NSWCDD/MP-92/222

HIGH-VOLTAGE PULSE GENERATOR CAPABLE OF 2000 J AT 10 kV

BY HARRY E. CLEAVER

RESEARCH AND TECHNOLOGY DEPARTMENT

31 JULY 1992

NAVAL SURFACE WARFARE CENTER
DAHLGREN DIVISION • WHITE OAK DETACHMENT
Silver Spring, Maryland 20903-5000

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FOREWORD

This document describes the operation and construction of the 10-kV High-Voltage Pulse Generator that is used in the Energetic Materials Division as a power source to illuminate explosive tests for high-speed photography. The document serves as an owners/operators manual and contains detailed information for servicing and calibrating the instrument. Detailed drawings and instructions are provided in order to build a duplicate pulse generator.

Company and trade names used in this document 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 10-kV Pulsers in use today are 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 10-kV High-Voltage Pulse Generator is used to deliver high-energy pulses to exploding wire or flash-lamp illuminators used in high-speed photography of explosive tests. With properly rated components, the pulser is capable of an energy content of 2000 J at 10 kV. Components presently installed limit the output to 900 J at 6 kV. At this limit, the pulser delivers a peak current of 3500 A into a 1.25-Ω resistive load.

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CHAPTER 1

INTRODUCTION

This High-Voltage Pulse Generator is commonly referred to as the 10-kV Pulser because of its maximum potential voltage. It is used primarily to power low-impedance exploding wire or xenon flash-lamp light sources for high-speed photography of explosive tests. While the maximum operating potential of the pulser is 2000 J at 10 kV, limits of the actual operating range depend on the Triggered Spark Gap (TSG) and Energy-Storage Capacitors installed. With one exception, the 10-kV Pulsers furnished up to this time have been supplied with two 25-μF, 6-kV Maxwell pulse-discharge capacitors connected in parallel, for a maximum energy content of 900 J from the capacitor bank at their maximum 6-kV operating voltage limit. When tested in this configuration at 6 kV, the 10-kV Pulser delivered a peak current pulse of 3200 A into a 1.25-Ω resistive load.

The 10-kV Pulser completes an integrated system for safely firing both the explosive initiating device and the camera lighting source when used with a 5-kV High-Voltage Pulse Generator[1] for detonator initiation, a Firing Line Safety Lockbox (Appendix A), a High-Voltage Pulse Generator Monitor and Control (Appendix B), and the bombproof Master Control Panel.

After the Energy-Storage Capacitors are slowly charged through a resistive charging network, they are discharged quickly through the light source via 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. Also 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-85-10, is rated at 10-kV SBV, 2000 J. The operating range with this TSG is 2.5 to 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 10-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

[1] Cleaver, Harry E., *High-Voltage Pulse Generator Capable of 200 J at 5 kV*, NSWCDD/MP-92/224, 31 Jul 1992.

divider and displayed on a digital voltmeter on the Front Panel. After the desired 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.

The large Energy-Storage Capacitors are mounted outside of the pulser instrument chassis to allow the users of the instrument to tailor the capacitor bank to fit particular energy needs. Because the exposed capacitor bank can be charged to lethal potentials, the pulser must be mounted in an enclosed instrument rack having a back door fitted with a Door Interlock switch (see Appendix C). A door Safety Interlock system installed in the pulser will shut down the high-voltage circuits and discharge the capacitor bank if the door to the rack is opened.

A second safety concern is that all Energy-Storage Capacitors installed should not be operated above their maximum safe operating voltage. A Voltage Safety Limit monitor circuit on the Pulser Control Board must have its trip-point set at, or below, the safe operating voltage of the capacitors such that the high-voltage circuits will shut down if the capacitor voltage rises above the safe limit. The Voltage Safety Limit trip-point setting can be read on the Digital Panel Meter at any time by using the Voltage Safety Limit switch on the Front Panel.

It is the **operator's responsibility** to make certain that the Voltage Safety Limit is set to correspond to the specific capacitor bank installed in the system in order to protect the equipment and personnel from damage or injury by the possible explosion of the capacitor bank. Should the capacitor voltage rise above the safety limit trip-point, the high-voltage charging system will be turned off and disabled, the capacitor bank will be discharged, and the High-Voltage Capacitor Overvoltage warning light will be turned on. **Again, the Voltage Safety Limit circuit must be set to the proper voltage by the equipment operator to prevent damage to equipment or injury to personnel.**

Each 10-kV Pulser was furnished at the time of its delivery with:

- a five-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 2.5 to 6 kV,
- a 2000-J limit on the spark gap,
- a 2500 A for 20-μs rating on the Safety Output Relay, and
- a 6000-V operating limit on the capacitor bank.

Chapter 2 contains a copy of the form delivered with the pulsers.

The first 10-kV Pulsers were delivered in late 1985 and early 1986. There were three failures of the Maxwell capacitors at that time for undetermined reasons. Since replacing those capacitors, there has not been another reported failure of a Maxwell capacitor. 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. A future fix would be to redesign the Pulser Control Board to include some protective circuit design, which would limit the voltage impressed on the SCR. Two 10-kV Pulsers located in the same bombproof panel have had a continuing problem of the Door Interlock transistors failing for reasons unknown. Transistors have been replaced but no search for the cause has been undertaken.

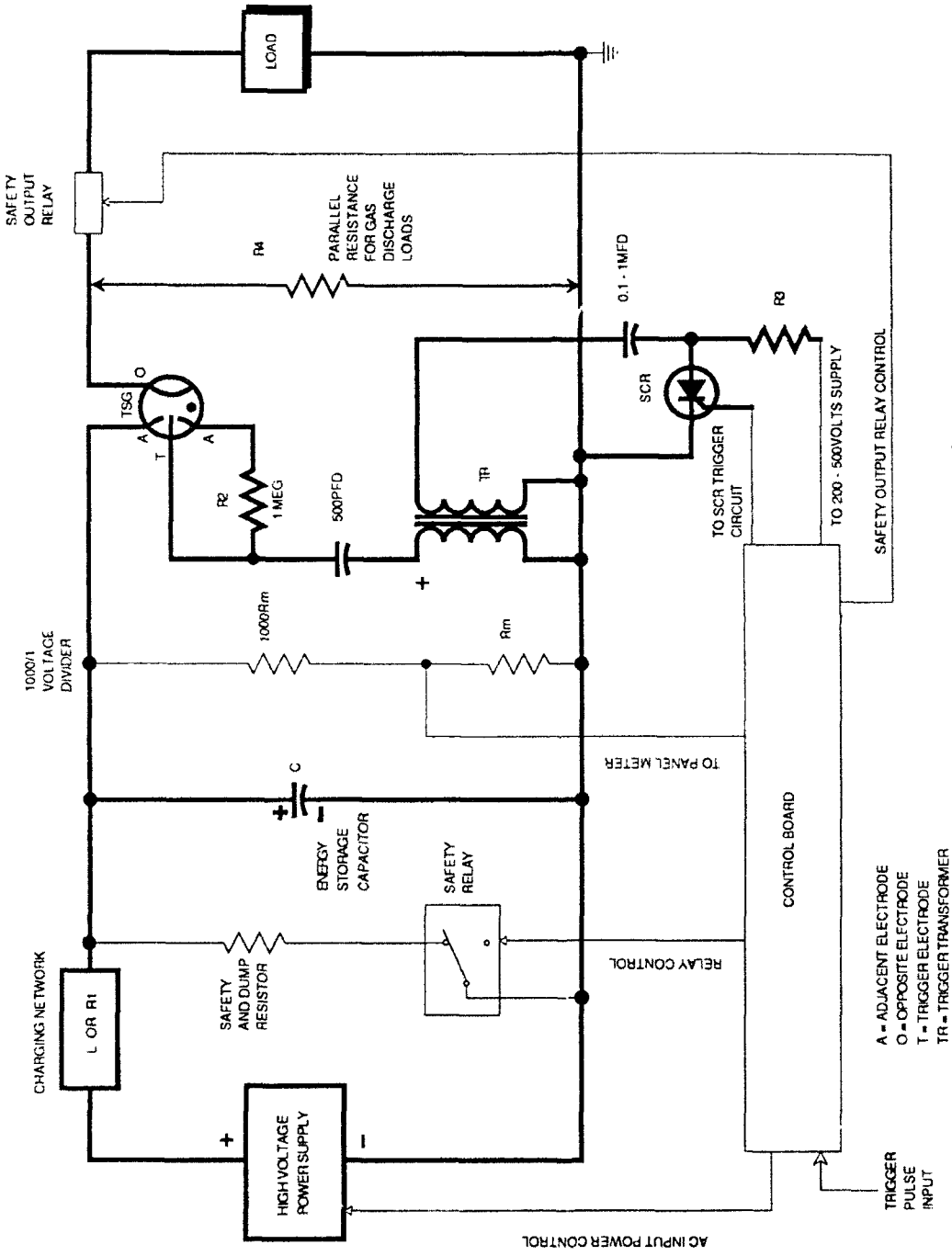


FIGURE 1-1. OVERVIEW OF PULSER SHOWING EG&G's MODE A TRIGGERING OF SPARK GAP

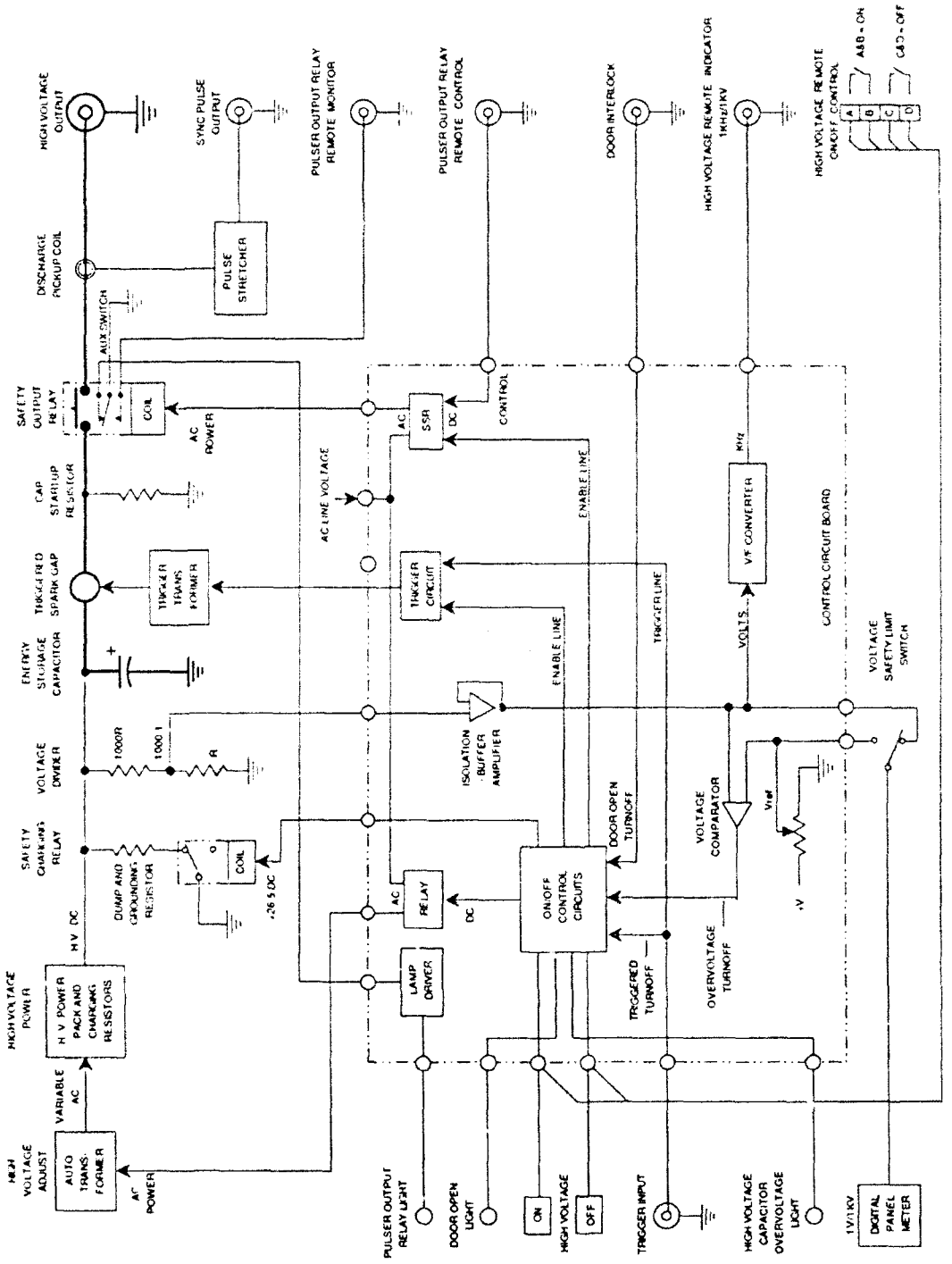


FIGURE 1-2. 10-kV PULSE GENERATOR BLOCK DIAGRAM

CHAPTER 2

SPECIFICATIONS AT INSTALLATION AND OPERATING INSTRUCTIONS

SPECIFICATIONS AT INSTALLATION

(Refer to given pulser serial number for exact specifications)

Operating Voltage Range	:	2.5 to 10 kV
Capacitor Installed	:	50 µF, 6 kV (2 x 25 µF), Maxwell No. 34034
TSG	:	EG&G GP-85-10, 10-kV SBV, 2000-J capacity. Maximum capacitance useable with this TSG at 10-kV operating voltage and 2000-J limit is 40 µF.
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, SLO BLO

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; also can display, on demand, the voltage level set on the Capacitor Overvoltage trip circuit: 1 V = 1 kV.
High-Voltage Capacitor Overvoltage	panel light On indicates voltage-to-storage capacitor exceeded safe limit trip-point; and high-voltage section has turned off and capacitor has discharged.

Voltage Safety Limit	switch connects overvoltage trip circuit to panel meter to adjust trip-point voltage level.
Door Interlock	light On indicates rack door is open and high-voltage section is turned off.
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 closed.
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.
Door Interlock	connects to normally open switch contacts of the Door Interlock switch - closure to ground required.

*not required for operation of the pulse.

INSTALLATION INSTRUCTIONS

WARNING!

The high-voltage Energy-Storage Capacitor for the 10-kV Pulser is located externally to the instrument case and presents a serious safety hazard. **Lethal**

voltage potentials can exist on the capacitor; therefore, the following installation is required:

1. House the instrument and storage capacitor in an enclosed instrument rack.

2. Erect a barrier around the capacitor terminals inside the rack.

3. Install a Door Interlock switch in the back door of the rack and connect it to the Door Interlock connector on the Back Panel of the pulser. Use a normally open switch and connect to ground.

4. **Always short-circuit the terminals on the capacitor before working on it.**

WARNING!

Exceeding the maximum operating voltage limit of the Energy-Storage Capacitor can cause an explosion and result in serious damage to instruments and personnel. Because the Energy-Storage Capacitor can be replaced by the pulser's operators with capacitors of other values as the need arises, it is the final responsibility of the operators to ensure that the pulser is operated within the safe limits of the capacitor voltage specifications. As a safety measure, a monitor circuit that continuously compares the voltage on the capacitor to a preset reference voltage limit set by the operator to the safe working limit of the capacitor in use is built into the pulser. If the voltage on the capacitor should rise above the safe reference voltage limit, the high-voltage section will turn off and discharge the capacitor. Instructions for adjusting the trip-point level are:

1. Remove the top cover of the pulser and locate the voltage level trimpot adjustment on the Pulser Control Board. The trimpot is labeled V-Ref Adj.

2. Turn on the AC Power and let the pulser warm up for a few minutes.

3. Press the Voltage Safety Limit switch on the Front Panel to connect the circuit to the panel meter.

4. Adjust the trimpot to set the voltage to the required level while viewing the panel meter: 1.00 V = 1.00 kV.

OPERATING INSTRUCTIONS

1. Connect output relay control cable to Pulser Output Relay Remote 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 the Door Interlock switch to Door Interlock.

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

5. Turn on the AC Power.

6. Check the High-Voltage Capacitor Overvoltage safety-limit system for the correct safe voltage setting.

7. Turn on the high voltage.

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

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

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

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

12. 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 the safe operating area of the spark gap 2000-J limit against operating voltage and capacitance. The capacitor bank must be operated within its safe working voltage, and must not be charged to an energy content greater than the limit of the spark gap.

Figure 2-2 shows the typical set of calibration photographs taken for each pulser at the time of assembly. The first print shows the alignment calibration of the two beams of the Tektronix 7844 Dual-Beam Oscilloscope before calibration of the pulser begins. The next two prints show the discharge of the pulser at its minimum and maximum operating points. The last print shows the Sync Pulse Output shape at the minimum operating point.

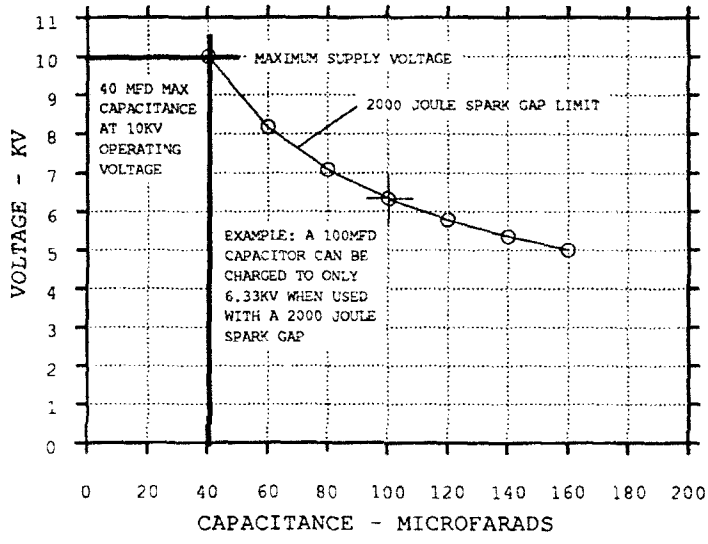
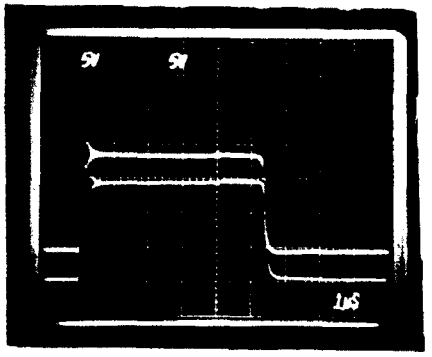
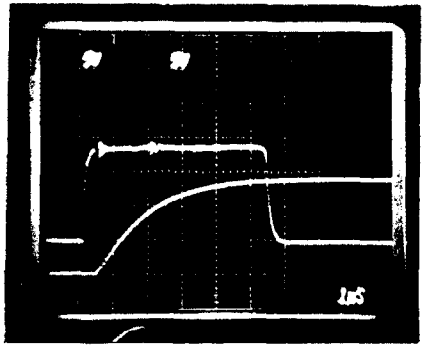


FIGURE 2-1. CHART FOR CAPACITOR SELECTION WITH 10-kV MAXIMUM SUPPLY AND A 2000-J SPARK GAP

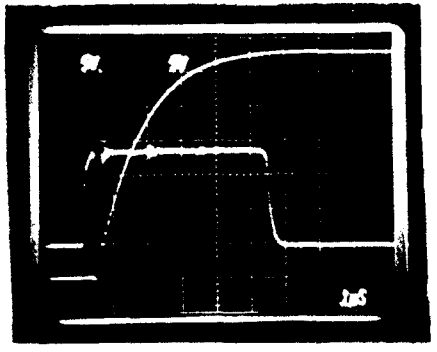
10-kV PULSE GENERATOR TEST
SERIAL NO.: 10-04
DATE TESTED: 2 JUN 86



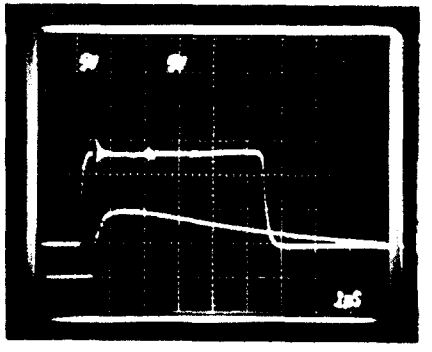
TRIGGER INPUT VERSUS TRIGGER INPUT
CALIBRATION OF UPPER AND LOWER BEAM
TIME BASE SYNCHRONIZATION



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



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



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

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

CHAPTER 3

THEORY OF OPERATION

POWER

Figure 3-1 is the schematic for the 10-kV 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. If the *Door Interlock system* is used and the door is closed, the only light to illuminate will be the power light. 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. At this point, the operator can check the Voltage Safety Limit setting by pressing the Voltage Safety Limit switch S4. If the safety limit has to be changed, the pulser will have to be turned off and removed from the rack in order to access the V-Ref Adj trimpot. Instructions for making the adjustment are spelled out in the section in Chapter 5 on calibration and in Chapter 2's operating instructions.

HIGH-VOLTAGE ON

When the 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 (2.2 kΩ, 30 W) is disconnected from the terminals of the Energy-Storage Capacitor bank. 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 bank, 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 output of the power pack rises, current flows through the charging resistor network to the high-voltage Energy-Storage Capacitors. The maximum load allowed on the power pack, 10 kV supplying 5 mA, would require a 2-MΩ, 10-kV, 50-W resistor, which is a large, bulky, and somewhat expensive resistor. The smaller charging resistors, R30 to R3? are 10-MΩ, 20-kV, 15-W resistors connected in parallel to share power dissipation and present an equivalent charging resistance of 2.5 MΩ to keep the charging time constant low, while keeping the current drawn from the power pack within the 5 mA allowed. The equivalent resistance of 2.5 MΩ,with the 50-μF capacitor bank gives a charging time constant of 125 s, or just over two minutes. Actual charging times are much longer, because as the voltage on the capacitor bank rises, the voltage differential across the charging network decreases, and the charging current drops off. The charging time can be shortened by carefully setting the output of the power pack above the desired operating point of the capacitor bank and then trimming back as the voltage approaches its desired final value. Of course, if the capacitor bank voltage is allowed to exceed the safety limit, the high-voltage system will be shut down.

Voltage on the capacitor bank 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 bank 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,
- the overvoltage trip circuit U3, and
- 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 0-10 V = 0-10 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. Operation of the overvoltage trip-point circuit will be explained later.

Once the capacitor bank 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 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 bank 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 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-1700). 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 the capacitor bank 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 bank);
- 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 the SCR 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 by 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.

OVERVOLTAGE SHUTDOWN

The Energy-Storage Capacitor voltage signal from the high-voltage divider circuit is impressed by the LM741 buffer/follower amplifier onto pin 2 of U3, an LM311 voltage comparator. The 311 comparator compares the signal on pin 2 to the reference voltage level on pin 3 as impressed by trimpot R34. When the signal on pin 2 rises above the voltage on pin 3, the output of the comparator changes state from a low level to a high one. The output circuit of the 311 comparator is an open collector transistor that effectively shorts out capacitor C15 when in the low state. When the output of the 311 comparator goes high, capacitor C15 charges up toward 15 V through R35 and the rising voltage on C15 triggers SCR Q6. When Q6 turns on, it activates three parts of the control circuit. First it discharges capacitor C5 in the shutdown circuit via diode D12 to open the contacts on relay K6 to initiate the shutdown sequence already described. In case of overvoltage shutdown, the fully charged high-voltage capacitor bank will be discharged through R28 and the ITT-Jennings Vacuum Relay contacts. A capacitor bank charged to 10 kV will send a maximum current of about 4.5 A through the relay contacts. The vacuum relay is rated at 12-kV, 50-A DC carry current.

