


FIGURE 3. Block diagram of the primary standard. For convenience, only one beat recording channel is shown in detail. Beats between Oscillator No. 5 and each of Nos. 2, 3, and 4 are counted and recorded in the same way

provided, one for each of the four pairs of crystals. Each beat-frequency output operates a counter, which counts 100 beats. At the end of each 100-beat interval a dot is printed on the paper strip in the recorder. A point is printed on the record for each beat frequency during every five-minute interval throughout the twenty-four hours. The record is really a *time* record (the time of 100 beats of the beat frequency) but is easily converted into frequency. A time record is used because all four records may be made simultaneously on the recorder. A change of frequency of one part in ten million, in any five-minute period, is easily seen on the record. The record gives a continuous check on the performance of any crystal in terms of the others. If any crystal changes frequency, the record indicates which one changed, how much it changed, and in which direction.

The integrator adds up the successive times of the 100-beat intervals for each of the four pairs of crystals. It is simply a system of four revolution counters arranged to record seconds. The integrator gives a very sensitive indication so that small frequency differences are measurable with high accuracy and in a short time. The integrator is particularly useful in detecting either a very small slow drift in frequency or in studying the small frequency changes resulting from arbitrary changes in circuit parameters, such as changes in filament or plate voltages.

The frequency distribution system consists of a bank of amplifiers, four channels being provided for each main output frequency of 1, 10, and 50 kilocycles. A system of about 30 tone circuits, extending to laboratories and shops, permits the use of the frequency standard at any required point in the building. As required, outputs at multiples of 1 kc, essentially free of other harmonics and of the fundamental, may be distributed from the selective amplifier. Other frequencies, up to 5000 cycles, are available from the linear beat-frequency oscillator. These may be monitored, if necessary, against the standard by means of the cathode-ray oscillograph. — J. K. CLAPP.

The GENERAL RADIO EXPERIMENTER

VOL. X. No. 12 — MAY, 1936

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

A PRECISION TUNING FORK

TUNING FORKS are widely used as low-frequency standards of frequency. These range in accuracy from the simple forks used as standards of musical pitch to the highly-accurate temperature-controlled instruments, driven by vacuum tubes and used as primary standards.

Much timing and low-frequency standardization work calls for a degree of precision intermediate between these two extremes. Tuning forks in this class are used for timing in geophysical exploration, in rating clocks and watches, in synchronizing facsimile transmission, and in 60-cycle standardization. For these and similar applica-

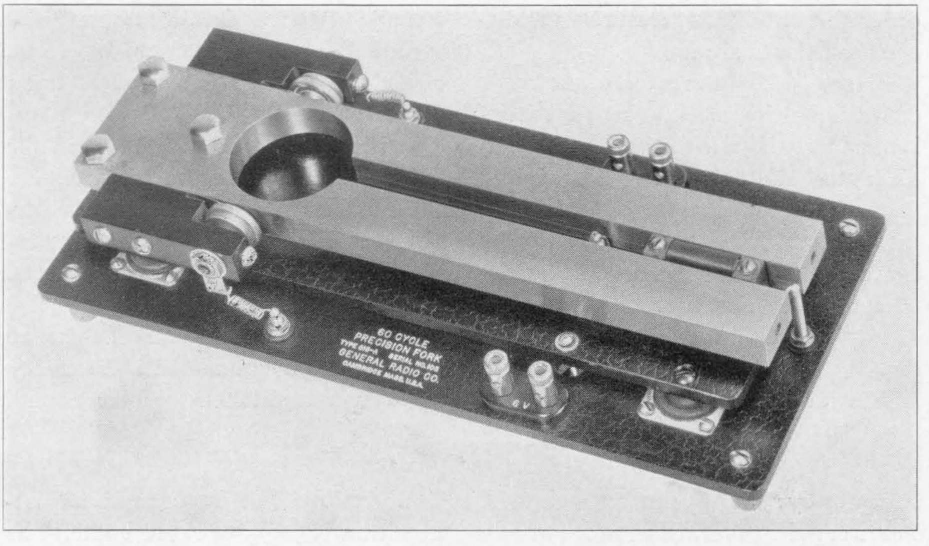


FIGURE 1. TYPE 815-A Precision Fork

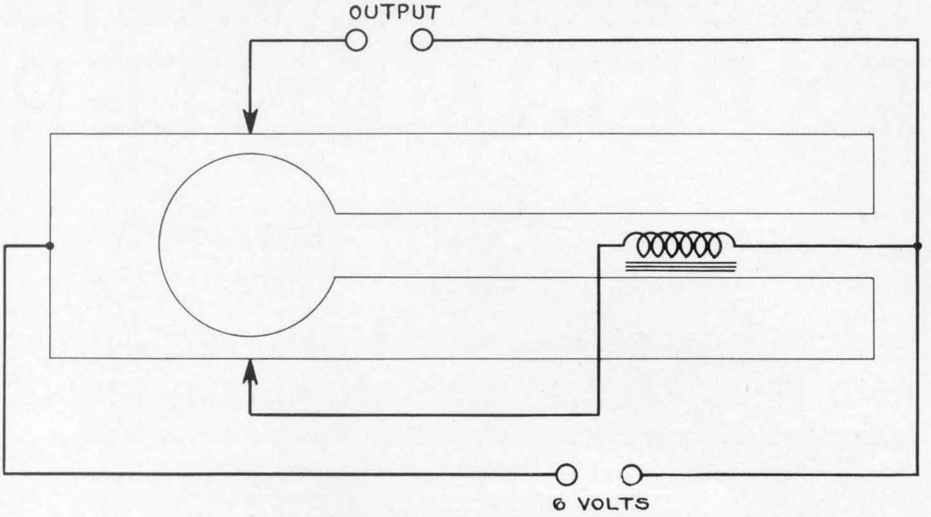


FIGURE 2. Circuit of the TYPE 815-A Precision Fork

tions the TYPE 815-A Precision Fork has been designed.

In this instrument high accuracy and stability have been combined with simplicity of construction and operation.

The fork is adjusted to within 0.005% of its rated frequency. The long period stability is of the same order since both temperature and voltage coefficients are low.

Figure 1 is a photograph of the TYPE 815-A Precision Fork. The fork itself is made of a low-temperature-coefficient steel alloy. It is mounted rigidly at the heel on a metal panel which also carries the driving magnet. This panel is attached to the main base by means of rubber shock absorbers to reduce energy dissipation through the mounting.

The decrement is extremely low. The two microphone buttons are mounted, one on each tine, near the heel of the fork where the amplitude of vibration is low. This minimizes the damping action which the presence of the microphones exerts on the fork. At the end of each tine adjusting screws are provided. Adjustment of these makes it possible to bring the frequency to the desired value and also to equalize the loading on the tines, which has a considerable effect upon the decrement.

Separate microphones are used for the driving and output circuits. No output filter or transformer is furnished since the different uses may require different circuit arrangements. The circuit is shown in Figure 2.

TYPE 815-A Precision Forks can be supplied for any fundamental frequency between 40 and 200 cycles per second.

SPECIFICATIONS

Frequency: 50 cycles per second. Forks can, however, be supplied at any frequency between 40 and 200 c.p.s.

Calibration: The frequency is adjusted within 0.005% of rated value. The calibration temperature is supplied.

Frequency Stability: The over-all stability is better than 0.01% under normal room-temperature conditions.

Temperature Coefficient: The temperature coefficient of frequency is negative and less than 10 parts per million (0.001%) per degree F.

Voltage Coefficient: The voltage coefficient of frequency is positive and less than 150 parts per million per volt (0.015%).

Power Supply: A 6-volt battery is used as the driving source. Driving current is less than 50 milliamperes.

Output: The power output is approximately 50 milliwatts. The impedance of the output microphone is 50 ohms.

Mounting: The fork assembly is mounted on a metal base for table or bench use.

Dimensions: 13 x 6 x 3 inches, over-all.

Weight: 8 pounds.

Code Word (50-cycle model): FAUNA.

Price: $150.00.

WINDING DATA FOR TYPE 677-U and TYPE 677-Y COIL FORMS

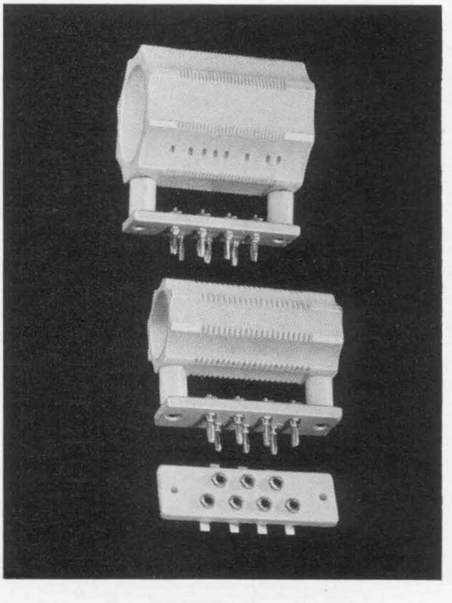
THE accompanying charts are for use with General Radio TYPE 677-U and TYPE 677-Y Coil Forms.

These coil forms are moulded of selected porcelain and are impregnated and coated with Victron lacquer in order to preserve the original high dielectric efficiency of the newly fired porcelain. Each form has eight longitudinal ribs notched to take up to 21 and 30 turns of No. 10 wire on the smaller and larger forms respectively.

The forms may be wound with bare No. 10 or No. 12 wire in each adjacent notch or, for low values of inductance, one or two empty notches may be left between each turn. These are the types of windings designated as "solid," "single spaced," and "double spaced" in Figures 1 and 2.

The values of inductance shown represent the increase in inductance added by breaking a short circuit between the plugs at the ends of the winding. In computations for the required number of turns in resonant tank circuits, allowance must be made for the inductance of the leads connecting the coil to its condenser and for the distributed capacitance of the coil. The charts shown are for coils wound with No. 12 bare copper wire.

(*See page 4 for Charts*)



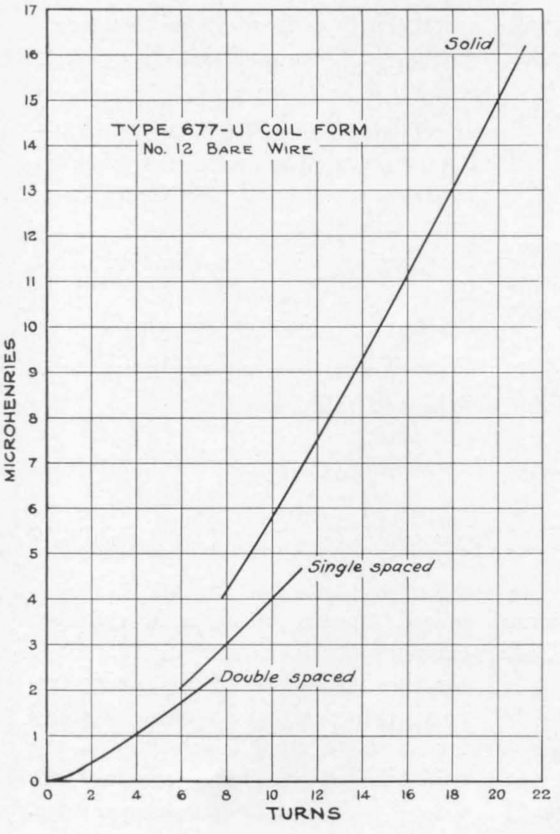


FIGURE 1. (*Left*) Winding data for TYPE 677-U Coil Form.

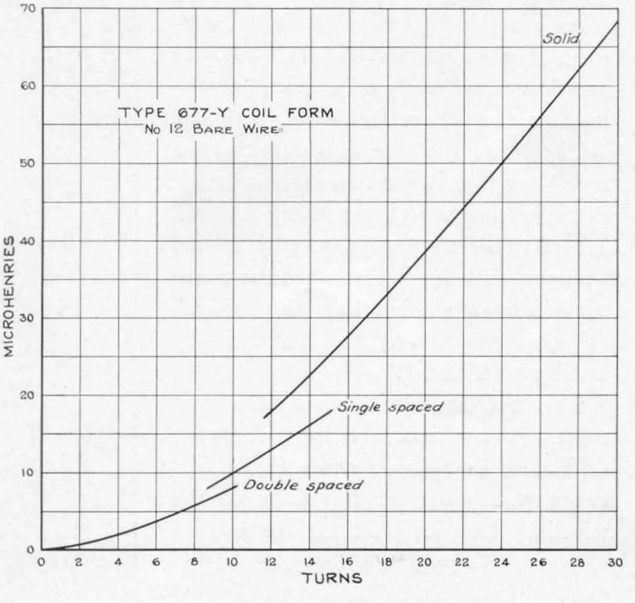


FIGURE 2. (*Right*) Winding data for TYPE 677-Y Coil Form.

AN INDEX OF EXPERIMENTER ARTICLES

THE following pages contain the index for Volume X of the General Radio *Experimenter*. In the future, a similar index will be published each year in the May issue, each index covering one complete volume.

No yearly index of the articles appearing in the *Experimenter* has been published since June, 1931. Many requests have been received from *Experimenter* readers for index material covering the years since that date. A complete index for that period is now in preparation and will be available for distribution within the next few months. The exact date will be announced in a forthcoming issue of the *Experimenter*.

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THE 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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The GENERAL RADIO
EXPERIMENTER

ELECTRICAL MEASUREMENTS TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

VOL. XI No. 1 JUNE, 1936

A MODERN STANDARD-SIGNAL GENERATOR

● **SIGNAL GENERATORS** have reached a stage of maturity when new designs may be directed at requirements in details of operation and elimination of sources of error rather than improvement in the fundamental method.

