INSTRUCTION MANUAL CHANGES

MODEL 400AB

VACUUM TUBE VOLTMETER

C12: change to -hp- Stock No. 18-31; Mfr., X

C26: change to -hp- Stock No. 18-40HP; Mfr., CC

C29: change to capacitor, fixed, electrolytic, 2 sections, 1500uf/sect., 15 vdcw; -hp- Stock No. 18-48HP; Mfr., CC

V1, V2: change to tube, electron, selected, 6CB6; -hp- Stock No. G-73W; Mfr., HP

V7: change to tube, electron, 6CB6; -hp- Stock No. 212-6CB6; Mfr., ZZ

Serial 1182 and above:

NOTE: The 1000:1 input voltage divider has been changed from a capacitive to a resistive type. References to a capacitive voltage divider should be changed accordingly: pg. 3-1 fig. 3; pg. 3-2 para. 3-2.

Page 4-9 fig. 6: call-out to C3 should read: "Adjust high frequency response on 3-volt range."

The text at the top half of page 4-4 should be changed to read as follows:

page 4-4

Calibration consists of two parts: (1) Adjusting the amplifier gain on the 1 volt range with R43 (see fig. 5). (2) Checking the frequency response adjustment of the 1000:1 divider on the 3 volt range. The compensation adjustment is made with C3. DO NOT DISTURB THIS ADJUSTMENT UNLESS A HIGH FREQUENCY STANDARD IS AVAILABLE. THIS ADJUSTMENT DRASTICALLY AFFECTS THE FREQUENCY RESPONSE OF THE INSTRUMENT ON THE 3 VOLT AND ABOVE RANGES.

Procedure:

a. Allow the instrument to heat for 5 minutes before calibrating.

b. Connect a low distortion test oscillator and an ac voltmeter accurate within 1/2% at 400 cps to the INPUT terminals of the Model 400AB.

c. Set the Model 400AB range swith to the 1 volt position and apply exactly 1 volt at 400 cps to the INPUT terminals.

d. Adjust R43 so that the instrument reads 1.00 volt.

This completes the basic calibration of the instrument. The following steps should be followed if suitable equipment is available for determining frequency response. An -hp- Model 410B, 400D voltmeter are excellent for this purpose.

e. Set the Model 400AB on the 3 volt range and apply 3 volts at 400 cps. Note the reading on the monitor meter.

f. Change the frequency to 500 kc and adjust the level until the monitor meter reads the same as at 400 cps. Adjust C3 to make the Model 400AB read the same as at 400 cps.

g. Check the response over the range of 100 kc to 600 kc. It may be desirable to adjust C3 slightly to split any error to obtain the best over-all accuracy.

Section 4-10 should read:

The high frequency response of the amplifier is affected by the value of C25, which never needs adjustment. The low frequency response at 10 cps is affected by the value of R56. Smaller values of resistance lower the response at 10 cps. The value of R56 is selected at the factory and should never need adjustment. Poor frequency response at 10 cps is usually due to weak tubes. V2 and V3 have the most affect. The amplifier has approximately 45 db of negative feedback which makes the frequency response almost independent of tube aging at mid-frequencies. Weak tubes will affect the frequency response some-what at 600 kc and 10 cps, where the feedback is less.

The 1000:1 resistive input divider is adjusted for flat frequency response with C3 on the 3-volt range. NO ATTEMPT TO ADJUST C3 SHOULD BE MADE UNLESS A REFERENCE VOLTMETER IS AVAILABLE WHICH HAS FLAT FREQUENCY RESPONSE FROM 400 cps TO 600 KC.

The Table of Replaceable Parts should be changed as follows:

R3,R4: change to resistor, matched, R3=10.31 megohms, R4=10.21K; -hp- Stock No. 400D-67; Mfr., HP

R5: delete this circuit reference

ADD R65: resistor, fixed, composition, 100 ohms, ±10%, 1/2 W; -hp- Stock No. 23-100; Mfr., B

ADD R66: resistor, 2.2 megohms, ±10%, Electrical value adjusted at factory; average value shown.

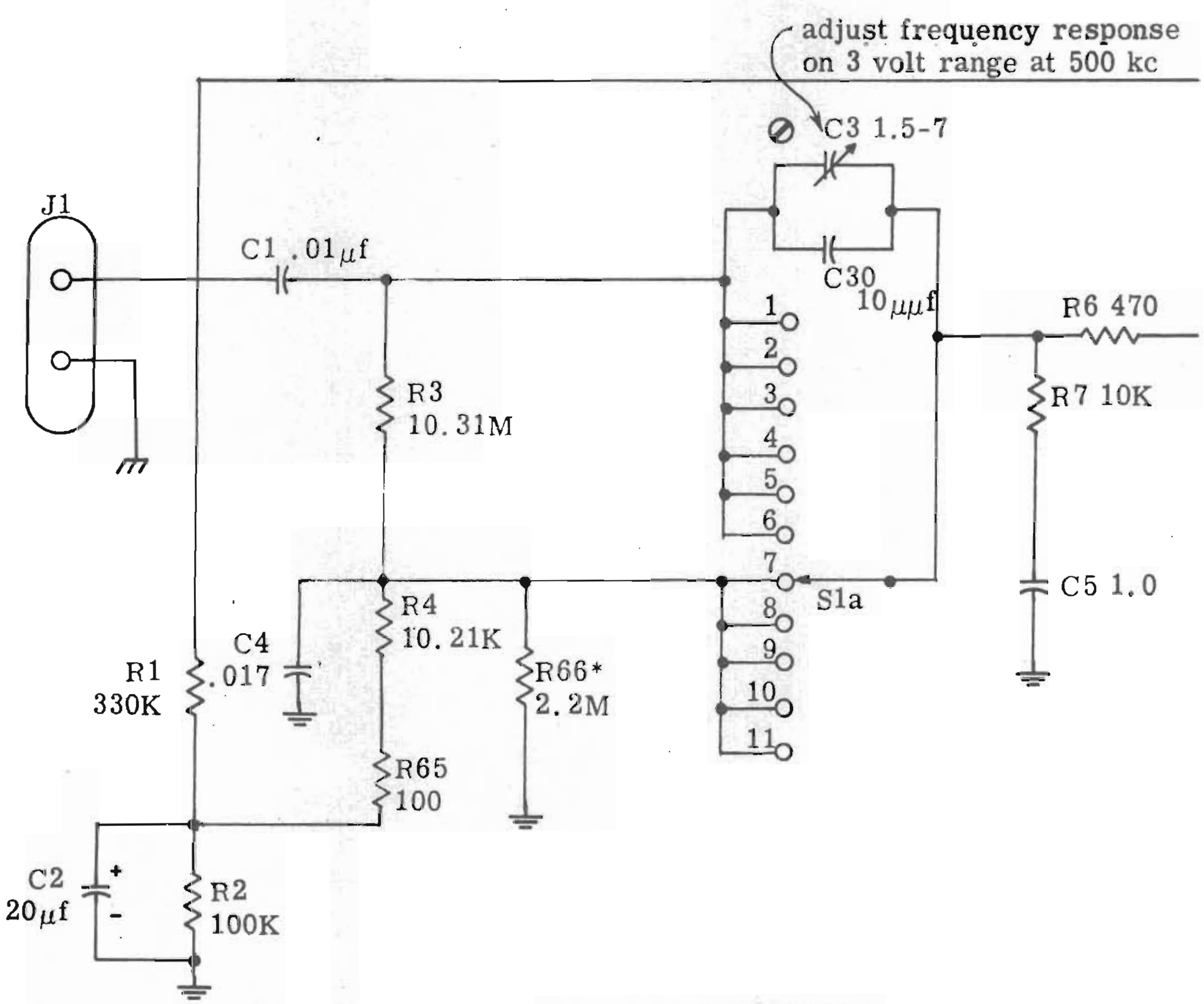
The schematic diagram should be changed as shown in the following sketch.

MODEL 400 AB

PRODUCATION CHANGE

Serial 1182 and Above

Input voltage divider changed from capacitive to resistive type.



* Value adjusted at factory.

OPERATING AND SERVICING MANUAL

FOR

MODEL 400AB

VACUUM TUBE VOLTMETER

Serial 982 and Above

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

TABLE 1. SPECIFICATIONS FOR MODEL 400AB

VOLTAGE RANGE:	0.3 mv to 300 volts. 11 ranges, selected with front panel switch. Full scale readings of: 0.003 volts, 0.1, 3.0, 100 0.01, 0.3, 10.0, 300 0.3, 1.0, 30
FREQUENCY RANGE:	10 cps to 600 KC.
ACCURACY:	With nominal line voltage ±10% (103 volts to 127 volts), overall accuracy is within ±2% of full scale, 20 cps to 100 KC, ±3% 10 cps to 600 KC.
CALIBRATION:	Reads rms value of sine wave. Voltage indication proportional to average value of applied wave. Linear voltage scales, 0 to 3 and 0 to 1.0; db scale, -12 db to +2 db, based on 0 dbm = 1 mw in 600 ohms, 10 db intervals between ranges.
INPUT IMPEDANCE:	10 megohms shunted by less than 25 μμf.
AMPLIFIER:	Output terminals are provided so voltmeter can be used to amplify small signals or monitor waveforms under test with an oscilloscope. At least 0.25 volts available from 600 ohm source. Amplifier response same as voltmeter above 20 cps.
POWER:	115/230 volts, ±10%, 50/1000 cps, approx. 75 watts.
SIZE:	Cabinet Mount: 11-1/2" high, 7-1/2" wide, 8-1/4" deep. Rack Mount: 19" wide, 7" high, 8-1/4" deep.
WEIGHT:	Cabinet Mount: Net 13 lbs.; shipping weight 19 lbs. Rack Mount: Net 16 lbs.; shipping weight 26 lbs.

TABLE OF CONTENTS

MODEL 400AB

VACUUM TUBE VOLTMETER

SECTION I

GENERAL

1-1 GENERAL DESCRIPTION

The Model 400AB is a compact vacuum tube voltmeter which will measure voltages from .003 volts full scale to 300 volts full scale over a frequency range from 10 cps to 600 KC. The input impedance is 10 megohms shunted by less than 25 $\mu\mu$f.

