NAVMC ELECT 2032 *(Non-Registered)*

MANUSCRIPT

TECHNICAL MANUAL

for

BRIDGE CAPACITANCE INDUCTANCE-RESISTANCE BRIDGE ZM-11/U

JAMES S. SPIVEY, INC.
WASHINGTON, D. C.

U.S. MARINE CORPS

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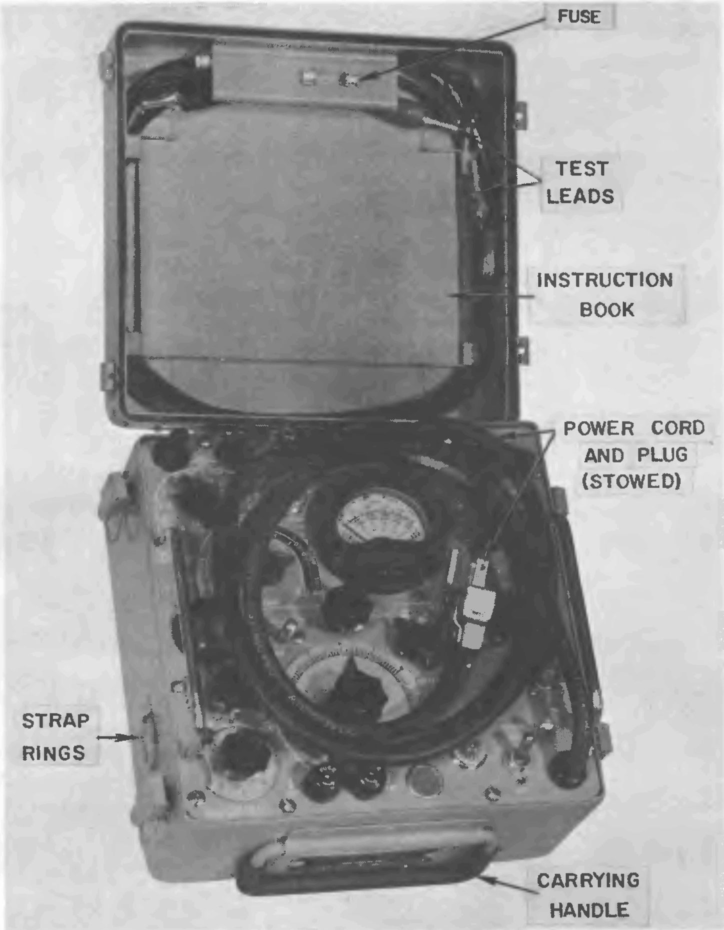


Figure 1-1.. Capacitance – Inductance – Resistance Bridge ZM-11/U

SECTION 1
GENERAL INFORMATION

1-1. EQUIPMENT ILLUSTRATION.

Figure 1-1 shows the complete Capacitance-Inductance-Resistance Bridge ZM-11/U with the instrument-case cover removed. The power cable is stowed on panel posts and test cords and technical manual are stowed in the cover.

1-2. FUNCTIONAL DESCRIPTION.

The ZM-11/U is used to measure capacitance, inductance, resistance, iron-cored transformer turns ratio, dissipation factor of inductors at 1000 cycles-per-second; and insulation resistance of capacitors and other electronic parts as well as leakage of electrolytic capacitors at direct current. The general condition of many capacitors may be determined without removal from their circuit using a test frequency of about 10.75 megacycles.

Although it is designed primarily for maintenance use, its over-all accuracy is about one-half that usually realized by laboratory instruments (see Table 1-1). It is completely self-contained except for a source of a-c line power.

1-3. FACTORY OR FIELD CHANGES.

There are no factory or field changes applicable to the ZM-11/U.

TABLE 1-1. RANGE AND ACCURACY

MEASUREMENT	RANGE		MAXIMUM ERROR REFERRED TO READING
(Test Current)	mmf: micromicrofarad MF: microfarad MH: millihenry H: henry meg: megohm	NORMAL CONDITIONS Temp. 24°C. Pressure 14.9 PSI. Relative humidity 70%	Temperature −54° to + 65°C Humid. 0–95% Line 115 volts ± 10% 50 to 1000 cycles.
Capacitance (1 kc)	10 mmf to 1 MF 1 MF to 10 MF 10 MF to 1100 MF	2% + 1 scale div. 3% + 1 scale div. 5% + 1 scale div.	4% + 1 scale div. 6% + 1 scale div. 6% + 1 scale div.
Inductance (1 kc)	0.1 MH to 1 H 1 H to 10 H 10 H to 110 H	2% + 1 scale div. 5% + 1 scale div. 10% + 1 scale div.	6% + 1 scale div. 10% + 1 scale div. 15% + 1 scale div.
Resistance (1 kc)	1 ohm to 11 meg	2% + 1 scale div.	5% + 1 scale div.
Insulation Resistance Test (d–c)	200 to 5000 meg 5000 to 1000 meg	3% + 100 megohms 3% + 200 megohms	20% + 100 megohms 20% + 250 megohms
Transformer Turn Ratio	0.01 to 110 (K=1)	2% + 1 scale div.	5% + 1 scale div.
D–C Leakage current of capacitors (d–c)	0 to 1, 5, & 25 milliamperes	3% of full scale	5% of full scale
D dissipation factor (1 kc)	0–.06(10mmf–.1MF) 0–.6(.1MF–1100MF)	20% + .02	30% + .03
Q storage factor (1 kc)	0.5 to 20	20%	30%
D–C applied to electrolytic capacitors	0 to 500 volts	5% of full scale	8% of full scale

1-4. QUICK REFERENCE DATA.

a. Range and accuracy. See Table 1-1.

b. Input power requirements: for normal bridge operation, 20 watts, 105 volts ± 10%, 50 to 1000 cycles, single phase; with 400 volts, 4 ma output from d-c supply, 36 watts.

TABLE 1-2. EQUIPMENT SUPPLIED

QUANTITY PER EQUIPMENT	NAME OF UNIT	OVERALL DIMENSIONS			VOLUME	WEIGHT
		HEIGHT	WIDTH	DEPTH		
1	Capacitance – Inductance – Resistance Bridge ZM-11/U	5-7/8	9-1/2	9	.29	15
1	Cable Assembly, R-F (W104)	1/2	1/2	48	*	*
1	Test Lead, Red (W101)	1/2	1/2	36	*	*
1	Test Lead, Black (W-102)	1/2	1/2	36	*	*
2	Technical Manual for Bridge ZM-11/U NAVMC ELECT 2032	6-7/8	4-9/16	1/2	*	*

Dimensions are in inches, volume in cubic feet and weight in pounds.

*Normalled stowed in instrument case cover and included in basic weight and volume.

1-5. EQUIPMENT LISTS.

a. EQUIPMENT SUPPLIED.-All equipment supplied is listed in Table 1-2.

b. SHIPPING DATA.-When packed for shipment, the complete equipment is 0.7 cubic feet in volume and weighs 23 pounds.

c. ELECTRON TUBE COMPLEMENT.-Table 1-3 is the electron tube complement listing for the ZM-11/U equipment.

TABLE 1-3. ELECTRON TUBE COMPLEMENT

CIRCUIT APPLICATION	NUMBER OF TUBES OF TYPE INDICATED							
	6E5	6J6	6AV6	6AG5	5626/ 6AL5W	6005/ 6AQ5W	6X4WA	Total
Electron Ray Indicator for bridge balance	1							1
Power Amplifier		1						1
Bridge Oscillator			1					1
Electron tube voltmeter			1					1
Amplifier, 1 kc				1				1
RF Rectifier					1			1
RF Power Oscillator						1		1
Line Power Rectifier							1	1
Total No. of ea. Type	1	1	2	1	1	1	1	8

SECTION 2
INSTALLATION

2-1. UNPACKING AND HANDLING.

Capacitance-Inductance-Resistance Bridge ZM-11/U may be received in an export or domestic packing case. When a new equipment is received, unpack and move to the location where it is to be installed. No special unpacking procedure is required so long as care is exercised to prevent damage to the unit. Inspect the equipment for completeness by comparison with the packing list, and for evidence of damage.

2-2. INSTALLATION.

Since the ZM-11/U unit is a self-contained portable instrument, the only installation precautions are to see that a suitable power source is conveniently available and that the bridge (ZM-11/U) and items to be tested are placed on a substantial support, preferably a work bench. Release and remove the cover of the ZM-11/U by means of the four snap catches. Uncoil the power cable from the panel posts and turn the POWER switch to OFF.

Check the power receptacle, making certain that the supply voltage and frequency are within the ranges stated on the nameplate, then connect the power cable to the power receptacle. It is not necessary to use an external ground wire for the ZM-11/U because it is automatically grounded when the power cable is connected.

Do not allow power or other cables to lay across the face of the bridge (ZM-11/U) nor in the vicinity of the binding posts.

2-3. INITIAL ADJUSTMENTS.

Turn the VOLTAGE CONTROL and OSCILLATOR knobs to 0 and OFF respectively. The ZM-11/U is now ready for operation.

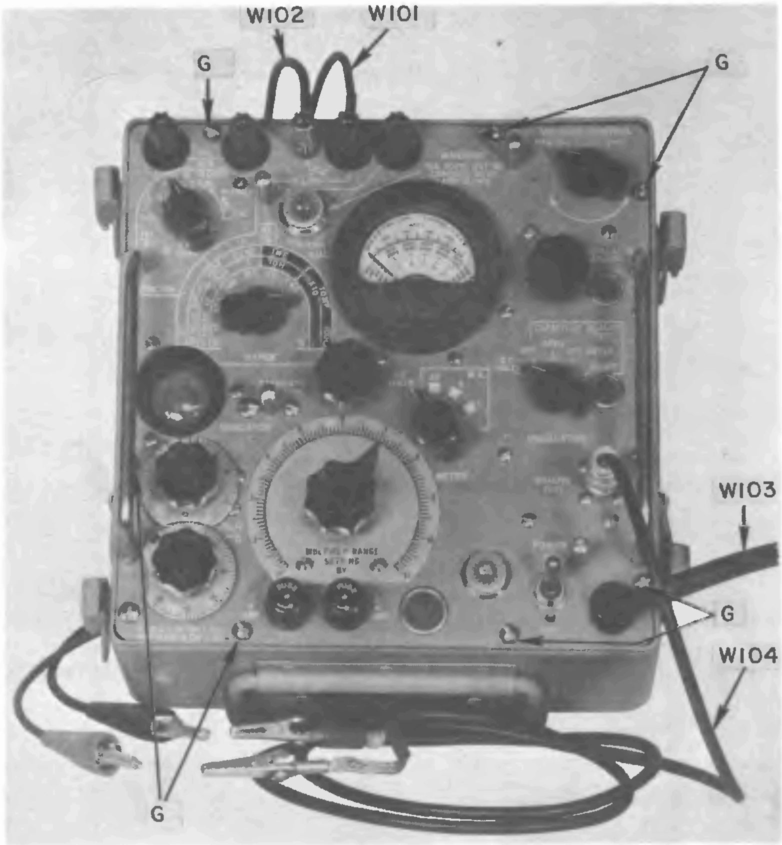


Figure 3-1. ZM-11/U Panel Layout.

SECTION 3
OPERATOR'S SECTION

3-1. FUNCTIONAL OPERATION.

Capacitance-Inductance-Resistance Bridge ZM-11/U measures resistance, capacitance, inductance and transformer turns ratio by means of bridge circuits. Incidental to these, the dissipation or storage factor of capacitors and inductances is balanced and read on suitable dials and this result may be applied to circuit problems with due regard for the test frequency which is 1000 cycles. Electrolytic capacitors may be polarized and leakage current measured while their capacitance and dissipation-factor measurements are being made.

Additionally, a quality test for ascertaining whether a capacitor is open or shorted even though a resistance or inductance remains connected across it at the time of measurement is included, and the insulation resistance of capacitors and other parts may be determined.

The overall accuracies and ranges of the ZM-11/U are given in Table 1-1.

3-2. OPERATING PROCEDURES.

a. INTRODUCTION. - The tests and measurements of which the ZM-11/U is capable are numerous and of wide range so it is well to become as familiar as possible with the panel and control layout as early as possible. Figure 3-1 shows a view of the panel and general appearance as set up for operation. The panel designations are necessarily abbreviated in many instances, consistent with the limited panel area available. These are now amplified with brief statements on what the various controls are for.

b. DESCRIPTION OF CONTROLS.

FUNCTION SWITCH - upper left, positions named clockwise.

CAP. QUAL.	Capacitor Quality. For general condition, short or open. NOT for capacitance measurement.
R	Resistance. Bridge measurement at 1000 cycles.
$\frac{N_1}{N_2}$	Turns Ratio. Bridge measurement. Refers to number of turns of respective windings of transformer.
L(D)	Inductance. Bridge measurement. Dissipation factor balanced and read on D dial at lower left.
L(Q)	Inductance. Bridge measurement. Storage factor of coil balanced and read on Q dial, just above D dial.
C	Capacitance. Bridge measurement. Losses are balanced and read on D dial.
C CHG.	Capacitance, Charge. Same as C function but with d-c polarization applied to unknown capacitor.
INS. RES.	5000 M(egohms) 10000 M(egohms) CAL (ibrate) } Insulation Resistance test with direct current. Two ranges available as named.

RANGE SWITCH - upper left. Selects the bridge ranges.

N_1/N_2 ring — Read when making Turns Ratio measurement. Ratios .01, 1, 1 or 10 to be multiplied by the setting of the MULTIPLY RANGE SETTINGS BY dial.

C

10 mmf (micromicrofarads)
100 mmf
1000 mmf
.01 MF (microfarads)
.1 MF
1 MF Note reserve color
10 MF sector these ranges.
100 MF D x 10

L ring

100 MH (millihenries)
10 MH
1 MH
.1 MH Note reverse color
10 H (henries) sector these ranges
1 H D x 10

R ring

1 (ohm)
10
100
1 KΩ (kilohm or 1000's of ohms)
10 KΩ
.1 MΩ (megohm or 1,000,000's of ohms)
1 MΩ

CAP. QUAL. Shows position of RANGE switch for capacitance quality tests.

Q DIAL - lower left

0-20 Storage factor of coil. This is infinity to .05 in dissipation, hence this dial overlaps:-

D Dial - lower left

0 - .06 Dissipation factor. Reads 0 - 0.6 when used on the D x 10 ranges of the L(D) and C functions.

MULTIPLY RANGE SETTING BY - main lower dial.

1.0-11.0 This is an interpolating control covering all increments between settings of the RANGE switch.

METER SWITCH - just below panel meter.

DC VOLTS - Range 0-500. Spring returns switch to this position.

25
5 MA
1
(milliampere - .001 ampere) Selects suitable range for reading leakage current.

OSCILLATOR SWITCH - right hand center

DC VOLTS - Connects r-f type power supply so that d-c voltage is available for capacitor charging and insulation resistance tests.

OFF Disconnects next above.

OPEN
SET METER
SHORT
Three positions for the CAPACITOR QUALITY TESTS.

OSCILLATOR ADJUST - to the right of the panel meter. Adjusts the 10.75 mc oscillator to exact quarter wave relationship with the line for making the Open Test - Capacitor Quality.

VOLTAGE CONTROL - upper right hand.

O - Max Adjusts the output from the d-c power supply. Used in connection with the Insulation Test, Capacitor Quality Tests and polarizing electrolytic capacitors.

CALIBRATE-INS. Test - lower left of panel meter.

Calibrates Insulation Test. Controls the initial indicator pattern prior to making the insulation test.

POWER, ON-OFF - lower right

Controls line power to all internal circuits. Pilot lamp at left indicates line "ON".

CAUTION

The ZM-11/U has its own self-contained sources of power for all tests described in this section. Before connecting any components in an electronic unit to the ZM-11/U, make certain that all sources of power to the former, both line and battery, are disconnected. Discharge all capacitors before connecting.

WARNING

Do not connect coaxial cable (W – 104) to QUALITY TEST receptacle nor turn OSCILLATOR switch to any CAPICATOR QUALITY TESTS position during periods of radio silence because 10.75 mc r – f signals may be radiated.

High voltages may be present on the RED binding posts when warning pilot lamp is lighted. Use insulated clips. Discharge capacitors immediately after test. Turn VOLTAGE CONTROL knob to 0 and OSCILLATOR switch to OFF immediately after use.

c. STARTING THE EQUIPMENT. - Turn the POWER switch to ON. The pilot lamp to its left should light and after a minute warm-up the greenish pattern should appear in the indicator tube.

d. CAPACITOR QUALITY TESTS.

(1) These tests determine the condition of a capacitor, in a general way, without removing it from its chassis or circuit. The tests are included for quick checks of many capacitors without disconnecting each one for testing. When the quality test indicates any abnormality, one end of the capacitor should be disconnected and the capacitor checked in the usual manner.

To start the test, remove the coaxial cable (W-104) from the cover and plug it into the QUALITY TEST receptacle at the right.

(2) OPEN test. Let the cable lay loosely to one side and make certain the clips are not touching each other. Turn the

FUNCTION switch to CAP. QUAL.
RANGE switch to CAP. QUAL.
D dial to 0.
VOLTAGE CONTROL to 0.
OSCILLATOR Switch to SET METER.

Advance the VOLTAGE CONTROL until the meter reads full scale and

Turn OSCILLATOR switch to OPEN.
Set OSCILLATOR ADJUST until the meter reads full scale.

The meter is calibrated and the oscillator is adjusted to the quarter wave frequency of the transmission line. Connect the clips to the capacitor to be tested, connecting the ground lead of W104 to ground lead or lead nearest ground of the capacitor being tested. If the meter continues to read full scale, the capacitor is open unless:-

(1) It is shunted by a resistor of less than 60 ohms.
(2) It is shunted by an inductor which resonates it to a frequency higher than 9 megacycles.
(3) It is less than 45 micromicrofarads.
(4) It is small and shunted by a resistor less than the value shown in Table 3-1.

If the meter reads downscale, that is, at other than full scale, the capacitor is either all right or short-circuited. The actual meter reading has no importance.

Applicability of (1), (3) or (4) is determined by inspection of the circuit constants of the device in which the capacitor is installed. Likewise, applicability of (2) may be determined from the tuning ranges of the device or from the product of the capacitor under test and the value of the shunting inductance. In general, if the product of the capacitor (in mmf) and the inductance (in microhenries) is less than 300, the inductor should be disconnected before testing the capacitor.

(3) Short Test. When the OPEN test indicates that the capacitor is short-circuited or not open, it is necessary to make the SHORT test to differentiate. Turn the OSCILLATOR switch

to SHORT and observe the meter reading. If it returns to full scale, as previously calibrated, the capacitor is short circuited. If it reads below full scale, the capacitor is not short circuited. This indication may be false if:-

(1) The capacitor is shunted by a resistance of less than 5 ohms.
(2) The capacitor has a nominal value greater than 50 microfarads.

This test is included for quick checks of many capacitors without disconnecting each one for testing. When the quality test indicates an adnormality, one end of the capacitor should be disconnected and the capacitor checked in the usual manner.

TABLE 3-1. MINIMUM SIZE SHUNTING RESISTOR BELOW WHICH OPEN QUALITY TEST IS VOID.

NOMINAL SIZE OF CAPACITOR MMF	MINIMUM SIZE OF RESISTOR OHMS	NOMINAL SIZE OF CAPACITOR MMF	MINIMUM SIZE OF RESISTOR OHMS
170	100	75	1000
140	200	60	2000
120	300	50	5000
110	400	47	10000
100	500	45	Infinite

Applicability of (1) or (2) can usually be determined from the circuit diagram and data of the device in which the capacitor is a part.

e. RESISTANCE MEASUREMENTS. - Range 1 ohm to 11.0 megohms.

(1) Turn the FUNCTION switch to R. Connect the unknown to the R posts, second and fourth from the left. Select a suitable

RANGE setting, reading from the R ring. Turn the MULTIPLY BY dial until the INDICATOR pattern shows the maximum possible opening, indicating balance. If this comes at either extreme of the dial, take the next higher or lower setting of the RANGE switch and rebalance. Multiply the RANGE setting by the MULTIPLY BY DIAL setting to get the resistance.

(2) The resistance as determined by the bridge circuit is the 1000 cycle value. Some difficulty may be had in obtaining a sharp balance with inductive resistors. Such units may be shunted by a variable capacitance during measurement, this being varied until a sharp balance point is obtained. The resistance value read from the bridge will not be affected by this reactance neutralization.

The resistance of highly inductive units may be better determined by measuring them as inductances and computing the 1000 cycle resistance from the Q or D determination thereof. The way to do this is fully explained in paragraph 3g.

(3) When non-inductive resistors of 100,000 ohms and higher are connected to the bridge with the test leads, the balance may be impaired by the capacitance between the leads. Connection of the resistor directly to the binding posts is recommended for the higher values.

f. TRANSFORMER TURNS RATIO MEASUREMENTS. - Range 0.01 to 110.

