MODEL 400C

VACUUM TUBE VOLTMETER

OPERATING AND SERVICE MANUAL

HEWLETT PACKARD

OPERATING AND SERVICE MANUAL

FOR

MODEL 400C

VACUUM TUBE VOLTMETER

This is a combined Operation and Service Manual for all -hp- Model 400C Vacuum Tube Voltmeters. The Model 400C is no longer manufactured and has been superseded by the improved -hp- Model 400D. This combined manual contains complete operating and servicing instructions for the 400C and replaces the discontinued Instruction and Operating Manual originally supplied with each instrument.

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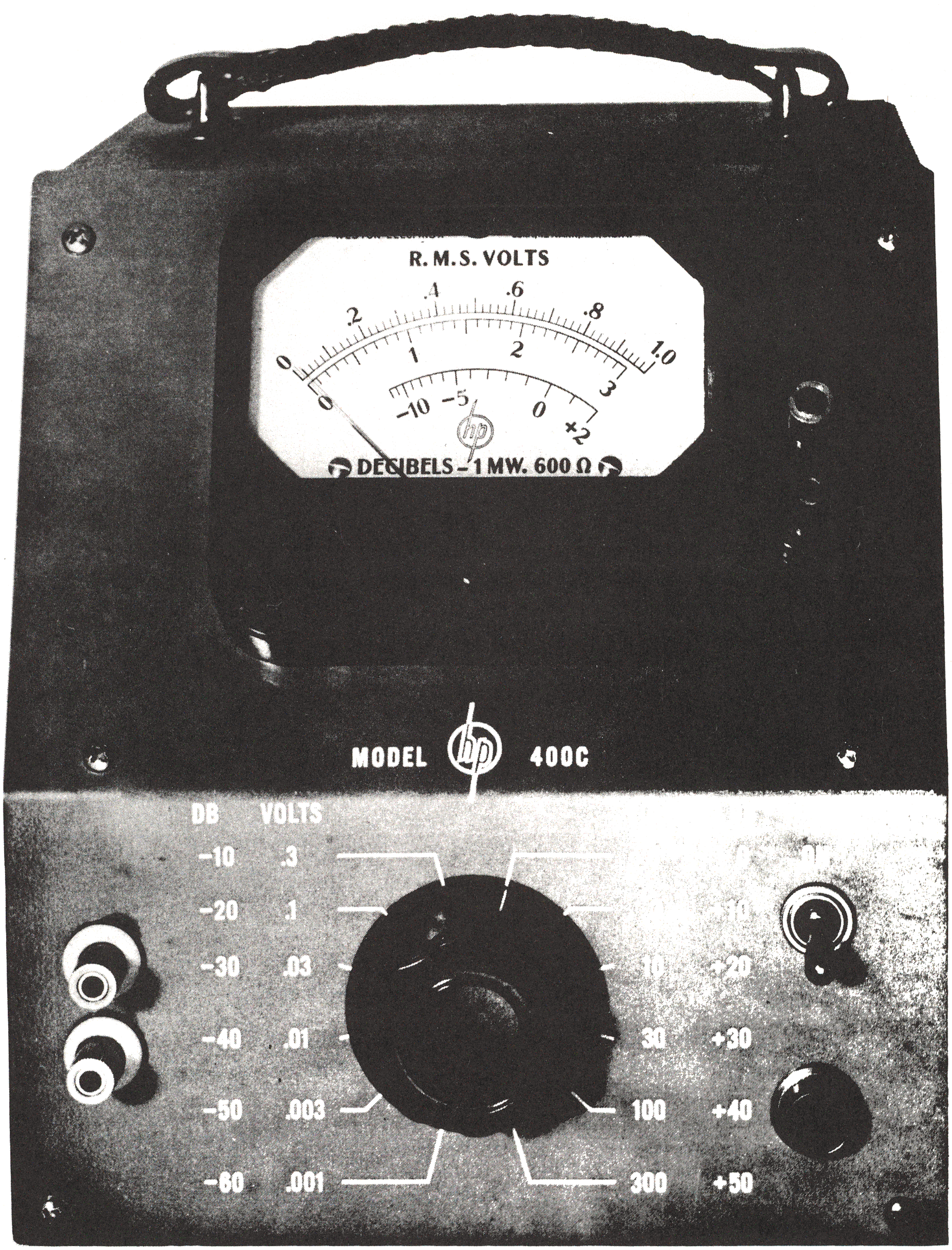


HEWLETT-PACKARD MODEL 400C TYPICAL FRONT VIEW

HEWLETT-PACKARD MODEL 400C VACUUM TUBE VOLTMETER
OPERATION & SERVICE MANUAL

Specifications, Operating Instructions, Schematic Diagrams, and a Circuit Description suitable for all hp Model 400C Vacuum Tube Voltmeters will be found on the following pages of the Service Manual following the Table of Replaceable Parts.

IMPORTANT

The portions of the Service Manual devoted to Operation and the procedure for making the Mechanical Zero Set Adjustment should be thoroughly read and understood before operating any Model 400C Vacuum Tube Voltmeter.

ACCESSORIES

The following accessories are available for use with the hp Model 400C Vacuum Tube Voltmeter. These accessories are not supplied with the instrument, but may be purchased from the Hewlett-Packard Company.

CAPACITIVE VOLTAGE DIVIDER hp MODEL 452A -

Extends the voltage range of the Model 400C to 25,000 volts.
Maximum Voltage . . . . 25,000 volts at 60 cps.
Division Ratio . . . . 1000 to 1.
Frequency Range . . . . 25 cps to 20 MC.
Accuracy . . . . ±3%.
Input Capacity . . . . 15 μμf, ±1.

CAPACITIVE VOLTAGE DIVIDER hp MODEL 454A -

Extends the voltage range of the Model 400C to 1,500 volts.
Maximum Voltage . . . . 1500 volts.
Division Ratio . . . . 100 to 1.
Frequency Range . . . . 20 cps to 2 MC.
Accuracy . . . . ±3%.
Input Impedance . . . 50 megohms shunted with 2.75 μμf.

SHUNT RESISTOR hp MODELS 470A THROUGH 470F -

These shunt resistors adapt the hp Model 400C for measurement of alternating current at low levels.

Accuracy . . . . . ±1% from 10 cps to 100 KC.
±5% from 100 KC to 4.0 MC. (470A, ±5% to 1 MC.)
Maximum Power Dissipation . . . . . . 1 watt.

MODEL	SHUNT RESISTANCE	MODEL	SHUNT RESISTANCE
470A	0.1 ohm	470D	100 ohms
470B	1.0 ohm	470E	600 ohms
470C	10 ohms	470F	1000 ohms

MODEL 400C VACUUM TUBE VOLTMETER

SERVICE MANUAL

The Hewlett-Packard Co. provides this Service Manual to aid in the repair and maintenance of the Model 400C Vacuum Tube Voltmeter. A general description of the Model 400C and the methods used to test and calibrate it are presented. There is also information on modernizing older instruments and trouble shooting on instruments with specific difficulties. Circuit diagrams, photographs, tables, and sketches are included in our effort to supply as much necessary information as possible.

INDEX AND TABLE OF CONTENTS

SPECIFICATIONS (All percentages refer to percentage of full scale)

1. Voltage Range - Full scale sensitivity from 0.001 volts to 300 volts in 12 ranges.

2. Meter Calibration -
   Meter calibrated to RMS value of a sine wave.
   Linear voltage scales 0-1 volt and 0-3 volts.
   Voltage ranges related by 10 db steps.
   DB scale calibrated -12 db to +2 db.
   Zero level = 1 milliwatt into 600 ohms.

3. Input Impedance - Equivalent to 10 megohms shunted by 15 μμf, 1V to 300V range. Equivalent to 10 megohms shunted by 24 μμf, 0.001V to 0.3V range.

4. Accuracy -
   ±3% of full scale reading on all ranges, from 20 cps to 100 KC.
   ±5% of full scale reading on all ranges, from 100 KC to 2 MC.

5. Line Voltage - Variations from 105 to 125 volts cause less than 2% variation in readings from 20 cps to 20 KC, 3% from 20 KC to 1 MC and 4% from 1 MC to 2 MC.

6. Over-voltage Capacity - Avoid continuous or frequent overloads. However, occasional overloads of 100 times normal will not damage meter movement.

7. Power Supply Rating -
   Voltage - 105 to 125 volts or 210 to 250 volts.
   Frequency - 50 to 60 cycles.
   Wattage - 70 watts.

8. Output Circuit Rating -
   Maximum open circuit voltage - 0.3 volts.
   Open circuit internal impedance - 100 ohms.
   Maximum gain (0.001 volt range) - 50 db.

HISTORY OF PRODUCTION

Over a period of years there have been many minor changes and improvements in the Model 400C. These will become evident when going through the notes in this Service Manual and should cause no trouble when repairing a unit from the information given here.

If the older unit is functioning well, there is no reason to make any major changes. The Electrical Performance Specifications of the Model 400C have not changed, and an older unit will give the same fine accuracy as a new instrument. The changes have been in the direction of greater stability; longer component life; ease of adjustment, testing and repair; and better manufacturing procedures.

If it becomes necessary to repair a unit with a serial number below 1360, the section on Modernization of Older Units should be checked and as many of the changes made as are applicable. There have been no major changes in serial numbers higher than 1360. At this point the power supply tube line-up was changed with attendant circuit revisions, and an Amperite Ballast tube was introduced. The mechanical layout is such that these changes cannot be made in older units.

At the serial number 960 certain power supply changes and others were made as described later. In general it would be advantageous to modernize the unit to agree with the series between 960 and 1360 whenever the instrument is undergoing repair or overhaul.

In the list of Modernizing changes presented, no one instrument will be subject to all the changes, and many will be subject to only minor revisions.

The following general discussion of the Model 400C applies equally well to instruments of any serial number or age.

IMPORTANT SCHEMATIC NOTICE

THE LAST THREE PAGES IN THIS SERVICE MANUAL CONSIST OF CIRCUIT DIAGRAMS FOR INSTRUMENTS OF DIFFERENT AGES. UNLESS OTHERWISE SPECIFIED, ALL CIRCUIT REFERENCES ARE TO THE CIRCUIT DIAGRAM LABELED FIG. 7. THE EQUIVALENT COMPONENT MAY THEN BE EASILY LOCATED ON OTHER CIRCUIT DIAGRAMS IF NECESSARY.

CIRCUIT DESCRIPTION

The circuit of Model 400C includes an input voltage divider, a stabilized amplifier, a rectifier and meter circuit, and a power supply.

The input voltage divider consists of a compensated resistance divider feeding into a cathode follower with a tapped wirewound resistor in the cathode circuit. This resistor serves as the multiplier on all of the ranges. On the higher ranges the input voltage is divided by a factor of one thousand before being applied to the grid of the cathode follower.

The input circuit is followed by the amplifiers V2 to V5. This amplifier has a uniform response over the very wide range from 20 cps to 2 MC per second. This wide response is achieved through the use of a novel circuit arrangement wherein the tubes are effectively operated as triodes with a high load impedance at low frequencies and as pentodes with a low load impedance at high frequencies. This effect is obtained by the use of special-value screen grid by-pass capacitors and a split plate load resistor. At low frequencies the by-passing of the screen grids is not effective so that the tubes operate as triodes with a load consisting of a 5600-ohm and an 8200-ohm resistor in series. At high frequencies the by-passing of the screen is effective. The tubes then operate as pentodes with a load resistor consisting only of the 5600-ohm resistor. In addition the cathode resistors of the tubes are not by-passed at low frequencies so that cathode degeneration is obtained. This system gives a uniform response which is further stabilized by the use of a negative feedback loop extending over the complete four-tube amplifier. This feedback loop has been carefully designed so that amplifier oscillation cannot occur.

