Models AC-30A and AC-30AS
Digital Power Mains Frequency Spark Testers
Instruction Manual
MODELS AC-30A and AC-30AS
Digital Mains Frequency Spark Testers

The AC-30 series of digital 30KV mains frequency spark testers, designed for large wire and cable, can be installed almost anywhere on the wire line. The system is comprised of 3 separate components:

- rugged electrode with visual and audible alarms, simple string-up, and automatic bead chain placement for full coverage of large products
- digital control unit that can be located up to 200 feet away
- adjustable height floor stand

The new AC-30AS features a unique self-adjusting transformer proven to maximize test voltage on high speed and high capacitance cables without an increase in current.

The control unit features easy-to-read digital test voltage and fault count displays. Wiring and setup are done externally-- there is no need to open up the unit. The digital display allows the operator to configure the spark tester for extrusion or rewind mode, or to set the length of time that process control relay contacts energize after a fault occurs.

Form C relay contacts are accessible on a rear panel connector for easy wiring to external alarms, lights or machinery that are to be controlled by the spark tester. Additionally, the AC-30A may be integrated into computer-controlled lines with a standard RS-485 interface or through optional Analog, Profibus, and Ethernet communication modules.

For operator protection, a safety interlock switch removes high voltage when the electrode cover is lifted.

The AC-30A and AC-30AS can be calibrated automatically with the new, lightweight STCAL Calibration System, now available from Clinton.
AC-30A & AC-30AS SPECIFICATIONS

Voltage Test Range .......... Approx. 1kV to 30kV rms, depending on electrode type and product under test.
Voltage Display .......... Red 3-digit 14.2mm high LED display, accuracy 2% of reading.
Test Frequency .......... Mains frequency 50 or 60Hz.
Output Current .......... 6mA resistive current.
Fault Indication .......... Red 3-digit 14.2mm high LED non-volatile display; amber indicating front panel light; audible alarm; flashing amber stack light (X3A).
Fault Resolution .......... 2 to 200 milliseconds, adjustable.
Detection Sensitivity .......... Less than 600 µA at 3kV.
Operating Modes .......... Continuous HV/Remove HV on Fault. Momentary Process Control / Latch until Reset.
Process Control .......... Relay form "C" contacts rated 1 amp max @ 120VAC, for both NO and NC circuits. Front panel, external or remote reset. In non-latch modes, closure time is adjustable from 50 milliseconds to 2-1/2 seconds.

Communication .......... RS-485 Serial Interface; Analog (optional); Profibus (optional); Ethernet (optional).
Line Speed .......... UL and CSA formula... (9 cycles)

Line Speed = 5/9 x frequency x electrode length in inches.

BS EN50356 formula ...

Line Speed = 1.2 meters per minute for each millimeter of electrode length.
Calibration .......... May be automatically calibrated with Clinton STCAL Calibration System (now available).

Input Power Requirements ...

120 or 240VAC, 2 amps, 49-61Hz (automatically internally switched)
Optional 100 or 200 VAC, 2amps, 49-61Hz.

Safety .......... IEC 1010-1

CE Approved.

Specifications subject to change without notice. 03/13 EN

Measurements:

Product size: Max 2" diameter

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Electrode Length</th>
<th>UL 60Hz</th>
<th>UL 50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-A230</td>
<td>4973</td>
<td>1263</td>
<td>9.73</td>
<td>29.02</td>
<td>48.36</td>
<td>17.36</td>
<td>17.36</td>
<td>30</td>
<td>30</td>
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<td>BD-A236</td>
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<td>1263</td>
<td>9.73</td>
<td>29.02</td>
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<td>17.36</td>
<td>17.36</td>
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</table>

Product size: Max 4" diameter

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Electrode Length</th>
<th>UL 60Hz</th>
<th>UL 50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-A406</td>
<td>31.73</td>
<td>805.84</td>
<td>2.60</td>
<td>11.28</td>
<td>48.36</td>
<td>17.36</td>
<td>17.36</td>
<td>6</td>
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</tr>
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<td>BD-A412</td>
<td>31.73</td>
<td>805.84</td>
<td>2.60</td>
<td>11.28</td>
<td>48.36</td>
<td>17.36</td>
<td>17.36</td>
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<tr>
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</tr>
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<td>BD-A424</td>
<td>4973</td>
<td>1263</td>
<td>9.73</td>
<td>29.02</td>
<td>48.36</td>
<td>17.36</td>
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<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Product size: Max 5" diameter

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Electrode Length</th>
<th>UL 60Hz</th>
<th>UL 50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-A506</td>
<td>31.73</td>
<td>805.84</td>
<td>5.69</td>
<td>14.91</td>
<td>34.63</td>
<td>34.63</td>
<td>34.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please consult factory for help in choosing equipment for specific applications.

