OPERATING AND MAINTENANCE INSTRUCTIONS

THERMOTROL*

MODELS 1053, 1253, 1109, & 1140

HALLIKAINEN INSTRUMENTS
1341 Seventh Street
Berkeley 10, California

*Design Patented under Patent No. 2838644

OPERATING INSTRUCTIONS

THERMOTROL MODELS 1053, 1253, 1109 & 1140

SHELL DEVELOPMENT DESIGN

PRINCIPLE:

The THERMOTROL is a general purpose laboratory temperature controller designed to control by any one of three methods: On-Off, Proportional, or Proportional with Reset.

For On-Off operation an AC Wheatstone bridge, with a resistance thermometer detector as the variable arm, is operated at balance using an adjustable ratio arm to select the temperature setting. A change in resistance produces an AC voltage which is amplified by a resistance coupled amplifier. This amplified AC voltage is then applied as a bias voltage to a thyratron tube which controls an enclosed mercury switch, turning the heater on and off.

During Proportional operation, a negative feedback signal is applied to produce an "on" period which is a function of the bridge unbalance voltage.

For Reset operation, a positive feedback circuit with an appropriate time constant is added to the negative feedback circuit to restore the AC bridge unbalance to zero.

CONTROLLERS IN GENERAL:

The optimum performance of a controlled system depends upon many factors other than the controller itself. For example, the bath liquid must be well stirred to avoid gradients. In any system it is advisable to supply heat to the point where it is being lost, otherwise a transfer of heat from another location will result in gradients. Time lag is to be avoided in heaters as well as in the temperature sensing elements.

The technique of placing the sensing element close to the heating element to obtain smooth control should also be avoided as this merely reduces the gain and introduces a droop for which the controller cannot compensate.

POWER:

The power required is 115 volt 60 cycle, 40 watts; for models 1053 and 1109, and 220 volt 60 cycle, 40 watts for models 1253 and 1140. The power connections are made by removing the back plate and connecting the leads to the lugs labeled "POWER" on the terminal strip. The letters H, N and G designate Hot, Neutral and Ground Legs of the power circuit, for 115 volt supply and H, H, N designate Hot, Hot, Neutral for 220 volt supply (see figures 5 and 6).

Load:

Models 1053 and 1109 are capable of supplying a maximum of 30 amperes (non-inductive) to a 115 volt. 60 cycle load circuit and models 1253 and 1140 a maximum of 20 amperes (non-inductive) to a 220 volt 60 cycle load circuit. The load connections are made on the same terminal strip on the back of the instrument to the terminals marked "load". These connections are polarized the same as those for power, H, N and G, and H, H and N.

Two terminals labeled "SPARE" are provided for auxiliary use, such as for connecting a stirrer. These terminals are wired to a 115 volt source of power on models 1053 and 1109, and 220 volts on models 1253 and 1140 and are energized when the main switch is on.

THERMOMETER:

The thermometer leads are also connected to the terminal strip at the back of the instrument. The terminals are labeled 1, 2, 3 and 4.

Standard Thermometers are listed below. Bulbs having other ranges or specifications than those listed are available on request.

THERMOMETER BULBS - LIQUID

MODEL 1221 - Nickel wound resistance bulb in stainless steel sheath, thin walled flat sensitive portion, response time 0.8 seconds, length 2-15/32" below thread, with AN connector and 5 feet rubber covered 4-conductor cable, 7/8"-14 NF mounting thread; range -70°C to 200°C.

MODEL 1080 - Bath type bulb using the same sensitive portion as Model 1221, with flange mounting, 5 feet rubber covered 4-conductor cable, overall length 10-1/4" below flange; range -70°C to 200°C.

MODEL 1106 - Bath type bulb similar to Model 1080, except with 1/2" NPT connection instead of flange mounting, overall length 10-1/4" below thread; range -70°C to 200°C.

THERMOMETER BULBS - AIR or GAS

MODEL 1085 - Nickel wound resistance bulb, 4" sensitive bare element with protecting guard, overall length 7-1/4" below flange, with 5 feet rubber covered 4-conductor cable, flange mounting; range -70°C to 300°C.

MODEL 1107 - Similar to Model 1085 except with 1/2" NPT connection for mounting, overall length below thread 7-1/4"; range -70°C to 300°C.

THERMOMETER BULBS FOR METAL BLOCK

MODEL 1144 - Flat sensitive element 1-7/16" long by 1/2" wide by .006" thick, mounted in Silicone impregnated Fibreglas block approximately 1-3/4" long by 1" wide by 1/4" thick; range -100°F to 300°F.

MODEL 1196 - Flat sensitive element molded in Silastic with stainless steel backing (.002" thick) for high temperature use. Sensitive element 1" square by 1/8" thick, mounted in Silicone impregnated Fibreglas block approximately 1-3/4" by 2" by 1/4" thick; range -100°F to 500°F.

The range of the THERMOTROL is determined by the range of the resistance thermometer bulbs used.

SENSITIVITY:

The temperature difference (or dead zone) required between "ON" and "OFF" operation is 0.001°C. It is specified in this manner rather than by how accurately it controls the temperature of a bath. In addition to the controller sensitivity, the temperature control of a bath involves the following factors; the time constants of the thermometer and heater, configuration of the bath components, stirring, etc.

The sensitivity of the THERMOTROL as a proportional controller is as follows:

Table 1

GAIN SWITCH POSITION	FRACTION OF MAX. GAIN	PROP. BAND TEMP. DIFF. 0 - 100% DUTY CYCLE °F	°C
Off	0	-	-
1	1/256	10.6	5.888
2	1/128	5.31	2.944
3	1/64	2.65	1.472
4	1/32	1.32	0.736
5	1/16	0.663	0.368
6	1/8	0.331	0.184
7	1/4	0.165	0.092
8	1/2	0.083	0.046
9	1	0.041	0.023

When the THERMOTROL is operated to regulate the set temperature of a bath using proportional and reset functions (see paragraph RESET), the Reset reduces the apparent Proportional band by a factor of 100. For example, if the gain switch is set on position No. 9, the Proportional band temperature differential, 0 - 100% duty cycle is 0.00023°C instead of 0.023°C.

RESET:

On any Proportional controller, the maximum gain that can be used depends solely upon the system being controlled. Higher gains result in "hunting" or oscillations about the set point, while lower gains produce a Proportional "offset" which is due to changes in "load" or heat demand of the system being controlled. In some systems it is necessary to use a relatively low gain in order to avoid "hunting". This, in turn, may cause an unacceptable Proportional offset, sometimes known as "droop", which is due to load changes. To overcome this, the function of Reset has been introduced in the THERMOTROL. This function reduces the droop to about 1% of that present in the absence of Reset. The principle described above has been used for many years in plant control systems, but it is applied to a laboratory controller for the first time in the THERMOTROL.

The reset rates provided on the THERMOTROL are adjustable as follows:

RESET RATE SECONDS On-Off, Proportional, 6, 9, 13, 19, 27, 40, 60 and 90.

OPERATION:

Connect the power, load and thermometer to the instrument terminals. These are located in the back of the instrument and are accessible by removing the back cover. Note that only one heater is required when the THERMOTROL uses Proportional and Reset operation, thus eliminating the multiple heaters commonly employed with an On-Off controller. The THERMOTROL supplies the power output by modulating the ratio of the On-Off action of the enclosed mercury relay K1. (See wiring Diagram.)

To obtain optimum control it is necessary to accurately adjust the Gain and Reset time. These controls are located on top of the chassis and are labeled Gain and Reset. Remove the four corner mounting screws on the front panel and

withdraw the instrument from the cabinet for access to "Gain" and "Reset" control knobs as shown in Figures 5 and 6. The adjustments are accomplished in the following manner.

With the THERMOTROL correctly connected to the system to be controlled:

1) Set Gain to positions "9", Reset to On-Off and the coarse and fine temperature control dials so that the controller operates at the desired temperature.

2) After the heater has cycled a few times, determine the period of the cycle (off to on to off) in seconds and note for future reference. One method of accomplishing this is to watch the pilot light on the front panel and measure the time, starting when the light just goes out at the end of the long "on" period to the time it just goes out at the end of the next long "on" period.

3) Set Reset to "P" (proportional) and adjust gain to maximum value possible without producing "hunting".

NOTE: The THERMOTROL proportions the heat output by time cycle modulations. Proper operation is indicated when the pilot light goes on and off about once per second in a steady manner. "Hunting" is present if the pilot light periodically increases and decreases its "duty cycle" or per cent "on" time. This action is not to be confused with On-Off type operation.

4) Set Reset to number of seconds noted in 2 above (or next higher value) and the adjustment is complete.

