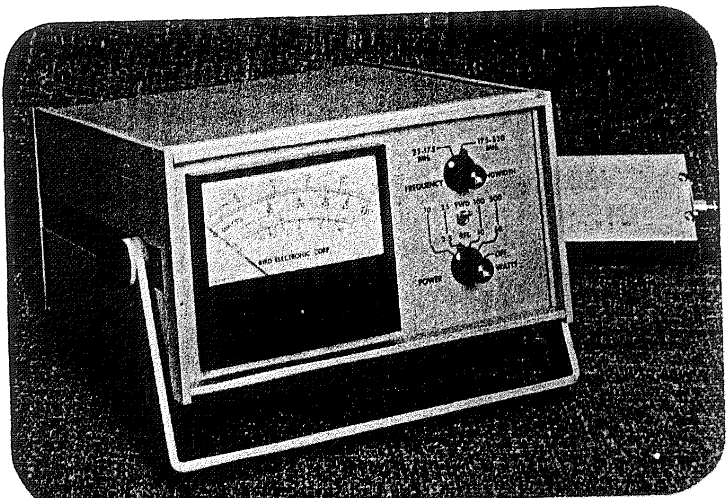
INSTRUCTION BOOK

THRULINE®
RF DIRECTIONAL WATTMETER

MODEL 4370



BIRD
Electronic Corporation
30303 Aurora Road, Cleveland (Solon) Ohio 44139

SECTION I

GENERAL DESCRIPTION

1. Purpose and Application

The Model 4370 multirange THRULINE Directional Wattmeter is an insertion type RF Wattmeter, designed to measure both forward and reflected power in 50-ohm transmission lines.

It is intended for use on CW, AM, FM and SSB signals, but is not suitable for pulsed sources. The Model 4370, when used on 50-ohm applications, has an insertion VSWR less than 1.10:1 throughout its frequency range and an accuracy of ±5% of full scale. The frequency band, power range, and direction of measurement, i.e., forward or reflected, are determined by appropriate switches on the front panel. The meter is direct reading in watts with additional relative dB scales useful in determining return loss (See Fig. 1).

2. Description

The Model 4370 is completely portable and may be used in the laboratory or field. It requires neither an internal or external power supply for operation. The sturdy metal handle folds under to position the wattmeter for convenience in meter reading and operation of controls. The handle can be firmly fixed in the desired attitude by tightening the two thumb-screws located at the sides of the unit.

The Model 4370 is cased in a wholly enclosed, structural-type aluminum housing. In operation, the housing shields the entire unit (line section excepted) from stray RF interference. The covered body of the line section fully shields itself, and its 4-foot metering cable is also fully shielded, serving as well to ground the line section and 4370 case to each other. The length of cable permits the line section and case to be separated for maximum operational utility.

SPECIFICATIONS

Forward Power Ranges	10, 25,100, 500 watts
Reflected Power Ranges	1, 2.5, 10, 50 watts
Frequency Range	25–520 MHz
Insertion VSWR	1.10 : 1 maximum with N Conn. (50 ohms)
Accuracy	±5% of full scale
Finish	Vinyl "Jute" coating
Weight	7¼ lbs.

