

OPERATION OF THE HEATHKIT G_m TUBE TESTER MODEL TT-1



SPECIFICATIONS

Power Requirements:	Voltage: 105-125, 60 cycle AC Watts: 10-60 (dependent upon tube under test).																					
Plate Supply (Silicon Rectifiers):	DC volts: 26, 90, 135, 225, variable 80 to 200. AC volts: 20, 45, 177. (Separate DC supply for space charge grids.)																					
Bias Supply (Silicon Rectifier):	Low Range: 0 to negative 5 volts DC. High Range: 0 to negative 20 volts DC.																					
Signal Voltages:	2, 1, .5, .25 volts AC, 5000 cycles.																					
Filament Supply:	<table border="0" style="margin-left: 20px;"> <tr> <td colspan="3">Voltages:</td> </tr> <tr> <td style="padding-right: 40px;">.65</td> <td style="padding-right: 40px;">5</td> <td>27.5</td> </tr> <tr> <td>1.1</td> <td>6.3</td> <td>35</td> </tr> <tr> <td>1.5</td> <td>7.5</td> <td>47</td> </tr> <tr> <td>2</td> <td>10</td> <td>70</td> </tr> <tr> <td>2.5</td> <td>13</td> <td>115</td> </tr> <tr> <td>3.3</td> <td>20</td> <td></td> </tr> </table>	Voltages:			.65	5	27.5	1.1	6.3	35	1.5	7.5	47	2	10	70	2.5	13	115	3.3	20	
Voltages:																						
.65	5	27.5																				
1.1	6.3	35																				
1.5	7.5	47																				
2	10	70																				
2.5	13	115																				
3.3	20																					

Currents: 300, 450, 600 ma.

NOTE: Filament voltage is reduced 10% during life test.

Testing Circuits

Gm:	Mutual conductance for amplifiers, 0-24,000 micromhos.
Emission:	Rectifiers and diodes.
Leakage:	Direct reading ohmmeter.
Grid Current:	1/4 microampere sensitivity.
Voltage Regulator:	Firing voltage and regulation tolerance.
Low Power Thyatron:	Grid characteristics, conduction capabilities.
Eye Tubes:	Control grid characteristics.

Meter

AC:	1000 ohms/volt (1 volt full scale).
DC:89 ma full scale.
Scales:	Gm: 0-3000 micromhos. VR Test volts: 0-200. Leakage: 0-10 megohms. Diodes: "OK" Rectifiers: "OK" Line check arrow at midscale.

Tube Complement:	1 - 3A4 oscillator. 1 - 12AV6 meter control.
----------------------------	---

Calibration Circuit:	Built-in, switch operated.
--------------------------------	----------------------------

Socket Accommodations:	4-pin, 5-pin, 6-pin, 7-pin combination and pilot light, 7-pin miniature, 7-pin subminiature, 8-pin subminiature, octal, loctal, 9-pin miniature, blank.
----------------------------------	---

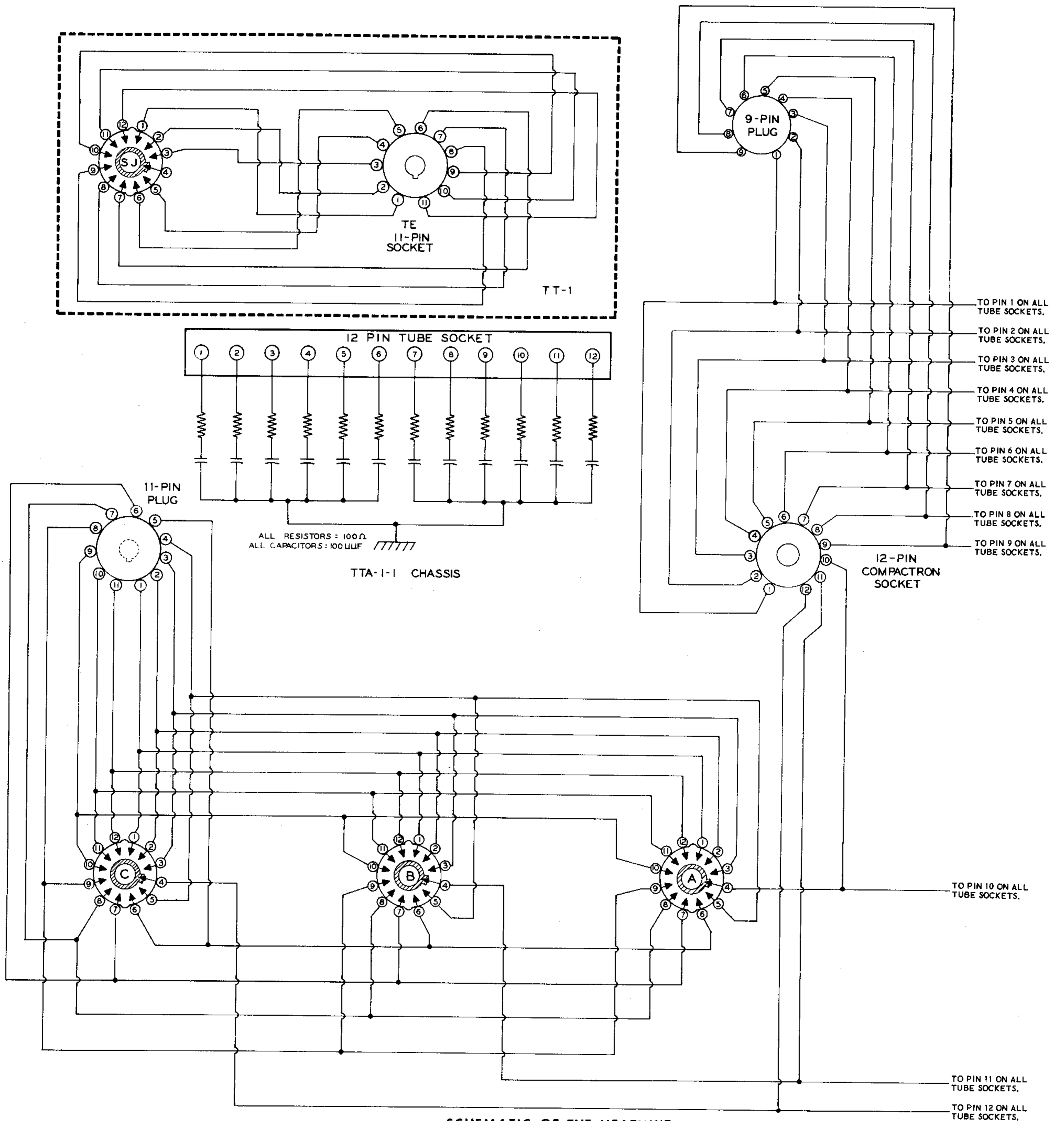
Line Voltage Adjustment:	Continuously variable.
------------------------------------	------------------------

Roll Chart Mechanism:	Constant tension, free rolling, dual thumb wheel operated, illuminated.
---------------------------------	---

Dimensions

Cabinet (outside):	17 3/4" wide x 13 1/2" high x 7 1/2" deep.
------------------------------	--

Panel and Chassis:	17" wide x 12 3/4" high x 5 1/2" deep.
------------------------------	--



**SCHEMATIC OF THE HEATHKIT
TUBE SOCKET ADAPTER
MODEL TT-1A**

POWER OUTPUT TESTING

This testing system is perhaps the most satisfactory in regards to similarity between test results and actual operation in the equipment. Since both the input and output powers are known, the other factors can be determined. In the case

of voltage amplifiers the voltage amplification and output voltage will be of prime interest. The power output test is ideally suited to testing power amplifiers, where the output power is of major concern.

LOW LINE TEST

In this testing system the input voltage to the equipment is lowered to 105 volts. Sufficient time should be allowed (10 minutes) for the tube

heaters to stabilize. If the questionable tube fails to function properly it should be replaced.

INSTRUMENT DESCRIPTION

The HEATHKIT Model TT-1 Tube Tester is a vacuum tube tester of the proportional mutual conductance type. It will also test voltage regulators, eye tubes and thyratrons. One of the outstanding features of this instrument is the switching system utilized in connecting the various tube elements to their proper potentials. By using nine single-circuit 12-position rotary switches, it is possible to connect the tube elements (through suitable resistance values) to separate filtered DC voltage supplies regardless of the pin numbers involved. The number of selector switches has been held to a minimum by providing two cap clips, one each for grid and plate caps, which are soldered directly into the circuit and therefore require no switching. The setup procedure has been further simplified by the use of the K, P, and G switches. These switches make it possible to check both sections of a tube having two identical sections with only one group of settings for all other switches and controls involved.

The roll chart mechanism is a unique design which permits the roll chart to run freely throughout its entire length without binding. The chart rollers are spring loaded to keep the chart taut at all times to present a smooth viewing surface. No difficulty in operation

should be experienced on the part of the left handed operator since thumb wheels have been provided on both sides of the panel to eliminate any crossover problems. The arrangement of the columns on the chart corresponds to the placement of the knobs on the panel so that the setup procedure may be accomplished in an orderly left-to-right, top-to-bottom sequence. The roll chart and meter have been illuminated to make the instrument more adaptable to use in darkened areas (such as the inevitable dark corner behind the TV receiver).

