INSTRUCTION BOOK

*for the*

## SERIES 6100

# TERMALINE RF WATTMETER

BIRD ELECTRONIC CORP.
CLEVELAND, OHIO

INSTRUCTION BOOK

*for the*

# TERMALINE RF WATTMETER

**IMPORTANT**

This Instruction Book covers the following Termaline Wattmeter Models --

Model 611 --- 15/60 Watt Scales

Model 612 --- 20/80 Watt Scales

Model 61 --- Special Scales

While illustrations, figures and data specifically refer to Model 61, with allowances for scales and other factors, the instructions apply to all Models.

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*Fig. 1-1. Front View RF Wattmeter Model 61*

# SECTION 1
# GENERAL DESCRIPTION

## 1. SCOPE OF MANUAL

This instruction book covers the description, theory, operation and maintenance of RF Wattmeter Model 61.

## 2. PURPOSE OF EQUIPMENT

a. RF Wattmeter Model 61 is designed to measure output power and facilitate tuning of transmitters falling within the following limits:

| | |
|---|---|
| Frequency | 30 to 500 megacycles/second or 30 to 1,000 megacycles/second |
| Power | up to 80 Watts |
| Output Circuit | Coaxial, 51.5 Ohms Nominal |
| Type of Modulation | CW, AM, FM or Television Type Signals. Not designed for use on pulsed power similar to radar. |

b. It can be used to measure RF power from any source within its rating.

c. It may be used as a Dummy Load of 51.5 ohms up to 80 watts.

## 3. DESCRIPTION (See Fig. 1-1)

a. Power is measured under non-radiating conditions, i.e., with the transmitter disconnected from its antenna and feeding into the wattmeter only. This is an absorption wattmeter as distinguished from the other general class of "transmitted power" or "thru" wattmeters.

b. The wattmeter is built around an accurate coaxial resistor which is the transmitter load element. This resistor terminates 51.5 ohm lines so well that the voltage standing wave ratio remains below 1.1 up to above 500mc/sec. The transmitter, when loaded by the wattmeter, then operates into a known resistance of the value for which it was designed, and to a degree not often realized with antennas, particularly broadband types.

c. Power input to the resistor is measured by means of a dual-range crystal voltmeter arrangement, the d-c meter of the voltmeter reading directly in rf watts.

d. This instrument is direct-reading in two ranges, range selection being made by inserting the crystal diode in the desired one of two sockets on the front panel. No reference to calibration charts is needed in normal use. The meter scales are expanded at lower readings, i.e., half full-scale deflection is attained at about one third full scale power.

## 4. SPECIFIC USES

Measurements from the RF Wattmeter Model 61 may be useful for the following purposes, among others:

a. Checking installation of transmitter.

b. Routine and trouble shooting maintenance.

c. Production and acceptance tests.

d. Transmitting tests.

e. Loss measurements on transmission lines.

f. Testing of coaxial line insertion devices, such as connectors, switches, relays, filters, tuning stubs, patch cords, etc.

g. As an accurate rf resistance, substantially independent of frequency and line length. See Section 4.

h. Modulation Monitor. Audio frequency amplitude modulation may be monitored by connecting phones, amplifiers or audio voltmeters to the d-c meter circuit.

## 5. MAJOR COMPONENTS (See Fig. 1-2)

a. Figure 1-2 shows all components of the RF Wattmeter Model 61 with the meter box detached to illustrate the arrangement for remote use of the indicating meter where the meter cannot be conveniently read when attached to the Resistor-Voltmeter unit.

b. ONE SHIELDED D-C CABLE is furnished: the short ($3\frac{1}{2}$ ft) cable W-101 for normal use. The long (25 ft) cable W-102 for remote meter location is furnished only on special order.

c. The sealed meter is protectively surrounded by the meter box and is shock mounted within the box. A protective flap (Fig. 1-1) covers the meter face opening for extra precaution when being carried around. The meter is equipped with a 39-inch shielded dc cable.

d. The RESISTOR-VOLTMETER unit (See Fig. 1-2) includes the coaxial load resistor R-101 surrounded by a finned radiator structure on which are mounted the spare crystal diode and various hardware items. The load resistor cylinder and conical reducer are OIL

FILLED. The cylinder is terminated at the rear in a synthetic rubber expansion diaphragm which prevents pressure rise with temperature.

e. The VOLTMETER HOUSING contains the rf portions of the dual voltmeter circuits. The circuits are separately coupled to the load resistor line by capacitive probes projecting into the dielectric space of the line. The d-c output connections of the two circuits are paralleled across a bypass condenser at the d-c output jack J-103. When one power range is activated by inserting the crystal diode, the other remains dead and without effect on the active one.

f. The crystal diodes CR-101 (working) and CR-102 (spare) are especially selected 1N79's, mounted in coaxial shielding holders (See Fig. 5-1). The two crystals furnished are carefully matched and may be used interchangeably for cross checks between them at any time.

## WARNING

CRYSTALS ARE NOT INTERCHANGEABLE BETWEEN WATTMETERS WITHOUT RECALIBRATION AND MIXUPS OF THIS KIND MUST BE AVOIDED BY ACTIVITIES HAVING MORE THAN ONE WATTMETER.

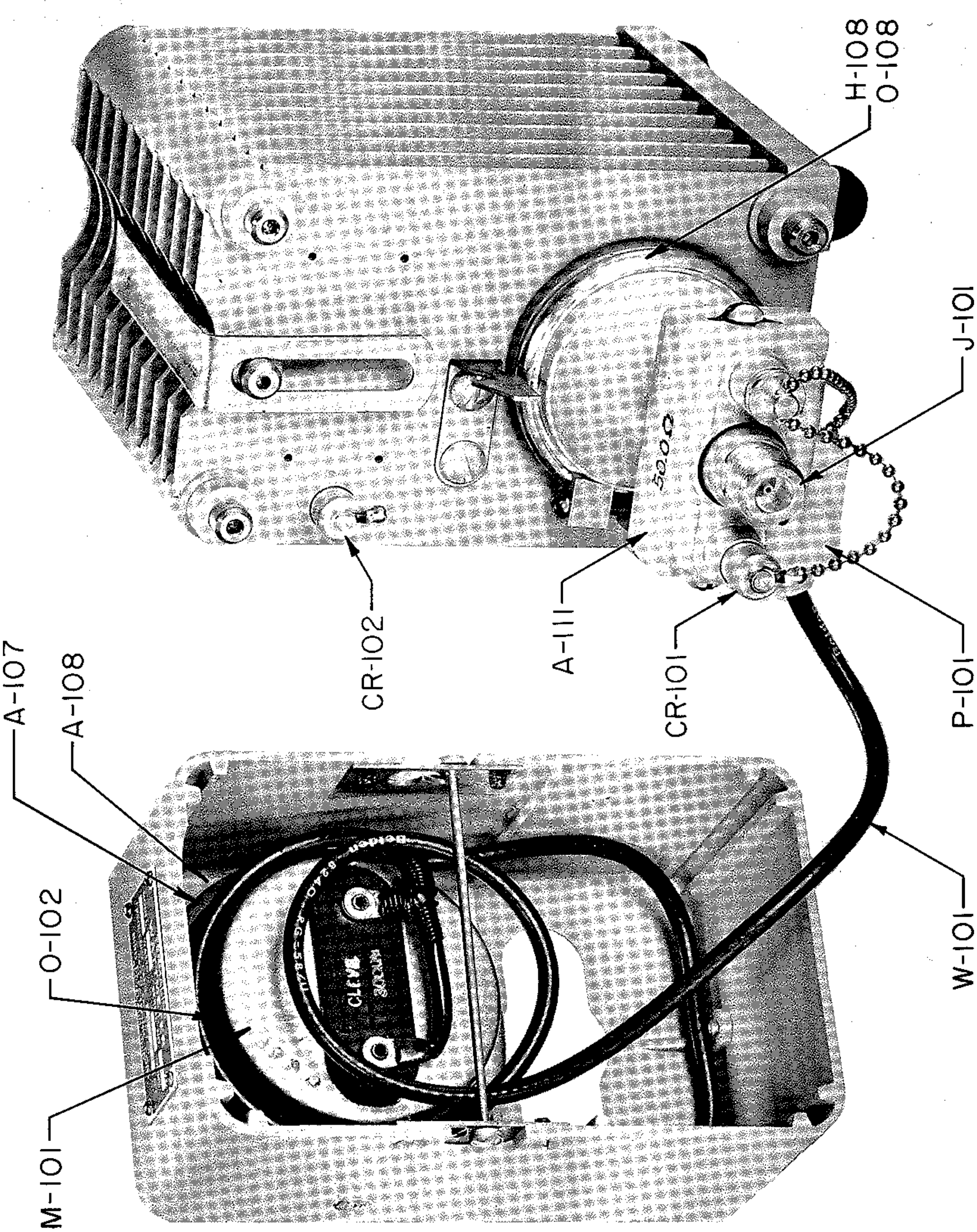


***Fig. 1-2. RF Wattmeter Model 61, Meter Box Detached***

# SECTION 2
# THEORY OF OPERATION

## 1. INTRODUCTION

There is very little lumped-constant, conventional circuitry in this instrument. Circuit elements are of the distributed constant type, machined and fabricated, as in microwave components.