In addition to initiating the shutdown sequence, Q6 also turns on the High-Voltage Capacitor Overvoltage light LP3 and relay K7 through the normally closed contacts of the High-Voltage On switch S2 via diode D14. Relay K7 turns On to break the power ground return of relay K1. Currents flowing through the overvoltage light and the coil of K7 are high enough to keep Q6 conducting so that the overvoltage indicator circuit is latched on. Diodes D12 and D14 isolate the 15-V portions of the circuits attached to Q6 from the 26.5-V lamp power source. Because the Capacitor Overvoltage fault condition is not indicated at the remote monitor station, the operator, seeing that the high-voltage section was off, could attempt to rearm the pulser using the remote High-Voltage On switch. With K7 latched on

through D14, High-Voltage On relay K1 is disabled, and the high-voltage charging circuits cannot be turned on from the remote-control location.

To turn off the overvoltage protection circuit and correct the fault conditions, the operator must be present at the pulser site. Press the High-Voltage On switch S2 on the Front Panel or turn off AC Power to the pulser. Pressing On switch S2 opens the normally closed contacts and breaks current flow to Q6, and it turns off. Relay K7 turns off and enables K1, which then turns on as power is applied when the normally open contacts of S2 close. The High-Voltage Off switch (S3) would then have to be used to turn off the high-voltage section.

DOOR INTERLOCK CIRCUIT

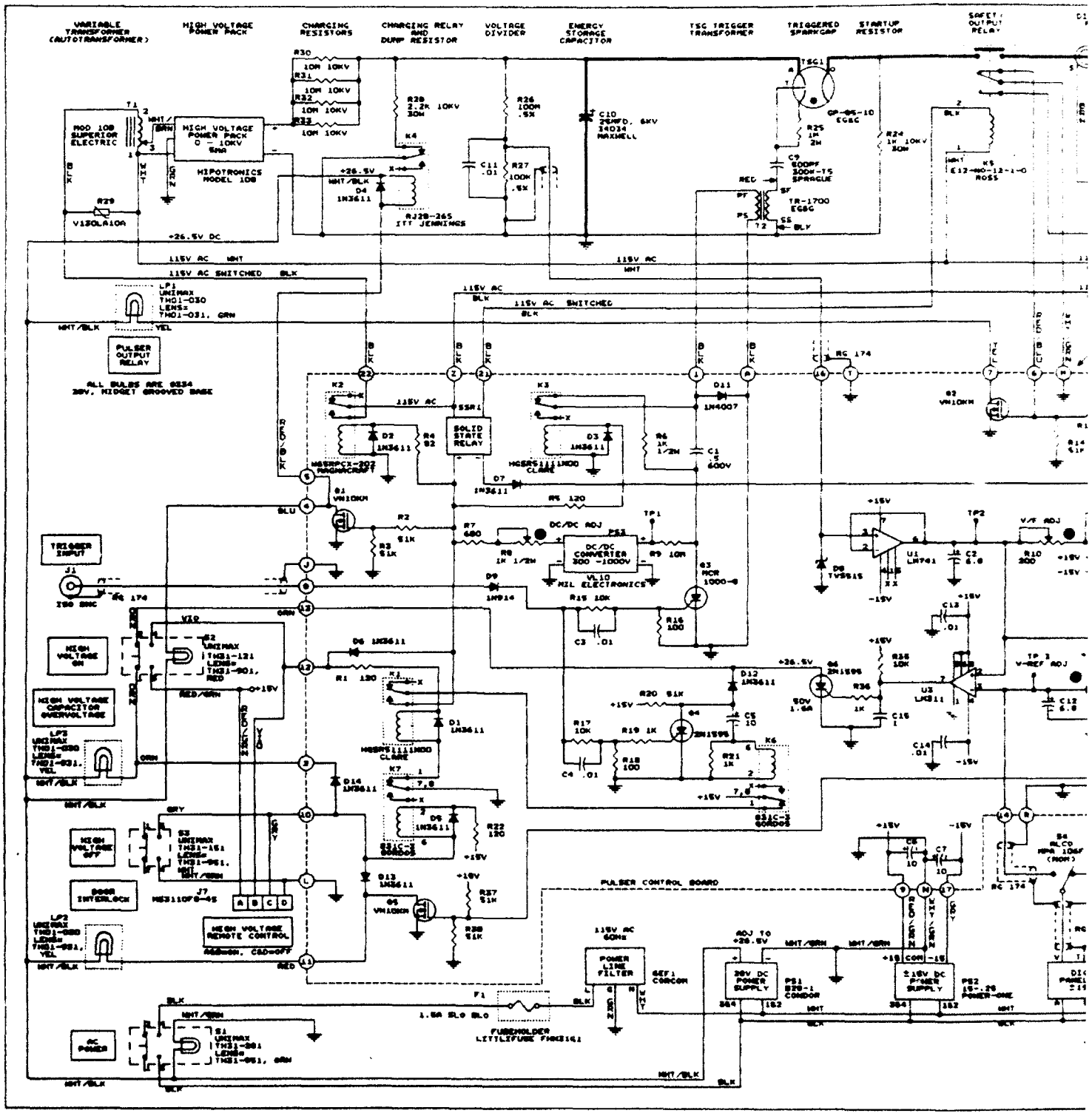
Normally-open contacts of a long-throw interlock switch mounted at the back door of the instrument rack are connected by a coaxial cable to the Door Interlock connector J9 on the Back Panel of the pulser. When the door is closed, the switch normally-open contacts are closed, shorting out R38 on the gate lead of transistor Q5 and turning it off. If the door is opened, the short on R38 is removed and the gate of Q5 rises to 7.5 V, turning it on. When Q5 goes on, it turns on the Door Interlock Open warning light and relay K7 via D13 to disable the high-voltage control section. Diode D13 isolates the 15-V part of the circuits connected to Q5 from the 26.5-V part. If the high-voltage section happened to be on when the door was opened, it would be turned off, and the capacitor bank would be discharged to protect personnel at the back door of the instrument rack. The high-voltage section remains disabled as long as the back door is open, because K7 breaks operation of the On relay Kl.

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 electromagnetic force generated when power to the coils is removed. Diode D11, a 1000-V reverse breakdown voltage-rated type, suppresses reverse EMF 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.


VARIABLE TRANSFORMER (AUTOTRANSFORMER)
HIGH VOLTAGE POWER PACK
CHARGING RESISTORS
CHARGING RELAY AND DUMP RESISTOR
VOLTAGE DIVIDER
ENERGY STORAGE CAPACITOR
TSG TRIGGER TRANSFORMER
TRIGGERED SPARKGAP
STARTUP RESISTOR
SAFETY OUTPUT RELAY
MOD 108 SUPERIOR ELECTRIC
HIGH VOLTAGE POWER PACK 0 - 10KV 5mA
HIPOTRONICS MODEL 108
V130LA10A
+26.5V DC
115V AC WHT
115V AC SWITCHED BLK
LP1 UNIMAX TH01-030 LENS= TH01-031, GRN
PULSER OUTPUT RELAY
ALL BULBS ARE 6834 28V, MIDGET GROOVED BASE
SOLID STATE RELAY
TRIGGER INPUT
J1 ISO BNC
HIGH VOLTAGE ON
HIGH VOLTAGE CAPACITOR OVERVOLTAGE
HIGH VOLTAGE OFF
DOOR INTERLOCK
HIGH VOLTAGE REMOTE CONTROL
AC POWER
DC/DC CONVERTER 300 -1000V
MIL ELECTRONICS VL10
PULSER CONTROL BOARD
POWER LINE FILTER
30V DC POWER SUPPLY
±15V DC POWER SUPPLY
FUSEHOLDER LITTLEFUSE FHM161
1.6A SLO BLO

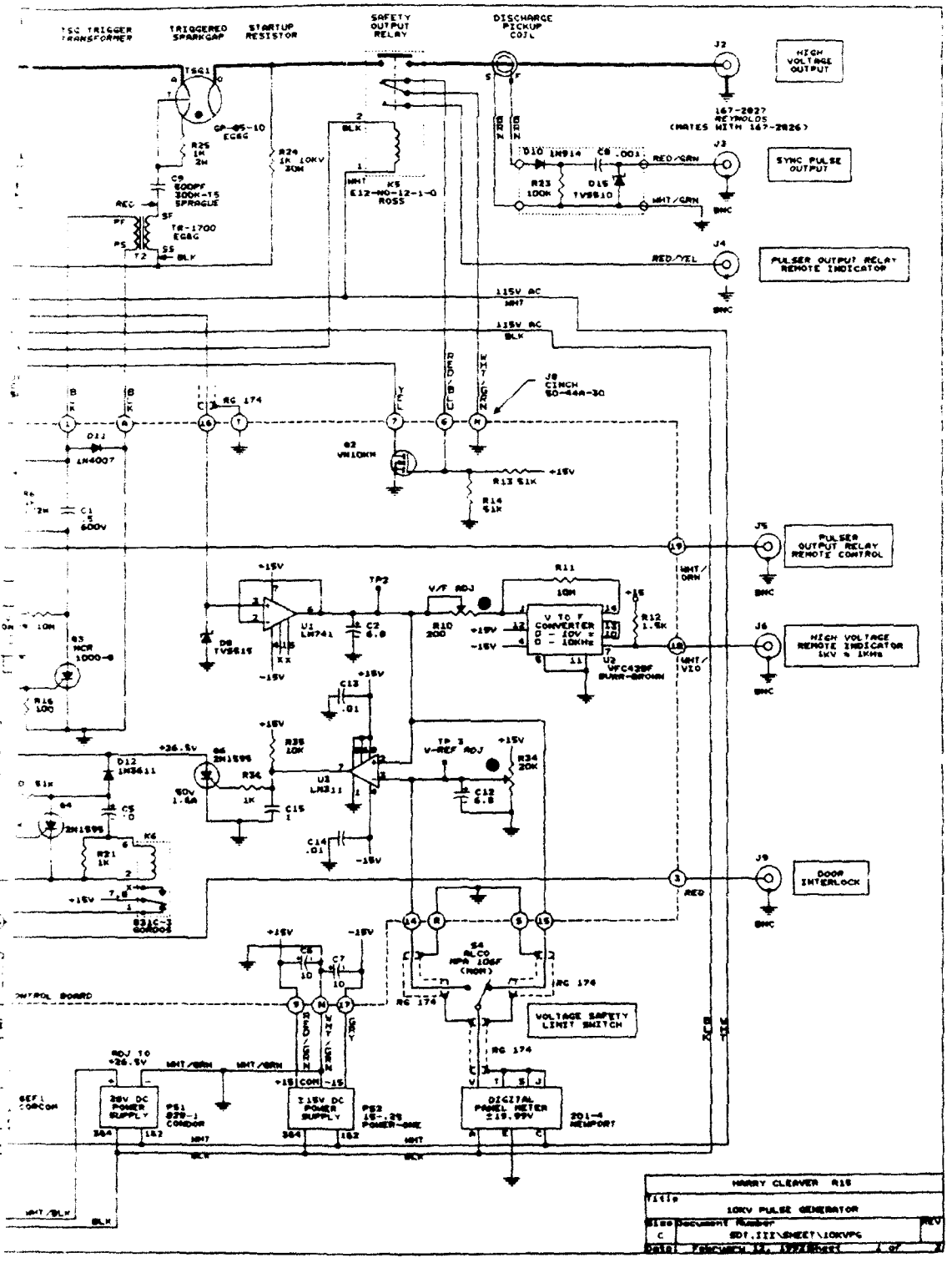


FIGURE 3-1. 10-kV PULSER SCHEMATIC

CHAPTER 4

ASSEMBLY INSTRUCTIONS

Eight pulsers of the 10-kV type were built between 1985 and 1990 by various people who followed the guidelines incorporated into 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 10-kV Pulser, noting that any individual pulser already in existence may have some slight variations in construction details.

The 10-kV 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, while 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 fitted 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 sharp knife should be used to cut a hole through the thin metal that follows the circumference of the hole in the panel. After all holes are cut in both front and rear panels, components can be mounted on them before they are secured in place.

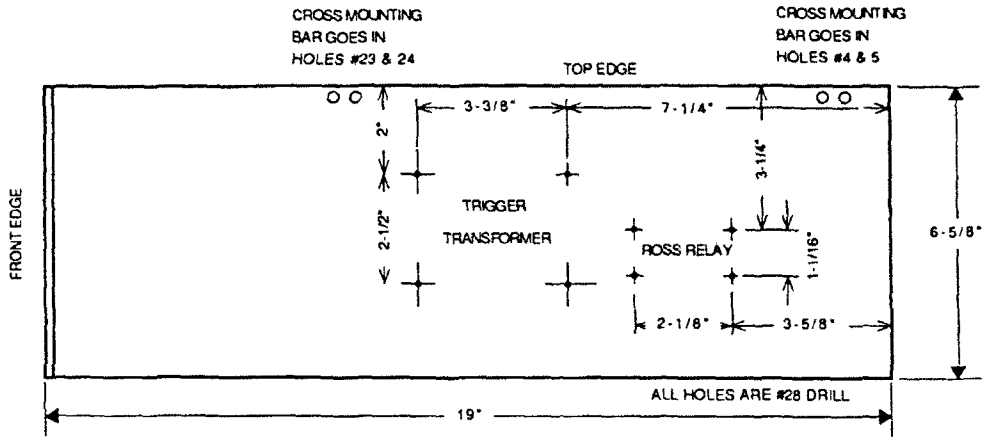
Next, construct the mechanical parts shown in Figures 4-7 through 4-10, and the pickup coil in Figure 4-11. The High-Voltage Resistor Board Component Layout

shown in Figure 4-12 is the current version of the board. While most 10-kV Pulsers (built before 1990) have an earlier version of this board, any repairs, updates, or new construction will have to use the new version because the old charging resistor product line was discontinued by its parent 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, 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.

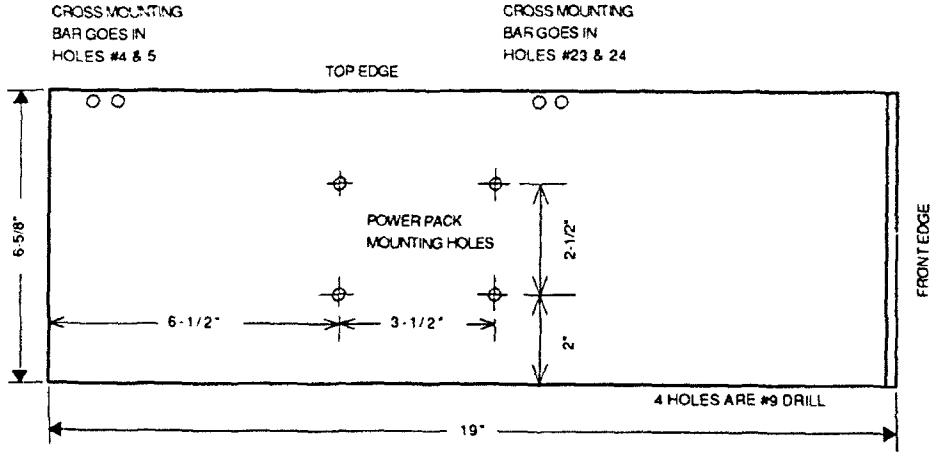
Figure 4-16 shows the Pulser Control Board component layout. A parts list for this board, derived from the complete parts list in Table 4-1, is shown in Table 4-2. This board can be constructed at any time but will not be needed while wiring of the chassis is being done. It will be the last item to be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



