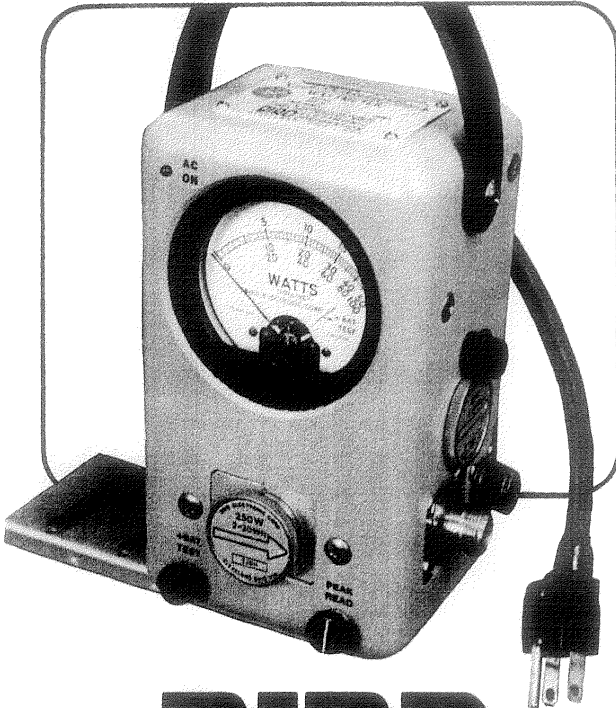


INSTRUCTION BOOK

**THRULINE<sup>®</sup>**  
**RF Directional**  
**Wattmeter**

**model 4311 - 4314**



**BIRD**

30303 Aurora Rd. Cleveland (Solon) Oh. 44139

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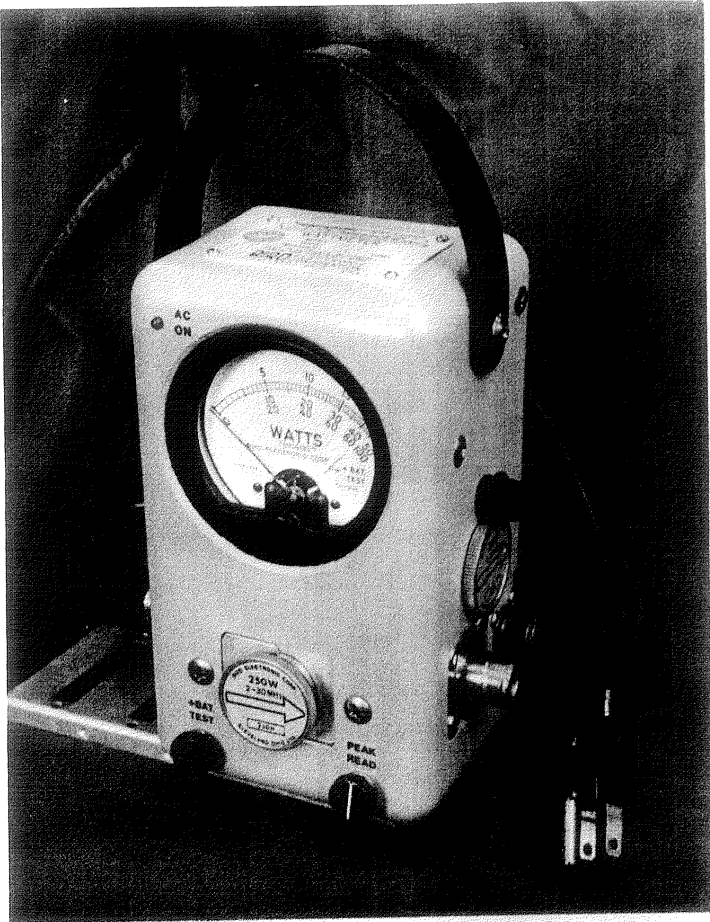


Figure 1-1. Thruline Wattmeter Model 4314.

# SECTION I. INTRODUCTION AND DESCRIPTION

## 1-1. SCOPE

1-2. This is an instruction manual for the THRULINE Wattmeter, Model 4314. See Figure 1-1. Information for the operation, service, troubleshooting, calibration, and repair of the unit has been incorporated in its contents.

This manual is prepared for use by the technicians to whom this equipment is issued and who are responsible for its operation and maintenance.

**TABLE 1. LEADING PARTICULARS**

Measuring Medium . . . . .	RF transmission in 50-ohm lines
RF power ranges:	
Average (CW) mode . . . . .	1 watt to 10 kilowatts ( $\pm 0.05$ of full scale)
Peak-pulse or envelope-power mode . . . . .	1 watt to 10 kilowatts ( $\pm 0.08$ of full scale)
Frequency Range . . . . .	0.45 to 2300 megahertz (either mode)
Pulse Parameters:	
Square pulses:	
Minimum duty factor . . . . .	$1.0 \times 10^{-4}$
Minimum repetition rate . . . . .	30 pps
Minimum pulse width . . . . .	0.4 microseconds at 100-2300 megahertz 1.5 microseconds at 26-99 megahertz 15 microseconds at 2-25 megahertz
Gaussian Pulses:	
Minimum duty factor . . . . .	$3.5 \times 10^{-4}$
Minimum repetition rate . . . . .	30 pps
Minimum pulse base width (at 10% of height) . . . . .	3 microseconds at 26-2300 megahertz 15 microseconds at 2-25 megahertz
Line Connectors:	
Standard . . . . .	Quick Change, Female N type
Optional . . . . .	Any common RF type
Weights:	
Set . . . . .	4 lbs. (1.8 kg)
Plug-In Elements . . . . .	3 oz. (85 g)
Basic Overall Dimensions:	
Height . . . . .	7 inches (177.8 mm)
Width . . . . .	4 inches (101.6 mm)
Depth . . . . .	3-5/8 inches (92.1 mm)
Input Power Requirements:	
Voltage . . . . .	104-126 volts/208-252 volts
Frequency . . . . .	50-60 Hz
Power . . . . .	1.5 watts
Batteries . . . . .	12V/50B, Gould-NiCad 6V/50B, Gould-NiCad

### 1.3. PURPOSE

1-4. The Model 4314 is an insertion-type Directional Wattmeter that measures and monitors RF power flow and load match in coaxial lines. It is used for measurement of CW, AM, FM, SSB, TV, and pulsed transmitter outputs, or practically any types of RF transmission in 50-ohm coaxial systems. It will indicate either average or peak power as required, according to the mode selected.

### 1-5. LEADING PARTICULARS

1-6. Leading particulars for the Model 4314 THRULINE Wattmeter are given in Table 1.

### 1-7. DESCRIPTION

1-8. The wattmeter is a portable unit encased in an aluminum housing fitted with a leather carrying strap. It is provided with a removable back panel to allow access to the operating components. It has four rubber bumpers on the upright or flat-laying position. The meter is shock mounted on the front panel. It has three scales to facilitate use with any of the available elements.

1-9. A line section casting, through which the RF transmission flows, is mounted in the housing so that one connector extends from the right side of the housing and the other connector extends from the left side. These ends are quick change type connectors secured to the line section body with four screws. Transmission lines are connected through mating connectors. Line connections can be reversed without affecting the accuracy or operation of the unit. A socket in the line section casting is provided for the insertion of the plug-in elements. This silver-plated brass line section is a precision unit that provides unimpaired impedance of the RF coaxial line into which it is inserted.

TABLE II. STANDARD PLUG-IN ELEMENTS

Use	Frequency (MHz)	Power Ranges (watts)
Average or pulse mode	0.45 - 2.5	1000, 2.5kW, 5kW, 10kW
	2-30	50, 100, 250, 500, 1000, 2500, 5000
	25-60, 50-125, 100-250, 200-500, 400-1000	5, 10, 25, 50, 100, 250, 500, 1000
Average or pulse mode	60-80, 80-95, 95-125, 110-160, 150-250, 200-300, 275-450, 425-850, 800-950	1 watt
	60-80, 80-95, 95-150, 150-250, 200-300, 250-450, 400-850, 800-950	2.5 watts
	950-1260, 1100-1800, 1700-2200, 2200-2300	1, 2.5, 5, 10, 25
Pulse Mode only	25-60, 50-125, 100-250, 200-500, 400-1000	2.5kW, 5kW, 10kW
	950-1260	50, 100, 250, 500, 2.5kW, 5kW

1-10. The wattmeter uses plug-in elements of the required frequency and wattage range to sense the transmission through the line section. These cylindrical elements are interchangeably inserted into the socket on the front face of the housing below the meter. By use of these plug-in elements the wattage range and frequency range is greatly expanded over that which could be provided in a fixed-element type meter. The plug-in elements incorporate the coupling circuits which sample the traveling waves in the line section. The elements are retained by a small catch at the lower left of the element flange of the line section. This catch assures proper retention and contact of the element in the line section. See Sec. 1-16.

