MODEL PDC-20HC
In-Line Pinhole Detector for Sheet and Film

- Dielectric flaw detector for continuous sheet and film
- Reliable pinhole detection at virtually any speed
- Tests wide range of products
- Regulated test voltage
- Digital voltage display

Manufacturers of continuous plastic film and sheet have long sought an economical method of locating pinholes and flaws during the production process. In-line optical and laser systems are costly and complicated, and manual inspections after the fact are time-consuming, sometimes yielding high scrap levels.

Clinton Instrument Company introduces the Model PDC-20HC In-Line Pinhole Detector, a low-cost, non-destructive electronic system that instantly locates defects in dielectric materials on the production line. The PDC-20HC consists of a control unit, a fault sensor, and a current limiting resistor assembly. The test product is positioned between the charged anode and a grounded electrode.

Defect-free product will insulate the sensor from ground. However, when a pinhole is detected, a discharge through the hole will occur that is instantly detected and reported by the system.

The control unit regulates and displays the applied test voltage on a digital voltmeter, reports faults on a digital counter and fault light, and provides various process control outputs that can activate external lights, alarms, and auxiliary machinery when a fault is found. Typical test products are sheet, film, and bags made of polyethylene, polyurethane, TFE, and PVC, with thicknesses from .001" to .100" and widths to 144". Please consult the factory regarding your specific application.

The PDC-20HC In-Line Pinhole Detector is easy to use and current limited for safe operation. Its advanced circuitry delivers optimum fault detection at virtually any production line speed.

The system is easy to install on an existing machine. Select a location for the anode. An ungrounded grounded conveyor roller is ideal for the grounded electrode. The product should travel over this roller as shown at the right. Test the product before trimming edges, as the product cannot be tested to the edge.
**PDC-20HC**

**SPECIFICATIONS**

Voltage Test Range: 500v to 20KV (minimum voltage varies on electrode design).

Output Current: 6 mA. maximum.

Fault Indication: red 3-digit 14.2mm high LED display; amber indicating light.

Fault Response: Less than 1 millisecond.

Fault Resolution: 1.5 milliseconds.

Detection Sensitivity: 600 µA. at 5KV.

Operating Modes: Continuous HV/Remove HV on Fault. Momentary Process Control/Latch until Reset.

Electrode/Sensor: Consult Factory.

Process Control: Relay, form “C” contacts rated 1 amp max @ 240VAC, 2 amps max @120VAC, for both NO and NC circuits.

Power Requirements:

- 100 to 240VAC 1 amp, 49-61 Hz. Power supply is self-adjusting.
- Communications: RS-485 Serial Interface; Analog (optional); Ethernet (optional); Profibus (optional).

Safety: Designed to IEC-1010.

---

**Front View**

**Side View**

**Mounting Dimensions**

Dimensions in inches [millimeters]

---

**CURTAIN SENSOR (ELECTRODE) DIMENSIONS**

- Drilled & Tapped 3/8-16 (2 places)
- Overall Unit Length: Electrode Length plus 4.32 inches
- 61/2 thru 2 places
- Bead Chain Length: 4.75 inches
- Electrode Length: Product Web Width less 1-1/2 inches

High-voltage interconnect not shown. Mounting hardware not included.

---

**Clinton Instrument Company**

295 East Main St. • Clinton, CT 06413 USA • Tel: 860.669.7548 • Fax: 860.669.3125 • www.clintoninstrument.com

Specifications subject to change without notice. 10/09 BN
Table of Contents

Safety .................................................................................................................................................................... 1
Electrical Shock Hazard from Production Line Spark Testers ................................................................. 2
Installation ........................................................................................................................................................... 3
Terminal Block Connections ............................................................................................................................ 5
Spark Tester Controls ........................................................................................................................................ 9
Front Panel Programming ..............................................................................................................................10
Programming through the RS-485 Interface ...............................................................................................14
Testing Your Product ......................................................................................................................................19
Calibration .........................................................................................................................................................21
Maintenance ......................................................................................................................................................23
Troubleshooting ...............................................................................................................................................24
Replacement Parts / Optional Accessories .................................................................................................25
Warranty ............................................................................................................................................................26
Electric Shock Considerations for Electric Vehicle Charging Systems ...................................................27
Grounding of Conductors During the Spark Test .......................................................................................Appendix
Safety

Do not install substitute parts or perform any unauthorized modification to the instrument.

The Caution symbol found in the instruction manual calls attention to a procedure, practice, or the like, which if not correctly performed or adhered to, could result in personal injury or damage to or destruction of part or all of the product. Do not proceed beyond a Caution symbol until the indicated conditions are fully understood and met.

Safety Symbols

The symbols depicted below are safety symbols placed on the spark test equipment. It is important to understand the meaning of each.

- **Instruction manual symbol.**
  - **Caution - refer to the manual to protect against damage to the equipment or to avoid personal injury.**

- **Caution - risk of electric shock symbol.**

- **Earth (ground) symbol.**

Environmental Conditions

The Model PDC-20HC Digital In-Line Pinhole Detection System is designed to be safe under the following conditions:
- Indoor use.
- Altitude to 2000 m.
- Temperatures from 5°C to 40°C.
- Humidity to 80% R.H. at 31°C, decreasing linearly to 50% R.H. at 40°C.

The Clinton Instrument Company certifies that this equipment met its published specifications at the time of shipment. Clinton further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology to the extent allowed by the Institute’s calibration facility. For customer service or technical assistance with this equipment, please contact:

The Clinton Instrument Company
295 East Main Street, Clinton, CT 06413 USA
Telephone: 860-669-7548 • Fax: 860-669-3825
Website: www.clintoninstrument.com
Email: support@clintoninstrument.com

Avoid the Risk of Fire!

Every time your line stops, be sure that the HV in the electrode goes off. If the HV remains ON while your line is stationary, the insulation within the electrode will heat and there is a danger of combustion. Refer to the table in “Installation” labelled “Terminal Block Connections,” under HV Enable on how to safely install your equipment.
Electrical Shock Hazard From Production Line Spark Testers

by Henry H. Clinton

The commonly accepted maximum values of 60 Hz. current passing through the human adult body which permit a subject to let go of electrodes are nine milliamperes for males and six milliamperes for females. At 3000 Hz. this value increases to about 22 milliamperes for men or 15 milliamperes for women. DC currents do not present the same let–go problems, but a subject can readily let go at a level of 60 milliamperes.

A continuous 60 Hz. current above 18 milliamperes stops breathing for the duration of the shock only. Ventricular fibrillation may occur above a level of 67 milliamperes.

The reaction current level of 60 Hz. is about .5 milliamperes. Above this level a muscular reaction can occur which can cause a secondary accident. The DC and 3 kHz. levels are probably considerably higher.

Capacitor discharge energy of 50 Joules (watt–seconds) is regarded as hazardous.

Clinton DC spark testers are current limited to 5 milliamperes or less. Three kiloHertz spark testers are limited to 4 milliamperes or less, and 60 Hz. types to 7 milliamperes. Impulse spark testers can deliver a maximum charge of about .2 Joules 248 times per second. All these spark testers have current outputs above the reaction level, but none above the let–go threshold level. Because of the possibility of secondary accidents caused by muscular reactions, operators should be protected against accidental shock. Electrodes are supplied with interlock switches, and these should not be disabled. The conductor under test should be grounded. If an operator must inspect the product by touching its surface while it is being spark tested, he should be electrically insulated from his environment, and any possible cause of a secondary accident caused by reaction should be eliminated.

Installation

CAUTION: The installation procedures listed below are to be performed by qualified service personnel only. Failure to follow these procedures may result in danger to personnel and equipment damage.

Introduction

The PDC-20A Digital In-Line Pinhole Detection System consists of a control panel and interconnecting cables that will connect to a customer-supplied electrode (fault sensor or CIC Test Module). The sensor should be designed to meet the requirements of your application. Please consult the factory if assistance is required with sensor design or installation.

