A Note From
Dave Miller (AA4DF) and Jill Bryant
at
http://www.aa4df.com

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-Dave Miller and Jill Bryant
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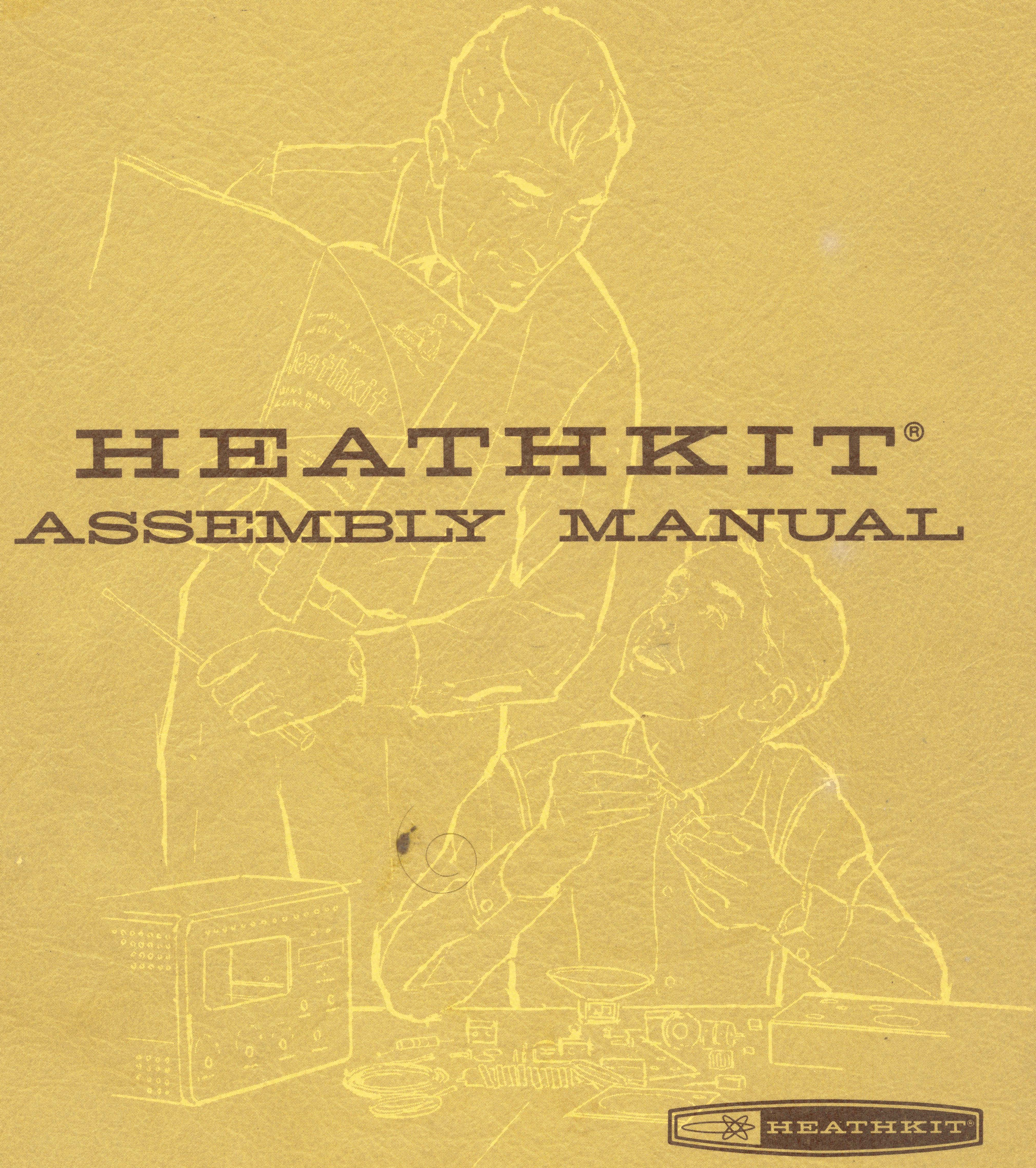
HEATHKIT®
ASSEMBLY MANUAL



HEATHKIT

LINEAR AMPLIFIER
MODEL SB-220

595-1122-07

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HEATH COMPANY
Benton Harbor, Michigan 49022

Assembly
and
Operation
of the

HEATHKIT

LINEAR AMPLIFIER

MODEL SB-220

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

TABLE OF CONTENTS

INTRODUCTION

The Heathkit Model SB-220 Linear Amplifier is a completely self-contained, table top, grounded grid, linear amplifier. It is designed to operate at the maximum amateur power limit on SSB, CW, and RTTY. Its styling matches the Heath SB series of amateur equipment.

The Amplifier is designed to be used with exciters which deliver 100 watts or more output. It can be used with less driving power, but will give a lower output.

A broad-band, tuned input circuit for each band feeds the two Eimac 3-500Z triode tubes connected in grounded grid configuration. The tubes are biased beyond cut-off in the receive mode, and zener-regulated bias controls the idling current in the transmit mode. The tubes are cooled by a fan.

An ALC circuit develops negative voltage to be fed back to the exciter to reduce its gain when the Amplifier is overdriven.

The antenna change-over relay is normally actuated by exciter relay contacts to place the Amplifier in the transmit mode.

The Amplifier can be operated from either 120 VAC or 240 VAC 50/60 Hz lines and can be easily changed from one to the other. Operation from a 240 volt line is recommended. Each side of the line cord is equipped with a circuit breaker to protect against overloads.

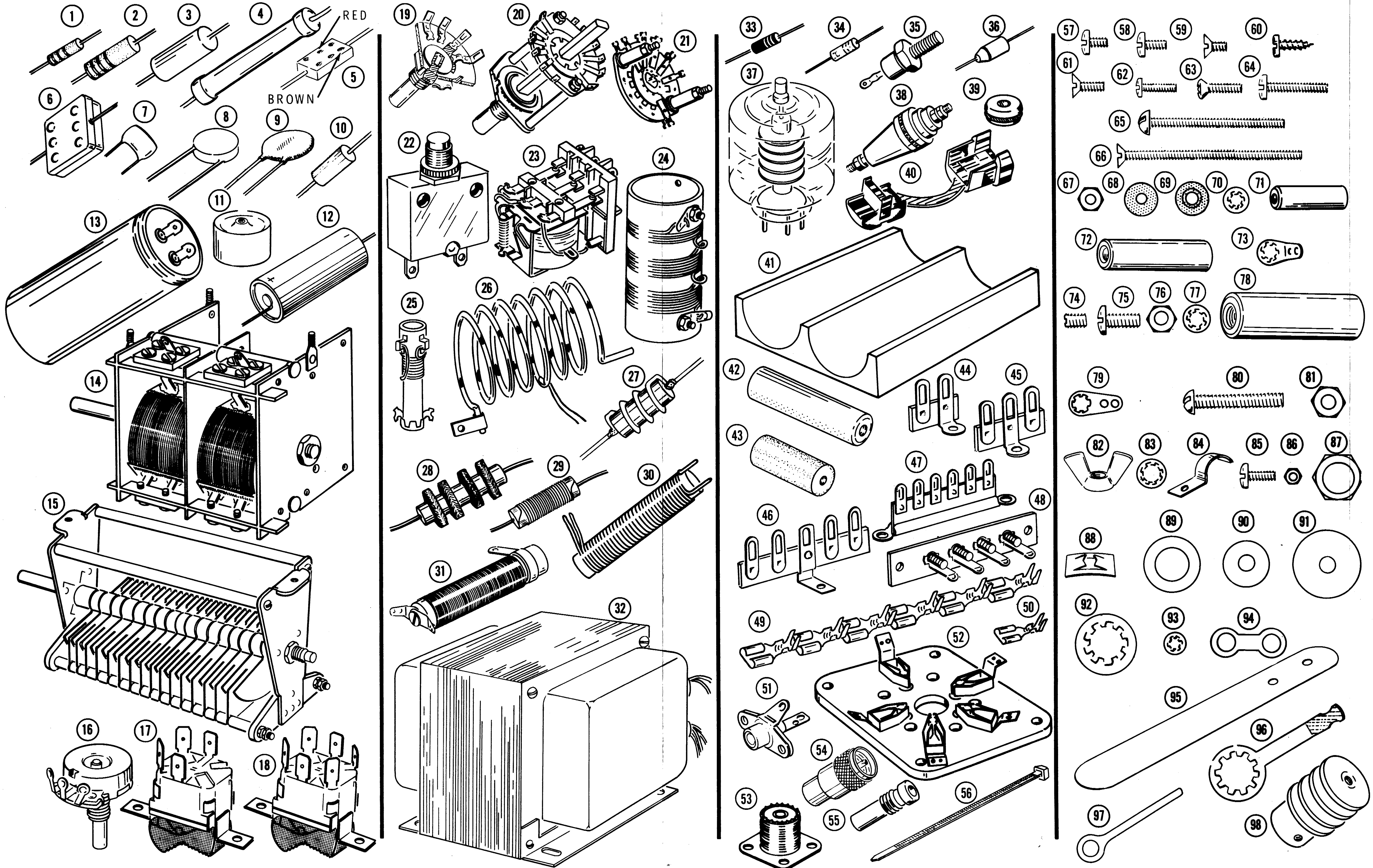
An important feature of this Amplifier is that it can be tuned up at the one kilowatt limit and can then be switched to operate on SSB at two kilowatts P.E.P. input. As the switching changes both the voltage and current to the final tubes, the impedance remains the same and no additional adjustment of tuned circuits is required.

The tubes are "instant heating" types, and transmission may be started as soon as the Amplifier is switched on (after tune-up).

Here is a full legal-limit Amplifier that can take its place on your operating table and give you years of trouble-free pleasure. This Amplifier has a commanding voice.

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

PARTS PICTORIAL



(continued on fold-out from Page 7)

PARTS LIST

This Parts List contains all of the parts used in the assembly of the kit. Some parts are packaged in envelopes with the part number of the contents printed on the outside. Except for the initial parts check, retain these parts in their envelopes until they are called for in the assembly steps.

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

Check each part against the following Parts List. The key numbers correspond to the numbers on the Parts Pictorial (fold-out from Pages 4 and 7).

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
RESISTORS			
1/2 Watt			
1	1-9	1	1000 Ω (brown-black-red)
	1-44	2	2200 Ω (red-red-red)
	1-18	1	5600 Ω (green-blue-red)
	1-22	1	22 kΩ (red-red-orange)
	1-23	1	27 kΩ (red-violet-orange)
	1-24	1	33 kΩ (orange-orange-orange)
	1-25	1	47 kΩ (yellow-violet-orange)
	1-26	1	100 kΩ (brown-black-yellow)
Other Resistors			
2	1-8-1	1	68 kΩ 1 watt (blue-gray-orange)
	1-38-1	3	4.7 MΩ 1 watt (yellow-violet-green)
	3-1-2	1	.82 Ω wire-wound 2 watt (gray-red-silver) (same size as 1 watt), 5%
3	3-25-5	1	1 Ω wire-wound, 5 watt, 1%
	3-22-5	1	3600 Ω wire-wound, 5 watt, 1%
4	5-2-7	8	30 kΩ film, 7 watt

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
CAPACITORS			
Molded Mica			
5	20-3	6	200 pF (red-black-brown)
6	20-123	1	500 pF (.0005 μF)
Mica			
7	20-99	2	22 pF
	20-124	2	115 pF
	20-103	1	150 pF
	20-105	1	180 pF
	20-120	1	220 pF
	20-116	2	400 pF
	20-113	2	470 pF
	20-107	2	680 pF
Disc			
8	21-79	1	.001 μF 6 kV
9	21-14	2	.001 μF 500 volt
	21-70	3	.01 μF 1.4 kV
	21-31	12	.02 μF 500 volt

Other Capacitors

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
10	21-28	1	10 pF (10 MMF or 10 $\mu\mu$F) tubular ceramic
11	21-165	2	.001 μF (1000 MMFD) 6 kV, ceramic
12	25-19	1	20 μF (MFD) electrolytic
13	25-224	8	200 μF (MFD) electrolytic
14	26-97	1	437-437 pF ganged variable, 2-section
15	26-131	1	250 pF variable

CONTROLS-SWITCHES

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
16	10-12	1	100 kΩ control
17	61-14	1	DPST rocker switch
18	61-15	1	DPDT rocker switch
19	63-47	1	3-position rotary switch
20	63-561	1	5-position rotary switch
21	63-562	1	Rotary switch wafer
22	65-28	2	Circuit breaker
23	69-55	1	TPDT 110 VDC relay

COILS-CHOKES-TRANSFORMERS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
24	40-597	1	80/20 plate coil
25	40-964	2	10/15-meter input coil
	40-965	1	20-meter input coil
	40-966	1	40-meter input coil
	40-1012	1	80-meter input coil
26	40-968	1	15/10 plate coil
27	45-53	2	Parasitic choke
28	45-4	3	1 mH RF choke
29	45-6	1	8.5 μH RF choke
30	45-78	1	9 μH RF choke
31	45-61	1	50 μH RF choke
32	54-237	1	High voltage transformer
	54-238	1	Filament and bias transformer

DIODES-TUBES

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
33	56-24	1	1N458 silicon diode (yellow-green-gray)
34	56-26	1	1N191 germanium diode (brown-white-brown)
35	56-82	1	1N3996A zener diode, 5.1V, 10 watt, w/mounting hardware
36	57-27	15	Silicon diode
37	411-245	2	3-500Z tube

INSULATORS-GROMMETS-TERMINAL STRIPS-CONNECTORS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
38	71-2	1	Ceramic feedthrough insulator (disassembled in bag)
39	73-4	1	5/16" grommet
	73-3	4	1/2" grommet
	73-2	1	3/4" grommet
40	75-123	1	Line cord strain relief
	75-124	1	6" x 4-1/2" fish paper insulator
41	75-125	8	Capacitor mounting insulator
42	255-39	1	6-32 x 1-1/4" tapped phenolic spacer
43	255-42	3	6-32 x 3/4" tapped phenolic spacer
44	431-14	1	2-lug terminal strip
45	431-10	3	3-lug terminal strip
46	431-42	1	5-lug terminal strip
47	431-20	1	6-lug terminal strip
48	431-13	1	4-screw terminal strip
49	432-137	6	Connector tab (large)
~~50~~	~~432-66~~	~~2~~	~~Connector tab (small)~~
51	434-42	2	Phono socket
52	434-93	2	5-lug ceramic tube socket
53	436-5	2	Coaxial jack
54	438-9	1	Coaxial plug
55	438-12	1	Coaxial plug insert

WIRE-CABLE-SLEEVING

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
	89-40	1	Line cord
	134-36	2	Phono cable assembly
	340-1	1	Bare wire
	343-2	1	Coaxial cable, RG-58A/U
	343-8	1	Coaxial cable, RG-8/U
	344-2	1	Small black stranded wire
	344-7	1	Large black stranded wire
	344-13	1	Blue hookup wire
	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 (thick insulation)
	345-1	1	Large metal braid
	345-2	1	Small metal braid
	346-4	1	Black sleeving
	346-7	2	Clear sleeving (large)
	346-29	1	Clear sleeving (small)
56	354-5	6	Cable tie

HARDWARE

#6 Hardware

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
57	250-138	9	6-32 x 3/16" screw
58	250-56	31	6-32 x 1/4" binder head screw
59	250-416	1	6-32 x 1/4" flat head screw
60	250-8	29	#6 x 3/8" sheet metal screw
61	250-32	18	6-32 x 3/8" flat head screw
62	250-89	13	6-32 x 3/8" binder head screw
63	250-218	4	6-32 x 3/8" phillips head screw
64	250-206	13	6-32 x 11/16" screw
65	250-40	2	6-32 x 1-1/2" screw
66	250-47	1	6-32 x 2" screw
67	252-3	62	6-32 nut
68	253-1	17	#6 fiber flat washer
69	253-2	2	#6 fiber shoulder washer
70	254-1	65	#6 lockwasher
71	255-71	4	6-32 x 3/4" tapped metal spacer
72	255-60	3	6-32 x 1-1/8" tapped spacer
73	259-1	19	#6 solder lug

#8 Hardware

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
74	250-43	8	8-32 x 1/4" setscrew
75	250-137	8	8-32 x 3/8" screw
76	252-4	~~10~~ 8	8-32 nut
77	254-2	8	#8 lockwasher
78	255-66	1	8-32 x 1-3/8" spacer
79	259-2	1	#8 solder lug

#10 Hardware

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
80	250-188	1	10-24 x 1" round head screw
81	252-30	1	10-24 nut
82	252-31	1	10-24 wing nut
83	254-3	4	#10 lockwasher

Other Hardware

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
84	207-8	2	Cable clamp
85	250-213	8	4-40 x 5/16" screw
86	252-15	8	4-40 nut
87	252-7	3	Control nut
88	252-10	2	Speednut
89	253-10	3	Control flat washer
90	253-42	14	1/2" flat washer
91	253-19	6	3/4" flat washer
92	254-4	2	Control lockwasher
93	254-9	16	#5 lockwasher
94	259-25	1	#10 double lug

Other Hardware (cont'd.)

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
95	258-115	1	Brass spring 5/8" x 3-1/2"
96	259-10	1	Control solder lug
97	259-24	1	Long solder lug
98	260-12	2	Plate connector
99	456-16	1	Shaft coupler

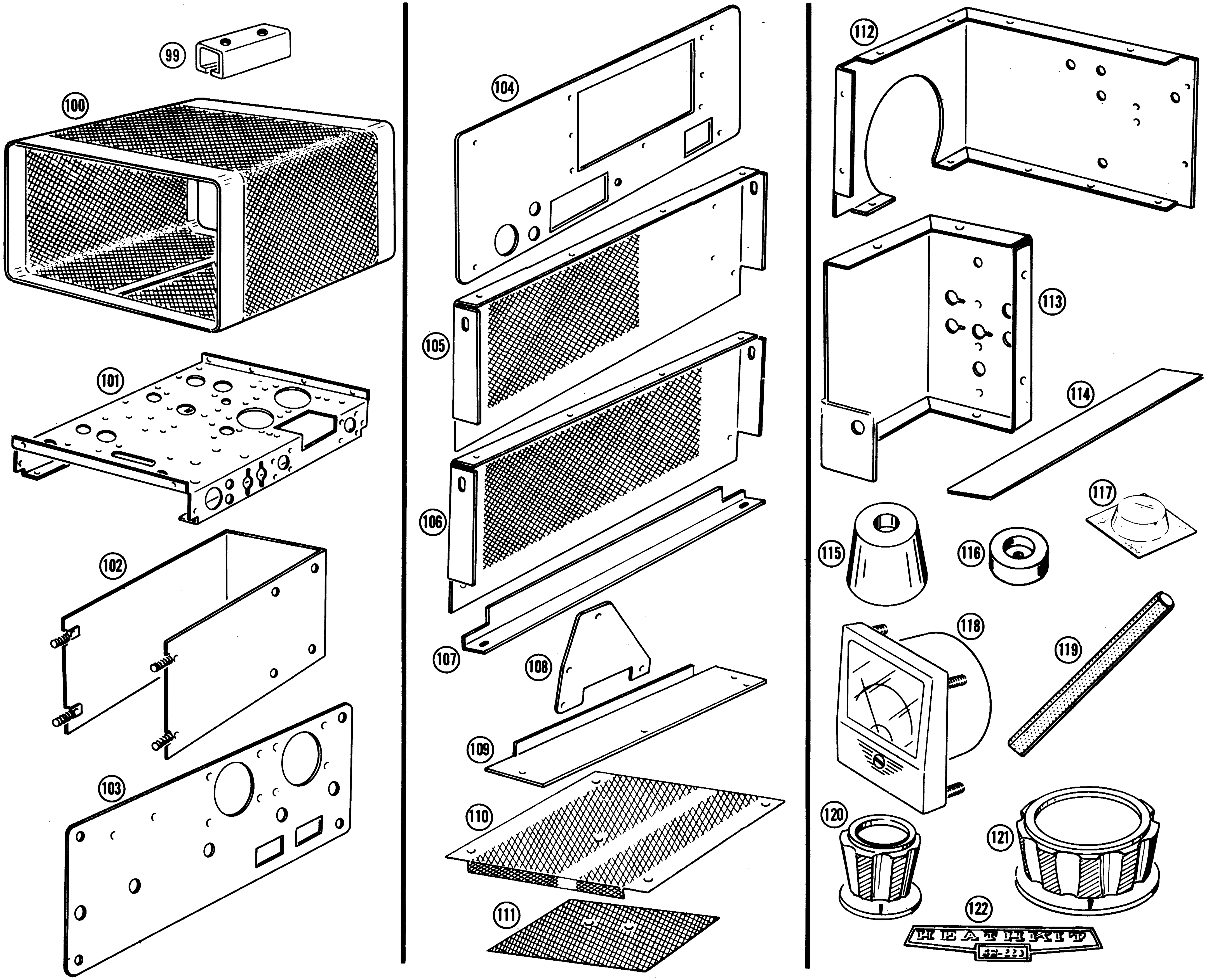
METAL PARTS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
100	90-464	1	Cabinet
101	200-583	1	Chassis
102	100-1022	1	Capacitor bank bracket
103	203-643	1	Front panel
104	203-644	1	Rear panel
105	203-646	1	Left side panel
106	203-645	1	Right side panel
107	204-1041	2	Angle bracket
108	204-1042	1	Plate coil bracket
109	205-723	1	Top rear plate cover
110	205-724	1	Perforated top cover
111	205-874	1	Perforated fan cover
112	206-493	1	RF shield
113	206-457	1	Coil mounting shield
114	212-36	1	Silver plated strip

MISCELLANEOUS

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION
	85-344-1	1	Printed circuit board
115	255-59	2	Black tapered spacer
116	261-9	4	Rubber foot
	266-~~[illegible]~~ 296	1	Fan blade
117	352-13	1	Silicone grease
118	407-145	1	Plate amperes meter
	407-146	1	Multi-meter
	420-~~63~~ 86	1	Fan motor
119	453-135	1	Phenolic shaft
120	462-191	2	Small knob
121	462-210	3	Large knob
	390-147	1	Danger high voltage label
122	391-64	1	Nameplate
	391-34	1	Blue and white 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

PARTS PICTORIAL (cont'd.)



STEP-BY-STEP ASSEMBLY

Before starting to assemble this kit, read the "Kit Builders Guide" for complete information on wiring, soldering, and step-by-step assembly procedures.

The illustrations in this section of the Manual are called Pictorials and Details. Pictorials show the overall operation for a group of assembly steps; Details are used in addition to the Pictorials to illustrate a single step. When you are directed to refer to a certain Pictorial "for the following steps," continue using that Pictorial until you are referred to another Pictorial for another group of steps.

As the drawings in the Manual may be slightly distorted to show all the parts clearly, look at the Chassis Photos (Pages 86 through 89) from time to time to see the actual positions of wires and components.

Lockwashers and nuts will be used with most screws when mounting parts, unless the assembly steps state otherwise. Consequently, the applicable steps will call out only the size and type of hardware used. For example, the phrase "Use 6-32 x 1/4" hardware" means to use 6-32 x 1/4" screws, one or more #6 lockwashers, and 6-32 nuts. Refer to the Details for the proper installation of hardware. Be sure to position each part as shown in the Pictorials. Follow the instructions carefully, and read the entire step before performing the operation.

When a step directs you to "connect" an insulated wire, first prepare its ends by removing 1/4" of insulation.

CIRCUIT BOARD

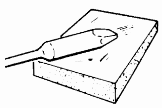
Solder a part or group of parts only when directed. Use 1/2 watt resistors unless directed otherwise in a step. Each resistor will be called out by the resistance value (in Ω, kΩ, or MΩ) and color code. Capacitors will be called out by the capacitance value and type.

On the circuit board, be especially careful not to cover unused holes with solder or bridge solder across foils during assembly. Perform the steps in Pictorial 1-1.

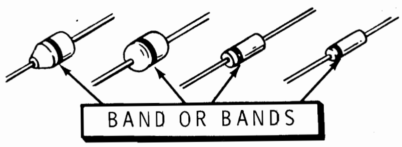
START

FOR GOOD SOLDERED CONNECTIONS, YOU MUST KEEP THE SOLDERING IRON TIP CLEAN...

WIPE IT OFTEN WITH A DAMP SPONGE OR CLOTH.



NOTE: DIODES MAY BE SUPPLIED IN ANY OF THE FOLLOWING SHAPES. THE CATHODE END OF THE DIODE IS MARKED WITH A BAND OR BANDS. ALWAYS POSITION THIS END AS SHOWN IN THE PICTORIAL.



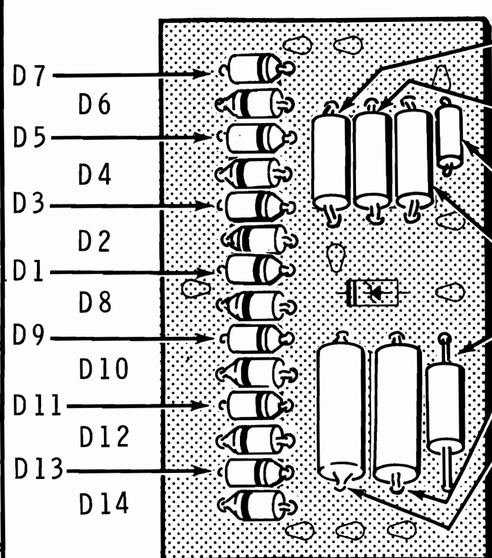
(✓) Position the circuit board as shown and install diodes (#57-27) at D7, D5, D3, D1, D9, D11, and D13. Make sure all seven cathode banded ends are to the right.

(✓) Solder all leads to the foil and cut off the excess lead lengths.

(✓) Install diodes (#57-27) at D6, D4, D2, D8, D10, D12, and D14 with their cathode ends to the left.

(✓) Solder all leads to the foil and cut off the excess lead lengths.

(✓) CAREFULLY INSPECT ALL DIODES IN THE PRECEDING STEPS TO BE SURE THEY ARE POSITIONED AS SHOWN IN THE PICTORIAL AND ON THE CIRCUIT BOARD.



CONTINUE

(✓) 4.7 MΩ 1 watt (yellow-violet-green).

(✓) 4.7 MΩ 1 watt (yellow-violet-green).

(✓) 5600 Ω (green-blue-red).

(✓) 4.7 MΩ 1 watt (yellow-violet-green).

(✓) .82 Ω 2 watt (gray-red-silver-gold).

(✓) 3600 Ω 5 watt.

(✓) 1 Ω 5 watt.

(✓) Solder all leads to the foil and cut off the excess lead lengths. Proceed to "Circuit Board Prewiring."

PICTORIAL 1-1

CIRCUIT BOARD PREWIRING

NOTE: To prepare lengths of hookup wire, as in the following step, cut the wire to the indicated length and remove 1/4" of insulation from each end. If the wire is stranded, twist the ends tightly and apply a small amount of solder to hold the strands together. Unless otherwise stated, "hookup wire" will mean the small solid-conductor wire supplied in various colors.

(✓) Prepare the following lengths of hookup wire:

5-1/4" red

3-3/4" black

6-1/2" black

17-1/2" small black stranded wire

7-1/2" orange

6-1/2" yellow

9-1/2" heavy blue (thick insulation)

2-3/4" heavy blue (thick insulation)

Refer to Pictorial 1-2 for the following steps.

From the component side of the circuit board, insert one end of each of the following wires into the designated hole. Solder each wire on the foil side.

(✓) Connect a 5-1/4" length of red hookup wire to hole A in the circuit board (S-1).

(✓) Connect a 3-3/4" length of black hookup wire to hole B on the circuit board (S-1).

(✓) Connect a 6-1/2" length of black hookup wire to hole C on the circuit board (S-1).

(✓) Connect a 17-1/2" length of black stranded wire to hole E on the circuit board (S-1).

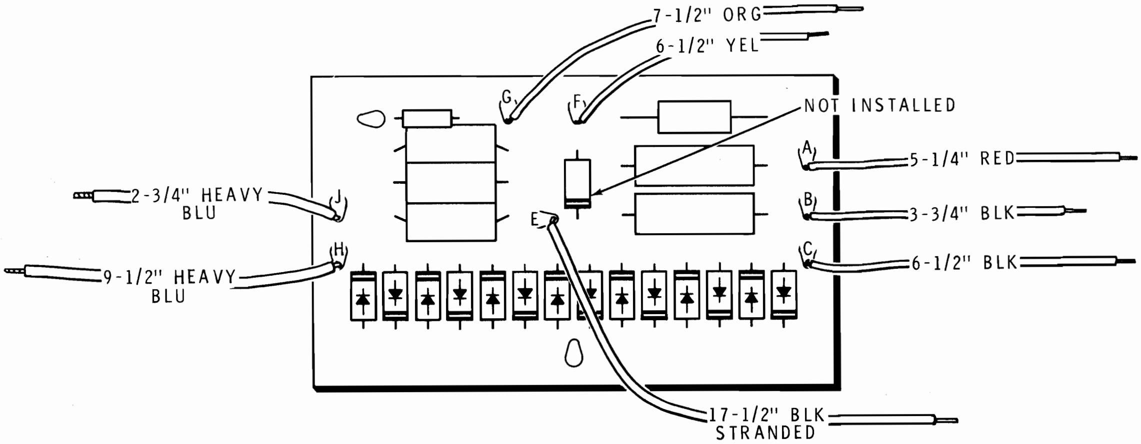
(✓) Connect a 7-1/2" length of orange hookup wire to hole G on the circuit board (S-1).

(✓) Connect a 6-1/2" length of yellow hookup wire to hole F on the circuit board (S-1).

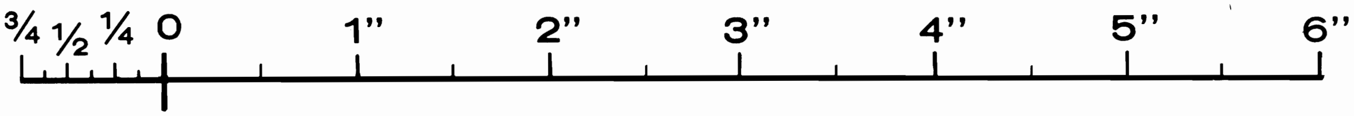
(✓) Connect a 9-1/2" length of heavy blue hookup wire to hole H on the circuit board (S-1).

(✓) Connect a 2-3/4" length of heavy blue hookup wire to hole J on the circuit board (S-1).

(✓) Trim all excess lead lengths from the foil side of the circuit board.



PICTORIAL 1-2



( ) Carefully inspect the foil side of the circuit board; all lettered holes except D and K should be soldered. Make sure there are no solder bridges between foils. Also note that one diode is not installed.

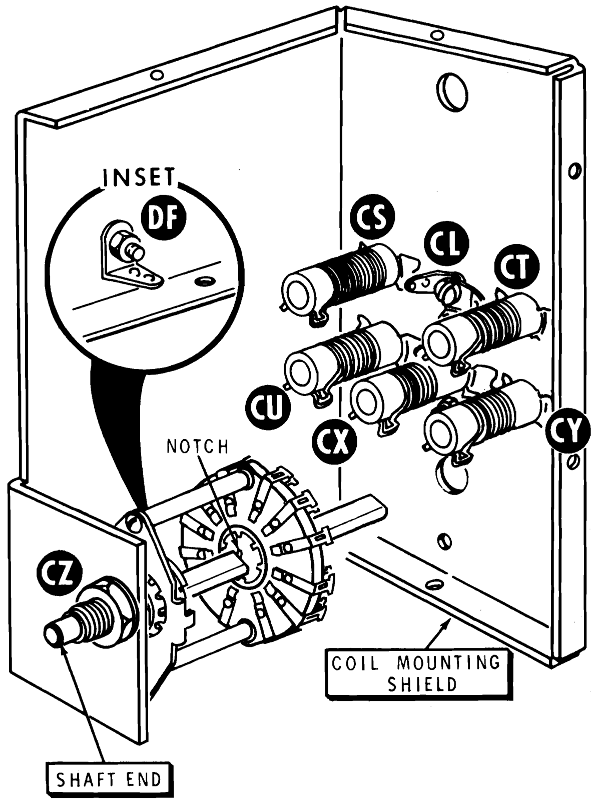
This completes the prewiring of the circuit board. Set it aside until called for later. Proceed with the "Input Coil Assembly" section.

INPUT COIL ASSEMBLY

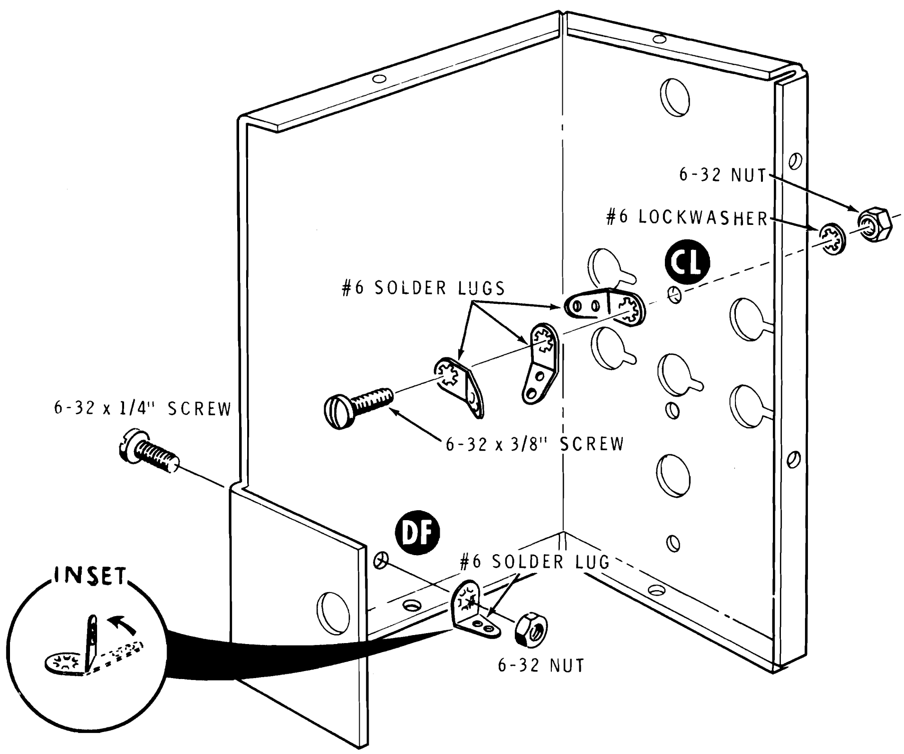
Refer to Pictorial 2-1 for the following steps.

Refer to Detail 2-1A for the next two steps.

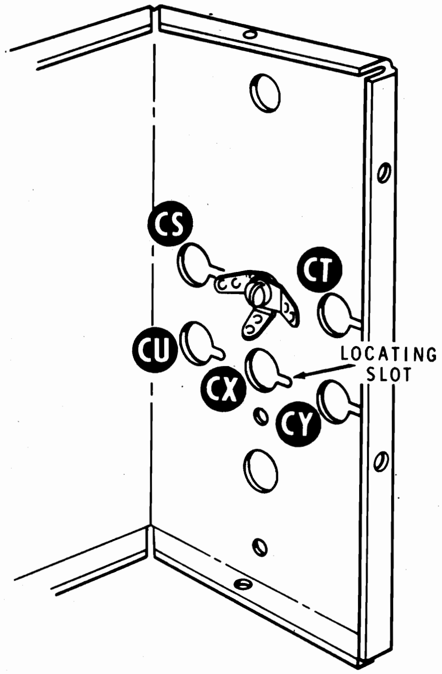
NOTE: A plastic nut starter has been provided with this kit. Use it to hold and start nuts on screws. See Page 3 of the "Kit Builders Guide" for more information.



PICTORIAL 2-1



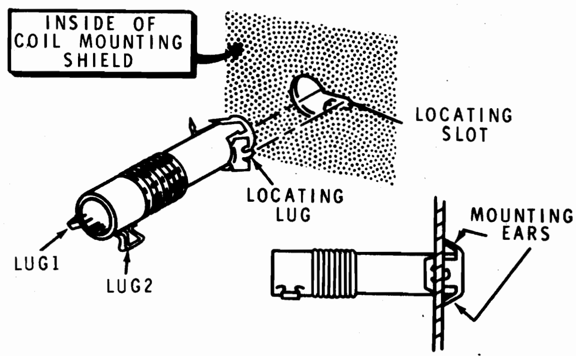
Detail 2-1A



Detail 2-1B

(✓) Install three #6 solder lugs on the coil mounting shield (#206-457) at CL with 6-32 x 3/8" hardware. Position the lugs as shown in Detail 2-1B.

(✓) Install a #6 solder lug at DF with a 6-32 x 1/4" screw and a 6-32 nut. Form the solder lug as shown.



Detail 2-1C

Detail 2-1B shows the coil mounting locations for the following steps. Note that the locating lug of each coil must be positioned in the locating slot, and that each coil must be pushed into its mounting hole until the mounting ears snap out to hold the coil in place as shown in Detail 2-1C.

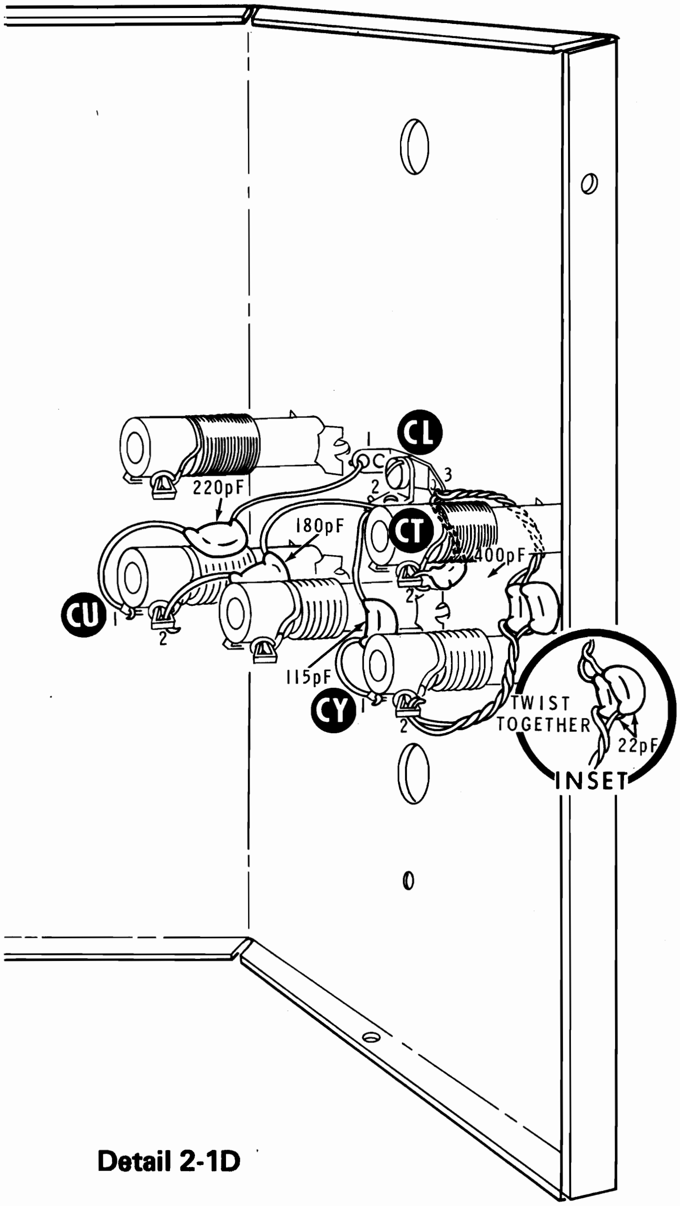
(✓) Install the 20-meter coil (#40-965) at CU. See Detail 2-1C.

(✓) Install a 10/15-meter coil (#40-964) at CX.

(✓) Install a 10/15-meter coil (#40-964) at CY.

(✓) Install the 80-meter coil (#40-1012) at CS.

(✓) Install the 40-meter coil (#40-966) at CT.



Detail 2-1D

Refer to Detail 2-1D for the following steps.

NOTE: When you wire capacitors to the five coils in the following steps, position the body of each capacitor against its coil. However, be sure the capacitor leads do not touch the wire of the coil.

Note the positions of lugs 1 and 2 of each coil as shown in Detail 2-1C, on Page 13.

(✓) Connect a 220 pF mica capacitor from lug 1 of coil CU (NS) to ground lug CL-1 (NS). Position the capacitor close to the coil as shown.

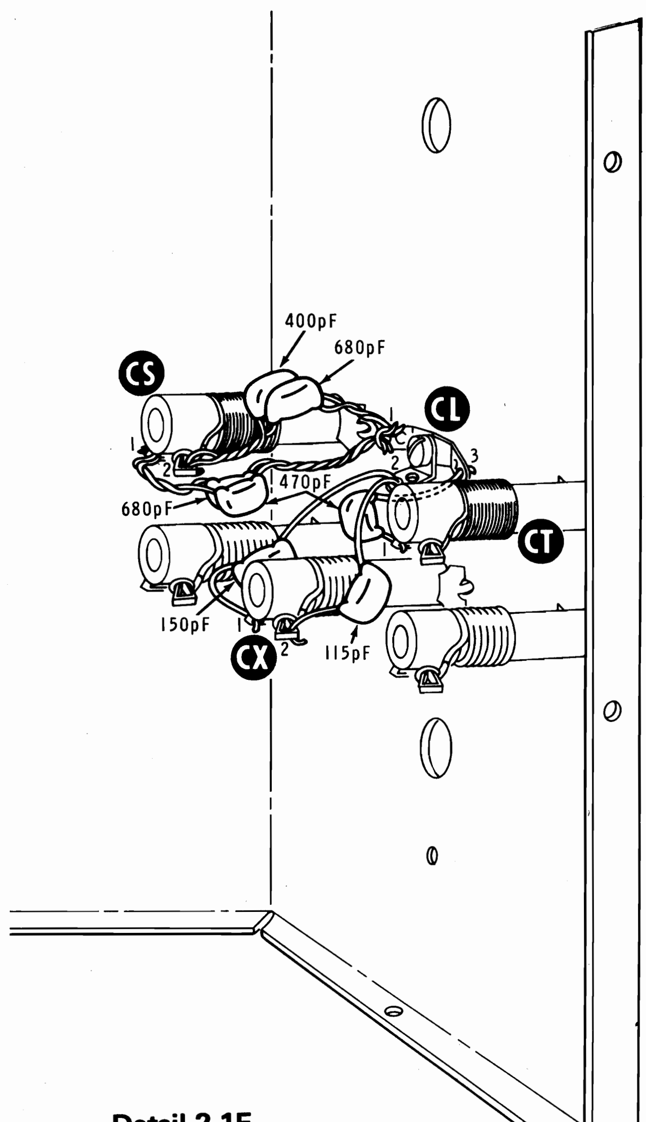
(✓) Connect a 180 pF mica capacitor from lug 2 of coil CU (NS) to ground lug CL-2 (NS).

(✓) Connect a 400 pF mica capacitor from lug 2 of coil CT (NS) to ground lug CL-3 (NS).

(✓) Connect a 115 pF mica capacitor from lug 1 of coil CY (NS) to ground lug CL-2 (NS).

(✓) Refer to the inset drawing on Detail 2-1D and twist together the leads of two 22 pF mica capacitors as shown. NOTE: Each twisted pair of leads will be counted as two leads in a solder step.

(✓) Connect one pair of leads to lug 2 of coil CY (NS) and the other pair of leads to ground lug CL-3 (NS).



Detail 2-1E

Refer to Detail 2-1E for the following steps.

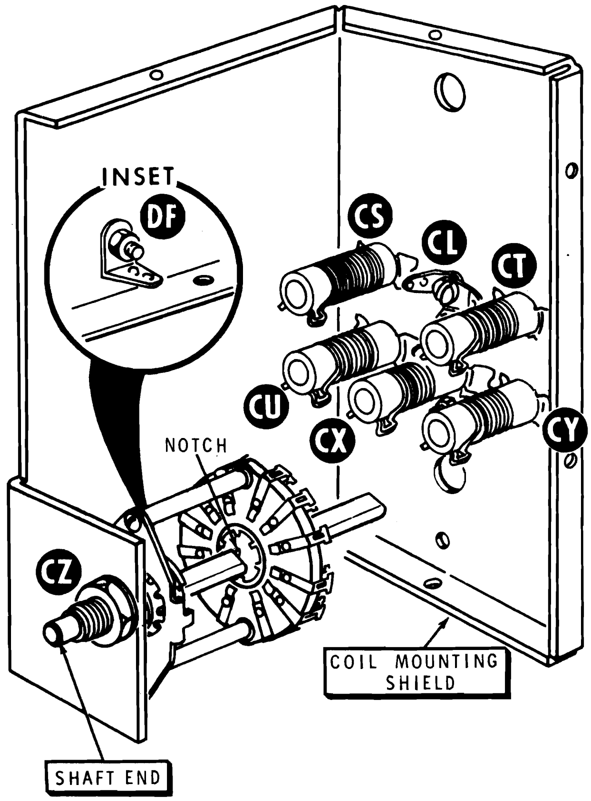
(✓) Connect a 150 pF mica capacitor from lug 1 of coil CX (NS) to ground lug CL-2 (NS). Position the capacitor as shown.

(✓) Connect a 115 pF mica capacitor from lug 2 of coil CX (NS) to ground lug CL-2 (S-4).

(✓) Twist the leads of a 470 pF and a 680 pF mica capacitor together as in a previous step. Connect one pair of leads to lug 1 of coil CS (NS) and the other pair of leads to ground lug CL-1 (NS). Position the capacitors as shown.

(✓) Twist the leads of a 400 pF and a 680 pF mica capacitor together. Connect one pair of leads to lug 2 of coil CS (NS) and the other pair of leads to ground lug CL-1 (S-5).

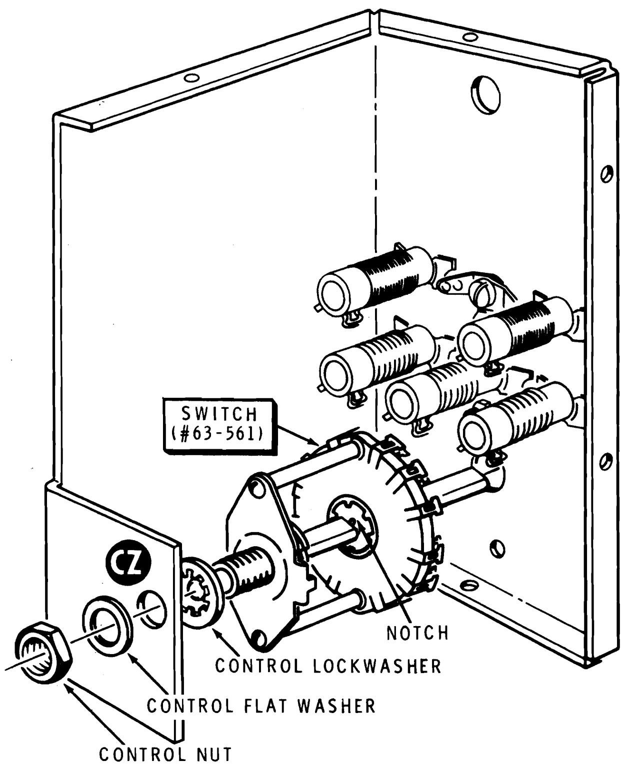
(✓) Connect a 470 pF mica capacitor from lug 1 of coil CT (NS) to ground lug CL-3 (S-4). Position the capacitor as shown.



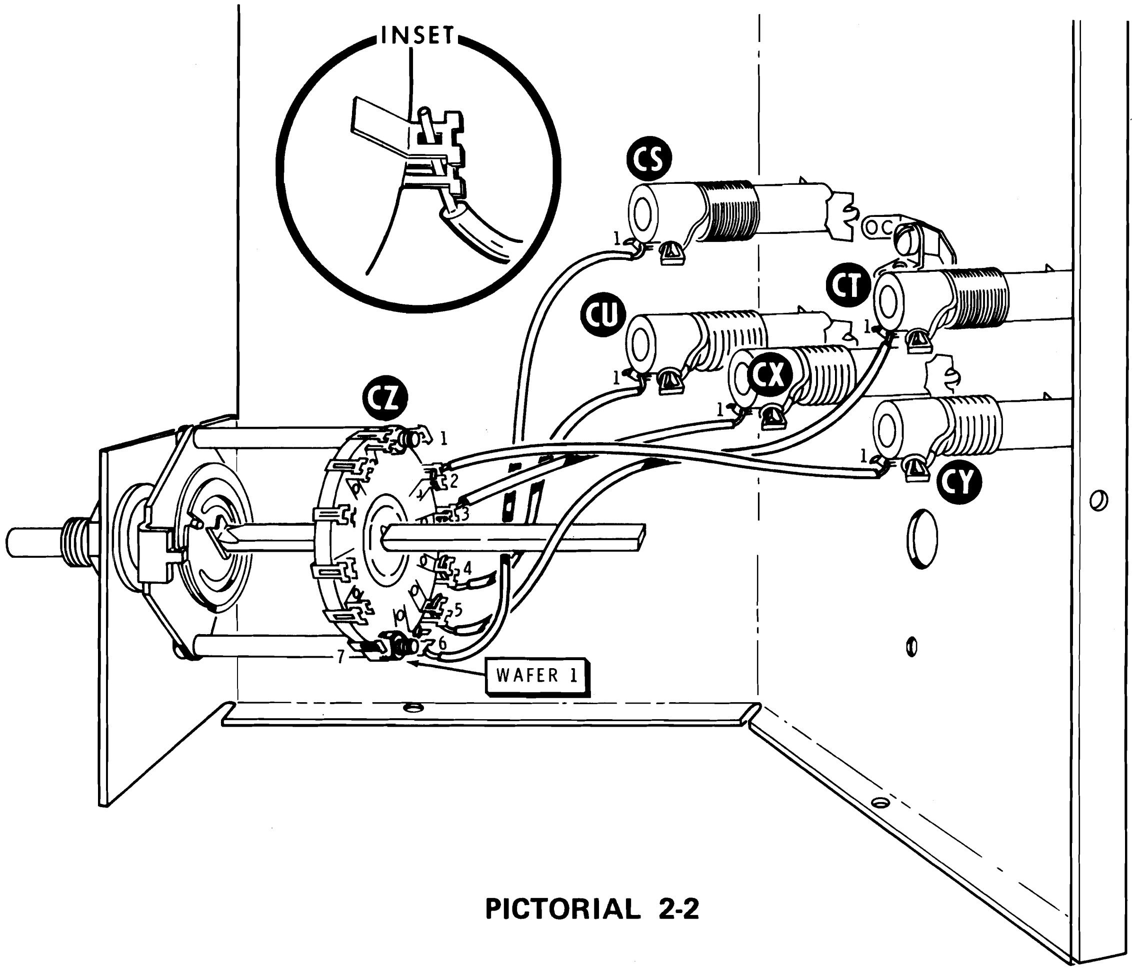
PICTORIAL 2-1
(Repeat)

(✓) Turn the shaft of the 5-position rotary switch (#63-561) fully clockwise as viewed from the shaft end.

(✓) Refer to Detail 2-1F and mount the 5-position rotary switch on the coil mounting shield at CZ. Use a control nut, a control lockwasher, and a control flat washer. Be sure the two switch spacers and the switch shaft are aligned vertically and that the notch in the rotor is positioned as shown.



Detail 2-1F



PICTORIAL 2-2

Refer to Pictorial 2-2 for the following steps.

( ) Prepare the following lengths of black hookup wire. The wires are listed in the order in which they will be used.

2-1/4"

3-1/2"

3-1/2"

1-3/4"

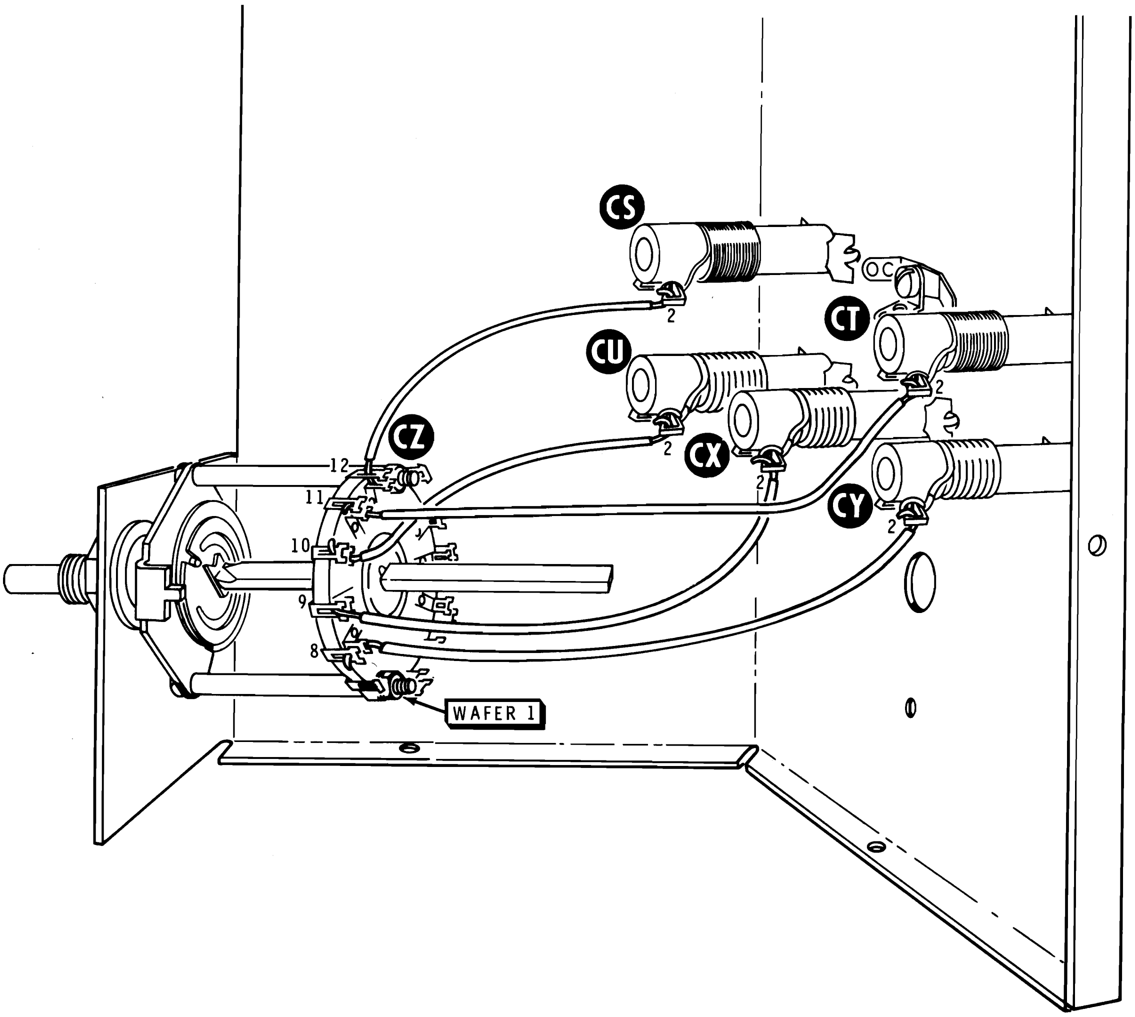
2"

NOTE: Switch CZ has lugs only on the front of the wafer at positions 1 and 7. All other positions on this wafer have lugs on the front and on the rear of the wafer. Be sure to connect the wire to both lugs when there are double lugs.

When a wire passes through a connection and then goes to another point, it will count as two wires in the solder instructions, one entering and one leaving the connection. Thus, when a wire passes through one switch lug and then goes on to the other switch lug at the same position, it will count as three wires (S-3) in the solder instructions.

Connect the prepared hookup wires from the coils to wafer 1 of switch CZ as follows:

	Wire Length	Connect From Lug 1 of	Connect to Wafer 1 of Switch CZ
( )	2-1/4"	Coil CU (S-2)	Lug 4 (S-3)
( )	3-1/2"	Coil CT (S-2)	Lug 5 (S-3)
( )	3-1/2"	Coil CS (S-3)	Lug 6 (S-3)
( )	1-3/4"	Coil CX (S-2)	Lug 3 (S-3)
( )	2"	Coil CY (S-2)	Lug 2 (S-3)



PICTORIAL 2-3

Refer to Pictorial 2-3 for the following steps.

( ) Prepare the following lengths of black hookup wire. Wires are listed in the order in which they will be used.

2-1/2"

2"

2-1/2"

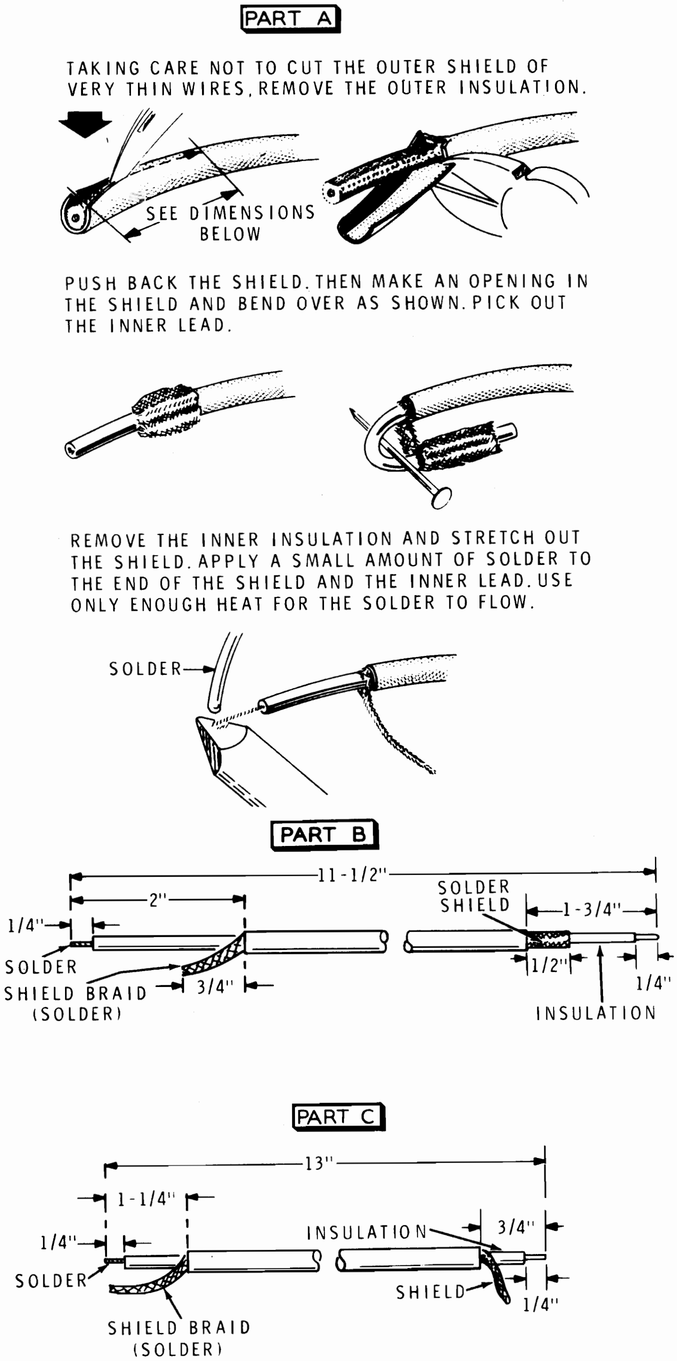
2-1/2"

2-1/2"

Connect the prepared hookup wire from the coils to wafer 1 of switch CZ as follows:

	Wire Length	Connect From Lug 2 of	Connect to Wafer 1 of Switch CZ
(✓)	2-1/2"	Coil CY (S-3)	Lug 8 (S-3)
(✓)	2"	Coil CX (S-2)	Lug 9 (S-3)
(✓)	2-1/2"	Coil CU (S-2)	Lug 10 (S-3)
(✓)	2-1/2"	Coil CT (S-2)	Lug 11 (S-3)
(✓)	2-1/2"	Coil CS (S-3)	Lug 12 (S-3)

¾ ½ ¼ 0 1" 2" 3" 4" 5" 6"



PICTORIAL 2-4

NOTE: When you prepare coaxial cables in the following steps, refer to Part A of Pictorial 2-4 for the method of removing the inside of the cable from the shield braid. Be careful not to melt the inner insulation.

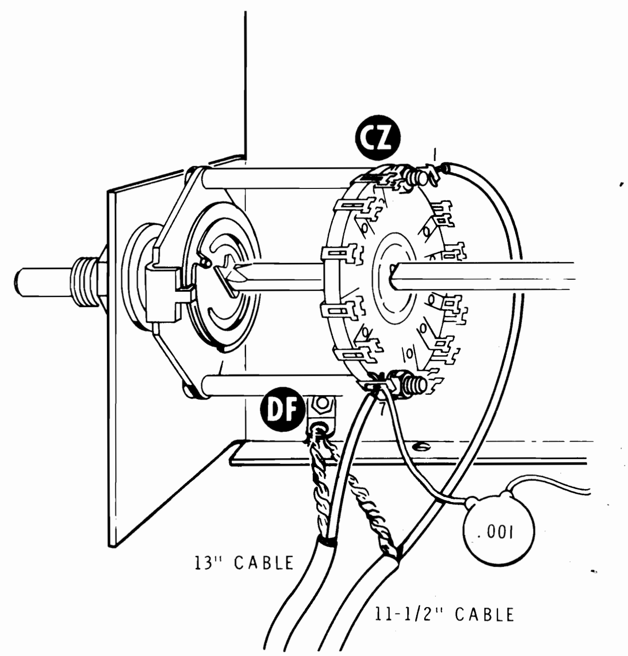
(✓) Prepare an 11-1/2" length of RG-58A/U coaxial cable as shown in Pictorial 2-4, Part B. Twist the center conductor wires together and apply a <u>small</u> amount of solder to each end to hold the small strands together. In a like manner, twist and solder the end of the shield braid.

