INSTRUCTION BOOK

for the

Thruline

WATTMETER

MODEL 43

BIRD ELECTRONIC CORP.

CLEVELAND, OHIO

SUMMARY

Circuit	-	50-ohm impedance - THRU LINE
Measures	-	R-F Power - 5W* to 1000W Full Scale Direct Reading in Watts, Frequency Range 2 - 1000 MC in six Element types, See Table 1, Section 4. *Also special Elements below 5W full scale.
Insertion VSWR	-	Less than 1.05 VSWR up to 1000 MC
Accuracy	-	±5% of Full Scale Power
Dimensions	-	Basic Overall 7"lg x 4"w x 3"h
Weight	-	4 Pounds
Connectors	-	Female and Male "N" Female and Male "HN" Female and Male "C" And all Standard 50-ohm AN Types } Not supplied on regular orders

2 Female "N" Connectors standard with equipment, unless otherwise specified.

SECTION A - PARTS LIST

Reference Designation	Part Name and Description	Function	Drawing No.
A-401	Housing Assembly: Aluminum die casting, 7 lg x 4w x 3h, w/latch and thumbscrew each side for spare elements, four rubber bumpers on base, leather carrying strap at top. Gray Enamel.	Houses and protects meter, holds r-f line section and spare element.	421018
A-402	Cover Assembly: Aluminum alloy sheet, .040 thk., 6-1/2 lg x 4w x 1-1/2h overall, has four rubber bumpers and slot closing ears. Gray Enamel.	Closes back of housing.	421005
E-401	Elements, Plug-In: Brass, w/teflon bottom cover, 1-7/16 lg x 1-1/4 cap dia. x 1 body dia. Gold Plate. Furnished in power and frequency types per Table I, Section 4, Paragraph 1.	Measuring element for THRULINE.	425020
E-402	Line Section Assembly: Brass Casting, normally supplied w/two female "N" connectors, 5-1/8 lg x 1-1/4w x 1-15/16h, 50-ohm line section and socket for plug-in element. Has d-c jack at side. Silver Plate.	R-F Line insertion section and measuring base.	423018
H-401	Carry Strap: Black Leather, 9 lg between centers, 5/32 x 7/8 section.	Carries meter housing.	85803
J-400	Connectors, RF: All types have 1-1/4 sq. mtg. flange, and 1/8 dia. x 5/16 lg. slotted connector pin at rear. Brass, with Teflon insulator. Silver plate. Fifteen types, viz:	RF connection for standard type connectors.	See individual part numbers listed below.
J-401	Female "N" - 1-5/32 lg.		424062
J-402	Male "N" - 1-1/4 lg.		424063
J-403	Female "HN" - 1-5/32 lg.		424073
J-404	Male "HN" - 1-3/8 lg.		424049
J-405	Female "C" - 1-1/16 lg.		424100
J-406	Male "C" - 1-7/16 lg.		424110
J-407	Female UHF (SO-239) 1-1/4 lg.		424050
J-408	Male UHF (PL-259) 1-5/8 lg.		424173
J-409	Female "BNC" - 1-5/32 lg.		424125
J-410	Male "BNC" - 1-9/32 lg.		424132
J-413	Female "LC" - 2-1/32 lg.		424031
J-414	Male "LC" - 2-1/2 lg.		424025
J-415	Female "LT" - 2-3/32 lg.		424018
J-416	Male "LT" - 2-1/2 lg.		424012
J-417	7/8" EIA Air Line 2-3/4 lg.		424002
J-411	D-C Connector Assembly: Brass fitting, w/phosphor bronze spring at rear, 1 dia. flange x 1-1/4 overall, 5/8 -24 thd. on connector body, center contact on front, teflon insulators. Silver Plate.	D-C Jack for line section assembly.	423010
M-401	Microameter: Weston Model 306, 1400-ohm resistance, 30ua full scale. Flush 3-1/2" bakelite case, solder terminals, special scale.	Meter for power reading. (For replacement usually furnished as #8000 Kit.	208002
	Replacement Meter Kit Consisting of: 1 - 208002 Meter 1 - 422097-1 Cable Assembly 3 - 422098 Bumper Feet		8000
P-401	Connector, Plug: Part of cable W-403, Brass fitting 1-1/4 lg x 5/8h x 3/4d, water proof. Silver Plate. Navy type DS-491859.	D-C Plug for RG-58/U meter cord.	75076
W-403	Meter Cable Assembly: RG-58/U cable, 2-3/4 feet long, w/d-c plug P-401 at one end.	Meter Cord.	422097-1

