NSWCDD/MP-92/224

HIGH-VOLTAGE PULSE GENERATOR CAPABLE OF 200 J AT 5 kV

BY HARRY E. CLEAVER

RESEARCH AND TECHNOLOGY DEPARTMENT

31 JULY 1992

NAVAL SURFACE WARFARE CENTER
DAHLGREN DIVISION • WHITE OAK DETACHMENT
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FOREWORD

This document describes the operation and construction of the 5-kV High-Voltage Pulse Generator that is used in the Energetic Materials Division as a power source to energize explosive initiating devices in explosive tests. The report serves as an owner's/operator's manual and contains detailed information for servicing and calibrating the instrument. Detailed drawings and instructions are provided to build a duplicate pulse generator.

Company and trade names used in this report are for technical information purposes only. Neither endorsement nor criticism is intended.

The contributions of Nicholas Vogle in the layout and construction of most of the 5-kV Pulsers in use today is sincerely appreciated.

This report has been reviewed by Lawrence E. Parker, Head, Explosion Dynamics Branch.

Approved by:

William H. Bohli

WILLIAM H. BOHLI, Head
Energetic Materials Division

ABSTRACT

The 5-kV High-Voltage Pulse Generator is used to deliver high-energy pulses to initiating devices for explosive tests. While the triggered spark gap installed has a 200 J rating, the energy storage capacitor used limits the output to 57.6 J at 4.8 kV. At this limit, the pulser delivers a peak current of 2400 A into a 1.25-Ω resistive load.

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CHAPTER 1

INTRODUCTION

The 5-kV Pulser is used primarily to fire low-impedance explosive initiating devices used in explosive tests. While the maximum operating potential of this pulser is 200 J at 5 kV, the actual operating range depends on the Triggered Spark Gap (TSG) and the Energy-Storage Capacitor installed. The 5-kV Pulsers have been supplied a 5-μF, 5-kV pulse-discharge Energy-Storage Capacitor for a maximum energy content of 57.6 J when fired at the spark gap limit of 4.8 kV. Tested in this configuration, the 5-kV Pulser has delivered a peak current pulse of 2400 A into a 1.25-Ω resistive load.

The 5-kV Pulse Generator can be placed with the 10-kV Pulse Generator in the rack described in Appendix C in Reference 1 and connected to a Firing Line Safety Lockbox (see Appendix A in Reference 1), a High-Voltage Pulse Generator Monitor and Control (see Appendix B in Reference 1), and the bombproof master control panel to complete a system for safely firing both the explosive initiating device and the camera lighting source.

After the Energy-Storage Capacitor is slowly charged through a resistive network, it is discharged quickly through the explosive initiator by way of a high-energy switch. The switch used is an EG&G Inc. ceramic-metal, three-electrode TSG connected in a series-switch, Mode A configuration. The heavy lines in Figure 1-1 show the typical wiring for Mode A operation as copied from EG&G Inc. literature. Shown are voltage polarities and trigger circuit requirements for Mode A operation, which generally gives the widest operating range and shortest delay times for the spark gap. The typical operating range of TSGs is about 25 to 80 percent of self-breakdown voltage (SBV). The spark gap installed, an EG&G GP-31B-6, is rated at 6-kV SBV, 200 J. The operating range for this TSG is 1.5 to 4.8 kV, and the time delay of the pulser from the trigger pulse input to the onset of discharge is 0.5 μs.

Figure 1-2 shows the block diagram of the 5-kV Pulser. The top quarter of the drawing shows the high-voltage section, and the rest of the drawing shows the control circuits. When power to the instrument is turned on, the control circuits are energized, but the high-voltage section remains dormant. Once the High-Voltage switch is turned on, AC-line power is passed to the autotransformer that controls the output of the High-Voltage Power Pack, the Safety Charging Relay is turned on to allow charging of the Energy-Storage Capacitor, and the spark-gap Trigger Circuit power supply is turned on. Voltage on the capacitor is monitored by a 1000:1 voltage divider and displayed on a digital voltmeter on the Front Panel. After the desired

[1] Cleaver, Harry E., *High-Voltage Pulse Generator Capable of 2000 J at 10 kV*, NSWCDD/MP-92/222, 31 Jul 1992.

operating voltage is reached, the Safety Output Relay can be turned on from a remote location to connect the output firing line to the load. A trigger pulse applied to the Trigger Input fires the spark gap via the trigger circuit and the trigger transformer. The input trigger pulse also starts a shutdown sequence that turns off the High-Voltage On/Off control circuit to shut down power to the Safety Output Relay, the Safety Charging Relay, the High-Voltage Power Pack, and the Trigger Circuit power supply.

Each 5-kV Pulser was furnished at the time of its delivery with:

- a three-page form listing the specifications at installation,
- a description of the function of all control and indicators,
- warnings about safe limits on voltages and energy ratings,
- a set of operating instructions, and
- a copy of oscilloscope traces of the test firing of the pulser at its minimum and maximum operating range.

Nominal specifications of the pulsers with the components installed at the time of their delivery were:

- an operating range of 1.5 to 4.8 kV (TSG operating range),
- a 200-J limit on the spark gap, and
- a 2500 A for 20-μs rating on the Safety Output Relay.

With the GP-31B-6 TSG and the 5-μF Energy-Storage Capacitor installed, the 5-kV Pulser has a maximum energy limit of 57.6 J. Chapter 2 contains a copy of the form delivered with the pulsers.

The first 5-kV Pulsers were delivered in late 1985 and early 1986. As noted in MP-92/222 on the 10-kV Pulser, a continuing problem has been the equipment operators destroying the Trigger Input's silicon-controlled rectifier (SCR) by applying voltages exceeding the 15-V maximum limit of the Trigger Input circuit. Equipment operators must now use attenuators for input voltages exceeding 15 V. A future fix would be to redesign the Pulser Control Board to include some protective circuit components, which would limit the voltage impressed on the gate lead of the SCR.

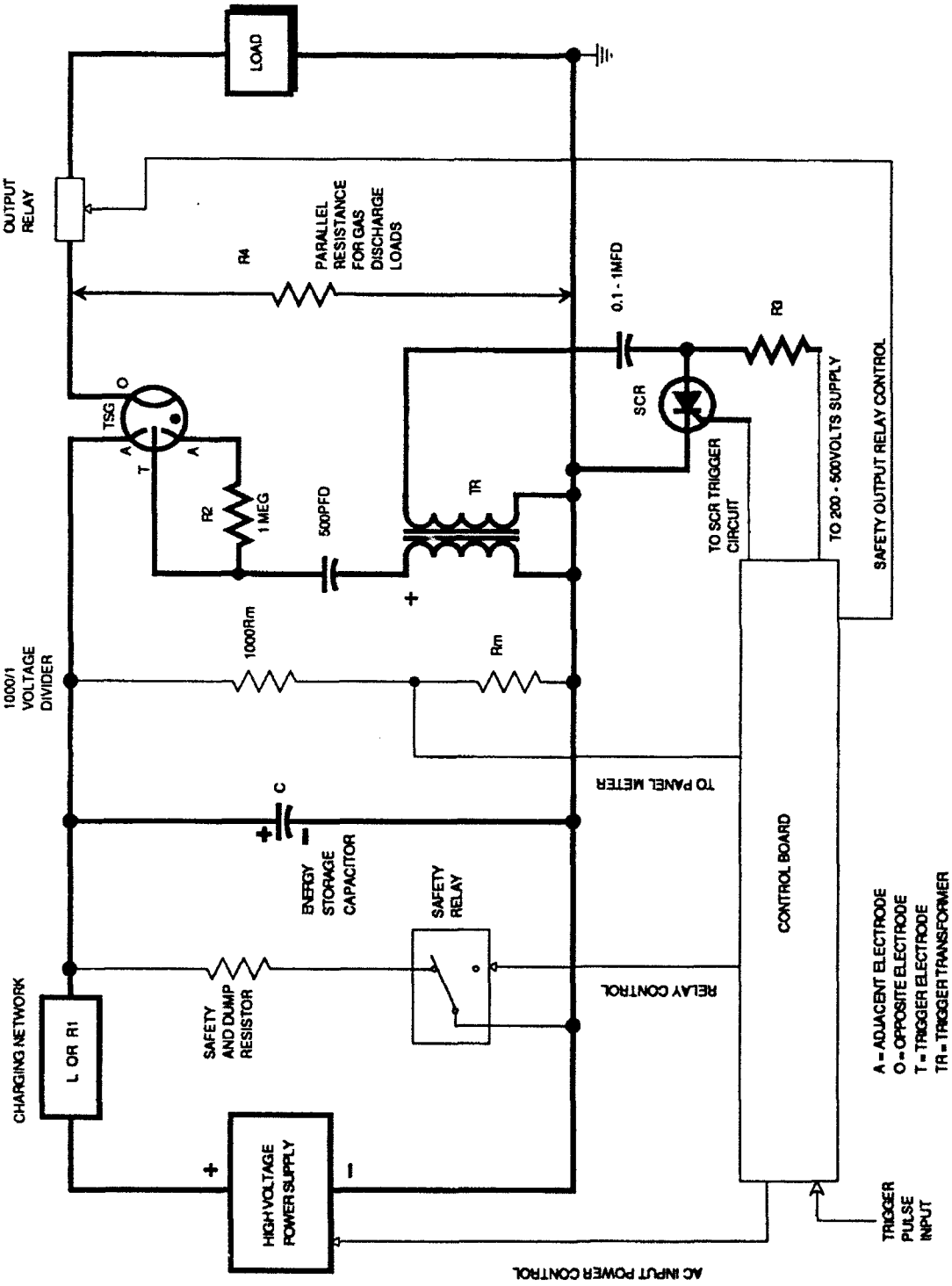


FIGURE 1-1. OVERVIEW OF PULSER SHOWING EG&G's MODE A TRIGGERING OF SPARK GAP

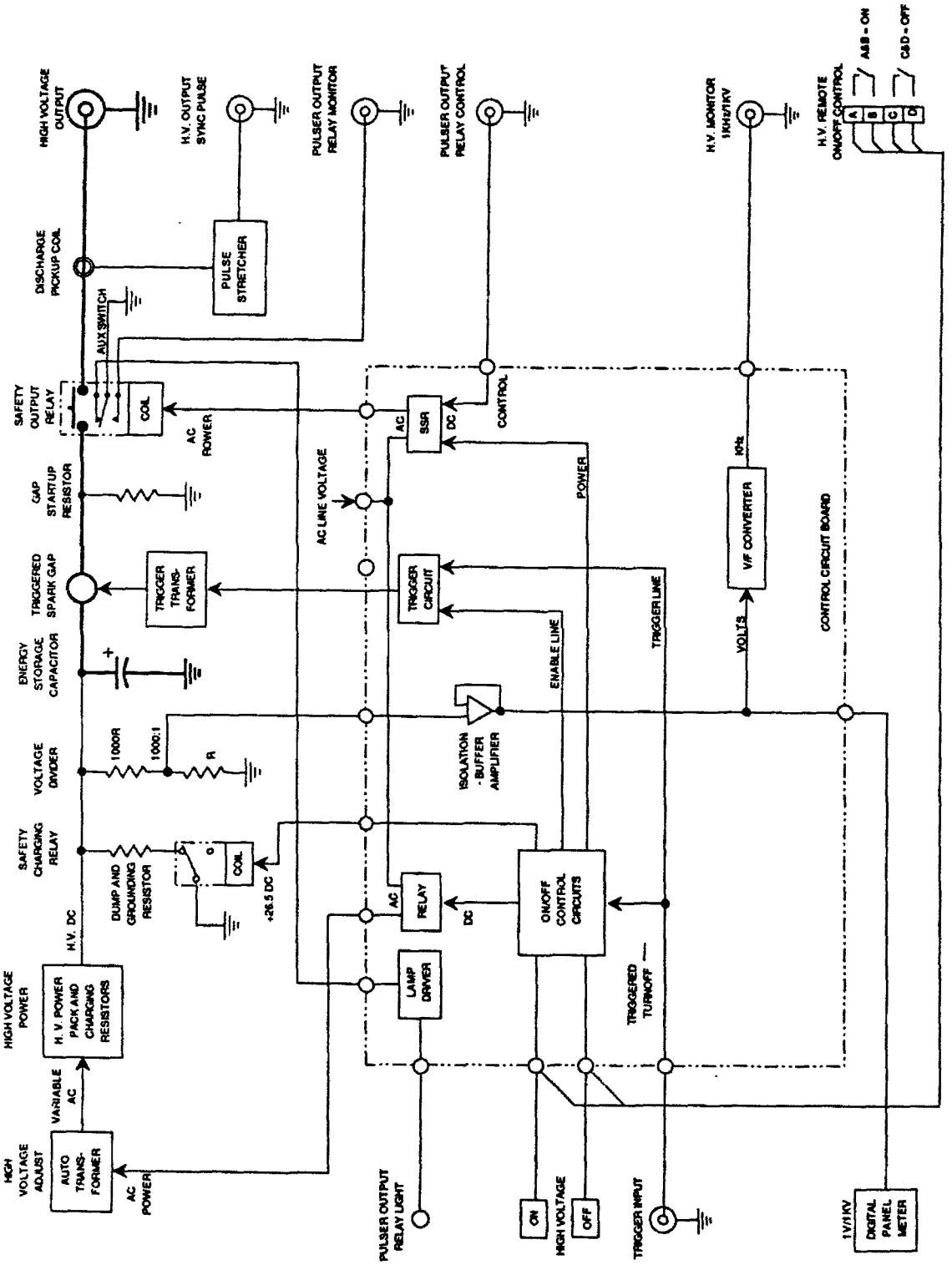


FIGURE 1-2. 5-kV PULSE GENERATOR BLOCK DIAGRAM

CHAPTER 2

SPECIFICATIONS AT INSTALLATION AND OPERATING INSTRUCTIONS

SPECIFICATIONS AT INSTALLATION

Operating Voltage Range	:	1.5-4.8 kV
Capacitor Installed	:	5 μF, 5 kV, Maxwell No. 34020
TSG	:	EG&G CP 31B-6, 6 kV SBV, 200-J capacity
Maximum Energy	:	57.5 J at 4.8 kV
Output Relay	:	Ross E12-NO-12-1-0, rated at 2500 A, capacitor discharge for 20 μs
Size	:	7-in high x 19-in wide x 19-in deep, rack mounted
Fuse	:	1.5 A

CONTROLS AND INDICATORS

FRONT PANEL	FUNCTION
AC Power	turns on/off AC Power.
High-Voltage On	turns on the high-voltage charging and control circuits.
High-Voltage Off	turns off the high-voltage section and discharges capacitors.
Voltage Adjust	controls high voltage stored on capacitors.
Digital Panel Meter	displays voltage level on storage capacitors.
Pulser Output Relay	light goes on when output relay is closed.
Trigger Input	+12- to 15-V max., 5-μs min. trigger pulse required to fire spark gap.

