OPERATING AND SERVICING MANUAL

MODEL 400A
VACUUM TUBE VOLTMETER
ALL SERIAL NUMBERS

THIS IS A COMBINED OPERATION AND SERVICE MANUAL FOR hp MODEL 400A VOLTMETER, ALL SERIAL NUMBERS. THIS MANUAL CONTAINS COMPLETE OPERATION AND SERVICING INSTRUCTIONS FOR THESE VOLTMETERS AND SHOULD BE USED IN PLACE OF THE MANUAL ORIGINALLY SUPPLIED WITH EACH INSTRUMENT.

Printed 4/60

Model 400A

SPECIFICATIONS

VOLTAGE RANGE:	Full Scale sensitivity from 0.03 to 300 volts in 9 ranges.
METER CALIBRATION:	Meter calibrated to rms value of a sine wave. Linear 0-1 volt and 0-3 volt voltage scales. Voltage ranges related by 10 db steps. DB scale calibrated -12 db to +2 db. Zero db = 1 milliwatt into 600 ohms.
FREQUENCY RESPONSE:	10 cycles per second to 1 megacycle per second.
INPUT IMPEDANCE:	0.03 to 30 volts - 1 megohm plus shunt capacity. 100 volt range - 3 megohms plus shunt capacity. 300 volt range - 2.4 megohms plus shunt capacity. Shunt capacity - Approximately 25 $\mu\mu$f all ranges.
ACCURACY:	10 cps to 100 KC - ±3% of full scale on all ranges.
	100 KC to 1 MC - ±5% of full scale on all ranges.
VOLTMETER STABILITY:	Line voltage variations from 105 to 125 volts cause less than ±2% variations in readings on all frequencies below 100 KC and less than ±5% on all frequencies between 100 KC and 1 MC.
OVER-VOLTAGE CAPACITY:	Avoid continuous or frequent overloads. Occasional overloads of 100 times normal volts will not damage the meter movement. DC voltage applied to the input terminals must not exceed 600 volts.
POWER:	105 to 125 volts, 50/1000 cps, 40 watts.
DIMENSIONS:	7-9/16 inches wide by 9-1/2 inches high by 10-1/4 inches deep.
WEIGHT:	15 pounds approximately.

CONTENTS

SECTION I
GENERAL INFORMATION

1-1 ACCESSORIES AVAILABLE

A number of hp accessories are available for use with Model 400A. Descriptions are given below and in Figure 1-2.

hp Model 454A Capacitive Voltage Divider -

Safely measures power, audio, supersonic and rf voltages up to 1500 volts. Accuracy ±3%. Division ratio, 100:1. Input impedance 50 megohms, shunted with about 2.75 uuf capacity. Frequency, 20 cps to 4 mc.

hp Model 452A Capacitive Voltage Divider -

Extends ac range to as high as 25,000 volts. Frequency range 25 cps to 20 mc, derated at high frequencies to limit rf current through capacitors. Fixed gap provides arc-over at about 28,000 volts. Voltage division 1000:1 ±3%. Input capacitance about 15 micromicrofarads. Shields banana plug connects directly to binding posts on 400A.

hp Models 470 Shunt Resistors -

A series of shunt resistors for measuring alternating currents as small as 1 μa. Accuracy ±1% from 10 cps to 100 kc, ±5% from 100 kc to 4 mc. Model 470A only, ±5% to 1 mc. Maximum power dissipation 1 watt.

Model	Shunt Resistance
hp Model 470A	0.1 ohm
hp Model 470B	1 ohm
hp Model 470C	10 ohms
hp Model 470D	100 ohms
hp Model 470E	600 ohms
hp Model 470F	1000 ohms

hp Model AC-60A Line Matching Transformer -

Connects a balanced system to Voltmeter. Frequency range, 5 kc to 600 kc. Balanced 135 or 600 ohm output. Permits bridging or terminated voltage measurements. Maximum level +22 dbm (10 volts across 600 ohms).

hp Model AC-60B Line Matching Transformer -

Covers audio range, 20 cps to 45 kc. Maximum level, +15 dbm (4.5 volts across 600 ohms).

Model 350 Attenuators -

Model 350A, 500 ohms; Model 350B, 600 ohms. Attenuation 110 db in 1 db steps. Frequency range, 0 - 100 kc.

Cable Assemblies -

AC-16A: Coaxial cable, RG-58/U, 50 ohms, 44 inches length, two dual banana plugs, 3/4" centers.

AC-16B: Coaxial cable, RG-58/U, 50 ohms, 45 inches length, one dual banana plug 3/4" centers, and one UG-88/U Type BNC male connector.

AC-16S: One red lead, one black lead, 60 inches length, each with alligator clip. Dual banana plug, 3/4" centers, on other end.

AC-16T: One lead with alligator clip, one lead with test probe, each 60 inches length. Dual banana plug, 3/4" centers, on other end.

CAUTION

The lower binding post instrument chassis, cabinet, and green grounding lead in the three-conductor power cable are electrically connected together at all times. When the third (green) grounding conductor is used in the proper manner, a ground path is established between the 400A and equipment which is also grounded. Do not connect the grounded binding post to any point which is not at ground potential because a short circuit will be created. If such a measurement is necessary, disconnect the green ground wire in the power cable. If a 3-prong "NEMA" type plug is used, use an adapter with the grounding pig-tail removed, and the cabinet insulated from ground. The 400A cabinet will be at the same potential as the negative test lead; caution must be used if the negative lead is connected to a point which is more than a few volts off ground. Because of the potential hazard to personnel, this method is not recommended.

One side of almost all power distribution systems is grounded. Extreme caution must be used if direct measurement of power system voltages is attempted. If the ground clip lead is accidentally connected to the ungrounded side of the line, severe damage to the 400A is possible when the green conductor is properly connected to ground because of the short circuit created. When the "NEMA" ground is used, power line voltages can be safely measured by contacting the grounded power conductor with the positive lead only. This will give a reading of 0 volts while contacting the grounded lead and a full line voltage reading when contacting the "hot" side of the power line.

The 400A is designed for the measurement of audio and rf voltages and is excellent for this purpose. In normal practice these voltages are almost always measured with respect to chassis ground and no concern need be given to grounds.

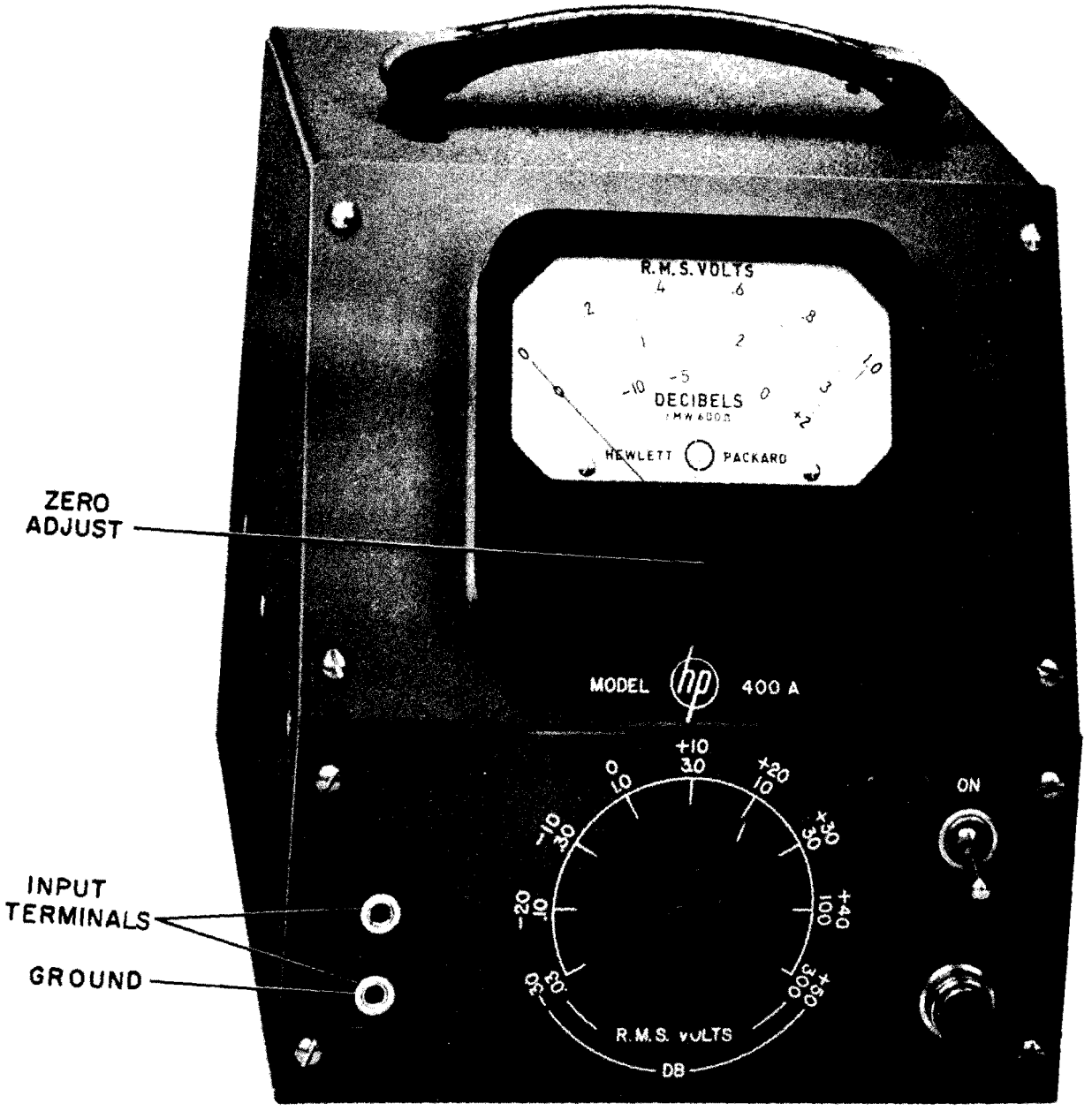
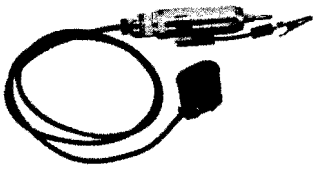
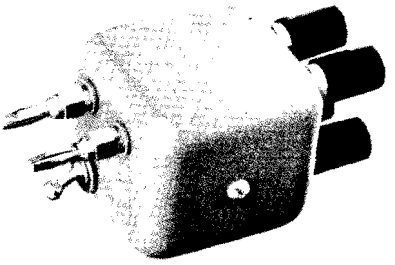


