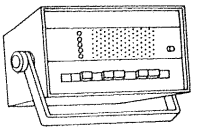
INSTRUCTION BOOK FOR THE THRULINE® WATTMETER MODEL 4371

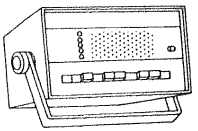
BIRD ELECTRONIC CORPORATION

30303 Aurora Road • Cleveland (Solon), Ohio 44139



GENERAL DESCRIPTION

The Model 4371 Multirange THRULINE Directional RF Wattmeter is an insertion type instrument for measuring RF power in 50-ohm coaxial transmission lines. The convenient push button control system across the front panel provides for measurement of RF power over the entire range of the instrument in either the forward or reflected mode. The digital indicating meter is directly calibrated in RF watts. A precisely machined 50-ohm line section is stored in the main housing. An interconnecting cable permits use of the line section up to five feet away from the Model 4371 main housing.



SPECIFICATIONS

Forward Power Ranges	10, 100, 1000 watts
Reflected Power Ranges	1, 10, 100 watts
Frequency Range	25-520 MHz
Insertion VSWR	1.10:1 maximum
Accuracy	±5% of full scale
Instrument Power Supply	4 watts (105-125V, 50-400 Hz)
Finish (Case)	Anodized Aluminum and Vinyl
Weight	9 lbs., 6 ozs.

Figure 1 illustrates operating and adjusting controls.

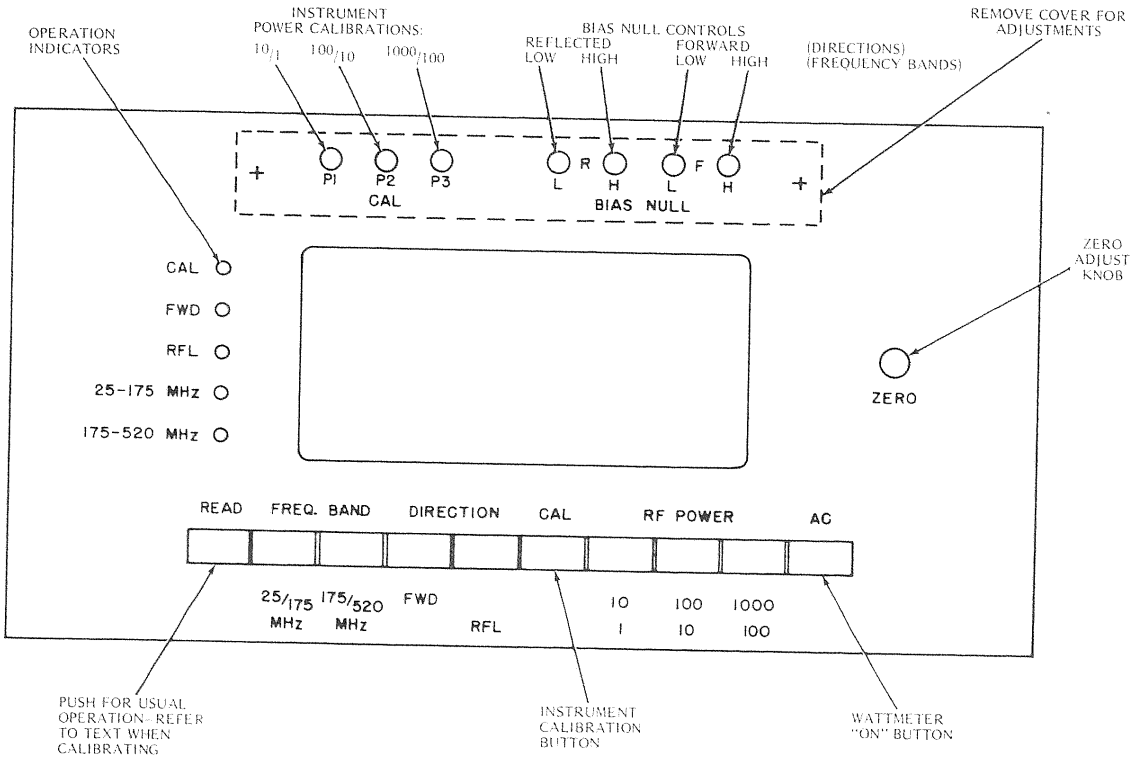
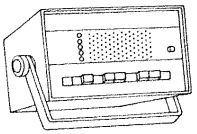