1-11. Plug-in elements are available in a wide range of frequencies and power levels. Most of them are designed to read both average and pulse-mode power. Some of them are designed exclusively for pulse-mode reading operation. Available plug-in elements are listed in Table II. The plug-in elements of earlier average-reading-only wattmeters can be used with the average-or-peak-reading Model 4314 for reading wattage in either average or peak modes of operation.

1-12. The Model 4314 requires the 115 volt ac line power only for battery charging. A six-foot power cord is supplied, which attaches to the receptacle at the right side of the wattmeter. Without use of a switch, it applies energy to the charger whenever ac line is connected. A fuse, mounted in the holder on the opposite side of the housing, protects the equipment from excessive power loads. The pilot lamp at the upper left front of the case indicates when ac charging voltage is on. In localities where only 230 volts, 50 or 60Hz, is available, insert suitable 2:1 voltage step-down transformer. Those provided for razor or small appliance use are satisfactory.

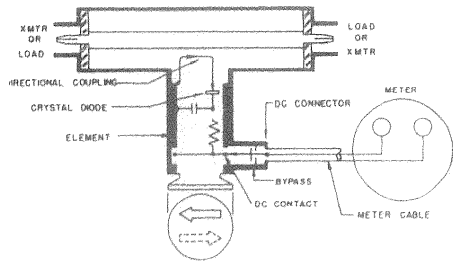
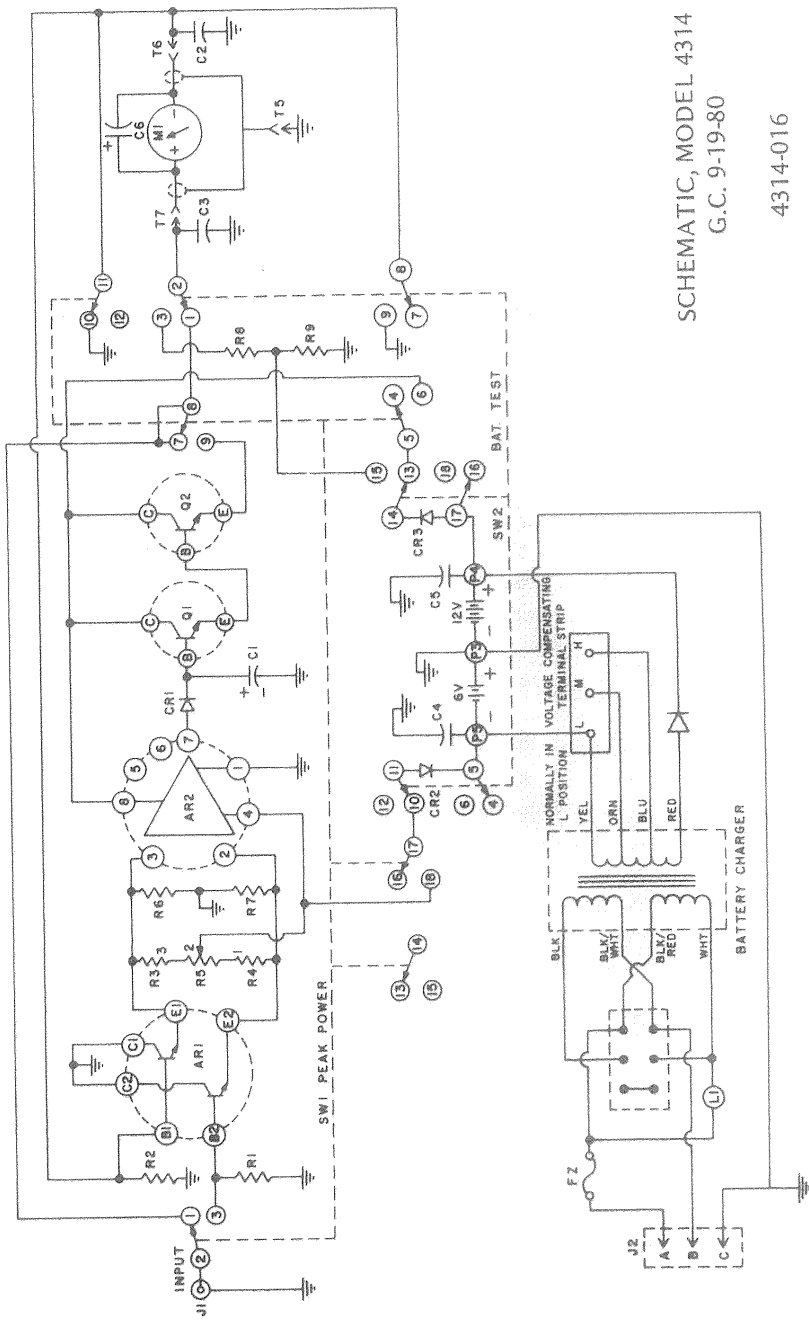


Figure 1-2. Wattmeter Average-Reading Operation, Schematic Diagram

1-12a. Batteries are mounted inside the rear cover of the meter. Battery types used are listed in Table I, Leading Particulars. These batteries power the amplifier section during peak-reading operation. The amplifier is mounted within the housing.

### 1-13. THEORY OF OPERATION

1-14. The operation of this wattmeter is based on the traveling wave concept of RF transmission. As RF power is applied to a transmission line, there is a forward wave traveling from the transmitter to the load, and a reflected wave traveling from the load to the transmitter. The closer the load is matched to the transmission line, the smaller the reflected wave will be. To determine the watts dissipated in the resistance, it is necessary to determine the wattage of the forward wave and the wattage of the reflected wave. The difference between the two will indicate load power.



SCHEMATIC, MODEL 4314  
G.C. 9-19-80

4314-016

Figure 1-3. Model 4314 Schematic Diagram

1-15. In the traveling wave concept, VSWR (Voltage Standing Wave Ratio) has become a widely used tool. The standing waves which are produced by interference between the forward and reflected waves do not affect the readings of the wattmeter, since the wattmeter reads only traveling waves. However, the VSWR can easily be determined by use of graphs, Figures 3-2, 3-3, without requiring the use of unwieldy, expensive, slotted line equipment. Many users find that the ratio of  $\frac{\text{Watts Reflected}}{\text{Watts Forward}}$  is a more useful tool than VSWR.

1-16. When the meter is connected into the system, the transmission is directed through the meter line section, which is a short, uniform section of air line that provides unimpaird impedance of the RF coaxial line into which it is inserted. When the plug-in element is installed in the socket of the line section, the RF waves traveling through the line produce energy in the coupling circuit of the plug-in element by inductance and capacitance (see Figure 1-2). The inductive currents will flow according to the direction of the traveling waves producing them. The capacitive portion of these currents is independent of the direction of traveling waves. It is therefore apparent that the current produced from the waves traveling in one direction will add in phase. The arrow on the plug-in element indicates the additive direction of wave travel. The element is so designed that the wave components traveling in the opposite direction of the arrow will nearly cancel each other out completely, making the element highly insensitive to the reverse wave direction. Because of the highly directional characteristics of the element, the resultant direct current which is sensed by the microammeter indicates the power level of only the RF waves traveling in the arrow direction.

1-17. The plug-in element is designed so that it can be rotated 180 degrees in its socket in the line section. When it is rotated, the meter will indicate the wattage in a direction opposite that of the initial reading, so that if the forward direction power was read first, the reflected direction power will be read after the plug-in element is rotated. The energy resulting from the inductively coupled component of the forward wave will bring about cancellation as described above.

