BOONTON ELECTRONICS CORPORATION

Instruction Book
Model 74D
Capacitance Bridge

BOONTON
ELECTRONICS
CORPORATION

ROUTE 287 AT SMITH ROAD
PARSIPPANY, N. J.– 07054

Instruction Book

Model 74D
Capacitance Bridge

BOONTON ELECTRONICS CORPORATION

ROUTE 287 AT SMITH ROAD
PARSIPPANY, N. J.— 07054

TABLE OF CONTENTS

MODEL 74D

SECTION 1

Specifications

CAPACITANCE: 200 μpF to 0.11 μF

Multiplier	Capacitance Range	Accuracy*
10	0.01 - 0.11 μF (2 pF/div.)	$\pm(0.25\% + \frac{1000}{R_p} + 2\ pF)$ Direct $\pm(0.25\% + \frac{1000}{R_p} + 2\ pF)$ Grounded
10	1000 pF - 0.01 μF (2 pF/div.)	$\pm(0.1\% + \frac{1000}{R_p} + 2\ pF)$ Direct $\pm(0.1\% + \frac{1000}{R_p} + 2\ pF)$ Grounded
1	100 - 1000 pF (0.2 pF/div.)	$\pm(0.1\% + \frac{1000}{R_p} + 0.2\ pF)$ Direct $\pm(0.1\% + \frac{1000}{R_p} + 0.5\ pF)$ Grounded
0.1	10 - 100 pF (0.02 pF/div.)	$\pm(0.1\% + \frac{1000}{R_p} + 0.05\ pF)$ Direct $\pm(0.1\% + \frac{1000}{R_p} + 0.5\ pF)$ Grounded
0.01	1 - 10 pF (0.002 pF/div.)	$\pm(0.1\% + \frac{1000}{R_p} + 0.01\ pF)$ Direct $\pm(0.1\% + \frac{1000}{R_p} + 0.5\ pF)$ Grounded
0.001	0.05 - 1 pF (0.0002 pF/div.)	$\pm(0.1\% + \frac{1000}{R_p} + 0.002\ pF)$ Direct $\pm(0.1\% + \frac{1000}{R_p} + 0.5\ pF)$ Grounded
0.001	0 - 0.05 pF (0.0002 pF/div.)	$\pm(2\% + \frac{1000}{R_p} + 0.0002\ pF)$ Direct

Where R_p is the equivalent parallel resistance of the test in ohms

*These specifications apply to tests made directly at the HI and LO TEST binding posts or coaxial recepticles. See Section 4 "Measuring Techniques" for limitations applicable to remote tests.

CONDUCTANCE: 0.001 to 1000 micromhos

Divider	Conductance Range	Accuracy*
1	100 to 1000 μmhos	$\pm$ (10% + $\frac{Q}{500}$ % +10 μmhos)
10	10 to 100 μmhos	$\pm$ (5% + $\frac{Q}{500}$ % +1 μmho
100	1 to 10 μmhos	$\pm$ (5% + $\frac{Q}{500}$ % +0.1 μmho)
1 K	0.1 to 1 μmho	$\pm$ (5% + $\frac{Q}{500}$ % +0.01 μmho)
10 K	0 to 0.1 μmho	$\pm$ (5% + $\frac{Q}{500}$ % +0.001 μmho)

RESISTANCE: 1000 ohms to 1000 MΩ

Multiplier	Resistance Range	Accuracy*
1	1 KΩ to 10 KΩ	$\pm$ (10% + $\frac{Q}{500}$ % + $\frac{R}{10^3}$ %)
10	10 KΩ to 100 KΩ	$\pm$ (5% + $\frac{Q}{500}$ % + $\frac{R}{10^4}$ %)
100	100 KΩ to 1 MΩ	$\pm$ (5% + $\frac{Q}{500}$ % + $\frac{R}{10^5}$ %)
1 K	1 MΩ to 10 MΩ	$\pm$ (5% + $\frac{Q}{500}$ % + $\frac{R}{10^6}$ %)
10 K	10 MΩ to ∞	$\pm$ (5% + $\frac{Q}{500}$ % + $\frac{R}{10^7}$ %)
Where R is the measured resistance in ohms.		

* Specified CONDUCTANCE and RESISTANCE accuracies apply only below 10,000 pF and when the test is connected directly to the HI and LO TEST binding posts or coaxial receptacles. For capacitance above 1000 pF refer to the Conductance Correction curve, page 9.

Note: See page 8 for Q formula

TEST FREQUENCY:	100 Kc/s ± 1%
TEST SIGNAL LEVEL:	Approximately 1 mV to 4 V
TUBE COMPLIMENT:	1-6X4, 1-OA2, 2-6AU6, 1-6C4
D.C. BIAS:	Internal: 0 to +110 V 0 to -7 V External: 400 V @ 100 mA MAX
POWER REQUIREMENTS:	105-125 V, 50-60 cps, 30 watts
WEIGHT:	35 pounds
SIZE:	Width: 19 1/2 " Height: 11 1/4 " Depth: 12 3/4 "

SECTION 2

GENERAL DESCRIPTION

The Model 74D Capacitance Bridge is designed to provide the industry with a versatile, precise instrument for measuring capacitance and conductance. It can measure both direct capacitance (three-terminal) and grounded capacitance (two-terminal).

When measuring direct-capacitance, stray or test cable capacitance to ground does not affect the measurement, and small values of capacitance may be measured easily and accurately.

A very wide range of capacitance (0.0002pF to 0.11 μF) and conductance (0.001 μmho to 1000 μmhos) can be measured. Below 10,000pF, the capacitance and conductance of the test are read directly from their respective dials.

An internal dc bias supply applies a dc voltage of 0 to +110 v or 0 to -7 v to the component under test. There are also binding post connections for applying up to 400 v @ 100mA from an external source to the test specimen.

The detector may be operated in a linear mode permitting measurements of the limit type to be made. Used with a relay meter, this provides a system for sorting capacitors within a specified tolerance.

SECTION 3

OPERATING PROCEDURE

3.1 EXPLANATION OF CONTROLS

CONTROL	FUNCTION
CAPACITANCE	Main capacitance dial
CONDUCTANCE	Main conductance dial
MULTIPLY C	Capacitance range switch
DIVIDE G MULTIPLY R	Conductance range switch
ADD CAPACITANCE	Activated in 10 Multiply C position only. Extends capacitance range to 0.11 μF.
C ZERO	Coarse and fine controls for zero balancing capacitance.
R/G ZERO	Zero balances conductance.
GND-DIR	Selects either direct (three-terminal) or grounded (two-terminal) mode of operation.
TEST LEVEL	Selects one of four over-lapping ranges of test signal level.
ADJUST (TEST LEVEL)	Varies the level of test voltage within a selected range.
SENSITIVITY	Adjusts the detector gain.
EXTERNAL METER	Provides for connection of an external null indicating meter.
NORMAL-LINEAR	Selects either normal (AGC) or linear mode of detector operation.
+INT, OFF, -INT, EXT	Selects positive or negative bias, no bias, or external bias.
ADJUST (BIAS)	Adjusts level of internal bias.

3.2 INITIAL SET-UP AND ZERO BALANCING

1. Select the desired method of capacitance measurement and set the GND-DIR switch accordingly. (See Section 5 "Direct Capacitance vs. Grounded Capacitance")

2. Set the DIVIDE G/MULTIPLY R switch to 1 K.

3. Set the MULTIPLY C switch to the position indicated below:

Capacitance to be Measured	MULTIPLY C Control Setting
1000 pF to 110,000 pF	10
100 pF to 1000 pF	1
10 pF to 100 pF	0.1
1 pF to 10 pF	0.01
0 to 1 pF	0.001

4. Set the CONDUCTANCE dial to zero

5. Set the CAPACITANCE dial to zero. (Both vernier and counter dials should read zero)

6. If they are required, connect test leads or fixtures as detailed in Section 4 "Measuring Techniques"

7. Move NORMAL-LINEAR switch to NORMAL position. (See Section 4.5 for Linear Operation)

8. Adjust R/G ZERO and C ZERO (COARSE and FINE) until the NULL INDICATOR meter reads zero. The FINE capacitance zero control should be set with the white dot at 12:00 o'clock before adjusting the COARSE control. The SENSITIVITY control should be set to approximately mid-position. Too high a gain setting will cause difficulty in obtaining a null. Too low a setting will result in reduced resolution and measuring accuracy.

9. If capacitance values above 10,000 pF are to be measured, the ADD CAPACITANCE switch should now be set to the required position.

10. Connect the test capacitor to the HI and LO TEST posts, or if making a remote measurement complete the connection to the test. (Refer to Section 4 "Measuring Techniques")

3.3 MEASURING

1. Adjust the CAPACITANCE and CONDUCTANCE dials for best null indication on the meter. The null should occur between 100 and 1000 on both the CAPACITANCE and CONDUCTANCE dials. If it occurs above or below these values, the next indicated MULTIPLY C and/or DIVIDE G/MULTIPLY R range should be used.

2. When using the 1 DIVIDE G/MULTIPLY R range it is necessary to deviate from convention in zero balancing conductance. In this position the R/G ZERO control is relatively insensitive in comparison to the main CONDUCTANCE dial. Zero balancing is achieved by setting the R/G ZERO to 12:00 o'clock and balancing with COARSE and FINE C ZERO and the main CONDUCTANCE dial. Balance should occur within one minor division on the CONDUCTANCE dial.

   NOTE: For ultimate accuracy, whenever the capacitance or conductance ranges are changed, the bridge must be zero balanced as detailed in Section 3.1. For many measurements of capacitance it is necessary to balance only on the most sensitive (0.001) MULTIPLY C range. When ranges are changed upscale, the zero should remain within two minor divisions in the direct mode and one major division using the grounded mode.