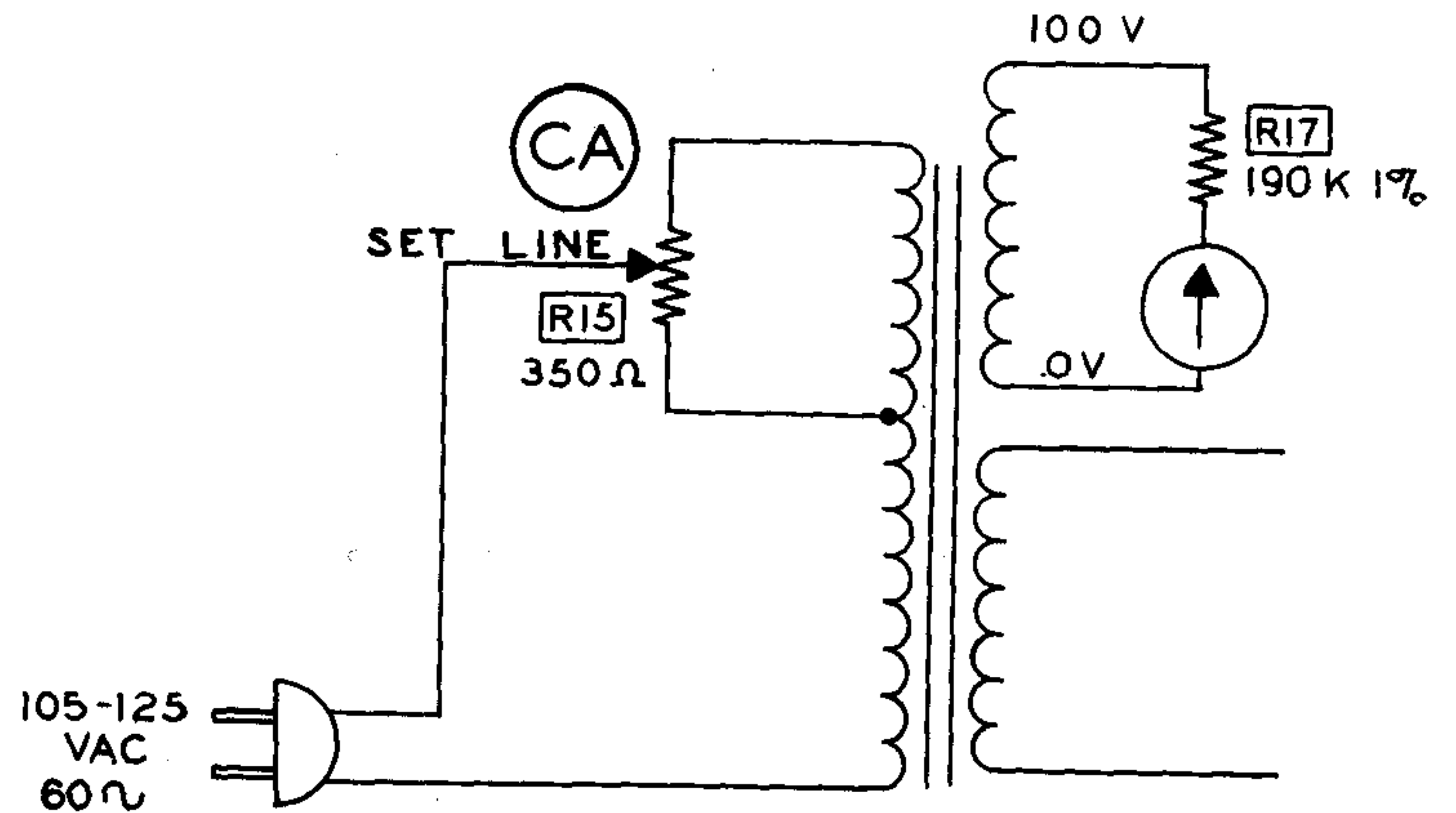
In addition to the usual selection of filament voltages, the TT-1 contains a constant current supply of either 600, 450 or 300 ma. to be used in the testing of series string tubes. This supply is connected through the filament switch and is used when called for on the roll chart just as any other filament switch setting.

As an additional convenience to the operator, the TT-1 has been designed with a removable line cord. A line voltage outlet is mounted on the upper right corner of the panel to provide power for another instrument, a trouble light or simply to replace the wall outlet used by plugging in the TT-1.

CIRCUIT DESCRIPTION

LINE TEST CIRCUIT

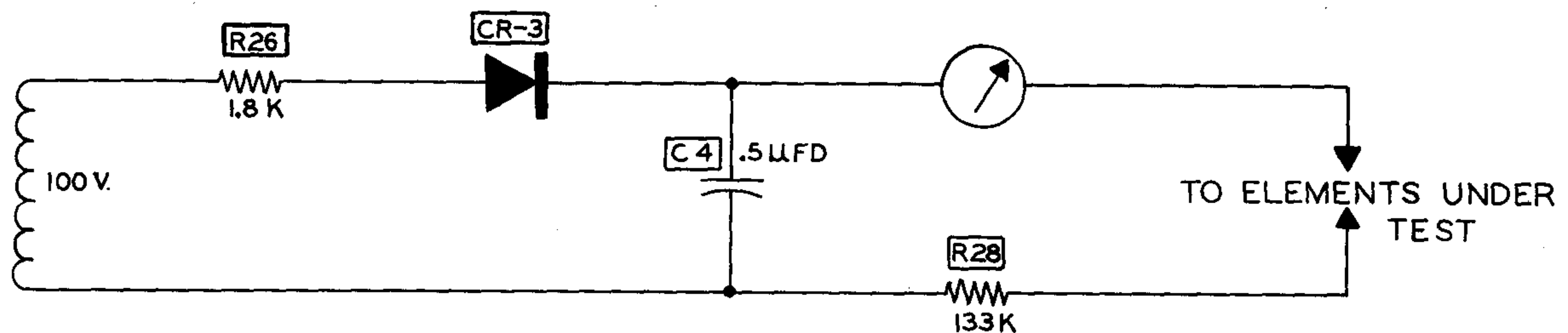
The line test circuit is in operation when the line test switch is in the "down" position. Changing the position of the tap on the control in the primary of the power transformer (rotating the SET LINE control) will, in effect, vary the turns ratio. The voltage across each of the four secondary windings will change simultaneously as the SET LINE control is varied. Therefore, adjusting one particular winding to the proper level automatically sets the voltage of all secondary windings to a specified value.



LEAKAGE TEST CIRCUIT

Leakage testing is controlled by the LEAKAGE switch which, in its numbered positions, disconnects all tube elements from the other testing circuits and connects them into the leakage test circuit. The meter deflection in each switch position is indicative of the resistance between the isolated element and other elements of the tube.

For this circuit the meter deflection is inversely proportional to the leakage resistance, a full-scale reading thus indicating zero resistance. Resistance values as high as 10 megohms can be measured. The element checked for a given position of the LEAKAGE switch is shown below.



<u>POSITION</u>	<u>MEASURES LEAKAGE BETWEEN</u>
1	Heater and cathode.
2	Suppressor grid and all other elements.
3	Plate and all other elements.
4	Screen grid and all other elements.
5	Control grid and all other elements.

A low or zero resistance indication for position 1 is normal for tubes that are of the filamentary type or have an internal heater-cathode connection.

The red line on the leakage scale is the 250,000 ohms mark and is the approximate value that causes the neon lamp to light in conventional

short test circuits.

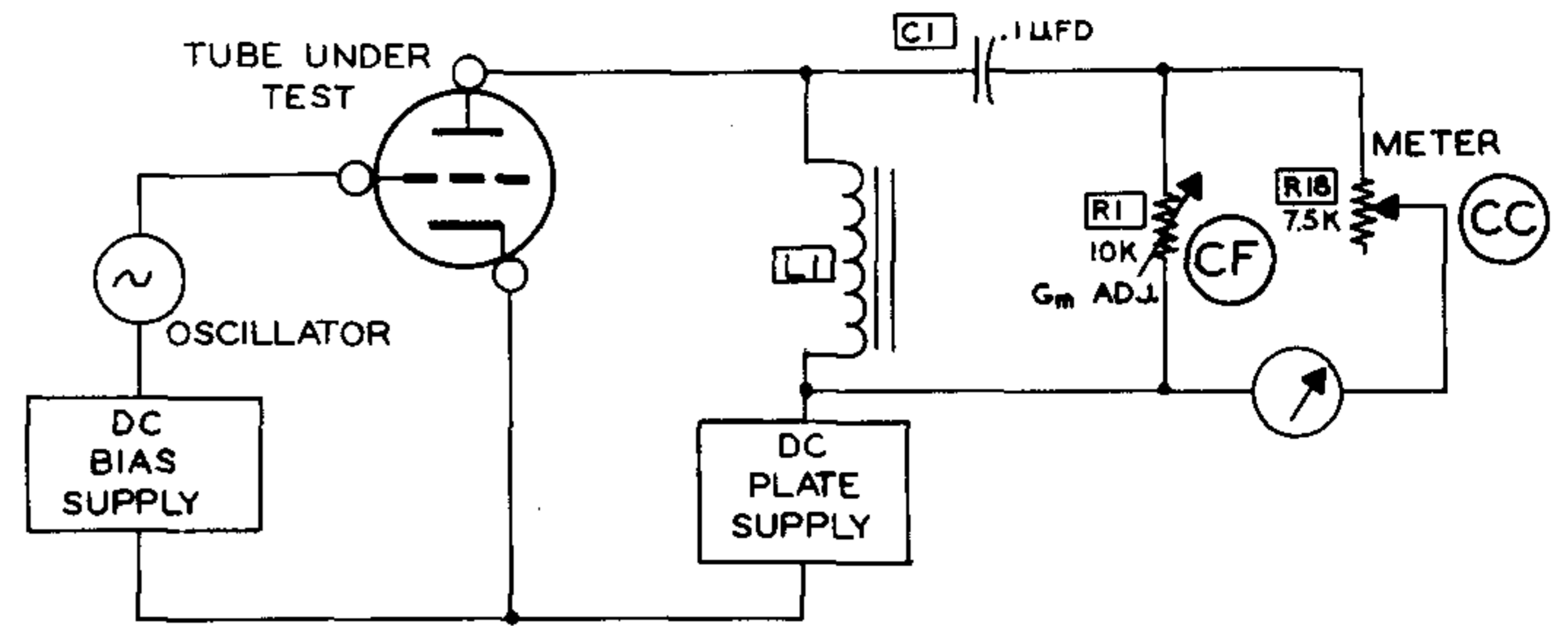
The leakage tests are performed at a DC potential of 125 volts. The element under test is connected into a series ohmmeter circuit as shown in the Diagram. Any deflection of the meter will be proportional to the value of resistance placed between the arrows.

Gm TEST CIRCUIT

Of the many measurable characteristics of vacuum tubes, mutual conductance is the one most closely associated with actual operating performance. This is the method used for testing amplifier tubes in the HEATHKIT Model TT-1. This test uses the circuit shown, and is performed in the following manner:

All element voltages on the tube under test are filtered DC potentials to give a more accurate and indicative test. The plate circuit consists of a variable DC plate supply and high-pass filter (L-1, C-1 and R-1) which is connected to the meter circuit. This filter passes only the 5000 cycle component of plate current and blocks the DC plate current and any 60 cycle ripple that may be present.

The grid circuit consists of the variable DC bias supply and the 5000 cycle oscillator. When a signal voltage (e_g) is impressed on the grid of the tube under test, a signal current (i_p) is produced in the plate circuit which gives a meter reading proportional to the value of grid signal and thus to the mutual conductance of the tube.



For a given signal, the meter can be calibrated to read in terms of g_m by using the following relationship: $i_p = e_g \times g_m$ where g_m is the mutual conductance. Rearrangement of the above gives: $g_m = i_p / e_g$.

