

VACUUM TUBE VOLTMETER

HEWLETT-PACKARD MODEL 400D

1. GENERAL

1.01 This section describes the Hewlett-Packard Model 400D vacuum tube voltmeter which is an ac operated voltmeter useful for frequencies from 10 cycles to 4 mc. It has 12 voltage ranges from a scale of 0 to 0.001 up to a scale from 0 to 300. This section also includes operating and maintenance information which is contained in the Instruction and Operating Manual prepared by the Hewlett-Packard Company. This manual is reprinted for Bell System use with the permission of that company and forms an attachment to this section.

1.02 Some of the performance data and component items of apparatus covered by the attached manual do not apply precisely for voltmeters having serial numbers previous to No. 30.

1.03 It should be noted that the electrolytic capacitors in this instrument are high quality capacitors which have a useful life of from 5 to 10 years. These should not be replaced unless they are proven defective by accurate tests.

1.04 Shunting resistors of the 145-type or 106-type are available through the Western Electric Company as is the No. 274MB General Radio plug. This plug provides a convenient means for connecting to the meter or for connecting between the meter and a cord for purposes of shunting a resistance across the meter.

1.05 The use of this meter for over-all circuit measurements of voice-frequency net loss is not recommended.

1.06 It is important that the calibration of the meter should be checked from time to time and it is especially important that the calibration in the carrier range for which the meter is to be used should be checked as well as its 1000-cycle accuracy. Calibration methods are discussed in this section.

1.07 Fig. 2 in the manual gives a correction graph for various impedances to which the meter may be connected, and this graph is valuable whenever the circuit impedance is other than 600 ohms and the voltage is to be expressed in db. The correction is a value in db to be added algebraically. As an example, suppose a meter reading of -2 db is obtained when the circuit impedance is 135 ohms. The graph shows a correction of +6.5 db, which added to -2 db gives the true value as +4.5 dbm.

1.08 An additional correction will be necessary if the voltage being measured is due to an input at two frequencies of equal magnitude, such as sometimes occurs with certain type N, O, and ON carrier system tests. This correction is due to the fact that the meter detector is of the averaging type rather than of the square-law type. This correction is +0.5 db and applies at either 600 ohms or 135 ohms.

1.09 Claims for damage in shipment and the return of the meter for repairs should be handled in accordance with the usual Company practices.

2. CALIBRATION METHODS

2.01 Although a method of checking calibration is given in the attached manual, the equipment suggested to do this usually will not be available in the field. Accordingly, the following procedure should be followed.

2.02 Apparatus:

7A or 30A Transmission Measuring Set.

2 - 2W15A Cords, or equivalent.

2.03 Procedure:

(1) Plug meter into a source of ac power (nominal 115 volts) and turn the meter on, allowing it to stabilize for at least 15 minutes.

(2) Connect the input of the transmission measuring set to the input of the vacuum tube voltmeter and also connect a source of 1000 cycles with adjustable output at the same point.*

(3)

(a) Using 7A transmission measuring set, adjust the output until 1 MW (0 dbm) is obtained on the 7A set, or

(b) Using the 30A transmission measuring set plug the cord into the ATTEN IN jacks and set the attenuator at 6 db. Then adjust the oscillator output to obtain +0.5 db on the meter of the 30A set (this effectively adjusts the oscillator to send +6.5 dbm).

(4) Read the vacuum tube voltmeter using the 1-volt scale on the VTVM. The reading should be between 0.745 and 0.805.

(5) If the departure is greater than this the meter may be opened and readjusted to obtain the correct alignment (0.775) by means of the R29 resistance (see Page 12 of the manual).

3. FREQUENCY RESPONSE

3.01 The accuracy of the calibration should be checked over the carrier-frequency range with which the meter is to be used. The 30A transmission measuring set may be used for this purpose up through the range of carrier frequencies employed for type M carrier.

3.02 Apparatus:

30A Transmission Measuring Set.

2 - 2W15A Cords, or equivalent.

200CD Hewlett-Packard Oscillator or equivalent source of adjustable carrier frequency.*

(1) Connect the vacuum tube voltmeter to a source of ac (nominal 115 volts) and allow the meter to stabilize for at least 15 minutes.

(2) Connect the ATTEN IN jacks of the 30A set to the input of the vacuum tube voltmeter and also connect the output of the oscillator to these terminals. Set the attenuator at 6 db and adjust the output of the oscillator to deliver +0.5 db as read on the 30A transmission measuring set (this effectively adjusts the oscillator to send +6.5 dbm).

(3) Slowly sweep the oscillator over the carrier range for which a check is desired, keeping the 30A set reading at +0.5 db by adjusting the oscillator output. It is desirable to carry this to at least 150 kc.

(4) Note the reading on the 1-volt scale of the VTVM.

Requirement: If the deviation is not greater than + 1-1/2 scale divisions for frequencies up to 150 kc it may be assumed to have a flat frequency response.

(5) If the departure is greater than this amount, corrections should be applied to the capacitors as discussed on Page 12 of the manual.

* The output impedance of the oscillator is not important.

Attached:

Reprint of Instruction and
Operating Manual for Hewlett-Packard
Model 400D Vacuum Tube Voltmeter

INSTRUCTION AND OPERATING MANUAL

FOR

MODEL 400D

VACUUM TUBE VOLTMETER

Serial 274 and Above

HEWLETT-PACKARD COMPANY
395 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

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INSTRUCTIONS
MODEL 400D
VACUUM TUBE VOLTMETER

Specifications

Ranges --

Volts -

0 to .001	0 to .03	0 to 1	0 to 30
0 to .003	0 to .1	0 to 3	0 to 100
0 to .01	0 to .3	0 to 10	0 to 300

Decibels -

-72 to -58	-42 to -28	-12 to +2	+18 to +32
-62 to -48	-32 to -18	-2 to +12	+28 to +42
-52 to -38	-22 to -8	+8 to +22	+38 to +52

Frequency Range --

10 cycles/sec. to 4 mc.

Accuracy --

With line voltages of 115 volts $\pm 10\%$, or 230 volts $\pm 10\%$, the following over-all accuracy is obtained on all ranges:

within $\pm 2\%$ of full scale value, 20 cps to 1 mc
within $\pm 3\%$ of full scale value, 20 cps to 2 mc
within $\pm 5\%$ of full scale value, 10 cps to 4 mc

Meter Calibration --

Meter calibrated to RMS value of sine wave
Linear voltage scales: 0 to 1 and 0 to 3
Voltage ranges: 10 db intervals between ranges
DB scale calibrated -12 to +2; zero level -- 1 milliwatt in 600 ohms

Input Impedance --

10 megohms shunted by 14 $\mu\mu\text{f}$ on ranges 1 volt to 300 volts
10 megohms shunted by 24 $\mu\mu\text{f}$ on ranges .001 volt to .3 volt

Output Circuit Rating --

Maximum open circuit voltage - .15 volt
Open circuit internal impedance - 50 ohms

Overload Capacity --

Meter will not be damaged by occasional overloads of 100 times normal.

Power Supply Rating --

Voltage - 115 volts $\pm 10\%$ or 230 volts $\pm 10\%$

Frequency - 50 to 1,000 cycles/sec.

Wattage - approximately 70 watts

Overall Dimensions --

7" wide x 10-3/4" high x 10-1/8" deep

Weight --

19 pounds

Operating Instructions

Inspection --

This instrument has been thoroughly tested and inspected before being shipped and is ready for use when received.

After the instrument is unpacked, it should be carefully inspected for damage received in transit. If any shipping damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" page at the back of this instruction book.

Controls and Terminals --

ON - This toggle switch controls the power supplied to the instrument from the power line. When the switch is in the ON position, the red indicator lamp will glow.

DB VOLTS - This rotary switch connects the proper multiplier resistors and capacitors into the circuit for the desired voltage range. The position of the switch indicates the full scale voltage of the range in use. The switch position also indicates the DB level when the meter pointer is at zero on the DB scale.

INPUT - The two binding posts located in the lower left corner of the control panel are connected to the input circuit of the instrument. The lower binding post is designated G, and is connected to the chassis. The binding posts will accept either a banana plug or wire, and are so arranged that any double banana plug with 3/4 inch spacing may be used.

CAUTION

The maximum voltage (the sum of the DC voltage and AC peak voltage) applied to the input terminals of the Model 400D Vacuum Tube Voltmeter must not exceed 600 volts. Higher voltages will break down the capacitors in the input system of the instrument.



Fig. 1. Model 400D Vacuum Tube Voltmeter

OUTPUT - The two binding posts located in the lower right-hand corner of the control panel are the output terminals of the amplifier. The lower binding post is connected to the chassis. The OUTPUT binding posts are of the same type and arrangement as the INPUT binding posts.

FUSE - The fuseholder, located on the back of the instrument, contains a 1 ampere cartridge fuse which is in the power supply input circuit. To replace the fuse, unscrew the fuseholder cap and remove the blown fuse, insert a new fuse of the same type, and replace the fuseholder cap. Replacement fuses must be of the "Slo-Blo" type as specified in the Table of Replaceable Parts.

NOTE: When the power transformer is connected for 230 volt operation, use a 1/2 ampere "Slo-Blo" cartridge fuse.

Operation --

When the Model 400D is received from the factory, the meter pointer may not indicate zero before the instrument is turned on. After the instrument is turned on, the meter pointer may show an indication of as much as two scale divisions, principally on the one volt range. This effect is normal and does not impair the accuracy of the instrument.

On the lowest three ranges of the instrument the high input impedance coupled with the gain of the amplifier causes the meter needle to be forced against the right-hand stop of the meter when the input terminals are unshielded. This condition is normal and is caused by stray voltages in the vicinity of the instrument.

If measurements are being made from a high-impedance source, hum pick-up can affect the meter indication because of the high impedance of both the source and the Model 400D. Shielded leads will reduce pick-up, although they will cause an increase in the capacity shunted across the source, with the possibility of excessive circuit loading.

Voltage Measurements -

1. Plug the power cable into a 115/230 volt power line, and turn the toggle switch to ON. Allow the instrument about five minutes to reach a state of stable operation.

NOTE: The green wire which projects from the plug end of the power cable may be connected to the power outlet box or other ground when it is desired to ground the chassis.

