Instruction Manual AVTM65-100Jd

for

Impulse Generator/Cable Test System
Catalog No. 651028

High-Voltage Equipment
Read the entire manual before operating.

Aparato de Alto Voltaje
Antes de operar este producto lea este manual enteramente.

AVO INTERNATIONAL
PO Box 9007
Valley Forge, PA 19485-1007 U.S.A.
610-676-8500

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Valley Forge Corporate Center
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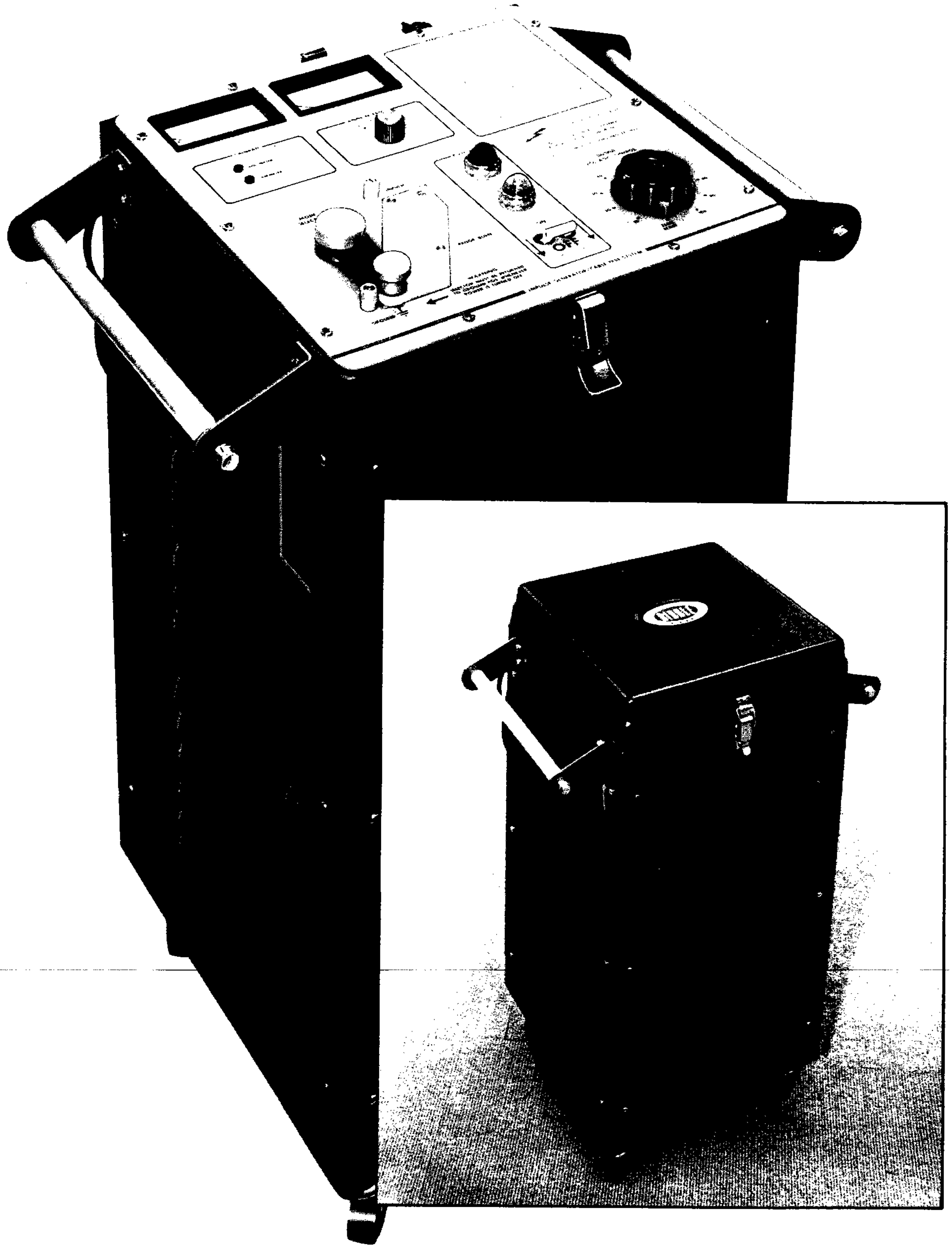

Figure 1: Cat. No. 651028 Impulse Generator/Cable Test System With and Without Cover.

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OPERATING PROCEDURE

WARNINGS

- MISUSE OF THIS HIGH VOLTAGE EQUIPMENT CAN BE EXTREMELY DANGEROUS.
- READ THE INSTRUCTION MANUAL FOR COMPLETE PROCEDURE.
- SAFETY IS THE RESPONSIBILITY OF THE OPERATOR.
- EQUIPMENT TO BE TESTED MUST BE DISCONNECTED FROM POWER.
- ALL PERSONNEL MUST BE KEPT CLEAR OF BARE LIVE PARTS.
- FOLLOW ALL OTHER SAFETY INSTRUCTIONS.

INITIAL SET-UP

- ALL EQUIPMENT MUST BE DE-ENERGIZED AND SAFETY GROUNDS MUST BE INSTALLED.
- FOR PERSONNEL SAFETY CONNECT CHASSIS GROUND AND GROUNDING PIN OF THE POWER PLUG TO A SECURE, LOW RESISTANCE GROUND.
- FOR EQUIPMENT PROTECTION CONNECT LOW VOLTAGE LEAD OF THE OUTPUT CABLE TO A SECURE, LOW RESISTANCE GROUND AND TO THE LOW VOLTAGE SIDE OF THE CABLE UNDER TEST. DO NOT EXTEND LOW VOLTAGE LEAD.
- CONNECT HIGH VOLTAGE LEAD OF OUTPUT CABLE TO HIGH VOLTAGE CONDUCTOR OF THE CABLE UNDER TEST.
- CONNECT TEST SET POWER INPUT CABLE TO A SUITABLE SERVICE.
- REMOVE SAFETY GROUNDS.

FOR PROOF/BURN MODE

- SET *MODE SELECTOR* TO *PROOF/BURN* POSITION.
- TURN *ON* THE *POWER* CIRCUIT BREAKER. *LINE ON* AMBER LAMP WILL LIGHT.
- SET *AMMETER RANGE X50* FOR BURN, OR *X1* OR *X10* FOR PROOF.
- SET *OUTPUT VOLTAGE CONTROL* KNOB FIRMLY ON *ZERO START* POSITION. *HV ON* RED LAMP WILL LIGHT.
- RAISE *OUTPUT VOLTAGE CONTROL* TO DESIRED LEVEL OF VOLTAGE OR CURRENT.
- TO END TEST, RETURN *OUTPUT VOLTAGE CONTROL* TO *ZERO.*
- TURN OFF THE *POWER* CIRCUIT BREAKER. AMBER AND RED LAMPS GO OUT.
- SET *MODE SELECTOR* TO *GROUND* POSITION. APPLY SAFETY GROUNDS.

FOR IMPULSE MODE

- SET *MODE SELECTOR* TO *IMPULSE* POSITION.
- TURN *ON* THE *POWER* CIRCUIT BREAKER. *LINE ON* AMBER LAMP WILL LIGHT.
- SET *AMMETER RANGE* TO *X50.*
- SET *OUTPUT VOLTAGE CONTROL* KNOB FIRMLY ON *ZERO START* POSITION. *HV ON* RED LAMP WILL LIGHT.
- RAISE *OUTPUT VOLTAGE CONTROL* TO DESIRED LEVEL OF VOLTAGE.
- TO END TEST, RETURN *OUTPUT VOLTAGE CONTROL* TO *ZERO* AND ALLOW ONE FINAL DISCHARGE.
- TURN OFF THE *POWER* CIRCUIT BREAKER. AMBER AND RED LAMPS GO OUT.
- SET *MODE SELECTOR* TO *GROUND* POSITION. APPLY SAFETY GROUNDS.

Figure 2: Condensed Operating Instructions.

SECTION A

INTRODUCTION

GENERAL

This test set is designed to locate cable faults by the high-voltage impulse method on cables rated up to 35 kV ac phase-to-phase. This is a combination type system because it combines the three related functions of a dc proof tester, a dc cable fault burner, and an impulse generator, all having a common power supply.

The test set is housed in a sturdy metal cabinet using welded construction throughout to withstand the rigors of operation from field vehicles. Holes are provided in the base of the cabinet to use either casters or a two wheel kit for easier transport. A folding hand truck is also available. If a permanent type installation in a van or trailer is desired, then the base skids may be utilized.

Safety, simplicity and long life are important characteristics of the set. It is easy to operate because it has a minimum number of controls and instrumentation, and requires few operator decisions. Details are described in Section D, Specifications, under Special Features.

This test set is composed of two main sections: PROOF/BURN and IMPULSE. Both of these sections are supplied with high-voltage from a self-contained high voltage power supply. In the PROOF/BURN mode the test set provides a continuous dc output which is used for the BURN operation as well as for PROOF testing. When in the IMPULSE mode, a high-voltage capacitor is periodically charged and discharged to produce a high energy pulse. This pulse is used as a traceable signal for cable fault locating.

PROOF TESTING

The PROOF test is performed to determine whether cable insulation is good or bad. The cable under test is raised to the required voltage and held there for a prescribed period of time. If the insulation can withstand this voltage, the proof condition has been meet and the cable is good. If the insulation is faulty (internal breakdown), the proof condition will not be met and additional testing will be required to locate the fault.

BURN OPERATION

The BURN operation is performed to alter the electrical characteristics of the cable fault so that it will break down within the impulse voltage range of the test set. This change is produced by burning the cable fault, so as to char the walls of the fault and reduce its internal resistance. This reduction in fault resistance means that the fault will break down at a lower voltage and will facilitate the use of a radar set or bridge to measure the distance to the fault.

IMPULSE TESTING

In the IMPULSE method of fault location, the test set repeatedly applies a high-voltage impulse to the defective cable. This impulse travels along the cable until it reaches the fault. At the fault the voltage causes a large current to pass through the return paths. The fault position along the cable length can be traced by a detector which is applied along the cable path. See Table I below for Biddle impulse detectors suitable for use.

TABLE I

BIDDLE DETECTORS

Catalog No.	Description	General Application
651103	Acoustic Detector	Direct buried cable
651113	Electromagnetic Detector	Ducted and buried cable

See Section H, Operating Procedure, for further instructions on proof testing, fault burning and impulse testing.

SECTION B

SAFETY PRECAUTIONS

MISUSE OF THIS HIGH-VOLTAGE EQUIPMENT CAN BE EXTREMELY DANGEROUS

SAFETY IS THE RESPONSIBILITY OF THE USER

The test set and the cable to which it is connected are sources of high-voltage electrical energy, and all persons performing or assisting in the tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. Persons actually engaged in the test must stand clear (by at least 3 feet) of all parts of the complete high-voltage circuit unless the test set is deenergized and all parts of the test circuit are grounded. Any persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades or warnings.

Users of high-voltage equipment should note that high-voltage discharges and other sources of strong electric or magnetic field may interfere with the proper functioning of heart pacemakers. Personnel using heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.

High-voltage electrical impulses and resultant current pulses create special safety problems as a large, rapidly changing current, even across small values of impedance, can generate high-voltage levels. The test set design provides two separate and distinct grounds: the apparatus chassis ground, and the surge ground. The chassis ground, which must be connected to a good local ground, is designed to protect the operator by preventing a difference of potential between the chassis and the ground in the immediate vicinity. The surge ground is designed to return the impulse current back to the capacitor. The low voltage lead of the output cable must not be extended, as this introduces excessive impedance in the return path.

On completion of a test, even after power has been removed from the test set, energy can still be stored in the impulse capacitor and cable. For this reason, both automatic grounding and manual grounding features are included in this equipment. These means will quickly reduce such stored energy to a safe low level, with the discharged condition being indicated by the kilovoltmeter. Immediately after use, the MODE SELECTOR switch should be returned to the GROUND position which places a low resistance circuit on the output cable and the power supply. The impulse capacitor is shorted automatically by the discharge resistor when not in use.

NEVER CONNECT THE TEST SET TO ENERGIZED EQUIPMENT OR USE THE TEST SET IN AN EXPLOSIVE ATMOSPHERE!

It is imperative not to operate the test set in the IMPULSE mode with either the side covers or the top panel removed. The energy storage.type capacitors used in this equipment have exhibited bushing failure; they can shatter and send pieces of porcelain, hardware, etc., in all directions at high velocity. The covers in place will prevent injury to personnel if this type of failure should occur.

If the test set is operated in accordance with the safety precautions noted above and in Section G, and if all grounds are correctly made, rubber gloves are not necessary. As a routine safety procedure, however, some users require that rubber gloves be worn, not only when making connections to the high-voltage terminals but also when manipulating controls. Biddle Instruments considers this an excellent safety practice.

Biddle Instruments recommends that a qualified operator be in attendance at all times while the test set is in operation.

SECTION C

RECEIVING INSTRUCTIONS

When your Biddle instrument arrives, check the equipment received to ensure that all materials are present. Notify Biddle Instruments, 510 Township Line Road, Blue Bell, PA 19422 of any shortage of materials.

Examine the instrument for damage received in transit. If any damage is observed, file a claim with the carrier at once and notify Biddle Instruments, or its nearest authorized sales representative, giving a detailed description of the damages observed.

This instrument has been thoroughly tested and inspected to meet rigid inspection specifications before being shipped. It is ready for use when set up as indicated in Section G.

SECTION D

SPECIFICATIONS

Power Input 120 Vac at 50 or 60 Hz Standard (must be specified)

Recommended source:	NEC 15 Ampere 120V single phase.
Recommended ground:	Solid metallic with a resistance of less than 5 ohms.
Voltage (rms):	120V: Nominal rating, 102 to 132V: Operating range.
Current maximum (rms):	9 Amperes continuous on BURN mode. 9 Amperes pulsing in IMPULSE mode.

Optional Power Input, 220 or 240V at 50 or 60 Hz (must be specified.)

Recommended source:	NEC 15 Ampere 240V single phase.
Recommended ground:	Solid metallic with a resistance of less than 5 ohms.
Voltage (rms):	240V full rating, 204 to 264V operating range or 220V full rating, 198V to 242V operating range.
Current maximum (rms):	5 Amperes continuous in BURN mode. 5 Amperes pulsing in IMPULSE mode.

Output

Impulse Mode

Peak Voltage:	25 kV maximum, continuously variable 0 to 25 kV.
Capacitance:	4 μF.
Stored Energy:	1250 Joules (watt-secs) at 25 kV (maximum).
Peak Current:	Approximately 16 kA (50 ft. output cable short-circuited).
Time for Voltage Pulse to decay to 5%:	150 microseconds (50 ft. output short-circuited).

Negative with respect to ground.

Fixed. 6 seconds for 60 Hz;
7.2 seconds for 50 Hz.

Less than 10 seconds to 1% of starting value (4 μF).

Less than 10 seconds to 1% of starting value for a test cable capacitance of 4 μF (time porportional to load capacitance).

30 kV maximum, continuously variable 0 to 30 kV.

Negative with respect to ground.

Time: 5 kV per second initial rate for 4 μF test cable.

Less than 10 seconds to 1% of starting value for a test cable capacitance of 4 μF. Time proportional to load capacitance.

50 mA continuous 50 or 60 Hz into short circuit.

stocked: 120V 50 Hz
220V 60 Hz
220V 50 Hz
240V 60 Hz
240V 50 Hz

~~ths on special order.~~

ked:

402 - Folding 2-wheel hand truck for portable use.
403 - Kit of 4 casters for station use.
404 - Kit of 2 - 10" semi-pneumatic wheels and leveling feet for field terrain.

Polarity:	Negative with respect to ground.
Impulse Timing:	Fixed. 6 seconds for 60 Hz; 7.2 seconds for 50 Hz.
Internal Energy Discharge Time:	Less than 10 seconds to 1% of starting value (4 μF).
Test Energy Discharge Time:	Less than 10 seconds to 1% of starting value for a test cable capacitance of 4 μF (time porportional to load capacitance).

Proof/Burn Mode:

Peak Voltage:	30 kV maximum, continuously variable 0 to 30 kV.
Polarity:	Negative with respect to ground.
Voltage Build-Up Time:	5 kV per second initial rate for 4 μF test cable.
Discharge Time:	Less than 10 seconds to 1% of starting value for a test cable capacitance of 4 μF. Time proportional to load capacitance.
Peak Current:	50 mA continuous 50 or 60 Hz into short circuit.

Available Options

Input Power, not stocked: 120V 50 Hz
220V 60 Hz
220V 50 Hz
240V 60 Hz
240V 50 Hz

Longer cable lengths on special order.

Accessories, stocked:

Cat. No. 650402 - Folding 2-wheel hand truck for portable use.
Cat. No. 650403 - Kit of 4 casters for station use.
Cat. No. 650404 - Kit of 2 - 10" semi-pneumatic wheels and leveling feet for field terrain.

CABLES FURNISHED (Standard)

One 50 ft. permanently connected shielded common HV output connecting cable consisting of coaxial high voltage and return leads with quick-release clamps. Unneeded length may remain coiled on cleats during use. Longer lengths on special order.

One 25 ft. 3-wire input cord with standard cap.
(NEMA 5-15P) 120V
(NEMA 6-15P) 240V

One 25 ft. No. 8 AWG grounding cable with clamp.