Specifications subject to change without notice. 03/13 EN
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Declaration of Conformance

Manufacturer: Clinton Instrument Company
295 East Main Street
Clinton, CT 06413 USA

Herewith declares that the Model AC-30A AC Power Mains Spark Tester is in conformance with the provisions of the following EEC directives:

- 2006/95/EC Electrical Safety Low Voltage Directive (LVD)


- CISPR 16:1999 Class A, Conducted Emissions, 150 kHz to 30 MHz
- CISPR 16:1999 Class A, Radiated Emissions, 30 MHz to 1 GHz
- IEC 61000-3-2:2000 Harmonics
- IEC 61000-3-3:1994 Flicker


- IEC 61000-4-2:1995 Electrostatic Discharge
- IEC 61000-4-3:1995 Radiated Immunity
- IEC 61000-4-4:2004 EFT/Burst, Power and I/O Leads
- IEC 61000-4-5:1995 Surge Immunity, Power Leads
- IEC 61000-4-6:1996 Conducted Immunity, Power and I/O Leads
- IEC 61000-4-11:1994 Voltage Dips and Interrupts

Conforms with safety requirements of EN 61010.

Clinton, CT USA  February, 2008

Marianne C. Szreders, President
Theodore P. Lane, Chief Engineer
Safety Symbols

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

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

- **Risk of electric shock symbol.**

- **Earth ground symbol.**

Environmental Conditions

The spark tester is designed to be safe under the following conditions:

- Indoor use.
- Altitude to 2000m.
- 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 wire line stops, be sure that the HV in the electrode goes off. If the HV remains ON while your wire line is stationary, the wire 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 spark tester.
Caution: Pacemaker Warning

Clinton Instrument Company strongly advises any individual using a pacemaker or other such medical device to avoid operating or being in the vicinity of spark testers. Current studies indicate that such medical devices can malfunction in the presence of electrical and magnetic fields. When a fault occurs in the electrode of a Clinton spark tester, both high and low frequency electromagnetic fields are generated. The strengths of these emissions are unknown, since they depend on test voltage and other variables. The danger is greater when a customer does not ground the inner conductors of a test product. While Clinton cautions its customers to ground the test product for safety reasons, many times this warning is ignored. In this situation, both the spark tester and the entire length of the wire line will radiate these emissions. There is also a serious risk of electrical shock if an individual comes into contact with an ungrounded test product.

gmail: support@clintoninstrument.com.
Electrical Shock Hazard From Production Line Spark Testers

by Henry H. Clinton

The commonly accepted maximum values of 60Hz. 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 and 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 3kHz. 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.

Unpacking

The AC-30A Spark Tester arrives packed in several boxes and strapped on a skid. Inspect the shipment on receipt and notify the carrier immediately if there is evidence of damage.

The spark tester consists of the following:

1. An X3A Horn/Light Tower with power cord and connecting cable kit.
2. An ARC control unit with power cord.
3. The AC-30A Electrode and power cord.
4. FS-6 Floor Stand components and hardware.

The X3A and ARC are packed in individual boxes and are placed on top of the electrode carton. Remove these cartons and the lid of the electrode box. Inside you will find the electrode and a box containing the Floor Stand components. Remove this box from the carton.

Floor Stand Assembly

The Floor Stand consists of 4 legs, 4 feet, 8 rails, a control unit mounting bracket, and a set of hardware. Before assembling the stand, determine the height of the wire line center. The wire line center of the electrode may be positioned from 39” to 42” (99.1 to 106cm) from the floor. Using the hardware supplied, bolt each Floor Stand foot to a leg at the appropriate height to provide the required height for the wire line center. Assemble the Floor Stand as shown.

The Floor Stand must be securely mounted to the floor. Locate it in its desired position along the wire line and anchor the feet securely to the floor system using four (4) 1/2” or 12mm diameter bolts.

Remove the AC-30 Electrode from the shipping carton and place it on the stand, aligning the four holes on the bottom of the Electrode chassis with four holes on the top lip of the stand. Insert four (4) 1/4-20 x 1/2” long bolts (supplied) through the Electrode chassis and secure with keeps nuts.
ARC Control Unit

A control unit mounting bracket is provided to mount the ARC on the Floor Stand beneath the AC-30A Electrode. If preferred, the ARC can be installed on top of the AC-30A Electrode or in a rack or panel as far as 200 feet away from the AC-30A spark tester. RS-485 cables for connection of the AC-30A to a computer or PLC must be purchased separately. Refer to the section entitled “Programming Through the RS-485 Interface.”