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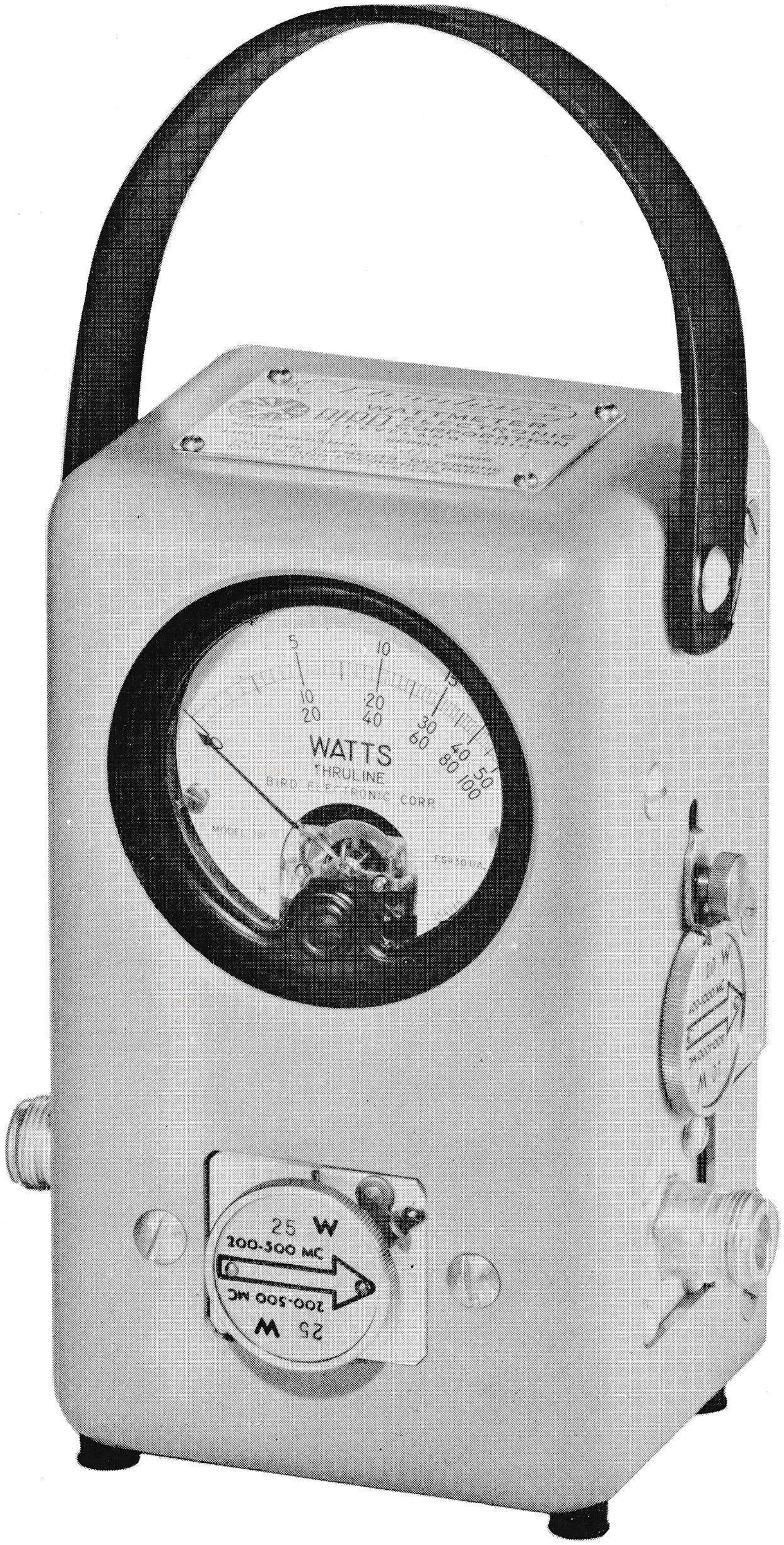


Fig. 1-1. View of Model 43 THRULINE

SECTION 1
GENERAL DESCRIPTION

1. PURPOSE AND APPLICATION

The Model 43 THRULINE WATTMETER is a directional r-f wattmeter, which measures power flow and load match in coaxial lines. It is for use with CW, AM, FM, and TV modulation envelopes, but is not for use on pulsed transmitters. Model 43 is designed for 50-ohm application, the insertion VSWR being less than 1.05 for frequencies up to 1000 MC in a standard 50-ohm circuit. The meter is direct reading (30ua d-c full scale), expanded down-scale for easy reading, and is graduated 25, 50, and 100 watts full scale. Further characteristics of the unit may be found in the summary sheet on page A.

2. DESCRIPTION (See Fig. 1-1)

The THRULINE WATTMETER is a portable unit contained in a die cast aluminum housing, with removable formed metal enclosure at the rear. The unit includes a leather carrying strap, four rubber bumper feet on the base, and four rubber bumpers on the back for use in standing or flat-laying applications. For further mechanical protection the microammeter is shock mounted between a hollow rubber back-up ring and three stem bumpers on the front flange of the meter. On the lower front face of the meter there is a slotted adjustment screw to zero the pointer. Below the meter opening is a rectangular aperture, at the front, through which projects only the top face of the line section casting, with the measuring element socket in the center.

A cable, entirely shielded against stray or r-f interference, connects the microammeter to the d-c jack attached to the side of the line section casting. This cable is nearly three feet in length, and permits the r-f line section to be removed from the housing. Connections to the meter may be readily maintained for any installations outside of the housing. Through the use of extra r-f bodies, permanent auxiliary installations may be maintained. See Section 3, INSTALLATIONS.

The d-c jack assembly has a filter capacitor nested inside, which shunts across the meter cable circuit. This more fully protects meter readings against the adverse effect of any stray r-f energy existant in the plug-in element. The d-c jack mounts a phosphor bronze spring finger. This opens into the plug-in element socket through a lateral clearance hole in the line section. The finger has a small silver button near its end, which mates with the contacts on the inserted elements. The line section is a silver plated brass casting, precision produced to provide unimpaired impedance of the r-f coaxial line in which it is inserted. For additional mechanical support the ends of the line section are machined to accurate size and nested in mating slots in the side wall of the housing. The r-f connectors at each end are of a quick-change type, being fastened down only by the four screws of the respective mounting flanges. The housing does not interfere with any connector changes.

To make measurements, the cylindrically shaped plug-in elements are inserted in the socket of the line section. A small catch in the upper right hand corner of the casting face presses on the shoulder of the plug-in element body, thereby maintaining the element in steady alignment with an assured bottom contact, to provide the most consistent electrical operation. The plug-in element has its terminals on diametrically opposite sides of the body, so that pick-up is made in either direction. The contacts on the plug-in element make connection with the d-c pick-up button only when the plug-in element is in the precise forward or reverse position. The small index pin on the element must be on the lower level of the casting face and against its respective stop.

The meter scale, as described above, is read according to the full scale rating stamped on the cap of the plug-in measuring element. These elements also fall in five frequency band groups, more fully described in Section 4, Paragraph 1.

SECTION 2
THEORY OF OPERATION

1. TRAVELLING WAVE VIEWPOINT

It is simplest to visualize the THRULINE idea from the TRAVELLING WAVE viewpoint on transmission lines, which shows that the voltages, currents, standing waves, etc., on any uniform section of line are the resultants of two travelling waves:

FORWARD WAVE travels (and its power flows) from source to load, has r-f 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 load to source and also has its 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:

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

$\overset{R}{W}$ = Watts Reflected = $\mathcal{E}^2/Z_o = \mathcal{I}^2 Z_o = \mathcal{E}\mathcal{I}$

Z_o is the characteristic impedance of the uniform line, and simplifies things by being a pure resistance, usually 50 ohms, for useful lines. The r-f main line circuit of the THRULINE is a short uniform section of air line, whose Z_o is exactly 50 ohms, and in which accurate measurements may be made.

2. COUPLING CIRCUIT

The coupling circuit which is sampling 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 shown in the schematic diagram, Fig. 2-1. Energy will be produced in the coupling circuit of the element both by mutual inductance and capacitance from the travelling r-f waves of the line section. The inductive currents will of course flow according to the direction of the travelling waves producing them. The capacitative portion of these currents is naturally independent of the direction of the travelling waves. Therefore, assuming that the element remains stationary, it is apparent that the current produced from the waves of one direction will add in phase, while those of the opposite direction will subtract in phase. The additive or "ARROW" direction is of course assigned to the forward wave, while the element is so designed and carefully balanced that the currents produced from the reverse wave will cancel each other almost completely. The resultant is a directivity always higher than 35db, 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 produce 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.