CONTROLS AND INDICATORS (See Figure 3)

Output MODE SELECTOR for selection of PROOF/BURN, IMPULSE or GROUND.

OUTPUT VOLTAGE CONTROL for continuous adjustment of output voltage.

POWER main circuit breaker to turn power ON and OFF.

LINE ON lamp to indicate the input is energized.

HV ON lamp to indicate high-voltage output is energized.

Viewing Window to show location and condition of the internal grounding arms (on left side, not shown in Figure 3).

Kilovoltmeter, 1 range, to indicate output voltage level.

Milliammeter, 3 ranges, to indicate output current level.

AMMETER RANGE switch to select appropriate range.

METERING

DC Kilovolts:	0 to 30 kV, PROOF/BURN mode. 0 to 25 kV, IMPULSE mode. 3 1/2" Taut Band ±2% Full Scale accuracy.
DC Milliamperes:	0 to 1, 10 mA, PROOF/BURN mode. 0 to 50 mA, IMPULSE mode. 3 1/2" Taut Band ±2% Full Scale accuracy.

NOTE: 1 and 10 mA range, average indicating; 50 mA range, rms indicating. Meter indicates charging current to capacitor in IMPULSE MODE.

SAFETY FEATURES

The output connecting cable and impulse capacitor are isolated from the chassis to eliminate the possibility of transient voltages developing between the chassis and the local earth when impulsing. This reduces the possibility of current flow in other spurious paths and reduces the possibility of damage to other equipment.

ZERO START interlock prevents energizing output at elevated voltages and insures that the output will always start from zero voltage.

Separate chassis grounding cable and the input power cable provide redundant grounding circuits.

Automatic resistance grounding of the power supply output, the impulse capacitor and the load on shutdown, eliminates a hazardous manual operation.

A manual grounding by means of the MODE SELECTOR provides a safe and convenient backup and/or override of automatic grounding.

Input circuit breakers provide overload protection on the input power circuits.

The metering circuits are of passive design for reliability.

An external interlock enables remote control of input power.

OPERATING FEATURES

A single shielded permanently connected common output cable consisting of coaxial high-voltage and return leads for all modes of operation, an internal switch eliminates any need to manually interchange high voltage connections between functions.

The milliammeter becomes a charge meter during impulsing to read the charging current as an indication of the fault condition.

An enclosed solid contact impulse switch with an opaque body assures quiet, flashless and dependable operation from 0 to 25 kV.

Negative output polarity conforms to U. S. standard practice.

Special extra flexible shielded output cable (specially terminated) for long service life and convenience.

Large removable hanger mounted on the rear of the test set for storage of accessory cable may be relocated on wall of van for greater convenience.

The common coaxial high-voltage output and return output cable design allows any unused cable to remain coiled on hanger, thus eliminating need to uncoil the entire length of separate leads on the ground as with other makes.

A modular control panel provides ease of operation and accessibility for service.

Condensed operating instructions are permanently printed on the Control Panel for ease of reference.

Automatic resistance discharge provides for quick and safe charge dissipation of both the impulse capacitor and the load upon shutdown, so as to protect the cable under test from undesirable transients.

Instrument design adapts to station use, to installation in van or trailer, or portable service with optional transport accessories.

Instrument design permits power to be supplied from either a system line service or from a portable engine-generator, 1.5 kVA contractor type (capable of starting heavy loads) rated for the appropriate voltage and frequency.

PHYSICAL CHARACTERISTICS

Dimensions:	16" square x 30" high (41 cm square x 76 cm). 38" high (96 cm) with semi-pneumatic wheel kit.
Weight:	195 pounds (88 kg).
Temperature, Operating:	14°F (-10°C) to 113°F (45°C), continuous duty.
Storage:	-22°F (-30°C) to 131°F (55°C).
Altitude:	7,500 feet (2286 m) maximum. Derate voltage at higher altitudes.
Humidity:	Operation and storage limits 5 to 95 R.H. non-condensing conditions.
Climate:	Operation prohibited in rain or snow.

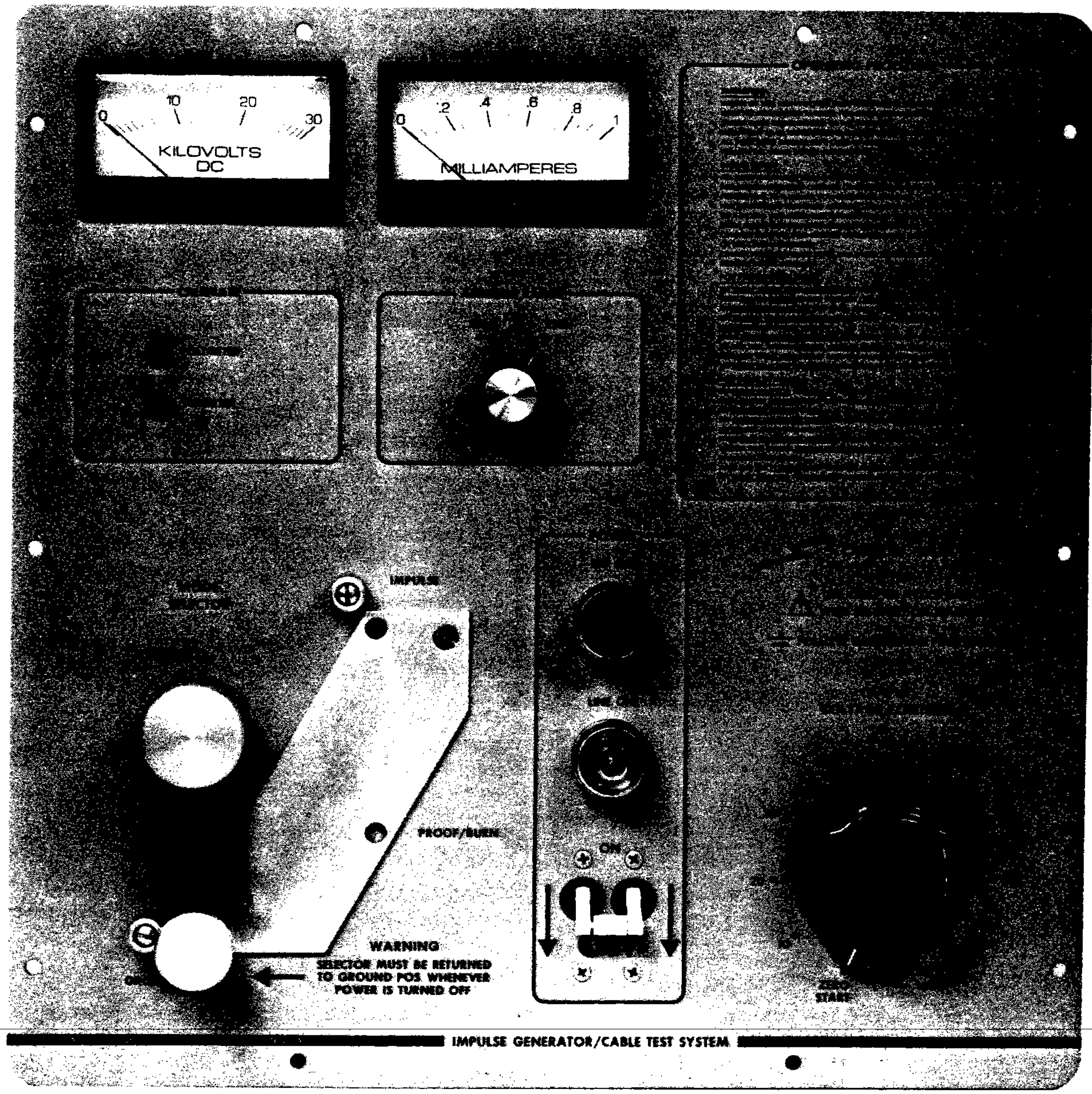


Figure 3: Control Panel

SECTION E

CIRCUIT DESCRIPTION

GENERAL

The Catalog No. 651028 Impulse Generator/Cable Test System has been designed as a modular unit for ease of serviceablility. It is divided into four major subunits or assemblies. The following is a functional description of each of these major assemblies. The sequence of each description duplicates the power flow from input to output. Also see the Schematic Diagram, Figure 4, page E4.

CONTROL PANEL ASSEMBLY, No. 19925 (includes Measuring Circuit Assembly No. 19470).

This assembly is the most complex part of the instrument and contains nearly all of the control components. Main power is brought in via the cable W1 which is fitted with a standard NEMA connector according to the nameplate rating of that test set. For voltages other than 120 Vac, an input buck-boost autotransformer is used. This is located internally. Notice that, although there is a white and black wire identification made in the test set, either of these wires may be elevated above the neutral. Thus, the test set will work from phase-to-neutral or phase-to-phase mains. Also notice that the ground wire (green wire) is connected internally to the chassis. A redundant ground connection is made to the chassis by means of a wing nut and a ground cable W2 in order to provide for safer operation.

The input power is brought directly to the POWER switch CB1 which is a 2-pole, 9-ampere circuit breaker. Notice that both input wires are interrupted and have overcurrent protection. The purpose of this circuit arrangement is to allow for connection to other than the USA standard sources. Immediately on the load side of the circuit breakers are MOV surge arresters RV1 and RV2 which are provided for transient suppression, both that coming into the test set and being generated within the test set and that radiating back through the power line. Relay K1 serves as a contactor for the test set to control the main power to the output circuit as well as to the control circuits. The relay contacts K1A feed the Variable Autotransformer T1 (OUTPUT VOLTAGE CONTROL), while contacts K1B provides the zero-start circuitry and the various means of interlocking the mode selecting operations.

The interlock circuitry of K1 forces a selection of one or the other of the two operating modes. The interlock circuitry is also brought out to provide means for connection to an external interlock. A conventional ZERO START circuit is used, which forces the OUTPUT VOLTAGE CONTROL to be turned to its most counterclockwise condition before the test set can be energized. This prevents a start-up with output voltage present. Switches SW1C and SW1D are controlled by the positioning of the MODE SELECTOR, where SW1D is closed in the PROOF/BURN position, and both switches are closed in the IMPULSE position. It is necessary that the AMMETER RANGE switch be in the X50 position to enable operation in the IMPULSE position. Note that a low voltage transformer is used to provide reduced voltage to operate the signal lamps, which are nominal 14 volts rating, and more readily available. The Kilovoltmeter and Milliammeter mounted on this panel have identical movements and are of a ruggedized taut band type. The related calibration, shunting, protection and switching circuits (Assembly 19470) are also mounted on this panel.

CURRENT LIMITING CHOKE L1, Nos. 19690-1 (60 Hz) or 19690-2 (50 Hz)

This current limiting or ballast choke limits the amount of current that can be drawn from the line and provides the impedance necessary to allow the unit to operate under short circuit output conditions without tripping the circuit breaker. The choke also provides the impedance necessary to limit the current when the power supply is charging the Impulse Capacitor C4.

HIGH VOLTAGE POWER SUPPLY ASSEMBLY NO. 19967

The voltage applied to the primary circuit of T2 is stepped up, then rectified by the half-wave voltage doubler circuit consisting of the Coupling Capacitor C1, the Rectifier Assembly No. 19941, and the Output Capacitor C2. Resistors R2 and R3 form a voltmeter divider that feeds M1 and measures the voltage present on C2.

The high voltage output from C2 passes through the peak current limiting resistor R1 to the pole of the MODE SELECTOR switch SW1.

MODE SELECTOR ASSEMBLY NO. 19955

The MODE SELECTOR permits the use of a single output cable and eliminates the need for reconnecting when changing from PROOF/BURN to IMPULSE or GROUND. The MODE SELECTOR is a large high-voltage switch which consists of two moveable arms and three sets of fixed contacts. In the PROOF/BURN mode, this switch connects the HV power Supply directly to the Output Cable W3. In the IMPULSE mode one arm of this switch connects the HV Power Supply to the Impulse Capacitor C4, thus providing the charge path for C4. The other arm of this switch connects the Impulse Capacitor to the Output Cable via the Impulse Switch SW4.

When the Impulse switch is closed, it completes the discharge path for the Impulse Capacitor. In the GROUND mode, the MODE SELECTOR connects both the HV Power Supply and the Output Cable to ground. A viewing window is located so that these grounding connections can be easily seen. In PROOF/BURN and IMPULSE modes, a cam on the MODE SELECTOR shaft will close a corresponding interlock switch. It should be noted that moving the MODE SELECTOR while in the high-voltage positions will automatically cause the test set to trip out and discharge both the internal Impulse Capacitor C4 and the Output Cable W3 and the load. **CAUTION! This is not the recommended method for removing high voltage and may cause damage to the cable under test.**

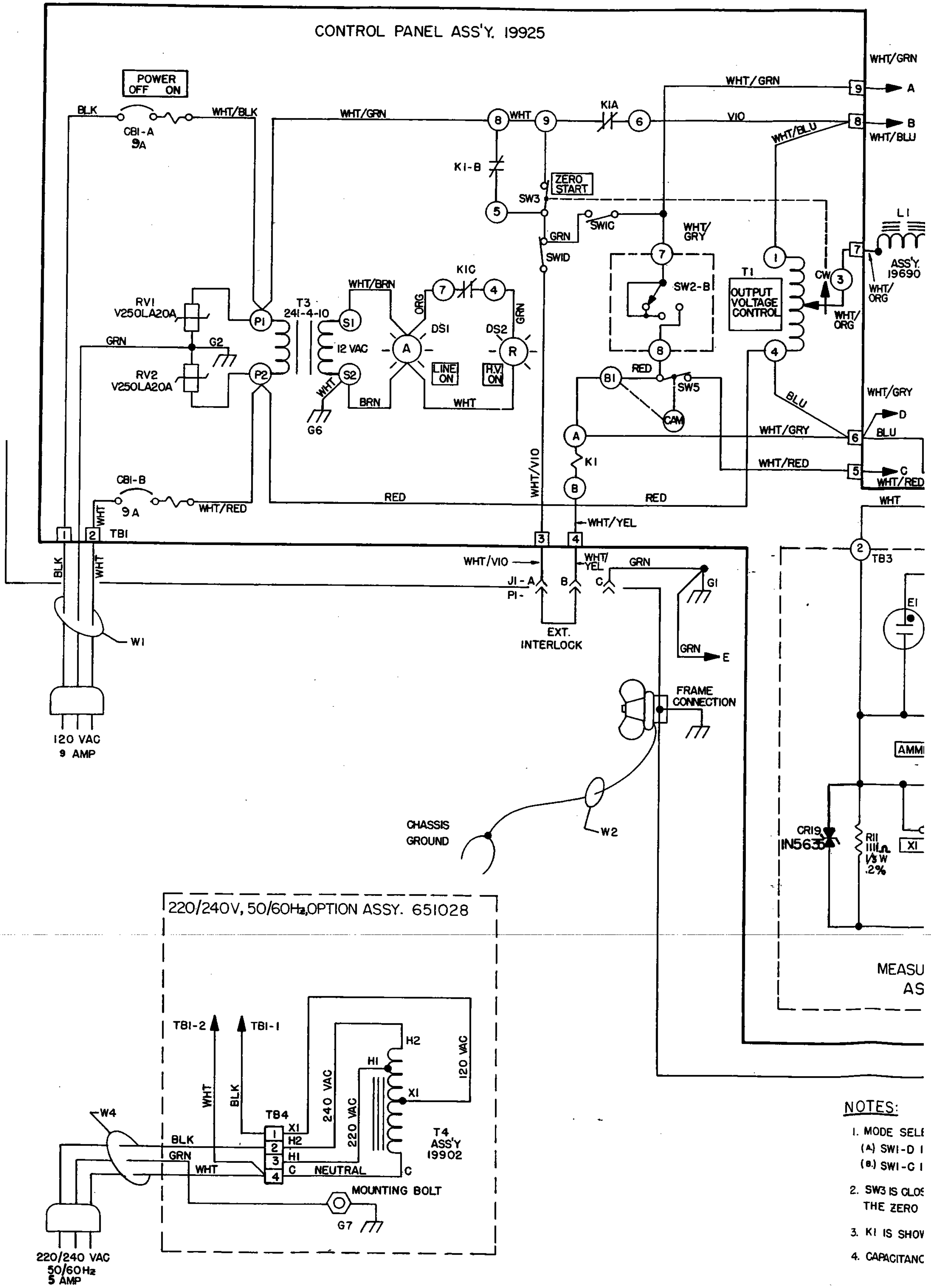
IMPULSE CAPACITOR C4, NO. 19264-1

The Impulse Capacitor C4 is a single capacitor located at the bottom of the main assembly and is rated at 4 microfarad, 25 kV. The operating life of this capacitor is 350,000 impulses at full rating. However, if the capacitor is operated at 30,000 volts the number of impulses is reduced to 75,000, thus it is necessary to control any use of the capacitor at overvoltage. Note that this capacitor is insulated by means of air and solid insulation from the chassis ground and the only surge ground components are the case of this capacitor and the shield of the output cable.

IMPULSE AND DISCHARGE PANEL ASSEMBLY NO. 19966

This panel contains the Impulse Switch SW4 No. 19864 and the Discharge Assembly No. 19966. The Impulse Switch is solenoid operated, having an ohmic double-make contact so that the Impulse Capacitor may be discharged down to voltages of less than 500 volts. This is sometimes useful in low voltage circuit testing.

