OPERATING INSTRUCTIONS

for

TYPE 1604-A
COMPARISON BRIDGE

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

NEW YORK CHICAGO LOS ANGELES

U. S. A.

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Form 790-A
June, 1952

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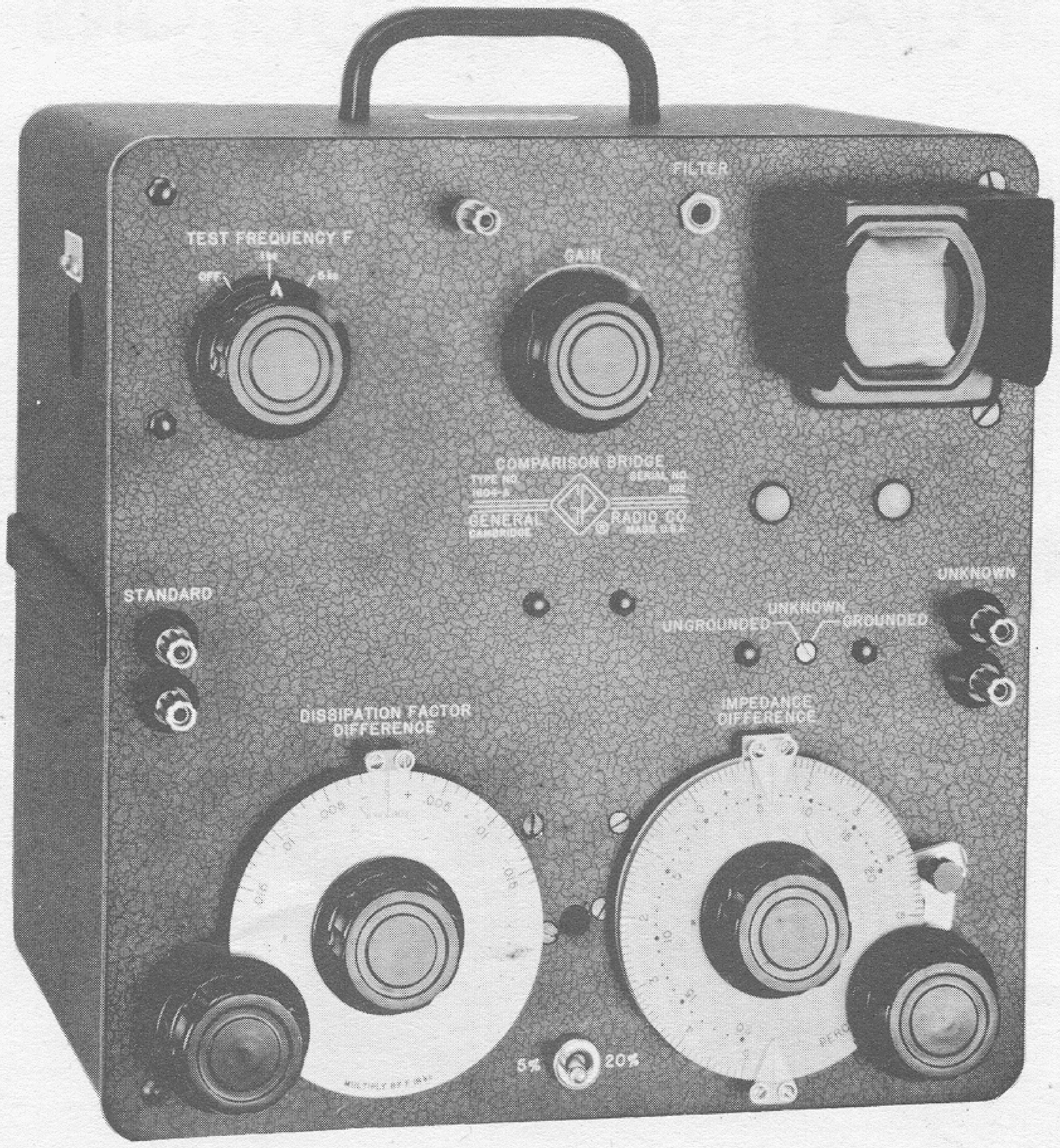


Panel View of Type 1604-A Comparison Bridge

SPECIFICATIONS

Deviation Range: For impedance, ±5% and ±20%, selected by a panel switch. For dissipation factor, ±.015 at 1 kc, ±.075 at 5 kc.

Impedance Range and Accuracy: Impedances between 2 Ω and 20 MΩ can be compared. For the 5% deviation range the basic accuracy is ±0.1%, but at extreme values of impedance the accuracy is somewhat poorer. The range for resistors, capacitors, and inductors for which the ±0.1% accuracy applies is given in the table:

	R	C	L
1 kc	2 Ω - 20 MΩ	50 µf - 50 µµf	500 µh - 250 h
5 kc	4 Ω - 4 MΩ	2 µf - 50 µµf	200 µh - 10 h

These ranges apply when comparing components whose dissipation factor differences do not exceed .02. On the 20% deviation range the accuracy is 0.5% over the same impedance ranges.

Dissipation Factor Accuracy: The accuracy of measurement of differences of dissipation factor at 1 kc is ±(.0005 + 2% of the impedance difference), and at 5 kc, ±(.0025 + 2% of the impedance difference).

Frequency: Frequencies of 1 kc and 5 kc are provided, selected by panel switch. The frequency is within ±3% of the nominal value.

Grounding: Two ground positions are provided, one of which grounds the junction of the standard and unknown impedances. With this connection the total impedances between the high terminals and ground are compared. In the other connection the junction of the ratio arms of the bridge is grounded, leaving both terminals of the standard and unknown ungrounded. With this connection the direct impedance between terminals of a component is measured, and terminal impedances to ground, within certain limits, will not affect the bridge balance.

Voltage Applied to Unknown: Approximately one volt, for impedances above 500 Ω. For lower values of impedance the voltage is decreased, corresponding to a source impedance of the order of 100 Ω.

Zero Adjustment: An adjustable index mark is provided with locking means so that the Zero can be offset to correspond to the deviation of the standard component from the desired nominal value.

Accessories Supplied: Line-Connector cord.

Accessories Required: For general purpose, use adjustable calibrated standards such as the Type 1432 Decade Resistors, Type 219 Decade Capacitors, and Type 1490 Decade Inductors. Fixed standards such as the Type 509 Standard Capacitors, Type 1481 Inductors, and Type 500 Resistors may also be used whenever appropriate values are available.

For production tests, the standard is often a component, of the type to be tested, that has been measured independently or otherwise selected.

Mounting: Welded aluminum cabinet.

Dimensions: (Width) 12 inches, (height) 14-1/4 inches, (depth) 10 inches.

Net Weight: 22-1/2 pounds.

OPERATING INSTRUCTIONS

for

TYPE 1604-A COMPARISON BRIDGE

SECTION 1.0 DESCRIPTION

1.1 GENERAL

The Type 1604-A Comparison Bridge provides a means for measuring the impedance of components rapidly in terms of percent difference from a standard component or impedance. It is especially useful in production work where resistors, capacitors, or inductors must be adjusted, selected, or paired within a given tolerance. Both the impedance and the dissipation factor of the components are compared. At balance, the dials read directly the impedance difference expressed as a percent of the standard impedance, and the difference of the dissipation factors of the standard and unknown impedances. Measurements can be made at either 1 kc or 5 kc as selected by the panel switch.

1.2 IMPEDANCE RANGE

The bridge can be used for the direct comparison of components over a very wide range of impedance, from approximately 2 Ω to 20 MΩ. The basic accuracy of the instrument over several decades of this range is ±0.1%. At the extremes of the impedance range the accuracy decreases somewhat. The ranges for which the ±0.1% accuracy applies are given in the table:

	1 kc	5 kc
R	2Ω - 20MΩ	4Ω - 4MΩ
C	50μf - 50μμf	2μf - 50μμf
L	500μh - 250h	200μh - 10h

The full accuracy of impedance-difference measurements is realized over these ranges provided the dissipation factors of the components being compared differ by less than ±.02. This .02 limit on dissipation-factor difference is only about one-fourth full scale on the dial at 5 kc and is indicated by the red engraving for convenience.