The basic accuracy of these measurements is ±2% of full scale indication on all ranges from 20 cps to 100 KC with a ±3% accuracy of full scale indications on all ranges over the entire range from 10 cps to 600 KC. It has a readable sensitivity to 0.3 millivolts which is sufficient to measure hum level and noise directly, as well as performing a variety of laboratory functions in measuring gain, network response, and output level.

The instrument is provided with output terminals so that it may be used as a high gain (40 db) broadband amplifier to increase the sensitivity of external equipment such as oscilloscopes or bridges.

1-2 DAMAGE IN TRANSIT

Should shipping damage become evident upon unpacking this instrument, follow the procedure outlined in the "Claim for Damage" section on the last page of this manual.

1-3 POWER TRANSFORMER CONVERSION

Should it be desired to convert the Model 400AB to operate from a 230v supply proceed as follows:

a. Remove the two bare wire jumpers on the terminal strip located on the right side of the instrument chassis above the power transformer. These jumpers connect the BLACK to the BLACK-GREEN lead and the BLACK-RED to the BLACK-YELLOW lead from the power transformer primary.

b. Insert a new jumper on the terminal strip which connects the BLACK-YELLOW to the BLACK-GREEN lead.

c. Change the line fuse to one with a 0.5 ampere slow-blow rating. As shown on the schematic diagram this alteration changes the primary windings of the power transformer from a parallel to a series arrangement.

1-4 ACCESSORIES AVAILABLE

Model 452A Capacitive Voltage Divider --

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

Maximum voltage:	25,000 volts
Frequency range:	25 cycles/sec. to 20 MC
Accuracy:	±3%
Division ratio:	1000:1
Input capacity:	15 $\mu\mu$f ±1 $\mu\mu$f

Model 454A Capacitive Voltage Divider --

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

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

Model 470A-470F Shunt Resistors --

These shunt resistors adapt the Model 400AB for measuring currents as small as 3 μa full scale.

Accuracy: ±1% to 100 KC, Models 480A-F:

±5% to 1 MC, Model 470A
±5% to 4 MC, Models 470B-F

Maximum power dissipation: 1 watt

Model	Shunt Resistance
470A	1 ohm
470B	1.0 ohm
470C	10.0 ohms
470D	100.0 ohms
470E	600.0 ohms
470F	1000.0 ohms

Model AC-60A Line Matching Transformer --

Adapts the Model 400AB 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.
Impedance, 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).

Model AC-60B Bridging Transformer --

Operates through the audio range to match or bridge the Model 400AB to balanced systems without disturbing the circuits under test.

Frequency range:	20 cps to 45 KC.
Impedance, primary:	600 ohms.
Terminating Resistance:	600 ohms or 10,000 ohms.
Insertion loss:	Less than 1 db at 1 KC.
Frequency response:	±1 db, 20 cps to 20 KC; ±2 db to 45 KC.
Distortion:	Less than 0.1%, 50 cps to 20 KC; Less than 0.5% at 20 cps.
Balanced:	Better than 60 db.
Maximum level:	+15 dbm, (4.5 volts at 600 ohms).

SECTION II

OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

Power Switch (ON)	This toggle switch controls the power supplied to the instrument from the power line. In the ON position the red pilot lamp will glow.
Range Switch (DB VOLTS)	This rotary switch selects the full scale voltage or the zero dbm decibel scale to be used.
INPUT	These binding posts of the universal type are the input terminals for the instrument. The lower terminal marked G is connected to the chassis. The terminals are arranged to accept a 3/4" spaced double-banana plug.
OUTPUT	These universal type binding posts are the output terminals for the amplifier section of the voltmeter.
FUSE	This fuseholder, located on the rear of the instrument, contains a 1 ampere cartridge fuse with a slow blow rating. When operating the instrument converted for 230 volt line voltage, the fuse should have a 0.5 ampere slow blow rating.
POWER CORD	The three conductor power cable is terminated in a polarized three-prong male connector. This termination is provided upon recommendation of NEMA and for the protection of operating personnel. Instead of breaking off the ground terminal, it is recommended that an adaptor be used to mate the three-terminal plug with a two terminal receptacle. This will (1) provide operating personnel with the safety advantage the polarized plug offers, and (2) retain the connector for use when the plant is equipped with grounded female receptacles.

2-2 OPERATION, GENERAL

When the Model 400AB is received from the factory, the meter pointer should indicate zero before the instrument is turned on as explained in paragraph 4-8. After the instrument is turned on, the meter pointer may show an indication as high as one scale divisions of the 0-1 scale. This effect is normal and does not impair the accuracy of the instrument.

Stray voltages in the vicinity of the instrument frequently cause erroneous pointer deflection when the instrument is operating on its lowest ranges. The condition arises because of the high input impedance of the instrument together with its amplifier gain.

When making measurements from a low impedance source, shielded leads will reduce the induced pickup.

If measurements are made from a high impedance source, stray pickup can also affect the meter indication. Shielded leads will reduce the pickup, but at the same time the shielding will increase the capacity shunted across the source, and may cause excessive circuit loading at high frequencies. In the case of low level measurements the use of an oscilloscope is recommended to monitor the waveforms under test.

The Model 400AB is an average responding device as discussed in paragraph 2-6 and as such has certain innate properties which affect measurement. Although the meter is calibrated RMS VOLTS the markings refer to the measurement of a true sine wave. If the signal under measurement contains harmonically related sinusoids, measurement errors will be encountered as described in Table 2-1.

2-3 VOLTAGE MEASUREMENT

Connect the instrument to a proper source. Allow about five minutes for the instrument to reach a stable operating condition after it is turned on.

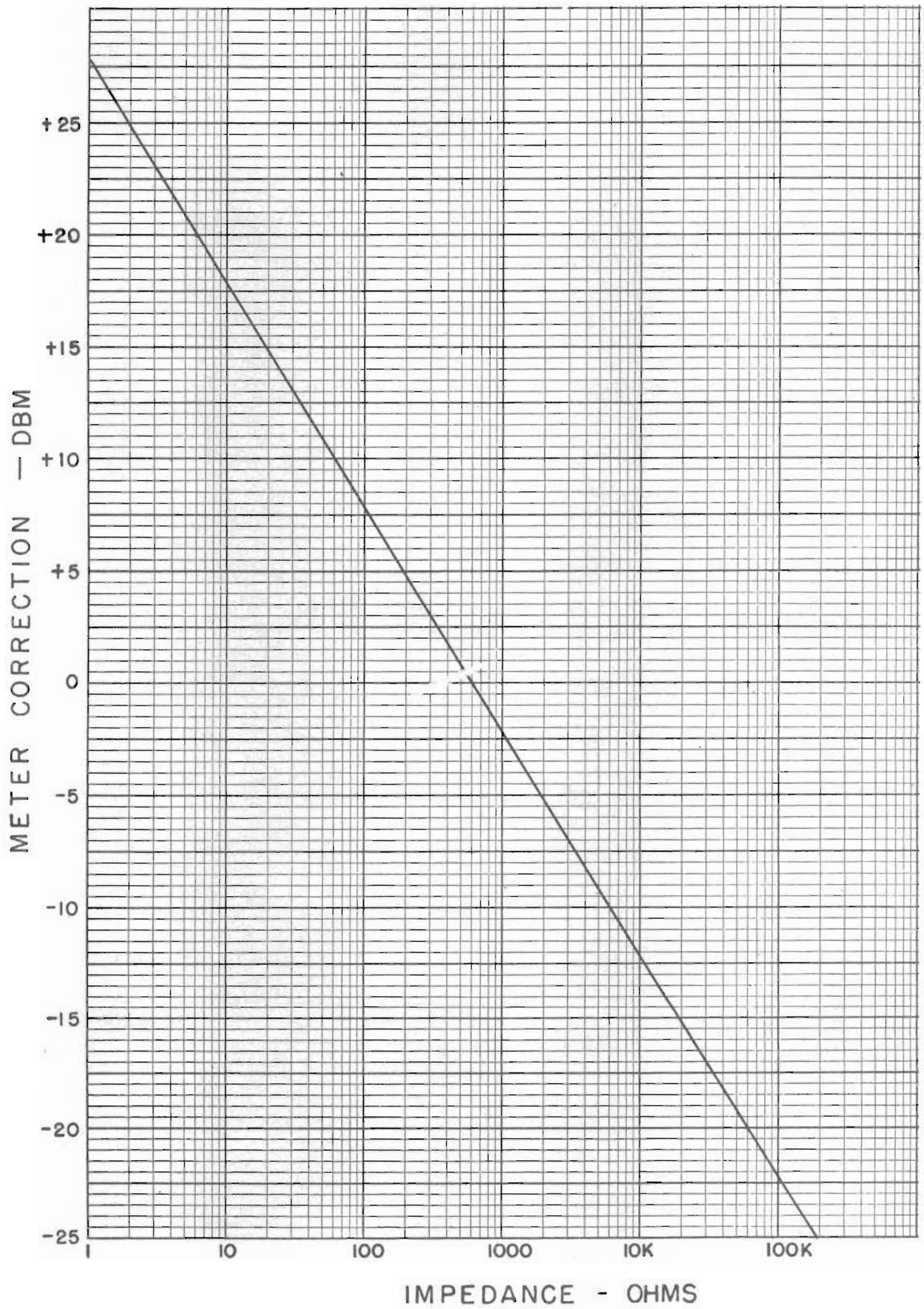


Fig. 2 Impedance Correction Graph

a. Connect the signal under measurement across in INPUT terminals.

b. The voltage under measurement equals the meter indication multiplied by the range switch position divided by the full scale value of the appropriate meter scale.

EXAMPLES

Meter Indication	Range Position	Meter Scale	Signal Volts
1.6	30	3	16
.7	.01	1	.007

2-4 DB MEASUREMENT

Measurements in terms of decibels are made the same way as voltage measurements except that the meter indication is read on the db scale. The level in dbm is the algebraic sum of the meter db indication and the range switch position when the measurement is made across 600 ohms. However, level differences may be read directly as db when the levels are measured across equal impedances.

EXAMPLES
(Across 600 Ω)

Meter Indication	Range Position	dbm
-6	-10	-16
+1	-20	-19

ACROSS EQUAL LOADS

Meter Indication	Range Position	db
A + 2	+10	+12
B - 3	-10	-13

db Difference = A - B
= 12 - (-13)
= 25 db

dbm ACROSS LOADS NOT EQUAL TO 600 OHMS

To obtain the level in dbm when making measurements across impedances other than 600 ohms the impedance correction graph, shown in Figure 2, is provided. The corrected dbm level is the algebraic sum of the instrument reading and the correction from the graph.

