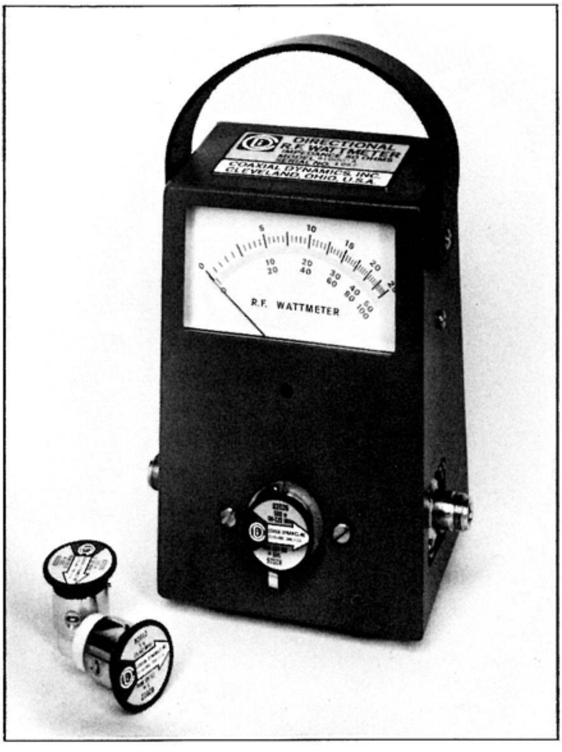
Coaxial Dynamics

MODEL 81000-A DIRECTIONAL RF WATTMETER



INSTRUCTION MANUAL

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The Model 81000-A Directional Wattmeter is an accurate and portable insertion RF Wattmeter using plug-in power detectors and QUICK MATCH RF connectors, which measures forward and reflected CW power. The Model 81000-A features a large scale, easily read meter movement. Standard ranges: 100mW to 10kW; 0.45-2300 MHz. Accuracy ±5% of full scale.

SPECIFICATIONS

Power Range	100 mW-10 kW
Frequency Range	0.45-2300 MHz
VSWR	1.05:1 max., with N connectors
Accuracy	±5% of full scale
Impedance	50 ohms
RF Connectors	Type N(F) Standard

Other "Quick Match" Connectors are available.
See 88000 Series Page 16

Weight	3.6 lbs. (1.6 kg.)
Element Weight	1.25 oz. (.035 kg.)

Catalog Numbers
For Plug-In Elements used With Model 81000-A Wattmeters

SCHEDULE 1
STANDARD ELEMENTS *(CATALOG NUMBERS)*

Power Range	Frequency (MHz) 2-30	25-60	50-125	100-250	200-500	400-1000	950-1300
5 watts		82012	82020	82028	82036	82045	82068
10 watts		82013	82021	82029	82037	82046	82069
25 watts		82014	82022	82030	82038	82047	82070
50 watts	82004	82015	82023	82031	82039	82048	82071
100 watts	82005	82016	82024	82032	82041	82049	82072
250 watts	82006	82017	82025	82033	82042	82050	82073
500 watts	82007	82018	82026	82034	82043	82051	
1000 watts	82008	82019	82027	82035	82044	82052	
2500 watts	82009						
5000 watts	82010						

MODEL NUMBERS

SCHEDULE 2
MILLIWATT ELEMENTS

100 mW	Cat. No.	250 mW	Cat. No.	500 mW	Cat. No.
20-23 MHz	820A022	70-80 MHz	820B075	25-30 MHz	820C028
44-50 MHz	820A047	72-76 MHz	820B074	65-90 MHz	820C078
62-70 MHz	820A066	105-120 MHz	820B113	72-76 MHz	820C074
74-76 MHz	820A075	310-350 MHz	820B330	105-120 MHz	820C113
105-120 MHz	820A113	416-436 MHz	820B426	130-170 MHz	820C150
135-165 MHz	820A150	800-900 MHz	820B850	300-350 MHz	820C325
190-205 MHz	820A198	900-950 MHz	820B925	800-900 MHz	820C850
310-350 MHz	820A330			900-950 MHz	820C925
416-436 MHz	820A426				
740-760 MHz	820A750				
800-900 MHz	820A850				

SCHEDULE 3
LOW POWER ELEMENTS

1 watt	Cat. No.	2.5 watts	Cat. No.
28-44 MHz	820D036	60-80 MHz	820E070
40-50 MHz	820D045	80-140 MHz	820E110
44-70 MHz	820D057	95-150 MHz	820E123
70-120 MHz	820D095	150-250 MHz	820E200
108-118 MHz	820D113	200-300 MHz	820E250
108-181 MHz	820D145	225-400 MHz	820E313
150-250 MHz	820D200	275-450 MHz	820E363
200-300 MHz	820D250	340-560 MHz	820E450
275-450 MHz	820D363	800-900 MHz	820E850
310-350 MHz	820D330		
327-543 MHz	820D435		
425-850 MHz	820D638		
800-950 MHz	820D875		

GENERAL DESCRIPTION

1. PURPOSE AND APPLICATION

1.1 PURPOSE. The Model 81000-A is a directional RF 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.

1.2 APPLICATION. The wattmeter is designed for 50-ohm application. The insertion VSWR of this equipment is very low, less than 1.05:1 for frequencies up to 2300 MHz in a 50-ohm circuit. The meter is direct reading, expanded down-scale for easy reading. The fifty divisions are graduated for 25, 50 and 100 full scale. By adjustment of the decimal point, these graduations may be used for any plug-in elements that are provided with this equipment.

