SERVICE NOTES

MODEL 400A

VACUUM TUBE VOLTMETER

SERVICE MANUAL

No. 400A-1

HEWLETT-PACKARD COMPANY 275 Page Mill Road Palo Alto, California

The Hewlett-Packard Company provides this Service Manual to assist with trouble location and parts replacement in the Model 400A Vacuum Tube Voltmeter. A detailed description of the voltmeter and the methods to calibrate it are presented in this manual. There is also information on modernizing older units and trouble shooting instruments with specific difficulties. Circuit diagrams, photographs, and tables are included in an effort to supply as much of the necessary information as practical.

INDEX AND TABLE OF CONTENTS

	Page No.
SPECIFICATIONS	3
ACCESSORIES	5
Capacitive Voltage Divider -hp- Model 452	5
Shunt Resistors -hp- Models 470A through 470F	5
OPERATION OF INSTRUMENT	6
Controls and Terminals	6
Operation	7
CIRCUIT DESCRIPTION	10
Input Circuit	10
Amplifier Circuit	10
Meter Circuit	11
Power Supply	11
HISTORY OF PRODUCTION	12
List of Production Changes	12
MODERNIZING OLDER UNITS	14
Replacement of 991 Reference Tube for V8	14
Installation of "Long Life" Electrolytics	15
TUBE REPLACEMENT PROCEDURE	17
Replacement of V1, V6, or V7	17
Replacement of 6AC7 for V2 or V3	17
Replacement of 6H6 for V4	17
Replacement of Type 991 Neon Glow Lamp for V8	18

SERVICE NOTES
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400A-2A

MODEL 400A VACUUM TUBE VOLTMETER
REPLACEMENT OF VOLTMETER SWITCH ASSEMBLY

A replacement Range Switch Assembly for the Model 400A Vacuum Tube Voltmeter is available under Stock No. 4A-19.

The switch assembly is easily installed and no precautions are necessary other than normal care in connecting all wires properly and in avoiding damage to the switch.

The 1.5 - 7 μμf variable ceramicon capacitor on the range switch is used to adjust the frequency response on the 0.1 volt range. The adjustment should be made with frequency response testing equipment. If such equipment is not available, an arbitrary setting can be made by adjusting the capacitor to have the same value as on the replaced switch. This can best be done with a bridge, but fair accuracy is obtainable by merely turning the capacitor rotor so that the adjustment slot is in the same relative position as on the replaced switch assembly.

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	Page No.
GENERAL TEST PROCEDURE	19
Steps for Complete Test Procedure	19
Power Supply Adjustment	19
Meter Zero Set Adjustment	20
Calibration	21
Line Voltage Response Check	23
Frequency Response Adjustment	23
POWER SUPPLY	27
B+ Regulated Supply Trouble	27
Bias Circuit Trouble	28
TROUBLE SHOOTING NOTES	30
Trouble Shooting Chart	30
SCHEMATIC DIAGRAM (Serial No. 5620 and Below)	39
SCHEMATIC DIAGRAM (Serial No. 8723 and Above)	40
TABLE OF SPECIAL REPLACEABLE PARTS	41

SPECIFICATIONS (All voltages refer to percentage of full scale)

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 shunted by approximately 25 μμf.
100 volts range. 3 megohms shunted by approximately 25 μμf.
300 Volts range. 2.4 megohms shunted by approximately 25 μμf.

ACCURACY -

±3% of full scale reading on all ranges, from 10 cps to 100 KC.
±5% of full scale reading on all ranges, from 100 KC. to 1 MC.

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 but not more than 600 volts will not damage the meter movement. The sum of the dc voltage and the ac voltage applied to the input terminals must not exceed 600 volts.

POWER SUPPLY RATING-

Voltage . . . . . 105 to 125 volts.

POWER SUPPLY RATING - (cont.)

Frequency	50 to 1000 cps.
Wattage	40 watts.

OVERALL DIMENSIONS AND WEIGHT -

Width	7-9/16 inches.
Height	9-1/2 inches.
Depth	10-1/4 inches.
Weight	15 pounds.

ACCESSORIES

The following accessories are available for use with the -hp- Model 400A vacuum tube voltmeter. These accessories are not supplied with the instrument, but may be purchased from the Hewlett-Packard Co.

CAPACITIVE VOLTAGE DIVIDER -hp- MODEL 452A -

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

Maximum Voltage	25,000 volts.
Division Ratio	1,000 to 1
Frequency Range	25 cps to 20 MC.
Accuracy	±3%
Input Capacity	15 μμf.

SHUNT RESISTOR -hp- MODELS 470A THROUGH 470F -

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

Accuracy - ±1% from 10 cps to 100 KC.
- ±5% from 100 KC. 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

OPERATION OF INSTRUMENT

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 in 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 in Fig. 4, 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, 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.

OPERATION OF INSTRUMENT (Cont.)

CONTROLS AND TERMINALS -

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.

OPERATION -

Zero Meter Indication -

The meter pointer may not coinside 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 accuracy when reading the meter scale use the 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

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.

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 reading 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

OPERATION - (cont.)

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. 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.

CIRCUIT DESCRIPTION

The -hp- 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 reading 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

CIRCUIT DESCRIPTION (cont.)

AMPLIFIER CIRCUIT - (cont.)

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.

HISTORY OF PRODUCTION

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

The Electrical Performance Specifications of the -hp- Model 400A have not changed, an older unit will give the same fine performance 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 the older unit is functioning properly, there is no need to undertake modernization.

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 THAT FOLLOW. 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 GIVEN IN FIGURE 6.

LIST OF PRODUCTION CHANGES -

1. To provide greater power supply stability, reference tube V8 was changed from a type 991 glow tube to a type OD3/VR150. This necessitated changes in value for R30, R32, and R33. Potentiometer R34 was incorporated to provide an adjustment for setting the regulated voltage output. This change can be added to older instruments (Serial No. 5620 and below) by following the special procedure in MODERNIZING OLDER INSTRUMENTS on page 14 .

2. The type 6SQ7 tube became more readily available than the 6SF5. Both types gave the same performance when used for V7, so the 6SQ7 was used in place of the 6SF5.

3. To conform with the -hp- policy of manufacturing highest quality equipment, special hermetically sealed "long life" electrolytic capacitors (with a life expectancy of from 5 to 10 years or longer) were used for the five can type electrolytic capacitors as soon as they became available. Use the "long life" capacitors for replacement purposes. Installation instructions are given in MODERNIZING OLDER INSTRUMENTS on page14 .

4. To make it easier to adjust the frequency response, the values of C3 and C4 were changed and trimmer C16 was added.

5. The exact values of R1, R2, R5, and R6 have varied slightly from time to time. These minor variations are unimportant as long as the ratios are correct for calibrating the 100 and 300 volt ranges.

6. 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.

7. The older type precision resistors for R1, R2, R5 and R6 were black, sealed in glass types. These should be replaced with the more modern Carbo-film type resistors.

MODERNIZING OLDER UNITS

The following two modifications may be made at any time. However, as long as an instrument is functioning as it should there is nothing to be gained by making the changes.

The procedure given for replacement of the 991 reference tube V8 is special for instruments with serial No. 5620 and below. The mechanical layout of these instruments is such that there is no room to mount R35 for controlling the output voltage. Instruments with serial No. 5621 and up already have this modification.