## 2. BASIC PRINCIPLES

a. The power dissipated in a resistor is given by the relation $W = E^2/R$, where E is voltage across resistance R and is shown in Fig. 2-1. One of the oldest methods of measuring transmitter power at low radio frequencies depends upon this relationship.

b. For accurate results, it is necessary that the voltmeter be connected directly across the resistor terminals, in addition to the obvious requirements that the voltmeter and resistor be accurate at, or corrected for, the operating frequency.

c. The RF Wattmeter Model 61 resistor and terminals are so designed as to have a constant characteristic impedance over a wide frequency range.

d. Since the coaxial lines and fittings for this frequency range generally are of 51.5 ohms nominal impedance, the wattmeter has been designed for this load resistance value. This accurately terminates such lines and fittings in their characteristic impedance, over their usable frequency range.

e. SCALE SHAPES

(1) The voltmeter E of Fig. 2-1 may be equipped with a direct-reading scale in watts, for use with a definite load resistance R. This scale would be linear in watts if the voltmeter were of the square law type similar to thermocouple or iron vane meters.

(2) When the voltmeter is a linear type, the watt scale will be as shown in Fig. 2-2. This compares equivalent voltage and power scales for a hypothetical 50 ohm, 50 watt, 50 volt instrument. Half full-scale deflection is obtained at one-fourth full-scale power, and this scale, expanded at low readings is convenient in getting better readability at low scale readings. The voltmeter used in the RF Wattmeter Model 61is approximately linear and scales are of the type shown in Fig. 2-2.

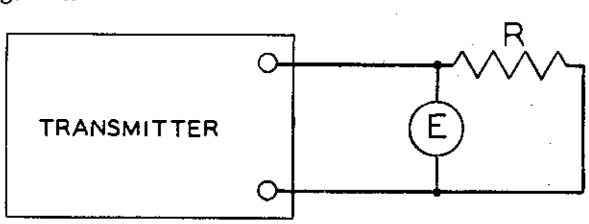


*Fig. 2-1. $E^2/R$ Method of Power Measurement*

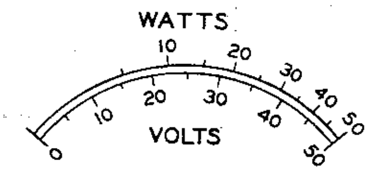


*Fig. 2-2. Comparison — Illustrative Watt and Volt Scales*

## 3. VOLTMETER CIRCUIT (See Fig. 2-3 and Fig. 2-4)

a. CIRCUIT DESCRIPTION - Capacitors C-101 and C-102 form an a-c voltage divider. C-101 is extremely small for minimum effect on the load resistance R-101. Crystal diode CR-101 functions to charge C-102 to the peak steady state a-c voltage developed across C-102 by the divider action. Resistor R-102 and the external microammeter are a d-c voltmeter circuit used to measure the d-c voltage developed across C-102, and capacitor C-103 is an rf bypass for M-101. This circuit is a shunt-diode voltmeter circuit.

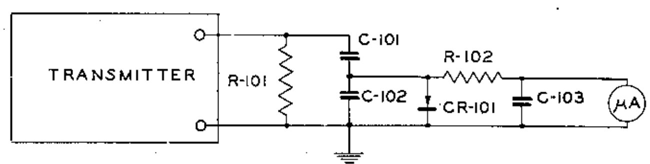


*Fig. 2-3. RF Wattmeter Model 61 Simplified Schematic*

b. DUAL VOLTMETER CIRCUIT - With the diode CR-101 removed, the circuit looking back from C-103H through R-102H is open to d-c. Therefore, another combination C-101L, C-102L and R-102L may be bridged across the load resistor, the two resistors having a common connection at C-103. The active circuit is then selected by inserting Crystal Diode CR-101 across either C-102H or C-102L. The inactive circuit being open to d-c does not affect the meter reading. This circuitry is employed in RF Wattmeter Model 61. The two circuits are identical except for the values of capacitors C-101H and C-101L.

c. RATIO BETWEEN RANGES - In the wattmeter the two voltmeter circuits require a two to one (2 to 1) voltage ratio or four to one (4 to 1) power ratio, for the same deflection. Since the same crystal is used in both circuits and since the scale shape (curve of power vs. microamperes) depends on the crystal diode, both ranges read accurately on one set of divisions, when calibrated at one point on the scale.

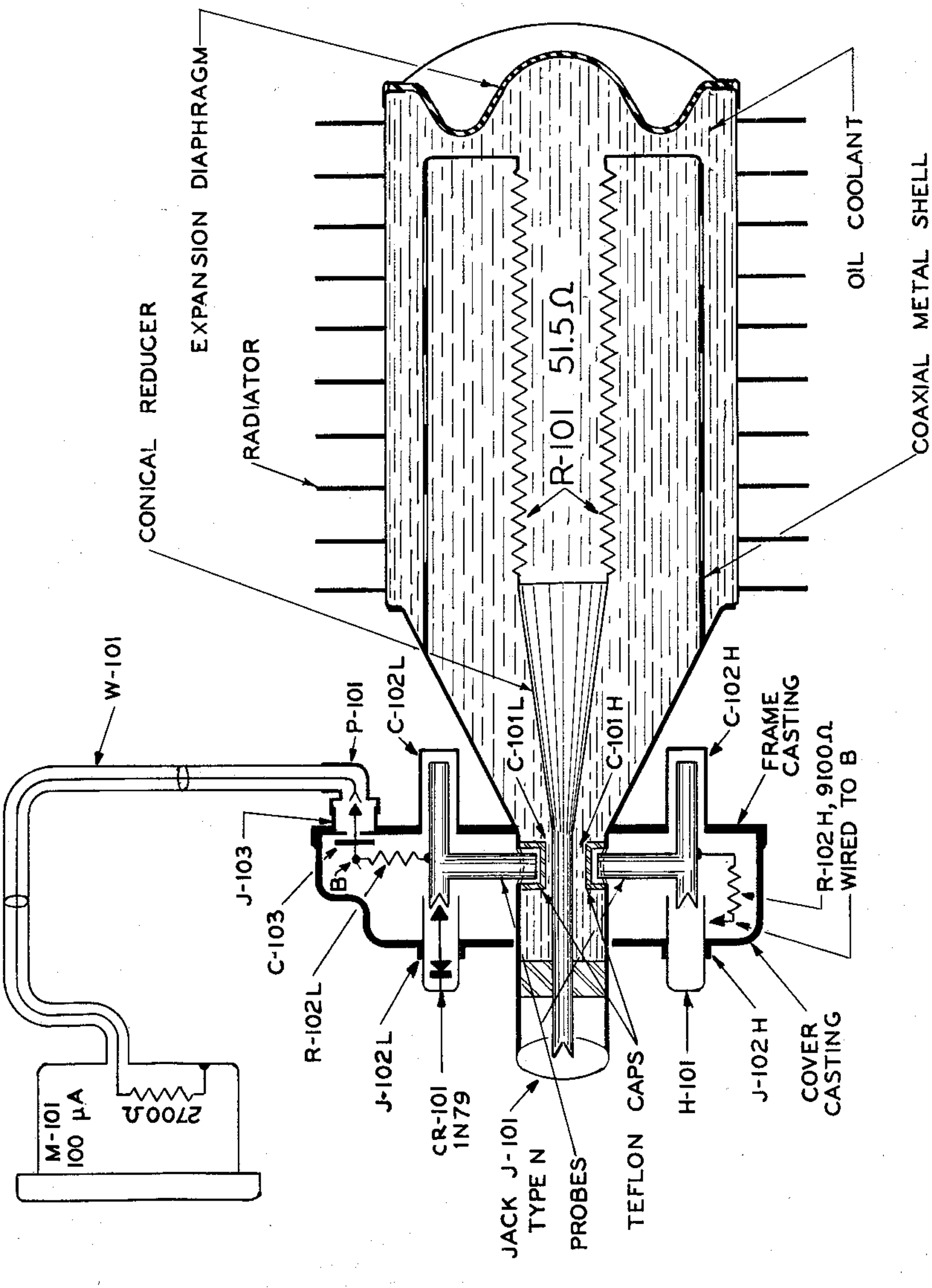


***Fig. 2-4. Schematic Diagram, RF Wattmeter Model 61***

## 4. LOAD RESISTOR CIRCUIT (See Fig. 2-4)

a. INPUT SECTION - The structure is coaxial, having a characteristic impedance of 51.5 ohms from the RF input Jack, J-101, to the large diameter end of the conical reducer. At the probes, a discontinuity is introduced by the lumped capacitances C-101L and C-101H between probe and center conductor, and compensation for this is obtained by proper choice of center conductor and sheath diameters. This portion of the circuit is essentially lossless.

b. RESISTOR PROPER - The load resistance proper begins at the large end of conical reducer. The active power dissipating portion of the resistor is the external surface of a cylindrical carbon-film-on-ceramic resistor, which forms the center conductor. At the far end of the film resistor, it is connected to a coaxial metal shell, which forms the return conductor. The constant resistance properties of the assembly are dependent upon the shape of this shell and the distribution of resistance along the length of the film. These factors have been worked out to give the desired results.

c. RF LOAD IMPEDANCE - Voltage Standing Wave Ratio Curves

(1) Fig. 2-5 shows the VSWR introduced by the wattmeter when connected to a 51.5 ohm coaxial line. This smooth curve is free from rapid cyclical changes of VSWR with frequency which occur with lossy-line loads.