The amplifier feeds a full-wave rectifier circuit with a meter connected to indicate the output level of the amplifier. The meter is calibrated in the rms value of a sine wave. The meter circuit is returned to ground through the cathode circuit of the first tube of the amplifier, constituting the overall negative feedback loop described above.

The power supply includes a conventional full-wave rectifier and degenerative type voltage regulator to maintain the plate voltage supply consistent over a wide range of line voltage fluctuation.

In serial numbers 1360 and above the power supply also furnishes regulated direct current for the heaters of tubes V1 through V5. In instruments bearing lower serial numbers, direct current is used for the heaters of V1, V2, and sometimes V3. In these instruments with lower serial numbers, there are also other minor changes in the power supply.

TERMINALS

Input Terminals - The two binding posts, located in the lower-left corner of the control panel, are connected to the input circuit of the instrument. The lower post is connected to the chassis.

Output Terminals - The two binding posts next to the meter are the output terminals of the amplifier. The lower post is connected to the chassis.

Fuse - The fuseholder, located on the back of the chassis, contains a 1-ampere cartridge fuse for 115 volt operation. The 1 ampere fuse should be replaced by a 0.5 ampere fuse when the instrument is operated from a 230 volt supply. The Model 400C is shipped from the factory with the power transformer primary connected for 115 volt operation.

Power Cable - The power cable consists of three conductors. Two of these conductors carry power to the instrument while the third (green wire) is connected to the instrument chassis. The third wire projects from the plug end of the cable and may be connected to a ground when it is desirable to have a grounded chassis.

OPERATION

CAUTION

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

Voltage Measurements - Plug the power cable into the power source and turn the toggle switch to "ON". Allow the instrument about five minutes to reach a state of stable operation. Set the "DB-VOLTS" range switch to the desired voltage range and connect the input terminals to the voltage being measured. The meter indication, times the multiplying factor (indicated by range switch position), equals the voltage being measured.

As a precaution in maintaining accuracy of measurements, it must be kept in mind that the instrument is an average reading device. Although the calibration on the face of the instrument is marked "RMS VOLTS", this simply means that the meter will read the rms value of a true sine wave. If the wave form of the voltage being measured contains appreciable harmonic voltages or other spurious voltages, errors in measurement will be encountered of a magnitude indicated by the following table:

EFFECT OF HARMONICS ON MODEL 400C VOLTAGE MEASUREMENTS

Input Voltage Characteristics	True RMS Value	Value Indicated by Model 400C
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

Amplifier - The amplifier in the Model 400C may be used by setting the range switch to the 0.001 position, connecting the input terminal to the voltage to be amplified, and connecting the output terminal to the device to be supplied by the amplifier. One millivolt is the maximum voltage that may be applied to the amplifier under the above conditions. The maximum voltage obtainable at the output terminals is 0.3 volts. To obtain optimum amplifier gain and minimum distortion, the load across the output of the amplifier must be not less than 10,000 ohms. Higher voltages may be applied to the input of the amplifier provided the position of the range switch indicates a full scale voltage equal to, or greater than the applied voltage. The gain of the amplifier goes down by 10 db for each step that the range switch is advanced toward the high voltage end. At the 0.3 volts position the amplifier has a gain of 1, and at higher voltage range switch positions the gain is less than unity.

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

If measurements are being made from a high-impedance source, hum pickup can affect the meter reading, due to the high impedance of both the source and the Model 400C itself. Shielded leads will reduce pickup, although they will cause an increase in the capacity shunted across the source to be measured, with the possibility of excessive circuit loading.

TROUBLE SHOOTING NOTES

ALL CIRCUIT REFERENCES REFER TO SCHEMATIC DIAGRAM "FIG. 7", UNLESS OTHERWISE DESIGNATED.

Tube Replacement - Any tubes with RETMA standard characteristics may be used for replacement. However, when replacing tubes V1, V2, and V3, select tubes which have low residual noise and microphonics.

The 6AK5 tubes may be replaced with the "reliable" or "5-star" improved version of the 6AK5. This is the type 5654 tube which is now available from radio parts jobbers. In general, the completely interchangeable 5654 is recommended as a replacement for two reasons:

1. The 5654 has much longer reliable life than the 6AK5. The G_m of the 5654 will remain constant over a longer period of time.

2. The G_m of the 5654 is far more consistant than that of the 6AK5.

In general, any 5654 with low microphonics may be used in the 400C, where selection is necessary for the 6AK5.

When 6AK5 tubes are used for replacement, tubes with an average G_m will give the best performance in the unit. If the G_m is too low, the frequency response and the response to line voltage changes will be poor. If the G_m is too high, the tube may oscillate and be unstable. A G_m of from about 4200 to 5400 micromhos is the most satisfactory for use in the Model 400C, regardless of whether 6AK5 or 5654 tubes are used.

When replacing the input tube or any 6AK5 which is heated by the heater supply, adjust the dc heater voltage as described in the "GENERAL TEST PROCEDURE" section. A defective replacement tube may draw excessive heater current and cause the heater voltage to be low. Other causes of low heater voltage are covered in the trouble shooting chart and the section on "DC HEATER VOLTAGE SUPPLY".

In units of serial No. 9901 and above, the 6X5 rectifier tube was replaced with a 6AX5. The 6AX5 is a direct replacement for the 6X5 and requires no circuit changes. The 6AX5 has a longer useful life and is recommended whenever replacement of the 6X5 is necessary.

Trouble Shooting Chart -

Symptom		Cause and Remedy
Meter "Dead"		
		Power Supply failure.
		Open crystal, CR1 or CR2.
		Open Meter.
		Defective tube.
		Failure of tube heater dc supply.
		Capacitor C13 shorted.
		Open ballast tube V10.
Very low and erratic readings		
		Open range switch resistor.
		Open or dirty range switch contact.
Motorboating		
	Under all conditions.	Defective electrolytic capacitor.
		Open range switch.
		Regulated B plus too low or regulator not functioning.
		Open R15a section of feedback resistor.
		R47 maladjusted.
		C9 open or defective.
		Defective V6, V7, V8, or V9 in voltage regulator circuit.
	At high line voltage only.	Install 5 $\mu\mu f$ from CR1 or CR2 to ground.
	On 1 volt and 0.001 volt ranges only.	Open decoupling electrolytic capacitor C6a in V1 plate circuit.
Abnormal low readings on all ranges.		
	Under all conditions.	Low dc heater voltage.
		Regulated voltage failure.
		Open C5, C10, C14, or C18 coupling capacitor.
		Defective tubes.
		Defective CR1 or CR2 crystal.
		Defective meter.
		Partially shorted C13 across meter.
	Especially on 1 volt and 0.001 volt ranges.	Defective input tube.
		Capacitor C5 shorted.
Difference in relative accuracy between upper 6 ranges and lower 6 ranges.		
	At low frequencies.	R1 and R2 have incorrect ratio.
		Replace with factory matched pair.
	Same error at high frequencies, but not at low frequencies.	Capacitor C3 maladjusted.
		Capacitor C2 defective.

Trouble Shooting Chart - Cont'd.

Symptom	Cause and Remedy
Calibration error on all ranges.	
	Resistor R47 maladjusted.
Abnormally high readings on all ranges.	
	Resistor R1 open.
	Resistor R15 open.
	Open circuit other than R15 in negative feedback loop.
Frequency error in calibration. (Poor frequency response.)	
Error progressively worse at higher frequencies.	Capacitor C2 defective or C3 maladjusted. Applies to 1 volt and higher ranges only.
	Defective or weak 6AK5 tube.
	Defective CR1 or CR2. Replace with factory selected crystal.
	Check for proper 6.3 volts on the tubes heated by dc. Replace electrolytic or selenium rectifier as necessary.
Dip in response on high ranges only, between 100 KC and 1 MC.	Lead from range switch to input divider must be soldered to a resistor mounting lug, not a capacitor mounting lug.
100 KC and up reads high, low, or has peaks or dips.	Bad 6AK5 - replace with factory selected tube.
Low response at 20 cps.	Replace V2 or V3 with factory selected 6AK5 tube.
	Defective C1, C5, C10, C14, or C18 coupling capacitor.
High peak at 1 MC or higher.	Range switch shield not grounded. Connect shield to the common ground bus.
Regulated B plus supply failure.	
	See special section on "B+ REGULATED SUPPLY". Refer to index.
"Turn-over" effect when measuring 60 cps voltages.	
	Defective V1, V2, or V3.
	Install a copper shorted band at least 1 inch wide around the transformer. See Fig. 1. This may be either inside or outside of transformer end bell. Replacement Hewlett-Packard transformer will have copper band.

Symptom	Cause and Remedy
High residual noise. IMPORTANT: Before attempting to correct high residual noise, please read section, "GENERAL TEST PROCEDURE" on ZERO SETTING of meter. Observe (on an oscilloscope) the output from the 400C. This will identify the unwanted signal as to whether it is noise, hum, parasitic oscillation, etc. SHIELD but do not short input terminals.	
Condition A: Meter indicates the same noise amplitude on all positions of the range switch.	The trouble source is between V2 and V5 inclusive. Look for defective 6AK5 tubes, noisy resistors, defective or poorly grounded electrolytics, or defective coupling capacitors. Check all solder joints and ground connections in this area. Noise from B plus and heater supply may be introduced into V2 and V3. In this case look for poor voltage regulation noisy VR tube or other power supply tube, defective electrolytics (C21, C22) in the dc heater supply, or defective selenium rectifier. See sections on "B+ REGULATED SUPPLY" and "DC HEATER VOLTAGE SUPPLY".
Condition B: Meter indicates the same noise level on 1 and 0.001 volt ranges, and in each case, becomes progressively less as the range switch is advanced to higher voltage ranges.	The noise is originating in the input tube (V1) or its associated components. Look for defective input tube V1, defective C6a on plate of V1, dirty or worn contacts on the range switch, defective coupling capacitor C5, end of range switch shaft touching shield or loose nut holding range switch to front panel. Tighten all grounding bolts in the vicinity of V1 so that all lock washers will penetrate the paint. Replace any missing lock-washers. Breakdown of insulation between selenium rectifier shaft and plates will introduce 120 cps hum. Replace rectifier or insulate shaft from chassis.

Trouble Shooting Chart - Cont'd.

Symptom		Cause and Remedy
High residual noise (Cont'd.)		
	Condition C: The noise indication is high on the 0.001 volt range only, becoming progressively less as the range switch is advanced.	The noise originates ahead of V1 or in the input voltage divider network. Shorting the input terminals usually eliminates this noise. Tighten all ground connections to deck, especially grounds in the input voltage divider network. Check for noisy or open resistors R1 and R2, poor or open connections in S1A switch wafer. Metal cabinet not properly grounded to chassis. Scrape off paint to insure good contact around bolts.
	General	Defective tube sockets.
		The rear end of the range switch shaft may be touching the shield, causing a ground loop.
		Part of selenium rectifier may be touching shield causing a ground loop.
		Resistor R44 (680 ohms, 1 watt) between the plate and screen of V7 (6Y6) may be missing, causing the tube to oscillate . Cut existing jumper between these two tube pins and install resistor. Be sure that B plus lead goes to plate (pin 3) and not to the screen (pin 4).
		Pilot light leads too close to range switch.
Microphonics		The same method used in the location of high residual noise may be used to isolate microphonics. Microphonics are usually caused by defective tubes, but they can be caused by other defective components, poor ground connections, poor solder joints, or a loose plastic sleeve on R1 or R2. Cement these sleeves in place or remove them. The resistors themselves may be defective. Many of the listed noise sources can also cause microphonics.

