INSTRUMENT COMPANY

Model IT-25B Instruction Manual

Clinton Instrument Company

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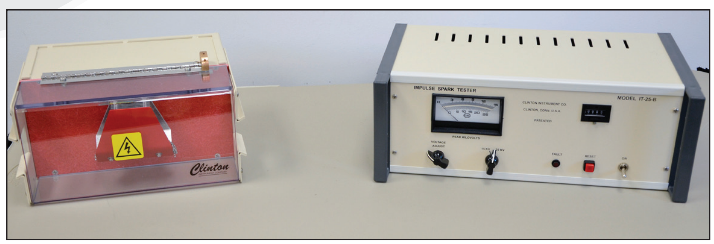
MODEL IT-25B

Impulse Spark Tester

- >> Impulse spark tester
- >> Regulated output voltage
- >> Meets MIL-C-13777E, MIL-W-16878D, NEMA specifications
- >> Process control output

IT-25B Control Unit

BD-E121 Bead Chain Electrode



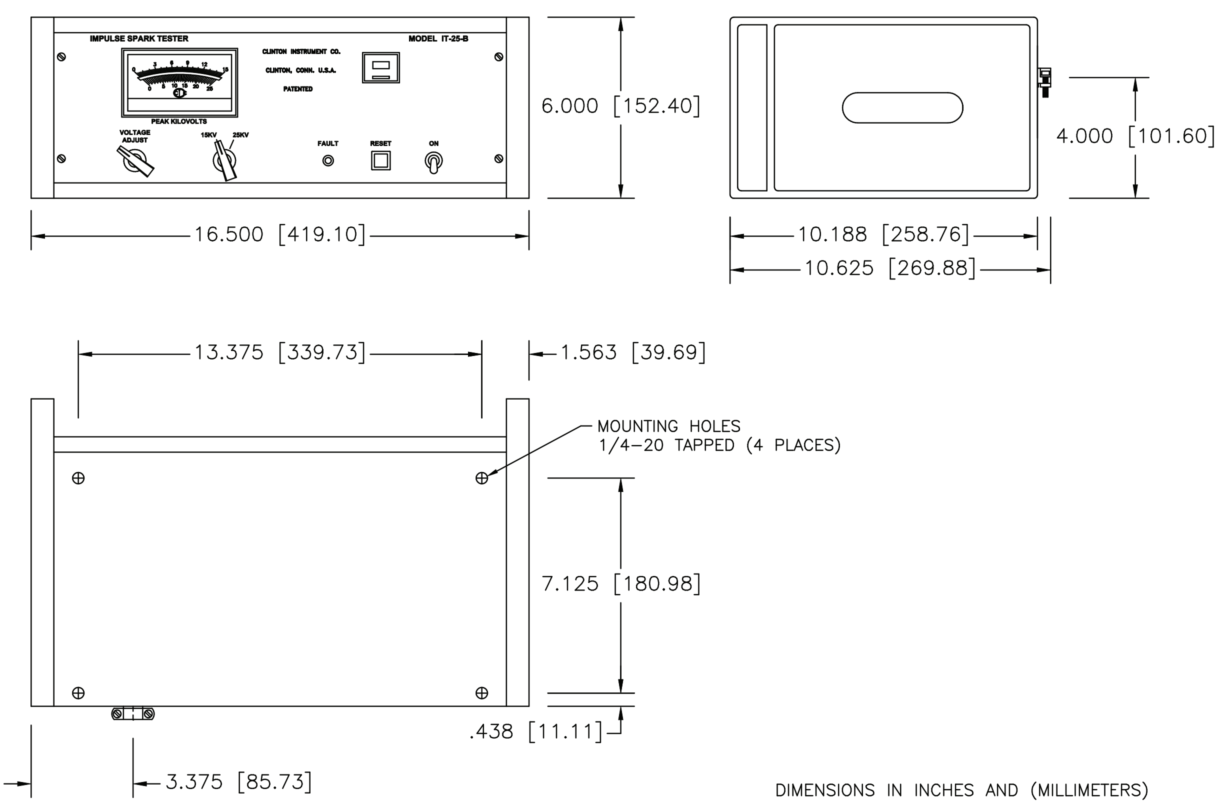
The IT-25B Impulse Spark Tester is designed to comply with the rigorous test requirements of Military Specifications MIL-C-13777E, MIL-W-16878, and NEMA Standards for hook-up wire used in high temperature wire applications. This method is favored as an alternate to wet dielectric test.