(2) The average curve represents results of tests on many instruments. All wattmeters will have VSWR's which fall below the "allowable limit" curve. Below 500 mc, the region 350 to 400 mc tends to show highest VSWR values.

(3) Below 150 mc, the VSWR curve is flat. The input impedance at J-101 is practically a pure resistance equal to the d-c input resistance. Value of this resistance is stamped on the top of the voltmeter housing.

(4) From 500 mc to 1500 mc, the VSWR may reach 1.2 at certain frequencies. The wattmeter may be used in this frequency range at full power rating, although the direct-reading wattmeter calibration will be off.

## 5. VOLTMETER HOUSING DESCRIPTION

a. The schematic diagram Fig. 2-4 indicates how the parts are arranged in the voltmeter housing, consisting of the FRAME CASTING and the COVER CASTING. The circuit elements are designed into the structure to obtain the necessary rigidity. Heat resistant dielectrics are necessary in this instrument and such parts are made of either teflon or ceramic.

### WARNING

NO PARTS IN THE VOLTMETER MAY BE REPLACED WITHOUT AFFECTING THE CALIBRATION.

b. DETAILED DESCRIPTION

(1) The probes, which form part of C-101L and C-101H, appear on Fig. 2-4 as heavy vertical conductors entering holes in the sheath of the rf load lines. Teflon caps surround the projecting portion of the probes and retain the coolant. These probes consist of a tubular sleeve, and a tip, adjustable by spring-locked threads. This calibrating adjustment serves to vary the capacitance of C-101 by varying the distance between the probe and center conductor.

(2) The shunt capacitors C-102L and C-102H are each coaxial, consisting of an outer brass tube electrode, a ceramic sleeve dielectric and a center beryllium copper electrode. The spring center contact for the crystal is integral with this center electrode.

(3) RESISTORS R-102L and R-102H are 1/2 watt conventional metalized resistors.

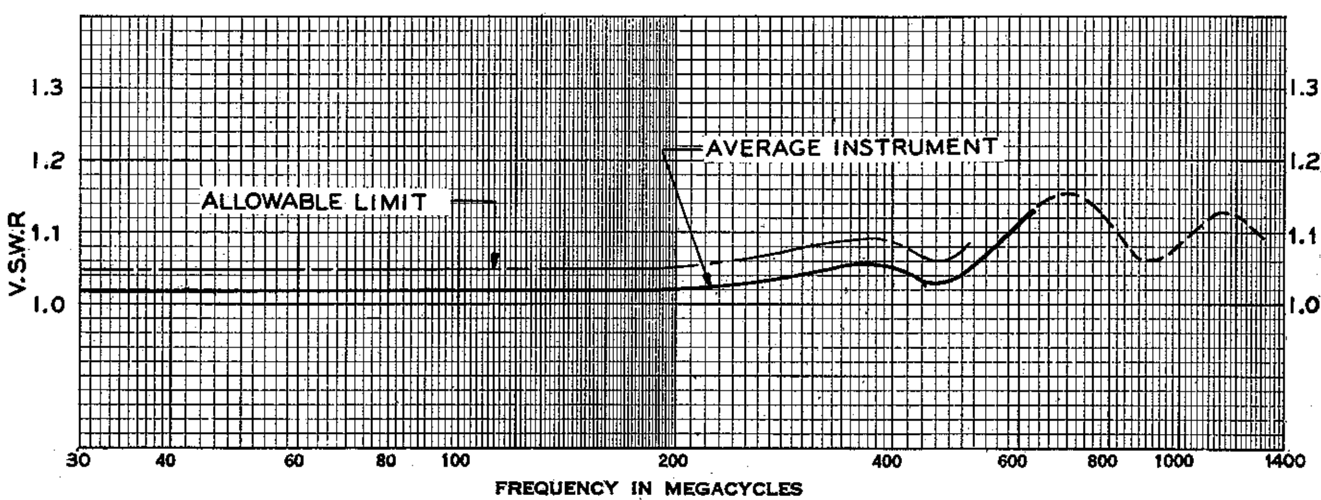


*Fig. 2-5. Voltage Standing Wave Ratio vs. Frequency — RF Wattmeter Model 61*

(4) BY-PASS CAPACITOR C-103 is a feed thru button mica type. This capacitor is built into d-c output jack J-103, to obtain the most effective by-pass action with a minimum of residual inductance. As a result of careful design of this by-pass arrangement as well as of shielded d-c cables and a shielded meter, the wattmeter is very insensitive to external rf fields which might otherwise get to the crystal along the hot d-c lead.

## 6. CRYSTAL DIODE HOLDERS (See Fig. 5-1)

a. SHIELDING - Since the crystal diode is detachable for range selection it is highly desirable that it be enclosed in a shielding holder. The main reason for this is to prevent high voltages from being impressed across the crystal at the moment of insertion or removal. Such voltages can appear as a result of static charges on the operator's body or from external rf fields. Since the shield makes contact with the wattmeter first, no externally caused voltages can appear across the crystal.

b. FLOATING MOUNT - It is important that the crystal be flexibly mounted in the holder to avoid radial pressure (side pressure) on the center contact pin of the crystal. Such pressure would occur in a rigid mount if any slight eccentricity existed in either crystal, holder or socket J-102. The design of the crystal holder is shown in Fig. 5-1 and is effective in preventing variation of readings as the crystal is repeatably inserted or rotated in its socket.

## 7. CRYSTAL VOLTAGE LEVEL

The crystals operate at 1.2 volts and 100 microamps, rectified d-c, for full scale on either range. These values are conservative with respect to overload damage. It has been determined that four times full scale power can be applied momentarily without appreciable change in crystal characteristics or calibration. Since the crystal voltmeter is connected across the load resistor, substantial power is required for voltage overload.

## 8. CRYSTAL STABILITY AND RELIABILITY

a. ADVANTAGES - The silicon crystal rectifiers used are comparable and in some respects superior to electron tube diodes. Some of their advantages are: Smaller size, no filament supply, and no zero shift with time or change in line voltage.

b. STABILITY - This wattmeter applies the output of crystal diode rectifiers for calibrated direct-reading voltage or power measuring use. Most people are familiar with crystal diodes in different applications, such as detectors in receivers. The stability realized may prove surprising to those who have not had the opportunity to use such crystals with good standards of rf measurement. From a long program of measurements in the laboratory and from field experience with many similar instruments in industrial use, it has been found that calibrations will hold as well as in electron tube voltmeters. There is no indication of long time aging and calibrations may be expected to hold within 2% for variations chargeable to the crystals.

## 9. CRYSTAL SELECTION

Joint Army-Navy (JAN) specifications on these crystals allow considerable variation in characteristics other than stability, making special selection for wattmeter applications necessary. For this use, crystals are selected for the following properties, which are not entirely independent:

a. Sensitivity at one point
b. For curve shape (rf input vs. d-c output) over the range used in the wattmeter.

The two crystals calibrated with and furnished with each wattmeter are selected for identical readings on both tests above. Crystal classification tests are made at one frequency only, since there is no significant frequency difference between crystals.

Crystals furnished with different wattmeters differ considerably in sensitivity. Difference is approximately 20% in power from the average crystal sensitivity. An error of about this magnitude (20% ±) could be expected if a randomly selected JAN-1N79 were used in an emergency.

## 10. VOLTMETER-FREQUENCY CHARACTERISTICS

CONTROLLING FACTORS - Three major factors were considered in design to provide flat frequency response:

a. The voltage ratio of the capacitance divider versus frequency. Mechanical design was made to get desired result.

b. The voltage sensitivity of the crystal versus frequency.

c. The time constant effect, which causes the sensitivity to decrease with frequency near the low end of the range. The time constant is the product of R-102 and C-102 in Fig. 2-3. This product must be made sufficiently high to maintain a full charge on C-102 between successive positive peaks of the input radio frequency.

## 11. POWER CALIBRATION VS. FREQUENCY (See Fig. 2-6)

a. Fig. 2-6 is an illustration of the blank of a Calibration Card (for Model 611) which is furnished with the respective wattmeter equipments. The scale accuracy at applicable power levels and the power correction factors over the assigned frequency range of the attached wattmeter are inscribed on the card. Sample figures for a typical equipment (not applicable to any unit) are inscribed on the figure blank.

b. These corrections will remain within the limitations of ± 2% of full scale for the power scale and ± 5% for variation due to frequency correction. If greater accuracy of measurement is desired, these factors may be applied where appropriate.