(1) Turn the FUNCTION switch to N_1/N_2. Connect one winding to the N_1 posts, second and fourth from left, and the other winding to the N_2 posts, second and fifth. At each of the four RANGE switch positions, N_1/N_2, run the MULTIPLY BY dial over its range while watching the INDICATOR pattern. If no balance is obtained, (balance is indicated by maximum opening of the eye tube) reverse the binding post connections to one winding and repeat. If balance is now had but is fuzzy or broad

reverse the connections to both windings to eliminate the effect of interwinding capacitance and rebalance. The turns ratio is the setting of the RANGE switch, read in the N1/N2 ring, times the setting of the MULTIPLY BY dial.

(2) Effect of Coupling Coefficient. The theory of the turns ratio measurement shows that the turns ratio is measured only when the transformer has complete magnetic coupling between the two windings, that is, a coupling coefficient of 1.0. The possible error, otherwise, is negligible for a ratio of 1.0 but increases with the ratio. To get a working idea of this, see Table 3-2.

The stated errors are in the direction that makes the measured ratio appear higher than actual.

Well designed two-winding transformers will usually have sufficiently close coupling so the errors will be negligible except for the highest ratios. The turns ratio test is useless on intermediate and radio frequency transformers because of the very slight coupling of such coils. For the same reason, their turns ratio is not usually of interest.

TABLE 3-2. ERROR IN TURNS RATIO DUE TO IMPERFECT COUPLING.

RATIO	1.0	2.0	5.0	10.0	100
COUPLING COEF. K	PERCENT ERROR	PERCENT ERROR	PERCENT ERROR	PERCENT ERROR	PERCENT ERROR
1.0	0.0	0.0	0.0	0.0	0.0
.98	0.0	0.8	1.3	1.8	2.0
.95	0.0	1.8	3.5	4.2	5.0
.90	0.0	3.5	8.2	9.0	10.8

g. INDUCTANCE MEASUREMENTS. - Range 100 microhenries to 110 henry.

(1) Connect the unknown inductor to the L posts, second and fourth from left. Turn the FUNCTION switch to the L(D) or L(Q) position depending on the probable loss factor of the coil being tested. Usually coils with powdered-iron cores designed for operation in the audio range will fall within the loss range of L(D) while others, such as RF and IF coils will fall in the loss range of L(Q). If unable to guess which, attempt a balance on the L(Q) setting. Select a probable RANGE setting, L ring, and attempt a balance by rotating the MULTIPLY BY dial. If any indication of balance is had, try to perfect it by simultaneous adjustment of the Q dial. If balance is approached at either end of the MULTIPLIER dial, try the next higher or lower RANGE setting and perfect the balance.

If a partial balance point is reached on the MULTIPLY BY dial but cannot be perfected because of lack of range on the Q dial, the coil probably has a Q factor greater than 20. Shift the FUNCTION switch setting to L(D) and perfect the balance using the D dial. Note the mechanical interlock between the D and Q dials which makes it necessary to return either one to its initial position before the other can be turned.

(2) Read the RANGE setting and multiply it by the setting of the MULTIPLY BY dial. The product is the inductance of the unknown. Note the setting of the D or Q dial at which balance was had. If inductance balance was had in one of the reverse color ranges, 10 or 1 henry, the D dial setting is to be multiplied by 10. If the apparent value of D, as measured on the L (D) function is in excess of 0.05, the balance point must have been missed on the L(Q) function or should be repeated there for best accuracy in the inductance determination.

(3) If the equivalent series resistance at 1000 cycles of the inductance is desired, it may be computed from

$$R = 6280L/Q$$

or from

$$R = 6280LD$$

In either computation, don't forget to point off three places if L is in millihenries, six if in microhenries.

NOTE

Where high accuracy of results is required, readings of the Q dial should be corrected in accordance with the correction curve found in the cover of the ZM-11 /U under the instruction manual.

(4) If test leads have been used for connection, eliminate or separate them as much as possible for minimum mutual capacitance where highest accuracy is needed. At 1000 cycles, sufficient capacitance may be present from bunched leads to cause the inductance to measure incorrectly.

h. CAPACITANCE MEASUREMENTS. - Range 10 micromicrofarads to 1100 microfarads.

(1) Connect the unknown capacitor to the C posts, third and fourth from left. Turn the FUNCTION switch to C. Select a suitable RANGE setting, C ring. Attempt a balance with the MULTIPLY BY dial, perfecting it by simultaneous adjustment of the D dial. With complete balance, read the capacitance as the product of the RANGE setting and the MULTIPLY BY dial. Read the D dial for the loss factor. Multiply the D dial reading by ten when using any RANGE in the reverse color sector.

(2) If required, the equivalent series resistance of the capacitor at 1000 cycles may be computed from

$$R = 159 \frac{D}{Cm}$$

where Cm is the measured value of the capacitor in microfarads. If the capacitor is in micromicrofarads, multiply by 1,000,000.

(3) When very small capacitors are measured, readings of D somewhat different than the actual dissipation of the capacitor will be obtained. This is due to the losses in the binding post and switch deck insulation as well as other inevitable solid dielectric material in parallel with the capacitor while it is being measured. When the true value of dissipation is required it may be computed from the graph in Figure 3-2. For values of C higher than 100 uuf, the correction is negligible for practical purposes.

(4) Electrolytic Capacitors. Observe the polarity marks adjacent to the C binding posts when making connections to the unknown. Turn the VOLTAGE CONTROL to 0. After this, turn the FUNCTION switch to C.CHG. and the OSCILLATOR switch to D. C. VOLTS. The pilot adjacent to the meter will light indicating that the charging power supply is connected. Advance the VOLTAGE CONTROL, slowly until the meter reads capacitor voltage rating. Failure of the meter to respond means a shorted or excessively leaky capacitor. One which has not seen service for some time will form or polarize very slowly. Some will perhaps require current that is in excess of the power output from the ZM-11/U power supply which is capable of:-

10 milliamperes up to 100 volts
5 milliamperes up to 300 volts
3.5 milliamperes up to 450 volts

When the voltmeter reading is stable at the rated capacitor voltage or lower if desired, proceed with measurement. Capacitance and dissipation are determined by balancing the bridge in the same manner directed for the C function. Electrolytic units often show somewhat different characteristics when polarized.

WARNING

High voltages are employed in the above test. Always use the insulated clips. Discharge capacitors immediately after used. Turn the voltage control to 0 and OSCILLATOR switch to OFF immediately after use.

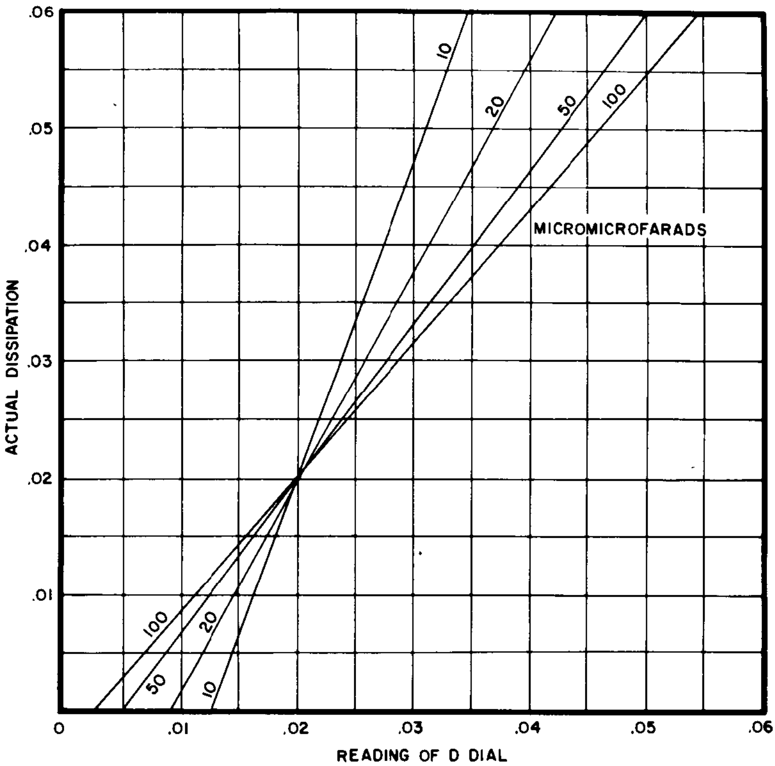


Figure 3-2. Correction Curve for D When Measuring Small Capacitors

(5) Direct Current Leakage. While the electrolytic capacitor is polarized as above, its direct current leakage may be determined by turning the METER switch to the 25 MA (milliampere) position. If the indicated current is less than 5MA, turn to the 5MA range and similarly to the 1 MA range in order to read well upscale on the meter.

Do not attempt to read the leakage current until complete polarization is indicated by a stable voltage reading. Failure to observe this may result in damage to the meter.

i. INSULATION RESISTANCE TESTS. - Range 200 to 10,000 megohms at d-c.

(1) Connect the sample to the INS. RES. posts, first and second from the left.

Turn FUNCTION switch to CALIBRATE

Turn OSCILLATOR switch to D. C. Volts.

Advance VOLTAGE CONTROL until meter reads 500 volts.

Turn CALIBRATE INS. TEST until INDICATOR pattern just closes.

Turn FUNCTION switch to 5000 M(egohms) or 10000 M (egohms)

If the INDICATION pattern closes permanently, the resistance of the sample is in excess of the full range selected. If the pattern opens, reduce the applied voltage (VOLTAGE CONTROL) until the pattern is just closed, the same as employed in calibration. Read the insulation resistance from the meter scale.

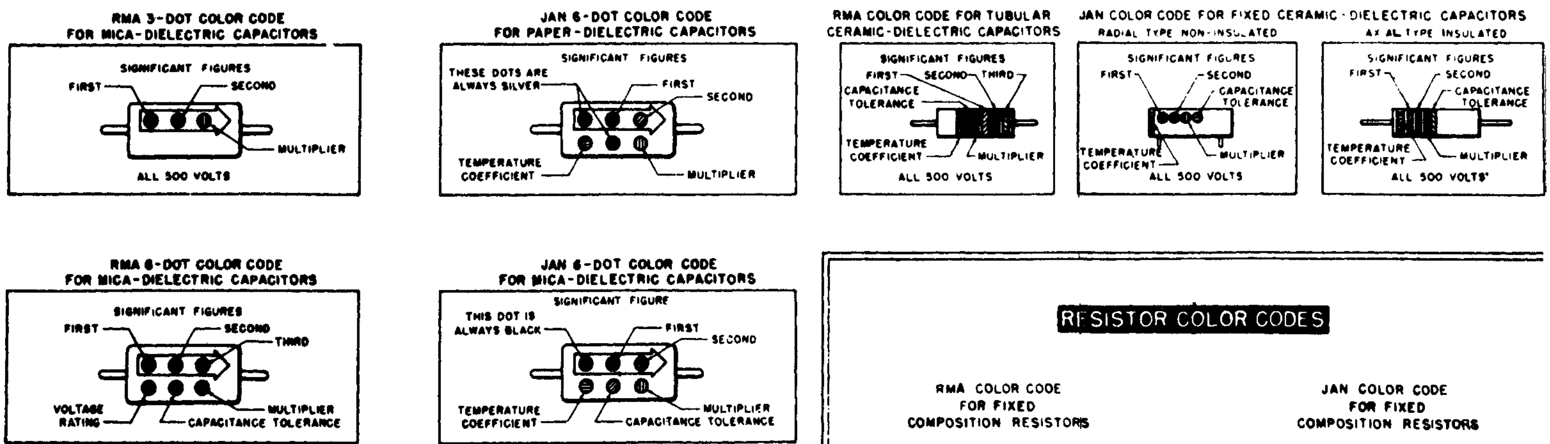
(2) It should be noted that the sample, if a capacitor, must charge through a very large resistance. If the capacitor is large this may take a matter of minutes. This delay may be a nuis-

ance, particularly if the line voltage fluctuates and further delay is required for the capacitor to assume its new charge. The test will be speeded if one of the test leads is connected to the GND binding post and its tip tapped on the left hand post while making the final adjustment of the INDICATOR pattern. This provides a low resistance charging path for the large capacitor.

3-3. COLOR CODE CHART.

Figure 3-3 gives the color codes for the various parts that can be measured with the ZM-11/U.

CAPACITOR COLOR CODES



RMA: RADIO MANUFACTURERS ASSOCIATION
JAN: JOINT ARMY-NAVY

VALUE IN MICROMICROFARADS | VALUE IN OHMS

CAPACITORS							RESISTORS	
VOLTAGE RATING	TEMPERATURE COEFFICIENT	MULTIPLIER: RMA MICA AND CERAMIC-DIELECTRIC	MULTIPLIER: JAN MICA AND PAPER-DIELECTRIC	MULTIPLIER: JAN CERAMIC DIELECTRIC	SIGNIFICANT FIGURE	COLOR	TOLERANCE	MULTIPLIER
	A	1	1	1	0	BLACK		1
100	B	10	10	10	1	BROWN		10
200	C	100	100	100	2	RED		100
300	D	1,000	1,000	1,000	3	ORANGE		1,000
400	E	10,000			4	YELLOW		10,000
500	F	100,000			5	GREEN		100,000
600	G	1,000,000			6	BLUE		1,000,000
700		10,000,000			7	VIOLET		10,000,000
800		100,000,000		0.01	8	GRAY		100,000,000
900		1,000,000,000		0.1	9	WHITE		1,000,000,000
1,000		0.1	0.1			GOLD	5	0.1
2,000		0.01	0.01			SILVER	10	0.01
500						NO COLOR	20	

RESISTOR COLOR CODES

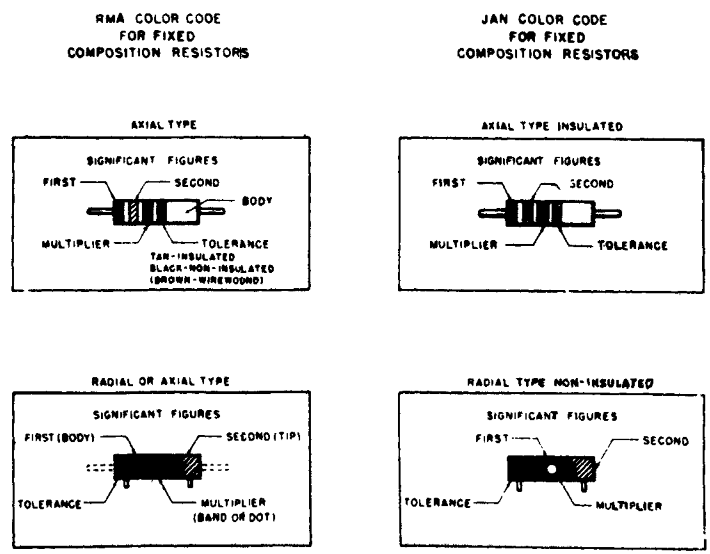


Figure 3-3. Color Code Chart.

SECTION 4
PRINCIPLES OF OPERATION

$$\frac{Rx}{Rs} = \frac{A}{B} \text{ or } Rx = \frac{A}{B} Rs$$

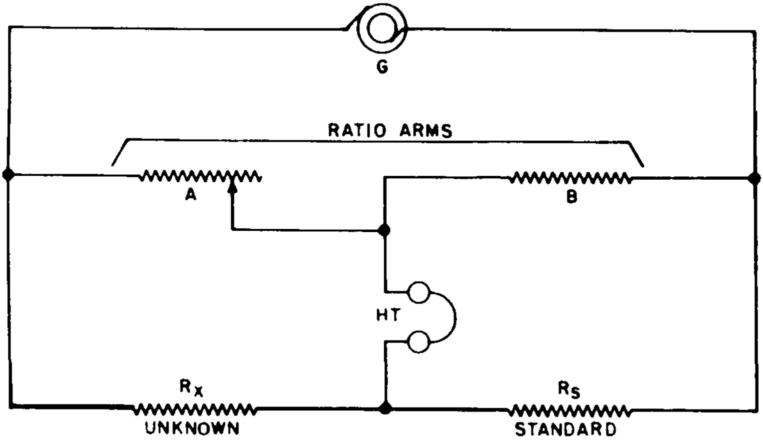


Figure 4-1. Basic Bridge Circuit, Generator and Indicator.

4-1. BASIC BRIDGE CIRCUIT, GENERATOR AND INDICATOR.

a. Figure 4-1 shows a bridge circuit in its most elementary form. An alternating current generator, G, passes current through two resistors, A and B, called the ratio arms and through resistors, Rx and Rs, called the unknown and standard, respectively. From consideration of the voltage drops, no current will pass through the headphone indicator, HT, when

$$\frac{Rx}{Rs} = \frac{A}{B} \text{ or } RX = \frac{A}{B} Rs$$

hence no response will be heard. If A and B are precalibrated in some convenient way, one has only to connect an unknown resistor and adjust A and B until silence is had in the head telephone; then the value of Rx may be read directly from the calibrations on A and B.

b. In practice, the generator must have special properties, such as low admittance to ground, in order that the accuracy will be preserved when using high ratios of A to B. It must also have adequate output of good waveform, since, in some applications, the bridge cannot be balanced simultaneously at the fundamental and a harmonic. The method used in generating the 1000 cycle test current used in capacitance Inductance Resistance Bridge ZM-11/U is shown in Figure 4-2. Vacuum tube V103 is the 1000 cycle oscillator, V102 amplifies the output thereof and transformer T102 connects the amplifier output to the bridge circuits.

Tube V103 is connected as an amplifier. Bias is supplied by a cathode resistor R141 which is by passed by capacitor C103. Plate voltage is through resistor R142. The signal output is passed into a ladder network of four capacitor-resistor combination; C122, R138; C121, R137; C120, R136 and C119, R135. Each combination shifts the phase somewhat, the proportions being such that a 1000 cycle impulse is shifted 180 degrees in passing through the four combinations. The shifted output is returned to the grid of V103 and, due to the amplifying property, sustained oscillation results. Any tendency to fly into wide swings of highly distorted waveform is effectively prevented by a slight pulse of grid current at the positive peak.

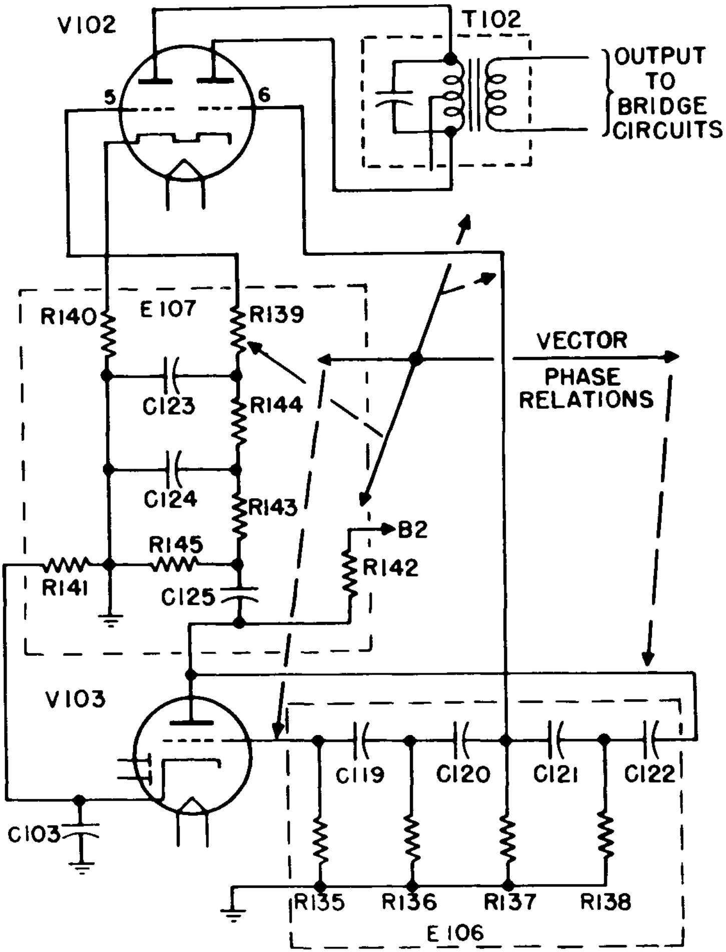


Figure 4-2. 1000 Cycle Generator.

One grid of a push-pull amplifier, V102, is connected to the junction between capacitors C120 and C121. Here the phase has not been through the full 180 degree reversal but the voltage is suitable. Some of the plate signal of V103 is taken off through a capacitor C125 and fed through a two-step ladder; R143, C124 and R144, C123. This ladder has shunt capacitors and series resistances while the other ladder (C122, R138 and C121, R137) shunt resistances and series capacitors. Thus the one advances the phase of the V103 plate signal while the other retards it. The various phase shifting elements are proportioned so that grid (5) is driven at the same amplitude as grid (6) but in opposite phase as required for true push-pull operation. Spurious oscillation in the amplifier is blocked by resistor R139 and resistor R145 provides a grid-leak to ground (through R139, R144 and R143).