3.4 INTERPRETING READINGS

1. Capacitance: After balancing capacitance and conductance to a satisfactory degree of precision, the capacitance is determined directly from the CAPACITANCE dial reading, multiplied by the factor indicated on the MULTIPLY C switch position. Capacitance values above 10,000 pF are determined by adding the reading of the CAPACITANCE dial (multiplied by 10) to the reading of the ADD CAPACITANCE switch.

   EXAMPLE 1: CAPACITANCE dial at 856.2, MULTIPLY C in position 10 and ADD CAPACITANCE in position 6.

   68,562 pF or 0.06852 μF

   EXAMPLE 2: CAPACITANCE dial at 147.6, MULTIPLY C in 0.01 position.

   1.476 pF

2. Conductance: For values below 10,000 pF,* the conductance of the test is determined by dividing the reading on the G scale of the CONDUCTANCE dial by the position of the DIVIDE G/MULTIPLY R control.

3. Ressitance: For values below 10,000 pF,* the resistance is determined by multiplying the reading on the R scale by the position of the DIVIDE G/MULTIPLY R control.

   EXAMPLE: CONDUCTANCE dial at 165.5 and DIVIDE G/MULTIPLY R in 1K position.

   0.1655 μmho or 6 megohms

4. The Q and Dissipation Factor (D) of the test capacitor at 100 KC may be computed from the following formulae:

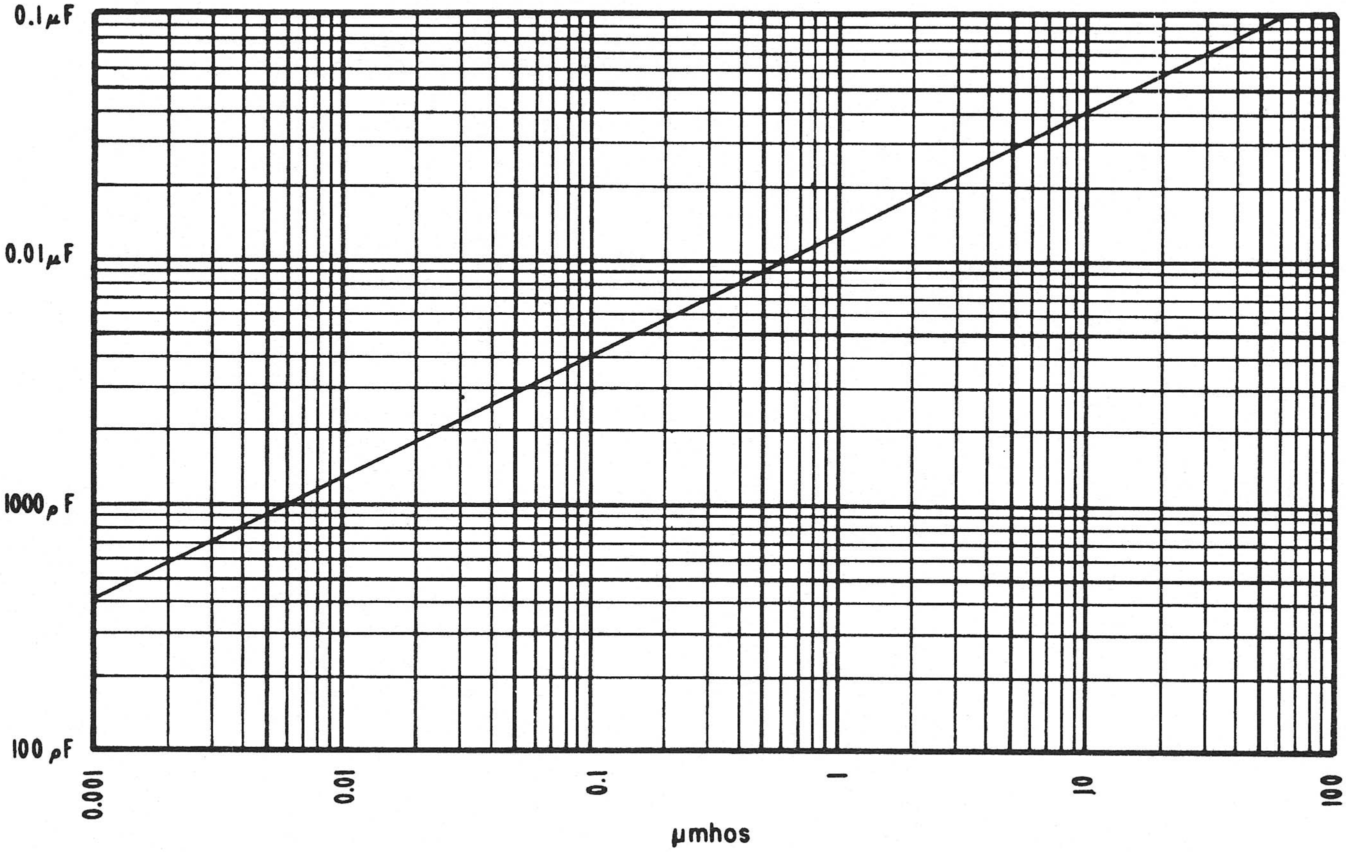
$$Q = \frac{0.628C}{G} \qquad D = \frac{1}{Q}$$

Where:
C is capacitance in pF
G is conductance in μmhos

* When measuring high Q capacitors above 10,000 pF, conductance and equivalent shunt resistance readings should not be used without special correction. The readings actually represent the difference in conductance/shunt resistance between the test capacitor and the capacitors of the ADD CAPACITANCE network that are in the circuit for the measurement. Reasonable accuracy for conductance or equivalent shunt resistance is obtained by referring to the table on the following page.

CONDUCTANCE CORRECTION FOR ADD CAPACITANCE SWITCH										
SWITCH POS.	1	2	3	4	5	6	7	8	9	10
ADD TO READING (μmhos)	1	2	4	7	8	11	14	17	21	24

CONDUCTANCE CORRECTION FOR INTERNAL SERIES RESISTANCE



SUBTRACT FROM CONDUCTANCE READING

Note: Corrections are to be applied to the measured value i.e. after range multiplication.

SECTION 4

MEASURING TECHNIQUES

4.1 GENERAL

Direct-capacitance measurements can be made to a higher degree of accuracy than grounded measurements, particularly when the test capacitance is small (less than 100 pF) and when long test leads are necessary. Use of the direct method also reduces hand capacitance effects as well as the test capacitor position error.

When direct-capacitance measurements are made at the end of coaxial cables, the cables may be bent, twisted, moved, and subjected to wide temperature variations without affecting test accuracy.

Much of the accuracy of capacitance measurements depends on the technique of connecting the test capacitor to the bridge. For example, when measuring the grounded-capacitance of a 10 pF mica capacitor the variation due to connection technique may be as much as 1 pF.

4.2 DIRECT-CAPACITANCE MEASUREMENTS

Whether measurements are being made at the TEST posts, or at the end of remote cables connected to the TEST coaxial receptacles, the test capacitor should be connected with leads as short as possible.

In many cases it may be convenient to connect the test capacitor by inserting its wire leads directly into the center conductors of the HI and LO TEST coaxial receptacles, This has the advantage that the outer shell of each jack shields the leads from each other for much of their length.

When certain limitations are kept in mind, remote measurements of capacitance may be made as easily, and in general, more accurately than those at the binding posts.

The use of reasonable lengths (up to 6 feet or so) of RG-58/U coaxial cable produces a small capacitance zero offset that is readily eliminated when zero balancing.

For values of test capacitance above about 1000 pF, the inductance and resistance of long coaxial cables result in an increase in capacitance and conductance readings that cannot be eliminated by zero balancing. The increase in capacitance reading is approximately +.008 % / 1000 pF of test capacitance/foot of extension of test cable (length of one cable). Conductance error is proportional to the length of cable and the square of the value of test capacitor.

It is given by the formula:

$$G = R\omega^2 C^2 \cdot 10^{-6}$$

Where: G = in μmhos
R = the resistance in ohms of the test cables
C = the test capacitance in farads
$\omega = 2\pi \times 10$

Increase in Capacitance Reading due to Inductance Of Remote Coaxial Cables (RG-58/U only)				
Capacitance Value Being Measured (pF)	Increase in Capacitance Reading			
	For 1 Ft. Cables		For 6 Ft. Cables	
	%	pF	%	pF
1,000	0.008	0.08	0.048	0.48
5,000	0.04	2	0.24	12
10,000	0.08	8	0.48	48

If maximum accuracy is required, it is usually best to use a test fixture to keep the capacitance between the leads of the test capacitor from influencing the measurement. (see figure 2)
All other conductors in the immediate vicinity of the elements under test must be connected to ground.

4.3 GROUNDED-CAPACITANCE MEASUREMENTS

Grounded-capacitance measurements are inherently less accurate than direct-capacitance measurements as there are unavoidable stray capacitance variations between the HI test lead and ground.

Although these variations may amount to 1 pF or more, it is usually possible to reduce this uncertainty to less than 0.5 pF by using the following procedure when preparing a test specimen:

1. Connect the ground side of the test capacitor to the LO binding post using a short length of wire.
2. Connect a short length of wire to the HI binding post. Bend this wire so it approaches the test sample perpendicularly and is away from all surrounding objects as much as possible. The free end should be spaced approximately 1/4 inch from the high terminal of the sample for bridge zero balance adjustments. The final measurement is made with this wire connected to the test specimen.

Contact fixtures may be used for production testing, provided their residual capacitance does not exceed the range of the COARSE and FINE C ZERO controls (approximately 10 pF).

4.4 DIFFERENTIAL MEASUREMENTS

1. Description

   The bridge may be used to measure very small capacitance differences between capacitors as high as 1,000 pF, hence, measurements of very small temperature coefficients can be made. The use of the direct method of measurement avoids errors resulting from stray or variable capacitance to ground.

