KS-15123, LIST 2 RECTIFIER
OPERATING METHODS

1. GENERAL

1.01 This section covers the operation of a regulated vacuum tube rectifier, which is designed to operate from 115- or 230-volt ±15 per cent, 50- to 60-cycle, a-c power service; and to deliver 130 volts d-c with automatic regulation to ±0.5 volt from 0.4- to 1.7-ampere load. Either the positive or the negative output must be grounded to reduce ripple voltage. Connections may be changed on the plate transformer to deliver an output of 150 volts instead of 130 volts. The rectifiers are suitable for use in room temperatures from −40F to 122F (−40C to 50C).

1.02 This rectifier may be used in type "N" carrier systems.

<u>Caution: Voltages inside the rectifier case are over 500 volts between terminals. Avoid all contact with terminals. Do not allow a test pick to touch two metal parts at the same time, or destructive and dangerous short circuits may occur. Disconnect a-c supply before working on rectifier except as necessary to make tests.</u>

1.03 Routine checks should be made during a period when they will cause the least service reaction.

1.04 The abbreviations CW and CCW, used herein, refer to clockwise and counterclockwise rotation respectively.

1.05 Information in this section is arranged under the following headings:

1.06 <u>List of Tools and Test Apparatus</u>
(Equivalents may be substituted)

Ammeter, d-c, Weston Inst. Corp., Model 280, 30-3-1.5 amp
Screwdriver, cabinet, 3"
Volt-ohm milliammeter, Weston Inst. Corp., Model 772, type 6
Watch, stop, KS-3008

2. OPERATION

<u>How the Rectifier Works</u> (See Fig. 2)

2.01 <u>Tube Operation</u>: The rectifying tubes are of the thyratron type, and the point in the a-c cycle at which they start firing (conducting current) is controlled by negative grid bias or difference in voltage between the grid and the filament. In general, the greater the negative grid bias, the higher the plate voltage must be before current starts to flow; and for any tube there is a critical grid bias beyond which the tube will not fire. After a tube starts firing, it continues to fire or conduct current for the rest of the a-c half-cycle. The output current, and therefore the maintained voltage, depends on how much of each half-cycle each tube is firing. V1 fires during one-half of each cycle and V2 fires during the other half, which gives full-wave rectification. Changes in input and output voltage are reflected through a 3-stage amplifying circuit to control the grid bias of the thyratrons and return the output voltage to the regulated value.

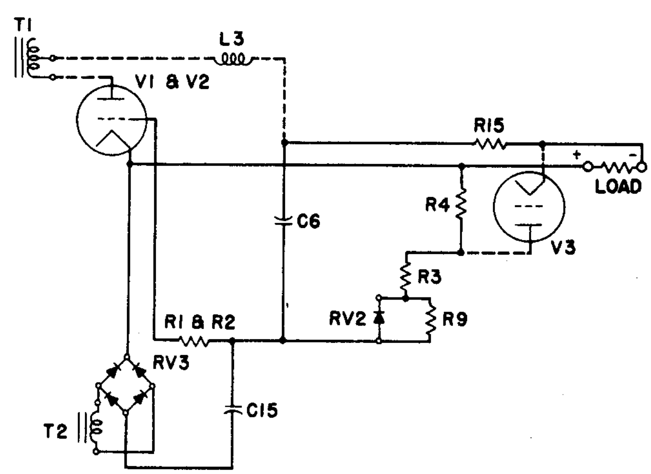

FIG. 1A

Starting Time Delay

2.02 When power is first applied to the power supply unit (see Fig. 1A), metallic rectifier RV3, which is connected across the 3-4 winding of transformer T2, furnishes a d-c output of about 36 volts. RV3 immediately charges capacitors C6 and C15 so that the voltage across each is approximately 18 volts. The voltage of C6 provides a negative grid bias for V1 and V2 of almost 18 volts to prevent these tubes from firing. C6 discharges and C15 charges further, very slowly, through the high-resistance circuit composed of R4, R3, R9, and RV2. The resistance of R9 is 3.3 megohms and the resistance of RV2 to current in this direction is about 10 megohms. After about 30 seconds, the grid bias of V1 and V2 is reduced to about 3 volts, at which point V1 and V2 fire. Firing before the filaments have been heated to operating temperature would ruin the tubes, due to bombardment of the filaments and consequent dissipation of their active material.

