HEWLETT · PACKARD
COMPANY

400D/H

VACUUM TUBE VOLTMETER

OPERATING AND SERVICING MANUAL

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OPERATING AND SERVICING MANUAL

FOR

MODEL 400D/H

VACUUM TUBE VOLTMETER

MODEL 400D
Serial 17971 and above

MODEL 400H
Serial 2238 and above

275 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

400DH001-1

SPECIFICATIONS

	MODEL 400D	MODEL 400H
VOLTAGE RANGE:	0.1 millivolt to 300 volts. Twelve ranges selected with front panel switch.	0.1 millivolt to 300 volts. Twelve ranges selected with front panel switch.

Full scale readings of (Model 400D):

0.001	0.100	10.00
0.003	0.300	30.00
0.010	1.000	100.0
0.030	3.000	300.0

Full scale readings of (Model 400H):

0.001	0.100	10.00
0.003	0.300	30.00
0.010	1.000	100.0
0.030	3.000	300.0

	MODEL 400D	MODEL 400H
DECIBEL RANGE:	-72 to +52 db, in 12 ranges.	-72 to +52 db, in 12 ranges.
FREQUENCY RANGE:	10 cps to 4 mc/s.	10 cps to 4 mc/s.
ACCURACY:	With line voltage of 115 volts, ±10% (103 to 127 volts), overall accuracy is within: ±2% of full scale value, 20 cps to 1 mc; ±3% of full scale value, 20 cps to 2 mc; ±5% of full scale value, 10 cps to 4 mc.	With line voltage of 115 volts, ±10% (103 to 127 volts), overall accuracy is within: ±1% of full scale value, 50 cps to 500 kc; ±2% of full scale value, 20 cps to 1 mc; ±5% of full scale value, 10 cps to 4 mc.
LONG TERM STABILITY:	Reduction in Gm of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 20 cps to 1 mc.	Reduction in Gm of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 20 cps to 1 mc.
CALIBRATION:	Reads rms value of sine wave. Voltage indication proportional to average value of applied wave. Linear voltage scales, 0 to 3.0 and 0 to 1.0; db scale, -12 db to +2 db, based on 0 dbm = 1 mw in 600 ohms; 10-db intervals between ranges.	Reads rms value of sine wave. Voltage indication proportional to average value of applied wave. Linear voltage scales, 0 to 3.0 and 0 to 1.0; db scale, -12 db to +2 db, based on 0 dbm = 1 mw in 600 ohms; 10-db intervals between ranges.

	MODEL 400D	MODEL 400H
INPUT IMPEDANCE:	10 megohms shunted by 15 $\mu\mu$f on ranges 1.0 to 300 volts; 25 $\mu\mu$f on ranges 0.001 volt to 0.3 volt.	10 megohms shunted by 15 $\mu\mu$f on ranges 1.0 to 300 volts; 25 $\mu\mu$f on ranges 0.001 volt to 0.3 volt.
AMPLIFIER:	Output terminals are provided so voltmeter can be used to amplify small signals or to monitor waveforms under test with an oscilloscope. Output approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response same as that of voltmeter. Internal impedance approximately 50 ohms over entire frequency range.	Output terminals are provided so voltmeter can be used to amplify small signals or to monitor waveforms under test with an oscilloscope. Output approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response same as that of voltmeter. Internal impedance approximately 50 ohms over entire frequency range.
POWER SUPPLY:	115/230 volts, ±10%, 50/1000 cps, approximately 70 watts.	115/230 volts, ±10%, 50/1000 cps, approximately 70 watts.
SIZE:	Cabinet Mount - 11-1/2 inches high, - 7-1/2 inches wide, - 12 inches deep. Rack Mount - 7 inches high, - 19 inches wide, - 11-3/4 inches deep.	Cabinet Mount - 11-1/2 inches high, - 7-1/2 inches wide, - 12 inches deep. Rack Mount - 7 inches high, - 19 inches wide, - 11-3/4 inches deep.
WEIGHT:	Cabinet Mount - 18 lbs.; shipping weight approx. 25 lbs. Rack Mount - 22 lbs.; shipping weight approx. 35 lbs.	Cabinet Mount - 18 lbs.; shipping weight approx. 25 lbs. Rack Mount - 22 lbs.; shipping weight approx. 35 lbs.
ALSO AVAILABLE:	ⓗⓟ Model 400D-db, with a special meter face having the db meter scale uppermost to permit greater resolution in db readings.	ⓗⓟ Model 400H-db, with a special meter face having the db meter scale uppermost to permit greater resolution in db readings.

CONTENTS

CAUTION

The ground terminal (G) of the INPUT and OUTPUT binding posts, the instrument chassis and cabinet, and the third (green) grounding conductor in the three-conductor power cable are electrically connected together at all times. When the NEMA connector is used in the proper manner, a ground path is established between the 400D/H and equipment which is also grounded. Do not connect the ground terminal of the instrument to any point which is not at ground potential, or a short circuit will be created. If such a measurement is necessary, disconnect the NEMA ground in the power cable by using an adapter with the grounding pig-tail removed, and the cabinet insulated from ground. The 400D/H cabinet will be at the same potential as the ground lead. Caution must be used if the clip lead is connected to a point which is more than a few volts off ground. Because of the potential hazard to personnel, this method is not recommended.

One side of almost all power distribution systems is grounded. Extreme caution must be used if direct measurement of power system voltages is attempted. If the ground lead is accidentally connected to the ungrounded side of the line, severe damage to the 400D/H is possible because of the short circuit created. Power line voltages can be safely measured by using the ungrounded (upper) terminal only. Contacting the grounded power conductor will give a reading of 0 volts, while contacting the ungrounded lead will give full line voltage reading.

When very low level voltages are being measured, there is a possibility of error caused by current flowing in the equipment grounding conductor and the ground signal input conductor. This current flow will cause a voltage to be developed in the connecting leads which is in series with the signal under measurement and will be read by the meter. This source of error can be removed by eliminating the ground loop between the meter and the circuit under test.

SECTION I
GENERAL DESCRIPTION

1-1 GENERAL DESCRIPTION

Throughout this manual, where reference is made to the 400D the information applies equally to the 400H. The major differences between the two instruments are tolerance refinements and a more accurate meter movement in the Model 400H.

The Model 400D Vacuum Tube Voltmeter is an accurate and sensitive average-responding rms calibrated voltmeter which will measure a-c voltages from 0.001 volt full scale to 300 volts full scale over a frequency range of 10 cycles to 4 megacycles. It has an input impedance of 10 megohms, effectively preventing disturbance to circuits under test. The distinctive features of this voltmeter make it valuable for measuring gain, network response, and output level with speed and accuracy. The wide frequency range makes it suitable for audio, r-f, and video measurements.

Table 1-1. Ranges

Switch Designator		Voltage Range	Decibel Range
-60	.0001	0 to 0.001	-72 to -58
-50	.003	0 to 0.003	-62 to -48
-40	.01	o to 0.01	-52 to -38
-30	.03	0 to 0.03	-42 to -28
-20	.1	0 to 0.1	-32 to -18
-10	.3	0 to 0.3	-22 to - 8
1	0	0 to 1	-12 to + 2
3	+10	0 to 3	- 2 to +12
10	+20	0 to 10	+ 8 to +22
30	+30	0 to 30	+18 to +32
100	+40	0 to 100	+28 to +42
300	+50	0 to 300	+38 to +52

The sensitivity of the voltmeter is sufficient in many instances to measure hum and noise level directly. The 400D voltmeter also may be used as an audio level (VU) meter; as a high-gain broadband amplifier to give increased sensitivity to oscilloscopes, bridges, and other equipment requiring additional sensitivity; and to detect nulls. In conjunction with an oscilloscope, the voltmeter may be used to monitor waveforms, and in conjunction with an oscillator, may be used to measure wide ranges of L and C as well as moderate ranges of R and Z. The 400D also may be used as an indicating device to measure coil Q.

1-2 DAMAGE IN TRANSIT

If upon initial inspection this instrument is found to be damaged in any way, refer to CLAIM FOR DAMAGE IN SHIPMENT for the necessary instructions. (See last page in instruction manual.)

1-3 POWER LINE VOLTAGE

When the instrument leaves the factory normally it is wired for 115-volt operation. If it is desired to operate the instrument from a 230-volt source, refer to the transformer conversion data on the schematic diagram for the correct procedure.

As shown on the schematic diagram, the alteration changes the primary windings of the transformer from a parallel (for 115-volt input) to a series (for 230-volt input) arrangement.

1-4 POWER CABLE

The three conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National electrical Manufacturers' Association. The third contact is an offset round pin, added to a standard two-blade connector, which grounds the instrument chassis when used with the appropriate receptacle. To use this NEMA connector in a standard two-contact receptacle, a three-prong adapter should be used. The ground connection emerges from the adapter as a short lead which should be connected to a grounded receptacle box for the protection of operating personnel.

1-5 ACCESSORIES

Accessories available for use with the Model 400D Vacuum Tube Voltmeter are listed below. These accessories are not supplied with the instrument but may be purchased from the Hewlett-Packard Company.

Model AC-60A Line Matching Transformer - Provides balanced 135 ohm or 600 ohm input to 600 ohm unbalanced output, for measurements on balanced lines.

Terminating Resistance:
600 ohms or 10,000 ohms

Frequency Range:
5 kc to 600 kc

Power Handling Capacity:
+22 dbm (10 volts at 600 ohms)

Balance:
Better than 40 db, entire frequency range

Model AC-60B Line Bridging Transformer - Provides balanced 600 ohm input to 600 ohm unbalanced output, for measurements on balanced lines.

Terminating Resistance:
600 ohms or 10,000 ohms

Frequency Range:
20 cps to 45 kc

Power Handling Capacity:
+15 dbm (4.5 volts at 600 ohms)

Model 452A Capacitive Voltage Divider -

Division ratio: 1000:1

Accuracy: ±3%

Input capacity: 15 $\mu\mu$f, ±1 $\mu\mu$f

Maximum voltage rating:	60 cps	25 kv
	1 mc	20 kv
	20 mc	7 kv
	100 kc	22 kv
	10 mc	15 kv

Model 454A Capacitive Voltage Divider -

Division ratio: 100:1

Accuracy: ±3%

Frequency range: 20 cps to 4 mc

Input Impedance: 50 megohms shunted with 2.75 $\mu\mu$f

Maximum Voltage: 1500 volts

Model 470A thru 470F Shunt Resistors -

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

Accuracy:	±1% to	100 kc,	470A-F
	±5% to	1 mc,	470A
	±5% to	4 mc,	470B-F

Maximum power dissipation: 1 watt

Model	Shunt Resistance
470A	0.1 ohms
470B	1.0 ohms
470C	10.0 ohms
470D	100.0 ohms
470E	600.0 ohms
470F	1000.0 ohms

SECTION II
OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

ON -
This toggle switch closes the line voltage to the power-supply transformer. With the switch at ON, the red indicator lamp will glow as soon as the power transformer is energized.

DB VOLTS -
This wafer-type rotary switch connects the proper multiplier resistors and capacitors into the circuit for the desired voltage range. The position of the switch indicates 1) the full scale voltage of the range in use and 2) the db level, when the meter pointer is at zero on the DECIBELS scale. Limits of each range are shown in Table 1-1.

INPUT AND OUTPUT TERMINALS -
The two binding posts designated INPUT are connected to the input circuit of the instrument. The two binding posts designated OUTPUT are the output terminals for the amplifier. The lower binding post in each pair, designated G is connected to the chassis. The binding posts will accommodate either a banana plug or wire, and are so arranged that any double banana plug with a 3/4 inch spacing may be used.

CAUTION

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

METER -
The 400D meter is a d-c milliammeter calibrated to indicate the rms value of a sine wave.