X3A Horn/Light Tower

An X3A Horn/Light Tower is supplied with the AC-30A Spark Tester. The red lamp of the X3A alerts the operator that HV is present in the electrode, and when a fault is found, the yellow lamp flashes and an alarm sounds.

Four (4) mounting bolts are provided on the side of the AC-30A Electrode to mount the X3A. If another location is preferred, a longer connecting cable may be required.

Provide for ventilation of the electrode:

In common with any apparatus producing a spark or electrical corona, the AC-30A Spark Tester produces ozone in the electrode region which must be removed by an air evacuation fan external to the AC-30A.

Wiring Requirements

Caution: be sure the external disconnecting device is OFF and locked out before continuing.

Install an external disconnecting device

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.

Mains Power

The AC-30A operating voltage is factory set for 120/240 volts or 100/200 volts. Note the spark tester’s operating voltage (WARNING! 120V OR 240V), which is marked beneath the ON/OFF switch on the back panel. If it does not match the power line voltage you will be using to energize the spark tester, contact the factory.
Terminal Block Wiring without the X3A

If you have chosen not to install the X3A, refer to the table below 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.

<table>
<thead>
<tr>
<th>Terminal Block Connections</th>
<th>Pin No.</th>
<th>Designation</th>
<th>Conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Control:</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>To activate external lights, alarms or relays* when a fault occurs, wire them between dry relay contact pins 5, 4 &amp; 3. If the Lch function is ON (set on the front panel), the dry relay contacts will remain closed until the RESET button is pressed or when pins 1 &amp; 3 are closed by remote switch or relay. If the Lch function is OFF, the dry relay contacts will return to normal state after the interval known as the PCd (Process Control Duration, set on the front panel) has elapsed.</td>
<td>8</td>
<td>COM</td>
<td></td>
</tr>
<tr>
<td>HV ON Indication:</td>
<td>7</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Dry relay contact pins 1 &amp; 2 will close when the test voltage exceeds 500v. 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></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>HV Enable:</td>
<td>4</td>
<td>not used</td>
<td></td>
</tr>
<tr>
<td>To reset the spark tester fault relay with an external switch, wire a momentary switch** between pins 1 &amp; 3. When these contacts close, the fault relay will return to a normal state. The interval that the contacts are closed must exceed 50 ms.</td>
<td>3</td>
<td>RESET</td>
<td>(3) 22 ga. stranded conductors</td>
</tr>
<tr>
<td>CAUTION: For HV on the electrode, install a normally closed switch or relay contact** between pins 1 &amp; 2. This switch or relay should open automatically when the wireline stop switch is activated or be opened manually by the system operator when the line stops. FAILURE TO DO SO COULD RESULT IN A FIRE HAZARD. If the HV remains ON in the electrode when your line is stationary, the wire insulation in the electrode will heat and there is a danger of combustion.</td>
<td>2</td>
<td>HV ENABLE</td>
<td></td>
</tr>
<tr>
<td>When connecting auxiliary equipment to dry 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 to pins 1, 2, &amp; 3 should be suitable for 24V low current applications.</td>
<td>1</td>
<td>GND</td>
<td></td>
</tr>
</tbody>
</table>
Terminal Block Wiring when using an X3A

1. If you have installed the X3A on the AC-30A spark tester, locate the items that were packed with it: a power cord (part #03780) and a 4-conductor cable assembly, which has a 9-pin terminal block connector on one end and a 10-pin connector on the other.

2. Wire pins 1 - 5 of the 10-pin connector to accessory equipment using 22 gauge or larger, stripped back 1/4” (6mm) and fed into the green terminal block connector at the proper pin numbers, as described on the following page. Pins 1 - 3 of the 9-pin connector should be wired as shown on the following page.

3. Make sure the spark tester is off before wiring to the X3A.

4. Locate the 10-pin green terminal block on the back of the X3A and the 9-pin terminal block on the back of the spark tester. Connect the 10-pin connector of the 4-conductor cable assembly into the X3A terminal block and the 9-pin connector to the spark tester terminal block.

5. Notice that pins 8 - 5 on the spark tester are now being used to communicate with the X3A. The functions of pins 8 - 5 on the spark tester have now been transferred to pins 1 - 5 on the X3A terminal block.