2. Set the DB VOLTS (range) switch to the desired voltage range.

3. Connect the voltage being measured to the INPUT binding posts.

4. To obtain the value of the voltage being measured, multiply the meter indication by the meter multiplying factor (DB VOLTS (range) switch position divided by the full scale value of the meter scale in use). For example, if the

range switch is on the .1 volt position and the meter indicates .64 on the 1 volt meter scale, to obtain the value of the voltage being measured:

$$.64 \text{ (meter indication)} \times \frac{.1 \text{ (range switch position)}}{1 \text{ (meter full scale value)}} = .064 \text{ volts}$$

If the range switch is on the 30 volt position and the meter indicates 1.6 on the 3 volt scale:

$$1.6 \text{ (meter indication)} \times \frac{30 \text{ (range switch position)}}{3 \text{ (meter full scale value)}} = 16 \text{ volts}$$

Harmonics - As a precaution in maintaining accuracy of measurement, it must be kept in mind that the instrument is an average reading device but that the meter is calibrated in terms of the RMS voltage of a pure sine wave. If the waveform of the voltage being measured contains appreciable harmonic voltages or other spurious voltages, the meter indication will deviate from the true RMS value on the order indicated by the following table.

EFFECT OF HARMONICS ON MODEL 400D VOLTAGE MEASUREMENTS		
Input Voltage Characteristics	True RMS Value	Value Indicated by Model 400D
Fundamental = 100	100	100
Fundamental + 10% 2nd harmonic	100.5	100
Fundamental + 20% 2nd harmonic	102	100 - 102
Fundamental + 50% 2nd harmonic	112	100 - 110
Fundamental + 10% 3rd harmonic	100.5	96 - 104
Fundamental + 20% 3rd harmonic	102	94 - 108
Fundamental + 50% 3rd harmonic	112	90 - 116

DB Measurements - Decibel measurements are made in the same way as voltage measurements except that the indication is read on the db scale. The level in decibels is the algebraic sum of the meter db scale indication and the DB VOLTS (range) switch position. For example, if the indication on the db scale is +1.5 and the range switch is at -40 db, the level in decibels is:

$$\begin{array}{l} -40. \quad (\text{range switch position}) \\ + 1.5 \quad (\text{meter db scale indication}) \\ \hline -38.5 \quad (\text{level in db of voltage being measured}) \end{array}$$

If the indication on the db scale is -5 and the range switch is at +20, the level in db is the algebraic sum of the two, +15 db.

a. To read the voltage directly in dbm (0 dbm = 1 milliwatt into 600 ohms), the measurement must be made across 600 ohms.

b. Comparative db measurements (without respect to the reference level) may be obtained by direct reading provided each measurement is made across the same value of impedance. Made in this manner, the difference in decibels between two or more voltages may be obtained directly from the DB scale indications.

NOTE: To obtain the level in dbm with respect to impedances other than 600 ohms, the meter correction graph shown in Fig. 2 may be used. The level in dbm of the voltage being measured will be the algebraic sum of the level as indicated on the meter and the correction shown on the graph. For example, if the range switch is at the +30 db position, the voltage being measured is across 90 ohms, and the indication on the DECIBELS scale is +1, the level in dbm is obtained as follows:

+1	(DB scale indication)
<u>+30</u>	(range switch position)
+31	(level in db as indicated by meter)
<u>+8</u>	(correction for 90 ohms impedance)
+39	dbm

For the same conditions, with the voltage being measured across 60,000 ohms:

+1	(DB scale indication)
<u>+30</u>	(range switch position)
+31	(level in db as indicated by meter)
<u>-20</u>	(correction for 60,000 ohms impedance)
+11	dbm

Amplifier - The Model 400D may be used as an amplifier. To obtain maximum gain, proceed as follows:

1. Plug the power cable into a 115/230 volt power line, and turn the toggle switch to ON.
2. Set the DB VOLTS (range) switch at the .001 volt position.
3. Connect the voltage to be amplified to the INPUT binding posts. To obtain optimum amplifier gain and minimum distortion, the load across the output of the amplifier must be at least 10,000 ohms.

With an input of .001 volt and the amplifier working into a 10,000 ohm load, the maximum voltage obtainable at the OUTPUT terminals is .3 volt.

Higher voltages may be applied to the input of the amplifier provided the position of the range switch indicates a full scale voltage equal to or greater than the applied voltage. However, the gain of the amplifier goes down by 10 db for each step that the range switch is advanced toward the high voltage end. At the

Model 452A Capacitive Voltage Divider --

Extends the AC voltage range of the Model 400D to 25,000 volts.

Maximum voltage: 25,000 volts
Frequency range: 25 cycles/sec. to 20 mc.
Accuracy: $\pm 3\%$
Division ratio: 1000:1
Input Capacity: $15\mu\mu\text{f} \pm 1\mu\mu\text{f}$

Model 454A Capacitive Voltage Divider --

Extends the voltage range of the Model 400D to 1500 volts.

Maximum voltage: 1500 volts
Frequency range: 20 cycles/sec. to 4 megacycles
Accuracy: $\pm 3\%$
Division ratio: 100:1
Input Impedance: 50 megohms shunted with $2.75\mu\mu\text{f}$

Model 470A-470F Shunt Resistors --

These shunt resistors adapt the Model 400D for measuring currents as small as 1 microamp full scale.

Accuracy: $\pm 1\%$ to 100 kc, Models 470A-F; $\pm 5\%$ to 1 mc, Model 470A
 $\pm 5\%$ to 4 mc, Models 470B-F

Maximum power dissipation: 1 watt

<u>Model</u>	<u>Shunt Resistance</u>
470A	.1 ohm
470B	1.0 ohm
470C	10.0 ohms
470D	100.0 ohms
470E	600.0 ohms
470F	1000.0 ohms

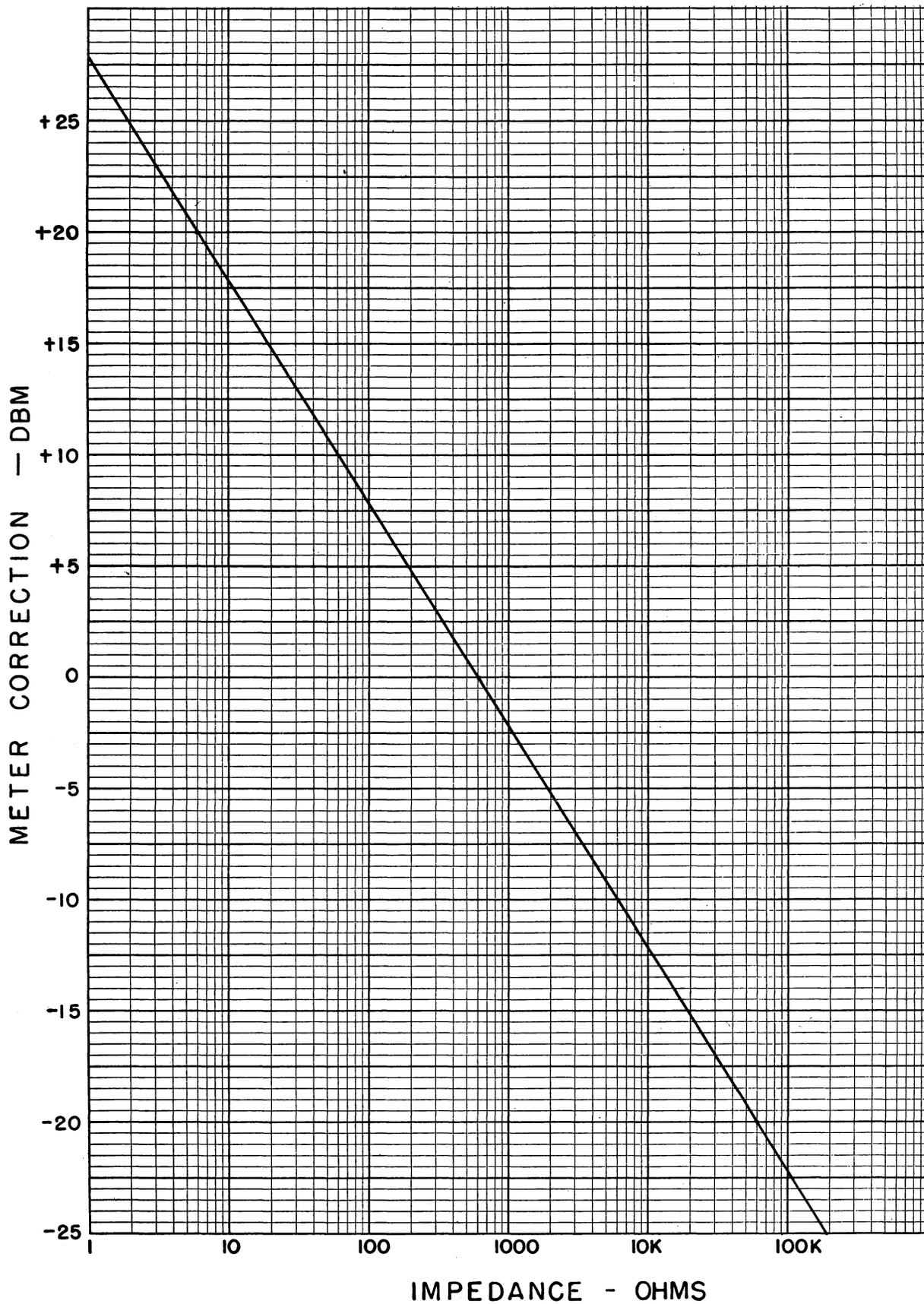


Fig. 2. Model 400D Impedance Correction Graph

Model AC-60A Line Matching Transformer --

Adapts the Model 400D for the measurement of voltages on either a 135 ohm or 600 ohm balanced line.

Frequency range: 5 kc to 600 kc

Impedance

Primary: 135 ohms or 600 ohms, balanced

Secondary: 600 ohms, one side grounded

Insertion loss: Less than .2 db at 100 kc

Frequency response: Less than .5 db reduction at 5 kc and 600 kc from mid-frequency value

Balance: Better than 40 db, entire frequency range

Power handling capacity: +22 dbm (10 volts at 600 ohms)

Circuit Description

General - The circuit of the Model 400D includes an input voltage divider, a stabilized broad-band amplifier, a rectifier and meter circuit, and a regulated power supply. Arrangement of the circuit is shown in block diagram form in Fig. 3, and diagrammatically on the schematic diagram.

Input Voltage Divider - The input voltage divider consists of a capacitive voltage divider feeding into the grid of tube V1, which is connected as a cathode follower with a resistance voltage divider in its cathode circuit. The input voltage divider is controlled by the RMS VOLTS (range) switch. This switch includes two mechanically-ganged sections, one of which sets up the connection with the capacitive divider, and the other with the resistance divider in the cathode circuit of V1. Input circuit arrangements for the various positions of the range switch are shown in Figs. 4 to 9. These diagrams are partial schematics which show for each range only the components actually in the input circuit when the switch is on the respective range.

Capacitive Voltage Divider - With the RMS VOLTS (range) switch on any one of the six lower ranges (.001 volt to .3 volt), section S1A of the range switch sets up the connections in such manner that the input voltage is applied directly to the grid of cathode follower V1 without being reduced by the capacitive divider. With the range switch on any one of the six higher ranges (1 volt to 300 volts), section S1A establishes the connection between the grid of V1 and the capacitive divider at the junction of resistor R5 and capacitor C4, and the input voltage is reduced a thousand-to-one before it is applied to the grid of V1.