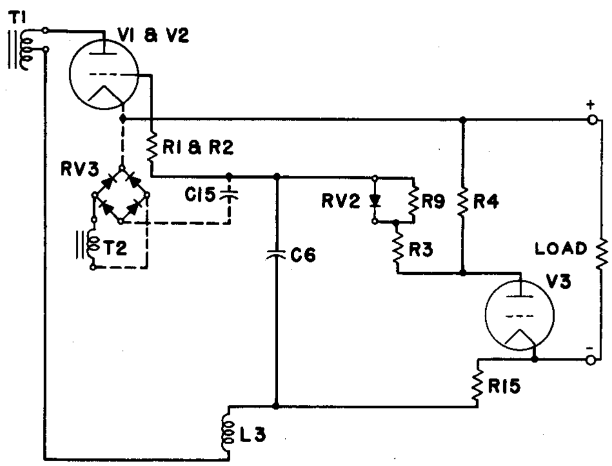

FIG. 1B

2.03 After V1 and V2 fire, the circuit condition is as shown in Fig. 1B. The output current from shunt tube V3 flowing through resistor R4 provides the drop used as the grid bias for V1 and V2. The polarity of C6 is reversed, and the voltage across it becomes, at full load, slightly higher than the output voltage of the power unit.

2.04 When power is disconnected, it takes about one-half second for the charge of C6 to discharge through the rectifier tubes and a resistance path which includes RV2 through which the current flow is now in the forward or low-resistance direction. During this short interval, while C6 holds the grid bias positive, the unit will start as soon as power is reconnected, but after one-half second a restart must follow the cycle described in 2.02 above. This avoids the starting time delay after very short interruptions of a-c power, during which tube filaments have not had time to cool appreciably.

Regulation

2.05 Output voltage changes are amplified by the 2-stage amplifier tube V4 to control the current through shunt tube V3. Current changes in V3, by changing the drop in resistor R15 and inductor L3, make correction for the output voltage changes. In addition, the current changes in V3, by changing the drop in resistor R4, control the grid bias of rectifier tubes V1 and V2 to change their output and complete the voltage correction.

2.06 A potentiometer, consisting of fixed resistors R8 and R10 and voltage-regulating variable resistor P1, is connected across the 130-volt output so that the current through it is proportional to the voltage across it. The voltage at the variable tap of P1 therefore varies in proportion to the voltage variation across the potentiometer and is applied to control grid 4 of tube V4. Cathode 6 of V4 is connected to the junction between fixed resistors R11 and R12, which are in series with fixed resistor R7 across the output. Constant voltage tube V5 is bridged across R11 and R12 so that any change in the output terminal voltage appears across R7 and not across R11 and R12. Consequently, the bias on V4 (difference in potential between grid 4 and cathode 6) varies in proportion to changes in the output voltage.

2.07 Any increase in the output terminal voltage, either due to an increase in input voltage or a decrease in load, results in an increase in voltage on tube V4, control grid 4, with respect to the voltage on cathode 6, so that grid bias is decreased. This decreased bias increases the current in plate circuit 5-6 of V4, the drop in resistor R6, and the negative grid bias on grid circuit 1-3 of V4. Any change in voltage of cathode 3 of V4 is negligible compared with change in associated control grid 1. This reduces current in plate circuit 2-3 of tube V4, the drop in R13, and the grid bias on tube V3. Any change in cathode voltage of V3 is negligible compared with the change in control grid voltage. Reduced bias on V3 increases its output, which has two effects. First, it decreases the current through coil L3 and fixed resistor R15 to help reduce the output voltage to the regulated value; and second, it increases the voltage drop in resistor R4, which causes increased bias on thyratrons V1 and V2 to decrease their output and reduce output voltage to regulated value. Reduced output voltage has the opposite effect.

2.08 Ripple: Capacitors C11 and C12 are selected to have low impedance to output ripple voltage. They increase grid bias changes between control grid 4 and cathode 6 of tube V4, due to ripple voltage in the output, which changes are amplified through tube V4 to V3 to reduce ripple in the output to a small value.

2.09 Singing: Capacitor C13 and resistor R16 permit feeding back certain frequencies into the regulating circuit in such phase that they are damped and prevent the output from "singing".

2.10 Filtering: The metallic rectifier RV1 and capacitor C17 rectify and filter the 180-volt a-c supply from winding 10-11 of transformer T2 for application to plate circuit 2-3 of tube V4.

2.11 Cover Switches: When the power supply unit front cover is removed, cover switches D1 and D2 open both sides of the line to protect operating personnel from the relatively high voltages within the unit. If it is necessary to make tests with the cover off, but with power on, it is suggested that one man hold the cover switches operated while another man performs the tests. The switches may thus be released immediately in case of accidents.

