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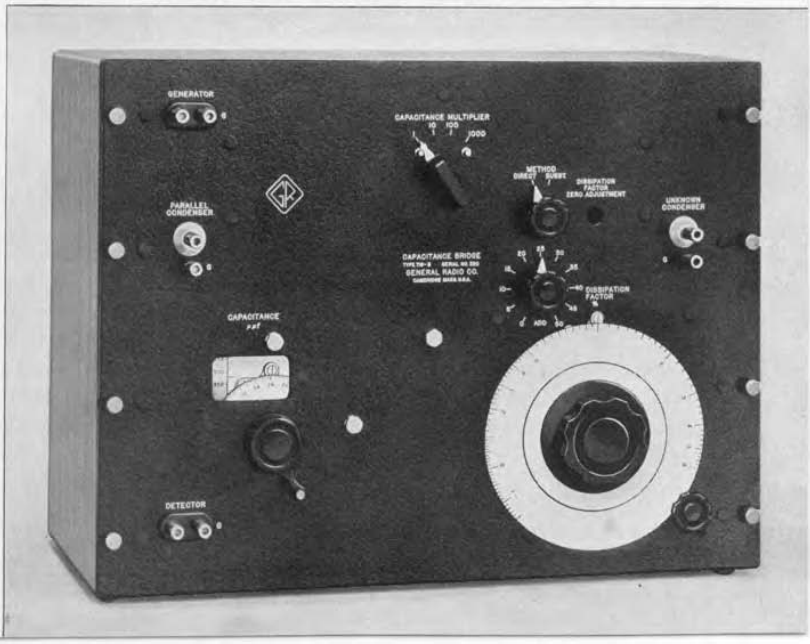
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

INCREASED POWER-FACTOR RANGE FOR THE CAPACITANCE BRIDGE

● **IN THE FIVE YEARS SINCE ITS ANNOUNCEMENT** the Type 716-A Capacitance Bridge has fulfilled its design specifications as an accurate instrument for the measurement of capacitance and as a worthy successor of the old Type 216 Capacity Bridge. Its direct-reading precision condenser, in conjunction with four decade-spaced ratio arms, makes it possible to measure capacitances from 100 $\mu\mu$f to 1 μf. Its use of the Schering bridge circuit simplifies the

Figure 1. Panel view of the Type 716-B Capacitance Bridge. The new features are the DISSIPATION FACTOR switch which controls a step condenser and the METHOD switch which allows either DIRECT or SUBSTitution measurements to be made.



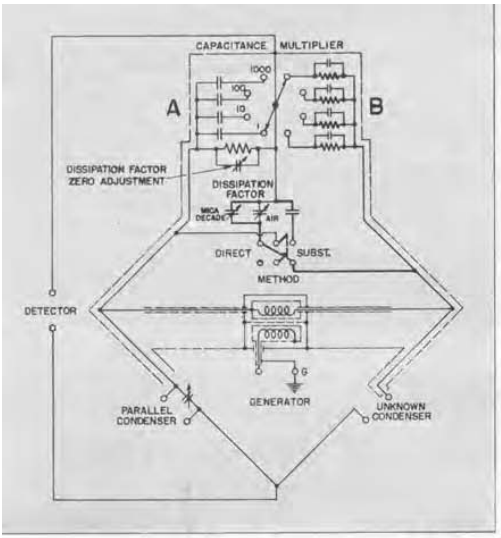


FIGURE 2. Circuit diagram of the new bridge. Changes and additions are shown by heavy lines. The mica decade condenser increases the dissipation factor range to 56%. The reversing switch makes possible a positive dissipation factor reading in substitution measurements.

measurement of dielectric losses by allowing the dial of the air condenser connected across the fixed ratio arm to be calibrated directly in dissipation factor.* The range of this dial, 0.06 (or 6%), has limited somewhat the usefulness of the bridge, particularly at frequencies below 1 kc, where the dissipation factor of commercial dielectrics tends to increase. It is both for this reason and to simplify the use of the bridge in substitution measurements that a new model, the TYPE 716-B Capacitance Bridge, is now introduced.

