OPERATING INSTRUCTIONS

TYPE 1611-B

CAPACITANCE TEST BRIDGE

1611-B

GENERAL RADIO COMPANY

H

OPERATING INSTRUCTIONS

TYPE 1611-B

CAPACITANCE TEST BRIDGE

Form 1611-0100-H
January, 1965

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

SPECIFICATIONS

CAPACITANCE RANGE:	0 to 11,000 μf in eight ranges.
TEST-VOLTAGE FREQUENCY:	60 cps with internal supply and filter; 120 cps with external supply on four higher multipliers; other audio frequencies to 1000 cps with reduced sensitivity, with external supply and filter.
CAPACITANCE ACCURACY:	±(1% + 1$\mu\mu$f) over the entire range.
DISSIPATION-FACTOR RANGE:	0 to 60% at 60 cps (x $\frac{f}{60}$ at other frequencies).
DISSIPATION-FACTOR ACCURACY:	±(2% of dial reading + 0.05% x $\frac{f}{60}$ dissipation factor). above 100 pf. Power factor equals $\frac{D}{\sqrt{1+D^2}}$ where D = dissipation factor.
VOLTAGE APPLIED TO SAMPLE:	Varies from 125 v at 100 $\mu\mu$f to less than 3 v at 10,000 μf with the internal 60-cycle supply.
POLARIZING VOLTAGE:	On the four highest multipliers (1 to 1000) a d-c polarizing voltage can be applied.
POWER SUPPLY VOLTAGE:	105 to 125 (or 210 to 250) volts, 60 cps.
ACCESSORIES SUPPLIED:	Power cord and spare fuses.
DIMENSIONS:	Width 14½ in., height 10 in., depth 16 in., over-all, including cover and handles. (370 x 255 x 410 mm).
WEIGHT:	30½ lb. (14 kg).

TABLE OF CONTENTS

Figure 1. Type 1611-B Capacitance Test Bridge.

TYPE 1611-B
CAPACITANCE TEST BRIDGE

Section 1
INTRODUCTION

1.1 PURPOSE. The Type 1611-B Capacitance Test Bridge (Figure 1) is a direct-reading capacitance bridge designed for wide-range capacitance and dissipation-factor measurements at 60 and 120 cps. (At 120 cps, an external generator is required; the Type 1214-D is recommended.) Measurements can be made at other audio frequencies up to about 1000 cps with reduced sensitivity. For such measurements an external generator and filter are required. The bridge is suitable for laboratory and shop testing of paper, mica, and electrolytic capacitors. It also meets the needs of the electric-power industry for shop testing of insulators, particularly for dissipation-factor measurement of bushings, insulators, transformer insulation, rotating machinery, and cables. For the wire and cable manufacturer, the bridge offers a convenient and rapid means of locating breaks in cable and of performing laboratory and production tests of dissipation factor and capacitance on all kinds of cable. The bridge's many applications in the communications industry include checking capacitance to ground of transformer windings, shields, and circuit elements, as well as routine capacitance and dissipation-factor tests on electrolytic capacitors and other components.

1.2 DESCRIPTION.

1.2.1 GENERAL. The circuit used is the series resistance-capacitance bridge (Figure 2), in which one ratio arm is continuously variable and calibrated to read directly in capacitance. The other ratio arm is variable in decade steps and serves as a multiplier for the direct-reading dial. The variable resistors in series with the standard capacitors are calibrated directly in dissipation factor. A visual null detector is used, consisting of a tuned amplifier and an electron-ray tube.

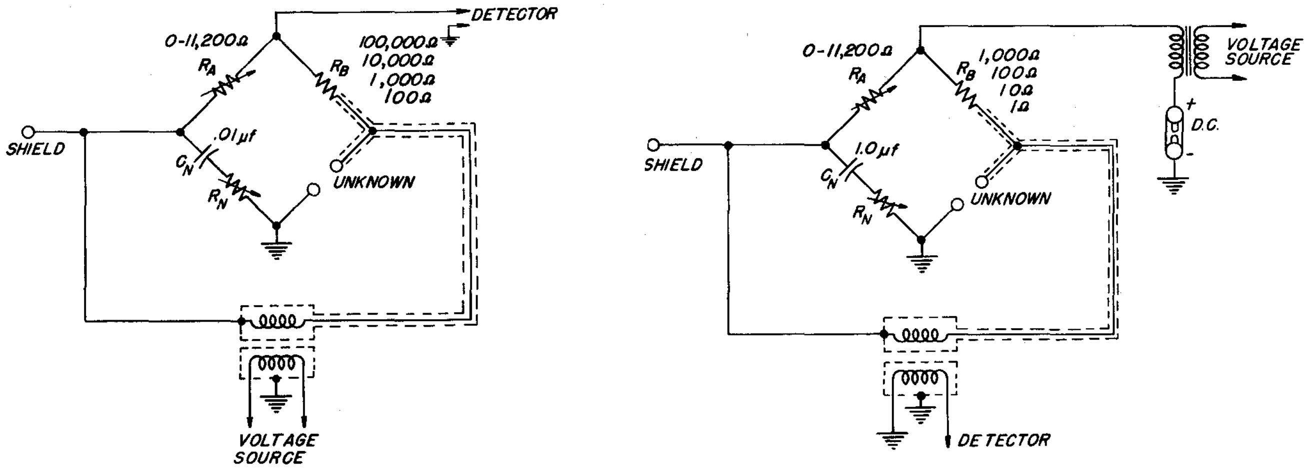


Figure 2. (a, left) Bridge Circuit for Four Lower Multiplier Positions.
(b, right) Bridge Circuit for Four Higher Multiplier Positions.

1.2.2 CONTROLS. The following controls are on the front panel of the Type 1611-B Capacitance Test Bridge:

Name	Type	Function
POWER	2-pos toggle switch	Main power switch
FILTER	3-pos rotary switch	Selects either internal 60-cps, 120-cps, or external filter.
DIR-STANDBY-REV	3-pos rotary switch	Provides opposite polarities of voltage applied to unknown or removes test voltage on four lower multipliers.
SENSITIVITY	Continuous rotary control	Controls detector sensitivity.
GEN	2-pos toggle switch	Adapts instrument for internal or external audio supply.
MULTIPLY CAPACITANCE BY	9-pos rotary switch	Selects capacitance range, or permits detector to be used independently of bridge.
DISSIPATION FACTOR	Continuous rotary control	Dissipation-factor balancing controls
CAPACITANCE	Continuous rotary control	Capacitance balancing controls
D	2-pos toggle switch	Adds 30% dissipation factor to continuous range.

1.2.3 CONNECTORS. The following connectors are on the Type 1611-B Capacitance Test Bridge.

Name	Type	Function
SHIELD	Jack-top binding post	Used in three-terminal measurements (paragraph 2.8)
EXT GEN	Binding-post pair	Connection for external audio generator
EXT FILTER	Phone jack	Connection for external filter
DC	Binding-post pair	Connection for dc polarizing voltage

1.2.4 MECHANICAL DETAILS.

1.2.4.1 General. The bridge is housed in a shielded airplane-luggage-type cabinet, with a cover that protects the panel and controls when the instrument is carried about and that keeps dust out when the bridge is not in use. Simplified operating instructions are mounted in the cover, as is the power cord.

1.2.4.2 Standard Capacitors. Two standard capacitors are used. One is a 0.01-μf mica capacitor, Type 505, mounted on a subpanel (see Figure 15). The other is a special 1.0-μf capacitor, made in two sections, with polystyrene tape used as the dielectric. After special heat treatment, aging, adjustment, and impregnation, it is mounted and sealed in the cylindrical metal containers located under the main shelf, as shown in Figure 15.

1.2.4.3 Dissipation-Factor Rheostats. The two rheostats (one for each capacitor) used to balance for dissipation factor are ganged to a common shaft and mounted on a subpanel (see Figure 14).

Each rheostat winding consists of two tapered sections. The resistances of the two sections are chosen so that the resulting scale permits precise readings at low values of dissipation factor, while at the same time retaining the convenience of a range up to 30% on a single scale. An etched dial scale is used, and four adjustable shunt resistors are provided, one across each section of each rheostat, to bring the actual resistance into agreement with the value required by the scale.

Two resistors controlled by a double-pole switch are connected one to each rheostat to increase the dissipation-factor range from 30% to 60%.

1.2.4.4 "A" Arm. The variable resistor R_A, by means of which the capacitance balance is obtained, is a tapered rheostat with a total resistance of about 11,000 ohms (see Figure 14). The taper is such that the dial scale is approximately logarithmic. An adjusting plate and cam built into the unit permit adjustment of the arm with respect to the dial at eight points. As adjusted at the factory, the resistance in kilohms corresponds to the dial reading within 0.5% over the main decade from 1.0 to 10.

1.2.4.5 Bridge Transformer. A shielded transformer couples the voltage source to the bridge (Figure 2a) or the bridge to the detector (Figure 2b). An electrostatic shield surrounds each winding, insuring a very low electrostatic coupling between windings. The primary shield is grounded and the secondary shield is connected to the bridge. The secondary shield-to-ground capacitance is part of the standard capacitance arm. For this reason the transformer is wound with polystyrene tape as insulation to insure a low and constant dielectric loss.

The transformer is mounted in a high-permeability case to minimize magnetic coupling to the rest of the circuit and to any external fields (see Figure 13). The entire assembly is treated and impregnated to minimize the possible effects of moisture.

1.2.4.6 The "Magic-Eye" Tube. The electron-ray tube (Type 6E5) is so mounted in a slotted tube that its position with respect to the panel can readily be changed. It is held in position by a thumbscrew, which is accessible when the instrument is removed from the case. When the bridge is used in brightly lit locations, or when the brilliance of the eye has been reduced with age, the tube can be slid back in its mounting to provide additional light shielding.

1.3 ACCESSORIES. Supplied with the Type 1611-B Capacitance Test Bridge are a power cord and spare fuses.

Section 2

OPERATING PROCEDURE

2.1 POWER SUPPLY. The instrument is shipped wired for either 105 - 125 or 210 - 250 volts, 60 cycles, as indicated on the nameplate near the power receptacle. The power transformer can be reconnected for either supply voltage in accordance with the information given on the schematic diagram, Figure 16.

For best results, connect the bridge to a good external ground. Use the ground terminal of either the UNKNOWN or DC binding-post pair.

The seven-foot line connector cord is mounted in the instrument cover. Plug it into the power source and snap the POWER switch on.

2.2 EXTERNAL GENERATOR FILTER. For measurements at 60 cps, both generator and filter are contained in the Type 1611-B.

2.2.1 FREQUENCIES OTHER THAN 60 CPS — FOUR HIGHER MULTIPLIERS. For measurements at 120 cps on the four higher multipliers, connect a suitable external generator (refer to paragraph 3.3.2) to the EXT GEN terminals, set the GEN switch to EXT and the FILTER switch to 120 c.

For frequencies other than 60 or 120 cps, connect a suitable external generator (refer to paragraph 3.3.2) to the EXT GEN terminals, connect the proper filter at the EXT FILTER terminals, set the GEN switch to EXT and the FILTER switch to EXT.

A transformer is normally required between the voltage source and the EXT GEN terminals, both for impedance matching and for isolation, since the dc polarizing voltage is connected on the ground side. The Type 1214-D Unit Oscillator is equipped with such a transformer. (Refer to paragraph 3.3.2.) A connection diagram for external audio oscillator, matching transformer, and limiting resistors is shown in Figure 3.