2. DESCRIPTION

2.1 WATTMETER UNIT. The Model 81000-A includes a meter and a line section with quick-match RF connectors contained in an aluminum housing having a removable metal enclosure at the rear. The unit has four rubber bumper feet on the base. Storage is provided for 2 extra elements. For mechanical protection the microammeter is shock mounted. Below the meter is socket for the plug-in detector element.

2.1.1 CONNECTORS. Model 81000-A RF Wattmeter is normally supplied with type "N" female connectors as described above. To avoid measurement errors caused by the use of "between series adaptors" we recommend the use of proper QUICK-MATCH connectors. Reference 88000 series RF connectors on Page 16.

2.2 PLUG-IN DETECTOR ELEMENTS. To make RF power measurements, the plug-in detector elements are inserted in the socket of the line section. Each element is designed for a particular RF power and frequency range. A retainer is provided on the casting face to maintain alignment and assure bottom contact of the element body. The contacts on the plug-in detector element make connection with the DC pick-up loop only when the plug-in detector element is in the precise forward or reverse position. The stylized arrow indicates the direction of power flow. Reference schedule (1), (2), and (3) for plug-in elements.

2.3 METER SCALE. The meter scale, as described above, is read according to the full scale rating indicated on the cap of the plug-in detector element.

3. THEORY OF OPERATION

3.1 TRAVELING WAVE CONCEPT. The operation of this wattmeter is based on the traveling wave concept of RF transmission. As RF is applied to a transmission line, there is a forward wave traveling from the transmitter to the load, and a reflected wave traveling from the load to the transmitter. The closer the load is matched to the transmission line, the smaller the reflected wave will be. To determine the RF power dissipated in the load, it is necessary to determine the RF power of the forward wave and the RF power of the reflected wave. The difference between the two will indicate power absorbed by the load.

3.2 TRAVELING WAVE vs STANDING WAVE. The interference between forward and reflected waves, produces a standing wave in the system. In the standing wave concept, VSWR (voltage standing wave ratio) is a widely used tool. There is a simple relation between forward power, reflected power, and VSWR.

Let W_f represent forward power

W_r represent reflected power

Then

$$\text{VSWR} = \frac{1 + \sqrt{\frac{W_r}{W_f}}}{1 - \sqrt{\frac{W_r}{W_f}}}$$

For example: 1% reflected power is about 1.2:1 VSWR and 10% is about 2.0:1 VSWR.

It can be seen the VSWR is an index of the magnitude of the mis-match between the source and the load. However, the quantities W_f and W_r are also an indication of the mis-match and are read directly on the Model 81000-A Directional Wattmeter.

The charts furnished in this Instruction Booklet may be used to convert W_f, W_r to VSWR.

3.3 COUPLING CIRCUIT

When the wattmeter is inserted in a transmission line the RF power flows thru a precision section of 50-ohm air line. The element installed in the line section socket is coupled capacitively and inductively to the main line. Voltages proportional to the RF voltage and current in the main line are therefore induced in the element circuitry. The coupling is so adjusted that the induced voltages add in the sensitive direction and cancel for the opposite direction. These voltages are rectified and the resulting DC current is applied to the meter which is calibrated to represent the RF power in the main line.

INSTALLATION

1. UNPACKING AND CHECKING

1.1 CHECKING. Check all components of the wattmeter for damage. Give particular attention to the meter in the wattmeter unit, to the threaded ends of the meter unit line section and to the cable ends. Report shortages or any damage promptly to your dealer or to the factory.

2. GENERAL

2.1 HANDLING PRECAUTIONS. Take reasonable precautions when handling the wattmeter unit and the plug-in detector elements. When moving or carrying the wattmeter unit, rotate the plug-in detector element which is installed in the built-in line section so that the arrow is pointing down. This will shunt the meter connection circuit and damp needle movement during handling or shipping. Make sure the thumbscrews which secure the spare elements are firmly tightened. Do not drop or bump the wattmeter. Though the microammeter is shock-mounted in the case, its delicate mechanism can be damaged by severe impact. Use reasonable care when handling the plug-in detector elements. Dropping and rough handling may change the calibration of the elements.