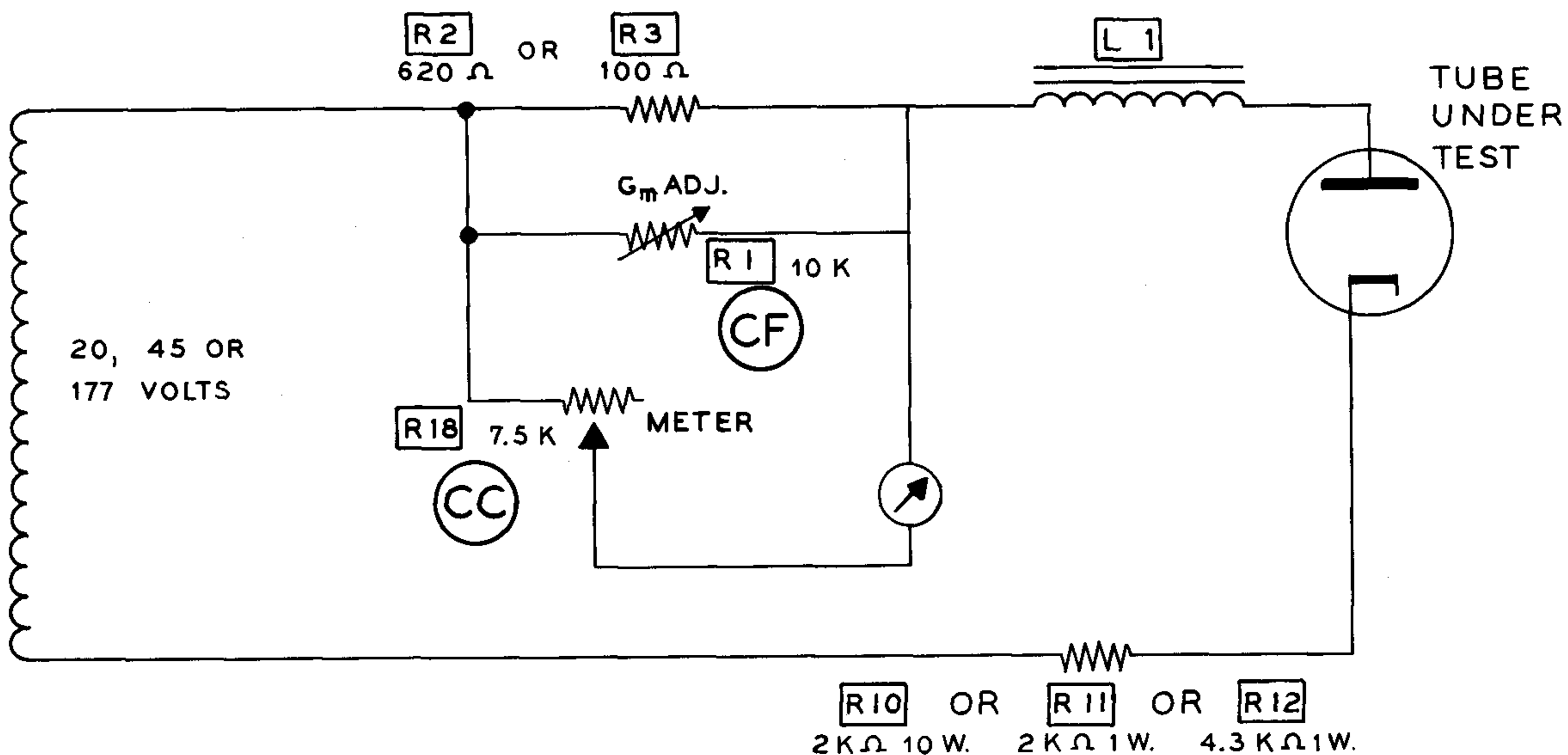
Therefore, if the grid signal is 1 volt and the plate current is 3 milliamperes, a full scale deflection of the meter corresponds to .003 mho. Since 1 mho = 1,000,000 micromhos, .003 mho = .003 x 1,000,000 = 3000 micromhos.

The term "proportional mutual conductance" is derived from the fact that proportional values of element voltages are applied to the tube under test.

DIODE AND RECTIFIER TEST CIRCUIT

The useful life of a diode or rectifier type tube ends when the emission capability of its cathode falls below some given level, the exact value of which may differ for each tube type. The circuit used to test these tubes is shown below:

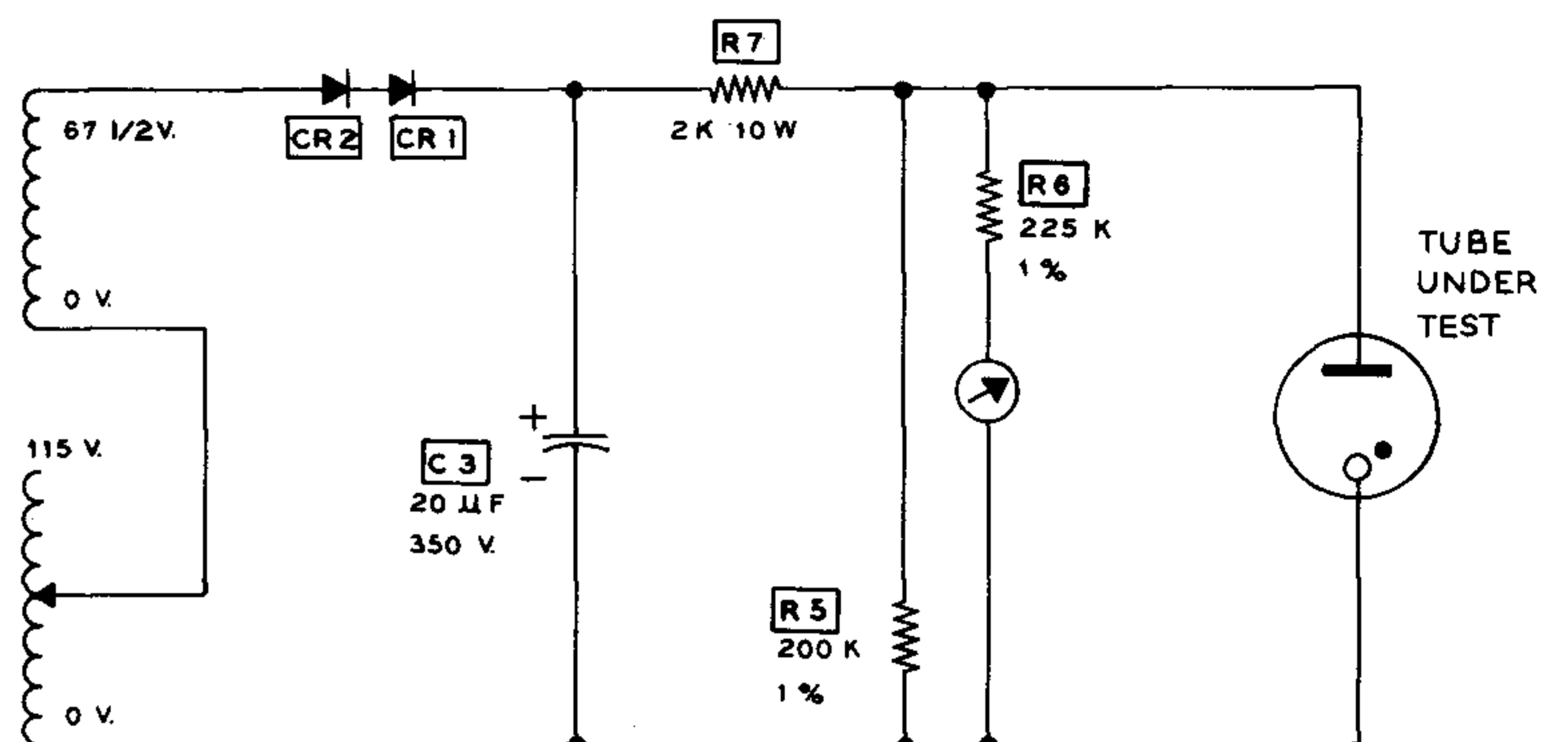
A milliammeter is connected in series with the tube under test to measure the tube current. For a given tube type, a suitable plate voltage and load resistor are selected by the plate switch and connected to the proper elements. Each rectifier and diode type is rated in terms of emissive capacity and must read above the appropriate scale marking to be considered good.



VOLTAGE REGULATOR (VR) TEST CIRCUIT

The testing of voltage regulator tubes is accomplished through the use of a variable DC power supply. The variable DC supply voltage is obtained by using two AC sources (one fixed and one tapped), two silicon rectifiers (CR-1 and CR-2) and a charging capacitor (C-3). DC potentials are applied to the voltage regulating tube under test through a current limiting resistor (R-7) which also serves as the regulating resistor. A voltmeter circuit (R-5, R-6 and the meter) indicates the firing voltage as the applied potential is varied over the range in which the tube should fire. The point at which the tube fires is indicated by a sudden downward deflection of the meter pointer. This occurs because it is the property of a voltage regulator tube to maintain a voltage across its elements in the order of five to thirty volts below its firing potential.

After the VR tube has fired, its value as a regulator can be determined by varying the applied voltage between the limits specified on the roll chart. Between these limits a variation from the regulating point will be an indication of the tube's



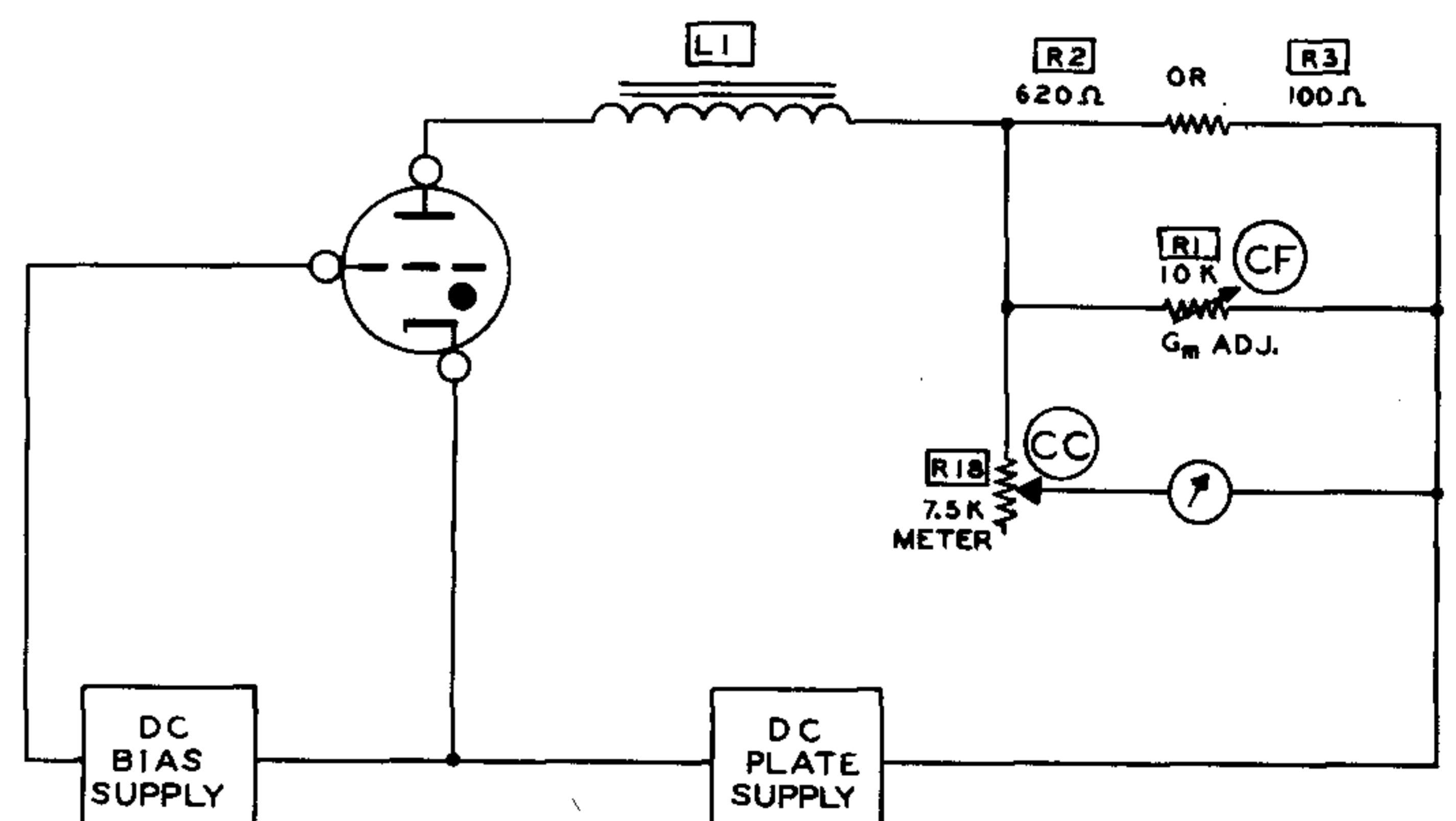
regulating capacity. For example, if the tube fires at 110 volts, let us assume that it will maintain a regulating potential of approximately 105 volts, with the following in the REMARKS column: "4.0 V Reg, Fil 5 to 70 V." Therefore, when the FILAMENT switch is rotated from 5 to 70, the meter, which now acts as a voltmeter across the VR tube, should not vary more than 4 volts. If the variation is more, the VR tube should be considered faulty and replacement is recommended.