Trouble Shooting Chart - Cont'd.

Symptom		Cause and Remedy
Poor Voltage Response. Meter reading changes excessively when line voltage is varied from 102 to 128 volts, especially when measuring high frequency voltages from 1 to 2 MC.		
	Serial No. 1359 and below.	Poor 6AK5 tubes. The G_m of these tubes may change radically with change in heater voltage. To isolate source of trouble, measure dc plate voltage of V2 (first 6AK5) and vary line voltage from 102 to 128 volts. Note change in plate voltage and repeat procedure with V3, V4, and V5. The tube with the greatest plate voltage change should be replaced. If the line voltage response still does not meet specifications, replace the tube that has the next highest plate voltage change and so on.
	Serial No. 1360 and above.	These instruments contain a ballast tube regulated heater supply and are not often subject to the above effects.
Low Heater Voltage.		
	All Models.	Defective selenium rectifier. Defective 2000 µf electrolytic. Defective tube in amplifier drawing too much heater current. Defective power transformer.
	Serial No. 1360 and above.	Defective ballast tube, V10 in Fig. 7.
60 cps Beat Note. Excessive swinging of the meter pointer when measuring a signal of approximately 60 cps. Check with a signal that is free from line frequency components, such as an -hp- Model 204A battery powered oscillator.		
		Modernize as in section on dc heater supply.
		Adjust the hum balance potentiometer, R32 (Fig. 6) for minimum beat.

Trouble Shooting Chart - Cont'd.

Symptom	Cause and Remedy
	Check power supply regulation as described in the B+ REGULATED SUPPLY section.
	Tighten lamination bolts on power transformer.
	Defective 2000 µf electrolytic in dc heater supply.

MODERNIZING UNITS SERIAL NO. 959 AND BELOW (Refer to Figs. 5 and 6)

After making these changes the instrument will then be equivalent to serial No. 1359 as shown in Fig. 6. Instruments above serial No. 1359 are somewhat different as explained in the section "HISTORY OF PRODUCTION". Units with serial numbers between 960 and 1360 require very little modernization.

1. Replace any plug-in electrolytic sockets with solder type base plates; solder in the electrolytic capacitors. Replace the electrolytics if they are leaking or otherwise defective.

2. If tube V7 is a 6V6, replace it with a 6Y6.

3. Check R44, the 680 ohm 1 watt resistor between the plate and screen of the 6Y6 (Fig. 6). If it is not already installed, install it, leaving the high voltage side on the plate (pin 3) of the tube. In some cases, the high voltage lead may be tied to the screen grid (pin 4). Move it to pin 3.

4. Remove the following parts completely:
   a. C23 -- was factory adjusted (Fig. 5).
   b. C24 -- approximately 100 µµf (Fig. 5).
   c. C29 -- was factory adjusted.
   d. C28 & C43 (series connected) -- remove both.

NOTE: - C28, C29, and C43 are not shown in Fig. 5 or Fig. 6 but will be found in the schematic diagrams of the manuals supplied with voltmeters containing these parts.

5. Set C7 (7 to 45 µµf ceramicon) to minimum capacity.

6. Tighten screws on panel, shields (especially shield for V2) and on the input multiplier resistor board.

7. Check the back end of the range switch shaft to be sure that it does not hit the shield and introduce an unwanted ground at that point.

8. Replace any "Solite" brand coupling capacitor.

9. Install C27 and R42 on the grid of V1 if they are not already in the instrument.

10. The power supply circuit is to be changed from that shown in Fig. 5 to that shown in Fig. 6. The circuit designations mentioned here are on the above diagrams only.

    a. Locate the triple 10 µf electrolytic C6a, C6b, and C6c (near 6Y6) and completely remove the lead which connects C6c to R16 (2200 ohms, 2 watt, mounted on board at rear of unit) Fig. 5. This is the end of the resistor to which pin 8 of the 6Y6 is connected.

    b. Disconnect the orange lead which connects the same C6c to R18 (10,000 ohms plate and screen dropping resistor for V4) from C6c.

    c. Connect free end of orange lead directly to pin 8 of the 6Y6.

11. The electrolytic terminal C6c is now empty. Move the blue plate lead for V1 from the junction of the two resistors R9 and R16 (Fig. 5) to C6c terminal. Connect a 10,000 ohms, 10%, 1 watt carbon resistor from C6c back to the junction of R9 and R16. Change R9 to 4700 ohms, ±10%, 2 watts.

12. Install C29 (40 or 60 µf, 450 vdcw, tubular electrolytic) in parallel with C6a. Section C6a terminal has an orange lead that connects to R9 and a red lead that passes through a hole in the large mounting board to connect to R4 (10,000 or 8,200 ohms).

13. Isolate the front panel end of R38 (10,000 ohms, 2 watts) on small mounting board by completely removing the two jumper wires connecting to the front end of the resistor. Connect a new jumper between R37 (560,000 ohms, 1 watt) and C20 (0.05 µf) on the mounting board, thus reconnecting these two points and leaving the end of R38 open. Connect a jumper from open end of R38 to pin 3 of the rectifier tube V6.

14. Install a 12,000 ohms, 10%, 2 watts, composition resistor between pins 3 and 8 of V6 tube socket.

15. Locate the triple 10 µf electrolytic capacitor C21a, C21b, and C21c (near 5Y3). Remove the jumper which connects sections C21a and C21b together. Connect the now empty terminal of C21b to pin 3 of V6 (5Y3) with a jumper.

ONE EACH OF THE FOLLOWING PARTS ARE REQUIRED FOR THE PRECEDING CHANGES:

Description	-hp- Stock No.
Resistor, 4700 ohms, 10%, 2 watts, composition	25-4700
Resistor, 10,000 ohms, 10%, 1 watt, compositon	24-10K
Resistor, 12,000 ohms, 10%, 2 watts, composition	25-12K
Capacitor, 40 μf, 450 vdcw, tubular, electrolytic	18-12

DC HEATER VOLTAGE SUPPLY

Use Fig. 6 for circuit references. There are two versions of the dc heater supply for the 400C. In the original design, the dc heater current was not regulated and supplied V1 and V2 only. The voltage was adjusted with R41 (15 ohms adjustable resistor). A 50 ohms potentiometer (R32) was then set to balance out the residual hum reading on the meter.

Serial No.1359 and below -

The following parts replacement and modifications are recommended for these instruments:

1. Check the dc heater voltage on the input tube V1. If it cannot be adjusted to 6.3 volts, it may be necessary to replace either C25 or the selenium rectifier. A new selenium rectifier (-hp-Stock No. 212-76) is best installed by drilling a hole and mounting as shown in Fig. 2. Complete installation instructions are supplied with the replacement rectifier.

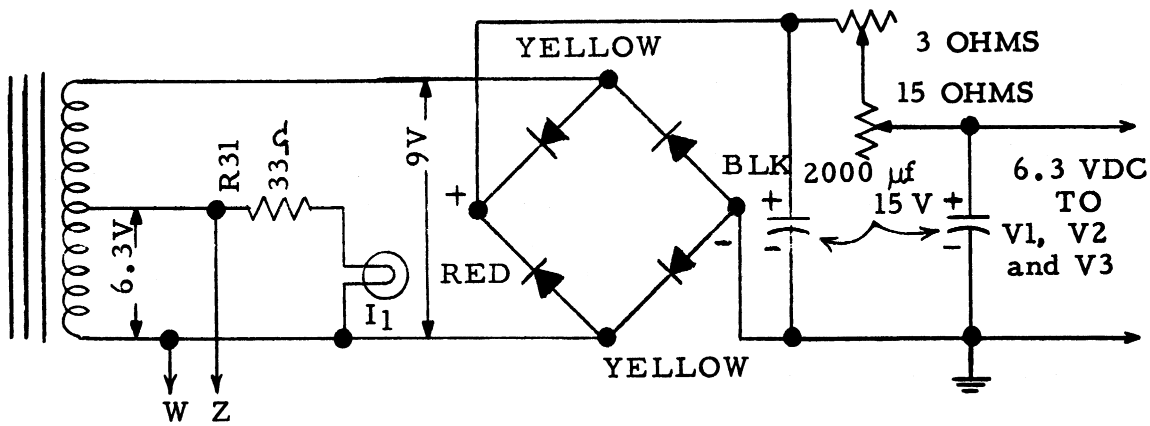
2. Install a 3 ohms potentiometer (-hp- Stock No. 210-3) in series with R41 (15 ohms adjustable resistor). THIS POTENTIOMETER MUST BE INSTALLED SO THAT THE SHAFT IS INSULATED FROM THE SHIELD OF THE UNIT. Use fiber extruded type washers of the correct size. The potentiometer is more easily adjusted than the 15 ohms adjustable type resistor.

3. If V3 is not connected to the dc heater supply, change the wiring so that it is. Leave V4 and V5 heaters connected to the ac source.

4. Set the dc heater supply to 6.3 volts at the tubes. If the voltage cannot be brought up to the 6.3 volt value by using both adjustments, short out the 15 ohms adjustable resistor, leaving only the 3 ohm potentiometer in the circuit.

5. If desired, the circuit may be modified further to reduce hum and to eliminate R32 hum balance potentiometer. The potentiometer is removed and the mounting hole is enlarged to 1-3/8".

A 2000 µf, 15 vdcw, can type, electrolytic capacitor is then mounted in this hole. Be sure to use lockwashers when bolting the mounting plate to the chassis. Be sure that there will be room to remove the adjacent tubes when mounting the electrolytic. Rewire the heater circuit to conform to the following diagram. Note that C19 (0.2 µf) is eliminated.



Serial No. 1360 and Above -

In all models with serial numbers 1360 and above, the dc heater supply was modified considerably. See Fig. 7. A power transformer with a 13 volt secondary winding for the dc heater supply was used. An Amperite ballast tube (V10) was introduced to regulate the heater current. All amplifier tube heaters were connected to the dc heater supply. Instruments with this type of heater circuit require no modifications. Older models (serial No. 1359 and below) cannot be changed to this design.

GENERAL TEST PROCEDURE

For circuit designations, refer to Fig. 7. The equivalent component may be easily located in Fig. 6 if desired.

The following steps must be followed when calibrating the 400C.

1. Adjust meter zero set.
2. Adjust regulated B plus supply.
3. Adjust dc tube heater voltage.
4. Adjust sensitivity on 1 volt range and check other ranges.

5. Adjust 0.3 volt range.
6. Check line voltage response.
7. Check frequency response.
8. Check amplifier output.

Mechanical Zero Set Adjustment -

The zero indication adjustment screw on the meter should not be changed unless adequate means of checking the tracking of the meter scale is available.

1. Set the range switch to the 300 volt range and short circuit the input terminals.

2. Note the meter indication with the instrument turned off and with the instrument turned on. Set the meter pointer to that point between the above indications where the most accurate meter scale tracking on the one volt range can be obtained. Refer to "Sensitivity Setting" in this section for further details.

CAUTION -- When first received from the factory or when the instrument has been recalibrated, the meter pointer may not indicate zero when the instrument is turned off. After the instrument is turned on, the meter pointer may show an indication of as much as two scale divisions with the input shorted. This effect is seen primarily on the 1 volt range and is normal. It is caused by the high gain and internal noise of the amplifier. This will not affect the calibration or accuracy of the instrument.

Regulated B+ Voltage Adjustment -

Set the regulated B plus voltage to 220 volts dc by adjusting the R38 potentiometer. Measure the voltage at the cathode of V7 when making this adjustment. If the desired voltage cannot be obtained or other trouble is encountered, refer to "B+ REGULATED SUPPLY" section.