EXAMPLE

400AB Indication	Load	Graph Correction	dbm
+30	90 ohms	+8(at 90)	+38

2-5 USING THE 400AB AS AN AMPLIFIER

The Model 400AB may be used as an amplifier to increase the sensitivity of external measuring equipment. The maximum voltage gain is approximately 100 when the range switch is in the 3 millivolt position, with at least 0.25 volts from a 600 ohm source appearing across the OUTPUT terminals.

Higher voltages may be applied to the amplifier INPUT provided that the position of the range switch indicates a full scale voltage equal to or greater than the input voltage. The amplifier gain is decreased in 10 db steps as the range switch is advanced toward the high end from the 3 millivolt position. At the 0.3 volt position of the range switch the amplifier has a gain of unity.

2-6 AVERAGE RESPONDING METERS

The Model 400AB is an average responding device calibrated to indicate rms values. It should be remembered that the rms calibrations on the meter face are based on the measurement of a true sine wave, and that the calibration is valid only when measuring a true sine wave.

Meters of the average responding type respond to those voltages which represent the absolute average of the variations from the dc mean value. Since the rms value of a sine wave is 1.11 times the absolute average, an average responding meter indicates 1.11 times the absolute average of any complex ac wave when the meter face is calibrated for the rms value.

Of particular interest in normal measurement is the sine wave partially distorted by harmonically related sinusoids.

If the waveform under measurement contains appreciable harmonics, errors of the magnitude shown in Table 2-1 may be anticipated.

This discussion in no way characterizes a limitation of the Model 400AB since these conditions are common to all average responding devices. It is mentioned to insure that any operator engaged in measurement be fully apprised of the signal characteristics he measures. Input signals of a doubtful nature should be viewed on an oscilloscope to prevent unexpected results when using accurate measuring devices.

TABLE 2

EFFECT OF HARMONICS ON MODEL 400AB VOLTAGE MEASUREMENTS		
Input Voltage Characteristics	True RMS Value	Value Indicated
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

SECTION III

THEORY OF OPERATION

3-1 GENERAL

Figure 3 shows that the Model 400AB consists of an input system which acts as a voltage divider, a wide range amplifier which amplifies the ac input signal, and a rectifier and meter section which converts the ac voltage to a dc current presented by the meter. The functions of these sections will be discussed separately in the following paragraphs:

3-2 Input Voltage Divider

3-3 Voltmeter Amplifier

3-4 Meter and Rectifier

3-5 Power Supply

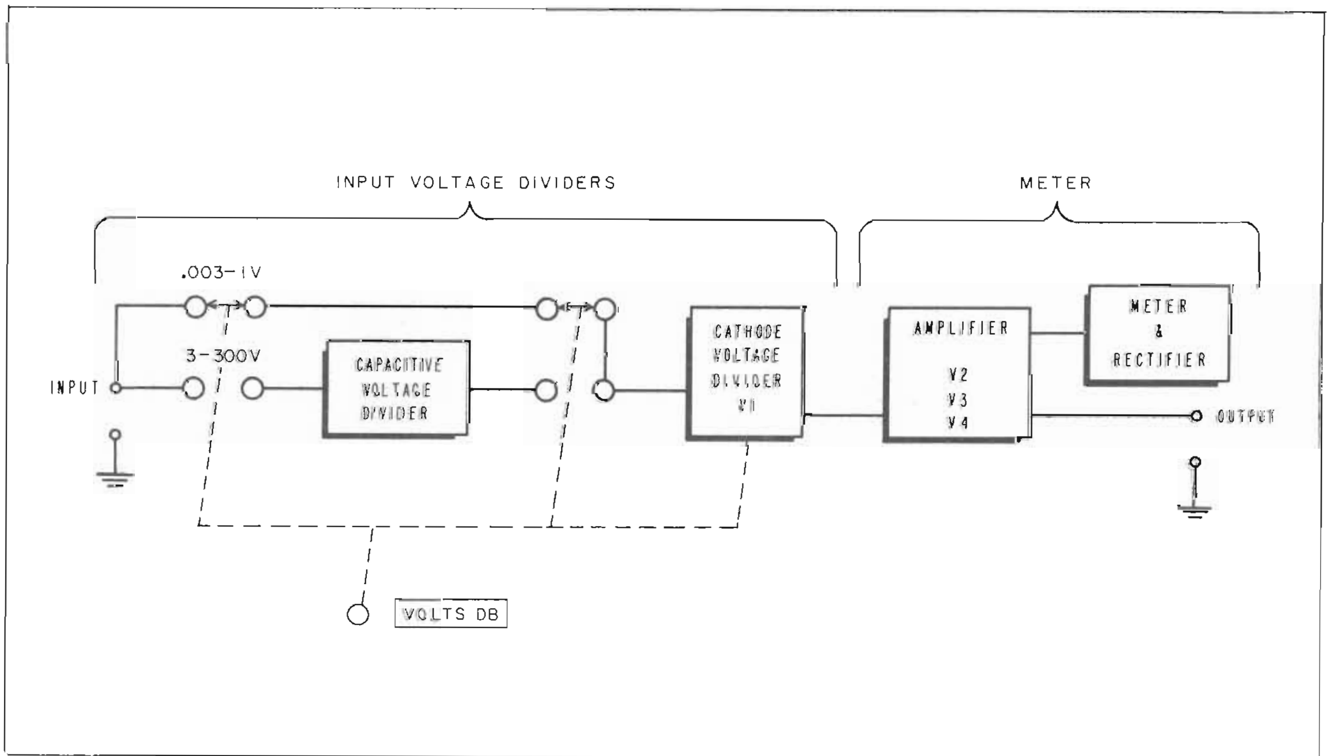


Fig. 3 Circuit Block Diagram

3-2 INPUT VOLTAGE DIVIDER

The voltage divider section consists of two separate voltage dividers, one of which is a capacitive voltage divider, and the other is the precision wound cathode resistor of V1.

The switching sequence from the .003 volt position to the 1 volt position of the range switch covers the entire range of the cathode voltage divider in 10 db steps of attenuation.

At the 3 volt position the capacitive voltage divider consisting of C3, C4, R3, and R4 is placed into the circuit and the entire switching sequency of the cathode voltage divider is repeated. In this manner the cathode voltage divider is used twice over the voltage range: once with and once without the input capacitive voltage divider.

3-3 VOLTMETER AMPLIFIER

The voltmeter amplifier V2, V3, and V4 is a straight forward frequency compensated circuit accepting the ac signal from the cathode follower V1 and furnishing two outputs with a gain of 40 db from V2 to V4. One output drives the rectifier and meter, while the other furnishes a signal across the OUTPUT terminals.

3-4 METER AND RECTIFIER

In the meter and rectifier section of the instrument the amplifier furnishes an ac signal to the rectifier section consisting of CR1 and CR2 which converts the ac voltage into a dc current which, in turn, is measured by the meter. The polarity of these two crystals is such that on each half cycle, they alternately charge and discharge the capacitors C23 and C24 through the meter in the same direction, as shown in Figure 4.

The two capacitors also furnish coupling to the feedback loop to the amplifier first stage V2. This negative feedback implicit in the loop consisting of R43, R22 and C25 serves to make the instrument more independent of tube variations, power supply changes, and circuit constants as well as to flatten the response of the amplifier.

3-5 POWER SUPPLY

The power supply consists of a full wave rectifier V5, a series regulator V6, a control tube V7, and a reference tube V8. Output ripple is coupled back to the control tube through capacitor C27.

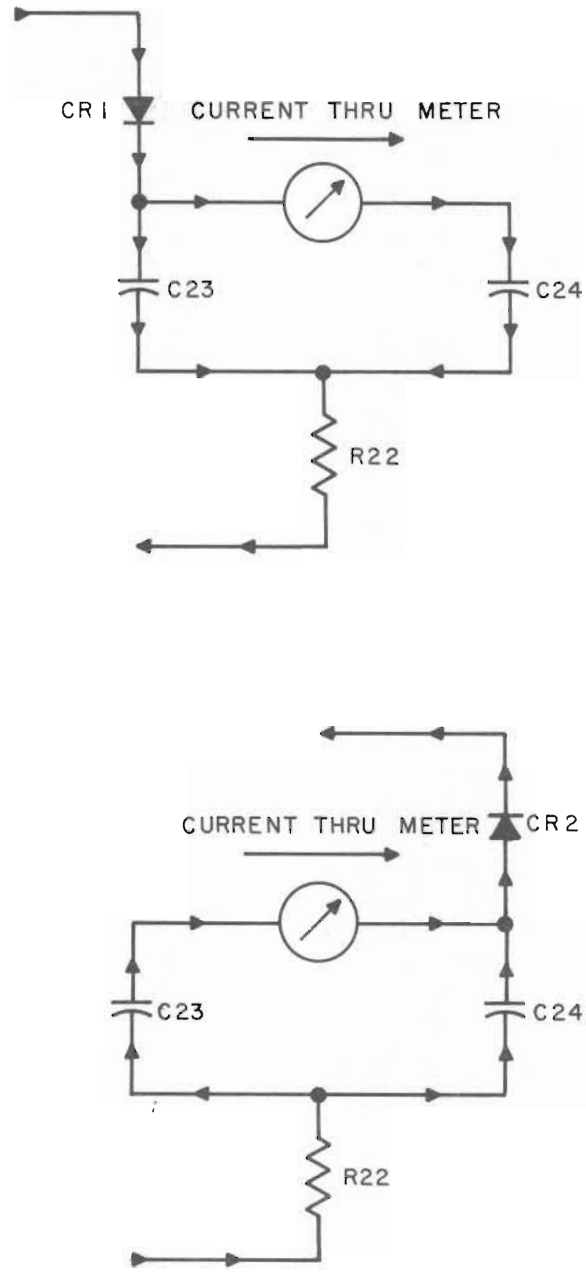


Fig. 4. Partial Schematic Showing Rectifier Action

SECTION IV

MAINTENANCE

4-1 INTRODUCTORY

Maintenance and service procedures are contained in this section in the following paragraphs.