THYRATRON TEST CIRCUIT

Low power thyratron tubes are tested by the TT-1 for their grid characteristics and their conduction capabilities. The tube to be tested is connected into the test circuit, as shown in the Diagram.

For this test the meter is connected in the plate circuit as a milliammeter. The tube is held to cutoff by means of a high bias applied to the grid. When the bias is decreased so that the grid becomes less negative with respect to the cathode, a point will be reached when the tube will suddenly conduct and give an indication on the meter. The value of BIAS setting at which this occurs should fall within the limits specified in the REMARKS column of the roll chart. For example, a tube having "Thyra; Fire 15-0 Bias" in the REMARKS column should fire between a BIAS setting of 15 and 0.

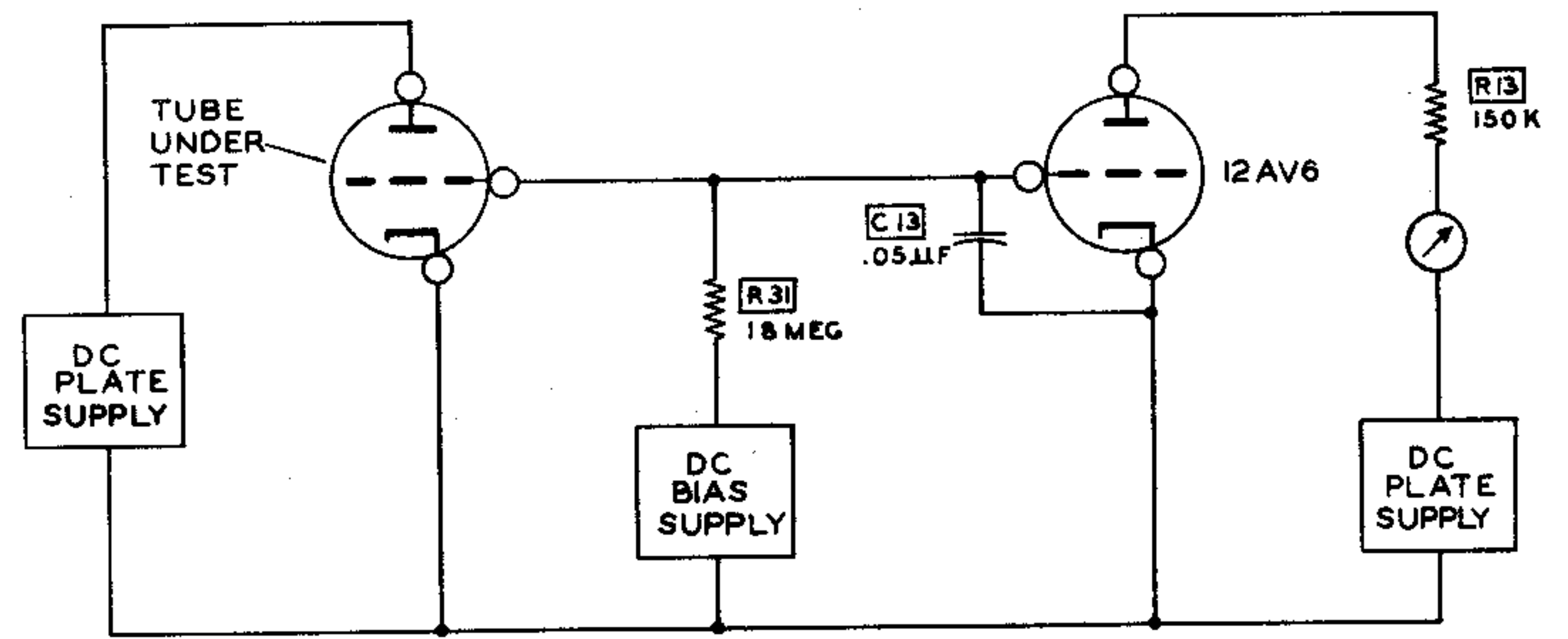
After the tube has fired, the pointer should fall within the specified portion of the scale for the tube to be considered good.



GRID CURRENT TEST CIRCUIT

The grid current test circuit will determine if, for any reason, the tube under test is drawing grid current. The most common reasons for grid current flow are: (1) gas; (2) leakage from grid to another element; (3) grid contamination (secondary emission), a condition existing when the active material from the cathode is deposited on the grid, thus causing it to emit electrons.

The grid of the tube under test is connected to the grid current testing circuit, as shown in the Diagram. The 12AV6 tube is biased beyond cutoff so that no plate current flows, hence no meter reading is indicated. Grid current flowing through the tube under test will develop a voltage across the 18 megohm resistor. This voltage raises the DC bias on the 12AV6, bringing

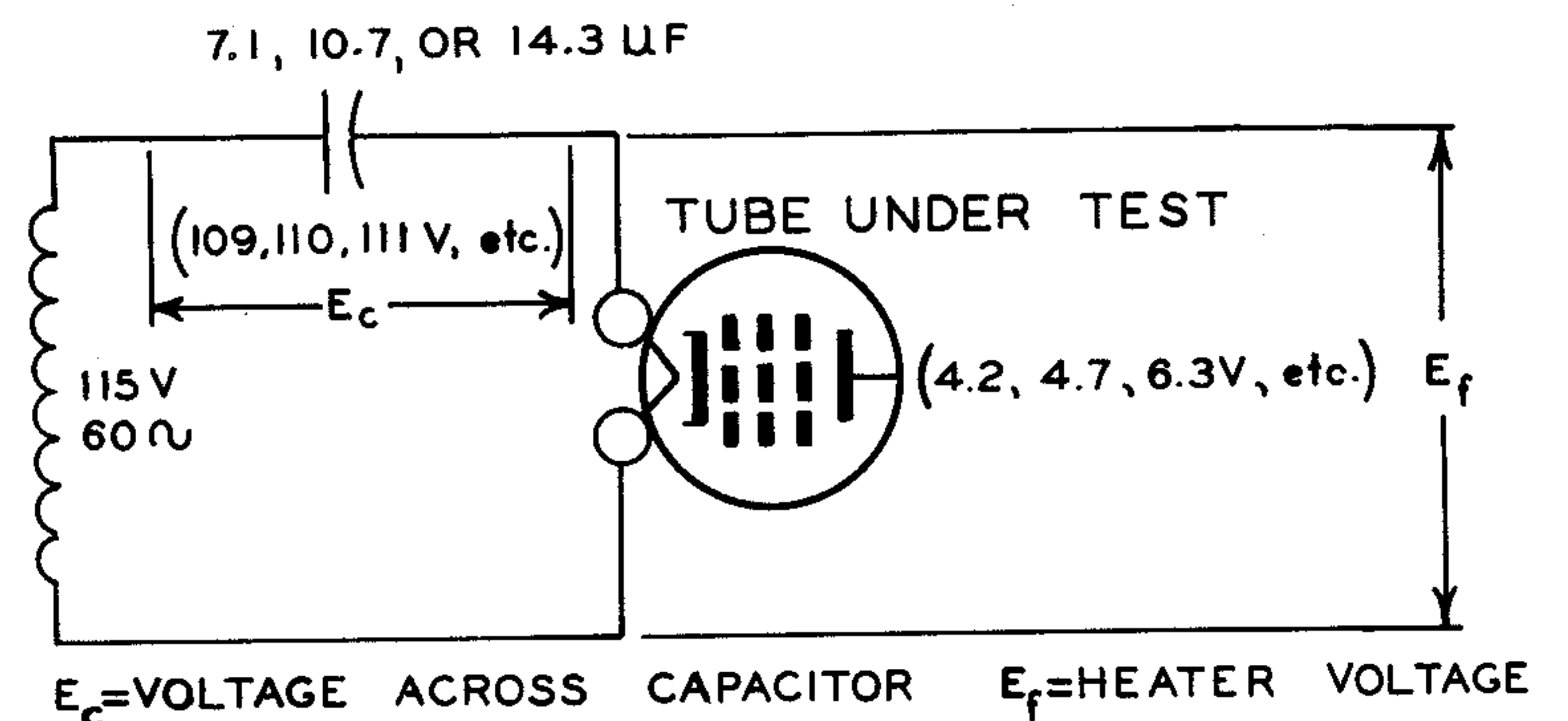


it above cutoff. Since the bias is now above the cutoff value, plate current will flow through the 12AV6 and the meter, thus indicating the grid current flow in the tube under test.

