the GENERAL RADIO Experimenter

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

RECENT DEVELOPMENTS IN MICA CONDENSERS

IN precise electrical circuits mica condensers have, for many years, played a very important part. Due to their low losses, they have been particularly successful in high-frequency communication circuits. The two general types available heretofore have been the very accurately adjusted primary standards of capacitance and the inexpensive moulded types which are usually adjusted only approximately to capacitance and are not particularly intended for use where their adjustment or constancy of capacitance is important. The precision kind is necessarily quite expensive and the cheaper ones have not been entirely satisfactory in many electrical circuits because of their drift due to atmospheric conditions and aging. This is particularly true in stable tuned circuits, as for instance beat-frequency oscillators, where the stability of adjustment depends upon the condensers remaining constant.

SIGNIFICANT improvements in the design and manufacturing methods have resulted in a new mica condenser having low losses, stability of calibration, temperature compensation, and several other features common in condensers of the precision-standard type. Yet the cost of the new unit is only a little more than that of the commercial types used as grid- and by-pass condensers in experimental equipment.

The General Radio Company has felt for some time the need for a well-designed mica condenser falling between these two classes. These condensers must not have appreciable drift with time, must not vary with atmospheric conditions, must have low losses, and must be adjusted to, and hold, a good accuracy.

With these requirements in mind, Mr. Greenleaf W. Pickard developed for the General Radio Company a completely different line of mica condensers.

Mica has established itself as one of the most efficient dielectric materials known. It is, however, a fair adsorbent for water. A thin film of moisture, perhaps a molecule thick, will collect on

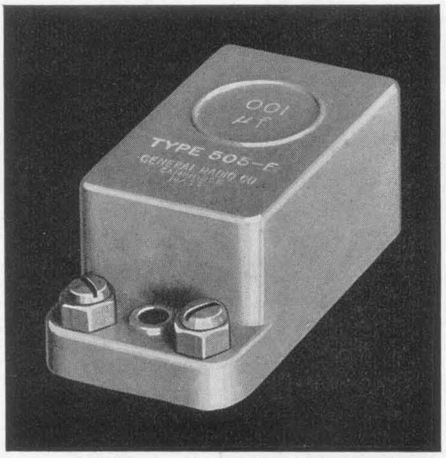


FIGURE 1. Photograph of a TYPE 505 Condenser

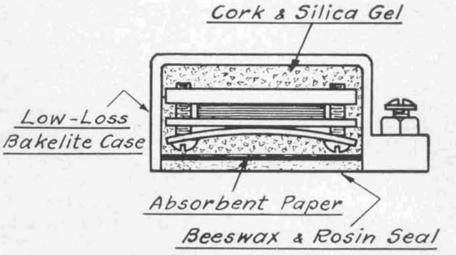


FIGURE 2. Cross section of a TYPE 505 Condenser showing the method of construction

the faces of mica and will increase its dielectric loss tremendously. In fact, the presence of such moisture can be detected most easily by the measurement of power factor. Therefore, the dielectric for the new condensers is kept at a temperature of 300° F. for a considerable time before the material is used. It is kept hot from the time that it is received until it is built into the condenser. In production, the mica and the conducting material are kept on a hot plate during assembly so that the elements are between 250° F. and 300° F., thus insuring dryness until they are finally sealed in their containers.

The next problem after the condenser is thoroughly dried is to keep it in that condition. This has been solved by placing the assembly in its case, together with a mixture of silica gel and ground cork, and enclosing it with a seal of rosin and beeswax. Silica gel is a very active desiccating agent. It will adsorb about 30% of its own weight in water and will maintain, in a closed space, a relative humidity of less than 0.5%.

The cases have less than a cubic inch of free air space. Enough silica gel is sealed in to adsorb all of the moisture that can be present in completely saturated air to a volume of 2000 times the free air in the containers before it will saturate. That is, there can be 2000 complete changes of air due to leakage before this desiccant will be used up; and this is for air having 100% relative humidity at room temperatures. It is estimated that it will take perhaps fifty years before this much breathing can occur.

Another most important cause for an increase in power factor is physical damage to the mica. Mechanical injuries, such as tiny scratches or any other accident that disturbs the crystalline structure, will cause large dielectric losses. Because of this, each piece of mica that is used in these condensers is very carefully inspected for physical damage. Thus, the two important causes for high dielectric loss have been taken care of, and, as a result, the condensers possess a remarkably low phase angle.

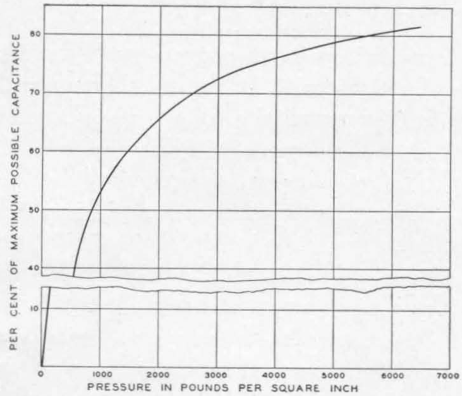


FIGURE 3. Variation of the capacitance of a mica condenser with pressure

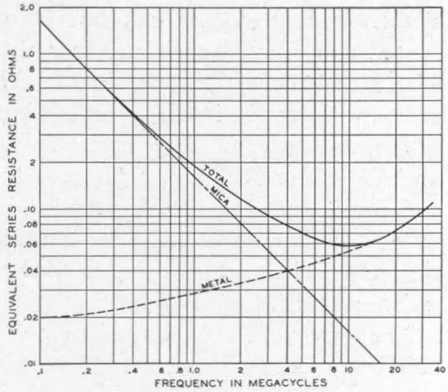


FIGURE 4. Equivalent resistance *vs.* frequency characteristic of a 400 $\mu\mu$f TYPE 505 Condenser. Note that the effect of the metal is important only at high radio frequencies

Figure 2 shows in cross section how the TYPE 505 Condensers are assembled.

The only other place where some electrical loss can be expected is in the possible absorption of power in the mounting case or the desiccating compound. The latter is eliminated because the field in it is essentially zero. The internal wiring and terminal arrangements are such that the electrostatic field through the case is very weak.

For this reason, ordinary moulded bakelite could be used. However, the added loss due tousing a standard bakelite case can actually be measured because of the low power factor achieved in the condenser itself. Therefore, a low-loss bakelite composition is used, the electrical loss in which is a fraction of that in bakelite. It is especially compounded for low-loss operation and is designated "XN-262 Natural" by the Bakelite Corporation.

It is well known that changes in pressure in a mica condenser will cause very appreciable changes in capacitance. Figure 3 indicates how this change in capacitance looks when plotted against pounds per square inch pressure as applied to the condenser stack. The curve is asymptotic and has a pronounced knee at approximately 2000 pounds per square inch. Since it is evident that changes in temperature will vary the pressure and, hence, the capacitance, the pressure on these condensers is adjusted well beyond the knee of the curve where the change in capacity with pressure is small.

As the temperature changes, a part of the contraction or expansion of the material with the resultant change in pressure is compensated for in the construction of the units. The amount that remains will vary the pressure somewhat, but, due to the fact that the change occurs over the flat portion of the curve, the total change in capacitance from this cause amounts to an exceedingly small increment. The temperature coefficient of capacitance is less than 0.006% per degree Centigrade from 0 to 50° Centigrade.

As has been mentioned previously, the electrical loss in the condenser is slight. Any condenser can be represented as a pure capacitance in series with a resistance which represents the electrical losses in it, the combination of the resistance and capacitance being an indication of the power factor. The series resistance representing the loss is called the equivalent series resistance. Figure 4 indicates the variation of this resistance with frequency.

The curves show how the losses divide between the metal parts of a typical TYPE 505 Condenser and the mica. Because of the fact that in solid dielectric condensers $R\omega C$ is approximately a constant, the equivalent series resistance due to the mica alone drops off nearly inversely as the frequency for a given capacitance. This straight-line relationship holds as long as the losses in the metal or conducting parts of the condenser are negligible. However, at the very high frequencies (above 3 megacycles), the metal losses, which are due to the eddy currents in the conducting and supporting material, and to skin effect, become appreciable as compared with the dielectric loss and the curve of the total equivalent series resistance begins to curve upward again above 10 megacycles. These curves were taken on a stock condenser having a capacitance of 400 $\mu\mu f$ and a power factor at 1000 cycles of 0.04%.

Data taken on a large number of condensers have proven the TYPE 505 Condensers to be remarkably uniform in characteristics. The power factors are well under 0.05%. The power factor of all condensers is checked at the factory at 1000 cycles and, as will be noted from the curve in Figure 4, will not depart appreciably from this value for any frequency under 2 megacycles. At 30 megacycles, the power factor is only 0.7%. The power factor is measured at room temperature. It changes with temperatures so that for an increase of 17° C. the power factor doubles; for a decrease of 17° C., it halves.

The strict specification for freedom from drift has been met adequately by the sturdy mechanical construction and a design that essentially eliminates changes due to temperature and humidity.

Tests in our laboratory for a period of over six months have indicated that the drift with time of both capacity and power factor is entirely negligible.

—A. E. THIESSEN

TYPE 505 Condensers are made in 9 sizes and each is mounted in a bakelite case 2½ inches long by 1¼ inches wide and 1 inch high.

Type	*Capacitance*	*Adjusted to Within*	*Maximum Peak Voltage*	*Code Word*	*Price*
505-A	100 $\mu\mu$f	10%	1200 volts	CONDENALLY	$3.50
505-B	200 $\mu\mu$f	5%	1200 volts	CONDENBELL	3.50
505-E	500 $\mu\mu$f	2%	1200 volts	CONDENCOAT	3.50
505-F	0.001 μf	1%	700 volts	CONDENDRAM	3.50
505-G	0.002 μf	1%	700 volts	CONDENEYRE	3.50
505-K	0.005 μf	1%	500 volts	CONDENFACT	4.00
505-L	0.01 μf	1%	350 volts	CONDENGIRL	4.00
505-M	0.02 μf	1%	350 volts	CONDENHEAD	4.00
505-Q	0.05 μf	1%	350 volts	CONDENJACK	4.50

A COMBINATION MONITOR AND FREQUENCY METER FOR THE AMATEUR

The TYPE 535-A Frequency Meter-Monitor

DUE either to failure to use any frequency-measuring device or to lack of confidence in the stability of their home-made frequency meters, amateurs in increasing number are attempting to operate their transmitters by setting them to a frequency "somewhere near the middle" of each amateur band. This condition tends to aggravate the already severe interference present in most of these bands.

Many amateurs whose transmitters are equipped with quartz-crystal control or with other power-amplifier combinations with oscillators of comparatively high stability assume that precise frequency-measuring apparatus is not required. Since many amateur power oscillators are operating in a highly regenerative state, it is comparatively easy for these amplifiers to oscillate, emitting signals which may be far outside of the band in which they were intended to function. In addition, transmitters, even of the power-amplifier type, when operating near the extremities of any amateur band, may easily drift out of the band through the normal shift in frequency caused by changes in temperature, supply voltage, and other effects. The amateur equipped with an accurate heterodyne frequency meter is able to operate on a frequency away from crowded portions of the band and to set his transmitter anywhere within the band.

For these reasons General Radio feels that a need exists for an amateur and experimental heterodyne-type frequency meter, the characteristics of which are such that the instrument may be used over comparatively long periods of time without recalibration.

Inherently, the Colpitts oscillator is probably the most stable of all the common oscillator circuits. This circuit, however, must be provided with additional stability before it can be used as a heterodyne frequency meter of relatively high precision. If the electron-coupled circuit is applied to the Colpitts and if voltage stabilization is secured, a frequency meter well suited to amateur and experimental use can be designed.

In the past, amateurs have made use of both a frequency meter to measure frequency and a separate monitor to check the character of actual transmissions. The need for two instruments has been due to the fact that, when sufficient coupling to the transmitter is secured to use the frequency meter as a monitor, the calibration of the frequency meter is impaired. In a new General Radio instrument the functions of both frequency meter and monitor are successfully combined, since the electron-coupled Colpitts circuit does not appreciably shift in frequency when coupled to an external load.

FREQUENCY STABILITY

For amateur use, certain factors which contribute to the absolute stability of a heterodyne frequency meter, such as temperature variations over a wide range, aging, change in tubes, mechanical shock, etc., may be disregarded since the calibration of an amateur frequency meter may be checked very readily when any such factors enter.

Under normal conditions of use, the General Radio frequency meter will have a working stability as follows:

Variable	*Range*	*Parts per Million at 2000 Kilocycles*
Supply Voltage	45-112 Volts	25
External Load	....	5
Temperature	±5° F.	500
Heater Voltage	±20%	10
Total (assuming all errors occur in the same direction)		540

The total deviation (deviation capability) of 540 parts per million represents the maximum to be encountered under normal operating conditions, when all of the variables cause a deviation in the same direction. The deviation capability of amateur heterodyne frequency meters has been grossly disregarded in rating the accuracy of such devices in that many factors adversely affecting the frequency stability have been ignored in order to claim greater precision. Practically, it is obvious that variation in "B" supply voltage from 112 to 45 volts will not be encountered, 90 to 67½ representing the probable maximum. Also heater voltage variation of 20% would result in the equipment being operated in semi-darkness!

The General Radio frequency meter is designed to operate on any fundamental frequency between 1700 and 2000 kilocycles, this frequency range being spread over 265 divisions of the tuning dial. The meter is sufficiently rich in harmonics to be operated in any of the amateur bands up to the highest.

To enable the user to read the frequency as precisely as possible, the meter is equipped with the 6-inch General Radio Type 706-A Precision Dial having 300 divisions. By means of the glass magnifier it is possible to estimate accurately the setting to within 1/5th of a dial division, or to within

250 cycles in the 1700- to 2000-kilocycle band. This precision of setting is better than that which can be obtained with the usual 100-division dial and true vernier indicator. The precision of setting is further enhanced due to the use of a dial scale which is individually engraved (not etched or stamped) or a precision dividing engine.

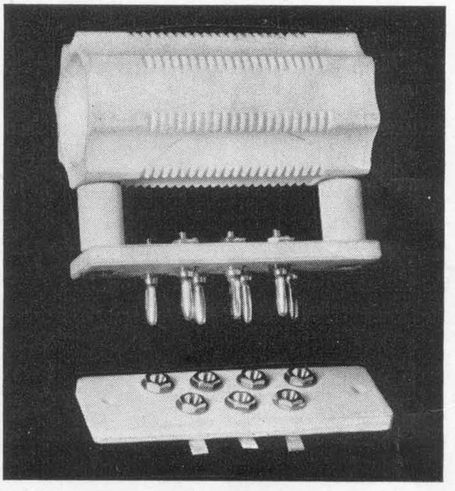
The meter is supplied with a calibration chart, the settings for thirteen frequencies in the 1700- to 2000-kilocycle band being determined from the General Radio primary standard of frequency, which is accurate to better than one part in a million. Additional calibration charts to assist the user in recalibrating the meter from standard-signal transmissions, and twelve calibration curve sheets to which the user may transfer the calibration data, are furnished with each meter.

The meter costs $42.50 and is known as the General Radio TYPE 535-A Frequency Meter-Monitor.

A NEW COIL FORM

For use by laboratories, amateurs, and experimenters in medium power oscillators, transmitters, and power amplifiers a need exists for a comparatively simple inductance form of low loss and moderate price.

The new General Radio TYPE 677-U Coil Form was designed for this purpose. This form is of moulded porcelain having six heavy ribs. The form is 2½ inches in outside diameter, 4⅝ inches long, and has twenty V-cut threads occupying a space of 3 inches. Any size wire up to No. 10 B. & S. gauge may be used. Twenty turns with a 500-micromicrofarad variable condenser will cover the 160-meter amateur band.



To facilitate use in circuits where quick change of inductance is desired, the coil can be supplied with plug and jack plates of moulded porcelain. In amateur and experimental transmitters these forms are suited to use in oscillator, buffer, and amplifier circuits. Plate and grid or plate and antenna inductances may be wound on one form, proper connections being possible through the seven plug and jack terminals. Holes at irregular intervals are provided along the length of one rib of the form to allow easy termination of coils.

The complete assembly (sold separately as desired) consists of a TYPE 677-U Coil Form (35 cents), two TYPE 677-P1 Coil Form Spacers (15 cents each), a TYPE 678-P Plug Base with seven TYPE 274-P Plugs (70 cents), and a TYPE 678-J Jack Base with seven TYPE 274-J Jacks (65 cents).

NEW PRECISION DIALS

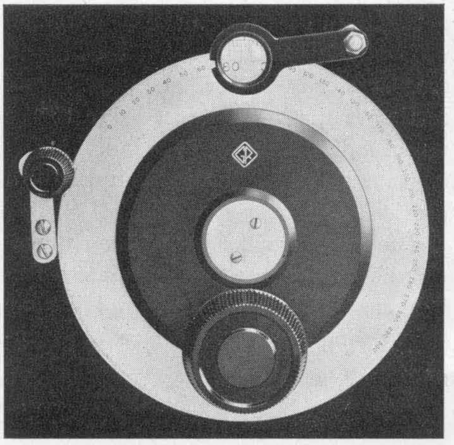
SEVERAL recent General Radio instruments are appearing with a new type of dial.

The new dials are distinguished by a smooth friction slow motion. An internal drive is used so that the driving knob rotates in the same direction as the dial. The black bakelite central portion of the dial is stationary.

The scale is carried on the nickel-plated moving rim. Divisions are engraved on a dividing head and are thus accurately spaced and identical in width.

The dials are easy to mount, requiring only one hole in the panel in addition to the instrument shaft hole. The new dials are made in four-inch and six-inch diameter with 180- and 270-degree scales.

Two other accessories are shown in the accompanying illustration. The TYPE 520-A Dial Lock can be mounted at the edge of the dial and can be used to lock the dial securely in position.



TYPE 706-A Dial with TYPE 519-A Lens and TYPE 520-A Dial Lock

This is desirable when the instrument is to be used at a single setting as a fixed standard.

The TYPE 519-A Lens is mounted above the indicator and serves to increase the accuracy of setting and reading. The features of the dials and accessories are summarized below.

Type	*Dial Diam.*	*Arc*	*Scale Divs.*	*Diam. of Knob*	*Approx. Reduc. Ratio*	*Weight*	*Code Word*	*Price*
704-A	4 in.	180°	200	1½ in.	1:6	10 oz.	DABBY	$7.50
704-B	4 in.	270°	300	1½ in.	1:6	10 oz.	DAIRY	7.50
706-A	6 in.	180°	300	2 in.	1:8	18 oz.	DASHY	8.00
706-B	6 in.	270°	450	2 in.	1:8	18 oz.	DATUM	8.00
519-A	....	....	...	....	..	....	ABASH	1.50
520-A	....	....	...	....	..	....	ABATE	.75

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

MIXER CONTROLS FOR DYNAMIC AND RIBBON MICROPHONES

IN June, 1931, the General Radio Company announced the Type 652 Volume Control for microphone mixer and general gain-control work in all sorts of voice circuits. Since that time, many hundreds of these units have been sold and operated with uniform success. Their performance has proved to be so reliable that they are widely used in talking motion-picture recording installations. The requirements for this service are particularly rigid since any failure in the mixer circuits may ruin completely an expensive shot.

The advent of the dynamic and ribbon microphones has brought up a new consideration in the design of microphone mixer controls and a new General Radio unit for this work.

Condenser microphones having a very high impedance necessarily work into the grid of a vacuum tube. Their output therefore is always pre-amplified before reaching the mixers. Incidental to this amplification has been the fact that the mixing is done at a relatively high level. The ribbon and dynamic microphones both have a low impedance, and, for this reason, it is desirable to arrange the mixers so that they operate directly from the microphones. This system does away with the all preamplification and the microphone volume controls operate at a much lower level than is the case with condenser microphones. This accentuates the necessity for a noiseless mixer control.

The new Type 653 Volume Control has been designed with the following most important requirements in mind:

(1) The most noiseless electrical operation possible.
(2) Rigid mechanical construction to eliminate any possibilities of mechanical or electrical breakdown.
(3) Ease of installation and maintenance.
(4) Good frequency characteristic.
(5) Small physical size and low weight for portable installations.
(6) Low price.

The greatest cause of electrical noise is a minute potential generated between

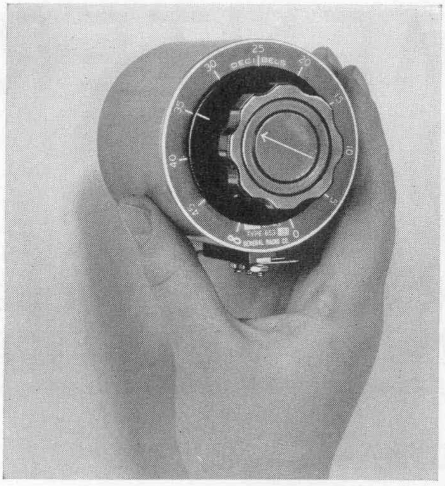


FIGURE 1. The new TYPE 653 Volume Controls give a smooth increase in attenuation from zero to cutoff at a noise level lower than the background-noise level in the quietest of amplifiers. They are interchangeable with other controls, having two mounting holes spaced 1½ inches apart

the contacts due to the fact that unlike metals in contact in air generate a small electrical potential. Another important source of noise is due to insecure connection between the switch arm and the contacts. The older TYPE 652 Volume Control is a slide-wire device in which an Advance metal slider operates across a resistance form wound with Advance wire. By using identical metals in this way, the contact noise was reduced to a very low value. Inherent, however, in slide-wire controls, is the difficulty in obtaining a sound contact between the slider and the resistance form. The new TYPE 653 Volume Control is a step-by-step device. A three-bladed switch slides over the contact points, making a firm and unvarying connection with each one. The best material available for such a switch is phosphor bronze. It would be ideal to make the switch contacts also of phosphor bronze, but this is not practicable, from the standpoint of wear, as the two metals do not operate well together mechanically. The contacts are made of a bronze alloy, which has been developed as a result of long experience in making precision decade boxes. The combination of these two metals results in no detectable contact potential, and the use of a well designed and stiff 3-leaf switch provides a firm mechanical contact. After thousands of operations, the contacts show no appreciable wear.

The resistance units are wound on cylindrical spools which are a part of the bakelite moulding carrying the contacts. This results in a rigid construction that will withstand any kind of rough usage which may be encountered in field work. Reference to Figure 3 will show the details of this mechanical construction. The whole assembly is interchangeable with the TYPE 652 Volume Control and other standard controls. The dial plate which carries the calibration in decibels serves as a drilling template for the mounting.

The circuit is a ladder network. Thirty-three steps are used and the attenuation is about 1.5 decibels per step. Actually, the switch bridges two contacts in its travel, approximately halving these steps. This increment is much smaller than can be detected by ear and it provides, therefore, a very smooth regulation of the volume. The ladder network is designed so that the attenuation is linear with angular rotation of the control knob for the first 29 contacts. Towards cutoff or infinite attenuation, the attenuation characteristic has an increasingly steeper slope, the attenuation per step rising above about

45 decibels. By this means a program can be faded out completely without introducing an abrupt cutoff.

The electrical circuit is such that the output impedance remains constant over the useful part of the scale. The output impedance remains at the nominal value up to infinite attenuation which is valuable, because if several mixers are set at zero output (that is, infinite attenuation) they will cause no impedance change in the mixer system.

The question of defining in quantitative units the noise level of a volume control is rather difficult. A pair of high-resistance head telephones bridged across a circuit operating at zero level (0.006 watts) will provide an extremely loud signal. A level of about 40 decibels below this will still give quite an appreciable signal in the phones. If, as often happens, an amplifier having a gain of 100 decibels precedes the circuit just mentioned, a noise having a level of −140 decibels will still be detectable in the headphones. For this reason a volume control which is used in low-level mixer circuits must have an inherent noise level less than 140 decibels.

The nature of the noise from a volume control depends upon the manner in which it is used. However, it is generally most objectionable when the control is turned very rapidly. By using great care in the design of a high-gain amplifier this noise can be amplified to a point that will just indicate on the most sensitive meters. The measurement is complicated by the fact that a carefully designed volume control will have a noise level so low that it is largely overridden by tube noise and extraneous pickup in the amplifier.

We can assume an arbitrary value for noise so detected which is known to be too low to interfere with voice-circuit operation even when worked in a dynamic microphone mixer at the micro-

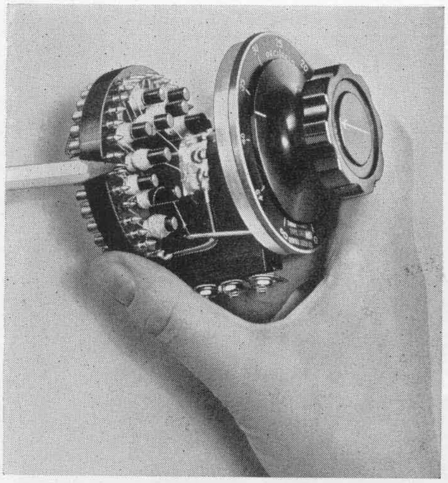


FIGURE 2. This unique construction guarantees ruggedness and a flat frequency characteristic for all settings over the entire attenuation range. Note that the shaft is insulated and that the frame is at ground potential

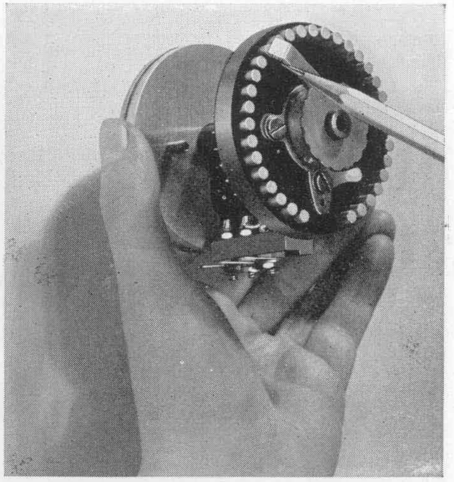


FIGURE 3. Noise has been practically eliminated from TYPE 653 Volume Controls through the use of a precision-type switch assembly and alloy contacts having a negligible contact potential with the switch blade

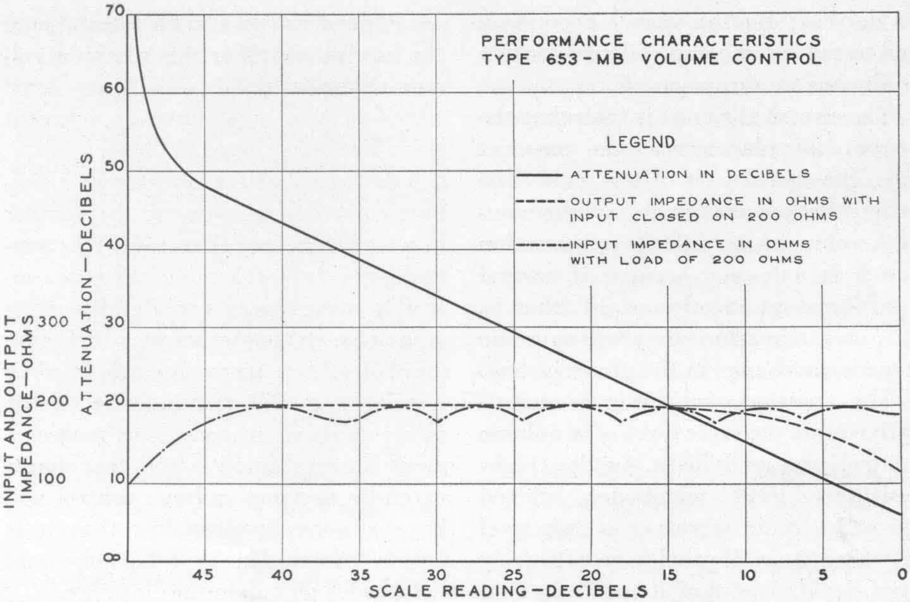


FIGURE 4. The ladder-type network used in TYPE 653 Volume Controls gives the linear attenuation characteristic and constant terminal impedances shown in the accompanying curves. The attenuation increases by increments of approximately 0.8 db per step so that the volume change is, for all practical purposes, continuous

phone level. Each General Radio TYPE 653 Volume Control is given such a test before it is shipped. If the noise indicated exceeds this arbitrary level, the control is rejected In this way, it will be known that the noise is below its in-

FIGURE 5. Inspecting TYPE 653 Volume Controls for noise. Every General Radio volume control is individually tested for noise, attenuation, and impedance, as well as the usual mechanical inspection

terference point so that when it is put in service no difficulties will arise.

In addition to this noise test the controls are also individually tested for the important mechanical and electrical characteristics.

The frequency characteristic is remarkably good. A series of experiments conducted in our laboratory indicates that a given control has no measurable change in its attenuation characteristic by comparison with a precision attenuation network for any frequency between 1000 and 10,000 cycles. The impedance also does not vary with frequency.—A. E. THIESSEN

TYPE 653 Volume Controls are made for use in 50-, 200-, and 500-ohm circuits as follows:

TYPE 653-MA	50 ohms
TYPE 653-MB	200 ohms
TYPE 653-MC	500 ohms

Price: $12.50, each

TRIAL OFFER—Send us your order for one or more of these new volume controls. Try them out for 10 days. Then, if you don't want to keep them, send them back in good condition and we'll either cancel the invoice or refund your money if you paid cash.

RECEIVER TESTING IN THE ULTRAHIGH-FREQUENCY BANDS

RECENT developments have indicated that the radio-frequency transmission band around 56 megacycles (5 meters) holds many interesting possibilities. The general usefulness in communication work of higher frequencies than those now commonly used has led many radio receiver designers into the investigation of the band above 30 megacycles.

To meet the need for an inexpensive instrument for measuring and testing the receivers at these ultrahigh frequencies, the General Radio Company has developed a new standard-signal generator embodying many interesting design features. It will operate at frequencies from 3 megacycles (100 meters) to as high as 100 megacycles (3 meters). Careful consideration of the requirements for a standard-signal generator to work in this band shows that part of the problems that are encountered in the design of the signal generator involve both the signal generator and the operation of the receiver under test when connected to it.

One difficulty, very serious at high frequencies and almost negligible at broadcast frequencies, is that the performance of a receiver depends, to a large extent, on the impedance of the antenna connected to its input terminals. In the more elaborate broadcast receivers, that influence is purposely minimized by careful design involving some sacrifice of sensitivity. Conditions are different in receivers using regenerative systems, at high frequencies in particular. It is for this reason that the TYPE 604-B Test-Signal Generator is arranged for coupling to the receiver under test by means of an antenna as well as the conventional shielded cable.

When using the one and one-half-foot low-inductance cable, particularly at frequencies above 50 megacycles, it must be kept in mind that the input voltage at the receiver may be different

FIGURE 1. A TYPE 604-B Test-Signal Generator showing the smallest of the three rod-type antennas. Voltage can also be delivered to the receiver under test by means of the cable, the jack for which is on the panel. The coil-mounting rack and the 13 coils supplied with the instrument can be stored in a compartment inside the cabinet

from the output voltage of the signal generator. Depending upon the impedance of the cable and the impedance of the receiver, the input voltage to the receiver may be higher or lower than the voltage at the signal generator. For any definite frequency, however, accurate comparative values can be obtained, as long as the receiver input impedance is unchanged.

It is to avoid many of these difficulties that a rod-type antenna is provided. By connecting any one of three antennas to a second output terminal in the cover of the generator, and by changing the distance between test-signal generator and receiver, a wide range of field-strength values can be obtained at the receiver. This method of testing has the advantage that the receiver can be used in connection with its proper antenna and, further, makes it possible to choose the best antenna for a receiver.

Figure 2 shows a functional schematic wiring diagram of the TYPE 604-B Test-Signal Generator, consisting essentially of the oscillating circuit, the attenuator, and the modulating system.

The oscillator is a 31-type tube, with anode voltages adjustable between 50 and 150 volts. The higher plate voltages are necessary only to obtain sufficient amplitude at the highest frequencies. The variable condenser of the tuned circuit has a maximum capacitance of 60 $\mu\mu$f. The capacitance in the circuit limits the frequency range of the coil to about 1 to 1.4 and to somewhat less at the highest frequency. The inductors are plug-in coils with plugs designed to have a small inductance. Thirteen coils are supplied to cover the entire range between 3 and 100 megacycles, space for the twelve spares being provided inside the cabinet.

A micro-ammeter is connected in series with the grid-leak of the radio-frequency oscillator. This is used for measuring the carrier amplitude. The actual control of amplitude depends upon the voltage applied to the plate and is adjusted by means of a potentiometer provided for this purpose. The method of amplitude indication depends upon the fact that the amount of rectified grid current will depend upon the grid swing of the tube, independent of frequency. The grid current is always set at one value, that corresponding to an attenuator input voltage of 10 volts.