METER AND OPERATING CONTROLS

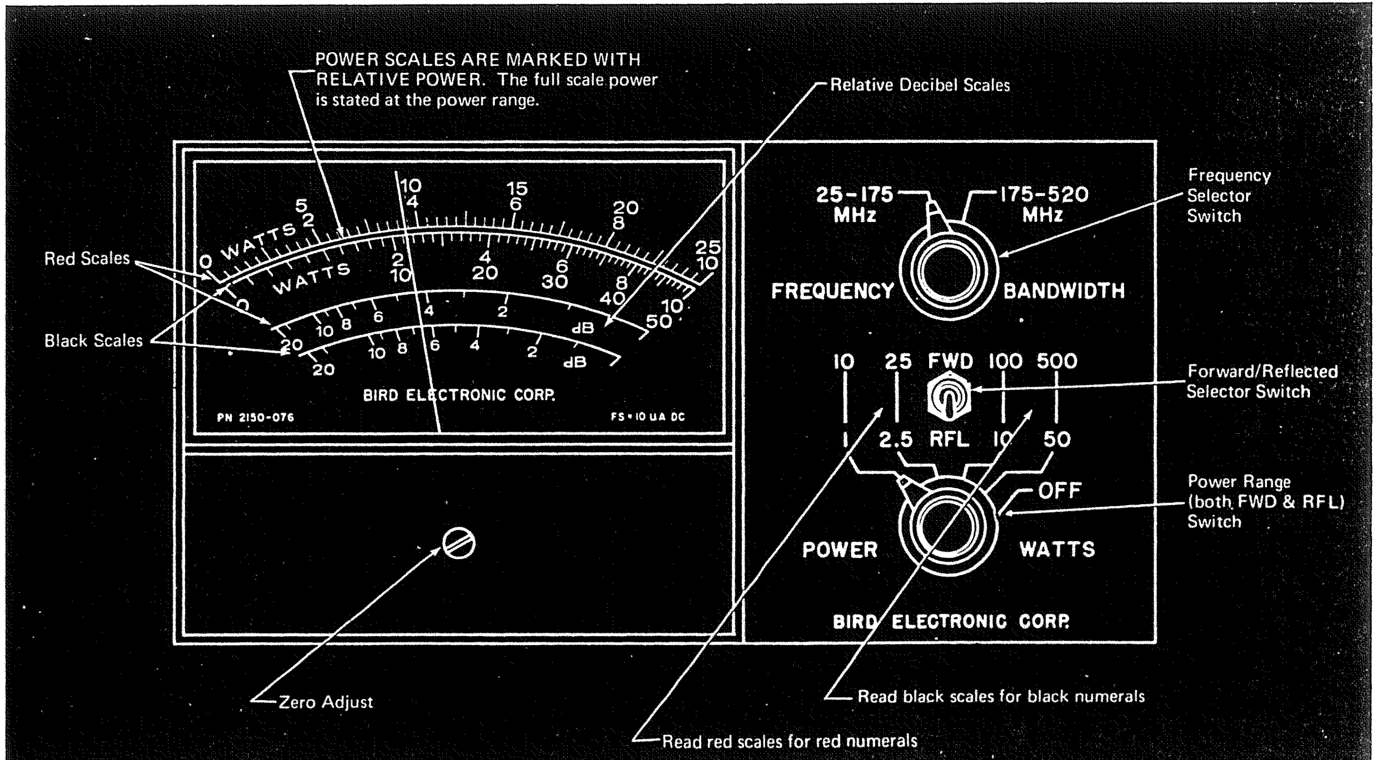


Fig. 1

SECTION II

THEORY OF OPERATION

1. Traveling Wave Viewpoint

The best way to visualize the THRULINE idea is from the TRAVELING WAVE viewpoint on transmission lines, which illustrates that the voltages, currents, standing waves, etc., on any uniform line section are the result of two traveling 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 *E* and current *I* in phase, with $E/I = Z_o$.

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

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

W_R = Watts Reverse = $E^2/Z_o = I^2 Z_o = EI$

Z_o 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_o is a very accurate 50 ohms, and in which correct measurements may be made.

2. Coupling Circuit

The coupling circuits which sample the traveling waves are contained in the line section. The basic circuitry is shown in figure 2. Energy will be induced into the coupling circuit by both mutual inductance and by capacitive coupling. The inductive currents will, of course, flow according to the direction of the traveling wave producing them. The currents induced by the capacitive coupling are, naturally, independent of direction. It is therefore

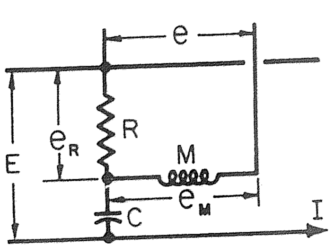


Fig. 2

apparent that the coupling currents from waves of one direction will add in phase, and those of the other direction will subtract in phase.

The electrical values of the coupling circuit are carefully selected so that the current from the reflected waves is almost completely cancelled. The resultant directivity in the Model 4370 is 25 dB min for all forward power ranges and 30 dB min for all reflected ranges. Typical test values for these couplings over their respective specified frequency ranges are exhibited in curves shown on Figure 5.

3. Standing Wave Radio vs. Reflected/Forward Power Ratio

As mentioned above, the THRULINE technique uses the TRAVELING 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 TRAVELING WAVES and STANDING WAVE viewpoints are given in most high frequency textbooks.

4. Signal Detection

The resultant RF voltage output described above is rectified and conducted from the Line Section coupler, through the 4-ft. cable, to the Wattmeter Assembly for further processing. This rectified voltage is proportional to the RF main signal envelope, i.e., it is DC in the case of CW, FM and single-tone SSB transmissions. It is a sine wave riding on DC in case of a sine-wave-modulated AM transmission, etc.