Cathode Resistor Voltage Divider - Two series-connected wirewound resistors (R10A, B and R11A, B, C, D) in the cathode circuit of cathode follower V1 constitute a resistance divider tapped for six output voltages.

There are two positions of the switch in section S1B for each resistor tap, one position being in the low voltage (.001 to .3 volt) ranges and the other being in the high voltage (1 to 300 volts) ranges. For instance, the range switch makes contact with the No. 2 resistor tap when the switch is at the 3 volt or .003 volt positions. It is to be noted that on the six higher ranges the input voltage is applied to the grid of V1 at one-thousandth its level at the INPUT terminals, whereas

on the lower ranges the input voltage is applied to the grid of V1 without reduction. Thus on the 3 volt and .003 volt ranges, the maximum voltage applied to the grid of V1 is .003 volt in both cases.

The output from V1 is applied to the grid of V2, the first stage of the amplifier. For full scale deflection of the meter, the maximum voltage which can be applied to the grid of V2 is .001 volt. The resistance divider in the cathode circuit of V1 provides such reduction on each range that for the maximum voltage at the INPUT terminals, the voltage applied to the grid of V2 will not exceed .001 volt.

The resistance-capacitance networks in the cathode circuit of V1 minimize switching transients while the ranges are being changed. The variable capacitors switched into the circuit on the .003 volt (Fig. 5), .01 volt (Fig. 6), 3 volt (Fig. 8) and 10 volt (Fig. 9) ranges are provided for adjustment of the high frequency response.

The V1 input circuit is stabilized with 35 db of feedback over the entire frequency range of the instrument.

Amplifier, Rectifier and Meter - The four-stage amplifier provides high gain over a wide frequency range. The amplifier output is applied to a full wave rectifier actuating a 1 milliampere meter movement. The amplifier-rectifier system is stabilized with an overall feedback loop which at the middle of the frequency range has a level of 60 db. At the edges of the frequency range, the amount of negative feedback is so proportioned as to provide the maximum stability consistent with the gain there available.

The amplifier circuit includes capacity-coupled pentodes V2 to V5. Feedback is returned from the plate of V5 through the rectifier to the cathode of V2 in such phase that it is negative in effect. An adjustment (variable capacitor C21 and variable resistor R29) is provided in the negative feedback loop. Frequency-compensating networks in the plate circuit of each stage, cathode degeneration at low frequencies (cathode resistors not bypassed at low frequencies), and the generous amount of negative feedback provide stable amplifier characteristics over an extremely wide frequency range. When the Model 400D is used as an amplifier, pentode V5 is operated as a cathode follower.

The rectifier-meter bridge includes a crystal diode and a capacitor in each branch, and is arranged to provide full wave rectification of the current which passes through the meter. The design of the amplifier-rectifier-meter circuit is such that the meter indicates the average value of the AC voltage applied at the INPUT terminals. The meter is calibrated in RMS volts.

The amplifier-rectifier-meter circuit is so designed that (1) pulsating direct current is provided for the meter circuit and (2) an alternating current which is of the same frequency as the AC input to the rectifier is provided for the feedback loop. A partial schematic of the circuit is shown in Fig. 10. A detailed explanation of the amplifier-rectifier-meter circuit is not within the scope of this instruction book, but in effect the functioning of the circuit may be described as follows.

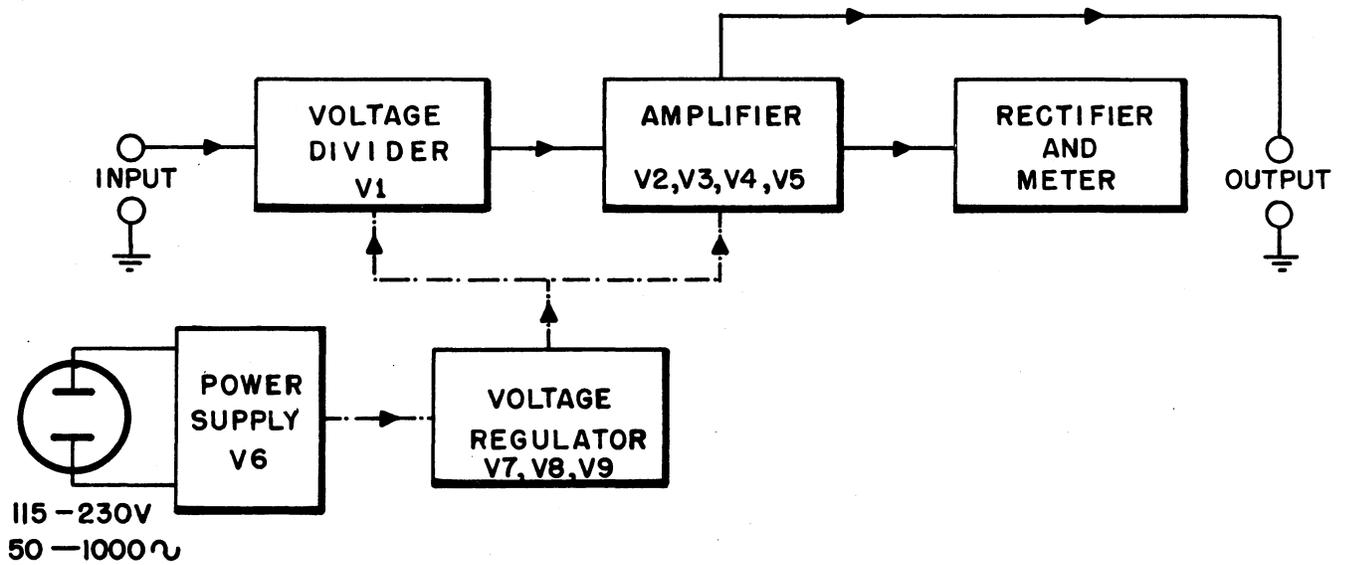


Fig. 3. Model 400D Block Diagram

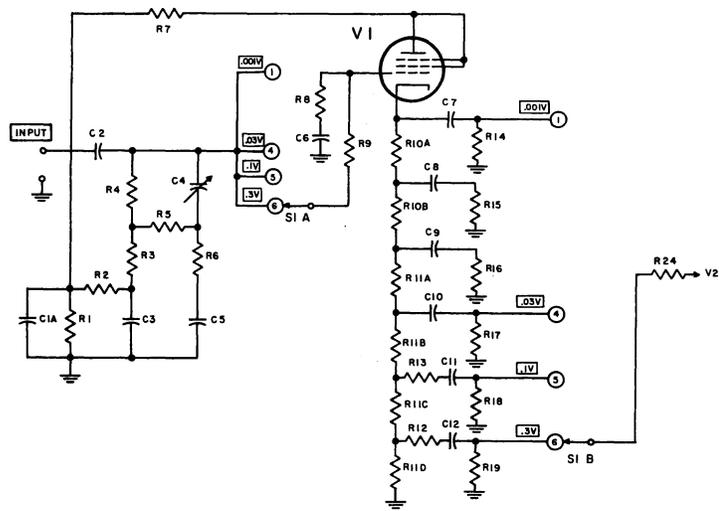


Fig. 4. Model 400D Input Circuit .001V, .03V, .1V, and .3V Ranges Partial Schematic

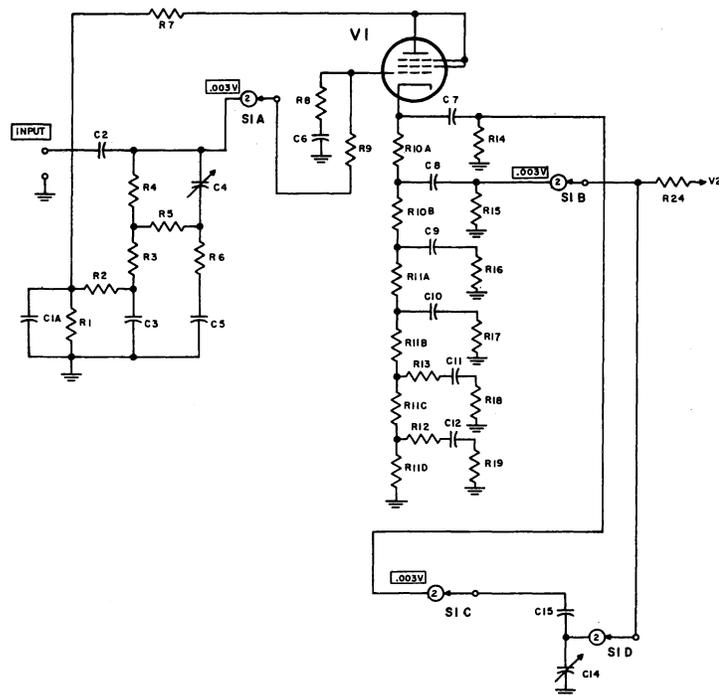


Fig. 5. Model 400D Input Circuit .003V Range Partial Schematic

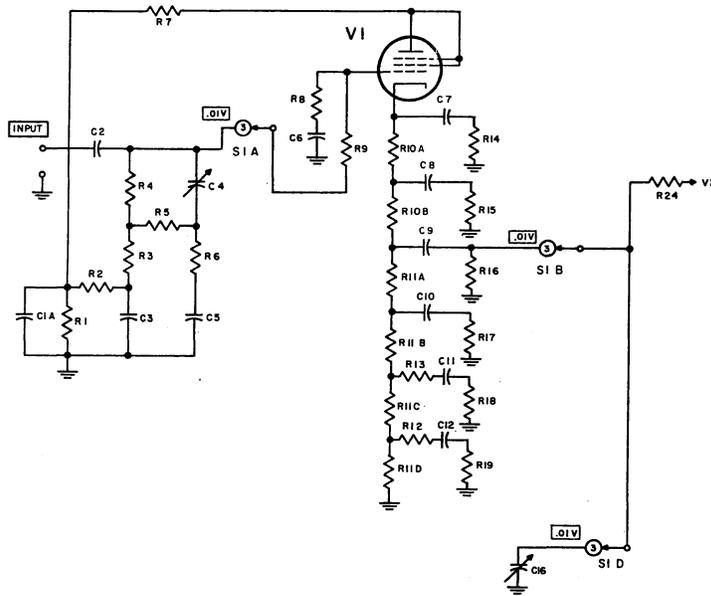


Fig. 6. Model 400D Input Circuit .01V Range Partial Schematic

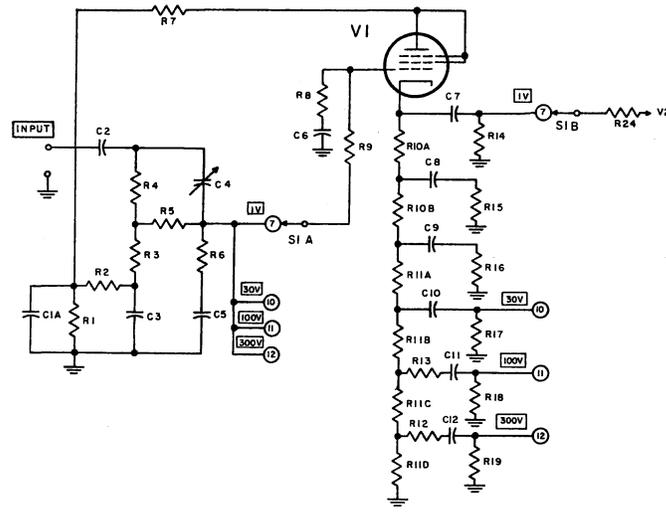


Fig. 7. Model 400D Input Circuit 1V, 30V, 100V, and 300V Ranges Partial Schematic