It has been found by careful test that, over the entire range of frequencies, no error greater than 10% will be made. This error is inconsiderable when it is remembered that inaccuracies of this order of magnitude can be expected at frequencies as low as 25 megacycles when thermocouples are used.

The most complicated problem in the design of the TYPE 604-B Test-Signal Generator was the attenuator and output system. The best resistance attenuators operate quite satisfactorily up to perhaps 30 megacycles but, due to unavoidable inductance and capacitance of the resistors, they are not usable over the higher frequency ranges.

A capacitance attenuator was selected as the best available, because of its small frequency error and simplicity of construction. It is built up in two stages, the first of which reduces the voltage from 10 volts to 1 volt for application to the antenna terminal.

The second stage consists of two condensers, one adjustable by the output-control dial and the other fixed. The jack for the output cable is connected in parallel across the fixed condenser. The maximum voltage available at this jack is 10,000; minimum, 5 microvolts.

Capacitances of the order of 0.001 μf, such as are required for the attenuator, cannot be used without elaborate precautions. The variable-condenser-attenuator is operated by means of the large dial at the right of the panel. Through a rack and pinion-gear arrangement, the dial drives a conical plunger that moves in and out of a recessed plate which is the stator of the condenser. The distance between the plunger and the plate determines the effective capacitance of the system. The capacitance variation is such that the output voltage from the attenuator varies almost logarithmically with angular rotation of the dial control. The electrical parts of the attenuator are carried in a cast aluminum housing.

As mentioned before, two sets of output terminals are available on the TYPE 604-B Test-Signal Generator. The antenna terminal is set for a constant

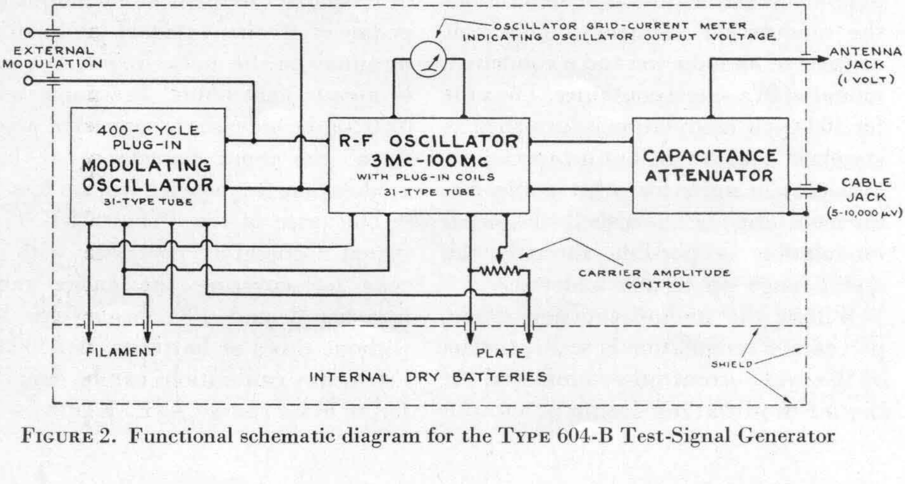


FIGURE 2. Functional schematic diagram for the TYPE 604-B Test-Signal Generator

value of 1 volt, and has an internal output impedance corresponding to a capacitance of about 90 $\mu\mu$f. This terminal is used to connect the plug-in vertical antenna. It is located almost in the center of the cabinet cover. In this way, the metal lining of the cabinet acts as a counterpoise and provides for a uniform field. The antenna is divided into three sections, the lengths of which are so chosen that the second and third ones give 10 times and 100 times the field strength obtained with the first. The total length for the three sections of the antenna is 15 inches.

The second output terminal is the jack located in the center of the panel. The internal output impedance corresponds to a capacitance of 200 $\mu\mu$f and is independent of attenuator setting.

The TYPE 604-B Test-Signal Generator is carefully shielded and the stray field is so small that it will not affect the accuracy of any measurement on a receiver within the output voltage range of the instrument.

Internal and external modulation are provided for the TYPE 604-B Test-Signal Generator. The internal modulation circuit consists of a 31-type tube and a plug-in oscillator unit that determines the modulation frequency. This unit consists of an inductor and a condenser mounted in a single container. The unit for 400-cycle modulation is furnished as standard equipment, but on special order, plug-in units for other audio frequencies can be furnished. External modulation is possible through the audio range up to 200 kilocycles.

Within the audio-frequency range, percentage modulation is set by means of the grid-current micro-ammeter. At higher modulating frequencies, the

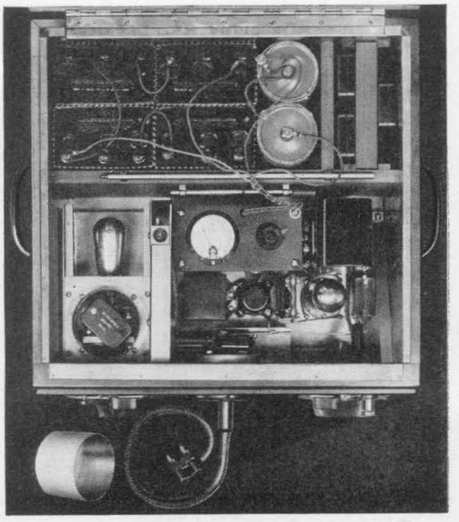


FIGURE 3. All batteries for the TYPE 604-B Test-Signal Generator can be mounted inside the cabinet. Note the capacitance attenuator, the antenna output jack, and the provision for coil storage. The cap-type shield on the table in front of the instrument was removed from the carrier-frequency coil in the left-hand corner of the cabinet

voltage applied to the external modulation terminals is to be set to a value corresponding to the calibration chart furnished with every instrument (5 volts is an average). In both cases, the modulation will be 30%. The modulation frequency should be less than 1.5% of the carrier frequency. The input impedance of the external modulation terminals in the audio-frequency range is about 5000 ohms. Inasmuch as a 0.002-$\mu\mu$f condenser is connected across them, the input impedance at high modulation frequencies will be less.

The price of the TYPE 604-B Test-Signal Generator, complete with 13 coils for covering the entire range between 3 and 100 megacycles but without tubes or batteries, is $300.00. Frequency calibrations can be supplied for an extra charge. — E. KARPLUS

THE EDGERTON STROBOSCOPE AT THE NEW YORK AUTO SHOW

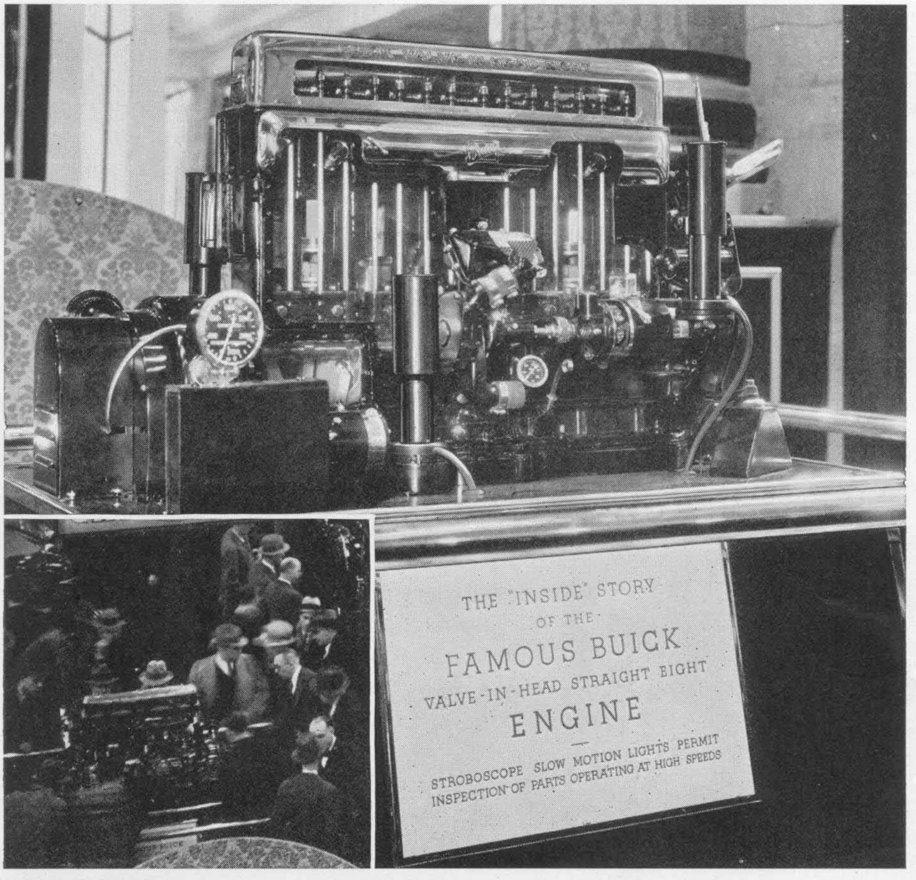


PHOTO BY WIDE WORLD

THE General Motors Corporation capitalized on the interest of every automobile buyer in the operating mechanism of his engine by demonstrating a cutaway Buick engine in stroboscopic slow motion. The demonstration was part of the General Motors exhibit at the New York Auto Show and, later, at the Chicago Show. The stroboscopic illumination was supplied by four Edgerton Stroboscopes mounted at strategic points around the engine block. The four stroboscopes gave sufficient illumination so that there was no difficulty in seeing the stroboscopic action in the brilliantly lighted exhibition hall.

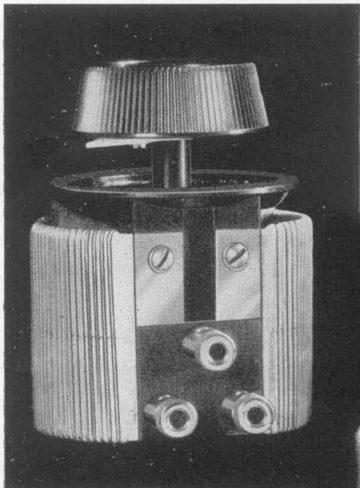
The engine was driven by an adjustable-speed electric motor, and the contactor mechanism, by means of which the timing of the stroboscope flashes was effected, was an integral part of the drive assembly. This exhibit, we are informed, will be shown in many of the larger cities, probably as part of a local Buick distributor's demonstration rather than in the public auto shows, the season for which is already well advanced.

TWO NEW RHEOSTAT-POTENTIOMETERS FOR HEAVY DUTY SERVICE

Two new series of rheostat-potentiometer units which combine the advantages of earlier models with a high power dissipation rating are now available. The smaller of the two, Type 333, has a power rating of 100 watts; the larger, Type 533, has a rating of 500 watts.

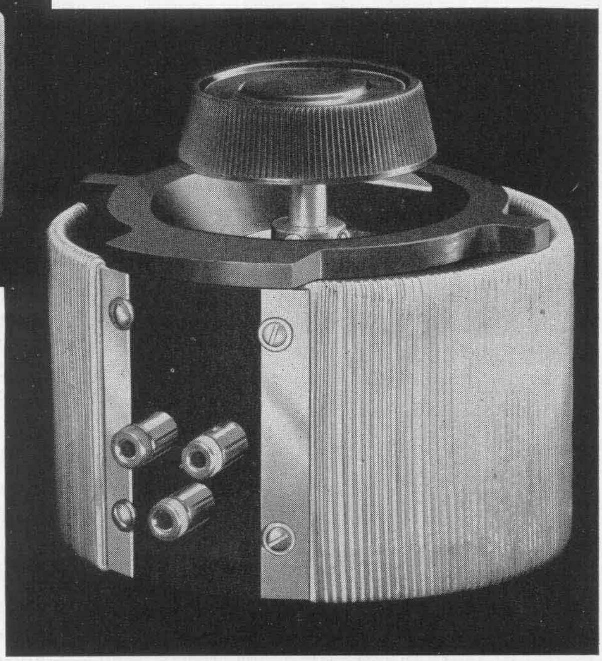
Both units are similar in general detail of design to the six other General Radio rheostat-potentiometer series. They can be mounted either behind the panel or on the table top, and each is fitted with three terminals so that it can be used as a rheostat for either direction of rotation or as a voltage divider.

The resistance wire is wound on an asbestos-covered aluminum form, thus assuring a maximum of heat radiation



The two new heavy-duty rheostat-potentiometers assembled for panel mounting. By loosening two collars and pushing through the shaft, the knob may be mounted on the other end for table mounting.

Left: Type 333-A, 100 watts.



Right: Type 533-A, 250 watts

and the elimination of hot spots when only a portion of the resistor is in use. Supporting frames are moulded from a bakelite compound having the ability to withstand operating temperatures well in excess of requirements.

The TYPE 333 Rheostat-Potentiometers are identical in over-all dimensions with the TYPE 371 and TYPE 471 Rheostat-Potentiometers. They have four times the power rating of the former.

The TYPE 533 Rheostat-Potentiometers are 5$\frac{3}{16}$ inches in diameter and 3½ inches in height, exclusive of the knob which adds $\frac{13}{16}$ inch to the over-all height. The shaft is of steel, and the contact arm is especially designed for low contact resistance so that troubles due to overheating at the contact have been definitely eliminated.

These two units will find their principal application in the control of voltage and current in power circuits where their convenient mounting, flexibility, and low cost will make them desirable where it has formerly been necessary to use the tubular type of rheostat.

Each unit is fitted with three jack-top binding posts arranged on the standard ¾-inch spacing, a decided convenience in temporary set-ups by students and workers in research laboratories.

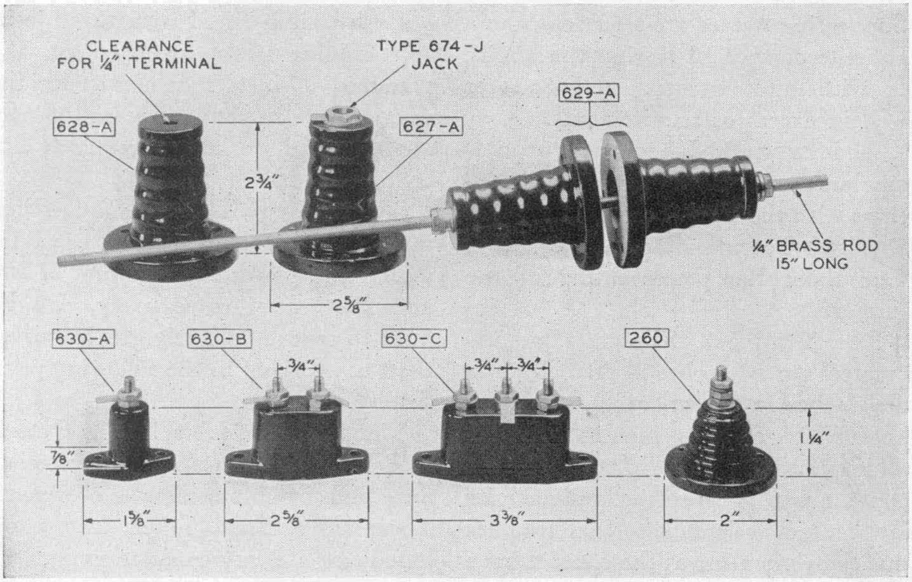
Seven sizes of each model are carried in stock but other resistance values within the power rating limits of 100 and 250 watts, respectively, can be built to order at slightly greater prices than those given in the following price list.

The following table lists the stock models and specifies the total resistance and maximum allowable current. These current and power ratings are based on a 100-degree Centigrade temperature rise where the unit is operated in the open without forced air circulation. Where the unit is to be enclosed, an allowance should be made for the resulting increase in ambient temperature.

SPECIFICATIONS

Type	*Total Resistance*	*Maximum Current*	*Code Word*	*Price*
333-A	1 ohm	10.0 a	VALOR	$4.00
333-A	3 ohms	5.8 a	VAPID	4.00
333-A	10 "	3.2 a	VENUS	4.00
333-A	30 "	1.9 a	VIGIL	4.00
333-A	100 "	1.0 a	VIGOR	4.00
333-A	300 "	0.6 a	VILLA	4.00
333-A	600 "	0.4 a	VIPER	4.00
533-A	1 ohm	15.8 a	MOLAR	6.00
533-A	3 ohms	9.1 a	MONAD	6.00
533-A	10 "	5.0 a	MORAL	6.00
533-A	30 "	2.9 a	MOTTO	6.00
533-A	100 "	1.6 a	MUGGY	6.00
533-A	300 "	0.9 a	MUMMY	6.00
533-A	600 "	0.6 a	MUSTY	6.00

NEW PORCELAIN INSULATOR ASSEMBLIES



Seven new General Radio insulator assemblies for amateur and laboratory use. Each is made of the best grade of glazed porcelain selected for great mechanical strength and a minimum of moisture absorption

SPECIFICATIONS

Type	*Description*	*Code Word*	*Price*
628-A	Insulator	MEDAL	$0.30
627-A	Jack-Top Insulator	MAYOR	.60
629-A	Lead-In Assembly	MERCY	.90
630-A	Single-Terminal Stand-Off Insulator	EDUCE	.10
630-B	Double-Terminal Stand-Off Insulator	EGRET	.20
630-C	Triple-Terminal Stand-Off Insulator	EJECT	.25
260	Wall Insulator	CONIC	.20

All insulator assemblies are supplied with wood screws and the lead washers so necessary to prevent breakage

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

MIXER CIRCUITS THAT WORK

A MIXER circuit is an arrangement of volume controls for combining into one program, in any desired proportions, program elements on several channels. All of the multiple-microphone, transition, and fading effects, which contribute so much to program continuity, are obtained with mixer circuits.

For instance, separate microphones may be used for a soloist and for the accompanying orchestra, and the outputs combined to form a balanced whole. Similarly, separate microphones may be used to pick up the various sections of a large orchestra. Since the volume on each microphone channel can be regulated independently of the others, a method of controlling the balance between the various sections is obtained which, unlike the usual "tone control," does not impair the quality of the individual instruments. A mixer is also used to "fade down" a musical transmission so that announcements or advertising talks may be superimposed. All of these effects contribute a degree of smoothness to a broadcast program or recording which would otherwise be impossible.

CHOICE OF CIRCUIT

The design of a high-quality mixer is quite simple. The actual choice of a circuit is determined mainly by the number of channels needed and by the impedance requirements of the system. If the mixer is to be used with equipment that is balanced to ground, this factor must also be taken into consideration. Several representative types of mixer circuits are shown in Figures I and II.

NUMBER OF CHANNELS ▲ ▲ ▲ In designing a mixer, it is advisable to allow a separate channel for each available microphone, line, or transcription pickup, thus making it unnecessary to patch circuits while a program is in progress. The cost of an extra volume control is negligible compared with the consequences of even a single program interruption.

IMPEDANCE RELATIONS ▲ ▲ ▲ The volume control used on each channel should have an impedance that matches approximately the equipment with which that channel is to

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The next issue will be April-May — In the mails May 15

be used. The three standard impedance ratings (50, 200, and 500 ohms) take care of practically all requirements. It is advisable, although not always necessary (see Figure IIa), to have all of the channel controls alike and to use impedance-matching transformers to couple the mixer to any equipment having a different value of impedance.

When the channel controls are not all of the same impedance, the circuit should be so designed that, as in Figure IIa, the attenuation is approximately equal on all channels.

The mixers shown in Figures I and II have all proven very satisfactory. In the four-channel series-parallel type (Figure IIb), the output impedance of the mixer is equal to the input impedance of each channel. In the series-type mixer (Figures Ia, IIb, and IIc), the output impedance is equal to the sum of the channel impedances, which is frequently an advantage where low-impedance channels are used, since the input impedance of most speech amplifiers is 200 or 500 ohms.

In a series-type mixer of more than two channels, some channels must be above ground potential. Usually this is of no consequence if the equipment connected to these channels is not grounded and the leads are reasonably short. If any noise pickup or crosstalk due to this condition is encountered, however, it may be remedied by using impedance-matching or circuit-isolation transformers on these channels.

Figures IIb and IIc show suggested uses for the above-ground channels in a series mixer. In these diagrams, channel #1 is equipped with a 500-ohm (or 125-ohm) transformer for coupling to the usual 500-ohm transcription equipment or program line. In Figure IIb a fader is also shown for transferring from one pickup to another. In Figure IIc, channel #4 is also equipped with a 500-ohm transformer for coupling to the usual program transmission lines.

TRANSFORMERS

In the above-mentioned cases the transformers are used both for circuit isolation and for impedance-matching. Transformers may, of course, be used equally well with the channels at ground potential in all of the mixers shown but are not necessary except for impedance-matching, balancing to ground, or keeping direct current out of the mixer.

Figure Id shows how a Type 585-C Transformer may be connected to give any one of four impedance ratios. It may be operated with either winding used as the primary, so this one transformer will perform most of the impedance-matching functions usually needed in mixers. It can also be used for circuit isolation purposes when coupling circuits at ground potential to circuits above ground potential and for coupling to 500- or 200-ohm balanced-to-ground circuits.

For isolating two 500-ohm circuits, the Type 585-R Transformer should be used. This is a 500-to-500-ohm transformer with both windings center-tapped (for balance to ground, if desired) and with an electrostatic shield between the windings. Similar General Radio transformers for operation at other impedances can also be supplied upon order.

MASTER GAIN CONTROLS

Although a master control is not an absolute necessity, it is a decided convenience where the monitoring operator must manage more than two channels and where considerable ranges of gain must be covered. General Radio Type 653 Volume Controls are recommended for mixers in which balance of the output to ground is unimportant. Balanced output circuits require a suitable isolation transformer or a Type 552-H Volume Control, balanced-H-type.

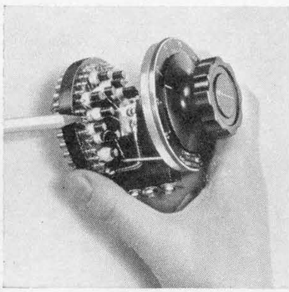
CHOOSING VOLUME CONTROLS

In any well-designed mixer the volume on each channel can be adjusted without altering that on the other channels. This is most easily accomplished by using volume controls of the constant-impedance type. Minor changes in impedance will have no noticeable effects upon the operation of the mixer. It is also extremely advisable that the controls be so arranged that a low-attenuation resistance network is still in the circuit when the control is turned to the minimum-loss position. This eliminates the possibility of the mixer opening up if any of the associated equipment is disconnected while its channel control is in the ON position. Of course each control should be individually shielded to eliminate crosstalk and noise pickup within the mixer itself, and should cut off completely in the OFF position.

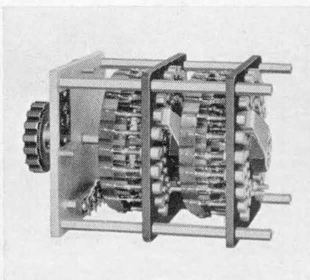
Because a mixer is followed by considerable amounts of amplification, only quiet volume controls can be used. The actual quantitative measurement of noise becomes increasingly more difficult as the noise level is reduced and actual figures should be liberally discounted. The determining factor in the selection of any volume control should be its actual performance in service and not mere claims of the manufacturer.

All of these features are combined in the General Radio Type 653 Volume Controls. Their impedance is practically constant with setting, their "cutoff" is practically complete, their noise level is below the tube noise level in the best broadcast amplifiers, and they are constructed for long life. We recommend them for every mixer requirement. —H. H. Scott

MIXER ACCESSORIES



Volume Controls
Type 653-MA, 50 ohms
Type 653-MB, 200 ohms
Type 653-MC, 500 ohms
Price: $12.50



Master Controls
Type 552-HB, 200 ohms
Type 552-HC, 500 ohms
Price: $48.00

Transformers
Type 585-C } See "Transformers" Page 2
Type 585-R
Price: $7.50

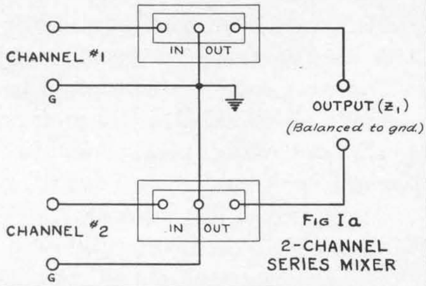


Fig Ia
2-CHANNEL SERIES MIXER

TYPE OF CONTROLS USED	INPUT IMPEDANCE OF EACH CHANNEL	OUTPUT IMPEDANCE OF MIXER (Z_1)
653-MA	50 Ω	100 Ω
653-MB	200 Ω	400 Ω
653-MC	500 Ω	1000 Ω

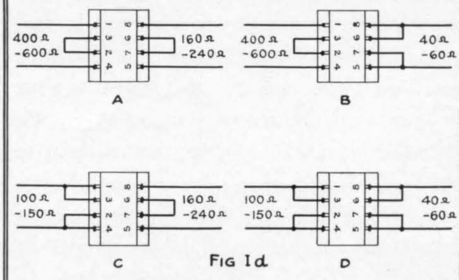


Fig Id

CONNECTIONS FOR 585-C IMPEDANCE-MATCHING TRANSFORMER

Note: Transformer may be operated in either direction, that is, either winding may be used as primary

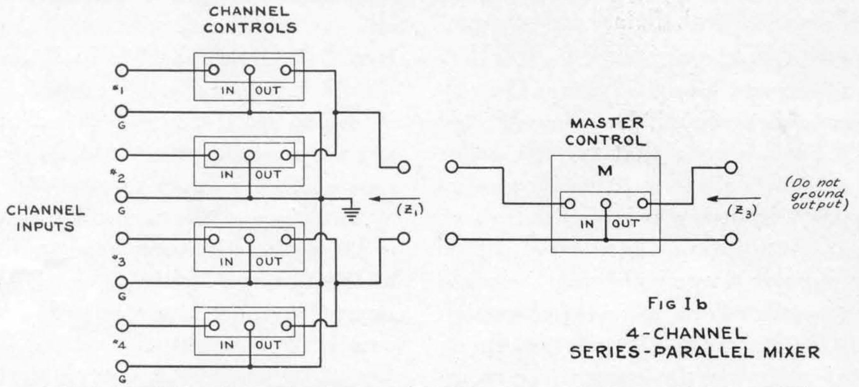


Fig Ib
4-CHANNEL SERIES-PARALLEL MIXER

TYPE OF CONTROLS ON CHANNELS	INPUT IMPEDANCE OF EACH CHANNEL	OUTPUT IMPEDANCE OF MIXER (Z_1)	TYPE OF CONTROL USED AS MASTER (M)	OUTPUT IMPEDANCE WITH MASTER (Z_3)
653-MA	50 Ω	50 Ω	653-MA	50 Ω
653-MB	200 Ω	200 Ω	653-MB	200 Ω
653-MC	500 Ω	500 Ω	653-MC	500 Ω

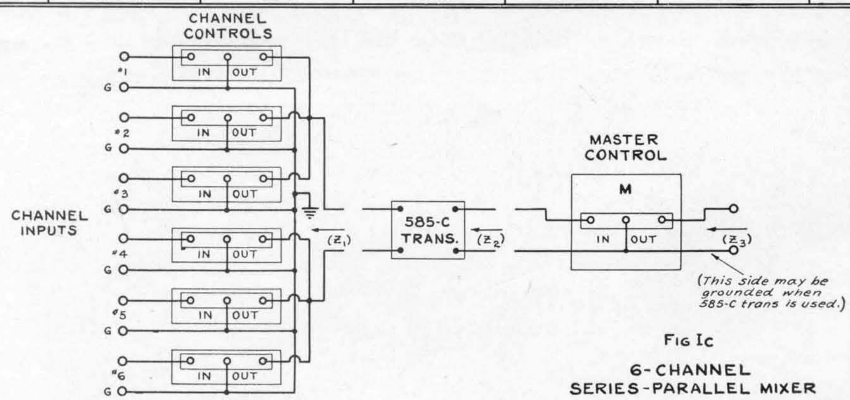


Fig Ic
6-CHANNEL SERIES-PARALLEL MIXER

TYPE OF CONTROLS ON CHANNEL	INPUT IMPEDANCE OF EACH CHANNEL	OUTPUT IMPEDANCE OF MIXER (Z_1)	585-C CONNECTIONS (SEE FIG Id)	Z_2	TYPE OF CONTROL USED AS MASTER (M)	OUTPUT IMPEDANCE WITH MASTER (Z_3)
653-MA	50 Ω	33 Ω	B (1-4 as SEC.)	500 Ω	653-MC	500 Ω
653-MB	200 Ω	123 Ω	C	200 Ω	653-MB	200 Ω
653-MC	500 Ω	333 Ω	NOT USED	——	653-MB	200 Ω

FIGURE I CONVENTIONAL MIXER CIRCUITS

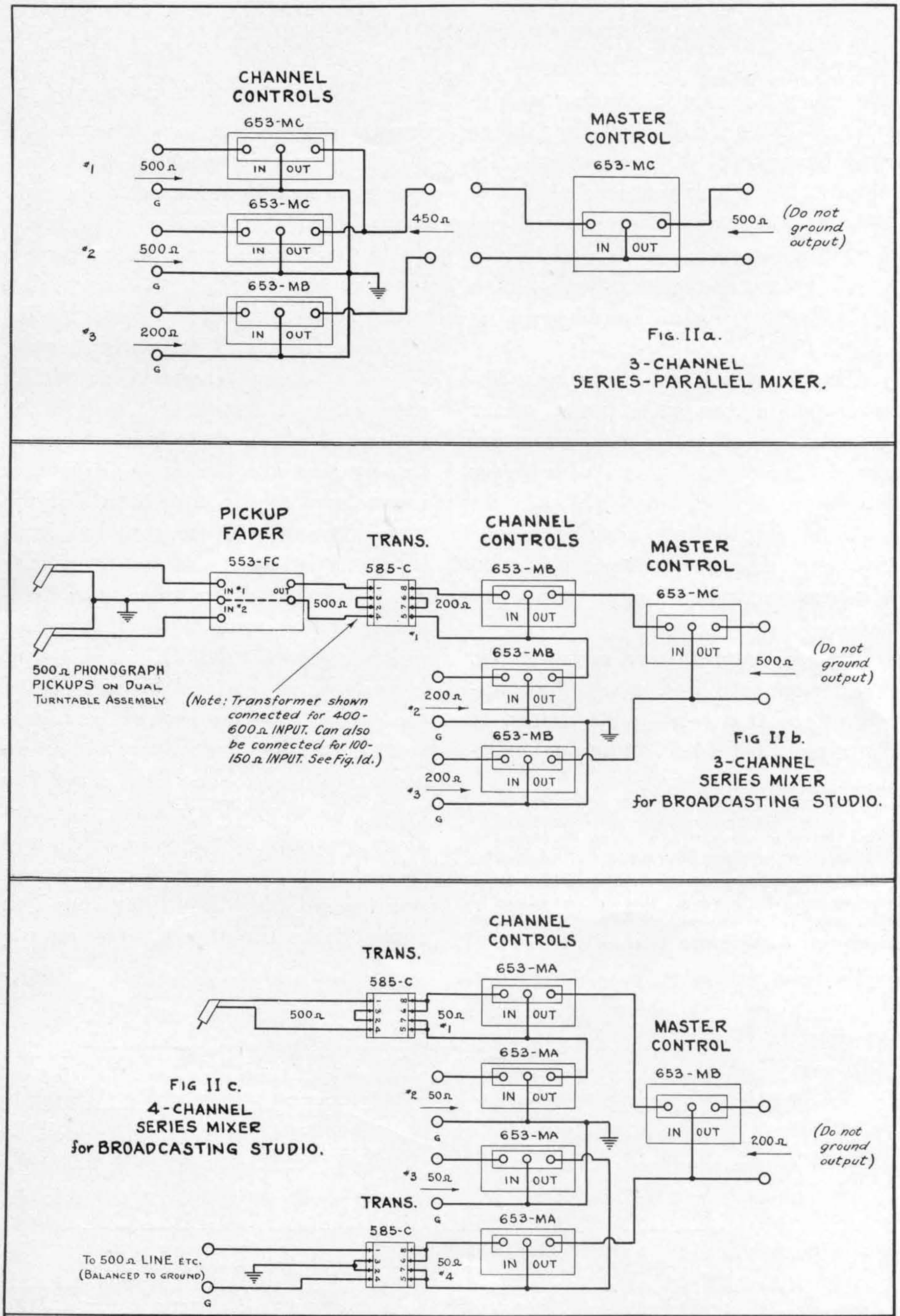


FIGURE II SPECIAL MIXER CIRCUITS

COMMERCIAL NOISE MEASUREMENT

INEXPENSIVE noise-measuring equipment is needed by machinery manufacturers to ascertain the amount of disturbance caused by their products and by acoustical engineers and manufacturers of sound-proofing materials to demonstrate the effectiveness of sound-proofing installations.