This unit produces a repetitive fast-rise negative voltage pulse, followed by an exponentially damped sinusoid having a frequency of several kilohertz. The electrode voltage is regulated against line voltage and load current changes. A repetition rate of 250 I.P.S. allows two test pulses in a 2 inch electrode at a wire speed of 1250 ft./min. Higher speeds may be attained by using a longer electrode when specifications permit.

The phase splitting feature allows for wire whip and vibration while retaining the high sensitivity necessary to insure the detection of low current arc faults. Process control output is provided for the operation of machinery or an external alarm.

IT-25B SPECIFICATIONS

Test Voltages	3-15KV, 3-25KV (negative peak volts).
Regulation: Line	±1% for line voltage 105-135V with 25 pf load.
Load	Less than 500V decreae from 25 pf to 50 pf load.
Voltage Metering	3-15 KV, 3-25 KV peak, ±3% FSD (true negative peak indication).
Inpulse Wave Form	Negative pulse with an exponentially damped sinusoid.
Rise Time	(10% to 90%) 10 ± 2 microseconds.
Positive Overshoot	Less than 80% of initial negative amplitude.
Impulse Repetition Rate	250 =0/-2% I.P.S.
Sensitivity	Resistance connected from electrode to ground required to register a fault; 500 kilohms, min.
Dynamic Response	Fault registration when a single impulse arc occurs between 1/2” ball electrodes connected from the high voltage terminal to ground.
Repetitive Fault Counting Rate	20 per second maximum.
Fault Indication	4 digit counter with manual reset.
Process Control Output	From C relay contacts 5 amperes.
Power Requirements	120 Vac 50/60HZ, 240 Volts, optional.
Dimensions: Cabinet	16 1/2” L x 6” H x 10 1/4” D (419 x 152 x 250 mm).
Electrode	11” L x 6 1/4” H x 6 1/4” D (279 x 159 x 159 mm).
New Weight: Cabinet	18.5 lbs. (8.5 kgs.)
Electrode	8 lbs. (3.6 kgs.)



DIMENSIONS IN INCHES AND (MILLIMETERS)

the clinton instrument company Clinton 295 EAST MAIN STREET, CLINTON, CT 06413 PHONE: (860) 669–7548 FAX: (860) 669–3825	THIS DRAWING IS THE PROPERTY OF THE CLINTON INSTRUMENT COMPANY, INC. THE INFORMATION CONTAINED HEREON MAY NOT BE REPRODUCED OR DISTRIBUTED WITHOUT THE EXPRESS PERMISSION OF THE CLINTON INSTRUMENT CO.	TITLE: OUTLINE DIMENSIONS			
		DATE: 08–14–01	USED IN: IT–25B	DWG. No: IT–25B	REV: NULL
		DRAWN BY: TPL	APPROVED BY: NLL		

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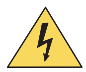
Table of Contents

Safety

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 symbols:

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 IT-25B Impulse Spark Tester is designed to be safe under the following conditions:

- Indoor use.
- Altitude to 2000 m.
- Temperatures from 5ºC to 40ºC.
- Humidity to 80% R.H. at 31ºC, decreasing linearly to 50% R.H. at 40ºC.

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

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.

email: support@clintoninstrument.com.

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.

For references, see: Dalziel, Ogden, Abbot, "Effect of Frequency on Let-Go Currents," Transactions of A.I.E.E., Volume 62, December 1943, and Dalziel, "Electric Shock Hazard," I.E.E.E., Spectrum, February 1972.

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

Remove the spark tester and electrode from the cartons. Retain the packing material in the event that the equipment is returned for calibration or service at some future time.

Site Preparation

Select a suitable location for the spark tester:

The IT-25B Spark Tester is designed for use in a fixed location, permanently connected to its power source. The equipment may be mounted on a table or on a Clinton floor stand and should be placed at wire line height and within easy reach of the operator.