CONSTANT CURRENT HEATER SUPPLY

The constant current heater supply used in the TT-1 operates from the 115 volt filament tap. This tap is connected to the tube heater through a ballast capacitor. Since the voltage drop across the tube is small in comparison to the voltage drop across the capacitor, the capacitor impedance will be the current determining element in this series circuit. The tube heater is, essentially, a resistive impedance. This means that the impedance of the two elements (resistive and capacitive) are approximately 90 degrees out of phase with each other. This fact, in addition to the magnitude of each impedance relative to the other, enables the capacitor to act as an efficient current regulating unit. The capacity value used for each current supply is:

300 ma	7.1 μ fd
450 ma	10.7 μ fd
600 ma	14.3 μ fd



USING THE HEATHKIT TT - 1 TUBE TESTER

ROLL CHART ABBREVIATIONS

In order to list the greatest number of tube types on a roll chart that is necessarily limited in size, abbreviations must be used to indicate control settings, procedures, etc. An explanation of these abbreviations is given below:

TYPE	List the tube according to the EIA (RETMA) number.	No Leak Check	Do not rotate LEAKAGE switch through positions 1, 2, 3, 4 or 5.
PLATE	Setting of the PLATE switch.	Leak On	A short circuit will be indicated on meter for the positions of the LEAKAGE switch following this abbreviation.
BIAS	Setting of the BIAS control and BIAS RANGE switch. Example: A setting of 20 L means that the BIAS control is to be set at 20 and the BIAS RANGE switch is to be set to the L (low) position.	Pe	Pentode section of tube is being tested.
FIL	Setting of the FILAMENT switch.	Tr	Triode section of tube is being tested.
METER	Setting of the METER (sensitivity) control.	P1 and P2	Tube shall be tested with switch P in both P1 and P2 positions.
SIG	Setting of the SIGNAL switch. NOTE: The Gm scale reading is not multiplied by the setting of this switch.	G1 and G2	Tube shall be tested with switch G in both G1 and G2 positions.
SELECTORS	Settings of each of the nine SELECTOR switches, reading from left to right, with the two rows separated by a dash.	K1 and K2	Tube shall be tested with switch K in both K1 and K2 positions. NOTE: Where the "2" positions of two or more of the K, P or G switches is called for, it is recommended that they be pulled down simultaneously. Unless otherwise stated, these switches must be in the K1, P1 and G1 positions.
R.P.	This is the Reject Point, or the value of the meter reading at or below which the tube being tested should be rejected.	Osc	Oscillator section of tube is being tested.
REMARKS	Any information pertaining to testing of the tube.	Whole Tube	Specifies that all elements in tube are being tested simultaneously.
F	Meter should indicate short when LEAKAGE switch is in position 1.	Reg	Shows by how many volts a regulator tube can vary on the "VR TEST VOLTS" scale.
		Firing Lim	The range of voltage following this abbreviation indicates the firing limits of the tube under test.

Plate Cap	Plate clip should be connected to the tube cap.
Grid Cap	Grid clip should be connected to the tube cap.
Thyra	Thyratron.
X1, X2, X3, etc.	(In the REMARKS column) Indicates the factor used to multiply the Gm scale reading to obtain the actual Gm value.

Additional abbreviations that appear in the SIG column are:

- R - Tube is to be tested as a rectifier.
- D - Tube is to be tested as a diode.
- VR - Voltage Regulator tube.
- E - Test procedure for eye tubes is to be used.

OPERATING INSTRUCTIONS

1. Place the TT-1 on a flat, solid, horizontal surface and plug the line cord into a 105-125 volt, 60 cycle source.
2. With the LINE TEST switch pulled down, adjust the meter pointer to the LINE CHECK arrow at midscale by rotating the SET LINE control, then release LINE TEST switch.
3. Refer to the roll chart for data on the tube to be tested.
4. Adjust PLATE, BIAS, FIL, METER, SIG and SELECTORS to correspond to roll chart information. The K, P and G switches should always be in Position 1 unless otherwise stated.
5. Set LEAKAGE switch to Position 1 and insert the tube in the proper socket.
6. Allow sufficient warmup time and then reset the SET LINE control, if meter pointer is not on the LINE CHECK arrow with LINE TEST switch pulled down.

7. Rotate LEAKAGE switch through Positions 1, 2, 3, 4 and 5, tapping the tube lightly for each position of the switch. If the meter indicates less than 500 K Ω , the tube should be rejected. In certain critical applications, such as audio preamplifiers or certain TV circuits, performance may be impaired if the heater-cathode and/or interelement leakages are less than 2 megohms.

NOTE: A leakage indication may be normal if listed in the REMARKS column. A meter indication on position 1 indicates heater-cathode leakages. Readings on Positions 2, 3, 4 and 5 indicate suppressor grid, plate, screen grid and control grid leakages, respectively.

8. With LEAKAGE switch in the TUBE TEST position, depress Gm TEST switch for Gm reading. If the meter indication is less than the value given in the R.P. column, the tube should be rejected.

NOTE: The reject point listed on the roll chart is given in terms of the basic 0-3000 micromhos scale. If the meter reads below the reject value, the tube should be considered faulty. However, it is possible, in certain special applications, that a tube must be replaced even though its Gm is still above the given reject point. Conversely, other tubes may function satisfactorily in certain equipment, even though their Gm has dropped to as low as 50% of their nominal or "bogie" values. In accordance with EIA (RETMA) standards, 65% of the nominal Gm value has been established as the rejection point (R.P.). The multiplying factor in the REMARKS column is used only to obtain the actual Gm, which is derived by multiplying the reading on the 0-3000 micromhos scale by the multiplying factor. Again, this factor is NOT used with respect to the reject point.

9. Turn the GRID CURRENT switch to the TEST position and hold it there for at least 5 seconds. If no increase in meter reading is noted, the tube is not drawing grid current and may be considered "good." Any meter deflection during this test indicates the tube is drawing grid current and should be rejected. There is no scale on the meter to indicate the magnitude of grid current flow since any amount may be considered as

detrimental to the operation of the tube. In some cases, however, a "borderline" condition may exist. That is, the tube is suspected to be drawing grid current in its normal application but there is no evidence of grid current shown by the tester. Grid current may be the result of an increase in bulb temperature due to prolonged operation or other nearby heat-producing components. A more thorough check on the "borderline" tube may be made by allowing the tube to remain in the tester until the temperature inside the bulb becomes higher. Since the tube is located "out in the open" (when in the tester), the movement of air around the bulb keeps the temperature down. Placing an unventilated tube shield around the tube will block off the air flow and raise the bulb temperature. As an extreme measure, the heater voltage may be increased, the amount of increase being left to the discretion of the operator.

10. Depress the LIFE TEST switch and allow a few minutes for the tube heater to stabilize. Readjust the SET LINE control, if necessary. Pull down the Gm TEST switch and note the Gm reading. If this reading shows more than 20% drop relative to the Gm value previously noted, it may be assumed that the useful life of the tube is about over. Since there is no positive method of determining the remaining life of a vacuum tube, this test provides you with only a "guestimate." A combination of your own experience, knowledge of the particular circuit in which the tube is used, and a thorough understanding of what the TT-1 is telling you, should serve as an adequate guide in answering the question, "To replace or not to replace?"
11. Observe the REMARKS column for P1, G1, K1 and P2, G2, K2, or any combination of these letters. This indicates the tube is a multi-section type, two sections of which may be tested with the same settings. Simply move the indicated switches (P, G, K) to Position 2 and repeat the testing as outlined above.
12. If there are two lines of control settings listed for a single tube type, depress DISCONNECT switch, change the control knobs as indicated, and return the DISCONNECT switch to the normal position. The tester is

now set up for the second test to be made on this tube. ALWAYS use the DISCONNECT switch when changing settings with a tube in the tester, in order to avoid damage to the tube under test.

The above instructions are intended for Gm testing of amplifier type tubes. Special instructions and precautionary notes in regard to other types are listed below.

DIODE AND RECTIFIER TUBES

1. Follow Steps 1 through 7, as listed above. NOTE: The SIG and BIAS controls have no effect when testing rectifiers or diodes and may therefore be in any position.
2. With LEAKAGE switch in the TUBE TEST position, depress the AMPL-RECT-DIODE switch to the RECT-DIODE position. If a D appears in the SIG column of the roll chart, a meter reading above the DIODES OK mark indicates an acceptable tube. If an R appears in the SIG column of the roll chart, the meter must read above the RECTIFIERS OK mark.

VOLTAGE REGULATOR (VR) TUBES

1. Refer to the roll chart for data on the tube to be tested.
2. Set LEAKAGE switch to TUBE TEST position. Set PLATE, FIL and SELECTORS to the indicated positions. The VR in the SIG column indicates that the procedure for testing voltage regulator tubes is to be followed.
3. Turn the SET LINE control fully counter-clockwise and insert the tube in the proper socket. Do not make a line check.
4. Turn the SET LINE control slowly clockwise, observing the point on the 200 volt test scale at which the tube fires. When the tube has fired, the pointer will fall back to a lower value of voltage.

The value which the pointer reaches just before falling down-scale should be within the firing limits, as specified on the roll chart. If the glow is not steady and/or the meter pointer is not steady, the SET LINE control should be increased (clockwise rotation) just enough so that BOTH are steady. Observe the meter reading after this final adjustment.

5. Leaving the SET LINE control set as is, vary the FILAMENT switch through the positions stated and again observe the meter reading. This new reading should not vary more than the value of "V Reg" as stated in the REMARKS column.

CAUTION: The following is a list of "DON'TS" to be observed during the testing of voltage regulator tubes.

1. DO NOT insert the tube in the socket until all controls to be used have been properly set.
2. DO NOT make a leakage test.
3. DO NOT change any of the SELECTORS while the tube is in the socket.
4. DO NOT rotate the SET LINE control after the tube has fired and the final adjustment has been made.

Failure to heed the above comments may result in a test that is meaningless.

LOW-POWER THYRATRON TUBES

1. Follow Steps 1 through 4 of the general instructions.

NOTE: The SIGNAL switch may be disregarded when testing thyratron tubes and may therefore be in any position.

2. Rotate BIAS control to 45 and insert the tube into the proper socket.
3. Depress AMPL-RECT-DIODE switch to RECT-DIODE position.
4. Slowly rotate the BIAS control toward zero, carefully observing the meter. Note the value of BIAS setting at which the meter suddenly deflects up-scale. This is a test of the tube's control grid characteristic; the value of BIAS setting should fall between the limits given in the REMARKS column. For example, a tube having "Fire 10-0 bias" in the REMARKS column should fire at a bias setting between 10 and 0.
5. With the AMPL-RECT-DIODE switch in the RECT-DIODE position, the meter pointer must fall in the RECTIFIERS OK portion of the scale to be considered good.

EYE TUBES

1. Follow Steps 1 through 7 of the general instructions.

NOTE: The SIGNAL and METER controls may be disregarded when testing eye tubes and may therefore be set in any position.

2. Vary the BIAS control and observe the shadow of the eye tube. Failure of the shadow to change as the BIAS control is rotated indicates a defective tube. Failure of the eye to close completely does NOT indicate a defective tube but only means that the tube's characteristics are "out of range" of the bias values available.

ROLL CHART DATA

The roll chart contains necessary data for the checking of currently used tubes. But it is not always possible to furnish a roll chart that has all the latest tubes on it, because of the constantly growing list of tubes and the time it takes to obtain sample tubes, conduct tests, and publish roll charts. Therefore, to keep your roll chart up-to-date, you may be interested in subscribing to the Heathkit Tube Test Data Service, which will regularly supply you with the latest data for newly released tubes. To subscribe to this service, fill out and send in the Heathkit Tube Test Data Service Card.