REAR PANEL	FUNCTION
High-Voltage Output	High-Voltage Output to firing line.
High-Voltage Sync Pulse	5- to 15-V positive pulse, load-current dependent.
Pulser Output Relay	
Remote Control	turns on output relay; requires switch closure to ground.
Remote Indicator*	auxiliary switch closure to ground to a monitor station when output relay is On.
High-Voltage Remote*	
Control	for remote operation of high-voltage section: • momentary switch closure on A-B turns on • momentary switch closure on C-D turns off.
Indicator*	1-kHz/1-kV frequency signal output to remote monitor - indicates high voltage level stored on capacitors.

*not required for operation of the pulse.

OPERATING INSTRUCTIONS

1. Connect Output Relay control cable to Pulser Output Relay Control.

2. Connect firing line to High-Voltage Output using Reynolds type-C cable. The following three connections are necessary **only** if remote control and monitoring is used.

   a. Connect remote on/off cable.
   b. Connect High-Voltage Remote Indicator to a monitor.
   c. Connect Pulser Output Relay Remote Indicator to a monitor.

3. Connect a trigger pulse generator to the Trigger Input. A +15-V max., 5-μs minimum trigger signal is required.

4. Turn on the AC Power.

5. Turn on the high voltage.

6. Charge the capacitor to the desired operating voltage. 1.00 V on the panel meter equals 1.00 kV on the capacitor.

7. Turn on the Pulser Output Relay using the remote control.

8. Trigger the pulser to discharge energy into the load.

9. Turn off the Pulser Output Relay using the remote control.

10. Turn off the AC Power when finished.

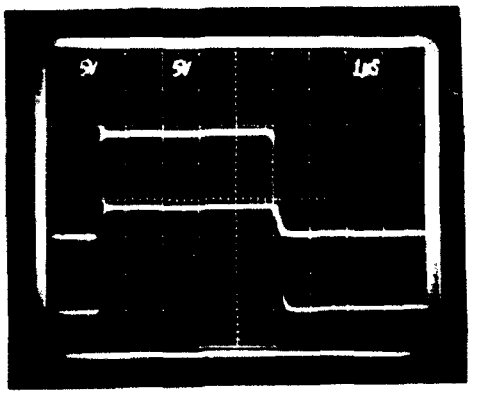
WARNING!

Serious injury to personnel or damage to equipment can result if this pulser is operated to exceed the:

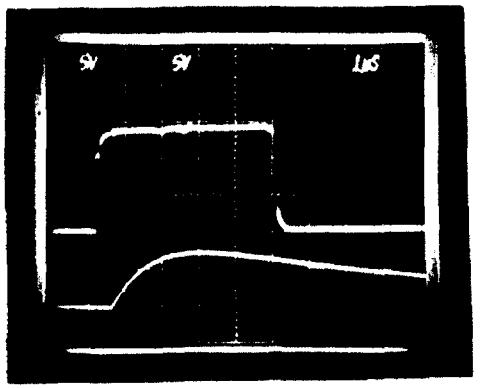
1. Energy-Storage Capacitor maximum working voltage,
2. maximum energy rating of the spark gap, or
3. operating range of the spark gap.

Figure 2-1 shows Polaroid photographs of typical test calibration of pulser firings at minimum- and maximum-rated voltages.

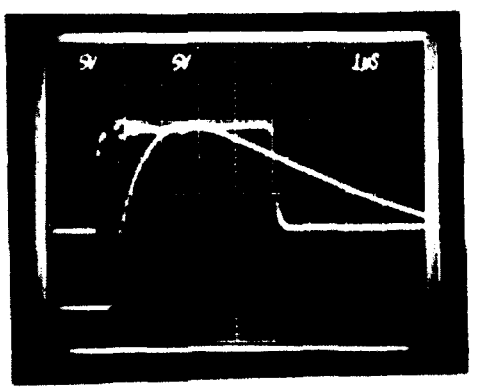
5-kV PULSE GENERATOR TEST
SERIAL NO.: 5-10
DATE TESTED: 23 JAN 91



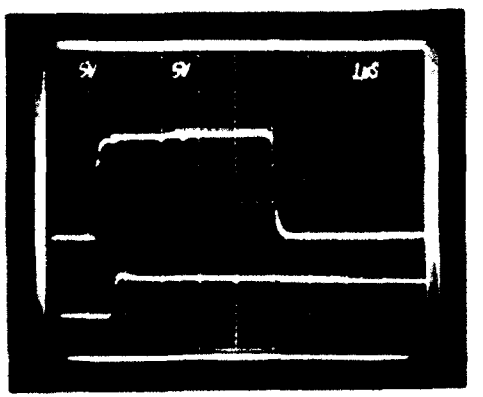
TRIGGER INPUT VERSUS TRIGGER INPUT
CALIBRATION OF UPPER AND LOWER BEAM
TIME BASE SYNCHRONIZATION



TRIGGER INPUT VERSUS CURRENT PULSE OUTPUT
1.25-OHM LOAD
1.5-kV POTENTIAL



TRIGGER INPUT VERSUS CURRENT PULSE OUTPUT
1.25-OHM LOAD
4.8-kV POTENTIAL



TRIGGER INPUT VERSUS SYNC PULSE OUTPUT
1.25-OHM LOAD
1.5-kV POTENTIAL

FIGURE 2-1. TYPICAL CALIBRATION TEST RESULTS FURNISHED WITH EACH PULSER DELIVERED

CHAPTER 3

THEORY OF OPERATION

POWER

Figure 3-1 is the schematic for the pulser. AC-line power enters the pulser through a Corcom 6EF1 Power-Line Filter. When the AC Power switch S1 is turned on, AC voltage is applied to the dual 15-V and the 28-V DC power supplies, the Digital Panel Meter, and pin Z of the Pulser Control Board edge connector J8. All lights are run off the 28-V power supply, which has been adjusted to 26.5-V output during assembly startup procedure to meet the operating voltage level of the ITT-Jennings Vacuum Relay K4. Fusing for the pulser power supplies is 1.5 A.

HIGH-VOLTAGE ON

When High-Voltage On switch S2 is momentarily pressed, relay K1 on the Pulser Control Board goes on. Contacts on K1 latch its coil on via diode D6 and resistor R1. The contacts on K1 also pass 15 VDC to:

- turn on transistor Q1, which turns on the High-Voltage ON light and Safety Charging Relay K4,
- turn on relay K2 to pass AC Power to the Superior Electric autotransformer (T1) primary winding,
- apply 15 VDC to the positive terminal of the Crydom solid-state relay SSR1,
- turn on relay K3, which removes the drain resistor R6 from across capacitor C1, the trigger circuit Energy-Storage Capacitor, and
- the DC/DC Converter supply used to charge capacitor C1 in the spark-gap trigger transformer circuit.

When relay K4 turns on, the 10-kV safety drain resistor R28 (2.2KΩ, 30W) is disconnected from the terminals of the Energy-Storage Capacitor. The high-voltage section is now ready to be charged. When relay K3 goes on, capacitor C1 charges up to the potential of the output of the DC/DC Converter via the 10-MΩ resistor R9. The nominal voltage on C1 can be read at Test Point 1 with a voltmeter having at least a 10-MΩ input impedance. Setting the output voltage of the DC/DC Converter is described in Chapter 2's section on calibration.

To charge the capacitor, the operator rotates the High-Voltage Adjust knob on the autotransformer clockwise to increase the AC voltage applied to the Hipotronics High-Voltage Power Pack. As the High-Voltage Output of the power pack rises, current flows through the charging resistor network (R30 and R31) to the capacitors.

The 5-MΩ charging resistors, R30 and R31, are connected in parallel to share power dissipation and present an equivalent charging resistance of 2.5-MΩ. The equivalent resistance of 2.5 MΩ with the 5-μF capacitor gives a charging time constant of 12.5 s. Actual charging times are longer because as the voltage on the capacitor rises, the voltage differential across the charging network decreases, and the charging current drops off. The charging time can be shortened by raising the output of the power pack above the desired operating point of the capacitor and then trimming back as the voltage approaches its desired final value.

Voltage on the capacitor is monitored by a 1000:1 voltage divider made up of R26 and R27, such that 10 kV = 10 V full scale on the Digital Panel Meter. R26 is a Caddock MG735, 100-MΩ, 10-kV, 0.5-percent resistor, and R27 is a MG712, 100-kΩ, 1-kV, 0.5-percent type. The capacitor C11 across R27 is an attempt to filter out some of the electrical noise generated by the high-voltage discharge of the capacitor before it reaches the monitor circuit on the Pulser Control Board. The voltage divider output is connected to pin 16 of the Pulser Control Board by a shielded coaxial cable and sent to U1, an LM741 operational amplifier (OP-AMP). D8 is a 15-V zener diode transient voltage suppressor connected to the incoming signal from the voltage divider to clip noise on the signal when the capacitor discharges. The LM741, selected for its lower frequency response, is connected as a high-input impedance unity gain voltage follower/buffer amplifier to drive the voltage divider signal to the Front Panel digital voltmeter and to a voltage-to-frequency (V/F) converter U2. Output of the LM741 amplifier is connected to Test Point 2 and further filtered by capacitor C2. The V/F Converter converts the voltage divider signal to frequency and sends it out to a remote monitor station via connector J6, without concern for voltage drops in long cable runs. The Burr-Brown VFC42BF converter has a range of 0 to 10 V = 0 to 10 kHz, with a nonlinearity error of ±0.01 percent. The Newport 201-4 Digital Panel Meter displays the buffered voltage divider signal with a range of 10.00 V ±.01 percent.

Once the capacitor has reached its desired operating voltage level and test firing is required, the Safety Output Relay, K5, is turned on from a remote location via a switch closure to ground on connector J5. Grounding connector J5 turns on the Crydom D2W202F solid-state relay to apply 115 V AC-line power to the Safety Output Relay, a Ross Engineering Corporation E12-NO-12-1-0 (12-kV, 2500-A) capacitor discharge relay. When the Ross relay closes, auxiliary switch contacts open to change the bias on transistor Q2 on the Pulser Control Board. Transistor Q2 acts to turn on the Pulser Output Relay light LP1. The normally open contacts of the auxiliary switch close to send a switch closure to ground signal to the Pulser Output Relay Remote Indicator connector J4 on the Back Panel. With the Safety Output Relay turned on, the pulser may be triggered to discharge the capacitor into the load.

TRIGGERING THE PULSER

Triggering the pulser is accomplished by sending a +15-V, 5-μs pulse to the Trigger Input connector J1 (isolated BNC type) on the Front Panel. The signal is carried on a shielded coaxial cable to the Pulser Control Board and goes through diode D9 to two circuits. Diode D9 is in the line to block electrical noise when the pulser discharges from being fed back to the trigger pulse generator. The circuit around the SCR Q3 is the pulse-forming network for the spark-gap trigger transformer. The input trigger pulse passes through R15 with its speed-up capacitor C3 and is divided down at the gate of the SCR by R16 to trigger Q3 into conduction. When Q3 breaks into conduction, capacitor C1, charged to the voltage output of the

DC/DC Converter, discharges through the primary of the spark-gap trigger transformer T2 (EG&G TR-180B). The 20- to 30-kV pulse output of T2 is capacitor-coupled by C9 to the trigger electrode of the spark gap. Triggered into conduction, the spark gap discharges high-voltage capacitor C10 through the Safety Output Relay and via the High-Voltage Output connector J2 to the load. Reynolds connectors and Reynolds Type C coaxial cable are used in the firing line system. R24, a Carborundum 886AS 1-kΩ, 10-kV, 30-W resistor, on the downstream side of the spark gap provides for a startup current path until load conduction starts if the gap is used for overvoltage triggering of a gas discharge tube. R24 also provides a discharge current path if the pulser is inadvertently triggered when the Safety Output Relay is in the Off condition.

At the time when the Trigger Input signal fires SCR Q3, it also triggers SCR Q4 in the high-voltage shutdown circuit. The input trigger pulse passes through the R17, R18, R19, and C4 network to the gate of Q4 and triggers it into conduction. When Q4 conducts, capacitor C5, charged to 15 V via R20, discharges through Q4, R21, and the coil of relay K6. R21, a 1-kΩ resistor across the coil of K6, is needed to ensure enough startup current through Q4 to kick it into conduction during the interval of the input trigger pulse. While C5 is discharging through the coil of K6, the normally closed contacts of K6 open to break the +15-V power connection to the contacts on relay K1. With the power connection broken to its coil, K1 turns off and power is thereby removed from:

- Q1, which turns off the High-Voltage On light and ITT-Jennings Vacuum Relay K4 (reconnects resistor R28 across the terminals of the capacitor C10);
- relay K2, which then turns off AC Power to the Superior Electric autotransformer to shut down the High-Voltage Power Pack;
- Crydom solid-state relay SSR1, which turns off the Ross Safety Output Relay and moves the auxiliary switch to turn off the Pulser Output Relay ready light LP1;
- relay K3, which turns off to reconnect drain resistor R6 across capacitor C1; and
- the MIL Electronics VL10 DC/DC Converter, shutting it down.

When the discharge current flow from capacitor C5 drops below the holding values for SCR Q3 and relay K6, they will turn off, and the SCR will recover to its blocking state. Capacitor C5 will then recharge to +15 V through resistor R20.