2.2.2 120 CPS ——— FOUR LOWER MULTIPLIERS. Place GEN switch in EXT position. Connect the external 120-cycle supply to the power socket of the bridge and remove the rectifier tube (V3) to reduce power consumption. Connect the external detector to the high EXT GEN binding post through a coupling capacitor, and to ground. An external polarizing voltage may be connected to the d-c binding posts, with a high-impedance choke between the EXT GEN binding posts.

2.3 ZERO ADJUSTMENT. The following adjustments have been made at the factory and in general need be checked only occasionally. For the best possible accuracy, especially for the measurement of small capaci-

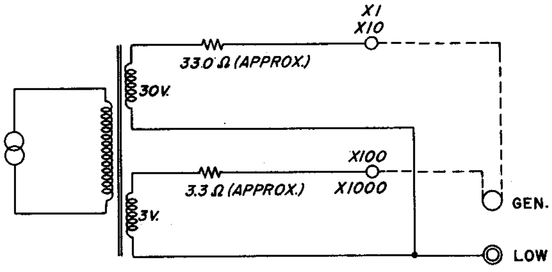


Figure 3. Connection Diagram for External Audio Oscillators.

tance, or to balance out lead capacitance, it is well to check the zero adjustment fairly often.

a. Set the MULTIPLY CAPACITANCE BY switch to 0.0001, the CAPACITANCE dial to zero, and the SENSITIVITY control fully clockwise. (Although capacitance less than 1000 μμf should normally be measured on the 0.0001 multiplier, it is sometimes more convenient to use the 0.001 range.)

b. Set the DIR-STANDBY-REV switch to DIR, and adjust the two screw-driver controls under the snap buttons at the upper left of the panel for a null (maximum angle of the dark sector in the null detector). The left-hand control is for dissipation factor, the right-hand control for capacitance.

c. Set the DIR-STANDBY-REV switch to REV, and adjust similarly the two screw-driver controls under the snap buttons at the upper right of the panel. The bridge is now ready for measurements.

2.4 LEAD CAPACITANCE.

Lead capacitance may be included in the zero adjustment if desired. The procedure is as follows:

a. Before making the zero adjustments described in paragraph 2.3, connect the unknown capacitance to the UNKNOWN terminals with the high lead disconnected at the capacitor terminal. A capacitance of about 15 μμf can be compensated in this manner.

b. If the lead capacitance is greater than 15 μμf, as for long leads or a cable, its effects on the measured values of capacitance and dissipation factor can be eliminated by measurement of cable or lead alone. Let the capacitance and dissipation factor of the lead or cable alone be C_E and D_E. Then the unknown capacitance and dissipation factor can be expressed by the following formulas:

$$C_{XS} = C - C_E \qquad (1)$$

$$D_X = \frac{DC - D_E C_E}{C - C_E} \qquad (2)$$

where C and D are the values with the unknown connected.

2.5 MEASUREMENT OF UNKNOWN CAPACITANCE AND DISSIPATION FACTOR.

a. Set the FILTER switch to the position corresponding to the test frequency (EXT for frequencies other than 60 or 120 cps).

b. Set the GEN switch to INT or EXT depending on whether the internal or an external test voltage supply is used.

c. Set the DIR-STANDBY-REV switch to STANDBY.

d. Connect the unknown capacitance to the UNKNOWN terminals, with the low or ground terminal of the unknown connected to the bridge G terminal.

e. Set the DIR-STANDBY-REV switch to DIR.

f. Set the SENSITIVITY control so that the eye just closes without overlap.

g. If the nominal capacitance value is known:

(1) Set the MULTIPLY CAPACITANCE BY to a range that will include the nominal value.

(2) Adjust the CAPACITANCE and DISSIPATION FACTOR controls for a null, changing the SENSITIVITY setting as necessary.

h. If the nominal capacitance value is not known:

(1) Set the MULTIPLY CAPACITANCE BY switch to 1000.

(2) Adjust the CAPACITANCE control for a null, changing the SENSITIVITY setting as necessary.

(3) If the null point is less than 1.0 on the dial, turn the MULTIPLY CAPACITANCE BY switch to 100, 10, etc, till the null is within the main decade (1.0 to 10) of the dial.

i. To eliminate the effect of extraneous voltages that may be induced (usually electrostatically) from adjacent electromagnetic fields at the power-line frequency:

(1) Obtain readings with the DIR-STANDBY-REV switch in both DIR and REV positions. The true result is the average of the two readings if the error is less than 10 percent.

(2) For strong interference causing large differences in readings, apply the following formulas:

$$D_X = \frac{D_1 C_1 + D_2 C_2}{C_1 + C_2} \qquad (3)$$

$$C_{XS} = \frac{C_1 + C_2}{2} \qquad (4)$$

where C_1 and D_1 are measured at one position of the STANDBY switch; C_2 and D_2 are measured in the other switch position.

j. Capacitance is indicated directly by the CAPACITANCE dial and multiplier switch to an accuracy of ±(1% + 1 μμf) over the entire range from 1 μμf to 11,000 μf.

k. Dissipation factor is indicated in percent on the DISSIPATION FACTOR dial, and this reading should be multiplied by $\frac{f}{60}$ where f is the frequency of the test voltage. In all unmodified formulas the dissipation factor must be expressed as a ratio (divide reading by 100). The accuracy of dissipation-factor measurement is ±(2% of dial reading $+\frac{f}{60}$ x .05% dissipation factor) over the range from 0.05% to 60% for capacitances greater than

100 $\mu\mu$f. Below 100 $\mu\mu$f, the decreasing sensitivity of balance increases the error inversely with capacitance.

1. Values of dissipation factor beyond the direct-reading range (60%) will occasionally be encountered, especially for electrolytic capacitors of very high value. The most convenient way of extending the range is by the use of an external parallel variable resistor between the SHIELD terminal and ground, with the DISSIPATION FACTOR control set at zero and the bridge balanced by the added resistance and CAPACITANCE dial. The dissipation factor of the unknown capacitor is given by:

$$D_X = \frac{1}{R_{NP}\omega C_N} \tag{5}$$

where D_X is in absolute value

R_{NP} is the added parallel resistance, in ohms

ω is 2π times test frequency, in cycles per second

C_N is standard capacitance from Table I, in farads

For a test frequency of 60 cycles, formula (5) becomes:

$$D_X = \frac{265.3}{R_{NP}C_N} \tag{6}$$

with D_X in %, R_{NP} in kilohms, and C_N in microfarads.

For a test frequency of 120 cycles, formula (5) becomes:

$$D_X = \frac{132.6}{R_{NP}C_N} \tag{7}$$

with D_X in %, R_{NP} in kilohms, and C_N in microfarads.

The measurement of a dissipation factor of 60% requires 442 kilohms on the four lower multipliers and 4.42 kilohms on the four upper multipliers. The capacitance thus measured is the parallel capacitance. The relation between series and parallel capacitance is given in paragraph 2.8.3 and in Figure 4.

2.6 MEASUREMENT OF RESISTANCE.

Since the bridge measures series capacitance, the series resistance of the unknown capacitors is given by the formula:

$$R_{XS} = \frac{D_X}{\omega C_{XS}} \tag{8}$$

where R_{XS} is series resistance, in ohms

D_X is dissipation factor, expressed as a ratio (or absolute value)

ω is 2π times test frequency, in cycles per second

C_{XS} is series capacitance, in farads.

For a test frequency of 60 cycles, formula (8) becomes:

$$R_{XS} = \frac{26.53 D_X}{C_{XS}} \tag{9}$$

with D_X in % and C_{XS} in microfarads.

For a test frequency of 120 cycles, formula (8) becomes:

$$R_{XS} = \frac{13.26 D_X}{C_{XS}} \tag{10}$$

with D_X in % and C_{XS} in microfarads.

Figure 6 can be used to determine series resistance for any pair of values of series capacitance and dissipation factor. Use the lower chart to determine the order of magnitude, and the upper chart to obtain significant figures.

Series resistance can be converted to parallel resistance by means of Figure 5.

2.7 MEASUREMENT OF ELECTROLYTIC CAPACITOR WITH POLARIZING VOLTAGE.

2.7.1 GENERAL. An external polarizing voltage up to a maximum of 500 volts can be applied to the capacitor under test on the four upper multipliers (1μf to 11,000μf). Connect the polarizing voltage to the D-C binding posts, observing the proper polarity. The impedance of the power source is placed in series with the a-c voltage supply of the bridge, and reduces both applied voltage and sensitivity. An adequate bypass capacitor across the D-C binding posts will restore sensitivity.

Measurement procedure is the same as that described in paragraph 2.4.

CAUTION

> To protect against the short-circuit current drawn by a defective capacitor, use a protective resistor of about 50 ohms per volt in series with the d-c supply.

2.7.2 LEAKAGE CURRENT. The measurement of leakage current of electrolytic capacitors is often required in conjunction with the capacitance measurement. The addition of a milliammeter in series with the polarizing voltage source permits this leakage current to be measured at the same time the bridge measurement is made.

2.7.3 CONTROL OF TEST VOLTAGE. In certain measurements, the maximum allowable a-c test voltage may be specified. The applied voltage can be controlled by a rheostat inserted across the D-C terminals or in series with the external d-c power supply, if one is used.

2.7.4 CONVERSION OF DISSIPATION FACTOR TO P. In Electronic Industries Association (formerly RETMA) Standard RS-154A (December 1957) dealing with polarized