1.3 DEVIATION RANGE

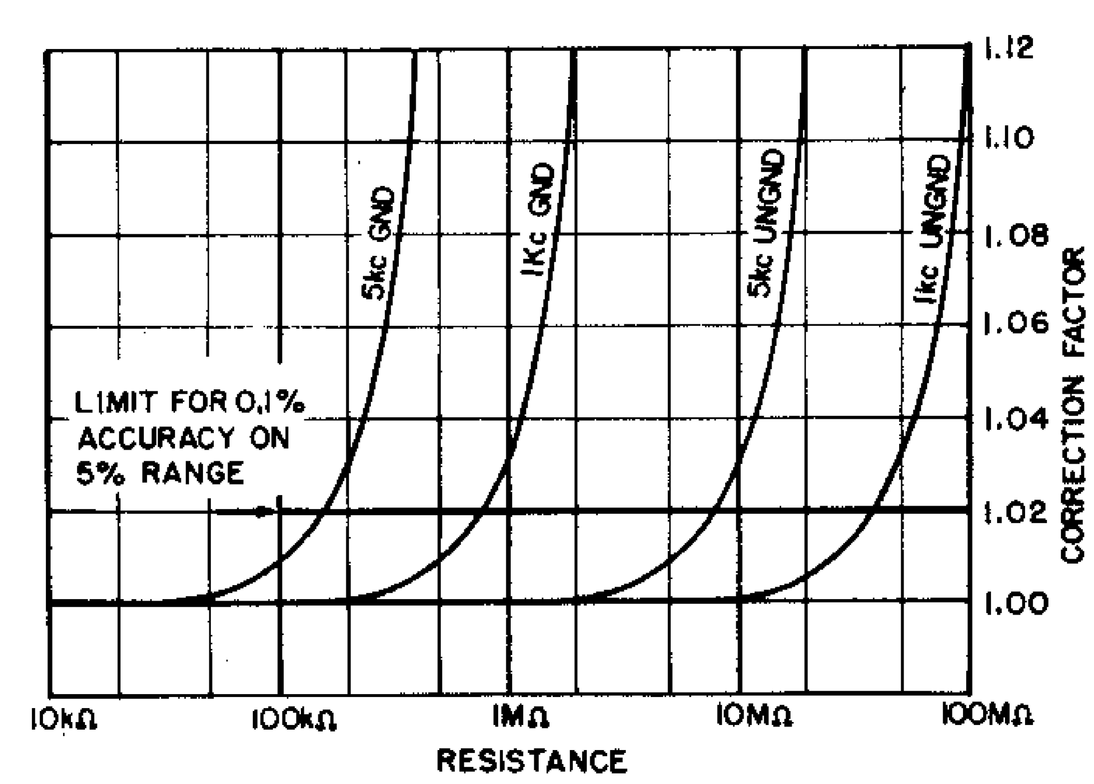
Two impedance-difference ranges are provided: one, 0 to ±5% for accurate comparison of components close to each other in value; the other, 0 to ±20%, of somewhat lesser accuracy, for checking to the common commercial tolerances of ±10% and ±20%.

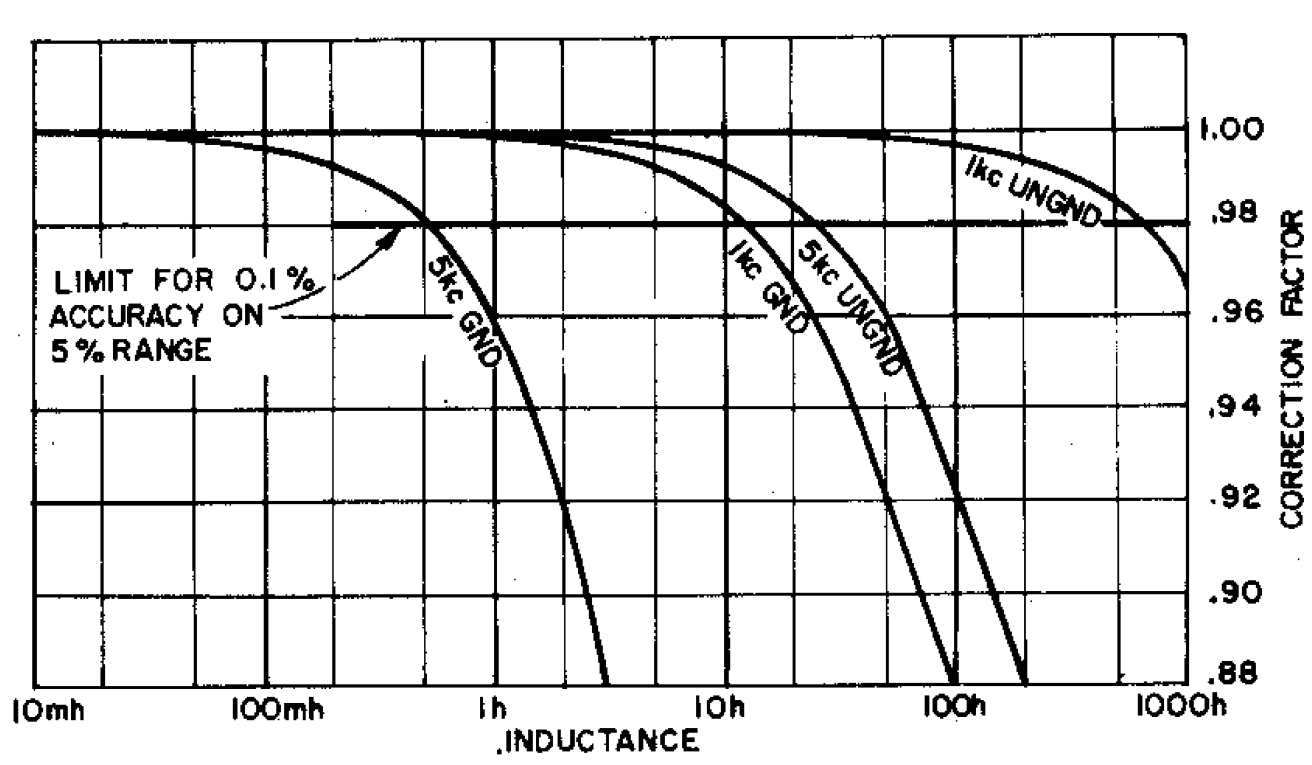
The dissipation-factor-difference range is ±0.015 at 1 kc and ±0.075 at 5 kc. The full accuracy of impedance-difference measurements is realized only when the components being compared differ in dissipation factor by less than ±.02.

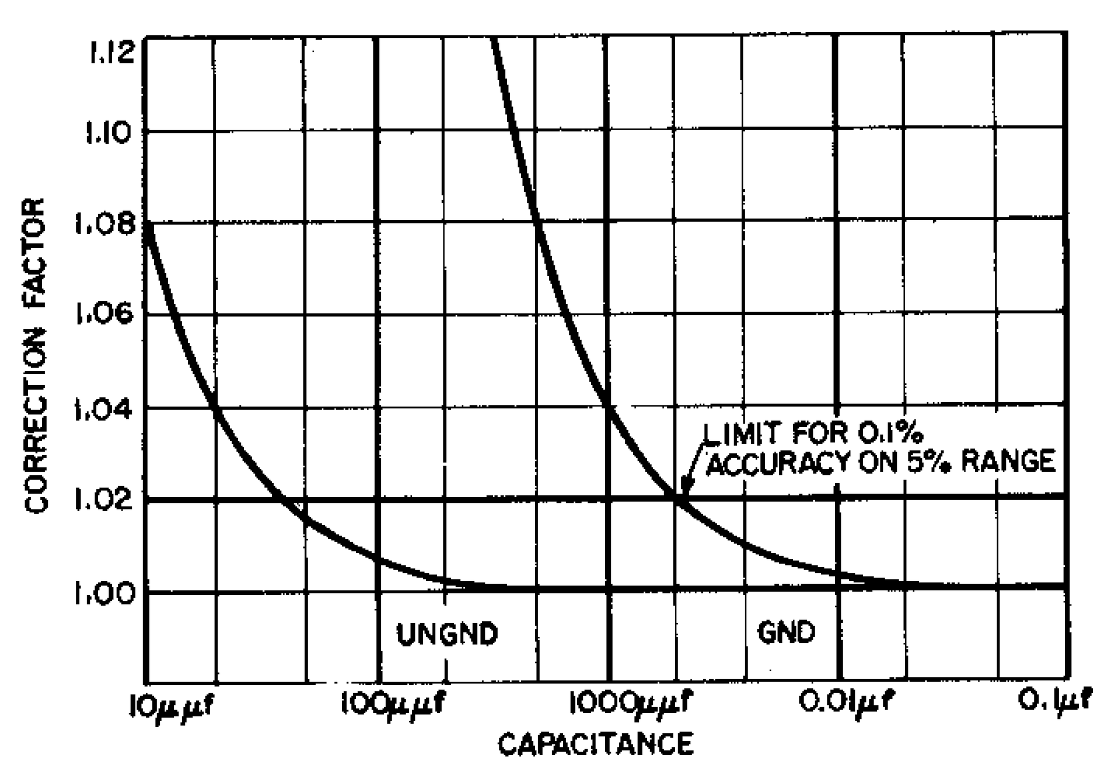
1.4 ACCURACY

The accuracy of the bridge is limited by three factors which become important only at the extreme values of impedance or for large impedance differences between components.

