INSTRUCTION MANUAL

for

Model 4340/4341 THRULINE®

Laboratory Standard RF Wattmeter

Models 4340/4341 THRULINE®
Laboratory Standard RF Wattmeter

SUMMARY
SPECIFICATIONS

Power (scale)	100 watts max., full scale
Impedance	50 ohms nominal
Insertion VSWR with N connectors	1.05 max. dc to 1000 MHz
Frequency Ranges (5 Element Types)	2-10, 10-30, 30-100, 100-500, 500-1000 MHz
4341 Custom Model	Power and frequency varies depending on Elements specified
Accuracy	±3% of full scale direct reading ±3% of reading - at 5 frequency levels of the 10 cardinal scale divisions per Element
Connectors	N connectors, Male and Female Bird "QC" type
Dimensions	8-1/4" h x 10-7/8" w x 6-5/16 d (210 x 276 x 160 mm)

Bird Electronic Corp.
30303 Aurora Road
Cleveland (Solon), Ohio 44139

Model 4340/41 THRULINE
Laboratory Standard RF Wattmeter

Table of Contents

Illustrations

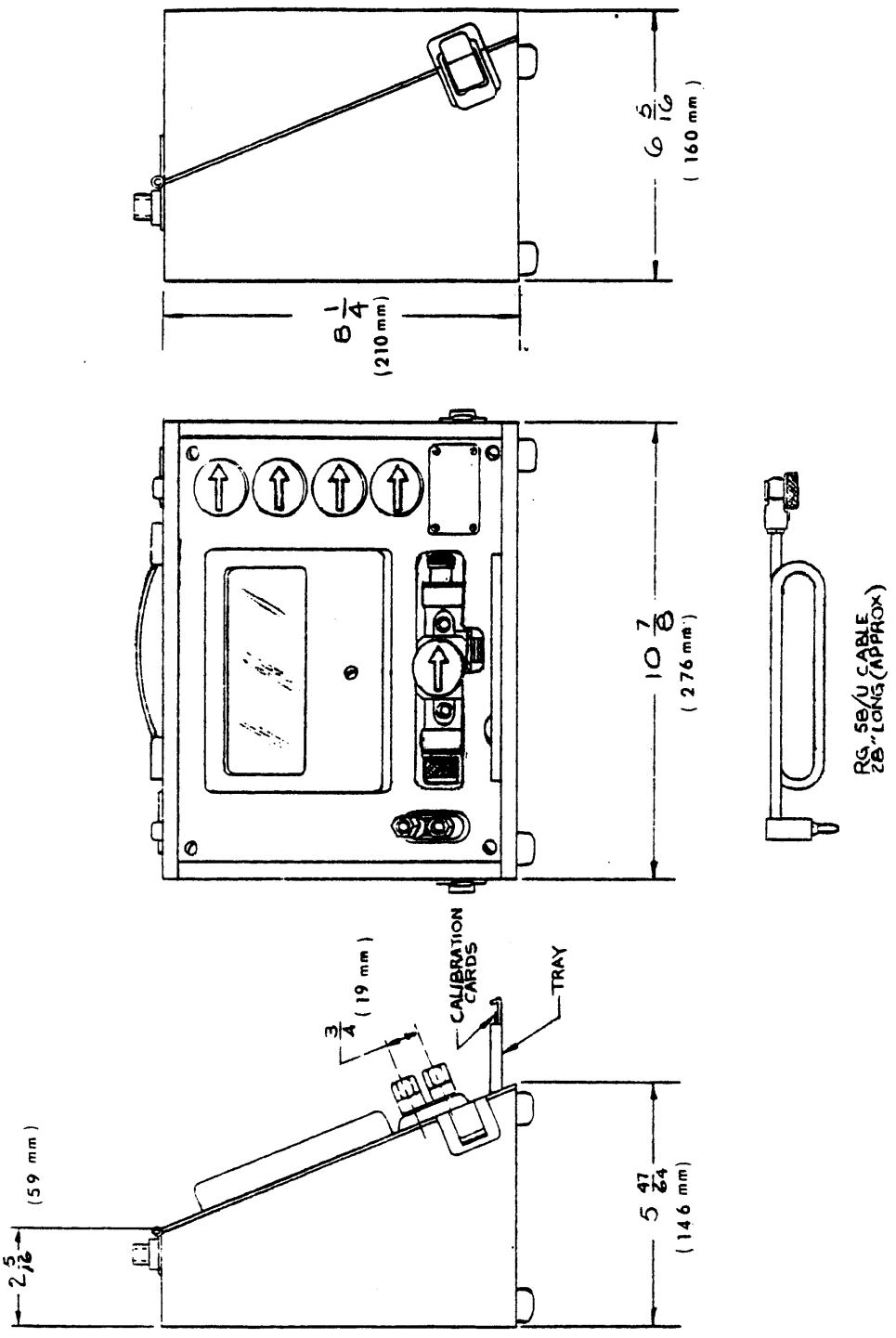

Fig. 1. Outline Dwg. Model 4340/41

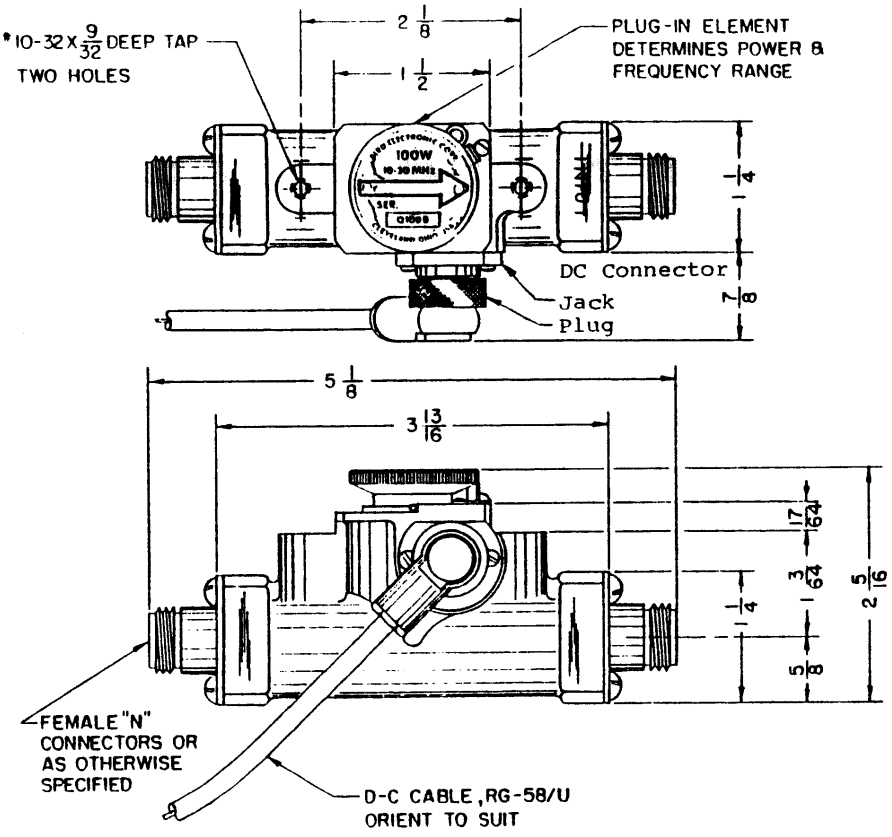

Fig. 2. Outline Dwg. Line Section

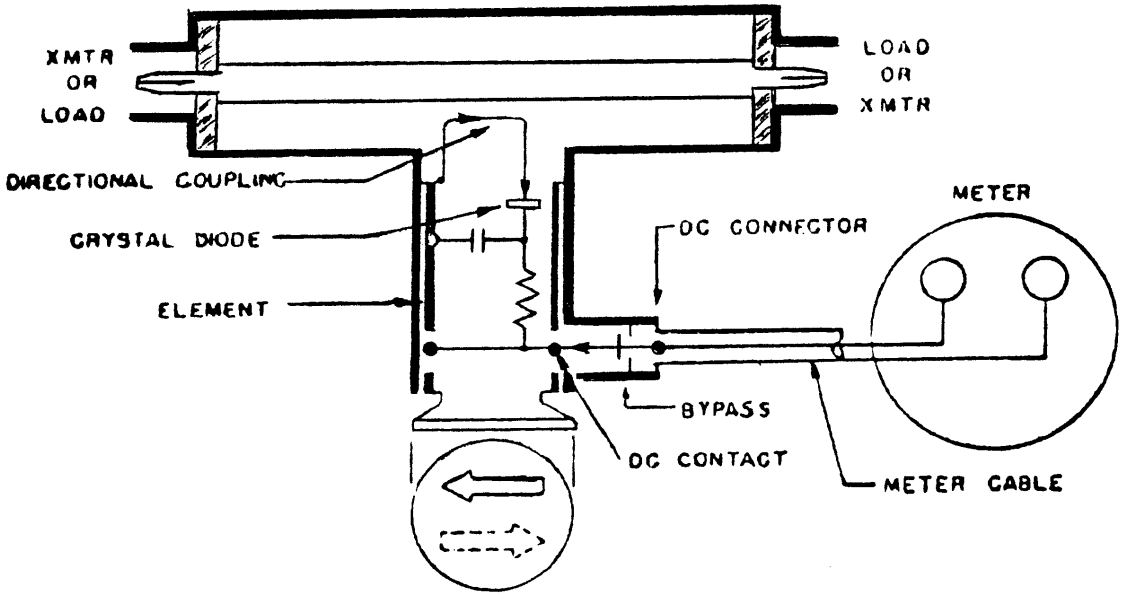

Fig. 3. Schematic Diagram

Model 4340/41 THRULINE®
Laboratory Standard RF Wattmeter

Section I - General Description

1. Purpose and Application

The Model 4340/41 is a laboratory standard insertion type RF Wattmeter. It is designed to accurately measure power flow in 50-ohm coaxial transmission lines and primarily used for maintenance and calibration of RF power instruments.

The Model 4340/41, when used in 50-ohm applications, has an insertion VSWR of less than 1.05:1 up to a frequency of 1000 MHz but the stated accuracy only applies when the system VSWR on the load side (output) is less than 1.2 to 1, with undesired signal transients below -30dB.