Tube Heater dc Voltage Adjustment -

The dc heater voltage should be adjusted to 6.3 volts at the tubes with the line voltage at 115 volts. On units with Serial No. 1360 and above, adjustment is made by varying the R46 loading resistor. Refer to Fig. 7. On units with lower serial numbers, the adjustment is made with R41. This resistor may be a 3 or 5 ohm potentiometer or a 10 or 15 ohm adjustable resistor. Refer to Fig. 6.

Calibration -

The Model 400C has been designed so that all ranges are adjusted by the setting of R47. This potentiometer controls the amount of negative feedback and thus determines the gain of the amplifier. If, after this adjustment has been made, the other ranges prove to be inaccurate, consult the TROUBLE SHOOTING NOTES section.

The basic calibration is done at a frequency between 100 and 1000 cycles. A sine wave with less than 1% distortion should be used. Larger amounts of distortion may affect the calibration as shown in the chart in the OPERATION section.

The Model 400C should be calibrated against a standard meter of at least 1% accuracy. Many standard meters are designed for use at 60 cycles, but are accurate or may be corrected for use at 100 cycles. It is not good practice to calibrate the 400C with a 60 cycle source, since there is a possibility of interaction between the signal source and the power line frequency.

Any signal generator which is capable of producing at least 100 volts with less than 1% distortion may be used. (The 300 volt range on the Model 400C may be checked at the 100 volt scale reading.) The Hewlett-Packard Signal Generator models 205A, 205AG, or 205 AH are recommended. A 100 volt output can be obtained by using the 5000 ohms output impedance terminals on these instruments.

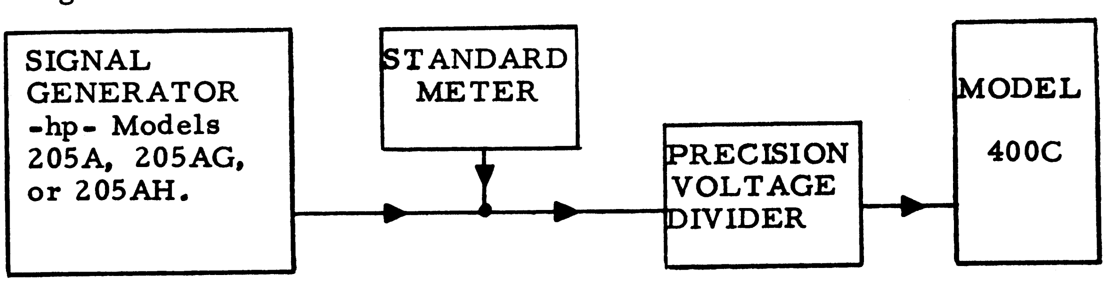
Greatest calibration accuracy will be obtained by using a standard 100 volt output from the signal generator, which is monitored by a standard meter and followed by a precision voltage divider. Three satisfactory voltage dividers for this use are:

(1) Hewlett-Packard Models 350A or 350B with 2% accuracy.

(2) Gertsch Products Inc., PT series Standard Ratio Transformers with approximately 0.005% accuracy.

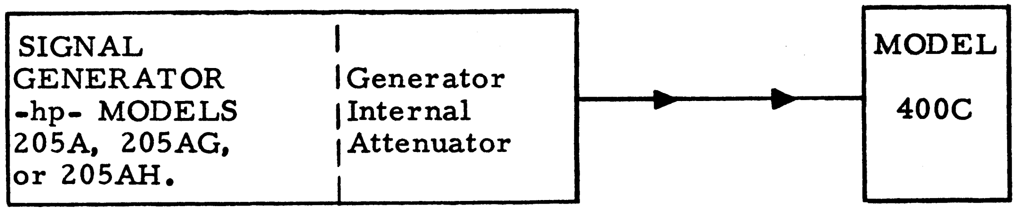
(3) Electro Measurements Inc., Model DP-211 or DV-211 Dekapots with 0.01% accuracy.

This method of calibration is illustrated in the following block diagram.



INSTRUMENT CONNECTIONS FOR MOST ACCURATE CALIBRATION

Somewhat less accuracy can be obtained by using a signal generator with internal attenuator and output meter. The external standard meter is not used. This method of calibration is illustrated in the following block diagram.



INSTRUMENT CONNECTIONS FOR ALTERNATE CALIBRATION METHOD

CAUTION - Care must be taken, when checking the high sensitivity ranges of the 400C, to be sure that no external ground loops exist. Such ground loops may cause pickup of hum or other unwanted signal voltages. Ground one side of the output terminals of the signal generator. The output of the 400C may be checked on an oscilloscope.

SETTING SENSITIVITY ON 1 VOLT RANGE -

With an input of exactly one volt, adjust the 400C to read 1 volt on the 1 volt range, by varying R47. This reading must be checked with the instrument in the case.

With the 1 volt full scale reading set, check the meter tracking across the scale. Readjust the mechanical zero set for the best tracking, and then return to the full scale reading. Readjust R47 as necessary. It may be necessary to repeat this process several times.

SETTING SENSITIVITY ON OTHER RANGES -

After the 1 volt range has been calibrated, switch to the 0.3 volt range and check for a 0.3 volt full scale reading.

Both higher and lower ranges may now be checked. Inaccuracies here are easy to detect and are corrected as described in "TROUBLE SHOOTING NOTES" section.

The 400C will now be calibrated for all ranges. However, further checks on the performance can be made. If trouble occurs, refer to "TROUBLE SHOOTING NOTES" section.

Line Voltage Response Check -

The response to variation in line voltage is checked by varying the line voltage from 105 to 125 volts. Set the 400C to any convenient voltage range and apply a signal of approximately 1 MC to the input terminals. Allow the meter 30 seconds or so to settle down after changing the line voltage. Check to see that the reading then obtained is within the 400C specifications. Refer to "TROUBLE SHOOTING NOTES" if necessary.

Microphonics -

See "TROUBLE SHOOTING NOTES" section.

Residual Noise -

See "TROUBLE SHOOTING NOTES" section.

Frequency Response Measurement Methods -

The Model 400C is designed with one frequency response adjustment on the upper six ranges and another adjustment on the lower six ranges. It is necessary, therefore, to check response only on one of the upper six ranges and again on one of the lower six ranges. The frequency response for other ranges in a group will be the same as on the particular range tested.

One method of checking the frequency response in the Model 400C is by direct comparison using a low distortion signal source and a standard meter capable of reading the higher frequencies being tested. This standard meter may be a thermo-couple meter or another vacuum tube voltmeter known to be accurate.

Another method of checking frequency response is to use a low frequency standard meter and a transfer device. Two transfer device methods will be described. One using the Hewlett-Packard Response Meter, Specification 70971 and the other using an oscilloscope.

HEWLETT-PACKARD RESPONSE METER, SPECIFICATION 70971 -

The Hewlett-Packard Company has available a frequency response meter which has been specifically designed for checking the frequency response of the Hewlett-Packard Model 400C instruments. This meter is used in conjunction with the Hewlett-Packard Model 650A Test Oscillator in Hewlett-Packard production testing of the Model 400C and may be purchased if desired. Please contact the Hewlett-Packard sales engineer in your area or contact the factory directly for additional information.

OSCILLOSCOPE FREQUENCY RESPONSE METHOD -

The required equipment consists of a cathode-ray oscilloscope, a low distortion signal source with the necessary frequency range, and a low frequency standard meter.

After the warm up, check the low frequency calibration against the standard meter.

Calibrate the cathode-ray tube of the oscilloscope by applying a low frequency voltage simultaneously tc the standard voltmeter and directly to the vertical deflection anodes of the cathode ray tube. No horizontal sweep voltage should be used. Directions for connecting to the deflection anodes are normally supplied by the manufacturer of the oscilloscope. By measuring the peak-to-peak deflection of the cathode ray tube trace on a graph screen and by noting the reading of the voltmeter, the deflection voltage of the tube can be quickly determined. It is important that the voltage used to calibrate the tube be essentially sinusoidal and free from harmonics.

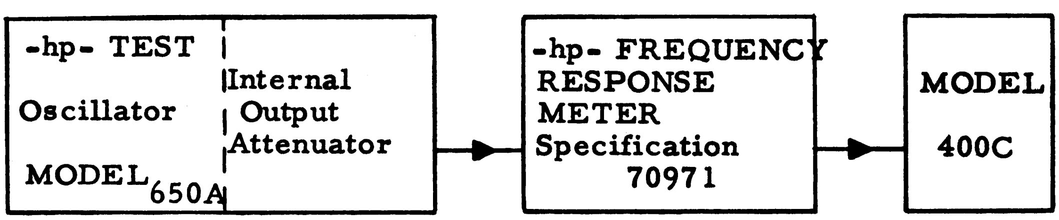
Now connect the Model 400C in parallel with the vertical deflecting plates of the tube and apply sinusoidal voltages up to 2 MC to the combination of the two instruments. The voltage shown by the Model 400C should closely agree with that indicated by the magnitude of deflection on the tube trace. If such is not the case, refer to "FREQUENCY RESPONSE ADJUSTMENT" and repeat the process.

This procedure will give a reasonably accurate check at all frequencies within the range of the Model 400C, although a check cannot be made of small voltages.

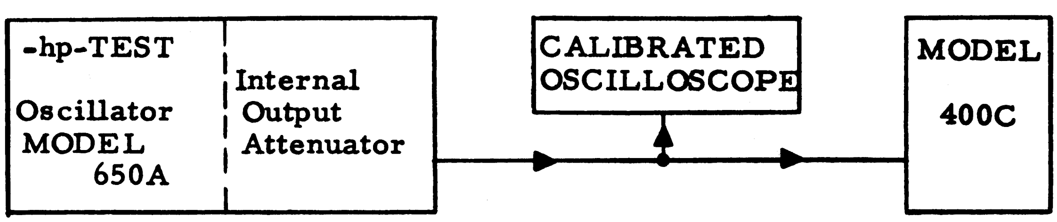
Low voltage ranges can be checked by starting with a voltage within one of the ranges checked on the oscilloscope and working downward. For example, if the accuracy and frequency response of the 100 volt range of the Model 400C have been checked on the oscilloscope, apply a 25 volt signal to the Model 400C and note the reading on the 100 volt range. Then switch to the 30 volt range to see if the reading is the same. By extending this procedure, all ranges of the instrument can be checked.

Although the above method will not give precision results, it will often prove helpful in determining whether or not tubes have exceeded their service life, or new tubes are satisfactory to use.

BLOCK DIAGRAMS OF FREQUENCY RESPONSE MEASUREMENT METHODS -



BLOCK DIAGRAM OF MOST ACCURATE METHOD



BLOCK DIAGRAM OF ALTERNATE METHOD

Frequency Response Adjustment -

The response on the 0.1 volt range should be checked first. On Models below serial No. 960, adjust the variable, C7 shown in Fig. 6. Additional adjustments is possible by changing the lengths of ground loops A, B, and C as shown in Fig. 3. The two leads going to B may be bent together and soldered, thus shortening the ground loop. If necessary, a jumper may be connected directly from A to C. For the opposite effect, the two leads may be spread apart or the lead from B to C replaced by a longer jumper.

On late models, capacitor C7 was eliminated as adjustment of the ground loop was found to be sufficient in most cases. However, if the 1 MC and 2 MC response remains low and higher G_m tubes do not correct this trouble, install a 30 or 50 $\mu\mu f$ capacitor from the center shield of tube socket V3 to center shield of socket for V4. This will raise the response at 1 MC and 2 MC. The response at 2 MC may now be readjusted with the ground loop if necessary. A jumper installed in place of the capacitor will give an even greater increase in the high frequency response.

The response on the 3 volt range should be checked next. Adjust variable capacitor C3, in the input voltage divider network. This capacitor is located directly under the input terminals in all models.