The General Radio Company has developed a low-priced noise meter to meet exactly these commercial needs. The TYPE 559-A Noise Meter contains in one unit all of the required equipment and compares favorably in performance with instruments costing many times as much.

Figures 1 and 2 show, respectively, the appearance and method of operation of this new noise meter. It contains a special dynamic noise-pickup unit* which is similar in construction to the usual permanent-magnet dynamic speaker and which is considerably more sensitive and rugged than the usual microphone.

An impedance matching transformer associated with the noise-pickup steps up the impedance to 600 ohms. Normally this transformer operates into a frequency-weighting network and transformer, across the output of which there is a calibrated step-by-step attenuator to adjust the input level to the amplifier. For the measurement of extremely high levels, a second attenuator of the T-pad constant-impedance type is inserted at the input of the frequency-weighting network. This additional attenuator is snapped in and out of the circuit by means of a toggle switch on the panel. Since all attenuators precede the first amplifier tube, the amplifier always operates at approximately the same level, and accordingly no error is introduced due to possible non-linearity. The output from the amplifier actuates a

*It is not claimed, of course, that an inexpensive pickup device of this sort is equal in all respects to a high-priced microphone designed for broadcasting and recording. Under the acoustic conditions generally encountered, however, standing waves, reflections, etc., render comparatively negligible any small irregularities in the pickup characteristic.

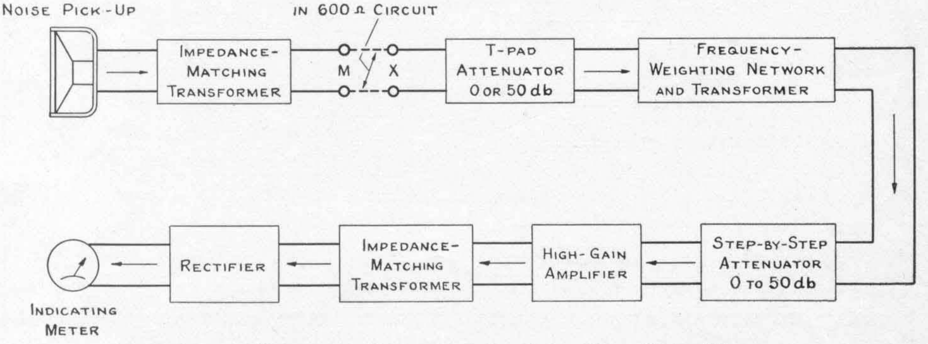


FIGURE 1. Schematic diagram of the TYPE 559-A Noise Meter

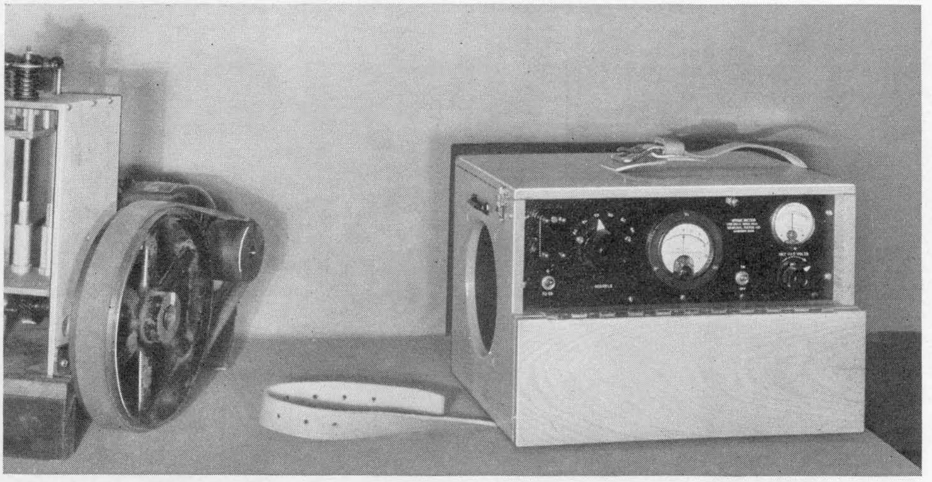


FIGURE 2. The TYPE 559-A Noise Meter is a complete, portable instrument containing the pickup unit and space for all batteries. Note the leather carrying strap

rectifier-type meter on the panel of the instrument.

The noise meter is calibrated directly in decibels above the normal threshold of hearing at 1000 cycles, and covers the range from +30 to +140 decibels. Expressed in decibels above one millibar, which is also frequently used as a reference level, this represents the range between +23 and +133 decibels.

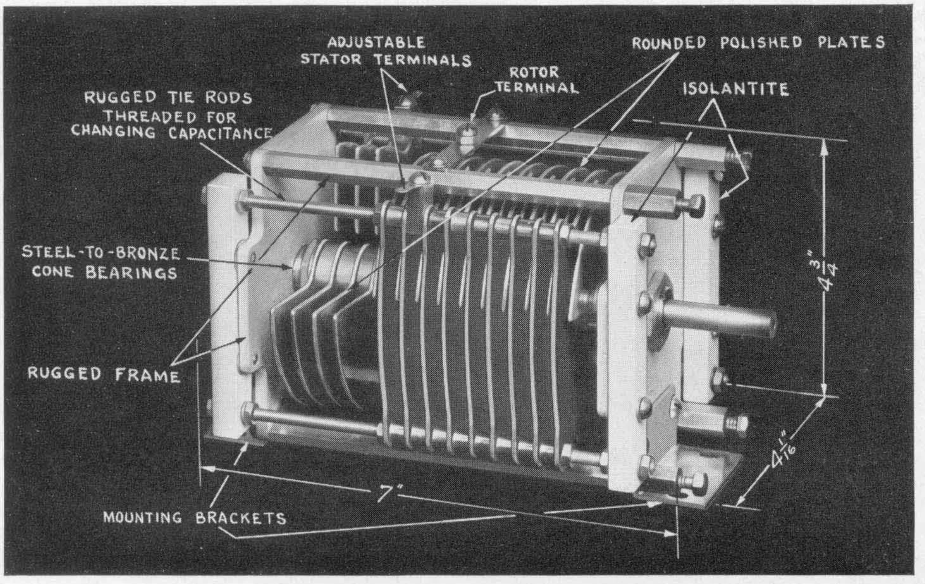
The frequency response characteristic of the noise meter amplifier, including the frequency-weighting network, closely resembles the response of the human ear. When the self-contained dynamic pickup is used, the over-all characteristic, including the pickup, follows the same curve quite closely through the important part of the noise spectrum. If a high-quality condenser microphone with a suitable pre-amplifier is used with the noise meter, the net characteristic will be an almost ideal approximation of the normal ear characteristic. Such precision is, however, seldom required.

Provision is made on the noise meter panel so that by removing a 4-terminal plug, the 600-ohm input circuit may be opened, allowing the connection of an external microphone or the insertion of filters for reducing or suppressing certain frequencies.

The TYPE 559-A Noise Meter is mounted in a compact, oak, carrying case which also accommodates the dynamic noise-pickup unit and all tubes and batteries. It is merely necessary to set the instrument in any desired location, turn on the switch and read the noise level directly from the panel meter and attenuator. —H. H. SCOTT

TYPE 559-A Noise Meter, with tubes but without batteries, $190.00. Weight, 37 lbs. without batteries. Dimensions, $16\frac{5}{8}$ x $10\frac{7}{8}$ x 12 ins. over-all.

A HIGH-VOLTAGE TWO-SECTION CONDENSER



THE TYPE 639-A Variable Air Condenser has the following features:

The capacitances *per section* are readily adjusted from 25 $\mu\mu f$ to 305 $\mu\mu f$. Used as a single-section condenser the maximum capacitance is 330 $\mu\mu f$ and the minimum is 25 $\mu\mu f$.

It is conservatively rated at 3500 volts, direct current.

Its low losses are due to the use of:

1. thick aluminum plates with all edges rounded and highly polished, minimizing corona loss
2. minimum amount of dielectric placed in a weak field
3. large rotor and stator supports and spacers (resulting in low contact resistance)
4. long conical bearings
5. heavy stator terminals, positions of which are adjustable to insure uniform current distribution.

Mechanical rigidity is secured through the use of heavy aluminum end plates, large hexagonal frame supports and adequate stator rods. The shaft is of 3/8-inch steel.

For panel mounting it is supported at four points and requires no sub panel. For shelf or bread-board mounting, two large angle brackets are supplied.

Price: TYPE 639-A Variable Air Condenser, $15.00.

GENERAL RADIO COMPANY
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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

THE CONVENIENT MEASUREMENT OF *C*, *R*, AND *L*

THE important considerations in the large majority of bridge measurements made in the average experimental laboratory are the ease and speed of making the readings, and the ability to measure any values of resistance, inductance, or capacitance, as they may exist in any piece of equipment. A completely satisfactory bridge should immediately indicate the answer to such questions as the following:

Is the maximum inductance of this variable inductor at least 5 mh, its minimum inductance 130 μh, and its direct-current resistance less than 4 Ω?[1]

Has this choke coil at least 20 h inductance and an energy factor Q of at least 20?

Has this tuning condenser a maximum capacitance of 250 μμf and a 20 to 1 range?

Has this filter condenser at least 4 μf capacitance and a power factor of only 0.5%?

Is the resistance of this rheostat 200 kΩ?

Is the zero resistance of this decade-resistance box only 5 mΩ?

The TYPE 650-A Impedance Bridge will furnish the answers to all these questions and many others. It will measure direct-current resistance over 9 decades from 1 mΩ to 1 MΩ, inductance over 8 decades from 1 μh to 100 h, with an energy factor ($Q = \frac{\omega L}{R}$) up to 1000, capacitance over 8 decades from 1 μμf to 100 μf, with a dissipation factor ($D = R\omega C$) up to unity.[2]

These results are read directly from dials having approximately logarithmic scales similar to those used on slide rules. The position of the decimal point and the proper electrical unit are indicated by the positions of two selector switches. Thus the CRL multiplier switch in Figure 1 points to a combined multiplying factor and electrical unit of 1 μf so that the indicated ca-

[1] These are the standard abbreviations of the Institute of Radio Engineers. Note that 1 mΩ is 0.001 ohm and that 1 MΩ is 1,000,000 ohms.

[2] The fact that this bridge is capable of measuring a condenser with large energy losses makes it necessary to distinguish between its dissipation factor $\frac{R}{X}$ and power factor $\frac{R}{Z}$. The two are equivalent when the losses are low. Since the bridge measures $R\omega C$ directly, the term dissipation factor has been used, even though the two terms are, for most condensers, synonymous.

pacitance as shown on the CRL dial is 2.67 μf, because the D-Q multiplier switch has been set on C for the measurement of capacitance. It also shows that the DQ dial is to be read for dissipation factor D with a multiplying factor of 0.1 yielding 0.26.

If the condenser had a smaller dissipation factor, this D-Q multiplier switch would have been set for the D dial with a multiplying factor of 0.01. Thus the D dial, as shown in Figure 1, indicates a dissipation factor of 0.0196 or a power factor of 1.96%.

For the measurement of pure resistance the D-Q multiplier switch would be set at R so that the CRL dial indicates a resistance of 2.67 Ω.

For the measurement of inductance the D-Q multiplier switch would be set at L and the CRL dial indicates 2.67 mh. Using the DQ dial the multiplier is 1 and the energy factor Q as shown in Figure 1 is 2.6. Had the coil under measurement been a large iron-core choke coil, the CRL multiplier switch might have been set at the 10 h point, thus indicating 26.7 h. Then the D-Q multiplier switch would have been set to indicate the Q dial with a multiplier of 100 and an energy factor Q of 41 as read on the Q dial.

The ease of balancing the bridge depends on the use of the logarithmically tapered rheostats and the two multiplier switches. To illustrate this, take first the measurement of direct-current resistance.

With the unknown resistor connected to the R terminals, the D-Q multiplier switch is set at R, the GENERATOR switch at DC, and the DETECTOR switch at SHUNTED GALV. The galvanometer immediately deflects, indicating by the direction of its deflection which way the CRL multiplier switch should be turned to obtain approximate balance. The CRL dial is then turned for exact balance, having thrown the DETECTOR switch to the GALV. position.

Because the calibration of the CRL dial extends to 0, the bridge can be balanced for a number of different settings of the CRL multiplier switch. This is very helpful in ascertaining the approximate value of a resistor. Obviously greatest accuracy of reading is obtained when the balance point on the CRL dial is within the main decade which occupies three-quarters of its scale length.

An inductor or condenser is measured by connecting it to the CL terminals. The GENERATOR switch is set at 1 KC. and the DETECTOR switch at EXT, head telephones being connected to the EXTERNAL DETECTOR terminals. The D-Q multiplier switch is set on L or C as the case demands, pointing to the DQ dial. The CRL dial is swept rapidly over its range to indicate the direction of balance. The CRL multiplier switch is then moved in the direction indicated and balance obtained on the CRL dial. The DQ dial is then turned for balance. From its setting the desirability of using the D dial or the necessity of using the Q dial will be indicated.

The reactance standards are mica condensers having all the excellent characteristics of the TYPE 505 Condensers described in the *Experimenter* for January.

The bridge circuit used for measuring condensers is the regular capacitance bridge having pure resistances for its ratio arms. Maxwell's bridge is used for inductors, whose energy factors Q are less than 10. Above this value Hay's bridge is used. The interdependence of the two balances of these last two

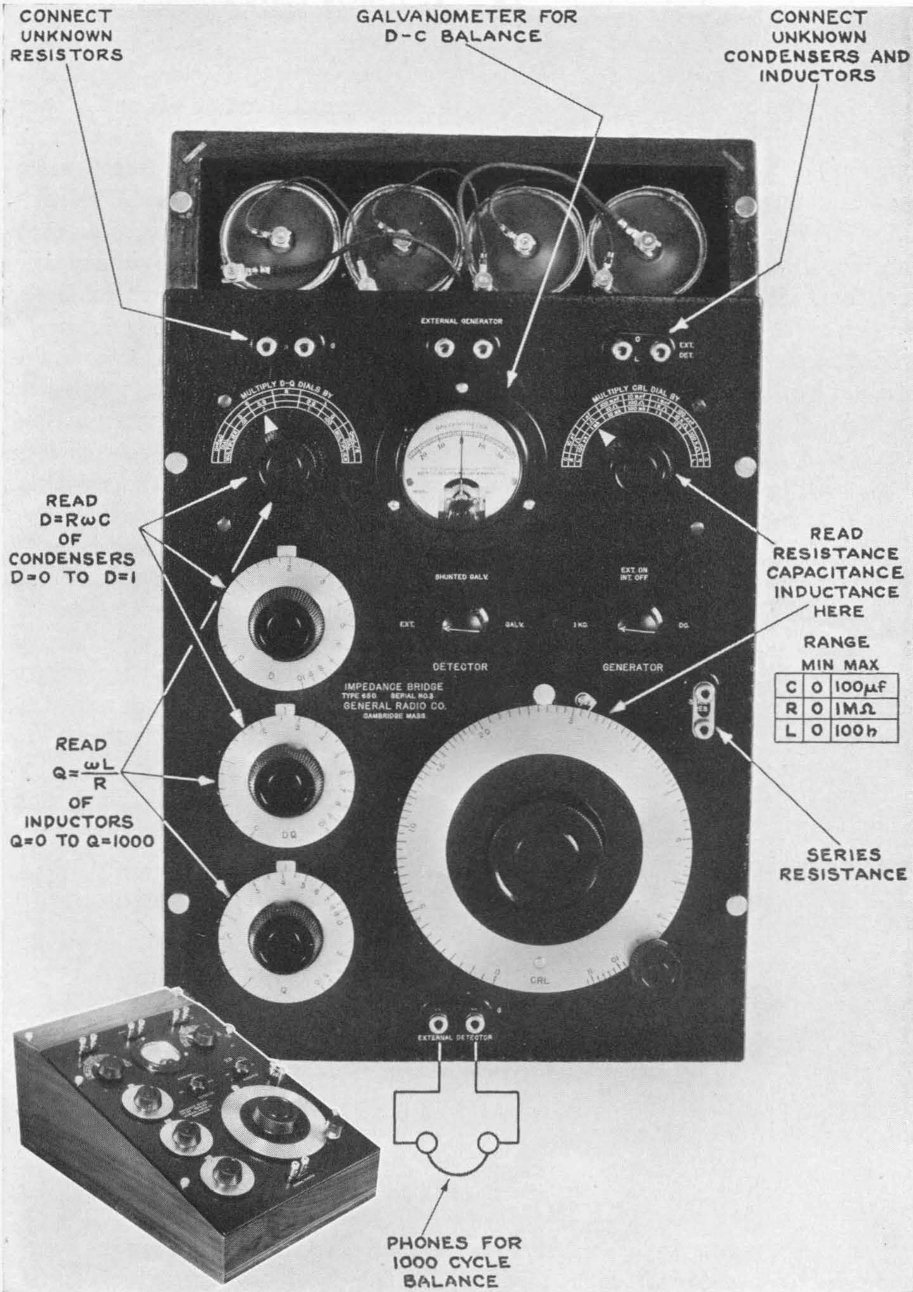


FIGURE 1. This photograph of the panel emphasizes the simplicity and wide range of the impedance bridge. In the corner at the left is a side view of the instrument

bridge circuits cannot, of course, be prevented, but the use of the logarithmic rheostats for balancing makes it very easy to follow the drift of the balance points.

The accuracy of calibration of the CRL dial is 1% over its main decade. It may be set to 0.2% or a single wire for most settings of the CRL switch. The accuracy of readings for resistance and capacitance is 1%, for inductances 2%, for the middle decades. The accuracy falls off at small values because the smallest measurable quantities are 1 mΩ, 1 μμf, and 1 μh, respectively. Zero readings are approximately 10 mΩ, 4 μμf, and 0.1 μh, respectively. The accuracy falls off at the large values, becoming 5% for resistance and capacitance and 10% for inductance. The accuracy of calibration of the DQ dials is 10%. The accuracy of readings for dissipation factor and energy factor is either 20% or 0.005, whichever is the larger.

The power for the bridge is drawn from four No. 6 dry cells mounted at the back of the cabinet. The liberal size of these batteries assures a very long life. External batteries of higher voltage may be used to increase the sensitivity of the bridge for the measurement of the highest resistances. The internal batteries operate a microphone hummer for the production of the 1-kc current. The capacitance of this hummer to ground is small and has been allowed for in the bridge calibration.

An external generator may be used, though its capacitance to ground may introduce considerable error. Subject to this limitation, the frequency may be varied over a wide range from a few cycles to 10 kc. The reading of the CRL dial is independent of frequency. The readings of the D and DQ dials must be multiplied by the ratio of the frequency used to 1 kc to give the correct values of dissipation and energy factors, while the reading of the Q dial must be divided by this ratio. For frequencies other than 1 kc the ranges of the DQ dials are altered so that they will no longer overlap. Additional resistance may be inserted by opening the SERIES RES. terminals. The TYPE 526 Rheostats, described on page 7, are quite satisfactory for this use.

—ROBERT F. FIELD

SPECIFICATIONS

Dimensions: Panel, (width) 12 x (depth) 16 inches. Entire instrument, (width) 12 x (depth) 23 x 9 inches, over-all.

Net Weight: 22 pounds. Batteries, 8¼ pounds additional.

Code Word: BEAST.

Price: $175.00, without batteries.

THE SKELETON-TYPE IMPEDANCE BRIDGE

THERE are many individual bridge measurements for which the wide range of the TYPE 650-A Impedance Bridge is unnecessary, while its ease and speed of making readings are essential. Examples of these uses are the following:

Limit bridges for resistance, inductance, and capacitance, whose ranges may be changed easily, though not instantaneously. Bridges for the individual experimenter who is willing to forego the convenience of multiple switching and to manually interconnect the various arms of the bridge for the sake of a considerable reduction in price.

Bridges for schools and colleges with which the student may make up the various bridge circuits.

The Type 625-A Bridge is eminently adapted to this type of measurement. It consists of a skeleton bridge circuit, in which one arm contains a direct-reading logarithmic rheostat and the other three arms are brought out to pairs of terminals. A 1-kc microphone hummer, batteries, and their associated switches are also connected in circuit. Type 500 Resistors may be used as ratio arms, Type 505 Condensers as reactance standards, and Type 526 Rheostats as added resistors to indicate energy factor Q and dissipation factor D. These resistors and condensers are plugged directly into the bridge terminals. The rheostats can be connected through Type 274 Plugs and cables.

The panel arrangement is shown in Figure 1. The wiring diagram is engraved in the lower left corner. The slide on which the ratio arms and standards may be stored is opened for inspection. Appropriate values of these units are 10,000 Ω, 1000 Ω, 100 Ω, 1 μf, and 0.01 μf. With these units resistance may be measured over 6 decades from 1 Ω to 1 MΩ, inductance over 6 decades from 100 μh to 100 h, capacitance over 6 decades from 100 μμf to 100 μf. By the addition of a few other units these ranges may be extended to the same values as are covered by the Type 650-A Impedance Bridge. (See page 3.)

Table I shows the proper combinations of these plug-in units for the entire range of values mentioned. This table is for all settings of the logarithmic rheostat between 10 Ω and 10,000 Ω.

Another table giving the values of the added resistance to be obtained from the Type 526 Rheostats, for values of dissipation factor D up to 1

Figure 1. The skeleton-type bridge with the drawer pulled out to show the method of storing standard resistors and condensers when not in use

FIGURE 2. TYPE 625-A Bridge

and values of energy factor *Q* up to 1000, is shown in the instruction book accompanying the bridge.

The wiring diagrams of the various bridges which should be used are shown in Figure 3. Capacitance is measured on a simple bridge having two resistance arms and two capacitance arms. Inductance is measured in terms of a standard condenser. The resistor added for making the resistance balance is placed either in parallel or in series with the standard condenser. The parallel connection is Maxwell's bridge and may be used for all values of energy factor *Q*, except that for large values the added resistance is too large to be obtainable on a variable resistor. The series connection is Hay's bridge and while it may also be used for all values of energy factor *Q*, the complicated correction term containing frequency becomes negligible only when *Q* is greater than 10. — ROBERT F. FIELD

TABLE I

Values of C, R, and L that can be measured with recommended standards. Unknown quantities in bold face type.

A ARM	*B* ARM	*P* ARM	*N* DIAL
100 Ω	10,000 Ω	**1000 Ω-1,000,000 Ω**	Unknown quantities (printed in bold face type) correspond to the complete range of 10 Ω-10,000 Ω, covered by the Logarithmic Rheostat *N*. Greatest accuracy is obtained by using the main decade on *N* (N = 1000 Ω to N = 10,000 Ω).
1000 Ω	10,000 Ω	**100 Ω- 100,000 Ω**	
10,000 Ω	10,000 Ω	**10 Ω- 10,000 Ω**	
10,000 Ω	1000 Ω	**1 Ω- 1000 Ω**	
10,000 Ω	100 Ω	**0.1 Ω- 100 Ω**	
10,000 Ω	10 Ω	**0.01 Ω- 10 Ω**	
10,000 Ω	1 Ω	**0.001 Ω- 1 Ω**	
100 Ω	**0.1 μf - 100 μf**	1 μf	
1000 Ω	**0.01 μf - 10 μf**	1 μf	
10,000 Ω	**1000 μμf- 1 μf**	1 μf	
1000 Ω	**100 μμf- 0.1 μf**	0.01 μf	
10,000 Ω	**10 μμf- 0.01 μf**	0.01 μf	
10,000 Ω	**1 μμf-1000 μμf**	1000 μμf	
100 mh-100 h	10,000 Ω	1 μf	
10 mh- 10 h	1000 Ω	1 μf	
1 mh- 1 h	10,000 Ω	0.01 μf	
100 μh-100 mh	1000 Ω	0.01 μf	
10 μh- 10 mh	100 Ω	0.01 μf	
1 μh- 1 mh	10 Ω	0.01 μf	

SPECIFICATIONS

Accuracy: The scale of the logarithmic rheostat is correct to 1%. The frequency of the internal microphone hummer is 1000 cycles to within 5%.

Power Supply: Power for driving the hummer and for d-c measurements is derived from two 4.5-volt batteries (Burgess No. 2370 or Eveready No. 771).

Accessories: Balance detectors suggested: head telephones for a-c measurements; zero-center, 200-μa full scale galvanometer for d-c measurements.

Standards: The following units make suitable standards and they can, for convenience, be ordered at the same time as the bridge if desired.

TYPE 500 RESISTORS
(See page 12, Catalog G)

500-AP	1 Ω	**$2.00**
500-BP	10 Ω	**2.00**
500-DP	100 Ω	**2.00**
500-HP	1000 Ω	**2.00**
500-JP	10,000 Ω	**2.00**

TYPE 505 CONDENSERS
(See January, 1933, *Experimenter*)

505-FP	0.001 μf	**$3.50**
505-LP	0.01 μf	**4.00**
505-QP	0.05 μf	**4.50**

A 1-μf condenser is also available: TYPE 625-P1, Code Word BAIZE, Price $2.00.

Dimensions: Panel, (width) 9 x (depth) 12 inches. Cabinet, (height) 7 inches, over-all.

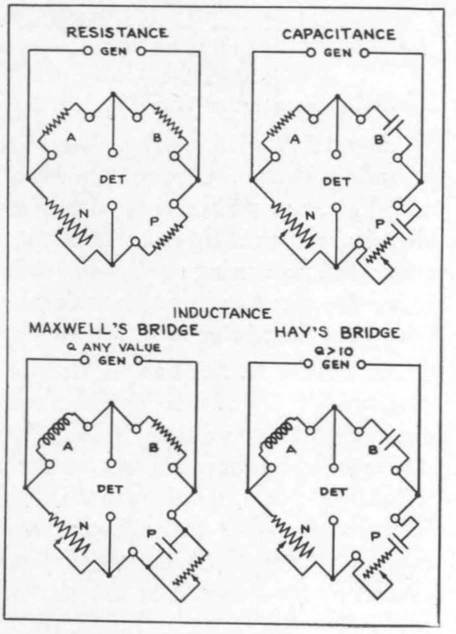


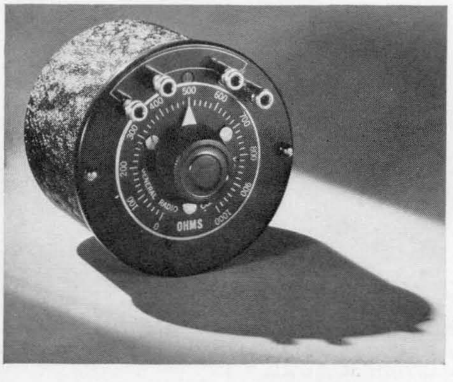
FIGURE 3. These are the basic circuits used in the TYPE 650-A Impedance Bridge and the ones recommended for use with the TYPE 625-A Bridge

Net Weight: 9 pounds. Batteries, 2 pounds additional.

Code Word: BEACH.

Price: $65.00 without batteries or the standards suggested in the *Accessories* paragraph above.

MOUNTED RHEOSTAT-POTENTIOMETERS



TYPE 471 Rheostat-Potentiometers are available mounted in drawn steel cases, the same size as used for the TYPE 247-G Variable Air Condenser. Each has an etched dial graduated in 50 divisions. The total resistance has been adjusted to within 2½% of the rated value.

Type	*Resistance*	*Price*
526-D	0-100 Ω	**$8.50**
526-A	0-1000 Ω	**8.50**
526-B	0-10,000 Ω	**8.50**
526-C	0-100,000 Ω	**8.50**

PITCH AND INTENSITY MEASUREMENTS WITH A VACUUM-TUBE OSCILLATOR

THE psychological and physiological departments of many universities, including Brown, Oregon, Princeton, and Yale, are making use of modern electrical vacuum-tube oscillators and associated measuring equipment to increase the speed and precision of audio-sound demonstrations and researches.

Dr. Robert H. Seashore of the University of Oregon, who has used this equipment for some time, writes, "We find the oscillator most useful for a number of demonstrations and experiments in the psychological and musical courses and special research projects. So far, we have used it as follows:

"(1) To demonstrate the range of the most useful portion of the audible sound stimuli

"(2) To show the independent variation of intensity at any pitch

"(3) To show the lowest audible tones (in a telephone receiver)

"(4) To demonstrate beats and difference tones when sounded with a tuning fork or other instrument

"(5) To demonstrate the small variations in pitch which lead to 'consonant' or 'dissonant' sound combinations (with a tuning fork)

"(6) The most important function for our purposes, to be able to measure pitch discrimination by the method of paired comparisons at any place in the musical scale."

The central instrument for this work is a vacuum-tube oscillator which, when used to operate ordinary telephone receivers or radio loudspeakers, produces sound vibrations of the sort obtained from tuning forks and other mechanical vibrators. The electrical oscillator has the great advantage over such mechanical oscillators that the vibration frequency can be adjusted rapidly and accurately over a wide range and that the amplitude can be

Any pitch between 5 and 10,000 vibrations per second is obtainable from the TYPE 613-B Beat-Frequency Oscillator. Incremental variations on either side of a given frequency are obtained by means of the condenser at the left

adjusted from zero to maximum by one turn of a switch.

Any tone in the range from 5 to 10,000 cycles per second can be selected instantly by setting the large central dial on which the frequency is engraved. The overtone or harmonic content of these well-designed electrical oscillators is negligible.

Experimenters have found that it is desirable to be able to vary the pitch over a small range from some base frequency. For this the TYPE 539-P Incremental-Pitch Condenser is provided. It is a direct-reading vernier adjustment for the electrical oscillator for changing its pitch by a total of 100 vibrations per second for a rotation of a full half turn of a large dial. This dial is calibrated for 100 divisions, each one effecting a change in pitch of *exactly* one vibration per second.

The base frequency of the oscillator can be anything from 100 cycles per second (about an octave below middle C) to 10,000 cycles (over five octaves above). The incremental pitch will read correctly for any setting in this range. Sufficient power output (about 10 milliwatts) is available to cause a strong tone in head telephones. For classroom demonstrations this sound volume can be enormously increased by the use of a vacuum-tube amplifier.

A third most useful auxiliary unit is a calibrated control of the volume of sound. The TYPE 529-B Attenuation Box is calibrated in steps of 2 decibels, the standard unit of relative sound volume, to cover a range from 0 to 60 decibels. This represents an attenuation control range from 0 to 1,000,000 in sound volume.

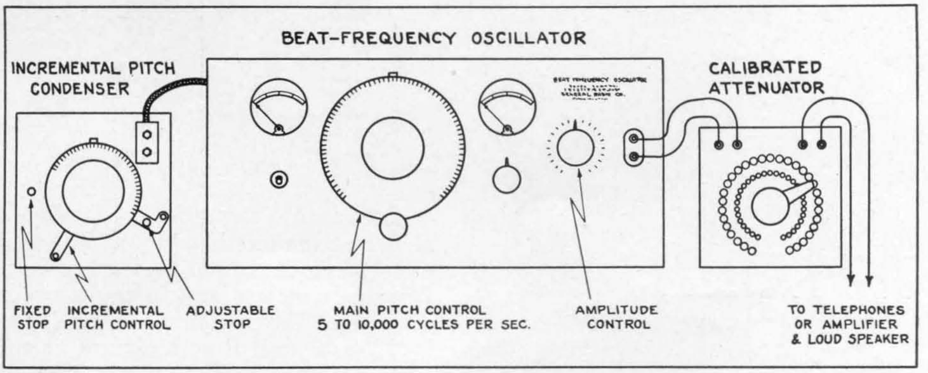
An interesting class demonstration is conducted by Dr. Harold Schlosberg of Brown University to determine, using the whole class and voting by a display of hands, the just noticeable difference of pitch at several frequencies. Then, with individuals selected from the class, using a headphone, the lower threshold of hearing at various frequencies is determined.

—ARTHUR E. THIESSEN

PRICES

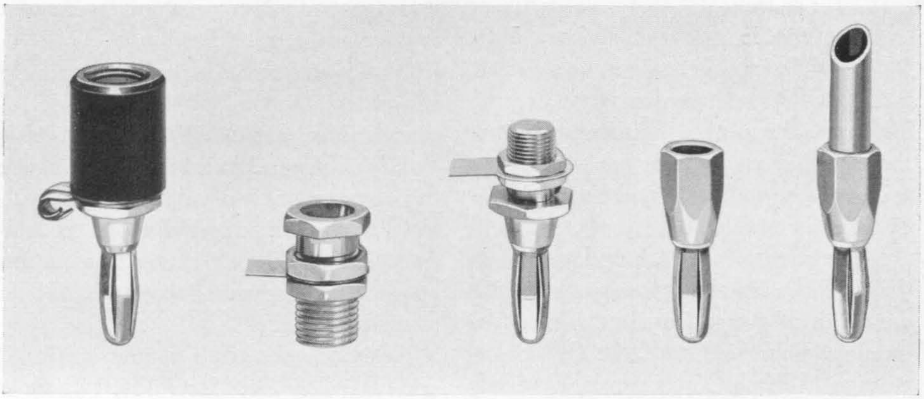
*TYPE 613-B Beat-Frequency Oscillator	$210.00
TYPE 539-P Incremental-Pitch Condenser	50.00
TYPE 529-B Attenuation Box	34.00

*This instrument must be modified slightly so that the incremental-pitch condenser can be used with it. The extra charge for this work and for the shielded connector is included in the price of the condenser.