REPLACEMENT OF 991 REFERENCE TUBE FOR V8 -

Two different types of neon lamp sockets have been used. One type required a $\frac{3}{4}$" mounting hole and the other a 1" hole. In order to simplify the mounting of the tube socket, an OD3/VR150 is recommended for use with the 1" hole. With the $\frac{3}{4}$" hole a type OA2 is recommended since the miniature tube socket for this tube type can easily be mounted in an adaptor plate. The results obtained from either type of tube will be the same. The instructions that follow, including the tube socket pin numbers, apply to either type of tube.

One each of the following parts will be required;

Description	-hp- Stock No.
Resistor; composition, 62,000 ohms, 1 watt . . .	24-62K
Resistor; composition, 27,000 ohms, 1 watt . . .	24-27K
Resistor; composition, 10,000 ohms, 2 watts . .	25-10K
Tube; regulator, OD3 (VR 150)	212-OD3
Socket; octal, tube, 1" mtg. hole	38-22
OR	
Tube; regulator, OA2	212-0A2
Socket; 7 pin, miniature tube	38-7

Procedure - (Refer to Fig. 5.)

1. Replace R32 (82,000 ohms) with 27,000 ohms, 1 watt resistor. Fig. 1 shows position only of R32 on RB2 resistor board.

2. Replace R33 (27,000 ohms) with 62,000 ohms, 1 watt resistor. Refer to Fig. 1 for R33 location.

REPLACEMENT OF 991 REFERENCE TUBE V8 - (cont.)

Procedure - (cont.)

3. Replace R30 (270, 000 ohms) with 10, 000 ohms, 2 watts resistor. Refer to Fig. 1 for R30 location.

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

5. Connect and solder remaining wire that formerly connected to the neon socket to pin 5 of new V8 socket.

6. Install new regulator tube in V8 socket and turn power on.

7. Measure the dc voltage at cathode pin 8 of 6V6 tube V8. The voltage should be approximately 215 volts. If the voltage is high, experimentally determine the value of a resistor which, when connected in parallel with R32, will give the 215 volt reading. If the measured voltage is low, connect the additional resistor in parallel with R33 instead of R32.

8. With the dc voltmeter connected as in step 7, vary the line voltage between 105 and 125 volts. The voltmeter reading should not vary by more than 2 volts. If trouble is encountered refer to the POWER SUPPLY section.

No further adjustments are necessary.

INSTALLATION OF "LONG LIFE" ELECTROLYTICS -

IMPORTANT - The replacement "long life" electrolytic can type capacitors are clearly coded on the side for the terminal connections. Note that these capacitors do not have the common or negative side connected to the can. The common or negative terminal is a lug protruding from the bottom insulator. This common terminal (usually No. 1) must be externally connected to the can. The ground connection for the can must be good in order to prevent noise. Connect both the common terminal and the can of the electrolytic to a good ground point with a short wire jumper. If the instrument has metal mounting plates for the electrolytics, solder can lugs to metal plate.

INSTALLATION OF "LONG LIFE" ELECTROLYTICS - (cont.)

Replacement of C5, C14, and C15 -

Capacitor C5 may be directly replaced by -hp- Stock No. 18-20S and C15 by -hp- Stock No. 18-40S. Install a new mounting wafer for C14 before replacing with -hp- Stock No. 18-31S. Other than the new mounting plate for C14, no special procedure is required. Connect can of electrolytic to common or negative terminal as previously explained.

Replacement of C9 -

Replacement capacitor -hp- Stock No. 18-42S with three sections can be used for C9. The two 20 µf sections of the 18-42S unit are connected in parallel to form C9a and C9c. The single 40 µf section is used for C9b. Refer to Fig. 6.

Replacement of C13 -

The following procedure should be followed when replacing the old four section electrolytic for C13 with the three section unit -hp- Stock No. 18-42S:

1. Remove the old electrolytic capacitor and mount the 18-42S unit in its place.
2. Ground the common terminal and the can of the new electrolytic as explained above.
3. 4 wires disconnected from the old electrolytic should remain. Connect the wire from junction of R24 and R25 to one 20 µf section of 18-42S electrolytic.
4. Connect the wire from junction of R25 and R26 to the remaining 20 µf section of 18-42S unit.
5. Remove wire connected to junction of R26 and R27. The other end of this wire is already free since it was disconnected from the old electrolytic capacitor.
6. One wire remains that is not yet connected. Connect this wire to the 40 µf section of 18-42S unit.
7. Check completed wiring of C13 with schematic shown in Fig. 6. Resistors R26 and R27 with the value of 5600 ohms each are now connected in series in place of the 12,000 ohms resistor shown for R26.

Installation of the five "long life" can type capacitors is now complete. Check the voltage output from the power supply and make any adjustments necessary as explained in POWER SUPPLY section.

TUBE REPLACEMENT PROCEDURE

REPLACEMENT OF V1, V6, OR V7 -

Any tubes with RETMA standard characteristics may be used for replacement of these tubes. The replacement tube may be plugged in and no further adjustments are necessary.

When replacing V7 install the same tube type as found in the instrument. This may be a type 6SF5 or a type 6SQ7 which give the same performance but are not directly interchangeable due to a difference in pin connections.

REPLACEMENT OF 6AC7 FOR V2 OR V3 -

Tubes with RETMA standard characterisctics may be used. However, it may be necessary to try several different tubes before one with the most desirable characteristics will be found. After installation of a new tube try the following tests. If the test results are not satisfactory, start over with another 6AC7 tube.

1. With instrument on, short input terminals - meter readings should be zero.

2. Reset sensitivity as described in GENERAL TEST PROCEDURE under CALIBRATION.

3. If instrument is too microphonic or if the meter needle drifts slowly to the value of voltage being measured, insert another 6AC7 and repeat step 2.

REPLACEMENT OF 6H6 FOR V4 -

Tubes with RETMA standard characteristics may be used. However, it may be necessary to try several different tubes before the one with the most desirable characteristics is found. Aged 6H6 tubes are available from Hewlett-Packard. A tube can be aged by running it in the instrument for at least overnight or longer. Procedure for replacing the 6H6 tube follows.

1. Set meter to zero with the 6H6 removed from the socket.

2. Insert new aged 6H6 and allow a few minutes for tube to heat. Set the range switch to 300 volt range and note the reading obtained on the 0 - 1 scale. This is an indication

TUBE REPLACEMENT PROCEDURE (cont.)

REPLACEMENT OF 6H6 FOR V4 - (cont.)

of the zero emission characteristics of the new 6H6 tube. The scale is calibrated to give best tracking when the zero emission is less than 1/2 division. If an aged 6H6 tube is not used, it may be necessary to repeat this operation after the instrument has been in use a few days.

3. Reset pointer to zero with new 6H6 tube in place. Reset Sensitivity as described in GENERAL TEST PROCEDURE under CALIBRATION.

REPLACEMENT OF TYPE 991 NEON GLOW LAMP FOR V8 -

Whenever it becomes necessary to replace the neon glow lamp used in early production of the Model 400A it is recommended that the circuit be modified to use a type OD3 voltage regulator tube in place of the neon glow lamp. Instructions for making this change will be found in the MODERNIZING OLDER UNITS section under the heading of REPLACEMENT OF 991 REFERENCE TUBE FOR V8.

If the type 991 neon lamp is to remain as the reference tube and requires replacement, the following procedure should be used.