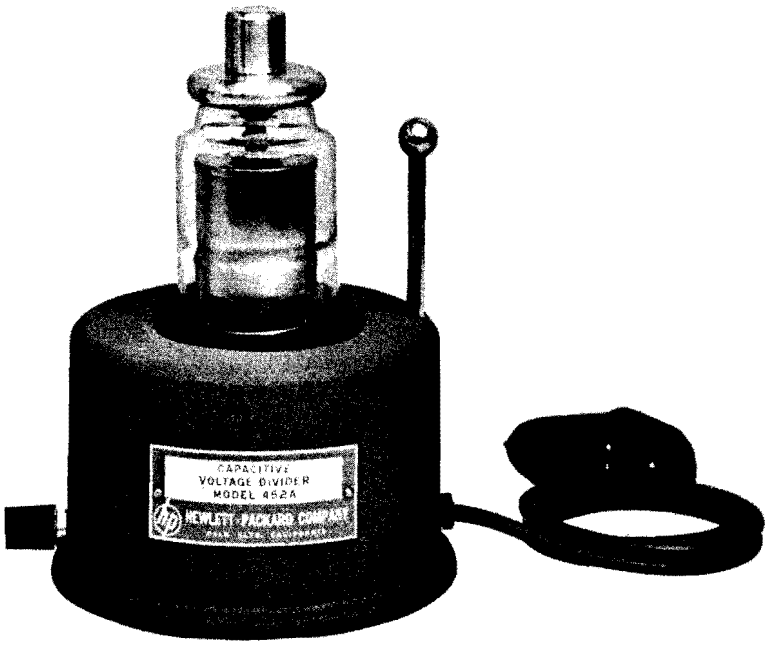
Figure 1-1. Hewlett-Packard Model 400A Typical Front View



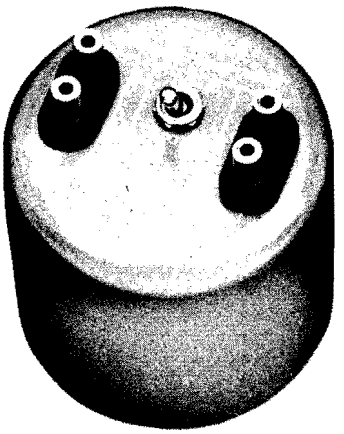
Model 454A
Capacitive Voltage Divider



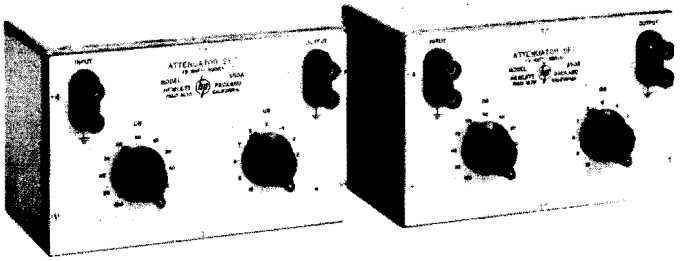
Model AC-60A
Line Matching Transformer



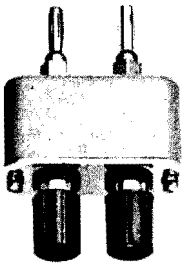
Model 452A
Capacitive Voltage Divider



Model AC-60B
Line Matching Transformer



Models 350A/B
Attenuators



Models
470A to 470F
Shunt Resistors
(Illustrated: Model 470B)

Figure 1-2. Accessories for Model 400A Voltmeter

SECTION II
OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

ON - The spst toggle switch controls the power applied to the power transformer primary. The red indicator will glow when this switch is placed on the ON position.

R. M. S. VOLTS - DB SWITCH - The rotary switch connects the proper multiplier resistors into the circuits for the desired voltage range. The position of the switch indicates the meter scale and the full scale voltage of the range in use. The switch position also indicates the db level across 600 ohms when the meter is initially set to zero db on the zero db range.

INPUT TERMINALS - The two binding posts, located in the lower left corner, are connected to the instrument input circuit. The lower post is connected to the chassis.

FUSE - The 0.6 ampere "slo-blo" fuse, F1 for the power transformer primary circuit is mounted inside the instrument on the underside of the chassis. Replacement is accomplished by disconnecting the power cord plug, removing the bottom cover plate, and inserting the replacement fuse in the clips provided. Use the 0.6 ampere "slo-blo" fuse for replacement in all Model 400A instruments.

POWER CABLE GROUND WIRE - A three conductor power cable is used. The white and the black wires carry power to the instrument. The green wire is connected to the chassis within the instrument and emerges from the power cable at the plug. This wire may be connected to a ground as required.

INTERNAL ACCESS - Access to the top side of the chassis is accomplished by removing the four screws on the back of the instrument and sliding the top cover backward. Access to the bottom side of the chassis is accomplished by removing the four screws on the bottom of the instrument and lifting off the bottom cover plate.

2-2 OPERATION OF INSTRUMENT

CAUTION

THE MAXIMUM VOLTAGE APPLIED TO THE INPUT TERMINALS OF THE MODEL 400A VACUUM TUBE VOLTMETER MUST NOT EXCEED 600 VOLTS, THE SUM OF THE DC VOLTAGE AND AC PEAK VOLTAGES. HIGHER VOLTAGES WILL BREAK DOWN THE CAPACITORS IN THE INSTRUMENT INPUT SYSTEM.

ZERO METER INDICATION - The meter pointer may not coincide with the zero scale mark when the instrument is turned off. This condition is normal.

VOLTAGE MEASUREMENT - Allow the hp Model 400A a warm-up time of at least 5 minutes. Set the R. M. S. VOLTS-DB switch to the desired voltage range and connect the voltage to be measured across the meter input terminals. The meter indication multiplied by the factor determined from the following table will give the rms value of the voltage measured. For best readability use lowest possible range.

R. M. S. VOLTS-DB Switch Setting	Meter Scale in use	Multiplication Factor
.03	0 - 3	1/100
.10	0 - 1	1/10
.30	0 - 3	1/10
1.0	0 - 1	1
3.0	0 - 3	1
10	0 - 1	10
30	0 - 3	10
100	0 - 1	100
300	0 - 3	100

If measurements are being made from a high impedance source, hum pickup may effect the meter reading, due to the high impedance of both the source and the Model 400A. Shielded leads will reduce this pickup. Shielding will cause an increase in the capacity shunted across the source being measured, which may result in excessive circuit loading.

As a precaution in maintaining accuracy of measurements, it must be kept in mind that the Model 400A is an average-responding instrument. The calibration on the face of the meter is marked "R. M. S. VOLTS", which means that the meter will read the rms value of a true sine wave. If the voltage being measured contains appreciable harmonic voltages or other spurious voltages, errors in measurement will result. The table that follows shows the amount of error that may be introduced by various harmonic content.

EFFECT OF HARMONICS ON MODEL 400A VOLTAGE MEASUREMENTS

Input Voltage Characteristics	True RMS value	Value Indicated by Model 400A
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 MEASUREMENT - Decibel measurements are made in the same way as voltage measurements except that the db scale is used. The db calibration of the hp Model 400A is based on a zero level of 1 milliwatt into 600 ohms (0.775 volts). The db level of any voltage appearing across 600 ohms may be read directly from the 400A decibel scales.

The decibel scales may also be used to determine the db difference between any two voltages provided both db levels are measured across the same impedance value.

The db level of any voltage is determined by the position of the "DB" switch and the meter indication. The meter indication is algebraically added to the "DB" switch setting. For example: If the "DB" switch setting is -20 and the meter indication is -8, the db level is -28 db. If the "DB" switch setting is -30 and the meter indication is +2, the db level is again -28 db.

SECTION III
THEORY OF OPERATION

3-1 CIRCUIT DESCRIPTION

The ℌ Model 400A Vacuum Tube Voltmeter can be divided into four basic circuits: (1) Input circuit with cathode follower. (2) Amplifier section with negative feedback for stability. (3) Average-responding meter circuit with full wave rectification. (4) Power supply with full wave rectification and regulated output.

INPUT CIRCUIT - On the lower six ranges the signal applied to the input terminals is passed directly through a dc blocking capacitor to the grid of a 6J5 triode tube. This tube is connected as a cathode follower with a precision wire wound resistor in the cathode circuit. The taps on this resistor function as multiplier resistors for the six lowest ranges.

Resistors R4, R5, and R6 form a dc voltage divider for proper bias of the 6J5. With the large bypass capacitor C5, at the junction of R4 and R5, this point is at ground potential for ac voltages. Hence, the grid resistor for the 6J5 is effectively composed of R5 and R6 connected in parallel.

On the 100 volt range, resistor R1 is effectively switched in series with the triode grid resistor. A voltage divider, frequency compensated by C1, is formed by these resistors to reduce the voltage applied to the 6J5 grid by a fixed ratio.

On the 300 volt range, resistor R1 remains connected as for the 100 volt range and resistor R2 is effectively switched in parallel with the 6J5 grid resistor. This changes the ratio of the voltage divider and a lower portion of the input signal is applied to the triode grid. The design value of R2 is chosen so as to change the ratio of the voltage divider to produce a 300 volt range. The ceramic trimmer capacitor, in parallel with R2, is used for frequency compensation of the 300 volt range only.

AMPLIFIER CIRCUIT - The output from the cathode follower stage is capacity coupled to the input of a broad band resistance coupled amplifier using two 6AC7 pentode tubes. Negative feedback is accomplished by returning the meter rectifier circuit, in plate circuit of second 6AC7, to ground through the cathode resistor for the first 6AC7 tube.

The over-all gain of the amplifier is controlled by adjusting the cathode resistor of the first 6AC7 stage. This has the effect of changing the amount of negative feedback which in turn will affect the over-all gain of the amplifier. This resistor, R11, is wire wound and the inductance is factory adjusted so as to produce the best possible frequency response. The over-all frequency response is also adjusted by capacitor C16 in the meter circuit.

METER CIRCUIT - The output of the amplifier is fed to a full wave rectifier with a type 6H6 twin diode. The average reading indicating meter is connected from the plate of one diode section to the cathode of the other diode section. Only a portion of the rectified current passes through the indicating meter.

POWER SUPPLY - A conventional transformer type power supply with full wave rectification is used. The output of the rectifier is fed to an r-c filter system that supplies plate voltage for the cathode follower stage and the second amplifier stage.

Tubes V6, V7, and V8 provide regulated voltage for the plate of the first amplifier stage and screen voltage for both amplifier stages.

Bias voltage of -1.5 volts for both amplifier stages is obtained from resistor R3 in series with the high voltage center tap lead. This voltage is filtered by an r-c filter composed of resistor R10 and capacitor C8.

SECTION IV
MAINTENANCE

4-1 GENERAL MAINTENANCE INFORMATION

Quality components are used throughout hp instruments and are conservatively operated for optimum instrument reliability. In case of failure, a systematic method of troubleshooting will usually make repair relatively simple.

If instrument is inoperative, first check simple items such as power fuse, line cord, power failure, or tube burnout, then try tube replacements. Trial replacements of tubes are preferred to testing with a tube checker. Always return good tubes to sockets from which they were removed.

If new tubes do not restore operation, refer to "Troubleshooting" procedures which list some simple symptoms and remedies. Do not alter adjustments until operation is restored.

Following repairs it is advisable to check calibration, and in some cases to make necessary adjustments. Instructions are included under Tube Replacement Procedures.

Standard electronic components for Model 400A can be obtained from a local parts distributor. Your hp Representative carries a stock of standard components as well as any special hp parts or assemblies required for hp instruments.

Should you have any difficulties with your instrument, do not hesitate to call your hp Representative for assistance with engineering, application, test, or repair problems.

4-2 CABINET REMOVAL

The cabinet is held to the chassis with screws at the rear. Do not remove phillips head screws on front panel.