The circuit diagram of the new model is shown in Figure 2. The changes and additions are shown with heavy lines. The dissipation factor range of the older model was limited by the capacitance of the air condenser to slightly over 6%, corresponding to a change in capacitance of 500 $\mu\mu$f. A decade condenser, in which the unit steps are 398 $\mu\mu$f, has been added in the new model. This condenser is mounted in the upper part of the insulated compartment containing the dissipation factor condenser, as shown in Figure 3. The various steps are controlled by a TYPE 380 Switch shown at the right of the condenser case and which appears on the panel in Figure 1 just above the DISSIPATION FACTOR dial. Each step adds 5% to the dissipation factor reading, giving a maximum value of 56%. For this value, dissipation factor and power factor differ by 13%, and consequently the designation POWER FACTOR used on the older model has been changed to DISSIPATION FACTOR. This increased range in dissipation factor at 1 kc extends correspondingly the range at lower frequencies, being 5.6% at 100 cycles and 3.3% at 60 cycles.

When the bridge is used for substitution measurements, a balancing condenser must be placed across the UNKNOWN CONDENSER terminals and the unknown connected to the PARALLEL CONDENSER terminals in parallel with the internal precision condenser. The reading of the DISSIPATION FACTOR dial must then decrease, and the short negative scale of 0.15% is sufficient only for condensers with relatively small dissipation factor. The alternative of causing the DISSIPATION FACTOR dial to read up-scale initially by adding a suitable condenser across the *B* ratio arm has proved cumbersome. In the new model a reversing switch has been added, as shown in Figure 2, which transfers the dissipation factor condensers from the *A* to the *B* ratio arm and at the same time connects a small condenser across the *A* arm, equal to twice the zero capacitances of those transferred. This condenser and the reversing switch are shown in Figure 3.

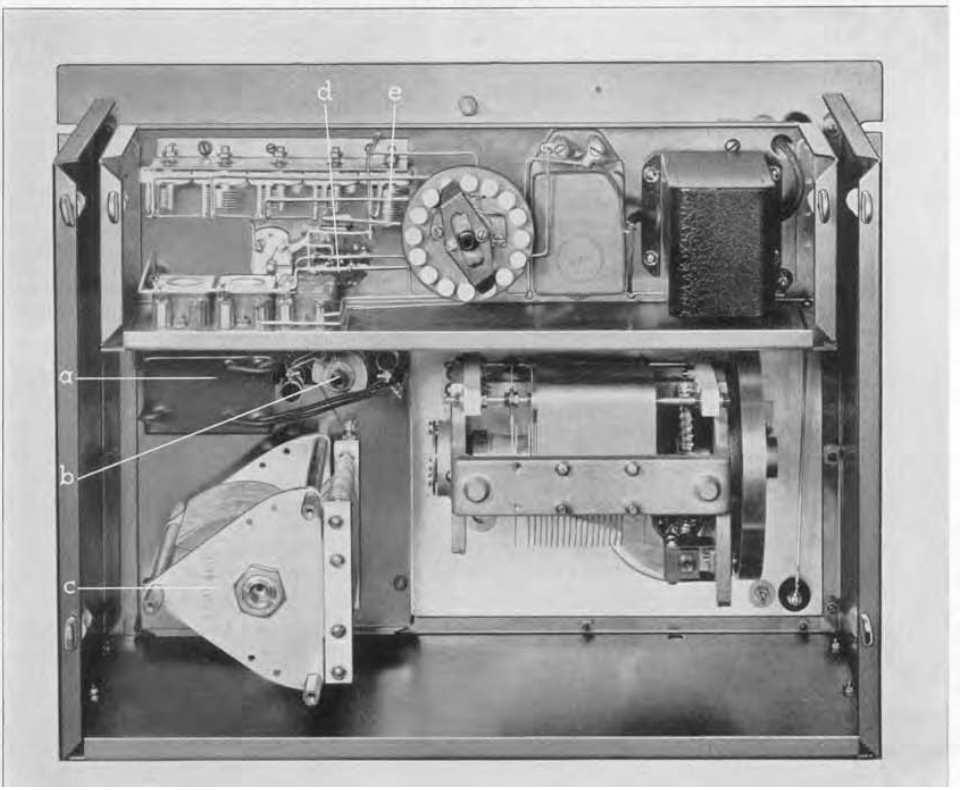
*Dissipation factor is the cotangent of the phase angle, while power factor is the cosine.

On the panel in Figure 1 the switch appears above the new DISSIPATION FACTOR switch as the METHOD switch with the two positions DIRECT and SUBSTitution. Schematic wiring diagrams of the bridge for these two positions of the METHOD switch are given in Figure 4. With the switch in the SUBSTitution position the dissipation factor range of the bridge at 1 kc is 56% multiplied by the ratio of the total capacitance to the unknown capacitance. The bridge can be balanced only for equal ratio arms with the CAPACITANCE MULTIPLIER switch set at 1.