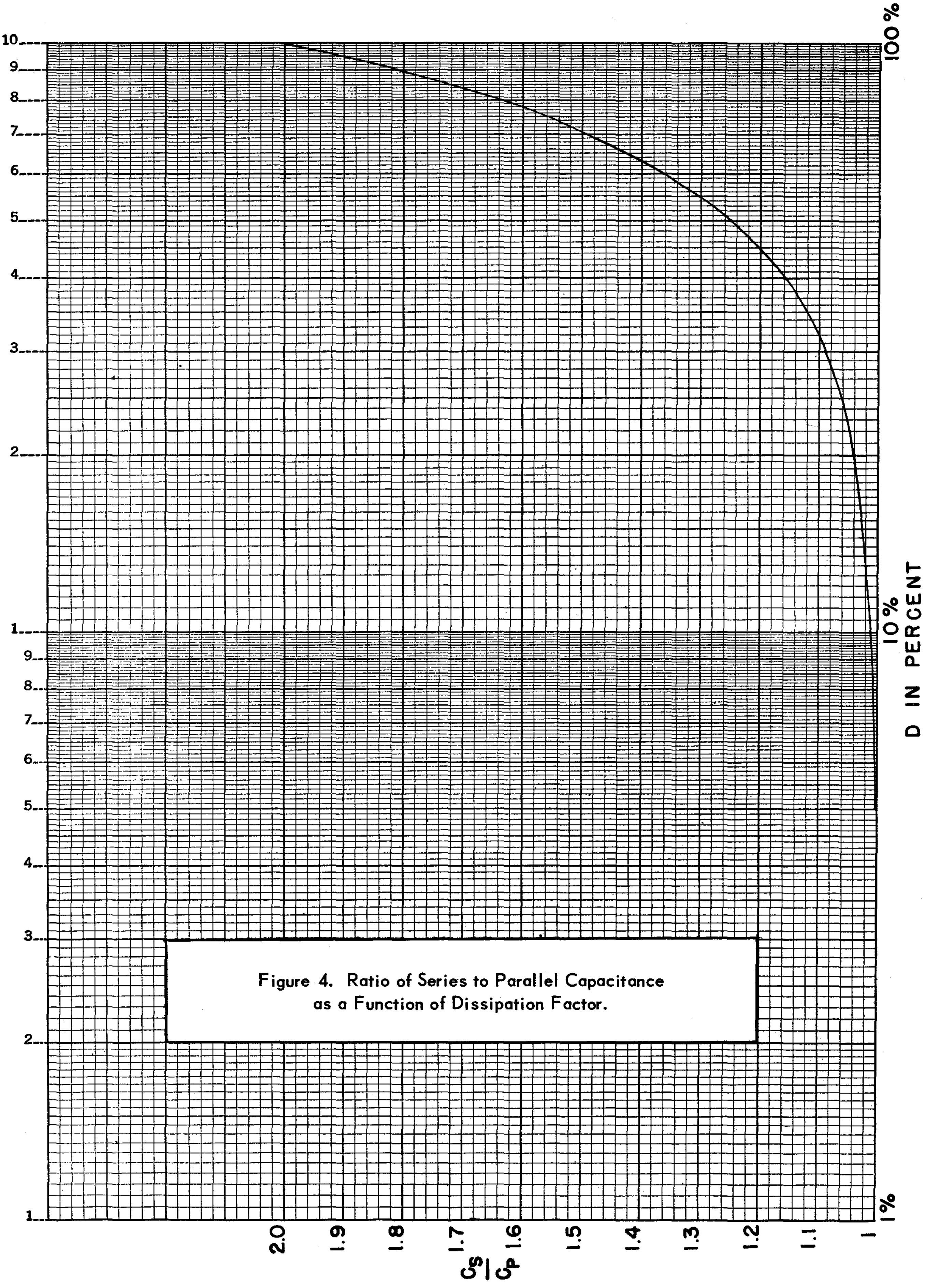


Figure 4. Ratio of Series to Parallel Capacitance as a Function of Dissipation Factor.

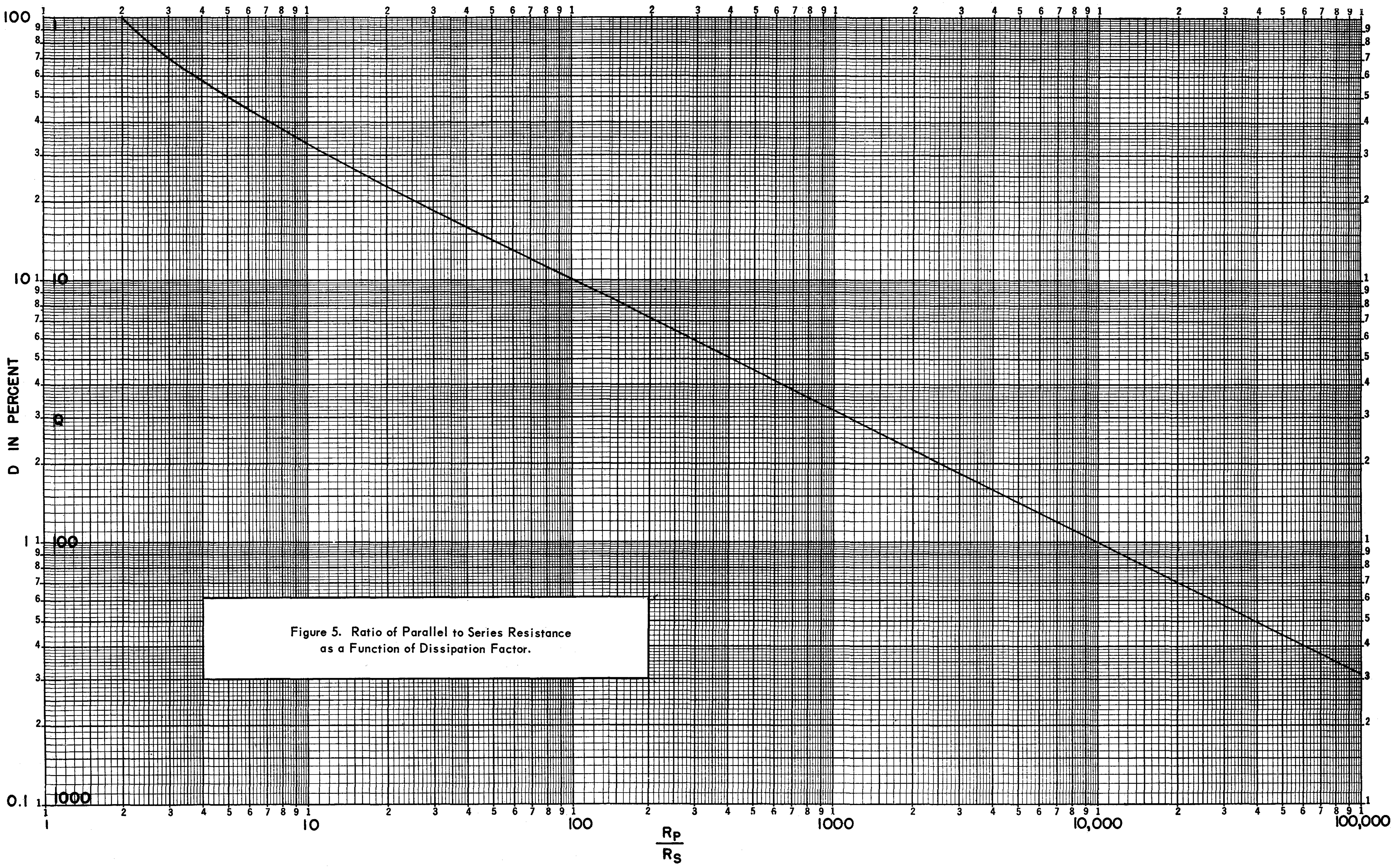
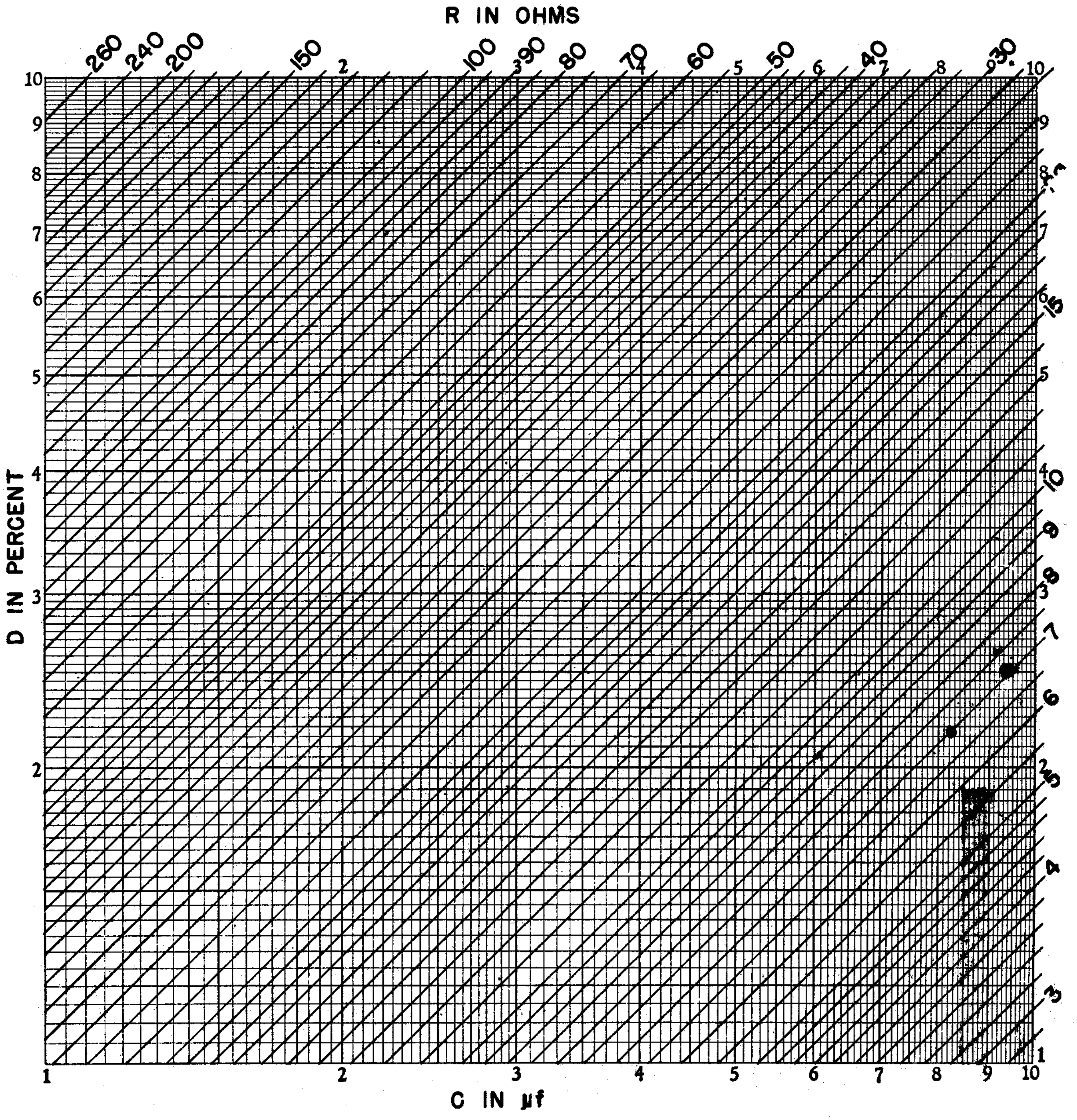


Figure 5. Ratio of Parallel to Series Resistance as a Function of Dissipation Factor.



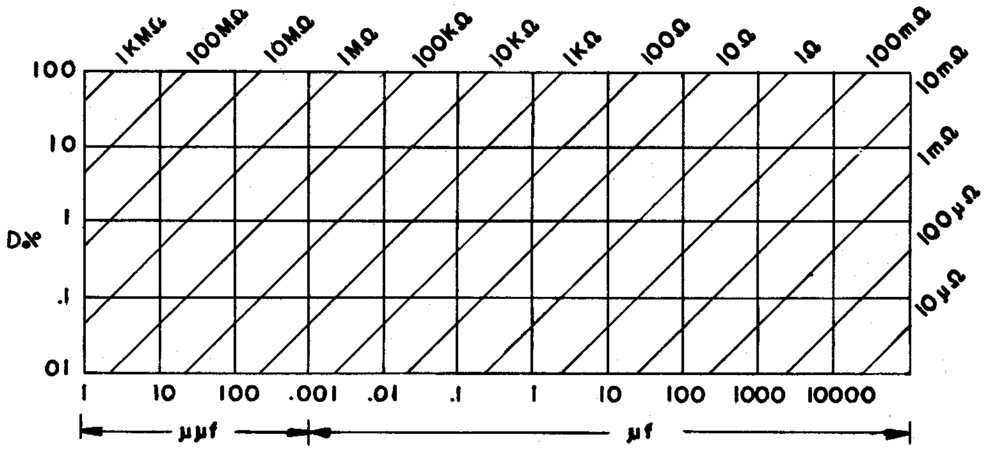


Figure 6. Series Resistance as a Function of Series Capacitance and Dissipation Factor. Use lower chart to determine order of magnitude, and upper chart for significant figures.

dry electrolytic capacitors for general use, maximum values of P are prescribed for various rated d-c voltages, where P is defined as rated capacitance in microfarads times equivalent series resistance in ohms, at 120 cycles. To determine the value P, simply multiply the dissipation factor (in percent) of the capacitor at 120 cps by 13.26.