The Discharge Assembly is composed of two resistors of approximately 390K ohms and of 1500 joules energy absorbing capability. Two gravity-drop, solenoid-operated switches complete the device. This assembly provides a fail-safe discharge for the external load and the internal capacitor.



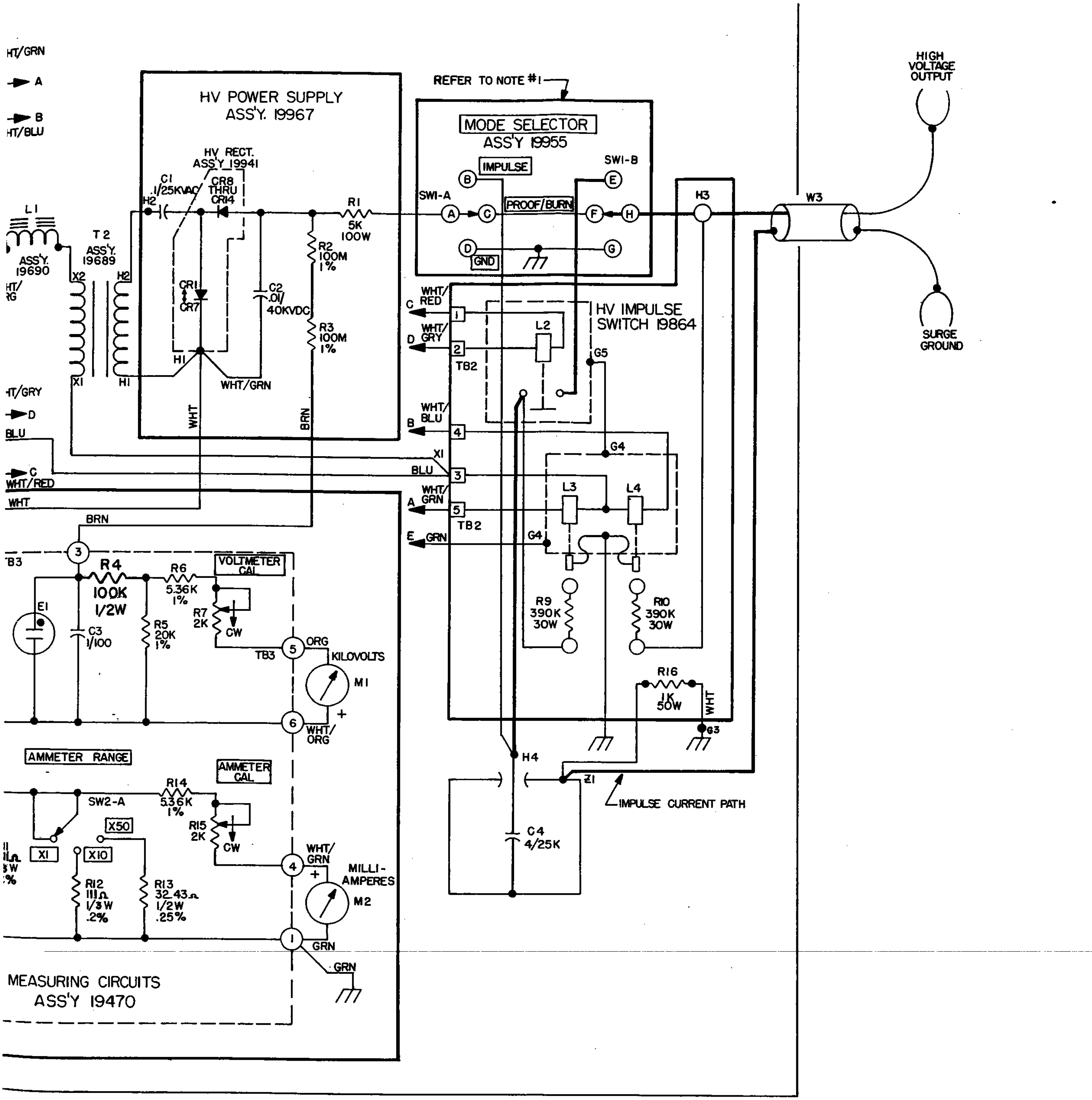
NOTES:

1. MODE SEL
(A) SWI-D I
(B) SWI-C I

2. SW3 IS CLO
THE ZERO

3. KI IS SHOV

4. CAPACITANC



ES:

ODE SELECTOR IS LOCATED ON CONTROL PANEL ASS'Y. 19925.
) SW1-D IS CLOSED IN THE PROOF/BURN AND IMPULSE POSITION.
) SW1-C IS CLOSED IN THE IMPULSE POSITION.

W3 IS CLOSED WHEN OUTPUT VOLTAGE CONTROL IS IN
HE ZERO START POSITION.

1 IS SHOWN ENERGIZED, PROOF/BURN POSITION

APACITANCE IN μf/VOLTS.

Figure 4: Schematic Diagram of Cat. No. 651028.

SECTION F

CONTROL AND CONNECTION IDENTIFICATION

GENERAL

The various controls and connections are displayed and identified in Figures 5 and 6.

Figure 5 is a front view, and will be found on page F3.

Figure 6 is a rear view, and will be found on page F4.

The function of all controls and connections illustrated in Figure 5 and 6 are listed in Table II below.

The operating procedure for the controls and connectors is explained in Sections G and H.

For the location of the various adjustments, see Troubleshooting and Repair, Section L.

TABLE II: CONTROLS AND CONNECTORS

NAME	FUNCTION
POWER ON switch:	Applies input power.
LINE ON lamp:	Amber lamp indicates input power ON.
HV ON lamp:	Red lamp indicates output voltage ON.
OUTPUT VOLTAGE CONTROL:	Variable autotransformer; used to adjust the high voltage output from minimum to maximum.
MODE SELECTOR:	Three-position switch for GROUND, IMPULSE or PROOF/BURN; selects mode of operation or provides for grounding of output and impulse capacitor.
VOLTMETER:	Monitors high voltage output.
AMMETER:	Monitors current for PROOF/BURN mode and recharging current for IMPULSE mode.

PROOF/BURN: indicates total dc current output of high voltage supply.

IMPULSE: in the X50 range, momentary needle deflection indicates the amount of input current required to recharge the Impulse Capacitor after each impulse. Full scale deflection indicates maximum recharging.

AMMETER RANGE: Three-position switch for X1, X10, X50 ranges. Monitors output current of high voltage supply in PROOF/BURN mode. Must be in X50 position to enable the IMPULSE mode.

mA and kV CAL: Milliammeter and Kilovoltmeter calibration can be adjusted through panel.

GROUND WINDOW: Permits a visual check of manual grounding.

INPUT CORD: Three-conductor, 16-gauge, 25 feet long. Connects input power.

OUTPUT CABLE: Coaxial cable: the white lead is the high voltage center conductor (red band); the black lead is the shield and low voltage return. Provides output power.

GROUND CABLE: #8 AWG single conductor insulated, stranded 25 feet long. Provides a redundant local station ground connection.

INTERLOCK: Provision for external interlock.

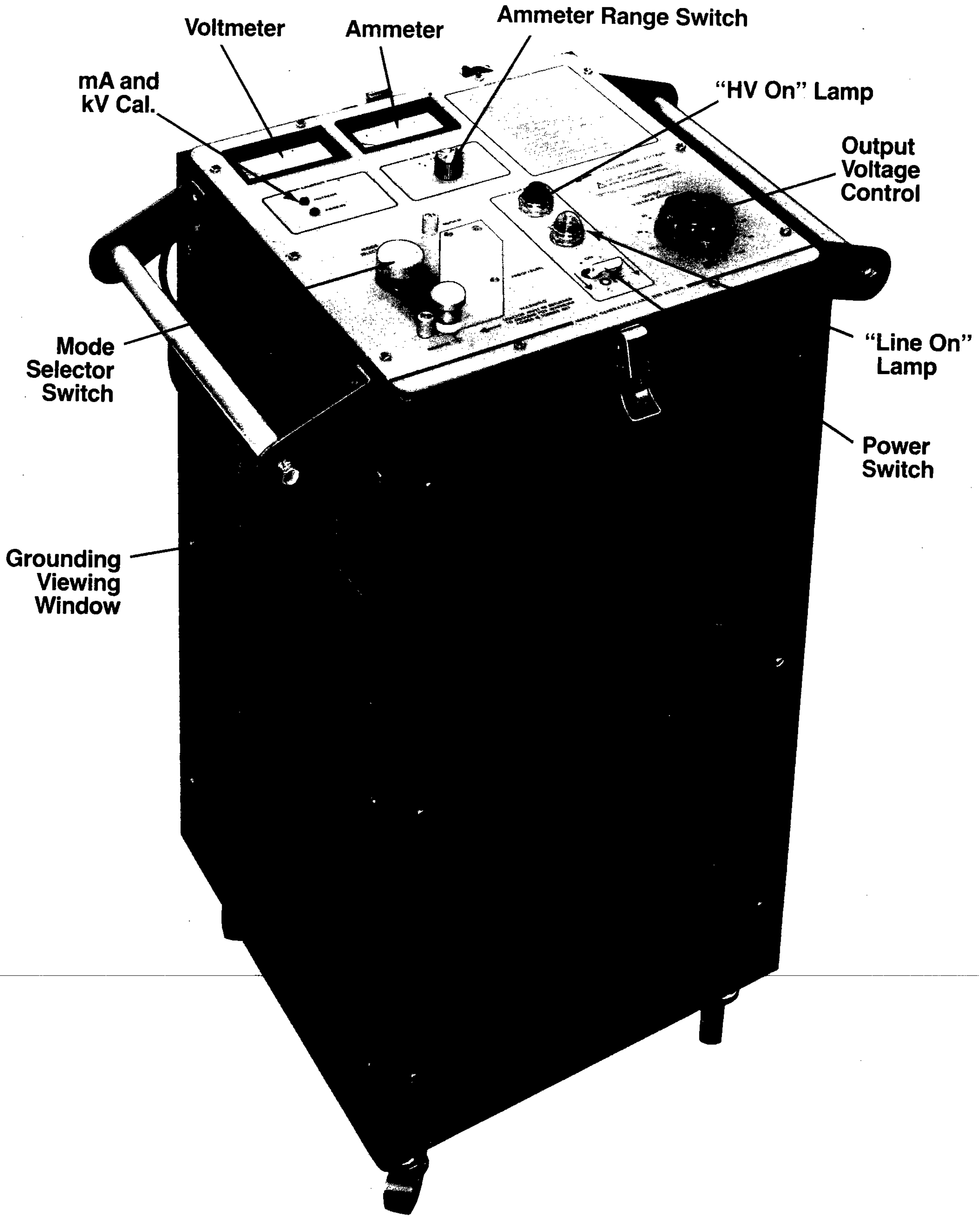


Figure 5: Front View of Cat. No. 651028 Test System.

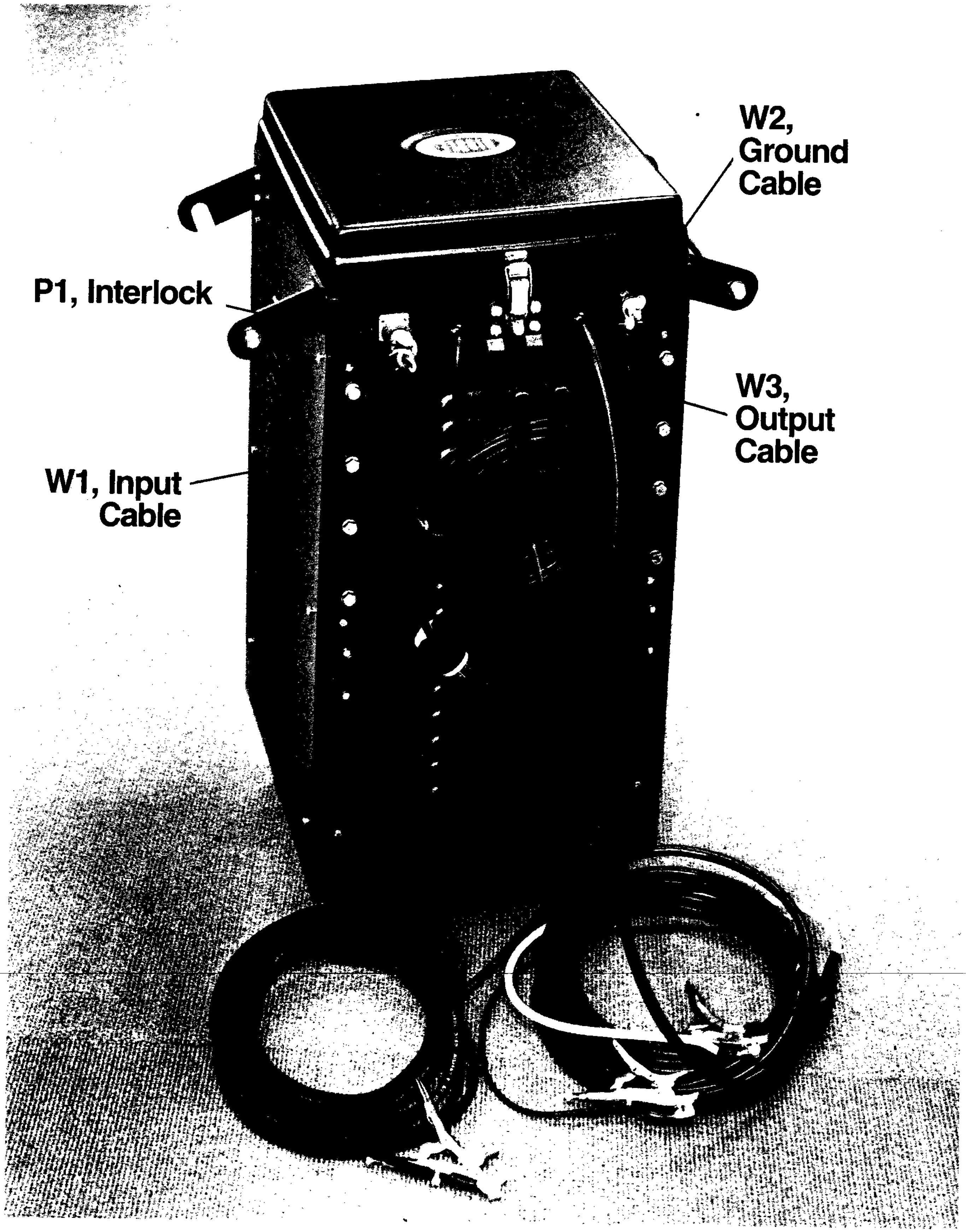


Figure 6: Rear View of Cat. No. 651028 Test System.

SECTION G

SETTING-UP

The following steps will serve as a general guide for setting-up.

> NOTE: Before operating, read Section B and Engineering Memo #147 and all other safety descriptions contained in this manual.

1. Observing all safety precautions, be sure all equipment is de-energized. Identify the faulted cables, isolate all ends, erect barriers and connect safety grounds to all cables to be tested and lift any lightning arresters.

2. Choose a location that meets the following conditions:

   a. Both the high voltage conductor and shield of the cable to be tested must be accessible.

   b. An electrical service suitable for the test set must be available within 25 feet of the chosen location unless a special longer input cord is supplied or an extension cord is available. The service ground wire must be connected to a secure low resistance ground.

   c. A secure low resistance ground must be located within 25 ft. of the test set, <u>without extending the ground cable</u>.

   d. The test set must be within 50 feet of the terminal of the cable under test, unless a special longer output cable has been supplied.

   e. The testing area should be as dry as possible.

   f. There should be no flammable material stored in the vicinity of the test set.

   g. There should be adequate ventilation in the test area.

   h. Warning lights are recommended.

3. For test set installed in vans or trailers:

   a. Locate the van or trailer so that it can be safely parked; set the brakes or block the wheels.

   b. The test set must be located within 50 feet of the terminal of the cable under test, unless a special longer output cable has been supplied.

c. A secure low resistance ground must be located within reach of the 25 feet of ground cable without extension. Provide a ground bond between the van or trailer frame and the test set chassis.

d. The location must also be within 25 feet of a service outlet of appropriate voltage, frequency and power, unless the test set includes a special longer input cord option, or if the test set system includes an engine-generator.

e. The location should be as dry as possible.

f. There should be no flammable material stored in the vicinity of the test set.

g. Set up suitable barriers to protect the operator from traffic hazards and to prevent intrusion by unauthorized personnel. Warning lights are recommended.

4. After a satisfactory location for the equipment has been selected, connect the chassis Ground of the test set to a secure low resistance ground.

5. Connect the test set output cable low voltage return lead to the grounded shield of the cable under test. Do not extend the low voltage lead! Be sure that this connection is made to a secure low resistance ground.

6. Connect the test set output cable high voltage lead to the faulted high voltage conductor of the cable under test, making a firm, low resistance connection. Be sure taht the exposed conductor and clamp are sufficiently insulated to withstand the test voltage. (See Table IV, Section M.)

7. Connect any other conductor of the cable under test to local ground making firm short connections.

8. Remove the safety grounds; be sure that the main switch is OFF, that the MODE SELECTOR switch is in the GROUND position, and the OUTPUT VOLTAGE CONTROL is set to zero at the ZERO START position.