Whenever in the Schering bridge circuit there are capacitances across both of the ratio arms, the simple bridge equations no longer hold, and the dial readings are in error for both capacitance and dissipation factors. These errors are approximately equal to the product of the dissipation factors of the two ratio arms. They are, therefore, proportional to the dissipation factor reading of the bridge and at the maximum reading of 56% can amount to almost 2%. Errors of a similar nature can occur even in substitution measurements.

The new edition of the operating instructions, Form 455-C, supplied with the TYPE 716-B Capacitance Bridge,

FIGURE 3. Rear view of the bridge with shields removed. The mica decade condenser, a, is controlled by a TYPE 380 Switch, b. The reversing switch, d, transfers the dissipation factor air condenser, c, together with the decade condenser, a, from the A to the B ratio arm for substitution measurements and at the same time places condenser, e, across the A ratio arm to make up for the zero capacitances of condensers, d, and, a.



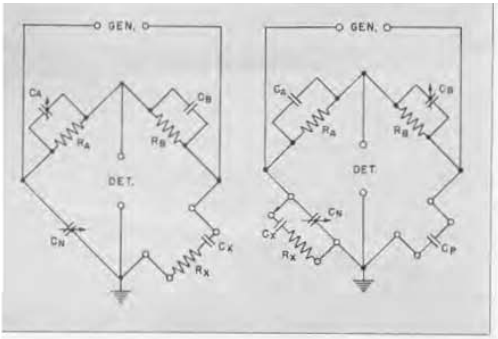


FIGURE 4. These diagrams show the bridge circuit for the two positions of the METHOD switch. The left-hand diagram is for the DIRECT position, the right-hand for the SUBSTitution position.

contains a complete discussion of the errors applying both to direct and substitution measurements. Conversion formulae for changing from series to parallel impedances are also included. Users of the older TYPE 716-A Capacitance Bridge will find the new booklet of considerable help in the measurement of a high resistance or any capacitance having very large dissipation factor. A copy will be sent on request.

— R. F. FIELD

SPECIFICATIONS

Ranges: Direct Reading — capacitance, 100 $\mu\mu$f to 1 μf; dissipation factor, 0.002% to 56% (0.00002 to 0.56 expressed as a ratio).

Substitution Method — capacitance, 0.1 $\mu\mu$f to 1000 $\mu\mu$f with internal standard; to 1 μf with external standards; dissipation factor, $56\% \times \frac{C'}{C_x}$ where C' is the capacitance of the standard condenser and C_x that of the unknown.

Accuracy: Direct Reading — capacitance, $\pm 0.2\%$ or ± 2 $\mu\mu$f $\times$ multiplier reading (0.2% of full scale for each range) when the dissipation factor of the unknown is less than 1%; dissipation factor ± 0.0005 or $\pm 2\%$ of dial reading, for values of D below 10%.

Substitution Method — capacitance $\pm 0.2\%$ or ± 2 $\mu\mu$f; dissipation factor, ± 0.00005 or $\pm 2\%$ for change in dissipation factor observed, when the change is less than 6%.

When the dissipation factor of the unknown exceeds the limits given above, additional errors occur in both capacitance and dissipation-factor readings. Corrections are supplied, by means of which the accuracy given above can be maintained over the entire range of the bridge.

Ratio Arms: The arm across which the dissipation factor condenser is normally connected has a resistance of 20,000 ohms. The other arm has four values, 20,000 ohms, 2000 ohms, 200 ohms, 20 ohms, providing the four multiplying factors 1, 10, 100, 1000. Suitable condensers are placed across these arms, so that the product RC is constant.

Standards: Capacitance, TYPE 722 Precision Condenser direct reading from 100 $\mu\mu$f to 1100 $\mu\mu$f; dissipation factor, TYPE 539-T Condenser with semi-logarithmic scale and decade-step condenser calibrated directly in dissipation factor at 1 kc.

Shielding: Ratio arms, dissipation-factor condensers, and shielded transformer are enclosed in an insulated shield. The unknown terminals are shielded so that the zero capacitance across them is not greater than 1 $\mu\mu$f. A metal dust cover and the aluminum panel form a complete external shield.

Frequency Range: All calibration adjustments are made at 1 kc and the accuracy statements above hold for an operating frequency of 1 kc. The bridge can be used, however, at any frequency between 60 cycles and 10 kc. Dissipation-factor readings must be corrected by multiplying the dial reading by the frequency in kilocycles.