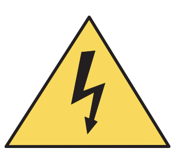
Provide for ventilation of the electrode:

As with any apparatus producing a spark or electrical corona, the Spark Tester produces ozone in the electrode region. While ozone reverts harmlessly to oxygen within a few minutes, an external air extraction system is recommended and should operate whenever the spark tester is in use. The exhaust of the external air extraction system should be discharged either outdoors or into some area well away from workers.

Wiring Requirements

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.



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

Mount the Spark Tester:

Mount the IT-25B control unit in place near the electrode. The electrode interlock leads (3 conductors) and high voltage lead (single conductor) determine the maximum separation between the units.

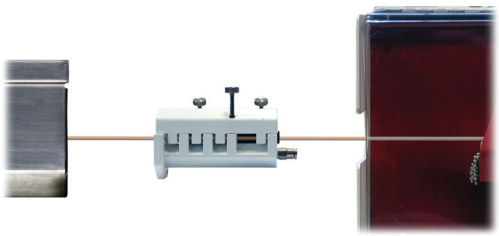
Wire the control unit:

1. Remove the two #6 sheet metal screws that hold the top of the control unit and slide the cover to the rear, allowing access to the terminal strip inside the unit.
2. Check the serial tag for the proper operating voltage.
3. Connect the indicated operating voltage source to the GND, L1, and L2 terminals as follows: systems ground (Green) to GND, Hot side (black) to L1, and Common (white) to L2.
4. Check to make sure that there is continuity between the spark tester cabinet and the take-up shaft.
5. Leave the jumper between terminals marked INTERLOCK 1 and INTERLOCK 2. Connect the 3-conductor cable coming from the electrode as follows: green wire to the control unit GND terminal, and the two wires with yellow tubing to INTERLOCK 1 and INTERLOCK 2 terminals.
6. Connect the HV lead from the electrode to the control unit HV terminal. Do not extend the length of this lead, and route it at least 1" away from any metallic framework. Use only plastic conduit if enclosure of the lead is desired.
7. Set desired mode of operation:

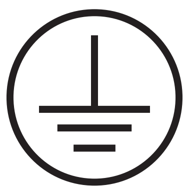
- *Mode A (Extruder Use: Continuous Voltage, Automatic Reset)*: Place a jumper between HV CONTIN and GND and remove any jumper between RESET and GND.
- *Mode B (Rewinder Use: Stop on Fault, Remove High Voltage, Manual Reset):* Place a jumper between RESET and GND and remove any jumper between HV CONTIN and GND.

8. Replace the equipment cover.

Prepare Your Product for Test



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. Efficient air wipes that can adequately dry the product before it enters the electrode are available from Marldon.



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.

Double Check Your Connections

Double check all connections. Plug the power cord(s) from your spark tester into your power source.

Spark Tester Controls

ON/OFF Power Switch.

This switch is located on the front panel of the spark tester.

Voltmeter and Range Switch.

The dual range analog voltmeter indicates the voltage at the electrode. When the range switch is set to 0-15kV, the voltage of the spark tester is indicated on the lower scale of the voltmeter. When the range switch is set to 0-25kV, the voltage of the spark tester is indicated on the upper scale.

VOLTAGE ADJUST control.

To adjust the voltage of the IT-25B, select the proper voltage range using the Range Switch and turn the Voltage Adjust control to the desired voltage. NOTE: The IT-25B does not operate below 3kV.

FAULT light and RESET button.

The FAULT light will illuminate in response to a single pinhole fault in the electrode. It also indicates that the FAULT relay contacts are in fault condition, activating any accessories that are connected. If the IT-25B is in Mode B (Rewinder Use: Stop on Fault, Remove High Voltage, Manual Reset) the FAULT light can be turned OFF in 2 ways: (1) by pressing the RESET button to the right of it; or (2) closing a NO remote switch or relay contacts wired between HV CONTIN & RESET on the terminal block. Simultaneously, the fault counter relay contacts will reset to normal position.

If the spark tester is in Mode A (Continuous High Voltage, Automatic Reset), the FAULT light will flash and the fault relay will activate momentarily and then return to the normal state.