2.8 MEASUREMENTS OF THREE-TERMINAL CAPACITANCE.

2.8.1 THREE-TERMINAL NETWORKS. Figure 7 shows two methods by which the bridge can be connected to measure one or all the capacitances of a three-terminal network. In Figure 7a, the third terminal is connected to the bridge SHIELD terminal to measure the capacitance or dissipation factor of C_{13}. In this connection, the capacitance C_{12} is placed diagonally across the bridge where it has no effect on the measurement, C_{23}, on the other hand, goes directly across the standard arm, and will cause both capacitance and dissipation factor to read low by an amount determined by the ratios of C_{23} and D_{23} to the capacitance and dissipation factor of the standard arm. The errors are usually negligible if C_{23} is less than 100 $\mu\mu$f.

An alternate method, shown in Figure 7b, takes advantage of the fact that the fourth corner of the bridge is also available on the panel, at the high EXT GEN terminal. With the third terminal of the unknown network connected to the EXT GEN terminal as shown in Figure 7b, the capacitance C_{23} is placed diagonally across the bridge and does not affect the measurement. Now, however, the capacitance C_{12} is across the B arm of the bridge. In this position it has little effect on the capacitance balance, but it causes the dissipation factor to read high by an amount $R_B \omega C_{12}$.

2.8.2 THE THREE-MEASUREMENT METHOD. To determine accurately all three capacitances of the networks of Figure 7, as well as associated dissipation factors, it is necessary to make three measurements, as follows:

a. Measure C_{12} and C_{23} in parallel, by grounding point 1 and measuring from point 2 to ground.

b. Measure C_{12} and C_{13} in parallel, by grounding point 2 and measuring from point 1 to ground.

c. Measure C_{13} and C_{23} in parallel, by connecting points 1 and 2 together.

d. Using the data from step a and the following formulas, compute C_A and D_A.

$$C_A = C_{12} + C_{23} \tag{11}$$

$$D_A = \frac{D_{12}C_{12} + D_{23}C_{23}}{C_{12} + C_{23}} \tag{12}$$

e. Using the data from step b and the following formulas, compute C_B and D_B.

$$C_B = C_{12} + C_{13} \tag{13}$$

$$D_B = \frac{D_{12}C_{12} + D_{13}C_{13}}{C_{12} + C_{13}} \tag{14}$$

f. Using the data from step c and the following formulas, compute C_C and D_C.

$$C_C = C_{13} + C_{23} \tag{15}$$

$$D_C = \frac{D_{13}C_{13} + D_{23}C_{23}}{C_{13} + C_{23}} \tag{16}$$

In solving the above simultaneous equations, the following expressions are useful:

$$C = \tfrac{1}{2}(C_A + C_B + C_C) \tag{17}$$

$$DC = \tfrac{1}{2}(D_AC_A + D_BC_B + D_CC_C) \tag{18}$$

In terms of these expressions, the three unknown capacitances and dissipation factors can be written as follows, in a form convenient for calculation:

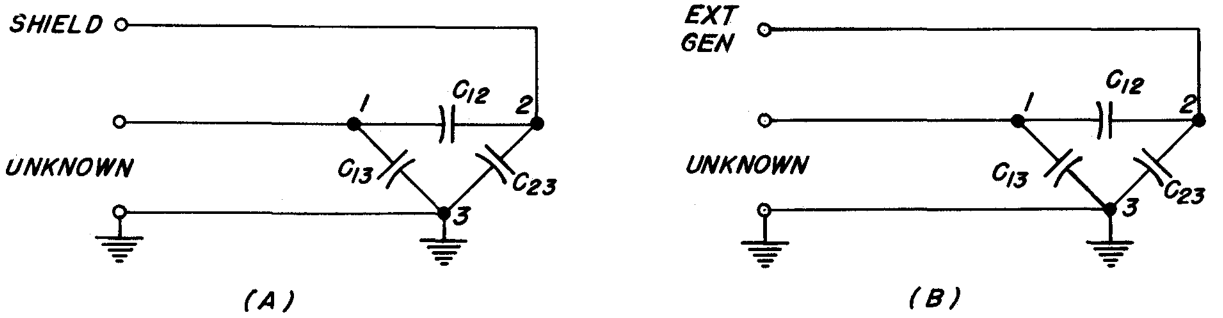


Figure 7. Equivalent Representation of a Three-Terminal Capacitance, and Two Methods of Connecting to Bridge.

$$C_{13} = C - C_A$$

$$C_{23} = C - C_B$$

$$C_{12} = C - C_C$$

$$D_{13} = \frac{DC - D_A C_A}{C_{13}} \tag{19}$$

$$D_{23} = \frac{DC - D_B C_B}{C_{23}}$$

$$D_{12} = \frac{DC - D_C C_C}{C_{12}}$$

A convenient tabular form of computation can be used, as illustrated by the following numerical example:

	D	C	DC
C_A	3.0	600	1800
C_B	4.0	500	2000
C_C	3.5	700	2450
Sum		1800	6250
½Sum		900	3125
C_{13}	4.41	300	1325
C_{23}	2.81	400	1125
C_{12}	3.38	200	675

2.8.3 EFFECTS OF LARGE DISSIPATION FACTORS. The formulas of paragraph 2.8.2 are based on the assumption that the measured values are parallel values of capacitance. For values of dissipation factor below 0.10 (10%) the difference between series and parallel components is insignificant. For larger values of dissipation factor, the measured series values of capacitance must be converted to parallel values before the formulas can be used. The conversion formula is:

$$C_{XP} = \frac{C_{XS}}{1 + D^2} \tag{20}$$

where C_{XP} is parallel capacitance
C_{XS} is series capacitance
D is dissipation factor (absolute value)

A chart by means of which parallel capacitance can be determined for any pair of values of series capacitance and dissipation factor is given in Figure 4.

2.9 INDUCTANCE MEASUREMENT.

2.9.1 SERIES-SUBSTITUTION METHOD. Inductance can be determined from the measurement of the net effective capacitance of the unknown inductor in series with a known capacitor of suitable value. The series capacitor must be small enough so that the net reactance of the combination is capacitive. At the same time, it must be large enough so that a significant change in effective capacitance results. The procedure is as follows:

a. Connect the unknown inductor and series capacitor as shown in Figure 8.

b. Short-circuit the inductor and measure the capacitor alone. Use C_1 and D_1 to denote the bridge readings.

c. Remove the short circuit and rebalance the bridge. Use C_2 and D_2 to denote the new readings.

d. Compute series inductance as follows:

$$L_{XS} = \frac{\Delta C}{\omega^2 C_1 C_2} \tag{21}$$

where L_{XS} is the unknown series inductance in henrys
ω is 2π times frequency in cycles per second
C_1, C_2 are as given in b and c above, in farads
$\Delta C = C_2 - C_1$

For 60 cycles:

$$L_{XS} = 7.04 \frac{\Delta C}{C_1 C_2} \tag{22}$$

where ΔC, C_1, and C_2 are in μf.

For 120 cycles:

$$L_{XS} = 1.76 \frac{\Delta C}{C_1 C_2} \tag{23}$$

where ΔC, C_1, and C_2 are in μf.

e. Compute series resistance as follows:

$$R_{XS} = \frac{D_2 C_1 - D_1 C_2}{\omega C_1 C_2} \tag{24}$$

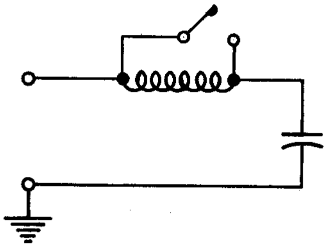


Figure 8. Connection Diagram for Series-Substitution Measurement of Inductance.

where R_{XS} is series resistance, in ohms

ω is 2π times frequency in cycles per second

C_1, C_2, D_1, D_2 are from b and c above, in farads and absolute value (or ratio).

For 60 cycles:

$$R_{XS} = 26.53 \frac{D_2C_1 - D_1C_2}{C_1C_2} \qquad (25)$$

where D_1 and D_2 are in percent

C_1 and C_2 are in μf.

For 120 cycles:

$$R_{XS} = 13.27 \frac{D_2C_1 - D_1C_2}{C_1C_2} \qquad (26)$$

where D_1 and D_2 are in percent

C_1 and C_2 are in μf.

f. Compute storage factor, Q, as follows:

$$Q_X = \frac{100\Delta C}{D_2C_1 - D_1C_2} \qquad (27)$$

where Q_X is storage factor

$\Delta C = C_2 - C_1$

C_1, C_2, D_1, D_2 are from b and c above, in farads and percent.

2.9.2 PARALLEL-SUBSTITUTION METHOD. Inductance can also be measured by a parallel-substitution method, with the conditions regarding the size of the parallel capacitor the reverse of those given for the series capacitor in paragraph 2.9.1. However, since the bridge measures series components, the parallel-substitution formulas are rather complicated. The easiest way of handling the computation is probably to convert bridge readings to parallel capacitance by means of equation (20). The procedure is as follows:

a. Connect the unknown inductor and parallel capacitor as shown in Figure 9.

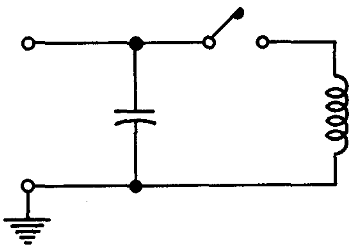


Figure 9. Connection Diagram for Parallel-Substitution Measurement of Inductance.

b. Disconnect the high lead of the inductor and balance the bridge. Use C_1 and D_1 to denote the capacitance and dissipation factor,

c. Reconnect the inductor and rebalance the bridge. Use C_2 and D_2 to denote the new readings.

d. Convert C_1 and C_2 to effective parallel values by using equation (20), and designate the new values C_1' and C_2'.

e. Compute parallel inductance as follows:

$$L_{XP} = \frac{1}{\omega^2 \Delta C'} \qquad (28)$$

where L_{XP} is parallel inductance, in henrys

ω is 2π times frequency in cycles per second

$\Delta C'$ is $C_2' - C_1'$, in farads.

For 60 cycles:

$$L_{XP} = \frac{7.04}{\Delta C'} \qquad (29)$$

where $\Delta C'$ is in μf.

For 120 cycles:

$$L_{XP} = \frac{1.76}{\Delta C'} \qquad (30)$$

where $\Delta C'$ is in μf.

f. Compute parallel resistance as follows:

$$R_{XP} = \frac{1}{\omega(D_2C_2' - D_1C_1')} \qquad (31)$$

where R_{XP} is parallel resistance, in ohms

ω is 2π times frequency in cycles per second

C_1' and C_2' are as given in d above, in farads

D_1 and D_2 are as given in b and c above, in absolute value.

For 60 cycles:

$$R_{XP} = \frac{265{,}300}{D_2C_2' - D_1C_1'} \qquad (32)$$

where D_1 and D_2 are in percent

C_1' and C_2' are in μf.

