

MODEL **IT-28 Capacitor Checker**

HEATHKIT[®]

ASSEMBLY MANUAL

HEATH COMPANY • NEWTON, MASSACHUSETTS • MICHIGAN



PRICE \$2.00



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595-991-04

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HEATH COMPANY
Benton Harbor, Michigan 49022

Prices and specifications subject to change without notice.

Assembly
and
Operation
of the



CAPACITOR CHECKER

Model IT-28

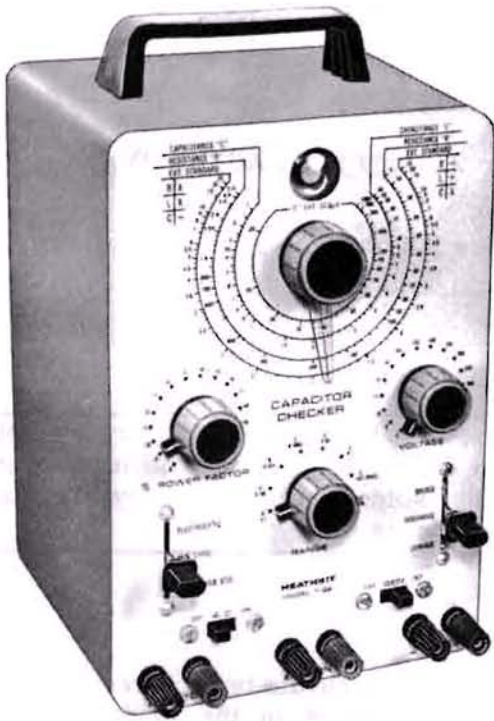


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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

SPECIFICATIONS

Test Circuit	AC bridge, powered by an internal 60 cycle supply or by an external audio generator with 10 volts output (see Page 28, EXT. GEN.). Upper frequency limit: 10 kc.
Capacitance, 5 Ranges	10 $\mu\mu\text{f}$ to .005 μfd . .001 μfd to .5 μfd . .1 μfd to 50 μfd . 20 μfd to 1000 μfd . External standard (comparison bridge; maximum ratio 25:1).
Capacitor Leakage	DC test voltages from 3 to 600 volts in 16 steps.
Resistance, 4 Ranges	5 Ω to 5000 Ω . 500 Ω to 500 K Ω . 50 K Ω to 50 megohms. External standard (comparison bridge; maximum ratio 25:1).
Inductance Check	External standard only.
Power Supply	Transformer-operated, half-wave rectifier.
Power Requirements	105-125 or 210-250 volts AC, 50/60 cycles, 30 watts.
Dimensions	9-5/8" high x 6-5/8" wide x 5" deep.
Net Weight	5 lbs.

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.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

INTRODUCTION

The HEATHKIT Model IT-28 Capacitor Checker is a general-purpose instrument designed for use by servicemen, engineers, and technicians in checking capacitors for value, leakage, shorts, and opens. The Checker may also be used to check resistance, inductance, and transformer turns ratios.

A bridge circuit and eye tube indicator are used

in making quick, accurate tests. Precision resistors and capacitors in the bridge circuit provide a high degree of accuracy and stability.

Terminals are provided on the front panel for the component under test (TEST), an external generator (EXT. GEN.), and external standard (EXT. STD.).

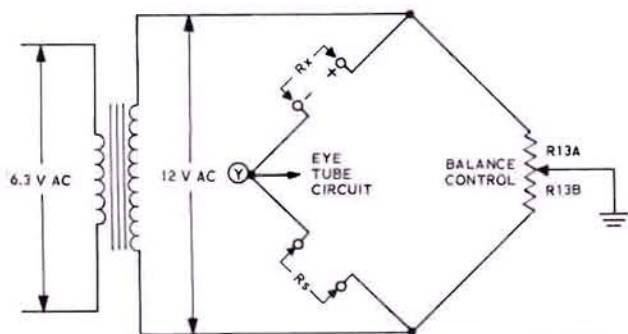
CIRCUIT DESCRIPTION

Frequent reference to the small schematic diagrams in this description will prove helpful in fully understanding how the circuit functions.

The heart of the Capacitor Checker is the AC-powered bridge. Balance control R13 is used to vary the resistance of two arms of the bridge. The third arm is the standard (internal or external) and the fourth arm is the component being tested.

BRIDGE RATIO CALCULATIONS

Referring to Figure 1, assume that $R_x = R_s$ (any value) and that Balance control R13 is in the center of its range so that $R_{13A} = R_{13B}$ (500 Ω each). Under this condition, with the bridge balanced and with R_x equal to R_s , the ratio of R_{13A} to $R_{13B} = 1:1$.



AC INPUT TO BRIDGE TRANSFORMER MAY BE 6.3 VOLTS FROM HEATER LINE OR FROM EXTERNAL GENERATOR.

$R_{13A} = R_{13B} = 1000 \Omega$ BALANCE CONTROL

$R_x =$ UNKNOWN

$R_s =$ STANDARD

Figure 1

If R_x did not equal R_s , balance of the bridge would occur with the Balance control at some point other than the center of its range. When balance occurs with $R_{13A} = 600 \Omega$, then $R_{13B} = 400 \Omega$. The ratio is now $600/400$, or $1.5:1$.

When balance occurs with $R_{13A} = 800 \Omega$, then $R_{13B} = 200 \Omega$. The ratio is $800/200$, or $4:1$.

Turning the Balance control changes the values of R_{13A} and R_{13B} . When the bridge is balanced, R_{13A} times $R_s = R_{13B}$ times R_x . Then the voltage at Y (see Figure 1) is minimum and the eye tube opens. The bridge circuit is basically the same for all types of measurements; only the standards and the unknown values change.

MEASURING RESISTANCE

When checking resistance, R_s becomes the resistance standard and R_x is the unknown resistance. The value of R_x is indicated on the front panel by the Balance control pointer when the bridge is balanced.

MEASURING CAPACITANCE

LOWER RANGES - $C \times .0001$ and $C \times .01$

Referring to Figure 2, the standard, C_s , is a capacitor (internal or external), and C_x is the unknown capacitance being measured. As in measuring resistance, the Balance control is adjusted for balance of the bridge. At balance R_{13A} times $X_{Cs} = R_{13B}$ times X_{Cx} . In this case, X_{Cs} is the capacitive reactance of C_s and X_{Cx} is the capacitive reactance of C_x .

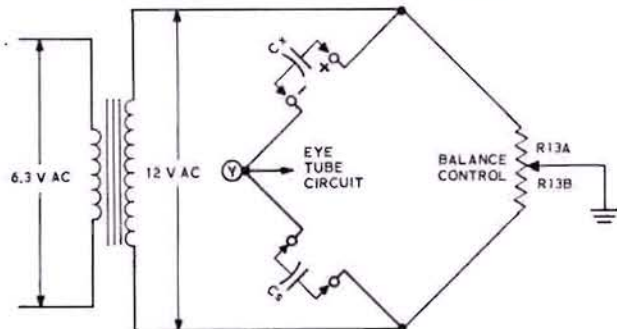


Figure 2

HIGHER RANGES - $C \times 1$ and C EXT Scale

Capacitors are measured on the higher ranges just as described for the two lower ranges, except for electrolytics.

Since electrolytic capacitors have a certain amount of internal series resistance, it is necessary to use POWER FACTOR control R14 along with Balance control R13 to properly balance the bridge. See Figure 3. The POWER FACTOR control is used to cancel the effect of series resistance in electrolytic capacitor C_x , and is used only on the two higher ranges. The formula for finding the series resistance of an electrolytic capacitor is:

$$\text{Series Resistance} = \frac{\% \text{ PF}}{2 \pi \text{ FC}}$$

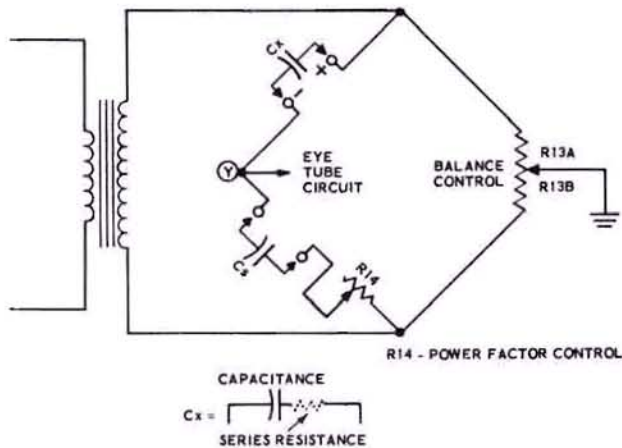


Figure 3

% PF = percent power factor
 $\pi = 3.14$
 F = frequency of applied voltage
 C = capacity in farads

For example, the series resistance of a $2 \mu\text{fd}$ capacitor with 5% PF at 60 cycles would equal:

$$\frac{.05}{2 \pi \times 60 \times 2 \times .000001} = 66.3 \Omega$$

NOTE: The POWER FACTOR control is calibrated, using internal $2 \mu\text{fd}$ capacitor C6 as a standard, at 60 cps. Therefore, when using an external generator at a frequency other than 60 cps, the value indicated by the POWER FACTOR control must be corrected by a factor of $\frac{FT}{60}$. FT is the external applied frequency.

EXAMPLE: Determine the % PF of a capacitor which measures 5% PF at 120 cps.

$$\% \text{ PF} = \text{measured \% PF} \times \frac{FT}{60}$$

$$\% \text{ PF} = .05 \times \frac{120}{60}$$

$$\% \text{ PF} = 10\%$$

USING THE EXTENDED SCALE

The capacitance scale is extended by adding 9000Ω resistor R34 in series with Balance control R13. The bridge is balanced as before, using the Balance control, plus the POWER FACTOR control for electrolytics. However,

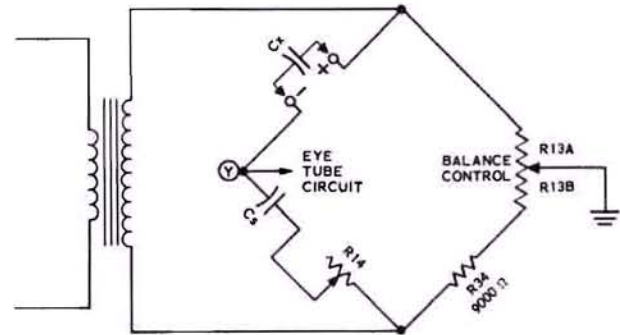


Figure 4

the ratio has now been changed due to the addition of R34. With the Balance control in the center of its range, $R13A = 500 \Omega$ and $R13B = 500 \Omega$. Therefore, the ratio is:

$$\frac{9000 \text{ plus } 500}{500} = 19:1$$

The standard internal capacitance value is $2 \mu\text{fd}$, which makes the center scale reading equal to 19 times $2 \mu\text{fd}$, or $38 \mu\text{fd}$. The remainder of the "C" EXTENDED SCALE is calculated in the same way.

MEASURING INDUCTANCE

Again, the bridge is balanced using Balance control R13. At balance, $R13A \text{ times } XLs = R13B \text{ times } XLx$. Here XLs = the inductive reactance of the standard, and XLx = the inductive reactance of the component being tested. An external standard must be used when measuring inductance.

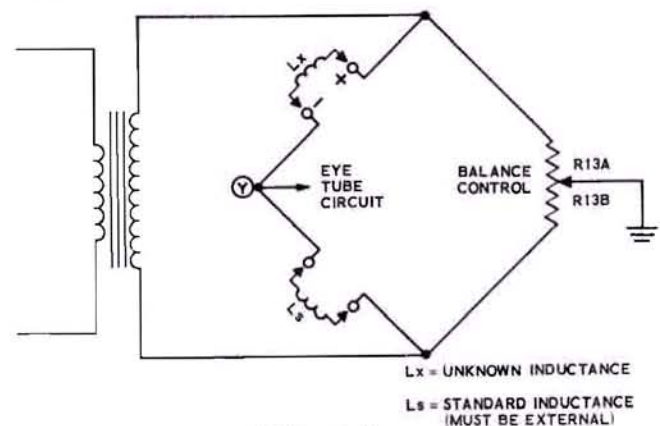
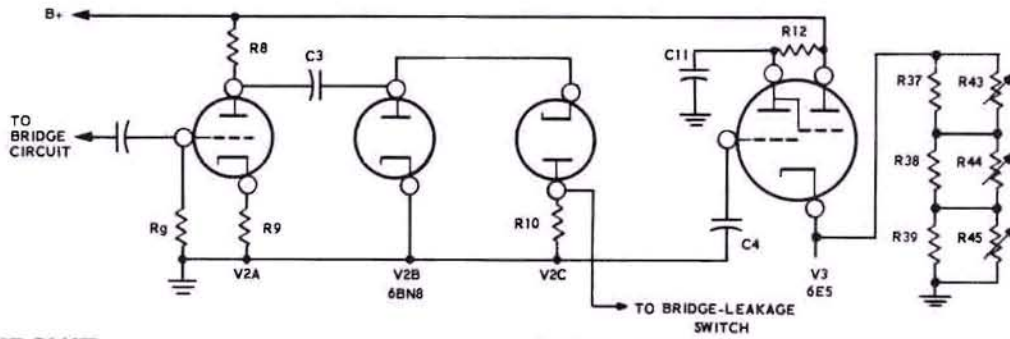


Figure 5

The AC series resistance (characteristic) of the external component should be similar to that of the test component to permit balancing, as the POWER FACTOR control is not used in the external standard circuit.

Figure 6



EYE TUBE CIRCUIT

When the bridge circuit is not balanced, an AC signal voltage is applied from point Y of the bridge to the grid of amplifier stage V2A. The amplified signal from V2A is then applied to the voltage-doubler rectifier circuit, consisting of V2B, V2C, C3, and C4. The resulting negative DC voltage is applied to the grid of eye tube V3, closing the eye.

When the bridge is balanced, no signal is applied from the bridge to V2A. Therefore, no negative DC voltage is present at the grid of the eye tube, and the eye stays open.

CAPACITOR LEAKAGE

CHECKING LEAKAGE

When checking a capacitor for leakage, V2A is connected as a DC amplifier. When voltage is applied to the capacitor under test, through 10 KΩ limiting resistor R40, the capacitor charges, drawing current through grid resistor Rg of V2A. The voltage drop across this resistor causes V2A to conduct due to a positive voltage developed on its grid. This changes the voltage at the plate of V2A and at the grid of the eye tube, causing the eye to close. When the capacitor is fully charged, current ceases to flow through grid resistor Rg, and the grid voltage of V2A returns to its original value. The plate voltage of V2A also returns to its original value and the eye tube opens. This indicates a good capacitor.

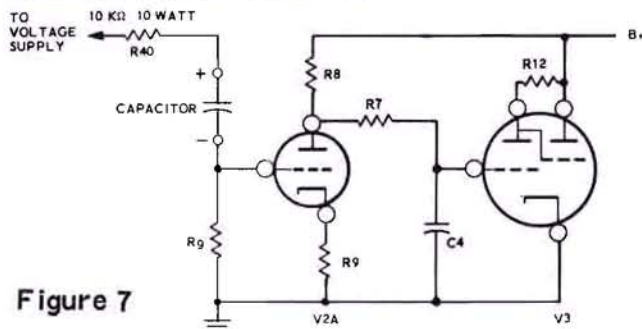


Figure 7

If the capacitor being checked is leaky or shorted, current continues to flow through grid resistor Rg, preventing the eye tube from opening.

Calibrate controls R43, 44, and 45, connected in parallel with Type switch resistors R37, 38 and 39, are adjusted for proper grid current through Rg for different types of capacitors.

LEAKAGE DISCHARGE

When the BRIDGE-LEAKAGE switch is moved from the LEAKAGE position to the DISCHARGE position, the capacitor under test is shunted to ground through resistors R40 and R36. During the resulting discharge time, a voltage is again developed at the grid of amplifier stage V2A. In turn, V2A causes a change in the grid voltage of eye tube V3, causing the eye to close. After the capacitor has discharged, the voltage on the grid of tube V2A returns to its original value and the eye tube opens.