2.12 Access: Access to tubes, metallic rectifiers, electrolytic capacitors, the fuse, or any other parts of the unit is obtained by removal of front and rear covers, which are held in place by Dzus fasteners.

2.13 Output Voltage Adjustment: The regulated output voltage is adjusted by turning the slotted shaft of the variable resistor P1 with a screwdriver.

Preparing to Start Initially

2.14 When putting the rectifier into service initially check to see that:

(a) correct tubes are properly seated in their sockets;

(b) F1 (6 amp) fuse is installed and a-c service is connected;

(c) transformer T1 primary is properly connected for the available a-c service voltage (see Fig. 2);

(d) variable artificial load in series with a portable ammeter is connected across the rectifier;

(e) front and rear covers are removed.

Initial Adjustments

2.15 Output Voltage: Operate and hold cover switches D1 and D2 and check that thyratron tubes V1 and V2 start to glow about 30 seconds later. Check the output voltage, using either the voltmeter on the associated equipment where provided, or using a portable KS-14510 voltmeter with test picks applied to jacks J1 and J2 on the unit, observing the proper polarity. If the output is not 130 volts, loosen the locking nut on the slotted shaft of potentiometer P1 and turn the shaft CW to raise voltage or CCW to lower voltage as required to obtain 130 volts. Tighten the locking nut.

2.16 Load Regulation: Adjust the variable artificial load for 0.4-ampere load. Gradually increase the load to 1.7 amperes while observing the output voltage. This voltage should not change more than ±0.5 volts.

3. ROUTINE CHECKS AND ADJUSTMENTS

3.01 To Turn On and Off: As no switch is provided on the unit, starting and stopping is under control of a switch mounted on the associated equipment.

3.02 Starting Time Delay: Periodically turn the rectifier off and, after allowing the tubes to cool, turn the rectifier on and check that the thyratron tubes start (indicated by output voltage build-up) in not less than 10 seconds.

3.03 Output Voltage: Periodically check and, if necessary, adjust the output to 130 volts as in 2.15.

3.04 Load Regulation: Periodically check the load regulation as in 2.16.

4. TROUBLES

4.01 Aging of constant-voltage tube V5 tends to give higher output voltage which may be reduced by CCW adjustment of variable resistor P1. If variable resistor P1 reaches the end of its travel and correct output can no longer be obtained by this adjustment, replace V5. Adjust P1 by turning slotted shaft. Aging of metallic rectifier RV3 reduces its output voltage and the starting time of the power supply unit. If the delay in starting, after connection to the a-c supply, is reduced below 10 seconds, replace metallic rectifier RV3.

4.02 Operation of the power supply unit will be unsatisfactory if either rectifier tube is defective. In case of trouble, put in two new tubes to check the circuit and then try the old tubes, one at a time, to see which should be replaced. Cathode trouble usually consists of an open filament or low emission. With low emission, the tube will glow and appear normal but still be unsatisfactory. Grid trouble may be high firing point or grid emission. High firing point is a condition where too high a plate voltage is necessary to fire the tube. While this can be compensated for to some extent by changes in variable resistor settings, the tube is inclined to be unstable at light loads and high line voltages. Such a tube should be replaced if causing erratic operation. Grid emission sometimes occurs due to cathode material which has been carried over to the grid. The effect of this is negligible until the temperature of the tube becomes high enough to cause this active material on the grid to give off electrons, thus causing the grid to lose control and resulting in high output voltage. This effect disappears as the tube cools, so that satisfactory operation may be possible at light loads but not possible at full load.

4.03 Trouble Location Chart: The following table indicates possible troubles and their causes and, together with the point-to-point voltage and resistance tables below, should give valuable assistance in the location of any trouble which may develop.

Trouble	Possible Cause
No d-c output voltage.	Blown line fuse F1. Failure or disconnection of input power supply. Failure of rectifier tube, possibly filament lighted but no emission from tube. Renew tube. One or more of capacitors C7, C8, C9, C10, or C14 shorted. (Fuse F1 will blow.) Cap off rectifier tubes V1, V2.
Low d-c output voltage.	Low a-c supply voltage. Variable resistor P1 set at wrong point. If voltage can not be raised and lowered by turning shaft of P1, it indicates trouble in the regulating part of the circuit. Rectifier tube V1 or V2 not functioning properly, possibly low emission but with tube still lighted. Amplifier tube V4 aged or defective.
High d-c output voltage.	High a-c input voltage. Variable resistor P1 set at wrong point. Rectifier tube V1 or V2 not functioning properly, possibly grid emission. Cold cathode tube V5 aged or not functioning properly. Amplifier tube V4 or shunt tube V3 aged or defective.
Erratic d-c output voltage.	Rectifier tube V1 or V2 with high firing point. Flicker in cold cathode tube V5. Loose connection, probably at one of the capacitors.
Time delay less than 10 seconds.	Metallic rectifiers RV3 and RV2 aged or defective.