The voltage processing is such that the meter needle indicates average signal on the black scales, i.e., it averages out symmetrical modulations riding on DC and indicates the DC value only. Since the DC is proportional to the desired RF value, the meter indicates the correct power level of CW, FM, single-tone SSB and symmetrical AM on the black scales.

Signal processing for the red scales includes squaring of the rectified envelope in order to present a nearly linear scale layout. In the case of CW, FM, and single-tone SSB the meter still indicates the desired RF power accurately, but any amplitude modulation in the main line transmission will now be squared (instead of averaged out) and result in an increased reading. It is, therefore, important that no modulation be present (including "hum") when using the red scales.

Special note—two-tone SSB (equal amplitude tones): The detected RF envelope for this type of transmission is similar to a full-wave rectified sine wave, and known correction factors can be applied to interpret the readings. On the black scales the reading represents 40.5% of the Peak Envelope Power, and on the red scale the needle indicates 50% of PEP.

5. Accuracy

The Wattmeter accuracy is ±5% of full scale reading, i.e., ±5% of 100 watts (full scale) is 5 watts. Thus, any reading made on the 100 watt scale may have a ±5 watt error.

6. Directivity

The 4370 has a directivity specification of 25 dB for all forward power ranges and 30 dB for all reflected power ranges. Actual directivity approaches 35 dB to 40 dB over most of the frequency ranges. Directivity is ability of the coupler to sense power flowing in one direction and be insensitive to any power which may be flowing in the reverse direction. (See Figure 5 Directivity Chart.)

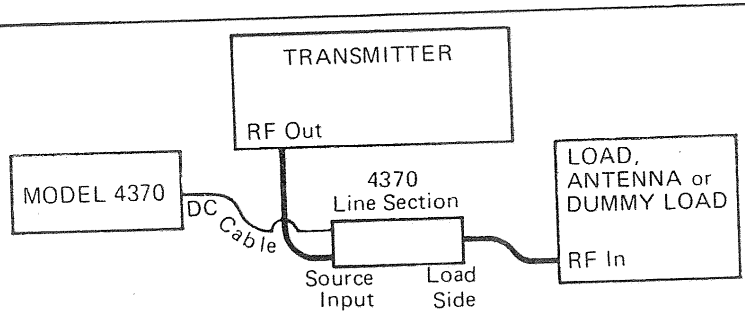


Fig. 3 FUNCTIONAL DIAGRAM MODEL 4370

SECTION III

INSTALLATION

1. General

As previously described, the Model 4370 is completely portable, and having no auxiliary power requirements, is very suitable for field or for laboratory use.

The Line Section and DC Cable are stored in a special compartment at the back of the Wattmeter case. To open, turn the small thumbscrew (counterclockwise) until the cover is released, and swing the door out on its hinges. The Line Section rests in special rubber-sponge cushion sections. *Caution: Use extra care in removing and handling the Line Section*—do not drop it. When replacing the Line Section in its compartment, take care to position it and the Cable properly. Close lid and turn thumbscrew to fasten. When transporting the Model 4370 Wattmeter make certain that the rear door is **closed** and that the thumbscrew is **tightened** securely. It should never be allowed to fall out.

The 4-foot long Cable is permanently attached to the Wattmeter. Do not pull on it or attempt to detach it. The rear door has a notch in the inside corner, so that it may be closed without pinching, while the Cable is out.

2. RF Cable Connections

The 4370 Line Section is equipped with Bird "Quick Change" Connectors. It is normally supplied with two Female N Connectors, or as specially ordered. Other "QC" Connector types are available. The Model 4370 is a directional device and the Line Section must be installed correctly for proper operation of the Wattmeter. The overall length of the Line Section as equipped with N Connectors is approximately 6½ inches. Fifty ohm cables and fittings must be used with the Model 4370. If cables other than 50 ohms are used, a mismatch will occur and erroneous power indications may result. Use the shortest connecting cables possible. Care in the choice of cables and connectors will provide optimum accuracies. In many cases, the Line Section may connect directly to the Source. It may also be desirable to substitute existing line section connectors with other "QC" types to avoid the use of adapters (See Maintenance Section). Use cables such as RG-8A/U, 9B, 213, 214 or equivalent.

3. Zero Adjustment

Before connecting the Wattmeter, ensure that the meter pointer rests exactly on "zero". Adjustment may be made turning the screw located in the center of the meter face panel just below the dial. Using a narrow-point screwdriver, turn the zero set screw very gently until the pointer is at the desired position.

SECTION IV
OPERATION

1. Introduction

The Model 4370 is especially useful in determining the operating conditions of transmitter and antenna systems. VSWR can be easily determined by comparison of forward and reflected powers and the VSWR graph on page 10, or by the ratio charts in the Appendix Section.