The meter indicates directly in watts and scale is expanded down scale for easy reading. There are three power ranges on the scale and the range to be read is determined by the Plug-In Element used, normally the 100W range. The other ranges generally apply only to the Custom Model 4341.

2. Description

The Model 4340/41 is a portable unit and is housed in a handsome wood-tone case with a leather carrying strap on top. The cover of the case is removable exposing a slanted panel on which the meter is mounted. Also on this panel are receptacles for storage of the line section and four elements. One element is stored in the line section. Just below the elongated storage receptacle for the line section is a pull out tray which contains a calibration card for each element supplied (normally five for the Model 4340).

2. Description (Continued)

These cards contain calibration data at fifty points for each element, i.e., five frequencies at each of the ten cardinal scale divisions.

The Measuring Section is a precision machined length of 50 ohm 7/8" coaxial line with a male "QC" type N connector on the output end and a female "QC" type N connector on the input end. In the center of the line section is a socket for the radio frequency coupling Plug-In-Element. This socket is precision bored to hold the rotatable Plug-In-Element in its calibrated position with a spring-loaded clasp to keep the Element firmly seated. The machined step on the top face of the socket engages the stop-pin on the rotatable Element to permit movement of only one-half circle, stopping on the axial center line.

The measuring socket has a hole bored through the side wall through which an insulated phosphor bronze contact finger projects. The Plug-In-Element has its terminals on diametrically opposite sides of the body, so that pick-up is made in either direction. A small silvered button tip contacts the THRULINE element only in the precise forward and reflected measuring position (against the end stops). A special design jack mounted on the side of the socket mates with the plug on DC cables furnished with the read-out meter.