The RESET button will have no effect on the number of faults registered on the Fault Counter.

Fault Counter.

The 4-digit Fault Counter registers a count each time a pinhole fault is detected in the electrode. Reset the number of counts to zero by pressing the button below the readout.

Bead Chain Electrode.

When the spark tester power is ON and the clear protective cover is down, the test voltage set on the spark tester front panel is applied to the product under test as it runs through the electrode. 2” and 4” bead chain electrodes are available. Other electrodes are available. Please contact factory for details.

Clear protective cover.

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

Safety interlock switch.

This switch turns OFF the high voltage in the electrode when the clear protective cover is lifted. Do not attempt to defeat the safety interlock switch.

Safety end guards.

Metal end guards on each end of the high voltage test module prevent the operator from reaching into the energized electrode. The test product should be centered in the electrode to avoid damage to the product.

Operation

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

CAUTION: When the spark tester 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 wireline is stationary, the product insulation within the electrode will heat and there is a danger of combustion. Refer to the "Installation" section of this manual on how to safely install your spark tester.

NOTE: In order to avoid spurious fault counts during normal operation, voltage levels less that 3kV should not be used. Military specifications generally do not permit voltage test below 5kV peak. The IT-25B was designed to operate and to meet military specifications between 5 - 25 kV.

- *Mode A (Extruder Use: Continuous Voltage, Automatic Reset)*:

  1. Thread your product through the bead chain electrode. Be sure the wire is centered in the electrode.
  2. Verify that the product conductor(s) are grounded. The conductor of the wire under test must be grounded so as to return to the ground terminal of the tester and also to earth ground. If this is not the case, do not proceed. Contact service personnel to review the spark tester installation.
  3. Turn the VOLTAGE ADJUST control fully counterclockwise.
  4. Turn ON the external disconnecting device to bring power to the spark tester.
  5. Turn the spark tester power switch ON.
  6. Start the wireline. Turn the VOLTAGE ADJUST control until the voltmeter indicates the desired test voltage value. NOTE: It is normal for the IT-25B to trigger during the initial turn-on period and while the voltage is being adjusted to a level above 3kV. Press the RESET and clear the counter to ready the tester for operation.
  7. When a fault passes through the electrode, an external alarm connected to the spark tester relay contacts is energized momentarily. Voltage will remain ON. The front panel counter indicates the number of faults detected. The counter can be reset

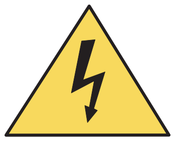
at this time if desired.

- *Mode B (Rewinder Use: Stop on Fault, Remove High Voltage, Internal Manual Reset):*

  1. Thread your product through the bead chain electrode. Be sure the wire is centered in the electrode.
  2. Verify that the product conductor(s) are grounded. The conductor of the wire under test must be grounded so as to return to the ground terminal of the tester and also to earth ground. If this is not the case, do not proceed. Contact service personnel to review the spark tester installation.
  3. Turn the VOLTAGE ADJUST control fully counterclockwise.
  4. Turn ON the external disconnecting device to bring power to the spark tester.
  5. Turn the spark tester power switch ON.
  6. Start the wireline. Turn the VOLTAGE ADJUST control until the voltmeter indicates the desired test voltage value. NOTE: It is normal for the IT-25B to trigger during the initial turn-on period and while the voltage is being adjusted to a level above 3kV. Press the RESET and clear the counter to ready the tester for operation.
  7. When a fault passes through the electrode, an external alarm connected to the spark tester relay contacts is energized and voltage will go OFF. Turn OFF the external alarm and turn ON the high voltage by pressing the RESET button on the front panel. The front panel counter indicates the number of faults detected. The counter can be reset at this time if desired.

Calibration

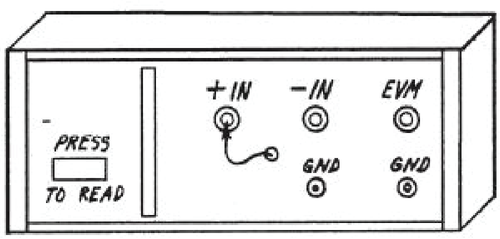
The IT-25B spark tester may be reasonably expected to retain its accuracy for a period of one year from the date of calibration under conditions of normal use.