4-3 TUBE REPLACEMENT

Any brand of tubes having standard EIA (JEDEC) characteristics may be used for replacements. Replace tubes according to following procedures:

Tube Replacement Procedures

V1, V6, or V5:	No adjustments required.
V7:	Replace with same type found in instrument (6SF5 or 6SQ7). Performance is equal with either type; they are not interchageable only because of differences in pin connections.

V2, V3: After installing these tubes, turn instrument on, and short input terminals. Meter should indicate zero; if not, adjust sensitivity as described in calibration procedure. If meter indication drifts, or if tubes are microphonics, try new 6AC7 replacements and repeat tests and adjustments.

V4: Aged 6H6 tube should be used for replacement; aged tubes are available from Hewlett-Packard Company. Regular stock tubes may be aged in instrument until stable.

Adjust meter to zero with 6H6 removed from socket. Insert replacement tube. Set range to 300 volts. Note zero emission of tube on 0-1 volt meter scale. Meter will track best when zero emission is less than 1/2 division. Adjust voltage calibration.

If unaged 6H6 is used, meter may require resetting after several days operation.

V8: Replacement of type 991 neon glow lamp with type OD3/VR150 or type OA2 regulator tube is recommended; refer to modification instructions.

If neon glow lamp is to be replaced with another type 991 glow lamp, proceed as follows: Use only aged (hp) Stock No. 211-10 glow lamps; unaged lamps will change characteristics after installation. Check regulation of dc supply as described in Power Supply Adjustments.

4-4 MODIFICATION PROCEDURES

History of Production

Minor changes have been made in Model 400A voltmeters throughout the years of production. Specifications, however, are the same for all instruments.

Improvements were made in the direction of increased component life, and ease of adjustment, testing, and repair. These changes are described here should you wish to add them. If your instrument is operating satisfactorily, there is no need to make any changes.

Following is a list of major changes:

1. Reference tube V8 was a type 991 neon glow tube in some instruments. Later models have a type OD3/VR150 voltage regulator tube in place of the neon lamp. A procedure is described below for replacing the neon lamp with an OD3/VR150 in serial no. 5620 or below.

2. Type 6SQ7 and type 6SF5 tubes were used for V7. Both tube types provide the same performance. They are not interchangeable directly because of differences in pin connections but either type can be used in the instrument. Refer to the two schematic diagrams.

3. Control C34 was added for easily adjusting the +215 volt supply. The values for R32 and R33 were subsequently changed. See schematic diagrams.

4. The values of C3 and C4 were changed, and trimmer C16 was added for easier adjustment of frequency response.

5. The absolute values of R1, R2, R5, R6 vary among instruments. These differences are unimportant as long as the ratios are correct for calibrating the 100 and 300 volt ranges.

   Some instruments had black, glass-sealed resistors for R1, R2, R5, and R6. These were replaced with deposited carbon type resistors listed in the Table of Replaceable Parts.

6. The values for control R13 and resistor R12 were changed for wider adjustment range. Later circuits have a 100 ohm control and a 27 ohm resistor.

7. Line fuse F1 was changed from a 1 ampere fast fuse to a 0.6 ampere slo-blo fuse. The 0.6 ampere slo-blo fuse should be used for replacement in all hp Model 400A instruments.

TWO DIFFERENT SCHEMATIC DIAGRAMS ARE INCLUDED IN THIS MANUAL. ONE DIAGRAM COVERS INSTRUMENTS WITH SERIAL NO. 5620 AND BELOW, THE OTHER COVERS INSTRUMENTS WITH SERIAL NO. 8723 AND ABOVE. INSTRUMENTS WITH SERIAL NUMBERS FALLING BETWEEN THESE TWO NUMBERS WILL HAVE ONE OR MORE OF THE MODIFICATIONS. COMPARISON OF THE TWO SCHEMATIC DIAGRAMS WILL CLARIFY THE WIRING FOUND IN ANY SUCH INSTRUMENT. ALL SCHEMATIC REFERENCES REFER TO THE SCHEMATIC DIAGRAM FOR INSTRUMENTS WITH SERIAL NO. 8723 AND ABOVE.

Procedure for Installing OD3/VR150 Tube for V8 in Serial No. 5620 and Below.

This modification permits use of an OD3/VR150 or OA2 regulator in place of a 991 neon glow lamp. Because of space limitations a control for the dc output cannot be added. The modified circuit will therefore differ from Figure 4-9.

1. Note size of mounting hole for neon lamp socket. If hole is 1", OD3/VR150 regulator is recommended; if hole is 3/4", use OA2 regulator tube, miniature socket and adapter plate.

2. The following parts are required:

	hp Stock No.
One 62,000 ohm, 1 watt composition resistor . . .	24-62K
One 27,000 ohm, 1 watt composition resistor . . .	24-27K
One 10,000 ohm, 2 watt composition resistor . . .	25-10K
One octal tube socket, 1" mounting hole, for OD3/VR150 regulator tube	38-22
One 7-pin miniature socket, 3/4" mounting hole for OA2 regulator tube	38-7
Type OD3/VR150 regulator tube	212-OD3
Type OA2 regulator tube	212-OA2

3. Replace 82,000 ohm resistor for R32 with 27,000 ohm resistor. See Figure 4 for location of R32 on RB2 resistor board.

4. Replace 27,000 ohm resistor for R33 with 62,000 ohm resistor. See Figure 4 for location of R33.

5. Replace 270,000 ohm resistor for R30 with 10,000 ohm resistor. See Figure 4 for location of R30.

6. Connect and solder pin 2 of new V8 socket to ground.

7. Install new regulator tube in V8 socket.

8. Turn power on and measure dc voltage at pin 8 of 6V6 tube V6. Adjust output to about +215 volts by padding R32 to lower the voltage or by padding R33 to raise the voltage.

9. Vary line voltage from 105 to 125 volts. The dc output should remain constant within about 2 volts. If regulation is not satisfactory, refer to Power Supply Adjustments.

4-5 GENERAL TEST PROCEDURE

Circuit references mentioned in test procedures will be found in schematic diagram Figure 4-9. If your instrument agrees with Figure 4-8, refer to Figure 4-9 to identify part, then locate equivalent part in your instrument and in Figure 4-8.

A complete test and adjustment of Model 400A consists of the following procedures:

1. Adjustment of meter zero set. This is a mechanical adjustment of the meter pointer.

2. Adjustment of regulated B+ supply. This procedure checks dc output and regulation.

3. Check of line voltage response. This procedure can reveal defective tubes and components and should be performed prior to calibration.

4. Voltage calibration.

5. Frequency response adjustments.

4-6 ADJUSTMENT OF METER ZERO SET

Turn instrument on and allow to warm thoroughly. Set range to 300 volts. Turn mechanical zero adjustment screw on meter case clockwise until pointer is upscale. Continue turning screw clockwise only until pointer travels downscale to exactly zero. Repeat if pointer overshoots zero. Do not turn screw counterclockwise at any time.

Remove V4 (6H6) and observe change in meter indication. If pointer shifts more than about 1/2 division on 1 volt range, tubes V2, V3, and V4 may require replacement before best tracking can be obtained. Generally, the less shift observed when V4 is removed, the better the tracking. Insert V4, reset meter pointer to zero, and proceed to adjustment of regulated B+ supply.

4-7 ADJUSTMENT OF REGULATED B+ SUPPLY

Adjust line voltage to 125 volts. Connect a dc voltmeter across C14C. If voltage exceeds 450 volts, replace R35 with a resistor that will decrease voltage to 450 volts. If R35 is not present, add it to the circuit. Refer to Figures 4-6 and 4-7 for mounting locations and to Figure 4-9 for connections.

Reset line voltage to 115 volts. Connect dc voltmeter between chassis and cathode pin 8 of V6. If voltage is more, or less, than about 215 volts, adjust R34 for about 215 volts output. If control R34 is not present, add parallel resistor to R32 to lower voltage or to R33 to increase voltage.

Check regulation by varying line voltage from 105 to 125 volts. If +215 volt output varies more than ±5 volts in instruments with type 991 neon lamp for V8, or more than ±2 volts in instruments with OD3/VR150 regulator, refer to Trouble Shooting section.

Slowly reduce line voltage below 105 volts until output suddenly decreases. If sudden decrease occurs above 103 volts, refer to Trouble Shooting section.

Reset line to 115 volts. Measure -1.5 volt bias supply by connecting dc voltmeter between high voltage center tap of power transformer at junction R3 and R10, and ground. If bias supply is less than -1.4 volts or more than -1.7 volts, refer to Trouble Shooting section.

If variable line voltage source is not available, check regulation by temporarily connecting a 47,000 ohm, 2 watt resistor across +215 volt supply. A relatively large change in output indicates poor regulation.

4-8 SPECIAL INSTRUMENTS FOR VOLTMETER CALIBRATION

Voltmeter calibration and frequency response can be most easily checked or adjusted with hp Model 738AR, 739A, and 200S instruments. These instruments are also known as hp Spec 23678 Voltmeter Calibration Generator, Spec 23679 Frequency Response Generator, and Spec 23680 Wide Range Oscillator, respectively.

Model 738AR(23678) delivers accurate 400 cps and dc voltages from 300 microvolts to 300 volts in 25 steps, and 16 tracking voltages for the 0-1 and 0-3 meter scales. Peak-to-peak and rms ac voltages are available. DC is provided from a regulated 300 volt standard. Model 738A eliminates the need for a "standard" reference meter; the test set up is therefore very simple:

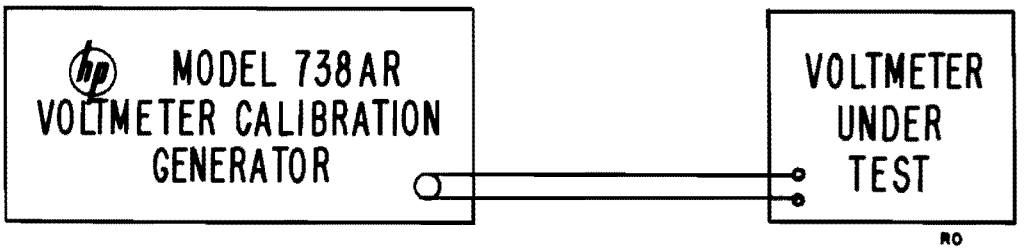


Figure 4-1A. Calibration with Model 738AR

Model 739AR(23679) delivers a "set level" signal up to 3 volts from 0.35 to 10 megacycles. An input connector is provided for an external signal generator to cover frequencies below 0.35 mc. Input impedance is 50 ohms for the external generator.

Output can be coupled to hp voltmeters with a BNC-to-banana connector. "Set Level" can be maintained constant with either the internal AGC circuit or with the control on the external generator.

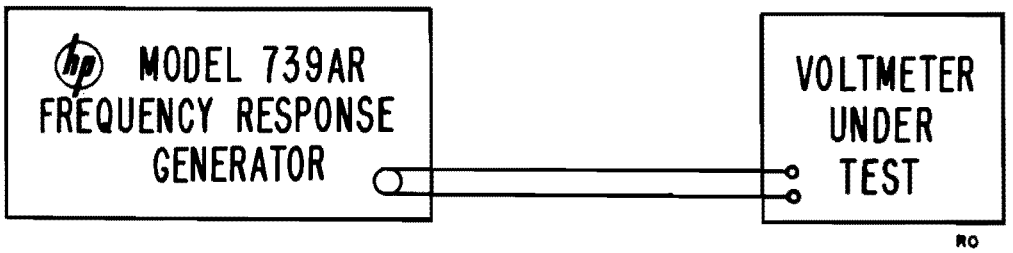


Figure 4-1B. Frequency Response Checking with Model 739AR

Model 200S delivers 5 cps to 600 kc at 50 ohms output impedance, matching Model 739AR. When used with Model 739AR, signals up to 3 volts from 5 cps to 10 megacycles are available. Output can be coupled to Model 739AR with a BNC-to-banana connector.