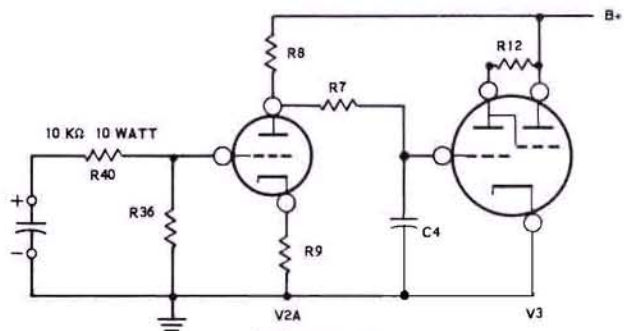


Figure 8

POWER SUPPLY

The transformer-operated power supply uses V1 in a half-wave rectifier circuit. The fused primary circuit of the transformer is symmetrically bypassed with C9 and C10 for increased accuracy when measuring low capacitance at 60 cps. The filament circuit is effectively center tapped with R41 and R42. Capacitors C1 and C2, with resistors R1, R2, R3, R4, and R5 make up a filter-voltage divider network to provide proper DC voltages to the circuit.

CONSTRUCTION NOTES

This manual is supplied to assist you in every way to complete your kit with the least possible chance for error. The arrangement shown is the result of extensive experimentation and trial. If followed carefully, the result will be a stable instrument, operating at a high degree of dependability. We suggest that you retain the manual in your files for future reference, both in the use of the instrument and for its maintenance.

UNPACK THE KIT CAREFULLY AND CHECK EACH PART AGAINST THE PARTS LIST. In so doing, you will become acquainted with the parts. Refer to the charts and other information on the inside covers of the manual to help you identify the components. If some shortage or parts damage is found in checking the Parts List, please read the Replacement section and supply the information called for therein.

Resistors generally have a tolerance rating of 10% unless otherwise stated in the Parts List. Tolerances on capacitors are generally even greater. Limits of +100% and -20% are common for electrolytic capacitors.

We suggest that you do the following before work is started:

1. Lay out all parts so that they are readily available.
2. Provide yourself with good quality tools. Basic tool requirements consist of a screwdriver with a 1/4" blade; a small screwdriver with a 1/8" blade; long-nose pliers; wire cutters, preferably separate diagonal cutters; a pen knife or a tool for stripping insulation from wires; a soldering iron (or gun) and rosin core solder. A set of nut drivers and a nut starter, while not necessary, will aid extensively in construction of the kit.

Most kit builders find it helpful to separate the various parts into convenient categories. Muffin tins or molded egg cartons make convenient trays for small parts. Resistors and capacitors may be placed with their lead ends inserted in the edge of a piece of corrugated cardboard until they are needed. Values can be written on the cardboard next to each component. The illustration shows one method that may be used.



PARTS LIST

To order a replacement part, refer to the "Replacement Parts Price List" and use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of the Manual.

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
RESISTORS		
1-3	4	100 Ω 1/2 watt (brown-black-brown)
1-119	2	560 Ω 1/2 watt (green-blue-brown)
1-7	2	680 Ω 1/2 watt (blue-gray-brown)
1-8	1	820 Ω 1/2 watt (gray-red-brown)
1-9	1	1000 Ω 1/2 watt (brown-black-red)
1-44	1	2200 Ω 1/2 watt (red-red-red)
1-16	1	4700 Ω 1/2 watt (yellow-violet-red)
1-20	9	10 K Ω 1/2 watt (brown-black-orange)
1-25	4	47 K Ω 1/2 watt (yellow-violet-orange)
1-26	1	100 K Ω 1/2 watt (brown-black-yellow)
1-29	2	220 K Ω 1/2 watt (red-red-yellow)
1-35	1	1 megohm 1/2 watt (brown-black-green)
1-36	2	1.5 megohm 1/2 watt (brown-green-green)
2-83	2	200 Ω 1/2 watt 1% precision
2-35	1	9000 Ω 1/2 watt 1% precision
2-38	1	20 K Ω 1/2 watt 1% precision
2-55	1	2 megohm 1/2 watt 1% precision
1-5-1	1	22 K Ω 1 watt (red-red-orange)
1-18-2	1	33 K Ω 2 watt (orange-orange-orange)
1-10-2	4	47 K Ω 2 watt (yellow-violet-orange)
3-7-10	1	10 K Ω 10 watt wire-wound
CAPACITORS		
20-2	1	200 $\mu\mu\text{f}$ molded mica (red-black-brown)
21-71	2	.001 μfd disc ceramic 1400 V
29-40	1	.02 μfd polystyrene
23-59	1	.05 μfd tubular
23-28	1	.1 μfd tubular

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
Capacitors (cont'd.)		
27-47	1	.1 μfd Mylar*
23-56	1	.5 μfd tubular
27-58	1	2 μfd Mylar*
25-41	2	40 μfd 350 V electrolytic

CONTROLS--SWITCHES

10-58	3	100 K Ω tab-mount control
11-101	2	1000 Ω (1 K Ω) control, wire-wound
60-1	1	SPST slide switch
60-2	1	DPDT slide switch
62-15	1	3-position lever switch
62-16	1	3-position lever switch
63-503	1	16-position rotary switch
63-504	1	8-position rotary switch

TUBES--TRANSFORMERS

411-128	1	6BN8 tube
411-120	1	6E5 tube
411-156	1	6AX4 tube
51-80	1	Bridge transformer
54-34-24	1	Power transformer

CONNECTORS--TERMINAL STRIPS--SOCKETS

100-16-2	3	Binding post cap, black
100-16-18	3	Binding post cap, red
427-3	6	Binding post base
431-1	2	Dual-lug terminal strip
431-12	1	4-lug terminal strip
431-11	2	5-lug terminal strip
431-16	1	2-lug terminal strip
434-31	1	Octal socket
434-12	1	6-pin tube socket
434-77	1	9-pin tube socket

METAL PARTS--KNOBS

90-414	1	Cabinet
200-525	1	Chassis
203-250-2	1	Front panel
462-97	2	Lever switch knob
455-50	4	Knob bushing
462-245	3	Knob
462-253	1	Pointer knob

HARDWARE

250-2	2	3-48 x 5/16" screw
250-18	2	8-32 x 3/8" screw
250-26	4	6-32 x 5/8" screw
250-48	4	6-32 x 1/2" screw

*DuPont Registered Trademark



<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
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Hardware (cont'd.)

250-89	17	6-32 x 3/8" screw
250-83	2	#10 sheet metal screw
252-1	2	3-48 nut
252-3	27	6-32 nut
252-4	2	8-32 nut
252-7	4	Control nut
252-22	2	Speednut
253-9	4	#8 flat washer
253-10	4	Control flat washer
254-7	2	#3 lockwasher
254-1	20	#6 lockwasher
254-2	1	#8 lockwasher
254-5	2	Small control lockwasher
254-4	2	Control lockwasher
255-1	1	1/8" spacer
255-13	4	1/4" spacer
259-1	6	#6 solder lug
259-2	1	#8 solder lug
208-6	1	Mounting clip

<u>PART No.</u>	<u>PARTS Per Kit</u>	<u>DESCRIPTION</u>
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INSULATORS-WIRE

73-1	4	Grommet
75-17	12	Binding post insulator
75-30	1	Strain relief, round cord
75-71	1	Strain relief, flat cord
89-23	1	Line cord
134-38	1	Wire harness
344-59	1	Hookup wire

MISCELLANEOUS

207-53	1	Tube retaining clamp
211-15	1	Handle
261-9	4	Rubber foot
421-20	1	1/2 ampere slow-blow fuse
422-1	1	Fuseholder
432-27	1	Line cord adapter
391-34	1	Identification label
490-5	1	Nut starter
597-260	1	Parts Order Form
597-308	1	Kit Builders Guide
	1	Manual (See front cover for part number.)
		Solder

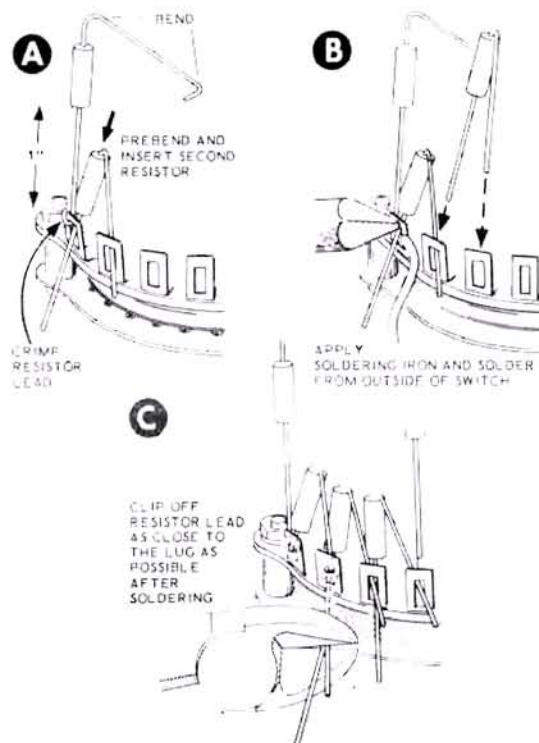
STEP-BY-STEP ASSEMBLY

VOLTAGE SWITCH CC WIRING

To install a resistor on VOLTAGE switch CC, bend one lead against the resistor body before making the connection. Cut off the excess lead after the connection has been soldered. See Detail 1A.

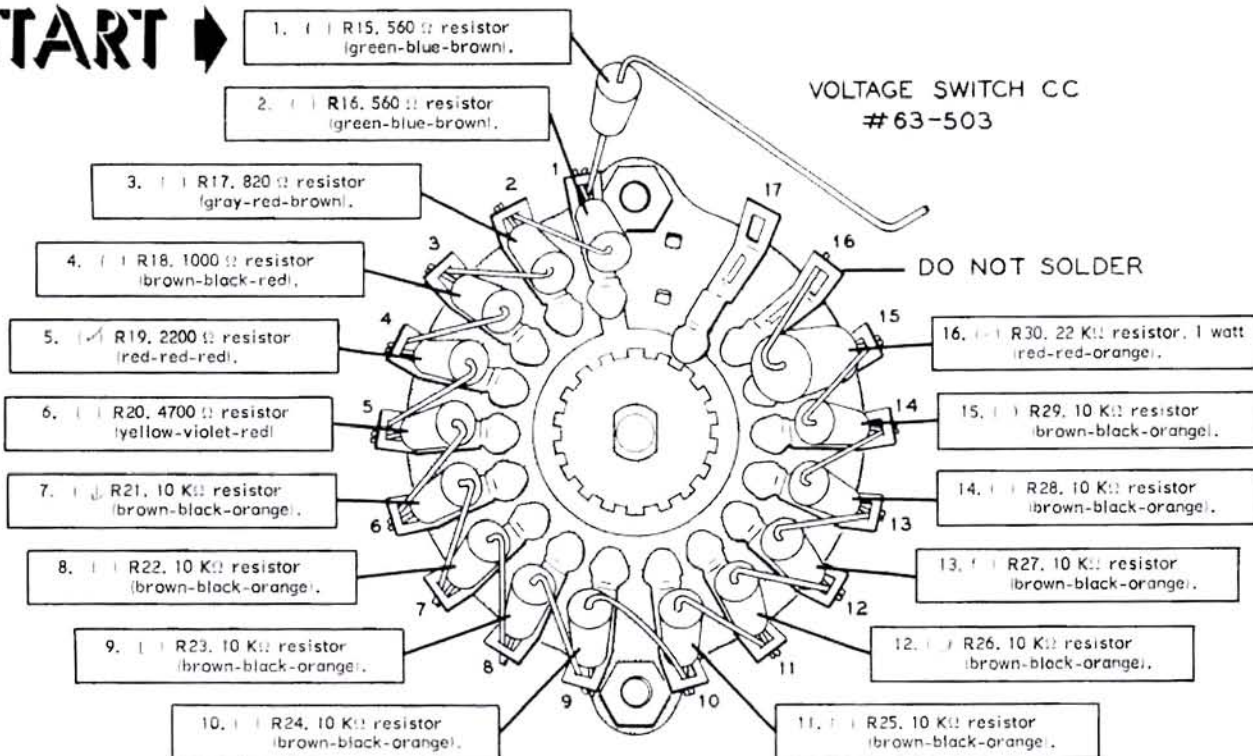
Perform the steps on Pictorial 1. All resistors are 1/2 watt except R30, which is a 1 watt resistor.

After completing the steps on Pictorial 1, check to be sure all connections except lugs 16 and 17 are soldered. Set this switch aside to be installed later.







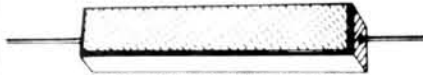
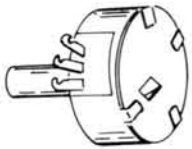
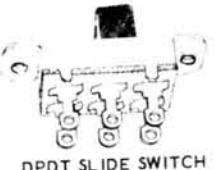



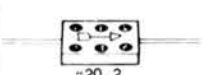
















Detail 1A

START ➔



Pictorial 1

PARTS PICTORIAL

RESISTORS-CAPACITORS		
 <p>1/2 WATT RESISTOR</p>  <p>1/2 WATT 1% PRECISION RESISTOR</p>  <p>1 WATT RESISTOR</p>  <p>2 WATT RESISTOR</p>  <p>10 KΩ 10 WATT WIRE-WOUND RESISTOR</p>	 <p>#11-101 1000 Ω CONTROL WIRE-WOUND</p>  <p>DPDT SLIDE SWITCH</p>	 <p>#252-1 3-48 NUT</p>  <p>#252-3 6-32 NUT</p>  <p>#252-7 CONTROL NUT</p>
 <p>#20-2 200 μf MOLDED MICA CAPACITOR</p>  <p>#27-47 .1 μf MYLAR CAPACITOR</p>  <p>TUBULAR CAPACITOR</p>  <p>MYLAR CAPACITOR (APPEARANCE MAY VARY)</p>  <p>#25-41 40 μf, 350 VOLT ELECTROLYTIC CAPACITOR</p>	<p>CONNECTORS TERMINAL STRIPS</p>  <p>#427-3 BINDING POST BASE</p>  <p>#431-11 5-LUG TERMINAL STRIP</p> <p>HARDWARE-INSULATOR</p>	 <p>#252-22 SPEEDNUT</p>  <p>#254-7 #3 LOCKWASHER</p>  <p>#254-4 CONTROL LOCKWASHER</p>
<p>CONTROLS - SWITCHES</p>  <p>#10-56 100 KΩ TAB-MOUNT CONTROL</p>	 <p>#250-2 3-48 x 5/16" SCREW</p>  <p>#250-18 8-32 x 3/8" SCREW</p>  <p>#250-26 6-32 x 5/8" SCREW</p>	 <p>#255-1 1/8" SPACER</p>  <p>#259-1 #6 SOLDER LUG</p>  <p>#75-17 BINDING POST INSULATOR</p>

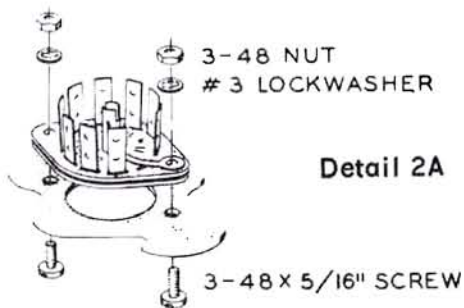
CHASSIS PARTS MOUNTING

Refer to Pictorial 2 (fold-out from Page 10) for the following steps.

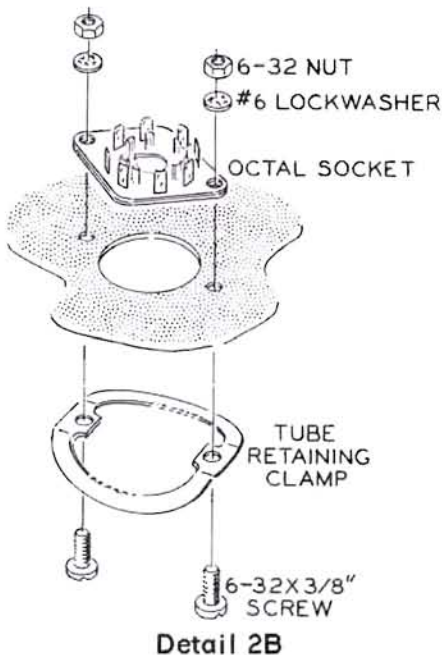
- () Install four rubber grommets in chassis holes A, B, C, and H.
- () Install a speednut at each square cut-out on the rear of the chassis. Make sure the flat side of each speednut faces outward.