OPERATION INDICATORS
INSTRUMENT POWER CALIBRATIONS:
10/1
100/10
1000/100
BIAS NULL CONTROLS
REFLECTED LOW HIGH
FORWARD LOW HIGH
(DIRECTIONS) (FREQUENCY BANDS)
REMOVE COVER FOR ADJUSTMENTS
+
P1
P2
P3
CAL
L
R
H
L
F
H
+
BIAS NULL
CAL
FWD
RFL
25-175 MHz
175-520 MHz
ZERO ADJUST KNOB
ZERO
READ
FREQ. BAND
DIRECTION
CAL
RF POWER
AC
25/175 MHz
175/520 MHz
FWD
RFL
10
1
100
10
1000
100
PUSH FOR USUAL OPERATION--REFER TO TEXT WHEN CALIBRATING
INSTRUMENT CALIBRATION BUTTON
WATTMETER "ON" BUTTON

Figure 1



SECTION 1
INSTALLATION

1. General

The Model 4371 is readily portable and may be used wherever line power is available. It is energized by 115 volt (or 230 volt, if designated) alternating current at 50 to 400 Hz. (Draws about 4 watts.) A three-wire cable, 8 feet long, with a 3-prong grounding plug for the Wattmeter socket, is provided. The entire equipment is housed in a ruggedly constructed, high strength aluminum case, fitted with a sturdy metal handle. The 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 position by tightening the two thumb-screws located at the sides of the unit.

RF Line Section

The Line Section is permanently connected to the Wattmeter by a shielded cable (approximately 5 feet long) which permits separation of the coupler and meter. They can be placed then for optimum operator convenience.

The Line Section and the AC power cord are stored in a divided compartment at the back of the Wattmeter case. This space is reached by turning the thumb-screw counter-clockwise to release the hinged door. The Line Section is held in the lower section and protected by sponge rubber cushion linings. The Power Cord and the length of the Line Section Cable are kept in the upper section. The latter cable is captive to the housing—be careful not to pull it.

In replacing the Line Section, be sure to position it properly in the cushions. Turn thumb-screw clockwise to close door. Note a small notch in the upper inside corner of the compartment door, for cable passage, enabling the door to be closed while using the Wattmeter. (Caution: always handle the Line Section with care—do not drop it.) When transporting the Model 4371 make certain that the door is closed and that the thumb-screw is tightened firmly.

2. Cable Connections

The 4371 Line Section is equipped with Bird "Quick-Change" Type Connectors, and normally supplied with a Female N Connector at each end. Other "QC" Connector types are available; all are precise equivalents of Std. AN coaxial types. The Model 4371 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 6-1/2 inches.

Fifty ohm cables and fittings must be used with the Model 4371. If cables other than 50 ohms are used, a mismatch will occur and erroneous power indications may result. Use the shortest connecting cables possible. Avoid the use of angle plugs or adapters whenever 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. "QC" connectors are readily interchangeable—(see Maintenance Section). Use cables such as RG-8A/U, 9B, 213, 214 or equivalent.

3. Power Connection and Zero Adjustment

1) Use the AC Power cord provided with the equipment to connect the proper power source (see Specifications). In plugging to the Wattmeter socket, note the offset position of ground pin — orient plug properly.

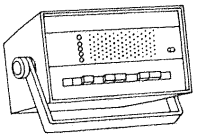
2) Press in the red "AC" button.