10KV PULSER SIDE PANEL - RIGHT SIDE
TECHMAR SIDE FRAME SF-SE-7H-19D

FIGURE 4-1. 10-kV RIGHT SIDE RAIL DRILL GUIDE



10KV PULSER SIDE PANEL - LEFT SIDE
TECHMAR SIDE FRAME SF-SE-7H-19D

FIGURE 4-2. 10-kV LEFT SIDE RAIL DRILL GUIDE

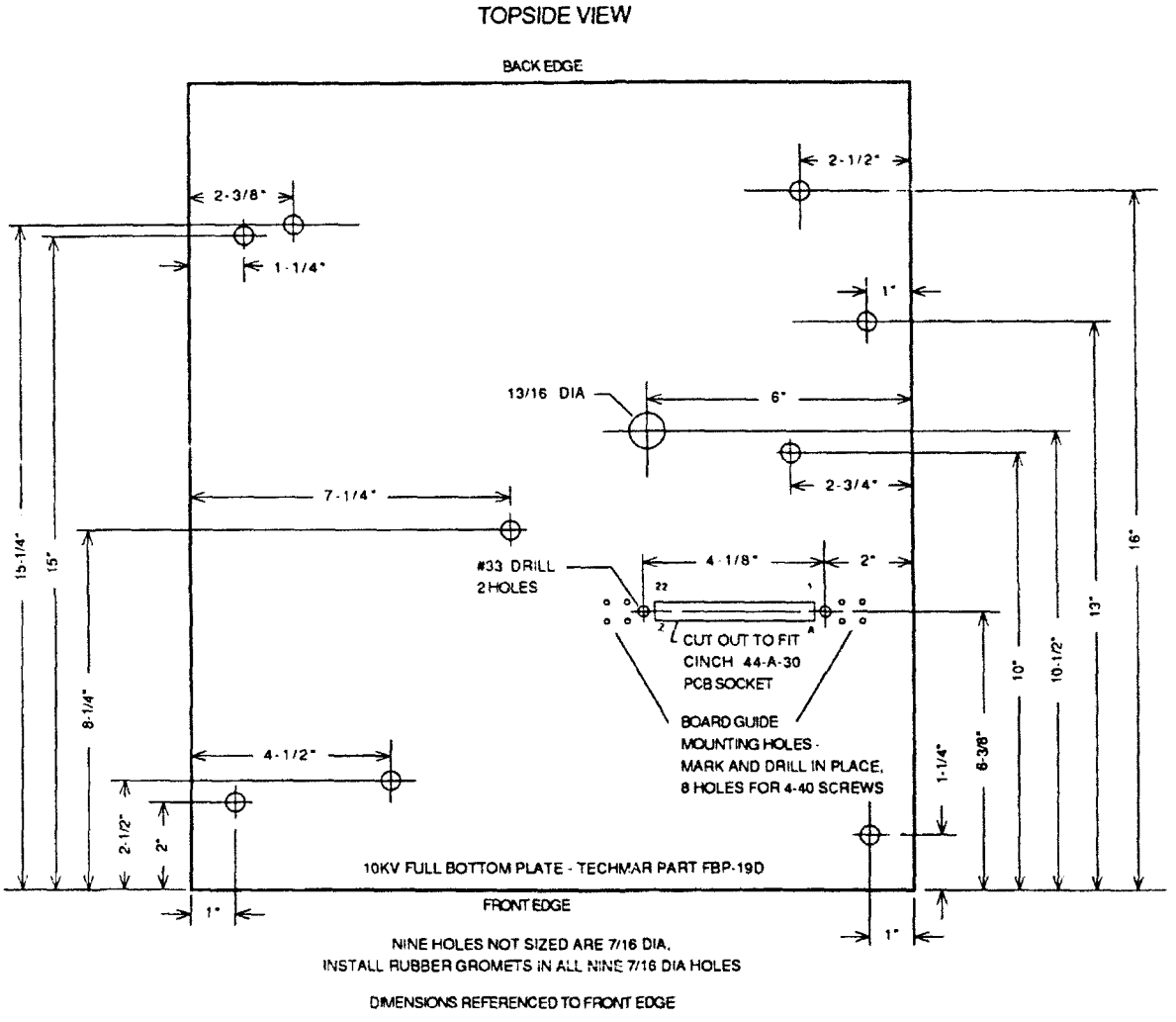


FIGURE 4-3. 10-kV BOTTOM MOUNTING PLATE CUT AND DRILL GUDIE

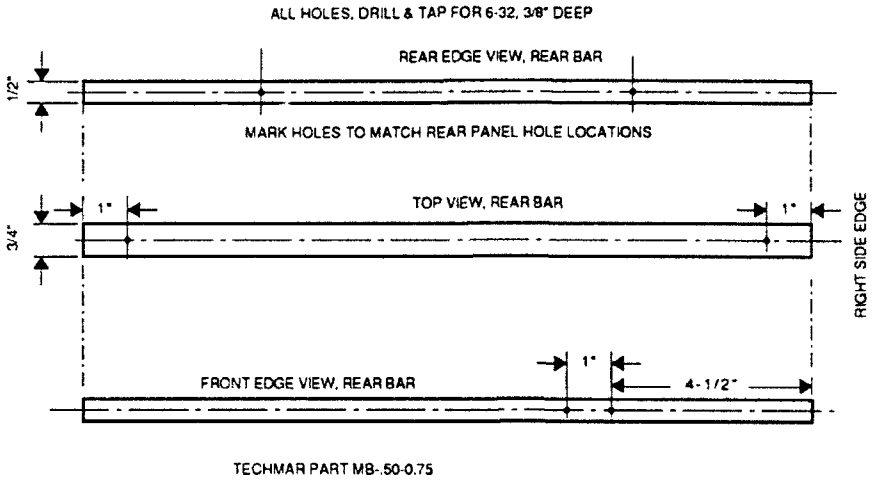


FIGURE 4-4. REAR CROSS MOUNTING BAR DRILL GUIDE

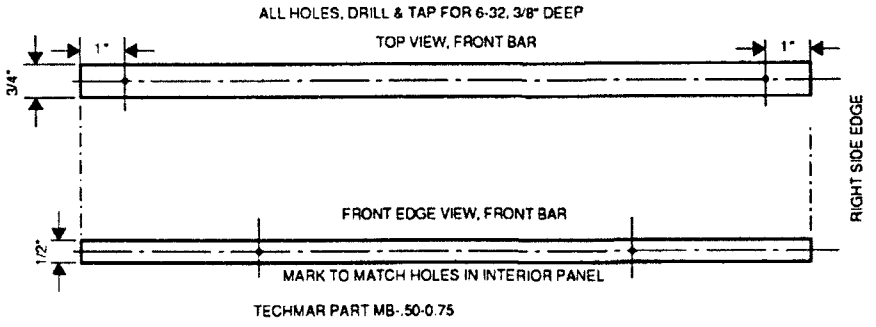


FIGURE 4-5. FRONT CROSS MOUNTING BAR DRILL GUIDE

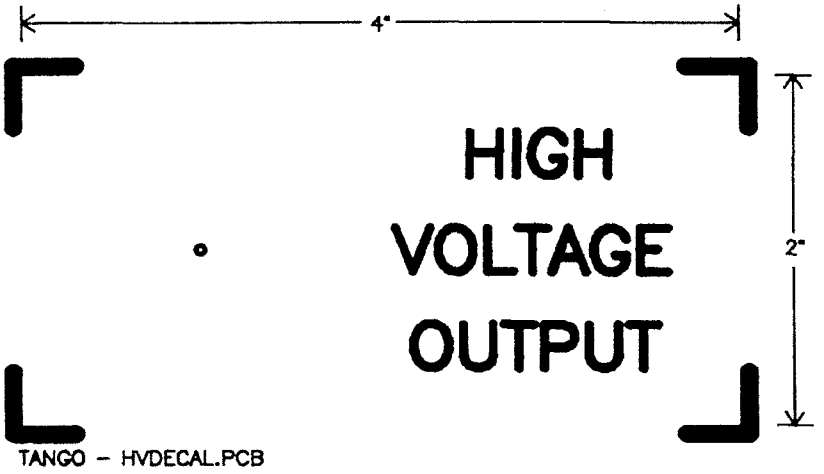


FIGURE 4-6. HIGH-VOLTAGE OUTPUT METAL FOIL DECAL

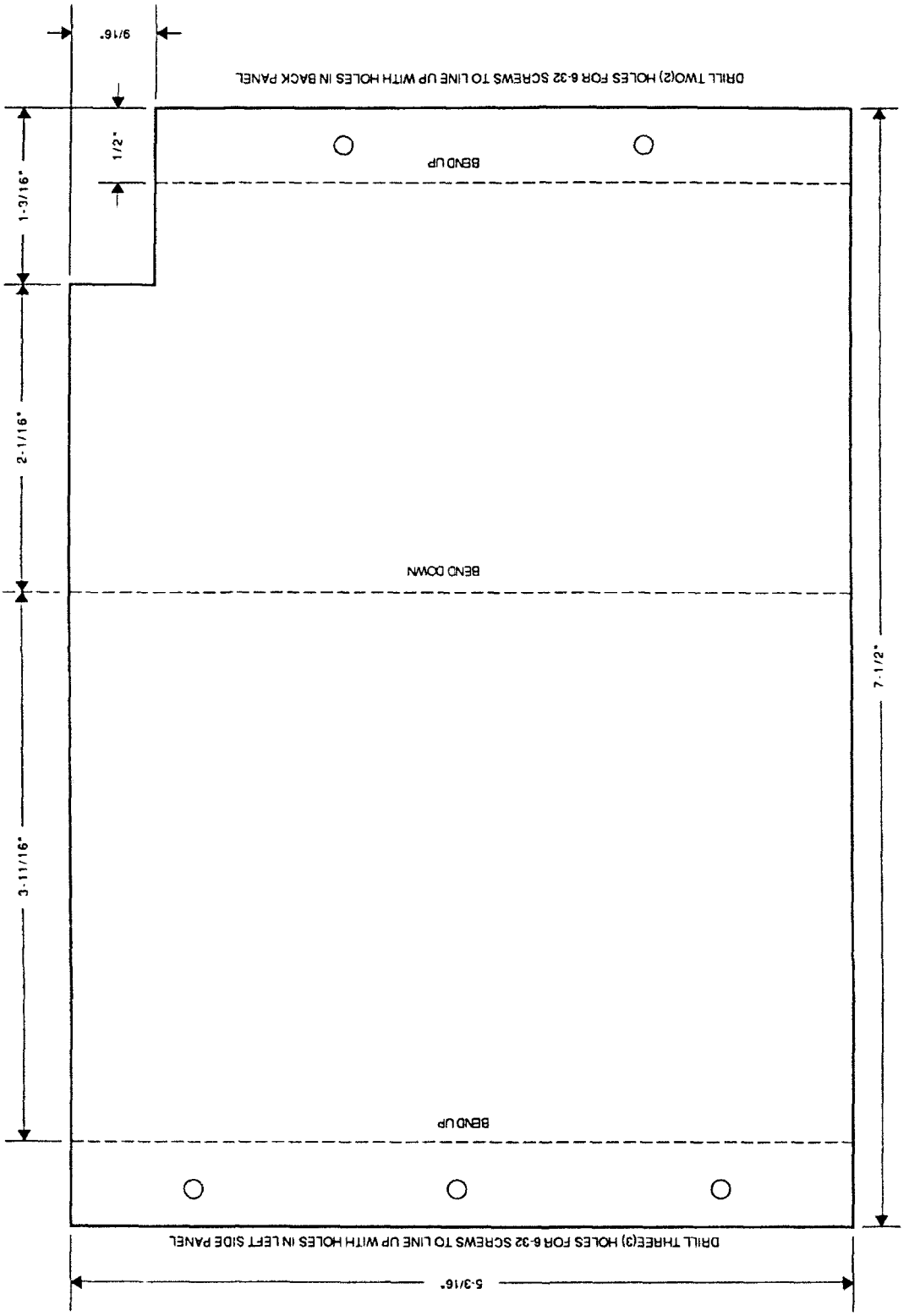
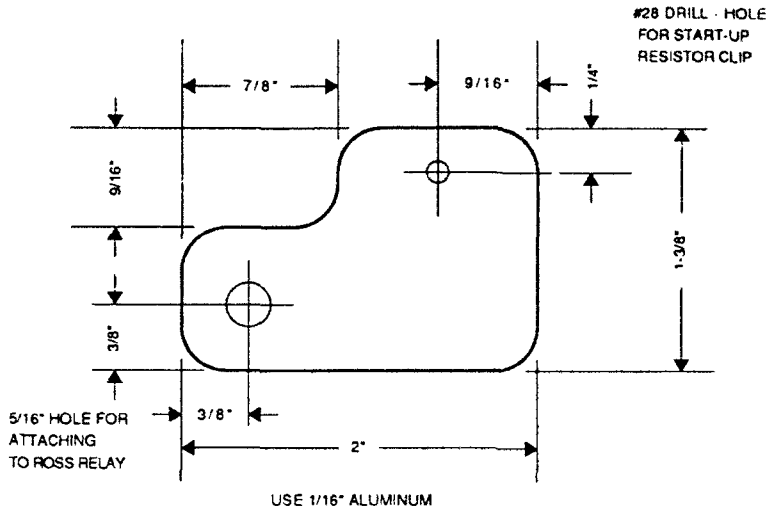
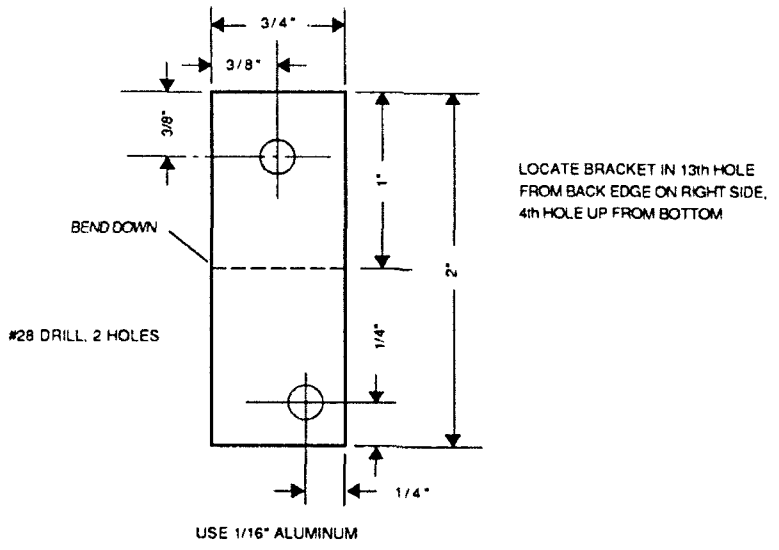


FIGURE 4-7. AC POWER INPUT SHIELD FABRICATION GUIDE



A. RELAY TERMINAL BRACKET



B. RIGHT SIDE WALL BRACKET

FIGURE 4-8. STARTUP RESISTOR CLIP MOUNTING BRACKETS

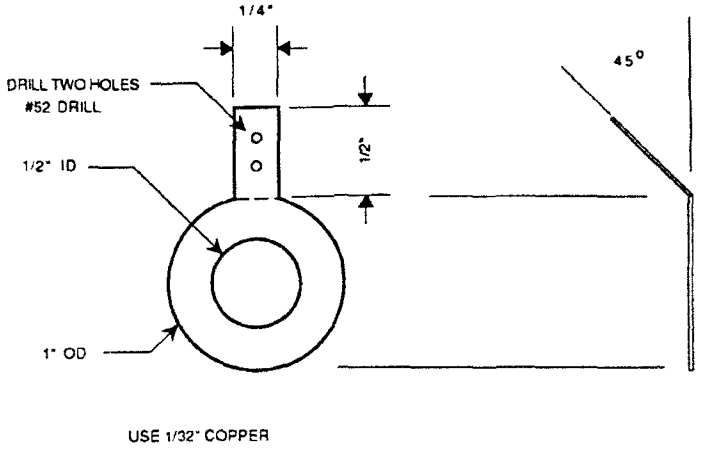


FIGURE 4-9. REYNOLDS HIGH-VOLTAGE CONNECTOR SOLDER LUG

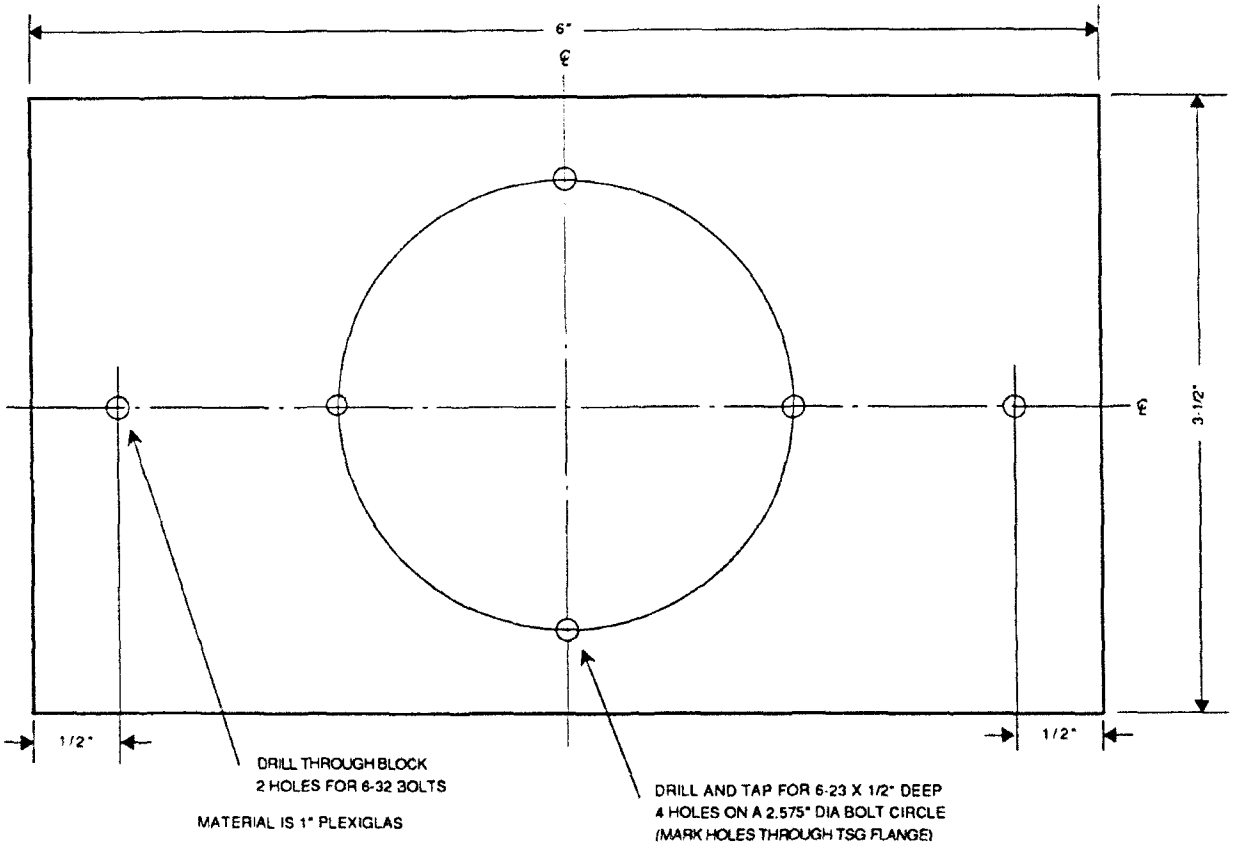


FIGURE 4-10. SPARK GAP INSULATED MOUNTING BLOCK CUT AND DRILL GUIDE

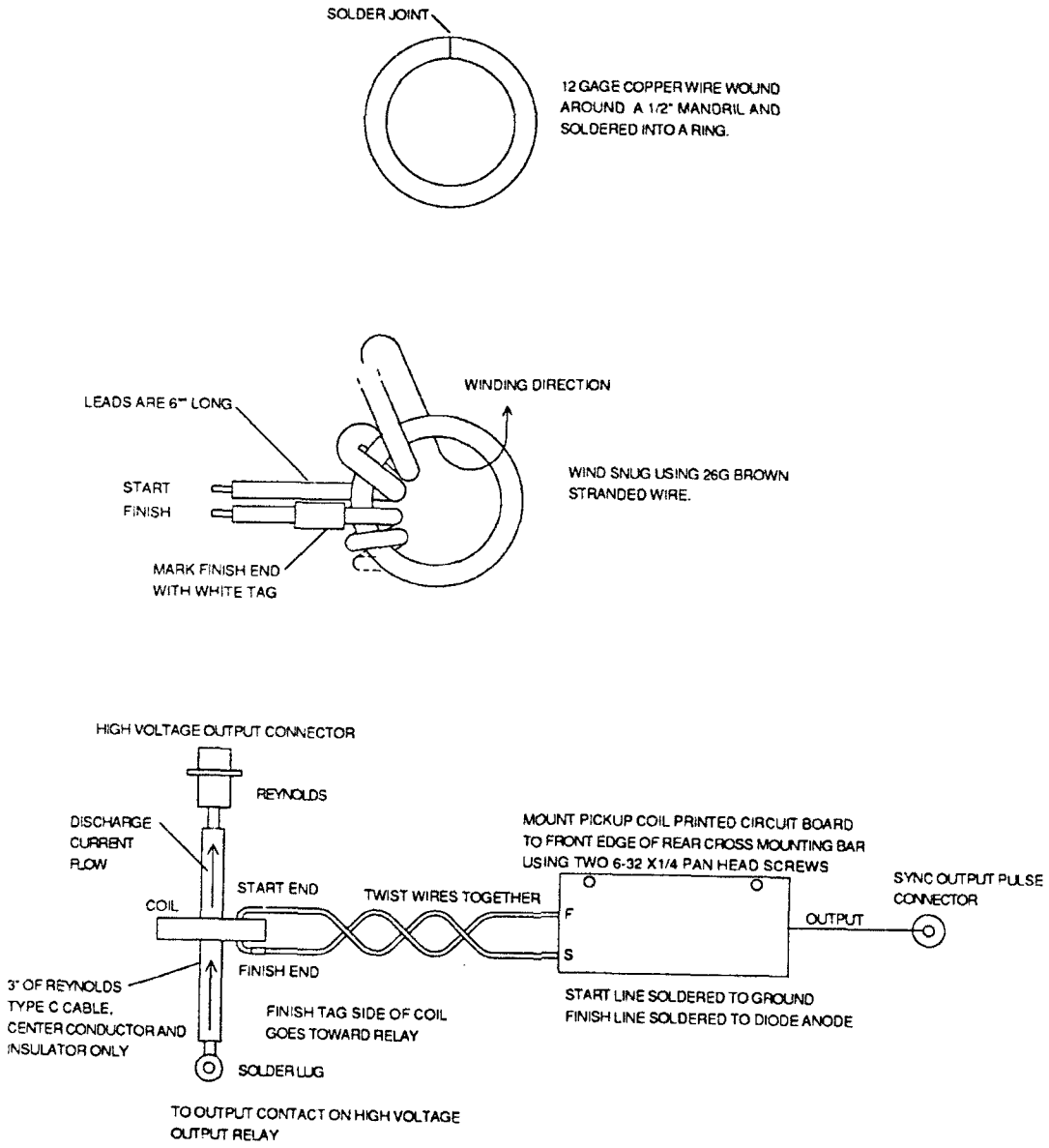


FIGURE 4-11. PICKUP COIL FABRICATION AND INSTALLATION

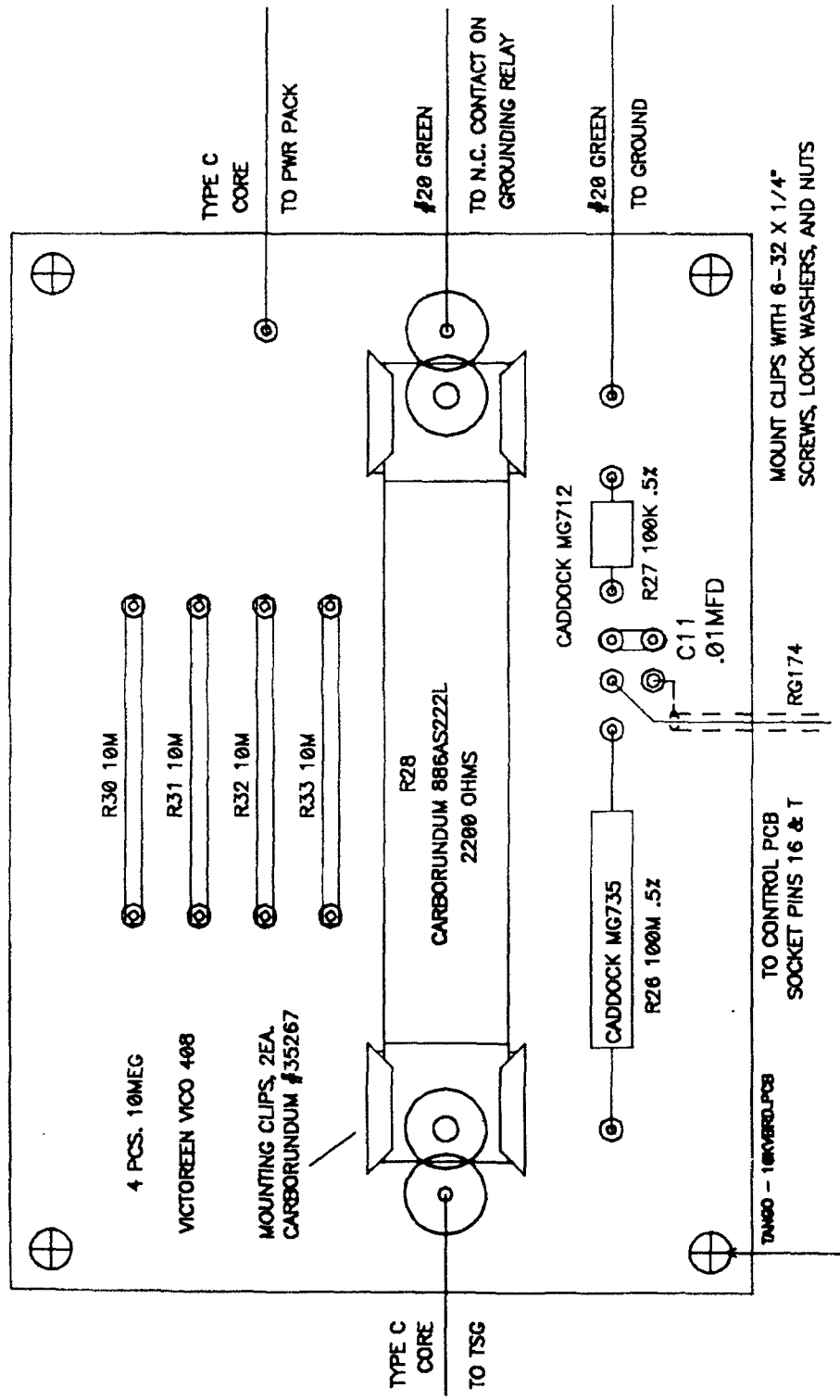


FIGURE 4-12. 10-kV RESISTOR BOARD COMPONENT LAYOUT

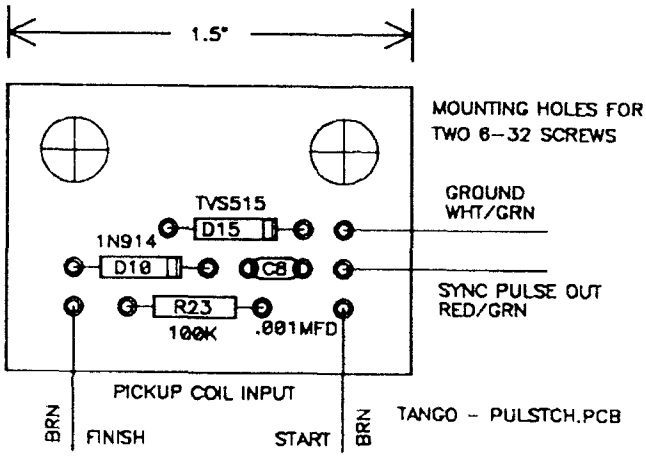
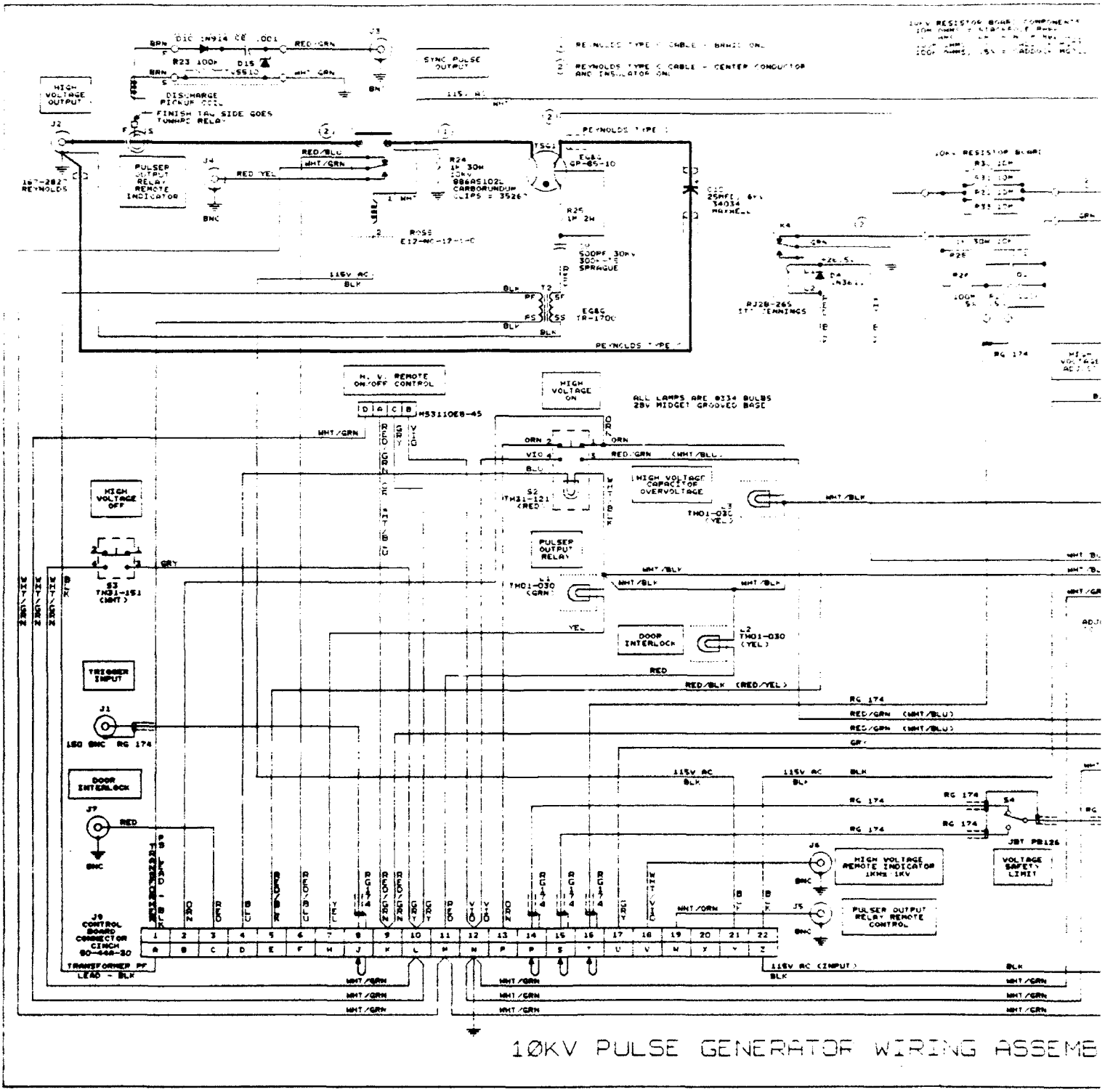