6. When the wiring is complete, connect a power cord from the X3A to the AC-30A spark tester.
## X3A to Spark Tester Connections

<table>
<thead>
<tr>
<th>X3A Horn/Light Tower Terminal Block Connections</th>
<th>Spark Tester Terminal Block Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor Designation</td>
<td>Terminal Block Connections</td>
</tr>
<tr>
<td>4-conductor cable supplied with X3A (22 gauge or higher)</td>
<td>To Spark Tester: Wire pins 10-7 to spark tester pins 8-5 on the spark tester terminal block connector</td>
</tr>
<tr>
<td></td>
<td>COM</td>
</tr>
<tr>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>COM</td>
<td>6</td>
</tr>
<tr>
<td>Not Used</td>
<td>5</td>
</tr>
<tr>
<td>(3) 22 ga. stranded conductors rated 250V, less than 10 meters in length, contained in a common insulating sheath</td>
<td>Process Control: To activate external lights, alarms or relays* when a fault occurs, wire them between dry relay contact pins 5,4 &amp; 3. If the Lch function is ON (set on the front panel), the dry relay contacts will remain closed until the RESET button is pressed or when pins 1&amp;3 are closed by remote switch or relay. If the Lch function is OFF, the dry relay contacts will return to normal state after the interval known as the PCd (Process Control Duration, set on the front panel) has elapsed.</td>
</tr>
<tr>
<td></td>
<td>COM</td>
</tr>
<tr>
<td></td>
<td>NO</td>
</tr>
<tr>
<td>22 ga. stranded conductors rated 250V, less than 10 meters in length, contained in a common insulating sheath</td>
<td>HV ON Indication: Dry relay contact pins 1&amp;2 will close when the test voltage exceeds 500v. For an indication that HV is ON in the electrode, wire a lamp or auxiliary device* here.</td>
</tr>
<tr>
<td></td>
<td>COM</td>
</tr>
<tr>
<td></td>
<td>NO</td>
</tr>
</tbody>
</table>

*When connecting auxiliary equipment to dry relay contacts pins 1, 2, 3, 4, or 5, observe maximum ratings of 120VAC at 2 amps or 240VAC at 1 amp.

**Switches and relays connected to pins 1, 2, & 3 should be suitable for 24V low current applications.

CAUTION: For HV on the electrode, install a normally closed switch or relay contact** between pins 1&2. This switch or relay should open automatically when the wireline stop switch is activated or be opened manually by the system operator when the line stops. **FAILURE TO DO SO COULD RESULT IN A FIRE HAZARD.** If the HV remains ON in the electrode when your line is stationary, the wire insulation in the electrode will heat and there is a danger of combustion.
Connecting the AC-30A to the ARC

The ARC control unit can be located up to 200’ away from the AC-30A Electrode. On the back of the ARC there are two RS-485 ports. Connect the female port on the ARC labeled “To test module,” located on the left hand side of the ARC back panel, to the male port on the AC-30A electrode labeled “RS-485” with an RS-485 connecting cable. An 6-foot cable is supplied with the AC-30A system, which is sufficient if the ARC is to be installed below the AC-30A Electrode on the bracket supplied with the Floor Stand. Contact the factory if a different length of RS-485 cable is required.

Connecting the RS-485 Interface

Programming and control of voltage settings can be done on the ARC control unit or through an RS-485 serial interface, which allows the AC-30A spark tester to receive commands and exchange information with a PLC or computer. The RS-485 interface is available on the ARC, through the ARC 9-pin D-Subminiature connector, or directly, without the ARC display, through the AC-30A RS-485 male port. ARC display buttons are not disabled when the serial interface is in use.

Find the ARC 9-pin D-Subminiature connector, which is located on the right side of the ARC back panel. The spark tester will receive commands and requests from a computer or PLC through pins 3 and 8 of the connector (shown here) 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

- Baud Rate: 9,600 bits per second
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Flow Control: None

RS-485 connecting cable(s) that you have purchased or wired yourself
are connected as shown below:

RS-485 Connections for the AC-30A with ARC

On the back of the ARC Remote Display there are two RS-485 ports. Connect the female port labeled “To test module,” located on the left hand side, to the male port on the AC-30A electrode labeled “RS-485 port,” with an RS-485 cable. Then connect the male port of the ARC labeled “RS-485 port” located on the right hand side, to a PLC or computer with an RS-485 cable.

RS-485 Connections for the AC-30A, no ARC

Connect the female end of the RS-485 cable to the male RS-485 port labeled “RS-485,” located on the left rear of the electrode. Then take the other end of the RS-485 cable and attach that to the appropriate RS-485 port on the computer or PLC.