1.41 At high values of impedance, the stray capacitance across the STANDARD and UNKNOWN terminals limits the accuracy of the IMPEDANCE DIFFERENCE dial. Figures 1, 2, and 3 show this effect for R, L, and C respectively. When the bridge is used in the UN-







Above - Figure 1

Far Left - Figure 2

Left - Figure 3

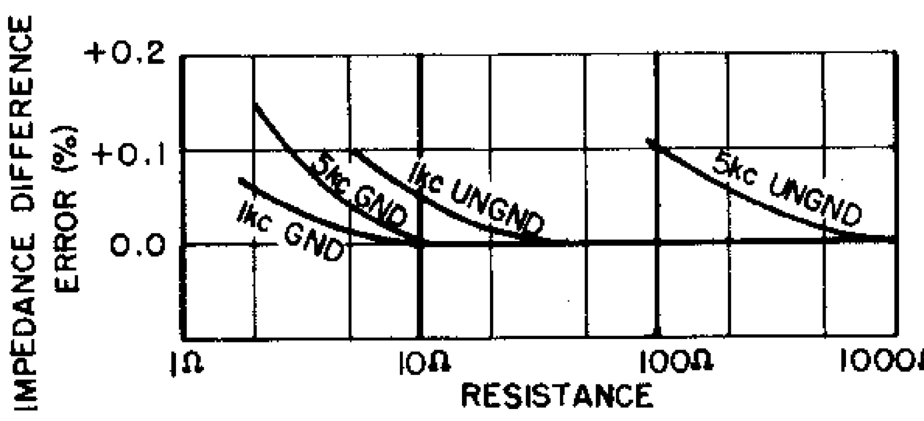


Figure 4

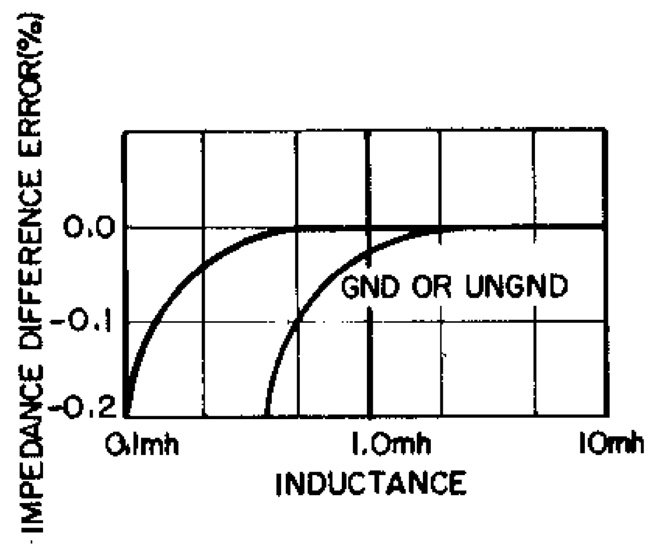


Figure 5

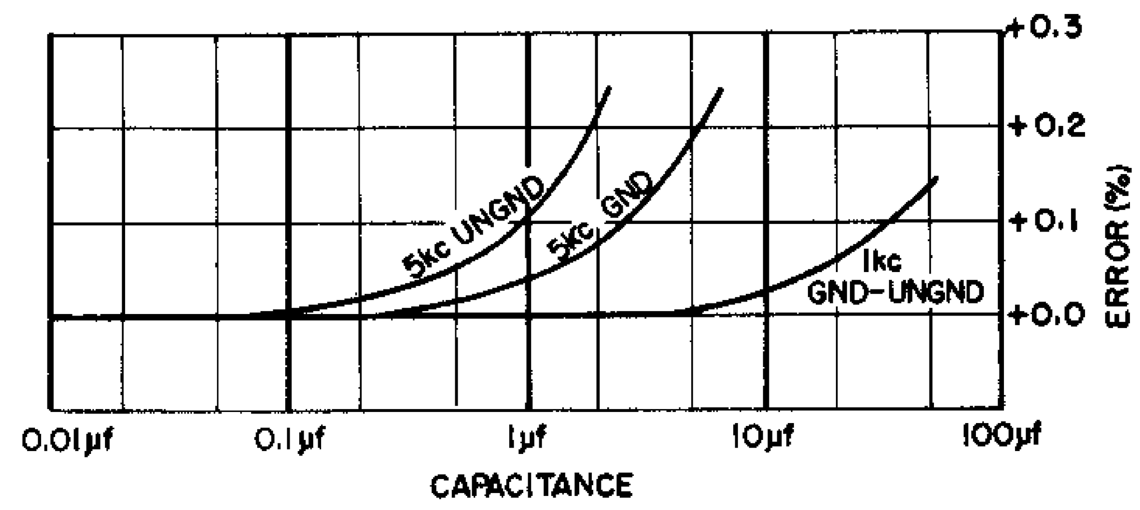


Figure 6

GROUNDED position (See Section 2.8), the shunt capacitance is reduced to about 0.8 $\mu\mu$f and measurements can be made to about 20 MΩ.

1.42 At low impedance, decreased sensitivity and small unbalance in the impedances in series with the STANDARD and UNKNOWN terminals combine to limit the accuracy. The series impedance unbalance tends to move the true bridge zero as is shown in Figures 4, 5, and 6 for R, L, and C respectively. These curves represent the worst conditions, individual instruments varying from zero error to this maximum error. If measurements are to be made with maximum accuracy at the extreme low-impedance limit, the bridge zero can be offset to take care of these small bridge errors. The errors can be determined accurately at a given impedance level by making an impedance-difference measurement, ΔZ_1 (%), in the normal manner with two components which are within 1% of each other, and then making a second measurement, ΔZ_2 (%), with the standard and unknown reversed. The true bridge zero is then

$$\frac{\Delta Z_1 + \Delta Z_2}{2}$$

For example, if ΔZ_1 were +0.9% and ΔZ_2 were -0.7%, then the true bridge zero would be at

$$\frac{+0.9\% + (-0.7\%)}{2} = +0.1\%$$

If the bridge zero is offset +0.1% and the measurement repeated, $\Delta Z_1 = -\Delta Z_2 = +0.8\%$.

1.43 The reading of the DISSIPATION FACTOR DIFFERENCE dial depends to a small extent on the reading of the IMPEDANCE-DIFFERENCE dial. This dependency is shown in Figure 7 and limits the accuracy of the DISSIPATION FACTOR DIFFERENCE dial.

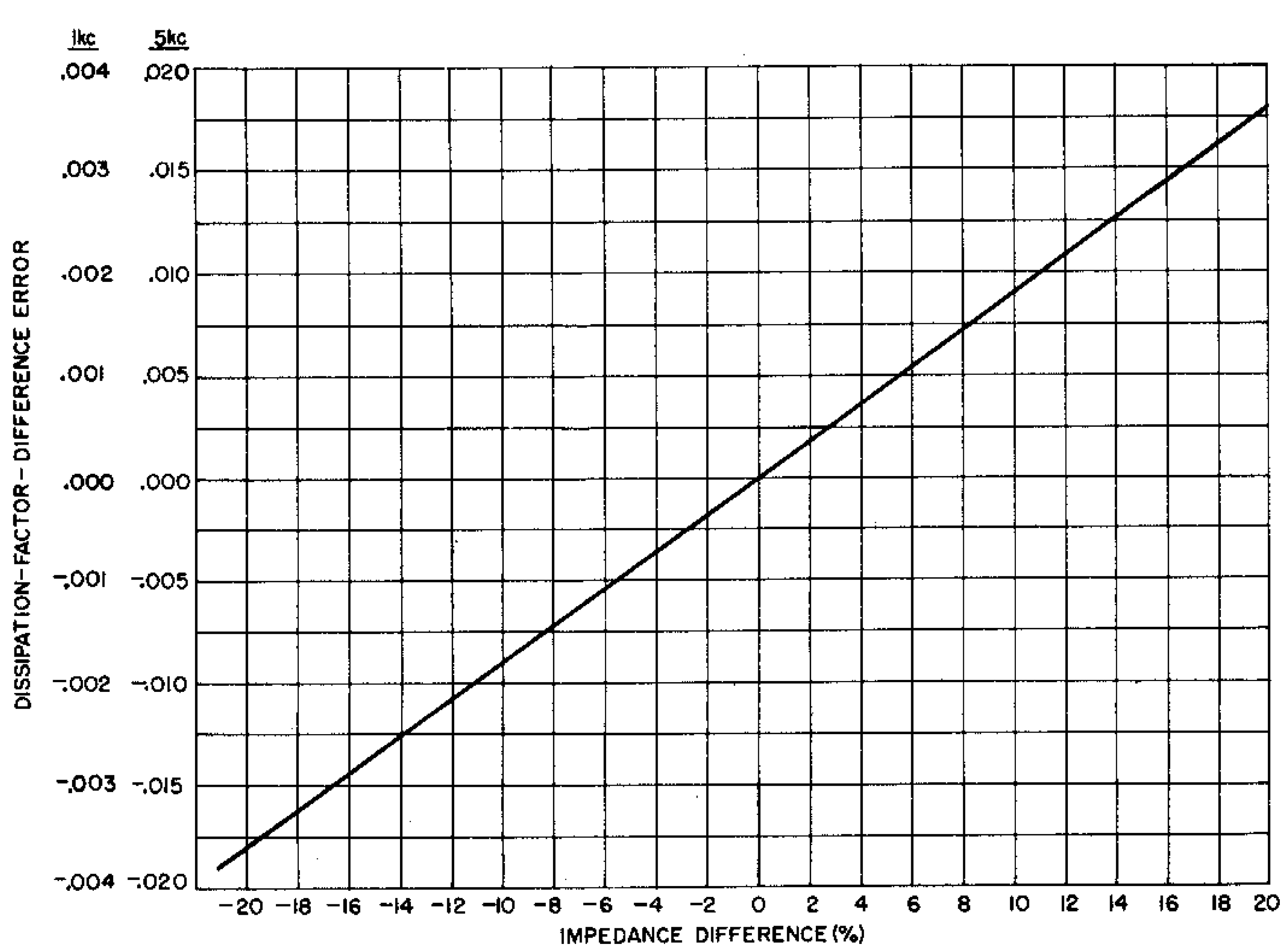
1.431 At 5 kc additional errors appear on both the IMPEDANCE DIFFERENCE dial and the DISSIPATION FACTOR dials. These are shown in Figures 8 and 9 and limit the bridge to dissipation-factor differences of 0.02 for full accuracy (see Specifications).

SECTION 2.0 OPERATION

2.1 GROUNDING

The ground terminal provided on the front panel should be connected to a good ground. This ground connection is recommended but is not always necessary.

