MODEL 4307

Instruction Manual

for

THRULINE

RF Wattmeter

Model 4307

SUMMARY SHEET

Circuit	- 75-ohm impedance - THRULINE
Measures	- RF Power - 25W to 5000W Full Scale Direct Reading in Watts, Frequency Range 2-1000 MHz in 31 Std. Element types.
Insertion VSWR	- Less than 1.05 VSWR up to 1000 MHz
Accuracy	- ±5% of Full Scale Power
Dimensions	- Basic Overall 7"lg x 4"w x 3"h
Weight	- 4 Pounds
Connectors	- Female "N" 75-ohm
	2 Female "N" Connectors standard with equipment

SECTION 1
GENERAL DESCRIPTION

1. PURPOSE AND APPLICATION

The Model 4307 THRULINE Wattmeter is an insertion type RF wattmeter, designed to measure power flow and load match in 75-ohm coaxial transmission lines. The Model 4307 when used in 75-ohm applications, has an insertion VSWR of less than 1.05:1 up to a frequency of 1000 MHz. The meter is direct reading in watts, expanded down scale for easy reading, and is graduated in 5, 10, and 20 unit increments. The power values used are determined by the Plug-In Elements, which fall in six frequency band groups and cover an overall range of 2 to 1000 MHz. See Table 1, page 8-1.

2. DESCRIPTION

The Model 4307 THRULINE is a portable unit contained in a die cast aluminum housing, with a formed metal enclosure on the back which is easily removed. Included with the unit is a leather carrying strap, four rubber shock feet on the base, and four rubber bumpers on the back, which allow the Model 4307 to stand or lie flat when used. For additional protection, the microammeter is specially shock mounted. A slotted screw is provided on the lower front face of the meter for zeroing the pointer. Below the meter, the RF line section face protrudes slightly from the wattmeter housing with the Plug-In Element socket in the center.

A shielded cable connects the microammeter to the dc jack which is attached to the side of the RF line section casting. This cable, nearly three feet long, permits removal of the RF line section from the Wattmeter housing. Meter connections may be maintained with any installations outside of the housing. This permits permanent additional installations to be made.

Inside the dc jack assembly, there is a filter capacitor which shunts the meter circuit to prevent mis-readings caused by stray RF energy existing in the Plug-In Element. Mounted on the dc jack is a phosphor bronze spring finger, which protrudes through a lateral hole and into the Plug-In Element socket of the RF line section. The finger has a button on its end which mates with the contacts of the Plug-In Element. The silver plated brass RF line section is precision made to provide the best possible impedance match to the coaxial RF transmission line in which the Model 4307 is inserted. The ends of the line section are nested in mating slots to provide additional mechanical support.

To make measurements, the cylindrical shaped Plug-In Element is inserted into the line section socket and rotated against one stop. A small catch in the upper right hand corner of the casting face presses on the shoulder of the Plug-In Element to keep it in proper alignment and assure a good contact with the dc jack and between the lower edge of the Element and line section body. On diametrically opposite sides of the Plug-In Element body are contacts to provide dc pick-up in either direction. These contacts make connection with the spring finger of the dc jack only when the Plug-In Element is in the precise forward or reverse position, and with the index pin on the Element on the lower level of the line section casting face against its respective stop.

SECTION 2
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 result 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 to 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:

$\overset{\backslash F/}{W}$ = Watts Forward = $E^2/Z_O = I^2Z_O = EI$

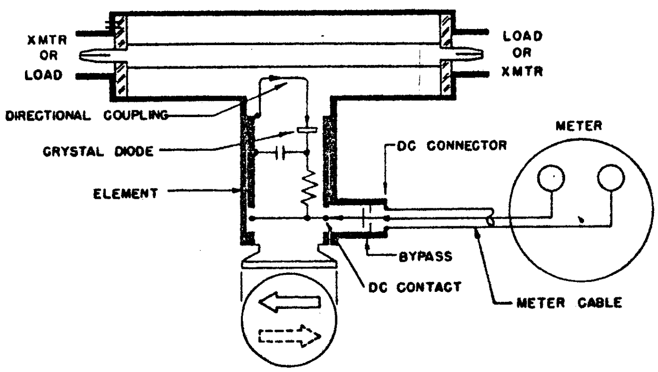

Fig. 2-1. Schematic Diagram

$\overset{\backslash R/}{W}$ = Watts Reverse $=\mathcal{E}^2/Z_O = \mathcal{I}^2 Z_O = \mathcal{E}\mathcal{I}$