4-2 CASE REMOVAL

To remove the case from the instrument, remove the two screws on the rear panel of the cabinet. Slide the case to the rear free of the instrument body. The bezel ring remains attached to the instrument body.

4-3 SERVICING EQUIPMENT REQUIRED

a. A dc voltmeter with a sensitivity of 20,000 ohms per volt or better a dc VTVM. (Such as the hp Model 410B.)

b. An ac voltmeter accurate within 1% of full scale at 400 cps.

c. A low distortion test oscillator. (Such as the hp Model 650A.)

4-4 TROUBLE LOCALIZATION

Electrical trouble shooting should be preceded with a visual inspection. Look for signs of damage, burned out components, overheating, looseness of parts, or cracks in printed wiring which, if not trouble sources themselves, suggest future trouble areas. A cold tube found simply by touch may save considerable time and effort in restoring the instrument to operation. The voltage and resistance diagram on the reverse side of the schematic diagram sheet is frequently of assistance in localizing unknown difficulties.

The Model 400AB consists of two major sections for the purpose of trouble shooting, and these sections should be checked in the following order:

a. Power Supply: Check the power supply voltages as shown in the schematic diagram. See paragraph 4-5 for instructions.

b. Voltmeter and Amplifier: Check the calibration and gain of the voltmeter and amplifier. See paragraph 4-6.

The chart in Table 4-1 is included to assist in analyzing common difficulties, and it is keyed to appropriate paragraphs in the text.

TABLE 4-1. TROUBLE SHOOTING CHART

SYMPTOM	POSSIBLE CAUSE	PARAGRAPH
Overall Instability	Inadequate power supply regualtion	4-5
Excessive noise and microphonics	Defective V1 or V2	4-7
Nonlinear meter tracking	Defective CR1 or CR2	4-6
Poor meter Calibration	R43 and/or C3 out of adjustment	4-6
Excessive residual meter reading	Noisy V1 or V2 Hum and ripple	4-7 4-8, 4-9
Hum, noise	Defective V6, V7, V8	4-5, 4-7
	Defective filter capacitors or broken ground joints	4-9

4-2 9/21/56 Serial 683

4-5 POWER SUPPLY

Before starting any service work check the power supply voltage between pin 8 of V6 and ground with a dc voltmeter. The voltage should be between 295 and 300 volts dc.

If low: Possible defective rectifier V5 or regulator V6. Replace if necessary.

If high: Possible defective control tube V7. Replace if necessary.

If erratic: Possible defective reference tube V8.

The regulated output requires no adjustment, except that erroneous output voltage reading can indicate faulty regulator action.

Check the regulation of the power supply circuit by varying the line voltage from 103v ac through 127v ac. The B+ voltage should exhibit little observable change through this range, less than ±1 volt.

DC FILAMENT ADJUSTMENT

a. Measure the dc voltage across C29 and ground, as shown in Figure 6.

b. Adjust R55, shown in Figure 6, as necessary to bring this voltage to 6.3v dc, with a line voltage of 115v.

4-6 VOLTMETER CALIBRATION AND GAIN

Weaknesses in this section are easiest to trace when the line voltage is reduced to approximately 103 volts ac with a known input voltage at a frequency of 10 cycles. Under these conditions a tube with insufficient emission (V2, V3, or V4) will be readily apparent, because the feedback around the amplifier is least at the low frequencies and the voltmeter will not be in calibration within specifications. The use of higher frequencies for a calibration check might permit the feedback to compensate for the weak stage. This check should be performed when any tube is replaced in the voltmeter amplifier to be sure that the replacement tube possesses normal gain characteristics. It has been found, for example, that replacement tubes in the V3 position may carry plate voltage changes from tube to tube over a range of 110 vdc to 145 vdc or greater. When V3 is replaced its plate voltage should be measured to insure that it is between 110v to 145v dc. Generally, variations outside this range degrade the calibration of the instrument at 10 cps.

The first step in calibration adjustment consists of adjusting the amplifier gain on the 1 volt range with R43 shown in Figure 5. The second step adjusts the input voltage divider on the 3 volt range with C3 shown in Figure 6.

After allowing the instrument to reach stable operating temperature the procedure is as follows:

a. Connect a low distortion test oscillator and an ac voltmeter (accurate to 1% full scale at 400 cps) to the INPUT terminals of the Model 400AB.

b. Set the Model 400AB range switch to the 1 volt position, and apply 1 volt (as read on the external voltmeter) at 400 cps to the INPUT terminals.

c. Adjust R43 (Fig. 5) so that the 400AB indication agrees with that of the external ac meter (1 volt full scale.)

d. Set the 400AB range switch to the 3 volt position and apply 3 volts at 400 cps to the INPUT terminals.

e. Adjust C3(Fig. 6) so that the 400AB indication agrees with that of the external ac voltmeter (3 volt full scale).

If instrument cannot be calibrated, usually the crystal rectifiers are at fault, poor meter tracking, i. e: - a non-linear error across the scale, indicates poor crystals which should be replaced.

When replacing amplifier tubes, consult paragraph 4-7.

4-7 TUBE REPLACEMENT

Any tube in the Model 400AB may be replaced with another of the same type having standard RETMA characteristics. Whenever a tube is replaced check the following chart.

CAUTION: The diodes used in the Model 400AB rectifier-meter circuit are special high performance junction type silicon diodes manufactured by the Hewlett-Packard Company, and must be obtained from hp. The part number given this silicon diode is G111A and replacements should be ordered by this number. These diodes are of the junction type. Because the junction is less than 1/2 mil in diameter, extra care must be taken not to subject them to excessive mechanical shock. Dropping them on a table or on the floor, etc. may cause a mechanical failure at the junction. When installed in the instrument, however, the diodes will withstand any shock which can be withstood by the instrument as a whole.

TABLE 4-2. TUBE REPLACEMENT CHART

TUBE	FUNCTION	ADJUSTMENT REQUIRED
V1	Input Cathode Follower	Calibrate Voltmeter, Paragraph 4-6, 4-9
V2, 3, 4	Voltmeter Amplifier	See paragraph 4-6 and adjust amplifier gain steps a, b, c. Also see para. 4-10.
V5	Rectifier	Paragraph 4-5
V6	Series Regulator	Paragraph 4-5
V7	Regulator Control Tube	Check B+ Voltage, Paragraph 4-5
V8	Reference Tube	See Paragraph 4-5

4-8 METER ZERO ADJUSTMENT

Zero set the voltmeter with the instrument turned OFF. Use the mechanical adjustment on the meter to zero the pointer. Turn the adjustment continuously in a clockwise direction to set zero and approach the zero from on-scale.

When the instrument is turned on, the meter pointer may rise above zero, but unless this residual reading exceeds two scale divisions when the range switch is on the 300v position, (on the 0-1 scale) the accuracy of the instrument is not impaired. However, when the residual reading exceeds one scale division refer to the following paragraph.

4-9 RESIDUAL METER READING

Excessive residual meter displacement can be caused by noise or hum in the voltmeter amplifier or by ripple in the power supply. When the effect is present, short circuit the INPUT terminals and change V1 and/or V2. Check the dc filament voltage. (6.3 vdc across point shown in Figure 6 and chassis). The 120 cycle ripple on the dc filaments should be less than .05 v rms.

Before checking noise or excess hum, be sure that a residual meter reading is not caused by an external rf field or by ground current effects in the measurement set-up before suspecting the Model 400AB of faulty operation. In checking hum and noise start with the power supply rectifier and regulator tubes, replace if necessary. Check filter capacitors in power supply. Check decoupling capacitors in B+ circuit. Check all ground connections for broken solder joints.

Measure noise on B+ at pin 8, V6 with another 400AB or 400D. This residual noise should be less than 2 mv.

4-10 FREQUENCY RESPONSE

High frequency compensation is established at the factory by value adjustment of the parallel network: R57, R58, and R59. No further adjustment of this network should be required.

No adjustment for frequency response is provided on the instrument since the 45 db of negative feed-back around the amplifier so lessens the effects of tube characteristics that such adjustment is unnecessary. However, the response of the instrument can be affected at 10 cycles if replacement tubes do not possess standard RETMA characteristics in the V2 and V3 positions. Selection of tubes with normal gain characteristics for these two positions may be necessary.

SERVICING PRINTED CIRCUIT BOARDS

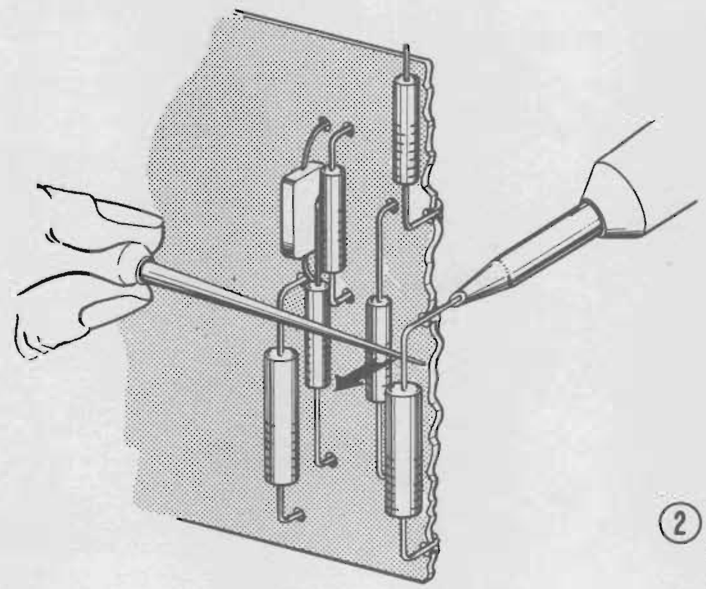
CAUTION

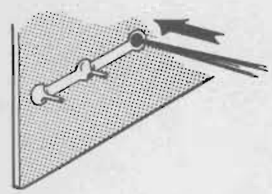
When servicing printed circuits DO NOT push or pull wires in such a way as to raise the printed wiring from the board.

When soldering leads, use 50 watt iron or smaller. Apply heat sparingly to the leads on the part to be replaced, not to the printed wiring on the board.

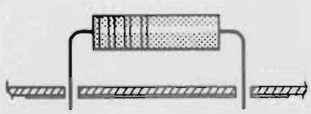
Before installing new parts, clean holes to receive new part without forcing. Have new leads tinned and if necessary fluxed to receive solder quickly with a minimum of heat and without residue.