ARC or AC-30A to PC Communication Adapters

The ARC and the AC-30A have 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 ARC or AC-30A from a PC, the RS-485 from the ARC or AC-30A must be converted to RS-232. There are many RS-485 to RS-232 converters available. Adapters will require a converter cable from the adapter to the ARC.
Prepare Your Product for Testing

• Insure that the product to be tested is dry as it enters the spark test electrode. The combination of water and spark testing is not a desirable one. A continuous film or sheath of water on the product can provide an effective electrical path to the nearest grounded point. Surface leakage can trigger a false count in the spark tester. Efficient air wipes that can adequately dry the product before it enters the electrode are available from Clinton.

• Ground the product conductor(s). This is a safety precaution as well as a requirement of most spark test specifications. Please see the paper, “Grounding of Conductors During the Spark Test,” included in this manual.

• Position the product in the center of the electrode, through the safety end guards. Be sure it will remain centered as it is being drawn through the electrode assembly. Lateral wire vibration which may be imperceptible can cause phantom faults to register on the spark tester. Properly positioned guides installed at entry to and exit from the electrode can eliminate this condition.
Spark Tester Controls

ON/OFF Power Switches

The ARC control unit has an ON/OFF switch on the back panel and on the front panel. The AC-30A Electrode also has an ON/OFF switch located on the rear panel.

ARC Voltmeter

The voltmeter indicates the voltage at the electrode. When the output voltage is adjusted to 5.0 KV, the voltmeter will read 5.00. A reading of 10.2 indicates that the voltage at the electrode is 10.2KV rms.

ARC VOLTAGE ADJUST buttons

The spark test voltage may be adjusted from 0 to 30,000 volts 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.

FAULT light

The FAULT light will illuminate in response to a single pinhole fault in the electrode. It also indicates that the process control 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.

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.
Fault Counter

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

COUNTER RESET button

Press to reset the number of faults shown on the Fault Counter to 0.

Electrode containment cover

The electrode containment cover protects the operator from coming into contact with the energized electrode.

Electrode

When the spark tester power is ON, and the electrode containment cover is down, the test voltage set on the ARC control unit is applied to the product under test as it runs through the electrode. Various electrodes are available to suit your application. Please contact factory for details.

Safety interlock switch

An interlock switch, a red switch located on the top of the AC-30A Electrode, turns ON the high voltage in the electrode when the electrode containment cover closes.

Do not attempt to defeat the safety interlock switch.
ARC Front Panel Programming

1. Turn ON the (2) ON/OFF power switches on the rear panels of the AC-30A and ARC.

2. Turn OFF the ON/OFF power switch that is located on the ARC front panel.

3. Press and hold in the RESET button while turning ON the ON/OFF power switch on the ARC front panel.

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

5. The first of 4 functions (Lch, rUF, PCd, and ELE), 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.

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 available functions.

9. When you have made your choices for each of the 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 process control 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 process control 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 (This is only available when Lch is ON.)</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 value</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 50ms. 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>
<tr>
<td>ELE</td>
<td>Electrode Length along the Wire Line</td>
<td>number</td>
<td>Choose a value of 1,2,3,4 or 5. This represents a 1”, 2”, 3”, 4” or 5” long electrode length along the wire line (the horizontal dimension of the electrode that will cover your test product).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,2,3,4,5</td>
<td></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>Test Module firmware version number</td>
</tr>
</tbody>
</table>
Testing Your Product

CAUTION: During installation, the AC-30A Spark Tester was programmed to report and respond to faults in specific ways. Internal settings must not be changed except by qualified personnel.

1. Place your product in the electrode. Close the electrode assembly and electrode containment cover. Be sure the wire is centered in the electrode.

2. Verify that the product conductor(s) are grounded. If this is not the case, do not proceed. Contact service personnel to review the spark tester installation.

3. Turn ON the external disconnecting device to bring power to the spark tester. Turn the (3) spark tester power switches ON.

4. Push the front panel RESET button and the COUNTER RESET button, if necessary, so that both the Voltmeter and Fault Counter 0.5.

5. Start the wire line. Press the VOLTAGE ADJUST up arrow button until the voltmeter indicates the desired test voltage value.

CAUTION: Do not touch the wire while it is being tested.

The spark tester will operate in accordance with the settings selected during “Installation” and “ARC Programming.” See the table below for possible spark tester functions.

CAUTION: When the AC-30A is operated with bare wire in the electrode for an extended length of time, i.e., several minutes or longer, damage to the equipment may result. This condition should be avoided, either by switching the spark tester OFF manually or by a zero speed switch operated by the machinery, each time the wire line is not moving.