1-18. The Model 4314 is designed to read peak power, in addition to average power described above, when the PEAK READ button is depressed. This is accomplished by use of the dc powered amplifier system shown in Figure 1-3. DC power is supplied by the 6 and 12 volt Ni-Cad batteries installed in the back cover, see Sec. 1-12a. Whenever the PEAK READ button is depressed battery power will energize the amplifier system (whether AC line is connected or not). Diodes CR2 and CR3 are installed in the dc power input circuit to protect the amplifier against the possibility of reverse dc supply voltage. The battery charging system is permanently connected to the batteries and a charge will be applied when 115V AC line is plugged in (See Section II, Preparation for Use). The primary of the charger circuit is fused by 0.3 amp. fuse (FZ). Neon lamp L1 across this input indicates when ac line is on, and batteries are undergoing charge.



1-18a. The battery test circuit is energized when the pushbutton of switch SW2 is pressed. If the voltage of 12 volt battery is within the limits necessary to properly operate the amplifier circuit, the needle of the meter will deflect beyond the battery test mark on the meter. If it fails to reach the mark, the batteries may require re-charge or replacement. The battery test circuit reads only the output of the 12 volt battery, but experience has indicated that the life of the 6 volt battery exceeds that of the 12 volt battery. The batteries require replacement if they fail to hold a charge or do not give a reasonable amount of service after full charge. Replacement of both batteries simultaneously will assure that sufficient battery power will be available for extended periods of time.

1-19. The amplifier circuit is designed to provide current to the meter which will indicate at a steady state the peak of the power applied to resistor R1. Resistor R1 exactly matches the resistance of meter M1, so that the existing circuit in the plug-in element is loaded exactly the same as during the average reading mode.

1-20. When switch SW1 is pressed, the dc input which is normally applied to the meter is interrupted and is applied instead to resistor R1 and differential amplifier AR1 which gives a current gain ratio of approximately 100:1. This output is applied to a resistance bridge consisting of resistors R3, R4, R5, R6 and R7. Variable resistor R5 of this bridge permits zero calibration of the amplifier circuit. Bridge output is applied to differential amplifier AR2 which provides a voltage gain of about 1000:1. The voltage gain ratio of this is extremely important in determining the minimum pulse duration which can be indicated, since it is the surge of voltage from the amplifier which charges capacitor C1. Capacitor C1 applies a potential to differential amplifiers Q1 and Q2 as long as the capacitor remains charged. These amplifiers provide a massive current gain ratio, but unity or slightly less voltage gain. This is applied to meter M1 to indicate the peak power in the line. A portion of the dc output of amplifiers Q1 and Q2 is fed back to resistor R2 and to amplifier AR1. Resistor R2 is matched to resistor R1 to provide unity gain to the amplifier. This feedback circuit maintains the output from AR1 and in turn from AR2 to keep capacitor C1 charged to that value which yields unity closed loop gain. The capacitor continues to energize Q1 and Q2 to maintain the reading of the meter even though the peak of the pulse is no longer applied to the amplifier assembly input. In this manner, only peak power is indicated, even though there is a wide fluctuation of input power.

1-21. Because of capacitor leakage, diode back resistance, and transistor input current (low as it may be), there will be a decay in the circuit to limit the time the amplifier system will retain its output level. As the circuit decays, the meter will return to zero provided no additional pulses are received at resistor R1.

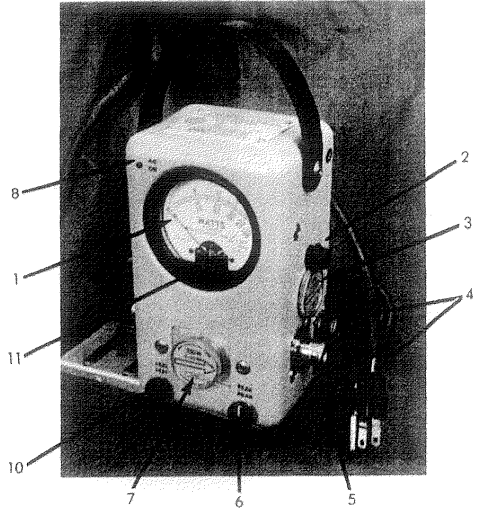
## SECTION II. PREPARATION FOR USE

### 2.1 WATTMETER INSTALLATION

2.2 The Thruline Wattmeter Model 4314 is a portable instrument, not specifically designed for attached mounting. The unit is designed with a leather carrying strap to facilitate movement from one location to another. When transporting the meter, turn the plug-in element in the line section of the meter so that the arrow points up. This will shunt the meter connection circuit and dampen needle action during handling and shipment. Make sure the spare plug-in elements are securely mounted in the sockets of the unit. Secure with the thumbscrews provided.

CAUTION

Dropping or rough handling of the test set plug-in elements will disturb the calibration. Handle them with reasonable care at all times. The microammeter is shock mounted in the housing, but dropping or other severe impact can damage the delicate mechanism of the meter.



- |                                  |                      |
|----------------------------------|----------------------|
| 1. Meter                         | 6. PEAK READ Switch  |
| 2. Spare Element Retaining Screw | 7. Plug-In Element   |
| 3. Spare Plug-In Element         | 8. POWER ON Lamp     |
| 4. AC Power Cord                 | 10. BATTERY TEST     |
| 5. RF Line Connector             | 11. Meter Zero Screw |

Figure 2-1. Meter Controls

2.3 Application of ac power to the Model 4314 is not necessary to obtain any of its designated output readings, see Table 1. The ac is needed only to recharge the batteries required by the peak-read amplifier. Although the batteries will take up to 18 hours usage before serious voltage loss occurs, do not leave PEAK READ button depressed longer than 10 hours without recharging. This will insure a long life for the batteries.

2-3a. After 10 hours continuous use, or equivalent without recharging, about 14 hours will be required to fully recharge the batteries. The charger may be left connected continuously, but if the Wattmeter is not being used regularly, it is recommended that the charger be disconnected. Maximum operating efficiency of the batteries is obtained at 65° to 85° F ambient temperature.

2-3b. The Model 4314 uses these batteries to operate the peak-read amplifier. Two batteries are required, see Table 1, Leading Particulars. To install batteries proceed as follows:

1. Remove the four #8-32 flat head machine screws at the sides of housing that secure the back cover. Carefully remove this cover from the housing, taking care not to break the interconnecting wires inside the wattmeter.
2. Unsolder all wires from the terminals of the batteries, using a small soldering iron with caution; note polarities and wire positions. Then pull batteries out of retainer clips. Loosening the clip fastening screw will assist in case of tightness.
3. Install new batteries, note polarities. Resolder leads to terminals, refer to Figure 3.1 illustration.

**CAUTION**

After batteries are installed, make sure the unit is not allowed to stand unused with the PEAK READ push button switch locked in the down position. Battery life with the button down is approximately 18 hours max., see above.

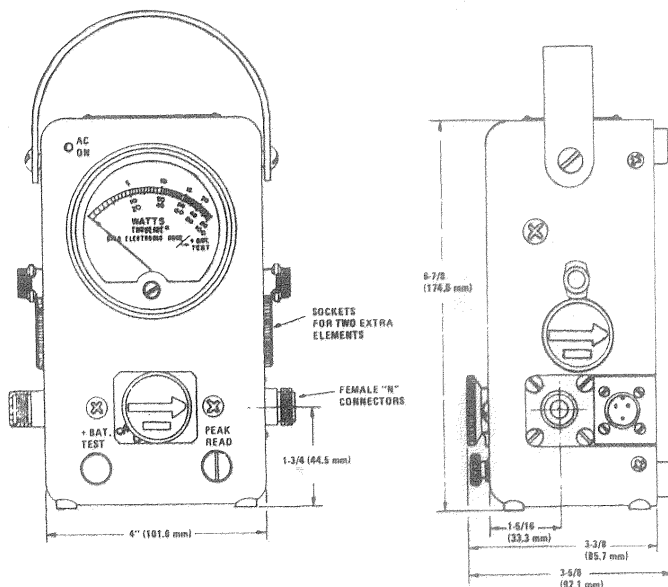


Figure 2-2. Wattmeter Dimensions

4. Press the BATTERY TEST push button and watch the meter indication. The meter pointer must move to the portion or arc to the right of the BATTERY TEST mark. This indicates that sufficient battery power is available to operate the amplifier circuit. If the meter fails to indicate to the required level with new batteries, it is probably due to one of the following:

- a) Insufficient battery charge.
- b) Improper installation.
- c) Damaged battery leads.