1. Use an aged type 991 lamp available under -hp- Stock No. 211-10. A lamp that has not been aged will change characteristics after a few hours operation and no longer provide the proper reference voltage for the regulated supply.

2. Insert replacement 991 lamp in socket.

3. Check the regulation of the regulated dc supply; connect a dc voltmeter (1000 ohms per volt or better) between pin 8 of V6 and the chassis. Set the line voltage to 115 volts and note the voltmeter reading which should be approximately 215 volts. Varying the line voltage from 105 to 125 volts will cause some change in the voltmeter reading. If the voltmeter reading makes a sudden change, install another neon lamp and repeat this step.

   If the voltmeter reading is not approximately 215 volts, refer to steps 4 through 8 of POWER SUPPLY ADJUSTMENT in GENERAL TEST PROCEDURE.

GENERAL TEST PROCEDURE

Refer to Fig. 6 for circuit designations. The equivalent component can be easily located in Fig. 5 if necessary.

STEPS FOR COMPLETE TEST PROCEDURE -

The following steps must be followed when calibrating the -hp- Model 400A. Allow approximately a 1 hour warm up period.

1. Adjust power supply.
2. Adjust meter zero set.
3. Adjust sensitivity on 1 volt range.
4. Repeat steps 2 and 3.
5. Check sensitivity of seven low ranges.
6. Adjust sensitivity of 100 volt and 300 volt ranges.
7. Check line voltage response.
8. Adjust frequency response.
9. Allow instrument to completely cool off and then recheck calibration after a 5 minute warm up. If there is appreciable change in calibration, refer to TROUBLE SHOOTING NOTES.

POWER SUPPLY ADJUSTMENT -

1. Connect 1000 ohms per volt or better dc voltmeter to measure voltage across C14c.
2. Adjust line voltage to 125 volts.
3. Voltmeter reading should not be higher than 450 volts. If voltage is higher, replace R35 with a resistor high enough in value to decrease the voltage to 450 volts. If the instrument does not have R35, add it to the circuit. Refer to Fig. 6 and Figs. 3 and 4 for connections and mounting location.
4. Reset line voltage to 115 volts.
5. Connect voltmeter between chassis and pin 8 (cathode) of V6.
6. Adjust R34 for a 215 volt reading on the voltmeter. If the instrument does not have the potentiometer R34, adjust the values of R32 and R33 as explained in Step 7 of Procedure for Replacement of 991 Reference Tube for V8 in MODERNIZING OLDER UNITS.
7. Adjust line voltage from 105 to 125 volts. The regulated voltage should not vary by more than ±5 volts if V8 is a type 991 neon tube or more than ±2 volts if V8 is a type OD3/VR150 voltage regulator tube.

POWER SUPPLY ADJUSTMENTS - (cont.)

8. Slowly reduce line voltage below 105 volts until the voltage from the regulated supply suddenly drops. If this point occurs above a line voltage of 102 volts, refer to POWER SUPPLY section to determine probable cause of trouble. Correct trouble before going any further.
9. Reset line voltage to 115 volts.
10. Connect negative side of dc voltmeter to junction of R3, R10, and power transformer high voltage center tap. Connect positive side of meter to chassis.
11. Voltmeter reading should be between 1.4 to 1.7 volts. If not, locate and correct the cause of trouble. Refer to POWER SUPPLY section.

A less exact check of regulation 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 relatively large change in dc voltage indicates poor regulation.

If trouble is encountered in any of the above adjustments, refer to the POWER SUPPLY section on page 27.

METER ZERO SET ADJUSTMENT -

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

With the instrument turned on and thoroughly warmed up, adjust the mechanical zero adjustment screw so that the meter needle coincides with the zero scale mark. This adjustment should be made with the DB/R.M.S. VOLTS switch set to the 300 volt range.

Remove the 6H6 tube V4 and note change in meter pointer indication. If the meter needle changes position more than approximately 1/2 division on the 1 volt scale, it will probably be necessary to replace any one or all tubes V2, V3 and V4 before best tracking can be obtained.

Generally, the lower the change when the 6H6 is removed, the better the tracking will be.

Reset the meter to zero with the 6H6 in place and check the sensitivity (calibration) and tracking as explained later in this same section.

CALIBRATION -

The Model 400A has been designed so that all ranges are adjusted by the setting of R13. This potentiometer controls the amount of negative feedback and thus determines the gain of the amplifier. The 100 and 300 volt ranges have an additional means of adjustment. If, after adjusting R13, one range only (below 100 and 300 volt ranges) proves to be inaccurate, consult TROUBLE SHOOTING NOTES.

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

The Model 400A 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 per second. It is not good practice to calibrate the 400A 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 400A may be checked at the 100 volt scale reading.) The Hewlett-Packard Signal Generator models 205A, 205AG, or 205AH are recommended. A 100 volt output can be obtained by using the 5000 ohms output impedance terminals on these instruments.

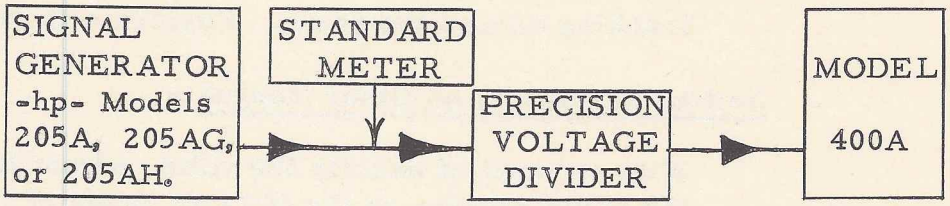
Greatest calibration accuracy will be obtained by using a standard 100 volt output from the signal generator, which is monitored by a standard meter and followed by a precision voltage divider.

Three satisfactory voltage dividers for this are:

1. Hewlett-Packard Models 350A or 350B with approximately ±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.

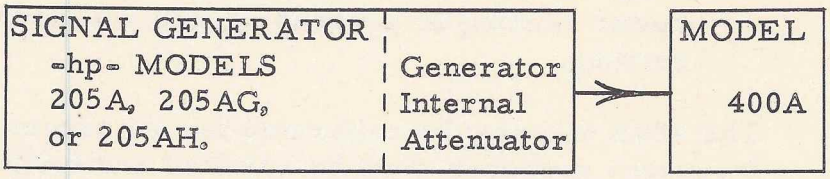
CALIBRATION - (cont.)

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 400A, TO BE SURE THAT NO GROUND LOOPS EXIST. SUCH GROUND LOOPS MAY CAUSE PICKUP OF HUM OR OTHER UNWANTED SIGNAL VOLTAGES. BE SURE THAT THE INSTRUMENT IS SITTING UPRIGHT ON THE BOTTOM PLATE AND THE ONLY GROUND CONNECTION IS MADE TO THE BOTTOM INPUT TERMINAL.

Setting Sensitivity on 1 Volt Range -

With an input of exactly 1 volt, adjust R13 to obtain a 1 volt reading on the 400A 1 volt range. Check this setting with the case for the 400A in place.

GENERAL TEST PROCEDURE (cont.)

CALIBRATION - (cont.)

Setting Sensitivity on 1 Volt Range - (cont.)

With the 1 volt full scale reading set, check the meter tracking across the scale. Replace 6H6 tube if necessary.

Setting Sensitivity on Other Ranges -

With an input of exactly 100 volts, adjust R1a to obtain the same reading on the 100 volt range of the 400A. Resistor R1a is adjusted by replacing the resistor with one of higher or lower value. Increasing R1a will decrease the meter reading or decreasing R1a will increase meter reading.