3. INSTALLATION

3.1 DIRECT INSTALLATION. Connection may be made directly to the quick-match RF connectors mounted on the internal line section. Make connections with any suitable coaxial cable of 50-ohm impedance. Connect the power source to one side of the wattmeter and connect the load to the opposite side. Power source and load can be connected interchangeably, since the direction of the plug-in detector element selects whether forward or reflected power will be sensed by the meter. Refer to figure 1 for dimensions of the wattmeter unit. Use only 50-ohm impedance cables for making connections to the wattmeter unit. Impedance mis-match can introduce inaccuracies in the power reading. Calculations of inaccuracies resulting from impedance mis-match are discussed in paragraph 5.1 on page 12.

3.2 POWER REQUIREMENTS. The wattmeter requires no external source of power, since the meter operates on power sensed from the transmission line into which it is connected. The unit contains no batteries or dry cells.

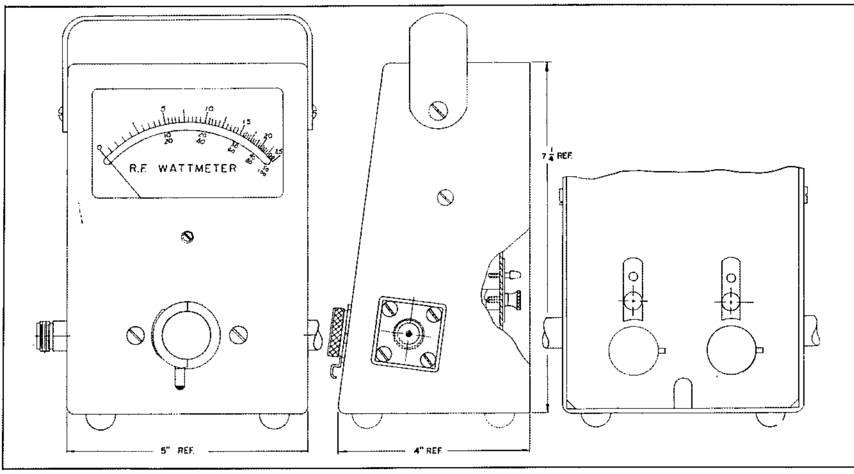


Figure 1. Wattmeter Overall Dimensions

OPERATION

1. GENERAL PROCEDURE

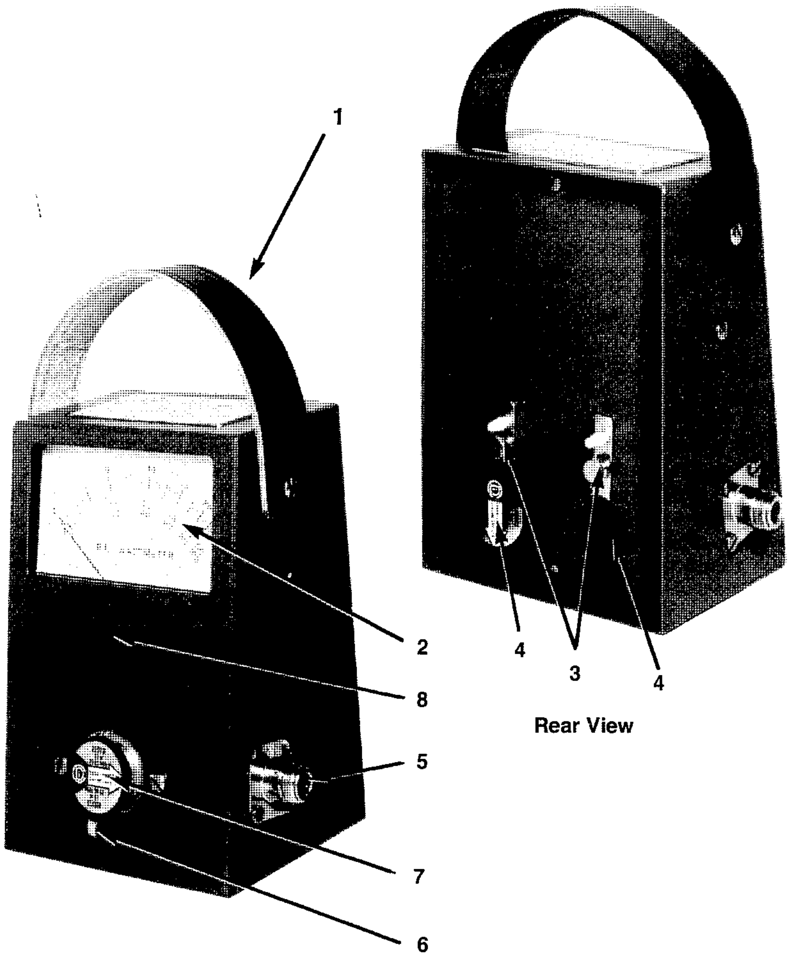
1.1 WATTMETER READINGS. To make readings with the wattmeter, it is necessary to select and install a plug-in detector element of the proper frequency and power range, connect the wattmeter into an RF line, and read the meter with the plug-in detector element in the forward and reverse direction. Subtraction of the reflected power from the forward power gives power dissipated in the load. Detailed operating instructions are provided in this section.