A simple hand-wound coil of wire is placed around the heavy discharge current wire connecting the Safety Output Relay to the High-Voltage Output connector J2. When discharge current flows through the wire, a current is induced in the pickup coil to produce a voltage across resistor R23 on the pickup-coil circuit board to charge capacitor C8. This circuit is uncalibrated, and its output signal is dependent upon the current pulse in the discharge line, but the signal may be used as a marker pulse, or as a trigger for a marker pulse. Diode D10 serves to shape the signal for a positive output by charging capacitor C8 to a positive voltage and blocking the voltage from bleeding off back through the low resistance of the pickup coil. Zener transient suppressor diode D15 is to limit the maximum signal output voltage. Resistor R23, in conjunction with the high impedance (1 MΩ) of the monitor circuit amplifier, tends to

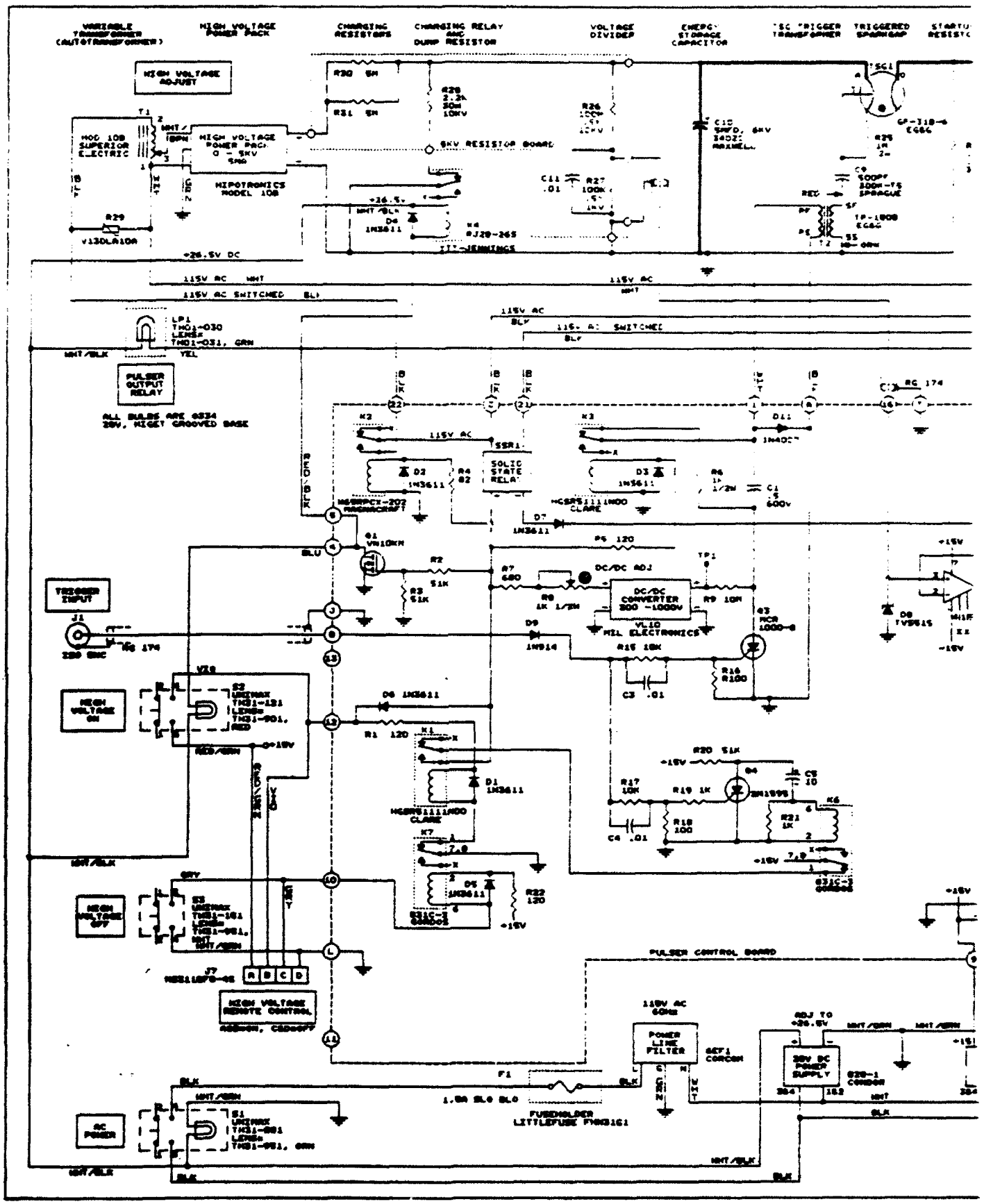
stretch the discharge of capacitor C8 to produce an output signal for a longer period of time.

HIGH-VOLTAGE OFF

Once on, the High-voltage section can be manually turned off by pressing the High-Voltage Off switch S3, which will turn on relay K7 to remove power from relay K1 and initiate the high-voltage section shutdown already described. Energy stored on capacitor C10 will be discharged through R28 by contacts on the vacuum relay K4, as described above, and the pulser will return to its standby condition.

MISCELLANEOUS

All DC relays have 1N3611 diodes across their coils to suppress reverse EMF generated when power to the coils is removed. Diode D11, a 1000-V reverse breakdown voltage-rated type, suppresses reverse electromagnetic force generated in the trigger transformer's primary winding to protect SCR Q3. A varistor, R29, is placed across the autotransformer primary to suppress noise generated when AC Power to the autotransformer is turned off.


HIGH VOLTAGE ADJUST
HIGH VOLTAGE POWER PACK
HIPOTRONICS MODEL 108
8KV RESISTOR BOARD
+26.5V DC
115V AC
115V AC SWITCHED
PULSER OUTPUT RELAY
TRIGGER INPUT
HIGH VOLTAGE ON
HIGH VOLTAGE OFF
HIGH VOLTAGE REMOTE CONTROL
AC POWER
DC/DC CONVERTER 500 -1000V
MIL ELECTRONICS
SOLID STATE RELAY
PULSER CONTROL BOARD
POWER LINE FILTER
50V DC POWER SUPPLY
FUSEHOLDER LITTLEFUSE FHM361
1.0A SLO BLO

1

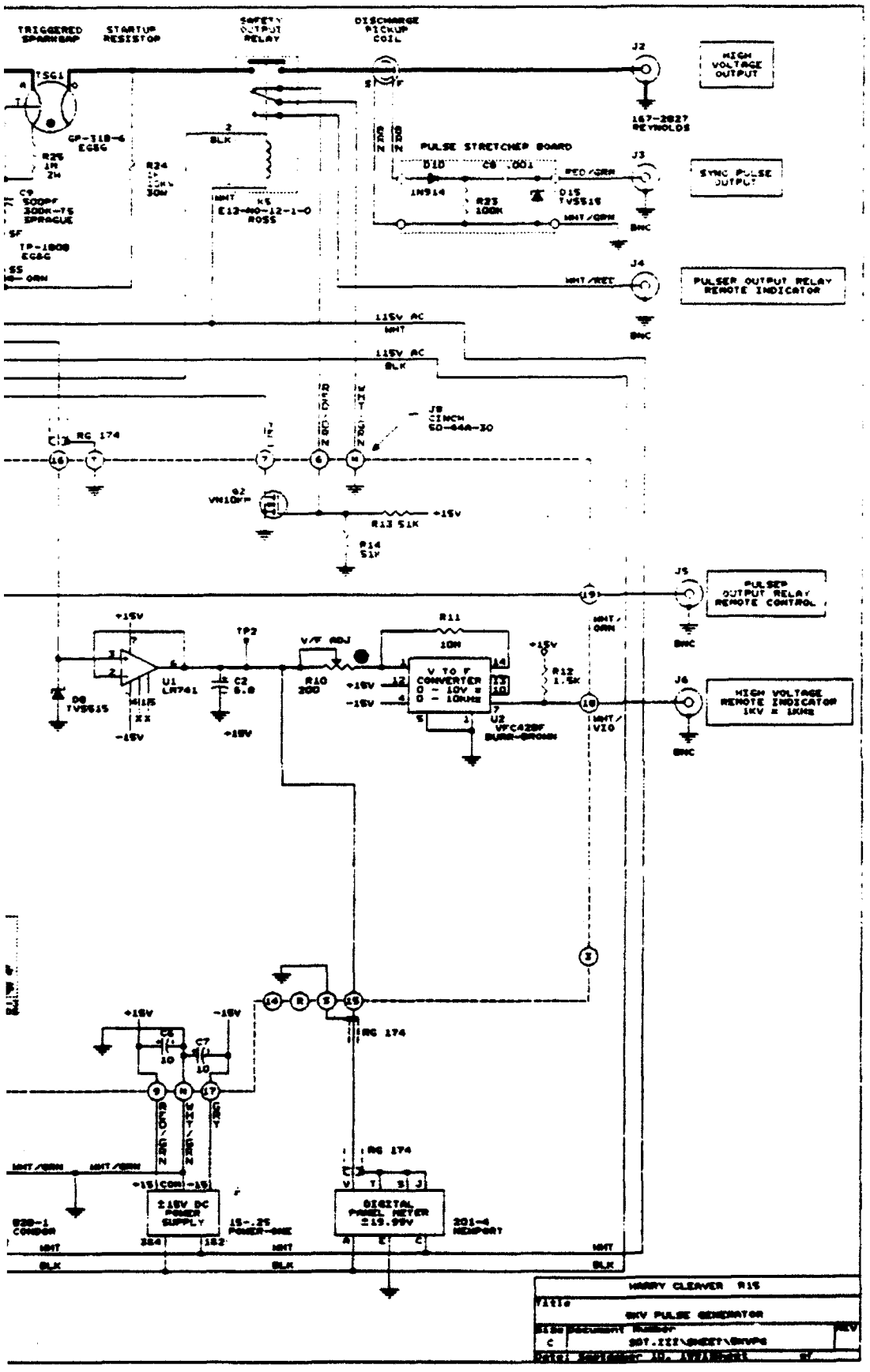


FIGURE 3-1. 5-kV PULSER SCHEMATIC

CHAPTER 4

ASSEMBLY INSTRUCTIONS

Ten pulsers of the 5-kV type were built between 1985 and 1990 by various people who followed the guidelines incorporated in this report. The result is that while the pulsers look and perform identically from the outside, there are some interior variations in construction details from unit to unit, such as wire colors and component placement in the high-voltage section. What follows is a generalized set of instructions for assembling a 5-kV Pulser, noting that any individual pulser already in existence may vary slightly in construction details.

The Pulser is constructed in a Techmar Corporation instrument package using their side rails, bottom mounting plate, cross mounting bars, covers, and handles. A parts list for the pulser is shown in Table 4-1. Construction efforts should begin with drilling or cutting all mounting holes in the side frames and bottom mounting plate as shown in Figures 4-1 through 4-3.

Because the bottom plate has turned-down edges fitted with captive nuts, cutting out the rectangular hole for the printed circuit board edge connector on the jigsaw must be done with the top side down on the saw table. These edges interfere with marking the bottom side of the panel for the rectangular opening, so a template was made for marking the connector hole size and location. After the board connector hole is ready, mount the connector from the underside of the panel. Insert the Pulser Control Board into the connector and, holding the printed circuit-board card guides in their proper places, mark where the four holes in each guide have to be drilled. Drill the eight holes for 4-40 screws. Once the side frames and bottom plate have been cut and drilled, they can be screwed together along with the two cross mounting bars.

The Interior Panel, the High-Voltage Cover Panel, and the Back Panel all have mounting hole locations marked in the surface artwork. When these holes have been cut and drilled, they can be loosely fit into the assembled side frames and bottom plate to mark corresponding hole locations on the cross mounting bars shown in Figures 4-4 and 4-5. The mounting bars can then be marked, drilled, and tapped as shown.

Once all holes in the Back Panel have been prepared, the decal shown in Figure 4-6 is attached. The decal, an adhesive backed thin red metal plate with "HIGH-VOLTAGE OUTPUT" imprinted in white, is affixed over the Reynolds connector hole aligned with marks in the panel. When the label is in place, a hole is cut through the thin metal with a sharp knife following the circumference of the hole in the panel. After all holes are finished in both front and rear panels, components can be mounted on them before they are secured in place.

Next, construct the mechanical parts shown in Figures 4-7 through 4-10, and the pickup coil in Figure 4-11. The High-Voltage Resistor Board Component Layout shown in Figure 4-12 is the old version of the capacitor-charging network board.

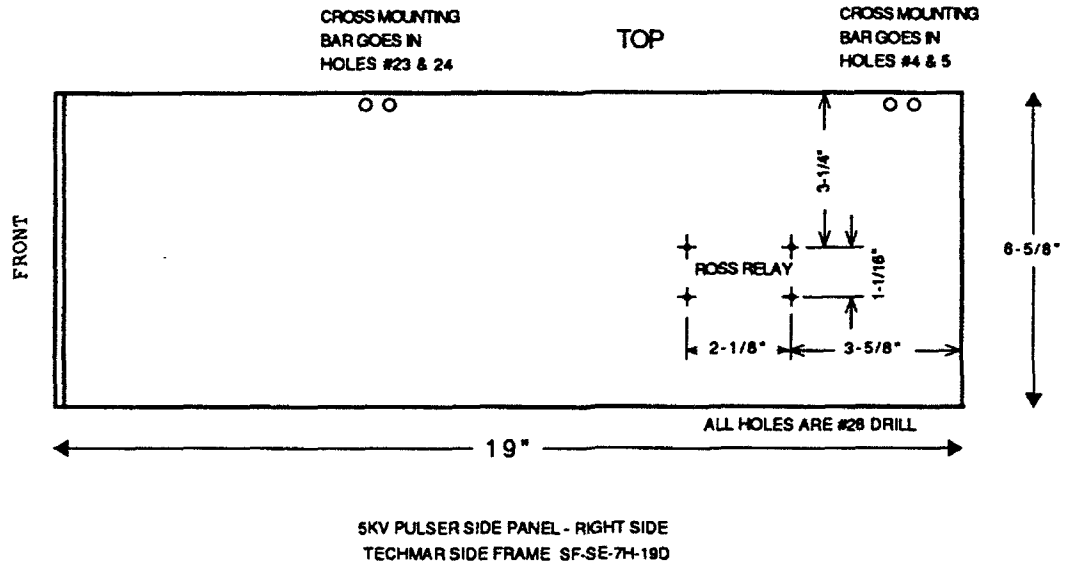
All 5-kV Pulsers built to date have this board, but any repairs, updates, or new construction will have to use the new board found in Reference 1 because the old charging resistor product line has been discontinued by its manufacturer. The high-voltage resistor board and the pickup coil board, shown in Figure 4-13, have to be available during wiring of the unit and can be constructed ahead of time.

When all the mechanical parts and the two printed circuits boards mentioned are ready, they can be assembled into a unit, and wiring of the pulser can begin by following Figure 4-14, the Wiring Layout Schematic, which shows wire color codes and tie points.

A separate component layout and wiring diagram of the high-voltage section is shown in Figure 4-15. After installing the power pack, vacuum relay, High-Voltage Output relay, charging resistor board, and AC Power shield, place the plastic insulator block for the spark gap circuit in the orientation shown in Figure 4-15, mark the mounting hole locations and drill the bottom mounting plate for 6-32 screws. Attach the spark-gap trigger transformer, coupling capacitor, and Energy-Storage Capacitor to the plastic block with aluminum straps bent around the components as shown in Figure 4-15. (Bend the straps, drill the ends for 6-32 screws, mark the hole positions on the plastic block and drill and tap the block for 6-32 screws.) Fasten the plastic block in place, and wire the high-voltage section as shown in Figures 4-14 and 4-15.