(✓) Refer to Pictorial 2-4, Part C, and prepare a 13" length of RG-58A/U coaxial cable as shown.

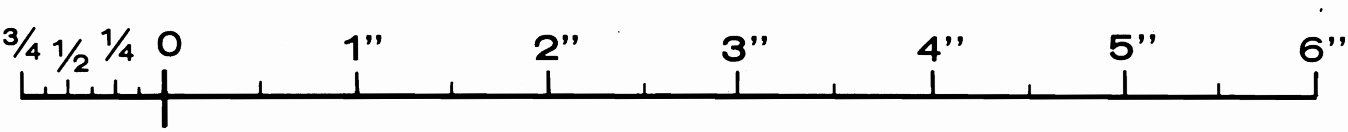
(✓) Refer to Pictorial 2-5 and connect the 1-1/4" end of the center conductor of the 13" coaxial cable to lug 7 of wafer 1 of switch CZ (NS). Connect the shield braid to solder lug DF (NS).

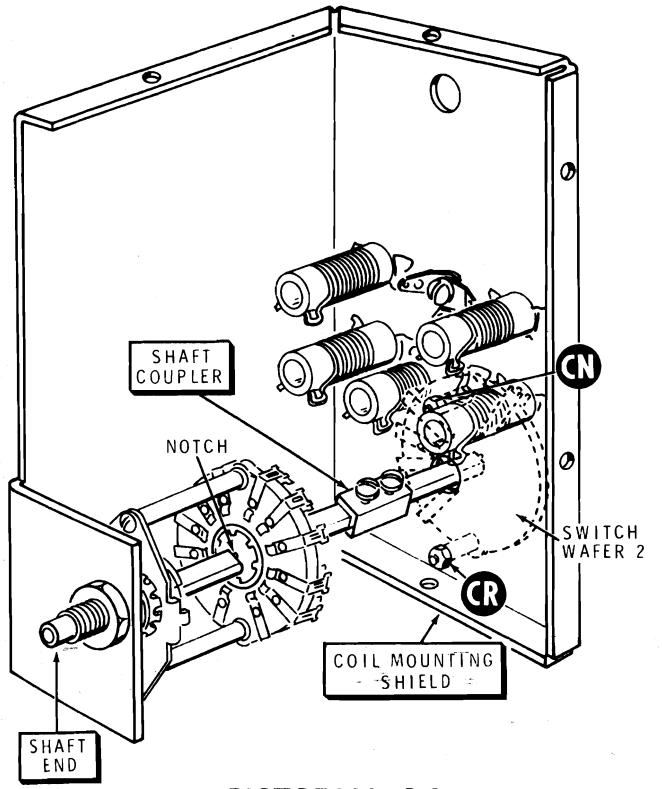
(✓) Cut each lead of a 500 volt (smaller) .001 μF disc capacitor to a length of 3/4". Connect one lead of this capacitor to lug 7 of wafer 1 of switch CZ (S-2). The other lead will be connected later.

(✓) Connect the 2" end of the center conductor of the 11-1/2" coaxial cable to lug 1 of wafer 1 of switch CZ (S-1). Connect the braid to solder lug DF (S-2). NOTE: The other ends of the coaxial cables will be connected later.



PICTORIAL 2-5

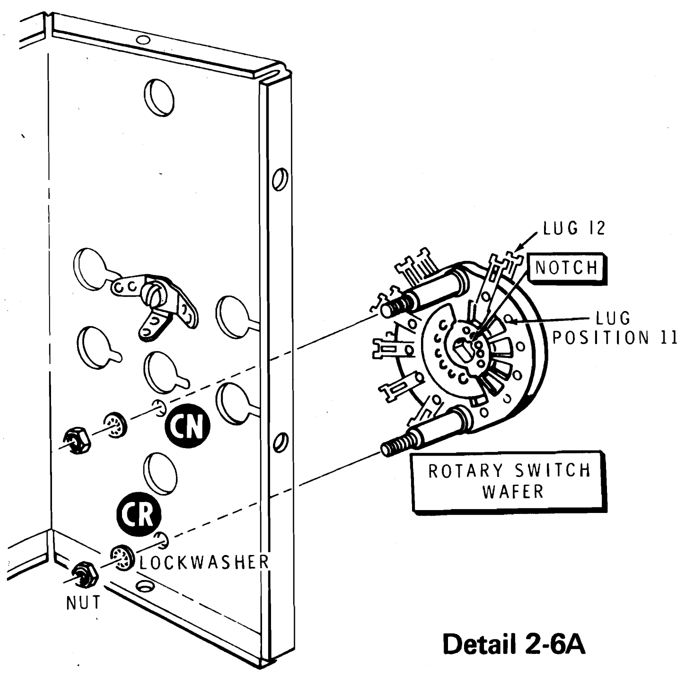




PICTORIAL 2-6

Refer to Pictorial 2-6 for the following steps.

(✓) Refer to Detail 2-6A and remove the two nuts from the screws passing through the two spacers of the separate rotary switch wafer (#63-562). Retain the spacers on the screws.

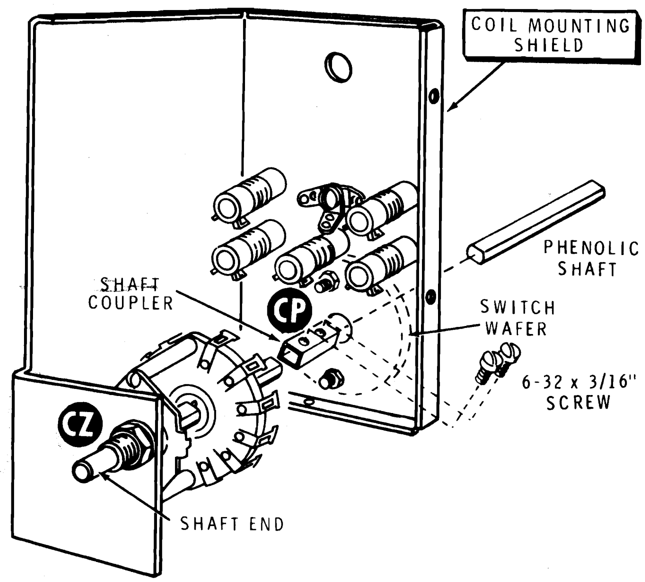


Detail 2-6A

(✓) Insert the bared screw ends into holes CN and CR of the coil mounting shield with lug 12 positioned as shown. Secure the switch with two #6 lockwashers and with the two nuts previously removed.

(✓) Position the rotating portion of the switch wafer as shown so the notch points between switch lugs 11 and 12. The phenolic shaft (#453-135) may be used to turn the switch rotor.

(✓) Check to be sure that switch CZ is still turned fully clockwise (viewed from the shaft end).



Detail 2-6B

Refer to Detail 2-6B for the following steps.

(✓) Start two 6-32 x 3/16" screws into the tapped holes of the shaft coupler (#456-16). Then slide half the length of the shaft coupler onto the shaft of switch CZ and tighten one screw. The screws should be at the one o'clock position (viewed from the shaft end).

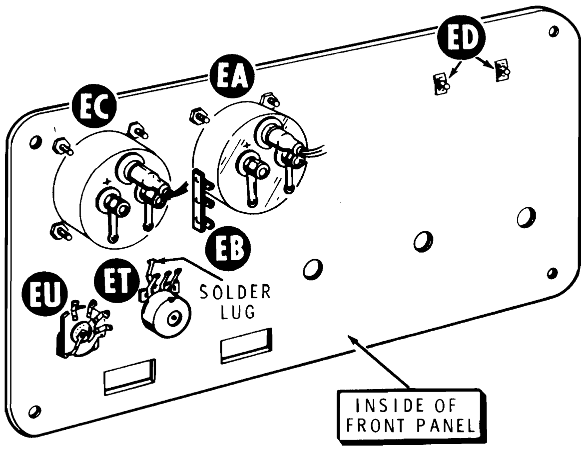
CAUTION: Be careful when you tighten the setscrew in the following step. Use an angle screwdriver if one is available.

(✓) Slide the phenolic shaft (#453-135) through the switch wafer on the rear of the coil mounting shield, through hole CP in the shield, and into the shaft coupler. Tighten the remaining setscrew in the shaft coupler onto the phenolic shaft.

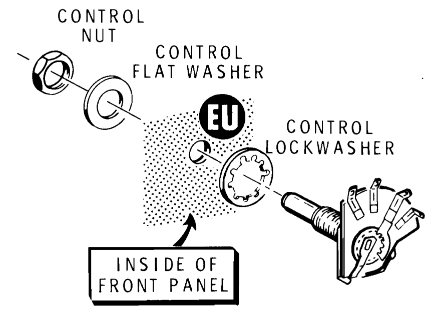
(✓) Turn the switch shaft to its stop in each direction and make sure that no wires interfere with the coupling.

This completes the "Input Coil Assembly."

Set the input coil assembly aside until it is called for later.



PICTORIAL 3-1



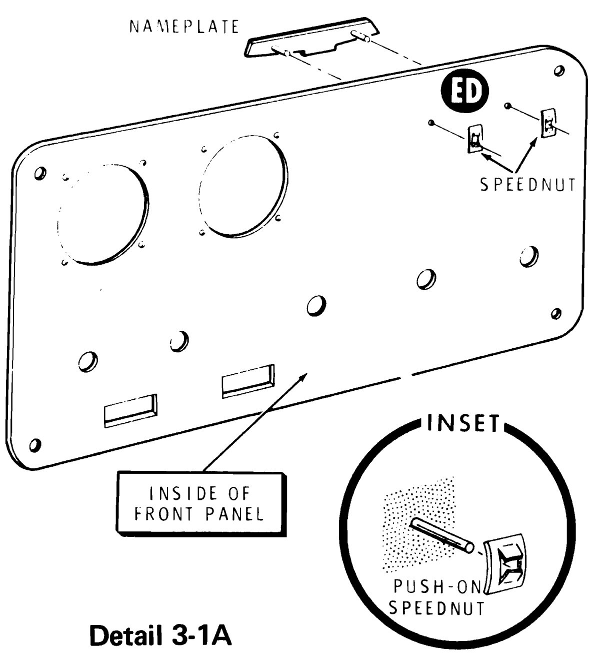
Detail 3-1B

FRONT PANEL

NOTE: To avoid scratching the front panel and meter faces during the following steps, place a soft cloth on your work table.

Refer to Pictorial 3-1 for the following steps.

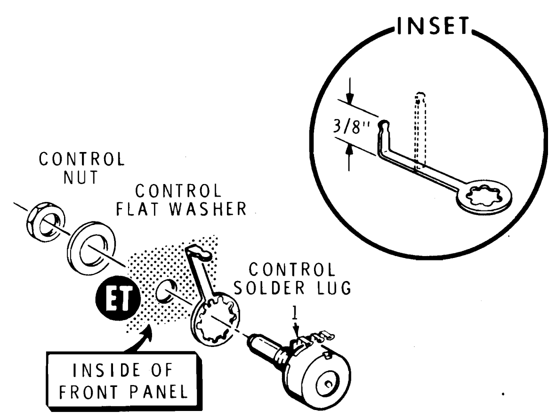
(✓) Refer to Detail 3-1A and install the Heathkit nameplate in the two holes marked ED. Use the two speednuts.



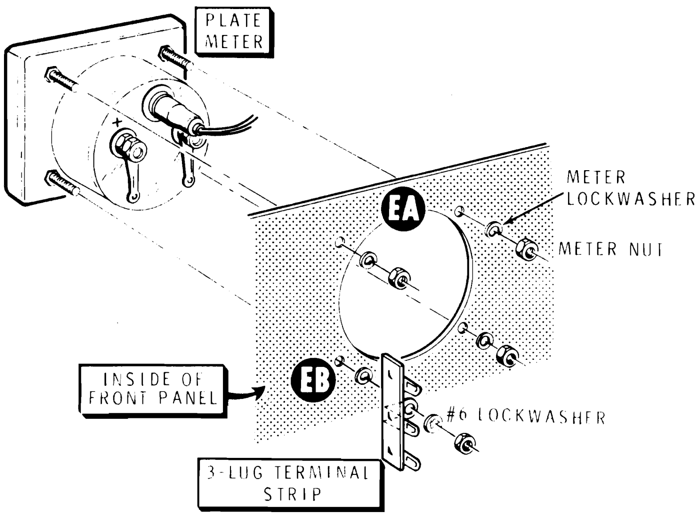
Detail 3-1A

(✓) Refer to Detail 3-1B and install the 3-position rotary switch (#63-47) at EU. Use a control lockwasher, a control flat washer, and a control nut. Position the switch lugs as shown in the Pictorial.

(✓) Refer to Detail 3-1C and install the 100 kΩ sensitivity control (#10-12) at ET. Use a control solder lug, a control flat washer, and a control nut. Form the control solder lug as shown. Then align the control solder lug with lug 1 of the control.



Detail 3-1C



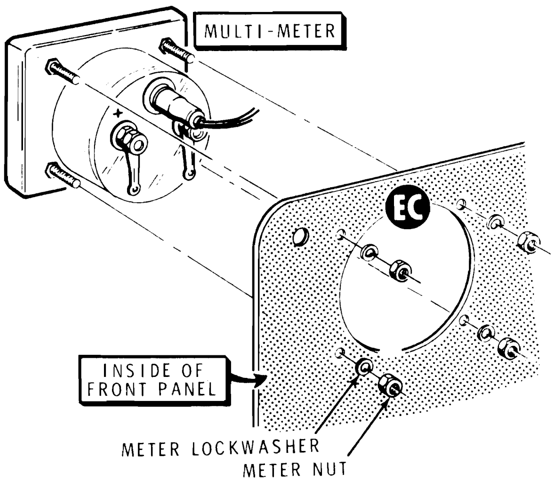
Detail 3-1D

NOTE: Before mounting the terminal strip in the following step, scrape away any paint around hole EB which would prevent the lockwasher and terminal strip foot from making good contact with the panel.

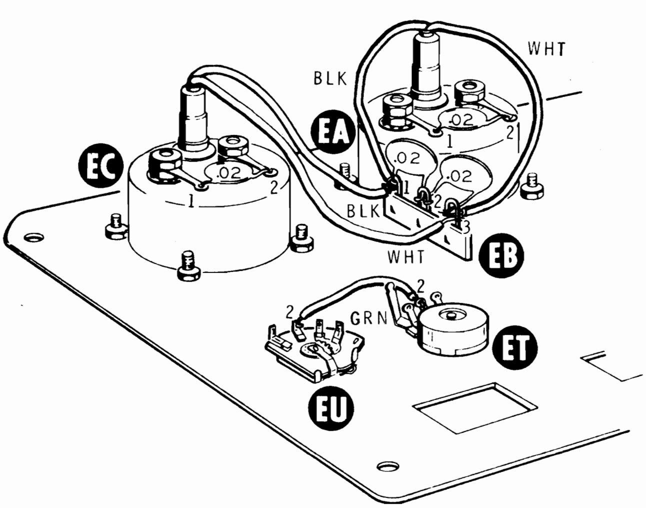
(✓) Refer to Detail 3-1D and install the plate meter (#407-145) at EA. Use the hardware supplied with the meter. Install a 3-lug terminal strip at EB. Note the lockwashers used. CAUTION: Do not overtighten the meter hardware as the meter case can be damaged.

(✓) Refer to Detail 3-1E and install the multi-meter (#407-146) at EC. Use the hardware supplied with the meter.

(✓) Remove and discard the wire jumpers between the meter terminals on each meter.



Detail 3-1E



PICTORIAL 3-2

Refer to Pictorial 3-2 for the following steps.

(✓) Connect a .02 μF disc capacitor between lugs 1 (NS) and 2 (NS) of meter EC.

(✓) Connect a .02 μF disc capacitor between lugs 1 (NS) and 2 (NS) of meter EA.

( ) Cut the leads of two .02 μF disc capacitors to a length of 1/2″. These capacitors will be used in the next two steps.

(✓) Install a .02 μF disc capacitor between lugs 1 (NS) and 2 (NS) of terminal strip EB.

(✓) Install a .02 μF disc capacitor between lugs 2 (S-2) and 3 (NS) of terminal strip EB.

(✓) Cut the black pilot lamp lead from meter EC to 3-1/2″ and the white lead to 4″.

(✓) Connect the black pilot lamp lead coming from meter EC to lug 1 of terminal strip EB (NS).

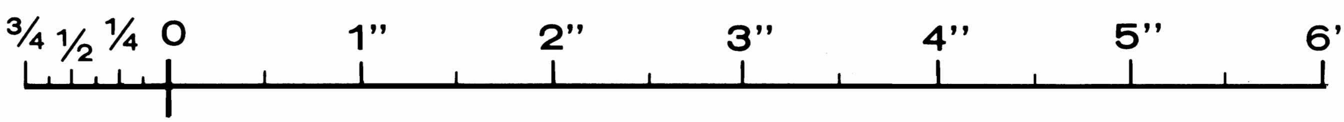
(✓) Connect the white pilot lamp lead coming from meter EC to lug 3 of terminal strip EB (NS).

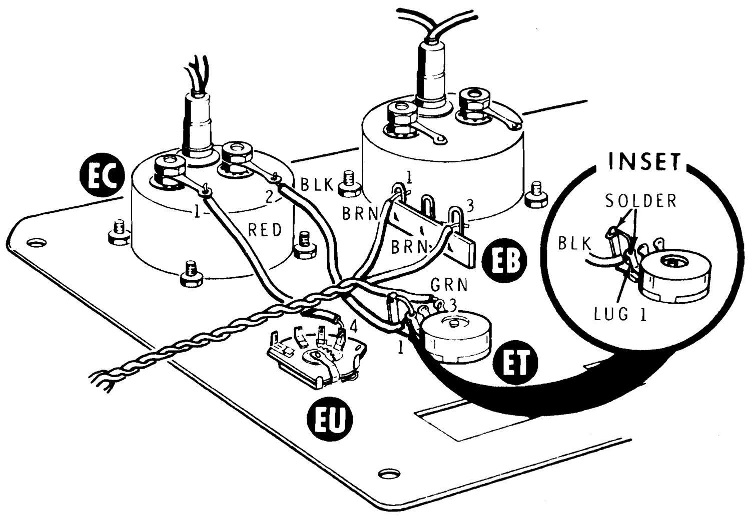
(✓) Cut the black pilot lamp lead coming from meter EA to 3″ and the white lead to 4″.

(✓) Connect the black pilot lamp lead coming from meter EA to lug 1 of terminal strip EB (NS).

(✓) Connect the white pilot lamp lead coming from meter EA to lug 3 of terminal strip EB (NS).

(✓) Connect a 3-1/2″ length of green wire from lug 2 of rotary switch EU (S-1) to lug 2 of control ET (S-1).





PICTORIAL 3-3

(✓) Prepare the following lengths of hookup wire:

3-1/2" black	18" brown
3-1/2" red	18" brown
	30" green

Refer to Pictorial 3-3 for the following steps.

(✓) Remove an additional 1/2" of insulation from one end of the 3-1/2" black wire. Pass this end through lug 1 of control ET (S-2) and wrap it around the control solder lug (S-1). Connect the other end of this black wire to lug 2 of meter EC (S-2).

(✓) Connect a 3-1/2" length of red wire from lug 1 (marked + on the case) of meter EC (S-2) to lug 4 of rotary switch EU (S-1).

(✓) Connect an 18" length of brown wire to lug 3 of terminal strip EB (S-4).

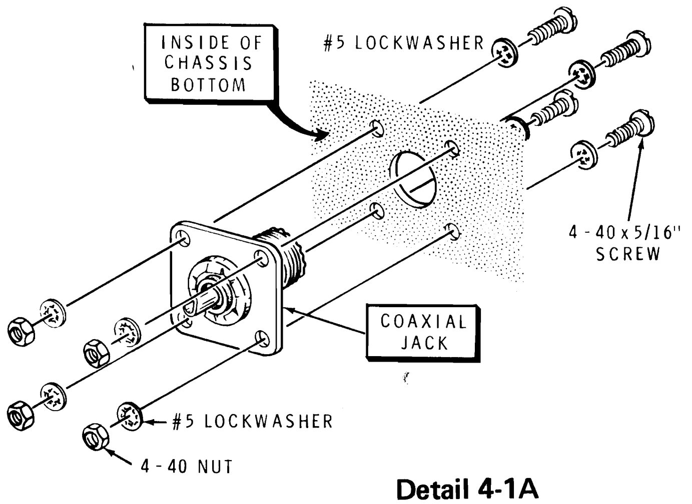
(✓) Connect an 18" length of brown wire to lug 1 of terminal strip EB (S-4).

(✓) Connect a 30" length of green wire to lug 3 of control ET (S-1).

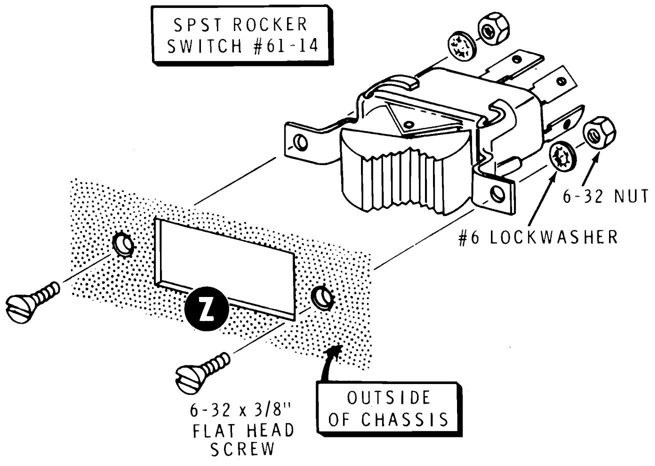
(✓) Gather the green wire and the two brown wires and twist them together approximately one turn per inch.

Set the front panel assembly aside until it is required in later steps.

CHASSIS



Detail 4-1A



Detail 4-1C

CHASSIS PARTS MOUNTING

Refer to Pictorial 4-1 (fold-out from Page 27) for the following steps.

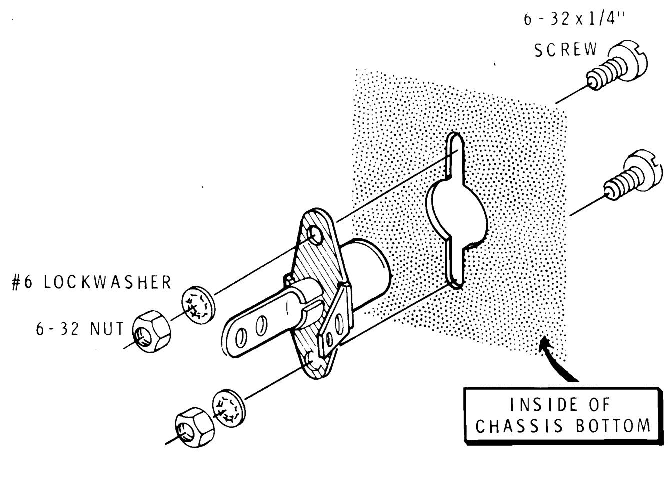
(✓) Install 1/2" rubber grommets at Y, T, AK, and AL.

(✓) Install a 3/4" rubber grommet at AH.

(✓) Refer to Detail 4-1A and mount a coaxial jack at A on the rear apron of the chassis. Use 4-40 x 5/16" hardware and #5 lockwashers.

(✓) In the same manner, mount another coaxial jack at L on the rear apron.

(✓) Refer to Detail 4-1B and mount a phono socket at U on the rear apron. Use 6-32 x 1/4" hardware. Position the ground lug toward the coaxial jack.



Detail 4-1B

(✓) Similarly, mount another phono socket at X.

NOTE: In the following steps, the switch mounting holes are off center and fit in one position only.

(✓) Refer to Detail 4-1C and mount the DPST rocker switch (#61-14) at Z on the front apron of the chassis. Use 6-32 x 3/8" flat head screws with lockwashers and nuts. Note the position of the lugs in the Pictorial.

(✓) Similarly, mount a DPDT rocker switch (#61-15) at AN on the chassis front apron.

NOTE: Discard any loose metal clips you find in the tube socket boxes.

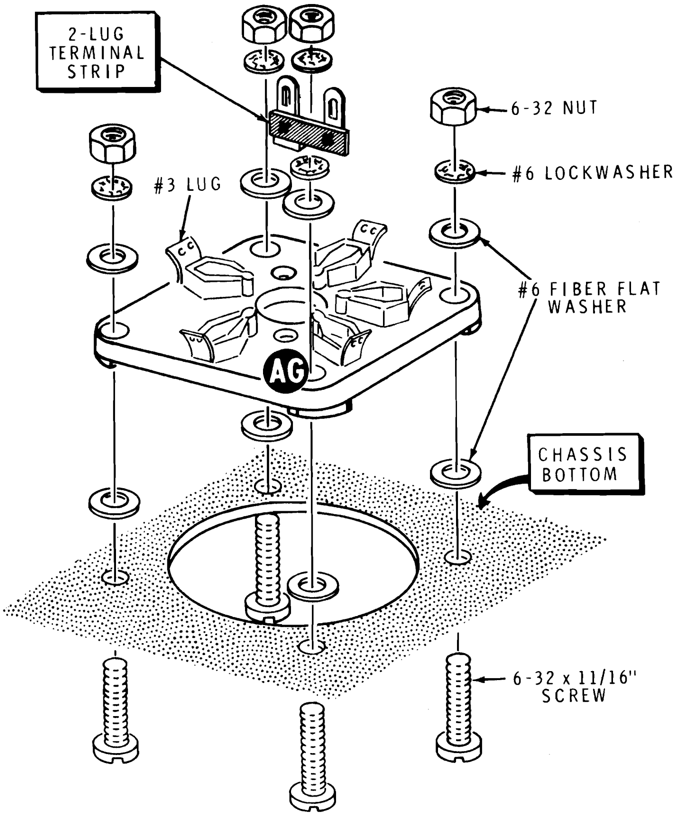
(✓) Refer to Detail 4-1D and mount a 5-lug ceramic tube socket at N with a 2-lug terminal strip at AG. Use 6-32 x 11/16" hardware and fiber flat washers. Be sure to properly position the socket, and to place a lockwasher under the terminal strip mounting foot.

(✓) Similarly, mount a 5-lug ceramic tube socket at D. Use 6-32 x 11/16" hardware and fiber flat washers. Do not use a terminal strip on this socket.

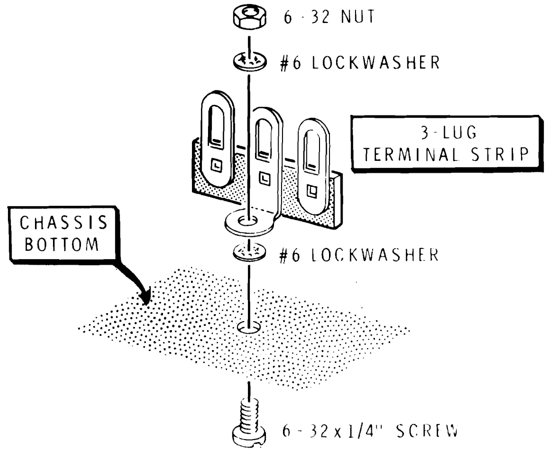
(✓) Refer to Detail 4-1E and mount two #6 solder lugs at C. Use 6-32 x 1/4" hardware. Be sure to position the lugs as shown in the Pictorial.

(✓) Similarly, mount two #6 solder lugs at M. Position these lugs as shown in the Pictorial.

(✓) Similarly, mount one #6 solder lug at E.



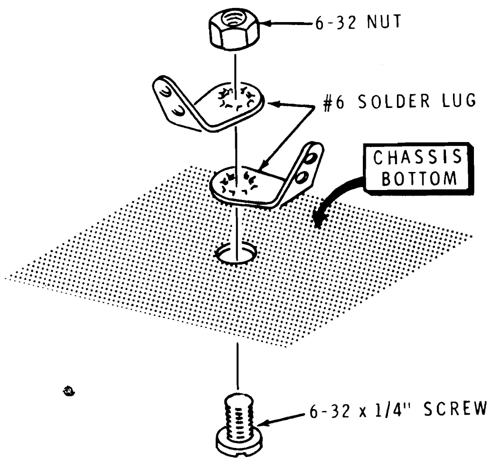
Detail 4-1D



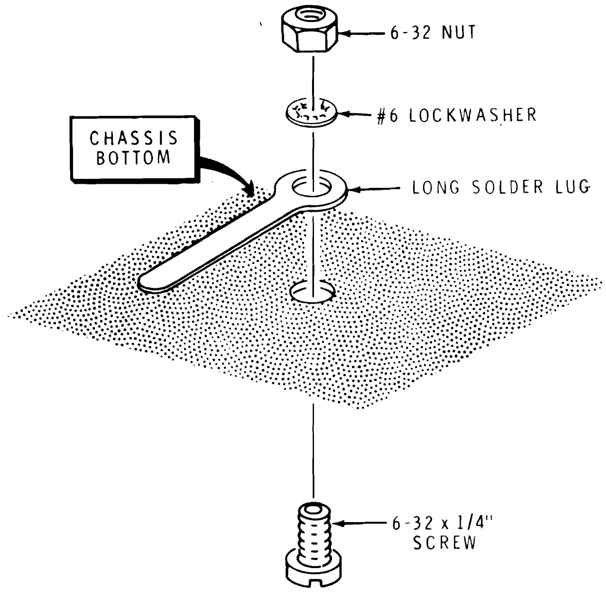
Detail 4-1F

(✓) Refer to Detail 4-1F and mount a 3-lug terminal strip at P. Use 6-32 x 1/4" hardware.

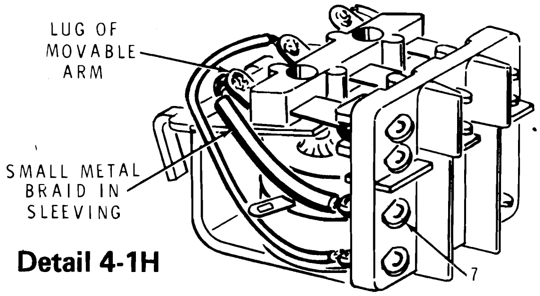
(✓) Refer to Detail 4-1G and mount a long solder lug at R. Use 6-32 x 1/4" hardware.



Detail 4-1E



Detail 4-1G



Detail 4-1H

(✓) Install a 5/16" rubber grommet at F.

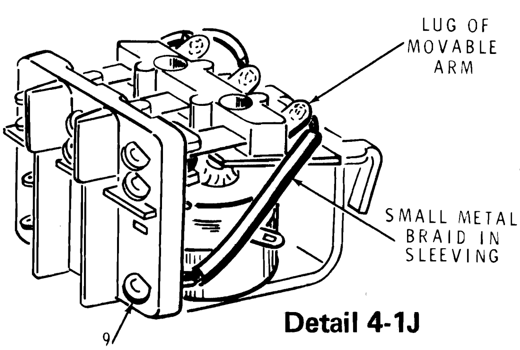
(✓) Refer to Detail 4-1H and position the relay (#69-55) with its lugs to the right as shown. Unsolder and discard the black insulated wire between lug 7 and the movable arm.

NOTE: When you solder the small metal braid in the following steps, use the minimum amount of heat necessary to secure a good connection.

IMPORTANT: Disregard any lug numbers stamped on the relays; refer to the steps and the illustrations for the correct lug numbers.

(✓) Replace the wire discarded in the previous step with a 3-1/4" length of small metal braid that is folded in the middle and pushed through a 1" length of black sleeving. Solder one end of the braid wires to relay lug 7 and the other end to the relay movable arm.

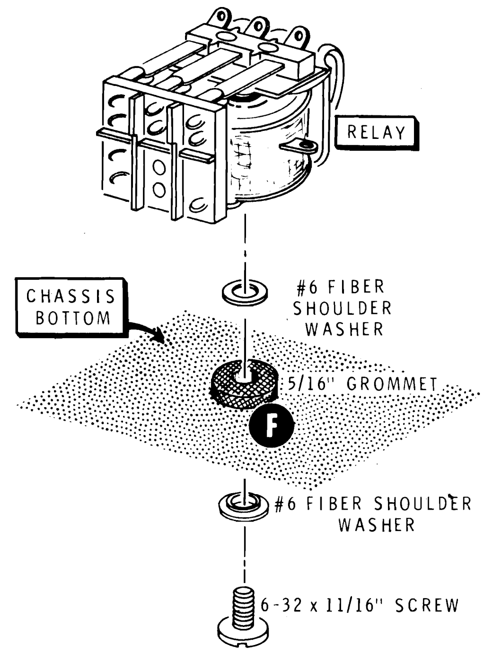
(✓) Refer to Detail 4-1J and position the relay with its lugs to the left. Unsolder and discard the black insulated wire between lug 9 and the movable arm.



Detail 4-1J

(✓) Replace the wire discarded in the previous step with a 4" length of small metal braid that is folded in the middle and pushed through a 1-3/8" length of black sleeving. Solder one end of the braid to lug 9 and the other end to the movable arm.

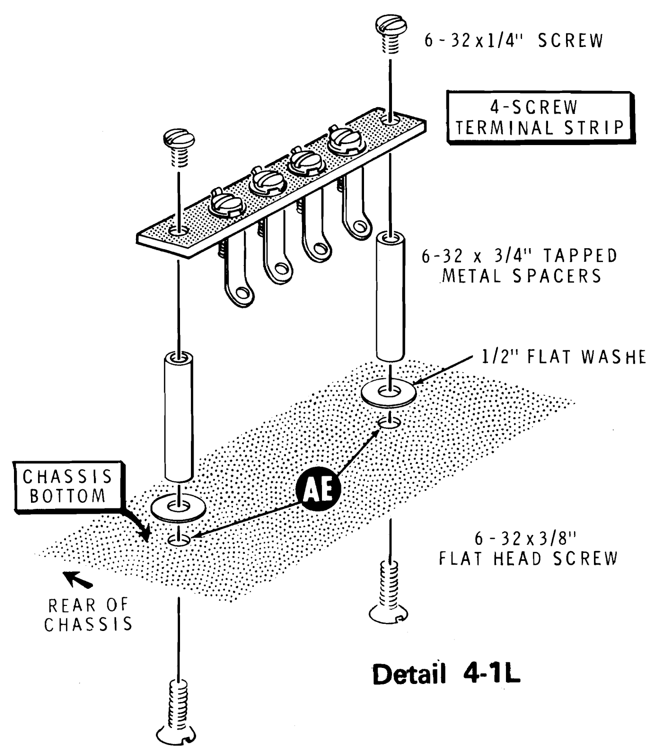
(✓) Refer to Detail 4-1K and mount the relay through grommet F. Use a 6-32 x 11/16" screw and two #6 fiber shoulder washers. Do not overtighten this screw. The rubber grommet is used to provide resiliency.



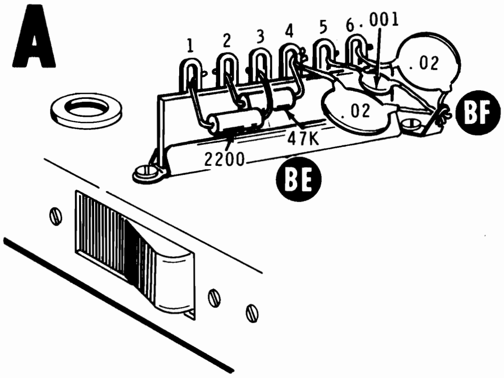
Detail 4-1K

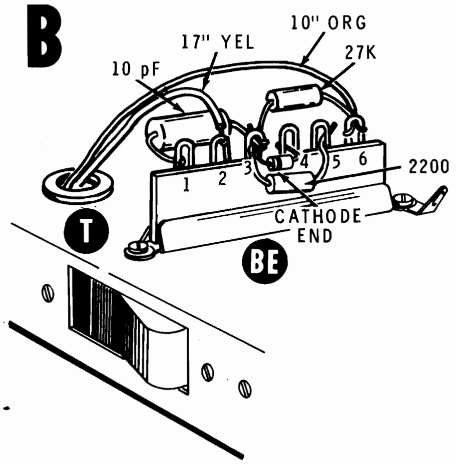
(✓) Inspect the relay to make sure that neither piece of metal braid can possibly touch the metal frame of the relay.

(✓) Refer to Detail 4-1L and mount the 4-screw terminal strip at AE. Use two 6-32 x 3/8" flat head screws, two 1/2" flat washers, two 6-32 x 3/4" tapped metal spacers, and two 6-32 x 1/4" binder head screws.

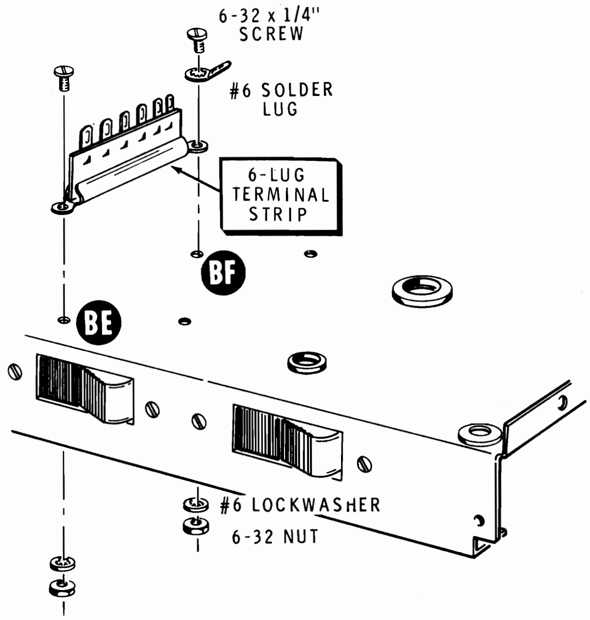


Detail 4-1L





PICTORIAL 4-2



Detail 4-2A

ALC WIRING

Refer to Pictorial 4-2 for the following steps.

(✓) Refer to Detail 4-2A and mount a 6-lug terminal strip on the top of the chassis at holes BE and BF with 6-32 x 1/4" hardware. Use a #6 solder lug at BF only.

Refer to Part A of the Pictorial for the next five steps. Note the positions of the components.

(✓) Connect a 47 kΩ (yellow-violet-orange) resistor from lug 2 (NS) to lug 4 (NS) of terminal strip BE.

(✓) Connect a 2200 Ω (red-red-red) resistor from lug 1 (NS) to lug 3 (NS) of terminal strip BE.

(✓) Connect a .02 μF disc capacitor from lug 4 of terminal strip BE (NS) to solder lug BF (NS).

(✓) Connect a 500 volt (smaller) .001 μF disc capacitor from lug 5 of terminal strip BE (NS) to solder lug BF (NS).

(✓) Connect a .02 μF disc capacitor from lug 6 of terminal strip BE (NS) to solder lug BF (S-3).

Refer to Part B of the Pictorial for the next eight steps.

(✓) Prepare a 10" length of orange hookup wire and a 17" length of yellow hookup wire.

(✓) Connect one end of the orange wire to lug 6 of terminal strip BE (NS).

(✓) Connect one end of the yellow wire to lug 2 of terminal strip BE (S-2).

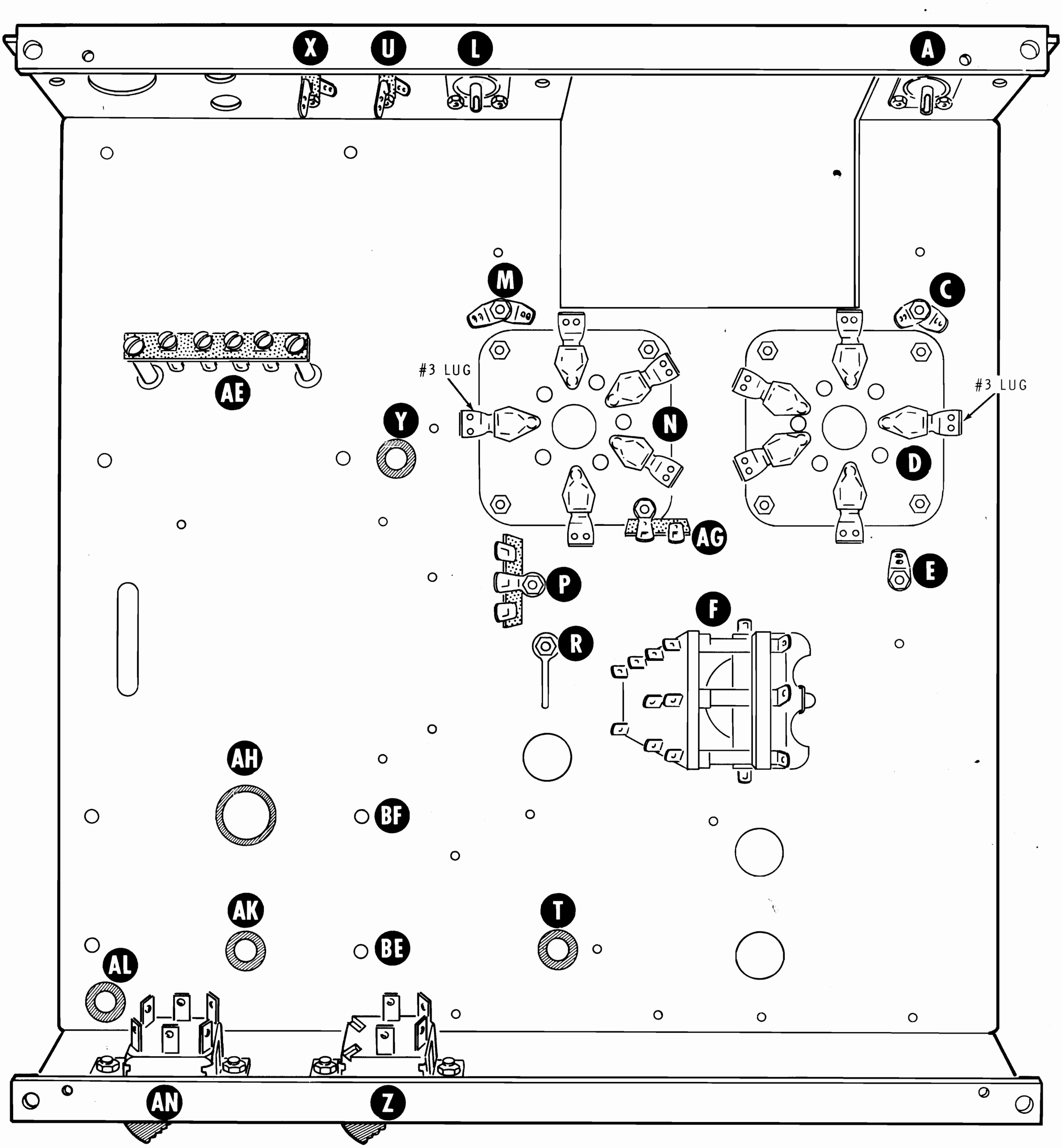
(✓) Pass the free ends of the yellow and the orange wires down through grommet T. To temporarily secure the ends of these wires, they can be passed up through some other hole in the chassis.

(✓) Connect a 2200 Ω (red-red-red) resistor from lug 3 (NS) to lug 5 (S-2) of terminal strip BE.

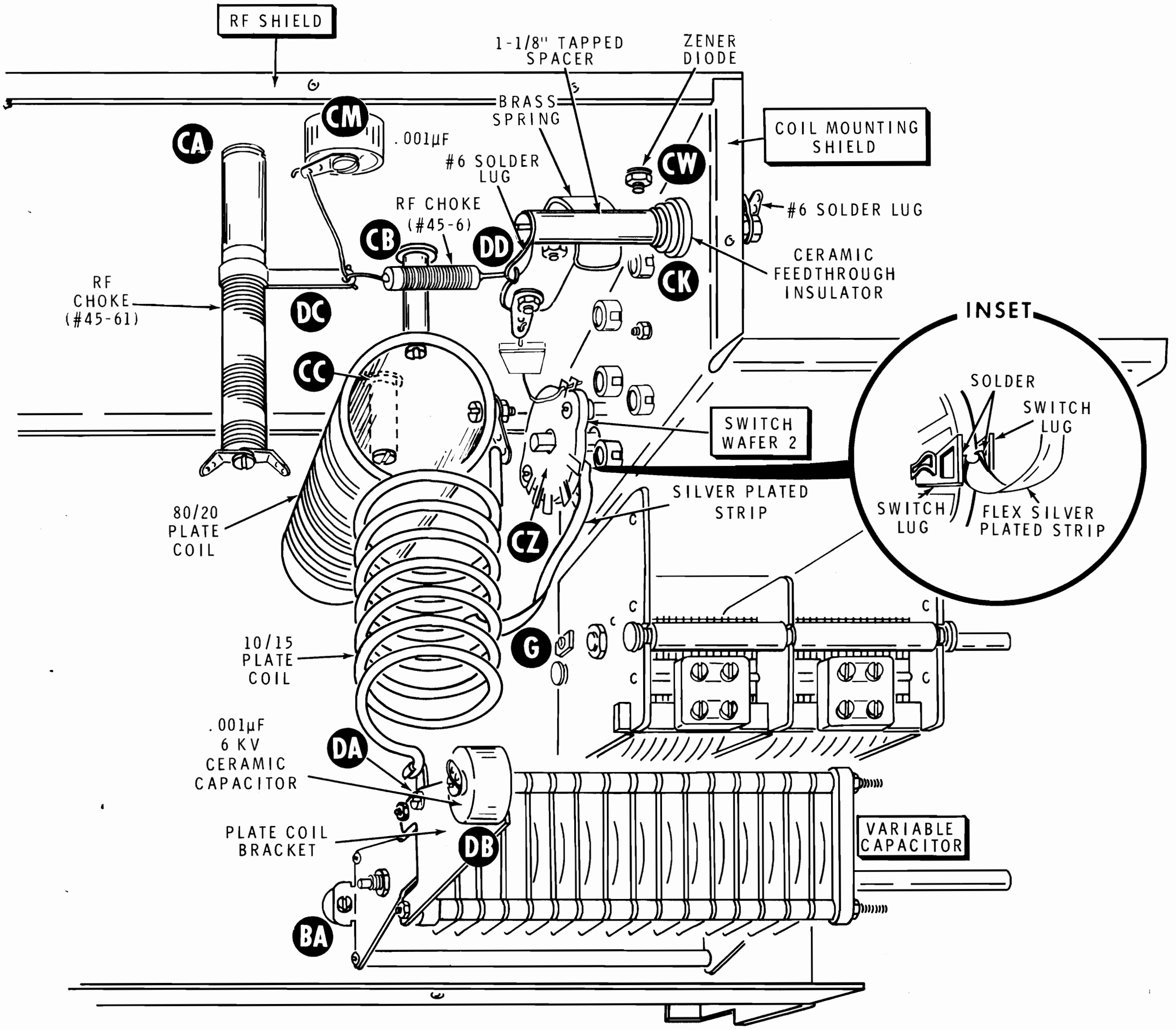
(✓) Connect a 27 kΩ (red-violet-orange) resistor from lug 3 (NS) to lug 6 (S-3) of terminal strip BE.

(✓) Connect the cathode lead of a silicon diode (#56-24, yellow-green-gray) to lug 3 (NS), and the anode lead to lug 4 (S-3) of terminal strip BE.

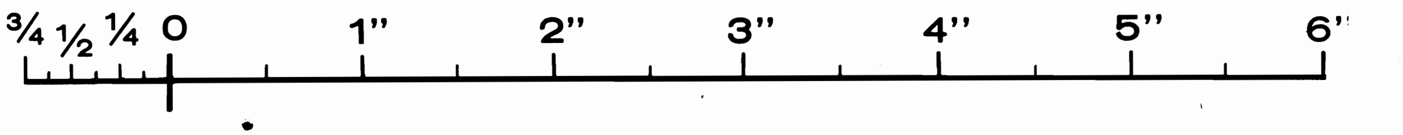
(✓) Connect a 10 pF (may be marked 10 μμF) tubular ceramic capacitor from lug 3 (S-5) to lug 1 (NS) of terminal strip BE.

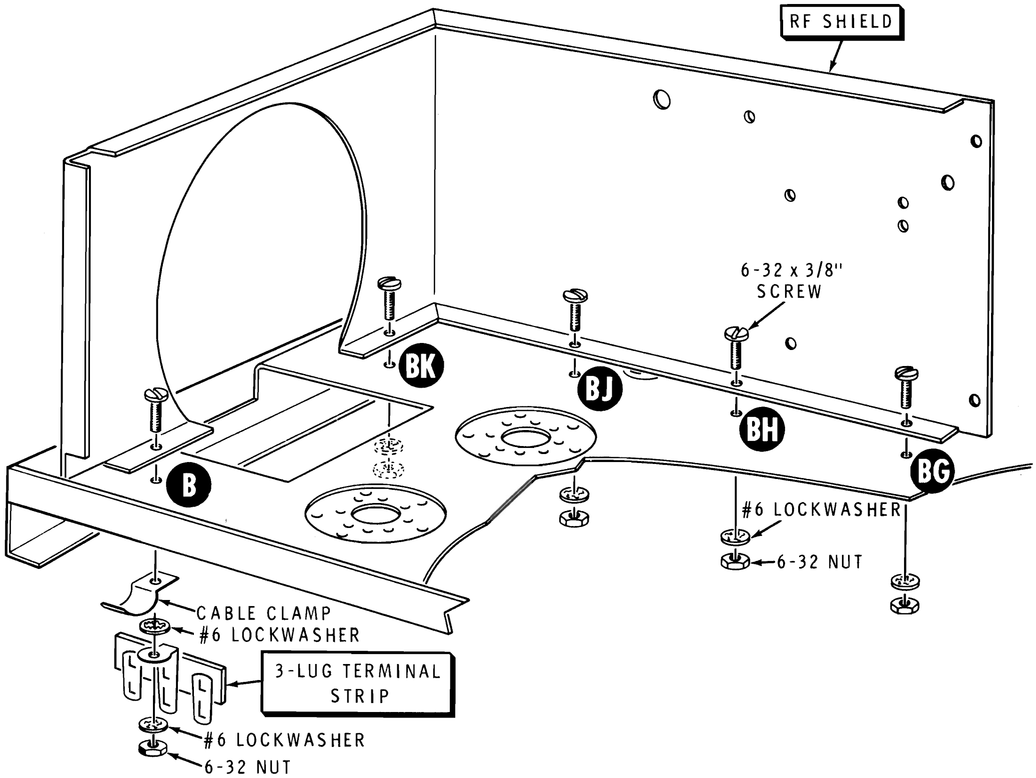


PICTORIAL 4-1



PICTORIAL 4-5





Detail 4-3A

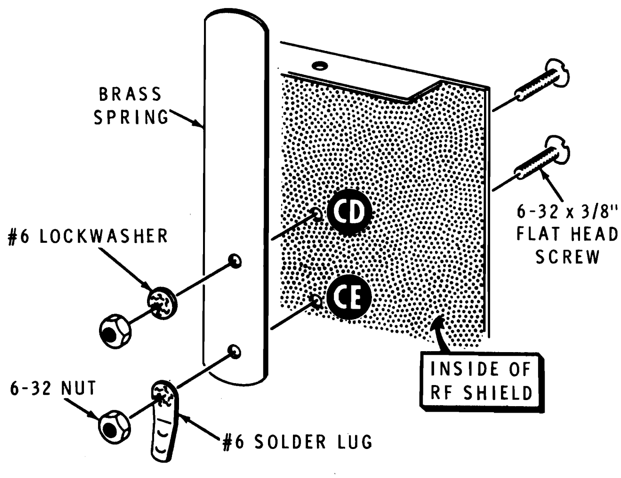
TOP-CHASSIS ASSEMBLY

Refer to Pictorial 4-3 for the following steps.

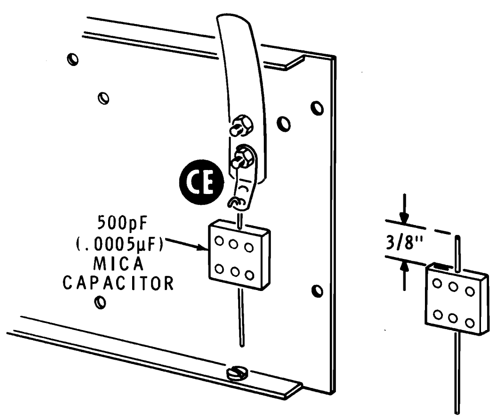
(✓) Refer to Detail 4-3A and mount the RF shield (#206-493) on the top of the chassis. At BG, BH, BJ, and BK, use 6-32 x 3/8" screws. At B, use a 6-32 x 3/8" binder head screw with a 3-lug terminal strip, a cable clamp, two #6 lockwashers, and a 6-32 nut.

(✓) Refer to Detail 4-3B and mount the brass spring (#258-115) at CD and CE on the RF shield. Use 6-32 x 3/8" flat head hardware with a #6 solder lug at CE. When the hardware is tightened, the end of the brass strip will contact the upper lip of the RF shield.

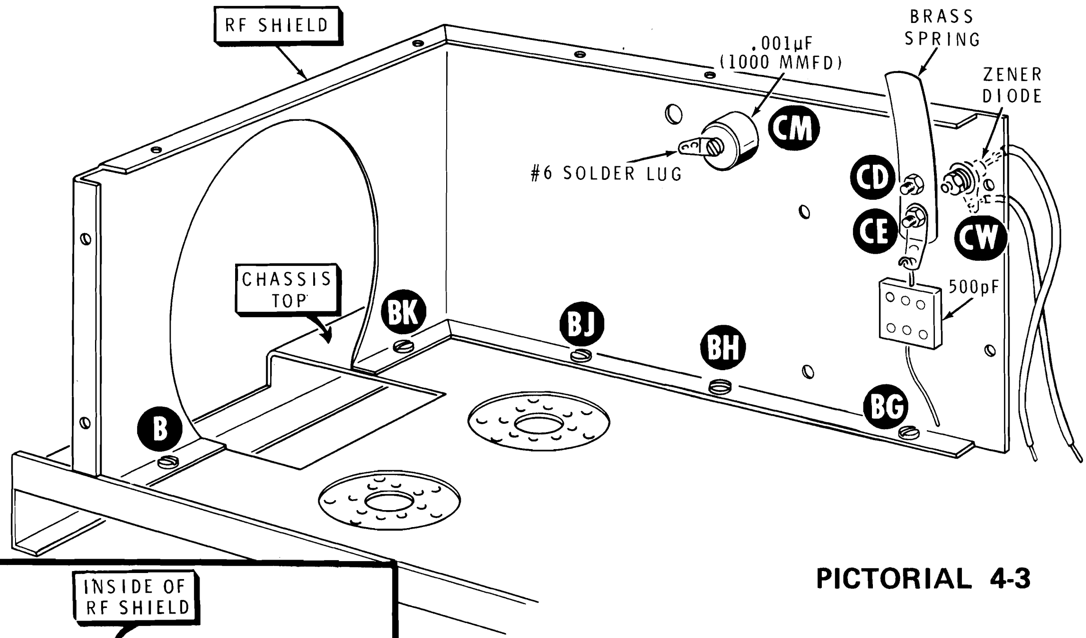
(✓) Refer to Detail 4-3C and cut one lead of a 500 pF mica capacitor (may be marked ".0005") to a length of 3/8". Connect this lead to the solder lug at CE (S-1). The other lead will be connected later.



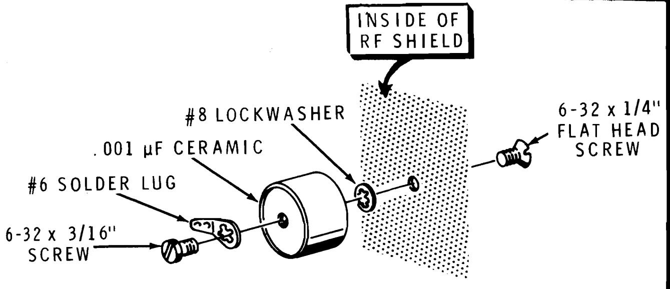
Detail 4-3B



Detail 4-3C



PICTORIAL 4-3



Detail 4-3D

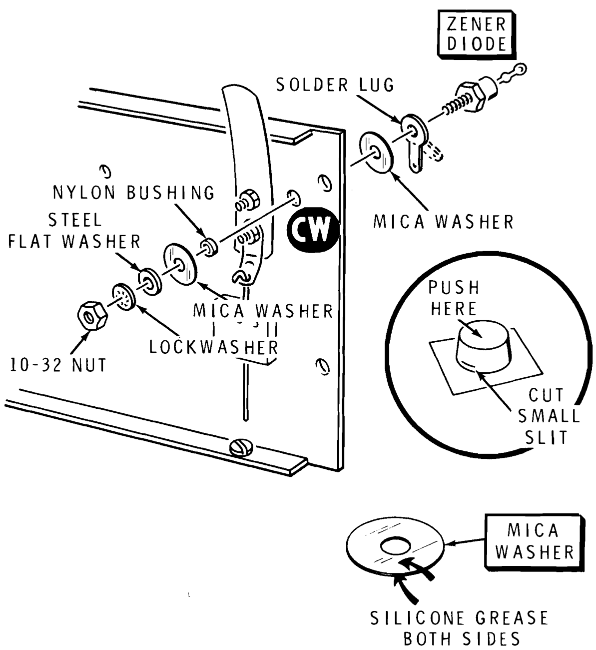
(✓) Refer to Detail 4-3D and mount a .001 µF ceramic capacitor (#21-165) at CM on the inside of the RF shield (this capacitor may be marked 1000 MMFD). Use a 6-32 x 1/4" flat head screw with a #8 lockwasher between the capacitor and the RF shield.

(✓) Install a #6 solder lug on the other terminal of the capacitor with a 6-32 x 3/16" screw. Position the solder lug as shown.

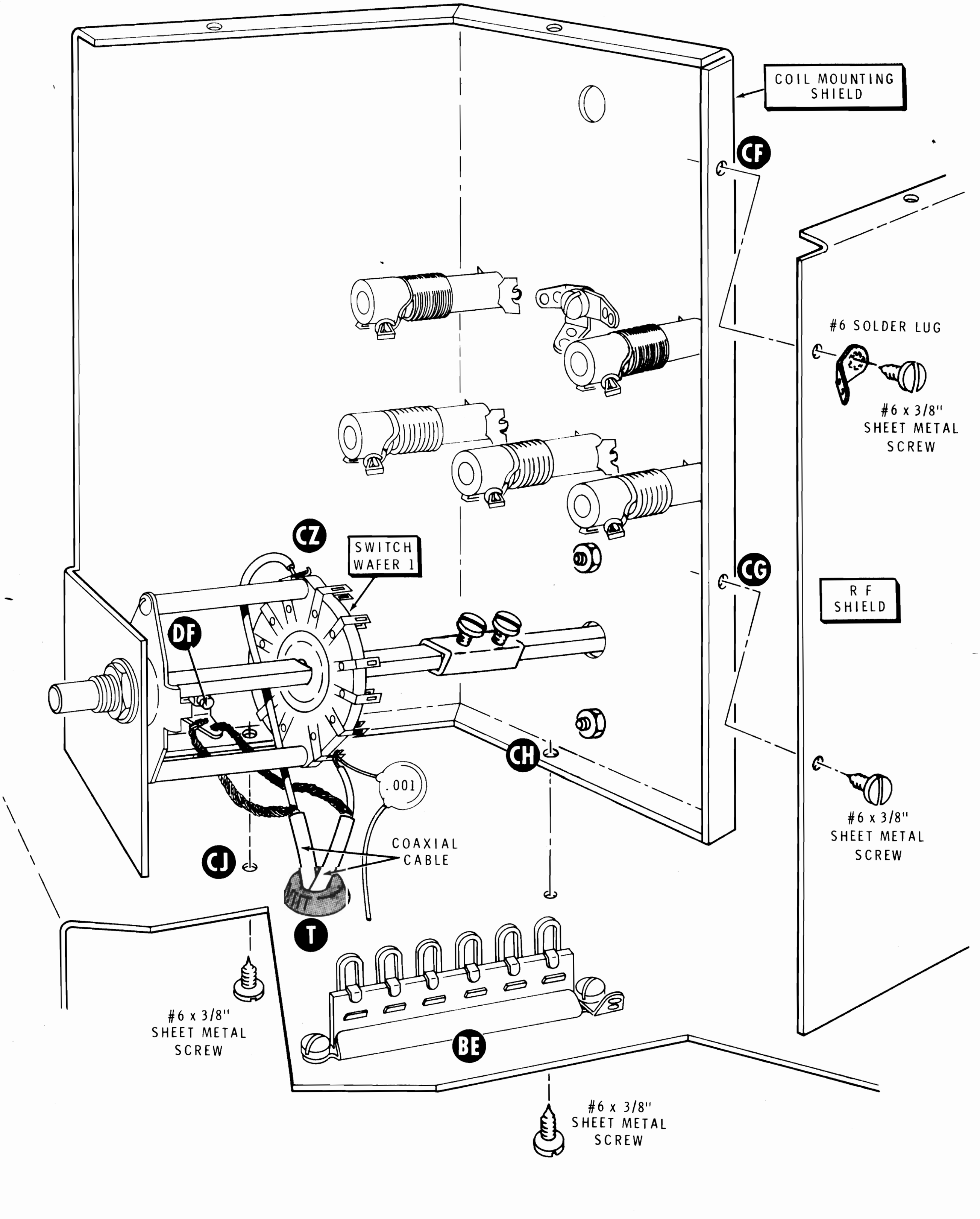
(✓) Refer to Detail 4-3E and install the zener diode at CW on the outside of the RF shield with the mounting stud and nut on the same side of the shield as the brass spring, as shown in the Pictorial. Cut a slit in the silicone grease pod (#352-13), squeeze out some grease, and with your finger coat both sides of each mica washer before you install it. Make sure the nylon bushing is centered in the hole and that the solder lug points toward the chassis. Tighten the nut firmly, but do not overtighten.