(1) APPLY HEAT SPARINGLY TO LEAD OF PART TO BE REPLACED. REMOVE PART FROM CARD AS IRON HEATS THE LEAD.

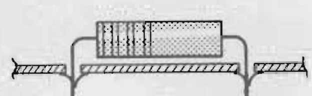




(2) USING A SMALL AWL, CAREFULLY CLEAN INSIDE OF HOLE LEFT BY OLD PART.



(3) BEND CLEAN LEADS ON NEW PART AND CAREFULLY INSERT THROUGH HOLES ON BOARD.



(4) HOLD PART AGAINST BOARD AND SOLDER LEADS.

Diagram showing how to replace parts mounted on printed circuit boards

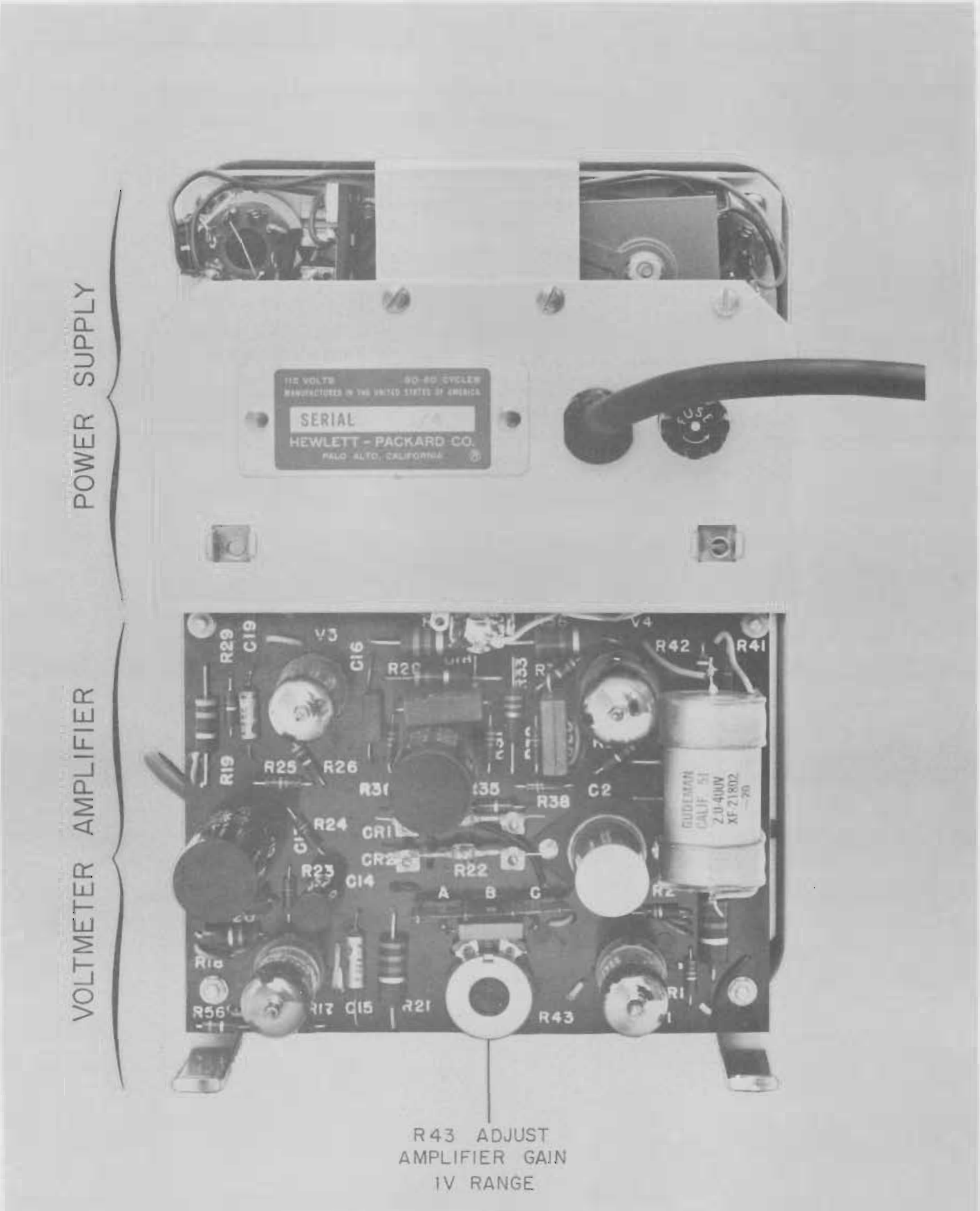


Fig. 5. Rear View Cover Removed

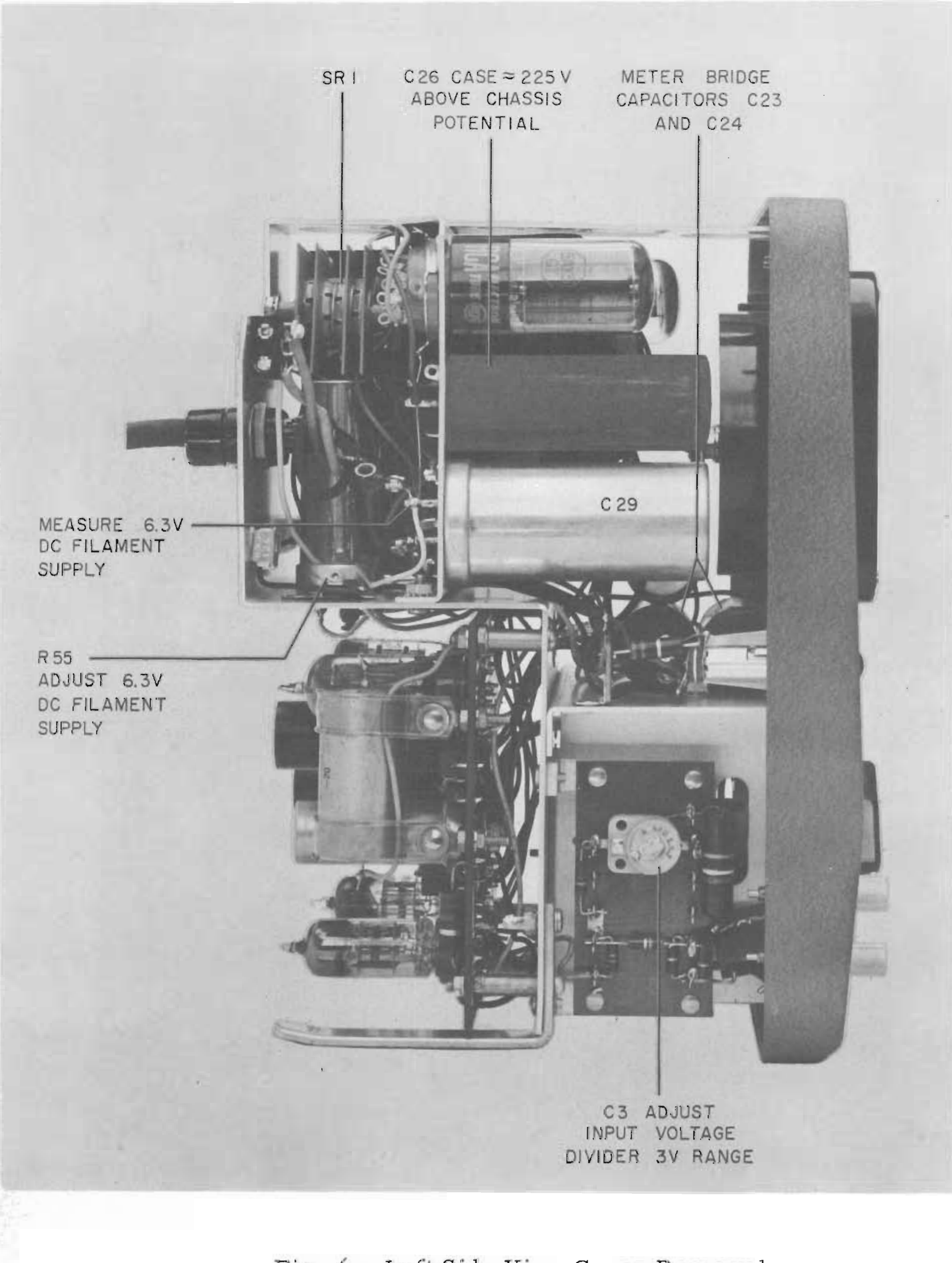


Fig. 6. Left Side View Cover Removed

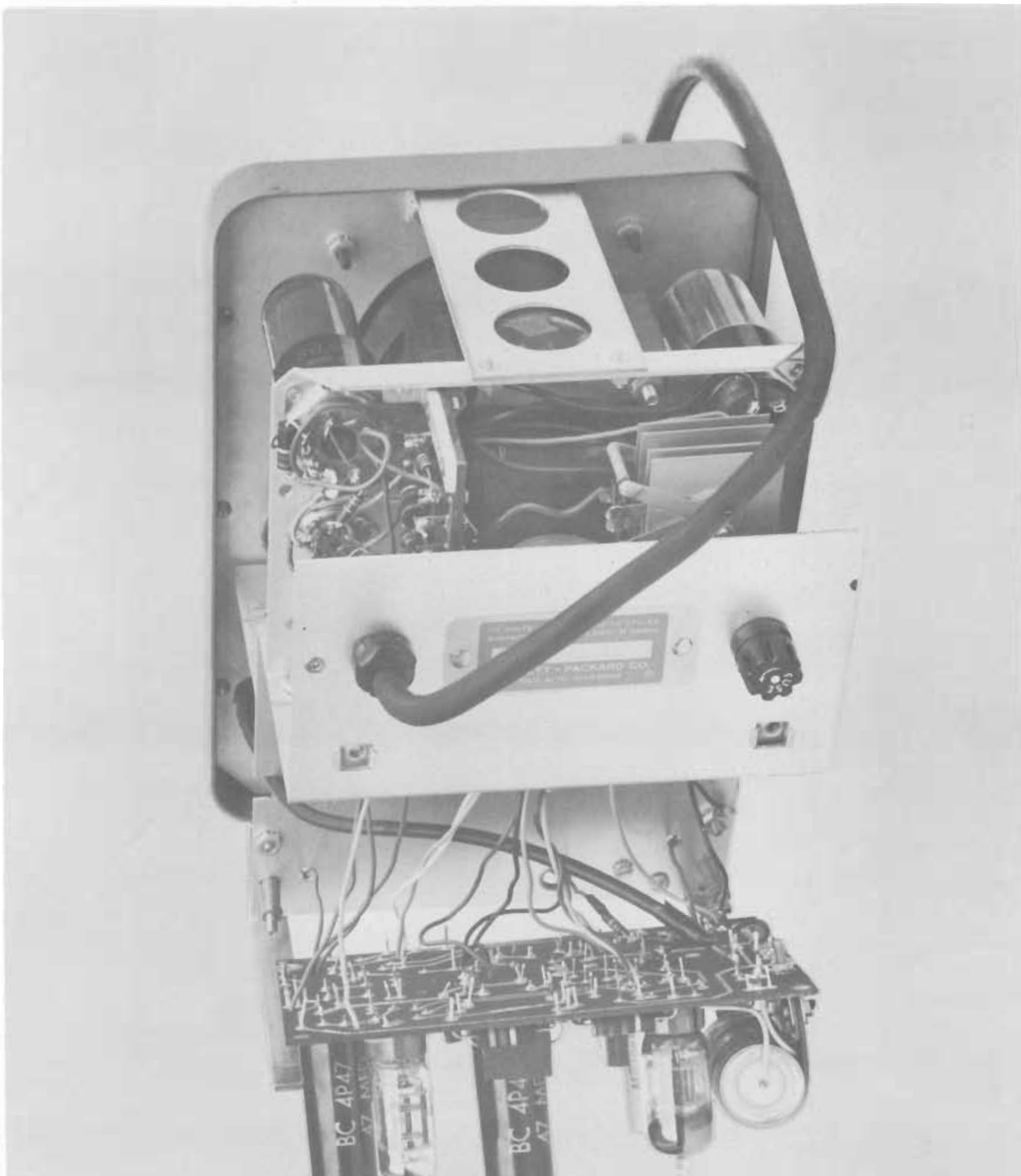
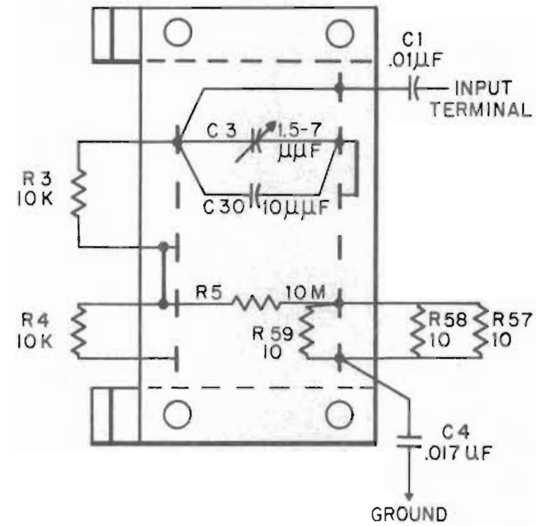
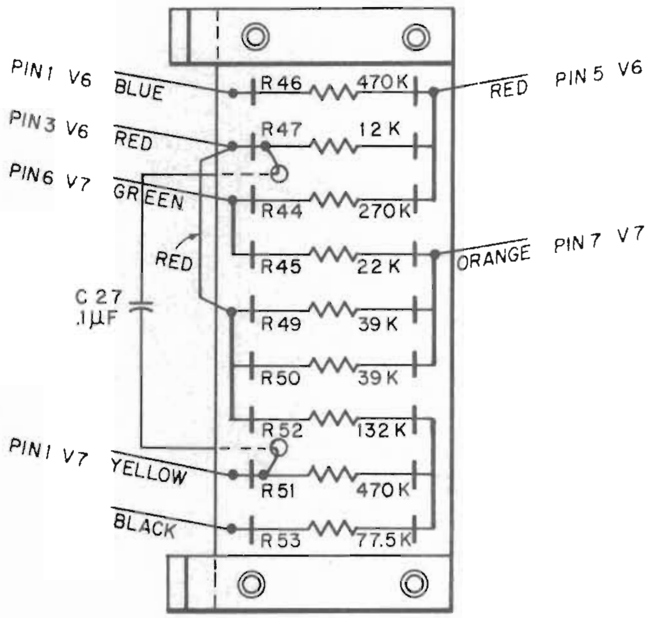