For 120 cycles:

$$R_{XP} = \frac{132{,}700}{D_2C_2' - D_1C_1'} \qquad (33)$$

where D_1 and D_2 are in percent

C_1' and C_2' are in μf.

g. Compute storage factor, Q, as follows:

$$Q_X = \frac{1}{D_X} = \frac{100\Delta C'}{D_X(D_2C_2' - D_1C_1')} \qquad (34)$$

where Q_X is storage factor

$\Delta C'$ is $C_2' - C_1'$, in farads

C_1' and C_2' are as given in d above, in farads

D_1 and D_2 are as given in b and c above, in absolute value.

h. Compute series inductance as follows:

$$L_{XS} = \frac{L_{XP}}{1 + D_X^2} \qquad (35)$$

where L_{XP} is series inductance

L_{XP} is parallel inductance

D_X is $\frac{1}{Q_X}$ from (34).

i. Compute series resistance as follows:

$$R_{XS} = \frac{R_{XP}}{1 + Q_X^2} \qquad (36)$$

where R_{XS} is series resistance

R_{XP} is parallel resistance

Q_X is storage factor from (34).

2.10 RESISTANCE MEASUREMENT.

2.10.1 SERIES-SUBSTITUTION METHOD. To measure the effective a-c resistance of a resistor, connect a capacitor of suitable size in series with the resistor and measure the dissipation factor. The difference between this value and the dissipation factor of the capacitor alone can be used to compute resistance. The procedure is as follows:

a. Connect the capacitor and resistor as shown in Figure 8, replacing the inductor with a resistor.

b. Short-circuit the resistor and measure the capacitor alone. Use C_1 and D_1 to denote the capacitance and dissipation factor.

c. Remove the short circuit and rebalance the bridge. Use C_2 and D_2 to denote the new values. C_1 and C_2 will be equal unless the resistor has a reactive component.

d. Compute the unknown resistance as follows:

$$R_{XS} = \frac{\Delta D}{\omega C} \qquad (37)$$

where R_{XS} is series resistance, in ohms

D is $D_2 - D_1$, absolute value

ω is 2π times frequency in cycles per second

$C = C_1 = C_2$ in farads.

For 60 cycles:

$$R_{XS} = 26.53 \frac{\Delta D}{C} \qquad (38)$$

where ΔD is in percent

C is in μf.

For 120 cycles:

$$R_{XS} = 13.27 \frac{\Delta D}{C} \qquad (39)$$

where ΔD is in percent

C is in μf.

Figure 5 shows the relation between series and parallel resistance as a function of dissipation factor.

2.10.2 PARALLEL-SUBSTITUTION METHOD. The procedure described in paragraph 2.9.2 may be used with the resistor in parallel with the known capacitor. The procedure is as follows:

a. Connect the resistor and capacitor as shown in Figure 9, replacing the inductor with a resistor.

b. Disconnect the high lead of the resistor and balance the bridge. Use C_1 and D_1 to denote the capacitance and dissipation factor.

c. Reconnect the resistor and rebalance the bridge, using C_2 and D_2 to denote the new values.

d. Convert C_1 and C_2 to effective parallel values by using equation (20) or Figure 4. C_1 and C_2 will be equal unless the resistor has a reactive component. Designate the new values C_1' and C_2'.

e. Compute the unknown resistance as follows:

$$R_{XP} = \frac{1}{\omega C'\Delta D} \qquad (40)$$

where R_{XP} is parallel resistance, in ohms

ω is 2π times frequency in cycles per second

C' is as given in d above, in farads

ΔD is $D_2 - D_1$, absolute value.

For 60 cycles:

$$R_{XP} = \frac{265{,}300}{C'\Delta D} \qquad (41)$$

where C' is in μf

ΔD is in percent.

For 120 cycles:

$$R_{XP} = \frac{132{,}700}{C'\Delta D} \qquad (42)$$

where C' is in μf

ΔD is in percent.

Figure 5 shows the relation between series and parallel resistance as a function of dissipation factor.

2.11 MEASUREMENT OF DIELECTRIC SAMPLES.

2.11.1 GENERAL. The dielectric constant and dissipation factor of an insulating material can be determined from the measurement of the capacitance and dissipation factor of an elementary capacitor, with the material used as the insulating medium between metallic electrodes of suitable dimensions.

2.11.2 TWO-ELECTRODE METHOD. A simple two-electrode method is sufficient for most purposes. The procedure is as follows:

a. If possible, choose a sample of such shape and dimension as to yield a capacitance of 100 $\mu\mu f$ or more. The calculation of dielectric constant is simplified if the thickness and area are easily measured and calculated, such as a disk or rectangle. If measurements are to be made at various frequencies, it is best to use sizes and shapes as specified in ASTMD-150 (available from American Society for Testing Materials, 260 Race Street, Philadelphia, Pennsylvania).

b. Measure and record the dimensions of the sample, and clean it thoroughly. (A mixture of half grain alcohol and half ether is recommended unless it is a solvent for the material.)

c. When the sample is dry, apply a very thin film of refined petrolatum to one surface. Place a thin metal foil electrode, preferably less than 1 mil thick, and larger than the sample, on this surface.

d. Press the electrode in place with a pad of cloth or squeegee roller and rub out any bubbles, so that the foil is in intimate contact with the surface. Then trim the foil to the same size as the sample.

e. Apply the other electrode to the sample as described in steps c and d.

NOTE

An alternate method of forming electrodes is to brush a good silver paint (such as Dupont No. 4132 Silver Paste) on the sample and to dry it overnight at 60°C. Such an electrode is porous to moisture, so that the dielectric can be conditioned at any desired relative humidity without removing the electrode.

f. Measure capacitance as described in paragraph 2.4.

g. Compute dielectric constant (to a first approximation) as follows:

$$K = \frac{4.45\,t\,C}{A} \qquad (43)$$

where K is dielectric constant

t is thickness of the sample, in inches

C is measured capacitance, in $\mu\mu f$

A is area of the electrodes, in square inches.

For a complete discussion of the effects of stray electric field at the edges of the electrodes, and the effect of the capacitance of the high electrode to ground, refer to ASTM D-150.

2.11.3 THREE-ELECTRODE (GUARD-ELECTRODE) METHOD. The guard arrangement, shown in Figure 10, is electrically equivalent to the three-terminal capacitance discussed in paragraph 2.7.1 and shown in Figure 7. To measure the characteristics of different parts of a nonhomogenous sample, place the electrodes over the part to be measured and block off the remainder by means of the guard electrode. If the guard electrode is connected to the SHIELD terminal, as described in paragraph 2.7.1, the guard-to-ground capacitance is placed across the capacitance arm of the bridge, where it will generally have a negligible effect on the measurement.

2.12 MEASUREMENT OF LIQUID INSULATION.

Liquid insulation, such as transformer oils and askarels, requires some type of cell for measurement of capacitance and dissipation factor. The cell in its simplest form can be a multiple-plate air capacitor immersed in the liquid, or a grounded cylindrical can with a slightly smaller insulated cylindrical electrode. Such cells do not allow the accurate calculation of dielectric constant, nor do they maintain a constant voltage gradient on the liquid. These difficulties are overcome by the use of a three-electrode cell, such as described in ASTM D-150. Such a cell is electrically equivalent to Figure 10, with a ter-

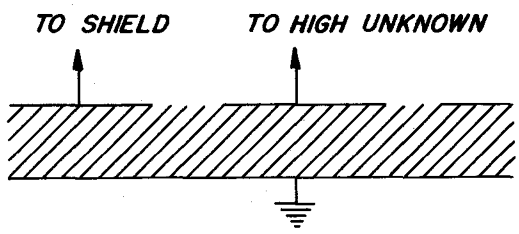


Figure 10. Guard-Electrode Arrangement for Measuring Dielectric Samples.

minal capacitance small enough to permit use of the SHIELD terminal as described in paragraph 2.7.1.

2.13 MEASUREMENT OF INSULATORS. Electrical insulators, such as bushings, may be measured as described in paragraph 2.5, since such insulators have one terminal grounded. To eliminate the effect of leakage over the surface of the insulation, place an electrode around the insulator surface and connect this electrode to the SHIELD terminal, as described in paragraph 2.8.1.

2.14 TRANSFORMER MEASUREMENTS. The insulation in a transformer, together with the primary and secondary windings and the transformer case, form a three-terminal network (refer to paragraph 2.8). All the direct capacitances are generally so large that the three methods described in paragraph 2.8.2 must be used to separate the three insulations: primary to case, secondary to case, and primary to secondary.

A sample of the oil in a transformer can be drawn off and tested by the method described in paragraph 2.12.

2.15 MEASUREMENT OF PARALLEL CAPACITANCE. Effective parallel capacitance can be measured by the use of an external decade-resistance box or other variable resistor to balance for dissipation factor. Connect the external resistor from SHIELD to ground and set the DISSIPATION FACTOR control at zero. Balance the bridge by means of the CAPACITANCE dial and the external resistance. Used in this way, the CAPACITANCE dial reads directly the parallel capacitance of the unknown. Compute parallel resistance as follows:

$$R_{XP} = R_{NP}\frac{R_B}{R_A} \qquad (44)$$

$$R_{XP} = R_{NP}\frac{C_N}{C_{XP}} \qquad (45)$$

where R_{XP} is the effective parallel resistance, in ohms

R_{NP} is the external resistance, in ohms

R_A in kΩ = the CAPACITANCE DIAL reading in μf

R_B is the resistance of R_B from Table 1 in kΩ

C_N is the value of the standard capacitor, from Table 1

C_{XP} equals bridge reading in μf.

2.16 USE AS A LIMIT BRIDGE. Because of the limiting characteristics of the null-detector response, the bridge is not as readily suitable for limit work as one having a linear detector response. Such linear response can be obtained by the removal of the Thyrite resistor across the grid of the 6E5 tube.

TABLE 1

MULTIPLIER	R_B	I_M	C_N	VOLTS APPLIED TO UNKNOWN WITH C DIAL AT	
	RESISTANCE	MAX CURRENT		MIN	MAX
0.0001	100,000 ohms	1.5 ma	0.01μf	128	121
0.001	10,000 ohms	5 ma	0.01μf	57	43
0.01	1,000 ohms	16 ma	0.01μf	13	5
0.1	100 ohms	55 ma	0.01μf	1.5	0.5
1	1,000 ohms	16 ma	1.0 μf	22	5
10	100 ohms	55 ma	1.0 μf	12	1.5
100	10 ohms	170 ma	1.0 μf	2.4	0.5
1000	1 ohm	550 ma	1.0 μf	1.4	0.15

R_A resistance in kΩ equals dial reading in μf

Section 3

PRINCIPLES OF OPERATION

3.1 BRIDGE CIRCUIT. In order to cover an extremely wide capacitance range effectively, two series-resistance bridge circuits are used, differing in the value of standard capacitance used and in the method of connecting the generator and detector. All necessary changes in circuit connections are made by the panel controls.

Figure 2a shows the basic bridge circuit used for the four lower multiplier positions (0.0001, 0.001, 0.01, 0.1). Figure 2b shows the arrangement used for the four high multipliers (1, 10, 100, 1000), where generator and detector are interchanged from the circuit of Figure 2a and the capacitance and resistance of the standard arm have been changed by a factor of 100.

The balance conditions are independent of generator and detector connections. They are given by:

$$C_{XS} = C_N \frac{R_A}{R_B} \qquad (46)$$

$$D_X = R_X \omega C_X = R_N \omega C_N = D_N \qquad (47)$$

where C_{XS} and D_X are the series capacitance and dissipation factor of the unknown capacitor and C_N and D_N are the series capacitance and dissipation factor of the standard arm.