(✓) Bend the end of the solder lug up away from the chassis at an angle of approximately 45 degrees.

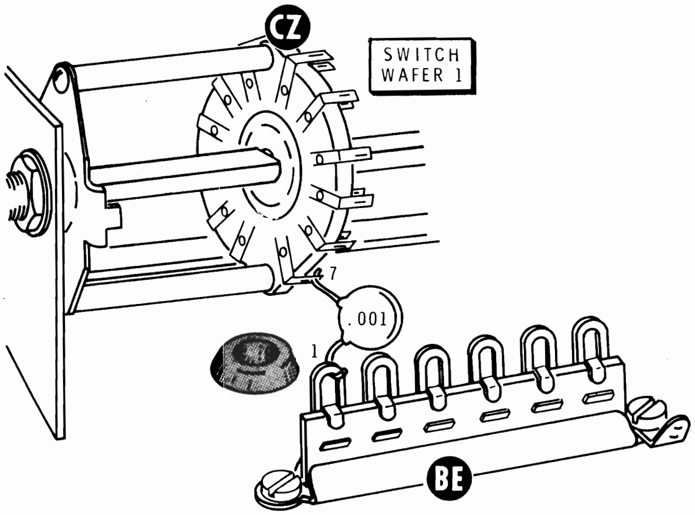
(✓) Prepare two 3" lengths of small black stranded wire. Connect one end of one wire to the solder lug at CW (S-1). Connect one end of the other 3" wire to the solder terminal on the zener diode (S-1). The other ends of these wires will be connected later.



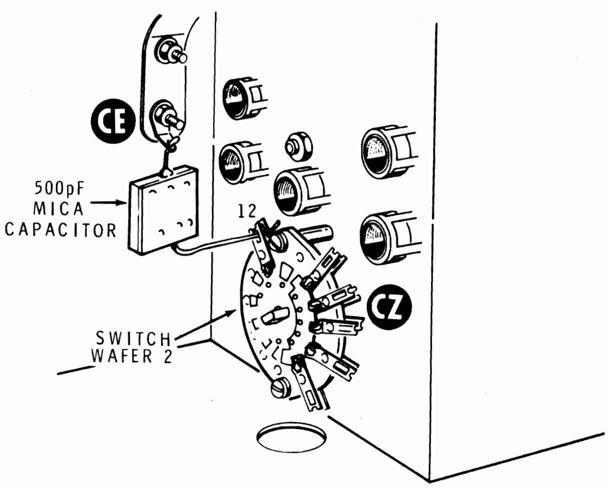
Detail 4-3E



PICTORIAL 4-4



Detail 4-4A



Detail 4-5A

Refer to Pictorial 4-4 for the following steps. For clarity, only the coil mounting shield is shown.

(✓) Start the ends of the two coaxial cables coming from wafer 1 of switch CZ down through grommet T, and lower the input coil assembly down onto the chassis. Pull the two coaxial cables through the grommet as you lower the assembly.

(✓) From the bottom of the chassis, install #6 sheet metal screws at CH and CJ into the coil mounting shield.

(✓) Make sure none of the parts on terminal strip BE contact any part on switch CZ.

(✓) Install a #6 sheet metal screw and a #6 solder lug at CF. Note the position of the solder lug.

(✓) Install a #6 x 3/8" sheet metal screw at CG.

(✓) Refer to Detail 4-4A and connect the free lead of the .001 disc capacitor from lug 7 of the switch wafer to lug 1 of terminal strip BE (S-3).

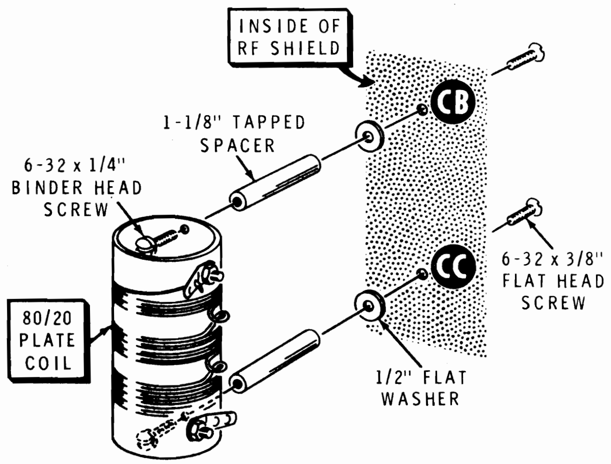
Refer to Pictorial 4-5 (fold-out from Page 28) for the following steps.

(✓) Refer to Detail 4-5A and connect the free end of the 500 pF mica capacitor at CE to lug 12 of rotary switch CZ wafer 2 (S-3). Be sure the capacitor lead is soldered to both lugs.

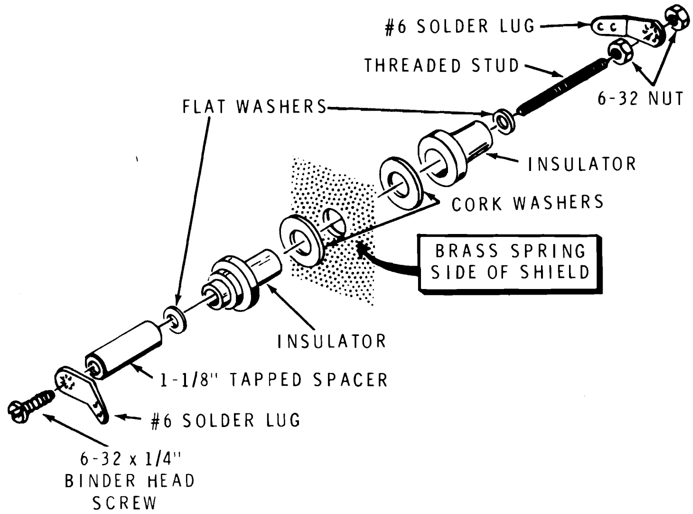
Refer to Detail 4-5B for the next two steps.

(✓) Install two 1-1/8" tapped spacers on the 80/20 plate coil (#40-597). Use 6-32 x 1/4" binder head screws.

(✓) Mount the plate coil assembly at CB and CC on the inside of the RF shield. Be sure to position the coil so the taps are on the side toward the brass spring. Use 1/2" flat washers and 6-32 x 3/8" flat head screws.



Detail 4-5B



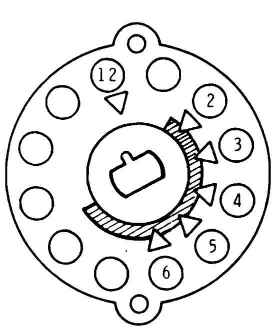
Detail 4-5C

(✓) Refer to Detail 4-5C and install a ceramic feedthrough insulator (#71-2) at CK. In addition to the parts in the plastic bag, use a 1-1/8" tapped spacer, two #6 solder lugs, and a 6-32 x 1/4" binder head screw. Before the spacer is screwed onto the threaded stud running through the insulator, hold the brass spring down so it will bear against the under side of the installed spacer as shown in the Pictorial. Discard the two unused nuts.

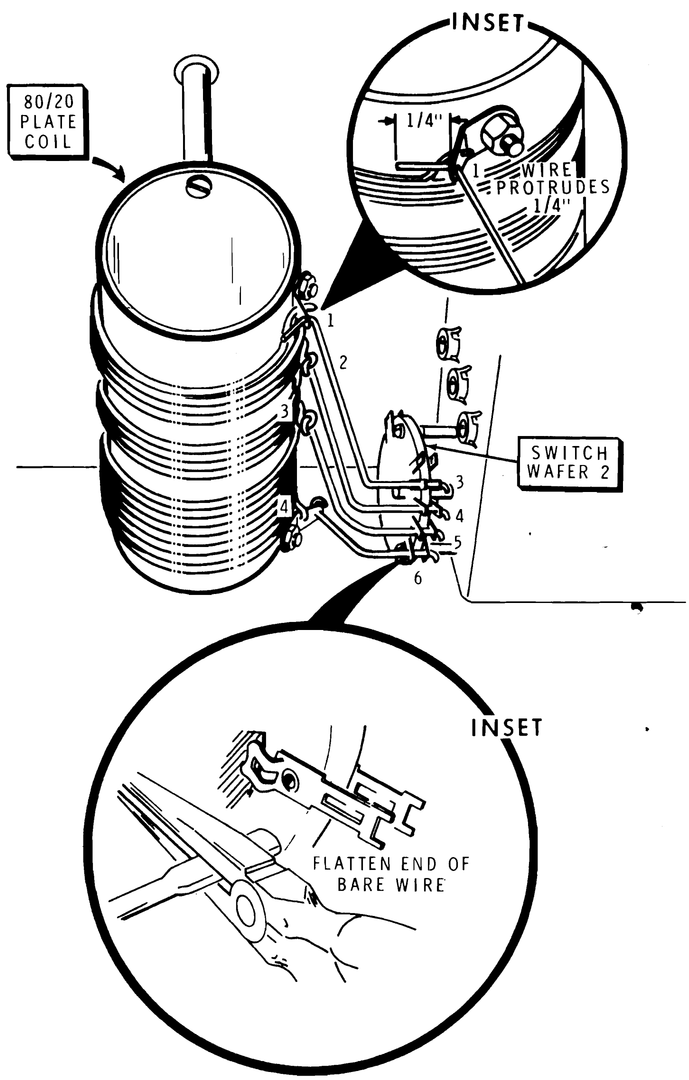
NOTE: In the following steps, wires will be connected between wafer 2 of switch CZ and the taps on the plate coil. Each wire should be fitted before it is soldered in place. The end of each wire going through the switch lugs must first be flattened as shown in the inset drawing of Detail 4-5E. DO NOT use the switch lugs to hold one end of the wire when forming it, as the switch lugs and the ceramic switch wafer can be damaged.

When soldering wires to the switch, make sure the wire is soldered to both switch lugs. After you fit the wires, cut off any excess wire lengths.

Refer to Detail 4-5D for the switch lug numbering system. The Detail shows the switch rotor as it was positioned when the shaft was installed (viewed from the rear).



Detail 4-5D

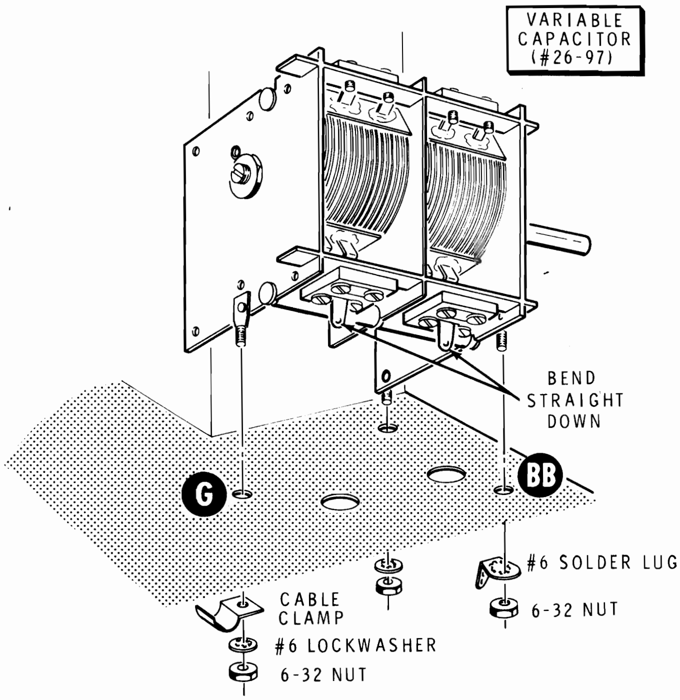


Detail 4-5E

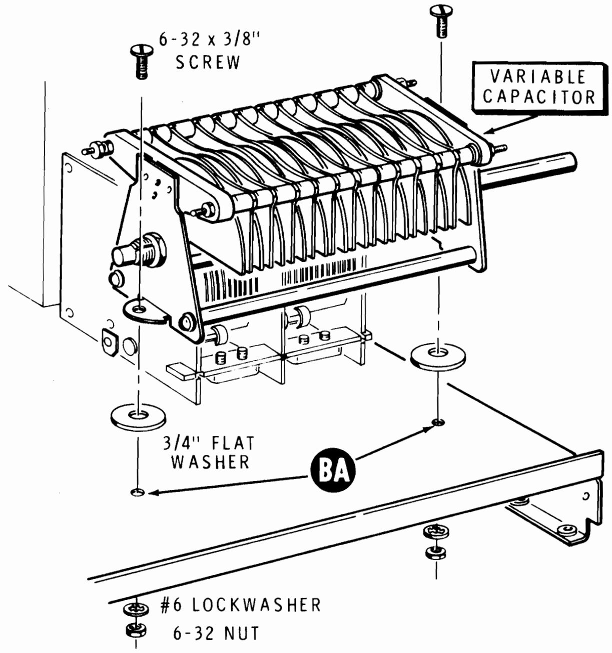
Refer to Detail 4-5E and connect bare wires from wafer 2 of rotary switch CZ to the taps on the plate coil as follows: Be sure to connect to both lugs at each switch position:

	Wire Length	Switch Lug No.	Coil Tap
(✓)	1-1/2"	6 (NS)	4 (S-1)
(✓)	2-1/2"	5 (S-3)	3 (S-1)
(✓)	3"	4 (S-3)	2 (S-1)
(✓)	3-1/2"	3 (S-3)	1 (NS)*

*Extend the wire 1/4" through the solder lug as shown in the upper inset.



Detail 4-5F

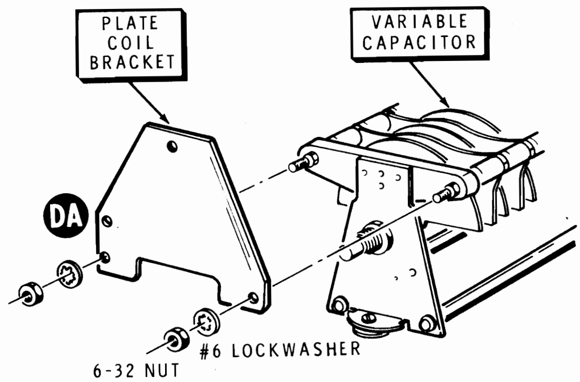


Detail 4-5G

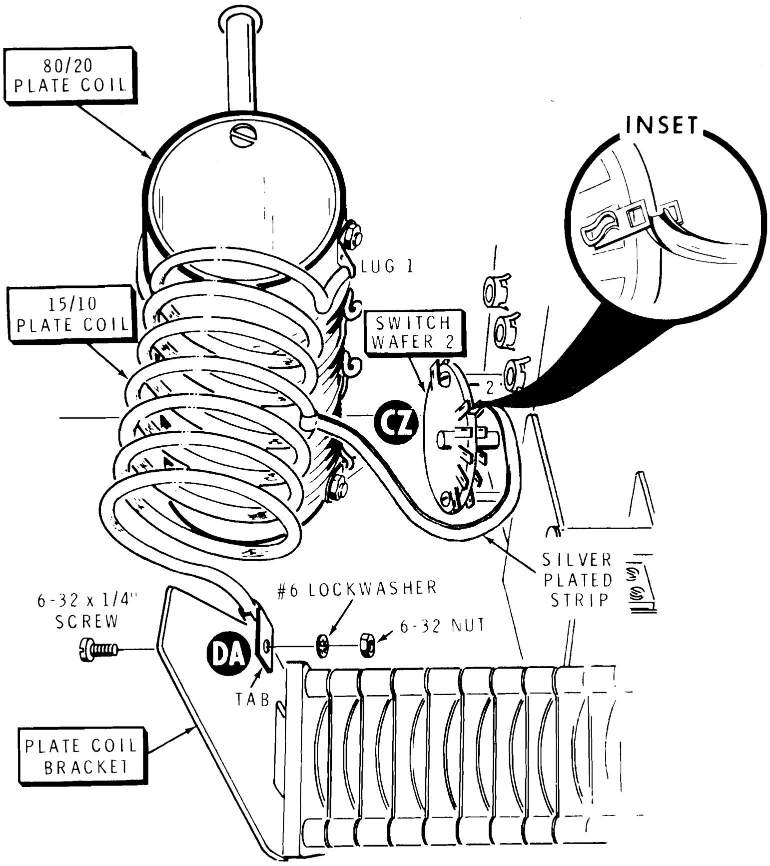
(✓) Refer to Detail 4-5F and mount variable capacitor (#26-97) on the chassis. Use a #6 solder lug and a 6-32 nut on the spade bolt at BB, a cable clamp, a #6 lockwasher, and a 6-32 nut at G, and a #6 lockwasher and a 6-32 nut on the third spade bolt. Bend the two indicated solder lugs straight down before installing the capacitor.

(✓) Refer to Detail 4-5G and mount variable capacitor (#26-131) at holes BA. Use 6-32 x 3/8" hardware and 3/4" flat washers.

(✓) Refer to Detail 4-5H and install the plate coil bracket (#204-1042) on the rear of variable capacitor BA. Use the two extra nuts and lockwashers supplied with the capacitor. Be sure to position the bracket with hole DA as shown.



Detail 4-5H



Detail 4-5J

Refer to Detail 4-5J for the following steps.

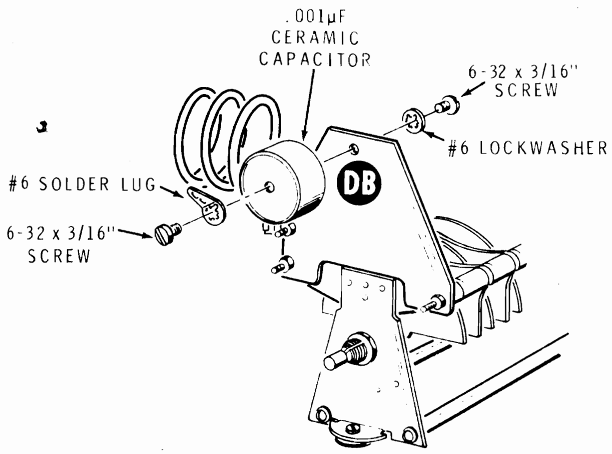
(✓) Position the 15/10 plate coil (#40-968) with the silver plated strip located as shown.

(✓) Place the open end of the coil tubing over the wire projecting from lug 1 of the 80/20 plate coil. Form the solder lug so the coil tubing will butt snugly against it.

(✓) Connect the tab on the coil to hole DA in the plate coil bracket. Use 6-32 x 1/4" hardware.

( ) Solder the coil tubing and the wire lead from the switch wafer to lug 1 of the 80/20 plate coil. Make sure the end of the tubing is against the solder lug and that this connection is well soldered.

(✓) Connect the free end of the silver plated strip to lug 2 of wafer 2 of switch CZ. Flex the end of the strip and place it between the switch lugs as shown in the inset drawing of the Detail (S-2).

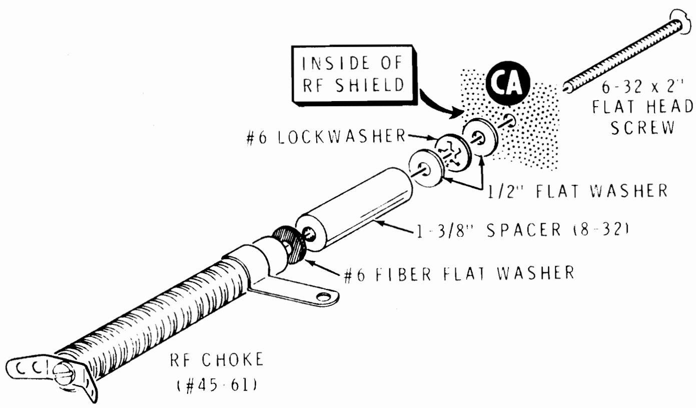


Detail 4-5K

Refer to Detail 4-5K for the following steps.

(✓) Install a #6 solder lug on one end of a .001 µF capacitor (#21-165). Use a 6-32 x 3/16" screw.

(✓) Mount this capacitor at DB on the plate coil bracket. Use a 6-32 x 3/16" screw and a #6 lockwasher. Before tightening the screw, position the solder lug as shown.



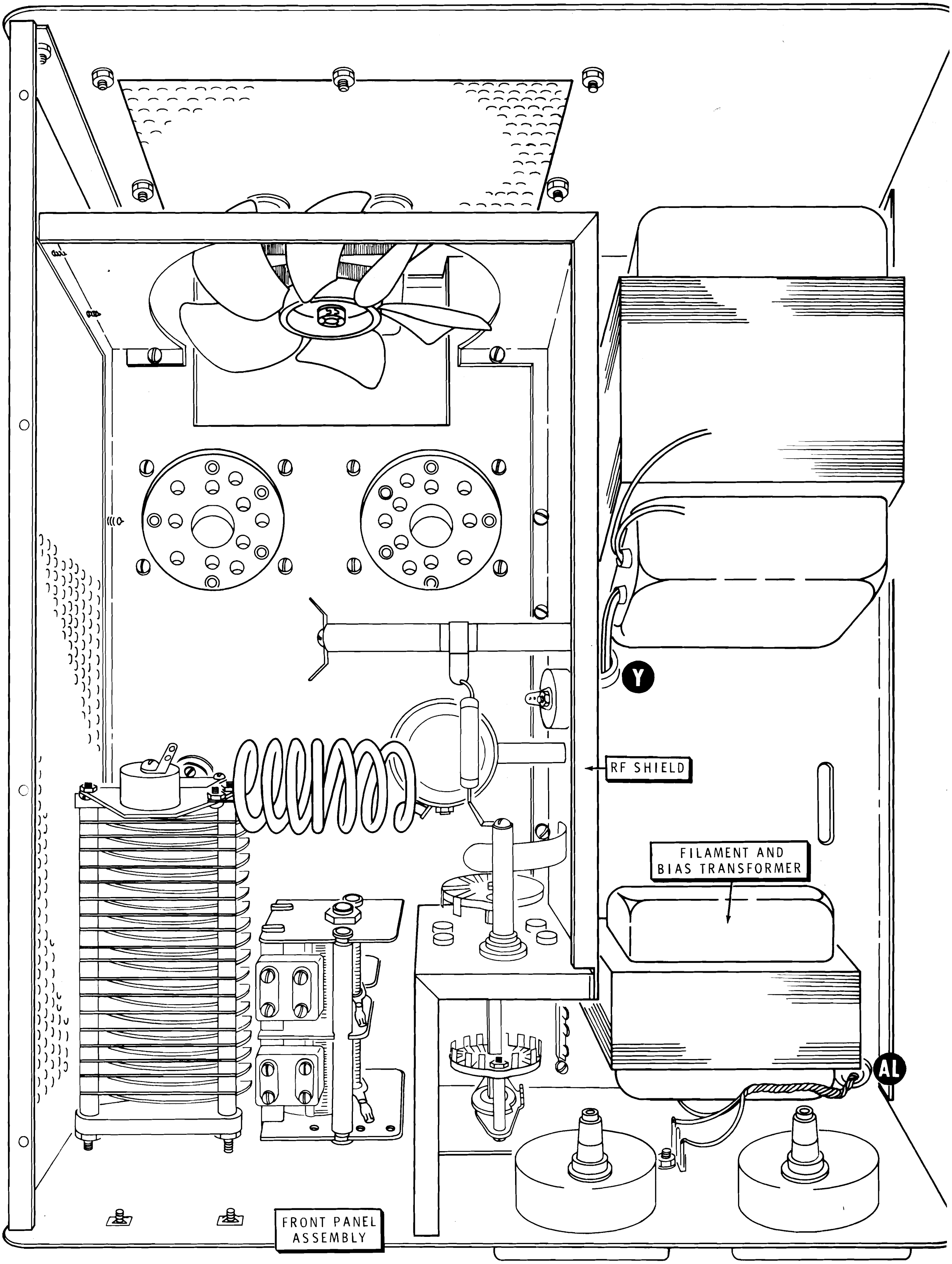
Detail 4-5L

(✓) Refer to Detail 4-5L and mount an RF choke (#45-61) at CA on the RF shield. Use a 1-3/8" spacer (8-32), two 1/2" flat washers, a #6 lockwasher, a #6 fiber flat washer, and a 6-32 x 2" flat head screw. Do not overtighten the screw as the threads in the ceramic choke form can be damaged. Position the choke so solder lug DC points toward spacer DD.

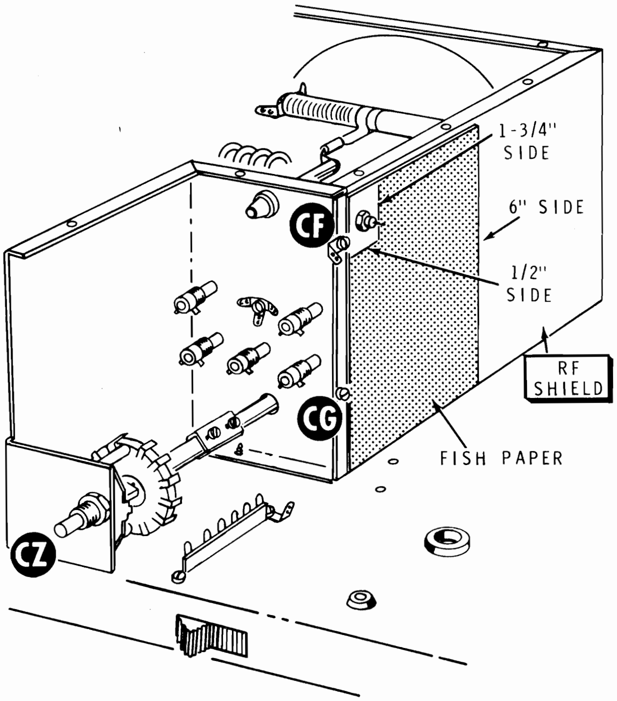
Refer to the Pictorial for the next two steps.

(✓) Connect a 1-1/2" bare wire from the solder lug on capacitor CM (S-1) to RF choke solder lug DC (NS).

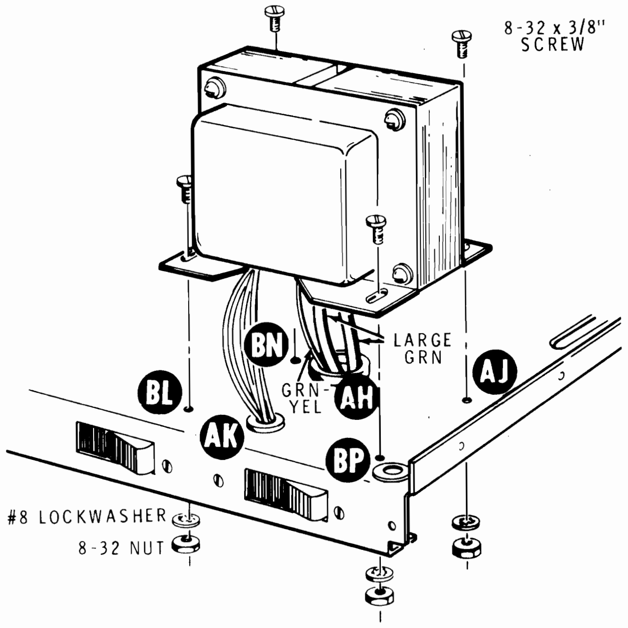
(✓) Cut each lead of RF choke #45-6 to a length of 3/8". Connect one lead to choke lug DC (S-2) and the other lead to solder lug DD (S-1).



PICTORIAL 4-6



Detail 4-6A



Detail 4-6B

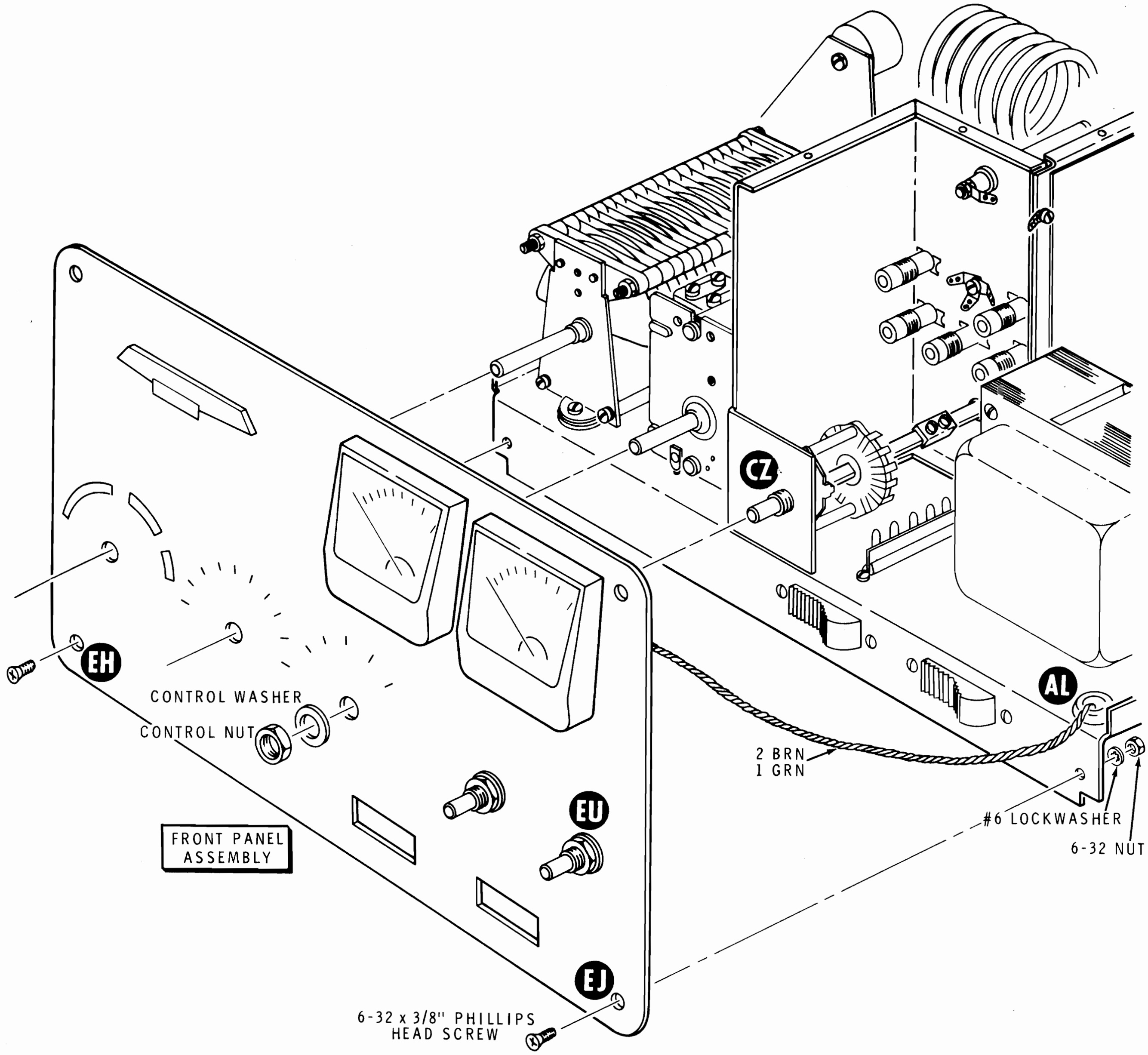
Refer to Pictorial 4-6 (fold-out from Page 36) for the following steps.

(✓) Refer to Detail 4-6A and notch out one corner of the 4-1/2" x 6" fish paper insulator as shown. Make sure the 1-3/4" side of the notch is along the 6" side of the fish paper.

(✓) Position the fish paper with the 6" side vertical and with the adhesive side against the RF shield. Make sure the fish paper clears the zener diode and the sheet metal screw at CG. Rub the paper firmly into place.

(✓) Refer to Detail 4-6B and mount the filament and bias transformer (#54-238) on the top of the chassis. As you position the transformer, insert the two large green leads and the green-yellow lead down through grommet AH. Insert the other leads through grommet AK. Use 8-32 x 3/8" hardware at AJ, BL, BN, and BP. Push the transformer toward the front of the chassis as far as possible before you tighten the hardware.

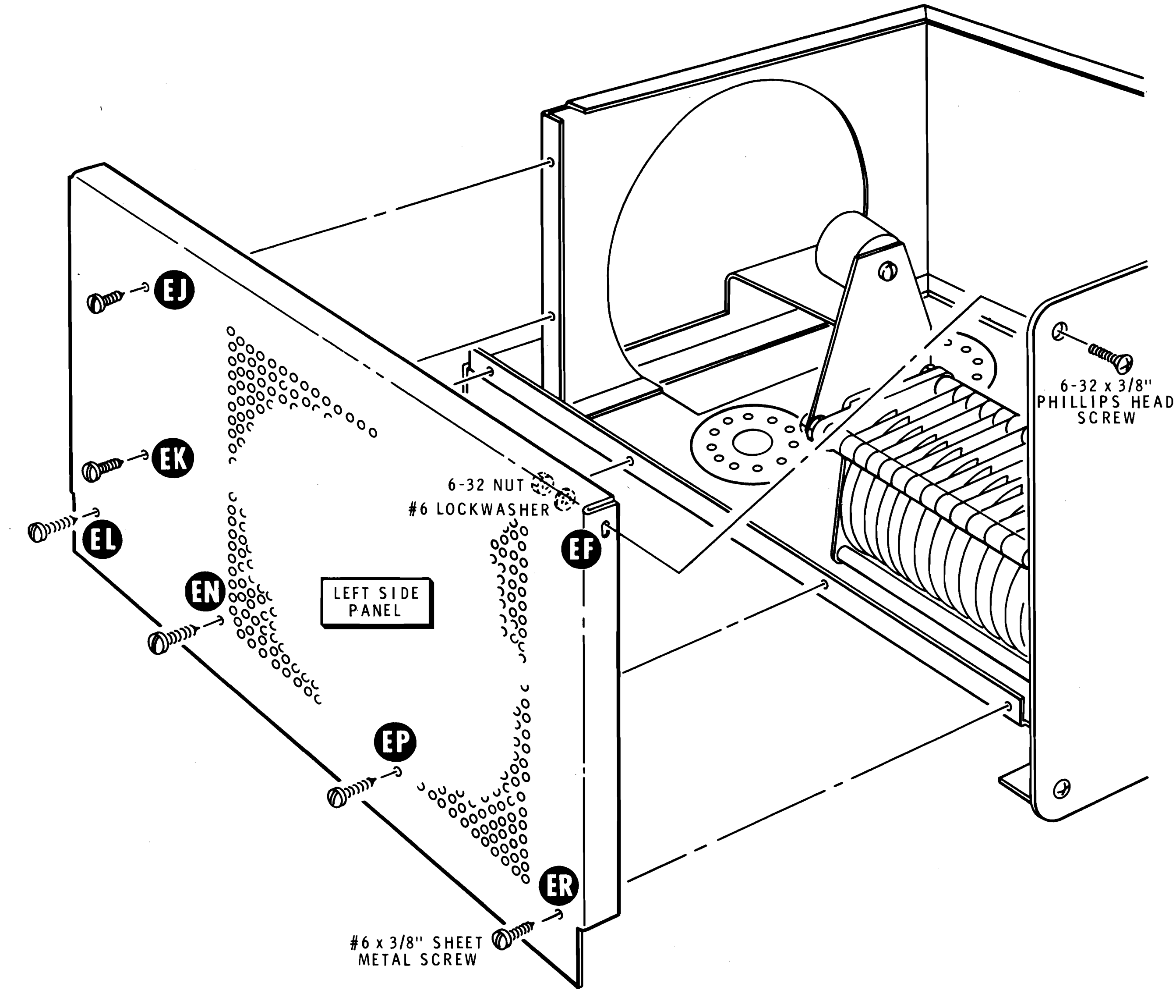
( ) Temporarily remove the control nut and the control flat washer from rotary switch CZ. (Detail 4-6A).



Detail 4-6C

(✓) Refer to Detail 4-6C and mount the front panel assembly on the front of the chassis. Insert the twisted hookup wires (two brown and one green) down through grommet AL. Use 6-32 x 3/8" phillips head hardware at EH and EJ.

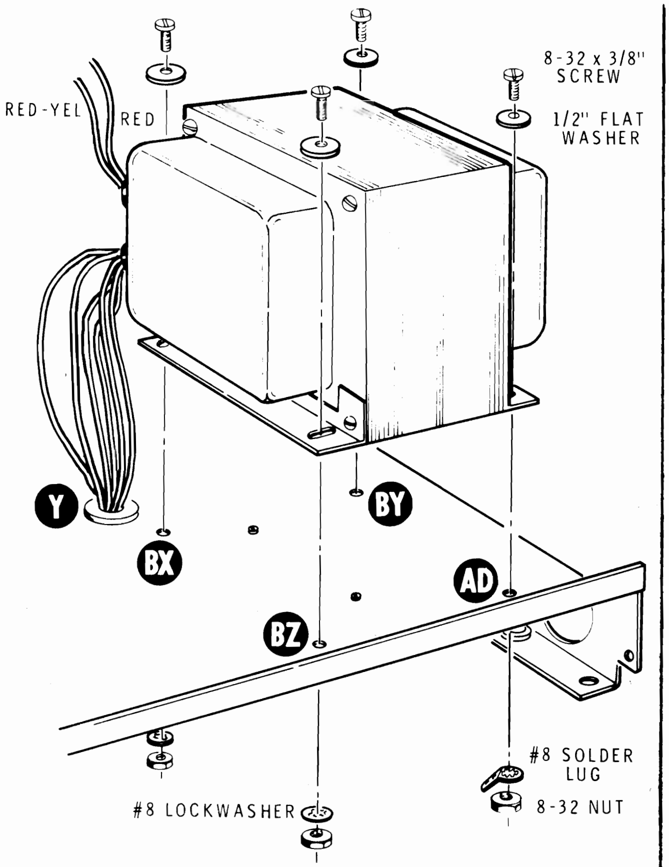
(✓) Replace the control flat washer and the control nut on switch CZ.



Detail 4-6D

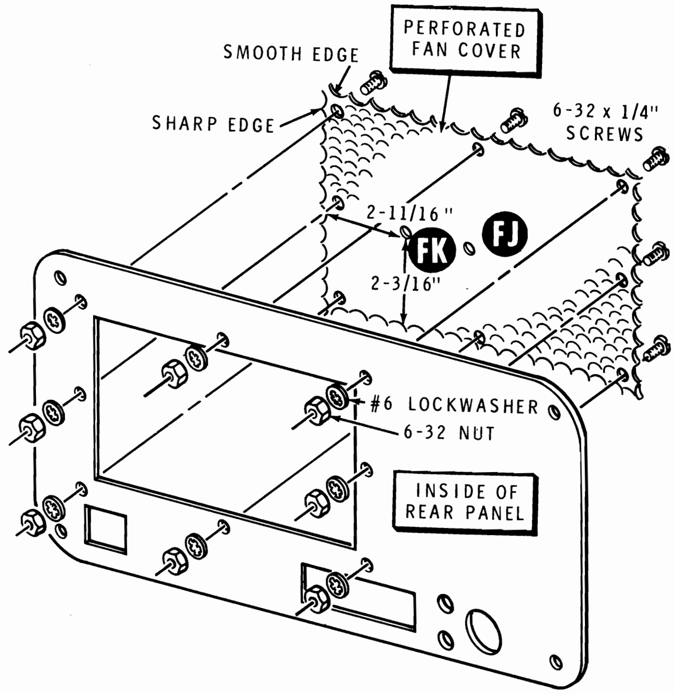
(√) Adjust the position of the filament and bias transformer to insure approximately 1/16" clearance between the transformer end bell and any connections to the lugs of switch EU.

(√) Refer to Detail 4-6D and install the left side panel (#203-646). Use 6-32 x 3/8" phillips hardware at EF. Use #6 x 3/8" sheet metal screws at EJ, EK, EL, EN, EP, and ER.



Detail 4-6E

( ) Refer to Detail 4-6E and mount the HV transformer. Position the wires from the end bell so they are above grommet Y. Insert all leads <u>except</u> the red and the red/yellow leads down through grommet Y. Use an 8-32 x 3/8" screw, a 1/2" flat washer, a #8 solder lug and an 8-32 nut at AD. At BX, BY and BZ, use 8-32 x 3/8" hardware with a 1/2" flat washer at each location. Before you tighten the hardware, make sure the transformer end bell does not protrude beyond the chassis rear apron.

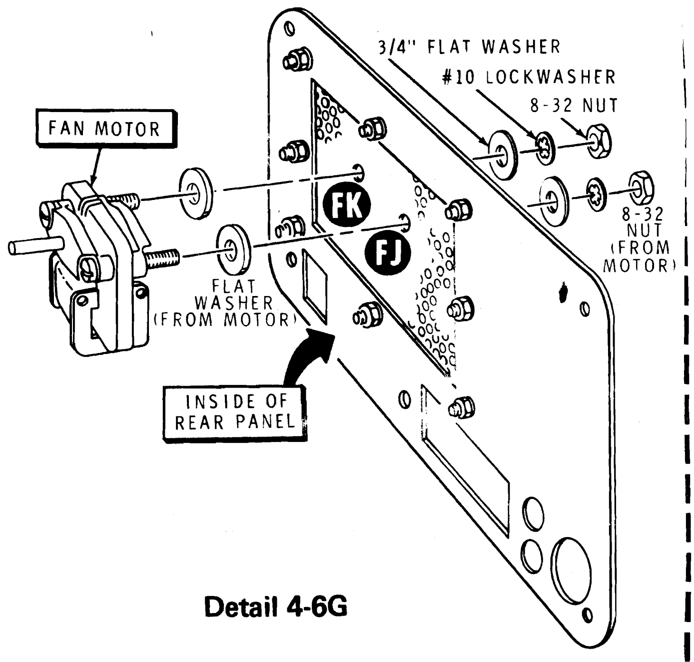


Detail 4-6F

( ) Refer to Detail 4-6F and locate the perforated fan cover (#205-874) and the rear panel (#203-644). The edges of the fan cover are smooth on one side and sharp on the other. Before placing the sharp edge against the rear panel, check the two off-center holes (FK and FJ) which, if viewed as shown in the Detail, must be closest to the bottom left-hand corner.

( ) Fasten the perforated fan cover to the rear panel with 6-32 hardware. The sharp edge of the fan cover should be turned toward the rear panel.

Page 40 — Left column.
Replace the entire column.



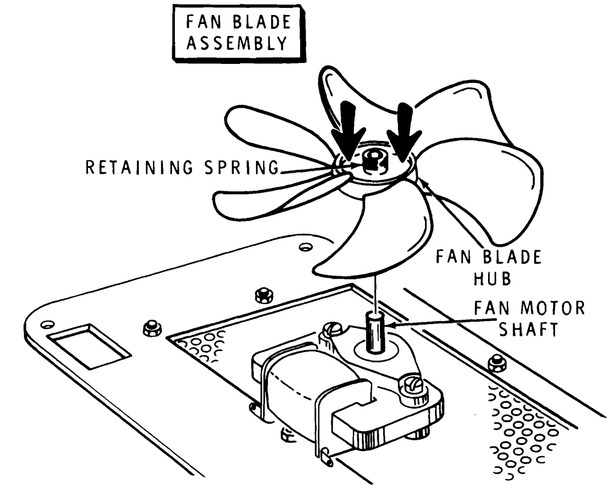
Detail 4-6G

(✓) Locate the fan motor and remove the two 8-32 nuts from its mounting screws. Leave the two flat washers on the mounting screws.

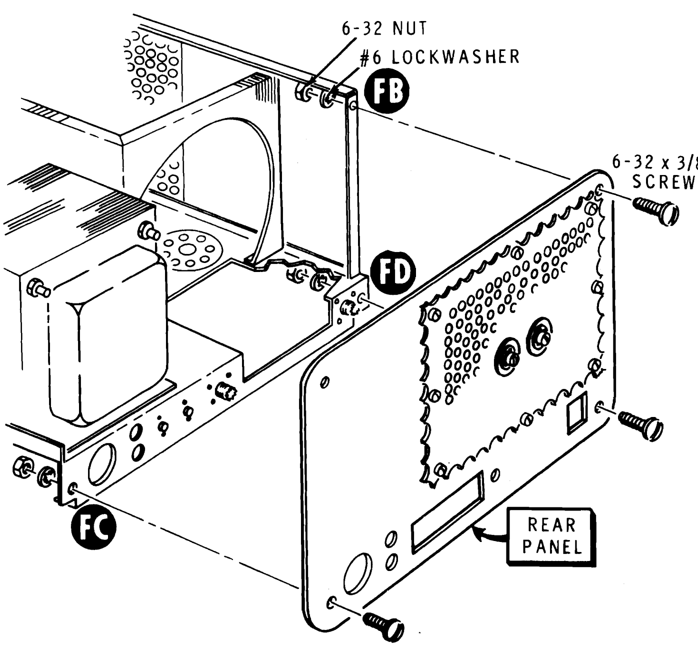
(✓) Refer to Detail 4-6G and mount the fan motor on the perforated fan cover at holes FJ and FK. Use 3/4" flat washers, #10 lockwashers as shown and the two 8-32 nuts supplied with the motor.

(✓) Refer to Detail 4-6H and install the fan blade assembly (#266-296) on the fan motor shaft. Position the fan motor and the blade assembly as shown, and apply firm downward pressure with both thumbs on the fan blade hub. A slight rocking motion will help. Push the fan blades onto the motor shaft until there is 1/16" to 1/32" clearance between the fan blade hub and the motor frame.

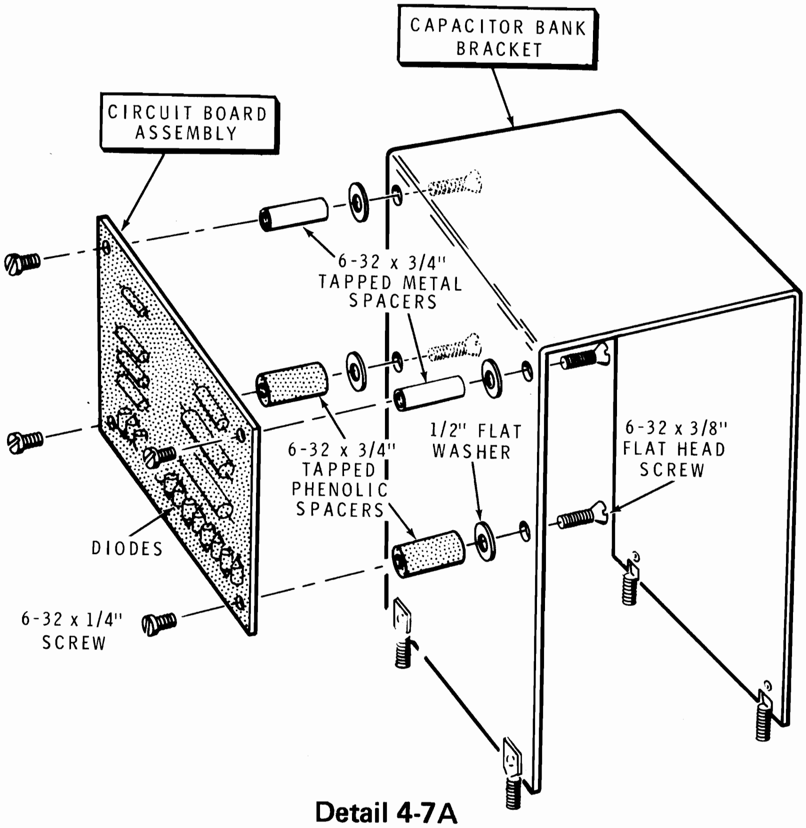
(✓) Refer to Detail 4-6J and mount the rear panel to the chassis rear apron at FC and FD, and to the left side panel at FB. Use 6-32 x 3/8" hardware.



Detail 4-6H



Detail 4-6J



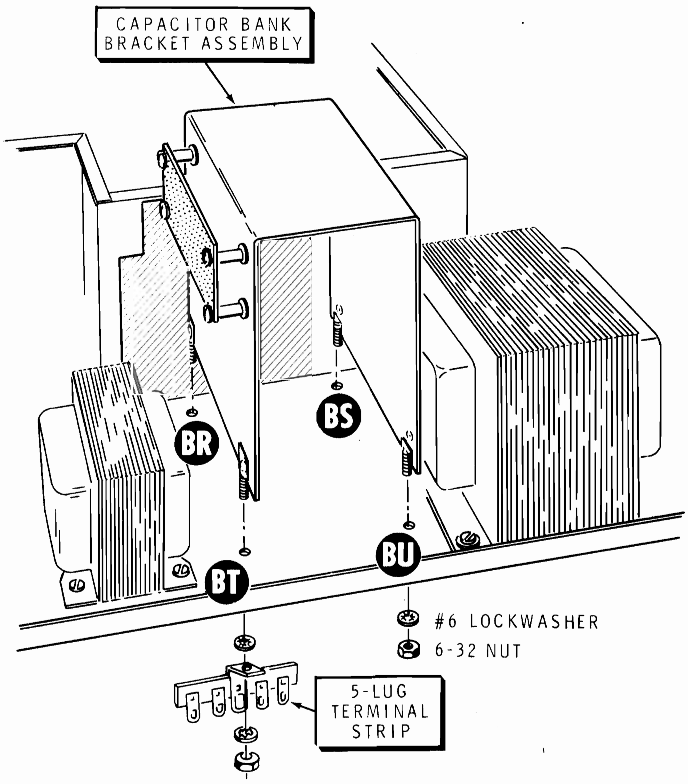
Detail 4-7A

Refer to Pictorial 4-7 (fold-out from Page 43) for the following steps.

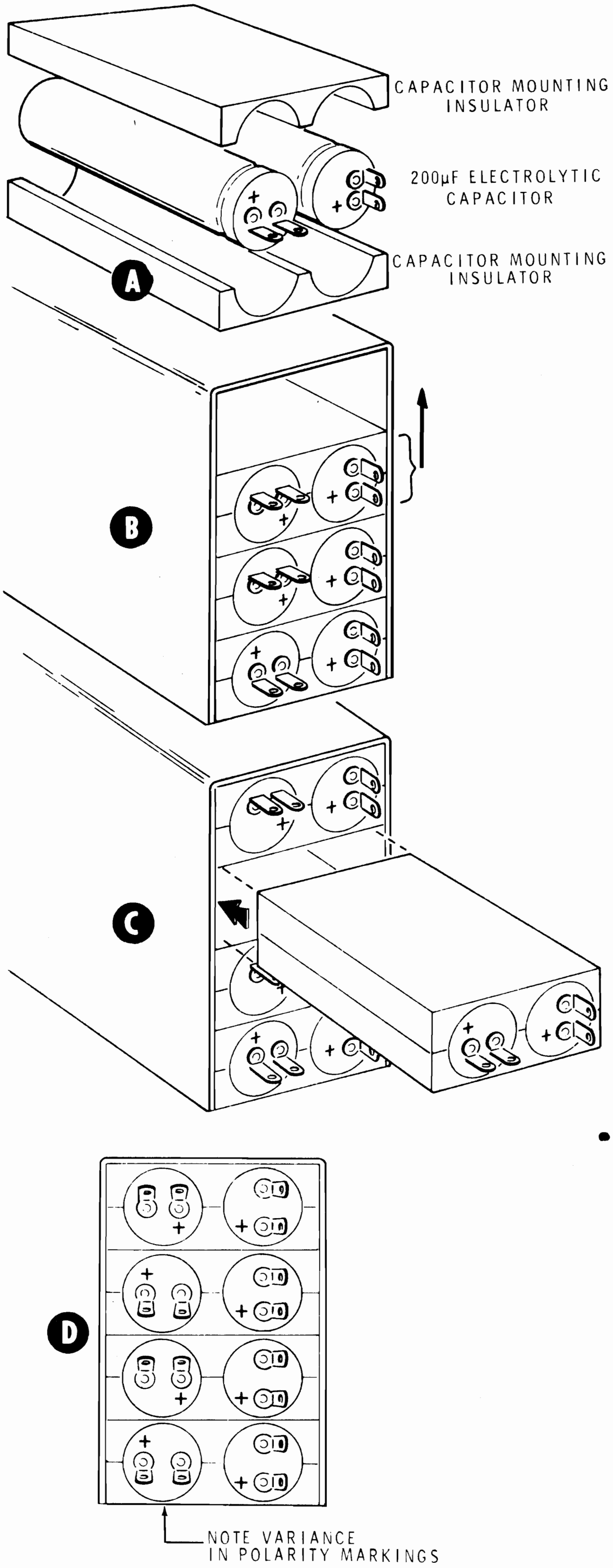
(✓) Refer to Detail 4-7A and mount the circuit board assembly on the capacitor bank bracket. Use 6-32 x 1/4" screws, 6-32 x 3/4" tapped metal spacers, 6-32 x 3/4" tapped phenolic spacers, 1/2" flat washers, and 6-32 x 3/8" flat head screws. Note that the diodes, and the phenolic spacers, are along the lower edge of the circuit board.

(✓) Refer to Detail 4-7B and mount the capacitor bank bracket with one spade bolt entering each of holes BR, BS, BT, and BU. Use #6 lockwashers and 6-32 nuts only on spade bolts BR, BS, and BU. Leave the nuts flush with the ends of the spade bolts.

(✓) Mount a 5-lug terminal strip (#431-42) on spade bolt BT. Use two #6 lockwashers and a 6-32 nut. Leave the face of the nut flush with the end of the spade bolt.



Detail 4-7B



Detail 4-7C

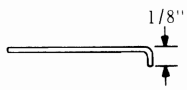
Refer to Detail 4-7C for the steps covering the capacitor bank assembly.

(✓) Part A: Assemble four capacitor sections, each composed of two capacitor mounting insulators (#75-125) and two 200 µF electrolytic capacitors (#25-224).

(✓) Part B: Stack three capacitor sections in the capacitor bank bracket. Then lift up the top section to the top of the bracket.

(✓) Part C: Insert the fourth capacitor section into the vacated space in the bracket.

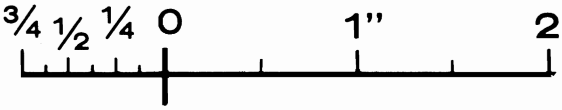
( ) Part D: Align the capacitor lugs and the + polarity markings as shown. Then push the capacitors snugly against the fish paper and tighten the spade bolt nuts on the bottom of the chassis just to the point where you can no longer rotate the capacitors with your fingers. Do not overtighten. Note the position of the terminal strip mounting foot in Detail 4-7B.



Detail 4-7D

(✓) Refer to Detail 4-7D and cut four pieces of bare wire 1-5/8" long and one piece 1-3/8" long. Bend down 1/8" at one end of each. These wires will be used in the capacitor bank wiring.

(✓) Cut four pieces of small black sleeving 3/4" long for use in wiring the capacitor bank.



NOTE: When you connect resistors in the following steps, align them as shown in the Pictorial. Space the resistors 1/2" from the capacitors as shown in the inset drawing. After fitting and soldering the resistors, cut off and discard any excess lead lengths. No resistor should be closer than 1/4" to any metallic object to which it is not intentionally connected.

(✓) Refer to the Pictorial and place one of the 3/4" lengths of sleeving on one lead of a 30 kΩ resistor. Connect this lead to the positive (marked +) lug of capacitor 1 (NS). Pass the other resistor lead through the positive lug of capacitor 2 (S-2) to the negative lug of capacitor 4 (NS).

(✓) Place one of the 3/4" lengths of sleeving on one lead of a 30 kΩ resistor and connect this lead to the positive lug of capacitor 5 (NS). Pass the other lead through the positive lug of capacitor 6 (S-2) to the negative lug of capacitor 8 (NS).

(✓) Pass the straight end of one of the 1-5/8" bare wires through the negative lug of capacitor 2 (NS). Place the bent end of the wire into the positive lug of capacitor 1 (S-2).

(✓) Connect the black hookup wire coming from hole B on the circuit board to the negative lug of capacitor 1 (NS).

(✓) Connect a 30 kΩ resistor from the negative lug of capacitor 1 (S-2) to the negative lug of capacitor 2 (S-2).

(✓) Connect the bent end of one of the 1-5/8" bare wires to the negative lug of capacitor 3 (NS) and the straight end to the positive lug of capacitor 4 (NS).

(✓) Place a 3/4" length of sleeving on one lead of a 30 kΩ resistor and connect this lead to the negative lug of capacitor 3 (S-2). Connect the other lead to the negative lug of capacitor 4 (S-2).

(✓) Place the bent end of a 1-5/8" bare wire in the positive lug of capacitor 5 (S-2), and the straight end in the negative lug of capacitor 6 (NS).

(✓) Connect a 30 kΩ resistor from the negative lug of capacitor 5 (NS) to the negative lug of capacitor 6 (S-2).

(✓) Place the bent end of a 1-5/8" bare wire in the negative lug of capacitor 7 (NS) and the straight end in the positive lead of capacitor 8 (NS).

(✓) Place a 3/4" length of sleeving on one lead of a 30 kΩ resistor and connect this lead to the negative lug of capacitor 7 (S-2). Connect the other lead to the negative lug of capacitor 8 (S-2).

(✓) Connect the blue wire from hole H of the circuit board to the positive lug of capacitor 7 (NS).

(✓) Connect one lead of a 30 kΩ resistor to the positive lug of capacitor 7 (S-2). Connect the other lead to the positive lug of capacitor 8 (S-2).

(✓) Connect one lead of a 30 kΩ resistor to the positive lug of capacitor 3 (NS). Connect the other lead to the positive lug of capacitor 4 (S-2).

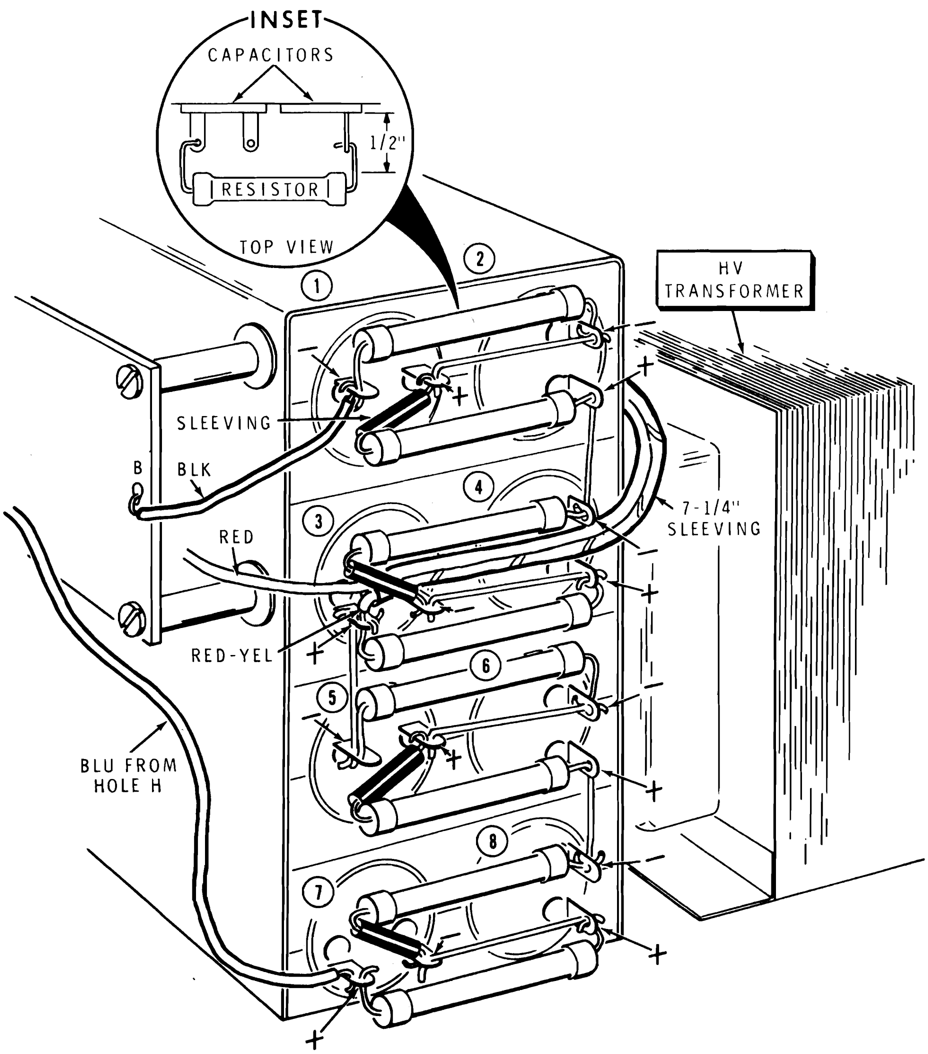
(✓) Connect the bent end of the 1-3/8" length of bare wire to the positive lug of capacitor 3 (NS) and the straight end to the negative lug of capacitor 5 (S-2).

(✓) Pass a 7-1/4" length of clear sleeving over the red and the red-yellow wires coming from the HV transformer. Slide the sleeving on the wires as far as it will go.

(✓) Cut off the red-yellow wire 1/2" beyond the end of the sleeving. Remove 1/4" of insulation.

(✓) Connect the red-yellow wire to the positive lug of capacitor 3 (S-3).