3) Put the "CAL" and the "READ" (red) button in the out position.

4) Press in the lowest RF Power button (10/1) and observe reading.

5) Zero the meter by adjusting the small thumbscrew at the right of the meter window.

6) The equipment is now ready for calibration checks and subsequent operation (see Section 3).



SECTION 2
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 demonstrates that the voltages, currents,, standing waves, etc., on any uniform line section are the result of traveling waves.

The forward wave travels from the source to the load, has an RF voltage E_f and a current I_f in phase and is directly proportional by the characteristic impedance Z_O.

$$E_f = Z_O I_f$$

Reflected waves originate from discontinuities and impedance deviations of a 50-ohm line configuration and travel back toward the source with the voltage (E_r) and current (I_r). The power/voltage relationship in the transmission line, which is the same for the forward and reflected waves, is:

$$\text{Forward Power} = E_f^2/Z_O$$

$$\text{Reflected Power} = E_r^2/Z_O$$

The coupling circuit in the line section samples the RF voltage capacitatively and the current inductively, and by using basic traveling wave theory, the RF voltage and current are so balanced that the resultant is a voltage output that is sensitive to one direction of energy flow only; i.e., the voltage and current components add in the forward direction and cancel out in the reverse.

2. Signal Detection

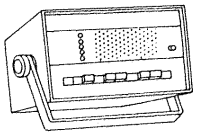
The resultant RF voltage output described above is rectified and conducted from the Line Section coupler, through the 5-ft. cable, to the Wattmeter Assembly for further processing. This rectified voltage is proportional to the RF main signal envelope, i.e., it is DC in the case of CW, FM and single-tone SSB transmissions. It is a sine wave riding on DC in case of a sine-wave-modulated AM transmission, etc.

Signal processing for the digital readout wattmeter includes squaring of the rectified envelope in order to present a nearly linear situation. In the case of CW, FM, and single-tone SSB the wattmeter indicates the desired RF power accurately. However, any amplitude modulation in the main transmission line will now be squared (instead of averaged out) and result in a reading of diminished accuracy.* It is, therefore, important that no amplitude modulation be present (including "hum") when using the Model 4371 RF Wattmeter.

Also to be noted—with 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 will therefore be read with reduced accuracy also.

*Other average reading instruments, like the Bird Model 43, take a voltage envelope and read it on a D'Arsonval meter, which by its design averages out the signal—the signal is not processed, the scale does the squaring. In the Model 4371 the squaring is done in the circuit.

The Model 4371 Wattmeter therefore measures the average heating power of the RF signal at all power ranges, and gives readings according to the AVERAGE Power column in Fig. 2, produced herewith. Any amplitude modulated signal will be indicated as shown in the column, but at reduced accuracy as compared to CW.



3. Accuracy

The Wattmeter accuracy is ±5% of selected power value, i.e., ±5% of 100 watts (full scale) is 5 watts. Thus, any reading made on the 100 watt button may have a ±5 watt error up to 125% of full scale.

4. Directivity

The 4371 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 to be insensitive to any power which may be flowing in the opposite direction.

