

Assembly
and
Operation
of the



REFLECTED
POWER METER
AND
SWR BRIDGE

MODEL HM-15



HEATH COMPANY
BENTON HARBOR,
MICHIGAN

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INTRODUCTION

The Heathkit Model HM-15 Reflected Power Meter and SWR Bridge indicates, reliably but inexpensively, whether the RF power output of your transmitter is being transferred efficiently to the radiating antenna. The Reflected Power Meter is primarily intended for use with Amateur Radio transmitters, but it can be used with other transmitters. If it is used with a transceiver it will not affect receiver operation.

The combination of very low insertion loss and high power rating permits the Reflected Power Meter to be inserted permanently in a 50-52 Ω or 70-75 Ω transmission line. This permits continuous monitoring of reflected power or SWR (standing wave ratio) to determine proper trans-

mitter tuning, transmission line-to-antenna impedance matching, and relative power output.

The Reflected Power Meter can also be used for other applications, such as designing antenna coupling networks, checking other transmission systems, etc. Because of its small size and the fact that it needs no external power source, it can be moved about conveniently. The input and output connectors are standard VHF coaxial connectors.

NOTE: Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

PARTS LIST

The numbers in parentheses are keyed to the numbers on the Parts Pictorial to aid in Parts identification. The instructions in the Kit Builders Guide show you how to identify resistors and capacitors.

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>	<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
RESISTORS			HARDWARE		
		1/2 Watt	(6) 250-8	6 ✓	#6 sheet metal screw
(1) 1-103	1 ✓	33 Ω (orange-orange-black)	(7) 250-172	2 ✓	3-48 x 3/8" screw
1-83	1 ✓	56 Ω (green-blue-black)	(8) 250-49	4 ✓	3-48 x 1/4" screw
1-146	1 ✓	75 Ω (violet-green-black)	(9) 250-93	2 ✓	8-32 x 1/4" setscrew
1-i23	1 ✓	100 Ω (brown-black-brown)	(10) 252-1	6 ✓	3-48 nut
CAPACITORS-CONTROL-SWITCH-DIODE			(11) 252-7	2 ✓	Control nut
(2) 21-14	2 ✓	.001 μ fd disc capacitor	(12) 253-1	2 ✓	#6 fiber washer
(3) 10-11	1 ✓	50 K Ω control	(13) 253-10	2 ✓	Control flat washer
(4) 63-177	1 ✓	2-position rotary switch	(14) 254-4	1 ✓	Control lockwasher
(5) 56-26	2 ✓	1N191 diode (brown-white-brown)	(15) 254-7	8 ✓	#3 lockwasher
			(16) 259-10	1 ✓	Control solder lug ✓



PART No.	PARTS Per Kit	DESCRIPTION
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MISCELLANEOUS

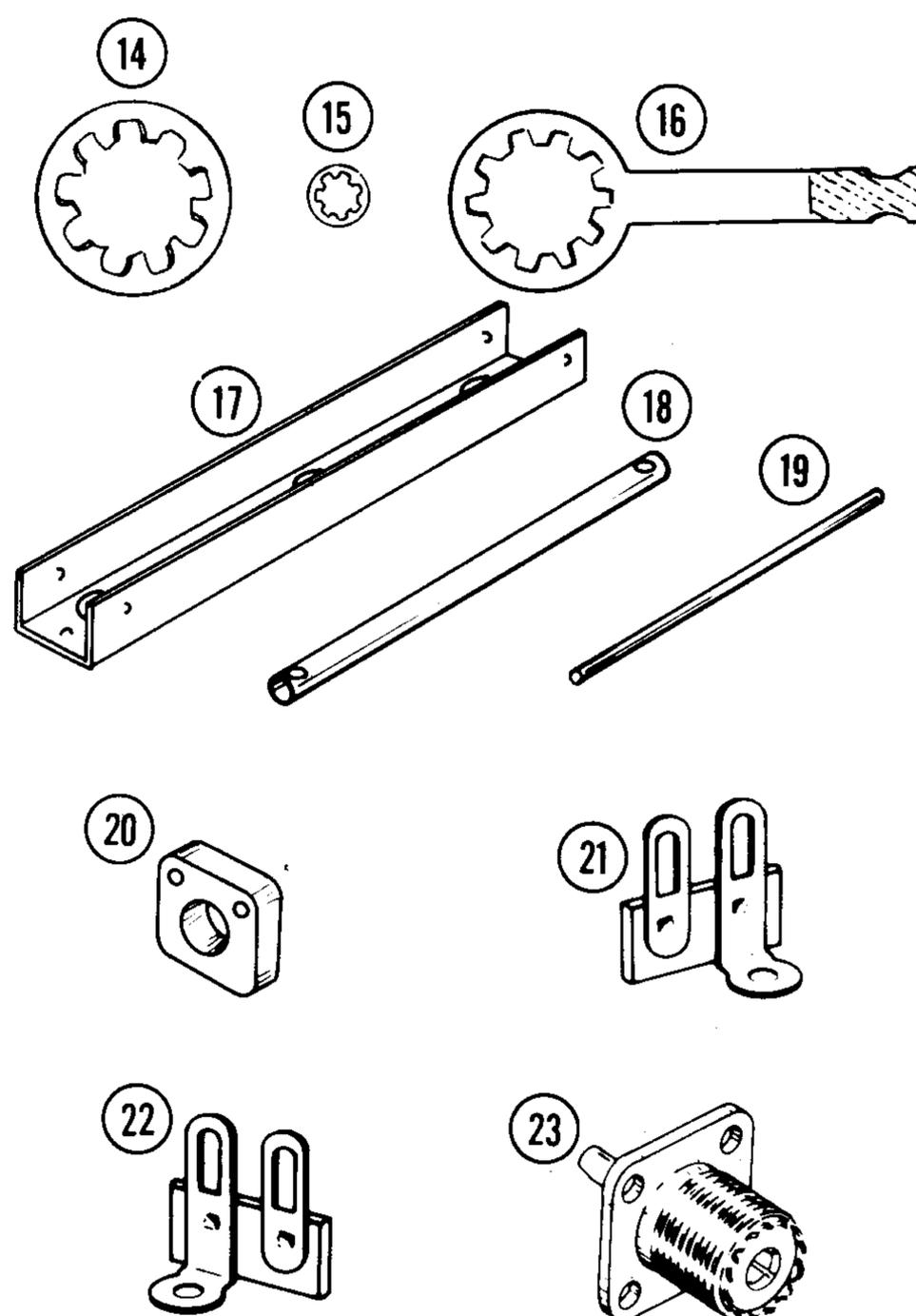
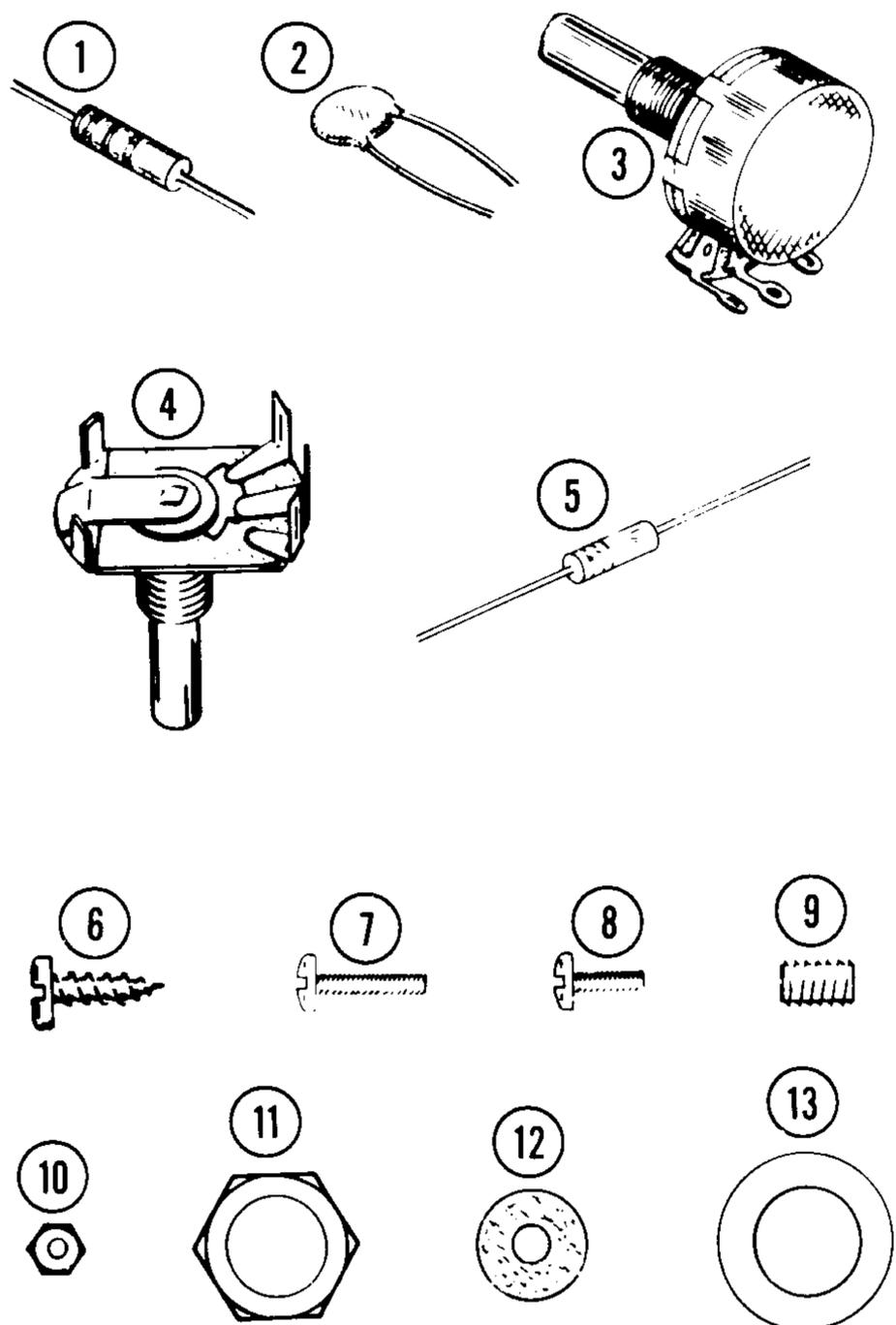
90-327-1	1 ✓	Chassis
90-320-1	1 ✓	Cabinet
(17) 40-100	1 ✓	Coaxial cavity
(18) 40-98	1 ✓	RF driver element
(19) 40-99	2 ✓	RF pickup element
(20) 255-12	3 ✓	Plastic spacer
261-4	4 ✓	Rubber foot
344-50	1 ✓	Length hookup wire
407-112	1 ✓	100 μ a meter
(21) 431-14	1 ✓	2-lug terminal strip