Figure 7



2.2 POWER CONNECTION

Connect the bridge to a suitable power source as indicated on the plate over the power receptacle (115 v. or 230 v., 50 - 60 c). Turn the power on by setting the TEST FREQUENCY switch from OFF to the 1 kc or 5 kc position.

2.3 FREQUENCY SELECTION

Measurements may be made at 1 kc or 5 kc by setting the TEST FREQUENCY F switch to the desired frequency. The DISSIPATION FACTOR DIFFERENCE dial must be multiplied by 5 in the 5 kc position. For rated accuracy, the DISSIPATION FACTOR DIFFERENCE dial must not exceed ±.02. This limit is marked on the dial.

2.4 RANGE SELECTION

Select either the 5% or 20% impedance-difference range depending upon the tolerance of the components being compared.

2.5 GAIN CONTROL

Set the GAIN control so that the band of light on the oscilloscope covers about 1-1/2 inches. Generally, a position can be selected so that a readjustment of the GAIN control is unnecessary as the bridge balance is approached. Setting the gain too high initially will make the balance point difficult to find.

2.6 BALANCE PROCEDURE

Adjust the IMPEDANCE DIFFERENCE and DISSIPATION FACTOR DIFFERENCE dials until the band of light on the oscilloscope is of minimum width. At this balance point the right-hand dial reads directly the impedance difference expressed as a percent of the standard impedance. The left-hand dial reads the difference of the dissipation factors.

2.61 A brilliance control for the oscilloscope tube is located under the left-hand snap button immediately below the tube. A vertical centering control is located under the right-hand snap button.

The projecting light shield can be slid off the tube bezel if not required, and it may be slid on in any direction to give maximum protection from external light.

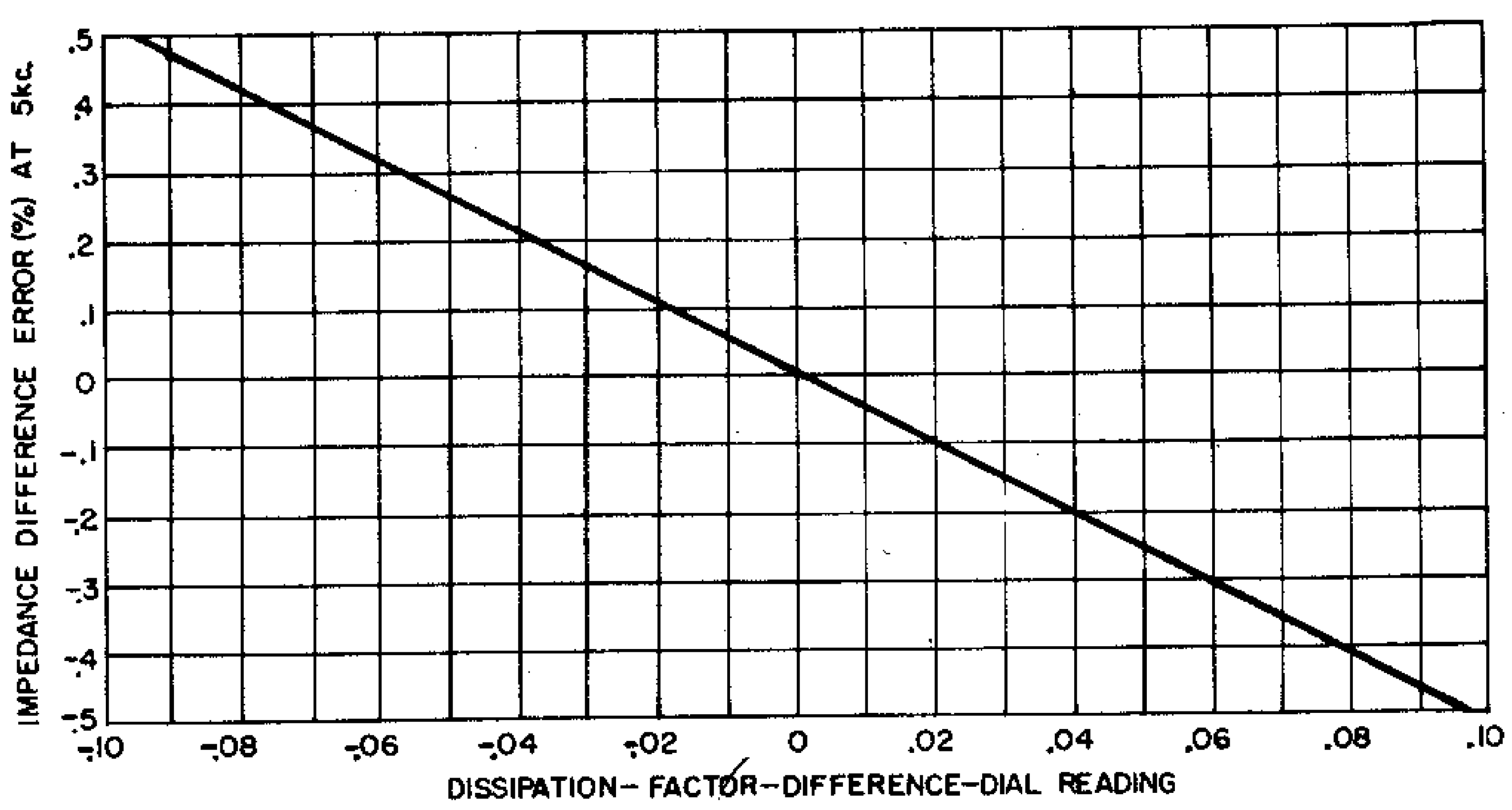


Figure 8

2.7 OFFSET ZERO

The true zero of the IMPEDANCE DIFFERENCE dial is indicated by the index line engraved under the word PERCENT and the indicator at the bottom of the dial. A second indicator is provided at the top of the dial which can be moved by releasing the locking knob at the right of the dial. This permits off-setting the indicated zero to allow for error in the standard. For example, if the impedance of an available standard is 0.8% higher than the desired nominal value, move the adjustable indicator 0.8% clockwise. The reading of the dial is now the deviation from the desired nominal value. When the zero is offset, there is introduced an error equal to the product of the offset and the indicated impedance difference. Thus, with an offset of 2% and an impedance difference of 5%, the error is only 0.1%.

2.8 UNKNOWN GROUNDED - UNGROUNDED SWITCH

2.81 UNKNOWN GROUNDED: For this connection the lower terminals of the STANDARD and UNKNOWN are grounded so that the impedances being compared are the total impedances from the high STANDARD and UNKNOWN terminals to ground. Thus the capacitance and leakage to ground from the high terminals of the standard and unknown being compared are included in the measurement. In addition, there is stray circuit capacitance of approximately 40 $\mu\mu$f across each pair of terminals. These shunt impedances, although unimportant when comparing low values of impedance, will cause errors at high-impedance levels. For this reason, high values of impedance should be compared in the UNGROUNDED connection for which the capacitance across the terminals is only about 0.8 $\mu\mu$f. See also Paragraph 2.83.

2.811 If for any reason high-impedance components must be measured with one terminal grounded, the error in the IMPEDANCE DIFFERENCE dial introduced by the 40 $\mu\mu$f can be estimated with reasonable accuracy:

For capacitance, the bridge reads low and the dial reading must be multiplied by

$$1 + \frac{40}{C_x} \quad (C_x \text{ in } \mu\mu f) \quad \text{See Figure 3.}$$

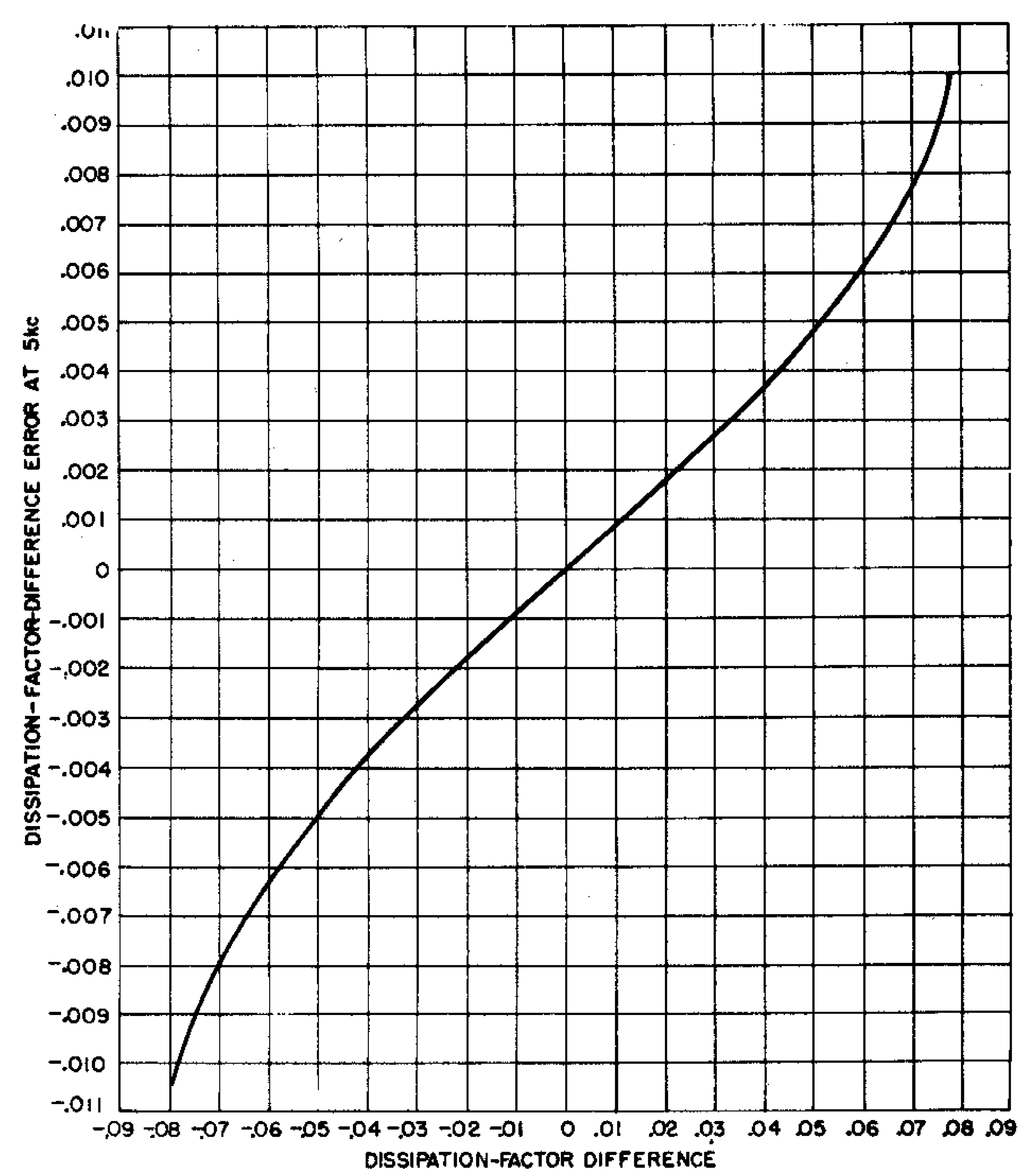
For inductors, the bridge reads high and the dial reading must be multiplied by