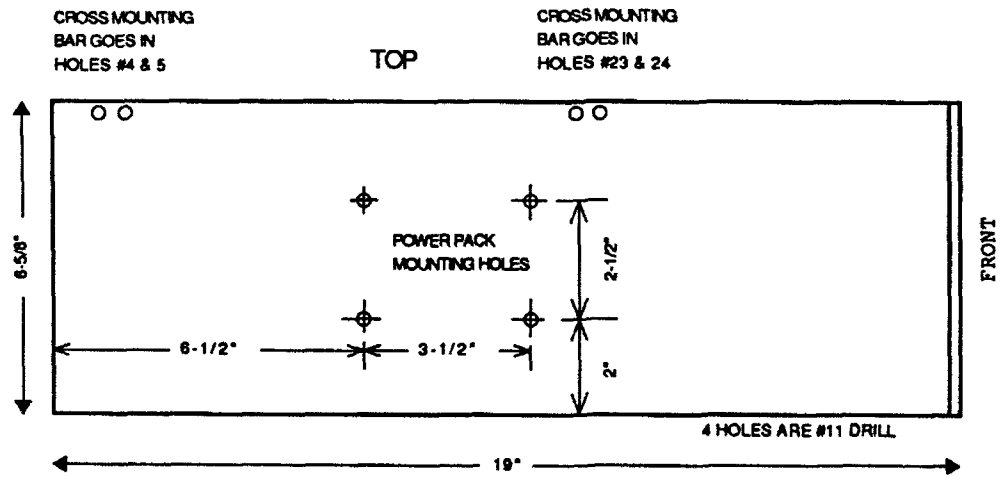
Figure 4-16 shows the Pulser Control Board component layout. A parts list for this board, derived from the complete parts list in Table 4-1, is shown in Table 4-2. This board can be constructed at any time but will not be needed while wiring of the chassis is being done. It will be the last item to be inserted into the pulser after initial turn-on adjustments are made.

When the chassis assembly and wiring is finished, leave the top cover and the high-voltage section cover off, and follow the instructions in Chapter 5 for the initial turn-on and calibration procedures.



5KV PULSER SIDE PANEL - RIGHT SIDE
TECHMAR SIDE FRAME SF-SE-7H-19D

FIGURE 4-1. 5-kV RIGHT SIDE RAIL DRILL GUIDE



5KV PULSER SIDE PANEL - LEFT SIDE
TECHMAR SIDE FRAME SF-SE-7H-19D

FIGURE 4-2. 5-kV LEFT SIDE RAIL DRILL GUIDE

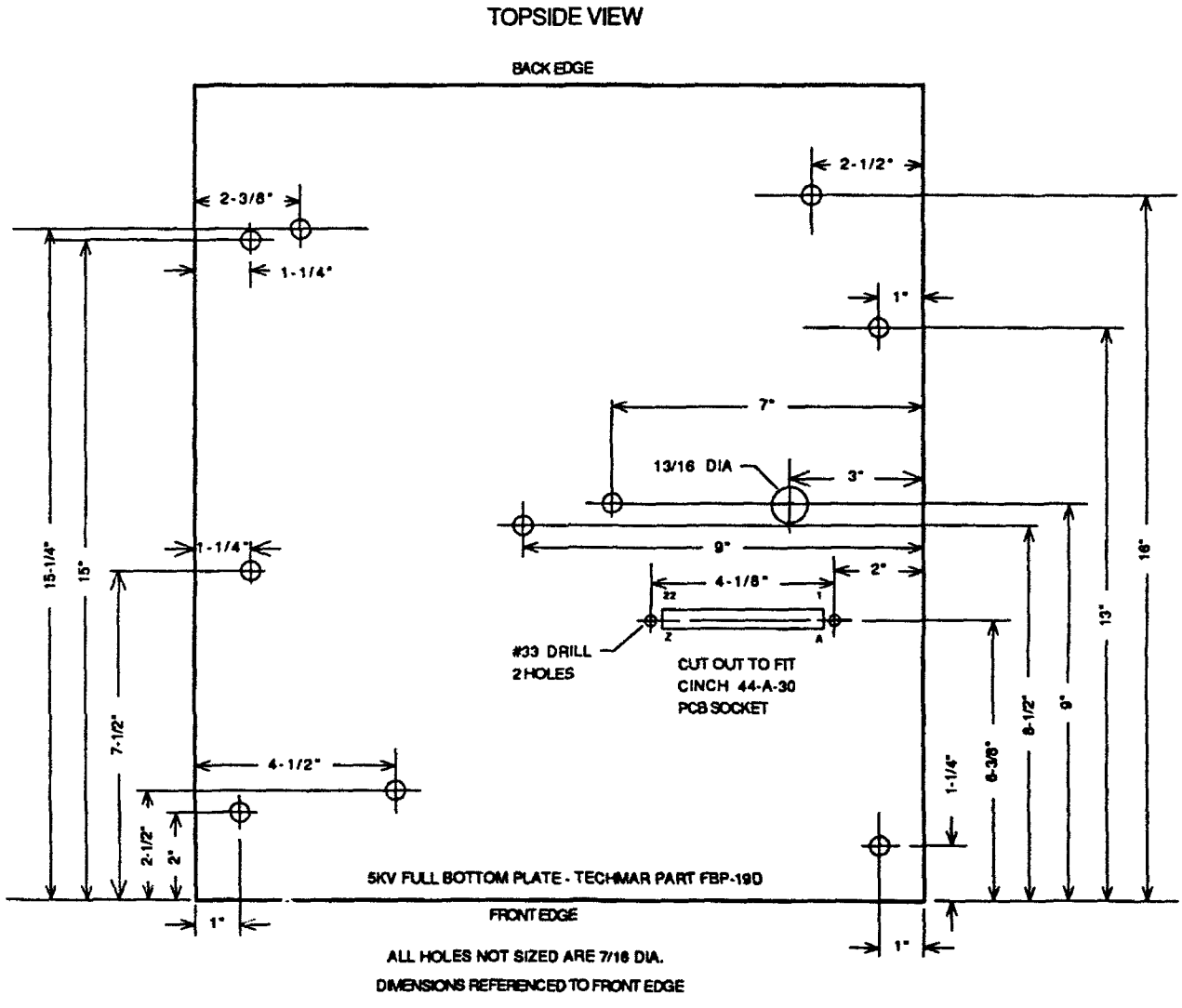


FIGURE 4-3. 5-kV BOTTOM MOUNTING PLATE CUT AND DRILL GUIDE

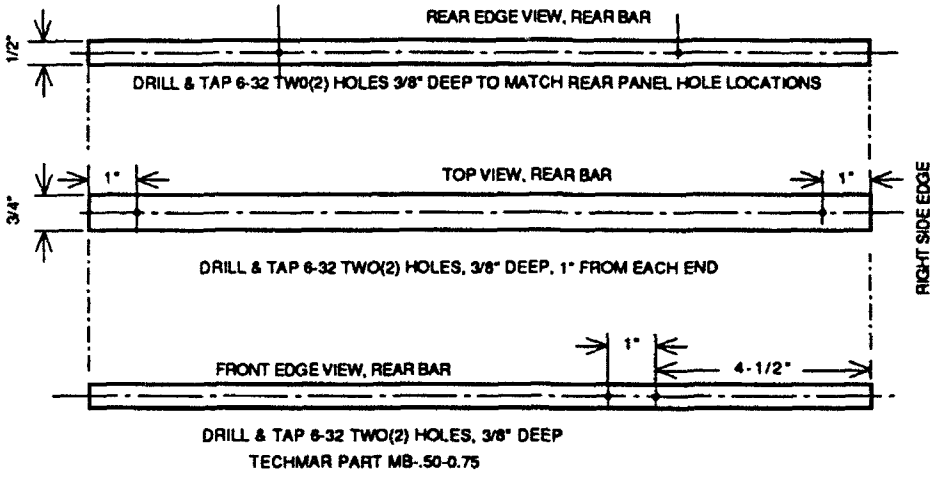


FIGURE 4-4. REAR CROSS MOUNTING BAR DRILL GUIDE

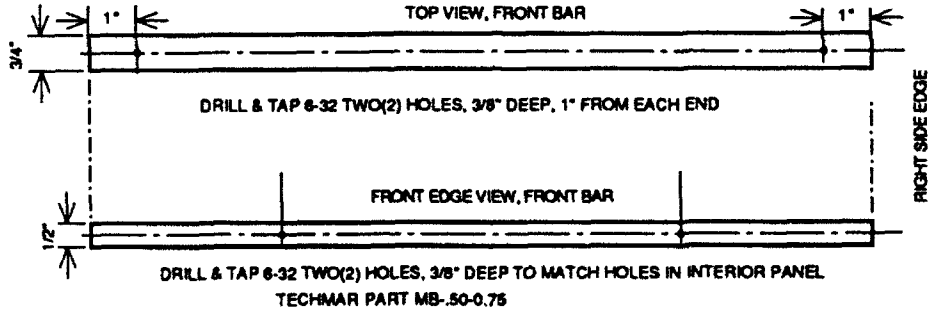
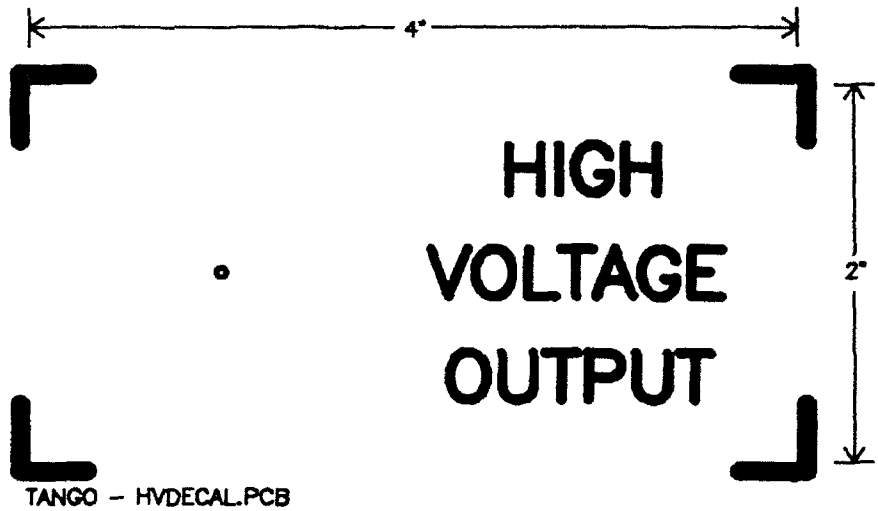


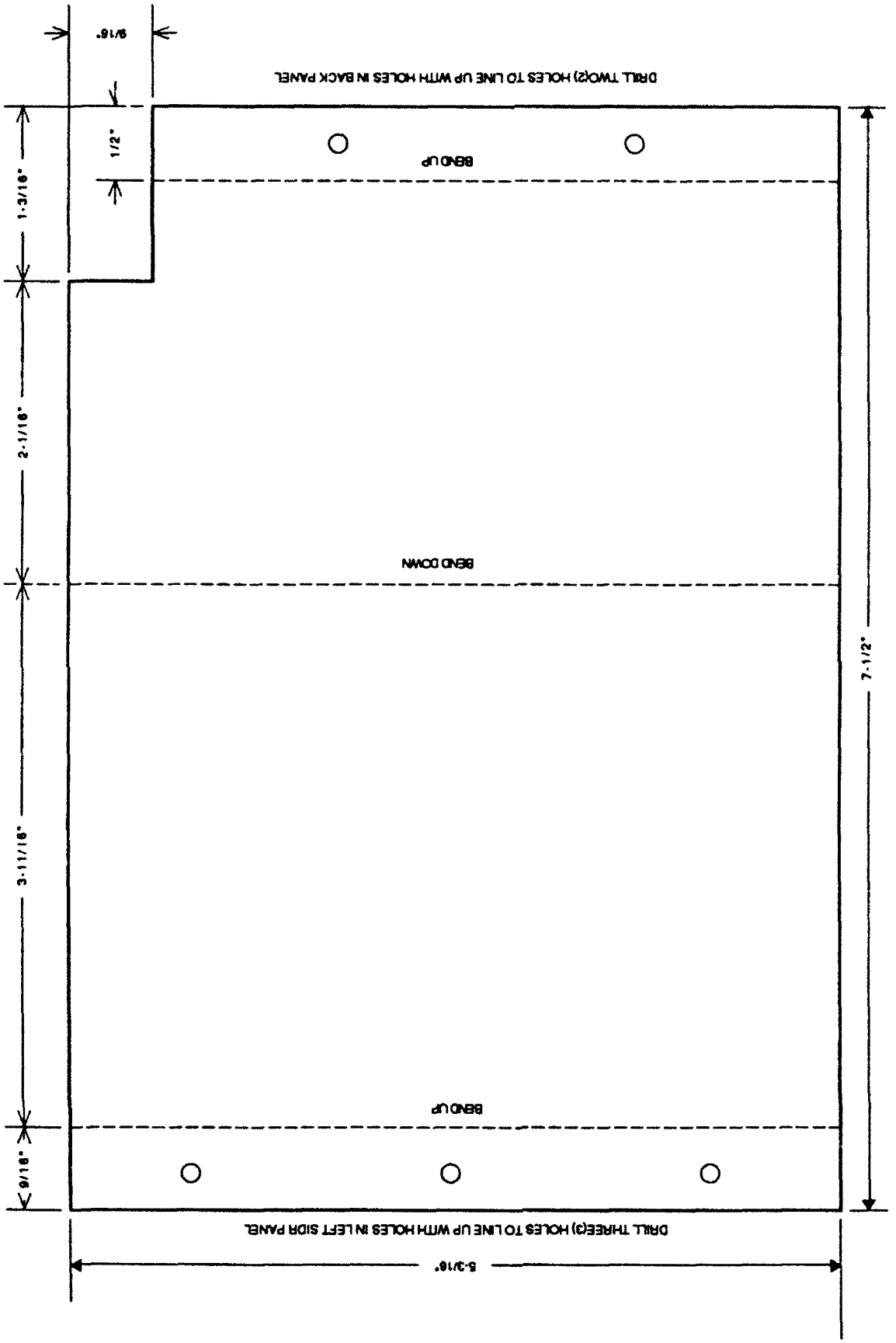
FIGURE 4-5. FRONT CROSS MOUNTING BAR DRILL GUIDE