The construction of the output transformer T102 is shown in Figure 5-4. The primary, hidden by its supporting bracket, which is also the interwinding shield, is tuned to 1000 cycles for highest efficiency and to suppress harmonics in the output. The secondary is supported with a minimum of solid material to keep the capacitance and leakage to the core at a minimum. Placing of the primary and secondary at the opposite ends of the long core produces high leakage inductance and causes the output to be self regulating with respect to the connected impedance.

c. Headphones lack the necessary sensitivity for balancing and are supplanted by a balance indicator for the MZ-11/U. It consists of an amplifier, V105, together with an electronray tube indicator, V101. The amplifier-indicator combination is necessarily so sensitive that only a fraction of a millivolt is needed to cause an appreciable closure of the eye pattern. Normally the pattern would close entirely with only a few millivolts input, corresponding to a very small unbalance and show no further movement for greater unbalance. This would be undesirable since balance is more readily reached if the operator has some idea of the direction of the needed change, even when far from the actual balance. To make this possible a simple automatic gain control has been embodied in the amplifier; eye-pattern activity may be seen at levels as high as one volt.

Figure 4-3 shows the connections of the amplifier-indicator for all bridge circuit positions of the FUNCTION switch. The four elements, R146, C127, C126 and R152, form a broadly resonant 1000 cycle filter to the amplifier input, V105. Cathode bias is from resistor R147 which is not bypassed except on the 100-1100 microfarad range where extra gain is required due to the large bridge-arm ratio employed. Screen supply is from the junction of R148-R155 while plate supply is through R149. C129 and R153 act as blocking-capacitor and grid leak, respectively, for V101, while the four elements, R149, C129, R153 and C130 form another filter broadly resonant to 1000 cycles like the one in the input. For a large signal to the amplifier, the grid of V101 rectifies and becomes negative due to the capacitor-leak action. This voltage is filtered by combination R150-C128 and is returned to the amplifier grid through R152 and the amplification is accordingly reduced. As bridge balance is approached, this automatic gain control voltage is reduced until, near balance, it becomes essentially zero; the amplifier-indicator then acts as maximum gain permitting very close balance indications.

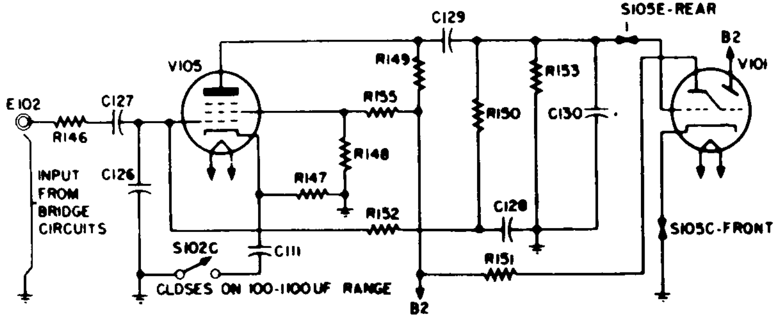


Figure 4-3. Amplifier-Indicator Circuit

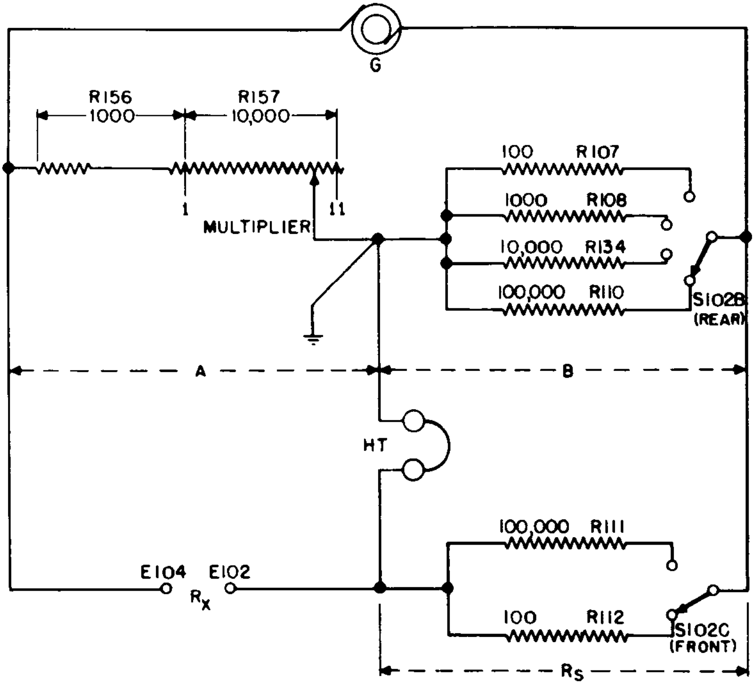


Figure 4-4. Resistance Bridge, Essential Circuits

The symbolic generator and the headphone indicator will continue to be used in discussion of the various bridge circuits employed in the ZM-11/U, it being understood that the actual counterparts described above are in use.

4-2. RESISTANCE BRIDGE.

a. When the FUNCTION switch is turned to "R" (resistance) the bridge circuit is connected as shown in Figure 4-4.

Comparison of this with Figure 4-1 shows that the "A" arm is actually a potentiometer R157 which carries the MULTIPLY RANGE SETTING BY calibration 1 to 11 on the panel (see Figure 3-1). This is padded at its lower end, R156, so that the panel setting of 1.0 includes exactly 1000 ohms and higher settings correspondingly higher values; also, that the "B" arm is one of four decimally related values selected by a switch. There are two values of the standard "Rs". Both switches shown are parts of RANGE switch S102.

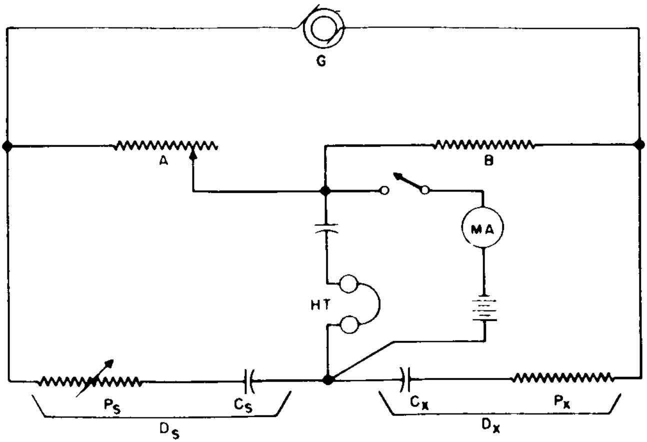
b. The action of the two sections of S102 is such that seven resistance bridge ranges are obtained, each being ten times the previous range, as shown in Table 4-1.

TABLE 4-1. RESISTANCE BRIDGE RANGES

Range No.	Range Switch On	Mult. By Dial	Resis. "A"	Resis. "B"	Stand Res. Rs	$Rx = \frac{A}{B} X Rs$
1	1 Ω	1.0	1000	100,000	100	1.0
	1 Ω	11.0	11000	100,000	100	11.0
2	10 Ω	1.0	1000	10,000	100	10.0
	10 Ω	11.0	11000	10,000	100	110.0
3	100 Ω	1.0	1000	1,000	100	100
	100 Ω	11.0	11000	1,000	100	1,100
4	1 K Ω	1.0	1000	100	100	1,000
	1 K Ω	11.0	11000	100	100	11,000
5	10 K Ω	1.0	1000	10,000	100,000	10,000
	10 K Ω	11.0	11000	10,000	100,000	110,000
6	.1 M Ω	1.0	1000	1,000	100,000	100,000
	.1 M Ω	11.0	11000	1,000	100,000	1,100,000
7	1.0 M Ω	1.0	1000	100	100,000	1,000,000
	1.0 M Ω	11.0	11000	100	100,000	11,000,000

4-3. CAPACITANCE BRIDGE.

a. Figure 4-5 shows a simplified circuit of the capacitance bridge. As the balance equation shows, it is actually the capacity-reactance rather than the capacitance which is balanced. Reversal of the positions of the standard and unknown with respect to the arms (compare with Figure 4-1) causes the A arm to retain its linear calibration. If the same relationship were



$$\frac{A}{B} = \frac{X_S}{X_X} = \frac{\frac{1}{2\pi f C_S}}{\frac{1}{2\pi f C_X}} = \frac{C_X}{C_S} \quad \text{ALSO } 2\pi f C_S P_S = 2\pi f C_X P_X \text{ OR } D_S = D_X$$

WHERE $X_S = \frac{1}{2\pi f C_S}$ (THE CAPACITY REACTANCE)

AND $X_X = \frac{1}{2\pi f C_X}$

Figure 4-5. Capacitance Bridge, Essential Circuits used as for the resistance measurement, the A arm would have to have a new calibration which would be non-uniform, corresponding to a reciprocal relationship.

b. In addition to its reactive property, the unknown capacitance will always have some loss. This loss may have the property of either a shunt or series resistance or may be a combination of both. Whatever its true nature it can be represented by a simple series resistance, Px, as has been done in Figure 4-5 and which can be balanced by a calibrated series resistance, Ps, in the standard side. Rather than to calibrate this control in its actual resistance it is an operational convenience to calibrate it in dissipation, D, as defined in Figure 4-5, then the control provides the means for completing the capacitance balance and its dial shows a merit figure for the capacitor under test.

c. The actual circuit arrangement for capacitance measurement is in Figure 4-6, corresponding to the "C" position of the FUNCTION switch. Note that the "A" arm is the same one used for resistance measurements as is the "B" arm with the addition of one resistor for an extreme range. Similarly, two capacitance standards are used. With these arrangements, eight continuous and progressive ranges in capacitance are formed as shown in Table 4-2.

d. Because two values of standard capacitance are used, two values of the dissipation control must also be provided. These are ganged on one shaft which bears the "D" panel dial. Note that these controls do not bear the same ratio to each other as their respective standard capacitances. Table 4-2 shows that the 1000 mmf standard is used through the first four capacitance ranges, 10 mmf to 0.11 MF. The capacitors measured in this range are usually of mica or paper dielectric and cannot have very high dissipation before they are considered defective.

For this reason, a maximum range of 'D' of 0.6 was selected for use with the 1000 mmf standard. This gives best readability in the region of usual interest.

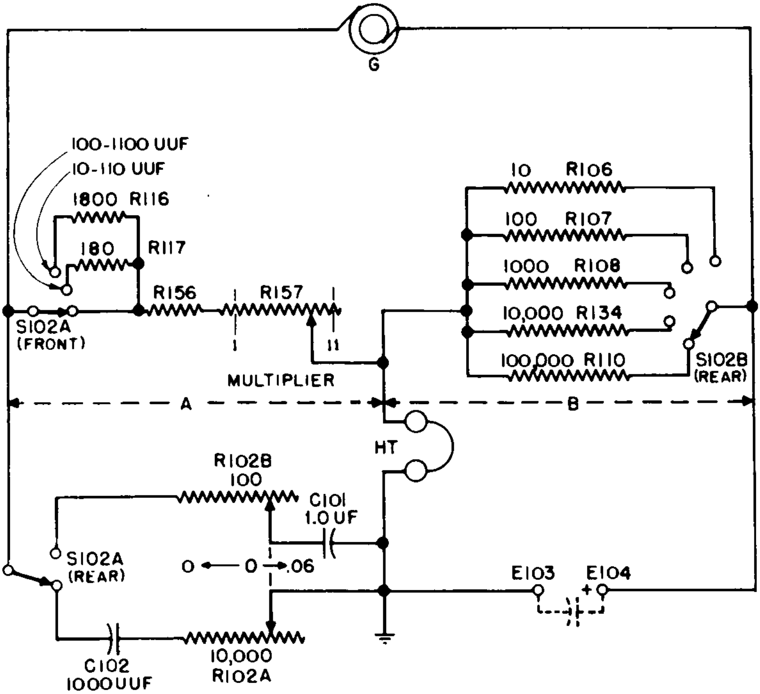


Figure 4-6. Capacitance Bridge, Measuring Circuit

The remaining four capacitance ranges cover 0.1 MF to 1100 MF. Particularly in the higher end of this range, the capacitor tested is apt to be of electrolytic construction and a wider range of 'D' is required to balance acceptable units. Hence a range of 0 to 0.6 in 'D" is provided in these ranges. Attention is called to this feature in the reverse color segment of the RANGE switch designation marked 'D x 10", indicating that all 'D" dial readings are to be multiplied by ten when using these ranges.

TABLE 4-2. CAPACITANCE BRIDGE RANGES

Range No.	Range Switch On	Mult. By Dial	Resis. "A"	Resis. "B"	Stand. Capac. Cs	$Cs = \frac{A}{B} \times Cs$
1	10 mmf	1.0	1000	100,000	1000 uuf	10 uuf
	10 mmf	11.0	11000	100,000	1000 uuf	110 uuf
2	100 mmf	1.0	1000	10,000	1000 uuf	100 uuf
	100 mmf	11.0	11000	10,000	1000 uuf	1100 uuf
3	1000 mmf	1.0	1000	1,000	1000 uuf	1000 uuf
	1000 mmf	11.0	11000	1,000	1000 uuf	11000 uuf (0.011 uf)
4	.01 MF	1.0	1000	100	1000 uuf	.01 uf
	.01 MF	11.0	11000	100	1000 uuf	.11 uf
5	.1 MF	1.0	1000	10,000	1.0 uf	.1 uf
	.1 MF	11.0	11000	10,000	1.0 uf	1.1 uf
6	1.0 MF	1.0	1000	1,000	1.0 uf	1.0 uf
	1.0 MF	11.0	11000	1,000	1.0 uf	11.0 uf
7	10 MF	1.0	1000	100	1.0 uf	10.0 uf
	10 MF	11.0	11000	100	1.0 uf	110.0 uf
8	100 MF	1.0	1000	10	1.0 uf	100.0 uf
	100 MF	11.0	11000	10	1.0 uf	1100.0 uf

e. The capacitance between the panel binding posts, E103 and E104, together with that of the connecting wiring and switch contacts which amounts to 17 to 18 mmf is already taken care of in every capacitance measurement. This prevents possible error or neglect on the part of the operator to include the necessary correction for stray capacitance.

It will be noted that for the 10 to 110 mmf range, the resistance of the "A" arm is 100 ohms per mmf, thus for this range an 1800 ohm resistance inserted in the "A" arm has the effect of subtracting 18 mmf from the reading of the MULTIPLY RANGE SETTING BY dial. Similarly, insertion of 180 ohms has the effect of subtracting 18 mmf on the 100 to 1100 mmf range. These insertions of selected resistors, R116 and R117, are made automatically by suitable contacts on the FUNCTION and RANGE switches. The residual capacitance is negligible on the higher ranges and its effect is uncompensated.

4-4. POLARIZING CAPACITORS - D. C. SUPPLY.

NOTE

Capacitors of electrolytic construction for d.c. operation often require the application of a d.c. voltage in order to exhibit the same capacitance and dissipation factor that they would in practical circuit operation. When a d.c. voltage equal or less than the marked working voltage is applied there is a sudden rush of current which falls back to a smaller steady value after 3 or 4 minutes, if the capacitor is in good condition. This steady value of current is called the leakage current. When the stable current value is reached the capacitor is said to be polarized.

a. If Cx in Figure 4-5 is electrolytic constructed, its capacitance and dissipation may be desired under simulated operating conditions and, for this, an hypothetical battery and meter are shown. A series capacitor blocks the battery from the indicator and the d-c flow will be through the "B" arm and the unknown, Cx, Px. The d-c leakage current may be read on the meter.

b. In the ZM-11/U the battery function is by a power supply of the RF type. Figure 4-7 shows the circuit when the OSCILLATOR switch is in the D. C. VOLTS position. V107 cooperates with transformer assembly T103 to oscillate at about 300 kilocycles. It has a secondary winding of very high Q and inductance/capacitance ratio which develops a relatively high RF voltage. This is rectified by tube V106 and smoothed by a resistance-capacitance combination, R121, C107, C105 and C106. Plate supply to the oscillator tube is at B1. The amplitude of the RF oscillation, and hence the d-c output, is controlled by the VOLTAGE CONTROL, R105, which controls the screen supply to the oscillating tube. With the FUNCTION switch in the C-CHG (charge) position, this d-c is connected into the bridge circuit in a manner analogous to the battery connection of Figure 4-5.

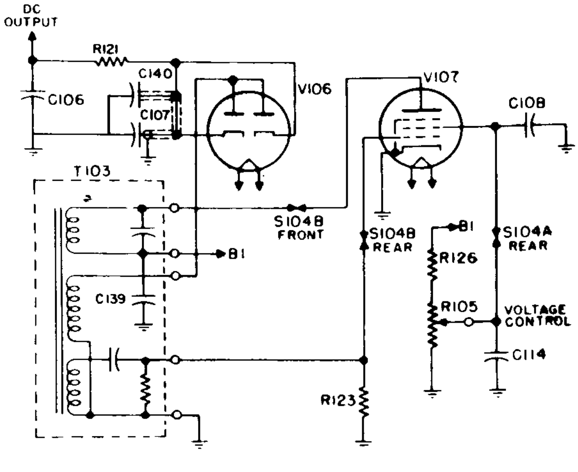


Figure 4-7. D-C Power Supply, RF Type

c. The advantages of an RF type supply, when compared to direct rectification and filtering of line power, are several; ease of filtering, due to the higher frequency; control by a small low-wattage of potentiometer; high efficiency; poor regulation at high currents, making the unit self protective for shorted capacitors and protecting the operator against high-current shocks; and manifest savings in weight and bulk of equipment.

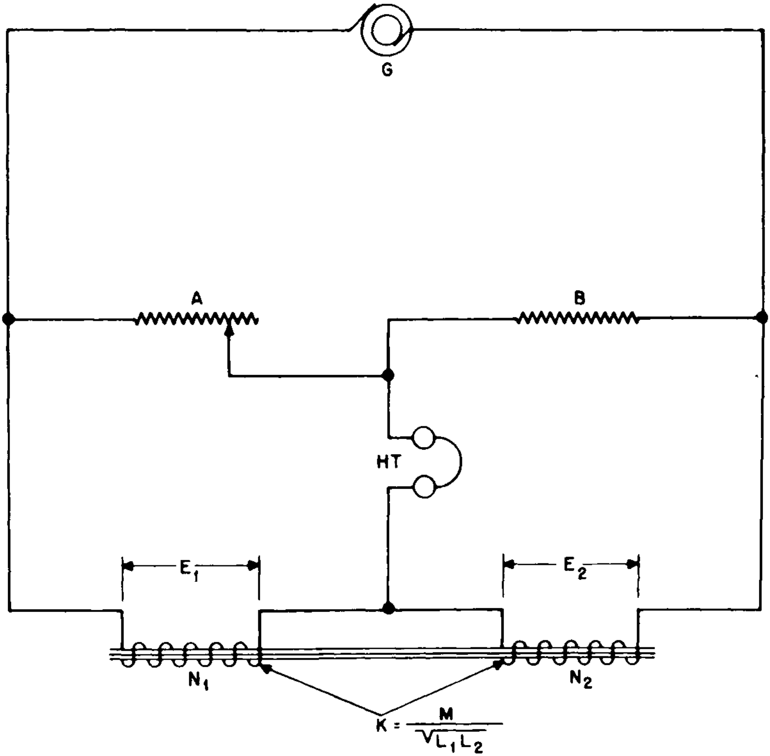
d. For control of the direct current the panel meter, M101, is normally connected as a 0-500 voltmeter so the operator can observe the potential applied to the sample. When the METER switch S103 is turned to MA positions, current ranges of 25, 5 and 1 milliampere are selected in turn to measure the current leakage through the connected electrolytic capacitor.

e. Attention is called to the fact that the d-c power supply and meter circuits are so arranged and connected that the normal capacitance-bridge circuits are in no way interfered with, therefore the capacitance and dissipation of the electrolytic capacitor may be measured while the capacitor is polarized to the desired extent.

4-5. TURNS RATIO TEST FOR TRANSFORMERS.

a. If operation of the basic bridge circuit, Figure 4-1, is interpreted as a balancing of the ratio arms against the respective voltage drops across R_X and R_S, then it is apparent that the same ratio arms can be balanced against the voltage drops across two windings of a transformer. This is shown schematically in Figure 4-8. If N_1 and N_2 are the turns of two closely coupled windings connected series-aiding as shown, then the bridge current through these will cause voltages, E_1 and E_2 proportional to the respective turns. Obviously, the bridge will balance when A and B have this same ratio.

b. With the FUNCTION switch set at N_1/N_2, the connections are the same as shown in Figure 4-4 for resistance except for omission of the resistance standards. Since there are only four basic ratios (four values of the B arm) there are only four marked values of turn-ratio on the RANGE switch against which the MULTIPLY BY dial applies.



$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{A}{B} \quad \text{WHEN } K = 1$$

Figure 4-8. Turns Radio Test

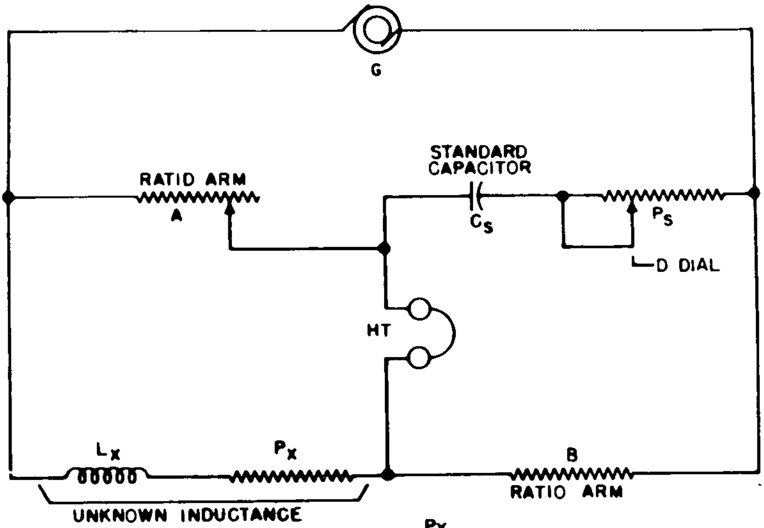
4-6. INDUCTANCE BRIDGE CIRCUITS.

a. These circuits employ the existing capacitance standards and loss controls so far as possible. Also, a wider range of dissipation must be provided to accommodate the practical range of inductors; powdered iron core coils designed for audio filters will show relatively low dissipation when measured at 1000 cycles while RF coils, even though of low-loss construction for their normal operating frequency, will show high dissipation when measured at 1000 cycles.