Set input to exactly 300 volts (100 volts may also be used) and adjust R2a to obtain the same reading on the 300 volt range of the 400A. Increasing R2a will increase the meter reading or decreasing R2a will decrease the meter reading.

The 400A will now be calibrated for all ranges. However, the frequency response must be adjusted and further checks on the performance should be made. If trouble occurs, refer to TROUBLE SHOOTING NOTES.

LINE VOLTAGE RESPONSE CHECK -

The response to variation in line voltage is checked by varying the line voltage 10 volt plus and minus from a 115 volt reference. Set the 400A to the 1.0 volt range and apply a 1 MC signal 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 is within 5% of the original reading. Repeat with a 100 KC signal; reading should not change more than 3%.

FREQUENCY RESPONSE ADJUSTMENT -

The Model 400A is designed with four frequency response adjustments. One each for ranges of 0.1 volt, 30 volts, 100 volts, and 300 volts. The remaining ranges will be correct after adjustment of the 30 volt range.

FREQUENCY RESPONSE ADJUSTMENT - (cont.)

Lead dress in important in the Model 400A. When making repairs in the instrument, return the leads to their original positions. Heater leads should be close to the chassis. In some cases dressing leads may be used to adjust the frequency response. The location of coupling capacitor C10 also effects frequency response on all ranges. An additional adjustment can be obtained by moving this capacitor.

After making a frequency response adjustment, turn instrument upright and sit on bottom cover before noting effect of this adjustment on the meter reading.

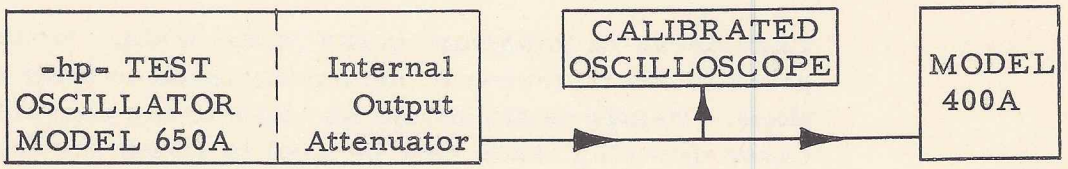
One method of checking the frequency response in the Model 400A is by direct comparison using a low distortion signal source and standard meter capable of reading the high and low frequencies being tested. This standard meter may be either a dynamometer or thermo-couple type or another vacuum tube voltmeter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

Another method of checking frequency response is to use a low frequency standard meter and an oscilloscope which has been calibrated by means of the low frequency standard meter.

Calibrate the cathode ray tube of the oscilloscope by applying a low-frequency sinusoidal voltage simultaneously to the low frequency standard meter and the vertical deflection plates of the cathode ray tube. No horizontal sweep voltage should be used. Directions for connecting to the deflection plates are usually given by the manufacturer of the oscilloscope. By dividing the standard meter reading by the height of the pattern measured in any convenient unit of length the volts per unit length sensitivity of the cathode ray tube will be known. By multiplying this figure by the height of any other applied voltage the value of the voltage can be determined. It is important that the voltage used to calibrate the cathode ray tube be essentially sinusoidal and free from harmonics.

Now connect the Model 400A in parallel with the vertical deflection plates of the calibrated cathode ray tube. Apply signal voltages up to 1 MC to the combination of the two instruments. The voltage shown by the Model 400A should closely agree with that indicated by the magnitude of the cathode ray tube trace.

FREQUENCY RESPONSE ADJUSTMENT - (cont.)



BLOCK DIAGRAM OF OSCILLOSCOPE METHOD FOR FREQUENCY RESPONSE CHECK

When making the following adjustments it may be necessary to introduce some error at one point to bring another point within specifications. Often the 300 volt range must be set 5% high at one megacycle to be less than 3% low at 100 KC.

1. Separate C4 and C7, on input resistor board, as far as their leads will permit. Refer to Fig. 4 for location.

2. Adjust C16, dress leads to C11 and R18 or move C10 and R18 to obtain as flat a response curve as possible on the 30 volt range. Movement of C10, R18, and C11 leads controls the coupling between V3 plate and grid circuits. Increasing this coupling will reduce the response at 1 MC and higher while decreasing this coupling will have just the reverse effect.

   In some instruments, particularly those without C16 trimmer, the distributed capacity of R11 or the capacity between this resistor and the chassis will also affect the frequency response. The windings on R11 can be moved as desired to obtain a change in the frequency response. If C16 is already in the instrument or has just been added, the windings on R11 should be evenly distributed along the form. Moving R11 closer to, or away from, the chassis will also affect the frequency response.

   These instruments are made only on the 30 volt range and should not be disturbed when adjusting the other ranges. If the low frequency response is poor; replace tubes in the amplifier, recalibrate, and recheck the frequency response.

FREQUENCY RESPONSE ADJUSTMENT - (cont.)

3. Check the 0.03 volt range. If the response is not within specifications, repeat steps 1 and 2.

4. Adjust response on 0.1 volt range by adjusting C6.

5. Adjust response on 100 volt range by adjusting C1.

6. Adjust response on 300 volt range by adjusting C2.

7. Check response on all other ranges. Refer to TROUBLE SHOOTING NOTES if response is not correct on other ranges.

POWER SUPPLY

The power supply of the Model 400A is a straight forward full wave rectifier circuit followed by an r-c filter network.

Failure of the rectifier tube or power transformer will result in a dead instrument. A rectifier with low emission, a shorted or leaky electrolytic capacitor, or a shorted tube will cause low voltage. Open electrolytic capacitors will result in a high hum level or low sensitivity.

When replacing the electrolytic capacitors refer to INSTALLATION OF "LONG LIFE" ELECTROLYTICS in MODERNIZING OLDER UNITS section.

Resistor R35 will not be found in all instruments. This resistor should be added to the circuit of any instrument where the voltage across C14c is over 450 volts when the line voltage is at 125 volts. For power supply adjustment procedure refer to POWER SUPPLY ADJUSTMENT in the GENERAL TEST PROCEDURE.

B+ REGULATED SUPPLY TROUBLE -

The B plus regulator in the Model 400A is basically the same as in other -hp- instruments. Early production of the Model 400A used a type 991 neon glow lamp as the reference tube. This type of regulator circuit is shown in Fig. 5. Later production used a type OD3 voltage regulator tube as shown in Fig. 6.

Conversion of instruments with the type 991 lamp to an OD3 regulator tube for V8 is recommended whenever it becomes necessary to replace the 991 lamp. Refer to REPLACEMENT OF 991 REFERENCE TUBE FOR V8 in the MODERNIZING OLDER UNITS section.

Control tube V7 was a type 6SF5 in early production and was later changed to a type 6SQ7 tube. Refer to HISTORY OF PRODUCTION.

Power supply adjustment procedure is given in GENERAL TEST PROCEDURE on page 19.

Three types of failure can occur in the regulated supply:

1. Failure to supply an output voltage.

B+ REGULATED SUPPLY TROUBLE - (cont.)

a. Shorted B plus voltage elsewhere in unit.
b. Dead V6 series regulator tube.
c. Shorted V7 control tube.
d. Failure of supply voltage.
e. Electrolytic capacitor C14 shorted.

2. Oscillation.

a. Defective V8 reference tube.
b. Defective V6 series regulator tube.
c. Defective V7 control tube.
d. Defective electrolytic capacitor.