FUSE -
The fuseholder, located on the back of the instrument, contains a 1-ampere cartridge fuse which is in the power supply input circuit. Replacement fuses must be of the "Slo-Blo" type as specified in the Table of Replaceable Parts.

NOTE

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

2-2 OPERATION

When the Model 400D is received from the factory, the meter pointer should indicate zero before the instrument is turned on. If it does not, adjust the pointer to zero as explained under Section IV, paragraph 4-2. After the instrument is turned on, the meter pointer may show an indication of as much as two scale divisions, principally on the one-millivolt range. This effect is normal and does not impair the accuracy of the instrument.

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

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

a. Voltage Measurements -
1) With the instrument plugged into a power source of specified voltage and frequency, and the toggle switch at ON, allow the instrument about five minutes to reach a state of stable operation.

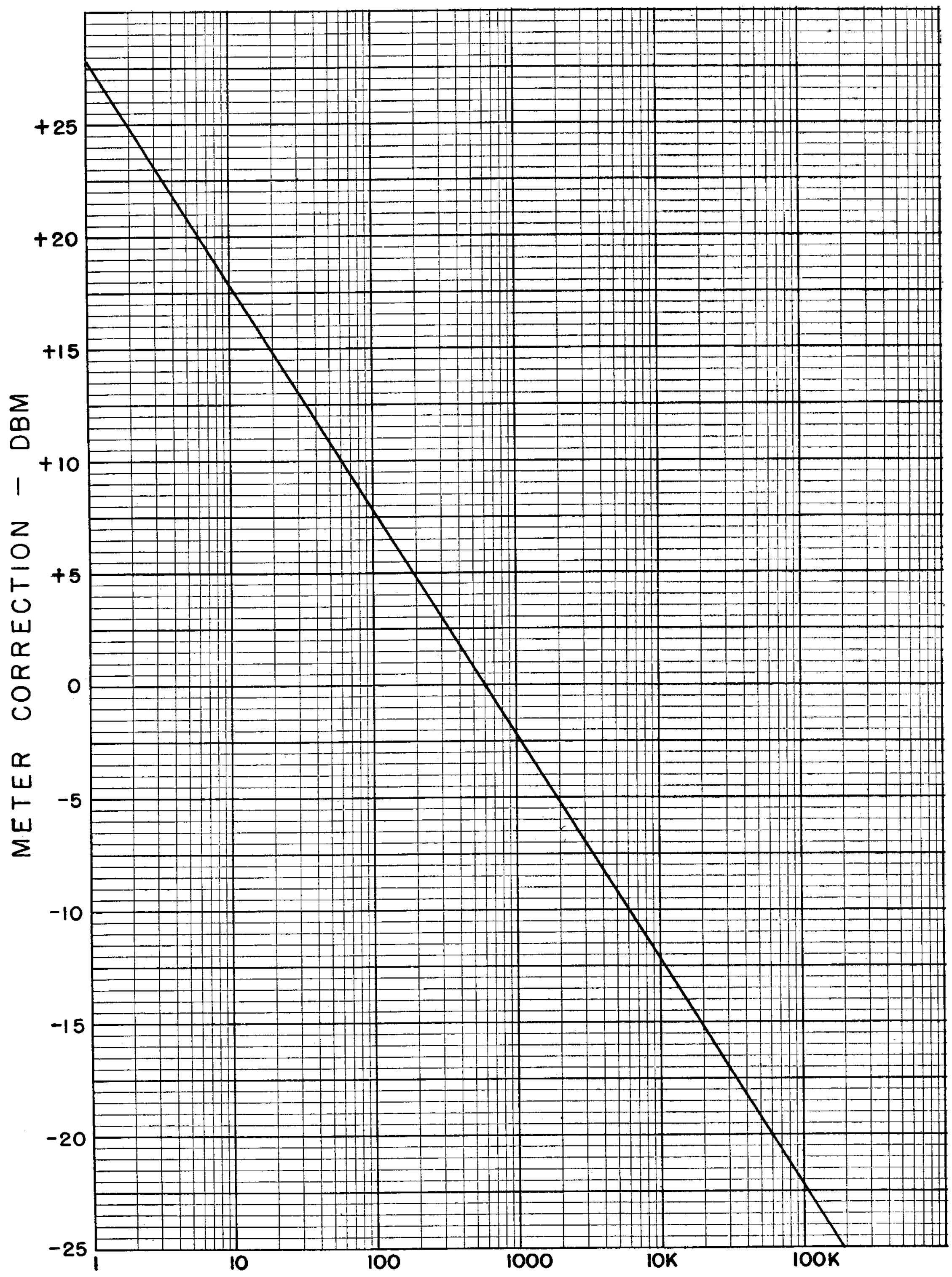

Figure 2-1. Model 400D/H Impedance Correction Graph

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

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

4) The value of voltage being measured will be indicated on one of two scales: 0-to-1 volt or 0-to-3 volts. When the range used contains the integer "1", the value of the voltage being measured will be indicated on the 1-volt scale: when the range used contains the integer "3", the value of the voltage will be indicated on the 3-volt scale. Each range switch position shows the maximum voltage that can be measured on the appropriate meter scale.

PRECAUTION

In order to maintain accuracy of measurement, it must be kept in mind that the instrument is an average-responding device but that the meter is calibrated in terms of the rms voltage of a pure sine wave. If the waveform of the voltage being measured contains appreciable harmonic voltages or other spurious voltages, the meter indication will deviate from the true rms value on the order indicated by Table 2-1.

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b. Decibel Measurements -
Measurements in terms of decibels are made in the same way as voltage measurements except that the indication is read on the db scale (-12 to +2 decibels). The level in decibels is the algebraic sum of the meter db-scale indication and the DB VOLTS (range) switch position.

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

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

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

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

For the same conditions, with the measurement made across 60,000 ohms:

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

Table 2-1. Effect of Harmonics on Model 400D/H Voltage Measurements

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

EXAMPLES:

Range Switch	Meter Scale	Meter Reads	Actual Volts
VOLTAGE MEASUREMENT			
300	3	1.8	180
10	1	0.44	4.4
.003	3	2.3	.0023
.001	1	.27	.00027
DB MEASUREMENT			
+40 db	db	+ 2 db	+42 db
+40 db	db	- 7 db	+33 db
+10 db	db	- 6 db	+ 4 db
-30 db	db	0 db	-30 db
-30 db	db	- 8 db	-38 db
* -50 db	db	-11 db	-61 db
* -60 db	db	- 1 db	-61 db

* NOTE: In case where a meter scale reading below -8 db is obtained, it is best to switch to the next lower range on the instrument so a reading will be obtained in the upper portion of the scale where highest accuracy may be obtained.

The same situation exists for voltage measurements. When a reading is obtained in the lower 1/3 scale, the range switch should be switched to the next lower range to obtain a reading in the upper 2/3 scale.

c. Amplifier

The Model 400D may be used to amplify small signals. With full-scale meter deflection, the amplifier open-circuit output is approximately .15 volt rms on all ranges. The response of the amplifier is flat across the band from 10 cycles to 4 mc. The impedance, looking into the OUTPUT terminals, is approximately 50 ohms over the entire frequency range. To obtain maximum gain, proceed as follows:

1) Turn the toggle switch to ON, and allow a warm-up period of approximately five minutes.

2) Set the DB VOLTS (range) switch at the .001-volt position.

3) Connect to the OUTPUT binding posts the equipment which is to receive the amplified signal. When the impedance of the load across the amplifier output is approximately 50 ohms, the output voltage will be approximately half the open-circuit voltage, or approximately .075 volt.

4) Connect the voltage to be amplified to the INPUT binding posts. Up to .002 volt may be applied to the amplifier with the range switch at the .001-volt position.

NOTE

Amplification also may be obtained on the .003, .01, .03, and .1 volt ranges, but maximum gain is available only on the .001 volt range because of the 10 db loss per step inserted by the DB VOLTS switch as the switch is turned in a clockwise direction.

SECTION III
THEORY OF OPERATION

3-1 GENERAL

The circuit of the Model 400D includes a two-step voltage divider in the input, a stabilized broadband amplifier, a rectifier and meter circuit, and a regulated power supply. Arrangement of the circuit is shown in block diagram form in Figure 3-1, and in detail on the schematic diagram.

The voltage under measurement is applied to the voltmeter at the input terminals. On the lower ranges the voltage is coupled directly to the grid of a cathode follower, the cathode of which is connected as a voltage divider tapped for six outputs. On the higher ranges the voltage is reduced to a thousandth of its value at INPUT before it is applied to the grid of the cathode follower. Out of the six-tap divider the voltage is coupled to a four-stage amplifier. The output of the amplifier feeds into a full-wave rectifier bridge with a d-c milliammeter across its midpoints, and a current proportional to the input voltage flows through the meter movement. The meter is so calibrated that the resulting deflection indicates the rms value of a sine-wave voltage applied at INPUT.

The circuit of the 400D voltmeter is discussed in greater detail in the following paragraphs.

3-2 INPUT VOLTAGE DIVIDER

The input voltage divider consists of a 1000:1 resistive voltage divider feeding into the grid of tube V1, and a six step resistance voltage divider feeding into the first stage (V2) of the amplifier. The 6 step voltage divider is connected into the cathode circuit of V1, which is arranged as a cathode follower. Connections to both resistive dividers are set up by the DB VOLTS switch, by means of which the circuit may be arranged to operate on any one of twelve ranges.

a. 1000:1 Voltage Divider - With the DB VOLTS (range) switch on any one of the six lower ranges (.001 volt to .3 volt), section

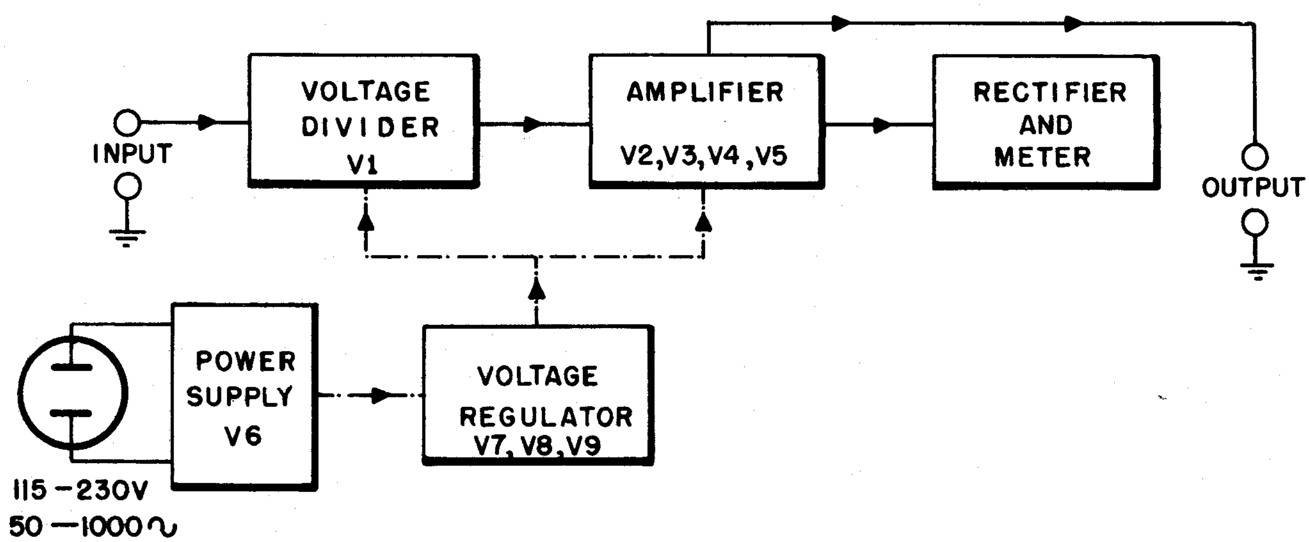

Figure 3-1. Model 400D/H Block Diagram

S1A of the range switch sets up connections in such a manner that the input voltage is applied directly to the grid of cathode follower V1 without being reduced by the 1000:1 divider. With the range switch on any one of the six higher positions (1 volt to 300 volts), section S1A establishes the connection between the grid of V1 and the resistive divider at the junction of resistor R4 and R3, and the input voltage is reduced a thousand-to-one before it is applied to the grid of V1.