In the new General Radio TYPE 605-A Standard-Signal Generator, the emphasis is on improved convenience and accuracy of operation. Perhaps no feature of earlier generators has been more annoying than the necessity for changing coils when operating over a wide frequency range, and this has been eliminated by the use of a range switch — and the frequency control dial is direct reading, doing away with calibration curves at the same time. Another long-desired feature — a-c operation — has been incorporated, but the generator may also be operated on batteries if desired. Electrically also, many annoyances of earlier instruments have been eliminated. Frequency modulation is negligible, as is reaction of the attenuator setting on carrier frequency. And no more will a blown thermocouple bring the day's work to a permanent end.

The instrument is the result of nearly two years' study of the problem of designing and manufacturing a signal generator which combines accuracy and general utility with a price that most radio receiver manufacturing laboratories, colleges, and engineers can afford to pay.

A wide frequency range is of primary importance in any general utility signal generator. The range of the TYPE 605-A Standard-Signal Generator extends from 9.5 to 30,000 kilocycles, covering carrier, supersonic and high audio frequencies as well as most of the radio-frequency spectrum.

The inductance and capacitance have been so proportioned that only two frequency scales are necessary on the dial of the tuning condenser. Seven coils are used in conjunction with a condenser having a 10 : 1 ratio of maximum to minimum capacitance. The

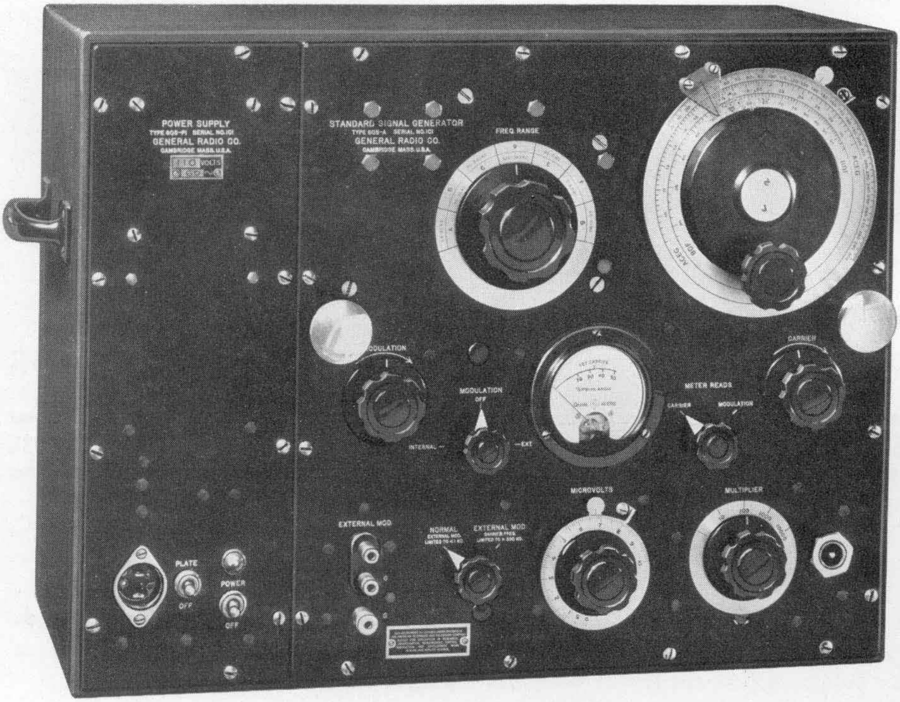

FIGURE 1. Panel view of the TYPE 605-A Standard-Signal Generator

ratio of maximum to minimum frequency for each coil is, therefore, the square root of 10, or 3.16, and the actual ranges in kilocycles are 9.5 to 30, 30 to 95, 95 to 300, and so on up to 30,000 kilocycles. Figure 2 shows the dial and scales in detail.

The main tuning condenser operated by this control has been designed to provide a logarithmic change in frequency with angular rotation. A given rotation will cause the same percentage change of frequency at any setting, and the percentage accuracy of reading is constant over the entire frequency range of the instrument.

The tuned circuit has been designed for a high degree of frequency stability. This is achieved by using a high value of circuit capacitance (1400 to 140 micromicrofarads) and by careful design of the inductors.

The three lowest-frequency coils for the range 9.5 to 300 kilocycles are wound on sectioned isolantite forms. The four higher-frequency coils are wound on treated low-loss linen-bakelite tubes. One of the isolantite coils is illustrated in Figure 3. This type of construction has reduced the frequency drift with time to less than 0.01% at any frequency after an initial warming-up period of 20 or 30 minutes.

Each coil has a magnetic-metal dust core which is adjusted to obtain correct inductance, and, once adjusted, the core is locked in place by two setscrews. Associated with each coil is a trimmer condenser. These features make it possible to adjust the oscillator coil to the correct inductance for its low-frequency point and to adjust the minimum capacity for the high-frequency end of scale. In this way the frequency scale is made direct-reading. The coils are selected by the band-

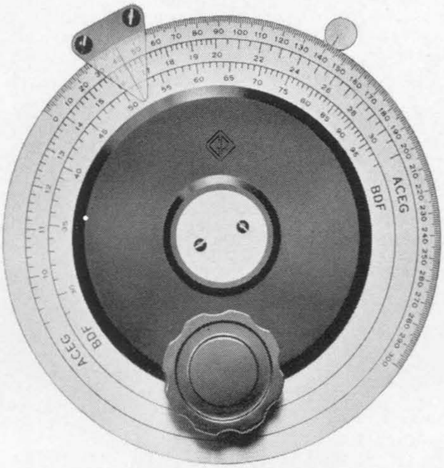

FIGURE 2. The main frequency control dial

change switch controlled from the panel. On the dial, which is illustrated in Figure 4, each coil range is lettered and the actual range engraved on either the inner or outer circle of numbers. The inner and outer circle refer to the corresponding circle on the main frequency control so that there will be no confusion as to which scale to use for a given frequency band.

The band-change switch itself, which is shown in Figure 5, has been designed especially for this instrument. Both the movable and fixed contacts are of silver. A positive detent action is provided so that the correct centering of the switch at each stop is assured.

Frequency modulation and the reaction of the attenuator setting on carrier frequency have long been bothersome defects in commercial standard-signal generators. Both can be eliminated almost completely by the use of a master-oscillator power-amplifier circuit in which the modulation is introduced into the amplifier stage. The amplifier isolates the oscillator circuits from both the modulation and the output circuits, and this accomplishes the required result. These MOPA circuits are very easily achieved in single-frequency generators such as transmitters, but for a wide-frequency-range signal generator the problem is much more complicated. The conventional circuit involves the use of a complete duplicate set of radio-frequency tuning inductors, of which there are seven in the TYPE 605-A, and two ganged variable air condensers. The two tuned circuits must be accurately aligned for all frequencies. It also involves the push-pull output tube arrangement if high percentages of modulation are required.

The principal difficulty is that the duplicate tuned and push-pull circuits, with the attendant increase in calibration and adjustment costs, rules out the method for a moderately-priced instrument. An investigation of untuned radio-frequency amplifier circuits indicated that satisfactory results would be possible with aperiodic coupling, even over the extremely wide fre-

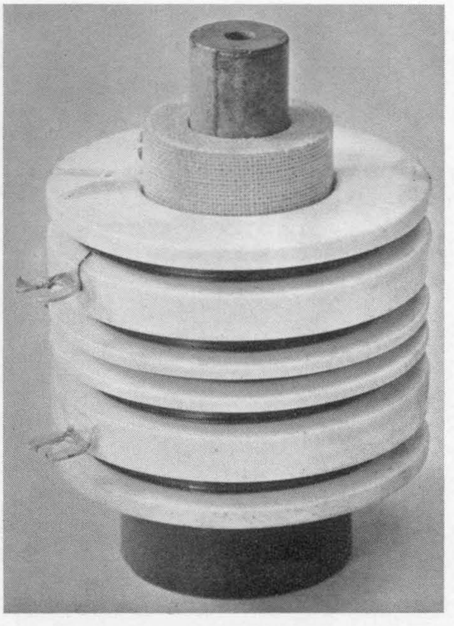

FIGURE 3. One of the low frequency coils showing construction

quency range required for a standard-signal generator.

The use of an untuned output circuit reduces the output power available but has the advantage of simplicity and also eliminates the probability of side-band clipping at high modulation frequencies. Even without a tuned output circuit quite high percentages of modulation can be achieved if two amplifier tubes are used in a push-pull circuit. These balanced circuits, however, also require a rather elaborate and expensive arrangement of additional equipment, especially when working into a grounded unbalanced attenuator system.

For these reasons, a single tube with an aperiodic output coupled directly into the attenuator has been used.

The maximum percentage of modulation depends entirely upon the amount of radio-frequency and audio-frequency distortion that can be tolerated. The latter distortion is rather more important. The r-m-s value of the audio-frequency harmonics in this instrument has been reduced to 3%* at 30% modulation; at 50% modulation the harmonics are somewhat less than 5%*. Therefore, 50% modulation was selected as the maximum.

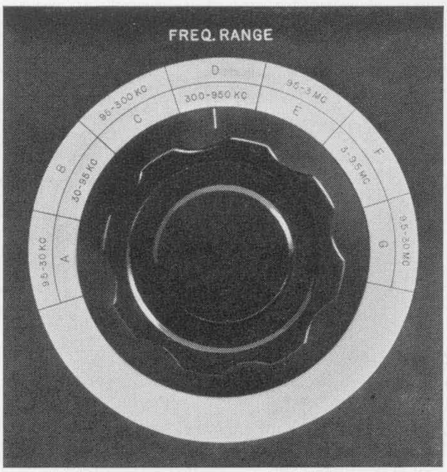

FIGURE 4. The band-change dial

The TYPE 605-A Standard-Signal Generator is provided with a 400-cycle internal modulating oscillator. Its output is introduced into the grid circuit of the amplifier-modulator tube and is adjustable from zero amplitude to the maximum of 50% modulation. Its

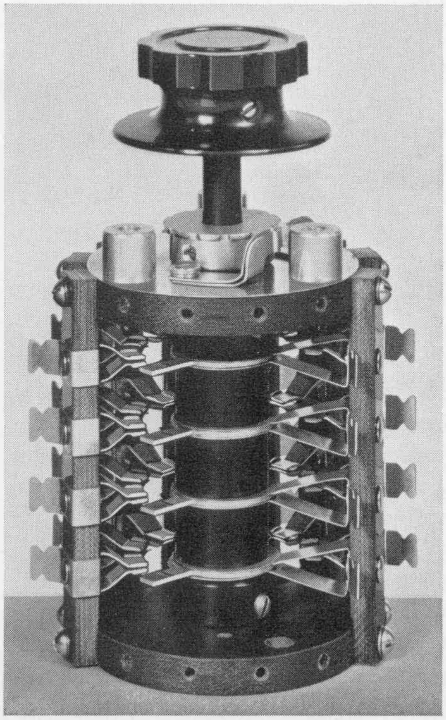

FIGURE 5. Construction of the band-change switch

amplitude is read on the lower scale of the panel meter shown in Figure 6.

Terminals are provided for external modulation, which is obtained from any external oscillator. The frequency range is from 30 to 15,000 cycles. Since the modulation is applied in a vacuum-tube grid circuit the power required is very low. Only five volts across 2500 ohms (10 milliwatts) are needed for

*These figures include the distortion in the audio-frequency oscillator itself.

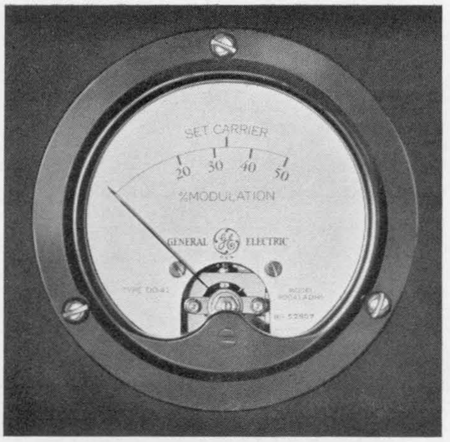

Figure 6. Vacuum-tube voltmeter scales

30% modulation. In order to prevent effectively any radio-frequency leakage at the external-modulation terminals, two low-pass filters are provided. Below 300 kilocycles the maximum modulating frequency is limited to 1000 cycles. Above 300 kilocycles carrier frequency, the full external-modulation range of 30 to 15,000 cycles may be used.

For purposes of reliability and accuracy, vacuum-tube voltmeters are used to measure the amplitude of the carrier and the modulation voltage. Both voltmeters use the same microammeter, which can be switched from one circuit to the other as desired.

The audio-frequency modulating voltage is impressed on a Type 84 Rectifier Tube operating in a full-wave rectifier circuit. The current drain is so slight that the waveform is not affected by the rectifier across it.

The carrier-frequency vacuum-tube voltmeter is bridged across the carrier output of the radio-frequency amplifier at the beginning of the output attenuator system. It is essential that its input capacitance be low so that it will not bypass the higher radio frequencies. A Type 955 Tube has been selected as the most suitable. It is, in fact, the only readily-available commercial tube that will do the work successfully. The meter circuit may be adjusted to take care of slow drifts in the tube sensitivity due to reduced cathode emission over long periods of time.