PART No.	PARTS Per Kit	DESCRIPTION
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Miscellaneous (cont'd.)

(22) 431-16	1 ✓	2-lug terminal strip
(23) 436-5	2 ✓	Coaxial connector
462-191	2 ✓	Knob
490-5	1 ✓	Nut starter
490-6	1 ✓	Allen wrench
331-6	✓	Solder
597-308	1 ✓	Kit Builders Guide
391-34	1 ✓	Identification label
597-260	1 ✓	Parts Order Form
595-774	1 ✓	Manual

PARTS PICTORIAL



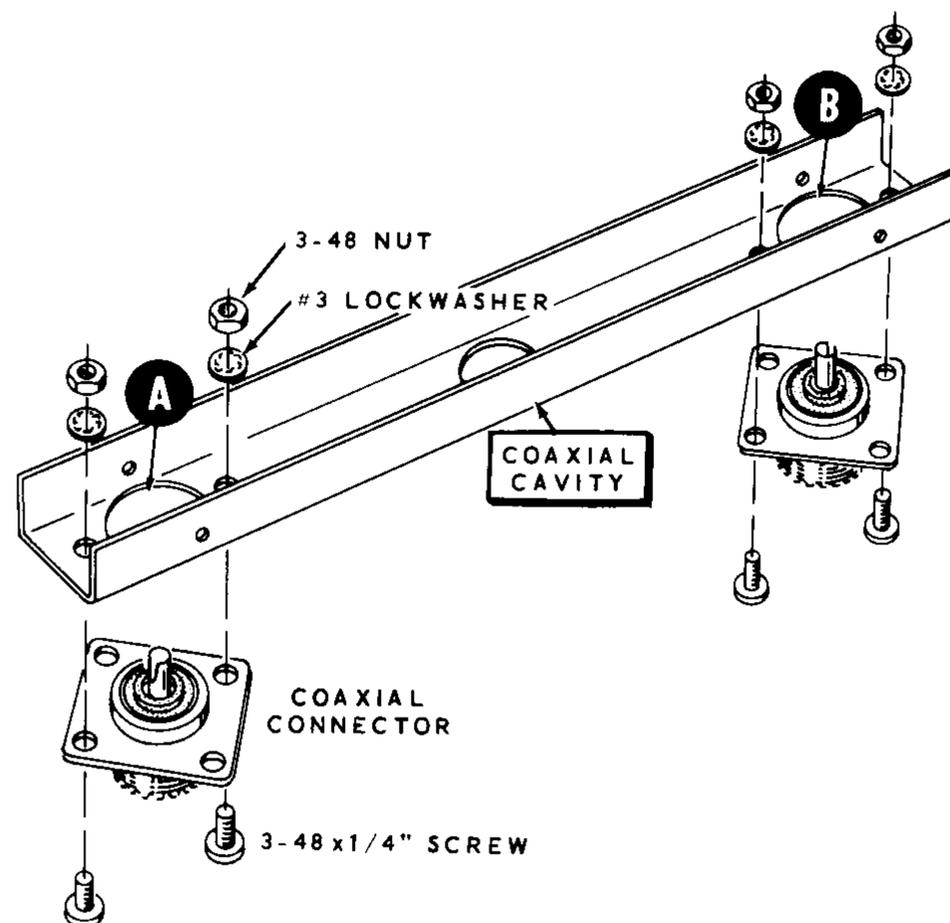
STEP-BY-STEP ASSEMBLY

Before starting to assemble this kit, read the Kit Builders Guide for complete information on wiring, soldering, and step-by-step assembly procedures.

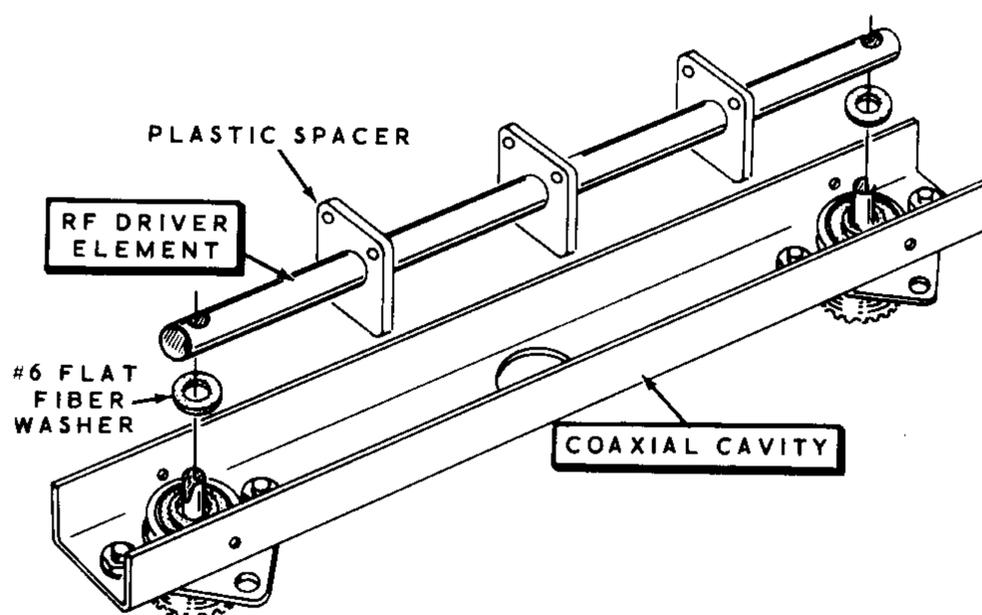
PARTS MOUNTING AND WIRING

Refer to Pictorial 1 for the following steps.