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

The six taps are brought out to contacts on section S1B of the DB VOLTS switch. The movable member of S1B is fashioned with two contacting arms, spaced at 180°. Thus as the switch is moved through the full range of its rotary travel, contact is made twice with each of the six taps, once on the travel through the six lower ranges and once on the travel through the six higher ranges. Since on the six higher ranges the input voltage is divided by a thousand before it is applied to the 6 step divider, each tap in the resistive divider serves two ranges, thus making available a total of twelve ranges.

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

The r-c networks in the cathode circuit of V1 minimize d-c switching transients while the ranges are being changed. The variable capacitors switched into the circuit on the .01/10 volt and .003/3 volt ranges are provided for adjustment of the high-frequency response. The trimmer capacitor connected across the 1000:1 divider compensates for stray capacity to keep the division ratio constant over the full frequency range.

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

3-3 AMPLIFIER, RECTIFIER AND METER

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

a. Amplifier -
Between the grids of V2 and V5 the amplifier yields a net gain of approximately 55 to 60 db over a 10-cycle to 4-megacycle band. A high level of negative feedback, frequency compensating networks in the plate circuit of each stage, and cathode degeneration at low frequencies (the cathode resistors are not bypassed at low frequencies) provide an amplifier of high stability which can operate over an extremely wide (10-cycle to 4-mc) band. The feedback of the amplifier is returned from the plate of the last stage, V5 through the rectifier-meter circuit, to the cathode of first stage V2 in such phase as to be degenerative in effect. The gain is adjusted by means of variable resistor R29 in the feedback loop. Another adjustment in the feedback loop, variable capacitor C21, is used for adjusting the frequency response of the amplifier at high frequencies.

The stages of the amplifier are resistance-capacitance coupled. The coupling circuitry between each stage is frequency-compensating, and provides separate coupling for low and high frequencies. This feature of the circuit design contributes to the flatness of the frequency response across the wide band over which the voltmeter is rated to operate.

When the 400D is used as an amplifier, pentode V5 is operated as a cathode follower and supplies voltage at the OUTPUT terminals. The impedance, looking into the OUTPUT terminals, is approximately 50 ohms.

The output from the plate of V5 is delivered to a full-wave rectifier.

b. Rectifier and Meter -
The rectifier-meter circuit is arranged in a bridge-type configuration, with a crystal diode and a capacitor in each branch and a d-c milliammeter connected across its midpoints. The diode connection provides fullwave rectification of the input current. The design of the bridge is such that 1) a pulsating direct current is delivered to the meter circuit and 2) an alternating current of the same frequency as the current at the rectifier input is delivered to the output of the bridge. From the rectifier-bridge output, the ac flows through the feedback loop to the cathode of V2.

The current through the meter is proportional to the average value of the waveform of the voltage applied to the input of the rectifier. Since calibration of the meter in rms volts is based on the ratio that exists between the average and effective values of a voltage that is a true sine wave, deviation in a waveform from that of a true sine wave may cause meter measurements to be in error. Table 2-1 gives an indication of the limits of possible error due to the presence of harmonics in the waveform of a voltage under measurement.

NOTE

This table is universal in its application since these errors are inherent in all voltage measuring equipment of the average responding type.

The current flow through the rectifier-meter circuit is shown in Figure 3-2. For purposes of explanation, the amplifier (tubes V2-V5) may be considered as a signal generator with the output from the plate of V5 as one side, and the cathode of V2 as the other side. The rectifier-meter circuit may be considered as a bridge across the generator. On the positive half of the cycle, current flows into the bridge from the top. On the negative half of the cycle, current flows into the bridge from the bottom.

On the positive half of the cycle, diode CR1 conducts, and current flows through CR1 to the juncture between the meter and capacitor C32, where it divides, a portion placing a charge on capacitor C32 and the rest flowing through the meter. Since diode CR2 is nonconducting, the current from the meter output flows to capacitor C33, placing a charge thereon. As capacitor C32 and C33 discharge, current flows to the generator.

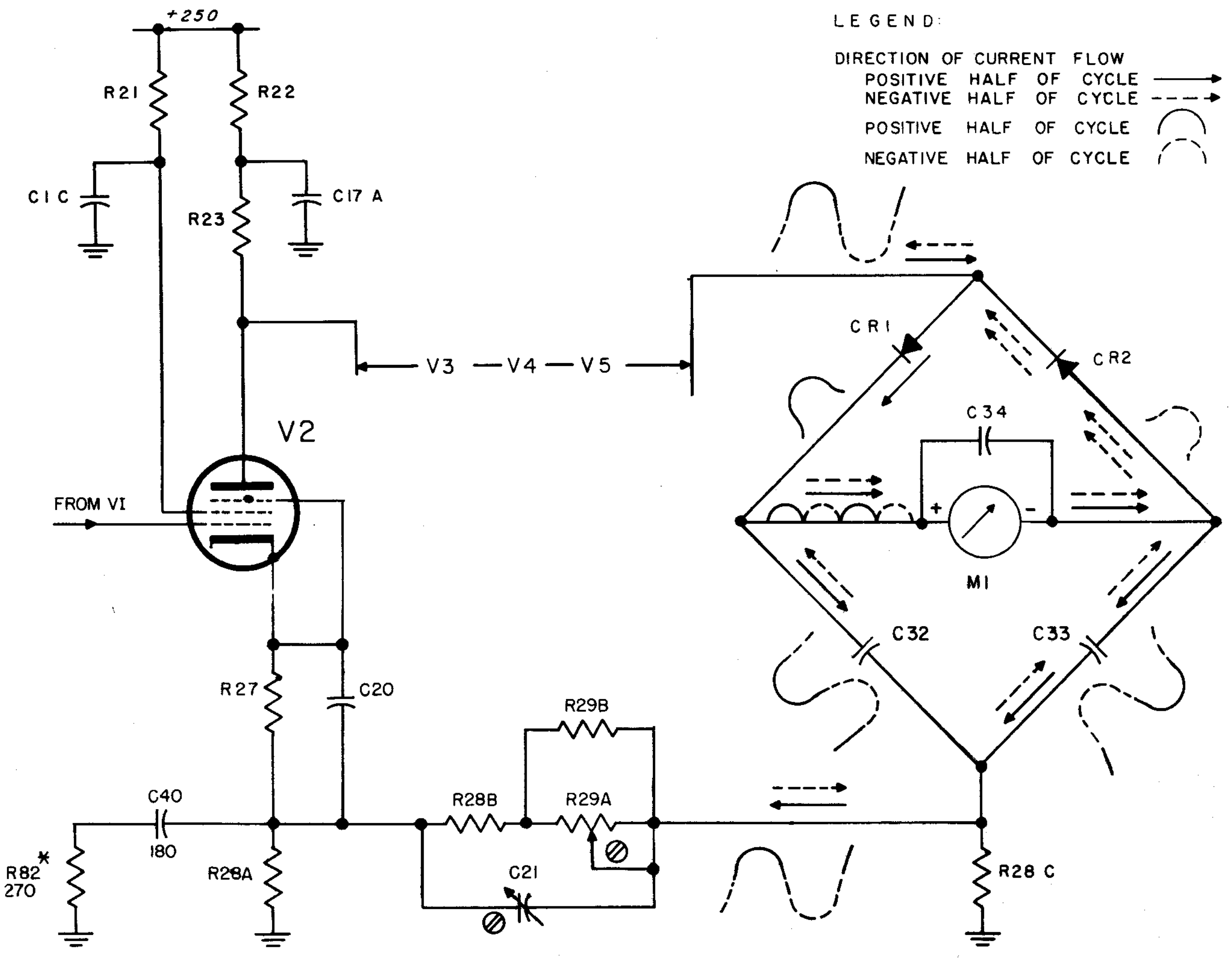

Figure 3-2. Model 400D/H Direction of Current Flow through Rectifier-Meter Bridge Partial Schematic

On the negative half of the cycle, diode CR2 is biased to conduct, and diode CR1 is nonconducting. The current flowing into the bridge at the juncture between capacitors C32 and C33 divides, half placing a charge on C32 and the other half on C33. Since diode CR1 is nonconducting, as capacitor C32 discharges, current flows through the meter and diode CR2 to the generator. As capacitor C33 discharges, current flows through CR2 to the generator. The action of capacitors C32 and C33 results in the flow of an alternating current in the feedback loop, so phased that it is negative in effect with respect to the signal on the grid of V2. Capacitor C34 across the meter provides a bypass path for any a-c component that may be present.

3-4 POWER SUPPLY

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

a. Input Circuit -
The primary windings of power transformer T1 may be connected for operation from either a 115 volt (±10%) or a 230 volt (±10%) 50/1000 cps source. The primary circuit is fused. When switch S2 is in the ON position, power from the line is applied to the primary winding of transformer T1.

b. High-Voltage Supply -
Current for the high-voltage supply is rectified by dual diode V6, and regulated by triode V7. Amplified control voltage is supplied to grid of V7 by the pentode section of V8. The triode section of V8 acts as a d-c cathode follower driving the pentode section.

Noise from reference tube V9 is eliminated by low-pass filter R63 and C35.

D-c drift due to changes in V8 filament voltage is canceled by differential action between the two sections of V8.

c. Filament Supply -
Current for the low-voltage d-c filament supply is rectified by selenium rectifier SR1 and is filtered by capacitors C39A and C39B. Variable resistors R66 provides a means for adjusting the level of the rectified voltage.

SECTION IV
MAINTENANCE

4-1 INTRODUCTORY

This section contains instructions for maintaining and trouble shooting the Model 400D as well as procedures for replacing tubes and making internal adjustments. A tube replacement chart lists the checks and adjustments required after tube replacement, and a trouble shooting chart assists in localizing most types or troubles which might occur. Photographs showing the physical location of components, a voltage and resistance diagram, and a schematic diagram are also provided for convenience in trouble shooting.

The more intricate adjustment procedures described in this section are provided for those who have the necessary skill and test equipment. When qualified personnel and test facilities are not available, it is suggested that adjustments not be made in the field. Instructions are given on the Warranty page at the back of this instruction manual for the procedure to be followed should repair service be required.

The following information appears in this section:

4-2 METER ZERO ADJUSTMENT

Whenever the meter pointer does not indicate exactly on zero, the pointer should be reset to zero. For the most accurate positioning of the meter pointer, the instrument should be allowed to reach operating temperature before the adjustment is made. With the instrument in its case, the instrument should be allowed to heat for at least 15 minutes. Shut off the power and wait at least 2 minutes for all capacitors to completely discharge, then proceed as follows:

The adjust screw is in the meter frame at a midpoint immediately below the meter face. The adjustment is made properly only when the pointer is traveling in the opposite direction to the turn of the adjust screw. Although the adjust screw may be turned in either direction, a practical procedure is to turn the screw in a clockwise direction until the pointer starts to swing back toward zero. Then, still turning the screw clockwise, bring the pointer (now traveling counterclockwise) back to zero.

4-3 CASE REMOVAL

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

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

4-4 CAPACITOR REPLACEMENT

Electrolytic capacitors in the Model 400D are high-quality capacitors that have a useful life of from five to ten years. Do not replace these capacitors unless proved defective by accurate tests.

4-5 REPLACEMENT OF CRYSTAL DIODES

Meter tracking is affected by the characteristics of the diodes in the rectifier-meter circuit. When a diode is replaced, therefore, it is important 1) that the replacement diodes have the proper characteristics and 2) that the meter calibration be checked and, if necessary, readjusted.