Fig. 7. View Showing Amplifier Card Aside for Servicing



RESISTOR BOARD
A

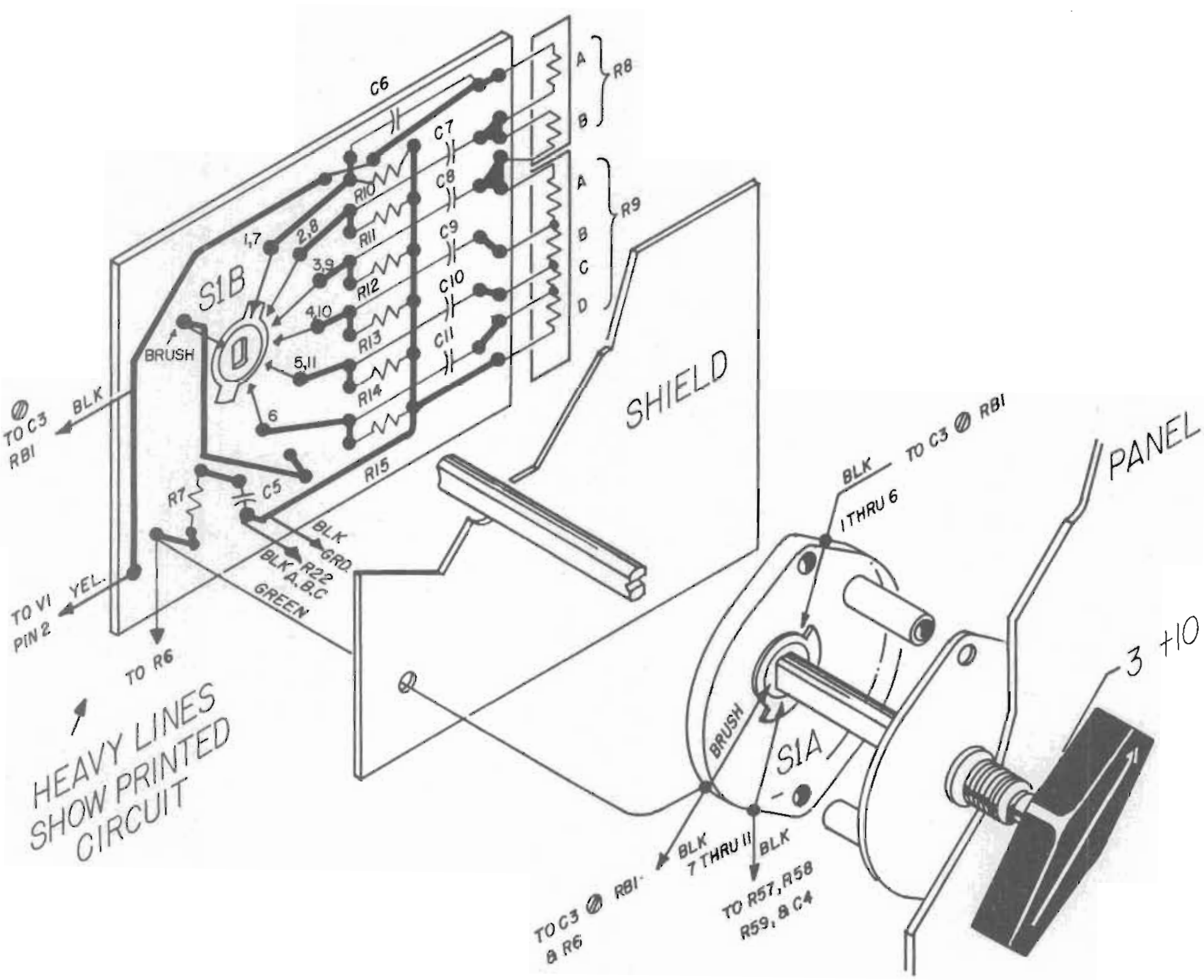


RESISTOR BOARD
B

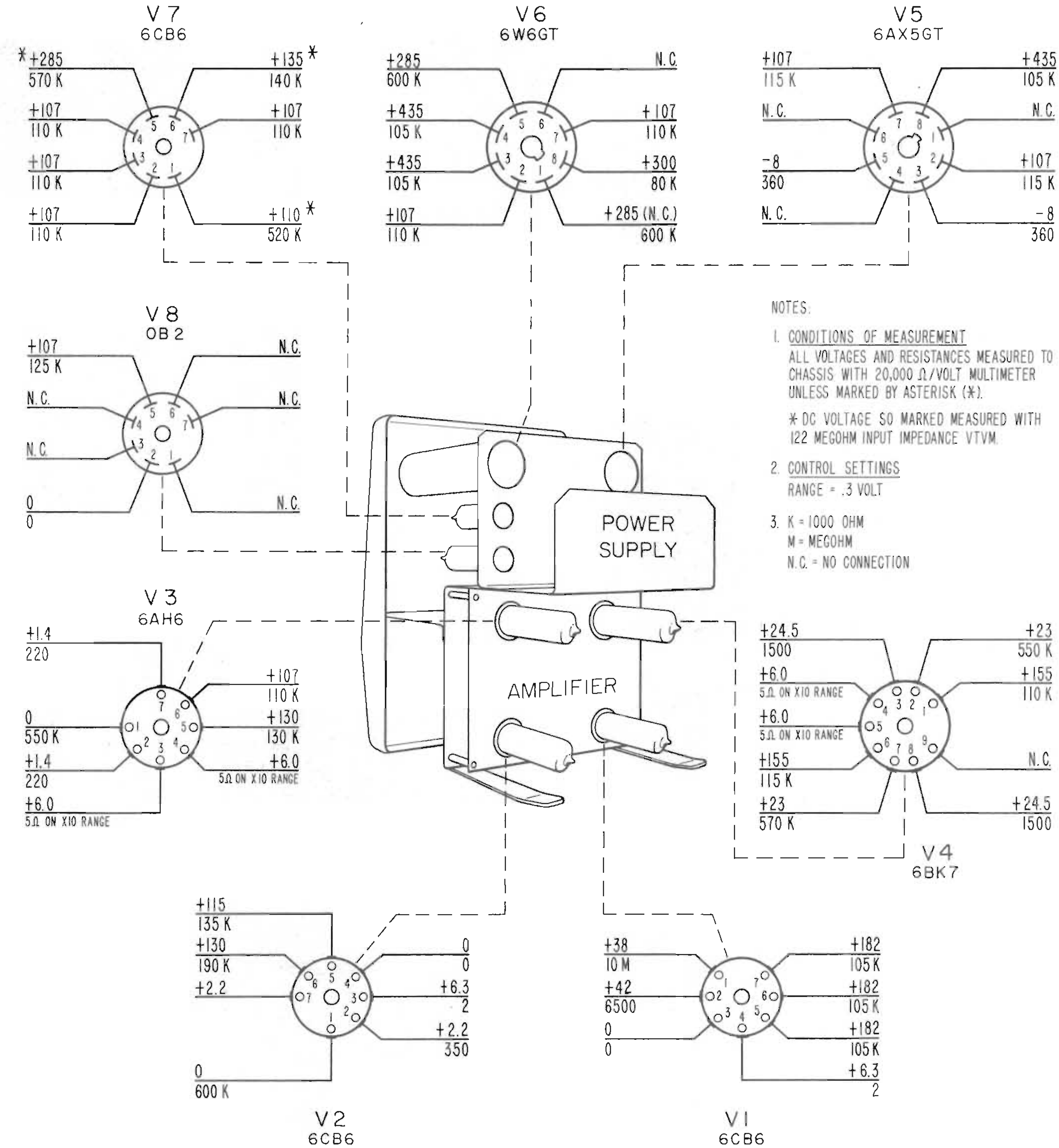
Resistor Board Details

NOTE: ON RESISTOR BOARD B ----

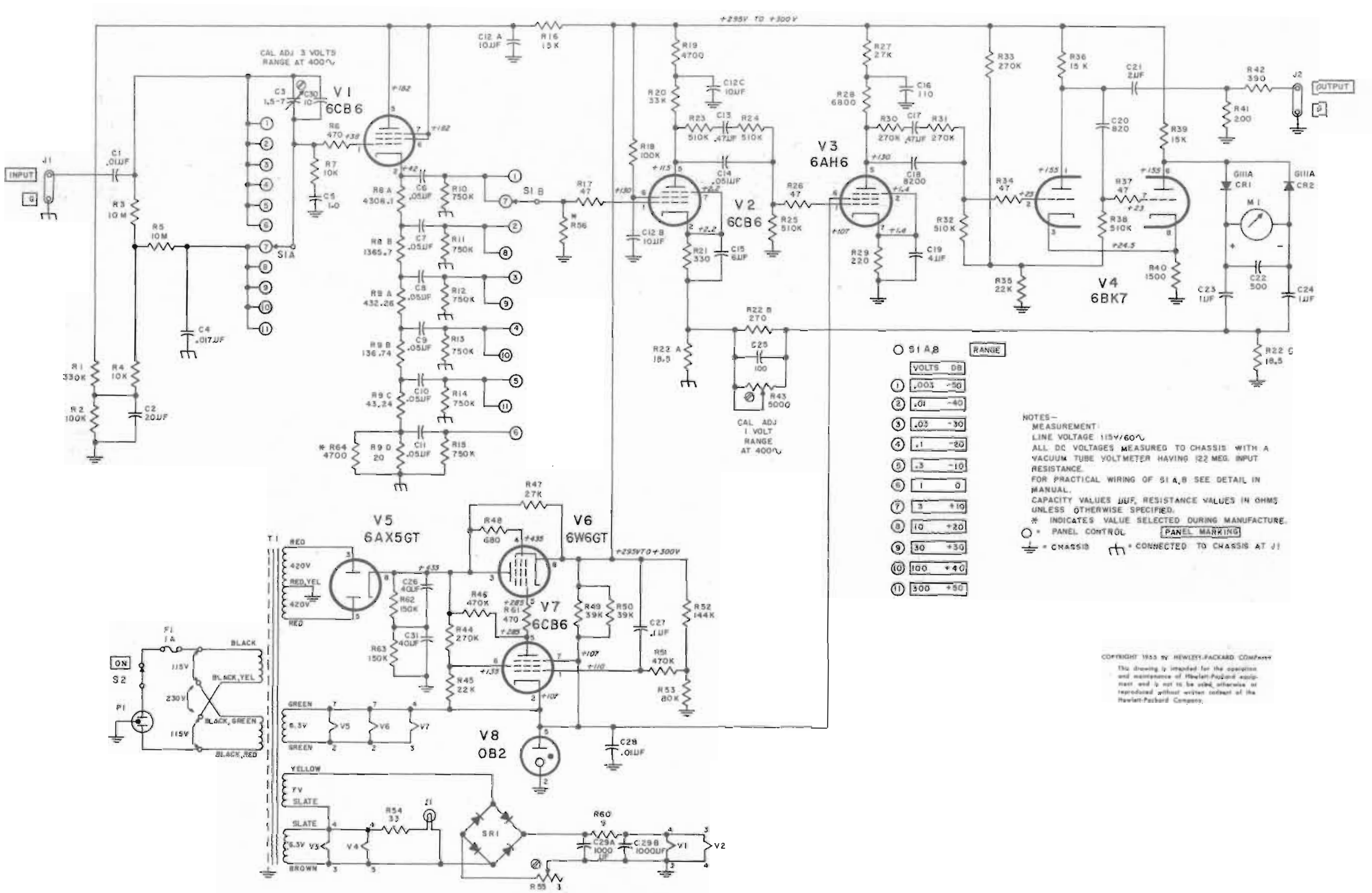
In some instruments R53 is 80K and R52 is 144K. In others R52 consists of 144K and 3.9M in parallel.



Range Switch Detail



hp MODEL 400AB



hp MODEL 400AB

VACUUM TUBE VOLTMETER

SERIAL 982 & ABOVE

SECTION V

TABLE OF REPLACEABLE PARTS

NOTE

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

When ordering parts from the factory always include the following information:

Instrument model number
Serial number
-hp- stock number of part
Description of part

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C1	Capacitor: fixed, paper dielectric, .01μf, ±10%, 600 vdcw	16-11	CC 109P10396
C2	Capacitor: fixed, electrolytic, 20μf, 150 vdcw	18-9	X
C3	Capacitor: variable, ceramic dielectric, 1.5 - 7μμf, 500 vdcw	13-7	L TS2A-NPO
C4	Capacitor: fixed, silver mica, 17,000μμf, ±2%, 300 vdcw	15-101	J 1A3S17
C5	Capacitor: fixed, titanium dioxide dielectric, 1.0μμf, ±10%, 500 vdcw	15-102	DD Type GA
C6 to C11	Capacitor: fixed, paper dielectric, .051μf, ±10%, 200 vdcw (Part of Range Switch Assembly)	16-84	Z Type 33
C12 A, B, C	Capacitor: fixed, electrolytic, 3 section, 10μf/sect., 450 vdcw	18-31	X FP-375.8
C13	Capacitor: fixed, paper dielectric, .47μf, ±10%, 400 vdcw	16-99	A P153N
C14	Capacitor: fixed, paper dielectric, .051μf, ±10%, 400 vdcw	16-89	J Type BC
C15	Capacitor: fixed, electrolytic, 6μf, ±25%, 4 vdcw	18-45	CC Type 101D
C16	Capacitor: fixed, mica, 110μμf, ±5%, 300 vdcw	14-71	V Type PQ
C17	Same as C13		
C18	Capacitor: fixed, mica dielectric, 8200μμf, ±10%, 500 vdcw	15-98	J Cat. No. 1A5D82