TANGO – HVDECAL.PCB

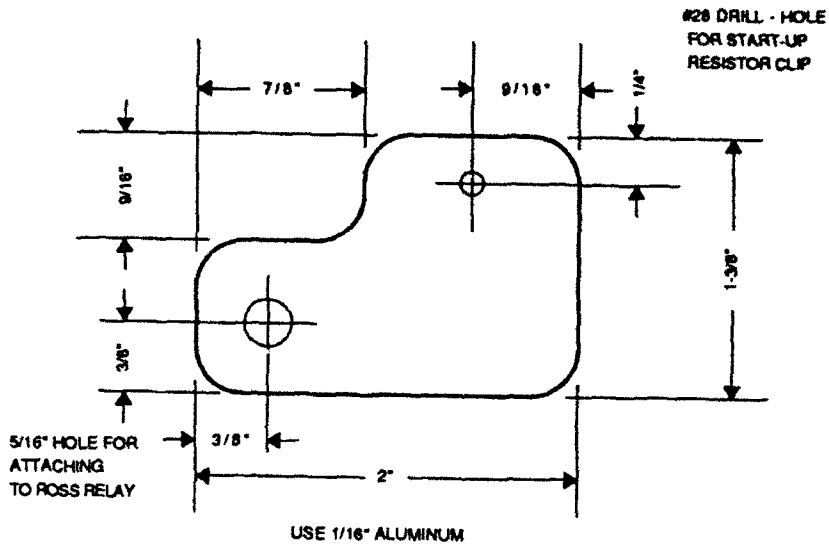
WHITE LETTERS ON RED BACKGROUND
USE THIN, ADHESIVE BACKED METAL FOIL DECAL
CUT TO INSIDE OF CORNER MARKS

FIGURE 4-6. HIGH-VOLTAGE OUTPUT METAL FOIL DECAL

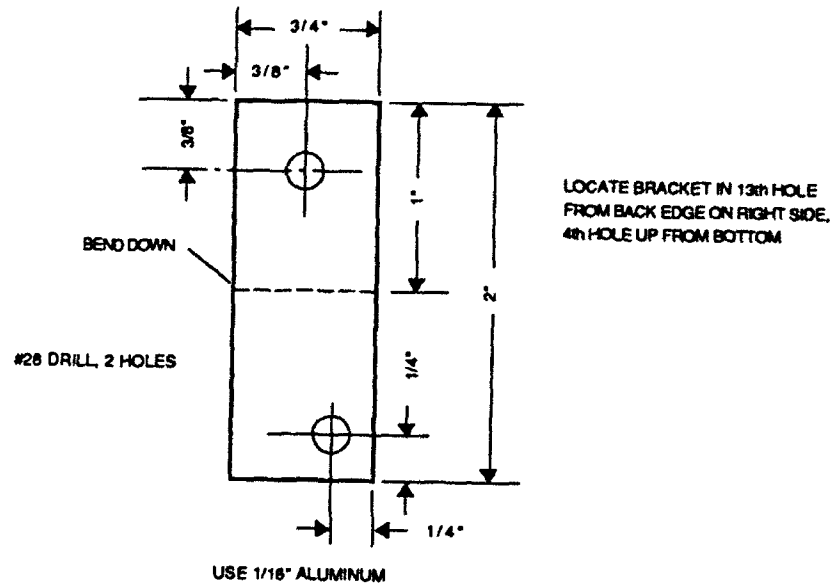


USE 1/16" THICK ALUMINUM

FIGURE 4-7. AC POWER INPUT SHIELD FABRICATION GUIDE



A. RELAY TERMINAL BRACKET



B. RIGHT SIDE WALL BRACKET

FIGURE 4-8. STARTUP RESISTOR CLIP MOUNTING BRACKETS

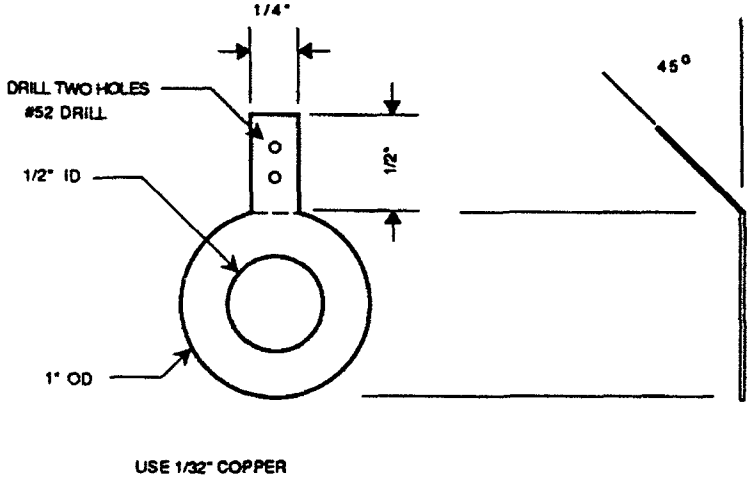
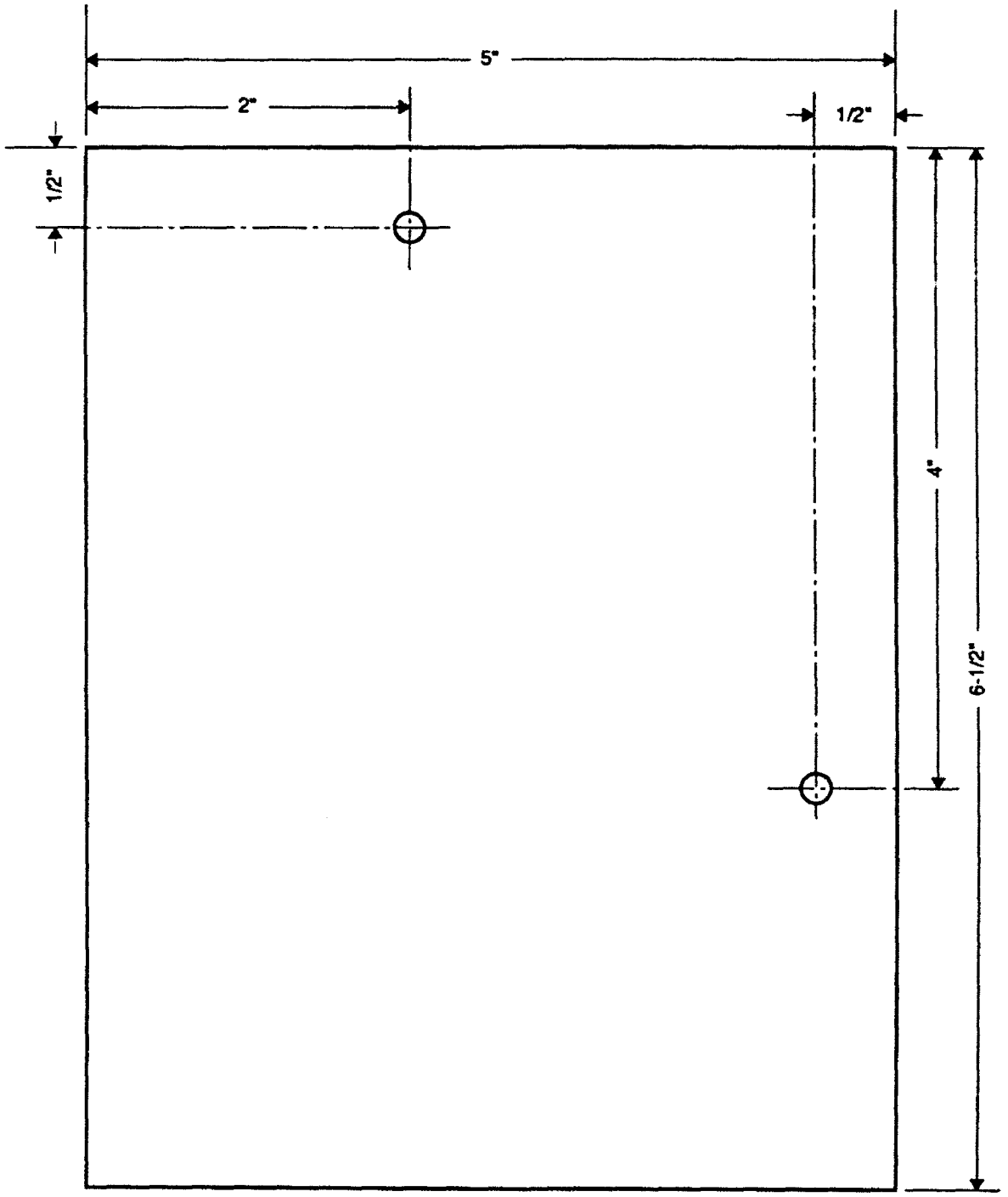