Studies involving intensity changes as well as pitch changes can be made by adding a calibrated attenuator to the apparatus shown on the opposite page

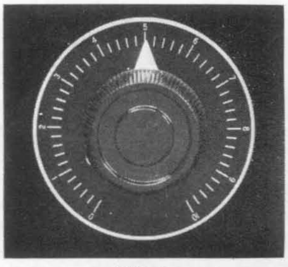
LARGE SIZE PLUGS AND JACKS



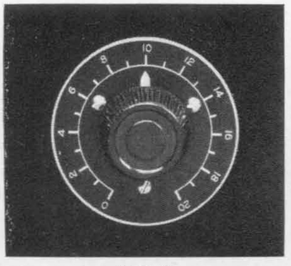
674-D $0.50 674-J $0.25 674-P $0.35 674-C $0.20

Plug-in inductors made of ¼-inch copper tubing can be sweated into the new TYPE 674-C Plug shown at the right. The cup is tinned. Illustration approximately one-half size

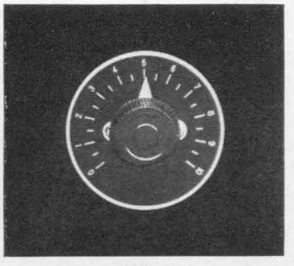
DIAL PLATES



523-A

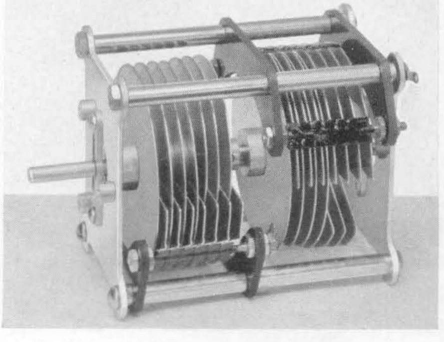


318-A



522-A

Dial plates made of etched nickel silver are now available for use with General Radio rheostat-potentiometers. TYPE 523-A is for TYPES 371, 314, and 471; TYPE 318-A is for TYPE 214; and TYPE 522-A is for TYPE 301. Price: $0.35, each



A TWO-SECTION BAND-SPREAD CONDENSER

The new TYPE 756-A Condenser shown at the left is adapted for use in Colpitts oscillators in transmitters and frequency meters and in multi-circuit receivers. The maximum capacitance is 225 $\mu\mu$f and the minimum is adjustable between 100 $\mu\mu$f and 180 $\mu\mu$f. Price $6.00.

AN A-C POWER SUPPLY FOR BROADCAST FREQUENCY MONITORS

THE General Radio Company has recently developed the TYPE 531-A Power Supply for use with the TYPE 575-D Piezo-Electric Oscillator. By means of this power pack, users of General Radio Frequency Monitors can dispense with batteries and operate the crystal oscillator from the alternating-current line.

The TYPE 531-A Power Supply includes two rectifiers with their associated filters. A copper-oxide rectifier is used in the 6-volt circuit which supplies current for the tube filament and the temperature-control relay. The plate-supply rectifier is an 83 mercury-vapor tube. Both circuits are adequately filtered, and voltage adjustments are provided wherever necessary. Satisfactory operation can be obtained on line voltages between 105 and 120 volts, 60 cycles.

The whole assembly is mounted on a standard 19-inch relay-rack panel, 7 inches high. The panel is finished in black crackle lacquer to match the oscillator panel.

The price of the TYPE 531-A Power Supply is $100.00, exclusive of the rectifier tube.

VOLTAGE REGULATOR TRANSFORMER

This TYPE 440-R Transformer is a voltage-regulating device capable of handling a load of 100 volt-amperes. Its output voltage remains constant at a voltage between 112 and 115 volts for input voltage variations between 95 and 130 volts, 60 cycles, alternating current. Its price is $40.00 complete with cord

PRECISION RESISTORS WITH A HIGH POWER RATING

THE laboratory worker engaged in electrical measurements must often make a choice between the risk of burning out a precision resistor and using a less-accurate standard. Inevitably in experimental work, the requirements of many problems lie just beyond the safe limits of precision units.

The General Radio Company has recently designed a precision-type resistor capable of dissipating large amounts of power. This resistor, shown in Figure 1, consists of a mica card wound with resistance wire, clamped between two aluminum castings and insulated from them by two thin sheets of mica, the whole unit being supported on porcelain insulators. The aluminum castings are heavily ribbed to give a large heat-radiating surface.

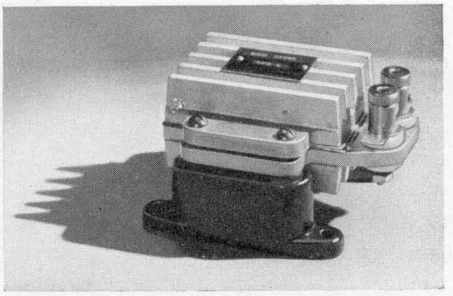


FIGURE 1. TYPE 525-L Resistor

The TYPE 525 Resistor is conservatively rated at 50 watts dissipation, although considerably more power can be dissipated for long periods without any damage to the resistor, since it is built to withstand high temperatures. A plot of temperature rise versus power dissipation is shown in Figure 2. These data were taken in still air, and if a fan is used to keep the air in motion, the temperature rise is much smaller. The increase in resistance with temperature is small, since the temperature coefficient is only 0.002% per degree at temperatures below 100° Centigrade.

Heavy-duty resistors are extensively used in the determination of the power output of radio transmitters. All such resistors have appreciable series inductance and shunt capacitance, and the resistance usually tends to rise with frequency as shunt resonance is ap-

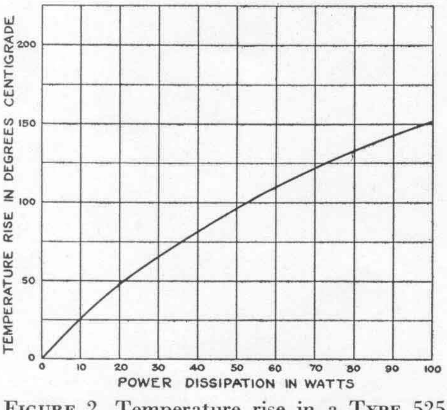


FIGURE 2. Temperature rise in a TYPE 525 Resistor as a function of power dissipation. This is essentially the same for all sizes

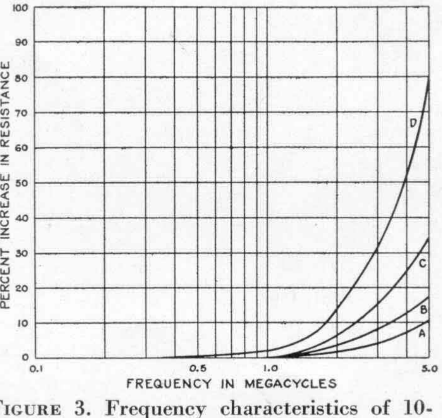


FIGURE 3. Frequency characteristics of 10-ohm (*A* and *B*) and of 40-ohm (*C* and *D*) TYPE 525 Resistors. Data for *A* and *C* were taken with the shield floating, *B* and *D* with the shield connected to one terminal

proached. Superimposed on this effect is the increase in resistance due to skin effect in the resistance wire itself.

That portion of the resistance which is due to reactance depends upon the equivalent inductance $\hat{L} = L - R^2C$.* For positive values of $\hat{L}$ the resistance (disregarding skin effect) increases with frequency, and for negative values of $\hat{L}$ it decreases.

The TYPE 525 Resistor shows extremely good radio-frequency characteristics, particularly in the smaller sizes. Figure 3 shows the variation of resistance with frequency for two of these units.

Curves A and B are for the 10-ohm resistor and curves C and D for the 40-ohm size. A and C represent the resistance with the aluminum shield floating and curves B and D with the shield connected to one (*continued on page 14*)

*"Frequency Characteristics," Robert F. Field, General Radio *Experimenter*, February, 1932.

SALE OF DISCONTINUED RESISTANCE DEVICES

When a new catalog is issued, some of our older instruments are dropped in favor of more up-to-date designs. It is seldom possible to avoid having small stocks of the discontinued items when this change is made, and a number of such instruments are now available. At least one of each of the resistance devices listed in the following table are available at substantial reductions in price so long as the supply lasts. Additional specifications will be found in Catalog F.

Every item is new and carries with it the same promise of satisfactory operation as though the regular price were paid.

DECADE-RESISTANCE BOXES

Type		*Former Price*	*SALE PRICE*
102-J	11,110 ohms in steps of 1 ohm—4 dials	$50.00	**$30.00**

ATTENUATION BOXES

Type		*Former Price*	*SALE PRICE*
329-H	55 db in steps of 0.5 db—H— 600 ohms	$140.00	**$50.00**
329-K	55 db in steps of 0.5 db—H—6000 ohms	185.00	**50.00**
329-L	55 db in steps of 0.5 db—Balanced-H—6000 ohms	190.00	**50.00**
329-P	22 db in steps of 0.2 db—Balanced-H—6000 ohms	200.00	**50.00**
429-K	55 db in steps of 0.5 db—T—6000 ohms	175.00	**50.00**
429-R	22 db in steps of 0.2 db—T—6000 ohms	200.00	**50.00**

VOLUME CONTROLS

(Can Be Used as Attenuation Boxes)

Type		*Former Price*	*SALE PRICE*
552-LA	30 db in steps of 1.5 db—L— 50 ohms	$28.00	**$15.00**
552-LB	30 db in steps of 1.5 db—L—200 ohms	28.00	**15.00**
552-LC	30 db in steps of 1.5 db—L—500 ohms	28.00	**15.00**

PRECISION RESISTORS WITH A HIGH POWER RATING
(Concluded)

terminal. In the latter case, the shunt capacitance is greater, resulting in a lower resonant frequency.

The characteristics of the 4-ohm unit are similar to those of the 10-ohm. The 600-ohm unit has an effective inductance which is always negative. This factor is much larger than the skin effect, and the resistance will, therefore, decrease with frequency.

TYPE 525 Resistors are available in the following values:

SPECIFICATIONS

Type	*Resistance*	*Accuracy*	*Code Word*	*Price*
525-C	4 ohms	0.1%	CABAL	$8.00
525-D	10 ohms	0.1%	CABIN	8.00
525-F	40 ohms	0.1%	CABOB	8.00
525-H	100 ohms	0.1%	CADDY	8.00
525-L	600 ohms	0.1%	CADET	8.00

SPECIAL PRICE ON CATHODE-RAY OSCILLOGRAPH TUBES

WE have five Western Electric No. 224-B Cathode-Ray Oscillograph Tubes in our laboratory stock that are now available for sale at a price well below the list price. They were purchased for use by our own engineering staff before development was completed on the General Radio Cathode-Ray Oscillograph and we now have no use for them.

This is an excellent opportunity for interested laboratories to replenish their stocks of these tubes. No. 224-B is similar to and interchangeable with No. 224-A; the former taking a smaller filament current.

Each tube is in its original sealed carton. Price: $30.00, each.

AN OUTPUT TRANSFORMER FOR THE NEW 2A3 TUBES

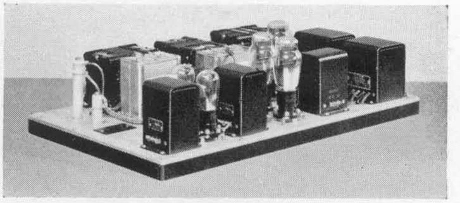
THE new 2A3 amplifier tube should be of exceptional interest to all who are interested in high-quality reproduction, since two of these tubes in a push-pull output stage have a greater power handling ability than the usual push-pull pentode output stage and compare very favorably in this respect with Class B systems. In addition, a Class A output stage, using the 2A3's, will generate considerably less harmonic distortion than either of these other two commonly-used output systems.

The General Radio Company has developed a new output transformer for use with these tubes. Because of its unusually high efficiency, nearly all of the output power is actually delivered to the speaker. This transformer, which is known as the Type 541-D, has a practically flat characteristic from 20 to above 10,000 cycles per second. The secondary is tapped to match impedances from 1.5 to 12 ohms. This allows operation into any of the more usual types of dynamic speakers, or several speakers in parallel or in series.

The accompanying diagrams show an amplifier (and associated rectifier) designed particularly for the 2A3 tubes.

The actual quality delivered by an amplifier of this type is extremely good. The maximum power output is approximately 10 to 12 watts, which will overload two or three dynamic speakers of the usual type used in receiver sets. When operated at normal room volume, there is no fuzziness (as is often encountered in Class B amplifiers) and power peaks are easily taken care of, resulting in a brilliancy and realism in the reproduction which are quite amazing for an amplifier of these proportions.

— H. H. Scott



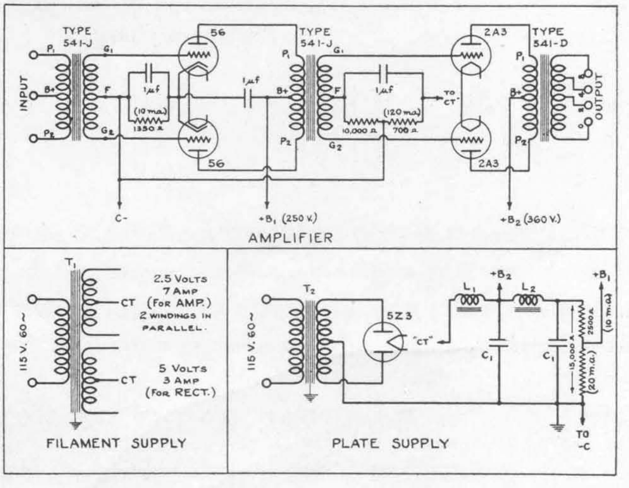
An amplifier using the new 2A3 tubes and parts described in the accompanying article

PRICE LIST

Type	*Description*	*Price (each)*
541-D	Transformer	**$7.50**
541-J	Transformer	**7.50**
349	4-Prong Socket (3 req'd)	**.35**
438	5-Prong Socket (2 req'd)	**.35**
	C_1—Pyranol Condenser, 4 μf; peak voltage 1980	**6.60**
***AD18**	T_1	**3.00**
***AD20**	T_2	**5.05**
***AD30**	L_1	**4.55**
***AD40**	L_2	**4.55**

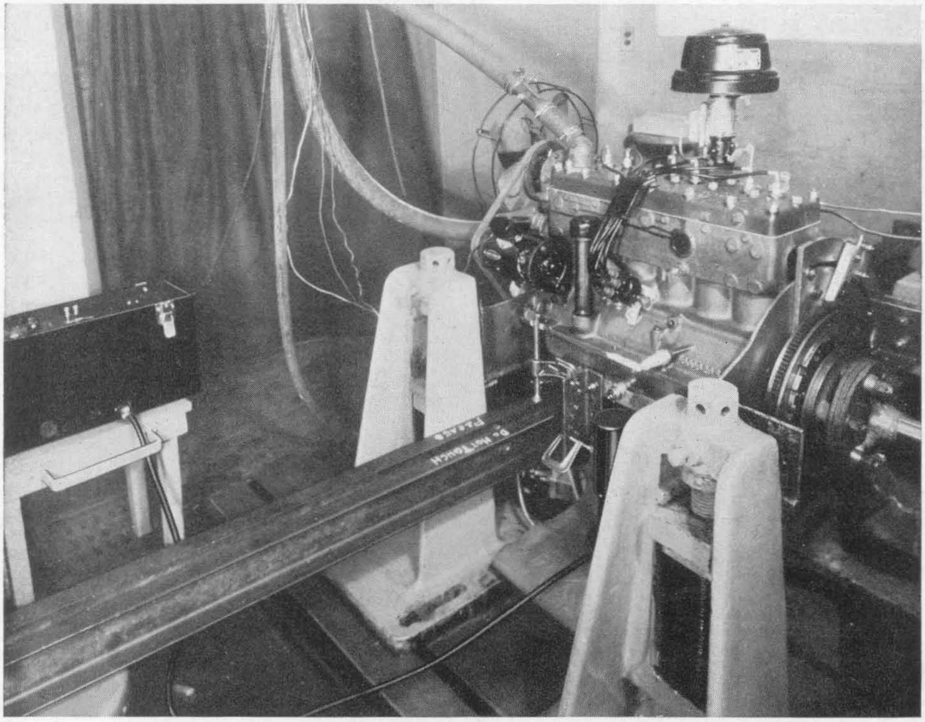
Any standard by-pass condensers and resistors having satisfactory voltage and current ratings can be used.

*These are manufactured by the Delta Manufacturing Company and are obtainable from General Radio at the regular net prices given above.



Wiring diagram for the 2A3 amplifier shown above. Note that other standard input transformers are available, for use on 500-ohm lines, for instance

USING THE EDGERTON STROBOSCOPE IN AUTOMOTIVE RESEARCH



Chrysler engineers measure crankshaft whip and vibration with the Edgerton Stroboscope. For an interesting description of the method, see page 75 of *Instruments* for April, 1933. Reprints can be had from General Radio Company without charge

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

SOME IMPROVEMENTS IN CATHODE-RAY OSCILLOGRAPHS

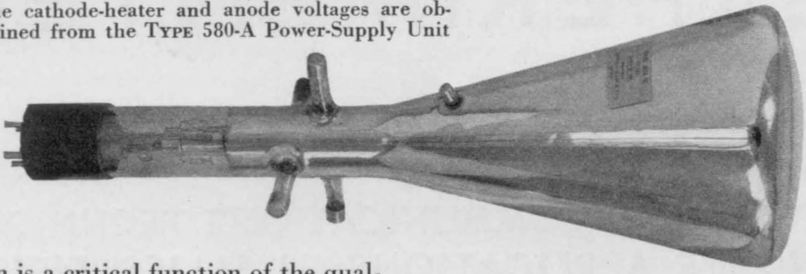
THE mad search for practicable television in the past few years may or may not be considered worth while, depending upon one's own personal inclinations and commercial affiliations. There is no doubt, however, that it has given the laboratory worker a better cathode-ray oscillograph.

Television was the inspiration for the first of the so-called "brilliant" oscillograph tubes that General Radio made available two years ago. Television was also responsible for the underlying ground work of development on which the harder tubes, used in two new General Radio cathode-ray oscillographs, are based. Oscillograph tubes are highly complicated—their apparent simplicity to the contrary notwithstanding—and it is the laboratory man's good fortune that the tube manufacturers' vision of a public clamor for television tubes gets him better oscillograph tubes.

Both the common vacuum tube and the cathode-ray tube have cathodes emitting electrons which are drawn to positive anodes with velocities of the same order of magnitude (about $3x10^7$ meters per second for a fall through 2500 volts). Here, however, the similarity ends for electrons in the vacuum tube travel a very short distance. In the cathode-ray tube, on the other hand, the path may be a foot or more long, and, in addition, the electron cloud must be concentrated in a small spot on the fluorescent screen. Since each electron carries the same negative charge, diffusion rather than concentration is the natural tendency, and much of the design problem resolves itself into making the electron clouds behave.

Focusing by means of residual gas within the tube has been the conventional method. Since gas molecules become ionized on being struck by high-velocity electrons, the electron beam drills its way through the gas and lines its path with a layer of slow-moving positive ions, the field of which effects the desired concentration. Obviously, the amount of ionization and, correspondingly, the concentration of the

FIGURE 1. The two auxiliary voltages required by the TYPE 528-A Cathode-Ray Tube in addition to the cathode-heater and anode voltages are obtained from the TYPE 580-A Power-Supply Unit



beam is a critical function of the quality and pressure of the gas. And "there's the rub;" in fact, the rub has at least four important points of contact with oscillograph-tube design.

(1) Anything that affects the gas in the tube, such as temperature, progressive clean-up, or pollution from occluded gas, can alter the focusing.

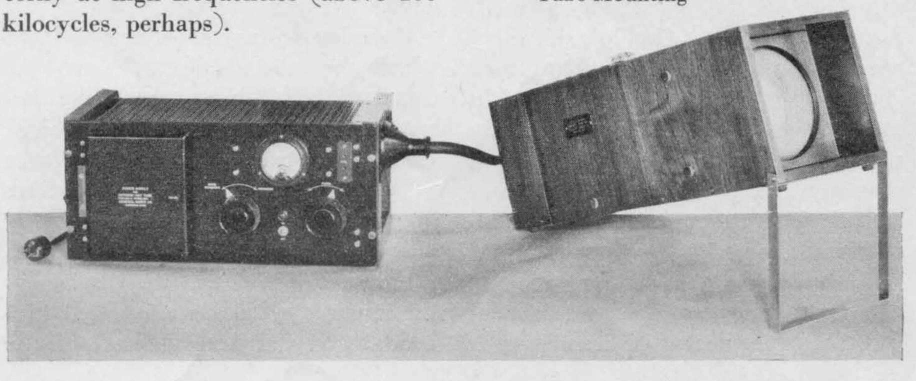
(2) The negative cathode on a gaseous tube can receive an unmerciful beating from any positive ions lobbed at it around the edges of its protecting shield.

(3) Since focusing depends on the slow ions being more or less in equilibrium, the "frequency of deflection" can easily become so high that the focusing condition never has time to re-establish itself after one deflecting impulse before the next one arrives. Hence, some gaseous tubes will not focus satisfactorily at high frequencies (above 100 kilocycles, perhaps).

(4) As the deflecting voltage passes through zero in a gaseous tube, a barely perceptible nick appears in the line on the screen due to ions in the path between deflecting plates. This seldom causes trouble in any but the most exacting work.

All of these defects of the gaseous type of tube have either been eliminated or reduced to negligibility in both tubes used in the two new oscillographs. "Hard" is an entirely relative adjective, in fact we described the older General Radio tube as "hard" (less gas), as indeed it was in comparison with previous tubes. The new tubes are considerably harder than the ordinary radio tubes of comparable voltage; only enough is left to make a

FIGURE 2. The power-supply unit, tube, and TYPE 579-A Tube Mounting



path along which electrons can return from the screen to the cathode. Hence, it will probably be some time before the new tubes are forced into the soft class by still harder tubes.

A detailed description of focusing mechanisms in hard tubes would be out of order here—not that there is any particular secret about them—but it's a long story. Briefly, use is made of electric fields in which the electrons are guided (by shaping of the electric lines of force along which they move) in a manner directly analogous to the guiding of light rays in an optical lens. It sounds strange, but it works.

TYPE 528 CATHODE-RAY OSCILLOGRAPH ASSEMBLY

This (Figure 2) is a complete oscillograph built around the TYPE 528-A Cathode-Ray Tube designed and built for General Radio by Westinghouse. Because of its large screen, it will prove to be the oscillograph best adapted to lecture room demonstrations and precision measurement problems in the laboratory. The patterns are brilliant—more so than in the older General Radio oscillograph.

The tube itself (Figure 1) has an indirectly heated cathode and a focusing system requiring the application of an adjustable positive voltage to a "first anode." In addition to this and the usual "second" or accelerating anode, there is a grid, a negative voltage applied to which decreases the brilliancy and enables the pattern to be "modulated." The four deflecting plate connections are brought out through separate glass arms, and the operating voltages, with the exception of that for the second anode, are delivered through a large five-pin base.

The silvered coating which lines the entire conical portion of the tube is the second anode, and its voltage is applied through the stud on the surface of the cone. The screen is willemite, giving a green trace of excellent visual and good photographic brilliancy.

At maximum brilliancy (anode, 3000 volts), the voltage sensitivity for either pair of deflecting plates is approximately 110 d-c volts per inch. It increases proportionally as the anode voltage (and brilliancy) is reduced to 500 volts.

The tube is guaranteed for 500 hours of operation or for one year, whichever comes first.

The power-supply unit shown at the left in Figure 2 delivers a d-c voltage between 500 volts and 3000 volts as controlled by the knob at the left of the anode voltmeter on the panel. The positive focusing voltage covers the range between 7 per cent and 21 per

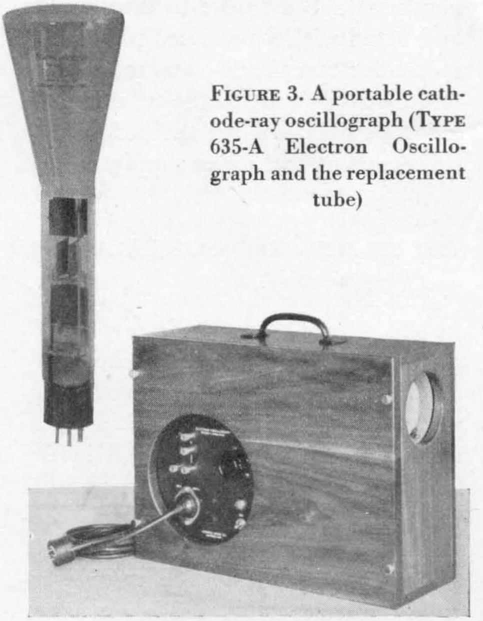


FIGURE 3. A portable cathode-ray oscillograph (TYPE 635-A Electron Oscillograph and the replacement tube)

cent of the anode voltage by means of the right-hand knob. Also on the panel, but protected by a cover, are a rheostat and voltmeter for the heater-current supply. It is designed for a maximum of 3 volts and 3 amperes. The negative grid voltage is adjustable between 0 and 15 per cent of the anode voltage by a control placed next to the filament rheostat. On the panel at the right is a jack plate through which external modulating voltages may be applied.

The tube mounting is a walnut case fitted with an elevating bracket and a door on the side through which the deflecting plates may be reached for making connections to the permanent binding post plate on the top side. The capacitance across either pair of terminals is so small as to be negligible up to frequencies where the inductance of the connecting wires becomes appreciable (say 100 Mc). A cable permanently attached to the tube mounting and fitted with a polarized plug is the means for transferring power from the power-supply unit to the tube mounting. The plug engages the jack on the side panel of the power-supply unit.

TYPE 635-A ELECTRON OSCILLOGRAPH

This instrument (Figure 3) is an effort to reduce the cathode-ray oscillograph to its lowest terms in simplicity of operation and price. Being a complete, readily portable unit, it is ideal for use in the laboratory and in the field as an auxiliary for the larger, more versatile assembly previously described.

The tube mounting and the power-supply unit are combined in one case, access to the tube being obtained by removing four thumb screws. Terminals for the deflecting plates appear on the panel immediately above the receptacle through which 60-cycle power is applied. Cathode heater power for the tube is adjusted by means of a rheostat (maximums of 2.2 amperes and 2.5 volts, respectively) located inside the cabinet. Once adjusted for the tube in use, it need not be changed. The focusing voltage is adjusted by means of the knob on the panel between 0 and 300 volts and can be made either positive or negative by reversing connections. For simplicity, the anode voltage remains fixed at 1000 volts.

The tube (Figure 3) supplied with the instrument is built for General Radio by Hygrade-Sylvania. All voltages, including connections for the deflecting plates, are brought out through the standard six-pin base. A positive focusing voltage is used. The willemite screen has essentially the same characteristics as those of the Type 528-A Cathode-Ray Tube and the brilliancy is slightly better for equal accelerating voltages. The voltage sensitivity is approximately 75 d-c volts per inch for one pair of plates and 100 d-c volts per inch for the other pair. The capacitance across either pair of deflecting-plate terminals as measured at the panel of the oscillograph is less than 50$\mu\mu$f. The effective diameter of the screen is approximately 3 inches. The tube is guaranteed for 300 hours of operation or for six months, whichever comes first.

—John D. Crawford

[For additional specifications, including prices, on both oscillographs, see the supplementary specifications on page 15.]

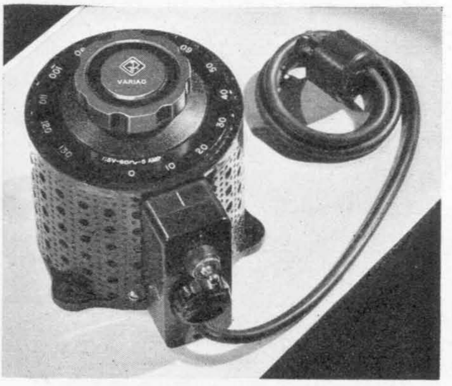
THE VARIAC—A NEW ADJUSTABLE TRANSFORMER

It is frequently necessary to obtain various voltages from the standard 115-volt, 60-cycle mains. Transformers having several taps are generally used for the purpose, but have the disadvantages that a change in voltage necessitates an interruption of current, since, even with a switching arrangement, one tap must be disconnected before another is connected in order that there shall be no short-circuited turns at any time. Due to the large potential difference between taps on a transformer of this kind, no very fine degree of control can be had. Transformers in which the coupling coefficient between the windings is varied generally result in poor regulation.

To meet the need for a continuously variable source of 60-cycle alternating voltage, the General Radio Company has developed a new unit which has been named the *VARIAC*. This is a toroidal auto-transformer with which the desired results are obtained by using a sliding contact on the transformer winding. Shorting of turns with consequent overheating is eliminated by means of a carbon brush which has sufficient resistance to limit the current caused by connecting two adjacent turns together.

Since the potential between adjacent turns is of the order of 0.5 volt, the circulating current carried by the brush is not great. The brush itself is mounted in a metal holder of sufficient size to dissipate effectively the small amount of heat generated.

The *VARIAC*, since it is wound on a toroidal core, is quite similar in appearance to a heavy-duty potentiometer. Because of the small potential difference between turns, very close adjustment of the output voltage is possible.



The Type 200-CM Variac is an adjustable auto-transformer delivering voltages between 0 and 130 volts from the 115-volt line. (Patent applied for)

When the *VARIAC* is connected across a 115-volt, 60-cycle line the output voltage may be varied from 0 up to 130 volts by merely turning the large calibrated dial. The calibration on the dial is only approximate, since, of course, the output voltage will vary somewhat with load, but for all rated load values, the output voltage may be adjusted by means of the calibrated dial within ± 2.5 volts r-m-s, providing, of course, the line voltage is 115 volts. The unit will safely carry currents up to 5 amperes.

An almost unlimited number of uses may be found for the *VARIAC*. For instance, such a unit is of great value in controlling theater lights and other decorative lighting installations. Manufacturers of a-c operated household appliances or radio receivers may use the *VARIAC* to check the performance of their products over a wide range of line voltages.

The *VARIAC* is manufactured in

two different models: (Type 200-CM) the one shown in the photograph, and the other (Type 200-CU), without the shield, terminal plate, switch, and cord for mounting on a panel. The latter has screw terminals.

The maximum power loss in the unit is about 30 watts and provision should be made for sufficient air circulation.

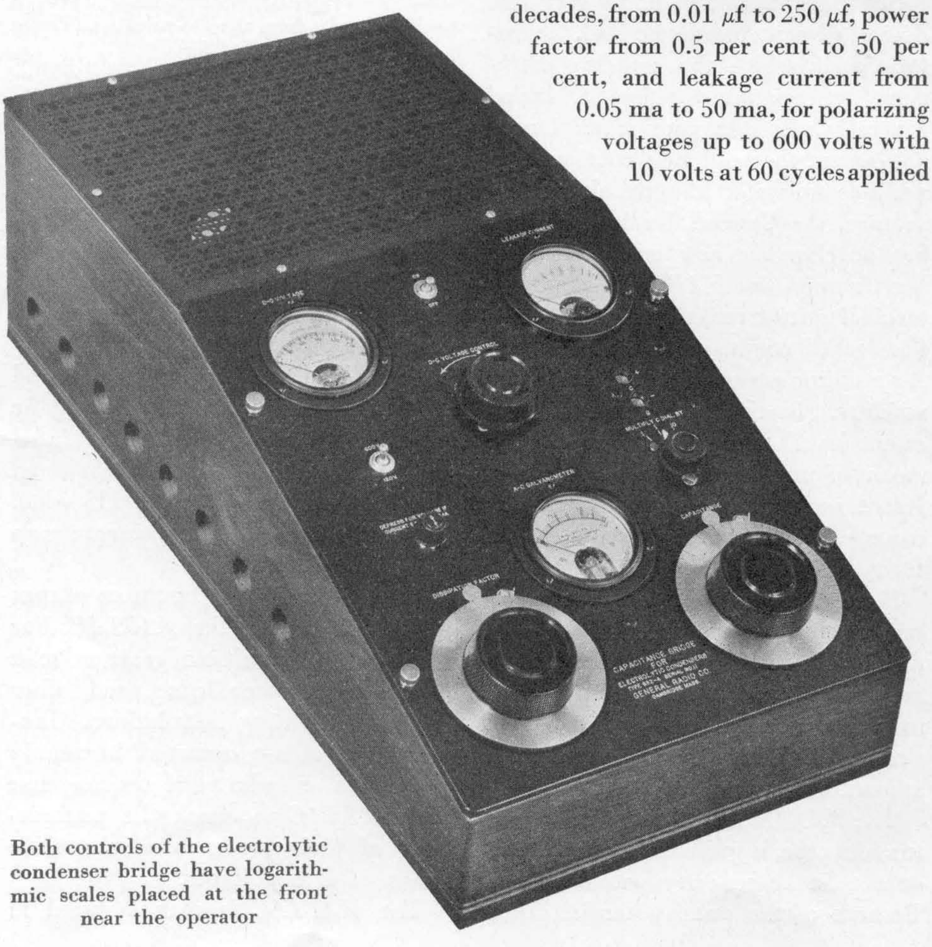
—H. H. Scott

[For additional data, see page 15.]