   Note: Differential measurements cannot be made in the 10 MULTIPLY C position because the ratio between the standard and test arms is no longer 1:1.

2. Operating Procedure for Differential Measurements

   a. Switch to DIRECT

   b. Set the CAPACITANCE dial at mid-scale (500 pF). Select a MULTIPLY CAPACITANCE switch position that will give a suitable range of capacitance. Either the 0.01 or 0.001 range may be required, depending on the range of expected differential capacitance.

   c. Balance the bridge, using the COARSE and FINE C ZERO controls and the conductance zero.

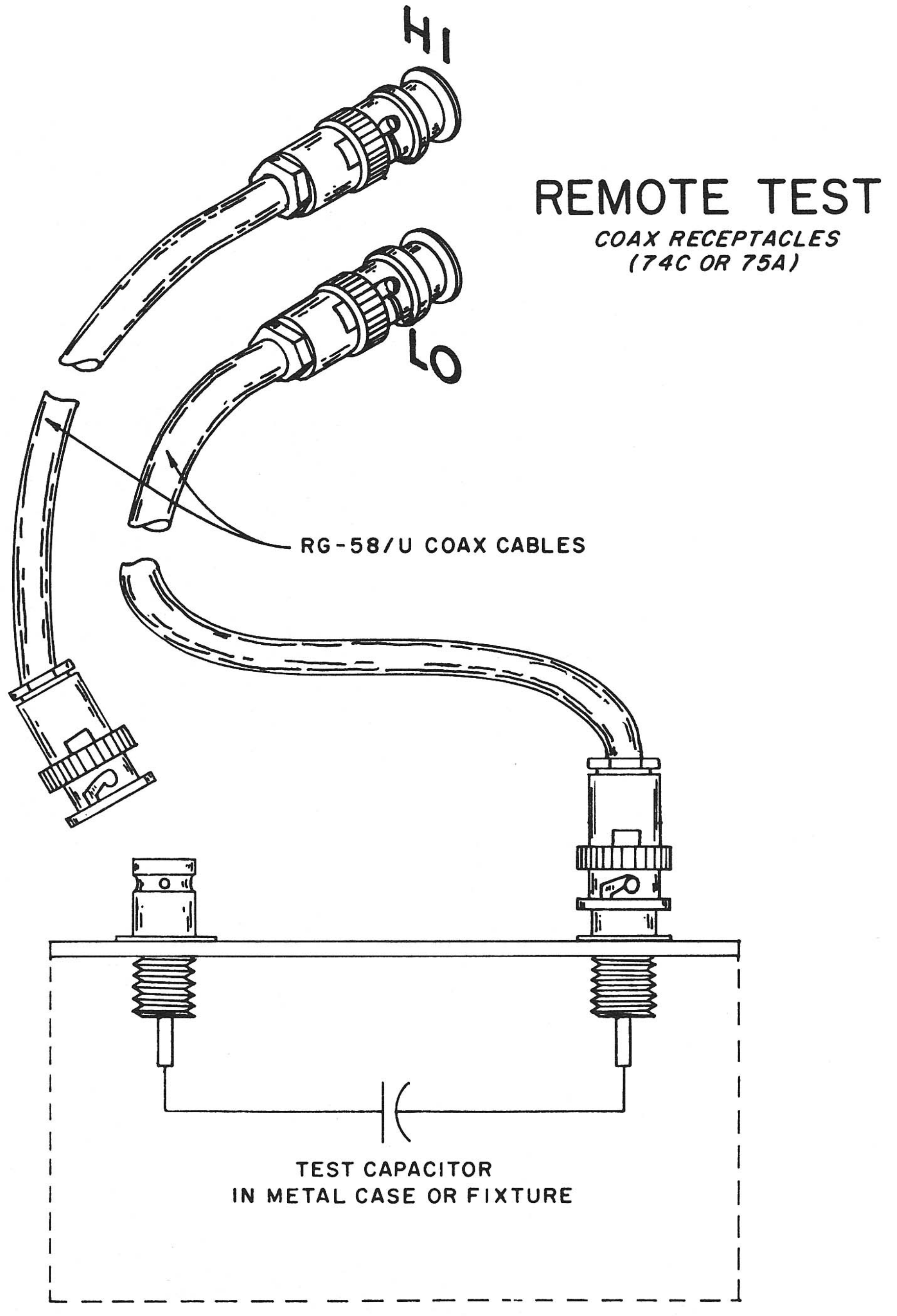
   d. Connect the reference capacitor to the STD coaxial receptacles and the test capacitor to the HI and LO TEST binding posts or coaxial receptacles.

   e. Adjust the CAPACITANCE and CONDUCTANCE dials of the bridge to restore balance. (The conductance reading is the difference in conductance between the reference capacitor and the test, hence should not be considered as reflecting the actual conductance of either capacitor).

   f. The change in capacitance as indicated by the dial and its MULTIPLYING factor is the differential capacitance. (pF difference in CAPACITANCE dial reading from 500.0 pF, times the MULTIPLYING CAPACITANCE factor used). The dial reading is direct sensing, i.e., a higher-than-500 pF reading indicates that the test capacitor is higher in capacitance than the reference one.

3. Suggestion for obtaining greatest accuracy

   Additional accuracy can also be obtained by interchanging the two capacitors and re-measuring their difference. Ideally the amount of difference from 500 pF should be identical, and the reading should be in the opposite direction from the 500 pF point. Due to minor internal lead unbalances, the usual result will be two readings that are not symmetrically offset from 500 pF and which may both be in the same direction from it. One half of the difference between readings is the amount by which the two capacitors differ. The "difference readings" are always direct sensing in that the connection giving the higher reading is the one where the capacitor connected to the TEST recep-



SETUP FOR REMOTE MEASUREMENT OF CAPACITORS USING COAXIAL CABLES (DIRECT ONLY)

PROCEDURE:

1. *Connect both cables to the bridge, and connect the* LO *cable to the case receptacle of the test that has the greatest capacitance to case (if any).*

2. *Balance the bridge*

3. *Connect the* HI *cable to the other case receptacle and measure.*

Figure 2

(830,070A)

tacles is larger than that on the STD receptacles.

4. T.C. measurements

Probably the most useful application of the differential method of measurement is in determining the temperature coefficient of capacitors. The Model 74D is ideally suited for this because of its high degree of resolution and extreme stability.

Here the "Direct" method of measurement is invaluable, for it allows the use of flexible shielded cables between the bridge and the capacitor to be tested, without introducing errors due to cable or stray capacitance to ground. Standard temperature chambers may be used without difficulty.

A stable reference capacitor should be used, preferably one of low temperature coefficient to minimize the effects of room temperature variations.

No external reference capacitor is necessary when the capacitor to be tested is less than 10 pF. In this case the CAPACITANCE dial can be set to 500 pF (mid-scale) on either the 0.01 or 0.001 range, and the C ZERO controls used to balance the Bridge (in place of a "reference" capacitor).

4.5 LINEAR OPERATION

When the NORMAL-LINEAR switch is in the LINEAR position, the detector is operated without AGC and gives an indication directly proportional to the capacitance or conductance unbalance. This permits "limit" type measurements to be made in which the NULL INDICATOR reading represents a given percentage of capacitance. The NULL INDICATOR meter is protected against overload under all conditions.

The EXTERNAL METER jack provides for connection of an external current meter in series with the NULL INDICATOR meter. This is particularly suitable for meters of the relay type which could provide a mechanical decision. There is no protection for an external meter as this would restrict the user to meters of 200 μA full scale or lower.

An example of a linear application is the selecting of 10 pF capacitors to within ± 1%. The bridge is balanced on the 0.01 MULTIPLY C range. A capacitor is chosen at random from the lot to be sorted and its value is determined by measuring it in the NORMAL mode. After measuring, leave the bridge balanced and switch to the LINEAR mode. Offset the CAPACITANCE dial by an amount equal to the tolerance desired (± 1%). The NULL INDICATOR is then set to read 100 by adjusting either SENSITIVITY or TEST LEVEL. Reset the CAPACITANCE dial to 1000 (10 pF).

Capacitors may now be sorted by connecting them and reading the meter indication. Any capacitor that causes a reading of more than 100 on the NULL INDICATOR is out of tolerance, i.e.; lower than 9.9 pF or higher than 10.1 pF. If the Q of the capacitor is 500 or above (or the Conductance is very consistant) a high order of accuracy will be achieved without rebalancing the conductance component each time. For Q'S below 500 it may be necessary to adjust the CONDUCTANCE control for minimum meter indication.

4.6 D.C BIAS

The Model 74D has provision for biasing the component under test with DC from internal supplies, or from an external source. This is very useful in measuring "varactors" and also finds application in measuring diodes, transistors and other non-linear devices.

Bias is restricted to the DIRECT mode of operation. The switch selects internal bias of either polarity, no bias, or external bias. The level of the internal bias is continuously adjustable from 0 to +11V or -7V and the voltage and current may be monitored at the "VOLTAGE" posts and "CURRENT" jack.

Switching to the EXT position permits up to 400V at 100 mA to be applied from an external source.

4.7 TEST LEVEL

Front panel controls provide for continously varying the test voltage level (in four over lapping ranges) from approximately 1 mV to 4 V. * Control of the test voltage is essential in measuring the capacitance of non-linear devices such as diodes, transistors and vacuum tubes. With this type of component a low-test voltage is required to obtain a sharp null. In some instances, the capacitance of the component varies with test level.

Test Level Switch Pos.	Approximate Test Voltage (LO to GND) Minimum	Maximum
HI	0.8 V	4 V
	50 mV	1 V
	15 mV	75 mV
LO	1 mV	20 mV

* The test voltage is reduced by 20 db when using the 10 MULTIPLY C position due to the ratio transformer.