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 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. A good load resistor, such as the Bird TERMALINE®, 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 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 $\phi = W_R / W_F$ when the THRULINE is used. It will be noted that, even without bothering to calculate the ratio exactly, the two meter readings W_R and W_F give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem, the main thing usually is to minimize W_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.

3. Graph – ρ vs. ϕ

Since there are definite simple relationships between standing wave ratio and the reflected/forward power ratio ϕ indicated by the THRULINE, the latter may be conveniently used to measure VSWR. The relationship is given in Fig. 4 .

Note, that around ϕ = 10% (10 dB), below which W_R will appear insignificant and become 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 gain in W_L. TV transmitter antenna lines, and VHF Omnirange transmitters, are among systems requiring much lower levels of reflected power for reasons other than simple power transmission. Note also in Fig. 4 , the very small level of reflected power, ϕ = .06 percent, (32.2 dB), corresponding to ρ = 1.05.

4. Measurement & Monitoring

Little more need be said about this, in view of LOAD POWER paragraph above. The THRULINE will monitor transmitter output, and may be found useful in continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

5. Use of dB Scales

The dB scales of the Model 4370 can also be used to determine VSWR or return loss. By noting the reading on the dB scale, with the FWD/RFL switch in the FWD position, then switching to the RFL position, VSWR can be determined in the following manner:

Return Loss (dB) = (RFL dB – FWD dB) + 10dB

If other reflected power ranges are used, i.e., other than the one corresponding to the forward range, different attenuation factors must be used instead of 10dB (See Table I).

6. Low Power Forward Measurements

The Model 4370 may also be used to measure full scale value of 1, 2.5, and 50 watts forward power. Reverse the RF connections to the line section and put the FWD/RFL switch in the RFL position. This method provides a total of seven full scale forward power measurement values, 1 to 500 watts.

CAUTION

When using reflected power scales for forward power measurement, take extra care not to exceed given full scale power values.