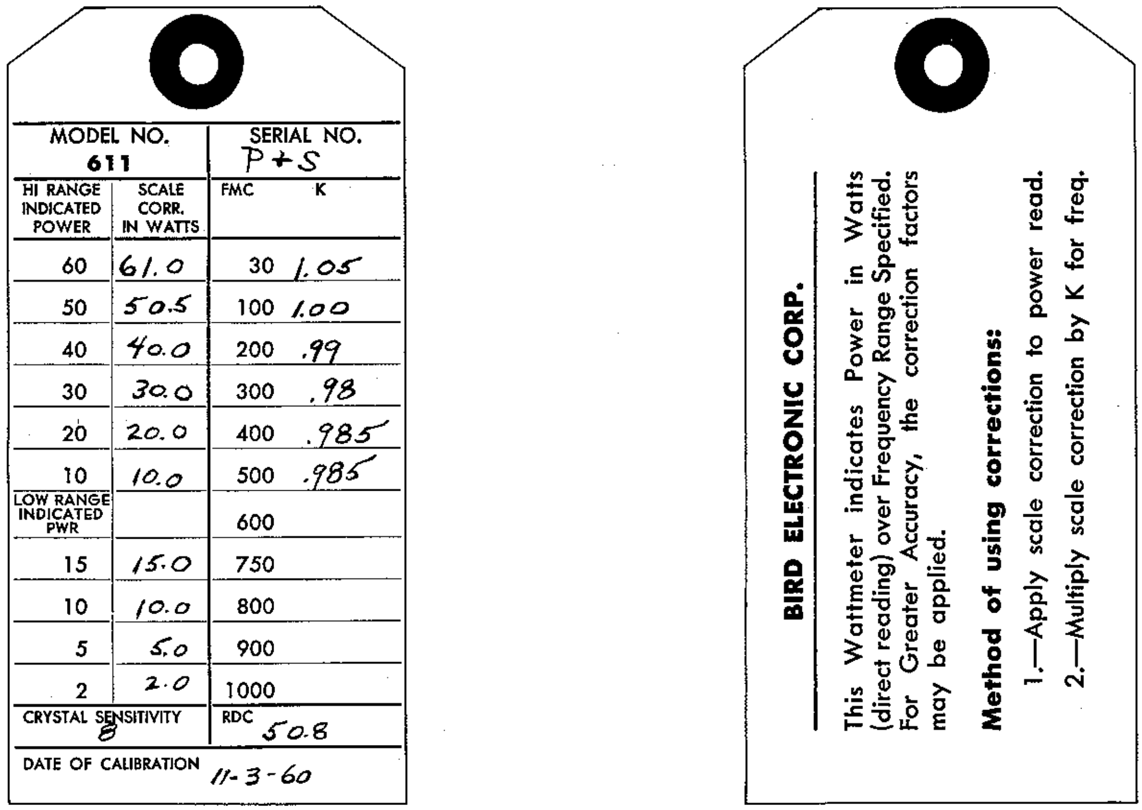


*Fig. 2-6. Power Calibration vs. Frequency — RF Wattmeter Model 61*

## 12. OVERALL ACCURACY

a. The combined effect of frequency and scale errors is within ± 5% for direct readings in the assigned frequency range. Of the two, the frequency error is the greatest and more difficult to control. Certain frequency corrections can be made as outlined above.

b. Frequency error and scale error are independent. Scale error is merely the combined effect of d-c meter errors and deviations from standard crystal curve shapes.

## 13. CALIBRATION METHODS

a. Wattmeters are calibrated at the factory with a special "THRU" or transmitted power direct-reading wattmeter. The wattmeters are rigidly connected to this special wattmeter.

b. The wattmeter reads power at the rf input Jack J-101, so that connecting cable losses, if they matter in field use, are to be added to the wattmeter readings to get the exact power output of the transmitter.

## 14. COOLING SYSTEM

a. HEAT TRANSMISSION

(1) To assure full power rating, the cylindrical film resistor, R-101, is immersed in oil which carries heat by convection to the inside wall of the enclosing cylinder thru openings in the coaxial metal shell. From there heat is conducted thru the fins and carried away by air convection. The cooling system of the wattmeter is conservatively rated. It will handle rated power (80 watts) continuously without damage at an ambient temperature of 30° Centigrade (86° Fahrenheit).

(2) The coolant used is a high flash point transformer oil, conforming to Federal Specification VV-0-401.

b. ELECTRICAL SIGNIFICANCE OF COOLANT

The unit must be reasonably full of proper coolant or the rf input impedance and calibration will be changed. The dielectric constant of the coolant is an important factor in determining the input impedance. Careful attention has been given to obtaining a design which is leak proof under service conditions. In order to get both high quality rf connectors and a leakproof design, teflon insulators compressed as gaskets for the rf connections and "O" rings of synthetic high temperature resistant rubber are used.

Slight leaks are not of too great significance except in the case where they appear to come from within the voltmeter housing. In this case the leak probably originates around the teflon caps sealing off the voltmeter probes. If this occurs the calibration should be checked as in Section 4, Paragraph 9. Leaks at other points, including the rf input connector J-101 will be of much less consequence and become serious only thru cumulative loss of coolant. From this standpoint, a loss of 10% of the coolant volume has a negligible effect on calibration and power rating.

## 15. TEMPERATURE EFFECTS

a. Particular attention has been given to design so that ambient temperature has negligible effect on power calibration and input impedance within its specified temperature range.

b. The Voltage Standing Wave Ratio changes less than .02 between "no" load and full load (80 watts). The voltmeter circuits have a small temperature coefficient, amounting to an increase in power readings of less than 0.08% per degree Centigrade for metal temperatures measured on the outside of the voltmeter housing. At this point, the full load temperature rise is about 30° Centigrade, so that the temperature error is not over 2.4% at full load.

## 16. INPUT RESISTANCE-D-C, SIGNIFICANCE OF

a. An accurate measurement of the d-c resistance at rf input Jack J-101 is a very good check on the condition of the load resistor with respect to rf input impedance and calibration. The d-c resistance measured at calibration will be found stamped on the top of the voltmeter housing. A check of the d-c resistance will show up anything significant which may happen to the rf input impedance, except for the effect of radically low coolant level or substitution of wrong coolant.

b. This d-c resistance measurement should be made with an accuracy of plus or minus 1% on a bridge such as Resistance Bridge ZM-4/U. A measured value differing by more than two ohms from the value marked on the voltmeter housing is significant of calibration change. A resistor which has been subjected to considerable overload normally measures higher in resistance.

# SECTION 3
# INSTALLATION

## 1. PORTABILITY

The RF Wattmeter Model 61 is essentially a portable test equipment instrument. It should be placed as close as possible to the point at which the power output reading is desired.

## 2. OPTIONAL FIXED MOUNTING

a. The wattmeter may be fastened to an operating table, test bench, etc. For this purpose, the four rubber feet may be unscrewed from the bottom of the radiator, and the four tapped holes used to mount the wattmeter.

b. If the wattmeter is to be mounted on rigid benches, etc. which are not shock mounted, use shock mounts under the wattmeter, to replace the shock protection afforded by the rubber feet. The central bushings of suitable small shock mounts may be attached to the tapped holes in the bottom of the wattmeter, and the flanges of the mounts screwed to the mounting surface or to an auxiliary metal plate.

## 3. LOCATION

a. Free circulation of air around the wattmeter is necessary if operated above 30 watts for more than a few minutes. Keep it reasonably in the clear, and avoid mounting it on, or alongside of, heated surfaces.

b. Where possible, operate in the normal position, feet resting on a horizontal surface, with at least 4" clearance on all sides. Space above wattmeter should be kept as clear as possible for good heat convection. Air cooling is most effective in this position and it is important above 30 watts.

c. AVOID operation in the "J-101 UP" position, i.e. resting on the expansion diaphragm cap at the rear of the radiator. In this position, any air within the coolant space will collect around the voltmeter probes (Fig. 2-4) and a change of dielectric constant in this region will affect calibration.

## 4. REMOTE USE OF METER BOX

a. The meter box is quickly detachable, as shown in Fig. 1-2. This box contains only the d-c indicating meter, which may be located remote from the resistor-voltmeter unit if required.

b. D-C connection, for remote meter operation, is made with the d-c cable W-101, normally coiled inside the meter box; or other shielded wiring.

c. The d-c circuit external to the resistor-voltmeter unit is not critical as to length, placement or to circuit resistance if this resistance is less than 50 ohms. If wiring other than the cables furnished are used they should be shielded, ungrounded, have good insulation and be reasonably free from audio and rf crosstalk. The d-c meter has a 100 microampere, 270 millivolt, full scale sensitivity. If the entire d-c circuit is not visible, check it with a volt ohmmeter before connecting to the meter M-101. Be sure that the circuit will not be disturbed while in use.