SECTION 5

DIRECT-CAPACITANCE VS. GROUNDED CAPACITANCE

Direct-capacitance is the capacitance existing between two conducting elements, excluding all stray capacitance that may exist to other conducting elements.

Typical examples of direct-capacitance measurements are:

1. Capacitance between the control grid and plate of a pentode vacuum tube, excluding capacitance to cathode, screen grid, or suppressor.
2. Capacitance between any two conductors in a cable, excluding capacitance to all other conductors.
3. Capacitance between any two conductors of a printed circuit, excluding capacitance to all other conductors.
4. Capacitance between any two windings of a transformer, excluding capacitance to all other windings or shields.

Grounded-capacitance is the capacitance existing between two conducting elements when one element is grounded, and includes all stray capacitance from the high side of the element to ground, either directly or by way of adjacent elements. For this reason, a grounded-capacitance reading will always be greater than a direct-capacitance reading and will depend on the proximity of the chassis, adjacent components, and measuring technique.

SECTION 6

THEORY OF OPERATION

6.1 GENERAL

The Model 74D Capacitance Bridge consists of three major units; a 100 Kc, low distortion oscillator, a modified Young bridge; and a high gain, two stage, I.F. coupled detector.

The 100 Kc/s oscillator signal is fed to the bridge input transformer through a low impedance link coupling. The bridge unbalance signal is impressed across the primary of the bridge output transformer. This unbalance signal is low impedance coupled to the input of a 100 Kc/s I.F. amplifier. The amplifier output is then rectified and measured by a dc microammeter.

6.2 OSCILLATOR

The oscillator unit is housed in a well shielded case. It is of the series-fed Hartly type in which energy is coupled back to the tuned grid circuit in short pulses,sustaining oscillation. This is frequently referred to as the 'fly-wheel effect'. These pulses are inductively coupled into the tuned grid circuit (T301 and C301) by the lower section of T301 (cathode to ground). The oscillator output signal is taken from the resonant tank by transformer coupling to a low impedance link. The level of signal sent to the bridge is varied by both changing the oscillator B+ voltage and switching an attenuator network in or out of the link.

6.3 BRIDGE (See Figure 3)

The oscillator signal is link coupled to the bridge input transformer, T201, the secondary of which is part of the bridge proper. This specially designed transformer produces two signals exactly equal in amplitude and opposite in phase. Because of very tight coupling in the secondary, any unbalance or loading in one half reflects an equal and opposite unbalance in the other. This results in an extremely well balanced secondary.

The bridge output transformer, T202, has its primary winding connected to the detection corners of the bridge. When the capacitance and resistance of the bridge test arm are exactly equal to the capacitance and resistance of the standard arm, no signal is present at the output transformer resulting in a null condition.

In the 10 MULTIPLY C position, the bridge input transformer becomes a 10:1 ratio transformer and balance is achieved when the capacitance of the test arm is exactly ten times that of the standard arm. The resistance network is switched to both the tap on the standard arm as well as the test arm and therefore remains a 1:1 ratio. This means that resistance and its reciprocal, conductance, are not affected by the MULTIPLY C switch setting.

6.4 DETECTOR

The secondary of the bridge output transformer is part of a low impedance link which couples the unbalance signal to the detector. When the NORMAL-LINEAR switch is in the NORMAL position, an AGC signal is applied to both I.F. stages. This provides hunting action i.e.; even in a condition of high unbalance it is possible to see movement of the NULL INDICATOR meter. When close to null, no AGC is developed and the detector operates with maximum sensitivity resulting in high resolution.

In the LINEAR mode no AGC is used, but the rectified signal, which is now directly proportional to the capacitance and conductance unbalance, is still measured by the NULL INDICATOR meter. For further information on LINEAR operation, refer to section 4.5.

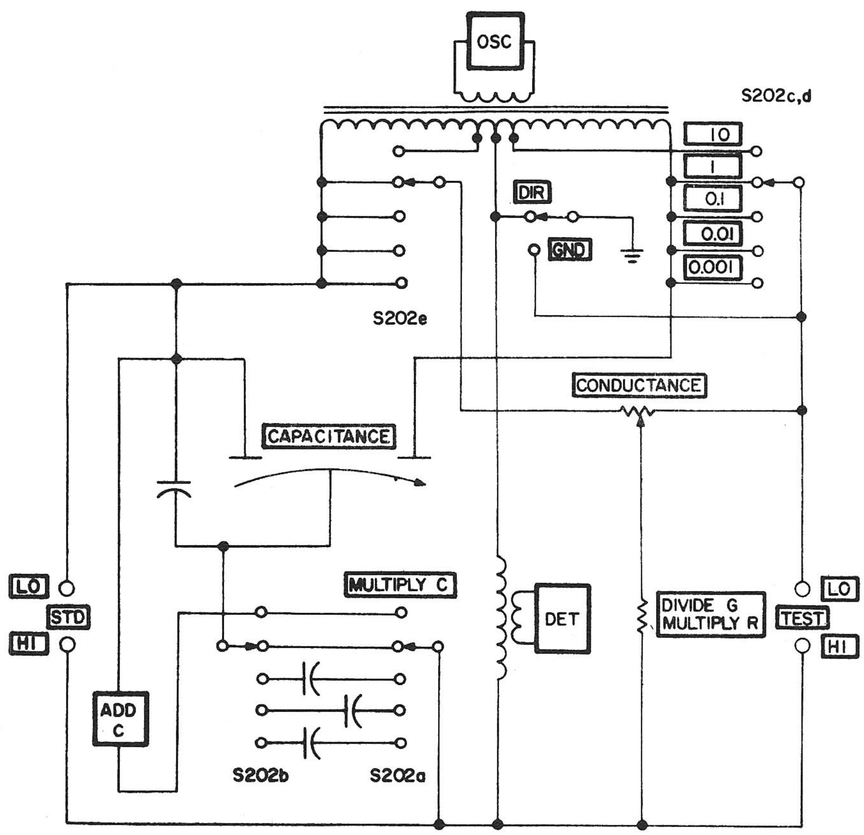


Figure 3. Simplified Diagram, Model 74D

SECTION 7

MAINTENANCE

7.1 GENERAL

This instrument has been carefully calibrated at the factory against precision three-terminal capacitance standards certified by the National Bureau of Standards. Re-calibration by other than the manufacturer is inadvisable unless the customer has comparable standards.

Boonton Electronics Type CS Direct Capacitance Standards are available and are recommended for this purpose. They are described fully on a sheet preceding the schematic at the end of this book. Also suitable are the General Radio Type 1403 and 1409 Standard Capacitors.

See Section 8.2 Capacitance Calibration for calibration information.

7.2 NORMAL D.C. OPERATING VOLTAGES

To remove instrument from cabinet it is necessary to remove only four 10-32 screws located near the outside edges of the front panel.

CONDITIONS: TEST LEVEL AND SENSITIVITY at maximum.

P402 disconnected from J402

Line input 117 V, 50-60 c/s

All voltages are referenced to front panel ground.

NOTE: Voltages given are approximate. Variations of 10% or higher can be expected.

	PIN NUMBER						
TUBE	1	2	3	4	5	6	7
V101 6X4							260 V
V102 oA2	150V	0			150V		0
V301 6C4	210V				210V		0
V401 6AU6		0			140V		2
V402 6AU6		0			150V	135V	2

7.3 CHECK OF OVERALL PERFORMANCE

This series of tests, requiring no auxiliary equipment, can detect several forms of mechanical and electrical malfunctioning.

A bridge that passes is not guaranteed to be normal, but a normal bridge should pass with no difficulty.

1. Dial Stop

(Checks the dial stop action and correctness of dial alignment with main capacitor rotary position.) Rotate the CAPACITANCE dial until the stop is reached (at -50). The hairline should be over the mark on the counter (outer) dial, and should coincide with 0 on the inner dial (within ±2 small divisions). Turn to the upper stop. It should actuate at approximately 1050 (within ±5 major divisions).

2. Capacitance Zero

(Checks the setting of internal zero adjustments and general balancing of the capacitance network at zero.) Refer to zero balancing procedure as outlined in Section 3.2. Set the MULTIPLY C switch to 0.001, the DIVIDE G/MULTIPLY R to 1 K and the GND-DIR switch to DIR. After careful balancing, switch to progressively higher MULTIPLY C ranges, each time restoring balance with the main CAPACITANCE dial. In all cases the setting of the vernier (inner) dial should not change more than ±2 minor divisions. If the same test is made in the GND mode, a change of no more than ±1 major division is normal.

3. Conductance Zero

(Check of internal adjustments and balance of conductance network.) Follow standard zero balance procedure except: switch both MULTIPLY C and DIVIDE G/MULTIPLY R to 1, set R/G ZERO control to 12 o'clock and balance with main CONDUCTANCE dial. Null should occur within ±1 minor division. Switch to progressively higher DIVIDE G/MULTIPLY R ranges, each time restoring balance with R/G ZERO. In all cases it should not change more than ±1/2 hour from 12 o'clock.

4. Sensitivity

(Checks overall system operation.) Zero balance bridge with MULTIPLY C in 0.001 position, DIVIDE G/MULTIPLY R at 1 K, TEST LEVEL at maximum and SENSITIVITY full clockwise. An increase or decrease of 1 dial pF on the CAPACITANCE dial should produce a reading of at least 25 μA on the NULL INDICATOR.

5. Capacitance Dial Backlash

(Checks for normal operation of the entire variable capacitor system, including the main capacitor and its gearing and drive mechanisms.) Zero balance bridge on 1 MULTIPLY C range. When the CAPACITANCE dial is turned from at least 10 dial pF off null into the null, the null should occur at the same dial point whether approached from a clockwise or counter-clockwise direction. If it differs by more than 1 small division, the backlash is excessive. The instrument is still usable, however, if the null point is always obtained when approached from the same direction.