Z_O is the characteristic impedance of the uniform line.

2. COUPLING CIRCUIT

The coupling circuit which samples the travelling waves is in the Plug-In Element. The circuitry of the Element and its relationship to the other components of the THRULINE are illustrated in the schematic diagram, Figure 2-1. Energy will be produced 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 Plug-In Element remains stationary, it is apparent that the coupling currents produced from the waves of one direction will add in phase, and those produced from waves of the opposite direction will accordingly subtract in phase. The additive or "ARROW" direction is, of course, 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 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.

3. STANDING WAVE RATIO vs. REFLECTED/FORWARD POWER RATIO

As mentioned above, the THRULINE technique uses the TRAVELLING WAVE viewpoint to measure most of the outstanding facts about transmission line operation. Another widely used and related viewpoint, is the STANDING WAVES, which is quite elaborately developed both mathematically and in existing equipment. This technique can be traced to the early development of slotted lines as tools of exploration.

The slotted line is a standing wave instrument, and emphasizes this viewpoint. However, the slotted line is too long, too expensive if good, not portable, and slow in operation. These objections increase rapidly as the frequency drops below 1000 MHz. Whereas the THRULINE is surprisingly quick, convenient, and accurate by comparison. With the exception of phase angle reflection (distance, load to minimum) it tells everything a slotted line will.

The relationships between TRAVELLING WAVES and STANDING WAVE viewpoints are given in most high frequency textbooks.