- (✓) Refer to Detail 1A and mount a coaxial connector at A on the coaxial cavity. Use 3-48 x 1/4" screws, #3 lockwashers, and 3-48 nuts.
- (✓) Mount a coaxial connector at B on the coaxial cavity. Use 3-48 x 1/4" screws, #3 lockwashers, and 3-48 nuts.
- (✓) Place a #6 fiber flat washer over the center pin of coaxial connectors A and B as shown in Detail 1B.
- (✓) Fit the end holes in the RF driver element over the center pins of the coaxial connectors as shown in Detail 1B. If it does not fit properly, loosen the hardware on the coaxial connectors and move them to obtain a proper fit. Now remove the driver element.
- (✓) Slide the three plastic spacers on the RF driver element. Then reinstall the RF driver element on the center pins of the coaxial connectors. Be sure that the small holes in the plastic spacers are up as shown in Detail 1B.
- (✓) Slide all three of the plastic spacers to the center of the RF driver element. Solder the ends of the driver element to the center pin on each coaxial connector. Refer to the inset on Pictorial 1.
- (✓) Slide the RF pickup elements through the small holes on the top of the plastic spacers. Position the plastic spacers and RF pickup elements as shown by the dimensions on Pictorial 1.

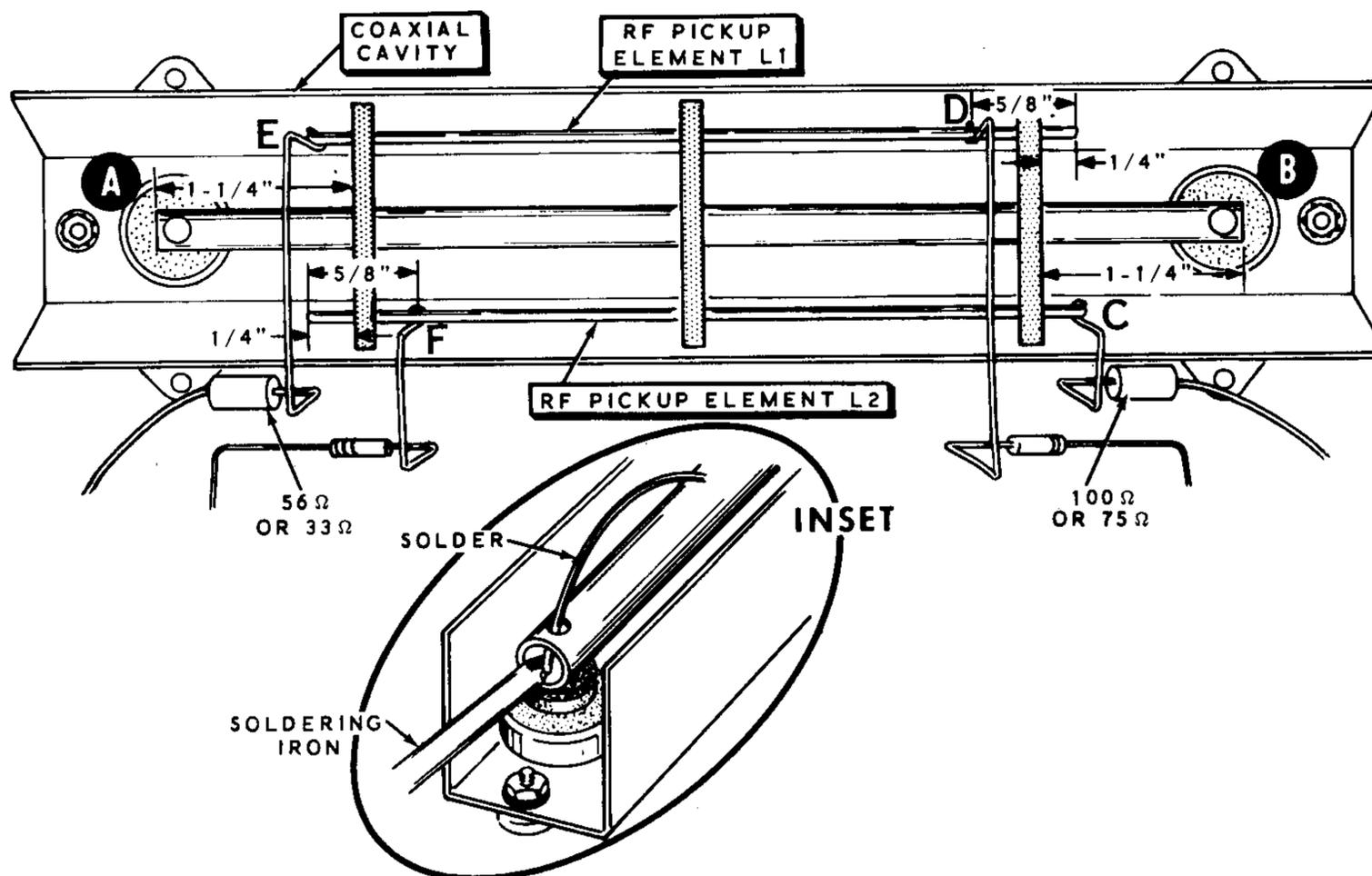


Detail 1A



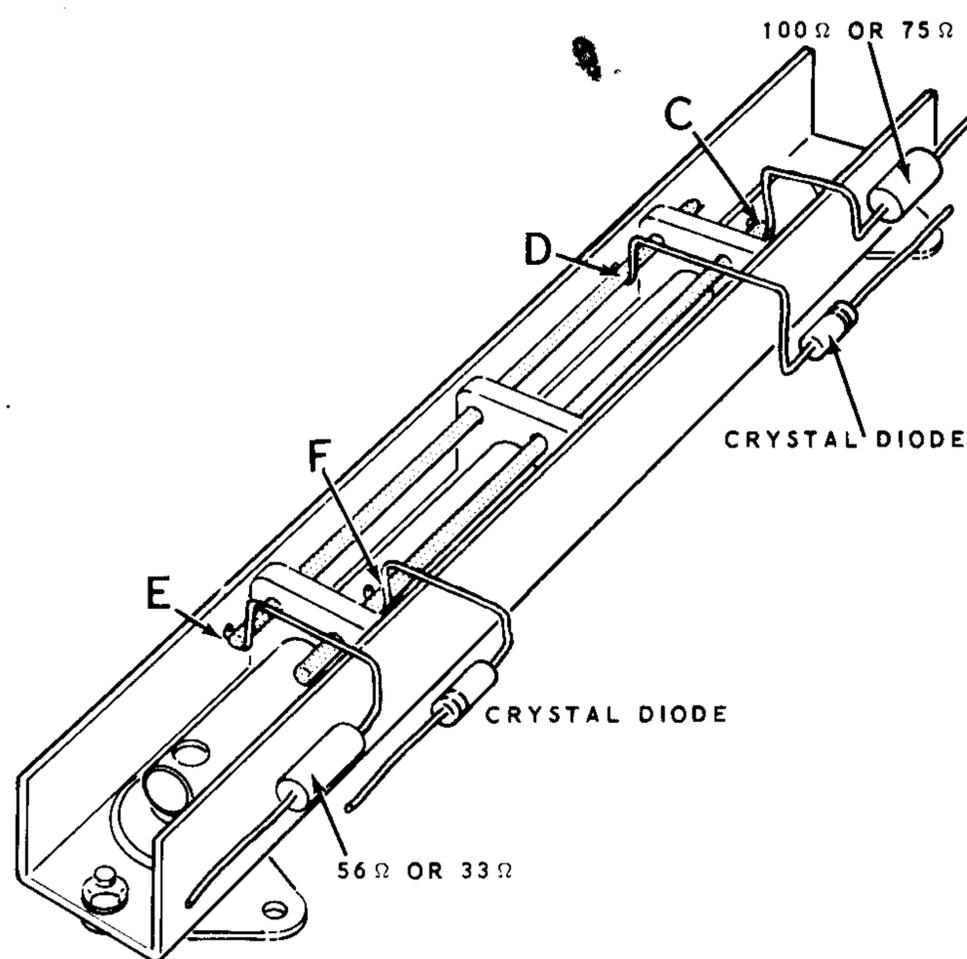
Detail 1B

Select the two proper resistors to be used in the next two steps. If the Reflected Power Meter is going to be used with a 50-52 Ω line, use the 100 Ω (brown-black-brown) resistor and the 56 Ω (green-blue-black) resistor. If it is going to be used on a 70-75 Ω line, use the 75 Ω (violet-green-black) resistor and the 33 Ω (orange-orange-black) resistor.