FIGURE 4-13. PULSE STRETCHER BOARD COMPONENT LAYOUT



10KV PULSE GENERATOR WIRING ASSEMB

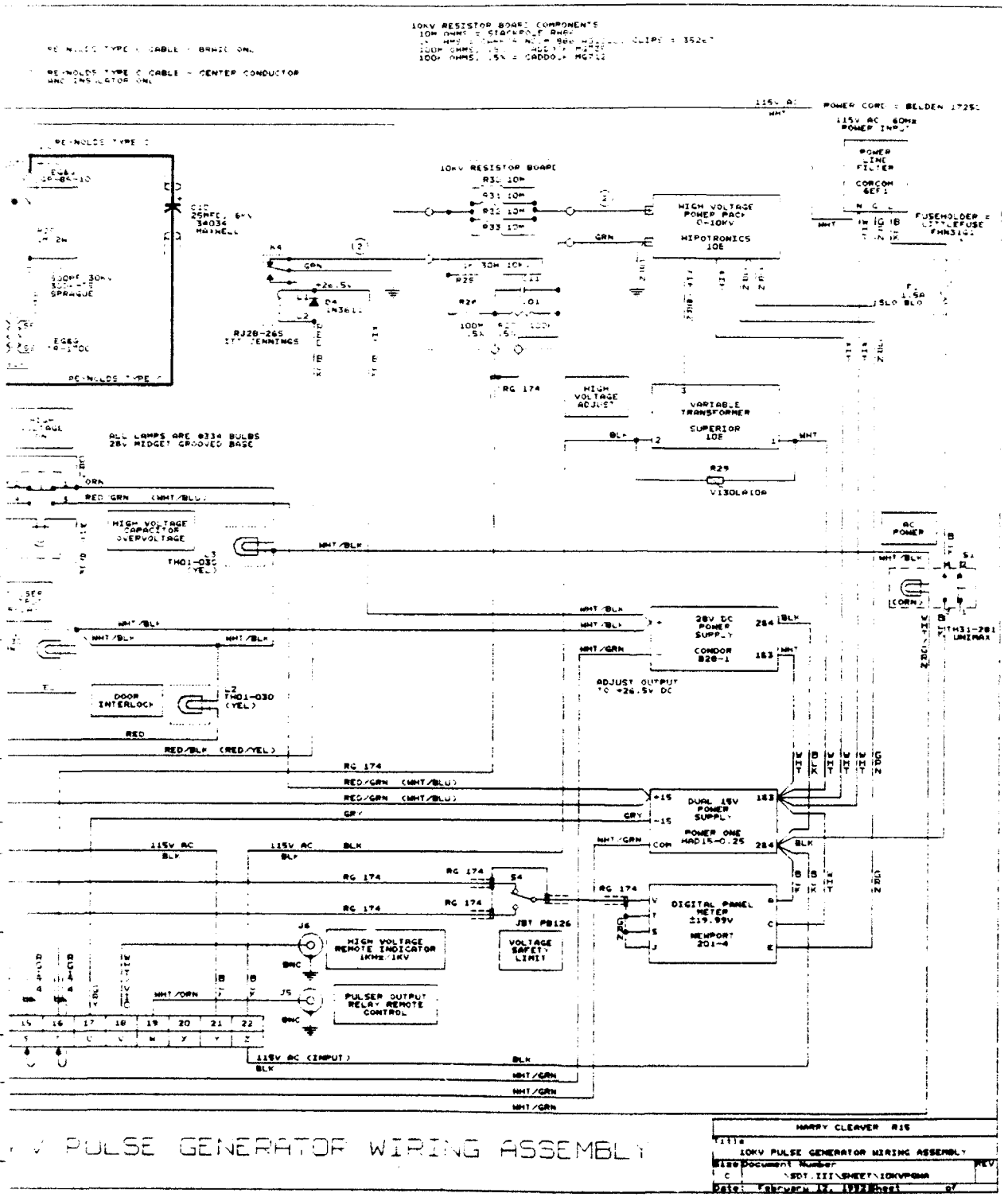


FIGURE 4-14. 10-kV WIRING ASSEMBLY

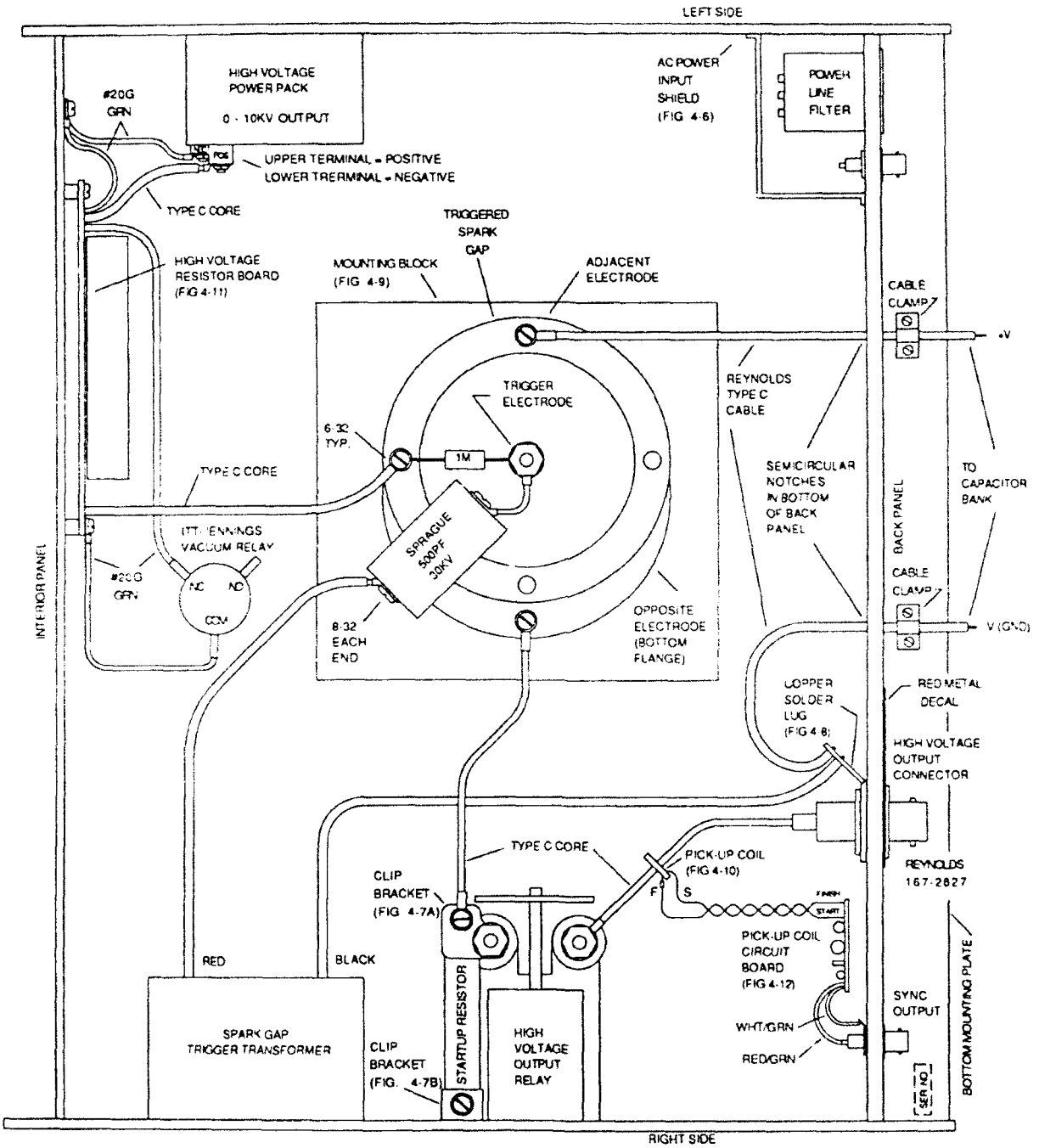


FIGURE 4-15. HIGH-VOLTAGE COMPARTMENT ASSEMBLY

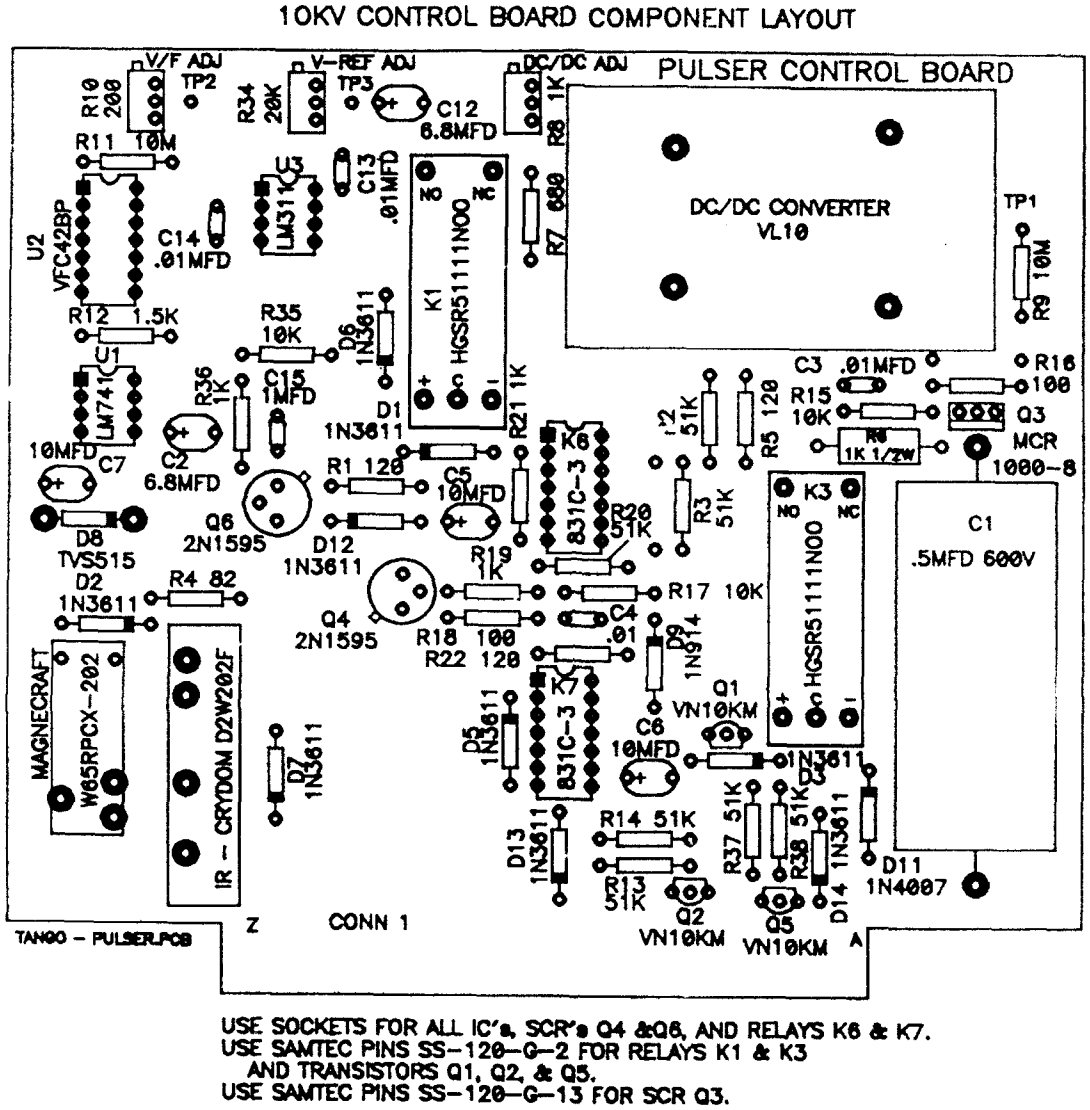


FIGURE 4-16. 10-kV PULSER CONTROL BOARD COMPONENT LAYOUT

TABLE 4-1. 10-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	2	C2, C12	6.8 µF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3745 (11071)
3	5	C3, C4, C11, C13, C14	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	C15	1 µF, 5-V CERAMIC	SERVMART, 5910-00-010-8721 (11090)
8	10	D1-D7, D12-D14	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	5	J3-J6, J9	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

TABLE 4-1. 10-kV PULSER PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
25	1	LP1	LAMP HOLDER	UNIMAX TH01-030 (GRN)
26	2	LP2, LP3	LAMP HOLDER	UNIMAX TH01-030 (YEL)
27	3	Q1, Q2, Q5	FIELD-EFFECT TRANSISTOR	SILICONIX VN10KM, 5961-01-123-5416
28	1	Q3	SILICON-CONTROLLED RECTIFIER	MOTOROLA MCR 1000-8
29	2	Q4, Q6	SCR 2N1595	5961-00-814-8865
30	3	R1, R5, R22	120 Ω, 1/4 W	SERVMART, 5905-00-119-8812 (03334)
31	7	R2, R3, R13, R14, R20, R37, R38	51 kΩ, 1/4 W	SERVMART, 5905-00-136-3890 (03362)
32	1	R4	82 Ω, 1/4 W	SERVMART, 5905-00-104-8363 (03250)
33	1	R6	1 kΩ, 1/2 W	SERVMART, 5905-00-110-0196 (03278)
34	1	R7	680 Ω, 1/4 W	SERVMART, 5905-00-135-6046 (03361)
35	1	R8	1-kΩ TRIMPOT	BOURNS 3299X-1-102
36	2	R9, R11	10 MΩ, 1/4 W	SERVMART, 5905-00-121-9919 (03339)
37	1	R10	200-Ω TRIMPOT	BOURNS 3299X-1-201
38	1	R12	1.5 kΩ, 1/4 W	SERVMART, 5905-00-106-1356 (03263)
39	3	R15, R17, R35	10 kΩ, 1/4 W	SERVMART, 5905-00-106-3666 (03265)
40	2	R16, R18	100 Ω, 1/4 W	SERVMART, 5905-00-141-1183 (03389)
41	3	R19, R21, R36	1 kΩ, 1/4 W	SERVMART, 5905-00-110-7620 (03282)
42	1	R23	100 kΩ, 1/4 W	SERVMART, 5905-00-110-0388 (03280)
43	1	R24	1 kΩ, 10 kV, 30 W	CARBORUNDUM 886AS102L DS
44	1	R25	1 MΩ, 2 W	SERVMART, 5905-00-182-7455 (03400)
45	1	R26	100 MΩ, 10 kV, .5 percent	CADDOCK MG735
46	1	R27	100 kΩ, 1 kV, .5 percent	CADDOCK MG712
47	1	R28	2.2 kΩ, 10 kV, 30 W	CARBORUNDUM 886AS222L
48	1	R29	VARISTOR, TRANS. SUPPRESSOR	GE (NOW HARRIS) V130LA10A
49	4	R30-R33	10 MΩ, 20 kV, 15 W, 5 percent	VICTOREEN SLIM-MOX 408 15W
50	1	R34	20 kΩ TRIMPOT	BOURNS 3299X-1-203, 5905-01-015-3529
51	1	S1	SW, SPDT, ALT, LIGHTED	UNIMAX TH31-281 (ORN)

TABLE 4-1. 10-kV PULSER PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
52	1	S2	SW, SPDT, MOM., LIGHTED	UNIMAX TH31-121 (RED)
53	1	S3	SW, SPDT, MOM., UNLIGHTED	UNIMAX TH31-151 (WHT)
54	1	S4	PUSHBUTTON SWITCH SPDT, MOM., ALCOSWITCH, MPA106F	SERVMART, 5930-00-618-6979 (11264)
55	1	T1	AUTOTRANSFORMER	SUPERIOR ELECTRIC, MOD 10B, 5950-00-688-2881
56	1	T2	TRIGGER TRANSFORMER	EG&G, TR-1700
57	1	TSG1	TRIG. SPARK GAP, 2000 J, 10 kV	EG&G, GP-85-10
58	1	U1	LM741 OP-AMP	SERVMART,
59	1	U2	VOLTAGE-TO-FREQUENCY CONVT.	BURR-BROWN VFC42BF
60	1	U3	LM311 VOLTAGE COMPARATOR	SERVMART, 5962-LL-L07-7120 (11605)
61	1		HIGH-VOLTAGE POWER PACK, 10 kV, 5 MA	HIPOTRONICS MOD 10B
62	1		POWER-LINE FILTER	CORCOM 6EF1, 5915-00-365-9951
63	1	SSR1	SOLID-STATE RELAY	CRYDOM D2W202F
64	1	PS1	28-V DC POWER SUPPLY	CONDOR B28-1
65	1	PS2	DUAL 15-V POWER SUPPLY	POWER-ONE 15-.25
66	1	PS3	DC/DC CONVERTER	MIL ELECTRONICS VL10
67	1		DIGITAL PANEL METER	NEWPORT 201-4
68	2		PCB CARD GUIDE	GIBSON-EGAN 600 SERIES, 3.5 in (NOW TEXTOOL TEST & INTERCONNECT PRODUCTS DEPT, 3M E.P. DIV)
69	2		TO-5, TRANSISTOR SOCKET	AUGAT 8059-2G1, 5905-01-077-9755
70	2		8-PIN DIP SOCKET	AUGAT 508-AG10D, 5935-01-005-9795
71	3		14-PIN DIP SOCKET	SERVMART, 5935-00-152-9571 (11303)
72	19		SOCKET STRIP PINS, FOR .015-.022 LEADS	SAMTEC SS-120-G-2, 5935-01-150-3508
73	3		SOCKET STRIP PINS, FOR .025-.030 LEADS	SAMTEC SS-120-G-13
74	5		#334 BULB, 28-V MIDGET, GROOVED BASE	SERVMART, 6240-00--295-1617 (11902)
75	9		RUBBER GROMMET	SERVMART, 5935-00--263-6632 (10612)
76	4		RESISTOR MOUNTING CLIPS	CARBORUNDUM 35267

TABLE 4-1. 10-kV PULSER PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
77	2		SIDE FRAMES	TECHMAR SF-SE-7H-19D
78	1		FULL BOTTOM PLATE	TECHMAR FBP-19D
79	2		SOLID COVER	TECHMAR SANC-19D
80	2		OVAL SECTION HANDLES	TECHMAR OSH-5
81	2		CROSS MOUNTING BAR	TECHMAR MB-.50-0.75
82	MISC.		CABLE TIES	SERVMART, 5975-00-727-5153 (14597)

TABLE 4-2. 10-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	2	C2, C12	6.8 μF, 50 V, 10 TOL, POLARIZED, TANTALUM	SERVMART, 5910-LL-L07-3745 (11071)
3	4	C3, C4, C13, C14	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)
7	1	C15	1 μF, 5-V CERAMIC	SERVMART, 5910-00-010-8721 (11090)
8	9	D1-D3, D5-D7, D12-D14	1N3611 DIODE	SERVMART, 5961-00-957-6865 (11542)
9	1	D8	TRANSIENT SUPPRESSOR, 15 V	UNITRODE TVS 515
10	1	D9, D10	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
27	3	Q1, Q2, Q5	FIELD-EFFECT TRANSISTOR	SILICONIX VN10KM, 5961-01-123-5416
28	1	Q3	SILICON-CONTROLLED RECTIFIER	MOTOROLA MCR 1000-8
29	2	Q4, Q6	SCR 2N1595	5961-00-814-8865
30	3	R1, R5, R22	120 Ω, 1/4 W	SERVMART, 5905-00-119-8812 (03334)
31	7	R2, R3, R13, R14, R20, R37, R38	51 kΩ, 1/4 W	SERVMART, 5905-00-136-3890 (03362)
32	1	R4	82 Ω, 1/4 W	SERVMART, 5905-00-104-8363 (03250)
33	1	R6	1 kΩ, 1/2 W	SERVMART, 5905-00-110-0196 (03278)
34	1	R7	680 Ω, 1/4 W	SERVMART, 5905-00-135-6046 (03361)
35	1	R8	1-kΩ TRIMPOT	BOURNS 3299X-1-102
36	2	R9, R11	10 MΩ, 1/4 W	SERVMART, 5905-00-121-9919 (03339)
37	1	R10	200-Ω TRIMPOT	BOURNS 3299X-1-201

TABLE 4-2. 10-kV PULSER CONTROL BOARD PARTS LIST (Continued)

ITEM	QUANT.	REF.	PART	SOURCE
38	1	R12	1.5 kΩ, 1/4 W	SERVMART, 5905-00-106-1356 (03263)
39	3	R15, R17, R35	10 kΩ, 1/4 W	SERVMART, 5905-00-106-3666 (03265)
40	2	R16, R18	100 Ω, 1/4 W	SERVMART, 5905-00-141-1183 (03389)
41	3	R19, R21, R36	1 kΩ, 1/4 W	SERVMART, 5905-00-110-7620 (03282)
50	1	R34	20-kΩ TRIMPOT	BOURNS 3299X-1-203, 5905-01-015-3529
58	1	U1	LM741 OP-AMP	SERVMART,
59	1	U2	VOLTAGE-TO-FREQUENCY CONVT.	BURR-BROWN VFC42BF
60	1	U3	LM311 VOLTAGE COMPARATOR	SERVMART, 5962-LL-L07-7120 (11605)
63	1	SSR1	SOLID-STATE RELAY	CRYDOM D2W202F
66	1	PS3	DC/DC CONVERTER	MIL ELECTRONICS VL10
69	2		TO-5, TRANSISTOR SOCKET	AUGAT 8059-2G1, 5905-01-077-9755
70	2		8-PIN DIP SOCKET	AUGAT 508-AG10D, 5935-01-005-9795
71	3		14-PIN DIP SOCKET	SERVMART, 5935-00-152-9571 (11303)
72	19		SOCKET STRIP PINS, FOR .015-.022 LEADS	SAMTEC SS-120-G-2, 5935-01-150-3508
73	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 or connecting the Energy-Storage Capacitor bank, 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. If all wiring is correct, the Door Interlock light will go On to lock out high-voltage charging. In order to continue testing, place a short across the Door Interlock BNC connector J9 on the rear panel.

Next, press the Capacitor Overvoltage switch and adjust the trip-point level to match the safe limit of the capacitor bank that is to be connected to the pulser. The adjustment pot is on the top edge of the Pulser Control Board and the voltage level can be read on the Digital Panel Meter while holding in the switch.

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's charging circuit is displayed on the Front Panel Meter. With no capacitors connected to the charging circuit, output of the power pack will rise rapidly as the High-Voltage Adjust control is rotated upscale to test its operation. Slowly raising the High Voltage past the Capacitor Overvoltage trip point level will test operation of the overvoltage shutdown circuit. If the circuit trips as expected, recycle the High-Voltage On switch and test the High-Voltage Off switch. Then turn on the High Voltage and remove the short on the Door Interlock connector to verify that the high-voltage charging system goes off and can't be turned on. Replace the short before going on with the testing.

