BIRD

INSTRUCTION BOOK

THRULINE®
RF Directional Wattmeter

model 3122/4342

SUMMARY SHEET

Circuit	-	50-ohm impedance - THRULINE®
Measures	-	RF Power - 1W to 10KW Full Scale Direct Reading in Watts, Frequency Range 2 - 2300 MHz in specially paired Element types, see Table below.
Insertion VSWR	-	1.035 max. to point of measurement 1.07 max. overall
Accuracy	-	±5% of Full Scale Power
Dimensions	-	Basic Overall 19 lg x 5-7/32 h x 2-5/8 deep (483 x 133 x 67 mm)
Weight	-	3-3/4 pounds (1.7 kg)
Connectors	-	2 Female N Connectors standard with equipment, unless otherwise specified.

ELEMENTS - POWER/FREQ. PARAMETERS

Applicable THRULINE Plug-In Element pairs providing 10 to 1 power ratios and matching frequencies. In cases of difference in the discrete (frequency) bands, usable range will cover only the actual overlapping frequency values.

RANGES	WATTS RFL/FWD	FREQUENCY RANGE	CATALOG TABLE
Low	1/10	60-950 MHz	II , I
	2.5 /25	950-2300 MHz	III
Med. Low	5/50	25 to 1000 MHz	I
	10/100	950-1260 MHz	III
	25/250		
Med.	50/500	2-1000 MHz	I
	100/1000		
Med. High	250/2500	2-30 MHz	I
	500/5000		
High	1000/10K	.45 to 2.5 MHz	IV