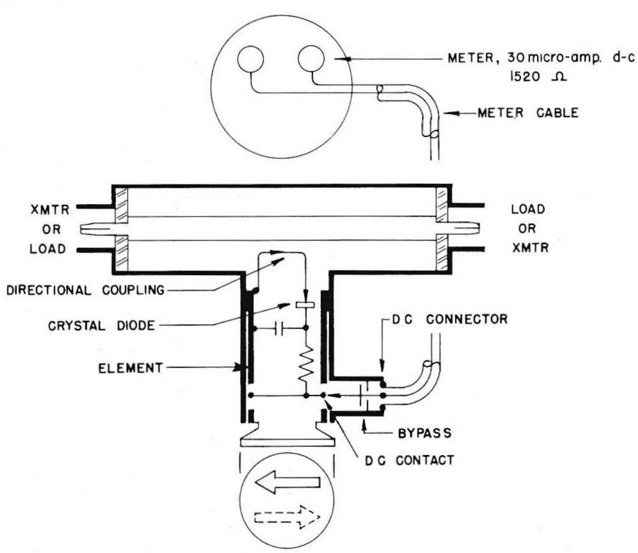


Fig. 2-1. Schematic Diagram

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

As mentioned above, the THRULINE uses a TRAVELLING WAVE viewpoint to measure most of the significant facts about transmission line operation. The STANDING WAVE viewpoint is another, quite elaborately developed, both mathematically and in existing instruments, which is widely used. Relationships between these viewpoints and their mathematical systems are given in most high frequency texts.

It is believed here that the more widespread use of the standing wave viewpoint and mathematics can be traced to the earlier development of slotted lines as exploring tools with which quantitative figures are obtained from the line. The slotted line is a standing wave instrument in fact, and use of it emphasizes the standing wave viewpoint.

There is not much question that slotted lines are too long, too expensive if good, not portable, and are slow and exacting in operation, these objections increasing rapidly as frequency drops below 1000 MC. The THRULINE is surprisingly quick, convenient and accurate by comparison. With the exception of reflection phase angle (distance, load to minimum) it tells everything a slotted line will tell.

SECTION 3
INSTALLATION

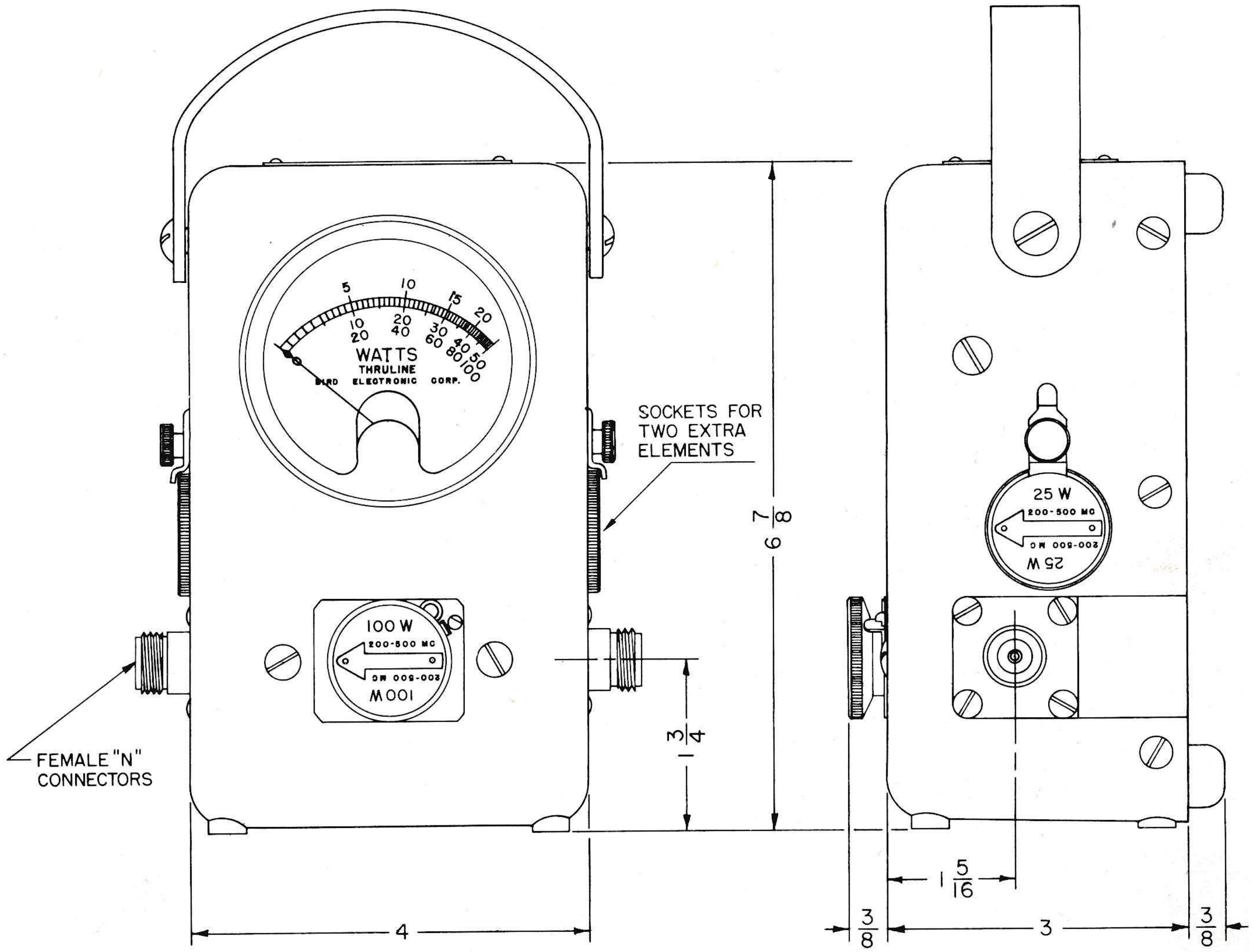


Fig. 3-1. Outline Drawing, Model 43 THRULINE

1. PORTABILITY

The Model 43 is essentially a portable instrument, and the housing is not specifically designed for attached mounting, see Outline Drawing, Fig. 3-1. A strap is provided for carrying purposes. Special Precaution - while transporting the THRULINE, it is best to insert a Plug-In Element and point the ARROW UPWARDS. This will shunt the meter connection circuit and serve to actively dampen needle action during handling or shipping. Also, at these times, secure the spare Plug-In Elements firmly by use of the thumbscrews for each socket. A fall could disrupt the calibration of the Elements, and they should be handled with reasonable care at all times.