Both for reference and measurement it is convenient to introduce the storage factor, Q, which is the ratio of inductive reactance to resistance of a coil. It is also the reciprocal (1/D) of the dissipation factor.

In order to accommodate the large existing range in loss factors, two basic circuits are employed; the Hay bridge for coils with low losses at 1 kc (low D or high Q); and the Maxwell circuit for those having higher losses (high D, or low Q).

b. Hay's circuit, in effect when the FUNCTION SWITCH is at L(D), and its basic balance equations are shown in Figure 4-9. Equations (3) and (4) assume that D^2 may be neglected with respect to 1.0 under certain conditions. For D = 0.5, the error from so doing is 1/4%; above this, the error rises rapidly and becomes appreciable with respect to the basic accuracy of the ZM-11/U. This limitation is expressed on the panel in abbreviated form by "IF D(L) .05 ON L(D). REBALANCE ON L(Q)". In other words, if the dissipation, when using the Hay circuit exceeds 0.05, change to the Maxwell circuit, discussed in the next paragraph, and balance the loss factor of the coil in terms of the Q of the coil.



$$D_L = \frac{P_X}{2\pi f L_X}$$

$$L_X = \frac{ABC_S}{1+(2\pi f C_S P_S)^2} = \frac{ABC_S}{1+D^2} \qquad (1)$$

$$P_X = \frac{AB(2\pi f C_S)^2 P_S}{1+(2\pi f C_S P_S)^2} = \frac{AB(2\pi f C_S)^2 P_S}{1+D^2} \qquad (2)$$

(1) and (2): BALANCE EQUATIONS MUST BE SIMULTANEOUSLY BROUGHT ABOUT TO BALANCE BRIDGE.

WHEN D^2 IS SMALL WITH RESPECT TO 1

$$L_X \approx ABC_S \qquad (3)$$

$$P_X \approx AB(2\pi f C_S)^2 P_S \qquad (4)$$

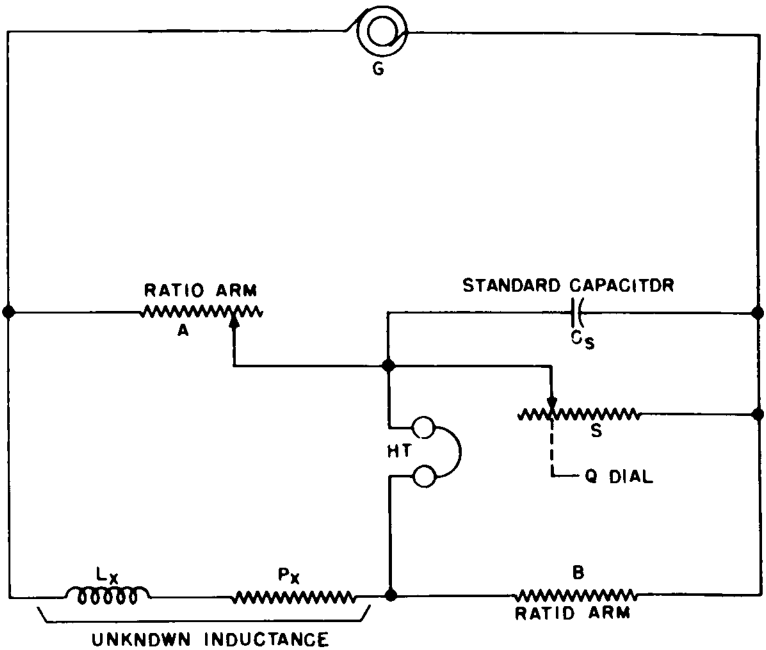
DIVIOING (4) BY (3) ANO $2\pi f$:–

$$\frac{P_X}{2\pi f L_X} = 2\pi f C_S P_S = D \qquad (5)$$

$2\pi f C_S P_S = D$: BASIC CALIBRATION OF 'D' DIAL

$\frac{P_X}{2\pi f L_X}$: THIS IS $\frac{1}{Q}$ OR D OF THE INDUCTOR.

Figure 4–9. Inductance Bridge, Hay's Circuit



$$Q_L = \frac{2\pi f L_X}{P_X}$$

$L_X = ABC_S$ (1)

$SP_X = \frac{L_X}{C_S}$ (2)

(1) and (2) MUST BE SIMULTANEOUSLY TRUE TO BALANCE BRIDGE.

SINCE $Q_L = 2\pi f \frac{L_X}{P_X}$ AND FROM (2) $\frac{L_X}{P_X} = C_S S$

$Q_L = 2\pi f C_S S$ (3)

Figure 4–10. Inductance Bridge, Maxwell's Circuit

c. Figure 4-10 shows the basic form of the bridge connection used for measuring coils having larger losses than expressed by D = .05. The only change is a new loss-control in shunt to the standard capacitor, rather than the series control used in the Hay bridge. The control is conveniently calibrated in Q and the storage factor of the inductor is thereby measured. This requires a second loss-control on the panel of the ZM-11/U marked Q. This control is in effect when the FUNCTION SWITCH is turned to L(Q).

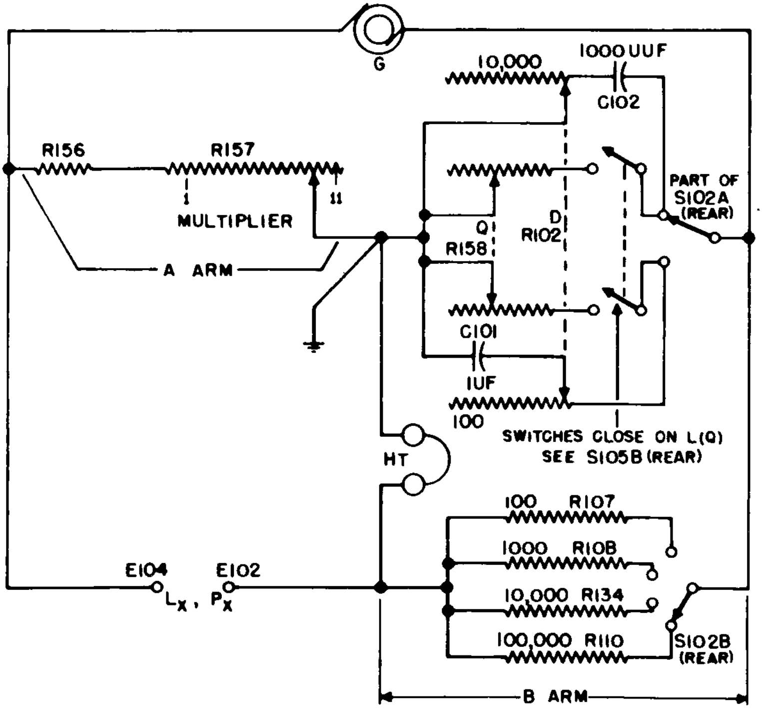


Figure 4-11. Inductance Bridge, Measuring Circuit

d. Comparison of equation (3) of Figure 4-9 with equation (1) of Figure 4-10 shows that the balance, for inductance, is the same for either circuit. This permits use of the same markings on the RANGE SWITCH for both the L(D) and L(Q) settings of the FUNCTION SWITCH. The simplified and combined circuit of Figure 4-11 shows that the only change is substitution of the shunt control R158 for the series control R102. The electrical switching is completed by a mechanical interlock between the D and Q dials necessitating that either must be returned to its initial position before the other can be turned appreciably.

Note, the resistors of the B arm are arranged in the same manner with respect to the standard capacitances that was employed for the capacitance-bridge connection. The principle difference is that the measured result now depends on the product of the ratio arms, A x B, rather than on the quotient, A/B. This accounts for the unsystematic arrangement of the inductance ranges.

4-7. CAPACITOR QUALITY TESTS.

a. Special testing facilities are included in the ZM-11/U for determining if a capacitor is either shorted or open without disconnecting it from its circuit and even though it is shunted with a resistor or inductor of not too low a value. (This limitation is fully covered in Section 3.) With the FUNCTION and RANGE switches in the required positions for this test, the essential circuits are shown in Figures 4-12 and 4-13. Both show the triode, V104, connected as an electronic voltmeter of the grid rectifying type. Figure 4-12 shows its grid grounded in the SET METER position of the CAPACITOR QUALITY TEST switch so the meter in its plate circuit may be set to full scale by potentiometer, R105 (VOLTAGE CONTROL). Recall now that the grid rectifying electronic voltmeter gives full scale deflection for zero input and deflects down-scale for appreciable applied voltage.

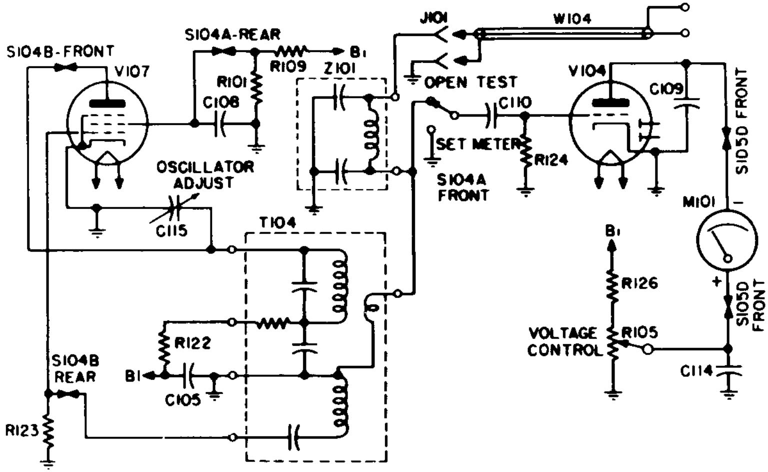


Figure 4-12. Capacitor Quality, Calibrate and Open Test Circuit

b. In the OPEN test connection, the electronic voltmeter is connected across the output winding of the oscillating transformer T104. Connected in parallel to these are the impedance element Z101, and the quality test cable P101. The impedance element acts as terminal loading for the cable so that the combination has the qualities of a quarter-wave transmission line at a frequency of about 10.75 megacycles. It will be recalled that an impedance connected to the output end of a quarter wave line is reflected to the sending end as the reciprocal of the connected impedance, that is, an open on the output end appears as a short on the sending end and vice-versa.

Thus, with the cable clips open, a short appears across the T104 output winding when the frequency is carefully adjusted to the quarter-wave frequency of the line by means of the panel controlled capacitor, C115. The electronic voltmeter connected in parallel to this short accordingly reads full scale, corresponding to zero voltage.

c. If the cable output is now clipped across a good capacitor, still connected in its circuit, some impedance other than zero will appear across the input of the quarter-wave combination and the voltage across the v.t.m. will rise causing the meter reading to drop. If the presumed capacitor is open, there will be no change in reading of meter M101.

d. The OPEN test is subject to certain limitations with respect to the size of the capacitor being examined and the relative size and kind of impedance connected across it in its own circuit.

If the capacitor is shunted by a resistor of less than 60 ohms, the reaction of the resistor alone on the quarter-wave line raises the input end impedance causing the electronic voltmeter to read down scale. This is the indication for "capacitor not open". Since the low valued resistor alone can produce the same reading the capacitor may, in fact, be open.

If the capacitor is shunted by an inductor and together they resonate to a frequency higher than the test frequency, then the parallel circuit so formed will have inductive rather than capacitive reactance at the test frequency. The condition of the capacitor is accordingly masked.

If the capacitor is 45 mmf or less it has a capacitive reactance of 500 ohms or more at the test frequency and this will be reflected to the cable input at 2.5 ohms reactance or lower. This is sufficiently close to the open end cable condition to show "open" capacitor, whereas the capacitor is merely too small to give proper indication.

Likewise, if the capacitor is between 45 and 170 mmf and is shunted by a resistor that is low relative to its reactance at the test frequency, the capacity reactance is obscured by the low resistance and false indication may result.

e. The SHORT test, Figure 4-13, employs the same electron tube voltmeter and meter setting procedure as the other test, but is supplied from the 1000 cycle generator of the ZM-11/U. The cable has no special electrical properties at this frequency and serves simply as a connecting means to the doubtful capacitor. Obviously, if the capacitor is shorted, the electronic voltmeter will receive no input and will remain at full scale. If the capacitor is not shorted, the meter reading will drop.

If the capacitor is 50 microfarads or more it will have a capacitive reactance of 3 ohms or less at the 1000 cycle test frequency. This low value will indicate a short, whereas the capacitor is merely exhibiting its normal reactance to the test circuit.

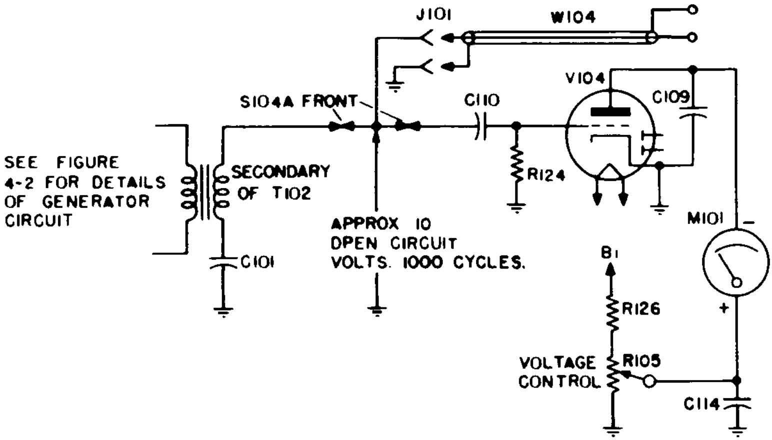


Figure 4-13. Capacitor Quality, Short Test Circuit

Likewise if some smaller capacitor is shunted by a resistor of 5 ohms or less, the resistor alone will cause a short indication which may be false.

4-8. INSULATION RESISTANCE TEST.

a. This is for determining d-c resistance of the order of 200 to 10,000 megohms such as might be found as the leakage in a paper or mica capacitor or across the contacts of a dirty switch. It is controlled by three positions of the FUNCTION switch marked INS. RES. (insulation resistance) and the principle is the voltmeter-ammeter method wherein R = E/I. Figure 4-14 shows the embodiment of this principle in the Model ZM-11/U.

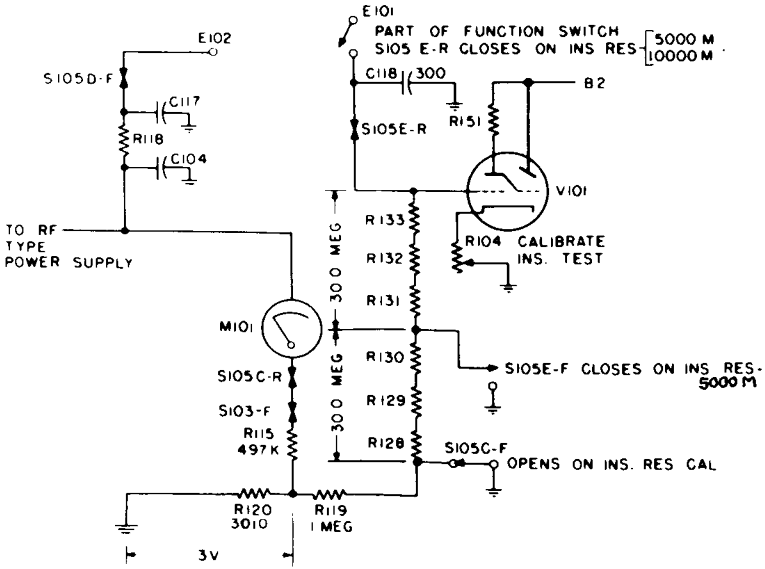


Figure 4-14. Insuletion Resistance Circuit

b. In the CAL(ibrate) INS. RES. position of the FUNCTION switch, the RF type d-c power supply and electronic voltmeter described in paragraph 4-4 are connected and energized. With the meter set to full scale, exactly 1.0 milliampere flows in the meter circuit and establishes a + 3.0 volt drop across the resistor R120. This is applied to the grid of V101 through a 60 megohm resistor chain and would normally cause the eye-pattern to open fully. This is countered by an adjustable cathode bias, R104 (CALIBRATE INS. TEST on panel), so that the pattern can be made to just close, but not overlap. The applied calibrating voltage is the same as that which would be applied in the grid of V101 by a current of 0.05 microampere through the 60 megohm resistor, hence, the eye-tube has, in effect, been calibrated as an ammeter of 0.05 uA sensitivity.

c. With the FUNCTION switch in the 10,000 M(egohm) position, the calibrating voltage is shorted out and the power supply with supervisory voltmeter are connected to the panel post E102. The grid circuit of V101 is likewide connected to the panel post E101. With the unknown connected between these two panel posts, the applied d-c voltage is adjusted until the eye-pattern again just closes, indicating that the current through the sample is just 0.05 uA. The required voltage, divided by 0.05 uA is then the resistance of the sample connected to the panel posts. As an operating convenience, this division has already been made and applied to the meter as a special calibration. It is read directly in megohms.

d. With the FUNCTION switch in the 5,000 M(egohm) position, half the grid resistor of V101 is shorted out. This decreases the sensitivity of the eye-tube microammeter by one-half to 0.1 uA. The range in megohms is accordingly halved.

e. As stated in paragraph a, the method is basically the voltmeter-ammeter method where R = E/I. Thus on the 10,000 megohm range I is always 0.05 uA. At an applied voltage of

300, for example, the indicated resistance will be 300/0.05 uA or 6,000 megohms. On the 5,000 megohm range, I is always 0.1 uA and with, say, 250 volts applied the indicated resistance is 250/0.1 uA or 2,500 megohms.

SECTION 5
TROUBLE-SHOOTING

5-1. GENERAL.

a. PHYSICAL. - Capacitance - Resistance - Inductance Bridge ZM-11/U is constructed in two major sub-assemblies: the panel assembly and the chassis assembly. These two assemblies are sandwiched into one unit and mounted in an aluminum combination instrument case. The equipment can be completely trouble-shot and most repairs effected without unsandwiching.

b. PRECAUTIONS. - Careless inspection and replacement of parts often makes new faults inevitable. Note the following:

(1) Do not unsandwich the equipment unless tests prove it necessary (See section 6, Repair).

(2) Avoid pointless tampering at all times. Never release the dial set screws on a panel control unless reasons for doing so have been thoroughly considered and facilities for recalibration are at hand.

(3) Do not needlessly push or pull on leads. This may necessitate a time consuming recalibration when only a simple replacement is required.

(4) Before unsoldering a part, note the position of the leads so they can be restored to their original position. When connecting or removing a resistor that has a short lead, grasp the lead between the resistor and the lug with pliers, then apply a freshly-cleaned well-tinned iron to the lug to release or apply solder. The pliers will draw off the heat from the lead.

(5) Never permit solder or other metal particles to fall into the instrument since they may cause shorted circuits, likewise, never use steel wool within the instrument.

5-2. SELECTION OF TEST EQUIPMENT.

The following test equipment is required for trouble-shooting the ZM-11/U:

a. Cathode Ray Oscilloscope, such as OS-8/U.
b. Volt-Ohm Ammeter; 20,000 ohms/volt on d.c. 1,000 ohms/volt on d.c.; such as AN/PSM-4.

5-3. OVERALL TROUBLE-SHOOTING.

Table 5-1 furnishes instructions for an overall trouble-shooting procedure for the ZM-11/U.

5-4. FUNCTIONAL SECTION TROUBLE-SHOOTING.

The ZM-11/U has basic bridge balance functions for

Resistance
Turns Ratio
Inductance
Capacitance

Auxiliary functions are

Capacitance Charging
Insulation Resistance Test
Capacitor Quality Test

The 1000 cycle oscillator-amplifier (V103, V102), the amplifier-indicator (V105, V101) and the "A" ratio arm are common to all the bridge functions so failure of one of these will cause bridge to fail to balance or to balance broadly in all functions and all ranges. Likewise, an inaccuracy in the "A" arm will be reflected as a corresponding inaccuracy in all of the ranges and functions.

The "B" arm, viewed as a resistor group, is common to all bridge functions, but defects in any one resistor of the group will be reflected only in certain ranges.