CAUTION: If the HV remains ON in the electrode while your wire 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.
**Spark Tester Modes**

Below are the sample settings for different spark test modes:

<table>
<thead>
<tr>
<th>Spark Tester Function</th>
<th>Display Programming</th>
<th>Terminal Block Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extruder Mode:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When a fault occurs, the relay closes momentarily for an interval between .05 seconds and 2.5 seconds (known as the PCd), activating auxiliary devices for that interval. The relay then automatically returns to normal state and the fault light goes OFF. Voltage on the electrode stays ON.</td>
<td>Lch off</td>
<td>Jumper between Pins 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>rUF N/A</td>
<td>Auxiliary devices on 7, 8, &amp; 9</td>
</tr>
<tr>
<td></td>
<td>PCd a value between .05 and 2.5 seconds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELE 1, 2, or 3</td>
<td></td>
</tr>
<tr>
<td><strong>Respooler Mode, High Voltage OFF:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When a fault occurs, the relay latches, the fault light goes on, auxiliary devices are activated, and voltage on the electrode is removed until the front panel RESET button is pressed.</td>
<td>Lch on</td>
<td>Jumper between Pins 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>rUF on</td>
<td>Auxiliary devices on 7, 8, &amp; 9</td>
</tr>
<tr>
<td></td>
<td>PCd N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELE 1, 2, or 3</td>
<td></td>
</tr>
<tr>
<td><strong>Respooler Mode, High Voltage ON:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When a fault occurs, the relay latches, the fault light goes ON, and auxiliary devices are activated until the front panel RESET button is pressed. Voltage on the electrode stays ON.</td>
<td>Lch on</td>
<td>Jumper between Pins 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>rUF off</td>
<td>Auxiliary devices on 7, 8, &amp; 9</td>
</tr>
<tr>
<td></td>
<td>PCd N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELE 1, 2, or 3</td>
<td></td>
</tr>
<tr>
<td><strong>External RESET:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When a fault occurs, the relay latches, the fault light goes on, auxiliary devices are activated, and voltage on the electrode is removed until a remote reset switch is pressed.</td>
<td>Lch on</td>
<td>Jumper between Pins 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>rUF on or off</td>
<td>Remote switch between Pins 1 &amp; 3</td>
</tr>
<tr>
<td></td>
<td>PCd N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELE 1, 2, or 3</td>
<td></td>
</tr>
<tr>
<td><strong>Remote ON/OFF HV:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remove the jumper between Pins 1 &amp; 2 and wire a remote ON/OFF switch here.</td>
</tr>
<tr>
<td><strong>HV ON Indication:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire an external lamp or auxiliary device on pins 5 &amp; 6. Pins 5 &amp; 6 will close when voltage on the electrode exceeds 500v, activating this circuit.</td>
</tr>
</tbody>
</table>
X3A Operation

X3A Horn/Light Tower will respond to faults depending on how your spark tester is configured. Please see the chart below for the X3A response:

<table>
<thead>
<tr>
<th>Spark Tester Configuration</th>
<th>X3A Response to Fault in Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lch on</td>
<td>Red HV On Lamp will go off. Audible alarm will sound, and Yellow Fault Light will flash until the spark tester reset button is pressed.</td>
</tr>
<tr>
<td>rUF on</td>
<td></td>
</tr>
<tr>
<td>PCd nA</td>
<td></td>
</tr>
<tr>
<td>Lch off</td>
<td>Red HV On Lamp will go off. Audible alarm will sound, and Yellow Fault Light will flash for length of PCd (Process Control Duration) - 2.00 seconds in this case.</td>
</tr>
<tr>
<td>rUF on</td>
<td></td>
</tr>
<tr>
<td>PCd 2.00 sec</td>
<td></td>
</tr>
<tr>
<td>Lch on</td>
<td>Red HV On Lamp will stay on. Audible alarm will sound, and Yellow Fault Light will flash until the spark tester reset button is pushed.</td>
</tr>
<tr>
<td>rUF off</td>
<td></td>
</tr>
<tr>
<td>PCd nA</td>
<td></td>
</tr>
<tr>
<td>Lch off</td>
<td>Red HV On Lamp will stay on. Audible alarm will sound, and Yellow Fault Light will flash only for length of PCd.</td>
</tr>
<tr>
<td>rUF off</td>
<td></td>
</tr>
<tr>
<td>PCd 2.00 sec</td>
<td></td>
</tr>
</tbody>
</table>
Calibration

The AC-30A Spark Tester 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.