TABLE OF CONTENTS

SECTION 1 - GENERAL DESCRIPTION

SECTION 2 - THEORY OF OPERATION

SECTION 3 - INSTALLATION

SECTION 4 - OPERATION

SECTION 5 - MAINTENANCE

LIST OF ILLUSTRATIONS

LIST OF TABLES

APPENDIX

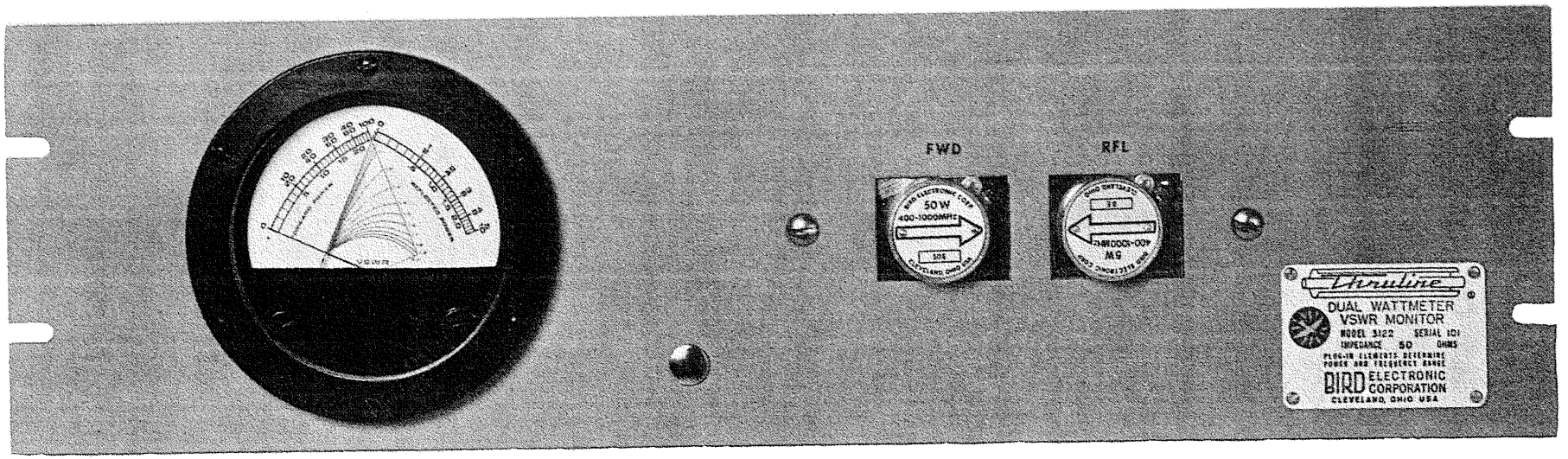


Fig. 1-1. View of Model 3122 THRULINE Wattmeter

SECTION 1
GENERAL DESCRIPTION

. PURPOSE AND APPLICATION

The Bird Directional Wattmeter/VSWR Monior is a continuous service equipment designed for bservation of performance, and for convenient ieasurement of mismatch conditions in 50-ohm adio frequency transmission systems. By use of a nique, specially designed dual-pointer meter, forard and reverse RF Power and VSWR are contiuously and simultaneously displayed - without witching. The entire Wattmeter is mounted on a tandard size relay rack panel for incorporation in ack mounted equipment systems (See Installation ection III, and Fig. 1-1).

The Model 3122 Directional Wattmeter is capaile of measuring forward power values from 10 to 0,000 watts in frequencies from .45 to 2300 MHz depending on power value). Element pairs are ised in 10 to 1 power level ratios only - consult he Summary Page for Table of Parameters of cceptable Plug-In Element combinations presently vailable.

2. METER

The meter has two distinct pivot-and-pointer ssemblies mounted opposite to each other, and perating electrically independently. The scale on he left hand side of meter "face" reads forward power flowing thru the coaxial line section of the Wattmeter and the right hand scale simultaneously indicates the reflected power.

In the unique design feature of this meter the arc lengths of the pointers and their pivot positions are so arranged so as to produce in the overall locus of the intersection of the two knife-edged pointers, a quadrilateral of the optimum form. This form has the best proportion of height to width to properly display the curves within it.

Described in red lines in this form is the array of VSWR curves which lead to the readout scale on the right hand edge. In use, the VSWR is readily taken by referring the intersection of the pointers to the appropriate curve under it and following over to the VSWR scale.

3. POWER MEASUREMENT

Power readings are made on the respective scale of the meter (forward and reflected), and they read directly according to the full scale value in watts on the nameplate of the applicable plug-in measuring Elements. For proper resolution of the VSWR scale reading, these Elements must be in a 10 to 1 power ratio at all levels. To keep readings within stated accuracy, the signal frequency in the RF line must be within the bands of paired Elements, see Section 4, Paragraph 4.

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 $E/I = Z_0$.

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 $\mathcal{E}/\mathcal{I} = Z_0$.

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

W_F = Watts Forward = $E^2/Z_0 = I^2 Z_0 = EI$

W_R = Watts Reverse = $\mathcal{E}^2/Z_0 = \mathcal{I}^2 Z_0 = \mathcal{E}\mathcal{I}$

Z_0 is the characteristic impedance of the uniform line, and simplifies matters by being a pure resistance, usually 50 ohms, for useful lines. The main RF circuit of the THRULINE is a short piece of uniform air type line section, whose Z_0 is a very accurate 50 ohms, in which correct measurements may be made.

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.

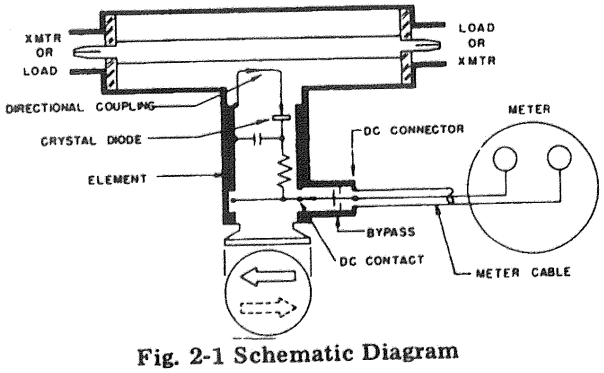


Fig. 2-1 Schematic Diagram

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 30 dB, 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 WAVE, 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.