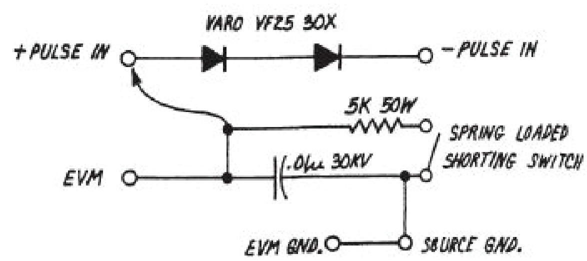
CAUTION: The calibration procedures listed below are to be performed by qualified service personnel experienced in high voltage safety procedures only. Failure to follow these procedures may result in danger to personnel and equipment damage.

Calibration with EVM and Negative Peak Adaptor

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.



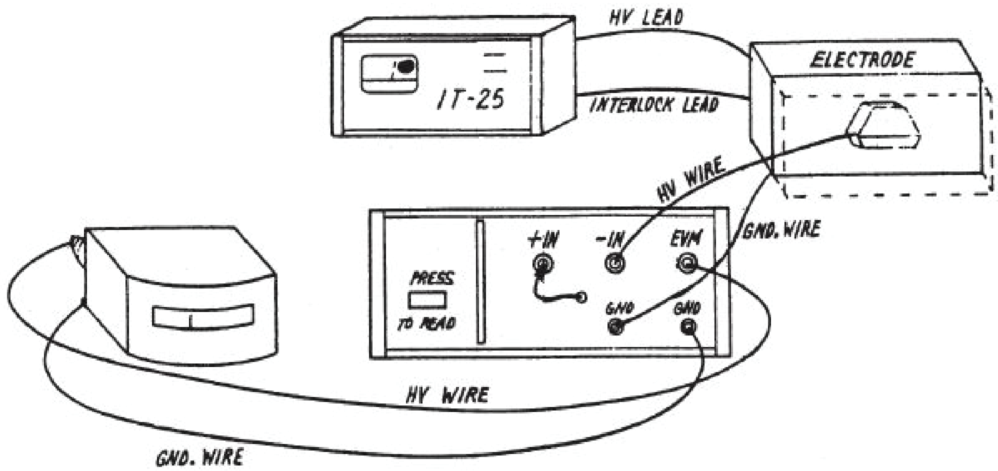
a typical Peak Adaptor



Schematic of a typical Peak Adaptor

WARNING: Be sure to discharge the Negative Peak Adaptor's large capacitor next to the terminal strip with a 250 ohm 5 watt resistor before working on the equipment and after the final voltage reading. The capacitor retains a charge that is reflected in the EVM reading, so it is important during calibration to start at a low voltage and adjust the voltage control knob upward ONLY if you are to accurately read the correct electrode voltage.

1. Turn OFF the spark tester.



2. Make connections as above. Be sure to use high voltage wire on the leads to the electrode and the hot lead to the EVM. Also, be sure to ground the Negative Peak Adaptor to equipment ground.

3. Set the EVM to the 20kV range and zero the meter.

4. Set the IT-25B range switch to the 15kV range. Zero the IT-25B voltmeter.

5. Turn ON the spark tester. It will immediately show a fault.

6. Press and hold the PRESS TO READ button on the Peak Adaptor and push the RESET button on the IT-25B. Both the meter on the spark tester and the EVM will indicate voltage.

7. Still holding in the PRESS TO READ button, turn the IT-25B voltage up slowly until the EVM reads 7.93kV. (NOTE: the Negative Peak Adaptor causes the EVM to read 70 voltage LESS than the actual actual voltage.) Use the reading obtained after the meter needle has come to rest, not while it is moving. If the IT-25B voltmeter does not read 8kV, adjust trimpot R10 (located on the main PC Board Assembly 25011) until the meter reads exactly 8kV. Be sure to eliminate any parallax error that might result from viewing the meter from a slight angle.

8. Release the PRESS TO READ button. The IT-25B will show a fault and the EVM will reset to zero. Note that the EVM contiues to read the maximum voltage you have reached even when the voltage has been reduced.