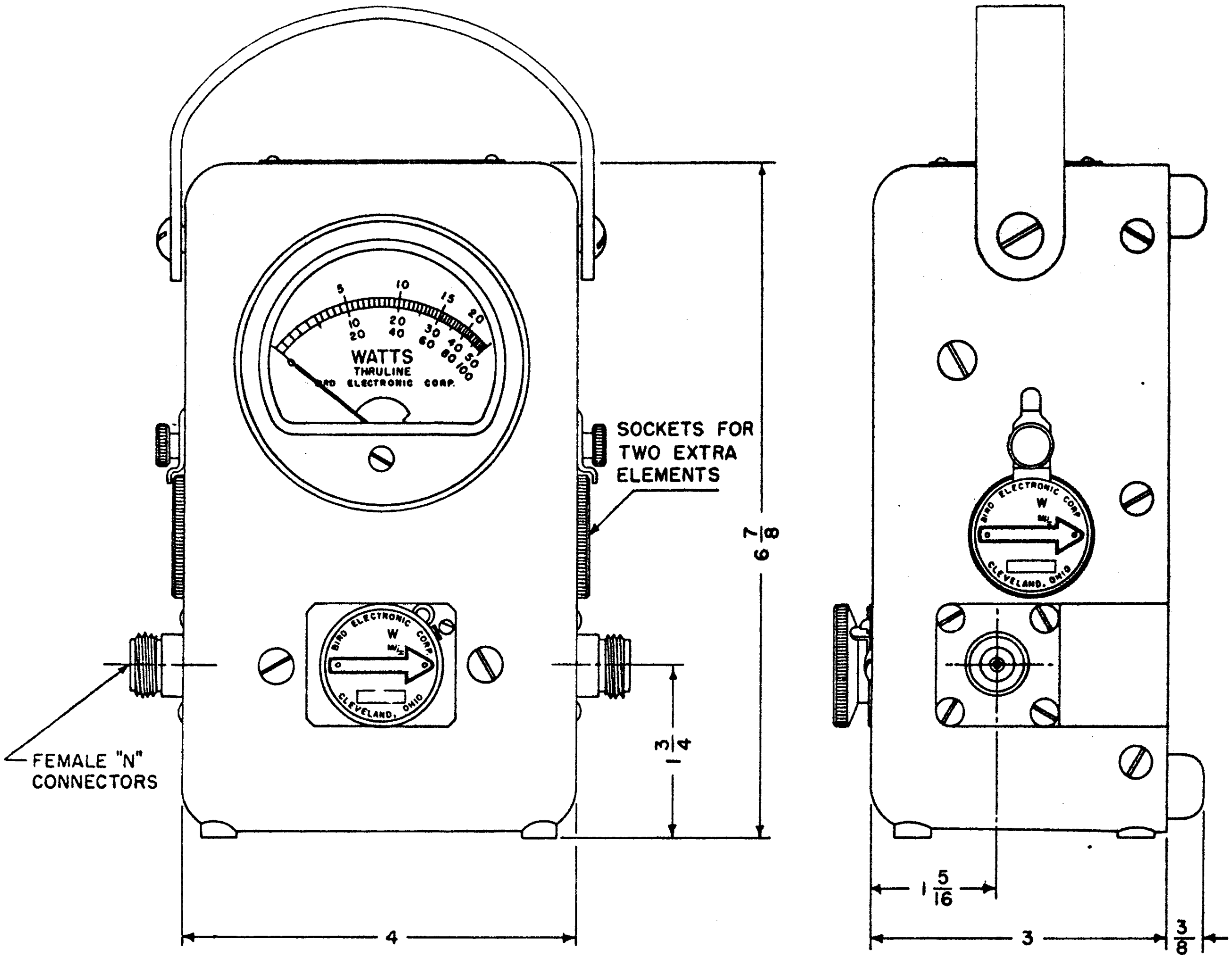

Fig. 3-1. Outline Drawing, Model 43 THRULINE

1. PORTABILITY

The Model 4307 is a portable instrument, and the housing is not designed for fixed mounting (see Outline Drawing, Figure 3-1). A strap is provided for carrying purposes.

While transporting the THRULINE, it is best to insert a Plug-In Element, secure with the catch, and point the ARROW upwards. This will shunt the meter circuit and serve to protect the meter by dampening needle action during handling or shipping. Also, secure the spare Plug-In Elements in their receptacles with the thumbscrew and clamp. Handle the Plug-In Elements with care at all times. Calibration could be disturbed if they are dropped.

CAUTION

Do not drop the THRULINE or its Elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

2. CONNECTIONS

Insert the Model 4307 THRULINE in coaxial transmission lines of 75 ohms nominal impedance. It is indifferent to which respective side the power source and the load connections are made. If cables other than 75 ohms are used, a mismatch will occur causing probable serious inaccuracies in readings.

The Model 4307 is normally supplied with two 75 ohm Female N-Type connectors.

3. REMOTE INSTALLATION

The RF line section can be removed from the meter housing for remote installation. To remove the line section from its housing:

a. Unscrew the six #8-32 flat head machine screws holding the back cover.

b. Grasp the cover by the side filler tabs and pull directly backwards. The back cover assembly will come off with the speed nuts remaining attached.

c. Remove the two #10-32 oval head machine screws on the front of the housing.

d. Slide the line section backwards out of the housing. Do not loosen the two oval head screws on the sides of the housing in line with the meter. These hold the meter supporting shock ring in place.

e. Substitute the cable which attaches the line section to the meter with a sufficient length of cable to make the remote installation.

f. To replace the RF line section, reverse the above procedure.

It may be desirable to have two or more line sections permanently installed in continuous operating equipment. In this case, one set of Elements and one meter may be used to measure several RF transmission lines WITHOUT INTERRUPTION OF RF LINE for insertion of the THRULINE. Additional RF line sections (Figure 3-2) are available.