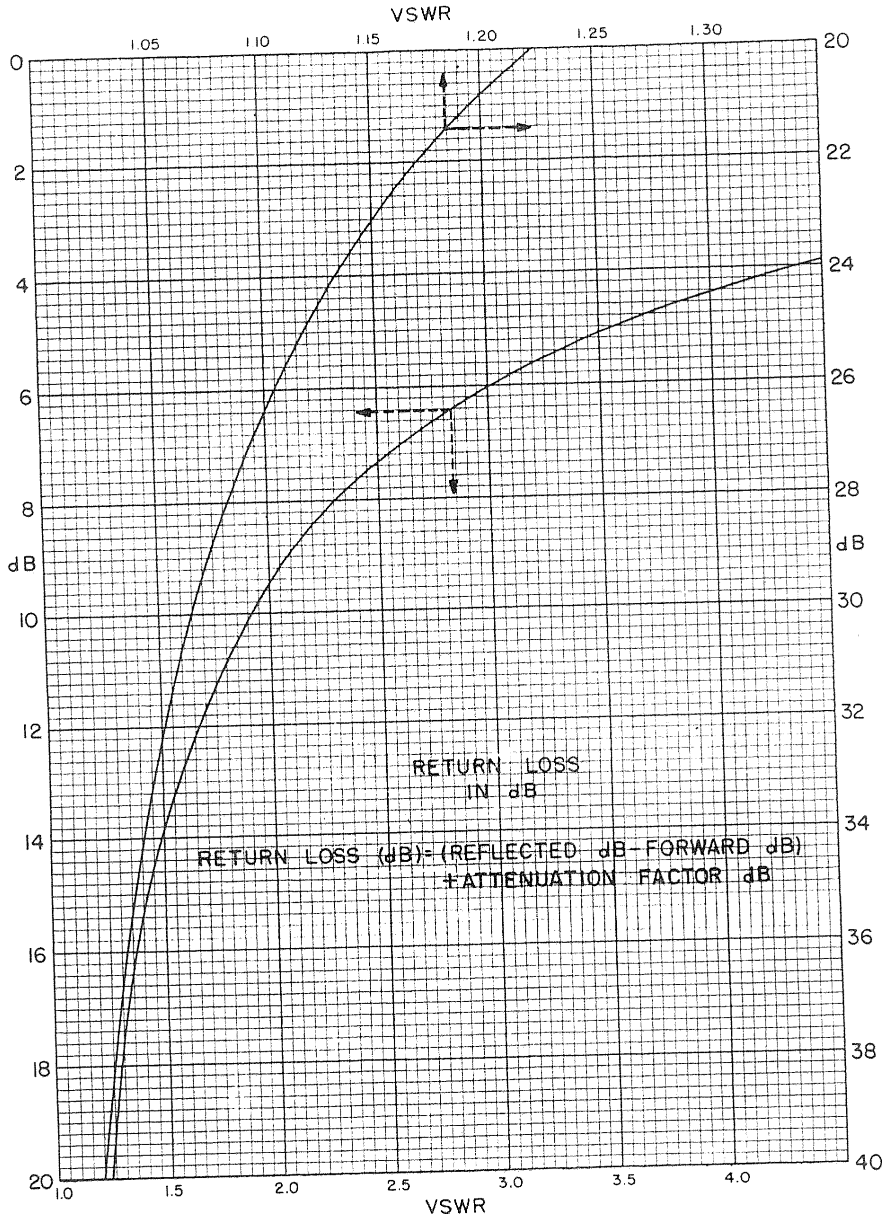
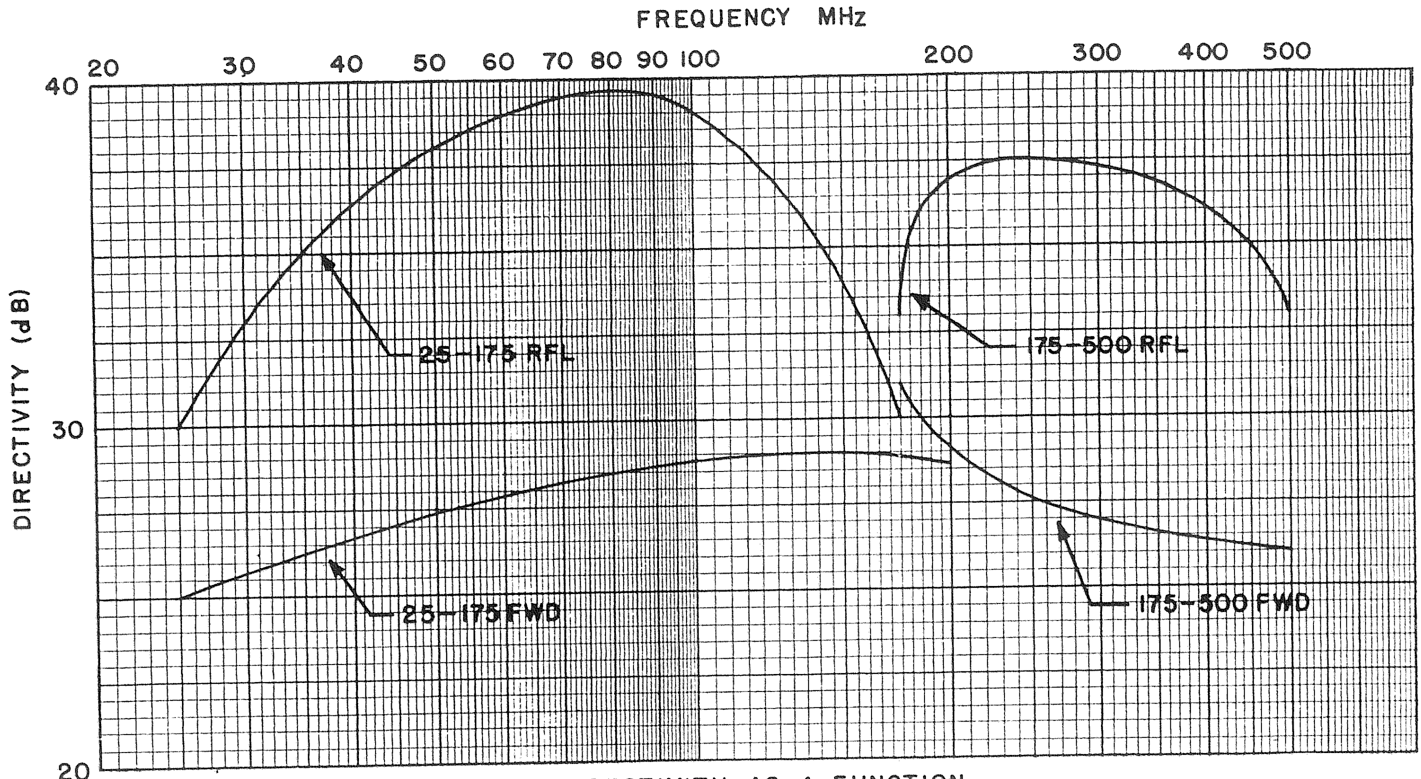