9. Set the EVM range switch to the 30kV test voltage range and zero the EVM meter.

10. Set the IT-25B range switch to the 25kV range. Zero the IT-15B voltmeter.

11. Turn ON the IT-25B Spark Tester. It will immediately show a fault.

12. Press and hold the PRESS TO READ button on the Peak Adaptor and push the RESET button on the IT-25B. Both the meter on the spark tester and the EVM will indicate voltage.

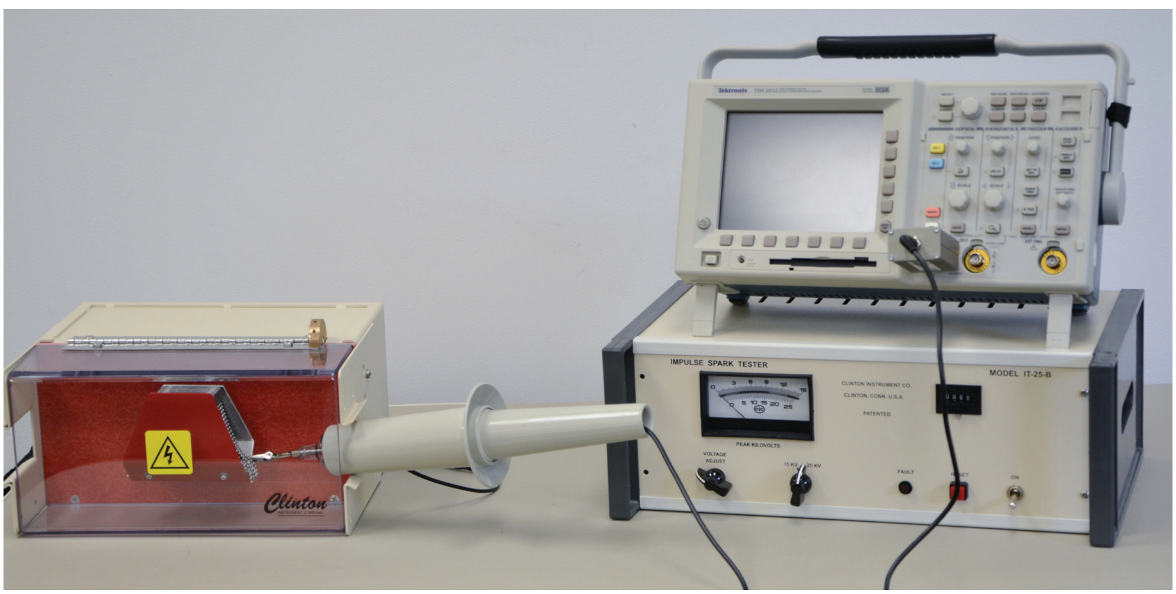
13. Still holding in the PRESS TO READ button, turn the IT-25B voltage up slowly until the EVM reads 14.93kV. (NOTE: the Negative Peak Adaptor causes the EVM to read 70 voltage LESS than the actual actual voltage.) Use the reading obtained after the meter needle has come to rest, not while it is moving. If the IT-25B voltmeter does not read 15kV, adjust trimpot R16 (locted on the main PC Board Assembly 25011) until the meter reads exactly 15kV. Be sure to eliminate any parralax error that might result from viewing the meter from a slight angle.

14. Release the PRESS TO READ button.

15. Turn OFF all power. Discharge the Peak Adaptor capacitor. Disconnect the EVM and Negative Peak Adaptor.

Calibration with Tektronix Oscilloscope and P6015A HV Probe

Clinton recommends the Tektronix P6015A High Voltage Probe and a Tektronix Oscilloscope to measure the negative peak voltage.



1. Set up the oscilloscope as follows (Note that settings may vary depending on the make of the oscilloscope): set the Time scale to 100uS/Division. Set the Voltage scale to 2V/Division.

2. Remove end guard adjusting plates from side of electrode. Make connections as above. Connect the HV Probe clip to the bead chain electrode and the black ground clip to the ground lug on the back of the IT-25B control unit.