Calibration

1. Before connecting to the EVM, turn ON the spark tester 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 AC-30A. 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:

<table>
<thead>
<tr>
<th>Maximum Test Voltage Applied</th>
<th>EVM Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4KV</td>
<td>5KV</td>
</tr>
<tr>
<td>4.1KV-8KV</td>
<td>10KV</td>
</tr>
<tr>
<td>8.1KV-16KV</td>
<td>20KV</td>
</tr>
<tr>
<td>16.1KV-30KV</td>
<td>30KV</td>
</tr>
</tbody>
</table>

4. Turn the spark tester ON. Using the VOLTAGE ADJUST buttons, slowly increase the voltage until the EVM reads the exact test voltage at the following cardinal points: 1KV, 2KV, 3KV, 4KV, 5KV, 10KV, 15KV, 20KV, 25KV, and 30KV. Record the ARC Voltmeter reading at each of these points.

5. Compare the Voltmeter readings to the EVM true voltages. If the
ARC voltage readings are within factory specifications (within 2% of the EVM reading), turn OFF the spark tester and disconnect the EVM from the AC-30A Electrode and GND.

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

Recalibration

1. Turn OFF the ARC.

2. Press and hold the VOLTAGE ADJUST down button and the COUNTER RESET button.

3. Turn ON the ARC.

4. Using the VOLTAGE ADJUST arrow buttons, adjust the voltage to 15KV. The Voltmeter & Counter will indicate that the spark tester is at a Set Point (SP) of 15KV.

5. Press the COUNTER RESET button. The ARC Voltmeter & Counter will indicate the spark tester's Voltage Output (UO).

6. Adjust the voltage using the VOLTAGE ADJUST buttons until the EVM reads the equivalent of what is displayed in the voltmeter. (ex. 15KV).

7. Press the COUNTER RESET button until SP is shown on the ARC Counter.

8. Return to steps 4 through 7 above to take calibration readings for the following voltages: 1KV, 2KV, 3KV, 4KV, 5KV, 10KV, 20KV, 25KV, and 30KV.
Maintenance

Caution: Only qualified personnel trained in high voltage equipment should perform maintenance and parts replacement on this equipment. Remove power to the spark tester before proceeding.

Fuses

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

A fuse associated with the spark tester’s operating voltage is located in the ON/OFF power switch on the back panel of the AC-30. 120V and 240V units require a 5 amp slo-blow fuse. If 100V or 200V operating voltage is required, contact the factory for information on the required fuse and rewiring of the HV transformer. There is also a fuse inside the power entry module of the ARC.

Two additional 2 amp slo-blow fuses that could be defective are found on the back panel of the AC-30A.

Periodic Inspection

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

Insulation and water deposits can reduce the effectiveness of the spark test. Bead chain assemblies contaminated with insulation residue may be cleaned with a wire brush. Broken plates and electrode assemblies with worn brushes or missing beads should be replaced immediately. However, bead chain assemblies are subject to damage and contamination that is not always visible. They should be replaced if current leakage occurs.

Electrode Replacement

The following chart indicates the electrode sizes that can be used in a given electrode containment:

<table>
<thead>
<tr>
<th>Containment Size</th>
<th>Electrodes that can be Accommodated</th>
</tr>
</thead>
<tbody>
<tr>
<td>30”L x 17” H</td>
<td>BD-406, BD-412, BD-418</td>
</tr>
<tr>
<td>48”L x 17” H</td>
<td>BD-406, BD-412, BD-418, BD-224, BD-230, BD-236</td>
</tr>
<tr>
<td>30”L x 19.6”H</td>
<td>BD-406, BD-412, BD-418, BD-506</td>
</tr>
</tbody>
</table>
CAUTION: Do NOT install an electrode that is longer than recommended, because high voltage can arc to the electrode containment chassis.

Consult the factory before choosing a different electrode, because longer electrodes may result in diminished voltage output. Shorter electrodes may not meet test specifications.
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.

- Phantom faults are being indicated.
  1. The electrode assembly or high voltage mounting plate may be contaminated with dirt or conductive material. Clean or replace.
  2. Inspect proper grounding of inner conductor.
  3. Water on the test product can cause false counting. Use airwipes and shivs to remove water before it reaches the spark tester.
  4. If, after 1, 2 & 3 have been corrected, you still experience false counting due to a capacitive loading effect on your test product, change the Fault Sensitivity setting (see “ARC Front Panel Programming”) from 0 (Normal) to 1 (Reduced Sensitivity). Note that your spark tester will now meet the NEMA standard for sensitivity but not the British standard.

- The Voltmeter LED Display blinks 00.0.
  1. The electrode containment cover 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.

- I adjust the voltage to a higher set point, with product in the electrode, but seconds after I release the voltage adjust button, a lower voltage is displayed.
  1. The spark tester may have reached the highest voltage possible for this product due to a capacitance loading effect from the test product. Consult the factory regarding your application.

- 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 fuses on back panel of the AC-30.