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 bank can proceed. First, connect the capacitor bank to the pulser. The high-voltage cover and the top cover can be left off at this time until operation of the pulser is certified. Next, 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.

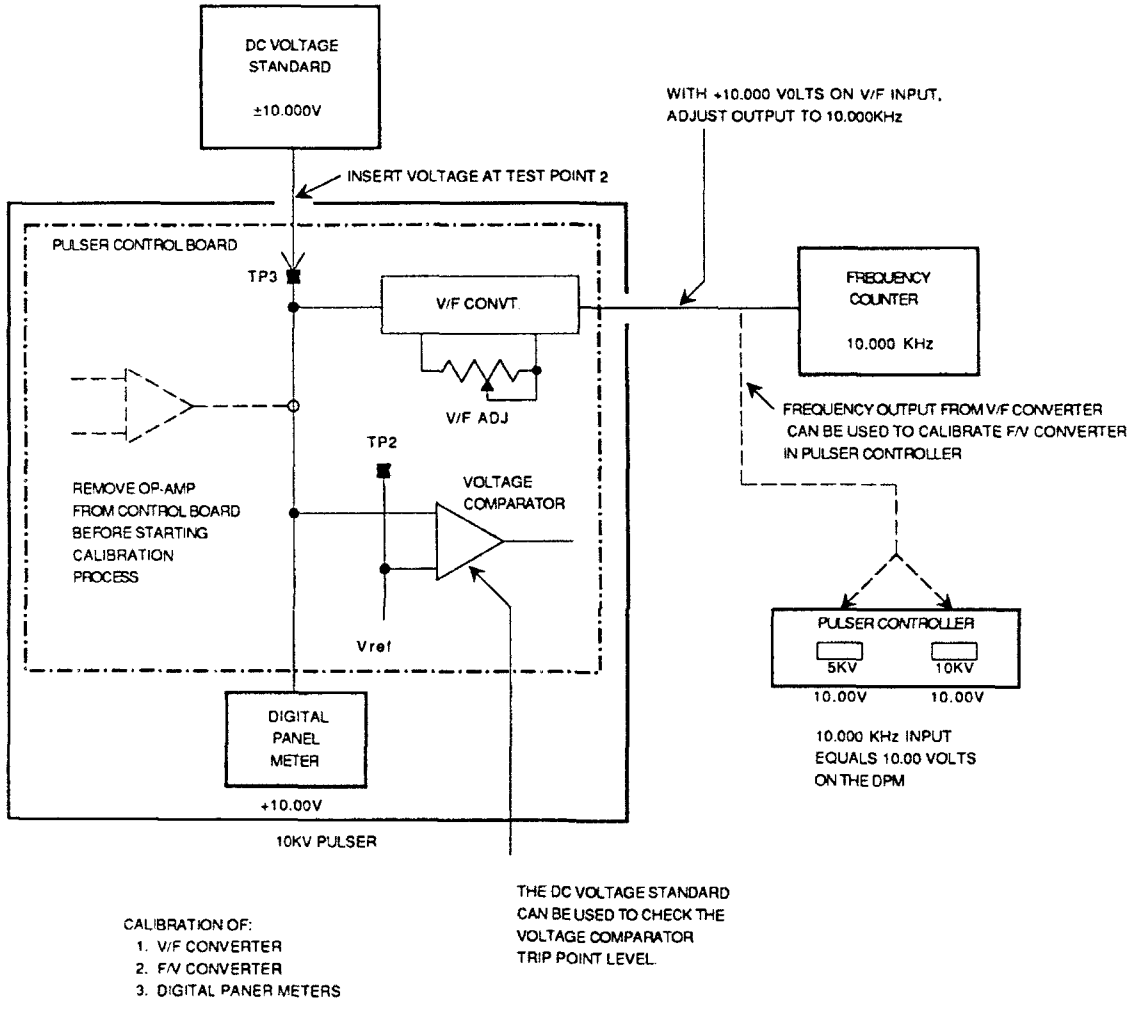


FIGURE 5-1. 10-kV PULSER CALIBRATION

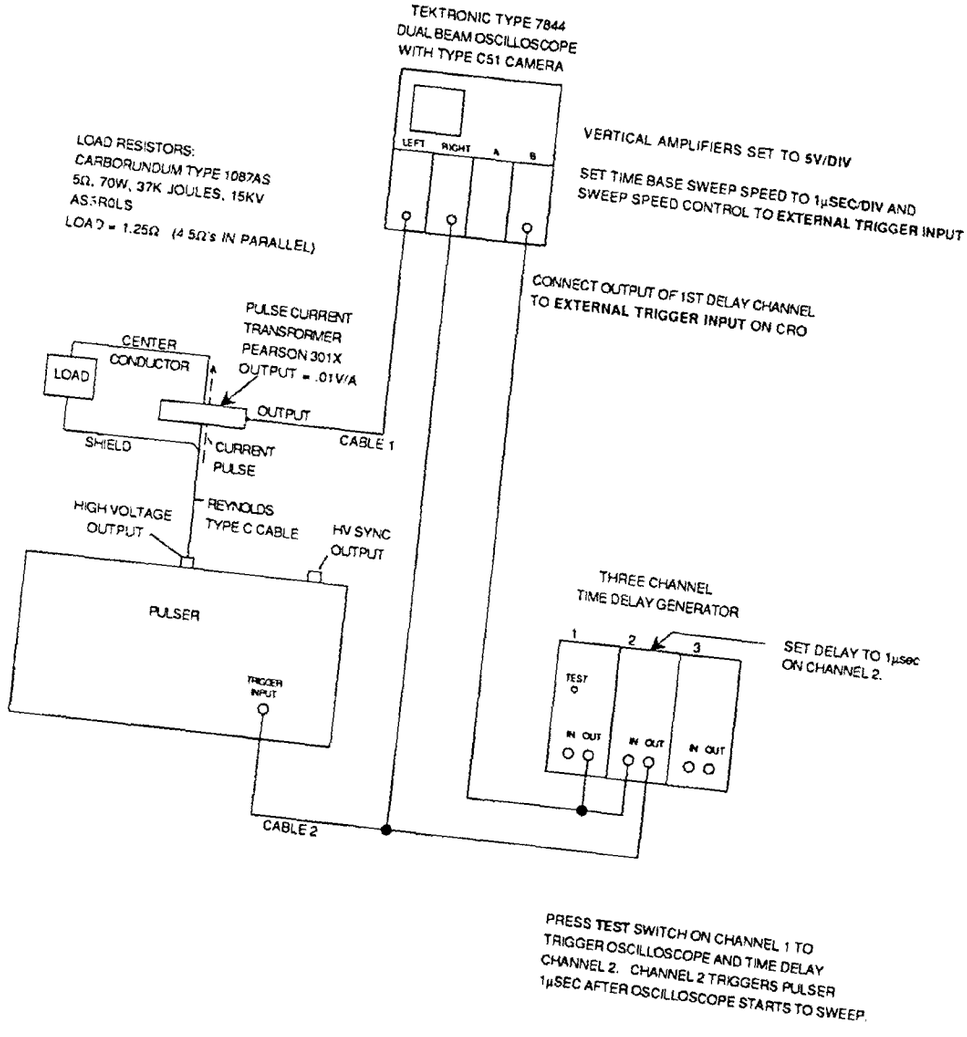


FIGURE 5-2. PULSER HIGH-VOLTAGE OUTPUT TEST APPARATUS

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
OP-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

APPENDIX A

FIRING LINE SAFETY LOCKBOX

The Firing Line Safety Lockbox provides for a break in the firing line between the high-voltage energy sources and the charge in the bombproof interior firing chamber. Safety features of the box are provisions for the Safe grounding of the firing line that leads into the chamber, a removable Safety Jumper in each line, and a lockable door that cannot be closed with the firing line plugged into the Fire connector. Safety regulations require the ordnance man to be in possession of the Safety Jumpers and the key to the lockbox when in the firing chamber if a charge is present.

The parts list for the lockbox is shown in Table A-1. Figure A-1 shows the labeling on the NEMA 1 electrical enclosure used for the lockbox, a Hoffman A-12N126 fitted with cylindrical lock kit A-L12AR. The Firing Line Safety Lockbox label was made in the electronic shop using an adhesive backed plastic material. It measures 9 in x 3-1/2 in and has white letters on a red background. The letters are 1-in high and about 5/32-in wide; the lines are 1/2-in apart, and there is a 1/2-in border. Figure A-2, the interior of the lockbox, shows the layout of the box and reveals labeling, wiring, and connector part numbers. The box is divided by a Horizontal Partition into two sections. The lower section is recessed so that the firing line can be plugged into the Safe grounding connector with the enclosure door closed and locked. The upper section is positioned forward enough that the door cannot be closed when the firing line is plugged into the Fire connector. The upper and lower sections are each divided into three compartments by vertical partitions to provide electrical isolation among the various parts of the system. The plastic water pipe is used to isolate the input cable where it passes through the lower compartment. The Front Panels and all partitions are made from Plexiglas so that a visual inspection of the wiring in the box is available at all times.

Figure A-3 shows the guide for drilling holes in the enclosure for cable access and partition mounting screws. Drawings showing how to make all the partitions and a copper solder lug for the Reynolds' connectors are shown in Figures A-4 through A-8.

Because of the 1/2-in lip around the opening of the enclosure, the partition system shown in Figure A-2 and in cross section in Figure A-9 cannot be assembled outside of the enclosure and then inserted. Attach the Lower Front Panel to the three Lower Vertical Partitions, with the notched edge at the back and bottom, and place this subassembly into the enclosure. With the assembly centered and resting on the bottom, mark the screw hole locations through the back and bottom of the enclosure. Remove the assembly and drill and tap the back and bottom edges of the Lower Vertical Partitions 1/2-in deep for 8-32 screws. Reassemble the lower section inside the enclosure and fasten the lower partitions with 8-32 screws through the back and bottom of the box. Place the Horizontal Partition and the three Upper Vertical Partitions, with the notched edge at the top and back, inside the enclosure. Attach

the Upper Front Panel to the vertical partitions. Center this assembly and mark hole locations on the top and back of the partitions through the holes in the top and back of the enclosure while the box is in the upright position. Remove the upper assembly and drill and tap the top and back of the three partitions 1/2-in deep for 8-32 screws. Place the horizontal assembly with the two 8-in pieces of plastic water pipe inserted through it into the enclosure and add the Upper Vertical Partitions. Align the upper assembly and fasten the partitions with 8-32 screws through the top and back of the enclosure. Once the upper and Lower Vertical Partitions are fastened in place, remove both Front Panels in preparation for connector assembly and wiring.

Put the Reynolds connectors, with the ground lug shown in Figure A-6 on each connector, onto the Front Panels using the layout shown in Figure A-3. Solder the two Reynolds type C cable links between the Safety Jumper output connectors and the Fire connectors as shown in Figure A-10, the inner compartment wiring diagram. As shown in the outer compartment wiring, Figure A-11, solder the 10 kΩ, 1 percent metal film resistors between the Safe connectors center conductor and ground lug and 5 in of braided wire having a solder ring for an 8-32 screw on one end. Screw the braided wires onto the grounding flange built into the enclosure. Make firing lines with appropriate connectors and lengths of Type C cable. Pass the ends on the firing lines through the holes in the Lower Front Panel from the front and out through the holes in the bottom of the enclosure as shown in Figure A-10. Make pulser output cables of the required length. Pass the bare ends of the cables up through the plastic pipes in the enclosure and solder them onto the Safety Jumper input connectors as shown in Figure A-11. Place a cable clamp around each cable to give strain relief on the Reynolds connector. Secure both Front Panels in place with 8-32 screws.

Installation of the Firing Line Safety Lockbox is done on a case-by-case basis and is not described here.

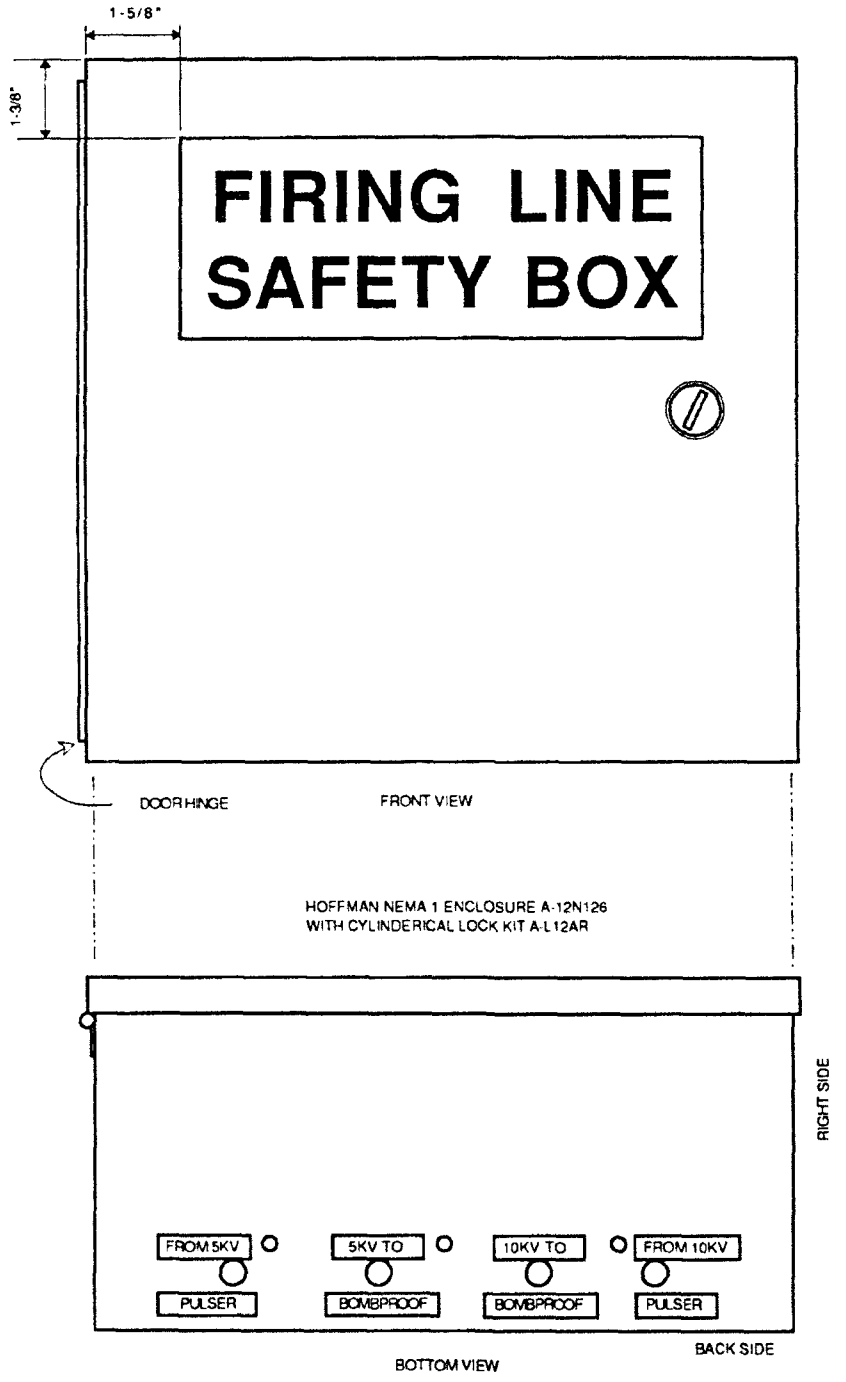


FIGURE A-1. FIRING LINE SAFETY LOCKBOX LABELS

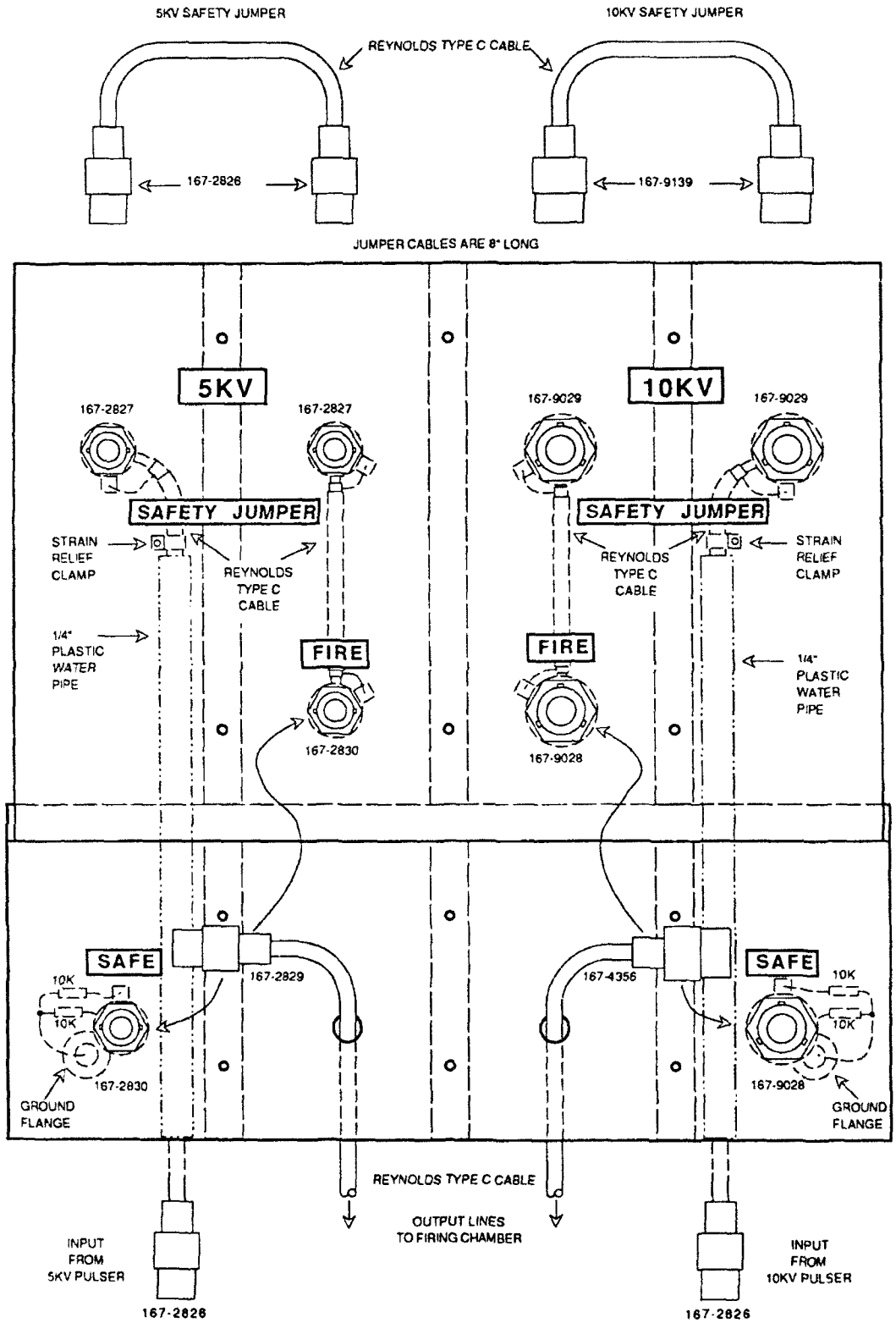


FIGURE A-2. REYNOLDS CONNECTOR PART NUMBERS AND LOCATIONS

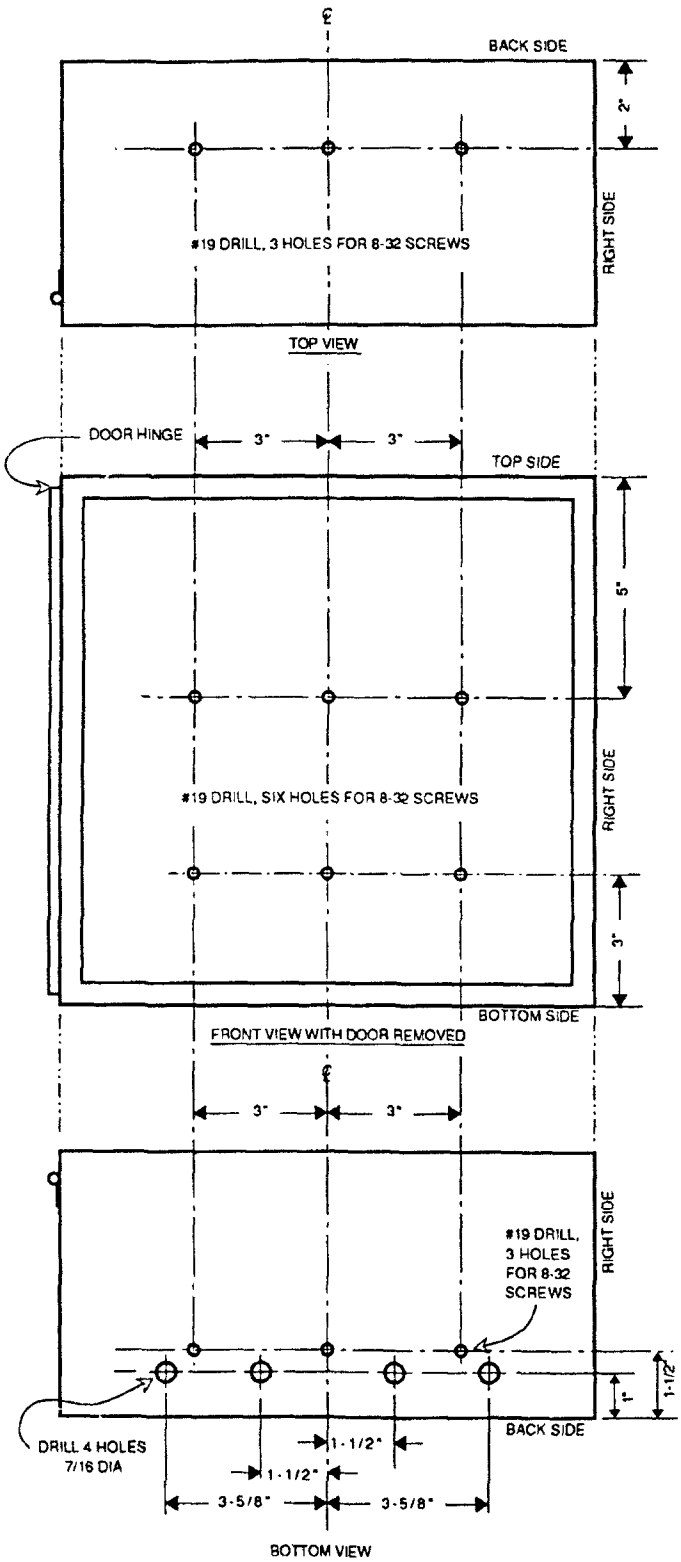
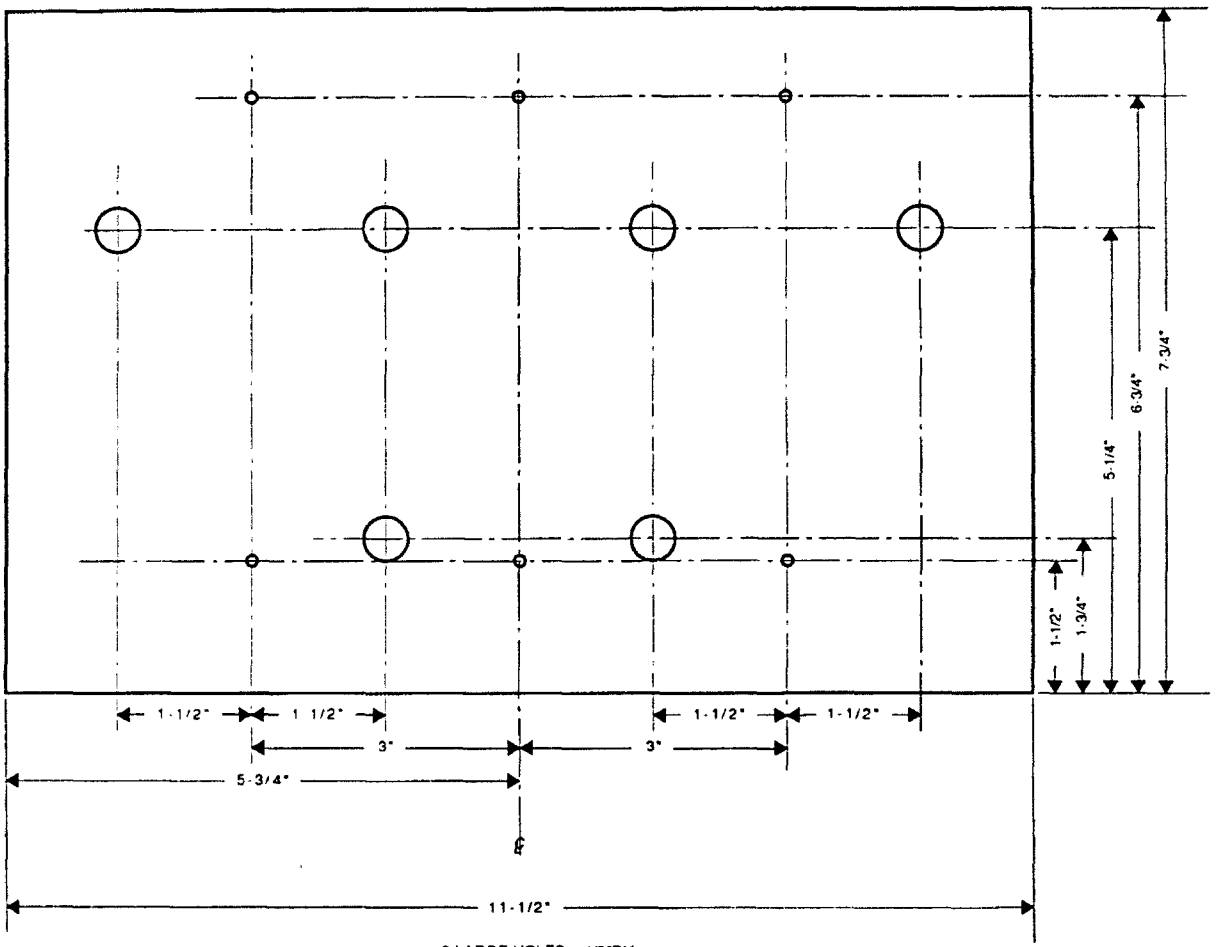