3. Failure to regulate.

a. Defective tube in any position.
b. The reference tube V8 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 regulator circuit is designed to handle the normal circuit requirements. Shorted V2, C3, C7, and C10 or leaky or shorted C8, C9, and C14 will cause excessive current drain.
e. If the regulated voltage is set too high or too low, poor regulation will result. Check voltage whenever a tube is changed.
f. Shorted V6 or dead V7 will cause regulated voltage to be excessively high.

The dc output voltage of the regulator is adjusted to 215 volts by following the procedure given in steps 5 through 8 of POWER SUPPLY ADJUSTMENT on page 19.

BIAS CIRCUIT TROUBLE -

A bias voltage of approximately -1.5 volts is developed across resistor R3 in series with the center tap of the power transformer high voltage winding. This voltage is filtered by R10 and C8 before being applied to the grid circuits of V2 and V3.

BIAS CIRCUIT TROUBLE - (cont.)

About the only trouble that develops in this circuit is that the 50 μf capacitor C8 becomes leaky or shorted. When this happens, the bias applied to the two 6AC7 tubes, V2, and V3, is too low and the tubes pass excessive current. The excessive current will cause the plate load resistors R14 and R18 to overheat and in some cases change value or burn out. The 6AC7 tubes are also sometimes damaged and must be replaced. Replacement of the plate load resistors or the tubes will necessitate recalibration of the instrument.

TROUBLE SHOOTING NOTES

Trouble in the amplifier section will generally show up the same regardless of the setting of the range switch. However, trouble in the input circuit and cathode follower stage will vary depending upon the position of the range switch. With this in mind, it is sometimes possible to locate the trouble source much more quickly.

ALL SCHEMATIC REFERENCES REFER TO FIG. 6 SCHEMATIC DIAGRAM.

TROUBLE SHOOTING CHART -

Symptom		Cause & Remedy
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.
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.

TROUBLE SHOOTING CHART - (cont.)

Symptom		Cause & Remedy
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.

TROUBLE SHOOTING CHART - (cont.)

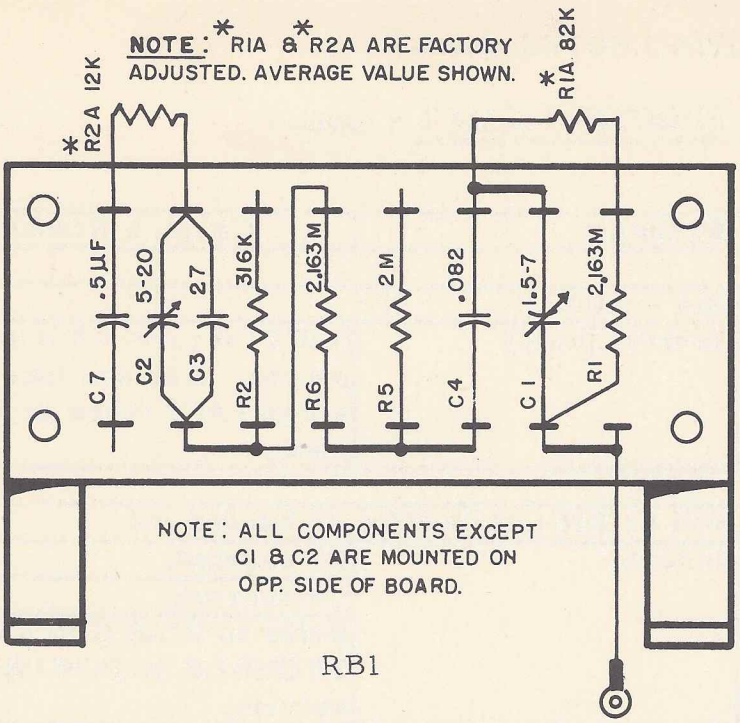
Symptom		Cause & Remedy
Abnormal meter indication - (cont)		
	Meter needle jumpy on 100 and 300 volt ranges only.	R1, R1a, R2, or R2a defective. Use -hp- exact replacement part.
	Slow rise in meter reading then sharp drop to original reading.	Capacitor C8 defective.
	Meter reading low on 0.1 volt range 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 300volt ranges.	R6 defective.
		R1 or R1a defective.
		C5 defective.
	Input terminals open, meter reads full scale. Input terminals shorted, zero reading on 1.0and 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.

TROUBLE SHOOTING CHART - (cont.)

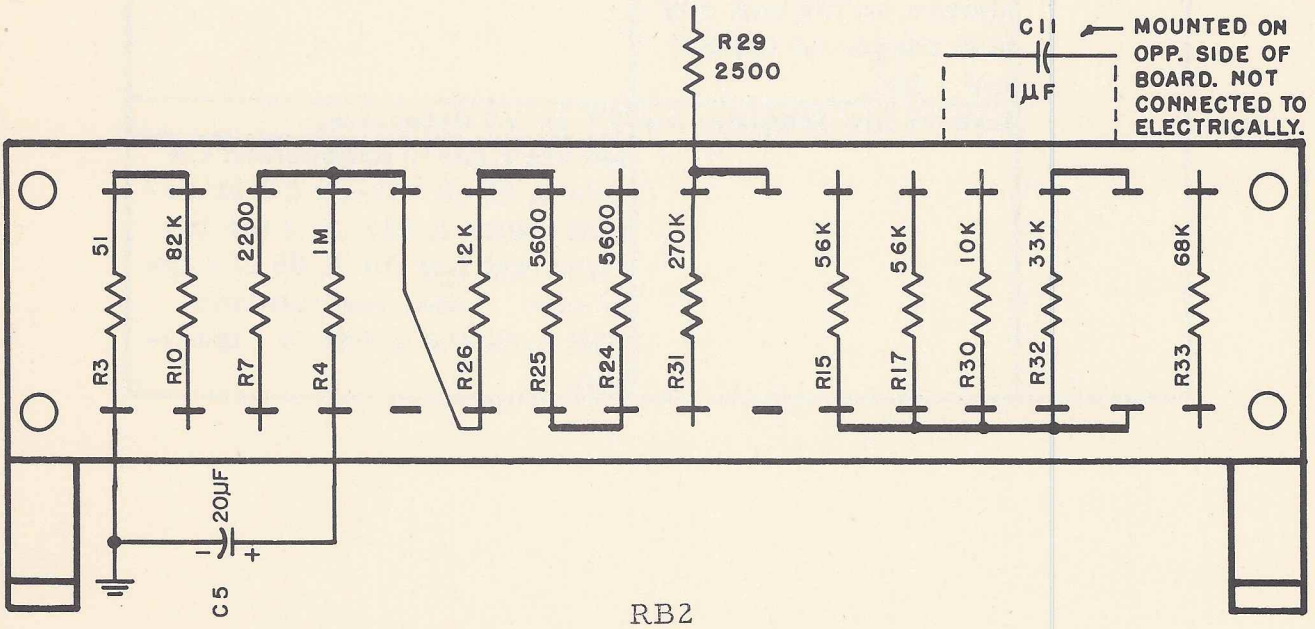
Symptom		Cause & Remedy
Abnormal meter indication - (cont.)		
	Meter pointer indicates a steady reading well up on scale with no input voltage. Needle appears to quiver or oscillate slightly. This condition may or may not change with range switch position and V8 may or may not flicker.	V8 oscillating. This is more probable in older instruments where V8 is a type 991 neon glow lamp. Replace lamp with and 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.