## 5. LATCH MECHANISM

a. Referring to Fig. 1-2 and 3-1, the meter box is normally retained on the resistor voltmeter unit (as in Fig. 1-1) by bowed-spring action of the LATCH SPRING, a rod of heavy music wire.

b. The box is removable by raising the buttons, first one, then the other, to lift the spring above the notch in the hook.

c. Pull the box forward and rotate to the approximate position shown in Fig. 1-2. Uncoil cable from meter box and connect dc plug to J-103 on the voltmeter block. Locate resistor-voltmeter unit and meter box as desired. The meter box should be used in the horizontal position. If it must be read in vertical position, the rubber foot may be unscrewed from bottom of meter box. To avoid loss, screw it back into the same hole but from inside the box.

d. To reassemble, disconnect at voltmeter, J-103. Coil the cable W-101 within the meter box and around the meter, as in Fig. 1-2. With meter box in about the relative position of Fig. 1-2, tuck excess cable in by working the loops out into corners of meter box. See that both crystal diode CR-101 and Cap-H-101 are plugged in. Reconnect to J-103 as shown in Fig. 1-2. Rotate the meter box to position, engaging 4 pins or corners of radiator and noting that cable W-101 is not kinked or pinched. Engage the latch spring per Fig. 3-1, first one button, then the other. The second will be found to resist with stiff spring action. Check by pulling on the meter box.

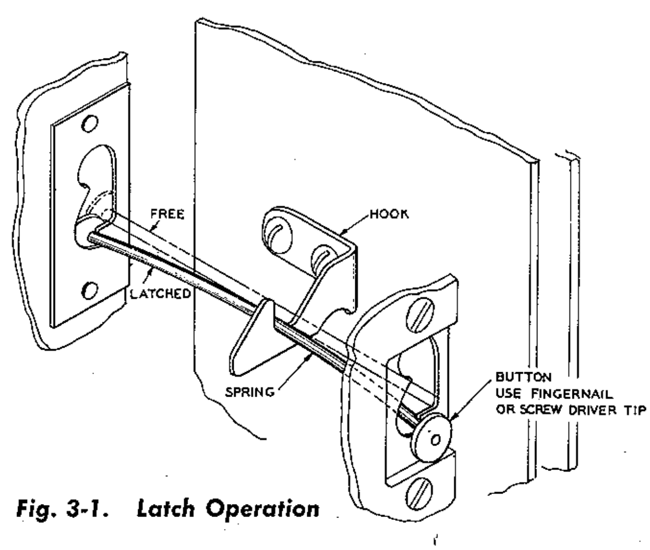


*Fig. 3-1. Latch Operation*

# SECTION 4
# OPERATION

## 1. TO MEASURE TRANSMITTER POWER

a. Locate the wattmeter where a short patch cord, preferably not over 5 ft. long, will connect the transmitter to the wattmeter and where conveniently readable while adjusting the transmitter.

b. Insert the crystal holder CR-101 in either J-102L or J-102H, thus selecting the desired power range, marked above the jacks on the meter flap. If in doubt select the high range. Push the crystal holder V-101 firmly in the jack until a positive stop is felt.

c. With the TRANSMITTER OFF, disconnect the antenna line and connect the wattmeter as shown in Fig. 4-1.

d. Use a patch cord, consisting of a 50 ohm cable such as RG-8/U and 50 ohm Type "N" plug, such as the UG-21/U series.

e. Turn the TRANSMITTER ON. The wattmeter will indicate the power being delivered. Read the wattmeter, using the 15 watt range if indication is below that value.

f. If adjustment of the transmitter is necessary, follow the pertinent instruction book. OBSERVE SAFETY PRECAUTIONS about high voltages in the transmitter. The wattmeter indicates results of tuning direct in watts for the standardized termination of 51.5 ohms afforded by the wattmeter.

g. When desired output power has been obtained, NOTE THE READINGS of the wattmeter, and of the meters provided on the transmitter, particularly of the plate current and voltage meters on the final stage and of antenna line monitor. These readings bear a direct relationship to power output, and are useful in relating transmitter output to its antenna to output into the wattmeter.

h. TURN TRANSMITTER OFF before opening RF connections to the wattmeter.

i. RECONNECT THE ANTENNA LINE, TURN TRANSMITTER ON and note its meter readings. If the antenna impedance (VSWR) is correct, the transmitter meters will read as they did with wattmeter connected. Some allowances should be made for the fact that VSWR's around 2 to 1 are normal at some frequencies in the range of good broad-band antennas.

j. In case of a significant difference between transmitter meter readings on wattmeter and antenna, RETUNE THE FINAL TANK AND ANTENNA COUPLING, using plate dip methods or antenna monitor readings as specified in instruction book for transmitter.

k. REPEAT THE ENTIRE PROCESS FOR EACH NECESSARY FREQUENCY.