A BRIDGE FOR TESTING OF ELECTROLYTIC CONDENSERS

Electrolytic condensers are characterized by high capacitance, large power factor, appreciable leakage current, and polarizing d-c voltage. In addition, they must be tested at their operating frequency, either 60 or 120 cycles.

The Type 632-A Capacitance Bridge has been designed to meet these special requirements of electrolytic condensers. It will measure capacitance over four decades, from 0.01 μf to 250 μf, power factor from 0.5 per cent to 50 per cent, and leakage current from 0.05 ma to 50 ma, for polarizing voltages up to 600 volts with 10 volts at 60 cycles applied



Both controls of the electrolytic condenser bridge have logarithmic scales placed at the front near the operator to the condenser. These ranges cover all electrolytic condensers now manufactured, both wet and dry, except the low-voltage condensers for filament filters of 1000 μf to 4000 μf capacitance.

The appearance of the instrument is shown in Figure 1. The bridge controls are placed at the front of the panel near the operator. The bridge is balanced for capacitance and power factor by two logarithmically tapered rheostats.

The CAPACITANCE dial is calibrated over two decades from 0.25 μf to 25 μf, the main decade extending from 2.5 μf to 25 μf and covering three-quarters of the dial. Its range is extended up and down one decade by a multiplier switch having three multipliers (0.1, 1, and 10).

The DISSIPATION FACTOR dial is calibrated in per cent power factor from 0.5 per cent to 50 per cent. Dissipation factor $D = R\omega C$ is the same as power factor except at large values.

The null detector is a two-stage resistance coupled amplifier using 57-type tubes and operating a TYPE 488-B A-C Voltmeter through a transformer tuned to 60 cycles. This meter is protected by a high series resistance from deflecting off-scale, even if the bridge is completely out of balance, as when condensers are disconnected. At the same time, its sensitivity for the small voltages obtaining near balance is not materially lowered. This feature is made possible by the non-linear resistance characteristic of the copper-oxide rectifier.

The D-C VOLTAGE is controlled by a large potentiometer and measured by a double-range voltmeter. The LEAKAGE CURRENT is measured by a d-c meter having a semi-logarithmic scale covering three decades from 0.05 ma to 50 ma. This valuable feature is obtained by the use of a copper-oxide rectifier shunt and depends on the non-linear properties of this material. Owing to the large values of leakage current occurring at the instant of application of the polarizing voltage to an electrolytic condenser, it is highly desirable that this meter have a wide range without the use of manually controlled shunts. The resulting decrease in accuracy of this meter is unimportant because of the wide momentary fluctuations in leakage current which occur even under normal operating conditions.

The CAPACITANCE dial is calibrated to within 2 per cent over its main decade. It can be set to 0.5 per cent. The accuracy of calibration of the DISSIPATION FACTOR dial is 10 per cent. The accuracy of reading two dials should be 5 per cent and 20 per cent, respectively. The polarizing voltage may be read to within 2 per cent of full-scale reading. The leakage current may be read to within 10 per cent for 50 ma, 20 per cent for 5 ma, and 100 per cent for 0.05 ma.

The power for the entire bridge is obtained from the 110-volt, 60-cycle supply. The 600-volt polarizing voltage is also used for the two-stage amplifier.

—ROBERT F. FIELD

[For additional data, see page 16.]

BRIDGE + VACUUM TUBE = MEGOHM METER

THE rapid and easy measurement of high resistances by means of a portable instrument has always been attended with considerable difficulty.

The bridge method demands the use of a suspended coil galvanometer, using a telescope or spot of light. This is necessary to make up for the loss of sensitivity due to the relatively low resistance of the galvanometer. The direct deflection method also needs a sensitive galvanometer and, in addition, a high voltage supply. The unknown resistor is either compared with a lower resistance standard by means of a calibrated galvanometer shunt or is measured directly in terms of a calibrated scale. For the latter case, the high voltage is frequently supplied from a hand-cranked generator.

The Type 544-A Megohm Meter is a bridge having a vacuum-tube voltmeter as the null detector. It has sufficient sensitivity so that the indicating meter may be a pointer-type galvanometer. The bridge is balanced by means of a logarithmically tapered rheostat, calibrated directly in megohms, over two decades from 0.1 MΩ to 10 MΩ. The larger decade from 1 MΩ to 10 MΩ covers three-quarters of the dial, or 5¾ inches, and provides approximately constant fractional accuracy of reading. Five multiplying factors (0.1, 1, 10, 100, and 1000) are provided by a switch which varies the resistances in two arms of the bridge in decimal steps. The complete range of the bridge is six decades from 0.01 MΩ to 10,000 MΩ, with a total scale length of 44 inches.

This range of resistance covers most of the high resistances met with in practice. All grid leaks and coupling resistors for vacuum tubes may be measured. The insulation resistance of all low-voltage electrical apparatus, such as motors, transformers, and heating devices; of sufficiently long lengths of high-voltage cables; of paper condensers; and of slabs of most insulators may be determined. The extremely long scale allows the effects of temperature and humidity on insulating materials to be studied.

The operation of the meter is as follows. With the control switch set at CHECK, the galvanometer is brought to zero by means of the ZERO ADJUST knob. The pointer and knob move in the same direction. The control switch is then set at OPERATE and the MULTIPLIER switch turned until the galvanometer pointer swings through zero. Final balance is obtained by means of the MEGOHMS dial.

The principle of operation of the bridge is shown diagrammatically in Figure 2. The two low-resistance arms A and B are connected across the supply voltage of 90 volts. The two high-resistance arms P and Q, one being the unknown resistor, are tapped across them.

The voltage on the bridge varies from 90 volts down to 1 volt. The various voltages for the vacuum tube are supplied through a drop wire connected across the supply. In thus using a common voltage for bridge and detector, it is no longer possible to connect the grid and filament terminals across opposite junctions of the bridge. Instead, the grid is connected alternately to these junctions. Such a procedure would ruin all the advantages of an ordinary null detector. But because for a vacuum-tube voltmeter the initial plate current must be balanced out, no sacrifice of sensitivity occurs with this method.

The grid current of the 32-type screen-grid tube depends on the voltage of the screen-grid tube and the negative bias of the control grid. It is due to positive ions and is about 300 $\mu\mu$a as used in this meter. The possible error due to this grid current is eliminated by so arranging the control switch that the two high-resistance arms are included in the grid circuit in the CHECK position.

The MEGOHMS dial is calibrated to 2 per cent over its main decade. It can be set to 0.5 per cent. The two smaller standards are wire-wound and adjusted to 0.25 per cent. The large standard used on the two highest MULTIPLIER steps is of the sputtered-filament type and is adjusted to 10 per cent. It may be easily measured in terms of the middle valued standard, the correct value of which is supplied with the instrument. The readings of the bridge should be accurate to 3 per cent for the three lower MULTIPLIER steps and to 5 per cent for the two highest steps, when this correction is applied.

The megohm meter is mounted in a shielded cabinet with a hinged cover and carrying handle. Space for the power supply is provided in the rear of the panel. Either dry batteries or an a-c power pack (see specifications, page 16) may be used.

—ROBERT F. FIELD

FIGURE 1. The MEGOHMS dial and MULTIPLIER switch are placed in the most convenient operating position. Above them are the ZERO ADJUST knob, control switch, and zero-center galvanometer

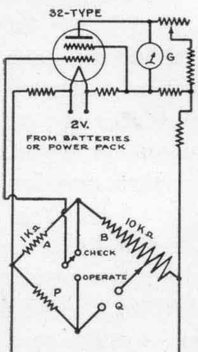


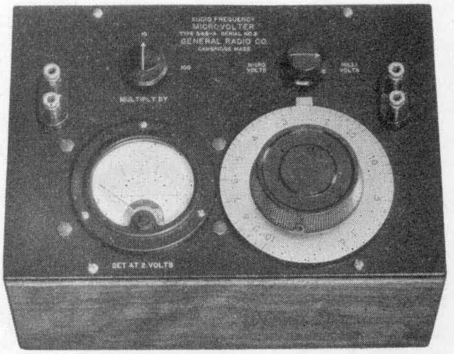
FIGURE 2. Schematic diagram for the TYPE 544-A Megohm Meter

A METHOD OF SECURING SMALL AUDIO VOLTAGES

SINCE the advent of the vacuum tube, quantitative measurements of its performance have involved voltages so small as to be below the range of the most sensitive voltmeters. It has been necessary, therefore, to use the vacuum tube itself as a voltmeter.

The great difficulty in obtaining accurate results has been in knowing the gain—or sensitivity—of the vacuum-tube voltmeter. As a result, a special technique has been developed for measurements of this character. It is well illustrated by the method of gain measurements described in the General Radio *Experimenter* for January, 1931.

The fundamental principle involves starting with a voltage large enough to be determined accurately by convenient and stable voltmeters. This voltage is then attenuated by some known amount, with the result that there is available a voltage comparable in magnitude to the unknown voltage in question. An amplifier of suitable form is now switched alternately between the known and unknown voltages, and the known voltage is adjusted until the output of the amplifier is the same in both cases. While such methods are commonly referred to as comparison measurements, it will be seen that, in effect, the gain of the amplifier is being determined for each setting, inasmuch as the input voltage for a given indicated output is known.



When supplied from a low-power oscillator, the audio-frequency microvolter enables known voltages between 1 volt and less than a microvolt to be obtained

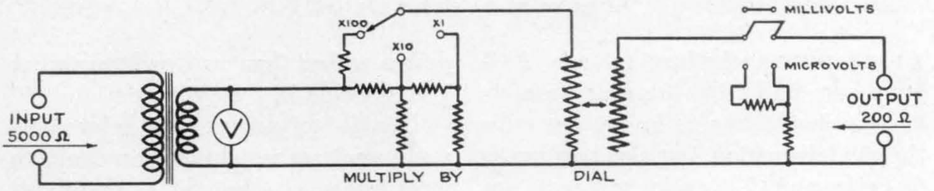
It will be recognized that the essential element in such a measurement is the calibrated attenuator. For moderately low voltages, reasonably accurate results may be obtained with a potentiometer arrangement. For potentials of the order of one microvolt, however, considerable care must be taken in the design in order that extraneous voltages (due either to capacitance coupling or to leakage) do not exceed a value which would cause an appreciable error in the output voltage.

For convenience in use, and in the computation of results, it is desirable that the impedance of the attenuator as measured at its output terminals should be constant.

These several essential features have been included in the new calibrated attenuator recently developed.

The attenuator is in three sections. One, controlled by a three-position switch, reduces the voltage by decimal increments. A second, controlled by a two-position switch, alters the output voltage by a factor of 1000 to 1.

The third is a specially designed slide wire covering a range of two decades and having an exponential scale. The general arrangement of the scale on this element is similar to that of the resistance arm of the TYPE 650-A Bridge, described in the last issue of



Schematic diagram of the TYPE 546-A Audio-Frequency Microvolter. The open-circuit voltages shown by the calibration are obtained when the voltmeter reads 2 volts

the *Experimenter*. The slide-wire attenuator is provided with a compensating resistance by means of which the impedance is maintained constant.

In view of the very considerable range of voltages covered by this instrument—from 1 volt to below 1 microvolt—the selection of the attenuation steps has been made with a view to simplifying the reading of the instrument. The dial of the slide-wire unit reads from 1 to 10 on the decade covering the major portion of the scale. The extension is calibrated from 1 to 0.1. With the two-step attenuator out of circuit, these units correspond to millivolts, the three-step attenuator serving as a multiplier, having factors of 1, 10, and 100. Under these conditions, therefore, the three-step attenuator and the slide wire cover a range from 0.1 volt to 1 volt. By cutting in the 1000 to 1 attenuator, these voltages are reduced by a factor of 1000, and, consequently, are most conveniently expressed as microvolts.

The voltage indicated by the three attenuators (after the input voltage has been adjusted for a 2-volt deflection on the voltmeter) refers to the open-circuit voltage at the output terminals of the instrument. When working into a load of finite impedance the equivalent generator resistance of 200 ohms must be taken into account.

Inside the instrument is an impedance-matching transformer preceding the alternating-current voltmeter. This has been designed to give the instrument an internal input impedance of 5000 ohms. It is possible, as a result, to obtain sufficient power from oscillators such as the TYPE 377-B, TYPE 513-B, or TYPE 613-A, to maintain a reference potential of 2 volts.

While the transformer has been designed to have a reasonably flat characteristic over the frequency range, it is evident, since it precedes the voltmeter, that transformer losses do not enter into the measurements in any way. For convenience, the switching arrangement provides for maintaining constant the impedance of the attenuator as seen from the generator side. While this is not essential from the standpoint of voltage computations, it is convenient to avoid the necessity for readjusting the input power as the attenuation is altered.

This new unit has many applications in measurement work involving low voltages. It is useful for conveniently adjusting the output of vacuum-tube oscillators or other sources of alternating current. Used with the TYPE 486 Output Meters or a TYPE 583-A Output Power Meter it provides all the equipment necessary for measuring gain. —J. W. HORTON

WAVE ANALYSIS

In deciding whether to use 2A3 tubes or 2A5 tubes in a power amplifier we should like to know, not only the total distortion, but also how much 60-cycle and 120-cycle voltages are present and how much the output is modulated by the power frequencies. Further, in designing the amplifier, it is desirable to see whether or not the transformers introduce distortion at low frequencies and whether or not, in a push-pull stage, the second harmonic remains balanced out at high audio frequencies. Perhaps it is never absolutely necessary to answer questions like these—amplifiers have been built without them—but the ability to get answers when it seems necessary is a very valuable tool. It at least enables one to remove all technical doubts and to spend his time in developing a good design rather than in wondering what is happening in the circuit.

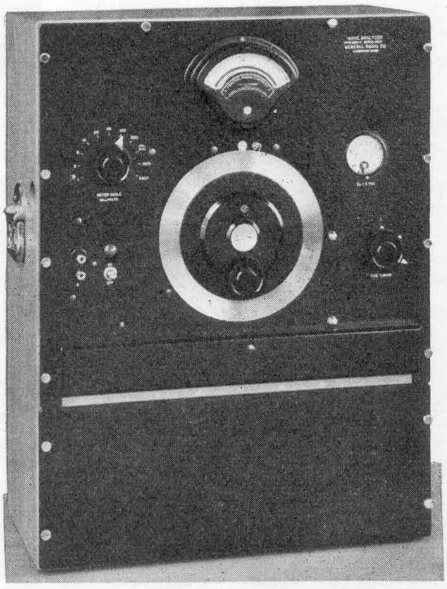


Figure 1. Above the frequency-control dial of the wave analyzer is the voltmeter shown in Figure 2. At the left is the meter multiplier

This is to describe a heterodyne wave analyzer which has been built to meet this need. The unit as completed is essentially a wide range voltmeter, responding to one very narrow band in the vicinity of any frequency between 0 and 15,000 cycles as chosen by the setting on a dial. The instrument consists of three parts, a heterodyning oscillator, a balanced modulator, and a 50,000 cycle amplifier, employing two quartz-crystal filters.

The oscillator frequency can be varied between 50,000 cycles and 35,000 cycles by means of a suitably shaped air condenser similar to that used in General Radio beat-frequency oscillators. An 8-inch dial is engraved to read directly the difference between the oscillator frequency and 50,000 cycles.

The balanced modulator circuit is shown in Figure 2. Its operation may be readily understood by considering the static case where a carrier signal of frequency P is applied in the common branch of the grid circuit and the voltage Q from grid to grid is varied.

When this voltage is zero, it is obvious by symmetry that no signal appears at the output. When grid *1* is positive with respect to grid *2*, the mutual conductance of tube *1* will be greater than that of tube *2* so that its output will be greater than that of the second tube and a signal will appear between the two plates. Further, for small unbalances the amplitude of the plate-to-plate signal will be proportional to the grid-to-grid unbalance.

When the tube is worked dynamically by applying a sinusoidal signal

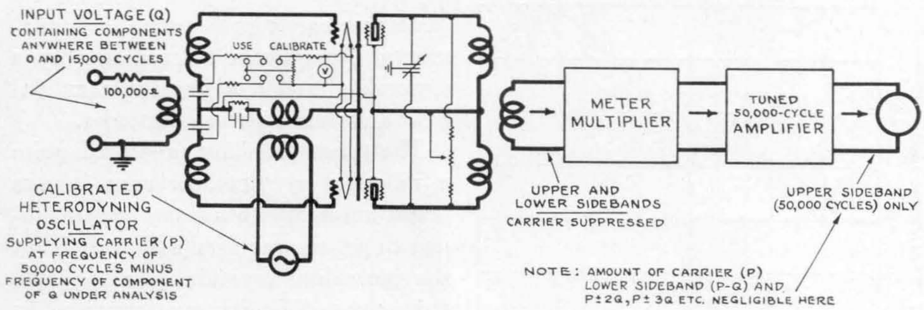


FIGURE 2. The TYPE 636-A Wave Analyzer has better frequency discrimination as well as other advantages over the conventional tuned-circuit analyzer

from grid to grid, the output will consist of the upper and lower side-bands, the carrier P being suppressed. The envelope of the output will be a series of half sine waves like the output of a full-wave rectifier.

Quite obviously the ratio of side-band amplitude to input signal amplitude will be proportional to the ratio of unbalanced carrier output to the grid-to-grid unbalancing voltage. This fact is made use of in calibrating the instrument. Thus the heterodyning oscillator is set to the frequency of the tuned amplifier and known incremental biases are inserted in the grid circuit. An uncalibrated volume control is then varied until the amplifier gives a predetermined output. This calibration is entirely self-contained and is dependent solely on the ratio of incremental bias and signal voltage. Detector tubes of a different type might, for example, be substituted, yet the

TWO EXAMPLES OF WAVE-ANALYZER PERFORMANCE

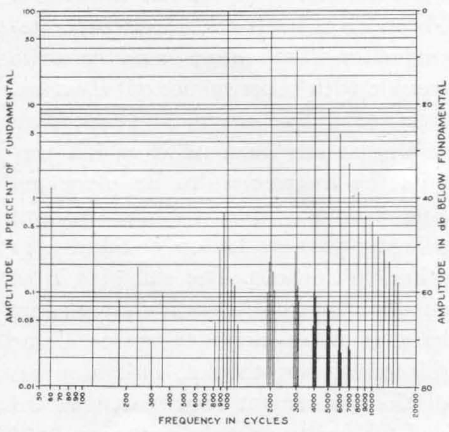


FIGURE 3. Output of a 1000-cycle multivibrator after amplification in an a-c-operated amplifier. This accounts for the presence of 60-cycle harmonic components as well as the upper and lower side-band frequencies of the 1000-cycle harmonics

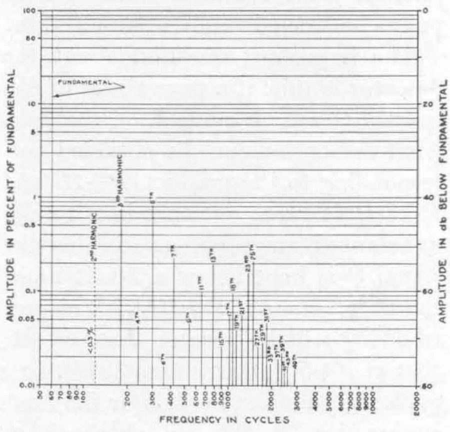


FIGURE 4. Wave analysis on a commercial 60-cycle circuit for components up to the 50th harmonic. The relative amplitudes were obtained directly from the analyzer's voltmeter by adjusting the fundamental for a deflection of 100 volts

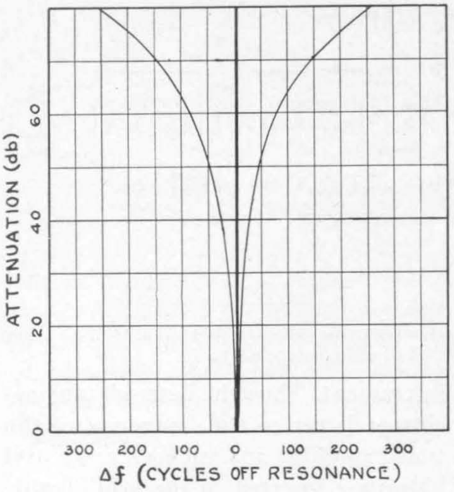


FIGURE 5. Over-all characteristic of the 50,000-cycle quartz-crystal filter in the wave analyzer. This filter passes the upper side-band only

same calibration would hold throughout

The circuits have been so arranged that the frequency characteristic is negligible. It will be noticed that the input circuit has an impedance of 100,000 ohms. The amplifier with output meter has been arranged with a multiplier to have full-scale value for 11 points between 1 millivolt and 2 volts.

The important question about the detector is this: if a pure signal of frequency Q were impressed on the grid, what response would be obtained corresponding to the products $P+2Q$ and $P+3Q$? It turns out that in a totally unbalanced amplifier, as long as the signal Q is kept below a 2-volt limit, the suppression of $P+2Q$ with respect to $P+Q$ will be greater than 60 db, that of $P+3Q$ greater than 80 db. In a perfectly balanced modulator the same suppression would be obtained to $P+3Q$, while $P+2Q$ would disappear entirely. Without using selected tubes we have had no difficulty in getting a suppression of 70 db for $P+2Q$, a value which is ample for most work. In particular research problems the fundamental Q might be filtered out (by a distortion factor meter, for example) before measuring the harmonics.

The tuned amplifier presented quite a practical problem, because it was found necessary to use two crystal filters to get the required selectivity, but the individual crystals were so sharp that some difficulty was expected in matching them. One of the crystals arranged in a three-electrode filter, as measured in a proper circuit where careful precautions have been taken to avoid regeneration and reaction of the measuring circuits, has a Q of about 25,000 giving a half-band width for 6 db of only 2 cycles. In practice, one of the crystals was allowed to operate at a Q of about 20,000 while the Q of the other is decreased to about 5000 by electrical damping. This makes it easy to match the two crystals and also keeps the amplifier from becoming too sharp for practical work. The filter characteristic is given in Figure 5. Three electrically-tuned circuits (included for other reasons) avoid possible trouble with other modes of vibration.

A carefully shielded 10-megohm multiplier has been made which permits the instrument to be connected almost anywhere in a circuit without using by-pass condensers or taking any other precautions. The shielding is so effective that no frequency error could be detected up to 50,000 cycles. Using this multiplier, the full-scale readings of the instrument range between 0.1 and 200 volts or a full range of 0.02 to 200 volts, since the meter may be used at approximately 1/10 scale. Probably this arrangement will be found the most convenient one in the majority of cases. — L. B. ARGUIMBAU

SUPPLEMENTARY SPECIFICATIONS

A Summary of Data Not Included in the Article Describing the Instrument

TYPE 528 CATHODE-RAY OSCILLOGRAPH ASSEMBLY

(*See page 1 also*)

NOTE: This equipment includes the following 3 units:

TYPE 528-A Cathode-Ray Tube
TYPE 579-A Tube Mounting
TYPE 580-A Power-Supply Unit

TUBES: The TYPE 528-A Cathode-Ray Tube should be ordered separately. *Code Word:* CAMEL. *Price*, $115.00. The rectifier tube is included in the power-supply unit.

POWER SUPPLY: The TYPE 580-A Power Supply Unit supplies filament, anode, and focusing voltage for the TYPE 528-A Cathode-Ray Tube from the 115-volt, 60-cycle mains. A TYPE 143-D Rectifier Tube is included. *Code Words:* TYPE 580-A, CULPA; TYPE 143-D (replacement), FAIRY. *Prices:* TYPE 580-A, $170.00; TYPE 143-D (replacement), $3.00.

TUBE MOUNTING: The TYPE 579-A Tube Mounting is a convenient means of supporting the tube, of protecting it against accidental breakage, and of making connections. It includes the cable and jack for making power connections to the power-supply unit. *Code Word*, COFIN. *Price*, $45.00.

DIMENSIONS: TYPE 580-A, (width) 19¼ x (height) 9⅛ x (depth) 10 inches, over-all. TYPE 579-A, (length) 25 x (height) 10 x (depth) 9 inches, over-all exclusive of cable.

NET WEIGHT: TYPE 580-A, 36 pounds. TYPE 579-A, 18½ pounds, including TYPE 528-A Tube and Cable.

PRICE: $330.00. See TUBES, POWER SUPPLY, and TUBE MOUNTING (above) for prices of the three components of this assembly.

TYPE 635-A ELECTRON OSCILLOGRAPH

(*See page 1 also*)

TUBES: The TYPE 635-P1 Cathode-Ray Oscillograph Tube required for this instrument is supplied.

POWER SUPPLY: The instrument operates from the 115-volt, 60-cycle mains. A 6-foot attachment cord is supplied.

DIMENSIONS: (Height) 13½ x (width) 16 x (depth) 6¼ inches, over-all.

NET WEIGHT: 19 pounds, including tubes.

CODE WORDS: TYPE 635-A, CUPID; TYPE 635-P1 Cathode-Ray Tube (replacement), CURLY; TYPE 143-D Rectifier Tube (replacement), FAIRY.

PRICE: TYPE 635-A Electron Oscillograph, $90.00, including tubes. TYPE 635-P1 Cathode-Ray Tube (replacement), $30.00. TYPE 143-D Rectifier Tube (replacement), $3.00.

TYPE 200 VARIAC

(*See page 5 also*)

DIMENSIONS: TYPE 200-CM, (height) 5½ x (diameter) 6⅞ inches, over-all. TYPE 200-CU, (depth behind panel) 4⅛ x (diameter) 6 inches, over-all.

NET WEIGHT: 8 pounds.

CODE WORDS: TYPE 200-CM, BALMY; TYPE 200-CU, BAKER.

PRICE: TYPE 200-CM, $16.50; TYPE 200-CU, $14.00.

Continued on following page

SUPPLEMENTARY SPECIFICATIONS (Concl'd)

TYPE 544-A MEGOHM METER

(*See page 7 also*)

TUBES: One 32-type required and supplied with the instrument.

POWER SUPPLY (BATTERIES): *Filament*, two No. 6 dry cells. *Plate*, two 45-volt block batteries, Burgess No. 5308 or equivalent. Space for mounting all batteries is provided inside the cabinet. Connections are made by a 7-prong plug and coded cable supplied. Batteries are not supplied. *Weight of Batteries*, 7½ pounds.

POWER SUPPLY (*60-cycle a-c*): A TYPE 544-P1 Power Supply Unit that fits the battery compartment can be ordered separately to supply both plate and filament power from a 115-volt line. The 82-type and 874-type tubes and the line cord required are supplied. *Net Weight*, 7½ pounds. *Code Word*, ALOOFAPACK. *Price*, $35.00 with tubes.

DIMENSIONS: *Cabinet with cover closed*, (width) 8½ x (length) 22½ x (height) 8 inches, over-all.

NET WEIGHT: 13½ pounds without batteries.

CODE WORD: ALOOF.

PRICE: $165.00 including tubes, but without batteries or TYPE 544-P1 Power-Supply Unit.

TYPE 632-A CAPACITANCE BRIDGE (For Electrolytic Condensers)

(*See page 6 also*)

TUBES: The two 57-type and one 523-type tubes required are supplied with the instrument.

POWER SUPPLY: All power is derived from the 115-volt, 60-cycle mains, a 6-foot cord for connecting which is included.

DIMENSIONS: *Panel*, (width) 12 x (depth) 15 inches. *Entire instrument*, (width) 12 x (depth) 24½ x (height) 8 inches, over-all.

NET WEIGHT: 46 pounds.

CODE WORD: BEADY.

PRICE: $300.00 including tubes.

TYPE 546-A MICROVOLTER

(*See page 10 also*)

DIMENSIONS: (Width) 7⅛ x (length) 10 x (height) 5¾ inches, over-all.

NET WEIGHT: 8¼ pounds.

CODE WORD: CROWN.

PRICE: $70.00.

TYPE 636-A WAVE ANALYZER

(*See page 12 also*)

TUBES: Three 41-type and two 78-type tubes are required and supplied with the instrument.

POWER SUPPLY: *Filaments*, from 6-volt storage battery by means of plug-and-clip leads supplied. *Plates*, from three 45-volt blocks, mounting space for which is available in a compartment behind the lower panel section of the instrument.

DIMENSIONS: *Panel* (*2 sections*), (width) 19 x (height) 24¼ inches. *Cabinet*, (width) 20½ x (height) 25 x (depth) 11 inches, over-all.

NET WEIGHT: 65 pounds.

CODE WORD: ABOVE.

PRICE: $475.00 with tubes but without batteries.

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

CHRONOGRAPH MEASUREMENTS IN CHEMISTRY

HIGH precision time measurements have recently enabled chemists to measure accurately for the first time the minute change in viscosity which occurs when a pinch of salt is added to a quart of water. By so doing, they were able to prove experimentally certain new modifications of the theory of electrolytic dissociation and to show that in weak solutions of some salts the viscosity actually increases with concentration instead of decreasing as conventional theory predicts.*

This was done by comparing the time required for a given volume of the solution to drain through a certain capillary tube with the time required for the same volume of pure water under identical conditions of temperature, hydrostatic head, etc. It was necessary to determine a time interval of approximately 10 minutes to within 0.01 second, a precision of one part in 60 thousand or 0.002 per cent.

The viscometer used, see Figure 1, was constructed of fused quartz and mounted in a water bath, thermostat-regulated to within 0.001° C. The liquid to be measured was sucked up through the capillary tube until it more than filled the enlargement therein, so that the meniscus was above the upper constriction. Two beams of light were passed through the glass walls of the thermostat tank and accurately focused upon the two constrictions.

As the liquid drained under gravity

*Professor Grinnell Jones and Dr. Samuel Talley, Malinckrodt Chemical Laboratory, Harvard University, through whose courtesy we publish this article. See Jones and Talley: *Jour.* Amer. Chemical Society, Vol. 35, p. 624; *Physics*, Vol. 4, June, 1933.

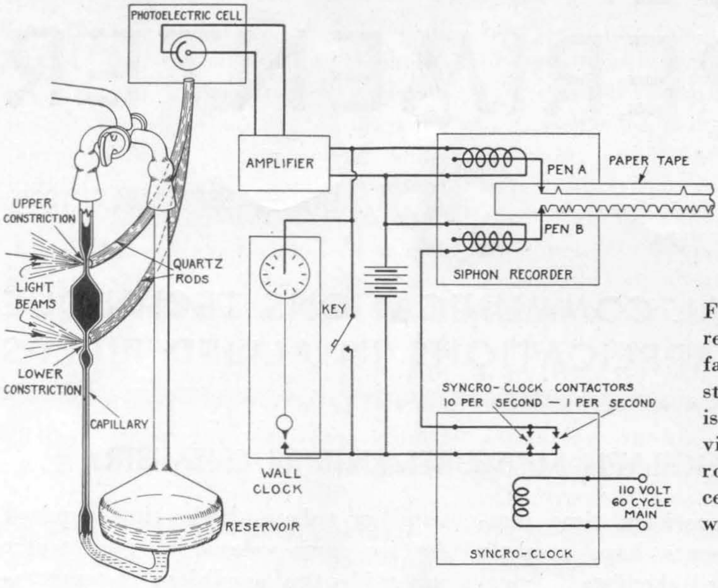


FIGURE 1. The time required for liquid to fall from one constriction to the other is a measure of its viscosity. The quartz rods, photo-electric cell, and chronograph were essential elements in this work

back into the reservoir, the falling meniscus would first pass the upper constriction; and, about 10 minutes later, the lower constriction.