Unpacking

Remove the Pinhole Detector from the carton. Retain the packing material in the event that the unit is returned for calibration or service at some future time.

The following items are included:
1. PDC-20HC Pinhole Detection System.
2. High voltage cable assembly 91611 & Interlock cable assembly 90334B-10.
3. A power cord.
4. A green terminal block connector for process control connections. After it is wired, it will plug into the terminal block on the back of the spark tester.
6. Rack Mount Kit.

Site Preparation

Select a suitable location for the PDC-20HC:
The PDC-20HC is designed for use in a fixed location, permanently connected to its power source. The unit may be mounted on a table and should be placed at wire line height and within easy reach of the operator. Review the diagram located on the specification sheet for mounting dimensions.

To mount the PDC-20HC on a horizontal surface:
With a screwdriver, remove the (4) plastic feet from the tapped inserts in the bottom of the spark tester chassis. Insert (4) M-6 screws through the mounting surface into the (4) tapped inserts. Be sure the screws do not extend into the chassis more than ½ inch (12mm).
Model PDC-20HC In-Line Pinhole Detection System

Installation Cont.

CAUTION: Be sure the external disconnecting device is OFF and locked out before continuing.

Rack Mount Assembly:

To install the PDC-20HC in a rack or panel, the space must be 6” H x 19” W to insure that there is a minimum clearance of 1/4” on the top and bottom of the control unit for ventilation. Install the rack mount kit (supplied with the control unit) using the 6 8-32 x 1/2” screws and lockwashers provided. Slide the control unit carefully into place.

Install an external disconnecting device (“Panic” or “Kill” Switch):

Install an external switch or circuit breaker in close proximity to the spark tester and within easy reach of the operator. The switch or circuit breaker must meet the relevant requirements of IEC 947-1 and IEC 947-3 and should be marked as the disconnecting device for the equipment. The rating of the circuit breaker or fuse should be no greater than 5 amperes.

Ground the PDC-20HC:

Locate the safety ground terminal on the back panel of the spark tester. Remove the outer nut and the crimp terminal. Crimp a 16 ga. (1, 29 mm², 1, 31 cross section) stranded insulated wire (preferably green with a yellow stripe) to the crimp terminal. Fasten this to the safety ground terminal and secure with the keps nut. Connect the other end to a safety ground system in accordance with EN 60204-1:1993, Section 5.2, Table 1.

Terminal Block Wiring:

Refer to the table on the following page for information on pin functions. Locate the green terminal block on the back of the spark tester and its companion green terminal block connector that came with the unit. Conductors connecting auxiliary equipment, relays and switches should be shielded 22 gauge or larger and should be stripped back ¼” (6mm) and fed into the green terminal block connector at the proper pin number. Shields from conductors connecting auxiliary equipment should be grounded to the safety ground terminal.
## Wiring: Terminal Block Connections

<table>
<thead>
<tr>
<th>Terminal Block Connections</th>
<th>Pin No.</th>
<th>Designation</th>
<th>Conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fault Indication:</strong> To activate external lights, alarms, or relays* when a fault occurs, wire them between fault relay contact Pins 7, 8, &amp; 9. In Latch Mode (Lch = ON) (set on the display), the fault relay contacts NO &amp; COM will remain closed until the RESET button is pressed or when Pins 1 &amp; 3 are closed by remote switch or relay. In Non-Latch Mode (Lch = OFF), the fault relay contacts will return to normal state after the interval known as the PCd (Process Control Duration, set on the display) has elapsed.</td>
<td>9</td>
<td>NC</td>
<td>(3) 22 ga. stranded conductors rated 250V, less than 10 meters in length, contained in a common insulating sheath.</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>COM</td>
<td>FAULT RELAY</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td><strong>HV ON Indication:</strong> HV ON relay contact Pins 5 &amp; 6 will close when the test voltage exceeds 50v. For an indication that HV is ON in the electrode, wire a lamp or auxiliary device* here.</td>
<td>6</td>
<td>COM</td>
<td>HV ON RELAY</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td><strong>External Reset:</strong> To reset the sparktester fault relay with an external switch, wire a normally open switch** between Pins 1 &amp; 3. When the switch closes, the fault relay will return to a normal state. The interval that the switch is closed must exceed 100 ms.</td>
<td>3</td>
<td>RESET</td>
<td></td>
</tr>
<tr>
<td><strong>HV Enable:</strong> <strong>CAUTION:</strong> For HV on the electrode, install a normally closed switch or relay contact** between Pins 1 &amp; 2 (GND and HV ENABLE). This switch should be linked to your wireline stop switch so that the connection between pins 1 &amp; 2 opens automatically whenever your wire line stops. <strong>FAILURE TO DO SO COULD RESULT IN A FIRE HAZARD.</strong> If the HV remains ON in the electrode when your line is stationary, the wire insulation within the electrode will heat and there is a danger of combustion.</td>
<td>2</td>
<td>HV ENABLE</td>
<td>(3) 22 ga. stranded conductors.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>GND</td>
<td></td>
</tr>
</tbody>
</table>

* When connecting auxiliary equipment to relay contact pins 5, 6, 7, 8, or 9, observe maximum ratings of 120VAC at 2 amps, 240VAC at 1 amp.

** Switches and relays connected here to pins 1, 2 & 3 should be suitable for 24V low current applications.
Cable Assemblies for customer-supplied sensors/electrodes

Insert the white probe of the 91611 HV cable assembly into the jack located on the top left hand side of the spark tester back panel. Connect the other end of the cable assembly to the HV input of your electrode/sensor (customer supplied). Connect the ground terminal to the metal electrode containment. Connect the green connector of the 90334B-10 interlock cable assembly into the 3-pin green connector marked “interlock”, located on the bottom left hand side of the spark tester back panel. Connect the other end to a NO switch that closes when the protective guard (customer supplied) over your electrode/sensor is in place, allowing high voltage to be present.

Mains Power

Insert the power cord provided with the PDC-20HC into the power entry module on the back of the unit. Mains power for these units is self-adjusting from 100-240 VAC lamp, 49-61 Hz.

Connecting the RS-485 Interface

The PDC-20HC is equipped with an RS-485 serial interface so that the spark tester can receive commands and exchange information with a PLC or Computer. Programming and control of voltage settings, which can be done manually on the DC-10/20A display, can also be done through this interface. Control display buttons are not disabled when the serial interface is in use.

Locate the 9-pin D-Subminiature connector(s) on the back of the spark tester or remote display. The spark tester will receive commands and requests from a computer or PLC through pins 3 and 8 of the connector shown below and will transmit responses via pins 2 and 7. Pin 5 is GND. A corresponding 9-pin D-Subminiature connector is supplied for each back panel connector. If you intend to supply your own RS-485 connecting cables, wire this connector with Alpha 5473C (a 3-pair 24 gauge cable with foil shield) or an RS-485 equivalent.

2 TX+
3 RX+
5 GND
7 TX-
8 RX-
RS-485 Port Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud Rate</td>
<td>9,600 bits per second</td>
</tr>
<tr>
<td>Data Bits</td>
<td>8</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Stop Bits</td>
<td>1</td>
</tr>
<tr>
<td>Flow Control</td>
<td>None</td>
</tr>
</tbody>
</table>

The PDC-20HC has external RS-485 serial ports allowing external monitoring and control. A standard PC has at least one RS-232 serial port. To communicate with the PDC-20HC from a PC, the RS-485 from the PDC-20HC must be converted to RS-232. There are many RS-485 to RS-232 converters available.

If there are serial ports available on your PC, the following converter has been tested and approved by Clinton.

B & B Electronics part number 4WSD9R 2-4 wire 422/485 9 Pin Converter.