5. POINT-TO-POINT VOLTAGES

5.01 These typical point-to-point voltages were taken with an analyzer using the 10-volt scale for voltages under 10 volts, 50-volt scale for 10 to 50 volts, 250-volt scale for 50 to 250 volts, and 1000-volt scale for 250 to 1000 volts. The cover switches D1 and D2 must be held closed while the voltages are being read.

> Caution: Do not touch live terminals with the hands, as high voltages are present. Do not allow a test pick to touch two metal parts at the same time, or destructive and dangerous short circuits may occur.

5.02 Input and output, while obtaining these readings, were as follows:

60-cycle A-C Input		D-C Output	
Volts	Amps	Volts	Amps
115	4.2	130	1.7

5.03 The following typical d-c voltage readings are with both 1000-ohm-per-volt and 20,000-ohm-per-volt sensitivity, except where 1000-ohm-per-volt readings unbalance the circuit. Connect the minus lead of analyzer to the negative side of the output and the plus lead of analyzer to terminal indicated below, except where readings are minus, in which case these connections must be reversed.

1000-ohm-per-volt

Tubes	Terminals							
	1	2	3	4	5	6	7	8
V1 & V2	130	130					130	130
V3			120	120	-8.3			
V4		115	108					
V5					108			

20,000-ohm-per-volt

Tubes	Terminals							
	1	2	3	4	5	6	7	8
V1 & V2	130	130		127			130	130
V3			120	120	-8.3			
V4	105	227	108	74	105	75		
V5					108			

5.04 The following typical a-c voltage readings are with 1000-ohm-per-volt sensitivity. Connect a-c terminals of analyzer to terminals listed.

Transformer T1 ("Y" Wiring)

Terminals	A-C Volts
1-4	115
6-8	525

7 is mid-point of 6 to 8

Transformer T2

Terminals	A-C Volts
1-2	115
3-4	30
5-6	6.3
7-9	5.1
10-11	175

8 is mid-point of 7 to 9

6. RESISTANCE TABLE

6.01 Values shown below with a-c supply and load disconnected. If power supply unit has been operating, either discharge the electrolytic capacitors or allow time for them to discharge before taking resistance readings.

From Terminal Listed Below to Negative Side of Line (Pin Jack J2)	Resistance in Ohms	
Terminal 5 of V5	28,100	±20%
Terminal 2 of V4 (positive to Terminal 2)	Over 1 megohm	
Terminal 4 of V4 (P1 extreme CW)	16,500	±20%
Terminal 4 of V4 (P1 extreme CCW)	22,100	±20%
Terminal 5 of V4	500,000	±20%
Terminal 6 of V4	26,700	±20%
Terminal 3 of V3*	27,900	±20%
Terminal 5 of V3	500,000	±20%
Terminal 1 of V2*	27,700	±20%
Terminal Cap of V2 or V1	17	±20%

*On readings marked with asterisk (*), allow interval for electrolytic capacitors to charge.

Attached: Fig. 2

CIRCUIT NOTES:

101. A RESISTOR WHOSE VOLTAGE DROP AFFECTS OPERATION IS SHOWN VERTICALLY.
102. THE VOLTAGE PICKUP POINT OF EACH CONTROL GRID IS SHOWN AT A LOWER LEVEL THAN THAT OF THE ASSOCIATED CATHODE TO INDICATE GRID BIAS GRAPHICALLY.
103. "X" OPTION FOR 230 VOLT A-C SERVICE. "Y" OPTION FOR 115 VOLT A-C SERVICE.
104. FOR NEGATIVE D-C OUTPUT GROUND POSITIVE OUTPUT LEAD. FOR POSITIVE D-C OUTPUT GROUND NEGATVE OUTPUT LEAD.
105. ONLY "M" WIRING PER FIGURE 3 SHOWN.