7.4 OSCILLATOR AND DETECTOR ADJUSTMENTS

1. Oscillator

Unless the OSC FREQ (T301) control has been disturbed or V301 replaced, no adjustment of the oscillator tuned tank is required. If it is necessary that the operating frequency be exactly 100 Kc, a counter or frequency meter may be connected from LO TEST to GND. The GND-DIR switch should be in the DIR position and the TEST LEVEL at maximum. Set the oscillator frequency using the OSC FREQ control located on the oscillator case.

2. Detector

To check the alignment or to re-align the I.F. amplifier, set both TEST LEVEL and SENSITIVITY to maximum and zero balance the bridge on the 0.001 MULTIPLY C range. Using the CAPACITANCE dial, offset the null so that the NULL INDICATOR reads approximately 50 μA.

Starting with T403, adjust for a peak on the NULL INDICATOR. Continue alignment with the adjustment of T402 and T401. If necessary re-set the CAPACITANCE dial so that a reading of approximately 50 μA is maintained. To insure that optimum alignment has been achieved, perform sensitivity check described in Section 7.4,

Re-alignment is normally necessary only if amplifier tubes V401 or V402 are replaced.

SECTION 8

CAPACITANCE AND CONDUCTANCE CALIBRATION

8.1 GENERAL

Calibration of the capacitance network is not recommended unless three-terminal standards are available.

Although the following instructions include re-calibration information as well as a check of existing calibration, it is urged that only the latter be done by the customer. If it is determined that the bridge calibration is out of specification then the instrument should be returned to the factory where it will be completely re-calibrated by trained personnel. The customer, however, has the option of performing his own re-calibration but must realize that once the bridge warrenty seals are broken, the guarantee becomes void.

8.2 CAPACITANCE CALIBRATION

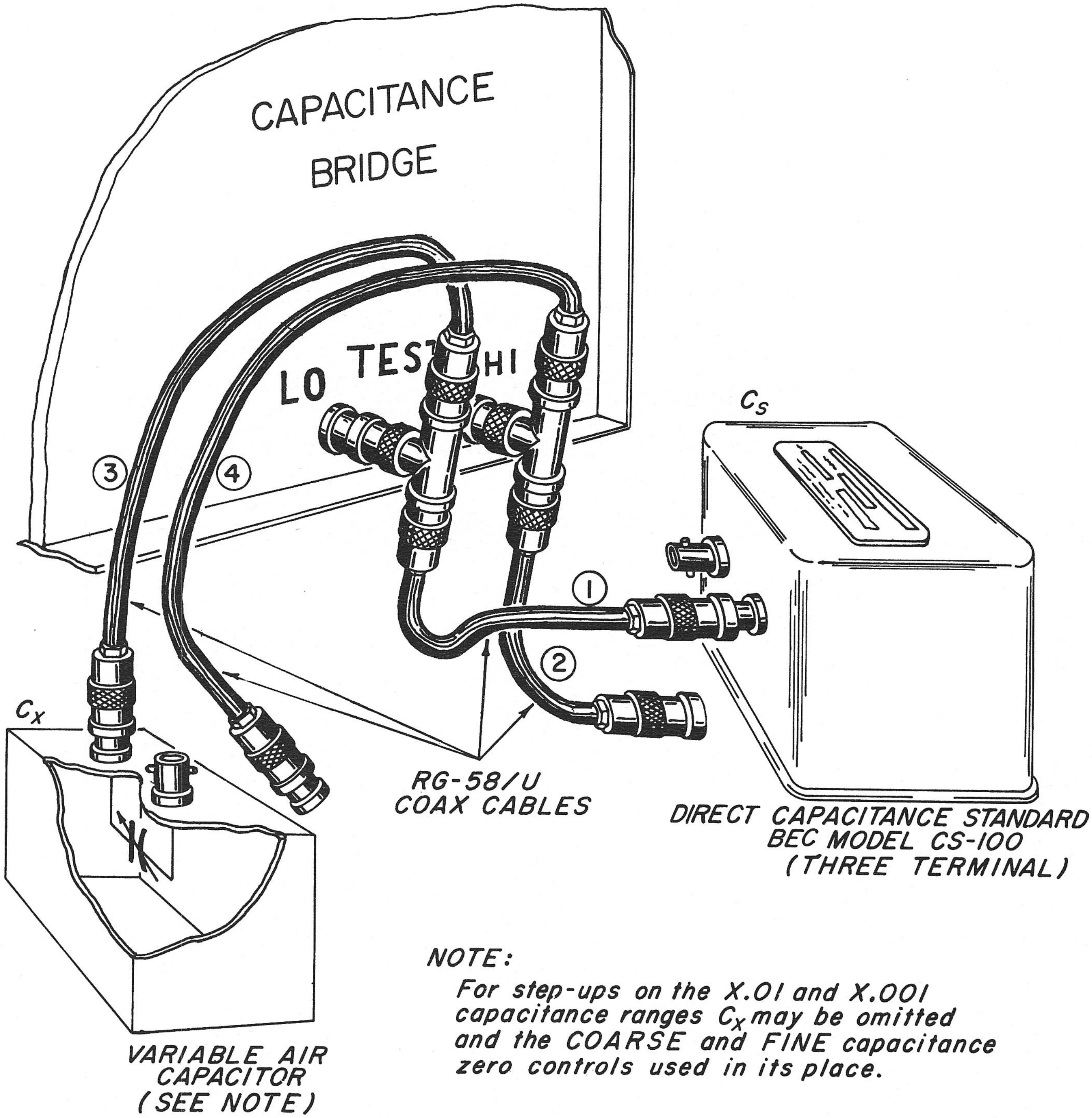
It is necessary to check the calibration of the main capacitor first. This is done on the 1 MULTIPLY C range. A check of the three major calibration points (100, 500, 1000) is sufficient but more extensive dial calibration can be achieved by checking every 100 pF.

A less expensive method than buying individual standards for determining calibration accuracy involves use of the measuring technique known as "step-up". *Basically this involves reading a standard C_s on the bridge, then disconnecting it and substituting a variable capacitor C_x, which is adjusted to restore the bridge balance. Next C_s and C_x are both carefully connected (in parallel) to the bridge and read. This gives a dial calibration point for $2 \cdot C_s$. Again disconnecting C_s and restoring bridge balance by re-setting C_x, then re-connecting C_s and reading gives dial calibration at $3 \cdot C_s$. This process is repeated until all the desired dial calibration points have been obtained. For the 1 MULTIPLY C range a check of calibration at every 100 pF point can be obtained by using this "step-up" method with a 100 pF standard capacitor.

Extension of this method to include coverage of all capacitance ranges of the bridge, and to give as many check points on the dial as desired is entirely feasible.

A recommended minimum set of three-terminal standards would include 1000, 100, 10, 1, and 0.1 pF.

*See Figure 4.



CONNECTIONS FOR STEP-UP MEASUREMENTS

Figure 4

1 MULTIPLY C Range Calibration				
Nominal Capacitance	*Tolerance (pF)	Allowable Range of Dial Reading		
100 pF	± 0.3	99.7	-	100.3 (dial) pF
200	± 0.4	199.6	-	200.4
300	± 0.5	299.5	-	300.5
400	± 0.6	399.4	-	400.6
500	± 0.7	499.3	-	500.7
600	± 0.8	599.2	-	600.8
700	± 0.9	699.1	-	700.9
800	± 1.0	799.0	-	801.0
900	± 1.1	898.9	-	901.1
1000	± 1.2	998.8	-	1001.2

*This includes only the capacitance bridge tolerance, ±(0.1% +0.2 pF). The tolerance of standards used must also be considered.

If the calibration of the 1 MULTIPLY C range is found to be out of tolerance then the instrument should be returned to the factory for re-calibration as this involves an intricate procedure and requires special equipment.

The 10 MULTIPLY C range calibration is checked by the same procedure. Its accuracy is directly related to the main capacitor and therefore also warrants factory re-calibration.

10 MULTIPLY C Range Calibration				
Nominal Capacitance	*Tolerance (pF)	Allowable Range of Dial Reading		
1000 pF	± 3	99.7	-	100.3
2000	± 4	199.6	-	200.4
3000	± 5	299.5	-	300.5
4000	± 6	399.4	-	400.6
5000	± 7	499.3	-	500.7
6000	± 8	599.2	-	600.8
7000	± 9	699.1	-	700.9
8000	± 10	799.0	-	800.0
9000	± 11	899.9	-	901.1
10000	± 12	998.8	-	1001.2

*This includes only the capacitance bridge tolerance. The tolerance of the capacitance standards used must also be considered.

NOTE: Above 1000 pF, error due to lead inductance becomes appreciable even at 100 Kc/s. Figure 5 on the following page shows the increase in capacitance reading.

To perform re-calibration of the following capacitance ranges it is necessary to remove the rear bridge shield. This involves breaking one of the warranty seals. Caution should be exercised so that no adjustments other than those involved in re-calibration, are disturbed.

0.1 MULTIPLY C Range Calibration

Nominal Capacitance	*Tolerance (pF)	Allowable Range of Dial Readings
100 pF	± 0.15	998.5 to 1001.5 dial pF
50 pF	± 0.10	499.0 to 501.0 dial pF
10 pF	± 0.06	99.4 to 100.6 dial pF

*This includes only the capacitance bridge tolerance. The tolerance of the capacitance standards used must also be considered.

If the 1 MULTIPLY C range is within tolerance but the 0.1 range is not, it is possible to re-calibrate by adjustment of C206. This adjustment is located on the MULTIPLY C switch. The entire assembly is within an enclosed shield and access to this adjustment is through the port marked X0.1. It is recommended that an insulated screwdriver be used. C206 is adjusted so that a 100 pF standard capacitor reads correctly at 1000 on the CAPACITANCE dial.