3. Set the IT-25B range switch to the 15kV range. Zero the IT-25B voltmeter.
4. Turn ON the spark tester. It will immediately show a fault.
5. Push the RESET button on the IT-25B. Both the meter on the spark tester and the oscilloscope will indicate voltage.
6. Turn the IT-25B voltage up slowly until the negative peak of the waveform on the oscilloscope reads the equivalent of 8kV (Neg 8V). If the IT-25B voltmeter does not read 8kV, adjust trimpot R10 (located on the main PC Board Assembly 25011) until the meter reads exactly 8kV. Be sure to eliminate any parallax error that might result from viewing the meter from a slight angle.
7. Turn OFF the oscilloscope. The IT-25B will show a fault.
8. Set the IT-25B range switch to the 25kV range. Zero the IT-25B voltmeter.
9. Turn ON the IT-25B Spark Tester. It will immediately show a fault.
10. Push the RESET button on the IT-25B. Both the meter on the spark tester and the oscilloscope will indicate voltage.
11. Turn the IT-25B voltage up slowly until the negative peak of the waveform on the oscilloscope reads the equivalent of 15kV (Neg 15V). If the IT-25B voltmeter does not read 15kV, adjust trimpot R16 (locted on the main PC Board Assembly 25011) until the meter reads exactly 15kV. Be sure to eliminate any parallax error that might result from viewing the meter from a slight angle.
12. Turn OFF all power. Disconnect the oscilloscope and HV probe.

Maintenance

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. The red 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.

The red electrode mounting plate, clear cover, and bead chain assemblies are subject to damage and contamination that is not always visible. They should be replaced if current leakage occurs.

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.

The spark tester controls are ON but the equipment does not function.

The circuit breaker on the rear of the control unit may have tripped.

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.

Part Number	Part Description
For IT-25B Control Unit:	
25011i	Main PC Board ASsembly IT-25B
25010i	Filter Board Assembly X-0258
25008	Heat Sink Assembly IT-25B
20059	High Voltage Transformer, IT-25B, Y-1077
01434-25	Voltmeter with 0-15/0-25 scale & bezel
01319	Lamp 12V, 200 ma.
91308	Counter 120VDC, 4-digit
00924	Relay 12VDC
00613	SCR, C106M
00425	Transformer X-0591, R4772-1
03706	High Voltage Wire
01003	Circuit Breaker, 2 amp (&B W28-XQ1A-2
03009	Switch Pushbutton SPST, RESET
For Electrodes:	
12000	Slotted Metal Cam & Failsafe Interlock Switch Assembly
01561	Hinge, Stainless Steel, X-0857
01732i	Clear Plexiglas Cover for use with 12000
01738	Red Mounting Plate for BD-12 and BD-14, Y-1087
25002	Bead Chain Assembly with trough, BD-12
20026	Bead Chain Assembly with trough, BD-14

MEASURING & TESTING
clinton instrument company

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.

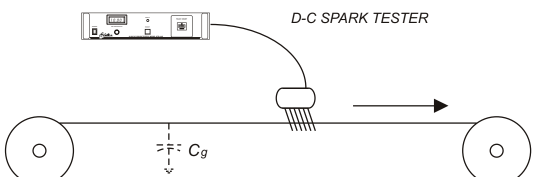


FIG. 1

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_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.

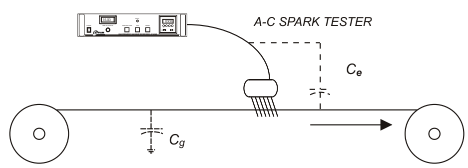
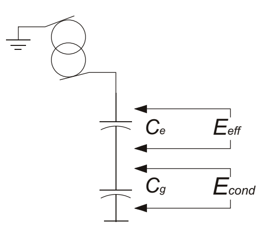


FIG. 2

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.



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

$$E_{cond} = E_{app} - E_{eff}$$

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

If C_g is very large compared to C_e, Eeff is nearly equal to Eapp. 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 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_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 Cg, 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 Econd, 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.

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Electronic Instrumentation For Industry

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Electric Shock Considerations for Electric Vehicle Charging Systems

By Walter 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 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 $I = 6.3\ T\text{-}0.7$. 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.

Burns

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).

Ground-Fault Circuit Interrupter

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.