DESIG.	VALUE OR CODE	DESIG.	VALUE OR CODE
C1	3M.F.	R1, R2	24,000 OHMS ± 5%
C2, C3, C4, C5	.01 M.F.	R3, R12	43,000 OHMS ± 5%
		R4	160 OHMS ± 5%
C6, C15, C17	4 M.F.	R5	47 OHMS
		R6, R13	470,000 OHMS ± 20%
C7, C8, C9, C10	400 M.F.	R7	2500 OHMS ± 5%
		R8	18,000 OHMS ± 5%
C11, C12, C16	0.5 M.F.	R9	3.3 MEGOHMS ± 5%
		R10, R11	20,000 OHMS ± 5%
C13	.0022 M.F.	R14, R16	2200 OHMS ± 20%
C14	80 M.F.	R15	10 OHMS ± 10%
		V1, V2	393A
		V3	6Y6G
P1	10,000 OHMS ± 10%	V4	6SL7GT
		V5	OC3/VR105

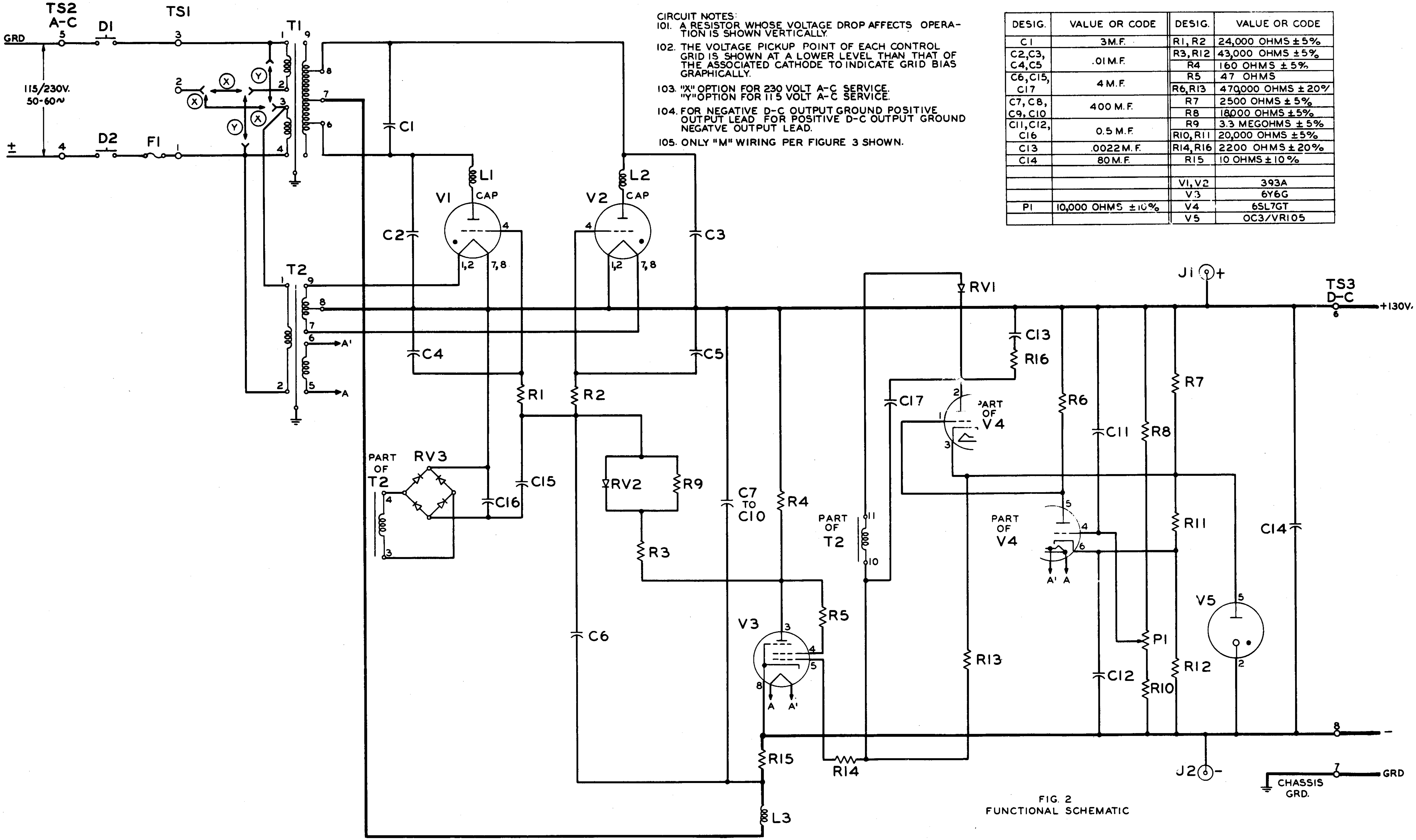

FIG. 2
FUNCTIONAL SCHEMATIC