Other ranges may now be checked. It will be found that adjustment of the 0.1 and 3 volt ranges will bring the other ranges within specifications.

If difficulty is encountered refer to "TROUBLE SHOOTING NOTES" section.

Output Check -

Turn to the 0.3 volt range. With the meter indicating an input voltage of 0.3 volts, the output should be approximately 0.3 volts (unity gain). With 100 cps input, observe the output waveform on an oscilloscope. The output should be free of distortion or peak clipping.

B+ REGULATED SUPPLY

The B plus regulator in the 400C is basically the same as in other Hewlett-Packard instruments, with some minor variations. The diagrams in the back of the book show three versions of this circuit in the 400C. Diagram of Fig. 5 shows the original design for this regulator and Fig. 6 shows a modified version of the same circuit. Diagram of Fig. 7 shows the latest design. This later version uses a 6AU5 (or a 6AV5) in place of the 6Y6, and a 6AV6 in place of the 6AQ6.

Failure of the circuit to regulate will result in instability of the entire instrument, both from the dc voltage variations and from increased hum, noise, and coupling through the common power supply.

Regulation may be tested by measuring either the ac or the dc voltage between the cathode of the series regulator tube and ground and then varying the line voltage with a variable transformer. Neither the ac or the dc voltage should vary appreciably as long as regulation continues. The ac voltage present will normally be below 15 millivolts. A less exact check may be made without varying the line voltage. This check consists of temporarily connecting a resistor of 47,000 ohms, 2 watts, across the regulated supply to momentarily increase the load on the supply. A change in either ac or dc voltage under these conditions indicates poor regulation.

Three types of failure can occur:

1. Failure to supply an output voltage.
   a. Shorted B plus voltage elsewhere in the unit.
   b. Defective series regulator or amplifier tube.
   c. Failure of supply voltage.
   d. Shorted 0.05 μf capacitor.

2. Oscillation
   a. Defective type OA2 reference tube.
   b. Defective series regulator tube. In some older instruments with a 6Y6 series regulator tube, resistor (680 ohms) R44 from plate to screen may be missing. Install resistor as explained in step 3 of "MODERNIZING UNITS" section. Refer to Fig. 6.
   c. Defective electrolytic capacitor.

3. Failure to regulate
   a. Defective tube in any position.
   b. The reference tube is gas filled and should glow when in operation. Failure to do so indicates a defective tube or failure of the supply voltage to the tube. Some tubes will glow and yet not function properly.
   c. Too low a supply voltage from the output of the rectifier circuit. A defective power transformer, rectifier tube, or electrolytic capacitor may be the cause.
   d. Excessive current drain. The series regulator tube will handle about 55 milliamperes. If the current drain is higher than this the regulator will not function properly. Check tubes and coupling capacitors.
   e. If the regulated voltage is set too high or too low poor regulation will result. This should be checked whenever a tube is changed.

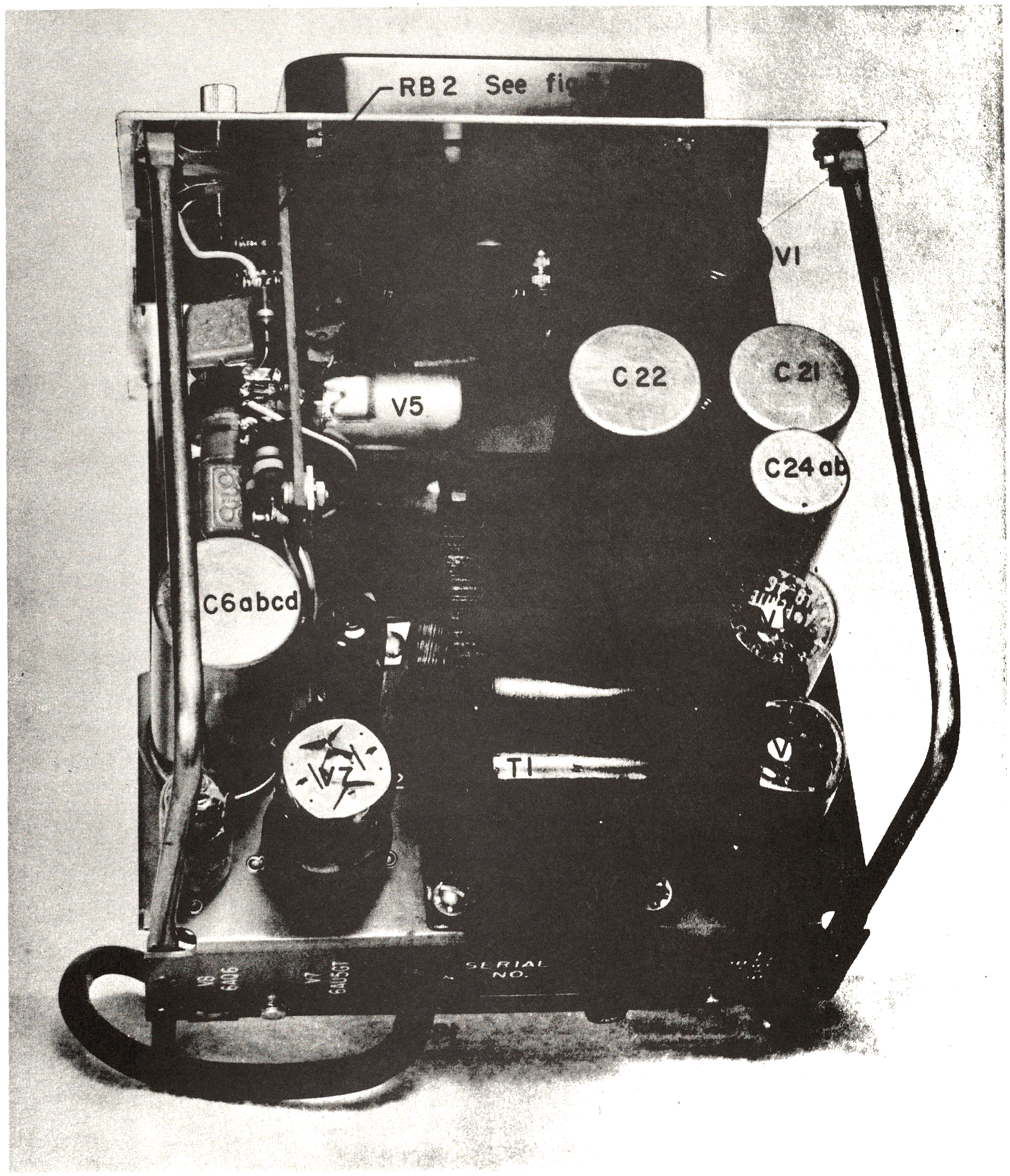
The dc output voltage of the regulator is adjusted to 220 volts by the setting of the R38 potentiometer. This adjustment controls the bias on the V8 amplifier tube and consequently the output voltage. Refer to Fig. 7. The resistor between the grid of the amplifier tube and the voltage divider acts with the C23 capacitor in lowering hum. The resistor has no other function.

DESCRIPTION AND STOCK NUMBERS FOR SPECIAL PARTS -

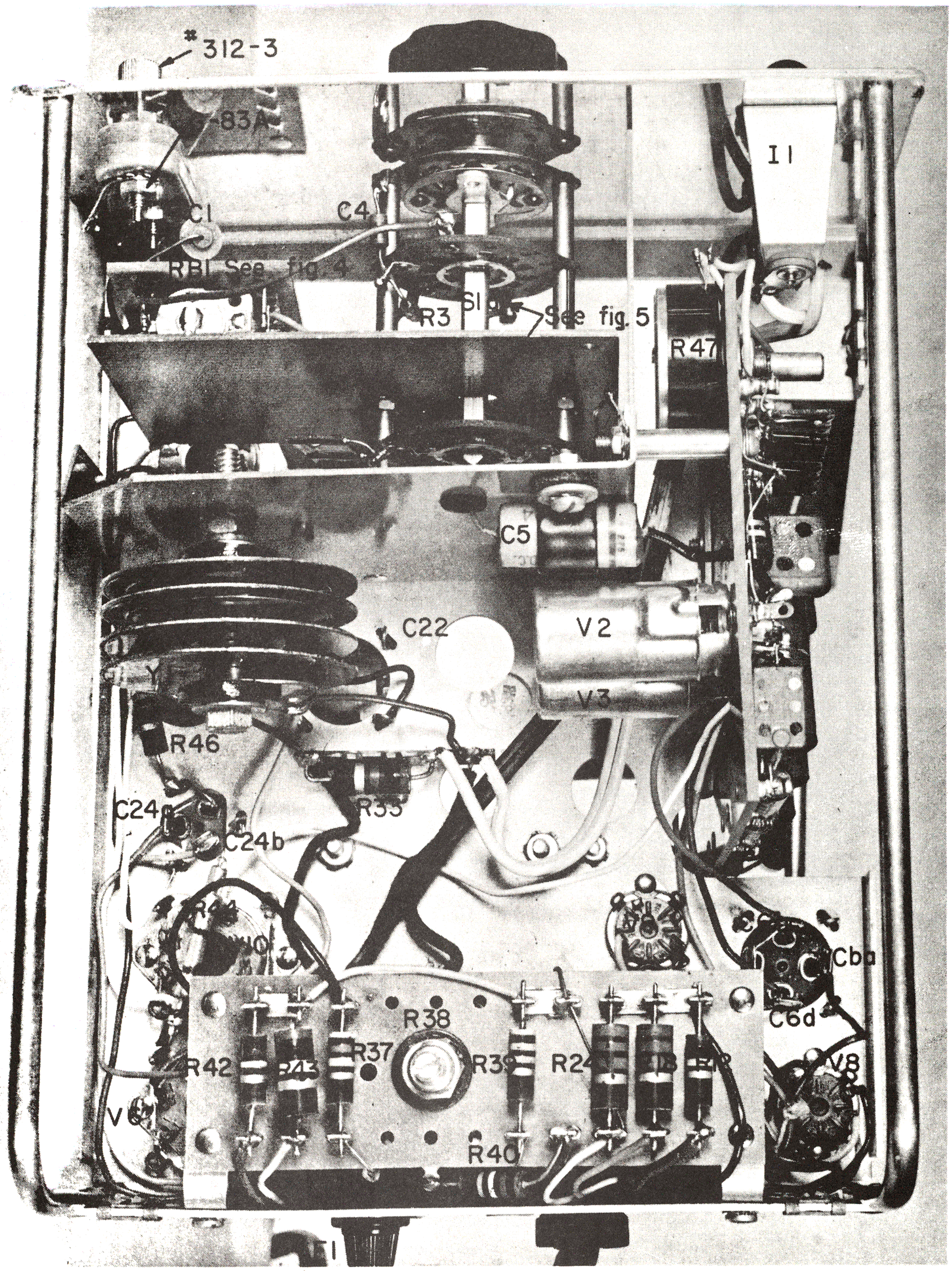
This parts list contains only those items which are not normally carried in jobber stocks. These items may be procured from the Hewlett-Packard Company.