DO NOT DROP the THRULINE or subject it to hard blows. The microammeter is shock mounted in the housing to protect it against ordinary hazards, but its delicate mechanism may be damaged by severe impact.

The r-f line section, Fig. 3-2, may be removed from the housing for use elsewhere than in the meter housing. This may be accomplished by unscrewing the six #8-32 flat head machine screws around the back (three on each side). Then grasp the back cover by the side filler tabs and pull directly backwards. The entire back assembly will come off, with the speed nuts remaining attached. Now the line section may be loosened by removing the two #10-32 oval head machine screws on the front of the housing, right in line with the r-f section axis. It may now be slid directly backwards right out of the housing.

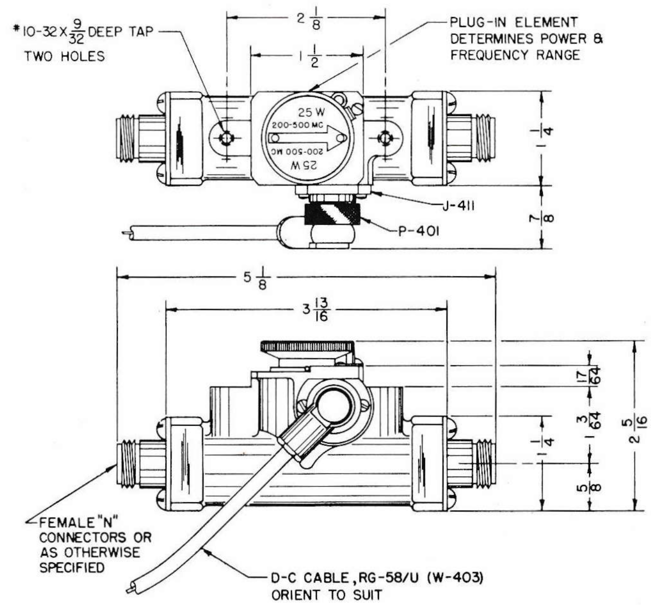


Fig. 3-2. Installation Drawing, R-F Line Section

2. REMOTE INSTALLATION

It is frequently advisable to mount the r-f section in a fixed location, particularly above 200 MC, to keep r-f lines short and to allow rigid connections without flexible cables. The standard meter cable, coiled within the housing, is 2-3/4 feet long. Longer meter cables are available on special order, 25 feet being a semi-stock length. As long as shielded cable is used (preferably RG-58/U), users may improvise their own extension cables. Additional interchangeable r-f bodies (Fig. 3-2) are available. It may be desirable to have two or more such bodies permanently installed in continuously operating equipment. In this case, one set of elements and one meter may be used to measure several r-f lines WITHOUT INTERRUPTION OF R-F LINES for insertion of the THRULINE.

If it is desired to panel mount the r-f line section, it blends very readily to this type of installation. A layout for the panel mount cutting is given in Fig. 3-3. The preferred panel thickness is 1/4 inch, but variations thicker or thinner will be acceptable. The use of a properly designed shim plate or of washers will make installation with thinner panels quite satisfactory. To simplify cable connections the r-f line section may be mounted in any convenient direction. Attach the r-f unit so that the finger catch is in the most accessible position.

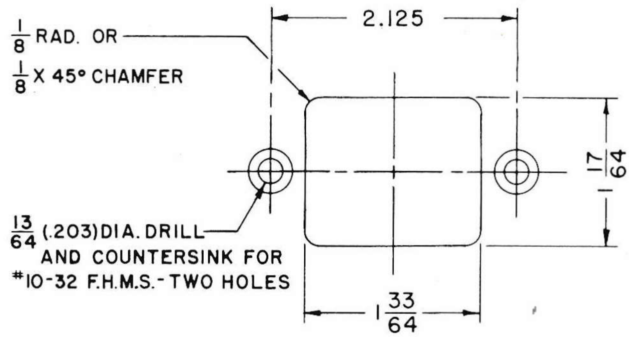


Fig. 3-3. Panel Cut for Mounting R-F Body

3. CONNECTIONS

The THRULINE is inserted in an r-f circuit with any suitable coaxial cable of 50-ohms impedance only. It is quite indifferent as to which respective side the power source and the load connections are made. If cables of other than 50-ohms impedance are used, mismatch will occur and introduce probably serious inaccuracies in the readings. We strongly urge the avoidance of this condition. Nevertheless, in the possible event of need, the calculation of results from same are discussed in Section 4, Para. 7.

The equipment is normally supplied with two female "N" type connectors. Connection is readily made with male "N" cable plugs. However, the following types of these quick-change connectors are now available:

Female "N"	Female "BNC"
Male "N"	Male "BNC"
Female "HN"	Female "LC"
Male "HN"	Male "LC"
Female "C"	Female "LT"
Male "C"	Male "LT"
Female UHF (SO-239)	7/8" EIA Air Line
Male UHF (PL-259)	

These may be purchased from Bird Electronic Corp. as required. See Parts List, Section A. Any of these above connectors can be changed readily by removing the #8-32 round head machine screws at each corner of the square flanges, and pulling straight outwards, carefully disengaging the spring fingers of the center conductor. Reverse this procedure to attach the connectors.

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 below.

See paragraph 4 of this chapter for frequency band flatness, and performance of the elements outside of stated frequencies. Elements for additional ranges (power or frequency) may be ordered without returning the THRULINE for calibration, since the r-f 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 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 r-f connection is selected, since the elements are reversible and the r-f circuit is symmetrical end for end. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

The THRULINE used with a TERMALINE resistor of proper power rating forms a highly useful absorption wattmeter. With ARROW set toward the load, it is unnecessary to reverse because reflected power may be neglected.

In cases where readings are being made when the meter unit is connected to an auxiliary r-f line section body, always remove any measuring element from the unused r-f line section. Otherwise, the d-c 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 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.