(✓) Carefully compare your work in the foregoing steps to the Pictorial (and the Details) for wiring errors and for proper capacitor polarity. Incorrect connections in this high-voltage circuit area can cause serious damage.



PICTORIAL 4-7

Refer to Pictorial 4-8 for the following steps.

NOTE: In the following step, if solder on the bare end of the red wire prevents its entry into hole D, carefully cut off just enough of the soldered wire end to allow it to fit into the hole. Be careful not to cut the wire too short.

(✓) Connect the red wire coming from the HV transformer to hole D on the circuit board (S-1). Reach in between the circuit board and the capacitor bracket to solder this connection. Make sure this connection is well soldered.

(✓) Pass one lead of a .001 μF, 6 kV, capacitor through solder lug CF (S-2) to hole K in the circuit board (S-1). Connect the other lead of this capacitor to solder lug CK (NS).

Refer to the inset drawing of Pictorial 4-8 and Detail 4-8A for the next two steps.

(✓) Connect the black cathode wire, coming from the solder lug of zener diode CW, to the foil side of the circuit board (S-1). Detail 4-8A shows the foil pattern.

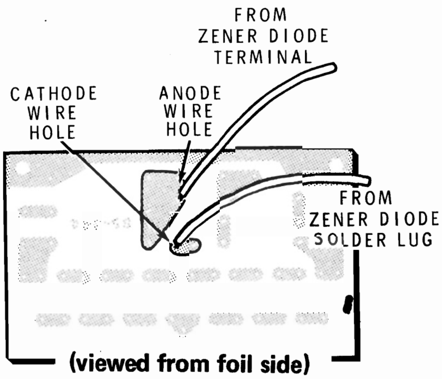
(✓) Connect the other black wire, coming from the anode of zener diode CW, to the foil side of the circuit board (S-1). Refer to Detail 4-8A for the foil configuration.

Connect the wires coming from the component side of the circuit board as follows:

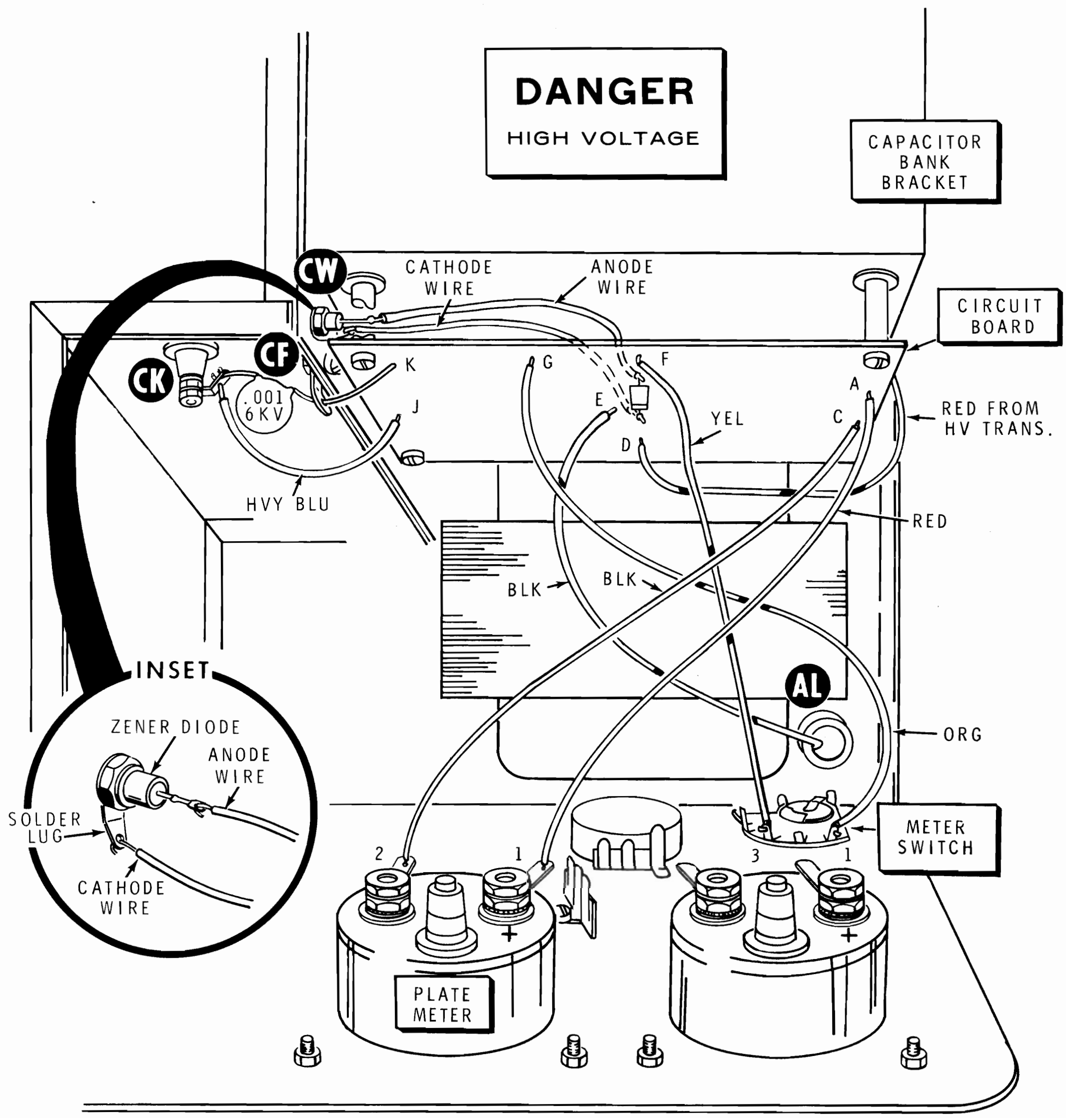
	Wire Color	From Hole	Connect to
(✓)	HVY Blue	J	Solder lug CK (S-2).
(✓)	Yellow	F	Lug 3 of meter switch (S-1).
(✓)	Orange	G	Lug 1 of meter switch (S-1).
(✓)	Black	C	Lug 2 of plate meter (S-2).
(✓)	Red	A	Lug 1 of plate meter (S-2).

(✓) Insert the black stranded wire coming from hole E in the circuit board down through grommet AL.

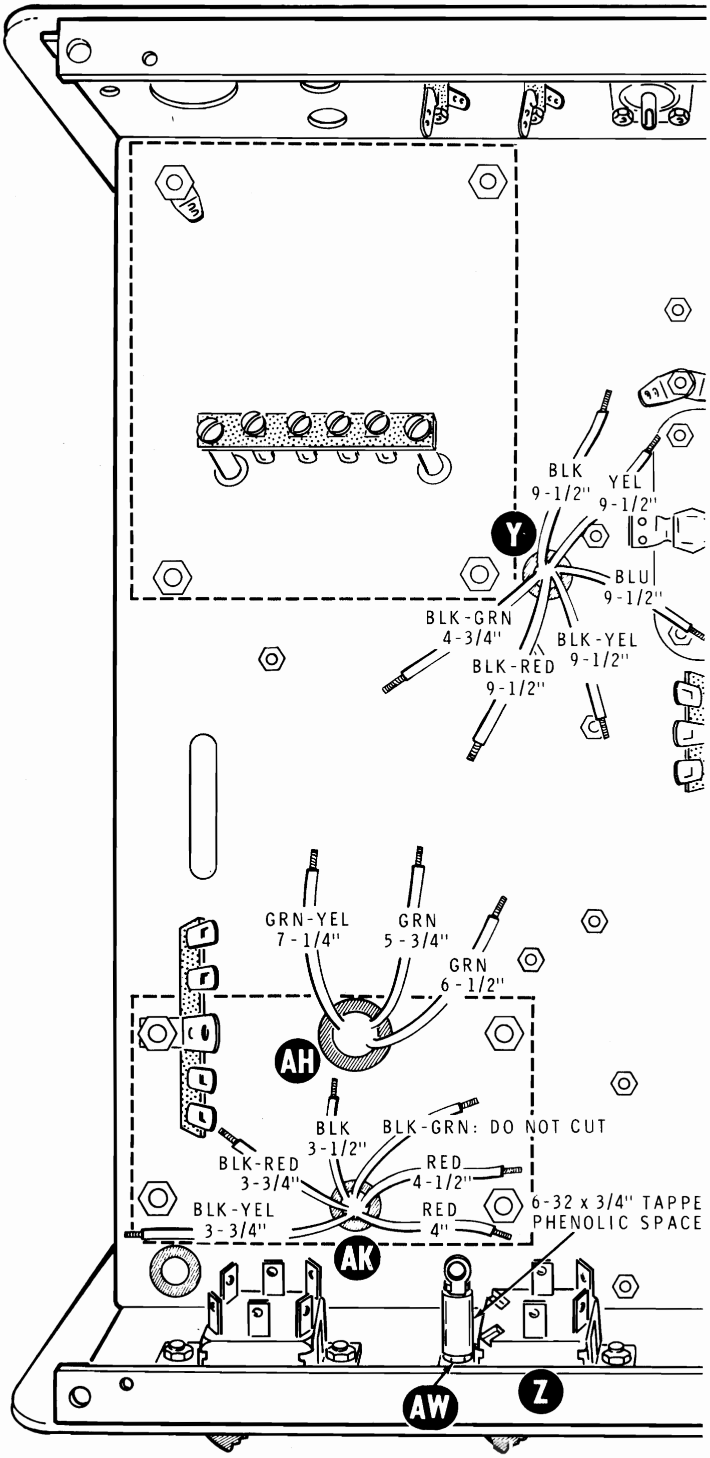
(✓) Peel off the backing paper from the DANGER label and press it into place on the top of the capacitor bank bracket.



Detail 4-8A



PICTORIAL 4-8



PICTORIAL 4-9

UNDER-CHASSIS WIRING

Refer to Pictorial 4-9 and cut the transformer leads coming through the chassis at Y, AH and AK to the indicated lengths. Be sure you have selected the proper location before you cut. Measure the length of each lead from the chassis.

(✓) At grommet Y, cut the transformer leads as follows:

Blue	9-1/2"
Yellow	9-1/2"
Black	9-1/2"
Black-red	9-1/2"
Black-Yellow	9-1/2"
Black-Green	4-3/4"

(✓) At grommet AH, cut the transformer leads as follows:

Green	6-1/2"
Green-Yellow	7-1/4"
Green	5-3/4"

(✓) At grommet AK, cut the transformer leads as follows:

One red	4-1/2"
Other red	4"
Black-Red	3-3/4"
Black-Yellow	3-3/4"
Black	3-1/2"
Black-Green	Do not cut

NOTE: When you remove insulation from transformer leads in the following steps, grasp the wires where they emerge from the chassis so no strain will be placed on the connections at the transformer end of the leads.

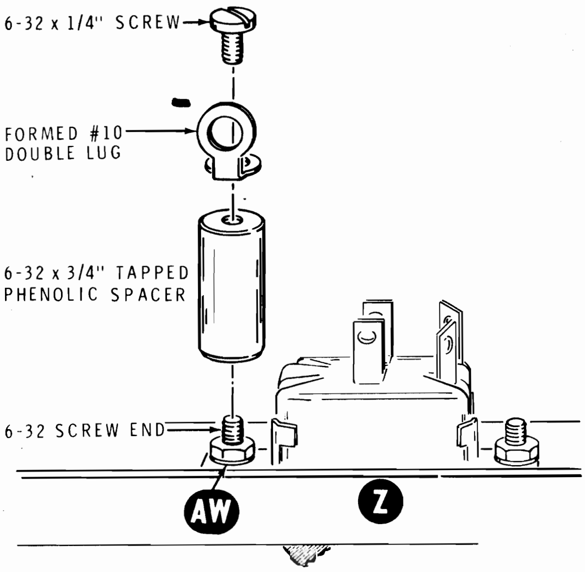
(✓) Remove 1/4" of insulation from the cut ends of the two heavy green leads coming from AH. Melt a small amount of solder on the bared wire ends.

(✓) Remove 1/4" of insulation from the end of each remaining transformer lead. Twist the fine wire strands together and melt a small amount of solder on each bared end.

Detail 4-9A

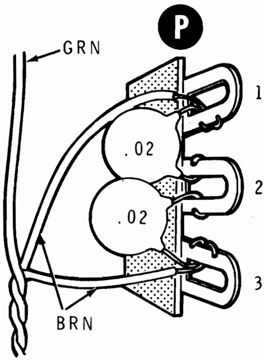
( ) Refer to Detail 4-9A and form a #10 double lug (#259-25) as shown.

( ) Refer to Detail 4-9B and screw a 6-32 x 3/4" tapped phenolic spacer onto screw AW. Then install the formed lug on the inner end of the phenolic spacer with a 6-32 x 1/4" screw. Position the lug as shown.



Detail 4-9B

NOTE: Before starting the wiring in the following steps, look ahead to the under-chassis photograph on Page 86. Observe how wires are routed down the center of the chassis and are then bound together by ties to form a cable. As an aid in forming a neat cable, you can mark the main wiring guide lines on the under side of the chassis with a magic marker or china marking pencil. Then follow these guide lines when routing the individual wires.



Detail 4-10A

Refer to Pictorial 4-10 (fold-out from Page 49) for the following steps.

( ) Route the twisted green and brown wires from grommet AL between grommet AH and grommet AK. Refer to Detail 4-10A and connect one of the brown wires to lug 1 (NS) and the other brown wire to lug 3 (NS) of terminal strip P.

( ) Connect a .02 μF disc capacitor from lug 1 (NS) to lug 2 (NS) of terminal strip P.

( ) Connect a .02 μF disc capacitor from lug 3 (NS) to lug 2 (S-2) of terminal strip P.

( ) Connect the green wire from grommet AL to lug 1 of terminal strip B (NS).

Connect the transformer leads from grommet AK as follows:

	Lead	Connect to
( )	4-1/2" Red	Terminal strip BT, lug 3 (NS).
( )	4" Red	Terminal strip BT, lug 4 (NS).
( )	Black-green	Terminal strip AE, lug 3 (NS).

Connect the following transformer leads coming from grommet Y to switch AN:

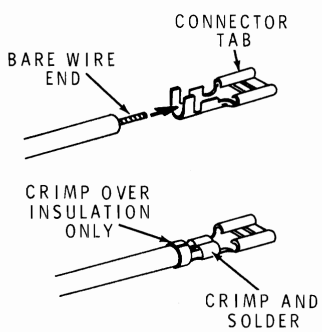
Lead	Lug of Switch AN
( ) Black-yellow	1 (S-1).
( ) Yellow	5 (S-1).
( ) Blue	6 (S-1).
( ) Black-red	2 (S-1).

( ) Connect a 2" black hookup wire from lug 3 (S-2) to lug 1 (NS) of terminal strip BT.

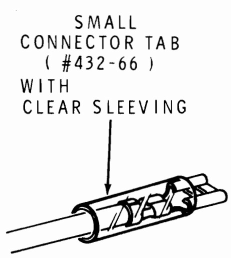
( ) Connect the yellow hookup wire from grommet T to lug 1 of phono socket U (NS).

( ) Connect the orange wire from grommet T to lug 2 of terminal strip BT (NS).

( ) Prepare a 4-1/4" length of large black stranded wire.



Detail 4-10B



Detail 4-10C

Refer to Detail 4-10B for the next two steps.

( ) Locate the large connector tabs (#432-137). If these tabs are connected to one another, cut the strip of tabs into six individual tabs as shown.

( ) Install one of these large connector tabs (#432-137) on one end of the 4-1/4" wire (S-1).

Refer to the Pictorial for the following steps.

( ) Push the connector tab from the preceding step onto lug 3 of switch Z. Connect the other end of this wire to double lug AW (NS).

( ) Connect the black lead from grommet AK to double lug AW (NS).

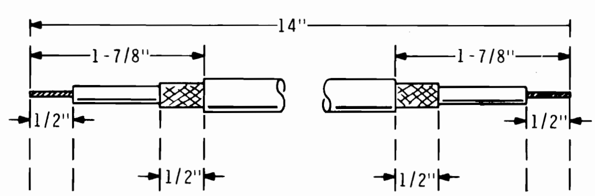
( ) Connect the black lead from grommet Y to double lug AW (NS).

( ) Prepare a 16" length of small black stranded wire. Place a 1" length of large, clear sleeving on one end of this wire.

( ) Install a small connector tab (#432-66) on the end of the wire with the clear sleeving on it. Then push the clear sleeving halfway on the connector tab, as shown in Detail 4-10C.

( ) Connect the other end of this wire to double lug AW (S-4). The end with the connector tab will be connected later.

( ) Connect the center conductor of the coaxial cable coming from lug 7 of switch CZ to lug 1 (NS) and the shield wires to lug 2 (S-1) of terminal strip AG.



Detail 4-10D

( ) Refer to Detail 4-10D and prepare a 14" length of RG-8/U coaxial cable. Tin the exposed braid at each end, being careful not to melt the inner insulation.

( ) Loosen the cable clamp at G, place the shield braid under the clamp, and connect the center conductor to lug 9 of relay F (S-1).

( ) Similarly, place the shield braid at the other end of the cable under cable clamp B and connect the center conductor to coaxial fitting A (S-1).

( ) Tighten both cable clamps and solder the shield braid at each end of its cable clamp. Be careful not to melt the inner insulation.

Refer to Pictorial 4-11 for the following steps.

( ) Prepare the following lengths of large black stranded wire:

4-1/2"

13-1/2"

13-1/2"

( ) Install a large connector tab (#432-137) on one end of each of the three wires.

( ) Push the tab on the 4-1/2" wire onto lug 4 of switch AN.

( ) Push the connector tab on one of the 13-1/2" wires onto lug 1 of switch Z, and the connector tab on the other 13-1/2" wire onto lug 2.

( ) Prepare a 12-1/2" length of large black stranded wire.

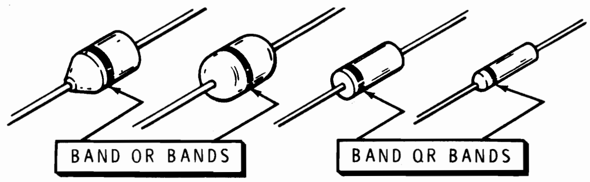
( ) Connect the free end of the black-yellow wire coming from grommet AK and one end of the 12-1/2" wire in the preceding step to one large tab connector (S-2). Then push this connector tab onto lug 3 of switch AN.

( ) Connect the free end of the black-red lead coming from grommet AK and the free end of the black wire coming from lug 4 of switch AN to one large tab connector (S-2). Push this tab onto lug 4 of switch Z.

The free ends of the "tabbed" wires in the preceding steps will be connected later.

( ) Refer to Detail 4-11A and connect the cathode lead of a silicon diode (#57-27) to lug 5 (NS) and the anode lead to lug 4 (S-2) of terminal strip BT.

NOTE: DIODES MAY BE SUPPLIED IN ANY OF THE FOUR SHAPES SHOWN IN THE FOLLOWING ILLUSTRATION. THE CATHODE END OF THE DIODE IS MARKED WITH A BAND OR BANDS. THIS END SHOULD ALWAYS BE POSITIONED AS SHOWN IN THE PICTORIAL WHERE IT IS INSTALLED.



Detail 4-11A

( ) Connect a 33 kΩ (orange-orange-orange) resistor from lug 1 (NS) to lug 2 (NS) of terminal strip BT.

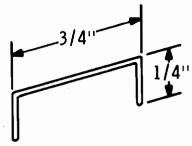
( ) Connect a 22 kΩ (red-red-orange) resistor from lug 2 (S-3) to lug 5 (NS) of terminal strip BT.

( ) Connect the positive lead (marked +) of a 20 μF electrolytic capacitor to lug 5 (NS) and the other lead to lug 1 (S-3) of terminal strip BT.

( ) Connect the black stranded wire coming from grommet AL to lug 5 of relay F (S-1).

( ) Connect a 3" red hookup wire from lug 2 (NS) to lug 11 (S-1) of the relay.

( ) Connect a 9-1/2" length of red hookup wire from lug 5 of terminal strip BT (S-4) to lug 2 of the relay (NS).

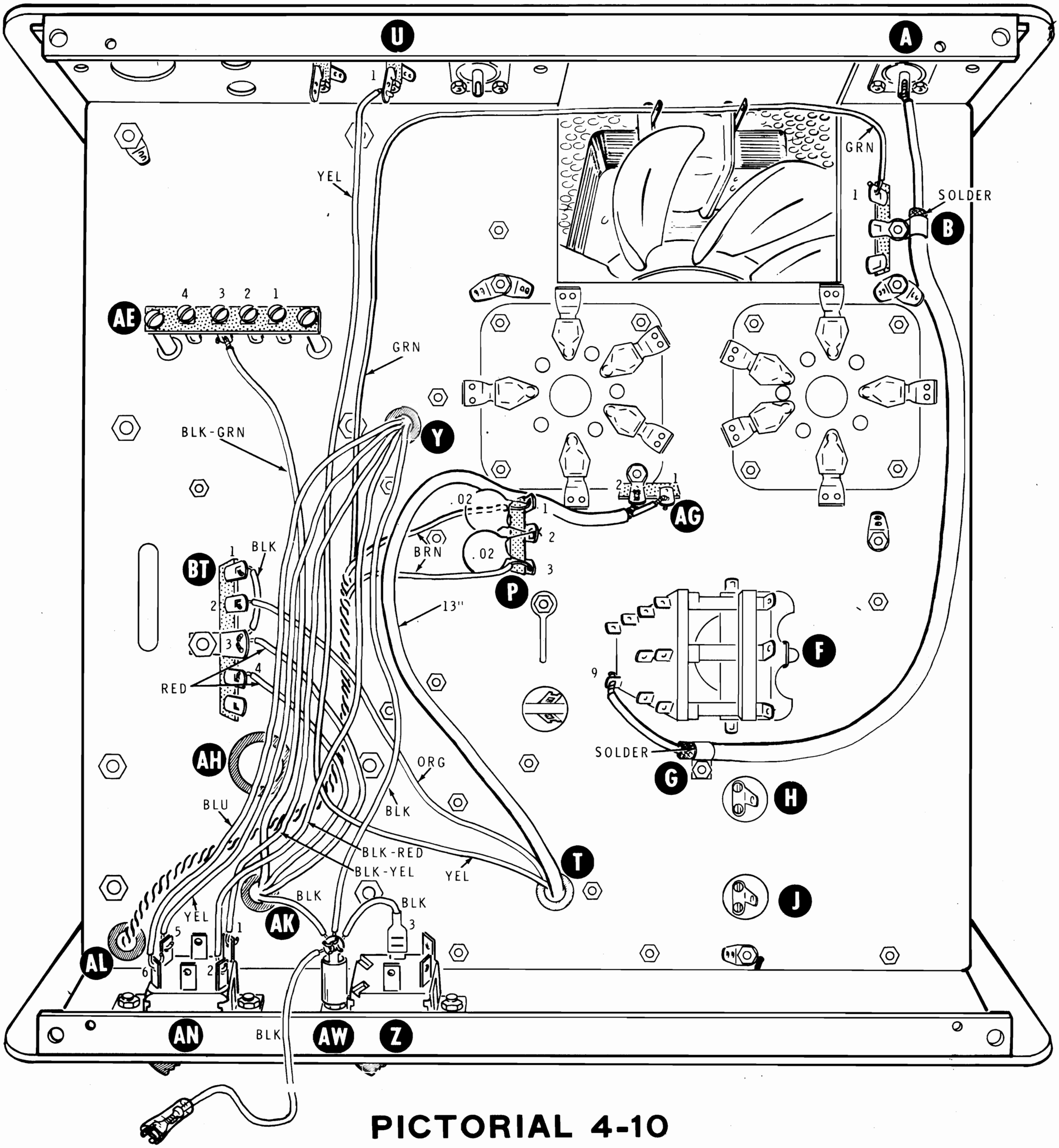


Detail 4-11B

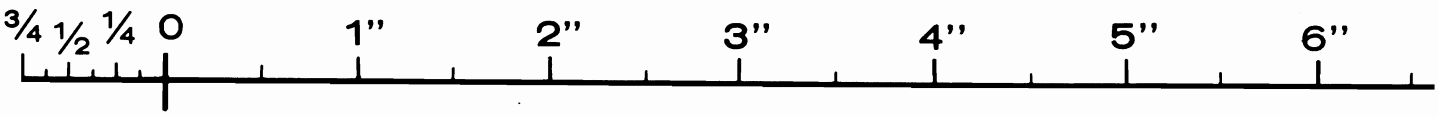
( ) Refer to Detail 4-11B and form a 1-1/4" length of bare wire as shown.

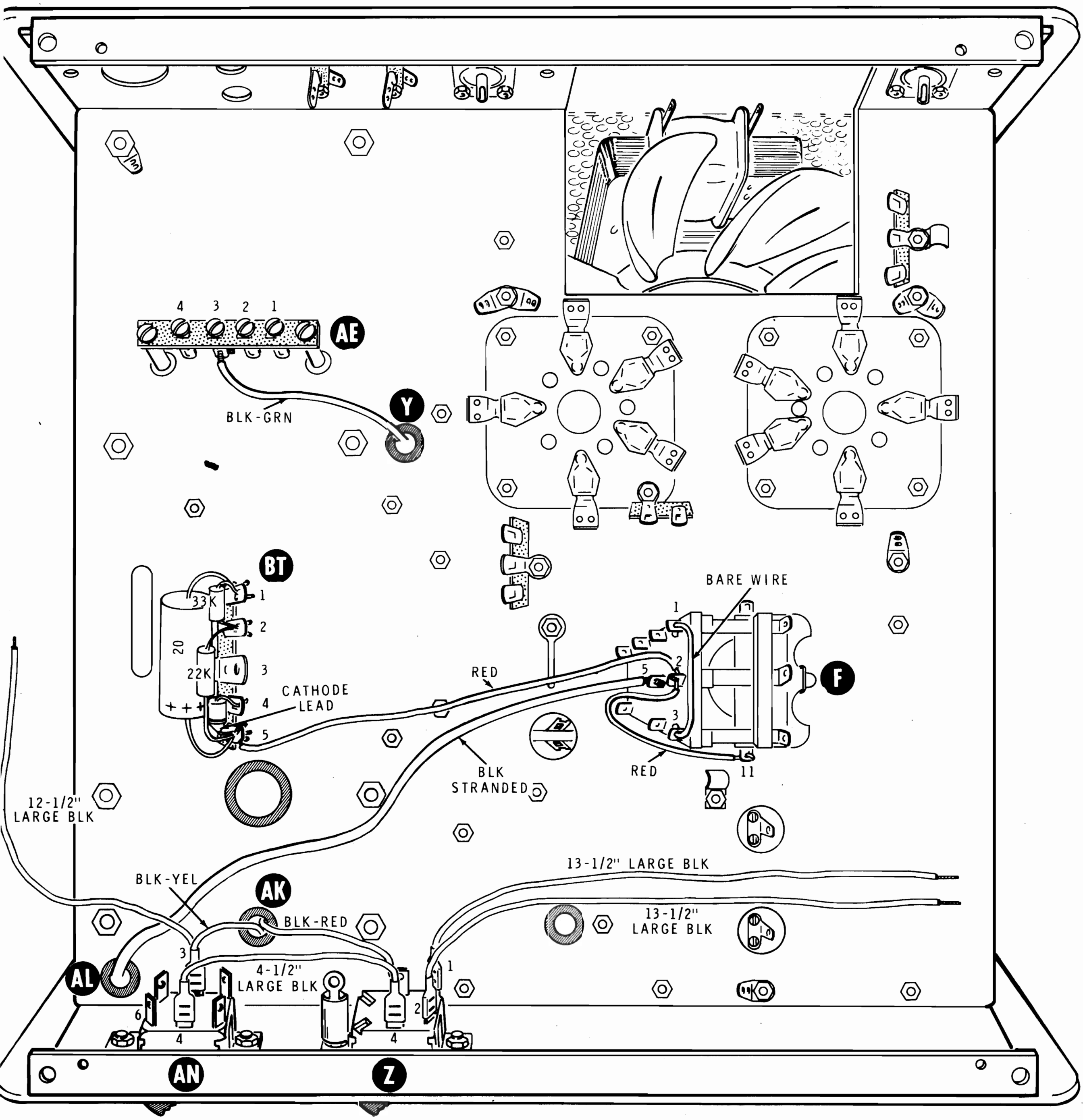
( ) Connect the bare wire from lug 1 (S-1) to lug 3 (S-1) of relay F.

( ) Connect the black-green transformer lead from grommet Y to lug 3 of terminal strip AE (S-2).

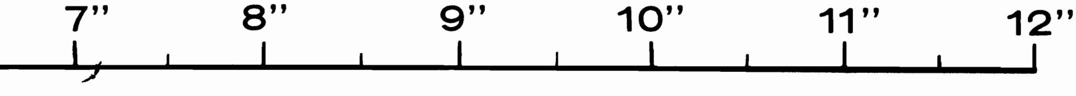


PICTORIAL 4-10

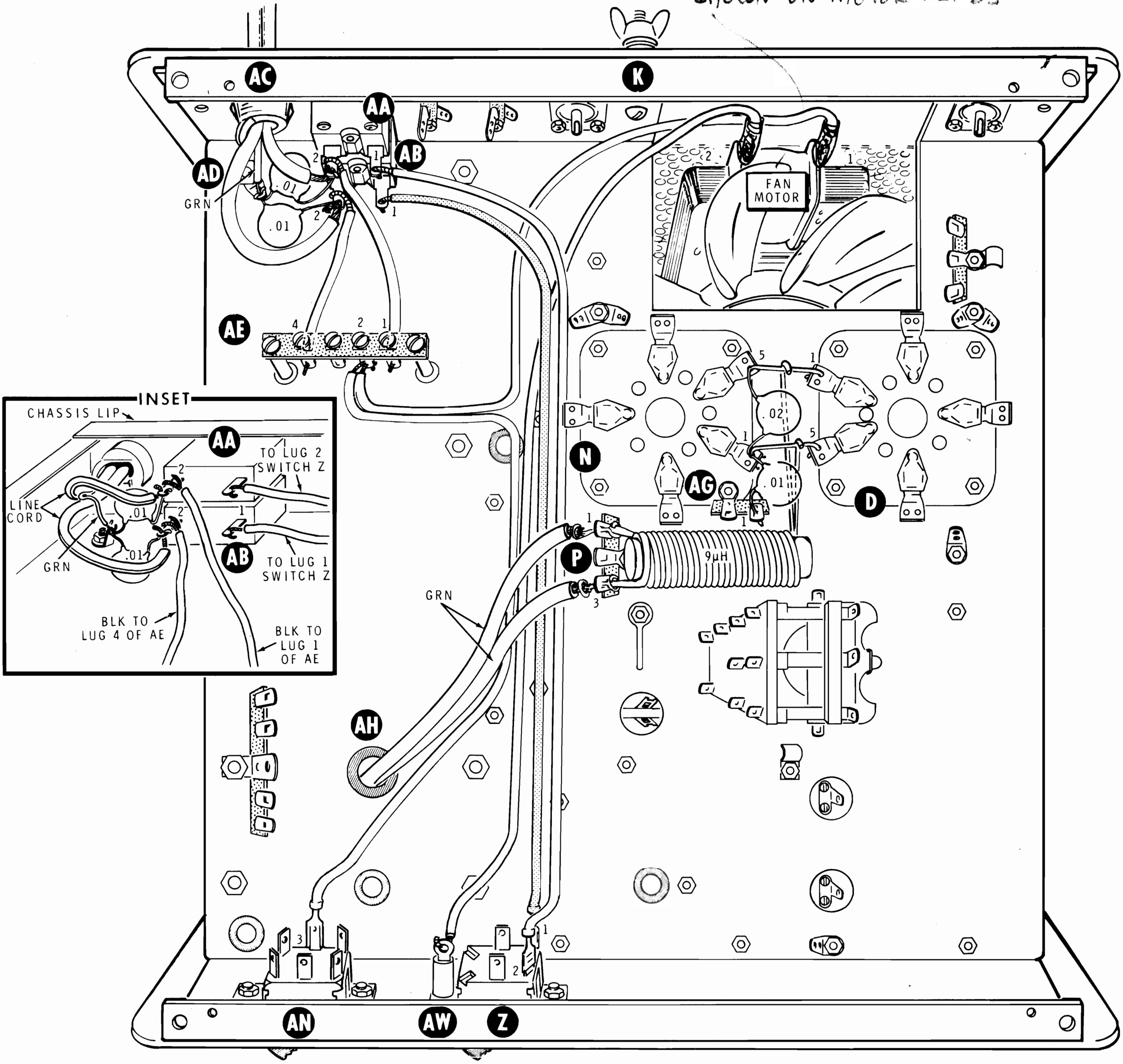




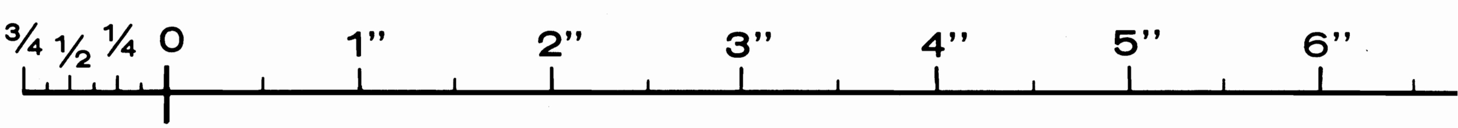
PICTORIAL 4-11

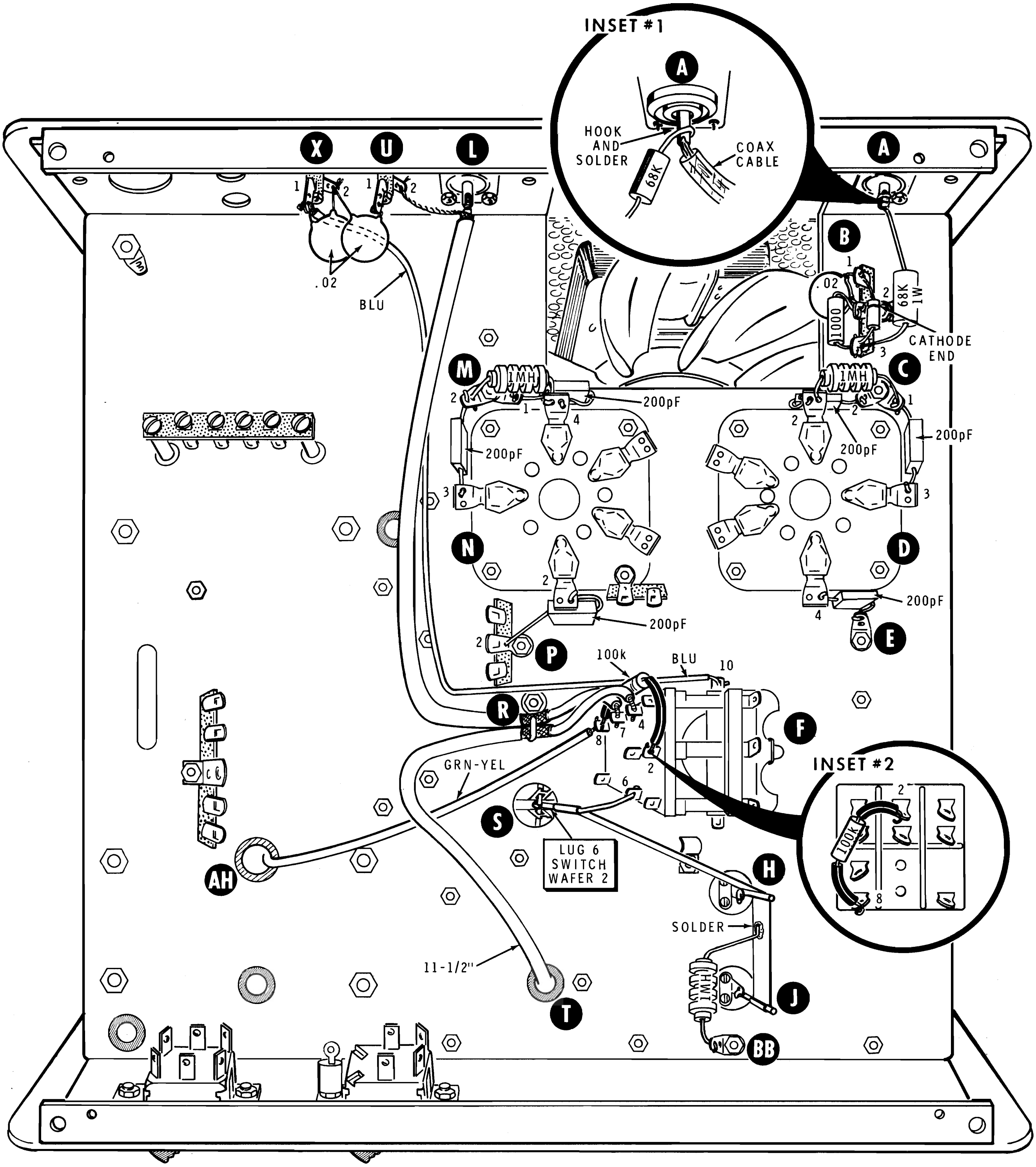


DISREGARD SLEEVING SHOWN ON MOTOR LEADS



PICTORIAL 4-13





PICTORIAL 4-12

7" 8" 9" 10" 11" 12"

Refer to Pictorial 4-12 (fold-out from this page) for the following steps.

(✓) Connect the green-yellow transformer lead from grommet AH to lug 8 of relay F (NS).

(✓) Connect a 13" blue hookup wire from lug 10 of relay F (S-1) to lug 1 of phono socket X (NS).

(✓) Connect a .02 μF disc capacitor from lug 1 (S-2) to lug 2 of phono socket X (NS).

(✓) Connect a .02 μF disc capacitor from lug 1 of phono socket U (S-2) to lug 2 of phono socket X (S-2).

Connect 200 pF molded mica capacitors (#20-3) to tube socket lugs as follows:

Tube Socket and Lug	**Connect to**
(✓) Socket D, lug 4 (S-1)	Solder lug E (S-1).
(✓) Socket D, lug 3 (S-1)	Solder lug C1 (NS).
(✓) Socket D, lug 2 (NS)	Solder lug C2 (S-1).
(✓) Socket N, lug 3 (S-1)	Solder lug M2 (NS).
(✓) Socket N, lug 4 (NS)	Solder lug M1 (S-1).
(✓) Socket N, lug 2 (S-1)	Terminal strip P, eyelet of lug 2 (S-1).

(✓) Connect a 1 mH RF choke (#45-4) from lug 2 of tube socket D (S-2) to solder lug C1 (S-2).

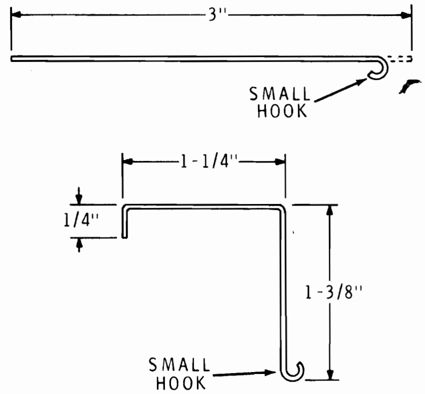
(✓) Connect a 1 mH RF choke from lug 4 of tube socket N (S-2) to solder lug M2 (S-2).

(✓) Connect a .02 μF disc capacitor from lug 1 (NS) to lug 2 (NS) of terminal strip B.

(✓) Connect one lead of a 1000 Ω (brown-black-red) resistor to lug 2 (S-2) and the other lead to lug 3 (NS) of terminal strip B.

(✓) Connect the cathode (banded) end of a germanium diode (brown-white-brown) to lug 1 (S-3) and the other lead to lug 3 (NS) of terminal strip B.

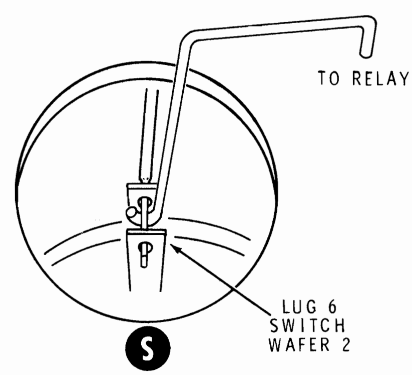
(✓) Connect one lead of a 68 kΩ (blue-gray-orange) 1 watt resistor to lug 3 of terminal strip B (S-3). Hook the other lead of this resistor around coaxial connector A as shown in inset drawing 1 of the Pictorial (S-1).



Detail 4-12A

(✓) Refer to Detail 4-12A and form a 3" length of bare wire as shown. The hook should be just large enough to fit around another piece of the same size of bare wire.

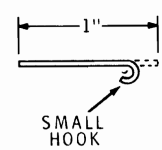
(✓) Refer to Detail 4-12B and connect the hook on the end of the formed wire through hole S to lug 6 of wafer 2 of switch CZ (S-4). Connect the other end of this wire to lug 6 of relay F (S-1) as shown in the Pictorial.



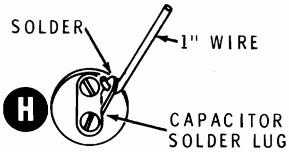
Detail 4-12B

(✓) Refer to Detail 4-12C and form two 1" lengths of bare wire as shown.

(✓) Bend the capacitor lugs at H and J so they are approximately centered in the two holes.



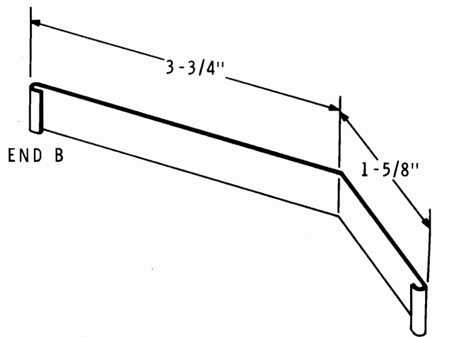
Detail 4-12C



Detail 4-12D

(✓) Refer to Detail 4-12D and connect the hook on one bare wire to the capacitor solder lug at H (S-1). The wire should be at right angles to the chassis.

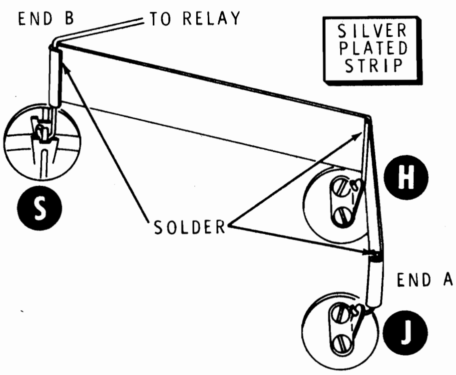
(✓) Similarly, connect the other formed bare wire to the capacitor solder lug at J (S-1).



Detail 4-12E

(✓) Refer to Detail 4-12E and form and fit a 5-3/4" length of silver-plated strip as shown. The hooks in the ends of the strip should be of a size to fit around the bare wires at S and J in the Pictorial.

(✓) As shown in Detail 4-12F, fit the silver-plated strip onto the bare wires. Fit the loop at end B around the bare wire at S. Then pass the strip around the back of the bare wire at H and slip the loop at end A down over the bare wire at J. Crimp the loops around the wires at S and J.

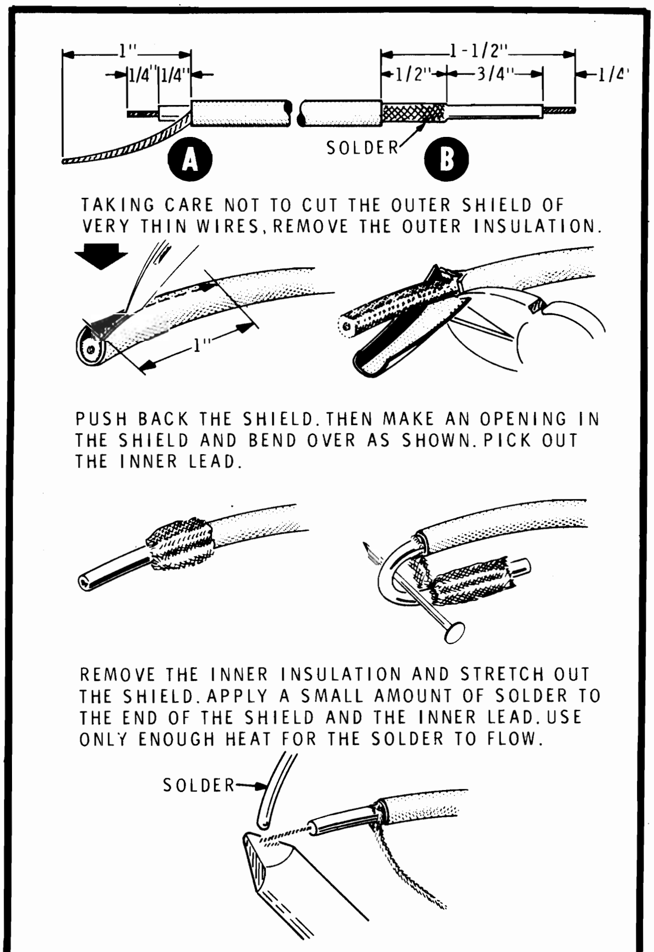


Detail 4-12F

(✓) Adjust the strip so there is at least 1/4" clearance between its lower edge and the chassis. Then solder the strip to the bare wires at S, H, and J.

(✓) Bend a small "foot" on the end of one lead of a 1 mH RF choke. Connect the other lead to solder lug BB (S-1). Position the choke parallel to the chassis with clearance of approximately 1/2". Then solder the "foot" to the silver-plated strip as shown in the Pictorial.

(✓) Refer to Detail 4-12G and prepare an 11-1/2" length of RG-58A/U coaxial cable. Note that 1" of outer insulation is first removed from end A, and that the center conductor and inner insulation are then cut back as shown.

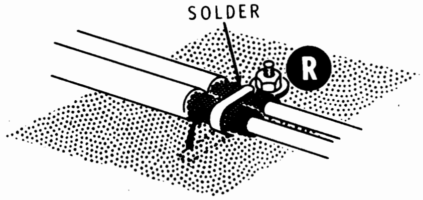


Detail 4-12G

( ) Tin the shield braid on end B. Use a minimum amount of heat and avoid melting the inner insulation.

( ) Connect the coaxial cable center conductor at end B to lug 7 of relay F (S-1).

( ) Connect the center conductor of the remaining coaxial cable coming from grommet T to lug 4 of relay F (S-1). Be sure this lead does not touch any other lug of the relay.



Detail 4-12H

( ) Refer to Detail 4-12H and position the exposed shields of the coaxial cables connected in the two preceding steps, over the long solder lug at R. Bend the solder lug back over both shield braids and solder. Use a minimum, but adequate, amount of heat.

( ) Connect the center conductor at the free end of the coaxial cable to the center conductor of the coaxial fitting at L (S-1). Connect the shield wires to lug 2 of phono socket U (S-1).

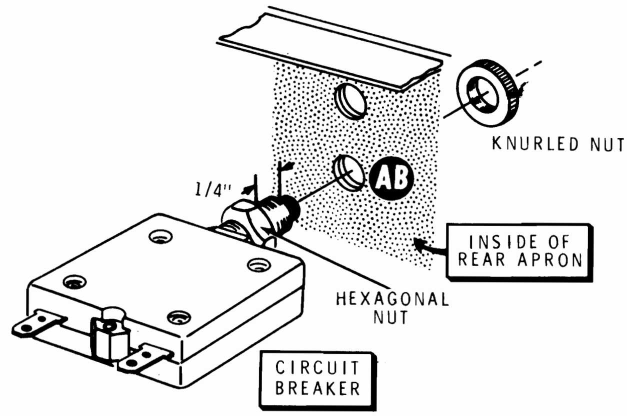
( ) Cut one lead of a 100 kΩ resistor (brown-black-yellow) to 3/4" and the other lead to 1". Place a 1/2" length of black sleeving on the 3/4" lead and a 3/4" length of black sleeving on the 1" lead.

( ) Connect the 3/4" lead of the 100 kΩ resistor to lug 8 (S-2) and the 1" lead to lug 2 (S-3) of relay F as shown in inset drawing 2 of the Pictorial.

Refer to Pictorial 4-13 (fold-out from Page 50) for the following steps.

Refer to Detail 4-13A for the following three steps.

( ) Remove a knurled nut from each of the two circuit breakers (#65-28).



Detail 4-13A

( ) Position the face of each hexagonal nut 1/4" from the end of the mounting bushing.

( ) Mount a circuit breaker on the chassis rear apron at AB. Use the knurled nut provided. NOTE: For convenience in wiring, position the solder lugs to provide the maximum distance between the chassis and the lugs.

( ) Similarly, mount the other circuit breaker at AA.

NOTE: In the following steps the fan motor will be connected with push-on connectors. Be careful not to bend or break the motor lugs out of their plastic frame work in the process.

Page 52 — Right column.
Replace the "Note" and the next three steps.

NOTE: In the following steps the fan motor will b connected. Be careful not to tear the motor leads out o their plastic frame work in the process.

( ) Route one of the fan motor leads to terminal strip AE as shown. Cut off the excess lead length and remove 1/4" of insulation from the remaining lead.

( ) Connect the prepared lead to lug 2 of terminal strip AE (NS).

( ) Connect the other fan motor lead to double lug AW (S-4). Cut to size, if necessary.

Connect the wires from switches AN and Z as follows:

Wire Coming from	Connect to
Lug 3, switch AN ✓	Lug 2, terminal strip AE (S-2).
Lug 1, switch Z ✓	Lug 1, circuit breaker AB (S-1).
Lug 2, switch Z ✓	Lug 1, circuit breaker AA (S-1).

(✓) Prepare a 3" and 3-1/2" large black stranded wire by cutting to length and removing 1/4" of insulation from each end of each wire.

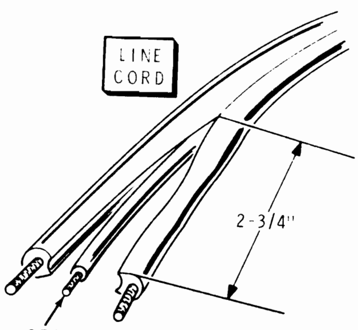
(✓) Connect one end of the 3" wire to lug 4 of terminal strip AE (S-1). Connect the other end of this wire to lug 2 of circuit breaker AB (NS). Use the hole next to the circuit breaker body.

(✓) Similarly, connect the 3-1/2" wire from lug 1 of terminal strip AE (S-1) to lug 2 of circuit breaker AA (NS).

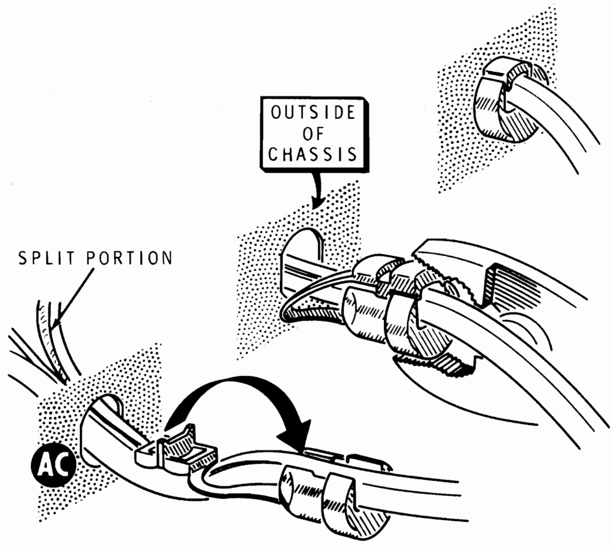
(✓) Connect a .01 μF, 1.4 kV, disc capacitor from solder lug AD (NS) to lug 2 of circuit breaker AB (NS).

(✓) Connect a .01 μF, 1.4 kV, disc capacitor from solder lug AD (NS) to lug 2 of circuit breaker AA (NS).

( ) Refer to Detail 4-13B and prepare the end of the line cord as shown. Remove 3/8" of insulation from the end of each of the three conductors. Melt a small amount of solder on the end of each.



Detail 4-13B



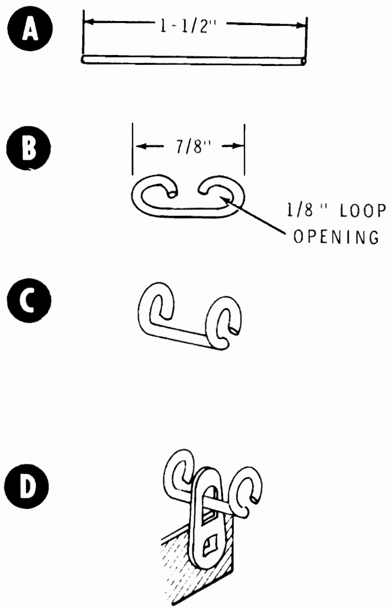
Detail 4-13C

(✓) Refer to Detail 4-13C and place the strain relief on the line cord just beyond the split portion of the cord, as shown. Use a pair of gas pliers to compress the strain relief, and then insert it into hole AC from the outside of the chassis.

(✓) Connect the green line cord wire to solder lug AD (S-3).

(✓) Connect one line cord conductor to lug 2 of circuit breaker AB (S-3).

(✓) Connect the other line cord conductor to lug 2 of circuit breaker AA (S-3).



Detail 4-13D

Refer to Detail 4-13D for the following steps.

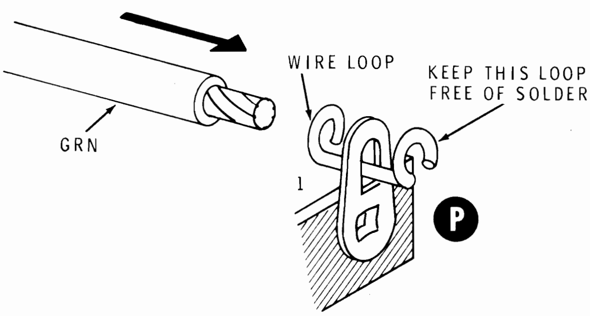
( ) Part A. Cut a 1-1/2" length of bare wire.

( ) Part B. On each end of the bare wire, form a loop having an inside diameter of approximately 1/8". Adjust the size of the loops so they will just slide onto the tinned end of one of the large green transformer leads from hole AH.

( ) Part C. Bend the two wire loops up as shown.

( ) Part D. Pass the formed wire through lug 1 of terminal strip P.

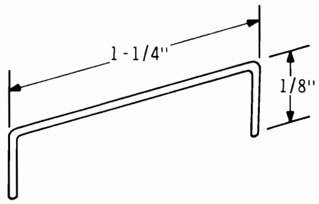
( ) Form another bare wire in the same manner, except pass this wire through lug 3 of terminal strip P.



Detail 4-13E

( ) Refer to Detail 4-13E and position the wire loops at lug 1 of the terminal strip so they point up away from the chassis. Then insert the end of the 6-1/2" green lead from hole AH all the way into the wire loop. Be careful to keep the two wire loops equally distant from the terminal strip solder lug. Then use pliers to compress the wire loop on the green wire. Solder the green lead to the wire loop and the wire loop to the solder lug, but be sure to keep the other wire loop free of solder. Also solder the lead from the .02 µF disc capacitor and the brown wire to lug 1 at this time.

(✓) Repeat the preceding step at lug 3 of terminal strip P for the 5-3/4" green lead.



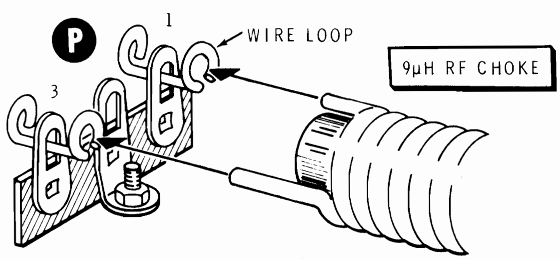
Detail 4-13F

(✓) Refer to Detail 4-13F and form two 1-1/2" lengths of bare wire. Then, fit one wire from lug 1 of tube socket D (S-1) to lug 5 of tube socket N (NS).

(✓) Fit the other 1-1/2" wire from lug 5 of tube socket D (S-1) to lug 1 of tube socket N (NS).

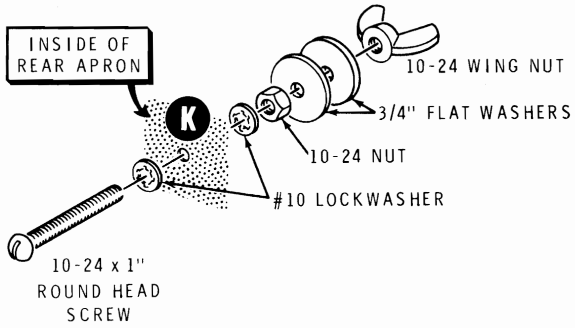
(✓) Connect a .02 µF disc capacitor from lug 5 (S-2) to lug 1 (NS) of tube socket N.

(✓) Connect a .01 µF, 1.4 kV, disc capacitor from lug 1 of tube socket N (S-3) to lug 1 of terminal strip AG (S-2).



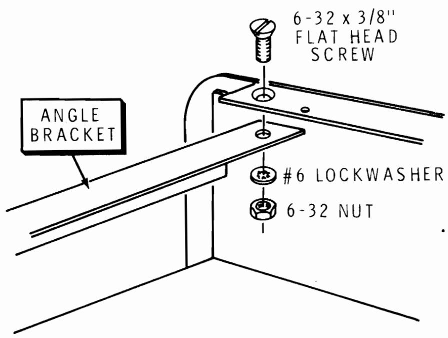
Detail 4-13G

(✓) Refer to Detail 4-13G and fit the 9 µH RF choke (#45-78) so the two short leads at one end fit into the two wire loops on terminal strip P. At the other end of the choke, form the two leads so they loop around the bare wire filament leads between the two tubes as shown. Make sure the RF choke leads clear the chassis by at least 1/8". Solder the four RF choke leads carefully as these leads carry heavy current.



Detail 4-13H

(✓) Refer to Detail 4-13H and install the ground post at K on the chassis rear apron. Use a 10-24 x 1" round head screw, two #10 lockwashers, a 10-24 nut, two 3/4" flat washers, and a 10-24 wing nut.

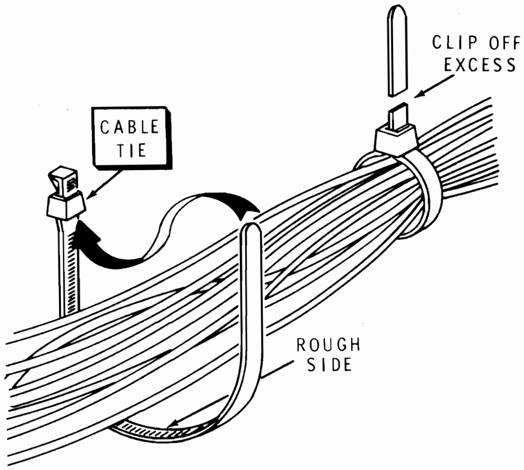


Detail 4-14A

Refer to Pictorial 4-14 for the following steps.

(✓) Refer to Detail 4-14A and install an angle bracket (#204-1041) on the chassis at AS and AT. Use 6-32 x 3/8" flat head hardware.

(✓) Similarly, install the other angle bracket between AP and AR.



Detail 4-14B

(✓) Refer to Detail 4-14B and pass a cable tie (#354-5) around all of the wires at each of the six points shown in the Pictorial to form a neat cable. Equalize any slack in each wire between the ends of the wire. Then pull each cable tie snug and clip off the excess length of the tie.

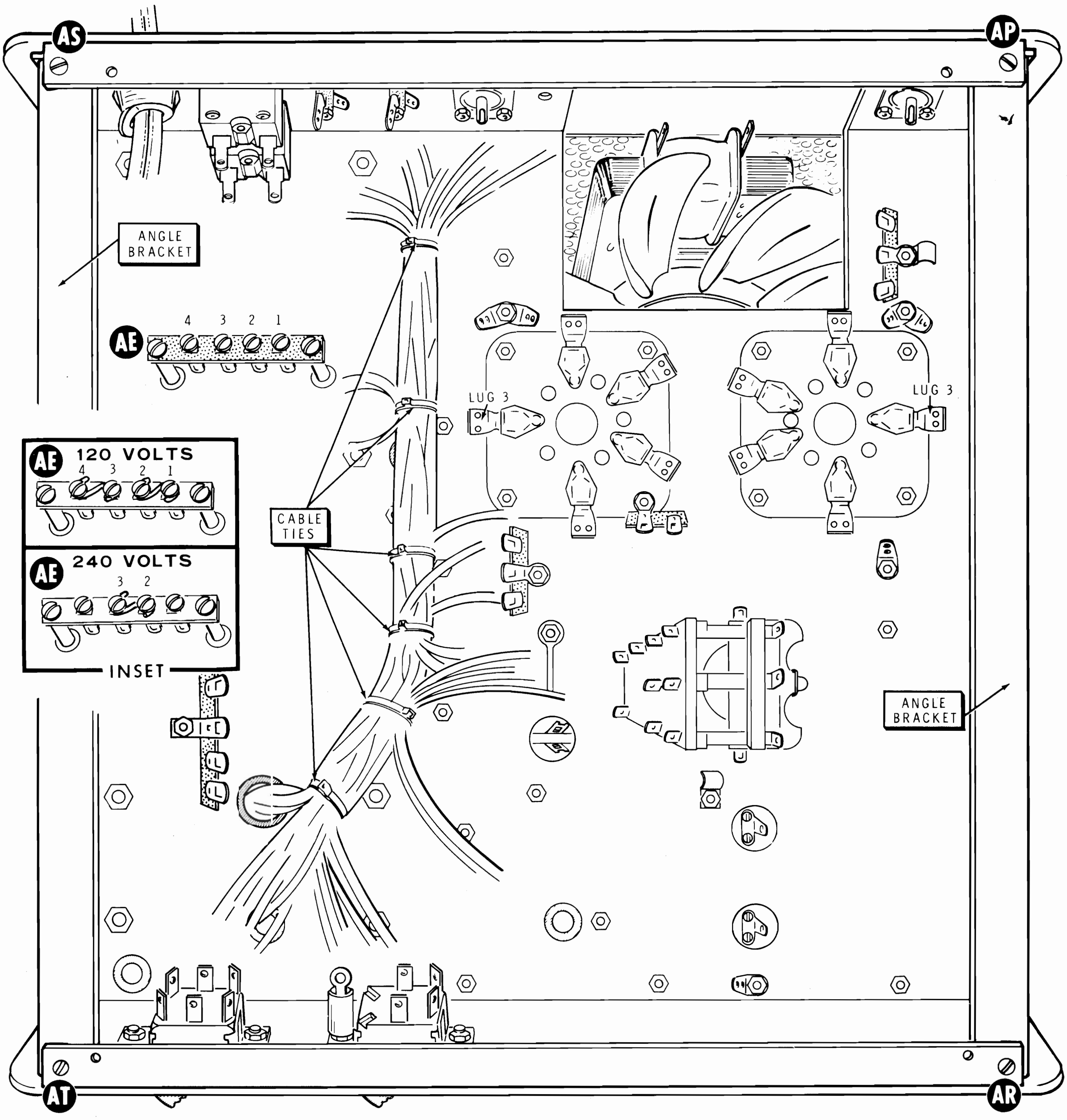
120-240 VOLT WIRING

This amplifier can be operated from 120 or 240 volts, 50/60 hertz, alternating current.