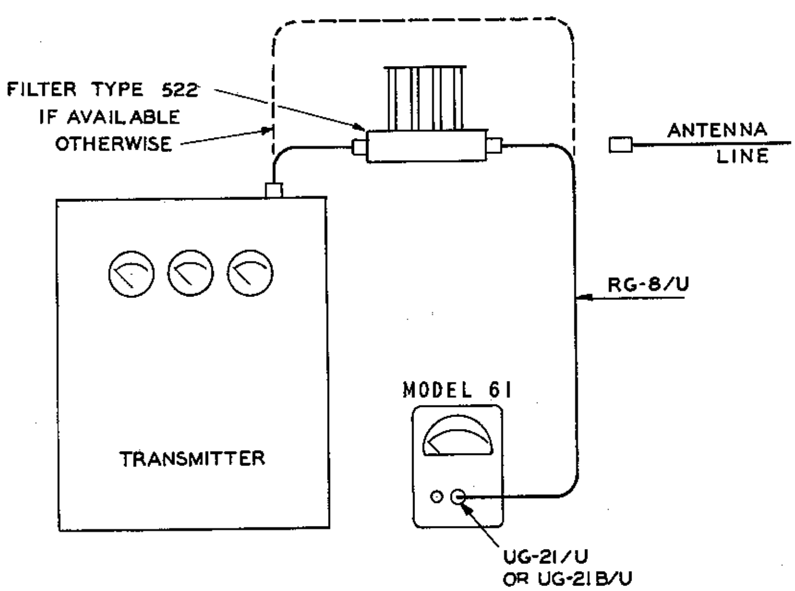


*Fig. 4-1. Typical Connections to Transmitter*

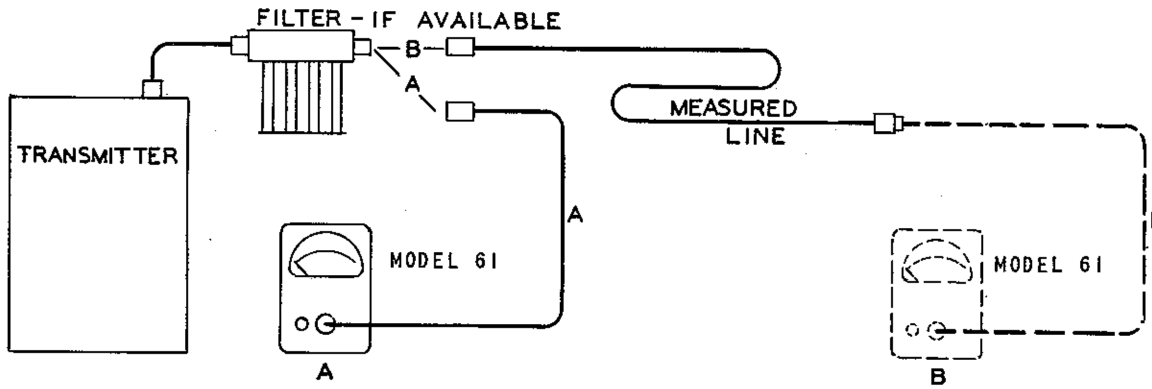


*Fig. 4-2. Line Loss Measurement — Block Diagram*

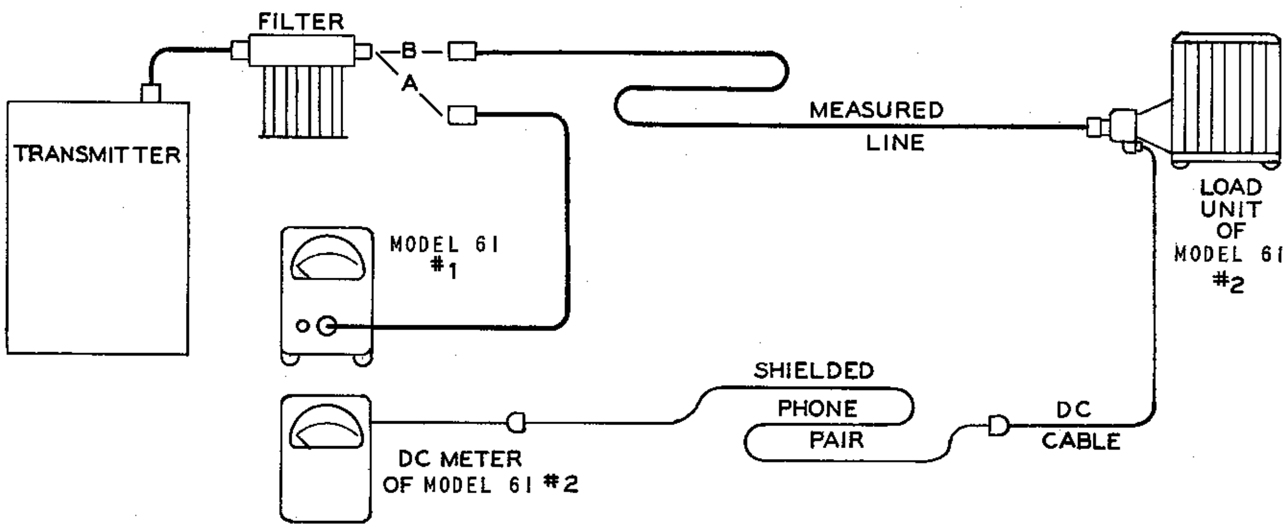


*Fig. 4-3. Line Loss Measurement — Remote Use of D-C Meter — Block Diagram*

## 2. TO MEASURE LINE LOSS

a. GENERAL - Loss measurements on 50 to 52 ohm coaxial cables may be made with the wattmeter. A transmitter whose rated output is 15 watts or more is required as a test power source. Assuming a power source of 30 watts and a minimum reading of 1 watt on the 15 watt range, the range of measured loss is 0 to 15 decibels for readable accuracy.

b. TEST PROCEDURE (See Fig. 4-2 and 4-3)

### WARNING

Always turn power off when connecting or disconnecting wattmeter or antenna.

(1) Connect the wattmeter to the transmitter ("A" connection of Fig. 4-2 and 4-3). Read output power and tune final stages of transmitter for maximum power output "$P_1$".

(2) Connect line to be measured to transmitter and connect wattmeter to far end of line ("B" connection of Fig. 4-2 and 4-3). Read power "$P_2$" if the transmitter meters do not indicate a significant change in loading. Good lines terminated by the wattmeter should show little change in transmitter loading from that with wattmeter alone. Where significant changes occur, the voltage standing wave ratio of the line is high and attenuation measurements by this method should be disregarded. Cause of high VSWR should be investigated.

(3) The loss may be expressed either as a power ratio P1/P2, or in decibels using the formula:

$$\text{Loss} = 10 \log_{10} \frac{P1}{P2} \text{ decibels}$$

(4) Example: Assume $P_1$ is equal to 30 watts with wattmeter connected to transmitter. Assume $P_2$ for the "B" connection is 11.5 watts, with the transmitter operating conditions unchanged. Substituting these figures in the above formula:

$$\text{Loss} = 10 \log_{10} \frac{30}{11.5} = 10 \times .416 = 4.16 \text{ db.}$$

c. ACCURACY

(1) The procedure and accuracy of this method is suitable for installation, operating and maintenance activities. It is a practical measurement in that the combined effects of true attenuation (power lost in heating the line) and of reflections caused by the line are given by one measurement.

(2) With reasonable care in holding the transmitter power constant, this method is accurate to within 0.5db. Under the best conditions, results within 0.2 db. are obtainable, providing the VSWR of the measured line is low.

d. ALTERNATE CONNECTIONS

(1) When both ends of measured line terminate in the transmitter room, one wattmeter measurements are convenient (See Fig. 4-2).

(2) A dual set-up with wattmeters and personnel at each end of the line may be used where the far end of the line to be measured is remote, especially when a number of frequencies or parallel lines are to be checked. With readings to be taken at both ends, a telephone connection serving as an order wire will save time.

(3) Fig. 4-3 shows one way of carrying out line measurements from the transmitter room only, when far end of line is remote.

(4) Another way, when two or more rf lines run parallel between measurement points, is to join two lines with a patch cord at the remote end, then measure the loop back to the transmitter room. For identical lines, the loss of one is half the loop loss, or the loss of one good line can be otherwise determined and subtracted from the loop loss.

## 3. TO CHECK COAXIAL INSERTION DEVICES

a. The term insertion devices is used to mean all forms of connectors, patch cords, switches, relays, filters, tuning stubs, etc. These devices are normally low loss units and true power loss is frequently below that measurable with accuracy. Insertion devices specifically designed for high attenuation may be checked for their loss as outlined in Paragraph 2 above.

b. Tests made in accordance with Paragraph 2 above will not show a readable power loss for a low loss insertion device in good condition. These tests may be considered "IN-OUT" tests in which the optimum performance is indicated by no readable change in wattmeter reading, whether the insertion device is in or out.

c. Tests may be either routine, simply to see that the device works, or they may attempt to discover more closely just what the insertion effect is. In the latter case time stability of the transmitter is all important since the results depend on the difference between two readings not taken simultaneously.

## 4. MODULATION MONITOR

On amplitude modulation, the d-c meter action of the wattmeter is typical of diode rectifiers, i.e., meter reading generally is constant regardless of normal modulation.

a. AUDIO AVAILABLE - When connected to an amplitude modulated transmitter, audio signals are present across the d-c meter terminals thru the demodulating action of the voltmeter diode. This signal may be used conveniently for monitoring modulation aurally, and for certain measurements on audio characteristics of the transmitter. Specific connectors are not provided for this use.

b. CONNECTIONS

(1) High impedance phones may be bridged across the d-c meter, most conveniently by cutting into the long d-c cable W-102, or by using the d-c plugs P-101 from this cable together with other cables of RG-58/U made up for this purpose. Refer to Figs. 5-2, 5-3 for details of the plugs and of cable service, which does not require soldering.

(2) If an audio coupling capacitor, of .01 to 0.1 mfd. value, is used in series with the phones, the power calibration will be unaffected by the d-c shunting action of the phones.

(3) Higher audio signal level is available by connecting phones only to J-103 (i.e. d-c meter disconnected). However, where possible, it is preferred to bridge the phones across the meter.

(4) In all cases, connect an rf bypass capacitor, 100 to 500 mmf button mica, across the d-c cable (the wattmeter side) at the point where the center conductor emerges from the shield. Keep leads very short, or eliminate by soldering cable conductors directly to the bypass condenser terminals. While in most cases this precaution would be unnecessary, it would give additional protection to the crystal for occasional moments when stray voltage could be externally impressed across the phone terminals.

**Caution**

In all such use of the wattmeter, use care to avoid stray voltage being impressed across the d-c cable from the wattmeter. Remove crystal before changing connections to the external d-c circuit. A small shielded box for the phone jack is advisable. Because of body static particularly, and rf secondarily, don't touch the hot d-c lead while connected to the crystal.

## 5. AUDIO RESPONSE MEASUREMENTS

With suitable auxiliary equipment including an audio oscillator, audio voltmeter and amplifier, the audio response curve of a transmitter may be run. Best results are obtained by connecting a resistance, 500 to 1000 ohms, in place of the d-c meter, and the amplifier input across this resistance. Without an amplifier, an audio voltmeter, approximately 1 volt full scale, will give usable deflections connected across J-103, without any shunt resistance or d-c meter. Bypass capacitor C-103, 500 mmf., will in most cases have negligible effect on high audio frequency transmissions.

## 6. DISTORTION

The crystal diode CR-101 is not linear enough as a voltage rectifier to make accurate checks on distortion percentages. However, serious forms of distortion in the transmitter can be detected aurally.

## 7. USE AS A DUMMY LOAD ONLY

By removing crystals, RF Wattmeter Model 61 becomes an accurate termination of 51.5 ohms at all frequencies from zero (d.c.) to the top frequencies at which 51.5 ohm coaxial lines are usable.

## 8. USE AS A LOW FREQUENCY WATTMETER

Below the calibrated range power may be measured by utilizing the wattmeter as a dummy load as specified above and measuring the terminal voltage with an accurate electronic voltmeter suitable for the frequency being measured. The power may then be calculated from the equation $W=E^2/51.5$ where E is the root mean square voltage measured by the vacuum tube voltmeter. Caution: Do not exceed the rated power dissipation of the wattmeter which is 80 watts.

## 9. GENERAL OPERATING NOTES

a. (1) Be careful about the condition of rf cables and connectors used in the rf circuit to the wattmeter. Proper assembly of connectors to cables is important for electrical reasons.

(2) Avoid faulty assembly of the UG-21/U Plug connecting to J-101 on the wattmeter. The center contact sleeve of J-101 is not easily replaceable if damaged.

(3) Patch cord lengths, adaptors and connectors should be kept to a minimum. Type "N" or other constant impedance, 50 ohm, connectors and adaptors should be used.

(4) Where non-constant impedance connectors must be used, as with transmitters having the output jack, Navy type 49194 (Type SO-239), keep them at the transmitter jack only, so that patch cord will be free from standing waves. In other words, the VSWR will be low on good 50 ohm cables and fittings, from the wattmeter back to the first significant discontinuity, and this should include as much of the total circuit length as possible.

(5) Adaptors, of any type, should be used at the transmitter end rather than at the wattmeter end.