With "high multiplier" connection of Figure 2b, there is provision for connecting a d-c voltage in series with the a-c bridge voltage for polarizing capacitors. One terminal of the d-c source is at ground potential, so that almost any available d-c source can be used. This arrangement also avoids the necessity for a high-impedance choke.

3.2 DETECTOR. The detector system consists of a single stage of amplification and an electron-ray tube ("magic eye"), which is used as a visual indicator. As shown in Figure 11, the amplifier is made selective to the operating frequency by means of a parallel-resonant circuit in the plate circuit. The detector system is designed to be very sensitive when the bridge is at or near balance, but relatively insensitive when the bridge is out of balance. This is accomplished by means of a Type 6E5 remote-cutoff electron-ray tube, in conjunction with a voltage-sensitive resistance element (Thyrite) shunting its input. The resulting characteristics greatly simplify the process of locating the balance, and the necessity of using the manual sensitivity control is greatly reduced.

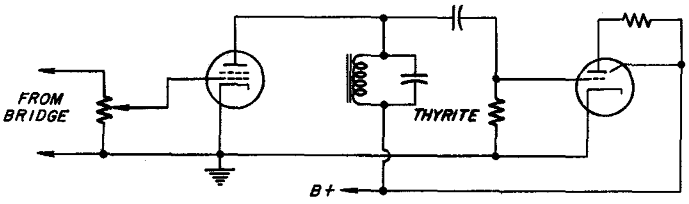


Figure 11. Diagram of Detector System, Showing Resonant Circuit Used for Frequency Selectivity.

To disconnect the detector from the bridge, it is necessary only to turn the multiplier switch to DET. The bridge detector can then be used as a null indicator for any other bridge. The input to the detector is between the high EXT GEN binding post and a G terminal.

The FILTER switch provides a choice of: 60-cycle internal filter, 120-cycle internal, or untuned. With the switch in the EXT (untuned) position, an external filter (parallel-resonant tuned circuit) can be connected to the EXT FILTER jack for measurements at frequencies other than 60 or 120 cps. An external detector may be connected to these terminals if desired.

3.3 BRIDGE VOLTAGE SUPPLY.

3.3.1 INTERNAL 60-CYCLE SUPPLY. Because of the wide impedance range presented by the bridge, no single source of voltage can efficiently supply the test voltage for all ranges. Four separate sources are used, one for each pair of the eight multiplier positions (see Figure 12).

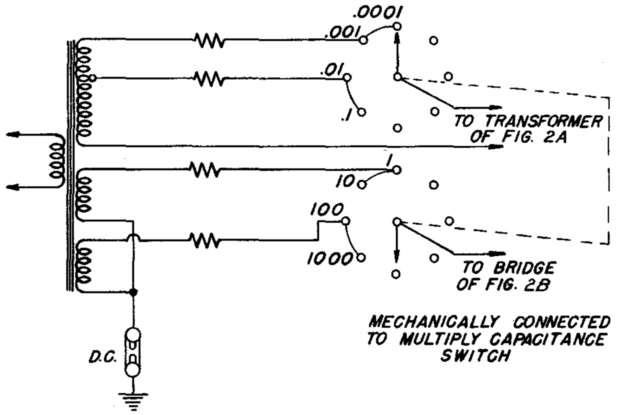


Figure 12. Diagram of Internal Bridge-Voltage-Supply Connections.

The voltages and series resistances are chosen to deliver approximately the maximum safe power to the bridge under all conditions. The proper source is selected by a switch mechanically connected to the switch that controls the bridge ratio arm. The approximate voltages applied to the unknown are given in Table 1.

3.3.2 EXTERNAL SUPPLIES. At 120 cycles, the impedance presented by the bridge at the EXT GEN terminals is approximately 1000 ohms for 1 μf and approximately 1 ohm for 10,000 μf. To provide reasonable impedance match, an arrangement similar to that used in the internal 60-cycle supply is recommended. (Refer to paragraph 3.3.1.)

With the voltages and resistances as shown in Figure 3, the bridge cannot be overloaded at any setting. If a low-power audio oscillator is used as a source, the limiting resistors may not be needed. The maximum power that should be delivered to the bridge is ½ watt, the rating of the resistors R_B.

Most R-C oscillators commercially available are not able to deliver the desired power to the bridge on low-impedance, high-capacitance multipliers. A Type 1206-B Unit Amplifier (with a Type 1203-B Unit Power Supply) can be used to raise the voltage to a satisfactory level.

A Type 1304-B Beat-Frequency Oscillator can be used directly without an external transformer (one is included in its output circuit). Connect the oscillator to the EXT GEN terminals and set the output to 30 volts on X1 and X10 and to 3 volts on X100 and X1000 multipliers with the unknown disconnected. Use the proper limiting resistors as shown in Figure 3.

The Type 1214-D Unit Oscillator is designed specifically as a 120-cycle source for the Type 1611-B Bridge, and requires no additional accessories. The transformer of this Unit Oscillator may be used with any oscillator to provide impedance match.

3.4 COMPENSATING CIRCUITS.

3.4.1 RATIO-ARM COMPENSATION. Any loss in the standard capacitor causes the bridge to read low in dissipation factor by an amount equal to the dissipation factor of the standard capacitor. Since this value may be as much as 0.0012, it must be compensated in order to realize the rated accuracy of the bridge. Compensation is accomplished by fixed capacitors connected across the resistors in the opposite arm. These capacitors are of such values that $R_B \omega C_B$ approximates D_O, the dissipation factor of the standard capacitor. No compensation is used on the 1- and 10-ohm resistors corresponding to the 100 and 1000 multipliers, since the dissipation factor of the standard capacitor associated with these multipliers is only 0.0003.

Section 4

SERVICE AND MAINTENANCE

4.1 GENERAL. The two-year warranty given with every General Radio instrument attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), requesting a Returned Material Tag. Use of this tag will insure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.2 ROUTINE MAINTENANCE. Switch blades, contacts, and contact surfaces of the wire-wound rheostats should periodically be cleaned and lubricated. A recommended cleaning method is to use a mixture of half ether and half alcohol, followed by a few light strokes with crocus cloth. A very thin smear of petrolatum should then be applied on the wire-wound rheostats.

4.3 DIAL CALIBRATION PROCEDURES.

4.3.1 GENERAL. The following calibration procedures require the use of a Wheatstone bridge accurate to at least ±0.25%.

4.3.2 CAPACITANCE DIAL CALIBRATION.

a. Make certain that the rheostat R19 is clean, that the setscrews are tight, and that the cam follower mechanism is operating freely.

b. Remove one connection to R19, and connect the Wheatstone bridge to the rheostat.

c. Measure the resistance in ohms, using the Wheatstone bridge. The resistance should be 1000 times the setting of the CAPACITANCE dial. If it is not, proceed to step d.

d. Turn the CAPACITANCE dial to a point near its center. This will bring the cam follower to a point opposite one of the cam plate screws. Adjust this screw until the resistance in ohms is 1000 times the dial reading.

e. Progressing up and then down the scale, adjust each cam plate screw in the same manner. As a final check, see that each main point on the dial as well as points 0.5 and 0.1 check within 0.5% of the correct resistance value. If it is found that the whole cam plate is adjusted too high or too low, loosen the set screws in the dial, shift its position on the shaft, and start the cam plate adjustment over again.

4.3.3 DISSIPATION FACTOR DIAL CALIBRATION.

a. Make certain that the blade on each rheostat passes from the last wire to the terminal within one-half division of the dial ZERO. If necessary, shift the dial and/or blades to meet this condition. It is especially important that the ZERO of the high-resistance rheostat (R31A, B) match the dial.

b. Connect the Wheatstone bridge between ground and the junction of R26A, R30, C13, and C14. Set the DISSIPATION FACTOR dial to 5% and adjust R30 to obtain exactly 132.6 ohms.

c. Set the dial to 30% and adjust R27 to obtain exactly 795.8 ohms.

d. Connect the Wheatstone bridge between ground and the junction of R28, R31A, and C12.

e. Set the DISSIPATION FACTOR dial to 5% and adjust R28 to obtain 13,500 ohms.

f. Set the dial to 30% and adjust R29 to obtain 81,100 ohms.

4.4 TROUBLE-SHOOTING PROCEDURE.

4.4.1 GENERAL. If the bridge fails to function, check the positions of the bridge controls and the condition of the sample being measured before looking for trouble in the bridge. Failure to obtain a balance may well be caused by reasons outside the bridge, e.g. a short-circuited sample. Make certain, if possible, that the impedance of the sample under test does not exceed in magnitude the limits of the bridge.

Before removing the bridge from its case, check that the voltage and frequency of the power line are correct, test the power cord for open circuits or for poor contacts in the power outlets, and check the fuses mounted on top of the panel both for continuity and for tightness.

4.4.2 DETAILED TROUBLE-SHOOTING PROCEDURE.

4.4.2.1 Indicating Eye Does Not Light.

a. Check tube V1 and voltages per Table 2.

b. Check operation of switch S1.

c. Check transformer T1 for open windings and proper connections.

d. Check resistor R1 for open or short circuit and for proper value.

e. Check capacitor C1 for open or short circuit and for leakage.

4.4.2.2 Eye Does Not Deflect Properly.

a. Refer to paragraph 4.4.2.1.

b. Check V2 and voltages per Table 2.

c. Check R3 for open or short circuit and for proper operation.

d. Check C2 for open or short circuit and for leakage.

e. Check inductor L1 for open or short circuit.

f. Check contacts and operation of S2, second and third decks from panel.

g. Check detector circuit gain:
  (1) Turn MULTIPLY CAPACITANCE BY switch to DET.
  (2) Apply 0.5 v, 60 cps between DET terminal and chassis.
  (3) Check that voltage from pin 3, V1 to chassis is approximately 5.0 v.

h. Check Thyrite resistor R2:
  (1) Apply between 1.1 and 3.3 v across R2.
  (2) Check that current is appoximately 1 μa.
  (3) Apply between 3.8 and 5.2 v across R2.
  (4) Check that current is approximately 10 μa.

4.4.2.3 No Balance On Any Position of MULTIPLY CAPACITANCE BY Switch.

a. Check that the sample under test is not defective.

b. Check T2 for open windings and proper connections. Check that inner conductors of shielded leads, as well as sheath to SHIELD terminal and S2, are not grounded.

c. Check R19 through R31, and R34 for open or short circuit and for proper values.

d. Check capacitors C8 and C10 through C15 for open or short circuit and for leakage.

e. Check contacts and operation of S2, fourth and fifth decks from panel.

f. Check that UNKNOWN + terminal is not shorted to ground.

g. Refer to paragraphs 4.4.2.1 and 4.4.2.2.

4.4.2.4 No Balance on One or More Positions of MULTIPLY CAPACITANCE BY Switch.

a. Check T1 for open windings and proper connections.

b. Check contacts and operation of S2, deck nearest panel.

c. Check R7 through R10 for open or short circuit and proper values for capacitance range involved.

4.4.2.5 Zero Adjustments Impossible.

a. Check R11 through R18, and R32 for open or short circuit and for proper values.

b. Check C7 for open or short circuit and for leakage.

c. Check contacts and operation of S3.

d. Refer to paragraphs 4.4.2.1 through 4.4.2.4.

4.4.3 TEST VOLTAGES. Table 2 lists tube socket voltages from pin to ground, as measured with a 20,000-ohm-per-volt meter. Line voltage should be 115 volts, 60 cps, MULTIPLY CAPACITANCE BY switch set to 1, and DISSIPATION FACTOR, CAPACITANCE, and SENSITIVITY controls all set to maximum. Deviations up to 20% in d-c voltages should not be considered abnormal.