SECTION 3
INSTALLATION

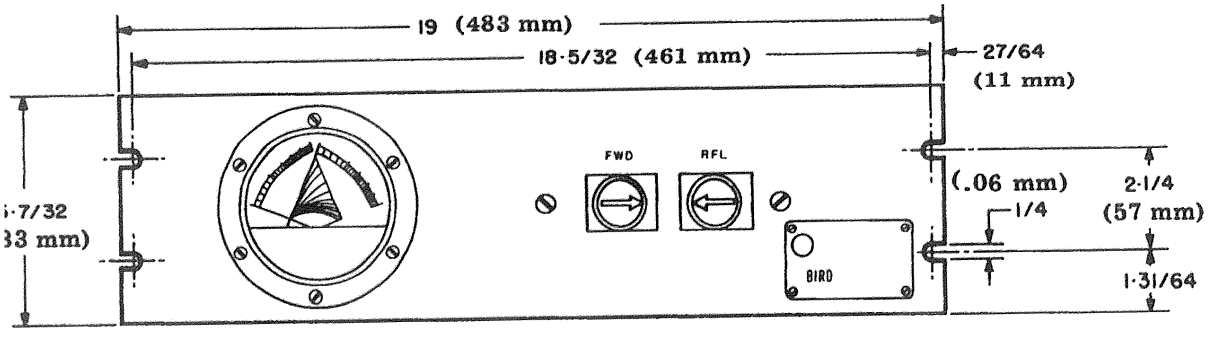


Fig. 3-1 Installation Drawing, Model 3122 THRULINE

1. MOUNTING

The THRULINE Model 3122 equipment is incorporated entirely on its panel mount. It is a Size C panel of the American Standard relay rack panels for use in the ASA relay rack. The panel is 1/8" thick - refer Installation Dwg., Fig. 3-1.

The Directional Wattmeter may be installed at the transmitter RF output or between the driver and output tubes. When installed at the transmitter output, place as close as possible to the transmitter for maximum observance of conditions beyond this point. In placing the Wattmeter in the rack, seek convenience of meter reading and short cabling.

The zero adjust screws for the dual micro-ammeter are on the back of the meter case. Normally, these should be correctly adjusted at the factory. Inspect the pointer positions carefully - if adjustment is required this is best done before the panel is mounted.

The THRULINE Section is marked "INPUT" on the top side of the line block at the appropriate end; and the panel is labeled for "FWD" and "RFL" Plug-In Element sockets. It is essential that the high power Element be placed in the FWD socket. The Elements must have their direction arrows pointed toward each other, and be selected according to Power/Freq. Parameters on Summary Table, Page A. Caution - do not expose reflected Element to forward power (due to mis-direction of Element or a reversed power setup). Damage to meter and/or the Element could result from the overloading. The Wattmeter/VSWR Monitor is set up for proper performance, and its calibration is verified, in the positions designated - Install only this way.

2. CONNECTIONS

The Line Section is normally equipped with two Bird "QC" Female Type N Connectors. These are readily interchanged with the other Bird "QC" connector types - See listing on Parts List, Section 6. With these other connector types refer to specifications for effect on transmission capability. All connections are made behind the panel. Use of RG-8A/U, -9B/U, -213/U or -214/U cables with appropriate N connectors is suggested. Keep cables as short as possible, avoid sharp cable bends, and minimize use of angles and adapters. Fasten all connectors snugly.

After installation, the Wattmeter requires but little attention. To avoid instrusion of dust or foreigh material into the Line Section, do not leave Element Sockets open. If desired, the Plug-In Elements may be turned to vertical arrow direction (up or down) to de-energize the meter.

Table I **STANDARD ELEMENTS (CATALOG NUMBERS)**

Power Range	Frequency Bands (MHz) 2-30	25-60	50-125	100-250	200-500	400-1000
5 watts	—	5A	5B	5C	5D	5E
10 watts	—	10A	10B	10C	10D	10E
25 watts	—	25A	25B	25C	25D	25E
50 watts	50H	50A	50B	50C	50D	50E
100 watts	100H	100A	100B	100C	100D	100E
250 watts	250H	250A	250B	250C	250D	250E
500 watts	500H	500A	500B	500C	500D	500E
1000 watts	1000H	1000A	1000B	1000C	1000D	1000E
2500 watts	2500H					
5000 watts	5000H					