9. Connect the power input cable to the service outlet.

10. For vans or trailers having a engine-generator:

a. Make sure that the ground and neutral of the generator are securely tied to the machine frame and the chassis of the vehicle. Be sure that the vehicle chassis is connected to a secure low resistance ground.

b. Start the engine-generator and warm up sufficiently to assure normal stable operation.

c. Check the engine-generator voltage to ensure proper input voltage for the test set.

11. Operation from a portable engine-generator:

a. Locate the engine-generator at last 10 feet from the test set.

b. Store spare fuel in a suitable safety container well away from both the engine-generator and the test set.

c. Provide a ground bond between the engine-generator frame and a local secure low resistance ground. Be sure that the green neutral wire is grounded. These leads should be no longer than 25 ft. and should be equivalent to No. 8 AWG or larger.

d. Start the engine-generator and warm up sufficiently to assure normal stable operation.

e. Check the engine-generator voltage to ensure proper input voltage for the test set.

f. Connect the test set to the engine-generator using the test set input cord.

NOTE: Be careful when refueling a engine-generator to avoid fire. Do not refuel while running.

When these procedures have been completed, the test may be conducted in accordance with the procedures given in Section H.

NOTE: Refer to Section I and J before operating the test equipment.

SECTION H

OPERATING PROCEDURE

WARNINGS!

- **MISUSE OF THIS HIGH VOLTAGE EQUIPMENT CAN BE EXTREMELY DANGEROUS.**
- **READ THIS INSTRUCTION MANUAL FOR PROPER USE.**
- **SAFETY IS THE RESPONSIBILITY OF THE OPERATOR.**
- **EQUIPMENT TO BE TESTED MUST BE DISCONNECTED FROM POWER.**
- **ALL PERSONNEL MUST BE KEPT CLEAR OF BARE LIVE PARTS.**
- FOLLOW ALL OTHER SAFETY INSTRUCTIONS.

PRELIMINARY CHECK

To insure a safe test set-up, the following preliminary procedure is recommended.

1. It is necessary that the shield of the cable under test be connected to a secure low resistance ground in the vicinity of the cable termination. This is to insure that it is adequately grounded.

2. Connect the test set output cable high voltage lead (center conductor) to the conductor of the cable under test, making a firm low resistance connection. Be sure that the exposed conductor and the clamps are sufficiently insulated to withstand the test voltage. (See Table IV, Section M).

3. Connect the test set chassis ground cable and the output cable low voltage return lead to the local ground.

4. Place a temporary jumper (10-gauge wire) from the junction connection of Step 2 to the shield of the cable under test. This connection will complete a low resistance path from the test set output through the shield of the cable under test, to the ground connection of that shield and through the local ground back to the test set.

5. Set the MODE SELECTOR to the PROOF/BURN position. Turn on the POWER circuit breaker. The LINE ON amber lamp will light indicating that power is being supplied to the test set. Set the AMMETER RANGE switch to X50 for the BURN mode or to X1 or X10 for the PROOF mode. Set the OUTPUT VOLTAGE CONTROL knob firmly on the ZERO START position. The HIGH VOLTAGE

red lamp will light indicating power is available to the high voltage power supply. Raise the test voltage slowly, (PROOF/BURN mode) being careful not to exceed 500 volts on the test set voltmeter. Continue to increase the test voltage until either the test set milliammeter reaches 50 milliamperes, or the kilovoltmeter reaches 500 volts. With a current reading of 50 milliamperes and an output voltage of 500 volts or less, the cable shield has an adequate ground connection and the required high voltage testing may be performed.

6. Turn the test set output voltage to zero. Place the MODE SELECTOR in the GROUND position. Remove the jumper and connect the test set output cable low voltage return lead to the shield of the cable under test.

7. Proceed with the required testing.

8. DO NOT continue testing if the current or voltage requirement is not met. This is an indication that the shield ground connection is not adequate.

PROOF/BURN MODE

Depending upon the test requirement, the PROOF/BURN mode is used to conduct a proof test and/or to burn-down a fault as explained further in Section I, Operation Notes.

Should failure of a proof test occur at less than 25 kV, the operator may (1) stop the test to prevent further fault damage, or he may (2) continue to apply high voltage to burn-down the fault resistance, further reducing the voltage, or he may (3) transfer to the IMPULSE mode for fault-locating purposes.

If failure of the proof test occurs at more than 25 kV, the operator may (1) stop the test to prevent further fault damage, or (2) he may continue to apply voltage to burn-down the fault resistance, reducing the voltage to less than 25 kV for application of the IMPULSE mode.

To conduct either a proof test and/or a burn-down:

1. Set the MODE SELECTOR to the PROOF/BURN position.

2. Turn the POWER circuit breaker to ON. The LINE ON amber lamp will light indicating that power is being supplied to the test set.

3. Set the AMMETER RANGE switch to X50 mA for the BURN mode and X1 or X10 for the PROOF mode.

4. Set the OUTPUT VOLTAGE CONTROL knob firmly to the ZERO START position. The HIGH VOLTAGE red lamp will light indicating power is available to the high voltage power supply.

5. Raise the OUTPUT VOLTAGE CONTROL to the desired level of voltage of current.

   5.1 A proof test is made by gradually increasing the OUTPUT VOLTAGE CONTROL from zero in small increments so that the output voltage reaches the desired level within 10 seconds and not exceeding 60 seconds, and by then holding that voltage for the prescribed period of time with no further adjustment of the OUTPUT VOLTAGE CONTROL. Failure is indicated by inability of the kilovoltmeter to stabilize at the desired voltage without readjustment.

   5.2 A burn-down is accomplished by gradually increasing the OUTPUT VOLTAGE CONTROL to the proof test voltage level, or until the output current develops to a maximum of 50 mA, then readjusting as necessary to maintain either condition until the output voltage falls below 25 kV or below any other prescribed limit for impulse voltage.

   At this point the operation may be discontinued and transferred to the IMPULSE mode, or it may be continued to further reduce the voltage across the fault at the discretion of the operator. However, it is advisable not to reduce the voltage below that which is necessary to achieve breakdown in the IMPULSE mode because the lower the breakdown voltage, the weaker will be the resulting acoustic signal, even when a much higher impulse voltage is applied.

6. If desired for proof testing purposes, switch the AMMETER RANGE to X1 or X10 to observe the current. Switch back to X50 before burning.

   6.1 The X50 range reads the rms value for burning control.

   6.2 The X1 and X10 ranges read the true dc value for proof testing purposes.

7. To shut-down or to transfer to the IMPULSE mode, see "Shut-Down or Transfer".

SHUT-DOWN OR TRANSFER

These procedures are to be followed whenever shutting down a test or transferring modes of operation. Never move the MODE SELECTOR during a test because shut-down will occur, but more importantly, damage to the cable under test or test set could result.

1. If shutdown or transfer is desired from the PROOF/BURN mode, turn the OUTPUT VOLTAGE CONTROL fully counterclockwise, then turn the POWER switch to OFF. This will automatically operate the discharge assembly and reduce the output voltage to a safe level. The MODE SELECTOR switch may now be moved to another position.

2. If shutdown or transfer is desired from the IMPULSE mode, turn the OUTPUT VOLTAGE CONTROL fully counterclockwise, allow the impulse switch to operate once, then turn the POWER switch to OFF. This will automatically operate the discharge assembly and reduce the voltage to a safe level. The MODE SELECTOR switch may now be moved to another position.

3. For safety during a temporary or permanent shutdown, disconnect the power cord from the source.

4. To disconnect the set-up, manually ground the output cable high voltage lead with a safety ground.

5. Remove the test clamps from the conductor and the shield or ground, leaving the jumper in place to drain any relaxation charge for a period of at least four times as long as the test voltage had been applied.

6. Remove the case ground clamp from the station ground.

IMPULSE OPERATION

With a few exceptions, cable faults can usually be impulsed at any voltage higher than the breakdown voltage that developed in the PROOF/BURN mode. If it does not break down below the proof test level or within the 25 kV limit of the IMPULSE mode, the PROOF/BURN mode must be applied to further reduce the breakdown voltage, as mentioned previously. Of course, the IMPULSE mode can also be applied directly without prior testing to determine whether a fault may be impulsed without need to burn-down.

To Impulse a Fault:

1. Set the MODE SELECTOR to the IMPULSE position.

2. Turn the POWER circuit breaker to ON. The LINE ON amber lamp will light indicating that power is being supplied to the set.

3. Set the AMMETER RANGE switch to X50.

4. Set the OUTPUT VOLTAGE CONTROL knob firmly to the ZERO START position. The red HV ON lamp will light.

5. Raise the OUTPUT VOLTAGE CONTROL to the desired level. Do not exceed 25 kV for any extended period of time.

   5.1 To determine the minimum impulse breakdown level of the fault, increase the voltage every 10 seconds in small increments, say every 2 kV, starting at 2 kV until breakdown is observed. A slight increase will enhance a clean-cut breakdown. As explained in Impulse Voltage Limits, page I4, some users prefer not to impulse above this minimum breakdown level. On the other hand, if a stronger impulse signal is to be used, increase the voltage per Step 5.2 described below.

   5.2 To impulse at 25 kV or at some other limit below 25 kV, increase the voltage every 10 seconds, starting with large increments but approaching the limit gradually so as not to overshoot that point. If the fault had been burned down previously, the initial breakdown will usually occur before the final voltage is reached.

   5.3 If the fault fails to break down before reaching the proof test voltage level of the cable, it will be necessary to transfer to the PROOF/BURN mode in order to burn-down the fault and reduce the voltage per instructions given earlier.

6. To shut down or to transfer to the PROOF/BURN mode, see "Shut Down or Transfer" instructions beginning on Page H3.

SECTION I

OPERATION NOTES

GENERAL

The information provided in this section is intended only as a guide for cable fault locating, not a complete study of the subject. Theoretical and practical information about cable fault locating is provided in the Biddle Publication 65T5 entitled "Power Cable Fault Locating" supplied as an appendix to this instruction manual. Biddle Instruments recommends that the operator(s) of this test equipment become completely familiar with the principles and practices covered in manual 65T5 before actual cable fault testing is attempted.

PROOF TESTING

Prior to actually locating a fault or following cable repairs, it is common practice to test the cable by applying a dc voltage as proof that the conductor is faulted or that the conductor will support voltage. To perform this test, the test set is operated in the PROOF/BURN mode (refer to Section H) and the cable under test is raised to the required test voltage. If the cable can withstand the test voltage without any internal sparking or burning for the necessary time interval (usually 15 minutes), the proof condition has been met and the cable is good. If the cable fails to pass the proof test, the cable is considered faulty and further testing is required so that the fault(s) can be located.

IMPULSE TESTING

To perform this test, the test set is operated in the IMPULSE mode (refer to Section H). The output voltage is slowly raised to the test level without exceeding the recommended proof test rating of the cable. Once breakdown is achieved, the kilovoltmeter will dip (momentary downward needle deflection) with each impulse. This indication means that there is an energy transfer with each impulse from the test set to the cable.

If the output voltage is held constant and the cable fault is not breaking down, the kilovoltmeter will promptly stabilize. This indication means the cable is charged to the applied output voltage of the test set. If the cable load is light, then this charging may occur within one or two impulses. Continue to increase the output voltage until it is high enough to cause the cable fault to break down. When this occurs the momentary dip of the kilovoltmeter and the momentary rise of the milliammeter will both widen. To ensure that the fault breakdown occurs with each impulse the output voltage should be raised slightly above the fault breakdown level as a minimum. (See "Impulse Voltage Limits", page I4.)

If the rise of the milliammeter is about full scale at 25 kV, the fault resistance at breakdown is near zero. This condition will provide the best electromagnetic tracing signal because the current drawn from the test set will be maximum and the resulting electromagnetic field will be maximum. However, the acoustic signal may be small with this kind of fault.

If the impulse voltage is raised to 25 kV or to the recommended proof test voltage rating of the cable, and the fault does not break down, then the operator must resort to the PROOF/BURN mode in order to condition the fault by burning so as to break down at 25 kV or less. In the PROOF/BURN mode the test set can provide a maximum of 30 kV.

BURN OPERATION

This operation is similar to a proof test in that the test set is operated in the PROOF/BURN mode and the same controls are used. The difference between this operation and a proof test is the way the test set is used.

In a proof test, the output voltage is raised to a prescribed level and held at this voltage for a specified period of time. The objective is to prove whether the cable under test can withstand this voltage level.

In the BURN operation, the output voltage is increased until the cable fault breaks down. When this happens the fault resistance momentarily decreases allowing a spark to char the fault path. By further increasing the OUTPUT VOLTAGE CONTROL, more current passes through the fault thus accelerating the process. Should a fault fail to break down up to the maximum 30 kV PROOF/BURN voltage available, this maximum level should remain applied for a period of time to attempt to initiate burning as indicated by a gradual increase in the milliammeter. The objective is to continue to increase the output power from the test set so that sufficient current is supplied to the cable fault for a long enough period to burn the insulation at the fault. This will permanently char the walls of the fault and alter its internal resistance from high to low. The resulting reduction in fault resistance will change the electrical characteristics of the fault in such a way that the fault will break down at a lower voltage. By this process, the breakdown voltage can be decreased below the 25 kV maximum impulse voltage level thus enabling fault locating operations to proceed.

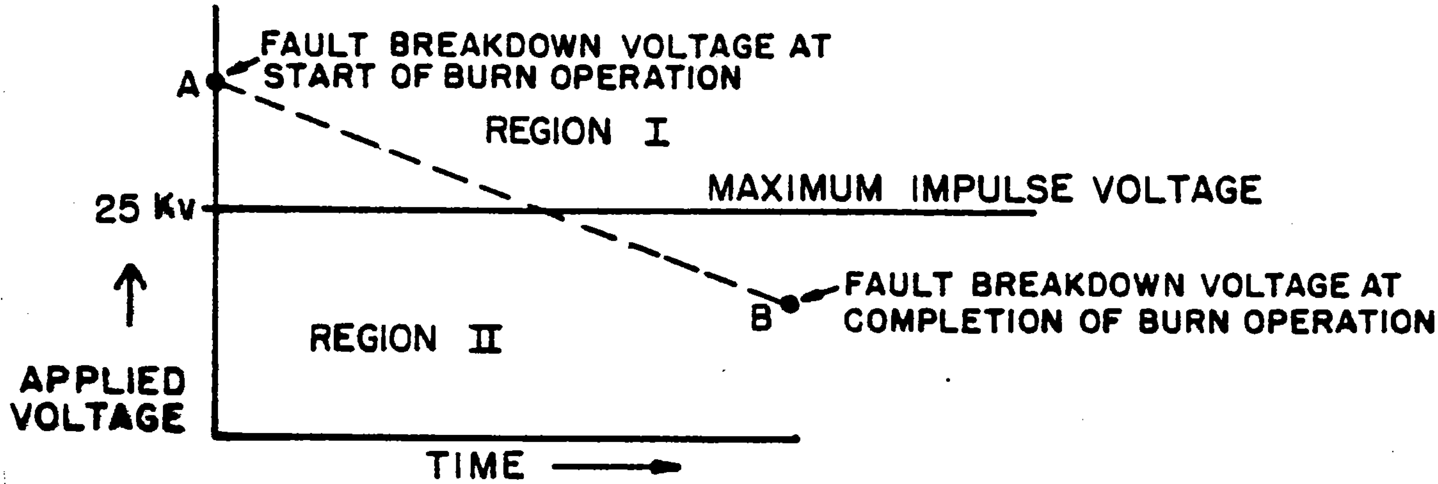


Figure 7: Burn Characteristics of a Typical Cable Fault

The plot of a typical cable fault is shown in Figure 7 to illustrate the electrical changes which occur when a cable fault is burned. Before the BURN operation the required voltage to cause the fault to break down is very high. This high breakdown voltage is due to the high internal resistance of the cable fault. It should be noted that with the breakdown level at A the fault cannot be located by impulse testing because the required voltage is above 25 kV, the maximum output voltage available for impulse testing. After the burn operation the required breakdown voltage has been reduced as indicated by point B. This reduction in breakdown voltage is due to the lower internal resistance of the cable fault. This change has moved the breakdown voltage requirement from region I above 25 kV, to region II below 25 kV. This change in the electrical characteristics of the cable fault means that the impulse method of cable fault locating can now be used to locate the cable fault.

To summarize, the BURN operation is an effective way to alter the electrical characteristics of a cable fault so that an impulse signal can be produced or a low voltage terminal type of fault locator, such as a radar or bridge, may be used. The BURN operation should only be used when the situation warrants the advantages of reduced voltage and increased current that this operation provides.

OPERATION WITH A ELECTROMAGNETIC DETECTOR

A common cable construction consists of three conductors bundled in a lead sheath and installed in a conduit or duct. In such a construction, a sheath ground bond is usually present at every manhole. For cables of this type, the Biddle Electromagnetic Detector is most effective. Because the conductors are not concentric with respect to the sheath, an external magnetic field exists around the cable and the Electromagnetic Detector may respond to this field or to the magnetic field due to current in the bonds. (See the Instruction Manual for the Biddle Electromagnetic Detector for additional details).

When using the Electromagnetic Detector, it is suggested that the pickup coil be applied to the cable at a point close to the test set prior to patrolling the cable. The pickup should be applied to sense the current in the shield extension or at the first bond. This will confirm an established signal and thereby check the detector prior to the test.