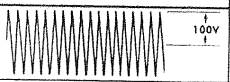
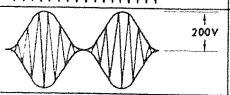
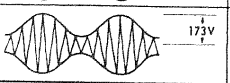
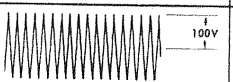
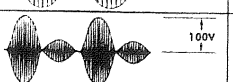
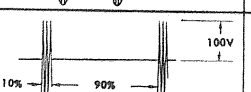
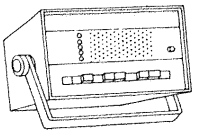
TRANSMISSION TYPE and SCOPE PATTERN	FREQUENCY SPECTRUM (C: Carrier)	PEV_{rms} (arbitrary)	PEP = PEV^2_{rms}/Z_o	4371 AVERAGE (Heating) POWER	4311 in PEAK MODE	4311 in CW MODE or Model 43
Table A CW 		$\frac{100}{\sqrt{2}}$ V	100W	100W	100W	100W
Table B AM 100% Mod. 		$\frac{200}{\sqrt{2}}$ V	400W	150W	400W	100W
Table C AM 73% Mod. 		$\frac{173}{\sqrt{2}}$ V	300W	127W	300W	100W
Table D SSB 1 tone 		$\frac{100}{\sqrt{2}}$ V	100W	100W	100W	100W
Table E SSB 2 tone 		$\frac{100}{\sqrt{2}}$ V	100W	50W	100W	40.5W
Table F SSB 3 tone 		$\frac{100}{\sqrt{2}}$ V	100W	(33.3W)	100W	–
Table G SSB Voice 		$\frac{100}{\sqrt{2}}$ V	100W	–	100W	–
Table H Pulse 		$\frac{100}{\sqrt{2}}$ V	100W	(10W)	100W	–

Fig. 2. Interpreting Readings on THRULINE® Wattmeters such as Models 43, 4311 (Peak Reading) and 4371 with CW, AM, SSB and Pulsed Signals.

In the table Z_o = 50 ohms, PEP is Peak Envelope Power, and PEV is Peak Envelope Voltage. The PEV of the Carrier (or suppressed Carrier) C was arbitrarily chosen at 100 volts in all examples. $PEV_{rms} = PEV/\sqrt{2}$.



SECTION 3
OPERATION

1. General

The 4371 THRULINE Wattmeter is used to measure RF power including CW, FM, single-tone SSB, and (within certain limitations) symmetrical AM, in both the forward and reflected directions.

Before using the Wattmeter, the instrument calibration should be checked. Be sure the Meter zeros properly (see Section 1, Installation). Zero the meter with only the "AC" and Lowest Power buttons on—adjust small thumbscrew at right of meter face. Press in CAL button with the READ button out. Then push in each RF POWER button successively (vis., 10, 100, and 1000 FWD). If each does not show a meter display of 1000, then instrument calibration is required. Ignore decimal point.

Remove the facing nameplate at the top of the front panel by releasing the two small thumbscrews at ends of the plate. With a small screwdriver (13/64 tip width) set P1, P2, and P3 potentiometers respectively, for the matching power levels on the Power Level buttons (above). Set each to read 1000. This completes the power level calibration of the instrument itself.

Then release the CAL button, and push the READ button in. Push in the lowest RF POWER Level (10/1) button again; keep this Low Power button in throughout these adjustments. Now push in the Low Frequency (25/175 MHz) button and the RFL Direction button. Check the Meter reading—if it does not show zero, set by adjusting the first potentiometer on the left of the four in the BIAS NULL Section, R/L. Push in the High Freq. (175/520 MHz) button and adjust the second pot (R/H) to zero the Meter. Then switch to the FWD Direction to check or adjust in the same way for the remaining two "forward" potentiometers of the bias null. The instrument is now ready for use.

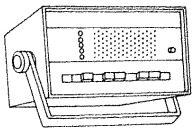
The Model 4371 is especially useful in determining the operating condition of transmitter and antenna systems. VSWR determinations are easily made by comparison of forward and reflected powers and by reference to the VSWR charts in the back of the manual.

Transmitter tuning is greatly simplified by using several of the Model 4371 power ranges. Tuning is first accomplished at lower power levels; higher power ranges are switched in as power is increased.

2. 1 Watt, 10 Watt and 100 Watt Full Scale Forward Power Measurements.

To measure low values of forward power, reverse the line section cable connections so that forward power enters the reflected (load) end of the line section. Push the RFL button.

Caution: It should be noted here that accuracy of the meter will generally extend to 125% of full scale value. On the two lower power ranges the meter can be used above this value, at reduced accuracy, until it "over-ranges" (3 of the 4 digits will blink or blank out). On the highest range do not exceed 125% of full scale, especially when operating above 300 MHz. If this power condition occurs, damage to the coupler circuitry will result.