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

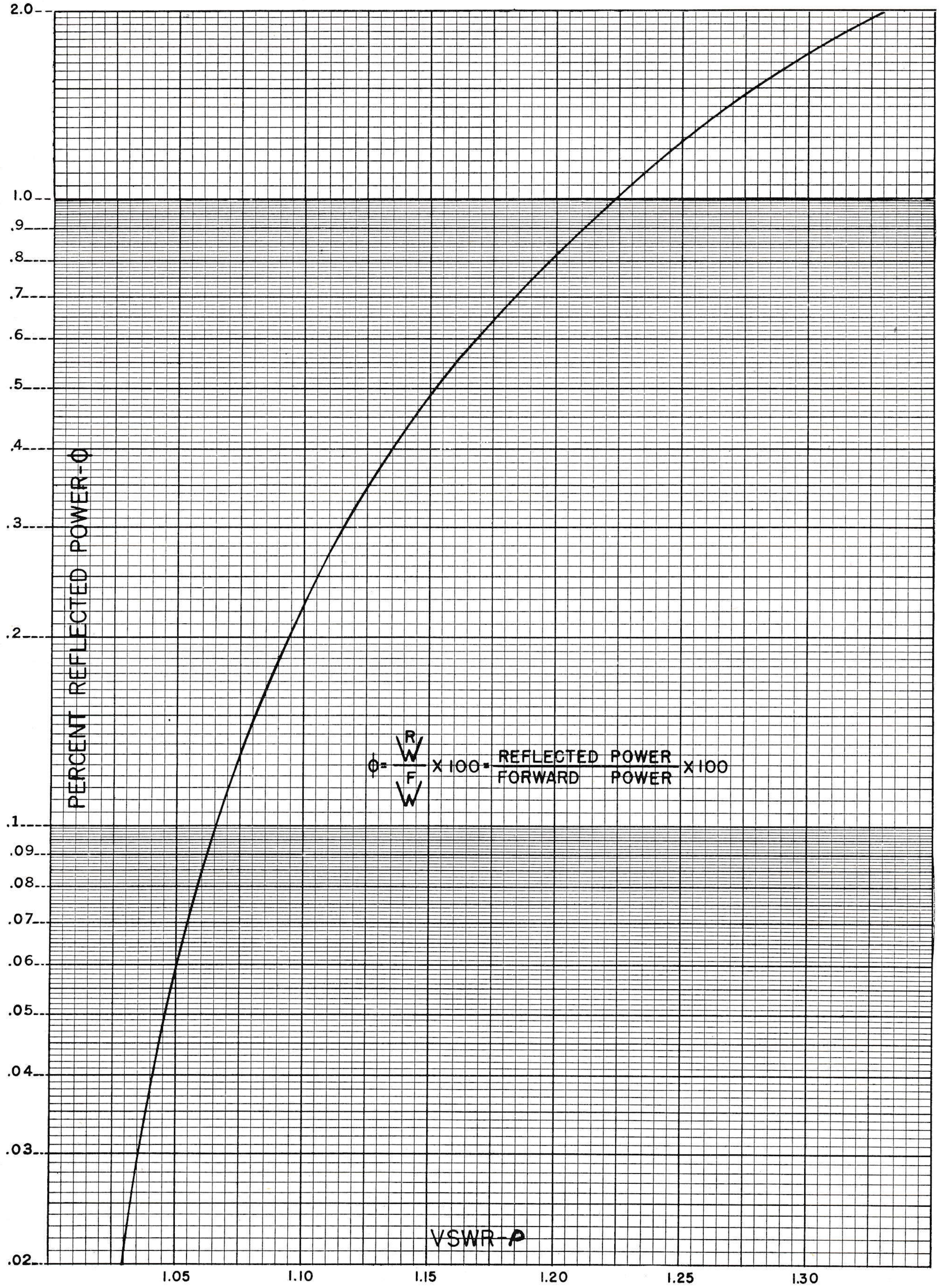
(a) Why make something similar to a hypothetical d-c volt ohmmeter with control pots for the voltmeter multipliers? Even more complications arise when diodes at r-f are involved.

(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.