The attenuator system has received particular attention. The amplifier tube works into an L-type attenuator having an impedance of 50 ohms. The circuit is shown in Figure 7. The shunt element, which is the most critical as to accuracy, is in appearance similar to the General Radio Type 301-A Potentiometer. The resistance wire is wound by the Ayrton-Perry method on a thin, narrow form. The magnetic field around this potentiometer is practically eliminated by an aluminum center which reduces the area enclosed by the movable switch blade. By proper proportioning of the various elements, almost all of the residual inductance is eliminated, making the potentiometer practically a pure resistance at all frequencies. The series rheostat is similar in construction. This L-network provides a continuous variation of the calibrated output voltage range over a

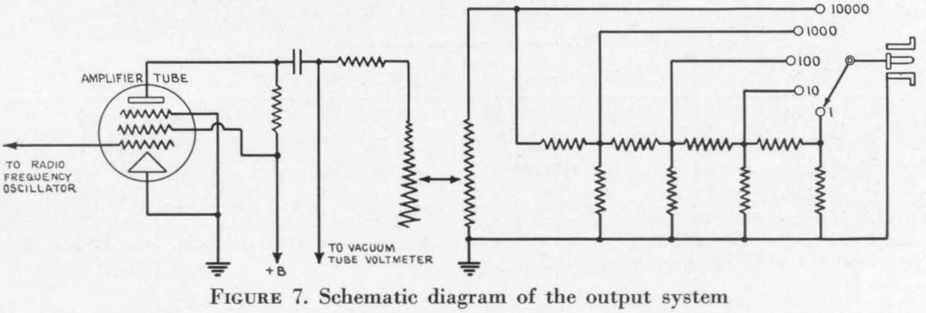

Figure 7. Schematic diagram of the output system

ratio of 1 to 20. Its control scale is calibrated from 0.5 to 10 in microvolts. The slide-wire assembly is followed by a five-step ladder network. Each step changes the output by a factor of 10, providing multiplying factors of 1, 10, 100, 1000, and 10,000. The resistor elements of the ladder are wound on very small mica cards in the conventional manner except that, by better proportioning of the dimensions, their frequency characteristics have been considerably improved. They are carefully shielded, and a concentric output plug is provided so that the shielding is maintained intact through to the end of the concentric shielded connector cable, also provided. The output microvoltage is continuously variable from 0.5 to 100,000 microvolts. The attenuator output impedance is constant at 10 ohms up to 10,000 microvolts and increases to 50 ohms for the range of 10,000 to 100,000 microvolts.

The instrument is designed for operation directly from the commercial alternating-current power mains. Since it is important that the output amplitude and frequency remain constant at all times, an automatic voltage-regulating transformer is used. It is possible to regulate the plate voltage by means of a gas-filled regulator tube or other means, but this does not eliminate the slow drifts due to changing cathode temperatures. The entire power input is, therefore, voltage regulated by means of a saturated-core-type regulating transformer. Care has been taken in its design to reduce external electromagnetic fields. Since a given design of this type of transformer is only suitable for a narrow range in the vicinity of one supply frequency, three models are available for use on 60-, 50-, or 42-cycle supply mains, which include most of the commercial frequencies used either in this country or abroad.

Battery operation is sometimes essential for mobile work. For this use, a battery power control panel may be ordered with the instrument instead of the alternating-current power unit. This control panel is equipped with a suitable meter for reading both *A* and *B* voltages, a filament, and a plate adjusting rheostat. The cathodes are operated at 6 volts (from an automobile storage battery for example), with total current requirements of 1.70 amperes. A single 200-volt battery capable of delivering 37 milliamperes continuously is required for the *B* supply. No other batteries are needed. The power input leads are filtered to prevent radio-frequency leakage.

The whole assembly is housed in a copper-shielded cabinet. The greatest care has been used to reduce radio-frequency leakage to a value so low that an unshielded receiver will not be affected by leakage even when working at the lowest microvolt levels.

— ARTHUR E. THIESSEN

The TYPE 605-A Standard-Signal Generator was designed by Mr. E. Karplus in collaboration with Messrs. L. B. Arguimbau and A. G. Bousquet.

Type	*Power Supply*	*Code Word*	*Price*
605-A	60 cycles	ANNUL	$415.00
605-A	50 cycles	ANODE	415.00
605-A	42 cycles	ANVIL	415.00
605-A	Battery	APART	415.00

This instrument is licensed under patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction, and development work in pure and applied science.

The GENERAL RADIO
EXPERIMENTER

ELECTRICAL MEASUREMENTS
TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

VOL. XI Nos. 2 and 3 JULY-AUGUST, 1936

QUIET, PLEASE

● "HOW QUIETLY IT RUNS!" We often hear this comment regarding the most popular makes of all mechanical devices ranging from automobiles and refrigerators down to the cheapest of gadgets. In fact, we have reached the stage where we take it for granted that the products of the better known manufacturers will give entirely satisfactory performance, and often the deciding factor between various makes is only the quietness with which the equipment operates.

The psychological and physiological effects of noise have been the subject of a considerable amount of analytical study.[1] Qualitatively, everyone recognizes their existence through personal experience with noisy appliances in the home as well as in the office and factory.[2] To meet the demand for quietness, manufacturers have not only designed mechanical equipment to operate quietly, but have tried to deaden any remaining sounds through the use of sound-absorbing and -insulating materials.

This interest in the reduction of noise has created a need for measuring instruments and has fostered an entirely new industrial application of science, commercial noise measurement. Many types of sound measuring equipment involving various principles of operation have been developed in order to provide industry with definite and reproducible readings to act as a basis of comparison between different sounds. Many of the early methods involved matching an audible tone with the measured sound.[3] This arrangement, however, relied upon the ear and the judgment of the operator, both of which are rather variable factors. The need for simpler and more reliable equipment rapidly brought forth a large number of various "noise meters" or "sound level meters" which indicated directly on a meter the total sound level, giving a reading totally

ALSO IN THIS ISSUE: A General Purpose Amplifier, page 6.

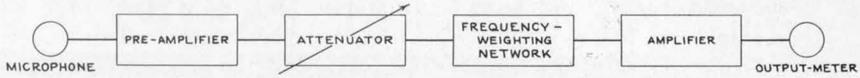

FIGURE 1. Functional diagram of a system for measuring sound level

independent of the judgment or hearing capacity of the operator.

Basically, a noise meter, or sound level meter, as they are now more generally called, consists of a microphone, an amplifier, and some sort of indicating meter which will respond to the audio-frequency voltages obtained from the amplifier. This system is shown in Figure 1. Since the human ear does not respond equally to all frequencies, it is desirable to adjust the over-all frequency response of the sound-measuring equipment to approximate that of the human ear. Also, since a wide range of sound levels must be measured, the amplifier gain should be adjustable, or suitable attenuators should be incorporated into the circuit, so that a reasonable deflection can be obtained on the indicating meter at all levels within the range of the equipment. Practically all modern sound level meters operate on the same principle and differ mainly in details of design.

Because of the relatively high price of some of the first complete outfits on the market, many manufacturers of mechanical devices used merely assemblies of standard microphones, amplifiers, and power-level-indicator meters which provided approximate measurements at but a fraction of the original cost for the equipment.[4] This method gave useful results for measuring differences in noise level, but was not convenient for absolute measurements because of the frequent and inconvenient calibration procedure necessary for such work. Unfortunately, some of the first sound level meters shared this same disadvantage.

Early types of sound-measuring equipment gave manufacturers of mechanical devices and acoustical materials a convenient means for comparing their products with those of other makes and, except in a few border-line cases, the readings obtained actually showed which product was the best from a standpoint of quietness. Lack of standardization, however, made it impossible to compare readings made with different types of meters because of their differing characteristics. This was of no great importance at first, but when it began to seem desirable to incorporate noise level data in purchase specifications, and when manufacturers began to advertise the low decibel ratings of their products, the need for standardization became obvious. Unless the type of noise meter and the conditions under which the measurements were made were carefully specified in each case, the noise ratings were practically valueless, since it was impossible to duplicate the readings or to compare them satisfactorily with the ratings of other manufacturers.

Many early types of noise meters[5] read directly in decibels above the average threshold of hearing at 1000 cycles (approximately 0.45 millibar) and contained a single weighting network giving an over-all frequency response not greatly different, throughout the most important parts of the range, from the low level characteristic specified in the new standards. There was, nevertheless, no general agreement among manufacturers and users of noise meters regarding reference levels and frequency characteristics. The various levels constituted only a minor annoyance, since it was possible to compare readings taken with respect to one level with readings referred to another level by merely adding or subtracting a fixed number of decibels. For instance, another common reference level at that time was 1 millibar, which is approximately 7 decibels higher than the average threshold of hearing. A meter calibrated in this manner read 7 decibels less on any given sound, providing, of course, that the instruments were alike in other respects.

Unfortunately, however, two different makes of meters were seldom alike in other characteristics. Any appreciable differences in frequency characteristics produced variations in readings for which it was almost impossible to compensate. Furthermore, practically all of the microphones used had pronounced directional properties, that is, their response at various frequencies depended upon the direction from which the sound was coming. In some applications, it was possible to point the microphone at the source of the noise, thus minimizing directional errors, but for measuring sound in automobiles, airplanes, etc., this was impossible, since the sound was coming from all directions.

As a consequence noise measurements made with different types of meters could be compared only very roughly, if at all. This situation was, of course, well understood by both manufacturers and users of noise meters, but was the cause of considerable confusion among consumers.

As a result of this situation, the American Standards Association, at the request of the Acoustical Society of America, undertook to develop a set of standards for noise measurements and for sound level meters.[6] Practically all companies interested in sound level measurements, either as manufacturers or as users of the equipment, were represented on the co-operating committees, and a set of tentative standards has recently been approved. The rapidity with which the new standards are being adopted indicates the general desire to clarify the sound-measuring situation. Apparently no serious difficulties are being encountered in meeting the important points in the new standards and, accordingly, it should be possible to compare the readings made with the new sound level meters with a satisfactory degree of accuracy.

The most important of the standards adopted by the committee concern (1) frequency characteristic, (2) reference level, and (3) indicating instrument characteristics. Furthermore, standard methods were specified for determining the degree to which any instrument complied with the standard specifications.

The frequency characteristic specified for all noise meters is that shown in Figure 2, Curve A. If more than one frequency response is provided, that of Curve B or a flat response or both may be used.

The reference level adopted is 10^{-16} watts per square centimeter at 1000 cycles in a free progressive wave.

The dynamic characteristics of the indicating instrument are so specified that the difference in indication obtained between short, transient sounds and steady sounds approximates the effect on the ear. Even before the tentative standards were finally approved, their influence was already noticeable, particularly in regard to reference level, and the reference point finally approved by the committee, namely, 10^{-16} watts per square centimeter at 1000 cycles per second, was rapidly

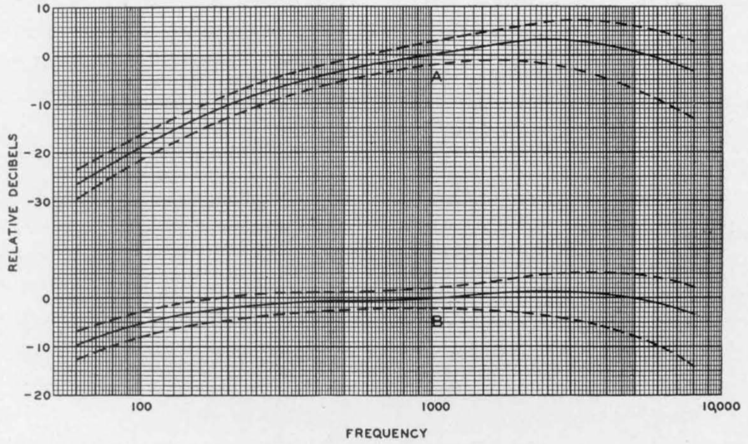

FIGURE 2. Frequency characteristics specified by the A.S.A. Curves A and B are respectively the so-called 40 db and 70 db equal-loudness contours modified to take account of the differences between random and normal free-field thresholds. Allowable tolerances are shown by the broken lines. These same tolerances are allowed on a flat characteristic

adopted for general use. To co-operate in the standardization, the General Radio Company modified its noise meter and announced the TYPE 559-B.[7] This instrument used the new reference level, which meant that for any given sound it read 7 decibels higher than the earlier model. At the same time, the sensitivity of the instrument was increased appreciably. The changes were, however, of a minor nature and the earlier models could be converted to the later type.

Recognizing, however, that a noise meter designed with the sole aim of meeting the new specifications would be little better than previous models as far as convenience, portability, freedom from maintenance difficulties, and similar considerations were concerned, the General Radio Company has for some time been working on an improved and unusual type of noise meter which is the result of careful study to determine exactly what type of sound-measuring device would best meet the needs of the greatest number of customers.

Mechanically the meter is arranged for maximum convenience, including the use of accessories such as a vibration pickup[8], with a minimum of operating controls. The type of microphone used — and its method of mounting — minimize directional effects. Batteries are carried inside the cabinet, yet the entire instrument is light in weight and easily portable.

Permanence of calibration over a wide range of battery voltages and a simple means of checking and resetting the sensitivity are features of the electrical design. A wide range of sound levels is covered. Provision for selecting any one of the three frequency characteristics specified by the A.S.A. assures its acceptance for all types of noise and sound measurement.

The last feature, and one of the most important, is low price.

The new TYPE 759-A Sound Level Meter will be completely described in next month's *Experimenter*.

— H. H. SCOTT

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3. E. E. Free, "Practical Methods of Noise Measurement," *Journal of the Acoustical Society of America*, Vol. II, No. 1, p. 18; July 1930, summarizes several methods of noise measurement current at time of writing.