C19	Capacitor: fixed, electrolytic, 4μf, 10 vdcw	18-37	CC Type 101D
C20	Capacitor: fixed, silver mica, 820μμf, ±2%, 500 vdcw	14-49	Z
C21	Capacitor: fixed, paper dielectric, 2μf, ±20%, 400 vdcw	16-81	AJ SU5E205M
C22	Capacitor: fixed, electrolytic, 500μf, 15 vdcw	18-5	X TC 1505
C23, 24	Capacitor: fixed, paper dielectric, 1μf, ±10%, 400 vdcw	16-74	J PJ4W1

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C25	Capacitor: fixed, mica, 100μμf, ±10%, 500 vdcw	14-100	V OXM
C26	Capacitor: fixed, electrolytic, 40μf, 450 vdcw	18-40	X #FP-146
C27	Capacitor: fixed, paper dielectric, .1μf, ±10%, 400 vdcw	16-35	CC 109P10494
C28	Capacitor: fixed, ceramic dielectric, .01μf, tol. -0% +100%, 1000 vdcw	15-43	CC 36C99
C29 A, B	Capacitor: fixed, elec-- lytic, 2 section, 1000μf/sect., 15 vdcw	18-46"S"	CC Type DFP
C30	Capacitor: fixed, ceramic dielectric, 10μμf, ±.5μμf, 500 vdcw	15-30	K Type CI-1
C31	Same as C26		
R1	Resistor: fixed, composition, 330,000 ohms, ±10%, 1/2 W	23-330K	B EB 3341
R2	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W	23-100K	B EB 1041
R3	Resistor: fixed, composition, 10 megohms, ±5%, 1/2 W	23-10M-5	B EB 1065
R4	Resistor: fixed, composition, 10,000 ohms, ±5%, 1/2 W	23-10K-5	B EB 1035
R5	Resistor: fixed, composition, 10 megohms, ±10%, 1/2 W	23-10M	B EB 1061
R6	Resistor: fixed, composition, 470 ohms, ±10%, 1/2 W	23-470	B EB 4711
R7	Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 W	23-10K	B EB 1031
R8, 9	Resistor: fixed, special wirewound (Part of Range Switch Assembly)	400D-71	HP
R10 to R15	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W (Part of Range Switch Assembly)	23-750K-5	B EB 7545
R16	Resistor: fixed, composition, 15,000 ohms, ±10%, 2 W	25-15K	B HB 1531
R17	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	23-47	B EB 4701