TABLE 2

TUBE (TYPE)	PIN	VOLTS	TUBE (TYPE)	PIN	VOLTS
V1 (6E5)	1-6	6.3 ac	V2 (Cont.)	5	0
	2	155*		6	22*
	3	-6.6**		8	150
	4	155*			
	5	0	V3 (6X5GT/G)	1	0
V2 (6SJ7)	1	0		2-7	6.3 ac
	2-7	6.3 ac		3	260 ac
	3	0		5	260 ac
	4	-3.0		8	300

*Use VTVM

**May vary up to ±50%

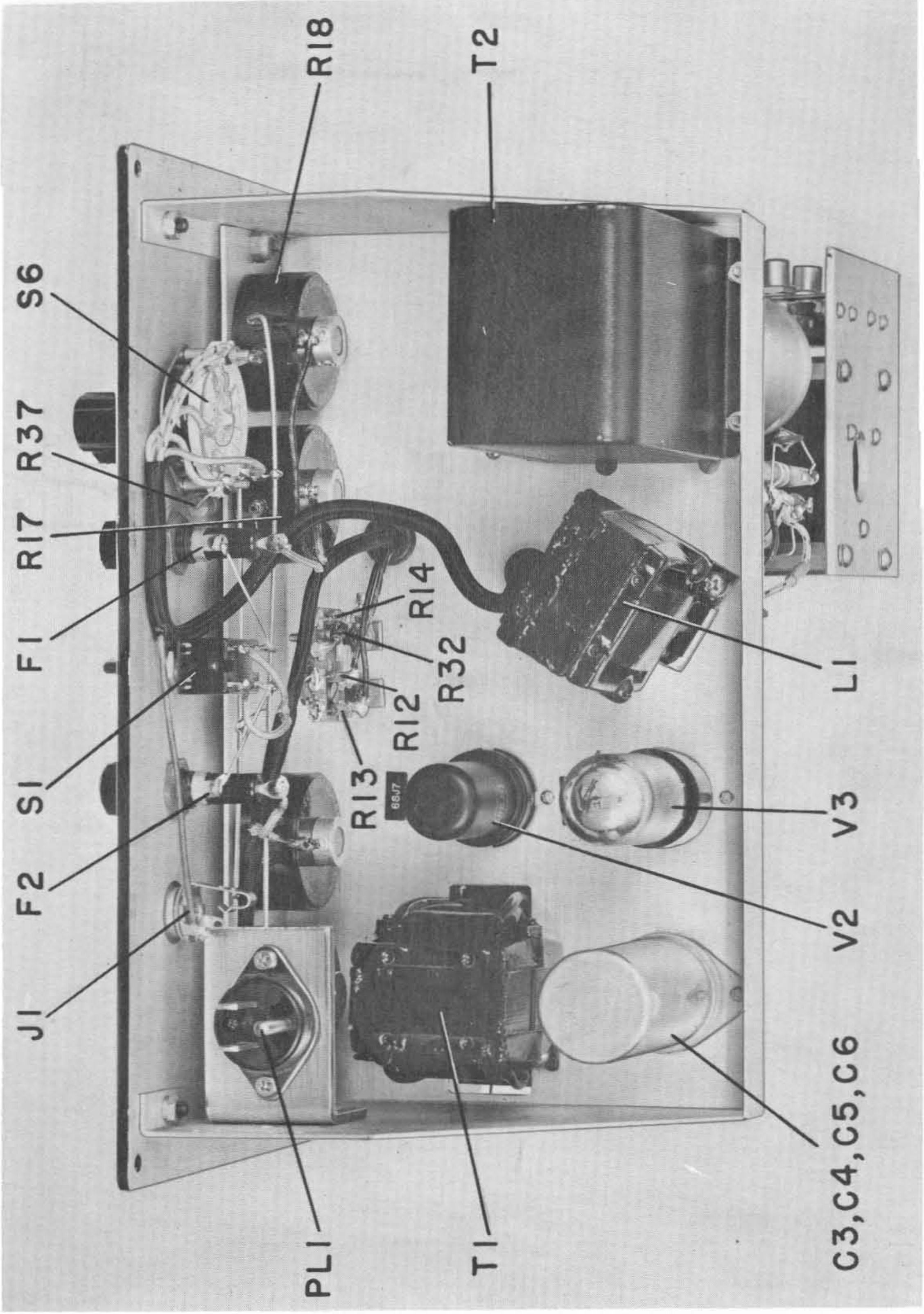


Figure 13. Top Interior View.

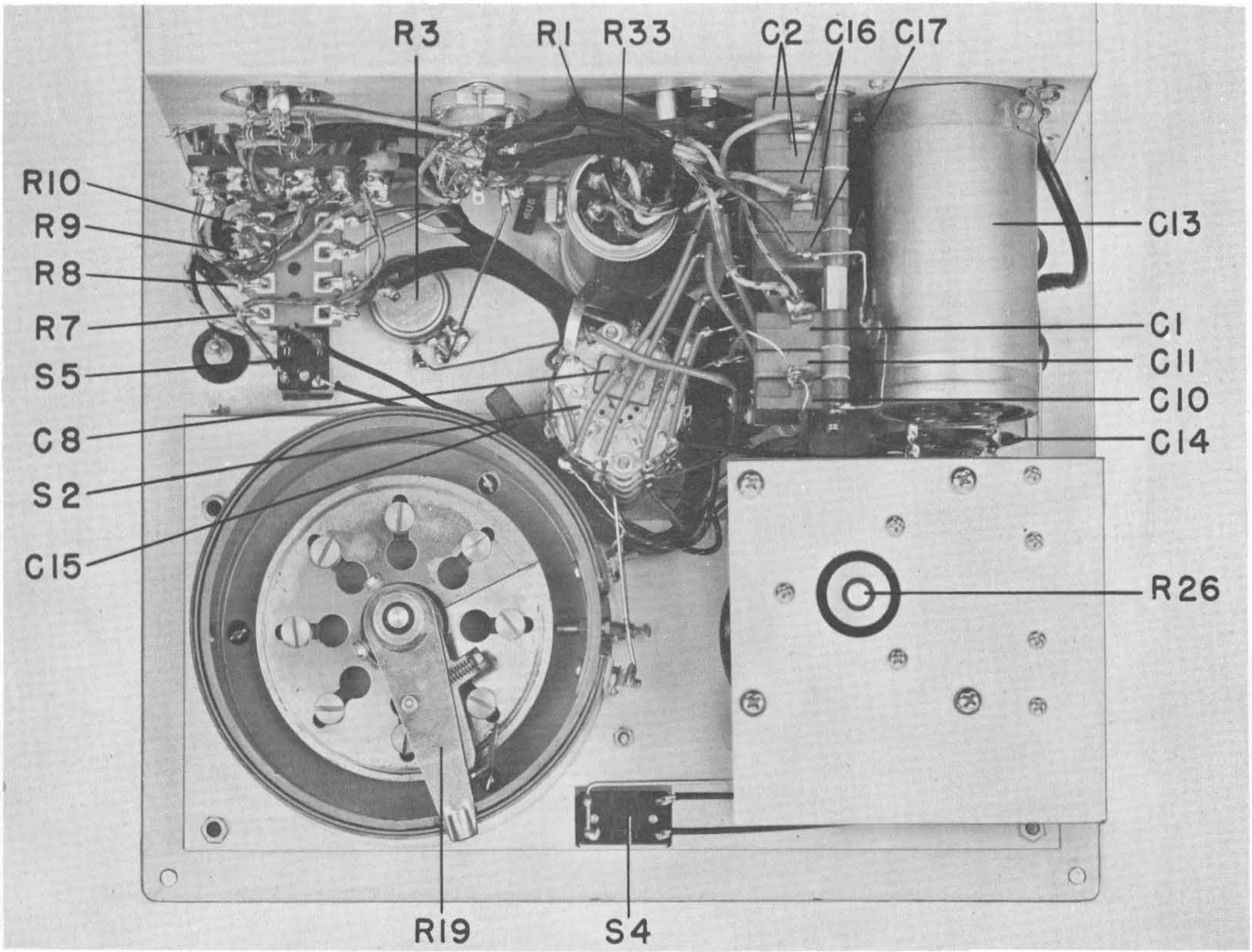


Figure 14. Bottom Interior View.

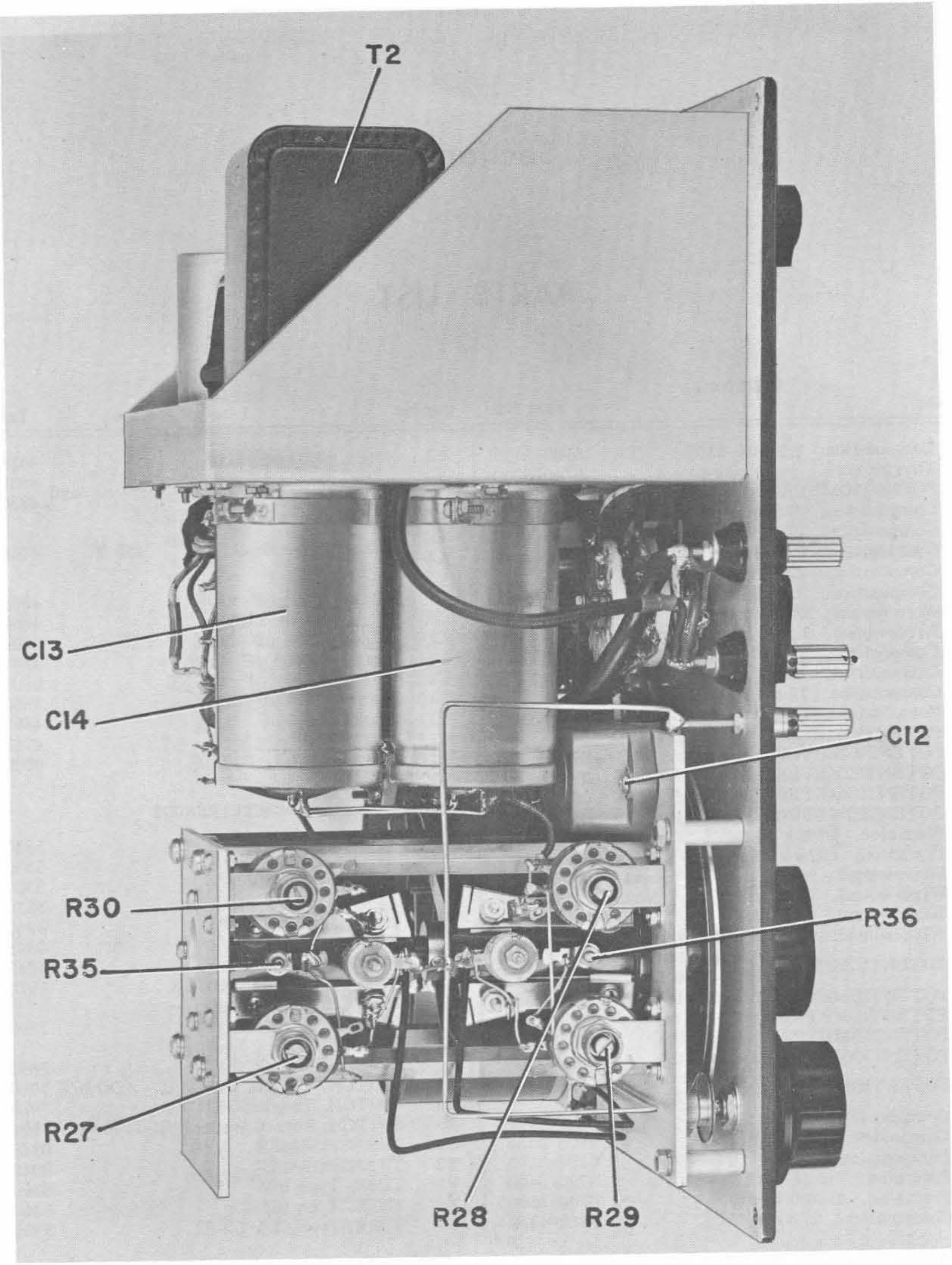


Figure 15. Left Side Interior View.