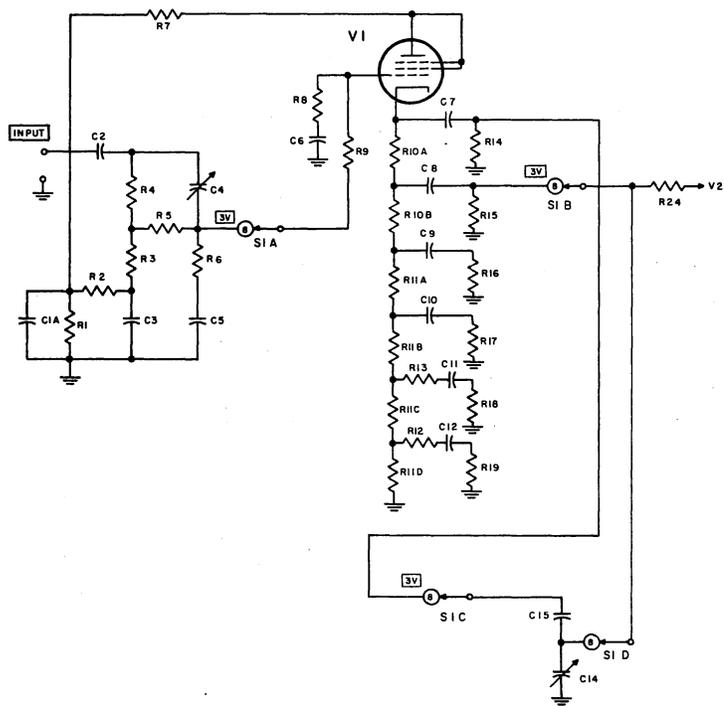


Fig. 8. Model 400D Input Circuit 3V Range Partial Schematic

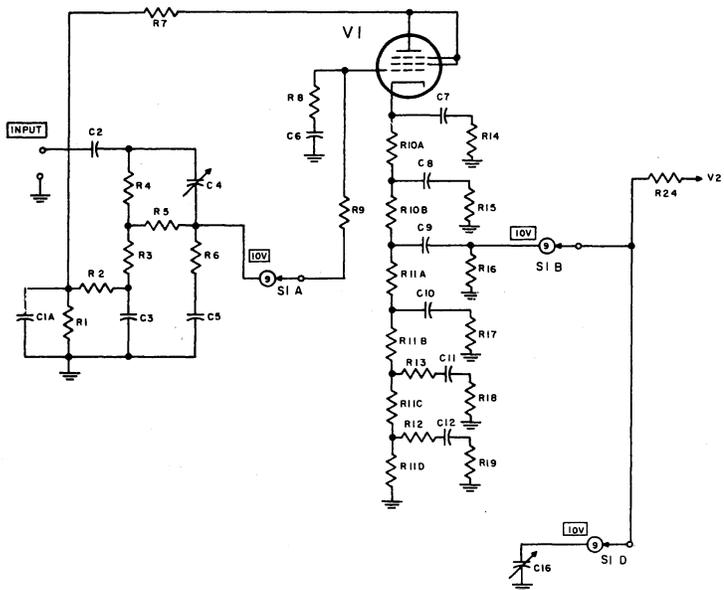


Fig. 9. Model 400D Input Circuit 10V Range Partial Schematic

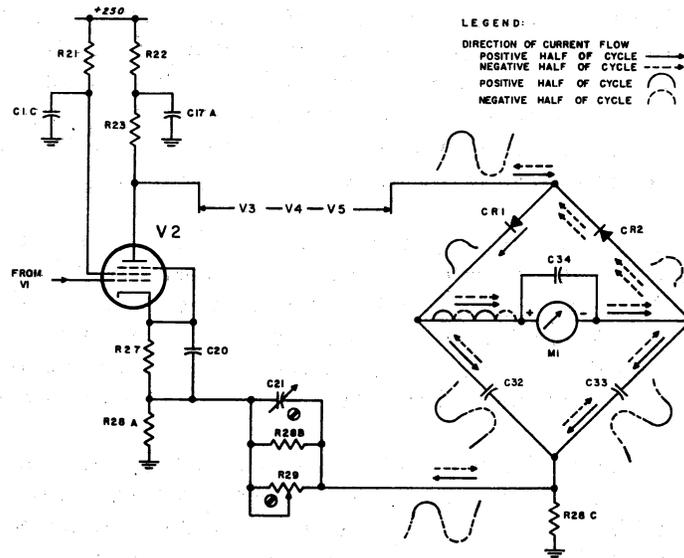


Fig. 10. Model 400D Direction of Current Flow Through Rectifier - Meter Bridge Partial Schematic

For the purposes of explanation, the amplifier (tubes V2-V5) may be considered as a signal generator. The output from the plate of V5 may be considered as one side of the generator and the cathode of V2 may be considered as the other side of the generator. The rectifier-meter circuit may be considered as a bridge across the generator. On the positive half of the cycle, current flows into the bridge from the top. On the negative half of the cycle, current flows into the bridge from the bottom.

On the positive half of the cycle, diode CR1 conducts, and current flows through CR1 to the juncture between the meter and capacitor C32, where it divides. Half the current flows through the meter. Since diode CR2 is not conducting, the current flowing from the meter output passes to capacitor C33, placing a charge thereon. The other half of the current passes to capacitor C32, charging it. As the capacitors discharge, current flows to the generator.

On the negative half of the cycle, diode CR2 is biased to conduct, and diode CR1 is not conducting. The current present at the juncture between capacitors C32 and C33 divides, half placing a charge on capacitor C32 and the other half on C33. Since diode CR1 is not conducting, as capacitor C32 discharges, current flows through the meter and through diode CR2 to the generator. As capacitor C33 discharges, current flows through CR2 to the generator.

The action of capacitors C32 and C33 results in the flow of an alternating current in the feedback loop, so phased that it is negative in effect with respect to the signal on the grid of V2. Capacitor C34 across the meter smooths out the dc and provides a bypass path for any AC component that may be present.

Power Supply - The power supply circuits provide a high voltage regulated DC for the plate circuits of tubes V1 to V5 and a low voltage unregulated DC for the filament circuits of tubes V1 to V4. The filament circuits of tubes V5 to V8 are supplied directly with 6.3 volt AC from windings in the secondary of power transformer T1.

The primary winding of power transformer T1 may be connected for operation from either a 115 volt ($\pm 10\%$) or a 230 volt ($\pm 10\%$) 50/1000 cps source. The primary circuit is fused. When switch S2 is in the ON position, power from the line is applied to the primary winding of transformer T1. With the energization of the four secondary windings, lamp I1 and the tubes light.

Current for the high voltage supply is rectified by dual diode V6 and regulated by pentodes V7 and V8. Voltage reference tube V9 holds the cathode of V8 at a constant potential. Capacitor C30C provides a filtering action.

Current for the low voltage DC supply is rectified by selenium rectifier SR1 and is filtered by capacitors C37 and C38. Variable resistor R66 provides a means for adjusting the level of rectifier voltage if necessary.

Maintenance

NOTICE

The more intricate adjustment procedures described in the Maintenance section of this instruction book are provided for those who have the necessary skill and test equipment. When adequate personnel and test facilities are not available, it is suggested that adjustments not be made in the field. Send the instrument to the Hewlett-Packard Company where a reasonable charge will be made for the necessary repair work. For packing and shipping instructions, see the "Shipping" paragraph at the back of this book.

Meter Zero Adjustment --

The meter zero adjust screw is sealed at the factory for the best tracking of the meter, and no attempt should be made to change this adjustment. If the meter pointer does not indicate exactly on zero, the accuracy of the meter need not be doubted.

CAUTION: The method used by the factory to seal the zero adjust screw is such that any attempt to move the screw will damage or break it.

Case Removal --

The instrument case is fastened to the chassis at the rear with two screws. To remove the case, remove the screws, and slide the case to the rear and off the instrument.

NOTE: When replacing the case, pull the power cable through the opening at the rear of the case. Be sure the cable is free of the case along the entire length of the cable so that it cannot get caught between the chassis and the case as the case is slid onto the instrument.

Tube Replacement --

Any tube in the Model 400D may be replaced with a tube having corresponding RETMA standard characteristics. Whenever a tube is replaced, the following table should be consulted to determine whether or not the characteristics of the replacement tube will necessitate circuit adjustments. The procedure for performing these adjustments will be found below, under Adjustments.

<u>Tube</u>	<u>Function</u>	<u>Required Circuit Adjustment</u>
V1	Cathode Follower	Calibration
V2	Amplifier	*Calibration, steps 1, 2, 3
V3	Amplifier	*Calibration, steps 1, 2, 3
V4	Amplifier	*Calibration, steps 1, 2, 3
V5	Amplifier	*Calibration, steps 1, 2, 3
V6	Rectifier	Not Critical
V7	Power Supply Series Regulator	Plate Voltage Regulator

Tube Replacement (Continued)

<u>Tube</u>	<u>Function</u>	<u>Required Circuit Adjustment</u>
V8	Power Supply Control Tube	Plate Voltage Regulator
V9	Reference Voltage for Regulator	Plate Voltage Regulator

*NOTE: If the gain of the replacement tube differs from that of the original tube, resistor R29 is adjusted to restore calibration. If the capacitance of the replacement tube differs from that of the original tube, the frequency response may be altered. See the Frequency Response adjustment below, and note the information in regard to test equipment required.

Capacitor Replacement --

The electrolytic capacitors in the Model 400D are very high quality capacitors which have a useful life of from five to ten years. Do not replace these capacitors unless they are proven defective by accurate tests.