3. Coupler Calibration

If the 4371 Wattmeter is suspected of inaccurate RF power readings—after the Instrument Calibration and Bias Null procedures at the opening of this Section, and the Meter Zero (Installation, Par. 3) are satisfied or have been rechecked—calibration of chassis amplifier will be required. This may be necessary only for certain individual meter values, so care is suggested in approaching this process.

For Amplifier calibration a suitable RF power source (having a steady output at adequate power level and frequency), and a reliable RF power comparison Standard will be required. For the power standard you may use a Calorimeter (similar to the Bird Model 6020); or perhaps another insertion type of Wattmeter (such as THRULINE Model 4340—recently checked). Connect the standard measuring unit to the Coupler of the 4371 Wattmeter as directly as possible (on the output of the Coupler in the case of a Calorimeter or a termination wattmeter). Use this equipment setup in conjunction with requisite low-pass filter(s) and low-reflection line termination where necessary.

To reach the chassis calibrating potentiometers, turn the Wattmeter upside down. Remove the two Phillips head machine screws on the rear flange of the bottom cover and slide cover right out the back. This will expose a chassis underside protector plate. Its rectangular cut-out provides access to all of the adjustable potentiometers without removing this metal sheet. With the wattmeter's front panel facing to the operator's right, the potentiometer array will look like Fig. 3. Make the calibrations at approximately the middle of the respective frequency ranges, vis.; 108 MHz for the low range, and 300 MHz for the high range if possible. At these frequencies, to obtain optimum accuracy

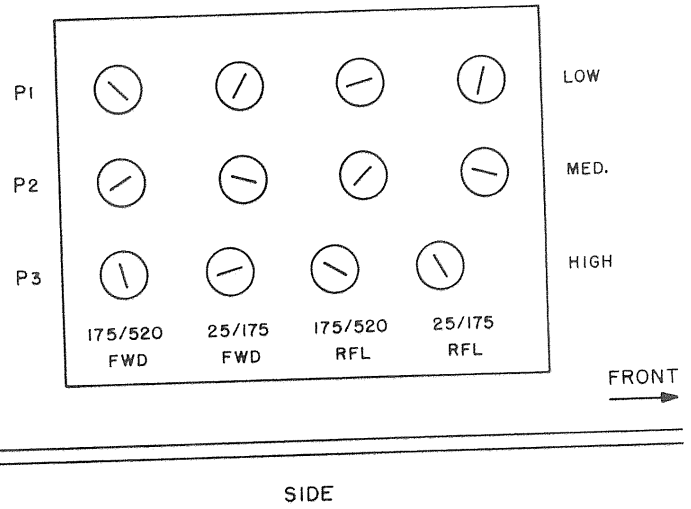
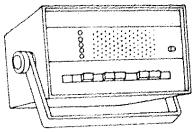


Fig. 3 Coupler Calibration Array

over the respective frequency bands, set the power readings on the Wattmeter as follows:—

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

Do not make calibrations at less than 80% of full scale values. Note that these adjustments, when made, are done with the Wattmeter in just the same modes as for regular RF power readings, with all panel selections appropriate to the potentiometer value being set (only one potentiometer for each condition). The readings are rather sensitive to potentiometer movement, so care is suggested in approaching this operation. A small size screwdriver tip, as on panel calibrations, may be used. Restore bottom cover after completing adjustments.



SECTION 4
MAINTENANCE

1. Introduction

Only a moderate amount of preventative maintenance is required for the Model 4371 Wattmeter. Use reasonable care in handling; do not drop the Wattmeter or the Line Section. (See Installation, Section 1.)