$$1 - \omega^2 LC \quad (C = 40\ \mu\mu f) \quad \text{See Figure 2.}$$

For resistors, the bridge reads low and the dial reading must be multiplied by

$$1 + \frac{R^2\omega^2C^2}{2} \quad (C = 40\ \mu\mu f) \quad \text{See Figure 1.}$$

Figure 9



2.82 UNKNOWN UNGROUNDED: When the switch is in this position, the junction of the bridge ratio arms is grounded leaving both terminals of the STANDARD and UNKNOWN ungrounded (see Figure 10). Thus the direct impedances between terminals of the components are compared. Impedance from the lower STANDARD or UNKNOWN terminals to ground will appear across the detector input and will not affect the bridge balance point. Impedance for the upper STANDARD or UNKNOWN terminals to ground appears across the resistive ratio arms and, therefore, must be as high as possible compared to the 25 KΩ ratio arms. Reasonable leakage and shunt capacitance can be tolerated across these ratio arms.

2.83 The adjustable capacitor (C-16), accessible under the snap-button between the dials, is provided for equalizing the capacitance across the bridge arms. The correct setting of this capacitor is different for the two positions of the UNKNOWN-UNGROUNDED-GROUNDED switch because of the slightly different stray capacitances in the two cases. To adjust this capacitor properly, set the IMPEDANCE DIFFERENCE dial to zero and balance the bridge with C-16 and the DISSIPATION FACTOR DIFFERENCE dial. This adjustment should be made with the UNKNOWN and STANDARD terminals open. This adjustment may also be made with leads attached to compensate for small differences in lead capacitance.

SECTION 3.0 DIAL CALIBRATIONS

3.1 IMPEDANCE DIFFERENCE DIAL

This dial reads the magnitude of the impedance of the unknown minus the magnitude of the impedance of the standard expressed as a percent of the impedance of the standard:

$$\frac{|Z_X| - |Z_N|}{|Z_N|}$$

For components that are nearly pure R, L, or C, the bridge reads:

3.11 Resistors:

$$\frac{R_X - R_N}{R_N} \times 100\ (\%)$$

3.12 Inductors:

$$\frac{L_X - L_N}{L_N} \times 100\ (\%)$$

3.13 Capacitors:

$$\frac{\frac{1}{C_X} - \frac{1}{C_N}}{\frac{1}{}} = \frac{-(C_X - C_N)}{C_X} \times 100\ (\%)$$

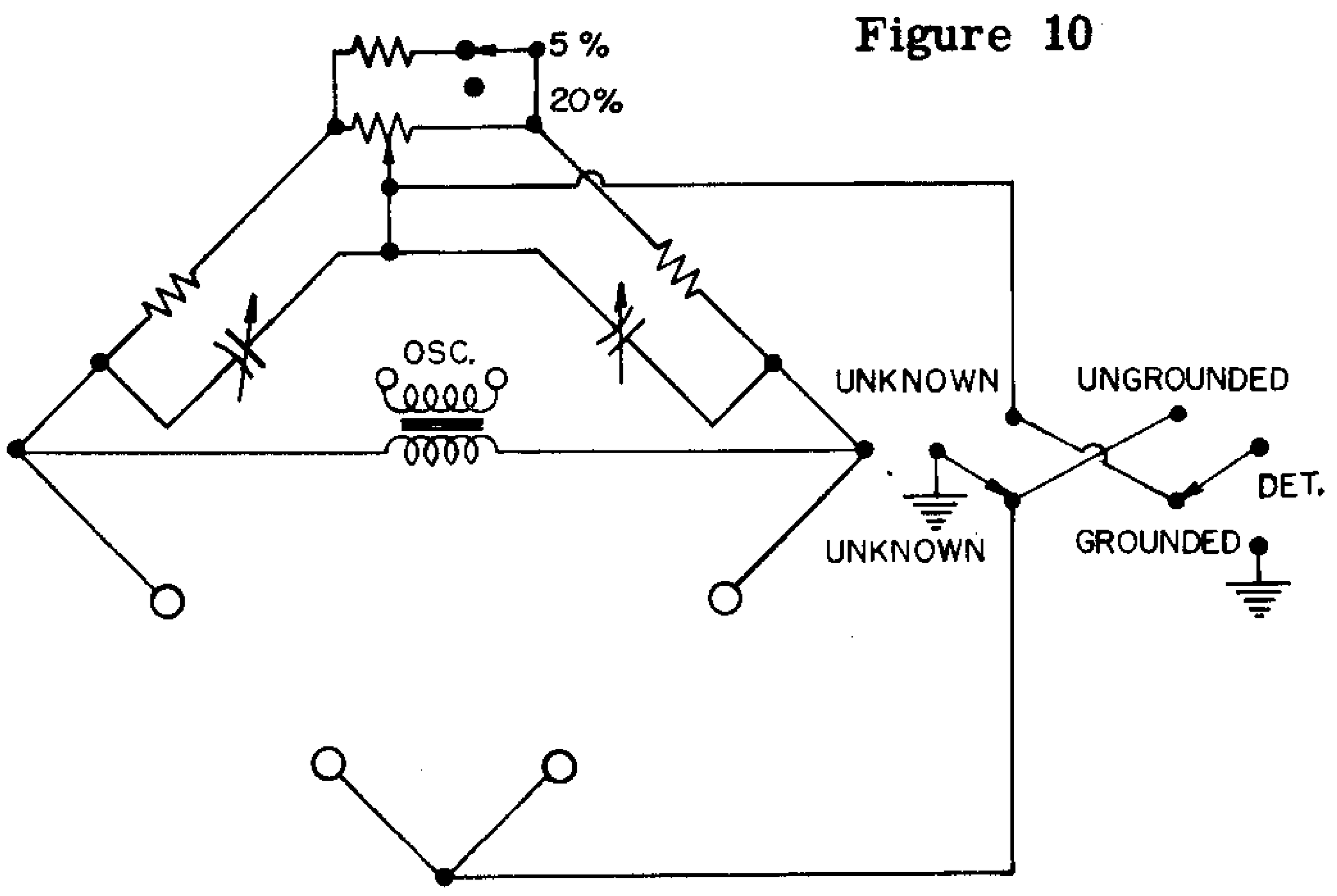


Figure 10

NOTE: If the positions of the unknown and the standard are interchanged this expression becomes

$$\frac{C_X - C_N}{C_N} \times 100\ (\%)$$

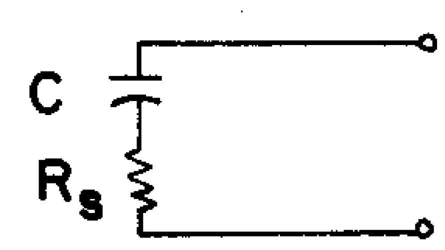
The dial then reads in terms of capacitance difference rather than impedance difference.

If the dissipation factor of a component is not zero, the use of R, L, or C in place of Z will cause the bridge reading to be in error by the factor $\sqrt{1 + D^2}$. Even for D = 0.1 this factor is only 1.005 and can be neglected completely.

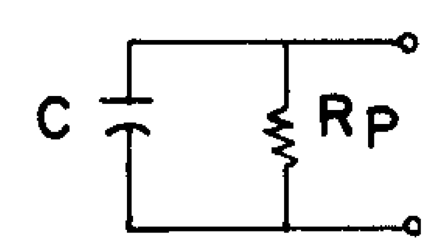
3.2 DISSIPATION FACTOR DIFFERENCE DIAL

When capacitors or inductors are compared, this dial indicates the dissipation factor of the component connected to the UNKNOWN terminal minus the dissipation factor of the component connected to the STANDARD terminal ($D_X - D_n$). When resistors are compared, the dial indicates $-(Q_X - Q_n)$, where Q and D are defined as below.