- The spark tester controls are ON but the equipment does not function.
  1. The electrode containment interlock switch is not closed.
  2. The terminal block connector is not plugged in.

- The power entry fuse is blown.
  1. 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.
• Display shows “Err 001”.
  1. The ARC may be unable to communicate with the AC-30A Electrode. Make sure that the serial cable between the ARC and the AC-30A electrode is secure and connected to the correct ports. If the cable is properly installed and the problem continues, contact Clinton Instrument for assistance.
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><strong>ARC Control Unit</strong></td>
<td></td>
</tr>
<tr>
<td>02603</td>
<td>1 amp low breaking time delay fuse, 5X20mm</td>
</tr>
<tr>
<td>91088</td>
<td>Printed circuit board, display</td>
</tr>
<tr>
<td>90985</td>
<td>Membrane display unit for ARC (no PCB)</td>
</tr>
<tr>
<td>91061</td>
<td>Power Entry Module (rear panel)</td>
</tr>
<tr>
<td>03018</td>
<td>Power Switch, Front Panel</td>
</tr>
<tr>
<td>00473</td>
<td>Power Supply</td>
</tr>
<tr>
<td>91101</td>
<td>Printed Circuit Board, RS-232 to RS-485</td>
</tr>
<tr>
<td><strong>AC-30 Electrode</strong></td>
<td></td>
</tr>
<tr>
<td>91354</td>
<td>Printed Circuit Board, Main</td>
</tr>
<tr>
<td>91343</td>
<td>Printed Circuit Board, Voltage Selector</td>
</tr>
<tr>
<td>02606</td>
<td>Fuse, T2A</td>
</tr>
<tr>
<td>91400</td>
<td>Fuse, T5A</td>
</tr>
<tr>
<td>91061</td>
<td>Power Entry Module (rear panel)</td>
</tr>
<tr>
<td>91422</td>
<td>Transformer, 30kV</td>
</tr>
<tr>
<td>01303</td>
<td>Lightbulb</td>
</tr>
<tr>
<td>90550</td>
<td>Variac, Staco 501B</td>
</tr>
<tr>
<td>90592</td>
<td>Replacement Brush</td>
</tr>
<tr>
<td>90570</td>
<td>Transformer, Isolation</td>
</tr>
<tr>
<td>90754</td>
<td>Voltage Servo-motor</td>
</tr>
<tr>
<td>91371</td>
<td>Standoff-Ceramic</td>
</tr>
<tr>
<td>A406</td>
<td>Bead Chain Electrode Assembly 4”dia 6” along wire line</td>
</tr>
<tr>
<td><strong>Electrode Stand</strong></td>
<td></td>
</tr>
<tr>
<td>FS-6</td>
<td>Electrode Stand, complete</td>
</tr>
</tbody>
</table>
Warranty

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 S. Skuggevig, 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 tentanization. Tentanization is defined as the state of continuous contraction of a muscle undergoing a series of rapidly repeated stimuli. A person with tentanized 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. Tentanization 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, tentanization 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 tentanization, 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 tentanization. Therefore, limits for continuous current (e.g., lasting over five seconds or so) are usually based on muscle tentanization 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
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 than the trip rating that flows 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

N early 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 defect passes through the electrode, an arc forms between the electrode and the conductor. The current flowing through this arc charges capacitance \( C_e \), 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 suify 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.

If \( C_g \) is very large compared to \( C_e \), \( E_{eff} \) is nearly equal to \( E_{app} \). For example, if \( C_g = 5pf \) and \( C_e = 1000pf \), 99.5% of the applied test potential is impressed across the product insulation. If \( C_g \) is 100pf, however, the effective test voltage 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
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mains frequency, the ungrounded conductor will be elevated to nearly the full test potential. If an operator comes into contact with a bare spot in the insulation at this time, current can flow through his body to ground. The maximum value of this current will be the maximum output level of the spark tester. For Clinton mains frequency spark testers this level is less than the “let-go” threshold and is not dangerous in itself. However, as in the D-C case, the event is unexpected and unpleasant, and can lead to a secondary accident. From the standpoint of flaw detection, the detector circuitry must differentiate between normal electrode current and the new level when the arc connects \( C_g \) to the electrode, which is a small increment. As in the D-C case, grounding of the conductors under test is a practical necessity.

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 \( C_p \) is kept small. For a 2 in. electrode \( C_p \) might be typically 2 to 20pF, increasing with the applied potential. The other change is the low reactivity 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 \( C_g / C_p \) 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, \( C_p \) 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 \( C_g / C_p \) can be experimentally determined by measuring \( E_{cond} \), the conductor to ground potential, with a high impedance A-C voltmeter or an oscilloscope.

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

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.

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