It is recommended that the appropriate power supply be purchased as well. B & B Electronics part number 485PS 12VDC Power Supply Adapter

When installing the converter, set the 4WSD9R switches to:
- RS-485
- Echo On
- 4 Wire
- 4 Wire

For purchasing and additional information, please refer to the B & B Electronics company website. (www.bb-elec.com)

A converter cable will be required to connect the 4WSD9R to the PDC-20A. The pinout is shown to the left.

If no serial port is available, there are two additional choices, USB (laptop or desktop) or PCMCIA (laptop only). For more information, proceed to the following sections.
If there are USB ports available on your PC, the Saelig USB-COMi (USB-to-RS-485) converter has been tested and approved by Clinton. You may find this product at many websites, including the Saelig company website (www.saelig.com). An internet search will also produce additional vendors.

A converter cable is required to connect the USB-COMi to the PDC-20HC. The pinout is shown to the left.

<table>
<thead>
<tr>
<th>DC-10/20A Pin</th>
<th>USB-COMi Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

If your laptop does not include a serial port, one option is to use the PCMCIA slot, which is standard on many laptops. The following converter has been tested and approved by Clinton.

Quatech RS-422/485 Serial PCMCIA (part number SSP-200/300).

For purchasing and additional information, refer to the Quatech company website (www.quatech.com).

A converter cable is required to connect the SSP-200/300 to the PDC-20HC. The pinout is shown to the left.

<table>
<thead>
<tr>
<th>DC-10/20A Pin</th>
<th>SSP-200/300 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

Double check all connections. Plug the power cord into the connector on the back panel of the spark tester and the other end into your power source.

Check to make sure that all RS-485 cables are plugged into the proper port.

*See page 14 for RS-485 programming information.*
Spark Tester Controls

1. ON/OFF Power Switch.
   This switch is located on the rear panel of the unit.

2. Voltmeter.
   The voltmeter indicates the voltage at the electrode. When the output voltage is adjusted to 1.0 KV, the voltmeter will read 1.0. A reading of .5 indicates that the voltage at the electrode is 500V.

3. VOLTAGE ADJUST buttons.
   The spark test voltage range is 500v - 20.0 KV.

   The PDC-20HC can be adjusted in 100 volt increments by pressing the up and down VOLTAGE ADJUST arrow buttons under the voltmeter. Press and hold a button to increase the speed at which you change the voltage setting.

   The test voltage can be turned OFF or ON from a remote location under the following conditions: (1) the power switch is ON; (2) there is a remote switch connected between Pins 1 & 2 of the terminal block that is located on the back of the unit.

4. FAULT light.
   The FAULT light will illuminate in response to a single fault in the electrode. It also indicates that the FAULT relay contacts are in fault condition, activating any accessories that are connected. If the Lch (Latch on Fault) function is ON, the FAULT light can be turned OFF in 2 ways: (1) by pressing the RESET button below it; or (2) closing a NO remote switch or relay contacts wired between Pins 1 & 3 of the green rear panel terminal block. Simultaneously, the fault counter relay contacts will reset to normal position. If the Lch function is OFF, the FAULT light will go OFF automatically and the fault relay will return to the normal state after an interval known as the Process Control Duration (PCd, which is programmed on the front panel) has elapsed.
5. **RESET button.**
   If the Lch (Latch on Fault) function is ON, the RESET button will return the fault relay contacts to their normal state and turn OFF the FAULT light. The RESET button will have no effect on the number of faults registered on the Fault Counter.

6. **Fault Counter.**
   The 3-digit Fault Counter registers a count each time a fault is detected in the electrode. It can be reset to zero with the COUNTER RESET button.

7. **COUNTER RESET button.**
   Press to reset the number of faults shown on the Fault Counter to zero.

---

**Front Panel Programming**

1. Turn OFF the PDC-20HC ON/OFF power switch, located on the back panel.

2. Press and hold in the RESET button while turning ON the ON/OFF power switch on the back panel.

3. On startup, the unit will identify itself by briefly displaying the model number in the VOLTMETER and FAULT COUNT display.

4. The Voltmeter and Fault Counter will read: CON SYS (Configure System), indicating that you can now configure the pinhole detection system. Release the RESET button.

5. The 7 functions (Lch, rUF, PCd, ELE, FS, dFn, or EFn), described in the table on the following page, will be displayed on the Fault Counter. The selected option for that function will be displayed on the Voltmeter. Please note that only the first five functions need to be set and that the final 2 functions (dFn & EFn), simply display firmware version numbers of the spark tester.
6. Press an up or down VOLTAGE ADJUST button to choose a different option for that function.

7. To program the next function, press the COUNTER RESET button, and it will display on the Fault Counter. The selected option for this function will display on the voltmeter. Press a VOLTAGE ADJUST up or down arrow button to select a different option for that function.

8. Repeat this sequence for all 7 available functions.

9. When you have made your choices for each of the 7 functions, press the RESET button and they will be accepted and saved by the system. The system will immediately begin to function according to the new system configuration with the voltage at the last preset value.
<table>
<thead>
<tr>
<th>Function</th>
<th>Function Description</th>
<th>Option</th>
<th>Option Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lch</td>
<td>Relay Latches when a fault occurs</td>
<td>ON</td>
<td>When a fault occurs in the electrode, the fault relay (pins 7, 8, &amp; 9) latches in fault mode until manual or remote reset.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OFF</td>
<td>When a fault occurs in the electrode, the fault relay (Pins 7, 8 &amp; 9) closes momentarily, returning to normal position after the PCd (Process Control Duration) interval has elapsed.</td>
</tr>
<tr>
<td>rUF</td>
<td>Remove Voltage on Fault</td>
<td>ON</td>
<td>When a fault occurs, the voltage in the electrode will be removed until manual or remote reset.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OFF</td>
<td>When a fault occurs, the voltage in the electrode will stay ON.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nA</td>
<td>The Remove Voltage on Fault function is not available if the Lch function (Relay Latch on Fault) is OFF.</td>
</tr>
<tr>
<td>PCd</td>
<td>Process Control Duration</td>
<td>numeric</td>
<td>The Process Control Duration (PCd) operates only when the Lch function (Latch on Fault) is OFF. It is an interval that begins when a fault is detected in the electrode and it determines the length of time the fault relay contacts remain closed, energizing any auxiliary equipment connected to those contacts. The PCd may be set for lengths from 100 ms. to 2-1/2 sec. Many alarms and lights require a signal of at least one second in length before responding; the fault relay contact closure time should be set to the duration needed to activate accessories connected to the relay. If a second arc should occur in the electrode before the Process Control Duration has elapsed, the contacts remain closed until that interval has ended.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nA</td>
<td>The Process Control Duration does not apply if the Lch function (Relay Latch on Fault) is ON.</td>
</tr>
</tbody>
</table>

Continued on page 13...
<table>
<thead>
<tr>
<th>Function</th>
<th>Function Description</th>
<th>Option</th>
<th>Option Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPL</td>
<td>Fault Pulse Length</td>
<td></td>
<td>To avoid counting a single fault multiple times, it is necessary to extend the fault pulse to exceed the dwell time. For best results, the fault pulse should be 1.5 times the dwell time.</td>
</tr>
<tr>
<td></td>
<td>The length of time in which additional faults are ignored after detecting the initial fault. The time is in milliseconds.</td>
<td>10-1000</td>
<td>Dwell time is defined as the amount of time that a single point on the product remains within the voltage field supplied by the electrode.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>To calculate the dwell time the formula is:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T = \frac{5L}{Y}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Where:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T =$ Dwell or transit time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$L =$ Electrode length for most applications use a value of 2 inches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$Y =$ Line speed in feet per minute.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For example, a line speed of 50 feet per minute, the dwell time would be 0.20 seconds or 200 milliseconds. A fault pulse value of 300 ms is recommended</td>
</tr>
<tr>
<td>FS</td>
<td>Detection Sensitivity</td>
<td>0 - 99</td>
<td>0 = Most Sensitive (default)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>99 = Least Sensitive</td>
</tr>
<tr>
<td>dFn</td>
<td>Display firmware version number.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFn</td>
<td>Test Module firmware version number</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When the RS-485 interface is connected and the spark tester is powered up, the Interlock Status will be sent automatically over the serial interface. Other information that is required at startup must be requested.