Inspect battery leads and repair if damaged. Observe battery installation for correct polarity. Recharge batteries, as described in text, for about 14 hours. NOTE: Wattmeter batteries or battery replacements are furnished by the supplier in an uncharged condition. New equipment or replacements should be charged before using.

There is a terminal strip with markings H, M, L located inside the rear cover next to the batteries. This terminal is for charging rate adjustment, to compensate for high, medium, and low supply voltage areas. Since overcharging may shorten rechargeable battery life it may be desirable, in higher voltage areas, to move the wire attached to the minus side of the six volt battery to another position on the terminal strip. Normally this wire is attached to the terminal marked "L".

5. When proper meter indications are attained, install the meter back panel with the four machine screws.

## 2-4. CONNECTIONS

2-5. The line section of the wattmeter is normally fitted with two female N type connectors. Connections are readily made using male N type cable plugs. However, other line section connector types are available from Bird Electronic Corporation as required. The quick-change connectors can be replaced by removing the four screws from each corner of the square flanges of the connector and pulling straight outward, carefully disengaging the spring fingers of the center conductor. Install the new connector by reversing the removal procedure. The alternate connectors available are listed after the parts section in the back of this manual.

2-6. Install the wattmeter into an RF coaxial circuit having a 50-ohm impedance only. Connecting into lines of other impedance values will cause a mismatch, with wide differences resulting in very inaccurate readings. Avoid this condition if possible. In case of exceptional need, the unit can be connected to lines of mismatched impedance. Refer to Paragraph 3-22 for an indication of the degree of inaccuracy caused by this mismatch.

2-7. Normally the RF line is connected to the connectors of the line section of the wattmeter. No other connections are required for operation. Take care that the plug-in element installed in the socket of the line section has a sufficiently high wattage rating to indicate the line load when it is first applied to the RF line. Severe damage to the plug-in element or meter can result from exposure of the element to excessive RF power in the line.

## SECTION III. OPERATING INSTRUCTIONS

### 3-1. CONTROLS AND INSTRUMENTS

3-2. The location, purpose, and use of operating controls and instruments are given in Table III and Figure 2-1.

### 3-3. ZERO ADJUST THE METER

3-4. Before taking any readings with the test set, it is necessary to zero the meter under no-power conditions. Proceed as follows:

- (a) Rotate the plug-in element (7, Figure 3-1) so that the arrow points up.
- (b) Using a small screwdriver, turn the meter zero screw (12) clockwise or counterclockwise as necessary so that the meter pointer exactly aligns with the zero of the meter scale.

### 3-5. PLUG-IN ELEMENT SELECTION AND INSERTION

3.6 Use a plug-in element (7, Figure 2-1) which has an adequate power rating and the required frequency range to properly indicate the power of the RF line. If the approximate wattage of the line is not known, start with an element which will be sure to adequately cover the maximum wattage of the transmitter to prevent overloading the test set. Substitute a lower reading element for the first element if its indicating range is too high for accurate power determination. Remove the insert elements as follows:

- (a) Loosen the spare element retaining screw (2, Figure 2-1) to release the clip which retains the spare element (3) in the side of the test set. Remove the spare element.
- (b) Release the catch (10) that secures the element in the line section body of the test set. Remove the element (7).
- (c) Hold the catch in the released position and insert the replacement element in the line section body. Release the catch to retain the replacement element. Install the removed element in the spare element socket and retain with the spare element retaining screw (2).

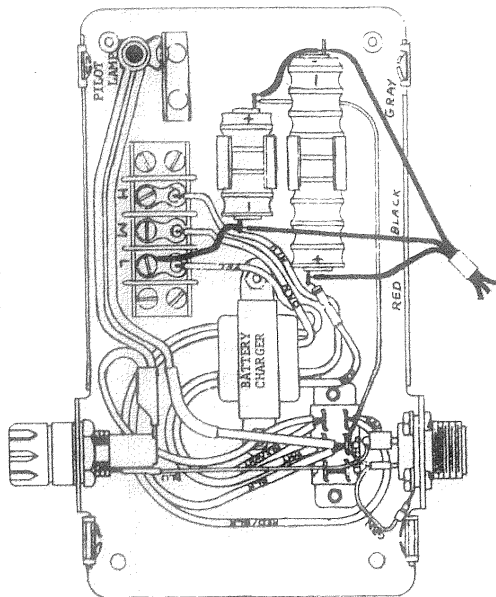


Figure 3-1  
Installation of Batteries

### 3-7. DETERMINING AVERAGE LOAD POWER

3-8. Thruline Model 4314 provides easy measuring or monitoring of transmitter power. Assuming that the proper element is installed in the unit and that the RF lines are connected to the threaded ends of the RF line connectors (5), determine average load power as follows:

(a) Rotate the plug-in element (7, Figure 2-1) so that the arrow on the element points in the line direction of the load. Note the reading given on the meter (1). This is the forward power.

(b) Rotate the plug-in element so that the arrow on the element points in the line direction of the transmitter. Note the reading given on the meter. This is the reflected power.

(c) Subtract the reflected power from the forward power to get watts delivered to and dissipated in the load as follows:

$$\text{Watts (load)} = \text{Watts (forward)} - \text{Watts (reflected)}$$

(d) The importance of the reflected power varies depending upon the load. Where appreciable power is reflected, as with an antenna, the subtraction of the reflected power is necessary to obtain a true average wattage reading. However, this step may be unnecessary when the load is a good resistor so that the reflected power becomes negligible (less than 1 percent).

### 3-9. DETERMINING PEAK POWER

3-10. To determine peak pulse power or peak envelope power of the traveling waves, proceed as directed in 3-8 above for average power, except that the PEAK READ switch (6) must be depressed. It may be locked in the depressed position by a slight clockwise turn.

### 3-11. DETERMINING VSWR

3-12. This unit is not designed to provide direct VSWR (volts-standing-wave ratio) readings. It is felt that VSWR readings are no more valuable than the ratio of forward to reflected power. In fact, most operators find that in transmitter tune-up, antenna matching, and similar problems dealing with RF circuits, the forward-power-to-reflected-power ratio is a highly useful tool. However, VSWR readings can be determined by use of graphs as follows:

(a) Determine the forward power and the reflected power as directed in paragraph 3-8.

(b) Refer to the appropriate graph (Figures 3-2, 3-3) to convert the forward wattage reading and the reflected wattage reading to VSWR. Note that the graphs convert the readings directly into VSWR values without any intermediate computations.

Following the vertical and horizontal grid, determine intersection of forward and reverse power values. Slanted lines passing closest to this point indicate VSWR.