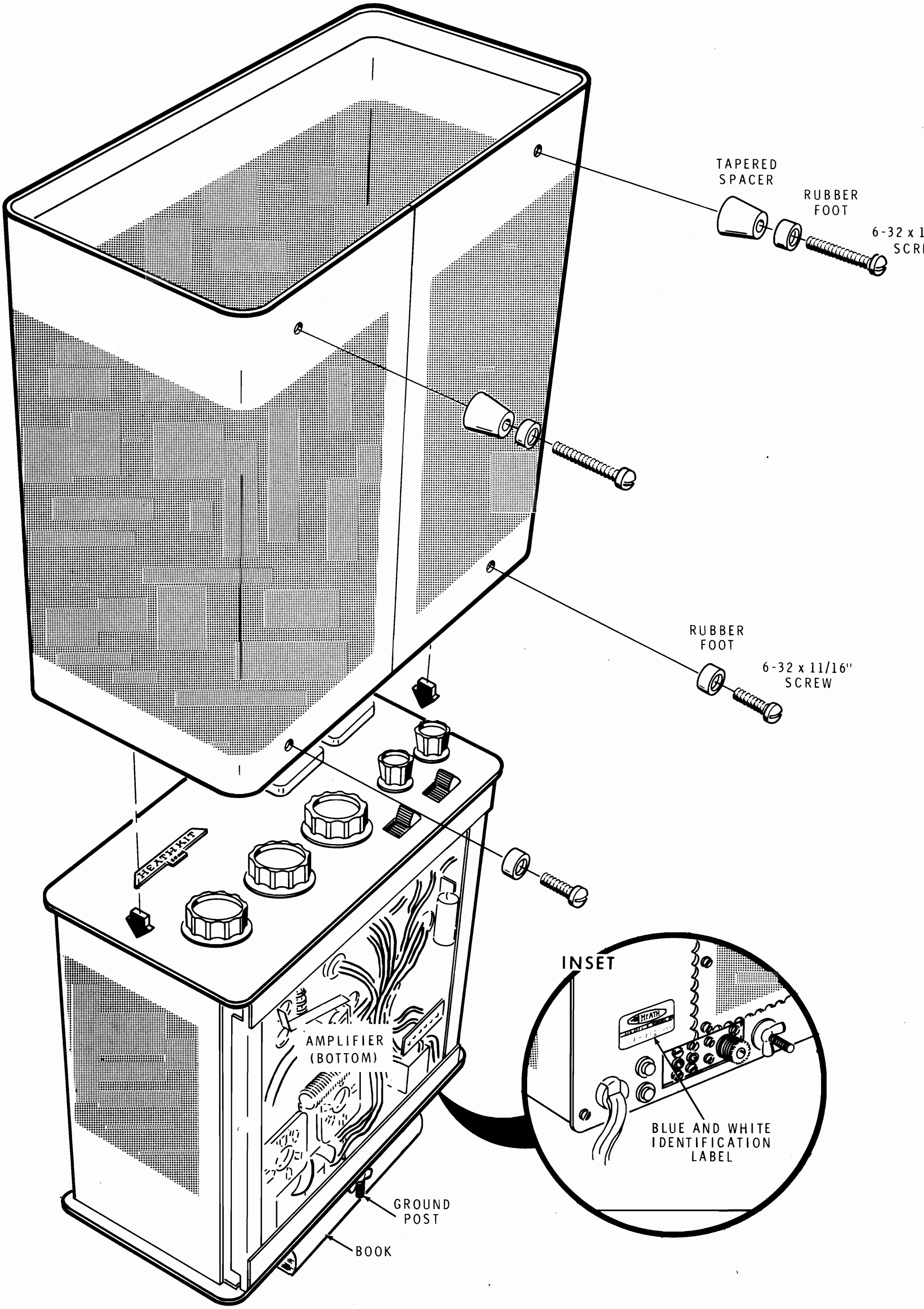
Make the proper connections on terminal strip AE for the supply voltage you will use. Refer to the inset drawing of Pictorial 4-14 and perform one of the following steps, depending on the line voltage to be used.

(✓) For 120 VAC operation, connect a bare wire between terminals 1 and 2 and another bare wire between terminals 3 and 4 of terminal strip AE.

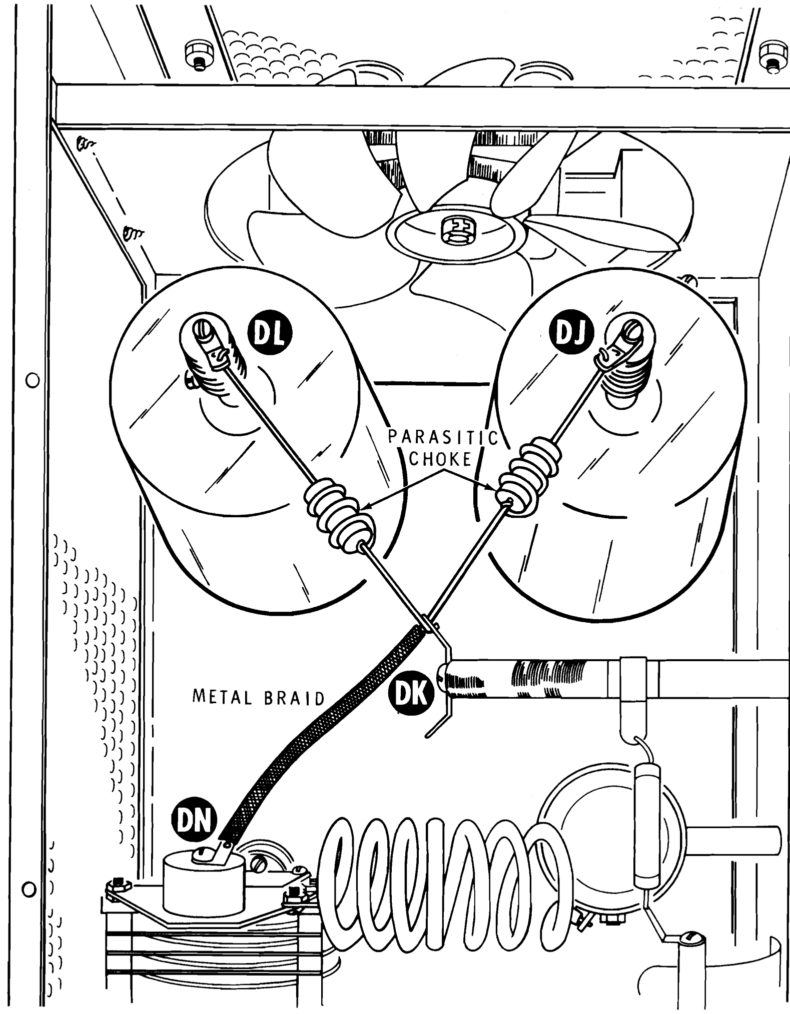
( ) For 240 VAC operation, connect a bare wire between terminals 2 and 3 of terminal strip AE.



PICTORIAL 4-14



PICTORIAL 4-20



PICTORIAL 4-15

FINAL TOP-CHASSIS WIRING

Refer to Pictorial 4-15 for the following steps.

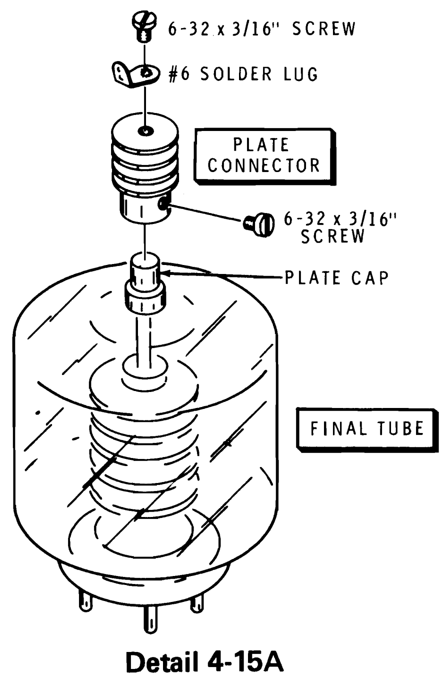
Refer to Detail 4-15A for the following three steps.

( ) Install a #6 solder lug on the top end of each plate connector (#260-12). Use a 6-32 x 3/16" screw, but leave it loose.

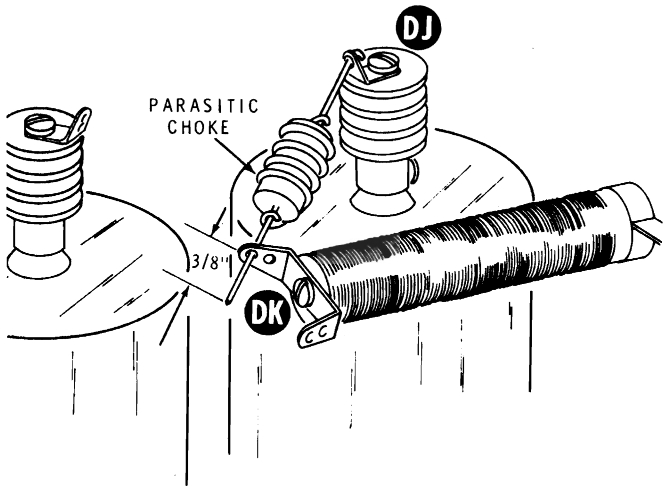
( ) Start a 6-32 x 3/16" screw into the side of each plate connector.

( ) Place each plate connector on the plate cap of a final tube (3-500Z) and tighten the screw on the side of each connector.

( ) Place a final tube in each tube socket.



Detail 4-15A



Detail 4-15B

NOTE: When you install parasitic chokes in the following steps, center the chokes between the solder lugs.

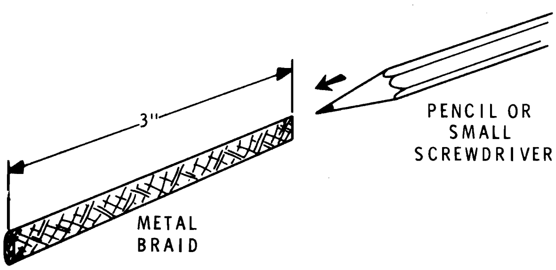
( ) Cut each lead of the two parasitic chokes (#45-53) to a length of 7/8".

( ) Refer to Detail 4-15B and install a parasitic choke from solder lug DJ (S-1) to solder lug DK (NS). Note that the lead of the parasitic choke extends through solder lug DK for approximately 3/8". Leave this lead straight as shown in the Detail.

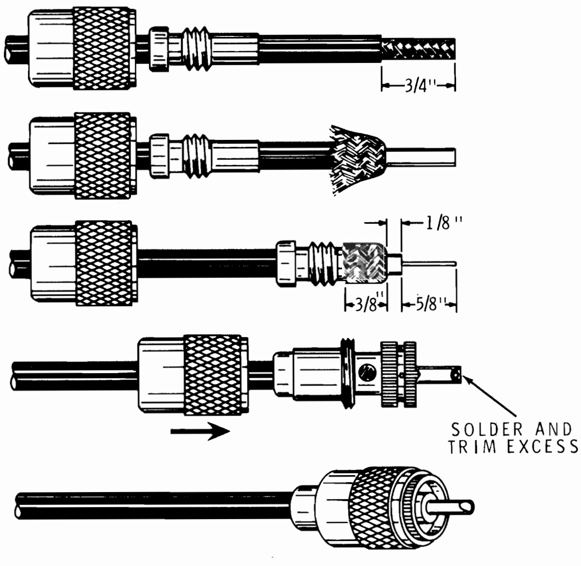
( ) Install the other parasitic choke from solder lug DL (S-1) to solder lug DK (NS).

( ) Tighten the screws in the tops of the two plate connectors.

( ) Refer to Detail 4-15C and open up the ends of a 3" length of metal braid with a pencil. (Note that the metal braid is actually flattened tubular braid.) Push one end onto the 3/8" projecting end of the parasitic choke at DK (S-3). Push the other end over the solder lug on the capacitor at DN (S-1).



Detail 4-15C



PICTORIAL 4-16

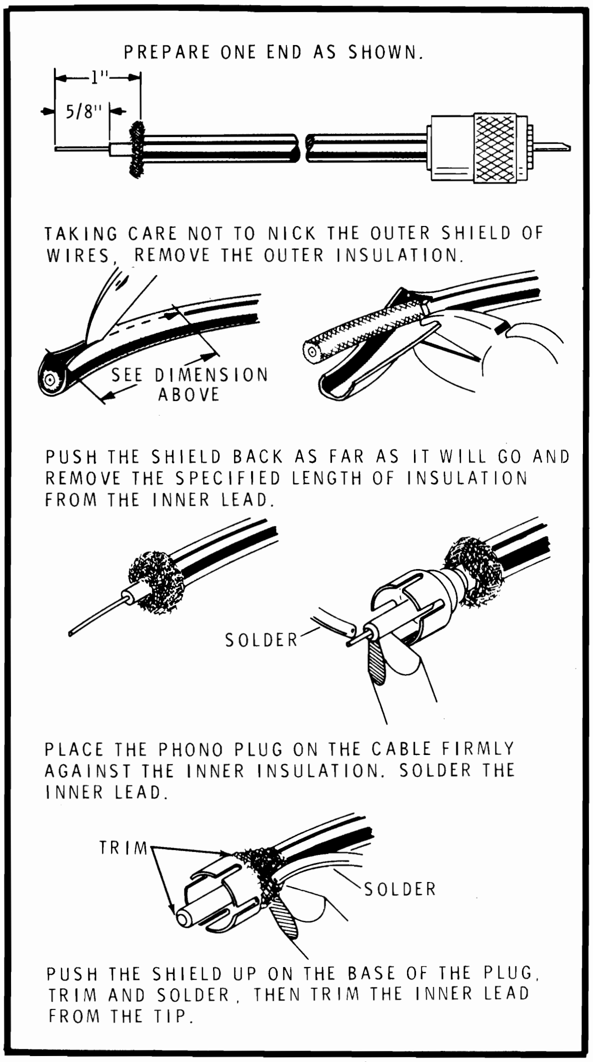
CABLE PREPARATION

( ) Cut a length of RG-58A/U coaxial cable which will conveniently reach from the output of your exciter to the RF Input connector on the rear panel of the Amplifier (4' maximum recommended).

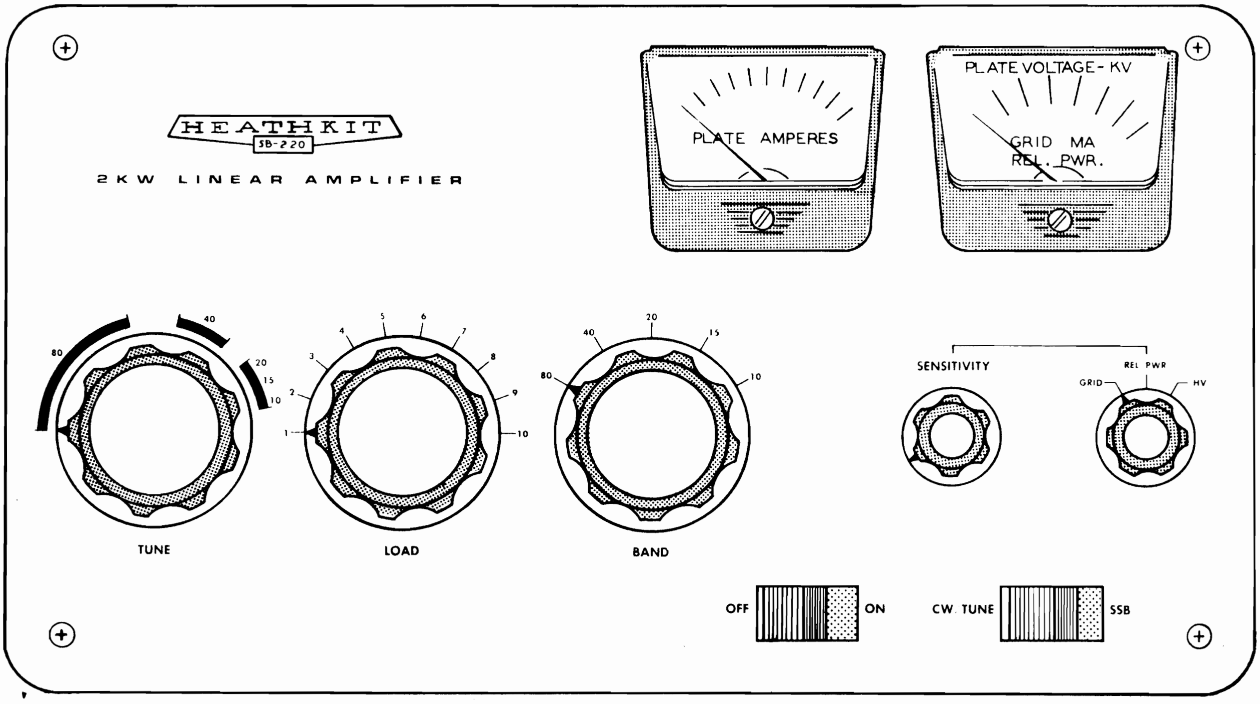
( ) Refer to Pictorial 4-16 and install a coaxial plug (#438-9) and a coaxial plug insert (#438-12) on one end of the coaxial cable.

( ) On the other end of the coaxial cable, install a connector (not furnished) which will mate with the output connector of your exciter. Refer to Pictorial 4-16 or Pictorial 4-17, as appropriate.

Lay the cable aside for use later.



PICTORIAL 4-17



PICTORIAL 4-18

KNOB INSTALLATION

Refer to Pictorial 4-18 for the following steps.

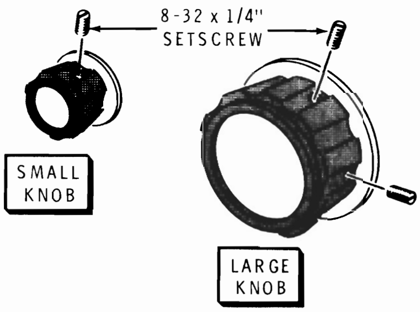
( ) Refer to Detail 4-18A and start two 8-32 x 1/4" setscrews into each of the three large knobs. Start a single setscrew into each of the two small knobs.

( ) Turn the shafts of the Tune and Load capacitors so the plates of each are fully meshed.

( ) Turn the three other shafts fully counterclockwise.

( ) Install the knobs on the shafts so the index marks are positioned as shown in the Pictorial, and tighten the setscrews.

Proceed to "Test and Final Assembly."



Detail 4-18A

CAUTION

Use extreme care during initial testing and all subsequent operation of this Linear Amplifier. While the SB-220 is designed for maximum safety, never lose respect for the high voltage present in this unit. Protect yourself always against lethal or severe electric shock.

HEATH COMPANY

TEST AND FINAL ASSEMBLY

The input coils are factory adjusted and do not require any further alignment.

The brass spring and the metal spacer form a safety "interlock" which grounds the high voltage power supply and removes the high voltage from points which are exposed when the perforated cover is removed.

Refer to the chassis photographs for the location of the interlock and the resistance test points.

RESISTANCE CHECK

(√) IMPORTANT: Refer to Figure 1, push down the brass spring of the interlock, and temporarily insert a rubber foot between the brass spring and the metal spacer. If you fail to do this, the high voltage circuit will be short-circuited, you will be unable to obtain a plate connector resistance reading, and damage will result if power is applied.

(√) The resistance between the plate connectors and the chassis should measure approximately 200 kΩ after the meter stabilizes.

(√) The resistance between lug 3 of each tube socket and the chassis (Pictorial 4-14) should measure approximately 20 Ω.

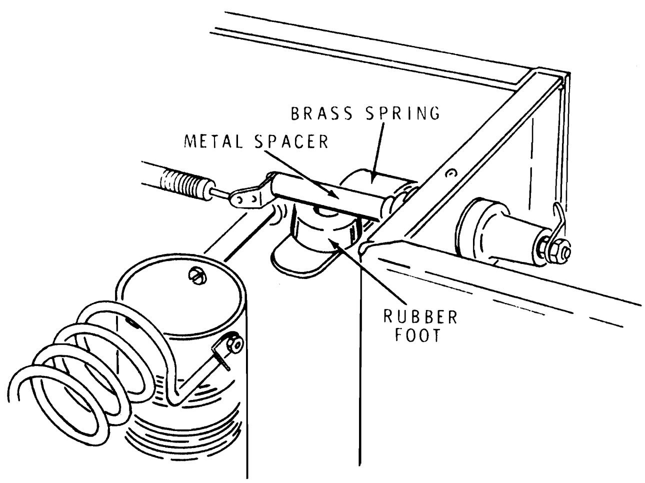
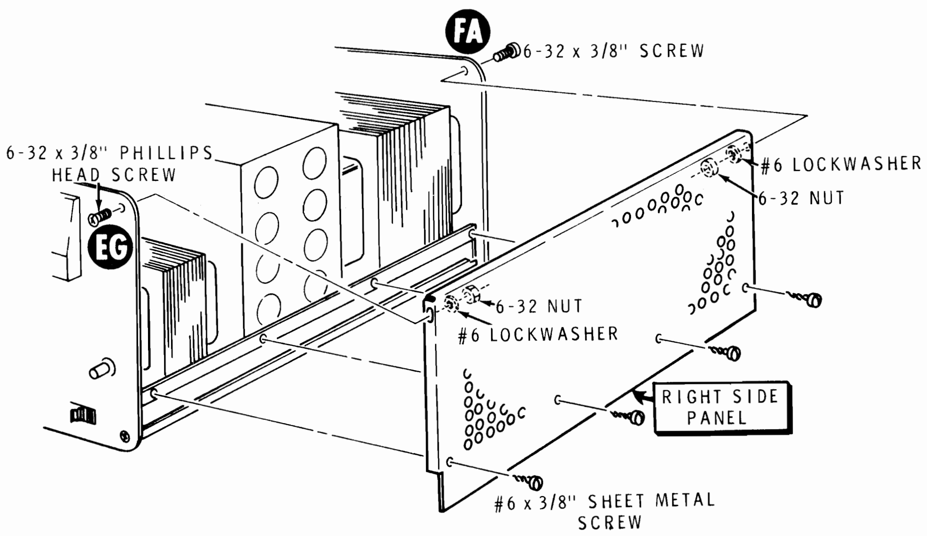


Figure 1

If any difficulty is encountered in obtaining either of these resistance readings, refer to the "In Case of Difficulty" section of the Manual on Page 75.

(√) Remove the rubber foot from the interlock.



Detail 4-19A

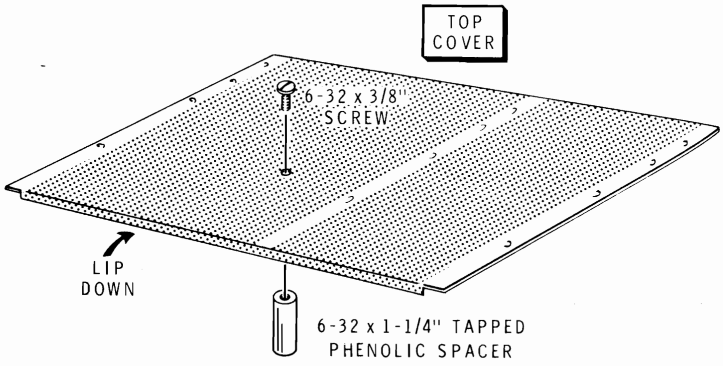
Refer to Pictorial 4-19 for the following steps.

(✓) Refer to Detail 4-19A and install the right side panel. Use #6 x 3/8" sheet metal screws along the lower edge, 6-32 x 3/8" hardware at FA, and 6-32 x 3/8" phillips head hardware at EG. CAUTION: After the panel is installed, check to make sure there is at least 1/4" clearance between the point of the sheet metal screw and any connections to the positive (+) lug of filter capacitor #7. (See Pictorial 4-7, fold-out from Page 43.)

(✓) As shown in the Pictorial, place the perforated top cover (#205-724) on the top of the Amplifier with the lip against the front panel pointing down. Align the mounting screw holes. Then mark the hole in the cover which is directly over that portion of the brass spring which protrudes beyond the metal spacer.

(✓) Refer to Detail 4-19B and install a 6-32 x 1-1/4" tapped phenolic spacer (#255-39) on the underside of the perforated cover at the marked hole. Use a 6-32 x 3/8" screw.

(✓) Install the perforated top cover and the top rear plate cover (#205-723) on the top of the amplifier. Use #6 x 3/8" sheet metal screws. First, install a screw near each corner of the top cover and then check visually to make sure that the phenolic spacer on the under side of the top cover pushes the interlock spring down away from the metal spacer mounted on the feedthrough insulator. Any required repositioning of the phenolic spacer should be accomplished before completing the top cover installation. Then install the rest of the sheet metal screws.



Detail 4-19B

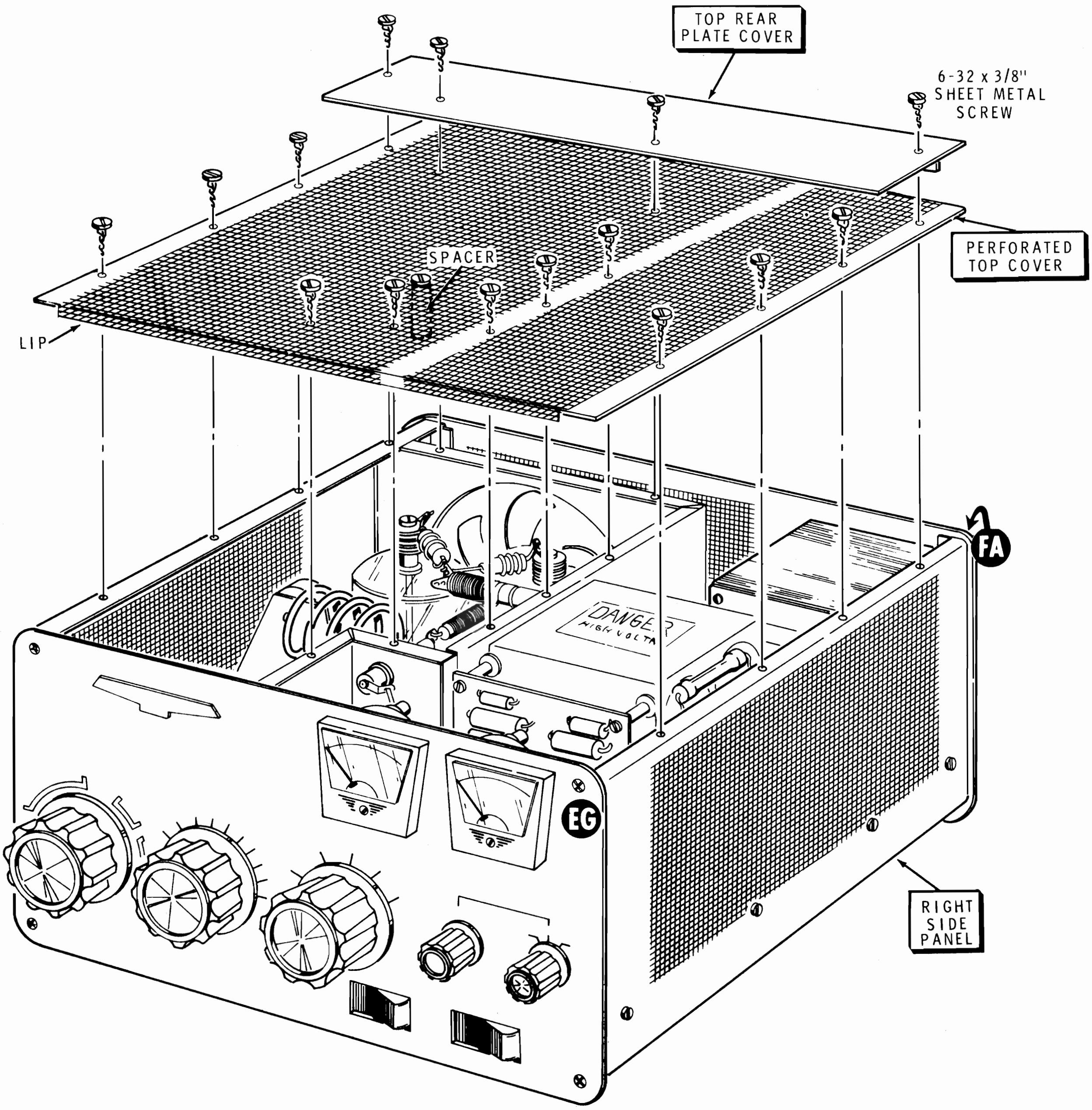
(✓) If necessary, adjust each meter pointer to "0" with the meter adjusting screw (see Figure 3-1 fold-out from Page 68).

NOTE: If at any time during the testing and operation the Linear Amplifier does not perform as described, unplug the Linear Amplifier line cord and refer to the "In Case of Difficulty" section of the Manual.

Position the switches and controls as follows:

TUNE	9 o'clock
LOAD	9 o'clock
BAND	Any
SENSITIVITY	12 o'clock
METER SWITCH	HV
POWER SWITCH	OFF
MODE SWITCH	CW/TUNE

(✓) Plug the line cord into the power source for which the unit is wired, either 120 volts or 240 volts AC.



PICTORIAL 4-19

CAUTION: ***LETHAL VOLTAGES ARE PRESENT IN THIS UNIT. USE EXTREME CARE WHEN MAKING ANY TESTS.***

(✓) Push the POWER switch to ON.

(✓) Check to see that the tube filaments and meter pilot lamps light, and that the fan operates. The right-hand meter should read approximately 2500 volts.

(✓) Push the MODE switch to SSB. The meter should read approximately 3000 volts.

NOTE: There should be no indication on either panel meter except when the METER SWITCH is at the HV position.

(✓) Push the POWER switch to OFF and unplug the line cord.

NOTE: Read through the following steps and decide whether you want your amplifier to sit level, or whether you wish the front of the chassis elevated. Then select the feet and mounting hardware so the parts will be immediately available as you install the cabinet. The screws for the mounting feet will be inserted through the four holes in the cabinet bottom and screwed into the captive nuts in the flange of the chassis.

Refer to Pictorial 4-20 (fold-out from Page 56) for the following steps.

( ) Place a book on a flat surface and balance the amplifier chassis on the book, front panel uppermost.

( ) Lower the cabinet onto the chassis so the captive nuts in the chassis bottom flange are aligned with the four holes in the cabinet.

Perform only one of the following two steps, depending upon how you wish the amplifier cabinet positioned.

( ) If you wish to have the amplifier cabinet sit level, install a rubber foot at each corner of the cabinet. Use 6-32 x 11/16" screws.

( ) If you wish the front of the cabinet to be elevated, install a rubber foot on each rear corner with 6-32 x 11/16" screws. Then, install a tapered spacer and a rubber foot at each front corner of the cabinet with 6-32 x 1-1/2" screws.

NOTE: The blue and white identification label shows the Model Number of your kit. Refer to these numbers in any communications with the Heath Company.

( ) Install the identification label in the following manner.

1. Select a location for the label where it can easily be seen when needed, but will not show when the unit is in operation, such as on the rear panel (see the inset drawing in Pictorial 4-20).

2. Carefully peel away the backing paper. Then press the label into position. You will avoid smearing the numbers on the label if you will put the piece of waxed backing paper on top of the label and then rub on it instead of directly on the label.

This completes the assembly of your Linear Amplifier. Proceed to "Installation."

INSTALLATION

LOCATION

The amplifier should not be operated in excessively warm locations or near heating vents or radiators. Free air circulation around and through the amplifier cabinet, and an unobstructed air inlet for the blower should be provided. No books, magazines, or equipment should be placed on top of the cabinet to impede the free flow of air.

POWER CONSIDERATIONS

Because of the power involved, this Amplifier should preferably be served by its own 240 VAC electric service line, having three 12 gauge conductors and fused in each "hot" wire for 10 amperes. However, if a single 240 VAC line must serve the entire station, make an effort to connect your equipment so the load will be balanced between the two "hot" wires as nearly as possible.

If only 120 VAC can be provided, use a separate line having 10 gauge conductors and 20 ampere fuses.

DO NOT use this Amplifier at its full ratings on a regular house wiring circuit, as the ratings of the wire will almost certainly be exceeded.

Avoid excessively long runs of wire from your service entrance. A heavy flow of current in such a line results in a voltage drop which can affect the performance of your equipment.

If you use a power cord plug that is different from the one now on the power cord, cut off the furnished plug.

When you install the new plug, make sure it is connected according to your local electrical code. Keep in mind that the green line cord wire is connected to the amplifier chassis.

For your convenience in identifying conductors, one edge of the heavy line cord is beaded. The other edge is smooth.

ANTENNA

The output circuit of the Amplifier is designed for connection to an unbalanced transmission line of 50 Ω characteristic impedance. Lines of other characteristic impedance may be used providing the SWR (standing wave ratio) does not exceed 2:1.

The antenna connector is a UHF type SO-239. A mating PL-259 plug is furnished for your transmission line. See "Equipment Interconnections" for information on how to install this plug.

Coaxial cables RG-8/U, RG-11/U, or similar types, should be used for the transmission line. The smaller types RG-58/U and RG-59/U are not recommended because of the power level.

The "A.R.R.L. Antenna Book" is commonly available and includes comprehensive reference work on transmission lines and antennas. Other similar handbooks for the amateur are offered for sale and can often be found in a public library.

GROUNDING

A good earth or water pipe ground should be connected to the ground post on the rear apron of the Amplifier. Use the heaviest and shortest connection possible.

Before using a water pipe ground, inspect the connections around your water meter and make sure that no plastic or rubber hose connections are used which interrupt electrical continuity to the water supply line. Install a jumper around any insulating water connectors found. Use heavy copper wire and pipe clamps. It is best to ground all equipment to one point at the operating position and then ground this point as discussed above.

EQUIPMENT INTERCONNECTIONS

Interconnections between this Amplifier and other Heath equipment are shown in the Figure 2 series of illustrations. Other makes of equipment will usually follow the same general pattern.

CABLES FURNISHED

Two phono cables are furnished. These are shielded cables which have a phono plug molded at each end. Use one cable to connect the amplifier ALC output to the exciter ALC input. Use the second cable to connect the amplifier antenna relay socket to the exciter antenna relay socket.

An RG-58A/U coaxial cable was made up earlier. This cable is used to connect the exciter RF output to the amplifier RF input.

Antenna Relay

OPERATION

The antenna relay circuit in the Amplifier must be grounded in the transmit mode. Heath exciters contain a provision to accomplish this action. If a relay terminal, or other switching provision is not available, this function must be provided by other means. If a separate coaxial send-receive relay is used in your station, it may have external contacts available. A separate switch can also be used.

HEATH TRANSCEIVERS WITH 11-PIN POWER PLUGS

If you will use your Amplifier with a Heath transceiver which has an 11-pin power plug on the rear panel, refer to Pictorial 5 and perform the following steps to accomplish the Antenna Relay connection.

However, if you have previously changed the interior wiring of the transceiver to use one of the spare phono sockets to bring out the exterior antenna relay connection, disregard the following steps and proceed to the "Operations" section.

( ) Cut off and discard the phono plug from one end only of one of the phono cables furnished.

( ) Remove 3/4" of the gray outer insulation of the cable.

( ) Unwind the shield wires from the inner insulation. Then twist the shield wires tightly together and melt a small amount of solder on the ends of the wires.

( ) Remove 1/4" of insulation from the inner conductor, twist the exposed bare wires tightly, and melt a small amount of solder on the wire ends.

( ) Remove the transceiver power cable socket cap and slide it back on the power cable. Then push the prepared end of the phono cable through the socket cap as shown in the Pictorial.

NOTE: When soldering the power socket in the following steps, be very careful that you do not get the hot soldering iron against the clear sleeving already installed on the adjacent lugs.

( ) Connect the center conductor of the phono cable to lug 11 (S-1), and the shield wires to lug 5 (S-1) of the power socket.

( ) Snap the power socket cap back into place.

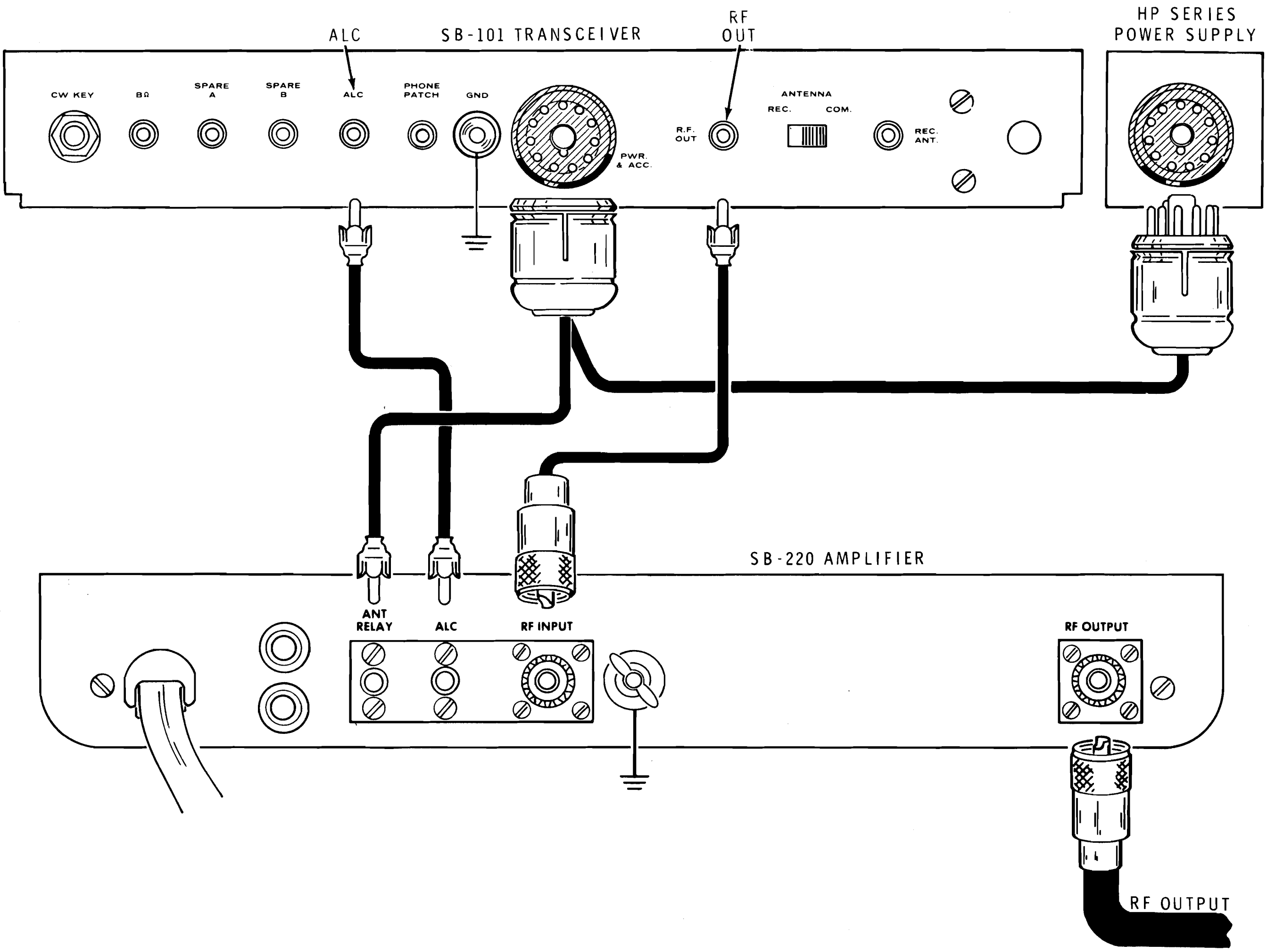
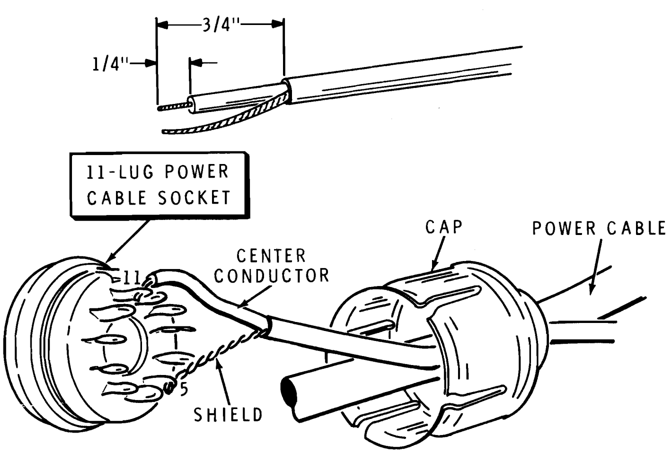


Figure 2-1



PICTORIAL 5

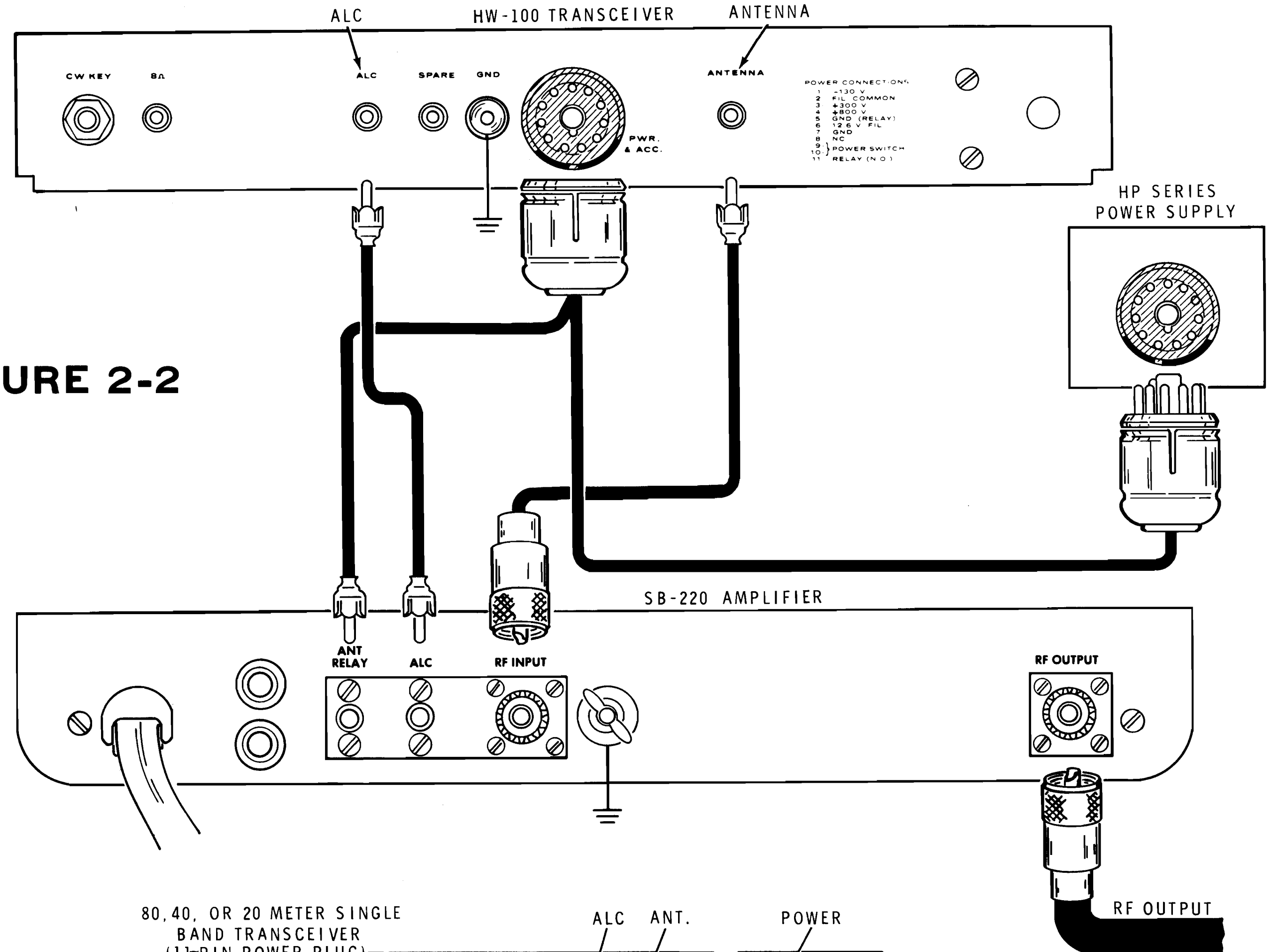


FIGURE 2-2

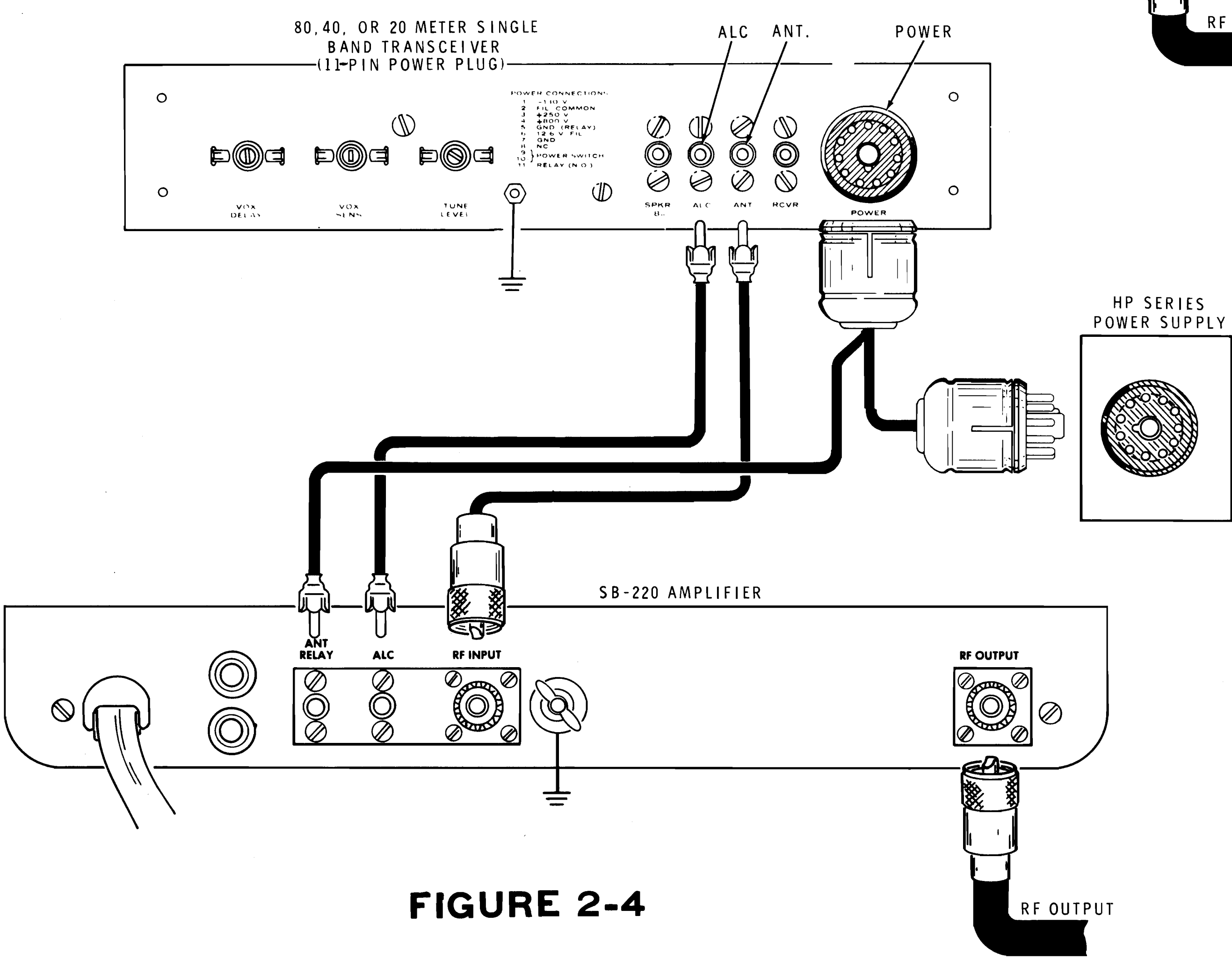


FIGURE 2-4

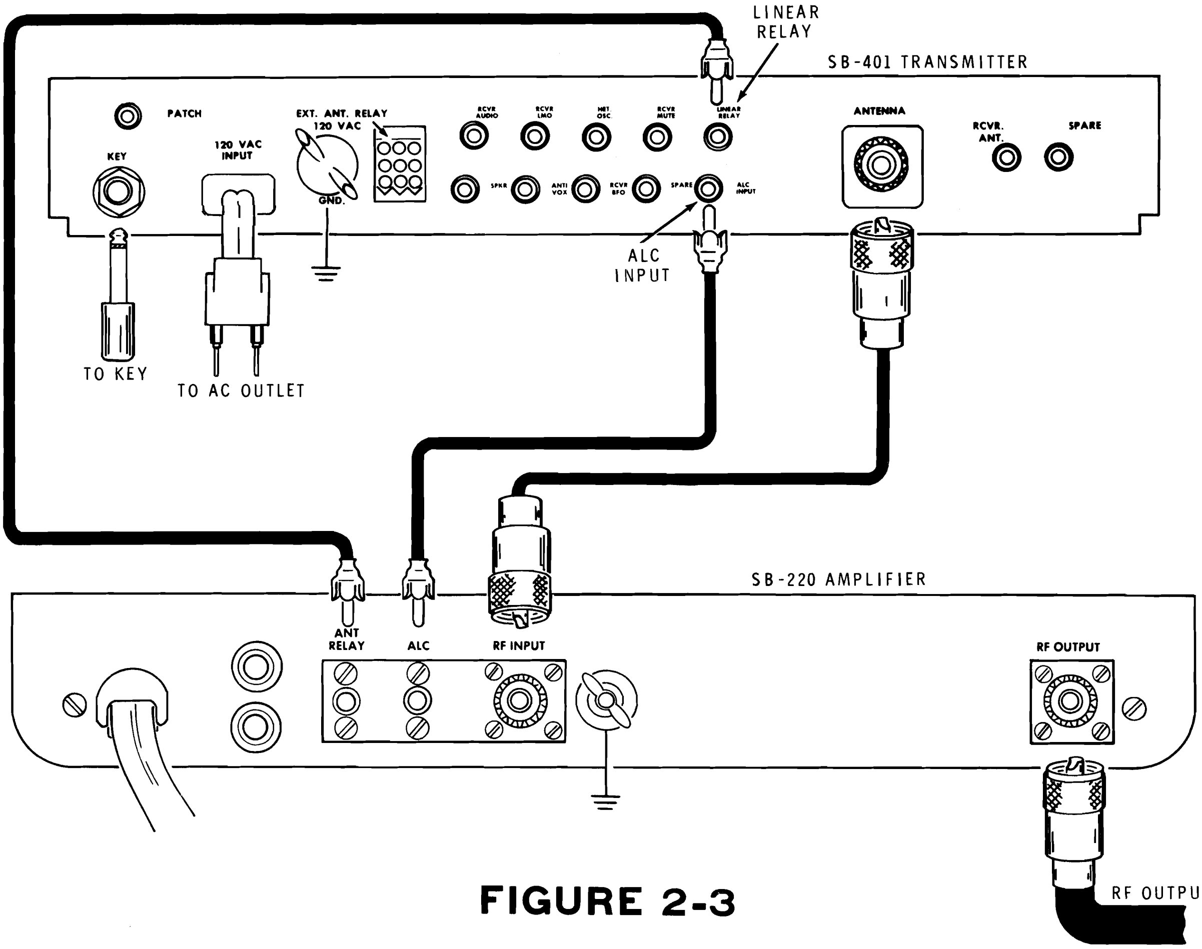


FIGURE 2-3

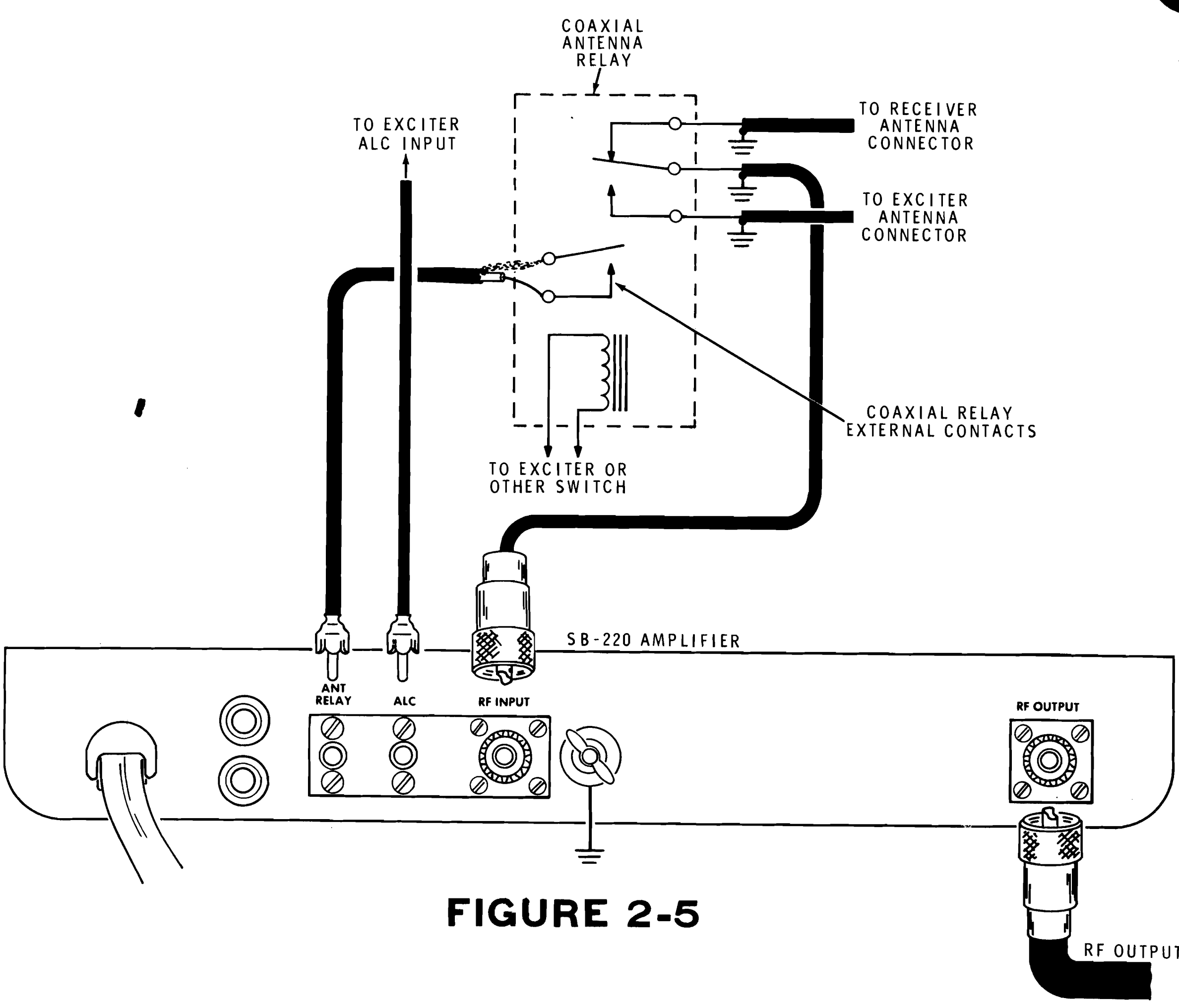


FIGURE 2-5

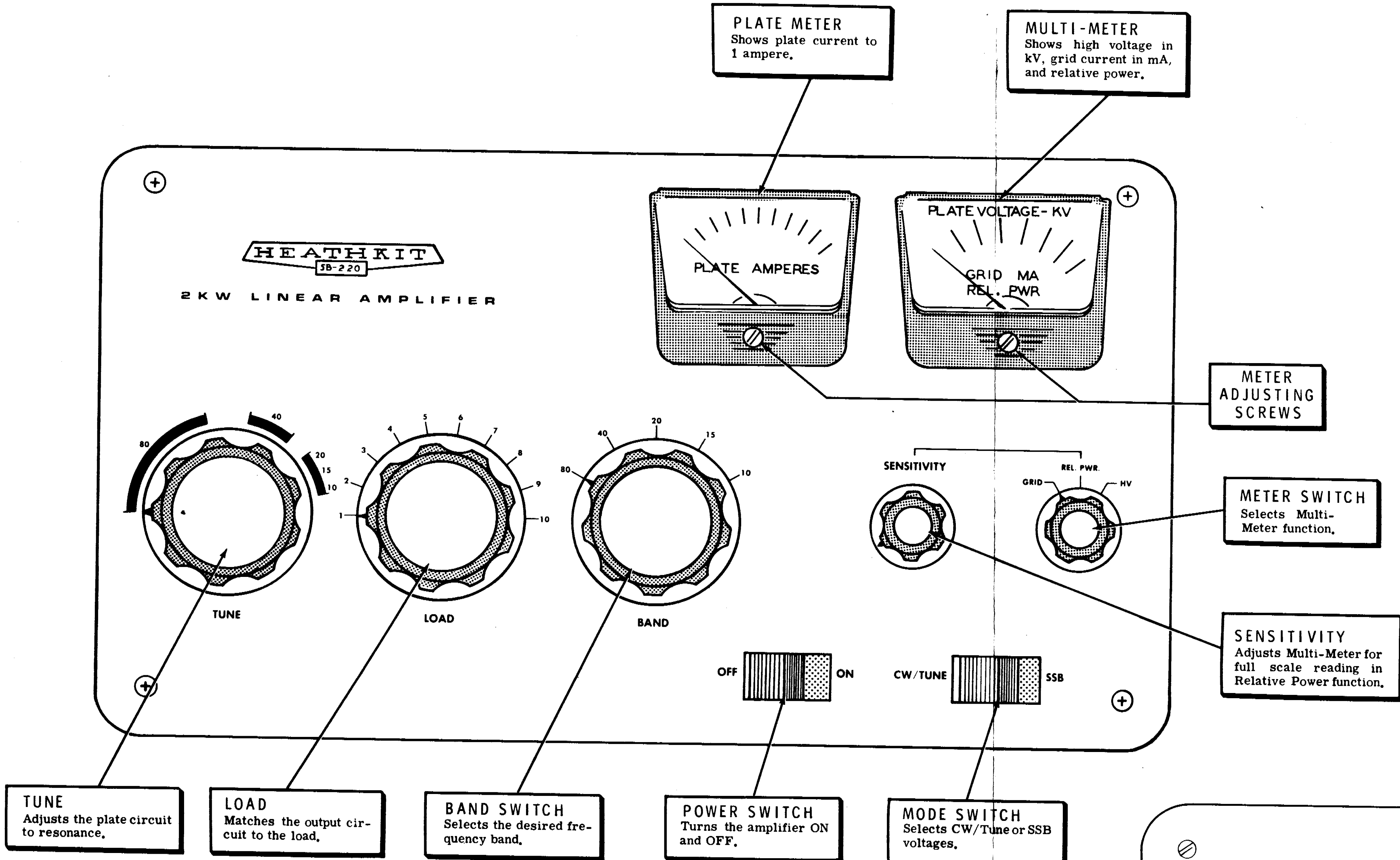


FIGURE 3-1

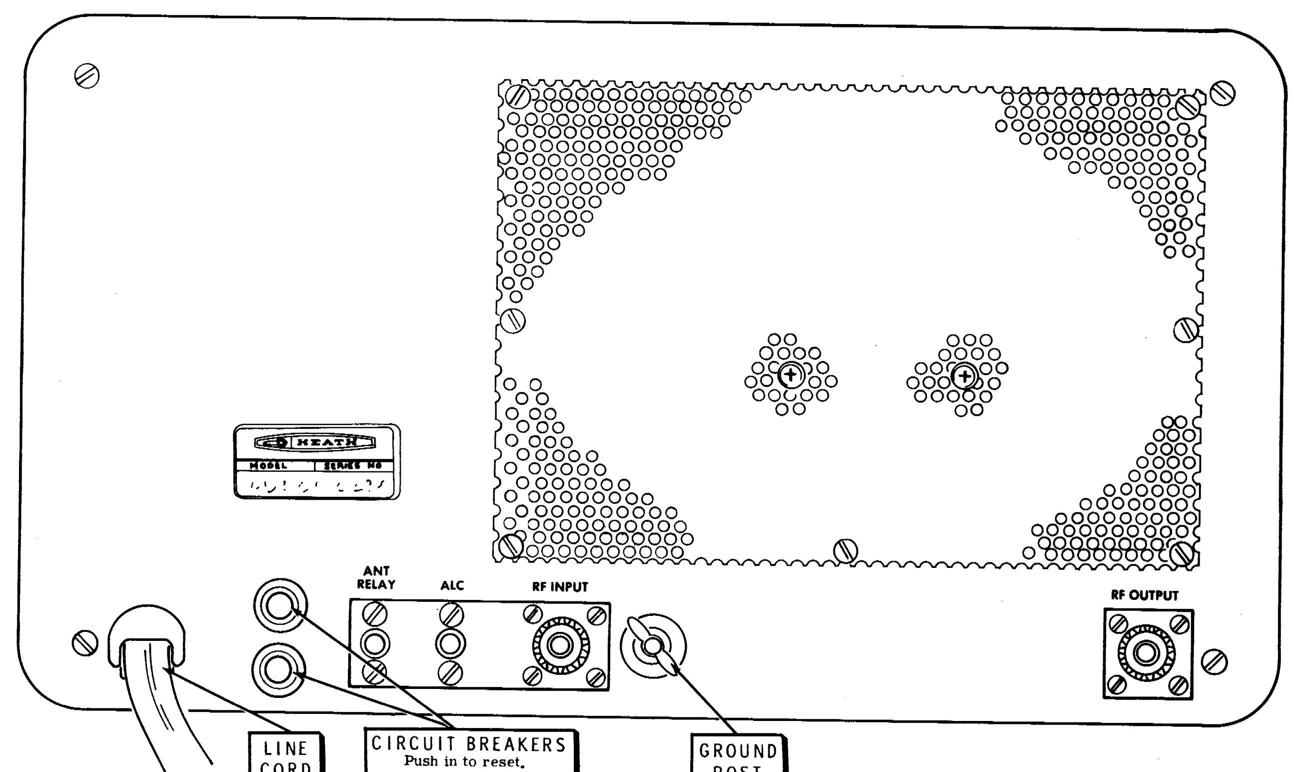


Figure 3-2

OPERATION

CONTROLS, CONNECTORS, AND METERS

Refer to Figure 3-1 (fold-out from Page 68) for identification of the front panel controls and a concise description of the functions of each.