When certain events occur during operation of the spark tester, messages will be automatically sent by the spark tester to the computer or PLC. These include:
- Opening or closing the safety door (Interlock Status - IS)
- When a fault is detected in the electrode (Fault Count - FC)
- Reset of the relay, either manually or when the Process Control Duration times out (Fault Status - FT)
- When the intended test voltage is changed

There are three types of messages that go between the PLC or computer and the spark tester. The first is a Command, which is sent to the spark tester by a PLC or computer to set operational parameters. A common example command would be to set the test voltage of the spark tester to 7.5kV. In reply to this particular Command, the spark tester will send a response message indicating that test voltage has been set to 7.5kV. The last type of message is a Request, sent by the PLC or computer to the spark tester to call for the condition of a specific parameter, such as the actual voltage at the electrode.

All messages are ASCII and use the Format:
```
#ccXXXXSS<CR><LF>
```

Where cc is the two-letter Command, Response or Request; Commands and Responses are in all capital XXXX is the data (present in Commands and Responses, but not normally on Requests). SS is the two-digit hexadecimal checksum of the message excluding the checksum, CR and LF.

<CR> is an ASCII carriage return (hexadecimal 0D)

<LF> is an ASCII line feed (hexadecimal 0A)

Note: The checksum is optional. It is used to determine if a message has been corrupted.

**Checksum Calculation**

The checksum is determined by adding the ASCII characters of the message starting at the # and ending before the checksum. The resulting checksum is a hexadecimal sum represented in ASCII.

An example:
For the Message #PC1237 the sum is calculated by adding the values of each character starting at the # as shown on the left:
We will only use the last 2 digits of the total (83), so the resulting message would be: #PC123783 followed by a CR and LF. If the checksum contains letters, they must be in upper case.

Upon receipt, the message checksum is verified. If the checksum is good, the recipient responds with a ! (ASCII 21H). If the checksum is bad, the response is a ? (ASCII 3FH). A sample message sequence between the PC and a DC-10/20A is shown below. Note the sender should retry sending the message upon receiving a ?. If the checksum is not used, then the characters ! and ? should not be used.

Retries
If the checksum is not used, there should be no retries, otherwise a message will need to be resent under two conditions. The first is the receipt of a negative acknowledgment (the ? character). The second is no response after 30ms. The sender should resend a message up to 5 times at an interval of 30 milliseconds.

The serial interface can be used in place of the buttons and displays on the front panel. The correlation between message and button is shown below. Note that the checksum, CR and LF are absent in these examples.

<table>
<thead>
<tr>
<th>PC/PLC Description</th>
<th>PDC-20HC Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#avFA</td>
<td>Request for current voltage at the electrode</td>
</tr>
<tr>
<td>!</td>
<td>An acknowledgment indicating the message checksum was valid</td>
</tr>
<tr>
<td>#AV008587</td>
<td>Response indicating the voltage at the electrode is 8.5kV</td>
</tr>
<tr>
<td>!</td>
<td>An acknowledgment indicating the message checksum was valid</td>
</tr>
<tr>
<td>#SP007592</td>
<td>A command to set the Set Point (requested voltage) to 7.5kV</td>
</tr>
<tr>
<td>!</td>
<td>An acknowledgment indicating the message checksum was valid</td>
</tr>
</tbody>
</table>

### Programming
The serial interface can be used in place of the buttons and displays on the front panel. The correlation between message and button is shown below. Note that the checksum, CR and LF are absent in these examples.

<table>
<thead>
<tr>
<th>Button(s)/Display/Lights</th>
<th>PDC-20HC Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Adjust Buttons</td>
<td>#SPXXXX Commands the intended voltage (Set Point) to be set to XXXX (hundreds of volts)</td>
</tr>
<tr>
<td>Voltmeter Display</td>
<td>#av Requests the actual voltage at the electrode</td>
</tr>
<tr>
<td></td>
<td>#AV0085 A Response indicating the actual voltage is 8.5kV</td>
</tr>
<tr>
<td>Reset Button</td>
<td>#FR0000 Commands the Test Module to reset the fault relay and light</td>
</tr>
<tr>
<td>Fault Light</td>
<td>#ft Requests the state of the fault relay and light</td>
</tr>
<tr>
<td></td>
<td>FT0001 A response indicating the fault light is ON and the relay is closed</td>
</tr>
<tr>
<td>Fault Count Display</td>
<td>#fc Requests the current Fault Count</td>
</tr>
<tr>
<td></td>
<td>#FC0031 A Response indicating there were 31 total faults detected</td>
</tr>
<tr>
<td>Counter Reset Button</td>
<td>#CR0000 Requests the fault count to be reset to 0</td>
</tr>
<tr>
<td></td>
<td>#FC0000 A response indicating the current Fault Count is 0.</td>
</tr>
</tbody>
</table>
## Commands

The Response chart below indicates the source of the information on Responses.

<table>
<thead>
<tr>
<th>Command Field</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>Sets the Fault Count of the Test Module to 0</td>
<td>Always 0000</td>
</tr>
<tr>
<td>ET</td>
<td>Sets the Electrode Length along the wire line. This is factory set. If the electrode length is changed, this command must be changed so that faults in the electrode are not counted twice.</td>
<td>0001 - 1 inch electrode along the wire line (BD-11, BR-1A) 0002 - 2 inch electrode along the wire line (BD-12, BD-22, BDR-22) 0003 - 3 inch electrode along the wire line (BD-13) 0004 - 4 inch electrode along the wire line (BD-14) 0005 - 5 inch electrode along the wire line (BD-15)</td>
</tr>
<tr>
<td>FM</td>
<td>Sets the Fault Mode of the Test Module.</td>
<td>0000 - Latch OFF (Fault light on and relay closes momentarily for the length of the Process Control Duration). Remove Voltage on Fault is OFF. 0001 - Latch ON (Fault light remains on and process control relay latches after fault until reset). Remove Voltage on Fault is OFF. 0002 - Latch ON, Remove voltage on Fault ON.</td>
</tr>
<tr>
<td>FR</td>
<td>Resets the Fault Relay (process control relay) in the Test Module.</td>
<td>Always 0000</td>
</tr>
<tr>
<td>PC</td>
<td>Sets the Process Control Duration, the length of time the process control relay remains closed after fault detection. Not available if FM is 0001 or 0002.</td>
<td>4 Digits, Indicating time is in ms, from 50ms - 2.5 seconds (0050 - 2500)</td>
</tr>
<tr>
<td>RV</td>
<td>Instructs the Test Module to Remove Voltage at electrode. Does not affect the Set Point.</td>
<td>4 digits, always 0000</td>
</tr>
<tr>
<td>SP</td>
<td>Sets the Set Point, which is the intended voltage at the electrode.</td>
<td>4 Digits representing hundreds of volts (e.g. 0123 represents 12,300 volts)</td>
</tr>
</tbody>
</table>
### Requests