PICTORIAL 1

- () Cut one lead of either a 100 Ω or a 75 Ω resistor to 3/4". Bend a hook in the end of this lead and connect it to point C on RF pickup element L1 (S-1). Bend the lead of this resistor so it is positioned exactly as shown in Detail 1C and Pictorial 1. The other lead will be connected later.
- () Cut one lead of either a 56 Ω or a 33 Ω resistor to 1-1/8". Bend a hook in the end of this lead and connect it to point E on RF pickup element L2 (S-1). Bend the lead of this resistor so it is positioned exactly as shown in Detail 1C and Pictorial 1. The other lead will be connected later.
- () Bend a hook in the end of the lead at the unbanded end of a crystal diode. Connect this lead to point D on RF pickup element L2 (S-1). Bend this lead so it is positioned as shown in Detail 1C and Pictorial 1. The other lead will be connected later.
- () Cut the lead at the unbanded end of a crystal diode to 3/4". Bend a hook in the end of this lead. Connect this lead to point F on RF pickup element L1 (S-1). Bend this lead so it is positioned as shown in Detail 1C and Pictorial 1. The other lead will be connected later.



Detail 1C

Refer to Pictorial 2 for the following steps.

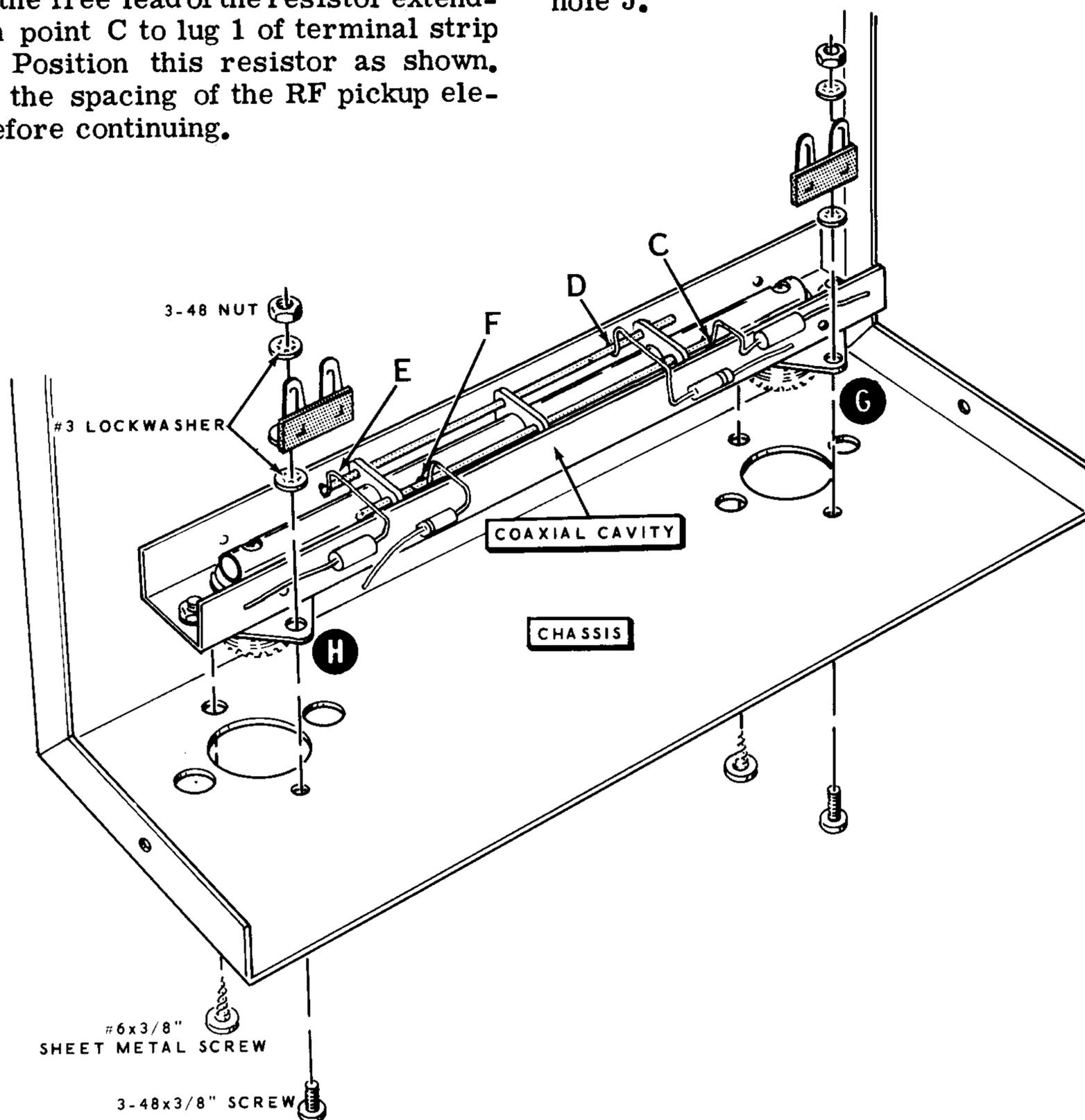
NOTE: In the following steps be sure the spacing of the pickup elements does not change from the dimensions listed on Pictorial 1.

NOTE: The 2-lug terminal strips mounted in the following step are physically different. Carefully match the terminal strips with Detail 2A when they are mounted.