TABLE 5-1. PRELIMINARY CHECK

STEP	PRELIMINARY ACTION	NORMAL INDICATION	NEXT STEP
1.	Ground line cord tab, plug in line, turn POWER to ON	Line pilot should light. After 1 minute, INDICATOR should show pattern.	If neither, check for blown fuse, broken line plug or dead power receptacle. IF INDICATOR patterns but no pilot, check for dead pilot. If pilot lights but no INDICATOR, REFER TO Table, 5-3, Step 1.
2.	Turn VOLTAGE CONTROL to 0; FUNCTION to C. CHG.; OSCILLATOR TO D.C. VOLTS	Binding post pilot should light.	If not, replace pilot, if still not, refer to Table 5-3, Step 2, NOW.
		DO NOT CONTINUE TESTS WITHOUT PILOT PROTECTION	
3.	Advance VOLTAGE CONTROL slowly and watch panel meter.	Smooth adjustment to 500 volts should be had.	If adjustment erratic, refer to Table 5-3. If no or low voltage, refer to Table 5-3, Step 4.
4.	Connect to 120,000 ohm resistor to C posts and repeat (3)	Smooth adjustment to 450 volts should be had.	If erratic, refer to Table 5-3, Step 3. If can't secure 450 v. refer Table 5-3, Step 4.

TABLE 5-1. PRELIMINARY CHECK - (Continued)

STEP	PRELIMINARY ACTION	NORMAL INDICATION	NEXT STEP
5.	Hold (4) and 450 v. and turn METER to 25, then 5 MA	Read 3.75 MA each range + 3% plus resistor tolerance.	If out of tolerance, see Table 5-3, Step 5.
6.	Calibrate INS. RES. per Sec 3 Par. 3-2i.	Meter should adjust to full scale. INDICATOR pattern should appear as described.	If not refer to Table 5-3, Step 6.
7.	Calibrate CAPACITOR QUALITY TEST as per Sec. 3, Par. 3-2d.	Meter should adjust full scale as per the instructions.	If can't adjust, electron voltmeter is defective, Refer Table 5-3, Step 7.
8.	Turn OSCILLATOR to OPEN. Adjust per Sec. 3, Par. 3-2d. Short clips of R-F Cable, W104.	Meter remains full scale with open test clips. Meter should drop to 300 v. or less.	If not refer to Table 5-3, Step 8. Higher reading means weak r-f oscillator. See Table 5-3, Step 8.
9.	Turn OSCILLATOR to SHORT. Open clips of R-F Cable, P101.	Meter remains full scale with clips shorted Meter should drop to 250 v. or less	If not, short in output. See Table 5-3, Step 9. If higher, 1000 cycle oscillator-amplifier may be weak. Table 5-3, Step 9.
10.	Measure various spare components, standards if available, on various bridge functions.	Compare measured values with marked nominal values.	If out of tolerance, chart your results and refer to Table 5-2 to isolate defective bridge element.

The standard resistors (R111, R112) are employed only for the resistance balance while the capacitance standards (C101, C102) are employed for both the capacitance and inductance bridge functions. In either case, which of the standards employed depends on the function and range in use.

The various combinations of ratio arms and standards used for the various functions and ranges are clarified by Table 5-2

TABLE 5-2. ACTIVE ELEMENTS OF THE BRIDGE CIRCUITS

RANGE NO.	"A" ARM	"B" ARM (Ratio)	FUNCTION	MARKED RANGE	Std. R	Std. C	D Control	Q Control	A Arm Compensation.
1	R157		N_1/N_2	.01					
	R156		C	10 mf		C102	R102A		R116
	R156	R110	L	100 MH		C102	R102A	R158A	
			R	1 Ω	R112				
2			N_1/N_2	.1					
	R157	R134	C	100 mmf		C102	R102A		R117
	R156		L	10 MH		C102	R102A	R158A	
		(1.0)	R	10 Ω	R112				
3			N_1/N_2	1.					
	R157		C	1000 mmf		C102	R102A		
	R156	R108	L	1 MH		C102	R102A	R158A	
		(10)	R	100 Ω	R112				
4			N_1/N_2	10.					
	R157		C	.01 MF		C102	R102A		
	R156	R107	L	.1 MH		C102	R102A	R158A	
		(100)	R	1. KΩ	R112				
5			N_1/N_2						
	R157		C	.1 MF		C101	R102B		
	R156	R134	L	10 H		C101	R102B	R158B	
		(1.0)	R	10 KΩ	R111				
6			N_1/N_2						
	R157		C	1 MF		C101	R102B		
	R156	R108	L	1 H		C101	R102B	R158B	
		(10)	R	.1 MΩ	R111				
7			N_1/N_2						
	R157		C	10 MF		C101	R102B		
	R156	R107	L						
		(100)	R	1 MΩ	R111				
8			N_1/N_2						
	R157		C	100 MF		C101	R102B		
	R156	R106	L						
		(1000)	R						
See switch sections:				(f–front of deck, r–rear of deck)					
S102	S105 A,C,D	S102 B–r	S105 Marks	S102 Marks	S102 C–f	S102 A–r		S105	S102A–f S105A–f

which shows the specific element in use for each range and function by its symbol number. Additionally, the portion of the switch controlling the insertion is shown at the bottom of the table.

The internal RF type power supply is used for capacitor charging and as a source for the Insulation Resistance test. Its output is continually supervised by the panel voltmeter so its failure or weakening will ordinarily be apparent from the meter readings.

The Insulation Resistance rest employs the indicator tube (V101) of the amplifier-indicator so that broad bridge balance together with difficulty in calibrating the Insulation Test will ordinarily point to some weakness in this tube or its immediate circuit. Likewise, the 1000 cycle oscillator-amplifier circuit is common to the bridge functions and to the Short Test of the Capacitor Quality determination. The electronic voltmeter formed by the panel meter and tube V104 is employed throughout the Capacitor Quality Tests. The tube V107 functions as an RF oscillator for both the d-c charging supply and in the Open Test of the Capacitor Quality circuits, so any weakness will be reflected in both operations.

Specific troubles and the methods used for tracing them are shown in Table 5-3.

5-5. VOLTAGE AND RESISTANCE DIAGRAM.

CAUTION

Withdraw the line plug from the power receptacle before measuring resistance. Failure to observe this precaution may damage the ohmmeter as well as the ZM-11/U.

TABLE 5–3. TROUBLE SHOOTING CHART.

STEP	SYMPTOMS CONTROL SETTINGS	PROBABLE LOCATION OF FAULT	PROCEDURE CORRECTIONS
1.	No INDICATOR pattern but pilot lights with line POWER "ON".	High voltage power supply	Make socket v. analysis V108. If a-c ok but cathode low, replace V108 or look for short in B_1 or B_2 leads.
		Indicator tube or circuit.	Make socket v. and r. analysis of V101 ond/or replace V101.
2.	Binding post pilot does not light on C CHG.	High voltage power supply.	See (1) above.
		Pilot light circuit	Check R154 and continuity from I101 through S105E to chassis.
3.	VOLTAGE CONTROL errotic.	Resistor R105	Worn or damaged? Replace.
4.	Can't get 450 v. output with load. (Table 5–1, 4)	Weak r–f power unit	Make socket v. analysis of V107. If OK replace V107. Do same V106. If not OK make socket r. analysis V107 and V106. Inspect contacts S104B. Test T103 for open or high resistance.
		Voltmeter off calibration	Check M101, R115, R120
5.	Milliammeter reads off tolerance. Table 5-1, 5.	Meter, shunts or switch S103	Check M101, R113, R114, S103
6.	INS. RES. test won't calibrate.	Meter calibration	See (4) above.
		R–F power supply	See (4) above.
	If meter reods 500 and can't adjust.	Indicator circuit	Make socket v. analysis of V101, especially cathode and R104. If OK replace V101. Check 3 v. drop across R120 when panel meter reads 500 v.
7.	CAPACITOR QUALITY TEST won't calibrate.	Electron voltmeter circuit	Make socket v. analysis of V104. If no plate voltage, check contacts of S105C, S104A, R101 and R109. If voltage OK replace V104.

TABLE 5-3. TROUBLE SHOOTING CHART. - (Continued)

STEP	SYMPTOMS CONTROL SETTINGS	PROBABLE LOCATION OF FAULT	PROCEDURE CORRECTIONS
8.	CAP. QUAL. OPEN test Meter drops with open test clips. Meter doesn't drop to 300 with shorted test clips	J101, Z101 W104	Test for shorts to ground.
		W104, J101	Test for open or bad contact. Also contacts S104A-f. Output winding T104 open?
		Weak r-f oscillator	Make socket v. analysis of V107. If OK replace V107 unless performance on C. CHG was OK. Check all resistances, T104.
9.	CAP. QUAL. SHORT Meter drops with open test clips. Meter doesn't drop to 250 v. with open test clips.	Cable W104	Test for open. Also contacting of cable in J101
		W104 and J101 Low amplifier-oscillator output	Check for shorts. Check secondary voltage T102-10 v. a-c. If OK, trace it through switches and thence to end of W104.
10.	Broad balance or no balance. All bridge functions.	Oscillator-amplifier	If T102 output is weak, inspect insulated joint in T102 mount. Make socket v. analysis of V103. If OK replace V103. Same for V102. If still weak analyze E106.
		Amplifier-indicator	If T102 output OK, analyze socket v. of V105 and V101. Analyze elements of E109.
11.	Inoccuracies. All bridge functions ond ranges.	MULTIPLY BY dial	Check for loose or forced pointer on R157. Damaged R157 or R156. Replace and/ or recalibrate R157 per Section 6.
12.	Inaccuracies. Certain functions and/or ranges.		Investigate and chart the difficulties until the specific element can be isolated by reference to Table 5-2.

Magnitudes of the voltage and resistance to chassis from the base pins of all tubes are contained in the voltage-resistance diagram, Figure 5-1. Observe carefully the notes calling for particular settings of the controls and switches in order to obtain the values shown. Access to the pin sides of tubes V106, V107 and V104 is had only after removal of the bottom pan shield as shown in Figure 5-2. It is secured with seven binderhead screws.

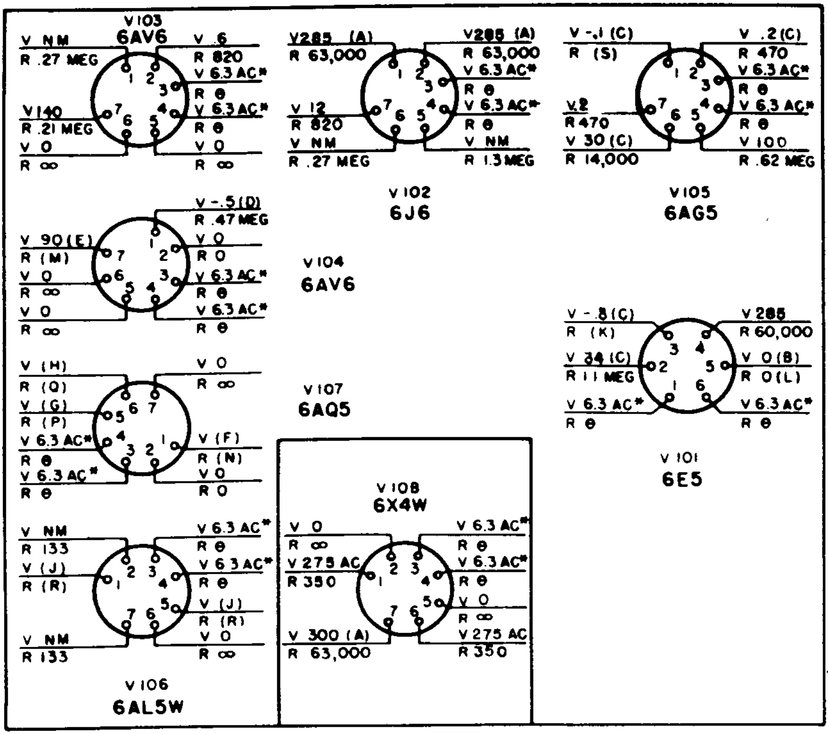


Figure 5-1. Voltage and Resistance Diagram

5-6. LOCATION OF PARTS.

Figures 5-2, 5-3 and 5-4 show the location of parts and tubes.

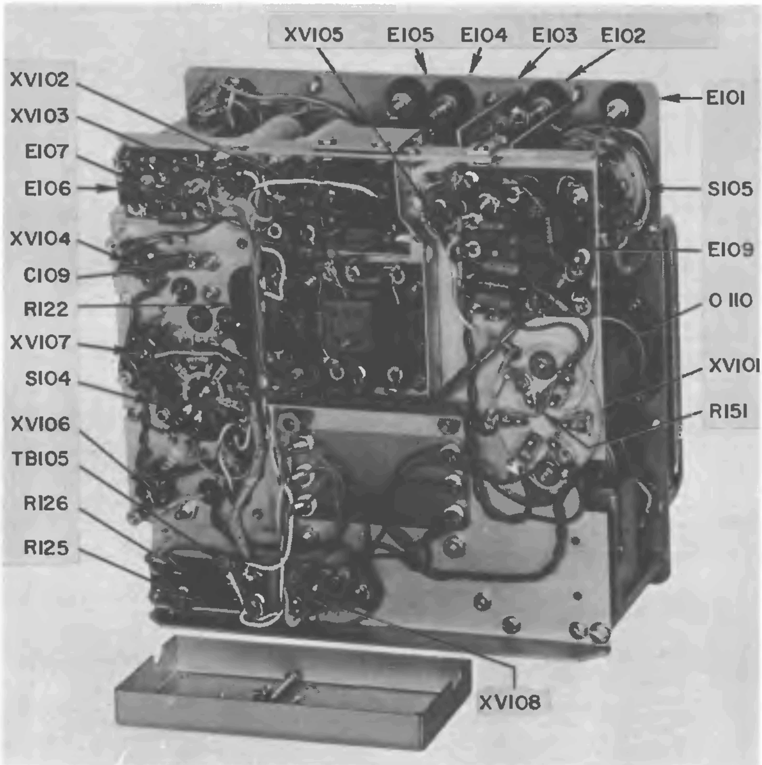


Figure 5–2. ZM-11/U, Removed From Case

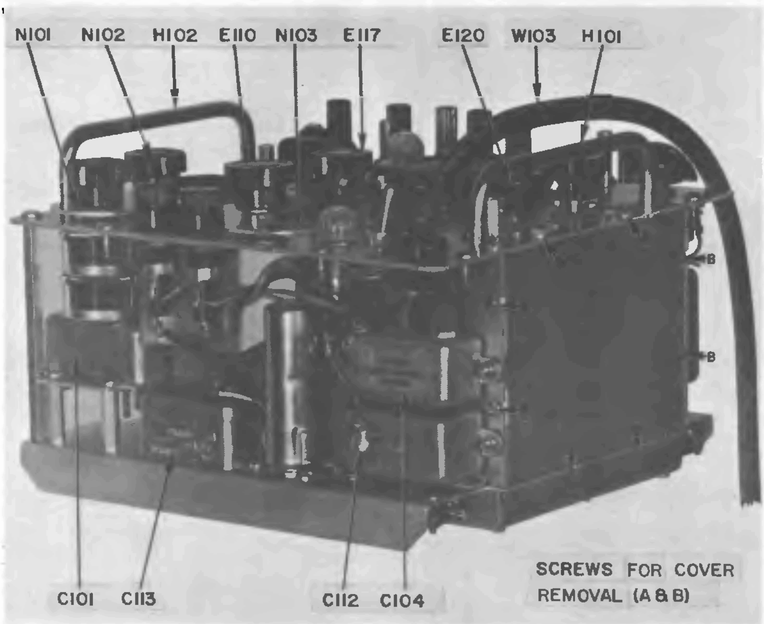


Figure 5-3. ZM-11/U, Front Side

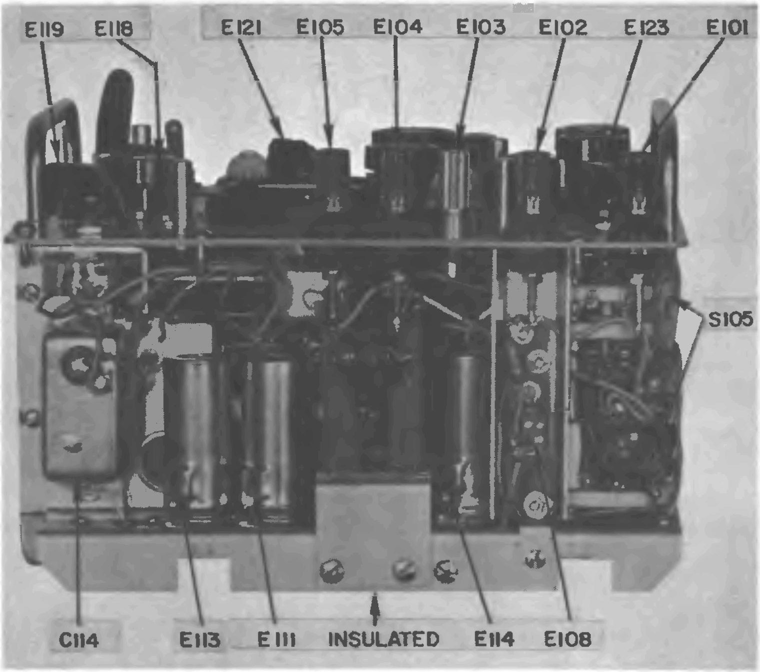


Figure 5-4. ZM-11/U, Back Side

SECTION 6
REPAIR

6-1. FAILURE REPORT.

Report each failure of the equipment, whether caused by a defective part, wear, improper operation, or an external cause. Use ELECTRONIC FAILURE REPORT form DD787. Each pad of the forms includes full instructions for filling out the forms and forwarding them to the Marine Corps Supply Activity, Philadelphia, Pa. However, the importance of providing complete information cannot be emphasized too much. Be sure that you include the model designation and serial number of the equipment (from the equipment identification plate), the type number and serial number of the major unit (from the major unit identification plate), and the type number and reference designation of the particular defective part (from the technical manual). Describe the cause of the failure completely, continuing on the back of the form if necessary. Do not substitute brevity for clarity. And remember - there are two sides to the failure report -

YOUR SIDE

Every FAILURE REPORT is a boost for you:

1. It shows that you are doing your job.
2. It helps make your job easier.
3. It insures available replacement.
4. It gives you a chance to pass your knowledge to every man on the team.

MARINE CORPS SIDE

The Marine Corps uses the information to:

1. Evaluate present equipment.
2. Improve future equipment.
3. Order replacements for stock.
4. Prepare field changes.
5. Publish maintenance data.

Always keep a supply of failure report forms on board. You can get them from the nearest District Publications and Printing Office.

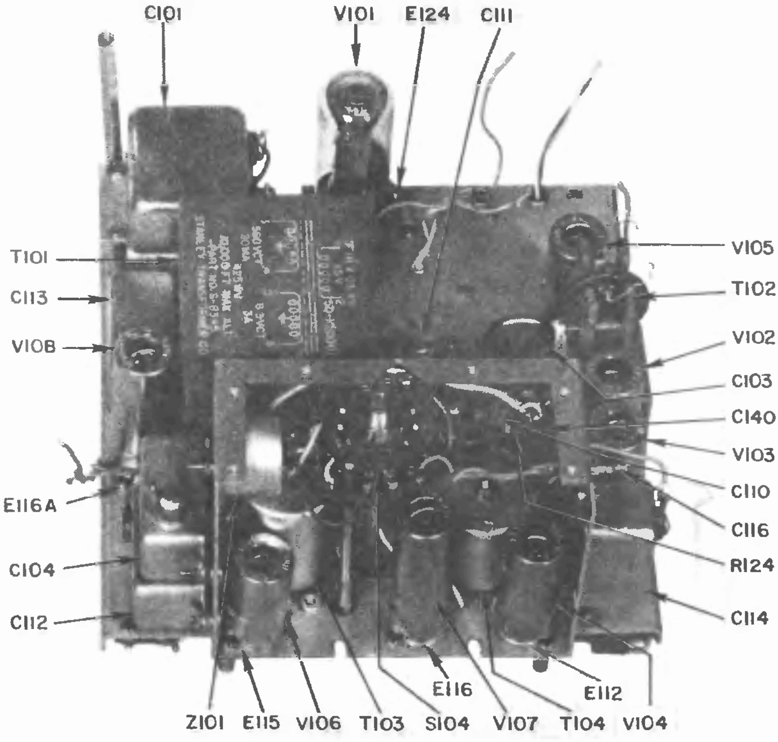


Figure 6-1. Chassis Assembly, Unsandwiched

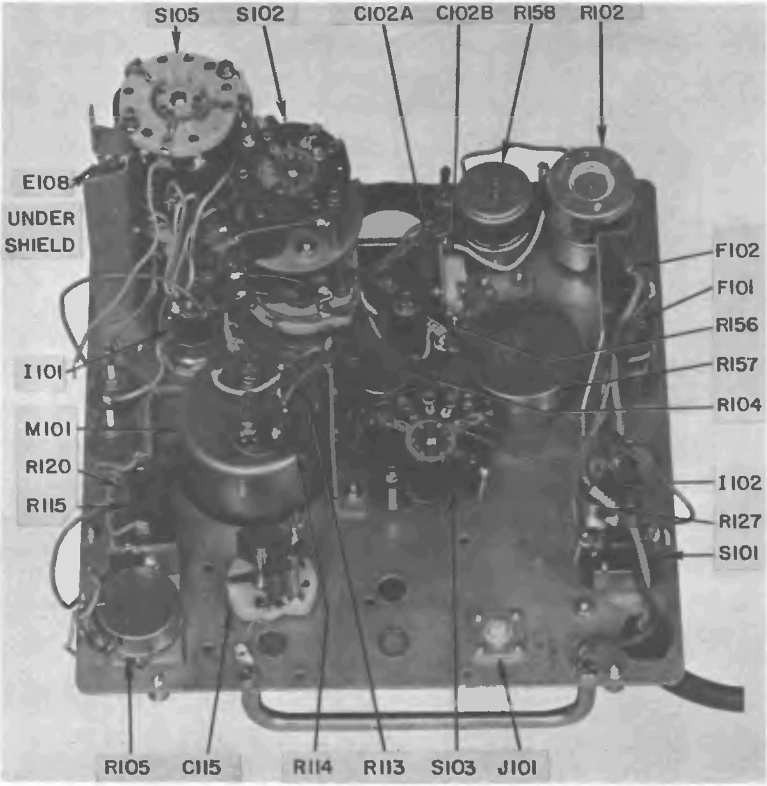


Figure 6-2. Panel Assembly, Unsandwiched

6-2. TUNING AND ADJUSTMENT.

a. TEST EQUIPMENT AND SPECIAL TOOLS. - The following equipment is needed for complete test and calibration of Capacitance - Inductance - Resistance Bridge ZM-11/U (see also Par. 5-2):

(1) Resistance bridge, wide range d-c type, accuracy o.15 percent, such as the ZM-4/U equipment.