A branched, solid quartz rod was placed in the bath at approximately right angles to the incident light beams, the branched ends terminating close to and on a level with the constriction points. The common end of this quartz Y assembly was brought up from the surface of the thermostat bath and presented to a photo-electric cell.

Whenever the meniscus passed either constriction, the change in the diffraction properties of the filled and the empty tube caused a beam of light to rotate rapidly about the constriction point, in a horizontal plane through the water bath. This beam was momentarily picked up by the corresponding branch of the Y rod so that a short, sudden pulse of light, carried by internal reflection in the bent quartz rod, was passed into the photo-electric cell.

The General Radio TYPE 456 Duplex Siphon Recorder served as the chronograph. This device contained two independently operated pens making adjacent lateral records on a strip of "ticker tape" advanced by a series motor, the speed of which could be adjusted at will.

One of these pens *A* was energized by three independent means: (1) by either the upper or the lower transit of the meniscus, (2) by 1-second impulses from an invar 2-second pendulum in a high grade wall clock, known to be accurate to better than the desired precision, and (3) by a hand key operated to identify any desired second read on the face of the wall clock. The second pen *B* of the chronograph was energized ten times per second by a pair of cam-operated contacts driven by a 600-rpm shaft in the General Radio TYPE 511-S Syncro-Clock, which was energized by the 60-cycle city supply main. This syncro-clock would keep perfect time if supplied with a current of exactly 60 cycles. By means of a second cam contact (60 rpm), 1-second intervals were likewise indicated on this *B* pen record midway between two of the adjacent high-speed pulses.

Shortly before the falling meniscus reached the upper constriction point (see Figure 1) the operator started the paper tape at full speed and depressed the key momentarily to identify a given second on the face of the wall clock. A few seconds after the upper meniscus transit had been recorded by the *A* pen, the tape was run slowly and, after a 10-minute interval, as the meniscus was seen to approach the lower constriction point, the paper was speeded up and the same procedure repeated.

The accuracy of timing did not depend upon the frequency of the 60-cycle main, but upon the precision of the wall clock. The 0.1-second intervals supplied by the syncro-clock served merely to decimate the 1-second interval recorded by the wall clock within which the meniscus record occurred. In this manner, a frequency stability of the 60-cycle main of only 1 per cent over a 1-second interval was required. Likewise, a paper speed variation of 10 per cent within 0.1 second would not introduce an appreciable error. Since the tape traveled at approximately 12 inches per second, it was readily possible to interpolate to 0.01 second between the 0.1-second markings supplied by the syncro-clock.

Accurate chronographic measurements can thus be made placing no reliance upon the uniform movement of the chronograph tape itself. This is a desirable feature.

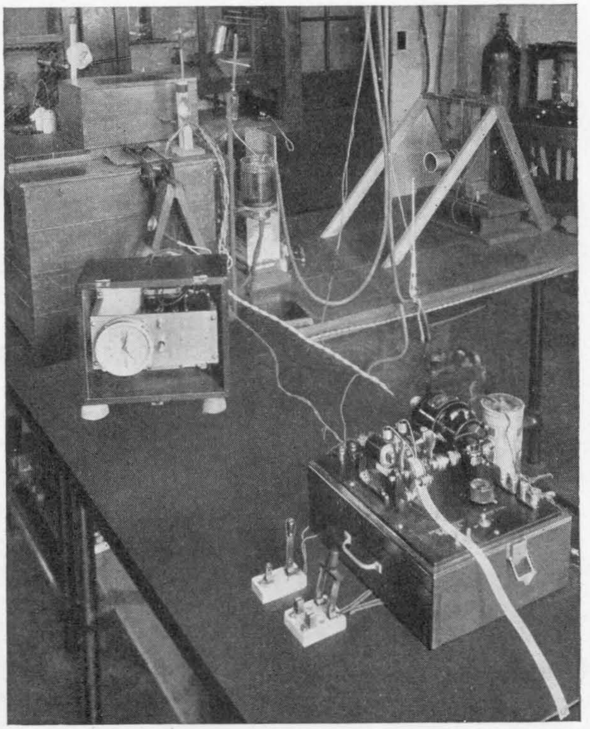


FIGURE 2. The viscosity measuring apparatus. In the foreground is the siphon recorder, behind it the syncro-clock, and, at the rear, the water bath containing the viscosimeter. The light source is at the extreme right

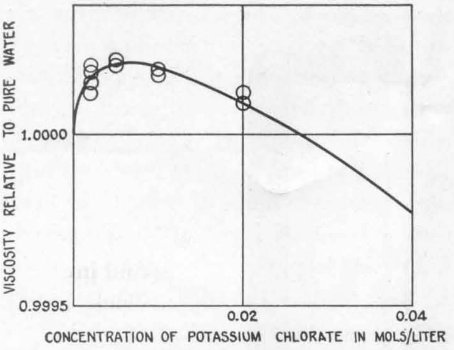


FIGURE 3. Conventional theory predicts a *decrease* in viscosity with an increase of concentration. The data showing *increase* supply evidence for a new modified theory

Had the syncro-clock been driven by an alternating-current source of 60 cycles, or any other frequency with suitable design of the clock, which was constant at all times to the order of one part in one hundred thousand, it would not have been necessary to use the wall clock as a basis of time measurement.

It was possible to secure measurements on duplicate consecutive runs which were identical to within 0.01 second for the 10-minute interval. While taking data, frequent runs were made with distilled water for reference values. This procedure eliminated the possible error due to slow variations in the rate of the wall clock over long periods of time.

An example of the data obtained is indicated in Figure 3, where the abscissa scale represents the fractional part of normal concentration of potassium chlorate, and the ordinate scale represents the measured viscosity in terms of distilled water. The increase in viscosity at low concentration above that of pure water is clearly apparent.

—HORATIO W. LAMSON

A LARGER EDGERTON STROBOSCOPE

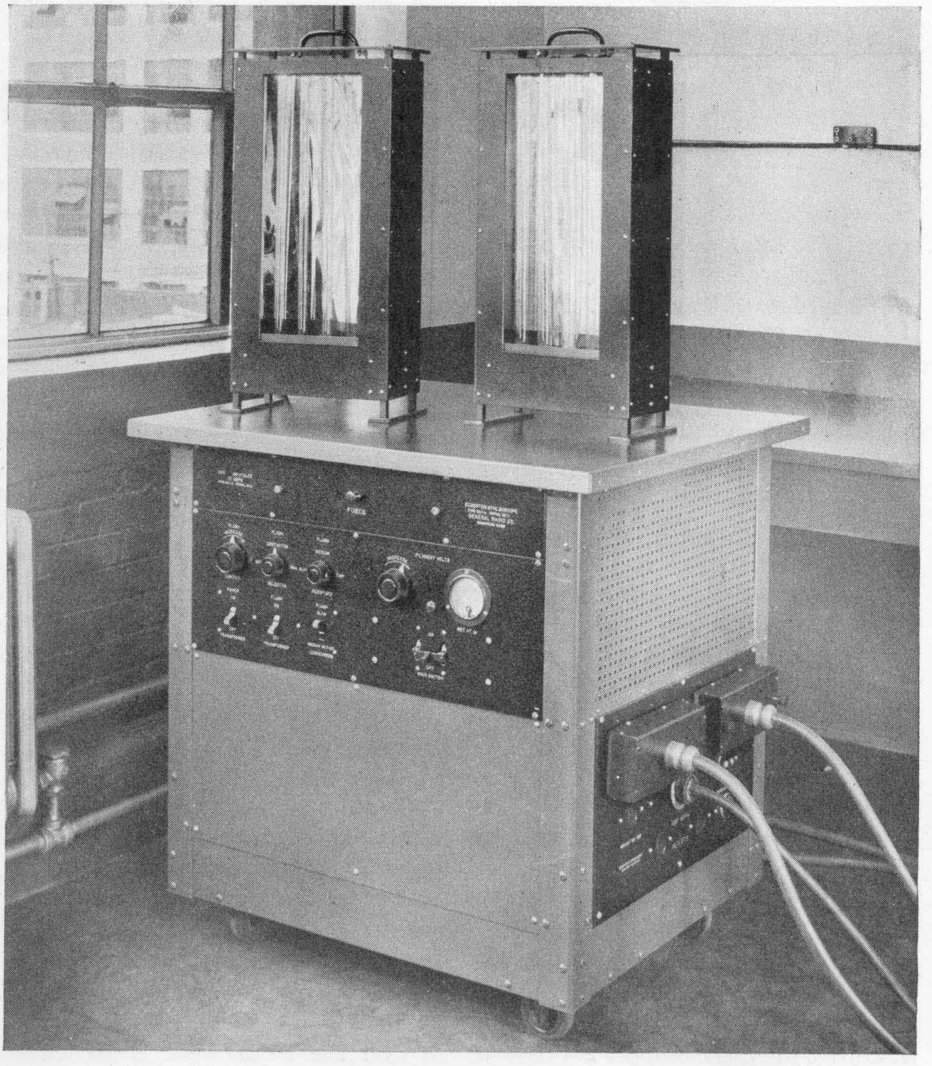
WITH both lamp banks of this new Edgerton Stroboscope in operation, a fair-sized room can be literally flooded with stroboscopic light. Due to the greater brilliance of the illumination provided, this equipment is essentially useful for large scale inspection operations, for the observation of large machines, and for photography.

The TYPE 521-A Edgerton Stroboscope operates from any 115-volt, 60-cycle supply main and requires from 1 kw to 3.5 kw, depending upon the operating conditions. One lamp bank may be used alone or the two may be used simultaneously. Both can be moved around within the range of the long cables.

The stroboscope may be flashed by a motor-driven contactor, by the 60-cycle line, or by an oscillator, provided that sufficient voltage is available. About 100 volts is required at 60 cycles and somewhat higher voltages for the higher frequencies.

Arrangements can be made to take instantaneous flash photographs such as would be required for the analysis of non-repeating motions.

This apparatus is representative of



The power supply and the control equipment for the TYPE 521-A Edgerton Stroboscope are contained inside the truck. The two lamp banks on the table top can be moved anywhere within range of the cables at the right

a new line of high power stroboscopes that General Radio has had under development for some time. Designs have been completed for standard modifications to meet special conditions by the addition of standardized accessories. The price of the TYPE 521-A Edgerton Stroboscope with one lamp bank is $1200. Specific performance data will gladly be sent on request. A statement of the proposed operating conditions should, if possible, be included.

IMPROVING QUALITY IN BROADCAST TRANSMISSION

A FEW weeks ago, the owner of a fair-sized broadcasting station came to us with a tale of woe. For some reason, people didn't listen to his station and program sponsors were becoming scarcer and scarcer.

The studios of this particular station, although not equipped like those of some of the large metropolitan broadcasters, were modern and entirely adequate. Acoustical treatment had been installed and the station boasted of its dynamic and ribbon microphones. Its transcription equipment was the best.

Nevertheless, a few minutes of listening to this station disclosed why it was not more popular. We were tempted to ask the owner if he had ever listened to his own transmitter. Certainly the program sponsor would not be particularly pleased with the inhuman racket which the transmitter ground out as his program.

A careful checkup of the transmitter with a General Radio modulation meter and distortion-factor meter disclosed that, under some conditions, the total harmonics in the output exceeded 30 per cent (the upper limit that the distortion-factor meter will measure). Furthermore, the frequency-response characteristic was down approximately 30 decibels at 60 cycles and at 5000 cycles.

Replacement of a few tubes and a defective transformer, together with readjustment of biasing voltages in the modulator unit, produced a marked improvement. By careful adjustment, the harmonic distortion was brought down to 5 per cent and the frequency characteristic was made a practically straight line. The total cost of the new tubes and transformer and of the necessary measuring equipment was considerably less than the station had previously spent in a vain effort to improve the quality of the transmission.

The owner of this broadcasting station had spent large sums for elaborate equipment, much of which was not really necessary, and, at the same time, had neglected other parts of his transmitting setup, taking it more or less for granted that they were perfect because they were expensive. While well-designed transmitters do not easily get out of adjustment, normal aging and changes in climatic conditions may produce shifts which will affect the operation very seriously.

This is particularly true of vacuum tubes, which frequently change their characteristics as they grow older to such an extent that appreciable amounts of harmonic distortion and frequency discrimination are introduced into the transmitting system. Resistors used as grid leaks, bias controls and voltage dividers frequently open up or shift with climatic changes, so that the adjustment is no longer correct for best operating conditions. Some audio-frequency transformer cores become saturated or lose their permeability after continued use.

Most of these effects take place slowly and are hardly noticeable at first. As the sum total of distortion begins to increase, however, a marked reduction in the quality of transmission becomes apparent. By the time

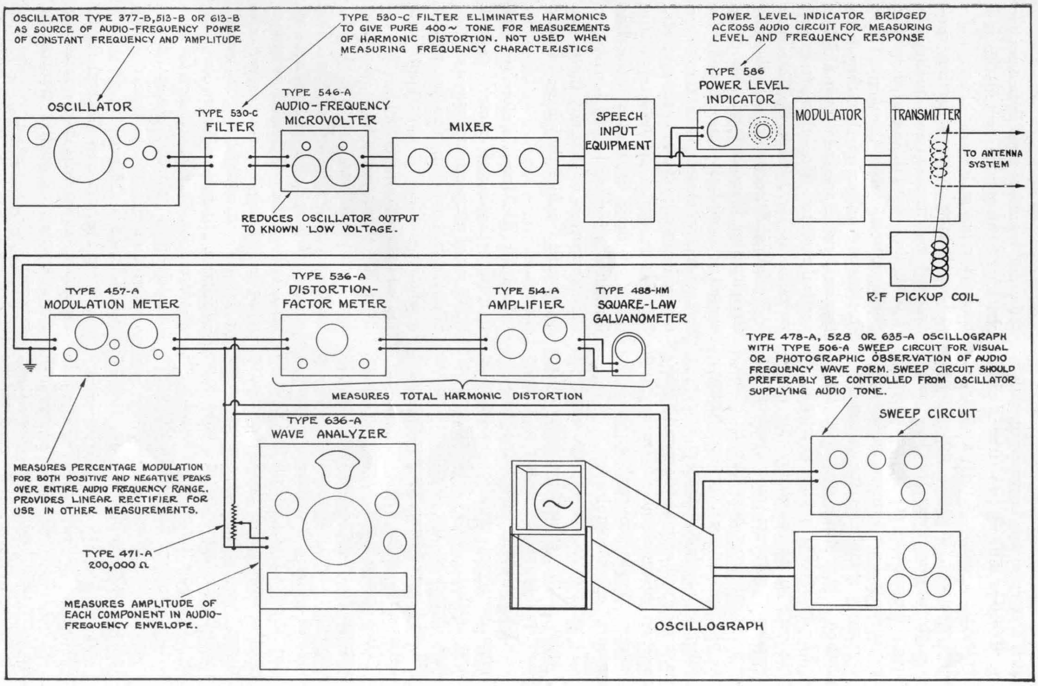


FIGURE 1. Schematic diagram showing apparatus required for broadcast transmission measurements. (See opposite page)

such distortion has become noticeable, it is very difficult to trace, since replacing a single faulty component will generally, in itself, not produce enough improvement to be readily detected except by sensitive measuring instruments. Furthermore, any attempt to remedy a fault by the cut-and-try method is necessarily uneconomical.

The question of quality is constantly receiving more attention by both broadcast listeners and sponsors of commercial programs. The Bell Telephone Laboratories' recent binaural transmission demonstration seems to have received as much favorable comment on the remarkable frequency and volume ranges covered as on the binaural effects obtained.

There is no reason why the owner of a small station should not insist on as good quality as the owner of a large multi-kilowatt transmitter. Broad-range receivers require broad-range broadcasting. With 2A3 tubes and diode detectors, the broadcast listener will no longer blame the squawks and rattles on his set.

The General Radio Company manufactures all the equipment necessary to determine closely the quality of transmission of any broadcasting station. The Type 457-A Modulation Meter* and the Type 536-A Distortion-Factor Meter,* as well as several styles of audio-frequency oscillators, have been used for some time by leading broadcasting stations. Several of the newer instruments, such as the Type 546-A Audio-Frequency Microvolter† and the Type 636-A Wave Analyzer,† are also extremely valuable for this work. There is hardly any need to mention the Type 586 Power-Level Indicators,* which are quite generally used by the radio and sound-picture industries for checking frequency characteristics and measuring power levels.

Two Boston stations having consistently high transmission quality are WNAC and WAAB, operated by the Shepard Broadcasting Company. These stations are unique in that they both transmit simultaneously from a single vertical radiator. The other afternoon, we called up Mr. Paul A. DeMars, who is Technical Director of the Shepard Broadcasting Company and who purchased a modulation meter and distortion-factor meter when they were first announced, several years ago. Mr. DeMars is quite enthusiastic in his praise of these instruments. He has instituted a regular testing routine for the transmitters so that any faults can be remedied before they have become serious.

Said Mr. DeMars, "Before we had the distortion-factor meter, correct lining up of a transmitter was a matter of anybody's opinion. Now, we set up a definite standard of operation which the equipment must meet."

At 30 per cent modulation, the limit for harmonic distortion which Mr. DeMars has set is 3 per cent. This means that at lower percentages of modulation, the distortion is somewhat less, being less than 1 per cent at 10 per cent modulation. By careful adjustment, it is possible to keep the distortion low even at high percentages of modulation. For instance, at 90 per cent modulation, the harmonic distortion is less than 10 per cent.

Figure 1 shows how General Radio measuring equipment is connected to a transmitter. A perfect transmitter

*See Catalog G, General Radio Company.

†General Radio *Experimenter*, June–July, 1933.

(Continued on page 10)

NEW KNOBS AND DIALS

WHERE controls have to be manipulated for long periods or where fine adjustment of controls has to be made, all present types of knobs fail to be entirely satisfactory. To meet the need for an easier-to-handle knob, General Radio has designed a series of new knobs of polished black bakelite.

TYPE 637 FLUTED KNOBS

1⅛-INCH DIAMETER

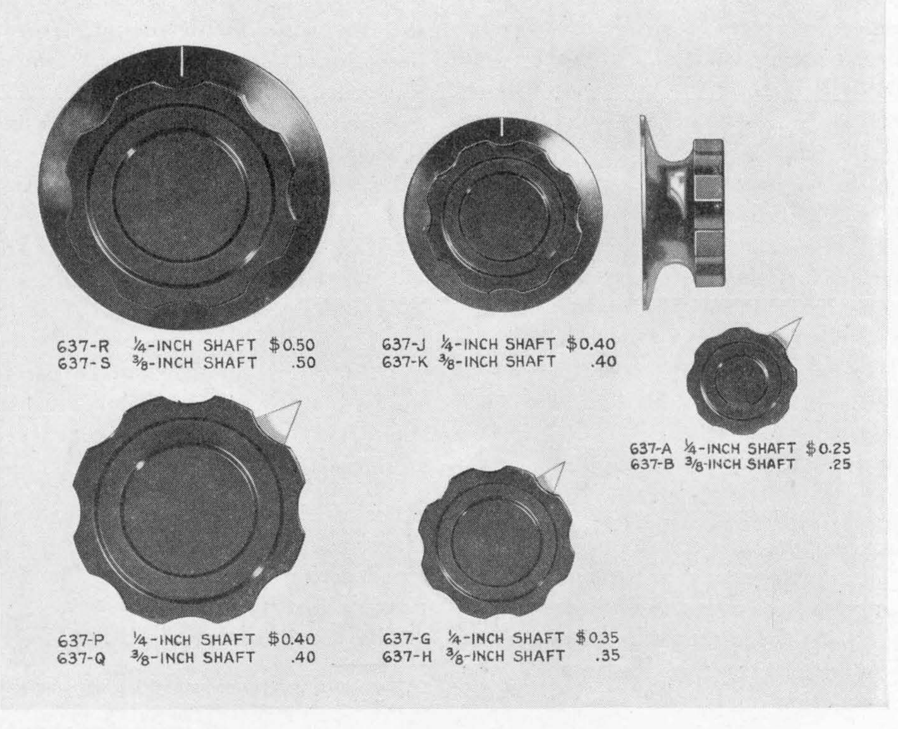
Type	*Shaft Diam.*	*Description*	*Code Word*	*Price*
637-A	¼ in.	With Pointer	NURLNOBANT	$0.25
637-B	⅜ in.	With Pointer	NURLNOBOY	.25

1⅝-INCH DIAMETER

Type	*Shaft Diam.*	*Description*	*Code Word*	*Price*
637-G	¼ in.	With Pointer	NURLNOBGUN	$0.35
637-J	¼ in.	With Skirt (2 1/16″ diameter) and Engraved Line	NURLNOBJIM	.40
637-H	⅜ in.	With Pointer	NURLNOBHAT	.35
637-K	⅜ in.	With Skirt (2 1/16″ diameter) and Engraved Line	NURLNOBKOP	.40

2⅜-INCH DIAMETER

Type	*Shaft Diam.*	*Description*	*Code Word*	*Price*
637-P	¼ in.	With Pointer	NURLNOBPIG	$0.40
637-R	¼ in.	With Skirt (3″ diameter) and Engraved Line	NURLNOBRAM	.50
637-Q	⅜ in.	With Pointer	NURLNOBQUO	.40
637-S	⅜ in.	With Skirt (3″ diameter) and Engraved Line	NURLNOBSUM	.50



The new knobs are fluted with all contact edges rounded to minimize wear and tear on the fingers of the operator; they are supplied with two setscrews to insure permanent setting, and they are available with either a celluloid pointer (which may be pried off) or with a wide flanged skirt which assists in ease of handling, prevents the fingers from touching any "live" parts and materially improves the appearance of the associated equipment. The skirted knobs are provided with a white engraved index line.

The present general-purpose types of General Radio dials are also available with the new knobs. For the present we will stock both styles of knobs and dials for the convenience of persons using equipment with the old-style knob.

TYPE 702 FRICTION-DRIVE DIALS
TYPE 710 PLAIN DIALS
2¾-INCH DIAMETER

Type	*Shaft Diam.*	*Dial Arc*	*Dial Divisions*	*Friction-Drive Ratio*	*Knob Style*	*Code Word*	*Price*
702-A	¼ in.	180°	100	1:3.3	637-J	DIACK	$1.75
710-A	¼ in.	180°	100	....	637-J	DIALY	1.00
702-B	¼ in.	270°	100	1:3.3	637-J	DIBOG	1.75
710-B	¼ in.	270°	100	....	637-J	DIBIN	1.00
702-F	⅜ in.	180°	100	1:3.3	637-K	DIFAG	1.75
702-G	⅜ in.	270°	100	1:3.3	637-K	DIGOD	1.75
710-G	⅜ in.	270°	100	....	637-K	DIGUT	1.00

TYPE 703 FRICTION-DRIVE DIALS
TYPE 717 PLAIN DIALS
4-INCH DIAMETER

Type	*Shaft Diam.*	*Dial Arc*	*Dial Divisions*	*Friction-Drive Ratio*	*Knob Style*	*Code Word*	*Price*
703-A	¼ in.	180°	100	1:5	637-R	DIANT	$2.00
717-A	¼ in.	180°	100	....	637-R	DIARM	1.50
703-B	¼ in.	270°	200	1:5	637-R	DIBUT	2.00
717-B	¼ in.	270°	200	....	637-R	DIBAR	1.50
703-F	⅜ in.	180°	100	1:5	637-S	DIFUN	2.00
717-F	⅜ in.	180°	100	....	637-S	DIFIT	1.50
703-G	⅜ in.	270°	200	1:5	637-S	DIGUM	2.00
717-G	⅜ in.	270°	200	....	637-S	DIGAR	1.50

(Continued from page 8)

would, of course, have equal percentage modulation on both positive and negative peaks for any audio-frequency and any percentage modulation up to 100 per cent. Careful adjustment of most transmitters will result in a close approach to this condition.

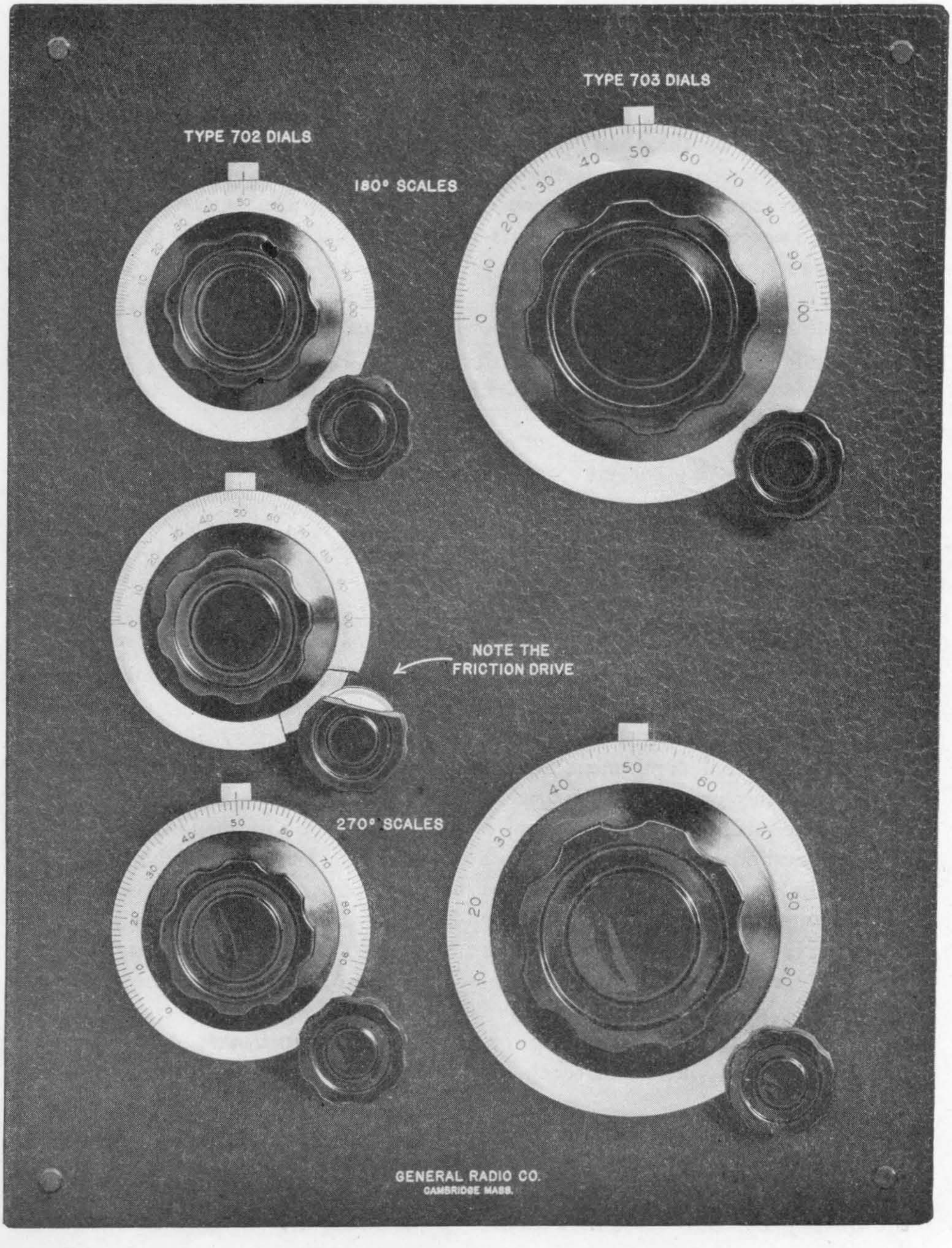
If the frequency of the audio oscillator is varied over the audio-frequency band and the input to the mixer system held constant, the readings of the modulation meter will give a direct indication of the frequency response of the transmitting system as a whole.*

The distortion-factor meter reads directly in total harmonic distortion. This, together with the modulation meter and suitable accessories (see Figure 1), is indispensable in any broadcasting station desiring the best possible quality.

The wave analyzer will be found

*This instrument has no appreciable frequency error up to 20,000 cycles per second.

(*Continued on page 12*)



Both the TYPE 702 (2¾ inch) Dials and the TYPE 703 (4 inch) Dials shown above are available without the friction drive. (See the table on the opposite page)

NEW SPECIFICATIONS FOR TYPE 505 CONDENSERS

The Type 505 Condensers are a new line of semi-precision mica condensers described in the January, 1933, issue of the *Experimenter*. Since the publication of that article, additional laboratory data and information gained from manufacturing experience have made necessary the several specification changes noted in the following table.

The statement of a maximum peak voltage in connection with a frequency means that the condenser will stand the alternating-current voltage whose peak equals the given rating, up to the given frequency. Above that frequency the allowable voltage decreases inversely with the square root of the frequency. This is due to the fact that the power loss and, therefore, the allowable voltage increase with the square of the frequency.

Type	*Capacitance*	*Adjusted to Within*	*Power Factor*	*Maximum Voltage*		*Price*
				Voltage	*Frequency*	
505-A	100 μμf	10%	0.1%	1200 volts	1100 kc	$3.50
505-B	200 μμf	5%	0.1%	1200 volts	550 kc	3.50
505-E	500 μμf	2%	0.05%	1200 volts	220 kc	3.50
505-F	0.001 μf	1%	0.05%	700 volts	320 kc	3.50
505-G	0.002 μf	1%	0.05%	700 volts	160 kc	3.50
505-K	0.005 μf	1%	0.05%	700 volts	64 kc	4.00
505-L	0.01 μf	1%	0.05%	350 volts	160 kc	4.50
505-M	0.02 μf	1%	0.05%	350 volts	80 kc	5.50
505-Q	0.05 μf	1%	0.05%	350 volts	32 kc	7.50

(Continued from page 10)

valuable for measuring harmonic distortion at frequencies other than 400 cycles and for measuring the amplitude of each individual component in the audio-frequency envelope. The oscillograph is helpful, since the shape of a distorted audio wave frequently gives a clue to the source of distortion. These instruments and the distortion-factor meter may, of course, be bridged across practically any audio circuit to measure the distortion in different parts of the system. Complete operating instructions are supplied with each instrument.

A careful checkup on the operating characteristics of any transmitter will prove of great assistance in improving the quality of transmission. Without exact data as to the nature and cause of any distortion which may take place, attempts to remedy it are generally unsatisfactory. Any broadcasting station doing a reasonable amount of business should be equipped with the proper apparatus for maintaining a high quality of output. Stations which cannot afford complete equipment of this sort would do well to engage the services of reliable consulting engineers who have the necessary equipment.

An investment in good transmission pays large dividends in the form of more and bigger commercial accounts. Other things being equal, the station having the best quality transmission is certain to be the most highly favored by the listener. —H. H. Scott

GENERAL RADIO COMPANY
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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

SIMPLIFYING EXPERIMENTAL-EQUIPMENT CONSTRUCTION

IN modern experimental setups the original "breadboard" assembly is rapidly disappearing, especially where high-frequency, multi-tube circuits are involved. For one to properly judge the operating performance of a circuit, the use of metallic panels, bases, and shields is always desirable and in many cases absolutely imperative. To the experimenter lacking machine-shop facilities, the most difficult part of assembling experimental equipment is the mechanical work of cutting, drilling, and finishing panels, base plates, dust covers, shields, and other parts.

The General Radio Company has recently developed new unit-panel equipment designed to facilitate the fabrication of experimental and semi-permanent assemblies. An advantage of the unit-panel idea is that all parts are interchangeable. The complete assembly is mechanically rugged and neat in appearance. The apparatus is equally suited to relay-rack or table mounting. Circuit changes can be made at any time without disfiguring the panel, and the unit is easily disassembled for conversion into an entirely different instrument.

> **UNIT PANEL CONSTRUCTION**
>
> is adapted to all kinds of communications equipment:
>
> Laboratory apparatus
> Public address systems
> Experimental receivers and transmitters

The parts required for a complete metal box are a base, two end plates, a dust cover, a panel, and the accessories supplied with the panel. All of the principal parts are made of Eraydo, a non-magnetic, non-corrosive alloy of copper, silver, and zinc, which is stronger than materials commonly used for such parts. One side of the Eraydo is satin finished and coated with clear lacquer. Where good contact between surfaces is essential for shielding, the lacquer may be removed with fine sandpaper.