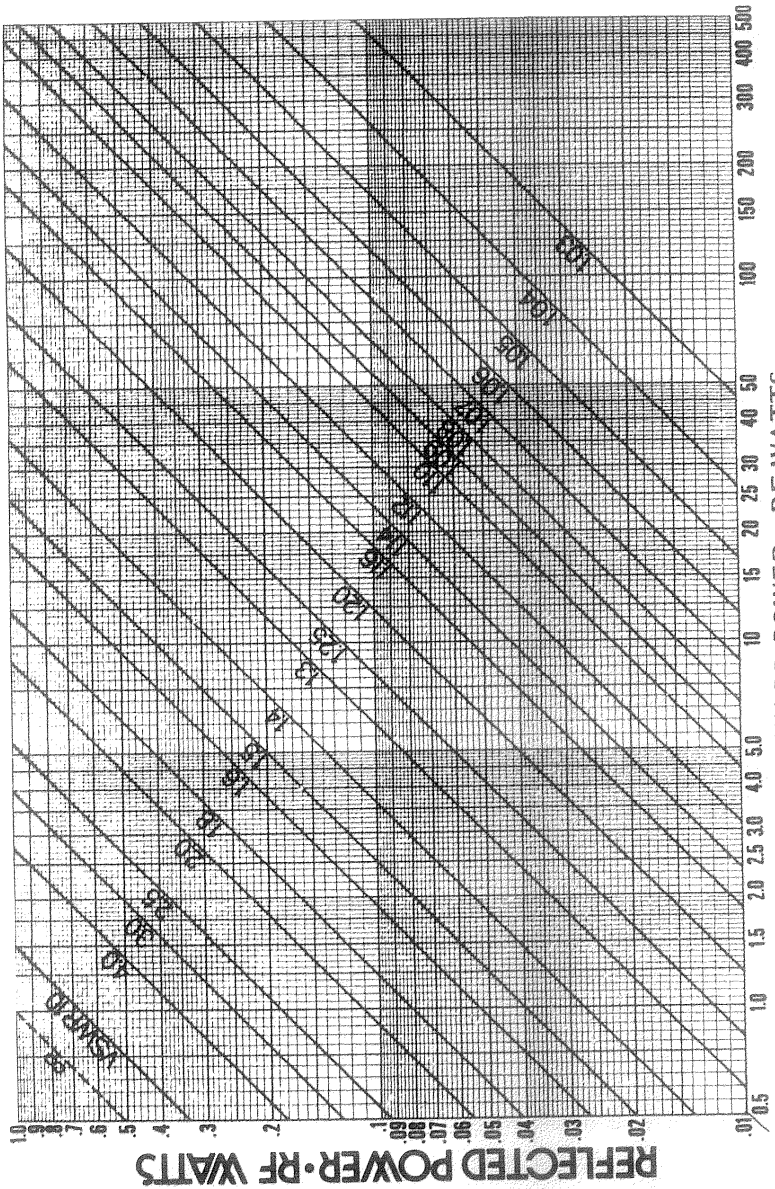
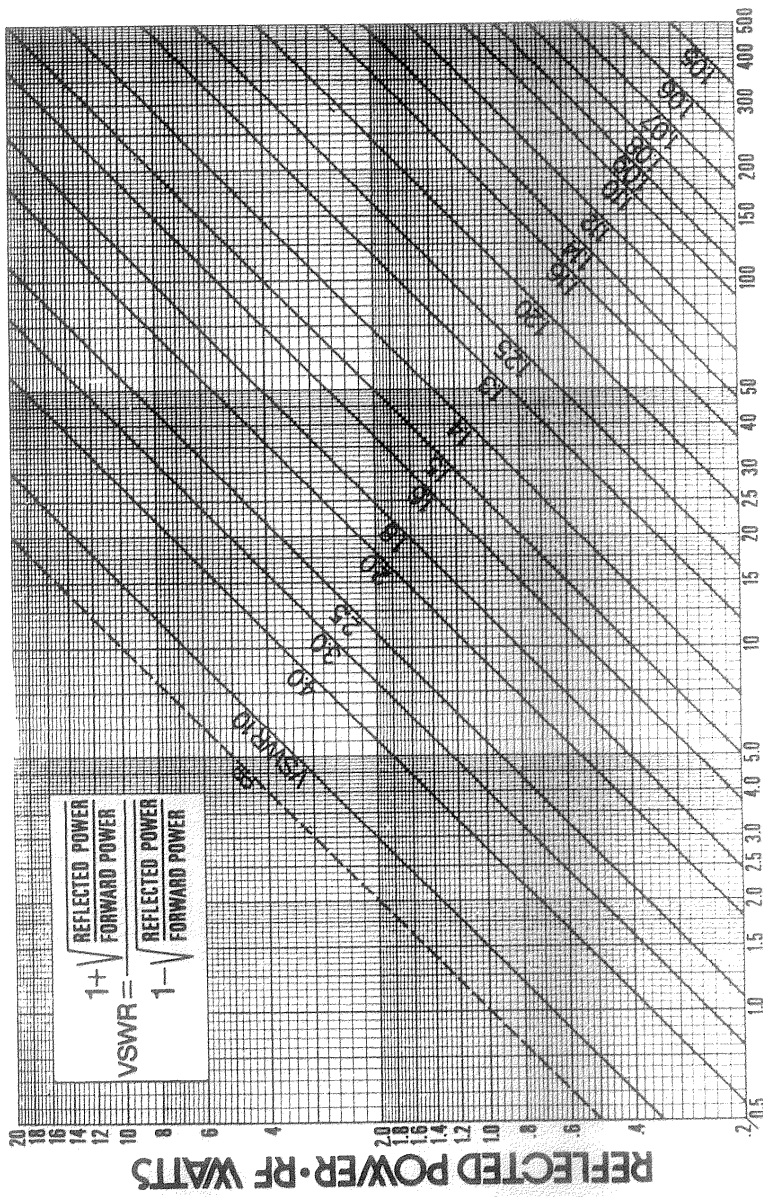


Figure 3-2. Power Values VS VSWR



FORWARD POWER • RF WATTS  
 Figure 3-3. Power Values VS VSWR



TABLE III. CONTROLS AND INSTRUMENTS

Index No. Fig. 2-1	Control Name	Purpose and Use
1	Meter	Indicates watts sensed by the instrument. Contains three scales proportional to ratings of various plug-in elements.
3	Spare Plug-In Element	When it replaces the installed plug-in element, it changes the wattage and/or frequency ranges of the instrument.
6	PEAK-READ Switch	In normal position, meter indicates average wattage. When operated, meter indicates peak pulse power or peak envelope power.
7	Plug-In Element	Determines whether forward or reflected waves are being sensed. When arrow points to load, instrument senses forward waves. When arrow points to transmitter, instrument senses reflected waves.
8	AC ON Lamp	Lights when ac power is applied to battery charger.
Not Shown	Element Catch	Retains and releases, plug-in element in element socket of line section.
10	+BAT TEST Switch	When depressed, it causes meter to indicate state of battery charge.
11	Meter Zero Screw	Provides a zero adjustment for the meter.
Not Shown	Line Voltage Switch	Located on rear panel. Must be in correct position to match local line voltage.
Not Shown	Fuse	Protects the test set from damage due to excessive ac input voltage.

### 3-13. MAKING LOW REFLECTION READINGS

3-14. It is sometimes desirable to make very accurate low reflection readings. This can be done using two elements, provided that care is taken to prevent application of high forward power to the low-reading element. This procedure is limited to use with higher power transmitters only. Proceed as follows:

- (a) Measure watts forward, using the proper plug-in element. Reverse the arrow direction of the element and get a reading to determine the general level of reflected power.
- (b) Remove the plug-in element and insert a second, lower reading element which has a maximum rating of more than the reflected power indicated in step (a) above. Insert the element so that it reads reflected power only.

#### CAUTION

When making low-reflection readings using two elements, take care to insert the lower reading element so that it senses reflected power only. Do not rotate the lower reading element in the socket so that it is subjected to forward power. This could result in damage to the plug-in element, to the meter, or both.

- (c) Read the reflected power on the meter in the usual manner.
- (d) When using the two-element method of reading low reflected power, do not use a pair of elements which has a full scale power ratio of greater than 10 to 1.

### 3-15. FREQUENCY RESPONSE

3-16. Each plug-in element of the wattmeter is designed to operate within a specific frequency range. The use of these elements to measure direct power outside of the stated frequency range is not recommended. The frequency response of the elements is very flat over their designated range, as shown in Figure 3-4. Note that the fall-off above and below the assigned frequency range is greater for low-power elements than for high-power elements. The curves shown in Figure 3-4 may be assumed to be typical for all listed band types.

3-17. Harmonics outside of the element frequency band may be known to exist in the measuring circuit. If so, a rough approximation of the response of the element to these harmonics can be made using the curves shown in Figure 3-4. The frequency ordinate on the graph will be obtained by proportioning the frequency of the element used with that of the one illustrated. Interpolate the curve values to get an approximation of the strength of the harmonic signals being measured by the element.

### 3-18. TESTING LINES, CONNECTORS, FILTERS, AND RELATED COMPONENTS

3-19. Lines, connectors, filters, and related components can be tested using the RF Power Test Set. The method of testing used depends upon the circumstances involved for any particular test. Some of these tests are as follows:

(a) The standing wave ratio or the reflected-power-to-forward-power ratio of a line can be determined by terminating the line with a good load resistor, such as a Bird Termline®. Proceed as described in paragraph 3-12. Low reflected power may be measured as described in paragraph 3-14.