Description	Stock No.
Complete Range Switch Assembly	4C-19W
Indicating Meter Movement	112-6
Rectifier, Selenium (for all instruments)	212-76
Resistor, Fixed Precision (range switch strip)	4C-71
Resistor, Fixed Precision (feed back)	4C-26
Resistors, Fixed (matched set for input divider)	*31-10.31K *31-10.31M
Transformer, Power (Serial 1360 and above)	910-76
Transformer, Power (Serial 1359 and below)	910-67
1N34 Crystal Diode (selected for 400C).	G-11F
6AK5 Tube (selected for 400C)	G-73B
Amperite 10-4C Regulator Tube	211-39

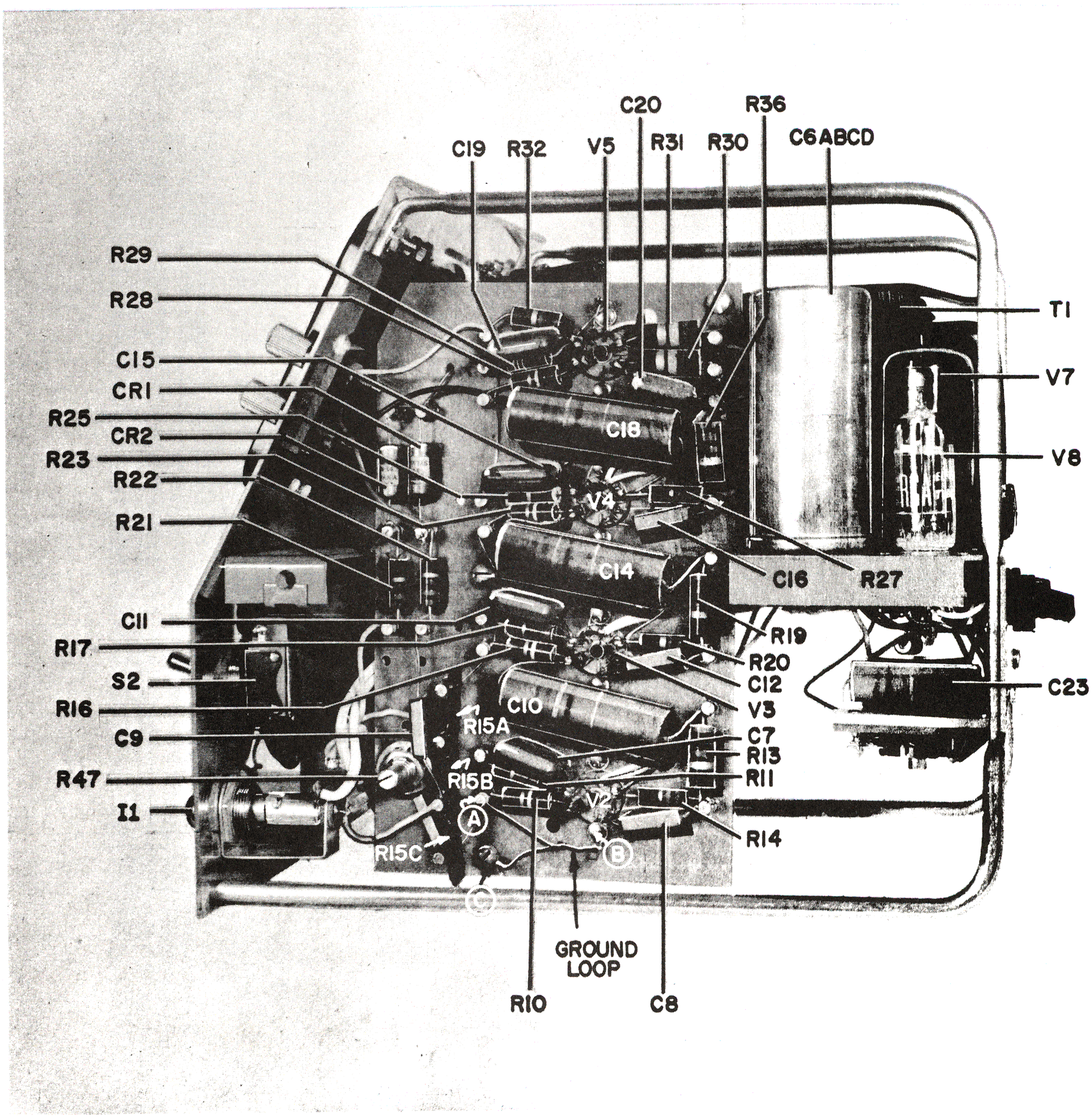
* Order in pairs giving both stock numbers.



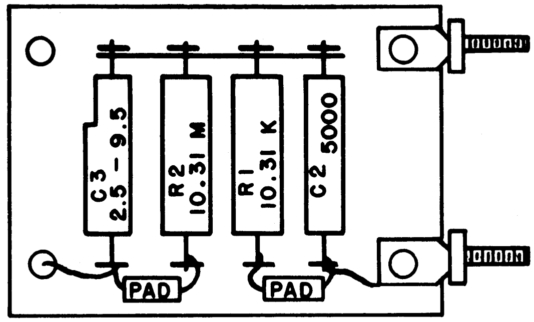
Model 400C Top View
(Case Removed)
Fig. 1



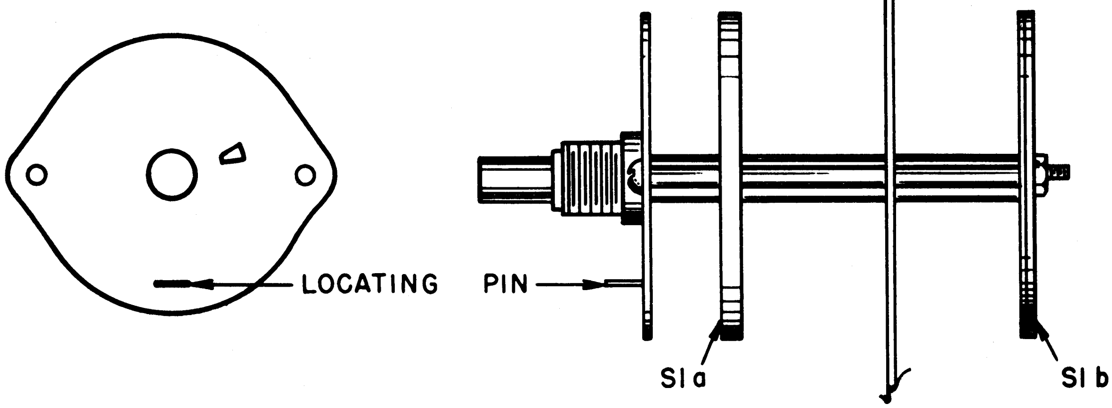
Model 400C Bottom View
(Case Removed)
Fig. 2



Model 400C Side View
(Case Removed)
Fig. 3

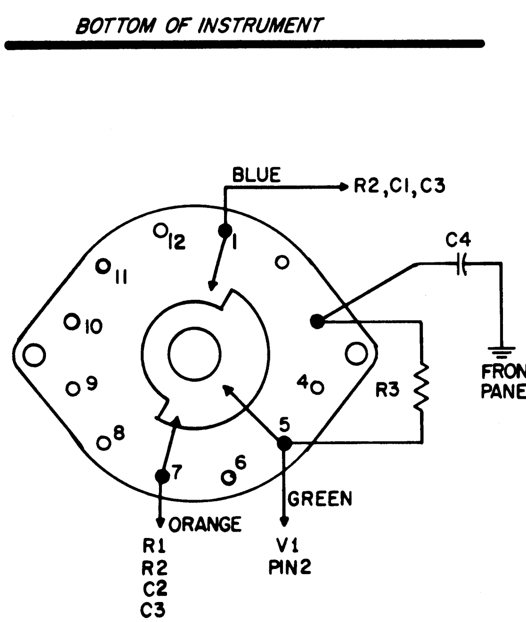


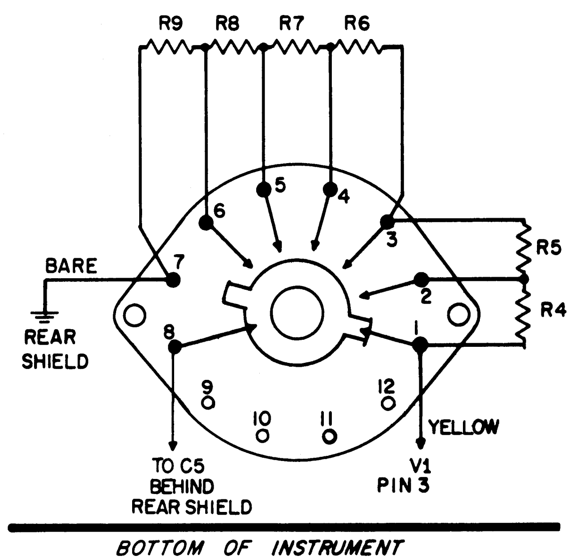
RB1
LAYOUT OF INPUT VOLTAGE
DIVIDER NETWORK



NOTES:

1. ALL CIRCUIT REFERENCES CORRESPOND TO THOSE IN THE SCHEMATIC WIRING DIAGRAM.



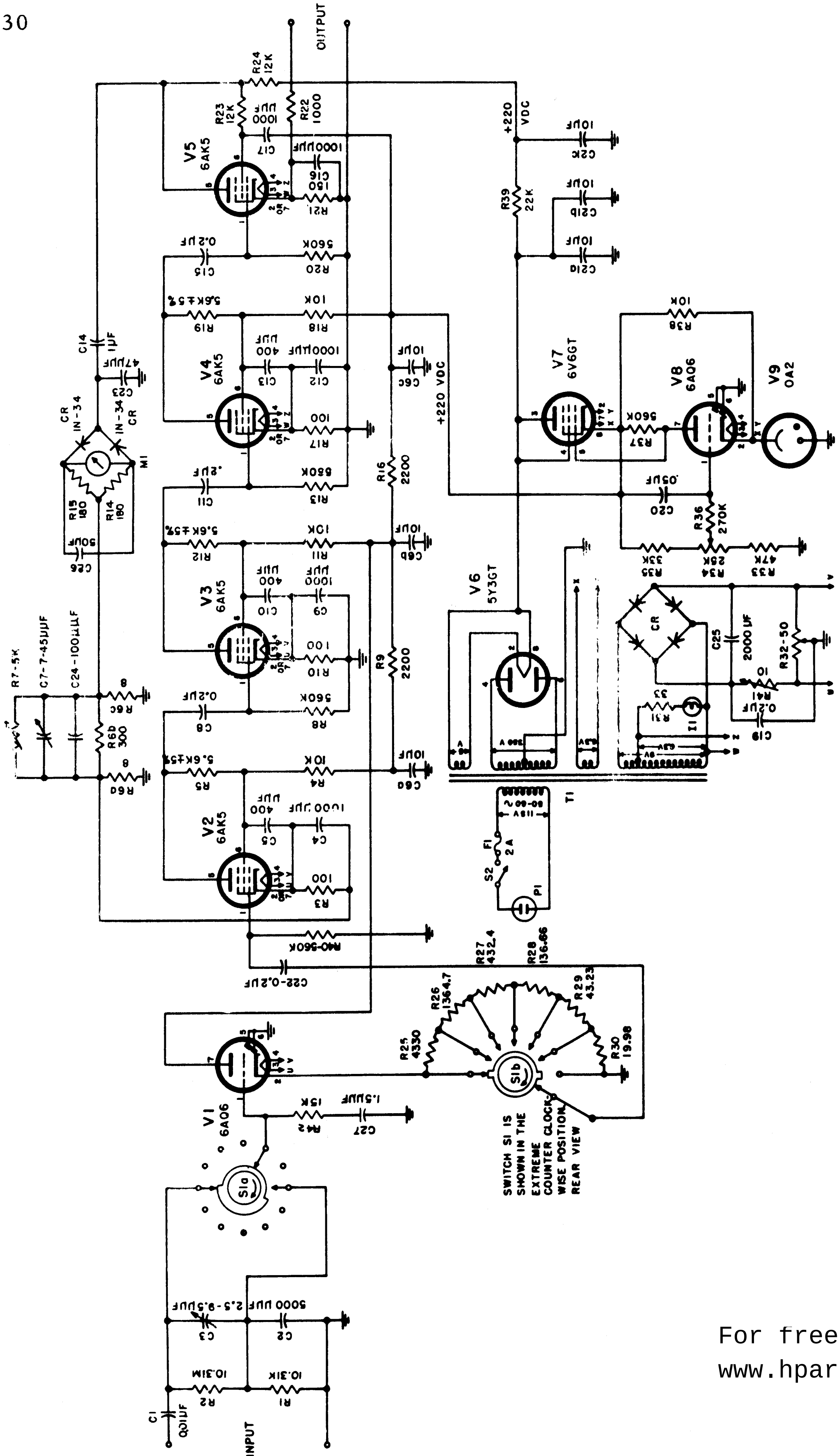


S1A FRONT VIEW
(FRONT WAFER)

S1B REAR VIEW
(REAR WAFER)

RANGE SWITCH S1. CONNECTIONS SHOWN IN 1 VOLT POSITION.