EXAMPLE CONTROL PROBLEM:

A 7 gallon water bath is to be controlled at 60°C. The control period is 22 seconds and the maximum Gain (proportional band) useable is 4 on the gain switch (see Table 1).

The THERMOTROL is set: Gain position 4 and Reset position 27 (see RESET RATE SECONDS).

The bath is designed to use a 250 watt control heater and it requires 120 watts input to control at the desired 60°C. The heat loss to the room is about 4 watts per °C above room temperature.

If this bath is controlled with a proportional controller having the gain (as determined) as 0.73°C and a 250 watt control heater, a change of 5°C in the room temperature causes a change of set point; -

$$T = \frac{L\ t\ G}{W}$$

$$T = \frac{4 \times 5 \times 0.73}{250} = 0.058°C$$

where:

T = Change in set point °C
L = Heat loss to room watts/°C
t = Temperature change of room °C
G = Gain 0 - 100% proportional band °C
W = Heater watts

If the power supply changes by 10 volts, the bath requires a change of set point of:

$$T = \frac{W - \frac{(V_2)^2 W}{(V_1)^2}}{W} \cdot G$$

where:

V_1 = Initial line voltage

V_2 = New line voltage

$$T = \frac{250 - \frac{(105)^2 \times 250}{(115)^2}}{250} \cdot 0.73 = 0.12°C$$

In either case the set point change is less than 0.001°C when Reset is used.

MAINTENANCE:

The wiring diagram of the THERMOTROL has the check voltages recorded. All DC measurements are made with a 20,000 Ohm per volt meter. The DC voltages are indicated by a rectangle and the AC voltages by parenthesis. All the test points are easily accessible on the tube sockets.

The following procedure should be used to determine that the THERMOTROL is operating properly:

1) Check all plate voltages. The voltages should be between 30 to 50 volts on stages 1, 2 and 3, and 170 volts on stage 4 (B+).
2) Set the Reset switch to On-Off control.
3) Connect two 100 Ohm carbon resistors between terminals 1 - 2, and 2 - 3.
4) Set Gain to "off" position. Connect oscilloscope lead to Test Point. The Reading on a calibrated oscilloscope should be less than 0.2 volts. If a higher reading is obtained, insert another 12AX7 tube in the first stage.
5) Remove the 2D21 thyratron tube from socket.
6) Set Gain to "off" position.
7) Set Reset switch to On-Off position. A DC meter connected between the test point and the chassis should indicate -2.2 volts, approximately.
8) Short the relay contacts by connecting a jumper from Power-H to Load-H. The meter should still indicate -2.2 volts, approximately.
9) Set Reset switch to "P" (proportional). The meter should now indicate -8.5 volts, approximately.
10) Set Reset switch to "6". The meter should read -2.2 volts, approximately.
11) Turn Reset switch through remaining positions to "90". The meter readings should remain the same over a period of time. Increasing negative voltage indicates leakage of the 4 mfd capacitor C5.
12) Replace the thyratron tube.

Parts List & Wiring Diagram Legend

Thermotrol

Models 1053A, 1053B, 1109A, 1140A

Item	Description	Part No.	No. Req'd
C1A	Capacitor, .001 mfd, 600 volt	DT 422	1
C1	" 10 mfd, 50 volt	DT 414	1
C2	" 10,10,10 mfd, 450 volt	DT 415	1
C3	" .03 mfd, 400 volt	DT 416	1
C4	" .05 mfd, 200 volt	DT 417	1
C5	" 4 mfd, 150 volt	DT 419	1
C6	" .007 mfd, mica	DT 418	1
C7	" 1 mfd, 200 volt	DT 420	1
C8	" 1 mfd, 200 volt	"	1
C9	" 8 mfd, 450 volt	DT 421	1
C10[c,d]	" .003 mfd, 200 volt	DT 435	1
D1	Rectifier, selenium, 20 ma	DU 404	1
D2	" " "	DU 405	1
E1	Resistance Thermometer. See Operating Instructions	-	-
F1[a,c]	Fuse, 1/2 Amp.	DV 409	1
F1B[b,d]	" 1/4 "	DV 417	1
K1	Relay, Mercury, 30 Amp. 115V, 20 Amp. 230V	EV 413	1
P1[a,c]	Pilot Light, with Neon Lamp	CN 425	1
P1B[b,c]	Pilot Light, with Neon Lamp	CN 426	1
R1	Resistor, Special, Manganin (approx. .945 ohm)	DY 479	1
R2	Potentiometer, 25 ohm, 5%, .5% Lin	DZ 417	1
R3	" 500 " " "	DZ 418	1
R4	Resistor, Special (Approx. 100 ohm)	Part of Item E	1
R5	Resistor, 47K Ohm, 1/2 watt, 5%	DY5EB47K5-1/2	1
R6	" 24K " " "	DY5EB24K5-1/2	1
R7	" 12K " " "	DY5EB12K5-1/2	1
R8	" 6.2K " " "	DY5EB6.25K5-1/2	1
R9	" 3K " " "	DY5EB3K5-1/2	1
R10	" 1.5K " " "	DY5EB1.5K5-1/2	1
R11	" 750 " " "	DY5EB750 5-1/2	1
R12	" 390 " " "	DY5EB390 5-1/2	1
R13	" 360 " " "	DY5EB360 5-1/2	1
R14	" 220 " " "	DY5EB220 5-1/2	1
R15	" 10K " " "	DY5EB10K5-1/2	1
R16	" 680K " " "	DY5EB680K5-1/2	1
R17	" 150K " " "	DY5EB150K5-1/2	1
R18	" 1M " " "	DY5EB1M5-1/2	1
R19	" 680K " " "	DY5EB680K5-1/2	1
R20	" 1M " " "	DY5EB1M5-1/2	1
R21	" 150K " " "	DY5EB150K5-1/2	1
R22	" 680K " " "	DY5EB680K5-1/2	1
R23	" 220K " " "	DY5EB220K5-1/2	1
R24	" 470K " " "	DY5EB470K5-1/2	1
R25	" 22M " " "	DY5EB22M5-1/2	1
R26	" 15M " " "	DY5EB15M5-1/2	1
R27	" 10M " " "	DY5EB10M5-1/2	1
R28	" 6.8M " " "	DY5EB6.8M5-1/2	1