The RF Line Section of the Model 4307 blends very readily to panel type mounting. A layout for the panel mount cut is given in Figure 3-3. The thickness of the panel should be about 1/4 inch. On panels less than this, build up the thickness with pads or washers to achieve a flush-face mounting. Cable connections are simplified because the RF line section may be mounted in any convenient direction. Attach the line section so that the finger catch is in the most accessible position.

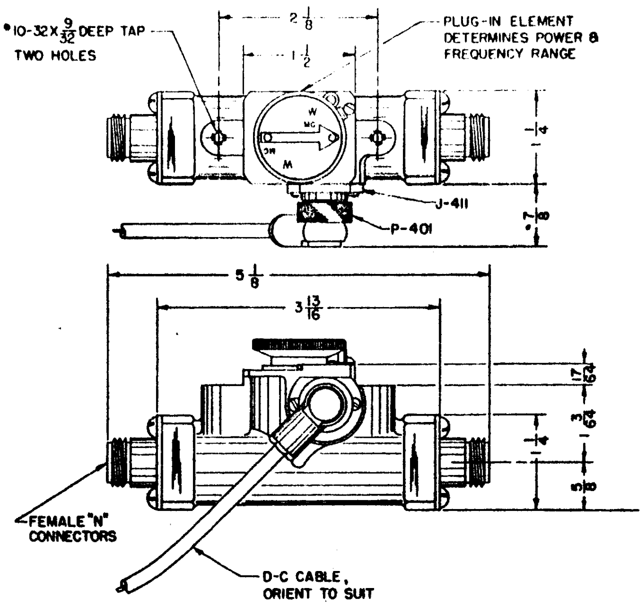

Fig. 3-2. Installation Drawing, R-F Line Section

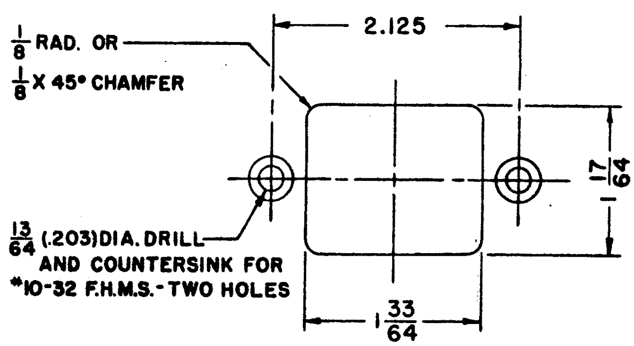

Fig. 3-3. Panel Cut for Mounting R-F Body

SECTION 4
OPERATION

1. GENERAL

The apparent features of the THRULINE equipment have been discussed in Section 1, GENERAL DESCRIPTION, and in the instructions of Section 3, INSTALLATION. Measurements are made by the insertion, and operation of the Plug-In Elements previously mentioned.

The Elements determine the power range to be read on the meter scale, and the major markings (viz. 50W, 100W, etc.) 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. Elements are available according to those identified in the table on page 8-1.

ARROW on Plug-In Element indicates Sensitive DIRECTION, i.e., the direction of power flow which the meter will read. ARROW and REVERSE are directional terms used in reference to the THRULINE ELEMENT, and mean respectively the sensitive and null directions of the Element. ROTATE ELEMENT to reverse the sensitive direction. FORWARD and REFLECTED are directional terms used in reference to the source - load circuit. Note that the transmitter may attach to either connector of the THRULINE. It makes no difference which external RF connection is selected, since the Elements are reversible and the RF circuit is symmetrical end for end. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

In cases where readings are being made when the meter unit is connected to an auxiliary RF line section body, always remove any measuring Element from the unused RF line section. Otherwise, the dc circuit will be unbalanced or shorted according to the arrow position of the other Element, causing inaccurate or no reading on the meter.