NOTE: A plastic nut starter has been provided with this kit. Use it to hold and start nuts on screws. See Page 3 of the Kit Builders Guide for more information.

- () Mount the 9-pin tube socket at V2. Use 3-48 screws, #3 lockwashers, and 3-48 nuts as shown in Detail 2A. Orient the blank space as shown in Pictorial 2.



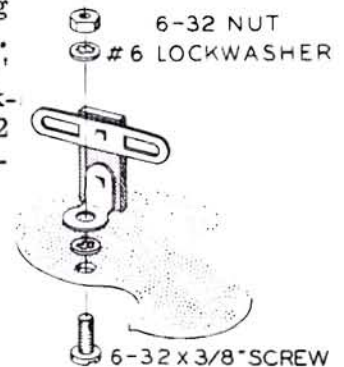
- () Mount the octal tube socket and the tube retaining clamp at V1 as shown in Detail 2B. Use 6-32 x 3/8" screws, #6 lockwashers, and 6-32 nuts. Position the socket with its keyway as shown.



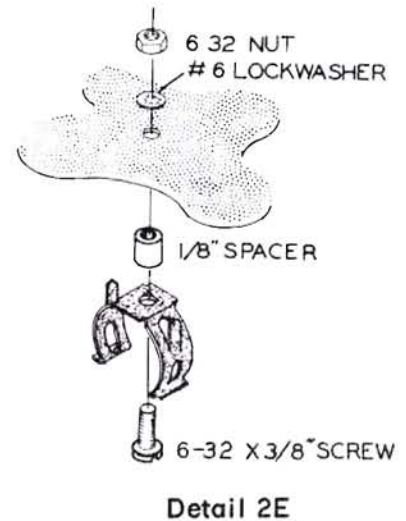
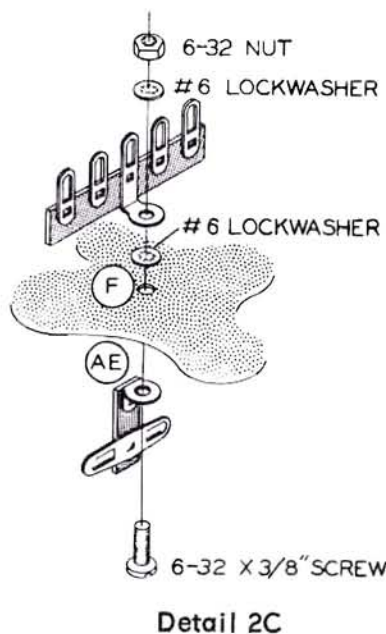
- () Referring to Detail 2C, mount a dual-lug terminal strip at AE and a 5-lug terminal strip at location F on the same mounting screw. Use a 6-32 x 3/8" screw, two #6 lockwashers, and a 6-32 nut.

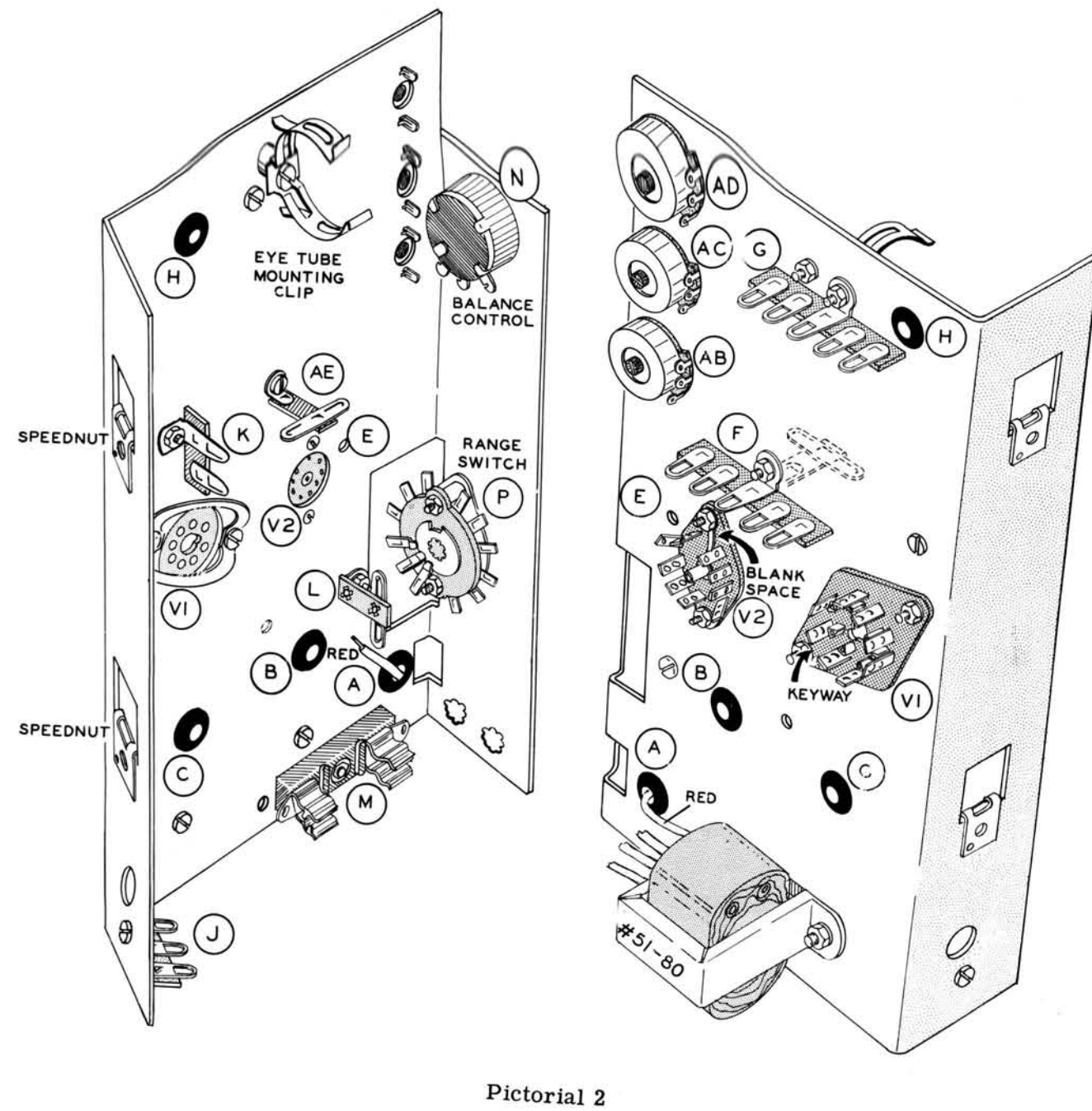
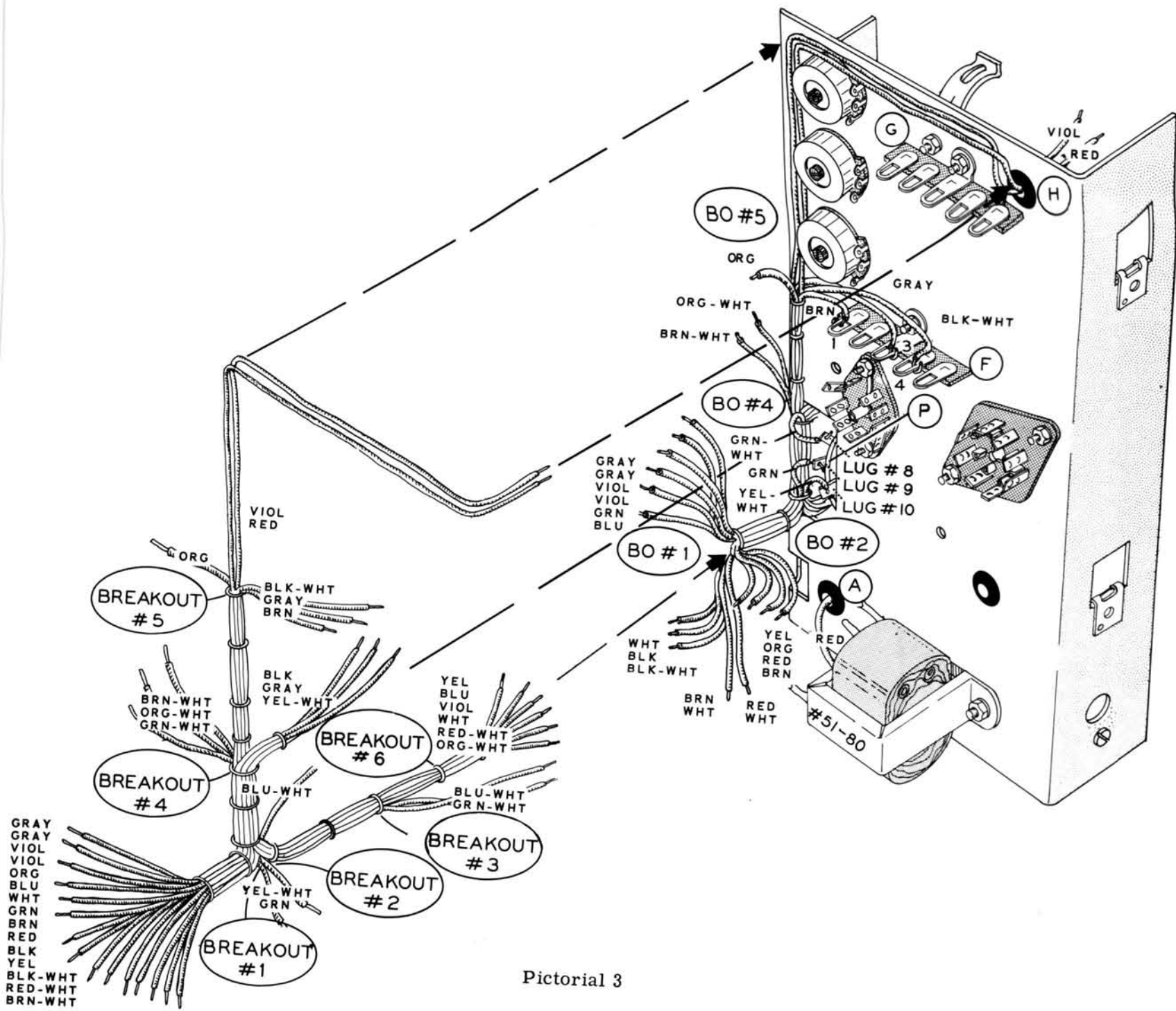
- () Mount a dual-lug terminal strip at L. Use a 6-32 x 3/8" screw, #6 lockwashers, and 6-32 nut as shown in Detail 2D.

Detail 2D



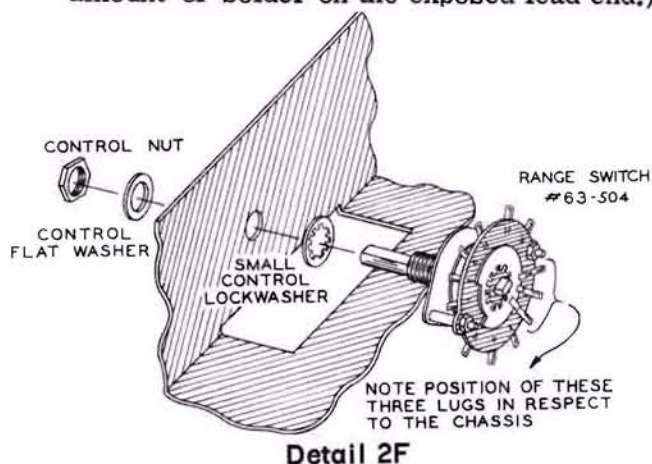
- () Similarly, mount a 2-lug terminal strip at K.
- () Mount 4-lug terminal strip J on the rear flange of the chassis. Use a 6-32 x 3/8" screw, two #6 lockwashers and a 6-32 nut.
- () Mount fuseholder M, using a 6-32 x 3/8" screw, #6 lockwasher, and 6-32 nut.
- () Mount the eye tube mounting clip as shown in Detail 2E. Use a 6-32 x 3/8" screw, 1/8" spacer, #6 lockwasher, and 6-32 nut.
- () Mount 5-lug terminal strip G, using a 6-32 x 3/8" screw, #6 lockwashers, and 6-32 nut. Make sure the terminal strip is mounted on the screw nearest grommet H as shown in Pictorial 2.





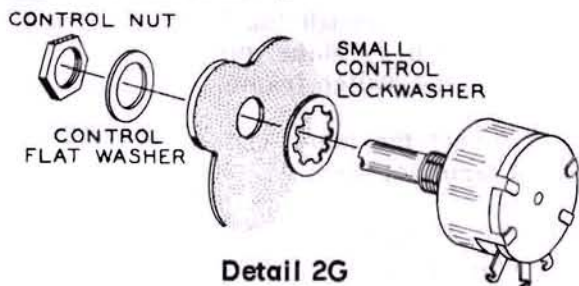
Cut the leads of the bridge transformer (#51-80) to the following lengths:

- | COLOR | LENGTH |
|------------------|--------|
| (✓) Red | 5-1/4" |
| () Red-yellow | 3-1/4" |
| () Black | 2-1/2" |
| () Black-yellow | 2-1/2" |
- () Strip 1/4" of insulation from the end of each lead and tin. ("Tin" means to melt a small amount of solder on the exposed lead end.)



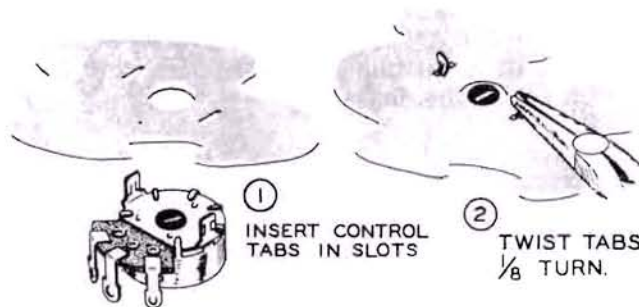
Detail 2F

- () Mount the bridge transformer (#51-80), using 6-32 x 3/8" screws, #6 lockwashers, and 6-32 nuts. Insert the red lead through grommet A to be connected later.
- () Mount the RANGE switch (#63-504) at P. Use a small control lockwasher, a flat washer, and control nut as shown in Detail 2F. Position this switch with its lugs as shown in Pictorial 2.
- () Similarly, mount the Balance control (#11-101) at N. Use a small control lockwasher, a flat washer, and control nut. Position as shown in Pictorial 2.



Detail 2G

- (✓) R43. Refer to Detail 2H and mount a 100 KΩ tab-mount control at AB. Position the control as shown and twist the tabs 1/8 turn to secure the control.



Detail 2H

- (✓) R44, 45. In a like manner, mount 100 KΩ tab-mount controls at AC and AD.

HARNESS AND RANGE SWITCH P WIRING

Refer to Pictorials 3 (fold-out from Page 10) and 4 for the following steps.

- (✓) Locate the wire harness and form it as shown in Pictorial 3.
- (✓) Install the harness on the chassis as shown. Except for the green-white, brown-white, and orange-white wires from breakout #4, and the yellow-white and green wires from breakout #2, all the wires from these two breakouts go through the chassis as shown, on either side of the RANGE switch.
- () Connect the green-white wire from breakout #4 to lug 8 of switch P (S-1).
- () Connect the green wire from breakout #2 to lug 9 of switch P (S-1).
- (✓) Connect the yellow-white wire from breakout #2 to lug 10 of switch P (S-1).

Connect the following three wires from breakout #5 to terminal strip F.