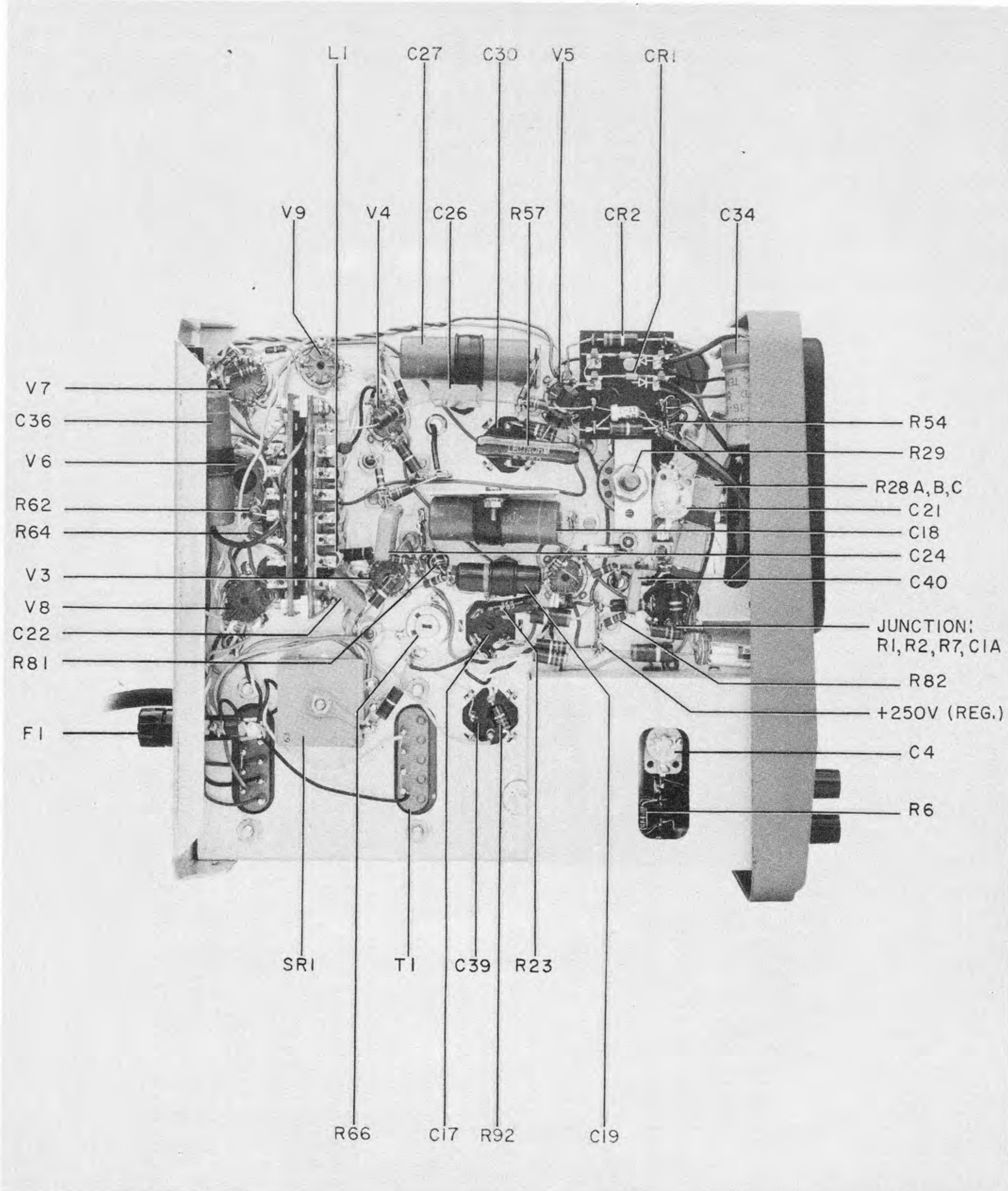

Figure 4-1. Model 400D/H View of Left Side Instrument Case Removed

The diodes used in the Model 400D rectifier-meter circuit are special high performance junction type silicon diodes manufactured by the Hewlett-Packard Company, and must be obtained from ⓗ. The part number given this silicon diode is G111A and replacements should be ordered by this number.

CAUTION

These diodes are of the junction type. Because the junction is less than 1/2 mil in diameter, extra care must be taken not to subject them to excessive mechanical shock. Dropping them on a table or on the floor, etc. may cause a mechanical failure at the junction. When installed in the instrument, however, the diodes will withstand any shock which can be withstood by the instrument as a whole.

4-6 TUBE REPLACEMENT

Any tube in the Model 400D may be replaced with a tube having corresponding RETMA standard characteristics. However, for the utmost in accuracy from the Model 400D, it is recommended that whenever a tube is replaced, Table 4-1 be consulted and the specified adjustment checked. The procedure for performing these adjustments may be found in paragraph 4-6.

When checking tubes by replacing with new tubes, if no improvement in operation is noticed, return original tube to its socket. Do not transpose tubes since this may mask any marginal operation that may exist.

NOTE

If the gain of the replacement tube differs from that of the original tube, resistor R29 is adjusted to restore calibration. If the frequency response of the 400D is altered by a replacement tube, it is recommended that another replacement tube be sought that has capacitance characteristics similar to those of the original tube.

The 6CB6 tubes in positions V1 and V2 have been replaced by type 6DE6 tubes. This change has been made because of an apparent superiority of type 6DE6 tubes with respect to microphonics.

Because of the decreased filament drain of the 6DE6 tubes, a resistor (R84, 270 ohms, ±10%, 1 W) has been added to the instrument across C39B to balance the filament current. If the 6DE6 tubes are replaced with type 6CB6 tubes, balancing resistor R84 must be removed.

Table 4-1. Tube Replacement

TUBE	FUNCTION	CIRCUIT ADJUSTMENT
V1 - 6CB6 (6DE6)	Cathode Follower	Calibration, steps 1, 2, 3, 4, 5. Filament Adjustment
V2 - 6CB6 (6DE6)	1st Amplifier	Calibration, steps 1, 2, 3. Filament Adjustment
V3 - 6CB6	2nd Amplifier	Calibration, steps 1, 2, 3. Filament Adjustment
V4 - 6CB6	3rd Amplifier	Calibration, steps 1, 2, 3. Filament Adjustment
V5 - 6CB6	4th Amplifier	Calibration, steps 1, 2, 3.
V6 - 6AX5	High Voltage Rectifier	None
V7 - 12B4A	Power-Supply Series Regulator	Check +250 vdc regulated
V8 - 6U8	Power-Supply Control Tube	Check +250 vdc regulated
V9 - 5651	Reference Tube	Check +250 vdc regulated

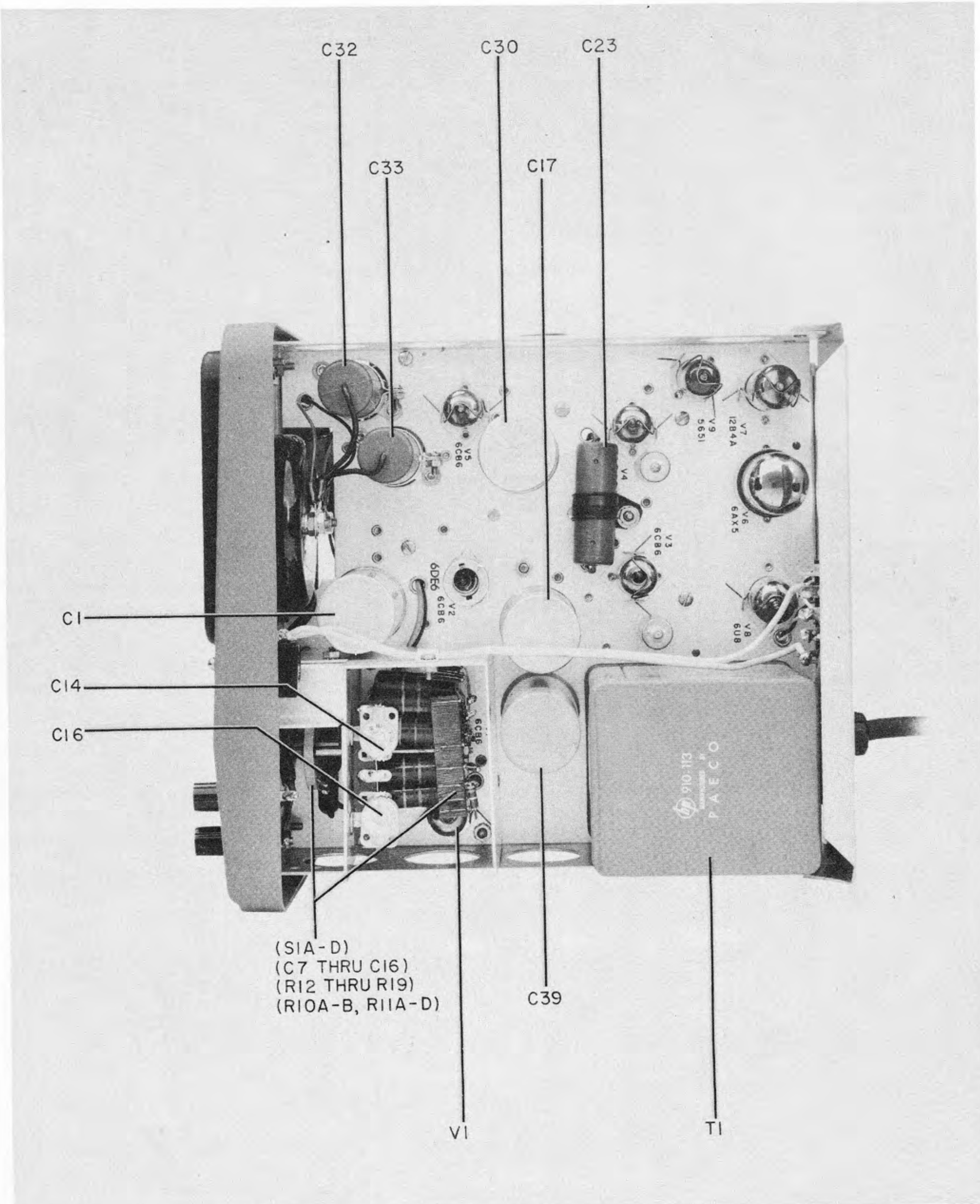

Figure 4-2. Model 400D/H View of Right Side Instrument Case Removed

4-7 ADJUSTMENTS

a. Required Test Equipment -
The following auxiliary test equipment is required in making adjustments on the 400D voltmeter:

1) Hewlett-Packard Model 410B voltmeter (or any of 20, 000 ohms-per-volt or more sensitivity that furnishes facilities for making d-c measurements).

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

3) An a-c voltmeter accurate within 1/2% of full scale at 400 cycles.

4) A transfer frequency response standard which is flat from 10 cps to 6.5 mc and which operates at approximately 0.1V, 3V and 10V levels.

b. Filament Voltage Adjustment -
1) Using a variable output transformer, adjust supply voltage to instrument to be exactly 115 volt.

2) Connect an accurate d-c voltmeter to pin 3 of V3 and chassis.

3) Adjust R66 so that d-c voltage is exactly 12.6 volts.

4) Check to see that voltage from pin 4 of V2 to ground is in the range of 6.1 to 6.5 volt. If not, one of the tubes (V1, V2, V3, or V4) has improper resistance, causing excessive unbalance in the series-parallel string. Replace tubes one at a time starting with V4. If replacing V4 causes no change, return it to its socket and then try V3, etc. By replacing one tube at a time and returning a tube to its original socket, chances of replacing a good tube with a bad one are minimized.

Note: Refer to Table 4-1 after replacing any tubes for checks needed to verify proper circuit operation.

c. High-Voltage Regulator Check -
After replacement of V7, V8, and/or V9 in the power supply, the level of voltage at the regulator output should be measured since a difference in tube characteristics will alter the performance of the regulator circuit. This voltage, measured from pin 3 of tube V7 to chassis, should be 250 volts, ±5 volts.