<table>
<thead>
<tr>
<th>Request Field</th>
<th>Description</th>
<th>Data Sent</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>av</td>
<td>Requests the actual high voltage at the electrode in the Test Module</td>
<td>N/A</td>
<td>AV</td>
</tr>
<tr>
<td>et</td>
<td>Requests the Electrode Length</td>
<td>N/A</td>
<td>ET</td>
</tr>
<tr>
<td>fc</td>
<td>Requests the Fault Count</td>
<td>N/A</td>
<td>FC</td>
</tr>
<tr>
<td>fm</td>
<td>Requests the Fault Mode</td>
<td>N/A</td>
<td>FM</td>
</tr>
<tr>
<td>ft</td>
<td>Requests the Fault Status</td>
<td>N/A</td>
<td>FT</td>
</tr>
<tr>
<td>is</td>
<td>Requests the Interlock Status</td>
<td>N/A</td>
<td>IS</td>
</tr>
<tr>
<td>pc</td>
<td>Requests the Process Control Duration, the length of time the Process Control signal remains on after fault detection.</td>
<td>N/A</td>
<td>PC</td>
</tr>
<tr>
<td>sp</td>
<td>Requests the Set Point, which is the intended voltage at the electrode. <strong>Note:</strong> Under certain high load conditions, the actual voltage at the electrode (AV) may not be the same as the set point (SP). It is important to request the actual voltage (AV) when polling the spark tester during operation in order to verify that the spark tester is working at the desired test voltage. Requests the HV transformer type, either normal (0-15kV) or Low-Z (0-10kV)</td>
<td>N/A</td>
<td>SP</td>
</tr>
<tr>
<td>vn</td>
<td>0001 - requests the Control Panel version 0002 - requests the Test Module version</td>
<td>0001</td>
<td>VN</td>
</tr>
</tbody>
</table>
### Responses

<table>
<thead>
<tr>
<th>Request Field</th>
<th>Description</th>
<th>Data</th>
<th>Source of Info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV</td>
<td>Indicates the actual voltage at the electrode of the Test Module</td>
<td>4 digits representing hundreds of volts</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>[e.g. 0123 represents 12,300 volts]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET</td>
<td>Indicates the Electrode length</td>
<td>0001 - 1 inch electrode along the wireline</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>(BD-11, BR-1A)</td>
<td>0002 - 2 inch electrode along the wire line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(BD-12, BD-22, BDR-22)</td>
<td>0003 - 3 inch electrode along the wire line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(BD-13)</td>
<td>0004 - 4 inch electrode along the wire line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(BD-14)</td>
<td>0005 - 5 inch electrode along the wire line</td>
<td></td>
</tr>
<tr>
<td>FC</td>
<td>Indicates the current Fault Count</td>
<td>Number of Faults registered on the counter</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>(0000 - 0999)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM</td>
<td>Indicates the Fault Mode</td>
<td>0000 - Latch OFF [Fault light on and relay</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>[Momentary only lasts for the length of the Process Control Duration]</td>
<td>closes momentarily for the length of the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Process Control Duration]. Remove Voltage on Fault is OFF.</td>
<td>Process Control Duration]. Remove Voltage on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0001 - Latch ON (Fault light remains on and process control relay latches</td>
<td>Fault is OFF.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>after fault until reset). Remove Voltage on Fault is OFF.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0002 - Latch ON, Remove Voltage on Fault ON.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>Indicates that a Fault was just detected [Momentary only lasts for</td>
<td>0000 - No Fault or beyond Process Control</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>Process Control Duration]</td>
<td>Duration].</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0000 - 0999)</td>
<td>0001 - Fault Detected</td>
<td></td>
</tr>
<tr>
<td>IS</td>
<td>Indicates the Interlock Status</td>
<td>0000 - Interlock Open</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>0001 - Interlock Closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Indicates the length of the Process Control Duration ([the interval for</td>
<td>4 digits. Indicating time is in ms, from</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>which the process control relay remains closed after fault detection]</td>
<td>50ms - 2.5 seconds (0050 - 2500)</td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>Indicates the Set Point, which is the intended voltage at the electrode</td>
<td>4 digits representing hundreds of volts</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>[e.g. 0123 represents 12,300 volts]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note: Under certain high load conditions, the actual voltage at the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>electrode (AV) may not be the same as the set point, which is the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intended voltage at the electrode (SP). It is important to request the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>actual voltage (AV) when polling the spark tester during operation in</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>order to verify that the spark tester is working at the desired test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>voltage.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>Indicates the HV transformer Model, either Normal or Low-Z</td>
<td>0001 - Normal (0 - 15kV)</td>
<td>Test Module</td>
</tr>
<tr>
<td></td>
<td>0002 - Low-Z (0 - 10kV)</td>
<td>This is factory set.</td>
<td></td>
</tr>
<tr>
<td>VN</td>
<td>The firmware version numbers for the Control Panel and the Test Module</td>
<td>VN1xyz - indicates the Control panel version</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[x.y.z]</td>
<td>VN2xyz - indicates the Test module version</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[x.y.z]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Under certain high load conditions, the actual voltage at the electrode (AV) may not be the same as the set point, which is the intended voltage at the electrode (SP). It is important to request the actual voltage (AV) when polling the spark tester during operation in order to verify that the spark tester is working at the desired test voltage.
Testing Your Product

CAUTION: During installation, the PDC-20HC Spark Tester was programmed to report and respond to faults in specific ways. Internal settings must not be changed except by qualified personnel.

CAUTION: If the HV remains ON in the electrode while your line is stationary, the product insulation within the electrode will heat and there is a danger of combustion. Refer to the table “Terminal Block Connections” in the “Installation” section of this manual on how to safely install your spark tester.

1. Place your product in the electrode.
2. Turn ON the external disconnecting device to bring power to the unit.
3. Turn the unit's power switch ON. Push the front panel RESET button and the COUNTER RESET button, if necessary, so that both the Voltmeter and Fault Counter 0.
4. Start the line. Press the VOLTAGE ADJUST up arrow button until the voltmeter indicates the desired test voltage value.

The pinhole detector will operate in accordance with the settings selected during “Installation” and “Front Panel Programming.” See the table on the following page for possible spark tester functions.
<table>
<thead>
<tr>
<th>Pinhole Detector Modes/Functions</th>
<th>Display Programming</th>
<th>Terminal Block Connections</th>
</tr>
</thead>
</table>
| **Momentary Process Control, HV ON:** When a fault occurs, the fault relay closes momentarily for the Process Control Duration, activating auxiliary devices on 7, 8, & 9 for that interval. The relay automatically returns to normal state and the FAULT light goes OFF. Voltage on the electrode stays ON. | Lch = OFF          
rUF = OFF            
PCd = a value between 0.05 and 2.5 seconds | Switch or jumper between pins 1 & 2 for HV in electrode. Auxiliary devices on 7, 8 & 9. |
| **Latch, HV OFF:** When a fault occurs, the fault relay latches, the FAULT light goes ON, auxiliary devices on 7, 8, & 9 are activated, and voltage on the electrode is removed until RESET. | Lch = ON          
rUF = ON            
PCd = N/A | Switch or jumper between pins 1 & 2 for HV in electrode. Auxiliary devices on 7, 8 & 9. |
| **Latch, HV ON:** When a fault occurs, the fault relay latches, the FAULT light goes ON, and auxiliary devices on 7, 8, & 9 are activated until RESET. Voltage on the electrode stays ON. | Lch = ON          
rUF = OFF            
PCd = N/A | Switch or jumper between pins 1 & 2 for HV in electrode. Auxiliary devices on 7, 8 & 9. |
| **External RESET:** A remote switch will reset any relay that is latched, reset any auxiliary devices connected to the relay contacts, turn OFF the front panel FAULT light, and reset the FAULT COUNT LED. | | Remote switch between pins 1 & 3. |
| **Remote ON/OFF HV:** | | Remove jumper on pins 1 & 2 and wire a remote ON/OFF switch in its place. |
| **HV ON Indication:** HV ON relay contact pins 5 & 6 will close when the test voltage in the electrode exceeds 50v. | | Lamp or auxiliary device between pins 5 & 6. |
| **Fault Sensitivity:** Regulates the threshold current. Products with higher capacitive loading characteristics may induce false counting when the fault threshold is at its minimum level (0 = most sensitivity). | FS = Number 0 - 4 | |
Calibration

The PDC-20HC Pinhole Detector may be reasonably expected to retain its accuracy for a period of one year from the date of calibration under conditions of normal use.

CAUTION: The calibration procedures listed below are to be performed by qualified service personnel experienced in high voltage safety procedures only. Failure to follow these procedures may result in danger to personnel and equipment damage.