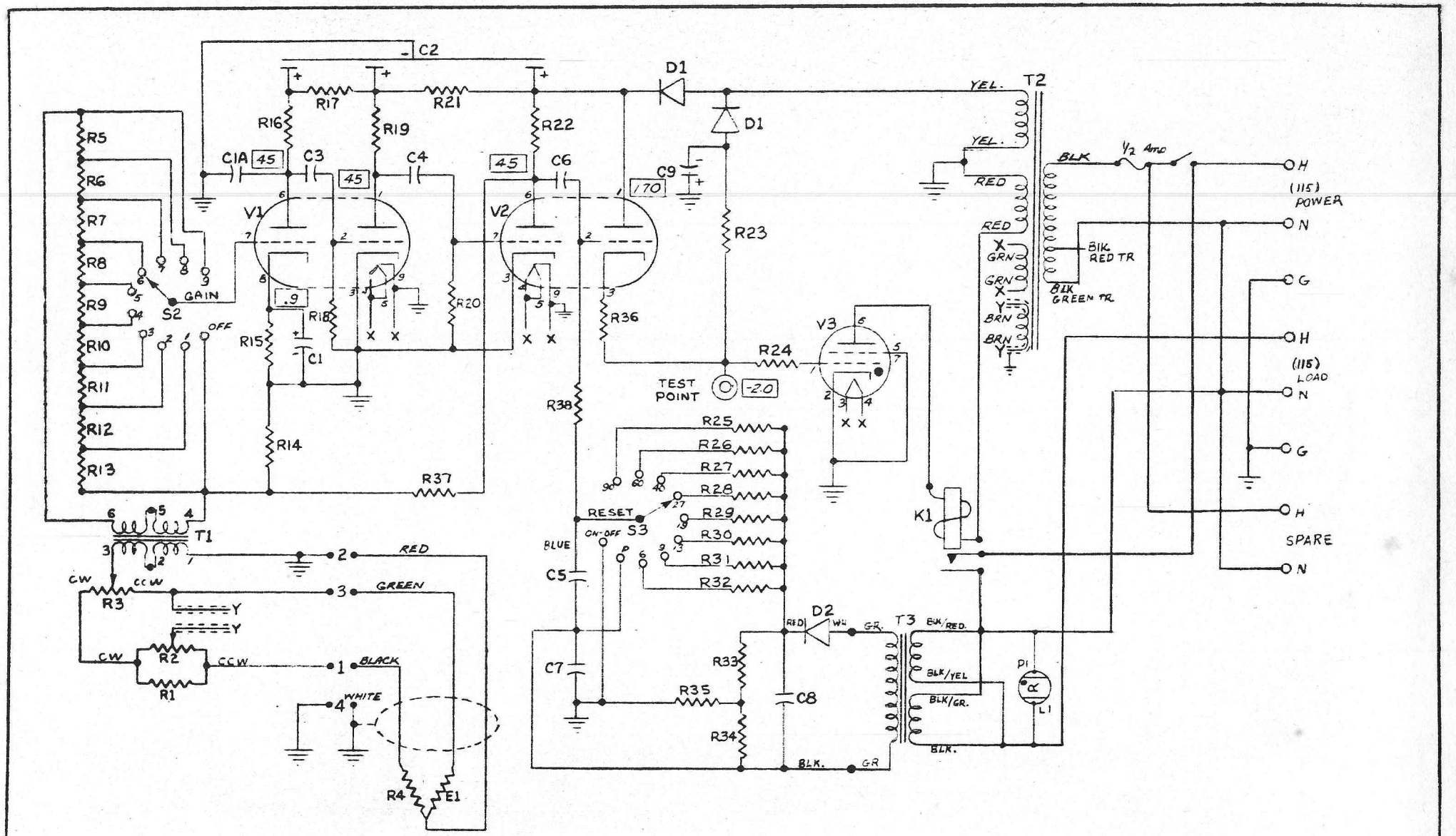
R29	Resistor, 4.7M Ohm, 1/2 watt, 5%	DY5EB4.7M5-1/2	1
R30	" 3.3M " " "	DY5EB3.3M5-1/2	1
R31	" 2.2M " " "	DY5EB2.2M5-1/2	1
R32	" 1.5M " " "	DY5EB1.5M5-1/2	1
R33	" 5.1K " " "	DY5EB5.1K5-1/2	1
R34	" 47K " " "	DY5EB47K5-1/2	1
R35	" 1M " " "	DY5EB1M5-1/2	1
R36	" 4.7K " " "	DY5EB4.7K5-1/2	1
R37	" 2.2M " " "	DY5EB2.2M5-1/2	1
R38	" 4.7M " " "	DY5EB4.7M5-1/2	1
R39[c,d]	" 36.5 " 1/4 watt, 1%	DY1BJR1HM36.51-1/4	1
R40	" 50 " " "	DY1BJR1HM501-1/4	1
R41	" 2.69 " " "	DY1BJR1HM2.691-1/4	1
R42	" 3.06 " " "	DY1BJR1HM3.061-1/4	1
R43	" 3.34 " " "	DY1BJR1HM3.341-1/4	1
R44	" 3.65 " " "	DY1BJR1HM3.651-1/4	1
R45	" 4.18 " " "	DY1BJR1HM4.181-1/4	1
R46	" 4.61 " " "	DY1BJR1HM4.61-1/4	1
R47	" 4.95 " " "	DY1BJR1HM4.951-1/4	1
R48	" 5.23 " " "	DY1BJR1HM5.231-1/4	1
R49	" 6.68 " " "	DY1BJR1HM6.681-1/4	1
R50	" 1.00 " " "	DY1BJR1HM1.001-1/4	1
R51	" " " " "	"	1
R52	" " " " "	"	1
R53	" " " " "	"	1
R54	" " " " "	"	1
R55	" " " " "	"	1
R56	" " " " "	"	1
R57	" " " " "	"	1
R58	" " " " "	"	1
R59	Potentiometer, 100ohm, 5%, 5% Lin.	DZ 424	1
R60	Resistor, 1.5 ohm, 1/4 watt, 1%	DY1BJR1HM1.501-1/4	1
R61	" 3.00 " " "	DY1BJR1HM3.001-1/4	1
S1	Switch, Toggle, SPST, 6 amp., 125 volt	EH427	1
S2	" Rotary, Selector, Gain	EH433	1
S3	" " " Shorting, Reset	EH434	1
S1B[b,d]	" Toggle, DPST, 20 amp., 250 volt	EH435	1
S4[c,d]	" Rotary, Selector, Shorting. Coarse	EH466	1
S5[c,d]	" " " " Medium	"	1
T1	Transformer, Input, Special	EE415	1
T2[a,c]	" Power, "	EE416	1
T3	" Filament, "	EE448	1
T2B[b,d]	" Power, "	EE418	1
V1	Vacuum Tube, 12AX7, Selected, First Stage	JF401	1
V2	" " " " Second "	JF401-2	1
V3	Thyratron, 2D21	JF404	1
XV1	Tube Socket, 9 Pin Miniature, for V1	DC407	1
XV2	" " " " " " V2	"	1
XV3	" " 7 " " " V3	DC408	1
XV4	Pin Jack, Pin Tip, Red	DP403	1
YV1	Tube Shield Base, For V1	EG405	1
YV2	" " " " V2	"	1
YV3	" " " " V3	EG404	1
ZV1	" " for V1	EG406	1

ZV2	Tube Shield, for V2	EG 406	1
ZV3	" " " V3	"	1
1	Terminal Strip, 4 Lug Solder Type	DK 426	1
2	" " Barrier Type, 12 Screw Terminals	DK 427	1
5	Sub-Panel Mounting Bracket	BQ 430	2
7	Fuse Holder, Miniature	DV 408	1
100	Dial, 10 Turn	BM 402	e
101	Cabinet	CX 411	1
101A	Back Panel	CU 438	1
102[a,b]	Front Panel	CU 406	1
103	Chassis	DL 410	1
105	Insulator, for Terminal Strip 2	GN 412	1
106	Sub-Panel, Integrator Circuit	DL 411	1
107	Mounting Bracket, Mercury Relay	BQ 416	1
108	Knob, Reset & Gain Switch	BK 413	2
109	Butt End Connector	GR 417	1
111	Mounting Washer, Fibre, for D1 & D2	K S15	4
112	Mounting Plate, Capacitor C2	CZ 435	1
113	Mounting Screw, Back Panel	D15SN11	2
114	" " Terminal Strip 2	D15SN19	4
115	" " Rectifier, D2	D15SN27	1
116	" " " D1	D15SN37	1
117	" " Front Panel & Chassis	D15SN11	8
118	" " Tube Socket & Shield Base	D7SN7	6
119	" " Mercury Relay Bracket	D18SN11	2
120	" " " "	D18SN19	2
122[a,c]	" " Transformer T2	D18SN11	4
123	" " " T3	D18SN53	2
124[b,d]	" " " T2B	A18SN53	2
125	" " Capacitor C2	D15SN7	2
126	" " Sub-Panel Brackets	D15SN7	2
127	" " " "	D15SN11	4
128	" " Capacitor C5	D15SN11	2
129	Mounting Nut, Terminal Strip, 2	AA15SN	4
130	" " Rectifier, D2	"	1
131	" " " D1	"	1
132	" " Tube Socket & Shield Base	X-AA7SN	6
133	" " Mercury Relay Bracket	AA18SN	2
134	" " " "	"	2
135	" " Transformer T1	AA15SN	2
136[a,c]	" " " T2	AA18SN	4
137	" " " T3	AA15SN	2
136B[b,d]	" " " T2B	AA18SN	2
138	" " Capacitor C2	AA15SN	2
139	" " Sub-Panel Bracket	"	2
140	" " " "	"	4
141	" " Capacitor C5	"	2
142	Lockwasher, Terminal Strip, 2	KL15SK	4
143	" Rectifier D2	"	1
144	" Tube Socket & Shield Base	KM7SK	6
145	" Mercury Relay Bracket	KL8SK	2
146	" " "	"	2
147	" Transformer T1	KL15SK	2
148[a,c]	" " T2	KL18SK	4

149	Lockwasher, Transformer T3	KL15SK	2
148B[b,d]	" " T2B	KL18SK	4
150	" Capacitor C2	KL15SK	2
151	" Sub-Panel Bracket	KL15SK	2
152	" " "	"	4
153	" Capacitor C5	"	2
154	Solder Lug, Sub-Panel & Chassis	GR 419	5
155	Terminal Lug, Mercury Relay, #10 Stud, Red	GR 420	2
156	" " " " " Blue	GR 418	2
157[b,d]	" " Switch SIB, #10 Stud, Blue	"	4
158	Solder Ring, Reset Switch S3	KL52SK	1
159	Grommet, Chassis	BR 406	3
160	" Back Panel	BR 407	4
161	Jumper Lead, Power	GP 419	1
162	" " Ground	GP 420	1
163	Harness Leads, Resistance Therm. to R1, R2, R3	GP 421	1
200[c,d]	Front Panel	CU 407	1
202[c,d]	Knob, Decade Switch, Coarse & Medium	BK 411	2