If regulator is not holding some fixed value between 245-255 volts after trying several V7, V8, and/or V9 tubes, then precision voltage divider resistor R62 or R64 probably has changed value and should be lightly padded (1 to 2 megohms, 1/2W). Padding R64 (100k) will raise B+. Padding R62 (181k) will lower it.

d. Calibration Adjustments -
The 1000:1 input voltage divider which is switched into the input circuit for the one-volt range and above, is a resistive type divider. The 1000:1 voltage division is determined at audio frequencies mainly by factory matched resistors R3 and R4 and very slightly by C4 which flattens the response of the 1000:1 divider at higher frequencies.

C4 also affects the calibration of the one-volt range and above even at low audio frequencies i.e.: 400cps. The calibration process is a part of the frequency-compensation adjustment process. Trimmer C4 has been properly set at the factory and should never need adjustment. If C4 is accidently disturbed the accuracy of the meter will be destroyed except at very low audio frequencies (under 100 cps).

CAUTION

Do not disturb the factory setting of trimmer capacitor C4. If C4 has been accidently disturbed, an approximate rough setting can be made by adjusting it so that the solder globule is at 3 o'clock, which is approximately 1/2 capacity.

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1) Remove the two screws (on the rear of the instrument) which secure the case to the chassis. To shield the instrument from any r-f field that may be present, leave as much of the wiring covered as possible, and slide the case back only far enough to reach variable resistor R29 and variable capacitor C4. R29 and C4 are identified in Figure 4-1.

2) Connect a low-distortion oscillator (such as a Hewlett-Packard Model 650A Test Oscillator) and an a-c voltmeter accurate to within 1/2% of full scale at 400 cycles to the INPUT terminals of the Model 400D.

NOTE

For the Model 400H, the reference meter should be considerably more accurate than 1/2%. A 1/2% instrument is a minimum, and ideally, accuracy of 0.2% is desirable in the reference standard.

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3) Set the Model 400D range switch to the .3 volt position, and apply .3 volt at 400 cycles to the input of the Model 400D. ADJUST R29 (Figure 4-1) until the 400D meter indicates exactly .3 volt.

4) Feed 400 cps at 1.000 volt into the meter with a monitoring device connected in parallel with the meter input that has a flat frequency response preferably from 10 cps to 6.5 mc. Note the reading on the monitor.

5) Increase the input frequency to 500 kc. Adjust the signal level until the monitor indicates the same value of signal as before (1.000 volt).

6) The instrument should still read 1.000 volt. If it does not, the setting of C4 is not correct and should be adjusted slightly to bring the meter pointer onto the exact reading.

7) Check the calibration of the 1000:1 division by feeding in 400 cps signals of exactly 0.300 volt and 1.000 volt. Both voltages should give exactly full scale deflections on their respective ranges. If they do not, the precision 1000:1 resistive divider is off. If 0.3 volt is correct and 1.0 volt is reading high, decrease the value of the pad in parallel with R3. If 1.0 volt reads low, increase the value of the pad in parallel with R3.

PRECAUTION

Do not attempt to calibrate the Model 400D in the presence of a strong r-f field. If the presence of an r-f field cannot be avoided, it is recommended that some sort of shielding be fabricated for the instrument.

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e. Optional Method of Setting C4 -

The above method of setting C4 is used by the factory. A second method which has been found satisfactory is described below. A square wave generator such as a ⓗⓟ Model 211A and a high frequency oscilloscope with a frequency response beyond 7 mc are required. The ⓗⓟ Model 150A Oscilloscope with a response to 10 mc is excellent for the purpose. The square wave generator is adjusted to produce 0.9 volt at a frequency between 2 and 3 kc, and is fed into the 400D INPUT. Set the 400D to the 1 volt range. Observe the shape of the output waveform at the 400D OUTPUT terminals. Adjust C4 until the top of the square wave is perfectly flat, with no rise or drop. Use an expanded sweep to detect slight changes with adjustment. This method is only successful when setting C4 and must not be used to set any other trimmers.

f. Frequency-Response Adjustment -

The frequency response characteristic of the 400D is excellent and once factory adjusted, should not change to any appreciable extent. When changes do occur, they will almost always occur below 20 cps and above 2 mc, with maximum errors at 10 cps and 4 mc.

Weak tubes are the main cause. Before any frequency response adjustments are made, all tubes (V1 thru V5) should be known to be new, good tubes, aged for 50 hours, if possible, before calibration (substandard tubes will usually fail before this time).

NOTE

If unusual or persistant trouble is encounterd in making frequency-response adjustments, consulation with your ⓗⓟ representative or the ⓗⓟ factory service department is recommended.

Unless special standards are available which are known to be flat from 10 cps to 6.5 mc, ±1%, it is recommended that no high-frequency adjustments be attempted; the unit should be returned to the factory for adjustment.

Adjustment to obtain a flat frequency response from 10 cps to 4 mc are described in the following paragraphs.

1) Required Test Equipment - The following test equipment is essential:

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

(b) A reference voltmeter with a frequency response flat from 10 cps to 6.5 mc.

2) Procedure -

(a) Connect a low-distortion oscillator and an accurate rms voltmeter, flat to 6.5 mc, to the Model 400D INPUT terminals.

(b) Set the Model 400D on the .1-volt range.

(c) Using a 400 cps signal of such amplitude as to give an indication near full scale on the Model 400D, monitor the input to the 400D with the reference voltmeter.

(d) Change the signal source to 4 mc, and reset to obtain the same level on the reference voltmeter.

(e) Adjust C21 to obtain the same reading on the instrument under test as established in step (c).

(f) Check the frequency response at 6.4 mc in the same manner. The response should be down from 4 mc. If it is more than 2% high at 6.4 mc, readjust C21 to bring the response down. Recheck the frequency response at 4 mc. It should not be down more than one or two percent.

If the response is down excessively, and known good tubes in V1 through V5, do not bring it up. It is suggested that the instrument be returned to the factory for repair.

(g) Repeat step (d) at 2 mc, 20 cps, and 10 cps. The 400D reading should be within 2% at 2 mc, 1% at 1 mc and 20 cps, and 3% at 10 cps. Weak tubes, particularly V3, V4 and V5 will affect 10 cps response and should be checked if response is out of specification.

The 10 and 20 cps response can be corrected by adjustment of either R80 or R81. The minimum value for either of these resistors is 2.2 megohms. Many instruments will have neither one of these resistors. Either one but not both may be added to correct frequency response. Adding R80 will lower the response at 10 and 20 cps while adding R81 will raise the response at these two frequencies.

(h) Set the instrument being tested to the .01-volt or 10-volt range and repeat steps (c) and (d).

(i) Adjust C16 to obtain the same reading on the instrument under test as established in step (h).

(j) Set the instrument being tested to the 1.0 volt range and repeat steps (c) and (d).

(k) Adjust C4 to obtain the same reading on the instrument under test as established in step (j).

NOTE

The proper setting of C4 should be extremely close to the setting previously made at 500 kc in the calibration procedure. If the setting is changed appreciably, the basic calibration will be destroyed on the 1.0 volt range and above.

(l) Set the instrument being tested to the 3-volt range and repeat steps (c) and (d).

(m) Adjust C14 to obtain the same reading on the instrument as established in step (l).

(n) Recheck calibration. The tested instrument should now be within published specifications. Resistor R82 along with capacitors C26 and C40 are factory adjusted for best instrument response. These factory adjusted values should not be changed. Capacitor C40 and resistor R82 will not be found in all instruments.

4-8 TROUBLE SHOOTING

To assist in trouble shooting, a chart has been prepared which lists various trouble symptoms, possible causes and/or remedies. If the cause of the trouble is of a more obscure nature than can be covered by the chart, trouble can be located by test: first by sectionalizing, and second by localization within the section by means of voltage and resistance measurements. The circuit sections are indicated in the block diagram (Figure 3-1).

a. The first step in sectionalizing is to check the output of the regulated high-voltage supply: the d-c voltage between pin 3 of V7 and ground should measure 250 volts, ±5 volts.

If the regulator output is not within these limits, see paragraph 4-9.

If the regulator output is within these limits, the power supply probably is functioning properly, and the remainder of the circuit should be tested.

Apply a signal at INPUT, and check the level of the signal voltage at the input and output of each of the sections shown in Figure 4-3, except the levels at 1st amplifier V2. (The low level of signal applied to the grid of V2, together with the large amount of negative feedback applied to its cathode, make any signal-voltage measurements at V2 impractical.) Typical signal voltages at the input and output of each section, for an input signal of 0.3 volt at 400 cycles, may be found in Figure 4-3, a servicing block diagram.

b. When trouble has been localized to a particular section, it is recommended that tube substitution be tried before any other tests are made. If tubes known to be good do not clear the trouble, voltage-resistance measurements should be made. Typical voltage and resistance values may be found on Tube Socket Voltage-Resistance Diagram, Figure 4-4.

For the circuitry in each section reference may be made to the schematic diagram. The servicing block diagram (Figure 4-3) shows the signal path in heavy line and directional arrows. Feedback paths are shown by means of directional arrows, but in lighter line.

Localization by d-c voltage analysis is discussed in paragraph 4-10.

Table 4-2. Trouble Shooting Chart

SYMPTOM	POSSIBLE CAUSE AND/OR REMEDY
Instrument dead, indicator lamp does not light.	Fuse Blown - replace. If fuse blows again, check for a short circuit or defective tube or component in power-supply and/or heater circuits. Off-on switch defective. Line cord defective.
Instrument dead, indicator lamp glows, meter does not indicate.	No output from regulated power supply. Refer to paragraph 4-9. Tubes V1, V2, V3, V4, and/or V5 defective. Defective component in amplifier. Defective CR1 and/or CR2 diode, C34 capacitor, or meter movement. Check instrument calibration after repair.
Residual meter reading erratic and higher than 2 divisions on the .001-volt scale. (Input must be well shielded.)	This is usually accompanied by erratic meter indications. See Meter Indication Erratic.
Residual meter reading steady and higher than 2 divisions on the 1-volt scale.	Trouble in power supply (see paragraph 4-9) V1, V2, V3, V4, and/or V5 defective. Defective component in amplifier. Noisy R 23. Capacitor C6 is formed by wires connecting to adjacent tie lug terminals. If the heater leads for V1 are dressed so that they pass between these terminals, hum is introduced.
Meter indication is equally erratic on all ranges.	Trouble in power supply (see paragraph 4-9). Tubes V2, V3, V4, and/or V5 defective. Crystal diode CR1 and/or CR2 defective. Capacitor C2 may be shorted or leaky. Noisy R23.
Meter indication more on one range then on other ranges.	Leaky 0.051 μf coupling capacitor in range switch. Replace defective Unit.
Meter pointer "beats" when power line frequency (usually 60 cps) or a harmonic thereof is applied to INPUT.	Trouble in power supply (see paragraph 4-9). Heater-cathode leakage in V1, V2, V3, V4 or V5. Replace one tube at a time. Readjust heater d-c voltage after final tube selections have been made. Recalibrate instrument (paragraph 4-7d). Open bypass or decoupling capacitor anywhere in instrument.

Table 4-2. Trouble Shooting Chart (Cont'd.)