FIGURE 4-9. REYNOLDS HIGH-VOLTAGE CONNECTOR SOLDER LUG



DRILL THROUGH BLOCK
2 HOLES FOR 6-32 BOLTS

MATERIAL IS 1" PLEXIGLAS

FIGURE 4-10. SPARK GAP INSULATED MOUNTING BLOCK CUT AND DRILL GUIDE

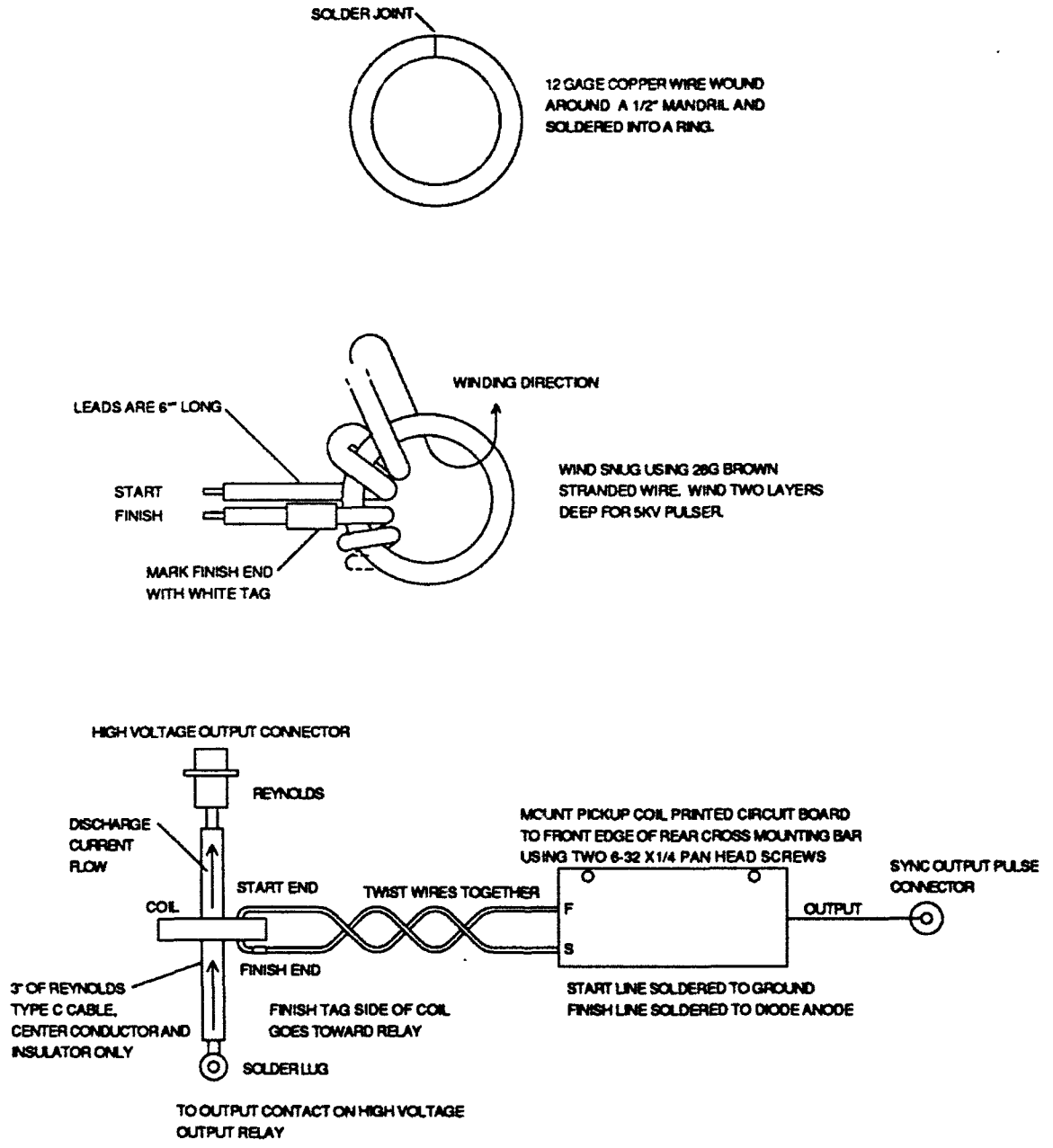


FIGURE 4-11. PICKUP COIL FABRICATION AND INSTALLATION

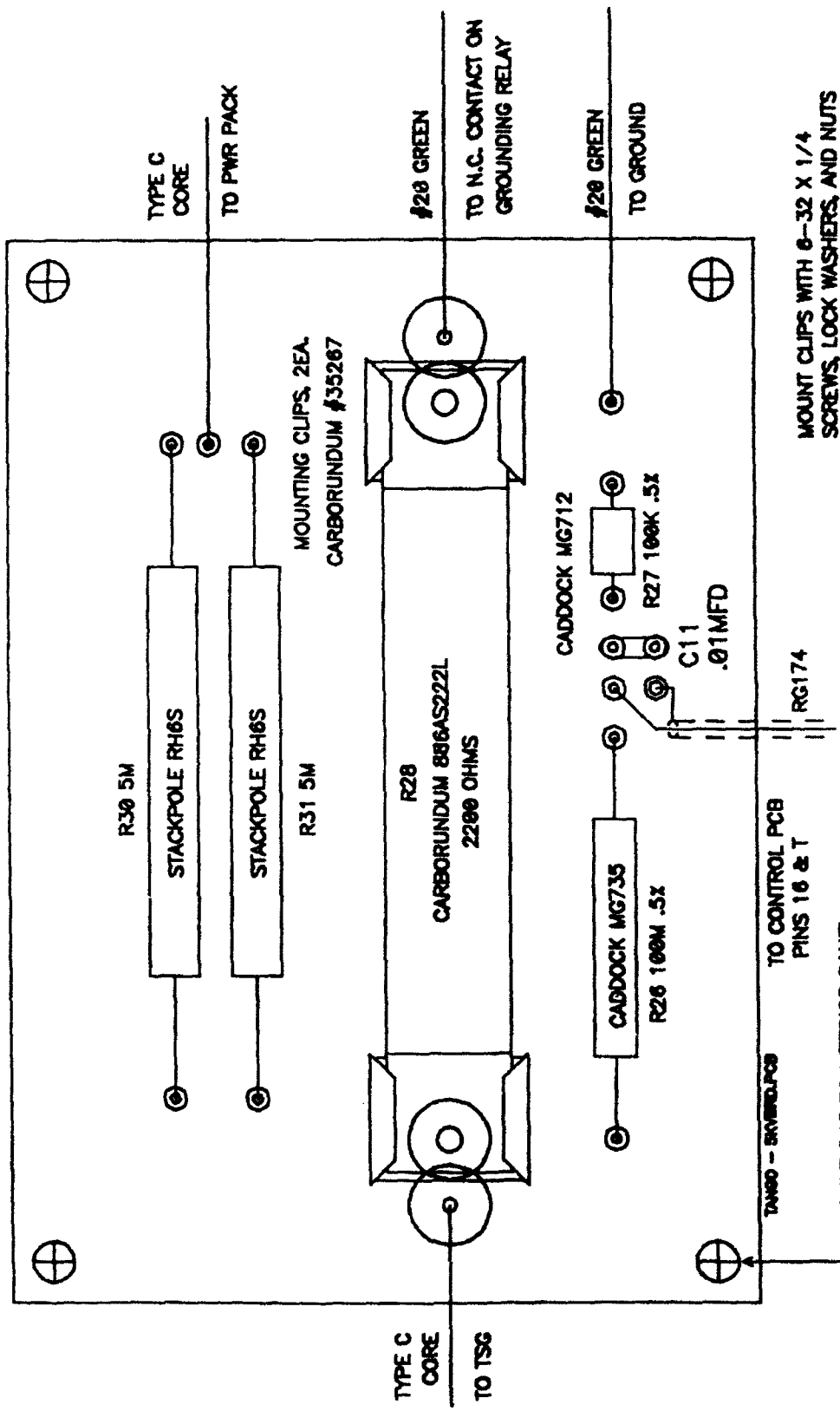


FIGURE 4-12. 5-kV RESISTOR BOARD COMPONENT LAYOUT

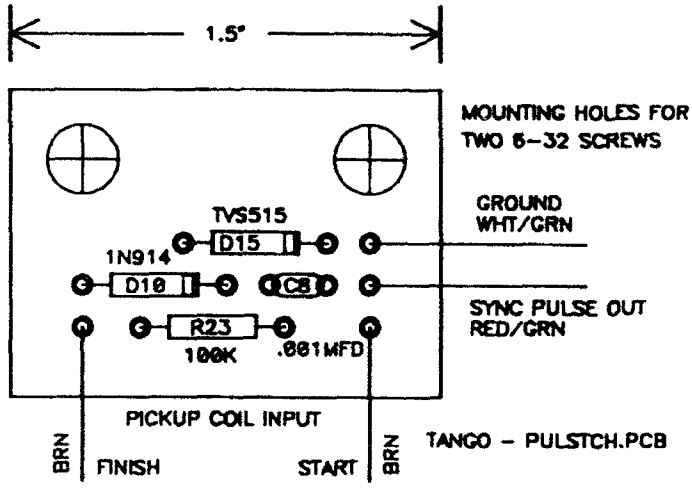
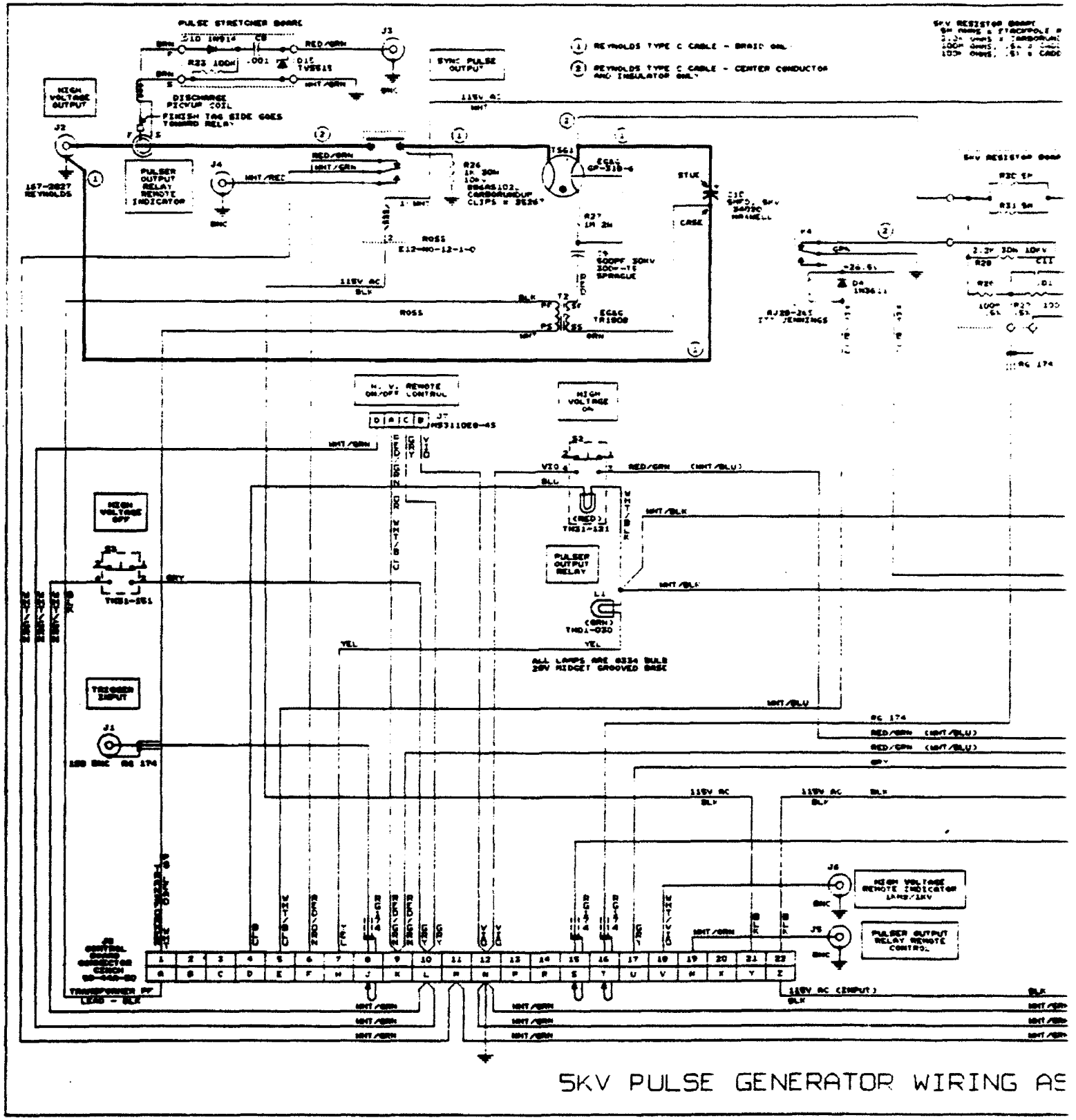
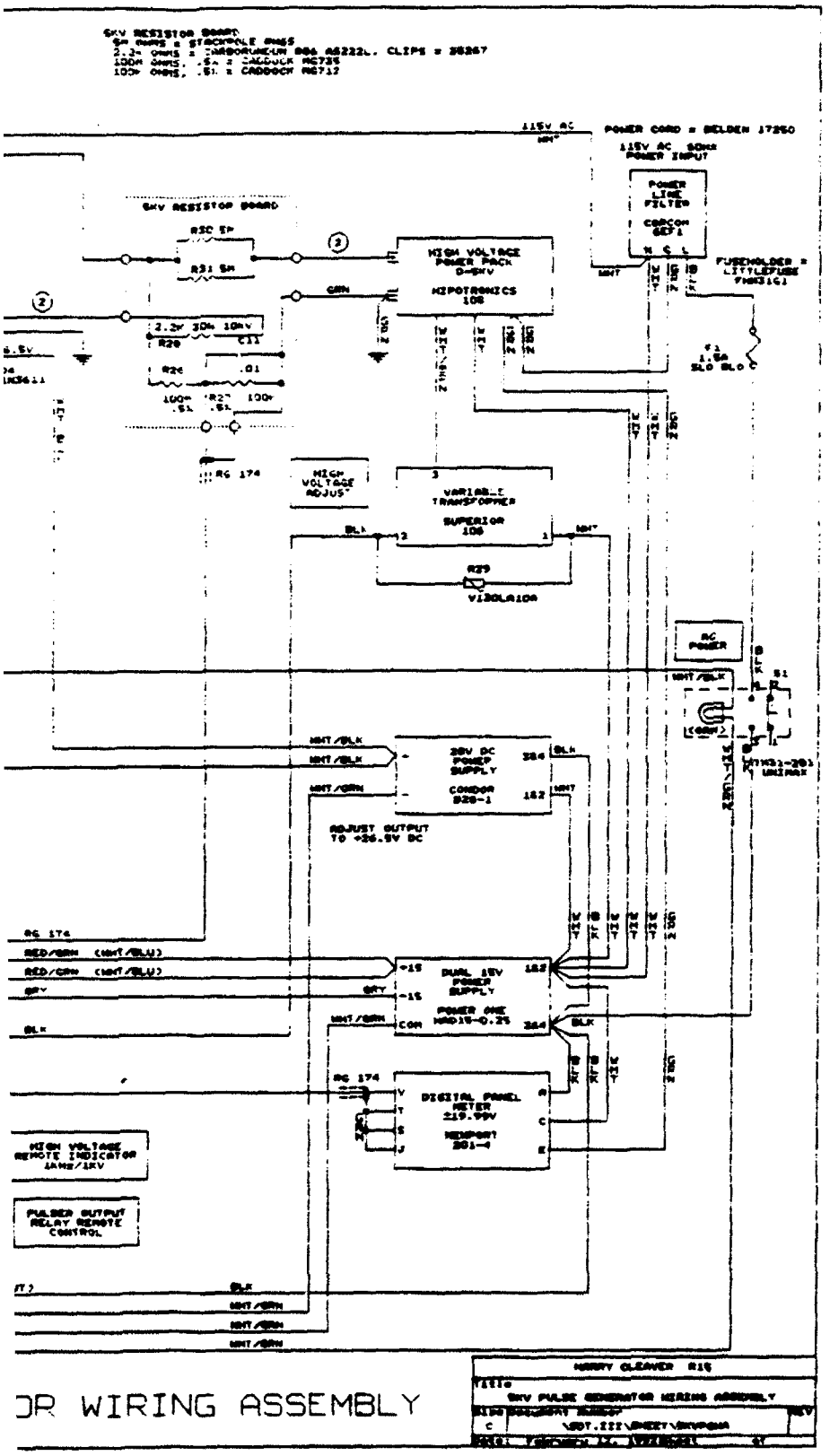


FIGURE 4-13. PULSE STRETCHER BOARD COMPONENT LAYOUT



5KV PULSE GENERATOR WIRING AS



DR WIRING ASSEMBLY

FIGURE 4-14. 5-kV WIRING ASSEMBLY

(2)

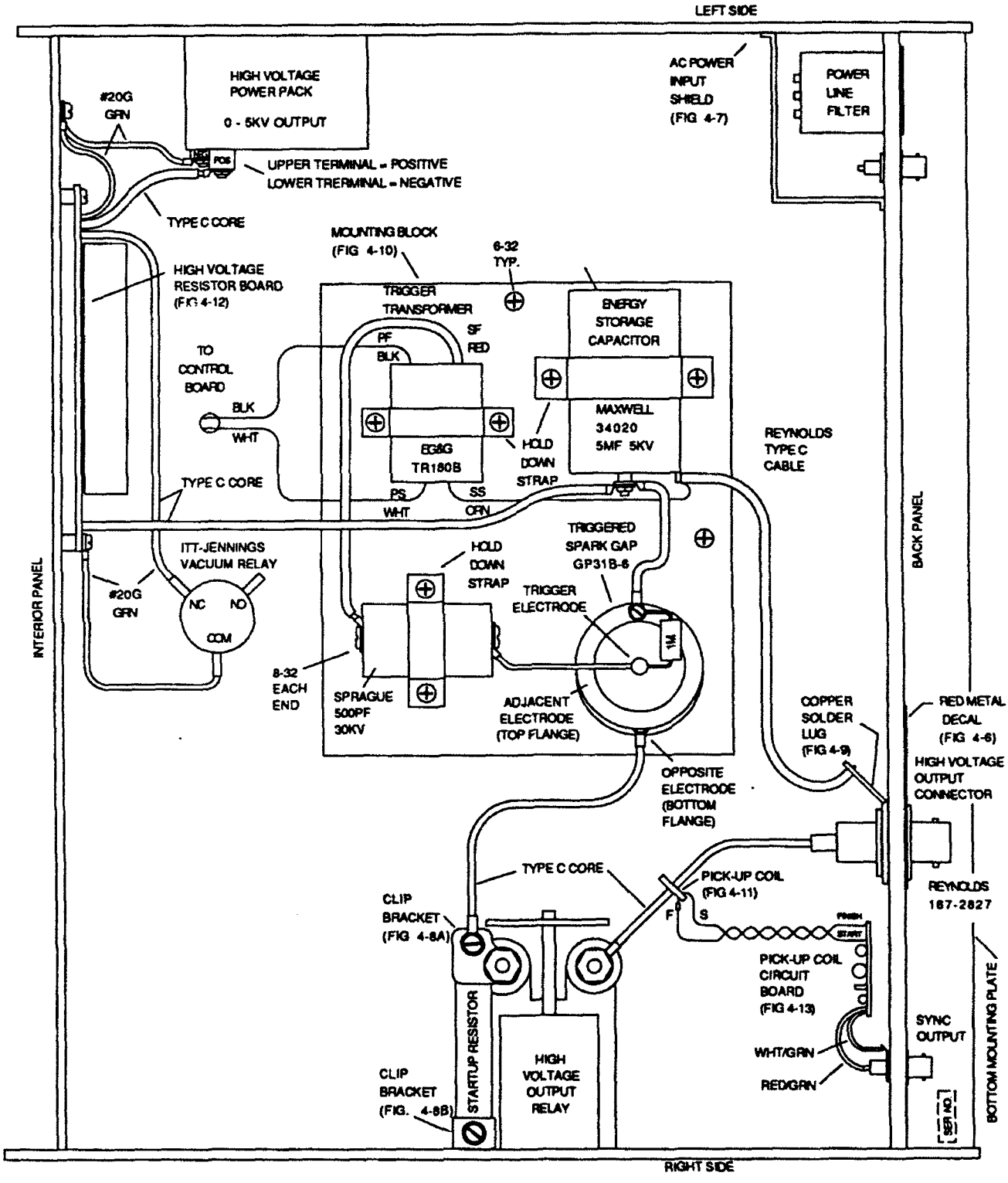
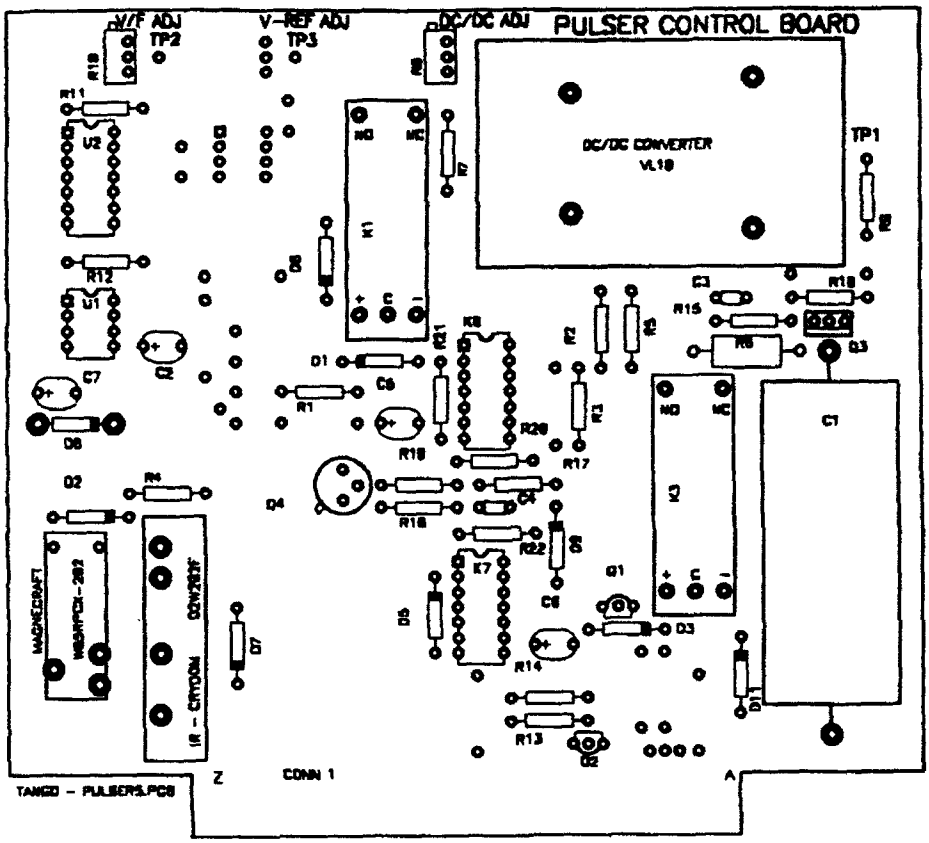