OPERATING SAFETY WARNING

It is important that the shield of the cable under test be connected to the output cable low voltage return lead with a short, firm connection and that this point is connected to ground. As the voltage at this junction may tend to increase during impulse, personnel should avoid contact with this point. Normally this voltage will be small (on the order of several volts); but transient voltages of up to 3000V may be present depending on the construction of the cable installation and the effectiveness of ground bonds.

IMPULSE VOLTAGE LIMITS

For some installations the available 25 kV impulse may be considered to be excessive. When such a limit exists, the operator must be cautioned not to exceed the specified voltage limit. The tendency is to use the maximum voltage but impressing excessive energy on a fault may result in clearing the carbon or conducting bridge of the fault so that it will no longer break down.

DISCHARGE OF CABLE

When a cable becomes charged, either because the fault has failed to break down or because it has been subjected to a proof test, it must be discharged before being handled.

Discharge Procedure

1. Turn the OUTPUT VOLTAGE CONTROL fully counterclockwise then turn OFF the POWER circuit breaker. This will remove input power and automatically place discharge resistors on the output load and the impulse capacitor.

2. Wait until the high voltage has discharged to less than 1 kV. This is indicated by the front panel voltmeter. This meter has a passive measuring circuit which means that the meter will operate normally even though the main power has been turned OFF. The voltage divider network for this meter is connected to the high voltage power supply.

3. Turn the MODE SELECTOR to the GROUND position.

WARNING!

DO NOT, except in emergency, place the MODE SELECTOR in GROUND position with the output voltage above 1 kV. This is a safety consideration intended to protect the cable, since a sudden discharge may produce a traveling wave which will double when reflected at the open terminal end. This doubling of amplitude may produce an overvoltage condition which might damage a good cable or the equipment to which it is connected.

4. With the MODE SELECTOR in the GROUND position the following safety check should be performed:

   a. Voltmeter should read zero.

   b. The position of the moving arms on the MODE SELECTOR switch should be visually checked through the viewing window to be sure they are in the GROUND position. When properly grounded, the moving arms will be engaged in the large ground bar electrode.

5. This completes the discharge procedure. As an additional safety precaution all exposed high voltage connections should be shorted with safety grounds.

TEST SET HANDLING

Depending on where or how the test set is used, the following options will facilitate handling:

Cat. No. 650402 - a light duty, folding hand truck may be used to move the test set from one place to another over smooth terrain.

Cat. No. 650403 - a set of four casters, used to move the test set within a building.

Cat. No. 650404 - a kit containing a heavy duty axle and 2 semi-pneumatic 10" wheels (readily installed by the customer) for use on relatively rough terrain.

Options are available for longer lenghts of both input and output cables, in order to reach to the rear of residential properties or other relatively inaccessible locations.

Various voltage and frequency options are also available.

The test set can be operated from a portable engine-generator when a service line is not available.

A portable engine-generator suitable for sustained operation of the test set alone must be rated at a minimum of 1.5 kVA. It must be equipped with a good governor that responds to load change rapidly but without excessive overshoot. The electrical output should be matched to the rated input voltage, frequency, and power.

For further instructions on the generator, see the appropriate manual for that equipment.

SECTION J

APPLICATION NOTES - THEORY

All faults can be represented electrically by a gap shunted by a resistance as illustrated below in Figure 8.

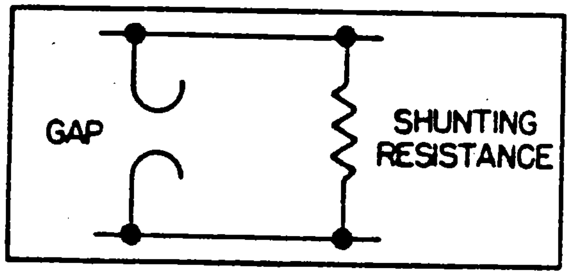


Figure 8: Typical Fault Diagram

Although the electrical circuit shown in Figure 8 is simple, variations in the conditions of the two paths can cover an extremely wide range; the resistance ranging from a dead short to many megohms, and the gap breakdown voltage varying from zero to many thousands of volts.

When the impulse voltage wave reaches the fault, it may dissipate either through the resistance path or by sparking over the gap. In either event, it releases energy in the return path, thereby providing a current that can be detected. If the cable is exposed, faults can usually be located by the sound of the arc discharge or by the flash itself. For more difficult cases where the cable is buried or the sheath is intact, either a electromagnetic or acoustic detector may be required. (See Table I). If the energy passes through only the resistance path, no spark will result; therefore, an electromagnetic detector must be used. Even if the resistance of the fault is infinitely high, the fault can be located by the impulse method, provided that the peak value and time duration of the voltage wave are sufficient to cause sparkover. It is for this reason that the impulse method is so generally applicable.

Basically, sparkover is determined by three factors: the nature of the fault, the capacitance of cable, and the capacitance of the impulse generator. If the capacitance of the generator is equal to or smaller than that of the cable to which the generator is connected, the fault may not break down on every closure of the impulse switch. This is a result of the capacitive voltage division between the cable and the generator. The frequency of breakdown can be increased by increasing the applied voltage, but at the risk of applying overvoltage to the cable.

SECTION K

ROUTINE MAINTENANCE

GENERAL

The test set is constructed to withstand use normally encountered in field testing for public utilities and industrial plants. To maintain this equipment in proper condition, a planned program of routine maintenance for all major components should be carried out every six months.

WARNING!

> **This is a high voltage system which can produce and contain dangerous voltages. Any service or repair of this equipment should be performed only by qualified persons who are aware of high-voltage hazards and the necessary precautions routinely taken to prevent injury.**

Before any inspection, service, or repair, the test set must be completely disconnected from the power supply and from any cable under test. The Manual Ground must be closed and must remain closed for at least fifteen minutes before access is gained to the interior of the test set. As a safety precaution, once access to the interior is gained and before any action is taken, a bond should be placed across all exposed capacitors and the high-voltage lead from the power supply.

If company policy requires that a defect report be provided to those performing maintenance, this report should be consulted prior to examining the test set and the items noted on the report should be investigated at the appropriate point in the maintenance procedure.

The inspection and maintenance of the test set should be carried out in accordance with the steps listed below.

MAINTENANCE PROCEDURE

1. Examine all cables to locate any loose or damaged terminals.

2. Inspect and clean the outer jacket of the output cable; check for breaks in this jacket.

   NOTE: As a temporary repair, apply at least four layers of vinyl tape over any such damage. The output cable must be replaced as soon as practical.

3. Check the action of all controls to be sure they operate freely.

4. Wipe the entire case clean and check for damage.

5. Check top panel for any damage to meters, switches, lights, etc.

6. Remove the sides from the case by removing the six screws in each panel, then apply a bond across the terminals of the capacitors.

7. Check to see that all screws, nuts and balls are tight.

8. Examine all electrical connections; check for evidence of corrosion or fracture.

9. Check the operation of the MODE SELECTOR to be sure that it engages properly in all positions.

10. Clean all bushings and electrical insulating supports with a clean soft cloth. Do not use solvents. Clean, low pressure air may be used.

11. As the cleaning proceeds, inspect all resistors for burned sections or loose bonds. Check the capacitors for oil leaks or evidence of case swelling.

12. To inspect and adjust the Impulse Switch, it must be removed from the test set. Disconnect all leads from the switch, then remove the four mounting screws located on the backplate of the switch.

    12.1 To inspect the inside of the switch, it is only necessary to remove the five screws holding the bottom plate which simply drops out of the container.

    12.2 If the inside of the switch is dirty, it is best cleaned by merely wiping vigorously with a soft cloth.

    12.3 To replace the shaft or the moveable arm, it is necessary to remove the groove pin that holds the shaft to the armature of the solenoid. Use care when removing the pin so as not to tear the shaft body. The contact assembly can now be removed and the defective shaft or moveable arm can be replaced. Reassemble, observing that the groove in the pin should be located on either side.

12.4 To replace the stationary contacts (which should be replaced in pairs), simply loosen the outside nuts and tap lightly on stud to loosen the contact body. Remove and replace.

12.5 To replace the solenoid, the groove pin holding the shaft to the armature of the solenoid must be removed. Remove the four screws holding the solenoid body; reverse this procedure for reassembly.

12.6 Readjustment of the switch is usally not necessary unless a component is replaced or if the generator fails to impulse at low voltage (about 500 volts). This is done by loosening the four screws holding the solenoid just enough to allow it to slide up and down. Connect an ohmmeter across the stationary contacts and insert a 3/64" shim between the solenoid body and armature. Slide the solenoid, shim and armature combination until the meter indicates. Tighten nuts, remove shim, reinstall switch.

13. Check of Surge Ground:

13.1 Coil the output cable around the cleats; and place the output cable low voltage return clamp so that it is well insulated from ground.

13.2 R16, the resistor between the impulse capacitor case and chassis, must be disconnected at either end. Measure the path between the output cable low voltage return clamp and the chassis ground terminal with a megohmmeter. This path should measure in excess of five megohms.

13.3 If a dielectric test set is available, the surge ground may be tested to ground at voltages up to 5 kV.

14. Before replacing the covers, clean the viewing window with a soft dry cloth, then replace the side panels by reversing the proceudre in Step 6.

15. When work on the test set has been completed, make a Performance Check in accordance with the procedure given in Section M.

In abnormally dirty areas or in difficult environments the routine maintenance schedule may be required more often than the average six-month period.

SECTION L

TROUBLESHOOTING AND REPAIR

GENERAL

Biddle Instruments maintains a complete repair service and recommends that its customers take advantage of this service in the event of any equipment malfunction.

If the test set fails to operate properly, the following information will be useful in determining the cause of the malfunction. Table III notes possible equipment malfunctions as observed during operation or checkout per Section M and suggests the possible cause and the means of determining the defective component. The circuit description schematic diagram, Figure 4 of Section E, and illustrations, Figures 10-15 of Section N, will be helpful in locating the components. Refer to Section N when ordering replacement parts.

To further localize a defect or to readjust the elements of the test set, see the appropriate paragraphs below. Any special equipment that is required for servicing the test set is identified in this section when applicable. SEE SAFETY PRECAUTIONS, SECTION B.

CAUTION!

THIS IS HIGH-VOLTAGE EQUIPMENT AND MAY CONTAIN DANGEROUS VOLTAGES; REPAIRS MUST ONLY BE MADE BY THOSE WELL QUALIFIED WITH SUCH HAZARD AND FAMILIAR WITH ROUTINE PRECAUTIONS REQUIRED TO PREVENT INJURY.

Prior to gaining access to the set, the input and output must be completely disconnected and the MODE SELECTOR must be in the GROUND position for at least 15 minutes. Any trouble reports submitted should be reviewed prior to work done under this section. Table III does not specifically suggest wiring or hardware defects since these are possible defects that must always be considered in every case and are not peculiar to this unit.

TABLE III

TROUBLESHOOTING GUIDE

MALFUNCTION	POSSIBLE CAUSE
CONTROL CIRCUITS	
MAIN CIRCUIT BREAKDER (CB1) TRIPS:	-Defective CB1. -Short circuit in mains. -T2 or T3 shorted. -RV1 and/or RV2 shorted.
START CIRCUIT INOPERATIVE:	-Open in interlock circuit. -Check relays & switches for proper operation (K1, SW3, SW1C or D, etc.) -Check MODE SELECTOR.
IMPULSE MODE	
LOW OR NO OUTPUT VOLTAGE:	-Component failure in voltmeter circuit. -Impulse Capacitor shorted. -Component failure in high-voltage power supply. -Defect in high-voltage discharge assembly. -Open or shorted output cable. -Impulse Switch defective.
VOLTAGE AVAILABLE BUT NO DISCHARGE:	-Impulse Switch defective. -Timing Switch defective.
PROOF/BURN MODE	
LOW OR NO OUTPUT VOLTAGE:	-Defective component on circuit board.

CALIBRATION OF MILLIAMMETER

A standard direct current ammeter is required, having the following ranges and accuracies at the reading point:

1 mA ±1%
10 mA ±1%
50 mA ±1%

Remembering to insulate all high-voltage connections from ground, connect the ammeter between the high-voltage lead and ground with the positive terminal to ground. In the PROOF position slowly adjust the OUTPUT VOLTAGE CONTROL until the standard ammeter reads 10 mA. Adjust the panel meter by means of the mA CAL adjustment potentiometer located just below the milliammeter. Check the 50 mA range. The standard ammeter should read 31.8 mA when the panel meter reads 50 mA. The difference between the two readings takes into account the effect of the waveform (excess ripple) at this level on the standard meter, but this level is equivalent to 50 mA rms in heating value at a fault. Check the 1 mA range.

CALIBRATION OF KILOVOLTMETER

To perform this calibration a standard dc voltmeter is required. The standard voltmeter must measure with an accuracy of ±1/2% at 30 kV. The instrument should preferably not draw more than 1/2 mA. If the dc voltmeter is polarity sensitive, it must be arranged so that the positive terminal is grounded and the negative terminal is elevated to the test voltage.

Proceeding with due regard to safety, arrange the test set and standard voltmeter so that they can be easily read. Then connect the output cable low voltage return lead to ground and the output cable high voltage lead to the high voltage terminal of the standard voltmeter.

On the Control Panel locate and remove the cover screw from the kV CAL adjustment. Adjust the mechanical zero of the voltmeter.

Now operate in the PROOF mode and make a direct comparison between the standard voltmeter and the voltmeter of the test set. If an error exists it can be corrected by the appropriate adjustment of the kV CAL. After calibration replace the adjustment cover screw.

OUTPUT CABLE CHECK

Do not shorten output cable to less than 40 feet. To check the cable perform the following: (1) insulate and space the two outboard clamps about 1/8-1/4 inches apart, (2) raise the output voltage in the PROOF/BURN mode according to Program B, Section M. Breakdown of the gap should occur at about 10 kV and at this time the voltmeter reading will decrease and the ammeter reading will increase. If this occurs the cable is satisfactory.

If the output cable is short-circuited, an ammeter reading will be present, but the gap at the output of the test cable will not spark over.

REPLACEMENT OF COMPONENTS ON CONTROL PANEL

Should it become necessary to replace major components on the Control Panel, the following procedures are recommended:

1. Remove the ten screws holding the panel in place.

2. Disconnect the four high voltage leads from the MODE SELECTOR and the two wires that feed down to the high voltage power supply.

3. Pull the panel free and turn it upside down. There is a service loop in the cable connections that is long enough to permit resting the panel on top of a table or workbench. (Refer to Figure 12.) This exposes all the electrical components and connections.

4. To install the Control Panel, reverse the foregoing procedure.

SECTION M

PERFORMANCE CHECK

GENERAL

The checkout procedures given below can be followed either in the shop after performing routine maintenance or in the field prior to conducting a fault-locating operation. If the indications described in programs A, B and C are obtained then the test set is functional and proper performance is verified.

IMPULSE FUNCTION TEST, PROGRAM A

To implement this program, perform the following sequential procedure:

1. Choose a safe test site as described in Section G, Step 2.

2. Connect the chassis ground of the test set to a secure low resistance ground.

3. Connect the low voltage lead of the output cable to a secure low resistance ground.

4. Connect the high voltage lead of the output cable to the same ground as the output low voltage lead.

5. Connect the input cable to a service outlet of the nameplate rating.

6. Set the MODE SELECTOR to the IMPULSE position.

7. Turn the POWER circuit breaker to ON. The LINE ON amber lamp will light indicating that power is supplied.

8. Set the AMMETER RANGE switch to X50 position.

9. With the OUTPUT VOLTAGE CONTROL in the ZERO START position, the HIGH-VOLTAGE red lamp will light and the Impulse Switch will automatically close and drop open every 6 seconds.

10. Slowly turn the OUTPUT VOLTAGE CONTROL fully clockwise and observe the following:

    a. Between each discharge the impulse capacitor will charge to approximately 25 kV as outlined on the Kilovoltmeter.

b. At each discharge, the Kilovoltmeter needle will swing downward to approximately 5% of full scale and then begin to increase as the impulse capacitor completes its charge.

c. In addition, at each discharge, the Milliammeter will swing upward to approximately 100% momentarily and then begin to fall back as the impulse capacitor completes its charge.

11. These meter indications mean that the IMPULSE portion of the test set is operating properly. If these indications are not observed, double check the procedure and refer to Troubleshooting and Repair, Section L.

12. This completes the IMPULSE FUNCTION TEST. Return the OUTPUT VOLTAGE CONTROL to the ZERO START position, POWER CIRCUIT BREAKER to the OFF position and MODE SELECTOR switch to GROUND position.

PROOF FUNCTION TEST, PROGRAM B

1. Perform steps 1, 2 and 3 of IMPULSE FUNCTION TEST described above.

2. Position the output cable high-voltage connector in a barricaded high voltage test area so that it is insulated from ground or any other conductive object by a minimum of two feet of air space.

3. Connect the input cable to a service outlet of the appropriate voltage, frequency and power.

4. Set the MODE SELECTOR to the PROOF/BURN position.

5. Turn the POWER circuit breaker to ON. The LINE ON amber lamp will light indicating that power is being supplied to the test set.

6. Set the AMMETER RANGE switch to X1.

7. With the OUTPUT VOLTAGE CONTROL in the ZERO START position, the HIGH VOLTAGE red lamp will light.

8. Slowly turn the OUTPUT VOLTAGE CONTROL fully clockwise and observe the following:

   a. The Kilovoltmeter will indicate 30 kV.

   b. The Milliammeter will indicate less than .05 milliamperes leakage current on the 1 mA range.