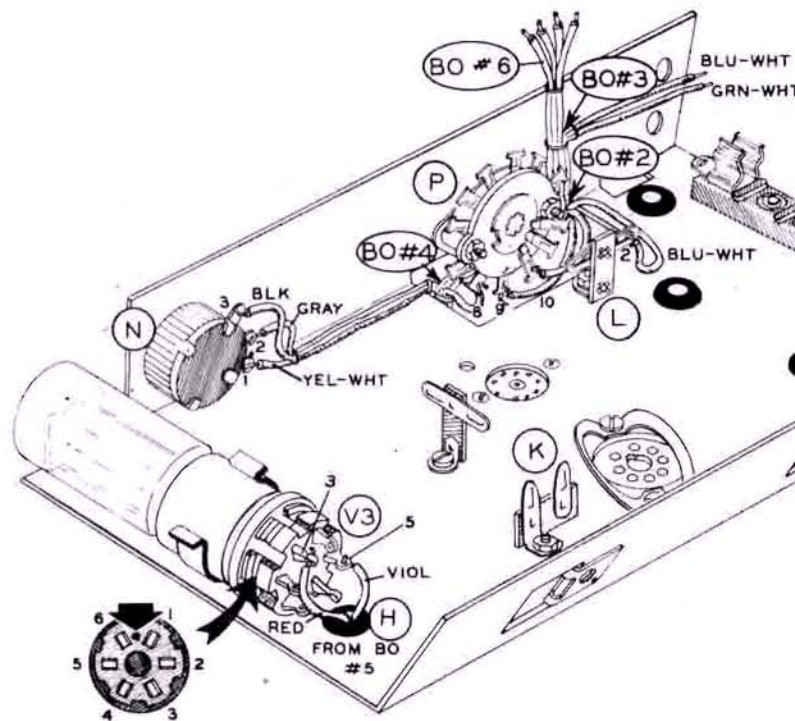
- (✓) Brown wire to lug 1 (NS).
- () Gray wire to lug 3 (NS).
- (✓) Black-white wire to lug 4 (NS).

- () Position the violet and red wires as shown in Pictorial 3 and insert their ends through grommet H.
- () Install the 6-pin tube socket on the 6E5 eye tube. Now place the tube into the eye tube mounting clip as shown in Pictorial 4. Position lugs 1 and 6 of the tube socket just above grommet H. The front end of the eye tube should be flush with the front flange of the chassis.
- () Referring to Pictorial 4, connect the red wire coming through grommet H to lug 3 of tube socket V3 (NS).

- (✓) Connect the violet wire coming through grommet H to lug 5 of tube socket V3 (NS).

Referring to Pictorial 4, connect the following three wires from breakout #4 to control N:

- () Yellow-white wire to lug 1 (S-1).
- (✓) Gray wire to lug 2 (S-1).
- (✓) Black wire to lug 3 (S-1).
- (✓) Position the blue-white wire from breakout #2 as shown and connect it to lug 2 of terminal strip L (NS).



PICTORIAL 4

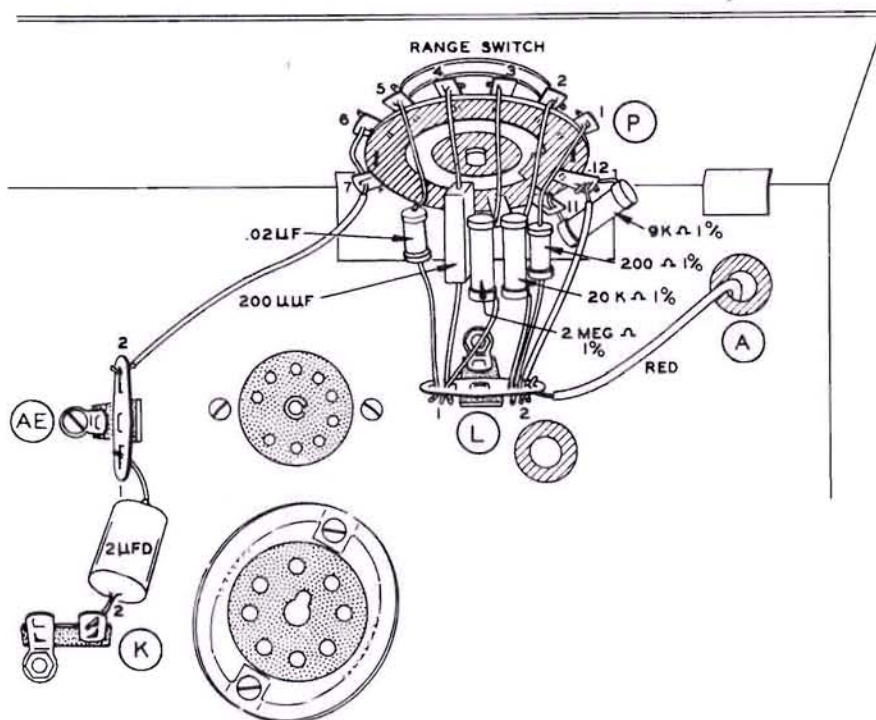
RANGE SWITCH P WIRING

Refer to Pictorial 5 for the following steps.

- () C6. Connect the 2 μ fd Mylar capacitor from lug 1 of terminal strip AE (S-1) to lug 2 of terminal strip K (NS). The appearance of this capacitor may vary.
- () Remove an additional 1/2" of insulation from a 3-1/2" wire. Connect this end of

the wire through lug 7 (S-2) to lug 6 (S-1) of switch P. Make sure the wire does not touch the switch frame.

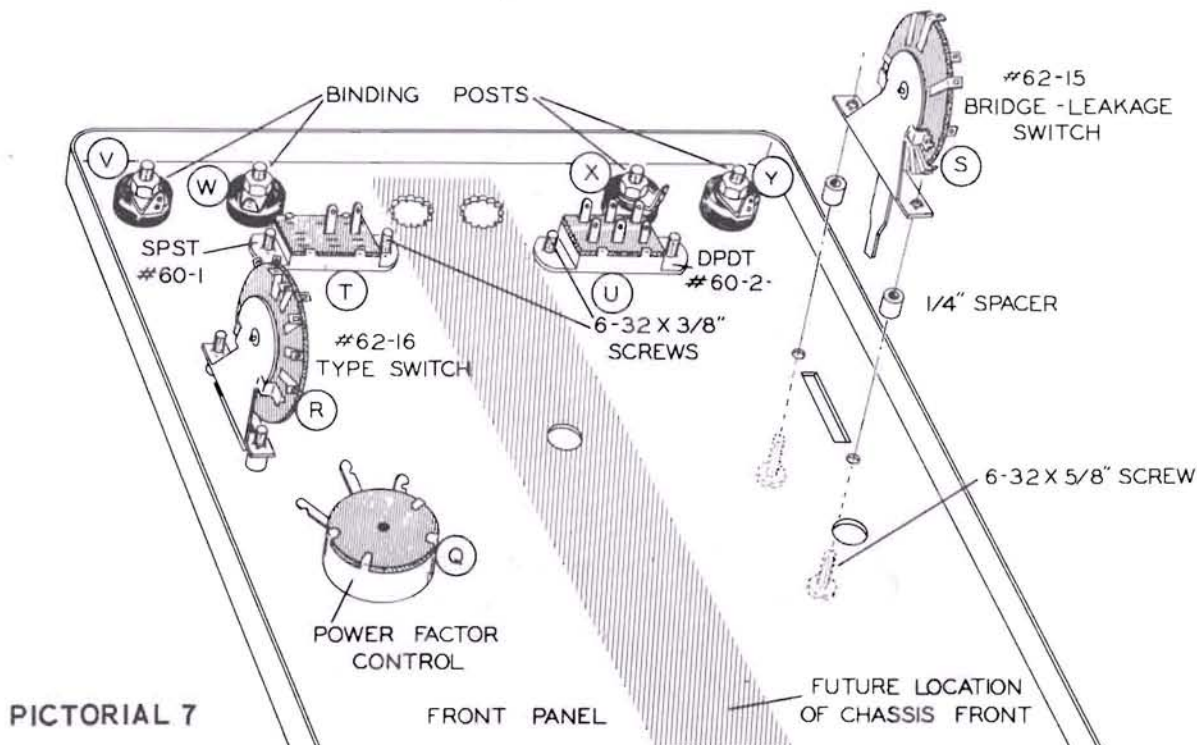
- () Connect the other end of the wire to lug 2 of terminal strip AE (S-1).
- (✓) R34. Connect a 9000 Ω (9 K Ω) precision resistor from lug 11 (S-1) to lug 12 (NS) of switch P. Position the resistor as shown.



PICTORIAL 5

- (✓) Connect a 1-1/2" wire from lug 12 of switch P (S-2) to lug 2 of terminal strip L (NS).
 - (✓) R31. Connect a 200 Ω precision resistor from lug 1 of switch P (S-1) to lug 2 of terminal strip L (NS).
 - (✓) R32. Connect a 20 KΩ precision resistor from lug 2 of switch P (S-1) to lug 2 of terminal strip L (NS).
 - () Connect the red lead from the bridge transformer coming through grommet A, to lug 2 of terminal strip L (S-5).
 - (✓) R33. Connect a 2 megohm precision resistor from lug 3 of switch P (S-1) to lug 1 of terminal strip L (NS).
 - () C7. Connect a 200 μμf (red-black-brown) molded mica capacitor from lug 4 of switch P (S-1) to lug 1 of terminal strip L (NS).
 - () C8. Connect the .02 μfd polystyrene capacitor from lug 5 of switch P (S-1) to lug 1 of terminal strip L (S-3).
- ### CHASSIS WIRING
- Refer to Pictorial 6 (fold-out from Page 19) for the following steps.
- () C3. Connect a .05 μfd capacitor from lug 2 (NS) to lug 7 (NS) of tube socket V2.
 - () Connect a 1-1/2" wire from lug 2 (S-2) to lug 6 (S-1) of tube socket V2.
 - () R7. Connect a 100 Ω (brown-black-brown) 1/2 watt resistor from lug 7 of tube socket V2 (NS) to lug 1 of terminal strip F (S-2). Position as shown.

- () R6. Connect a 1.5 megohm (brown-green-green) 1/2 watt resistor from lug 8 of tube socket V2 (NS) to lug 2 of terminal strip F (NS).
 - () R9. Connect a 680 Ω (blue-gray-brown) 1/2 watt resistor from lug 9 of tube socket V2 (S-1) to lug 3 of terminal strip F (NS).
 - () R10. Pass one lead of a 220 K Ω (red-red-yellow) 1/2 watt resistor through lug 1 of tube socket V2 (NS) to lug 4 of terminal strip F (S-2). Now solder lug 1 of V2 (S-2). Connect the other lead to lug 3 of terminal strip F (NS).
 - () Connect a 5" wire to lug 3 of tube socket V1 (NS). Position this wire beside terminal strip F. The other end will be connected later.
 - () Connect a 7" wire to lug 5 of terminal strip F (NS). Position this wire as shown and insert the other end through grommet H. It will be connected later.
- NOTE: The purpose of using twisted pairs of hookup wire is to provide cancellation of hum in the filament wiring. Best results will be obtained if the wires are twisted approximately two full turns per inch.
- () Twist together two 3-1/2" lengths of hookup wire. At one end of this twisted pair, connect either wire to lug 4 (NS) and the other wire to lug 5 (NS) of tube socket V2.
 - () At the other end of this twisted pair, connect either wire to lug 7 (NS) and the other wire to lug 8 of tube socket V1 (NS).
 - () Twist together two 10" lengths of hookup wire. At one end of this twisted pair, connect either wire to lug 7 (NS) and the other wire to lug 8 (NS) of tube socket V1.
 - () Position this pair as shown in Pictorial 6 and insert the other end through grommet H to be connected later.
 - () C1. Connect a 40 μ fd, 350 V electrolytic capacitor from lug 3 of tube socket V1 (NS) to lug 5 of terminal strip G (NS). The positive (+) lead goes to tube socket V1.
 - () R1. Connect a 47 K Ω (yellow-violet-orange) 2 watt resistor from lug 4 of terminal strip G (NS) to lug 3 of tube socket V1 (NS).
 - () R2. Connect another 47 K Ω (yellow-violet-orange) 2 watt resistor between the same two lugs, lug 4 of terminal strip G (NS) and lug 3 of tube socket V1 (S-4). Position as shown.
 - () R3. Connect a 47 K Ω (yellow-violet-orange) 2 watt resistor from lug 5 of terminal strip F (NS) to lug 4 of terminal strip G (NS).
 - () R4. Connect another 47 K Ω (yellow-violet-orange) 2 watt resistor between the same two lugs, lug 5 of terminal strip F (NS) and lug 4 of terminal strip G (S-4).
 - () R5. Connect a 33 K Ω (orange-orange-orange) 2 watt resistor from lug 5 of terminal strip F (NS) to lug 3 of terminal strip G (NS). Position as shown.
 - () C2. Connect a 40 μ fd, 350 V electrolytic capacitor from lug 3 of terminal strip F (NS) to lug 1 of terminal strip G (NS). The positive (+) lead goes to terminal strip G.
 - () Connect a 3" wire between lug 1 (S-2) and lug 5 (S-2) of terminal strip G. Position as shown.
 - () R37. Cut both leads of a 47 K Ω (yellow-violet-orange) 1/2 watt resistor to 1". Pass one lead through lug 1 (NS) to lug 2 (S-1) of control AB. Pass the other lead through lug 3 of control AB (NS) to lug 1 of control AC (NS).
 - () R38. Cut both leads of a 47 K Ω (yellow-violet-orange) 1/2 watt resistor to 1". Pass one lead through lug 1 (NS) to lug 2 (S-1) of control AC. Pass the other lead through lug 3 of control AC (NS) to lug 1 of control AD (NS). Now solder lug 1 of control AC (S-3).
 - () R39. Cut one lead of a 47 K Ω (yellow-violet-orange) 1/2 watt resistor to 1". Pass this lead through lug 1 (NS) to lug 2 (S-1) of control AD. Connect the other lead to lug 3 of control AD (NS). Now solder lug 1 of control AD (S-3).
 - () Connect a 4" hookup wire from lug 3 of control AD (S-2) to lug 3 of terminal strip G (S-2).
 - () Connect one end of a 7-1/2" wire to lug 1 of control AB (S-3). Dress the wire as shown and pass the free end down through grommet H for connection later.



- () Connect one end of an 11" wire to lug 3 of control AB (S-3). Position the free end of the wire down through the chassis cutout above switch P for connection later.
- () Connect one end of a 12" wire to lug 3 of control AC (S-3). Position the free end of the wire down through the chassis cutout as before, for connection later.

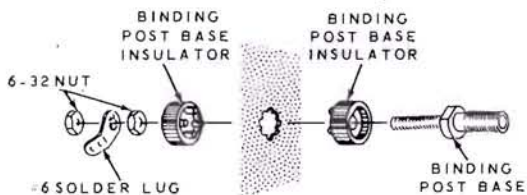
FRONT PANEL ASSEMBLY

Refer to Pictorial 7 for the following steps.

- () Mount the SPST slide switch (#60-1) at T, using 6-32 x 3/8" screws. Position this switch as shown.
- () In the same manner, mount the DPDT slide switch (#60-2) at U.
- () Mount binding post bases at V, W, X and Y as shown in Detail 7A. Position each

solder lug as shown in Pictorial 7. The hole in each binding post base should be parallel with the bottom of the panel. Do not install binding post bases in the EXT. GEN. locations at this time.

- () Mount the BRIDGE-LEAKAGE switch (#62-15) at S. Use 6-32 x 5/8" screws, 1/4" spacers, and position as shown.
- () Similarly, mount the Type switch (#62-16) at R. Position as shown.
- () Mount the POWER FACTOR control (#11-101) at Q. Use a control lockwasher, flat washer, and control nut as shown in Detail 2F. Position as shown in Pictorial 7.
- () Remove the control nut and flat washer from control N and switch P. Mount the front panel on the chassis. Do not pinch any of the harness wires. Now reinstall the flat washer and control nut on control N and switch P. Do not tighten yet.
- () Mount the two remaining binding post bases at AA and BB as shown in Detail 7A. Position the hole in each binding post base parallel with the bottom of the front panel. Position the solder lugs as shown in Pictorial 8 (fold-out from Page 19).
- () Now tighten the control nut on control N and switch P.



Detail 7A

Refer to Pictorial 8 for the following steps.

