THE General Radio EXPERIMENTER

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

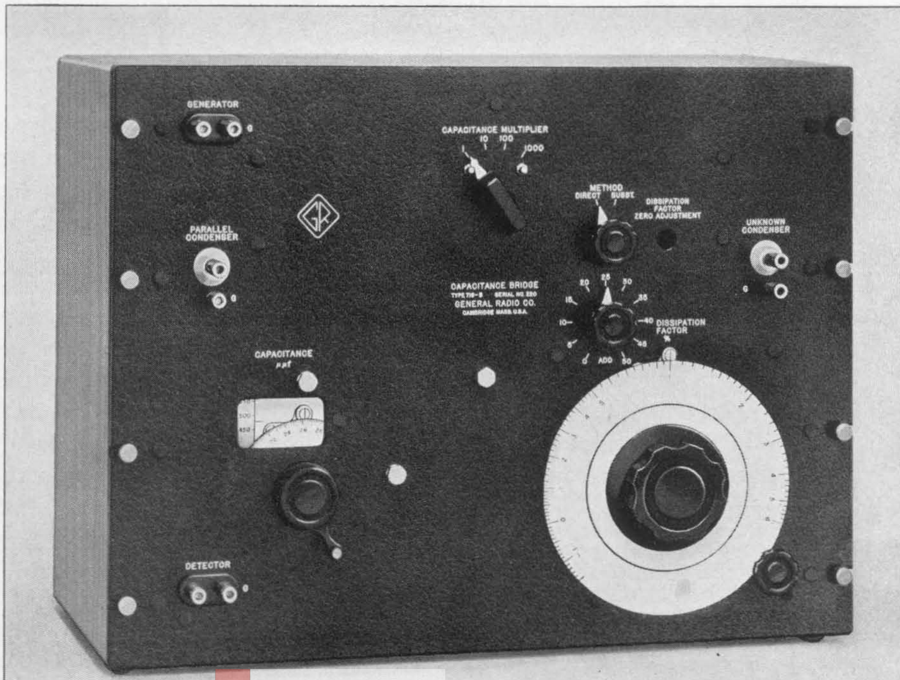
VOLUME XVI No. 11 APRIL, 1942

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.



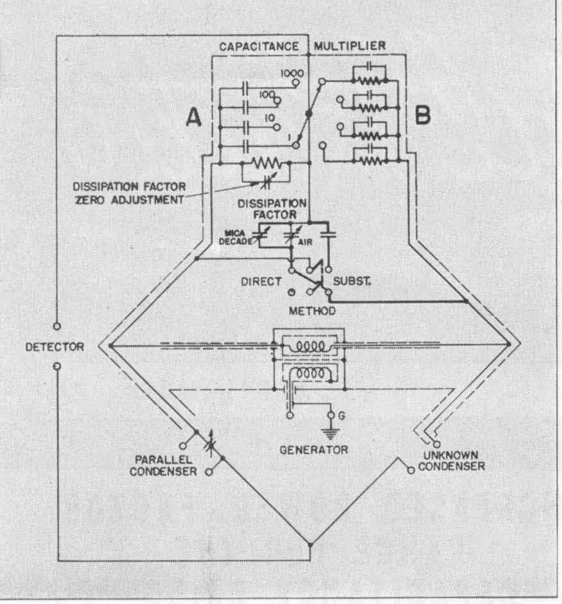


FIGURE 2. Circuit diagram of the new bridge. Changes and additions are shown by heavy lines. The mica decade condenser increases the dissipation factor range to 56%. The reversing switch makes possible a positive dissipation factor reading in substitution measurements.

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.