SYMPTOM	POSSIBLE CAUSE AND/OR REMEDY
Microphonics (Mechanical shock causes excessive fluctuation of voltmeter reading.)	With DB-VOLTS switch on 1-volt range, apply a 1 volt (400 to 1000 cps) signal to INPUT. Lightly tap lower right corner of meter case. If meter pointer pins sharply against right hand stop, tubes V1 and/or V2 are microphonic. If instrument seems to be equally microphonic on the 0.3-volt range with 0.3-volt input, change V2. If instrument is less microphonic on the 0.3-volt range, replace V1. Poor electrical contact in range switch. Clean and inspect switch contacts. Use a cleaning solvent that will not leave a deposit. Do not disturb any wires. Check any solder connections made during instrument repair. Loose or imperfect joints will appear as microphonics. V3, V4, and V5 may also cause microphonics.
Repeated adjustments to increase amplifier gain needed to maintain calibration.	Trouble in power supply (see paragraph 4-9). Tubes V1, V2, V3, V4, and/or V5 defective. Crystal diodes CR1 and/or CR2 defective. Capacitors C32, C33, and/or C34 defective.
Meter pegged against right hand stop on all ranges.	Amplifier section is oscillating. Repeated reduction of negative feedback to compensate for a loss of amplifier gain will eventually result in amplifier oscillation. See "Repeated Adjustments to Increase Amplifier Gain".
Meter pointer strikes peg sharply when switching ranges, particularly when switching from 0.3- to 1-volt range with no input.	Tubes V1, V2, and/or V5 are the most probable tube defects. However, V3 and/or V4 may be defective.
Delayed secondary switching transient particularly when switching from the 0.3- to the 1-volt range with no input.	The only disadvantage of this is a slight increase of instrument recovery time when switching ranges. Most probably caused by a gassy tube for V1, V2, and/or V5. May also be V3 and/or V4. A similar symptom may exist between any two ranges when any one of C7 through C12, C18 and/or C3 capacitors are leaky.
Response at 10 cps is low or high.	One or more of tubes (V1 thru V5) are weak. Try V3 and V4 first. Heater voltage is incorrectly set. Refer to paragraph 4-9.
Response at 4 mc low.	Weak tubes (V1 thru V5).

Table 4-2. Trouble Shooting Chart (Cont'd.)

SYMPTOM	POSSIBLE CAUSE AND/OR REMEDY
Motorboating.	Motorboating may be caused by low voltage from the regulated power supply, or from low a-c line conditions. Weak V2, V3, V4, V5 (see paragraph 4-10 to locate trouble). Trouble in power supply (see paragraph 4-9).
High plate or screen voltage for V2, V3, V4, and/or V5.	Weak or defective tube. Refer to paragraph 4-10. Open cathode resistor.
Low plate or screen voltage for V2, V3, V4, and/or V5.	Defective grid coupling, cathode, or screen bypass capacitor. Refer to paragraph 4-10. Defective tube.
Voltmeter reads low or high on 1-volt and higher ranges, error increasing as 300-volt range is approached. No error 0.001-volt to 0.3-volt ranges. Noticeable mostly at high frequencies.	Black jumper wire (on front wafer of range switch) which goes to an empty lug, is improperly positioned; this wire must be touching the rear shield plate. This lead is part of the capacity voltage divider and moving it will destroy calibration of the 1-volt range and above. If the leads are moved to properly position them it will be necessary to reset C4. All ranges 1 volt to 300 volts should now track. If the 100-volt and 300-volt ranges are still not accurate, but the 1-volt, 3-volt and 10-volt ranges are, replace C4 (dielectric constant is changing with voltage), and recalibrate the instrument. Divider trimmer capacitor C4 defective. Replace trimmer and recalibrate instrument.
Voltmeter reads high on two voltage ranges that are multipes of 1000 apart.	Defective range switch resistor. Correct by replacing entire range switch assembly.

4-9 POWER-SUPPLY LOCALIZATION CHECKS

If trouble is localized to the power-supply section, the following checks will be helpful in trouble shooting.

a. Set line voltage to exactly 115 volts.

b. The d-c voltage at plate pin 9 of 12B4A series regulator tube V7 or at cathode pin 8 of 6AX5 rectifier tube V6 should be between 400 and 420 volts.

Low voltage at this point may be due to rectifier tube V6, power transformer T1, or input capacitor C30C being defective.

To check V6, connect a d-c voltmeter between pin 8 of V6 and chassis. Reduce line voltage from 115 to 103 volts. The d-c voltmeter reading should drop immediately when the a-c line voltage is reduced and then remain steady. If the d-c voltage continues to drop at a slow rate, rectifier V6 is probably weak and should be replaced.

c. The d-c voltage between pin 3 of tube V7 and chassis should be 250 volts, ±5 volts.

If the regulated voltage is not within this range, replacement of V6, V7, V8, and/or V9 may be necessary. If changing these tubes does not correct the d-c voltage level, resistors R62 and/or R64 may have changed value and should be padded or replaced.

d. The a-c component present in the regulated power supply output (V7, pin 3) should not be more than 0.003 volt.

Excessive a-c ripple may be due to tubes V7, V8, and/or V9 being defective. Capacitor C36 may be open. Abnormal current drain caused by component failure elsewhere in the instrument can result in poor power-supply regulation.

e. Reperform step 3 while slowly varying the a-c line voltage from 103 to 127 volts. The regulated d-c voltage should not change by more than approximately ±0.5 volt from the value obtained with a 115V line. A noticeable change indicates a weak V6, V7, V8, or possibly V9.

f. Check heater d-c voltage.

1) The d-c voltage measured from pin 3 of V3 or V4 to chassis should be exactly 12.6 volts. Adjust R66 to obtain 12.6 volts with a-c line voltage at 115 volts.

2) The d-c voltage across heaters of V1 and V2 should be 6.3 volts, ±0.2 volt. Voltage of the same value should appear across heaters of V3 and V4.

CAUTION

The voltmeter used to measure heater voltages must not be connected to the same ground as the 400D under test. With the two voltmeters connected to a common ground, V1, V2, and C39 will be shorted out when voltage across V3-V4 is measured.

If voltages measured in b. are not within the specified tolerance, change tubes, reset R66, and again check voltage across V1-V2 and V3-V4.

Defective resistors, selenium rectifier, and/or filter capacitors will result in low heater voltage.

4-10 VOLTMETER LOCALIZATION CHECKS

To localize trouble by d-c voltage analysis, the following checks will be helpful.

a. With a line voltage of exactly 115 volts, check the d-c plate (pin 5) and screen (pin 6) voltages for V1, V2, V3, V4, and V5.

Plate and screen of V1 are tied together and should have a d-c voltage of +165 volts, ±5 volts.

Tubes V2, V3, and V4 should have a plate voltage of at least +90 volts but no higher than +120 volts.

Plate voltage for V5 should fall between +125 and +145 volts.

Screen voltages for V2, V3, V4, and V5 should be +120 volts, ±10 volts.

b. Reduce line voltage to 103 volts. Again measure V2 through V5 d-c plate and screen voltages.

If a tube is weak, plate and screen voltages will drift to a higher value after the initial slight change following the reduction in line voltage. This effect will be more noticeable at the plate of each tube.

c. Reset line voltage to 115 volts. Check that voltage from pin 3 of V3 or V4 to chassis measure 12.6 volts; readjust R66, if necessary. Measure d-c voltage at grid pin 1 of V2, V3, V4, and V5. A reading of zero volts will normally be obtained for V2, V3, and V4. The grid of V5 will be approximately +0.6 volts with respect to the chassis. A high-impedance vacuum tube voltmeter such as the ⓗⓟ Model 410B must be used for this measurement.

Leaking coupling capacitors from a previous stage will cause a more positive d-c grid-voltage for V2, V3, V4, or V5. Replace any coupling capacitors in doubtful condition.

Occasionally a coupling capacitor will be found that is slightly leaky only when the instrument is operated in its case. When the instrument is operated with its case off, components are permitted to cool off to below normal operating temperatures.

d. A cathode voltage of approximately +1.6 volts is normal for V2, +1.5 volts for V3 and V4, and +2.1 volts for V5.

An open cathode resistor will result in a relatively large increase in these voltages. A weak tube or a defective cathode bypass capacitor can result in low cathode voltage.

e. A cathode voltage of approximately +58 volts and grid voltage of +56 volts is normal for the grid of V1. Measure the grid voltage at the junction of R1 (110K) and R7 (220K) at terminal of capacitor C1A behind the pilot lamp socket (see Figure 4-1).

The actual values will vary slightly, but the cathode voltage will always be about 2 volts positive compared to the grid.

With a weak V1 the bias will be around 1 volt which will show up as instability when the range switch is rotated.

f. Excessive switching transients are often caused by a gassy V1. Gas current can be detected in the following way:

This test can only be done with a d-c VTVM with a floating ground and 122 megohms input impedance, such as a ⓗⓟ Model 410B with the chassis ungrounded. If the 410B power cable is equipped with the new NEMA 3-blade grounding male connector, an adaptor should be used to isolate the grounding wire from the receptacle while this test is being made.

1) Switch the 400D to 1-volt range.

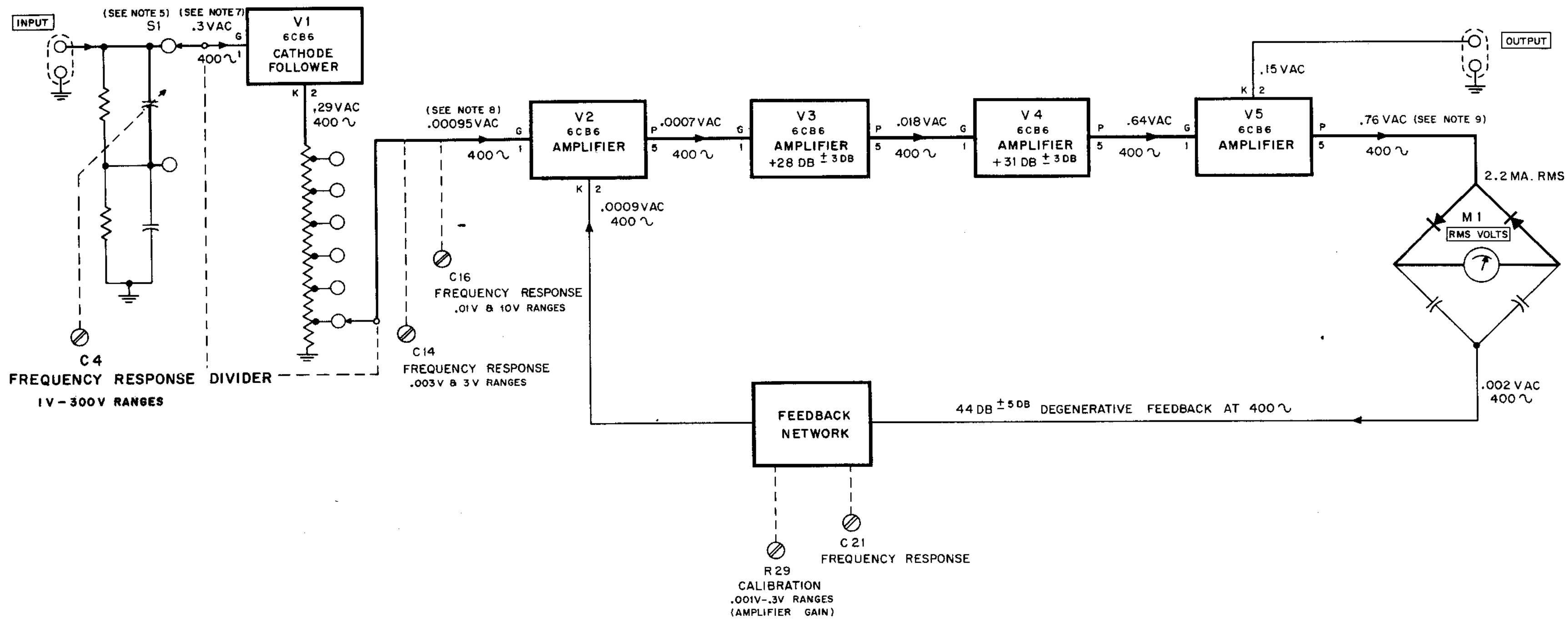
2) Set the 410B on (+) 1-volt d-c range.

3) Connect the 410B (-) lead to junction of R1(110K) R7 (220K), directly behind pilot light socket (see Figure 4-1).