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A GENERAL-PURPOSE AMPLIFIER

● **FEW INSTRUMENTS** are more useful in the communications laboratory than a high-gain portable amplifier. In addition to its use in increasing the sensitivity of bridge balances, there are an almost unlimited number of applications where a few extra decibels of gain are required. For maximum convenience, the general-purpose amplifier should be small, light, and readily portable and should have as high a maximum gain as is consistent with a good frequency characteristic. The output power should be sufficient for operating bridge detectors, such as a pair of phones or an oxide-rectifier voltmeter. It is also desirable that the maximum output voltage be sufficient for reasonable deflections on a cathode-ray oscillograph.

The new TYPE 814-A Amplifier is an excellent general-purpose instrument. Because of the use of 2-volt pentodes, the instrument, in spite of its high gain, has a very low battery drain, and will operate satisfactorily from small dry batteries, for which provision is made within the cabinet. The amplifier is of the resistance-capacitance coupled type, covering the range from 18 cycles to 10,000 cycles with a variation in gain of less than ±2 db, although the total gain, when operating into a high impedance circuit, is about 90 db. When operating into 20,000 ohms, which is approximately the impedance of an average headset at 1000 cycles, the gain is nearly 80 db. The amplifier is intended mainly for use with small input voltages (less than 0.5 volt), but a toggle switch on the panel allows the use of input voltages up to 5 volts without appreciable distortion. The gain is continuously adjustable by a tapered attenuator.

One unusual feature is the provision made for inserting a parallel resonant circuit in the grid circuit of the last stage in order to modify the frequency response of the amplifier. A jack is provided on the panel for connecting the resonant circuit. This arrangement provides extremely good selectivity at most bridge frequencies in the audible range, resulting in discrimination against harmonics and a greatly decreased noise level. Several standard filter units will be available.

FIGURE 1. Panel view of the TYPE 814-AM Amplifier

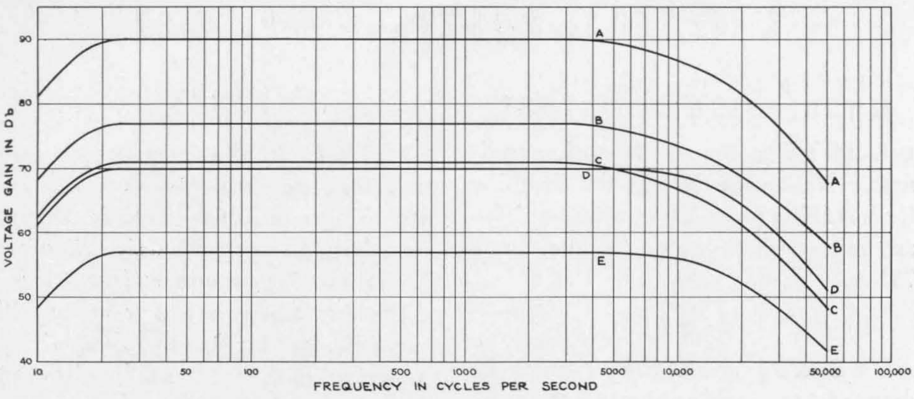

Figure 2. Frequency characteristics of Type 814-A Amplifier under various load conditions. Curves A and B were taken with loads of 1 megohm and 20,000 ohms respectively with the input voltage switch in the low position. Curves D and E were taken with the same loads, but with the switch on high. Curve C is the same as Curve B but with the gain control turned down 6 db

The new Type 814-A Amplifier is similar in appearance to the older Type 514-A, which has been on the market for several years and which has proved extremely popular in communications laboratories. The new instrument, however, provides practically twice the gain (in decibels) of the older unit, has a tapered volume control, and provision for tuning. The maximum output voltage from the new amplifier is also somewhat larger, being approximately 25 volts rms, which gives a very satisfactory deflection on the average cathode-ray oscillograph without noticeable distortion. In spite of the high gain of the new amplifier, the microphonic noises are actually less than in the older instrument, since the tube shelf has been cushioned in rubber.

The amplifier is supplied in two models, Type 814-AM, which is mounted in a walnut cabinet, and Type 814-AR, which is arranged for relay-rack mounting. The cabinet supplied on the Type 814-AM contains space for a complete set of batteries. The relay-rack mounting model has an extension on the right-hand side of the panel with provision for mounting a rectifier-type meter. A compartment is also provided on the back of this extension panel for holding a set of batteries. Both models have a rheostat for adjusting the filament voltage and a voltmeter which indicates filament and plate voltages.

— H. H. Scott

Type 814-A Amplifiers are available for immediate delivery. All vacuum tubes and batteries are included in the price.

Type		*Code Word*	*Price*
814-AM	Cabinet Model	APPLE	$97.50
814-AR	Relay-Rack Model	ALONE	97.50

This instrument is licensed under patents of the American Telephone and Telegraph Company solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.

MISCELLANY

MODULATION MONITORS

● **A NOTE** to broadcast station engineers: November first is the deadline for installing modulation monitors. We are still taking orders for the Type 731-A.

SALUTE

● **THE RCA REVIEW**, a quarterly devoted to contemporary developments in the field of radio communication, made its first appearance in July of this year. This journal is attractive in appearance and well printed. The articles in the first number cover many phases of radio communication. It is published by the RCA Institutes Technical Press, 75 Varick Street, New York City.

COVERAGE

● **APPROXIMATELY** 60 General Radio primary standards of frequency are in use in 18 countries including the United States. Russia alone has 8 of these.

CHANGE

● **BETWEEN** the engineering and production departments of active manufacturing companies there is usually a continual banter over design changes. The production superintendent dreams of the day when each new order will read "like last lot" and while awaiting the arrival of the fatal (used advisedly) day accuses (and with perhaps some justification) the design engineer of making changes for change's sake, but let him not forget the philosophy of Francis Bacon, who wrote, "That which man altereth not for the better, Time, the great innovator, altereth for the worse."

CIRCULATION

● **EXPERIMENTER** readers, domestic and foreign, number over 15,000. This is a larger circulation than that of any magazine in the radio field, with the exception of those published for amateurs and broadcast listeners.

THE 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.

GENERAL RADIO COMPANY

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EXPERIMENTER

ELECTRICAL MEASUREMENTS TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

VOL. XI Nos. 4 and 5 SEPTEMBER-OCTOBER, 1936

CONVENIENCE IN NOISE MEASUREMENT

A REALLY PORTABLE SOUND LEVEL METER

● **IN THE DESIGN** of noise-measuring equipment too much attention cannot be given to those mechanical features which provide a maximum of convenience in operation. Agreement upon a desirable set of electrical characteristics by manufacturers and users of noise-measuring instruments has resulted in the adoption of a set of tentative standards by the American Standards Association,[1] settling for the present any controversial points of over-all electrical performance. When these standard specifications can be met in a small, portable instrument, maximum utility is achieved. The new General Radio Type 759-A Sound Level Meter is the result of this approach to the problem of sound level measurement.

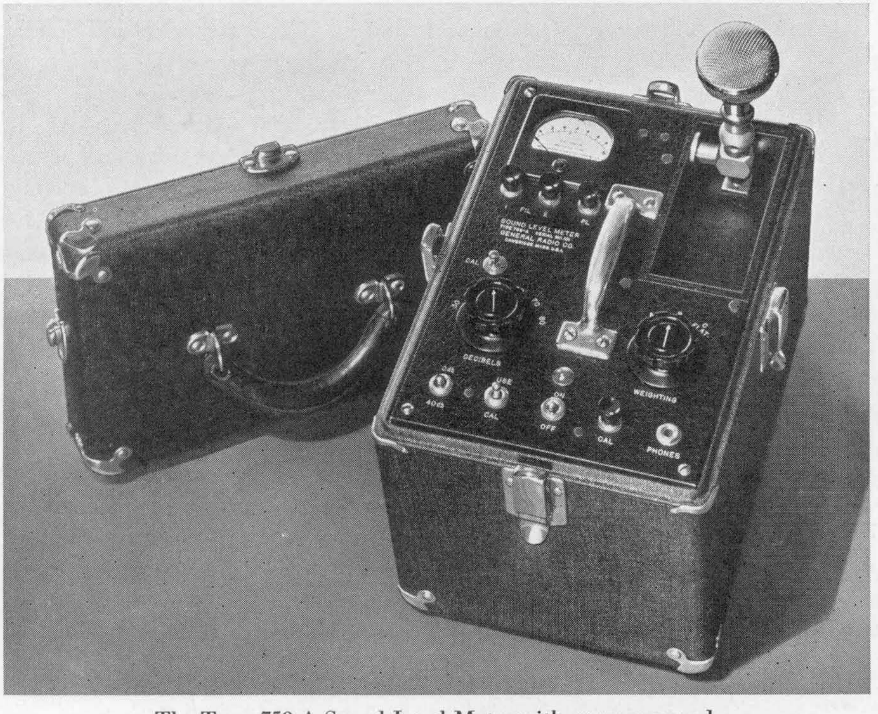
[1] See "American Tentative Standards for Noise Measurement," Bulletin Z24.2-1936 and "American Tentative Standards for Sound Level Meters for Measurement of Noise and Other Sounds," Bulletin Z24.3-1936, published by the American Standards Association.

This sound level meter, which is shown on page 2, is a simple, lightweight, and inexpensive instrument. Electrically, it complies with the A.S.A. standards. It is accurate and reliable, with a high degree of calibration permanence. Other features are a non-directional, wide-range microphone, unusual sensitivity, the provision of three weighting networks, freedom from magnetic pickup, elimination of all battery adjustments, and a simple but accurate calibrating system by means of which the sensitivity may be reset at any time to the factory value. The reference level for the new sound level meter is 10^{-16} watts per square centimeter, which is now quite generally agreed upon as a satisfactory and convenient standard. This value represents the threshold of hearing for a person whose ears are somewhat better than average.

OTHER ARTICLES IN THIS ISSUE

Regarding frequency weighting networks (which adjust the frequency response of the sound level meter to approximate that of the human ear at various levels), the new meter more than complies with the A.S.A. specifications. In simpler types of noise-measuring instruments, a single network adjusting the over-all response to that of the ear at a 40-db level is generally considered satisfactory, but most of the more elaborate types of sound level meters include also a high level network which the A.S.A. specifies may follow the ear characteristic at a 70-db level or, optionally, may provide an equal response throughout the frequency range. Obviously, limiting the frequency response to a single low level characteristic greatly reduces the usefulness of the instrument at high levels. In actual use, it has been found that there are appreciable differences in high level readings taken with the flat characteristic and similar readings taken with the 70-db characteristic. Accordingly, the General Radio Company has provided on its new sound level meter an adjustable frequency-weighting network which allows a selection of any one of these three characteristics by merely turning the knob.[2] This has several important advantages. In the first place, it allows readings of the Type 759-A Sound Level Meter to be compared with those of practically any other new standard meter with a degree of accuracy which would otherwise be impossible, since it is general practice to include only one or two weighting networks on most instruments. Secondly, it is desirable in many cases to use the so-called 70-db

[2] The 40-db and 70-db equal-loudness contours are shown in Figure 2, page 4, of the July-August, 1936, *Experimenter*. The third characteristic provides practically equal response to all frequencies from 30 to 8000 cycles per second.



The Type 759-A Sound Level Meter with cover removed characteristic for moderately high levels, that is, around 70 db, and the flat characteristic for extremely high levels, since this combination provides a better approximation of the action of the average ear.

One of the most important improvements in sound measurements is brought about by the availability of practically non-directional microphones. With earlier types of noise meters and, in fact, with some types of sound level meters available at the present time, appreciable errors are introduced into the readings by the fact that the microphone responds unequally to sounds coming from different directions. The Type 759-A Sound Level Meter uses a piezo-electric microphone of the "sound-cell" type which is characterized by practically non-directional response, uniform frequency characteristic, and dependability. Ordinary temperature and humidity changes, as well as mechanical vibration, wind, or other factors which appreciably affect other types of microphones do not change the operation of this type of microphone to any noticeable degree. Furthermore, the microphone can be used on any reasonable length of cable without any effect upon the frequency characteristics. A vibration pickup will also be available for use with the sound level meter for comparing vibrations in solids. For special applications, other forms of microphones can be used.

The indicating meter used in the Type 759-A Sound Level Meter has also received its share of attention. The new meter has a scale which is practically linear in decibels throughout its range, increasing both the ease and accuracy with which readings may be taken. This desirable result has been obtained by shaping the pole pieces and

Noisy street — 92 db

suppressing the zero point of the meter, so that its response to current is practically logarithmic. Other important features of the meter are the ballistic characteristics, which closely approximate the response of the human ear to transients, and the rectifier characteristic, which adds together various sound components in much the same way as the ear.

Weight requirements have had a direct influence on the electrical elements of the sound level meter. The amplifier is of the resistance-capacitance-coupled type using 2-volt pentodes, thus resulting in a remarkably low total current drain and allowing the use of very small batteries. The use of a high impedance microphone and a properly designed decibel meter eliminates the necessity of coupling transformers in the input and output circuits, and the frequency weighting networks are made up entirely of resistors and condensers. Consequently, no inductances are used in any part of the circuit. In addition to its influence on weight, this feature results in an instrument which is essentially unaffected by alternating magnetic fields, an important consideration when meas-

Home appliance — 62 db

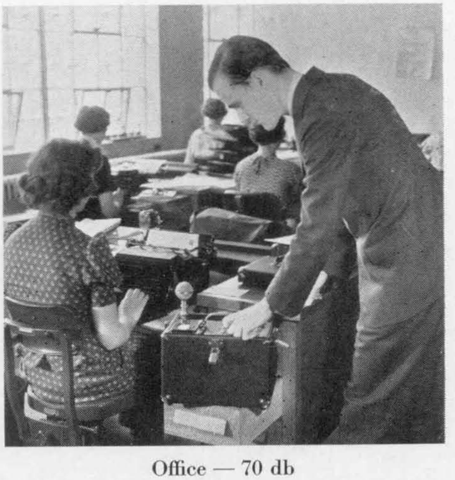
urements are to be made in the vicinity of electrical machinery.