The meter scale on the read-out meter reads full scale for the rating stamped on the cap of the Plug-In Element. The meter box, the Plug-In Element, and the THRULINE Section are all stamped with matching serial numbers. This equipment is supplied as a matched set, and the parts should not be interchanged with any other Model

2. Description (Continued)

4340/41 units. Such interchange of the measuring elements could produce readings outside the stated ±3% full scale accuracy.

The heart of this Lab. Standard is the Plug-In-Elements covering a continuous frequency range from 2 to 1000 MHz. Each element is individually calibrated with an integral potentiometer against our Master Calibration System (traceable to the National Bureau of Standards). The calibration potentiometers in each element are accessible in the field by removing the round nameplates, enabling personnel at facilities with Calorimetric standards to perform periodic checks.

Section II - Theory of Operation

1. Travelling Wave Viewpoint

The best way to visualize the THRULINE idea is from the TRAVELLING WAVE viewpoint on transmission lines, which illustrates that the voltages, currents, standing waves, etc., on any uniform line section are the results of two travelling waves:

FORWARD WAVE travels (and its power flows) from source to load, and has RF voltage E and current I in phase, with $E/I = Z_o$.

REFLECTED WAVE originates by reflection at the load, travels (and its power flows) from the load source and also has an RF voltage $\mathcal{E}$ and current $\mathcal{I}$ in phase, with $\mathcal{E}/\mathcal{I} = Z_o$.