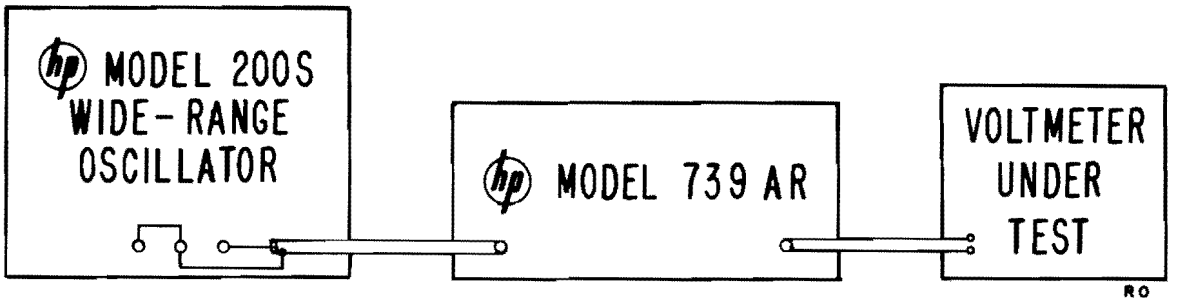


Figure 4-1C. Frequency Response Checking with Models 200S and 739AR

4-9 CONVENTIONAL INSTRUMENTS FOR CALIBRATION

Test instruments listed here enable you to check and adjust your voltmeter. Instruments of highest available accuracy should be used to avoid excessive cumulative error. Select appropriate test equipment for your voltage, frequency, and accuracy requirements.

Signal Generator	Range and Accuracy	Output Voltage and Application
Model 205A/AG	20 cps to 20 kc ±1 db	Up to about 150 volts at 5000 ohms impedance. Can be used for complete voltage calibration procedure.
Model 650A	10 cps to 10 mc ±1 db	3 volts maximum. Can be used for complete frequency response adjustment procedure.
Model 200CD	5 cps to 600 kc ±1 db	Up to 20 volts. Suitable for calibrating up to 30 volt range and up to 600 kc response.
Model 233A	50 cps to 500 kc ±1 db	Up to about 43 volts. Suitable for calibrating up to 30 volt range 50 cps to 500 kc.

Voltmeters

Standard meter accurate to 1% or better is desirable. Such meters are usually calibrated for 60 cps and are accurate or may be corrected for other frequencies. Avoid power line frequency or multiples thereof for voltage calibration.

Following voltmeters have high order of accuracy and cover frequency range required. They are not standard reference meters; however, for many purposes, calibration to accuracies possible with these meters may be satisfactory.

℗ Models 400H/L	10 cps to 4 mc. Accuracy, percent of full scale: ±1%, 50 cps to 500 kc ±2%, 20 cps to 1 mc ±3%, 20 cps to 2 mc	Monitoring voltmeter in lieu of standard galvanometer.

Attenuators

℗ Models 350A/B	0 to 100 kc. Accuracy: 0.125 db on 1 db steps; 0.25 db on 10 db steps to 80 db; 0.5 db on 90 and 100 db steps.	Can be used in tracking procedure of voltage calibration.
Attenuator in ℗ Model 650A	Approximately 2%	Can be used in lieu of standard attenuator
Electro Measurements, Inc., Model DP-211 or DV-211 Dekapot	0.01%	Suitable as standard for calibrating.

4-10 VOLTAGE CALIBRATION AND FREQUENCY RESPONSE ADJUSTMENTS

Voltage calibration must be correct before frequency response can be adjusted. Basic amplifier gain for these adjustments is made with feedback control R13, and frequency response is individually adjustable on four ranges (0.1, 30, 100, and 300 volts). Frequency response is also determined to some extent by positions of certain wires and components.

Test Equipment

A variety of test equipment can be used for testing or calibrating Model 400A. For fast and accurate testing or calibration, the special ℗ voltmeter calibration instruments are unexcelled. Refer to instructions for Models 738AR, 739AR, and 200S. These instruments were previously designated ℗ Spec 23678, 23679, and 23680, respectively.

Conventional voltage and signal generators in conjunction with standard meters and attenuators may also be used for testing and calibrating. Instruments of high accuracy and low distortion should be used to avoid excessive cumulative error.

The voltage divider circuit in Model 400A is so arranged that voltage calibration and frequency response adjustments can be performed as independent tests. It is not necessary, for example, to supply a 300 volt signal at 1 megacycle to check the 400A at this voltage and frequency. The recommended method is to adjust voltage calibration at a fixed frequency, followed by frequency response testing at a fixed voltage. This is relatively easy to do with two signal generators.

The first generator should supply all test voltages at 400 cps or at some other frequency between 100 and 1000 cps. Avoid power line frequencies or multiples thereof.

The second generator should supply signals for the entire frequency range of Model 400A. Output need only be adequate to get a readable indication on the 300 volt scale of Model 400A.

Check of Line Voltage Response

This test is recommended before adjusting voltage calibration or frequency response: Apply 1 megacycle signal to 1 volt range. Vary line voltage from 105 to 125 volts, allowing about 30 seconds for meter to stabilize after each change. Check meter indications against Specifications for voltage stability at front of manual. If not within Specifications, look for weak amplifier tubes. Replace defective or questionable tubes before proceeding with calibration procedures.

Voltage Calibration

CAUTION

WHEN CHECKING ANY HIGH SENSITIVITY RANGE, BE SURE NO GROUND LOOPS EXIST IN THE TEST EQUIPMENT. GROUND LOOPS CAN CAUSE HUM PICKUP AND OTHER INTERFERING VOLTAGES. TO AVOID GROUND LOOPS, SET INSTRUMENT UPRIGHT ON BOTTOM PLATE AND GROUND ALL TEST CONNECTIONS ONLY AT BOTTOM INPUT TERMINAL.

With input of exactly 1 volt, adjust feedback control R13 to obtain 1 volt indication on 1 volt range. Check this indication with 400A in cabinet.

Check meter tracking on 1 volt range. If meter does not track satisfactorily, try replacing V4 (6H6). If you replace V4, be sure to check meter zero adjustment and repeat adjustment of R13.

Calibration of seven lowest ranges depends on your previous adjustment of control R13. To check these ranges, apply full scale voltages to each range.

Calibration of 100 and 300 volt ranges should also be made by applying full scale voltages, although 100 volts may be used on the 300 volt range, if

necessary. On the 100 volt range, adjust R1a for full scale calibration. An increase in value for R1a will decrease the meter indication. On the 300 volt range, adjust R2a for full scale calibration. An increase in value of R2a will increase the meter indication.

The 400A is now calibrated on all ranges.

Frequency Response

Frequency response of 0.1 volt range is adjustable with trimmer C6. Response of 30 volt range is adjustable with C16, if present, and by dressing leads and components. Response of 100 volt range is adjustable with C1, and response of 300 volt range is adjustable with C2. Response of remaining ranges will be correct after 30 volt range is adjusted.

It is important to follow adjustment sequence given here and to observe following items: Avoid moving leads from original positions except for deliberate adjustment. Keep heater leads close to chassis to prevent hum pickup. Set instrument upright on bottom plate when reading meter.

1. First apply test frequencies from 10 cps to 1 megacycle on 30 volt range since this is the range which requires the total resistance of the cathode voltage divider R8. If adjustments are required for 30 volt range, separate C4 and C7 as far as leads will permit. Adjust C16, if present, and dress leads to C11 and R18, or move C10 and R18 to obtain most uniform response. These parts affect plate-grid coupling in V3. Increased coupling reduces 1 megacycle response while decreased coupling increases 1 megacycle response. In some instruments, especially those without C16, position of R11 also affects response. Part of winding on R11 may be removed to adjust response. If C16 is present, keep winding on R11 evenly distributed and adjust only C16.

   When leads and components are adjusted, leave them untouched for remaining adjustments.

2. After adjusting 30 volt range, check response of 0.03 volt range. If response on 0.03 range is not satisfactory, adjustments for 30 volt range must be repeated. Poor low frequency response can be caused by tubes.

3. After checking 0.03 volt range, check 0.1 volt range. Response for this range is adjustable with capacitor C6.

4. After checking 0.1 volt range, check 100 and 300 volt ranges. Response of 100 volt range is adjustable with C1. Response of 300 volt range is adjustable with C2. It may be necessary to adjust response up to 5% high at 1 megacycle to obtain specified response at 100 kilocycles.

   Since only a few volts signal at high frequencies are usually available from signal generators, meter indication for 100 and 300 volt ranges

will be very small. However, only enough indication is needed to judge uniformity of response at any point on either range. An external indicator such as an oscilloscope may be used if care is taken not to load the voltmeter amplifier in a way that will change its frequency response. A sensitive galvanometer could be temporarily substituted for the meter.

5. Check response of remaining ranges. If not within specifications, refer to Trouble Shooting section.

Final Checking

Allow instrument to cool completely, then recheck calibration after five minute warm-up. If calibration has changed appreciably, refer to Trouble Shooting section for remedial procedures.

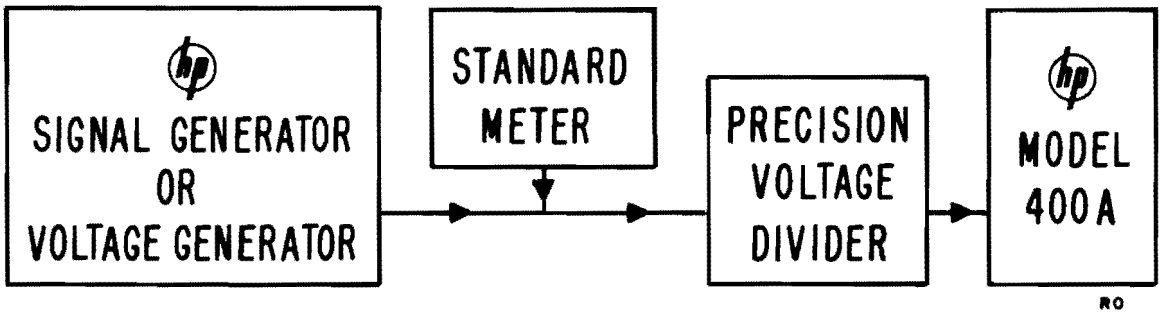


Figure 4-2. Basic Calibration Equipment

4-11 TROUBLE SHOOTING

Circuit designations refer to Figure 4-9.