An accurately calibrated Electrostatic Voltmeter (EVM) is required for this procedure. The EVM has a mirrored area to assist in eliminating errors in reading. The correct way to read the meter is to move the viewing position (your eye) until the reflection of the needle in the mirror is directly behind the needle itself, and observe the needle position on the scale. This eliminates any parallax error that might result from viewing the meter at a slight angle.

1. Before connecting to the EVM, turn ON the pinhole detector and adjust the voltage to 0 using the VOLTAGE ADJUST down arrow button. Turn OFF the spark tester.

2. With the power OFF, zero the EVM. Clip the HV lead from the EVM to the electrode of the PDC-20HC. Use high voltage insulated wire.

3. Connect the ground terminal of the EVM to ground. Set the EVM range switch to one of the following ranges:
   - If testing 1 - 4KV, set the EVM to the 5KV range.
   - If testing 4 - 8KV, set the EVM to the 10KV range.
   - If testing 8 - 16KV, set the EVM to the 20KV range.
   - If testing 15 - 20KV, set the EVM to the 30KV range.

4. Turn the spark tester ON. Using the voltage adjust buttons, slowly increase the voltage until the EVM reads the exact test voltage at which the spark tester is most often used (for example, 100V, 300V, 500V, etc.); record the PDC-20A Voltmeter reading at each of these points.

5. Compare the Voltmeter readings to the EVM true voltages. If the PDC-20HC voltage readings are within factory specifications (within 2% of the EVM reading), turn OFF the pinhole detector and disconnect the EVM from the pinhole detector and GND.

6. If the readings are not within tolerance, do not disconnect the EVM. Proceed to the next section.
Recalibration

7. Using the VOLTAGE ADJUST arrow buttons, adjust the voltage to 20KV. Once the voltage has been set, turn OFF the pinhole detector.

8. Press and hold the VOLTAGE ADJUST and COUNTER RESET buttons down and turn ON the pinhole detector.

9. The Voltmeter & Counter will display the following:

   This readout indicates that the units at a Set Point (SP) of 20KV.

10. Press the COUNTER RESET button. The PDC-20HC Voltmeter & Counter will display the following:

    This readout indicates the unit's Voltage Output (UO).

11. Adjust the voltage using the VOLTAGE ADJUST buttons until the EVM reads the equivalent of what is displayed in the voltmeter. (20KV)

12. Press the COUNTER RESET button. The PDC-20HC Voltmeter & Counter will display the following:

    This readout indicates the spark tester's Actual Voltage (AU).

13. Press a VOLTAGE ADJUST arrow button just once to adjust the voltage readout toward 20.0KV. Every time you press a VOLTAGE ADJUST button, you will see the FAULT light flash, and after a few seconds, the voltage readout will reflect the change. Repeat this step until the AU (actual voltage) displayed on the PDC-20HC Voltmeter matches the EVM reading.

14. Turn OFF the pinhole detector.

15. Return to steps 1 through 6 above to take calibration readings.
**Calibration Alternatives**

There are alternatives to the EVM calibration. Clinton Instrument recommends the use of a Fluke 80K-40 high voltage probe or equivalent high voltage probe with input resistance of 1000 megohms, in conjunction with a digital voltmeter. Please refer to manufacturer’s instructions on how to connect and use these devices.

**Maintenance**

**Fuses**

The fuses in the equipment are not expected to fail in normal operation. Their failure may be an indication of equipment malfunction requiring qualified repair personnel.

There is one fuse associated with the pinhole detector’s operating voltage, located in the ON/OFF power switch on the back panel of the unit. To change the fuse review the following instructions.

Use a 1 Amp 250VAC 5x20mm low breaking time delay fuse. This fuse is located in the ON/OFF power switch and is accessible with a flathead screwdriver as seen in the picture to the left.

Two additional fuses (for relay protection) that could be defective are found on the main printed circuit board as shown to the left.

**Periodic Inspection**

It is important to inspect the electrode periodically for residue and wear.

Insulation and water deposits can reduce the effectiveness of the pinhole test. An electrode mounting plate may be wiped with a clean, dry cloth. Bead chain assemblies contaminated with insulation residue should be removed from the high voltage test module and cleaned with a wire brush.

Broken safety covers and mounting plates and electrode assemblies with worn brushes or missing beads should be replaced immediately.

Refer to the “Troubleshooting” section for assistance with electrical problems.
Troubleshooting

CAUTION: Troubleshooting is to be performed by qualified service personnel only. Failure to follow the procedures in this manual may result in danger to personnel and equipment damage.

False counts are being indicated.
1. Lateral wire line vibration or water may be present. See “Installation” for information on drying, centering and restraining the product in the electrode.

2. The high voltage mounting plate may be contaminated with dirt or conductive material. Clean the mounting plate or replace.

3. Inspect proper grounding of inner conductor.

4. Contact factory to determine correct sensitivity levels.

The Voltmeter LED Display blinks 00.0.
1. The safety interlock is open.

2. There is no switch or relay contact between Pins 1 & 2 (GND and HV ENABLE). Refer to the table in “Installation” labelled “Terminal Block Connections,” under HV ENABLE.

Equipment at relay terminals COM and NO or NC is not activated when a fault occurs.
1. The PCd (process control duration) value may be too short for the auxiliary equipment to recognize.

2. Check fuse on main pc board.

The pinhole detector controls are ON but the equipment does not function.
1. The high voltage interlock switch is not closed.

2. The terminal block connector is not plugged in.

3. F101 fuse is blown.

4. There is no switch or relay contact between Pins 1 & 2 (GND and HV ENABLE). Refer to the table in “Installation” labelled “Terminal Block Connections,” under HV ENABLE.
Replacement Parts

Note: Printed circuit boards are carefully constructed and calibrated at the factory. Components are not supplied for field repair of boards. Please return faulty circuit boards to the factory or to your Clinton sales representative for quick and inexpensive repair and calibration.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>02606</td>
<td>2 amp low breaking time delay fuse, 5x20mm</td>
</tr>
<tr>
<td>02603</td>
<td>1 amp time lag fuse, 5x20mm</td>
</tr>
<tr>
<td>91611</td>
<td>Interlock cable assembly</td>
</tr>
<tr>
<td>91088-HC</td>
<td>Printed circuit board for display</td>
</tr>
<tr>
<td>91061</td>
<td>Power entry module (ON/OFF switch)</td>
</tr>
<tr>
<td>91178-HC</td>
<td>Printed circuit board, main (no HV power supply)</td>
</tr>
<tr>
<td>91363</td>
<td>Relay PC board</td>
</tr>
<tr>
<td>91069</td>
<td>Terminal block connector kit (green)</td>
</tr>
<tr>
<td>03780</td>
<td>Power cord</td>
</tr>
<tr>
<td>RM-5.25</td>
<td>Rack mount/panel mount option for 5.25” chassis</td>
</tr>
</tbody>
</table>
The information contained in this document is subject to change without notice. The Clinton Instrument Company makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose.

The Clinton Instrument Company shall not be liable for errors contained herein or for incidental damages in connection with the furnishing, performance, or use of this material.

We warrant to the original purchaser that the equipment described herein is free from defects in materials and workmanship for a period of one year from the date of invoice, our obligation under this warranty being limited to repair or replacement of the defective parts. This warranty does not apply to fuses, lamps, or any normally expendable parts. Any part appearing to have defects in material or workmanship, upon our examination only and as determined by us, and providing the equipment has not been subject to abuse, misuse, or alteration, will be repaired or replaced at no charge for materials and labor, either upon receipt of the defective part or equipment, transportation charges prepaid, at our plant or at the equipment location, as selected by us. No parts or equipment shall be returned without our prior permission. Any parts replaced under this warranty shall be warranted until the expiration date of the original warranty.