2. LOAD POWER

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

$$W_L = \text{Watts into Load} = W_F - W_R$$

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

VSWR scales, and their attendant 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 Ø 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 Ø = \R/ / \F/ when the THRULINE is used. It will be noted that, even without bothering to calculate the ratio exactly, the two meter readings \R/ and \F/ give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem, the main thing usually is to minimize \R/ , and anything done experimentally to this end is directly indicated 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.

SPECIAL NOTE

Always use great care with LOW SCALE Elements on HIGH power RF lines. Inadvertent exposure of these Elements too much FORWARD or even too high reflected power may permanently damage the measuring Element or the microammeter.

3. MEASUREMENT & MONITORING OF TRANSMITTER POWER

The THRULINE is useful for continuous monitoring of transmitter output, and may be found useful in continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

Like diode devices generally, the THRULINE indicates the carrier component on amplitude modulation, with very little response to side-band components added by modulation.

75 OHM ELEMENTS FOR MODEL 4307 (CATALOG NUMBERS)

	Frequency Bands (MHz)					
Power Range	2-30	25-60	50-125	100-250	200-500	400 1000
25 watts	----	75-25A	75-25B	75-25C	75-25D	75-25E
50 watts	----	75-50A	75-50B	75-50C	75-50D	75-50E
100 watts	75-100H	75-100A	75-100B	75-100C	75-100D	75-100E
250 watts	75-250H	75-250A	75-250B	75-250C	75-250D	75-250E
500 watts	75-500H	75-500A	75-500B	75-500C	75-500D	75-500E
1000 watts	75-1000H					
2500 watts	75-2500H					
5000 watts	75-5000H					

SECTION 5
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 upwards. This protects the meter and will not expose the Element crystal to dangerous potentials if the RF line section should be energized. If any of the contacts or line connectors become dirty, they should be cleaned with a little dry cleaning solvent, Inhibisol[1]; its equivalent, or trichlorethylene, on a cotton swab stick. Avoid excessive skin contact or inhalation of fumes when using. Observe special care if carbon tetrachloride is used. Clean all contact areas and especially the exposed faces of the teflon[2] insulators.

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 above. There must be a good contact between the base of the Plug-In Element and its socket to assure stable operation of the THRULINE.

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 requires 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 phosphor bronze spring and nests in a counterbore on the side of the RF body. When replacing the assembly, be sure that the bead is again properly inserted.

1 A carbon tet. replacement
2 A registered tradename

If there is any evidence of the 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.

2. TROUBLE SHOOTING

As a brief guide to the operator in isolating occassional difficulties that may occur in the use of the THRULINE, the following summary is included. The remedies for same are referenced to the text in this section or are self-evident:

DIFFICULTY	POSSIBLE CAUSES
No Meter Indication	No radio frequency power.
	Arrow on Plug-In Element pointing wrong direction.
	No pick-up from dc contact finger in the RF line section - adjust per Paragraph 1.
	Open or short circuit in dc meter cable.
	Plug-In Element burned out or damaged.
	Meter burned out or damaged.
Intermittent or in-consistent meter readings.	Faulty load.
	Faulty transmission line.
	Dirty dc contacts on Elements - Clean as in Paragraph 1.
	Sticky or defective meter.
High VSWR or high percent reflected power.	Bad load, or poor connectors - see Par.1
	Short or open transmission line.
	Foreign material in line section or in RF connector bodies - see Paragraph 1.

SECTION 6 - PARTS LIST

DESCRIPTION	QTY.	PART NO.
Housing Assembly	1	4210-018
Cover Assembly	1	4210-005-1
Element, Plug-In	As Ordered	See Table
Line Section Assembly	1	4307-002
Carry Strap	1	8580-003
Connectors, RF (Female "N") 72 ohm	1	4240-261
DC Connector Assembly	1	4230-010
Microammeter	1	2080-002
Replacement Meter Kit	1	
Consisting of:		
1 - 2080-002 Meter		
2 - 4220-097-1 Cable Assembly		
3 - 4220-098 Bumper Stem		8-000
Connector, Plug	1	7500-076
Meter Cable Assembly	1	4220-097-1