- () Connect either wire of the twisted pair coming through grommet H to lug 1 of tube socket V3 (S-1). Position as shown.
- () Connect the other wire of this twisted pair to lug 6 of tube socket V3 (S-1).
- () R12. Connect a 1 megohm (brown-black-green) 1/2 watt resistor from lug 2 (NS) to lug 4 (NS) of tube socket V3.
- () Connect the free hookup wire coming through grommet H from lug 5 of terminal strip F to lug 4 of tube socket V3 (S-2).
- () Connect the free end of the hookup wire coming through grommet H, from lug 1 of control AB, to lug 5 of tube socket V3 (S-2).
- () C4. Connect the .5 μ fd tubular capacitor from lug 3 of tube socket V3 (S-2) to lug 1 of terminal strip K (NS). The lead from the banded end of this capacitor goes to terminal strip K.
- () C11. Connect a .1 μ fd tubular capacitor from lug 2 of socket V3 (S-2) to lug 1 of terminal strip K (S-2). The banded end should connect to the terminal strip.
- () Connect an 8-3/4" wire from lug 2 of control Q (S-1) to lug 2 of terminal strip K (S-2). Position this wire under the harness wires going to switch P and around the 2 μ fd capacitor. See Pictorial 8.
- () Connect a 4-1/2" wire from lug 3 of control Q (S-1) to solder lug V (NS). Position as shown.
- () Insert one end of a 1-1/2" wire through grommet A. Connect the other end to solder lug BB (S-1).
- () Insert one end of a 2-1/4" wire through grommet A. Connect the other end to solder lug AA (S-1). The other ends of the two wires just installed will be connected later.
- () Connect a 2-1/2" wire from lug 1 of switch T (S-1) to lug 1 of fuseholder M (S-1).
- () Connect a 2-1/4" wire from lug 2 of fuseholder M (S-1) to lug 4 of terminal strip J (NS).
- () C10. Connect a .001 μ fd disc capacitor from lug 3 (NS) to lug 4 (S-2) of terminal strip J.
- () C9. In the same manner, connect the remaining .001 μ fd disc capacitor from lug 2 (NS) to lug 3 (S-2) of terminal strip J.
- () Separate the three wires of the line cord for a distance of 1-1/2" and remove 1/4" of insulation from the end of each lead.

(-) Twist together the small strands of wire at the end of each lead. Then melt a small amount of solder on the end of each lead to hold the separate strands together.

() Insert the line cord through hole Z as shown.

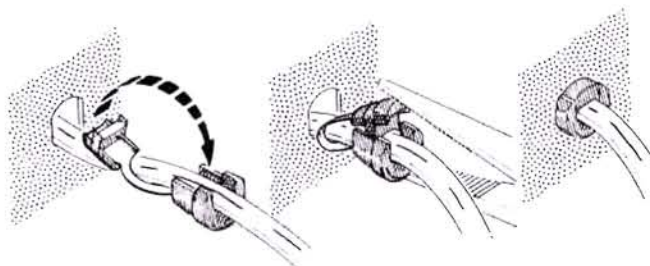
NOTE: Observe that the two edges of the flat line cord are different. One edge is smooth but the other edge is ribbed for identification.

() Connect the smooth line cord wire to the eyelet in lug 4 of terminal strip J (S-1). Refer to the Pictorial to locate eyelets.

() Connect the green line cord wire to the eyelet in lug 3 of terminal strip J (S-1).

(-) Connect the ribbed line cord wire to the eyelet in lug 2 of terminal strip J (S-1).

() Install the proper strain relief in hole Z. Detail 8A shows the strain relief (#75-71) for the flat line cord supplied with the kit. If a round line cord is used, install the other strain relief.



Detail 8A

Referring to Pictorial 8, connect the following harness wires from breakout #6 to Type switch R. Position the wires as shown:

<u>WIRE COLOR</u>	<u>LUG NUMBER</u>
-------------------	-------------------

() Violet 1 (S-1).

() Red-white 4 (NS).

() Orange-white 3 (NS).

() White 5 (NS).

() Yellow 6 (NS).

() Blue 9 (S-1).

(-) Now position the harness away from the movable contact of switch R.

(-) Connect one end of a 6-1/2" wire to lug 7 of switch R (NS). Insert the other end of this wire through hole E. It will be connected later.

() R35. Connect a 47 K Ω (yellow-violet-orange) 1/2 watt resistor from lug 6 (S-2) to lug 7 (S-2) of switch R.

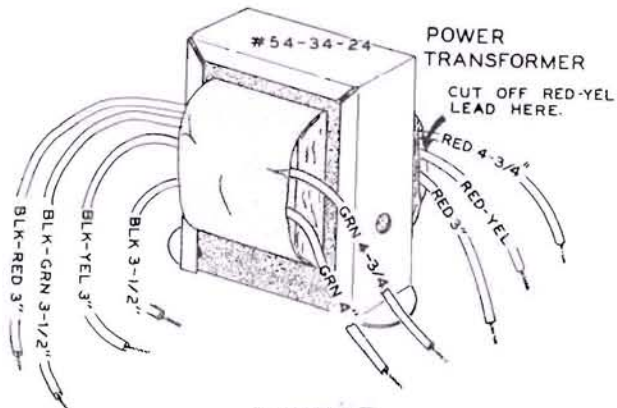
() R11. Connect a 100 Ω (brown-black-brown) 1/2 watt resistor from lug 3 (S-2) to lug 4 (S-2) of switch R.

() Connect the free end of the hookup wire coming through the cutout from lug 3 of control AB to lug 2 of switch R (S-1).

() Connect the free end of the other hookup wire coming through the cutout from lug 3 of control AC to lug 5 of switch R (S-2).

() Connect the green-white wire from breakout #3 to solder lug W (S-1).

() Connect the blue-white wire from breakout #3 to solder lug V (S-2).



Detail 8B

TRANSFORMER WIRING

- (.) Cut the power transformer (#54-34-24) leads to the lengths shown in Detail 8B. Strip 1/4" insulation from each lead end and tin.
- (.) Mount the power transformer in the position shown in Pictorial 8. Use two 8-32 screws, a #8 lockwasher, a #8 solder lug, and 8-32 nuts as shown in Detail 8C. The solder lug should be mounted at SS, on the mounting screw nearest tube socket V1. See Pictorial 10 (fold-out from Page 20). Both green leads go into grommet B and both red leads go into grommet C. They will be connected later.

CAUTION: If necessary, bend lug 2 of fuseholder M away from the transformer frame to prevent shorting the AC line voltage to the chassis.

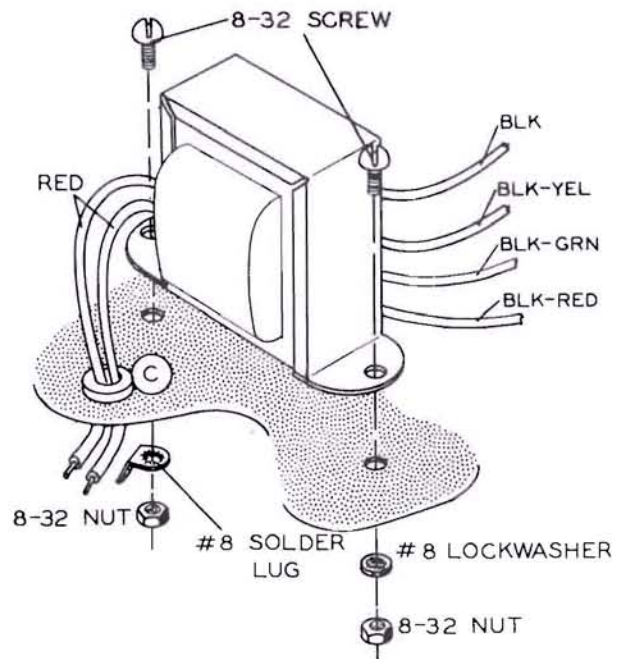
NOTE: The power transformer has dual primary windings and may be connected for either 120 or 240 VAC operation. Perform only the following group of steps that applies to the line voltage in your area.

120 VAC Wiring

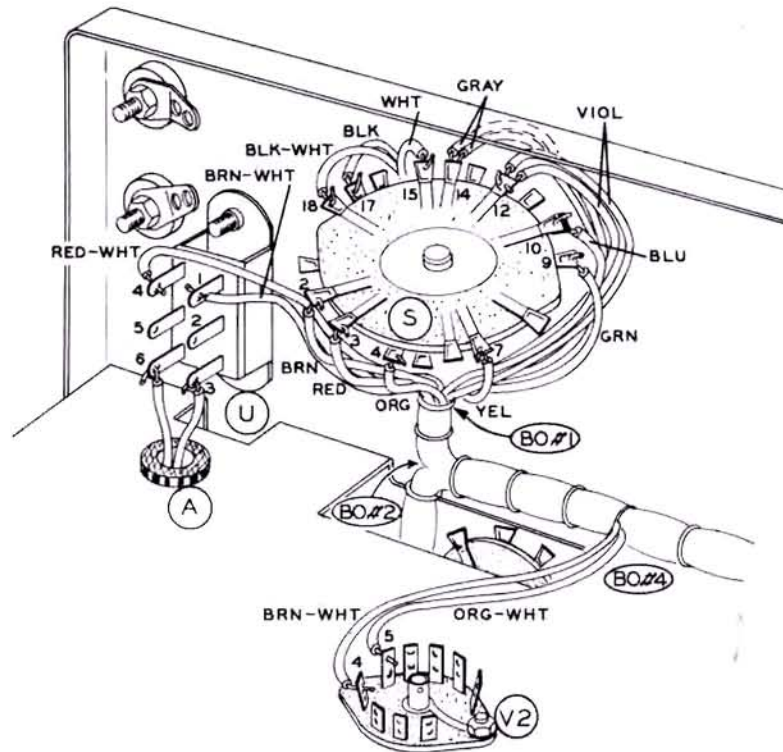
- () Connect the black and the black-green power transformer leads to lug 2 of switch T (S-2).
- () Connect the black-yellow and the black-red power transformer leads to lug 2 of terminal strip J (S-3).

240 VAC Wiring

- () Connect the black power transformer lead to lug 2 of switch T (S-1).
- () Connect the black-red lead to lug 2 of terminal strip J (S-2).
- () Connect the black-green and the black-yellow leads to lug 1 of terminal strip J (S-2).



Detail 8C



CHASSIS BOTTOM-FINAL WIRING PICTORIAL 9

Refer to Pictorial 9 for the following steps.

- () Connect either wire in grommet A to lug 3 of switch U (S-1).
- () Connect the remaining free wire from grommet A to lug 6 of switch U (S-1).
- () Connect the brown-white wire coming from breakout #1 to lug 1 of switch U (S-1).
- () Connect the red-white wire coming from breakout #1 to lug 4 of switch U (S-1).
- () Connect the brown-white wire coming from breakout #4 to lug 4 of tube socket V2 (S-2).
- () Connect the orange-white wire coming from breakout #4 to lug 5 of tube socket V2 (S-2).

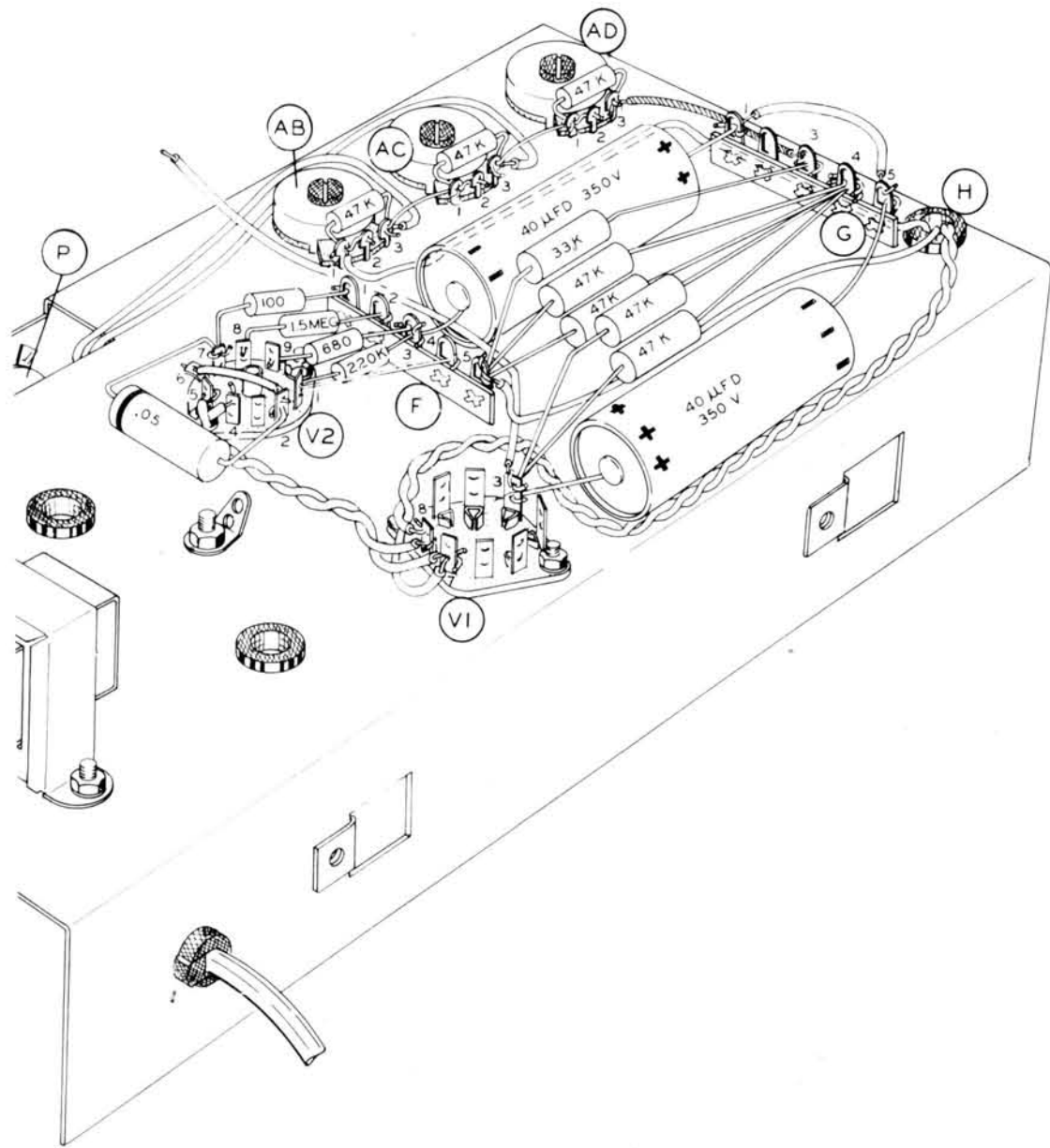
NOTE: Switch S will be wired next. Temporarily loosen the two mounting screws holding switch S to the front panel. This will provide more room for wiring of the switch. It is not necessary to completely remove the screws.