9. These meter indications mean that the PROOF testing portion of the test set is operating properly. If the leakage current is excessive, make sure that the high-voltage output connector is properly insulated before performing the troubleshooting and repair as described in Section L. Sometimes it is helpful to put the output connector in a plastic bag to reduce leakage.

10. This completes the Proof Function Test. Return the OUTPUT VOLTAGE CONTROL to ZERO START position, MODE SELECTOR switch to GROUND position, and POWER circuit breaker to OFF position.

BURN OPERATION TEST, PROGRAM C

1. Perform steps 1 thru 5 IMPULSE FUNCTION TEST mentioned earlier.

2. Set the MODE SELECTOR to the PROOF/BURN position.

3. Turn the POWER circuit breaker to ON. The LINE ON amber lamps will light indicating that power is being supplied to the test set.

4. Set the AMMETER RANGE switch to X50.

5. With the OUTPUT VOLTAGE CONTROL in the ZERO START position, the HIGH VOLTAGE red lamp will light.

6. Slowly turn the OUTPUT VOLTAGE CONTROL fully clockwise and observe the following:

   a. The Kilovoltmeter will indicate less than 500V.

   b. The Milliammeter will indicate 50 milliamperes.

7. These meter indications mean the BURN portion of the test set is operating properly. If these indications are not observed then double check the procedure and refer to Troubleshooting and Repair, Section L.

8. This completes the BURN OPERATION test. Return the OUTPUT VOLTAGE CONTROL to the ZERO START position, MODE SELECTOR switch to GROUND position and POWER circuit breaker to OFF position.

This basic check-out procedure can be performed at any time to verify the test set operation. As noted in Section J, fault characteristics can vary widely and in some cases can even temporarily clear themselves. For such unusual conditions, the check-out procedure can verify the proper performance of the test set so that the problem of fault characteristics can be clearly isolated.

As a guide in setting up the test, the minimum air clearance given in Table IV must be maintained between the exposed energized conductor and any adjacent grounds in order to prevent sparkover. Such additional sparkover may create a safety hazard. The clearance values shown in the table apply to the direct air path at the point of closest proximity to ground.

TABLE IV: AIR CLEARANCES

TEST VOLTAGE	DIRECT AIR PATH	PATH ALONG NYLON ROPE
5 kV	1 1/4 inches	1 1/4 inches
30 kV	2 7/8 inches	7 1/2 inches

If all conditions of programs A, B, and C are met, the test set is fully functional. If conditions are not met, proceed to Section L to isolate the problem and then make repairs.

OUTPUT REGULATION

The Voltage Regulation graph, Figure 9 on page M5, is a typical performance plot of the test set in the PROOF/BURN mode of operation. This graph shows both the voltage and current capability of the test set with respect to the varying load conditions.

If the fault resistance is above 5 megohms, the output voltage will be the limiting facctor as the OUTPUT VOLTAGE CONTROL is increased. If the fault resistance is low (less than 100K ohms) the output current will be the limiting factor as the OUTPUT VOLTAGE CONTROL is increased. With a fault resistance between these values (100K ohms to 5 megohms) the power capability of the test set will be the limiting factor as the OUTPUT VOLTAGE CONTROL is increased toward 100%.

The output voltage and current will change, as shown when the cable fault is burned - altered from a high resistance fault to a low resistance fault. With a high resistance cable fault the test set will have a low current draw at a high voltage. The output voltage-current intercept point will be in the upper left-hand portion of the graph. As the cable fault is altered from high resistance to low resistance, the output voltage will drop as the output current increases. With the OUTPUT VOLTAGE CONTROL maintained at a constant level, the voltage-current intercept point will shift to the lower right-hand portion of the graph as cable fault resistance is reduced. This change in the output voltage-current will form a curve which should conform to the general family of voltage-current curves shown.

Any variations in this voltage-current curve may be caused by either a change in source impedance or line voltage. Since these factors are difficult to control, they must be taken into consideration when checking the voltage regulation curve. Notice the difference between rms and dc meter indications.

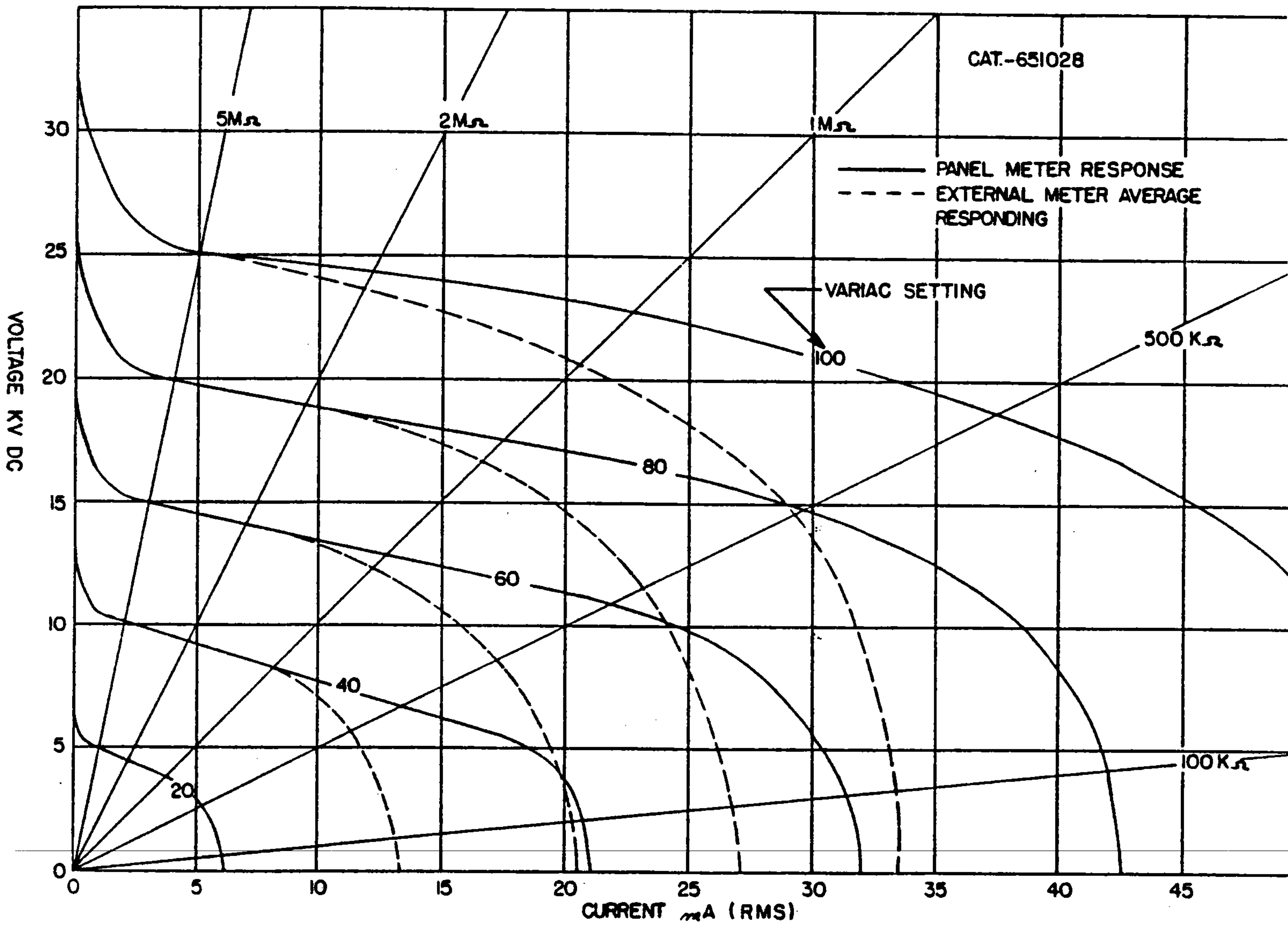


Figure 9: Typical Voltage Regulation Curve.

SECTION N

PARTS LIST

SYMBOL	DESCRIPTION	QTY	PART NO.
	CONTROL UNIT ASSEMBLY NO. 19925		
B1	Timer	1	7241-2
CB1	Circuit Breaker	1	6807-15
DS1	Indicator Light (Amber)	1	15099-2
DS2	Indicator Light (Red)	1	15099
K1	Relay	1	17831
M1	Milliammeter	1	19937-2
M2	Kilovoltmeter	1	19937-1
PCB1	Printed Circuit Board Assembly	1	19470
	a. SW2 A&B		19831-4
	b. Potentiometer		5694-1
	c. Surge Voltage Protector		10189
RV1, 2	Varistor	2	3384-2
SW3	Switch	1	19152
SW1	Mode Selector	1	19955
	a. SW1C, SW1D	2	19152
	b. Cam	1	19936
	c. Small Contact Holder	2	19944
	d. Large Contact Holder	2	19945
	e. Shaft & Arm Assembly	1	19956
T3	Transformer	1	15573-1
T1	Variable Autotransformer	1	16820
TB1	Terminal Block	1	7998-14
	Relay Socket	1	17832
	Cam (Zero Start)	1	16112
	Bulb (G.E. No. 1815)	2	3612-7
	HV POWER PANEL ASSEMBLY NO. 19967		
C1	~~Capacitor~~	~~1~~	~~18307-7~~
C2	Capacitor	1	18307-6
CR1-14	HV Rectifier Assembly	1	19941-1
R1	Resistor	1	9325-12
R2, R3	Resistor	2	4694-12

PARTS LIST (cont'd)

SYMBOL	DESCRIPTION	QTY	PART NO.
	IMPULSE & DISCHARGE PANEL ASSEMBLY NO. 19966		
L13, L4	Solenoid	2	3817-3
R9, R10	Resistor	1	18948-4
R16	Resistor	1	8199-3
SW4	HV Impulse Switch	1	19864
	a. Contact Plate & Shaft Assembly	1	19865
	b. Electrode Assembly	2	19870
	c. Housing	1	19873
	d. End Plate	2	19874
	e. Base Plate	1	19963
	f. Solenoid	1	3817-3
TB2	Terminal Block	1	7998-9
	IMPULSE GENERATOR/CABLE TEST SYSTEM #651028		
C4	Capacitor, 4 μF @ 25 kV	1	19264-1
	Insulating Tray for above	1	19939
	Capacitor Hold-Downs	2	25410
J1	Interlock Connector	1	10225
L1	Choke Assembly, 60 Hz	1	19690-1
L1	Choke Assembly, 50 Hz	1	19690-2
P1	Shorting Plug, Interlock	1	10226
T2	Transformer, HV	1	19689
T4	Step Down Autotransformer	1	19902
W1	Input Cable Assembly	1	19266-1
W2	Ground Cable Assembly	1	19265
W3	Output Cable Assembly	1	19962
	Cable Hanger	1	19861
	Viewing Window	1	19863
	Cover	1	19268
	Casters (if applicable)	4	8574

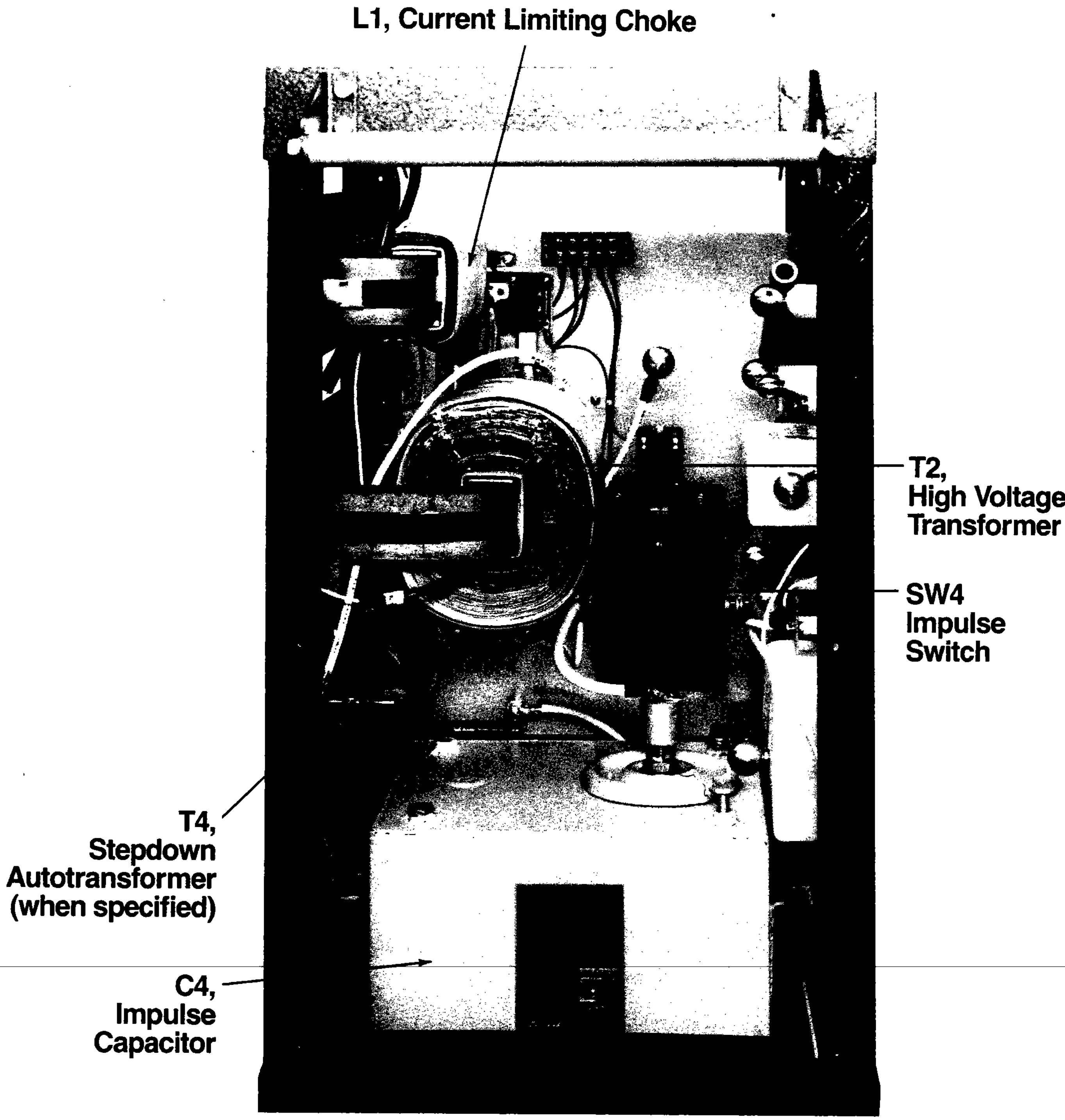


Figure 10: Right Side View.

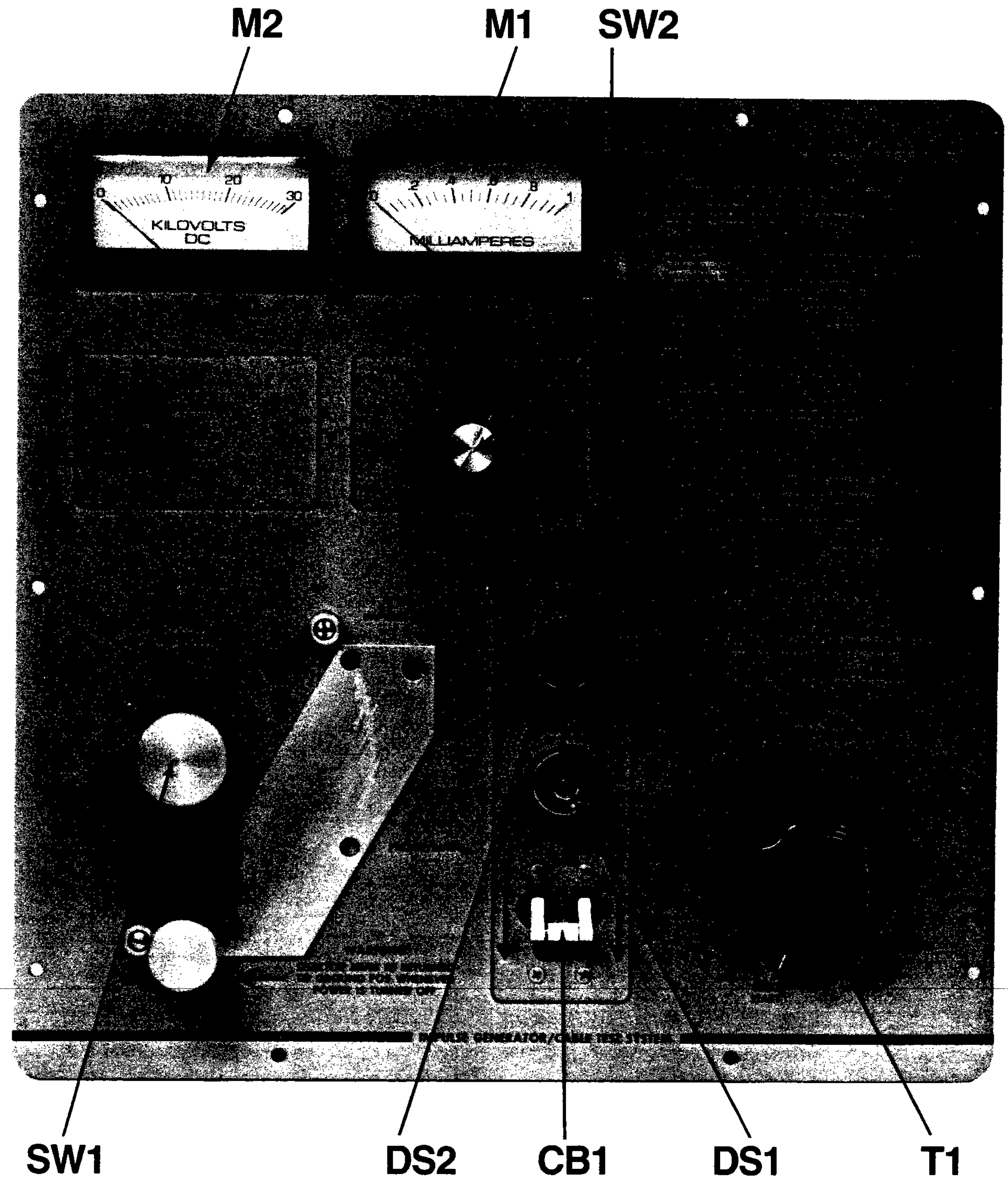


Figure 11: Control Panel, Front View.