Refer to Figure 3-2 for rear panel connections.

READING THE METER

Refer to Figure 3-3 for illustrations of the two panel meters.

Plate Meter

The Plate Meter is calibrated from 0 to 1 ampere. Note that by adding the proper number of zeros and dropping the decimal point, each scale number may be read as milliamperes. Thus .5 amperes would become 500 milliamperes.

Multi-Meter

Read the Multi-Meter scale which corresponds to the setting of the METER SWITCH:

METER SWITCH POSITION	MEASURES	SCALE READING
GRID	Grid current	0-350 milliamperes (lower scale)
REL PWR	Relative power output	0-350 (lower scale) (Adjust needle deflection to full scale with SENSITIVITY control after tune-up)
HV	High voltage	0-3.5 kilovolts (upper scale)

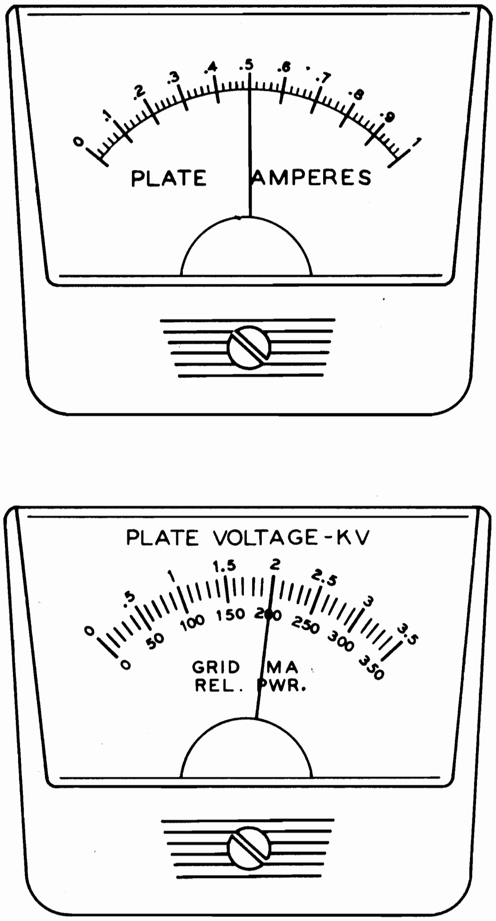


Figure 3-3

GENERAL

SAFETY INTERLOCK

Refer to the Chassis Photograph (Page 87) for the location of the interlock. When the amplifier top cover is in place, the insulator on the underside of the cover opens the interlock, and the high voltage circuit is operational. When the top cover is removed, the interlock closes and connects the high voltage circuit to chassis. This connection will discharge the filter capacitor bank and eliminate a shock hazard.

WARNING: *If the Amplifier is turned ON when the amplifier cover is removed, the high voltage power supply will be short circuited and may be damaged. If this occurs, DO NOT touch any part of the high voltage supply with your hands until all possible high voltage points have been checked with a separate voltmeter.*

CIRCUIT BREAKERS

Push in the red buttons on the two circuit breakers and note their position. When a circuit breaker opens, the red buttons will protrude farther and will be easily noticed.

If one or both circuit breakers open during operation of the Amplifier, turn the amplifier POWER switch OFF; then push the red buttons in to their former position, wait a few seconds, and push the POWER switch to ON. If the breakers will not stay closed, push the POWER switch OFF and locate the reason for the overload.

TUBES

The Amplifier uses "instant heating" type tubes. Therefore, after tune-up, you can turn the Amplifier off until you are ready to use it. Then, you can use the Amplifier immediately after it is turned on.

It is not abnormal for the tube plates to show a dull red color. If the plates show a bright orange or yellow color, tuning and drive conditions should be investigated immediately, and necessary corrections should be made.

After prolonged usage, let the Amplifier run for several minutes without excitation, so the fan will cool the tubes before the Amplifier is turned off.

DC INPUT POWER

In grounded grid amplifier operation, a considerable portion of the driving power is fed through the amplifier tube. The Amplifier output is the approximate sum of the driver output and the power added by the Amplifier. Both the driver and amplifier input powers must therefore be considered when calculating DC input power.

DRIVING POWER

This Amplifier is designed to operate at full ratings (see Specifications) when driven by an exciter delivering approximately 100 watts of RF output. An exciter of lower power output may be used as a driver, but the Amplifier's output will be less. If you use an exciter that delivers more than 100 watts, carefully adjust the driving power to avoid "over-drive" and the creation of spurious signals which create needless interference to others. The use of the Heathkit Model 610 Monitor Scope is highly recommended for continuous output monitoring. The display on an oscilloscope is the best readily available way of determining the amplitude of the voice peaks which, if excessive, can cause "flat topping" and the radiation of distortion products.

IMPORTANT: In no case should the MIC/CW Level of your exciter be advanced beyond the point where the Amplifier REL. PWR. indication ceases to increase. If the level control is turned past this point, nonlinear operation may be produced.

ALC (Automatic Level Control)

When the Amplifier is overdriven, the ALC circuitry creates a negative voltage which is fed back to the exciter to reduce its gain and help prevent "flat topping."

Protective circuitry of this nature is a valuable circuit element, but it is not a substitute for proper adjustment of the exciter drive.

TUNE-UP

The current and voltage figures given in this section are approximations. Actual readings will vary at each installation with such factors as line voltage, exciter drive, and load impedance.

The following procedure for tuning the Amplifier should take only a few seconds after you go through it a few times. Note the LOAD control position so it can be preset the next time a particular band is used.

CW AND RTTY PROCEDURE

Make sure the Amplifier has been installed as described and illustrated in the "Installation" section. IMPORTANT: Before proceeding, make sure you have a dummy load (such as the Heathkit Cantenna) or an appropriate antenna connected to the Amplifier output.

( ) Set the Amplifier controls as follows:

SWITCH OR CONTROL	POSITION	COMMENTS
TUNE	Desired band segment	
LOAD	4	After tune-up, note position so control can be preset in the future.
BAND	Desired band	
SENSITIVITY	12 o'clock	Keep needle on scale with SENSITIVITY control. After tune-up, adjust as desired.
METER	REL. PWR.	
POWER	OFF	
MODE	CW/TUNE	

(√) Tune your exciter for full CW output at the desired frequency. The MULTI-METER on the Amplfiier, when switched to indicate REL. PWR., will show the relative power output of the exciter and may be used even though the Amplifier is off.

(√) Reduce the exciter output to 0 by placing its controls in the receive mode; also turn its MIC/CW Level control fully counterclockwise.

(√) Turn the Amplifier on.

(√) Place the exciter in the tune mode. The amplifier plate meter should read approximately .12 ampere resting plate current. Then advance the Level control until the PLATE METER shows .3 ampere.

(√) Peak (adjust) the amplifier TUNE and LOAD controls for maximum REL. PWR. meter indication.

(√) Advance the drive to .4 ampere plate current and repeak the TUNE and LOAD controls. The Meter readings should then be approximately:

Plate amperes = .35
High voltage = 2100
Grid mA = 110

(√) Alternately adjust the TUNE, LOAD, and exciter drive controls for the desired input. Refer to Figure 3-4. The meter readings at 1 kw input will be approximately:

Plate amperes = .5
High voltage = 2000
Grid mA = 100-200

(√) Advance the SENSITIVITY control for the desired REL. PWR. meter reading.

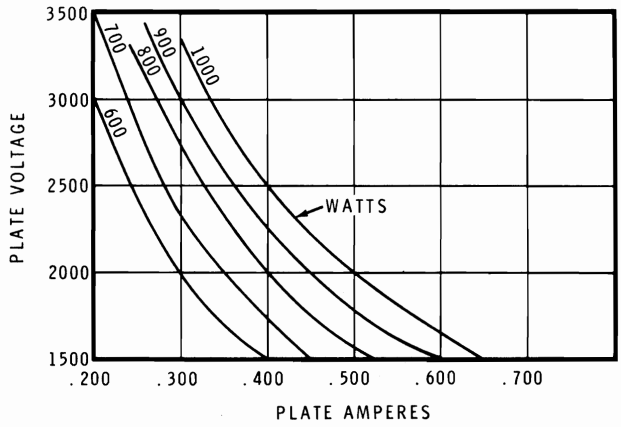


Figure 3-4

(√) Turn the exciter Mode switch to Standby or the desired transmission mode.

The Linear Amplifier is now loaded for operation on CW or RTTY. If an oscilloscope is being used for monitoring, a display similar to that shown in Figure 3-5 should be obtained. If you have a Heathkit Model 610 Monitor Scope, you may find that its optional trapezoid display pattern is more easily interpreted for voice patterns.

CAUTION: While actually transmitting, DO NOT switch between CW/TUNE and SSB modes.

SSB PROCEDURE

(√) Tune up the exciter and Amplifier as for CW operation. NOTE: In the absence of the recommended oscilloscope monitor, either the PLATE METER or the REL. PWR. indication can be used to monitor SSB transmission. The PLATE METER indications are easier to follow.

Low Power SSB

(√) For 1000 watts P.E.P. operation, switch the exciter only to the SSB mode. Leave the amplifier MODE switch at CW/TUNE.

(√) Adjust the exciter drive control so the PLATE METER will indicate between .12 and .2 ampere with average speech. Hard voice peaks should not exceed .250 ampere.

High Power SSB

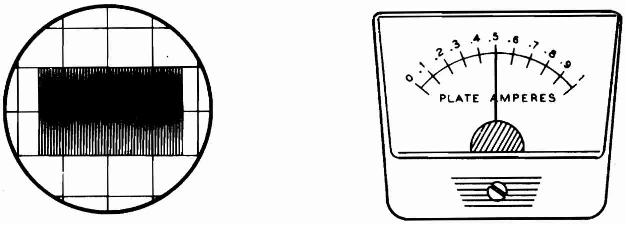
( ) For 2000 watts P.E.P. operation, switch both the exciter and the amplifier MODE switch to SSB.

( ) Advance the exciter drive level until the PLATE METER reads from .2 to .3 ampere with average speech and no higher than .33 ampere on hard voice peaks. A higher drive level will cause "flat topping."

An example of a proper SSB oscilloscope pattern is shown in Figure 3-6. Note that there are sharp, distinct peaks. The number of patterns or "christmas trees" will depend upon the operator's voice characteristics and the scope sweep speed. Set the scope for approximately 30 Hz sweep.

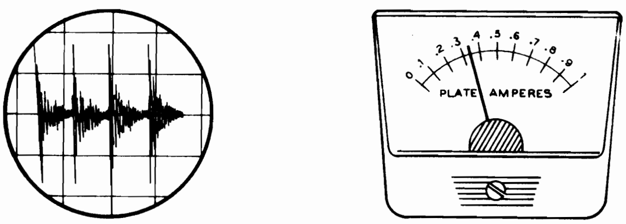
Note that the meter reading on voice peaks will not be high, due to meter inertia and voice characteristics; however, the height of the oscilloscope pattern is greater than that shown in Figure 3-5.

Figure 3-7 shows the same voice pattern but with extreme "flat topping." The oscilloscope shows that no more useful power is being developed. When the drive level is too high the meter reads higher, but only distortion is developed.



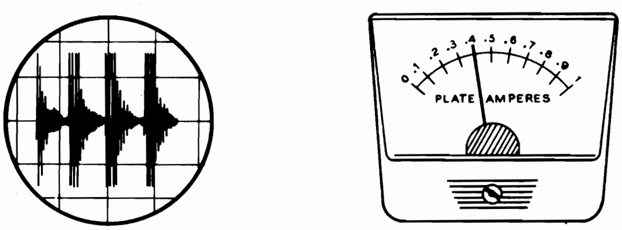
Oscilloscope pattern and plate meter reading resulting from carrier or "single tone" modulation. The meter indicates CW plate current input.

Figure 3-5



Oscilloscope pattern and plate meter reading in 2000 watt SSB mode. Notice the peaks on the oscilloscope pattern. They are sharp, indicating a clean signal, and they will attain a height greater than the "single tone" pattern of Figure 3-5, indicating maximum power input.

Figure 3-6



Oscilloscope pattern and plate meter reading resulting from overdrive. The meter reads higher, but the scope indicates peak flattening. Operation in this manner causes distortion and severe interference to adjacent frequencies.

Figure 3-7

PERIODIC MAINTENANCE

Remove the top cover of the Amplifier and remove the dust at least once a year. This can be done by using the blower connection on a vacuum cleaner, or by a soft bristle brush.

While the top cover is removed, add one drop of light machine oil to each fan bearing.

IN CASE OF DIFFICULTY

Refer to the Kit Builders Guide for Service and Warranty information.

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. The majority of the kits that are returned for repair, do not function properly due to poor connections and soldering. Many troubles can be eliminated by carefully reheating all connections to make sure that they are soldered as described in the Proper Soldering Techniques section of the "Kit Builders Guide."

3. Make sure that the tubes light up properly. If they do not, remove the tubes from their sockets and check for continuity between pins 1 and 5 with an ohmmeter. An infinite resistance will indicate a faulty tube filament.

4. Check the values of the 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.

5. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring.

6. A review of the Circuit Description will prove helpful in indicating where to look for trouble.

TROUBLESHOOTING CHART

DIFFICULTY	POSSIBLE CAUSE
1. No AC power	A. Circuit breakers open. B. Jumpers missing on terminal strip AE. C. Terminal strip AE wired wrong.
2. Meter inoperative in one position: A. GRID. B. REL. PWR. C. HV.	A. Resistor R1, R3. B. D17, R25, R24, C54, R26. C. R6, R7, R8, R9. D. Meter switch.
3. Meter circuits inoperative	A. Meter jumper wire not removed. B. R2, C3, C8. C. Meter switch.
4. Idle current over .15A in CW/TUNE position.	A. ZD1.
5. No idle current	A. Relay. B. ZD1. C. V1 - V2.
6. No high voltage	A. D1 - D14. B. C10 - C17. C. R12 - R19. D. T1. E. R1 or R3. F. C29. G. Top cover off (interlock).
7. Relay will not activate	A. D16. B. C4. C. Ant-Relay jack. D. T2. E. RL-1.
8. Final tune has no effect	A. Bandswitch wafer #2 180 degrees out of position. B. L7 installed wrong. C. Improper load on the Linear Amplifier. D. V1, V2.

DIFFICULTY	POSSIBLE CAUSE
9. No RF output	A. Relay wired wrong. B. L7 installed wrong. C. Coax shorted. D. C29.
10. ALC inoperative	A. Wiring error or component failure on terminal strip BE. B. ALC jack.
11. Amplifier hard to drive.	A. Coaxial leads to the input bandswitch reversed.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to Pages 14, 15, and 16 of the "Kit Builders Guide" and the following "Factory Repair Service" information.

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.) Or, if you wish, you can deliver your kit to a nearby Heathkit Electronic Center. These centers are listed in your Heathkit catalog. NOTE: Do not include wooden cabinets, which are easily damaged in shipment, when returning equipment for service.

To be eligible for replacement parts under the terms of the warranty, equipment returned for factory repair service, or delivered to a Heathkit Electronic 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 Heathkit Electronic Center, please ship it to the factory at Benton Harbor, Michigan and observe the following shipping instructions:

Prepare a letter in 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: Service Department, Benton Harbor, Michigan 49022.

Check the equipment to see that all parts and screws are in place. 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

SPECIAL SHIPPING INSTRUCTIONS FOR U.S. AND CANADA

DO NOT ship an assembled Model SB-220 amplifier unless it is packed in the Model 220 Service Pack. Due to the weight of the transformers, shipment without special packaging will almost certainly result in damage.

Order a #171-3167, Model SB-220 Service Pack from the Heath Company, Benton Harbor, Michigan 49022, and include a $5.00 deposit. The Service Pack will be sent to you with transportation prepaid. Package and ship the amplifier according to the instructions included.

The deposit for the Service Pack will be credited against any service charges or will be refunded, as applicable.

OVERSEAS SHIPMENT NOTE: Shipment from overseas sources with the transformers mounted is not recommended.

SPECIFICATIONS

Band Coverage	80, 40, 20, 15 and 10 meter amateur bands.
Driving Power Required	100 watts.
Maximum Power Input	SSB: 2000 watts P.E.P. CW: 1000 watts. RTTY: 1000 watts.
Duty Cycle	SSB: continuous voice modulation. CW: Continuous (maximum key-down 10 minutes). RTTY: 50% (maximum transmit time 10 minutes).
Third Order Distortion	-30 dB or better.
Input Impedance	52 Ω unbalanced.
Output Impedance	50 Ω unbalanced; SWR 2:1 or less.
Front Panel	Tune. Load. Bandswitch. Sensitivity. Meter switch. Power. CW/Tune – SSB. Plate meter. Multi-meter (Grid mA, Relative Power, and High Voltage).
Rear Panel	Line cord. Circuit breakers (two 10 A). Antenna Relay (phono). ALC (phono). RF Input (SO-239). Ground post. RF output (SO-239).

Tubes	Two 3-500Z.
Power Required	120 VAC, 50/60 Hz, at 20 amperes maximum. 240 VAC, 50/60 Hz, at 10 amperes maximum.
Cabinet Size	14-7/8" wide, 8-1/4" high, 14-1/2" deep.
Net Weight	50 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.

CIRCUIT DESCRIPTION

Refer to the Schematic (fold-out from Page 87) to identify the circuit components while reading this section.

POWER SUPPLY

The power supply uses high voltage transformer, T1, and a filament and bias transformer, T2. Each transformer has dual primary windings which are connected in parallel for 120 VAC operation, or in series for 240 VAC electric service. The transformers are protected by two 10 ampere circuit breakers, wired so they provide appropriate overload protection for either primary voltage.

The fan motor is connected across one of the primary windings on the high voltage transformer and always operates on 120 VAC.

The AC input line is by-passed for RF by capacitors C1 and C2.

HIGH VOLTAGE SUPPLY

The primary windings of the high voltage transformer, T1, are tapped, and the six leads are connected to the Mode and Power switches.

When the Mode switch is in the CW/Tune position, the entire portion of each primary winding is connected to the power line. When this switch is in the SSB position, only the tapped portion of each primary winding is connected to the power line.

When the tapped windings (fewer turns) are connected to the power source, a higher secondary-to-primary turns ratio is being used and a higher secondary voltage for SSB operation results.

The transformer secondary is connected in a full-wave, voltage-doubling circuit. The AC voltage is rectified by diodes, D1 through D14, and it is filtered by series-connected electrolytic capacitors C10 through C17. Resistors R12 through R19 parallel the filter capacitors and equalize the voltage drop across each capacitor in the series. They also act to discharge the filter capacitors after the power switch is turned off.

The red-yellow transformer lead is connected to the junction of capacitors C13 and C14. During the half-cycle when this lead is positive, capacitors C14 through C17 are charged. During the other half-cycle, the red lead is positive and capacitors C10 through C13 are charged. These two capacitor strings are in series across the load, and the voltages of each group add together.

Resistors R1 and R3 are discussed under "Metering Circuits."

Chokes RFC 1 and RFC 2 and bypass capacitors C6 and C7 are used to keep RF energy out of the power supply circuits.

The interlock grounds the output of the high voltage supply when the top cover of the Amplifier is removed. This feature protects the user against a shock from undischarged filter capacitors. The Amplifier must not be turned on while the top cover is removed as the high voltage supply is short-circuited under these circumstances.

FILAMENT AND BIAS SUPPLY

Transformer T2 has two secondary windings. One winding furnishes 5 VAC at 30 amperes for the amplifier tube filaments. The two #47 pilot lamps for meter illumination are also connected across the filament line.

Filament supply is fed to the two tubes through RFC 3, a coil which is bifilar wound on a ferrite core. This coil forms a choke to raise the tube filaments above RF ground so the driving voltage will not be short-circuited.

The second winding on transformer T2 is used in a half-wave rectifier circuit for the bias supply voltage, to operate relay RL1, and to furnish ALC threshold voltage. The AC voltage from this winding is rectified by D16 and filtered by C4. This DC voltage is connected to lugs 2 and 11 of relay RL1. In the receive mode, this voltage is applied through lug 8 to the center-tap of the filament winding. This positive voltage increases the voltage difference between the tube grids (which are grounded for DC) and the tube filaments, which now carry the positive DC voltage in addition to the AC filament voltage. The tube grids are consequently biased beyond cutoff and no plate current flows.

In the transmit mode, the center-tap of the filament winding is connected to ground through lugs 8 and 5 of the relay, the 5.1 volt zener diode ZD1, and R3. The plate current through the zener develops 5.1 VDC operating bias for the tubes and limits the idling plate current.

RELAY

The relay has three sets of single-pole, double-throw contacts. When the relay coil circuit is open the contacts are in the receive mode.

Approximately 120 VDC is connected to one side of the relay coil at lug 11. Lug 10 connects the other side of the relay coil to the Antenna Relay jack on the rear panel. This jack is usually connected to normally open relay contacts in the exciter (such as a VOX or PTT relay). When these relay contacts close, they must connect the amplifier relay coil circuit to ground. The amplifier relay will then close and its contacts will be in the transmit mode.

The function of amplifier relay contacts 2, 5 and 8 was discussed in the "Bias Supply" section.

Relay contact 7 is connected to the RF INPUT connector. In the receive mode the incoming signal is transferred directly to the RF Input through relay contacts 9, 3, 1, and 7. In the transmit mode, the RF Input voltage is connected through relay contacts 7 and 4 to lug 1 of Band-switch wafer 1F.

In the transmit mode, the RF Output is connected through relay contacts 9 and 6 to the pi network output circuit of the Amplifier.

RF CIRCUITS

INPUT CIRCUIT

An input impedance-matching pi network circuit for each band is connected by Band-switch wafer 1. After passing through the matching circuit, the RF driving power is coupled to the tube filaments by C32. Capacitor C21 equalizes any RF voltage difference between the filament leads.

TUBES

The amplifier tubes are connected in parallel in a class B grounded grid circuit. RF driving power is applied to the filaments in the normal cathode-driven configuration. As mentioned in "Power Supply" section, RFC 3 holds the filaments above RF ground.

Pins 2, 3, and 4 of each tube are connected together internally. Each of the three grid pins is bypassed to ground. This combination of RF chokes and capacitors provides a predetermined level of negative feedback at the tube grids to further reduce intermodulation distortion.

PC-1 and PC-2 are parasitic chokes in each tube plate lead to suppress any VHF parasitic oscillations.

The positive side of the power supply is connected in parallel to the tubes through RFC 1.

Cooling air is circulated around the tubes by the fan.

OUTPUT CIRCUIT

The tuned output circuit of the Amplifier is a pi network composed of plate tuning capacitor C55, loading capacitors C56 and C57, and coils L6 and L7.

Band-switch wafer 2 progressively shorts out the unused portions of coils L6 and L7. The coil turns in use are tuned to resonance by Tune capacitor C55. Load capacitor C57 is tuned to complete the impedance match between the tubes and the load connected to the RF OUTPUT. On the 80 meter band, fixed capacitor C56 is switched in parallel with C57 to provide the additional capacitance required on this band.

If a DC voltage is unintentionally applied to the plate output circuit, RFC 6 will provide a DC path to ground, thus short-circuiting the high voltage supply and opening the circuit breakers.

ALC CIRCUIT

Approximately 60 VDC ALC threshold voltage is available at the junction of resistors R4 and R5, which form a voltage divider across the bias supply winding of transformer T2. C5 is an RF bypass, and R11 is an isolation resistor.

C47 couples some RF driving voltage to voltage divider R21-R22. C48 and C49 are frequency compensating capacitors for R21 and R22, respectively.

When the RF driving voltage at the junction of R21-R22 exceeds the ALC threshold voltage, D18 will rectify the negative half-cycles. C51 and C53 act as filters and RF bypasses. R23 is an isolation resistor.

The negative voltage appearing at the ALC connector may be coupled back to the exciter to reduce its gain and help reduce "flat-topping" of voice peaks due to overdrive.

METERING CIRCUITS

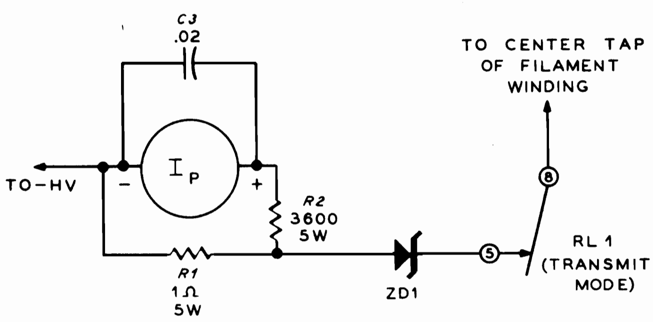


Figure 4-1

PLATE METER (Figure 4-1)

The Plate Meter reads the total plate current drawn by both tubes from 0 to 1 ampere. It is placed in series with a multiplier resistor, R2, and it measures the voltage drop across shunt resistor R1 through which the plate current passes.

MULTI-METER

Grid Current (Figure 4-2)

To read grid current, the Multi-Meter is switched in parallel with shunt resistor R3. The grid circuit return is to the center tap of the filament winding of transformer T2. Note that grid current only passes through R3, as the return for the high voltage circuit is through R1, R2, and the Plate Meter.

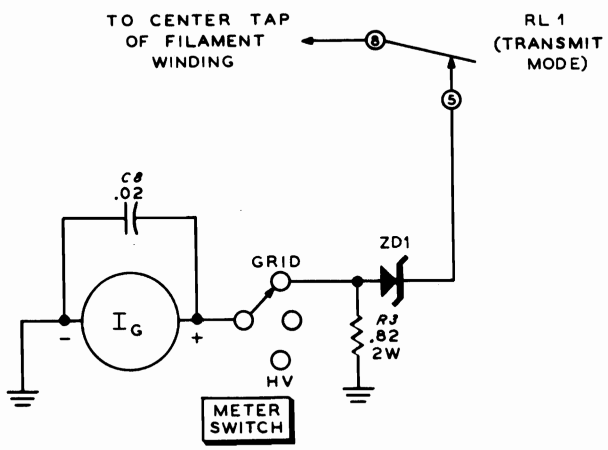


Figure 4-2

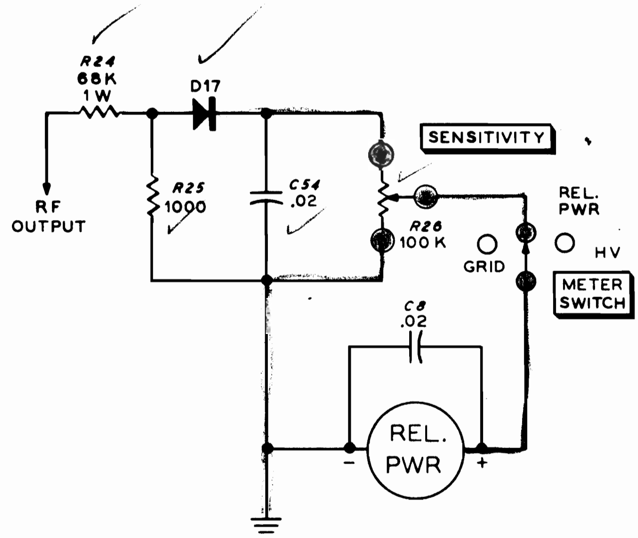


Figure 4-3

Relative Power (Figure 4-3)

Voltage divider R24 and R25 is connected across the RF OUTPUT. The voltage at the junction of these resistors is rectified by diode D17, filtered by C54, and applied through Sensitivity control R26 to the Multi-Meter. The Sensitivity control adjusts the Multi-Meter for the desired reading.

High Voltage (Figure 4-4)

High voltage is measured by switching the Multi-Meter to the junction of the multiplier resistors (R6, R7, and R8) and the shunt resistor R9. The meter scale is calibrated to indicate voltage, based upon the current flowing through the meter and R9 in parallel, the combination being in series with the multiplier resistors R8, R7 and R6.

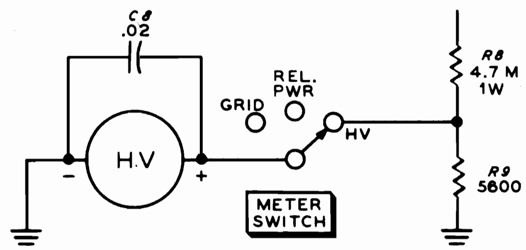
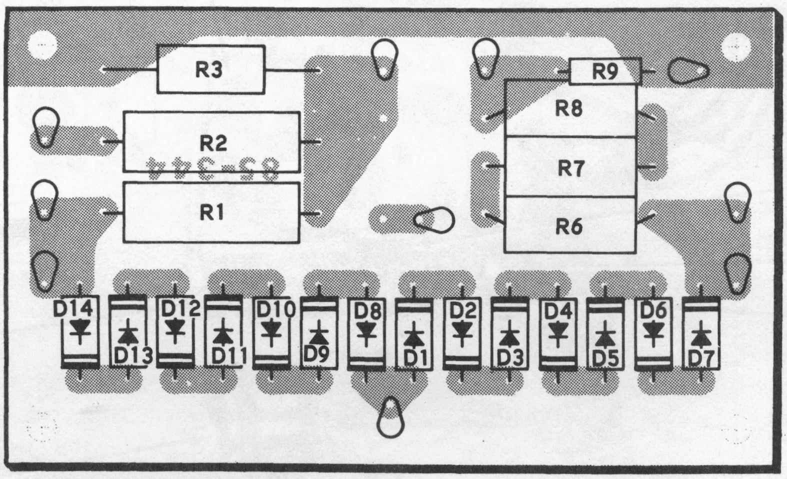


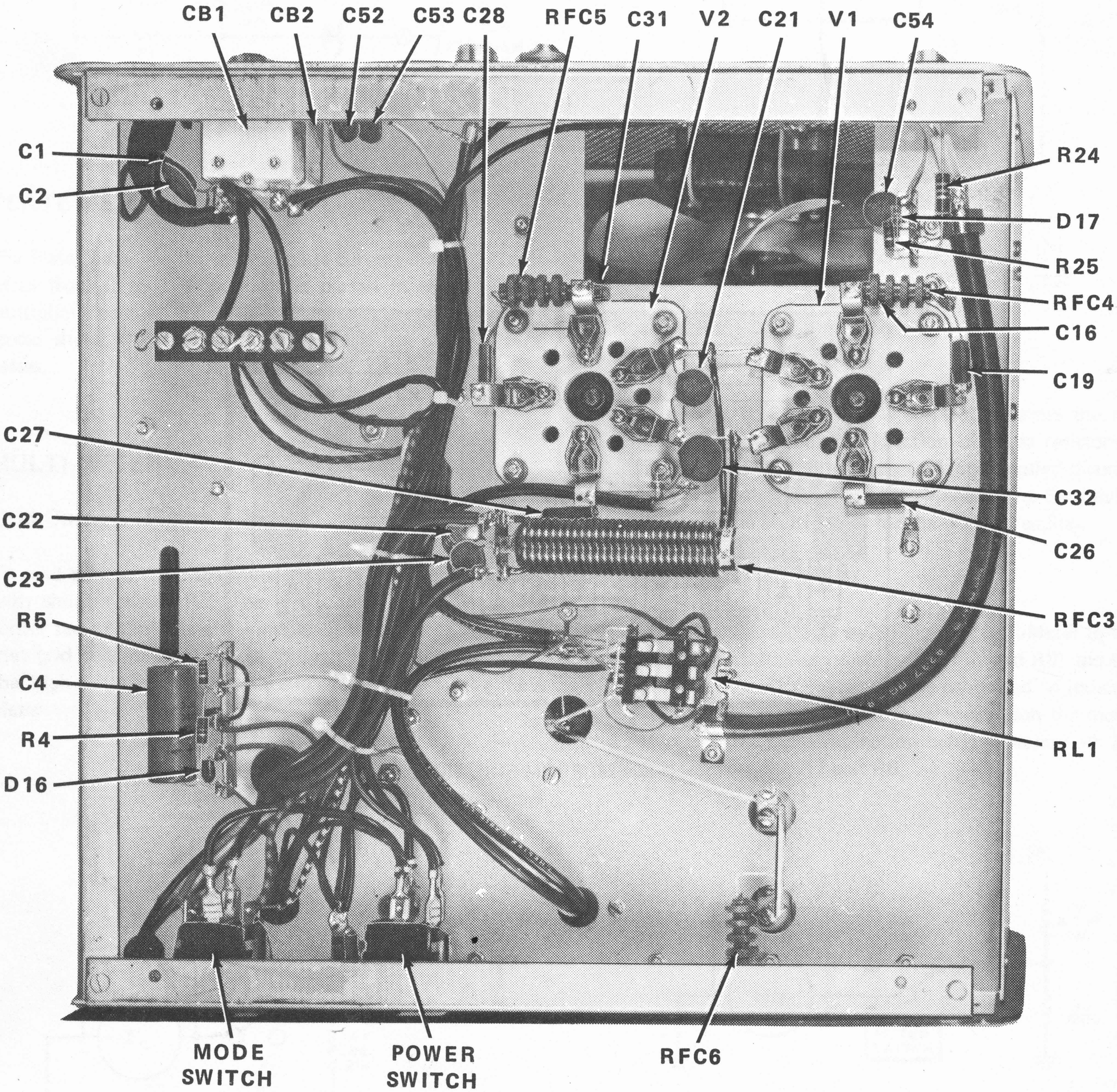
Figure 4-4

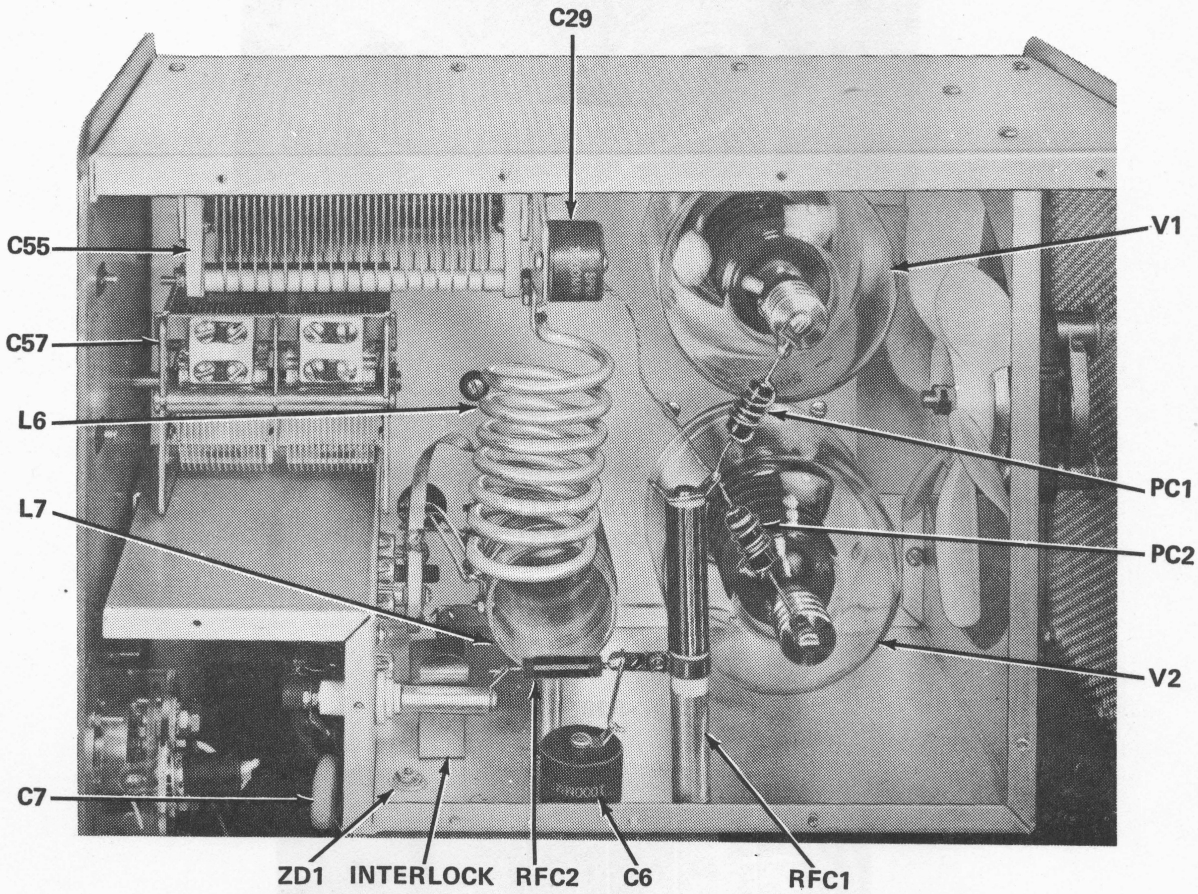
CIRCUIT BOARD X-RAY VIEW



(VIEWED FROM FOIL SIDE)

CHASSIS PHOTOGRAPHS

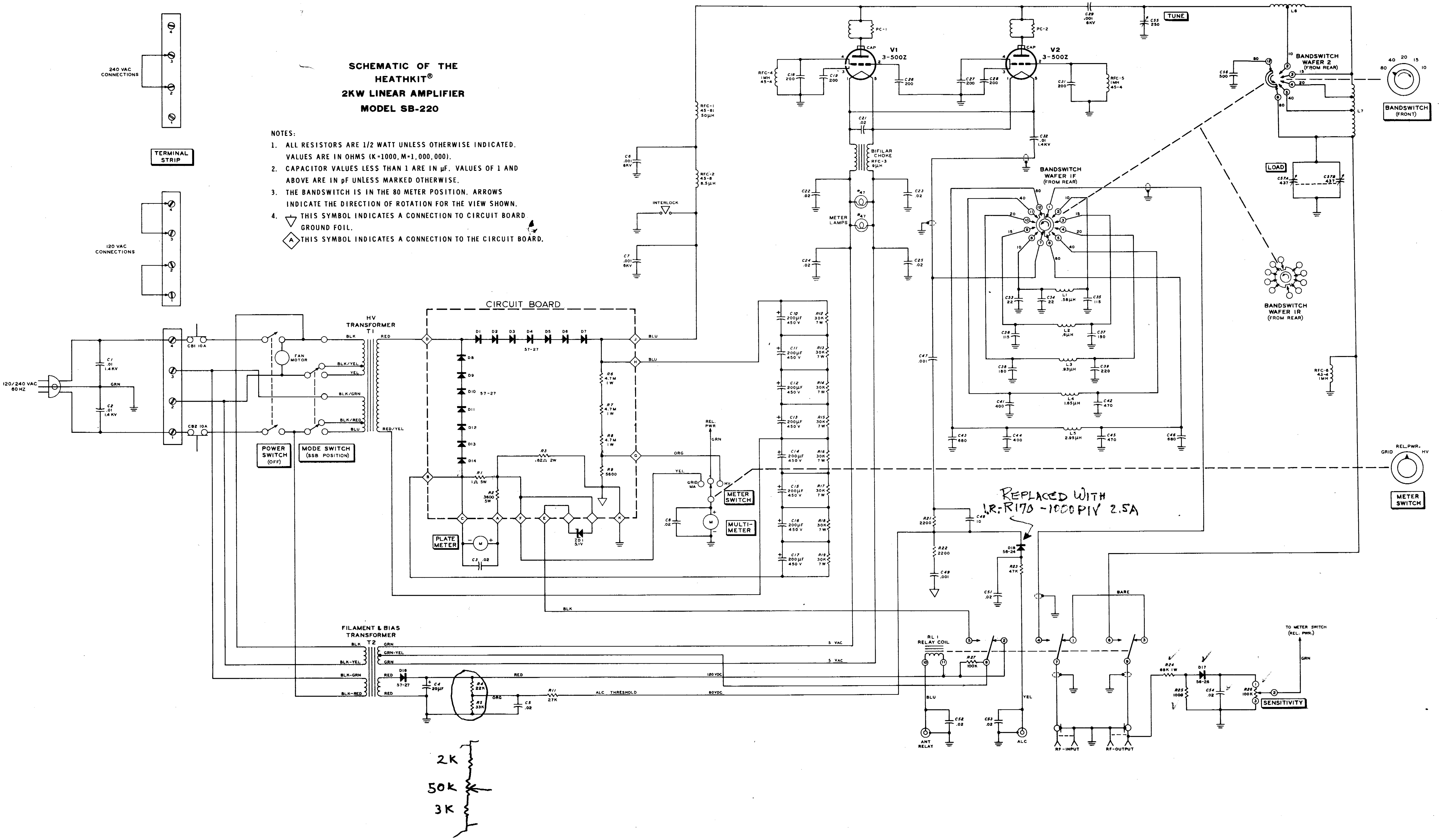


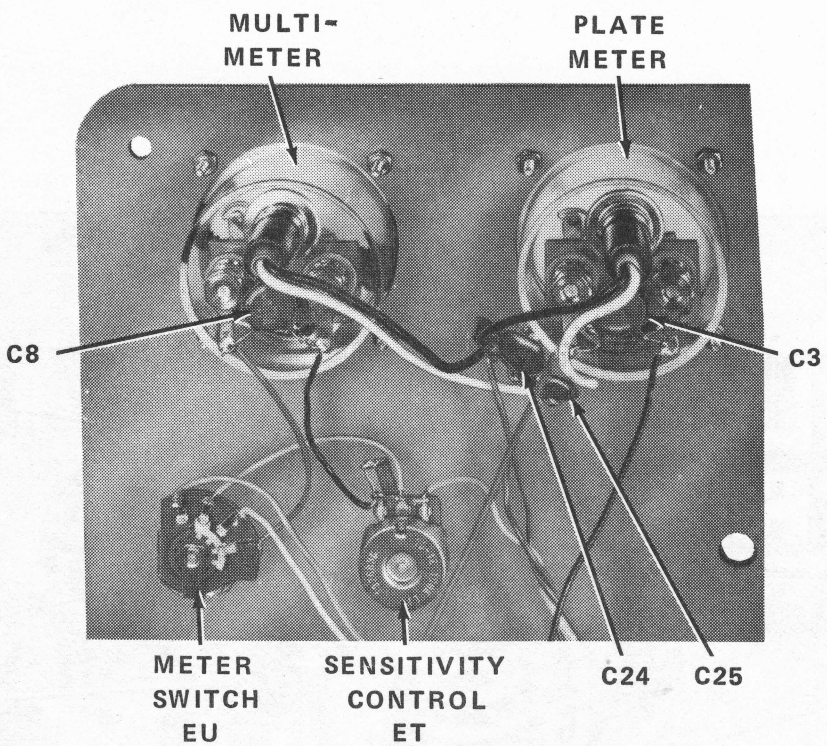

C29
C55
C57
L6
L7
C7
V1
PC1
PC2
V2
ZD1
INTERLOCK
RFC2
C6
RFC1

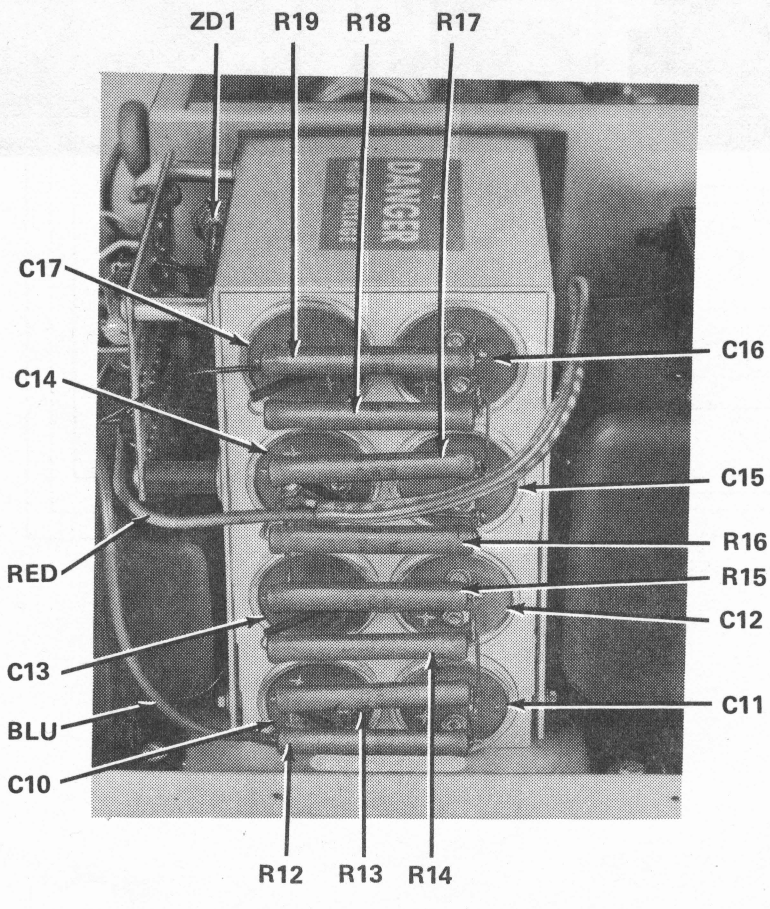
SCHEMATIC OF THE HEATHKIT® 2KW LINEAR AMPLIFIER MODEL SB-220

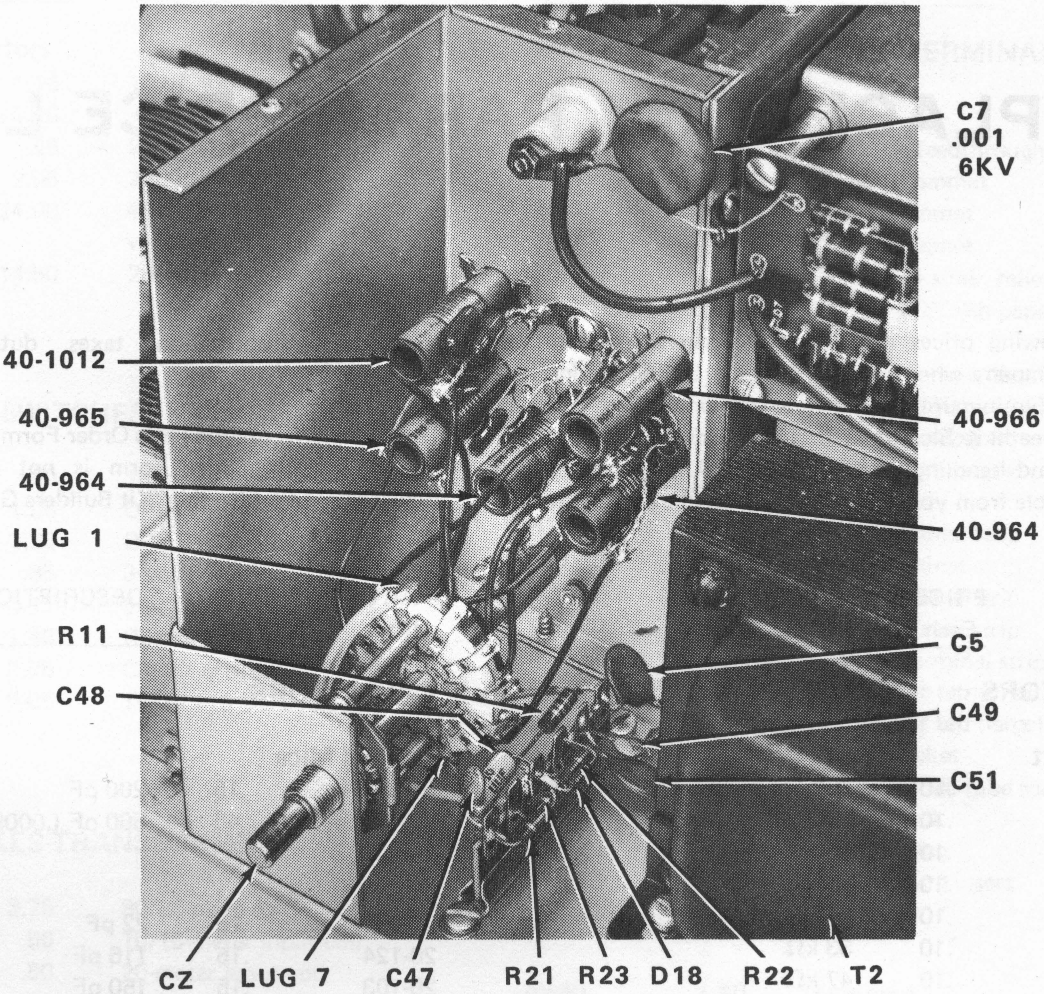
NOTES:

1. ALL RESISTORS ARE 1/2 WATT UNLESS OTHERWISE INDICATED. VALUES ARE IN OHMS (K=1000, M=1,000,000).
2. CAPACITOR VALUES LESS THAN 1 ARE IN µF. VALUES OF 1 AND ABOVE ARE IN pF UNLESS MARKED OTHERWISE.
3. THE BANDSWITCH IS IN THE 80 METER POSITION. ARROWS INDICATE THE DIRECTION OF ROTATION FOR THE VIEW SHOWN.
4. ▽ THIS SYMBOL INDICATES A CONNECTION TO CIRCUIT BOARD GROUND FOIL.
   ◇A THIS SYMBOL INDICATES A CONNECTION TO THE CIRCUIT BOARD.




MULTI-
METER
PLATE
METER
C8
C3
METER
SWITCH
EU
SENSITIVITY
CONTROL
ET
C24
C25


ZD1
R19
R18
R17
C17
C16
C14
C15
R16
RED
R15
C12
C13
C11
BLU
C10
R12
R13
R14


C7
.001
6KV
40-1012
40-965
40-966
40-964
40-964
LUG 1
R11
C5
C48
C49
C51
CZ
LUG 7
C47
R21
R23
D18
R22
T2

REPLACEMENT PARTS PRICE LIST

The following 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.

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

PART No.	PRICE Each	DESCRIPTION
RESISTORS		
1/2 Watt		
1-9	.10	1000 Ω
1-44	.10	2200 Ω
1-18	.10	5600 Ω
1-22	.10	22 kΩ
1-23	.10	27 kΩ
1-24	.10	33 kΩ
1-25	.10	47 kΩ
1-26	.10	100 kΩ
Other Resistors		
1-8-1	.10	68 kΩ 1 watt
1-38-1	.10	4.7 MΩ 1 watt
3-1-2	.25	.82 Ω wire-wound 2 watt (same size as 1 watt), 5%
3-25-5	.90	1 Ω wire-wound, 5 watt, 1%
3-22-5	1.45	3600 Ω wire-wound, 5 watt, 1%
5-2-7	.20	30 kΩ film, 7 watt

PART No.	PRICE Each	DESCRIPTION
CAPACITORS		
Molded Mica		
20-3	.15	200 pF
20-123	.45	500 pF (.0005 μF)
Mica		
20-99	.15	22 pF
20-124	.15	115 pF
20-103	.15	150 pF
20-105	.20	180 pF
20-120	.20	220 pF
20-116	.30	400 pF
20-113	.30	470 pF
20-107	.40	680 pF
Disc		
21-79	.60	.001 μF 6 kV
21-14	.10	.001 μF 500 volt
21-70	.15	.01 μF 1.4 kV
21-31	.10	.02 μF 500 volt

PART No.	PRICE Each	DESCRIPTION
Other Capacitors		
21-28	.15	10 pF tubular ceramic
21-165	1.75	.001 μF 6 kV, ceramic
25-19	.55	20 μF electrolytic
25-224	2.95	200 μF electrolytic
26-97	24.90	437-437 pF ganged variable, 2-section
26-131	14.80	250 pF variable

CONTROLS-SWITCHES

PART No.	PRICE Each	DESCRIPTION
10-12	.50	100 kΩ control
61-14	1.95	DPST rocker switch
61-15	2.25	DPDT rocker switch
63-47	.85	3-position rotary switch
63-561	3.15	5-position rotary switch
63-562	1.45	Rotary switch wafer
65-28	2.05	Circuit breaker
69-55	5.05	TPDT 110 VDC relay

COILS-CHOKES-TRANSFORMERS

PART No.	PRICE Each	DESCRIPTION
40-597	3.75	80/20 plate coil
40-964	.50	10/15-meter input coil
40-965	.50	20-meter input coil
40-966	.50	40-meter input coil
40-1012	.50	80-meter input coil
40-968	3.05	15/10 plate coil
45-53	.40	Parasitic choke
45-4	.45	1 mH RF choke
45-6	.25	8.5 μH RF choke
45-78	4.05	9 μH RF choke
45-61	.55	50 μH RF choke
54-237	29.70	High voltage transformer
54-238	10.05	Filament and bias transformer

DIODES-TUBES

PART No.	PRICE Each	DESCRIPTION
56-24	.60	1N458 silicon diode
56-26	.25	1N191 germanium diode
56-82	2.70	1N3996A zener diode, 5.1 V, 10 watt, w/mounting hardware
57-27	.50	Silicon diode, 1A., 600 PIV
411-245	34.00	3-500Z tube

INSULATORS-GROMMETS-TERMINAL STRIPS-CONNECTORS

PART No.	PRICE Each	DESCRIPTION
71-2	.60	Ceramic feedthrough insulator
73-4	.10	5/16" grommet
73-3	.10	1/2" grommet
73-2	.10	3/4" grommet
75-123	.15	Line cord strain relief
75-124	.35	6" x 4-1/2" fish paper insulator
75-125	.30	Capacitor mounting insulator
255-39	.35	6-32 x 1-1/4" tapped phenolic spacer
255-42	.25	6-32 x 3/4" tapped phenolic spacer
431-14	.10	2-lug terminal strip
431-10	.10	3-lug terminal strip
431-42	.10	5-lug terminal strip
431-20	.20	6-lug terminal strip
431-13	.15	4-screw terminal strip
432-66	.10	Connector tab (small)
432-137	.10	Connector tab (large)
434-42	.10	Phono socket
434-93	3.80	5-lug ceramic tube socket
436-5	.85	Coaxial jack
438-9	.90	Coaxial plug
438-12	.30	Coaxial plug insert

WIRE-CABLE-SLEEVING

PART No.	PRICE Each	DESCRIPTION
89-40	1.40	Line cord
134-36	.75	Phono cable assembly
340-1	.05/ft	Bare wire
343-2	.10/ft	Coaxial cable, RG-58A/U
343-8	.25/ft	Coaxial cable, RG-8/U
344-2	.05/ft	Small black stranded wire
344-7	.05/ft	Large black stranded wire
344-13	.05/ft	Blue hookup wire–THICK INSULATION
344-50	.05/ft	Black hookup wire
344-51	.05/ft	Brown hookup wire
344-52	.05/ft	Red hookup wire
344-53	.05/ft	Orange hookup wire
344-54	.05/ft	Yellow hookup wire
344-55	.05/ft	Green hookup wire
344-56	.05/ft	Blue hookup wire ~~(thick insulation)~~
345-1	.10/ft	Large metal braid
345-2	.05/ft	Small metal braid
346-4	.05/ft	Black sleeving
346-7	.05/ft	Clear sleeving (large)
346-29	.05/ft	Clear sleeving (small)
354-5	.10/ft	Cable tie

HARDWARE

#6 Hardware

PART No.	PRICE Each	DESCRIPTION
250-138	.05	6-32 x 3/16" screw
250-56	.05	6-32 x 1/4" binder head screw
250-416	.05	6-32 x 1/4" flat head screw
250-8	.05	#6 x 3/8" sheet metal screw
250-32	.05	6-32 x 3/8" flat head screw
250-89	.05	6-32 x 3/8" binder head screw
250-218	.05	6-32 x 3/8" phillips head screw
250-206	.05	6-32 x 11/16" screw
250-40	.05	6-32 x 1-1/2" screw
250-47	.05	6-32 x 2" screw
252-3	.05	6-32 nut
253-1	.05	#6 fiber flat washer
253-2	.05	#6 fiber shoulder washer
254-1	.05	#6 lockwasher
255-71	.15	6-32 x 3/4" tapped metal spacer
255-60	.15	6-32 x 1-1/8" tapped spacer
259-1	.05	#6 solder lug

#8 Hardware

PART No.	PRICE Each	DESCRIPTION
250-43	.05	8-32 x 1/4" setscrew
250-137	.05	8-32 x 3/8" screw
252-4	.05	8-32 nut
254-2	.05	#8 lockwasher
255-66	.70	8-32 x 1-3/8" spacer
259-2	.05	#8 solder lug

#10 Hardware

PART No.	PRICE Each	DESCRIPTION
250-188	.05	10-24 x 1" round head screw
252-30	.05	10-24 nut
252-31	.05	10-24 wing nut
254-3	.05	#10 lockwasher

Other Hardware

PART No.	PRICE Each	DESCRIPTION
250-213	.05	4-40 x 5/16" screw
252-15	.05	4-40 nut
252-7	.05	Control nut
252-10	.05	Speednut
253-10	.05	Control flat washer
253-42	.05	1/2" flat washer
253-19	.05	3/4" flat washer
254-4	.05	Control lockwasher
254-9	.05	#5 lockwasher
259-25	.05	#10 double lug

Other Hardware (cont'd.)