TROUBLE SHOOTING CHART - (cont.)

Symptom		Cause & Remedy
Microphonics - (cont.)		
	General (cont)	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.
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.



RB1



RB2

Fig. 1. Model 400A Resistor Board Details

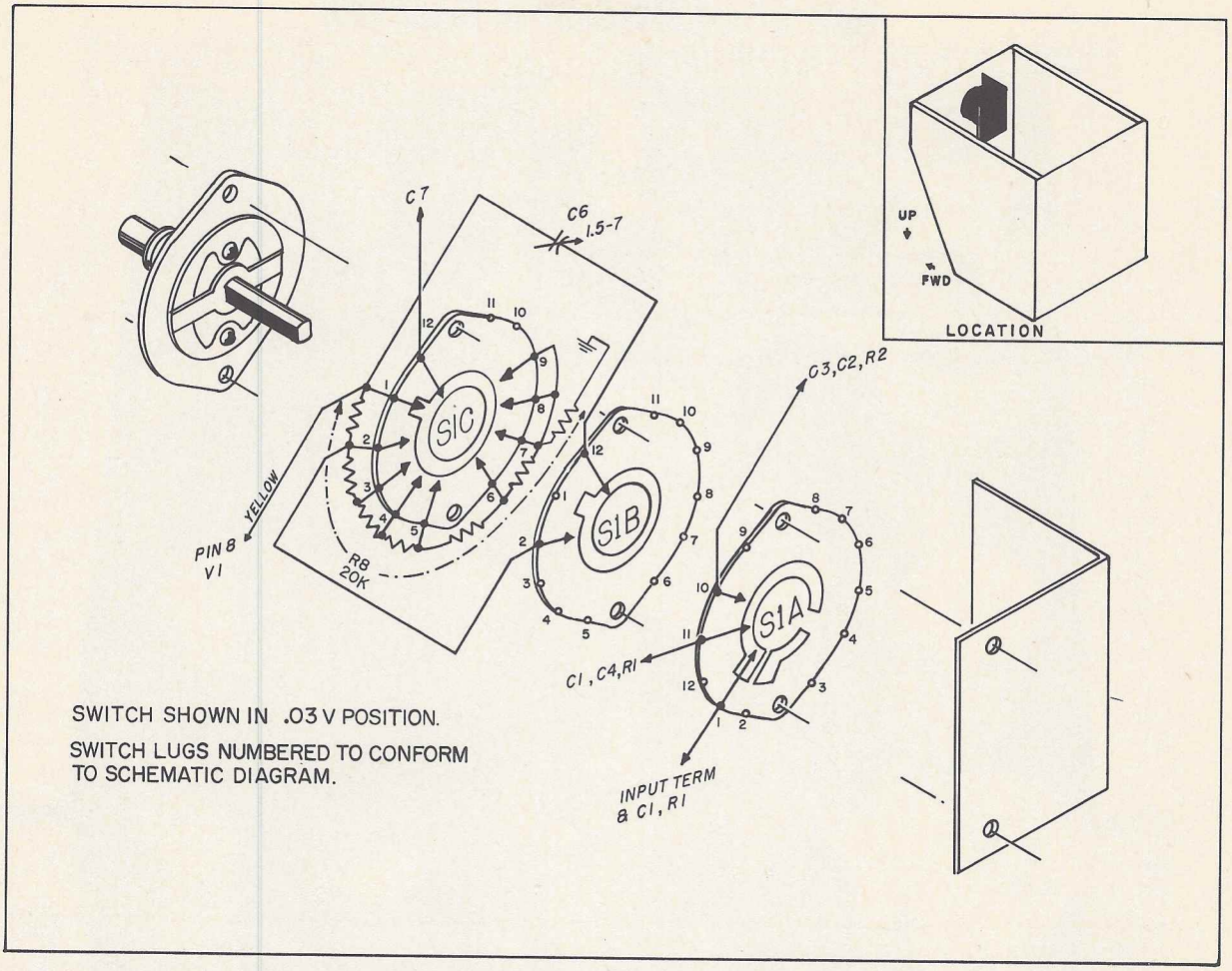


Fig. 2. S1ABC Range Switch Detail

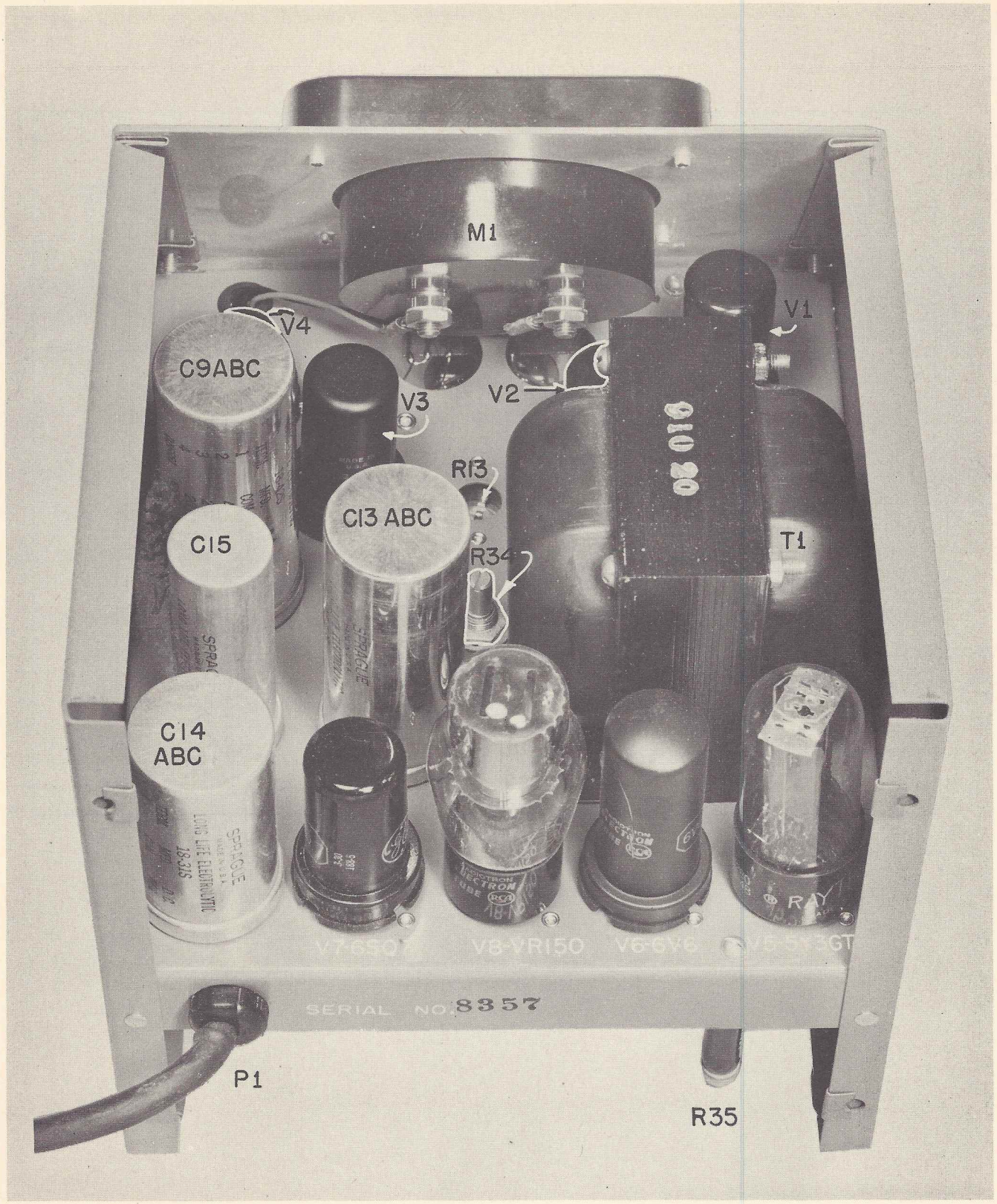


Fig. 3. Model 400A Top View Cover Removed

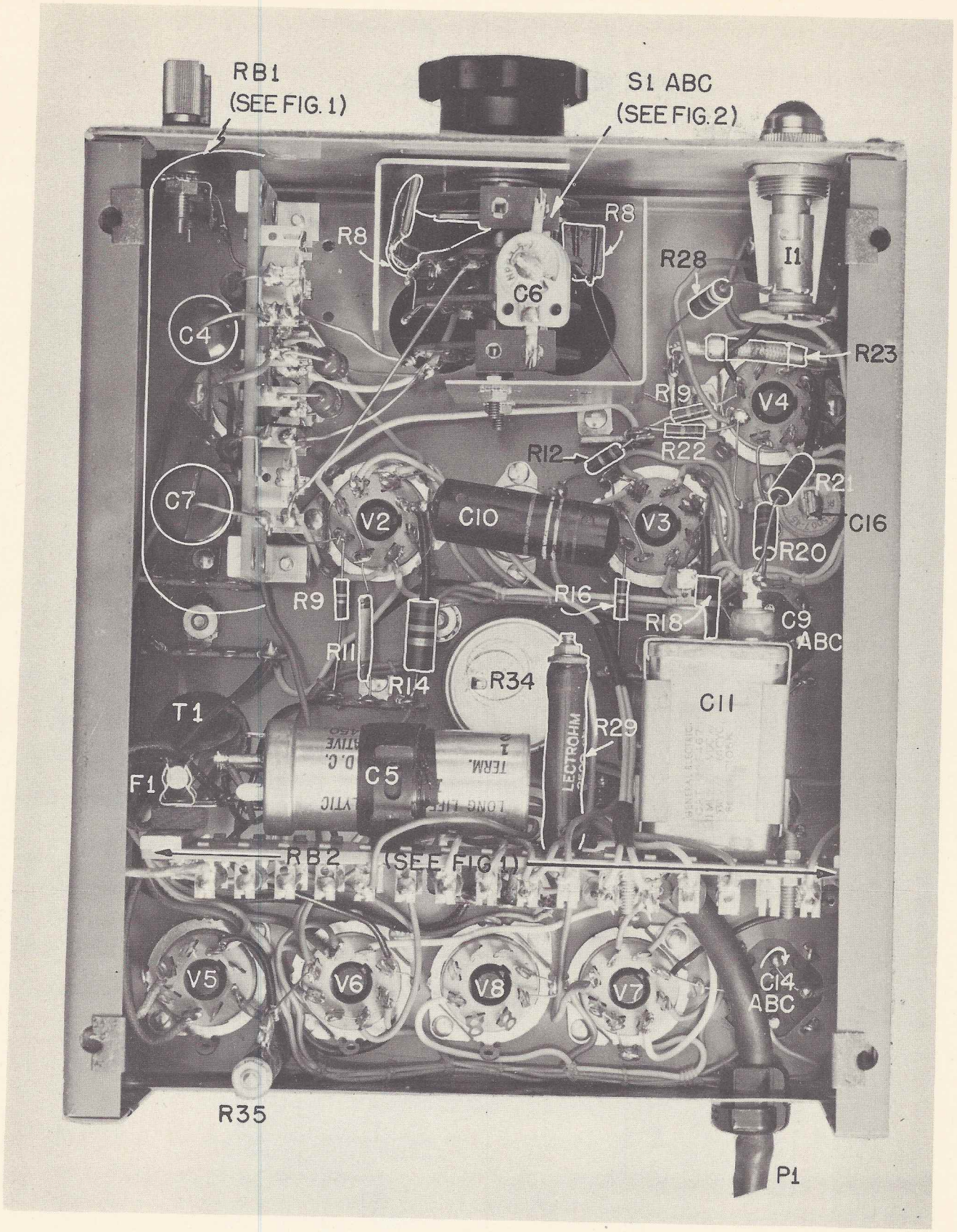
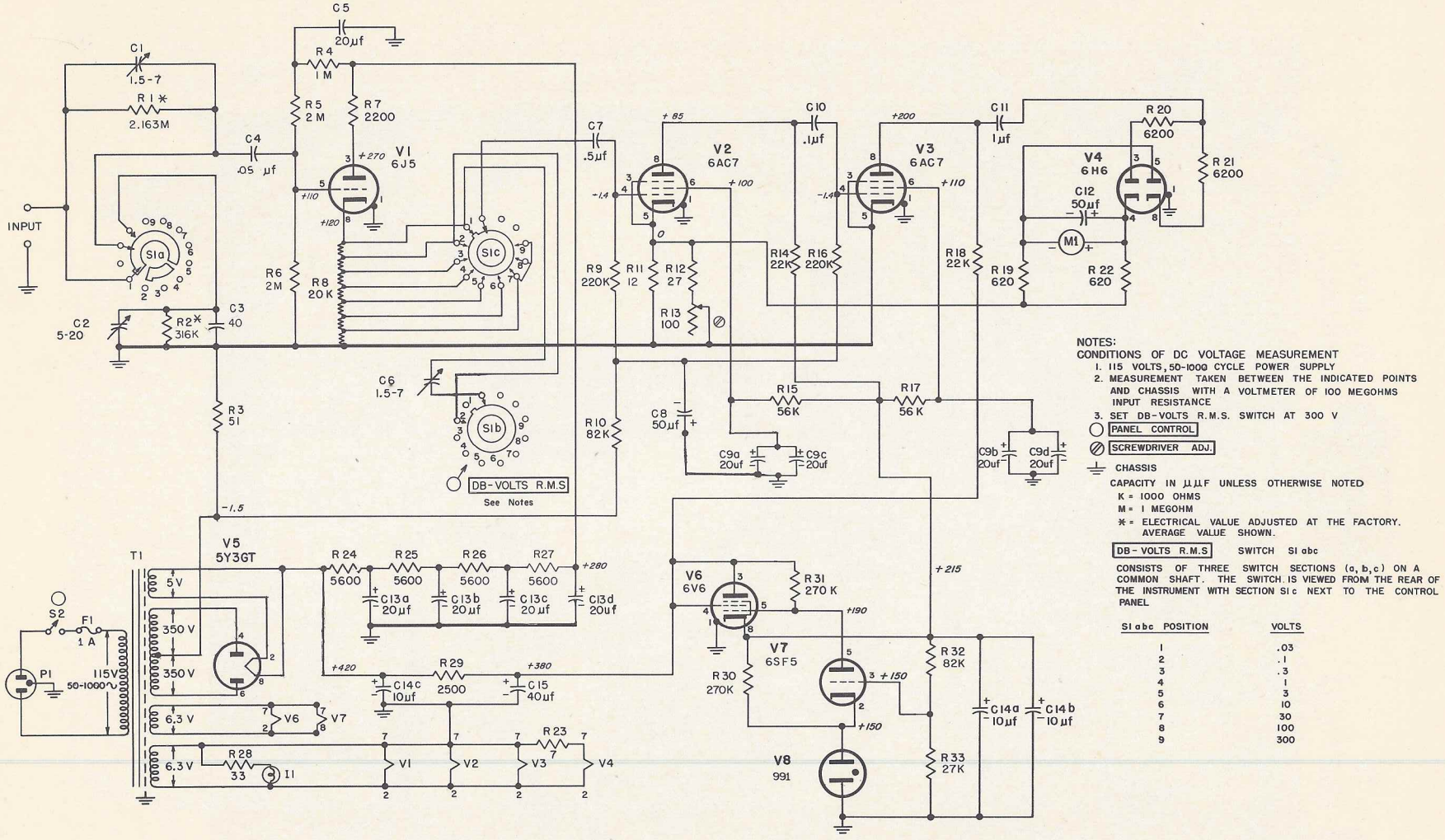