Fig. 4



SCHEMATIC DIAGRAM OF MODEL 400C

SERIAL 1 THROUGH 959

THIS CIRCUIT IS BASICALLY CORRECT, BUT SMALL DIFFERENCES MAY EXIST FOR ANY PARTICULAR INSTRUMENT. COMPARISION AND CROSS-CHECKING WILL ENABLE IDENTIFICATION OF NECESSARY PARTS.

FIG. 5

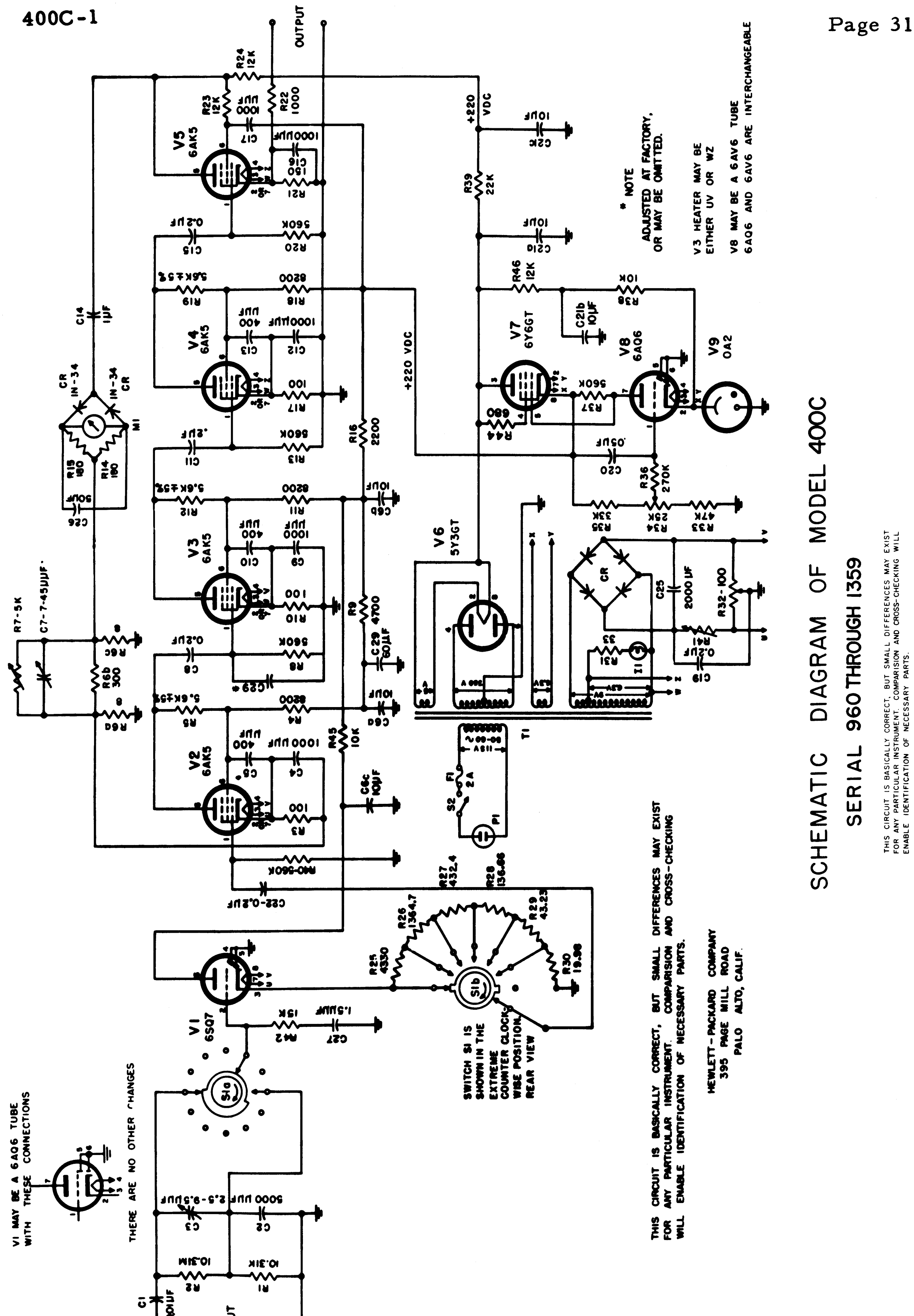

SCHEMATIC DIAGRAM OF MODEL 400C
SERIAL 960 THROUGH 1359
THIS CIRCUIT IS BASICALLY CORRECT, BUT SMALL DIFFERENCES MAY EXIST FOR ANY PARTICULAR INSTRUMENT. COMPARISON AND CROSS-CHECKING WILL ENABLE IDENTIFICATION OF NECESSARY PARTS.
* NOTE
ADJUSTED AT FACTORY, OR MAY BE OMITTED.
V3 HEATER MAY BE EITHER UV OR WZ
V8 MAY BE A 6AV6 TUBE
6AQ6 AND 6AV6 ARE INTERCHANGEABLE
V1 MAY BE A 6AQ6 TUBE WITH THESE CONNECTIONS
THERE ARE NO OTHER CHANGES
SWITCH S1 IS SHOWN IN THE EXTREME COUNTER CLOCKWISE POSITION. REAR VIEW
THIS CIRCUIT IS BASICALLY CORRECT, BUT SMALL DIFFERENCES MAY EXIST FOR ANY PARTICULAR INSTRUMENT. COMPARISION AND CROSS-CHECKING WILL ENABLE IDENTIFICATION OF NECESSARY PARTS.
HEWLETT-PACKARD COMPANY
395 PAGE MILL ROAD
PALO ALTO, CALIF.
INPUT
OUTPUT
+220 VDC

FIG. 6

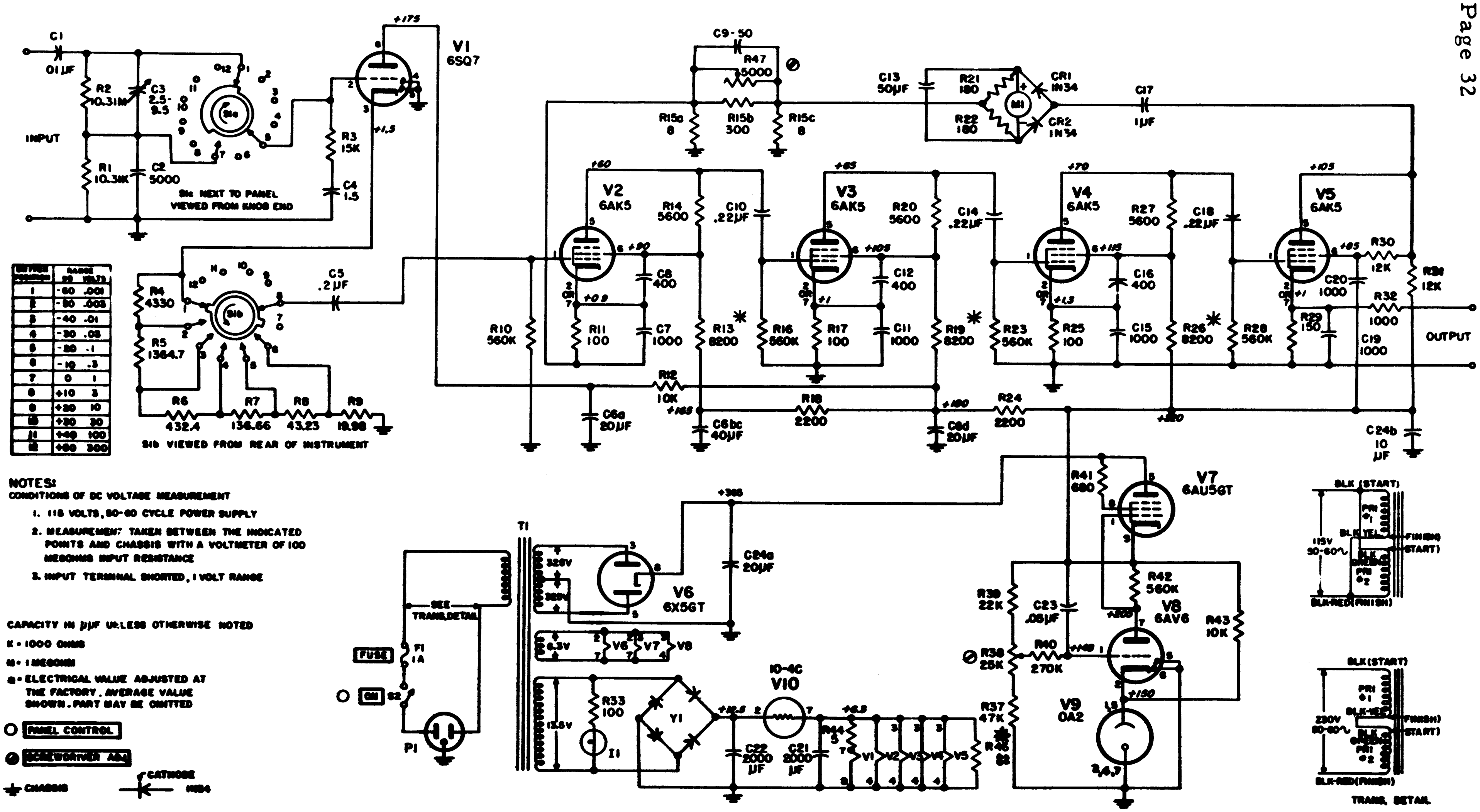


FIG. 7

SWITCH POSITION	RANGE DB	VOLTS
1	-60	.001
2	-50	.003
3	-40	.01
4	-30	.03
5	-20	.1
6	-10	.3
7	0	1
8	+10	3
9	+20	10
10	+30	30
11	+40	100
12	+50	300

NOTES:
CONDITIONS OF DC VOLTAGE MEASUREMENT

1. 115 VOLTS, 50-60 CYCLE POWER SUPPLY
2. MEASUREMENT TAKEN BETWEEN THE INDICATED POINTS AND CHASSIS WITH A VOLTMETER OF 100 MEGOHMS INPUT RESISTANCE
3. INPUT TERMINAL SHORTED, 1 VOLT RANGE

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

PANEL CONTROL

SCREWDRIVER ADJ

CHASSIS

CATHODE 1N34

V8 MAY BE EITHER A 6AV6 OR 6AQ6 TUBE

SCHEMATIC DIAGRAM OF MODEL 400C
SERIAL 13608 & ABOVE

THIS CIRCUIT IS BASICALLY CORRECT, BUT SMALL DIFFERENCES MAY EXIST FOR ANY PARTICULAR INSTRUMENT. COMPARISON AND CROSS-CHECKING WILL ENABLE IDENTIFICATION OF NECESSARY PARTS

TABLE OF REPLACEABLE PARTS

The following parts list may be used to determine replacement parts for all -hp- Model 400C Vacuum Tube Voltmeters. To determine the correct replacement part, first refer to the schematic diagram for the instrument involved as determined by instrument serial number and identify same component in schematic diagram given on page 32 of the Service Manual. Use circuit reference obtained from schematic on page 32 to identify correct component in the Table of Replaceable Parts.