TESTING UNLISTED TUBES

The following procedure may be used as a guide in determining control and switch settings for testing tubes not listed on the roll chart or supplement sheet. Testing a tube in this manner will show the tube to be either operative or inoperative, but will not indicate the degree of operative condition. While there may be several combinations of control and switch settings that will produce a meter deflection, valid Gm readings can be obtained only by that combination of settings determined in the laboratory as correct for that tube type. If several tubes of the same type are available, they may be tested on a comparison basis to determine which has the greater amplification under a given set of test conditions.

SELECTOR Switch Positions

The SELECTOR switches correspond to tube pins, reading left to right, top to bottom.

Position 0 - The tube pin is disconnected from all voltage supplies and all other tube pins.

- Position 1 - Cathode bus.
- Position 2 - Suppressor grid bus.
- Position 3 - Plate bus.
- Position 4 - Screen grid bus.
- Position 5 - Control grid bus.
- Position 6 - Heater connection (high side).
- Position 7 - Heater connection (ground side).
- Position 8 - Space charge grid bus.

The above listed positions are active when the K, P and G switches are in the #1 Position. With these switches in the #2 Position, the cathode bus, plate bus and control grid bus are switched to the K, P and G positions of the SELECTOR switches.

PLATE Switch Positions

- 0 - 26 V DC
- A - 20 V AC
- B - 45 V AC
- C - 90 V DC
- D - 135 V DC
- E - 177 V AC
- F - 225 V DC
- G - Variable DC (for VR tubes)

BIAS Control and RANGE Switch

Range switch in L (low) position:

- Control range is 0 to 5 volts negative.
- Control setting of 10 is approximately 1 volt.
- Control setting of 20 is approximately 2 volts, etc.

RANGE switch in H (high) position:

- Control range is 0 to 20 volts negative.
- Control setting of 10 is approximately 4 volts.

Control setting of 20 is approximately 8 volts, etc.

SIGNAL switch positions:

- 1 - 2 volts RMS
- 2 - 1 volt RMS
- 4 - .5 volt RMS
- 8 - .25 volt RMS

The following example is based on the 6AU6 and illustrates the steps involved in testing an unlisted tube type.

1. Reference to a tube manual (Specification Sheet, Schematic Diagram, etc.) shows that pin 1 of the tube is the control grid connection. The SELECTOR switch corresponding to this pin should therefore be placed in the control grid position (Position 5). Pin 2 is the suppressor grid connection; the second SELECTOR switch is placed in Position 2. Pin 3 is a heater connection - SELECTOR switch to either Position 6 or 7 ; Pin 4 (other heater connection) connects to the remaining heater position. Pin 5 is the plate connection - this SELECTOR switch is indexed to Position 3. Pin 6 is the screen grid connection (Position 4 on SELECTOR switch) and Pin 7 is the cathode connection (Position 1). The remaining two SELECTOR switches are not used for a 7-pin tube and are therefore placed in the 0 Position. The SELECTOR switch setup for this tube would be:
52763-4100.
2. Set the FILAMENT switch to the proper voltage or current position. If neither the voltage nor the current can be set exactly as called for, use the next lower voltage value. The 6AU6 would use the 6.3 volt position of the FILAMENT switch.
3. Set the PLATE switch to the available voltage nearest to that specified (always use the lowest plate voltage that will produce a useable meter reading; in addition to subjecting the tube under test to high plate current, excessive plate voltage may give a grid current indication on a good tube). The "Typical Operation" chart for the 6AU6 lists 100 volts as the plate voltage; the PLATE switch should therefore be set to Position C (90 V DC).

4. Adjust the BIAS control and RANGE switch to obtain the desired bias voltage. Referring again to the "Typical Operation" chart of the tube manual, it is noted that a bias value of -1.0 volt should be used in conjunction with the 100 volt plate voltage. One volt bias corresponds to a setting of 10 L. (Always use as high a value of bias as possible, consistent with obtaining a useable meter reading. The high bias value will prevent the flow of excessive plate current which might damage the tube, the tester, or both.)
5. The SIGNAL switch should be at Position 8.
6. The METER control should be at maximum counterclockwise.
7. K, P and G switches should be in Position 1. LEAKAGE switch in Position 1.
8. Plug in the tube and observe it closely as it warms up. Turn off the power to the TT-1 at any sign of sparking, gas ignition, overheating, etc. Excessive dimming of the panel lamps may be another indication of trouble. Should any of these unusual conditions exist, carefully recheck the setting of the SELECTOR switches.
9. After the tube has warmed up, rotate the LEAKAGE switch through all positions. If the tube passes all leakage tests, place LEAKAGE switch in TUBE TEST position. Pull down the Gm test switch and advance the METER control until the meter shows an indication. Half-scale deflection (LINE

CHECK arrow) is usually a good place to start when comparing several tubes of the same type. If only one tube is to be tested, the existence of a meter reading shows the tube to be responding to the AC signal voltage injected at the grid. Proceed to make the other usual tests on the tube (grid current, etc.).

10. If no meter reading was obtained in Step 9 above, return the METER control to its maximum counterclockwise position and advance the SIGNAL switch to the next higher signal voltage (Position 4). Again advance the METER control. If no meter reading is obtained, move the SIGNAL switch to Position 2. Continue on to Position 1 if necessary. ALWAYS start with METER control maximum counterclockwise to avoid "pinning" the meter.
11. If, after advancing signal voltage to Position 1, no meter reading is obtained, cautiously increase the DC plate current through the tube by either increasing the plate voltage or decreasing the bias.
12. When maximum conditions have been reached (highest plate voltage, 0 bias, highest signal voltage, maximum meter sensitivity) and the meter still shows no deflection, it may be assumed the tube is completely inoperative and should be replaced. Your own experience and knowledge must be relied upon to decide upon replacement in cases where excessive voltage and signal conditions are required to produce a meter reading.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to

incorporate new features in instruments previously sold.

To order replacement parts, refer to the "Replacement Parts Price List" and use the Parts Order Form furnished with this kit.

PARTS LIST

Refer to the Parts Pictorial on the fold-out from
Page 19.

PART No.	PARTS Per Kit	DESCRIPTION	PART No.	PARTS Per Kit	DESCRIPTION
Resistors			Capacitors (cont'd.)		
1-1	1	47 Ω 1/2 watt	25-16	3	20 μ fd 350 volts
1-13	1	2.7 K Ω 1/2 watt	25-20	1	40 μ fd 150 volts
1-16	1	4.7 K Ω 1/2 watt	25-28	2	100 μ fd 50 volts
1-26	1	100 K Ω 1/2 watt (for testing)	25-44	2	25 μ fd 25 volts
1-27	1	150 K Ω 1/2 watt	Transformers-Choke		
1-70	1	22 megohm 1/2 watt (for testing)	46-27	1	Choke
1-74	1	18 megohm 1/2 watt	51-52	1	Oscillator transformer
1-93	1	1.8 K Ω 1/2 watt	54-94	1	Power transformer
1-123	1	100 Ω 1/2 watt 5%	Switches		
1-131	1	620 Ω 1/2 watt 5%	60-1	1	SPST slide
1-28-1	1	100 K Ω 1 watt	60-3	3	DPDT spring return slide
1-50-1	1	2 K Ω 1 watt 5%	60-4	4	SPDT slide
1-51-1	1	4.3 K Ω 1 watt 5%	63-217	9	12-position 1-circuit rotary
1-52-1	1	3 K Ω 1 watt 5%	63-218	1	8-position 6-section rotary
1-10-2	1	47 K Ω 2 watt	63-219	1	6-position 4-section rotary
2-50	1	10 K Ω precision	63-220	1	4-position 1-circuit rotary
2-54	1	200 K Ω precision	63-221	1	20-position 1-circuit rotary
2-58	1	1 K Ω precision	63-222	1	4-position 2-section rotary
2-75	1	225 K Ω precision	63-223	1	2-position 2-section rotary (spring return)
2-101	2	500 Ω precision	62-12	1	2-position 5-circuit lever
2-140	2	250 Ω precision	62-13	1	2-position 9-circuit lever
2-142	1	190 K Ω precision	Sheet Metal Parts		
2-143	1	133 K Ω precision	100-242	1	Panel escutcheon
2-144	1	2.24 K Ω precision	200-237	1	Chassis
3-7-7	1	360 Ω 7 watt	200-238	1	Subchassis
3-19-10	2	2 K Ω 10 watt	203-189-1	1	Panel
Controls			204-190	2	Take-up roller bracket
10-57	2	10 K Ω linear (tab mount)	204-276	1	Right hand roll chart bracket
11-34	1	10 K Ω linear (screwdriver adjust)	204-277	1	Left hand roll chart bracket
11-35	1	7.5 K Ω linear	204-278	1	Right hand subchassis mounting bracket
11-36	1	7.5 K Ω linear (semi-precision)	204-279	1	Left hand subchassis mounting bracket
11-37	1	350 Ω 25 watt	204-280	1	Right hand panel support bracket
Capacitors			204-281	1	Left hand panel support bracket
23-8	1	.02 μ fd 600 volt	204-282	1	Panel lamp mounting bracket
23-15	1	.5 μ fd 400 volt	204-283	1	Reflector bracket
23-53	1	.1 μ fd 400 volt	204-284	1	Calibration switch mounting bracket
23-59	1	.05 μ fd 200 volt			
23-71	1	4 μ fd 200 volt			
23-82	1	.22 μ fd 200 volt 2%			
24-4	1	3-section: 3.6 μ fd at 125 volts AC 3.6 μ fd at 125 volts AC 7.1 μ fd at 125 volts AC			

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
Sheet Metal Parts (cont'd.)		
204-287	1	Capacitor mounting bracket
205-194	1	Meter mounting plate
Cable Harnesses-Wire		
89-3	1	Line cord
134-10	1	Plate switch harness
134-11	1	Leakage switch harness
134-12	1	Grid current switch harness
134-13	1	Selector switch to tube socket harness
134-14	1	Tube socket to tube socket harness
134-15	1	Filament switch harness
134-16	1	Power transformer harness
341-1	1	Length black test lead
344-50	1	Black hookup wire
344-51	1	Brown hookup wire
344-52	1	Red hookup wire
344-53	1	Orange hookup wire
344-54	1	Yellow hookup wire
344-55	1	Green hookup wire
344-56	1	Blue hookup wire
344-57	1	Violet hookup wire
344-58	1	Gray hookup wire
344-59	1	White hookup wire
346-1	1	Length insulated sleeving
Terminal Strips		
431-2	4	2-lug (#6 mounting hole)
431-14	2	2-lug
431-20	6	6-lug
431-32	2	2-lug (#8 mounting hole)
431-33	1	3-lug (#8 mounting hole)
Sockets-Retaining Rings		
432-4	1	Line cord socket
434-1	1	Blank socket
434-4	1	Octal socket
434-6	1	Loctal socket
434-9	1	4-pin socket
434-11	1	5-pin socket
434-12	1	6-pin socket
434-13	1	7-pin socket w/pilot light socket
434-14	1	7-pin miniature socket
434-15	2	7-pin wafer socket
434-17	1	9-pin socket
434-20	1	AC outlet socket
434-21	2	Pilot light socket