The case of the sound level meter is of "airplane luggage" construction, which is light and at the same time unusually strong. It is completely shielded and covered with a durable waterproof material. The battery compartment is built into the case and all connections to the batteries are made automatically when the cover of this compartment is closed. The panel and microphone compartment consist of a single aluminum alloy casting which is light, tough, and rigid, and which is finished in black crackle lacquer. All other mechanical parts have been designed for light weight and small size.

In portable instruments it is desirable to have as few extra parts as possible. In the TYPE 759-A Sound Level Meter the microphone is mounted directly on a support on top of the instrument, and when not in use the whole microphone assembly folds down into a compartment in the panel. Thus, for average noise measurements, it is merely necessary to lift the microphone out of its compartment and turn on the battery switch. No microphone connections need be made, nor are any tripods, microphone stands, or long cables necessary in most measurements. An extension cable and tripod are available, however, for those few applications where they are deemed necessary.

The sound level meter is distinguished by the unusual simplicity of its controls. The two large knobs on the panel control the decibel switch and weighting networks. Push buttons are provided for checking the battery voltages. A red line on the meter shows when the batteries should be replaced. Because of the use of a ballast tube and a compensated amplifier circuit, the exact battery voltages are not important. This eliminates the need for any filament rheostat or other battery adjustments, which is a great advantage since such adjustments are frequently overlooked or forgotten, with resulting errors in the readings.

The total sound intensity range covered by the sound level meter is

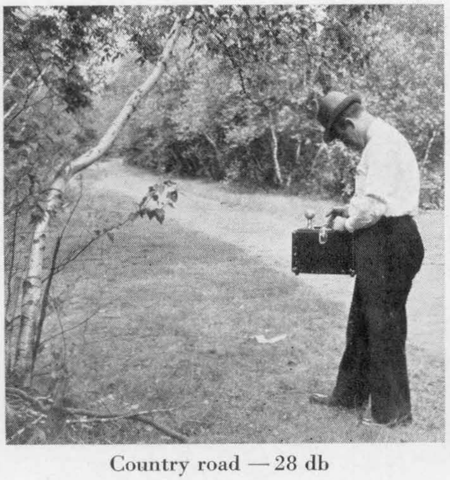


Office — 70 db

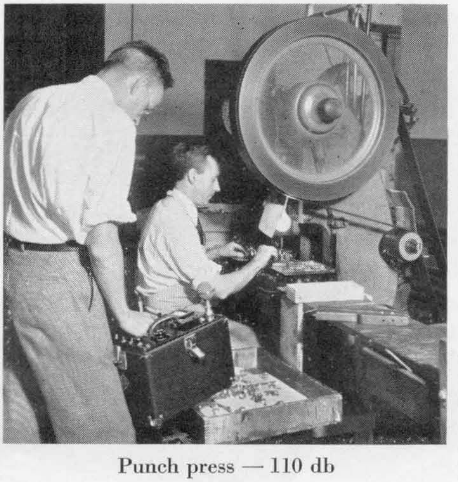
from 24 to 130 decibels above the standard reference level. This 106-db range actually represents a sound power ratio of about 4×10^{10} or a sound pressure ratio of 2×10^{5}. Of course, the lower limit of 24 db will not always be required for ordinary types of sound measurements, since a minimum of 30 or 35 db has generally been found satisfactory for most commercial work. Nevertheless, it is extremely convenient to have this sensitivity available and with the increasing demands for lower noise levels it is expected that the lower range of the instrument will be used considerably more within the next few years. Similarly, the upper limit of 130 db is above the threshold of feeling, but accurate readings in this range are necessary in order to measure small improvements in high sound levels, since it is frequently through a series of relatively small reductions that the total level is finally brought down to a reasonable value. In addition, many common sounds such as automobile horns, etc., are within the upper range of the instrument. The accompanying photographs show many common applications of sound level meters and indicate average db readings in typical cases.

With normal tubes and batteries, changes in sensitivity of the sound level meter are surprisingly small as the batteries run down. This is due mainly to the compensated amplifier circuit and the use of a ballast tube. The battery circuits in the instrument are suitably isolated so as to minimize degenerative or regenerative effects caused by the increasing resistance of the batteries as they wear out.

This means that for most practical purposes the sensitivity of the instrument may be considered as constant and the calibration checked only at infrequent intervals. It is realized, however, that occasional sets of tubes or batteries will behave somewhat differently from the average, and that for some types of work comparative measurements to a fraction of a db are required. Accordingly, a calibration checking system has been built into the sound level meter which allows the sensitivity to be reset quickly and easily to the original value. In order to check the calibration the instrument is connected to an a-c power line of any commercial voltage or frequency. This supplies an alternating voltage which is used to check the amplifier gain. Convenient push buttons and switches on the panel allow the check to be made quickly, and a screw driver adjustment is provided for resetting it if necessary. In those few locations where



Country road — 28 db



Punch press — 110 db

an a-c power line is not available, an audio-frequency oscillator may be used equally well.

To minimize errors resulting from mechanical vibration, all tubes are suspended on a rubber mounted shelf. The method of suspension is such that the movement of the shelf is quite free for small vibration amplitudes but is sufficiently damped so that no clamping mechanism is necessary. The case itself is provided with soft rubber feet which reduce still further any vibrations which may be transmitted to the tubes as well as cushioning the entire assembly.

The result is a sound level meter which can be carried about easily and used practically anywhere. The total weight, including all batteries, is somewhat under twenty-four pounds, and the assembly is virtually unaffected by ordinary shocks or vibration, or by magnetic fields. In accuracy and simplicity of operation the TYPE 759-A Sound Level Meter represents a distinct advance in the design of noise measuring apparatus. — H. H. SCOTT

The price of the TYPE 759-A Sound Level Meter includes all tubes and one set of batteries. If an extension cable is required for the microphone, the TYPE 759-P1 Cable and tripod should be used. The cable is twenty-five feet long and the tripod is of the folding type which can easily be carried. The price of the cable and tripod is $9.50.

All sound level meters in the initial manufacturing lot have been sold. Additional units will be available December 20, 1936. Complete specifications are listed on page 7 of Catalog J.

Type		*Code Word*	*Price*
759-A		NOMAD	$195.00

TYPE 759-A Sound Level Meter is manufactured under the following U. S. Patents and license agreements:
1. Patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.
2. Patent No. 1,542,995.

AN OHMMETER FOR THE MEGOHM RANGES

● **IN JANUARY, 1925**, the General Radio TYPES 287-A and 287-B Ohmmeters were announced to the succinct description, "This instrument consists of a battery and meter in series with a resistance, and a rheostat shunted across the meter to provide a zero adjustment. The dial is calibrated directly in ohms. Clip leads are provided for convenience in connecting the ohmmeter to the device to be measured." The instruments were 0 to 5 milliampere meters connected in series with the unknown external and a known internal resistance and had ranges of 0-2000 or 0-10,000 ohms. Internal 1.5- or 4.5-volt batteries supplied the measuring power. The instruments simply measured the total current flowing when the unknown was connected and were calibrated directly in ohms. These ohmmeters were used for the checking and servicing of radio and electrical devices to such an extent that instruments of similar construction will be found today to be the basis of every radio service and repair kit.

The upper limit of resistance is directly dependent on the sensitivity of the milliammeter used and hence the range is restricted to that possible with the most sensitive indicator commercially available in an inexpensive model. By employing a vacuum-tube amplifier ahead of the indicating meter, however, the range of measurement

Sufficient overlaps are provided on the TYPE 487-A Megohmmeter to permit the use of the open portion of the scale for all values of resistance within the normal range of the instrument

can be extended by a factor of 10^6, the change in range being roughly parallel to that obtained by using a vacuum-tube indicator in the conventional bridge circuit.*

The TYPE 487-A Megohmmeter, illustrated at top of page, is a direct-indicating ohmmeter for the megohm ranges of resistance made possible through the use of a vacuum-tube voltmeter as the indicator. The internal battery has been replaced by the voltage drop across a portion of the output of a power-line rectifier which also supplies the operating voltages for the vacuum-tube voltmeter.

In operation the unknown high resistance is compared in a series connection with an internal standard of 1, 10, 100, or 1000 megohms. As in the conventional ohmmeters, the precision of indication of the megohmmeter is greatest when the internal resistances are nearly equal. The scales of both instruments are similar in spread. The four successive ranges of the megohmmeter differ in readings by factors of 10 to 1, while in each range the comparison of the unknown against the standard can be made accurately within a ratio range of 10 to 1 in either direction from the center-scale value. The generous overlap thus provided makes an open portion of the scale available for all measurements within the normal range of the instrument.

The equivalent ohmmeter battery voltage is fixed at 150 volts, but the actual voltage applied to the specimen varies with the scale reading, being zero at the low-resistance end of the scale and half the total voltage, or 75 volts, at the center-scale reading where the unknown and standard resistances are equal.

There is no danger whatever of shock from the exposed test terminals, for their internal output impedance is never less than one megohm and may be 10, 100, or 1000 times that value.

In the design of the instrument, particular care has been given to the elimination of the objectional features that might be expected to be inherent in the adaptation of the ohmmeter and vacuum-tube voltmeter to the measure-

* R. F. Field, "Bridge + Vacuum Tube = Megohm Meter," General Radio *Experimenter*, Vol. VIII, Nos. 1-2, June–July, 1933.

Editor and notorious photographer

The infirm collapsed

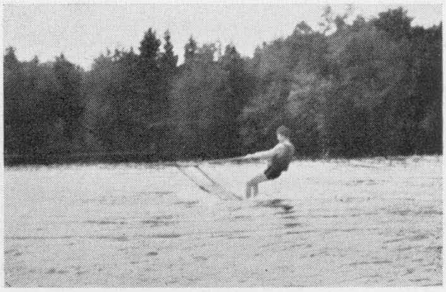
ENGINEERS RELAX

● FOR SEVERAL YEARS Mr. Robert F. Field has been host to the Engineering Department at an annual house party in his Lake Winnipesaukee summer cottage. Here the group breaks up to pursue the various amusements of cards, aquaplaning, mountain climbing, swimming, badminton, according to age and temperament. The affair starts Friday evening and ends Sunday afternoon. About twenty are usually present, and a good time is had by all.

The usual program was varied this year by a kind and courageous luncheon invitation from the Keith Henneys (**Electronics** editor and notorious professional amateur photographer) who have a place about fifty miles away (making them neighbors in New Hampshire). Well stuffed with chicken and things, the more infirm members of the staff collapsed on the grass, while the others wandered about the neighboring mountainside calling to the birds. Having consumed all the food, the party returned to Mr. Field's, and so, after a variety of amusements, to bed.

Sunday was a day of rest for most but some went aquaplaning (and did their resting Monday).

Some went



aquaplaning

The GENERAL RADIO
EXPERIMENTER

ELECTRICAL MEASUREMENTS TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

VOL. XI No. 6 NOVEMBER, 1936

LOSSES IN AUDIO-FREQUENCY COILS

● **IN DESIGNING** electrical communication equipment, it is frequently necessary to select low-loss inductance coils for use in tuned circuits and filters. Experimental data accumulated over a period of several years at the General Radio Company have shown that a set of formulae derived by means of approximations of limited validity hold very well in practice. These expressions are so simple that they have been of considerable assistance in selecting the best type of coil for a particular use, and they are presented here because of their wide application.

The discussion will be limited to measurements in the frequency range between 10 and 100,000 cycles per second and to frequencies far removed from resonance. For iron-core coils it will be assumed that the voltages are very low in order that hysteresis may be neglected in comparison to eddy-current loss. Most of the measurements have been made on iron-core coils (with and without air gap) and multi-layer audio-frequency coils of the type usually met in filter practice.

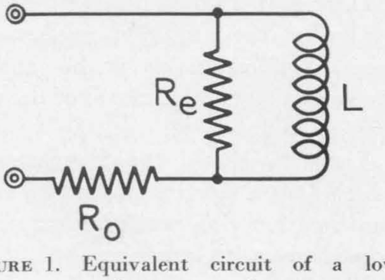


FIGURE 1. Equivalent circuit of a low-frequency coil

With these restrictions it has been found that all coils may be represented by the equivalent circuit shown in Figure 1 where R_o is the d-c resistance and R_e is a resistance due to eddy-currents and is *independent of frequency*.

This is based on the following considerations: A conductor placed in the magnetic field of a coil may be considered a terminated secondary winding. As long as the circulating currents are mainly determined by the *resistance* of the path rather than by its inductance the termination impedance is resistive, and the secondary circuit will reflect a resistance in parallel with the primary

ALSO IN THIS ISSUE

winding. In particular, the circulatory currents may exist in an iron core and may include induced currents set up in the wire itself, usually spoken of as skin effect.