Note that each component wave is mathematically simple, and is completely described by a single figure for power, for instance:

$\underset{\sim}{F}$ = Watts Forward = $E^2/Z_o = I^2 Z_o = EI$

$\underset{\sim}{R}$ = Watts Reflected = $\mathcal{E}^2/Z_o = \mathcal{I}^2 Z_o = \mathcal{E}\mathcal{I}$

Z_o is the characteristic impedance of the uniform line, and

Section II - Theory of Operation (Continued)

1. Travelling Wave Viewpoint (Continued)

simplifies matters by being a pure resistance, usually 50 ohms, for useful lines. The main RF line circuit of the THRULINE is a short piece of uniform air line section, whose Z_o is exactly 50 ohms, in which accurate measurements may be made.

2. Coupling Circuit

The coupling circuit which samples the travelling waves is in the Plug-In Element. Energy will be absorbed in the coupling circuit of the Element by both mutual inductance and capacitance from the travelling RF waves of the line section. The inductive currents will, of course, flow according to the direction of the travelling waves producing them. The capacitive portion of these currents is naturally independent of the direction of the travelling waves. Therefore, assuming that the element remains stationary, it is apparent that the current produced from the waves of one direction will add in phase, and those of the opposite direction will subtract in phase. The additive or "ARROW" direction is assigned to the forward wave.

The electrical values of the element circuits are carefully balanced and so designed that the current produced from the reverse wave will cancel the other almost completely. The resultant is a directivity always higher than 25dB, which means that the element is highly insensitive (nulled) to the "REVERSE" direction wave. Being highly directional, the THRULINE element is sensitive (at one setting) only to one of the travelling waves which produces standing waves by interference. THRULINE measurements are therefore

Section II - Theory of Operation (Continued)

2. Coupling Circuit (Continued)

independent of position along standing waves. It may be said that the THRULINE doesn't know, doesn't care, and doesn't need to care where it is along a standing wave. The circuitry of the element and its relationship to the other components of the THRULINE are illustrated in the schematic diagram, Page D.

Section III - Installation

1. Portability

The Models 4340 is a portable instrument and the case is not designed for fixed mounting. A strap is provided for carrying purposes.

While transporting the unit, it is best to be sure the shorting bar is connected across the meter connection binding post. This will shunt the meter circuit and serve to protect the meter by dampening needle action.

CAUTION

Do not drop the THRULINE, or its Elements, or subject them to hard blows. The microammeter has a delicate mechanism that may be damaged by severe impact. Handle the Plug-In-Elements with care at all times. Calibration could also be disturbed by a hard blow or severe impact.

2. Connection

The Model 4340 RF Standard Wattmeter is ready for use without needing any preliminary tests or calibration. The following procedure is all that is required to put it into service:-

1. Remove the cover by unfastening the latches and pushing it to the side so that it slides out of the hinges.

2. Remove the line section and position it so that the input side may be connected to the source of power. The instrument to be checked or calibrated should always be placed on the output or opposite to the end marked input.

3. Remove the meter shunt by loosening the terminals of the binding post and allowing the metal shorting bar to drop to the bottom terminal.

Section III - Installation (Continued)

2. Connection (Continued)

4. Remove the cable assy. from cover and insert the plug into the binding post so that the white lined side of the plug goes into the white terminal. When this plug is reversed the meter will deviate below zero. Screw the connector at the other end of the cable securely on the jack on the line section.

5. Insert the proper element into the line section, and rotate so that the arrow on the cap points in the direction of power flow. Selection of proper Element depends on the frequency of the RF power to be measured.

6. The RF power must be properly filtered before the measuring line section and acceptably terminated in a 50 ohm coaxial system.

NOTE: Stated accuracy applies only when system VSWR on the load side is less than 1.2 to 1 with undesired signal constituents below -30dB.

Section IV - Operation

1. General

The evident features of the THRULINE equipment have been discussed in Section I, General Description, and in the instructions of Section III, Installation. Measurements are made by the insertion and operation of the Plug-In Elements previously mentioned.

The elements agree with the power range as read on the meter scale, and the major markings are the FULL SCALE POWER value for that element. Elements are also marked for FREQUENCY RANGE. The transmitter frequency must be within the band of the element used.