Three standard ⅛-inch panels are

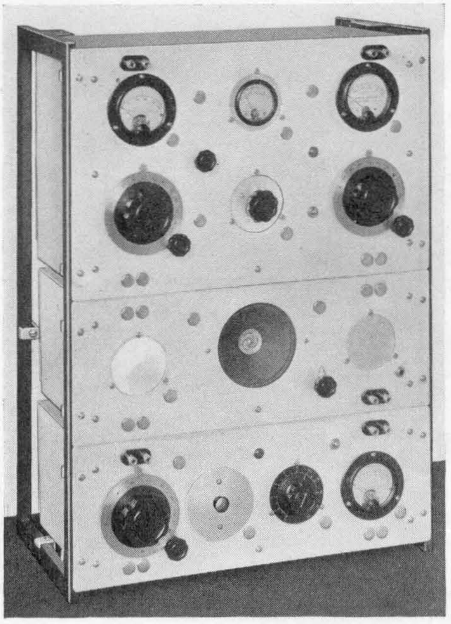


FIGURE 1. Some of the combinations that are possible with General Radio unit-panel construction. The TYPE 660-A Universal Rack and the method of clamping it to wall or table are clearly shown. See page 6 for rack details

available: one, 19 by 12 inches and two, 19 by 7 inches. Type numbers and the location of all holes are shown on page 4. Each panel has several 2⅞-inch diameter holes symmetrically placed. Around each of these holes three small mounting holes are provided, the combination being suitable either for mounting the standard bakelite*(Navy type) meter case, or for fastening the various mounting discs to the panel. Adjacent to each large panel hole is a ½-inch hole for the slow-motion mechanism of the 4-inch TYPE 503 or TYPE 703 Dials.

Other ½-inch holes are machined in each panel. At both top and bottom near either end are located pairs of holes on ¾-inch centers to fit TYPE 274-Y Panel Terminal Insulators and TYPE 138-VD Binding Posts for input and output connections. Other holes are intended for single-hole-mounting parts such as rheostats, neutralizing condensers, telephone jacks, toggle switches, anti-capacitance switches, etc. Bushings for reducing the diameter of the holes to 7/16 inch or ⅜ inch are furnished with the panel. The unused holes are plugged with TYPE 661-P4 Snap Buttons which match the panels in finish and are easily removable.

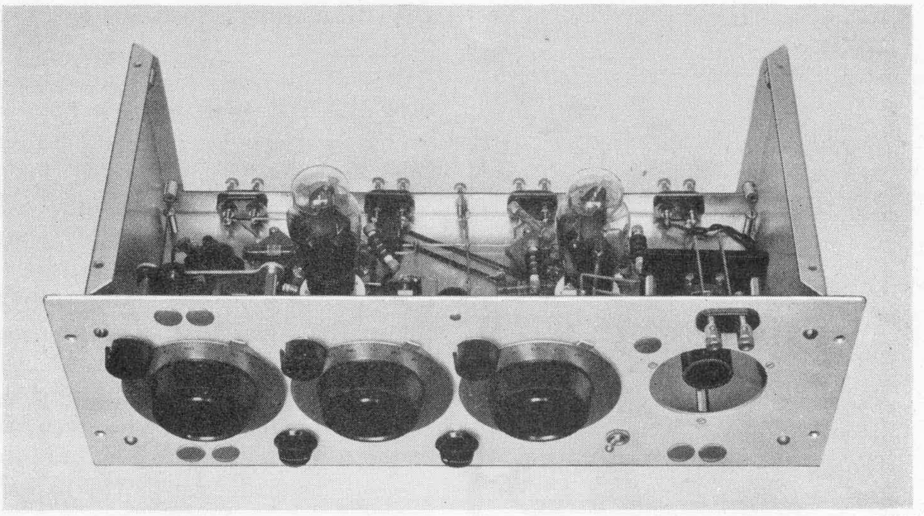
One panel is furnished with a 5-inch permanent-magnet dynamic loud-speaker, the input impedance of which is 3000 ohms.

Four types of mounting discs are available. The TYPE 661-P1 Blank Mounting Disc is a blank fastened to either the front or the back of the panel by means of machine screws and three small holes which line up with the three meter-mounting holes in the panel. The blank discs are used either to cover the large panel holes not in use, or to mount parts other than those manufactured by General Radio. The center of each blank is prick-punched on the reverse side to assist the user in laying out mounting holes.

The TYPE 661-P2 3-Hole Mounting Disc has three small holes drilled on a ⅞-inch radius to mount any standard General Radio part such as condenser, rheostat, potentiometer, etc. Short spacers which are sometimes necessary to provide clearance for the panel-mounting screws are furnished with the

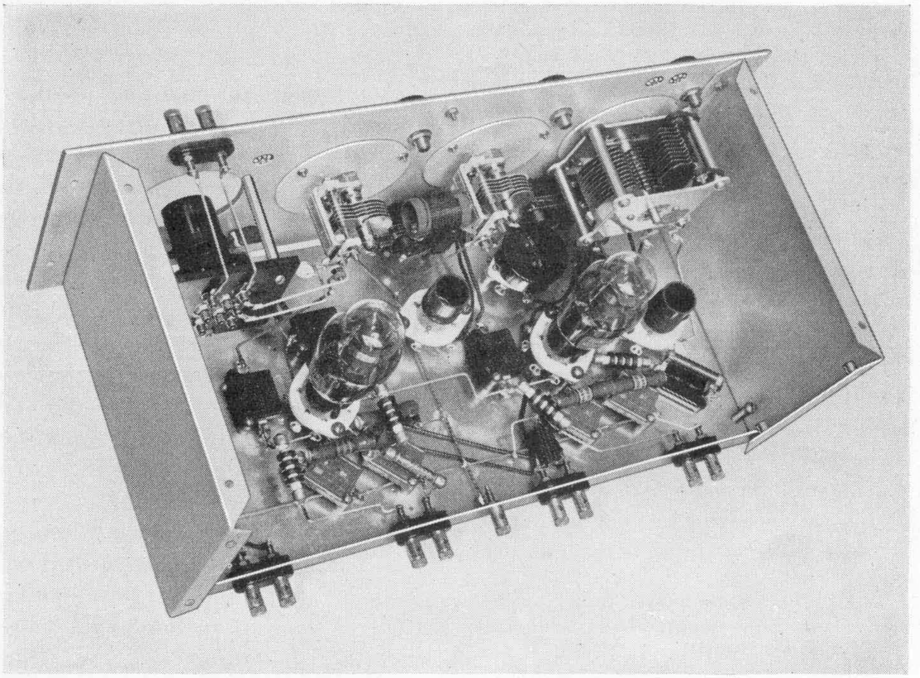
(*Continued on page 6*)

* All bakelite-case meters do not meet the dimension requirements of the Navy specifications, although all, or practically all, meter manufacturers can supply them. Many of the non-standard metal and bakelite cases ordinarily carried in stock by some manufacturers can be mounted satisfactorily.



Courtesy of *QST*

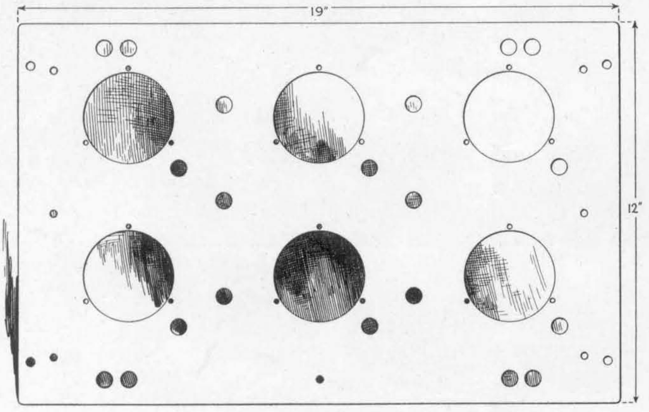
FIGURE 2. A universal exciter unit for 5-band amateur operation as constructed by the editorial staff of *QST*. Everything is mounted on a TYPE 661-B Unit Panel and a TYPE 661-L End- and Base-Plate Assembly. Using the panel upside down as the designer did here in order to get his switches at the bottom is all right, if the assembly calls for no meters!



Courtesy of *QST*

FIGURE 3. The interior of the exciter unit shown in Figure 2. An unshielded TYPE 177-B Inductor Form is plugged into a jack base at the right. Note that General Radio unit-panel construction does not limit you to General Radio parts

Figure 4. UNIT PANELS AND ACCESSORIES (Drawings ⅙th Actual Size)

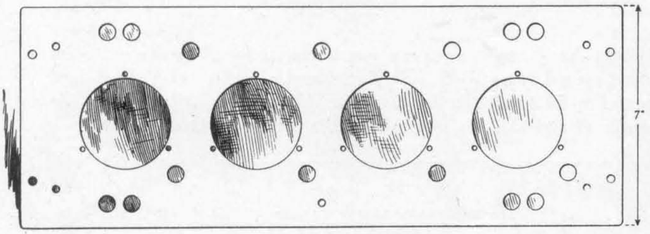


Type 661-A Unit Panel

(19 x 12 inches) $6.00

Including following accessories

Number Supplied	*Type*	*Description*
3	661-P1	Blank Mounting Discs
3	661-P2	3-Hole Mounting Discs
20	661-P4	Snap Buttons
2 pr.	661-P5	Panel Clamps
12	661-P6	Mounting Spacers
6	661-P8	⅜-inch Bushing
6	661-P9	7/16-inch Bushing
25		Machine screws and nuts (for base, ends, and discs)

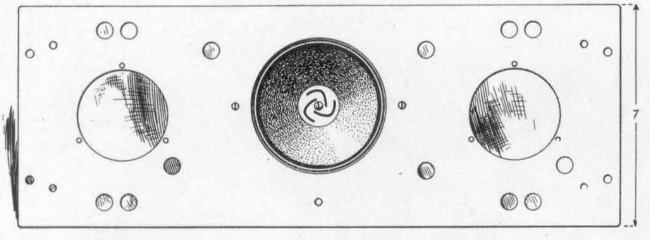


Type 661-B Unit Panel

(19 x 7 inches) $4.00

Including following accessories

2	661-P1	Blank Mounting Discs
2	661-P2	3-Hole Mounting Discs
15	661-P4	Snap Buttons
2 pr.	661-P5	Panel Clamps
9	661-P6	Mounting Spacers
4	661-P8	⅜-inch Bushing
4	661-P9	7/16-inch Bushing
17		Machine screws and nuts (for base, ends, and discs)



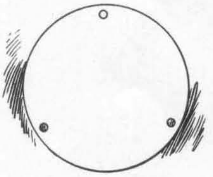
Type 661-C Unit Panel

(19 x 7 inches) $6.50

Including following accessories

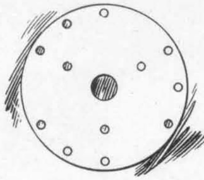
1	666-P1	Blank Mounting Discs
1	666-P2	3-Hole Mounting Discs
13	666-P4	Snap Buttons
2 pr.	666-P5	Panel Clamps
6	666-P6	Mounting Spacers
4	666-P8	⅜-inch Bushing
4	666-P9	7/16-inch Bushing
13		Machine screws and nuts (for base, ends, and discs)
1		5-inch Dynamic Speaker and Clamp

ACCESSORIES (⅓rd Actual Size)



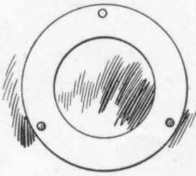
Type 661-P1
Blank Mounting Disc

For use as blank cover or special drilling. Center prick-punched for easy layout. $0.15 each.



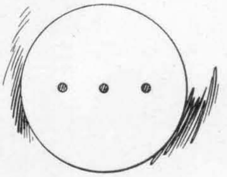
Type 661-P2
3-Hole Mounting Disc

For 3-hole mounting, 120° apart on ⅞-inch radius. 12 possible positions. $0.20 each.



Type 661-P3
Adapter Disc

For 2 1/16-inch meters (*e.g.*, Weston 506). $0.15 each



Type 661-P11
Cover Plate

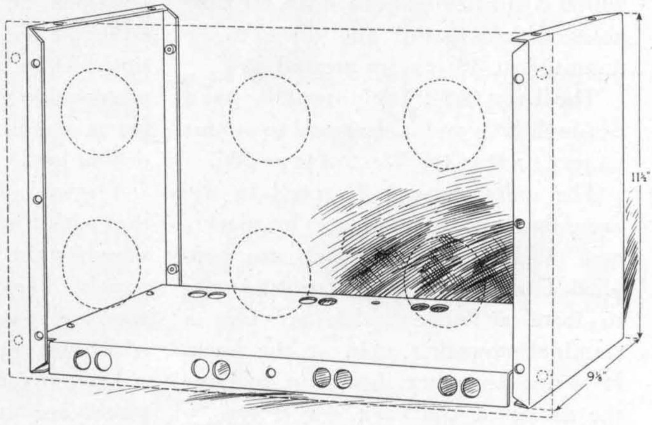
For use with Type 177-B Inductor Form and Type 177-K Inductor Shield. $0.15 each

Figure 5. ENDS, BASES, DUST COVERS (Drawings ⅙th Actual Size)

Type 661-K End- and Base-Plate Assembly

For 19 x 12-inch Panels
$5.00

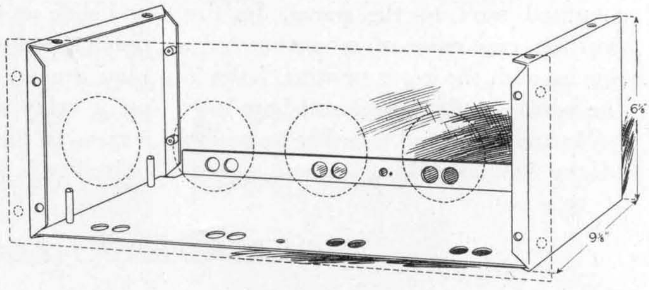
Base plate can be mounted in any one of four positions. Machine screws and spacing pillars supplied. Order panel (shown dotted) and dust cover separately.



Type 661-L End- and Base-Plate Assembly

For 19 x 7-inch Panels
$4.00

Base plate can be mounted in any one of four positions. Machine screws and spacing pillars supplied. Order panel (shown dotted) and dust cover separately.



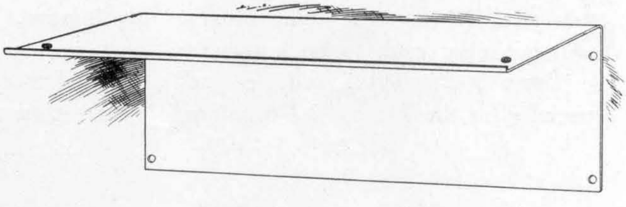
Type 661-R Dust Cover

For 12-inch Panels
$1.50

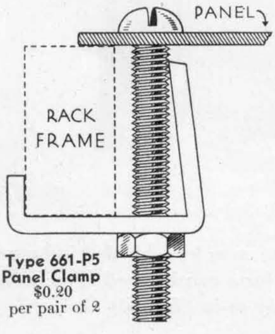
Type 661-S Dust Cover

For 7-inch Panels
$1.25

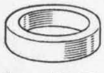
Fit closely. Can be attached and removed when panels are mounted one above another on a rack. Machine screws for back supplied.



ACCESSORIES (Shown Actual Size)

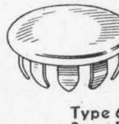


Type 661-P5 Panel Clamp
$0.20
per pair of 2



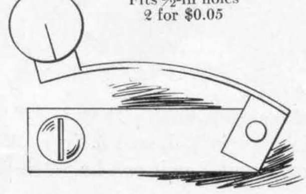
Type 661-P8 ⅜-in Bushing
Fits ½-in holes
4 for $0.10

Type 661-P9 ⁷⁄₁₆-in Bushing
Fits ½-in holes
4 for $0.10



Type 661-P4 Snap Button
Fits ½-in holes
2 for $0.05

Type 661-P6 Mounting Spacers
Provide clearance for parts interfering with disc-mounting screws
6 for $0.10



Type 661-P7 Dial Indicator
For G. R. dial. Supplied free with each dial when order specifically requests it. $0.10.

panel. Around the edge of the disc, which is finished on both sides, are nine holes which permit the discs to be mounted at 30° angles around 360°.

The TYPE 661-P3 Adapter Disc has a 2⅛-inch hole and is designed to mount meters such as the Weston type 506.

The metal base is fastened to the lower flange of the end plates by spacers and machine screws which are supplied. One edge is bent at right angles to form a flange which provides a terminal-mounting strip at the back. It is not necessary, however, to have the flange at the back, for it can be mounted next to the panel. In this position two pairs of mounting holes line up with the lower terminal holes in the panel so that panel and base may be securely clamped together by means of the insulated binding-post assemblies. The base mounts in any of four positions, i.e., flange up, flange down, either at the back or the front. Additional ½-inch holes on ¾-inch spacing are provided for terminals. Small holes for mounting sockets, etc., are easily drilled in the base.

The end plates are sold in combination with the base and are made in two sizes: for the 12-inch and for the 7-inch panels. They are bolted to their respective panels by machine screws which are supplied.

Dust covers for the two sizes of end plates are available. They fit tightly and slide on from the rear so that they may be removed when the panel assemblies are mounted one above another on a relay rack. Only four machine screws at the back of the unit are required to hold the dust cover in place.

UNIVERSAL RELAY RACK

GENERAL RADIO is announcing a new relay rack to be known as the TYPE 660-A Rack and designed especially for the TYPE 661 Unit-Panel equipment. The rack consists of two rectangular steel frames which mount parallel to each other as shown in the illustration on page 2.

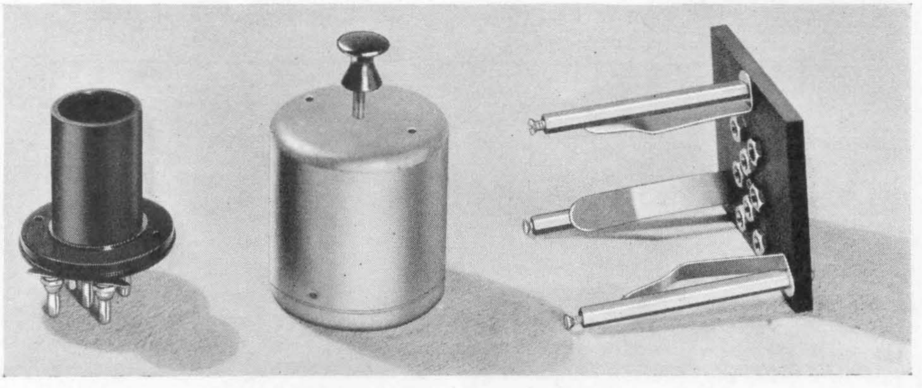


FIGURE 6. These three parts, with a TYPE 661-P11 Cover, make the complete shielded inductor assembly shown in Figures 1, 7, and 8. In addition, the bakelite form can be used alone as in Figures 2 and 3 or it can be fitted with the shield only as in Figure 9

Various methods for obtaining sufficient rigidity suggest themselves. The frames may be screwed to the bench at the proper separation or they may be fastened to the bench and wall by four clamps supplied with each rack. The clamps are similar to the TYPE 661-P5 Panel Clamps except that a long wood screw replaces the machine screw. Holes at the top and bottom of the frames can be used to mount a brace between the frames if it is necessary to increase rigidity of the assembly. The rack can be used for panels of any width.

TYPE 661-P5 Panel Clamps will clamp a panel to the rack in any desired position. Four of these clamps are supplied with each of the TYPE 661 Unit Panels, but they must be ordered separately when it is desired to mount other panels on the rack.

The height of TYPE 660-A Rack is 26½ inches (fifteen 1¾-inch rack units). Its price is $5.00. Code Word: NINNY.

PLUG-IN INDUCTORS

ANYONE who has ever been up against a short-wave coil design problem will appreciate the advantages of these new plug-in inductor forms after a glance at the accompanying photographs. There are four basic components, and these can be assembled in three ways. The bakelite form can be

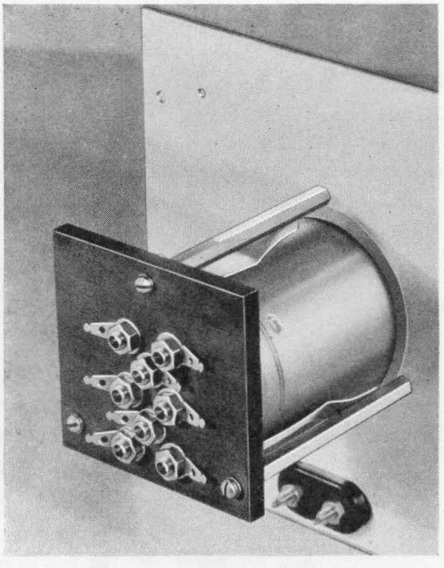


FIGURE 7. The complete shielded inductor (Figure 8) mounts in this manner on a unit panel. The three springs on the TYPE 661-P10 Jack Base guide the inductor into place. See the bottom panel of Figure 1, second position from the left, for a front-of-panel view of this assembly

FIGURE 8. The shield base is securely locked to the shield top by the three bayonet catches to make a single unit. In the center is the threaded rod which engages a threaded insert in the jack base and draws the cover plate firmly against the panel. One plug has been removed to show small holes for lead wires

used alone, or, if desired, the shield can be attached to make one integral unit. Then, when a shielded inductor is required for use with unit-panel assemblies, the cover plate is added. The jack base can be used behind the unit panel, or mounted horizontally on a shelf.

An important feature in short-wave work is the excellent noise-free contact provided by the use of spring-type plugs and jacks. The eight sets of contacts are adequate for the most elaborate circuit. When fewer circuits are needed, the plugs and jacks can, if desired, be removed.

Figure 8 shows how the shielded inductor is assembled for use with unit panels. As the inductor is plugged into the base plate, the end of the threaded rod engages a threaded insert. Then a turn of the knob draws the cover plate firmly against the panel to make a joint that is electrically and mechanically tight. All holes are carefully aligned, and there is absolutely no difficulty in slipping the inductor into position or in clamping it in place.

If the shielded inductor is to be used in the manner shown in Figure 9, the bakelite base can be fastened firmly to the rod by means of two nuts (supplied with the shield). One is placed on the inside, and one on the bottom outside face of the form.

TYPE 177-B Inductor Form: Can be used alone, with shield, or with shield and cover plate for unit-panel mounting. See photographs. Supplied with eight removable plugs (with lockwashers and lugs). Winding form: 1¼ inches (diameter), 1¾ inches (length).

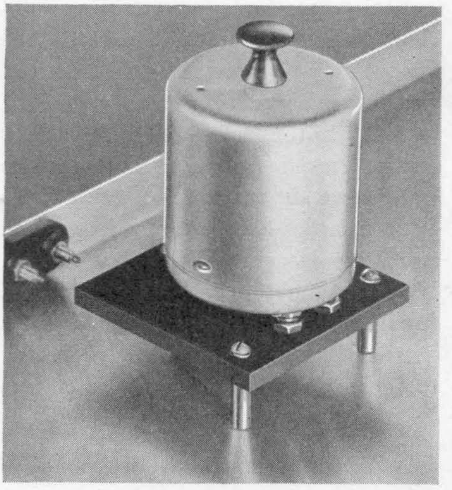


FIGURE 9. The jack base can, if desired, be mounted on a horizontal base plate to accommodate a shielded inductor as shown here. Note also that the unshielded inductor unit can be used in this jack base

Moulded bakelite. Price: $0.85. Code Word: INDUCTBOAT.

TYPE 177-K Inductor Shield: Aluminum. Fastens to TYPE 177-B Inductor Form with two machine screws supplied. The knob, clamping rod, and nuts (see photographs) are included together with assembly instructions. See page 4 for description of TYPE 661-P11 Cover Plate. Price: $0.65. Code Word: INDUCTKEMP.

TYPE 661-P10 Jack Base: Includes eight removable jacks and lugs. Unique locating device makes plugging in coils extremely easy. Spacer bars fit unit panels. Base can, if desired, be mounted on shelf base (spacers not included). Designed for shielded or unshielded TYPE 177-B Inductor Form. Price: $1.50. Code Word: UNIPANBASE.

The GENERAL RADIO EXPERIMENTER

VOL. VIII. No. 6 NOVEMBER, 1933

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

CATHODE-RAY OSCILLOGRAPHS AND THEIR APPLICATIONS

FOR many types of experimental work, the cathode-ray oscillograph is particularly adaptable. The new designs eliminating the use of gas as a focussing medium increase the maximum frequency range far beyond that which can be obtained with any other oscillograph.

The electron beam can be deflected either magnetically or electrically. The former has the disadvantage that the magnetic coils required have a relatively low impedance and may well be a serious load on low-power circuits. The electrostatic deflecting plates have a very high capacitive reactance,* and, consequently, do not disturb the circuits to which they may be connected. For this reason all General Radio cathode-ray oscillograph tubes have electrostatic deflection

*The electrode capacitance of the TYPE 528-A Cathode-Ray Oscillograph Tube is less than 2 $\mu\mu$f. That of the tube used in the TYPE 635-A Electron Oscillograph is less than 50 $\mu\mu$f.

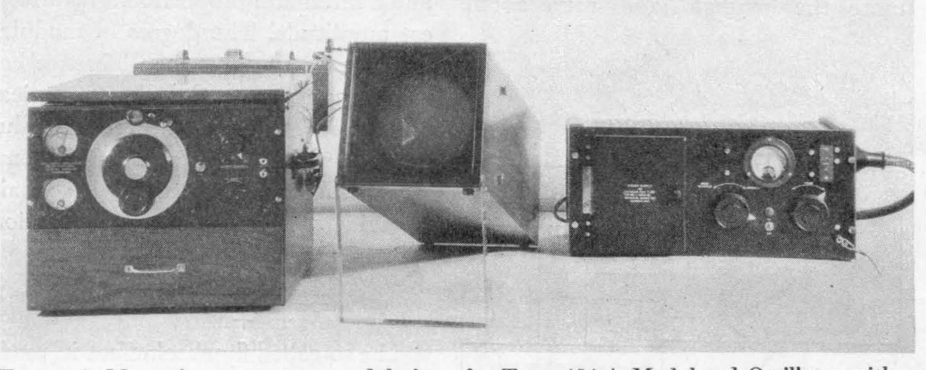


FIGURE 1. Measuring percentage modulation of a TYPE 484-A Modulated Oscillator with a TYPE 528 Cathode-Ray Oscillograph by the method shown in FIGURE 2. An amplifier was used between the audio oscillator and the horizontal deflecting plates, the TYPE 219 Decade Condenser (behind the oscillator) being used to correct the phase shift in the amplifier. Illustration from an unretouched photograph

plates for both horizontal and vertical deflections.

In addition, the ruggedness of cathode-ray oscillographs recommends them for general work. They cannot be permanently harmed by heavy overloads.

The upper frequency limit of electromechanical oscillographs such as the string or mirror types is limited by the inertia of the moving element. The limit is usually around 10 kilocycles. The cathode-ray beam, on the other hand, is practically inertialess and the theoretical upper limit of frequency in a hard tube is determined by the point at which the period of the high frequency approaches the time required for the electron to pass through the deflecting plates. This limit for a well-designed tube is about 200,000 kilocycles. The hard cathode-ray tube, therefore, is particularly adapted for the observation of high-frequency phenomena. It will, of course, operate quite as well as any electromechanical oscillograph at low frequencies and, because of such adaptability, is becoming more and more the general handy-man about

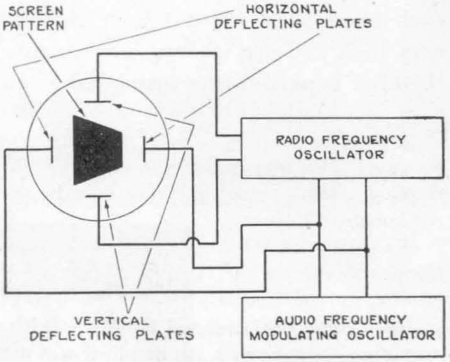


FIGURE 2. Method of measuring percentage modulation with a cathode-ray oscillograph

the laboratory. It is far beyond the range of this brief story to discuss all or even a majority of these uses. There are, however, certain functions that a cathode-ray oscillograph performs with particular effectiveness. We can discuss a few of these.

In Figure 2 is sketched a means for measuring the percentage of modulation of a radio-frequency oscillator. The modulated radio-frequency voltage under observation is impressed across the two vertical deflecting plates of a cathode-ray oscillograph. Across the horizontal plates is impressed a voltage of the modulating-oscillator frequency. For the sake of simplicity, the schematic is drawn with the same audio-frequency source modulating the radio-frequency oscillator and deflecting the beam horizontally. The amplitude of oscillation of the radio-frequency oscillator varies at the same rate that the spot is swept back and forth across the screen by the audio-frequency source. Therefore, there results a trapezoidal pattern on the screen which has a maximum amplitude proportional to the peak of the radio-frequency wave and a minimum proportional to its lowest amplitude. The degree of modulation is measured by the difference between the greater and the lesser vertical deflection. The actual degree of modulation can then be determined by comparing the two amplitudes with a pair of dividers. The percentage modulation is expressed by

$$\frac{MAX-MIN}{MAX+MIN}\,100.$$

The so-called flywheel effect in modulated radio-frequency oscillators, or the tendency of the radio-frequency amplitude to overshoot the amplitude

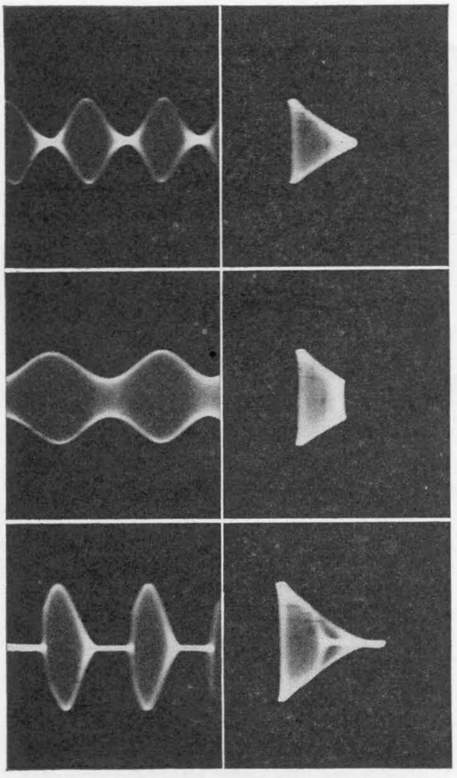


FIGURE 3. Oscillograms showing, respectively, 100%, 43%, and severe over-modulation, on a TYPE 484-A Modulated Oscillator. The figures at the right were obtained by the method outlined in FIGURE 2; those at the left by applying to the vertical deflecting plates the modulated carrier and to the horizontal plates a voltage from a TYPE 506-A Bedell Sweep Circuit controlled by the audio modulating voltage

of the modulation, shows up in these patterns as narrow loops on the sloping sides of the pattern. A perfectly modulated oscillator will show an almost perfect trapezoidal pattern.

The cathode-ray oscillograph makes an excellent peak voltmeter or ammeter. The deflection of the beam is linear with applied voltage, but the sensitivity depends upon the anode potential that is used. High anode potentials result in electrons having a high velocity and low sensitivity (but a bright spot). Low anode potentials mean greater sensitivity. With the TYPE 528-A Cathode-Ray Tube with 3000 volts on the anode, about 100 volts on either pair of plates will give a deflection of one inch. Anode voltage of 1000 gives a sensitivity of 33 volts per inch deflection. The voltage sensitivity can be calibrated by direct current; and the direct-current calibration will hold with good accuracy up to high radio frequencies. In order to investigate the amplitudes attained in transient phenomena, it is only necessary to observe the path of motion of the spot and to note its maximum amplitude.

The type of screen used on the TYPE 528-A and to a lesser degree on the TYPE 635-A General Radio Oscillographs has an appreciable persistence of fluorescence; that is to say, after the transient trace has passed, the screen will continue to glow for a very short length of time, but sufficient to allow the eye to note its general shape and amplitude. To study the behavior of the mercury-vapor type of rectifier tube wherein the initial current surge at each reversal of current in a cycle is very high and abrupt, the current into the filter is passed first through a small

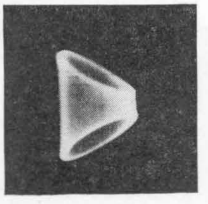


FIGURE 4. This type of pattern, instead of the trapezoid, results when the variations in carrier amplitude are not in phase with the audio-frequency voltage applied to the horizontal plates. Shunting the amplifier output with an adjustable condenser restores the trapezoid

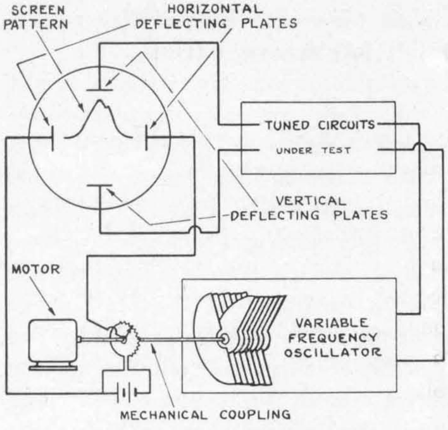


FIGURE 5. Diagram showing how a cathode-ray oscillograph can be used for tracing resonance curves

resistor across which the vertical deflecting plates are attached. The primary voltage at the input of the step-up transformer is impressed across the horizontal plates. The resultant pattern is not a true indication of the actual shape of the current wave, but excellent ideas of its amplitude and the effect of various types of filter inputs can be obtained.