4) Touch d-c probe to center terminal of C4 (junction of C2, R4, and C4 on schematic diagram).

5) Re-zero the 410B with d-c probe on C4.

6) Switch the 400D to 0.3-volt range and observe the 410B. If meter moves 1 division = 0.02 volt dc or more, V1 has too much gas and is cause of switching transcients. Replace V1.



NOTES:

1. Heavy line indicates main circuit.

2. Light line indicates auxiliary circuits or controls.

3. Variable controls are indicated by circle and dotted line dropped from point in circuit where connected. Line thru circle indicates screwdriver control.

4. Letters and numbers outside tube blocks indicate tube element and socket pin.

5. S1 = DB VOLTS (range) switch.

6. Conditions of voltage measurement

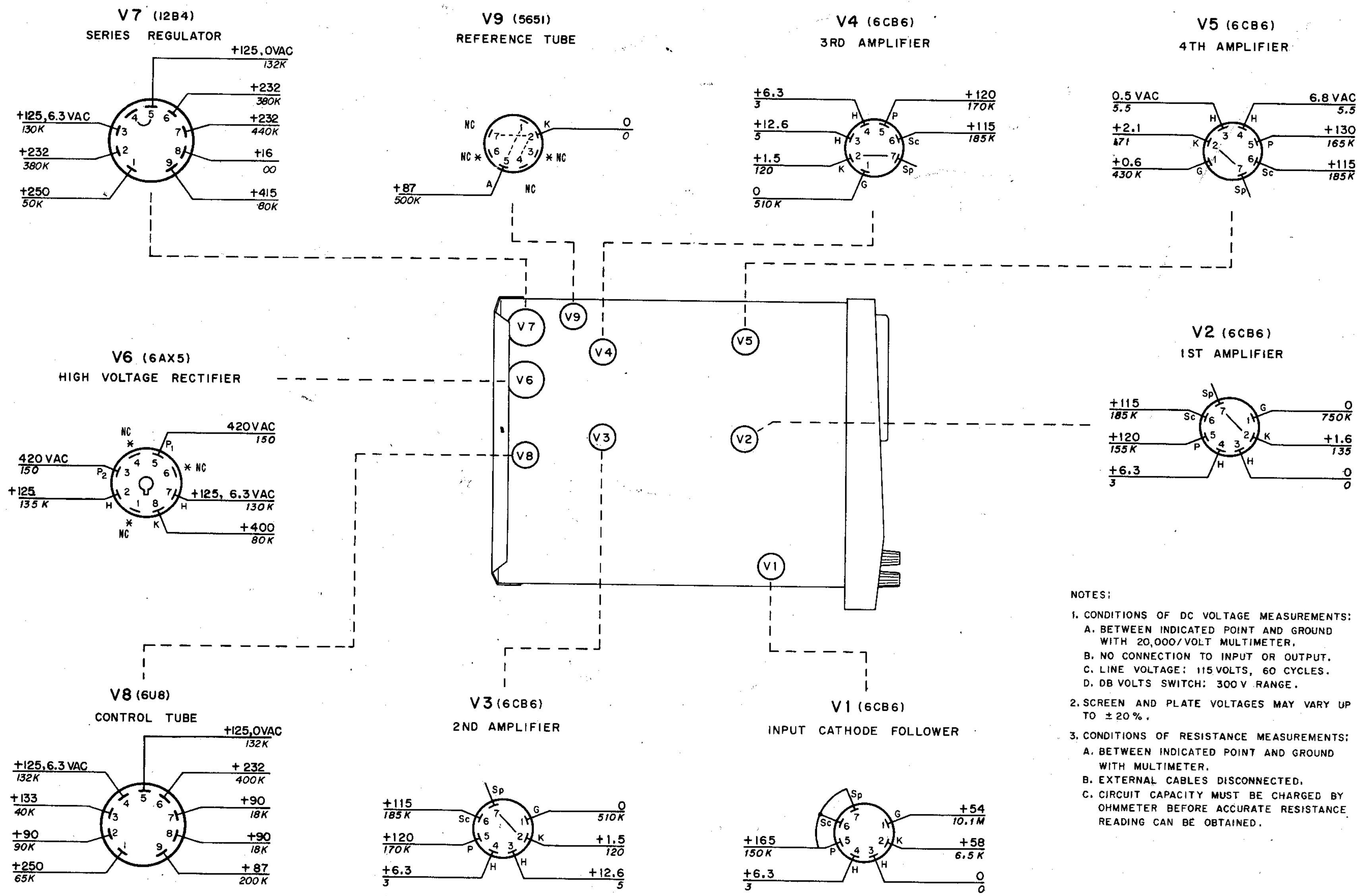
   A. Input signal: .3V rms, 400 ∿
   B. DB VOLTS switch: .3V range
   C. Between indicated point and ground with voltmeter ME-6/U or another ME-30A/U; rms value given.

7. Voltage will vary with level of input signal and position of S1; should not exceed .3V at 400 ∿.

8. Signal measurements in first stage not practical due to extremely low signal level and large degeneration applied to V2.

9. CAUTION - When checking tube V5, avoid shorting crystal diodes CR1 and CR2 to ground. With power turned on, the diodes will burn out if their terminals are shorted to ground.

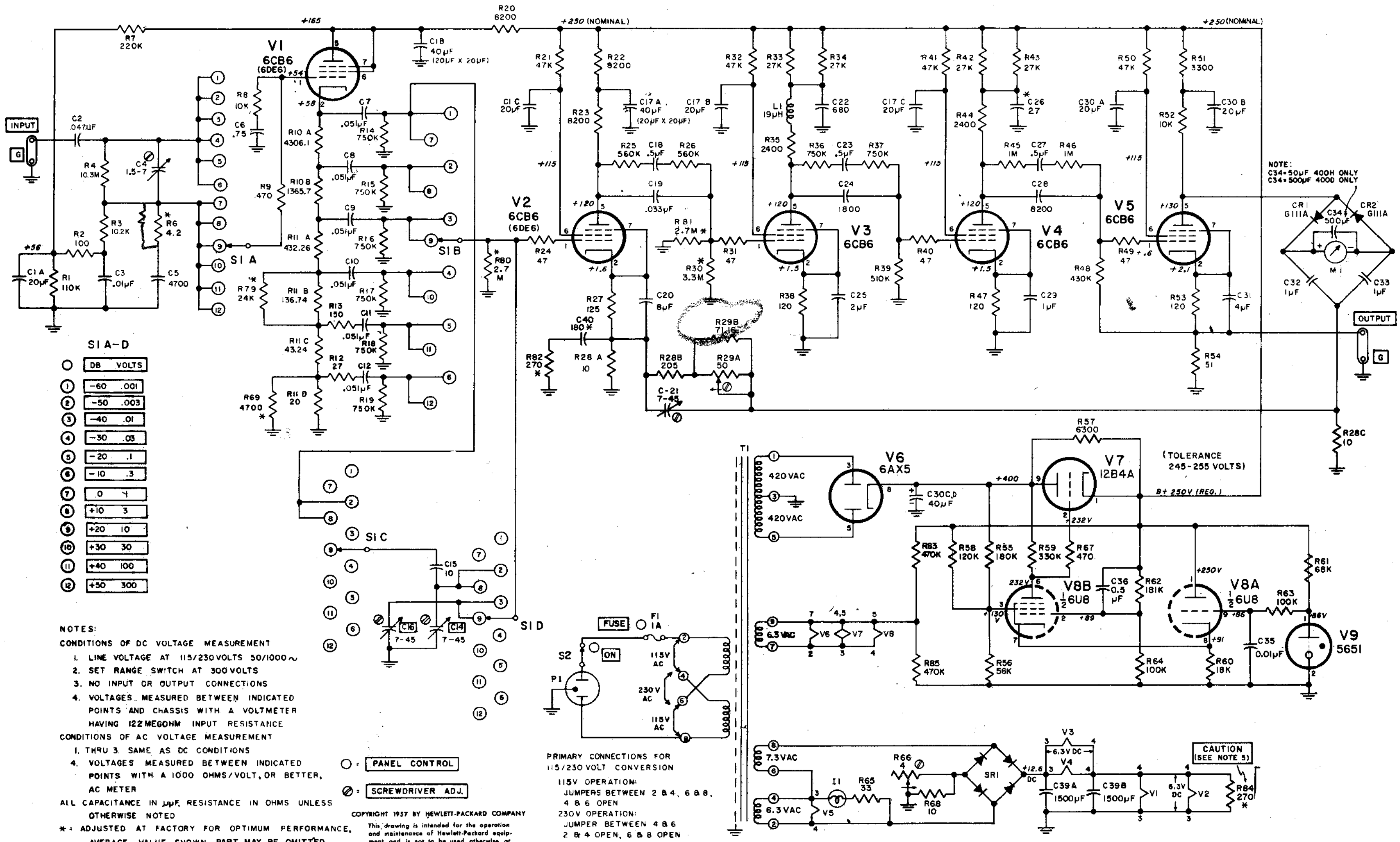
Figure 4-3. Model 400D/H Servicing Block Diagram



NOTES:

1. CONDITIONS OF DC VOLTAGE MEASUREMENTS:
   A. BETWEEN INDICATED POINT AND GROUND WITH 20,000/VOLT MULTIMETER.
   B. NO CONNECTION TO INPUT OR OUTPUT.
   C. LINE VOLTAGE: 115 VOLTS, 60 CYCLES.
   D. DB VOLTS SWITCH: 300 V RANGE.
2. SCREEN AND PLATE VOLTAGES MAY VARY UP TO ± 20%.
3. CONDITIONS OF RESISTANCE MEASUREMENTS:
   A. BETWEEN INDICATED POINT AND GROUND WITH MULTIMETER.
   B. EXTERNAL CABLES DISCONNECTED.
   C. CIRCUIT CAPACITY MUST BE CHARGED BY OHMMETER BEFORE ACCURATE RESISTANCE READING CAN BE OBTAINED.

Figure 4-4. Model 400D/H Voltage and Resistance Diagram



S1 A–D	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. LINE VOLTAGE AT 115/230 VOLTS 50/1000 ~
2. SET RANGE SWITCH AT 300 VOLTS
3. NO INPUT OR OUTPUT CONNECTIONS
4. VOLTAGES MEASURED BETWEEN INDICATED POINTS AND CHASSIS WITH A VOLTMETER HAVING 122 MEGOHM INPUT RESISTANCE

CONDITIONS OF AC VOLTAGE MEASUREMENT

1. THRU 3. SAME AS DC CONDITIONS
4. VOLTAGES MEASURED BETWEEN INDICATED POINTS WITH A 1000 OHMS/VOLT, OR BETTER, AC METER

ALL CAPACITANCE IN μμF, RESISTANCE IN OHMS UNLESS OTHERWISE NOTED

* = ADJUSTED AT FACTORY FOR OPTIMUM PERFORMANCE, AVERAGE VALUE SHOWN. PART MAY BE OMITTED.

1K = 1000 OHMS   1M = 1MEGOHM   ⏚ = CHASSIS

5. R84 MUST BE USED IF V1 & V2 ARE 6DE6'S
R84 MUST BE REMOVED IF V1 & V2 ARE 6CB6'S

○ = PANEL CONTROL

⊘ = SCREWDRIVER ADJ.