ARROW on Plug-In Element indicates Sensitive DIRECTION, i.e., the direction of power flow which the meter will read. FORWARD and REVERSE are directional terms used in reference to the THRULINE element, and mean respectively the sensitive and null directions of the element. Rotate elements to reverse the sensitive direction. FORWARD and REFLECTED are directional terms used in reference to the source-load circuit. Note that the transmitter may possibly attach to either connector of the RF line section. It makes no difference which external RF connector is selected, however, the input side of the line section should be observed, and the input connector installed on this end for greatest accuracy. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

2. Accuracies Obtainable

The Model 4340 RF Standard Wattmeter has an accuracy of ±3% of full scale direct reading or ±3% of reading at the calibration

Section IV - Operation (Continued)

2. Accuracies Obtainable (Continued)

points supplied.

It should be understood that two instruments being checked against one another can both be within stated tolerance and still show a difference that is greater than the maximum of either. In other words in an extreme set of conditions, the two instruments being compared might have their full allowable error in opposite directions. For example, a ±2% Calorimeter and the ±3% Model 4340 could show a difference of as much as 5% in reading. Another example could be a ±5% RF Wattmeter and the ±3% Model 4340 could show a difference of 8% in reading.

However, under normal expectancy the difference in readings should not be greater than the least accurate instrument.

CAUTION - The Wattmeter, the THRULINE Element, and the RF line section (referred to as THRULINE in remainder of this section) all have matched serial numbers - do not intermix these parts with other units.

The RF must be well filtered and without significant modulation products. Harmonic signals should be at least 30dB down and preferably 50dB down from the signal being measured.

The Operator contributes to the final result in two ways. One, through the amount of his experience, carefulness, and reasoning ability and two, through limitations of visual resolution of meter readability.

Section IV - Operation (Continued)

2. Accuracies Obtainable (Continued)

Great care has been taken in the Model 4340 RF Standard Wattmeter to obtain the highest obtainable accuracy. However as pointed out above the actual accuracy in use is also dependent on the purity of the RF energy and on the experience of the operator.

3. Load Power

Power delivered to (and dissipated in) a load is given by:

$|L| =$ Watts into Load $= |F| - |R|$

i.e., where appreciable power is reflected, as with an antenna, it is necessary to subtract reflected from forward power to get load power. This correction is negligible (less than 1 percent) if the load is such as to have VSWR of 1.2 or less. Good load resistors, such as our Model 8100 Series RF Loads, will thus show negligible or unreadable reflected power.

VSWR scales, and their attendent controls, for setting the reference point, have been intentionally omitted from the THRULINE for two reasons:

(a) Why make something similar to a hypothetical DC volt-ohmmeter with control pots for the voltmeter multipliers? Even more complications arise when diodes at RF are involved.

(b) Experience using the THRULINE on transmitter tune-up antenna matching etc., i.e., on OPERATING PROBLEMS shows that the power ratio ϕ is no mean competitor, in practical usefulness, to the ratio ρ = VSWR.

A trial is suggested for a few days - forget VSWR and try thinking in terms of $\phi = |R| / |F|$ when the THRULINE is used. It will

Section IV - Operation (Continued)

3. Load Power (Continued)

be noted that, even without bothering to calculate the ratio exactly, the two meter readings $\backslash R/$ and $\backslash F/$ give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem, the main thing usually is to minimize $\backslash R/$, and anything done experimentally to this end is noted directly when the THRULINE is in the reflected position. Furthermore, the ratio of readings, only mentally evaluated, is a reliable guide to the significance of the remaining reflected power.

4. ρ vs ϕ and Its Significance

Since there are definite simple relationships:

$$\rho = \frac{1 + \sqrt{\phi}}{1 - \sqrt{\phi}} \quad \text{and} \quad \phi = \left[\frac{\rho - 1}{\rho + 1}\right]^2 \quad \text{where} \quad \rho = \text{VSWR} \quad \text{and} \quad \phi = \frac{\backslash R/}{\backslash F/}$$

between standing wave ratio ρ and the reflected/forward power ratio ϕ indicated by the THRULINE, the latter may be conveniently used to measure VSWR. Note, that around ϕ = 10%, below which $\backslash R/$ will appear insignificant and may be hard to read, you are close to the commonly accepted lower limit ρ = 2, below which improved antenna match becomes less and less worthwhile in many systems. Experimentally, using the THRULINE, it is readily shown that minimizing ϕ below 10% produces little in $\backslash L/$. TV transmitter antenna lines, and VHF omnirange transmitters, are among those systems requiring much lower levels of reflected power for reasons other than simple power transmission. A very small level of reflected power ϕ = .06 percent, corresponds to ρ = 1.05. With a single Element detection of reflected power is possible down to about ϕ = 1 percent.