TROUBLE SHOOTING CHART

Symptom	Cause and Remedy
Power supply	
Dead instrument	Defective V5, fuse, or transformer.
Poor regulation	Defective tube, low dc output caused by defective transformer, filter, rectifier; excessive load caused by shorted V2, C3, C7, C8, C9, C14; dc output set too high or too low. V8 may glow and still be defective.
No output	Shorted load on B+, dead V8, shorted V7, failure of supply voltage, shorted filter capacitor.
Oscillation	Defective V8, V6, V7, filter capacitor.
Regulated dc too high	Defective V5, V6, V7, V8; R33 open or wrong value; C14 shorted.
Regulated dc too low	Defective V7, V8, V6; R32 open or wrong value.
Bias supply incorrect	Defective R3, R10, C8. These can damage R14, R18 or 6AC7 tubes. Recalibrate after replacing R14, R18, or 6AC7 tubes.
Meter Dead	
On all ranges.	Fuse F1 burned out. Replace with 0.6 amp slo-blo fuse.
	Power supply failure.
	V4 (6H6) defective.
	Meter open.
	C7, C10, or C11 open.
	C12 shorted.
	V1, V2, or V3 defective.
On some ranges.	R8 open.
	Range switch S1 defective.

TROUBLE SHOOTING CHART (Con't.)

Symptom		Cause and Remedy
Regulated voltage not correct		
	Too low.	Defective V5, V6, V7 or V8.
		R33 open or changed to a high value.
		C14 leaking.
	Too high.	V7 or V8 defective.
		V6 shorted.
		R32 open or changed to a high value.
Motorboating		
	On .03 volt range only.	C13 defective.
		C9 open.
	On lower 3 ranges only.	R5 or R6 open.
	On all ranges.	Defective electrolytic.
		V8 defective.
		Defective component(s) in B plus regulator circuit.
Sensitivity potentiometer R13 has insufficient range		
	Very early chassis.	A 50 ohm potentiometer was used for R13, and R12 was a higher value. Range of R13 can be increased in these instruments by replacing R13 with 100 ohm potentiometer hp Stock No. 210-28 and R12 with 27 ohms, ±10%, 1/2 watt, composition resistor.
	Late production.	Low sensitivity in amplifier caused by any one or more components breaking down.
		V2 or V3 defective.
		C9 defective.
Abnormal meter indication		
	Meter off scale at high end on all ranges.	C9, C14, or C15 defective.
		C8 open.
		Reference tube V8 is oscillating. If circuit has 991 lamp for V8, modernize as directed in MODERNIZING OLDER UNITS section.
	Meter needle jumpy on all ranges.	R14 or R18 defective.
		C5 defective.
		V1, V2, V3, or V8 defective.
		Poor ground connection for any tube socket or electrolytic capacitor mounting bracket.
		R5 or R6 defective, Use hp exact replacement part.
	Meter needle jumpy on 100 and 300 volt ranges only.	R1, R1a, R2, or R2a defective. Use hp exact replacement part.
	Slow rise in meter reading then sharp drop to original reading.	Capacitor C8 defective.
	Meter reading low on 0.1 volt range and high on upper range.	V2 or V3 defective.
	Meter reading high or low on all ranges.	V1, V2, or V3 defective.
		C7, C10, or C11 defective.
		Power supply trouble.
		6H6 (V4) defective.
		Open resistor; may be any one of many.
	Reading low on 100 and 300 volt ranges.	R6 defective.
		R1 or R1a defective.
		C5 defective.

TROUBLE SHOOTING CHART (Con't.)

Symptom	Cause and Remedy
Abnormal meter indication (Con't.)	
Input terminals open, meter reads full scale. Input terminals shorted, zero reading on 1.0 and 30 volt scales vary by as much as 2 scale divisions.	V1 (6J5) defective.
On 100 volt scale, readings over 50 volts slowly drop by more than 5%.	V1 (6J5) defective.
Normal readings on first seven ranges; low readings on 100 and 300 volt ranges.	R1, R1a, R2, R2a, R5, or R6 defective. Use hp exact replacement part.
Inaccurate readings on .03 and .10 volt ranges.	C7 defective.
	Range switch defective.
Meter pointer indicates a steady reading well up on scale with no input voltage. Needle appears to quiver or oscillate slightly. This condition may or may not change with range switch position and V8 may or may not flicker.	V8 oscillating. This is more probable in older instruments where V8 is a type 991 neon glow lamp. Replace lamp with an OD3 regulator tube as described in the MODERNIZING OLDER UNITS section.
	Line voltage may be fluctuating and so low that the regulator circuit is not functioning.
	V1 (6J5) shorted.
High residual noise level	
General	C16 shorted.
	V8 defective.
	Noisy tube in any position.
	C8 defective.
With meter needle vibrating.	C8 open.
	V2 or V3 defective.
Varying level.	Poor ground contact on V5 and V8 tube socket mounting rings.
Which can be eliminated by shorting input terminals.	Various ground points have been used for heater circuit of V1, V2, V3, and V4. Ground V2 pin 7 to adjacent lug on tube socket mounting ring. Remove any other ground connections to pins 2 or 7 for these four tubes.
	Heater leads too close to grid pins or wires connected to grid of V1 or V2. If pickup is in V1 grid circuit, the meter reading will drop as the range switch is advanced to higher voltage range.
Microphonics	
General	Defective resistors anywhere in circuit. Check R1, R2, R14, R15, R17, and R18 first.
	6AC7 tube for V2 is microphonic. Replace tube or reverse 6AC7 tubes in instrument.
Resistors R14 or R18 overheating or burned out.	
General	C7 shorted.
	C8 shorted.
	Refer to BIAS CIRCUIT TROUBLE in POWER SUPPLY section.

TROUBLE SHOOTING CHART (Con't.)

Symptom		Cause and Remedy
Frequency response		
	High at low frequencies	V2 or V3 defective.
		C8 defective.
	Normal response on low ranges. Low response on 100 and 300 volt ranges at 100 KC and 1 MC.	C1 or C2 defective.
	Low at low frequencies	V2 or V3 defective.
		On very early production C4 was 0.05 μf. Check C4 or replace with 0.082 μf if the instrument has the 0.05 μf capacitor. Later instruments will have the 0.082 μf capacitor.