Adjustments --

Auxiliary Equipment Required - Hewlett-Packard Model 410A or Model 410B High Frequency Vacuum Tube Voltmeter (or any other DC voltmeter of a sensitivity of 20,000 ohms-per-volt or more)

Hewlett-Packard Model 650A Test Oscillator (or any other low-distortion oscillator)

An AC voltmeter accurate within 1% of full scale at 400 cycles

Filament Voltage Adjustment -

1. Remove the instrument case.
2. Connect a DC voltmeter (such as a Hewlett-Packard Model 410B) to pin 3 of tube V4. Adjust variable resistor R66 to obtain a meter indication of 12.6 volts. The location of resistor R66 and the socket of tube V4 are shown in Fig. 11.

Plate Voltage Regulator - Voltage for the plate circuit is electronically regulated, and should not require adjustment. After replacement of tube V7, V8, or V9, however, the level of voltage at the regulator output should be measured since a difference in tube characteristics will alter the performance of the regulator circuit.

The voltage from the regulator output to ground should be within 245 to 255 volts. The measurement may be made from pin 3 of tube V7 (Fig. 11) with a DC voltmeter, such as a Model 410B.

If regulator output voltage is not within the 245-255 volt limit, characteristics of the replacement tube are not suitable for the regulator circuit. Another tube should be substituted and the voltage re-measured.

NOTE: If an output voltage within the 245-255 volt limits cannot be obtained when tubes are replaced, resistance may be connected in parallel with resistors R62 and R64 (Fig. 14) to obtain a voltage within limits.

Calibration - The calibration of the Model 400D may be checked as follows:

1. Remove the instrument case.
2. Connect a low distortion oscillator (such as a Hewlett-Packard Model 650A Low Frequency Oscillator) and an AC voltmeter accurate to within 1% of full scale at 400 cycles to the INPUT terminals of the Model 400D.
3. Set the Model 400D range switch to the .3 volt position, and apply .3 volt at 400 cycles to the input of the Model 400D. Adjust R29 (Fig. 11) until the Model 400D indicates exactly .3 volt.
4. Set the Model 400D range switch to 1 volt, and apply 1 volt at 400 cycles to the input of the Model 400D. Adjust capacitor C4 (Fig. 11) until the Model 400D meter indicates exactly 1 volt. This completes calibration of the instrument.

Frequency Response Adjustment -

CAUTION - Adjustments to obtain a flat frequency response from 10 cps to 4 mc have been set at the factory, and it is improbable that the frequency response will require readjustment. If adjustment ever should be deemed necessary, however, it is recommended that the instrument be returned to the factory, since NO READJUSTMENT SHOULD BE ATTEMPTED UNLESS THE REQUIRED TEST EQUIPMENT IS AVAILABLE.

The following test equipment is essential:

A stable 4 mc signal source (such as a Hewlett-Packard Model 650A Test Oscillator)

A reference voltmeter with a frequency response flat to 4 mc

Procedure -

1. Connect a low-distortion oscillator (such as a Hewlett-Packard Model 650A) and an accurate RMS voltmeter, flat to 4 mc, to the Model 400D INPUT terminals.
2. Set the Model 400D on the .1 V range.
3. Using a 10 kc signal of such amplitude as to give an indication near full scale on the Model 400D, monitor the input to the 400D with the reference voltmeter.
4. Change the signal source to 4 mc, and reset to the same level on the reference meter as used at 10 kc.
5. Adjust capacitor C21 (Fig. 11) to bring the Model 400D meter indication to the same indication as at 10 kc. At this setting of capacitor C21, spot check the frequency response at other frequencies between 10 kc and 4 mc (such as 100 kc, 1 mc, and 2 mc). It may be necessary to readjust capacitor C21 at 4 mc for a meter indication above or below the 10 kc reference to compensate for deviations from the reference at other frequencies. Adjustment of C21 will affect the frequency response on all ranges.

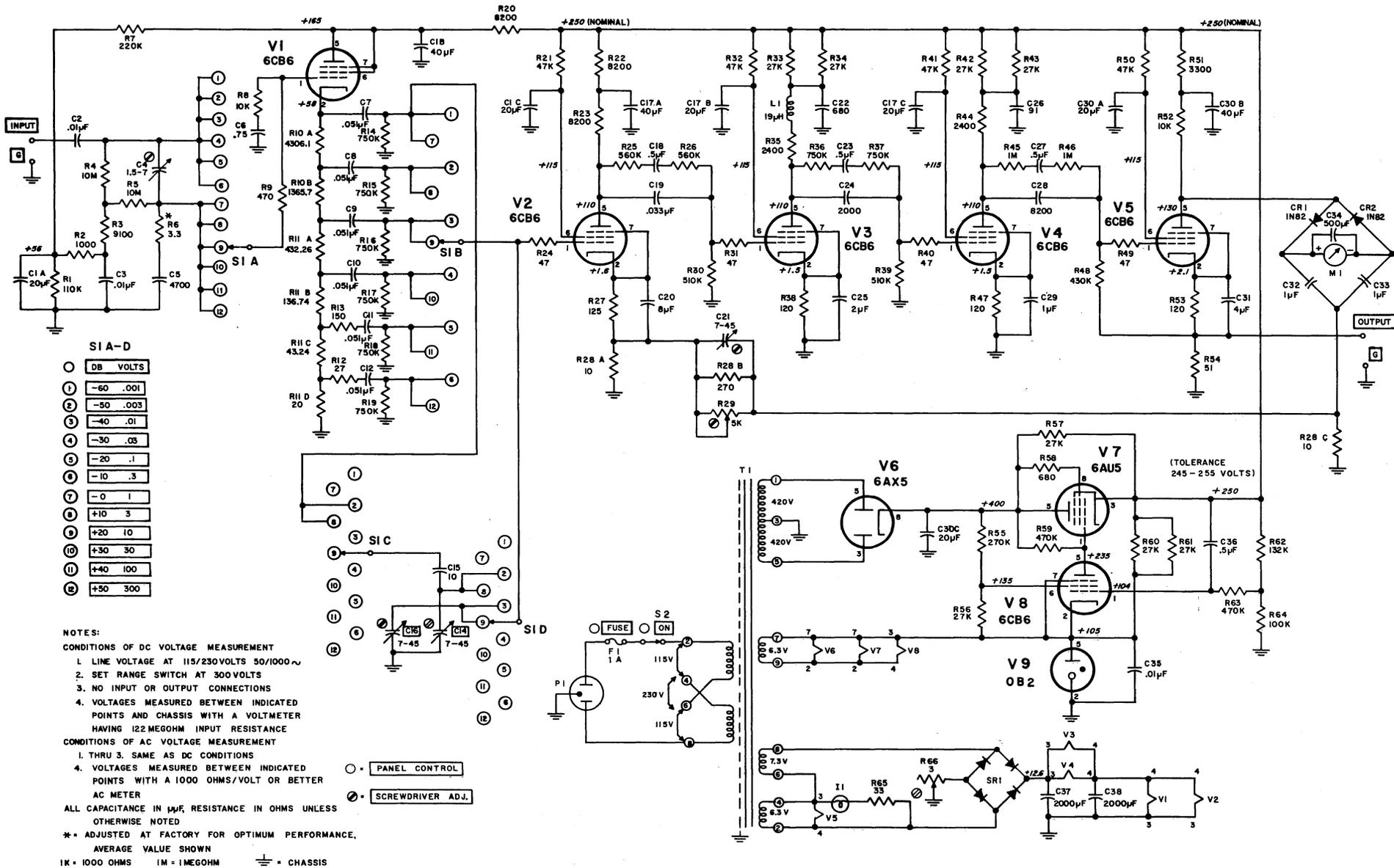
The frequency response on the .003V and 3V ranges can be adjusted in a similar manner by adjustment of capacitor C14, and the .01V and 10V ranges can

be set by adjusting capacitor C16. Capacitor C14 or C16 should be set after capacitor C21 has been set.

Trouble Shooting --

The following information is designed to aid in trouble shooting a defective instrument.

<u>Symptoms</u>	<u>Causes</u>	<u>Remedies</u>
Instrument inoperative (Indicator lamp will not light)	Blown fuse	Clear short circuit and replace fuse
	Open power cable	Repair or replace power cable
Instrument inoperative (Indicator lamp lights, no meter indication)	Defective tube, check tube V6 first	Replace tube (see Tube Replacement above)
	Filaments not lighted. Short circuit in capacitor C37	Replace capacitor
	Rectifier SR1 defective	Replace rectifier
	Resistor R66 open	Replace resistor
	Short circuit in capacitor C30C	Replace capacitor
	Short circuit in coupling capacitors, or screen or plate bypass capacitors	Replace capacitor
Gain drops or tracking becomes nonlinear	Open circuit in resistor R60 or R61	Replace resistor
	Crystal diode defective	Replace diode
Meter indication erratic. (Excessive voltage has been applied to input terminals of instrument)	Input capacitor C2 short circuited	Replace capacitor C2
Tubes V1 and V2 do not light	Capacitor C38 short circuited	Replace capacitor