Table II **LOW-POWER ELEMENTS**

1 watt	Cat. No.	2.5 watts	Cat. No.
60-80 MHz	060-1	60-80 MHz	060-2
80-95 MHz	080-1	80-95 MHz	080-2
95-125 MHz	095-1	95-150 MHz	095-2
110-160 MHz	110-1	150-250 MHz	150-2
150-250 MHz	150-1	200-300 MHz	200-2
200-300 MHz	200-1	250-450 MHz	250-2
275-450 MHz	275-1	400-850 MHz	400-2
425-850 MHz	425-1	800-950 MHz	800-2
800-950 MHz	800-1		

Table III **HIGH-FREQUENCY ELEMENTS (CATALOG NUMBERS)**

Power Range	Frequency Bands (MHz) 950-1260	1100-1800	1700-2200	2200-2300
1 watt	1J	1K	1L	1M
2.5 watts	2.5J	2.5K	2.5L	2.5M
5 watts	5J	5K	5L	5M
10 watts	10J	10K	10L	10M
25 watts	25J	25K	25L	25M
50 watts	50J			
100 watts	100J			
250 watts	250J			

Table IV **LOW-FREQUENCY ELEMENTS (CATALOG NUMBERS)**

Power Range	Frequency Band .45 to 2.5 MHz
1000 watts	1000P
2500 watts	2500P
5000 watts	5000P
10000 watts	10000P

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 placing and positioning 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 listed in the tables on Summary Page A.

See paragraph 4 of this chapter for frequency band flatness and performance of the Elements outside of stated frequencies. Other Element pairs (power or frequency) may be ordered without returning the THRULINE for calibration, since the RF bodies and meters are standardized, and are designed for a wide range of coaxial transmission power values and frequencies.

ARROW on Plug-In Element indicates Sensitive DIRECTION, i.e., the direction of power flow which the meter reads. ARROW and REVERSE are directional terms used in reference to the THRULINE ELEMENT, and mean respectively the sensitive and null directions of the Element. FORWARD AND REFLECTED are directional terms used in reference to the source - load circuit. Model 3122 is arranged for a given direction of RF flow - see Installation, Section 3. Reversal of this will switch readings on the meter and could cause damage to the meter or Plug-In Elements under high power conditions. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

2. LOAD POWER

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

$$W_L = W_F - W_R$$

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 a VSWR of 1.2 or less. Good load resistors, such as our TERMALINES, will thus show negligible or unreadable reflected power.

There are definite simple relationships

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

$$\text{and } \phi = \frac{W_R}{W_F}$$

between standing wave ratio ρ and the reflected/forward power ratio ϕ indicated by the THRULINE. The VSWR ρ is of course derived directly by using curve array, and the power ratio ϕ may be easily obtained by dividing the power readings indicated. A handy cross-reference between these values is provided by the Bird nomographs appended herewith. These serve simply as a useful check or to apply in determining VSWR from other THRULINE equipments.

SPECIAL NOTE

DON'T ROTATE low power Elements while TRANSMITTER is on. Always use great care with LOW SCALE Elements on HIGH power RF lines. Inadvertent exposure of these Elements to too much FORWARD or even too high reflected power may permanently damage the measuring Element or the microammeter.

3. MEASUREMENT & MONITORING OF TRANSMITTER POWER

Little more need be said about this, in view of LOAD POWER paragraph above. 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 sideband components added by modulation.

4. FREQUENCY RESPONSE

The Plug-In Elements have a very flat frequency response over a frequency ratio of more than 2½ to one. This characteristic provides a practically flat response within the assigned frequency ranges for all the Elements, see Tables I thru IV on page 4-0, opposite.