SAFETY FIRST

HIGH VOLTAGE WARNING. When operating this equipment in conjuction with RF power of 200 watts or higher, the potential of the center conductor of the RF line section will be 100 volts or higher. Do not contact the center conductor. If cleaning becomes necessary, shut off the RF power.

1.2 ZERO ADJUST METER. Before installing the plug-in element and taking any readings with the wattmeter, it is necessary to zero the meter under no-power conditions. Using a small screwdriver, turn the meter zero-adjust screw (8) clockwise or counterclockwise as necessary so that the meter pointer exactly aligns with the zero of the meter scale.

1.3 PLUG-IN ELEMENT SELECTION AND INSERTION. Use a plug-in detector element (7) which has a high enough wattage rating and the required frequency range to properly indicate the power of the RF line. If the approximate RF power of the line is not known, start with an element which will be sure to adequately cover the maximum RF power of the transmitter to prevent overloading the wattmeter. Substitute a more sensitive element for the first element if the indication is too low for accurate power determination.



1. Carrying Strap
2. Meter Assembly
3. Spare Element Retaining Screw
4. Spare Element Storage
5. Line Section RF Connector
6. Element Latching Assembly
7. Installed Plug-In Detector Element
8. Meter Zero-Adjust Screw

Figure 2. Wattmeter Components

1.4 ELEMENT REMOVAL AND INSERTION. The selected element must be installed in the line section of the wattmeter unit connected into the RF line to be checked.

(a) Loosen the spare element retaining screw (3, figure 2) to release the clip which retains the spare element (4) on the back of the wattmeter. Remove the spare element.

(b) Release the latch (6) that secures the element in the line section body of the wattmeter or of the remote RF accessory line section; remove the element (7).

(c) Hold the latch in the disengaged position and insert the replacement element in the line section body. Return the latch to retain the replacement element. Install the removed element in the spare element socket and retain with the spare element retaining screw (3).

2. NORMAL OPERATING PROCEDURES

2.1 DETERMINING LOAD POWER. Use the following step-by-step procedure to determine load power:

(a) With the transmitter energized, rotate the plug-in element so that the arrow on the element points in the direction of the load connection to the RF line section. Read the meter to determine forward load power in watts. The meter face is marked in three scales of 25, 50 and 100, full scale readings. By adjusting the position of the decimal point, these scales provide direct reading of the values indicated when any plug-in detector element is inserted. If the meter indicates a power level too low for accurate reading, use a plug-in detector element with a lower power rating.

(b) Rotate the plug-in detector element so that the arrow points in the direction of the power source connection to the line section. The meter will then indicate reflected power in watts.

(c) To determine the power dissipated in the load, subtract the reflected power from the forward power. This step is necessary where appreciable power is reflected by the load, as is the case with many antennas. When a good load resistor is used, reflected power will be negligible and frequently unreadable.

2.2 DETERMINING VSWR. The wattmeter is not designed to provide direct VSWR readings. It is felt that VSWR readings are no more valuable than the ratio of forward to reflected power. In fact, most operators find that, in transmitter tune-up, antenna matching, and similar problems dealing with RF circuits, the forward power-to-reflected power ratio is a highly useful tool. However, VSWR readings can be determined easily by the use of the provided graphs as follows:

(a) Determine the forward and reflected power as described in paragraph 2.1

(b) Refer to the appropriate graph (figure 3) to convert the forward wattage readings and reflected wattage readings to VSWR. Note that the graphs convert the readings directly to VSWR without any intermediate computations.

2.3 MAKING LOW REFLECTION READINGS. It is often desirable to make accurate low reflection readings. This can be done by using two elements, providing care is taken to prevent application of high forward power to the low-reading element. Proceed as follows:

(a) Measure forward power, using the proper plug-in element. Reverse the arrow direction of the element and determine the general level of reflected power.

(b) Remove the plug-in element and insert a second, lower reading element which has a maximum rating of more than the reflected power indicated in step (a) above. Insert the element so that it reads reflected power only.

CAUTION

When making low reflection readings using two elements, take care to insert the lower reading element so that it senses reflected power only. Do no rotate the lower reading element in the socket so that the unit is subjected to forward power. This will result in damage to the plug-in element, the microammeter, or both.

(c) Read the reflected power on the meter in the usual manner.

(d) When using the two-element method of reading low reflected power, do not use a pair of elements which has a power rating difference greater than 10 to 1 or at the very greatest, 25 to 1.