(6) The coaxial cable (patch cord) connecting the transmitter to the wattmeter should be made up of a 50 ohm cable with a UG-21/U series plug at one end for the wattmeter connection and a plug mating with the transmitter jack for the other connection. This procedure eliminates the need for additional adaptors. For example, if the transmitter utilizes a Navy Type 49194 Jack, the connecting cable should be made up of a UG-21/U series plug, RG-8/U cable, and a Navy type 49195 plug.

(7) Use only 50-52 ohm cables and fittings if possible. Thus, even in the case of a transmitter having nominal 75 ohm output, 50 ohm lines should be used up to the necessary point of change to something else, at the output jack of the transmitter. Equal impedance of wattmeter and cable is more important than equality between transmitter and cable.

b. OPERATORS TESTS FOR ACCURACY

(1) Operating checks should consist mainly of comparison between wattmeters of this type.

(2) The spare crystal may be checked at any time against the installed crystal. When a steady power reading has been obtained with one crystal, remove it and insert the other. Repeat if necessary to eliminate transmitter variations with time. Results should check within 3% of full scale.

### WARNING

INSERT ONLY ONE CRYSTAL AT A TIME

(3) The two power ranges may be cross checked most accurately at 10 to 15 watts input power. The 60 watt range should read within 2 watts of the reading on the 15 watt range.

(4) Comparison of two wattmeters is a practical check on both. Using precautions about time stability of the transmitter, readings should be equal within 10% of the reading (not of full scale) and normally within 5%, for readings above 1/5 of full scale. Assuming both wattmeters unchanged from time of calibration, the largest sources of error in this comparison are:

(a) The real error due to the possible differences in frequency calibration curves (Fig. 2-6).

(b) The apparent error due to normal differences between the exact input impedance values of the two wattmeters.

Minimizing (b) above depends upon whether the transmitter shows a direct relationship between final plate current and power output and whether it has an antenna coupling adjustment. Wattmeter comparisons can be more accurately made by adjusting tuning and coupling on the final tank to the same plate current and voltage values for each wattmeter.

c. WATTMETER VS. ANNTENNA AS LOADS

(1) The wattmeter may load the transmitter differently from the antenna. This may be normal for broad band antennas due to voltage standing wave ratio variation at different frequencies. Since the purpose of the transmitter is to drive the antenna, a slight retuning of the final tank and antenna coupling may be advisable as described below.

(2) An antenna line monitor (provided in certain transmitters) indicates relative voltage or current at one point in the antenna circuit. The final adjustments should aim at peaking this meter. It will correctly indicate relative power output as long as the load impedance remains fixed. A change of antennas or frequency may cause large variations in load impedance and therefore the monitor readings are unreliable for indicating absolute power.

(3) The line monitor may show a large change of reading, roughly as much as 2 to 1 for a 2.0 VSWR, when the antenna is substituted for the wattmeter.

(4) The power values into the antenna and the wattmeter will be essentially equal if the VSWR on the antenna line is small. This condition may be recognized if after peaking employing either the line monitor or plate current dip as an indicator, the final amplifier plate current and plate voltage are the same.

d. RESPONSE TO HARMONICS AND PARASITICS

(1) The wattmeter is a broad band instrument and its action with presence of harmonics or other spurious frequencies should be considered.

(2) Wattmeter sensitivity decreases with frequency above 500 mc and below 1400 mc. Laboratory and field experience indicate that low order harmonics in this range do not appear to be serious sources of error. However, to avoid measurement error and interference troubles it is highly desirable to eliminate all frequencies except the carrier desired. Such filters as have been provided for interference control should be installed when employing the wattmeter as shown in Fig. 4-1, 4-2, 4-3.

(3) Above 1400 mc, two sensitivity peaks are present in the wattmeter sensitivity curve. These are approximately 1700 and 2600 mc where resonances occur in the voltmeter circuit and cannot be eliminated without ruining the flat sensitivity obtained for normal frequencies. These peaks are of the order of 20 db above the wattmeter sensitivity at normal frequencies, so that erratically high readings occur if a spurious frequency in the transmitter output coincides with one of them. Low pass filters, such as Type 522, will eliminate such trouble should it appear.

(4) Operating symptoms of wattmeter response to these high spurious frequencies are:

(a) Erratic high readings.
(b) Occurs usually at certain carrier frequencies only.
(c) Reading very sensitive to slight movement of the crystal diode CR-101, in and out of the Jack, J-101, within the contacting range. Normally this makes very little difference.
(d) Transmitter tuning adjustments much more critical than normal.

(5) To attenuate these spurious responses, insert a Low Pass Filter, such as Type 522 for tests below 400 mc, and a similar filter but of higher cutoff frequency if measurements must be made above 400 mc. Such filters have been found to eliminate the trouble completely in cases where it has occurred. Operation of the wattmeter should not continue when large spurious responses are present since the crystal may be damaged by excessive voltage overload.

# SECTION 5
# MAINTENANCE

## 1. INTRODUCTION

The circuit simplicity and mechanical design of the wattmeter result in a minimum of maintenance since all electrical circuits are sealed and rigidly mounted.

Parts within the rf unit of the RESISTOR-VOLTMETER unit, Fig. 1-2, are not subject to field maintenance. This unit should not be opened except at the filler plug to check coolant level.

Preventive and corrective maintenance are grouped together in this section.

## 2. GENERAL MAINTENANCE

a. Keep jacks and plugs clean. The best method is to make sure that crystal diodes CR-101 and CR-102, and Cap H-101 are inserted in their jacks at all times. D-C connector of Cable W-101 should be kept connected to exclude dirt and moisture.

b. The Plug P-101 should be kept tightly screwed on to its jack. If it has been undisturbed for long periods, loosen the knurled collar slightly, and move right angle barrel to clean contact surfaces. Then retighten.

c. Dropping is the most likely source of damage, the D-C Meter M-101 being the critical item. DO NOT DROP IT. Close the METER FLAP when not in use, particularly when carrying the wattmeter around.

d. DO NOT allow the crystal diodes to be separated from the wattmeter. Keep the working crystal diode CR-101 and Cap H-101 on the ball chain provided for them. Restore the spare crystal CR-102 to its socket (under the meter box) after use, and secure with tape to supplement the grip of the socket.

e. If the spare crystal is to become the working crystal, attach it to the chain. This change may be readily made at the crystal end.

**Note**

New crystals should be requisitioned immediately upon damage to either CR-101 or CR-102. The serial number of the wattmeter for which intended MUST be entered on the requisition.

f. When two wattmeters are used together, do not allow the crystals to be mixed up between wattmeters. They are NOT interchangeable between wattmeters without loss of calibration.

g. The same precaution applies to interchanging meter boxes and resistor-voltmeter units, although calibration changes will be small. Matching serial numbers appear on the nameplate mounted on the meter box and stamped on one of the bottom corner rails of the RESISTOR-VOLTMETER unit. (See Fig. 1-2)

## 3. CRYSTAL UNIT

Fig. 5-1 shows the mounting of the crystal diode in its holder. Refer also to Section 2, Paragraph 6 and 8.

a. The SEAL "O" RING, Fig. 5-1, should be checked semi-annually and kept lubricated very lightly, with Dow Corning "4" compound, a non-melting silicone dielectric and lubricant manufactured by Dow Corning Corporation, Midland, Michigan.

b. The shield contact fingers may need occasional attention to maintain pressure against the inside wall of the Jacks, J-102L and J-102H. Make slight adjustments by bending. CAUTION. Do not allow tool to touch center contact of crystal.

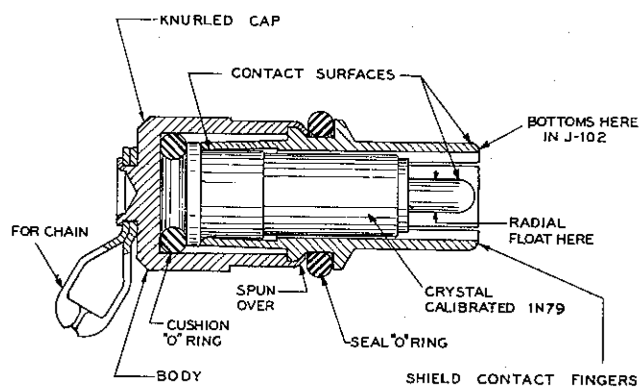


*Fig. 5-1. Crystal Unit, Rectifying Crystal Diode, CR-101, CR-102*

c. In an EMERGENCY where the wattmeter must be used and both crystals supplied with instrument have been damaged or lost, any 1N79 crystal may be used in the wattmeter with a probable error ranging up to 20%. See Section 2, Paragraph 9. To remove crystal from the holder (See Fig. 5-1) remove the seal "O" ring and file off the lip marked "Spun Over". If a drill press or lathe is available chuck the knurled cap and file while the holder rotates. The new crystal may then be used in the body of the crystal holder without the knurled cap.

## WARNING

KEEP CRYSTAL RECTIFIERS IN METAL BOX OR WRAPPED IN METAL FOIL EXCEPT WHEN IN USE OR BEING TESTED. WHEN INSERTING CRYSTAL RECTIFIER IN HOLDER, HOLD CRYSTAL RECTIFIER BY BODY AND TOUCH FINGER TO GROUND TO DISCHARGE ELECTROSTATIC CHARGES BEFORE INSERTION.