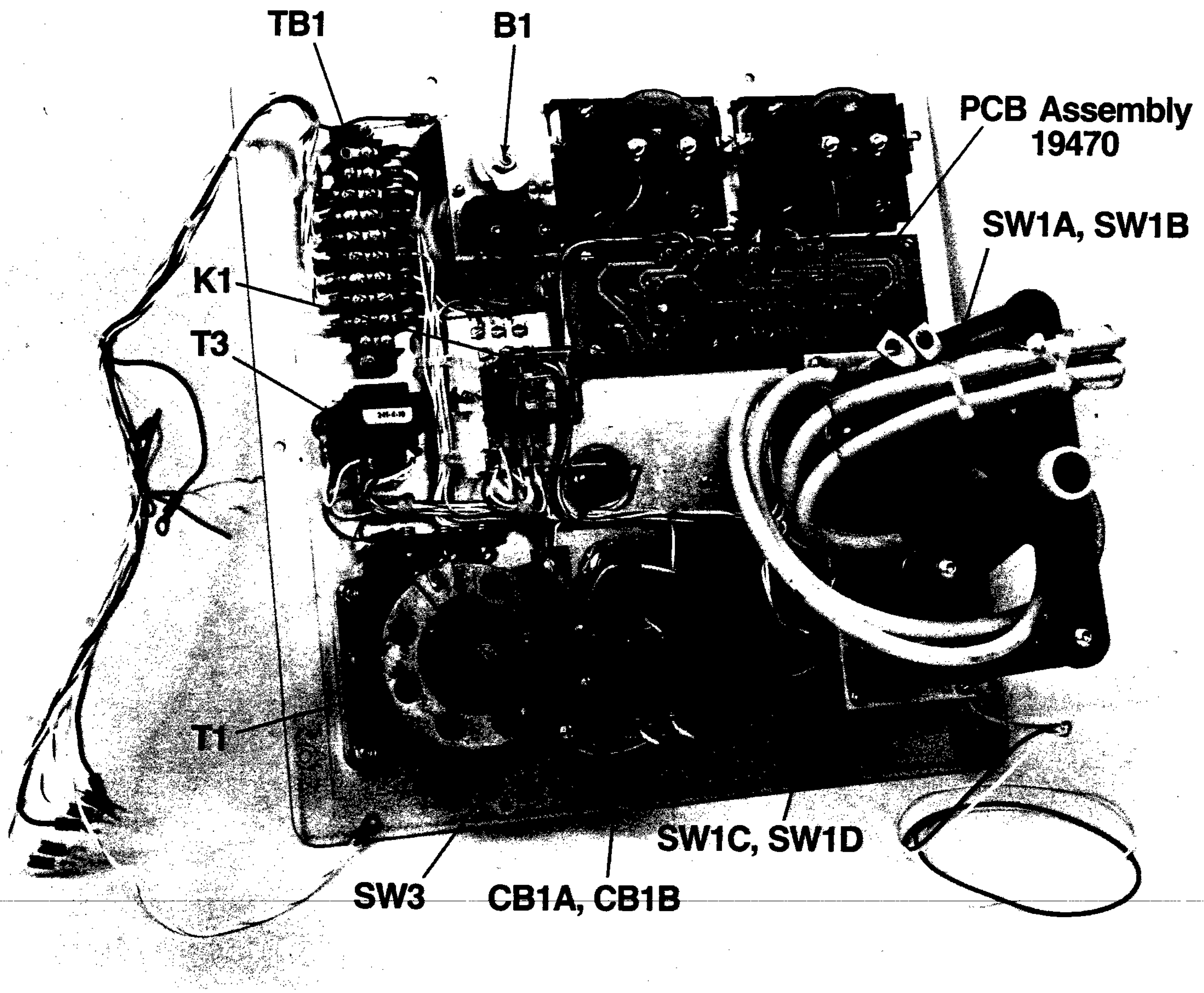


Figure 12: Control Panel, Rear View.

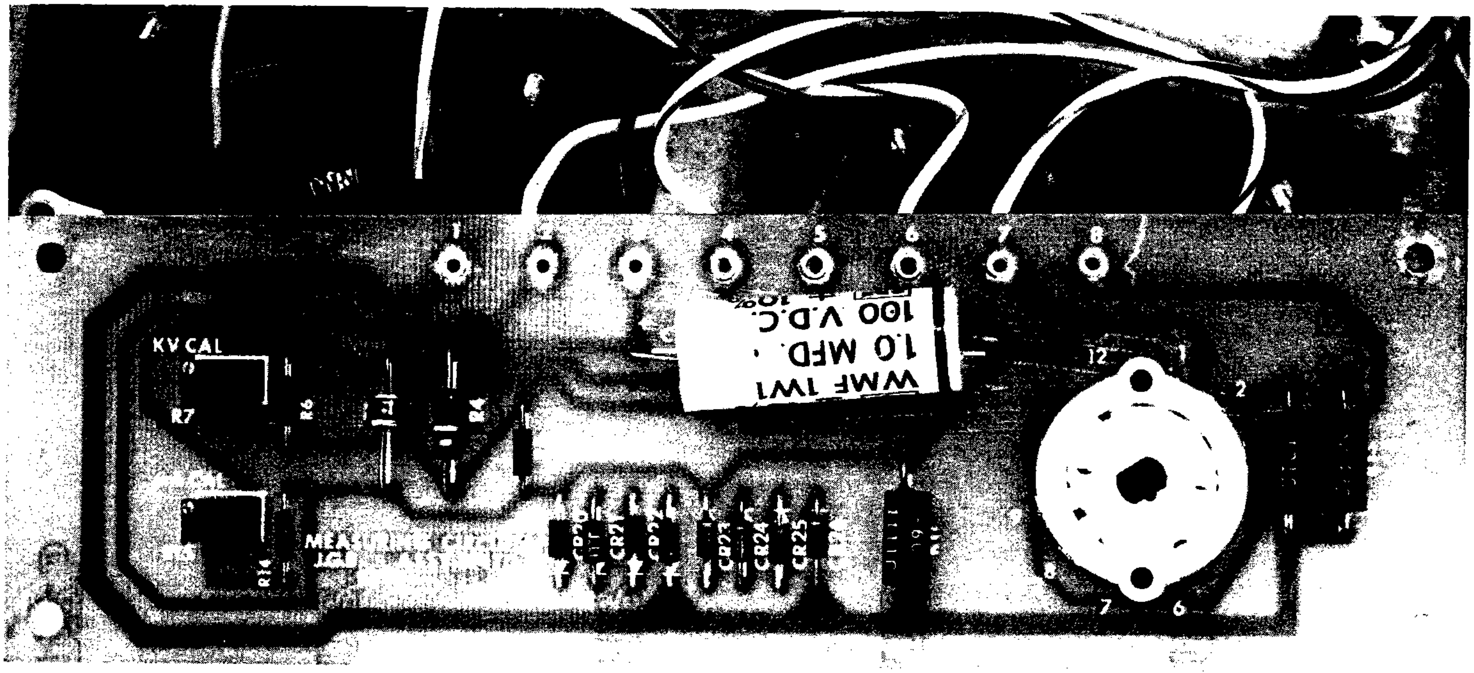


Figure 13: P.C. Board Assembly.

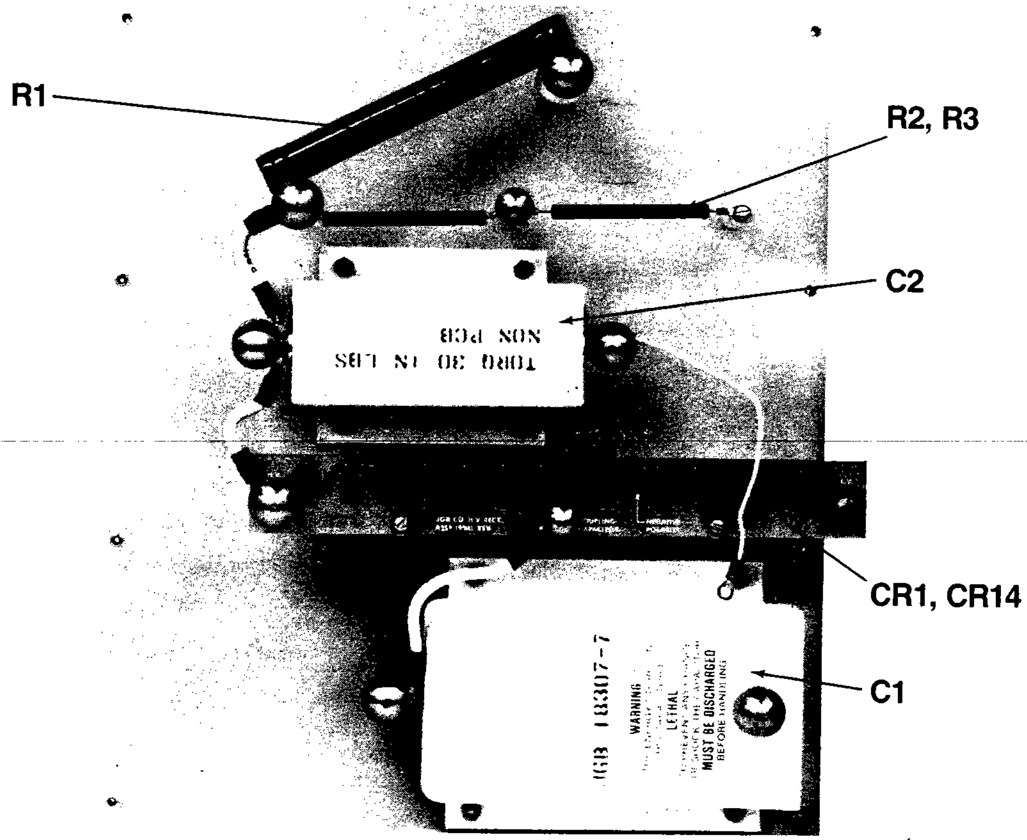


Figure 14: High Voltage Power Supply Assembly.

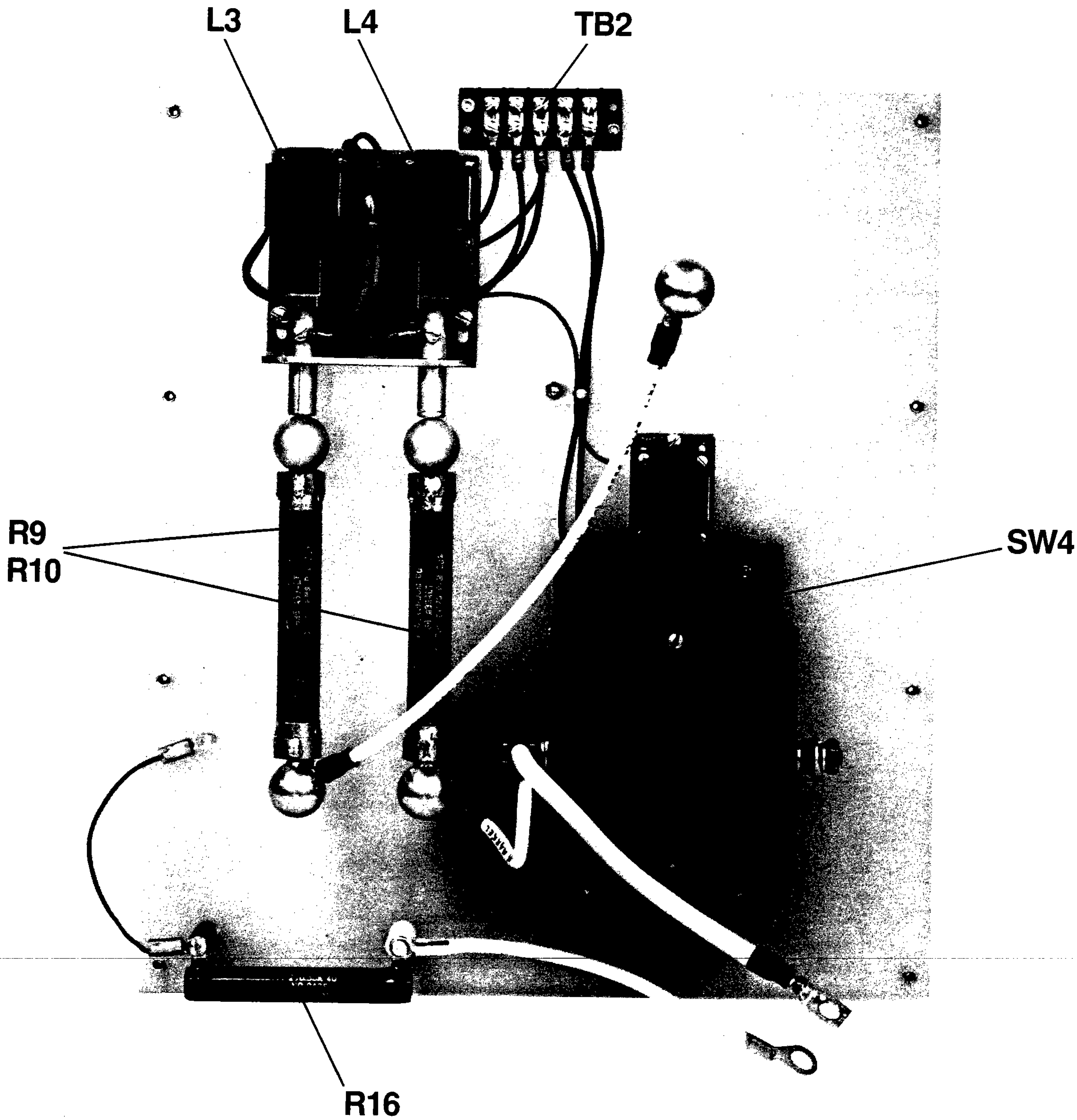


Figure 15: Impulse and Discharge Panel Assembly.

SECTION P

WARRANTY AND REPAIRS

All products supplied by Biddle Instruments are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped Prepaid and Insured. The warranty does not include batteries, lamps, or tubes, where the original manufacturer's warranty shall apply. WE MAKE NO OTHER WARRANTY.

The warranty is void in the event of abuse or failure by the customer to perform specified maintenance as indicated in the manual.

REPAIRS

Biddle Instruments maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend that it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured, and marked for the attention of the Instrument Service Manager.

ENGINEERING MEMORANDUM

NO. 147

SUBJECT

CONNECTIONS OF HIGH VOLTAGE IMPULSE GENERATORS FOR CABLE FAULT LOCATING.

ABSTRACT

This memo covers the correct connections and use of High Voltage Impulse Generators for Cable Fault Locating. Safety of personnel and equipment is stressed.

DESCRIPTION

High Voltage Impulse Generators or "thumpers" for locating cable faults are designed to be used primarily only on insulated conductors having an individual coaxial metallic shield, a concentric neutral, a common metallic (lead) sheath, or a metallic armor. In the usual installation, the metallic shield, neutral, sheath or armor will normally be grounded solidly either continuously or at convenient intervals along the length, usually at each splice. For impulsing purposes, the conductor must be de-energized and isolated at all terminations with all other conductors grounded. The purpose of the Impulse Generator is to create a discharge at the fault that results in a sonic, visual, or electromagnetic signal which can be traced to the fault.