VSWR
1.05
1.10
1.15
1.20
1.25
1.30
0
2
4
6
8
dB
10
12
14
16
18
20
20
22
24
26
28
dB
30
32
34
36
38
40
RETURN LOSS IN dB
RETURN LOSS (dB)=(REFLECTED dB-FORWARD dB) +ATTENUATION FACTOR dB
1.0
1.5
2.0
2.5
3.0
3.5
4.0
VSWR

Fig. 4



DIRECTIVITY AS A FUNCTION
OF FREQUENCY

Fig. 5

TABLE I

Fwd. Pwr. Range Watts	Reflected Power Ranges — Watts			
	1	2.5	10	50
10	10	6	0	—
25	14	10	4	-3
100	20	16	10	3
500	27	23	17	10

Attenuation Factors dB

TABLE OF ATTENUATION FACTORS-dB

SECTION V

MAINTENANCE

1. Introduction

Only a moderate amount of preventive maintenance is required for the Model 4370 Wattmeter. Use reasonable care in handling; DO NOT DROP the Wattmeter or the Line Section (See Installation, Section III).

2. Care and Cleaning

A main factor in effective preventive maintenance is cleanliness. For optimum performance and service life, the 4370 must be kept in a clean and dust-free condition. When not in use, keep the Wattmeter in a clean, **cool** environment. The line section should be stored in the meter case when not in use. The RF connectors on the line section must be kept very clean. Carefully wipe the insulators, metallic contact surfaces and connector bodies using a dry cleaning solvent such as Inhibisol or trichloroethylene. A cotton swab stick is useful. AVOID breathing the fumes. The operating panel should be wiped clean with a soft cloth. Wipe the meter face only when necessary and use a lint-free static-treated cloth.

3. Connector Replacement

As previously mentioned, in Section III, the 4370 RF Connectors are a special "Quick-Change" design, permitting rapid and easy interchange with other Bird "QC" connectors. If replacement of an RF connector is desired, proceed as follows:

(1) Remove the four #8-32x 5/16 pan head machine screws from the corners of the RF connector.

(2) Pull connector straight out.

(3) Reverse above procedure to install new connector, making certain that the projecting center contact pin of the "QC" connector is carefully engaged and properly aligned with the mating socket of the line section.

Typical "QC" connector types available from the manufacturer are:

TYPE	PART NO.	TYPE	PART NO.
Female N	4240-062	Female UHF	4240-050
Male N	4240-063	Male UHF	4240-179
Female C	4240-100	Female BNC	4240-125
Male C	4240-110	Male BNC	4240-132
Female HN	4240-268	Female TNC	4240-156
Male HN	4240-278	Male TNC	4240-160

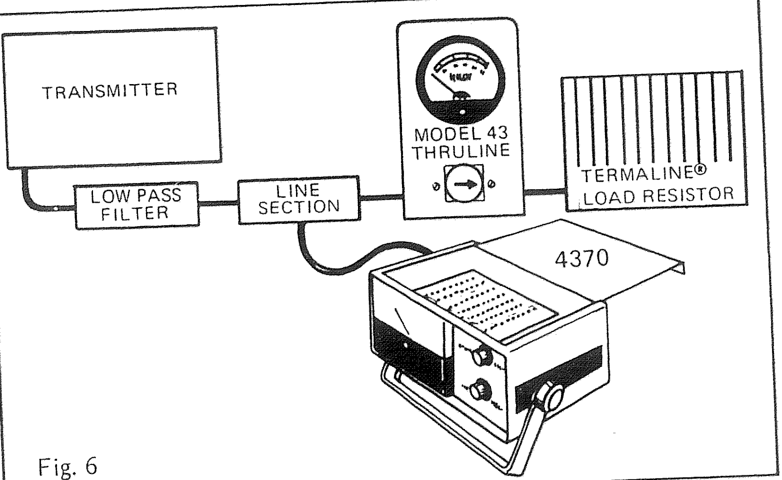


Fig. 6

4. Calibration

If recalibration is necessary, set up the wattmeter as shown in Figure 6, above. Insert the Low Pass Filter on the "Source" side of Model 4370 Line Section and the Comparison Std. Wattmeter on the "Load" side. Attach as directly as possible to the Line Section. Suggested equipment:

Transmitter(s) – suitable for power and frequencies to be tested.