**SCHEMATIC DIAGRAM OF MODEL 400D
SERIAL 74 & ABOVE**

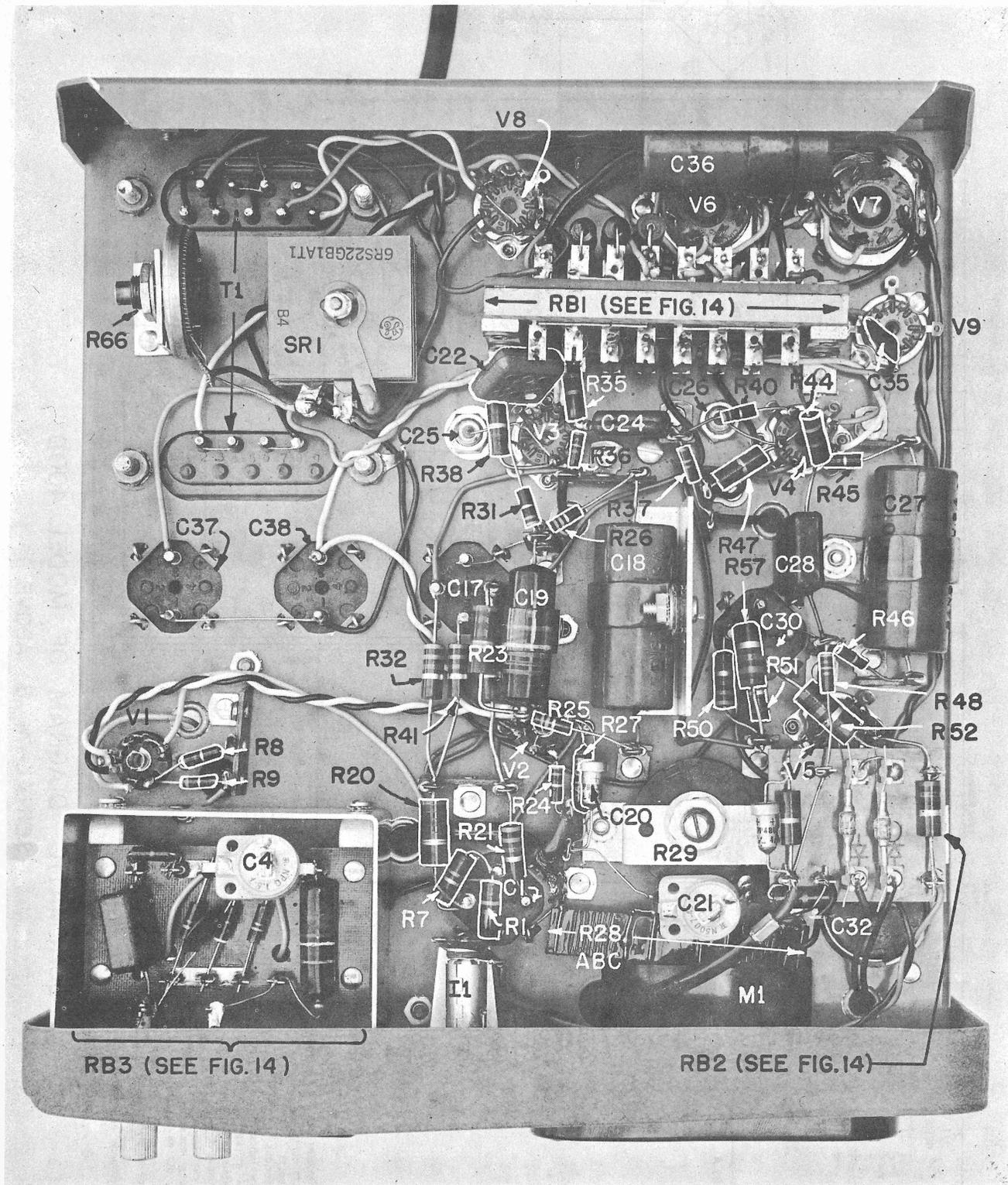


Fig. 11. Model 400D View of Left Side Instrument Case Removed

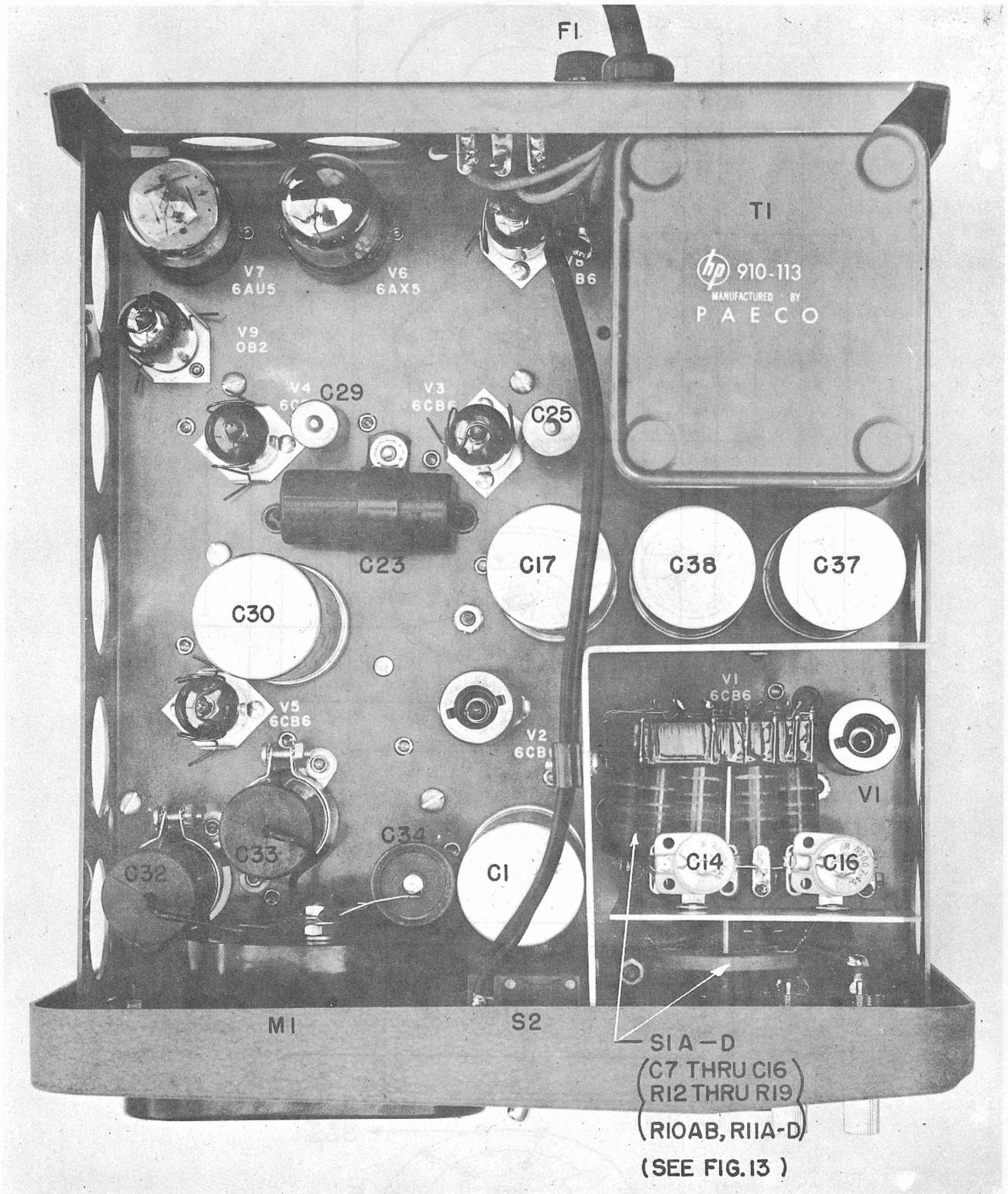


Fig. 12. Model 400D View of Right Side Instrument Case Removed

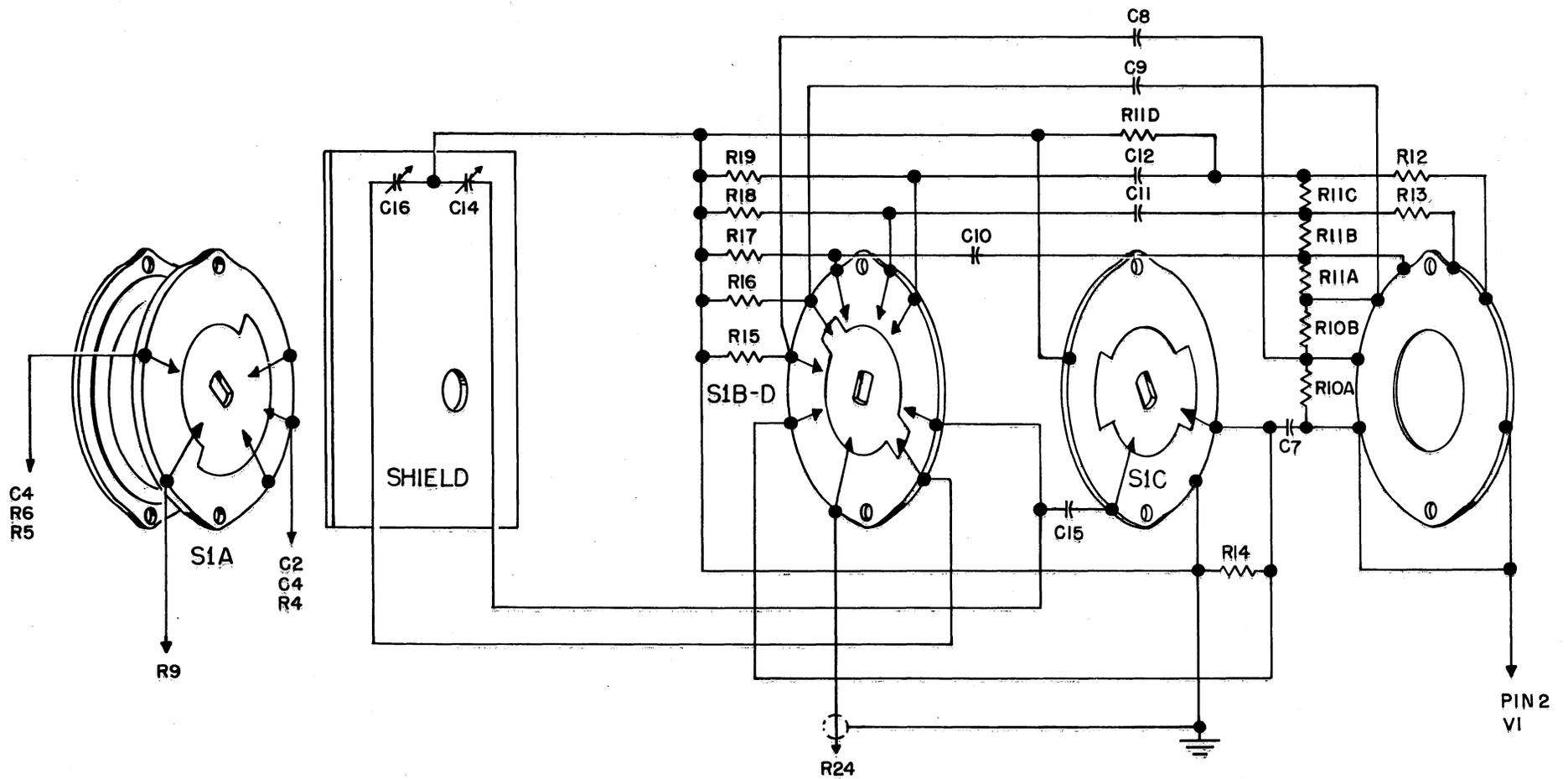
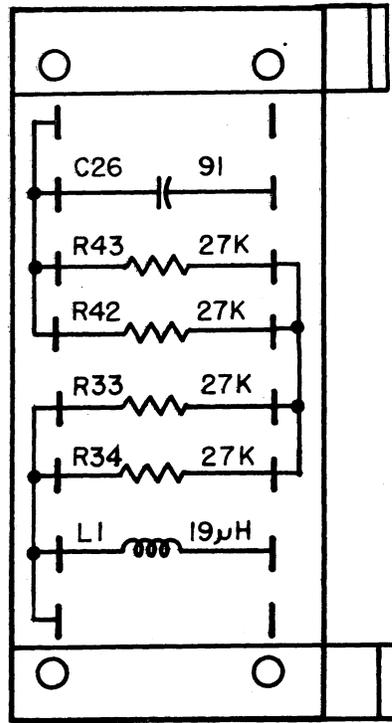
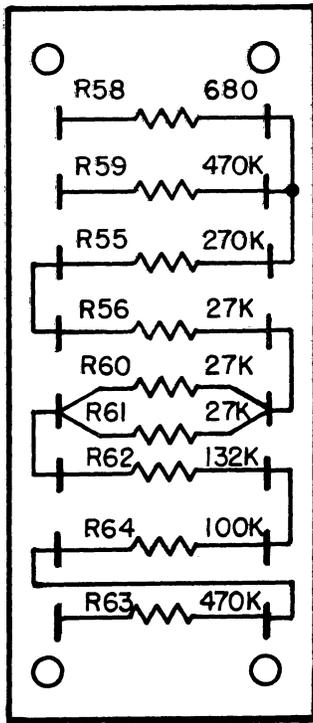
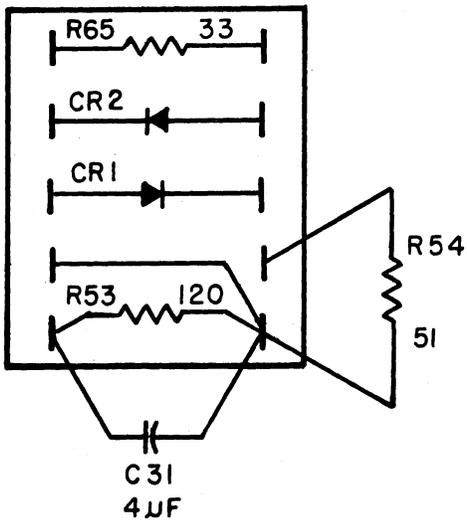