3.21 Capacitors:

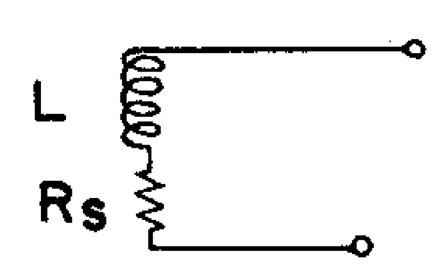


$D = R_s \omega C$

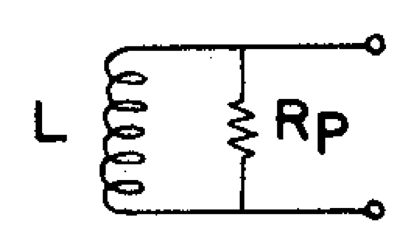


$D = \frac{1}{R_p \omega C}$

3.22 Inductors:

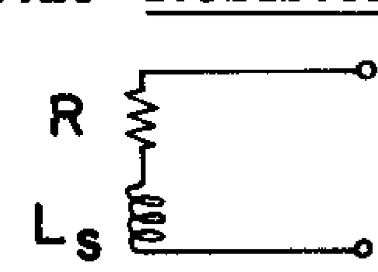


$D = -\frac{R_s}{\omega L}$

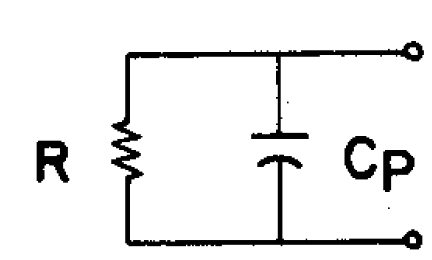


$D = -\frac{\omega L}{R_p}$

3.23 Resistors:



$Q = -\frac{\omega L_s}{R}$



$Q = +R\omega C_p$

For D less than 0.25, the DISSIPATION FACTOR DIFFERENCE dial reading can be considered as direct reading in radians. This can be converted to a phase angle in degrees by multiplying the dial reading by 57.3.

SECTION 4.0 SPECIAL MEASUREMENTS

4.1 RAPID SORTING OPERATION

The Type 1604-A Comparison Bridge can be used as a visual "go, no-go" device to sort components to any desired tolerance with an accuracy of 0.1%. In this use no balancing operation is necessary. The cathode ray oscilloscope gives an instantaneous indication.

4.11 Preliminary Set-Up:

4.111 Connect the "standard" to the STANDARD terminals.

4.112 Connect one of the components to be sorted to the UNKNOWN terminals and balance the bridge in the usual manner.

4.113 Turn the vertical centering control (see Paragraph 2.61) completely counter-clockwise.

4.114 Displace the IMPEDANCE DIFFERENCE dial from the balance position by the desired sorting tolerance.

4.115 Adjust the GAIN control so that the top of the band of light on the oscilloscope is on the indicator line.

4.116 Set the DISSIPATION FACTOR DIFFERENCE dial to zero.

4.117 Return the IMPEDANCE DIFFERENCE dial to its true zero, or, if there is an error in the standard, to its offset zero (see Paragraph 2.7). The bridge is now set up for a sorting operation.

4.118 If the impedance of the standard is less than 2000 Ω, steps 4.111 through 4.117 must be repeated whenever the impedance of the standard is changed markedly.

4.12 Procedure: Connect one of the parts to be sorted to the UNKNOWN terminals. If the resulting band of light on the oscilloscope extends above the indicator line, the component is outside the desired tolerance either in impedance or phase angle. Thus instantaneous indication is given which permits sorting components as rapidly as connections can be made to them.

4.2 MEASUREMENTS OF SMALL CAPACITORS

Capacitors from 0.1 $\mu\mu$f to 20 $\mu\mu$f can be measured directly and conveniently without the use of small standard capacitors.

4.21 Preliminary Set-Up:

4.211 Place the UNKNOWN GROUNDED - UNGROUNDED switch in the UNGROUNDED position.

4.212 Place range switch at 5%.

4.213 Connect two capacitors 100 $\mu\mu$f $\pm$2% across the STANDARD and UNKNOWN terminals.

4.214 Balance the bridge in the normal manner.

4.215 Set the offset zero indicator so that the dial reads zero.

4.22 Operation:

4.221 Add the unknown capacitor to be measured in parallel with the 100 $\mu\mu$f capacitor on the UNKNOWN terminals.

4.222 Balance the bridge in the normal manner.

4.23 Range: The IMPEDANCE DIFFERENCE dial is now direct-reading in $\mu\mu$f added to the 100 $\mu\mu$f capacitor, the full-scale range being $\pm$5 $\mu\mu$f ($\pm$5% of 100 $\mu\mu$f). When different shunting capacitors are used, the full scale reading can be varied, the bridge always reading $\pm$5% of the shunting capacitor. In the same way, the bridge can be set up on the $\pm$20% range to cover a larger range with reduced accuracy.

SECTION 5.0 ELECTRICAL CIRCUITS

5.1 GENERAL

The Type 1604-A Comparison Bridge is completely self-contained, consisting of an oscillator, bridge, visual detector, and associated power supplies.

5.2 BRIDGE

The bridge circuit is shown in Figure 10. The impedance difference is balanced by the resistive divider in the ratio arms, and the dissipation-factor difference by a differential capacitor across these arms. A switch (5% - 20%) is provided to decrease the range of the impedance-difference potentiometer from 20% to 5% by shunting the potentiometer with a fixed resistor.

5.3 OSCILLATOR

The oscillator is a resistance-capacitance oscillator (see Figure 11). The phase-shift capacitors are switched (TEST FREQUENCY F switch) when frequency is changed so that the impedance is the same at both frequencies. Limiting is obtained by using a non-linear resistor (Thyrite) in the plate circuit of the oscillator. A cathode follower is used to couple the oscillator to the bridge input transformer. Capacitive coupling through the bridge transformer is eliminated by careful shielding of both primary and secondary windings. Any unbalance of the capacitance from each half of the secondary winding to its shield is corrected with differential capacitor C-16.

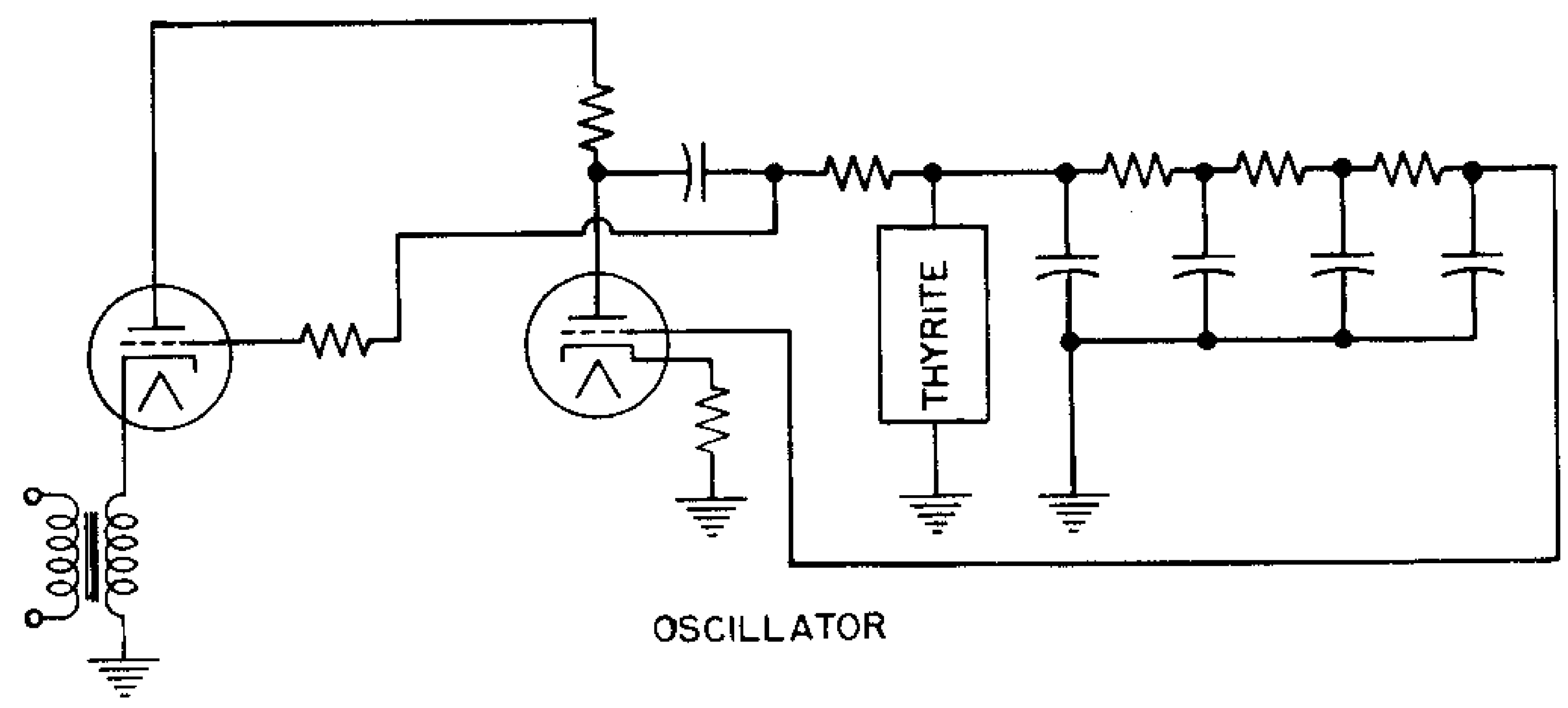


Figure 11

5.4 DETECTOR

A high-gain, three-stage amplifier is used to supply a push-pull error voltage to the vertical deflection plates of the cathode-ray-tube indicator. A FILTER jack is provided at the grid of the second stage for the insertion of a 1-kc or 5-kc filter of the parallel-resonant-circuit type, such as the Type 1231-P2 or 1231-P5. While this filter is not necessary, it will provide a somewhat cleaner null especially when measuring high impedances in the presence of stray fields.