Filter(s) – Low Pass (with Fem. N Conns.):

Type	Cut Off	Watts	MHz
5440	160 MHz	250	100 (108)
or 5451J	160 MHz	100	100 (108)
5262	400 MHz	200	300

Comparison Std. Wattmeter: Bird Model 43 THRULINE – Certified Data Accuracy to ±3% F.S.

Terminal Load Resistor: Bird Model 8135, 150W; and/or Model 8201 (or 8401), 500W.

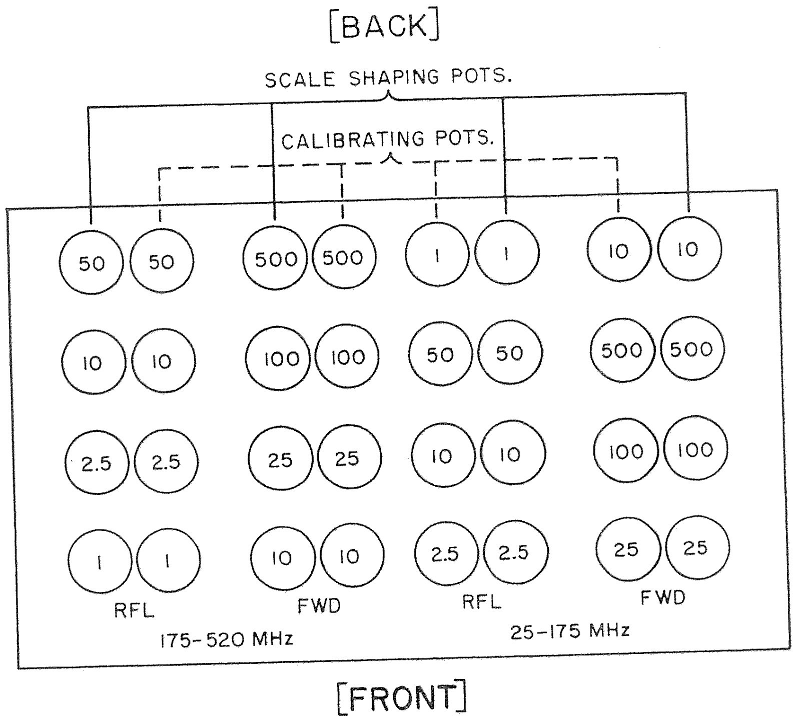


Fig. 7

Make all connections as short as possible and keep connections true and snug.

Remove the top cover on Model 4370 by releasing two pan head screws on the rear flap of cover (top panel, Item 10), and sliding it straight out the back end of case. This will expose 32 calibration pots. Identification of pots is shown in figure 7. Calibration should be carried out as follows:

Set frequency switch to 25-175 MHz, FWD/RFL switch to Fwd. Set power range switch to range to be calibrated. Apply RF power of known value (Comparison Std.) equivalent to 80% of full scale, adjust calibration pot so that Model 4370 reads 80% of full scale. Reduce power to 40% of full scale on standard and adjust shaping pot for 40% of full scale.

These adjustments should be repeated until there is no further resetting necessary for both points on the scale. The procedure is the same for all power ranges and for both frequency bands. To calibrate the reflected ranges the line section must be turned around. For accurate readings across the entire frequency band calibration should be performed as follows:

Freq.	Fwd.	Refl.
108 MHz	exact	2.5% high
300 MHz	1.5% high	3.3% high

After calibration apply GE Glyptal cement (or equal) to all pots to insure that they do not move.

5. Meter and Switch Repair

To secure access to these components, remove cover as for Calibration procedure above. The printed circuit board (mounting 32 pots) must now be removed. Release (2) #4-40 rd hd screws fastening PC board to the rear cross-bar, lift the back end of the PC board up slightly and pull backwards gently to remove the board from its connectors.

The meter and switches are now accessible from the inside of the front panel. It may facilitate the work to remove the front panel from the case, also. Simply undo the screws at the ends of the top front cross-bar, and slide the panel up out of its grooves in the side frames. The meter, Item 1, is held by two #6-32 studs at its sides. Remove nuts from these and the wire lugs from terminal posts, lift meter out front of panel. Note carefully in restoring meter leads, the gray wire goes to the positive (+) terminal, yellow to ground.

The panel switches, Items 2, 3 and 4, may be changed by the usual means for radio components. Before unsoldering any wires, note very carefully the lead connections to the respective switch item.