(b) Line attenuation (power lost by heat in the line) can be determined by inserting the line of unknown value between two RF power test sets. The end of the line must be terminated by a load resistor. By comparing readings made at the two places, the attenuation of the line can be determined. Where very small values of attenuation are involved, allowances must be made for normal instrument error. Slight juggling of zero settings is permissible for convenience of eliminating computations, provided the readings are fairly high on the meter scale.

(c) Attenuation can also be determined by the open circuit method. The test set exhibits good equality between forward and reflected readings when the load connector is open or short circuited. When this is checked on an open circuit and an open-circuited length of line of unknown attenuation is connected to the load connector, the ratio shown is the attenuation in two passes along the line (down and back). This can be converted to decibels as follows:

$$\text{Attenuation (decibels)} = 10 \log \frac{\text{forward power}}{\text{reflected power}}$$

The decibel reading must be halved because twice the line length is being measured (down and back). This measurement must be supplemented with a reflected power-to-forward power ratio check (subparagraph (a) above) or with a dc continuity check or leakage check, since open circuits or shorts may exist part of the way along the line.

(d) Attenuation can also be determined as described, in paragraph (c) above, by using a short circuit rather than an open circuit. The open circuit method is preferred because the initial equality (forward power-to-reflected power) is more easily achieved in an open circuit.

### 3-20. MEASURING PERCENTAGE OF POSITIVE MODULATION

3-21. Measuring the percentage of positive modulation in an amplitude modulation system is easily done by employing the average and peak reading characteristics of the unit, since:

$$\text{Percent pos. mod.} = \frac{E_{\text{max}} - E_{\text{carrier}}}{E_{\text{carrier}}} \times 100$$

By substitution we get:

Percentage pos. mod. =

$$\left( \frac{\sqrt{P_p} - \sqrt{P_c}}{\sqrt{P_c}} \right) \times 100$$

When:

$P_p$  = peak power as read with PEAK READ switch down.

$P_c$  = carrier power as read with PEAK READ switch up.

or:

Percent pos. mod. =

$$\left( \frac{\sqrt{P_p}}{\sqrt{P_c}} - \frac{\sqrt{P_c}}{\sqrt{P_c}} \right) \times 100$$

and by cancellation

Percent pos. mod. =

$$\left( \frac{\sqrt{P_p}}{\sqrt{P_c}} - 1 \right) \times 100$$

After determining average and peak readings, consult the graph, Figure 3-5, to determine the percentage of positive modulation.

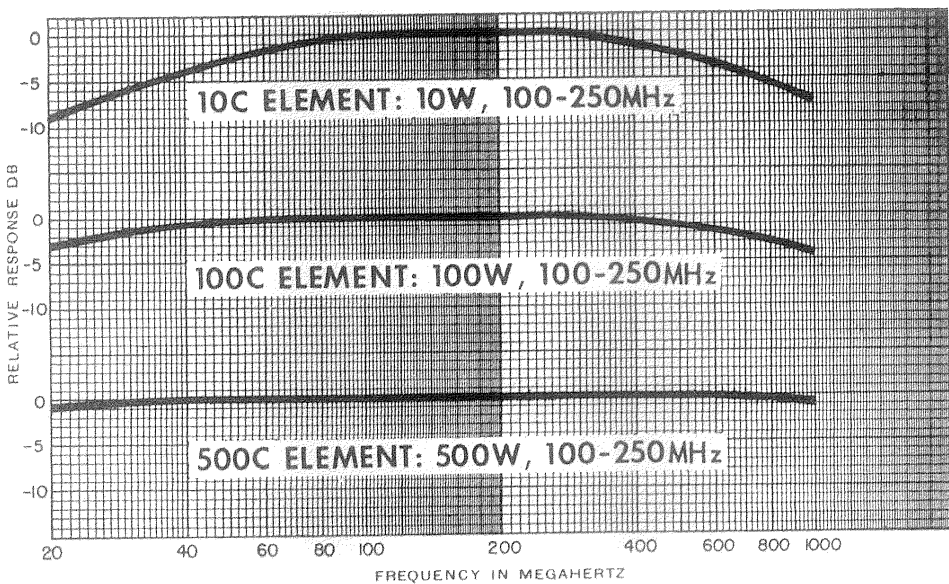


Figure 3-4. Wattmeter Response at Various Frequencies

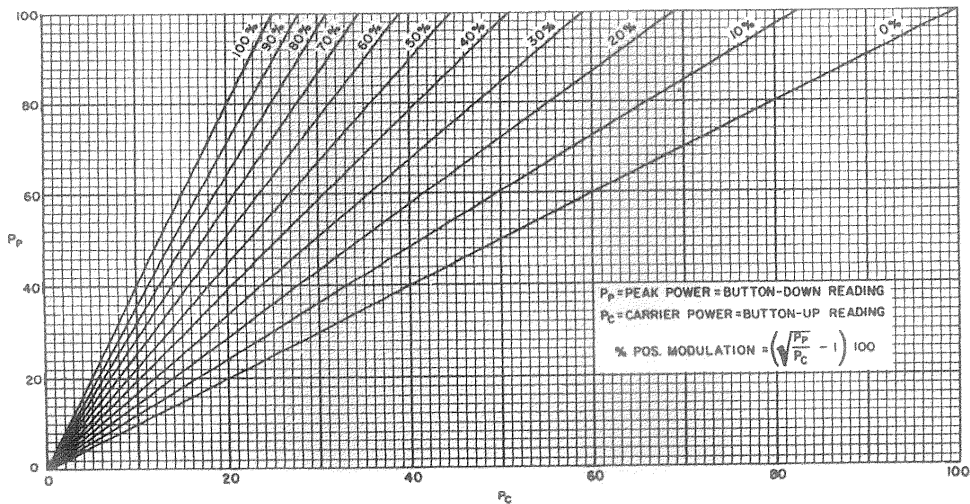


Figure 3-5. Graph Converting Carrier Power and Peak Power to Percent Positive Modulation

### 3-22. IMPEDANCE MISMATCH

3-23. This test is designed to check power in a 50-ohm circuit. When the test set is connected into the RF line, it inserts a 4-inch section of 50-ohm line into that circuit. When this is inserted into a line having an impedance other than 50 ohms, the load on the transmitter will change because of the insertion. This change is not serious if the power reflection factor is less than 10 percent or if the frequency is less than 200 megahertz. At values higher than these, the insertion of the 50-ohm line will result in a different load impedance even if the transmitter is tuned up with the test set inserted into the line. The test will indicate zero reflection when the unit is connected into a 50-ohm, pure resistive line. When a 70-ohm line is connected on the load side of the test set, under ideal conditions, the 50-ohm test set will indicate 3 percent reflected power or a VSWR of  $70/50 = 1.4$ . The test set can show this same reflected percentage when a  $50/1.4 = 35.7$  - ohm, pure resistive load is applied to the 70-ohm line. This could exist with 10 percent reflected power on the 70-ohm line (VSWR = 2). From this it can be seen that when the 50-ohm test set is applied to a 70-ohm line, the line could have 10 percent reflected power with a VSWR of 2.0, but the meter would indicate only 3 percent reflected power (VSWR = 1.4). If it is necessary to make wattage readings on a 70-ohm line with the 50-ohm test set, it is especially important to subtract the reflected power from the forward power.

## SECTION IV. MAINTENANCE INSTRUCTIONS

### 4-1. MAINTENANCE

4-2. Maintenance of the Model 4314 is normally limited to cleaning. The amount of cleaning necessary can be minimized by taking the following precautions:

- (a) Keep the plug-in element in the socket of the line section as much as possible. This serves as an effective seal against the entry of dust and dirt. Cover the socket opening when the element is removed.
- (b) Protect the RF connectors on the line section against the entry of dust and dirt by keeping them connected to the line or by covering them when the line is disconnected.

### 4-3. CLEANING

4-4. All contacts must be kept clean to assure low-resistance connections to and within the unit. Clean contacts as follows:

(a) Clean RF connectors with a cotton swab stick dampened with dry cleaning solvent, such as inhibisol, or its equivalent.

#### WARNING

Prolonged breathing of dry cleaning solvents is dangerous. Make certain adequate ventilation is provided.

(b) Clean the inside of the line section socket bore and the entire circumference of the plug-in element with a cotton swab stick dampened with solvent. Pay particular attention to the cleaning of the bottom rim of the element body and to the seat of the socket in the line section.