Voltage: Voltage applied at the GENERATOR terminals is stepped up by a 1-to-4 ratio shielded transformer. A maximum of 50 volts can be applied to the transformer. If desired, power can be applied to the bridge between the junctions of the pairs of resistance and capacitance arms. With equal ratio arms, a maximum of 700 volts can be applied.

Mounting: The bridge is supplied for mounting on a 19-inch relay rack or for cabinet mounting.

Accessories Required: Oscillator, amplifier, and telephones or rectifier meter. TYPE 608-A Oscillator, TYPE 814-A Amplifier, and Western Electric TYPE 1002-C Telephones are recommended.

For substitution measurements, a balancing condenser is needed. This may be either an air-dielectric model, TYPE 539-C, or a fixed mica condenser of the TYPE 505 series.

Accessories Supplied: One TYPE 274-M Plug, one TYPE 274-NC Shielded Conductor, and one TYPE 274-NE Shielded Plug and Cable.

Dimensions: (Length) 19 x (height) 14 x (depth) 9 inches, over-all.

Net Weight: 41½ pounds, relay-rack model; 53¾ pounds, cabinet model.

Type		*Code Word*	*Price*
716-BR	For Relay-Rack Mounting	BONUS	$335.00
716-BM	Cabinet Mounted	BOSOM	360.00

SUBSTITUTE MATERIALS

● **RECENT CONSERVATION ORDERS** of the War Production Board particularly concerning aluminum have made substitutions for this metal imperative. New conservation regulations covering other materials are constantly being issued, and one of the principal jobs of our design staff is to find adequate substitutes for all of these critically scarce materials.

A primary objective of our substitution program must be to make use of the new materials with the minimum effect upon performance and with as little interference with the present rush production program as possible. This task is by no means a simple one, because the performance and utility of precision equipment frequently depend upon the materials used, and because even slight changes in design will occasion delays in production. Nevertheless, progress is being made, and substitutes are gradually being found which can be used without adversely affecting the performance specifications.

The problem is further complicated by the fact that shortages sometimes develop in substitutes, so that it may be necessary to use different materials at different times for a given instrument part. It should be recognized, therefore, that two instruments of the same type number made at different times may not weigh the same or even look exactly the same.

All of our facilities are devoted to war production. We must try in every way possible to keep vital material moving, but if your deliveries are delayed we hope that you will be patient while the technical and manufacturing problems connected with substitutions are being solved.

—A. E. THIESSEN

PRIORITIES AND REPAIRS

● **BECAUSE PRACTICALLY ALL OF OUR MANUFACTURING FACILITIES**, as well as those of our suppliers, are devoted to war projects with high priority ratings, it is becoming increasingly difficult for us to repair instruments or to supply replacement parts under the repair rating of A-10. Reasonable delivery of materials and components such as wire, metal parts, meters, condensers, resistors, tubes, batteries, etc., cannot usually be had except under priority ratings much higher than A-10.

If equipment is being used directly or indirectly on war projects covered by a rating higher than A-10, then a properly executed preference rating extension will insure the repair being made within a time consistent with the higher rating. Otherwise, it will be necessary for us to order replacement parts or material under the A-10 repair rating, and it is quite probable that delays of many months will result. We must receive the proof of preference rating and purchase order before work is started on any repair.

The Service Department is equipped to handle repairs very promptly. Returned instruments being used on high priority projects are given preference in accordance with their individual ratings and dates, which, of course, are beyond our control. Whether or not you have a preference rating, remember that a set of our Service and Maintenance Notes will often enable you to make repairs and readjustments in your own plant.

—H. H. DAWES

A NEW TYPE 274-M DOUBLE PLUG

● **ANOTHER FAMILIAR STAPLE** of the General Radio line takes on a new and streamlined form with the announcement of the new TYPE 274-M Double Plug.

The new plug, which replaces both the TYPE 274-M (black bakelite) and the TYPE 274-ML (yellow bakelite), is molded from polystyrene, a comparatively new molding material with greatly superior electrical characteristics.

The new TYPE 274-M has a power factor of about .07% at 1000 cycles per second as compared to a power factor of 13.2% for the black bakelite and 1.70% for the yellow bakelite of the previous type. The leakage resistance between pins is greater than 10^8 megohms. This is of the same order of magnitude as the earlier yellow bakelite plug but compares with only 65,000 megohms for the black bakelite.