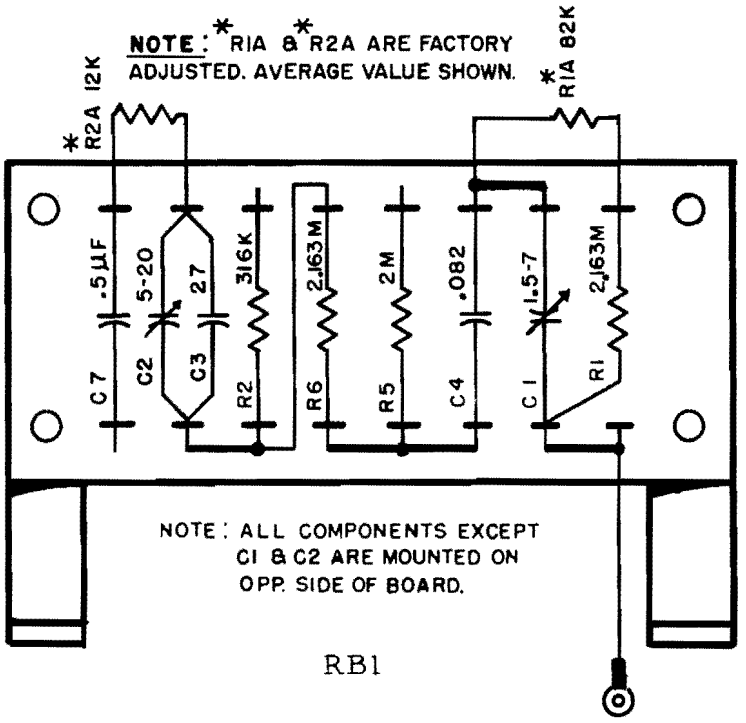


Figure 4-3. Model 400A Resistor Board Details

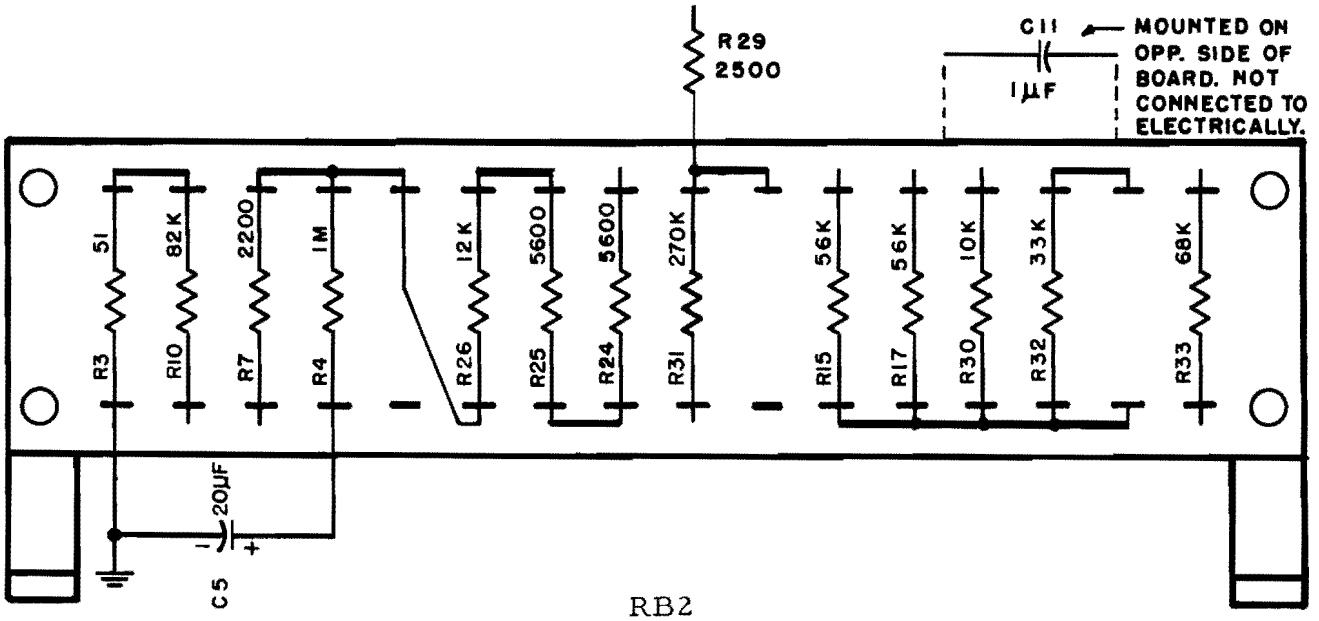


Figure 4-4. Model 400A Resistor Board Details

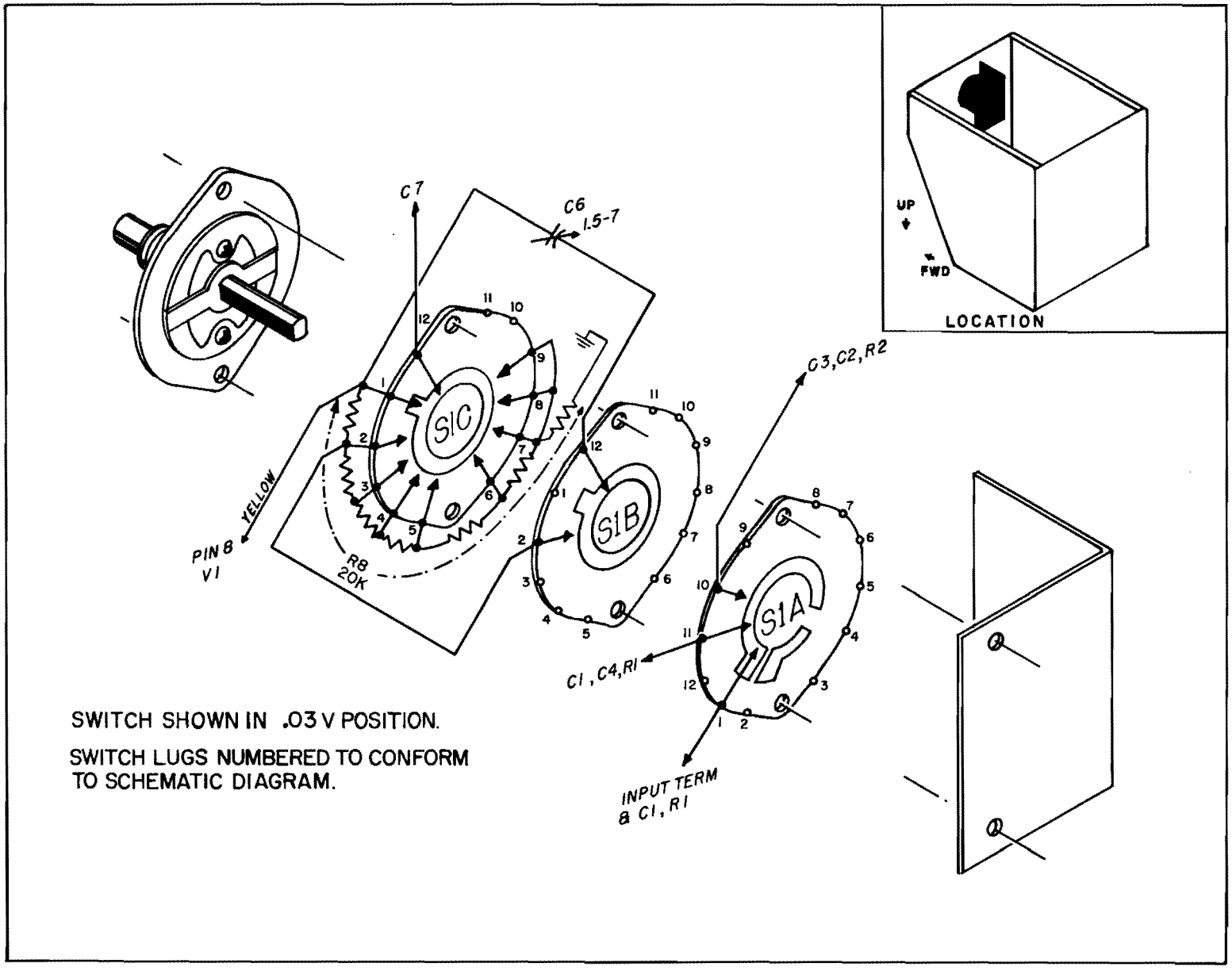


Figure 4-5. S1 ABC Range Switch Detail. Model 400A

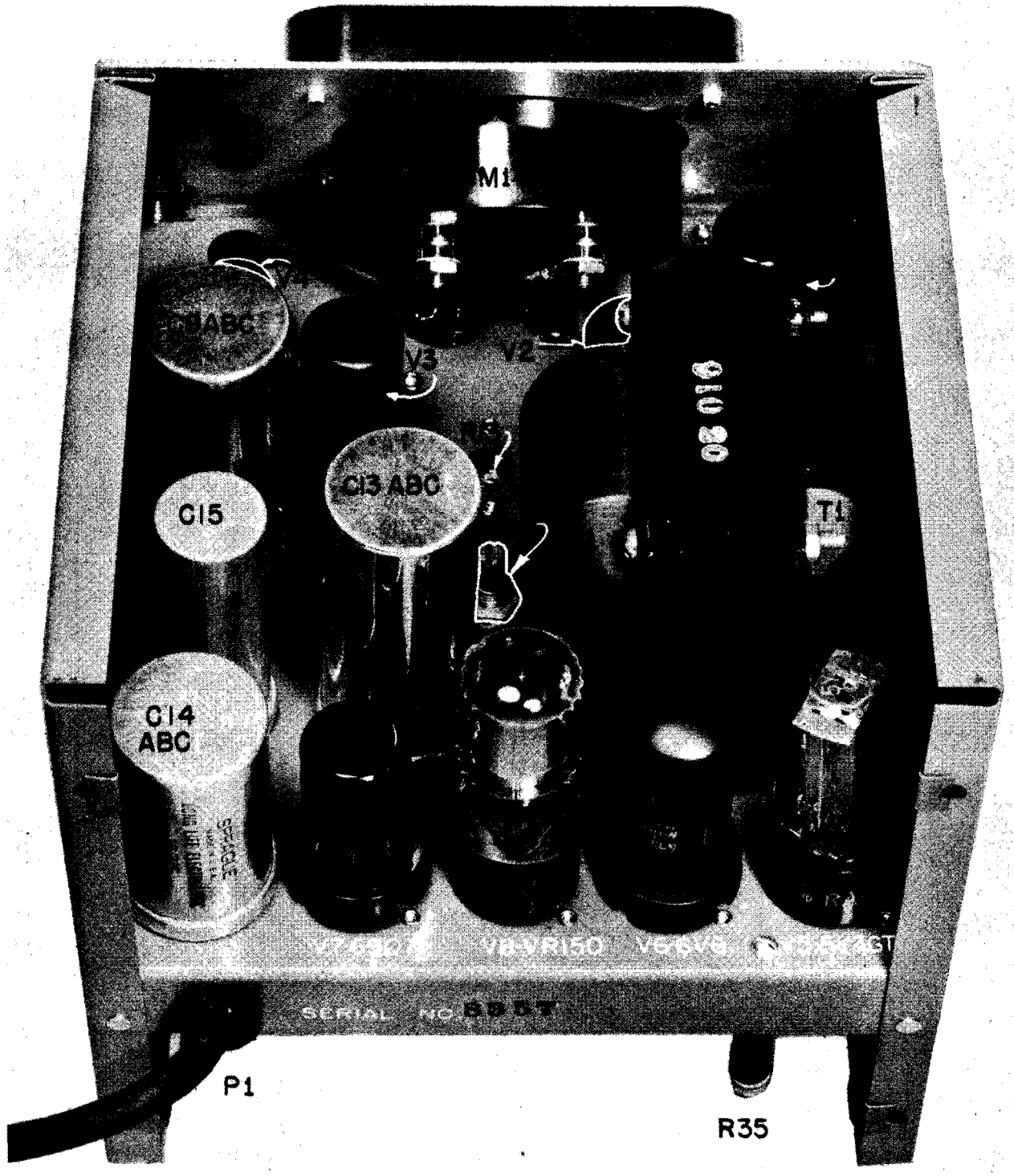


Figure 4-6. Model 400A Top View Cover Removed

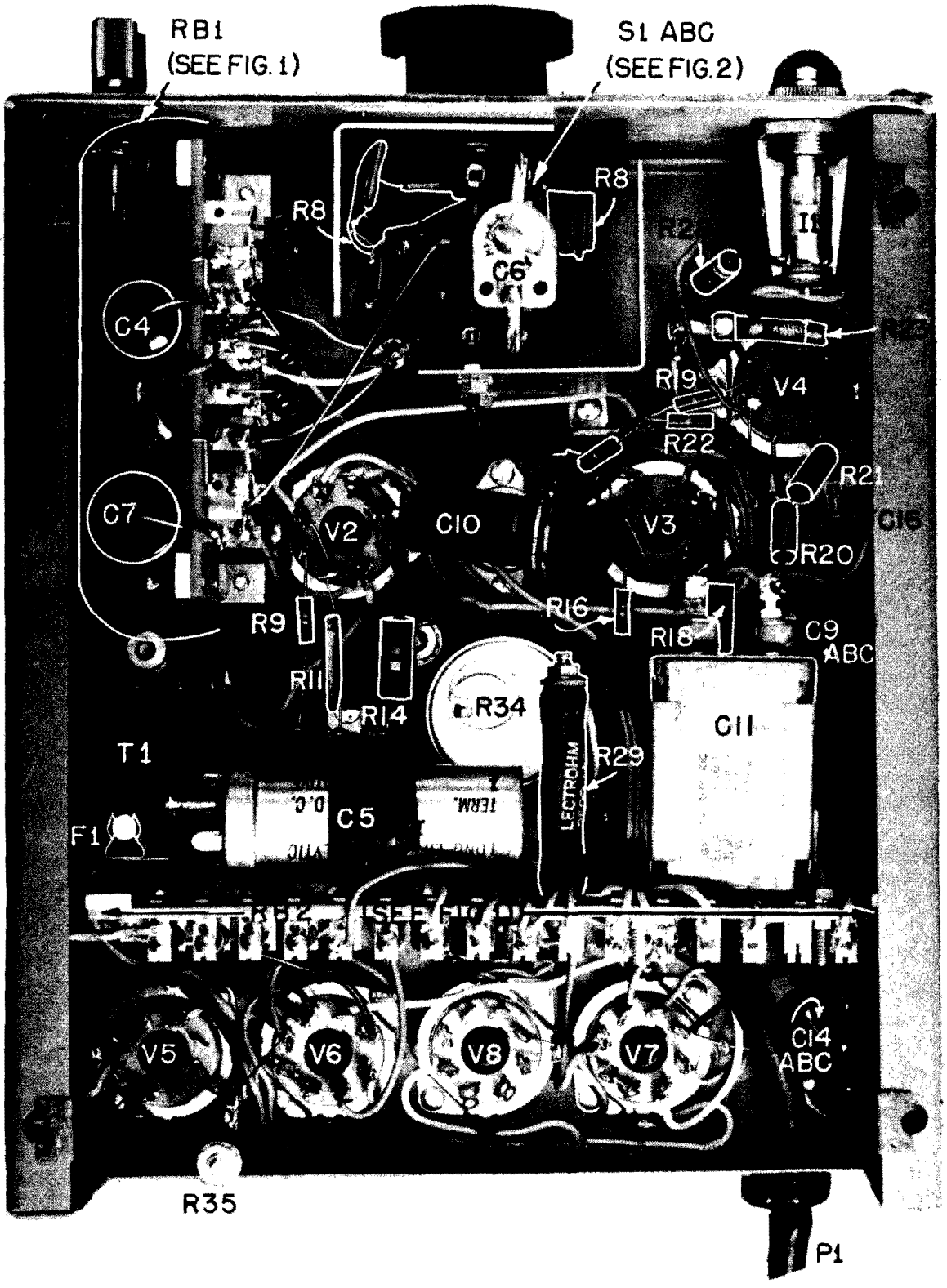
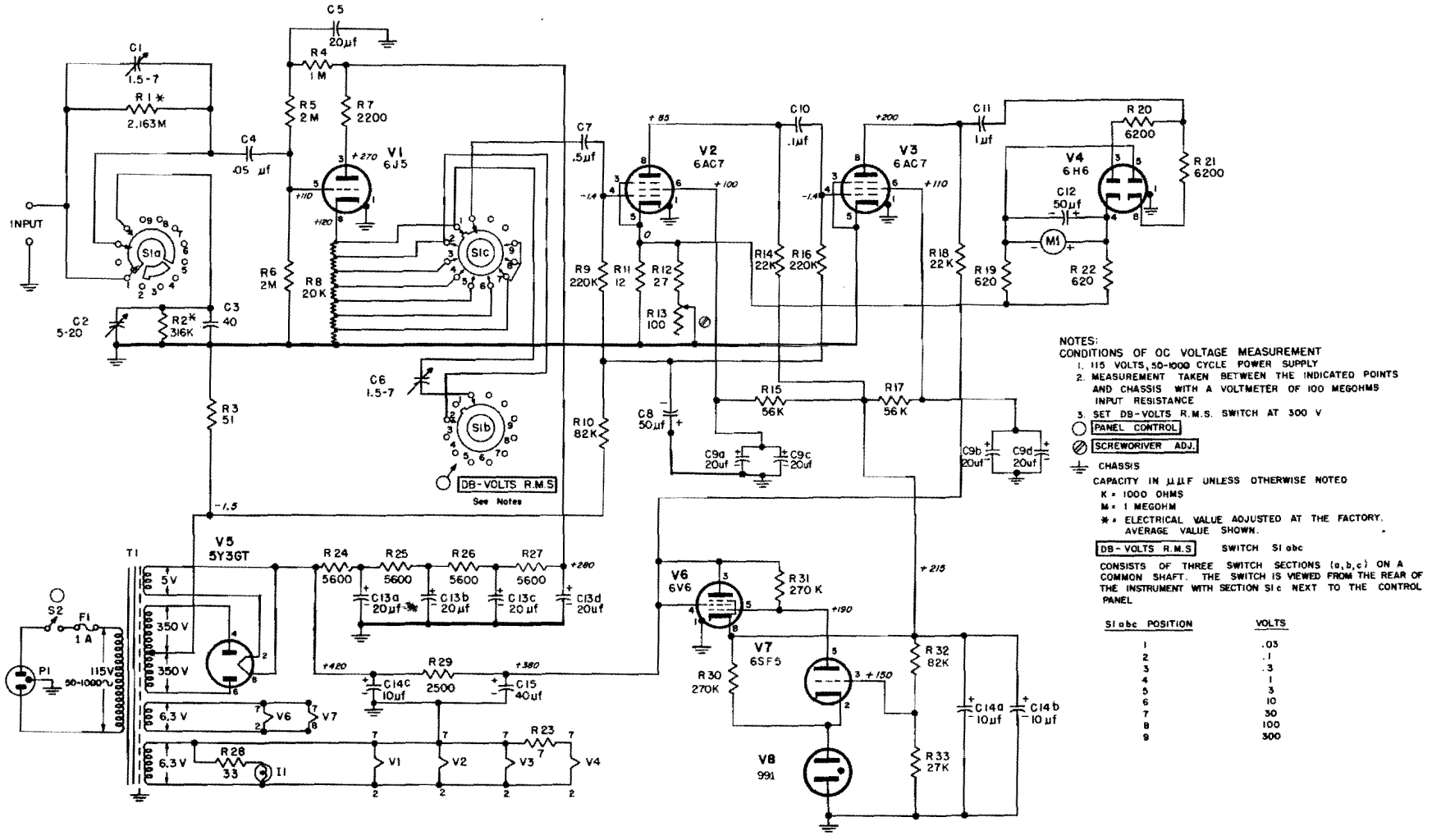