In many applications the reactance to resistance ratio, known as "Q", serves as a convenient factor of merit. From the simplicity of the equivalent circuit shown in Figure 1, it might be expected that the curve of Q versus frequency for any coil would be given by a fairly simple expression. The application of ordinary circuit theory to Figure 1 gives the approximate results:

$$X = 2\pi fL$$

$$R = R_o + \frac{(2\pi fL)^2}{R_e}$$

which gives for Q,

$$Q = \frac{2\pi fL}{R} = \frac{1}{\frac{R_o}{2\pi fL} + \frac{2\pi fL}{R_e}}$$

which has a maximum value, Q_m, of

$$Q_m = \frac{\pi f_m L}{R_o} \qquad (1)$$

or

$$Q_m = \frac{1}{2}\sqrt{\frac{R_e}{R_o}} \qquad (2)$$

at a frequency $f_m = \dfrac{\sqrt{R_o R_e}}{2\pi L}$ (3)

where,

f_m is the frequency of maximum Q. At any other frequency, f, the corresponding value of Q (denoted by Q_f) is

$$Q_f = \frac{2Q_m}{\frac{f}{f_m} + \frac{f_m}{f}} \qquad (4).$$

It will be noticed that this expression is symmetrical with respect to $\frac{f}{f_m}$ and $\frac{f_m}{f}$ and will give a curve shape which is invariant on logarithmic paper.

To tabulate available Q data it is sufficient to plot the point of maximum Q and use a standard template for drawing the curve (this template may be obtained by replotting a curve of Figure 2 on standard logarithmic paper).

In iron-core coils, the eddy-current losses in the copper are usually negligible in comparison to those in the core so that, for a given core and volume of copper, wire size has little influence on Q. One interesting point to be noted for iron-core coils is that the maximum Q for a given structure but with various air gaps is very nearly constant. This can be explained by the fact that the core may be regarded as a single turn secondary of constant termination. This reflects a given shunt resistance across the winding regardless of its inductance. Since the copper resistance is constant, it follows that the ratio of shunt eddy-current to series copper resistance must be constant and hence from expression (2) Q_m must stay the same. Experimental results check fairly closely with the relationship given by (3) which shows that the frequency of maximum Q varies inversely with the inductance as the air gap is varied.

Figure 2 shows the characteristics of an audio transformer core as the air gap in the magnetic circuit is varied. It will be noticed that the maxima are practically independent of the magnitude of the gap. With no gap, the maximum Q is about 50 and occurs at a frequency of 90 cycles. With a 0.125-inch air gap the maximum Q is 45. With a gap of 0.95 inches the maximum Q stays about the same, at 42, even though the gap corresponds to a total removal of the center leg.

Figure 3 shows the frequency at which Q is a maximum for the same core as a function of the inductance in accordance with equation (3).

Figure 4 gives the loci of points of maximum Q for several types of coils. Curve B corresponds to the data of Figure 2 and Curve A shows the characteristics of another type of iron core.

Curve C gives the locus of Q_m points for a set of multi-layer air-core coils of given mechanical form but varying wire size. It will be noticed that the larger wire sizes have lower maxima as might be expected from the larger dimensions of the individual eddy-current circuits. The straight line drawn through the three experimental points was drawn in accordance with equation (1), with a unit slope corresponding to what would be expected of the variation of Q_m with the frequency at which the maximum occurs when the ratio of $\frac{L}{R_o}$ is held constant, as it is with a given geometry and weight of copper.

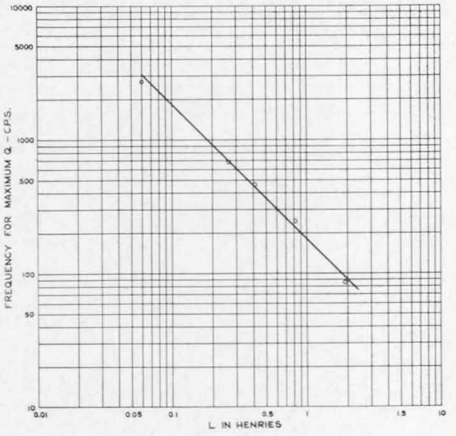


FIGURE 3. Frequency of maximum Q of the iron-core coil of Figure 2 as a function of inductance. The inductance variation is obtained by varying air gap. The curve is drawn as a straight line of slope (-1) in accordance with equation (3)

Tests made on high-frequency dust cores show that at audio frequencies the effective series resistance of a coil is virtually unchanged as the core is brought into the field, but the inductance is increased, and Q increases directly as the inductance. The particular case is more complicated than the previous ones because essentially the coil may be thought of as consisting of two parts, first an air-core coil of the type previously considered and, sec-

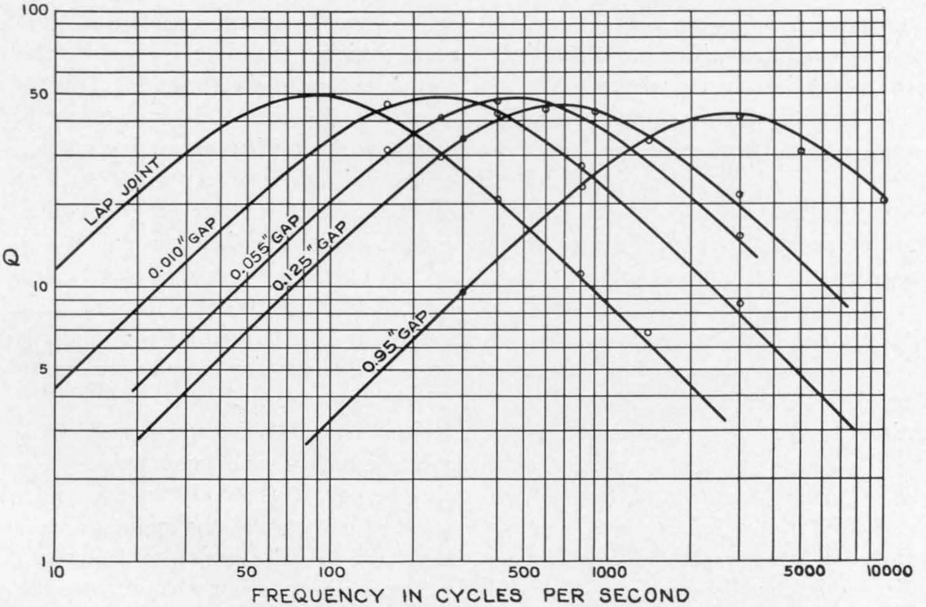


FIGURE 2. Frequency characteristic of Q for an iron-core coil with various air gaps. The curves are drawn with a template made in accordance with the equation

$$y = \frac{1}{x + \frac{1}{x}}$$

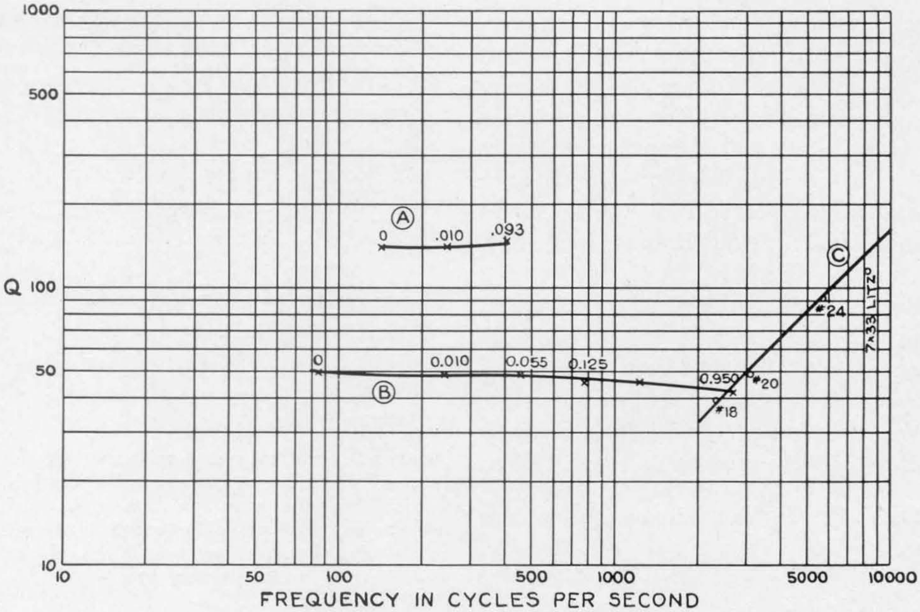


FIGURE 4. Loci of maximum Q points for various coil types

Curve A is for a large transformer with 0.007-inch silicon-steel laminations. Curve B is for the coil of Figure 2, which is an audio transformer with 0.018-inch silicon-steel laminations. In both curves, the numbers refer to air-gap distance in thousandths of an inch

Curve C is for a group of multi-layer air-core coils with the same cross section but using different wire sizes

ond, a loss-free inductance. As the amount of iron in the field is varied, such a structure will have a vertical locus, that is, the maximum Q will vary, but the frequency at which it occurs will be unchanged.

One application of these ideas about Q may be noted. In constant-K low-pass filters it is frequently desirable to keep the attenuation within the transmitted band very nearly constant. It is often stated that, in order to achieve this, Q should be very high. Actually the change of attenuation is due almost entirely to the shunt component of the loss. To assure constant transmission, a coil should be operated at frequencies well below that which makes Q a maximum; in this region the effective series resistance is constant, and the loss, which is almost entirely governed by this effective series resistance, is also constant.

Another application is in oscillator coil design. To assure constant output as a tuning condenser is varied, the equivalent parallel resistance should be constant, because this resistance is equal to the anti-resonant impedance of the coil and represents the loading on the tube. Constant parallel resistance is achieved when the coil is operated at frequencies well above the frequency of maximum Q since in this range the effect of series resistance is negligible and the remainder must clearly be constant.

The value of this analysis, after a few measurements have been made on a sample coil, lies largely in the viewpoint which it gives the engineer, enabling him to make more intelligent estimates of coil behavior without actually calculating the constants of successive models.

— L. B. ARGUIMBAU

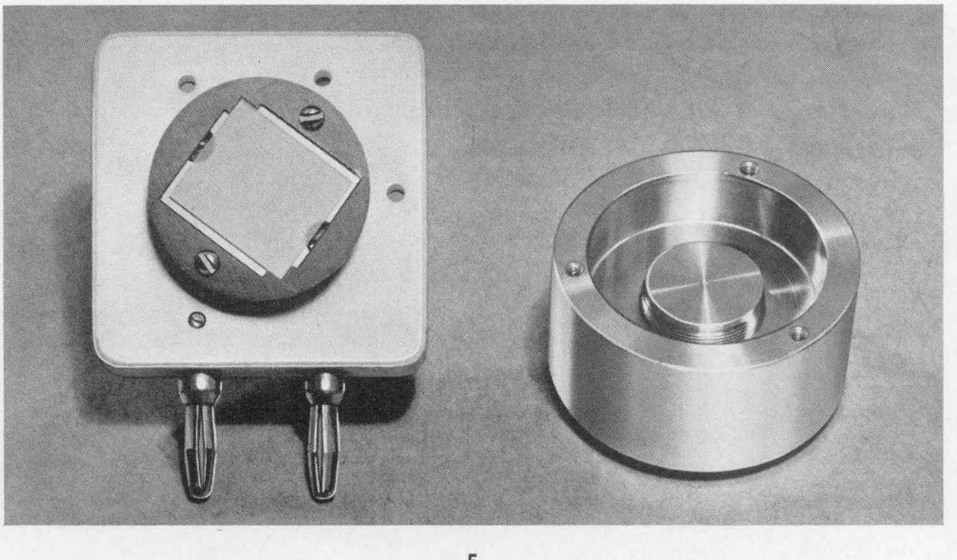
LOW-TEMPERATURE-COEFFICIENT QUARTZ PLATES

● **THE WIDE USE** of piezo-electric quartz plates as standards for frequency measurement and monitoring has stimulated research directed toward more stable piezo-electric elements and circuits. For the past few years considerable work has been done on reducing the temperature coefficient of frequency, which is the largest single source of frequency variation. An investigation of this field, together with a study of general methods of cutting and grinding quartz, has been carried out by the General Radio Company over a period of more than a year. Studies have been made not only on the thin plates used in monitoring, but also on the quartz bars used in primary standards.

This work has produced a plate which not only has a low temperature coefficient but is more active piezo-electrically and is free from both spurious frequencies and abrupt jumps in frequency when the temperature is varied.

FIGURE 1 (above). External view of holder used for TYPE 376-L Quartz Plates

FIGURE 2 (below). TYPE 376-L Quartz Plate with cover removed. The retaining ring is so shaped that little random motion of the plate is possible. The heavy aluminum cover with its threaded plug provides stability of air-gap adjustment and uniform heat distribution

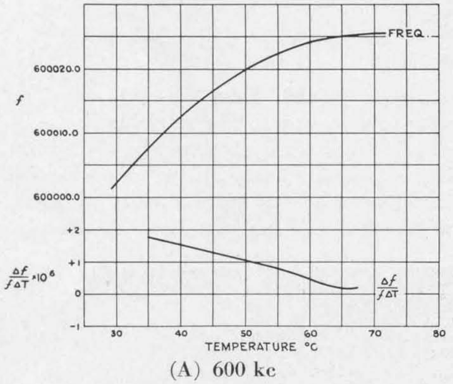


While the temperature coefficient is, in general, very low — less than one part per million per degree C. — it is evident that *zero* temperature coefficient cannot always be obtained in a desired temperature range. If a zero coefficient is reached, it is only for a single temperature.

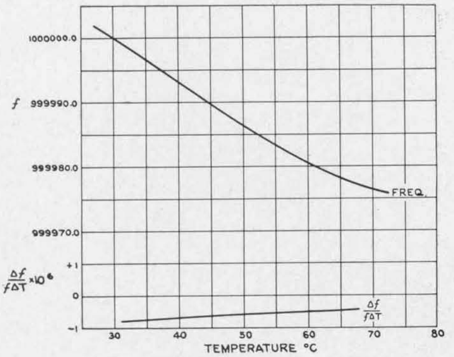
The temperature-frequency characteristics of these plates are shown in Figure 3, in which the upper curves show the actual variation in frequency with temperature, while the lower curves show the temperature coefficient (measured at 5-degree intervals) in parts per million per degree Centigrade.