0.01 MULTIPLY C Range Calibration

Nominal Capacitance	*Tolerance (pF)	Allowable Range of Dial Readings
10 pF	± 0.02	998.0 to 1002.0 dial pF
5 pF	± 0.015	498.5 to 501.5 dial pF
1 pF	± 0.011	98.9 to 101.1 dial pF

*This includes only the capacitance bridge tolerance. The tolerance of the capacitance standards used must also be considered.

Provided that the 1 MULTIPLY C range is within tolerance, the 0.01 range may be re-calibrated by adjustment of C207, also located on the MULTIPLY C switch, which is accessible through the port marked X0.01. It is adjusted (using an insulated screwdriver) so that a 10 pF standard capacitor reads correctly at 1000 on the CAPACITANCE dial.

REMOTE MEASUREMENT ERROR DUE TO CABLE INDUCTANCE

(INCREASE IN CAPACITANCE READING PER FOOT OF RG-58/U CABLES)

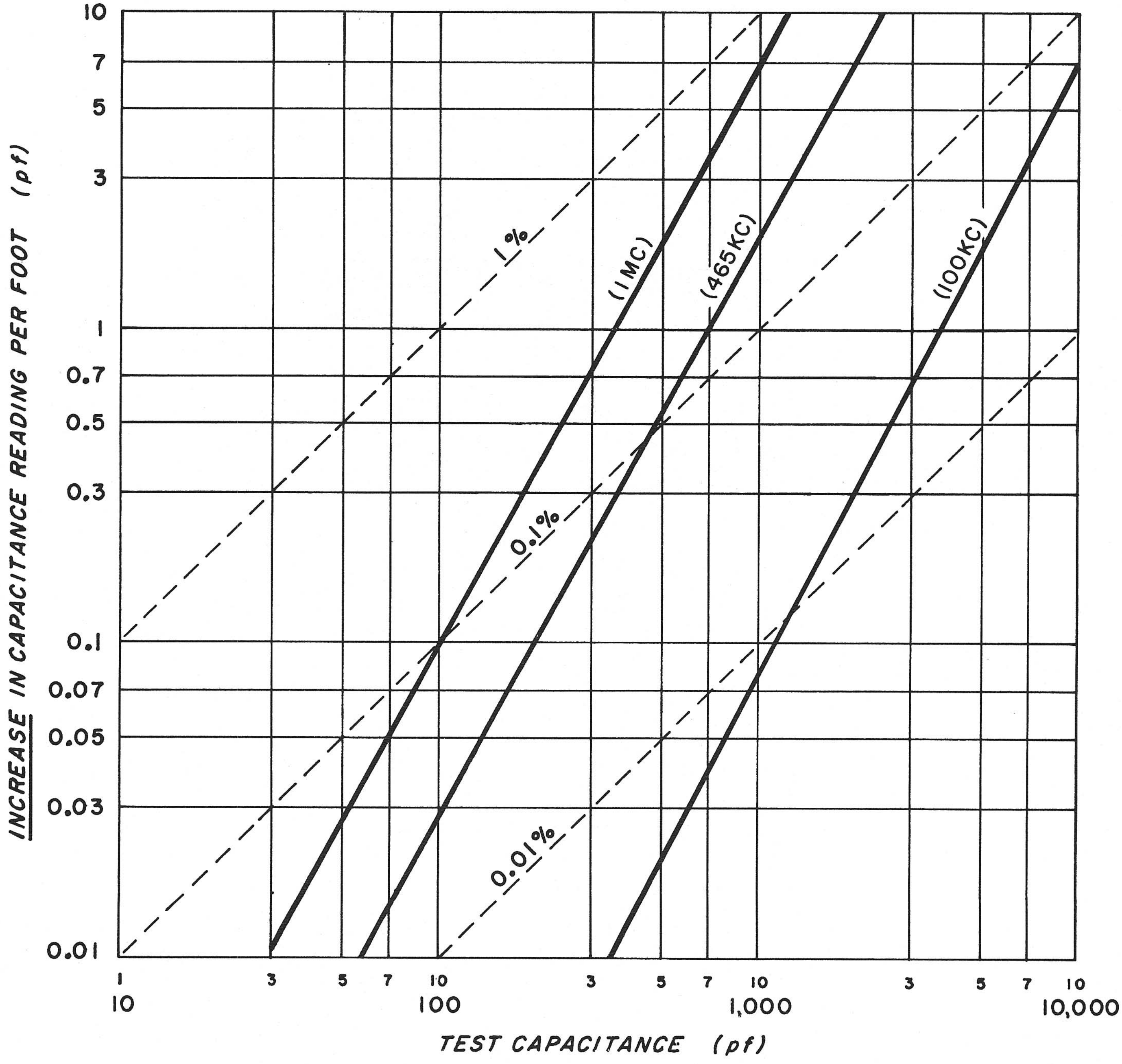


Figure 5

(830,067C)

0.001 MULTIPLY C Range Calibration					
Nominal Capacitance	*Tolerance (pF)	Allowable Range of Dial Readings			
1 pF	± 0.003	997.0	to	1003.0 dial	pF
0.5 pF	± 0.0025	497.5	to	502.5 dial	pF
0.1 pF	± 0.0021	97.9	to	102.1 dial	pF

*This includes only the capacitance bridge tolerance. The tolerance of the capacitance standards used must also be considered.

Provided that the 1 MULTIPLY C range is within tolerance, the 0.001 range may be re-calibrated by adjustment of C208. Access to this adjustment, located on the MULTIPLY C switch, is through the port marked X0.001. Using an insulated screwdriver, adjust so that a 1 pF standard capacitor reads correctly at 1000 on the CAPACITANCE dial.

8.3 CONDUCTANCE CALIBRATION

The accuracy of the conductance ranges is checked by measuring 1/4 W or 1/2 W 1% deposited carbon resistors. Individual resistors should be used as mounting them on a switch or making series or parallel combinations may introduce some error.

The following results should be obtained:

DIVIDE G/MULTIPLY R RANGE	RESISTOR	TOLERANCE (μmhos)			
1	1 K	890	to	1110	(± 11%)
10	10 K	94	to	106	(± 6)
100	100 K	9.4	to	10.6	"
1 K	1 Meg	0.94	to	1.06	"
10 K	10 Meg	0.094	to	0.106	"

SECTION 9

WARRANTY AND RETURN INSTRUCTIONS

BOONTON ELECTRONICS CORPORATION quarantees to the original purchaser that each instrument it manufactures is free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, choppers, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

PROCEDURE TO FOLLOW IF INSTRUMENT BECOMES DEFECTIVE

1. Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.

2. If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables, or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.

3. If the instrument is within warranty, we will repair and return it, transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it, unless approval on a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

SECTION 10

BIBLIOGRAPHY

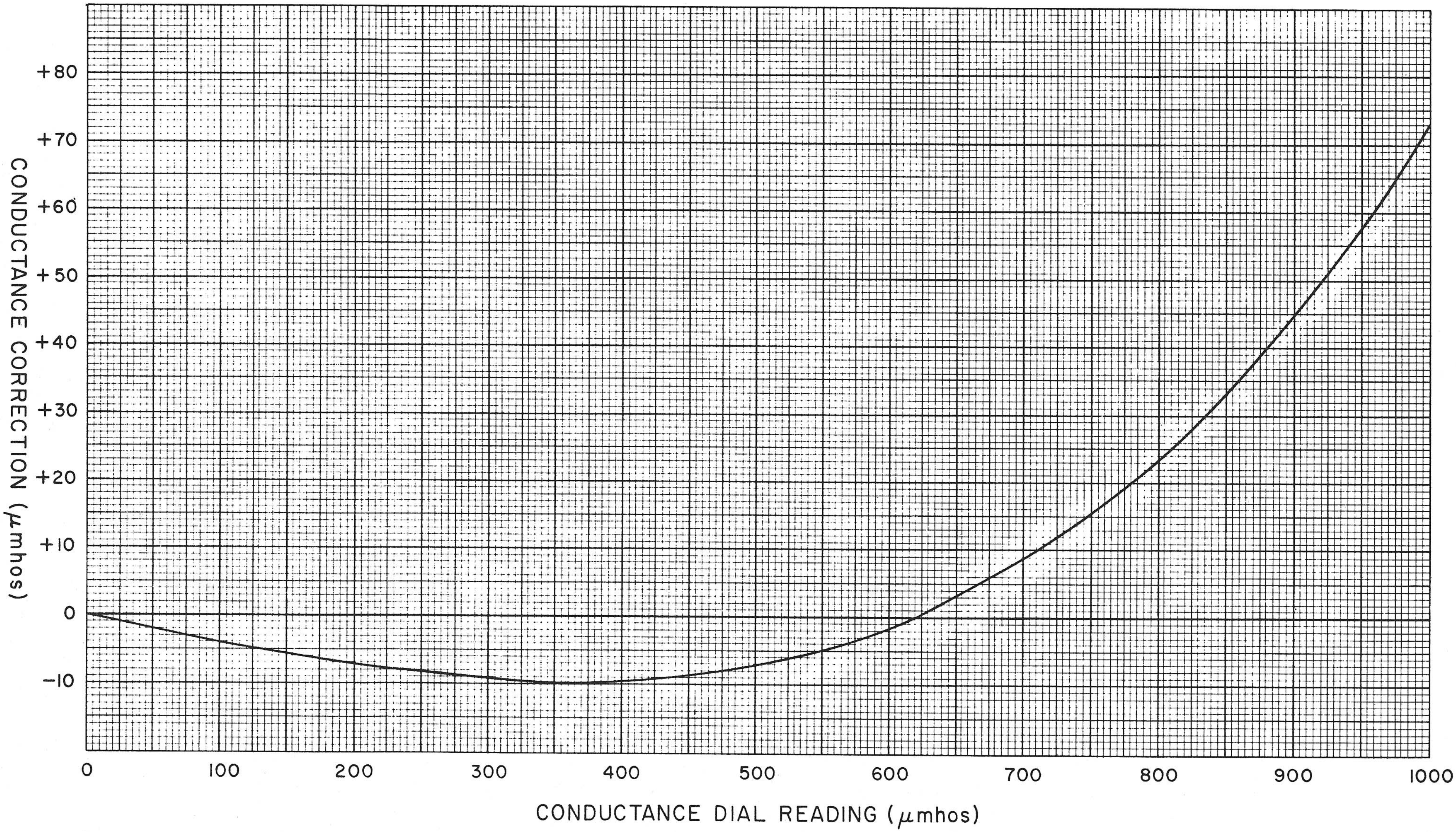
1. "Measuring Interelectrode Capacitance", C.H. Young Tele-Tech, Vol. 6, Feb., 1947, Pg. 68-70, 109.