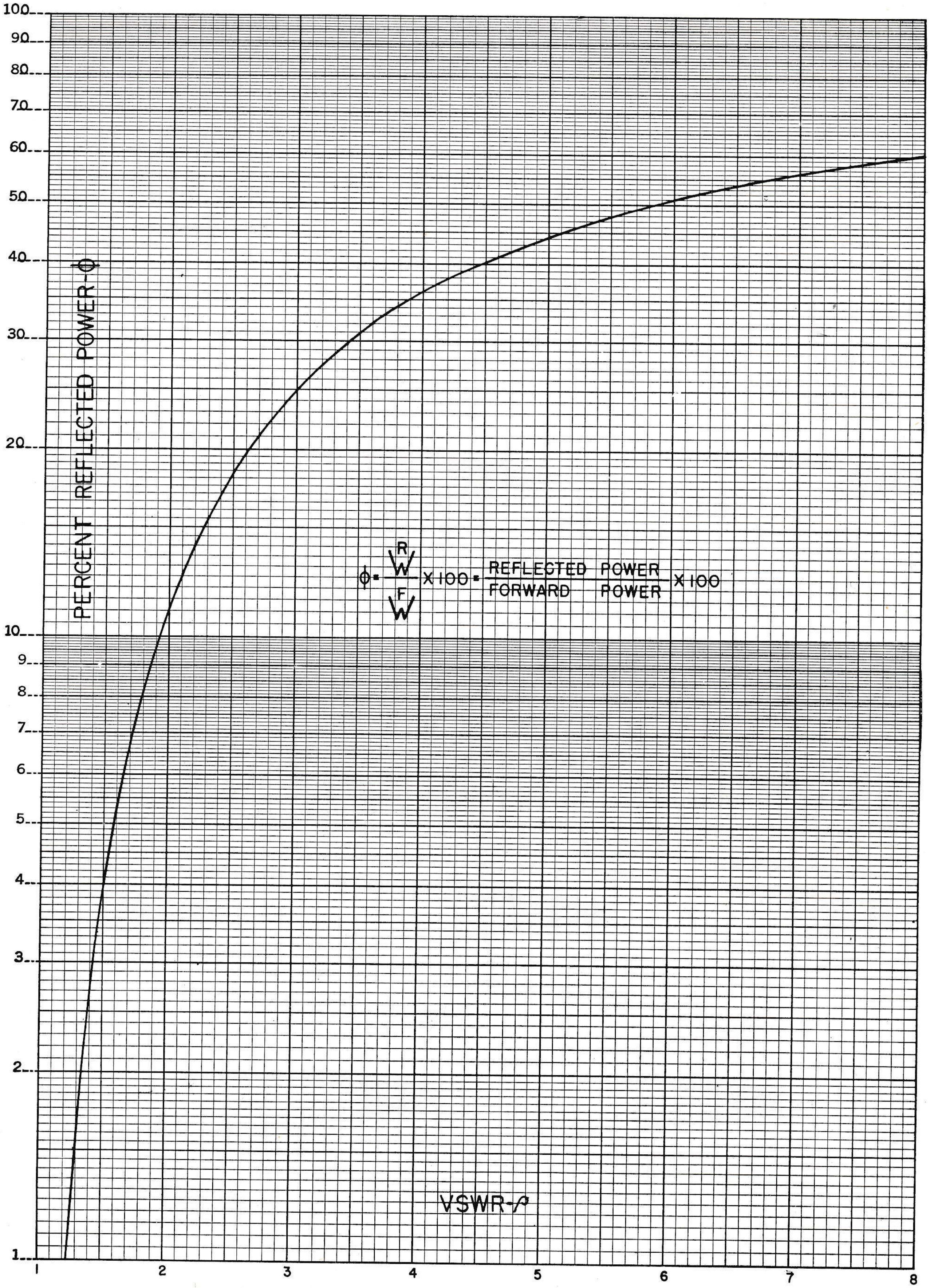
TABLE 1—RANGE OF ELEMENT TYPES

STANDARD THRULINE ELEMENT TYPES									
TYPE	Frequency Band - Mcs	WATTS FULL SCALE							
		5	10	25	50	100	250	500	1000
H	2-30	-	-	-	50H	100H	250H	500H	1000H
A	25-60	5A	10A	25A	50A	100A	250A	500A	1000A
B	50-125	5B	10B	25B	50B	100B	250B	500B	1000B
C	100-250	5C	10C	25C	50C	100C	250C	500C	1000C
D	200-500	5D	10D	25D	50D	100D	250D	500D	1000D
E	400-1000	5E	10E	25E	50E	100E	250E	500E	1000E

1 and 2.5 watt element made on special order for narrow frequency ranges, except 2-30 mc ("H" Band)



4-1a. Graph. - Percent Reflected Power vs. VSWR (1.0 to 1.3).



4-1b. Graph. - Percent Reflected Power vs. VSWR (1.0 to 8.0).

A trial is suggested for a few days -- forget VSWR and try thinking in terms of $\phi = \overset{R}{W} / \overset{F}{W}$ when the THRULINE is used. It will be noted that, even without bothering to calculate the ratio exactly, the two meter readings $\overset{R}{W}$ and $\overset{F}{W}$ give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem, the main thing usually is to minimize $\overset{R}{W}$, 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 AND ITS SIGNIFICANCE

Since there are definite simple relationships

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

$$\text{and } \phi = \frac{\overset{R}{W}}{\overset{F}{W}}$$

between standing wave ratio ρ and the reflected/forward power ratio ϕ indicated by the THRULINE, the latter may be conveniently used to measure VSWR. The relationship is given in Fig. 4-1a and b.

Note, that around $\phi = 10\%$, below which $\overset{R}{W}$ will appear insignificant and become hard to read, you are close to the commonly accepted lower limit $\rho = 2$, 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 $\overset{L}{W}$. 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. 4-1a, the very small level of reflected power, $\phi = .06$ percent, corresponding to $\rho = 1.05$. With a single element, detection of reflected power is possible down to about $\phi = 1$ percent, $\rho = 1.2$; if $\overset{F}{W}$ approaches full scale, measurement is possible down to about $\phi = 5$ percent, $\rho = 1.5$.

LOW-REFLECTION MEASUREMENTS may be extended below this with two elements. Say 80 watts are available, and you have 100 watt and 10 watt elements.

> Measure $\overset{F}{W}$ with the 100 watt element. Remove 100 W element and insert 10 watt element.
>
> CAUTION: 10 watt element must be ONLY in the REFLECTED direction. ARROW toward