The capacitance between pins has also been somewhat reduced. It is now about 1 $\mu\mu$f compared with 1.5 and 1.75 for the yellow and the black bakelite respectively.

The new plug is of improved appearance, in conformity with present tendencies for simple forms, and is so shaped that it can be easily and positively gripped by the fingers. A dot is molded into the rim of one jack in order to make possible the identification of terminals.

Type		*Code Word*	*Price*
274-M	Double Plug	STANPARBUG	$0.50
	Package of 10		3.50

LOW-CAPACITANCE TERMINALS

● **A COMPANION ITEM** to the new TYPE 274-M Double Plug is the TYPE 138-UL Binding Post Assembly, designed for uses where low capacitance and low leakage conductance are required.

FIGURE 1. View of a pair of TYPE 138-UL Terminals mounted on a metal panel.

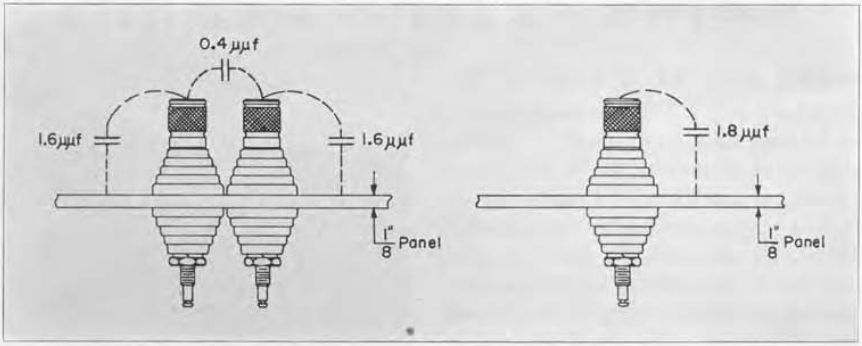


FIGURE 2. Capacitances associated with a pair of terminals and a single terminal mounted on a ⅛" metal panel. The capacitance between binding post and panel includes the capacitance to free space.

The TYPE 138-UL Binding Post Assembly consists of a nickel-plated brass binding post (with knurled top), and two hollow conical insulators, molded of polystyrene. It is designed for mounting on panels from 1/16" to ¼" thick, through a 11/16" hole. With this mounting hole the spacing between panel and stud exceeds ¼", insuring a very low capacitance to panel. The power factor associated with this capacitance is low, because the only solid dielectric is low-loss polystyrene. The d-c leakage resistance through the polystyrene is also low, and the effect of surface leakage is minimized by the use of a stepped conical insulator, which increases the length of the leakage path over that of a smooth cone. Figure 1 shows a pair of terminals mounted on a panel, while Figure 3 shows the details of the various parts.

The sketches of Figure 2 show the capacitances associated with a pair of terminals and with a single terminal, mounted on a ⅛" metal panel. The effective leakage resistance is greater than 10^8 megohms.

The shank is slotted to take a wire or a pin terminal and is drilled to take a TYPE 274 Plug. Two of these terminals can be mounted with ¾" spacing to take the TYPE 274-M Double Plug.

Although they are not designed primarily for high-voltage use, these terminals can safely be used at voltages up to 5000 volts.

Type		*Code Word*	*Price*
138-UL	Binding-Post Assembly	STANPARULE	$0.50
	Package of 10		4.00

FIGURE 3. View of a TYPE 138-UL Terminal disassembled, showing the component parts. The projections on the base of the two polystyrene pieces interlock so that the terminal can be mounted on a panel as thin as 1/16". The narrow slot is provided to take a projecting key on the mounting hole to prevent the insulator from turning.

SERVICE AND MAINTENANCE NOTES

● **ONE WAY OF AVOIDING INTERRUPTIONS** in war production is to be sure that testing and measuring equipment is maintained in its proper operating condition. Returning equipment to the manufacturer because of a minor difficulty such as a defective tube, resistor, or condenser, may mean a serious delay to you. A copy of our Service and Maintenance Notes will help you to avoid this situation with General Radio equipment.

These notes, which have been compiled from the records of the Service Department, Standardizing Laboratory, and Engineering Department, will, in most cases, enable the user to locate and remedy ordinary operating difficulties that do not require the use of elaborate equipment for testing and checking.

The notes are sent free of charge to users of General Radio equipment. They have already been distributed to many of our customers and have proved their value in obviating the return of instruments to our factory for minor repairs.

We urge you to send us the type and serial numbers of your General Radio equipment so that your copy of Service and Maintenance Notes can be mailed promptly.

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

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