(c) When cleaning the socket bore, take care not to disturb the spring finger of the dc contact. If necessary, the spring finger of the dc contact can be adjusted manually. The contact button must be positioned out far enough to make good contact with the element body contact, but it must not restrict the entry of the element body. Adjustment of the phosphor bronze spring can be accomplished from the front of the unit by placing the blade of a small screwdriver behind the spring close to its base, and gently prying the spring towards the center of the socket. This procedure may be repeated until the 'contact but no restriction' requirements are met.

(d) Check the inside of the line section for dirt and contamination. Clean the reachable portions of the line section with a cotton swab stick. Blow out the remaining dirt with low-pressure, dry compressed air.

#### CAUTION

Do not attempt to remove the RF line conductor from the line section. Any attempt to remove it will ruin the assembly.

## SECTION V. TROUBLESHOOTING

### 5-1. TROUBLESHOOTING CHART

5-2. Table IV, Troubleshooting Chart, provides a list of the most probable causes of trouble which might develop in the wattmeter. For each trouble there is a list of probable causes and remedies. Refer to the troubleshooting chart in the event of trouble in the unit.

### 5-3. CHECKING POWER SUPPLY OUTPUT

5-4. If the PEAK READ system of the test set fails to operate, check the power supply output to assure that required voltages are being provided. Voltage across CR2 (IN3828A) should be 5.7 to 6.7 volts, and the voltage across CR-3 (IN3023B) should be 12 to 14 volts

5-4a. REFER TO SECTION I Para. 1-18a., & SECTION II Para. 2-3A & b.

**TABLE IV. TROUBLESHOOTING CHART**

TROUBLE	PROBABLE CAUSE	REMEDY
NO METER INDICATION (AVERAGE OR PEAK)	<ul style="list-style-type: none"> <li>Arrow on plug-in in wrong direction.</li> <li>No radio frequency power.</li> <li>No pick-up from dc contact finger.</li> <li>Open or shorted dc meter cable</li> <li>Meter burned out or damaged.</li> </ul>	<ul style="list-style-type: none"> <li>Correct arrow direction.</li> <li>Check transmitter for faults.</li> <li>Adjust spring finger (par. 4-4c).</li> <li>Replace cable.</li> <li>Replace meter.</li> </ul>
NO METER INDICATION (Peak Read)	<ul style="list-style-type: none"> <li>Batteries discharged.</li> <li>Batteries don't charge.</li> <li>Batteries defective (won't charge).</li> <li>Battery leads broken.</li> <li>Defective component in amplifier section (or PEAK READ switch).</li> </ul>	<ul style="list-style-type: none"> <li>Check BAT TEST and recharge.</li> <li>No AC ON Light, Check AC power and/or replace fuse F1.</li> <li>Replace batteries, Par. 2-3b.</li> <li>Repair battery leads.</li> <li>Replace defective component, or replace amplifier, (par. 7-6).</li> </ul>
INTERMITTENT OR INCONSISTENT METER READINGS	<ul style="list-style-type: none"> <li>Faulty load.</li> <li>Faulty transmission line.</li> <li>Dirty dc contacts on elements.</li> <li>Sticking or defective meter.</li> </ul>	<ul style="list-style-type: none"> <li>Correct fault in load.</li> <li>Correct fault in transmission line.</li> <li>Clean dc contacts (par. 4-4).</li> <li>Replace meter.</li> </ul>
HIGH PERCENTAGE OR REFLECTED POWER	<ul style="list-style-type: none"> <li>Faulty load.</li> <li>Poor connectors.</li> <li>Shorted or open transmission line.</li> <li>Foreign material in line section.</li> </ul>	<ul style="list-style-type: none"> <li>Correct fault in load.</li> <li>Check for high-resistance connections.</li> <li>Correct fault in transmission line.</li> <li>Clean line sections thoroughly (par. 4-4).</li> </ul>
BATTERY CHARGE CHECK INDICATES LOW	<ul style="list-style-type: none"> <li>115/230 VAC switch in 230v position with 115v input.</li> </ul>	<ul style="list-style-type: none"> <li>Set 115/230 VAC switch to 115v position.</li> </ul>
NO METER INDICATION (Peak Read)	<ul style="list-style-type: none"> <li>115/230 VAC switch in 115v position with 230v input.</li> <li>Fuse blows.</li> </ul>	<ul style="list-style-type: none"> <li>Set 115/230 VAC switch to 230v position, replace fuse.</li> </ul>



## SECTION VI. CALIBRATION

### 6-1. GENERAL

6-2. Thruline Wattmeter Model 4314 normally requires no calibration other than zero adjustment of the meter. This should be done any time the meter pointer is not exactly aligned with the zero mark on the meter scale when no readings are being made. Any other adjustments are discouraged unless one or more components are replaced in the amplifier section. If this has been done, proceed as directed in paragraph 6-4 below.

### 6-3. AVERAGE-TO-PEAK VOLTAGE LEVEL ADJUSTMENT

6-4. To assure that the meter reads correctly for both average and peak operation, a direct current from a battery source is applied to the input of the amplifier circuit. Refer to Figure 1-3. The steady direct-current peak level should be the same as the average current level, because no peaks exist in this current. Apply a direct current and adjust as necessary so that the same reading is attained in both average and peak modes. Proceed as follows:

- (a) Install a voltage-dropping variable voltage dividing potentiometer and a battery in series with the input of the amplifier. Make sure the resistor is set for zero output. Connect the positive (+) side of the circuit to input and the negative (-) side to ground. Install a voltmeter across the circuit. Slowly operate the potentiometer to adjust output to apply approximately 21 millivolts. A suitable resistive network must be used to assure that the battery voltage is properly reduced.
- (b) Check the reading of the meter. It should indicate about half of total scale reading. Press the push button of PEAK POWER switch SW1 while watching the meter pointer. There should be no deviation of the pointer from average to peak reading.
- (c) If the pointer reads a different value for peak reading than for average reading, rotate the adjusting cap on resistor R5 on the amplifier until the two readings coincide.

## SECTION VII. REPAIR INSTRUCTIONS

### 7-1. GENERAL

7-2. Repair of the Thruline Wattmeter Model 4314 consists primarily of soldering of broken leads and replacement of faulty parts and assemblies. Because most parts are operating at levels much lower than their rated levels, the frequency of part replacement is very low, provided the unit is properly handled, not subjected to excessive loads, and properly maintained. If repair or parts replacement is required, follow procedures consistent with good electronic repair practice.

7-3. When replacing components, make sure to use parts which have the same ratings and tolerances as the parts being replaced. Failure to use parts having the required ratings and tolerances will result in widely divergent readings on the meter.

### 7-4. METER REMOVAL AND REPLACEMENT

7-5. Replace the meter as follows:

- (a) Carefully remove the back panel from the test set. Disconnect the leads from the meter terminals.
- (b) Remove the two machine screws that hold the meter at the sides of the meter housing. Lift the meter from the housing.
- (c) Position the new meter in the housing; secure with two machine screws. Connect the leads of the meter cable to the meter, making sure the wire color code matches with the meters. Install the back panel on the meter housing.

### 7-6. AMPLIFIER REMOVAL AND REPLACEMENT

7-7. Remove and replace the amplifier assembly as follows:

- (a) Remove the back panel from the test set. Disconnect the three power supply cable leads from the terminals of the amplifier. Disconnect the three meter cable leads from the terminals of the amplifier.
- (b) Disconnect the dc lead cable from the amplifier input terminal.
- (c) Remove the four machine screws that secure the amplifier assembly to the bottom of the housing. Lift the amplifier assembly from the housing.
- (d) Position the new or repaired amplifier assembly in the housing; secure with four machine screws.
- (e) Connect the leads of the power supply cable and the meter cable to the terminals of the amplifier, taking care to match the color codings of the terminals with the color codings of the cable leads.
- (f) If major components of the amplifier have been replaced, calibrate the amplifier as described in paragraph 6-4.
- (g) After calibration, connect the dc cable between the amplifier and the line section.
- (h) Install the back panel on the test set assembly.