Fig. 4. Model 400A Bottom View Bottom Plate Removed



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.

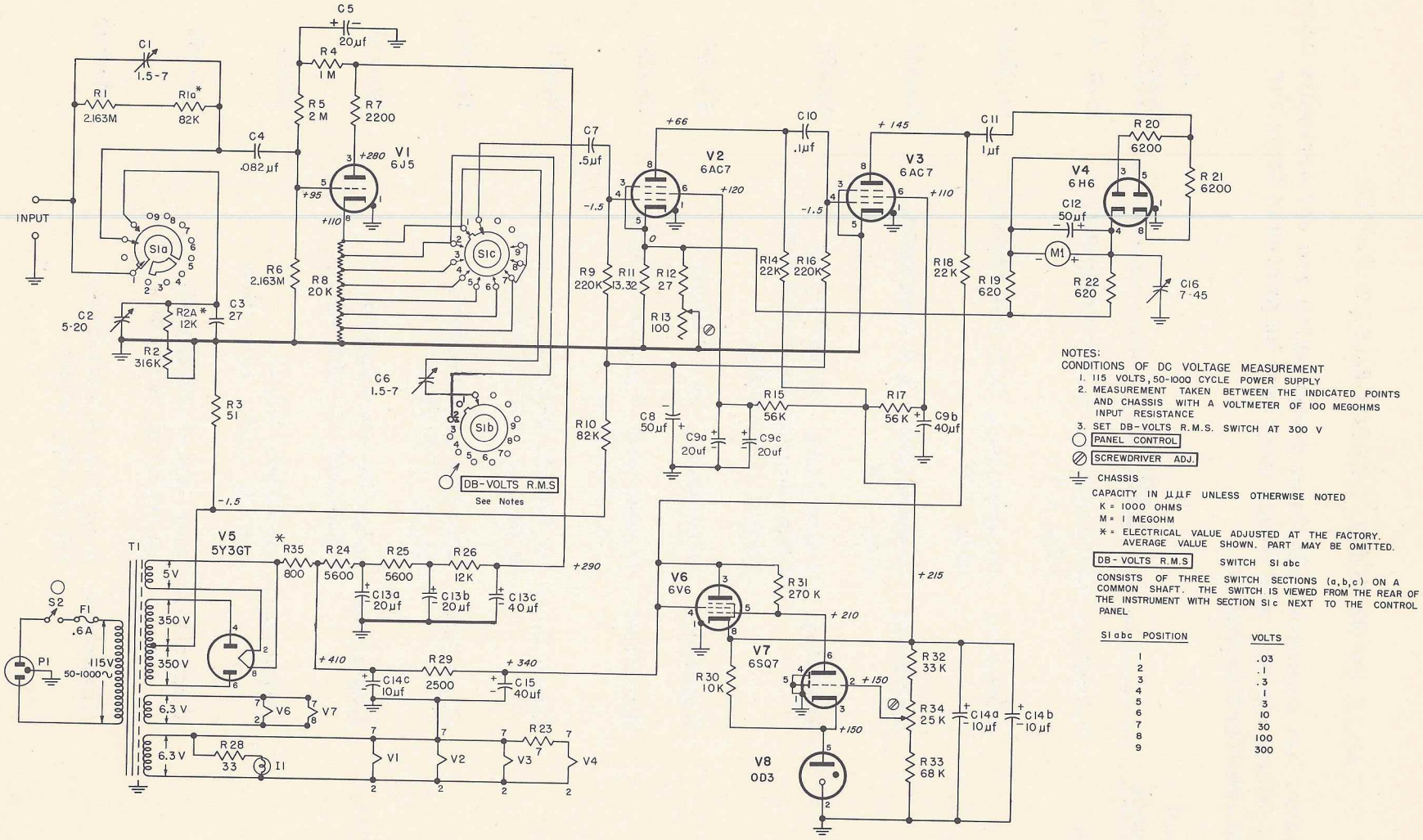
DB-VOLTS R.M.S SWITCH S1 abc

CONSISTS OF THREE SWITCH SECTIONS (a, b, c) ON A COMMON SHAFT. THE SWITCH IS VIEWED FROM THE REAR OF THE INSTRUMENT WITH SECTION S1 c 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

MODEL 400A
VACUUM TUBE VOLTMETER
SERIAL 5620 & BELOW

FIGURE. 5



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

hp MODEL 400A
VACUUM TUBE VOLTMETER
SERIAL 8723 & ABOVE

FIGURE. 6

TABLE OF SPECIAL REPLACEABLE PARTS

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

Circuit Reference	Description	-hp- Stock No.
R1, R6	Resistor: composition, 2.163 megohms, ±1%, 1 W.	31-2.163M
R2	Resistor: composition, 3.6,000 ohms, ±1%, 1 W.	31-316K
R5	Resistor: composition, 2.0 megohms, ±1%, 1 W	31-2M
R8	Resistor: wirewound, 20,000 ohms (Also furnished with Range Switch Assembly.)	4A-71
R11	Resistor: wirewound, 13.32 ohms	4A-90
R23	Resistor: wirewound, 7 ohms, ±10%, 2 W, flexible.	26-18
C4	Capacitor: oil filled, paper, 0.082 μf, ±10%, 600 vdcw	16-70
C5	Capacitor: long life electrolytic, 20 μf, 450 vdcw	18-20S
C9, C13	Capacitor: long life electrolytic, 20-20-40 μf, 450 vdcw	18-42S
C11	Capacitor: oil filled, paper, 1.0 μf, ±10%, 600 vdcw	17-12
C14	Capacitor: long life electrolytic, 10-10-10 μf, 450 vdcw	18-31S
C15	Capacitor: long life electrolytic, 40 μf, 450 vdcw	18-40S

Circuit Reference	Description	-hp- Stock No.
F1	Fuse: 0.6 ampere, slo-blo	211-49
M1	Meter movement	112-6
S1	Switch assembly: Range, including R8	4A-19
S1	Switch only: Range, less components	310-29
T1	Transformer: power	910-20
V4	Tube: 6H6, aged	212-6H6
V8	Neon lamp: type 991, aged	211-10
--	Socket: 1" mounting hole, for neon lamp.	38-1
--	Socket: $\frac{3}{4}$" mounting hole, for neon lamp.	38-N
--	Handle: carrying, leather, with brackets	144-5