3. FREQUENCY RESPONSE

3.1 FREQUENCY CURVE. Each plug-in element of the wattmeter is designed to operate within a specific frequency range. The use of these elements to measure direct power outside of the stated frequency range is not recommended. The frequency response of the elements is flat over the designated range. The response generally falls off above and below the assigned frequency range, greater for lower power elements than for high-power elements.

4. TESTING LINES, CONNECTORS, FILTERS, AND RELATED COMPONENTS

4.1 TEST METHODS. Lines, connectors, filters, and related components can be tested using the wattmeter. The method of testing used depends upon the circumstances involved for any particular test. Some of these tests are described as follows:

4.1.1 TESTING LINE USING LOAD RESISTOR. The standing wave ratio or the reflected power-to-forward power ratio of a line can be determined by terminating the line with a good load resistor. Proceed as described in paragraph 2.1. Low reflected power may be measured as described in paragraph 2.3.

4.1.2 DETERMINING LINE ATTENUATION USING TWO WATTMETERS. Line attenuation (power lost by heat in the line) can be determined by inserting the line of unknown value between two wattmeters or between two wattmeters' accessory line sections. If the latter method is used one wattmeter unit and one element can be used to make both readings. In either case, the end of the line must be terminated by a load resistor. By comparing readings made at the two places, the attenuation of the line can be determined. Where very small values of attenuation are involved, allowances must be made for normal instrument error. Slight juggling of zero settings is permissible for convenience of eliminating computations, provided the readings are fairly high on the meter scale.