## 7-8. AMPLIFIER ASSEMBLY REPAIR

7-9. When repairing the amplifier, pay particular attention to the following:

(a) If soldering of the amplifier components is required, either remove all plug-in amplifiers or unplug the soldering iron before soldering. This will prevent damage to semiconductors from possible electrical leakages from soldering irons.

(b) The integrated circuits which comprise AR1 and AR2 are not interchangeable. AR1 is "D" type in epoxy encasement, as are Q1 and Q2. The flats on these types are directed to the arrows etched on the printed circuit board. Q1 and Q2 are identical and interchangeable. AR2 in a TO-5 can has a tab at its base, which is aligned with the arrow on the printed circuit board for proper installation.

(c) When soldering components of the amplifier, take care to prevent damage due to excessive heat. Always use a pair of long-nosed pliers or tweezers between the solder connections and diodes to provide a heat sink when soldering diodes into place.

(d) If either resistor R1 or R2 is damaged, replace both of the parts as a matched set. Unless these are replaced as a matched set, the peak wattage indications of the meter may be grossly inaccurate. Refer to the Parts List for resistor set part number.

## REPLACEMENT PARTS LIST

### 8-1. GENERAL

8-2. The parts lists in this section list the replacement parts for the test set. The parts lists are supported by Figures 8-1, 8-2, etc., which illustrate all replacement parts of the unit. The last column of the list provides the reference designation identification of the applicable parts. Refer to the schematic diagram in Figure 1-3 to cross-reference the parts list to the equipment.

## REPLACEMENT PARTS LIST

Fig. & Index No.	Bird Part No.	Description	Units per Assy.	Ref. Desig.	
8-1-	4314-000	Test Set, RF Power	—		
-1	4314-003	Housing Assembly	1	M1	
-2	2120-005	Meter	1		
-3	4311-040	Harness, Meter hookup	1		
-4	*	Element, Plug-In	As req.		
-5	4230-036-8	Connector and Cable Assy., DC	1		
**N1	4311-053	Push Button Kit, Batt. Test	1		
-7	4311-005	Assembly, PC Board (See Fig. 8-2 and associated list for breakdown)	1		
-8	4314-004	Cover Assembly, Housing	1		
-9	5-733-2	Battery, 12.0V — NiCad 50B	1		
-10	5-733-1	Battery, 6.0V — NiCad 50B	1		
-11	5-983	Holder, Battery	2		
-12	4311-204	Harness, Battery	1		
**N1	4311-054	Push Button Kit, Peak Read	1		
-14	4311-064	Line Section Assembly	1		
-15	4311-052	Clamp Kit, Spare Element	2		
-16	4314-013	Charger, Battery Serv.	1		
-17	5-547	Holder, Fuse	1		
-18	5-548	Connector, Power Cord	1		
**N1	P5-579	Fuse, 0.3 amp (3 AG)	1		FZ
-20	4314-010	Pilot Lamp Assy.	1		L1
-21	5-553	Rectifier Diode	1		
-22	5-1088	Switch, Slide	1		
-23	5-1118	Terminal, Charge Rate	1		

\*\*Not illustrated

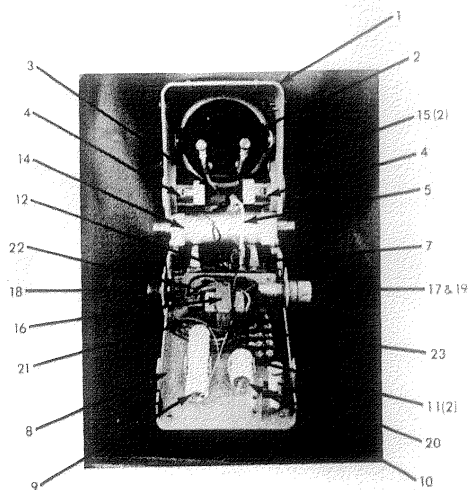


Figure 8-1. Model 4314 Replacement Parts

Fig. & Index No.	Bird Part No.	Description	Units per Assy.	Ref. Desig.
8-2-	4311-005	Assembly PC Board	1	
-1	4311-058	Amplifier	1	AR1
-2	4311-050	Amplifier	1	AR2
-3	4311-056	Amplifier	2	Q1, Q2
-4	5-497	Switch	2	SW1, SW2
-5	4311-061	Diode	1	CR3
-6	4311-062	Diode	1	CR2
-7	5-526-2	Diode	1	CR1
-8	4311-035	Resistors, Matched Pair, 1.4 K $\sim$ $\pm$ 1%	2	R1, R2
-9	5-521-1	Resistor 20K $\sim$	2	R3, R4
-10	5-671	Potentiometer 20K $\sim$	1	R5
-11	5-521-5	Resistor 4750 $\sim$	1	R6
-12	5-521-4	Resistor 4990 $\sim$	1	R7
-13	5-521-2	Resistor 383K $\sim$	1	R8
-14	5-521-3	Resistor 2550 $\sim$	1	R9
-15	5-522-1	Capacitor 10 MFD 20V	1	C6
-16	5-341	Capacitor .01 MFD 20V	4	C5, 4, 3, 2
-17	5-525-1	Capacitor 1 MFD 35V	1	C1

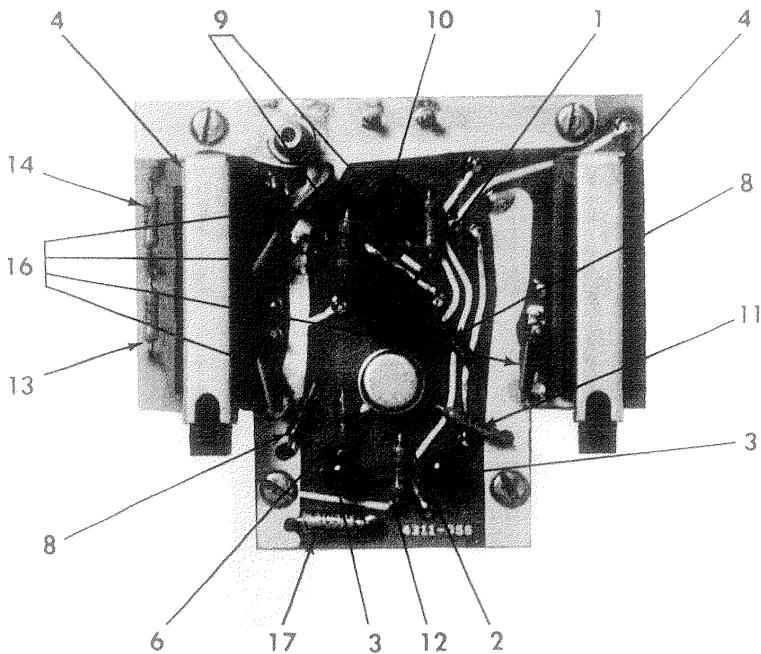


Figure 8-2. Model 4314 Amplifier Replacement Parts

## Addenda Sheet for Model 4311

The Model 4311 Peak Reading Wattmeter is similar to the Model 4314 except that it does not have the convenience of battery rechargeability.

This instruction book for Model 4314 can be used for the Model 4311 as the configuration and theory of operation for these models are the same. However, when switch SW2 is pressed, energizing the battery test circuit, and the meter indicates that the batteries are low, they must be replaced.

The batteries used in the Model 4311 are as follows:

- 5.4 volts (Mallory TR-164R or equal)
- 12.6 volts (Mallory TR-169 or equal)

To install batteries proceed as follows:

1. Remove the six machine screws that secure the wattmeter back to the housing. Carefully pull the back from the housing.

**CAUTION**

Careless removal of the wattmeter back will break the wires that connect the batteries to the amplifier.

2. Slide the metal battery retaining strap to the right, insert batteries in position carefully observing the polarity markings on the battery bracket.
3. When batteries are positioned in the brackets provided, install the retaining strap to secure them.

4311-000 Test Set, RF Power — Replacement Parts List that differ from those of the Model 4314. Refer to figure 8-1.

ITEM	DESCRIPTION	PART NO.
-1	Housing, Assembly	4311-003
-8	Cover Assembly, Housing	4311-022
-9	Battery, 12.6V (P.R. Mallory No. TR-169)	5-492
-10	Battery, 5.4V (P.R. Mallory No. TR-169R)	5-493
-11	Clip, Battery	4311-011
-12	Harness, Battery Hookup	4311-047