In the example shown in Figure 5 the tuned circuits of the receiver are slightly out of line, which accounts for the double hump in the output resonance curve. By the observation of the pattern during the adjustment of the alignment condensers, the set can be brought into adjustment with considerable speed. The tuning condenser of the oscillator and the potentiometer, which determines the horizontal deflection of the pattern, is kept continuously in rotation by a small motor. The rate of rotation is adjusted so that the trace repeats itself eight or ten times a second, thus providing a continuous indication of the resonance curve of the high frequency amplifier.

Frequency comparisons are a particularly useful application of cathode-ray tubes. In comparing two frequencies by the zero beat method, listening to them with a pair of phones, the observer may be handicapped by two difficulties.

1. The two oscillators, unless well isolated, may have a tendency to lock into step over a fairly wide frequency range if working into a common detector.

2. Beats lower than about twenty cycles per second cannot be heard. Two equal frequencies impressed respectively on the vertical and horizontal plates will result in a stationary elliptical pattern. The mutual conductance between these pairs of plates is practically nil, thus the locking-in tendency is very slight. Any motion of the pattern at all is immediately apparent so that the comparison at zero frequency difference is readily accomplished.

The deflecting plates of the General Radio TYPE 635-P1 Electron Oscillograph Tube have a capacity reactance comparable to the usual grid admittance of a triode radio receiving tube. The TYPE 528-A Cathode-Ray Oscillograph Tube has only about one-tenth this capacitance. Transformers and other input devices for these tubes can be of the same design as those intended for ordinary vacuum tubes, but of course must be capable of operating with a secondary peak voltage between 50 and 200 volts. Practically all standard radio- or audio-frequency transformers are suitable.

In discussing applications for these versatile tubes, the tendency is to carry on indefinitely and only a few possibilities have been mentioned in the foregoing.

—A. E. THIESSEN

DIRECT CAPACITANCE AND ITS MEASUREMENT

THE ordinary two-terminal condenser — whether air, mica, or other dielectric — is composed of at least three separate capacitances connected in a closed loop or delta. Besides the main capacitance connected between the two terminals and called the direct capacitance, each terminal has a "stray" capacitance to surrounding objects such as a shield or the ground, as shown in Figure 1. The condenser thus becomes a three-terminal system.

Usually the direct capacitance is much larger than the stray capacitances so that the total capacitance that would be measured between the two terminals differs from the direct capacitance by a few per cent at most. Figure 1, on the other hand, shows four instances in which the stray capacitances cannot be ignored.

In the shielded cable, the stray capacitances are of the same order of magnitude as the direct capacitance.

In a shielded transformer the shielding is placed to reduce direct capacitance between primary and secondary to a very small amount. There the stray capacitances are a hundred times the direct capacitance.

The two binding posts,* for example, have a direct capacitance between them of only 0.3 $\mu\mu$f, yet the capacitance obtained by an ordinary measurement is 2.0 $\mu\mu$f because each terminal has a capacitance of 3.4 $\mu\mu$f to the metal panel.

If, however, one terminal were "grounded" to the metal panel, thus short circuiting one stray capacitance, the total capacitance measured between terminals would be $0.3 + 3.4 = 3.7$ $\mu\mu$f. This illustrates the fact that the exact capacitance of any condenser depends on the manner in which its terminals are connected to each other and to nearby objects, either directly or via external circuits. It shows the importance of being able to measure direct and stray capacitance.

One method of measuring direct capacitance is shown in Figure 2. The three measurements indicated there are made with one of the three capac-

*General Radio TYPE 138-VD. The two terminal plates are TYPE 274-Y.

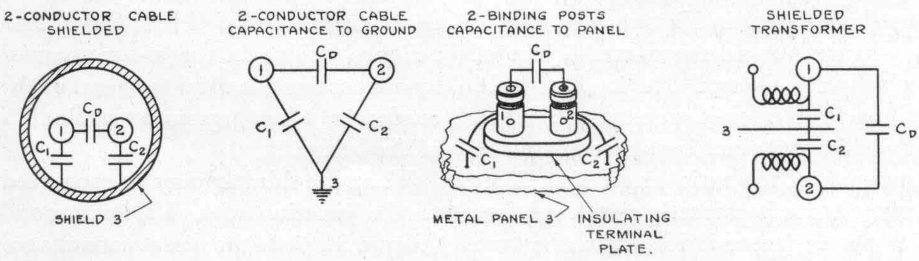


FIGURE 1. Four instances in which it is essential to know the direct and stray capacitances of a condenser

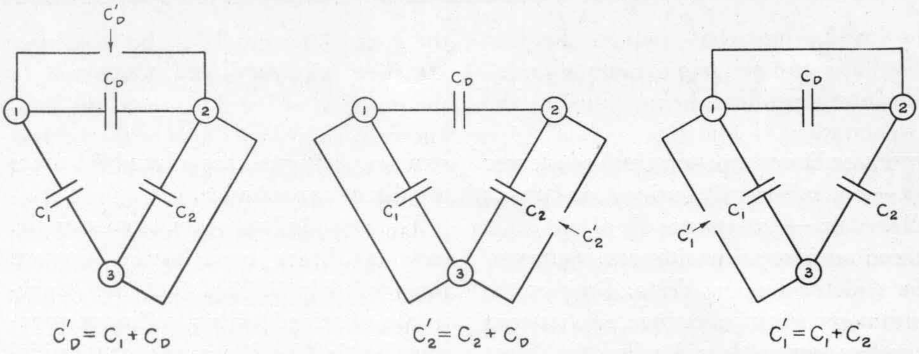


FIGURE 2. Direct capacitance can be calculated from the results of the three measurements indicated above. Note that, when any one of the capacitances is short circuited, no change in the equation results if the capacitance across the other capacitance is measured, e.g., across C_2 instead of C_1 in the right-hand drawing

itances short circuited each time. The capacitances are given by

$$C_D = \frac{C_D' - C_1' + C_2'}{2},$$

$$C_1 = \frac{C_D' - C_2' + C_1'}{2},$$

$$\text{and } C_2 = \frac{C_1' - C_D' + C_2'}{2}.$$

The dissipation factor ($R\omega C$) of the direct capacitance is given by

$$D_D = \frac{D_D'\ C_D' + D_2'\ C_2' - D_1'\ C_1'}{2C_D}.$$

A second and somewhat more convenient method, because it eliminates calculation, involves the measurement of direct capacitance by connecting the third terminal to some point on the bridge such that the stray capacitances are no longer included in the measurement as shown in Figures 3, 4, and 5.

Figure 3 is an equal-arm bridge of which the General Radio TYPE 216 Capacity Bridge is an example. When the third terminal is connected to the junction of the ratio arms, the direct capacitance is correctly measured, but its power factor is less than the true value by $B\omega C_2$, where B is in ohms, ω in radians per second, and C in farads. The capacitance C_1 disappears across the detector.

The third terminal may also be connected to the junction of one ratio arm and standard condenser N as in Figure 4. The direct capacitance is then in (fractional) error by the term $\frac{C_1}{C_N}$ because the capacitance C_1 is placed in parallel with the arm N. Its power factor will also be in error, if the power factor of the C_1 is large. The other capacitance C_2 merely shunts the generator. This connection is often used in unequal-arm bridges where B is much greater than A, so that C_N is greater than C_P and, as a result, the fractional error term $\frac{C_1}{C_N}$ becomes negligible.

Direct capacitance is measured on the General Radio TYPE 650-A Impedance Bridge in the above manner by connecting the third terminal of the condenser to any ground terminal G of the bridge.

When the third terminal is connected to the junction of a Wagner ground (Figure 5), both the direct capacitance and its power factor are measured correctly. The balancing procedure is, however, somewhat tedious because the main and Wagner ground balances are interdependent, being joined by the capacitances C_1 and C_2.

There is an important difference between a shielded three-terminal capacitance, in which the shield is the third terminal, and an unshielded condenser for which the third terminal is ground, although both may be represented schematically by Figure 1. When the shield forms the third terminal, it may generally be placed where wanted without reference to the point at which the bridge is grounded. When ground is the third terminal, only that type of connection may be used which a particular bridge allows.

When the junction of the capacitance arms N and P is grounded, as will occur on the TYPE 216 Capacity Bridge, one ground capacitance (C_1 of Figure 3) is short circuited, so that only the three capacitance method of Figure 2 may be used. The condenser is measured when directly connected and when transposed, giving C_D' and C_2'. For the third measurement (C_1'), the *1* and *2* terminals of the condenser are short circuited and connected to the junction of the B arm and the "unknown capacitance" arm of the bridge.

When either the junction of the arms A and N, as in the TYPE 650-A Impedance Bridge, or the junction of the two ratio arms A and B is grounded, the direct capacitance of the condenser is measured, as in Figures 3 and 4. Its power factor is in error, as previously discussed.

When a Wagner ground is used, the direct capacitance and its power factor are correctly measured.

The shield of a three-terminal capacitance frequently has a considerable capacitance to ground, making it, in effect, a four-terminal capacitance. For this case care must be taken that this shield-to-ground capacitance is either short circuited or placed where it does not affect the measurements.

For all of these measurements, substitution methods may be used. The formulae applying in each instance will be unchanged.

—ROBERT F. FIELD

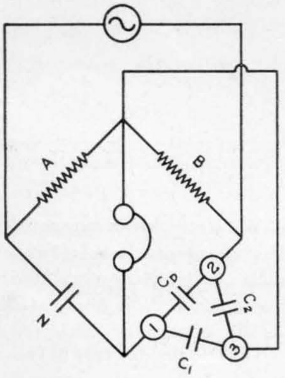


FIGURE 3. Direct capacitance measurement on an equal-arm bridge such as TYPE 216 Capacity Bridge

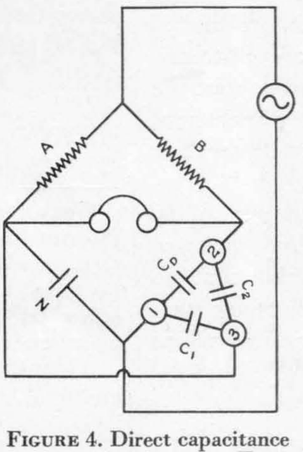


FIGURE 4. Direct capacitance measurement on a TYPE 650-A Impedance Bridge. Oscillator and detector can be interchanged

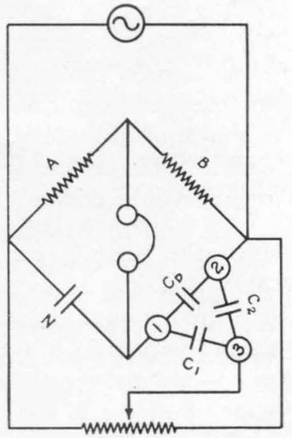
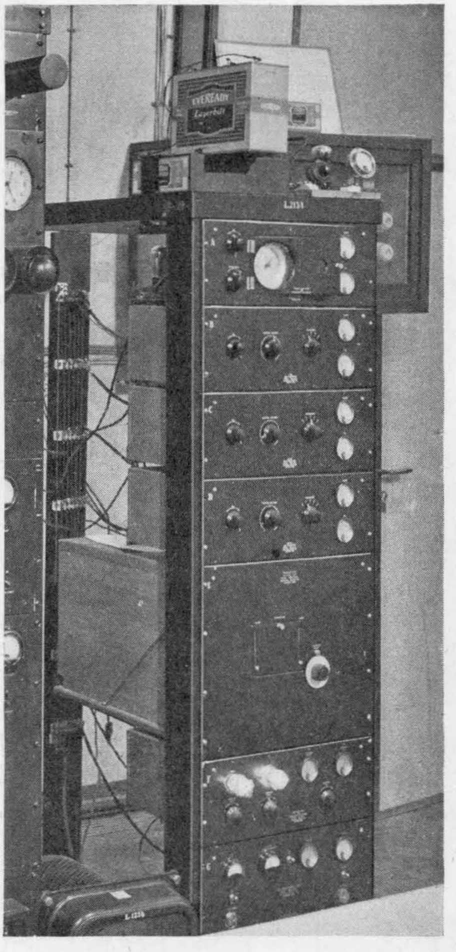


FIGURE 5. Direct capacitance measurement on a bridge using a Wagner ground connection

ON SERVICE IN TROPICAL JAVA

THE Colonial Department of the Dutch Government, which maintains radio telephone and telegraph service between the Hague and the Netherlands East Indies, is maintaining a General Radio primary standard of frequency at its station in Bandoeng, Java. Mr. H. Van der Veen, the engineer in charge, has just reported on its performance.

". . . You will be interested to know that the Standard-Frequency Equipment which our service bought from your company some years ago has been in constant use ever since its installation and that it has given very satisfactory results. All our high-frequency routine checking, as well as other work, is done by means of the controlled frequencies from your standard equipment. I am enclosing a photograph of the installation at Bandoeng."



This installation is a Class C-21-H Standard-Frequency Assembly, consisting of a 50-kc quartz crystal oscillator and a clock for measuring the crystal frequency in terms of time signals. From it are obtained hundreds of harmonics throughout the audio- and radio-frequency spectrum, each of which is known to better than one part in a million.*

The unit at Bandoeng is one of 26 now in operation in various parts of the world, but it is probable that no one of the others operates under such severe climatic conditions. Java has a tropical forest climate characterized by very high humidity.

*For a description of the apparatus consult Bulletin 10, a 70-page manual on frequency measurements published by the General Radio Company. Copies are free to engineers and others professionally concerned with radio measurements.

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

IMPROVEMENTS IN RADIO-FREQUENCY BRIDGE METHODS FOR MEASURING ANTENNAS AND OTHER IMPEDANCES

SINCE the announcement of the TYPE 516-A Radio-Frequency Bridge some months ago,* this bridge has been in use continuously in the General Radio laboratories. Its applications have included the measurement of both lumped and distributed impedances at radio frequencies and the results obtained not only show the practicability of the method but also point the way to improvement in the design of the bridge itself.

The range of usefulness of the original model was greatly limited by the inductance of the resistance decade and by its change with dial setting. Although this inductance is less than one microhenry, it has an appreciable reactance at radio frequencies. Both this total reactance and its change as the decade dial setting is changed produce an error in capacitance measurement.

The effective capacitance of a condenser in series with an inductance is given by the expression,

$$\hat{C} = \frac{C}{1 - \omega^2 LC}$$

where $\hat{C}$ = effective capacitance in farads,

C = capacitance of the condenser in farads,

L = inductance in henrys, and

$\omega = 2\pi$ in radians per second,

and the effective capacitance is always larger than the nominal capacitance by the factor $\frac{1}{1 - \omega^2 LC}$. If an inductance of one microhenry is placed in series with a condenser of 500 $\mu\mu$f capacitance, the effective capacitance will be 510 $\mu\mu$f (an error of 2%), at a frequency of one megacycle. Since the error depends upon the square of the frequency, however, it is between 8% and 9% at 2 megacycles. With smaller capacitances, the error is less; with larger ones it is greater.

The inductance of the resistance decade varies from a few tenths to one

*"Bridge Methods for Measurements at Radio Frequencies," Charles T. Burke, General Radio *Experimenter*, July, 1932.

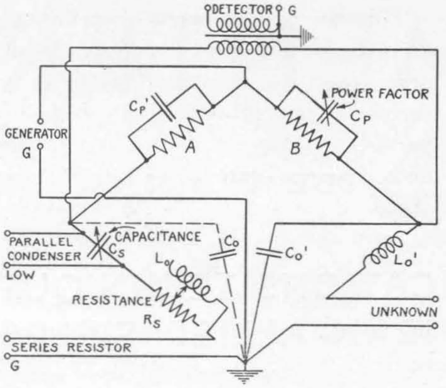


FIGURE 1. Careful elimination or compensation of parasitic capacitance and inductance makes the new radio-frequency bridge direct reading over a wide range

microhenry, depending upon the decade setting, and it presents a serious barrier to the use of the bridge as a direct-reading instrument.

In the design of a new model, therefore, considerable attention has been given to making the inductance of the decade constant with dial setting and to providing in the unknown arm of the bridge an equal amount of inductance to compensate. When this is done, the bridge can be made direct reading in capacitance and the case of making measurements is greatly improved.

This new bridge is shown schematically in Figure 1. Ratio arms A and B are equal as in previous models.

The inductance-compensated decade is shown in the lower left-hand arm of the bridge. This decade is so arranged that, when the resistance setting is increased, an amount of inductance equal to the inductance of the added resistance cards is removed from the circuit. When the dial setting is decreased, a like amount of inductance is added. Thus an inductance equal to the total inductance of the decade is in circuit at all times. In order that its total value shall not cause an error in capacitance readings, an approximately equal amount of inductance L_0' is placed in series with the unknown arm of the bridge. The magnitude of L_0' is adjusted to make the total inductance in the X arm (including leads to terminals) equal to L_0 plus the stray lead inductance in the standard arm.

It will be seen from Figure 1 that neither side of the standard condenser C_s is at ground potential, and therefore each side has a definite capacitance to ground. The capacitance of the rotor to ground is shunted across the standard resistance R_s and its effect on the resistance standard is entirely negligible over the useful range of the bridge. The capacitance of the stator to ground (C_0 in Figure 1) is in shunt with the entire standard arm of the bridge and can cause a serious error* in the setting of the resistance decade R_s.

In order to eliminate this error, an equal capacitance C_0' is connected across the unknown arm as shown in Figure 1. This makes the bridge direct reading in resistance.

The standard resistance R_s of the new bridge uses a decade of tenth-ohm steps instead of the slide wire used in previous models. The condenser C_p

*The effective resistance is given by the expression

$$\hat{R} = \frac{R}{\left[1 - \frac{C_0}{C}(1 - \omega^2 LC)\right]^2}$$

where $\hat{R}$ = effective resistance in ohms
R = decade dial setting (ohms)
C_0 = ground capacitance (about 30 $\mu\mu$f) in farads
C = capacitance setting of C_s in farads.

across ratio arm *B* in Figure 1 serves two purposes. It allows a finer adjustment of resistive component than is given by the tenth-ohm decade and it also permits power factor measurements to be made without calculation. The dial is calibrated directly in power factor at 1 megacycle. At other frequencies the dial reading is multiplied by the frequency in megacycles. In order that the bridge read correctly at the zero power factor setting of C_p, a condenser C_p' equal to the zero capacitance of C_p is placed across arm *A*.

The TYPE 516-C Radio-Frequency Bridge is direct reading up to 111 ohms and 1150 $\mu\mu$f. For the measurement of inductance or of higher values of capacitance, a small fixed condenser may be placed in series with the unknown as shown in Figure 3a. When the resistance of the unknown is above 111 ohms a parallel condenser or a combination of series and parallel units (see Figures 3b and 3c) can be selected to produce a balance. While in each of these cases the bridge is not direct reading, the necessary calculations are not difficult.

The terminals marked PARALLEL CONDENSER in Figure 1 are provided in order that capacitances may be measured by the substitution method. A parallel condenser can also be connected here to extend the range of the standard condenser. An additional pair of terminals engraved SERIES RESISTOR is provided. The direct-reading range of the bridge may be extended by adding a plug-in resistor or an unknown resistor may be connected to these terminals and measured by direct substitution.

The substitution method* for capacitance and resistance measurements is recommended where precise results are

* "An Equal-Arm Capacitance Bridge," R. F. Field, General Radio *Experimenter*, January, 1930.

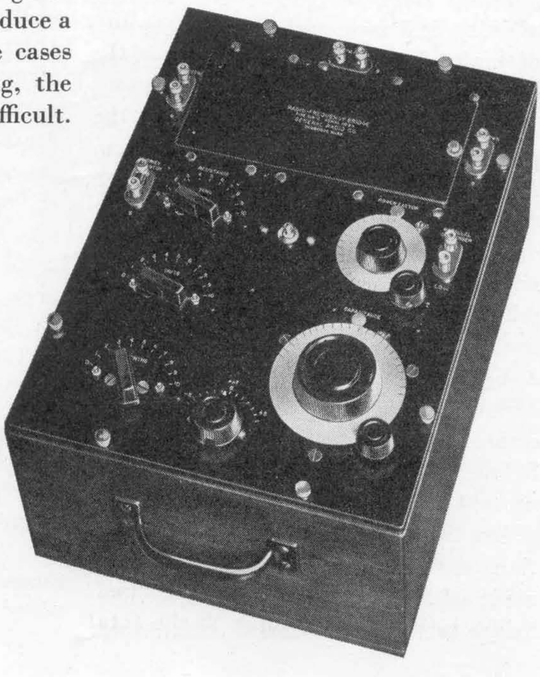


FIGURE 2. Panel layout of the TYPE 516-C Radio-Frequency Bridge. The circuit details are shown in Figure 1

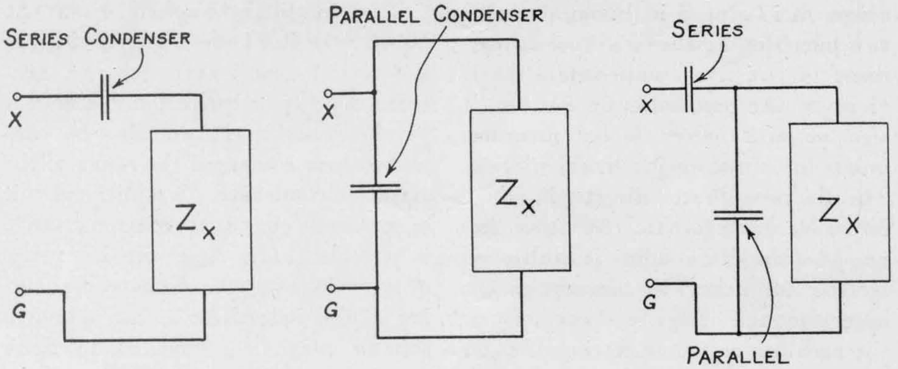


FIGURE 3. Because of the very high values of resistance and reactance encountered in impedance measurements near resonance, the impedance can be modified by series, parallel, or series-parallel condensers to bring it within range of the bridge: (*a*) series connection for all inductive and for large capacitive reactances; (*b*) parallel connection for resistances greater than 111 ohms; and (*c*) series-parallel connection where both (*a*) and (*b*) are required

desired. When the bridge is used as a direct-reading instrument, some accuracy is sacrificed. The over-all accuracy obtainable is, however, extremely good in the range where the bridge is direct reading. Even at frequencies in the vicinity of 5 megacycles, the accuracy of comparison is about 5%. At broadcast frequencies it is about 1%.

The standards themselves are, of course, subject to some variation with frequency, due to skin effect in the resistors and inductance in the condenser frame. The resistance decade is adjusted at direct current to well within 0.1%, and at one megacycle comparison with straight-wire standards shows a discrepancy of only about 0.1%. At high capacitance settings, the frequency error in the condenser is detectable, but below 500 $\mu\mu$f no serious error occurs up to 4 or 5 megacycles.

One particularly important application of the bridge is in the measurement of antenna characteristics. The bridge method has several advantages over resistance substitution or resistance variation methods.

First among these is low power. The

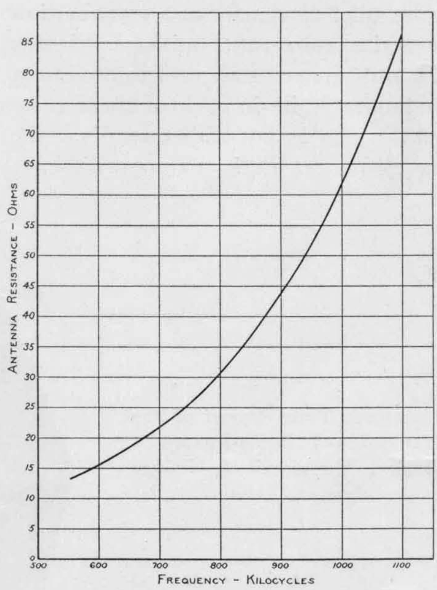


FIGURE 4. Resistance of a broadcast transmitter antenna operated considerably above its fundamental

bridge may be operated from a small, portable, battery-operated oscillator, whose output is one watt or less. This has other advantages than merely convenience. A low power oscillator can be completely shielded and direct pickup between the oscillator and the antenna can be eliminated. This, together with the avoidance of stray impedance errors, gives a decided advantage to the bridge method.

Resistance measurements on a broadcast antenna made with the radio-frequency bridge are shown in Figure 4. This antenna is operated considerably above its fundamental (frequency) and consequently all measurements were taken with a series condenser (Figure 3a). Since an antenna is entirely resistive at its fundamental, this point can be identified as the frequency where the capacitance read on the bridge is equal to the capacitance of the series condenser used.

Figure 5 shows the resistance of an antenna from below its fundamental to

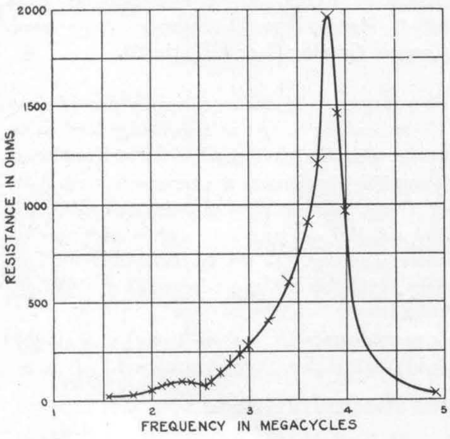


FIGURE 5. Resistance of a receiving antenna from below its fundamental to above its half-wave point

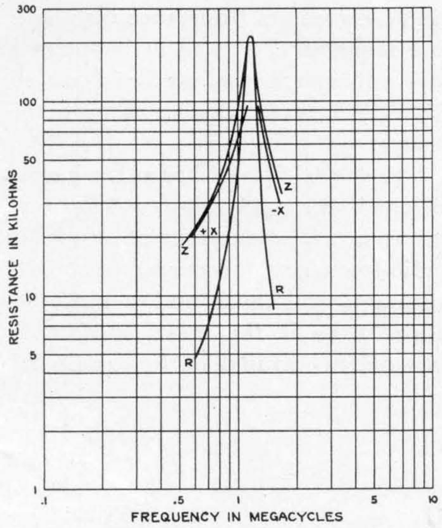


FIGURE 6. Resistance and reactance characteristic of a multi-section choke in the vicinity of resonance. Note that both inductive $(+X)$ and capacitive $(-X)$ are, for convenience, plotted as positive to the same scale as the resistance

above its half-wave point (parallel resonance). In this measurement it was necessary to use a series condenser up to 2600 kilocycles and the parallel condenser connection above 2600 kilocycles when the resistance exceeded 111 ohms. The hump at the low end of the curve is due to energy absorption by another antenna nearby.

Other types of measurements conveniently made with the bridge include the frequency characteristics of radio-frequency coils and chokes.

The results of one set of measurements are shown in Figure 6, which represents the impedance characteristics of a radio-frequency choke for use at broadcast frequencies. These measurements were made with the parallel condenser shown in Figure 3b and the results calculated from the parallel circuit equations. Resistance, reactance and impedance, as well as inductance and self-capacitance, can be calculated from the data obtained by means of the bridge.

The TYPE 516-C Radio-Frequency Bridge is the result of several years of research and development work in radio-frequency measurements. Its accuracy, wide range, and ease of operation make it the most satisfactory instrument available for radio-frequency impedance measurement. It should be emphasized that the bridge is not intended to be completely a "fool-proof" instrument and, when improperly used, erroneous results can be obtained. In the hands of those possessing experience in the technique of high frequency measurements it will fill a long-recognized need and will give dependable and accurate results.

—C. E. WORTHEN

TYPE 516-C RADIO-FREQUENCY BRIDGE

SPECIFICATIONS

Capacitance Range: 0 to 1150 $\mu\mu$f, direct reading. Can be extended to infinity by using a series condenser as described in the foregoing article.

Resistance Range: 0 to 111 ohms, direct reading. Can be extended to several thousand ohms by using a condenser in parallel with the unknown.

Frequency Range: 500 kc to 5000 kc with output transformer furnished. With proper output transformer, range can be extended downward to audio frequencies.

Accuracy: As a direct-reading bridge, 1% to 5% up to 5 megacycles. With direct substitution methods, greater accuracy can be obtained.

Accessories: The bridge is supplied complete with output transformer but without a radio-frequency generator or detector. Operating instructions are also included.

Additional Accessories Required: As a radio-frequency generator a TYPE 484-A Modulated Oscillator is suggested. See the October, 1932, issue of the General Radio *Experimenter*.

Detector: A radio receiver covering desired frequency range. A TYPE 619-A or TYPE 619-B Heterodyne Detector may be used. Consult Catalog G or Bulletin 10.

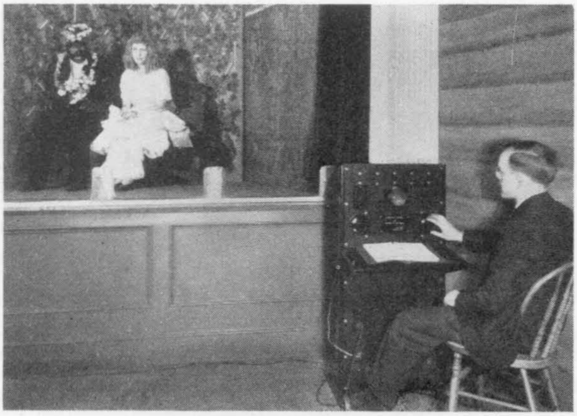
Condensers: If measurements outside the direct-reading range of the bridge are to be made, plug-in fixed condensers are required. TYPE 505 Condensers are recommended. A set of these, whose capacitances are 100 $\mu\mu$f, 200 $\mu\mu$f, 500 $\mu\mu$f, and 1000 $\mu\mu$f, is adequate for most purposes. See the *Experimenter* for January, 1933, and August-September, 1933.

Dimensions: 18 inches (long) x 12 inches (wide) x 8 inches (height) over-all.

Net Weight: 23 pounds.

Code Word: BATCH.

Price: $225.00.



THEATER NOTES

Little Eva Goes to Heaven on a Variac

COSTUMES can be rented and a cast, by many rehearsals, can be developed to give a creditable performance, but the mechanical auxiliaries such as lighting and scenery introduce difficulties that are extremely troublesome in amateur dramatics production. These difficulties are especially serious where funds are limited and the production must be given on a stage rented for the one performance.

It was such a problem that confronted the "Friends of the Drama," an experienced play-producing group of Arlington, Massachusetts, when they gave a melodrama based on Harriet Beecher Stowe's "Uncle Tom's Cabin." Simon Legree and his blood hounds could chase Eliza across the ice realistically enough, but how was heaven to open and take up little Eva when she died? The conventional method of pulling her to the bridge over the stage with a block and tackle was out of the question from the dramatic as well as the mechanical standpoint, for the audience would most certainly have seen humor instead of the pathos that was intended.

The "Friends of the Drama" were fortunate enough to have just com-

The control panel designed for "Friends of the Drama" by Stage-Manager Dawes. Dials for the two Variacs are in easy reach of the operator who works with his elbows on the cue-sheet desk pleted an unusual control system for its stage lights and this was pressed into service to produce the death scene by means of lighting effects. As little Eva died, the stage lights gradually dimmed and a golden shaft of light, behind the bed and pointing heavenward, grew gradually brighter as death came. The method was simple, yet extremely effective.

The control system was the panel shown in the accompanying photograph, an asbestos board fitted with wheels for portability on which were mounted dimming and power distribution circuits. The dimming controls were General Radio Type 200-CM Variacs.[1] These are small adjustable transformers that enable the operator to apply any voltage to his lights from a full 115 volts down to zero in steps of only ½ a volt. The operator sat in the first row with this small board and cue sheet before him and adjusted the briliancy of the stage lights and the spot in steps so gradual as to be imperceptible.

This installation demonstrated several very real advantages of the Variac over conventional resistance-type controls in addition to the obvious ones of small mounting space and low price. The Variac dissipates a much smaller amount of heat, and although this may not make for comfort of the operator during rehearsals in an unheated hall, it should please the fire marshal. In addition, the voltage control on a Variac is essentially independent of the load current. Hence it can be used for any number of lamps up to the maximum permitted by its current rating[2] and the operator can control the briliancy from maximum down to complete "black out." —J. D. C.

[1]See General Radio *Experimenter* for June-July, 1933.

[2]The Type 200-C Variac is rated at 5 amperes, and, although overloading is not recommended, currents 50% greater can be safely handled for periods of as much as 3 minutes. Variacs having larger current ratings are under development.

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