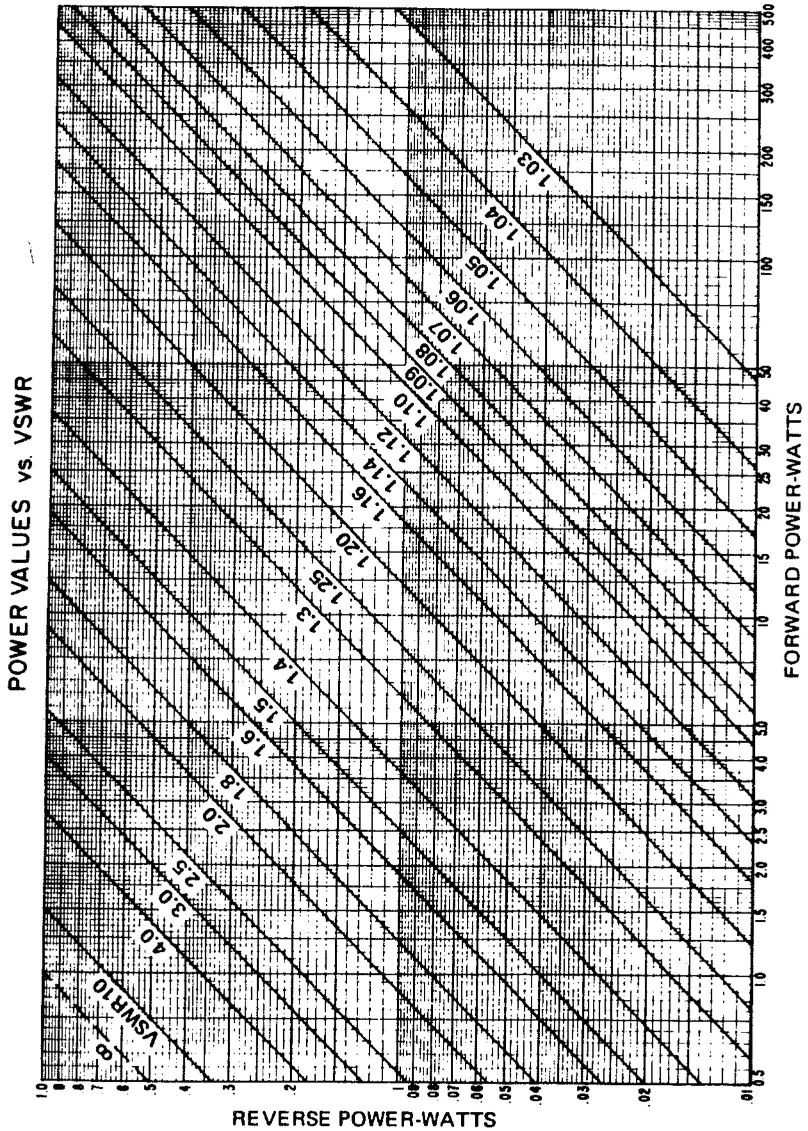


Figure 3. VSWR Nomograph - Sheet 1

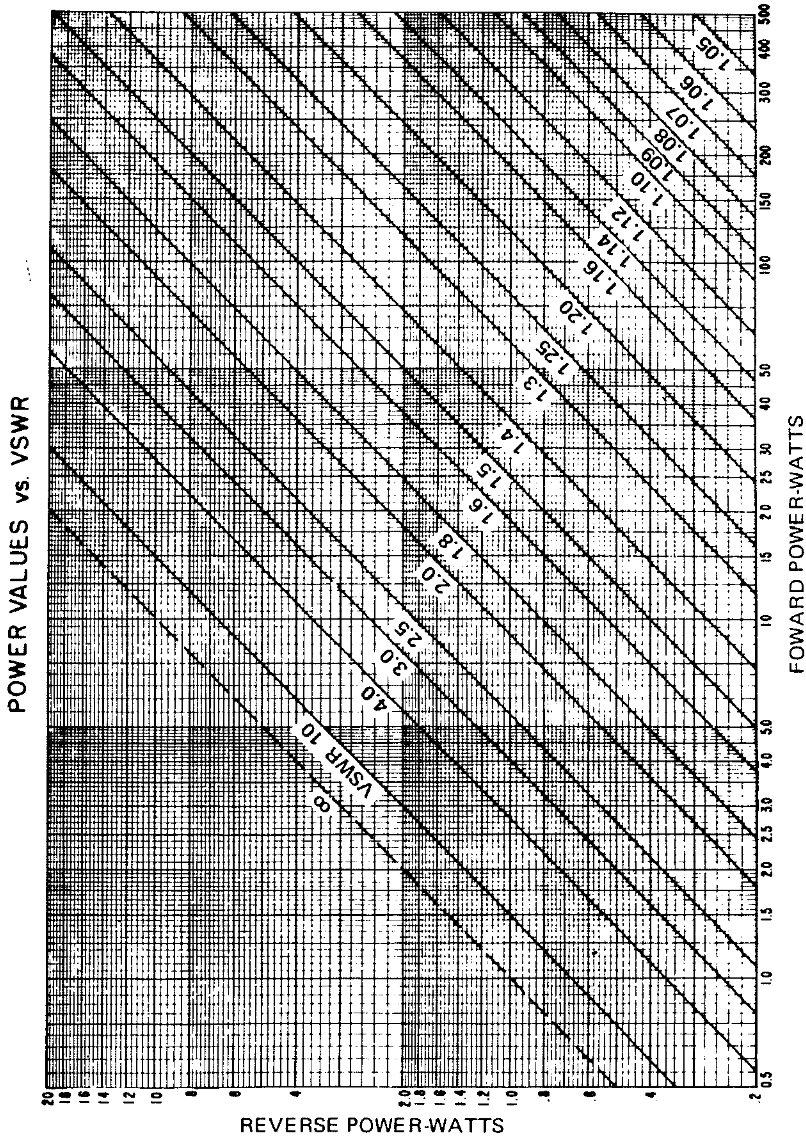


Figure 3. VSWR Nomograph - Sheet 2

4.1.3 DETERMINING ATTENUATION BY OPEN CIRCUIT METHOD. Attenuation can also be determined by the open circuit method. The wattmeter exhibits good equality between forward and reflected readings when the load connector is open or short circuited. When this is checked on an open circuit and an open circuited length of line of unknown attenuation is connected to the load connector, the new ratio shown is the attenuation in two passes along the line (down and back). This can be converted to decibels as follows:

$$\text{Attenuation (decibels)} = \frac{10}{2} \log \frac{\text{forward power}}{\text{reflected power}}$$

The decibel reading must be halved because twice the line length is being measured (down and back). This measurement must be supplemented with a reflected power-to-forward power ratio check (paragraph 4.1.1 above) or with a DC continuity check or leakage check since open circuits or shorts may exist part of the way along the line.

4.1.4 DETERMINING ATTENUATION USING SHORT CIRCUIT METHOD. Attenuation can also be determined as described in paragraph 4.1.3 above by using a short circuit rather then an open circuit. The open circuit method is preferred because the initial equality (forward power-to-reflected power) is more easily achieved in an open circuit.

5. IMPEDANCE MIS-MATCH

5.1 IMPEDANCE MIS-MATCH COMPUTATIONS. This wattmeter is designed to check power in a 50-ohm circuit. When the wattmeter is connected into the RF line, it inserts a section of 50-ohm line into that circuit. When this is inserted into a line having an impedance other than 50-ohms, the load on the transmitter will change because of the insertion. This change is not too serious if the power reflection factor is less than 10 per cent or if the frequency is less than 200 MHz. At values higher than these, the insertion of the 50-ohm line will result in a very different load impedance even if the transmitter is tuned up with the wattmeter inserted into the line. The wattmeter will indicate zero reflection when the unit is connected into a 50-ohm pure resistive line. When a 70-ohm line is connected on the load side of the wattmeter, under ideal conditions, the 50-ohm wattmeter will indicate 3 percent reflected power or VSWR of 70/50 = 1.4. The wattmeter can show this same reflected percentage when a 50/1.4 = 35.7-ohm, pure resistive load is applied to the 50-ohm line. This could exist with 10 percent reflected power on the 70-ohm line (VSWR = 2). From this it can be seen that the 70-ohm line could have as much as 10 per cent reflected power with a VSWR of 2.0, but the meter would indicate only 3 per cent reflected power (VSWR = 1.4). If it is necessary to make wattage readings on a 70-ohm line with the 50-ohm wattmeter, it is especially important to subtract the reflected power from the forward power.