A Thyrite limiter is connected between the push-pull plates of the third amplifier stage to decrease the gain for large error voltages. The gain is automatically increased as the null is approached, thus permitting rapid balancing of the bridge.

5.5 SWEEP

A free-running multivibrator is used to provide a high-frequency push-pull sweep. The resulting band of light provides a convenient and simple off-balance indication.

5.6 POWER SUPPLIES

A half-wave rectifier is used to supply +270 volts to the oscillator, amplifier, and the second anode of the CRO. A conventional resistance-capacitance filter is used. An additional half-wave rectifier is used to supply -300 volts to the cathode of the cathode-ray-oscilloscope.

SERVICE AND MAINTENANCE NOTES

This service information, together with the information given in the Operating Instructions, should enable the user to locate and correct ordinary difficulties resulting from normal use.

Major service problems should be referred to our Service Department which will cooperate as far as possible by furnishing information and instructions as well as supplying any replacement parts required.

When contacting our Service Department regarding any difficulties in operation or service of the instrument the serial number as well as the type number of the instrument should always be mentioned. A complete report of the troubles encountered, with specific reference to the numbered paragraphs in the Operating Instructions and the Service Information pertaining to these particular troubles, as well as any further information concerning the use of the instrument and steps taken to eliminate the difficulties, should also be included in any correspondence.

Please write to our Service Department for a Returned Material Tag, which includes shipping instructions, to insure proper handling and identification before returning any instrument or parts for repair. A purchase order covering material returned for repair should also be forwarded to avoid any unnecessary delay.

1.0 LACK OF SENSITIVITY

1.1 Low oscillator voltage will lower the sensitivity of balance appreciably, particularly when low impedances are being compared.
1.2 When a 1000-ohms-per-volt a-c meter is used, the voltage between the upper STANDARD and UNKNOWN terminals should be 2 volts ±20%.
1.3 Replace the oscillator tube V-4 to satisfy this condition.

2.0 LACK OF DEFINITION ON CATHODE-RAY TUBE

2.1 When V-7 has been replaced or after V-7 has operated for a long period of time, the line visible on its screen at balance may become thicker and lack sharpness.
2.2 Set the GAIN control fully counterclockwise and adjust the focus control R-46, located on the chassis to the left of the base of V-7, for minimum thickness of the line.
2.3 If the brilliance control (located under the left-hand snap button immediately below the CRO tube) is at its maximum clockwise position, the CRO trace may lack sharpness. For maximum sharpness, decrease the brilliance slightly.

3.0 NO HORIZONTAL DEFLECTION ON SCREEN AT V-7.

3.1 Replace horizontal sweep tube, V-5.
3.2 Check voltages for V-5 per table in Paragraph 6.1 if replacement tube does not restore operation.

4.0 NO VERTICAL DEFLECTION ON SCREEN OF V-7

4.1 Refer to Paragraph 1.0 above.

4.2 Check or replace vertical amplifier tubes V-1, V-2, and V-3.
4.3 Refer to voltage table in Paragraph 6.0 for V-1, V-2, and V-3 if replacements do not restore operation.

5.0 SCREEN OF V-7 COMPLETELY DARK

5.1 Replace rectifier tube V-6.
5.2 Refer to voltage table in Paragraph 6.0 for V-6 and V-7.
5.3 Replace V-7 if replacement of V-6 does not restore operation and voltages at V-6 and V-7 are normal.

6.0 TUBE VOLTAGES

6.1 Conditions of Measurements:
Line Voltage - 115 volts
D-C voltages are measured with a 20,000-ohms-per-volt d-c meter connected between the tube socket terminal and the chassis (ground) except where noted below.*

A-C voltages are measured with a 1,000-ohms-per-volt a-c meter connected between the tube socket terminal and the chassis (ground) except for V-6 and V-7 where connections are made between the terminals indicated by the "H" as noted below.

All readings are subject to 20% variation.

Power Input - 30 watts

7.0 TRANSFORMER T-2 RESISTANCE

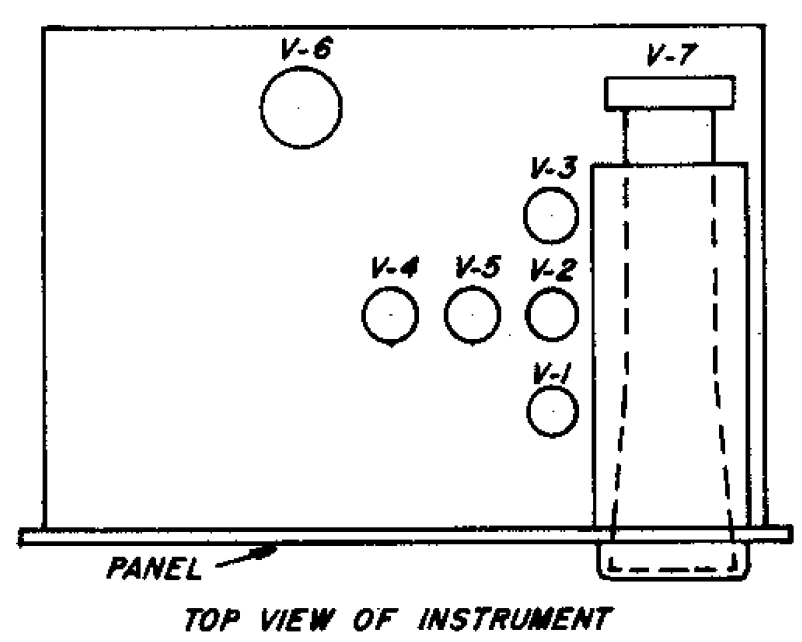
Primary - 1200 ohms
Secondary - 55 ohms

Tube	Type	Tube Socket Terminal Number											
		1	2	3	4	5	6	7	8	9	10	11	12
V-1	6AU6	0	0	0	6.4 a.c.	24	25	0					
V-2	6AU6	0	0.8	0	6.4 a.c.	155	32	0.8					
V-3	12AT7	144	45 - 72	72	6.4 a.c.	6.4 a.c.	144	45	72	0			
V-4	12AT7	275	0	5.0	6.4 a.c.	6.4 a.c.	144	0	1.8	0			
V-5	12AT7	70	-1.4	0	6.4 a.c.	6.4 a.c.	70	-1.4	0	0			
V-6	117Z6-GT		H	285 a.c.	340	-290	—	H	285 a.c.				
V-7	2BP1	H	0-40*	—	40-130*		144	144	440*	70	70		H

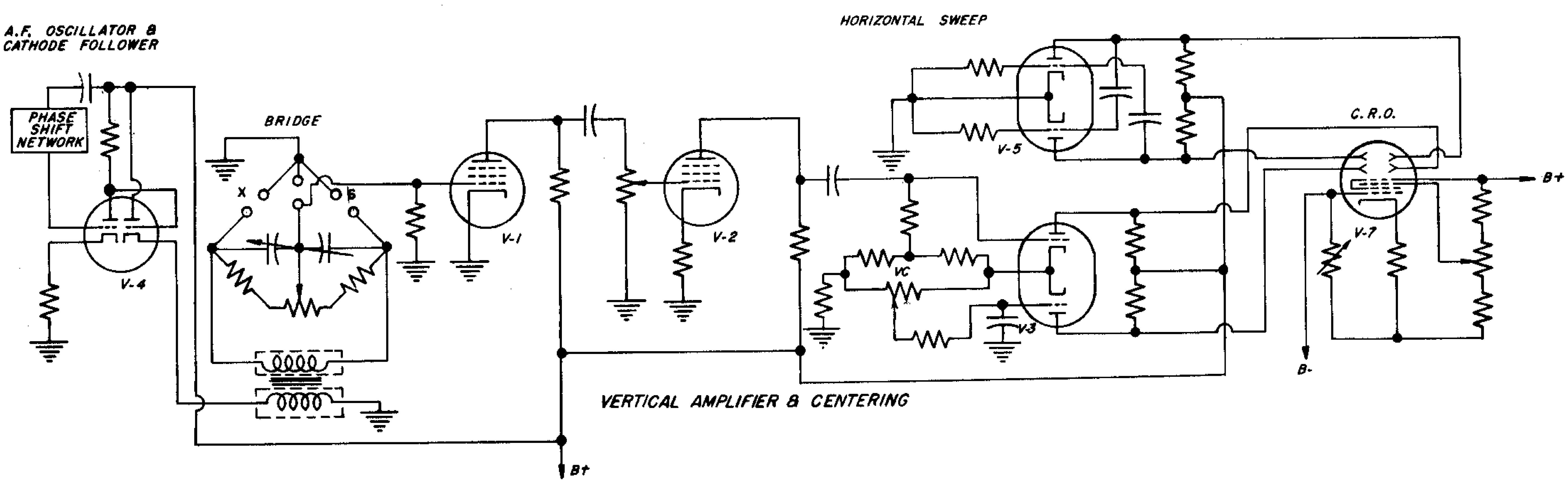
*Negative side of meter connected to terminal 3 of V-7.