(2) Two four-dial decade resistance boxes, 11,110 ohms per box, accuracy o.0 per cent at 1000 cps. In lieu of these, stable non-inductive resistors freshly calibrated on a precision bridge (subpar (1) above) may be used.

(3) Standard capacitance of 10 mmf, 100 mmf, 1000 mmf, 0.01 mf and 1.0 mf; accuracy 1mmf or 0.5 percent, whichever is greater.

(4) Standard inductors are available. Inductance and dissipation or storage factor at 1000 cps should be known; 0.5 percent for inductance and 5 percent for the factor.

(5) D-C voltmeter, 0-500 or 600 volts, accuracy 1% or better.

(6) D-C milliammeter, 0-5 and 0-25 ma, accuracy 1% or better.

b. CONTROL SETTINGS.-Set up and adjust the ZM-11/U as described in Section 3.

6-3. REMOVAL, ADJUSTMENT, REPAIR AND REASSEMBLY OF PARTS AND SUBASSEMBLIES.

a. REPLACEMENT OF ELECTRON TUBES: FUSES AND PILOT LAMPS.—Any electron tube, fuse or lamp in the ZM-11/U may be replaced without unsandwiching the chassis and panel assemblies.

Figure 5-2 shows the locations of the electron tubes as seen from the bottom of the chassis and Figure 6-1 shows the locations from the top of the chassis. Tubes V104, V106 and V107 are located behind an end shield (Fig. 5-3) which must be removed for access. To remove this shield, remove the two screws marked "A", loosen the six screws marked B and lift the shield off.

Two fuses in turn - cap fuse holders appear on the panel, Figure 4-1, and one spare fuse is located in the instrument case cover. The proper size is 3/4 ampere as marked adjacent to the fuse holders. Access holes in the top of the turn - caps permit insertion of test prods for determining the condition of the fuses and power connection.

Pilot lamps may be replaced from the panel side by unscrewing the jewelled cap of the lamp holder after which the lamp may be released by a slight CCW twist.

b. REMOVAL FROM CASE.

CAUTION

Never remove the equipment from the case without disconnecting the power cable.

Upend the instrument case and remove the screw appearing in the bottom of the case. Back off the seven round-head captive screws appearing around the edge of the panel marked G in Figure 3-1. These can be identified by their bright nickel finish. Then grasp the panel handles and lift the entire chassis -panel assembly clear of the case. During this operation it is necessary to tilt the assembly slightly forward to clear the panel mounting posts.

c. CAPACITOR ASSEMBLY, C101. - This unit, see Figures 5-3 and 6-1, consists of one major capacitor of 1.0 uf, or slightly less, swamp - adjusted by none to three smaller capacitors and all mounted on a metal mounting plate. Because of the close tolerance maintained in its construction it is replacable only as a unit. The whole plate should be removed when replacement is contemplated.

d. CAPACITOR-RESISTOR ASSEMBLY, E106 - This is called out in Figure 5-2 and detailed in Figure 6-3. To remove it:-

Remove three connection leads.
Remove two hex nuts.

This terminal board is preferably replaced as a unit. In an emergency, individual parts may be replaced always within the tolerances stated in the Parts List. The frequency of the oscillator-amplifier must then be checked to 1000 cycles ± 5 percent. If the frequency fails outside this, individual selection of components will have to be made to correct the frequency. Increasing the size of elements decreases the frequency and vice-versa. In checking the frequency, the input of the calibrating oscilloscope should be connected to either plate of V102 (pin 1 or 2) and chassis. In this way the input impedance of the oscilloscope cannot alter the frequency.

e. CAPACITOR-RESISTOR ASSEMBLY E107. - This appears at the upper center of the chassis, Figure 5-2 and again in detail in Figure 6-4. To remove it:-

Remove six connecting wires.
Remove four hex nuts.

It is preferably replaced as a unit, although in an emergency minor replacements of a single element may be made. Major replacement will require that a check be made of the phase of the grid voltages on amplifier V102. These must be substantially 180 degrees out of phase and equal in amplitude to secure true push-pull operation of the amplifier. This can be checked with Oscilloscope OS-8/U or equivalent. Connect the vertical input across the cathode resistor R140 of the amplifier V102. Key the linear sweep externally to the output of amplifier V102.

When the ideal push-pull condition has been brought about the vertical deflection will be either zero or show a small symmetrical trace of harmonic frequency, that is, the 1000 cycle fundamental will cancel out in the cathode lead.

f. CAPACITOR-RESISTOR ASSEMBLY E108. - This unit, shown in detail in Figure 6-5, mounts in a shielding channel beneath the binding post E102, Figure 5-4. Do not remove the shield channel or the bracket but simply:-

Remove the two connecting leads.
Remove the two hex nuts (bearing on E108)

The bakelite panel will now come out. It is preferably replaced as a whole although individual elements may be replaced. If each element is within specified tolerance satisfactory operation will be had without special test.

g. CAPACITOR-RESISTOR ASSEMBLY E109. - This appears at the upper right of the chassis in Figure 5-2. A detail is shown in Figure 6-6. To remove it:-

Remove nine connecting leads.
Remove four hex nuts.

This panel is preferably replaced as a unit due to the close and interdependent tolerances involved. If replacement of individual parts is necessary, test the remaining values to make certain they are within specified tolerance. Connect the vertical side of the oscilloscope to the grid (pin 1) of V105 and the horizontal to the plate (pin 2) of V101. Measure some capacitor on the ZM-11/U in the usual manner and then unbalance until the indicator pattern shows about 1/16 inch fringe on each side. Adjust the oscilloscope gains until a square phase pattern is formed. If the indicated phase exceeds 15 degrees, suitable selection of either or both C129 and C130 should be made to correct it.

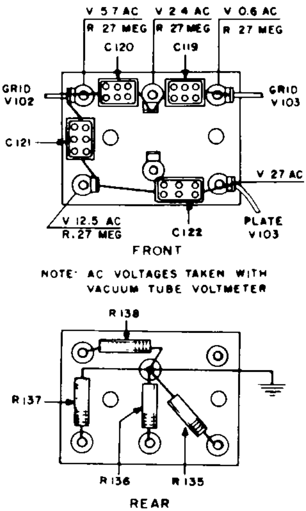


Figure 6-3. Capacitor-Resistor Assembly, E106

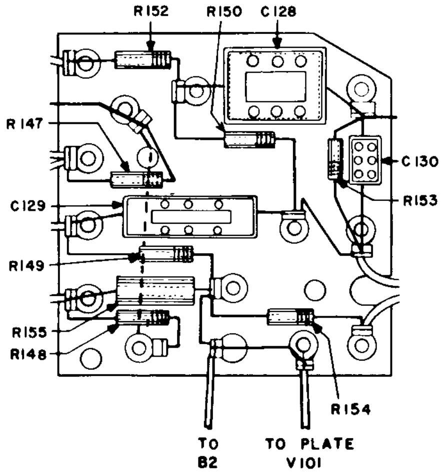


Figure 6-6. Capacitor-Resistor Assembly, E109

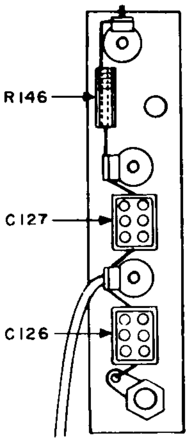


Figure 6-5. Capacitor-Resistor Assembly, E108

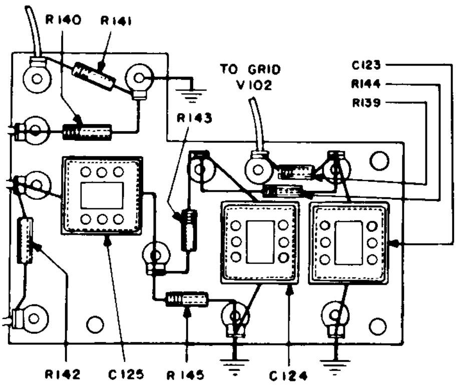


Figure 6-4. Capacitor-Resistor Assembly, E107

h. RF FILTER Z101. To remove this unit:-

Remove the tube access shield, Figure 5-3.
Remove three connections.
Remove one hex nut securing Z101, Figure 6-1.

The unit may now be removed from the shield partition. It is always replaced as a unit.

i. TRANSFORMER T102. - To remove this unit:-

Remove two secondary leads from upper end, adjacent to binding posts. (See Figure 5-4)
Remove three primary leads from lower end, under chassis. (See Figure 5-2)
Remove terminal board E107 (See Par. 6-3d)
Remove two screws, thereby exposed, holding the rear end of the transformer bracket.
Remove the two nuts and screws securing the front of the transformer bracket to the flange of the chassis. Note position of and save the insulating strip between bracket and chassis and the two extruded bakelite washers between chassis flange and nuts.

The transformer T102 can now be tilted forward and out of the assembly. It is ordinarily replaced as a unit. The primary tuning capacitor may be replaced provided facilities are at hand to permit selection of proper capacitance to tune the primary to resonance at 1000 cycles.

In reassembling, pay particular attention to insulation of the joint between the end of the transformer bracket and the chassis. If this bracket shorts to the shield it acts as a low resistance short-circuited turn on the transformer and low 1000 cycle output will result. There is no other test method for this joint, hence the closest visual inspection is necessary.

j. TRANSFORMER T103. - To remove this unit:-

Remove the tube access shield, Figure 5-3. This will expose the parts shown in the lower portion of Figure 6-1, except that the panel will still be in place.
Remove V106 together with its shield.
Remove Z101 as instructed in Paragraph 6-3h.
Remove four connections from T103 under chassis.
Remove two hex nuts from T103 under chassis.

The transformer may now be snaked out. It may be replaced as a unit, or the nut on top of the shield may be removed, then the shield. With the shield removed filter capacitor C139, tuning capacitor C132, grid capacitor C133 and grid-leak R161 will be in view. These may be replaced individually with units of tolerance specified in the Parts List.

k. TRANSFORMER, T104. - To remove this unit:-

Remove the tube-access shield, Figure 5-3
Remove V104, together with its shield.
Remove the knob from OSCILLATOR ADJUST. This will expose two screws on the panel side which should be removed, releasing capacitor C115.
Disconnect the ground lug from C115 and lay the capacitor to one side.
Remove four connections from T104, underside of chassis.
Remove two hex nuts from T104, underside of chassis.

The transformer may now be snaked out. It may be replaced as a unit or the shield may be removed by taking off one hex nut above it. Removal of the shield exposes the coil L102, tuning capacitor C134, bypass C135, grid-blocker C136 and isolation resister R162. These may be individually replaced as desired from parts in accordance with the parts list.

1. UNSANDWICHING. - Review of Subparagraphs c thru k above indicates that many of the major parts of the ZM-11/U are accessible without separating the panel assembly from the chassis assembly as has been done in the companion views, Figures 6-1 and 6-2. Careful study of other situations should be made before attempting this unsandwiching operation for, as will be seen from the disconnect schedule below, many connections must be disconnected before the units may be separated.

(1) Remove tube access shield, Figure 5-3.

(2) Disconnect the following:-

Left side of ZM-11/U

Red lead at C101
Gray lead at contact 9, S102C
Yellow Lead at contact 10, S102C
White-Green lead at contact 5, S105E
Gray lead at contact 7, S105A
Blue lead at contact 8, S105C
Yellow lead at contact 9, S105C

Binding post side (Fig. 5-4)

Two bare leads at T102
Gray lead at C126, C127 on E108
White lead at R105
Red lead at C106
Orange lead at C114

Right side

Blue lead at C115
Brown lead at J101

Fuse-holder side (Fig. 5-3)

Brown lead at C104
Gray lead at S101
Gray lead at X1102

Underside of chassis (Fig. 5-2)

Green lead at R153 on E109
Red lead at R154 on E109

(3) Remove the knob, 3/8 inch nut and lockwasher from the OSCILLATOR switch, S104.

(4) Remove six hex-head screws from the right side of the panel. Two are just below the QUALITY TEST jack: two to the left of the OSCILLATOR switch; and two just above the OSCILLATOR ADJUST knob.

(5) Remove two #8-32 binding head screws from the underside of the chassis, corresponding to the lower ends of the hex-shaped panel supports (Fig. 6-2) and the bolt securing the shield for E108 to the chassis. The chassis and panel assemblies are now separated and may be layed back from each other.

6-4. CALIBRATION

NOTE

The calibration procedures assume a normal room temperature of 22 degrees Centigrade throughout.

a. "A" RATIO ARM (R156, R157). -

Disconnect one end of the secondary of transformer T102 to prevent its appearing in shunt to the ratio arms. Turn the FUNCTION SWITCH to N_1/N_2. Connect the precision d-c bridge to binding posts E103 and E104 where it will now measure R157 and R156 in series. Now set the d-c bridge to measure 1000 ohms and turn the shaft of R157 until balance is had. At this rotation of R157 the pointer must read exactly 1.0. If it does not, the pointer set screws should be released and the pointer turned until this is true. Other points of the dial should be checked for the tolerances shown in Table 6-1.

TABLE 6-1. TOLERANCES FOR MULTIPLY BY DIAL.

Mult. By Dial	RESISTANCE - OHMS	
	Low	High
1.0	1000	1000
4.0	3910	4090
7.0	6880	7120
10.0	9850	10150

If the arm is outside the tolerances shown, the potentiometer R157 is worn out or damaged beyond use and should be replaced. After calibration or replacement, the connection to the secondary of T102 should be resoldered.

b. "B" RATIO ARM.-

Disconnect one end of the secondary of transformer T102 to prevent its appearance in shunt to the ratio arm. Connect the precision d-c bridge to binding posts E103 and E105. Turn the FUNCTION Switch to N_1/N_2. Table 5-2 shows which of the "B" arm resistors is in service at each setting of the RANGE switch. Measure each value. It should be within 1/2 percent of the value stated in the parts list. If any value is found out of tolerance, the unit should be replaced. When all five values of the "B" arm measure correctly in the eight positions of the RANGE SWITCH, the secondary of T102 should be reconnected.

c. BASIC RATIOS.

The basic ratios of the ZM-11/U may be checked, together with the performance of the 1000 cycle oscillator-amplifier and amplifier - indicator by turning the FUNCTION switch to N_1/N_2 and connecting standard resistors to the corresponding N_1/N_2 posts. These standard resistors are most conveniently settings of two decade resistance boxes but may also be a pair of ordinary radio type resistors carefully measured on the precision d-c bridge and their ratio calculated, just prior to use. Such a pair will be required for each ratio to be tested. The basic ratio of the ZM-11/U with the MULTIPLY BY dial at 10.0 is shown in parenthesis in Table 5-2 under the "B" arm resistor symbol for each position of the RANGE switch. Other settings than 10.0 may be employed, the ratio being proportionate to the dial setting. If this ratio test is carefully carried out for all ranges, the results should be found to be within the tolerance indicated for Turn Ratio in Table 1-1. If not, then probably some faulty element has been overlooked in the tests of Paragraphs 6-4a or 6-4b and that work should be repeated. When the stated accuracies have been confirmed, the accuracy of the ratio arms has been confirmed for all bridge functions. Additionally, the basic accuracy of the Turns Ratio test is assured because there is no consideration of coupling to be considered as would be the case with actual transformer samples.

d. RESISTANCE STANDARDS.-

The standard resistors R111 and R112 may be checked independent of the ratio arms by connecting the precision d-c bridge to binding posts E102 and E105 and turning the FUNCTION switch to R. The standard in service is shown in Table 5-2 for various settings of the RANGE switch. The standards should measure within 0.5 percent of nominal value.

Confirming data on the resistance ranges may be had by energizing the ZM-11/U Bridge and measuring a decade resistance box at various settings or various resistor units previously measured on the precision d-c bridge.

e. CHECKING THE CAPACITANCE RANGES.-

Examination of Table 5-2 shows that, if the basic ratios of the bridge are correct as tested in Paragraph 6-4c, the accuracy of the capacitance measurements depends on the accuracy of the capacitance standards C101 and C102, except for the first two ranges where the values of the compensating resistors R116 and R117 also enter.

To check the accuracy of the standard C101 and, thereby the probable accuracy of the upper four capacitance ranges, repeat the ratio test for the number 5 position of the RANGE switch and, with externally connected standard resistors having a ratio of exactly 1.00, balance the bridge and record the exact reading of the MULTIPLY BY dial. This may not be exactly 10.0 but some value such as 9.95 or 10.03. Now, turn the FUNCTION switch to C and connect the 1.0 uf external standard to the C posts and balance it on the ZM-11/U as an unknown. The exact balance point on the MULTIPLY BY dial should be the same as previously noted in the ratio test or to as much as 1/2 percent higher, corresponding to the permissible tolerance in C101. If this is not the case, then probably the standard capacitor C101 is out of tolerance (+0.0, - 1/2 percent). Confirm this, if possible by direct measurement on a precision capacitance bridge before discarding C101. If larger external standard capacitors are available, the upper ranges of the ZM-11/U may be checked against these; otherwise they will have to be taken for granted premised on the ratio tests and the test on internal standard C101.

The smaller internal standard C102 is never replaced for any but the grossest defects inasmuch as it is adjustable within the ZM-11/U. To find out if such adjustment is necessary, make the ratio test with the RANGE switch in the number 4 position and with externally connected resistors having a ratio of exactly 10.00. Balance the bridge and record the exact required setting of the MULTIPLY BY dial. Turn the FUNCTION switch to C and connect the external 0.01 uf standard capacitor to the C posts. Balance the ZM-11/U for C in the usual manner. The required balance point on the MULTIPLY BY dial should be exactly the same as was required and noted in the ratio test. If it is not, insert a long insulated screw driver into the bridge from the front, alongside the fuses, to engage the slot in capacitor C102B (see Figure 6-2) and adjust as necessary to obtain exactly the same balance point obtained in the ratio test. The smaller of the internal standards has now been adjusted for the third and fourth capacitance ranges, but the compensation for binding post and stray capacitances remains to be checked in the first and second ranges.

Turn the RANGE to 100 mmf and balance the 100 uuf and 1000 uuf external standards successively on this range. Record the reading of the MULTIPLY BY dial for each. If there is any discrepancy in common to the two readings, a correction in the compensating resistor R117 is indicated. For example, assume the 100 uuf standard balanced at 1.1 (110 mmf) and the 1000 uuf standard at 10.13 (1013 mmf). The common discrepancy is 10 mmf and the MULTIPLY BY dial has a variational rate of 10 ohms per mmf in this range, hence the indication is to increase R117 by 100 ohms over its existing value.

In the same way, the first range is tested for compensation by balancing the 10 uuf and 100 uuf external standards on the 10 mmf setting of the RANGE switch. The common discrepancy is again noted while the compensating resistor R116 for this range is altered at the rate of 100 ohms per uuf of common discrepancy.

f. DISSIPATION CONTROL.-

This is actually a dual control, R102A and R102B. The terminals of the control are conveniently accessible under the lower left-hand corner of the panel and they are best checked with the d-c precision bridge. Table 6-2 shows tolerances for various settings of the 'D' dial.

TABLE 6-2. D DIAL - RESISTANCE TOLERANCES.

D Dial	R102A-FRONT		R102A-BACK	
	Low	High	Low	High
	Ohms		Ohms	
0	0	320	0	3.2
.02	2540	3820	25.4	38.2
.04	5410	7310	54.1	73.1
.06	8280	10820	82.8	108.2

g. "Q" CONTROL.-

This is also a dual control, R158A and R158B. The resistance elements of the control are swamped by resistors R159 and R160 respectively. At low settings of the Q dial, the swamps have little effect on the calibration. At higher settings the swamps affect the calibration materially. These calibrations are also readily checked by connecting the d-c precision resistance bridge directly to the terminals of the unit in question. The FUNCTION switch should be in the CAP. QUAL. position to eliminate extraneous resistance elements from the determination. Resistance for the "Q" controls are shown in Table 6-3.