MAINTENANCE

1. MAINTENANCE

1.1 SCOPE OF MAINTENANCE. Maintenance of the Model 81000-A is normally limited to cleaning. The amount of cleaning necessary can be minimized by keeping the plug-in element in the socket of the line section as much as possible. This serves as an effective seal against the entry of dust and dirt. Cover the socket opening when the element is removed. Also, protect the RF connectors on the line section against the entry of dust and dirt by keeping them connected to the line or by covering them when the line is disconnected.

1.2 CLEANING. All contacts must be kept clean to assure low resistance connections to and within the unit.

1.2.1 CLEANING RF CONNECTORS. Clean RF connectors with a cotton swab stick dampened with inhibisol or trichlorethylene.

SAFETY FIRST

Do not use any solvent other than inhibisol or trichlorethylene for cleaning the wattmeter. When using this fluid, avoid inhalation of fumes and avoid unnecessary and repeated contact with the skin. Make sure the cleaning area is well ventilated.

1.2.2 CLEANING LINE SECTION SOCKET. Clean the inside of the line section socket bore and the entire circumference of the plug-in element with a cotton swab stick dampened with inhibisol or trichlorethylene. Pay particular attention to the cleaning of the bottom rim of the element body and to the seat of the socket in the line section. When cleaning the socket bore, take care not to disturb the spring finger of the DC contact. If necessary, the spring finger of the DC contact can be adjusted manually. The button must be positioned out far enough to make good contact with the element body, but it must not restrict entry of the element body. Remove two machine screws that secure the DC jack to the line section. Remove the DC jack from the line section, taking care not to lose the small positioning bead that straddles the base of the phosphor bronze spring and nests in the counterbore on the side of the RF body. After adjusting to meet the requirements, make sure that the bead is properly inserted.

1.2.3 CLEANING INSIDE OF LINE SECTION. Check the inside of the line section for dirt and contamination. Clean the reachable portions of the line section with a cotton swab stick. Blow out the remaining dirt with low-pressure, dry compressed air. Do not attempt to remove the RF line center conductor from the line section. Any attempt to remove it will ruin the assembly.

2. TROUBLESHOOTING

2.1 TROUBLESHOOTING CHART. Refer to Table 1 for a listing of troubles that might occur during operation of the wattmeter. Probable causes of troubles and remedies for the troubles are also listed.

TABLE 1. TROUBLESHOOTING CHART

TROUBLE	PROBABLE CAUSE	REMEDY
NO METER INDICATION	Arrow on plug-in element in wrong direction.	Correct arrow direction.
	No radio frequency power.	Check transmitter for faults.
	No pickup from DC contact finger in line section.	Adjust finger.
	Open or shorted DC meter cable.	Replace cable.
	Meter burned out or damaged.	Replace meter.
INTERMIT-TENT OR IN-CONSISTENT METER READINGS	Faulty load.	Correct fault in load
	Faulty transmission line.	Correct fault in transmission line.
	Dirty DC contacts on elements.	Clean DC contacts.
	Sticking or defective meter.	Replace meter.
HIGH PER-CENTAGE OF REFLECTED POWER	Faulty load.	Correct fault in load.
	Poor connectors.	Check for high resistance connections.
	Shortened or open transmission line.	Correct fault in transmission line.
	Foreign matter in line section.	Clean line section thoroughly.