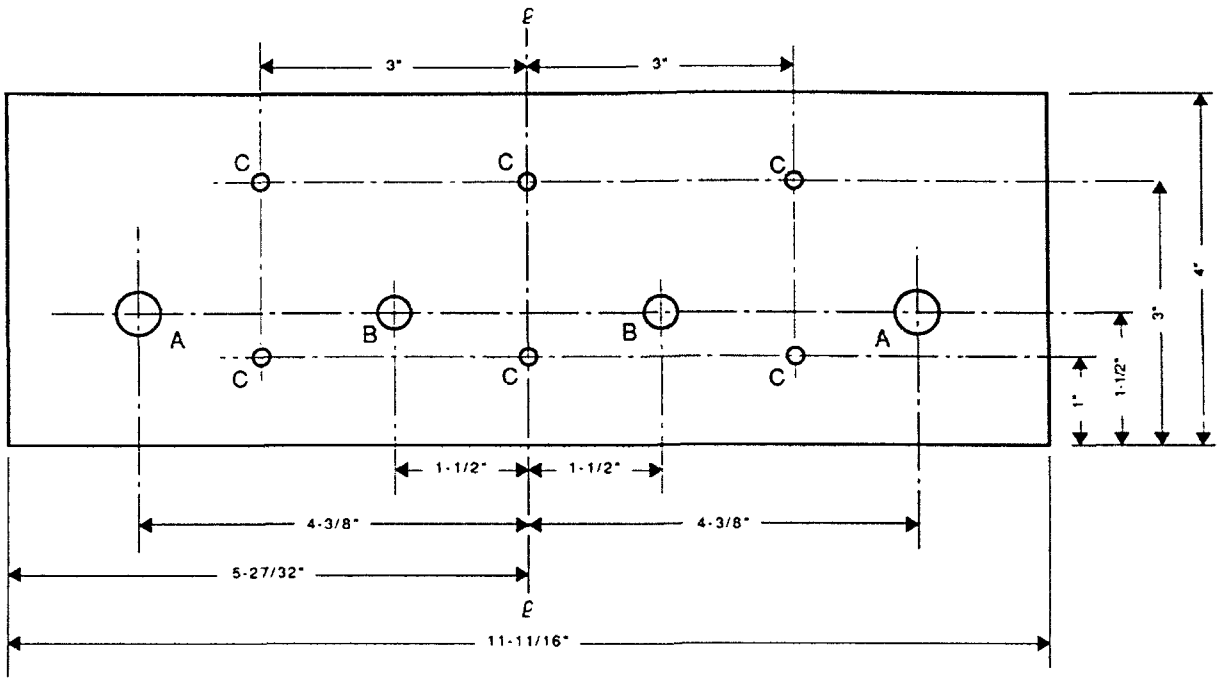
FIGURE A-3. HOFFMAN NEMA 1 ENCLOSURE A-12N126 DRILL GUIDE



6 LARGE HOLES = 1/2"DIA
6 SMALL HOLES =#19 DRILL FOR 8-32 SCREWS

1/4" PLEXIGLAS, MAKE 1

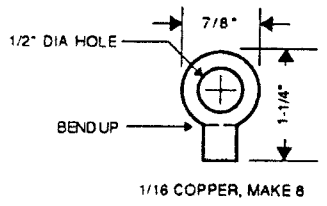
FIGURE A-4 UPPER FRONT PANEL CUT AND DRILL GUIDE



A = 1/2" DIA, 2 HOLES
B = 3/8" DIA, 2 HOLES
C = #19 DRILL, 6 HOLES FOR 8-32 SCREWS

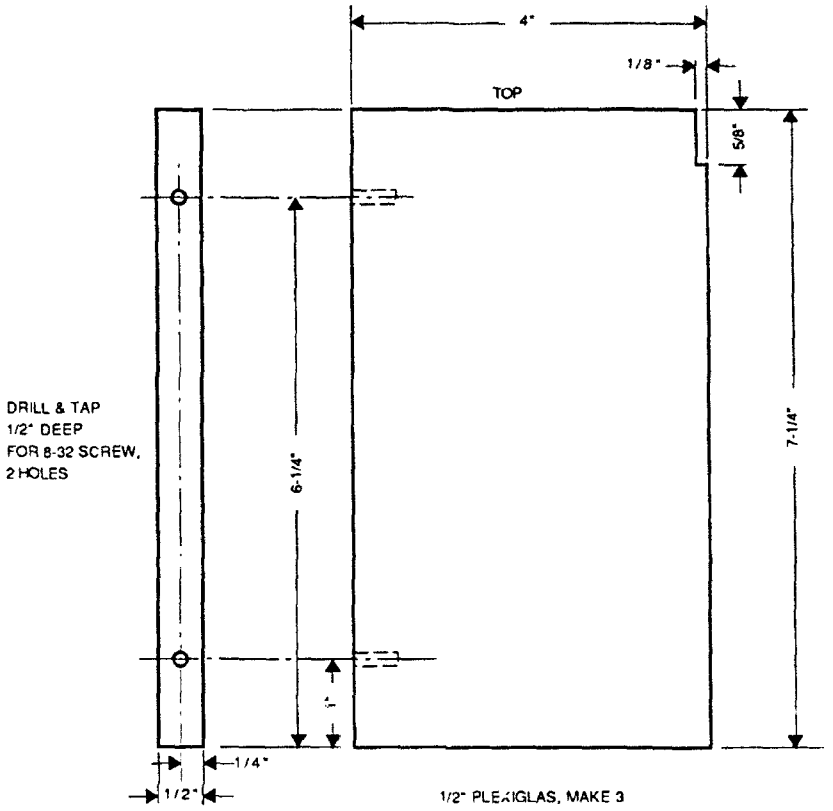
1/4" PLEXIGLAS, MAKE 1

FIGURE A-5. LOWER FRONT PANEL CUT AND DRILL GUIDE

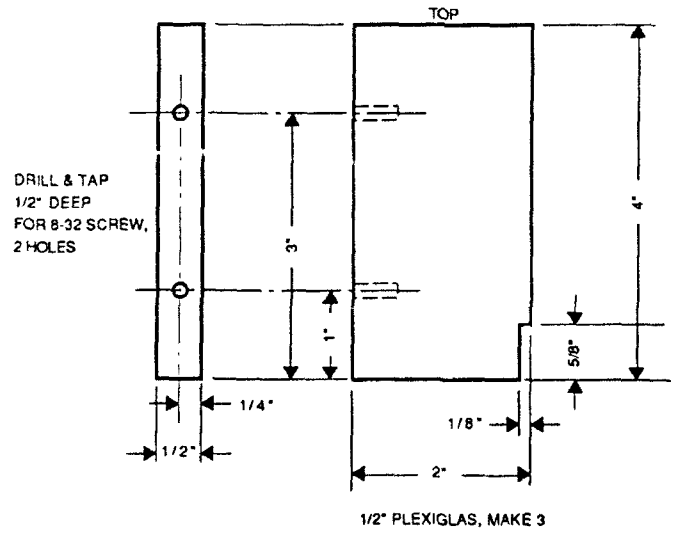


1/16 COPPER, MAKE 8

FIGURE A-6. REYNOLDS CONNECTOR GROUND SOLDER LUG



UPPER PARTITION



LOWER PARTITION

FIGURE A-7. UPPER AND LOWER VERTICAL PARTITION DIMENSIONS

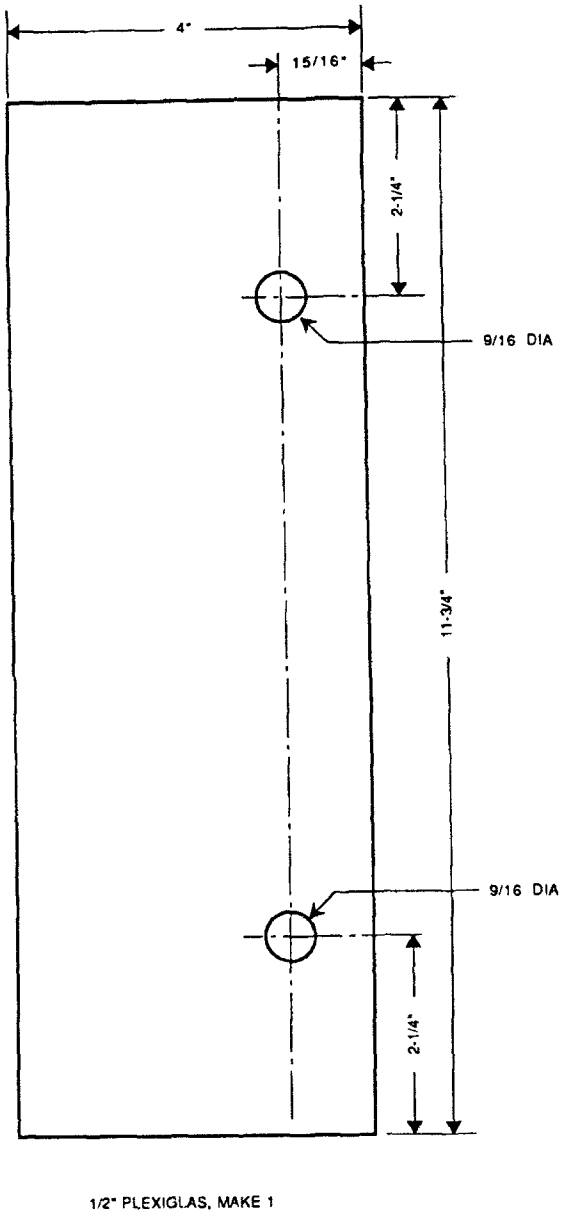


FIGURE A-8. HORIZONTAL PARTITION DIMENSIONS

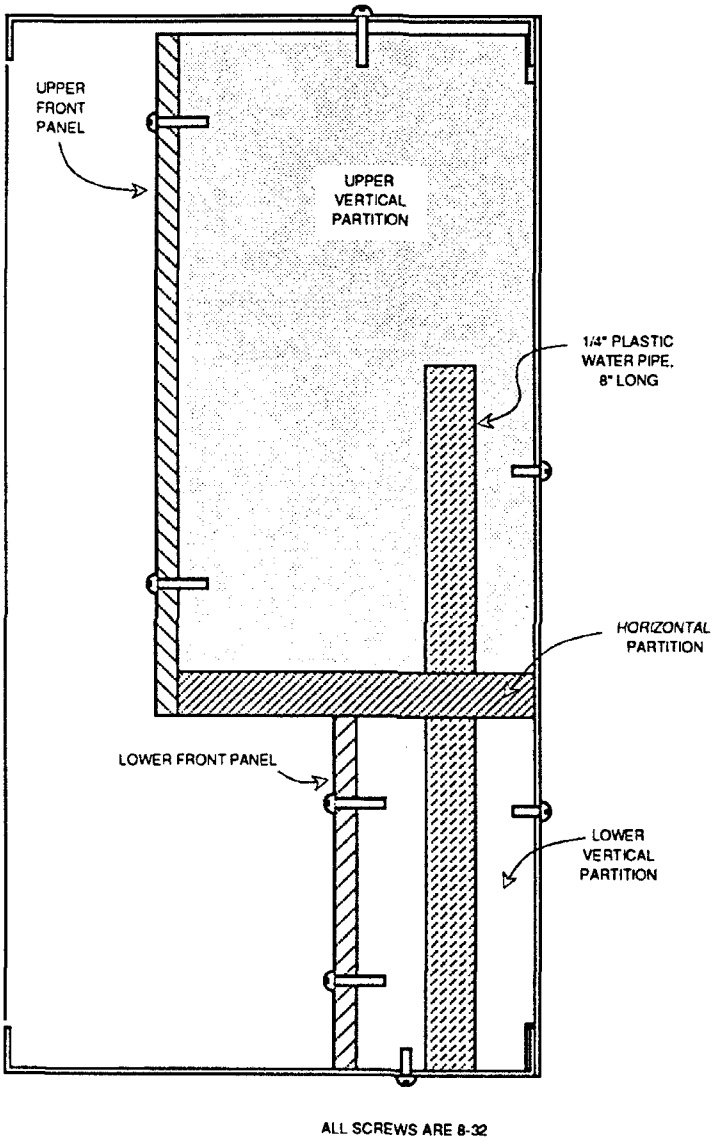


FIGURE A-9. ENCLOSURE PARTITION ASSEMBLY

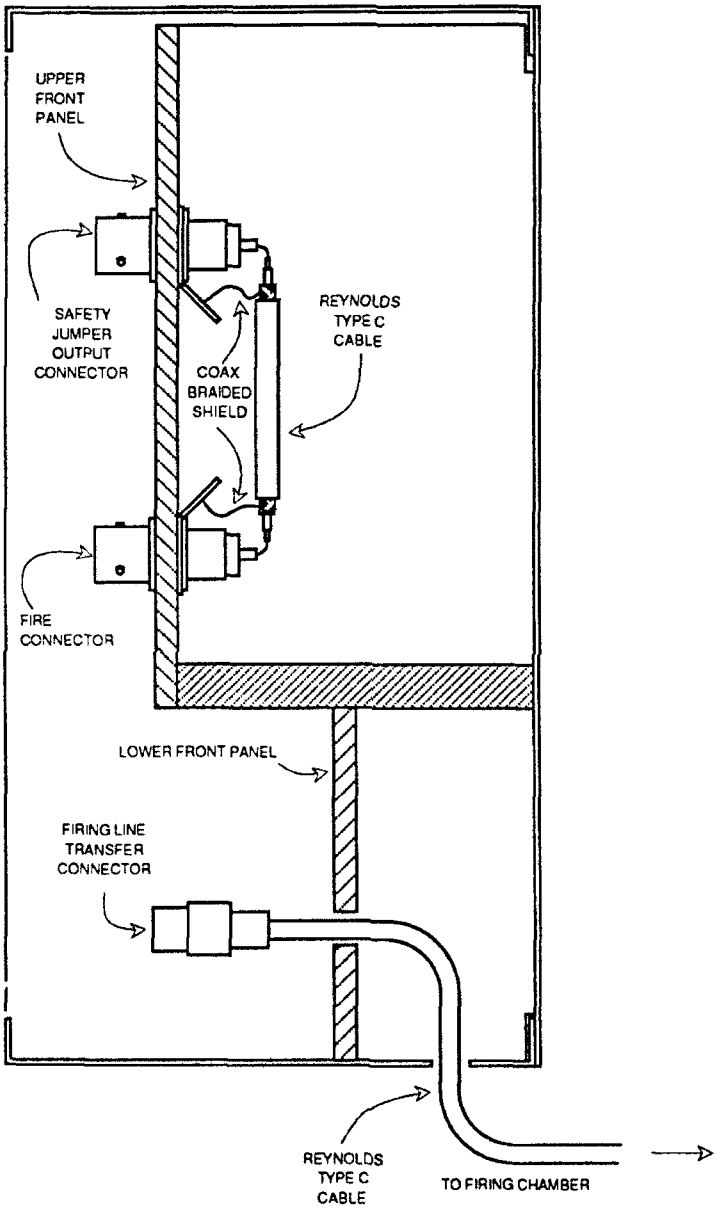


FIGURE A-10. INNER COMPARTMENT WIRING

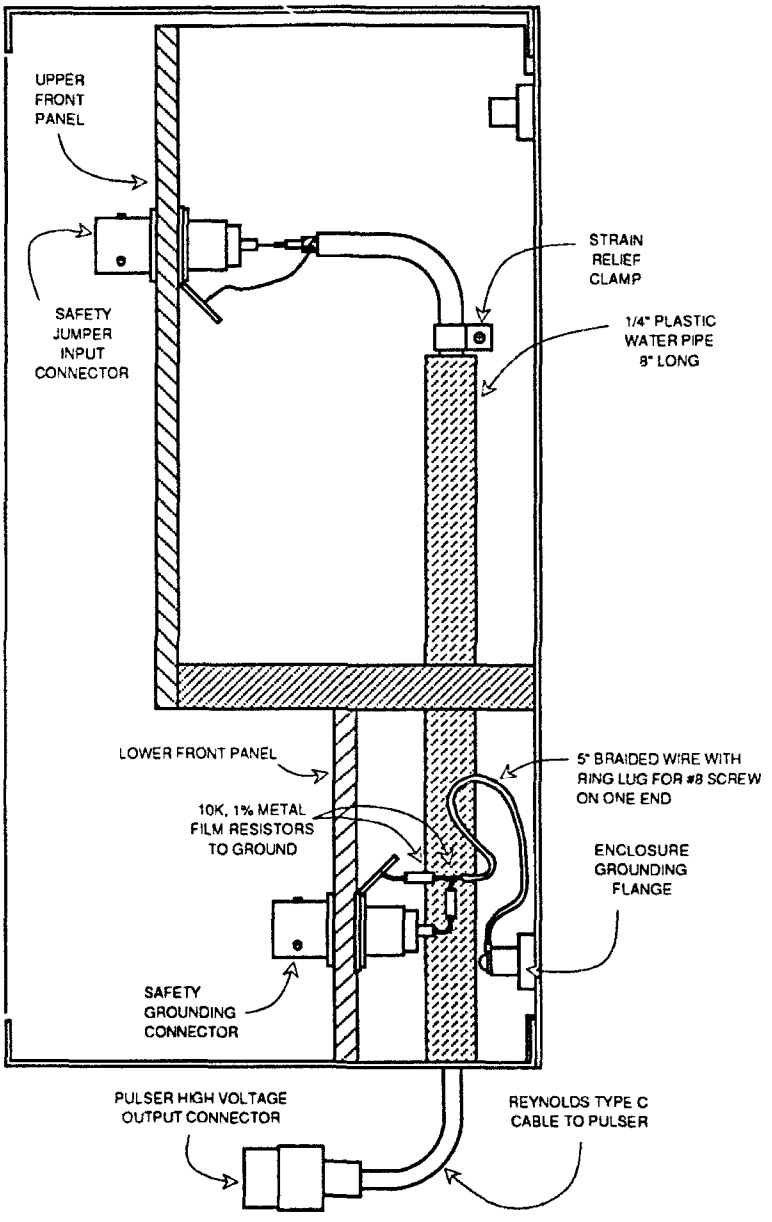


FIGURE A-11. OUTER COMPARTMENT WIRING

TABLE A-1. FIRING LINE LOCKBOX PARTS LIST

ITEM	QUANT.	REF.	PART	SOURCE
1	1	LOCKBOX	NEMA 1 ELECTRICAL ENCLOSURE	HOFFMAN A-12N126
2	1	LOCK	CYLINDRICAL LOCK KIT	HOFFMAN AL12AR
3	2	PIPE	1/4-in PLASTIC WATER PIPE, 8-in LONG	STORES
4	1	FRONT PANEL	11-1/2 x 7-3/4 x 1/4 in	1/4-in PLEXIGLAS
5	1	FRONT PANEL	11-11/16 x 4 x 1/4 in	1/4-in PLEXIGLAS
6	1	HORIZ. PART.	11-3/4 x 4 x 1/2 in	1/2-in PLEXIGLAS
7	3	VERT. PART.	7-1/4 x 4 x 1/2 in	1/2-in PLEXIGLAS
8	3	VERT. PART.	4 x 2 x 1/2 in	1/2-in PLEXIGLAS
9	2	CONNECTOR	5-kV CHASSIS	REYNOLDS 167-2827
10	2	CONNECTOR	5-kV CHASSIS	REYNOLDS 167-9028
11	2	CONNECTOR	5-kV CABLE	REYNOLDS 167-2826
12	1	CONNECTOR	5-kV CABLE	REYNOLDS 167-2829
13	2	CONNECTOR	10-kV CHASSIS	REYNOLDS 167-9029
14	2	CONNECTOR	10-kV CHASSIS	REYNOLDS 167-9028
15	2	CONNECTOR	10-kV CABLE	REYNOLDS 167-9139
16	1	CONNECTOR	10-kV CABLE	REYNOLDS 167-435
17	4	RESISTOR	10 kΩ, 1-PERCENT METAL FILM	5905-01-060-3862
18	8	SOLDER LUG	1-1/4- x 7/8- x 1/16-in COPPER	SHOP

APPENDIX B

HIGH-VOLTAGE PULSE GENERATOR MONITOR AND CONTROL

INTRODUCTION

The monitor and control instrument is designed to be connected to both the 5-kV Pulser and 10-kV Pulser and to the building Master Control Panel. The controller presents a display of the voltage stored on both pulsers and the status of the Pulser Output Relays, which are the last link in the firing-line Safety system. The monitor and control instrument provides for direct control of the Pulser Output Relays by a signal from the Master Control Panel, indicating that all conditions required by the Master Control Panel have been met. One of the usual conditions of any Master Control Panel is the use of a deadman lookout switch. This means that ultimately, after all other conditions have been met, the Pulser Output Relays are directly controlled by the deadman lookout switch operator.