A method of mounting has also been developed which restricts random motion of the crystal in the holder without materially affecting its freedom to vibrate. In the top of the holder is a fine-threaded plug, the bottom of which serves as the upper electrode. The quartz plate and the retaining ring rest on the lower electrode which is in the form of a plate secured to the isolantite base.

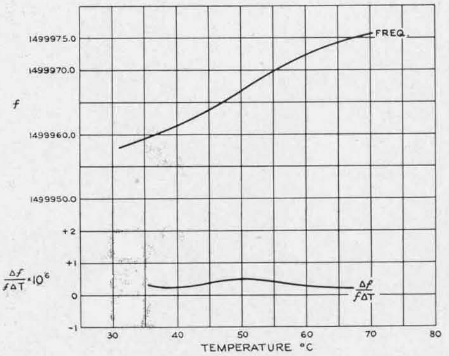
Type 376-L Quartz Plates now replace the Type 376-J and Type 376-K Quartz Plates formerly used in monitoring instruments. Each Type 376-L Quartz Plate is adjusted at its normal operating temperature until its frequency differs from that specified in the order by less than one cycle per second or 0.0001% (1 part in 10^6) whichever is the larger. When used in General Radio Type 475-A Frequency Monitor or Type 675-H Piezo-Electric Oscillator, the frequency is guaranteed to 0.002% (20 parts in 10^6) for a period of one year, provided the plate is operated under the conditions specified in the certificate of calibration. The temperature coefficient of frequency is guaranteed to be less than 3 parts per million per degree Centigrade between 20° and 70° C.



(A) 600 kc



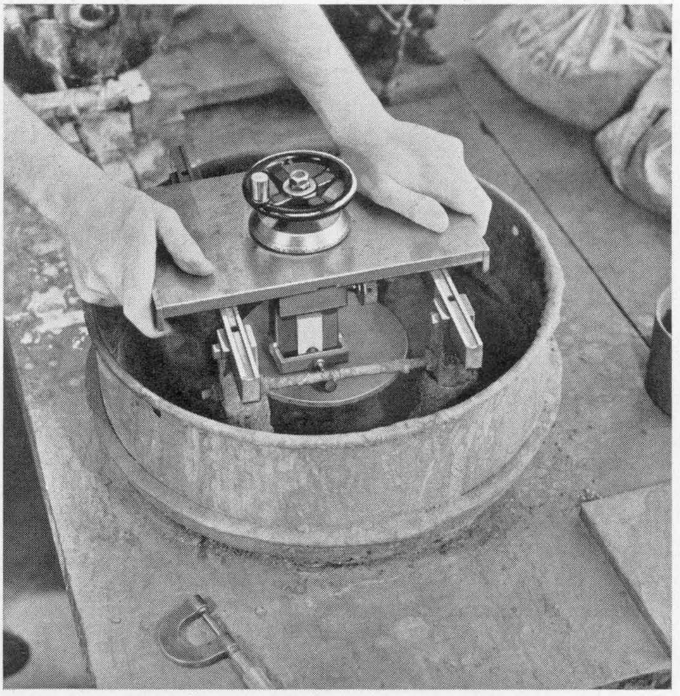
(B) 1000 kc



(C) 1500 kc

Figure 3. Curves showing the variation of both frequency and temperature coefficient of frequency as the temperature is varied for three plates in the standard broadcast band. The upper curves show the change of frequency in cycles per second; the lower curves, the temperature coefficient in parts per million per degree Centigrade

FIGURE 4. One of the grinding operations in the production of General Radio quartz plates. The edge of the plate is held against a rotating disk, and the calibrated head shows the amount ground from the edge



Although General Radio frequency monitors are provided with a precise temperature-control system, adequate to maintain the above-mentioned accuracy with older types of plates, the use of the new low-temperature-coefficient plates provides a better margin of safety. In addition, if, for any reason, temporary failure of the temperature control occurs, the frequency error is greatly reduced. The price of TYPE 376-L Quartz Plate is $85.00, but for those users of General Radio frequency monitors who wish to replace their present crystals with the new type, a liberal credit allowance for the returned holder will be made as explained below.

TYPE 376-L Quartz Plates have been approved by the Federal Communications Commission for use in General Radio frequency monitors.

Studies on low-frequency quartz bars have reduced the temperature coefficients of TYPE 676-A Quartz Bars, used in the Class C-21-H Standard-Frequency Assemblies and in Class C-10 Secondary Frequency Standards to between one and two parts per million per degree C. In quartz bars, the temperature coefficients are practically constant over the range of temperatures of test, in contrast to the quartz plates in which variations in the temperature coefficients are observable.

— J. K. CLAPP

General Radio quartz plates are licensed under all patents and patent applications of Dr. G. W. Pierce pertaining to piezoelectric crystals and their associated circuits.

REPLACEMENT QUARTZ PLATES FOR FREQUENCY MONITORS

● WHEN a TYPE 376-J or TYPE 376-K Quartz Plate is returned to be replaced by a TYPE 376-L Quartz Plate, the new plate will be mounted in the returned holder, regardless of whether or not this holder is of the type shown on page 5. Under these conditions a credit of $20.00 will be allowed for the returned holder, making the price of the replacement plate $65.00. Those who wish to make the exchange should write directly to the Service Department for shipping instructions in order that each exchange may be handled as promptly as possible. Under no conditions should plates be returned without first communicating with our Service Department.

MISCELLANY

● **AMONG THE RECENT** distinguished visitors to our laboratories and factory were His Excellency, Professor Ing. Giancarlo Vallauri and his Assistant, Professor Gori.

Professor Vallauri is Vice-President of the Accademia d'Italia, President of the Societa' Idroelettrica Piemontese, President of the Ente Italiano Audizioni Radiofoniche, President of the Elettrica Piemonte Centrale, Dean of the Politecnico of Turin, Italy, and one of the leading scientists invited to participate at the Tercentenary Celebration at Harvard University.

● **AN INDEX** has been compiled for the General Radio *Experimenter* covering the period from June, 1931, to May, 1935, inclusive. This is printed in two parts, one for Volumes VI and VII (1931-1933) and the other for Volumes VIII and IX (1933-1935). Copies will be furnished to all who request them.

● **A CHECK** of our stock of back issues shows that a considerable supply of the numbers listed here is still available:

Vol. I, Nos. 1-3
Vol. II, Nos. 1-8, 11, 12
Vol. III, Nos. 1-10
Vol. IV, Nos. 5-12
Vol. V, Nos. 1-6, 8-12
Vol. VI, Nos. 1-12
Vol. VII, Nos. 1-4, 6-12
Vol. VIII, Nos. 2-12
Vol. IX, Nos. 1-12
Vol. X, Nos. 1-12
Vol. XI, Nos. 1 to date.

A limited stock of the following numbers is available:

Vol. III, Nos. 11 and 12
Vol. IV, Nos. 1-4
Vol. V, No. 7
Vol. VII, No. 5
Vol. VIII, No. 1.

The issues in Volumes IV to XI are the same size as the present *Experimenter*. The page size for Volumes I to III is 9 x 12 inches.

We shall be glad to send any of these back copies to those who request them. Those issues which are limited in number will be distributed while they last.

THE 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.

GENERAL RADIO COMPANY

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The GENERAL RADIO

EXPERIMENTER

ELECTRICAL MEASUREMENTS
TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

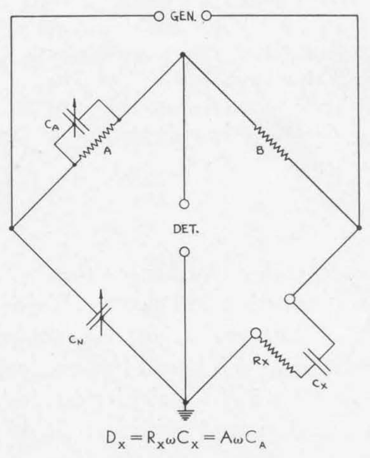
VOL. XI No. 7 DECEMBER, 1936

AN AUDIO-FREQUENCY SCHERING BRIDGE

● **THE PRESENT TREND** in a-c bridges, as in other measuring instruments, is toward direct-reading dials, which, in conjunction with decade multiplying switches, extend this direct-reading feature over a very wide range. It is equally desirable that the electrical quantities thus measured be those truly characteristic of the unknown impedance.

The two most important characteristics of any condenser are its capacitance and power factor. For any solid dielectric condenser these quantities remain practically constant over a wide frequency range. The Schering bridge circuit, Figure 1, in which the resistance balance of the bridge is obtained by connecting a variable air condenser across the ratio arm opposite the unknown capacitance, is well adapted for the direct measurement of power factor, for this air condenser can be calibrated to read directly in power factor at any one frequency.

The Type 716-A Capacitance Bridge makes use of the Schering bridge circuit. Its three controls are conveniently arranged on its panel as shown in Figure 2, power factor dial on the right, capacitance dial and drum on the left, with the capacitance multiplier above. Capacitances up to 1 μf and power factors up to 6% (0.06 expressed as a ratio) at a frequency of 1 kc can be read directly. This range embraces



$$D_X = R_X \omega C_X = A \omega C_A$$

Figure 1. Schematic diagram of a conventional Schering bridge

ALSO IN THIS ISSUE

A Redesign of Type 200-B Variac

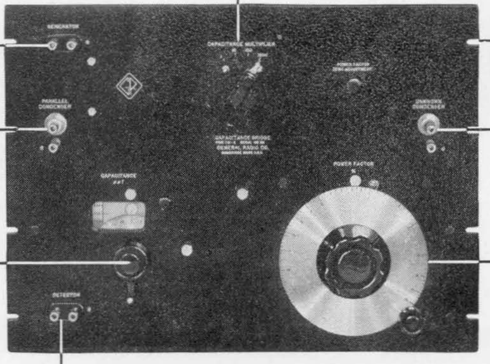


FIGURE 2. Panel view of the TYPE 716-A Capacitance Bridge showing principal controls

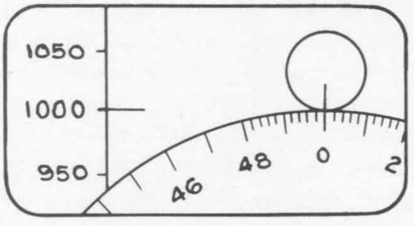
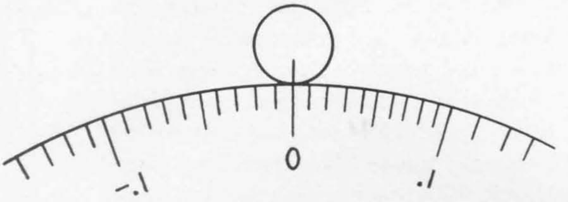


FIGURE 2a (left). This is a full-size drawing of the precision-condenser scale. The smallest division is 0.2 $\mu\mu$f and 0.04 $\mu\mu$f can be estimated

FIGURE 2b (right). The power-factor scale is also shown here full size. The open scale allows a power factor of 0.002% to be estimated



most of the capacitances met with in communication and electrical engineering; all but the largest sizes of paper condensers, mica condensers, cables, slabs of solid dielectric, liquids in large cells, and ground capacitances of generators and transformers.

This bridge can also be used for all the various substitution methods. The direct-reading controls greatly simplify not only the two balancings of the bridge but the calculations as well. The direct-reading range of the standard condenser, a TYPE 722-D Precision Condenser with only the large 1000-$\mu\mu$f scale, embraces most air condensers, small mica condensers, ceramic and all other kinds of insulators, slabs of all types of solid dielectrics and liquids such as insulating oils in oil cells.

Capacitances greater than 1000 $\mu\mu$f and up to 1 μf may be compared by direct substitution. The standard condenser in the bridge, together with its multiplier, may act merely as a balancing arm, or may also take up the difference between the unknown and the external standard. The bridge is thus eminently suited to the inter-comparison of sets of standards and to production testing, in which the differences between the standard and the production units in both capacitance and power factor may be seen to fall inside or outside predetermined limits.

The resistance balance of the bridge may also be made by means of an external resistor, a TYPE 602 Decade Resistance Box, connected in parallel with one of the capacitance arms. Placed across the standard condenser (see Figure 3) the bridge becomes direct reading in parallel resistance and capacitance. This covers all ordinary measurements of the resistance of electrolytes. Greater accuracy may be obtained by using a substitution method.

When an external precision condenser is used, as was always the case with the older TYPE 216 Capacity Bridge, the resistance balance may be made with a series resistance. Tenth-ohm steps in this resistance give a finer adjustment than it is possible to read on the power factor dial, except at frequencies below 200 cycles. In this manner the power factor balance may be made to 0.0001% (0.000001 expressed as a ratio).

The various features of the TYPE 716-A Capacitance Bridge, which make possible the wide range of uses just catalogued, are shown pictorially in Figure 2 and Figure 4. The most prominent of these are the open scales of the TYPE 722-D Precision Condenser used as the standard of capacitance and of the TYPE 539-TA Air Condenser used for measuring power factor. FIGURE 2a shows that 1 $\mu\mu$f, for which the precision condenser is direct reading, covers a space of 0.2 inches or 5 divisions. The limit of backlash and linearity of the worm are about 0.1 $\mu\mu$f, which is ½ division, and 0.04 $\mu\mu$f has some significance. FIGURE 2b shows that around the zero of the power factor scale the smallest division is 0.01% (0.0001), so that 0.002% (0.00002) may be estimated. The negative portion of the scale is introduced so that in substitution measurements, in which the unknown condenser is connected across the internal standard, the power factor balance can be obtained without introducing extra loss in the balancing condenser connected across the UNKNOWN CONDENSER terminals. The scale of the power-factor dial is approximately logarithmic from 0.1% up and extends to 6%.