The warranties herein are in lieu of all other warranties, expressed or implied, and of all other obligations or liabilities on our part concerning this equipment.
Electric Shock Considerations for Electric Vehicle Charging Systems

By Walter Skjeggevig, Research Department, Melville, reprinted courtesy of Underwriters Laboratories Inc. This technical paper was presented in December 1993 at the National Conference on Electric Vehicle Infrastructure, sponsored by the Electric Power Research Institute, Arizona Public Service, Salt River Project, and the Electric Vehicle Association of the Americas.

Electric Shock - What Is It?

Before electric shock can be addressed with a view toward prevention, the term and the concept should be explained. There are a number of physiological effects that can occur from electric current through the human body. From the standpoint of electrical safety, critical physiological effects are startle reaction - related to perception, muscle tetanization, ventricular fibrillation and burns. Each effect occurs at a different or increased level of electric current.

Perception and Startle Reaction

A few microamperes available from a conductive surface can be felt as a tingling sensation if the conductive surface is lightly rubbed or tapped with the finger. These small currents are harmless, but if perceived by a consumer, the “electric” sensations might appear sinister. The tingling sensation can raise suspicions, although perhaps not warranted, about the safety of a product.

A 60-Hz sinusoidal current over 0.5 mA RMS can cause an involuntary startle reaction, particularly in women. The current itself is harmless, but the uncontrolled movement of a startled person can cause secondary accidents including spills and falls. The American National Standards Institute (ANSI) document C101-1992 specifies 0.5 mA as the general limit for 60-Hz leakage current from appliances.

At frequencies lower and higher than power distribution frequencies, higher current is necessary to produce the same level of sensation. For direct current, a limit of 2 mA is often used. Continuously flowing direct current may not produce a particularly strong sensation, but a sudden change in the current caused either by making or breaking the circuit can produce a strong, momentary sensation. The higher the DC current, the stronger the sensation when the current is started or interrupted. At frequencies of approximately 1
kHz and higher, it can be estimated that the threshold of startle reaction is approximately equal to 1 mA per kHz of frequency. For example, if a specific level of reaction from current at 1 kHz occurs at 1 mA, then a similar level of reaction would occur from 10 mA at 10 kHz. The same level of reaction would occur from 100 mA at 100 kHz, and so on. Leakage current measuring instruments, such as those specified in ANSI C101-1992, take into account the effect of high frequencies on the body. These instruments produce readings that are “frequency-weighted,” and indicate the level of possible physiological effect. The readings correspond to the current magnitude in mA only at low frequencies such as 60 Hz.

**Muscle Tentanization**

Electric current over 5 mA at 60 Hz can cause muscle tetanization. Tetanization is defined as the state of continuous contraction of a muscle undergoing a series of rapidly repeated stimuli. A person with tetanized muscles may be unable to let go of a conductive part, may be immobilized (frozen), or may be unable to breathe while the current flows. Tetanization lasts as long as the current flows. When the current stops, the effect stops, and the muscle returns to normal function. However, the effect can be fatal if breathing stops long enough. If immersed in water, an immobilized person could drown. In a manner comparable to perception, tetanization occurs at a higher current threshold for DC and for higher frequencies.

**Ventricular Fibrillation**

Ventricular fibrillation is a disorder involving disorganized arrhythmic motion of the heart that affects blood circulation. Unlike muscle tetanization, ventricular fibrillation can be triggered by a short-duration burst of current of sufficient magnitude. Ventricular fibrillation is not spontaneously reversible in humans and, if not treated quickly with special defibrillating equipment, will continue until the person dies (within a few minutes) from loss of circulation of the blood.

The magnitude of limb-to-limb current sufficient to cause ventricular fibrillation is greater than that which would cause muscle tetanization. Therefore, limits for continuous current (e.g., lasting over five seconds or so) are usually based on muscle tetanization considerations.
A general limit that has been used by UL for a number of product categories including ground-fault circuit-interrupters is described as $I = 20 T^{-0.7}$ for bursts of 60-Hz current down to 20.9 milliseconds. $I$ is in RMS mA calculated over the duration of the current; $T$ is the current duration in seconds. For durations between four and 20.9 milliseconds, the current is limited to 300 mA. Below four milliseconds, the current is limited by $I = 6.3 T^{-0.7}$. These equations represent curves drawn under threshold fibrillating data points from laboratory experimental work conducted with animal subjects.

For durations shorter than a tenth of a second, the limits for AC and DC current are the same. For current lasting only a few milliseconds, a narrow piece of a 60-Hz sinusoid is not substantially different from a rectangular DC pulse. For durations over a tenth of a second, direct current has higher limits. Animal test data indicates that for long duration exposures to combinations of AC and DC, the parameter of current that is most related to the threshold of ventricular fibrillation is the peak-to-peak value of the current, if the DC component is low enough so that there is reversal of the current each cycle. In fact, as long as the current reverses, the presence of a DC component is not significant with regard to the ventricular fibrillation threshold. If the DC component is high enough to preclude reversal of the current of each cycle of the AC component, then the occurrence of ventricular fibrillation is more related to the peak value of the composite waveform. In no case should the peak of the composite continuous waveform of AC and DC exceed the peak-to-peak value of the AC component at its maximum permitted value. For example, at one second duration or longer, if the ventricular fibrillation limit for an AC sinusoidal current is 20 mA RMS, the corresponding limit for a direct current would be 40, which is 56.6 mA. If the duration is between 0.1 and 1.0 second, the equation $I = 56.6 T^{-0.25}$ describes a suitable limit for DC current.

Prevention of electrical burns is a very complex subject. There are many variables that are difficult to control or estimate. A limit of 70 mA RMS, independent of frequency, has been used in a number of standards to address burns. At this current level, it is not likely that a severe burn injury would occur that would involve an appreciable volume of
Burns Cont.

Skin tissue. This limit becomes important at frequencies over several kHz, because limits addressing other hazards would not automatically prevent burns.

There are a number of commonly used techniques to reduce the risk of electric shock. Each has attributes that render it more effective for certain applications. In some cases, a combination of techniques may be the best method to reduce the risk of electric shock to an acceptable level. The protective mechanism should be compatible with the nature of the product, its ratings, habits and behavior of the people using the product, and the environment in which the product is used.

Grounding

The principle of equipment grounding can be described as follows: all accessible conductive parts are connected together and to earth by a network of low-impedance conductors to create an equipotential environment. Two important considerations are the reliability of the connections and the impedance of the conductors at the frequencies involved. Ground monitors that interrupt current and/or sound an alarm can enhance reliability. Low impedance in the grounding conductor circuitry is important in order to maintain low voltage to ground on accessible conductive parts during a fault before an interrupting device shuts off the circuit.

Double Insulation

Double insulation enhances the reliability of the electrical insulation of a product to reduce the likelihood of insulation breakdown that could cause an electric shock. Each part of a double-insulation system should be independent and must be fully capable of acting as the sole insulation. If one insulation fails, the other must have all of the required attributes to prevent electric shock. It is important that the two parts of the double-insulation system are as truly independent as feasible. Both insulations should not be vulnerable to the same act (e.g., a drop on a hard surface or immersion in water) or deteriorating agent (e.g., high temperature or over-surface contamination).
A ground-fault circuit-interrupter (GFCI) monitors the difference in the current flowing between the power conductors serving a load. If the difference exceeds a predetermined level, it is assumed that the difference in current could be flowing through a person's body, and the GFCI rapidly trips. The speed of interruption is, by design, fast enough to avert ventricular fibrillation. A typical Class A GFCI trips in approximately one cycle of 60 Hz, and is intended for use on circuits that have no more than 150 volts to ground. Circuits with more than 150 volts to ground could cause higher body currents during a ground-fault that would require a considerably shorter trip time to avert ventricular fibrillation. Class A GFCIs used in the United States for electric shock protection have a differential current trip rating of 5 mA. As such, these devices protect consumers from ventricular fibrillation, as well as muscle tetanization, which prevents them from breaking contact.