2. Care and Cleaning

A main factor in effective preventative maintenance is cleanliness. For optimum performance and service life, the 4371 must be kept in a clean and dust-free condition. When not in use, keep the Wattmeter in a dry, 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 1, the 4371 RF Connectors are a special "Quick-Change" design, permitting rapid and easy interchange with other "QC" connectors. If replacement of an RF connector is desired, proceed as follows:

(1) Remove the four #8-32 x 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.

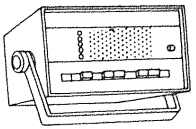
Typical "QC" connector types available from the manufacturer are:

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

4. Repair

Special equipment is required for internal repair of Model 4371 THRULINE Wattmeters. In general, field repairs are not practical. The only electrical components of the Wattmeter that we feel are suitable for field replacements are the Fuse and Fuse Holder, and (2) Operational Amplifier units on the printed circuit chassis.

On the back panel of the Wattmeter, the fuse is released just by pushing the insert in and slightly downwards—allowing the fuse cap to spring out. The fuse is replaced in the cap. For protection of the equipment, do not replace fuse with any of a higher rating than the 1/16A installed. When re-inserting the cap, make sure the word FUSE reads horizontally. To change Fuse holder, Item 11, P/N 5-998 unscrew the Phillips head screws at the back flange of top cover and slide it out. Lift out the Cable-holder Box by removing the four #4-40 screws fastening its flanges to the top rails. The box cannot be pulled too far from the Wattmeter because the DC cord is clamped to the compartment wall—be careful not to pull on the internal connections of this cord. Unsolder the leads on the fuse holder. Pinch the clamps on the sides of the holder, and pull it out of the panel. Notice in replacing this part that the word TOP on its body is properly located.



SECTION 4 (CONT'd.)
MAINTENANCE

The only other replaceable electrical components of the Wattmeter are the Operational Amplifiers—Item 12, P/N 5-1018. If Wattmeter readings are erratic or inexplicably high, the fault may be in these units. To gain access to the Op-Amps, unscrew the bottom cover, as for coupler calibration in Section 3 above, then remove the chassis protective plate by loosening the four #4-40 screws securing it to the frame. Just take out two screws on one side, the sheet may be lifted up and slipped out.

Check the condition of the Op-Amps. With AC power on, Pin No. 10 on each unit should register zero potential. It is faulty if there is more than 3 volts to ground. Locate this pin by counting counter-clockwise 10 pins from the corner lobe on the part outline (printed on the PC Board). The Op-Amp unit can be pulled directly up and out of its socket. When replacing the Op-Amp in its socket, the small notch in the end of the block faces the end of the socket with the corner chamfer (also lobe on frame).

Do not attempt to change other components in this Wattmeter. The two socket-mounted matched diodes are glyptal-cemented in place. Do not attempt to remove them.

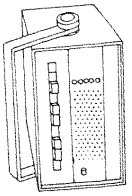
It is suggested that the unit be returned to the factory in event of a malfunction. The Customer Service Department should be contacted for return authorization and shipping instructions. Please furnish Model AND Serial Number. Unauthorized field repairs may void the product warranty.