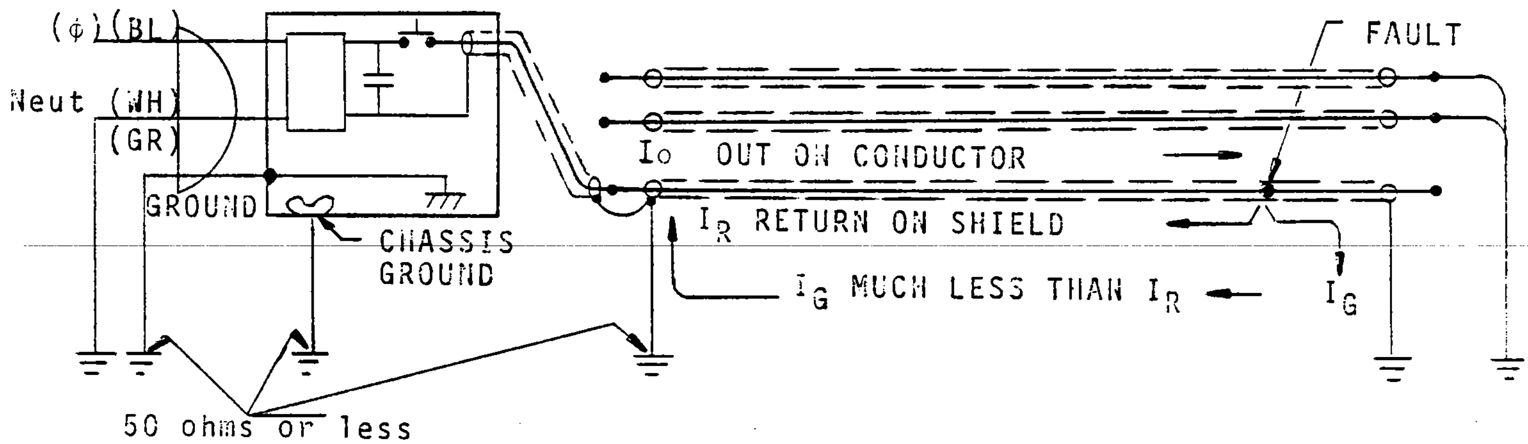


Fig. 1 Shielded Cable

By H. L. Latham
5-28-80

Shielded Cable. As shown in Figure 1, the shielded output cable of the Impulse Generator must be connected with the high voltage lead (center conductor) to the insulated conductor being tested and with the low voltage lead (shield) to the shield, concentric neutral, lead sheath or armor of the cable-under-test. The low voltage lead of the output cable must be solidly grounded at this point, even though the shield, neutral, or armor is also grounded at numerous other points. A connection is required from the wing nut on the Impulse Generator panel or chassis to a solid ground(driven rod, water pipe, etc.) This connection parallels the grounding wire in the input power cable and increases personnel safety. The Biddle Suitcase Thumper (Catalog No. 651401) is an exception to this rule because the extra ground lead is not required since the maximum output power is lower.

Isolated Output. In the Biddle Cat. No. 651401, 651027-1, 651028, 651620, 653030,and 653031, the high voltage output circuits are internally isolated from the remainder of the test set. This is to minimize the risk of damage to the Impulse Generator or other equipment located nearby. This technique controls the path of the return current as shown in Figures 1 and 2.*

Grounding. When a portable field generator or an inverter is used for the ac source, the supply neutral, ground return and other frame numbers always must be grounded to local earth. Any variation from the specified connections may result in a hazard to personnel or in damage to the Impulse Generator or other equipment nearby. Although they are shown grounded at separate points, there should always be less than 50 ohms of resistance between the output low voltage lead, the supply source, the chassis ground, and the local earth. The lower all these resistances are the better.

Output Extension. As stressed in instruction manual, it is a serious violation of the specified connections to extend the length of the low voltage lead of the output cable, as this may introduce excess impedance in the return path and overstress the insulation of the output circuit and cable. An adequate length of output cable is provided with each model to accommodate almost any situation. Should it be impossible to reach a terminal for testing, any extension must be grounded at the output low voltage lead and the extension must consist of a shielded conductor so as to maintain the integrity of the shield and its insulation throughout. Thus, it actually becomes an extension of the cable-under-test rather than of the output cable.

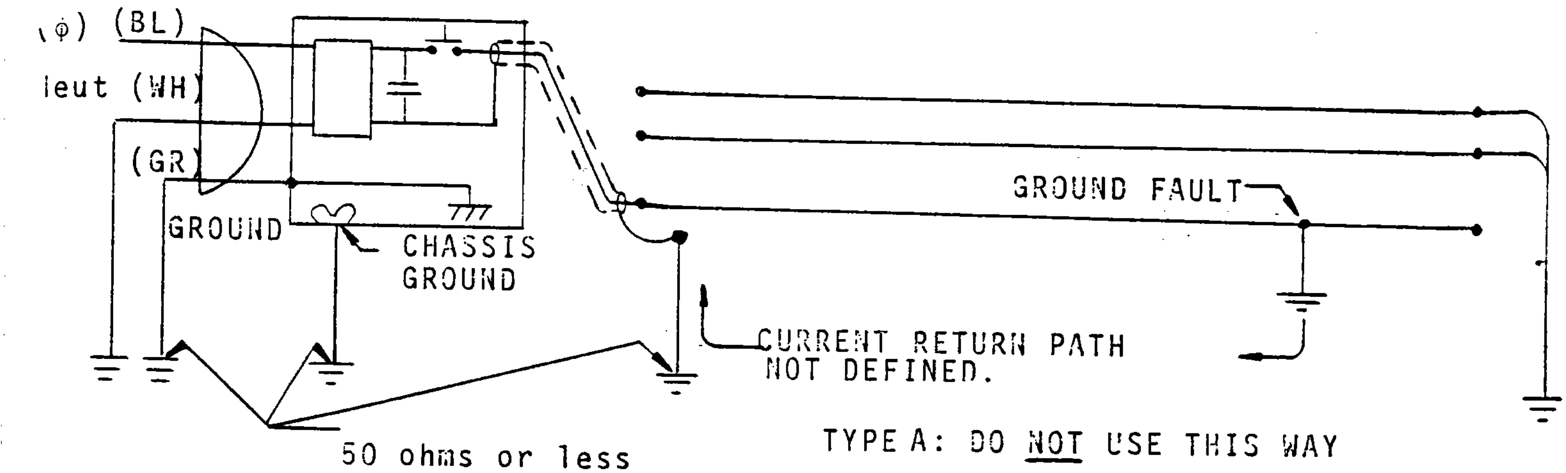
*For further details, see Biddle Technical Manual page 65-P24 and reprint 65-P2 "A Safer Thumper has Insulated Impulse Circuit".

Nonshielded Cable. There are two types of faults in unshielded cable which may be located using an Impulse Generator. Figure 2 (A) shows a type where the Impulse Generator should not be used for fault location. In this case there is a hazard in instantaneously elevating the earth or conduit surrounding the fault to a high voltage with each discharge. Because of the absence of an intimate shield, concentric neutral, lead sheath, or armor, that can be connected to the output low voltage lead, the discharge at the fault releases a high instantaneous surge current that will find its way over any available path in returning to the Impulse Generator. Such paths represent an excessive impedance to the surge return with possible overstress of the Impulse Generator or other equipment. Personnel or livestock on the surface may be subjected to shock or discomfort; other nearby cables, piping, conduit or other metallic structures may pick up and carry the surge some distance with similar effects. It does not help to connect the output low voltage lead to a good parallel conductor that was grounded at the opposite end as this would only re-direct the surge return through a different high impedance path. Also, the relatively high impedance earth return will severely reduce the magnitude of the impulse. The solution of this problem is to use a low voltage method, such as the Biddle 651000-1 DC Earth Gradient Fault Locator for direct buried nonshielded cable, a method which actually takes advantage of the potential gradient in the earth surrounding a fault to locate it, but does so at much safer voltages, typically 1-3kV.

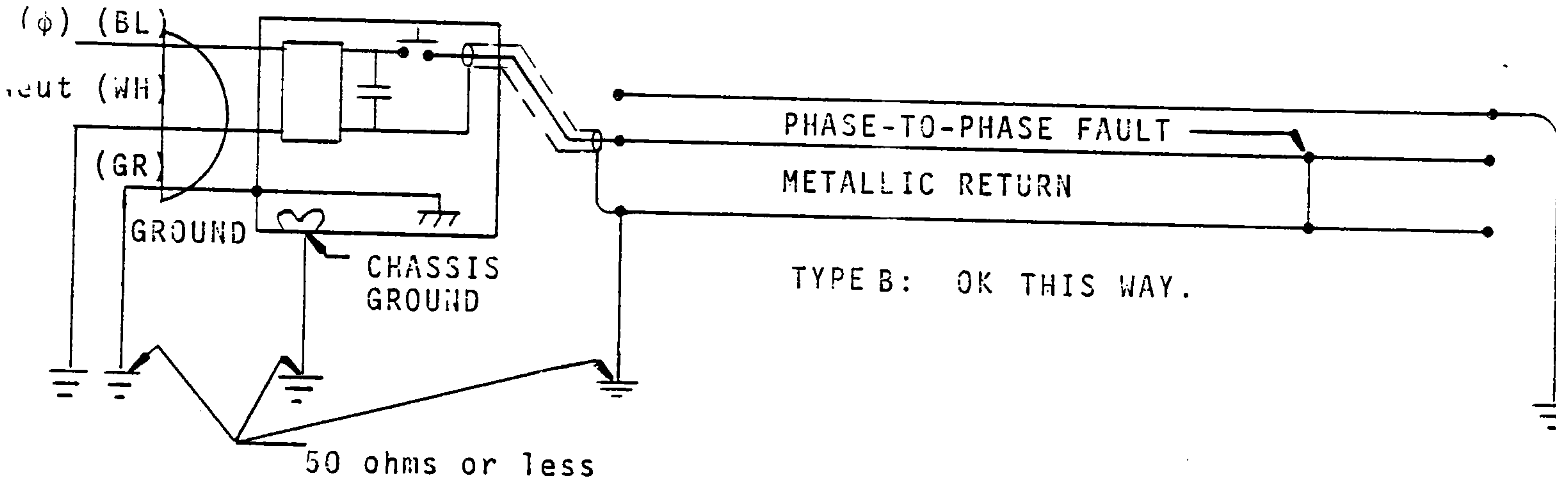
Figure 2 (B) shows circumstances when a High Voltage Impulse Generator may be used safely on nonshielded cable. These occur when there are other parallel conductors in the same route, as with triplexed secondaries. One is a phase-to-phase fault, as shown in Figure 2, Type B, where one of the faulted phases can be used for the low voltage return. The other is an open circuit fault as shown in Type C below where a good conductor can be jumpered to the faulted one at the opposite end and thus used for the low voltage return so that the impulse can be discharged across the open circuit. In each of these latter two there is a metallic return, just as there would be with shielded cable.

Of course, the connections for types B and C could also be used on shielded cable when contending with phase-to-phase or open circuit faults on that kind of cable.

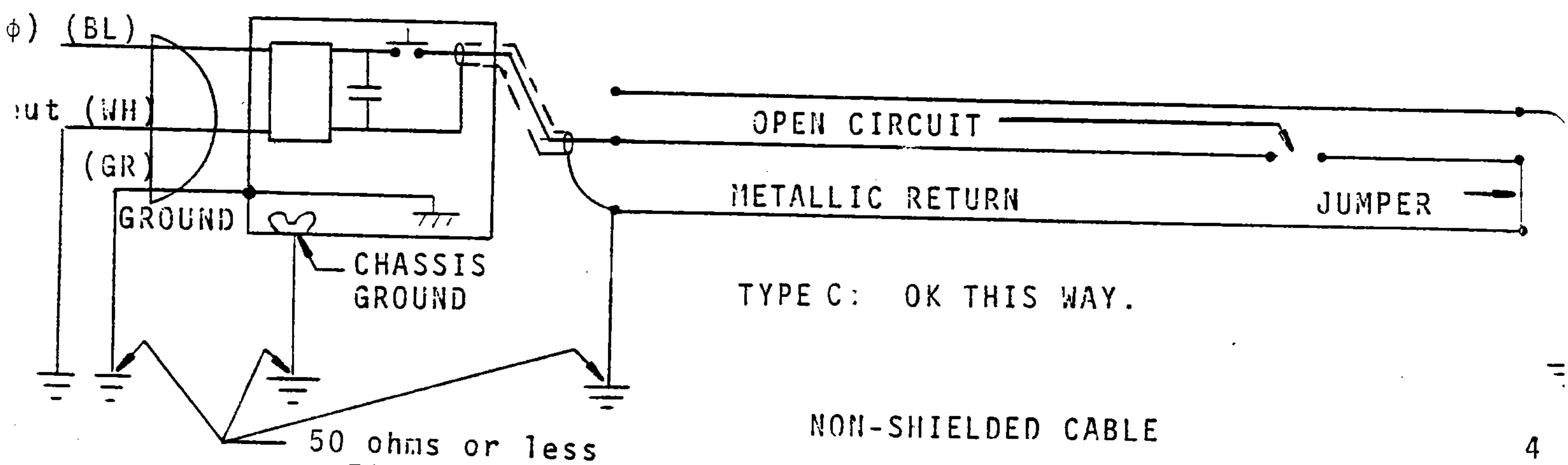
Low voltage buried URD cable of the kind having duplex or two parallel conductors bound under a common co-concentric neutral is considered to be shielded cable and may be impulsed provided that, as with any cable, the neutral is unbolted and isolated at all service connections.



TYPE A: DO NOT USE THIS WAY



TYPE B: OK THIS WAY.



TYPE C: OK THIS WAY.

NON-SHIELDED CABLE

Fig. 2

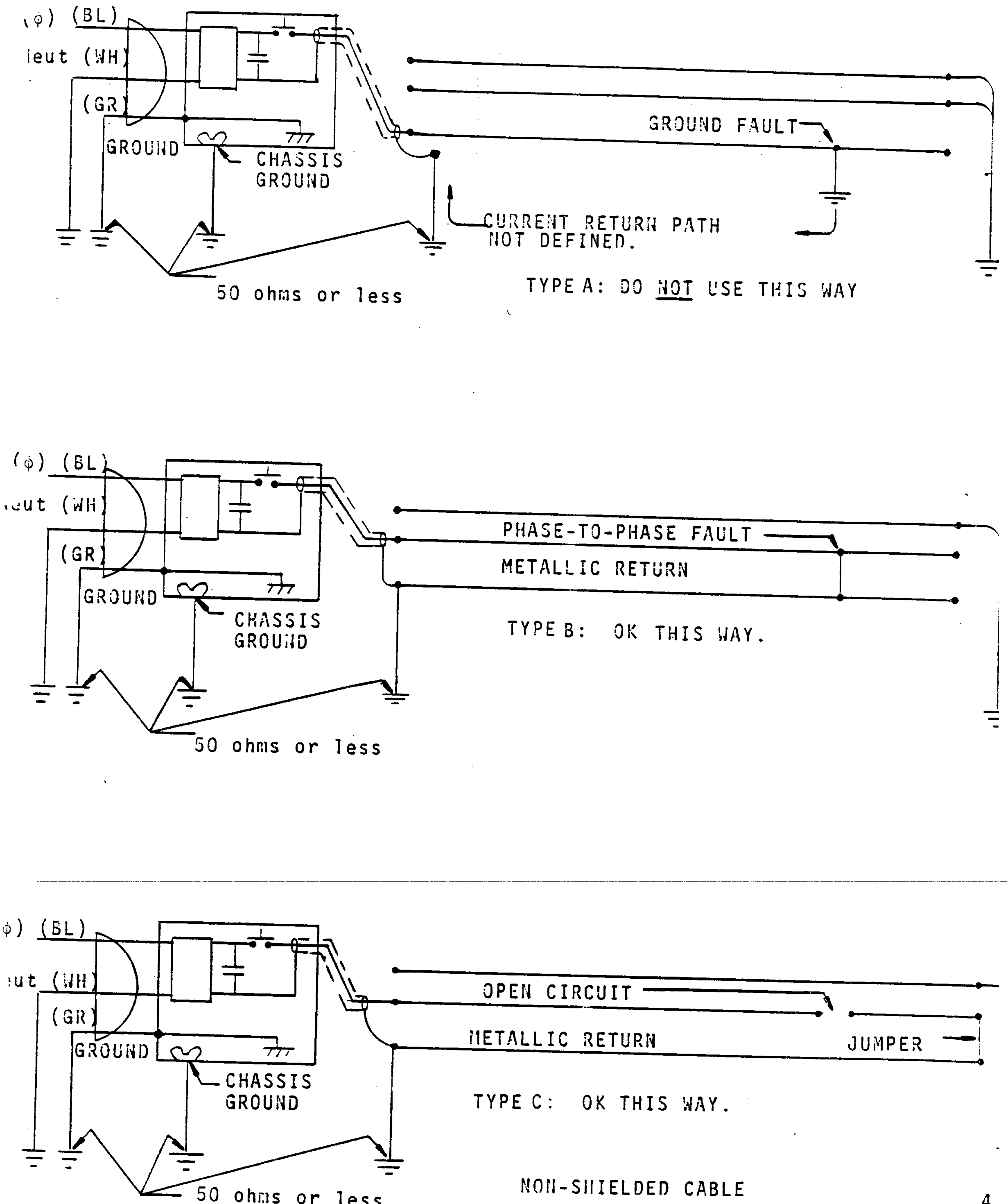

(φ) (BL)
Neut (WH)
(GR)
GROUND
CHASSIS GROUND
GROUND FAULT
CURRENT RETURN PATH NOT DEFINED.
50 ohms or less
TYPE A: DO NOT USE THIS WAY
(φ) (BL)
Neut (WH)
(GR)
GROUND
CHASSIS GROUND
PHASE-TO-PHASE FAULT
METALLIC RETURN
TYPE B: OK THIS WAY.
50 ohms or less
(φ) (BL)
Neut (WH)
(GR)
GROUND
CHASSIS GROUND
OPEN CIRCUIT
METALLIC RETURN
JUMPER
TYPE C: OK THIS WAY.
NON-SHIELDED CABLE
50 ohms or less

Fig. 2