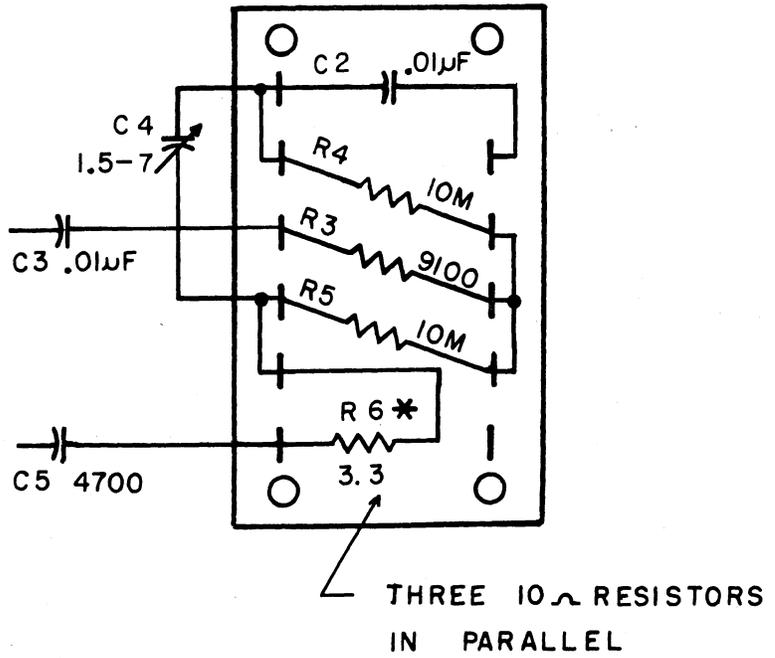
Fig. 13. Model 400D Range Switch Detail



RB1



RB2



RB3

Fig. 14. Model 400D Resistor Board Detail

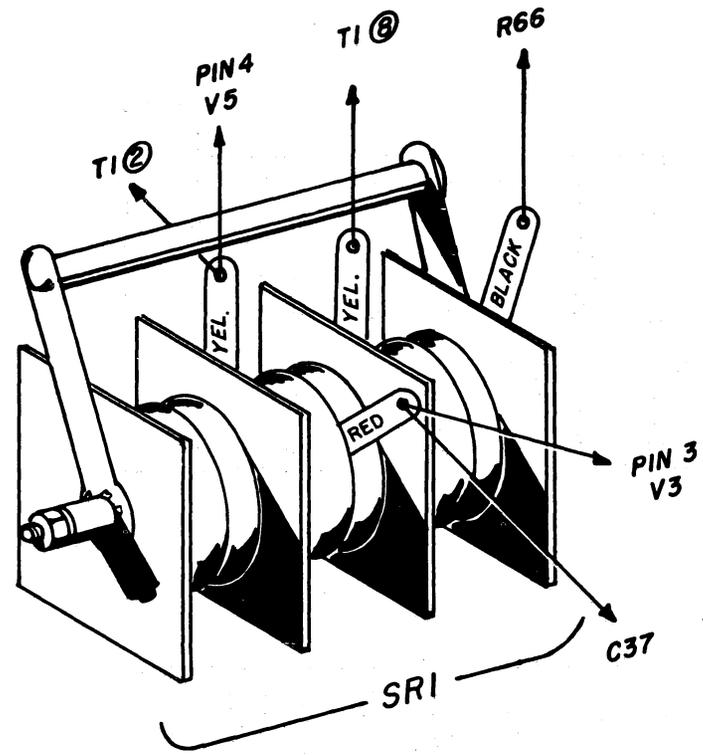
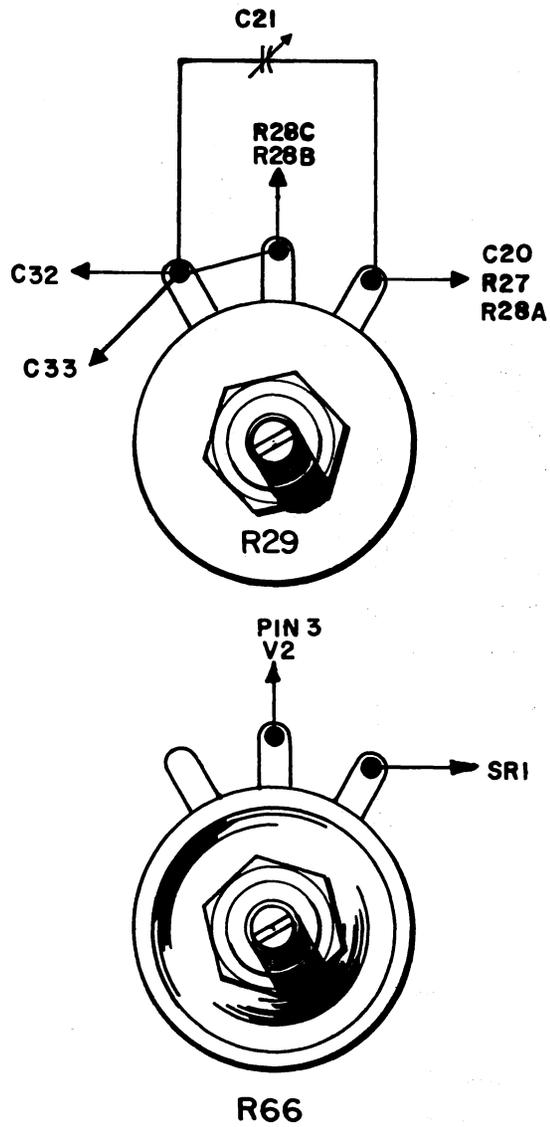


Fig. 15. Model 400D Variable Resistor and Selenium Rectifier Detail

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C1 ABC	Capacitor: fixed, electrolytic, 3 sections: 20, 40, 20 μ f, 450 vdcw	18-42S	CC D-16651
C2	Capacitor: fixed, paper, .01 μ f, $\pm 10\%$, 600 vdcw	16-11	CC 73P10396
C3	Capacitor: fixed, ceramic, .01 μ f, $+100\%$, -0% , 500 vdcw	15-43	A Type BPD .01
C4	Capacitor: variable, ceramic, 1.5 - 7 μ f, 500 vdcw	13-7	L TS2A NPO
C5	Capacitor: fixed, silver mica, 4,700 μ f, $\pm 5\%$, 500 vdcw	15-81	Z CR-1247
C6	Capacitor: fixed, air, .75 μ f, (Air gap between R8 lug and ground lug of tie - point)	---	
C7 - C12	Capacitor: fixed, paper, .051 μ f, $\pm 5\%$, 600 vdcw (Part of Range Switch Assembly)	16-53	CC Type 73P
C13	This circuit reference not assigned.		
C14	Capacitor: variable, ceramic, 7 - 45 μ f, 500 vdcw (Included in Range Switch Assembly)	13-1	L TS2A
C15	Capacitor: fixed, ceramic, 10 μ f, $\pm .5 \mu$ f, 500 vdcw (Included in Range Switch Assembly)	15-30	K CI-1
C16	Capacitor: variable, ceramic, 7 - 45 μ f, 500 vdcw (Included in Range Switch Assembly)	13-1	L TS2A
C17 ABC	Capacitor: fixed, electrolytic, 3 section: 40, 20, 20 μ f, 450 vdcw	18-42S	CC D-16651
C18	Capacitor: fixed, paper, .5 μ f, $\pm 10\%$, 400 vdcw	16-58	Z 300405
C19	Capacitor: fixed, paper, .033 μ f, $\pm 10\%$, 600 vdcw	16-13	CC 73P33396
C20	Capacitor: fixed, electrolytic, 8 μ f, $+20\%$, -15% , 30 vdcw	18-17	Fansteel PP8B30A1
C21	Capacitor: variable, ceramic, 7 - 45 μ f, 500 vdcw	13-1	L TS2A
C22	Capacitor: fixed, mica, 680 μ f, $\pm 10\%$, 500 vdcw	14-21	V Type W