- () Before making connections, route the har-

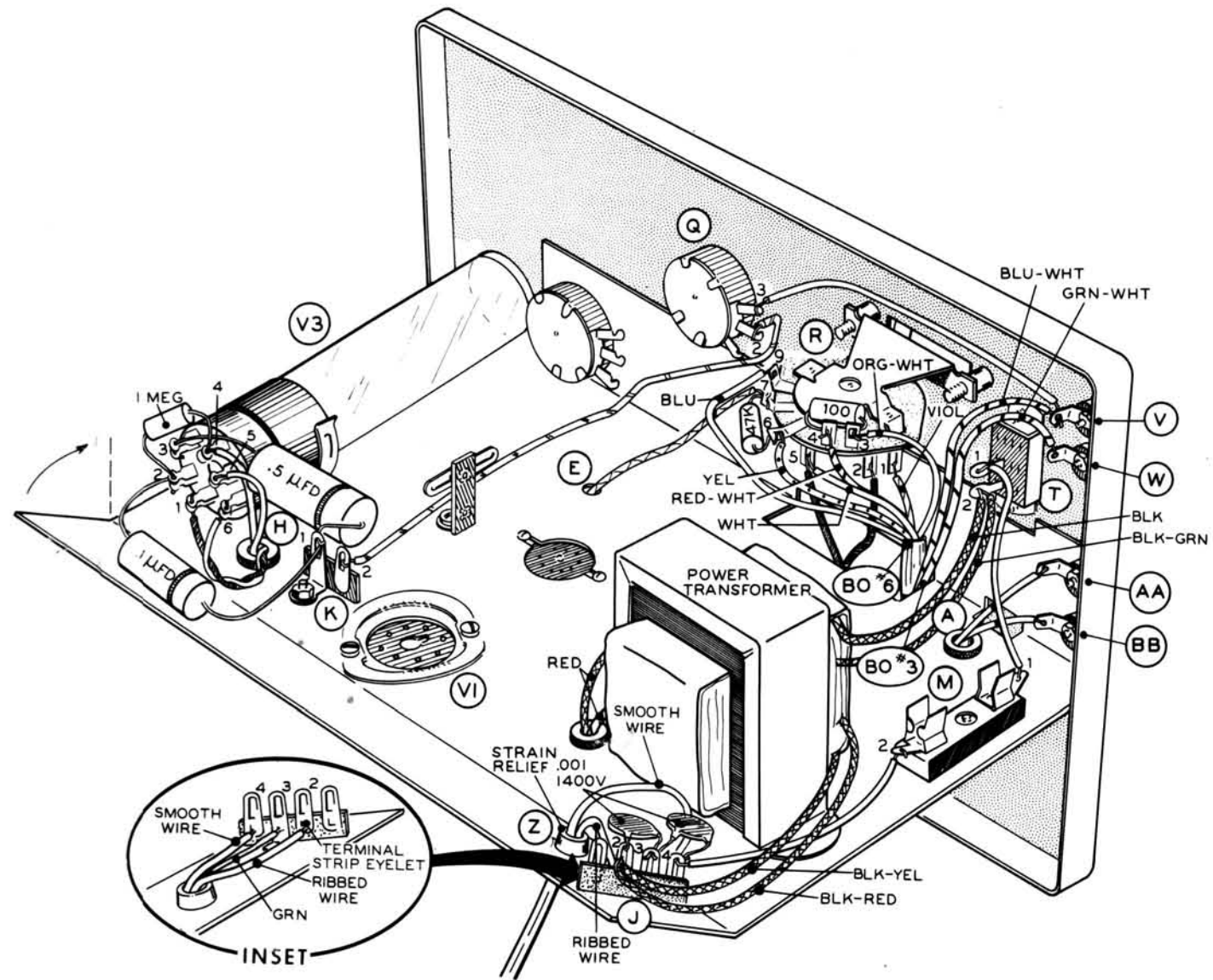
ness wires from breakout #1 to their terminating points on switch S. See Pictorial 9.

Connect the following harness wires from breakout #1 to BRIDGE-LEAKAGE switch S. Position the wires as shown in Pictorial 9.

WIRE COLOR	LUG NUMBER
() Brown	2 (S-1).
() Red	3 (S-1).
() Orange	4 (S-1).
() Yellow	7 (NS).
() Green	9 (S-1).
() Blue	10 (S-1) solder both lugs.
() Both violet	12 (S-2).
() Both gray	14 (NS).
() White	15 (S-1).
() Black	17 (NS).
() Black-white	18 (S-1).



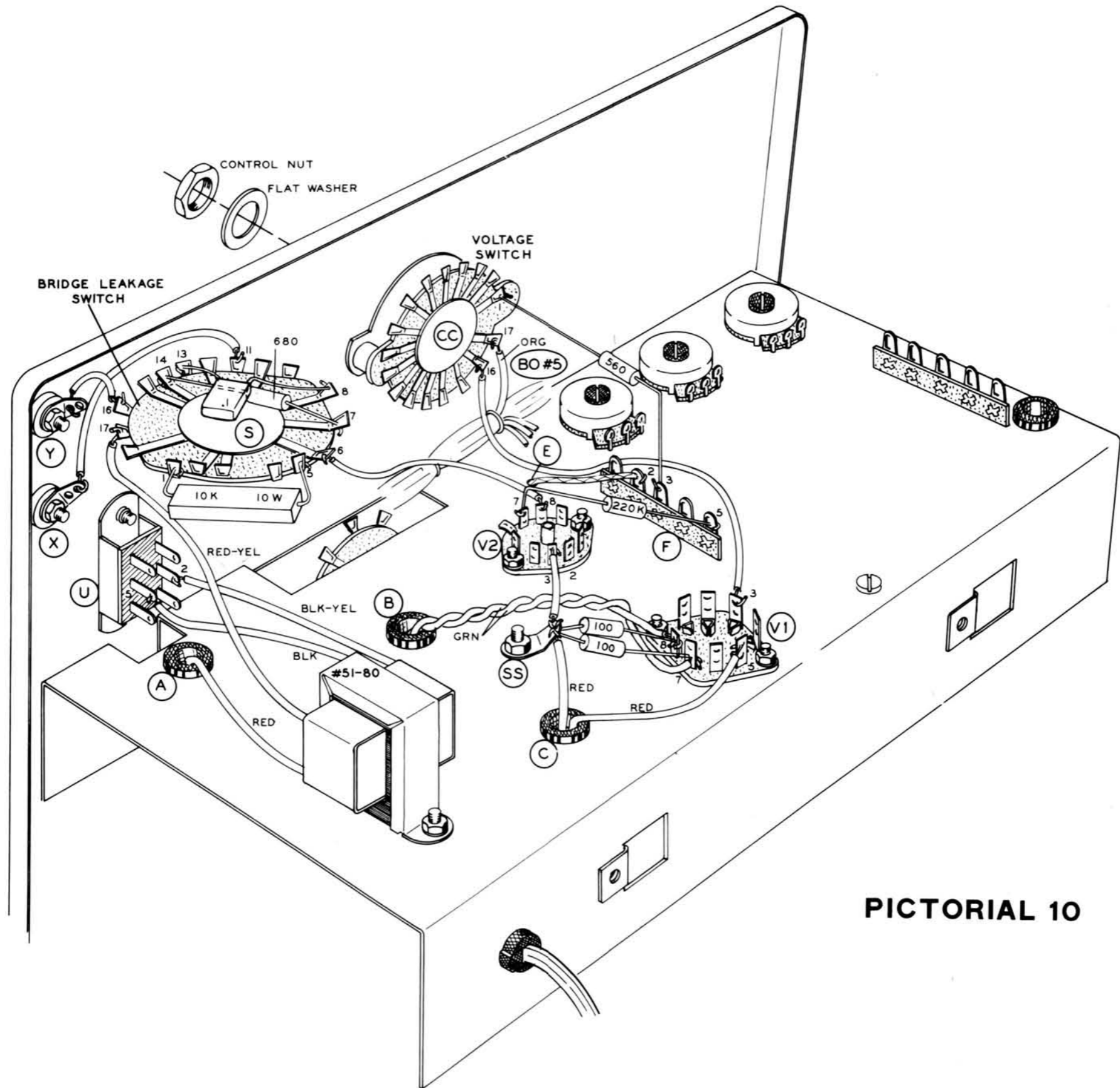
PICTORIAL 6



PICTORIAL 8

Refer to Pictorial 10 for the following steps.

- () Connect the free end of the wire coming from hole E to lug 2 of terminal strip F (S-2).
 - () Connect a 3-1/2" wire from solder lug X (S-1) to lug 11 of switch S (S-1). Position as shown.
 - () Connect a 1-1/2" wire from solder lug Y (S-1) to lug 16 of switch S (S-1).
 - () R36. Connect a 680 Ω (blue-gray-brown) 1/2 watt resistor from lug 14 (S-3) to lug 7 (S-2) of switch S. Solder both lugs. Make sure the resistor leads do not touch any metal part of the switch.
 - () C5. Connect a .1 μ fd Mylar capacitor from lug 13 (S-1) to lug 8 (S-1) of switch S. Make sure the capacitor leads do not touch any other switch contacts.
- NOTE: The mounting screws for switch S may now be retightened. Do not pinch any of the wires when tightening the screws.
- () Connect the black-yellow lead from the bridge transformer to lug 2 of switch U (S-1).
 - () Connect the black lead from the bridge transformer to lug 5 of switch U (S-1).
 - () Connect the red-yellow lead from the bridge transformer to lug 17 of switch S (S-2).
 - () Twist together the two green power transformer leads, coming from grommet B, and connect either lead to lug 7 of tube socket V1 (NS).
 - () Connect the other green lead to lug 8 of tube socket V1 (NS).
 - () R41. Connect a 100 Ω (brown-black-brown) 1/2 watt resistor from lug 7 of tube socket V1 (S-4) to solder lug SS (NS).
 - () R42. Connect the remaining 100 Ω (brown-black-brown) 1/2 watt resistor from lug 8 of tube socket V1 (S-4) to solder lug SS (NS).
 - () Connect the shorter red lead from the power transformer to solder lug SS (NS).
 - () Connect the remaining red lead from the power transformer to lug 5 of tube socket V1 (S-1).
 - () Connect a 2" wire between lug 3 of tube socket V2 (S-1) and solder lug SS (S-4).
 - () R8. Connect a 220 K Ω (red-red-yellow) 1/2 watt resistor from lug 5 of terminal strip F (S-5) to lug 7 of tube socket V2 (S-3). Position as shown in Pictorial 10.
 - () Connect a 4" wire from lug 8 of tube socket V2 (S-2) to lug 6 of switch S (S-1).
 - () R40. Connect a 10 K Ω 10 watt wire-wound resistor from lug 1 (S-1) to lug 5 (S-1) of switch S. Position as shown in Pictorial 10.
 - () Locate VOLTAGE switch CC (#63-503) and, using a control lockwasher, flat washer and control nut, mount it with its lugs in the position shown in Pictorial 10. If necessary, bend the resistors of this switch inward to avoid interference with the wiring of tube socket V2.



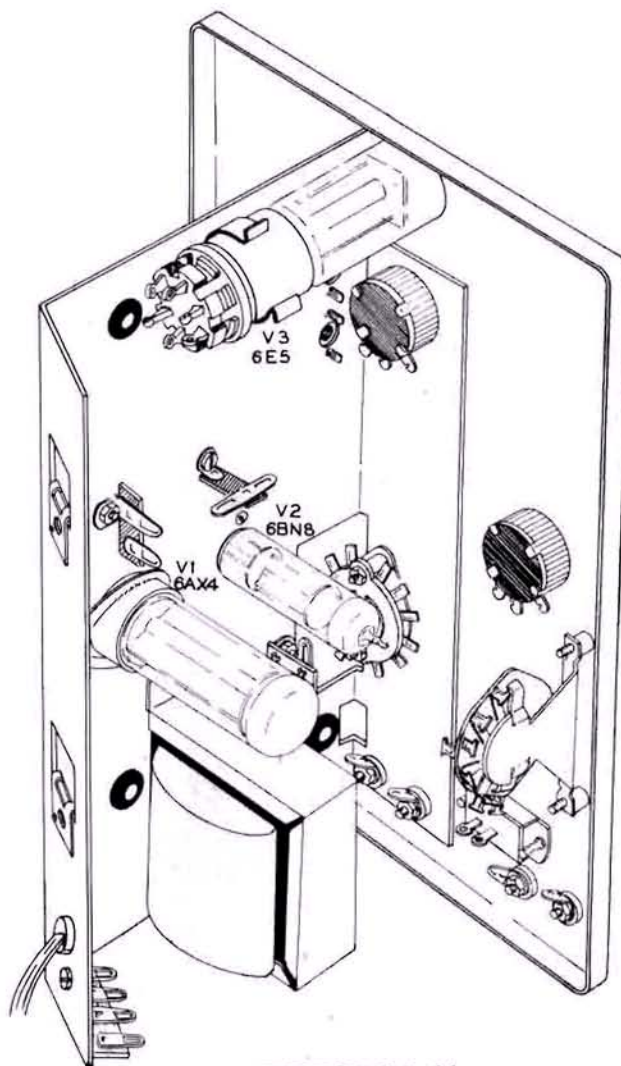
PICTORIAL 10

- () Connect the wire coming from lug 3 of tube socket V1 to lug 16 of switch CC (S-2).
- () Connect the orange wire coming from break-out #5 to lug 17 of switch CC (S-1).
- () Connect the free lead of the 560 Ω resistor coming from lug 1 of switch CC to lug 3 of terminal strip F (S-5).

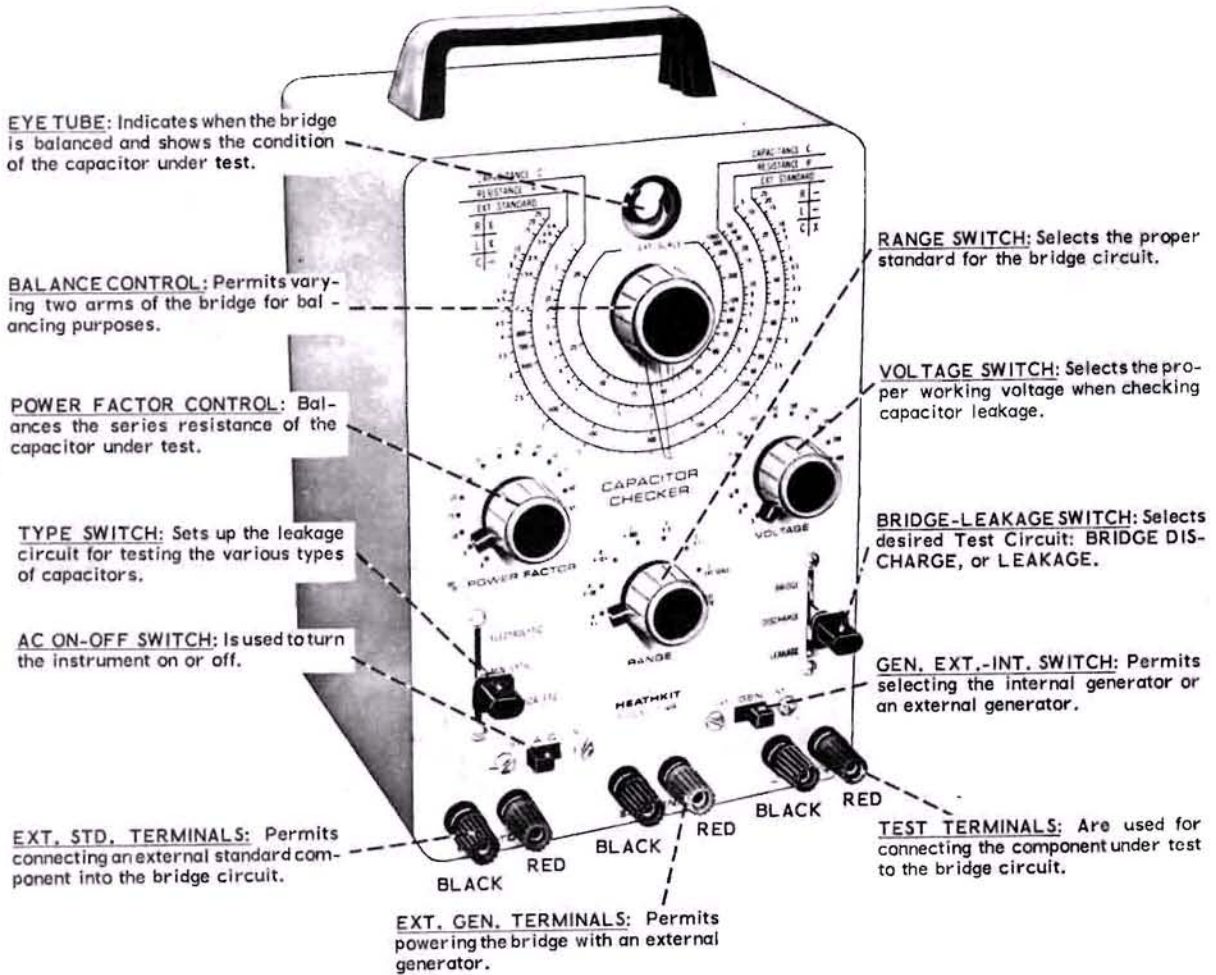
This completes all wiring of the Capacitor Checker. Recheck all connections to see that they are securely soldered. Also, make sure that all wires and components are placed and connected as shown in the illustrations.

FINAL ASSEMBLY

- () Install the 6BN8 and 6AX4 tubes in their proper sockets as shown in Pictorial 11.
- () Slide the eye tube forward until the end of the tube touches the front panel.
- () Install the 1/2 ampere slow-blow fuse in the fuseholder (1/4 ampere for 240 VAC).