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R18	Resistor: fixed, composition, 100,000 ohms, ±10%, 1 W	24-100K	B GB 1041
R19	Resistor: fixed, composition, 4700 ohms, ±10%, 1 W	24-4700	B GB 4721
R20	Resistor: fixed, composition, 33,000 ohms, ±10%, 2 W	25-33K	B HB 3331
R21	Resistor: fixed, composition, 330 ohms, ±10%, 2 W	25-330	B HB 3311
R22 A, B, C	Resistor: fixed, wirewound (special)	400AB-26A	HP
R23 to R25	Resistor: fixed, composition, 510,000 ohms, ±5%, 1/2 W	23-510K-5	B EB 5145
R26	Same as R17		
R27	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R28	Resistor: fixed, composition, 6800 ohms, ±10%, 1 W	24-6800	B GB 6821
R29	Resistor: fixed, composition, 220 ohms, ±10%, 1/2 W	23-220	B EB 2211
R30, 31	Resistor: fixed, composition, 270,000 ohms, ±5%, 1/2 W	23-270K-5	B EB 2745
R32	Same as R23		
R33	Resistor: fixed, composition, 270,000 ohms, ±10%, 1 W	24-270K	B GB 2741
R34	Same as R17		
R35	Resistor: fixed, composition, 22,000 ohms, ±10%, 1/2 W	23-22K	B EB 2231
R36	Same as R16		
R37	Same as R17		
R38	Same as R23		
R39	Same as R16		
R40	Resistor: fixed, composition, 1500 ohms, ±10%, 1 W	24-1500	B GB 1521

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R41	Resistor: fixed, composition, 200 ohms, ±5%, 1/2 W	23-200-5	B EB 2015
R42	Resistor: fixed, composition, 390 ohms, ±10%, 1/2 W	23-390	B EB 3911
R43	Resistor: variable, composition, linear taper, 5000 ohms, ±20%, 1/2 W	210-122	BO UPM-45
R44	Resistor: fixed, composition, 270,000 ohms, ±10%, 1 W	24-270K	B GB 2741
R45	Resistor: fixed, composition, 22,000 ohms, ±10%, 1 W	24-22K	B GB 2231
R46	Resistor: fixed, composition, 470,000 ohms, ±10%, 1 W	24-470K	B GB 4741
R47	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	25-27K	B HB 2731
R48	Resistor: fixed, composition, 680 ohms, ±10%, 1 W	24-680	B GB 6811
R49, 50	Resistor: fixed, composition, 39,000 ohms, ±10%, 2 W	25-39K	B HB 3931
R51	Same as R46		
R52	Resistor: fixed, deposited carbon, 144,000 ohms, ±1%, 1 W	31-144K	NN DC-1
R53	Resistor: fixed, deposited carbon, 80,000 ohms, ±1%, 1 W	31-80K	NN DC-1
R54	Resistor: fixed, composition, 33 ohms, ±10%, 1 W	24-33	B GB 3301
R55	Resistor: variable, wirewound, 4 ohms, ±20%	210-114	AT Type A control
R56 to R59	These circuit references not assigned		
R60	Resistor: fixed, wirewound, 9 ohms, ±10%, 5 W	26-88	S Type C
R61	Resistor: fixed, composition, 470 ohms, ±10%, 1/2 W	23-470	B EB 4721
R62, 63	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	24-150K	B GB 1541

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R64	Resistor: fixed, composition, 4700 ohms, ±10%, 1/2 W	23-4700	B EB 4721
	Binding Post Assembly: black	G-10C	HP
	Binding Post Assembly: red	G-10D	HP
	Insulator, binding post:	G-83A	HP
	Insulator, binding post:	G-83G	HP
CR1, 2	Rectifier, sillicon diode:	G-111A	HP
F1	Fuse, cartridge: 1 amp, 250V	211-18	E MDL-1
	Holder, fuse:	140-16	T 342003
	Knob: bar	G-74N	HP
L1	Lamp, incandescent: 6-8V, .15 amp	211-47	O #47
M1	Meter	112-6	BF Model 801 (special scale)
P1	Cable, power:	812-56	Electric Cords c/o Eckert-Lloyd
S1	Switch, rotary:	310-163	W 68009-H2C
	Range Switch Assembly: includes S1, C6, 7, 8, 9, 10, 11 R10, 10, 12, 13, 14, 15	400AB-19W	HP
S2	Switch, toggle: [illegible]PST	310-11	Fisher 80994-NV
SR1	Rectifier, metallic:	212-101	BV 60-9284
T1	Transformer, power:	910-139	Paeco
V1, 2	Tube, electron: 6CB6	212-6CB6	ZZ

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
V3	Tube, electron: 6AH6	212-6AH6	ZZ
V4	Tube, electron: 6BK7	212-6BK7	ZZ
V5	Tube, electron: 6AX5GT	212-6AX5-GT	ZZ
V6	Tube, electron: 6W6GT	212-6W6GT	ZZ
V7	Same as V1,2		
V8	Tube, electron: OB2	212-OB2	ZZ

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

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

Code Letter	Manufacturer	Address
A	Aerovox Corporation	New Bedford, Mass.
B	Allen-Bradley Company	Milwaukee 4, Wis.
C	Amperite Company	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Company	St. Louis, Mo.
F	Carborundum Company	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Company	Chicago 24, Ill.
HP	Hewlett-Packard Company	Palo Alto, Calif.
I	Clarostat Mfg. Company	Dover, N. H.
J	Cornell Dubilier Elec. Company	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corporation	Erie 6, Penn.
M	Fed. Telephone & Radio Corporation	Clifton, N. J.
N	General Electric Company	Schenectady 5, N. Y.
O	General Electric Supply Corporation	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Company	Danbury, Conn.
R	International Resistance Company	Philadelphia 8, Penn.
S	Lectrohm Incorporated	Chicago 20, Ill.
T	Littlefuse Incorporated	Des Plaines, Ill.
U	Maguire Industries Incorporated	Greenwich, Conn.
V	Micamold Radio Corporation	Brooklyn 37, N. Y.
W	Oak Manufacturing Company	Chicago 10, Ill.
X	P. R. Mallory Co., Incorporated	Indianapolis, Ind.
Y	Radio Corporation of America	Harrison, N. J.
Z	Sangamo Electric Company	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Company	Brooklyn 37, N. Y.
CC	Sprague Electric Company	North Adams, Mass.
DD	Stackpole Carbon Company	St. Marys, Penn.
EE	Sylvania Electric Products Company	Warren, Penn.
FF	Western Electric Company	New York 5, N. Y.
GG	Wilkor Products, Incorporated	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Company	New York, N. Y.
KK	Switchcraft, Incorporated	Chicago 22, Ill.
LL	Gremar Manufacturing Company	Lynn, Mass.
MM	Carad Corporation	Redwood City, Calif.
NN	Electra Manufacturing Company	Kansas City, Mo.
OO	Acro Manufacturing Company	Columbus 16, Ohio
PP	Alliance Manufacturing Company	Alliance, Ohio
QQ	Arco Electronics, Incorporated	New York 13, N. Y.
RR	Astron Corporation	East Newark, N. J.
SS	Axel Brothers Incorporated	Long Island City, N. Y.
TT	Belden Manufacturing Company	Chicago 44, Ill.
UU	Bird Electronics Corporation	Cleveland 14, Ohio
VV	Barber Colman Company	Rockford, Ill.
WW	Bud Radio Incorporated	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Company	Plainville, Conn.
YY	Cinema Engineering Company	Burbank, Calif.
ZZ	Any brand tube meeting RETMA characteristics.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Incorporated	Columbus, Neb.
AD	The Drake Mfg. Company	Chicago 22, Ill.
AE	Elco Corporation	Philadelphia 24, Penn.
AF	Hugh H. Eby Company	Philadelphia 44, Penn.
AG	Thomas A. Edison, Incorporated	West Orange, N. J.
AH	Fansteel Metallurgical Corporation	North Chicago, Ill.

Code Letter	Manufacturer	Address
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Company	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corporation	Chicago 18, Ill.
AM	Insuline Corporation of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corporation	San Jose, Calif.
AO	E. F. Johnson Company	Waseca, Minn.
AP	Lenz Electric Mfg. Company	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Acron 8, Ohio
AS	Model Eng. & Mfg., Incorporated	Huntington, Ind.
AT	The Muter Company	Chicago 5, Ill.
AU	Ohmite Mfg. Company	Skokie, Ill.
AV	Resistance Products Company	Harrisburg, Penn.
AW	Radio Condenser Company	Camden 3, N. J.
AX	Shallcross Manufacturing Company	Collingdale, Penn.
AY	Solar Manufacturing Company	Los Angeles 58, Calif.
AZ	Sealectro Corporation	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Company	Mansfield, Ohio
BD	Torrington Manufacturing Company	Van Nuys, Calif.
BE	Vector Electronic Company	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corporation	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	Los Angeles 58, Calif.
BI	Electronics Tube Corporation	Philadelphia 18, Penn.
BJ	Aircraft Radio Corporation	Boontan, N. J.
BK	Allied Control Co., Incorporated	New York 21, N. Y.
BL	Augat Brothers, Incorporated	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBD Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Incorporated	West Orange, N. J.
BQ	Curtiss-Wright Corporation	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Exsel Transformer Company	Oakland, Calif.
BT	General Radio Company	Cambridge 39, Mass.
BU	Hughes Aircraft Company	Culver City, Calif.
BV	International Rectifier Corporation	El Segundo, Calif.
BW	James Knight Company	Sandwich, Ill.
BX	Mueller Electric Company	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Penn.
BZ	Radio Essentials Incorporated	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Company	Newton, Mass.
CB	Tung-Sol Lamp Works, Incorporated	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corporation	Union, N. J.
CF	Weckesser Company	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electric Incorporated	Santa Monica, Calif.
CI	Malco Tool	Los Angeles 42, Calif.
CJ	Oxford Electric Corporation	Chicago 15, Ill.
CK	Camlo Fastner Corporation	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Penn.
CM	Union Switch	Swissvale, Penn.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Company	Bridgeport 2, Conn.
CQ	Birnbach Radio Company	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (The American Elite Co)	New York, N. Y.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY

Laboratory Instruments for Speed and Accuracy

275 PAGE MILL ROAD PALO ALTO. CALIF. U.S.A.

CABLE "HEWPACK"