The capacitance range of the bridge is extended to 1 μf by using four different ratio arms. The switching needed to control these ratio arms is shown schematically in Figure 5. Associated with each ratio arm in the B arm is a mica condenser of such size that the resistance-capacitance product is approximately constant. The exact equalizing of these products is carried out in

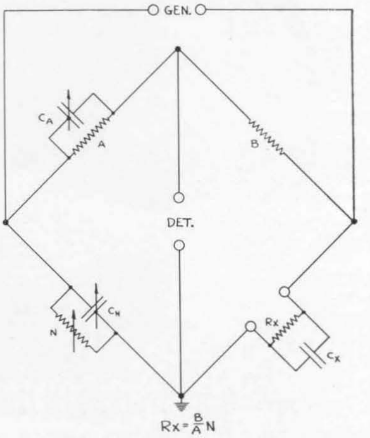


FIGURE 3. Showing how a decade resistor can be connected to read parallel resistance

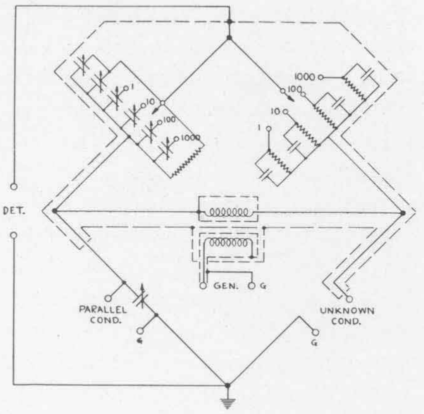


FIGURE 5. Complete circuit diagram of the TYPE 716-A Capacitance Bridge

the A arm by means of four variable air condensers. A fifth air condenser, whose control on the panel is marked POWER FACTOR ZERO ADJUSTMENT, is provided to compensate for the temperature coefficient of the terminal capacitance of the input transformer.

The success of a direct-reading bridge depends on so arranging the various component parts that no extra capacitances are placed across the capacitance arms. To attain this end both ratio arms with their adjusting condensers, the power factor condenser, and the input transformer are mounted on insulated sub-panels and completely enclosed by dust covers. This shield is connected to the junction of the ratio arms so that all terminal capacitances of these parts are placed across these arms and balanced out by the initial adjustment of the power factor condensers. The shielding is extended to the high UNKNOWN CONDENSER terminal and through the panel with the result that the capacitance across these terminals is not greater than 1 $\mu\mu$f. The input transformer is doubly shielded and the direct admittance of the generator winding to the insulated shield is kept very small. Its effect on the reading of the power factor dial is small and comparable to the change in power factor of the standard condenser with setting.

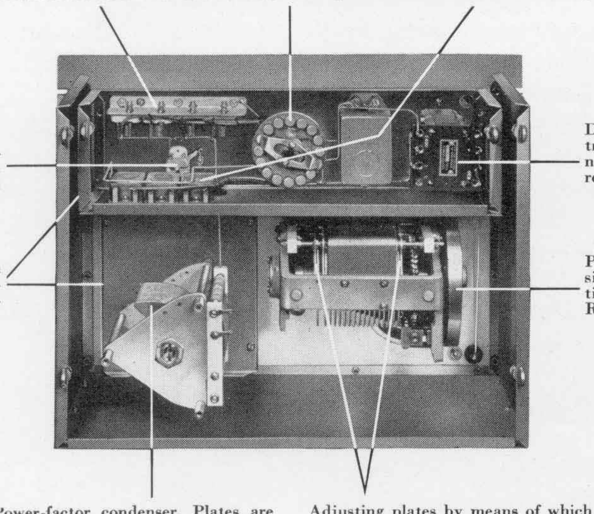


FIGURE 4. Rear view of the bridge with outer and inner shields removed, identifying the principal components

As a result of these design features the accuracy of the direct readings of the bridge at a frequency of 1 kc over the capacitance range of 100 $\mu\mu$f to 1 μf is for capacitance $\pm 0.2\%$ or ± 2 $\mu\mu$f times the MULTIPLIER setting, and for power factor ± 0.0005 or $\pm 2\%$ of the dial reading. For substitution measurements the accuracy in the power factor readings is improved to ± 0.00005 or $\pm 2\%$ for the change in power factor observed. Two condensers can be compared to an accuracy of ± 0.2 $\mu\mu$f or $\pm 0.02\%$.

While the bridge is designed to be used at a frequency of 1 kilocycle, it may be used over the whole audio-frequency range from 60 cycles to 10 kc. Since the readings of the power factor dial are proportional to frequency, its range is restricted at the low frequencies and extended at the high frequencies.

The input and output terminals are marked GENERATOR and DETECTOR for the connections which place the input voltage across the ratio arms and give maximum sensitivity under most conditions. The voltage thus placed across the bridge is limited to 100 volts. By interchanging generator and detector connections, a maximum of 700 volts, the safe voltage of the standard condenser, can be applied across the DETECTOR terminals for equal ratio arms and for 1 kc.

Being provided with a dust cover, this bridge may be mounted on a panel rack with its oscillator and amplifier as shown in Figure 6. The TYPE 508-A Oscillator and TYPES 714-A or 814-A Amplifier are available for this use. This assembly conserves bench space and is particularly desirable for permanent installations and production testing. The bridge is also available mounted in a walnut cabinet and may be used with its panel either vertical or horizontal, as is found most convenient.

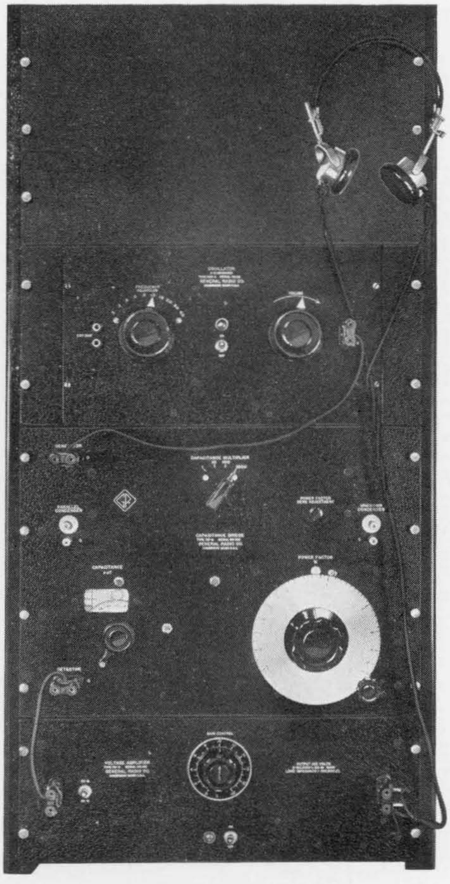


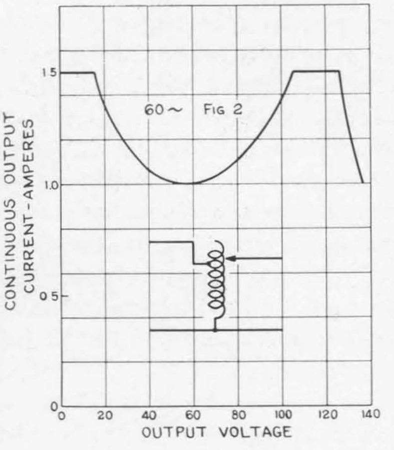
FIGURE 6. Showing how the bridge can be mounted in a relay rack with TYPE 508-A Oscillator and TYPE 714-A Amplifier

— R. F. FIELD

Complete specifications for TYPE 716-A Capacitance Bridge are given on pages 79 and 80 of Catalog J. Prices are as follows:

Type	*Mounting*	*Code Word*	*Price*
716-AR	Relay Rack	BONUS	$335.00
716-AM	Cabinet	BOSOM	360.00

A REDESIGN OF TYPE 200-B VARIAC



● **IMPROVED** manufacturing methods have made it possible to furnish the Type 200-B Variac with an output voltage range of 0 to 135 volts. This has been accomplished without materially increasing either size or weight. The new design permits this type of *VARIAC* to be used for a number of purposes to which the older model was not adapted because of its limited output voltage.

Figure 1 is a plan view of the winding showing the terminals. The *VARIAC* can be so connected that the maximum output is equal to the line voltage (115 volts) or is above line voltage (135 volts). Each of these conditions can be obtained for either table mounting or panel mounting, necessitating provision for four sets of connections as shown.

The dial which reads directly in output voltage is reversible, reading 0 to 115 volts on one side and 0 to 135 volts on the other.

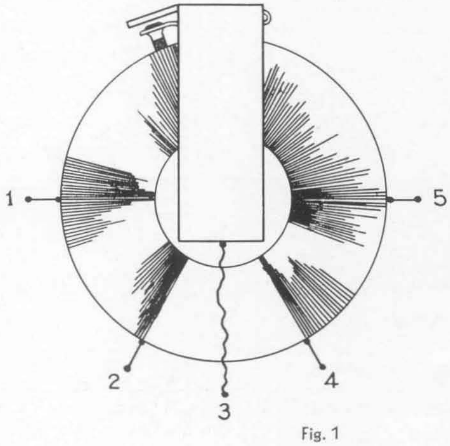
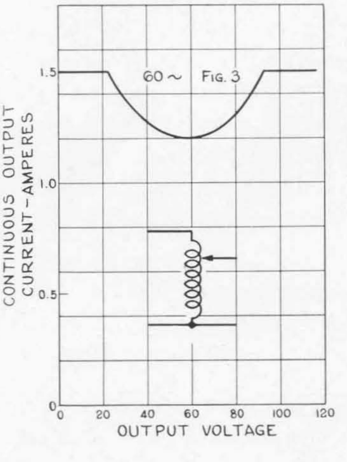


Fig. 1



Type 200-B Variacs are wound on the machine shown above

Output-current vs. output-voltage characteristics for both 60-cycle and 50-cycle operation are shown in Figures 2 to 5. Since the no-load loss is greater on 50-cycle supply, the maximum output current is correspondingly reduced.

Humming caused by vibration of the two halves of the core was often present in the older model. Each lamination in the new model is a complete annulus and no tendency to hum exists.

These new *VARIACS* are now being supplied on all orders for Type 200-B.

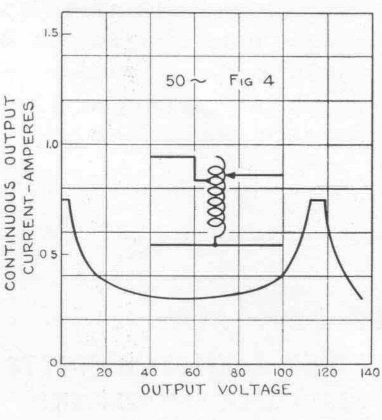
SPECIFICATIONS

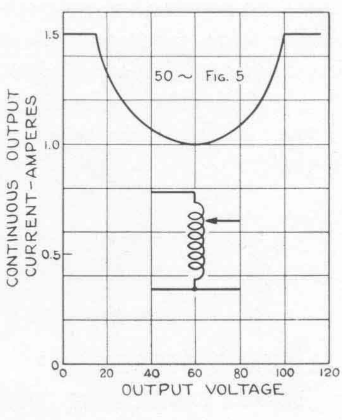
Dimensions: 4 x $3\frac{5}{16}$ x $3\frac{13}{16}$ inches, over-all.

Net Weight: $3\frac{3}{4}$ pounds. **Code Word:** BALSA.

Price: $10.00.

VARIACS are manufactured under U. S. Patent No. 2,009,013.





MISCELLANY

● **AMONG THE INSTRUMENTS** exhibited by General Radio at the Rochester Meeting of the Institute of Radio Engineers were the TYPE 721-A Coil Comparator and the TYPE 726-A Vacuum-Tube Voltmeter. Both instruments will be described in early issues of the *Experimenter*.

● **ON OCTOBER 1,** Dr. Donald B. Sinclair joined the Engineering Department of the General Radio Company. Dr. Sinclair was educated at the University of Manitoba and Massachusetts Institute of Technology, receiving the degrees of S.B. (1931), S.M. (1932) and Sc.D. (1935) from the latter institution.

Since 1932 he has been connected with M.I.T. as a research associate. During this period, part of his time was spent at General Radio in research work on high-frequency measurements. It is with distinct pleasure that the Engineering Department welcomes him as a full-time colleague.

● **MR. H. B. RICHMOND** (General Radio's treasurer) has just returned from an extensive trip of exploration to California. Going out by boat, he arrived on the strike-bound coast just in time to heave a line in docking the ship. Hollywood seems to have occupied most of the California time. (He says business, our private reports have not come in yet.) Texas was next on the itinerary, for a first-hand comparison of the relative attractions of the Fort Worth and Dallas Fairs. Continuing east through New Orleans and way states, he emerged unscathed from the ordeal of eleven nights in a sleeper.

● **MR. EDUARD KARPLUS** has resumed his work on the General Radio Engineering Staff after a several weeks' trip to Austria, U. S. S. R., and France. Mr. Karplus visited relatives in Vienna and called upon our Austrian representatives, Dr. Paul Holitscher and Company. In Moscow he conferred with officials of Technopromimport regarding pending contracts for laboratory installations. In Paris, he called upon Radiophon, our French representatives, in company with whom he investigated the bright lights of Paris.

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