Note:

a) Used with Model 1053A only
b) " " " 1253A "
c) " " " 1109A "
d) " " " 1140A "
e) One req'd for Models 1109A & 1140A; two required for Models 1053A & 1253A

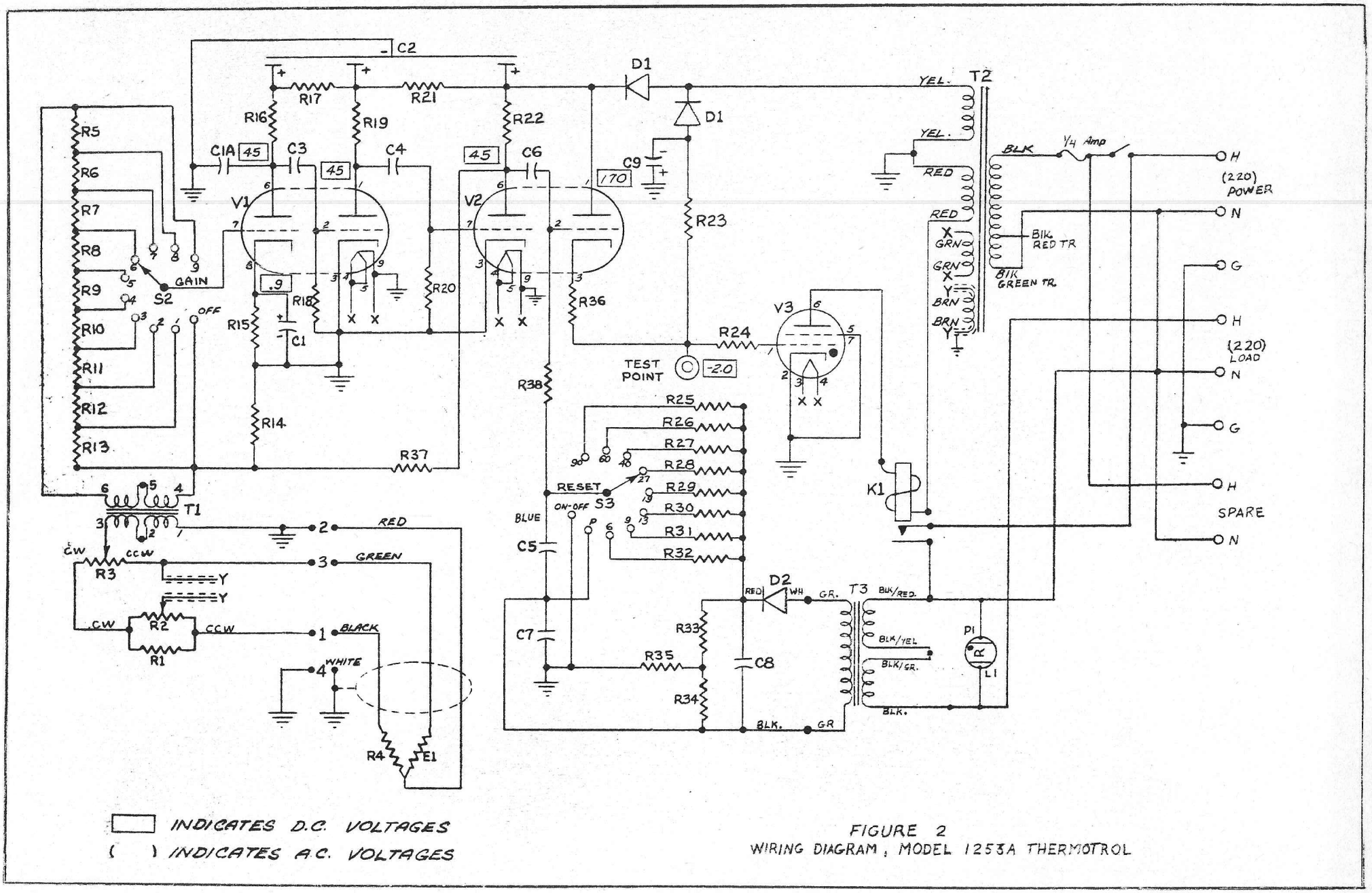


▭ INDICATES D.C. VOLTAGES

( ) INDICATES A.C. VOLTAGES

FIGURE 1

WIRING DIAGRAM, MODEL 1053A THERMOTROL