The unit also allows for the remote control of the High-Voltage On/Off condition of the pulsers should such operation be desired. Remote turn-on operation would require presetting the desired operating voltage on High-Voltage Adjust control before leaving the bombproof. Remote turn-off allows the equipment operator to discharge the pulsers before reentering the bombproof.

All functions and connections on the controller panels are duplicates of those found on the pulsers. One four-conductor cable and three coaxial cables are required to connect the controller to each pulser. One coaxial cable is required to connect the controller to the Master Control Panel. Internal circuit design also provides for possible connection of the controller to a computer for automated monitor and control.

OPERATION

Figure B-1 shows the schematic for the controller, and Table B-1 is the parts list. The High-Voltage On/Off switches are parallel duplications of their counterparts. Voltage on the downstream side of the On switch is applied to transistor Q1 on the 10-kV half of the controller through resistors RI and R2 and and to Q2 through R11 and R12 on the 5-kV side. When the voltage goes on to indicate the pulser is armed, Q1 and Q2 turn on the lights in the On switches. As stated in the pulser report, the voltage level on the capacitor bank is made available as a calibrated frequency signal at 1 kV = 1 kHz. The frequency signal coming into the controller is sent to a Burr-Brown VFC42BP V/F Converter integrated circuit connected in the F/V Converter mode with a 10 kHz = 10 V function. The VFC42BP output voltage signal is then sent to a Newport 201-4 Digital Panel Meter for readout on the Front Panel. Calibration of the system is accomplished by feeding in a controlled 10.000 kHz frequency signal to the F/V Converter and trimming its output to equal 10.00 V. Calibration of the F/V Converter circuit can be done while

calibrating the pulser's V/F Converters using a DC voltage standard as outlined in Chapter 5's section on pulser calibration.

The signal required from the Master Control Panel to operate controller relays K1 and K2 is a switch closure to ground. When the Master Control signal goes to ground, relays K1 and K2 go on to provide the ground closure required to turn on the High-Voltage Output Relays in the pulsers. When the High-Voltage Output Relays go on, auxiliary switches on those relays turn on the green relay-ready lights on the controller Front Panel.

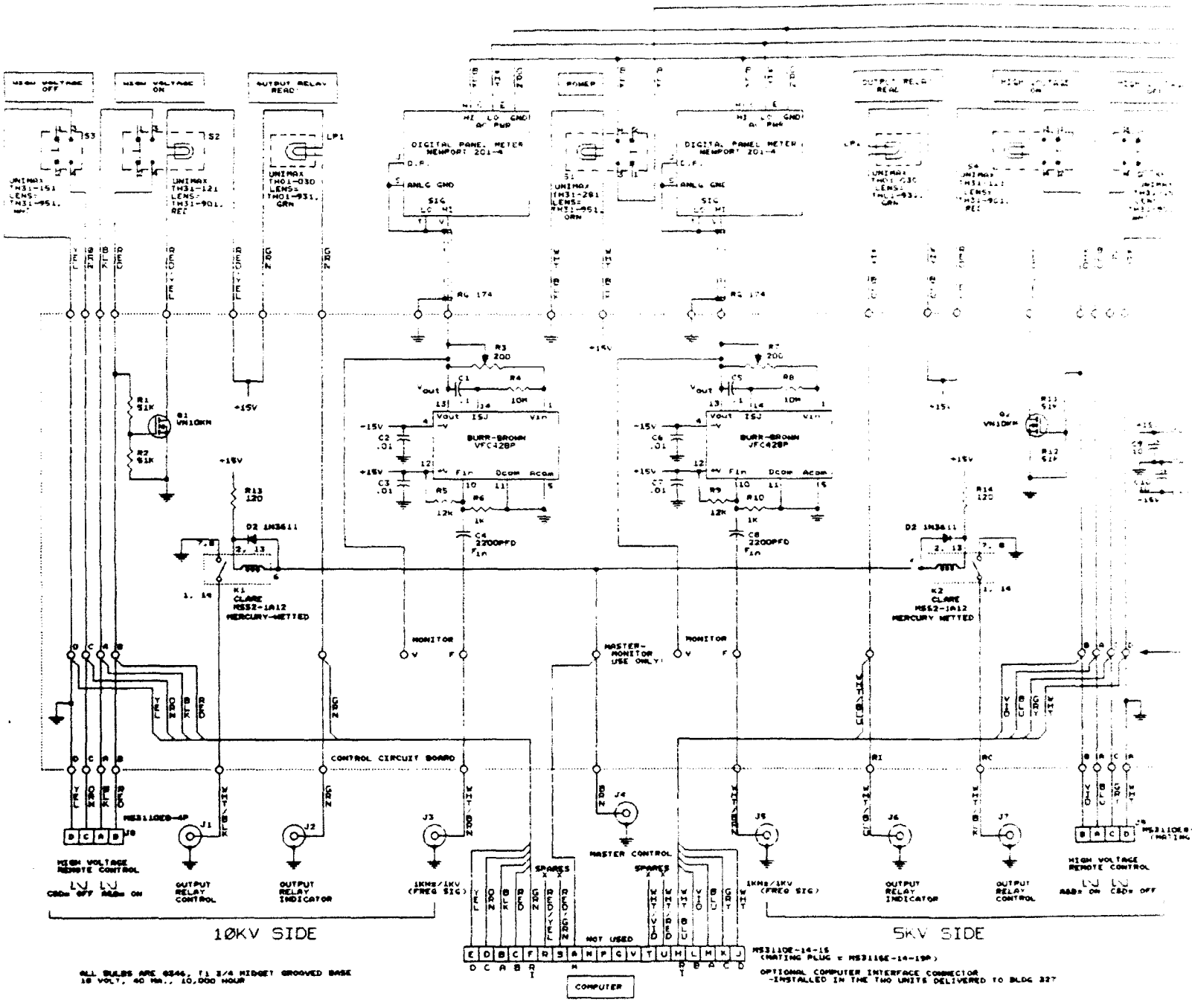
CONSTRUCTION

The instrument is housed in a Teckmar kit using their side frames, cross mounting bars, covers, and handles. The front and rear panels are made in the electronic shop from 1/8-in aluminum using the metal-photo process from artwork and cut-and-drill guides provided. Assembly of the hardware is shown in Figure B-2. First install the Digital Panel Meters in the Front Panel, then connect the side frames to the Front Panel and the cross mounting bars. Put the Back Panel in place and mark the mounting hole locations on the centerline of the top and bottom cross mounting bars. Drill and tap the bars for 6-32 screws 3/8-in deep. Mount the Back Panel with 6-32- x 3/8-in screws and lock washers.

Holes to mount the printed circuit board and power supply on the two forward mounting bars are not located on the centerlines of the bars, so place the components as follows and mark through their mounting holes. Center the printed circuit board on the two forward bars and mark the corner hole locations. Drill and tap through the bars for 6-32 screws. Mount the board with 6-32- x 1/2-in screws with a cable clamp at each corner.

Position the power supply on the forward bars as shown with the bottom mounting holes 1-3/8-in from the left side. Check for clearance between the supply, the panel meter, and the left side frame. Mark the locations on the bars and drill through holes for 8-32 screws. Mount the power supply with 8-32- x 5/8-in screws, lock washers, and nuts.

Electronic circuits are mounted on the printed circuit board with the layout shown in Figure B-3. Put all components on both front and rear panels, and wire the controller as shown in Figure B-4.



HIGH VOLTAGE PULSER MONITOR AND CONTROL

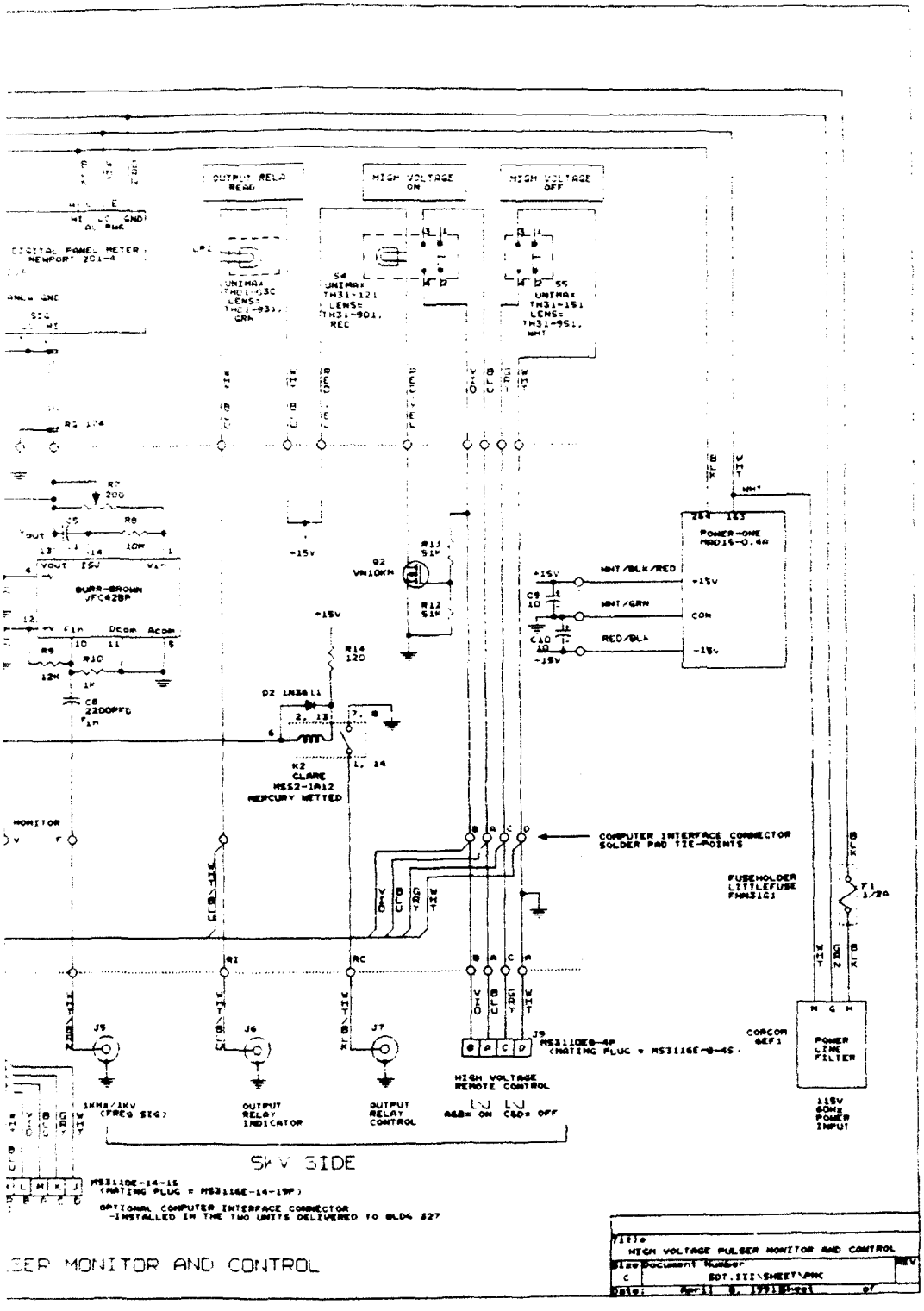


FIGURE B-1. HIGH-VOLTAGE PULSE GENERATOR MONITOR AND CONTROL SCHEMATIC

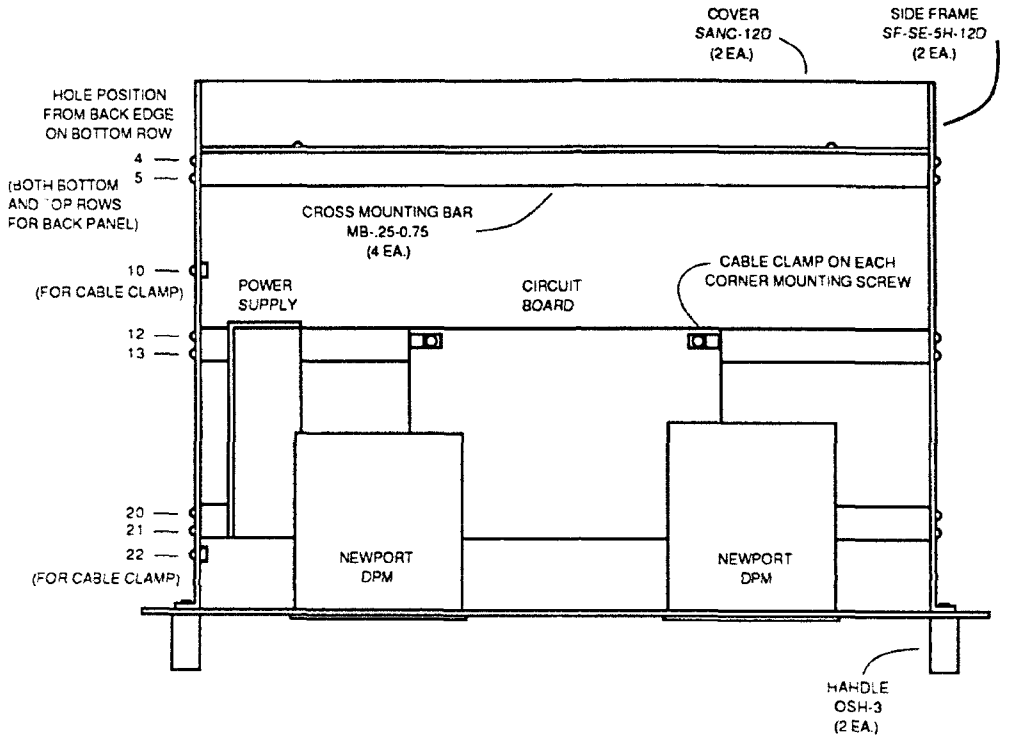
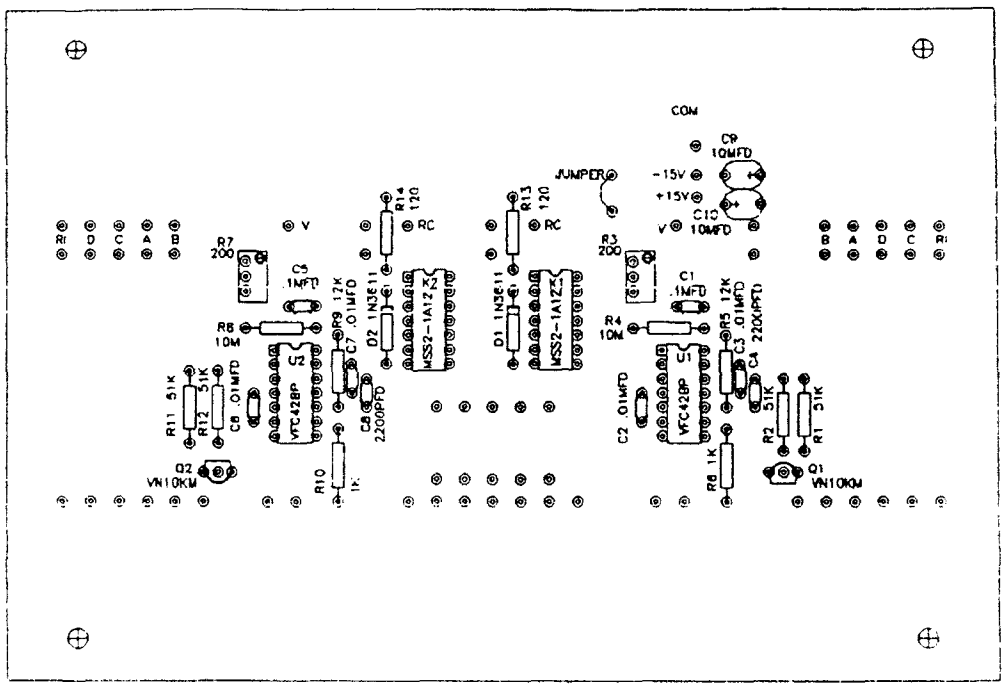
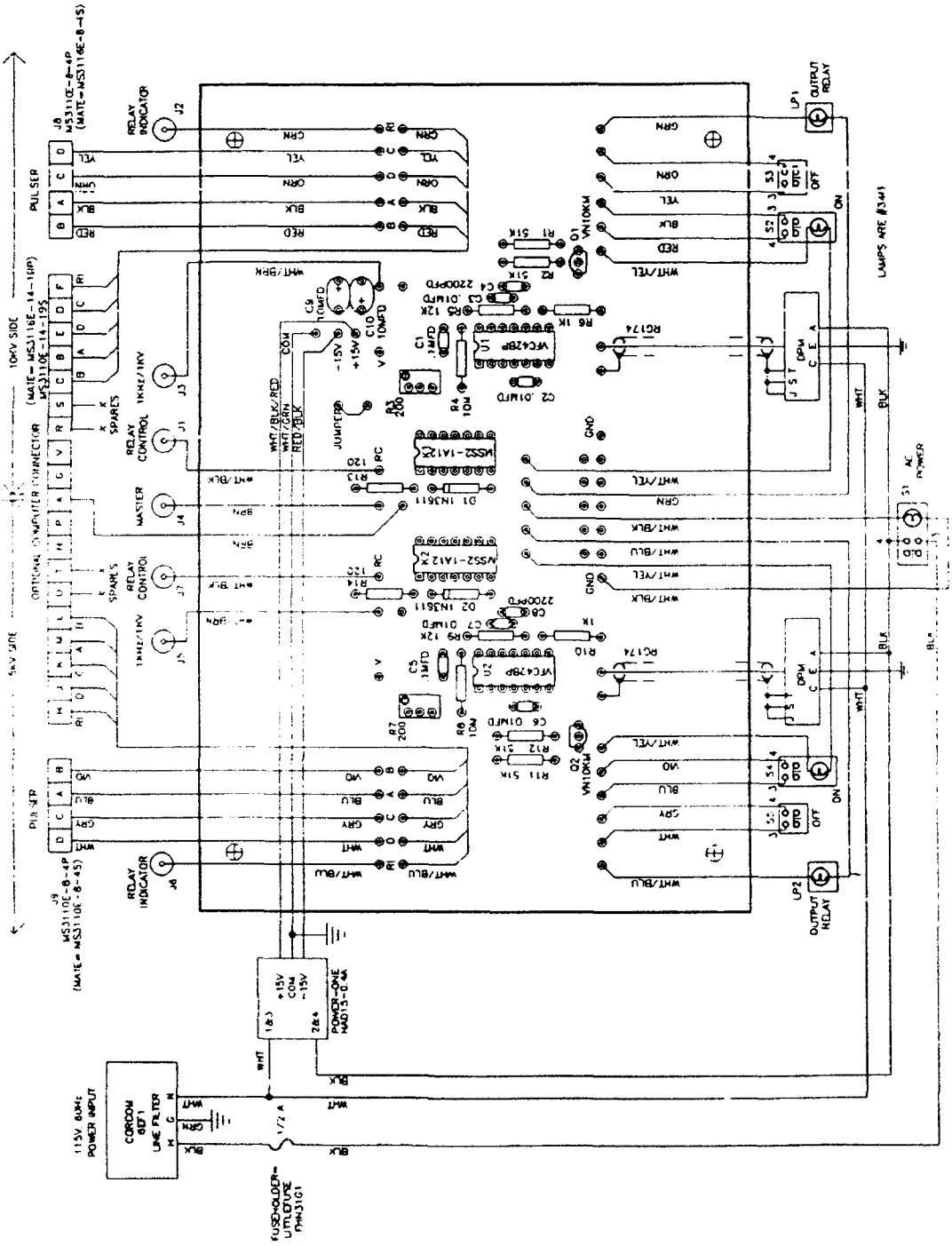


FIGURE B-2. CHASSIS MECHANICAL ASSEMBLY



PULSER MONITOR AND CONTROL COMPONENT LAYOUT

FIGURE B-3. CIRCUIT BOARD COMPONENT LAYOUT



PULSER MONITOR AND CONTROL WIRING ASSEMBLY

FIGURE B-4. CHASSIS WIRING ASSEMBLY

TABLE B-1. PULSER CONTROLLER PARTS LIST

ITEM	QUANT.	REF.	PART	SOURCE
1	2	C1, C5	0.1 μF	SERVMART, 5910-00-010-8717 (11089)
2	4	C2, C3, C6, C7	0.01 μF, 100-V CERAMIC	SERVMART, 5910-00-124-0659 (11135)
3	2	C4, C8	2200 pF	SERVMART, 5910-01-019-5107 (11055)
4	2	C9, C10	10 μF, 50 V, 10 TOL POLARIZED TANTALUM	SERVMART, 5910-LL-L07-3750 (11072)
5	2	D1, D2	1N3611 DIODE	SERVMART, 5961-00-957-6865 (11542)
6	1	F1	FUSE, 1/2 A	SERVMART, 5920-00-669-8978 (11230)
7	1		FUSEHOLDER	SERVMART, 5920-00-892-9359 (11235)
8	7	J1 - J7	COAXIAL CONNECTOR, BNC PANEL	SERVMART, 5935-00-853-7546 (03869)
9	2	J8, J9	CONNECTOR, MS3110E8-4P	SERVMART, 5935-00-817-2782 (11346)
10	1	J10 (OPTIONAL)	CONNECTOR, 19-PIN, MS3110E-14-19S	SERVMART, 5935-00-849-7189 (11352) (MATES WITH 5935-00-755-3804)
11	2	K1, K2	DIP MERCURY-WETTED RELAY	C. P. CLARE, MSS2-1A12
12	5	L1 - L5	LAMP, T 1-3/4, MIDGET GROOVED BASE, #346, 18 V, 40 mA	SERVMART
13	2	LP1, LP2	LAMP HOLDER	UNIMAX TH01-030 (GRN)
14	2	M1, M2	DIGITAL PANEL METER	NEWPORT 201-4
15	1	PLF	POWER LINE FILTER	CORCOM 6EF1, 5915-00-365-9951
16	1	PS	DUAL 15-V POWER SUPPLY	POWER-ONE HAD15-0.4A
17	2	Q1, Q2	FIELD-EFFECT TRANSISTOR	SILICONIX VN10KM, 5961-01-123-5416
18	4	R1, R2, R11, R12	51 kΩ, 1/4 W	SERVMART, 5905-00-136-3890 (03362)
19	2	R3, R7	200-Ω TRIMPOT	BOURNS 3299X-1-201
20	2	R4, R8	10 mΩ, 1/4 W	SERVMART, 5905-00-121-9919 (03339)
21	2	R5, R9	12 kΩ, 1/4 W	SERVMART, 5905-00-106-1278 (03262)
22	2	R6, R10	1 kΩ, 1/4 W	SERVMART, 5905-00-110-7620 (03282)
23	2	R13, R14	120 Ω, 1/4 W	SERVMART, 5905-00-119-8812 (03334)
24	1	S1	SW, SPDT, ALT, LIGHTED	UNIMAX TH31-281 (ORN)
25	2	S2, S4	SW, SPDT, MOM., LIGHTED	UNIMAX TH31-151 (RED)
26	2	S3, S5	SW, SPDT, MOM., UNLIGHTED	UNIMAX TH31-050 (WHT)
27	4	SCK	14-PIN DIP SOCKET	SERVMART, 5935-00-152-9571 (11303)
28	6	SS	SOCKET STRIP PINS	SAMTEC SS-120-G-2, 5935-01-150-3508
29	2	U1, U2	V/F CONVERTER, VFC42BP	BURR-BROWN CORP.
30	2		SIDE FRAME	TECHMAR SF-SE-5H-12D
31	2		COVER	TECHMAR SANC-12D
32	2		OVAL SECTION HANDLE	TECHMAR OSH-3
33	4		CROSS MOUNTING BAR	TECHMAR MB-.25-0.75

APPENDIX C

HIGH-VOLTAGE PULSER RACK ASSEMBLY

A 5-kV and a 10-kV Pulser are mounted in an AMCO Engineering Company Vertical Console No. 2241, which measures 29-9/16-inH x 22-1/16-inW x 25-1/2-inD with 21 in of Front Panel height for mounting instruments. The 5-kV Pulser goes into the top 7 in of the rack, and the 10-kV Pulser goes right below it. The bottom 7 in of panel space is covered with a blank panel having a DANGER HIGH VOLTAGE label attached. The space inside the rack underneath the 10-kV Pulser is used to hold the 10-kV high-voltage Energy-Storage Capacitors.