PRIMARY CONNECTIONS FOR 115/230 VOLT CONVERSION
115V OPERATION:
JUMPERS BETWEEN 2 & 4, 6 & 8, 4 & 6 OPEN
230V OPERATION:
JUMPER BETWEEN 4 & 6
2 & 4 OPEN, 6 & 8 OPEN

hp MODEL 400D/H

VACUUM TUBE VOLTMETER

400D: SERIAL 17971 & ABOVE
400H: SERIAL 2238 & ABOVE

Figure 4-5

SECTION V
TABLE OF REPLACEABLE PARTS

NOTE

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

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

Instrument Model Number
Serial Number
hp Stock Number of Part
Description of Part

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗ STOCK NO.	#			
C1 ABC	Capacitor: fixed, electrolytic, 4 section, 20μf/sect., 450 vdcw	CC*	18-42	3			
C2	Capacitor: fixed, paper dielectric, .047μf, ±10%, 600 vdcw	CC*	16-15	1			
C3	Capacitor: fixed, ceramic dielectric, .01μf, tol. -0% +100%, 1000 vdcw	CC*	15-43	2			
C4	Capacitor: variable, ceramic dielectric, 1.5 to 7μμf, 500 vdcw	L*	13-7	1			
C5	Capacitor: fixed, silver mica, .0047μf, ±5%, 500 vdcw	V*	15-81	1			
C6	Capacitor: fixed, air, .75μμf (air gap between R8 lug and ground lug of tie point)						
C7, 8, 9, 10, 11, 12	Capacitor: fixed, paper dielectric, .051μf, ±5%, 600 vdcw	CC*	16-53	6			
C13	This circuit reference not assigned						
C14	Capacitor: variable, ceramic dielectric, 7 to 45μμf, 500 vdcw	L*	13-1	3			
C15	Capacitor: fixed, ceramic dielectric, 10μμf, ±.5μμf, 500 vdcw	K*	15-30	1			
C16	Same as C14						
C17 ABC	Same as C1 ABC						
C18	Capacitor: fixed, paper dielectric, 0.5μf, ±10%, 400 vdcw	J*	16-58	4			
C19	Capacitor: fixed, paper dielectric, .033μf, ±10%, 600 vdcw	CC*	16-13	1			
C20	Capacitor: fixed, electrolytic, 8μf, -15%, +20%, 30 vdcw	AH*	18-17	1			
C21	Same as C14						
C22	Capacitor: fixed, mica, 680μμf, ±10%, 500 vdcw	Z*	14-21	1			
C23	Same as C18						
C24	Capacitor: fixed, mica, 1800μμf, ±10%, 500 vdcw	Z*	14-47	1			
C25	Capacitor: fixed, paper dielectric, 2.0μf, -15%, +25%, 200 vdcw	RR*	16-67	1			
C26	Capacitor: fixed, mica dielectric, 27μμf, ±5%, 300 vdcw	V*	14-78	1			
C27	Same as C18						

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
\# Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
C28	Capacitor: fixed, mica dielectric, 8200μμf, ±10%, 500 vdcw	J*	15-98	1			
C29	Capacitor: fixed, paper dielectric, 1.0μf, -15%, +25%, 200 vdcw	RR*	16-66	1			
C30 ABCD	Same as C1 ABC						
C31	Capacitor: fixed, electrolytic, 4μf, -15%, +20%, 60 vdcw	AH*	18-15	1			
C32, 33	Capacitor: fixed, paper dielectric, 1μf, ±10%, 400 vdcw	J*	16-74	2			
C34	Capacitor: fixed, electrolytic, 500μf, 15 vdcw (400D only)	X*	18-5	1			
	Capacitor: fixed, electrolytic, 50μf, -10%, +200% (400H only)	A*	18-50	1			
C35	Same as C3						
C36	Same as C18						
C37, 38	These circuit references not assigned						
C39 AB	Capacitor: fixed, electrolytic, 2 section, 1500μf/sect., 15 vdcw	CC*	18-48"S"	1			
C40	Capacitor: fixed, mica, 180μμf, ±10%, 500 vdcw	Z*	14-51	1			
R1	Resistor: fixed, composition, 110,000 ohms, ±5%, 1 W	B*	24-110K-5	1			
R2	Resistor: fixed, composition, 100 ohms, ±10%, 1/2 W	B*	23-100	1			
R3, 4	Resistor: fixed, composition R3: 10.31K ohms R4: 10.3 M ohms (R3, R4 are matched resistors)	HP*	400D-67	2			
R5	This circuit reference not assigned						
R6	Resistor: fixed, composition, 4.2 ohms, ±10%, 1/2 W (consists of two 10 ohm and one 27 ohm, ±10%, 1/2 W, all connected in parallel.) Electrical value adjusted at factory	B*	23-27	1			
R7	Resistor: fixed, composition, 220,000 ohms, ±10%, 1 W	B*	24-220K	1			
R8	Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 W	B*	23-10K	1			
R9	Resistor: fixed, composition, 470 ohms, ±10%, 1/2 W	B*	23-470	2			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗ STOCK NO.	#			
R10 AB	Resistor: fixed, wirewound, (range switch resistor) A: 4306.1 ohms B: 1365.7 ohms	HP*	400D-71	1			
R11 ABCD	Resistor: fixed, wirewound, (range switch resistor) A: 432.26 ohms B: 136.74 ohms C: 43.24 ohms D: 20 ohms	HP*	400D-71	1			
R12	Resistor: fixed, composition, 27 ohms, ±10%, 1/2 W	B*	23-27	1			
R13	Resistor: fixed, composition, 150 ohms, ±10%, 1/2 W	B*	23-150	1			
R14, 15, 16, 17, 18, 19	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W	B*	23-750K-5	8			
R20	Resistor: fixed, composition, 8200 ohms, ±10%, 2 W	B*	25-8200	2			
R21	Resistor: fixed, composition, 47,000 ohms, ±10%, 1 W	B*	24-47K	4			
R22	Same as R20						
R23	Resistor: fixed, 8200 ohms, ±5%, 1 W	AB*	331-8200	1			
R24	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	B*	23-47	4			
R25, 26	Resistor: fixed, composition, 560,000 ohms, ±10%, 1/2 W	B*	23-560K	2			
R27	Resistor: fixed, wirewound, 125 ohms, ±10%, 1/2 W	AC*	26-58	1			
R28 AC	Resistor: fixed, wirewound	HP*	400D-26B	1			
R28 B	Resistor: fixed, wirewound	HP*	400D-26C	1			
R29 A	Resistor: variable, composition, 50 ohms, ±10%, 2 W	B*	210-186	1			
R29 B	Resistor: fixed, deposited carbon, 71.16 ohms, ±1%, 1/2 W	NN*	33-71.16	1			
R30	Resistor: fixed, composition, 510,000 ohms, ±5%, 1/2 W Electrical value adjusted at factory	B*	23-510K-5	2			
R31	Same as R24						
R32	Same as R21						
R33, 34	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	B*	25-27K	4			
R35	Resistor: fixed, composition, 2400 ohms, ±5%, 1 W	B*	24-2400-5	2			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
R36, 37	Same as R14						
R38	Resistor: fixed, composition, 120 ohms, ±10%, 1 W	B*	24-120	3			
R39	Same as R30						
R40	Same as R24						
R41	Same as R21						
R42, 43	Same as R33						
R44	Same as R35						
R45, 46	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W	B*	23-1M	2			
R47	Same as R38						
R48	Resistor: fixed, composition, 430,000 ohms, ±5%, 1/2 W	B*	23-430K-5	1			
R49	Same as R24						
R50	Same as R21						
R51	Resistor: fixed, composition, 3300 ohms, ±10%, 1 W	B*	24-3300	1			
R52	Resistor: fixed, composition, 10,000 ohms, ±10%, 2 W	B*	25-10K	1			
R53	Same as R38						
R54	Resistor: fixed, composition, 51 ohms, ±5%, 1 W	B*	24-51-5	1			
R55	Resistor: fixed, composition, 180,000 ohms, ±10%, 2 W	B*	25-180K	1			
R56	Resistor: fixed, composition, 56,000 ohms, ±10%, 1 W	B*	24-56K	1			
R57	Resistor: fixed, wirewound, 6300 ohms, ±10%, 10 W	S*	26-61	1			
R58	Resistor: fixed, composition, 120,000 ohms, ±10%, 1 W	B*	24-120K	1			
R59	Resistor: fixed, composition, 330,000 ohms, ±10%, 1 W	B*	24-330K	1			
R60	Resistor: fixed, composition, 18,000 ohms, ±10%, 1 W	B*	24-18K	1			
R61	Resistor: fixed, composition, 68,000 ohms, ±10%, 1 W	B*	24-68K	1			
R62	Resistor: fixed, deposited carbon, 181,000 ohms, ±1%, 1 W	NN*	21-181K	1			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	#			
R63	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W B*	23-100K	1			
R64	Resistor: fixed, deposited carbon, 100,000 ohms, ±1%, 1 W NN*	31-100K	1			
R65	Resistor: fixed, composition, 33 ohms, ±10%, 1 W B*	24-33	1			
R66	Resistor: variable, wirewound, 4 ohms, ±20%, 1 W AT*	210-114	1			
R67	Same as R9					
R68	Resistor: fixed, composition, 10 ohms, ±10%, 1 W B*	24-10	1			
R69	Resistor: fixed, composition, 4700 ohms, ±10%, 1/2 W Electrical value adjusted at factory B*	23-4700	1			
R70 thru R78	These circuit references not assigned					
R79	Resistor: fixed, composition, 24,000 ohms, ±5%, 1/2 W Electrical value adjusted at factory - may not be present B*	23-24K-5	1			
R80, 81	Resistor: fixed, composition, 2.7 megohms, ±10%, 1/2 W Electrical value adjusted at factory - may not be present B*	23-2.7M	2			
R82	Resistor: fixed, composition, 270 ohms, ±10%, 1/2 W Electrical value adjusted at factory - may not be present B*	23-270	1			
R83	Resistor: fixed, composition, 470,000 ohms, ±10%, 1/2 W B*	23-470K	2			
R84	Resistor: fixed, composition, 270 ohms, ±10%, 1 W Electrical value adjusted at factory B*	24-270	1			
R85	Same as R83					
CR1, 2	Rectifier, silicon diode special -hp- design HP*	G111A	2			
F1	Fuse, cartridge: 1 amp, slow-blow (115V)	211-18	1			
	Fuse, cartridge: 0.5 amp, slow-blow (230V) E*	211-20	1			
I1	Lamp, incandescent: 6-8V, .15A O*	211-47	1			
L1	Coil, R.F.: 19 μh HP*	608A-60T	1			
M1	Meter (400D only) 1.00 ma f.s. 1% accuracy BF*	112-6	1			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	#			
M2	Meter (400H only) f.s. = 1 ma ±3%, tracking ±1/2% of f.s.	BF*	112-66	1			
P1	Cable, power:	TT*	812-56	1			
S1 ABCD	Range Switch Assembly	HP*	400D-19W	1			
	Switch rotary: (less resistors and capacitors)	W*	310-135				
S2	Switch, toggle: SPST	D*	310-11	1			
SR1	Rectifier, metallic:	BV*	212-101	1			
T1	Transformer, power	Paeco*	910-113	1			
V1, 2	Tube, electron: 6CB6 or 6DE6	ZZ*	212-6CB6 or 212-6DE6	2			
V3, 4, 5	Tube, electron: 6CB6	ZZ*	212-6CB6	3			
V6	Tube, electron: 6AX5-GT	ZZ*	212-6AX5-GT	1			
V7	Tube, electron: 12B4A	ZZ*	212-12B4A	1			
V8	Tube, electron: 6U8	ZZ*	212-6U8	1			
V9	Tube, electron: 5651	ZZ*	212-5651	1			
	Binding Post Assembly: black	HP*	AC-10C	2			
	Binding Post Assembly: red	HP*	AC-10D	2			
	Holder, fuse:	T*	140-16	1			
	Insulator, binding post: single	HP*	AC-54D	1			
	Insulator, binding post: double	HP*	AC-54A	1			
	Knob range switch	HP*	G-74N	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
# Total quantity used in the instrument.

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

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

CLAIM FOR DAMAGE IN SHIPMENT

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

WARRANTY

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

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

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

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

SHIPPING

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

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY

Laboratory Instruments for Speed and Accuracy

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

CABLE "HEWPACK"