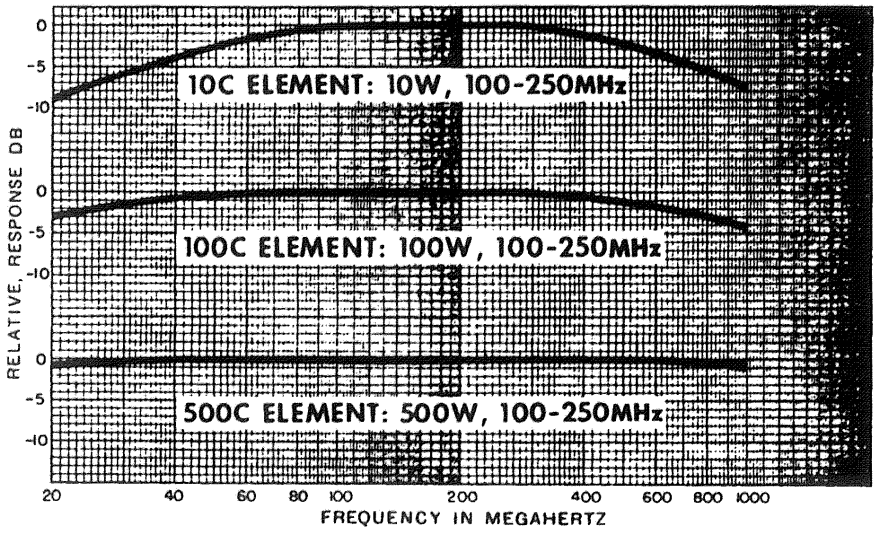
An illustrative set of curves for three Elements of one of these frequency bands is shown in Fig. 4-1. Notice that on the LOW POWER Element, the fall-off above and below the assigned frequency band is more pronounced than it is for the HIGH POWER Element. The degree of drop in response varies progressively less for each power level from low to high, with the average difference at approximately the mean power level. These curves, Fig. 4-1, may be assumed to be about typical at their respective stated frequencies.

Harmonics, or sub-harmonics, may be known to exist in the measured circuit (outside of the Element frequency band). If so, a rough approximation of the response of the Element to these harmonics may be made by the use of these curves. The frequency ordinate to be read on the graph will be obtained by proportioning the frequency of the Element used with that of one illustrated. Interpolation of the curve values will give an approximation of the extent that these harmonic signals are being measured by your Element.

The use of the Elements for direct power measurements outside of their stated frequency range is not recommended.

SPECIAL NOTE

For the convenience of users, a set of VSWR conversion nomographs is appended to the handbook. With these charts, VSWR's may be directly ascertained from forward and reverse power values read from the THRULINE Wattmeter.



FREQUENCY RESPONSE
THRULINE ELEMENTS
100-250 MHz

Fig. 4-1 Graph - Representative Frequency Response

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. To keep the sockets plugged while the THRULINE Plug-In Elements and the Meter are unoperative, the Plug-In Elements should be held in their sockets and 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* or 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* 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.

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 occasional 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 — replace defective cable (RG-58/U)
	Meter burned out or damaged.
Intermittent or inconsistent 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 Paragraph 1.
	Shorted or open transmission line.
	Foreign material in line section or in RF connector bodies — See Paragraph 1.

**INHIBISOL is a registered trade name of a carbon tet replacement manufactured by the Penetone Co., Tenafly, N.J.*

**DuPont Trade Mark*

SECTION 6 — PARTS LIST

Item	Qty.	Part Name	Part No.
1	1	Panel, Rack Mounted	3122-002
2	1	Line Section, THRULINE*	4522-002
3	-2-	(P/O Item 2) Bracket, L.S. Mtg.	4522-009
4	1	Meter, Dual Pointer	4342-020
5	1	Cable Assy. Meter	4220-097-4 9"
5A	1	Cable Assy. Meter	4220-097-5 16"
6	-1-	(P/O Item 5) Plug, Meter Cable	7500-076
7	-1-	(P/O Item 2) DC Conn. Line Section	4230-010
*Comes normally equipped with (2) Bird "QC" Type Female N Conn's and mtg. brackets. (Item 3)			

The "QC" connector may be readily replaced with other AN types. Some applicable connector types available from the manufacturer are:

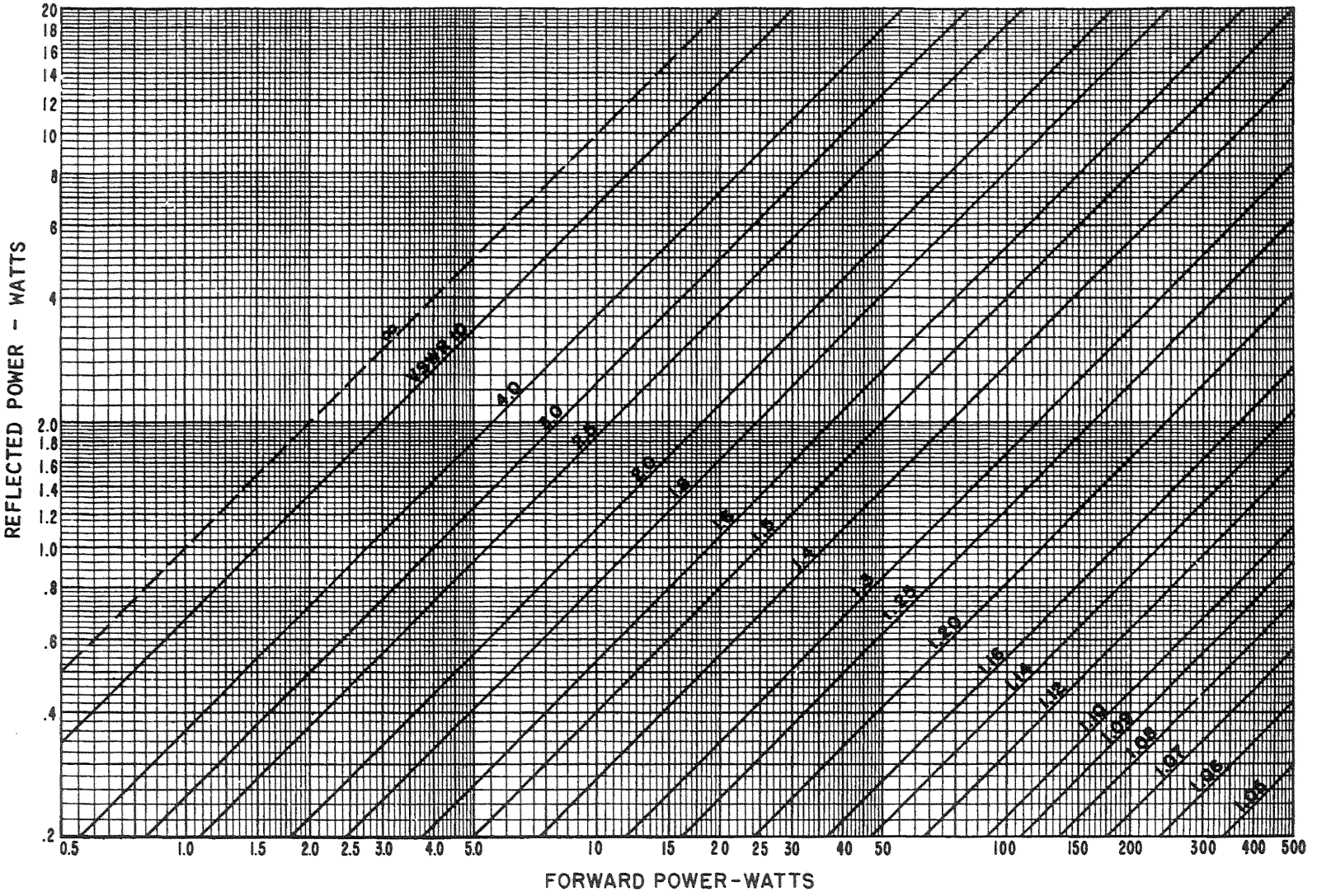
Female	N	424062	Female	HN	424268	Female	BNC	424125
Male	N	424063	Male	HN	424278	Male	BNC	424132
Female	C	424100	Female	UHF	424050	Female	TNC	424156
Male	C	424110	Male	UHF	424173	Male	TNC	424160

The Parts List for the Model 4342 is as listed below:

Item	Qty.	Part Name	Part No.
1	1	Meter	4342-020
2	1	Case	4342-007
3	1	Line Section	4342-002
4	2	Connector (Fem "N")	4240-062
5	2	Meter Cable	4220-097-3
6	1	Carrying Strap	8240-055
7	2	Meter Cable Plug	7500-076