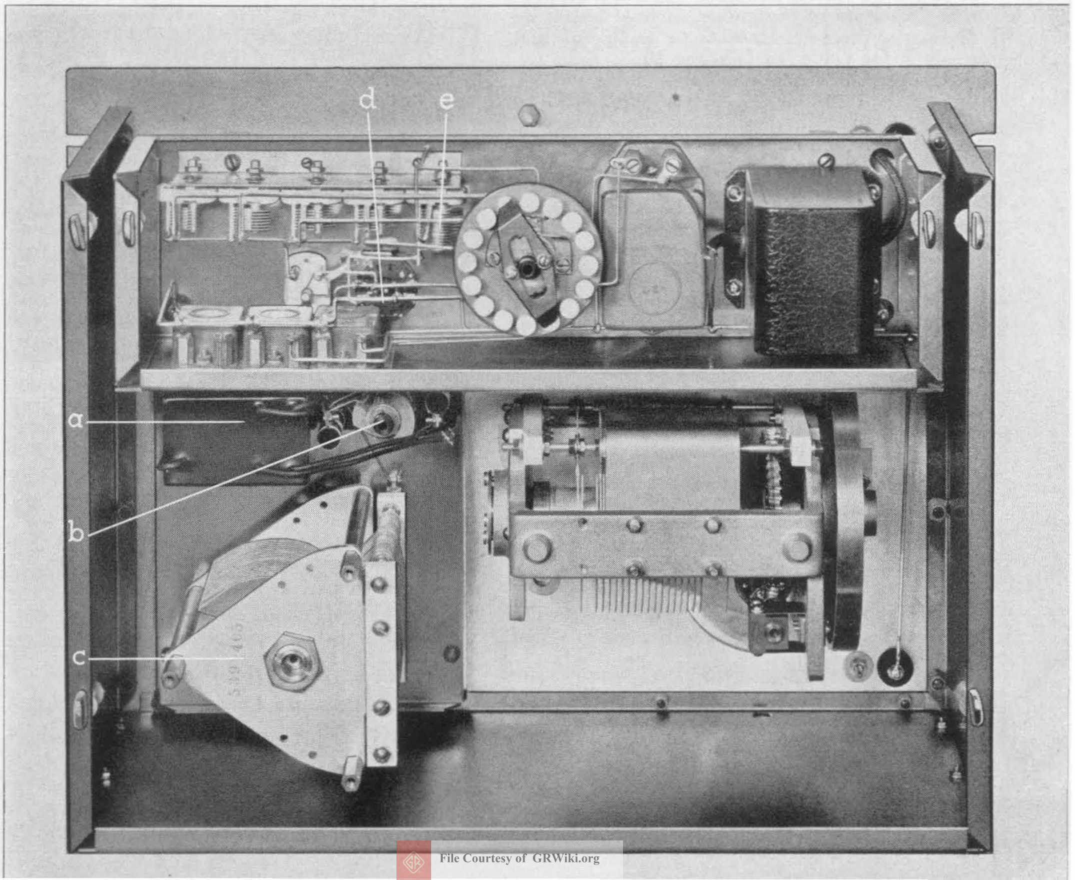
*Dissipation factor is the cotangent of the phase angle, while power factor is the cosine.

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.



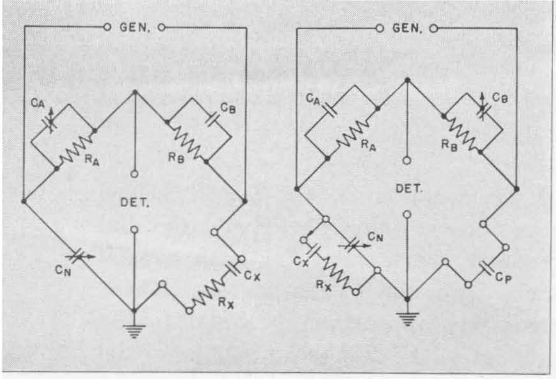


FIGURE 4. These diagrams show the bridge circuit for the two positions of the METHOD switch. The left-hand diagram is for the DIRECT position, the right-hand for the SUBSTitution position.

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, ±0.2% or ±2 $\mu\mu$f × 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 ±2% of dial reading, for values of D below 10%.

Substitution Method — capacitance ±0.2% or ±2 $\mu\mu$f; dissipation factor, ±0.00005 or ±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