If the Q dial has been removed from R158 or the control has been replaced, turn the shaft of R158 counter-clockwise to the stop. Place the Q dial squarely, as it appears in Figure 3-1 and secure the dial set screws. Turn the dial to read exactly 15, with the precision d-c bridge, select the swamps R159 and R160 until the effective resistance values Q - 15, Table 6-3 are secured. For the other Q dial settings of Table 6-3, measure the terminal resistances and record them. This is the data for a new correction curve in the cover of the ZM-11/U.

TABLE 6-3. Q DIAL - CALIBRATION DATA

Actual Q	Resistance R158A - Front Ohms	Q Dial	Resistance R158B - Rear Ohms	Q Dial
.5	79,500	______	79.5	______
1	159,000	______	159	______
2	318,000	______	318	______
3	477,000	______	477	______
5	795,000	______	795	______
10	1,590,000	______	1,590	______
15	2,385,000	15	2,385	15
20	3,180,000	______	3,180	______

h. INDUCTANCE RANGES.-

The basic design and construction of the ZM-11/U Bridge is such that, if the basic ratios check according to Paragraph 6-4c and the capacitance ranges check in accordance with Paragraph 6-4e, it is a valid assumption that the inductance ranges are correct, assuming that good clean balances can be obtained through the "L" ranges.

If suitable inductance standards are at hand, ranges corresponding to their values may be cross-checked, however, by connecting such standards as unknowns and balancing them on the ZM-11/U. In order to obtain a check, it is particularly important that the inductance standards used shall have been certified at 1000 cycles and that, if they contain iron cores, they shall have been certified at values of voltage across terminals comparable to those impressed by the ZM-11/U.

i. VOLTMETER.-

Make certain that the line cord of the ZM-11/U is not in the power socket and turn the FUNCTION SWITCH to C CHG. Connect the positive terminal of the precision voltmeter and its connected power supply to binding post E102, second from the left, and the negative terminal to E103, third from the left. The precision voltmeter should now be set to various cardinal values throughout the range 0 to 500 volts and the corresponding readings of the ZM-11/U meter recorded. Such readings should be true to within one percent plus 10 volts. Failure to meet these tolerances probably indicates improper value of the multiplier resistence R115, a shorted or open sub-multiplier R120 or incorrect current sensitivity in the meter M101, which should be proportional to 1.0 milliampere full scale and ± 0.02 MA at any scale division.

j. MILLIAMMETER.-

Insert a 10,000 ohm variable resistance in series with the standard milliammeter (or millivoltmeter arranged as a milliammeter) and connect the combination to the C posts, observing the polarity marking. Turn the FUNCTION switch to C. CHG; the OSCILLATOR switch to D.C. VOLTS; and the RANGE switch to 100 MF. With various settings of the VOLTAGE CONTROL, adjust the external series resistance to the desired panel meter current and compare with the reading of the external standard. Tolerances are stated in Table 1-1.

Failure to meet tolerance in the 1 MA range will be accounted for by the basic current sensitivity of meter M101 (1 ma). Discrepancies in the basic meter current will also be evident in the 5 MA and 25 MA ranges in addition to discrepancies in the respective current shunts R113 and R114. The stated values of these shunts is premised on a meter drop of 100 millivolts ± 2-1/2 percent at 22 degrees C.

k. INSULATION RESISTANCE TEST.-

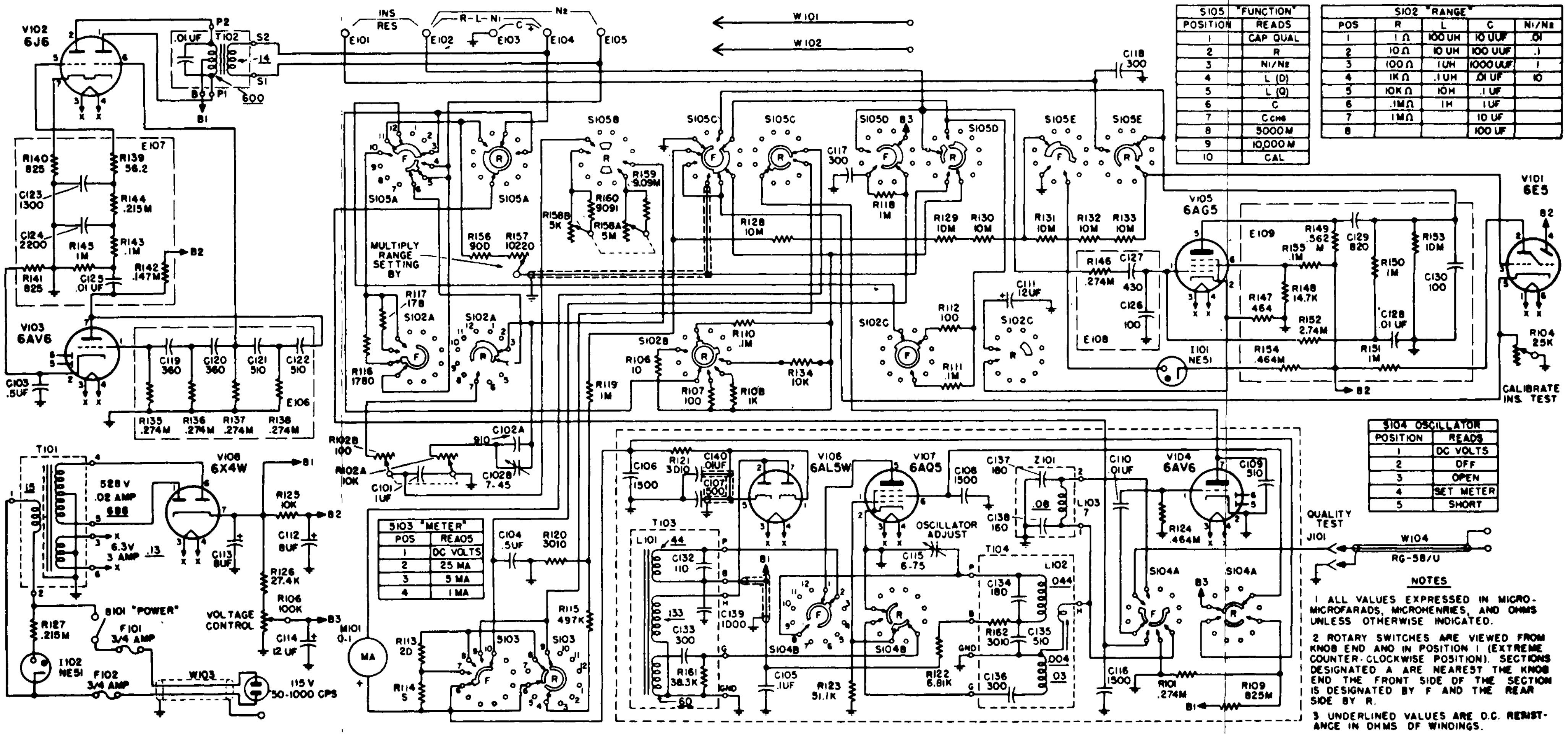
The panel voltmeter calibration, Paragraph 6-4i, is part of the Insulation Test calibration.

With the precision d-c bridge, measure the resistance from the grid (pin 3) of V101 to CHASSIS with the FUNCTION switch in the 10000M position and again with the FUNCTION switch in the 5000M position. These values should be 60 megohms and 30 megohms, respectively, ± 1 percent. If the precision bridge lacks range or sensitivity to measure these values the individual resistors R128, R129, R130, R131, R132, and R133 may be measured and summed. Now, measure the value of the drop resistor R120. This is 3000 ohms.

Accurate and stable standards of resistance of the order measured by the Insulation Test are unusual and assuming that the operations above are properly carried out and that the Insulation Test circuits are functionally correct as indicated by (5) of Table 5-1, the calibration of the Test will be assumed to be correct.

6-5. SCHEMATIC DIAGRAMS.

Figure 6-7 is the overall schematic diagram of the ZM-11/U and Figure 6-8 is the schematic of switch-deck component installation.



S105 "FUNCTION"	
POSITION	READS
1	CAP QUAL
2	R
3	N1/N2
4	L (D)
5	L (Q)
6	C
7	C CHG
8	5000 M
9	10,000 M
10	CAL

S102 "RANGE"				
POS	R	L	C	N1/N2
1	1 Ω	100 UH	10 UUF	.01
2	10 Ω	10 UH	100 UUF	.1
3	100 Ω	1 UH	1000 UUF	1
4	1K Ω	.1 UH	.01 UF	10
5	10K Ω	10 H	.1 UF	
6	.1M Ω	1 H	1 UF	
7	1M Ω		10 UF	
8			100 UF	

S103 "METER"	
POS	READS
1	DC VOLTS
2	25 MA
3	5 MA
4	1 MA

S104 OSCILLATOR	
POSITION	READS
1	DC VOLTS
2	OFF
3	OPEN
4	SET METER
5	SHORT

NOTES

1 ALL VALUES EXPRESSED IN MICRO-MICROFARADS, MICROHENRIES, AND OHMS UNLESS OTHERWISE INDICATED.

2 ROTARY SWITCHES ARE VIEWED FROM KNOB END AND IN POSITION 1 (EXTREME COUNTER-CLOCKWISE POSITION). SECTIONS DESIGNATED A ARE NEAREST THE KNOB END THE FRONT SIDE OF THE SECTION IS DESIGNATED BY F AND THE REAR SIDE BY R.

3 UNDERLINED VALUES ARE D.C. RESISTANCE IN OHMS OF WINDINGS.

Figure 6-7. Overall Schematic Diagram

6-6. CABLE ASSEMBLY W104.

This cable has a critical electrical length because it is part of an 10.75 mc quarter-wave line section. It is important that when repair or replacement is made the resultant cable length is between 47 and 48 inches when measured from the tip of center conductor of the connector (UG-88C/U) to the end of the insulated alligator clip. The correct cable type is RG-58C/U.

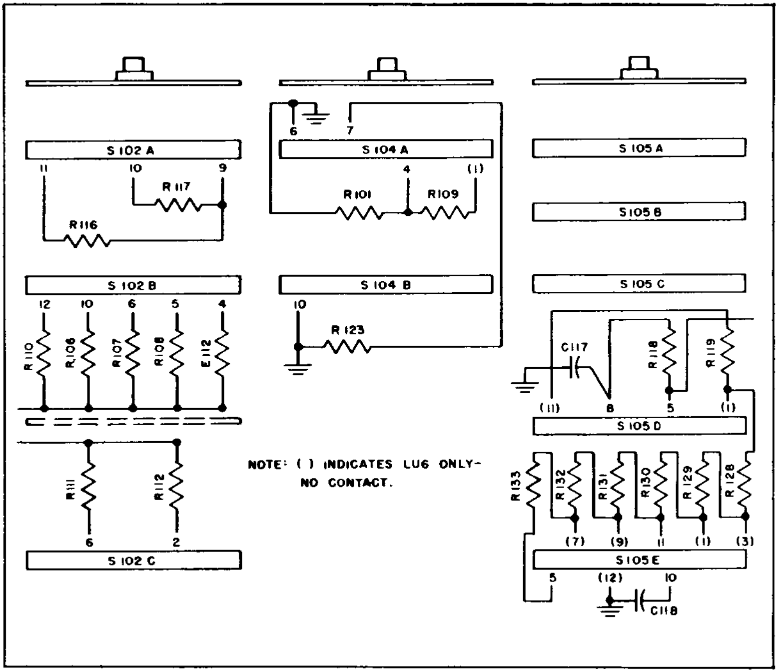


Figure 5-12. Components Mounted Between Switch Decks.

SECTION 7
PARTS LIST

7.1. INTRODUCTION.

Reference designations (previously referred to as circuit symbols, reference symbols, etc.) have been assigned to identify all maintenance parts of the equipment. They are used for marking the equipment (adjacent to the part they identify) and are included on drawings, diagrams and the parts list. The letters of a reference designation indicate the kind of part (generic group), such as resistor, amplifier, electron tubes, etc. The number differentiates between parts of the same generic group. Sockets associated with a particular plug-in device, such as an electron tube or a fuse, are identified by a reference designation which includes the reference designation of the plug-in device. For example, the socket fuse F1 is designated XF1.

7.2. MAINTENANCE PARTS LIST.

Table 7-1 lists all maintenance parts. Column 1 lists the reference designations of the various parts in alphabetical and numerical order. Column 2 lists the federal stock numbers. Column 3 gives the name and describes the various parts. Complete information is given for all key parts (parts differing from any part previously listed in this table). The name and description are omitted for other parts. However, reference is made to the key part for the data. Notes indicated in description of certain items are explained in 7-5 below. Column 4 indicates how the part is used and gives its functional location in the equipment. It also includes the figure number of the pictorial illustration on which the part is identified.

7.3. STOCK NUMBER IDENTIFICATION.

See the Repair Parts List, SIG-M8, for stock number identification of repair parts.

7-4. LIST OF MANUFACTURERS.

Table 7-2 lists manufacturers of parts used in the equipment. The first column includes the abbreviations used in Table 7-1 to identify manufacturers.

7-5. NOTES.

The following notes provide additional information about items listed in Table 7-1.

1. Non-replaceable in this application. Listed for reference only.
2. Fabricate locally from bulk material.
3. Manufacture in USMC shop.

TABLE 7-1 MAINTENANCE PARTS LIST

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
C101	5910-666-6701	CAPACITOR ASSEMBLY: matched capacitors; 1 mf plus o, minus 0.5%; 600 vdcw; 2-1/2" lg x 2" w x 1-7/8" h. JSS part/dwg. 850-0107	Capacity Standard Figures 5-3, 6-1
C102A	5910-195-1942	CAPACITOR, FIXED, MICA DILECTRIC: 910 mmf ± 2%; 500 vdcw; CM30E911G; MIL-C-5	P/O Capacity Standard Figure 6-2
C102B	5910-197-6734	CAPACITOR, VARIABLE, CERAMIC DIELECTRIC: 7-45 mmf; CV11D450; MIL-C-81	P/O Capacity Standard Figure 6-2
C103	5910-577-1515	CAPACITOR, FIXED, PAPER DIELEC- 0.5 mf ± 20%; 200 vdcw; CP25A3EC - 504M; MIL-6-25	V103 Cathode bypass Figure 6-1
C104	5910-667-4937	CAPACITOR, FIXED, PAPER DIELECTRIC: 0.5 mf; ± 20% 600 vdcw; CP53BEF504M; MIL-C-25	RF Filter Figures 5-3, 6-1

C105	5910-557-5237	CAPACITOR, FIXED, PAPER DIELECTRIC: 0.1 mf; ± 20%; 600 vdcw; CP29A3EF104M; MIL-C-25	RF Filter
C106	5910-280-8377	CAPACITOR, FIXED, CERAMIC DIELECTRIC: feed-thru type; 1,500 mmf plus 50%, minus 20%; vdcw; CRL type FT-1500	RF Filter
C107		Same as C106	RF Filter
C108		Same as C106	By-pass
C109	5910-270-5381	CAPACITOR, FIXED, MICADIELECTRIC: 510 mmf. ± 5%; 300 vdcw; CM15c511J; MIL-C-5	V104 Plate By-pass Figure 5-2
C110	5910-666-0504	CAPACITOR, FIXED, CERAMIC DIELECTRIC: .01 mf; 500 vdcw; CK63Y103Z; MIC-C-11015	Coupling to Grid V104 Figure 6-1
C111	5910-577-9380	CAPACITOR, FIXED: electrolytic; 12 mf; 250 vdcw; CE62C120M; MIL-C-62A	Cathode By-pass V105 Figure 6-1

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
C112	5910-270-9479	CAPACITOR, FIXED: electrolytic: 8 mf; 350 vdcw; CE 62D80P; MIL-C-62	Power Filter Figures 5-3, 6-1
C113		Same as C112	Power Filter Figures 5-3, 6-1
C114		Same as C111	Power Filter Figures 5-3, 6-1
C115	5910-643-9297	CAPACITOR, VARIABLE, AIR DIELECTRIC: 6-75 mmf; CT1E075; MIL-C-92	Oscillator Tuning Figure 6-2
C116		Same as C106	RF Filter Figure 6-1

C117	5910-699-2919	CAPACITOR, FIXED, MICA DIELECTRIC: 300 mmf; ± 10%; 500 vdcw; CM 15C301K; MIL-C-5	RF Filter Figure 6-8
C118		Same as C117	RF Filter Figure 6-8
C119		CAPACITOR, FIXED, MICA DIELECTRIC: 390 mmf; ± 5%; 500 vdcw; CM 15C361J; MIL-C-5 (See Note 1)	P/O E106 Figure 6-3
C120		Same as C119	P/O E106 Figure 6-3
C121		Same as C109	P/O E106 Figure 6-3
C122		Same as C109	P/O E106 Figure 6-3
C123		CAPACITOR, FIXED, MICA, DIELECTRIC: 1300 mmf; ± 5%; 500 vdcw; CM30B132J; MIL-C-5 (See Note 1)	P/O E107 Figure 6-4
C124		CAPACITOR, FIXED, MICA DIELECTRIC: 2200 mmf; ± 5%; 500 vdcw; CM30B222J; MIL-C-5 (See Note 1)	P/O E107 Figure 6-4

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
C125		Same as C110	P/O E107 Figure 6-4
C126	5910-270-4872	CAPACITOR, FIXED, MICA DIELECTRIC: 100 mmf; ± 10%; 500 vdcw; CM15C101K; MIL-C-5	P/O E108 Figure 6-5
C127	5910-577-9381	CAPACITOR, FIXED, MICA DIELECTRIC: 430 mmf; ± 5%; 300 vdcw; CM15C431J; MIL-C-5	P/O E108 Figure 6-5
C128		Same as C110	P/O E109 Figure 6-6
C129		CAPACITOR, FIXED, MICA DIELECTRIC: 820 mmf; ± 5%; 500 vdcw; CM25B821J; MIL-C-5 (See Note 1)	P/O E109 Figure 6-6
C130		Same as C126	P/O E109 Figure 6-6
C131		(Not used)	

C132		CAPACITOR, FIXED, MICA DIELECTRIC: 110 mf; ± 2%; 500 vdcw; CM15C111G; MIL-C-5	P/O T103
C133		Same as C117	P/O T103
C134		CAPACITOR, FIXED, MICA DIELECTRIC: 180 mmf; ± 2%; 500 vdcw; CM15C181G; MIL-C-5	P/O T104
C135		Same as C109	P/O T104
C136		Same as C117	P/O T104
C137		Same as C134	P/O Z-101
C138		CAPACITOR, FIXED, MICA DIELECTRIC: 160 mmf; ± 2%; 500 vdcw CM15C161G; MIL-C-5	P/O Z-101
C139		CAPACITOR, FIXED, CERAMIC: 1,000 mmf; 500 vdcw; CY61Y102Z: MIL-C-11015	P/O T103
C140		Same as C110	RF Filter V106 Cathode

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
E101	5940-556-6072	POST: binding; black polyethelene insulation; 5-way type; includes feed thru insulation bushings; GR type 938-WR	Bridge Terminal Figure 5-4
E102	5940-552-3622	POST: binding; red polyethelene insulation; 5-way type; includes feed-thru insulator bushings; GR type	Bridge Terminal Figure 5-4
E-103	5940-235-7993	POST: binding; nickel plated; 5-way type; includes non-rotate spacer; GR type 938-P	Bridge Terminal Figure 5-4
E104	5940-552-3622	Same as E102	Bridge Terminal Figure 5-4
E105	5940-552-3622	Same as E102	Bridge Terminal Figure 5-4

E106	6625-618-1023	CAPACITOR-RESISTOR ASSEMBLY: pre-tuned; c/o C119 thru C122 and R135 thru 138 mtd on phenolic term hd; 1-5/8" lg x 1-1/8" w x 7/16" h; JSS type 850 - 0075	Oscillator Network Figure 5-2
E107	6625-618-1024	CAPACITOR-RESISTOR ASSEMBLY: pretuned; c/o C123, C124, C125 and R139 thru R145 mtd on phenolic term hd; 2-3/4" lg x 2-5/8" w x 38"h; JSS type 850-0065	Oscillator Output Phasing Ckt. Figure 5-2
E108		CAPACITOR-RESISTOR ASSEMBLY: C126, C127 and R146 mtd on phenolic term hd; 2-3/8" lg x 1/2 w x 5/16" h; JSS type 850-0108	Amplifier Input Ckt. Figure 5-4
E109	6625-679-3764	CAPACITOR-RESISTOR ASSEMBLY: pretuned; c/o C128, C129, C130, R147, thru R150 and R152 thru R155 mtd on phenolic thru hd; 2-1/8" lg x 2-1/4" w x 3/8" h; JSS type 850 - 0069	Amplifier Filter Ckt. Figure 5-2
E110	5355-680-1250	KNOB: rd; plastic with brass pointer; 1/4" dia shaft hole; K-K type S-308-64-40277-BB	Actuates R157 Figure 5-3