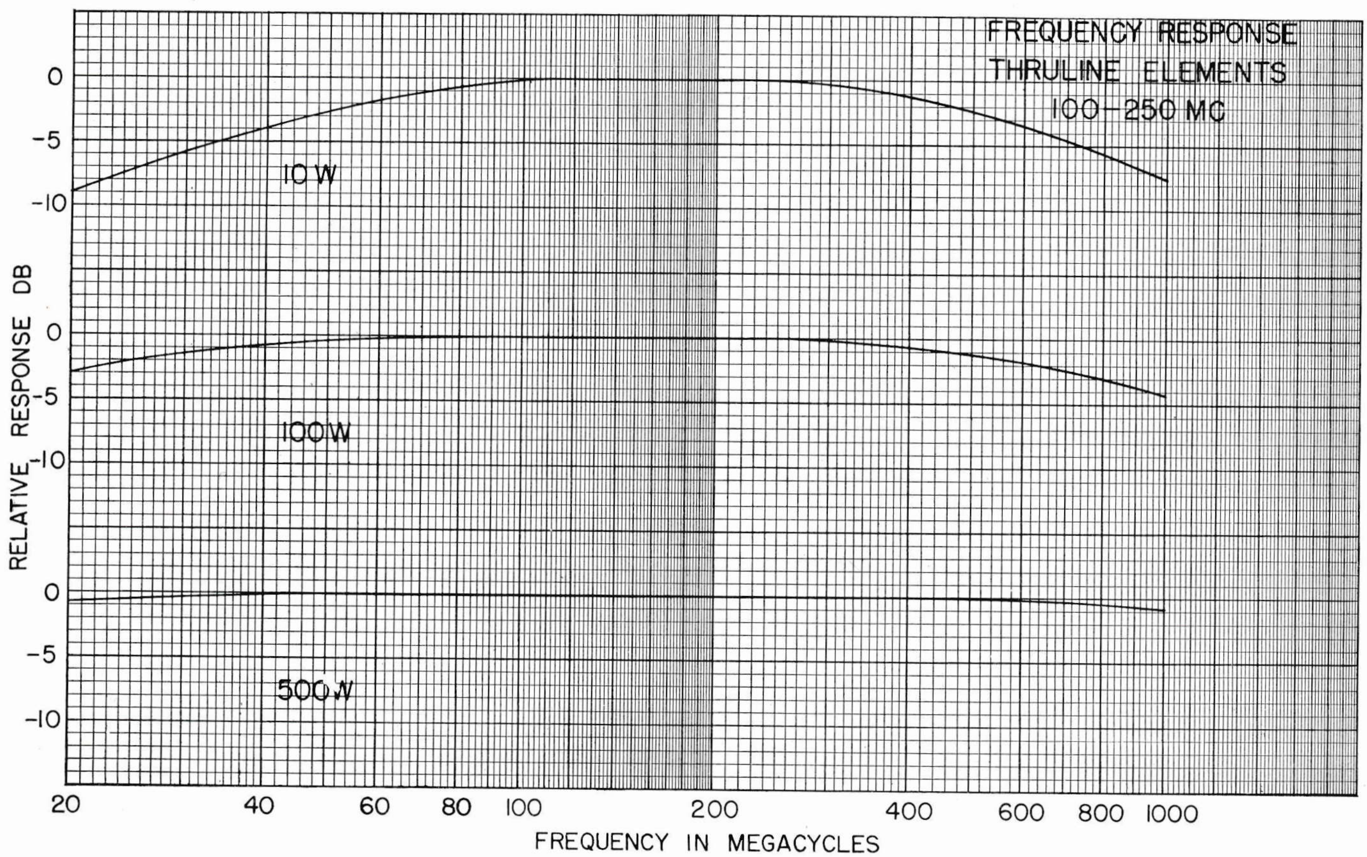


Fig. 4-2. Graph - Frequency Response

TRANSMITTER. Insert and remove ONLY this way.

Now read $\frac{R}{W}$ on the 10 watt element.

SPECIAL NOTE

DON'T ROTATE 10 watt element while TRANSMITTER is on. Always use great care with LOW SCALE elements on HIGH power r-f 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.

In this case, measurement down to at least .5 watt reflected is possible which means to

$\emptyset = \frac{.5}{80,}$ say .6 percent, or to about $\rho = 1.16$

and detection of reflections is possible down to about .1 watt,

$\emptyset = \frac{.1}{80} = .00125$, say .1 percent, or to about $\rho=1.06$

Caution is necessary in the above method, and preferably it should not be used with element ranges differing more than 100 to 10, although 250 to 10 can be used with extreme caution. With available elements no more sensitive than 10 watts full scale, as at present, the above method is limited to use with higher powered transmitters.

4. FREQUENCY RESPONSE

The plug-in elements have a very flat frequency response over a frequency ratio of more than 2-1/2 to one. This characteristic provides a practically flat response within the assigned frequency ranges for all the elements, see Table I in this Section.

An illustrative set of curves for three elements of one of these frequency bands is shown in Fig. 4-2. 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. 4-2, may be assumed to be about typical for all of the listed band types (A, B, C, D & E) 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 the 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.

5. 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.

6. TESTING OF LINES, CONNECTORS, FILTERS, ETC.

The THRULINE is highly useful for this purpose, and may be employed in several ways.

(a) VSWR (Insertion) or $\emptyset$ (Insertion) may be measured with the line terminated in a good load resistor (Termaline). The lower limits of sensitivity in this are given above under LOW REFLECTION MEASUREMENTS.

(b) ATTENUATION (Power lost by heat in the line) as well as VSWR (Insertion) and $\emptyset$ (Insertion) may be measured by inserting the unknown line between two THRULINES, or between two r-f bodies used with one meter and one set of elements. (End of line to be terminated in a load resistor). This method applies also to insertion between the THRULINE and a TERMALINE absorption wattmeter.

Very small values of attenuation require allowance for normal instrument errors. The correction may be determined by direct rigid connection of the THRULINES, or of the THRULINE-TERMALINE combination, in cascade. Slight juggling of zero settings is permissible for convenience in eliminating computation, provided readings are being taken fairly well up on scale.

(c) ATTENUATION BY OPEN OR SHORT CIRCUIT METHOD. Neater by far than (b) method is one depending on the high directivity (null balance) to which the THRULINE elements are held. They should, and do, exhibit good equality between forward and reflected readings when the load connector is open or short circuited. In this condition $\emptyset$ = 100 percent, the forward and reflected waves being equal in magnitude, and $\rho = \infty$ Say that this is checked on open circuit, and then a length of line of unknown attenuation, also open circuited, is connected to the load connector. The ratio $\emptyset$ then shown is the attenuation in two passes along the line (down and back).

Expressed in db, (using the equation $N_{db} = 10 \log \frac{W_F}{W_R}$), the db figure may be compared with published data for line type and length by remembering to halve N_{db}* because twice the line length is actually being measured.

This measurement should be supplemented by one of Ø (Insertion) as in (a) above, or at least by d-c continuity and leakage checks, since the attenuation measurement alone can be in error from faults such as open or short circuits part way down the line.

Open circuit testing is somewhat to be preferred to short circuit, since the reference short (used to check equality initially) must be good, and because the initial equality is somewhat better on open than on short circuit.

Again, for quite low values of measured attenuation, it is advisable to note exact readings (or difference) on the initial equality check, and to allow for this difference.

7. IMPEDANCE MISMATCH

There may be cases where it is necessary to use the THRULINE on other than the 50-ohm circuit for which it is designed.

*Or to double the line length.

Using the THRULINE, you will be inserting a 4-inch length of 50-ohm air line and the load on the transmitter will be changed from its original condition without the THRULINE. For a power reflection factor under 10% and frequency below 200 MC, the 4-inch length mismatch is not too serious. But going any higher than these values, even if the transmitter is tuned up with the THRULINE in place, the load impedance will be very different when it is removed.

The THRULINE, of course, indicates zero reflection when the load, at its load connector, is 50 ohms, pure resistive. An ideal condition on a 70-ohm line on the load side of the THRULINE will show 3% reflected power, i.e., THRULINE load is 70 ohms resistive, VSWR in the 50-ohm THRULINE is 70/50 = 1.4. The THRULINE can also show this same reflected percentage with 50/1.4 = 35.7 ohms pure resistive load, which could exist with 10% reflected power on the 70-ohm line (VSWR = 2 on the 70-ohm line). From this you can see that the 70-ohm line could have as much as 10% reflected power and VSWR = 2 when the THRULINE indicates 3% reflected power or VSWR = 1.4.

It should be especially remembered that with 70-ohm lines it is most important to get the reflected power indication and subtract it from the forward, because of this factor being so much more critical here than with intended 50-ohm line.