Figure 4-7. Model 400A Bottom View Bottom Plate Removed



NOTES:
CONDITIONS OF DC VOLTAGE MEASUREMENT

1. 115 VOLTS, 50-1000 CYCLE POWER SUPPLY
2. MEASUREMENT TAKEN BETWEEN THE INDICATED POINTS AND CHASSIS WITH A VOLTMETER OF 100 MEGOHMS INPUT RESISTANCE
3. SET DB-VOLTS R.M.S. SWITCH AT 300 V

○ PANEL CONTROL
⊘ SCREWDRIVER ADJ.
⏚ CHASSIS

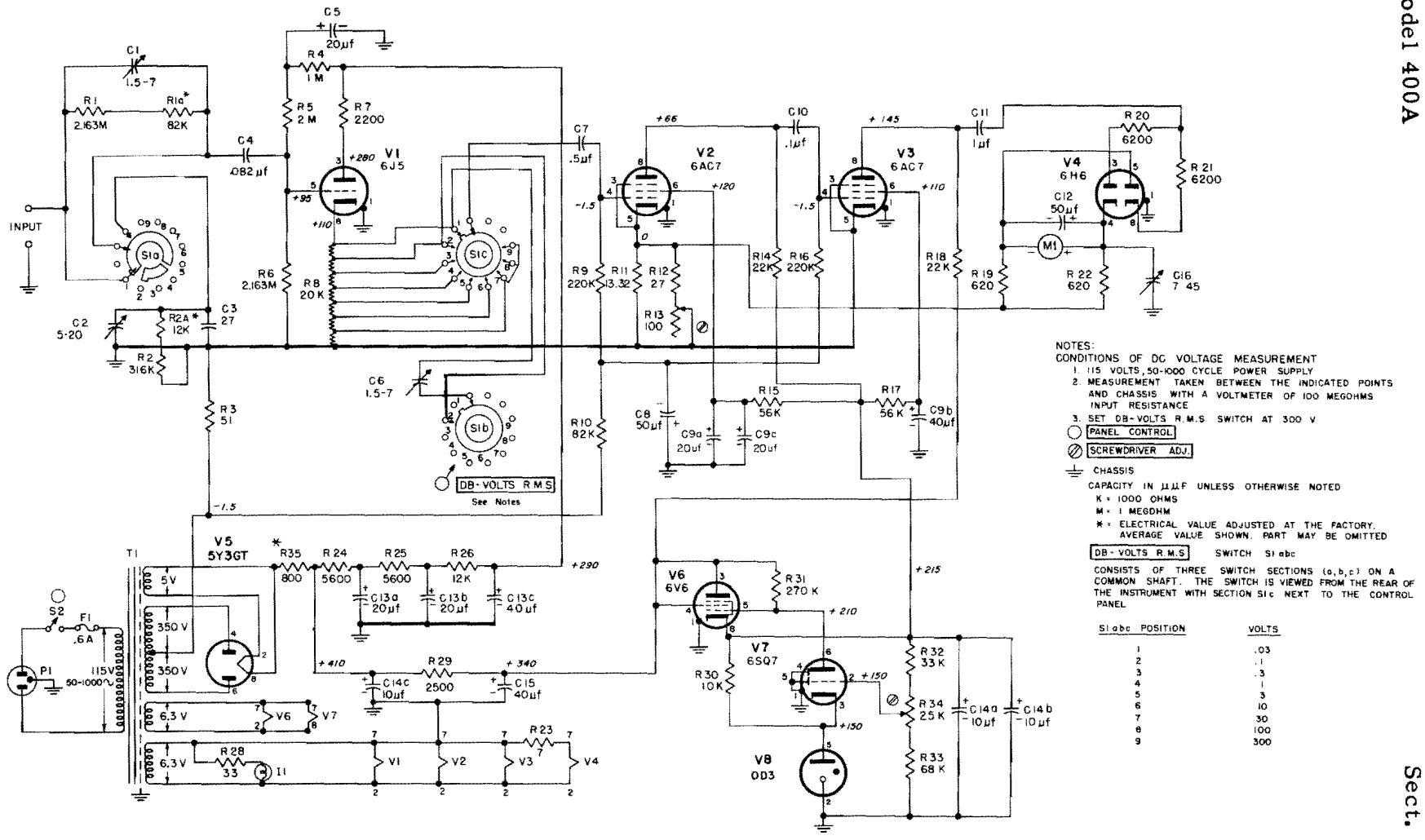
CAPACITY IN µµF UNLESS OTHERWISE NOTED
K = 1000 OHMS
M = 1 MEGOHM
* = ELECTRICAL VALUE ADJUSTED AT THE FACTORY. AVERAGE VALUE SHOWN.

DB-VOLTS R.M.S. SWITCH S1 abc

CONSISTS OF THREE SWITCH SECTIONS (a,b,c) ON A COMMON SHAFT. THE SWITCH IS VIEWED FROM THE REAR OF THE INSTRUMENT WITH SECTION S1c NEXT TO THE CONTROL PANEL

S1 abc POSITION	VOLTS
1	.03
2	.1
3	.3
4	1
5	3
6	10
7	30
8	100
9	300

Figure 4-8. Ⓗ Model 400A Vacuum Tube Voltmeter
Serial 5620 & Below



NOTES:
CONDITIONS OF DC VOLTAGE MEASUREMENT
1. 115 VOLTS, 50-1000 CYCLE POWER SUPPLY
2. MEASUREMENT TAKEN BETWEEN THE INDICATED POINTS AND CHASSIS WITH A VOLTMETER OF 100 MEGOHMS INPUT RESISTANCE
3. SET DB-VOLTS R.M.S. SWITCH AT 300 V

○ PANEL CONTROL

⊘ SCREWDRIVER ADJ.

⏚ CHASSIS

CAPACITY IN µµF UNLESS OTHERWISE NOTED
K = 1000 OHMS
M = 1 MEGOHM
* = ELECTRICAL VALUE ADJUSTED AT THE FACTORY. AVERAGE VALUE SHOWN. PART MAY BE OMITTED

DB - VOLTS R.M.S. SWITCH S1 abc

CONSISTS OF THREE SWITCH SECTIONS (a, b, c) ON A COMMON SHAFT. THE SWITCH IS VIEWED FROM THE REAR OF THE INSTRUMENT WITH SECTION S1c NEXT TO THE CONTROL PANEL

S1 abc POSITION	VOLTS
1	.03
2	.1
3	.3
4	1
5	3
6	10
7	30
8	100
9	300

Figure 4-9. ℎp Model 400A Vacuum Tube Voltmeter
Serial 8723 & Above

SECTION V
TABLE OF REPLACEABLE PARTS

NOTE

Standard components have been used in this instrument, whenever possible. Special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1. ℌ Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed, give complete description, function and location of part.

Corrections to the Table of Replaceable Parts are listed on an Instruction Manual Change sheet at the front of this manual.