4. ρ vs ø and Its Significance (Continued)

ρ = 1.2; if $|F|$ approaches full scale, measurement is possible down to about ø = 5 percent, ρ = 1.5.

Section V - Maintenance

1. Introduction

With the simple construction and generally self-contained nature of the THRULINE equipment, there is only a moderate amount of maintenance required. One of the major precautions is in handling: Use reasonable care and do not drop the THRULINE equipment or the Plug-In Elements.

The main factor in maintenance is care and cleanliness. The element socket should be kept plugged as much as possible to prevent the intrusion of dust. When a Plug-In Element is used for this purpose (use highest power element available), it should be positioned with the ARROW pointing at 90° to the center conductor. This protects the meter and will not expose the element crystal to dangerous potentials if the RF line section should be energized.

2. Cleaning

Inspect the equipment occasionally. Wipe the case and meter face with a soft cloth and mild detergent if necessary. If any of the contacts or line connectors become dirty, they should be cleaned with a little dry cleaning solvent, Inhibisol, or its equivalent on a cotton swab stick. Avoid excessive skin contact or inhalation of fumes. Observe special care if carbon tetrachloride is used. Clean all contact areas and especially the exposed faces of the teflon insulators.

Section V - Maintenance (Continued)

2. Cleaning (Continued)

It is particularly important to keep the mating surfaces of the socket and Plug-In Element clean. This applies to the bore of the socket and the circumference of the THRULINE element body, but most important to the bottom rim of the element body and the seat at the base of the socket in the line section. Also, check the ends of the insulated DC contacts on the THRULINE element to see that they are clean and smooth. These parts should be carefully cleaned with a cotton swab stick and dry cleaning solvent, as mentioned. There must be a good contact between the base of the Plug-In Element and its socket to assure stable operation of the THRULINE.

3. Contact Adjustment

In cleaning the socket bore, the operator should be careful not to disturb the spring finger of the DC contact. It is important that the operating position of this part be properly maintained. If the spring finger of the DC contact required adjustment, it may be done manually if carried out with care. The button must be positioned far enough out to maintain good contact with the element, but not so as to interfere with easy entry of the element body. The DC jack (with spring finger) may be removed for access by unscrewing the two #4-40 fillister head machine screws which fasten it to the side of the RF line section. Then retract its assembly, watching carefully not to lose the small teflon positioning bead that straddles the base of the phospor bronze spring and nests in a counterbore on the side of the RF body. When replacing the

3. Contact Adjustment

assembly, be sure that the bead is again properly inserted.

4. Line Section Care

If there is any evidence of contamination inside the RF line section, the reachable portions should be likewise wiped and the interior carefully blown out. Under no circumstances attempt to remove the RF center conductor. It is tightly frozen in place and any attempt to remove it will ruin the assembly. Keep all connections tight, and keep the nut of the meter cord plug turned tight on the line section DC jack. This connection may often be serviced by simply loosening the nut of the DC plug, swinging the body several times through a fraction of a turn, and retightening the knurled nut securely.

There are no replacement parts furnished with this equipment. As previously mentioned, components of these matched units cannot be interchanged or individually replaced. The replaceable portions to the Line Section are standard parts of the coaxial line fastenings.

Section VI

Model 4340 THRULINE®
RF Standard Wattmeter

Replacement Parts List

Qty.	Description	Part No.
1	Case Assembly	4340-002
1*	Meter	2090-010
1	Meter Cable Assembly	4340-007
1	Binding Post	5-598
1	D.C. Cable & Plug Assembly	4340-008
-1-	Binding Post Plug (included in	5-599
-1-	D.C. Plug P/N 4340-008)	7500-076
1*	Line Section Assembly	4230-005-2
-1-	D.C. Connector, Jack (included in P/N 4230-005-2)	4230-010
-1-	RF Connector Female N, "QC" Type	4240-062
-1-	RF Connector Male N, "QC" Type (Connectors included in P/N 4230-005-2)	4240-063
1*	Element 2-10 MHz	434-11
1*	Element 10-30 MHz	434-12
1*	Element 30-100 MHz	434-13
1*	Element 100-500 MHz	434-14
1*	Element 500-1000 MHz	434-15

*These items are not normally field replaceable without voiding the 3% instrument accuracy. It is advisable to return the unit to Bird Electronic Corp. should replacement of these parts become necessary.