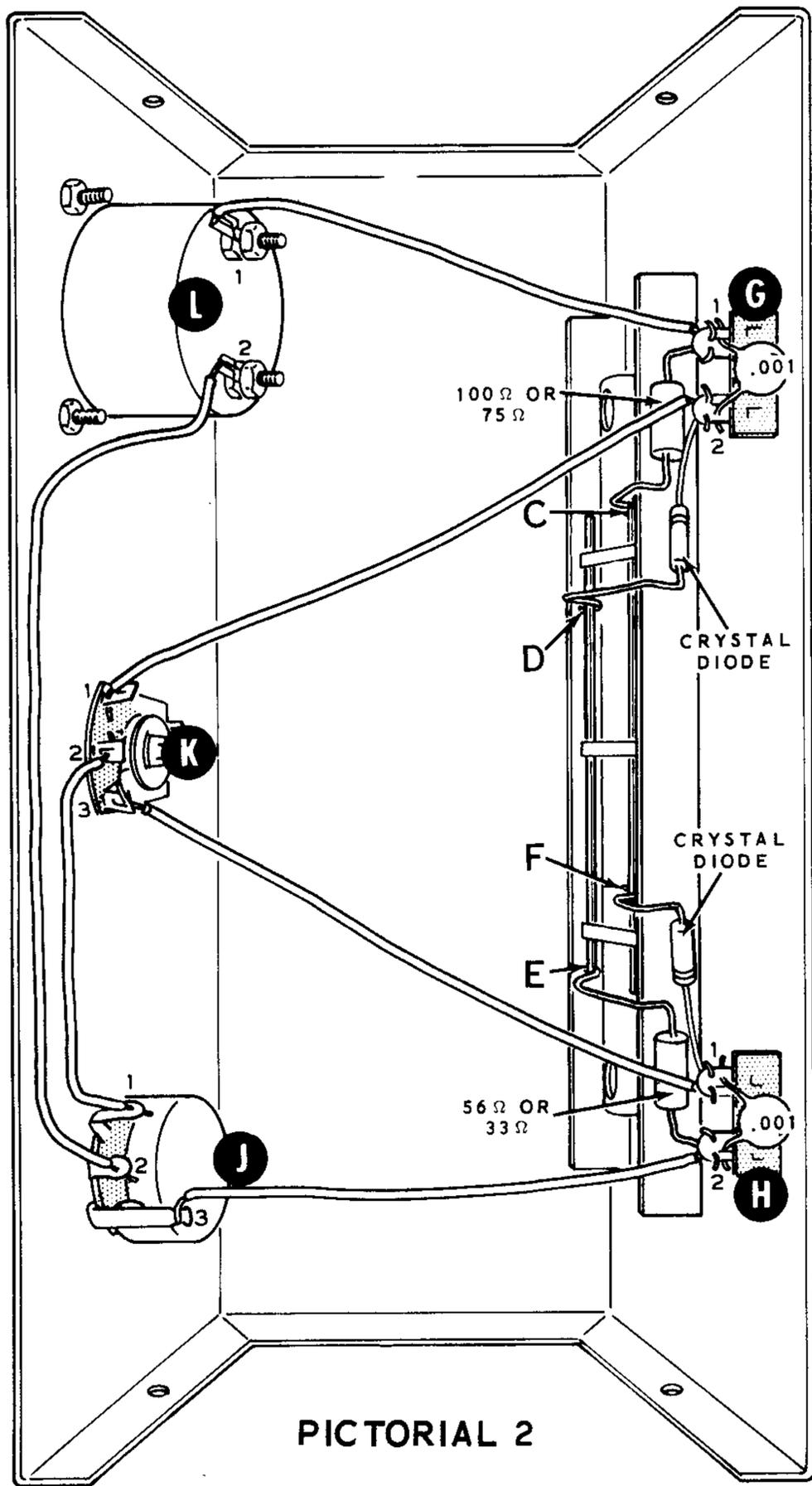
- () Refer to Detail 2A and mount the coaxial cavity in the chassis with 2-lug terminal strips at G and H. Use 3-48 x 3/8" screws, #3 lockwashers, and 3-48 nuts. Position the cavity and terminal strips as shown in Pictorial 2 and Detail 2A. Secure the remaining corner of each coaxial connector with a #6 x 3/8" sheet metal screw.
- () Connect the free lead of the resistor extending from point C to lug 1 of terminal strip G (NS). Position this resistor as shown. Recheck the spacing of the RF pickup elements before continuing.

- () Connect the free lead of the crystal diode extending from point D to lug 2 of terminal strip G (NS). Position the diode as shown.
- () Connect the free lead of the resistor extending from point E to lug 2 of terminal strip H (NS). Position this resistor as shown.
- () Connect the free lead of the crystal diode extending from point F to lug 1 of terminal strip H (NS). Position this diode as shown.
- () Place a solder lug on the bushing of the 50 K Ω control and rebend the solder lug so it touches lug 3 of the control. See Detail 2B.

NOTE: Before you mount the 50 K Ω control in the next step, be sure to scrape away any paint that might be around the inside of the chassis at hole J.

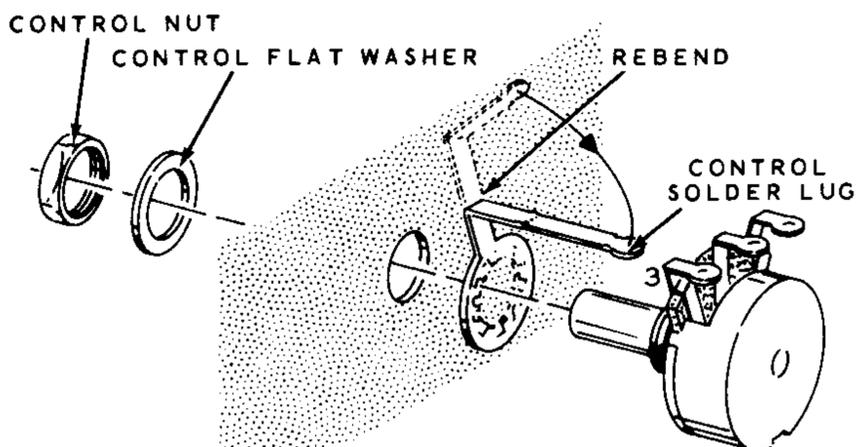


Detail 2A



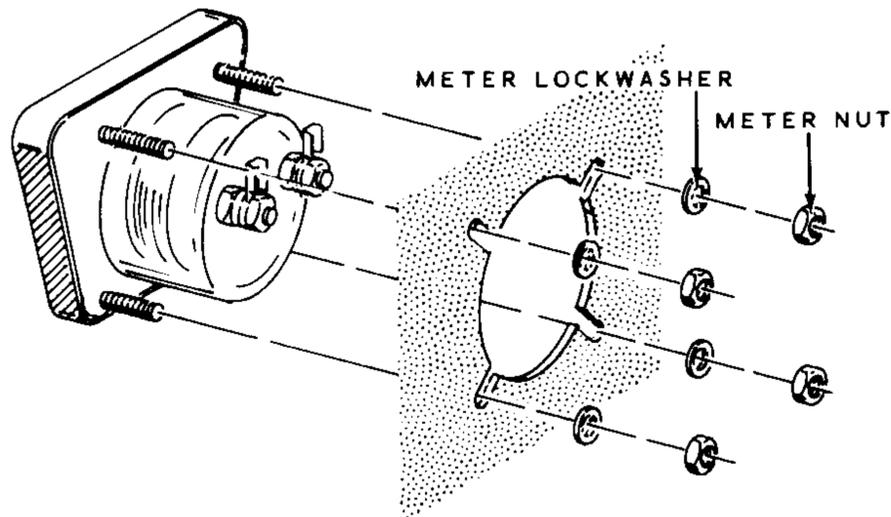
PICTORIAL 2

- () Refer to Detail 2B and mount the 50 KΩ control on the chassis at J. Use the prebent control solder lug, a control flat washer, and a control nut. Position the control lugs as shown in Pictorial 2.