PICTORIAL 11



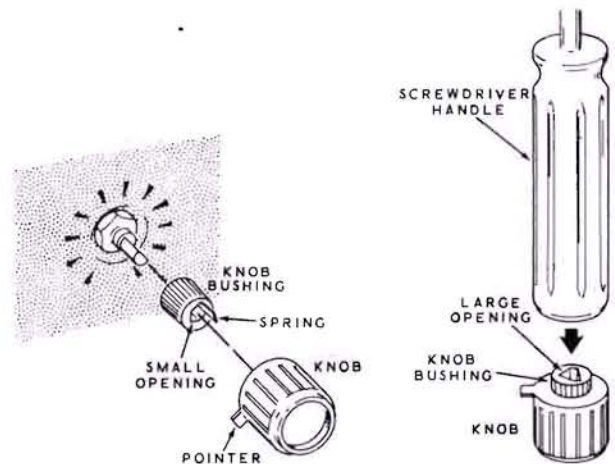
PICTORIAL 12

Refer to Pictorial 12 and Detail 12A for the following steps.

NOTE: The knobs supplied with this kit use knob bushings that provide permanent positive gripping without the use of setscrews. In the following steps you will install a knob on each of the four shafts as shown in Pictorial 12 and Detail 12A. Perform these steps carefully since it is very difficult to remove a knob bushing from a knob once it is fully inserted.

Each knob will be made to align with particular panel markings. Whenever you remove a knob, be sure to replace it on the same shaft.

- () Push a knob bushing part way onto each of the Voltage switch, Range switch and Power Factor control shafts. Then turn all shafts to their full counterclockwise position.



Detail 12A

- () Line up the pointer of each knob with the full counterclockwise marking on the panel. Then press the knob slightly onto the knob bushing.
- () Turn the two switch knobs clockwise to each of the switch stop positions. Check to see that the pointer lines up with each panel marking.

NOTE: Perform the next three steps only if the pointer does not line up at each switch marking.

1. () Turn the knob pointer to one of the mid-position markings on the panel.
2. () Remove the knob from the bushing and turn it slightly to line up the pointer with the mid-position markings.
3. () Press the knob slightly onto the knob bushing. Then turn the knob to each switch position and recheck the pointer alignment. If more than a slight error is noticed at either end position, repeat these three steps.

() Carefully remove the knob bushing and knob together.

() Place the knob on a table or other hard surface, then press the knob bushing firmly into the knob. Use a towel or soft cloth on the work surface to avoid scratching the knob.

() Press the knob and bushing firmly onto the switch shaft.

() Repeat the above Knob Installation steps to install knobs on the remaining shafts except for the pointer knob on the Balance control shaft, which will be installed later.

() Install a lever switch knob on each of the two lever switches.

() Install the six binding post caps in the position shown in Pictorial 12.

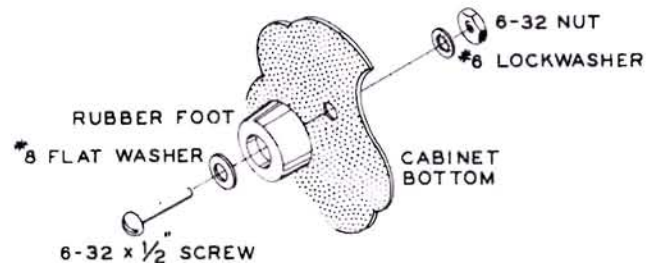
- () Refer to Detail 12B, and slightly spread the open end of the binding posts with a phillips head screwdriver after the binding post caps have been screwed on. Tap the phillips head screwdriver lightly. This will keep the binding post caps from falling off.



Detail 12B

- () Fasten the handle to the cabinet, using two #10 x 1/2" sheet metal screws.

- () Referring to Detail 12C, fasten the rubber feet to the cabinet using four 6-32 x 1/2" screws, #8 flat washers, #6 lockwashers, and 6-32 nuts.



Detail 12C

- () Carefully peel away the backing paper from the blue and white identification label. Then press the label onto the rear of the cabinet (or chassis). Be sure to refer to the numbers on this label in any communications you have with the Heath Company about this kit.

Set the cabinet aside to be installed later. The only remaining parts should be a 200 Ω 1% precision resistor, a 1.5 megohm resistor, and a 100 K Ω resistor which will be used in calibration.

TEST AND CALIBRATION

TESTING

If any of the following steps do not produce the desired results, turn the instrument OFF and refer to the In Case Of Difficulty section.

Make sure the line cord is plugged into an outlet of the proper voltage. Turn the instrument on by moving the AC slide switch to the ON position. After a few seconds for warmup, the eye tube should have a green glow and the filaments of the 3 tubes should be lit.

Set the controls to the following positions.

<u>CONTROL</u>	<u>POSITION</u>
() BRIDGE-LEAKAGE	BRIDGE
() GEN.	INT.
() Type switch	Any
() VOLTAGE	3
() POWER FACTOR	0
() RANGE	*

*For positions R X1 through C X1, the eye tube should be closed with the Balance control in any position except maximum clockwise. The tube should be open when the Balance control is maximum clockwise. Position the Balance control maximum clockwise and with your finger touch the negative TEST terminal. The eye tube should tend to close when the RANGE switch is in positions R X100 through C X.01.

- () Set the RANGE switch to C EXT. SCALE. In this position, the eye tube should be closed regardless of the Balance control position.
- () Now set the RANGE switch to EXT. STD. In this position, the eye tube should be open regardless of the Balance control position. As before, touching the negative TEST terminal or the red EXT. STD. terminal should close the eye tube.

- () Switch the GEN. switch to EXT. position. The eye tube should remain open regardless of the RANGE switch or Balance control positions.

VOLTAGE TEST

- () Connect a voltmeter (VTVM or 1000 Ω /volt) to the TEST terminals. Set the voltmeter to read high DC+. Set the BRIDGE-LEAKAGE switch in LEAKAGE position and the TYPE switch to ELECTROLYTIC. Now turn the VOLTAGE switch through its 16 positions. The voltmeter reading should be essentially the same as the VOLTAGE switch indications.

BRIDGE CALIBRATION

Connect the 200 Ω 1% precision resistor to the TEST terminals. Set the RANGE switch to the R X1 and the BRIDGE-LEAKAGE switch to the BRIDGE position. Set the GEN. switch to INT. Push a knob bushing onto the BALANCE CONTROL shaft, and adjust the shaft very carefully for maximum opening of the eye tube. Position the pointer knob so the pointer index line is straight down and is over the "1" at the center of the EXTERNAL STANDARD scale. Push the knob partially onto the bushing. As before, remove the knob and bushing together, fully insert the bushing into the knob, and replace the pointer knob on its shaft.

- () Remove the 200 Ω resistor and keep it for future calibration checks.

LEAKAGE CALIBRATION

There are two calibration procedures which can be used; the first without and the second with a milliammeter. The first is quite satisfactory, however, the second procedure will provide greater accuracy.

CALIBRATION WITH NO MILLIAMMETER

1. Turn the instrument on, and allow it to warm up.
2. Connect a 100 K Ω (brown-black-yellow) resistor across the TEST terminals.
3. Set the controls as follows:
 VOLTAGE -- 300 volts.
 Type -- ELECTROLYTIC.
 BRIDGE-LEAKAGE -- LEAKAGE.

4. Adjust the eye tube to "just closed" with the top (AD) calibrate control.
5. Move the BRIDGE-LEAKAGE switch to DISCHARGE and remove the 100 K Ω resistor.
6. Connect a 1.5 megohm (brown-green-green) resistor across the TEST terminals.
7. Set the controls as follows:
VOLTAGE -- 25 volts.
Type -- MIN.'LYTIC.
BRIDGE-LEAKAGE -- LEAKAGE.
8. Adjust the eye tube to the "just closed" position with the bottom (AB) calibrate control.
9. Set the controls as follows:
VOLTAGE -- 3 volts.
Type -- PAPER.
BRIDGE-LEAKAGE -- LEAKAGE.
10. Adjust the eye tube to "just closed" position with the center (AC) calibrate control.
11. Return the BRIDGE-LEAKAGE switch to DISCHARGE and remove the 1.5 megohm resistor from the Test terminals.
7. Reduce the VOLTAGE switch setting and rotate the 2 megohm control until the meter reads 15 μ a.
8. Adjust the eye tube to the "just closed" position with the bottom (AB) calibrate control.
9. Set the controls as follows
Type -- PAPER.
BRIDGE-LEAKAGE -- LEAKAGE .
10. If necessary, reduce the VOLTAGE switch setting, and increase the 2 megohm control until the meter reads 2 μ a.
11. Set the eye tube to the "just closed" position with the center (AC) calibrate control.

LEAKAGE REFERENCE CHECK

Due to component tolerances and line voltage variations, it is usually not possible to draw 2 ma from the power supply on the 25 volt setting of the VOLTAGE switch. To determine the degree of closure of the eye tube under short conditions, set the VOLTAGE switch to 25, BRIDGE-LEAKAGE switch to LEAKAGE, and the Type switch to ELECTROLYTIC. Momentarily short the TEST terminals with a screwdriver and observe the eye tube. The size of the opening remaining should be mentally retained as an indication of short conditions on the 25 volt setting only. The 50 volt position should completely close the eye. NOTE: A completely shorted capacitor will be detected during the value test (Bridge Circuit). It is not recommended that the leakage test be performed on a capacitor known to be shorted since possible damage to the power supply could occur.

CALIBRATION WITH A MILLIAMMETER

1. Connect the meter in series with a 2 megohm control (not supplied) across the TEST terminals.
2. Turn the instrument on and allow it to warm up.
3. Set the controls as follows:
VOLTAGE -- 50 volts.
Type -- ELECTROLYTIC.
BRIDGE-LEAKAGE -- LEAKAGE.
4. Adjust the 2 megohm control until the meter reads 2 ma.
5. Adjust the eye tube to the "just closed" position with the top (AD) calibrate control.
6. Set the controls as follows:
TYPE -- MIN. 'LYTIC.
BRIDGE-LEAKAGE -- LEAKAGE

EYE TUBE POSITIONING

With the BRIDGE-LEAKAGE switch in the BRIDGE position, rotate the Balance control for a very narrow opening of the eye tube. Next rotate the eye tube in its mounting clip until the eye tube opening is vertical.

Install the cabinet using two 6-32 x 3/8" screws. The screws are placed through the rear of the cabinet and into the speednuts in the rear chassis flange.

OPERATION

Pictorial 12 (on Page 22) explains the eye tube, and front panel controls and terminals.

CAUTION: The circuit ground and the case of this instrument are both connected to the power line ground through the green wire of the line cord. Always connect the ground test lead of this device to the chassis, or ground, of the circuit being tested or measured.

NOTE: It is always best to connect the component under test directly to the TEST terminals. Long test leads may pick up stray AC fields and give inaccurate readings. If test leads must be used, keep them as short as possible.

RESISTANCE MEASUREMENT

Connect the unknown resistance to the TEST terminals. Set the RANGE switch to one of the "R" multipliers. The GEN. switch should always be in INT. position on all tests unless an external generator is used. The Type, VOLTAGE, and POWER FACTOR controls are not used in this test. Set the BRIDGE-LEAKAGE switch to the BRIDGE position. Adjust the Balance control for maximum eye tube opening. Read the resistance indicated by the Balance control pointer on the "R" scale and multiply by the RANGE switch setting.

CAPACITANCE MEASUREMENT

Lower Ranges - X .0001 And X .01

Connect the unknown capacity to the TEST terminals. The VOLTAGE switch is not used in this test.

Set the Type switch to its lower position, this position is for paper, mica, ceramic, glass, and any other small value capacitors. The RANGE switch should be in either the C X.0001 or C X.01 position, depending on the size of the capacitance under test. Set the BRIDGE-LEAKAGE switch to the BRIDGE position and adjust the Balance control for eye tube opening. Read the value of the capacitance on the "C" scale and multiply by the RANGE switch setting.

NOTE: To obtain sharper eye tube indications when measuring small capacitance values, connect an external generator to the EXT. GEN. terminals and set the GEN. switch to EXT. position. Set the generator to 1000 cps.

High Range - X1, Extended Scale

WHEN CHECKING ELECTROLYTIC CAPACITORS IT IS ESSENTIAL THAT POLARITY BE OBSERVED. The positive (+) lead of the capacitor should be connected to the positive (red) binding post, and the negative (-) lead to the negative (black) binding post of the TEST terminals. The VOLTAGE switch is not used in this test.

Set the Type switch to either the MIN. LYTIC or ELECTROLYTIC position, depending on the capacitor under test. **NOTE:** A MIN. LYTIC (miniature electrolytic) can be distinguished from an electrolytic by its high capacitance, low working voltage and small physical size. Miniature electrolytics are usually encased in ceramic or plastic and are completely sealed. Adjust the Balance control and the *POWER FACTOR control for the widest opening of the eye tube. Read the capacitance on the "C" scale or EXTENDED scale, depending on the RANGE switch setting. The capacitance is read at so much (%) power factor. For example: 40 μ fd at 6% power factor.

*Power Factor is the measure of the energy loss in an imperfect capacitor. In filter applications, a higher power factor decreases the effective capacity so that the effective capacity at 20 PF (Power Factor) is 98% of the measured capacity. At 30% PF, the effective capacity is decreased to 95%. While at 50% PF, the effective capacity is decreased to 87% of the measured capacity.

A significant point of the capacitor test, well worth remembering, is that a capacitor which will not balance on any of the ranges but allows the eye tube to open on the low end of the low range, is an open capacitor. A capacitor which allows the eye to open on the high end of the high range is a shorted capacitor. In either case, there is no reason to carry the test any further.

LEAKAGE TEST

After the capacitor value has been determined, a leakage test for quality can be made. Set the VOLTAGE switch to the voltage rating of the capacitor (the four voltage positions below 25 volts are to be used for miniature electrolytics only), which is usually printed on the capacitor itself. Push the BRIDGE-LEAKAGE switch to the LEAKAGE position and observe the action of the eye tube. A sudden closing and then return to normal shadow angle indicates a satisfactory capacitor. A partially closed eye or fluttering condition would indicate an intermittent condition. If the eye stays closed the capacitor is leaky.

NOTE: The eye may not open on some electrolytics, especially large electrolytics. This does not always mean the capacitor is shorted. Refer to the Capacitor Current section which follows.

After the leakage test, return the BRIDGE-LEAKAGE switch to the DISCHARGE position. When the eye tube opens, the capacitor under test is discharged and safe to handle.

CAPACITOR CURRENT

The eye will close when approximately 2 milliamperes of direct current are drawn through the test circuit when checking electrolytic capacitors. Approximately 15 microamperes of current are required to close the eye when checking miniature electrolytics, and approximately 2 microamperes are required when checking paper, mica, etc., capacitors.

Some electrolytic capacitors may allow 2 milliamperes of current to go through them and still be satisfactory. In this case, the eye will not open, showing the capacitor to be leaky or shorted. Leakage current is calculated with the following formula: $I = K \times C + .3$

I = milliamperes of maximum current through the capacitor.

C = capacitance in μfd .

K = constant relative to the voltage rating of the capacitor, as follows:

3 to 100 volts	$K = .01$
101 to 250 volts	$K = .02$
251 to 350 volts	$K = .025$
351 to 450 volts	$K = .04$

EXAMPLE: 40 μfd capacitor rated at 450 volts.

$$I = K \times C + .3$$

$$I = .04 \times 40 + .3$$

$$I = 1.6 + .3$$

$$I = 1.9 \text{ milliamperes.}$$

EXTERNAL STANDARD SCALES

Connect a component of known value to the EXT. STD. terminals. If the component to be tested is a resistor, then the EXT. STD. component must be a resistor; for checking capacitors, the EXT. STD. component must be a capacitor, etc; for checking inductance, use a coil of known value as the external standard. Set the RANGE switch to EXT. STD. and the BRIDGE-LEAKAGE switch to BRIDGE. Adjust the Balance control for eye tube opening. When measuring resistance or inductance and the pointer is on the left side of the scale, multiply the value of the EXT. STD. component by the pointer reading on the EXT. STD. scale. If the pointer is on the right side of the scale, divide the EXT. STD. component by the pointer reading.

When measuring capacitance, divide the value of the EXT. STD. component by the pointer reading when the pointer is on the left side; multiply the value of the EXT. STD. component by the dial reading when the pointer is on the right side.