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C23	Capacitor: fixed, paper, .5 μ f, $\pm 10\%$, 400 vdcw	16-58	Z 300405
C24	Capacitor: fixed, mica, 2,000 μ f, $\pm 10\%$, 500 vdcw	14-13	V Type W
C25	Capacitor: fixed, paper, 2 μ f, +25%, -15%, 400 vdcw	16-67	Astron MQCF-4-2M
C26	Capacitor: fixed, silver mica, 91 μ f, +5%, -5%, 500 vdcw	15-82	Z RR-1491
C27	Capacitor: fixed, paper, .5 μ f, $\pm 10\%$, 400 vdcw	16-58	Z 300405
C28	Capacitor: fixed, silver, mica, 8,200 μ f, $\pm 5\%$, 300 vdcw	15-79	Z CR-06282
C29	Capacitor: fixed, paper, 1 μ f, +25%, -15%, 200 vdcw	16-66	Astron Corp. MQCS-2-1M
C30 ABC	Capacitor: fixed, electrolytic, 3 section: 20, 40, 20 μ f, 450 vdcw	18-42S	CC D-16651
C31	Capacitor: fixed, electrolytic, 4 μ f, +20%, -15%, 60 vdcw	18-15	Fansteel PP4B60A1
C32	Capacitor: fixed, paper, 1 μ f, $\pm 10\%$, 400 vdcw	16-74	Z Type 30
C33	Capacitor: fixed, paper, 1 μ f, $\pm 10\%$, 400 vdcw	16-74	Z Type 30
C34	Capacitor: fixed, electrolytic, 500 μ f, 15 vdcw	18-5	X #TC 1505
C35	Capacitor: fixed, ceramic, .01 μ f, +100%, -0%, 500 vdcw	15-43	K Type BPD .01
C36	Capacitor: fixed, paper, .5 μ f, $\pm 10\%$, 400 vdcw	16-58	Z 300405
C37	Capacitor: fixed, electrolytic, 2,000 μ f, 15 vdcw	18-3(S)	CC D-16652
C38	Capacitor: fixed, electrolytic, 2,000 μ f, 15 vdcw	18-3(S)	CC D-16652
R1	Resistor: fixed, composition, 110,000 megohms, $\pm 5\%$, 1 W	24-110K-5	B GB 1145
R2	Resistor: fixed, composition, 1,000 ohms, $\pm 10\%$, 1/2 W	23-1000	B EB 1021

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R3	Resistor: fixed, composition, 9,100 ohms, $\pm 5\%$, 1/2 W	23-9100-5	B EB 9125
R4	Resistor: fixed, composition, 10 megohms, $\pm 5\%$, 1/2 W	23-10M-5	B EB 1065
R5	Resistor: fixed, composition, 10 megohms, $\pm 5\%$, 1/2 W	23-10M-5	B EB 1065
R6	Resistor: fixed, composition, 10 ohms, $\pm 10\%$, 1/2 W (Three 10 ohm resistors connected in parallel). Electrical value adjusted at factory.	23-10	B EB 1001
R7	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1 W	24-220K	B GB 2241
R8	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 1/2 W	23-10K	B EB 1031
R9	Resistor: fixed, composition, 470 ohms, $\pm 10\%$, 1/2 W	23-470	B EB 4711
R10A	Resistor: fixed, wirewound, 4306.1 ohms		
R10B	Resistor: fixed, wirewound, 1365.7 ohms		
R11A	Resistor: fixed, wirewound, 432.26 ohms		
R11B	Resistor: fixed, wirewound, 136.74 ohms		
R11C	Resistor: fixed, wirewound, 43.24 ohms		
R11D	Resistor: fixed, wirewound, 20 ohms		
R10A-R11D	(Part of Range Switch Assembly)		
R12	Resistor: fixed, composition, 27 ohms, $\pm 10\%$, 1/2 W (Part of Range Switch Assembly)	23-27	B EB 2701
R13	Resistor: fixed, composition, 150 ohms, $\pm 10\%$, 1/2 W (Part of Range Switch Assembly)	23-150	B EB 1511

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R14	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R15	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R16	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R17	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R18	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R19	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 6845
R20	Resistor: fixed, composition, 8,200 ohms, $\pm 10\%$, 2 W	25-8200	B HB 8221
R21	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1 W	24-47K	B GB 2731
R22	Resistor: fixed, composition, 8,200 ohms, $\pm 10\%$, 2 W	25-8200	B HB 8221
R23	Resistor: fixed, composition, 8,200 ohms, $\pm 5\%$, 2 W	25-8200-5	B HB 8225
R24	Resistor: fixed, composition, 47 ohms, $\pm 10\%$, 1/2 W	23-47	B EB 4701
R25	Resistor: fixed, composition, 560,000 ohms, $\pm 10\%$, 1/2 W	23-560K	B EB 5641
R26	Resistor: fixed, composition, 560,000 ohms, $\pm 10\%$, 1/2 W	23-560K	B EB 5641
R27	Resistor: fixed, wirewound, 125 ohms, $\pm 10\%$, 2 W	26-58	Dale Products GS-2
R28 ABC	Resistor: fixed, wirewound, 3 section: 10, 270, 10 ohm	400D-26	HP
R29	Resistor: variable, wirewound, 0 - 5,000 ohms, $\pm 10\%$, 3 W	210-7	G #21-010-357

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R30	Resistor: fixed, composition, 510,000 ohms, ±5%, 1/2 W	23-510K-5	B EB 5145
R31	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	23-47	B EB 4701
R32	Resistor: fixed, composition, 47,000 ohms, ±10%, 1 W	24-47K	B GB 4731
R33	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R34	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R35	Resistor: fixed, composition, 2,400 ohms, ±5%, 1 W	24-2400-5	B GB 2425
R36	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W	23-750K-5	B EB 7545
R37	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W	23-750K-5	B EB 7545
R38	Resistor: fixed, composition, 120 ohms, ±10%, 1 W	24-120	B GB 1211
R39	Resistor: fixed, composition, 510,000 ohms, ±5%, 1/2 W	23-510K-5	B EB 5145
R40	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	23-47	B EB 4701
R41	Resistor: fixed, composition, 47,000 ohms, ±10%, 1 W	24-47K	B GB 4731
R42	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R43	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R44	Resistor: fixed, composition, 2,400 ohms, ±5%, 1 W	24-2400-5	B GB 2425
R45	Resistor: fixed, composition, 1 megohms, ±10%, 1/2 W	23-1M	B EB 1051
R46	Resistor: fixed, composition, 1 megohms, ±10%, 1/2 W	23-1M	B EB 1051
R47	Resistor: fixed, composition, 120 ohms, ±10%, 1 W	24-120	B GB 1211

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R48	Resistor: fixed, composition, 430,000 ohms, $\pm 5\%$, 1/2 W	23-430K-5	B EB 4345
R49	Resistor: fixed, composition, 47 ohms, $\pm 10\%$, 1/2 W	23-47	B EB 4701
R50	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1 W	24-47K	B GB 4731
R51	Resistor: fixed, composition, 3,300 ohms, $\pm 10\%$, 1 W	24-3300	B GB 3321
R52	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 2 W	25-10K	B HB 1031
R53	Resistor: fixed, composition, 120 ohms, $\pm 10\%$, 1 W	24-120	B GB 1211
R54	Resistor: fixed, composition, 51 ohms, $\pm 5\%$, 1 W	24-51-5	B GB 5105
R55	Resistor: fixed, composition, 270,000 ohms, $\pm 10\%$, 1 W	24-270K	B GB 2741
R56	Resistor: fixed, composition, 27,000 ohms, $\pm 10\%$, 1 W	24-27K	B GB 2731
R57	Resistor: fixed, composition, 27,000 ohms, $\pm 10\%$, 2 W	25-27K	B HB 2731
R58	Resistor: fixed, composition, 680 ohms, $\pm 10\%$, 1 W	24-680	B GB 6811
R59	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$, 1 W	24-470K	B GB 4741
R60	Resistor: fixed, composition, 27,000 ohms, $\pm 10\%$, 2 W	25-27K	B HB 2731
R61	Resistor: fixed, composition, 27,000 ohms, $\pm 10\%$, 2 W	25-27K	B HB 2731
R62	Resistor: fixed, composition, 132,000 ohms, $\pm 1\%$, 2 W	31-132K	Electra Type DC-1
R63	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$, 1 W	24-470K	B GB 4741
R64	Resistor: fixed, composition, 100,000 ohms, $\pm 1\%$, 1 W	31-100K	Electra Type DC-1
R65	Resistor: fixed, composition, 33 ohms, $\pm 10\%$, 1 W	24-33	AB GB 3301

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R66	Resistor: variable, wirewound, 0-3 ohms, $\pm 10\%$, 2 W, linear taper	210-3	Carter Radio Div Precision Parts Co. #MP3
	Binding Post:	149-4	HP
	Binding Post Nut:	149-5	HP
	Binding Post Insulator:	G-83A	HP
CR1, CR2	Crystal, type 1N82, silicon diode	212-1N82	EE
F1	Fuse: 1A, Withstands 200% overload for 25 seconds - for 115V operation	211-18	E, MDL-1
F1	Fuse: 1/2A, Withstands 200% overload for 25 seconds - For 230V operation	211-20	E, MDL-1/2
	Fuseholder:	140-18	E
I1	Lamp: 6-8V, .15A	211-47	O, #47
	Lampholder:	145-2	Signal Indicator #807BS
L1	RF Coil: 19 μ H	608A-60T	HP
	Knob, bar: Range Switch	37-19	Dimco Gray Co. 46A42256
M1	Meter:	112-6	HP
P1	Power Cable:	812-56	HP
S1A-D, C7 - 16, R10A-B, R11A-D, R12 - 19	Range Switch Assembly:	400D-19W	HP
S2	Toggle Switch, SPST	310-11	R. H. Fisher Co.
SR1	Rectifier, selenium:	212-101	N 6RS22GB1AT1
T1	Power Transformer:	910-113	HP
V1	Tube: 6CB6	212-6CB6	ZZ
V2	Tube: 6CB6	212-6CB6	ZZ
V3	Tube: 6CB6	212-6CB6	ZZ
V4	Tube: 6CB6	212-6CB6	ZZ
V5	Tube: 6CB6	212-6CB6	ZZ
V6	Tube: 6AX5/GT	212-6AX5GT	ZZ
V7	Tube: 6AU5	212-6AU5	ZZ
V8	Tube: 6CB6	212-6CB6	ZZ
V9	Tube: OB2	212-OB2	ZZ

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

LIST OF MANUFACTURERS CODE LETTERS
FOR REPLACEABLE PARTS TABLE

<u>Code Letter</u>	<u>Manufacturer</u>
A	Aerovox Corp.
B	Allen-Bradley Co.
C	Amperite Co.
D	Arrow, Hart and Hegeman
E	Bussman Manufacturing Co.
F	Carborundum Co.
G	Centralab
H	Cinch Manufacturing Co.
HP	Hewlett-Packard
I	Clarostat Manufacturing Co.
J	Cornell Dubilier Electric Co.
K	Hi-Q Division of Aerovox Corp.
L	Erie Resistor Corp.
M	Federal Telephone and Radio Corp.
N	General Electric Co.
O	General Electric Supply Corp.
P	Girard-Hopkins
R	International Resistance Co.
S	Lectrohm, Inc.
T	Littelfuse, Inc.
V	Micamold Radio Corp.
X	P.R. Mallory Co., Inc.
Z	Sangamo Electric Co.
AA	Sarkes Tarzian
CC	Sprague Electric Co.
DD	Stackpole Carbon Co.
EE	Sylvania Electric Products, Inc.
FF	Western Electric Co.
HH	Amphenol
II	Dial Light Co. of America
KK	Switchcraft, Inc.
LL	Gremer Mfg. Co.
MM	Carad Corp.
ZZ	Any tube having RETMA standard characteristics