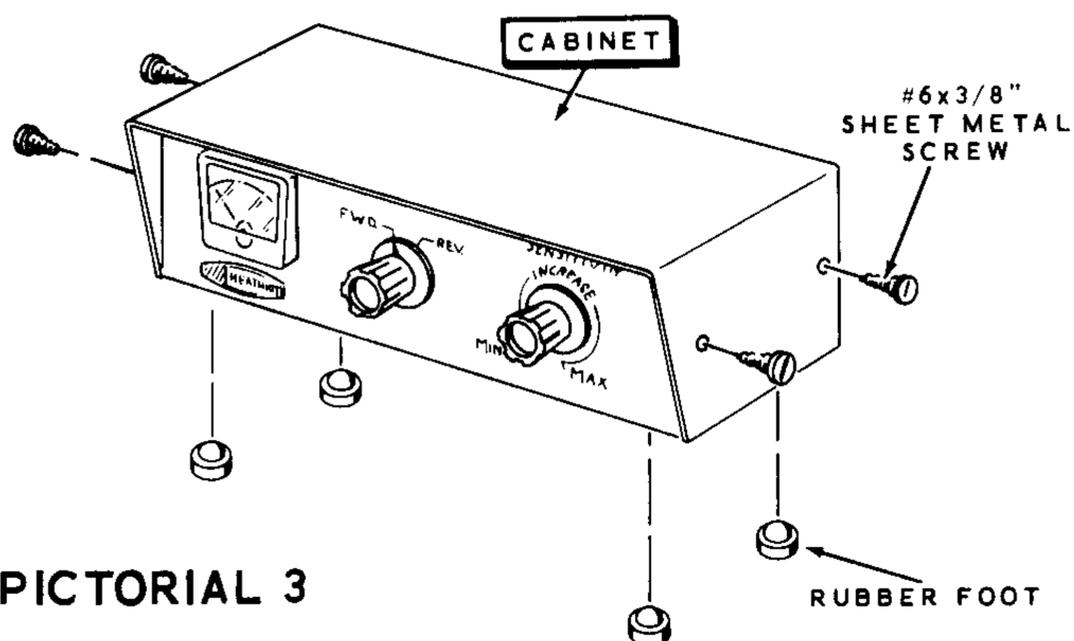
Detail 2B

- () Mount the 2-position rotary switch at K with a control lockwasher, a control flat washer, and a control nut. Position the switch lugs as shown.
- () Refer to Detail 2C and mount the meter at L. Use the hardware supplied with the meter.



Detail 2C

- () Remove the shorting wire connected between the meter lugs.
- () Connect a 6-1/4" wire from lug 2 of the meter (S-1) to lug 2 of control J (S-1).
- () Connect a 1-3/4" wire from lug 1 of the meter (S-1) to lug 1 of terminal strip G (NS).
- () Connect a .001 μfd disc capacitor between lugs 1 (S-3) and 2 (NS) of terminal strip G.
- () Connect a 3-3/8" wire from lug 2 of terminal strip G (S-3) to lug 1 of switch K (S-1).
- () Connect a 3-3/8" wire from lug 2 of switch K (S-1) to lug 1 of control J (S-1).
- () Connect a 3-3/8" wire from lug 3 of switch K (S-1) to lug 1 of terminal strip H (NS).
- () Connect a .001 μfd disc capacitor between lugs 1 (S-3) and 2 (NS) of terminal strip H.
- () Connect a 2-1/4" wire from lug 2 of terminal strip H (S-3) to the solder lug on control J (S-1). Also solder lug 3 of control J to the solder lug.



PICTORIAL 3

FINAL ASSEMBLY

Refer to Pictorial 3 for the following steps.

- () Install a rubber foot in each corner on the bottom of the chassis.
- () Carefully inspect all wiring and solder joints. Be sure the bare resistor and diode leads do not touch the coaxial cavity.

- () Install the cabinet and secure it with four #6 x 3/8" sheet metal screws.
- () Start an 8-32 setscrew in each knob. Use the allen wrench supplied.
- () Turn the switch and control shaft to their maximum counterclockwise positions; then install the knobs with the pointers fully counterclockwise.

NOTE: The blue and white identification label shows the Model Number and Production Series Number of your kit. Refer to these numbers in any communications with the Heath Company; this assures you that you will receive the most complete and up-to-date information in return.

- () Install the identification label on the rear or bottom of the chassis by peeling away the backing paper and pressing it into position.

This completes the assembly of your Heathkit Reflected Power Meter.

INSTALLATION

- () Connect the Reflected Power Meter in series between the transmitter output and antenna system. Input and Output coaxial connectors are provided on the rear of the cabinet. Place the Reflected Power Meter in a convenient location at the transmitter operating station.
- () Cut the coaxial transmission line at the proper place, and install male coaxial

connectors on the cable ends. Then connect the transmitter output cable to the Input connector and the antenna cable to the Output connector of the Reflected Power Meter.

NOTE: If an antenna tuner is used, connect the Power Meter between the transmitter and antenna tuner with coaxial cable of proper impedance. Then the tuner can be adjusted for minimum SWR and maximum output.



OPERATION

The Reflected Power Meter can only be used with 50-52 or 70-75 Ω transmission lines, and will not perform properly in lines of other impedances. It also will not work on transmission lines that are used as tuned feeders, since tuned feeders normally have a high SWR.

- () Before applying power to the transmitter, turn the SENSITIVITY control to MIN and the Function switch to FWD.
- () Apply power to the transmitter and tune it. Disregard the Power Meter readings at this stage. After the transmitter is properly tuned, set the SENSITIVITY control for a midscale meter reading. A minor "touch-up" tuning of the transmitter may show an increase in output on the meter. This indicates a closer match between the transmitter and the transmission line. Now set the SENSITIVITY control to give a full-scale (SET) meter reading.
- () Turn the Function switch to REV. This may be done while power is on and no switching transient will result, since the switch is connected in a low-power bridge circuit. The amount of power returned, or reflected, can now be read directly in percentage on the meter, or as the SWR.

NORMAL OPERATING CHARACTERISTICS

The Reflected Power Meter may be left in the transmission line at all times for continuous monitoring purposes. A power output of 70 watts is needed on 75 meters for full-scale deflection with the Function switch in the FWD position; and only 2 or 3 watts is needed for full-scale deflection on 6 meters.

The minimum power that is needed varies with frequency. At low power levels, any meter reading within the range of the SENSITIVITY control can be used as a normal-operation reference; midscale may be convenient. The meter readings would then be approximately proportional to the ratio between the meter reference level you choose and full-scale.

As the transmitter is being voice modulated, a slight downward deflection of the meter will be indicated. This will occur when the Function switch is in the FWD position and should not be confused with downward modulation. This effect is generally due to a nonlinear relationship between the voltage and current in the final amplifier of the transmitter, and it should not alarm the operator since it is entirely normal with high level modulation.

Control carrier modulation will "kick" the meter indication upward on peaks. SSB and DSB signals will give a bouncing indication when transmitting, so no SWR measurement can be made. Therefore, use a single-tone or CW carrier with sideband transmitters when taking readings. When operating SSB, any indication with no modulation indicates spurious or parasitic emission, or poor carrier suppression.

PHYSICAL PLACEMENT AND LOSSES

The meter readings may vary if the Reflected Power Meter is placed at different locations in the transmission line, or if the length of the transmission line is changed. For this reason, assume that the highest SWR reading is most correct. Keep in mind that the closer the SWR approaches 1:1; the more accurate the Reflected Power Meter becomes.

Misleading readings may be obtained with long transmission lines since the losses in the cable tend to "smooth out" the standing waves, giving a much better indication at the transmitter than actually exists at the antenna. Therefore, if you are using a transmission line long enough to have appreciable losses, locate the Reflected Power Meter near the antenna, especially when adjusting beams or tuning traps. You can better understand the extent of this effect when you realize that a line with a 3 db loss will show a SWR of 3 when it is terminated in a dead short. A line with a loss of over 10 db will show a SWR of practically 1:1, on this or any other SWR meter, regardless of what load or termination is connected at the far end.