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
Sockets-Retaining Rings (cont'd.)		
434-51	1	8-pin round subminiature socket
434-81-1	1	7-pin subminiature socket
435-1	8	Socket ring (1 spare)
435-2	2	7-pin miniature socket ring (1 spare)
435-3	1	Large socket ring
435-4	2	8-pin round subminiature socket ring (1 spare)
435-8	2	7-pin subminiature socket ring (1 spare)
Hardware		
250-2	4	3-48 x 5/16" RHMS
250-15	5	8-32 x 1/8" setscrew
250-18	8	8-32 x 3/8" RHMS
250-26	8	6-32 x 5/8" BHMS
250-29	6	6-32 x 3/4" RHMS
250-43	2	8-32 x 1/4" setscrew
250-89	70	6-32 x 3/8" BHMS
252-1	4	3-48 nut
252-3	44	6-32 nut
252-4	6	8-32 nut
252-7	19	Control nut
252-22	20	6-32 speednut
253-10	19	Control flat washer
253-21	6	Large #6 flat washer
253-36	4	1/4" dished spring washer
254-1	48	#6 lockwasher
254-2	12	#8 lockwasher
254-5	19	Control lockwasher
254-7	4	#3 lockwasher
255-13	4	1/4" spacer
255-37	4	3/4" spacer, tapped 8-32
258-4	2	Spring
259-1	2	#6 solder lug
Miscellaneous		
57-27	5	Silicon diode rectifier
73-2	10	3/4" rubber grommet
73-3	11	1/2" rubber grommet
73-19	1	Length rubber gasket
84-17	1	9-section P. E. C.
84-18	1	7-section P. E. C.
91-104	1	Cabinet
100-210	1	Take-up roller
100-243	1	Drive roller
260-3	2	Tube cap clip
390-88	1	Adhesive label
391-7	1	Nameplate
407-66	1	Meter

PART No. PARTS Per Kit DESCRIPTION

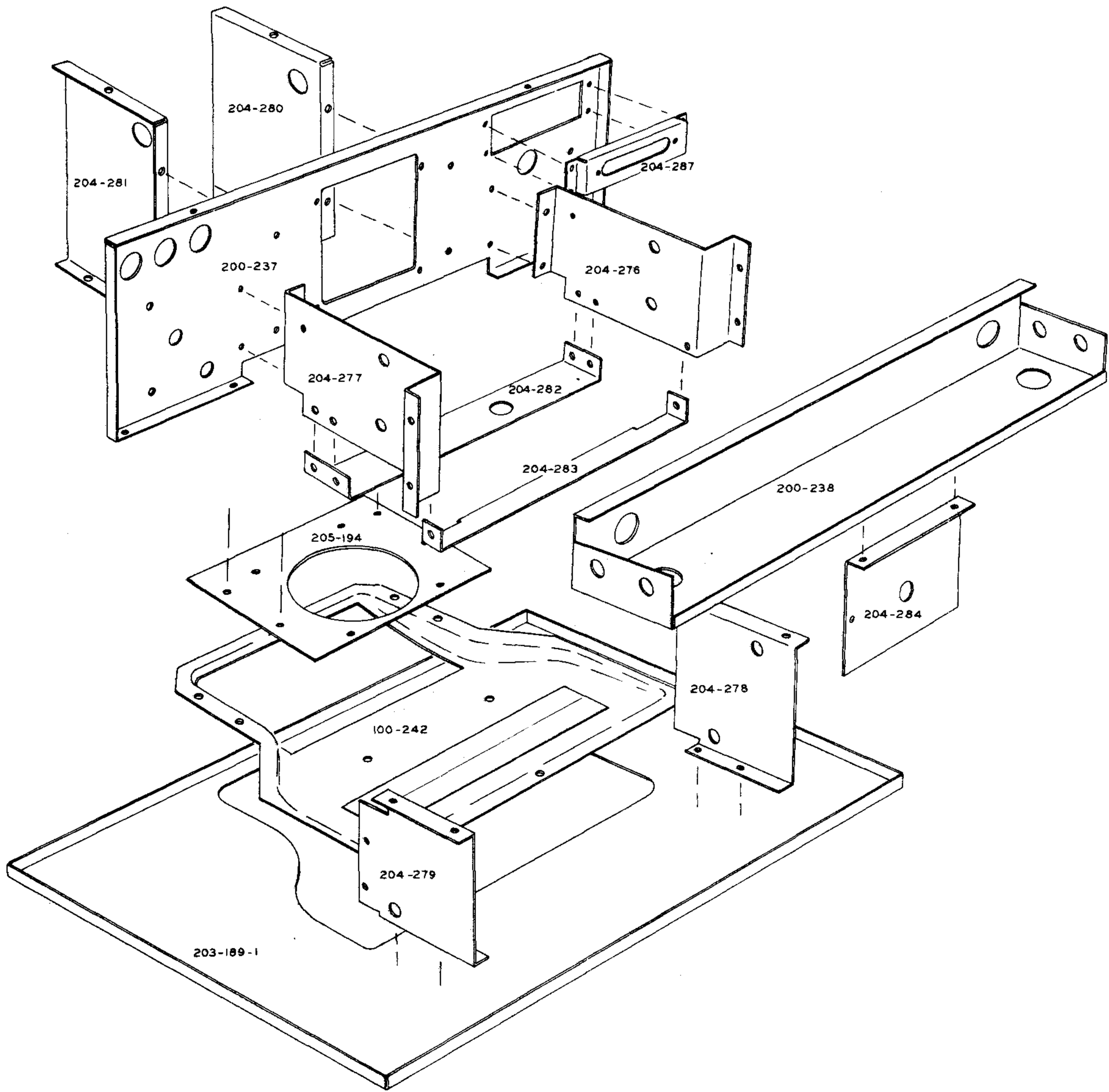
Miscellaneous (cont'd.)

411-11	1	6AU6 tube (for testing)
411-40	1	6AL5 tube (for testing)
411-52	1	12AV6 tube
411-137	1	3A4 tube
412-1	1	#47 pilot lamp
421-3	1	3AG2 ampere fuse
423-4	1	Fuse holder
445-6	1	Roll chart
451-17	1	Roll chart gear
453-48	1	Idler gear shaft

PART No. PARTS Per Kit DESCRIPTION

Miscellaneous (cont'd.)

455-15	5	1/4" retaining collar
462-7	3	Lever switch knob (1 spare)
462-67	19	Pointer knob (1 spare)
462-72	2	Thumb wheel knob
597-10	1	Supplement test sheet
597-397	1	Tube test data service card
	1	Construction manual (See front cover for part number.)
	1	Operational manual (See front cover for part number.)
		Solder



TRANSFORMER VOLTAGE CHART

All voltages measured with SET LINE control adjusted to give voltmeter reading of 100 volts between terminals 10 and 14.

Measurements taken with 5000 ohms per volt (AC) VOM.

Voltage measurements should correspond within $\pm 10\%$ of listed values.

TERMINALS	VOLTAGE	TERMINALS	VOLTAGE
1-2	3	21-8	2.0
1-30	3.3	21-9	1.5
10-11	196	21-22	.65
10-12	177	21-23	1.1
10-13	111	21-24	3.3
10-14	100	21-25	5.0
10-15	75	21-26	47
10-16	67.5	21-27	70
10-17	50	21-28	115
10-18	45	21-29	120
10-19	22.5	21-31	13.0
10-20	20	21-32	20
21-3	35	21-33	27.5
21-4	10.0	35-34	14
21-5	7.5	35-36	100
21-6	6.3	35-37	130
21-7	2.5	38-39	16
		38-40	17.8

OSCILLATOR TUBE VOLTAGE MEASUREMENTS
(With Gm Switch in TEST Position)

Measurements taken with VTVM (11 megohms DC, 1 megohm AC).

Negative Voltmeter Lead	Positive Voltmeter Lead	Voltage
Pin 1 of 3A4 (V1)	Pin 2 of 3A4 (V1)	+30 V DC
Pin 1 of 3A4 (V1)	A6 (on subchassis)	+70 V DC
Pin 1 of 3A4 (V1)	Pin 4 of 3A4 (V1)	-15 V DC
Pin 1 of 3A4 (V1)	R1 (under chassis)	-15 V DC
Pin 1 of 3A4 (V1)	Pin 7 of 3A4 (V1)	2.8 V AC

METER CONTROL TUBE VOLTAGE MEASUREMENTS
(With GRID CURRENT Switch in TEST Position)

Negative Voltmeter Lead	Positive Voltmeter Lead	Voltage
Pin 2 of 12AV6 (V2)	Pin 7 of 12AV6 (V2)	+160 V DC
Pin 2 of 12AV6 (V2)	R2 (under chassis)	+160 V DC
Pin 2 of 12AV6 (V2)	M1 (under chassis)	-5 V DC
Pin 2 of 12AV6 (V2)	Pin 4 of 12AV6 (V2)	12 V AC

REPLACEMENT PARTS PRICE LIST

To order parts, use the Parts Order Form furnished with this kit. If this Form is not

available, refer to "Replacement Parts" in the "Kit Builders Guide."

PART No.	PRICE Each	DESCRIPTION
Resistors		
1-1	.10	47 Ω 1/2 watt
1-13	.10	2.7 K Ω 1/2 watt
1-16	.10	4.7 K Ω 1/2 watt
1-26	.10	100 K Ω 1/2 watt (for testing)
1-27	.10	150 K Ω 1/2 watt
1-70	.10	22 megohm 1/2 watt (for testing)
1-74	.10	18 megohm 1/2 watt
1-93	.10	1.8 K Ω 1/2 watt
1-123	.10	100 Ω 1/2 watt 5%
1-131	.15	620 Ω 1/2 watt 5%
1-28-1	.10	100 K Ω 1 watt
1-50-1	.20	2 K Ω 1 watt 5%
1-51-1	.25	4.3 K Ω 1 watt 5%
1-52-1	.20	3 K Ω 1 watt 5%
1-10-2	.20	47 K Ω 2 watt
2-50	.20	10 K Ω precision
2-54	.20	200 K Ω precision
2-58	.20	1 K Ω precision
2-75	.20	225 K Ω precision
2-101	.60	500 Ω precision
2-140	.20	250 Ω precision
2-142	.30	190 K Ω precision
2-143	.30	133 K Ω precision
2-144	.30	2.24 K Ω precision
3-7-7	.15	360 Ω 7 watt
3-19-10	.20	2 K Ω 10 watt
Controls		
10-57	.35	10 K Ω linear (tab mount)
11-34	1.55	10 K Ω linear (screwdriver adjust)
11-35	2.00	7.5 K Ω linear
11-36	2.25	7.5 K Ω linear (semi-precisi- sion)
11-37	4.35	350 Ω 25 watt
Capacitors		
23-8	.15	.02 μ fd 600 volt
23-15	.60	.5 μ fd 400 volt
23-53	.20	.1 μ fd 400 volt
23-59	.20	.05 μ fd 200 volt
23-71	2.80	4 μ fd 200 volt
23-82	3.25	.22 μ fd 200 volt 2%
24-4	14.40	3-section: 3.6 μ fd at 125 volts AC 3.6 μ fd at 125 volts AC 7.1 μ fd at 125 volts AC