2. "A Close Look at Connection Errors in Capacitance Measurements", John F. Hersh G.R. Experimenter, July 1959.

3. "Direct Capacity Measurements", G.A. Campbell Bell System Tech. Journal, July 1922, Vol. 1, Page 18.

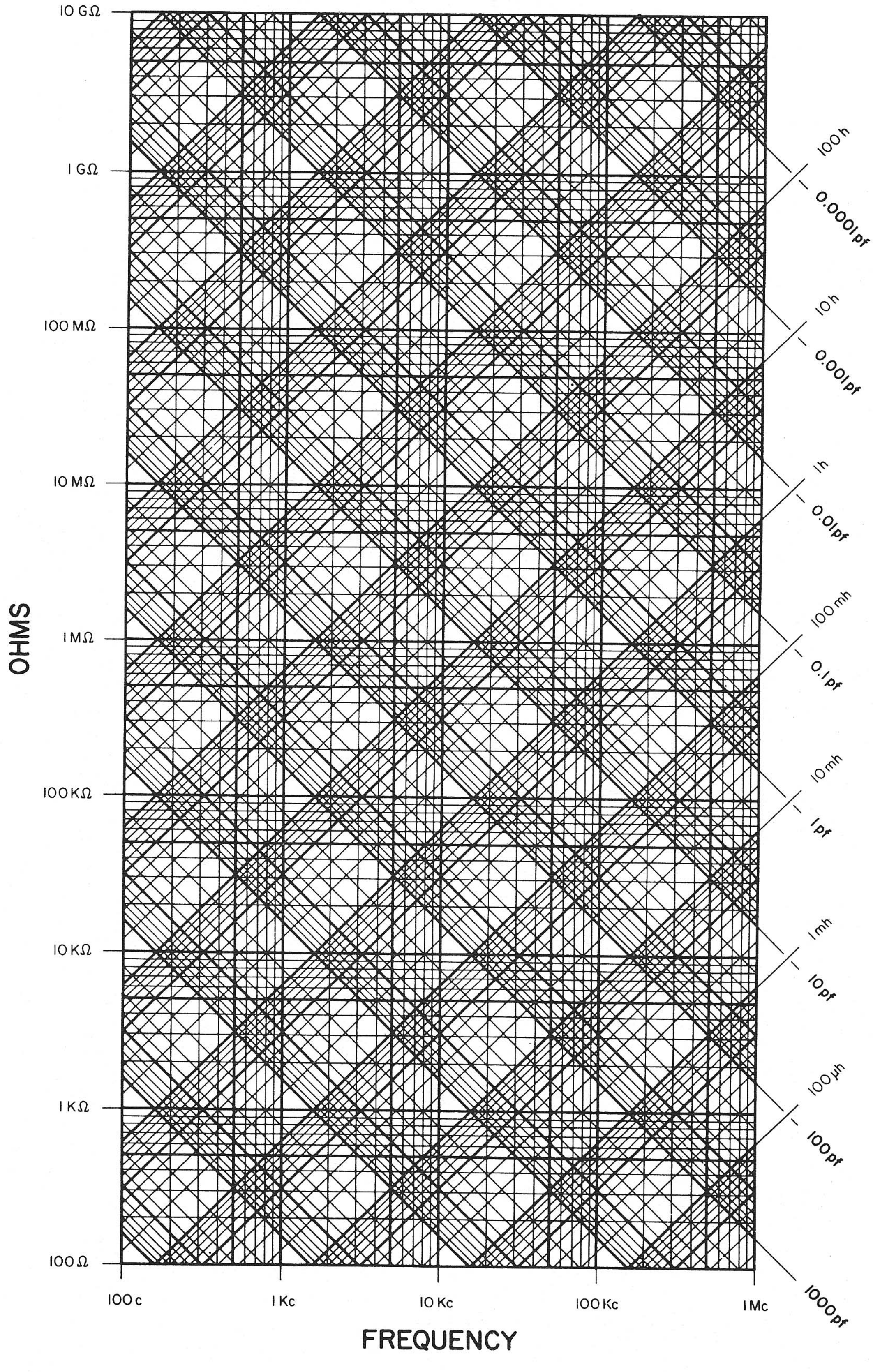
4. "The Precise Measurement of Small Capacitances", A.M. Thompson I.R.E. Transactions on Instrumentation, Dec. 1958, Vol. 1-7, #3 & 4, Pgs. 245-253.

5. "Electrical Measurements", F.K. Harris (Wiley) Direct Capacitance Bridge, Chapter 15, Pg. 727-730.



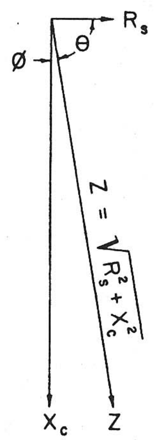
CORRECTION CURVE FOR DIVIDE G/MULTIPLY R X1 RANGE

CAPACITANCE BRIDGE REACTANCE CHART



CAPACITANCE/LOSS FORMULAS

TO OBTAIN ↓ / IN TERMS OF →	D	Q	G	R_s	R_p	Ø	θ
$D =$		$\frac{1}{Q}$	$\frac{G}{\omega C}$; $X_c G$	$\omega C R_s$; $\frac{R_s}{X_c}$	$\frac{1}{\omega C R_p}$; $\frac{X_c}{R_p}$	TAN Ø	COTAN θ
$Q =$	$\frac{1}{D}$		$\frac{\omega C}{G}$; $\frac{1}{X_c G}$	$\frac{1}{\omega C R_s}$; $\frac{X_c}{R_s}$	$\omega C R_p$; $\frac{R_p}{X_c}$	COTAN Ø	TAN θ
$G =$	$\omega C D$; $\frac{D}{X_c}$	$\frac{\omega C}{Q}$; $\frac{1}{Q X_c}$		$(\omega C)^2 R_s$; $\frac{R_s}{X_c^2}$	$\frac{1}{R_p}$		
$R_s =$	$\frac{D}{\omega C}$; $D X_c$	$\frac{1}{\omega C Q}$; $\frac{X_c}{Q}$	$\frac{G}{(\omega C)^2}$; $G X_c^2$		$\frac{1}{(\omega C)^2 R_p}$; $\frac{X_c^2}{R_p}$		
$R_p =$	$\frac{1}{\omega C D}$; $\frac{X_c}{D}$	$\frac{Q}{\omega C}$; $Q X_c$	$\frac{1}{G}$	$\frac{1}{(\omega C)^2 R_s}$; $\frac{X_c^2}{R_s}$			



The angle Ø in radians, by which the current fails to lead the voltage by 90°, is very nearly equal to the power factor for P.F.'s of 10% or less. It is also approximately equal to the dissipation factor, D, but at large angles of Ø, D departs more rapidly than P.F.

$$\text{P.F.} = \frac{R_s}{Z} = \frac{1}{\sqrt{1+Q^2}} = \cos\theta$$

$$\text{if } Q \geq 10, \quad \text{P.F} \approx \frac{1}{Q} = D$$

SECTION 11

TABLE OF REPLACEABLE PARTS

NOTE:

Components in the "Bridge" section have not been included, since in general their replacement must be followed by adjustments that require specialized equipment and techniques.

Reference		Description	BEC Part No.
		CAPACITORS	
C101	Electrolytic	20-20 μF /450 V Mallory FP-234	283,100
C102	Met. Paper	0.05 μF ±20% 200 V Aerovox P8292ZN	230,117
C213	Mylar	0.05 μF ±10% 400 V C-D PM4S5	234,002
C301	Sil. Mica	470 pF ±2% 500 V Arco DM19F471G	200,501
C302	Sil. Mica	10 pF ±5% 500 V Arco DM10C100J	200,022
C303	Sil. Mica	3300 pF ±2% 500 V Arco DM20E332G	201,164
C304	Met. Mylar	0.047 μF ±10% 400V Goodall X663FR	236,002
C305	Met. Mylar	0.047 μF ±10% 400V Goodall X663FR	236,002
C306	Met. Mylar	0.1 μF ±20% 400V Goodall X663FR	236,001
C307	Met. Mylar	0.047 μF ±10% 400V Goodall X663FR	236,002
C308	Met. Mylar	0.1 μF ±20% 400V Goodall X663FR	236,001
C401	Met. Paper	0.1 μF ±20% 200V Aerovox P8292ZN	230,136
C402	Met. Mylar	0.22 μF ±20% 100V Electron M1-224	236,005
C403	Met. Paper	0.05 μF ±20% 200V Aerovox P8292ZN	230,117
C404	Met. Paper	0.05 μF ±20% 200V Aerovox P8292ZN	230,117
C405	Mylar	0.01 μF ±20% 200V Goodall 620M10303	230,120
C406	Met. Mylar	0.22 μF ±20% 100V Electron M1-224	236,005