INDICATES D.C. VOLTAGES

( ) INDICATES A.C. VOLTAGES

FIGURE 2

WIRING DIAGRAM, MODEL 1253A THERMOTROL

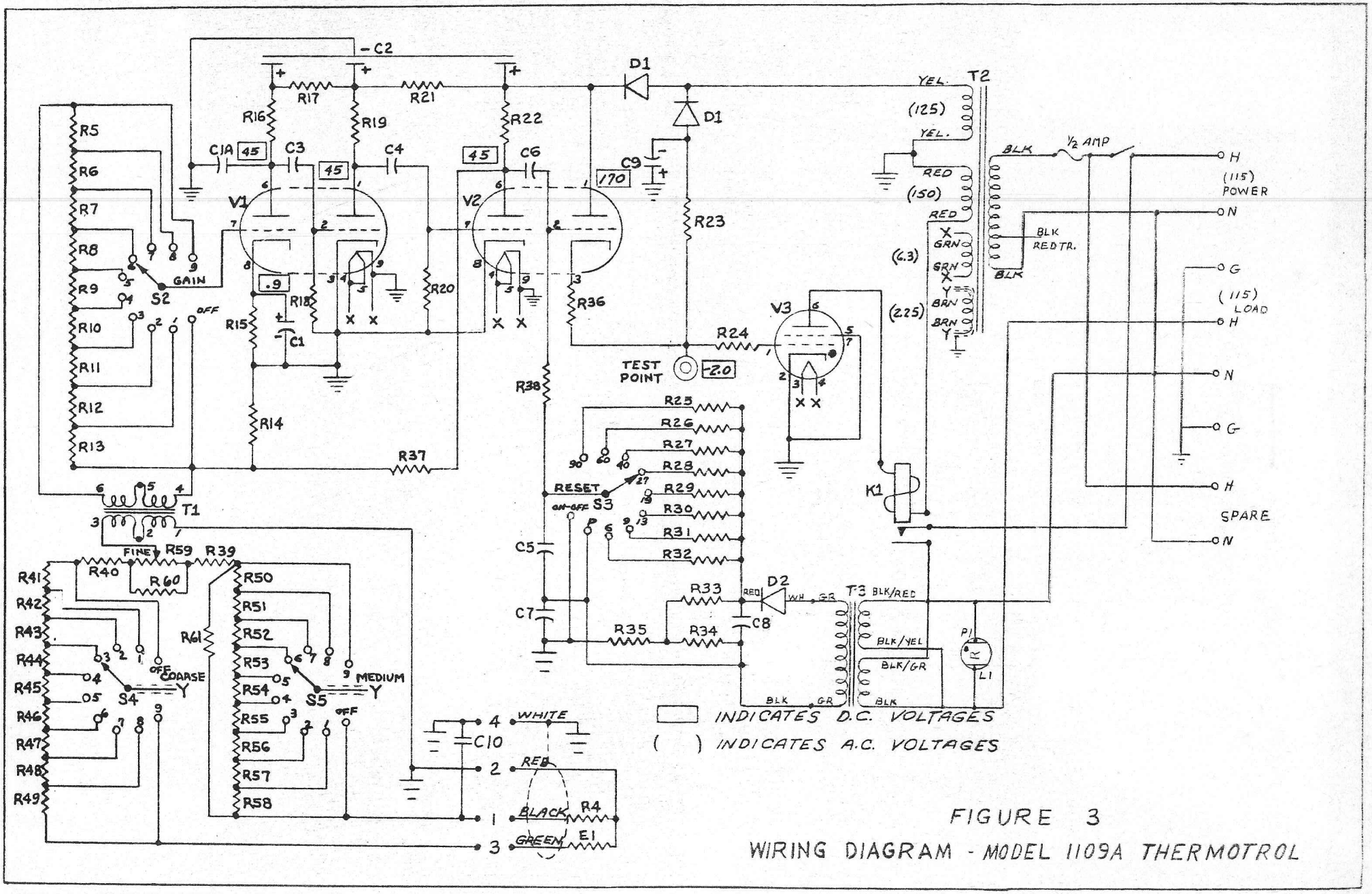


FIGURE 3

WIRING DIAGRAM - MODEL 1109A THERMOTROL

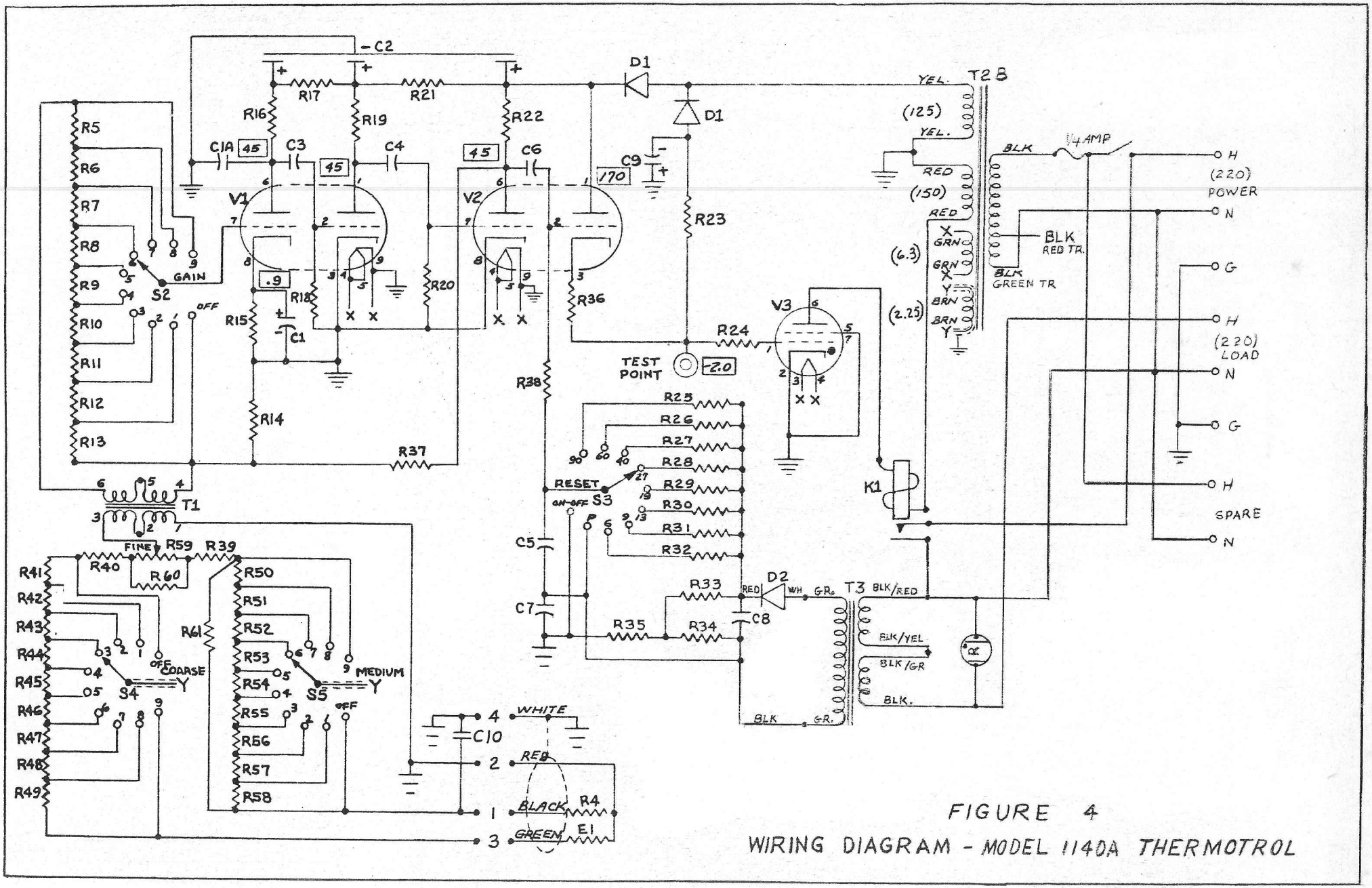
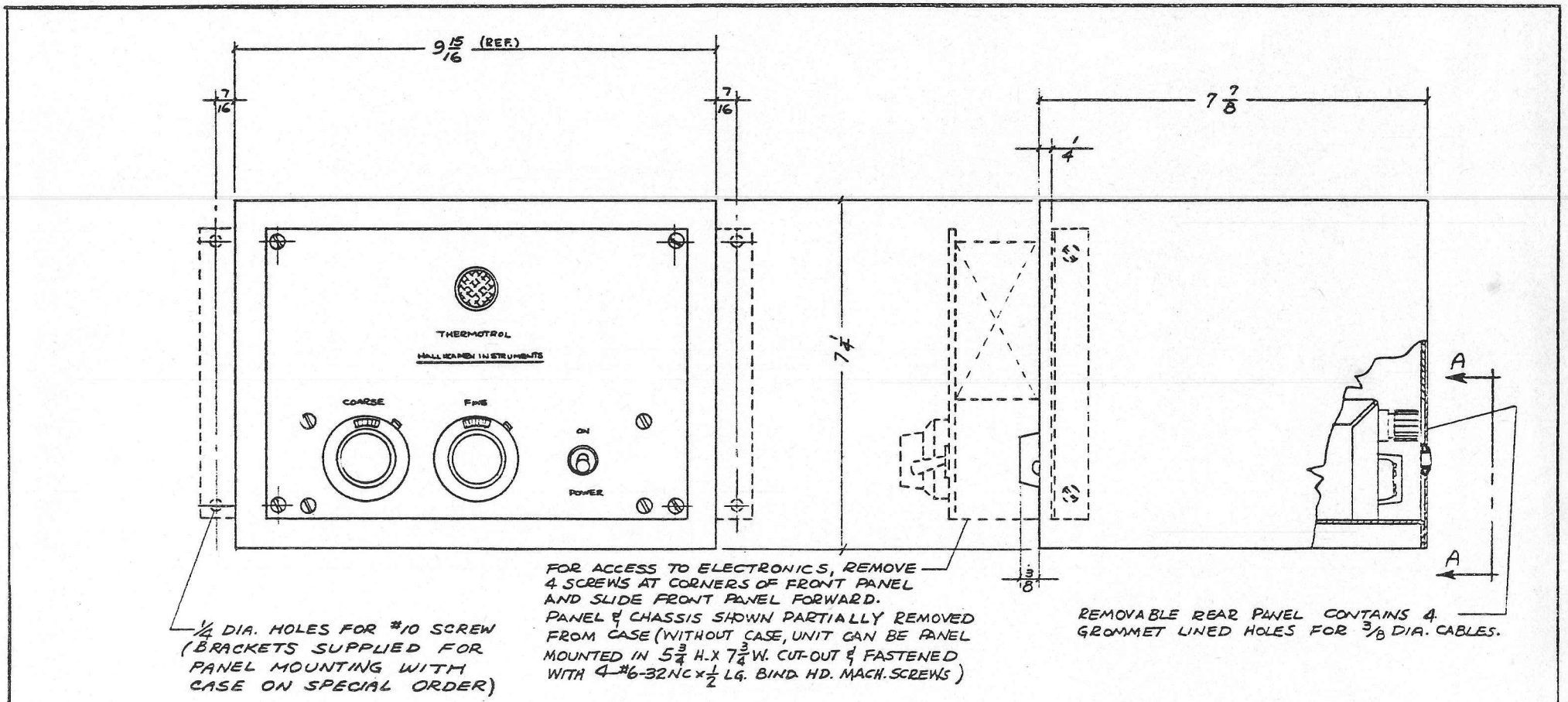