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATIDN	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
E111	5960-272-9094	SHIELD; ELECTRON TUBE: for 7-contact socket; 1-3/4" h; TS 102U02; MIL-S-28	Shield for V102 Figure 6-1
E112		Same as E111	Shield for V104 Figure 6-1
E113		Same as E111	Shield for V103 Figure 6-1
E114		Same as E111	Shield for V105 Figure 6-1
E115	5960-262-0015	SHIELD, ELECTRON TUBE: for 7-contact socket; 1-3/8" h; TS102U-1; MIL-8-28	Shield for V106 Figure 6-1
E116	5960-669-8808	SHIELD, ELECTRON TUBE: for 7-contact socket 2-1/4" h; TS102U03; MIL-S-28	Shield for V107 Figure 6-1

E116A		Same as E116	Shield for V108 Figure 6-1
E117	5355-667-9699	KNOB: rd; plastic; 1/4" dia shaft hole; K-K type S-619-64-B-BB	Actuates R104 Figure 5-3
E118	5355-667-9699	Same as E117	Actuates C115 Figure 5-4
E119	5355-160-5875	KNOB: bar, plastic; 1/4" dia shaft hole; K-K type S292-3L	Actuates S104 Figure 5-4
E120		Same as E119	Actuates S104 Figure 5-3
E121		Same as E119	Actuates S103 Figure 5-4
E122		Same as E119	Actuates S-102

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATIDN	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
E123		Same as E119	Actuates S105 Figure 5-4
E124	5960-151-7574	CLAMP: electrical; stainless steel; latch type; 1-5/32" dia x 3/4" h; BC type 926A	V101 Retainer Figure 6-1
F101	5920-230-9128	FUSE: Cartridge; 3/4a; 150V; instantaneous; 1-1/4" lg x 1/4" dia; Buss type 3AG3/4AMP	Line Power Protection Figure 6-2
F102		Same as F101	Line Power Protection Figure 6-2
H101	5340-659-8596	HANDLE: panel; brass; nickel pl; round; 4-3/4" lg x 1/4" w x 1-7/32" h; JSS type 850-0095	Panel Guard Figure 5-3

H102	5340-659-8596	Same as H101	Panel Guard Figure 5-3
I101	6240-295-1678	LAMP, GLOW: 115V; 1/25w; T-3-1/4 clear bulb; min bayonet base; GE type NE51	Warning Indicator Figure 6-2
I102		Same as I101	Power Indicator Figure 6-2
J101	5935-636-8293	CONNECTOR, RF: receptacle; UG-290 A/U; MIL-C-92	Cap. Qual. Receptl. Figure 6-2
M101	6625-229-0412	METER: arbitrary scale; panel mtd; 2-11/16" dia; O-1 madc; MR26WOO1DCMA; MIL-M-6	Volts/ Current Indicator Figure 6-2
N101		DIAL, CONTROL: knob type; 0 to .06 calibration; 1/4" shaft hole; 1-1/2" dia x 11/16" lg; JSS type 850-0114	"D" Dial Figure 5-3

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
N102	5355-680-1251	DIAL, CONTROL: knob type; .5 to 20 calibration; 1/4" shaft hole; 1-1/2" dia x 11/16" lg; JSS type 850-0015	"Q" Dial Figure 5-3
N103	5355-619-9829	DIAL: scale; calibrated 1 to 11 CW; graduated in 100 divisions; 3" dia; 3/8" mtg. hole; alum; JSS type 850-0120	Multiplier Dial Figure 5-3
R101	5905-577-6744	RESISTOR, FIXED, HIGH STABILITY: 274,000 Ω ± 1%; 1/8w; RN60B 2743F; MIL-R-10509	Voltage Divider Figure 6-8
R102	5905-577-9856	RESISTOR, VARIABLE, WIRE WOUND: 2 Sections; 10,000 and 100 Ω ± 10%; 4w; IRC type 4W2G	"D" Control Figure 6-2
R103		Not used	
R104	5905-577-3798	RESISTOR, VARIABLE, COMPOSITION: 25,000 Ω; RV2NAXSD253B; MIL-R-94	Ins. Res. Calibration Figure 6-2

R105	5905-577-2194	RESISTOR, VARIABLE, COMPOSITION: 100,000 Ω ; RV4NAXSL104F; MIL-R-94	Voltage Divider Figure 6-2
R106	5905-577-9845	RESISTOR, FIXED, WIRE WOUND: 10 Ω ± 1/2%: 1/3w; RB16AE10R00D; MIL-R-93	Ratio Arm Figure 6-8
R107	5905-577-6805	RESISTOR, FIXED, WIRE WOUND: 100 Ω ± 1/2%; 1/3w; RB16AE100R0D; MILR-93	Ratio Arm Figure 6-8
R108	5905-542-9179	RESISTOR, FIXED, WIRE WOUND: 1000 Ω ± 1/2%. 1/3w: RB16AE10000D; MIL-R-93	Ratio Arm Figure 6-8
R109	5905-201-9998	RESISTOR, FIXED, HIGH STABILITY: 825,000 ± 5%; 1/2w; RN20X8253J; MIL-R-10509	Voltage Divider Figure 6-8
R110	5905-549-4544	RESISTOR, FIXED, WIRE WOUND: 100,000 Ω ± 1/2%; 1/3w; RB16AE10002D; MIL-R-93	Ratio Arm Figure 6-8
R111		Same as R110	Resistance Standard Figure 6-8

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
R112		Same as R107	Resistance Standard Figure 6-8
R113	5905-577-2020	RESISTOR, FIXED, WIRE WOUND: 20 Ω ± 1%; 1/3w; RB16AE10R00F; MIL-R-93	Meter Shunt Figure 6-2
R114	5905-577-9844	RESISTOR, FIXED, WIRE WOUND: 5 Ω ± 1%; 1/3w; RB16AE5R000F; MIL-R-93	Meter Shunt Figure 6-2
R115	5905-549-7864	RESISTOR, FIXED, WIRE WOUND: 497,000 Ω ± 1%; 1w; RB18AE49702F; MIL-R-93	Meter Multiplier Figure 6-2
R116	5905-577-9846	RESISTOR, FIXED, HIGH STABILITY: 1,780 Ω ± 5%. 1/2w; RN20X1781J; MIL-R-10509	Capacity Compen-sation Figure 6-8

R117	5905-577-9850	RESISTOR, FIXED, HIGH STABILITY: 178 Ω ± 5%; 1/8w; RN601780J; MIL-R-10509	Capacity Compen- sation Figure 6-8
R118	5905-577-9848	RESISTOR, FIXED, HIGH STABILITY: 100,000 Ω ± 5%; 1/8w; RN60B1003J; MIL-R-10509	RF Filter Figure 6-8
R119	5905-577-9849	RESISTOR, FIXED, HIGH STABILITY: 1 meogohm ± 5%; 1/8w; RN60B1004J; MIL-R-10509	Isolates R120 Figure 6-8
R120	5905-279-4417	RESISTOR, FIXED, HIGH STABILITY: 3,010 Ω ± 1%; 1/2w; RN20X3011F; MIL-R-10509	Voltage Divider Figure 6-2
R121		Same as R120	RF Filter
R122	5905-644-8142	RESISTOR, FIXED, HIGH STABILITY: 6,810 Ω ± 5%; 1w; RN25X6811J; MIL-R-10509	RF Filter Figure 5-2
R123	5905-577-9853	RESISTOR, FIXED, HIGH STABILITY; 51,100 Ω ± 5%; 1/8w; RN60B5112J; MIL-R-10509	V107 Grid Resistor Figure 6-8

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
R124	5905-577-9852	RESISTOR, FIXED, HIGH STABILITY: 464,000 Ω ± 5%; 1/8w; RN60B4643J; MIL-R-10509	V104 Grid Resistor Figure 6-1
R125	5905-542-9398	RESISTOR, FIXED, HIGH STABILITY: 10,000 Ω ± 5%; 1w; RN25X1002J; MIL-R-10509	Power Filter Figure 5-2
R126	5905-539-4800	RESISTOR, FIXED, HIGH STABILITY: 27,400 Ω ± 1%; 1w; RN25X2742F, MIL-R-10509	Voltage Dropping Figure 5-2
R127	5905-577-9851	RESISTOR, FIXED, HIGH STABILITY: 215,000 Ω ± 5%; 1/8w; RN60B2153J; MIL-R-10509	Voltage Dropping Figure 6-2
R128	5905-552-5752	RESISTOR, FIXED, HIGH STABILITY: 10 megohms ± 1%; 1w; RN25X1005F; MIL-R-10509	Resistance Standard Figure 6-8
R129		Same as R128	Resistance Standard Figure 6-8

R130		Same as R128	Resistance Standard Figure 6-8
R131		Same as R128	Resistance Standard Figure 6-8
R132		Same as R128	Resistance Standard Figure 6-8
R133		Same as R128	Resistance Standard Figure 6-8
R134	5905-636-9729	RESISTOR, FIXED, WIRE WOUND: 10,000 Ω ± 1/2%; 1/3 w; RB16AE10001D; MIL-R-93	Ratio Arm Figure 6-8
R135		Same as R101	P/O E106 Figure 6-3
R136		Same as R101	P/O E106 Figure 6-3

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
R137		Same as R101	P/O E106 Figure 6-3
R138		Same as R101	P/O E106 Figure 6-3
R139		RESISTOR, FIXED, HIGH STABILITY: 56.2 Ω ± 5%; 1/8w; RN60B24R2J; MIL-R-10509	P/O E107 Figure 6-4
R140		RESISTOR, FIXED, HIGH STABILITY: 825 Ω ± 5%; 1/2w; RN20X8250J; MIL-R-10509	P/O E107 Figure 6-4
R141		Same as R140	P/O E107 Figure 6-4
R142		RESISTOR, FIXED, HIGH STABILITY: 147,000 Ω ± 5%; 1/2w; RN20X1473J; MIL-R-10509	P/O E107 Figure 6-4
R143		Same as R118	P/O E107 Figure 6-4

R144		Same as R127	P/O E107 Figure 6-4
R145		Same as R119	P/O E107 Figure 6-5
R146		Same as R101	P/O E108 Figure 6-5
R147		RESISTOR, FIXED, HIGH STABILITY: 464 Ω ± 5%; 1/8w; RN60B4640J; MIL-R-10509	P/O E109 Figure 6-6
R148		RESISTOR, FIXED, HIGH STABILITY: 14,700 Ω ± 5%; 1/4w; RN65B1472J; MIL-R-10509	P/O E109 Figure 6-6
R149		RESISTOR, FIXED, HIGH STABILITY: 562,000 Ω ± 5%; 1/4w; RN65B5623J; MIL-R-10509	P/O E109 Figure 6-6
R150		Same as R119	P/O E109 Figure 6-6
R151		Same as R119	V101 Plate Resistor Figure 5-2

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
R152		RESISTOR, FIXED, HIGH STABILITY: 2.74 megohm ± 5%; 1/2w; RN20X2744J; MIL-R-10509	P/O E109 Figure 6-6
R153		Same as R128	P/O E109 Figure 6-6
R154		Same as R124	P/O E109 Figure 6-6
R155		RESISTOR, FIXED, HIGH STABILITY: 100,000 Ω ± 5%; 1w; RN25X1003J; MIL-R-10509	P/O E109 Figure 6-6
R156	5905-666-2764	RESISTOR, FIXED, WIRE WOUND: 900 Ω ± 1%; 1/3w; RB16AE900R0F; MIL-R-93	Make-up for R157 Figure 6-2
R157	5905-577-9855	RESISTOR, VARIABLE, WIRE WOUND: 1 section; 10,220 Ω; ± 2% liniar taper Clarostat type 58 M	Multiplier Control Figure 6-2

R158	5905-264-7815	RESISTOR,VARIABLE,COMPOSITION: 2 sections; 5 meg and 5,000 Ω ± 10%; 2w; AB type 32380	"Q"Control Figure 6-2
R159	5905-577-9847	RESISTOR, FIXED, HIGH STABILITY: 9.09 megohm ± 5%; 1w; RN25X9094J; MIL-R-10509	P/O "Q" Control
R160	5905-615-3798	RESISTOR, FIXED, HIGH STABILITY: 9,090 Ω ± 5% 1/2w; RN20X9091J; MIL-R-10509	P/O "Q" Control
R161		RESISTOR, FIXED, HIGH STABILITY: 38,300 Ω ± 5%; 1/8w; RN60B3832J; MIL-R-10509	P/O T103
R162		Same as R120	P/O T104
S101	5930-050-2680	SWITCH: toggle; SPST; ST42A; MIL-S-23	Power Switch Figure 6-2
S102	5930-548-3550	SWITCH: rotary; 3 sections; 8 positions; non-pile up type; Oak 47341-H3c	Range Switch Figure 6-2

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
S103	5930-412-1263	SWITCH: rotary; 1 section; 4 positions; spring return to no. 1 position; Oak 47343 - QH	Meter Range Switch Figure 6-2
S104	5930-659-8597	SWITCH: rotary; 2 sections; 5 positions; non-pile up type; Oak 47340 - H2	Oscillator Switch Figure 5-2, 6-1
S105	5930-548-8293	SWITCH: 5 sections; 10 positions; none-pile up type; Oak 47343 - H5C	Function Switch Figure 6-2
T101	5950-647-5373	TRANSFORMER, POWER: step-down and step-up; H.S.; pri 115 vac, 50 - 1,000 cps; single phase; sec #1, 560v, .02 amp; sec#2, 6.3v, 3 2mp; TFIRX03YY; MIL-T-27; STC type S-B345	Power and Heater Supply Figures 5-2, 6-1

T102	5950-647-6962	TRANSFORMER, AF: plate coupling type; 14,700 Ω CT pri; 177 Ω sec; pri tuned to 1,000 cyc; unsealed; CB type T-9102	Bridge Trans-former Figure 5-4
T103	5950-648-0048	TRANSFORMER, RF: osc. type; freq 300 KC; 3 windings; aluminum shield can; JSS type 859 - 0128	Oscillator Coil Figures 5-2, 6-1
T104	5950-647-9586	TRANSFORMER, RF: osc type; freq. 17.75 MC; 3 windings; aluminum shield can; JSS type 850 - 0129	Oscillator Coil Figures 5-2, 6-1
V101		TUBE, ELECTRON: 6E5: tuning indicator; MIL-E-1B	Balance Indicator Figure 6-1
V102	5960-188-3967	TUBE, ELECTRON: 6J6: twin triode; MIL-E-1B	Amplifier Figure 6-1
V103	5960-188-0873	TUBE, ELECTRON: 6AV6; diode - triode; MIL-E-1B	Oscillator Figure 6-1
V104		Same as V103	VTVM Figure 6-1

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
V105	5960-188-8566	TUBE, ELECTRON: 6AG5; pentode; MIL-E-1B	Amplifier Figure 6-1
V106	5960-262-0185	TUBE, ELECTRON: 5726/6AL5W; twin diode MIL-E-1B	Rectifier Figure 6-1
V107	5960-269-6861	TUBE, ELECTRON: 6005/6AQ5W; pentode; MIL-E-1B	Oscillator Figure 6-1
V108	5960-272-9182	TUBE, ELECTRON: 6 x 4 WA: rectifier; MIL-E-1B	Rectifier Figure 6-1
W101	6625-618-1046	LEAD SET: test; 3 ft lg; JSS type 850 - 0131 - 1 (See Note 3)	Test Lead Figure 1-1
W101A		WIRE: electrical: stranded cond; #18 AWG; RI; 20,000 v puncture; red color; .140 dia. 3' lg Belden type 8899 (red) (See Note 2)	P/O W101
W101B		CLIP: electrical: crocodile style; steel, cad pl; 2-3/16" lg x 1/2" w x 11/32" h, Mueller type 85	P/O W101

W 101C		TIP: phone; rd point end type; brass nickel pl; o.149" wire hole; 1" lg x 3/16" dia 0A; tip 1/2" lg x .080" dia; Smith type 123	P/O W101
W101D		INSULATOR: electrical: polyvinyl acetate; 1/2" ID; 1/16" wall thickness; 1-3/4" lg; red colored; not rated for dielectric strength; Mueller type 87 (red)	P/O W101
W102	6625-618-1045	LEAD SET: test; 3 ft lg; JSS type 850-0131-2 (See Note 3)	Test Lead Figure 1-1
W102A		WIRE: electrical; stranded cond; #18AWG; RI; 20,000 v puncture; black color; .140" dia; 3' lg Belden 8899 (Black) (See Note 2)	P/O W102
W102B		Same as W101B	P/O W102
W102C		Same as W101C	P/O W102
W102D		INSULATOR: electrical: polyvinyl acetate; 1/2" ID; 1/16" wall thickness; 1-3/4" lg; Black colored; not rated for dielectric strength; Mueller type 87 (Black)	P/O W102

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
W103	6150-577-8419	CABLE ASSEMBLY: 3 cond; 7'lg; JSS type 300 - 0011 (See Note 3)	A-C Line Cable Figure 1-1
W103A		CABLE, POWER: 3 stranded #18AWG cond; RI; Underwriters type SJ, 7'6" lg (See Note 2)	P/O W103
W103B		CONNECTOR PLUG: male; 2 flat cont; grounding pin; UP121M; MIL-C-3767	P/O W103
W104	5995-577-8420	CABLE ASSEMBLY: RF: 4 ft lg overall; JSS type 850 - 0123 (See Note 3)	Cap. Qual. Test Cable, Figure 1-1
W104A		CABLE, RF: 45" lg; RG - 58C/U: MIL-C-17A	P/O W104
W104B		CLIP: electrical: alligator style; steel, cad pl; 2" lg x 7/16" w x 5/16" w; Mueller type 60S	P/O W104

W104C		CLIP: electrical: alligator style; steel, cad pl; 2-1/4" lg x 7/16" w x 5/16" h; plastic insulation; Mueller type 60HS	P/O W104
W104D		CONNECTOR PLUG: RF; UG - 88C/U; MIL-C-3608	P/O W104
XF101	5920-190-7228	FUSE HOLDER: extractor post type; phenolic body; 2-1/4" lg x 11/16" dia; Buss type HKP - H	Holder for F101 Figure 6-2
XF102	5920-190-7228	Same as XF101	Holder for F102 Figure 6-2
XI101		LIGHT, INDICATOR: with lens; 5/8" dia x 2-3/32" lg; accommodates T-3-1/4 bayonet base lamp; Drake type 101	Socket for I101 Figure 6-2
XI102		Same as XI101	Socket for I102 Figure 6-2

TABLE 7-1 MAINTENANCE PARTS LIST - (Continued)

REFERENCE DESIGNATION	FEDERAL STOCK NUMBER	NAME AND DESCRIPTION	LOCATING FUNCTION
XV101	5935-222-6473	SOCKET, ELECTRON TUBE: 6 cont.; ceramic body; Navy type CEJ - 49364	Socket for V101 Figure 5-2
XV102	5935-260-0516	SOCKET, ELECTRON TUBE: 7 cont.; top mtg; shield base type; TS102P01; MIL-S-12883	Socket for V102 Figure 5-2
XV103		Same as XV102	Socket for V103 Figure 5-2
XV104		Same as XV102	Socket for V104 Figure 5-2
XV105		Same as XV102	Socket for V105 Figure 5-2
XV106		Same as XV102	Socket for V106 Figure 5-2

XV107		Same as **XV102**	Socket for V107 Figure 5-2
XV108		Same as **XV102**	Socket for V108 Figure 5-2
Z101	6625-659-2756	FILTER, RF: operates at 10.75 mc when used with 4' RG-58C/U cable; 50 Ω input and output; aluminum shield can; JSS type 850 - 0130	P/O Quarter-wave Line Section Figure 6-1

TABLE 7-2. LIST OF MANUFACTURERS

ABBRE-VIATION	NAME	ADDRESS
AB	Allen-Bradley Company	136 W. Greenfield St. Milwaukee, Wisconsin
Belden	Belden Mfg. Co.	4647 W. Van Buren St., Chicago 44, Illinois
Buss	Bussman Mfg. Co.	University at Jefferson St. Louis 7, Missouri
CB	Clough Brengle Co.	6014 Broadway Chicago, Illinois
CRL	Central Radio Laboratory (Div. Globe Union, Inc.)	900 E. Keefe Avenue Milwaukee, Wisconsin
Clarostat	Clarostat Mfg. Co., Inc.	Dover, New Hampshire
Drake		
GE	General Electric Supply Corporation	705 Edgewood St. N.E. Washington 17, D.C.
GR	General Radio Co.	275 Massachusetts Ave. Cambridge, Massachusetts
IRC	International Resistance Co.	401 N. Broad Street Philadelphia 8, Pennsylvania

TABLE 7-2. LIST OF MANUFACTURERS (Continued)

ABBRE-VIATION	NAME	ADDRESS
JSS	James S. Spivey Inc.	4908 Hampden Lane Washington 14, D.C.
K-K	Kurz-Kasch	1421 South Broadway Dayton, Ohio
Mueller	Mueller Electric Co.	1582H East 31st St. Cleveland 14, Ohio
Oak	Oak Manufacturing Co.	1260 Clybourn Avenue Chicago 13, Illinois
Smith	Herman H. Smith, Inc.	2326 Nostrand Avenue Brooklyn 10, New York
STC	Stanley Transformer Co.	31-23 Vernon Boulevard Long Island City, New York