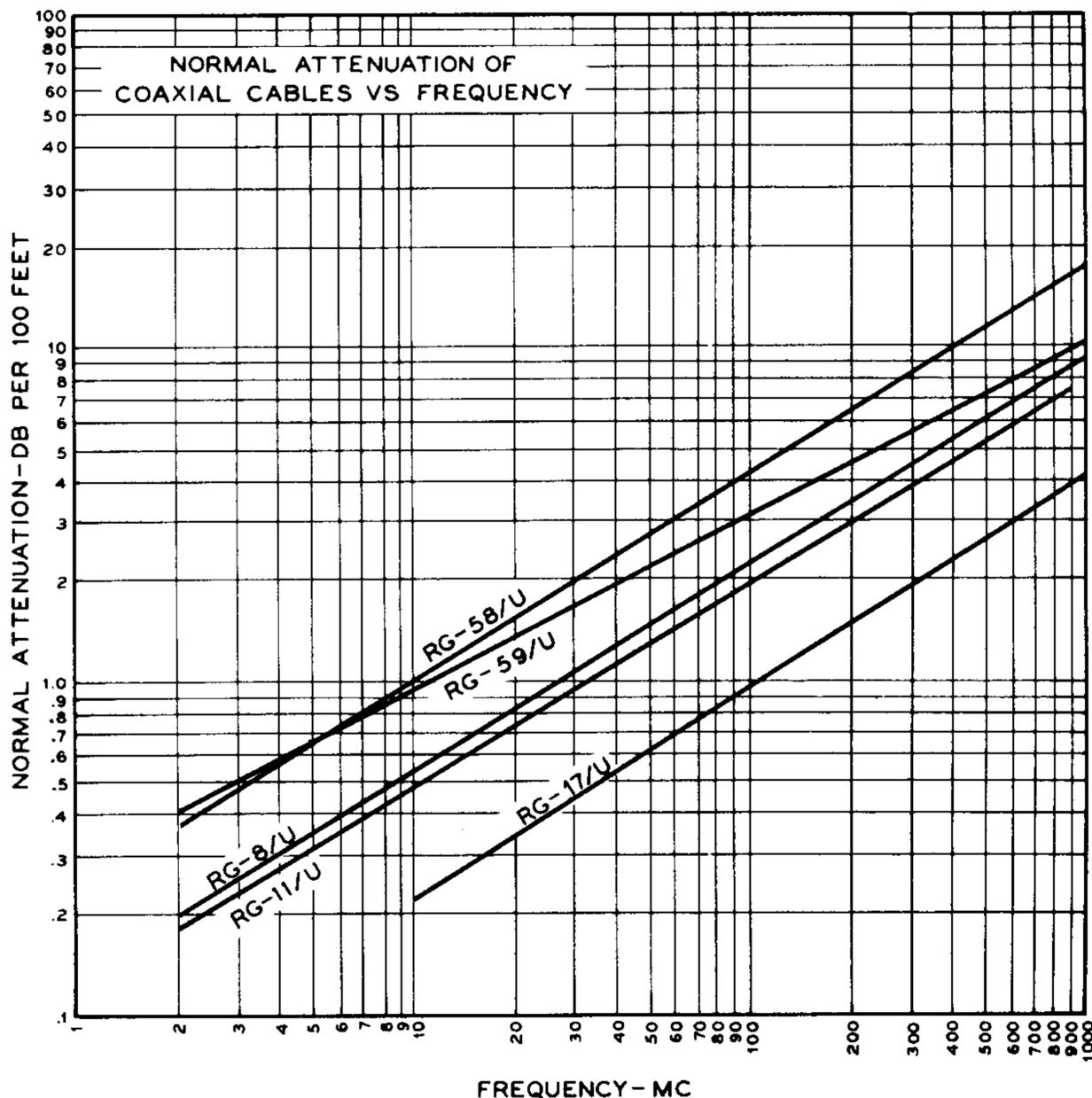


Figure 1

The power losses in these cases are occurring in the cable, but the SWR meter reading will not indicate that anything is wrong. When in doubt, make measurements at the antenna and at the transmitter, so future changes in the readings will be meaningful. The values of cable losses at various frequencies can be obtained from Figure 1. These losses become worse as time and moisture affect the cable.

With a high SWR, the transmission line losses may become so great that the radiated power is appreciably reduced; with high-power transmitters, the cable ratings may be exceeded. Figure 2 shows the effect of increasing cable losses caused by various values of SWR. When these losses occur, the RF power is turned into heat in the cable instead of being radiated from the antenna.

To obtain total losses in a given length of coaxial cable, determine the db loss per foot of the cable from Figure 1. This is done by

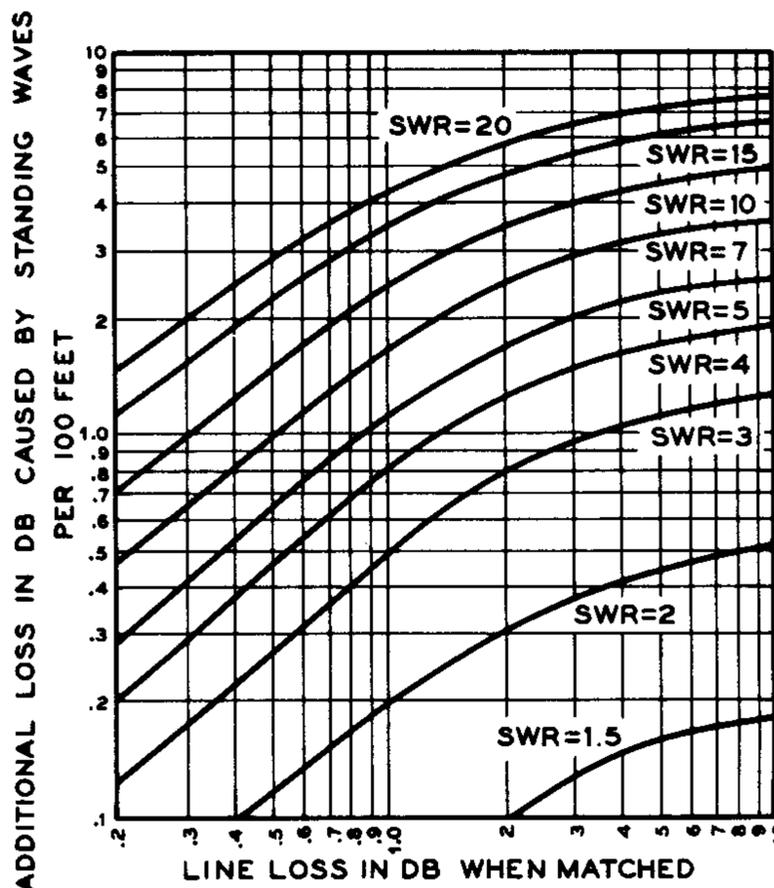


Figure 2



finding your operating frequency on the bottom line of the chart, and moving up to find the type of cable used. By looking at this same level on the left-hand side of the chart, you can read the db loss per 100 feet of the cable at that frequency.

Now determine the additional loss caused by the SWR from Figure 2 as follows: Use the amount of loss determined from Figure 1 and find this value on the bottom line of Figure 2. Now move up the graph until you come to the SWR of your antenna system. Move over to the left-hand side of the graph and determine the amount of loss caused by the SWR. To obtain the total loss of your system, add the value from Figure 1 to the value from Figure 2.

LOADING

The load presented to the transmitter output circuit may create conditions that make it touchy or impossible to load the transmitter. With a low SWR, the load that the transmitter sees is practically pure resistive. However, at a high SWR, the apparent load may change from a very low to a very high resistance, accompanied by either capacitive or inductive

reactance. These resistance and reactance values change when the transmission line length or frequency is changed.

Remember when you are using 52 or 72 Ω unbalanced feed lines, that the SWR cannot be changed by changing the transmission line length. However, the loading to the transmitter may be changed considerably, thus making it appear that "pruning" the cable length offers improvement, when it actually does not affect the SWR.

The SWR can only be changed by changing the load or termination at the end of the cable. If the transmission line length is changed, for example, with 50 Ω cable and a SWR of 3, the apparent load to the transmitter may vary from 16-2/3 Ω to 150 Ω resistive, with reactance varying from 66-2/3 Ω capacitive, to zero, to 66-2/3 Ω inductive. If the transmitter output tuning adjustments will not accommodate this impedance range, the transmitter will be difficult to load until the load is properly matched to the line. When the load is matched the SWR will be lower.

IN CASE OF DIFFICULTY

NOTE: Refer to the Kit Builders Guide for Service and Warranty information.