PART No.	PRICE Each	DESCRIPTION
Capacitors (cont'd.)		
25-16	.80	20 μ fd 350 volts
25-20	.60	40 μ fd 150 volts
25-28	.70	100 μ fd 50 volts
25-44	.50	25 μ fd 25 volts
Transformers-Choke		
46-27	2.45	Choke
51-52	3.10	Oscillator transformer
54-94	30.75	Power transformer
Switches		
60-1	.15	SPST slide
60-3	.50	DPDT spring return slide
60-4	.20	SPDT slide
63-217	1.00	12-position 1-circuit rotary
63-218	5.25	8-position 6-section rotary
63-219	3.70	6-position 4-section rotary
63-220	1.55	4-position 1-circuit rotary
63-221	3.05	20-position 1-circuit rotary
63-222	3.20	4-position 2-section rotary
63-223	3.55	2-position 2-section rotary (spring return)
62-12	1.65	2-position 5-circuit lever
62-13	3.00	2-position 9-circuit lever
Sheet Metal Parts		
100-242	1.35	Panel escutcheon
200-237	2.15	Chassis
200-238	1.55	Subchassis
203-189-1	4.40	Panel
204-190	.15	Take-up roller bracket
204-276	.40	Right hand roll chart bracket
204-277	.40	Left hand roll chart bracket
204-278	.45	Right hand subchassis mounting bracket
204-279	.50	Left hand subchassis mounting bracket
204-280	.40	Right hand panel support bracket
204-281	.40	Left hand panel support bracket
204-282	.25	Panel lamp mounting bracket
204-283	.25	Reflector bracket
204-284	.25	Calibration switch mounting bracket
204-287	.35	Capacitor mounting bracket
205-194	.35	Meter mounting plate

<u>PART No.</u>	<u>PRICE Each</u>	<u>DESCRIPTION</u>
Miscellaneous (cont'd.)		
411-52	.80	12AV6 tube
411-137	1.90	3A4 tube
412-1	.15	#47 pilot lamp
421-3	.30	3AG2 ampere fuse
423-4	.70	Fuse holder
451-17	.25	Roll chart gear
453-48	.20	Idler gear shaft
455-15	.10	1/4" retaining collar
462-7	.10	Lever switch knob (1 spare)
462-67	.25	Pointer knob (1 spare)
462-72	.30	Thumb wheel knob
331-6	.15	Solder

<u>PART No.</u>	<u>PRICE Each</u>	<u>DESCRIPTION</u>
Miscellaneous (cont'd.)		
	2.00	Construction manual (See front cover for part number.)
	2.00	Operational manual (See front cover for part number.)

The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from an authorized Service Center or Heathkit Electronic Center to cover local sales tax, postage and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties and rates of exchange.

FACTORY REPAIR SERVICE

You can return your completed kit to the Heath Company Service Department to have it repaired for a minimum service fee. (Kits that have been modified will not be accepted for repair.) If you wish, you can deliver your kit to a nearby Heath Authorized Service Center. These centers are listed in your Heathkit catalog.

To be eligible for replacement parts under the terms of the warranty, equipment returned for factory repair service, or delivered to a Heath Authorized Service Center, must be accompanied by the invoice or the sales slip, or a copy of either. If you send the original invoice or sales slip, it will be returned to you.

If it is not convenient to deliver your kit to a Heath Authorized Service Center, please ship it to the factory at Benton Harbor, Michigan and follow the following shipping instructions:

Prepare a letter duplicate, containing the following information:

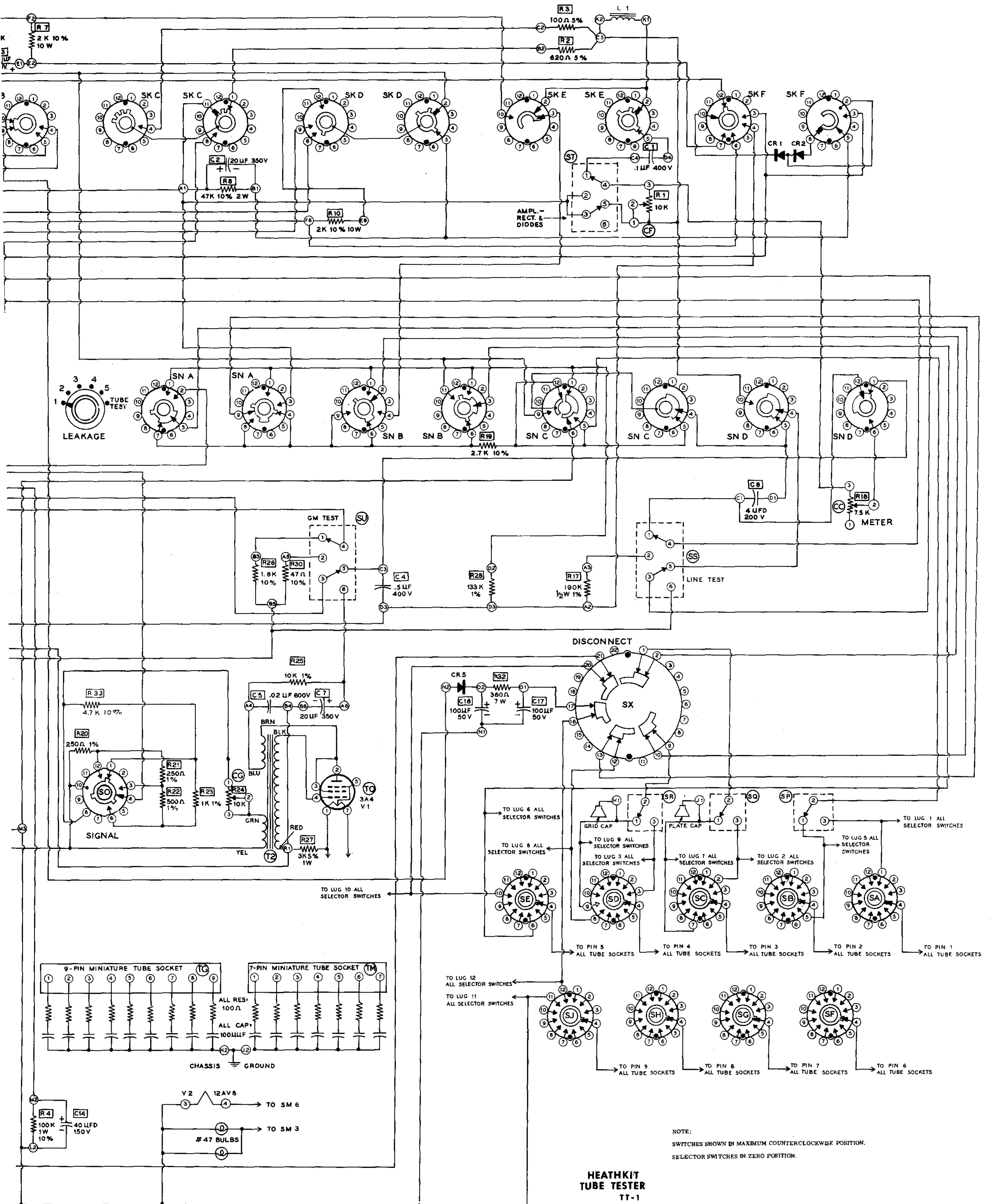
- Your name and return address.
- Date of purchase.
- A brief description of the difficulty.
- The invoice or sales slip, or a copy of either.

- Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the warranty.

Attach the envelope containing one copy of this letter directly to the unit before packaging, so that we do not overlook this important information. Send the second copy of the letter by separate mail to Heath Company, Attention: Shipping Department, Benton Harbor, Michigan.

Check the equipment to see that all parts and screws are in place. (Do not include wooden cabinets when shipping receivers, tuners, amplifiers, or TV sets, as these are easily damaged in shipment.) Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least THREE INCHES of resilient packing material (shredded paper, excelsior, etc.) on all sides, between the equipment and the carton. Seal the carton with gummed paper tape, and tie it with a strong cord. Ship it by prepaid express, United Parcel Service, or insured parcel post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022



NOTE:
 SWITCHES SHOWN IN MAXIMUM COUNTERCLOCKWISE POSITION.
 SELECTOR SWITCHES IN ZERO POSITION.

INTRODUCTION

A vacuum tube possesses a number of operating characteristics, any one of which may be used to indicate operational capabilities of the tube. Any number of tube testing devices are available, utilizing one or more of these characteristics, each one subject to its own limitations. It is universally recognized that no tube tester can provide a complete and accurate account of the condition existing within a given vacuum tube when that tube is in operation in the equipment. If maximum benefit is to be obtained from a tube

tester, regardless of its design, two things should be known:

1. the requirements placed on the tube.
2. the limitations of the tube tester.

With this thought in mind, we have listed some of the more commonly used methods of tube testing.

EMISSION TESTING

Testing the emission capabilities of the cathode provides the simplest and most economical means of determining the overall quality of a vacuum tube. This is accomplished by connecting all the grids to the plate and operating the tube as a rectifier. The actual emission of the cathode is then compared to a predetermined value accepted as standard for that tube type. If the cathode should have one particularly active portion, the emission checker will indicate the quality of the tube to be good, even though the

remainder of the cathode may be inactive. On the other hand, modern coated cathodes are capable of large emission, often far in excess of the emission required for the particular application. In some cases the emission checker will indicate the quality of the tube to be questionable or even unacceptable. This tube may not function in an application requiring a large emission but would probably operate satisfactorily for a long time in a circuit where the emission requirements are less stringent.

TRANSCONDUCTANCE TESTING

A transconductance tester places a standard voltage on each tube element, creating a plate current flow. Measurement of this plate current will indicate the transconductance of that particular tube under static conditions. Here again,

since the tube is not operating EXACTLY as it does in the equipment, the test may be termed inconclusive. An improved version of the transconductance test is available in:

DYNAMIC TRANSCONDUCTANCE TESTING

The dynamic transconductance of a tube is measured by using the circuit of the static transconductance tester and adding a signal generator. By applying a signal to the grid of the tube under test, the action of the plate current will be similar to that experienced in the receiver, varying in relationship to the input signal. This system gives an indication of how the tube

will operate under signal conditions, but is still somewhat limited. Certain types of tubes cannot be completely checked on any type of tester, even the dynamic transconductance tester. Particular offenders in this respect are tubes used in the vertical and horizontal deflection circuits of television receivers. The only method of accurately checking these tubes is by:

EQUIPMENT TESTING

No tube tester is required in this system of tube testing; simply insert a new tube in the equipment and observe the results. At first glance this appears to be the most inexpensive testing

system available. Bear in mind, however, that if all tubes were to be tested in this manner, a stock of tubes representing an investment of several hundred dollars would be required.