FIGURE 4

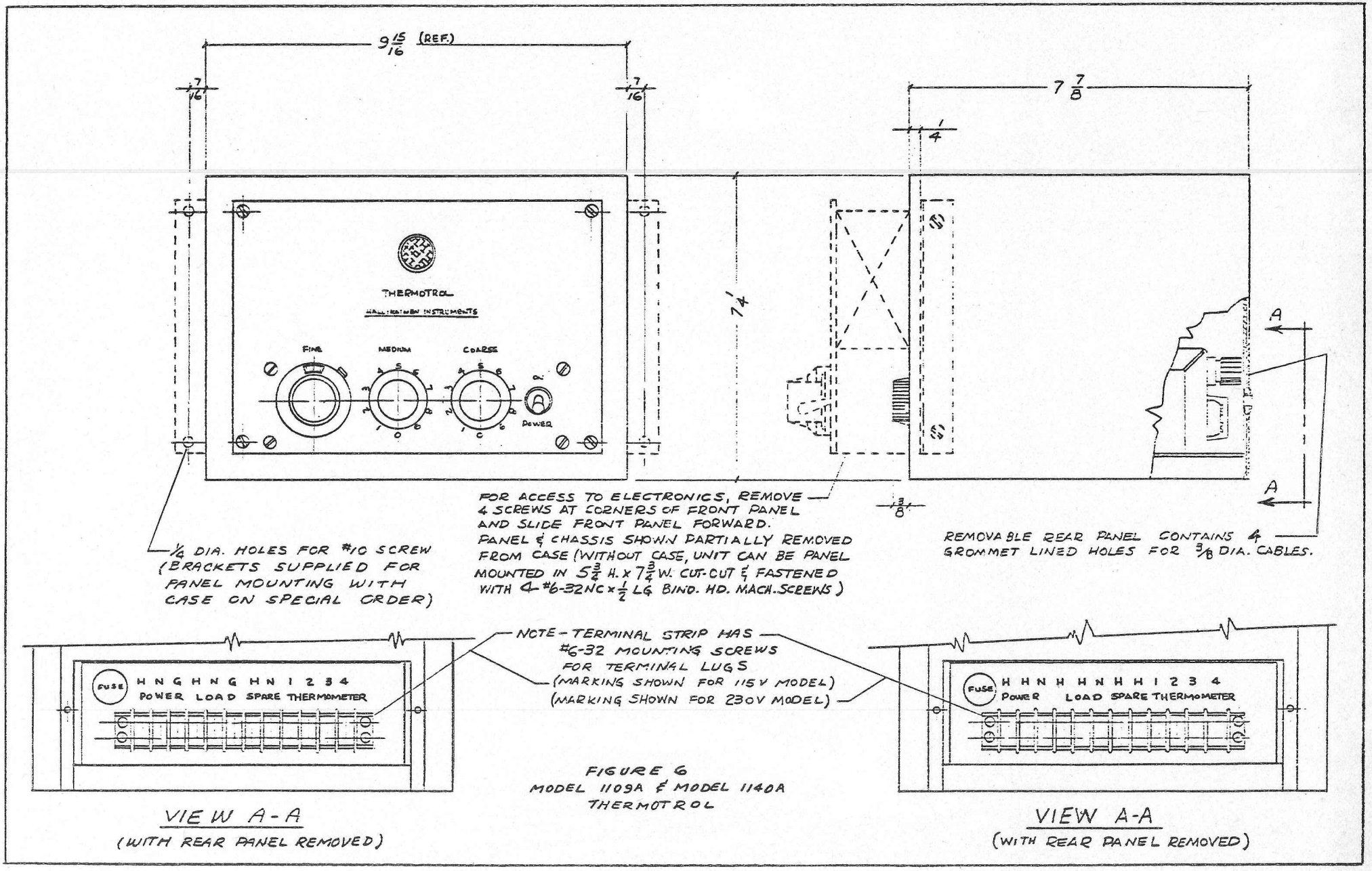
WIRING DIAGRAM - MODEL 1140A THERMOTROL



VIEW A-A
(WITH REAR PANEL REMOVED)

FIGURE 5
MODEL 1053A & MODEL 1253A
THERMOTROL

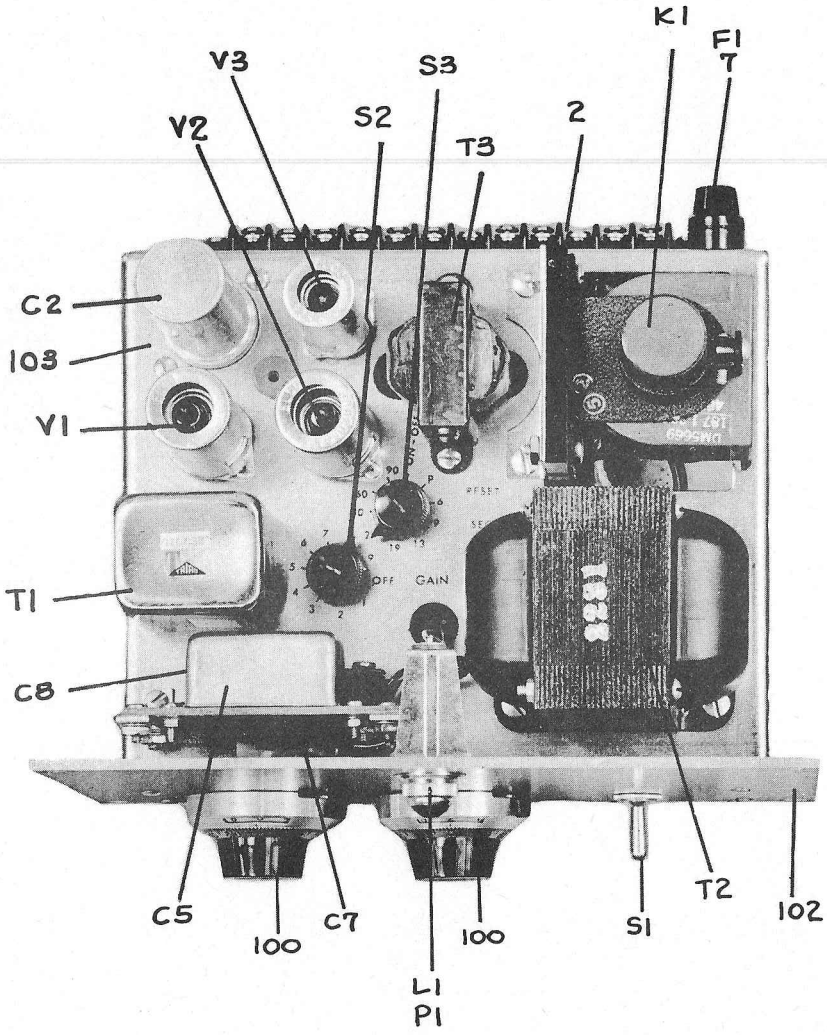
VIEW A-A
(WITH REAR PANEL REMOVED)



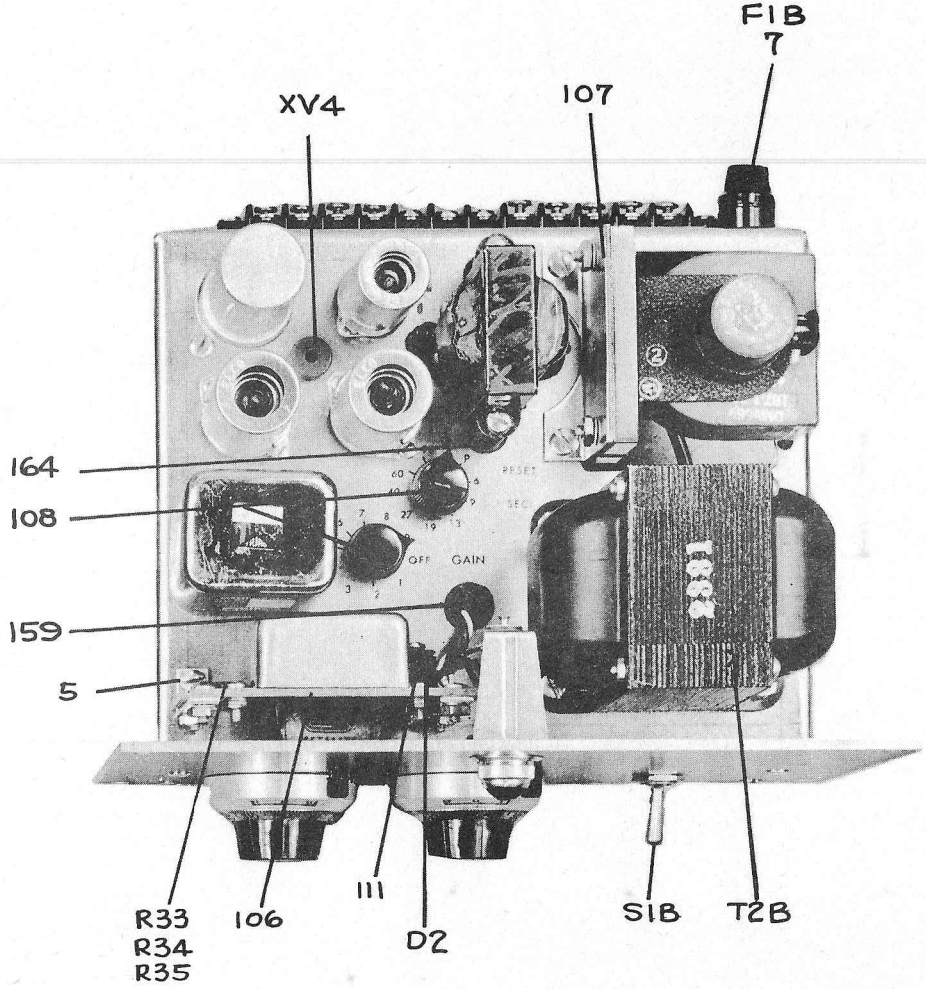
VIEW A-A
(WITH REAR PANEL REMOVED)