## 4. ELECTRICAL TESTS

a. The simplest overall test of the wattmeter is the comparison test discussed in Section 4, Paragraph 9.

**Caution**

REMOVE CRYSTALS FROM THE VOLTMETER WHEN MAKING TEST DESCRIBED BELOW

b. D-C METER TESTS - Testing of the meter should be attempted only by one familiar with circuits and instruments for testing of sensitive d-c microammeters because of the danger of damaging it in unsuitable circuits. Test the meter as a microammeter in series with a low voltage battery, variable resistor and an external microammeter. Full scale current on M-101 should be 100 microamperes ± 2%. Disconnect D-C Cable W-101 at Jack, J-103 so that W-101 will be tested with the meter.

**Caution**

M-101 is a sensitive microammeter. Do not attempt to check with an ohmmeter.

c. D-C PLUG AND CABLE TESTS may be made with an ohmmeter and megger. Disconnect cable from voltmeter Jack J-103 and meter M-101, by unsoldering leads, for test. Check continuity and leakage.

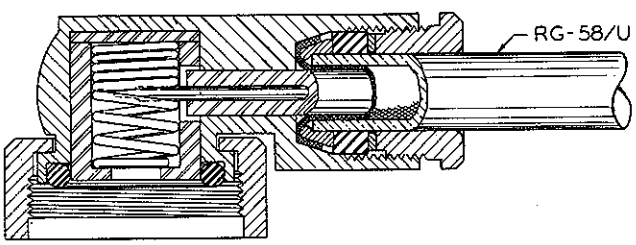


*Fig. 5-2. Connector, Plug (D-C Plug P-101)*

d. D-C PLUGS - CABLE SERVICE - Fig. 5-2 shows construction of the d-c plug P-101. Fig. 5-3 shows proper service of RG-58/U cable for these plugs. To remove cable from this plug unscrew the bushing and pull cable out. The center conductor of the cable makes tight contact between turns of the coil spring when assembled. For easiest assembly of cable to plug, flatten the end of center conductor as shown on Fig. 5-3, and align the resulting chisel point with turns of the spring while pushing in the serviced cable.

e. SIMPLE TESTS ON VOLTMETER CIRCUITS - Remove crystal and d-c plug from the voltmeter before making any tests.

(1) The resistance to ground measured at D-C Jack J-103 indicates the insulation resistance of both voltmeter circuits. This resistance should be over 20 megohms. Low insulation resistance probably indicates moisture within the voltmeter housing. The various jacks and the joint between frame and cover castings are not hermetically sealed.

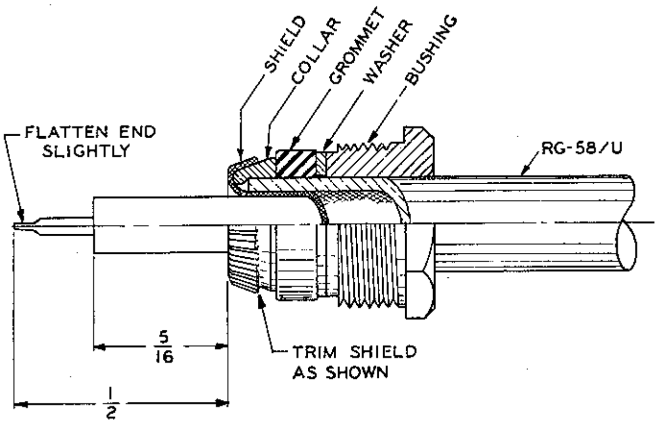


*Fig. 5-3. Cable Service For Connector, Plug (D-C Plug P-101)*

(2) Moisture within the voltmeter housing may be driven off by operating the wattmeter on rf power at 60 watts or by applying a maximum of 55 volts at 60 cycles to J-101.

(3) Resistors R-102L and R-102H may be measured between D-C Jack J-103 and respective center contacts of J-102L and J-102H. These resistors should measure 9100 ohms ± 10%. Differences within this tolerance are part of the calibration.

(4) Bypass capacitor C-103 may be checked with a capacitance tester, connected between the center contact of J-103 and ground with W-101 disconnected. Measured values should be 500 mmf plus or minus 20%.

f. TESTING THE LOAD RESISTOR

An accurate resistance measuring instrument such as A-N Type Resistance Bridge ZM-4/U good to 1% or better at 50 ohms is required. Refer to Section 2, Paragraphs 4 and 16. Using low resistance leads (preferably a short piece of RG-8/U connected to a UG-21/U plug) measure the load resistor R-101. A change of more than 2 ohms from the original value stamped on top of the voltmeter housing is an indication that the rf resistance has changed significantly and that the wattmeter should be replaced. The coolant level should also be checked when measuring the resistor.

## 5. CHECKING COOLANT LEVEL

The general significance of oil seepage or leaks which may occur has been discussed in Section 2, Paragraph 14. Avoid tampering with any of the various joints at which the oil is sealed.

The filler plug is on the conical reducer, Fig. 1-2 at the lower right. It is an "O" RING SEAL plug, removable with hex key wrench, size 3/16, Federal Standard Stock Catalog #41-W-2452. Before removing plug, place the RESISTOR-VOLTMETER unit in the "filler plug up" position. The coolant level should be at or within 1/4" of the innermost thread of the fitting. If necessary to add coolant, use only transformer oil, E-101, General Electric 10C Transil Oil, Bird part/dwg #5030.

# SECTION 6
# PARTS LIST

| SYMBOL | PART NAME AND DESCRIPTION | FUNCTION | QTY. |
|---|---|---|---|
| A-107 | SHOCK STRIP, Meter Mount: Neoprene tubing 5/16 O.D. x 9-1/2 in. long. Circled to fit A-108. Bird Electronic Corp. part/dwg. #750155. | Vibration mount for meter | 1 |
| A-108 | SHOCK MOUNT, Meter: Al alloy anodize, 3-1/2 O.D. x 3/32 thick. Circular shape formed to quarter round section. Two 10-32 steel nuts opposite diams. to fasten. Bird Electronic Corp. part/dwg #422087. | Holder for shock strip A-107. | 1 |
| A-111 | RESISTOR-VOLTMETER ASSEMBLY: Tapered and slotted coaxial line section with 51.5 ohm film resistor as center conductor. Female N connector. Includes 2 crystals (one spare), dummy crystal, O-ring 0-108 and clamping ring H-108. Bird Electronic Corp. part/dwg #750214. | Coaxial load resistor and voltmeter block assembly. | 1 |
| CR-101<br>CR-102 | RECTIFIER, Crystal: Silicon diode 1N79 calibrated, permanently installed in holder, 1-1/16 x 7/16 OA dimension. Bird Electronic Corp. part/dwg #750147. | RF rectifier. When ordering, specify Model and Serial Number of instrument. | 2 |
| E-101 | COOLANT: Dielectric fluid, GE 10C Transil oil. Bird Electronic Corp. part/dwg #5030. (one pint can) | Dielectric coolant. | - |
| H-108 | RING, Clamping: V-band Stainless steel, nickel plate 2-5/8 OD with two clamping blocks (one threaded) including #8-32 x 1 Rd. Hd. MS. Bird Electronic Corp. part/dwg #75047. | Holds resistor-voltmeter ass'y. A-111 to radiator. | 1 |
| M-101 | METER AND CABLE ASSEMBLY: DC microammeter, 100 ua 270 mv., 3-1/2 in. AWS dimension. 39" dc cable fixed to meter has dc connector P-101 at free end. Scaled as follows:<br><br>Model 61 - Specify scale -BEC part/dwg 750229-0<br>Model 611 - 0-12, 0-60 watts -BEC part/dwg 750229-1<br>Model 612 - 0-20, 0-80 watts -BEC part/dwg 750229-2 | Indicating meter. | 1 |
| O-102 | STEM BUMPER, Meter mount: Neoprene. Tapered pin 7/32 max dia x 11/32 lg. Bird Electronic Corp. part/dwg #750148. | Shock absorber for front of meter flange. | 3 |
| O-108 | SEAL, O-ring: Synthetic rubber ring 2 x 2-1/4 x 1/8 nominal - Linear #11-226. Bird Electronic Corp. part/dwg #75065. | Seal under clamping ring H-108. | 1 |
| P-101 | PLUG, DC: Part of Cable Ass'y. W-101. Silver plate 1-1/4 x 3/4 x 5/8 OA dimensions. Bird Electronic Corp. part/dwg #75076. | DC cable connector. | 1 |
| W-101 | CABLE, DC: Supplied with meter assembly. 39 in. RG-58/U with dc connector P-101 at one end. Bird Electronic Corp. part/dwg #81821-6. | DC meter cable | 1 |
| W-102 | CABLE, DC: Can be supplied in place of W-101 RG-58/U in any length for remote meter installation. Includes connector P-101. | Special dc meter cable | (1) |