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. As stated in Section 1, 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 against 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 r-f line section should be energized. The r-f connectors should be also protected against dirt and grime, either by keeping cable plugs in place, or by other suitable means. Quick-change connectors that are not mounted should be stored in a closed place. In handling and storing these, care should be used to avoid damaging the special contact prongs protruding from the inside face. If the r-f connectors become dirty, they should be cleaned with a cotton swab stick and carbon tetrachloride. Do not use any other fluid. Avoid breathing fumes when using. 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 the plug-in element clean. This applies to the bore of the socket and the circumference of the cylinder body, but most importantly to the bottom rim of the body and the seat at the base of the socket in the line section. Also, check the ends of the insulated d-c contacts on the body to see that they are clean and smooth. These parts should be carefully cleaned with cotton swab stick and carbon tetrachloride as above. There must be 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 d-c contact. It is important that the operating position of this part be properly maintained. If the spring finger of the d-c contact requires adjustment, this 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 d-c jack (with spring finger) may be removed for access by unscrewing the two #4-40 fillister head machine screws that fasten it to the side of the r-f line section. Then retract this 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 r-f body. When replacing the assembly, be sure that the bead is again properly inserted.

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

Except for zero-ing the meter, it requires no maintenance. The mechanism of the microammeter is very delicate. Do not tamper with it. See Parts List with Figs. 5-1 and 3-2 for illustration of the parts discussed in this section.

2. TROUBLE SHOOTING

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

DIFFICULTY	POSSIBLE CAUSES
No Meter Indication	Arrow on Plug-In Element pointing wrong direction. No radio frequency power. No pick-up from d-c contact finger in r-f line section - adjust per paragraph 1. Open or short circuit in d-c meter cable - replace defective cable (RG-58/U) Meter burned out or damaged.
Intermittent or inconsistent meter readings.	Faulty load. Faulty transmission line. Dirty d-c contacts on elements - Clean as in paragraph 1. Sticky or defective meter.
High VSWR or high % power reflected.	Bad load. Poor connectors - See paragraph 1. Shorted or open transmission line. Foreign material in line section or in r-f connector bodies - see paragraph 1.

3. CALIBRATION CHECKS—THRULINE VS. TERMALINE WATTMETERS

It is recognized that calibration of absorption wattmeters is difficult and likely to be inaccurate unless comparison is made with a transmission (through) type of standard. The THRULINE being of such type, a natural question is: can a THRULINE be used to check or recalibrate absorption wattmeters, such as the Bird Electronic TERMALINE, both being rated at ±5 percent accuracy? The main question is one of exact power calibration.

The answer is a qualified yes, although with both instruments being about equally old and known to be undamaged, there is not too much reason to prefer either on probable accuracy. The edge is somewhat in favor of the THRULINE, because each element covers only 2-1/2 to 1 in frequency and will be flatter originally over this range than the TERMALINE can be held initially over its very much wider (16.7 to 1) frequency range. Also the THRULINE will probably exhibit smaller changes with time, because of the narrower frequency range, because it is simpler in general design and easier in function (does not have to serve as a power load), and because it does not become heated in operation.

Certainly if the absorption wattmeter has gone years since calibration, or is reasonably suspected of inaccuracy, it may well be calibrated against the THRULINE as standard. (Rather than use correction factors, one can, with the TERMALINE Wattmeter, make use of the calibration adjustment screws used in factory calibration. These are concealed and not mentioned in instruction book to discourage tampering. Correspondence is necessary.)

If such calibration is undertaken, care and thoroughness are advised.

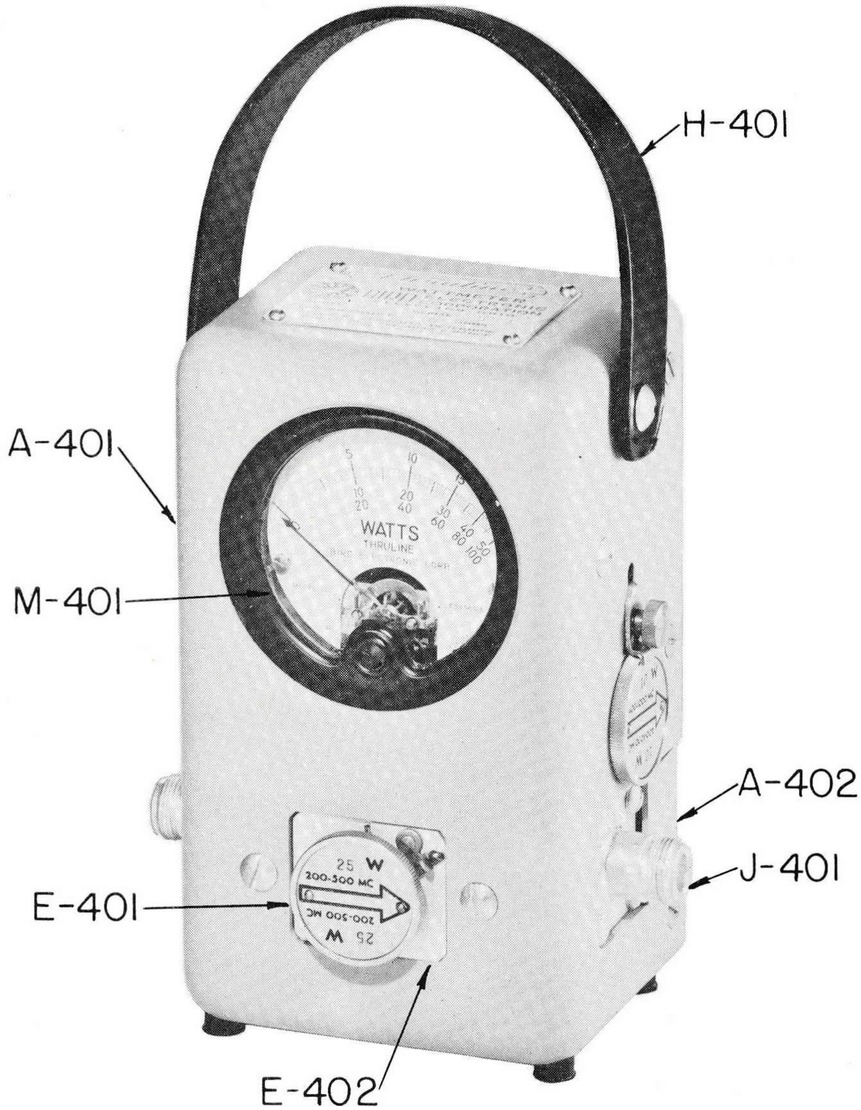


Fig. 5-1. Parts Illustration.