PART No.	PRICE Each	DESCRIPTION
258-115	.25	Brass spring 5/8" x 3-1/2"
259-10	.05	Control solder lug
259-24	.05	Long solder lug
260-12	.40	Plate connector
456-16	.20	Shaft coupler

METAL PARTS

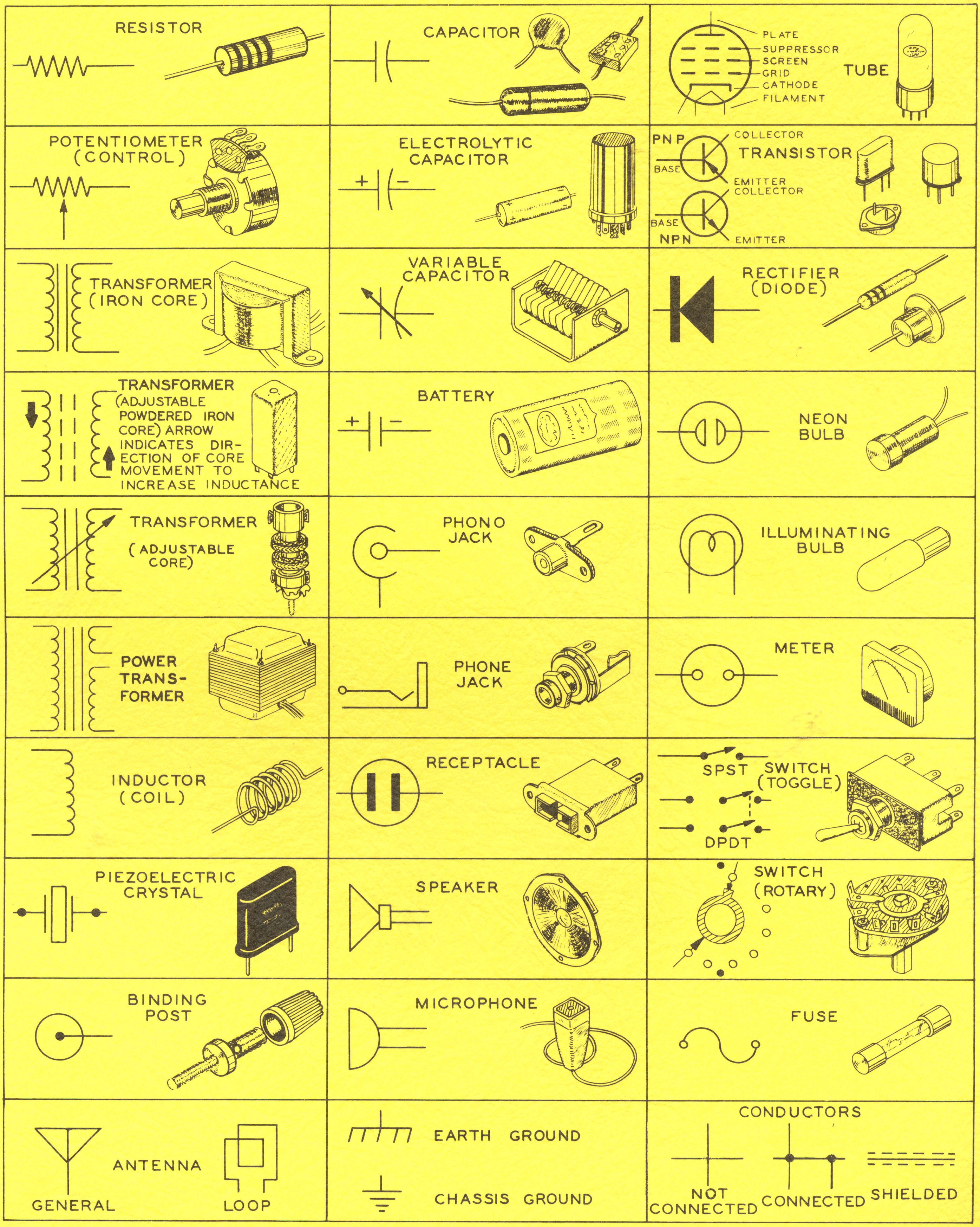
PART No.	PRICE Each	DESCRIPTION
90-464	15.20	Cabinet
200-583	4.45	Chassis
100-1022	1.25	Capacitor bank bracket
203-643	2.15	Front panel
203-644	2.05	Rear panel
203-646	1.60	Left side panel
203-645	.75	Right side panel
204-1041	.30	Angle bracket
204-1042	.20	Plate coil bracket
205-723	.45	Top rear plate cover
205-724	2.80	Perforated top cover
205-874	.70	Perforated fan cover
206-493	2.05	RF shield
206-457	1.05	Coil mounting shield
207-8	.10	Cable clamp
212-36	.10/ft	Silver plated strip ✓

MISCELLANEOUS

PART No.	PRICE Each	DESCRIPTION
85-344-1	1.30	Printed circuit board
255-59	.10	Black tapered spacer
261-9	.05	Rubber foot
266-~~250~~ 269	.60	Fan blade
352-13	.15	Silicone grease
407-145	11.90	Plate amperes meter
407-146	11.90	Multi-meter
420-~~83~~ 86	5.00	Fan motor
453-135	.30	Phenolic shaft
462-191	.70	Small knob
462-210	1.05	Large knob
390-147	.10	Danger high voltage label
391-64	1.20	Nameplate
490-5	.10	Nut starter
331-6	.15	Solder
	2.00	Manual (See front cover for part number.)

TYPICAL COMPONENT TYPES

This chart is a guide to commonly used types of electronic components. The symbols and related illustrations should prove helpful in identifying most parts and reading the schematic diagrams.



HEATH COMPANY

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THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

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the **weekender**

Inrush current protection for the SB-220 linear

Do you have adequate surge protection for your SB-220? If you own this fine piece of gear or similar equipment without the benefit of built-in surge protection, this article should be placed at the top of your project list. For about $10 in parts and six hours of bench work, you can breathe easy when you push the power switch. I call it the $10 insurance policy.

The subject of surge protection has been addressed by many in the past few years. In my opinion, one of the better articles was written by K. M. Gleszer, W1KAY, entitled "Upgrading Your SB-220 Linear Amplifier," which appeared in *QST*, February, 1979. Specific solutions were offered for operation with 117-Vac for filament inrush current, diode-transient and voltage-equalization protection, plus other items. But conspicuous by its absence was a scheme for diode inrush current protection. This protection is easily obtained with the simple circuit described here.

One other area where I'd suggest a change is the time-delay relay. The time-delay function is automatic with a standard relay coil and a current-limiting resistor. Therefore the high cost, plus purchase time and final alteration, of a time-delay relay can be avoided.

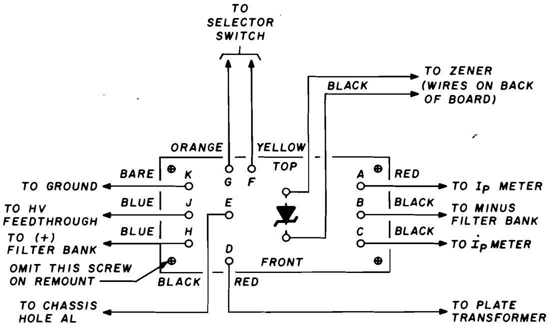


fig. 1. SB-220 rectifier board.

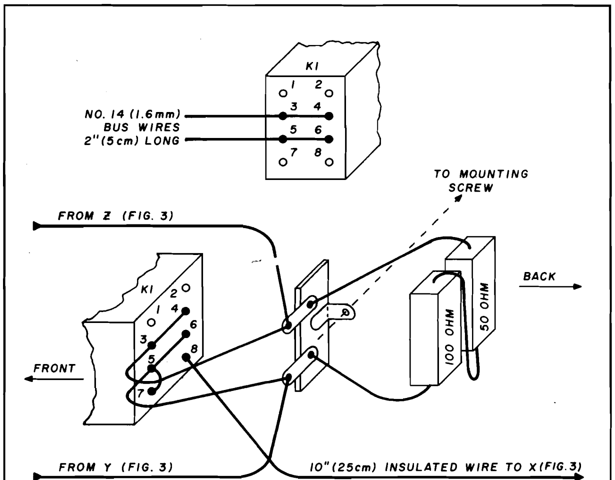


fig. 2. Relay connections for the surge-protection circuit.

The mods I've installed are not unfamiliar, as they've appeared in several 1970-series of the *Radio Amateur's Handbook*. However, I've described the procedures in a detailed order using short, sometimes elementary, phrases for clarification. I'm a stickler for the smallest detail, so you needn't bother with assumptions.

With the mods installed, the following benefits will be added to your SB-220:

1. Rectifier transient surge protection.

2. Rectifier reverse voltage equalization.

3. Rectifier inrush current protection.

4. Inrush current protection for the 3-500Z filaments.

This procedure is divided into two parts: rectifier protection and surge protection. You can elect to cancel one, but because the amplifier must be uncaged for installation of either, it seems wise to include both.

The fourteen original diodes in the SB-220 were not replaced with higher PIV units. This action is not necessary unless you break some during disassembly. These diodes are rated for 1 ampere average forward current at a PIV of 600 volts. The ratings are adequate for this application, and, combined with the modification, they will have a long life.

The nominal delay was selected as 5 seconds. This time can be altered by varying the total limiting resistance. A resistance of 200 ohms caused a long delay, and the resistors dissipated much power. At the op-

By F. T. Marcellino, W3BYM, 13806 Parkland Drive, Rockville, Maryland 20853

posite extreme, 100 ohms provided insufficient delay. Therefore, a satisfactory value of 150 ohms was selected. Note that the time delay and resistance values were selected using a line voltage of 220 Vac. I intended to operate this linear only on the higher line voltage for increased efficiency.

rectifier protection

1. Remove amplifier case, top shield cover, and right-side shield.

2. Remove the four rectifier board hold-down screws.

3. Make a wiring map of all twelve wires connected to the rectifier board and identify by color designator (**fig. 1**).

4. Unsolder all twelve wires at the board end, then remove diodes.

5. Wick twelve wire pads and all diode holes. Remove flux.

6. Drill out all *diode* holes using a No. 47 (2 mm) drill bit from the pad side of the board (assuming all boards are the same).

7. Using a No. 15 (4.5 mm) drill bit, deburr the new holes from the component side. Do not deburr the pad side.

8. Install resistors (470 k ½w) from the pad side, then install diodes and capacitors (0.01 at 1 kV) from the component side. Next:

- **a.** Solder each pad with its three wires.
- **b.** Clip component pigtails as you go.
- **c.** Clean board to remove flux.
- **d.** Ohmmeter check—note highs will be 470 k.

9. Connect board to SB-220 using the following sequence:

- **a.** Solder red wire to hole D.
- **b.** Solder blue wires at holes H and J.
- **c.** Mount board using three screws—omit lower LH.
- **d.** Solder bare wire at hole K.
- **e.** Solder black wire at hole E.
- **f.** Solder black wires to holes and pads for the zener. Observe proper polarity.
- **g.** Solder orange wire to hole G.
- **h.** Solder yellow wire to hole F.
- **i.** Solder red small wire to hole A.
- **j.** Solder black wire (minus filter bank) to hole B.
- **k.** Solder black wire (I_p meter) to hole C.

This completes the rectifier-board wiring. Dress all wires at right angles away from the board, then

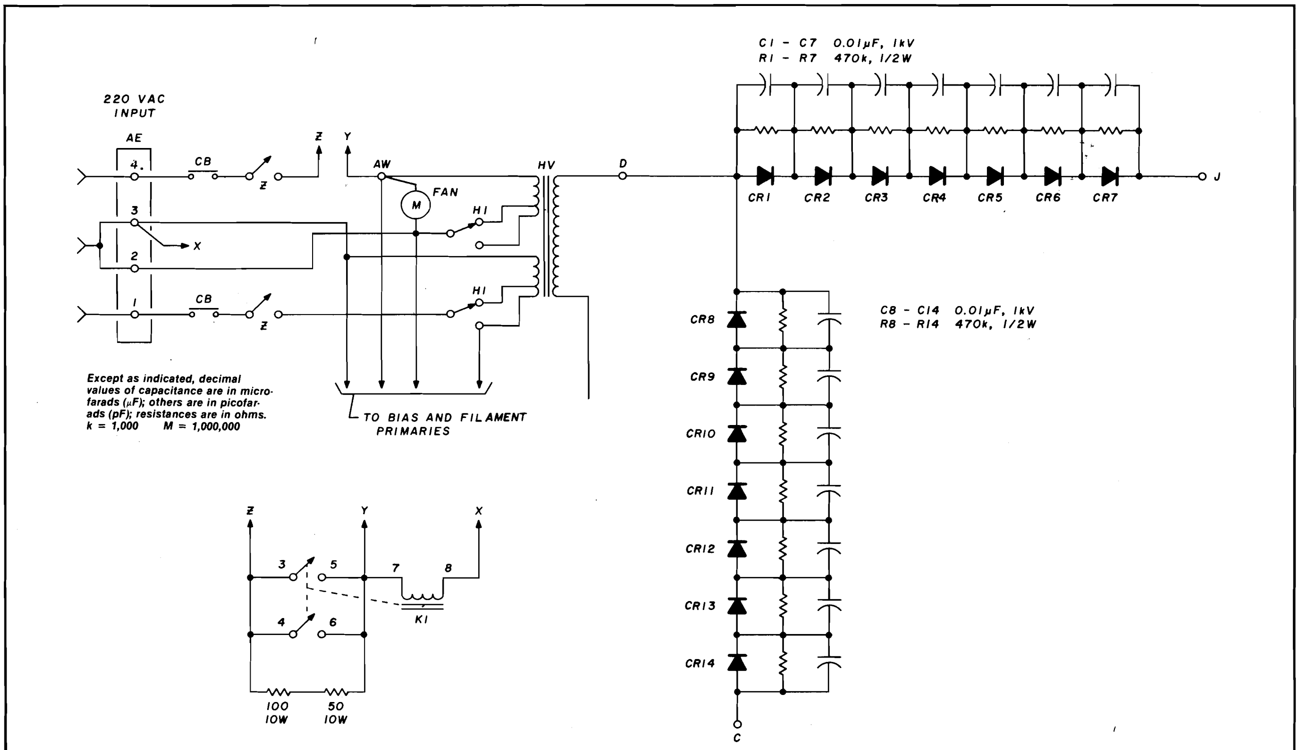


fig. 3. SB-220 surge modifications.

10. Reinstall right-side shield.

11. Oil felt pads on fan motor while top cover is off.

12. Install top shield cover.

13. Test the amplifier using a dummy load.

14. If OK, proceed to the next section.

surge protection

1. Solder No. 14 (1.6 mm) bus wire 2 inches (5 cm) long to pins 3 and 4 of relay K1 (**fig. 2**).

2. Solder No. 14 (1.6 mm) bus wire 2 inches (5 cm) long to pins 5 and 6 of relay K1.

3. Bend the two wires and solder to a two-lug tie strip.

4. Connect pin 5 to 7 using No. 20 (0.8 mm) bare wire.

5. Connect a black insulated wire (rated for 220 Vac, 10 amperes) about 10 inches (25 cm) long to K1 pin 8.

6. Stack the two current-limiting resistors (100 and 50 ohms) and connect in series. Solder this pair to the lower holes in the tie strip.

7. Mount the completed surge-protection into the SB-220 using the center ground lug on the tie strip and the existing chassis screw located about 2 inches (51 mm) forward of terminal strip AE. The relay case should rest against the chassis, being supported by the bus wires.

8. Connect the 10-inch (25-cm) black insulated wire (trim as required) from relay K1 pin 8 to terminal 2/3 on terminal strip AE of the linear.

9. Remove existing black jumper wire between power switch Z and front standoff AW.

10. Connect Z to pins 3 and 4 of K1 using the tie strip. Use insulated wire with (220 Vac, 10-ampere rating).

11. Connect Y from standoff AW to pins 5 and 6 using the tie strip. Use insulated wire with 220-Vac, 10-amp rating.

12. This completes the surge relay installation.

From the Heathkit manual, these codes are used:
AE 110/220 Vac input terminal strip.
AW front-mounted standoff tie point.
AL front corner hole.
Z power switch.

operation

Checkout of the surge protection circuit can be monitored each time the linear is fired up, assuming the filter capacitors have discharged to a low level. Place the selector switch in the HV position, while the mode switch can be in either the CW/TUNE or SSB position. After the power switch is pushed, there will be a time period of a few seconds of dead silence. This delay time is controlled by the value of the limiting resistors. During this period the plate voltage meter can be observed to slowly increase from zero to about 1500 Vdc. Additionally, the meter illumination lamps will *slowly* energize to about half brilliance. Since the 3-500Z filaments are in parallel with these lamps, they will be responding in the same way. If in doubt, turn off your room lights while energizing the linear and peer down through the case top.

The cooling fan will be turning very slowly while gradually building up speed. Therefore there will be no noise from this source during the initial few seconds.

After the five-second surge-delay period, adequate voltage will be available for surge relay K1 to pull in. During a brief interval K1 contacts will close and hold, thus shorting the limiting resistors and applying full line voltage to the transformers. Instantly the plate voltage will increase from 1500 Vdc to its normal maximum value. The 3-500Z filaments will glow with their normal brilliance, and the cooling fan will attain maximum speed. Don't be alarmed when you hear a brief buzzing sound as the relay closes. This sound is caused by K1 contacts bouncing (as all mechanical relays do) combined with slight inductive arcing.

Although this article is written specifically for the SB-220, other similar equipment could be surge protected using these mods.

For additional information on rectifier diode protection I suggest the April, 1980, edition of *Worldradio*, which has a fine article written by Joe Carr, K4IPV.

Once you've installed the mods as shown in **fig. 3**, you can place the problem of surge protection on the shelf for a well-deserved rest. I've used these circuits on two other homebrew linear amplifiers with total success. In addition I've used them on power supplies for several transmitters using the lower line voltage. The only difference is the selection of the limiting resistance for a satisfactory delay period.

Note: K1 is a dpdt relay, 5000-ohm coil, 120 Vac. Contacts are rated at 10A, 125 Vac. Dimensions: 1-5/8 x 1 x 3/4 inches (41 x 25.4 x 19 mm).

ham radio

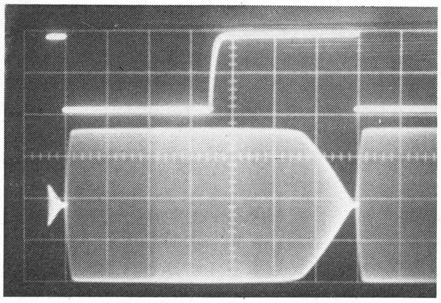


Fig. 4 — Rf envelope vs. keying waveform of the unit as received. The upper trace is the switching waveform at the FT-7B key jack and the lower trace is the output envelope. The horizontal scale is 10 msec per division.

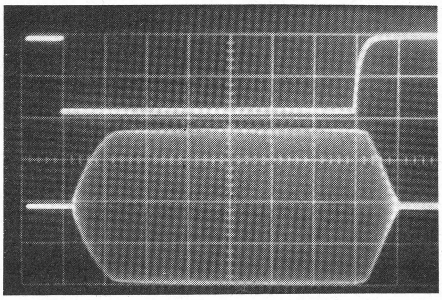


Fig. 5 — After radical surgery, the keying looked like this. In this photo, the horizontal scale is 5 msec per division. The modification information is printed in "Hints and Kinks."

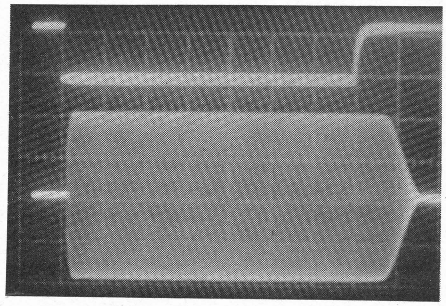


Fig. 6 — Here's the keying resulting from Yaesu's suggested modification (see text). Horizontal scale is 5 ms per division.

The YC-7B Frequency Display

Mobile operators must be able to determine their frequency quickly, with no more than a glance away from the road. The YC-7B remote digital display fills this need. The unit is an optional accessory that plugs into a rear-panel socket of the FT-7B. Stick-on Velcro strips allow the display to be mounted anywhere within reach of the umbilical cable.

The YC-7B counts the final mixer injection frequency. Preset commands from the FT-7B ensure proper carrier frequency readout on all modes. On 80 meters, an 18-MHz crystal oscillator heterodynes the LO signal to the proper range for the counter. The time-base frequency is 655.36 kHz. No special temperature compensation is used, but the overall stability should be at least an order of magnitude better than that of the FT-7B VFO. The readout resolution is 100 Hz, but the instrument counts down to 10 Hz, with a 0.1-second gate time. This unit does not add any spurious responses to the receiver.

Table 2

YC-7B Remote Digital Frequency Display

Specifications

Resolution: 100 Hz
Clock frequency: 655.36 kHz
Gate time: 0.1 sec.
Operating temperature: 0-40° C
Power connections: from FT-7B
Dimensions (HWD): 1-5/8 × 3-5/8 × 5-3/8 inches (40 × 93 × 135 mm)
Weight: 12-1/2 oz (360 g)
Price class: $110
Manufacturer: Yaesu Musen Co., Ltd., Tokyo, Japan

Construction

Most of the FT-7B circuitry is assembled on a dozen phenolic pc cards which plug into three mother boards. The card sockets are individual gold-plated spring pins soldered into the mother boards. The mobile operator needn't worry about the reliability of the sockets — the cards are held firmly in place by the top cover. Two wired-in pc boards and the VFO and PA modules complete the electronics. The VFO and PA are shielded, of course. Most of the tuned circuits are on the mother boards, so you can repeatedly remove and reinstall the plug-in cards without upsetting the alignment. The PA heat sink protrudes from the rear panel. The sink is adequate for voice and cw duty cycles. The a-m rating applies to RTTY and SSTV service. Two screws secure a flat plate to the heat sink fins. A small fan could be mounted to this plate very conveniently.

Aesthetics and Impressions

The unit certainly is compact. That's not surprising, considering the cars it was designed to be installed in. At a time when the styling of Amateur Radio equipment is diverging toward the "military" and "hi-fi/furniture" looks, the FT-7B represents a refreshing alternative to these extremes. The cabinet is painted a businesslike metallic blue that won't look out-of-place in your car or on your kitchen table. The four-color dial and meter are highly visible, yet not at all garish. For fixed service, the analog dial is easy to read, and with its 1-kHz resolution and good linearity, you really don't need the optional digital readout. It's handy, though, for precise clarifier tuning and keeping track of the VFO. All of the controls are conveniently located.

I experienced a small amount of TVI while operating the rig into a dummy load on the same table with my plastic-encased television set. You may have to scrape some paint off the mating metallic surfaces of the FT-7B enclosure if you live in a weak TV signal area.

A *QST* advertisement for the FT-7B reads: "Enough power to drive those linears!" The manual makes no mention of using the transceiver with an external amplifier, but if you dig into the schematic diagram, you'll find that the alc line and the 13.8-volt transmit line (to control a relay) are brought out to the power connector. There's an unused set of contacts on the T-R relay, but they aren't accessible from outside the transceiver.

The attention Yaesu paid to the a-m mode is perplexing. If the intent was to make the transceiver compatible with converted CB rigs, a better solution is to install BFOs in the CB rigs. If you want to participate in the second genesis of a-m, you'll never compete with those plate-modulated Valiants and DX-100s! I would much prefer to see the a-m mode scrapped in favor of some advanced ssb/cw features, such as sharp i-f selectivity, full break-in, VOX and even (bite my tongue) speech processing.

Tinkerers will love this rig, for one can remove most of the cards without unsoldering any wires. If you like, you can fabricate a completely new set of cards. Serious experimenters will undoubtedly conceive numerous worthwhile modifications. With a little ingenuity, a remote VFO could be plugged into one of the fixed-channel crystal sockets. Another possible improvement would be a VFO drift correction circuit using feedback from the YC-7B. If you apply the correction voltage to the wiper of the dial calibration potentiometer, you won't have to violate the VFO compartment.

The FT-7B offers something for everybody. You can have plenty of fun with it just like it is. And if you're ambitious, you can turn it into a truly deluxe station. The equipment is covered by a three-month limited warranty. — *George Woodward, W1RN*

HEATH SB-221 LINEAR AMPLIFIER KIT

10M KIT AVAILABLE

How does the SB-221 differ from the earlier SB-220[1] amplifier? The major difference, electrically, is an unfortunate by-product of FCC action to prevent amateur-equipment manufacturers from including our 10-meter band in linear amplifiers: The SB-221 does not operate on 10 meters! The band-switch panel markings read only "80, 40, 20 and 15" (meters).

Heath Company and other commercial manufacturers of hf-band amateur amplifiers are required to ensure that all amplifiers require at least 50 watts of driving power and that they must be incapable of operation at 27 MHz. They can't, therefore, operate at 28 MHz without elaborate and highly expensive circuitry which is beyond manufacturing reason. All of this came to pass because of widespread illegal operation by CBers who purchased amateur-band linear amplifiers and employed them at 27 MHz. The FCC's inability to enforce the CB regulations imposed a severe economic and marketing hardship on the amateur-equipment manufacturers as well as the amateurs. These regulations, fortunately, do not apply to vhf and uhf types of amplifiers.

SB-221 Features

The popular and reasonably priced amplifier can be made to work satisfactorily on 10 meters by converting it back to an SB-220. More on that later. But, let's examine the circuit and features for the benefit of those who are contemplating the purchase of a "pair of shoes" for that presently "barefoot" exciter.

In its present form, the SB-221 operates in the 80, 40, 20 and 15-meter bands. The required driving power is 100 watts maximum. Rf power amplification is accomplished by means of two 3-500Z triode tubes which are forced-air cooled. These well-proven tubes

[1] "Recent Equipment," *QST*, August 1970, p. 45.

The Heath SB-221 linear amplifier. Though it may appear to be "stock," this '221 operates in five bands. Modification information is given in the text.

Table 4

Results of SB-221 Tests Performed in ARRL Laboratory

Band	$P_{IN(watts)}$	$P_{OUT(watts)}$	*Input VSWR*	*Drive Power (watts)*	*Efficiency (%)*
80	1000	560	1.53:1	70	56
80	1900	1150	1.42:1	100 +	60
40	1000	600	1.41:1	70	60
40	1900	1200	—	100 +	63
20	1000	580	1.6:1	75	58
20	1900	1100	—	100 +	58
15	1000	560	1.79:1	75	56
15	1900	1050	—	100 +	55
10	1000	500	1.42:1	67	50
10	1900	1000	—	100 +	53

offer reliable service and good efficiency. They are the instant-heating-filament type. Hence, operation is permissible the moment the amplifier power switch is turned on.

Maximum dc power input is 2-kW PEP on ssb, 1 kW on cw and 1 kW on RTTY. This amplifier is rated, in terms of its duty cycle, for continuous voice modulation on ssb. For cw use the maximum key-down (steady carrier) time is 10 minutes. When operating the RTTY mode the manufacturer specifies a 50 percent duty cycle, or a *maximum* transmit time of 10 minutes.

The metering system enables the operator to monitor the plate current at all times by means of a 0- to 1-ampere dc meter. A second meter and related switch permits the monitoring of grid current, relative output power or dc plate voltage. There is a two-level plate-voltage setup which is programmed from the front panel by means of a rocker switch. One position provides the proper operating voltage for tune-up and cw. The alternate switch position is for ssb operation. In the latter position the plate voltage and current are elevated to provide the 2-kW PEP power input level while keeping the plate impedance the same as it is in the tune position. Therefore, no readjustment is needed when going from tune to the ssb mode.

Driving power is supplied to the grounded-grid 3-500Zs through switched, broadband pi-section matching networks. The amplifier input impedance is approximately 50 ohms. Hash noise is prevented during the standby period by automatic application of beyond-cutoff bias to the tubes. The proper idling current for the tubes during transmit is established with Zener-diode-regulated bias.

During transmit, an automatic limiting control (alc) circuit in the amplifier develops negative voltage which can be routed to the exciter to reduce its gain when the exciter output is sufficient to overdrive the amplifier. A phono jack is provided on the rear apron of the amplifier for alc takeoff. Another jack is located on the rear of the amplifier for a control line from the exciter which actuates the amplifier changeover relay. When this line is shorted, the relay closes. Fig. 7 shows the amplifier third- and fifth-order distortion product levels. Fig. 8 is a spectrum display of the amplifier spurious products. The harmonic levels are well within FCC limits. Additional TVI protection is offered by the double-shielding technique used in the SB-221: The rf deck has a perforated metal enclosure. The amplifier cabinet serves as the second shield. Rf bypassing is employed at the power-supply primary, the alc jack and the relay-control jack.

What About 10-Meter Operation?

This reviewer couldn't make an ounce of sense out of having this fine amplifier on the operating desk without being able to use it on 10 meters. So, a check was made between the schematic diagrams of the earlier SB-220 and the SB-221. Most of the circuit remained the same. The new version contained a sealed filter in the excitation line to prevent 27- or 28-MHz operation. The band switch lacked the necessary contacts for 5-band use. There was no 10/15-meter plate coil and the 10/15-meter input coil was missing. There were other differences (slight), but none that couldn't be resolved easily.

The lineup of required components was obtained from Heath. Here is the list needed for conversion back to the SB-220 format: 63-561 rotary switch, 63-562 wafer switch, 20-99 22-pF mica (2), 20-120 220-pF mica, 20-113 470-pF mica (2), 20-103 150-pF mica, 20-124 115-pF mica (2), 40-966 40-meter input coil, 40-964 10/15 meter input coil (2), 40-968 10/15 meter plate coil, 595-1122 SB-220 manual. The cost of the foregoing parts at the time of this writing is $31.50. Heath has agreed to sell these parts to SB-221 owners if a photocopy of the purchaser's valid amateur license accompanies the order. The filter in the SB-221 must be removed by drilling out the rivets which hold it to the main chassis. There is no 10-meter marking on the front-panel band switch. A white press-on decal can be added if that band position needs to be identified.

Converting an already-built SB-221 to the SB-220 format will require a certain amount of "unbuilding" first. Fortunately, the reviewer started from scratch with the amplifier kit and wired it as an SB-220. Everything went smoothly by working from the SB-220 manual. Now, the 10-meter band is situated in the "nothing" position on the panel, respective to band-switch indexing. Assembly time for an experienced amateur builder should be on the order of 20 hours. Neophytes should plan to spend up to 35 hours for a project of this nature. — *Doug DeMaw, W1FB*

Table 3

SB-221 Specifications

Size (HWD): 8-1/4 × 14-7/8 × 14-1/2 inches (210 × 378 × 368 mm).
Weight: 50 pounds (22.7 kg).
Color: Two-tone light and dark green.
Power requirements: 117 V ac at 50/60 Hz (20 A max.), or 240 V ac at 50/60 Hz (10 A max.).
Driving power: 100 W max.
Dc input power: 2-kW PEP for ssb and 1 kW for cw and RTTY.
Key-down maximum at full power: 10 minutes.
Frequency range: 3.5 through 21 MHz.
Price class: $620.
Manufacturer: Heath Company, Benton Harbor, MI 49022.

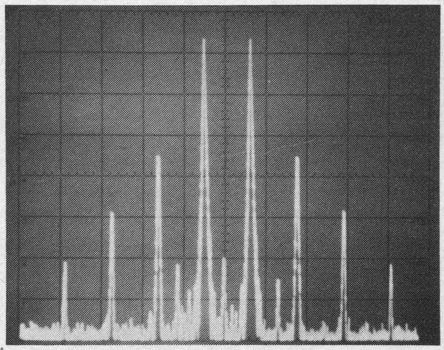


Fig. 7 — Spectral display of the SB-221 IMD characteristics at 3.5 MHz during a two-tone test. Vertical divisions are 10 dB; horizontal divisions are 1 kHz. Third-order distortion products are down approximately 35 dB from the PEP output. The individual tones are 6 dB down from the PEP output. All measurements were taken in the ARRL lab.

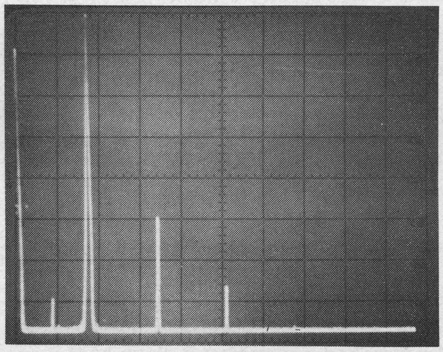


Fig. 8 — Spectral display of the SB-221 amplifier on 3.5 MHz. Vertical divisions are 10 dB; horizontal divisions are 2 MHz. The full-scale pip is the 3.5 MHz carrier with a low-level spur off to its left. The signal immediately to the right of the carrier is the second harmonic at approximately 50 dB below peak power. The third harmonic is 66 dB below peak power.

IMPROVING THE HEATHKIT SB-220 AMPLIFIER

☐ The life of some of the components in the SB-220 amplifier can be prolonged with simple circuit modifications. These modifications concern:

• *The 3-500Zs:* If 3-500Zs possessing above-average gain are used in a stock SB-220, the amplifier may occasionally oscillate near 110 MHz. (This problem is not unique to Heathkit® amplifiers.) The presence of this condition is indicated by occasional arcing at the TUNE capacitor and/or band switch. If a full-blown parasitic oscillation occurs, the result is usually a loud bang. Sometimes this results in a grid-to-filament-shorted 3-500Z, a shorted Zener bias diode, exploded grid bypass capacitors, open grid-to-ground RF chokes (RFC4 and/or RFC5 in the SB-220 circuit), or any combination of these effects. A full SB-220 parasitic cure includes: (1) installation of Q-damping resistors (R1A and R2A in Fig 1A) in the tube cathodes (necessary because the coaxial cable between the SB-220's band switch and the 3-500Z cathodes happens to resonate near the SB-220's parasitic-oscillation frequency!); (2) installation of low-Q parasitic suppressors in the 3-500Z anodes; (3) installation of a 10-Ω, 7- to 10-W, wirewound resistor in series with the anode-supply lead (R5A in Fig 1B) to serve as an HV fuse should a full-blown parasitic oscillation occur; and (4) replacement of the 3-500Z grid RF chokes (RFC4 and RFC5) with 24- to 30-Ω, ½-W resistors (R3A and R4A in Fig 1A) to protect the tubes from grid-to-filament shorts. Full information on steps 1 and 2, and a discussion of how and why VHF parasitics can cause component failures, can be found in my article, "Improving Anode Parasitic Suppression for Modern Amplifier Tubes," *QST*, October 1988, pp 36-39, 66 and 89.

• *Heat reduction:* The eight 30-kΩ, 7-W resistors (R12 through R19, inclusive) that equalize the voltage drops across the SB-220's electrolytic HV filter capacitors (C10 through C17, inclusive) are a major source of heat: They dissipate about 38 W. The filter capacitors are subjected to this heat. Problem: Over a period of time, this heating can cause the filter capacitors to fail prematurely, and can also cause the capacitors' molded-plastic holders to melt. This problem can be corrected by replacing each of the 30-kΩ equalization resistors with a 120-kΩ, 2-W, 2%-tolerance Sprague Q-line® resistor. This modification reduces the power dissipation of the equalization-resistor string by 75% and greatly extends the life of the HV filter capacitors. (Don't use carbon-composition resistors here; they tend to change value unpredictably with use. This trait could result in [potentially destructive] unequal voltage division across the SB-220's HV filter capacitors.)

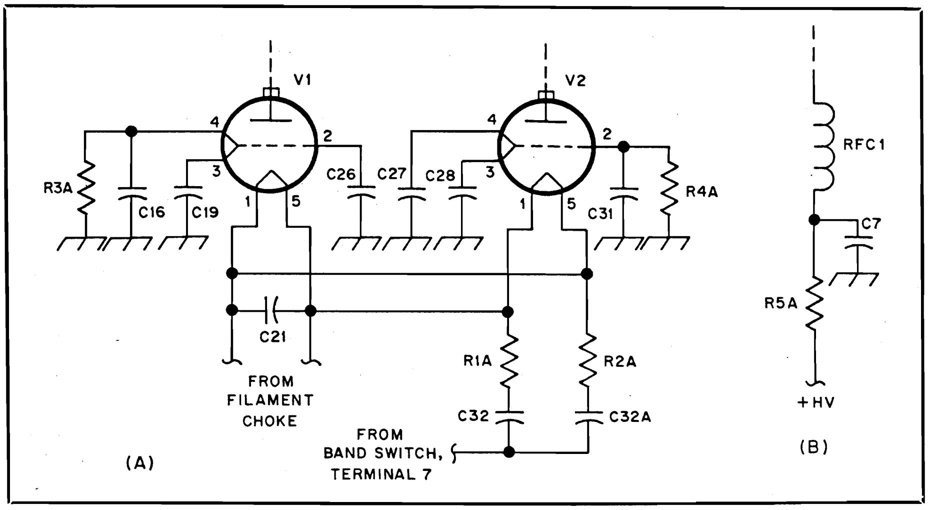


Fig 1—Part of the SB-220 VHF-parasitic-oscillation cure (A) consists of installing Q-damping resistors (R1A, R2A) in the amplifier cathode circuit and replacing the 3-500Z grid chokes with fuse resistors (R3A, R4A). Note that the installation of R1A and R2A also entails the addition of a second filament blocking capacitor (C32A).

Whether or not you apply parasitic-oscillation fixes to your SB-220, the installation of an HV fuse resistor (R5A, at B) is strongly recommended. The resistor protects the amplifier tubes by limiting, and opening in response to, the huge anode current pulse that occurs when the SB-220's 3-500Zs "take off" at VHF.

C32A—0.01 μF, 1 kV, disc ceramic.
R1A, R2A—10 Ω, 2 W, metal film.
R3A, R4A—24 to 30 Ω, ½ W.
R5A—10 Ω, 7 to 10 W, wirewound.

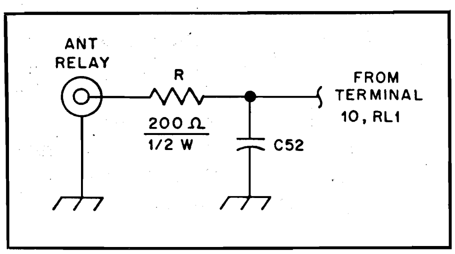


Fig 2—Relay contacts tend to be chewed up after several years of controlling an SB-220 because of the current pulse that occurs when C52 (the bypass capacitor at the SB-220's ANT RELAY jack) is discharged through the contacts. The addition of a current-limiting resistor (R) solves this problem.

• *Pitted contacts in the amplifier-control relay:* A common problem with the SB-220 is that it pits the contacts of the control relay in its associated transceiver after several years' operation. The contact pitting is caused by the repeated short-circuiting of C52 (the 0.02-μF bypass capacitor at the SB-220's ANT RELAY), which charges to +115 V during receiving periods. This problem can be solved by placing a 200-Ω, ½-W resistor in series with the center pin of the ANT RELAY jack to limit the capacitor discharge current (see Fig 2).

• *Fan lubrication:* The fan-motor bearings on early-production SB-220s did not have lubrication holes, and lack of lubrication sometimes led to premature failure of the fan motor. Small lubrication holes can be drilled into the top of the castings that hold the front and rear oilite bearings. This can be done without removing the fan motor.

Ordinary, SF-grade 20w motor oil is a satisfactory fan lubricant; 0.1 cc of oil in each of the two holes once each year is adequate. More oil is not better, just messier.

The SB-220 can be modified for 160-meter operation without sacrificing any of its HF coverage. For details, see "Adding 160-Meter Coverage to HF Amplifiers," *QST*, January 1989, pp 23-28.—*Richard L. Measures, AG6K, 6455 La Cumbre Rd, Somis, CA 93066*

BAND-PASS FILTERS FOR 80 AND 160 METERS

☐ Using the 80- and 160-m preamplifier described by Doug DeMaw in August 1988 *QST*[1] with a Beverage antenna, I encountered intermodulation from strong

[1]D. DeMaw, "Preamplifier for 80- and 160-M Loop and Beverage Antennas," *QST*, Aug 1988, pp 22-24.

USING THE SB-220 AMPLIFIER WITH SOLID-STATE TRANSCEIVERS

☐ The Heathkit SB-220 is one of the most popular amplifiers ever sold. It was designed in an era when most amateur equipment was based on vacuum-tube technology. Because of this, special care is needed if the SB-220 is to be used with a solid-state transceiver.

The SB-220 goes into the transmit mode when the hot contact of its rear-panel ANT RLY jack (J1 in Fig 1A) is shorted to ground, actuating K1, the SB-220 antenna relay. The open-circuit dc voltage at this jack is 125; the short-circuit current is 25 mA. Vacuum-tube-based exciters usually have no trouble switching power at this level. Solid-state rigs are a different story.

My ICOM IC-740 transceiver can't switch 125 V at 25 mA because the maximum ratings for its amplifier-control relay contacts are 24 V/1 A dc. Other solid-state transceivers likely use relays or open-collector transistors of similar ratings for amplifier control. The switching problem is complicated by the fact that the SB-220 antenna-relay solenoid is not shunted by a spike-suppression diode. The transient voltage developed by a solenoid's collapsing magnetic field can exceed the supply voltage. (If you've ever gotten a poke from relay-solenoid back EMF, you know that this voltage is not just theoretical!) With the 24-V rating of the IC-740's control contacts in mind, a direct amplifier-control connection between the SB-220 and the IC-740 seemed to invite trouble.

Fig 1B shows my solution to this problem. With Q1 and Q2 handling the actuation of K1, voltage at J1 is reduced to approximately +12. Short-circuit current through J1 is about 2 mA. Because the SB-220 must be opened to make this modification, now's a good time to install an OPERATE/STANDBY switch, S1, to save switching the SB-220's tube filaments on and off.

There's plenty of room under the SB-220 chassis for mounting the switching components; the entire circuit can be assembled on a tie strip and mounted to an available under-chassis screw. I installed my version of the Fig 1B circuit next to the SB-220's 125-V dc supply, just behind the SSB/CW rocker switch. (Take proper high-voltage safety precautions when you make this modification. Lethal voltages exist in the SB-220.) Dress the wiring for minimal coupling to RF circuits under the chassis and near the antenna relay. As installed in my SB-220, this circuit shows no susceptibility to RFI.—*James Hebert, K8SS, Livonia, Michigan*

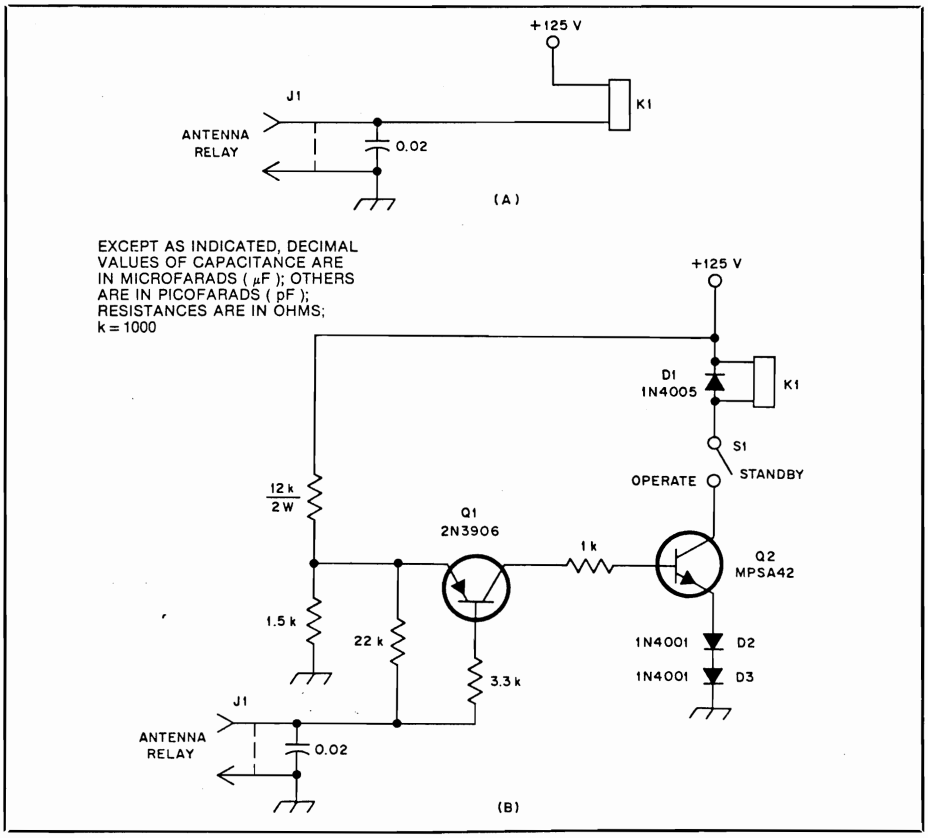


Fig 1—K8SS' SB-220 modification lowers the voltage at the ANT RLY jack, J1, from 125 at A to approximately 12 at B. Short-circuit current through J1 is reduced from 25 mA in the unmodified circuit to 2 mA in the circuit shown at B. J1, K1 and the 0.02-μF capacitor are SB-220 parts. Resistors are ¼-W, carbon-film units unless designated otherwise.

D1—1-A, 600-PIV diode.
D2, D3—1-A, 50-PIV diode.
Q1—General-purpose transistor.
Q2—High-voltage switching transistor, V_{ceo} = 300. ECG287 also suitable.
S1—SPST toggle.

QUICK REPLACEMENT FOR MULTIPIN CONNECTORS

☐ After I bought a Collins R-392 receiver at a summer swap meet, I discovered that I couldn't test it because I didn't have a mate for its power connector. Here's one solution to this problem. Obtain a package of solderless butt-splice connectors (wire size no. 22-18 in this example). Count out one for each of the pins you wish to access on the equipment plug. Crimp one end of each of the solderless connectors just enough for a snug, sliding fit on the equipment-plug pins. "Hard crimp" connecting wires to the other ends of the solderless connectors, and slide the connectors onto the appropriate pins of the equipment plug. (If you use uninsulated butt splices, slip a short piece of insulating tubing over each splice to avoid short circuits between the equipment pins.) I have successfully used this method to furnish speaker, mic and power connections to several pieces of equipment.—*Ken Kolthoff, K8AXH/6, Vandenberg AFB, California*

FLEXING DAMAGES COAXIAL CABLE

☐ If you've ever had trouble with fluctuating SWR and similar erratic behavior in a coax-fed RF system, my experience with three pieces of coax removed from 75-MHz IF amplifier modules may be of interest to you. The bandwidth, differential gain and phase response of the amplifiers would not stay put; the coax was the culprit.

Flexing of the coaxial cables had resulted in damage to the cable shield at several plugs. The IF-amplifier manufacturer had not provided access holes large enough for 90° coaxial adapters, necessitating that the coax be pulled away from chassis connectors at a 90° angle at several places. In this wide-band application, the integrity of the coax was critical in maintaining proper tuning of amplifier stages. Cable-shield damage resulted in signal leakage, circuit detuning and uncertain RF grounding. This was caused by 150 to 200 flexing cycles over a period of about 15 years. These cables were used indoors, by the way; wind flexing was not a problem.

Coaxial cable is particularly vulnerable to flexing damage at connectors and bulkheads. Protect it well, flex it minimally, keep bending radii as large as possible and take the action of weather into consideration. —*Kurt U. Grey, VE2UG, Sept Iles, Quebec, Canada* as near to the vehicle-body side as possible.

B) Mount one-piece transceivers under the dash or on the transmission hump, where they do not interfere with vehicle controls or passenger movement.

Antenna Installation

A) Use a permanently mounted antenna located in the center of the roof or rear-deck lid. Keep glass-mounted antennas as high as possible in the center of the rear window or windshield. If a magnetic-mount antenna must be used, carefully place it in a location recommended for a permanently mounted antenna. If a disguise-mount antenna is used, shield the matching network from vehicle electronics and wiring or mount the matching network in an area completely clear of vehicle electronics and wiring.

B) Radio-frequency energy affects each vehicle model and body style differently. When dealing with an unfamiliar vehicle, use a magnetic-mount antenna to check proposed antenna locations for unwanted effects. (Antenna location is a major factor in these effects.)

Antenna-Cable Routing

A) Always use high-quality coaxial cable (at least 95% shield coverage), and route it away from the Engine Control Module and other electronics modules.

B) Do not route feed line next to any vehicle wiring.

Antenna Tuning

A) It is important to properly match the antenna so that reflected power is kept to a minimum (keep SWR less than 2:1).

Radio Wiring and Connection Locations

A) Transceiver power leads:

Power connections, including the ground, should be made directly to the battery (or to the jump-start block on vehicles so equipped). Transceiver power leads should be no. 10 AWG or larger, installed as a twisted pair if possible. The ground lead should not be attached to the body at any point. Place appropriate fuses, as near the battery as possible, in both positive and ground leads. (A fuse in the transceiver ground lead prevents possible transceiver damage should the battery-to-engine-block ground be disconnected.)

Where ignition-switch control of dc power is desired for one-piece transceivers, install a 12-V power contactor in the transceiver positive lead. Install the contactor near the vehicle battery, and drive the contactor coil through an appropriate fuse from an available accessory or ignition circuit that is not powered during cranking. The contactor-coil ground should return directly to the negative battery terminal.

B) Handset or Control-Unit Battery and Ground:

Any ground lead from a handset or control unit should return directly to the negative battery terminal. The positive lead of a handset or control unit should be connected directly to the positive battery terminal. Fuse the handset or control unit power leads separately from the transceiver power leads. If the radio dc power must be controlled with the ignition switch, the handset or control-unit positive lead may be connected, through an appropriate fuse, to an available accessory or ignition circuit not powered during cranking.

C) Connections for multiple transceivers and receivers:

If multiple transceivers or receivers are installed in the vehicle, install heavy power conductors to the trunk or dash and terminate them in covered, insulated bus bars. Connect all radio power leads to the bus bars. (This makes a neater installation and reduces the number of wires running under the hood.)

Wire Routing

A) Bring radio power leads into the passenger compartment through a grommet in the driver's side of the firewall. For trunk-mounted transceivers, continue the cables along the driver's-side door sill(s), under the rear seat, and into the trunk through the rear bulkhead. If the battery is located on the passenger side, power leads should cross the vehicle in front of the engine. Maintain as much distance as possible between radio power leads and vehicle electronic modules and wiring.

B) For police vehicles, route radio power leads in the conduit provided with the option package.

Troubleshooting

A) Should vehicle problems develop following installation, the source of the problem should be determined prior to further vehicle operation.

B) Possible causes of vehicle problems include:

1) Power connections to points other than the battery.

2) Antenna location.

3) Transceiver wiring located too close to vehicle electronic modules or wiring.

4) Poor shielding or poor connections in the antenna feed line.

Contact and Feedback

A) GM vehicles have been designed and extensively tested for immunity to known sources of RF energy. It is impossible, however, to test every combination of RF source and installation. If [redacted] persistent condition in a G[redacted] your local GM representat[redacted] solution is found locally, write to: [redacted] Bldg 40, General Motors [redacted] Ground, Milford, Michigan 48042-[redacted].

[1]Surprisingly little information i[redacted]ailable about proper installation of two-way [redacted] vehicles containing microprocessors. [redacted]M recommendations are all that I have [redacted] aid those who wish to make competent, [redacted]ference-free installations of amateur gear [redacted]ay's electronically sophisticated autom[redacted]es.

Conversations with technic[redacted] who install police radios in Chrysler produ[redacted]ave yielded some unofficial information. T[redacted]icroprocessor is usually in the passenger-[redacted] kick panel. Police cruisers come equipp[redacted]ith a steel cable housing welded to the[redacted]me on the driver's side from the firewa[redacted]o the rear bumper. RF cables are rout[redacted] inside the housing to the antenna at th[redacted]ear of the vehicle. Power cables are kept [redacted]far as possible from the computer.

I would appreciate copies of a[redacted] additional official information. Send th[redacted] to Bob Schetgen, KU7G, Hints and [redacted]s Editor, 225 Main St, Newington, CT 06[redacted]

FLASH! VCR CURES TVI!

☐ Here is a tip on the use of a VHS videotape recorder. I live in the weak-reception area of several Los Angeles television stations. When the signals from those stations are very weak, my 7-MHz amateur transmissions produce a light cross-hatch pattern on Channel 5. I have found that the interference is eliminated when the received TV signal is passed through my operating VCR. I do not know the gain of the VCR front end, but it seems significant. —*K. C. Jones, W6OB, Hemet, California*

LIVING WITH TVI

☐ I live in a small apartment building at a summer resort area. During the colder half of the year, I am the only occupant and have no TVI worries. As warm weather approaches, however, the other apartments start filling up. Three tenants have hand-me-down TV sets with poor antennas that are particularly susceptible to TVI. (My own set is free of TVI even when I use my amplifier. Thus, my station emissions are clean. That doesn't cut any ice with the neighbors, however, who want to see their programs.) For my part, it is good practice to keep my neighbors happy. So, do I go QRT during all TV-viewing hours? Not on your life! I have set up a TV detector to determine when the neighbors are watching TV.

If you live in an apartment building, perhaps you have noticed that your AM broadcast receiver is little better than useless when your (or your neighbor's) TV is on. This is the result of interference from the TV horizontal-sweep oscillator, and it is especially prevalent near the low end of the AM-broadcast dial. Such interference is much worse on longwave frequencies (150-300 kHz). All I do is tune my receiver near 150 kHz (the 10th harmonic of the sweep frequency) and a loud roaring noise can be heard when a neighboring TV is on.

My discovery does not cure TVI, but it [redacted] allow me to operate many hours when I would [redacted] *J. Pankken, K4SYP/EA5CHT, Murcia, Spain*

MORE ON THE BALANCED GRID CIRCUIT FOR THE SB-200

[In Mark Tyler, K5GQ's hint (Aug 1986 *QST*) about the SB-200, he replaced C29, a fixed capacitor, with an 8- to 50-pF variable capacitor. Here is Mark's adjustment procedure for the new capacitor.—Ed.]

☐ The variable capacitor determines the amount of ALC sent to the exciter. To determine the variable capacitor setting:

1) Set the new component for maximum capacitance.

2) Momentarily increase the exciter to maximum RF output. (ALC through the new capacitor should limit the exciter output.)

3) Decrease the capacitance until maximum amplifier output is reached. (Decreasing the capacitance should increase amplifier drive and output by reducing the ALC signal.)

I installed a 20-pF fixed capacitor in NM5I's SB-200 because he does not use the ALC line.—*Mark Tyler, K5GQ, Katy, Texas*

See correction in april

Upgrading Your SB-220 Linear Amplifier

A modest outlay for parts and a few hours on the workbench . . . ingredients for "customizing" this Heath workhorse. The results will be longer life, higher reliability and more operating convenience.

By Kenneth M. Gleszer,* W1KAY

☐ In "Upgrading the SB-220 Linear Amplifier," February 1979 *QST*, R1 shown in Fig. 1 has an effective resistance of 50 ohms, not 100 ohms as is indicated in the text. The 50-ohm value works satisfactorily when the amplifier is being operated on 117-V house current, but on 234 V ac a value of 200 ohms at R1 provides better in-rush current control. It is also necessary to use contacts K1B for both 117 V and 234 V ac.

← CORRECTION

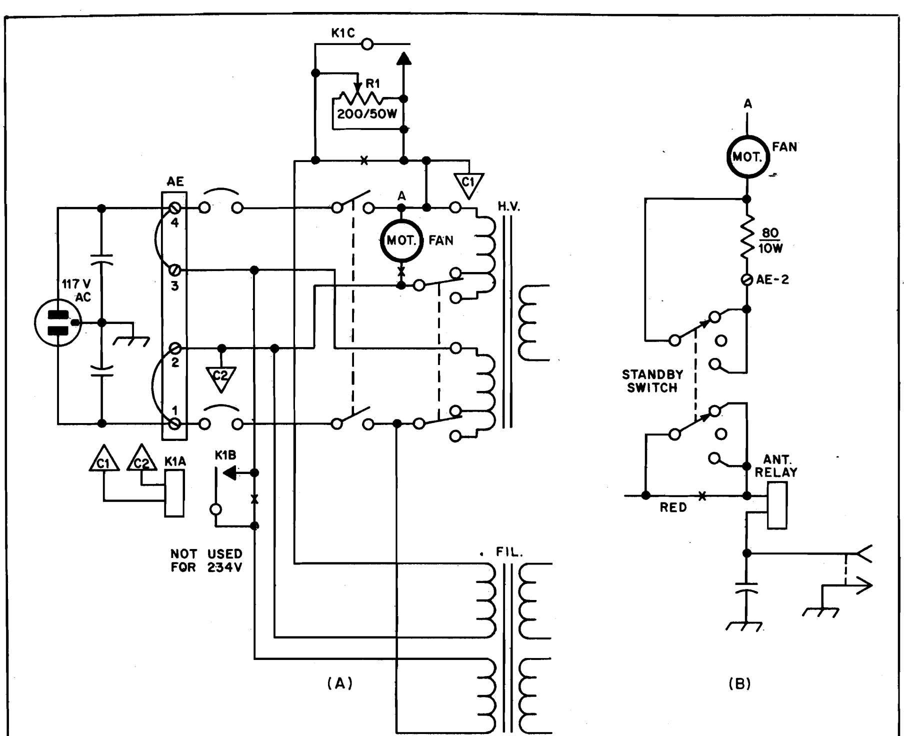
The continued popularity of the Heath SB-220 linear amplifier after eight years in production is not surprising, considering its price and good reputation. Since I was in the market for an amplifier I decided to do a bit of research on the SB-220. I decided to ask some on-the-air questions of present owners.

*P. O. Box 2234, Stamford, CT 06906

As a group, they seemed pleased with the unit's performance; however, most felt that there were a few areas that could be improved upon. A few experienced failure of one or more diodes in the high-voltage power supply. Many found the cooling fan to be excessively noisy. Some mentioned occasional arcing between the top inner shield of the case and the plate connections on the tubes. A STANDBY switch was felt to be desirable to enable on-the-air tests and facilitate tune-up and band changing without constantly turning the high-amperage 3-500Z filaments on and off. A few experienced what they felt was premature failure of the now fairly expensive 3-500Z power tubes. Most owners expressed the desire for a color that would match equipment other than Heathkit.

As none of these problems seemed difficult to correct, I began by purchasing and assembling a kit. It worked quite well and I began to use it on the air. After a short time operating with it, I was convinced that the suggestions made to me were worthwhile. I began to modify the unit one step at a time.

Fig. 1 — Schematic diagram of the modifications for standby switch, two-speed fan, and filament protection.
K1 — Time-delay relay, dpdt 10-A contacts, Potter and Brumfield. Available from Herbach and Rademan Inc., 401 East Erie Ave., Philadelphia, PA, stock no. 21K233.
R1 — Wire-wound resistor, 200 ohms, 50 watts; Clarostat type VP5OKA.



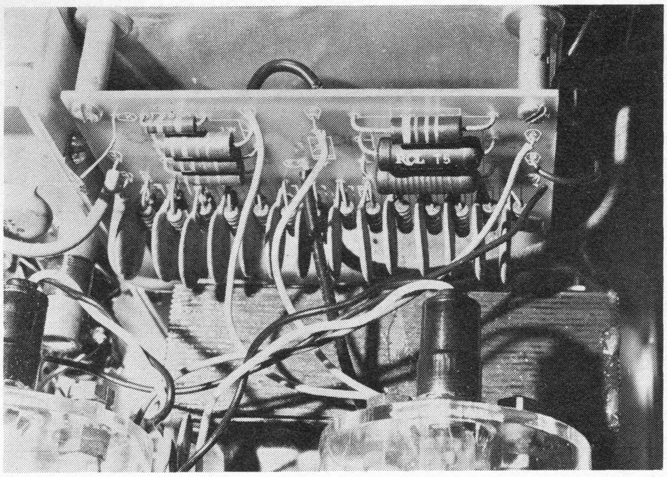
The Power Supply

The power supply circuit board did indeed look sparse with 14 1-A, 600-PIV diodes, unprotected by equalizing resistors and capacitors. Every time I turned the power switch on, I expected noise and smoke to appear because of the high current surge which occurs as the capacitor bank charges.

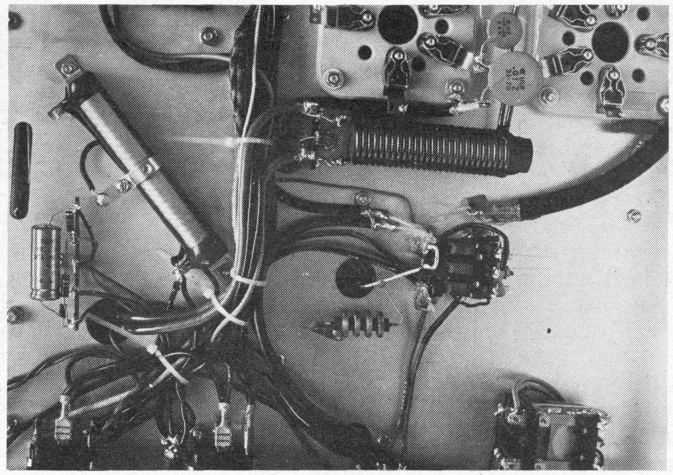
The fix was relatively simple. I removed the circuit board and the 14 diodes. Each diode lead hole was drilled out slightly larger from the foil side, just enough to accommodate two more component leads of about the same diameter. One by one each diode was replaced with a 1000 PIV, 2.5-A silicon diode and bypassed with a 0.01-μF, 1000-V ceramic disk capacitor and a 470-kΩ, half-watt resistor.

There was no difficulty in fitting in these extra components; they may be mounted on the top surface of the circuit board. I then reconnected the board to the appropriate color-coded leads and replaced it in its original position.

It is not possible to reinstall the lower



The modified power supply board for the SB-220. The added components are mounted above the diodes.



At left is the mounting location of the surge protection resistor. If the specified resistor is used, it can be mounted on existing screws.

inner mounting screw without disassembling the front panel. Due to the high strength of the circuit board and the solidity of the mounting arrangement, the loss of this one screw is unimportant.

The modified unit operates normally, although with slightly higher plate voltage. Now there should be no further worry about blown diodes.

Standby and Cooling Modifications

The cooling fan was indeed noisy. Heath told me that the fan motor had been redesigned and they would send a replacement. The new one appeared slightly smaller than the old one, with redesigned bearing mountings. A quick test on the bench disclosed that it was indeed quiet and vibration free.

The power tubes were removed to facilitate fan replacement. The fan lead was removed from terminal 2 of block AE. The other fan wire was cut approximately 1-1/2 inches (38 mm) from the old motor. After the old motor was removed, the nylon fan blade was mounted on the new motor and the assembly reinstalled.

I decided that I did not want my fan to run at high speed during periods of standby. I installed an 80-ohm, 10-watt resistor in series with the motor power leads. One end was soldered to the bottom of lug 2, terminal strip AE. The other end was connected to one of the motor leads.

The other motor lead was cut to a convenient length and soldered to the lead previously cut. Appropriate spaghetti tubing was used to cover the soldered junction. The circuit for this modification, along with the other described in this article, are given in Fig. 1. Anyone not wishing to complete the standby switch project, described below, should not bother with the 10-W resistor, as the fan speed may be too slow for continuous, high-power operation.

A double-pole, double-throw, center-off paddle switch was mounted on the front panel, in a position on line with the two rocker switches and centered between the band switch and the loading control. Care in drilling the mounting hole should be exercised so as not to chip the paint on the front panel.

The switch should be mounted so that the paddle moves left to right in preference to up and down. The red wire is removed from the relay coil and soldered to the lower center lug of the STANDBY switch. Another wire is connected between both lower end lugs of this switch and the relay coil. This permits standby in the center position and normal operation with the paddle left or right.