RECOMMENDED SPARE PARTS LIST

Column RS in the Table lists the recommended spare parts quantities to maintain one instrument for one year of isolated service. Order complete spare parts kits from the Factory Parts Sales Department. ALWAYS MENTION THE MODEL AND SERIAL NUMBERS OF INSTRUMENTS INVOLVED.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.
C1	Capacitor, variable, ceramic, 1.5-7 μμf, 500 vdcw	L*	13-7
C2	Capacitor, variable, ceramic, 5-20 μμf, 500 vdcw	L*	13-20
C3 †	Capacitor, fixed, mica, 39 μμf, ±5%, 500 vdcw	V*	14-70
	27 μμf, ±10%, 500 vdcw	V*	14-17
C4†	Capacitor, fixed, paper, .051 μf, ±5%, 600 vdcw	CC*	16-53
	.082 μf, ±10%, 600 vdcw	CC*	16-70
C5	Capacitor, electrolytic, can type, 20 μf, 450 vdcw	CC*	18-20
C6	Capacitor, variable, ceramic, 1.5-7 μμf, mounted on S1	L*	13-7
C7	Capacitor, fixed, paper .5 μf	CC*	16-53
C8	Capacitor, electrolytic, tubular 50μf, 50 vdcw	X*	18-50
C9	Capacitor, electrolytic, can type 4 sections, 20 μf each section, 450 vdcw	CC*	18-42HP
C10	Capacitor, fixed, paper, .1 μf, ±10%, 600 vdcw	CC*	16-1
C11	Capacitor, oil-filled, paper, 1 μf, ±10%, 600 vdcw	N*	17-12
C12	Capacitor, electrolytic, tubular 50 μf, 50 vdcw	X*	18-50
C13	Capacitor, electrolytic, can type, 4 section, 20 μf each section, 450 vdcw	CC*	18-42HP
C14	Capacitor, electrolytic, can type, 3 section, 10μf each section, 450 vdcw	CC*	18-31HP
C15	Capacitor, electrolytic, can type, 40μf, 450 vdcw	CC*	18-40HP
C16	Capacitor, variable, ceramic, 7-45 μμf, 500 vdcw	L*	13-1
R1	Resistor, fixed, deposited carbon, 2.163 megohms, ±1%, 1 W	NN*	31-2.163M
R1a	Resistor, fixed, composition, 82,000 ohms nominal. Value adjusted at factory.	B*	23-82K

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

† Refer to History of Production and schematic diagrams.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.
R2	Resistor, fixed, deposited carbon, 316,000 ohms, ±1%, 1 W	NN*	31-316K
R2a	Resistor, fixed, composition, 12,000 ohms nominal. Value adjusted at factory.	B *	23-12K
R3	Resistor, fixed, composition, 51 ohms, ±5%, 1 W	B*	24-75
R4	Resistor, fixed, composition, 1 megohm, ±10%, 1 W	B*	24-1M
R5	Resistor, fixed, deposited carbon, 2 megohms, ±1%, 1 W	NN*	31-2M
R6†	Resistor, fixed, deposited carbon, 2 megohms, ±1%, 1 W 2.163 megohms, ±1%, 1 W	NN* NN*	31-2M 31-2.163M
R7	Resistor, fixed, composition, 2200 ohms, ±10%, 1/2 W	B *	23-2200
R8	Resistor, wirewound, 7 section, 20,000 ohms total resistance	HP*	4A-71
R9	Resistor, fixed, composition, 220,000 ohms, ±10%, 1/2 W	B *	23-220K
R10	Resistor, fixed, composition, 82,000 ohms, ±10%, 1 W	B*	24-82K
R11	Resistor, wirewound, 13.32 ohms	HP*	4A-90
R12†	Resistor, fixed, composition, 27 ohms, ±10%, 1/2 W 47 ohms, ±10%, 1/2 W	B * B *	23-27 23-47
R13	Resistor, variable, wirewound, 100 ohms, ±10%	I*	210-28
R14	Resistor, fixed, composition, 22,000 ohms, ±10%, 2 W	B*	25-22K
R15	Resistor, fixed, composition, 56,000 ohms, ±10%, 1 W	B*	24-56K
R16	Resistor, fixed, composition, 220,000 ohms, ±10%, 1/2 W	B*	23-220K
R17	Resistor, fixed, composition, 56,000 ohms, ±10%, 1 W	B*	24-56K
R18	Resistor, fixed, composition, 22,000 ohms, ±10%, 2 W	B*	25-22K
R19	Resistor, fixed, composition, 620 ohms, ±5%, 1 W	B*	24-620-5

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

† Refer to History of Production and schematic diagrams.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.				
R20	Resistor, fixed, composition, 6200 ohms, ±5%, 1 W	B*	24-6200-5				
R21	Resistor, fixed, composition, 6200 ohms, ±5%, 1 W	B*	24-6200-5				
R22	Resistor, fixed, composition, 620 ohms, ±5%, 1 W	B*	24-620-5				
R23	Resistor, wirewound, fixed, flexible 7 ohms, ±10%, 1 W	I*	26-18				
R24	Resistor, fixed, composition, 5600 ohms, ±10%, 1 W	B*	24-5600				
R25	Resistor, fixed, composition, 5600 ohms, ±10%, 1 W	B*	24-5600				
R26†	Resistor, fixed, composition, 5600 ohms, ±10%, 1 W 12,000 ohms, ±10%, 1 W	B*	24-5600 24-12K				
R27	Resistor, fixed, composition, 5600 ohms, ±10%, 1 W	B*	24-5600				
R28	Resistor, fixed, composition, 33 ohms, ±10%, 1 W	B*	24-33				
R29	Resistor, wirewound, fixed, vitreous coated, 2500 ohms, 10 W	S*	26-7				
R30†	Resistor, fixed, composition, 270,000 ohms, ±10%, 1 W 10,000 ohms, ±10%, 2 W	B*	24-270K 25-10K				
R31	Resistor, fixed, composition, 270,000 ohms, ±10%, 1 W	B*	24-270K				
R32	Resistor, fixed, composition, 82,000 ohms, ±10%, 1 W 33,000 ohms, ±10%, 1 W	B* B*	24-22K 24-33K				
R33†	Resistor, fixed, composition, 27,000 ohms, ±10%, 1 W 68,000 ohms, ±10%, 1 W 62,000 ohms, ±10%, 1 W	B* B* B*	24-27K 24-68K 24-62K				
R34	Resistor, variable, composition, 25,000 ohms	G*	210-10				
R35	Resistor, fixed, wirewound, 800 ohms nominal, 5 W. Value adjusted at factory.	S*	26-6				
P1	Power Cable	HP*	812-56				

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

† Refer to History of Production

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.
S1	Range Switch Assembly, including R8	HP*	4A-19
	Knob	HP*	G-74S
S2	Switch, toggle, SPST	D*	310-11
T1	Power transformer	HP*	910-20
V1	Tube, electron, 6J5	ZZ*	212-6J5
V2, V3	Tube, electron, 6AC7	ZZ*	212-6AC7
V4	Tube, electron, 6H6, aged	HP* or ZZ*	212-6H6
V5	Tube, electron, 5Y3GT	ZZ*	212-5Y3GT
V6	Tube, electron, 6V6	ZZ*	212-6V6
V7†	Tube, electron, 6SF5	ZZ*	212-6SF5
	Tube, electron, 6SQ7	ZZ*	212-6SQ7
V8†	Tube, gas-filled regulator		
	Type OA2 Regulator	ZZ*	212-OA2
	Type OD3 Regulator	ZZ*	212-OD3
	Type 991 Neon Lamp; aged	HP*	211-10
	Socket for Neon Lamp V8, 1" mounting hole	II*	38-1
	Socket for Neon Lamp V8, 3/4" mounting hole	II*	38-N
	Binding Post: Black	HP*	G-10C
	Binding Post: Red	HP*	G-10D
	Insulator, binding post	HP*	G-83A
I1	Lamp, incandescent, 6-8 v, .15 amp	N*	211-47
	Indicator Lamp Assembly	BB*	312-10
M1	Meter movement	BF*	112-6
F1	Fuse, 0.6 ampere, slo-blo	E*	211-49
	Fuseholder	T*	312-8

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

† Refer to History of Production.

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

CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee 4, Wis.
C	Amperite Co.	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Co.	St. Louis, Mo.
F	Carborundum Co.	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.
HP	Hewlett-Packard Co.	Palo Alto, Calif.
I	Clarostat Mfg. Co.	Dover, N. H.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corp.	Erie 6, Pa.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.
N	General Electric Co.	Schenectady 5, N. Y.
O	General Electric Supply Corp.	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Co.	Danbury, Conn.
R	International Resistance Co.	Philadelphia 8, Pa.
S	Lectrohm Inc.	Chicago 20, Ill.
T	Littlefuse Inc.	Des Plaines, Ill.
U	Maguire Industries Inc.	Greenwich, Conn.
V	Micamold Radio Corp.	Brooklyn 37, N. Y.
W	Oak Manufacturing Co.	Chicago 10, Ill.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.
Y	Radio Corp. of America	Harrison, N. J.
Z	Sangamo Electric Co.	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.
CC	Sprague Electric Co.	North Adams, Mass.
DD	Stackpole Carbon Co.	St. Marys, Pa.
EE	Sylvania Electric Products Co.	Warren, Pa.
FF	Western Electric Co.	New York 5, N. Y.
GG	Wilkor Products, Inc.	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Co.	New York, N. Y.
KK	Switchcraft, Inc.	Chicago 22, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.
MM	Carad Corp.	Redwood City, Calif.
NN	Electra Manufacturing Co.	Kansas City, Mo.
OO	Acro Manufacturing Co.	Columbus 16, Ohio
PP	Alliance Manufacturing Co.	Alliance, Ohio
QQ	Arco Electronics, Inc.	New York 13, N. Y.
RR	Astron Corp.	East Newark, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.
TT	Belden Manufacturing Co.	Chicago 44, Ill.
UU	Bird Electronics Corp.	Cleveland 14, Ohio
VV	Borber Colman Co.	Rockford, Ill.
WW	Bud Radio Inc.	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.
YY	Cinema Engineering Co.	Burbank, Calif.
ZZ	Any brand tube meeting RETMA standards.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.
AD	The Drake Mfg. Co.	Chicago 22, Ill.
AE	Elco Corp.	Philadelphia 24, Pa.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.
AG	Thomas A. Edison, Inc.	West Orange, N. J.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Co.	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corp.	Chicago 18, Ill.
AM	Insuline Corp. of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
AO	E. F. Johnson Co.	Waseca, Minn.
AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
AT	The Muter Co.	Chicago 5, Ill.
AU	Ohmite Mfg. Co.	Skokie, Ill.
AV	Resistance Products Co.	Harrisburg, Pa.
AW	Radio Condenser Co.	Camden 3, N. J.
AX	Shallcross Manufacturing Co.	Collingdale, Pa.
AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
AZ	Sealectro Corp.	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Co.	Mansfield, Ohio
BD	Torrington Manufacturing Co.	Van Nuys, Calif.
BE	Vector Electronic Co.	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	San Francisco, Calif.
BI	Electronics Tube Corp.	Philadelphia 18, Pa.
BJ	Aircraft Radio Corp.	Boonton, N. J.
BK	Allied Control Co., Inc.	New York 21, N. Y.
BL	Augat Brothers, Inc.	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBS Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Excel Transformer Co.	Oakland, Calif.
BT	General Radio Co.	Cambridge 39, Mass.
BU	Hughes Aircraft Co.	Culver City, Calif.
BV	International Rectifier Corp.	El Segundo, Calif.
BW	James Knights Co.	Sandwich, Ill.
BX	Mueller Electric Co.	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Co.	Newton, Mass.
CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corp.	Union, N. J.
CF	Weckesser Co.	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electronics, Inc.	Santa Monica, Calif.
CI	Malco Tool & Die	Los Angeles 42, Calif.
CJ	Oxford Electric Corp.	Chicago 15, Ill.
CK	Camloc-Fastener Corp.	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Pa.
CM	Union Switch & Signal	Swissvale, Pa.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Co.	Bridgeport 2, Conn.
CQ	Birnbach Radio Co.	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
CT	Potter-Brumfield Co.	Princeton, Ind.
CU	Cannon Electric Co.	Los Angeles, Calif.
CV	Dynac, Inc.	Palo Alto, Calif.
CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

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"