H - 6.4 volts a-c for V-7 and 90 volts a-c for V-6 between indicated terminals.

Tube Layout



Schematic Wiring Diagram for Type 1604-A Comparison Bridge



Parts List

RESISTORS

				TYPE
R-1 =	470 k Ohms	±10%		REC-20BF
R-2 =	470 k Ohms	±10%		REC-20BF
R-3 =	220 k Ohms	±10%		REC-20BF
R-4 =	0.5 Megohms	±10%		POSC-12
R-5 =	1 k Ohm	±10%		REC-20BF
R-6 =	470 k Ohms	±10%		REC-20BF
R-7 =	100 k Ohms	±10%		REC-20BF
R-8 =	1 Megohm	±10%		REC-20BF
R-9 =	1200 Ohms	±10%		REC-20BF
R-10 =	1200 Ohms	±10%		REC-20BF
R-11 =	50 k Ohms	±10%		POSC-11
R-12 =				
R-13 =	27 k Ohms	±10%		REC-20BF
R-14 =	2.2 Megohms			REU-8
R-15 =	10 k Ohms	±10%		REC-20BF*
R-16 =	100 k Ohms	±10%		REC-20BF
R-17 =	100 k Ohms	±10%		REC-20BF
R-18 =	100 Ohms	±10%		REC-20BF
R-19 =	33 k Ohms	± 5%		REC-20BF
R-20 =	470 Ohms	± 5%		REC-20BF
R-21 =	22 k Ohms	± 1%	CCCo	X-1/2
R-22 =	39 k Ohms	± 1%	CCCo	X-1/2
R-23 =	39 k Ohms	± 1%	CCCo	X-1/2
R-24 =	39 k Ohms	± 1%	CCCo	X-1/2
R-25 =	2.2 Megohms			REU-8
R-26 =	470 k ohms	±10%		REC-20BF
R-27 =	470 k Ohms	±10%		REC-20BF
R-28 =				
R-29 =				
R-30 =				
R-31 =	220 k Ohms	±10%		REC-20BF
R-32 =	220 k Ohms	±10%		REC-20BF
R-33 =	25 k Ohms	±0.1%	IRC	WW-3
R-34 =	7.5 k Ohms	± 2%		314-411
R-35 =	25 k Ohms	±0.1%	IRC	WW-3
R-36 =	1.875 k Ohms	± 1%		510-369
R-37 =	400 Ohms	±10%		REPO-4
R-38 =	22 k Ohms	±10%		REC-20BF
R-39 =	5 k Ohms	± 5%		REPO-1031
R-40 =	33 k Ohms	±10%		REC-20BF
R-41 =	33 k Ohms	±10%		REC-20BF
R-42 =	82 k Ohms	±10%		REC-20BF
R-43 =	100 k Ohms	±10%		POSC-11
R-44 =				
R-45 =	120 k Ohms	±10%		REC-20BF
R-46 =	250 k Ohms	±10%		POSC-11
R-47 =	820 k Ohms	±10%		REC-20BF
R-48 =	220 k Ohms	±10%		REC-20BF
R-49 =	100 Ohms	±10%		REC-20BF
R-50 =	1 Megohm	±10%		REC-20BF

*R-15 adjusted at factory; resistance value depends on resistance of R-14.

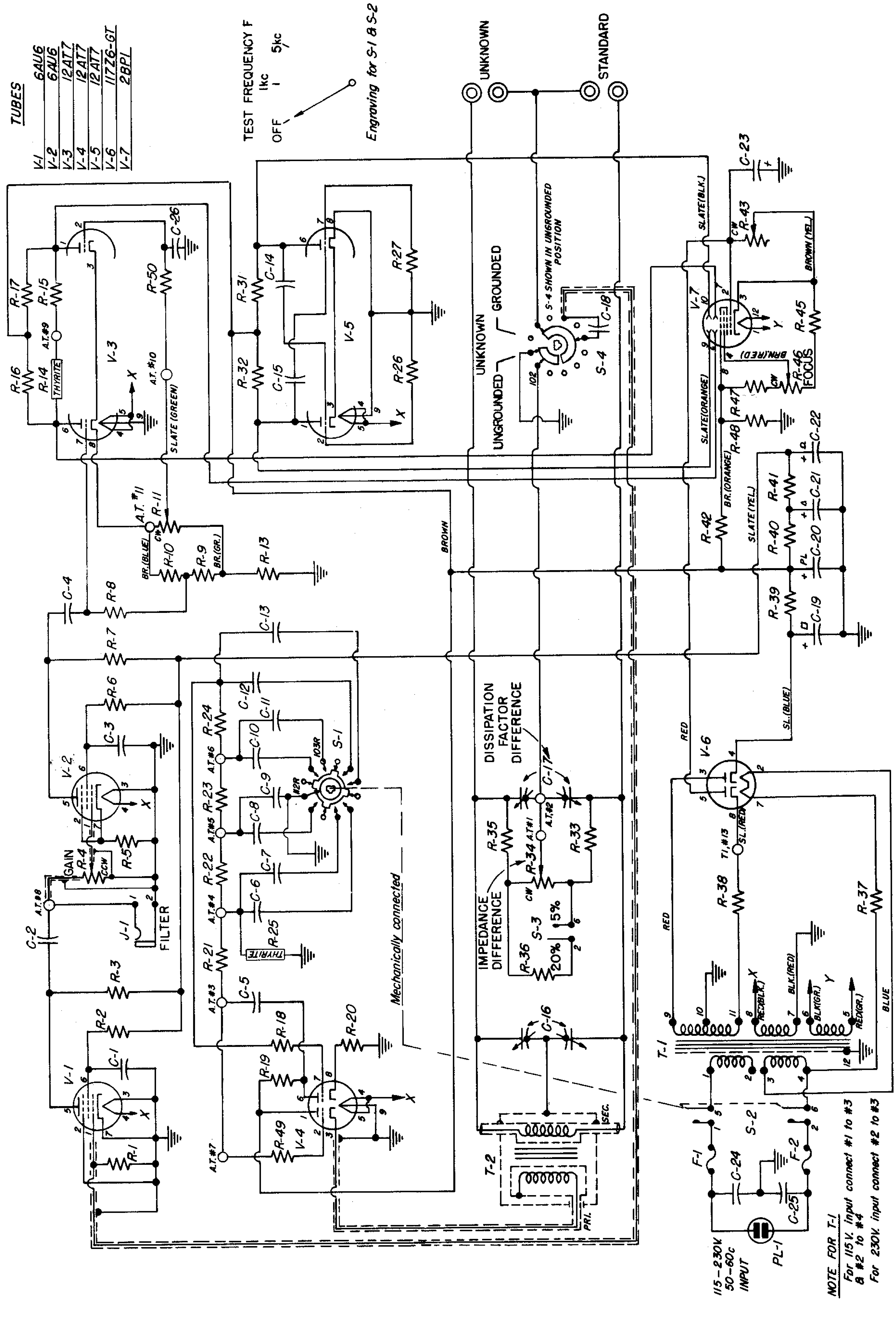
CONDENSERS

C-1 =	0.01 µf	±20%	COW-16
C-2 =	0.001 µf	±10%	COM-20B
C-3 =	0.01 µf	±20%	COW-16
C-4 =	0.001 µf	±10%	COM-20B
C-5 =	0.047 µf	±10%	COW-25
C-6 =	0.005 µf	± 1%	COM-30E
C-7 =	.001 µf	± 1%	COM-30E
C-8 =	0.005 µf	± 1%	COM-30E
C-9 =	.001 µf	± 1%	COM-30E
C-10 =	0.005 µf	± 1%	COM-30E
C-11 =	.001 µf	± 1%	COM-30E
C-12 =	0.005 µf	± 1%	COM-30E
C-13 =	.001 µf	± 1%	COM-30E
C-14 =	5 µµf	±20%	COM-20B
C-15 =	5 µµf	±20%	COM-20B
C-16 =	11 µµf		846-400
C-17 =	100 µµf	per section	368-411
C-18 =	0.001 µf	±10%	COM-20B
C-19 =	20 µf	450 DCWV	COEB-25 (C-19 to C-22)
C-20 =	20 µf	450 DCWV	
C-21 =	20 µf	450 DCWV	
C-22 =	20 µf	450 DCWV	
C-23 =	20 µf	450 DCWV	COE-14
C-24 =	0.01 µf	± 10%	COM-35B
C-25 =	0.01 µf	± 10%	COM-35B
C-26 =	0.0022 µf	± 10%	COL-71

MISCELLANEOUS

T-1 =	Transformer	485-439-2
T-2 =	Transformer	578-403
S-1 =	3 Position Switch	SWRW-60
S-2 =	DPST Switch Part of S-1	
S-3 =	SPST Switch	SWT-323
S-4 =	2 Position Switch	SWRW-61
F-1, F-2 =	0.5amp 3AG Slo-Blo 115V	FUF-1
F-1, F-2 =	0.3amp 3AG Slo-Blo 230V	FUF-1
J-1 =	Jack	CDSJ-820
PL-1 =	Input Plug	CDPP-562A

'A.T. Numbers Used: 1,2,3,4,5,6,7,8,9,10,11



Wiring Diagram for Type 1604-A Comparison Bridge