FIGURE 6
MODEL 1109A & MODEL 1140A
THERMOTROL

VIEW A-A
(WITH REAR PANEL REMOVED)

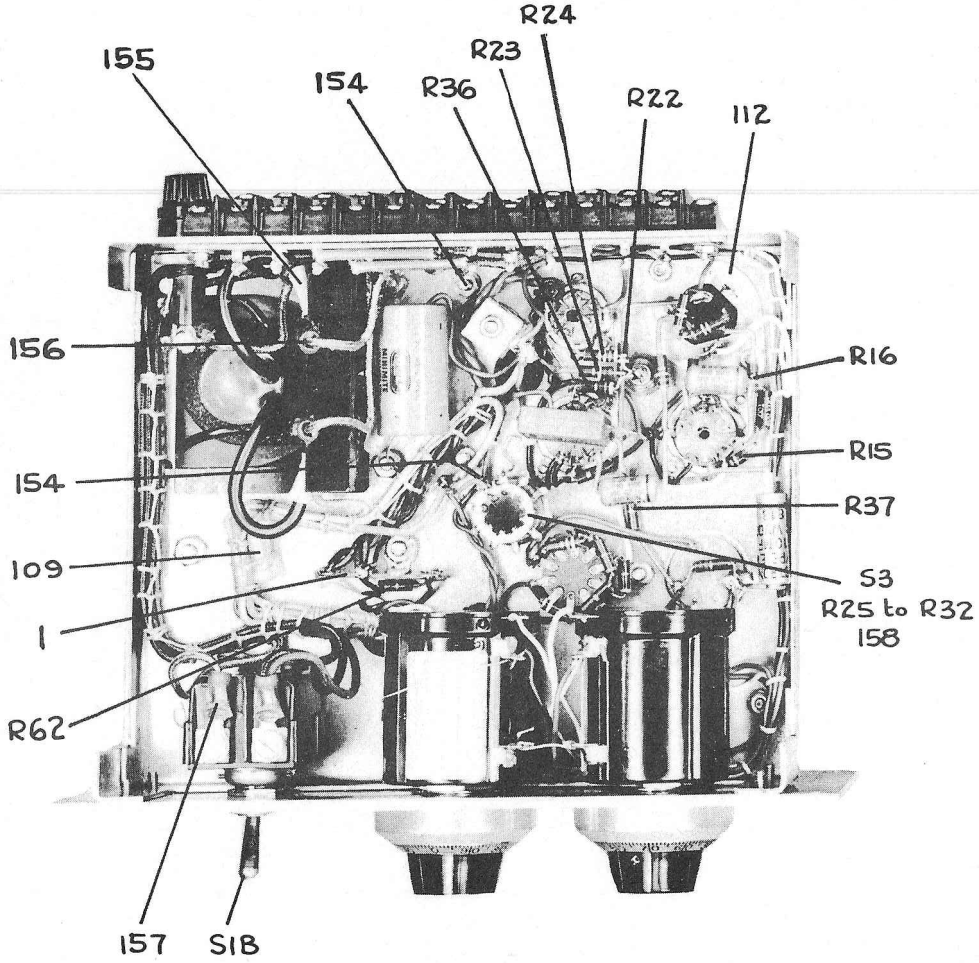


MODEL 1053A

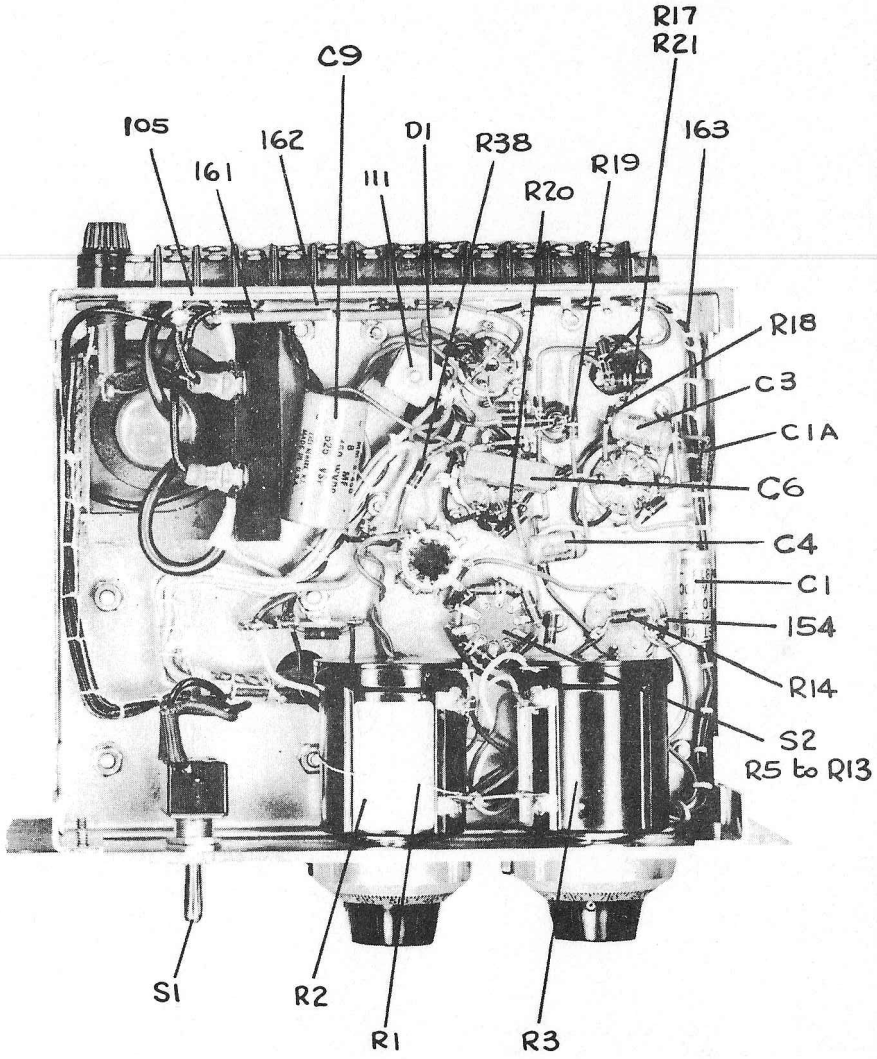


MODEL 1253A

FIGURE 7



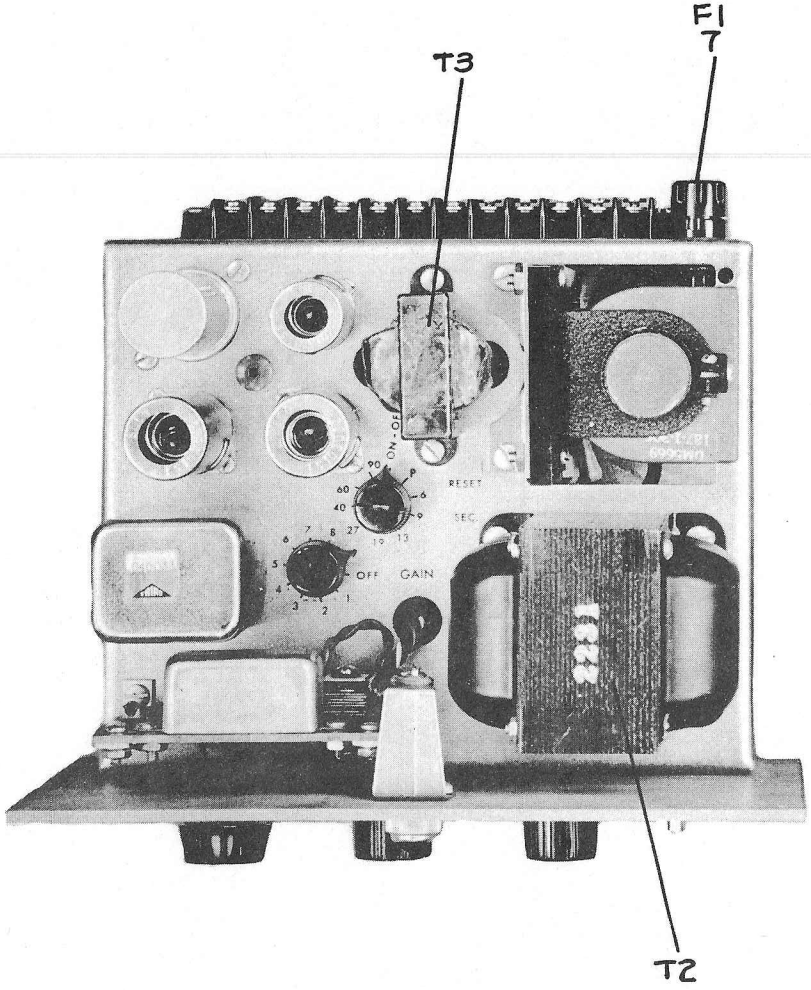
MODEL 1253A



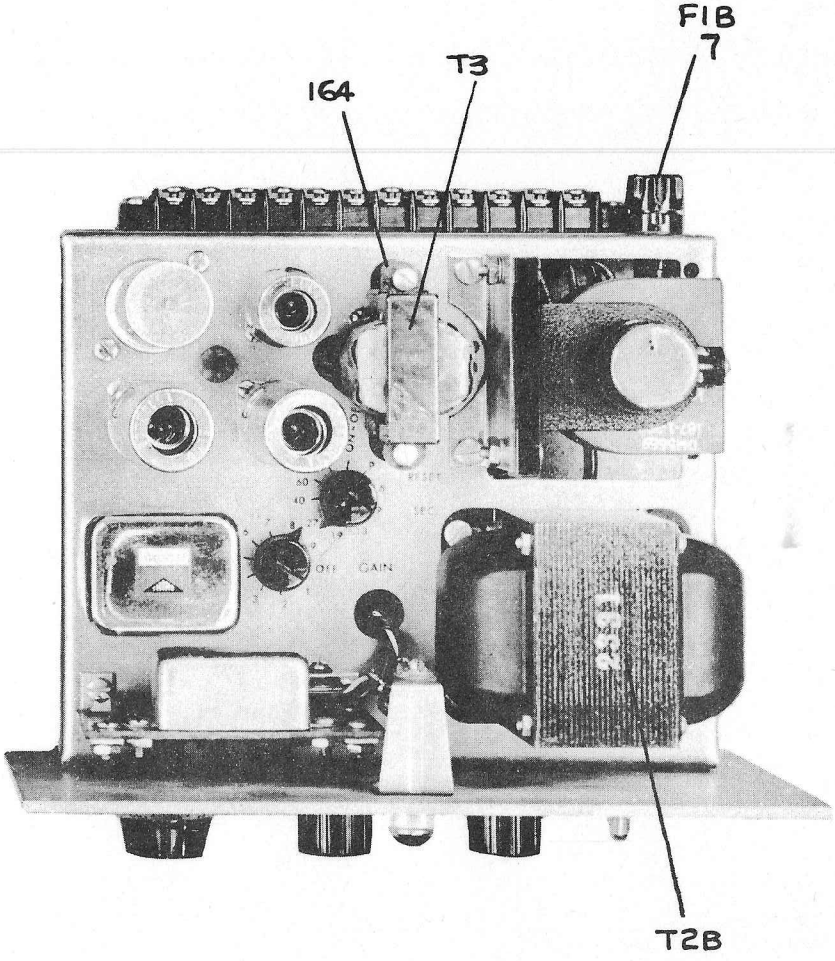
MODEL 1053A