HIGHER RATIOS

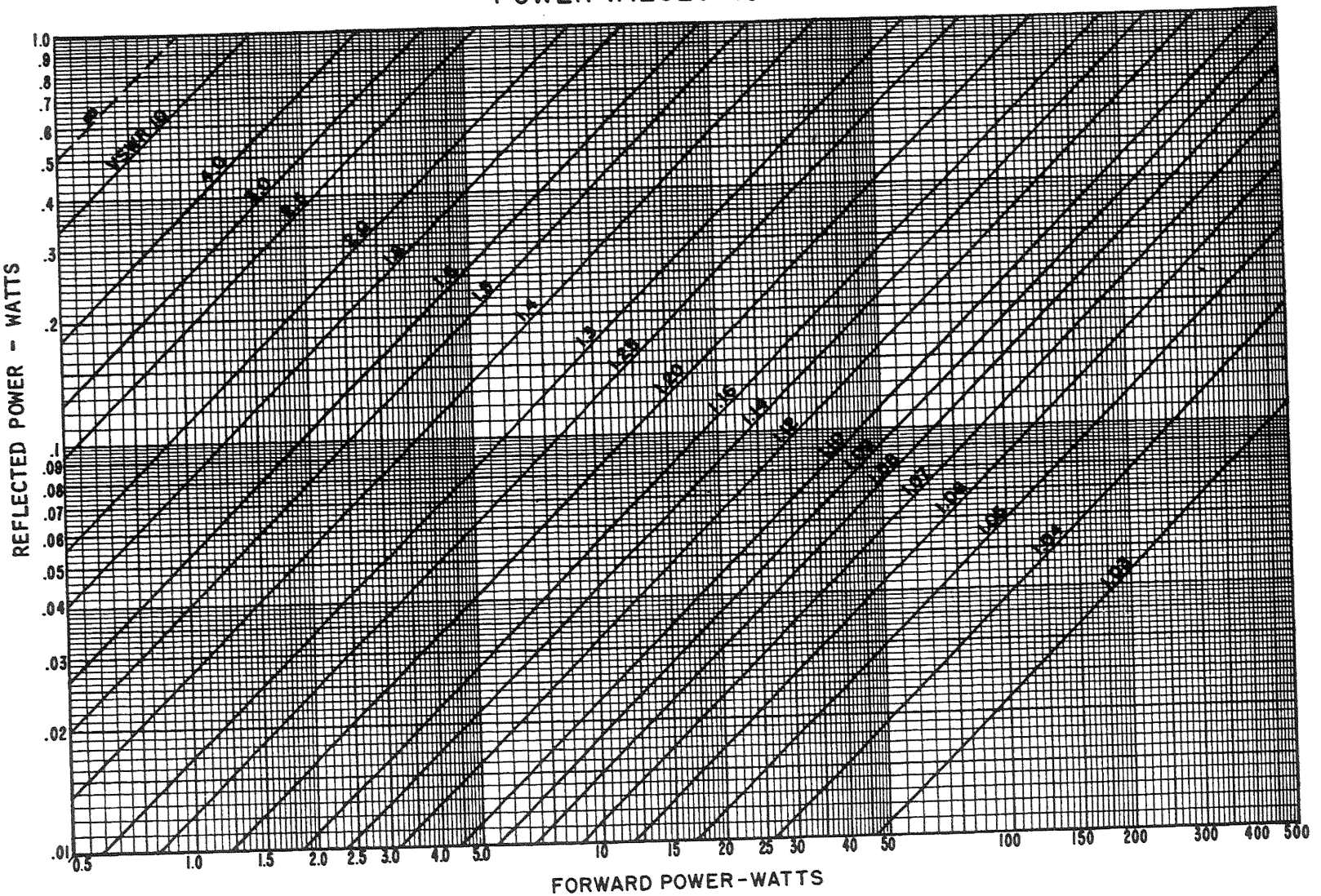
POWER VALUES vs. VSWR



APPENDIX

LOWER RATIOS

POWER VALUES vs. VSWR



APPENDIX

PREFACE

The Bird Model 4342 Directional Wattmeter/VSWR Monitor is a portable version of the Model 3122 which is panel mounted.

The instruction book for the Model 3122 is applicable to Model 4342 except for the section on Installation and the Parts List.

The basic overall dimensions of the Model 4342 are as follows:

6-5/8" H x 7-1/16" W x 3-7/8" D (168 x 179 x 98 mm)

The weight is 5-1/2 pounds (2.5 kg.).