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the constructor.
2. It is interesting to note that about 90% of the kits that are returned for repair, do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the Soldering section of the Kit Builders Guide.
3. Check the values of parts. Be sure that the proper part has been wired into the circuit, as shown in the Pictorial diagrams and as called out in the wiring instructions.
4. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring.
5. If the meter reads off scale to the left, either diode D1 or D2 is installed backwards.
6. If there is no meter indication diode D1 or D2 may be open, or the jumper wire may still be connected across the meter lugs.
7. A review of the Theory of Operation will prove helpful in indicating where to look for trouble.



SPECIFICATIONS

Operation.	Indicates percentage of forward and reflected power, and voltage standing wave ratio (SWR).
RF Power Handling Capability.	2 kilowatts P.E.P.
Input And Output Impedance.	50-52 Ω or 70-75 Ω .
Band Coverage.	160 through 6 meters.
Meter.	100 microamperes, full scale.
Dimensions.	9-1/32" wide x 2-9/16" high x 3-5/8" deep.
Net Weight.	1-1/2 lbs.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to

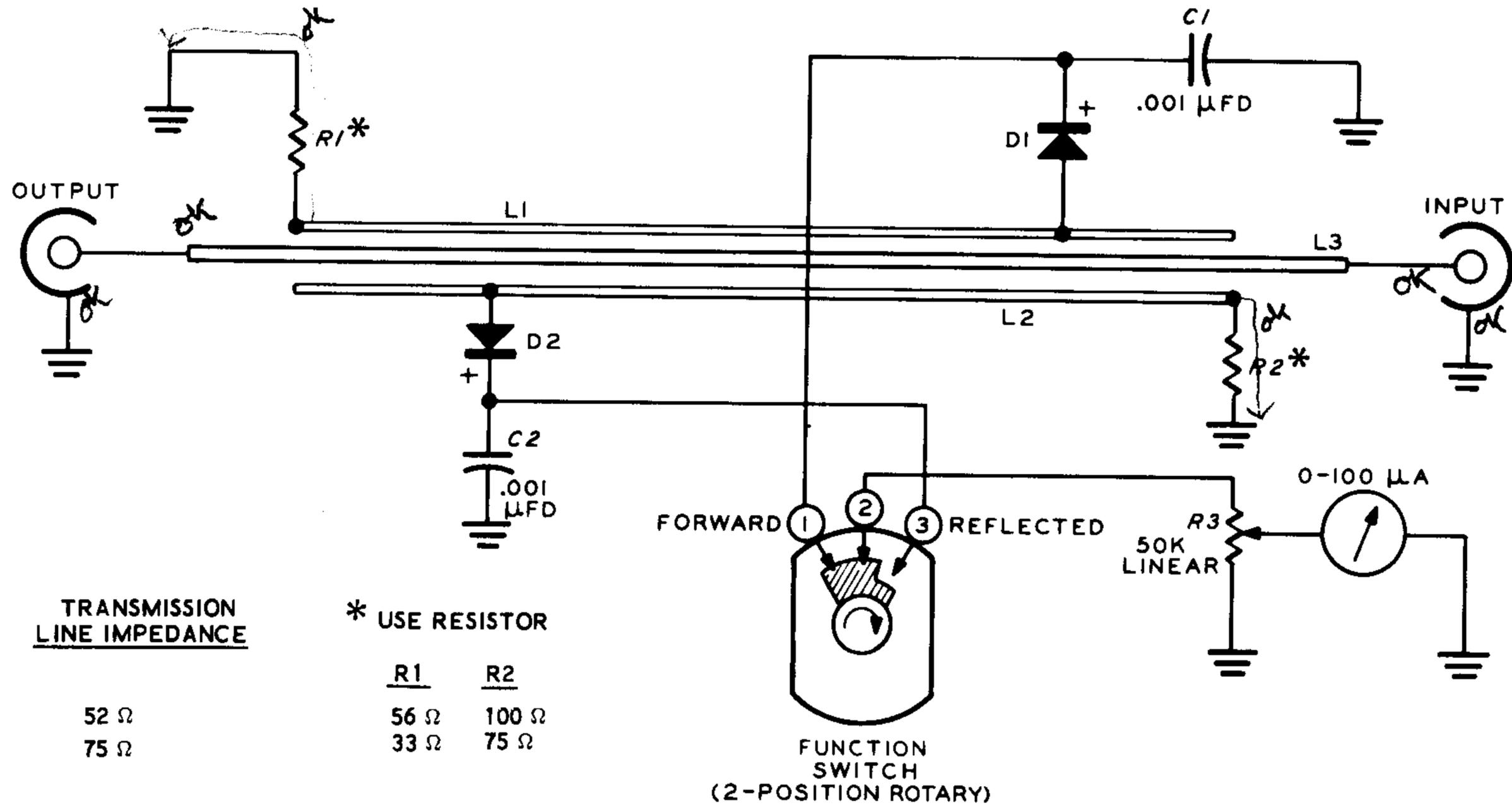
incorporate new features in instruments previously sold.

THEORY OF OPERATION

The circuit of the Reflected Power Meter and SWR Bridge is based upon that of a device developed at the U.S. Naval Research Laboratory, Washington, D.C., and described in N.R.L. report No. 3538, titled "A Reflectometer for H-F Band." Simplified versions have also been described in various amateur radiopublications.

In the broadest terms, the Reflected Power Meter consists of a short section of transmission line to which two small linear inductors are coupled, both inductively and capac-

itively. The radio frequency current flowing in each inductor and its load resistor is rectified by a germanium diode and filtered by a ceramic capacitor. Because L1 is terminated at the output and L2 is terminated at the input, the rectified current in L1 indicates forward relative power, while the rectified current in L2 indicates reverse relative power. The Function switch selects the direct current output of either diode and applies it to a variable-sensitivity metering circuit, consisting of a linear potentiometer and a microammeter. The meter indicates the reflected power and SWR.



SCHMATIC OF THE HEATHKIT[®]
REFLECTED POWER METER
AND SWR BRIDGE
MODEL HM-15

REPLACEMENT PARTS PRICE LIST

<u>PART No.</u>	<u>PRICE Each</u>	<u>DESCRIPTION</u>
RESISTORS		
1/2 Watt		
1-103	.10	33 Ω
1-83	.15	56 Ω
1-146	.10	75 Ω
1-123	.10	100 Ω
CAPACITORS-CONTROL-SWITCH-DIODE		
21-14	.10	.001 μ fd disc capacitor
10-11	.50	50 K Ω control
63-177	.85	2-position rotary switch
56-26	.30	1N191 diode
HARDWARE		
250-8	.05	#6 sheet metal screw
250-172	.05	3-48 x 3/8" screw
250-49	.05	3-48 x 1/4" screw
250-93	.05	8-32 x 1/4" setscrew
252-1	.05	3-48 nut
252-7	.05	Control nut
253-1	.05	#6 fiber washer
253-10	.05	Control flat washer
254-4	.05	Control lockwasher
254-7	.05	#3 lockwasher
259-10	.05	Control solder lug

<u>PART No.</u>	<u>PRICE Each</u>	<u>DESCRIPTION</u>
MISCELLANEOUS		
90-327-1	1.30	Chassis
90-320-1	.75	Cabinet
40-100	.20	Coaxial cavity
40-98	.55	RF driver element
40-99	.10	RF pickup element
255-12	.10	Plastic spacer
261-4	.05	Rubber foot
344-50	.05/ft	Hookup wire
407-112	5.75	100 μ a meter
431-14	.10	2-lug terminal strip
431-16	.10	2-lug terminal strip
436-5	.85	Coaxial connector
462-191	.70	Knob
490-5	.10	Nut starter
490-6	.10	Allen wrench
331-6	.10	Solder
595-774	2.00	Manual

The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Selling prices elsewhere in U.S.A. may be slightly higher to offset transportation and local taxes. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties and rates of exchange.