Some components with the same Circuit Reference and -hp- Stock Number vary slightly from one instrument to another. To assure receiving the correct replacement part be sure to include instrument Model and Serial numbers as well as the -hp- Stock Number and Description of the desired part. Failure to include this information may result in a wrong part being received or may require additional correspondence and delay.

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C1	Capacitor: fixed, paper, 0.01 µf, 600 vdcw or	16-11	A #684
	3900 µµf, 600 vdcw	16-24	A #P688
C2	Capacitor: fixed, mica, 5000 µµf, replace with; 4700 µµf, ±10%, 300 vdcw	14-44	Z Type C-1247
C3	Capacitor: variable, ceramic, 2.5 - 9.5 µµf, 500 vdcw	13-7	L type TS2A-NPO
C4	Capacitor: fixed, 1.5 µµf, 500 vdcw	15-38	DD type GA-3
C5	Capacitor: fixed, paper, 0.2 µf, replace with; 0.27 µf, 200 vdcw	16-36	CC #68P
C6 abcd	Capacitor: fixed, electrolytic, "long life", 20, 20, 40 µf, 450 vdcw	18-42S	CC # D 16651
	Standard type with same rating	18-42	X type EP-444
C7	Capacitor: fixed, mica, 1000 µµf, ±10%, 500 vdcw	14-11	V type W
C8	Capacitor: fixed, mica, 400 µµf, replace with; 390 µµf, ±10%, 500 vdcw	14-65	V type OXM
C9	Capacitor: fixed, mica, 50 µµf, replace with; 47 µµf, ±10%, 500 vdcw	14-67	V type OXM
C10	Capacitor: fixed, paper, 0.22 µf, 400 vdcw	16-48	A #P488
C11	Capacitor: fixed, mica 1000 µµf, ±10%, 500 vdcw	14-11	V type W

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

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C12	Capacitor: fixed, mica, 400 μμf, replace with; 390 μμf, ±10%, 500 vdcw	14-65	V type OXM
C13	Capacitor: fixed, electrolytic, 50 μf, 50 vdcw	18-50	X TC-39
C14	Capacitor: fixed, paper, 0.22 μf, 400 vdcw	16-48	A #P488
C15	Capacitor: fixed, mica, 1000 μμf, 500 vdcw	14-11	V type W
C16	Capacitor: fixed, mica, 400 μμf, replace with; 390 μμf, ±10%, 500 vdcw	14-65	V type OXM
C17	Capacitor: fixed, paper, 1.0 μf, 400 vdcw	16-44	CC #88P10504
C18	Capacitor: fixed, paper, 0.22 μf, 400 vdcw	16-48	A #P488
C19	Capacitor: fixed, mica 1000 μμf, ±10%, 500 vdcw	14-11	V type W
C20	Capacitor: fixed, mica, 1000 μμf, ±10%, 500 vdcw	14-11	V type W
C21	Capacitor: fixed, electrolytic, "long life" 2000 μf, 15 vdcw	18-3-S	CC #D16652
C22	Capacitor: fixed, electrolytic, "long life" 2000 μf, 15 vdcw	18-3-S	CC #D16652
C23	Capacitor: fixed, paper, 0.05 μf, ±10%, 600 vdcw	16-15	A type P688
C24 ab	Capacitor: fixed, electrolytic, "long life" 10, 10, 10 μf, 450 vdcw	18-31-S	CC #D16650
	Standard type with same rating	18-31	X type FP375.8
R1	Resistor: fixed, composition, 10.31 megohms, ±1%, 1 Watt	31-10.31M	HP
R2	Resistor: fixed, composition, 10,300 ohms, ±1%, 1 Watt	31-10.31K	HP
NOTE --	Order R1 and R2 as a matched pair giving both stock numbers.		

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R3	Resistor: fixed, composition, 15,000 ohms, ±10%, 1/2 Watt	23-15K	B EB 1531
R4 - R9	Resistor: fixed, precision, wire- wound, two sections	4C-71	HP 2500
R10	Resistor: fixed, composition, 560,000 ohms, ±10%, 1 Watt	24-560K	B GB 5641
R11	Resistor: fixed, composition, 100 ohms, ±10%, 1 Watt	24-100	B GB 1011
R12	Resistor: fixed, composition, 10,000 ohms, ±10%, 1 Watt	24-10K	B GB 1031
R13	Resistor: fixed, composition, 8200 ohms, ±10%, 2 Watts or 6800 ohms, ±10%, 2 Watts Factory adjusted electrical value	 25-8200 25-6800	 B type HB 8221 B type HB 6821
R14	Resistor: fixed, composition, 5600 ohms, ±5%, 1 Watt	24-5600-5	B GB 5625
R15 abc	Resistor: fixed, wirewound, precision, tapped, 8, 300, & 8 ohms	4C-26	HP
R16	Resistor: fixed, composition, 560,000 ohms, ±10%, 1 Watt	24-560K	B GB 5641
R17	Resistor: fixed, composition, 100 ohms, ±10%, 1 Watt	24-100	B GB 1011
R18	Resistor: fixed, composition, 2200 ohms, ±10%, 2 Watts	25-2200	B HB 2221
R19	Resistor: fixed, composition, 8200 ohms, ±10%, 2 Watts or 6800 ohms, ±10%, 2 Watts Factory adjusted electrical value	 25-8200 25-6800	 B type HB 8221 B type HB 6821
R20	Resistor: fixed, composition, 5600 ohms, ±5%, 1 Watt	24-5600-5	B GB 5625
R21	Resistor: fixed, composition, 180 ohms, ±10%, 1 Watt	24-180	B GB 1811
R22	Resistor: fixed, composition, 180 ohms, ±10%, 1 Watt	24-180	B GB 1811
R23	Resistor: fixed, composition, 560,000 ohms, ±10%, 1 Watt	24-560K	B GB 5641

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

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R24	Resistor: fixed, composition, 2200 ohms, ±10%, 2 Watts	25-2200	B HB 2221
R25	Resistor: fixed, composition, 100 ohms, ±10%, 1 Watt	24-100	B GB 1011
R26	Resistor: fixed, composition, 8200 ohms, ±10%, 2 Watts or 6800 ohms, ±10%, 2 Watts Factory adjusted electrical value	 25-8200 25-6800	 B type HB 8221 B type HB 6821
R27	Resistor: fixed, composition, 5600 ohms, ±5%, 1 Watt	24-5600-5	B GB 5625
R28	Resistor: fixed, composition, 560, 000 ohms, ±10%, 1 Watt	24-560K	B GB 5641
R29	Resistor: fixed, composition, 150 ohms, ±10%, 1 Watt or 220 ohms, ±10%, 1 Watt	 24-150 24-220	 B type GB 1511 B type GB 2211
R30	Resistor: fixed, composition, 12, 000 ohms, ±10%, 2 Watts	25-12K	B HB 1231
R31	Resistor: fixed, composition, 12, 000 ohms, ±10%, 2 Watts	25-12K	B HB 1231
R32	Resistor: fixed, composition, 1000 ohms, ±10%, 1 Watt	24-1000	B GB 1021
R33	Resistor: fixed, composition, 100 ohms, ±10%, 2 Watts	25-100	B HB 1011
R34- R36	These circuit reference not assigned		
R37	Resistor: fixed, composition, 47, 000 ohms, ±10%, 1 Watt	24-47K	B GB 4731
R38	Resistor: variable, composition, 25, 000 ohms, linear taper	210-11	G BAI-010-1990
R39	Resistor: fixed, composition, 22, 000 ohms, ±10%, 1 Watt	24-22K	B GB 2231
R40	Resistor: fixed, composition, 270, 000 ohms, ±10%, 1 Watt	24-270K	B GB 2741
R41	Resistor: fixed, composition, 680 ohms, ±10%, 1 Watt	24-680	B GB 6811
R42	Resistor: fixed, composition, 560, 000 ohms, ±10%, 1 Watt	24-560K	B GB 5641

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

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R 43	Resistor: fixed, composition, 10,000 ohms, ±10%, 2 Watts	25-10K	B HB 1031
R44	Resistor: fixed, composition, flexible, fiberglass construction, 5 ohms, ±10%, 2 Watts	26-33	I type FYG
R45	This circuit reference not assigned		
R46	Resistor: fixed, composition, 82 ohms, ±10%, 1 Watt or 100 ohms, ±10%, 1 Watt	24-82 24-100	B type GB 8201 B type GB 1011
R47	Resistor: variable, composition, 5000 ohms, linear taper	210-7	G 21-010-357
---	Resistor Board: input	4C-75A	HP
CR1	Crystal Rectifier: selected 1N34	212-G-11F	HP
CR2	Crystal Rectifier: selected 1N34	212-G-11F	HP
F1	Fuse: 1 ampere, 250 volts, FOR OPERATION FROM 115 VOLTS	211-18	E type MDL-1
F1	Fuse: 1/2 ampere, 250 volts, FOR OPERATION FROM 230 VOLTS	211-20	E type MDL-1/2
---	Fuseholder: for F1	312-8	T #342001
---	Indicator Light Assembly	312-10	BB 807BS
I1	Lamp: type 47,	211-47	O #47
---	Knob: 2" diameter	37-13	HP
---	Binding Post	AC-10A	HP
---	Binding Post Insulator: dual, black	AC-54A	HP
M1	Meter: 1 ma movement, 80 ohms	112-6	HP
S1 ab R4 - R9	Range Switch Assembly: includes R4 through R9	4C-19W	HP
S1 ab	Range Switch: less resistors	310-65	W 38089-H2
S2	Toggle Switch: spst, OFF-ON	310-11	D 20994-HW
T1	Power Transformer: Serial No. 1359 and below Serial No. 1360 and above	 910-67 910-76	 HP HP

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

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
P1	Power Cable:	812-56	HP
Y1	Rectifier: bridge, selenium, for all instruments	212-76	Westinghouse 4A41HA1
V1 **	Tube: 6SQ7	212-6SQ7	ZZ
V2 **	Tube: 5654	212-5654	ZZ
V3 **	Tube: 5654	212-5654	ZZ
V4 **	Tube: 5654	212-5654	ZZ
V5 **	Tube: 5654	212-5654	ZZ
V6 **	Tube: 6AX5GT	212-6AX5GT	ZZ
**	Refer to page 7 of Service Manual before ordering replacement tubes for V1, V2, V3, V4, V5, or V6.		
V7	Tube: 6AV5GT or 6Y6GT	212-6AV5GT 212-6Y6GT	ZZ ZZ
	Tube V7 may be a type 6V6GT, 6Y6GT, 6AU5GT, or 6AV5GT. Replace a 6V6GT or a 6Y6GT with a type 6Y6GT tube. Replace a type 6AU5GT or 6AV5GT with a type 6AV5GT. Types 6V6GT and 6Y6GT are interchangeable. Types 6AU5GT and 6AV5GT are interchangeable.		
V8	Tube: 6AV6 Tube V8 may be either a type 6AQ6 or a type 6AV6. These two types are interchangeable but the type 6AV6 is recommended for replacement.	212-6AV6	ZZ
V9	Tube: 0A2, 150 volt regulator	212-0A2	ZZ
V10	Tube: ballast, 10-4C	211-39	C #10-4C

*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 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	Barber 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.

CODE LETTER	MANUFACTURER	ADDRESS
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.

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CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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