Many GFCIs are rated for a 15- or 20-ampere, 60-Hz load. Many GFCIs have not been designed or tested for use on circuits involving larger loads, higher frequencies, non-sinusoidal waveshapes and DC components. New designs of GFCIs may be needed for use on some of the electric vehicle charging circuits.

A GFCI discerns load current from possible electric shock current by where the current flows. Current flowing both to and from the load through the differential transformer is considered by the device to be acceptable. Current greater that the trip rating that flow outside the differential transformer is not acceptable. If a load is configured so that a current carrier is connected to an accessible part, shock current might be able to flow and not be discerned by a GFCI as being different from ordinary load current. For example, if one side of the circuit is connected to the vehicle chassis, then shock current between an accessible energized part and the vehicle chassis would appear to the GFCI as load current. A GFCI would not be able to protect against this type of fault.

If the system contains more than one source of voltage that can be hazardous, a single GFCI may not be able to protect against electric shock. Both sources need to be considered by the protection scheme.
Shielding

Shielding can be used to limit voltages that can appear on accessible conductive parts during fault conditions when products generate high voltages internally. A properly connected shield will prevent voltage on the accessible conductive parts from exceeding line voltage during fault conditions. This can help a GFCI function within its design capabilities and protect people effectively from electric shock from products that would otherwise demand a faster trip speed of the GFCI for shock protection.

Fire hazards resulting from short-circuits involving the shield and internal high-voltage supplies can be controlled by overcurrent devices, temperature-sensitive devices and similar products.

Polarization

Polarization is a form of shielding. If the physical layout of a product is such that parts connected to one side of the line of a grounded system are more likely to be touched or fault to accessible parts, then the line connections should be such that the grounded side of the line is connected to those more exposed parts. This can involve the use of plugs and connectors that permit mating with only one polarity.

Interlocks and “Smart” Circuits

Interlocks and “smart” circuits can be used to keep potentially hazardous parts de-energized unless specific safety conditions are satisfied. Some of these “safety” conditions include specific covers that must be closed, specific connectors that must be fully mated with the proper receptacles, or a power source that “handshakes” with the intended load, and nothing else but the intended load.

“Smart” circuits may involve waveshaping and recognition networks that permit current of recognizable traits to flow, but that also de-energize the circuit if the current is not shaped by the load in precisely the expected way. The addition of a human body in the circuit would add a load of characteristics that are different from expected, and the source would be rapidly de-energized.

The protective mechanisms that should be required may be different for each product design. In general, the system of protection against electric shock should consist of one or more of those mechanisms that will effectively
reduce the risk of electric shock to an acceptable level. The choices should be appropriate, feasible and consistent with today’s technology.

The National Electrical Code contains requirements for the installation of electrical products, but product safety standards cover the details and complexities of the design and construction of the various products, including which protective mechanisms or combinations of protective mechanisms are considered satisfactory to meet the need for protection against electric shock.

Manufacturers of electric vehicles, charging ports and associated equipment need to consider this information as they design the electric cars of the future. If the new vehicle designs include the appropriate protection equipment to prevent potentially dangerous physiological effects, then electric vehicles will provide a modern, safe and environmentally friendly mode of transportation.
Grounding of conductors during the spark test

by Henry Clinton

Nearly all industry-wide specifications for insulated wire and cable pertaining to in-line spark testing require the grounding or earthing of the conductors under test. It is the purpose of this discussion to examine the reasons for this and to define the conditions which allow for a safe and effective spark test when conductors are not grounded. Although this testing mode cannot be used to satisfy most industry specifications, it can be useful when quality must be strictly monitored and conductor grounding is inconvenient or impossible.

D-C spark testing

If a direct potential is used for spark testing, it is absolutely necessary to ground the conductor or conductors under test. In Fig. 1, $C_g$ represents the capacitance of the product to ground, which could be in the range of 100 to 2,000 picofarads, depending on the size and length of the conductor.

If the conductor is not grounded, the potential on the conductor with respect to ground will rise when the first insulation fault passes through the electrode. This is because $C_g$ charges towards the D-C test potential applied to the electrode through the arc.

If the conductor is not grounded but is initially at ground potential, when the first insulation fault passes through the electrode, the arc which forms between the electrode and conductor. The current flowing through this arc charges capacitance $C_g$, elevating the potential of the conductor by a value which is a function of arc time duration and the value of the current. After the defect or fault has completed its passage through the electrode, $C_g$ retains this elevated potential, since $C_g$ has no discharge path to ground. The effective test potential on the product insulation is now reduced by this retained conductor potential. If a second insulation flaw traverses the electrode, additional charging of $C_g$ takes place, further reducing the effective test potential. Eventually the effective test potential falls below that required to cause an arc to occur on the passage of an insulation flaw, and all subsequent flaws will be undetected. Usually, current and traverse time are large enough to sully charge $C_g$ on the passage of the first flaw, so it will be the only one detected.

Furthermore, the entire length of product is now charged to the test potential. If the operator accidentally comes into contact with the conductor or with a flawed insulation area anywhere along the wire line, $C_g$ can discharge through his body to ground. If by coincidence a faulted insulation area is within the electrode, the maximum current output of the spark tester can also pass through his body. While this current, in the case of Clinton spark testers, is well below a dangerous level, the involuntary muscular reaction resulting from this event can itself cause a secondary accident.

It is thus apparent that from the dual standpoints of utility and safety the conductors of a product being spark tested with a D-C potential should be grounded.

A-C spark testing, general

If an A-C potential is used for the spark test, and the conductors are not grounded, the diagram in Fig. 2 applies.

Note that the electrode to product capacitance $C_e$ is shown, and that $C_e$ and $C_g$ comprise a voltage divider which determines the A-C potential from conductors to ground, and also the effective test potential applied across the product insulation.

$$E_{eff} = \frac{C_g}{C_e} E_{app}$$

If $C_e$ is very large compared to $C_g$, $E_{eff}$ is nearly equal to $E_{app}$. For example, if $C_e = 5pF$ and $C_g = 1000pF$, 99.5% of the applied test potential is impressed across the product insulation. If $C_g$ is 100pF, however, the effective test potential drops to 95% of the applied value.

Power mains frequency testing

When an insulation defect passes through the electrode, the arc which forms to the ungrounded conductor in effect connects the conductor to the electrode. If the spark tester operates at the
High Frequency spark testing

When the A-C test frequency is increased to 3Khz, two dramatic changes occur. First, because a short electrode is used, the capacitance to the conductor \( C_e \) is kept small. For a 2 in. electrode \( C_e \) might be typically 2 to 20pf, increasing with the applied potential. The other change is the low reactance of \( C_g \), which allows the current to be conducted readily to ground through a capacitive path rather than by direct connection.

The ratio of \( C_g / C_e \) is usually high, so that nearly all of the applied test potential appears across the product insulation. When an insulation flaw passes through the electrode, current drawn from the spark tester increases sharply in this same ratio, subject to the current limiting characteristics of the test equipment. This means that flaws can be detected reliably. If required, \( C_g \) can be increased by passing a considerable length of the product close to the grounded surface.

Although the maximum resistive current which can be delivered by a Clinton 3Khz spark tester is well below the “let-go” threshold, a mild shock could still be experienced if an operator contacts a bare spot on the product while a second defect is in the electrode. For this reason the entire line should be provided with protective guards to prevent this.

The ratio of \( C_g / C_e \) can be experimentally determined by measuring \( E_{cond} \), the conductor to ground potential, with a high impedance A-C volt-meter or an oscilloscope.

\[
\frac{C_g}{C_e} = \frac{E_{app} - E_{cond}}{E_{cond}}
\]

Summary

Spark testing of ungrounded conductors is usually not permitted by industry-wide specifications, and is unsatisfactory in any event if D-C or A-C power mains frequency test potentials are used. A satisfactory test for quality control purposes can be made on ungrounded conductors at 3Khz, however, if proper precautions are followed.

Henry Clinton is president of Clinton Instrument Co., Clinton, CT.