Section 5

PARTS LIST

RESISTORS

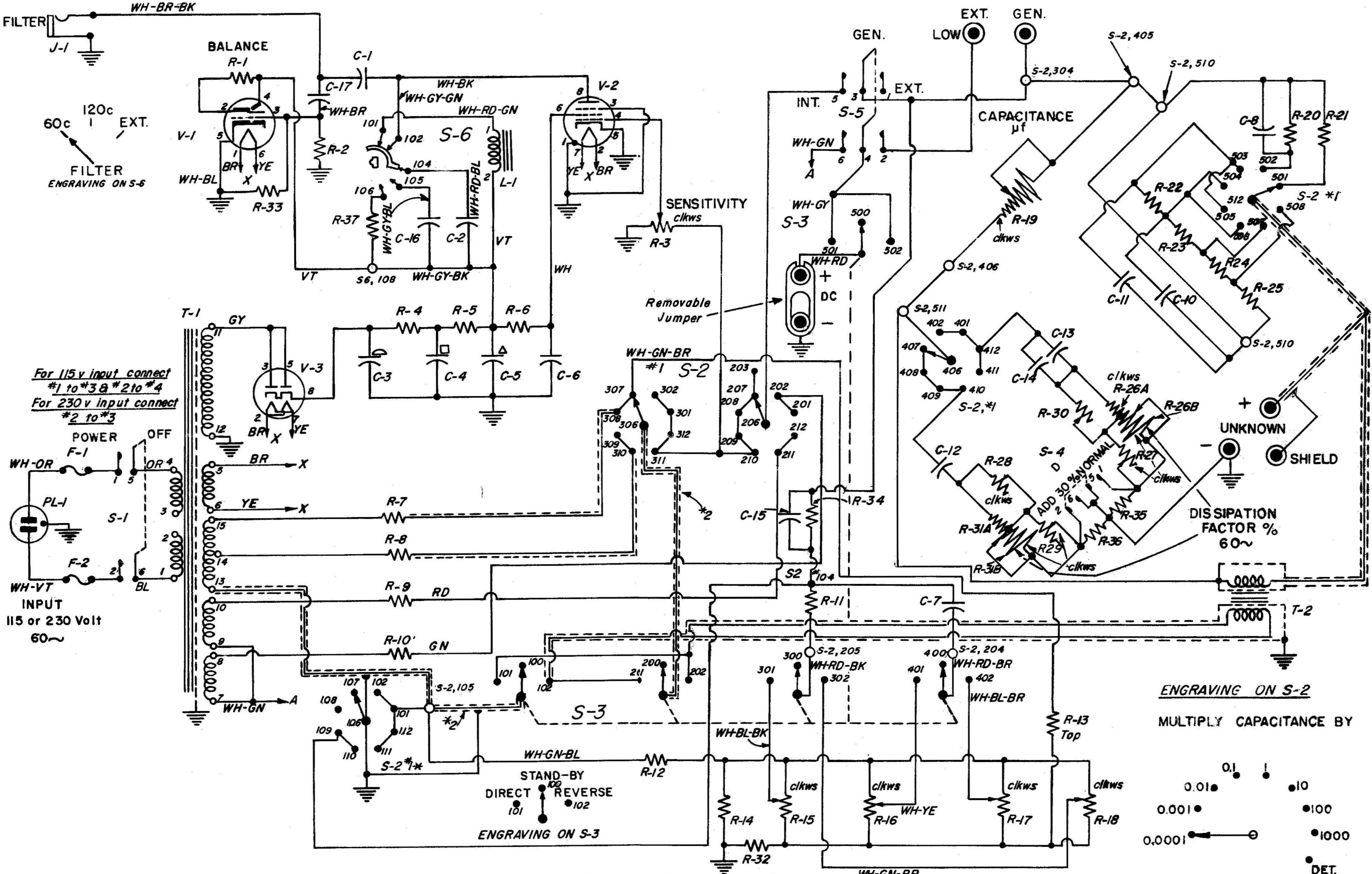
Ref No		Part No
R1	Composition, 3.3 MΩ ±10%	6100-5335
R2	Thyrite	6740-0300
R3	POTENTIOMETER, 1 MΩ ±20%	6000-1300
R4	Composition, 27 kΩ ±10%	6100-3275
R5	Composition, 27 kΩ ±10%	6100-3275
R6	Composition, 0.56 MΩ ±10%	6100-4565
R7	Composition, 22 kΩ ±10%	6120-3229
R8	Composition, 3.3 kΩ ±10%	6120-2339
R9	Wire-wound, 330 Ω ±10%	6760-1339
R10	Wire-wound, 3.3 Ω ±10%	6760-9339
R11	Composition, 10 MΩ ±10%	6100-6105
R12	Composition, 27 kΩ ±10%	6100-3275
R13	Composition, 27 kΩ ±10%	6100-3275
R14	Composition, 10 kΩ ±10%	6100-3105
R15	POTENTIOMETER, 20 kΩ ±5%	0973-4080
R16	POTENTIOMETER, 20 kΩ ±5%	0973-4080
R17	POTENTIOMETER, 20 kΩ ±5%	0973-4080
R18	POTENTIOMETER, 20 kΩ ±5%	0973-4080
R19	POTENTIOMETER, 11.2 - 11.7 kΩ	0433-4020
R20	Precision, 10 kΩ ±0.025%	0602-3052
R21	Precision, 100 kΩ ±0.1%	6710-1600
R22	Wire-wound, 900 Ω ±0.1%	part of 1611-0280
R23	Wire-wound, 90 Ω ±0.1%	part of 1611-0280
R24	Wire-wound, 9 Ω ±0.1%	part of 1611-0280
R25	Wire-wound, 0.988 Ω ±0.25%	part of 1611-0280
R26A R26B	POTENTIOMETER, 136.6 - 144.6 Ω 710 - 750 Ω	0371-4140
R27	POTENTIOMETER, 30 kΩ ±10%	6010-1200
R28	POTENTIOMETER, 0.5 MΩ ±10%	6010-2600
R29	POTENTIOMETER, 3 MΩ ±20%	6010-2600
R30	POTENTIOMETER, 5 kΩ ±10%	6010-0800
R31A R31B	POTENTIOMETER, 13,980 - 14,760 Ω 73,000 - 77,000 Ω	0371-4150
R32	Composition, 10 kΩ ±10%	6100-3105
R33	Composition, 3.3 MΩ ±10%	6100-5335
R34	Composition, 1 MΩ ±10%	6100-5105
R35	Precision, 796 Ω ±0.5%	6700-0400
R36	Precision, 81,100 Ω ±0.5%	6700-3500
R37	Composition, 270 kΩ ±10%	6110-4279

CAPACITORS

Ref No		Part No
C1	Mica, 0.02 µF ±10%	4830-0500
C2	Mica, 0.035 µF ±10%	4830-0500 and 4830-0300
C3 C4 C5 C6	Electrolytic Block, 20 µF 20 µF 20 µF 20 µF 450 V	4460-0900
C7	Mica, 0.001 µF ±10%	4660-6400
C8	Mica, 50 pF ±10%	4660-2000
C10	Mica, 0.005 µF ±10%	4800-1600
C11	Mica, 0.0005 µF ±10%	4800-0800
C12	Mica, 0.0099 µF ±0.25%	0505-4630
C13	Plastic, 0.5 µF ±1.5%	4860-4602
C14	Plastic, 0.5 µF ±1.5%	4860-4602
C15	Mica, 0.01 µF ±10%	4760-0100
C16	Mica, 0.0088 µF ±10%	4800-1900

MISCELLANEOUS

Ref No		Part No
F1	FUSE, 115 V, 0.2 A 230 V, 0.1 A	5330-0600 5330-0400
F2	FUSE, 115 V, 0.2 A 230 V, 0.1 A	5330-0600 5330-0400
J1	JACK, EXT FILTER	4260-1500
L1	INDUCTOR	0345-4450
PL1	PLUG, Power	4240-0700
S1	SWITCH, Toggle, POWER	7910-1300
S2	SWITCH, Rotary Wafer, MULTIPLY CAP BY	7890-0240
S3	SWITCH, Rotary Wafer, DIR-STANDBY-REV	7890-0252
S4	SWITCH, Toggle, NORMAL - ADD 30%	7910-1300
S5	SWITCH, Toggle, GEN	7910-1500
S6	SWITCH, Rotary Wafer, FILTER	7890-1680
T1	TRANSFORMER	0345-4430
T2	TRANSFORMER	0345-4430
V1	TUBE, Type 6E5	8360-4600
V2	TUBE, Type 6SJ7	8360-6600
V3	TUBE, Type 6X5-GT/G	8360-8300



*1 S-2 five wafer switch arm mechanically connected as viewed from rear of panel

*2 Twin Twisted Conductor Shielded lead from S-2 to S-3

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS,* 01781

617 369-4400
617 646-7400

SALES ENGINEERING OFFICES

METROPOLITAN NEW YORK*

Broad Avenue at Linden
Ridgefield, New Jersey, 07657
Telephone N.Y. 212 964-2722
N.J. 201 943-3140

SYRACUSE

Pickard Building
East Molloy Road
Syracuse, New York, 13211
Telephone 315 454-9323

PHILADELPHIA

General Radio Company
Fort Washington Industrial Park
Fort Washington, Pennsylvania 19034
Telephone 215 646-8030

WASHINGTON* and BALTIMORE

Rockville Pike at Wall Lane
Rockville, Maryland 20852
Telephone 301 946-1600

ORLANDO

113 East Colonial Drive
Orlando, Florida, 32801
Telephone 305 425-4671

CHICAGO*

6605 West North Avenue
Oak Park, Illinois, 60302
Telephone 312 848-9400

CLEVELAND

5579 Pearl Road
Cleveland, Ohio, 44129
Telephone 216 886-0150

LOS ANGELES*

1000 North Seward Street
Los Angeles, California, 90038
Telephone 213 469-6201

SAN FRANCISCO

1186 Los Altos Avenue
Los Altos, California, 94022
Telephone 415 948-8233

DALLAS

2501-A West Mockingbird Lane
Dallas, Texas, 75235
Telephone 214 Fleetwood 7-4031

TORONTO*

99 Floral Parkway
Toronto 15, Ontario, Canada
Telephone 416 247-2171

MONTREAL

Office 395, 1255 Laird Boulevard
Town of Mount Royal, Quebec, Canada
Telephone 514 737-3673

* Repair services are available at these offices.

General Radio Company (Overseas), 8008 Zurich, Switzerland
General Radio Company (U.K.) Limited, Bourne End, Buckinghamshire, England
Representatives in Principal Overseas Countries

Printed in USA