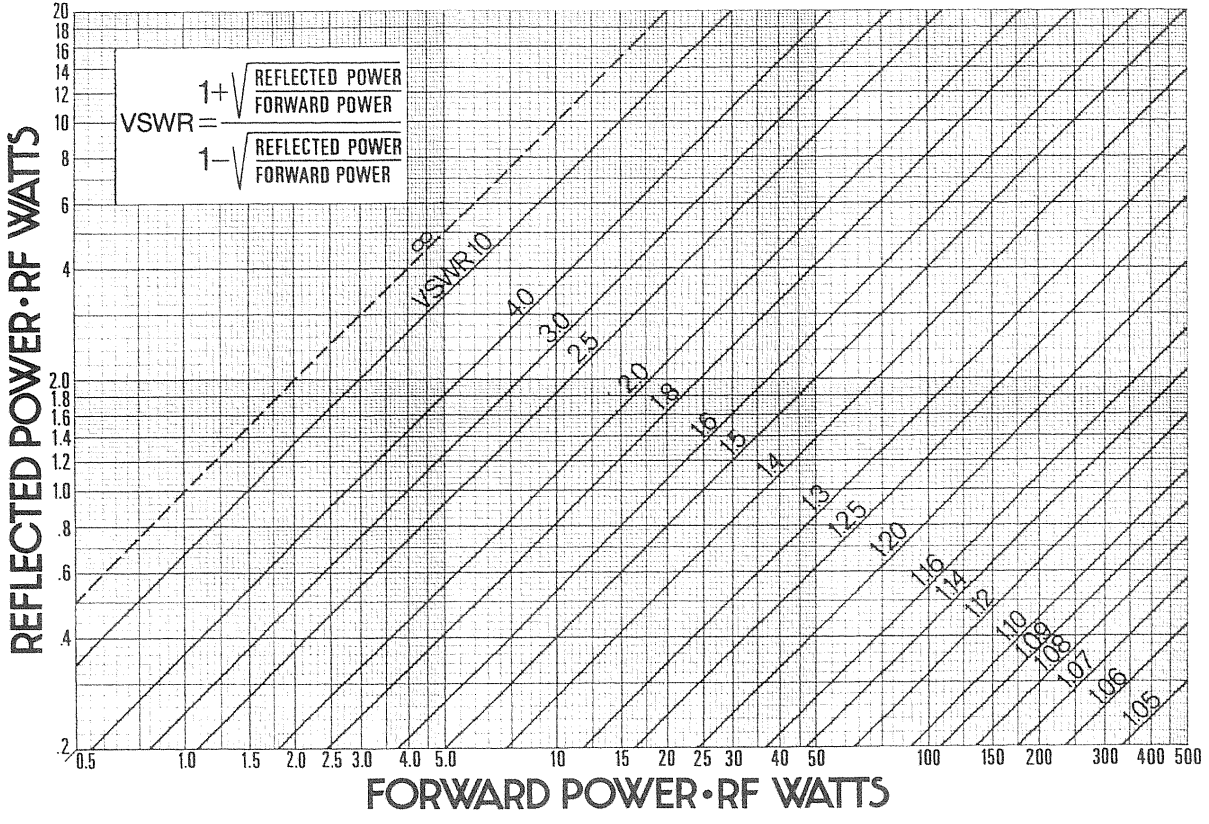
Address Repair Inquiries to: Bird Electronic Corporation
Customer Service Department
30303 Aurora Road
Cleveland (Solon), Ohio 44139

Telephone: 216-248-1200
TWX #: 810-427-2687

model 4371 parts list

Item	Req.	Description	Part Number
4	2	Knob, Carrying Handle	4370-034
5	2	Spacer, Handle, Inside	4370-035
6	2	Spacer, Handle	4370-036
7	1	Handle	4370-037
8	8	Button, Push – Gray	5-1024-2
9	2	Button, Push – Red	5-1024-1
10	1	Fuse – Littelfuse 3AG-1/16 Amp.	Std.
11	1	Fuseholder, Littelfuse	5-998
12	2	Op-Amp – Fairchild 777DC	5-1018
13	1	Cord, Power	5-1025
"QC" Connectors – (Installed on all except special order units)			
	2	"QC" Connector – Female N	4240-062




VSWR = (1 + √(REFLECTED POWER / FORWARD POWER)) / (1 − √(REFLECTED POWER / FORWARD POWER))
REFLECTED POWER • RF WATTS
FORWARD POWER • RF WATTS
20
18
16
14
12
10
8
6
4
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0.5
1.0
1.5
2.0
2.5
3.0
4.0
5.0
10
15
20
25
30
40
50
100
150
200
300
400
500
∞
VSWR 10
4.0
3.0
2.5
2.0
1.8
1.6
1.5
1.4
1.3
1.25
1.20
1.16
1.14
1.12
1.10
1.09
1.08
1.07
1.06
1.05

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