FIGURE 4-15. HIGH-VOLTAGE COMPARTMENT ASSEMBLY



USE SOCKETS FOR ALL IC's, SCR Q4, AND RELAYS K6 & K7
USE SAMTEC PINS SS-120-G-2 FOR RELAYS K1 & K3
AND TRANSISTORS Q1 & Q6.
USE SAMTEC PINS SS-120-G-13 FOR SCR Q3.

FIGURE 4-16. 5-kV PULSER CONTROL BOARD COMPONENT LAYOUT

TABLE 4-1. 5-kV PULSER PARTS LIST

ITEM	QUANT.	REF.	PART	SOURCE
1	1	C1	0.5 μF, 600 V	CDE KMP 6P5, 5910-00-807-4394
2	1	C2	6.8 μF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3745 (11071)
3	3	C3, C4, C11	0.01 μF, 100-V CERAMIC	SERVMART, 5910-00-124-0659 (11135)
4	3	C5, C6, C7	10 μF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3750 (11072)
5	1	C8	0.001 μF, 200-V CERAMIC	SERVMART, 5910-00-010-8666 (11087)
6	1	C9	500 μF, 20 kV	SPRAGUE 30DK-T5, 5910-00-971-6707
7	1	C10	5 μF, 5 kV	MAXWELL 34020
8	7	D1-D7	1N3611 DIODE	SERVMART, 5961-00-957-6865 (11542)
9	1	D8	TRANSIENT SUPPRESSOR, 15 V	UNITRODE TVS 515
10	2	D9, D10	DIODE, 1N914	SERVMART, 5961-00-842-9864 (11512)
11	1	D11	DIODE, 1000 V, 1 A	MOTOROLA 1N4007
12	1	D15	TRANSIENT SUPPRESSOR, 10 V	UNITRODE TVS 510
13	1	F1	FUSE, 1.5-A SLO BLO	SERVMART, 5920-LL-L07-0128 (11191)
14	1		FUSEHOLDER	SERVMART, 5920-00-892-9359 (11235)
15	1	J1	CONNECTOR, ISOLATED BNC PANEL	SERVMART, 5935-00-789-6082 (12815)
16	1	J2	COAXIAL CONNECTOR, 10 kV, PANEL	REYNOLDS 167-2827 (CABLE MATE = 167-2826)
17	4	J3-J6	COAXIAL CONNECTOR, BNC PANEL	SERVMART, 5935-00-853-7596 (03869)
18	1	J7	CONNECTOR, 4-PIN SOCKET, CHASSIS MOUNT, MS3110E8-4S	SERVMART, 5935-00-880-2668 (11355) (CABLE MATE = 5935-00-761-3881)
19	1	J8	CONNECTOR, 44-PIN PCB BOARD	SERVMART, 5935-00-355-4919 (13027)
20	2	K1, K3	MERCURY-WETTED RELAY, 12 VDC	CLARE HGSR51111N00
21	1	K2	RELAY, SPDT, 10 A, 115 VAC	MAGNECRAFT W65RPCX-202
22	1	K4	VACUUM RELAY, 12 kV, 50 A	ITT-JENNINGS RJ2B-26S, 5945-00-782-8148
23	1	K5	N.O. RELAY, 12 kV, 2500 A	ROSS E12-NO-12-1-0
24	2	K6, K7	DIP-REED RELAY	GORDOS 831C-3
25	1	LP1	LAMP HOLDER	UNIMAX TH01-030 (GRN)

TABLE 4-1. 5-kV PULSER PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
26	2	Q1, Q2	FIELD-EFFECT TRANSISTOR	SILICONIX VN10KM, 5961-01-123-5416
27	1	Q3	SILICON-CONTROLLED RECTIFIER	MOTOROLA MCR 1000-8
28	1	Q4	SCR 2N1595	5961-00-814-8865
29	3	R1, R5, R22	120 Ω, 1/4 W	SERVMART, 5905-00-119-8812 (03334)
30	5	R2, R3, R13, R14, R20	51 kΩ, 1/4 W	SERVMART, 5905-00-136-3890 (03362)
31	1	R4	82 Ω, 1/4 W	SERVMART, 5905-00-104-8363 (03250)
32	1	R6	1 kΩ, 1/2 W	SERVMART, 5905-00-110-0196 (03278)
33	1	R7	680 Ω, 1/4 W	SERVMART, 5905-00-135-6046 (03361)
34	1	R8	1-kΩ TRIMPOT	BOURNS 3299X-1-102
35	2	R9, R11	10 MΩ, 1/4 W	SERVMART, 5905-00-121-9919 (03339)
36	1	R10	200-Ω TRIMPOT	BOURNS 3299X-1-201
37	1	R12	1.5 kΩ, 1/4 W	SERVMART, 5905-00-106-1356 (03263)
38	2	R15, R17	10 kΩ, 1/4 W	SERVMART, 5905-00-106-3666 (03265)
39	2	R16, R18	100 Ω, 1/4 W	SERVMART, 5905-00-141-1183 (03389)
40	2	R19, R21	1 kΩ, 1/4 W	SERVMART, 5905-00-110-7620 (03282)
41	1	R23	100 kΩ, 1/4 W	SERVMART, 5905-00-110-0388 (03280)
42	1	R24	1 kΩ, 10 kV, 30 W	CARBORUNDUM 886AS102L DS
43	1	R25	1 MΩ, 2 W	SERVMART, 5905-00-182-7455 (03400)
44	1	R26	100 MΩ, 10 kV, .5 PERCENT	CADDOCK MG735
45	1	R27	100 kΩ, 1 kV, .5 PERCENT	CADDOCK MG712
46	1	R28	2.2 kΩ, 10 kV, 30 W	CARBORUNDUM 886AS222L
47	1	R29	VARISTOR, TRANS. SUPPRESSOR	GE (NOW HARRIS) V130LA10A
48	4	R30-R31	5 MΩ, 20 kV, 15 W, 5 PERCENT	STACKPOLE RH6S**
49	1	S1	SW, SPDT, ALT, LIGHTED	UNIMAX TH31-281 (ORN)
50	1	S2	SW, SPDT, MOM., LIGHTED	UNIMAX TH31-121 (RED)
51	1	S3	SW, SPDT, MOM., UNLIGHTED	UNIMAX TH31-151 (WHT)
52	1	T1	AUTOTRANSFORMER	SUPERIOR ELECTRIC, MOD 10B, 5950-00-688-2881

TABLE 4-1. 5-kV PULSER PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
53	1	T2	TRIGGER TRANSFORMER	EG&G, TR-180B
54	1	TSG1	TRIG. SPARK GAP, 2000 J, 10 kV	EG&G, GP-31B-6
55	1	U1	LM741 OP-AMP	SERVMART,
56	1	U2	VOLTAGE-TO-FREQUENCY CONVT.	BURR-BROWN VFC42BF
57	1		HIGH-VOLTAGE POWER PACK, 5 kV, 5 MA	HIPOTRONICS MOD 10B
58	1		POWER-LINE FILTER	CORCOM 6EF1, 5915-00-365-9951
59	1	SSR1	SOLID-STATE RELAY	CRYDOM D2W202F
60	1	PS1	28-V DC POWER SUPPLY	CONDOR B28-1
61	1	PS2	DUAL 15-V POWER SUPPLY	POWER-ONE 15-.25
62	1	PS3	DC/DC CONVERTER	MIL ELECTRONICS VL10
63	1		DIGITAL PANEL METER	NEWPORT 201-4
64	2		PCB CARD GUIDE	GIBSON-EGAN 600 SERIES, 3.5 in (NOW TEXTOOL TEST & INTERCONNECT PRODUCTS DEPT, 3M E.P. DIV)
65	1		TO-5, TRANSISTOR SOCKET	AUGAT 8059-2G1, 5905-01-077-9755
66	1		8-PIN DIP SOCKET	AUGAT 508-AG10D, 5935-01-005-9795
67	3		14-PIN DIP SOCKET	SERVMART, 5935-00-152-9571 (11303)
68	19		SOCKET STRIP PINS, FOR .015-.022 LEADS	SAMTEC SS-120-G-2, 5935-01-150-3508
69	3		SOCKET STRIP PINS, FOR .025-.030 LEADS	SAMTEC SS-120-G-13
70	3		#334 BULB, 28-V MIDGET, GROOVED BASE	SERVMART, 6240-00--295-1617 (11902)
71	9		RUBBER GROMMET	SERVMART, 5935-00--263-6632 (10612)
72	4		RESISTOR MOUNTING CLIPS	CARBORUNDUM 35267
73	2		SIDE FRAMES	TECHMAR SF-SE-7H-19D
74	1		FULL BOTTOM PLATE	TECHMAR FBP-19D
75	2		SOLID COVER	TECHMAR SANC-19D
76	2		OVAL SECTION HANDLES	TECHMAR OSH-5
77	2		CROSS MOUNTING BAR	TECHMAR MB-.50-0.75
78	MISC.		CABLE TIES	SERVMART, 5975-00-727-5153 (14597)

**DISCONTINUED, REPLACE WITH NEW BOARD USING VICTOREEN SLIM-MOX 408 15 W

TABLE 4-2. 5-kV PULSER CONTROL BOARD PARTS LIST

ITEM	QUANT.	REF.	PART	SOURCE
1	1	C1	0.5 μF, 600 V	CDE KMP 6P5, 5910-00-807-4394
2	1	C2	6.8 μF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3745 (11071)
3	2	C3, C4	0.01 μF, 100-V CERAMIC	SERVMART, 5910-00-124-0659 (11135)
4	3	C5, C6, C7	10 μF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3750 (11072)
8	6	D1-D3, D5-D7	1N3611 DIODE	SERVMART, 5961-00-957-6865 (11542)
9	1	D8	TRANSIENT SUPPRESSOR, 15 V	UNITRODE TVS 515
10	1	D9	DIODE, 1N914	SERVMART, 5961-00-842-9864 (11512)
11	1	D11	DIODE, 1000 V, 1 A	MOTOROLA 1N4007
19	1	J8	CONNECTOR, 44-PIN PCB BOARD	SERVMART, 5935-00-355-4919 (13027)
20	2	K1, K3	MERCURY-WETTED RELAY, 12 VDC	CLARE HGSR51111N00
21	1	K2	RELAY, SPDT, 10 A, 115 VAC	MAGNECRAFT W65RPCX-202
24	2	K6, K7	DIP-REED RELAY	GORDOS 831C-3
26	2	Q1, Q2	FIELD-EFFECT TRANSISTOR	SILICONIX VN10KM, 5961-01-123-5416
27	1	Q3	SILICON-CONTROLLED RECTIFIER	MOTOROLA MCR 1000-8
28	1	Q4	SCR 2N1595	5961-00-814-8865
29	3	R1, R5, R22	120 Ω, 1/4 W	SERVMART, 5905-00-119-8812 (03334)
30	5	R2, R3, R13, R14, R20	51 kΩ, 1/4 W	SERVMART, 5905-00-136-3890 (03362)
31	1	R4	82 Ω, 1/4 W	SERVMART, 5905-00-104-8363 (03250)
32	1	R6	1 kΩ, 1/2 W	SERVMART, 5905-00-110-0196 (03278)
33	1	R7	680 Ω, 1/4 W	SERVMART, 5905-00-135-6046 (03361)
34	1	R8	1-kΩ TRIMPOT	BOURNS 3299X-1-102
35	2	R9, R11	10 MΩ, 1/4 W	SERVMART, 5905-00-121-9919 (03339)
36	1	R10	200-Ω TRIMPOT	BOURNS 3299X-1-201
37	1	R12	1.5 kΩ, 1/4 W	SERVMART, 5905-00-106-1356 (03263)
38	2	R15, R17	10 kΩ, 1/4 W	SERVMART, 5905-00-106-3666 (03265)

TABLE 4-2. 5-kV PULSER CONTROL BOARD PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
39	2	R16, R18	100 Ω, 1/4 W	SERVMART, 5905-00-141-1183 (03389)
40	2	R19, R21	1 kΩ, 1/4 W	SERVMART, 5905-00-110-7620 (03282)
55	1	U1	LM741 OP-AMP	SERVMART,
56	1	U2	VOLTAGE-TO-FREQUENCY CONVT.	BURR-BROWN VFC42BF
59	1	SSR1	SOLID-STATE RELAY	CRYDOM D2W202F
62	1	PS3	DC/DC CONVERTER	MIL ELECTRONICS VL10
65	1		TO-5, TRANSISTOR SOCKET	AUGAT 8059-2G1, 5905-01-077-9755
66	1		8-PIN DIP SOCKET	AUGAT 508-AG10D, 5935-01-005-9795
67	3		14-PIN DIP SOCKET	SERVMART, 5935-00-152-9571 (11303)
68	19		SOCKET STRIP PINS, FOR .015-.022 LEADS	SAMTEC SS-120-G-2, 5935-01-150-3508
69	3		SOCKET STRIP PINS, FOR .025-.030 LEADS	SAMTEC SS-120-G-13

CHAPTER 5

PULSER STARTUP, CALIBRATION, AND TESTING

INITIAL STARTUP PROCEDURES

Immediately after assembly, with the top and high-voltage covers removed and before plugging in the Pulser Control Board, preliminary tests should be done to confirm proper operation of all control systems and power supplies. First, check the power supplies by turning on the AC Power, and adjust the 28-V supply to 26.5 V. The dual 15-V supply should be measured for proper voltages. If lamps (#334, 28-V midget grooved base) were not inserted in the lighted switches, do so at this time. The Power light should be the only light on. If the power supply voltages are correct, continue with the startup procedures. Turn off the power, insert the Pulser Control Board into its socket, and turn the power back on.