Solder a 12-inch (305-mm) piece of hook-up wire to the side of the 80-ohm resistor which is connected to the motor, and route the wire through the wiring harness to the front panel. Connect it to the upper center lug of the standby switch. Connect both upper end lugs of the switch together and then to terminal AW.

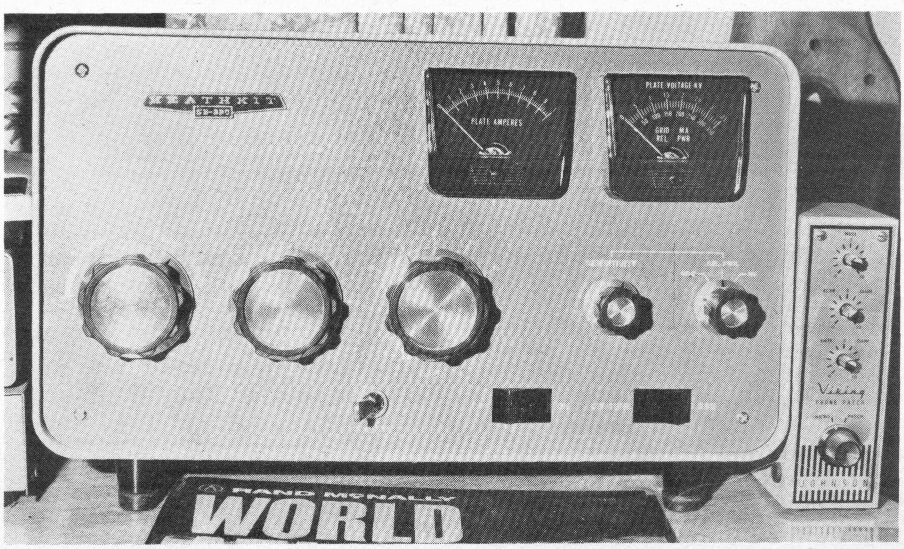
This should now give you low-speed fan operation on standby and high speed on either the left or right OPERATE position of the paddle switch. The fan speed reduction should be approximately 25 percent, which will provide ample air to cool the tubes while idling, but substantially less noise during standby. During standby, the exciter will operate straight through, even through the amplifier filaments are lit.

While the cover is off, bend the solder lugs on the plate connectors slightly downward from their original position. This opens up the space between these connections and the chassis substantially. Arcing will no longer be a problem after reassembly.

Filament In-Rush Current Protection

Eimac makes it clear in their literature on 3-500Z tubes that filament in-rush

The standby switch is mounted below the band switch and loading control. The function is labeled with press-on transfers and protected with a coat of clear acrylic spray.



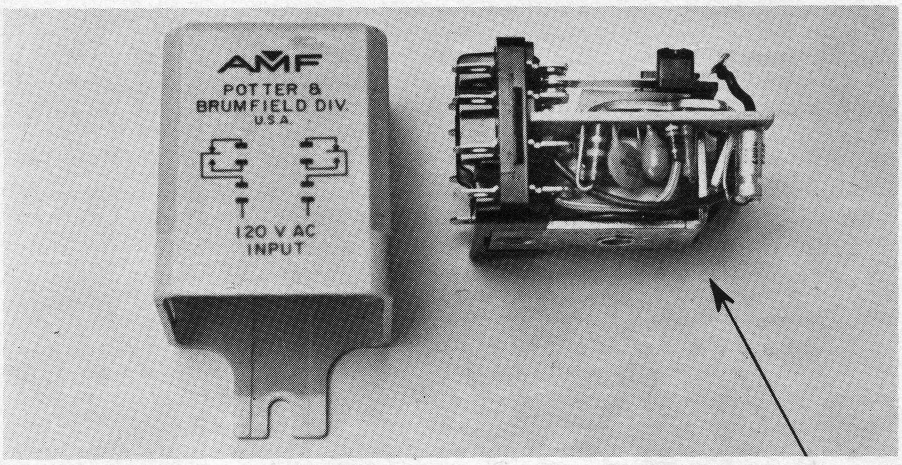
should be limited to two times the normal operating current. As the filaments present almost a dead short to the transformer when they are cold, the initial current passing through them can be far more than two times their rated current. Repeated fast heat-ups can ultimately cause mechanical deformation of the filament and shorts between it and other tube elements. Premature failure of 3-500Z tubes can be traced to this problem.

A relatively simple cure is to install 100 ohms of surge resistance in the primary winding of the filament transformer and, after approximately three to five seconds after turn-on, short this resistor out using a small time-delay relay. For reasons of convenience, I selected a 200-ohm, 50-W Clarostat wire-wound resistor which fit diagonally across the capacitor mounting-bracket screws already available on the bottom of the chassis. The slider should be positioned in the middle of the resistor. Solder a jumper between both end lugs. A 100-ohm, 50-W resistor will do just as well, but finding a space to drill holes in this area of the chassis is difficult.

I spotted a miniature solid-state-controlled time-delay relay in a Herbach and Rademan catalog, their stock no. 21K233. The plastic cover was removed and the existing 120-second time delay was reduced to 5 seconds by installing an 82-kΩ, 1/4-W resistor in parallel with the gray, 1.2-MΩ timing resistor. There is a hole already provided for mounting the resistor on the small circuit board within this relay.

Drill a hole for a no. 6-32 screw 2 inches from the front of the chassis and on a line exactly between the loading and tuning capacitors. Mount the relay with a 6-32 × 1/2-inch screw. A small rubber bushing or grommet should be inserted between the bottom of the relay and the chassis to eliminate the possiblity of hum.

The black filament-transformer primary wire is removed from lug AW and fastened to one end terminal of the resistor. The slider is connected to lug AW, which effectively inserts the resistor in a series with the primary.



The time-delay relay used in the surge-protection circuit. The arrow points to the resistor that must be decreased in value to shorten the time delay.

Two leads are now connected between the contacts of the time delay relay and one end of the resistor and terminal AW. One side of the relay coil is connected to terminal block AE, terminal no. 2. The other coil terminal is connected to terminal AW.

If you plan to operate your SB-220 on 235 volts only, this completes the surge protection project. If you are going to operate on 117 volts, you *must* remove the black-green wire from terminal 3 of block AE; pull it out of the wiring harness and connect it to the lower unused terminal on the time delay relay. The center unused terminal must now be connected back to terminal 3 of block AE. This eliminates one of the parallel windings of the filament transformer until the relay closes.

Reinstall the tubes and the inner chassis cover. Turn on the power switch. The filaments should take approximately three seconds to come up to half temperature. This is a bright red color. Two seconds later the relay closes and the tubes almost instantly reach normal operating temperature. In this hook-up the meter pilot lights follow the same heat-up sequence. This serves as a visual check that the time-delay relay is functioning properly.

Color

I finally had my SB-220 performing to my satisfaction. Now if only the cover and panel could be changed to match the color scheme of my Drake twins, I would be happy. I fired off a letter to Heath asking if they would consider making available a case and panel that would be compatible with most of the black boxes on the market. I did get a very nice answer back, but no encouragement. Maybe sometime in the future, but not now. Those who feel as I do should write to Heath.

The total time for completion of all the modification projects, after the parts are gathered together, should not exceed two hours. These changes are very worthwhile, as you can expect much longer life, reliability and convenience — and you'll have the satisfaction of owning a "custom-built" amplifier. QST

Strays

PUT YOUR VOICE TO GOOD USE

☐ Can you operate a tape recorder? Or can you read aloud and explain advanced scientific subjects? Could you learn to operate a tape-duplicating machine? Such volunteers are needed by the 29 units of Recording for the Blind, an organization that provides free textbooks to the blind and to those physically unable to handle a book. In addition to such subjects as physics, math, computer technology and chemistry, many Amateur Radio publications have been recorded and maintained in the master library of Recording for the Blind, 215 E. 58 St., New York, NY 10022. Check the phone book to see if there is a Unit in your city. If so — volunteer!

I would like to get in touch with . . .

☐ Novices and experienced traffic men interested in forming a Novice net on or around 21.150 MHz at 1800 UTC. Armond Brattland, K6EA, 1135 Magnolia Ave., Long Beach, CA 90813.

STATION NOW ABOARD *HMS BELFAST*

☐ The Amateur Radio station aboard the *HMS Belfast,* which is moored in the Pool of London, has been granted the use of the special call sign GB2RN for use when the ship is open to the public. The station is interested in establishing schedules with other museum and special-interest stations worldwide. Contact Don Walmsley, 153 Worple Road, Isleworth, Middlesex, TW7 7HT, England.

Circuit Improvements for the Heath SB-220 Amplifier—*Part 1*

The venerable SB-220 is one of the most popular Amateur Radio amplifiers ever made—and for good reason. But it isn't perfect. Here's how to make it better.

By Richard L. Measures, AG6K
6455 La Cumbre Rd
Somis, CA 93066

The Heath® SB-220/221 amplifier[1] made a notable impact on the world of Amateur Radio. It was the first reasonably priced *and* intelligently designed HF SSB/CW amplifier sold to the Amateur Radio community. Unfortunately, this amplifier is no longer manufactured. The SB-220 (and its successor, the HL-2200) has some excellent design features and a few easily corrected design weaknesses. In this two-part article, I'll discuss both topics, and some cures for the amplifier's weaknesses.

The High-Voltage Power Supply

Before the arrival of the SB-220, there was a popular notion that legal-limit SSB amplifiers needed heavy-duty power supplies that required two grown men to move them. Heath engineers knew that this idea was based more on folklore than on sound engineering principles.[2] They also knew that the average duty cycle of a human voice is only about 15%. Why build a 100% duty cycle "lock-to-talk" power supply when one wasn't required? So, they designed a power supply that would do the job at hand. That resulted in considerable size, weight and cost savings, which Heath passed along to SB-220 buyers.

At first, some people in the ham community had negative comments about the SB-220's "wimpy-looking" power supply. With time, it became apparent that the power supply did the job well. It had a low failure rate and no detectable ripple. This was no accident. Heath engineers wisely chose an HV-transformer design with an exceptionally low secondary resistance (only about 12.2 Ω). This minimizes the voltage drop under full load in the supply's full-wave voltage-doubling rectifier circuit. Such circuits have an extremely high peak-to-average output-current ratio, so minimizing the transformer-winding resistance is essential for good voltage regulation and reducing I^2R (heat) losses in the transformer's windings.

The voltage-doubling rectifier circuit has some advantages over the traditional full-wave-bridge rectifier circuit, including:

- Low ripple voltage. As one capacitor bank is charging, the other capacitor bank is simultaneously discharging, canceling the other's out-of-phase sawtooth waveform.

There is no safe substitute for pulling the electric-mains plug before putting your fingers inside any amplifier.

- Half as many transformer secondary wire turns as a comparable non-doubling supply, which yields a more efficient transformer design. Here's why: One layer of insulating paper is required between each layer of wires, so fewer turns means fewer layers of paper. The result is a transformer that has a high ratio of copper to paper, and thus a relatively high power-to-weight ratio.
- Excellent voltage regulation during current transients—exactly what's needed for CW and SSB operation—because no swinging-inductance filter choke is needed.

Cooling

Because about half of the power consumed by a linear amplifier is converted into heat, another important amplifier-design consideration is cooling. Most of the heat that a 3-500Z (or any other internal-anode tube) dissipates is carried away by heat radiation from its anode.

Here's how it works: During normal operation, the anode gets so hot that it glows a bright orange color. The surrounding objects are relatively much cooler, so the anode loses most of its heat to its surroundings by radiation, and a lesser amount by conduction through the anode stem and pins. Unfortunately, some of the components to which the anode loses heat are heat-sensitive parts of the 3-500Z, such as the tube's critical glass-to-metal seals and the solder used at the pins in the tube's base. These heat-sensitive parts must be cooled by forced air.

Heath's engineers came up with a deceptively simple method of effectively cooling the 3-500Zs. They realized that the expensive Eimac® air-system socket/glass-chimney cooling system had some serious trade-offs, such as: the difficulty of forcing enough air through the airflow restrictions in the system to adequately cool the filament pins and seals; inefficient anode-cap cooling (the horizontal fins on the standard anode-cap coolers were obviously not designed to be cooled by the vertical airflow through the Eimac air-system chimney); and those airflow restrictions require the use of a high-pressure centrifugal blower (and all high-pressure blowers are noisy). Heath needed a cooling system that would quietly move high-velocity air past the 3-500Z's hot filament pins,[3] filament and anode seals, and glass envelopes.

The Heath engineers knew that when horizontal air flows across vertical cylinders, such as a 3-500Z envelope and its pins, the air follows the curves of the cylinders, providing fairly uniform cooling to all areas of the cylinders (minimizing hot spots). They concluded that, with horizontal airflow, the cooling air has a direct path to the heat-sensitive parts of the tube, and allows the anode cooler's fins to take maximum advantage of the flow of cooling air. Because the filament pins are below the chassis and the filament and anode seals are above the chassis, the Heath engineers used

[1]Notes appear on p 29.

an open-ended chassis equipped with a single, 6-inch-diameter fan blade that could simultaneously blow cooling air above and below the chassis.

To position the four hot filament pins optimally in the under-chassis airflow, the pair of tube sockets was mounted with the two pairs of filament pins facing each other. This optimally positions the hottest parts in front of the tips of the fan blades.

The cooling-system design is brilliantly simple. It's relatively quiet and works well. Reports of tube-pin solder melting in SB-220 amplifiers are very rare (with the exception of cases where the fan-motor bearings seized because they were never oiled!). On the other hand, I have heard of many 3-500Z-pin solder-melting episodes in other amplifiers that used centrifugal blowers and air-system-chimney cooling.

One weakness in the SB-220's cooling system is that the infrared radiation (heat) reflected back into the tubes from the bright aluminum surfaces adjacent and parallel to the anodes shortens tube life. This deficiency is easily corrected: After removing the tubes, apply black liquid shoe polish to the vertical aluminum surfaces near the tubes.

Fan Oiling

An oversight in early SB-220s was the failure to provide oil holes for the fan-motor bearings. This problem can be corrected by drilling a small hole, no more than ¼ inch deep, above the front and rear bearings. It's not necessary to remove the fan motor to do this. The fan should be lubricated at least annually with a thin, *non-gumming* oil such as Hoppe's no. 1003.[4,5] Insert a drop or two of such oil into each hole. What isn't absorbed by the felt wicks that surround the bearings simply dribbles out. *More oil is not better, just messier.* The easiest way to get the desired amount of oil in the holes is to apply the oil with a disposable insulin syringe (available at most drug stores); each unit on such a syringe is equivalent to approximately one drop of oil.

Premature Filter-Capacitor Failure

Aluminum-electrolytic filter capacitors are very sensitive to heat. For every 10-°C increase above room temperature, capacitor life expectancy is approximately *halved.* The electrolytic filter capacitors in the SB-220 are subjected to high heat during normal operation, mostly because of their proximity to their eight associated 30-kΩ voltage-equalizing/bleeder resistors. During transmit, another (minor) source of capacitor heating is the 60-Hz ripple current flowing through each capacitor.

The capacitor-heating problem is compounded because cooling air does not reach the capacitors. In some cases, the heat present partially melts the ends of the capacitor holders that are nearest to the 30-kΩ resistors!

Heat dissipated by these resistors can be reduced by about 70% by replacing them with 100-kΩ, 2- or 3-W, 5%-tolerance film resistors. Other resistance values may be used, up to roughly 150 kΩ, provided that the resistors are rated to withstand the voltage applied to them and the resistor values are within 5% of each other. I do not recommend using ancient 2-W carbon-composition resistors for this application. They don't stay within their rated tolerance as they age. This simple modification greatly prolongs the life of the electrolytic filter capacitors.

Note: Increasing the equalizing-resistor values also increases the capacitor bleed-down time after the amplifier is shut off. Because this amplifier has a shorting HV interlock that grounds the HV-positive lead when the cover is removed, it's advisable to wait until the front-panel voltmeter indicates nearly 0 V before allowing the interlock to short the HV line to the chassis. Here's why: When the HV positive is shorted to ground, the energy stored in the filter capacitors is applied *directly* to the grid-current-meter shunt resistor, R3 (0.82 Ω), which is the only HV-negative path to chassis. The peak discharge current can be substantial, and damage to the meter shunt and movement can occur.

For example, if the filter-capacitors are at the 100-V level when the interlock shorts, the peak current through R3 is 100 V/ 0.82 Ω = *>100 A*. If a substantial voltage exists in the filter capacitors when the interlock shorts, R3 can be literally *blown away* by the discharge-current pulse! If the multimeter happens to be in the grid-current position, the meter can also be crispy-crittered. Meter damage can be avoided by parallel-reverse-connecting two ordinary 1-A (any PIV) silicon rectifiers across the terminals on each meter (see Fig 1).

For this reason, I removed the interlocks from both of my Heath amplifiers. Although this isn't necessarily a good thing for you to do, it isn't as unsafe as it sounds: the interlock protects you from residual charge in the HV filter capacitors, but it *does not* prevent operator contact with the potentially fatal voltage from the electric mains when the amplifier is plugged in and switched off. In other words, the safety interlock does not make the amplifier *safe.*

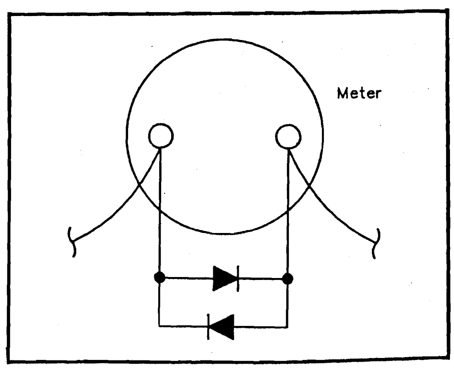


Fig 1—Meter damage caused by application of stored capacitor charge can be avoided by placing a pair of diodes across each meter movement.

For me, a major advantage of removing the interlock is that it allows the perforated cover to be removed for optimization of the tuned-input circuits (covered in Part 2). *There is no safe substitute for pulling the electric-mains plug before putting your fingers inside any amplifier.*

Intermittent Meter Readings

At least two problems can cause intermittent meter readings in the SB-220. If only the voltmeter exhibits this problem, the most likely cause is the three 4.7-MΩ, 1-W voltmeter-multiplier resistors (R6-R8). These resistors, which are rated at 350 V maximum per unit, are subjected to about *1 kV per unit* in the Heath circuit.[6] This can cause resistor deterioration, which leads to fluctuation and/or inaccuracy in the 0- to 3500-V meter indication. The abused resistors can simply be replaced with modern, 2-W flameproof spiral-film resistors designed to handle this voltage.

The other source of trouble lies inside the meters. Here's why: Different metals are used for the various parts of the meter. These parts, which conduct current to the meter armature, are fastened together with screws. Over time, moisture in the air causes electrolysis to take place at the junctions of the dissimilar metals. This increases the resistance at the junctions, causing intermittent meter indications.

This problem can be corrected by prying off the meter face, carefully removing the meter scale, and applying small dabs of conductive paint to all of the dissimilar metal junctions that carry current to the armature. (The conductive paint can be thinned with acetone to facilitate penetration into the narrow areas between the parts. As with any organic solvent, use extreme care when handling acetone—use it in a well ventilated area, don't get it on your skin or in your eyes, and don't breathe its vapors.) Allow conductive paint to dry for at least 15 minutes before replacing the plastic meter faces.

Transceiver-Relay-Contact Failure

During receive, the voltage across the ANT RELAY jack rises to about +115. A bypass capacitor, C52, is connected in parallel with this jack, so the capacitor charges to 115 V during receive. During transmit, the transceiver's relay (if one is used) places a short circuit across this jack—and the fully charged C52. The SB-220 relay-coil current is only about 25 mA, but the peak discharge current produced by placing a direct short on the charged capacitor can be surprisingly large. This action is like that of an electric spot welder. Over time, the contacts in the transceiver relay can become pitted and fail to make contact, or become welded together, causing the amplifier to go key-down continuously.

This problem can be corrected by placing a 100- to 200-Ω, ½-W current-limiting resistor in series with the center pin (blue wire)

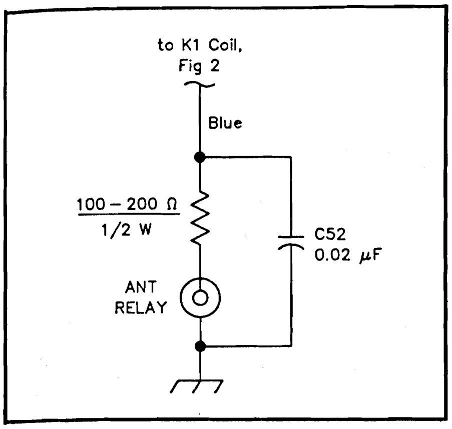


Fig 2—Transceiver-relay-contact pitting and eventual failure can result from use with the TR switching circuit in the SB-220. Adding a 100- to 200-Ω, ½-W resistor to the circuit as shown eliminates this trouble spot. All part numbers are those used by Heath.

on the antenna-relay jack. C52 must be connected to the blue-wire end of the resistor. See Fig 2. The drop across this resistor will be only about 5 V, which is insignificant to the 110-V relay coil.

The Filament Circuit

The most popular published modification for the SB-220 has been filament-inrush-current limiting. A large number of 3-500Zs in SB-220s suffered from filament to-grid shorts, so some people began to theorize that excessive filament-inrush current was the villain. Another theory was that the filament-to-grid shorts were caused by a manufacturing defect. Neither theory turned out to be true.

Curiously, none of the authors who wrote the SB-220 inrush-current-limiting articles published measured filament-inrush current. So, I decided to measure it with my HP 1706A oscilloscope. (After all, my name is Measures, so why not?)

Here's what I found: The maximum inrush current through the 3-500Z filaments in an SB-220 is only 60% of what Eimac allows. Heath accomplished this esoteric feat by the use of a special current-limiting core in the SB-220's filament transformer. The core is similar to those used in current-limiting neon-sign transformers. Externally, this core appears to be substantially different than the core used in the HV transformer.

The cause of virtually all grid-to-filament shorts in the 3-500Zs was later discovered to be a very brief, and usually very noisy, parasitic oscillation at roughly 110 MHz.[7] As will be discussed later, the large grid-current pulse that accompanies this oscillation creates a large electromagnetic pulse inside the 3-500Zs, pulling the hot filament wires off center, causing them to touch the grid cage.

Another interesting feature concerning the SB-220 filament circuit is that it normally operates near the low end of the recommended 3-500Z filament-voltage range; typically about 4.85 V (the recommended range is 4.75 to 5.25 V). This may not seem important, but according to Eimac, each 3% reduction in filament voltage (with no drop in PEP output) *doubles* the life expectancy of a 3-500Z. Thus, all other things being equal, the tubes in an SB-220 can be expected to last at least four times longer than the tubes in some other 3-500Z amplifiers.

For example, another (much more expensive)[8] 2 × 3-500Z amplifier that is considered by some to be a better designed, higher-output and more rugged amplifier than the SB-220 has a filament potential of more than 5.90 V at an ac-line supply of 240 V. This clearly exceeds the 3-500Z's maximum-filament-voltage rating, and reduces the useful emission life of the two 3-500Zs to only a few percent of what could have been realized if the tubes had been operated near the low end of the recommended filament-voltage range.

Although the filament circuit in the SB-220 needs no step-start circuit to protect the tubes from high filament-inrush current, there is another good reason to add such a circuit to the SB-220. If the amplifier is turned on in the SSB mode, when powered by stiff, 240-V ac mains, the inrush current through the power switch and other components is considerable. A step-start circuit will eliminate this potential source of trouble. (If an SB-220 is *always* started up in the CW/TUNE mode, and then switched to SSB, the inrush current is lower, and a step-start circuit is probably not needed.)

An easy-to-build step-start circuit is shown in Fig 3. In this circuit, the step-start relay can close only when the filter capacitors in the +110-V and HV power supplies have reached about ⅔ of their normal operating voltages of R1. If the step-start relay closes before the HV reaches ⅔ of its operating potential, increase the resistance of R1. If the relay closes unreliably, decrease the resistance (this will increase the current through the relay coil). If the circuit is functioning properly, the step-start relay will close about 1 second after turn-on, as the voltmeter indication passes the 2-kV level. The amplifier may be operated at "full throttle" 1 second after the relay closes.

The two 20- to 25-Ω, 10-W resistors and the step-start relay can be glued directly to the bottom of the chassis, directly under the filter-capacitor bank, using silicone-rubber adhesive.[9] The resistors should be held away from the chassis by a few millimeters by the silicone rubber. (This mounting method is appropriate because drilling mounting holes in this area could harm the filter capacitors.)

Because the step-start relay adds to the current burden on the +110-V power supply, it is a good idea to replace the stock, half-wave rectifier (D16) with a full-wave-bridge rectifier. If you do this, unground the grounded red wire on the transformer's 80-V-RMS winding and connect it to the input of the full-wave-bridge rectifier.

Adding a Standby Switch

Another popular modification for the SB-220 is the addition of a standby switch. A standby switch is really not necessary in this amplifier because the SB-220 uses "instant-on" tubes (3-500Zs use directly heated cathodes, which require only a very brief pre-use warmup period) and a current-limiting filament transformer. Because this transformer is very gentle to the filaments, the amplifier can be switched

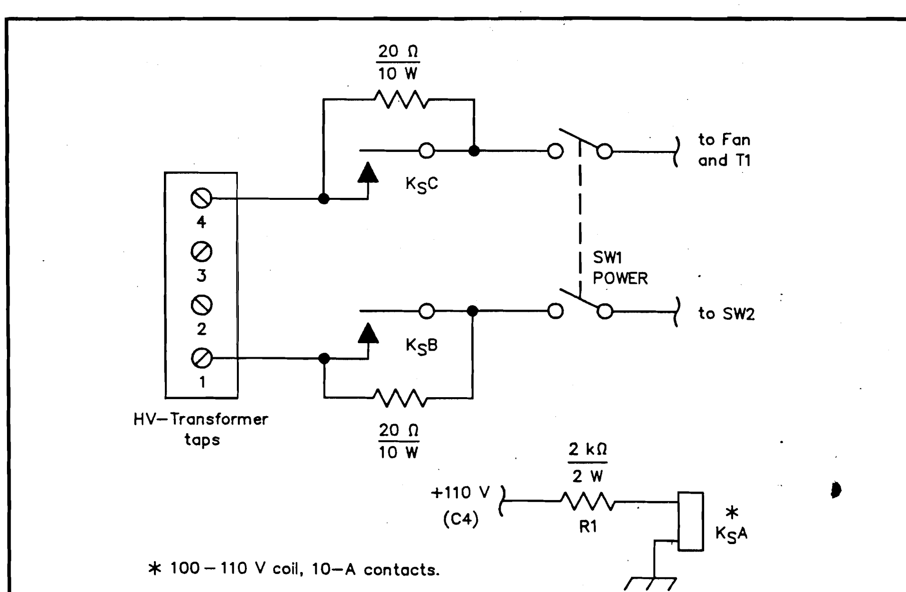


Fig 3—Adding a step-start circuit to the SB-220 minimizes power-on component stress. A 12-V-coil relay can be used in place of the 100- to 110-V unit; if you do so, connect the coil through R1 to the 5-V filament winding via a full-wave voltage doubler, and decrease R1 to about 20 Ω.

on or off as often as you like with no problem—with one exception: If you have just made a long RTTY or FM transmission, the glass-to-metal seals in the 3-500Zs should be allowed to cool for about 1 minute before you switch the amplifier off.

HV-Rectifier Protection

In the early 1960s, silicon-rectifier manufacturing technology was hit and miss. There was considerable variation between individual rectifiers of the same type. This variation led designers to use resistor-capacitor equalizer circuits in parallel with each rectifier. Today, silicon-rectifier manufacturing technology has improved considerably; rectifiers of the same type have very uniform parameters. Strings of identical, modern silicon rectifiers do not need to be equalized.[10] Unfortunately, old habits die a slow death, and many hams are still using outdated design methods. Much has been written about adding equalizing resistor-capacitor protection networks across the rectifiers in the SB-220's HV power supply. Unfortunately, these "protection" circuits not only *do not* perform as advocated, but they can lead to premature rectifier failure.

Here's why: The ½-W resistors typically used for voltage equalization are rated at 250 V maximum. How can a 250-V-rated resistor be trusted across a 600- or 1000-V rectifier? If anything breaks down in a series-rectifier circuit, it's like dominoes falling. One resistor failure can wipe out the remaining good parts in a series circuit.

The most frequent cause of failure in HV power-supply rectifiers is excessive reverse current. This problem can be eliminated if the total peak-inverse-voltage capability of the series-connected rectifiers substantially exceeds the peak voltage encountered in the circuit. In any series circuit, the current in all of the elements is exactly equal. The rectifiers are all in series, so, the reverse-current burden is exactly the same for each rectifier. How is it that things that are exactly equal need to be equalized?

During the half-cycle application of reverse voltage, it is important that all of the rectifiers in a series leg have similar junction capacitances. If they don't, then the reverse voltage across the lower-capacitance rectifiers will be greater than the voltage across the higher-capacitance rectifiers. Here's why: In a series circuit, smaller capacitors charge faster—and to a higher voltage—than larger capacitors.

Approximately 0.01 µF of bypass capacitance across each rectifier is probably a good idea if, for example, 1-A rectifiers are placed in series with 6-A rectifiers, because of the wide difference in junction capacitances between 1- and 6-A rectifiers. If all of the rectifiers in a series leg are similar, they will all have similar junction capacitances, so no external capacitors or resistors are needed.

Long ago, before they knew better, some commercial high-voltage silicon-rectifier-stack manufacturers used internal RC equalizing networks. These manufacturers stopped using these networks for the same reasons that were previously outlined. I don't know of any commercial HV-rectifier manufacturer who has not abandoned this malpractice.

Rectifier Failure

When a silicon rectifier fails from excessive reverse-current, the rectifier will short-circuit. This failure mode is very rare in SB-220s because the per-leg total rectifier PIV rating (more than 4.2 kV) is more than 1 kV higher than the actual PIV (3.1 kV) in the circuit. This is a conservative design; during a voltage surge, the chain of eight electrolytic filter capacitors, which is rated at 3.6 kV max, would likely fail before a 4200-PIV rectifier string.

A much more common type of rectifier failure in early production SB-220s is rectifier opening. This is caused by a defective spot weld inside the silicon rectifier. Eventually the weld breaks and the rectifier opens. The forward voltage jumps the gap at the open weld. When this happens, the heat generated by the arc blows a hole in the rectifier and a 60-Hz arc can usually be heard from inside the amplifier when current is being drawn from the HV supply. It is important to switch off the amplifier *immediately* when this noise is heard. Here's why: In a full-wave, voltage-doubler rectifier circuit, there are two series-connected filter capacitors.[11] One capacitor charges during the positive half of the cycle; the other charges during the negative half of the cycle. The two capacitors discharge in series. If one of the filter capacitors is not being fully charged by its rectifiers, when current is being drawn from the supply, the capacitor that is being charged may force reverse current through the capacitor that is not being fully charged. If unchecked, reverse current will cause electrolytic capacitors to discharge their corrosive electrolyte through their safety vents. In other words, reverse current will destroy polarized electrolytic capacitors in short order. Here's another measure of protection against this cause of capacitor failure: Place a reverse-biased rectifier diode across each capacitor. This allows reverse current to flow through the diodes, not the capacitors.

The Antenna and Bias Relay

A single three-pole relay switches the amplifier in and out of the coaxial line during operation, and handles tube-bias switching as well. A few improvements are in order in this area. See Fig 4.

- Add a diode across the relay coil to absorb the reverse-voltage spike that occurs when current stops flowing in the coil. This prolongs relay-coil-insulation life and quenches the magnetic pulse generated by the coil when it's switched off. If the magnetic pulse is unchecked, it can trigger the transceiver's VOX circuit and cause other problems.
- In the stock wiring configuration, +110 V is connected to a terminal of the relay. During receive, the relay connects this voltage to the center tap of the filament transformer, which is the dc cathode-current path to the 3-500Z filaments. The positive cathode voltage causes the tubes to cut off during receive by pulling the grids 110 V more negative than the cathodes.

A sticky problem arises if one of the tubes develops a filament-to-grid short (which, as mentioned earlier, is frequently the result of VHF parasitic oscillation). Because each grid is grounded for dc, a shorted tube also short-circuits the +110-V antenna-relay power supply, which is derived from the *unfused* filament transformer. Thus, if a filament-to-grid short occurs and the amplifier is not switched off *promptly*, the filament transformer will literally *melt down and short out*, and the black tar that comes out of the overheated transformer makes an unpleasant mess inside the amplifier. There are more pleasant ways to spend a Saturday morning than changing a smoked filament transformer!

This potential source of grief can be eliminated if the relay is rewired as shown in Fig 4. This circuit uses resistor-cutoff bias, using the existing 100-kΩ resistor (R27), which is rewired to another relay terminal. The current through this resistor during receive is usually less than 0.25 mA (R27 dissipates less than 7 mW), so its ½-W rating is more than adequate.

- The antenna relay is mounted on a rubber grommet. This was intended to reduce the vibration that the relay transmits to the chassis, which would otherwise act as a sounding board. Over time, the grommet hardens, increasing the acoustic noise generated by relay operation. This problem can be corrected by removing the mounting screw and the grommet from the top of the chassis and applying a small dab of silicone-rubber adhesive through the hole.

After the silicone rubber cures, an additional noise reduction can be gained by installing U-shaped strips of thin, flexible copper ribbon near the relay in series with the stiff wires soldered to relay terminals 4, 6, 7 and 9. The stiff wires should be shortened by about ¼ inch before the U links are soldered in. The flexible U links act as shock absorbers, and keep the stiff copper wires from transmitting vibration from the relay to the chassis. This simple modification results in a substantial noise reduction.

- During "barefoot" operation on 10 meters, when the amplifier is switched off, the SWR presented to the rig by the amplifier is less than wonderful. This is due to the inductive reactance in the amplifier's TR relay. The relay's inductive reactance can be canceled by adding capacitive reactance between a relay terminal and chassis ground (see Fig 4). The required capacitor

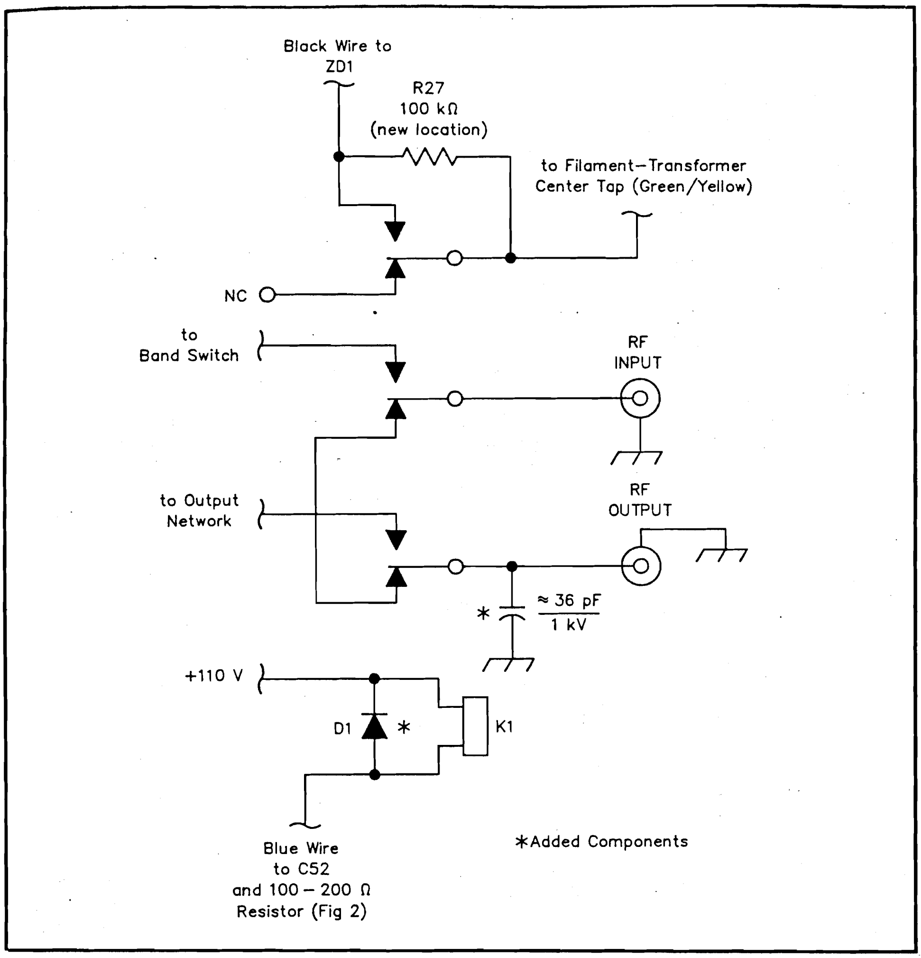


Fig 4—TR- and bias-switching-circuit modifications for the SB-220.

is usually about 36 pF (plus or minus a few standard 5% values) and should have at least a 1-kV rating. If you use a ceramic capacitor for this, the NP0 type is best.

Parasitic Oscillations

The most serious design weakness in the SB-220 is its tendency to support an intermittent VHF parasitic oscillation at roughly 110 MHz. This problem is far from being unique to the SB-220. I know of no model of commercial HF or MF/HF, ham-band, grounded-grid amplifier that has not occasionally had a VHF parasitic oscillation.

Briefly, the heart of the SB-220's VHF-parasitics problem lies in the use of high-VHF-Q copper conductors between the tuning capacitor and the anode connections (plate caps) on the 3-500Zs. The high-VHF-Q parts include the factory-stock parasitic suppressors!

This problem can be easily corrected by constructing low-VHF-Q parasitic suppressors with VHF-lossy nichrome, or even lossier nickel-chromium-iron alloy wire, and replacing the copper braid between the dc-blocking capacitor and the top of the HV RF choke with a pair of unequal-length nichrome wires.[12,13]

During the production life of the SB-220 and its successors, Heath made two changes in the amplifier's design that were related to the parasitic-oscillation problem. One change was to increase the voltage rating of the tuning capacitor, and the other was to decrease the values of the grid-to-ground capacitors from 200 pF to 115 pF. Three of these capacitors are used on each 3-500Z. The more-reactive 115-pF units canceled some of the internal grid inductance in the 3-500Zs, increasing the grid's VHF self-resonant frequency, making the amplifier slightly more stable. Unfortunately, this was not a sure cure.

Judging from numerous on-the-air and telephone conversations I've had with SB-220 users, Heath received many complaints from SB-220 owners who reported arcing at the tuning capacitor. In response to these complaints, Heath used a higher-voltage-rated capacitor in later amplifiers. That turned out to be a serious mistake.

Here's why: The original tuning capacitor already had a substantial breakdown-voltage safety factor, considering that the maximum peak (HF) RF anode potential in the SB-220 is less than 2.6 kV. The arcing was not being caused by normal HF RF voltage peaks: It was being caused by intermittent VHF parasitic-oscillation voltage. Increasing the voltage rating of this capacitor did stop the arcing at the capacitor, but it shifted the parasitic arcing to the output band switch as the parasitic voltage sought out the path of least resistance. If the band switch's contact spacing was increased to stop the band-switch arcing, the new, wide-spaced tuning capacitor would probably begin arcing.

Pitting on the plates of an air-dielectric variable capacitor can be cleaned up with a file, and the capacitor will be as good as new. Arcing on the fragile contacts of a band switch, however, is frequently fatal to the band switch. Heath didn't make a good trade in this case, but they didn't know what was causing the arcing at the time. Now that we understand parasitic oscillations in MF/HF amplifiers—and the cures for them—we can easily fix this problem.

The SB-220 is a well-designed amplifier. The fixes described here, and those covered in Part 2, considerably improve the SB-220's performance and life span.

Notes

1The SB-220 and the later SB-221 (like the SB-220, except that operation on the 10-meter band was not enabled at the factory) are considered to be identical for the purposes of this article. All part numbers referenced in this article are those used in Heath's SB-220 construction/operation manual.

2Unless specified otherwise, my statements about the SB-220's design are based on reverse-engineering and discussions with Heath's engineering staff.

3The filament pins receive a considerable amount of heat through conduction from the filament. The amount of heat present requires that continuous forced-air cooling be directed at the filament pins, even on standby.

4WD-40®, LPS and similar products are *not* non-gumming.

5This oil can be purchased in stores that sell fishing reels and/or firearms. Ordinary 10 or 20 SG-grade motor oil can also be used.

6When the SB-220 is powered from 120 or 240 V, the no-load HV is very close to 3 kV.

7R. Measures, "Parasitics Revisited—*Part 1,*" *QST*, Sep 1990, pp 15-18; and R. Measures, "Parasitics Revisited—*Part 2,*" *QST*, Oct 1990, pp 32-35.

8Just because something is more expensive doesn't necessarily mean it's better. For an extensive treatment of this subject, see "The Emperor's New Clothes" by Hans Christian Andersen.

9The areas to be bonded should first be degreased. After the step-start parts are in place, do not disturb the amplifier for at least 24 hours while the silicone-rubber adhesive cures.

10This subject is discussed in detail in S. Katz, "Diode Failure," Technical Correspondence, *QST*, Apr 1988, pp 46-47.

11In the SB-220, each of these two capacitors is made from four 200-μF, 450-V capacitors in series. Thus, the four capacitors in each leg act as a single 50-μF, 1.8-kV capacitor.

12If you would like to receive a 2-page information package and price list for improved parasitic-suppressor retrofit kits, send me a postcard or a QSL with your address.

13See note 7.

Circuit Improvements for the Heath SB-220 Amplifier—*Part 2*†

Have you made the modifications covered in Part 1? Here's more—much of which applies to other 3-500Z amplifiers, too.

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The Heath SB-220 was well designed, which is why so many of them are still in regular use. In Part 1 last month, I described how to eliminate weaknesses in the high-voltage power supply and other areas to increase the performance and service life of the SB-220 (and its descendants, the SB-221 and HL-2200). As in Part 1, all part numbers referred to in the text and diagrams, unless specified otherwise, are those used by Heath in the SB-220 documentation.

3-500Z Grid Protection

It's a good idea to replace each grid-to-ground RF choke (RFC-4 and RFC-5) with a 24- to 30-Ω, ½-W grid-fuse resistor. In the event of a parasitic oscillation or some other serious problem, the grid-fuse resistors open and protect the grids from excessive current. Carbon-film resistors are good for this application because they are much less able to withstand overloads than metal-oxide-film resistors (or the stock RF chokes, for that matter). In this application, we *want* them to blow up (fail open) in the event of a grid-current surge.

In order to protect these frangible resistors from RF during normal operation, the total grid-bypass capacitance per tube socket should be increased to at least 1800 pF. This capacitance is necessary if you use the amplifier on 10 or 15 meters in a continuous-carrier mode.

Zener-Diode Replacement

One of the more-common casualties during a VHF parasitic oscillation is the cathode-bias Zener diode. Because cathode current is the sum of the tube's anode and grid currents, the cathode Zener diode gets zapped by the large grid-current pulse that accompanies a VHF parasitic oscillation. This is the same current pulse that causes the vast majority of filament-to-grid shorts in SB-220 3-500Zs. This pulse also blows away R3 (the grid-current-meter shunt resistor), the multimeter movement (if the multimeter switch is in the grid-current position when the current pulse occurs), the stock, 1-mH grid-to-ground RF chokes, and the 200-pF mica grid-to-ground capacitors.[14]

Three disadvantages of Zener diodes are: they aren't adjustable; they can't take high current pulses; and, at least for high-power applications, they're expensive. A cheaper, more rugged, step-adjustable replacement for a 5.1-V, 10-W Zener diode (ZD1) can be made from a forward-biased series string of about seven 2.5-A rectifier diodes. These diodes can be mounted on a piece of perf board and placed in the power-supply section. Be sure to connect the diode string for forward bias—not reverse bias, like a Zener diode.

The replacement circuit is shown in Fig 5. The voltage can be controlled (in ≈0.8-V steps) by adding or subtracting diodes. This allows you to easily set the zero-signal (idling) anode current for the two 3-500Zs. The SSB-mode idling current should be 160 to 200 mA for best linearity.

Adding Full Break-In (QSK)

Full-break-in operation (less than 3-ms turnaround) can be added to the SB-220 for under $100—*if* you know where to buy the parts. The circuit is simple to construct and uses no exotic parts. The most expensive part is the high-speed vacuum relay, which can be purchased new (surplus) for about $75, or for about $120 (new) from Jennings or for about $100 new from Kilovac. The required RF-input relay can be purchased from Kenwood's Parts department (tel 800-637-0388) for about $11.

¹Notes appear on page 43.

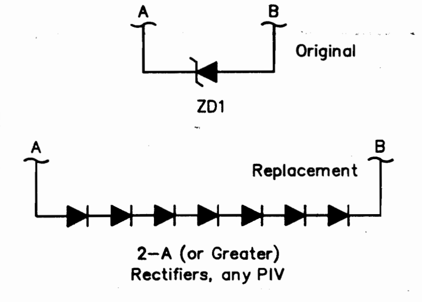

Fig 5—Replacing the cathode-bias Zener diode with a string of series-connected silicon-rectifier diodes allows easy adjustment of amplifier idling current.

Even if you don't operate much QSK CW, this modification is still worthwhile, because it makes working SSB VOX much more enjoyable. The relays are so fast and inconspicuously quiet, it's almost like talking on the telephone or in person.

The QSK circuit, suitable for the SB-220 and the Kenwood TL-922, was published in March 1989 *HAM RADIO*.[15] That article is not error-free, but it gives a basic idea of how the QSK circuit works. One of the features of this QSK circuit is that the electronic cathode-bias switch (ECBS) is always in perfect synchronization with the RF relays. In many other QSK circuits, this is not the case.

Here's why: In most QSK circuits, the ECBS is RF actuated. This may sound wonderful, but it is not so, because RF actuation allows the 3-500Zs to be switched in and out of their linear operating regions during and between softly spoken syllables on SSB. The result is increased IMD and splatter as the bias wanders between linear and nonlinear operation during speech. Making the RF relays and the ECBS RF actuated is not a suitable solution because this causes the RF relays to hot switch on every closure. A properly designed QSK circuit puts the QSK transceiver's amplifier-control line *completely* in charge of the amplifier. In this way, the 3-500Z bias is correct for linear operation any time the RF relays are actuated.

To ALC, or Not to ALC?

If you're using a Swan 500 (or some other high-power SSB rig) to drive your SB-220, you definitely need to use the amplifier's ALC (automatic level control) circuit. (If you're overdriving an amplifier in this way, I also recommend that you *not* display your call sign prominently at ham conventions and swap meets; this may help to avoid an unpleasant situation that may result in a spontaneous tar-and-feathering.)

If your transceiver output is less than about 130 W PEP, using ALC with your

†Part 1 of this article appeared in *QST*, Nov 1990, pp 25-29.

SB-220 is of no value, because your rig can't overdrive the amplifier.[16]

Operation on the 12- and 17-Meter Bands

One of the main problems with using older-design, ham-band-only amplifiers on the 12- and 17-meter bands is choke fires. Here's what happens: When a high-voltage RF choke is operated at or near one of its series-resonant frequencies, an extremely high RF voltage appears across the choke. This voltage can easily exceed four times the supply voltage, and can cause the insulation on the choke windings to break down and ignite. Amplifier manufacturers are careful to design RF chokes so that no resonances occur near the bands on which the amplifier is designed to operate, but the SB-220 was designed years before we acquired the 12- and 17-meter bands at WARC-79.

To prevent choke fires, all operating frequencies should be more than 5% away from any of the choke's series-resonant frequencies. The SB-220 operates well on the 12- and 17-meter bands because, fortunately, its HV RF choke doesn't have any series resonances below 40 MHz.

If you use a transistor-output transmitter to drive an SB-220, the amplifier's tuned input circuits for the 10- and 15-meter bands should be optimized for this purpose. (More on this later.) The only potential problem associated with 12- and 17-meter operation with the SB-220 is the increased current burden on the output band switch.

Here's why: In order for the amplifier to tune to the new frequencies without increased output-circuit inductance, the tuning and loading capacitors must be adjusted for about 35% more capacitance than optimum for the band-switch settings involved (15 m for 17-m operation, and 10 m for 12-m use). This increases the operating Q of the output π network by about 18%, which increases the RF-circulating current in the band-switch contacts by the same factor. Because power is proportional to the square of current, the increase in band-switch-contact dissipation is 1.18^2, or 1.39—a 39% increase in the power (heat) dissipated by the band-switch contacts.[17]

This is unlikely to be a problem for normal SSB operation without speech processing. For higher-duty-cycle operation, the amplifier should be switched to the lower-voltage CW/TUNE position in order to reduce the average heat dissipation in the output-band-switch contacts during operation on 12 and 17 meters.

Improving Input SWR

The tuned input circuits (Fig 6) in the SB-220 typically exhibit a maximum input SWR of about 1.9:1 (referenced to 50 Ω resistive). This is satisfactory when tube-output radios (and some solid-state rigs, such as those with internal antenna tuners) are used to drive the amplifier. Nowadays, though, transistor-output rigs with high-SWR protection are used extensively. Many transistor-output radios are so particular that they begin to cut back output when operating into a reactive load with an SWR as low as 1.2:1. Translation: The amplifier will not receive full drive power unless it has a very low input SWR. On many bands, this is the case with stock SB-220s. For those bands where this isn't the case, fortunately, the input SWR can be easily improved.

The job of a tuned input circuit is more complicated than just matching the input resistance of the amplifier tubes to 50 Ω. Here's why: The instantaneous input resistance of a class-B grounded-grid amplifier fluctuates wildly during the voltage swings of the sinusoidal input signal. When the input cathode voltage swings positive, the grounded grid looks negative with respect to the cathode, the tube is completely cut off; thus, the input resistance is nearly infinite. During the negative input-voltage swing, the grid looks more positive and a large current flows in the tube—the input resistance is very low.

For example, when the voltage driving a pair of 3-500Zs peaks at −117 V, the anode current is at its peak, the instantaneous anode voltage is swinging to its lowest point (about +250 V), and the total cathode current is 3.4 A.[18] Thus, the driving resistance at this point, R_{in}, is −117 V ÷ 3.4 A = 34.5 Ω and, incredibly, P_{peak} = −117 V × 3.4 A = *397 W.*

Thus, the resistance swings from nearly infinity with positive driving voltage, all the way down to 34.5 Ω.[19] The drive-power requirement varies from 0 W to 397 W over the positive and negative travel of the input signal! This is *not* the type of load that makes for contented transistor-output transceivers.

During the positive input-voltage swing, there is virtually no load on the driver, so the input circuit must store the drive energy until it is needed the most: during the negative input-voltage crest. Thus, the tuned input circuit's job is to act as a flywheel-like energy-storage system—*and* as a matching transformer.

Circuit Q is like the inertia of a flywheel. More Q makes for a better RF flywheel, which does a better job of smoothing the wild swings in input resistance. This results in a stable, lower input SWR. The trade-off is that higher Q means less bandwidth.

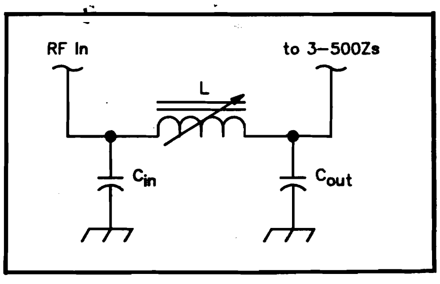

Fig 6—A typical SB-220 tuned input circuit. Changes in circuit Q, required for best amplifier-input SWR, are made by increasing C_{in} and C_{out}, and by removing turns from L.

With a too-high Q, the input SWR may be nearly 1:1 at the center of the band, but too high at the band edges. Thus, a compromise must be made.

Eimac® recommends using a Q of 2 for the tuned input circuits in a grounded-grid amplifier. As I will show, the SB-220 uses a Q of only about one. This is why the stock SB-220's input SWR is less than wonderful. (The SB-220 isn't the only one: Other commercial amplifiers designed in the era before transistor-output transceivers were common also used a Q of 1 *or even less.*)

Circuit Q is the ratio of the tuned input circuit's input resistance (50 Ω) to the reactance, in ohms, of the input capacitor (X_{Cin}). For example, in the SB-220, the 40-meter input capacitor (C42) is 470 pF. The reactance of C42 (X_{Cin}) at 7.15 MHz is $-j\,47.4$ Ω. Thus, the SB-220's input-circuit Q at 7.15 MHz is 50/47.4 = 1.05.

When the Q of a tuned input circuit is too low to start with, no amount of output-network adjustment can bring the input SWR down to an acceptable level. Improving the input SWR of an SB-220 is simple: increase the Q by decreasing X_{Cin} in the tuned input circuits. Because X_C is inversely proportional to C, this means more C_{in} is needed.

The resistance-matching ratio of a tuned circuit like that shown in Fig 6 is quasi-proportional to the X_C ratio of C_{in} to C_{out}. If C_{in} is increased to increase circuit Q, C_{out} must also be increased to maintain the same resistance-matching ratio. (In this case, that ratio is 50 Ω to 69 Ω.) Increasing both capacitances lowers the operating frequency of the tuned input circuit, so L must be decreased to bring the operating frequency back up to where it started. This can be accomplished by removing turns from the inductor and/or by adjusting the inductor's tuning slug.

Keep in mind that the matching ratio of a tuned circuit like the one shown in Fig 6 cannot be changed by adjusting the inductor alone. At least *two* component values must be adjusted to change the matching ratio of such a circuit.

Another factor that affects SB-220 input SWR is inductor Q. Higher inductor RF resistance corresponds to lower Q and worse SWR. Smaller wire has more resistance than larger wire, so it's important to use adequately large wire for these coils. As frequency increases, skin effect becomes more predominant, resulting in increased wire resistance. To compensate for this, the wire diameter must be increased in proportion to frequency.

For example, in a tuned input circuit operating at 1.8 MHz with 100 W of applied RF, the wire should be at least no. 24. At 29 MHz, no. 16 or larger wire is appropriate. In general, you can't go wrong by choosing a larger-diameter wire—unless it won't fit on the coil form.

A Q of 2 is usually slightly more than optimum if you need to cover a large frequency spread with a single input circuit. Prime examples are coverage of 3.5 to

4 MHz and 18 to 21.5 MHz (so that the 15-meter tuned input circuit also covers the 17-meter band). In these cases, a Q of about 1.5 should be used. This also applies to a 10-meter tuned input circuit if the amplifier will be used on the 12-meter band.

A Q of 1.5 corresponds to a reactance of about 33.3 Ω ($X_{C_{in}}$ = 50 Ω/1.5 = 33.3 Ω) for C_{in}. At 3.75 MHz, this requires a 1275-pF capacitor.[20] (The nearest standard value is 1300 pF.) Of course, capacitors can be paralleled to arrive at the desired C.

Measuring amplifier SWR is a very vague science. For example, different SWR meters give different readings in the same circuit! Changing the length of coax between the SWR meter and the amplifier can also change the indicated SWR. Another complication is that modern transistor-output transceivers, in order to maintain clean output signals, generally use a set of switched, 1.5-octave output filters. At the extremes of such a filter's passband, such as at 29 MHz, the filter can introduce reactance into the transmission line. This reactance can cause some peculiar results when you're trying to optimize the SWR of an amplifier's tuned input circuits.

For those who can do so, the easiest way to avoid this problem is to use a tube-type exciter when optimizing the SB-220 input circuits. The exciter must be tuned for maximum power into a 50-Ω termination, and then should not be retuned during adjustment of the input network's inductance and C_{out}. Retuning the exciter may introduce a reactance that will affect the indicated SWR.

If the tuned input circuit's Q has been increased by increasing C_{in} and decreasing L, C_{out} will also need to be increased. The easiest way to find the new (higher) optimum value for C_{out} is by inserting a trimmer in parallel with the stock C_{out}. Then, with the maximum peak drive power applied, alternately adjust L and C_{out} for the best match at the center of the band. C_{out} can then be removed, its capacitance measured, and a fixed capacitor of that value permanently installed in its place.

Adjusting the amplifier's tuned input circuits is much easier with the front panel removed, but the meter leads need to be lengthened to facilitate this. Also, a chassis-ground wire must be added between the panel and the amplifier chassis so that the multimeter will function when the panel is separated from the rest of the amplifier.

If the amplifier is driven with a continuous carrier, considerable stress is placed on the HV power supply, and the RF compartment becomes very hot. This stress can be reduced if the driver is set to the CW mode and keyed with a string of 50- to 60-WPM dots. The amplifier's current-meter readings should be approximately doubled to determine the actual current (meter inertia affects the readings, though, so this technique can't be used for exact measurements).

It's very important to avoid contacting the nearby HV feed-through insulator while you're adjusting the input networks. Doing so could result in your untimely appearance in Silent Keys. A reasonable way to avoid this is to use insulated tuning tools and to stand on a plastic mat with one hand behind your back during tuning. It's also advisable to wrap some 1-inch (25 mm) plastic electrical tape around the nuts on the HV feed-through insulator before plugging in the amplifier.

Table 1

Starting Points for Optimizing the SB-220's Input Networks

Band	*C_{in} (pF)*	*L (turns removed)*	*C_{out} (pF)*
80 m	2 × 680	4	1300
40 m	820	4	680
20 m	360	1	270
15 m	270	2	180
10 m	180	2	130

Notes

1. This amplifier did not have a pair of series-resonant RLC parasitic suppressors (25 pF/1 Ω) from the cathodes to ground. (These parts are supplied with some of my retrofit kits.) If these suppressors are installed in your amplifier, subtract 50 pF from each C_{out} value shown.
2. This amplifier was equipped with two 10-Ω (5 Ω net) cathode resistors (R_C). (See R. Measures, "Amplifier-Driver Compatibility," *QST*, Apr 1989, pp 17, 18, 20.) These resistors increase the input resistance of the 3-500Zs by about 8%.
3. The ALC circuit had been removed from this amplifier. This slightly reduces the load capacitance on the tuned input circuit.
4. The capacitors are 500-V mica units.

If you would prefer not to work around lethal voltages, you can adjust the tuned inputs without applying high voltage to the anodes of the 3-500Zs. Here's how:

1. Make the appropriate changes in the tuned input circuits with the amplifier unplugged (removing the inductors for modification is described shortly).
2. Disconnect the red secondary wire of the HV transformer from the rectifiers. Insulate the loose wire.
3. Reconnect the amplifier to the electric mains, key and drive the amplifier with about 5 W initially.
4. Observe the grid-current meter and apply only enough drive to obtain 250 mA or less grid current.
5. Adjust L and C_{out} for the best SWR.

This method is not as accurate as the full-power adjustment method, but it is safer. Table 1 shows the optimum values I found for the tuned inputs, using the full-power adjustment method. Other experimenters have reported finding slightly different optimum values, especially on 10 meters, so the best values for your amplifier may be slightly different than those listed in Table 1.

Removing the Tuned-Input-Circuit Inductors

It's much easier to remove turns from the inductors when the inductors have been removed from the amplifier. The inductors are fastened to the chassis by two spring tabs in the base of each inductor. When the inductor base is pushed through its mounting hole, the spring tabs are compressed as they pass through the hole. After passing through the mounting hole, the tabs spring out and lock in the inductor base.

To remove an inductor, both spring tabs must be compressed. The upper spring tab can be easily compressed with a screwdriver blade; the lower tab is difficult to reach without a special tool.

I made this tool out of 1/8-inch-diameter piano wire, which can be purchased in 36-inch lengths in many hobby shops. Here's one method of making the tool: Using a bench grinder or a hacksaw, cut off about 12 inches of wire. With a pencil-point flame from a propane torch, heat a spot on this 12-inch piece about an inch from one end of the wire, and when the metal is glowing red, grasp the end near the flame with pliers and bend an 85° angle in the wire. Let the thing cool.

The long end of this wire tool is the handle. Hook the short end under the inductor base and pull straight up to compress the lower spring tab.

Adding 160-Meter Coverage to the SB-220

Unfortunately, a number of technically unsound 160-meter conversions for the SB-220 have been published. Most of these conversions unnecessarily discard the original filament and/or HV RF chokes and ignore RF-design rules. A better 160-meter conversion can be found in January 1989 *QST*.

Conclusion

The Heath SB-220, and its younger cousins, the SB-221 and HL-2200, can provide many years of trouble-free service. All they need from their owners are a few circuit improvements, annual cleaning and regular fan oiling. If you have questions or comments about this or any of my articles, feel free to telephone me at 805-386-3734.

Notes

[14]In later models, the grid-to-chassis capacitors were changed to 115 pF.

[15]If you would like a copy of the original, 6340-word unedited, unexpurgated article with three pages of diagrams, which contains corrections and a better list of parts suppliers than the *HAM RADIO* version, I'll send you one for $2 (postpaid) via First-Class mail. For overseas airmail delivery, add $2.

[16]For more information, see R. Measures, "Amplifier-Driver Compatibility," *QST*, Apr 1989, pp 17, 18, 20.

[17]During use, the metal in the contacts gets hotter because of the increased current. This probably increases contact resistance, and thus, contact dissipation probably increases by more than 39%.

[18]At the instant of peak current, the grid current per tube is about 0.5 A, and the anode current per tube is about 1.2 A. Thus, the peak cathode current is 1.7 A per tube. This represents a meter-indicated anode current of about 800 mA for two 3-500Zs.

[19]The average input resistance for a pair of 3-500Zs is twice this value (about 69 Ω).

[20]The capacitors used should be 500-V silver-mica or 1-kV ceramic NP0 units.

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