To improve accuracy when checking small capacitance values, connect a generator to the EXT. GEN. terminals and push the GEN. switch to the EXT. position. Set the generator at 1000 cps and set the RANGE switch to EXT. STD. Balance the bridge for eye tube opening indication. If the pointer does not read "1" (center of scale), add capacitance to the appropriate terminals (TEST or EXT. STD.) until the pointer is at center scale with the bridge balanced. This capacitance should be left on the terminals when checking small value capacitances on the EXT. STD. scale.

NOTE: When measuring inductance, an external standard must be used as no internal inductance is provided. The external standard inductance should have characteristics similar to those of the inductance being measured. Multiply for pointer readings on the left side of the scale

and divide for readings on the right side of the scale.

MEASURING TRANSFORMER TURNS RATIO

Connect either pair of leads (primary or secondary) to the TEST terminals and the other pair to the EXT. STD. terminals. (Interchanging the primary and secondary leads only results in reading the ratio on the other side of the scale.) Set the RANGE switch to EXT. STD. and adjust the Balance control for eye tube opening. Read the TURNS RATIO directly on the EXTERNAL STANDARD scale.

Polarity is important when measuring turns ratio, due to transformer action. That is, a signal appearing in one winding will also appear in the other winding. If eye tube opening cannot be obtained, reverse the leads of one winding.

In some cases, the ratio may be misleading. This is due to the non-loaded condition of the transformer under test. For example, the filament winding of a transformer might show up as something other than 18:1. Assuming the primary winding is 117 volts and the filament winding is 6.3 volts, the turns ratio is equal to the primary

voltage (117 volts) divided by the secondary filament winding voltage (6.3 volts), which is approximately equal to 18:1.

EXT. GEN.

An external generator may be used for checking components at frequencies other than internal 60 cps. Any audio generator capable of delivering 2 volts or more to the EXT. GEN. terminals at the desired frequency may be used. A larger signal voltage will give a sharper null indication on the eye tube.

The maximum voltage that should be applied to the EXT. GEN. terminals is 6 volts, measured with the Capacitor Checker operating. The unloaded external generator voltage may be as high as 10 volts, but the very low impedance of this circuit permits a heavy current to be drawn, which results in a large voltage drop. The frequency limit of this circuit is 10,000 cps.

A point to remember, when using this instrument, is that the greatest error will occur at the ends of the scales. Therefore, for greatest accuracy, use the range that will give a null indication on the eye tube nearest center scale.

IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the constructor.
2. It is interesting to note that about 90% of the kits that are returned for repair, do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the Proper Soldering Techniques section of this manual.
3. Make sure that all tubes light up properly.
4. Check the tubes with a tube tester or by substitution of tubes known to be good.
5. Check the values of the component parts. Be sure that the proper part has been wired into the circuit, as shown in the pictorial diagrams and as called out in the wiring instructions.
6. Check for bits of solder, wire ends or other foreign matter which may be lodged in the wiring beneath the chassis.
7. If, after careful checks, the trouble is still not located and a voltmeter is available, check voltage readings against those found on the Schematic Diagram. NOTE: All voltage readings were taken with an 11 megohm vacuum tube voltmeter. Voltages may vary as much as 10% due to line voltage variations.
8. A review of the Circuit Description will prove helpful in indicating where to look for trouble.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

REPLACEMENT PARTS PRICE LIST

To order parts, use the Parts Order Form furnished with this kit. If Parts Order Form is not available, refer to Replacement Parts in the Kit Builders Guide.

PART No.	PRICE Each	DESCRIPTION
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RESISTORS

1-3	.15	100 Ω 1/2 watt
1-119	.15	560 Ω 1/2 watt
1-7	.15	680 Ω 1/2 watt
1-8	.15	820 Ω 1/2 watt
1-9	.15	1000 Ω 1/2 watt
1-44	.15	2200 Ω 1/2 watt
1-16	.15	4700 Ω 1/2 watt
1-20	.15	10 K Ω 1/2 watt
1-25	.15	47 K Ω 1/2 watt
1-26	.15	100 K Ω 1/2 watt
1-29	.15	220 K Ω 1/2 watt
1-35	.15	1 megohm 1/2 watt
1-36	.15	1.5 megohm 1/2 watt
2-83	1.00	200 Ω 1/2 watt 1% precision
2-35	1.00	9000 Ω 1/2 watt 1% precision
2-38	1.00	20 K Ω 1/2 watt 1% precision
2-55	1.00	2 megohm 1/2 watt 1% precision
1-5-1	.15	22 K Ω 1 watt
1-18-2	.20	33 K Ω 2 watt
1-10-2	.20	47 K Ω 2 watt
3-7-10	.50	10 K Ω 10 watt wire-wound

CAPACITORS

20-2	.25	200 μ f molded mica
21-71	.20	.001 μ f disc ceramic 1400 V
29-40	1.45	.02 μ f polystyrene
23-59	.50	.05 μ f tubular
23-28	.55	.1 μ f tubular
23-56	.60	.5 μ f tubular
27-58	5.00	2 μ f Mylar
25-41	1.50	40 μ f 350 V electrolytic
27-47	.30	.1 μ f Mylar

CONTROLS-SWITCHES

10-58	1.00	100 K Ω tab-mount control
11-101	2.55	1000 Ω control, wire-wound
60-1	.30	SPST slide switch
60-2	.45	DPDT slide switch
62-15	4.40	3-position lever switch
62-16	3.20	3-position lever switch
63-503	3.60	16-position rotary switch
63-504	2.75	8-position rotary switch

PART No.	PRICE Each	DESCRIPTION
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TUBES-TRANSFORMERS

411-128	2.45	6BN8 tube
411-120	4.40	6E5 tube
411-156	2.85	6AX4 tube
51-80	4.55	Bridge transformer
54-34-24	7.20	Power transformer

CONNECTORS-TERMINAL STRIPS-SOCKETS

100-16-2	.15	Binding post cap, black
100-16-18	.15	Binding post cap, red
427-3	.15	Binding post base
431-1	.15	Dual-lug terminal strip
431-12	.15	3-lug terminal strip
431-11	.15	5-lug terminal strip
431-16	.15	2-lug terminal strip
434-31	.15	Octal socket
434-12	.45	6-pin tube socket
434-77	.20	9-pin tube socket

METAL PARTS-KNOBS

90-414	8.20	Cabinet
200-525	1.00	Chassis
203-250-2	1.90	Front panel
462-97	.20	Lever switch knob
455-50	.15	Knob bushing
462-245	.40	Knob
462-253	1.05	Pointer knob

HARDWARE

250-2	.05	3-48 x 5/16" screw
250-18	.05	8-32 x 3/8" screw
250-26	.05	6-32 x 5/8" screw
250-48	.05	6-32 x 1/2" screw
250-89	.05	6-32 x 3/8" screw
250-83	.05	#10 sheet metal screw
252-1	.05	3-48 nut
252-3	.05	6-32 nut
252-4	.05	8-32 nut
252-7	.05	Control nut
252-22	.05	Speednut
253-9	.05	#8 flat washer
253-10	.05	Control flat washer
254-7	.05	#3 lockwasher
254-1	.05	#6 lockwasher
254-2	.05	#8 lockwasher



<u>PART</u> <u>No.</u>	<u>PRICE</u> <u>Each</u>	<u>DESCRIPTION</u>
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Hardware (cont'd.)

254-5	.05	Small control lockwasher
254-4	.05	Control lockwasher
255-1	.05	1/8" spacer
255-13	.05	1/4" spacer
259-1	.05	#6 solder lug
259-2	.05	#8 solder lug
208-6	.25	Mounting clip

INSULATORS-WIRE

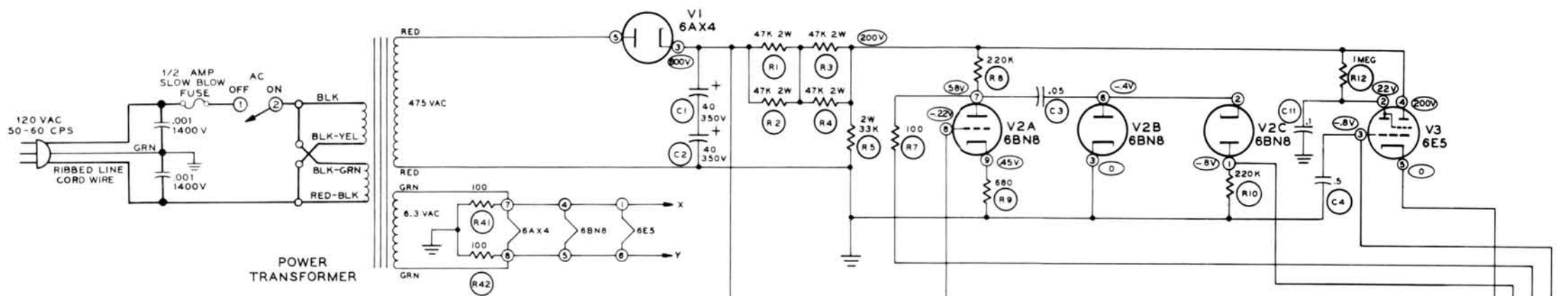
73-1	.15	Grommet
75-17	.15	Binding post insulator
75-30	.15	Strain relief, round cord
75-71	.15	Strain relief, flat cord
89-23	1.25	Line cord
134-38	2.80	Wire harness
344-59	.05/ft	Hookup wire

<u>PART</u> <u>No.</u>	<u>PRICE</u> <u>Each</u>	<u>DESCRIPTION</u>
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MISCELLANEOUS

207-53	.30	Tube retaining clamp
211-15	.35	Handle
261-9	.05	Rubber foot
421-20	.50	1/2 ampere slow-blow fuse
422-1	.40	Fuseholder
432-27	.40	Line cord adapter
331-6	.25	Solder
490-5	.15	Nut starter
	2.00	Manual (See front cover for part number.)

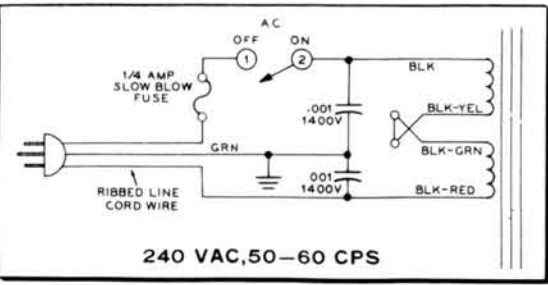
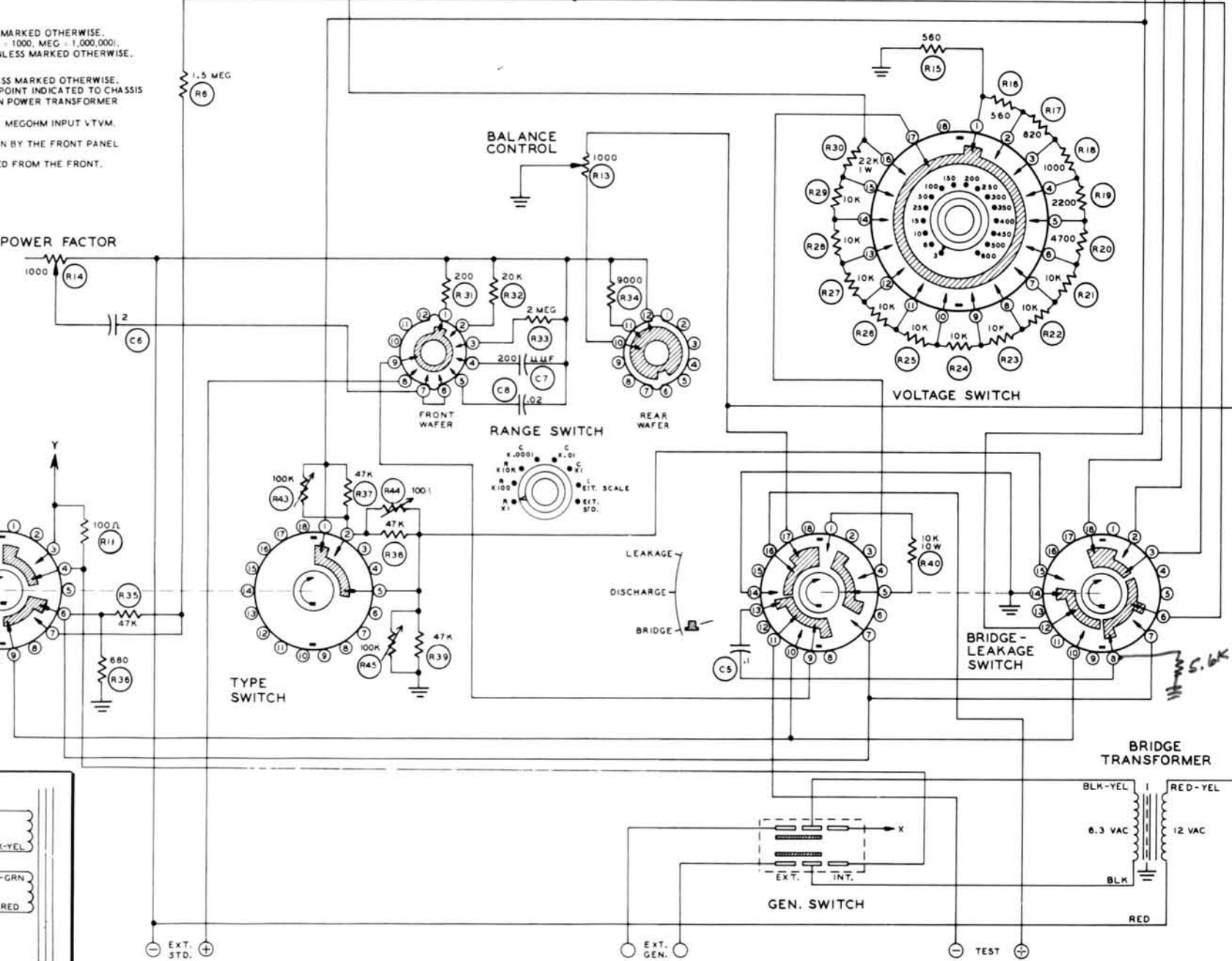
The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from a Heathkit Electronic Center to cover local sales tax, postage and handling. Outside the U.S.A. parts and service are available from your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



NOTES:
 ALL RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE.
 ALL RESISTOR VALUES ARE IN OHMS (K = 1000, MEG = 1,000,000).
 ALL CAPACITOR VALUES ARE IN μ F UNLESS MARKED OTHERWISE.
 ○ INDICATES VOLTAGE READING.
 ALL VOLTAGES ARE DC POSITIVE UNLESS MARKED OTHERWISE.
 ALL VOLTAGES ARE MEASURED FROM POINT INDICATED TO CHASSIS GROUND, EXCEPT AC VOLTAGES ON POWER TRANSFORMER WINDINGS.
 VOLTAGE READINGS TAKEN WITH AN 11 MEGOHM INPUT VTVM. VOLTAGES MAY VARY $\pm 10\%$.
 SWITCHES ARE IN THE POSITIONS SHOWN BY THE FRONT PANEL MARKINGS.
 RANGE AND VOLTAGE SWITCHES VIEWED FROM THE FRONT.

SCHEMATIC OF THE HEATHKIT® CAPACITOR CHECKER IT-28

PAPER, MICA, ETC.
 MIN'LYTIC
 ELECTROLYTIC



CUSTOMER SERVICE

REPLACEMENT PARTS

If you need a replacement part, please fill in the Parts Order Form that is furnished and mail it to the Heath Company. Or, if you write a letter, include the:

- Part number and description as shown in the Parts List.
- Model number and Series number from the blue and white label.
- Date of purchase.
- Nature of the defect.

Please do not return parts to the factory unless they are requested. Parts that are damaged through carelessness or misuse by the kit builder will not be replaced without cost, and will not be considered in warranty.

Parts are also available at the Heathkit Electronic Centers listed in your catalog. Be sure to provide the Heath part number. Bring in the original part when you request a warranty replacement from a Heathkit Electronic Center.

NOTE: Replacement parts are maintained specifically to repair Heathkit products. Parts sales for other reasons will be declined.

TECHNICAL CONSULTATION

Need help with your kit? Self-Service? Construction? Operation? Call or write for assistance. You'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek. . . please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit C.O.D. for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment.) Place the equipment in a strong carton with at least THREE INCHES of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022

HEATH

Schlumberger

HEATH COMPANY • BENTON HARBOR, MICHIGAN
THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

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