REFERENCE		DESCRIPTION					BEC PART NO.
C407	Met.Paper	0.05 µF	±20%	200V	Aerovox	P8292ZN	230,117
C408	Met.Paper	0.05 µF	±20%	200V	Aerovox	P8292ZN	230,117
C409	Sil.Mica	100 pF	± 5%	500V	Arco	DM15F101J	200,001
C410	Met.Mylar	0.047	±10%	400V	Goodall	X663FR	236,002
C411	Met.Mylar	0.047	±10%	400V	Goodall	X663FR	236,002

RESISTORS

R101	Comp.	1 M	±20%	1W	AB	Type GB	302,128
R102	Wire Wound	5 K	± 5%	10W	Ward Leonard 10F5000		312,101
R214	Var.Comp.Log	50 K	±10%	2W	AB	Type J	311,129
R215	Comp.	15 K	± 5%	2W	AB	Type HB	304,115
R301	Comp.	330 K	±10%	1/2W	AB	Type EB	301,028
R302	Comp.	4.7 K	±10%	1/2W	AB	Type EB	301,017
R303	Comp.	330 Ω	± 5%	1/2W	AB	Type EB	301,075
R304	Comp.	7.5 Ω	± 5%	1/2W	AB	Type EB	301,500
R305	Comp.	27 K	± 5%	1W	AB	Type GB	302,135
R306	Comp.	2.2 K	± 5%	1/2W	AB	Type EB	301,095
R307	Var.Comp.Linear	50K	±10%	2W	AB	Type J	311,125
R308	Comp.	47 K	± 5%	1W	AB	Type GB	302,141
R401	Comp.	470 Ω	± 5%	1/2W	AB	Type EB	301,079
R402	Var.Comp.Linear	10K	±10%	2W	AB	Type J	311,144
R403	Comp.	10 K	± 5%	1/2W	AB	Type EB	301,111
R404	Comp.	470 K	±10%	1/2W	AB	Type EB	301,029
R405	Comp.	2.2 K	± 5%	1/2W	AB	Type EB	301,095
R406	Comp.	470 K	±10%	1/2W	AB	Type EB	301,029
R407	Comp.	470 Ω	± 5%	1/2W	AB	Type EB	301,079
R408	Comp.	10 K	± 5%	1/2W	AB	Type EB	301,111
R409	Comp.	470 K	±10%	1/2W	AB	Type EB	301,029
R410	Comp.	68 K	±10%	1/2W	AB	Type EB	301,131

OTHER COMPONENTS

D101	Diode,Zener	6.8 V	±10%	3W	Unitrode UZ806	530,041
D401	Diode	1N58AS			Sylvania	530,021
D402	Diode,Zener	5.4 V	± 5%	1/2W	Hoffman HR5.4	530,020
D403	Diode,Zener	5.4 V	± 5%	1/2W	Hoffman HR5.4	530,020
F101	Fuse	0.5 Amp			BUSS AGC-.5	545,502
J205	Jack,Phone	3 circuit			Switchcraft 13B	479,118
J403	Jack,Phone	2 circuit			Switchcraft 12A	479,113
L101	Choke,Power	7hy 500		50 mA	Stancor C-1707	440,001
L301	Choke,RF	2.5 mh		200 mA		400,014
L302	Choke,RF	2.5 mh		200 mA		400,014
L303	Choke,RF	55 µh		300 mA		400,015
L304	Choke,RF	55 µh		300 mA		400,015
MI	Meter	Special Scale 200 µA			Ammon AM-2	554,151

REFERENCE	DESCRIPTION		BEC PART NO.
S101 Switch, Toggle	SPST	Carling 110-63	465,105
S205 Switch, Rotary	2P4T	Oak Type J, Special	466,171
S301 (a,b) Switch,Rotary	2P4T	Oak Type A, Special	466,156
S301 (c,d) Switch,Rotary	2P4T	Oak Type A, Special	466,157
S401 Switch, Slide	DPDT	Oak Type 78	465,112
T101 Transformer, Power		Stancor Special	446,007
T301 Transformer, Osc		BEC Special	074,306
T401 Transformer, IF		Summit Coil Special	410,012
T402 Transformer, IF		Summit Coil Special	410,013
T403 Transformer, IF		BEC Special	075,317
V101 Tube	6X4		526,6X4
V102 Tube	OA2		526,OA2
V301 Tube	6C4		526,6C4
V401 Tube	6AU6		526,6AU6
V402 Tube	6AU6		526,6AU6

Warranty

Boonton Electronics Corporation warrants its products to the original Purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of one year from date of shipment, provided they are used under normal operating conditions. This warranty does not apply to vacuum tubes that have given normal service, to sealed assemblies which have been opened, or to any item which has been repaired or altered without our authorization.

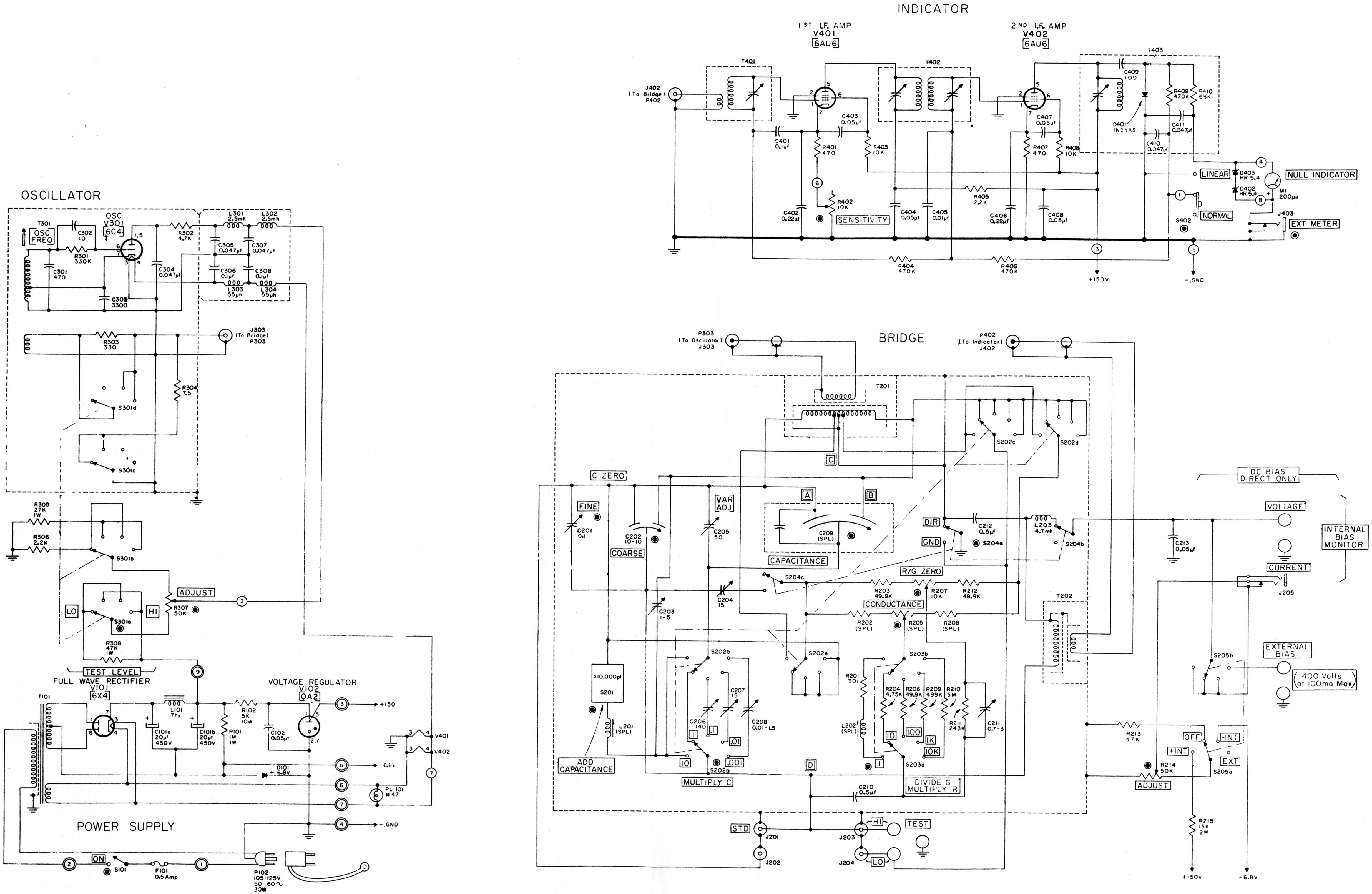
We will repair or, at our option, replace at no charge any of our products which are found to be defective under the terms of this warranty.

SHIPPING INSTRUCTIONS

If it becomes necessary to ship the instrument, the following steps should be followed:

a. Wrap the instrument with heavy wrapping paper and seal the seams with gummed tape, Place in fibreboard carton large enough to permit three inches of soft packing material between instrument and sides of box.

b. Alternatively Boonton Electronics will provide an appropriate shipping container and packing materials at nominal cost. These may be obtained by writing to the Sales Department, Boonton Electronics Corporation, Route 287 at Smith Rd., Parsippany, N. J. 07054.



NOTES:

CAPACITANCE IN pf UNLESS OTHERWISE NOTED.

RESISTANCE IN OHMS (K=1,000)

LAST NUMBERS USED
C102, L101, R102
C213, J205, L202, R215
C308, J303, L304, R308
C411, D402, J403, R410

PANEL GROUND

PANEL CONTROL

PIN NUMBERS ON P101 & J101

PIN NUMBERS ON P401 & J401

INTERNAL MARKING

EXTERNAL MARKING

SCHEMATIC DIAGRAM

CAPACITANCE BRIDGE
MODEL 74D
(TEST FREQ: 100KC)

BOONTON ELECTRONICS CORPORATION

830147 A & B