To test the high-voltage charging circuit, turn the High-Voltage Adjust control to its minimum setting (fully counterclockwise), then turn on the High-Voltage switch. Voltage output of the capacitor charging circuit is displayed on the Front Panel Meter. The voltage reading should rise as the adjustment knob is rotated clockwise.

To test operation of the Pulser Output Relay, turn on the high voltage and apply a switch closure to ground (a short) to the Pulser Output Relay Remote Control BNC connector J5 on the rear panel. The Ross relay will turn on with a loud mechanical snap and possible vibrational hum caused by the AC coil. The green light in the Pulser Output Relay indicator should go On to indicate operation of the Ross relay auxiliary switch circuit. Use an ohmmeter to test the Pulser Output Relay Remote Indicator BNC connector J4 for grounding as the relay is turned on and off.

Test operation of the High-Voltage Remote On/Off Control connector J7 by shorting pins A&B to turn On the high voltage, and by shorting pins C&D to turn Off the voltage. This connector allows remote control of the high-voltage section via switches on the Pulser Remote Monitor and Control accessory panel. In order to use remote turn-on of the high-voltage section, the operator of the pulser would have to set the High-Voltage Adjust control to the desired final operating voltage level required before leaving the pulser to go to the control room.

Finally, set the output of the DC/DC Converter on the Pulser Control Board to 300 VDC. Connect a voltmeter with at least 10-MΩ input impedance and a 1000-V range to Test Point 1. Turn on the High Voltage and use the DC/DC Adj pot to set the output voltage to 300 V.

PULSER CALIBRATION

Pulser calibration requires use of a DC voltage standard with 10.000-V resolution and a frequency counter with a resolution of 10.000 kHz. The two items to

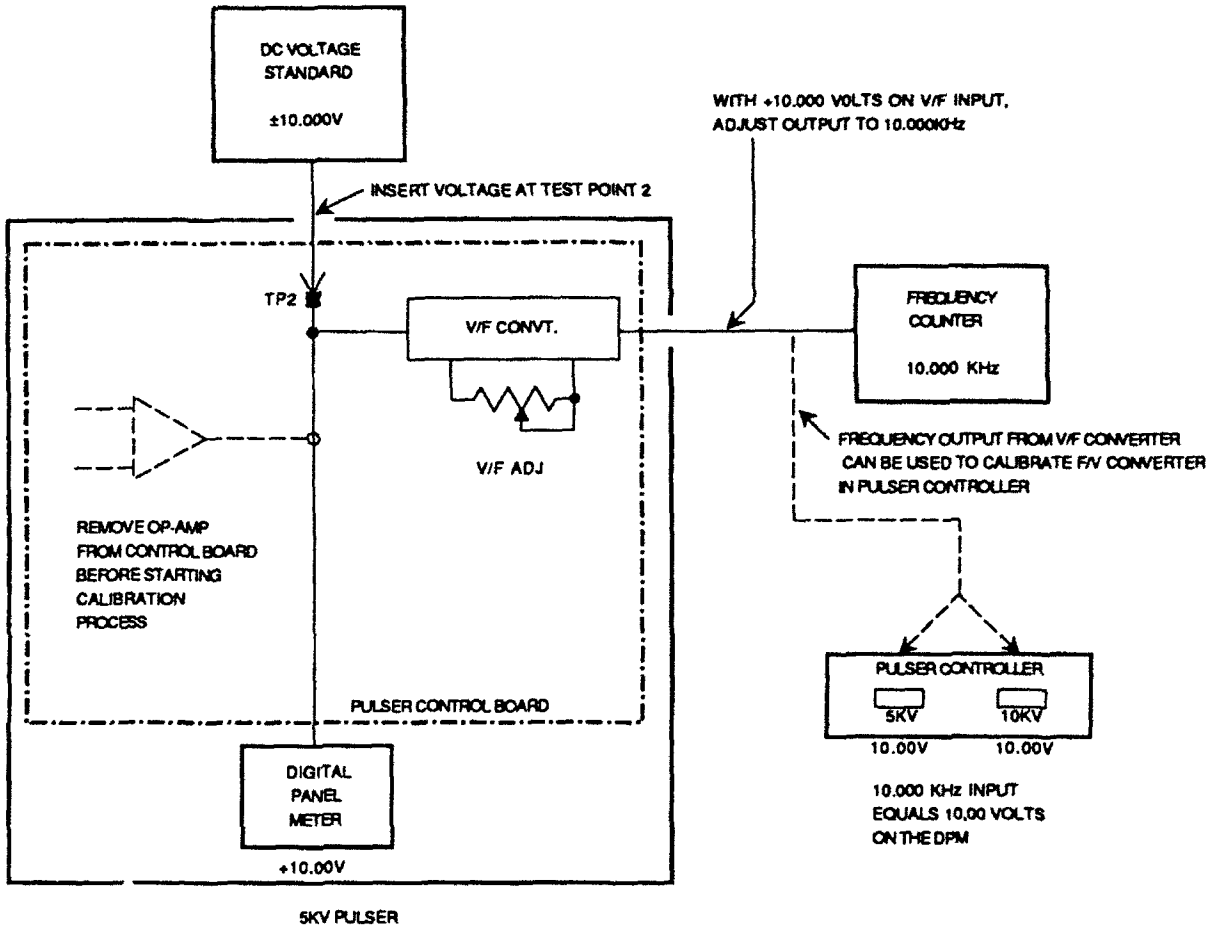
be calibrated are the Front Panel digital voltmeter and the V/F Converter. It is necessary to have the top cover removed in order to perform this calibration. First remove the 741 OP-AMP from the Pulser Control Board, and then turn on the power. As shown in Figure 5-1, connect the DC voltage standard to Test Point 2 on the Pulser Control Board, and the frequency counter to the High-Voltage Monitor 1-kHz/1-kV BNC connector on the Back Panel. Apply 10.000 V to Test Point 2 and adjust the output of the V/F Converter to 10.000 kHz using the V/F Adj pot on the top edge of the Pulser Control Board. The Digital Panel Meter should read 10.00 V; if not, refer to the manufacturer's literature to effect calibration.

If the pulser is to be used in conjunction with a Pulser Monitor and Control instrument, the controller can be calibrated at this time using the calibrated frequency output of the pulser to calibrate the F/V Converter in the controller. There is an F/V Adj pot in the controller to calibrate the incoming signal to the controller panel meter.

PULSER TESTING

Once calibration of the pulser operating and control system is complete, test firing of the capacitor can proceed. The high-voltage cover and the top cover can be left off at this time until operation of the pulser is certified. The test equipment setup shown in Figure 5-2 can be assembled in order to make the tests shown in the Polaroid photographs in Figure 2-2. The first step in generating these test photos is to calibrate the time relationship of the two beams of the 7844 Dual-Beam Oscilloscope. This is done by feeding the same output signal from the time delay generator to both beams at the same time and adjusting their relative horizontal displacements until they overlap in coincidence. Specifically, disconnect Cable 1 from the oscilloscope, and connect Cable 2 in its place to run the beam calibration.

When the beams are calibrated, reconnect the cables as shown. The Time-Delay Generator connections are such that Channel 1 triggers the oscilloscope sweep via the External Trigger Input at the same time it triggers Channel 2. The pulser is then triggered after the 1-μs time delay set in Channel 2. This allows the oscilloscope sweep to display a zero baseline before the signals arrive to make traces easier to read. Set the oscilloscope and camera controls as required, and photograph the discharge signal in the Pearson coil as the pulser is fired at its lower operating limit. Next, recharge the pulser to its maximum operating limit, and photograph that discharge signal. Finally, to photograph the Sync Pulse Output signal, remove Cable 1 from the Pearson Pulse Current Transformer, and connect it to the Sync Pulse Output BNC connector J3 on the Back Panel. Recharge the pulser to the lower operating limit, and fire again.



CALIBRATION OF:
1. V/F CONVERTER
2. F/V CONVERTER
3. DIGITAL PANER METERS

INSTRUMENTS REQUIRED:
1. DC VOLTAGE STANDARD WITH 10.000 VOLTS RESOLUTION
2. FREQUENCY COUNTER WITH 10.000KHz RESOLUTION

FIGURE 5-1. 5-kV PULSER CALIBRATION

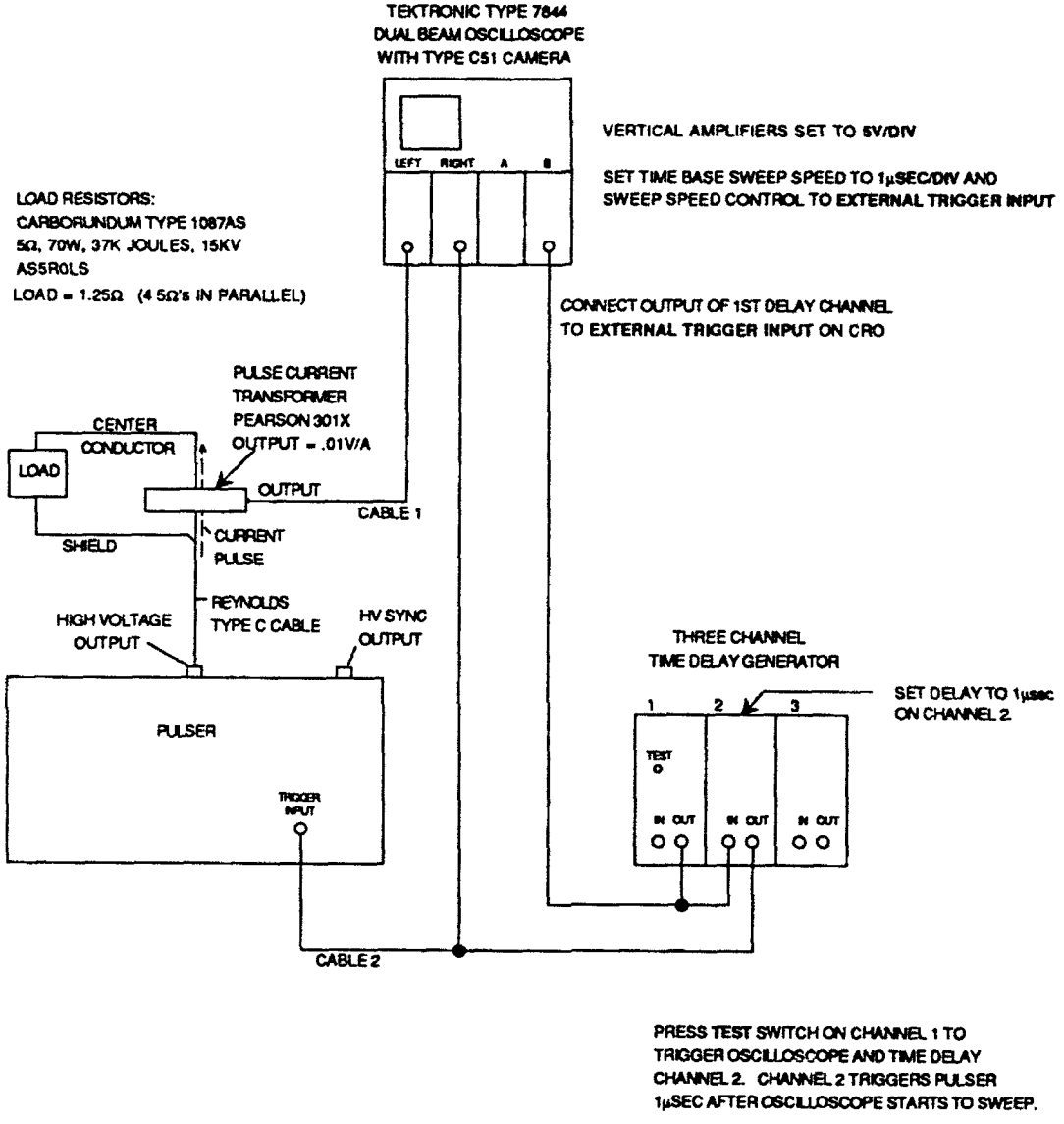


FIGURE 5-2. PULSER HIGH-VOLTAGE OUTPUT TEST APPARATUS

GLOSSARY

DC/DC Converter	DC-to-DC voltage converter
F/V Converter	frequency-to-voltage.converter
mA	current flow in milliamperes
μF	capacitance in microfarads
0P-AMP	operational amplifier
pF	capacitance in picofarads
SBV	self-breakdown voltage
SCR	silicon-controlled rectifier
TSG	Triggered Spark Gap
V/F Converter	voltage-to-frequency converter

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The 5-kV High-Voltage Pulse Generator is used to deliver high-energy pulses to initiating devices for explosive tests. While the triggered spark gap installed has a 200-J rating, the energy storage capacitor used limits the output to 57.6 J at 4.8 kV. At this limit, the pulser delivers a peak current of 2400 A into a 1.25-Ω resistive load.

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