FIGURE 8

SEE FIGURES 7 & 8, MODELS 1053A & 1253A
FOR REMAINING PARTS NOT SHOWN.



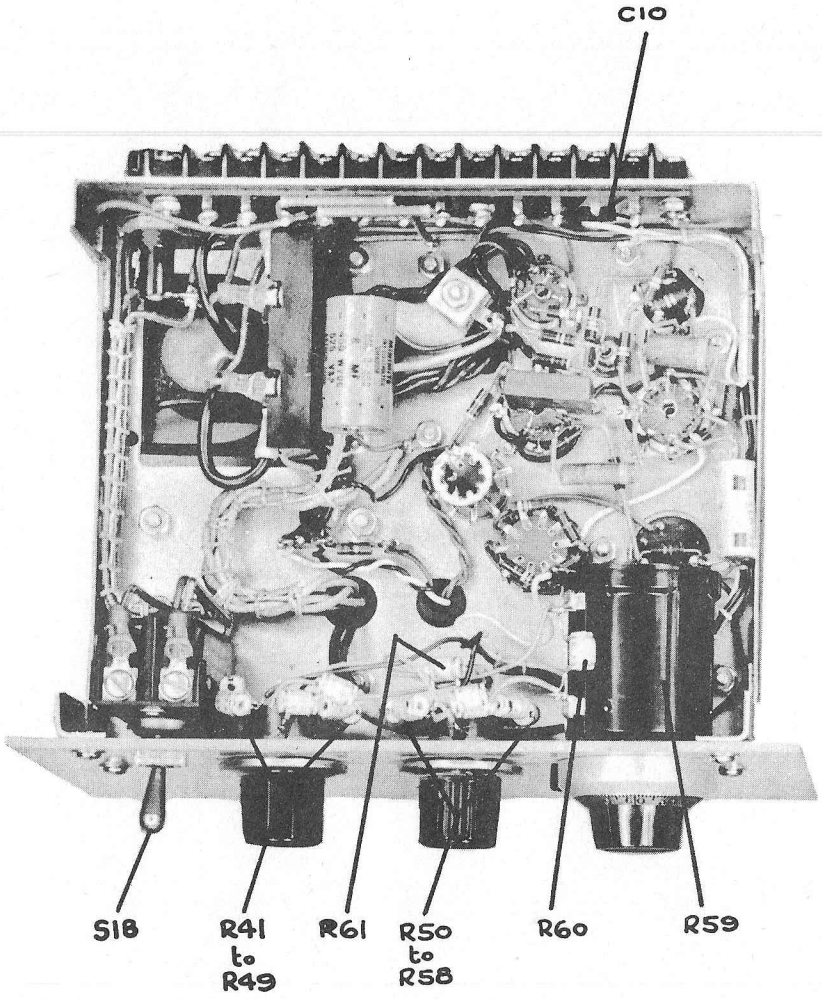
MODEL 1109A



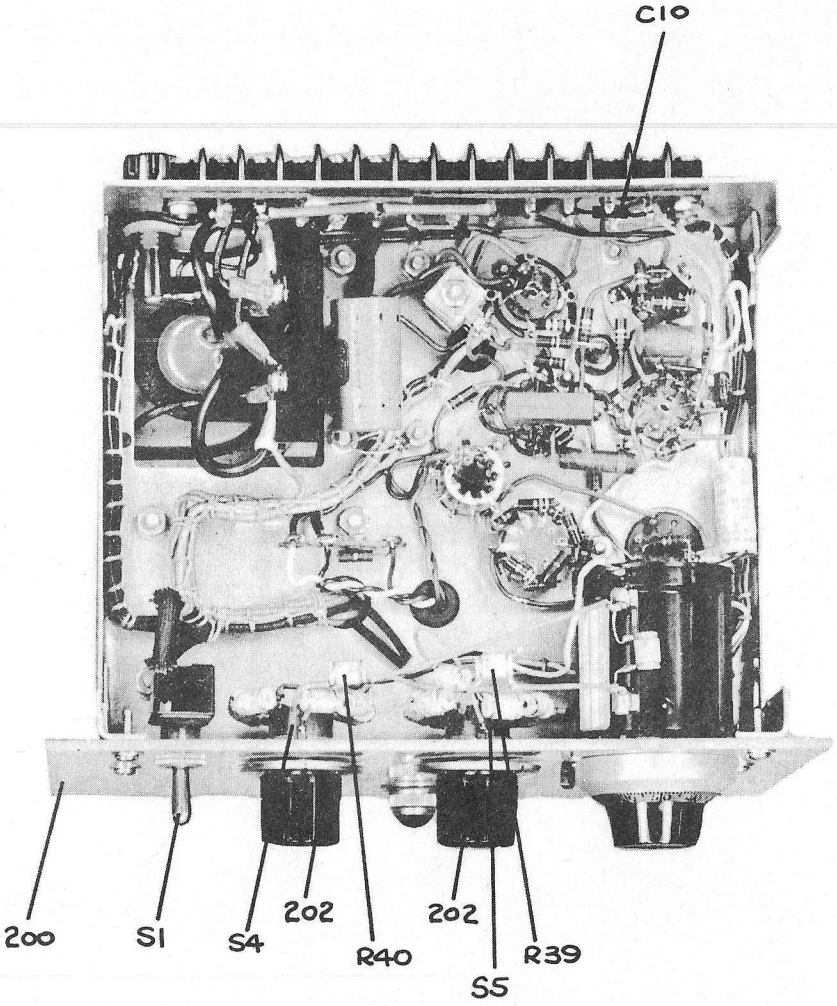
MODEL 1140A

FIGURE 9

SEE FIGURES 7 & 8, MODELS 1053A & 1253A
FOR REMAINING PARTS NOT NOTED.



MODEL 1140A



MODEL 1109A

FIGURE 10