6. Service

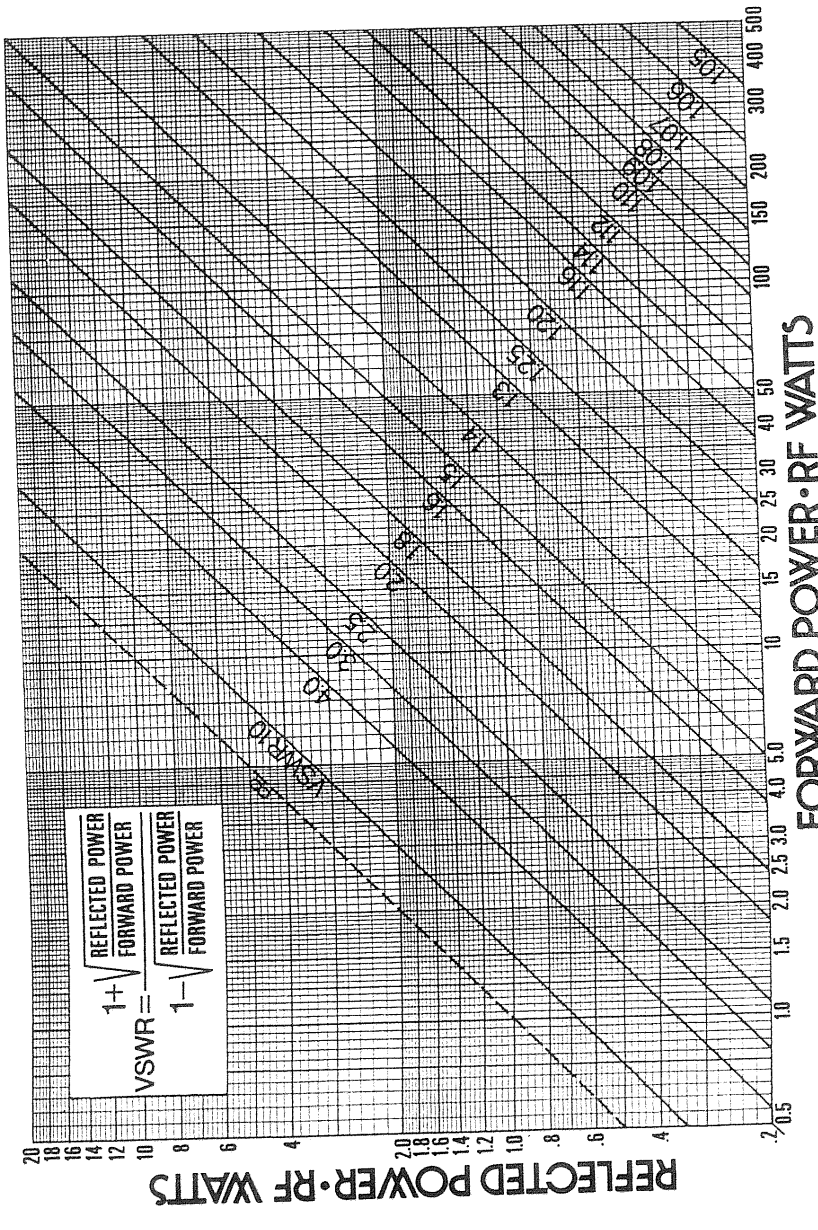
For any problems in the Wattmeter performance that cannot be solved by calibration, please consult the Company. In general, it is preferable that equipments are repaired at the factory. The Customer Service Department should be contacted for return authorization and shipping instructions. Please furnish Model and Serial Numbers (especially during warranty period).

MODEL 4370

REPLACEMENT PARTS LIST

Item	Req.	Description	Part No.
1	1	Meter	2150-076
2	1	Switch, FWD/RFL	5-922
3	1	Switch, Power Level	4370-057
4	1	Switch, Frequency Band	4370-058
5	1	Knob, Switch – Power Level	5-925-1
6	1	Knob, Switch – Freq. Band	5-925-2
7	1	Handle, Wattmeter Carrying	4371-010
8	2	Knob, Handle Locking	4371-044
9	4	Spacer, Handle	4370-036
10	1	Panel, Top	4371-090-1
11	1	Panel Assembly, Bottom	4371-091-1
12	1	Standoff, Screw Ret'r. P/O #14	5-1051-1
13	1	Screw, Latch – Rear Door P/O #14	5-1051-2
14	1	Panel Assembly, Rear	4370-064
"QC" Connectors – (Installed on all except special order units)			
	2	"QC" Connectors – Female N	4240-062

appendix


VSWR = (1 + √(REFLECTED POWER / FORWARD POWER)) / (1 − √(REFLECTED POWER / FORWARD POWER))
FORWARD POWER • RF WATTS
REFLECTED POWER • RF WATTS

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