Figure C-1 shows the finished rack assembly. A parts list for the rack assembly is shown in Table C-1. Assembly of the rack begins with installing the casters and bottom plate. AMCO sells a bottom plate for their racks, but the 24 x 19 x 1/8-in sheet of aluminum shown in Figure C-2 can be used. First remove the 2-in cowling below the rear door and discard it. Install the four casters (CAX1) using three of the four mounting holes in each gusset as shown in Figure C-3. Next install the bottom plate on top of the caster bolt heads and use the fourth hole in each caster bracket to hold the bottom plate in place. It may be necessary to use longer bolts than those supplied with the casters to reach through from the bottom plate to the caster nut.

Move the two rear vertical channels to the 10th hole position from the back. Mount two 18-in long 1-1/2 x 1-1/2 x 1/8-in (or 3/16-in) aluminum angle support rails at 7 in and 14 in down from the top of the Front Panel opening. Set the rails 1/2-in back from the edge of the front mounting channel. An easy way to mark the location of holes to be drilled in the aluminum angle is to turn the rack over on its back, set the 5-kV Pulser in the top 7 in of panel space, hold the aluminum angle in position against the bottom of the pulser, and mark where holes line up. Install the 5-kV support rails with the rack hardware provided. Use the same procedure to mark and install the 10-kV support rails.

Attach the Door Interlock switch (Cherry E69-00A) to the switch bracket shown in Figure C-4. The interlock switch has a long overtravel (.375 in) and is mounted such that merely rattling the rear door will not cause the switch to operate. Solder 3-1/2 ft of RG58 coaxial cable, having a BNC connector at one end, onto the switch. Solder the center conductor to the switch Common terminal and the shield to the Normally-Open terminal. Mount the Door Interlock switch bracket assembly in the third and sixth holes in the top horizontal channel at the upper left corner of the rear door. Secure the cable in place with cable ties to the top horizontal channels on each side of the rack so that the cable is out of the way as it crosses from one side to the other. Install the door stop bracket if it was not installed by the manufacturer. Test the interlock switch operation while opening and closing the door. The switch should be On if the door is closed and Off when the door is open.

The Plexiglas plates shown in Figure C-5 are used when installing the high-voltage capacitors. Use nylon tiewraps to secure the two Maxwell high-voltage

capacitors to the capacitor insulating plate, and bolt the insulating plate to the bottom panel.

When the 10-kV Pulser is installed and connections to the capacitor bank are complete, install the plastic barrier plate, as shown in Figure C-1, with the Reynolds cables going to the capacitors passing over the top edge of the barrier.

After the pulser rack is installed in its place of operation, all cables to the Back Panels of the pulsers pass under the back door in the 2-in space made available by removing the cowling. Cables passing under the door can then be secured to the bottom plate with strain relief clamps by drilling and tapping the plate wherever desired.

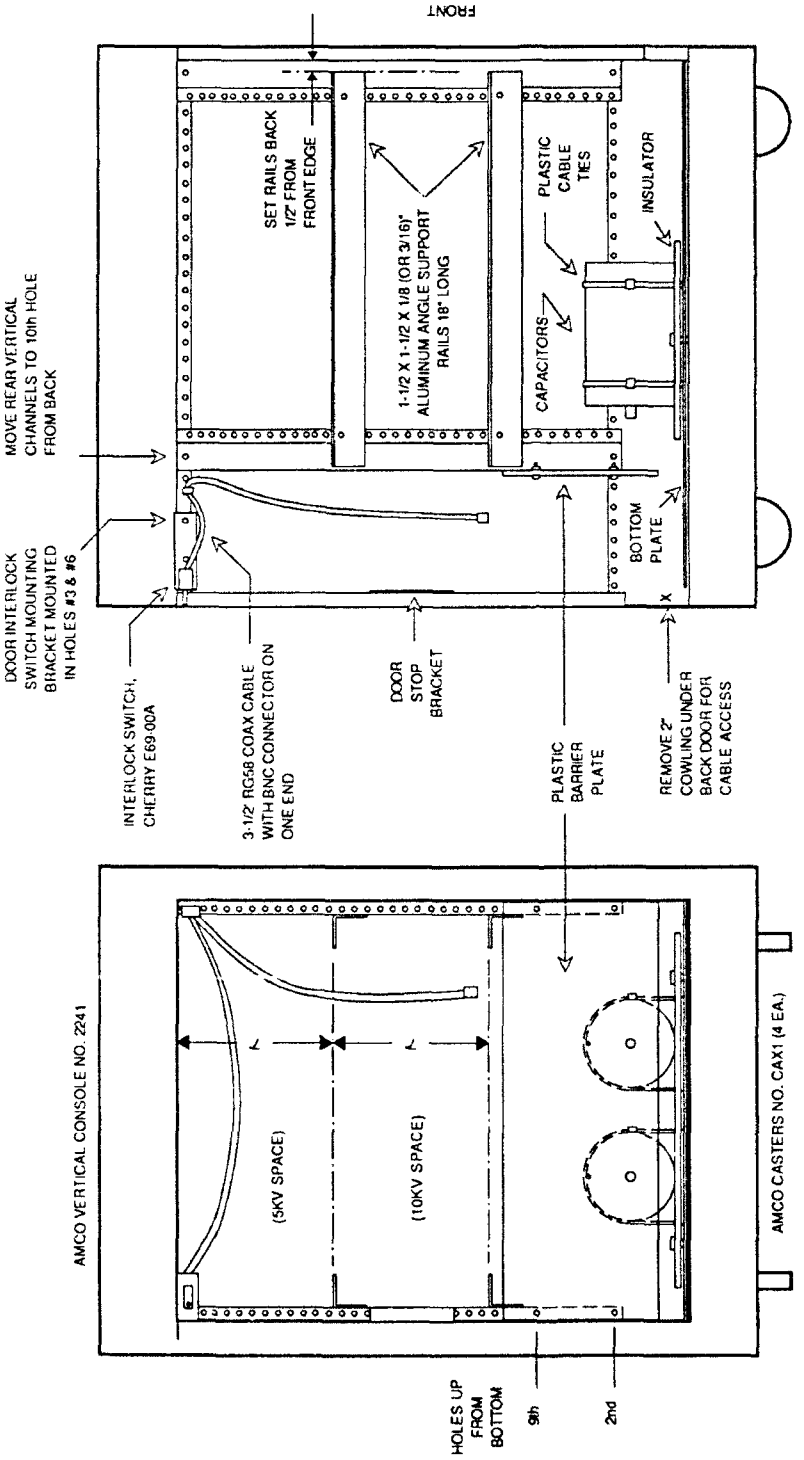


FIGURE C-1. PULSER RACK ASSEMBLY

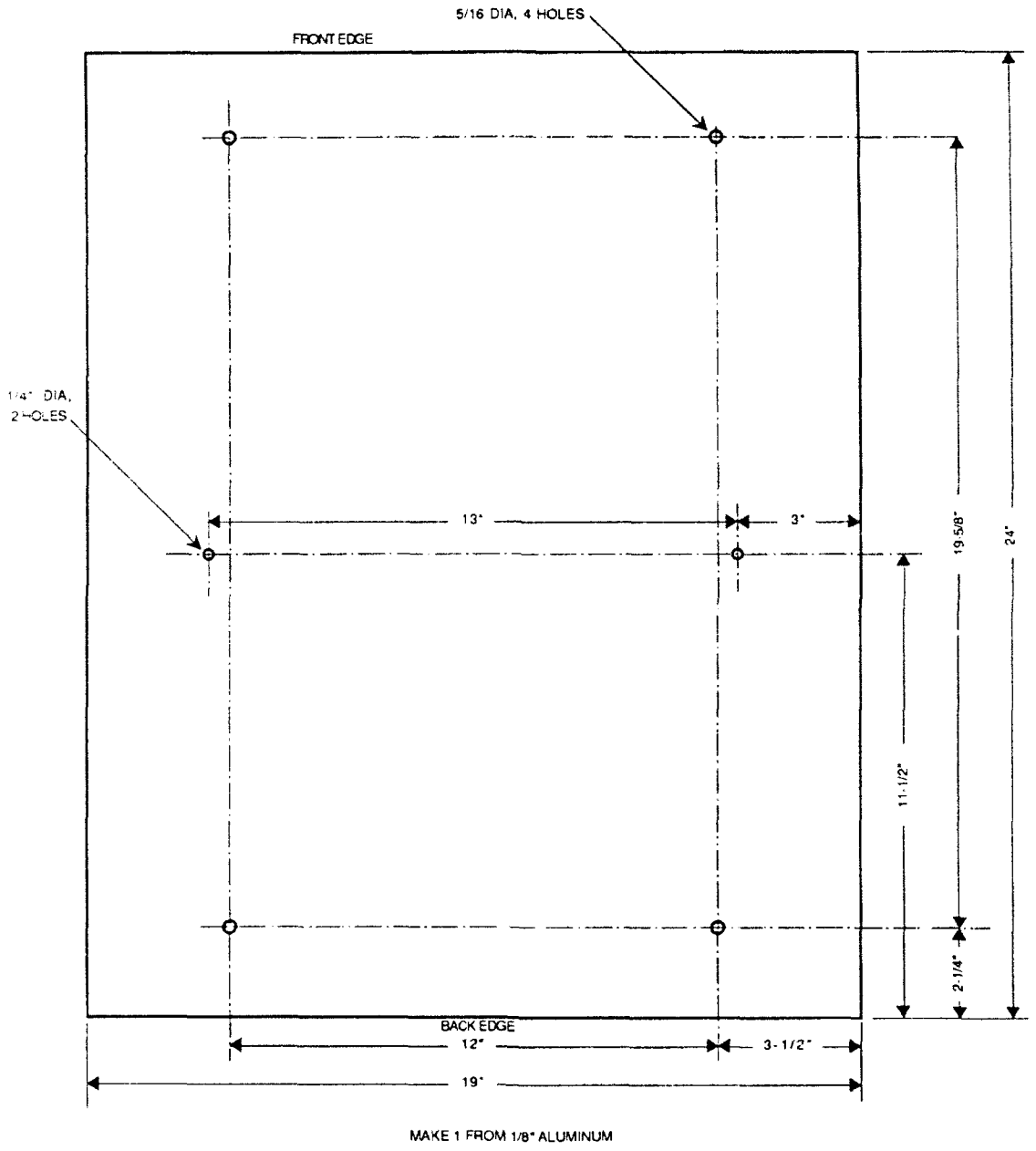


FIGURE C-2. BOTTOM PLATE CUT AND DRILL GUIDE

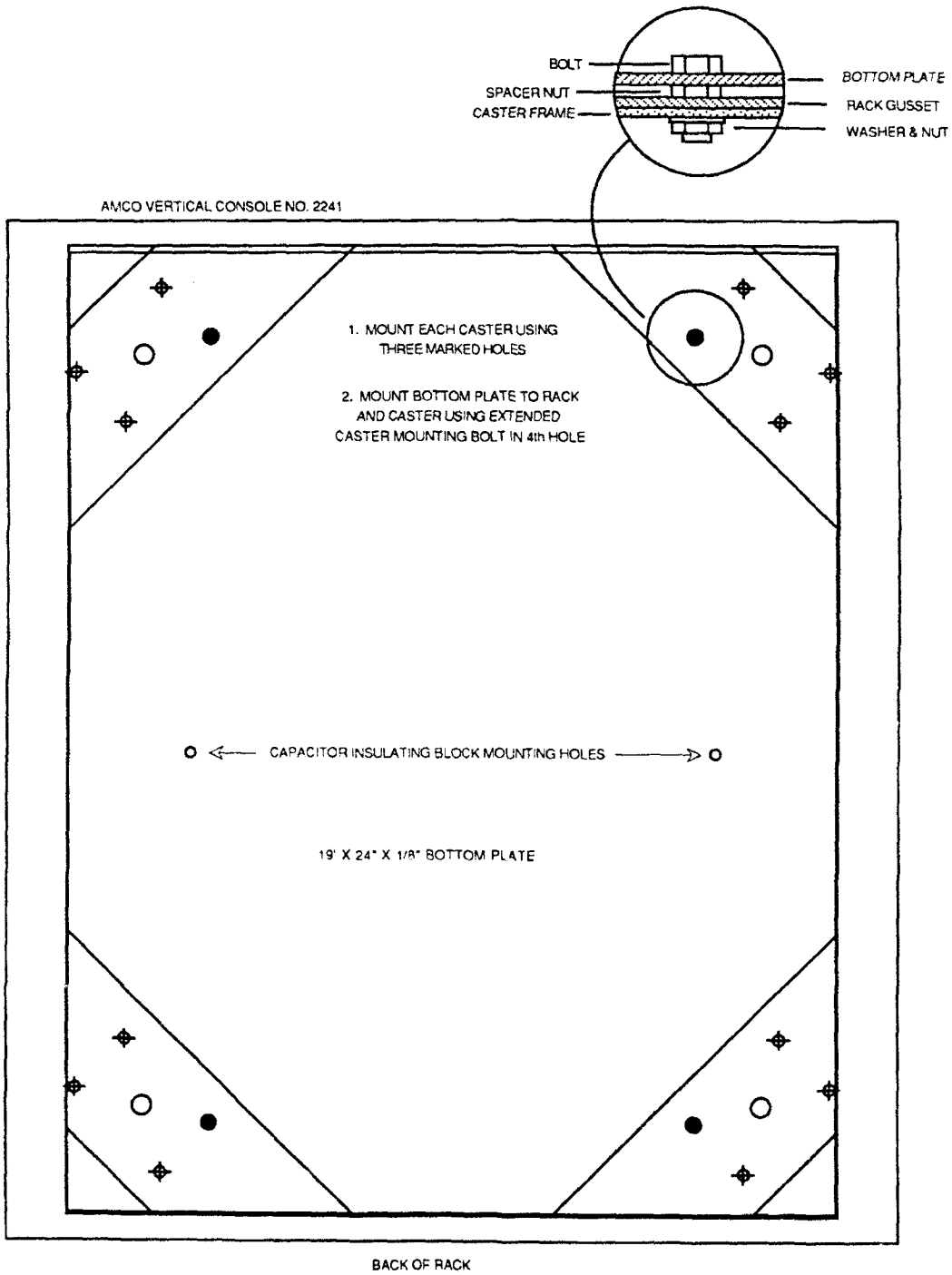


FIGURE C-3. BOTTOM PLATE INSTALLATION

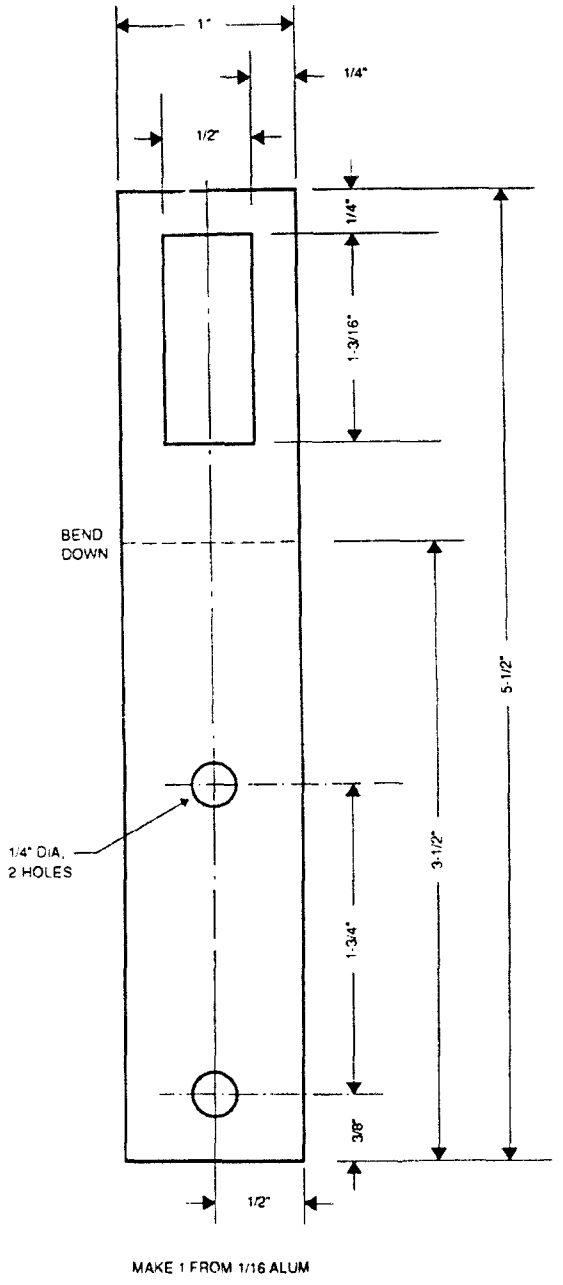
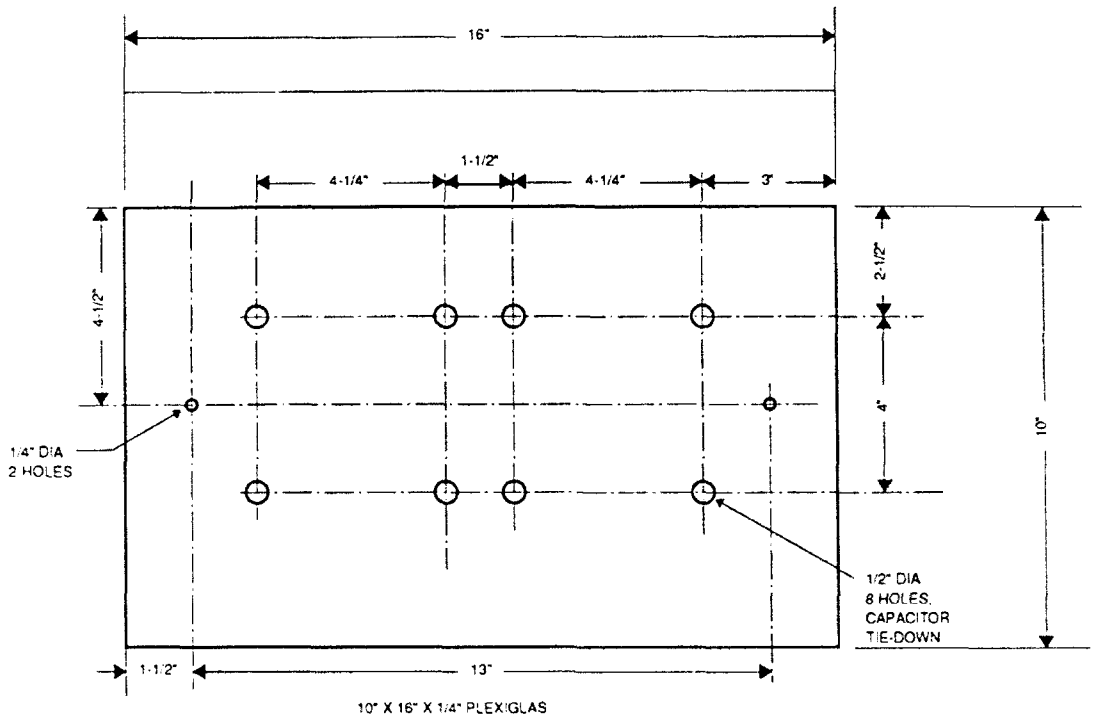
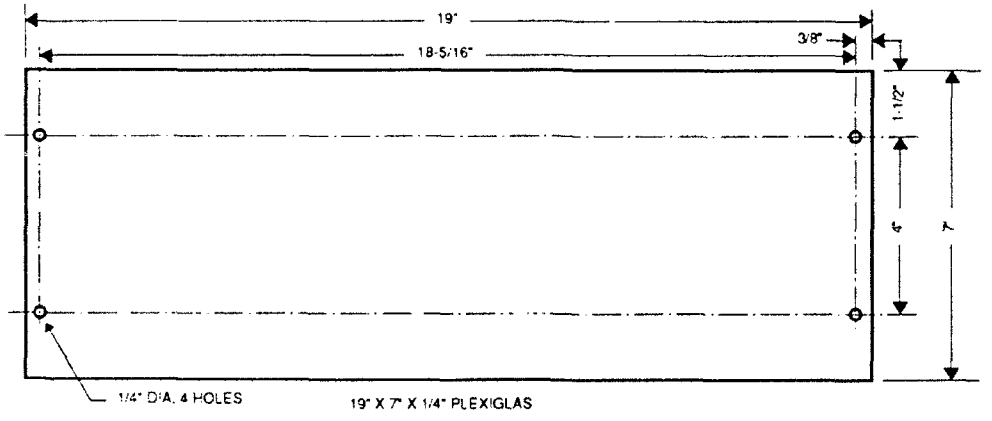


FIGURE C-4. DOOR INTERLOCK SWITCH MOUNTING BRACKET



HIGH VOLTAGE CAPACITOR INSULATING PANEL



SAFETY BARRIER PANEL

FIGURE C-5. PLEXIGLASS PANELS

TABLE C-1. HIGH-VOLTAGE PULSER RACK PARTS LIST

ITEM	QUANT.	REF.	PART	SOURCE
1	1	RACK	VERTICAL CONSOLE NO. 2241	AMCO ENGINEERING CO.
2	4	CASTER	CASTER CAX1	AMCO ENGINEERING CO.
3	1	SWITCH	E69-00A	CHERRY ELECTRIC
4	1	BRACKET	SWITCH BRACKET	SHOP
5	1	CABLE	3-1/2 ft RG58 COAX CABLE	SERVMART, 6145-00 542-6092 (04363)
6	1	CONNECTOR	BNC CONNECTOR, CABLE TYPE	SERVMART, 5935-00-828-2779 (11349)
7	4	ALUM ANGLE	1-1/2 x 1-1/2 x 1/8-in (or 3/16 in) ALUM ANGLE, 18-in LONG	SHOP
8	1	BOTTOM PLATE	24 x 19 x 1/8-in ALUM	SHOP
9	1	PANEL	10 x 13 x 1/4-in PLEXIGLAS	SHOP
10	1	PANEL	7 x 10 x 1/4-in PLEXIGLAS	SHOP
11	4	STRAP	CABLE TIE	SERVMART, 5975-00-133-8696 (11710)
12	2	CAPACITOR	25 μF, 6 kV, 450 J, no. 34034	MAXWELL LABORATORIES, INC.

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The 10-kV High-Voltage Pulse Generator is used to deliver high-energy pulses to exploding wire or flash-lamp illuminators used in high-speed photography of explosive tests. With properly rated components, the pulser is capable of an energy content of 2000 J at 10 kV. Components presently installed limit the output to 900 J at 6 kV. At this limit, the pulser delivers a peak current of 3500 A into a 1.25-Ω resistive load.

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