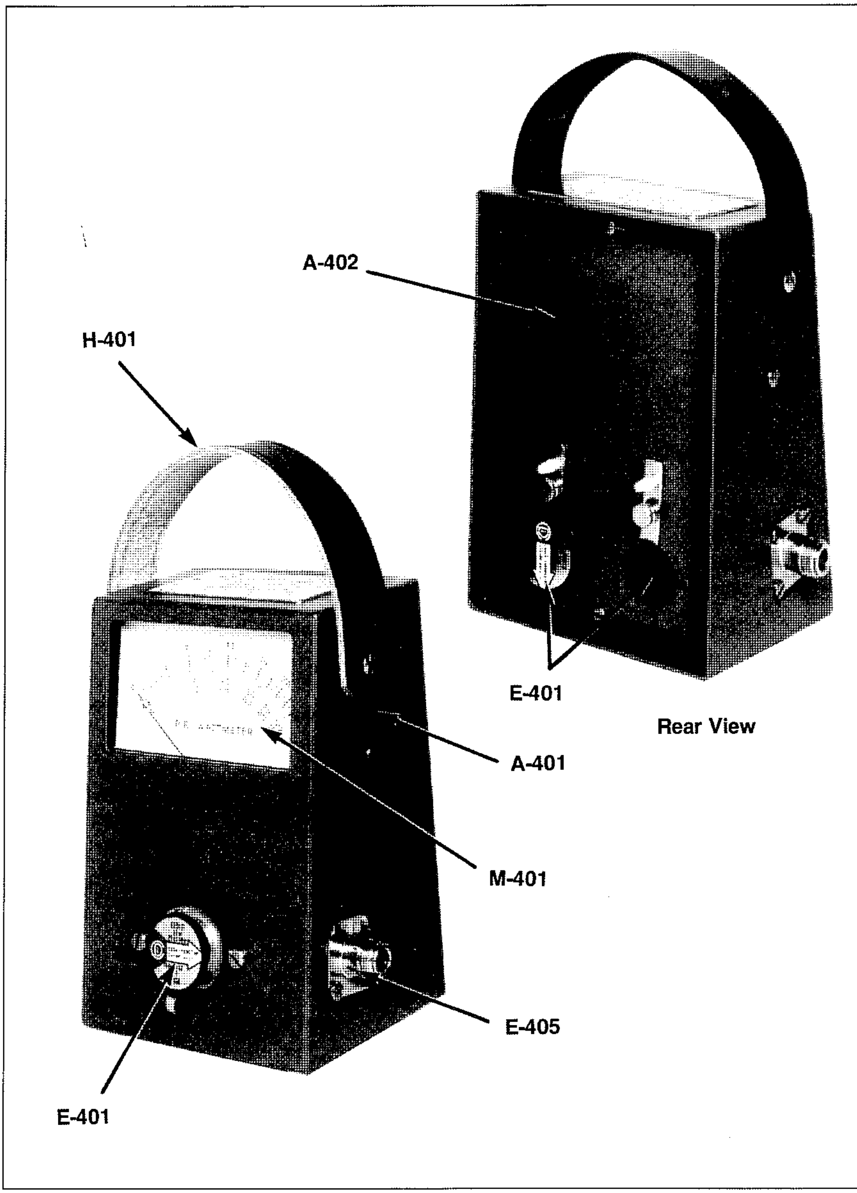


Figure 4. Parts Location

PARTS LISTING

Reference Designation	Part Name and Description	Part No.
	Wattmeter Parts	
A-401	Housing	81000-004
A-402	Cover Assembly	81000-005
E-401	Elements, Plug-In Detector	*See Table Page 2
E-405	Line Section Assembly	88500
H-401	Carrying Strap	9808
M-401	Microammeter	88950-A
FIG #5	Wiring Diagram	81000-010
A404	Case, Carrying (Not Shown)	88800

***Refer to page 2 for appropriate catalog number.**

88000 Series RF Quick Match Connectors

88000	N female	50 ohm
88001	N Male	50 ohm
88002	BNC female	50 ohm
88003	BNC male	50 ohm
88004	UHF female	50 ohm
88005	UHF male	50 ohm
88006	LC female	50 ohm
88007	LC male	50 ohm
88008	C female	50 ohm
88009	C male	50 ohm
88010	7/8" Swivel Flanged	50 ohm
88011	TNC female	50 ohm
88012	TNC male	50 ohm
88013	HN female	50 ohm
88014	HN male	50 ohm
88020	SMA female	50 ohm
88021	SMA male	50 ohm

"Specifications are subject to change without notice."

CIRCUIT DIAGRAM

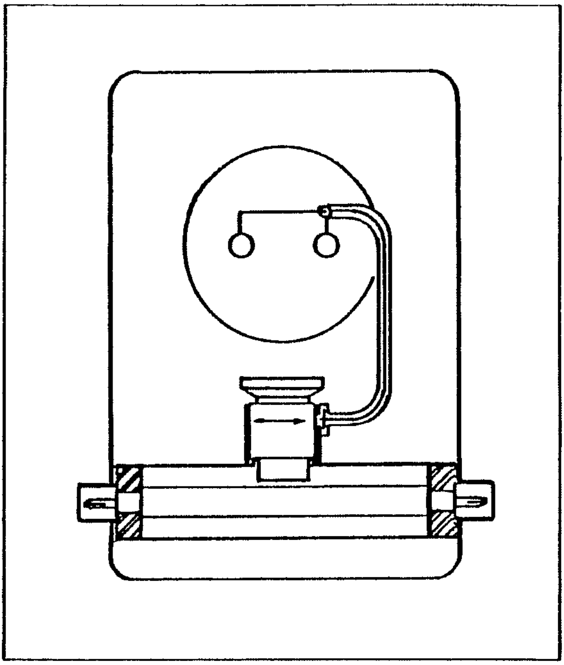


Figure 5. Wiring Diagram of Wattmeter With Plug-In Element Installed in Line Section.

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